Morphological response to urban development over 60 years: Highland Creek, Ontario

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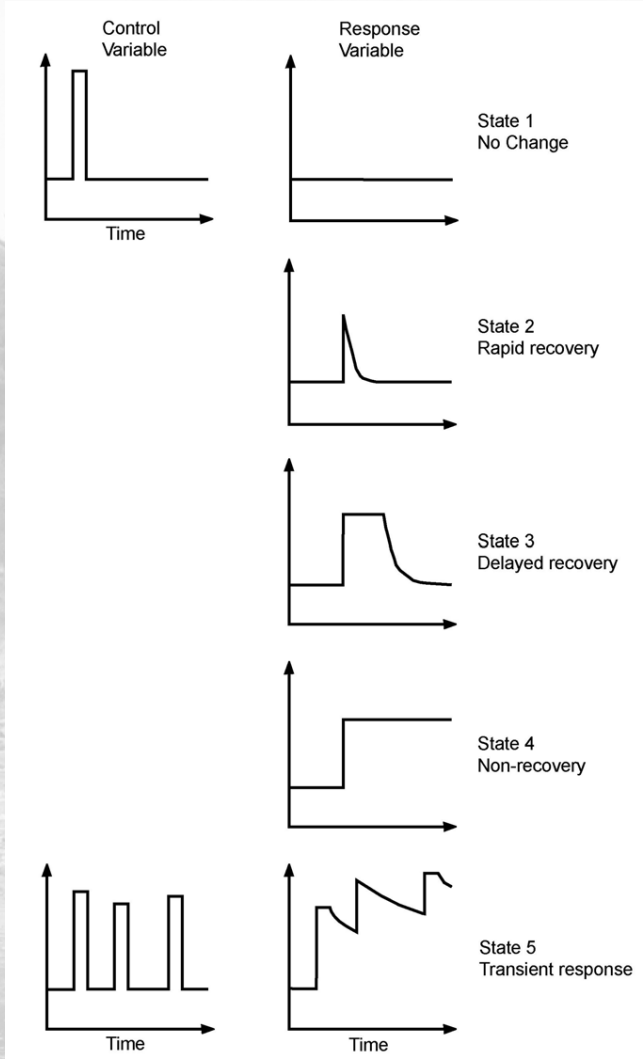
Overview

- Highland Creek, Toronto (Scarbz), Ontario
- Highly urbanized, degraded, adjusted (natural and anthropogenic), some failing historical treatments and designs
- Tracking progressive adjustment through the urbanization process
- Predictions and trajectory of change
- Practical application and design

Study Rationale

- River channel adjustment often studied in response to land-use and hydrological change
- Urbanization has known changes in morphological controls (primarily discharge)
- Few studies actually track channel adjustment over the course of urbanization, usually look only at end result (e.g. enlargement ratio)
- Seldom have these changes been analyzed in terms of expected adjustment from hydraulic geometry and regime theory and the actual processes of adjustment



Objectives

- Measure and map changes in channel width and length (sinuosity) over the period of urban development and hydrological change at multiple times
- Identify time, location, process and type (natural or engineered) of change.
- Determine whether channel adjustments fit expectations from regime theories, and if the pattern of change and the time trajectory reflects those from conceptual models of urban channel adjustment

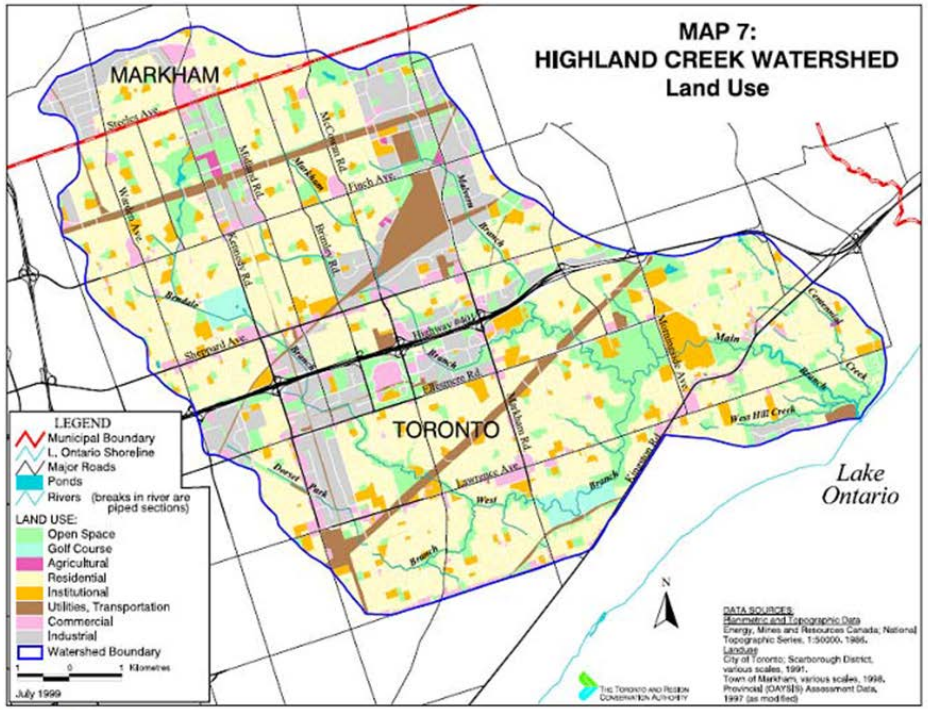
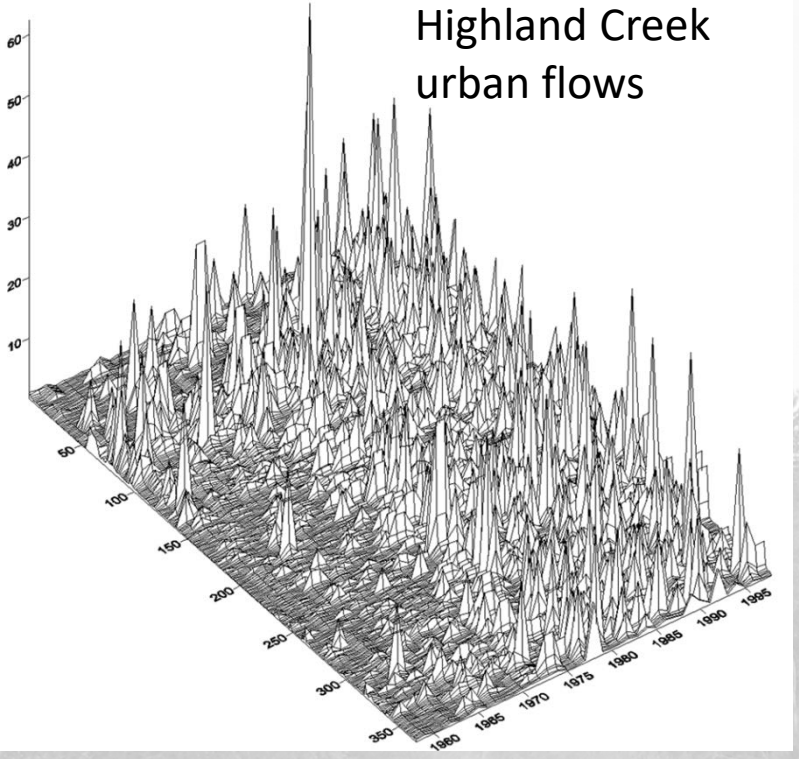


Figure 2.8b
(from TRCA and City of Toronto, 1999)

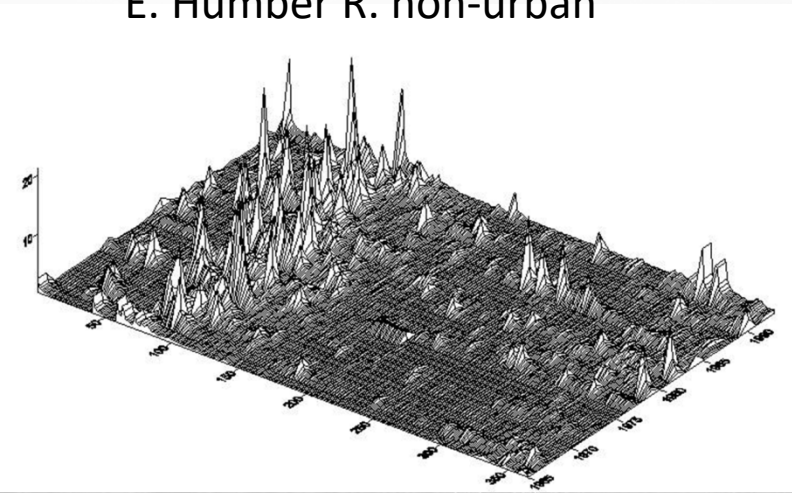
Drainage area ≈ 100 km^2
Total relief ≈ 125m
85% Urban land use
55 % of area impervious (Satgunarajah 2009)
Channel slope ≈ 1%
Semi-alluvial

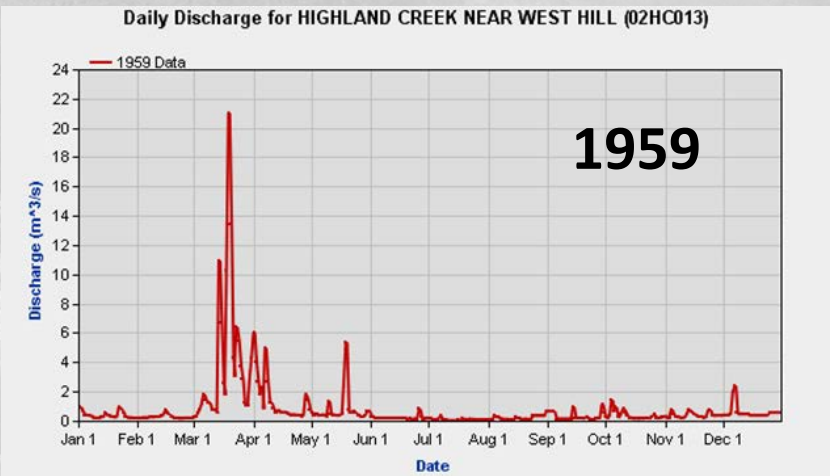
Headwater Engineering

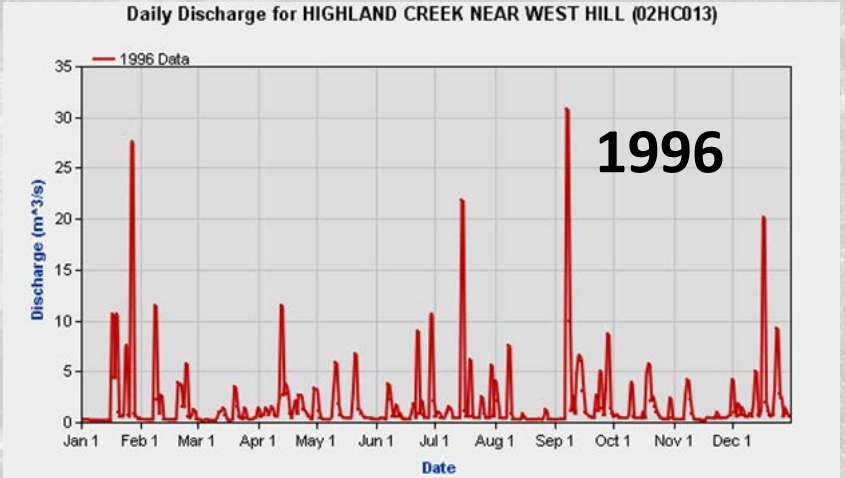
Highland Creek urban flows



E. Humber R. non-urban



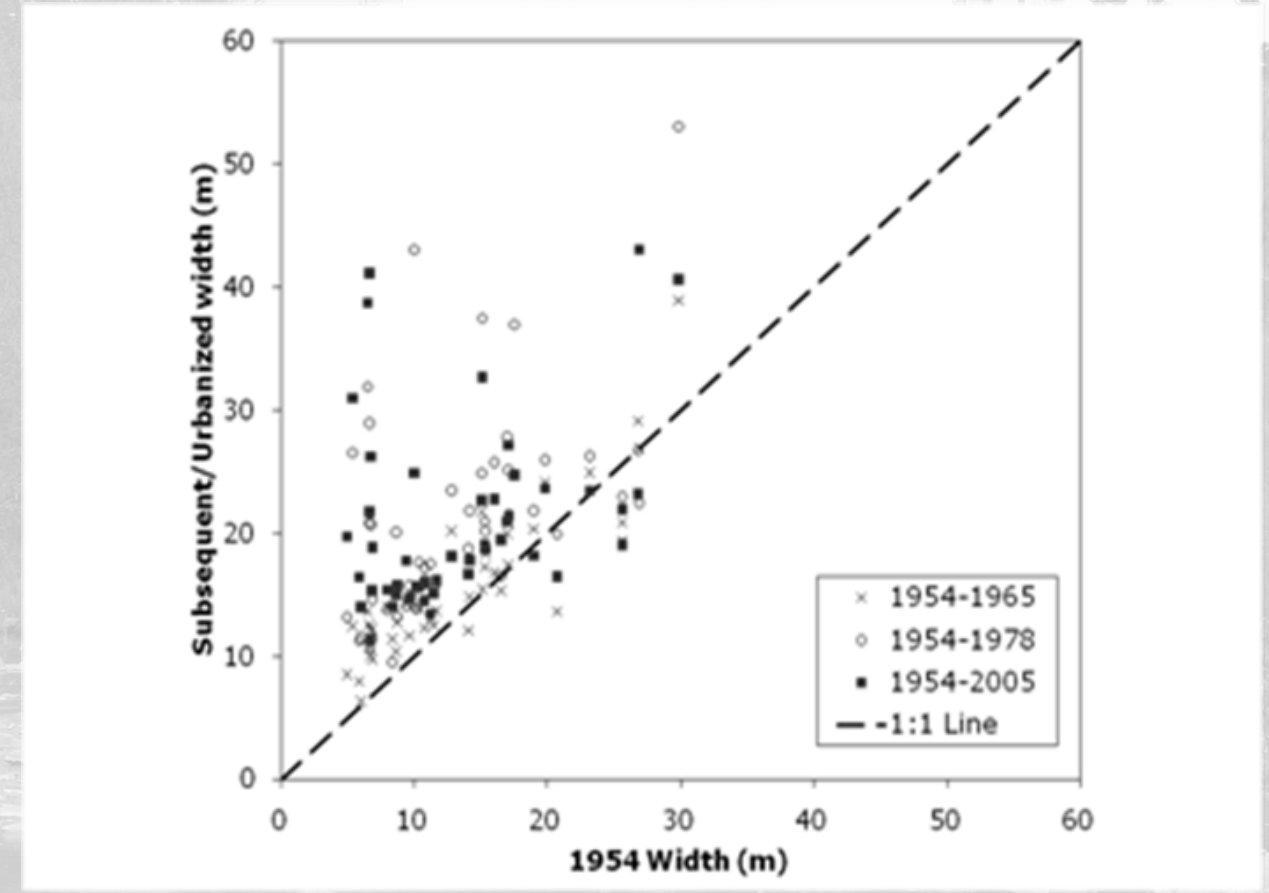




Data and analysis

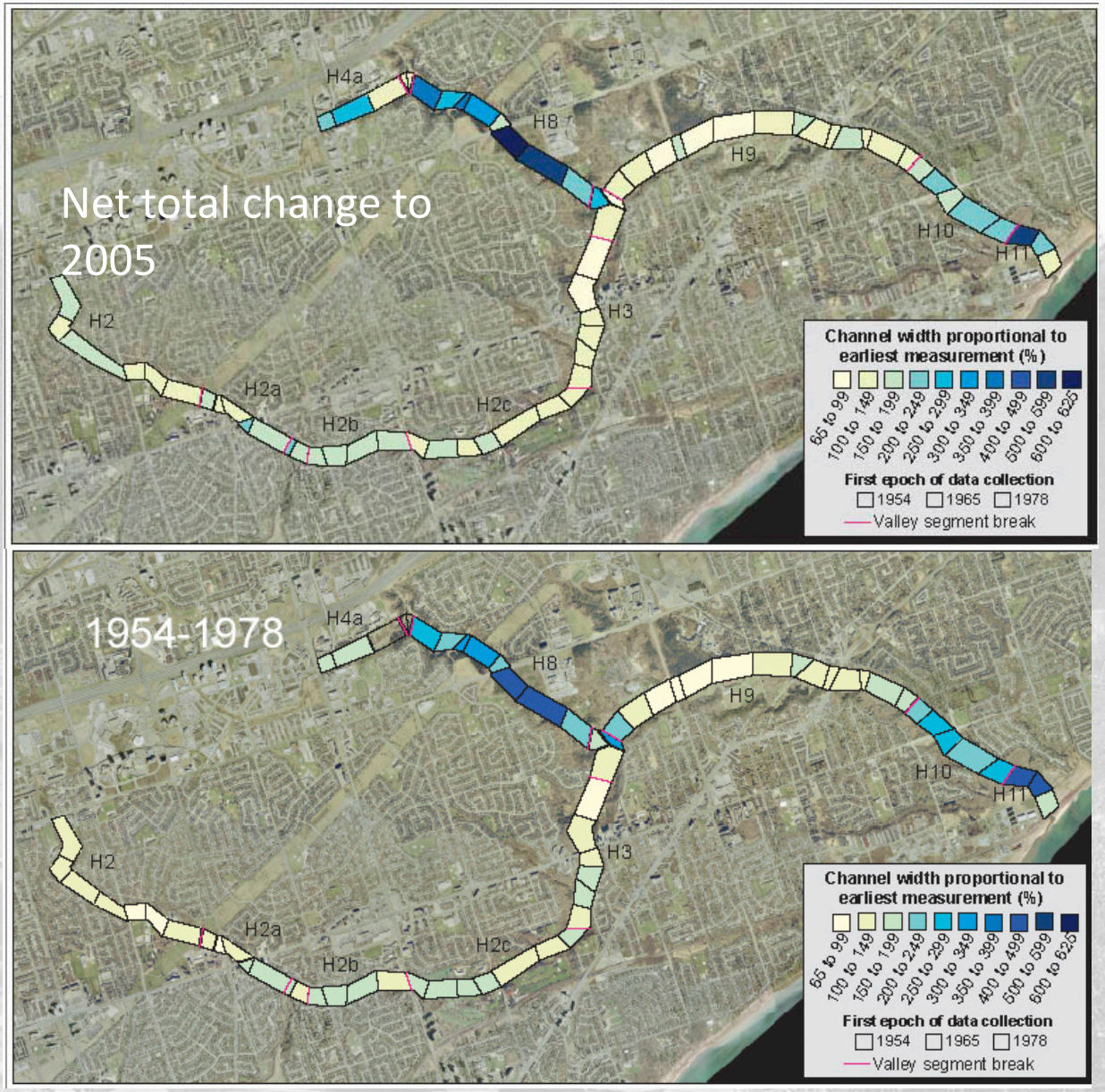
- Historical aerial photographs from several epochs:
- 1954 (pre-Hurricane Hazel)
- 1965
- 1974 (new)
- 1978
- 1986 (new)
- 1999 (new)
- 2005 (pre August 19th flood)
- 2015 (new)
- Orthorectified, geo-referenced and put in common coordinate system (UTM). Some digital orthophotos.
- Mapped channel area and centreline along main branch and 2 main upstream branches from L. Ontario upstream to Hwy 401. Using a grid along each valley segment.
- Calculated mean width from area and length (centreline)
- Streamgauge at Morningside Avenue used for flow data, applied to equations based on a unit-area rating.
- More recent changes to methodology.

Observed reach-averaged width changes

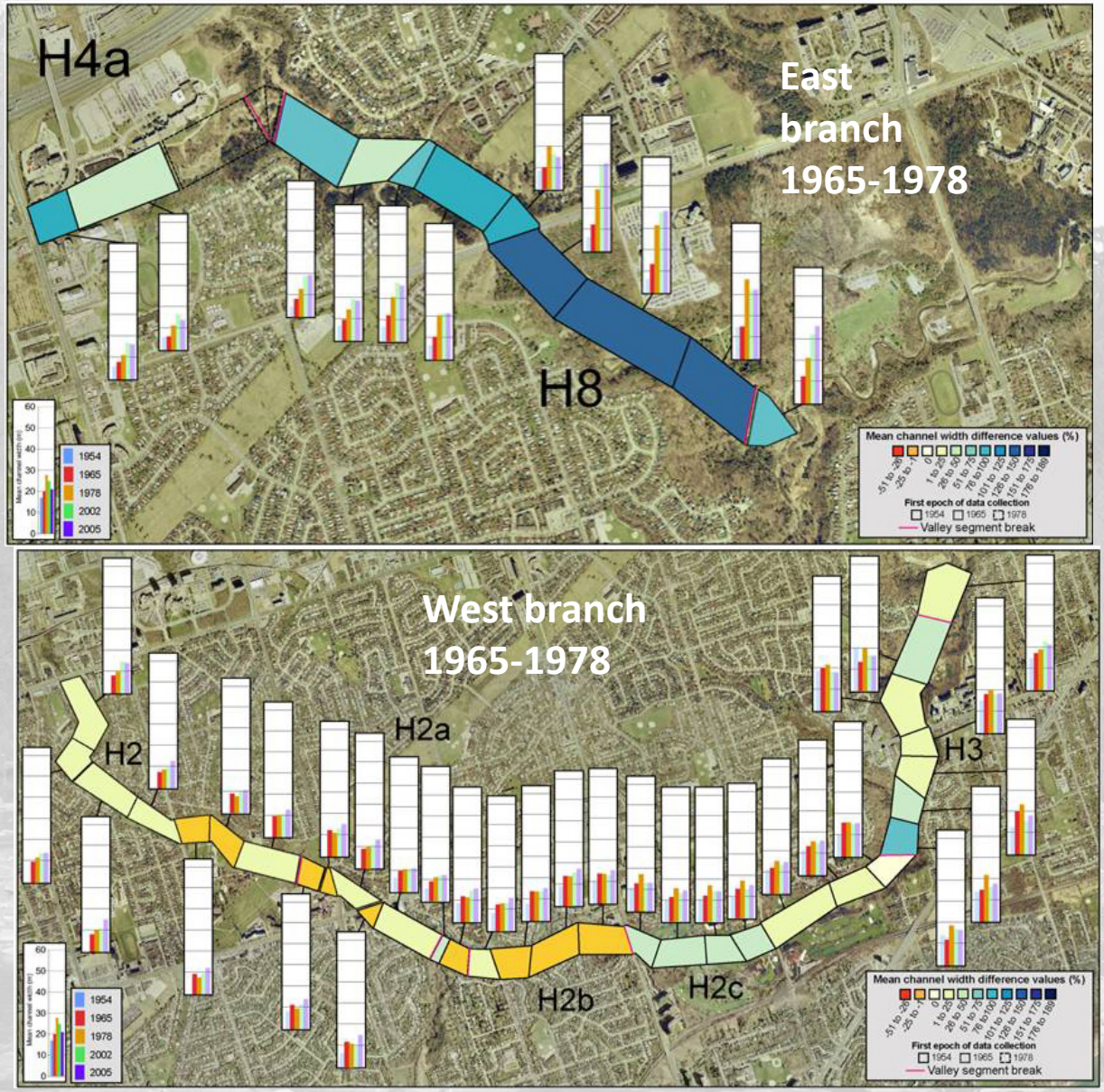


Observed changes in channel width

- Much had happened by 1978 – floods of mid -70s from which some narrowing has occurred
- Wide variation in proportional response to fairly uniform flow changes
- East branch is focus of major changes
- West branch shows little change after 1978
- Is this local variability in response (different slopes, material etc.) or something else?



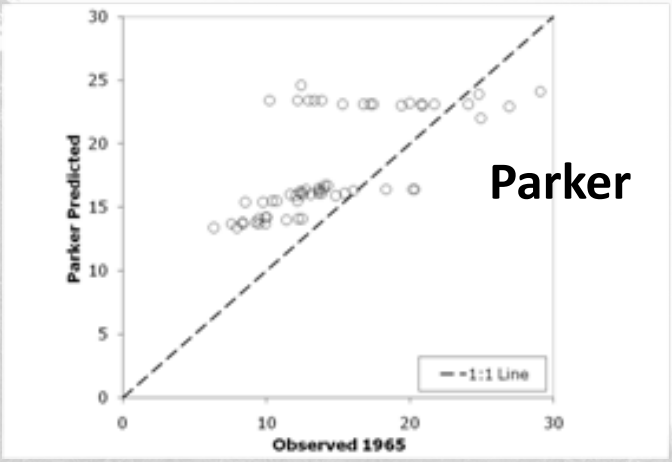
East vs west


H4a
East branch 1965-1978
H8
Mean channel width difference values (%)
First epoch of data collection
1954
1965
1978
Valley segment break
West branch 1965-1978
H2
H2a
H2b
H2c
H3
1954
1965
1978
2002
2005

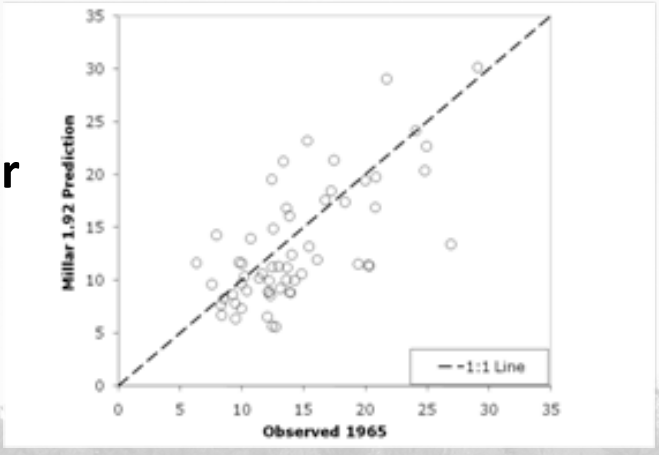
Predictions

- Rational regime relations of Henderson & Griffiths
- Ashmore empirical power vs width relation for gravel rivers
- $w = 2.06QbS^{7/6}D^{-3/2}$ (Henderson, 1966)
- $w = 5.28Qb\ S^{1.26}D^{-1.5}$ (Griffiths, 1981)
- $w = 0.87\Omega^{0.559}D^{-0.445}$ (Ashmore, 2001)
- Parker 'bankful predictor' (no slope)
- UBC – Millar-Eaton regime model "Millar"

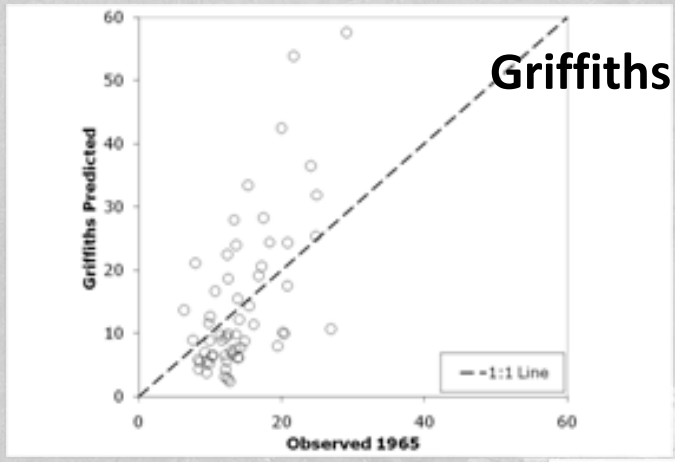
Parker



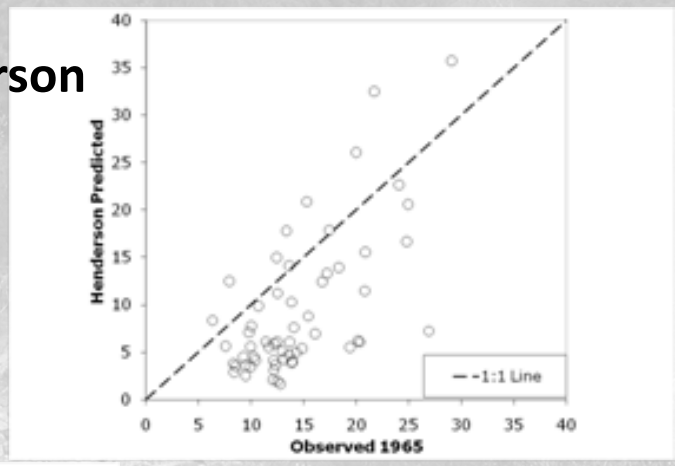
Millar



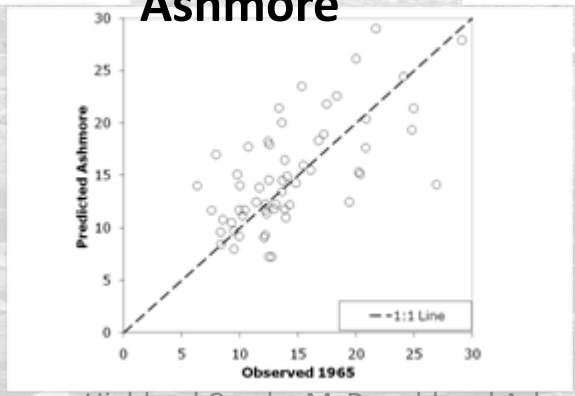
Griffiths



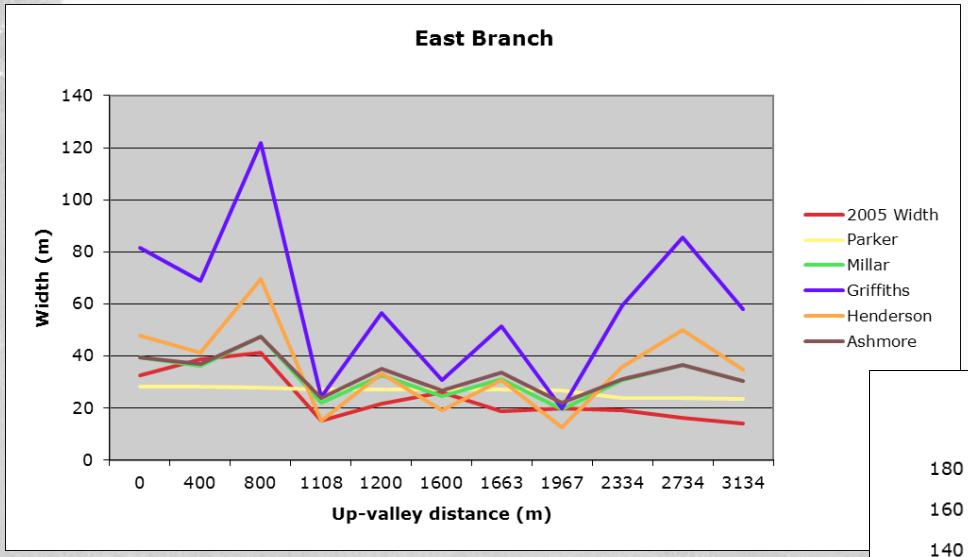
Henderson



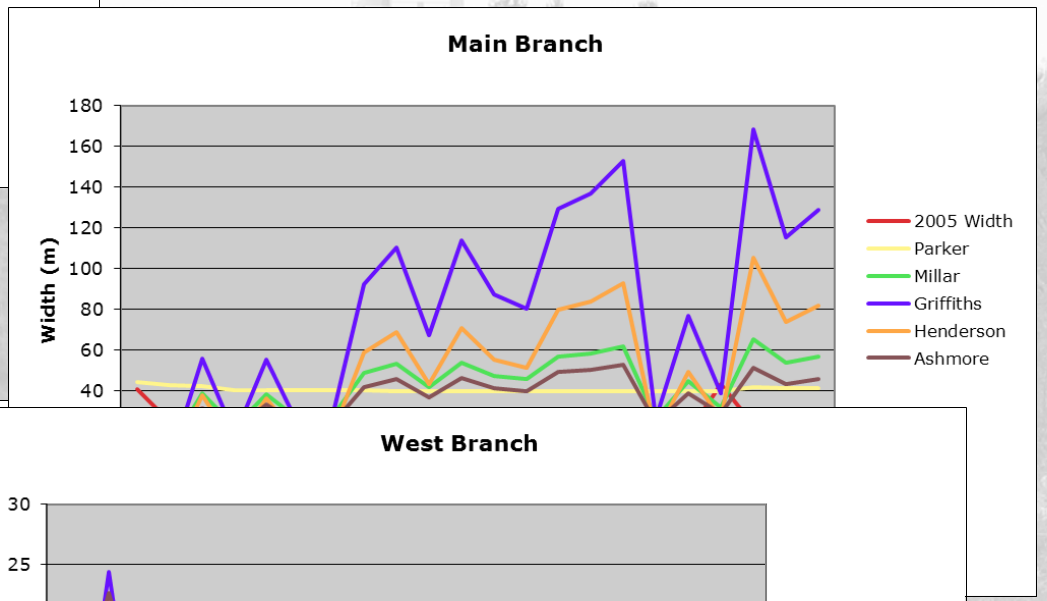
Ashmore

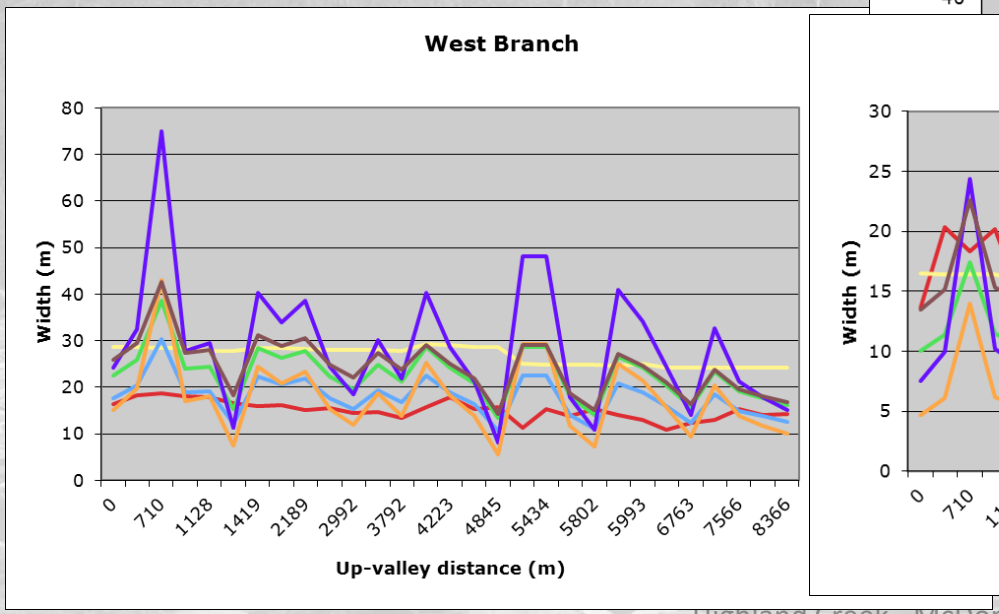


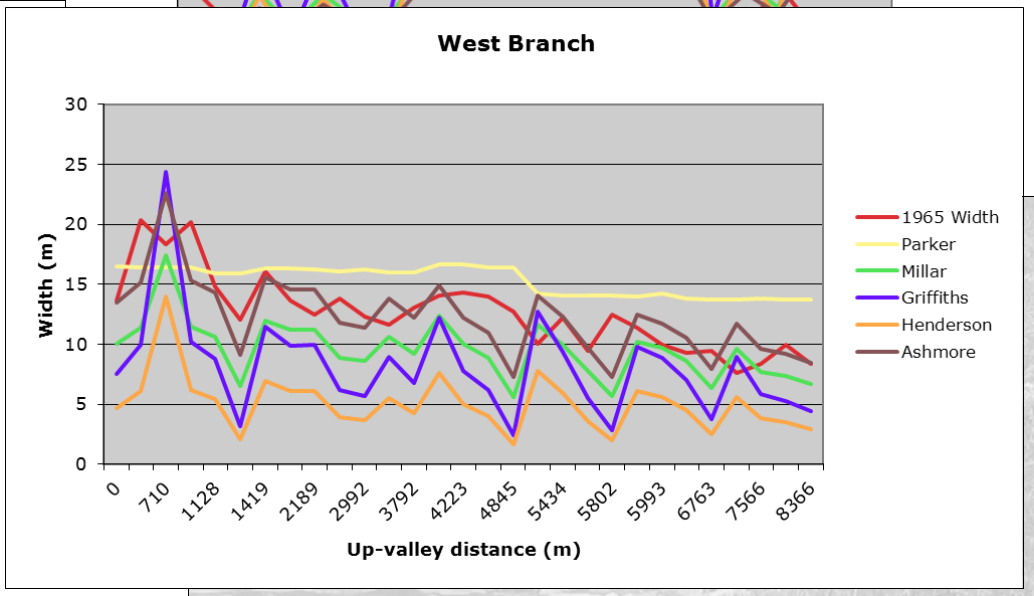
- Slope needed
- Griffiths ‘overdoes’ it
- Henderson conservative
- Significant errors even in the best predictors



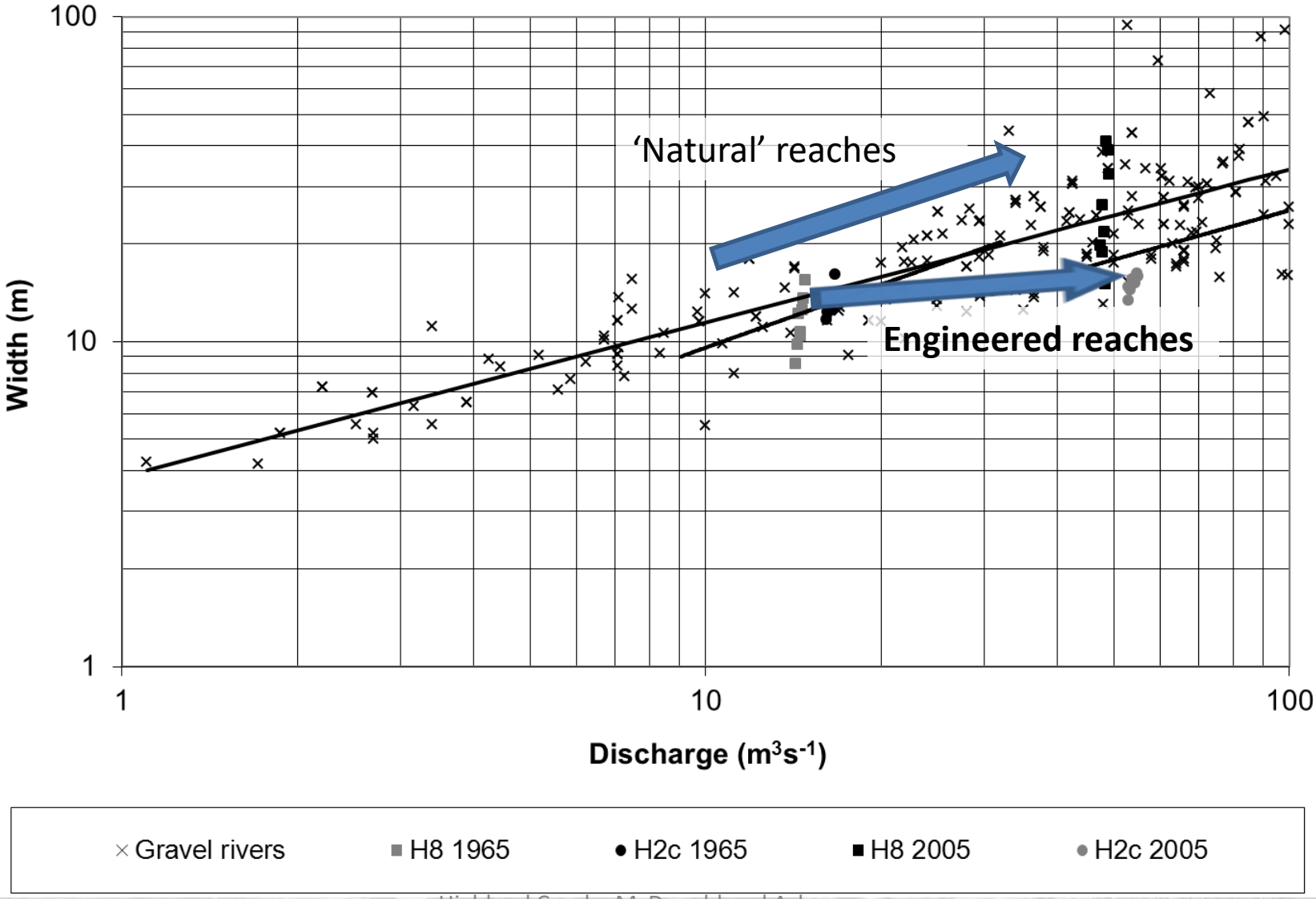
Pick up local variation and trends but over-prediction common except on east branch







engineering history and constraints muddy the response picture – channel change is combination of 'natural' and engineering response. time trajectory is mix of intervention and progressive or event-based natural adjustment



- **Predicted changes approximately correct for natural reaches and remain a useful design – anticipation tool**

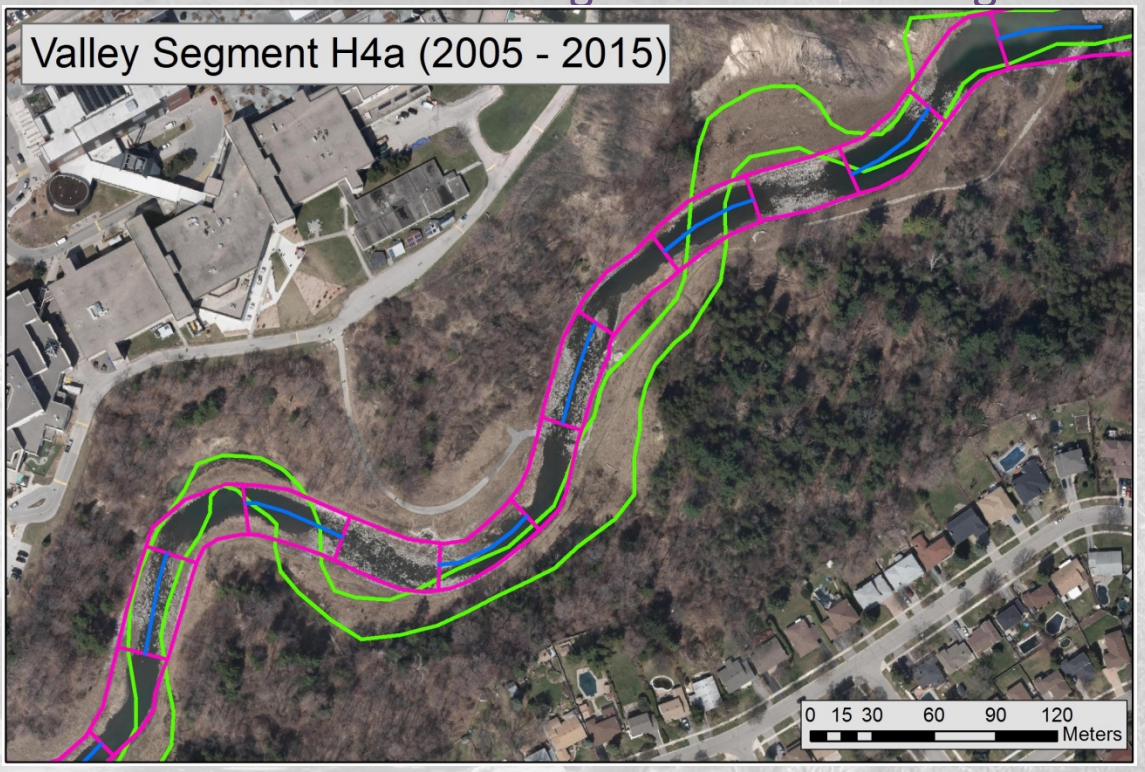
- **Time trajectory requires mapping of effects of significant floods and recovery, as well as the step/ramp change from generally increased flows (currently working on processing post-2005 data – some of which are now modified by further engineering)**

- **But understanding the urban response to increased flows requires understanding of engineering intervention, channelization and design approaches and constraints**

- **Not as controlled an experiment as we thought!**

Recent Work

- Digitized bankfull channel (estimated) using historical and recent air photos
- 2015 Plots of Valley Segment H4a show designs aligning better with predictive equations (for width).
- Attempting a 'moving window' method for assessing mean width along the channel
- H4a Prediction: 25-32m
- Measured Mean: 22m
- Design: Ask Bill.



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- Parish Geomorphic
- Aquafor Beech Ltd. (Mariette Prent-Pushkar & Roger Phillips)
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