The Effects of Aquatic Vegetation Growth on Discharge Calculation in Natural Watercourses: A High-Resolution Study Featuring Novel Techniques

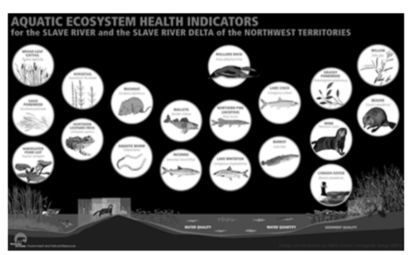
UNIVERSITY OF WATERLOO
FACULTY OF ENGINEERING
Department of Civil &
Environmental Engineering

Lorenzo Brignoli
PhD Candidate

Environmental flows estimation

Why are environmental flow rates important?

- Habitat sustainability assessments
- Water allocation
- Assessment of drought severity

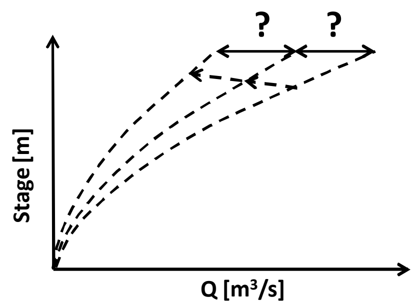


© L. Brignoli, W. K. Annable, 2016

Estimation of flow

To estimate flow rating curves are generally used.

Presence of vegetation however, can cause unpredictable shifts in the curve.



Introduction

© L. Brignoli, W. K. Annable, 2016

3

Problem statement

It is challenging to predict the rise in water levels caused by aquatic vegetation growth and associated flow rates.

This lack of knowledge prevents us from obtaining reliable environmental flow estimates in vegetated channels affecting persons/institutions that need them.

- Environmental agencies
- Practitioners
- Modellers

© L. Brignoli, W. K. Annable, 2016

Background

From lab studies:

Vegetation spatial distribution

α

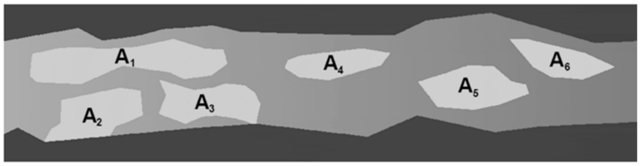
Flow resistance.

How do we apply this knowledge to the field?

Examples of field metrics used:
- Aerial cover
- Blockage factor

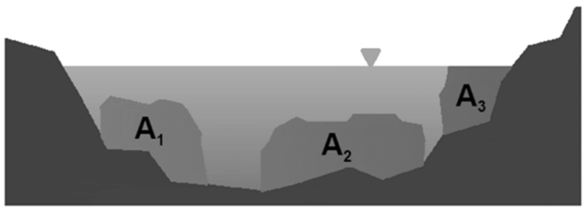
© L. Brignoli, W. K. Annable, 2016

Field studies: metrics used



Aerial cover

$$B_A = \frac{\sum A_i}{A_T}$$



Blockage factor

$$B_X = \frac{\sum A_i}{A}$$

(related to y_n/k)

© L. Brignoli, W. K. Annable, 2016

Research gap

- Few field studies undertaken
- Low spatial resolution
- Low temporal resolution
- Metrics not agreed upon and/or inconsistently estimated
- Lack of direct comparisons between vegetated and non-vegetated scenarios

© L. Brignoli, W. K. Annable, 2016

Research Objective

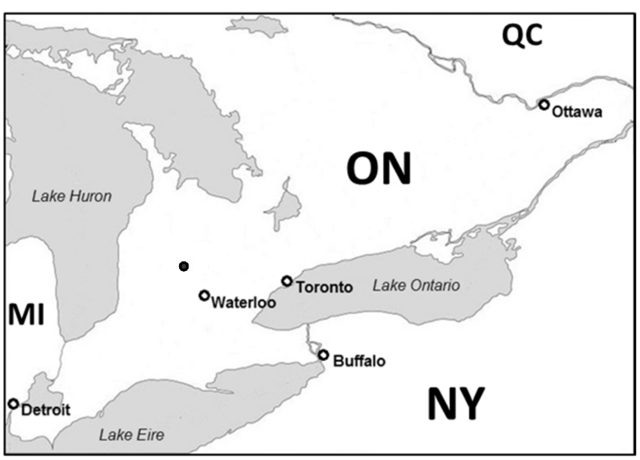
To correctly **quantify** the temporal effects of aquatic vegetation growth on discharge estimates

Through:

- Increasing spatial and temporal resolution of investigation
- Directly comparing water levels for vegetated and non-vegetated scenarios at the same flow rate
- Using non-disruptive, easy to reproduce methodologies to produce simple vegetation parameters

© L. Brignoli, W. K. Annable, 2016

Study site



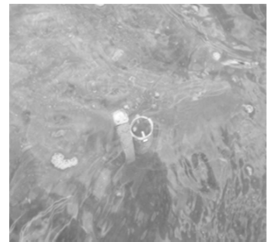
Two study reaches

L=106 – 121 m
W_{bf} = 7.5 – 11 m
S = 0.12 – 0.24%
Q=0.03–0.35 m^3/s

© L. Brignoli, W. K. Annable, 2016

Methods: continuous flow and water level measurement

- Water level at non-vegetated locations
- Water level at vegetated reaches
- Discharge measurements
- Goals:
  - Development of non-seasonal rating curve
  - Water level data is collected before and during vegetation growth so it can be compared directly (for same *Q*)
    - Roughness parameters can be calculated for the two scenarios



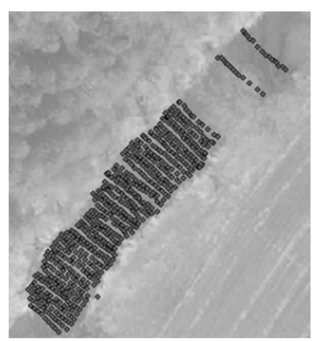
© L. Brignoli, W. K. Annable, 2016

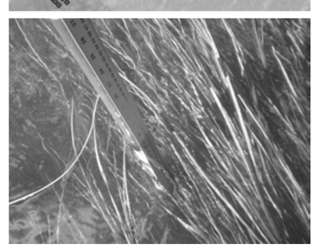
Methods: topographic vegetation surveys

Objective: estimating spatial distribution of vegetation.

Characteristics:

- Uses RTK-GPS unit (±1 cm)
- For each survey 40-60 cross sections (spacing 1.5 m on average)
- Cross-sectional point spacing 50 cm on average
- At each location, depth, vegetation height are recorded
- Repeated 7-12 times each summer





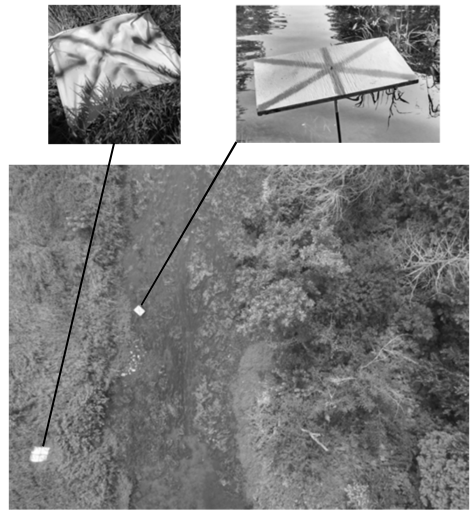
© L. Brignoli, W. K. Annable, 2016

Methods: photographic surveys

Objective: estimation of vegetation distribution at higher detail.

Aerial surveys with UAV

Geo-referencing via ground/bed control points

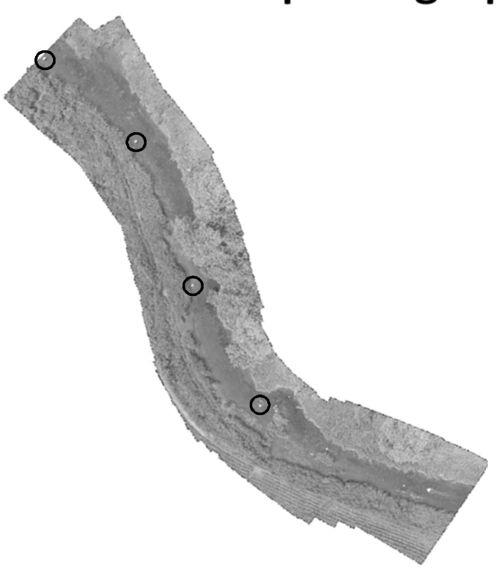


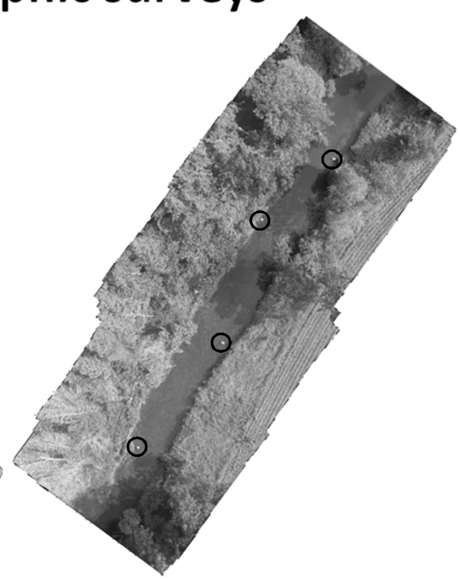
Methods

© L. Brignoli, W. K. Annable, 2016

UNIVERSITY OF WATERLOO 13

Methods: photographic surveys



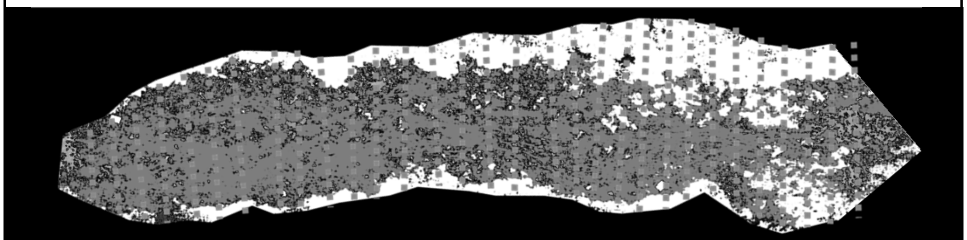


Methods

© L. Brignoli, W. K. Annable, 2016

UNIVERSITY OF WATERLOO 14

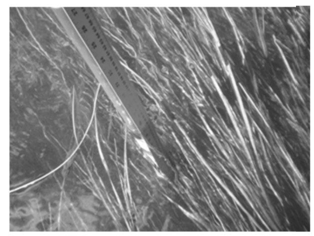
Results



Black: bare channel bed; White: emergent vegetation; Gray: submerged vegetation;

Processed image is compared to data obtained from topographic surveys.

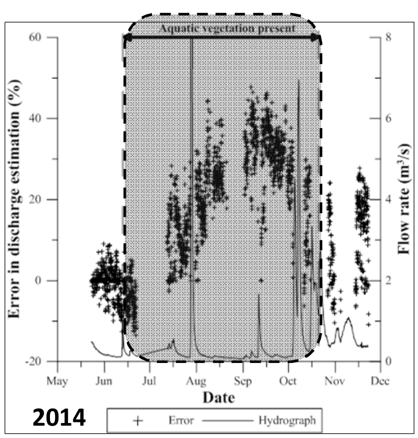
Preliminary analysis results: 5-10% error between GPS data vs processed data

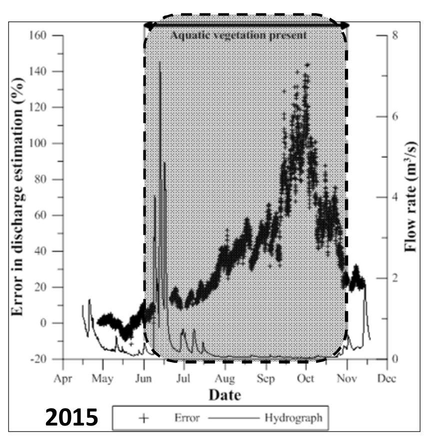


© L. Brignoli, W. K. Annable, 2016

Results

Aquatic plants cause a discharge overestimation ranging 50%-150% as water levels increase by 20-25 mm.

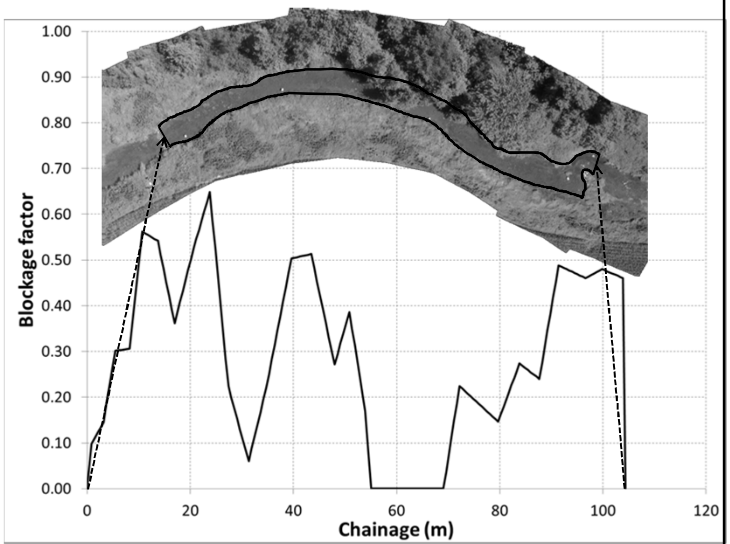




© L. Brignoli, W. K. Annable, 2016

Results

Spatial distribution of vegetation changes along the channel, from vegetation-free cross sections to highly blocked ones

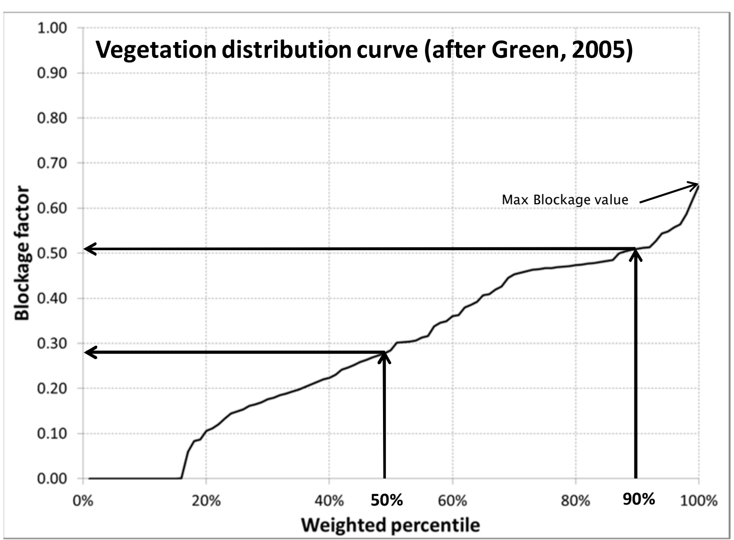


Results

© L. Brignoli, W. K. Annable, 2016

UNIVERSITY OF WATERLOO 17

Results



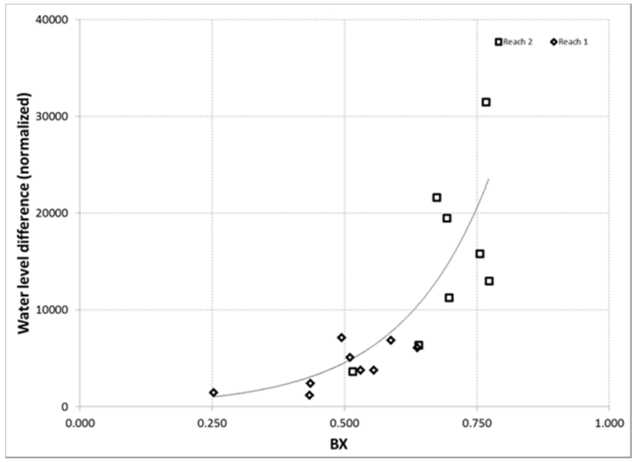
Results

© L. Brignoli, W. K. Annable, 2016

UNIVERSITY OF WATERLOO 18

Results: correcting Q data

Corrected discharge data is found by iteration



$$\boldsymbol{Q} = Q_{est} \pm \epsilon_Q = f_{n,3}(y_{vegetated} \quad y \pm \epsilon_y) = f_{n,3}(y_{non-veg} \pm \epsilon_y)$$

Results

© L. Brignoli, W. K. Annable, 2016

UNIVERSITY OF WATERLOO 19

Current work

Deployment to other sites

- Simulation how a practitioner would implement the results
  - Estimation of Q from vegetation distribution
- Validation
  - Correction factors might be necessary if size, slope of the river change
- Provide direction for future research

Canagagigue Creek (35-40% Q overestimation)

N. Maitland River (45-50% Q overestimation)

Conclusions

© L. Brignoli, W. K. Annable, 2016

UNIVERSITY OF WATERLOO 20

End users

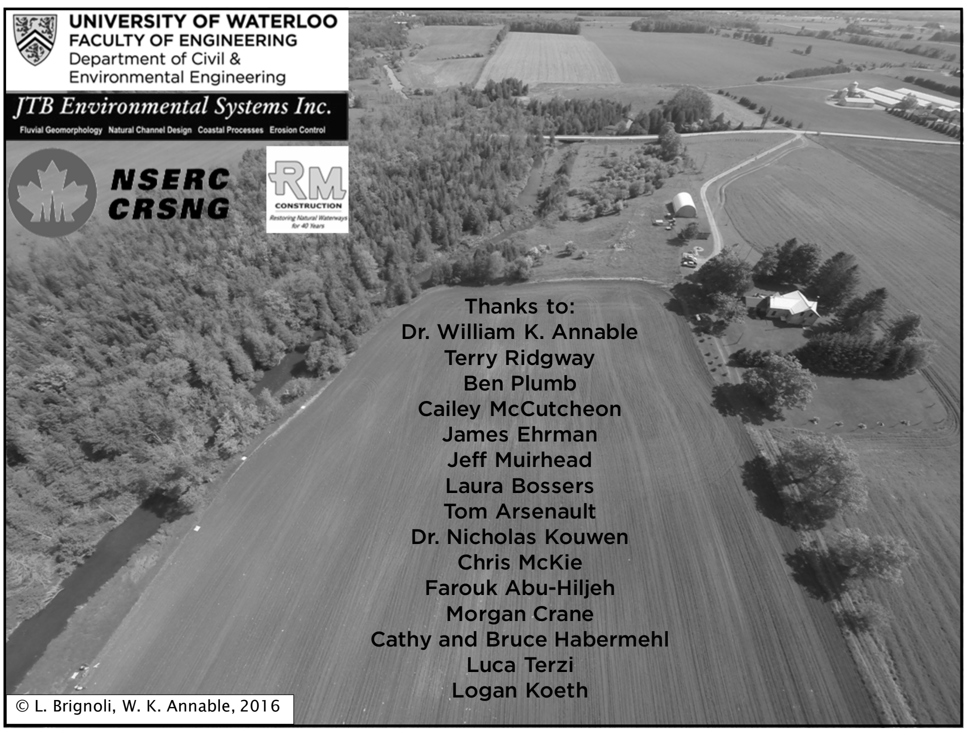
Who will use this dataset and research?

- Practitioners (engineers, biologists, hydrologists)
- Environmental agencies
- Modellers

Why is estimation of low flow important?

- Habitat sustainability assessment for fish, invertebrates
- Drought assessment for water allocation purposes
- Increased model (hydraulic and hydrologic) accuracy

Conclusions © L. Brignoli, W. K. Annable, 2016 UNIVERSITY OF WATERLOO 21



© L. Brignoli, W. K. Annable, 2016