2026 Natural Channels Conference

How Deep Do Streams Scour? Insights from Small Meandering Channels

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Discussion topics

1) **Definition and importance of scour**
2) **Challenges in scour estimation**
3) **Types of scour**
    - General
    - Natural
    - Local
4) **Case studies for scour types**
5) **Summary of scour measurements**
6) **Final remarks**

Why is scour important?

1) Infrastructure planning, design, protection and maintenance
2) Natural channel design (design to mimic naturally occurring ranges in bed elevation)

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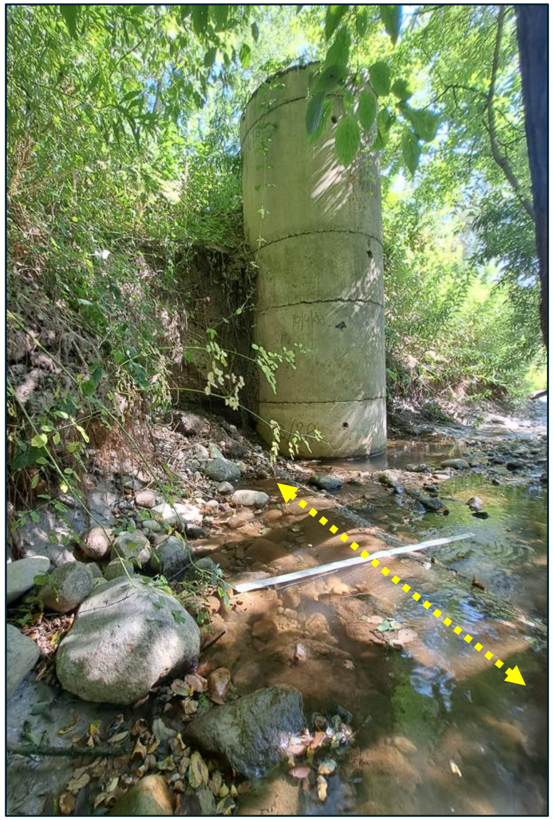
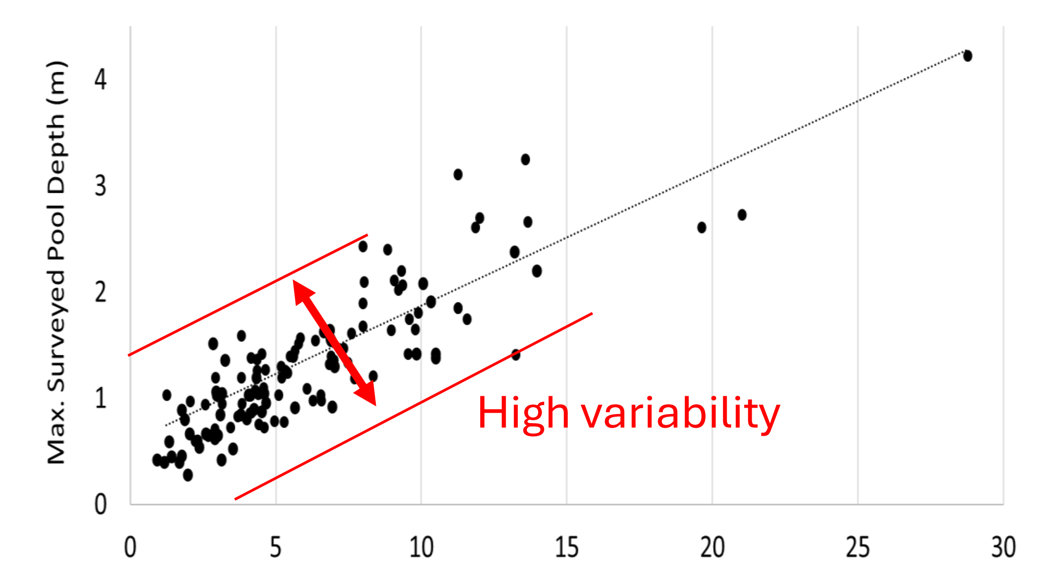


Challenges in Scour Estimation

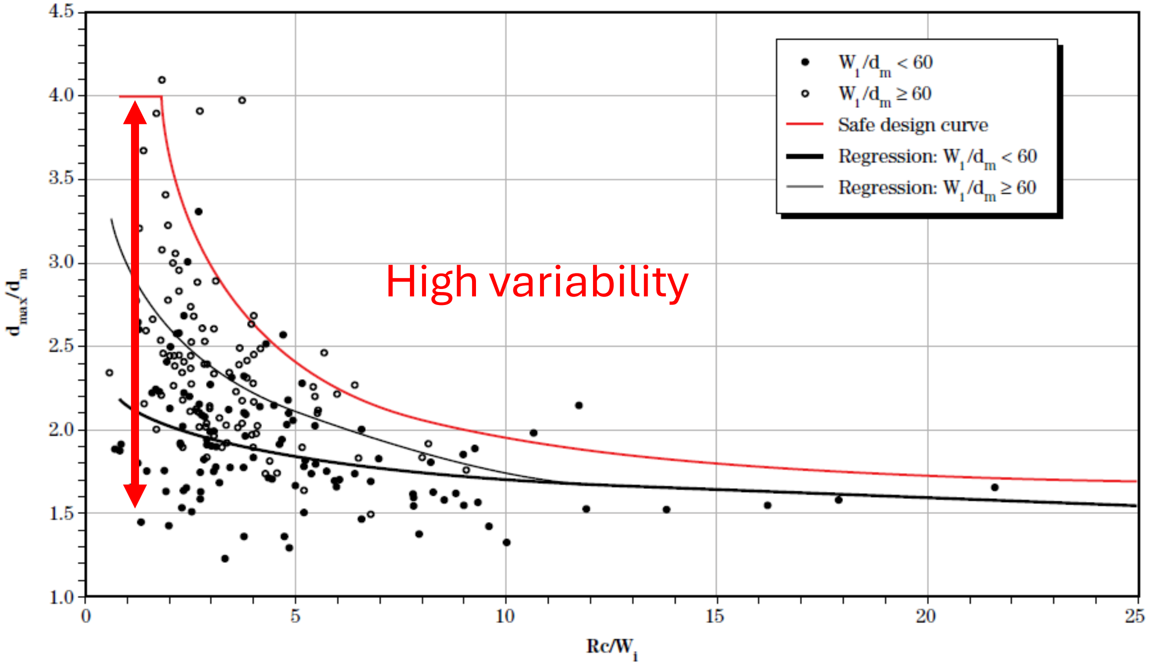
- High variability between scour estimation methods (e.g., USDA, MTO)
- Inconsistent application
  - Inconsistent design parameter selection, scour reference plane
  - Not accounting for all scour components (small and large spatial scale processes)
  - Models applied outside their intended range of applicability
- Findings often not related to a given planning horizon (e.g., 100-year limit)

Easy to overpredict or underpredict scour



Molder et al. 2023

Maynord (1996) & Thorne and Abt (1993) – Figure retrieved from NRCS National Engineering Handbook Part 654



How is scour estimated?

- Identification of the components that make up the ***scour hazard limit Z***

GENERAL SCOUR (Z_{Gs})

- Cross-sectional lowering of the channel bed

NATURAL SCOUR (Z_{Ns})

- Reach-scale systematic degradation or lowering of the average bed elevation

LOCAL SCOUR (Z_{Ls})

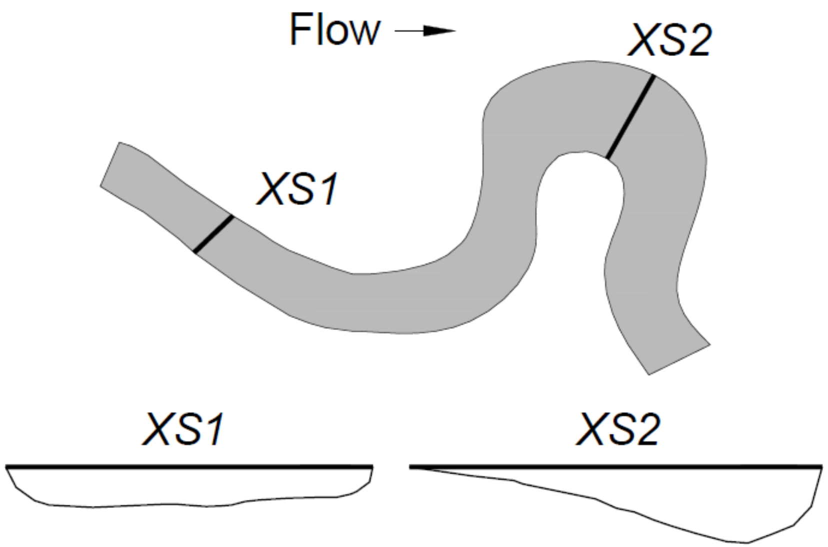
- Localized erosion (scouring) due to in-stream structures or obstructions

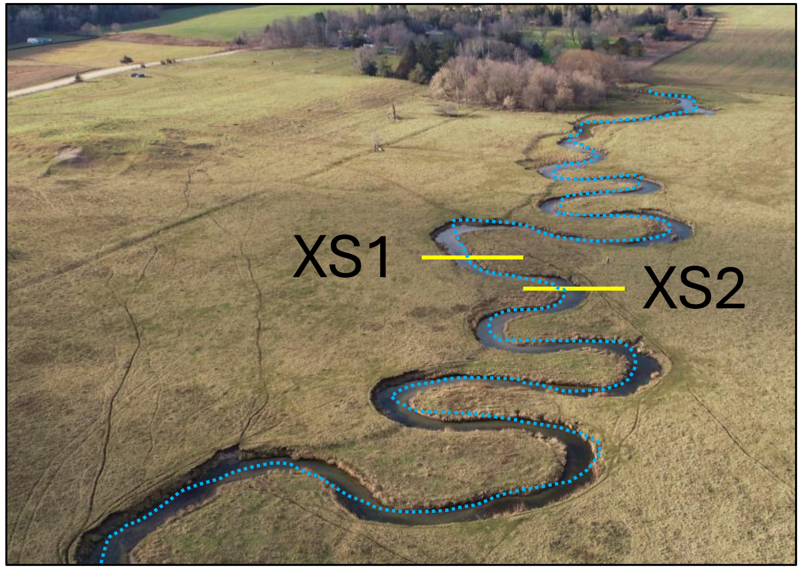
$$\boldsymbol{Z = Z_{Gs} + Z_{Ns} + Z_{Ls}}$$

Scour Components: General Scour

$$Z = \boxed{Z_{Gs}} + Z_{Ns} + Z_{Ls}$$

- **General Scour** is the cross-sectional lowering of the channel bed
- **Spatial Scale**
  - ❖ Channel cross-section
- **Temporal Scale**
  - ❖ Individual event
  - ❖ Years





Scour Components: General Scour

$$Z = \boxed{Z_{Gs}} + Z_{Ns} + Z_{Ls}$$

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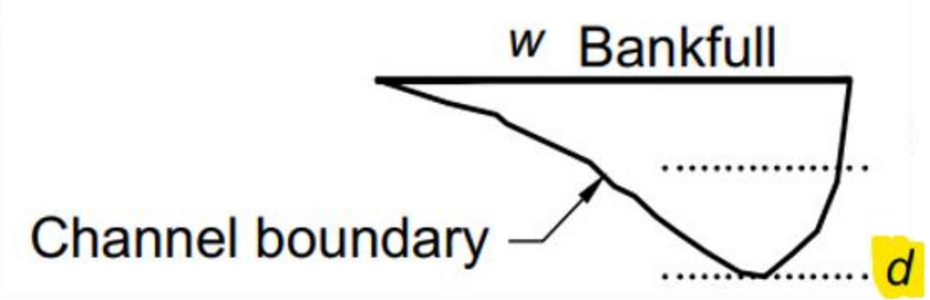
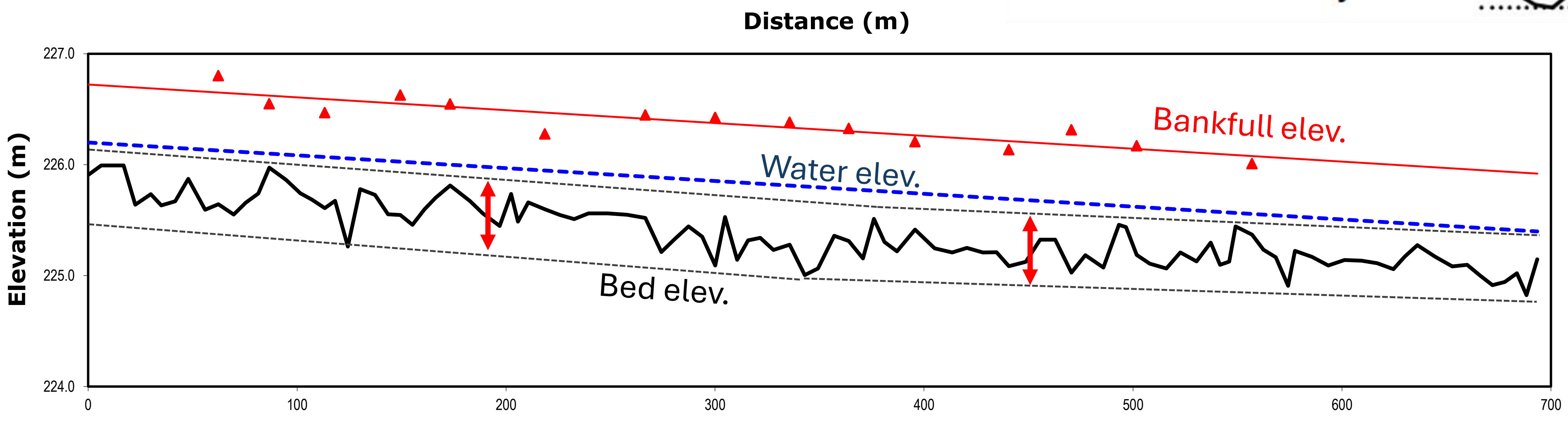
Example Study – Tributary of Nottawasaga River

- 7 m avg. channel width $\boldsymbol{w_{bk}}$
- 1 m avg. channel depth $\boldsymbol{d}$
- 1.4 m deepest pool $\boldsymbol{Z_{Gs}}$

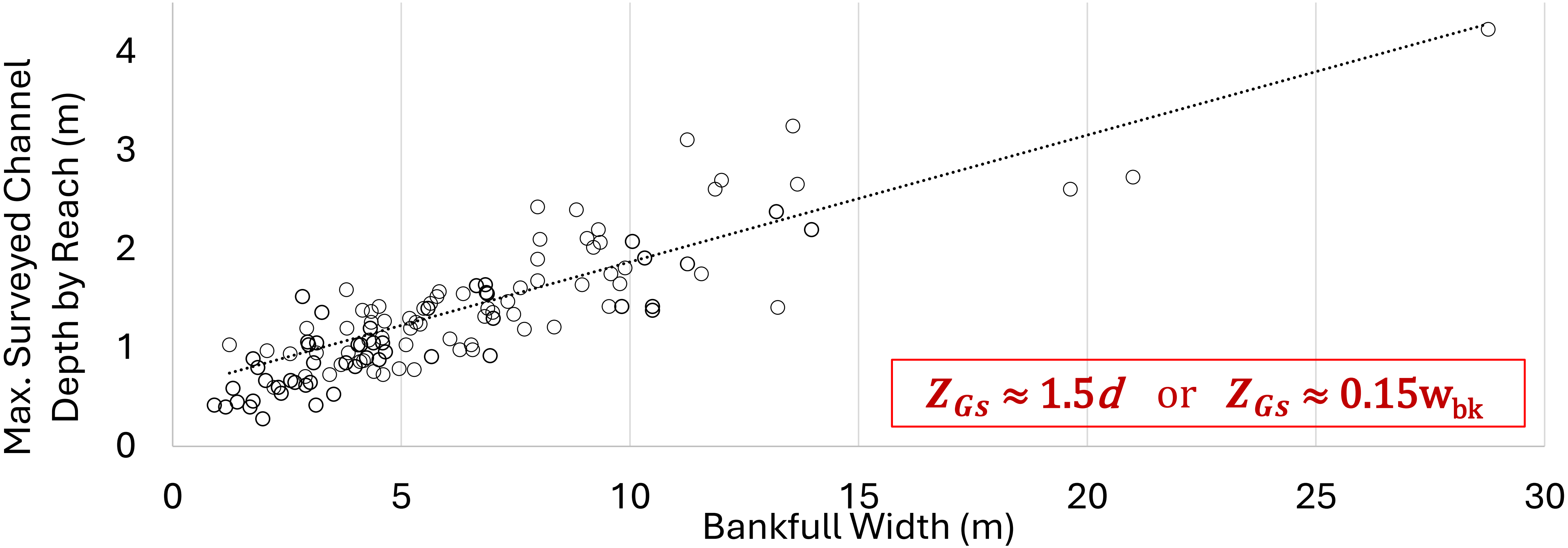




Scour Components: General Scour

$$Z = \boxed{Z_{Gs}} + Z_{Ns} + Z_{Ls}$$

Molder, Villard and Franssen (2023, 2025) investigated $\boldsymbol{Z_{Gs}}$ in 141 small meandering channels in glacially modified landscapes (Ontario)



Scour Components: Natural Scour

$$Z = Z_{Gs} + \boxed{Z_{Ns}} + Z_{Ls}$$

- **Natural Scour** Reach-scale systematic degradation or lowering of the average bed elevation (e.g., in response to catchment disturbance)

- **Spatial Scale**
  - ❖ Reach-scale

- **Temporal Scale**
  - ❖ Long-term (years, decades, centuries)

Scour Components: Natural Scour

Urban Setting or Disturbance

- Highland Creek alluvial avg: 3 m/100 yr (reported in CVC, 2019)
- Shale bedrock channels: 2 to 3 m/100 yr (reported in Tinkler & Parish, 1998)
- Other example studies:
  - ❖ Blom (2016); Booth & Henshaw (2010); Allen et al. (2008)
- Studies support that **cm/yr** bed lowering rates often arise in urban streams

Scour Components: Natural Scour

Source: GEO Morphix studies (partial list)

System	Estimated Rate of Bed Lowering (m/yr)	Notes
Burke Brook	**0.038 m/yr** **0.026 m/yr**	Survey comparison (16 year assessment period)
Bowmanville Creek	**0.065 m/yr**	Survey comparison (20 year assessment period) Dam removals/failures downstream
West Don River	**0.014 m/yr** (5 Reach average)	Incision measurement from historically placed infrastructure (~60 year period)
Etobicoke Creek	**0.014 m/yr**	Measured incision downstream of dam and entrenchment ratio comparison (~100 year period)
Morningside Creek	**0.022 m/yr**	Measured incision below historically bypassed meander

Scour Components: Natural Scour

- In quasi-stable / regime, or undisturbed river systems, rates can be very low (nearer to **0 m/yr**)

- Nearby robust grade controls (e.g., closed bottom culverts) can also mitigate Z_{Ns} **

Scour Components: Local Scour

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$$Z = Z_{Gs} + Z_{Ns} + \boxed{Z_{Ls}}$$

- Enhanced erosion potential due to presence of in-stream obstructions or structures

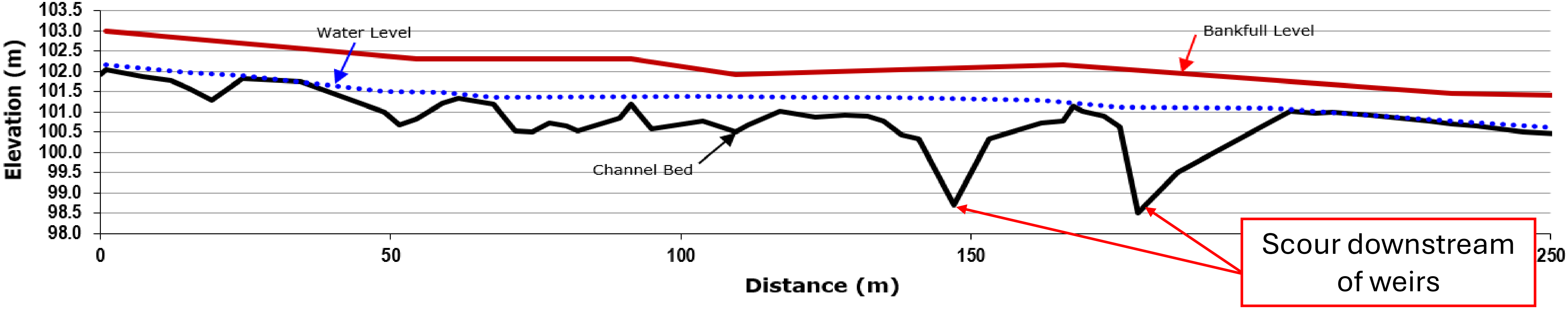
- **Spatial Scale**
  - ❖ Localized to obstruction area

- **Temporal Scale**
  - ❖ Individual event
  - ❖ Years

Scour Components: Local Scour

Example study 1) Scour downstream of two constructed weirs

- 10 m avg. channel width $\boldsymbol{w_{bk}}$
- 1.7 m avg. channel depth $\boldsymbol{d}$
- 3.4 m and 3.5 m deep scour $\boldsymbol{Z_{Ls}}$
- $Z_{Ls} \approx 2.1d$



Scour Components: Local Scour

Stream	Z_{u*}: d_{thal}
Cooksville Creek	2.0
Cooksville Creek	2.1
Cooksville Creek	1.3
West Don River	1.4
West Don River	1.4
Burke Brook	1.5
Highland Creek	2.7
Highland Creek	1.8
Vymer Creek	1.5
Highland Creek	2.8
Don River	1.4
Don River	1.6
Bowmanville Creek	1.8
Bowmanville Creek	2.3
Trib of Rouge River	1.9
Oshawa Creek	1.5
Gibson Creek	2.2
Clubinis Creek	2.0
Etobicoke Creek	1.3
Etobicoke Creek	3.1
Lynde Creek	1.5
Bronte Creek	2.8

- 22 channel surveys assessed with in-stream obstruction(s)
- 4 m – 28 m channel widths
- Exposed parent materials along bed
- $\boxed{Z_{Ls} < 3d}$ (median = 1.8)

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Summary of Measurements & Findings

Z_{Gs} ≈ **1.5*d*** or $Z_{Gs} \approx 0.15w_{bk}$

- ❖ Based on GEO Morphix / Molder et al. study on Ontario streams

Z_{Ns} rates vary considerably

- ❖ Z_{Ns} ≈ **0.0 m/yr** in regime or quasi-stable conditions (unmodified catchment)
- ❖ Z_{Ns} ≈ **0.01 to 0.03 m/yr** in review of longer-term rates reported for disturbed systems (urban streams)**

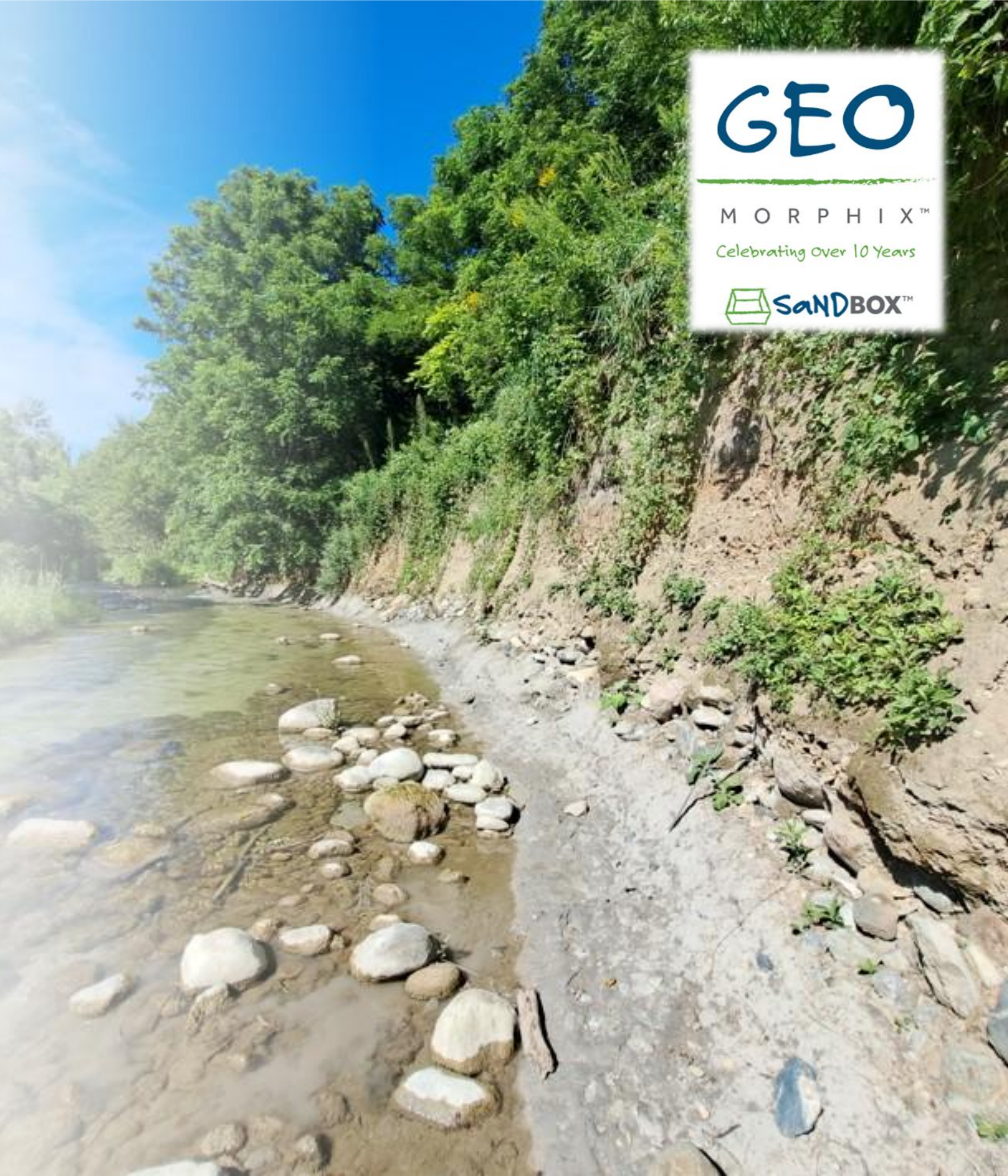
Z_{Ls} rates vary considerably — many different site-specific methodologies available

- ❖ Z_{Ls} **< 3*d*** for the 22 cases explored in this presentation

** Note caveats

Final Remarks

- **Early engagement** with and assessment by a **qualified professional** (e.g., fluvial geomorphologist).
- Scour is made up of multiple interacting **components**, each require consideration
- Apply a **range** of methodologies, supported with **site investigations** (e.g., survey)
  - Know the limitations/applicability of your applied methodologies
- Address scour through **prevention** or **geomorphic design**, coupled with monitoring



Listed References:

Allen, P. M., Arnold, J. G., & Skipwith, W. (2008). Prediction of channel degradation rates in urbanizing watersheds. *Hydrological Sciences Journal, 53*(5), 1013–1029.

Blom, A. (2016). Bed degradation in the Rhine River. *TU Delft DeltaLinks*. Delft University of Technology.

Booth, D. B., & Henshaw, P. C. (2001). Rates of channel erosion in small urban streams. In M. S. Wigmosta & S. J. Burges (Eds.), *Land use and watersheds: Human influence on hydrology and geomorphology in urban and forest areas* (Water Science and Application Series, Vol. 2, pp. 17–38). American Geophysical Union.

Credit Valley Conservation. (2019). *Credit Valley Conservation Fluvial Geomorphic Guidelines: Factsheet VI Scour Analysis*.

Molder, B., Villard, P., and Franssen, J. (2023). Scour estimation and measurement in small meandering channels in glacially modified landscapes. International Society for Soil Mechanics and Geotechnical Engineering. 1-11. Published in Proceedings of 2023 International Conference on Scour and Erosion, Copenhagen, Denmark.

Simon, A. (1994). Gradation processes and channel evolution in modified West Tennessee streams: Process, response, and form. *U.S. Geological Survey Professional Paper 1470*. U.S. Geological Survey.

Tinkler, K. J., & Parish, R. (1998). Instability and channel degradation in the Cooksville Creek system, Ontario. In K. J. Tinkler & E. E. Wohl (Eds.), *Rivers over rock: Fluvial processes in bedrock channels* (pp. 309–324). American Geophysical Union.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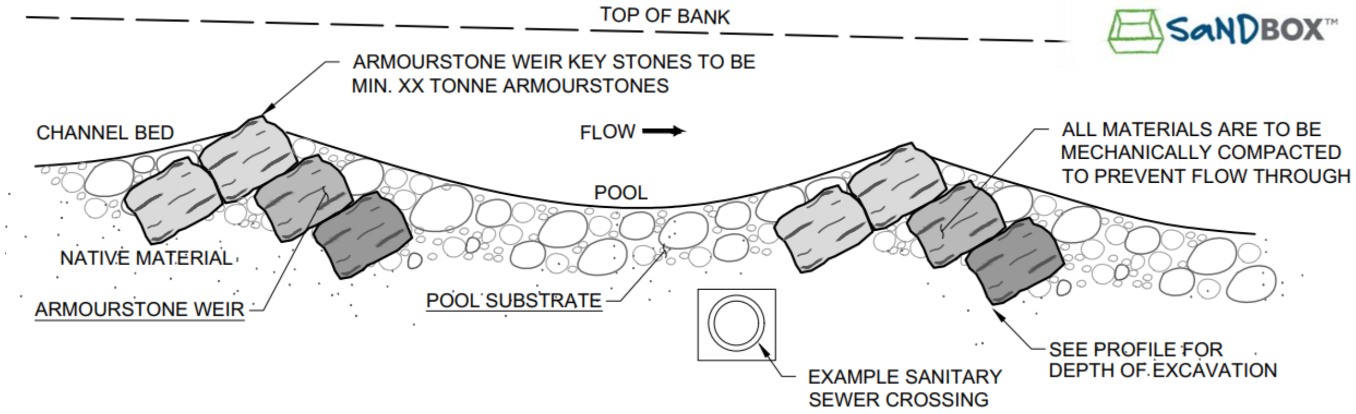
Addressing Scour

Protection Works with hydraulically-sized materials

- Grade controls (e.g., rocky ramps/riffles, vortex rock weirs)



Rounded boulders VRW

Subangular boulders VRW

Angular boulders (armourstone) VRW

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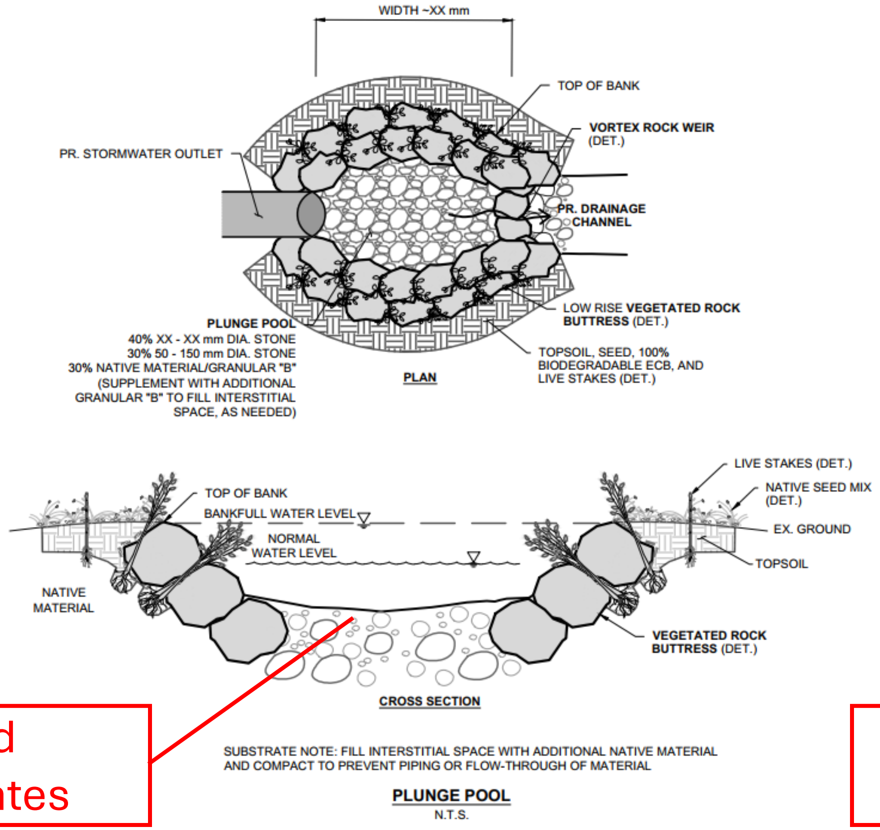
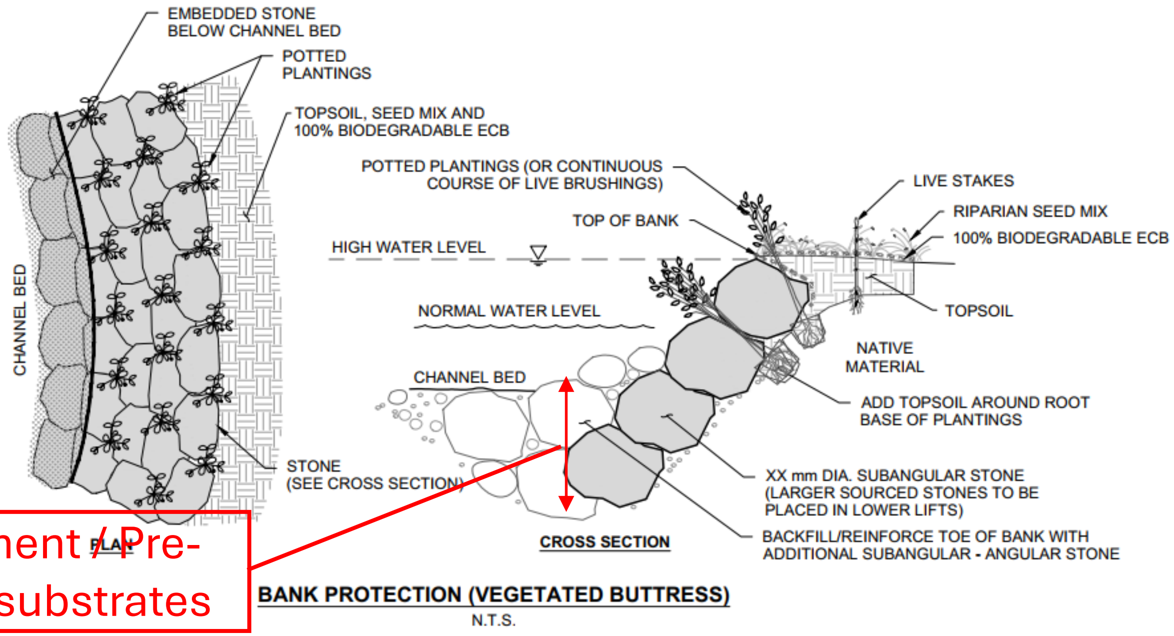
Addressing Scour

Protection Works

- Hydraulically sized substrates (e.g., plunge pools, bioengineering)



Sized substrates



Embedment / Pre-charged substrates