Innovative Stormwater Management:
A Synthesis of Monitoring and Research

Tim Van Seters

Toronto and Region Conservation

TRIECA Conference

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Toronto and Region Conservation for The Living City

Sustainable Technologies Evaluation Program

Sustainable Technologies Evaluation Program

- Multi-agency program led by TRCA
- Main program objectives:
  - ✓ Evaluate clean water and energy technologies
  - ✓ Assess barriers/opportunities for broader adoption of technologies
  - ✓ Develop tools, guidelines and policies
  - ✓ Education, advocacy, and technology transfer
- Program web address: www.sustainabletechnologies.ca

Program Partners

Region of Peel
Working for you

Toronto

Toronto and Region Conservation for The Living City

York Region

Ontario
Ministry of the Environment

Seneca

Government of Canada / Gouvernement du Canada
Great Lakes Sustainability Fund / Fonds pour la durabilité des Grands Lacs

Toronto & Region Remedial Action Plan

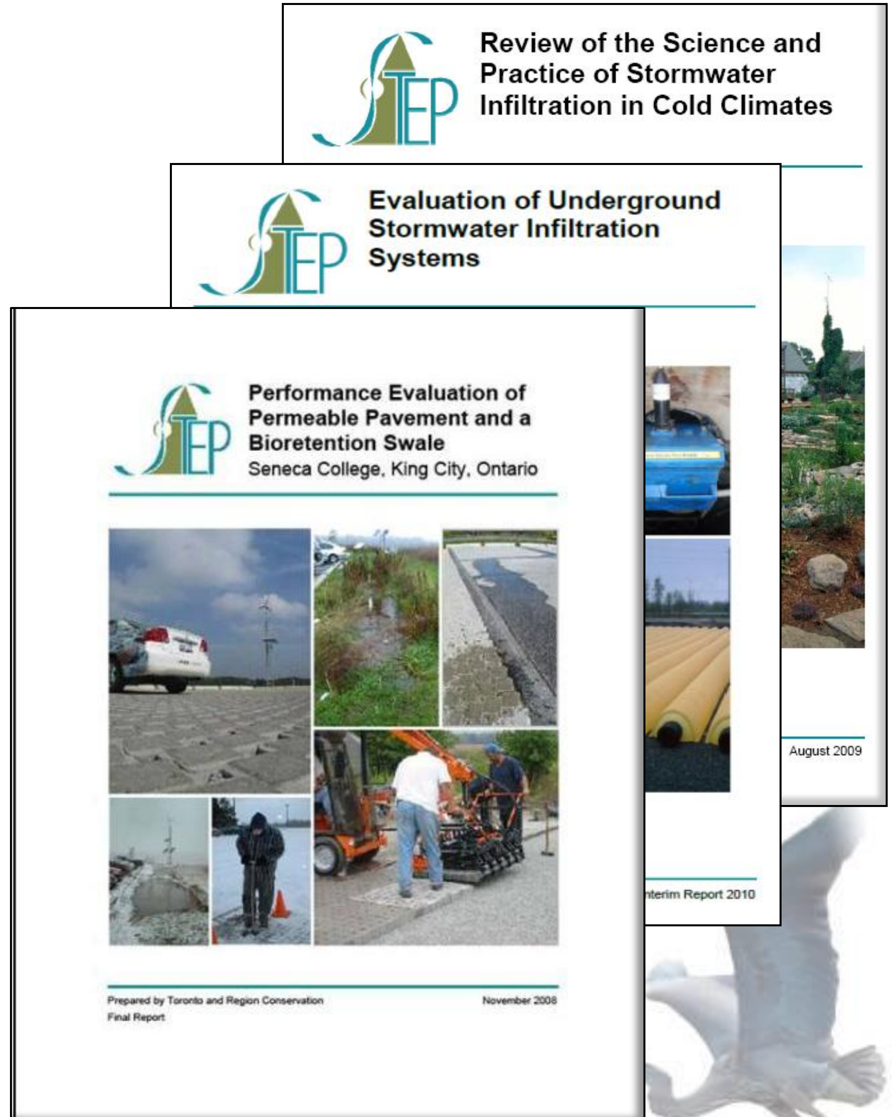
Fisheries and Oceans Canada / Pêches et Océans Canada

Stormwater Monitoring

- SWAMP – focus on end-of-pipe and conveyance controls
- STEP – focus on source controls:

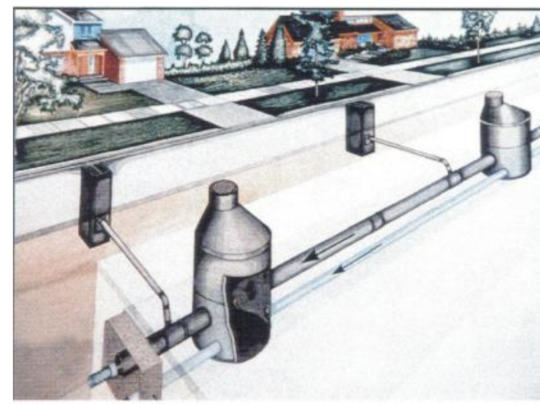
  green roofs, permeable pavements, rainwater harvesting, bioretention, soakaways, infiltration chambers/trenches etc.

- Literature reviews, design and costing tools, guidelines



Emphasis on….

- Cold climate conditions
  - High runoff during spring freshet
  - Low winter evapotranspiration
  - Release of accumulated contaminants in snowpack
  - Effects of de-icing compounds
- Local soils and geology
- Designs adapted to local conditions



Addressing Common Concerns

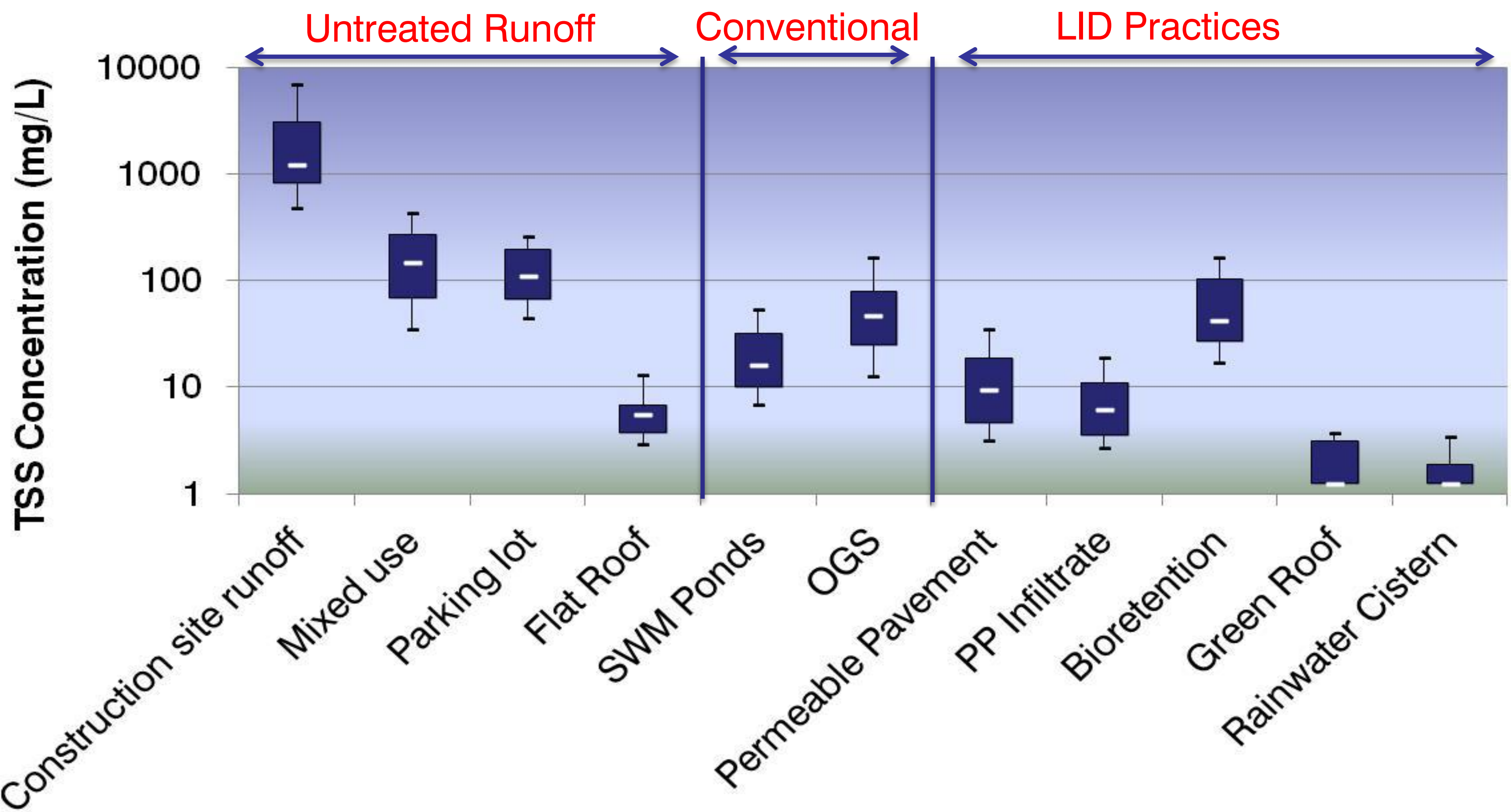
- Do practices provide ‘adequate’ treatment/control?
- How should infiltration practices be designed on fine textured soils?
- What is the risk of soil and groundwater contamination and how should it be managed?
- Are LID approaches affordable?
- How do we ensure that stormwater infrastructure is adequately maintained?

Do stormwater practices provide 'adequate' treatment, water balance and flow control?

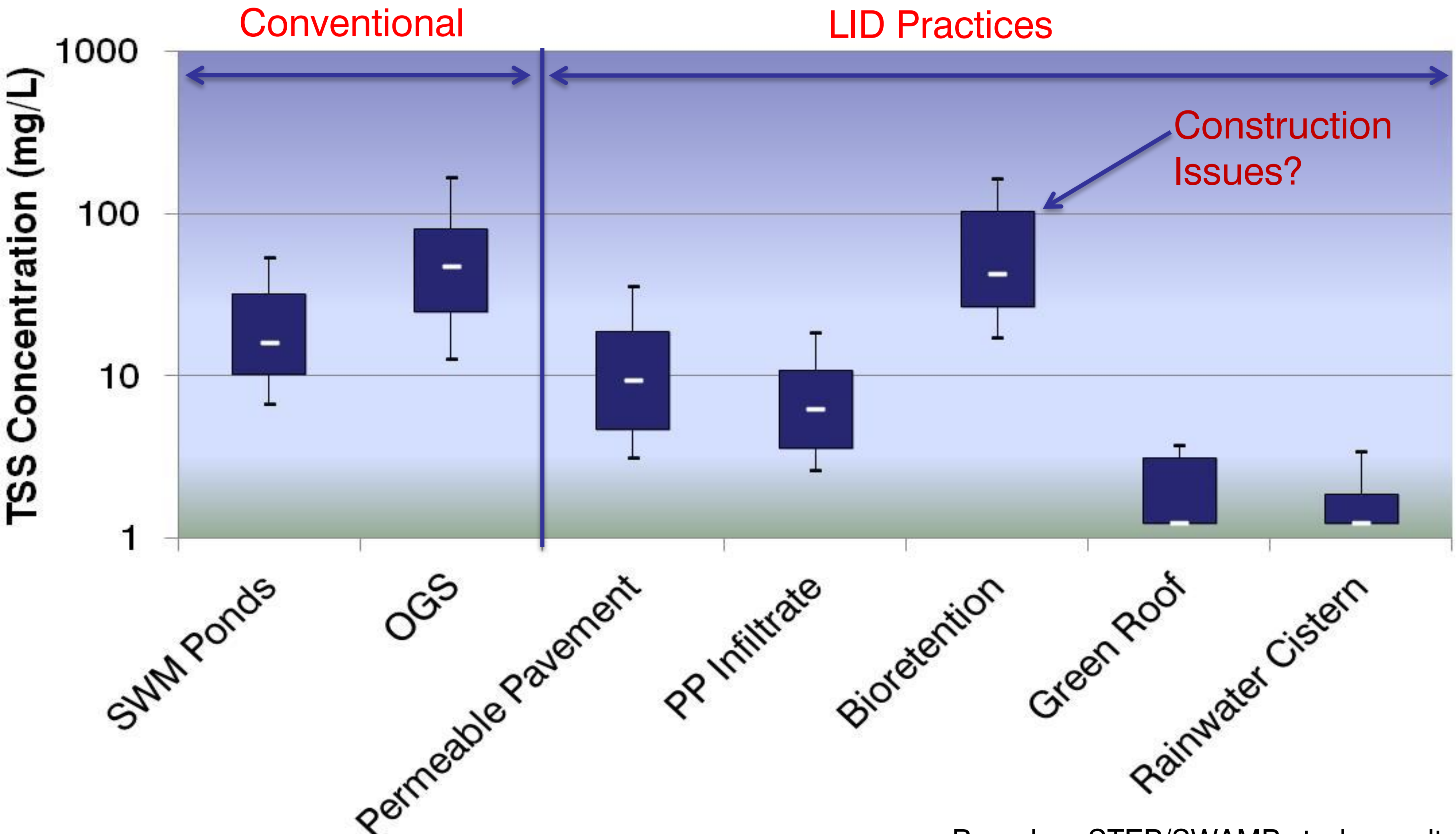
What is an ‘adequate’ level of protection?

- Water Quality
  - 80% removal?
  - Meet receiving water standards?
  - Thermal mitigation
- Stream Erosion Control
- Water Balance
  - Groundwater recharge
  - Mimic predevelopment hydrology
- Flood Control
- Protection of natural features

Water Quality – *Before and after treatment*

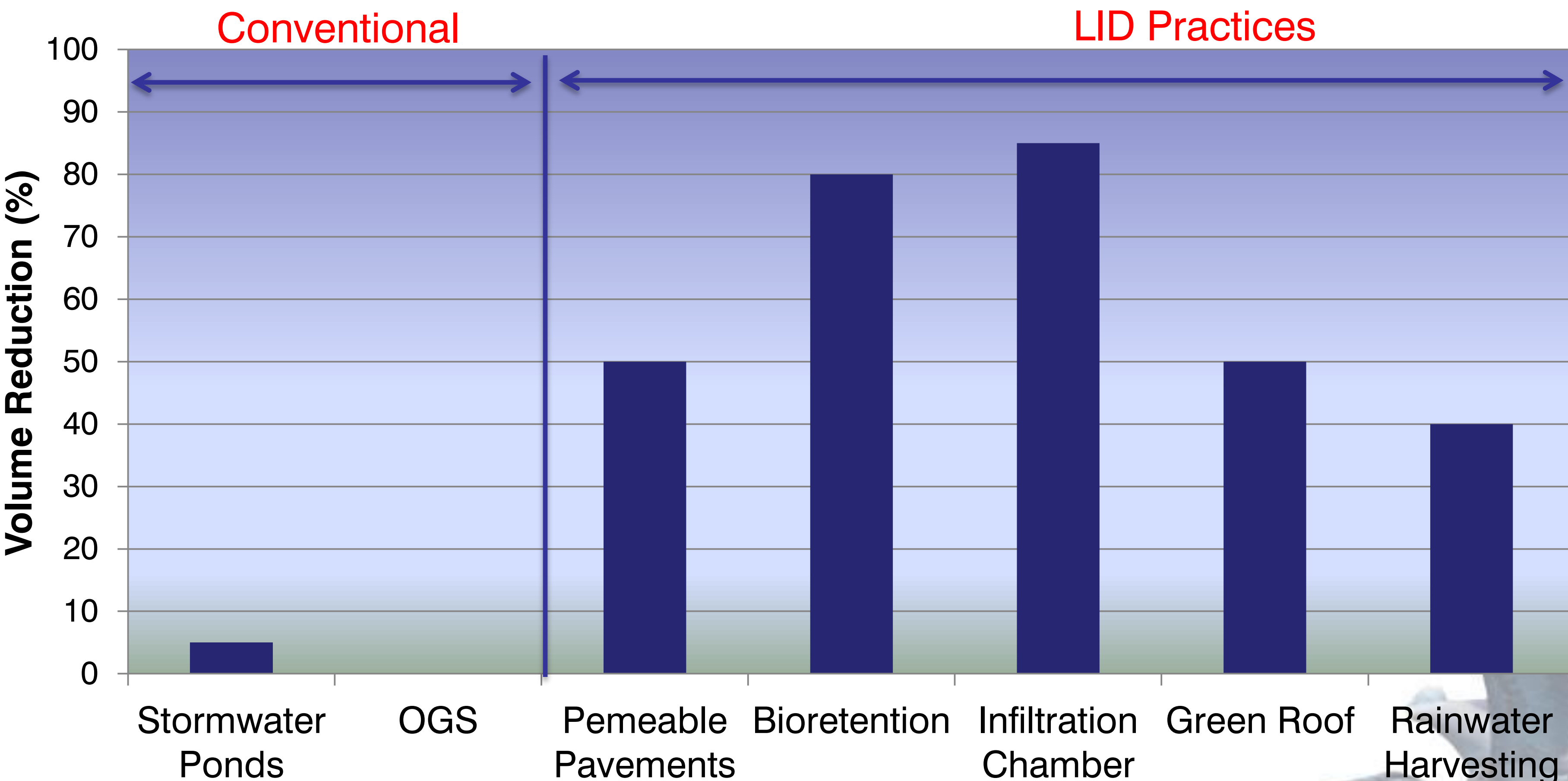


Water Quality – *TSS Effluent Concentrations*



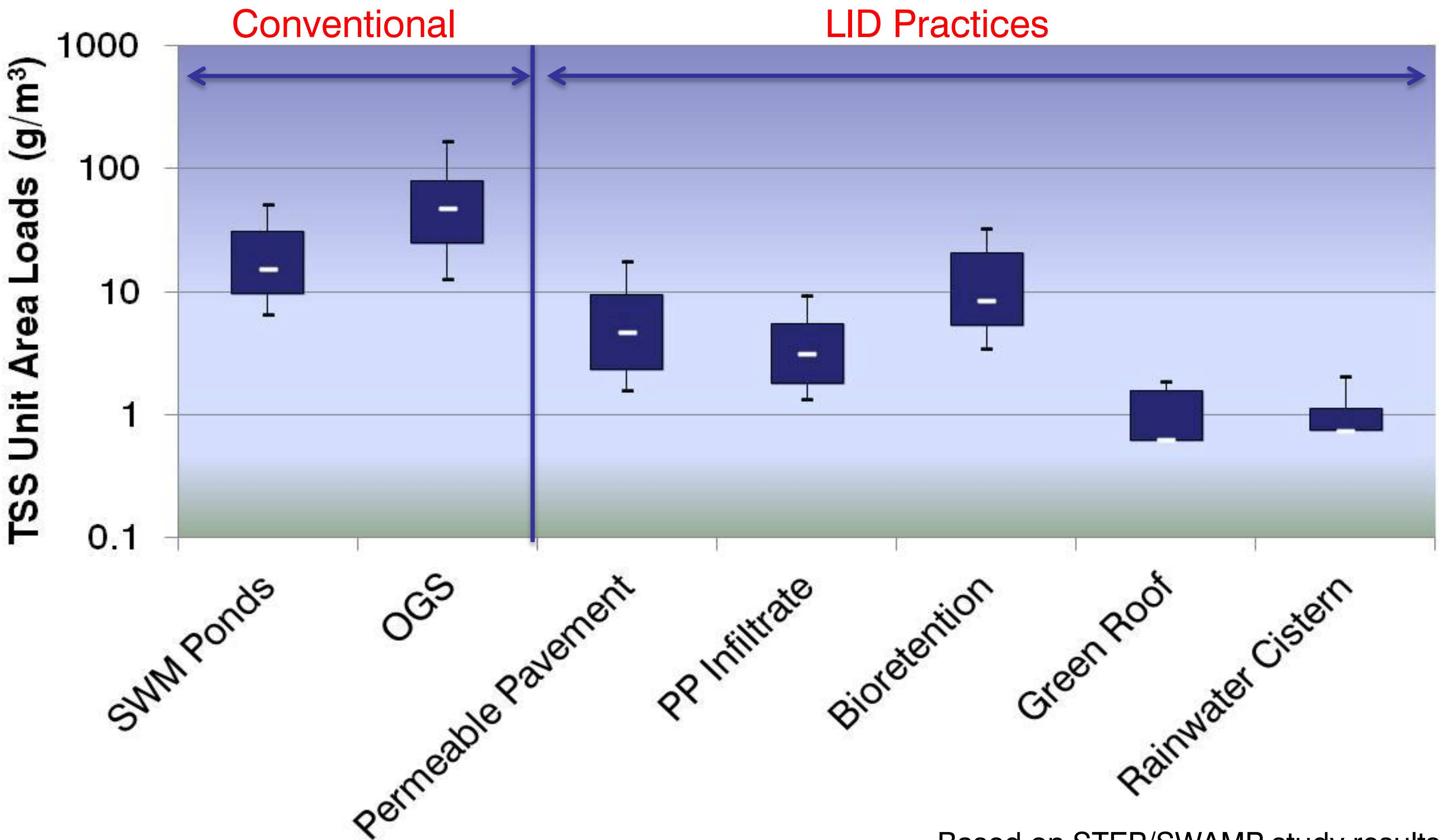
Based on STEP/SWAMP study results

Annual Volume Reductions



Based on STEP/SWAMP study results

Water Quality – *TSS Effluent Loads*



Based on STEP/SWAMP study results

Effluent Temperatures

- Stormwater ponds and wetlands
  - Maximums between 25 and 31 degrees C.
  - Inlet to outlet temp increases – 5 to 11 degrees C
- LID practices
  - Maximums are 3 to 6 degrees C less than asphalt runoff during the summer
  - Significant reductions in thermal loads

‘Adequate’ treatment?

- Water Quality: Not usually to receiving water standards, but substantially cleaner than untreated runoff
- Peak flow reductions: ponds and LID practices reduce peaks by 80% or more
- Volume reduction is critical to provide:
    - Groundwater recharge
    - Stream erosion control
    - Protection of Aquatic life and habitat
- Flood control – often requires end-of-pipe detention

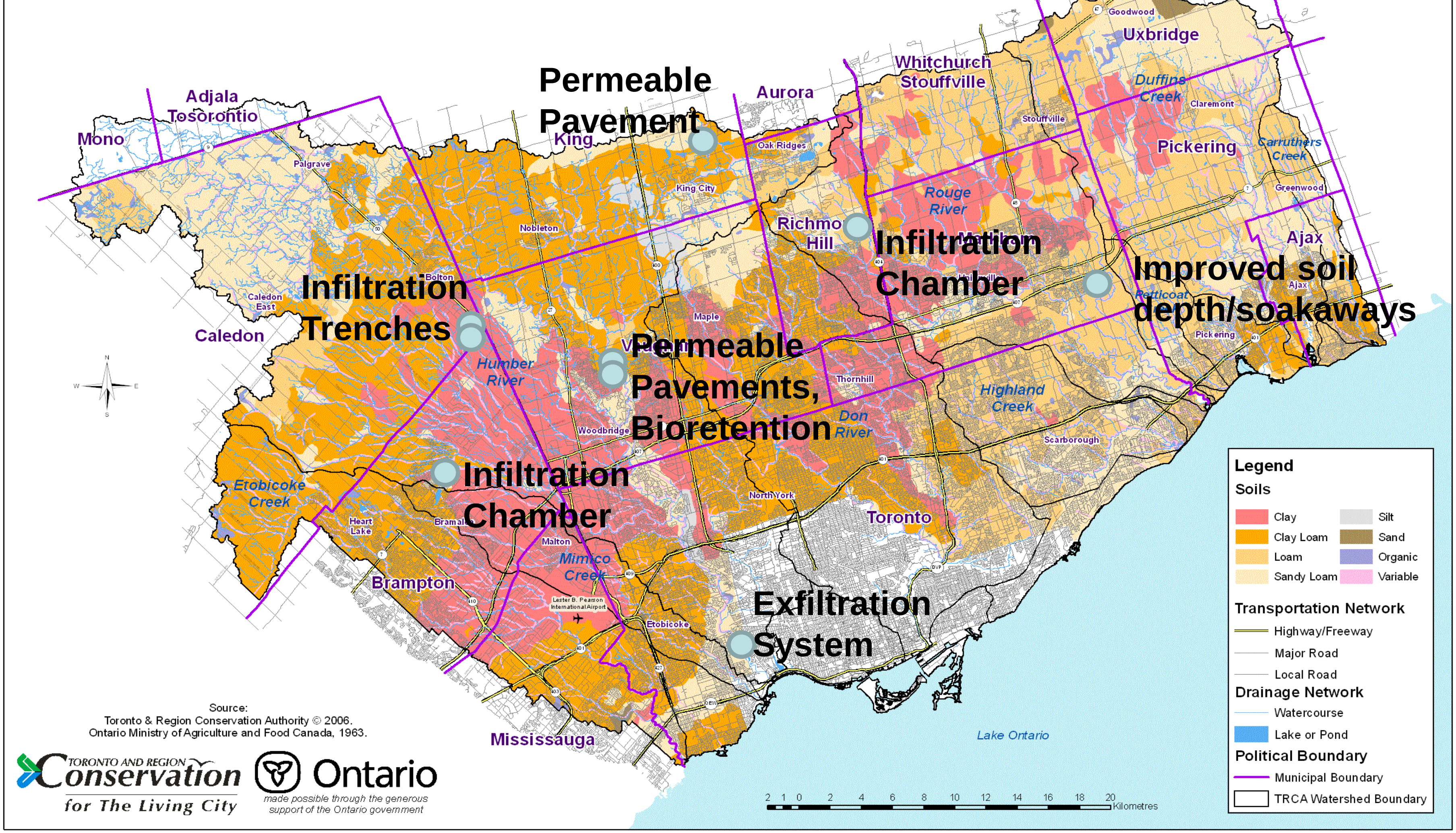
How should infiltration practices be designed on fine textured soils?

Guidelines for Minimum Soil Percolation Rate

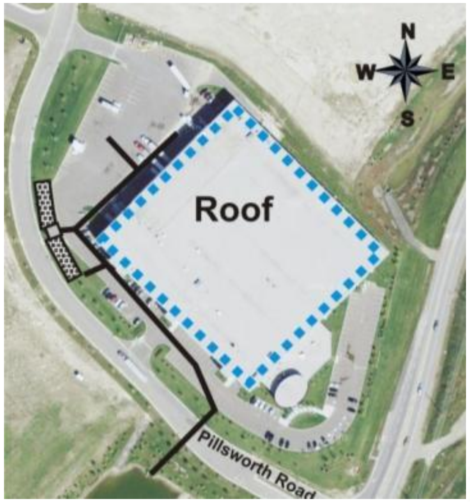
Reviewed manuals from 11 jurisdictions in Canada (4), Northeastern U.S. (6) and the UK (1)

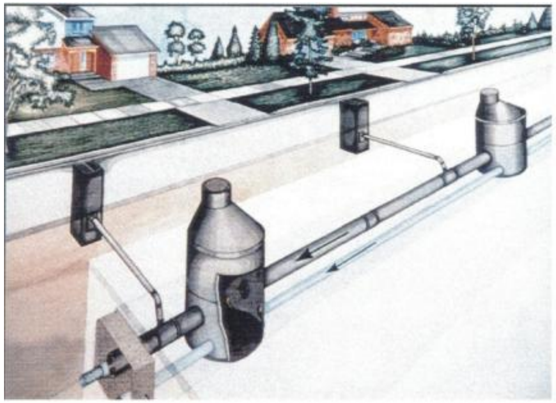
Jurisdiction	Recommendations
Ontario (2003), Halifax (2006)	**15 mm/h** (60 mm/h for Infil. Basins)
British Columbia (2002)	**No restrictions**; underdrain recommended where infiltration is slow
Maine (2006)	**13 mm/h** (not > 61 mm/h)
Pennsylvania (2006)	**2.5 mm/h** (not > 254 mm/h)
Minnesota (2008)	**No restrictions**; underdrain recommended where < 25 mm/h
New York (2003); Maryland (2000)	**13 mm/h** (clay content < 20%; silt + clay content < 40%)
United Kingdom (2007)	**No restrictions**

The Toronto And Region Conservation Authority

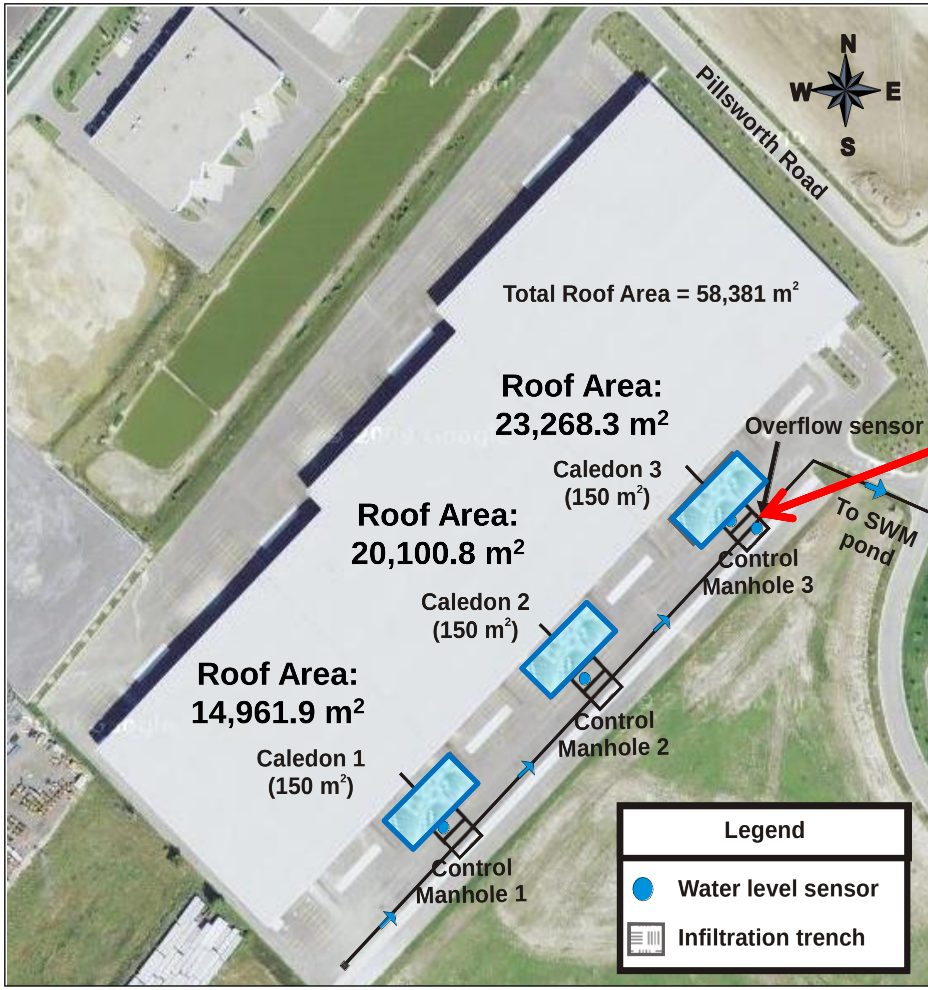


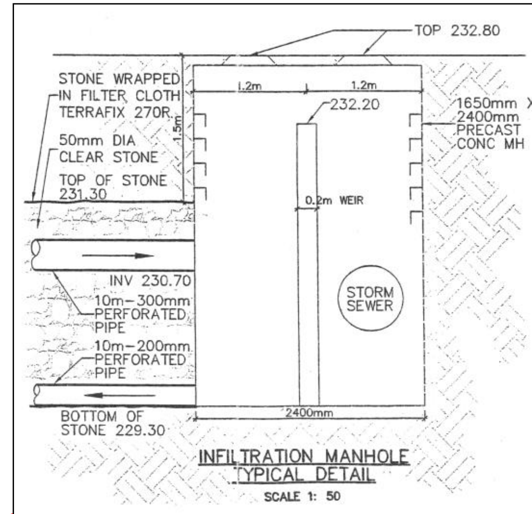
Infiltration Chambers and Trenches





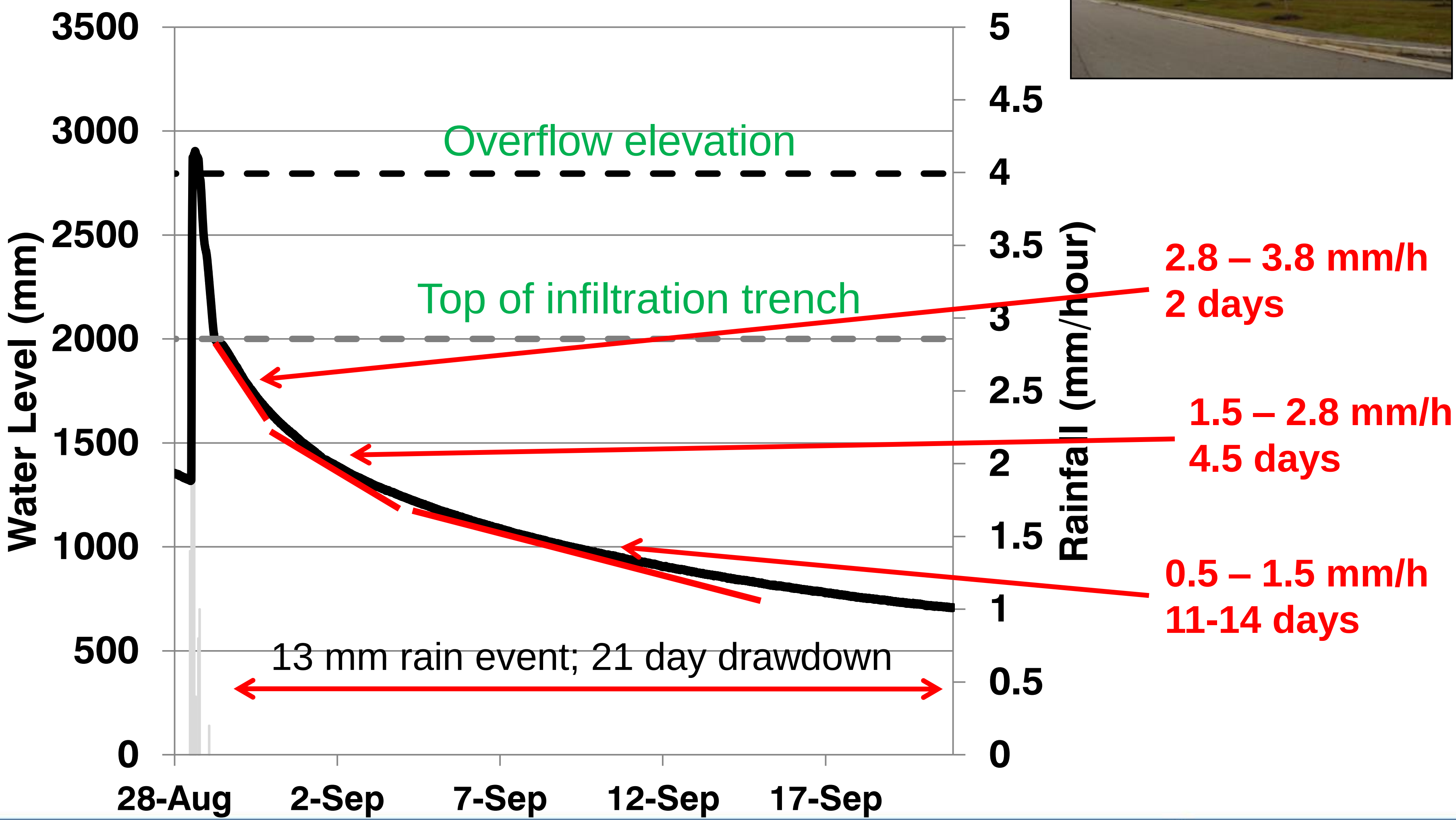
Infiltration trenches - Caledon



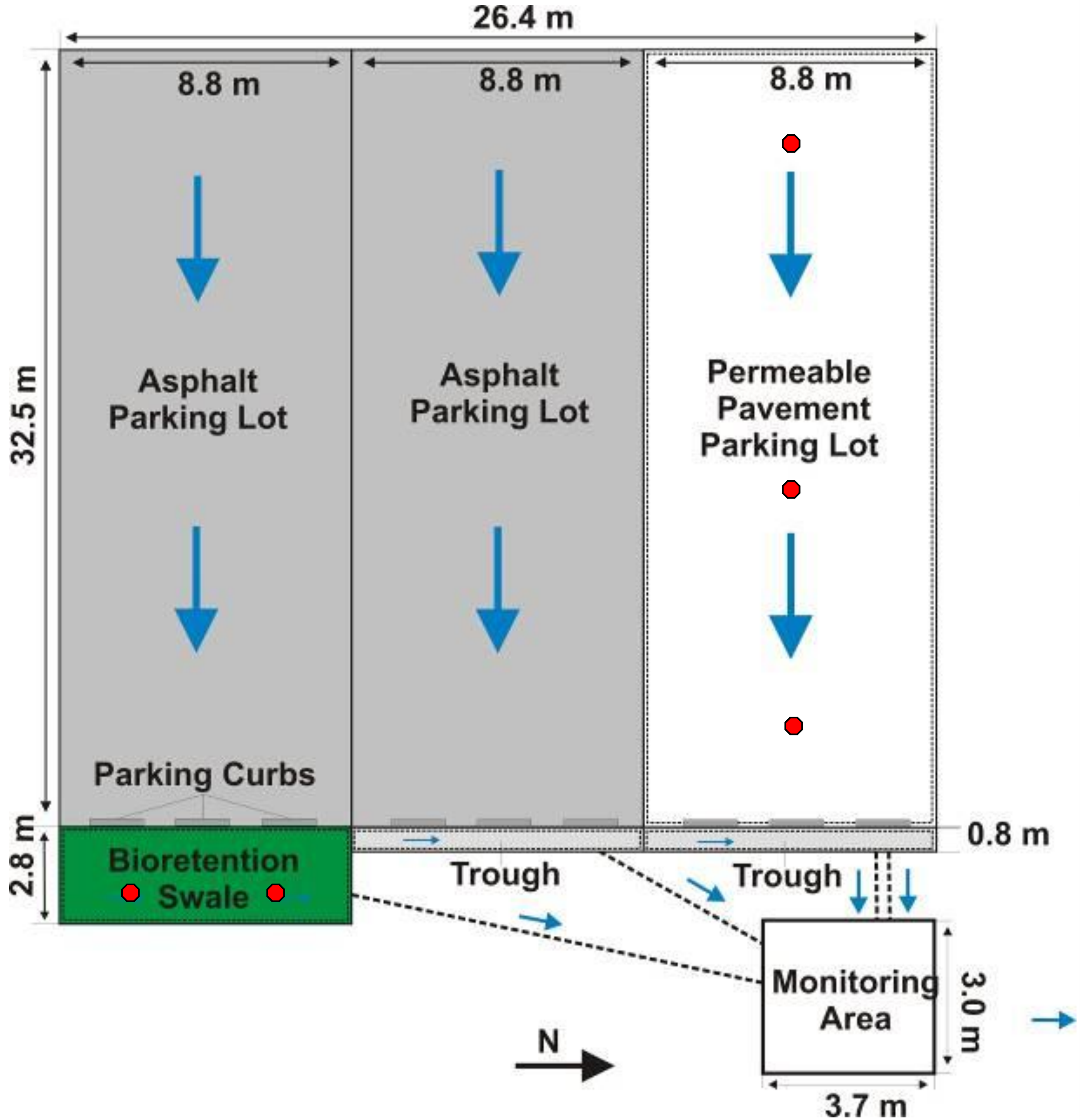


- Combined storage volume = **7 mm** event
- Annual infiltration volume target = **23,484 m³**
- Ratio of roof area to facility area ranges from **155:1 to 100:1**
- **Clayey silt till**
- Max. 48 hr infiltration rate: **3.1 to 5.6 mm/h**

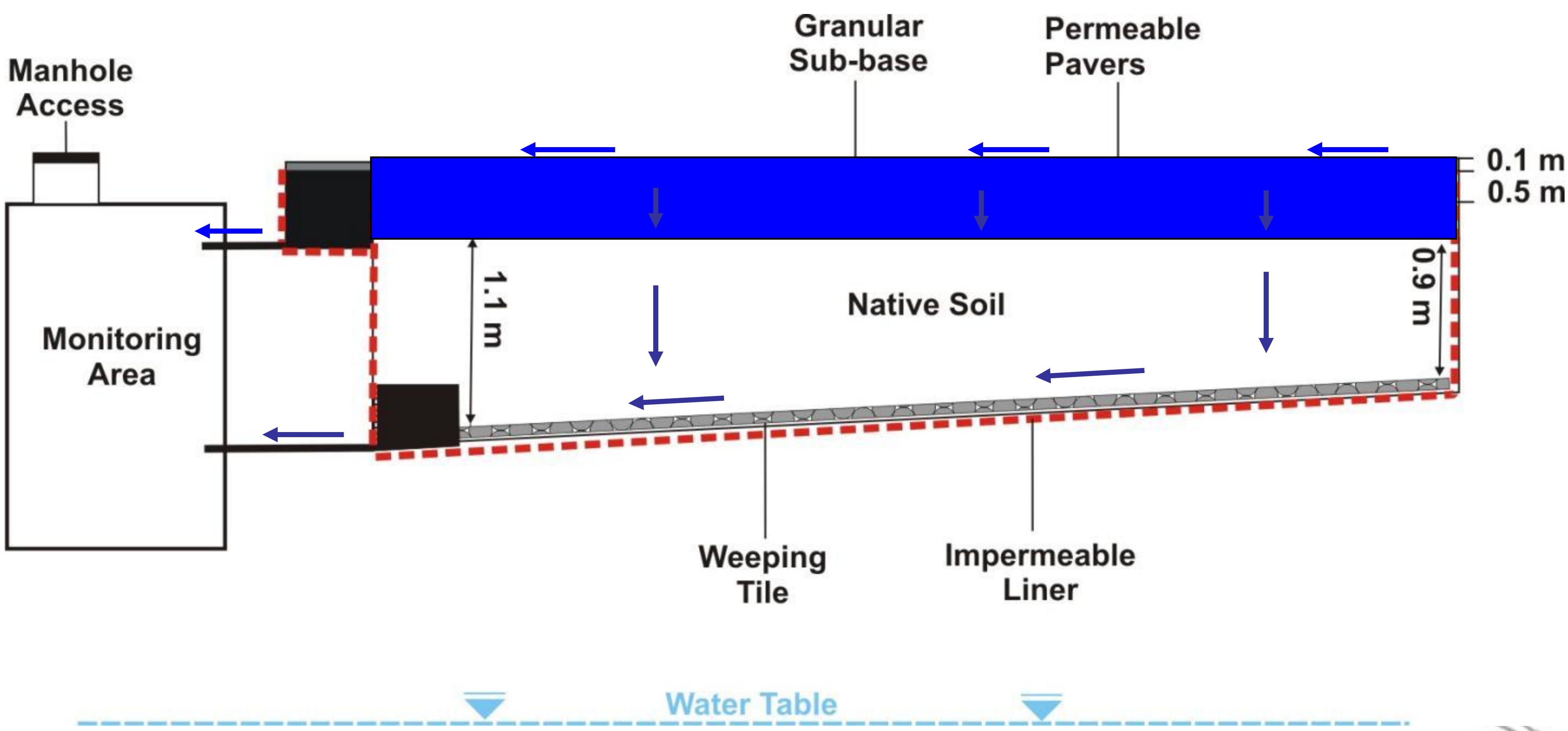
Infiltration Trench #3 - Caledon



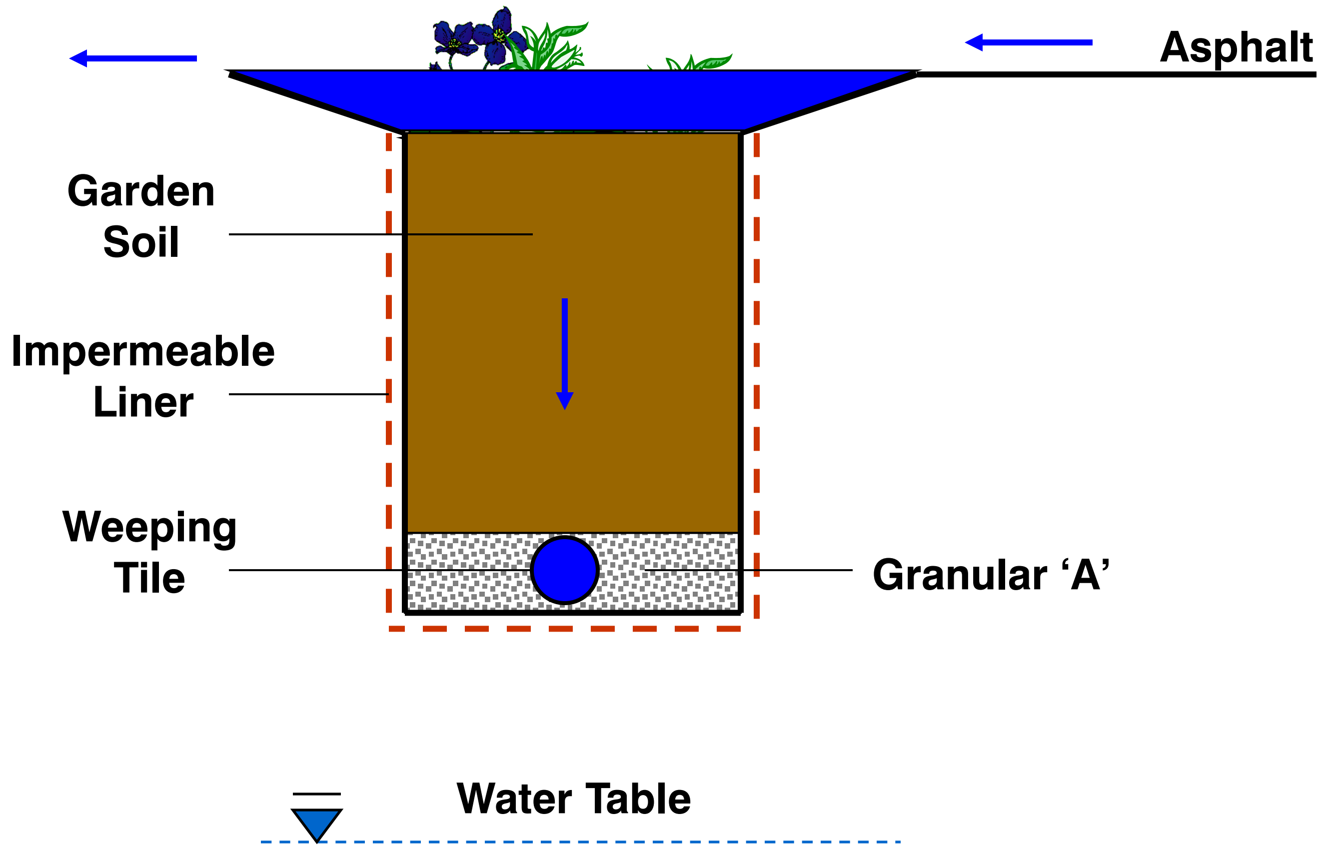
King City Study:
Plan View



Permeable Pavement – *King City*



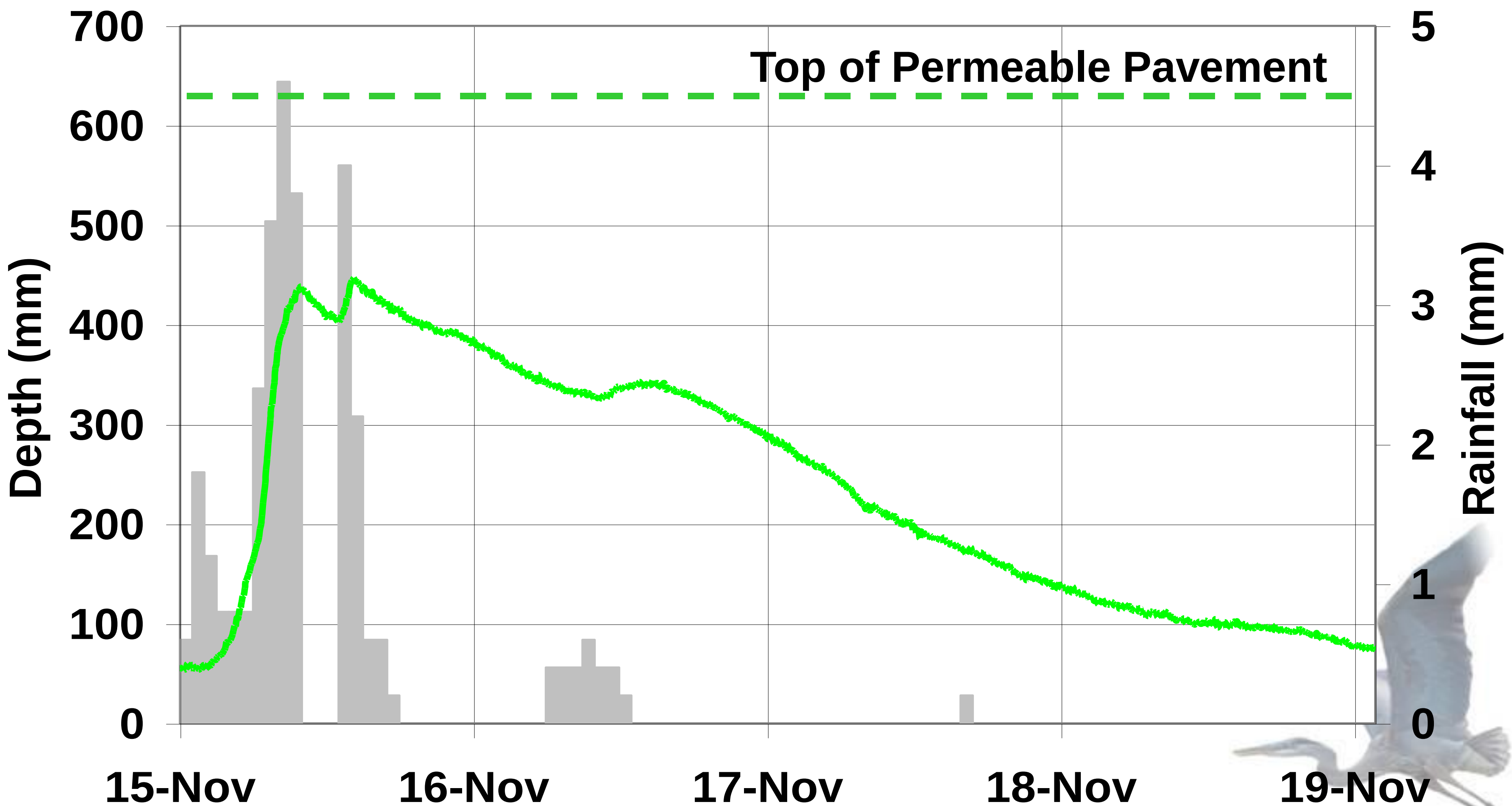
Bioretention *– King City*




Hanson

Surface Water Storage and Infiltration

31 mm Rain Event



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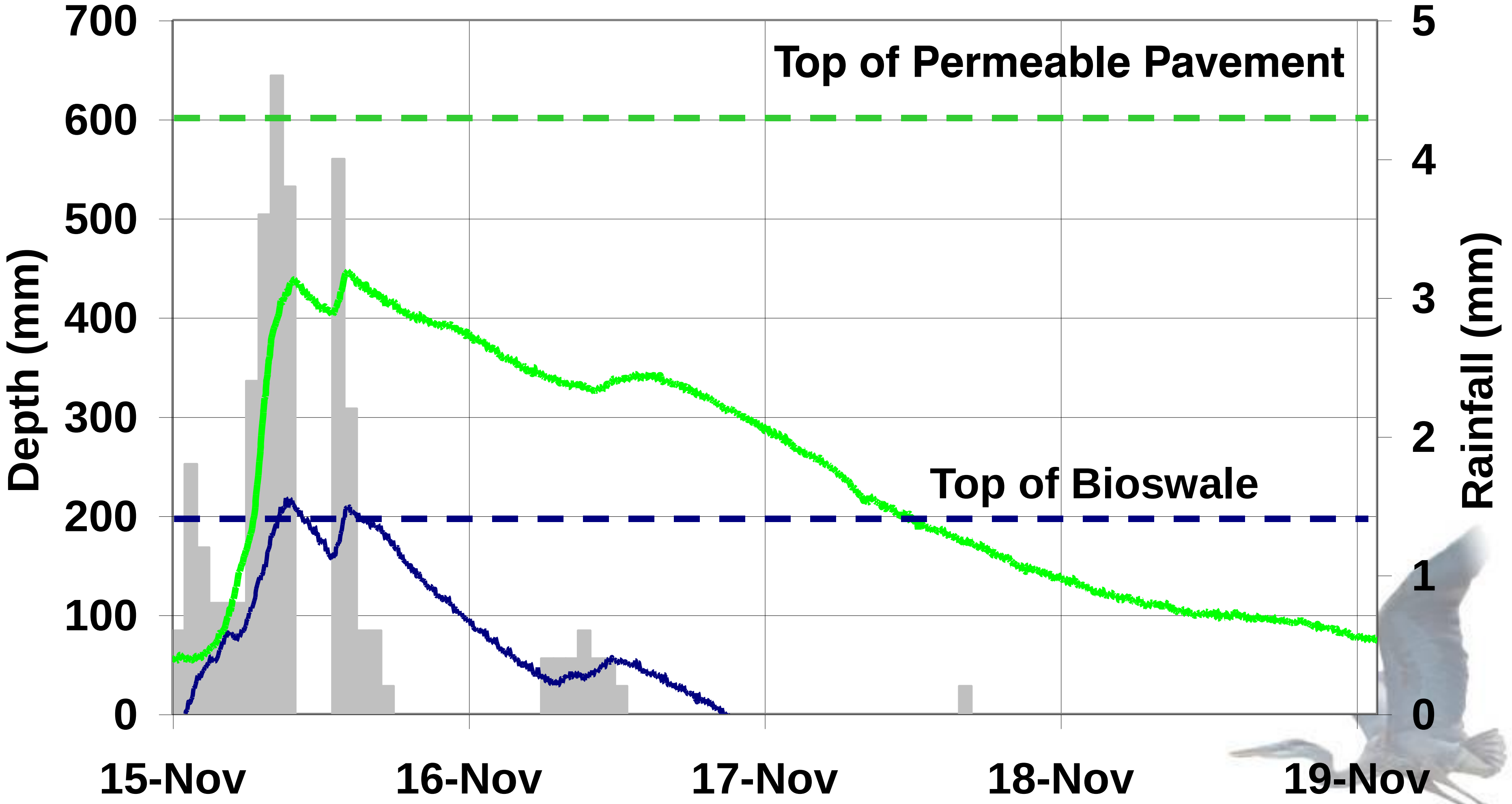


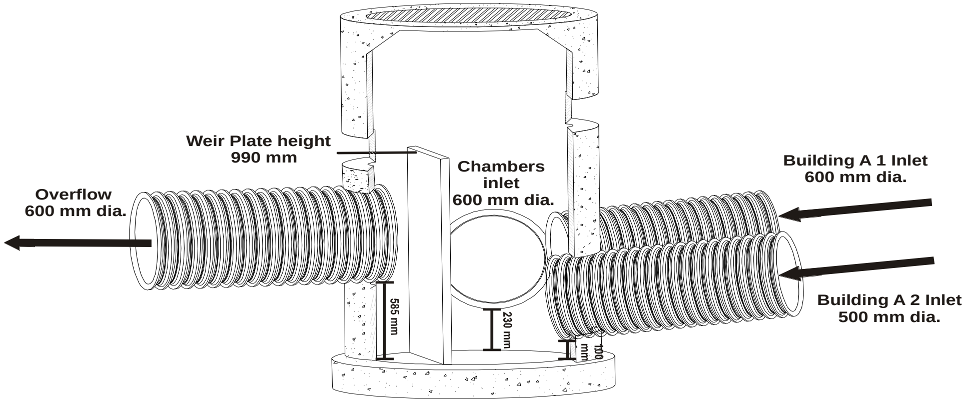
Performance on fine-textured soils: *Local studies*

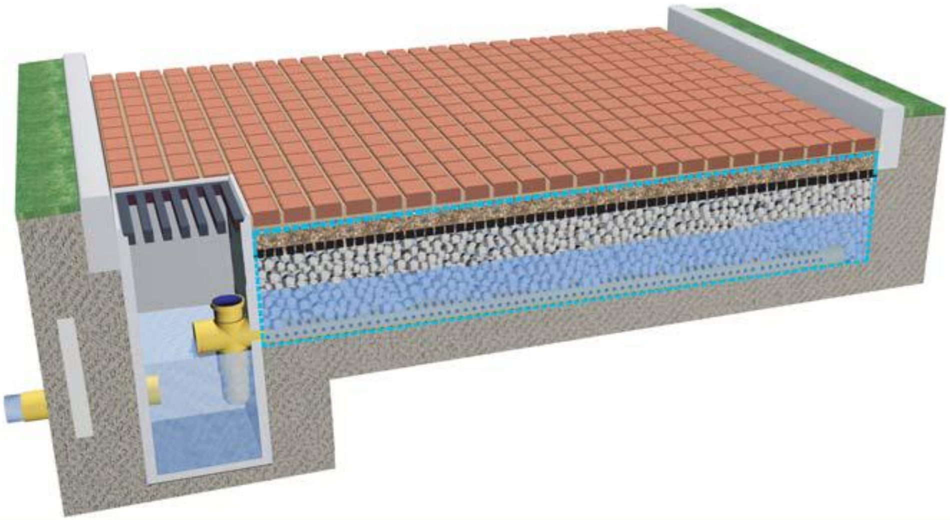
Study	Practice	Location	Soil Type	Runoff reduction	Underdrain
U of Guelph & TRCA, 2011	Permeable Pavements	Kortright Parking Lot	Silty Clay Till	**44%** (interim result 2012)	Yes
TRCA, 2008	Permeable Pavement	Seneca College Parking Lot	Silty Clay Till	**99%**	No
SWAMP, 2002	Perforated Pipe	Toronto Resid. road	Clay to Clay Silt Till	**47 to 86%**	No
TRCA, 2011	Infiltration Chamber	Richmond Hill Roof Runoff	Sandy Silt Till	**85%**	No
TRCA, 2011	Detention Chamber	Brampton Parking Lot	Silty Clay Till	**negligible**	No
TRCA, 2011	Bioretention	Kortright Parking Lot	Silty Clay Till	**Approx. 90%** (interim result)	Yes

Performance on fine-textured soils: *International Studies*

Study	Practice	Location	Soil Type	Runoff reduction	Underdrain
Fassman and Blackbourn, 2010	Permeable Pavement	Auckland, New Zealand	Silty Clay and clayey silt; 6.0 – 7.4% slope	**33 – 71%** (based on runoff coef.)	Yes
Collins et al, 2008	Permeable Pavements	Kingston, North Carolina	Sandy loam to sandy clay Loam	**36 – 67%** (median)	Yes
Dreelin *et al*., 2006	Grassed grid pavement	Georgia	35 – 60% Clay	**93%** (events < 20 mm)	Yes
Kwiatkowski *et al*, 2007	Pervious Concrete	Pennsylvania	Silty sand	**100%** (events < 50 mm)	No

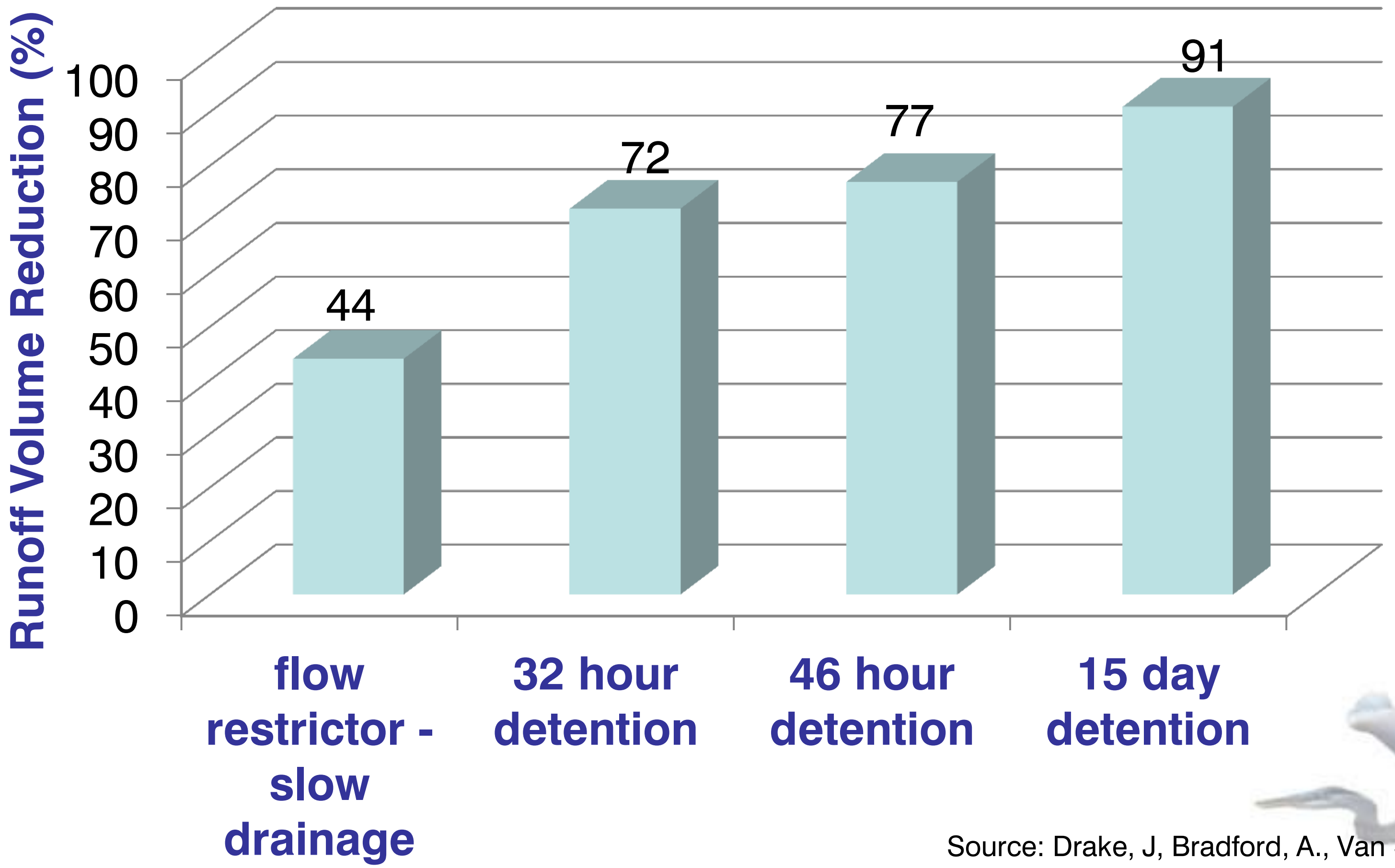
Underdrain and overflow configuration





Kortright Permeable Pavements

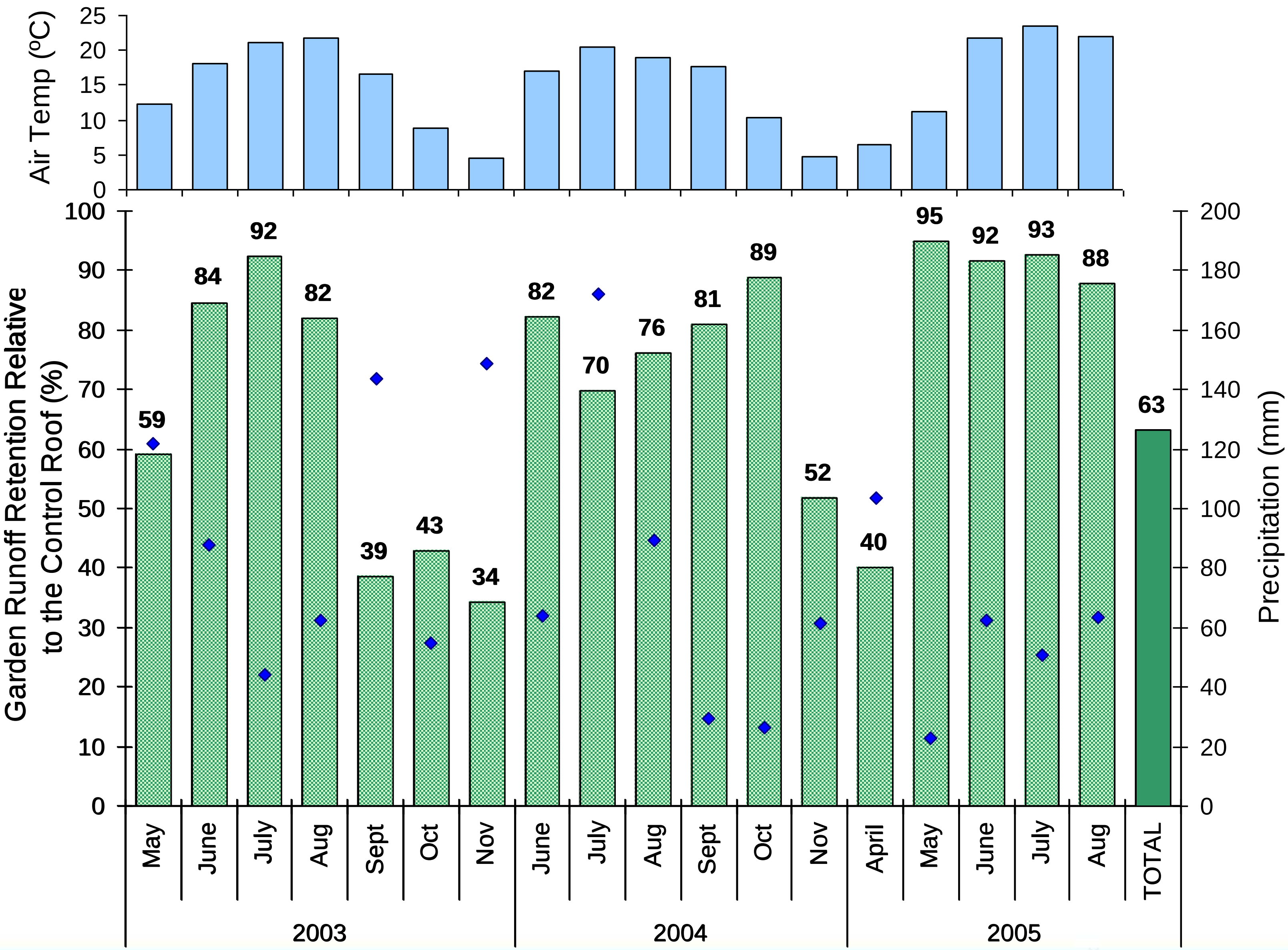
Volume Reduction



Source: Drake, J, Bradford, A., Van Sete

Reducing runoff through Evapotranspiration

Green roof runoff retention by month



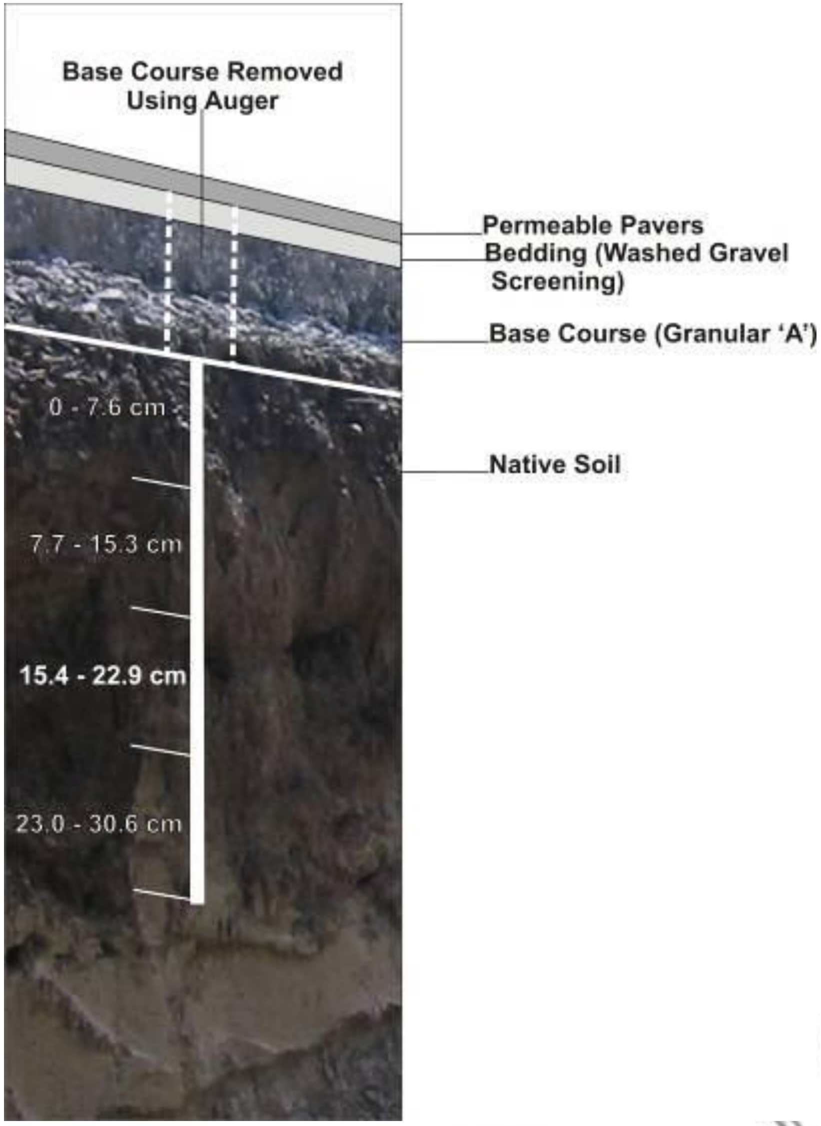
Design Guidance: *Fine textured soils*

- Need improved guidance in Ontario on:
  - minimum percolation rates for infiltration practices
  - design of infiltration practices on tight soils
- Design around limitations of soil permeability
  - Allow for evapotranspiration or re-use where feasible
  - Increase hydraulic head and allow incomplete drawdown between events where feasible
  - Provide redundancy in case of failure
  - Add flow restrictors to underdrains

What is the risk of soil and groundwater contamination from stormwater infiltration and how should it be managed?

Soil Quality Evaluation

- Depth profile of native soil beneath PICPs and bioswales
- Soil sample taken at nearby reference site for comparison



Surveys of Older PICP Sites

Belfountain Conservation Area (17 years)

Kortright Conservation Area (4 years)

Jerrett's Funeral Home (10 years)

Guelph University (13 years)

Sunset Beach (8 years)

Humberwood (12 years)

Humber College (4 years)

Surveys of Older 'Bioretention' cells/swales

York University (6 years)

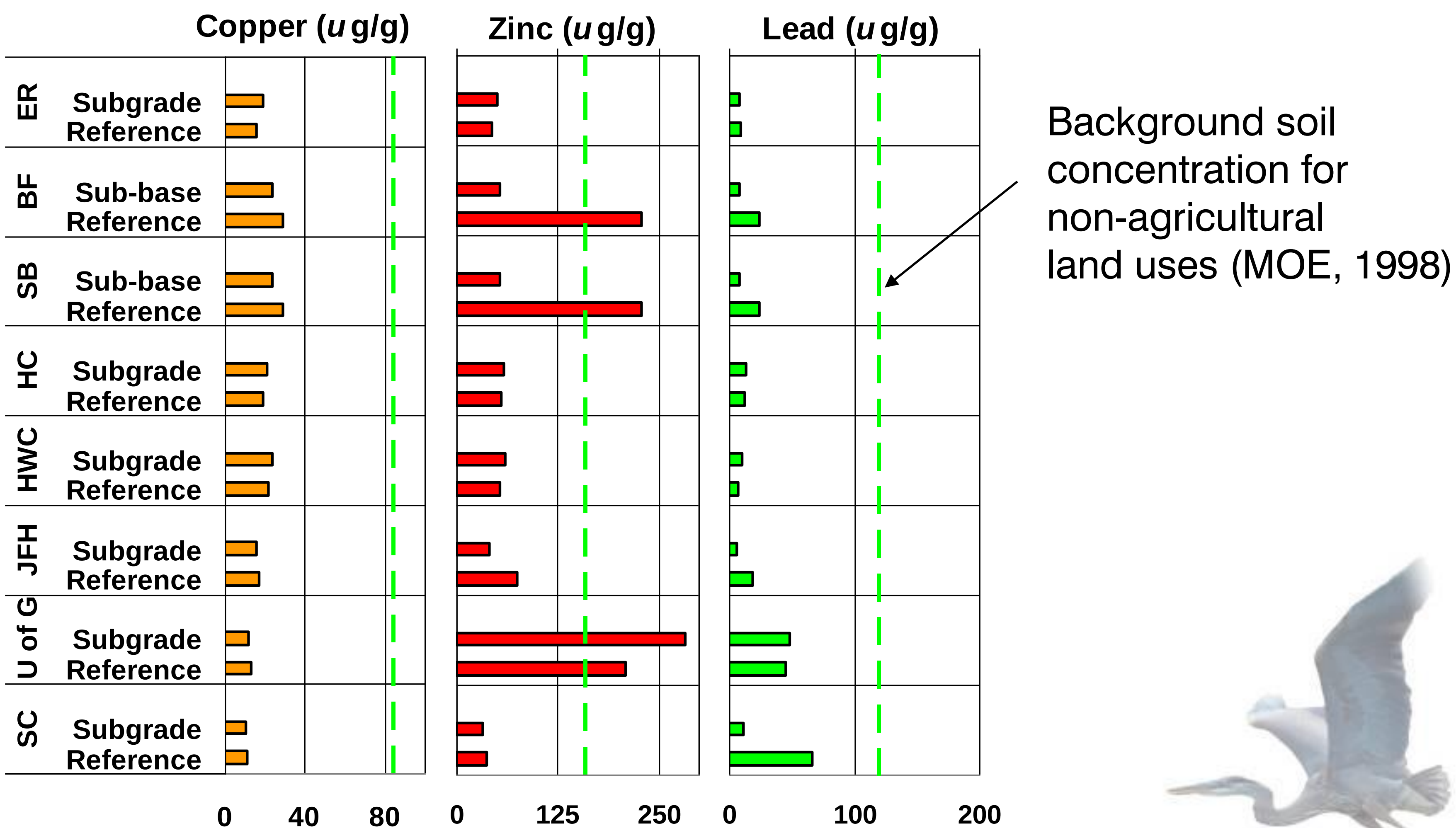
University of Toronto (2 years)

De Vere Gardens
(> 18 years)

TRCA head office
(11 years)

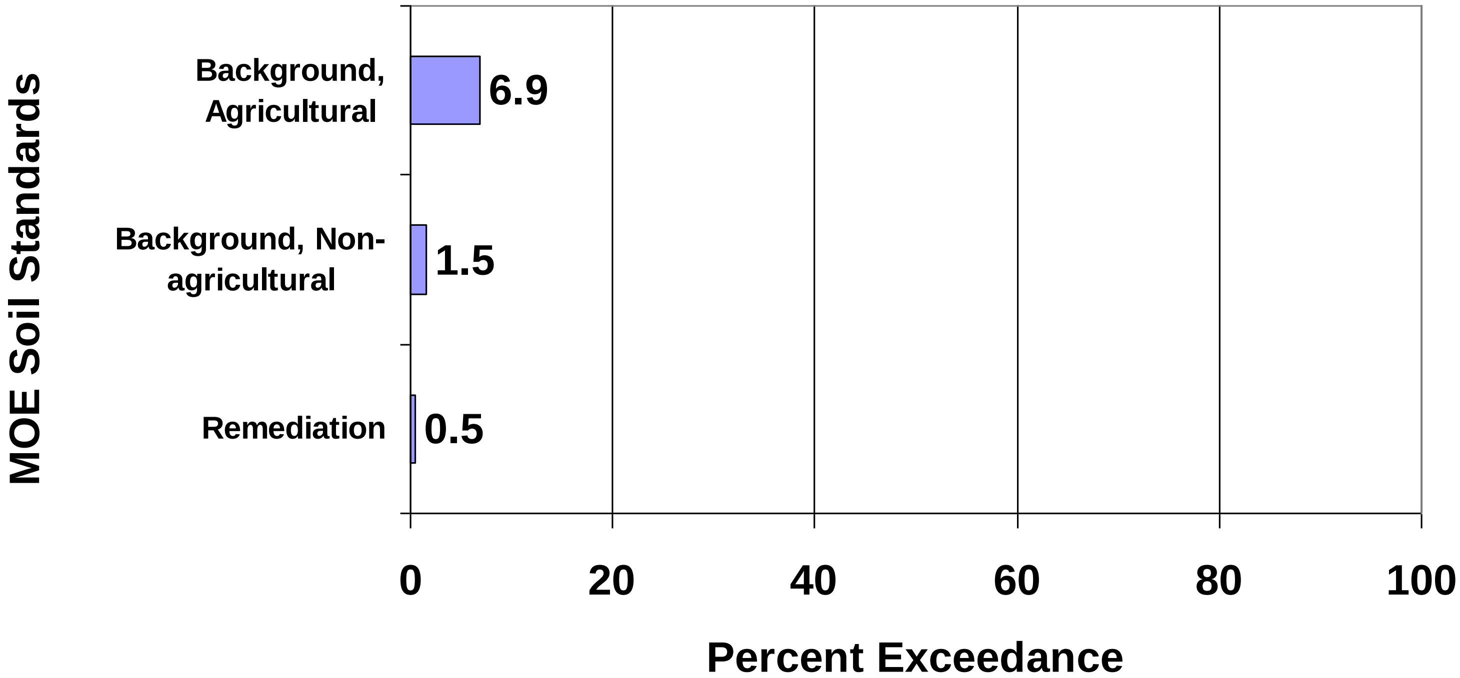
Royal York
(> 18 years)

Soil Quality



Soil Quality

- 14 sites (8 permeable pavement, 6 bioswales/ditches)
- 28 pollutants (12 metals, 16 PAHs)
- Age between 2 and > 20 years



Soil Quality – other studies

Study	Sites	Age of Sites	Soil depth at which metal concentrations exceeded Ontario standards
Dierkes and Geiger, 1999	3 Highway Vegetated Filter Strips, Germany	11 – 24 years	0 – 10 cm
Dechesne *et al*, 2005	4 infiltration basins, France	10 - 21 years	0 – 5 cm
Barraud *et al*, 1999	Soakaway, France	> 30 years	No exceedance at 0 – 65 cm
J.F. Sabourin & Assoc., 2008	3 Grassed swales, Residential roads, Ottawa	13 years	No exceedance at 0 – 15 cm

Soil Contamination Risk

- Potential for contamination highest in end-of-pipe infiltration basins and highway swales and filter strips

- Little evidence of contamination from distributed micro-controls, even after more than 10 years

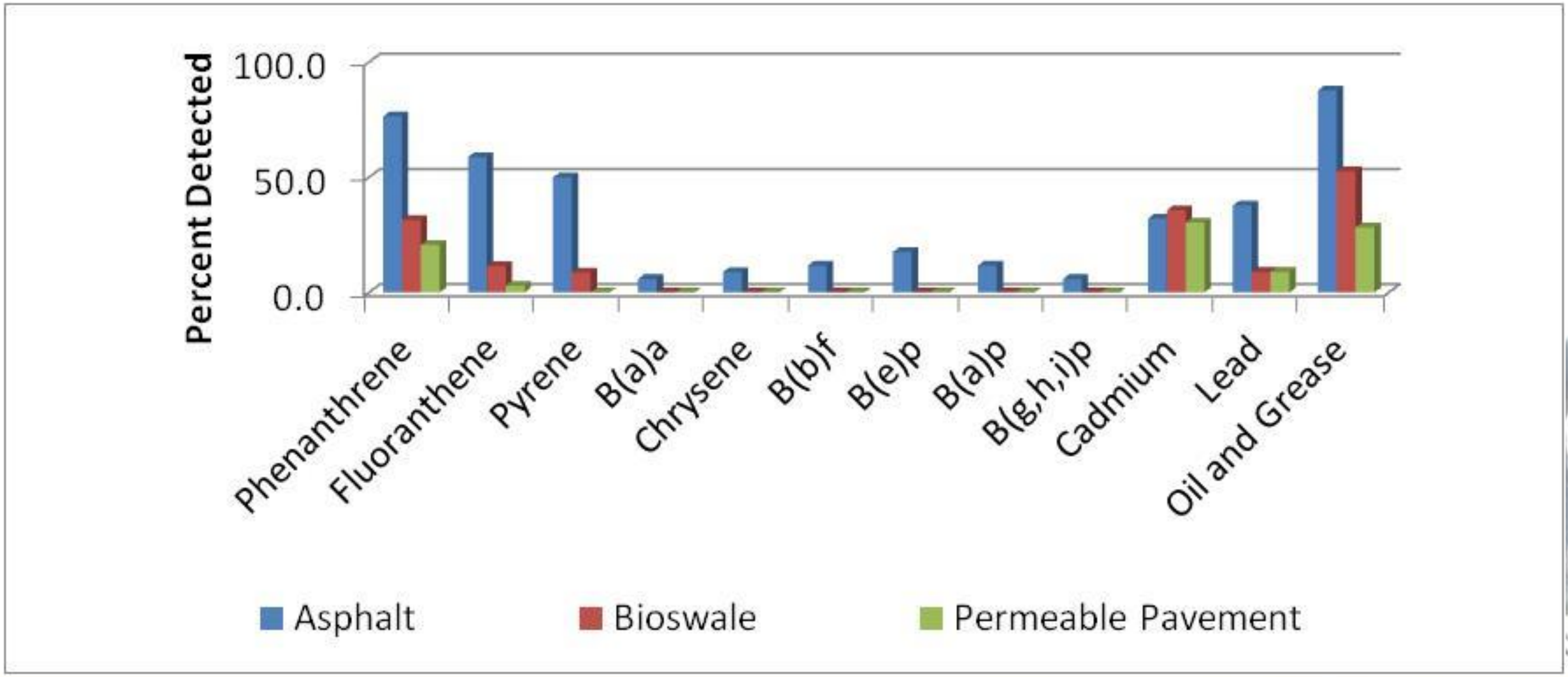
What is the risk of soil and groundwater contamination from stormwater infiltration and how should it be managed?

Risk of groundwater contamination

- Most pollutants retained within upper 0.5 m of soils;
- Notable exceptions include:
  - Nitrate but urban runoff concentrations are typically low;
  - Road de-icing salts;
- Infiltration of dissolved de-icing salts can increase mobility of certain heavy metals

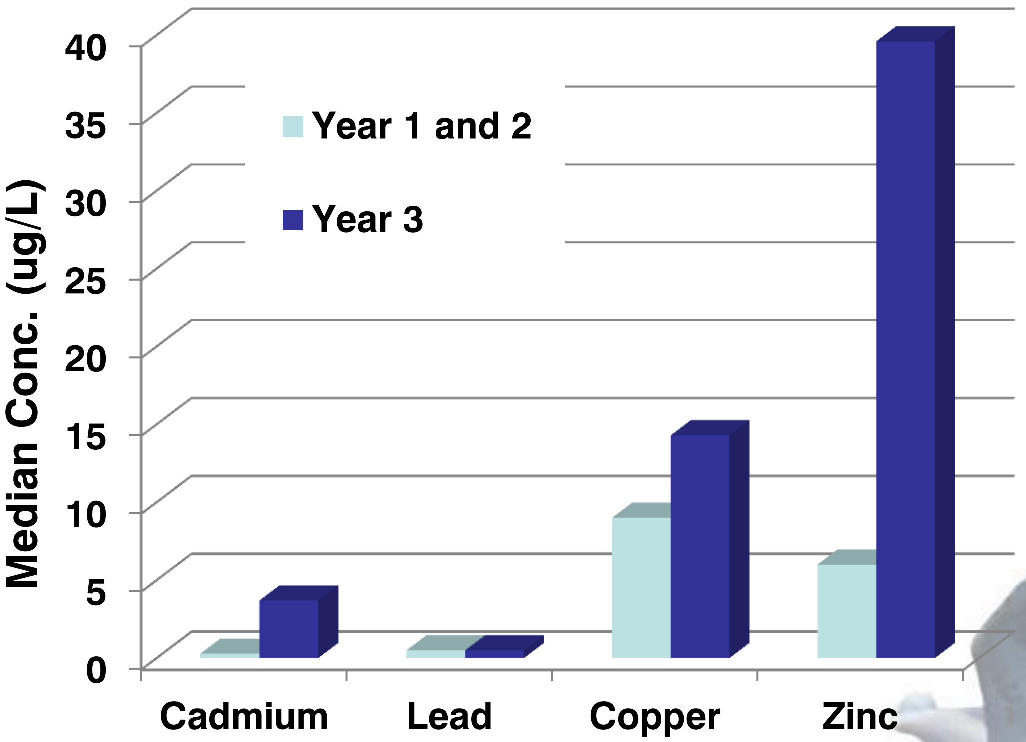
King City Study: *groundwater quality*

- Most potential groundwater contaminants were detected more frequently in asphalt runoff



Changes over time

- Metal mobility affected by road salt infiltration:
  - Ion exchange
  - Complexation
  - Colloid dispersion



But what about salts?

- Toxic to freshwater ecosystems
- Contaminate aquifers
- Adversely affect soil structure
- Increase contaminant mobility
- Hastens corrosion, etc.

- …but they are an inseparable part of our car culture!!

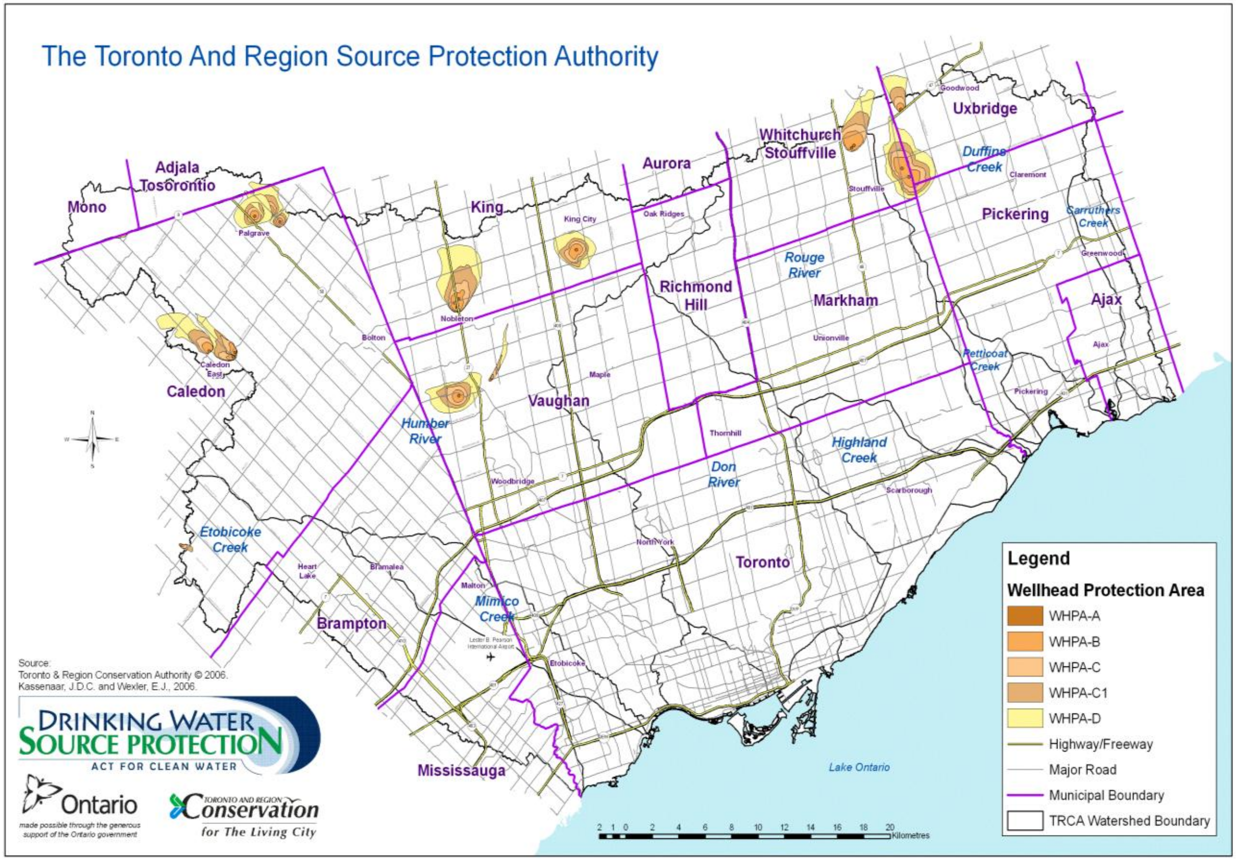
Drinking Water Source Protection:
Designated Threats (Ont Reg 287/07)

- Waste disposal
- Sewage facility
- Manure storage/spreading
- Commercial fertilizer
- Pesticide applications
- Road salt application/storage
- Snow storage
- Handling and storage of chemicals
- Dewatering
- Livestock grazing or pasturing
- Other 'vulnerable' areas

Groundwater Risk Assessment Framework

For designated threats, the framework considers:

- Proximity to wells
- Vulnerability of aquifer to contamination
- Contaminant type and quantity



Avoid groundwater contamination by…

- Understanding hydrogeologic context and local goundwater uses
- Consulting local drinking water source protection plans and assessments
- Adhering to at least 1 m. separation distance between the base and water table
- Only infiltrating runoff with low salt concentrations (e.g. roof, back alleys) in vulnerable areas

Are LID approaches affordable?

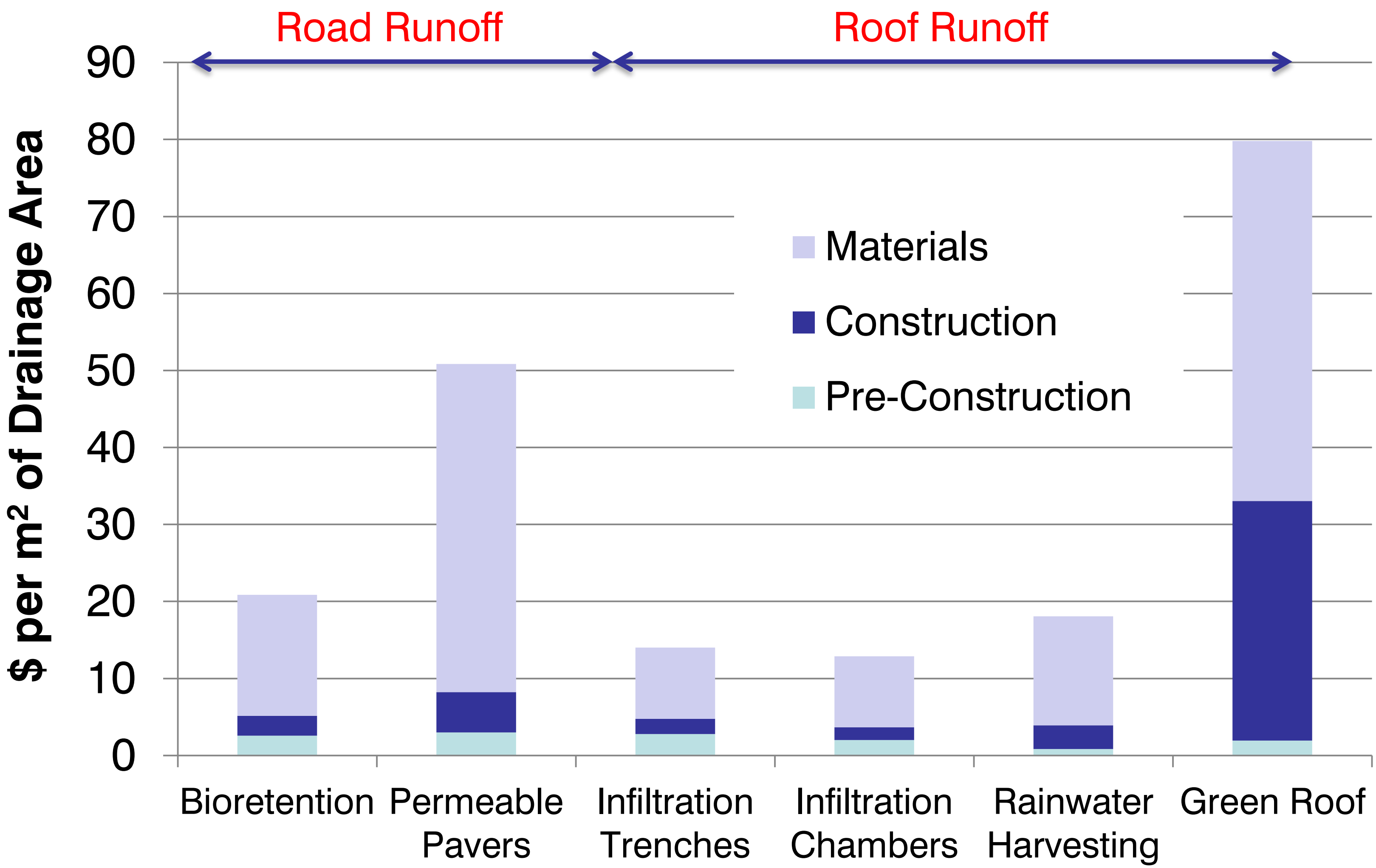
Costs vary depending on the context

- New or retrofit
- Incentives and 'credits'
- Economies of scale
- Space constraints and cost of buildable area
- Site specific factors
- Public Costs/benefits

Templated LID Practice Costs

- 2000 square meter drainage area
- Practices sized to LID design guide specs
- RS Means construction cost data and industry surveys
- Initial Capital and Life Cycle Costs
- Various scenarios – partial, full, no infiltration
- Site level costing tool for preliminary scoping

LID Capital Costs



Preliminary data

M. Uda and TRCA, 2012

Future work

Initial Capital costs

↓

Life cycle costs/benefits + case studies

↓

Site scale tool

↓

Public costs and benefits

How do we ensure that stormwater infrastructure is adequately maintained?

It can get ugly!

Operation and Maintenance

- Include maintenance requirements in site plan agreements and C of A
- Ensure the facility is operating according to design once constructed
- Inspect and maintain regularly
- Track inspections and servicing
- Enforce requirements

Enforcement tools

- Site plan and subdivision agreements
- Waste discharge or sewer use bylaw
- MOE Certificate of Approvals
- Mandatory maintenance contracts
- Easements

- Municipal success stories
  - London, Peterborough, Pickering…

Practices that require little maintenance

- LID practices that infiltrate roof runoff
- Perforated pipe systems on low traffic streets with good pre-treatment
- Bioretention and other vegetated practices?
- Compost blankets, improved top soil depth, downspout disconnect…

Improved maintenance will require…

- Compliance control programs
- User friendly inspection/servicing data bases
- Guidance on what needs to be done, when, and how
- Political will to enforce procedures and requirements
- Well resourced municipal O&M departments

Thank You

STEP website:

www.sustainabletechnologies.ca

Tim Van Seters
Phone: 289-268-3902
Email: tvanseters@trca.on.ca

Innovatve Stormwater Interactive Mapping Tool

www.iswm.ca

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STEP Sustainable Technologies Evaluation Program