Lot-level approaches to control urban flood risk and mitigate basement flooding

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ICLR Friday Forum

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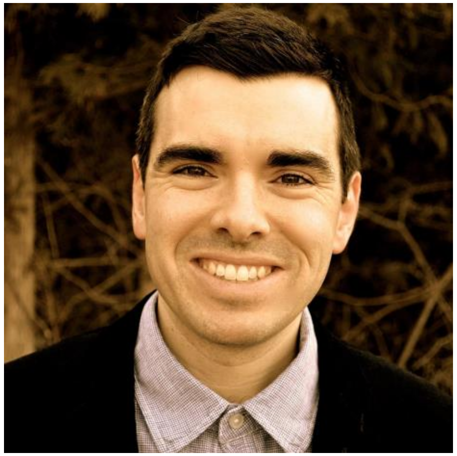
Introduction



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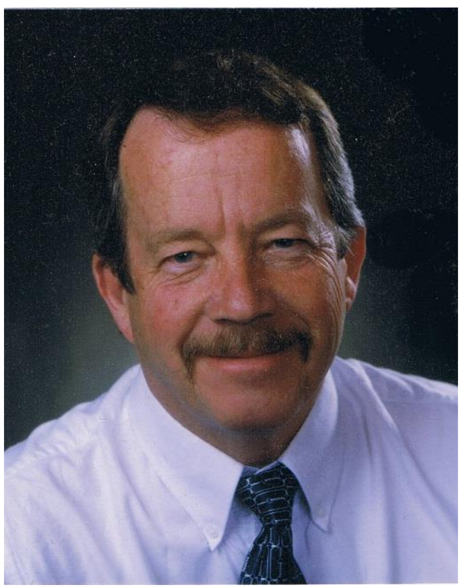

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IMPROVING LIFE

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Water Resources

Outline

1. Urban hydrology background

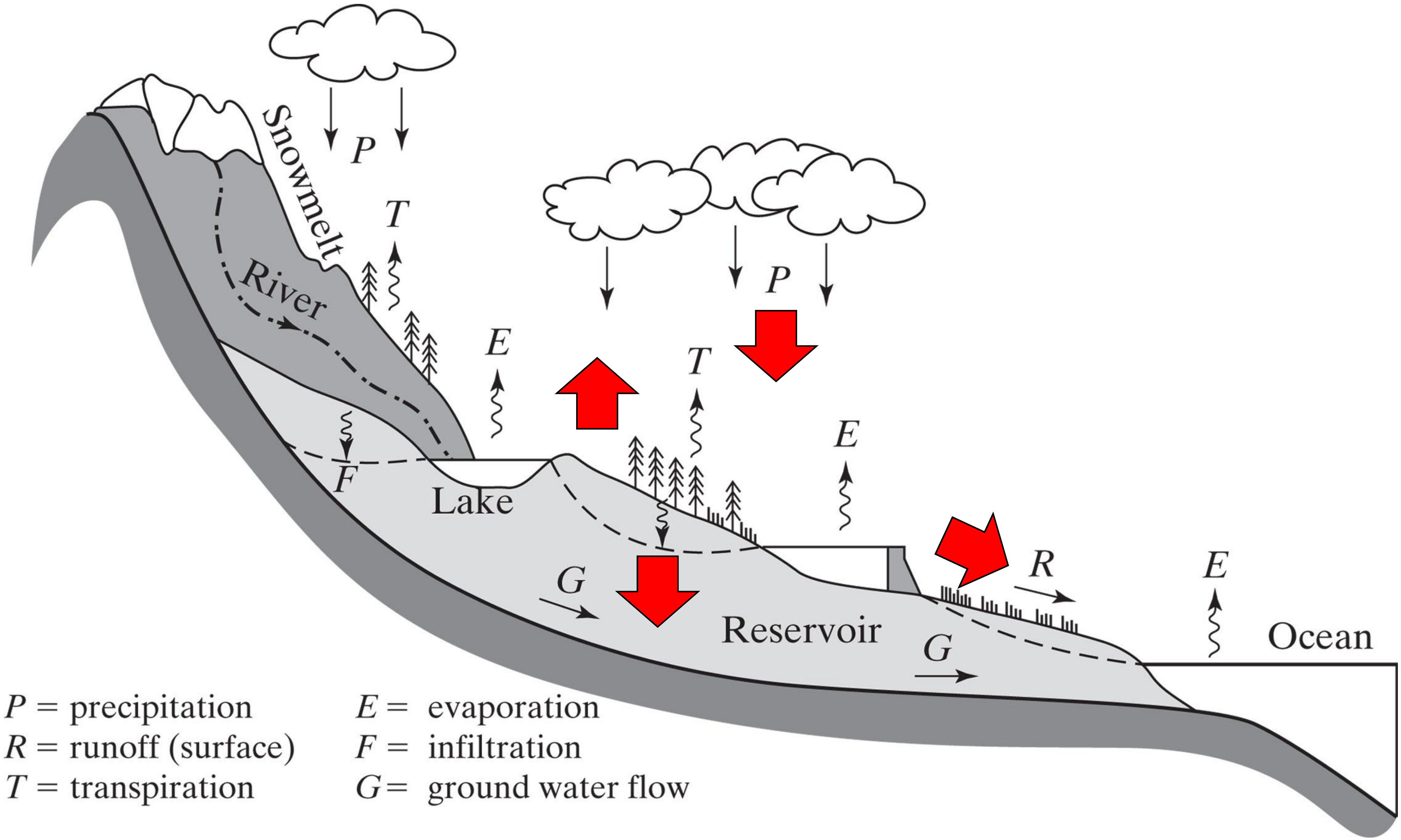
2. Basement flooding

3. Backwater valves

4. Future research direction

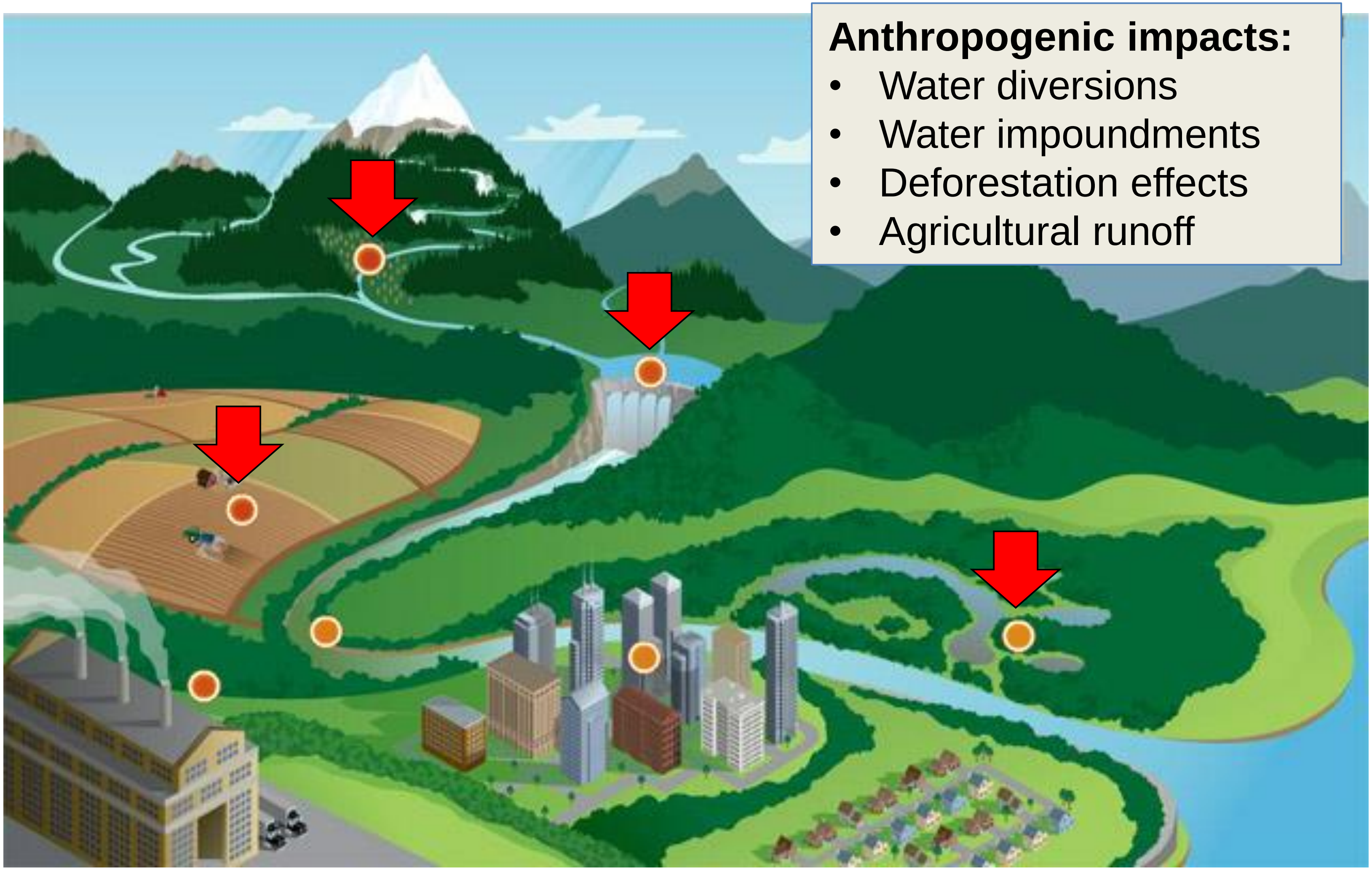
1. Urban hydrology background

Hydrologic cycle



From: Bedient et al. (2012)

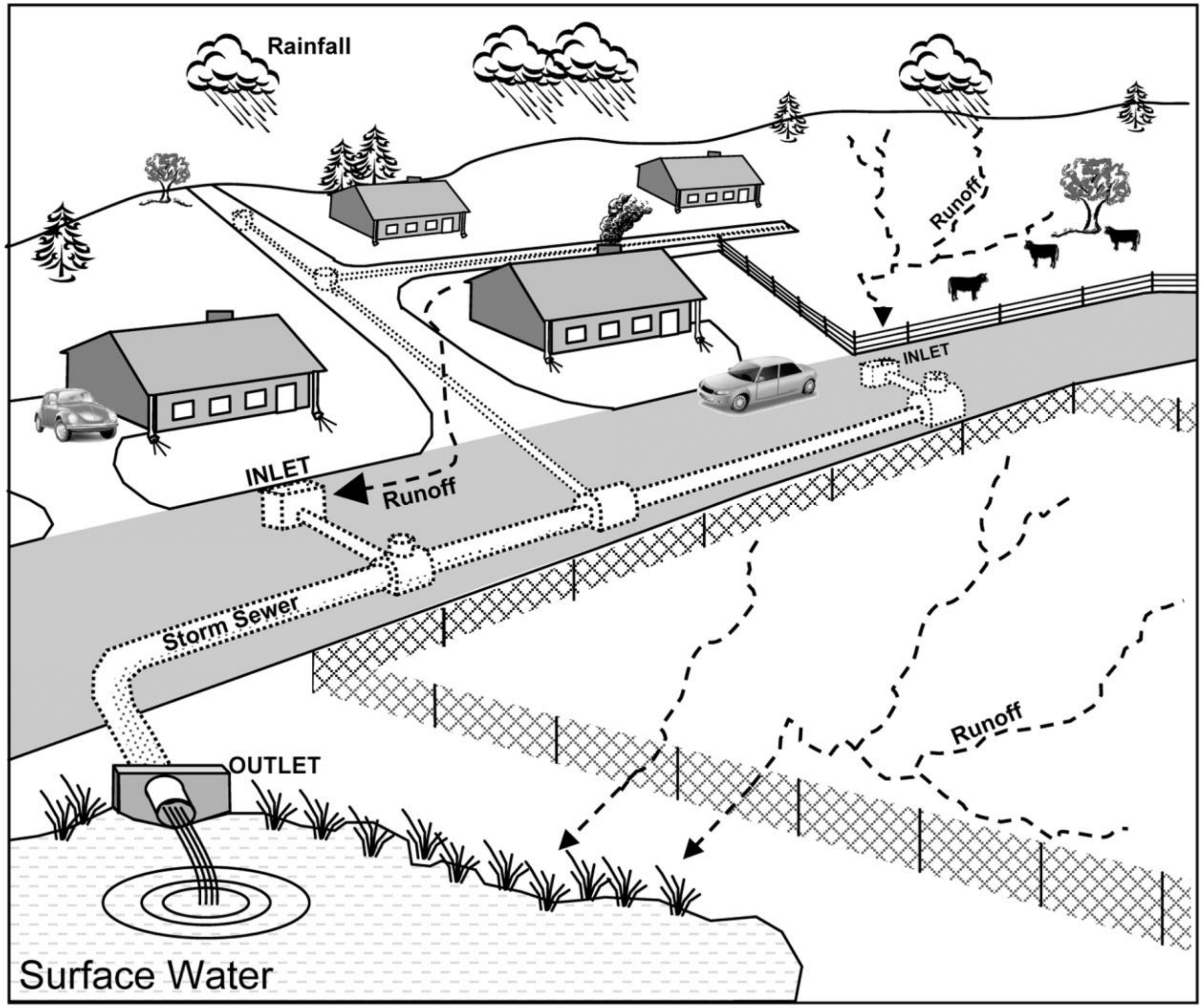
Anthropogenic effects:
Modifications to natural systems



Anthropogenic impacts:
- Water diversions
- Water impoundments
- Deforestation effects
- Agricultural runoff

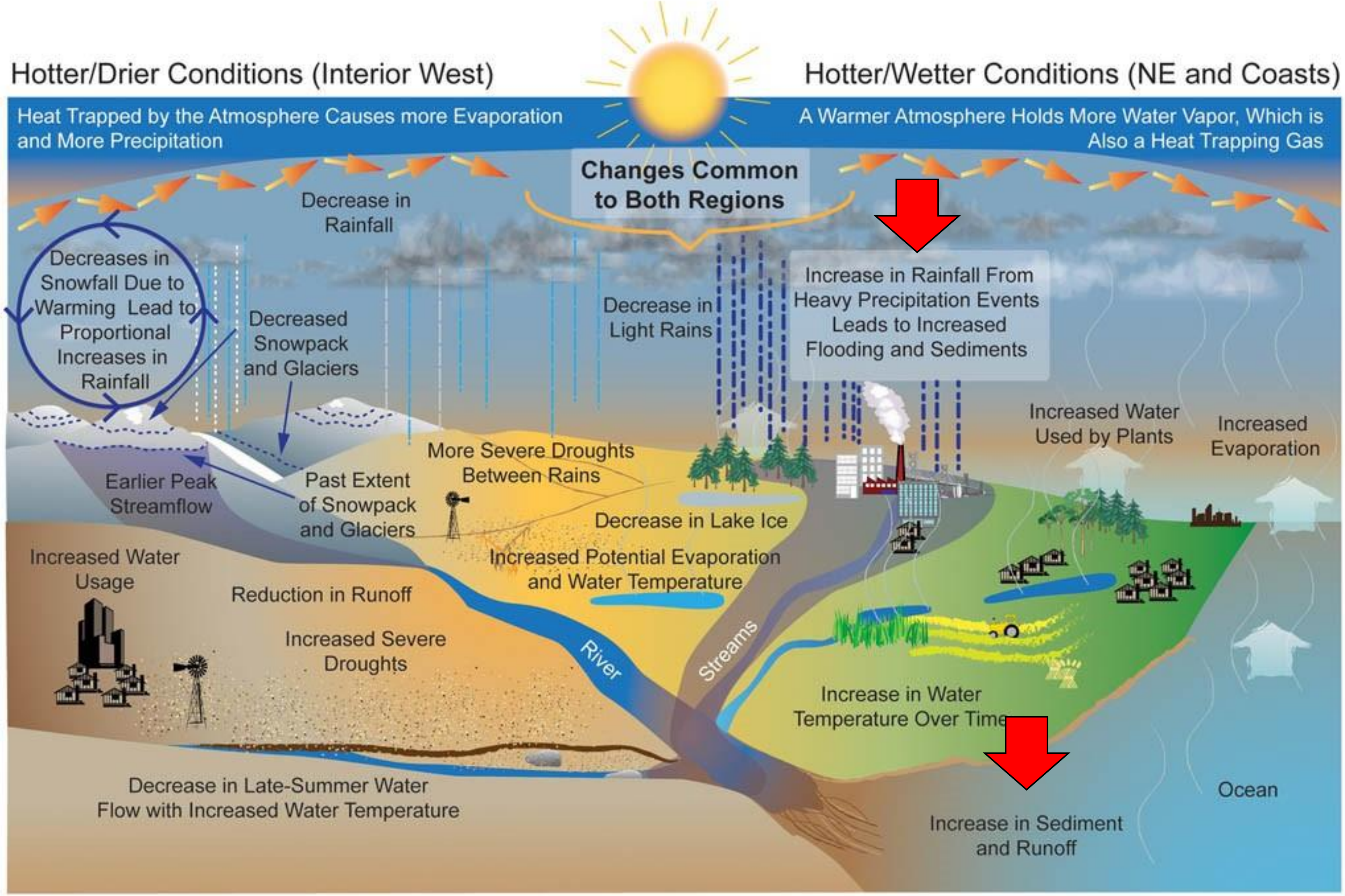
From: http://www.nature.org

Anthropogenic and land development effects



From: Bedient et al. (2012)

Anthropogenic and climate change effects



From: https://www.epa.gov

Recent examples of Canadian floods

Toronto 2013

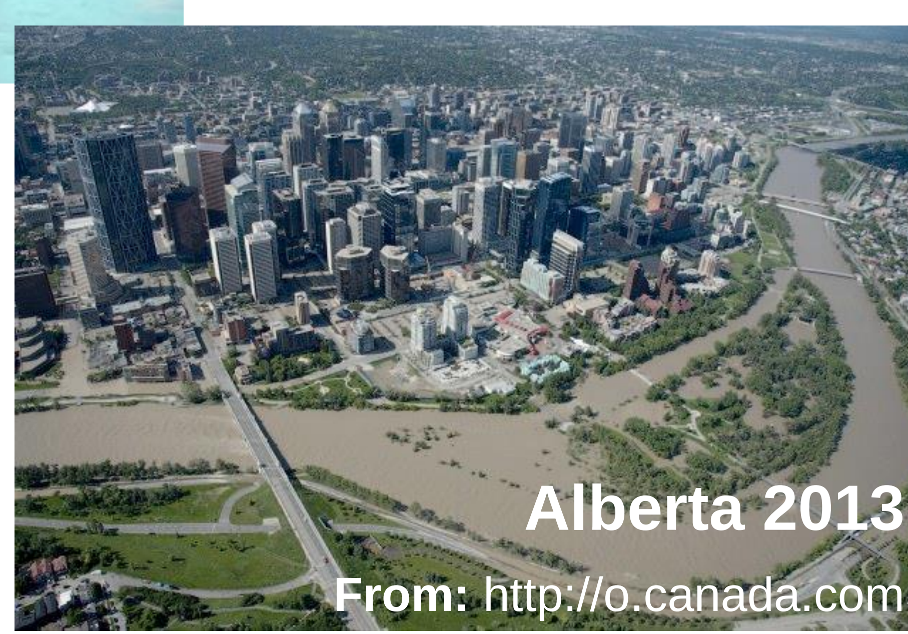
From: http://www.lexikubrak.com/

Kashechewan 2015

From: http://www.thestar.com

Essex County 2016 (Windsor, Tecumseh)

From: http://www.cbc.ca

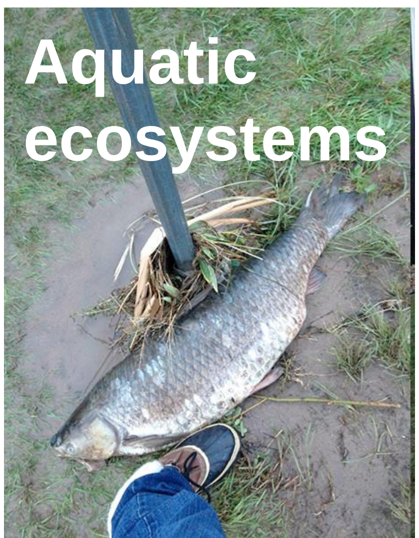


Alberta 2013

From: http://o.canada.com

Socio-economic impacts of floods

Basement flooding



http://i.huffpost.com

2. Basement flooding

Basement flooding

- Flood events in Canada
  - Largest property damage of all natural disasters (Burn and Whitfield 2016)

- Basement flooding
  - Largest source of home insurance claims in Canada (IBC 2014a,b; Sandink 2015)
  - $1.8 billion in insured losses for water damage incurred every year (Eleuterio et al. 2013)
  - This trend is increasing

Basement flooding

- Extreme precipitation events are increasing in frequency and magnitude (Wang et al. 2014)

- Urbanization and changes in land-use can increase the extent and damages due to flooding (König et al. 2002)

- Greater economic wealth and populations concentrated in urban areas increases damages and vulnerability to flooding (Spekkers 2015)

Long-term sustainability of Canadian stormwater infrastructure is a growing concern (Upadhyaya et al. 2014)

Economic impact of basement flooding

Date	City	Return period of storm	Basement flooding	Insurable damages (in millions of $)*
May, 2000	Toronto, ON	25 to 50 years	> 3000 basement floods	168
July, 2004	Edmonton, AB	200 years	> 4000 basement floods	199
June, 2005	Calgary, AB	200 years	Unknown	351
August, 2005	Toronto, ON	> 100 years	> 12,000 flooded basements	732
June, 2013	Calgary, AB	100 years	Unknown	1863
July, 2013	Toronto, ON	> 100 years	> 5000 basement floods	1019

Source for insurable damages: IBC, 2015

* **adjusted to 2014 dollars**

Three types of basement flooding

- Basement flooding occurs primarily due to inadequate sanitary and storm sewer systems or insufficient foundation and lot drainage systems (Kesik and Seymour 2003)

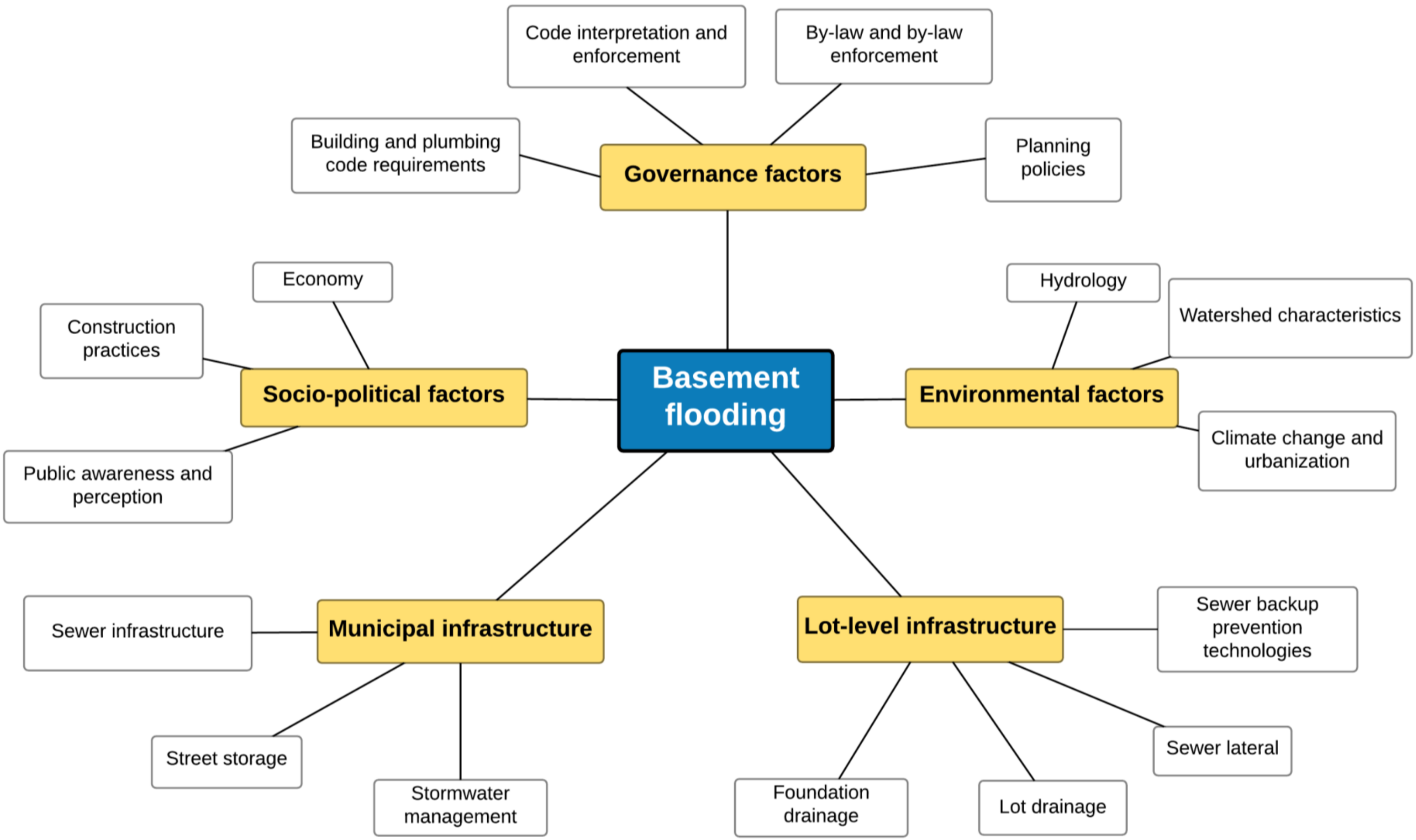
- Basement flooding can result from three mechanisms:

OVERLAND FLOODING

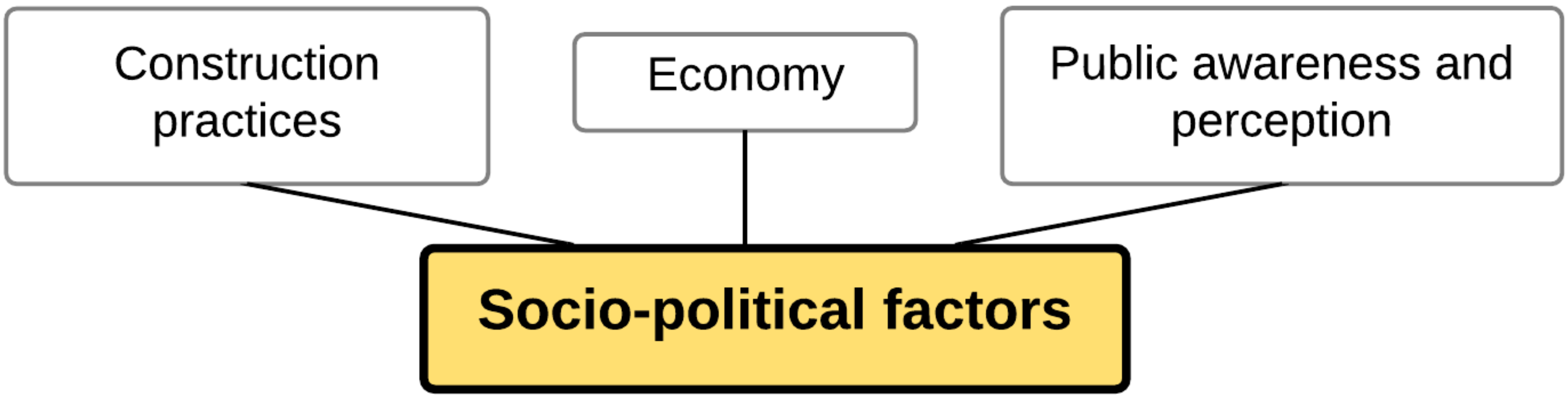
INFILTRATION FLOODING

SEWER SURCHARGE

Many factors influence basement flooding vulnerability

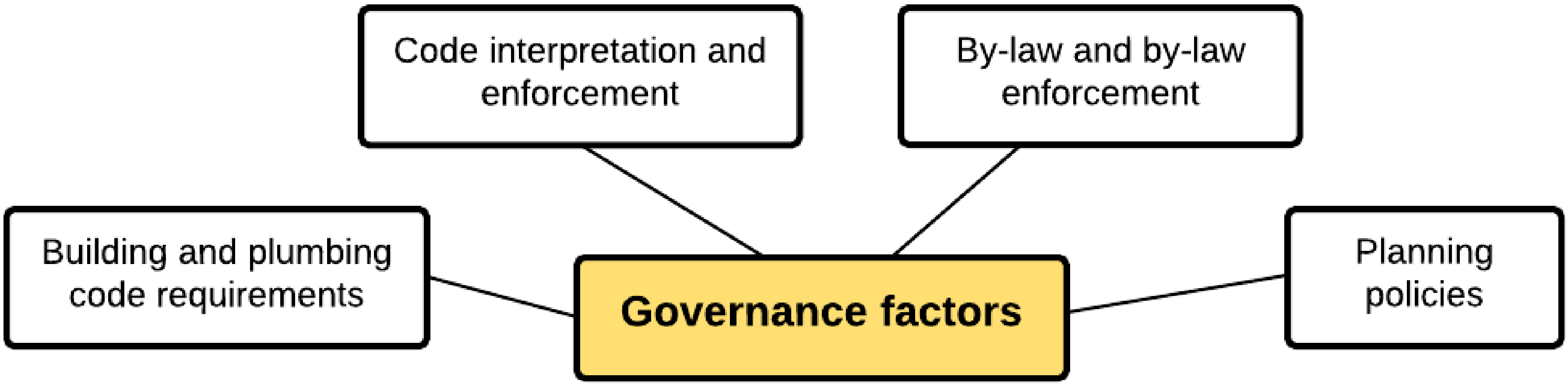


Factors affecting basement flooding vulnerability



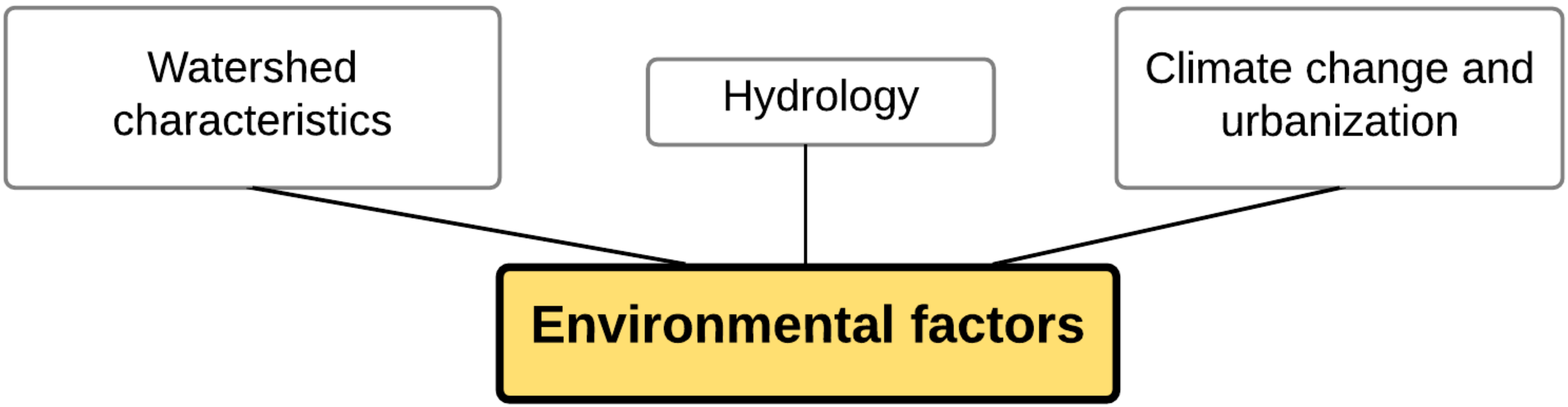
Affect the public and industry's approach to the construction and adoption of flood mitigation technologies

Factors affecting basement flooding vulnerability



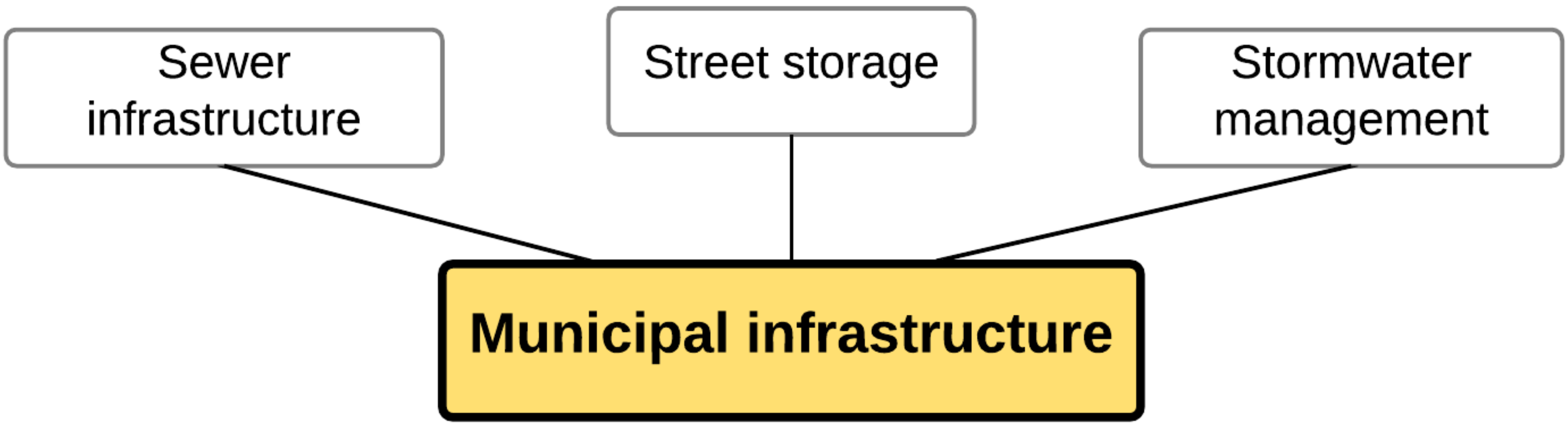
Affect decisions, requirements and legal aspects related to the installation of flood mitigation approaches and technologies

Factors affecting basement flooding vulnerability



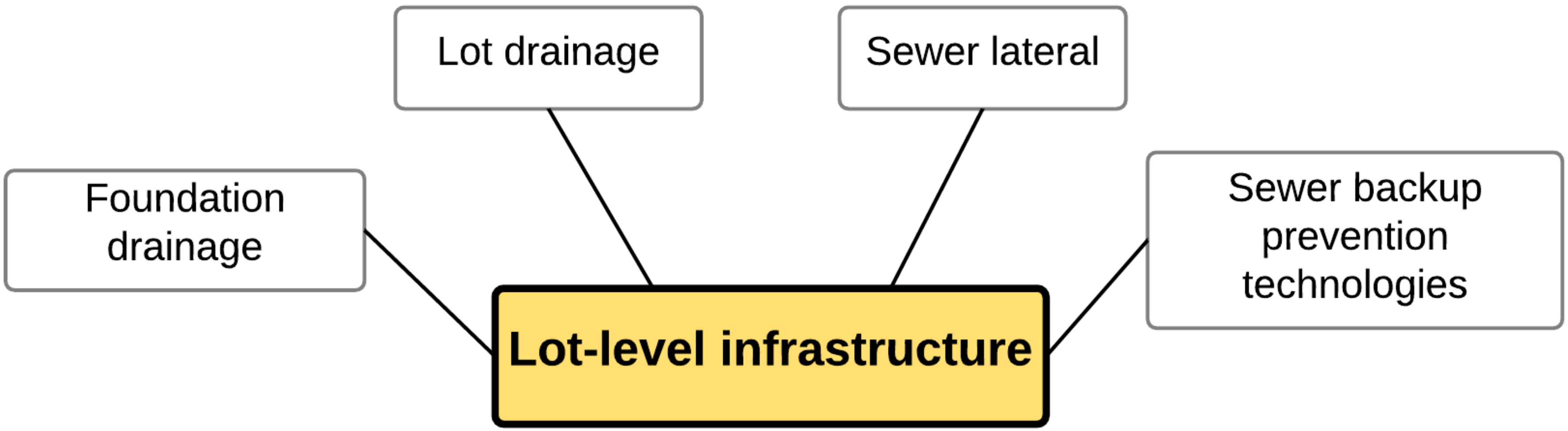
Responsible for the magnitude and frequency of the hydrometeorological events that produce flooding

Factors affecting basement flooding vulnerability



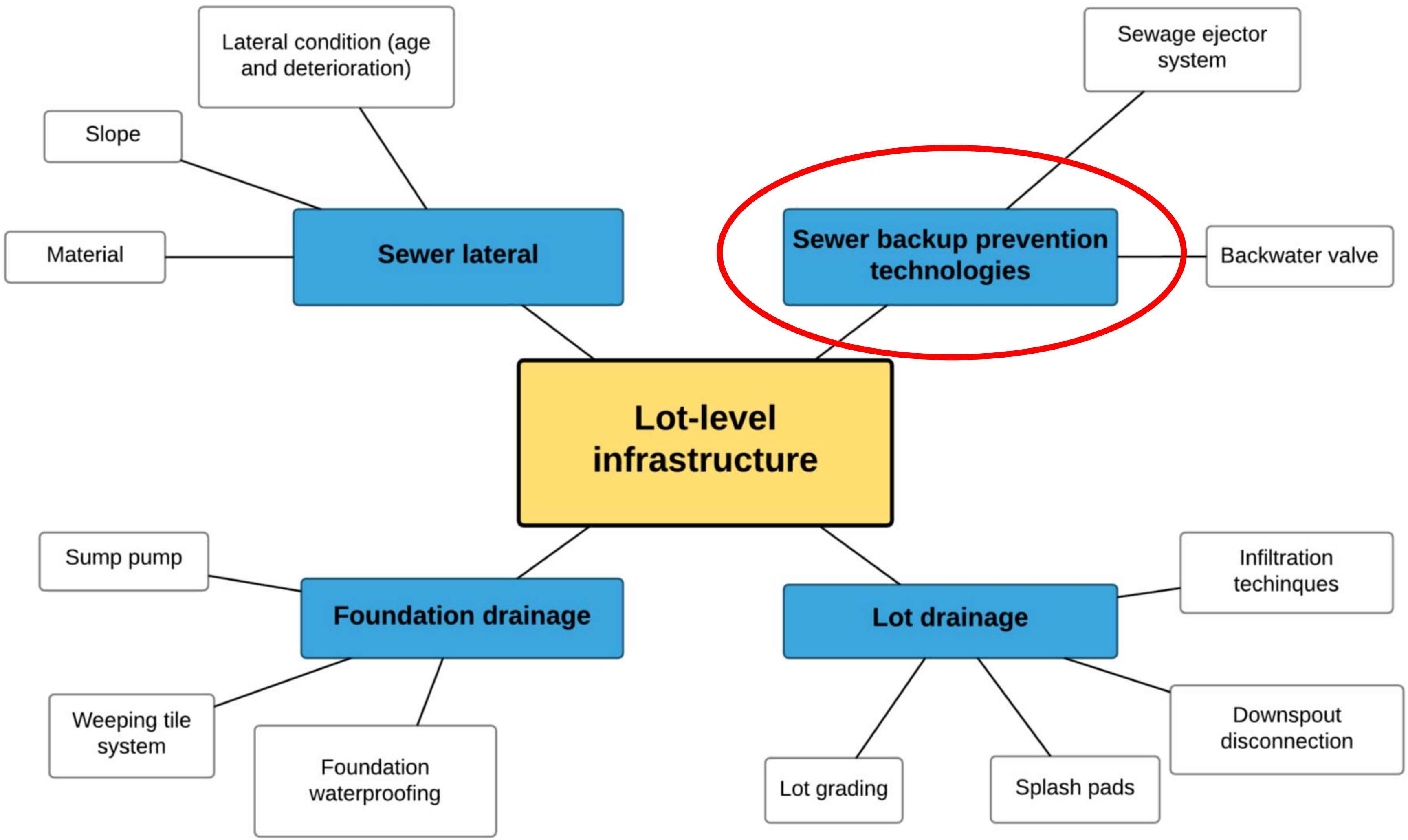
Systems or approaches that can be applied at the municipal level to manage stormwater and wastewater

Factors affecting basement flooding vulnerability



Technologies or approaches that can be applied to individual homes to reduce the risk of basement flooding

Lot-level approaches to reduce flood risk



Mitigating strategies

Infiltration flooding

Infiltration flooding

- Risk reduced by ensuring perimeter of the building is well-drained (e.g., weeping tile systems) and protecting the foundation wall against moisture (Swinton and Kesik 2008)

- Flood damages can be reduced through foundation drainage, waterproofing and flood proofing systems (Sheaffer et al. 1967)

- Failure potential due to clogging of the weeping tile system, sump pump failure and improper backfilling practice exist

Mitigating strategies

Overland flooding

Overland flooding

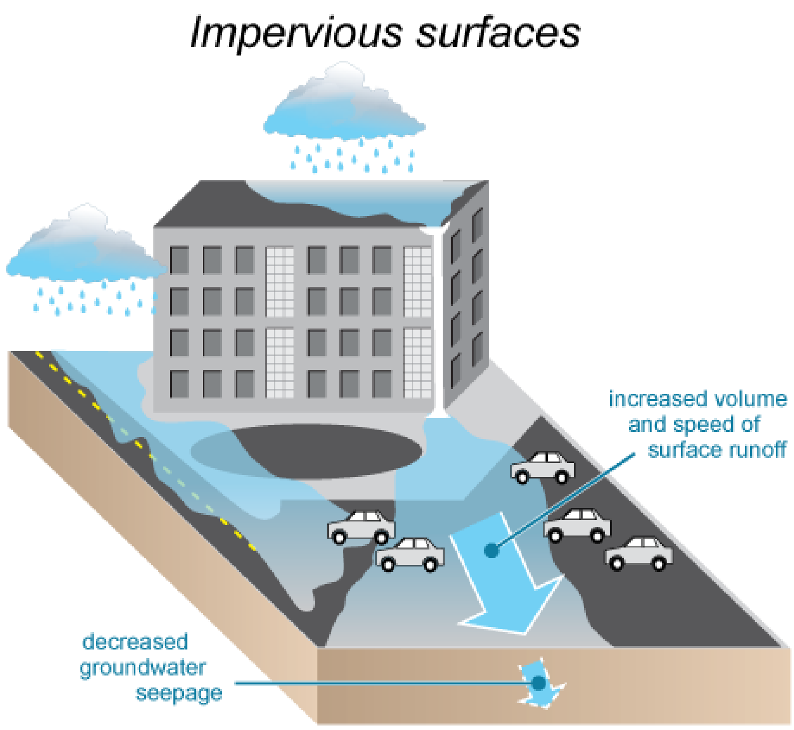
- Typically occurs where overland flow routes and municipal drainage system are overwhelmed
  - Water enters basements through windows, below-ground openings and foundation cracks

- Lack of pervious surfaces and insufficient lot drainage contribute to the increased risk of overland flooding

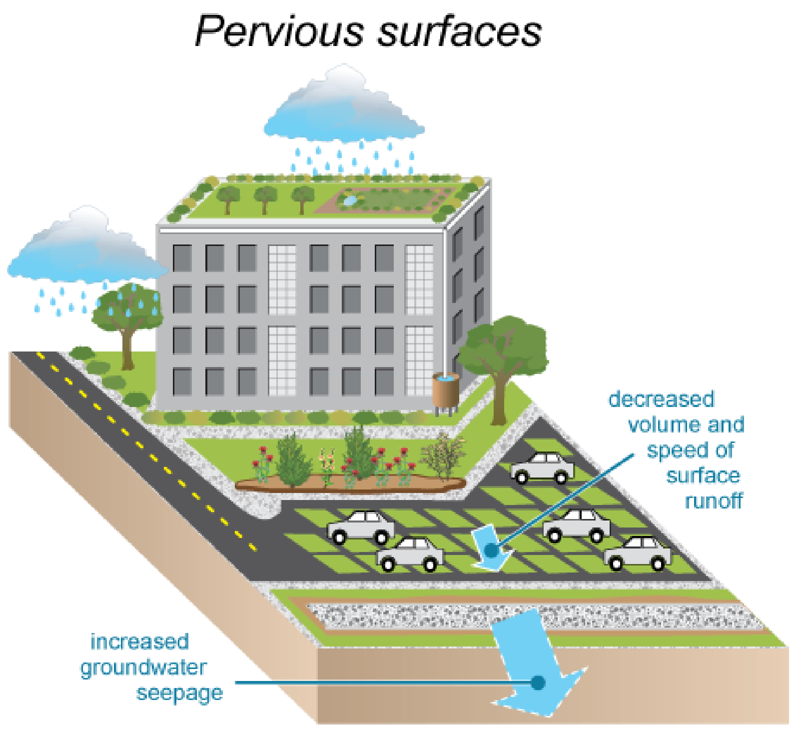
- Low impact development (LID) measures, large-scale SWM measures, and increased street storage capacity can reduce the risk of overland flooding

Management of water resources

Low impact development (LID) measures



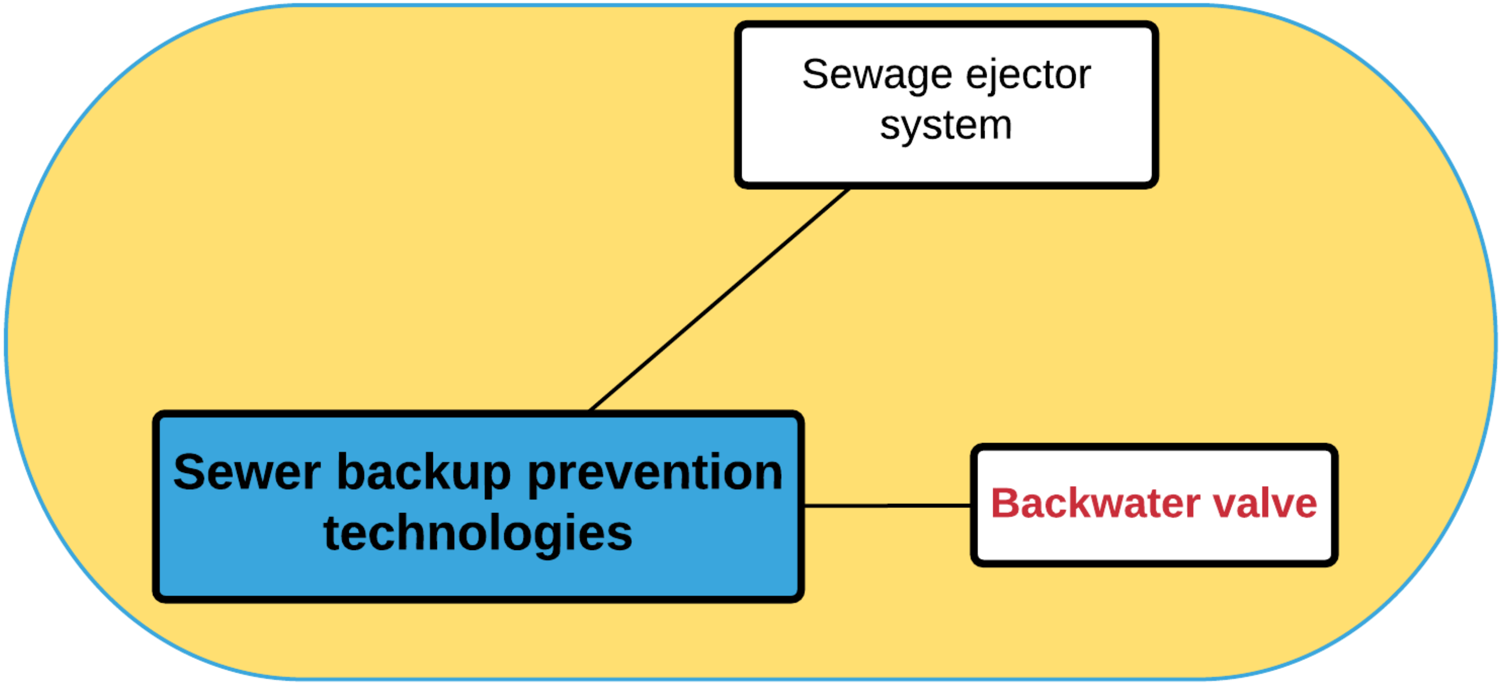
Impervious 'hard' surfaces (roofs, roads, large areas of pavement, and asphalt parking lots) increase the volume and speed of stormwater runoff. This swift surge of water erodes streambeds, reduces groundwater infiltration, and delivers many pollutants and sediment to downstream waters.



Pervious 'soft' surfaces (green roofs, rain gardens, grass paver parking lots, and infiltration trenches) decrease volume and speed of stormwater runoff. The slowed water seeps into the ground, recharges the water table, and filters out many pollutants and sediment before they arrive in downstream waters.

From: http://managingstormwater.blogspot.ca/

Lot-level approaches to reduce flood risk



Mitigating strategies

Sewer backup

Sewer backup

- Arises from overloaded storm or sanitary sewer systems and excessive I/I (inflow and infiltration) contributions

- Sewer backup prevention technologies help stop sewage from backing-up into the home during surcharge events
  - Backwater valves
  - Sewage ejector systems

- Installation and maintenance issues

3. Backwater valve research

Backwater valves

- One lot-side technology to reduce risk of sewer backup is the installation of backwater valves on sewer laterals in individual homes

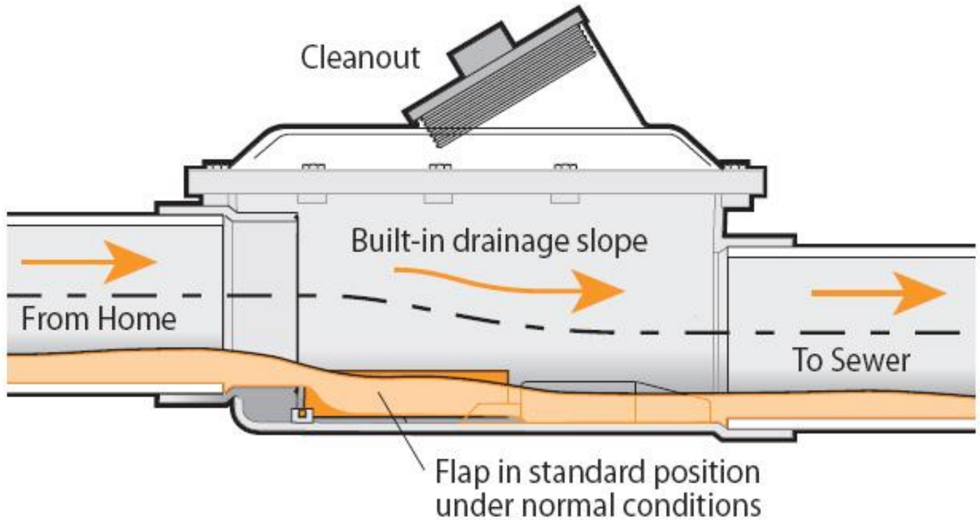
- Backwater valves have been in the market for 25 years and are gaining more widespread use in recent years (e.g., ~500,000 Mainline valves installed in Canada since 1998)

- Several backwater valve designs exist in the marketplace today (i.e., Mainline Backflow Products)

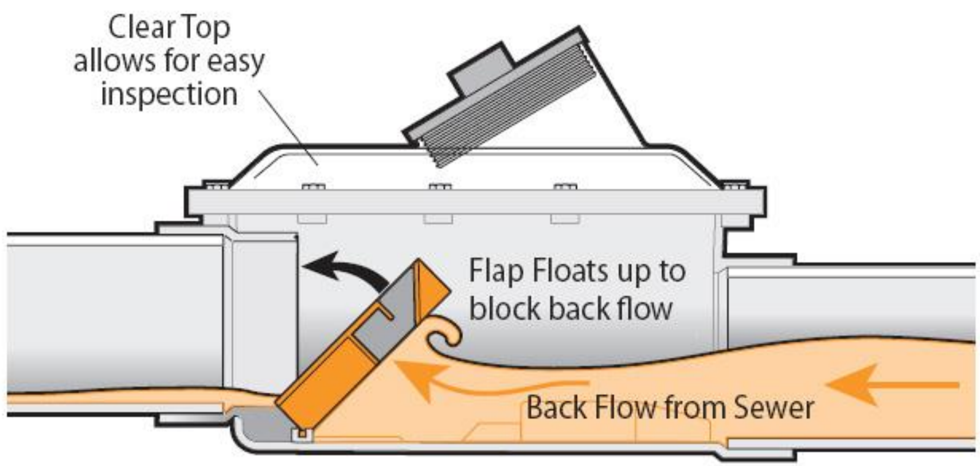
Source: http://backwatervalve.com

Backwater valves

Normal operation:



During surcharge events:



Source: http://backwatervalve.com

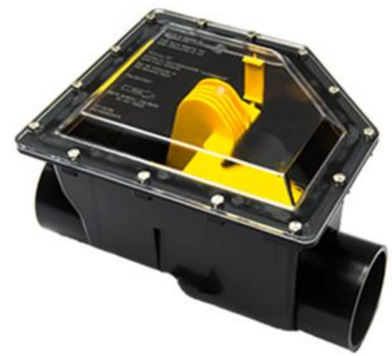
Backwater valves

- Either installed on individual branch connections in the home or on the main sanitary sewer connection

- Can operate in normally-open or normally-closed positions

- Valves can be physical gates that open and close or be an inflatable technology

Bladder, sensor operated (Aqua-Protec)



ML-FR4 (limited opportunity to appropriately grade valve)

Mainline Open-Port (where grading can be achieved)

Backwater valves

- Gated valves can be hinged from the top or the bottom of the device
- Also suitable for sewer laterals a large distance below basement floor
- May require homeowner maintenance
- Can be installed inside or outside home

Adapt-a-Valve

Backwater valves models

Model	Manufacturer	Description
1. Fullport	Mainline	• Normally-open allowing for ventilation of gasses • Flap hinge located at the base of valve • Clear lid allows for visual inspection of valve • Self-cleaning with built-in slopes
2. Straight fit	Mainline	• Normally-closed, for in-line installations • Features a flapper that guides cleaning and surveying equipment through the valve
3. Adapt-a-valve	Mainline	• Normally-closed or normally-open designs • Versatile model that can be adapted to serve several functions (i.e., laterals located deep under basement floor, pressure testing, etc.) • Self-cleaning step through design

Backwater valves models

Model	Manufacturer	Description
4. Fullport Retrofit	Mainline	• Normally-open allowing for ventilation of gasses • Gate hinge is located at top of valve for protection from debris accumulation • Valve works well at low slopes
5. Aqua-Protec	Inflotrolix	• Installed and housed in the main drainage cleanout allowing for ventilation of gasses • Inflatable balloon with built-in sensors that detect backflow events and trigger balloon to inflate and seal off sewer lateral • No retrofitting or demolition work required
6. Blokker	Secureleak Inc.	• Normally-open allowing for ventilation of gasses • Does not have a significant slope through the body permitting easier retrofit installations

Backwater valves

- Since the technology is relatively new, several key questions regarding the function and durability of backwater valves have yet to be addressed

Issue	Details
1. Debris accumulation in valve	• Affects performance over time • May affect movement of the valve, formation of the seal, or condition of floats
2. Suitability of specific backwater valve for situation	• New homes versus retrofit scenarios • Particular individual home plumbing and sewer lateral configuration
3. Installation, retrofit	• Loose, cross-threaded clean-out caps • Appropriate grading (e.g., >2%)
4. Variety of technologies	• Open-port, ML-FR4, adapt-a-valve, etc. • Bladder systems, etc.

Backwater valves

- **Addressing these questions will allow for the:**

1. Determination of the lifespan of particular backwater valve models

2. Identification of causes of valve failure

3. Assessment of optimal maintenance periods for values

4. Determination of optimal valve models for particular situations

Backwater valve research

No maintenance had been performed on this valve since installation (January 2011) [pictures taken November 2016)

Backwater valves to reduce the risk of basement flooding due to sewer surcharge

- Debris accumulation known to affect valve performance over time
- The adjacent pictures show an unmaintained Mainline Fullport backwater valve (installed January 2011)

Backwater valve failure

- Poor valve grading
- Field experience – approx. 25% of values not likely functional (valves ‘stuck’ as a result of oil and grease, grit, dental floss, etc.), flappers had to be pried off the body of valve with a screwdriver
- Most valves, once installed, have never been maintained

Example of debris build-up in backwater valve

Source: photo courtesy Protective Plumbing Canada Inc.

Backwater valve research

Recent basement flooding events in Canadian cities

- Most valve failures are due to debris build up
- This inhibits the valve from forming a proper seal during a surcharge event
- Periodic maintenance can assist in ensuring valve performance

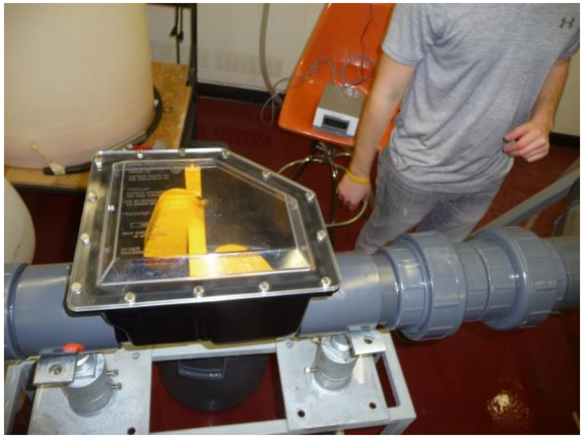
City	Cause of valve failure
Hamilton	Mechanical failures Low-lying location
Cambridge	Not reported
Thunder Bay	Debris build-up Mechanical failures Low-lying location
London	Debris build-up
Estevan	Not reported
Essex	Not reported
Tecumseh	Debris build-up
Waterloo	Not reported
Calgary	Debris build-up
Edmonton	Mechanical failures

Backwater valve research

Backwater valves laboratory and computational research

1. Characterization of backwater valve failure
2. Performance evaluation of backwater valves under varying conditions
3. Flow visualization to create computational model

Wastewater laboratory platform in Guelph



Laboratory model to test backwater valve performance

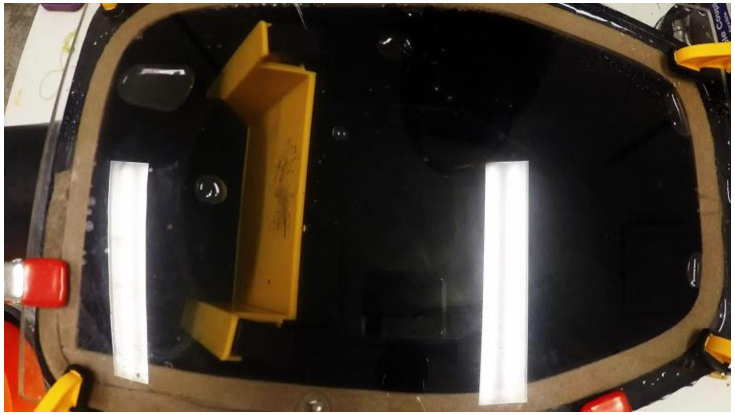
Backwater valve research

Preliminary results

- Dye tests to visualize the flow pattern in the laboratory model are used to validate a computational fluid dynamics (CFD) model

Flow visualisation of Mainline Fullport valve with gate open 15 degrees

Flow visualisation of Mainline Fullport valve with gate open 10 degrees

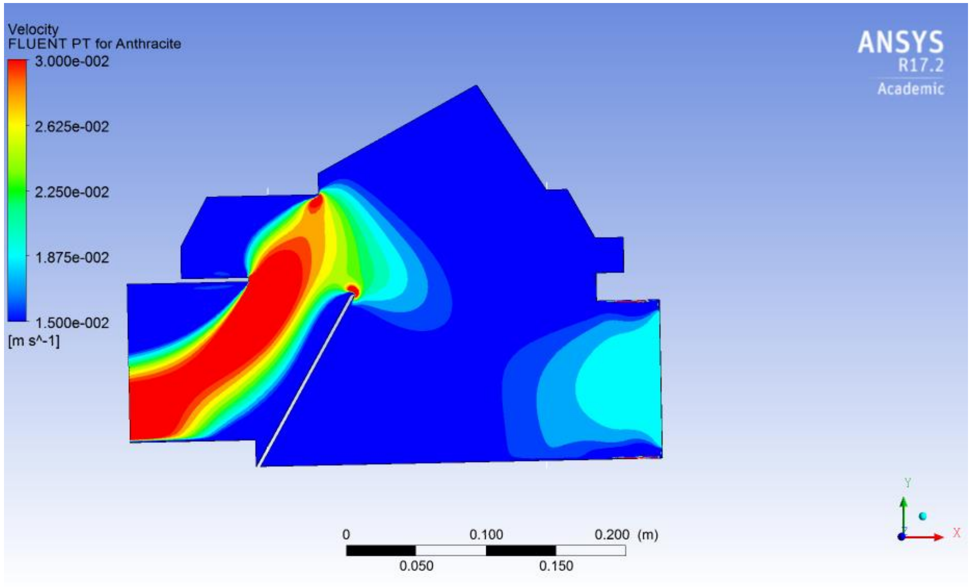


Laboratory model used to calibrate CFD model

Backwater valve research

Preliminary results

- CFD model will allow for long-term evaluation of backwater valve performance and failure



CFD backwater valve model results illustrating velocity distribution in the valve with gate failure (i.e., stuck in an open position)

4. Future research direction

GOAL OF RESEARCH

To evaluate the performance of various technologies and approaches to reduce the risk of occurrences of basement flooding and develop a more comprehensive understanding of the risk of basement flooding in Canadian cities

OVERLAND FLOODING

INFILTRATION

SEWER SURCHARGE

Initial focus

NSERC CRSNG

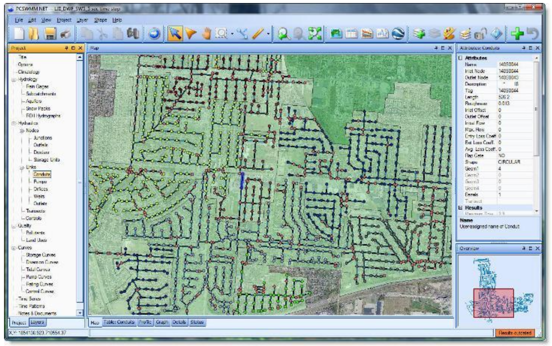
To be pursued over 2017-2021 with a NSERC Collaborative Research & Development 4-year grant

GOAL OF RESEARCH:
To evaluate the performance of various technologies and approaches to reduce the risk of occurrences of basement flooding and develop a more comprehensive understanding of the risk of basement flooding in Canadian cities

- To accomplish this goal the following specific objectives will be pursued:

1. Investigate the performance of **backwater valves** to reduce the risk of basement flooding due to sewer surcharge

2. Evaluate the effect of alternative **low impact development** measures on improved urban drainage and sewer network response to extreme events



From: https://www.tatukgis.com

Future research direction

a) Backwater valves to reduce the risk of basement flooding due to sewer surcharge

- Characterization of backwater valve failure

- Performance evaluation of backwater valves under varying conditions

Applying laboratory and computational methods

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Future research direction

- Characterization of backwater valve performance under different closure conditions
  - Laboratory tests
  - Flow visualization
  - Reasons for valve failure

- Computational fluid dynamics (CFD) modeling to extend range of scenarios and investigated long-term effects
  - Impact of partial blockages for debris build-up conditions

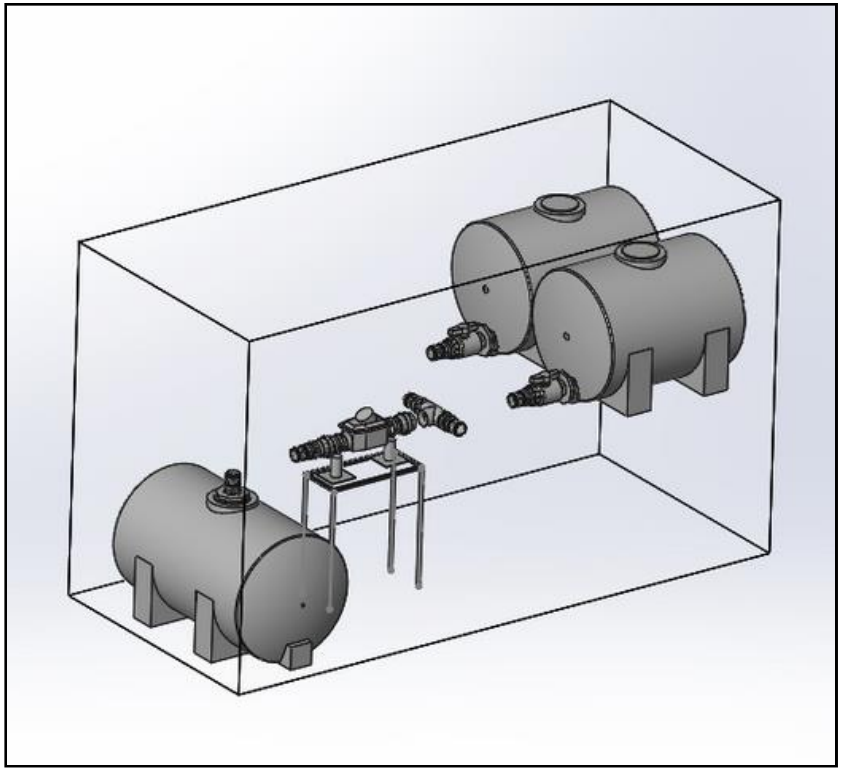
SOUTHERN ONTARIO WATER CONSORTIUM
LE CONSORTIUM POUR L'EAU DU SUD DE L'ONTARIO

Examples of backwater flow scenarios

Flow	Valve condition	Lateral slope	Lateral condition	Wastewater material
Normal flow	Normal (well-maintained)	Recommended grade (2%)	Ideal condition of lateral pipe	Normal domestic grey and black water
Sloshing effect	Un-maintained (i.e., presence of bio…	Steep grade (> 2%)	Root blockages	Presence of brine from water …oftener
Hydraulic high pressure jet flow (i.e., sewer flushing)	I… mai… i… screwed on clean-out)			…nce of non- …posable …aterials (i.e., baby wipes, Q-tips, etc.)
	Dried out (after prolonged period of non-use)	Reverse grade		Presence of excessive cooking materials (i.e., cooking oils)

CFD modeling allows for testing of many different scenarios

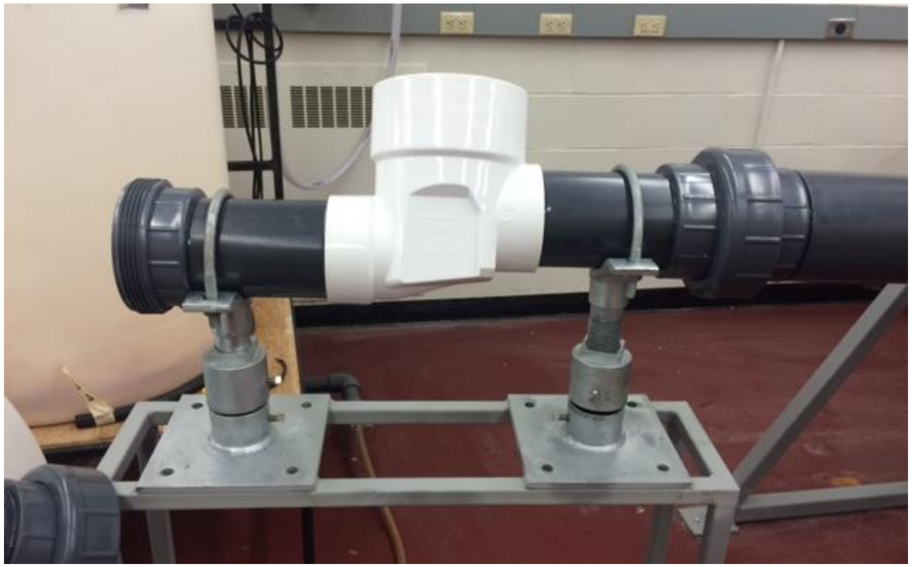
Future research direction



Schematic of backwater valve apparatus

Constructed backwater valve laboratory apparatus

Future research direction



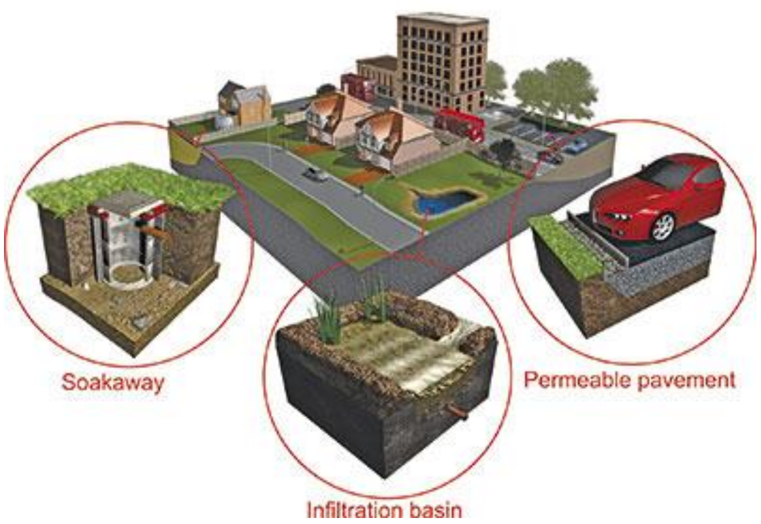
- Interchangeable backwater valve on the “sewer lateral”
- Option to vary the lateral slope
- Reversible valve to simulate surcharge event

Head tanks to mix grey and black water recipes

Other lot-level measures

b) Effect of low impact development on improved urban drainage and sewer network response

- Urban drainage and sewer network response to extreme events
- Effect of LID measures on reducing loading on sewer infrastructure



Source: http://www.nerc.ac.uk

PCSWMM

Significance and benefit to Canada

- **Results from this research will:**
  1. Provide guidance to improve guidelines for installation of backwater valves and O&M strategies

  2. Provide insurance industry with technical recommendations to develop appropriate policy

  3. Provide homeowners with greater information to implement lot-level measures to reduce risk of water damage due to basement flooding during surcharge events

  4. Develop a risk assessment tool to assist municipalities in developing mitigation strategies for locations sensitive to basement flooding

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Thank you

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