The Time-limited Resilience of River Morphology to Alteration: Examples from Across Canada

Robin McKillop and Dan McParland

6th Conference on Natural Channel Systems

May 24, 2018

PALMER
ENVIRONMENTAL
CONSULTING
GROUP INC.

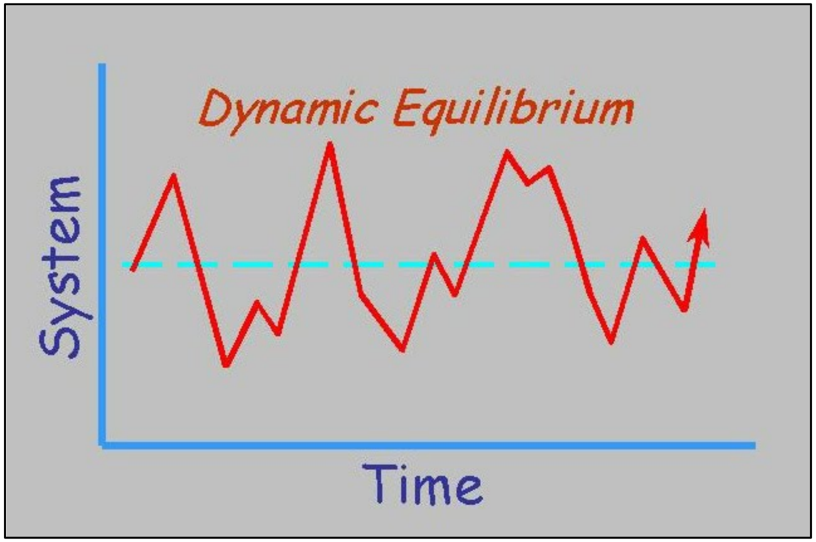
Outline

- A delicate balance
- Examples from across Canada
  – Aishihik River, YT
  – Nechako River, BC
  – German Mills Creek, ON
- Key concepts and implications

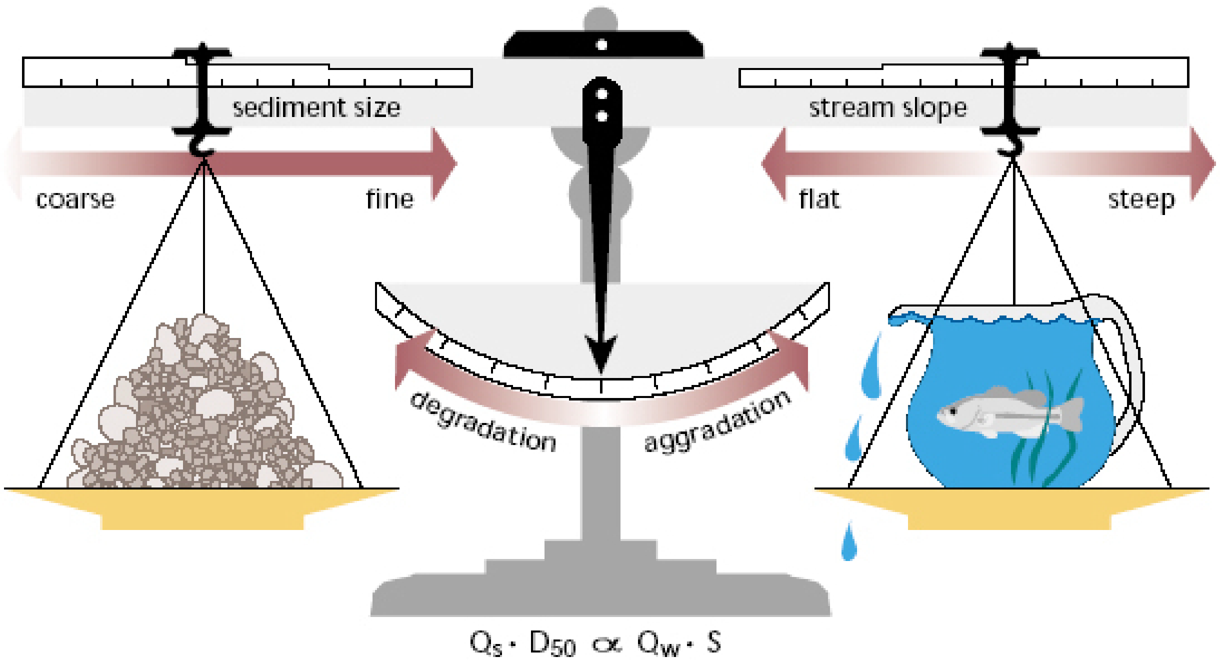
A DELICATE BALANCE

Balance

- Rivers are naturally dynamic – a balance of erosion, transport and deposition
- Key controlling factors – flow, sediment supply and gradient
- Dynamic equilibrium



Lane’s balance

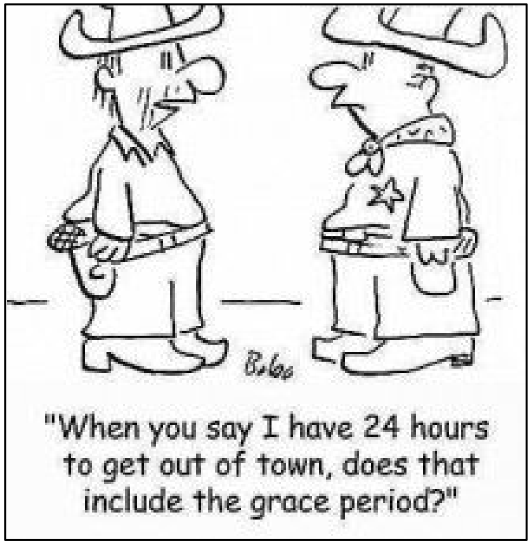


Rosgen (1996) adaptation of Lane (1955)

At ‘equilibrium’, slope and flow balance the size and quantity of sediment particles a stream transports

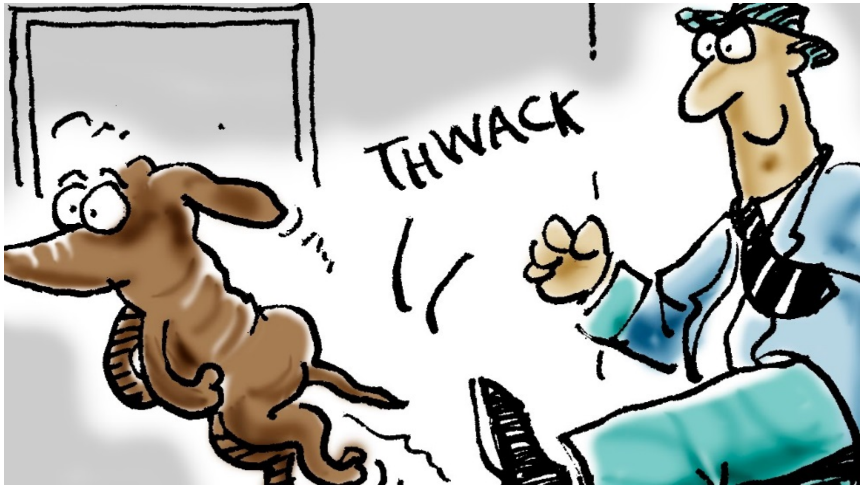
Response to perturbations

- Change in one (or more) geomorphic control affects balance
- Geomorphic response may not manifest immediately – *time lag?*
- 'Grace period' – period following disturbance during which channel morphology remains largely unchanged
  - A 'test' of a river's resilience



Tipping point

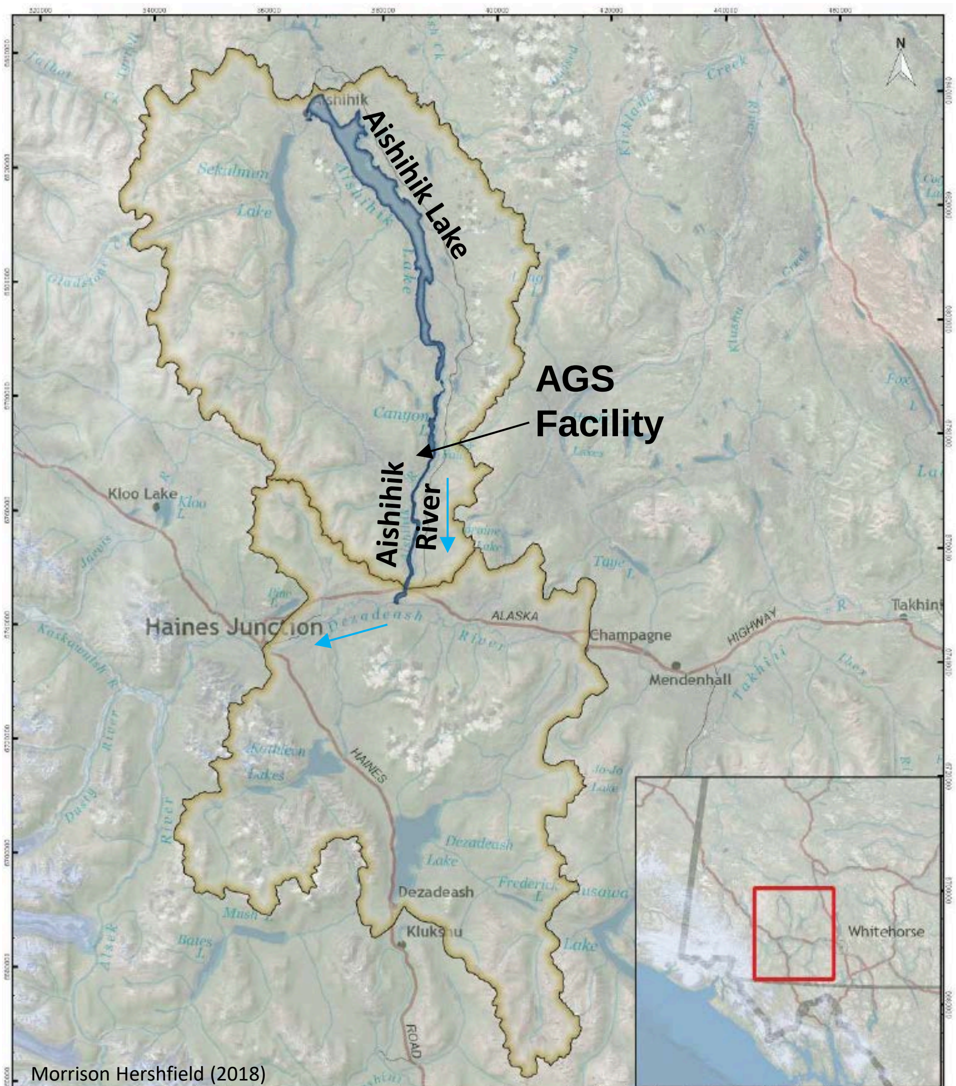
- “It’s like kicking a dog…” (Dr. Garry Clarke)



- Natural systems have finite limits of resilience before a ‘tipping point’ is reached

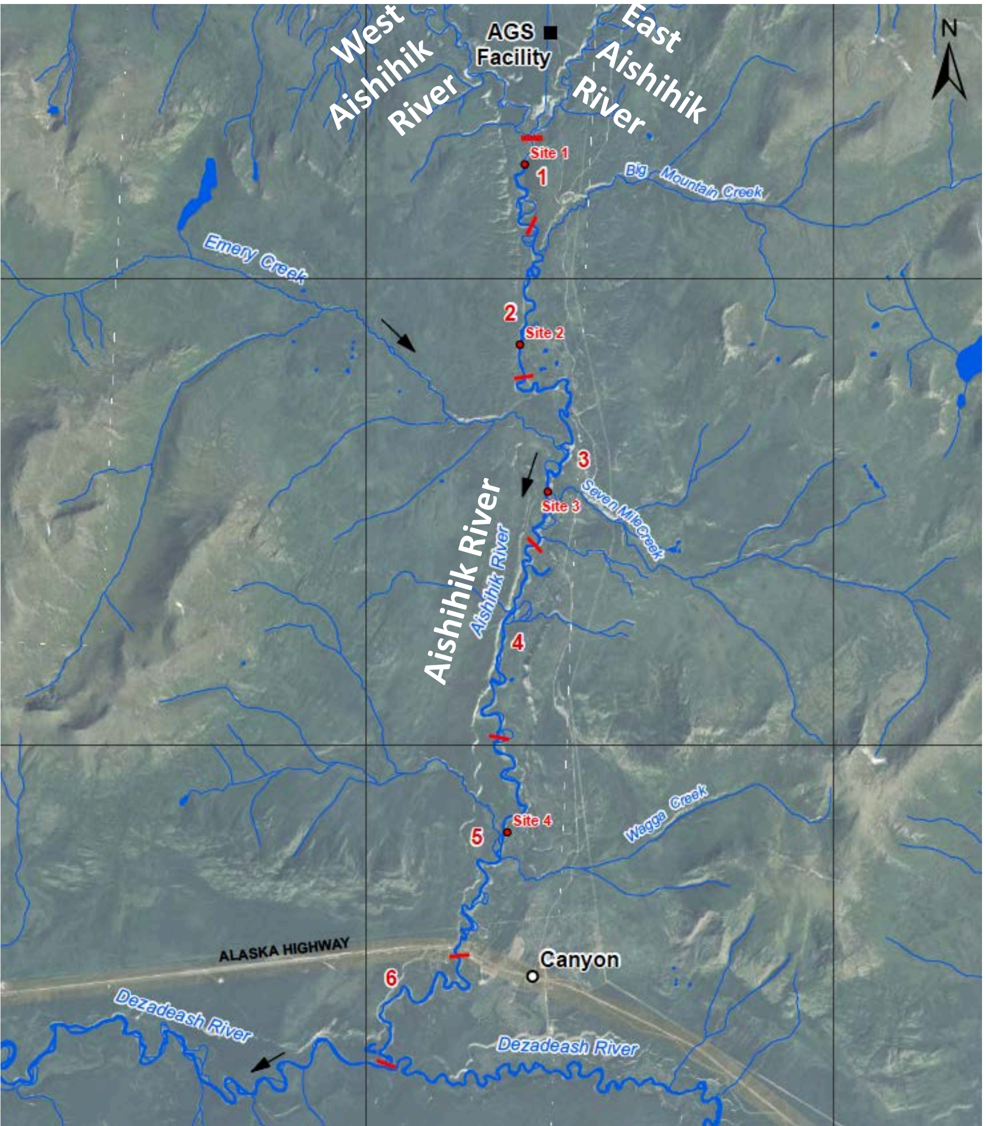
EXAMPLES FROM ACROSS CANADA

Aishihik River



- 110 km west of Whitehorse, Yukon
- Aishihik Generating Station (AGS) in operation since 1975
- PECG completed baseline geomorphology studies as part of re-licensing protocols

Since AGS construction…

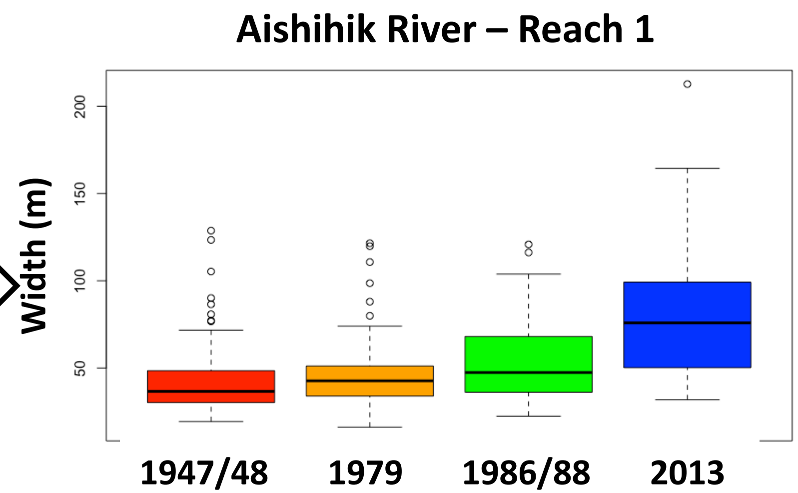


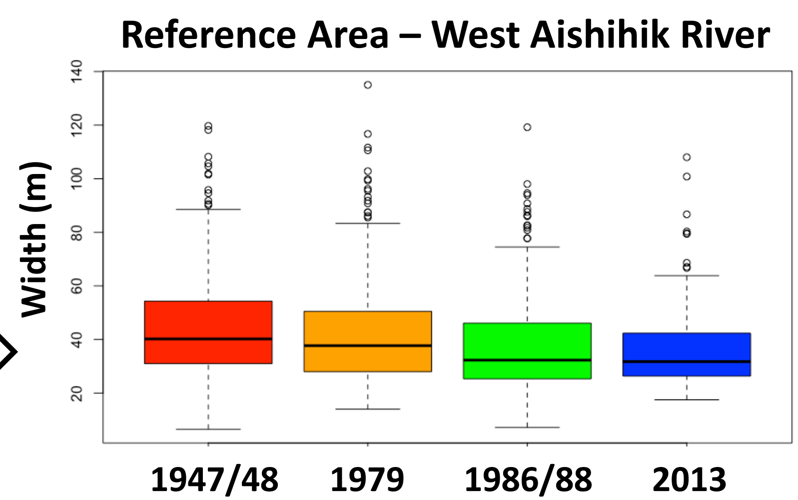
- Decreased spring and summer flows (e.g. freshet)

- Increased **magnitude** and **diurnal variation** of winter flows

Channel widths

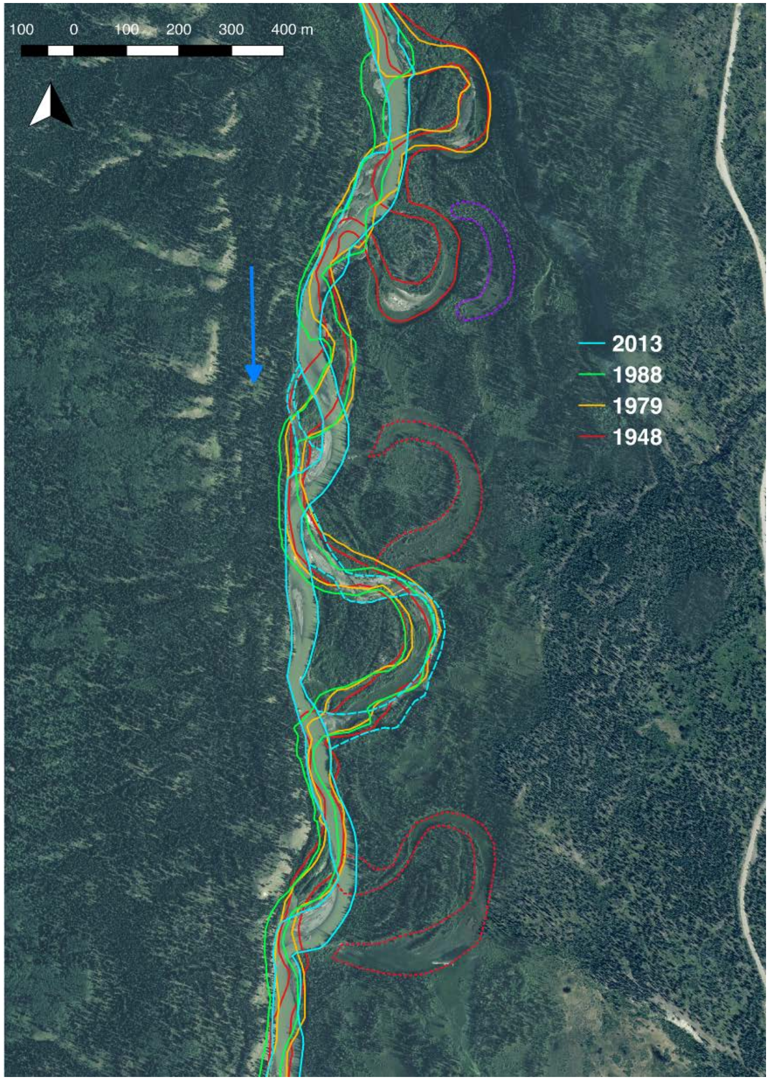
River	Reach	Average Unvegetated Channel Width[1] (m)			
		1947/48	1979	1986/88	2013
East Aishihik River[2] *(% change)*[3]		41.4	44.5 *(+7.0%)*	42.7 *(-4.2%)*	27.7 *(-54.2%)*
Aishihik River	1 *(% change)*	44.4	48.6 *(+8.6%)*	54.0 *(+10.1%)*	80.4 *(+32.8%)*
	2 *(% change)*	41.1	45.8 *(+10.3%)*	47.8 *(+4.1%)*	54.6 *(+12.4%)*
	3 *(% change)*	48.4	50.9 *(+4.9%)*	51.0 *(+0.2%)*	86.6 *(+41.1%)*
	4 *(% change)*	51.4	61.0 *(+15.8%)*	58.8 *(-3.6%)*	61.0 *(+3.5%)*
	5 *(% change)*	52.4	57.3 *(+8.5%)*	56.9 *(-0.7%)*	71.4 *(+20.3%)*
	6 *(% change)*	48.3	57.0 *(+15.2%)*	N/A[4]	51.9 *(-9.8%)*
West Aishihik River *(% change)*		45.1	43.1 *(-4.6%)*	37.9 *(-13.7%)*	36.3 *(-4.6%)*





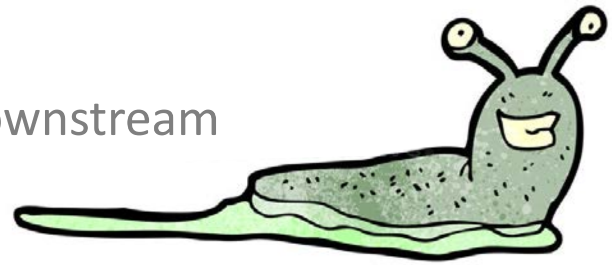
Sinuosity

River	Reach	Sinuosity (m/m)[1]			
		1947/48	1979	1986/88	2013
East Aishihik River *(% change)*[2]		1.16	1.15 (-1.1%)	1.16 (+1.5%)	1.20 (+3.4%)
Aishihik River	1 *(% change)*	1.75	1.37 (-28.5%)	1.35 (-1.0%)	1.38 (+2.4%)
	2 *(% change)*	1.42	1.33 (-6.9%)	1.18 (-12.4%)	1.11 (-6.2%)
	3 *(% change)*	1.85	1.88 (+1.3%)	1.78 (-5.4%)	1.28 (-38.2%)
	4 *(% change)*	1.40	1.38 (-1.0%)	1.40 (+1.5%)	1.49 (+5.9%)
	5 *(% change)*	1.55	1.56 (+1.1%)	1.49 (-5.2%)	1.41 (-5.1%)
	6 *(% change)*	1.53	1.75 (+13.0%)	N/A[3]	1.70 (-3.2%)[4]
West Aishihik River *(% change)*		1.54	1.48 *(-4.2%)*	1.53 *(+3.1%)*	1.58 *(+3.6%)*



Spatio-temporal resilience

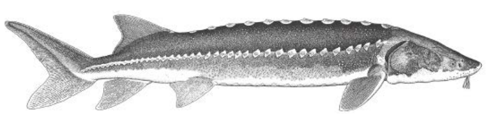
- Downstream progression of morphologic adjustments through time
  - Sediment ‘slug’ moving downstream



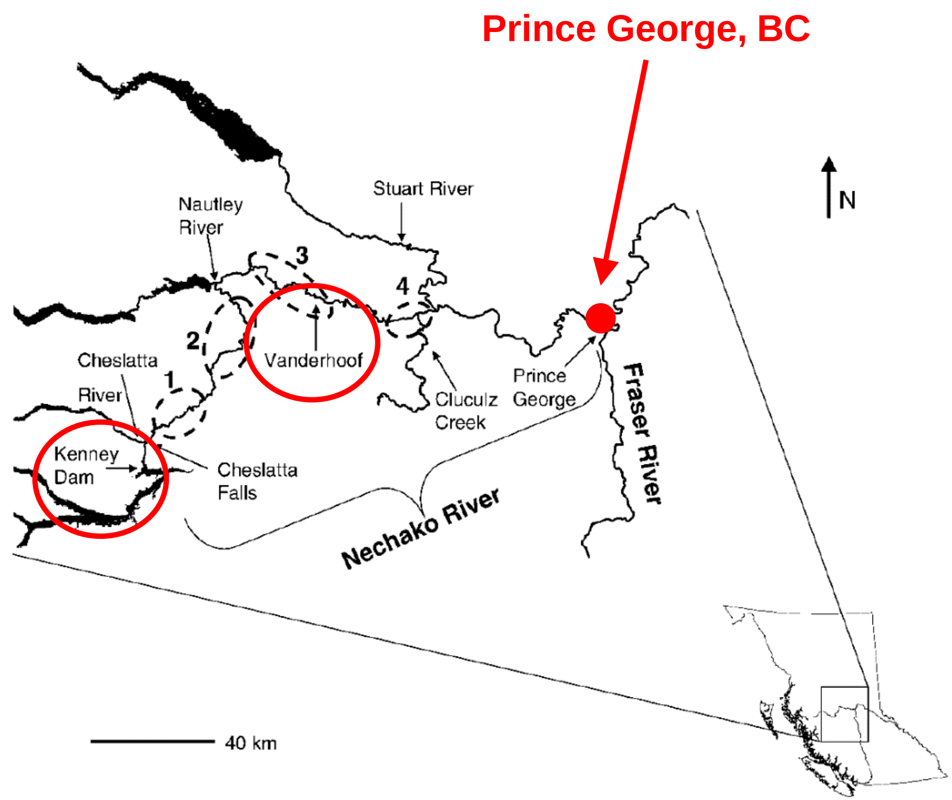
- *Upper reaches* – increased ice formation in winter appears to have increased active channel width, induced meander cut-offs and altered riparian vegetation communities
- *Lower reaches* – morphologic effects of AGS have yet to fully develop

Nechako River

- Kenney Dam became operational in 1952
- 45% reduction in annual peak discharge in Nechako River

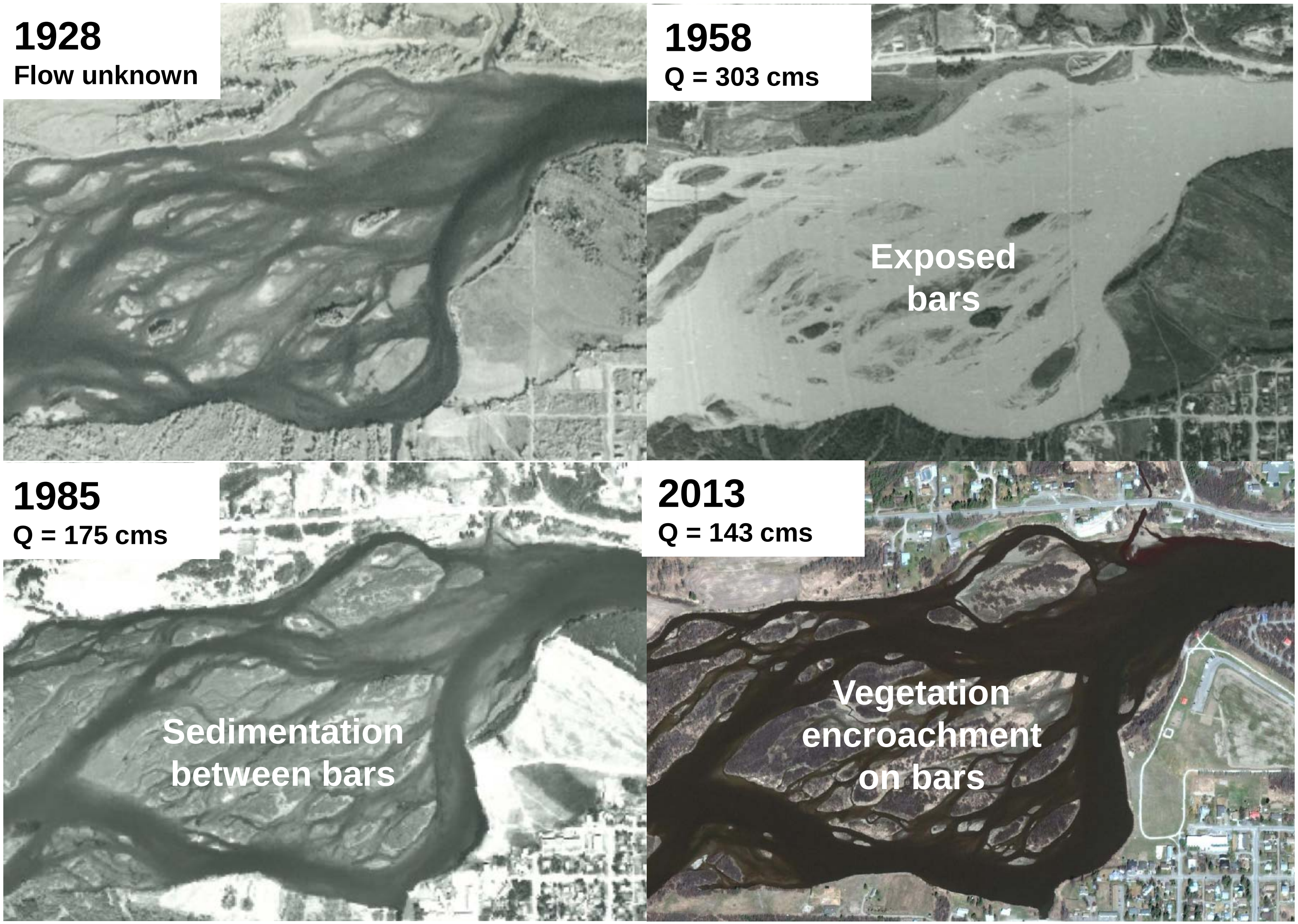


- Timing of peak flow has shifted from June to August
- PECG examined erosion rates and changes in channel morphology near Vanderhoof



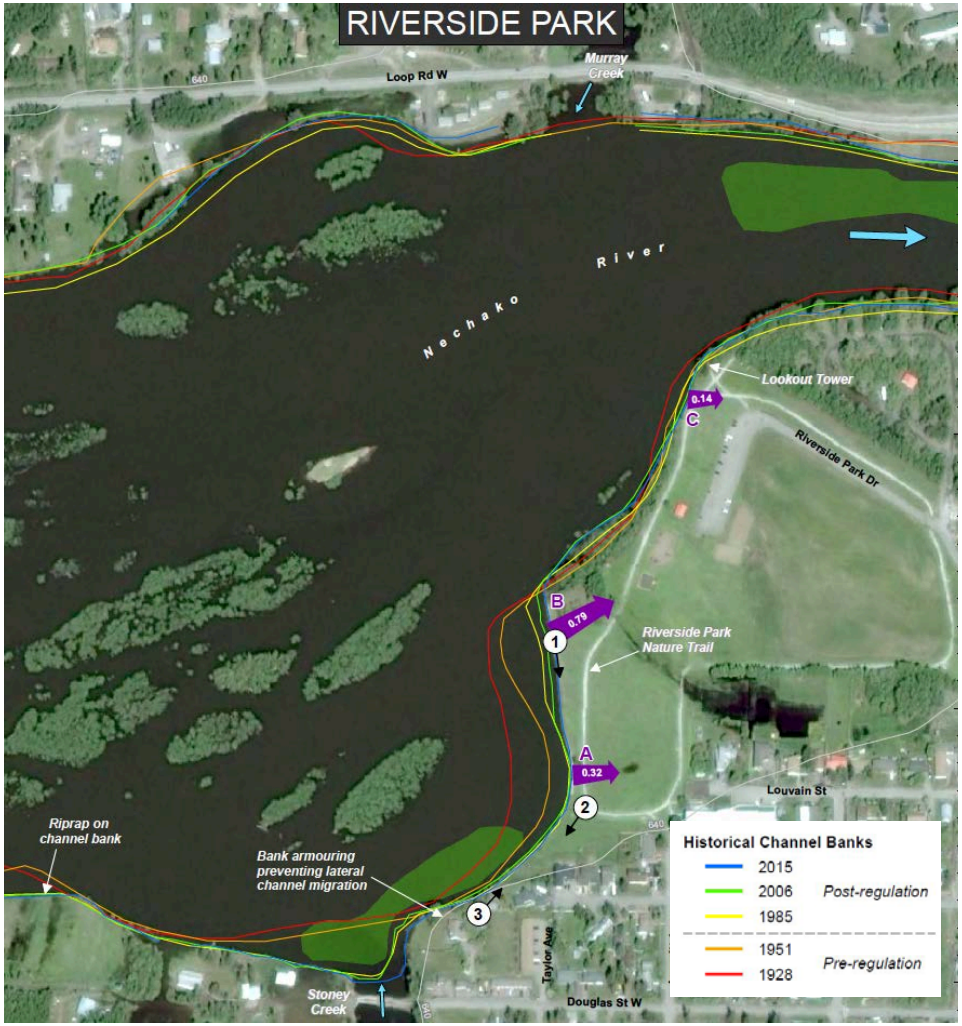
McAdam et al., 2005

River evolution at Vanderhoof

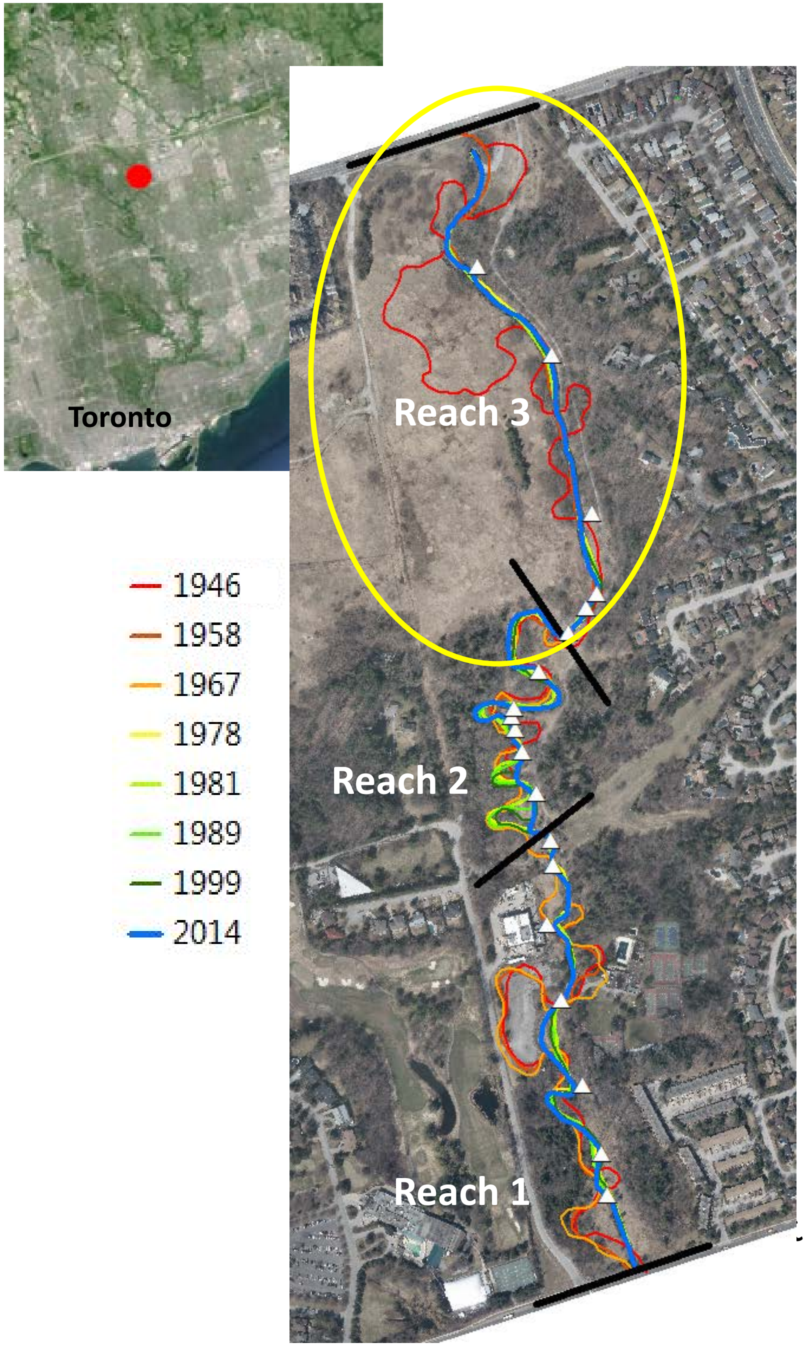


Delayed response

- Reduction in erosion rates post-regulation
- Vegetation encroachment on banks and bars took decades following regulation
- Fine 'sediment slug' associated with two dam-related avulsions ~150 km upstream reached Vanderhoof between 1966 and 1973
  - Coincides with White Sturgeon recruitment failure

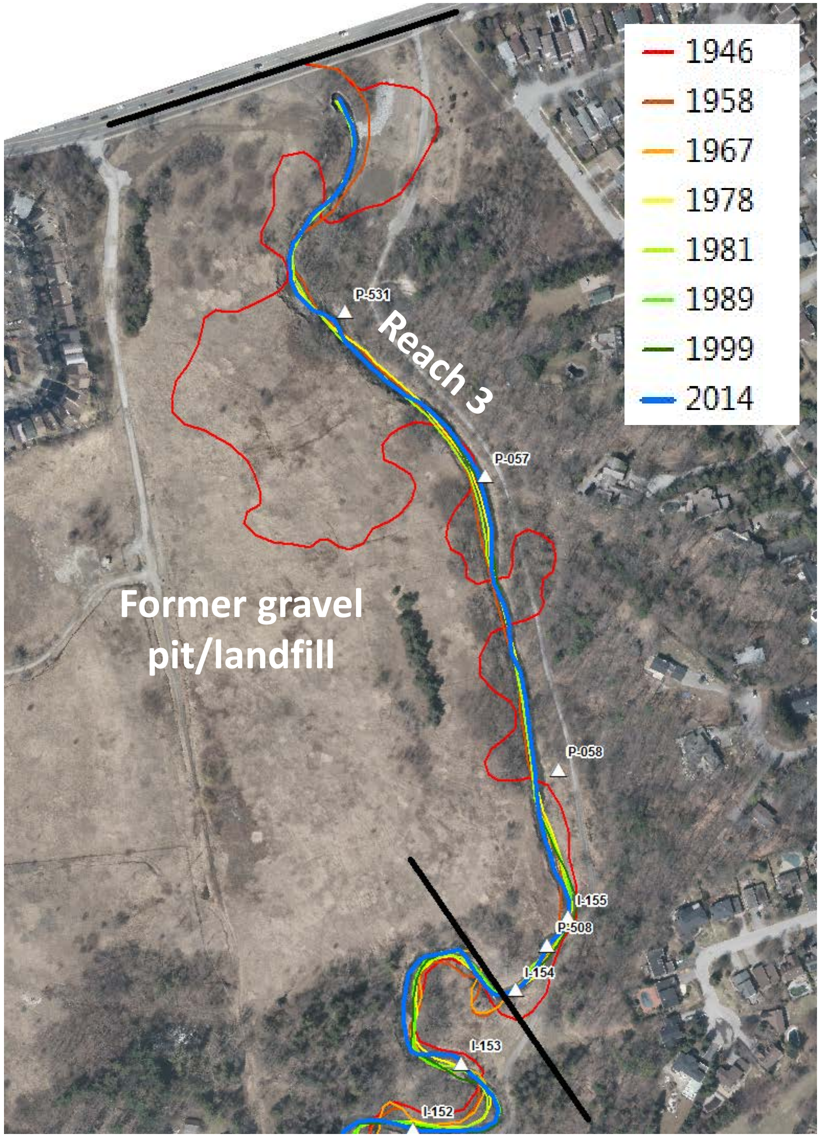


German Mills Creek



- Numerous at-risk crossings and encroachments of sanitary sewer
- History of alteration

Reach 3



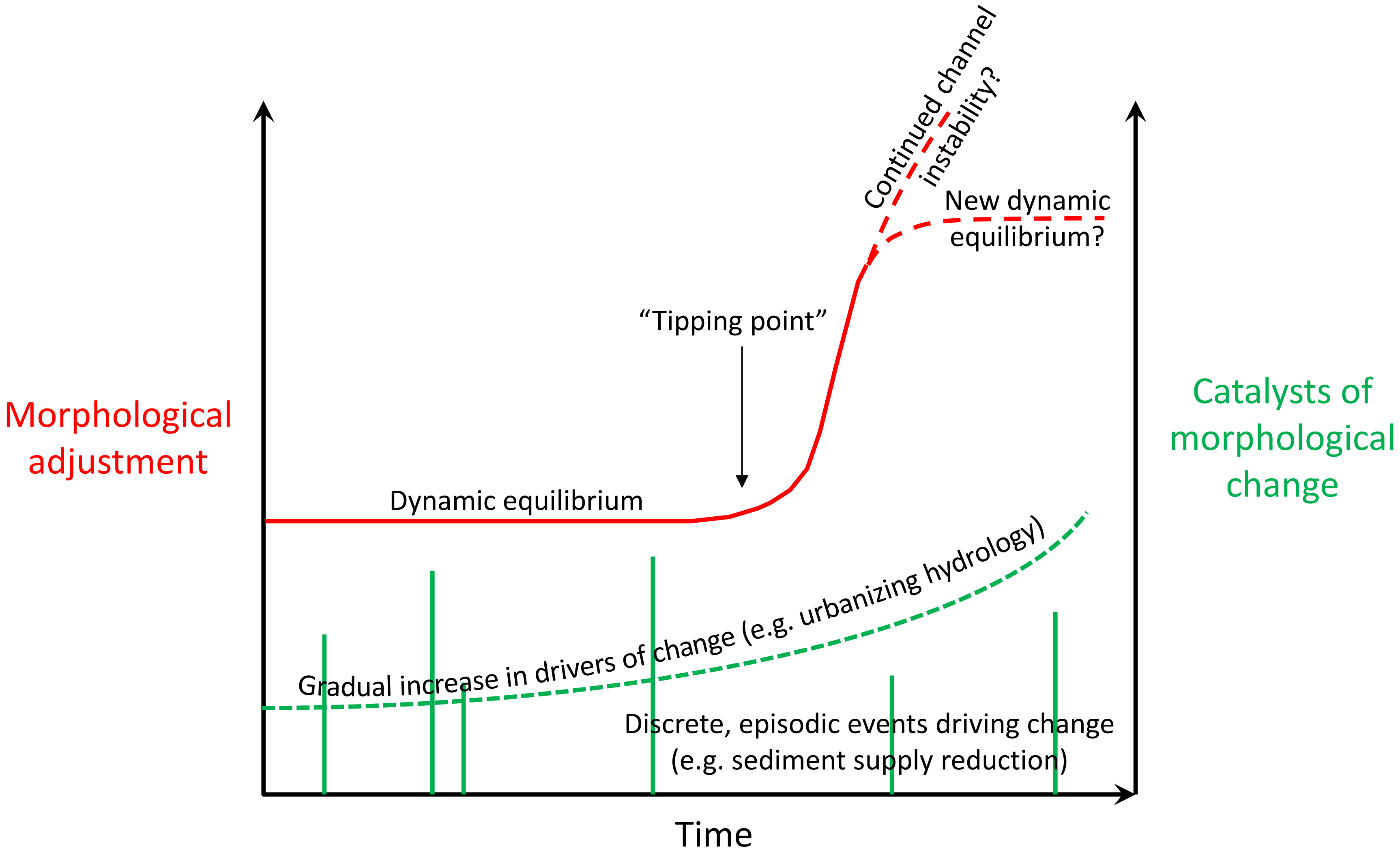
- Between 1946 and 1958, the meandering channel was straightened to follow the perimeter of a gravel pit (later landfill)
- 50% loss of channel length!...yet instability has only become apparent in the 2000s

Why the time lag?

- Constructed channel entrenched but **over-widened**
- Thalweg initially centred along straightened channel, away from banks, until **minor irregularities develop** and perturb flow
- Morphological adjustments accelerate once **large woody debris**, initially unavailable in the absence of riparian vegetation, begins to accumulate in channel and deflect flows

KEY CONCEPTS AND IMPLICATIONS

Time-limited resilience: concepts



Implications

- It's not all about flow! – Watershed managers must consider how and when channels are likely to respond to changes in sediment supply and transport patterns, as well as riparian vegetation growth
- Erosion mitigation projects must anticipate and accommodate geomorphic responses to both recent and historic events
- The occurrence of morphological adjustments years to decades after disturbance underscores the uncertainty in determining the effectiveness of natural channel design projects in typical (<3 year) post-construction monitoring programs

PALMER
ENVIRONMENTAL
CONSULTING
GROUP INC.