SCOUR AND HYDRODYNAMIC EFFECTS OF DEBRIS BLOCKAGE AT MASONRY BRIDGES

Prakash Kripakaran, ***University of Exeter***

Flow constriction increases scour and hydraulic loading

After RAIB (2010)

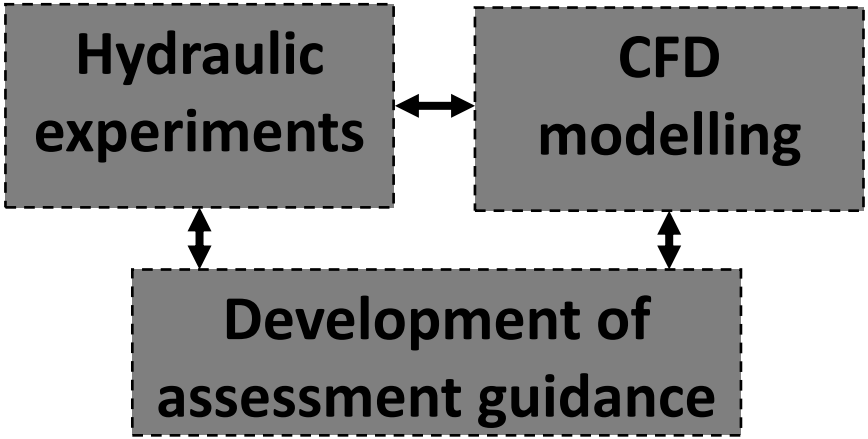
August 2017, Torrington
Courtesy of Bill Harvey

Project aims

- To develop methods to evaluate the hydrodynamic effects of debris accumulation upstream of masonry bridges and typical bridge piers under flooding scenarios, and
- To integrate findings into a risk-based approach for assessment of bridges under hydraulic action.

Note: Focus is on scour at piers and abutments, and lateral and uplift forces on the bridge due to debris blockage. Debris formation and forces from debris impact are not part of this investigation.

Work programme



Project duration: 3.5 years (now entering the final year)

Industry steering committee includes BOF, ADEPT, EA, Devon County Council, Network Rail, JBA Consulting…

Main objective: Characterise effects of DEBRIS blockage at masonry piers/bridges using a number of scaled experiments

Flow velocities
1st stage: ADV
2nd stage: PIV

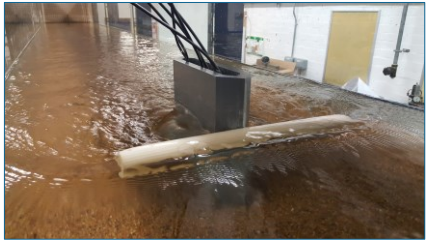
Scour

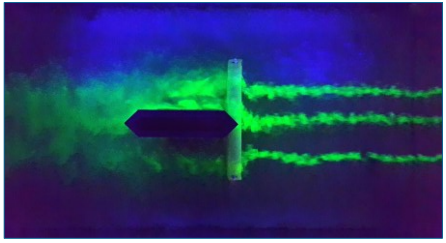
Hydrodynamic force & pressure

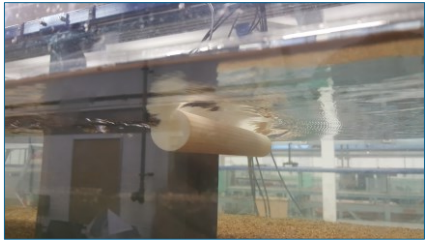
Data for CFD validation

- Simple scenarios for CFD validation

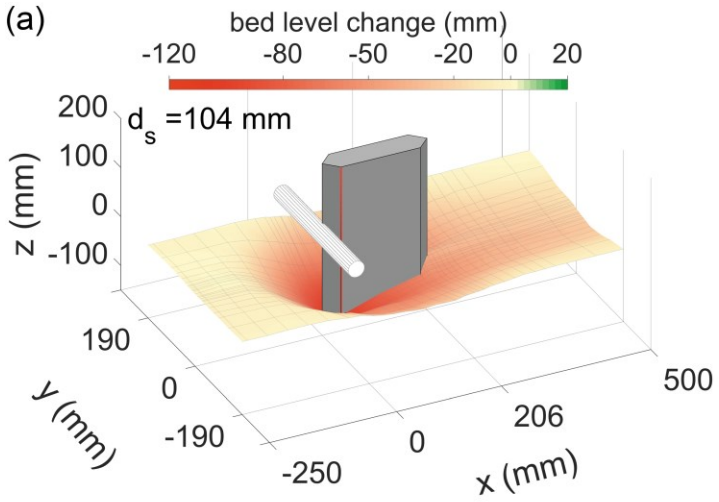
L x B = 10 x 0.6 m

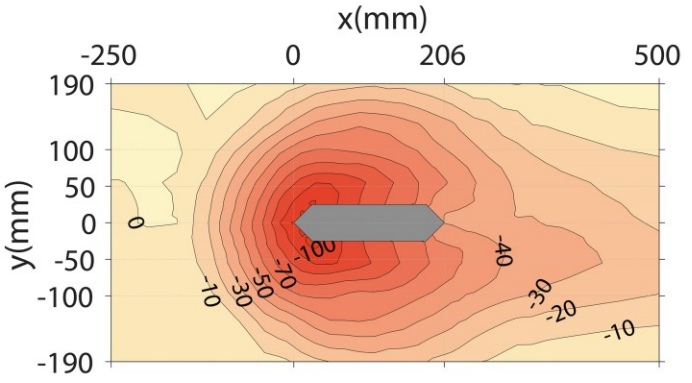




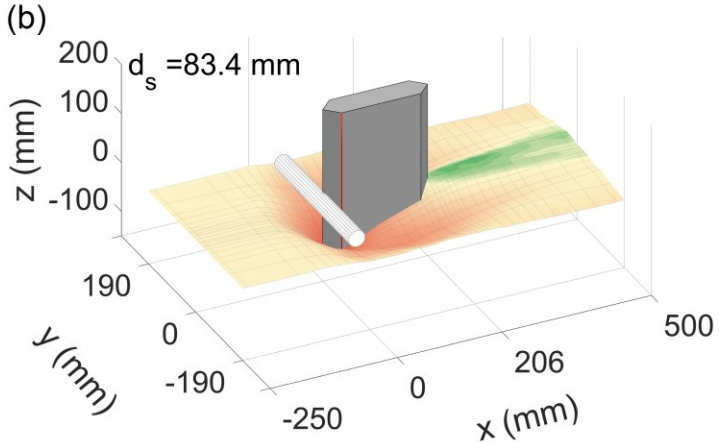


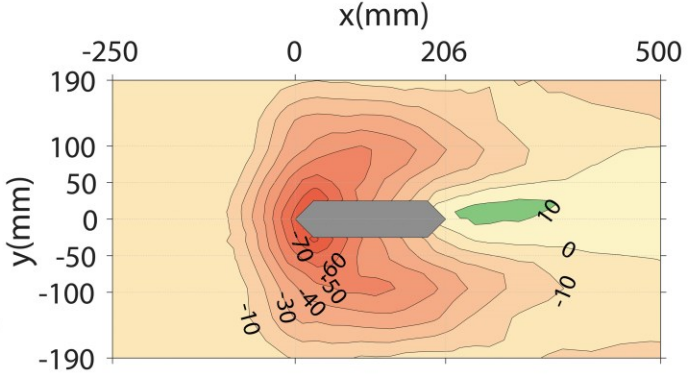
Typical scour maps



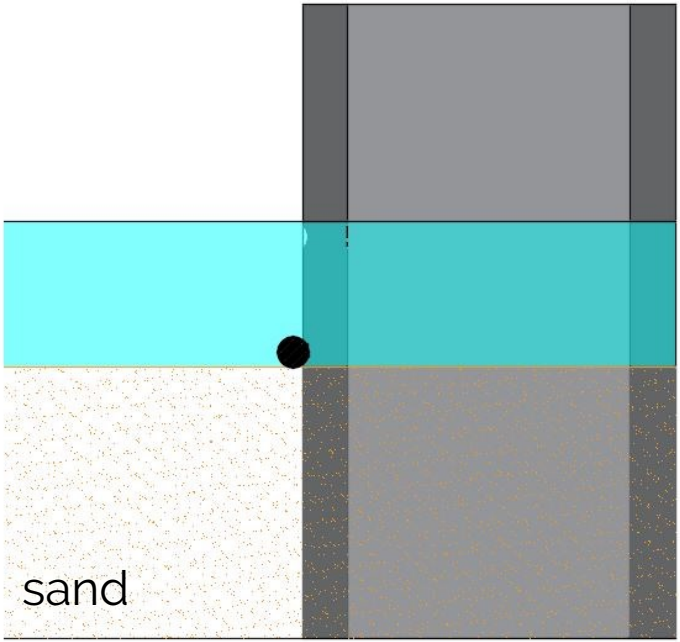


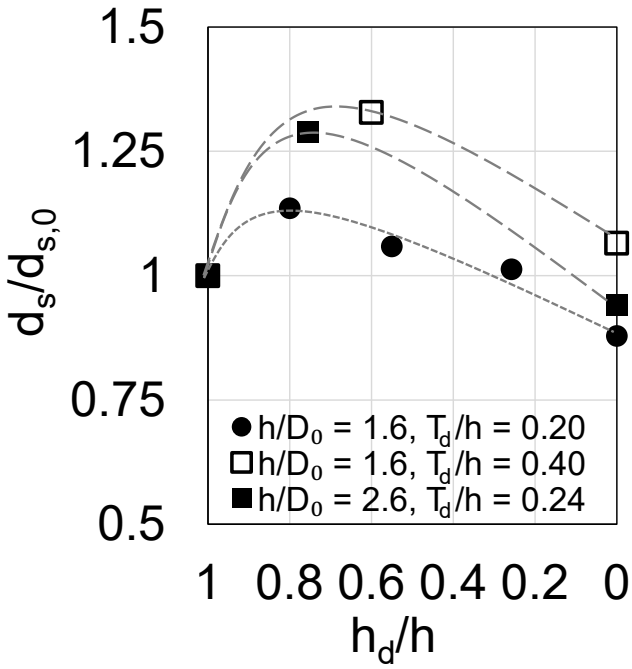
Plan



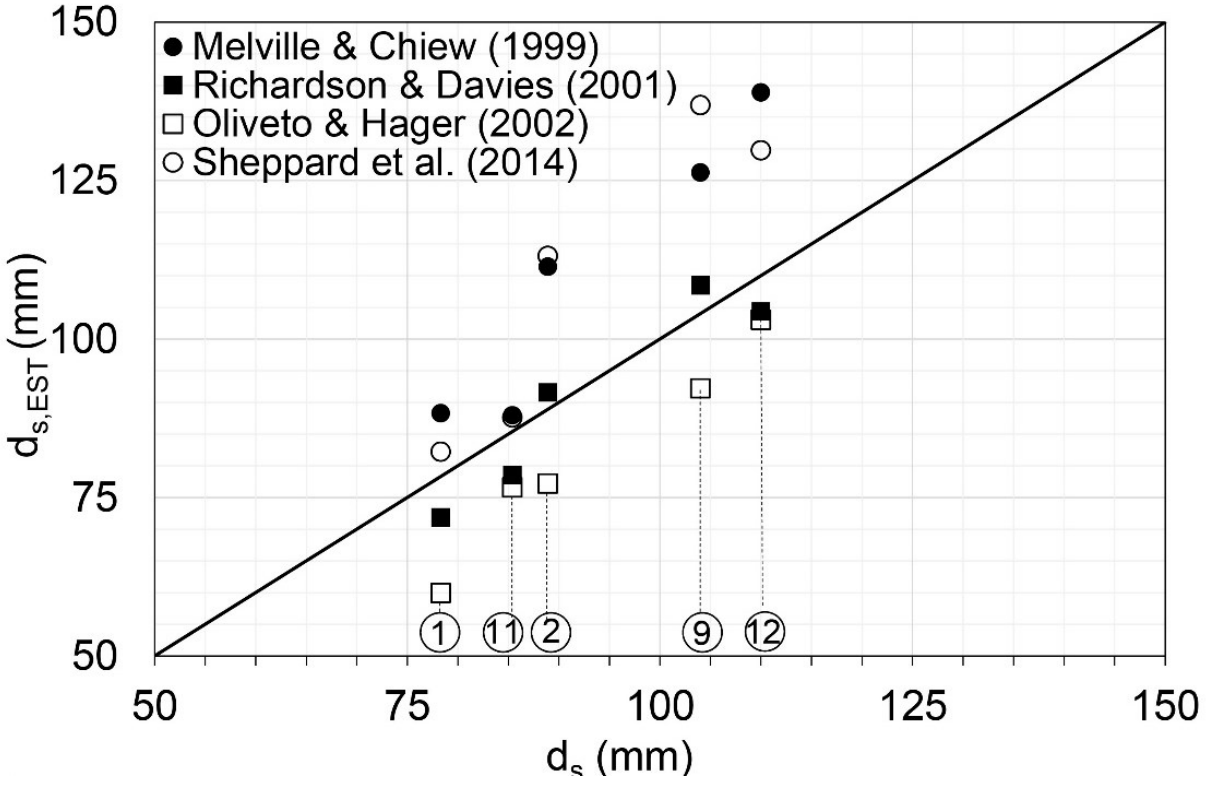


Effect of debris elev. on scour

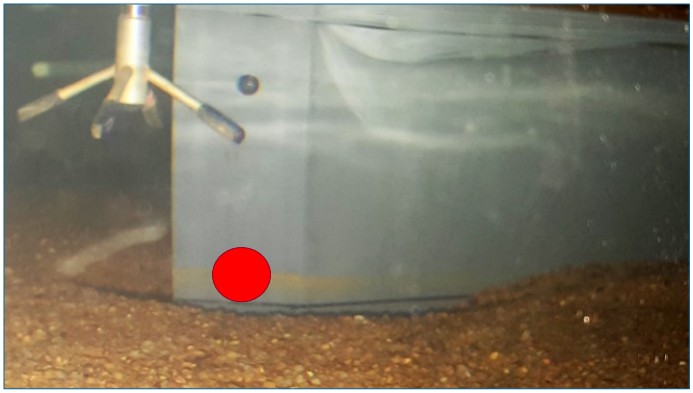


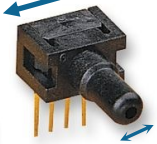


Estimated vs measured scour depth



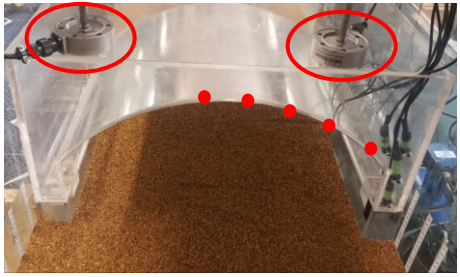
Pressure and uplift force

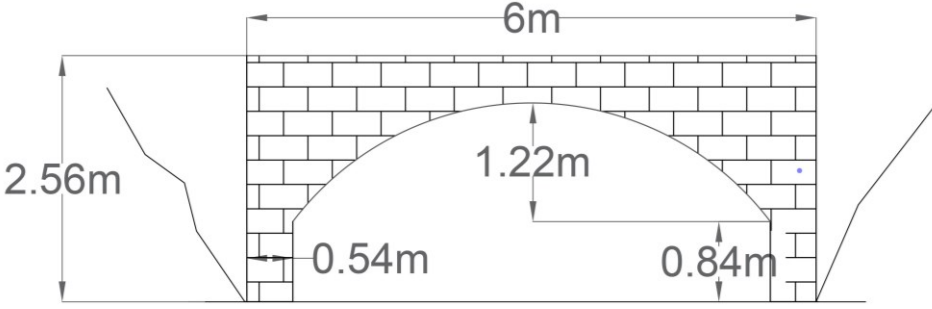




Range 1 psi (~70 mbar)
Low cost and small size

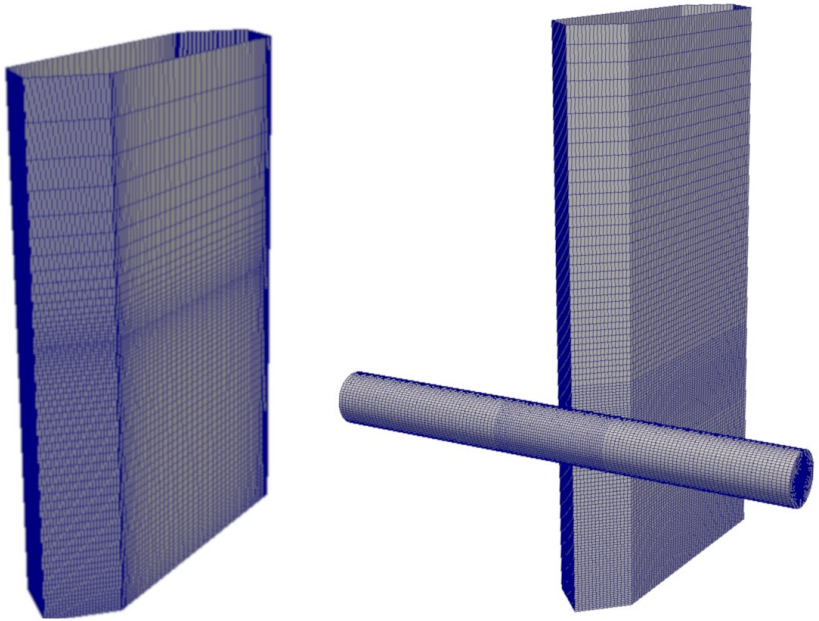
Flume scale → 1:11 → Prototype scale





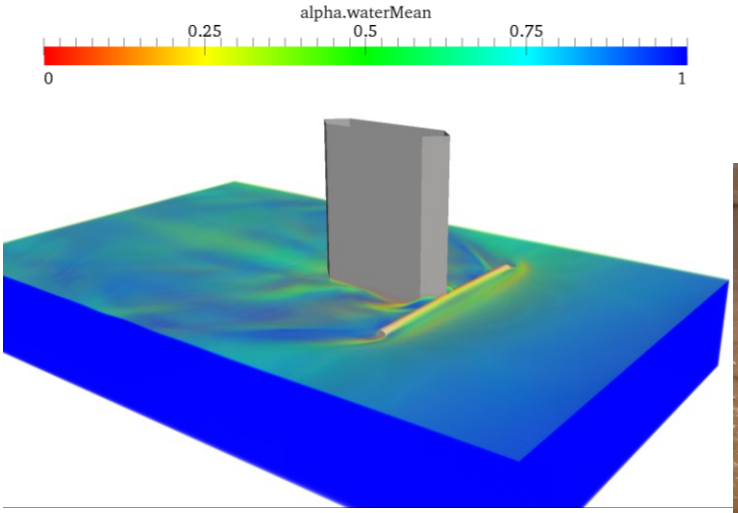
- Load cells for measuring uplift force
- Measuring pressure on the arch

Main objective: Validate CFD at lab-scale and then run simulations at full-scale for a range of real-life scenarios.



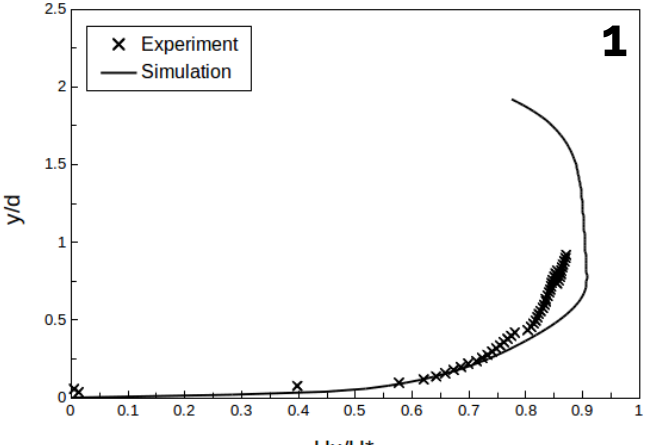
- Simulations without and with debris
- 40+ million cell mesh
- OpenFOAM for simulation

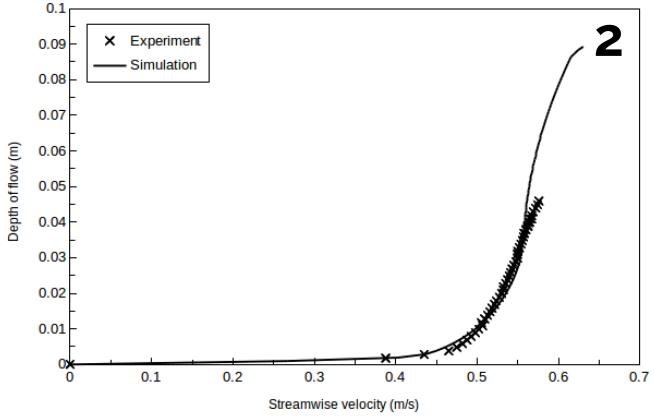
CFD | Free surface

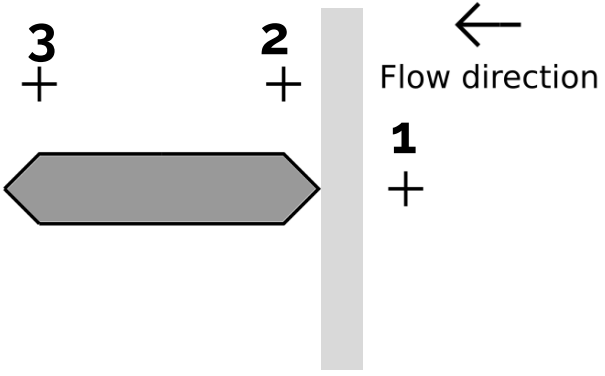


- Free surface comparison between simulation and experiment with debris

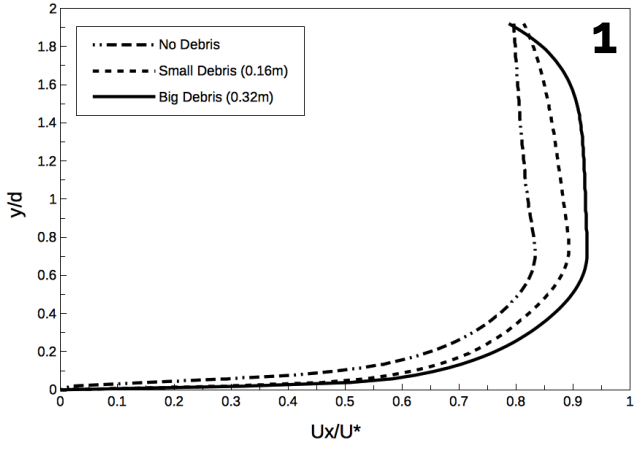
CFD | Velocity comparison

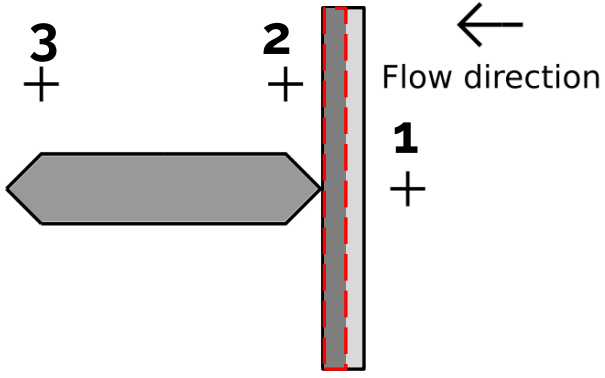


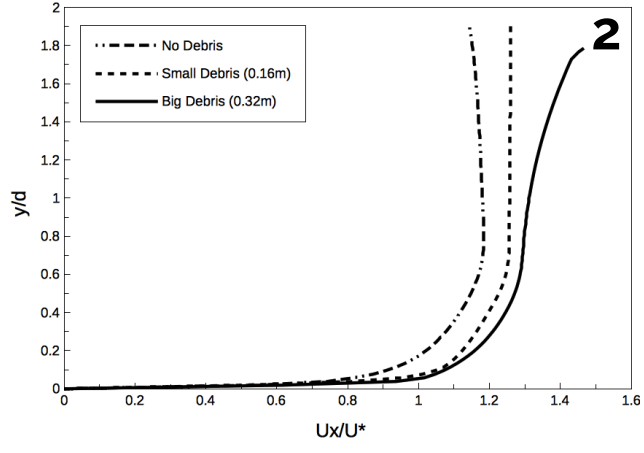


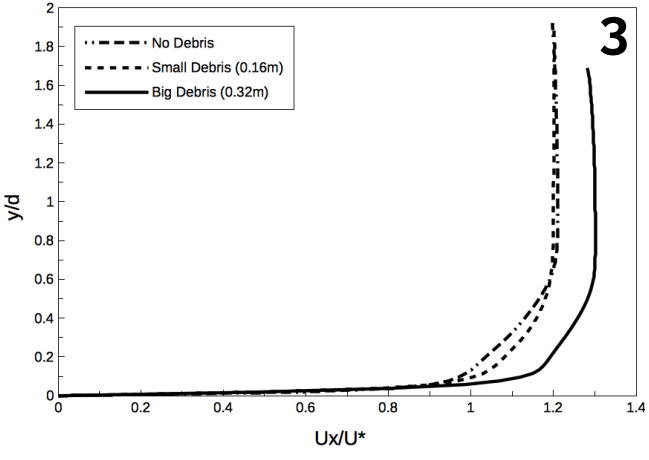


CFD | Effect of debris on velocity

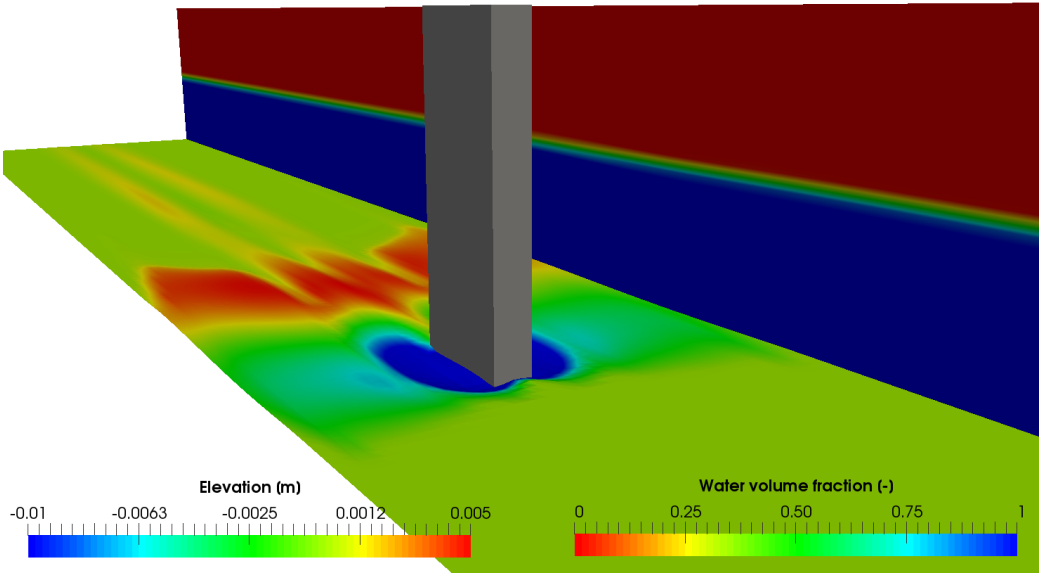






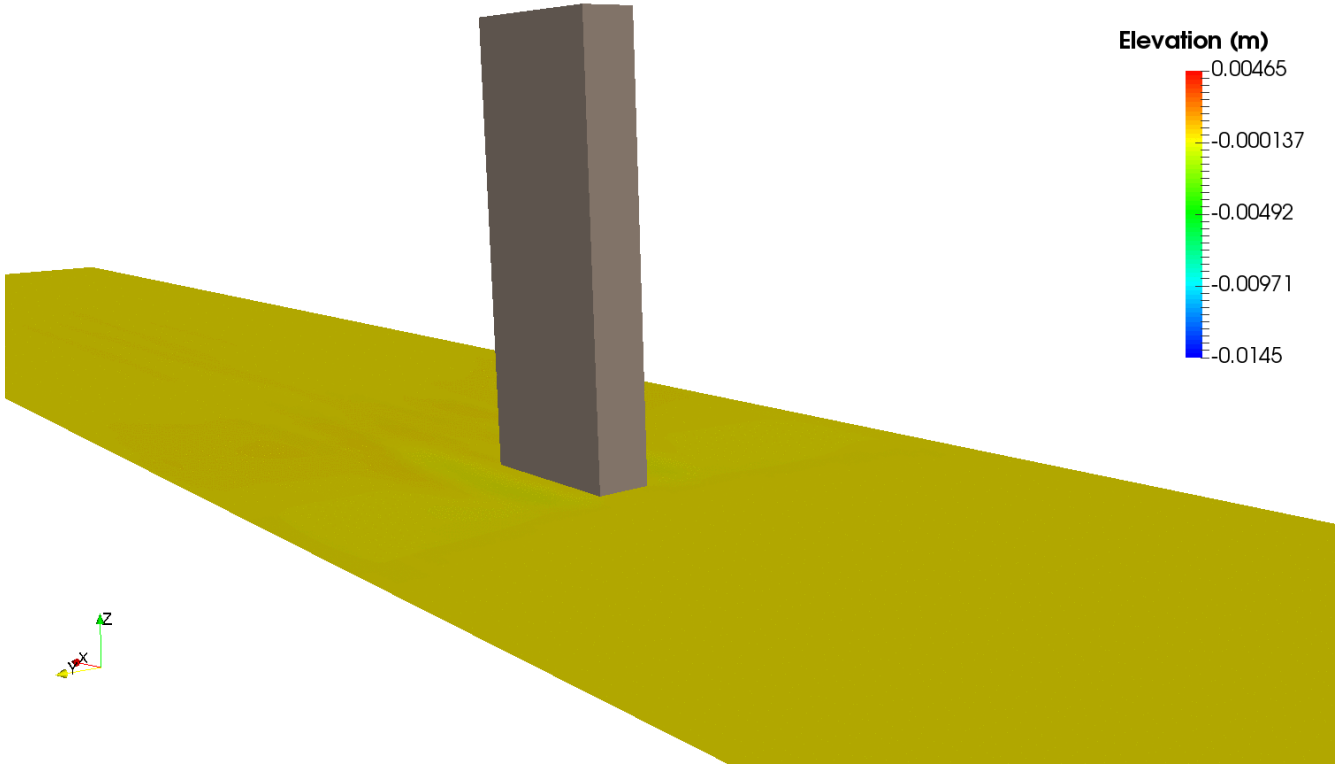


CFD | Scour



- Water and air modelled using a multiphase solver
- Turbulence accounted for using k-ω SST
- Water and sediment modelled through a deformable mesh

CFD | Scour



Preliminary findings

- Debris just under the free surface has the maximum effect on scour in comparison to any other position within the flow depth.
- The scour amplification due to debris may be significantly higher in shallow flow conditions than that in deep flow.
- CFD simulations are capable of capturing accurately the scour and hydrodynamic effects of debris.
- The effect of debris on scour can be included through the use of a *multiplier* within existing guidance.

Further work

- Validation of CFD scour modelling at full-scale using post-flood scour data
- Determination of hydrodynamic forces on inundated masonry arch bridges
- Creation of guidance that accompanies C742 for assessing risks due to debris blockage

University of Exeter | Centre for Water Systems

Heriot Watt University

University of Belgrade

EPSRC
Engineering and Physical Sciences Research Council

Thank you!

Any questions?