Habitat Hydraulics

the relationship between depth & discharge around large roughness elements in low flow conditions

Alison Miller

Habitat Hydraulics

- Environmental flow

- Local variability
  - Provision of habitat
  - build up of nutrients (food)
  - zones of aeration

- Little understanding of low flow hydraulic conditions

Media Release

Low Flow Initiative to Improve River Management 02/09/09

"Managing low flows will play an increasingly critical role in sustaining...river systems…"

Senator Penny Wong

Impact of large roughness elements on flow regime

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1. Generate extra resistance to the flow

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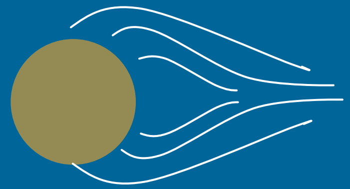

Impact of large roughness elements on flow regime

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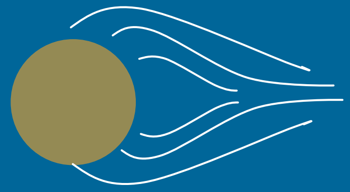

2. Generate a change in channel geometry

Impact of large roughness elements on flow regime

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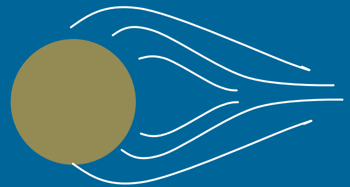
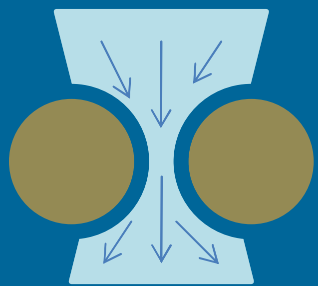


2. Generate a change in channel geometry



Traditional Open Channel Theory

Manning's Equation

$$Q = A\frac{1}{n}R^{2/3}S_0^{1/2}$$

- Assumes constant depth, velocity and cross section

- No longer dominated by the boundary shear

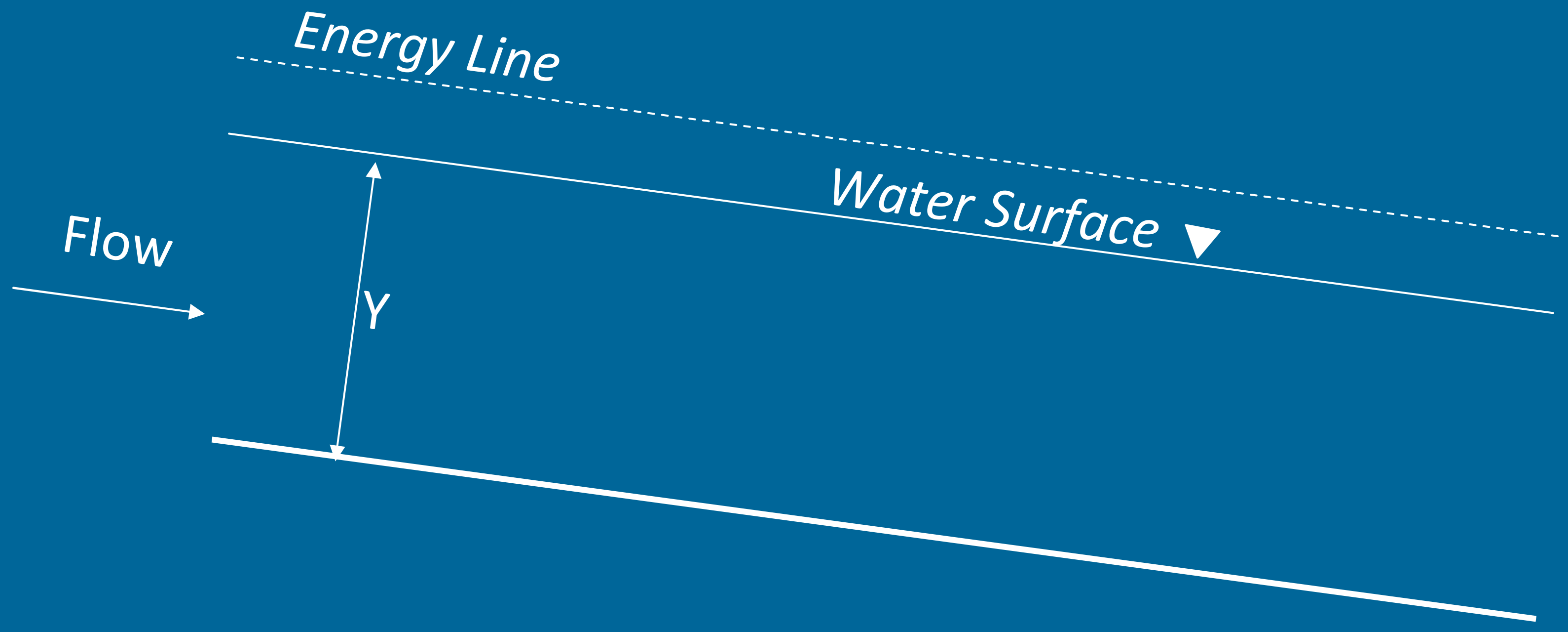
- Need extensive calibration of *n*

Project Aims and Overview

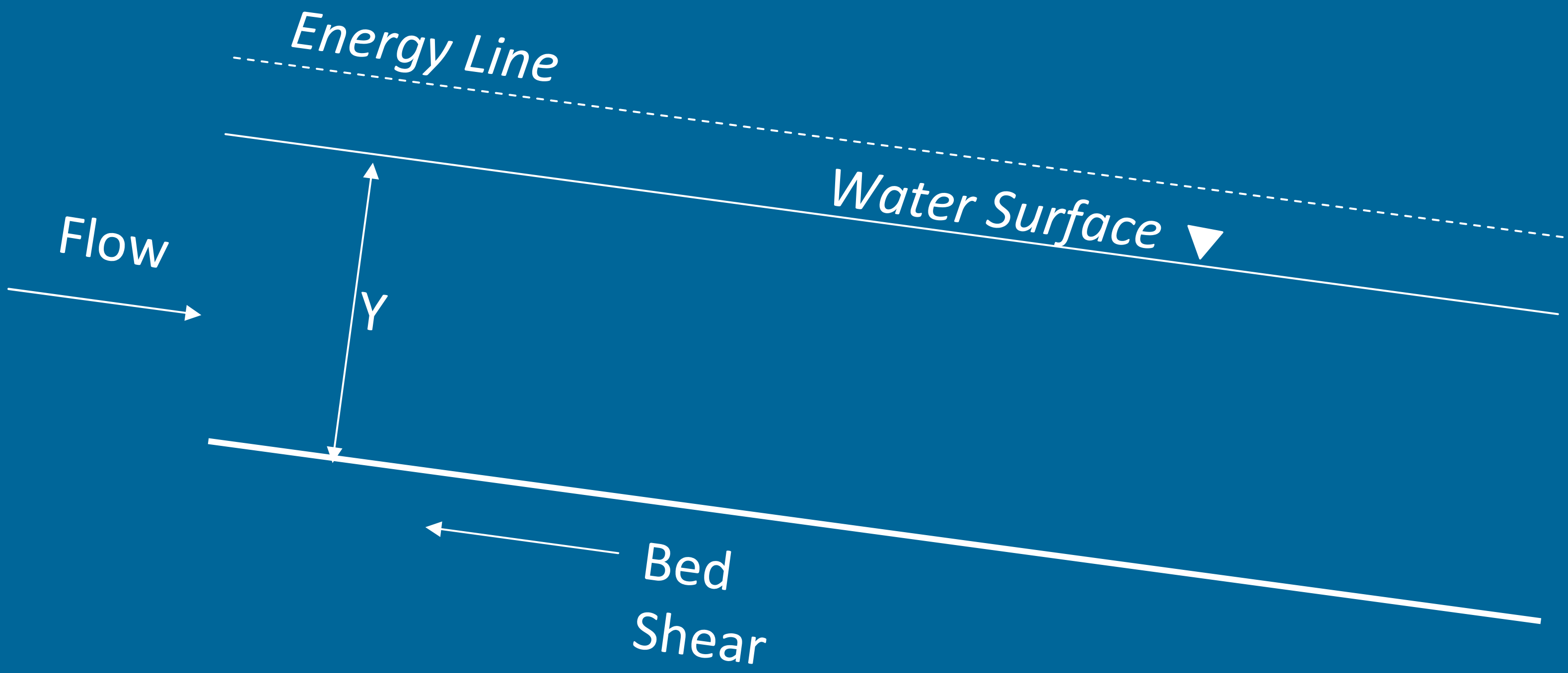
- AIM: Develop a theory which can better model effects of large roughness elements in low flows

- New approach

Drag Approach

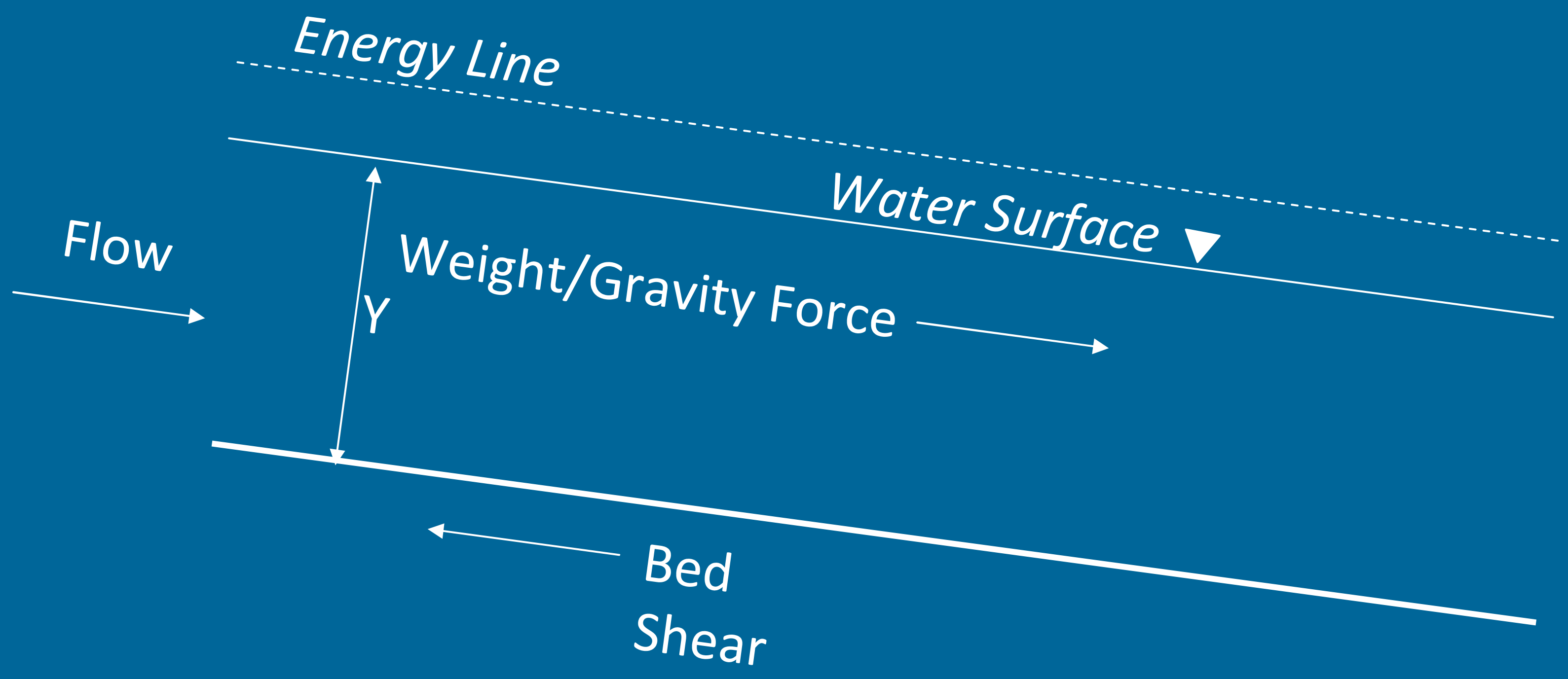


Drag Approach



$$Bed\ Shear = \gamma L w y S_f$$

Drag Approach



Bed Shear= $\gamma LwyS_f$ *Gravity Force* = $\gamma LwyS_0$

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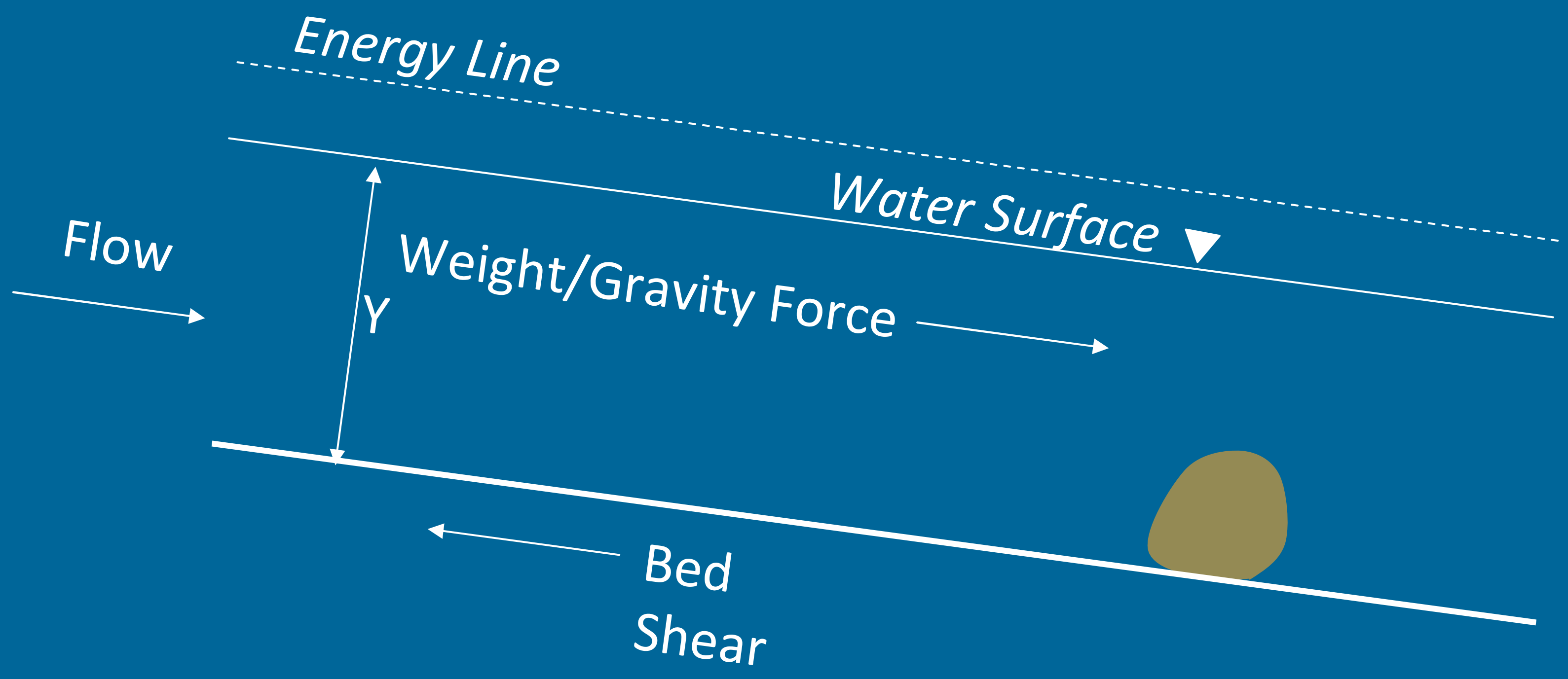

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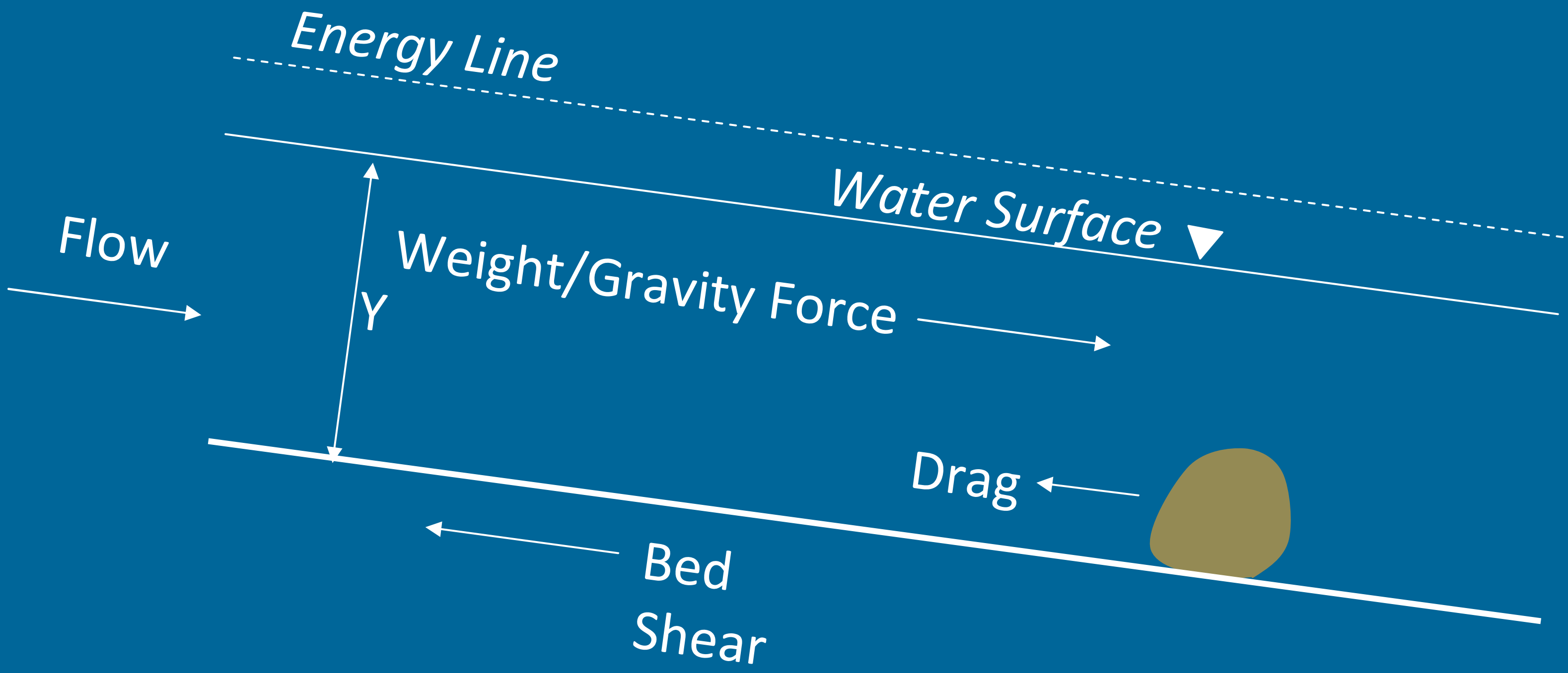
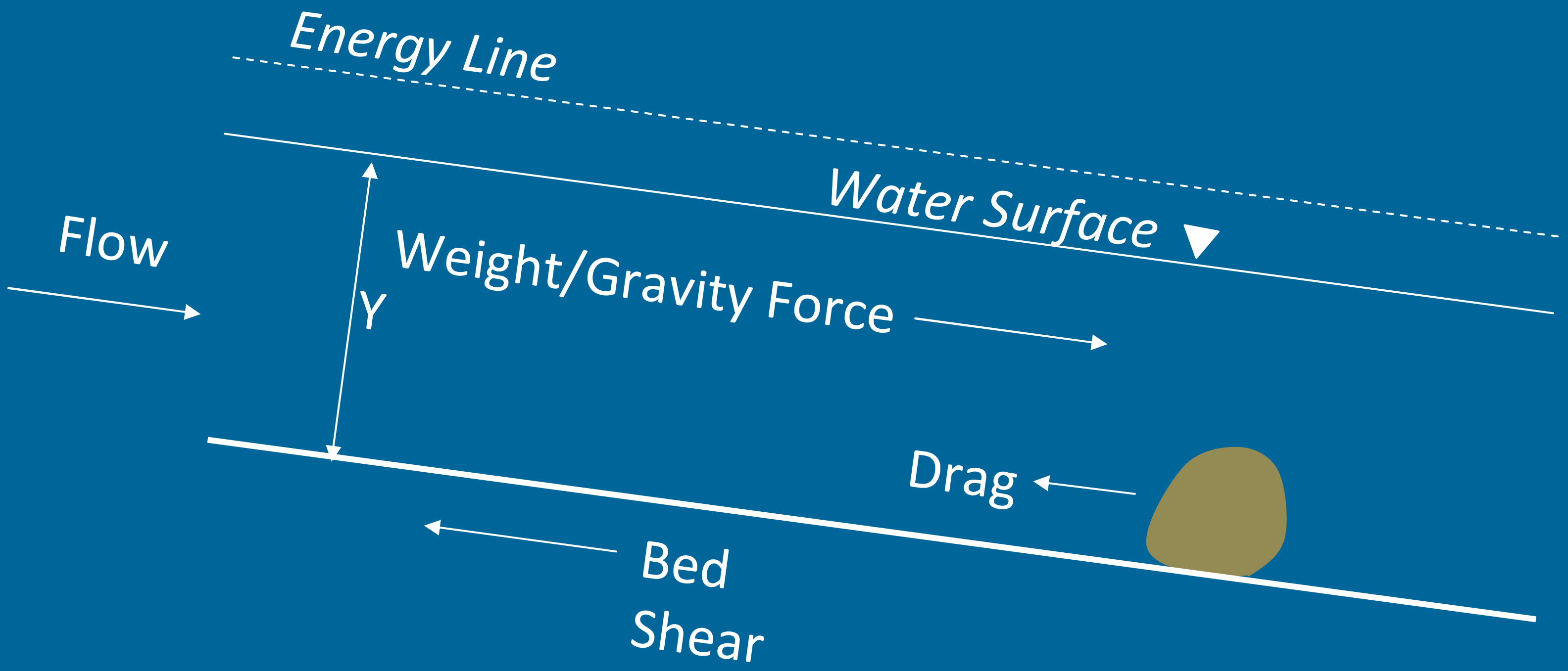


Bed Shear = $\gamma L w y S_f$ *Gravity Force* = $\gamma L w y S_0$

$$F_{drag} = \tfrac{1}{2} C_D(\gamma/g)V^2 A_x$$

Drag Approach



$$\underbrace{\gamma L w y S_0}_{\text{Gravity}} - \underbrace{\gamma L w y S_f}_{\text{Bed Shear}} - \underbrace{\tfrac{1}{2} C_D(\gamma/g)V^2 A_x}_{\text{Drag}} = 0$$

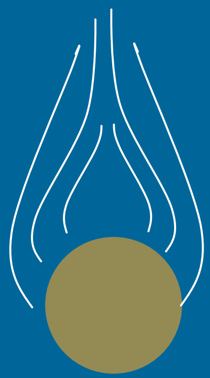
Preliminary Experiment

- Presence of large roughness elements causes an increase in normal depth
- <u>Normal depth predictions within 10%</u>
- Provides a foundation for the rest of the study

Large Roughness Elements (LREs) in Low Flow Rivers

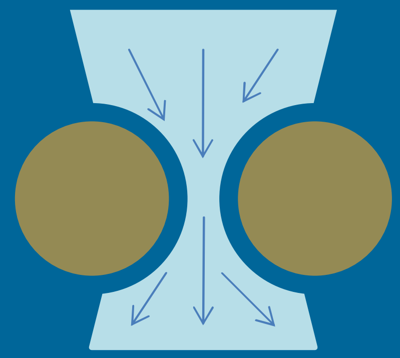
DRAG

increased resistance



GEOMETRIC EFFECTS

changes the to flow path



Geometric effects have not been included in previous studies of LREs

Theory – Geometric Effects

- Geometric Effects
  - Multiple adjacent LRE causes contractions to flow
    - Horizontal – change in bed level
    - Vertical – through adjacent LREs

Theory – Geometric Effects

- *Conventionally…*
- LRE size large: flow forced through critical depth

$$y_c = (\frac{q^2}{g})^{1/3}$$

Where y_c is the critical depth, q is the discharge per unit width and g is gravity

- Flat slope, energy conserved, can calculate upstream depth

$$E_1 = E_2 = y_1 + \frac{V_1^2}{2g} = y_2 + \frac{V_2^2}{2g}$$

Where E_1, E_2 are the upstream/ downstream energies, V_1,V_2 are the upstream/downstream velocities and y_1,y_2 are the depths

Theory – Geometric Effects

- PROBLEMS
  - Natural channels rarely horizontal
  - Total energy no longer constant:
    - *Can't calculate upstream depth*

THEREFORE

- - - Assume changes in depth are local, change over small distance
    - *Hence contribution of slope is negligible*

Theory – Geometric Effects

$$y_c = \left(\frac{q^2}{g}\right)^{1/3}$$

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$$E_1 = E_2 = y_1 + \frac{V_1^2}{2g} = y_2 + \frac{V_2^2}{2g}$$

$$\gamma L y w S_0 - \gamma L y w S_f - \frac{1}{2} C_D \frac{\gamma}{g} V^2 A_x = 0$$

Theory – Geometric Effects

- Re-arrange to calculate the slope for 'new' uniform flow
  - Friction slope and dimensionless *drag* slope

$$S_0 = S_f + \frac{C_D V^2 A_x}{2gLyw}$$

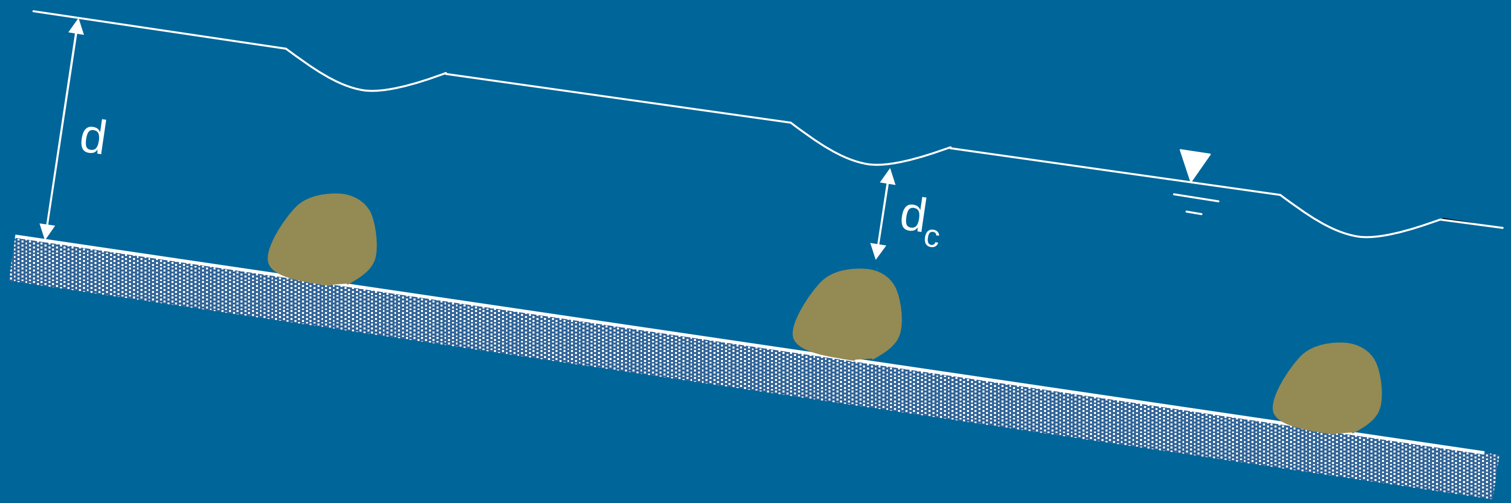
- Uniform flow

BUT

  - Multiple LREs?

Theory – Geometric Effects

• Proposed ‘pseudo-uniform’ flow regime



• Uniform ‘characteristic’ depth punctuated by points of critical depth generated by LREs.

• Critical depth causes local control

Theory – Geometric Effects

•PROPOSED:

- Can calculate slope which balances forces
- Marks transition between upstream/downstream control and local control
- Called the ‘active local control slope’

Experimental Methodology

3 experiments proposed

- Replicate effects of LREs observed in natural rivers
- Increase in complexity to study key variables
- Core of theory remains the same
  - Change contraction analysis

Low Flows Over LREs

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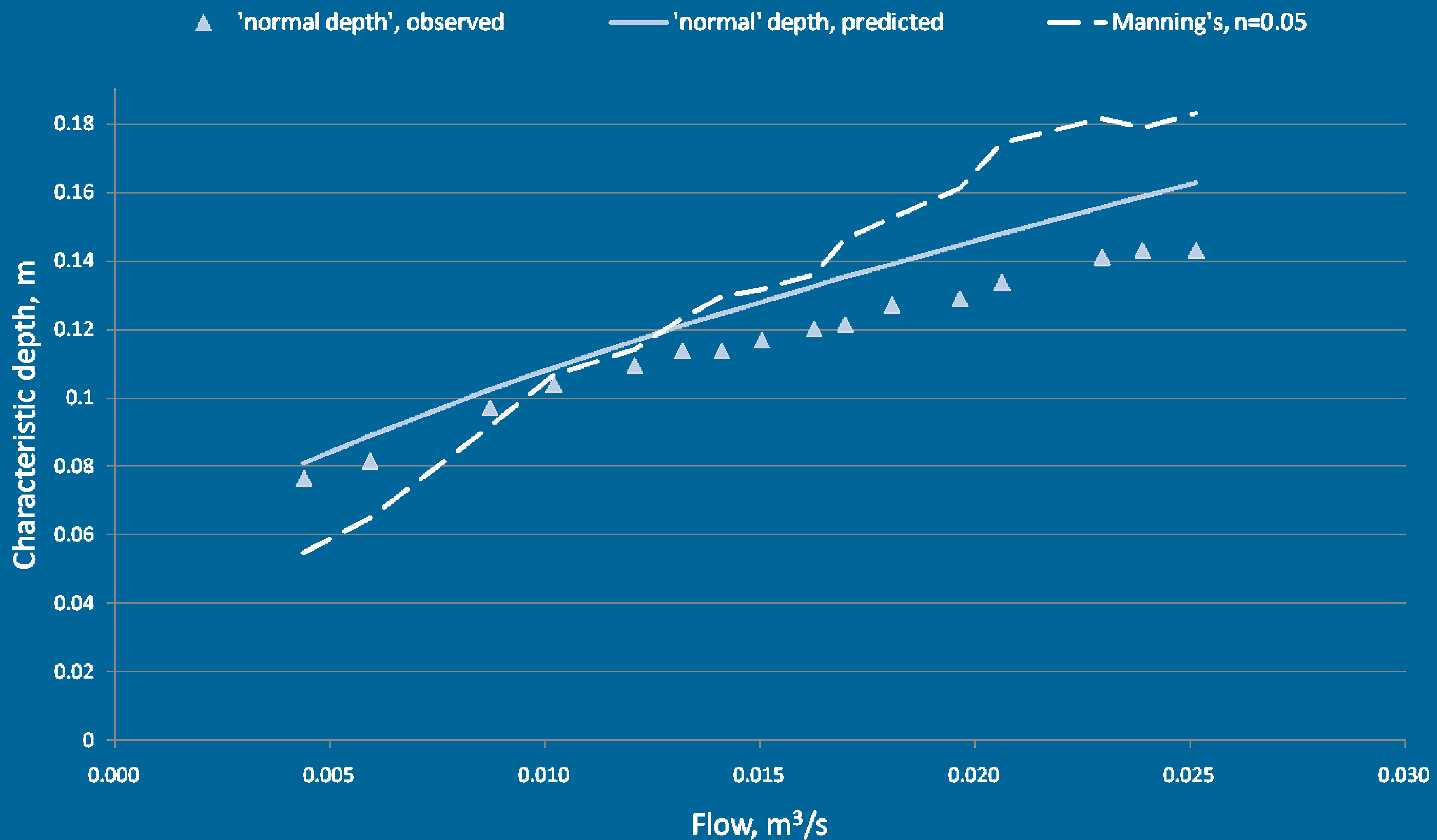

Low Flows Between LREs

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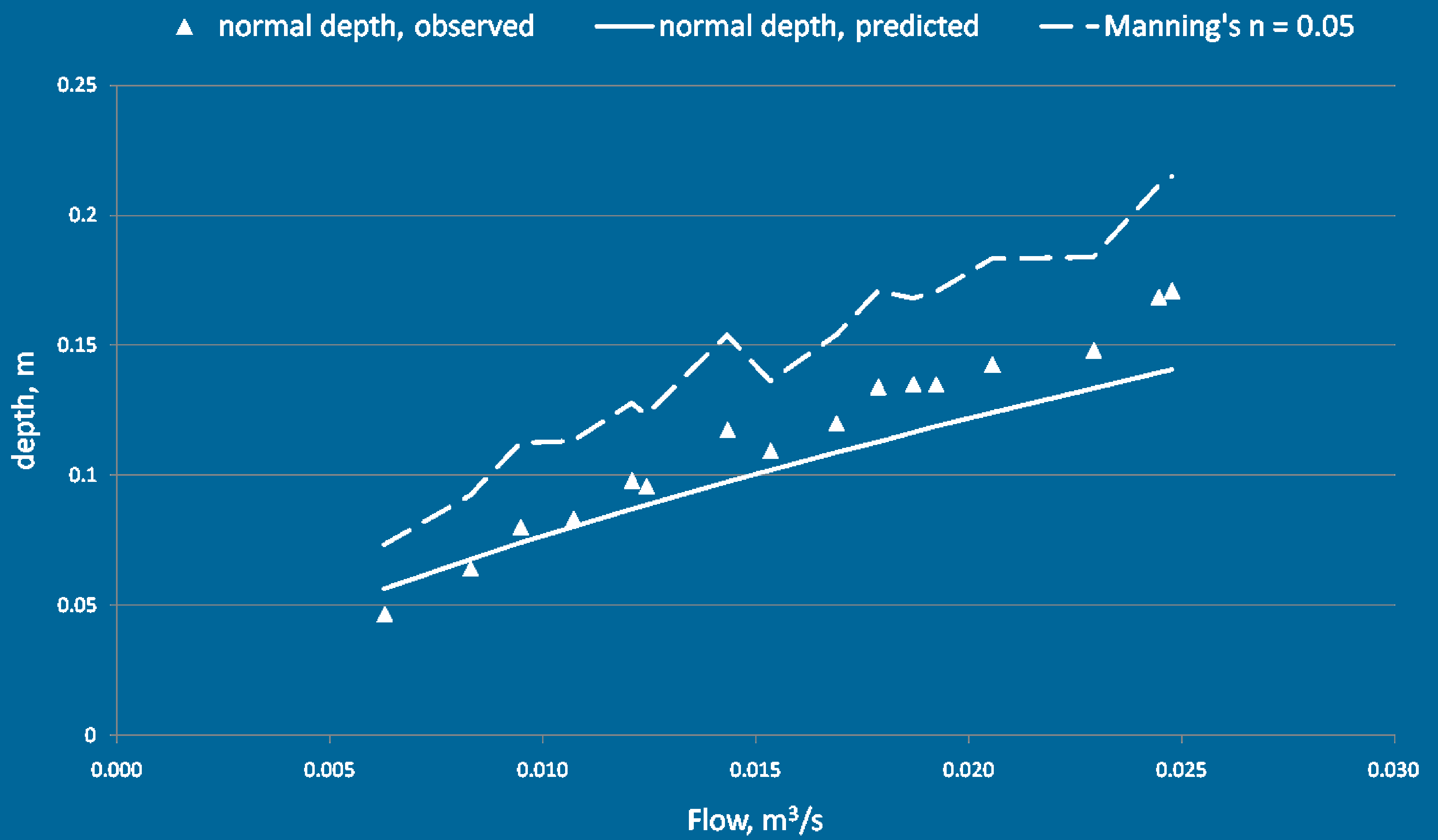
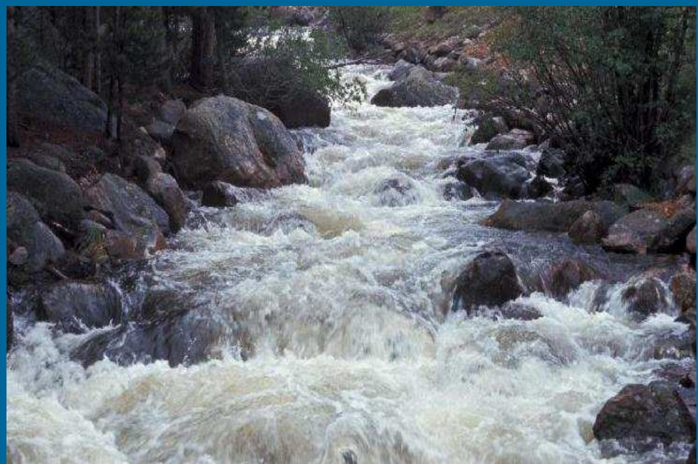
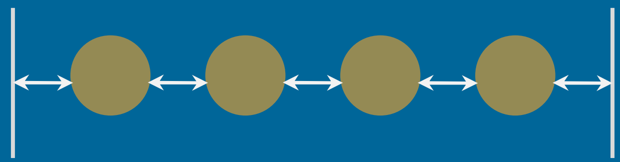


Low Flow Around Idealised Large Roughness Elements

- Hemispheres represent more natural LREs
- More complex than previous experiments
  - Multiple contractions
  - Flow over and between LREs

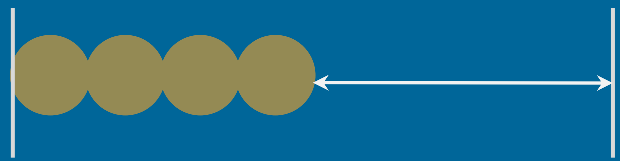


Assumptions



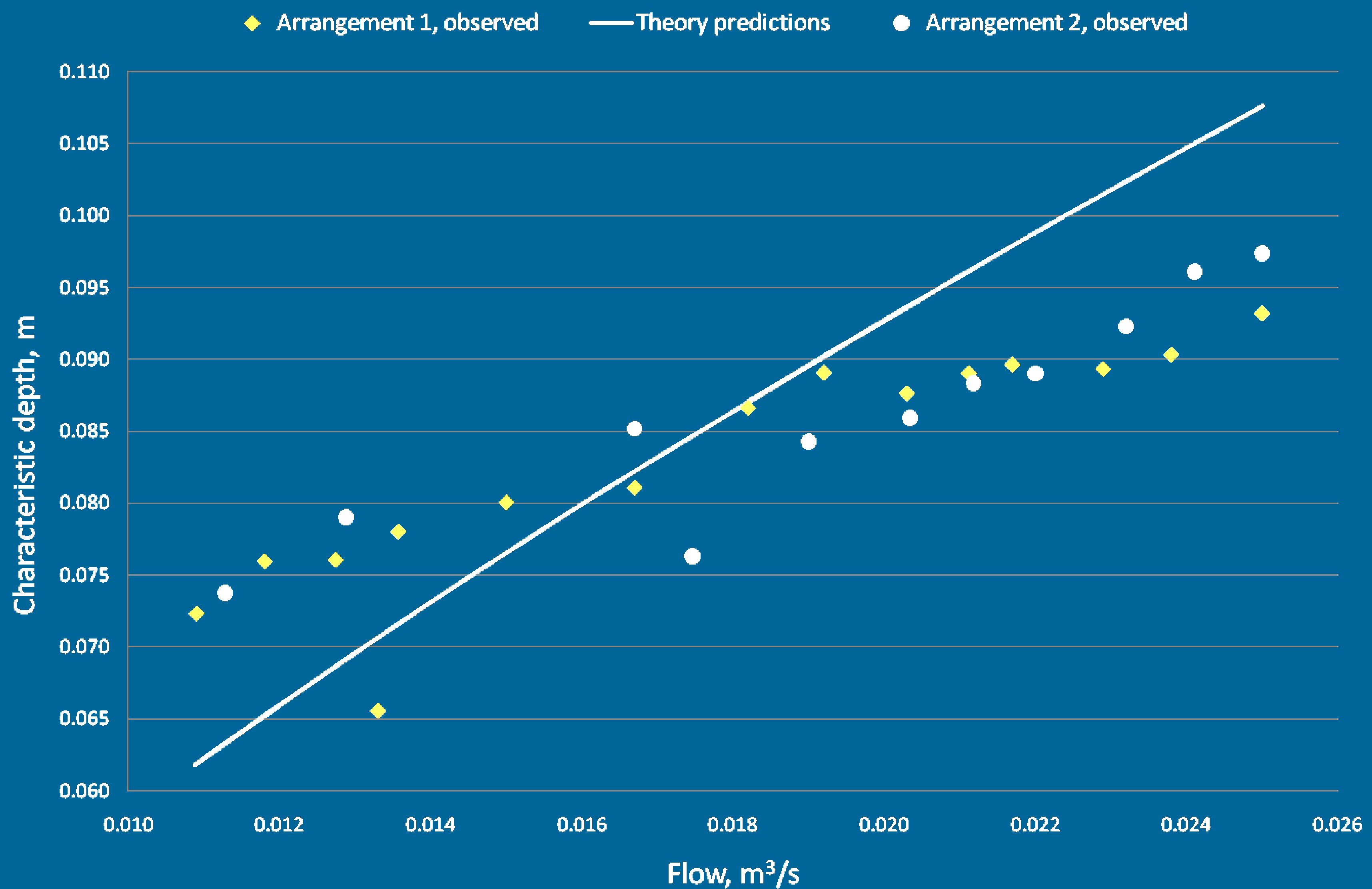
Sum of individual contractions

=



Equivalent contraction width

Results


Arrangement 1, observed
Theory predictions
Arrangement 2, observed
Characteristic depth, m
0.110
0.105
0.100
0.095
0.090
0.085
0.080
0.075
0.070
0.065
0.060
0.010
0.012
0.014
0.016
0.018
0.020
0.022
0.024
0.026
Flow, m³/s

Conclusion

- Drag approach is an appropriate representation of LREs

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- Contractions play an important role

Conclusion

- Drag approach is an appropriate representation of LREs
- Contractions play an important role
- Accuracy of theory shows promise for field applications in future

THANK YOU