“Where will our knowledge take you?”

Modelling of Bridge Pier Afflux in 2D

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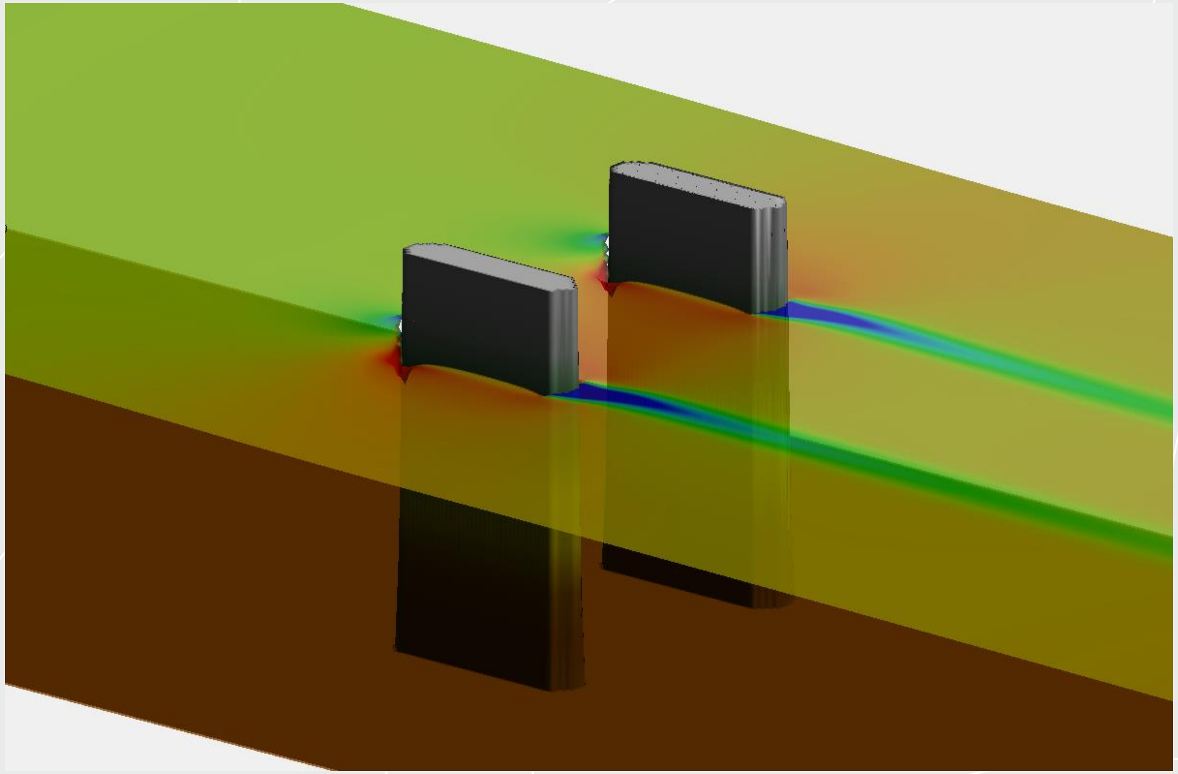


Presentation Overview

Modelling of Bridge Afflux

- Why is it important
- Common Methods used

Test Model

- Numerical Engines Used
- Model Configuration

Findings

- Recommendations
- Conclusions

Presentation Overview

Why is modelling of bridges important

- Can be key in controlling flood behaviour
- A range of different methods used in practice
- No specific guidelines for 2D modelling

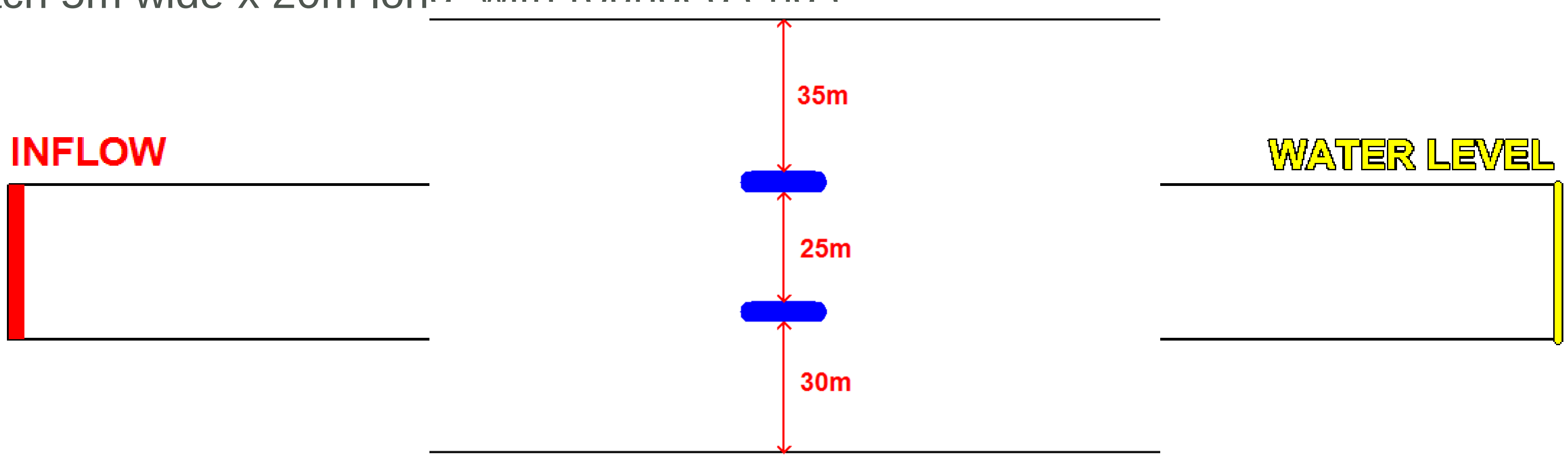
Focus of this presentation on the afflux caused by the

- Do different methods/schemes produce consistent results?
- Are results affected by
  - Model resolution
  - Cell alignment
  - Viscosity
  - Other parameters

Test Case Model

Simple Test Case Model

- 1000m x 100m rectangular channel
- Manning's n value of 0.025
- Fixed tailwater
- Inflow ramped up over 15minutes to 300m3/s and held steady for 45min
- 2 piers, each 5m wide x 20m long, with rounded ends



NUMERICAL ENGINES USED

TUFLOW “Classic”

- Grid based (square cells)
- Finite Difference Scheme
- Alternating Direction Implicit

TUFLOW GPU

- Grid based (square cells)
- 1st Order Finite Volume
- Explicit

TUFLOW FV

- Flexible mesh (quads and triangles)
- 1st and 2nd Order Finite Volume
- Explicit

Modelling Method
Block Cells Out

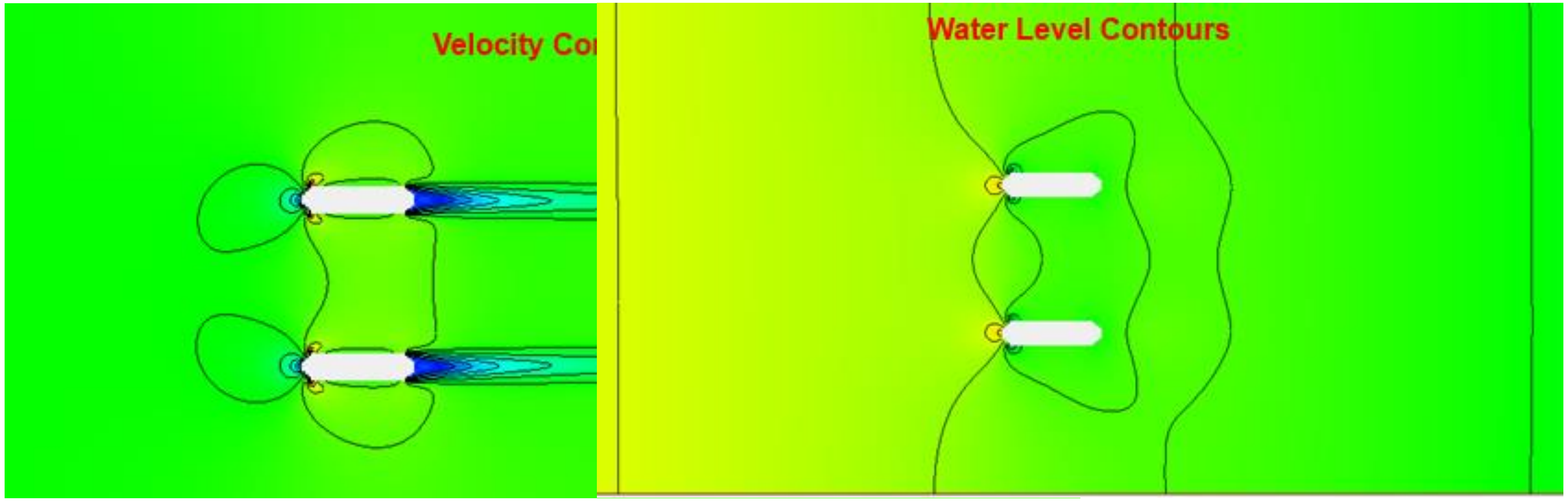
Elements are turned off, or raised to become dry

Pros

- Provides realistic velocities distribution

Cons

- Requires a high resolution mesh to resolve



Modelling Method
Form (Energy) Loss Coefficient (FLC)

Form Loss Coefficient (FLC)

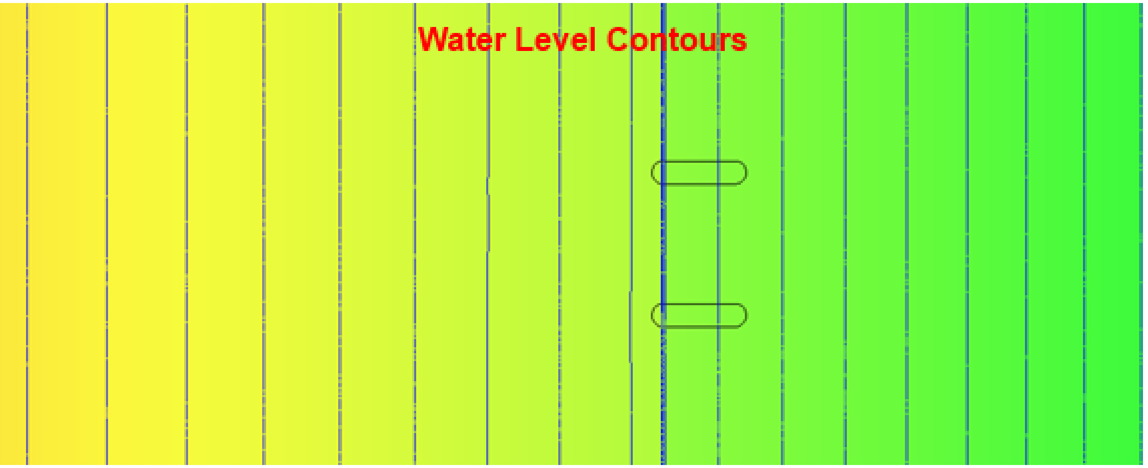
- Energy loss based on fraction of V2/2g

$$\Delta h = \zeta \cdot \frac{V^2}{2g}$$

Hydraulics of Bridge and Waterways

(Bradley, 1978; AUSTROADS)

- J = 10m (pier width) / 100m (flow width)
- Kp = 0.2
- Whole waterway value for bridge
- V = 1.6m/s,



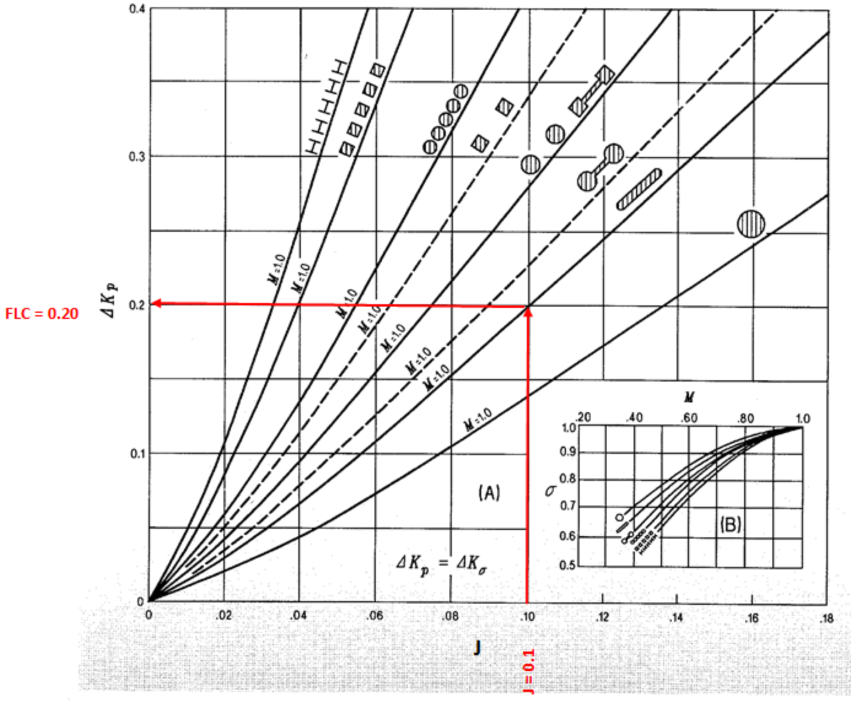


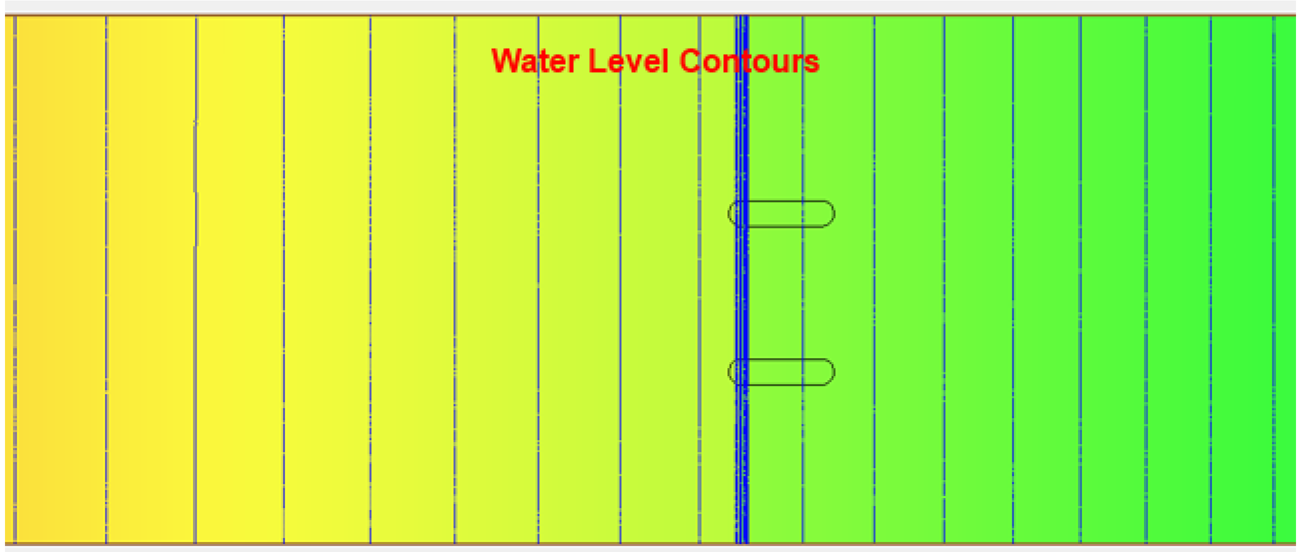
Figure 5.7 Incremental Backwater Coefficient for Piers

Modelling Method
Waterway FLC + Cell Width Reduction

FLC (as per previous method)

Cell width reduction applied

- 10% flow width reduction
- Applied equally to all cells across
- Reduction in flow width, gives increased velocity and therefore greater losses

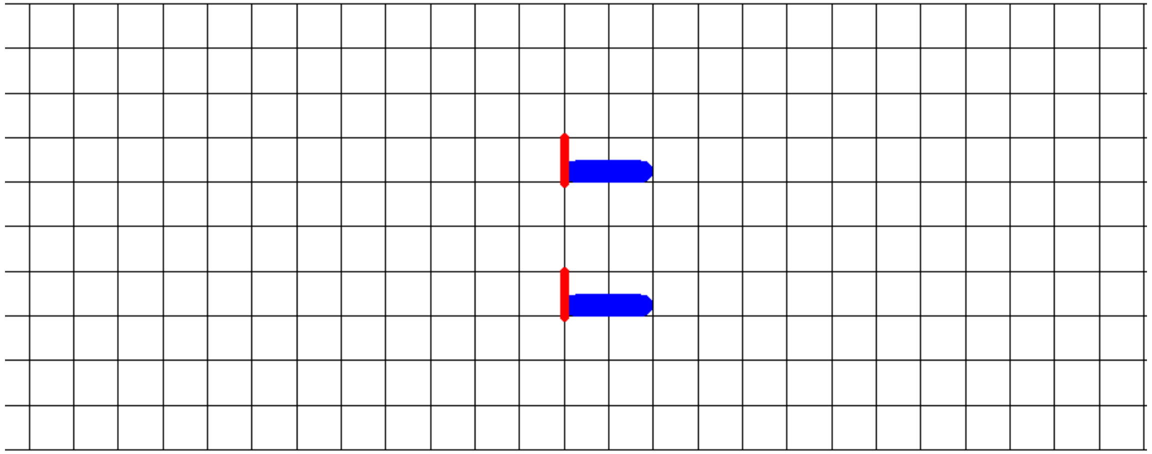


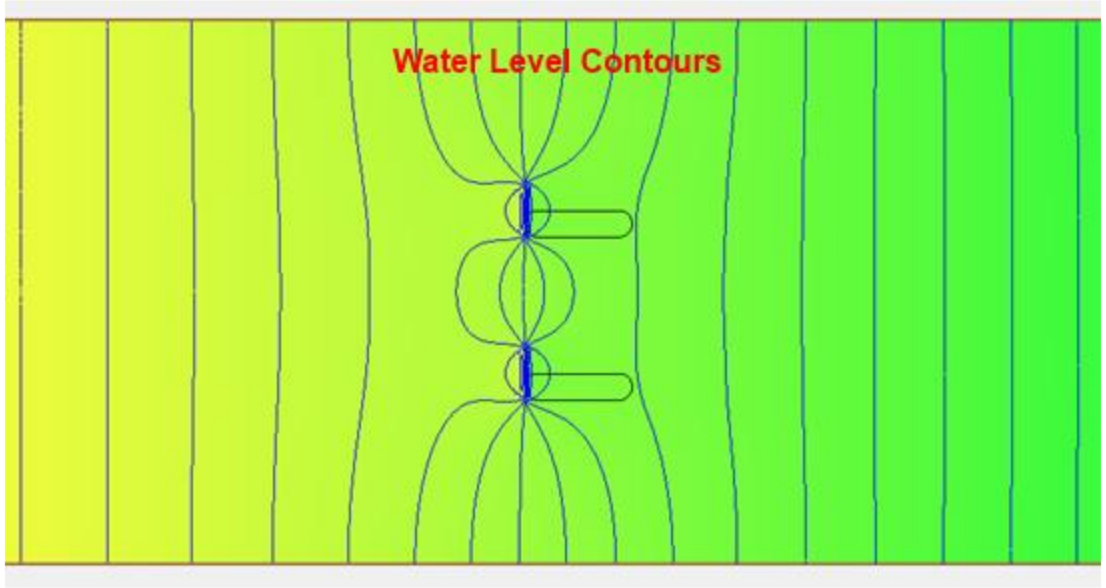
Modelling Method
FLC Only on Pier Cells

FLC only applied to pier cells

For pier only FLC factor up whole waterway FLC

- Waterway FLC = 0.2, but only applied over 2x10m width (based on a 10m cell resolution)
- Pier Only FLC = 0.2 x 100m/20m = 1.0
  (used same FLC and width of cells for finer grids for simplicity)



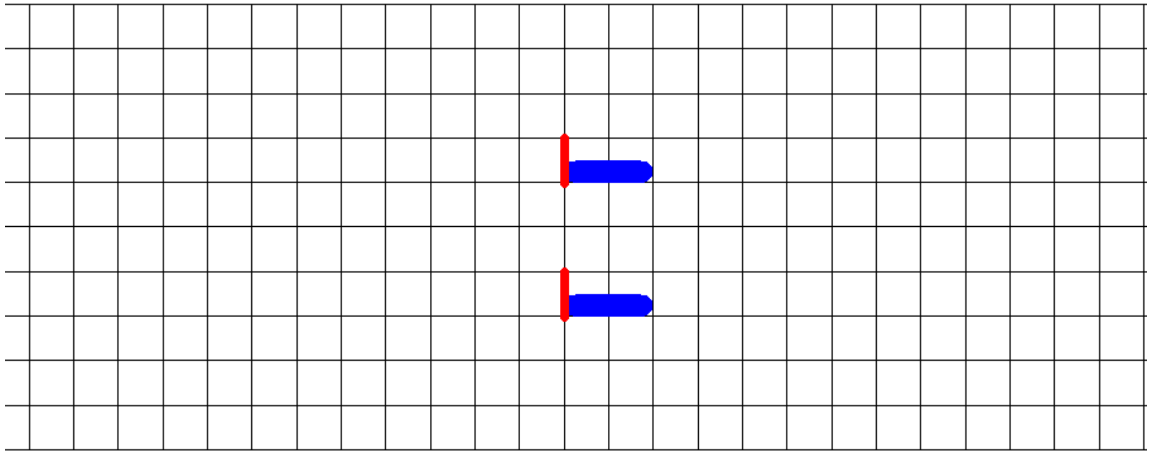


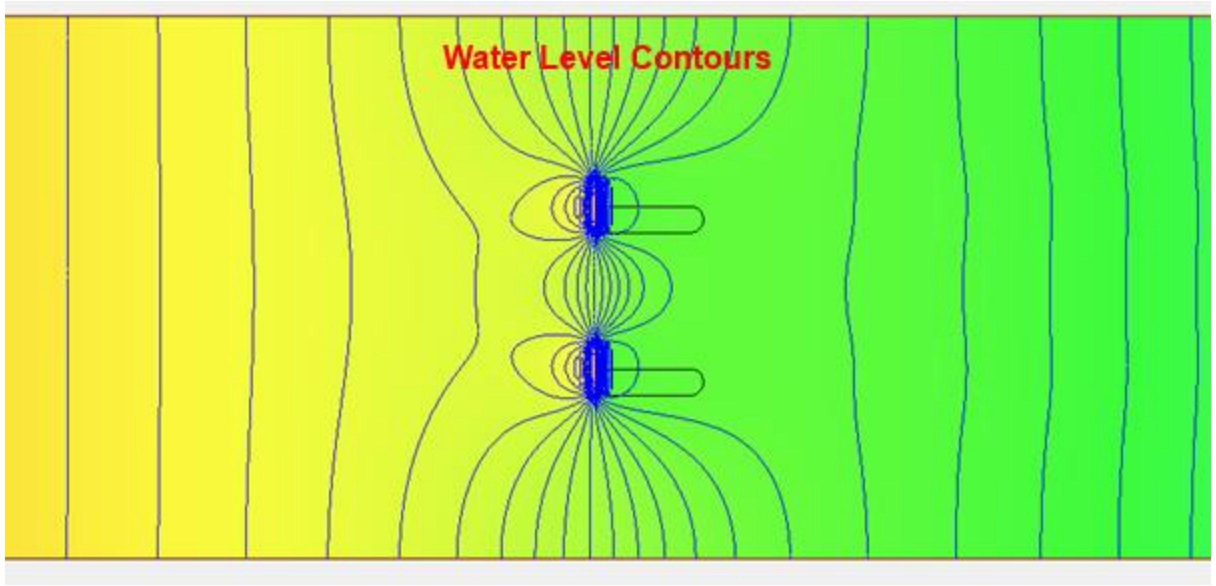
Modelling Method
Pier Only FLC + Cell Width Reduction

Pier Only FLC (as per previous)

Cell width reduction applied over the same cells

- reduced by 0.5 (5m pier width / 10m application width)





Preliminary Results
(Still need to QA review results)

Afflux in mm (50m upstream) CPU GPU FV 1st Order	10.0m	5.0m	2.5m	1.0m	0.5m	0.25m
Block Cells Out	71 196 98	28 83 39	20 46 37	17 28 30	15 22 26	na 20 na
Waterway FLC	26 26 25	26 25 25	26 25 25	26 25 25	26 25 25	na 25 na
Waterway FLC + Cell Width Reduction	30 41 30	29 36 30	28 35 30	28 34 30	28 34 30	na 34 na
Pier Only FLC	24 19 17	20 18 17	20 18 18	20 18 18	20 18 19	na 18 na
Pier Only FLC + Cell Width Reduction	28 45 35	25 36 36	26 40 37	26 45 38	26 48 40	na 58 na

Observations

Application of FLC across whole of waterway produces

- Correct and consistent afflux upstream
  (compared with Hydraulics of Bridge Waterways)
- Poor/incorrect near field velocity/water level distribution around piers

Blocking Cells Out

- Afflux resolution dependent – tends to decrease as the cell size decreases
- Afflux scheme dependent
  (1st order schemes may produce higher affluxes)
- Coarser resolutions tend to over predict afflux compared with HBW
  (especially 1st order schemes?)
- Finer resolutions better represent velocity field, but tending towards under-predicting afflux
  (may need additional losses)

Applying the Pier Only FLC tends to under predicts losses cf HBW – reducing cell widths seems to be needed

Other Considerations

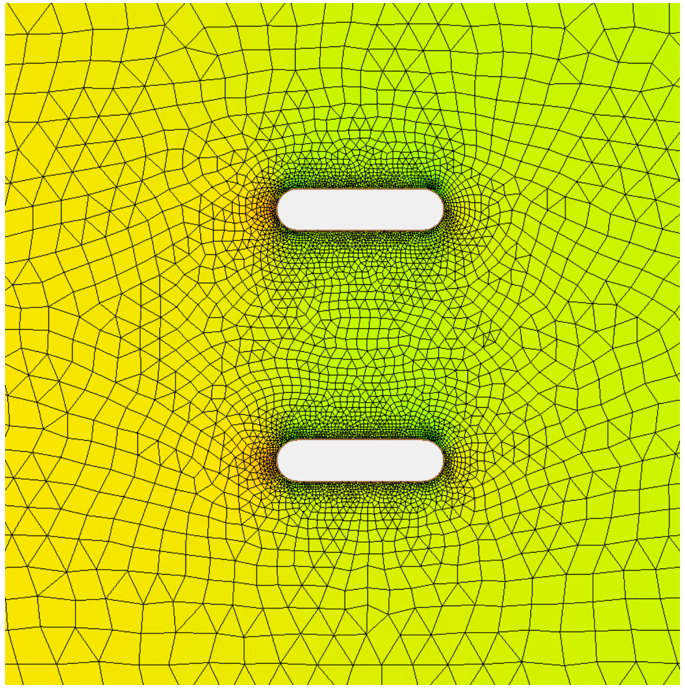
Cell alignment

- With fixed grid, very hard to align to all bridges in a model!
- This is much easier in a flexible mesh (results not ready as yet)

Influence of Viscosity

- Method (Constant / Smagorinsky)
- Viscosity parameters

Bridge pier shapes



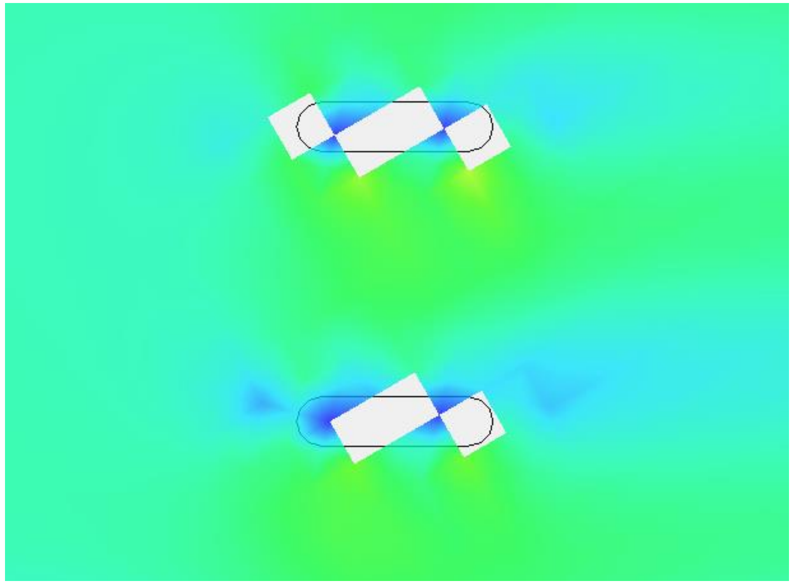
Cell alignment

Rerun model with alignment of 30 degrees

No effort to be careful in selecting cells

- Dry cell selected based on the cell centre falling within the pier
- Dry cell shown for 5m model on the right

	0 degree rotation			30 degree rotation		
	10.0m	5.0m	2.5m	10.0m	5.0m	2.5m
Block Cells Out	71	28	20	67	49	29
Waterway FLC	26	26	26	24	24	24
Waterway FLC + Cell Width Reduction	30	29	28	29	28	27
Pier Only FLC	24	20	20	30	24	20
Pier Only FLC + Cell Width Reduction	28	25	26	32	29	26



Viscosity Influence

Rerun model with 3 viscosity datasets

- Smagorinsky of 0.5 / Constant component 0.05 (current default)
- Smagorinsky of 0.2 / Constant component 0.1
- Constant formulation 1.0

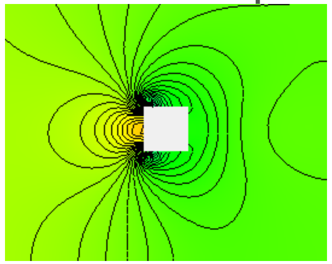
	Smagorinsky (0.5)				Smagorinsky (0.2)				Constant (1.0)			
	10.0m	5.0m	2.5m	1.0m	10.0m	5.0m	2.5m	1.0m	10.0m	5.0m	2.5m	1.0m
Block Cells Out	71	28	20	17	69	27	19	17	65	25	19	5
Waterway FLC	26	26	26	26	26	26	26	26	26	26	26	26
Waterway FLC + Cell Width Reduction	30	29	28	28	31	30	29	29	32	30	30	30
Pier Only FLC	24	20	20	20	23	20	20	20	21	21	21	21
Pier Only FLC + Cell Width Reduction	28	25	26	26	37	30	30	32	43	37	36	37

Pier Shape

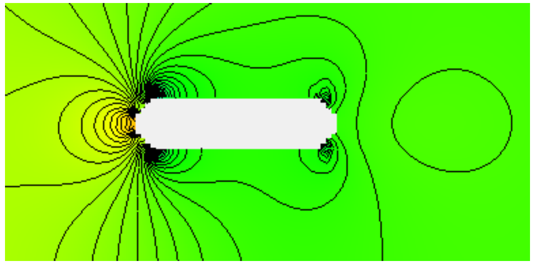
Run GPU solver with 3 different pier shapes

Elements blocked from mesh

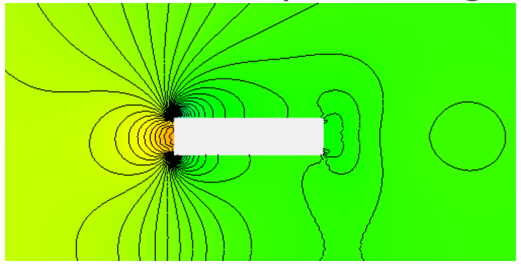
5m x 5m Square



5m x 20m Rounded



5m x 20m Square Edge



	10.0m	5.0m	2.5m	1.0m	0.5m
5m x 5m Square Edge	192	79	45	37	31
5m x 20m Rounded Edge	196	83	46	28	22
5m x 20m Square Edge	196	83	46	39	33

Findings

Based on the comparisons of the preliminary model simulations (>700 simulations thus far!)

Waterway or Pier Only FLC is the recommended approach

Provides consistent head loss (cf HBW) with variations in

- Cell size
- Cell Alignment
- Numerical schemes
- Viscosity

For complex 3D flow problems check your model results with other methods/literature

CFD or Physical modelling may be required for complex pier arrangements

Further Research

Analyse other pier configurations

Compare a wider range of schemes/methods

- 1D / 2D methods
- Flexible meshes

Provide benchmark tests / provide guidelines

Haven't even discussed what happens when the bridge deck surcharges!

thank you