2D Model Design Fundamentals

What 2D mesh resolution is necessary?

2018 FMA Conference
Reno, USA
Chris Huxley

BMT

"Where will our knowledge take you?"

Presentation Introduction and Overview

What is Cell Size Convergence?

"In well designed modelling software - cell size convergence refers to the tendency for model results to trend towards a common answer as cell size decreases"

Why is it worth talking about?

Small cell size = lots of cells = long simulations

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What's necessary?

1. Rural situations – Scenario testing
2. Urban situations – Scenario testing
3. Comparison to 2D modelling guideline

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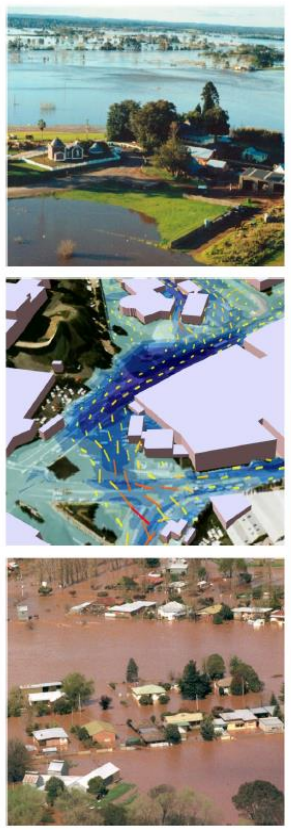
2D Modelling Guideline
Urban and Rural Floodplains (ARR, 2012)

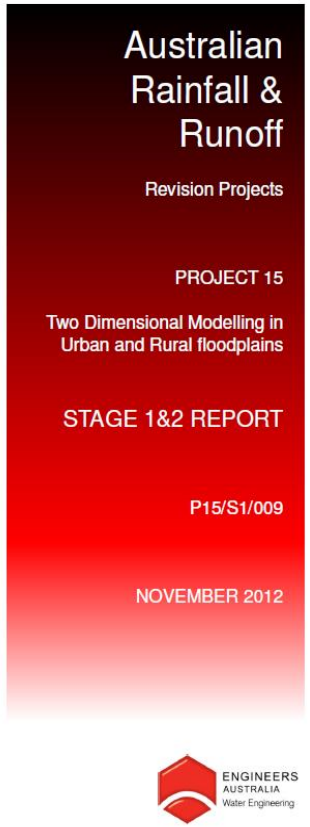
Factors to consider:

- *The scale of topographic and flow phenomena*
- *The desired level of output detail*
- *the length of event time and model run time*
- *The size of the area of interest*

Recommendations:

Modelling Case	Typical 2D Cell Resolution
Flow in Channel	≥ 5 grid/mesh elements laterally across the channel
Urban Overland	6ft to 15ft (2m to 5m)
Flow in Floodplain	30ft to 150ft (10m to 50m)
Lakes and Estuaries	Flexible mesh – range of cell sizes





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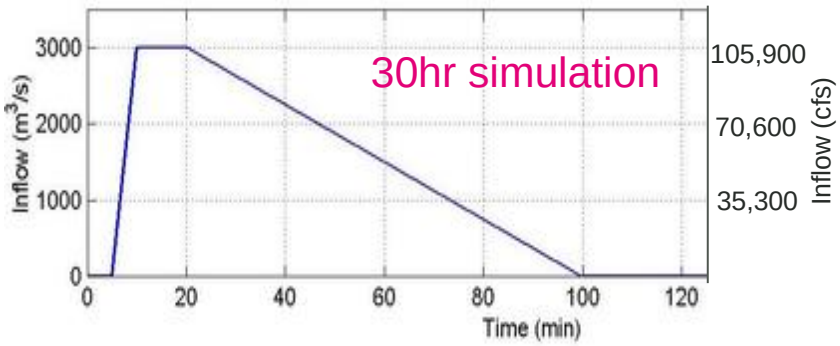
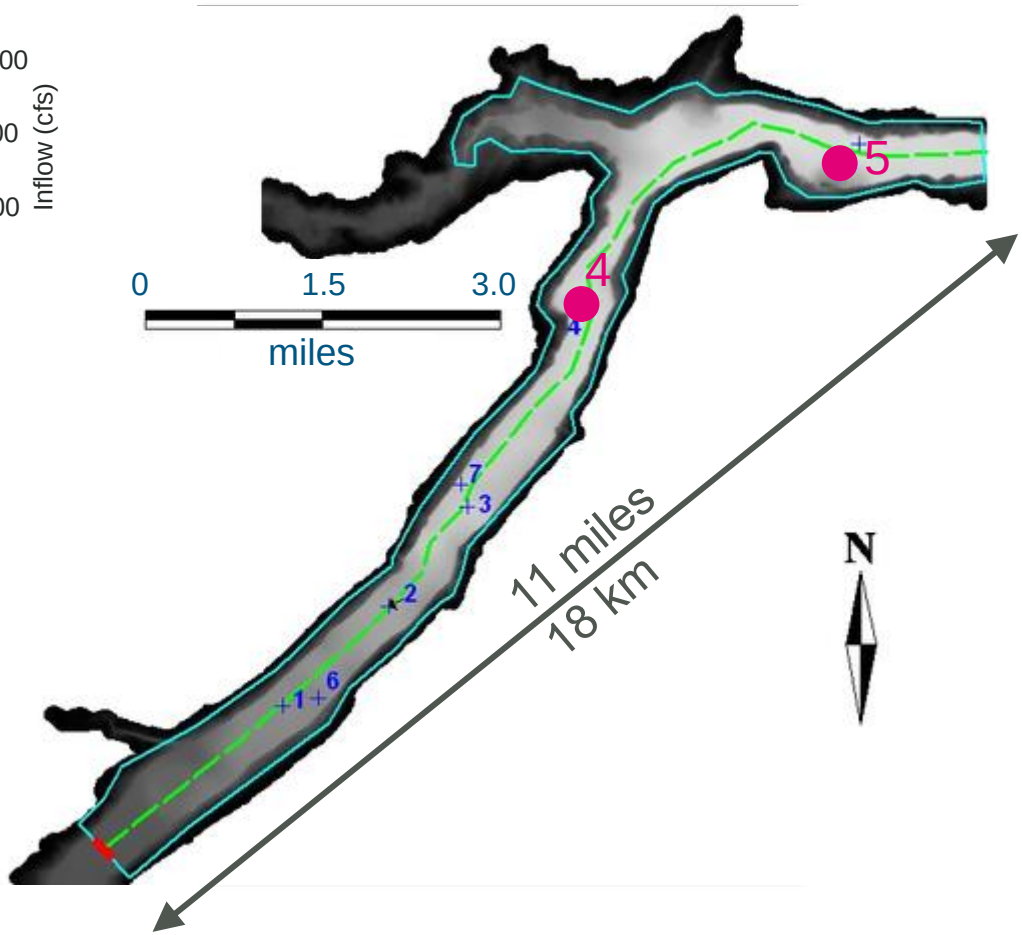
Rural Case Study
UK Environment Agency - Test 5



Test Cases

1. 10m (33ft)
2. 20m (66ft)
3. 50m (164ft)
4. 100m (328ft)
5. 150m (492ft)
6. 200m (656ft)
7. 250m (820ft)



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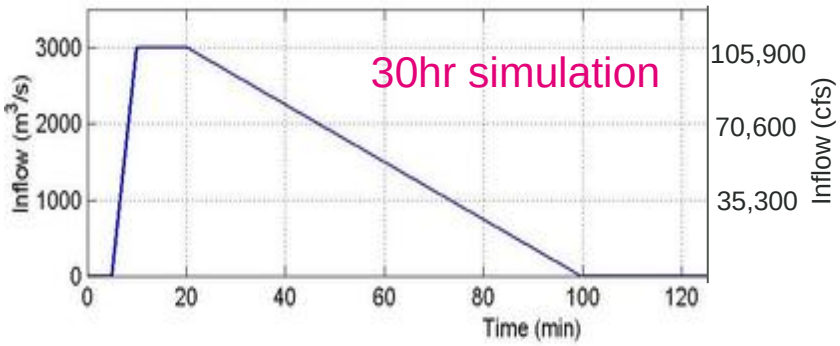

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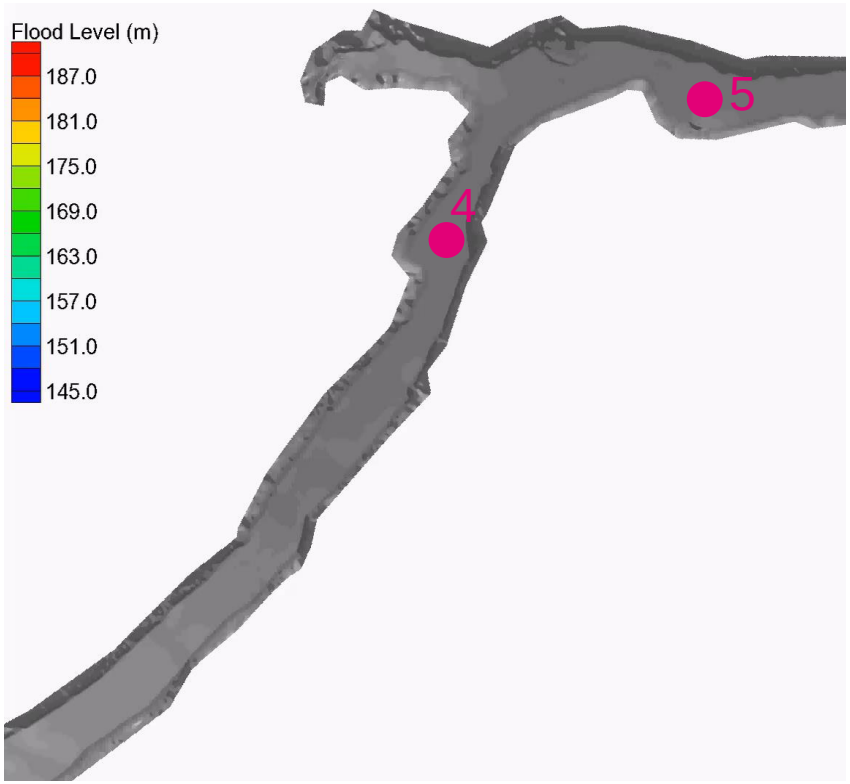

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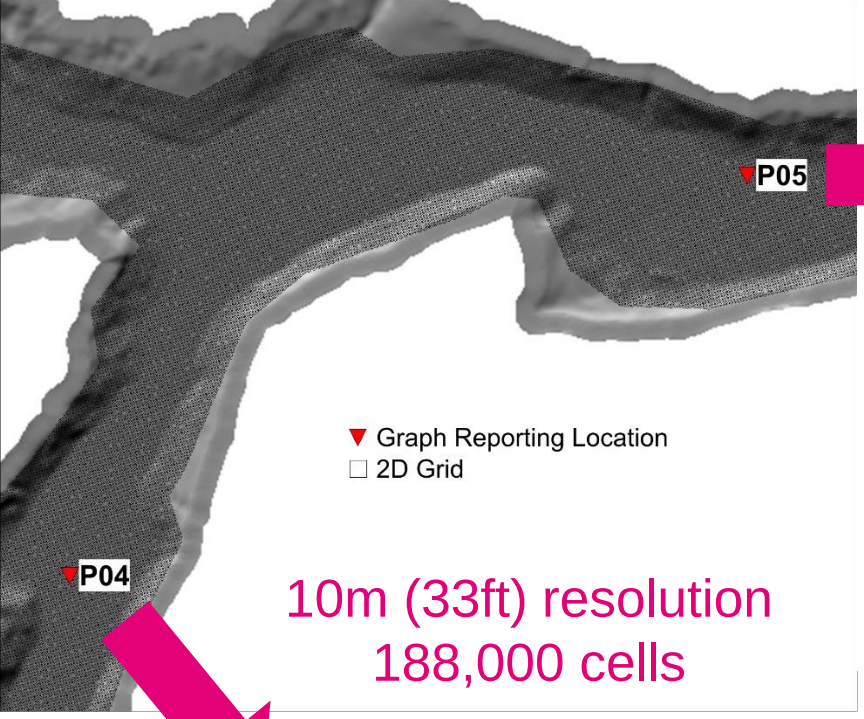
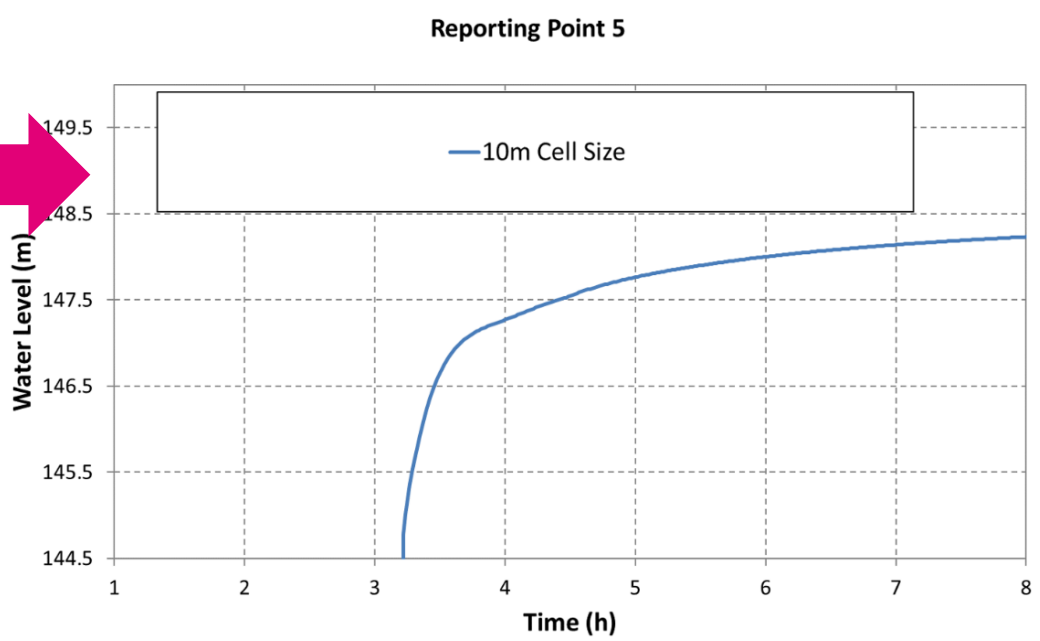
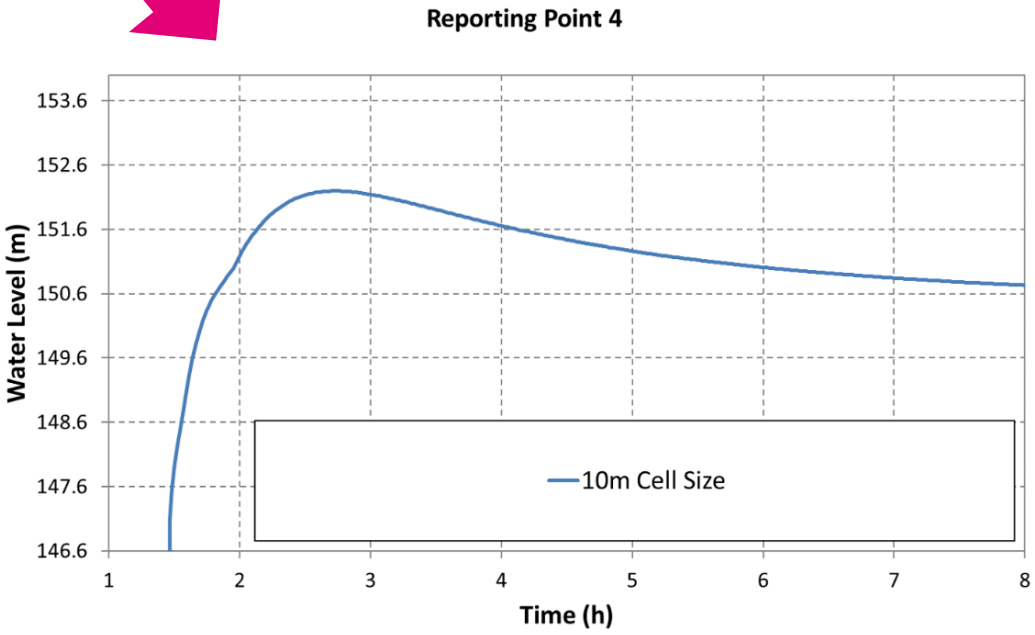


10m (33ft) resolution
188,000 cells





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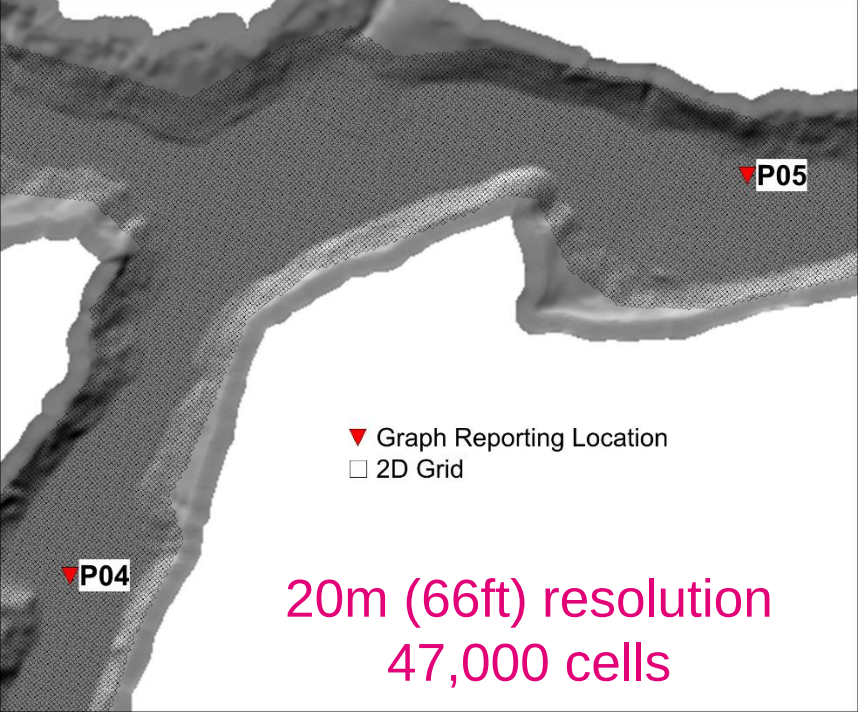

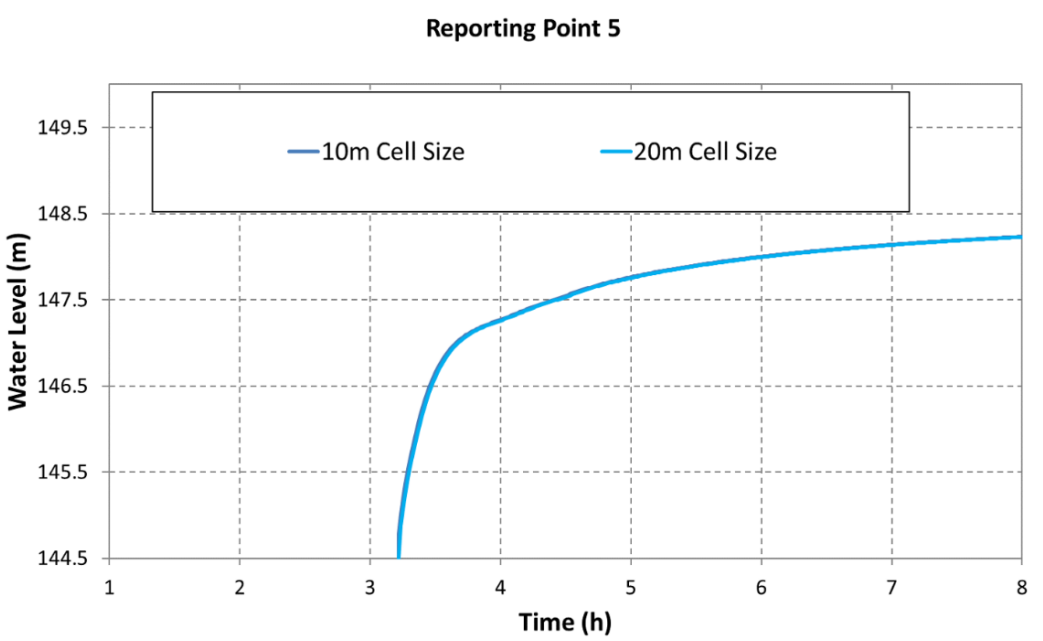

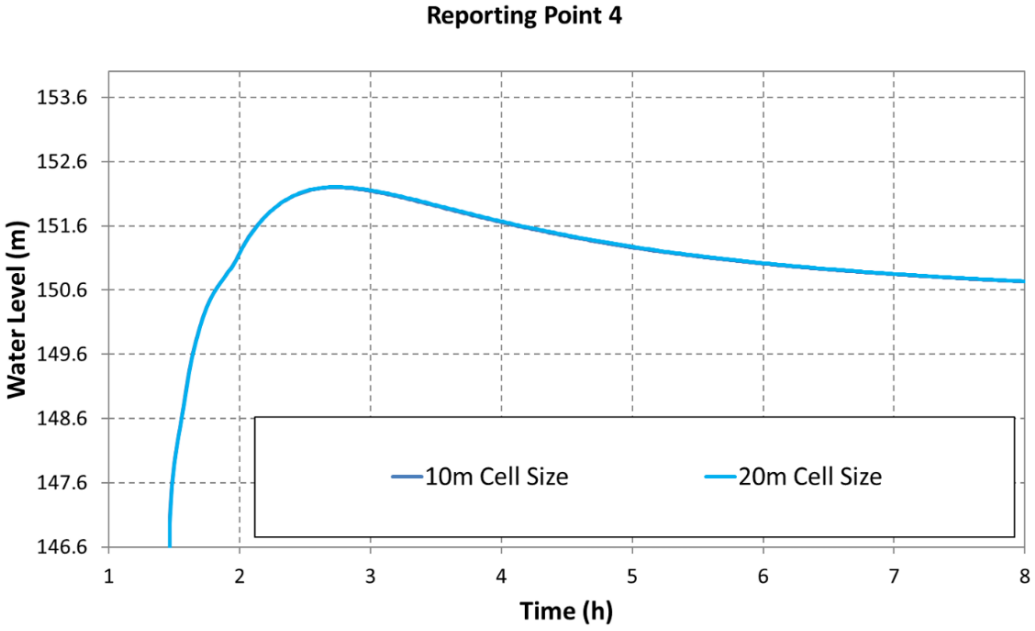

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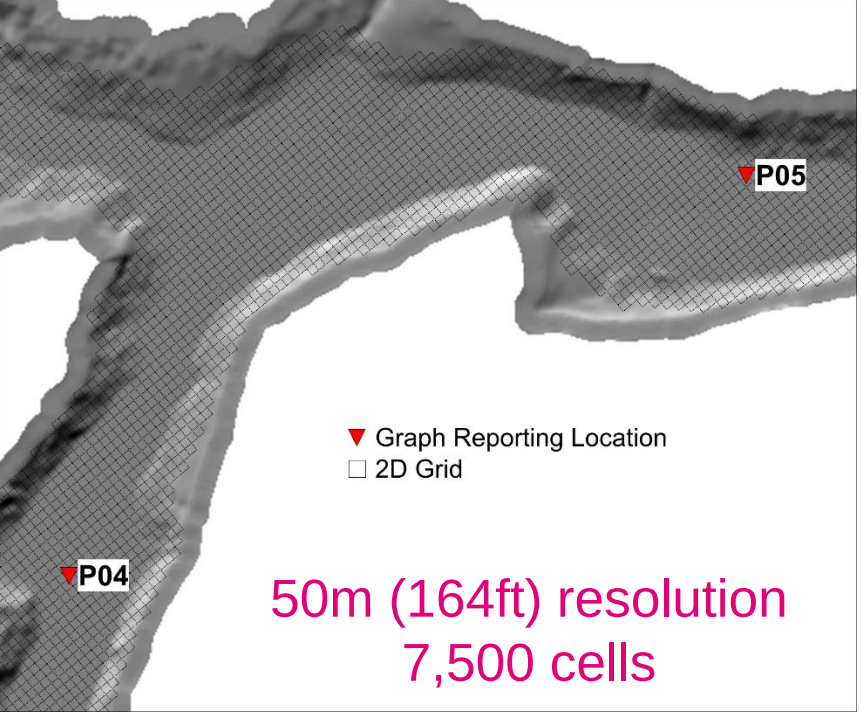

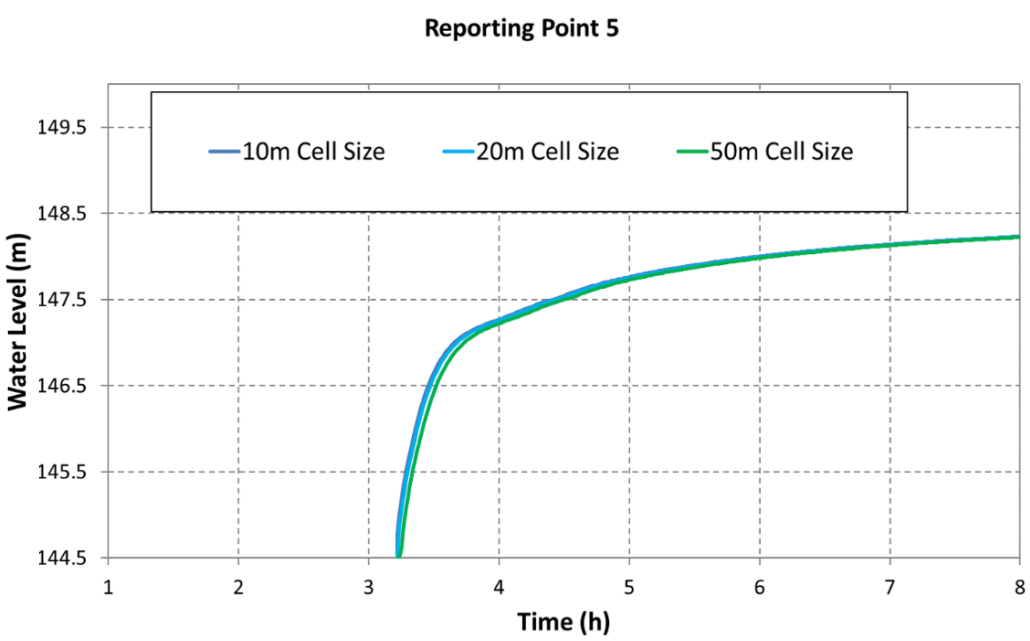

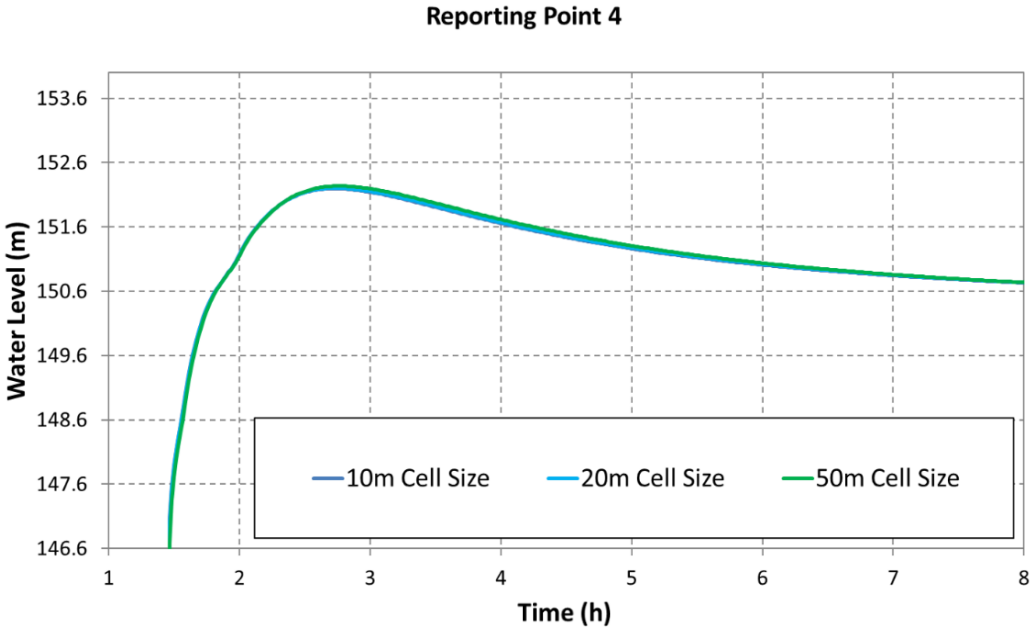

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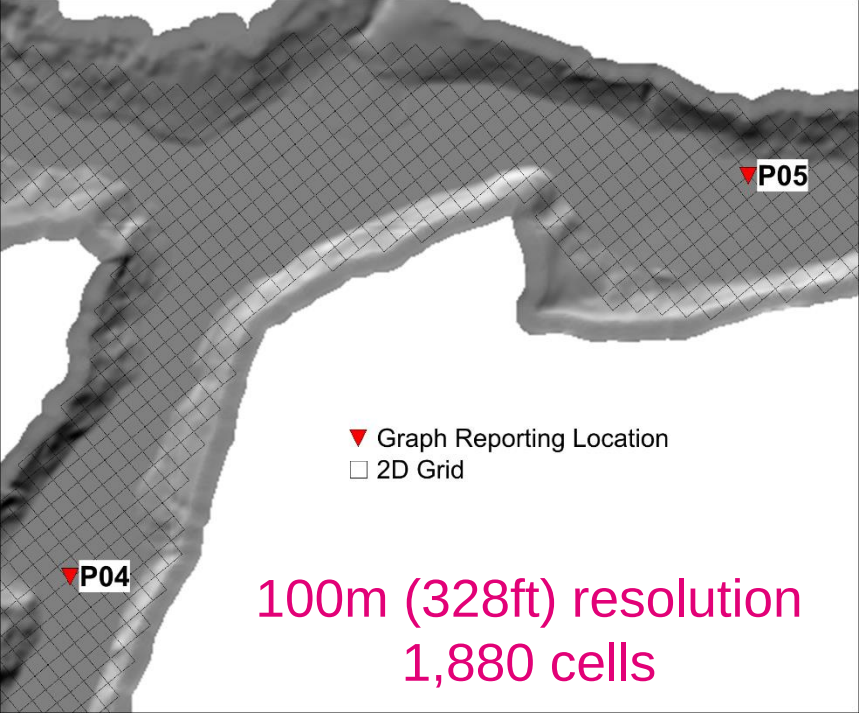

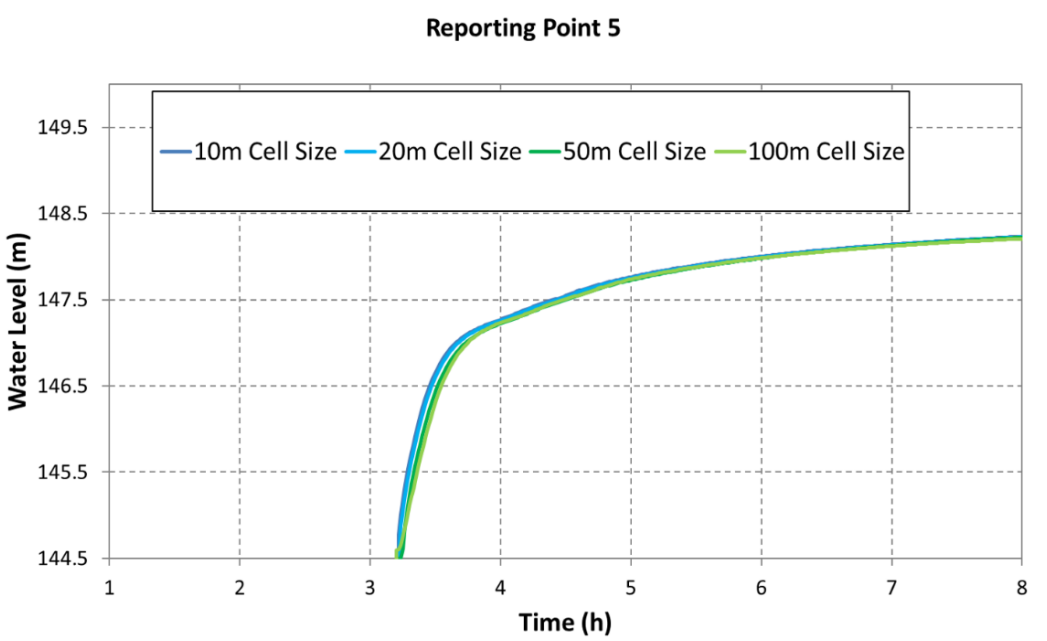

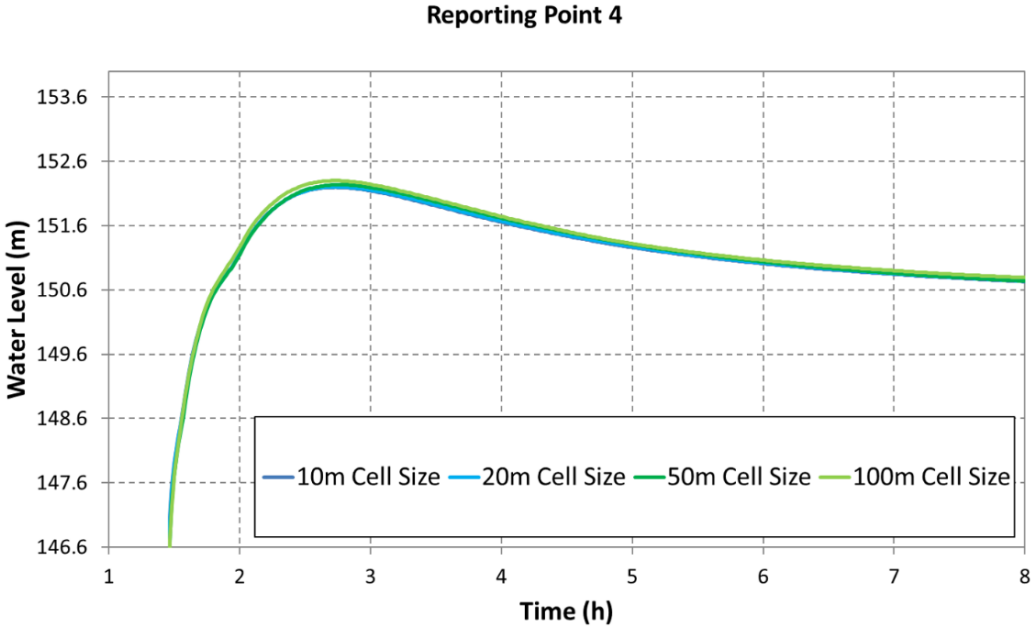

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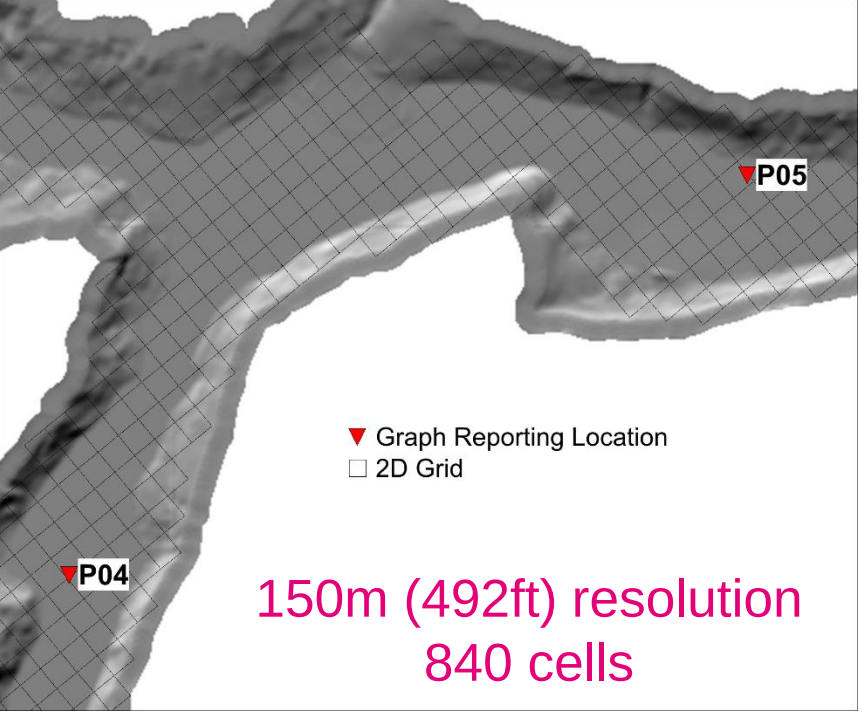

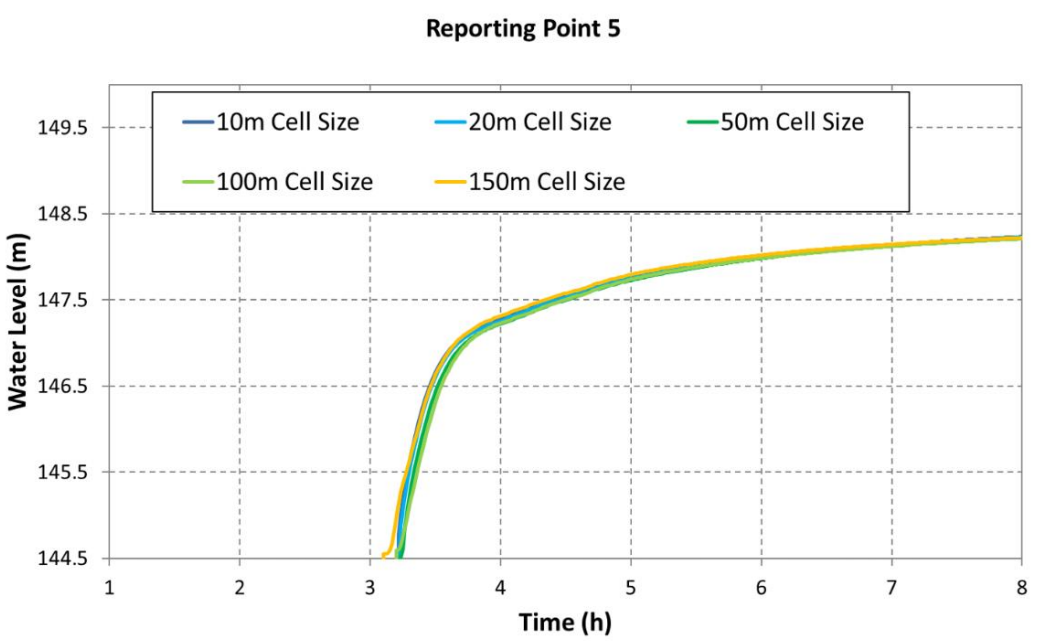

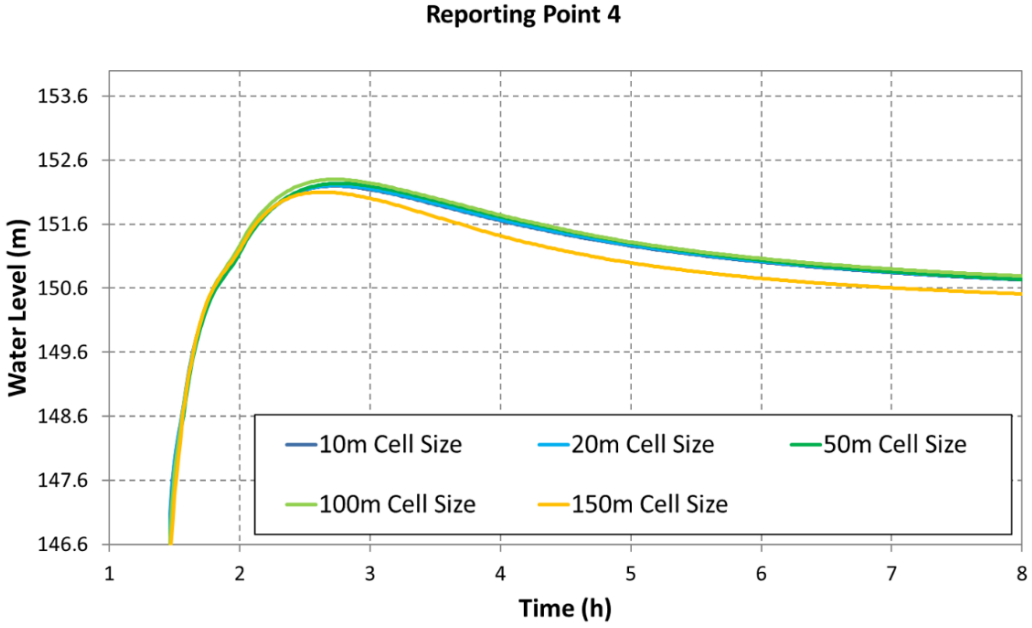

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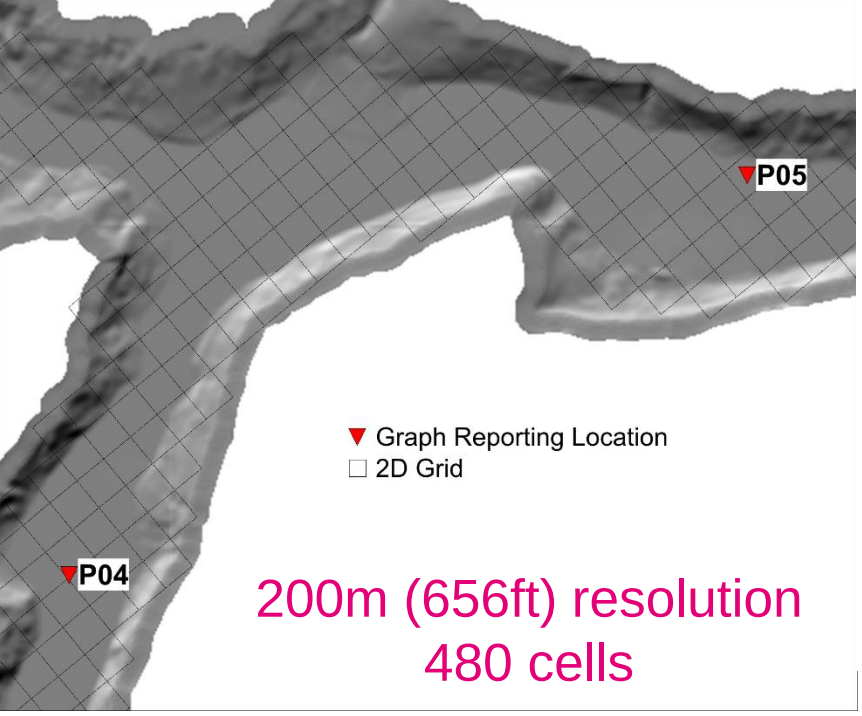

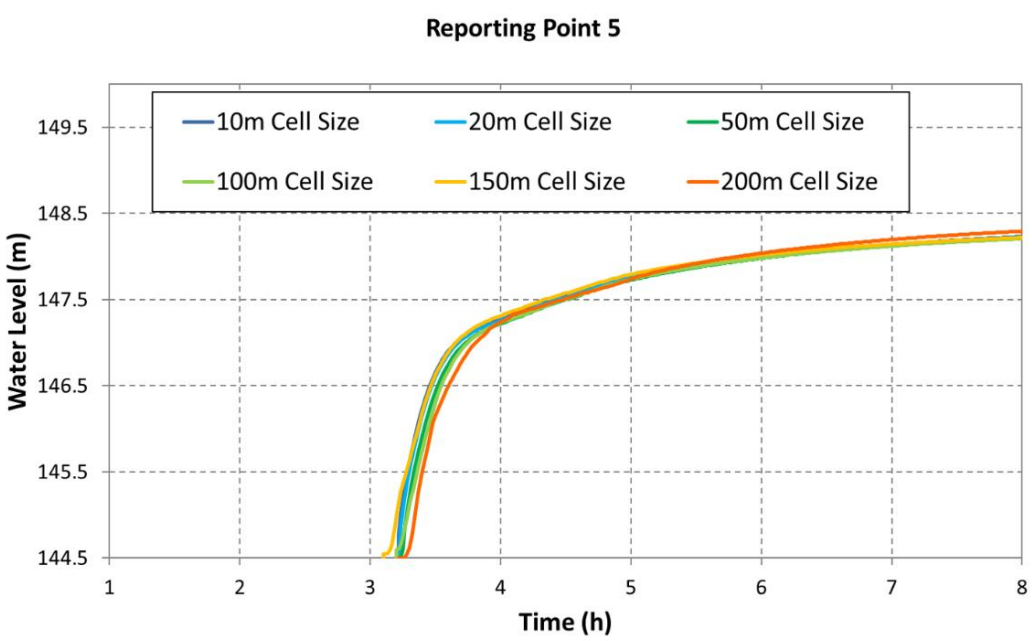

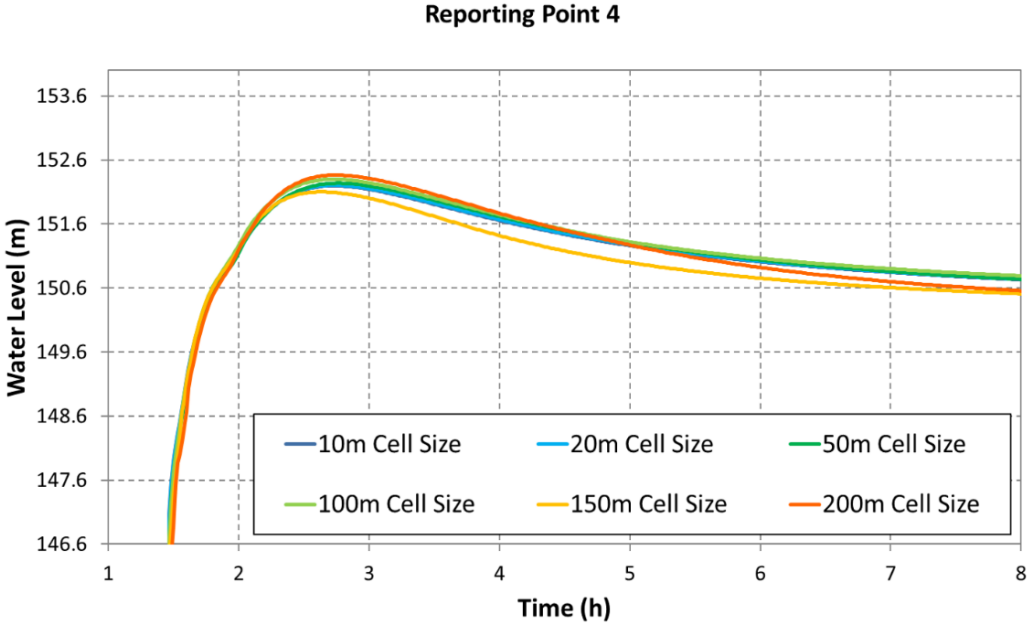

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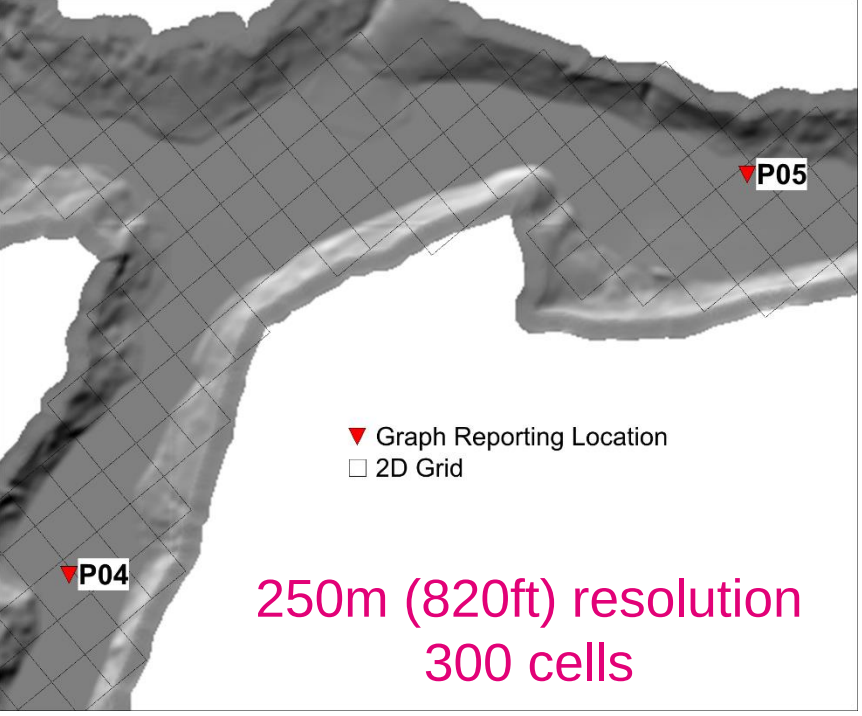

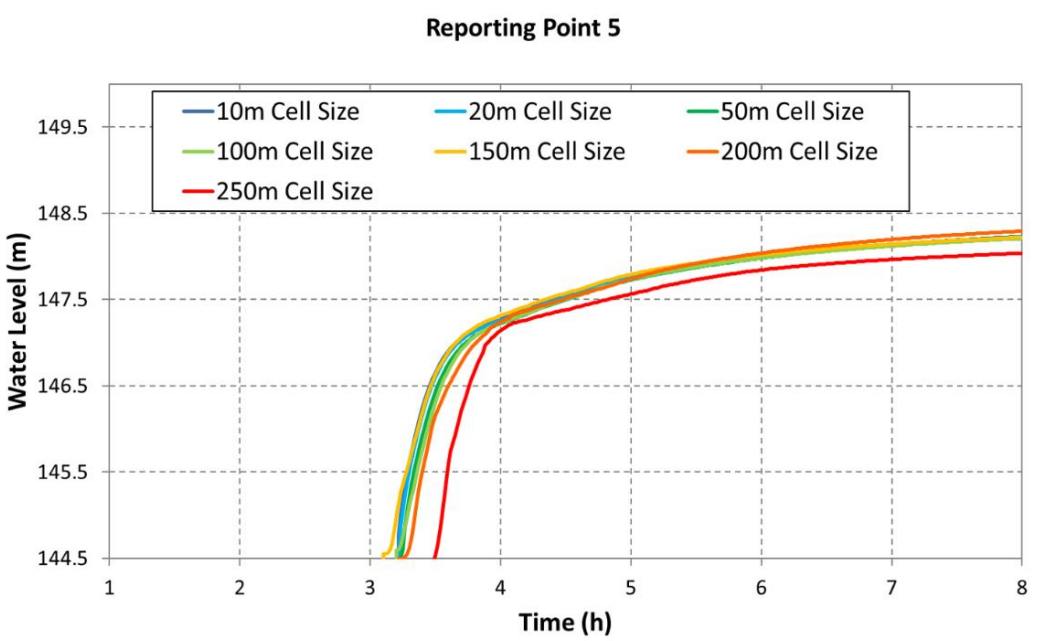

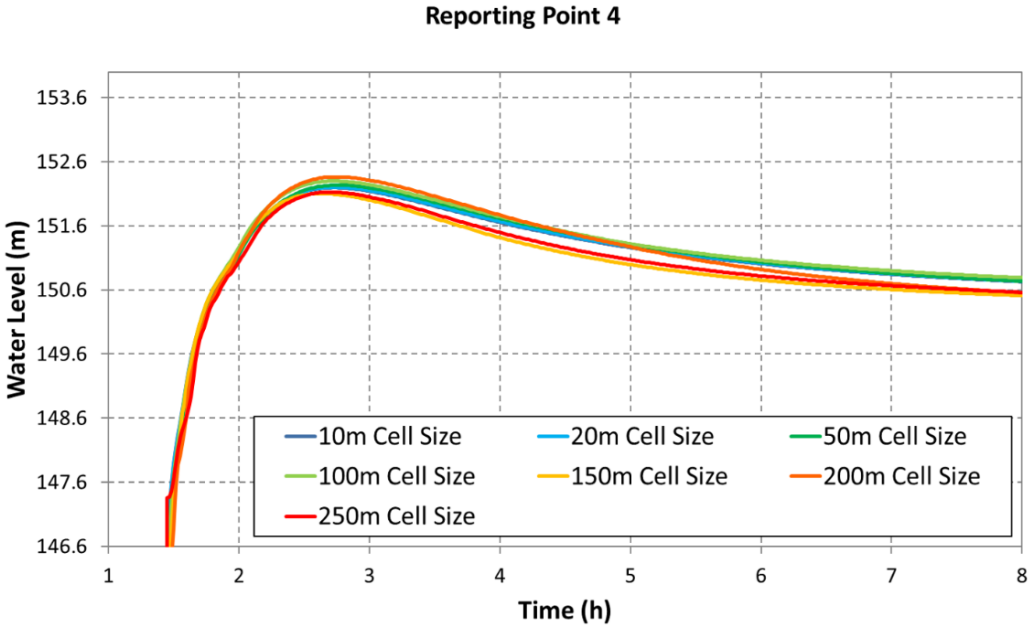

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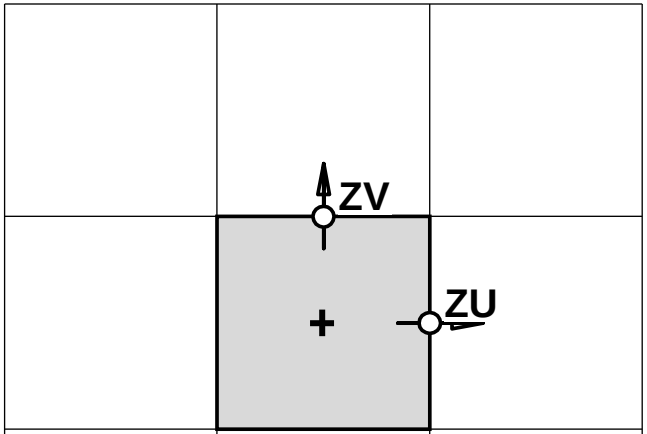
Result Discussion
Guideline Comparison

- **Flow magnitude means valley is acting like an open channel**
- **Convergence observed when ≥ 5 grid elements laterally across the valley**
- **Results agree with guideline recommendations**
- **Optimum resolution depends on modelling objectives**

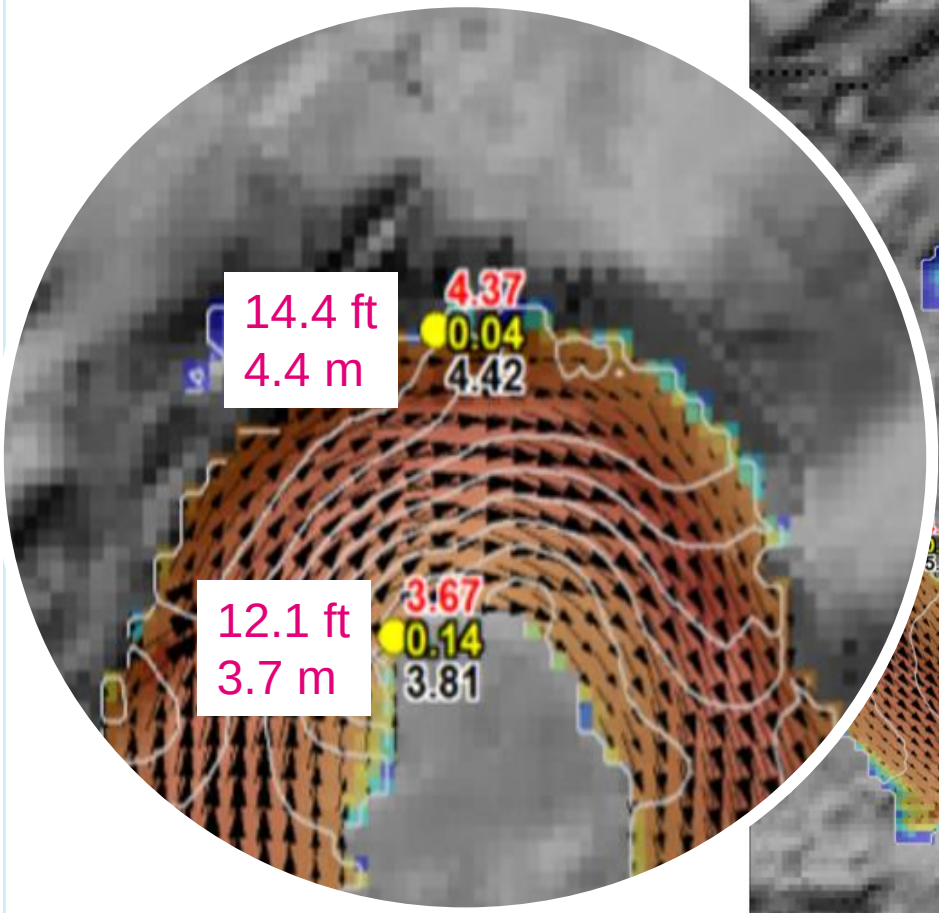
- **Why is this resolution necessary?**
  1. To adequately represent the valley cross-section shape
  2. To adequately define the cross-channel velocity distribution

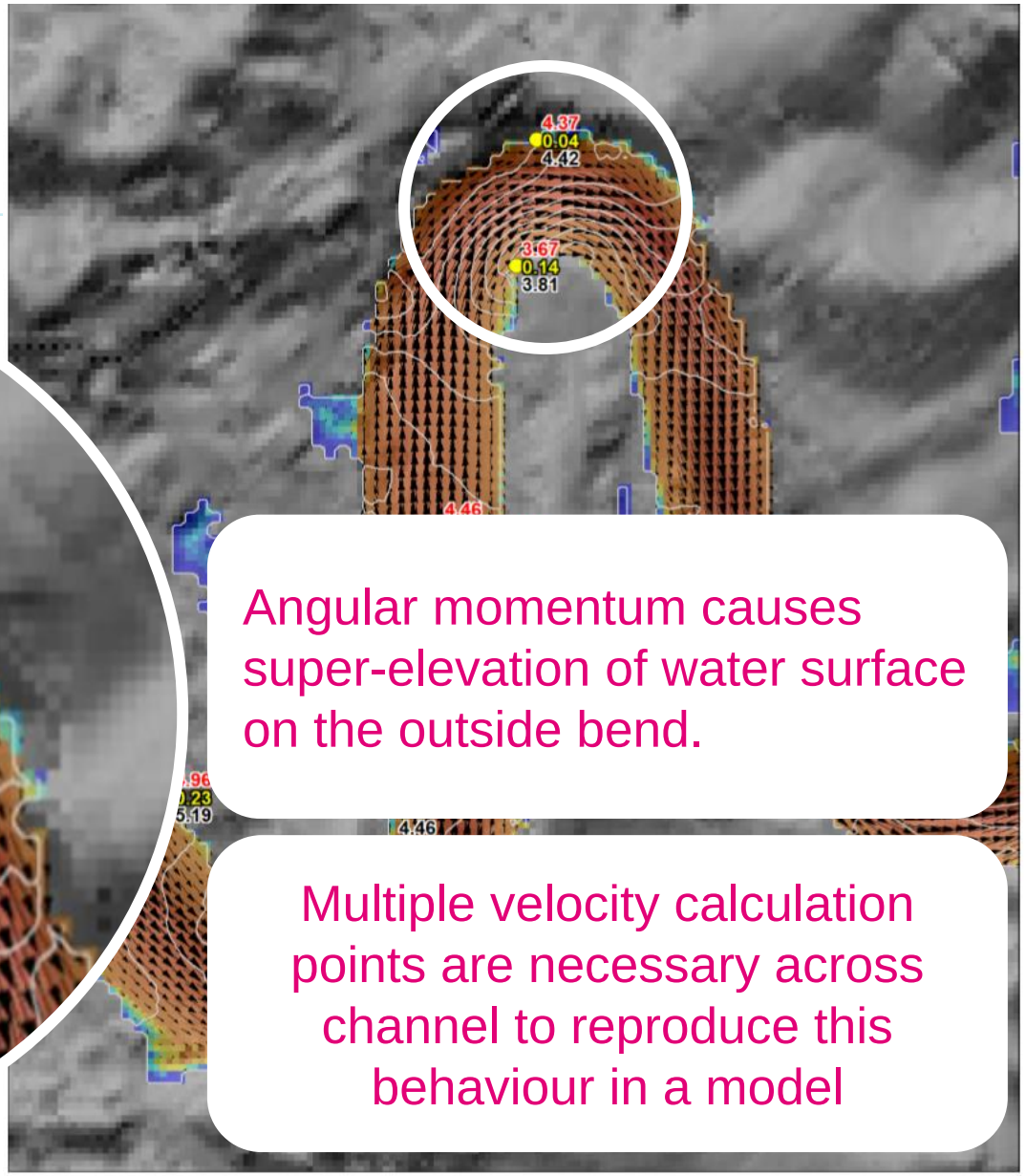
Accurate velocity results is essential for accurate treatment of momentum and inertia!



Note: Each 2D cell only calculates a single velocity per cell face.

Result Discussion
Recorded Water Levels





Angular momentum causes super-elevation of water surface on the outside bend.

Multiple velocity calculation points are necessary across channel to reproduce this behaviour in a model

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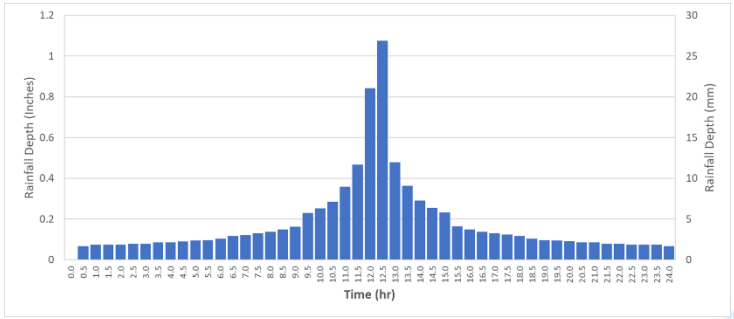
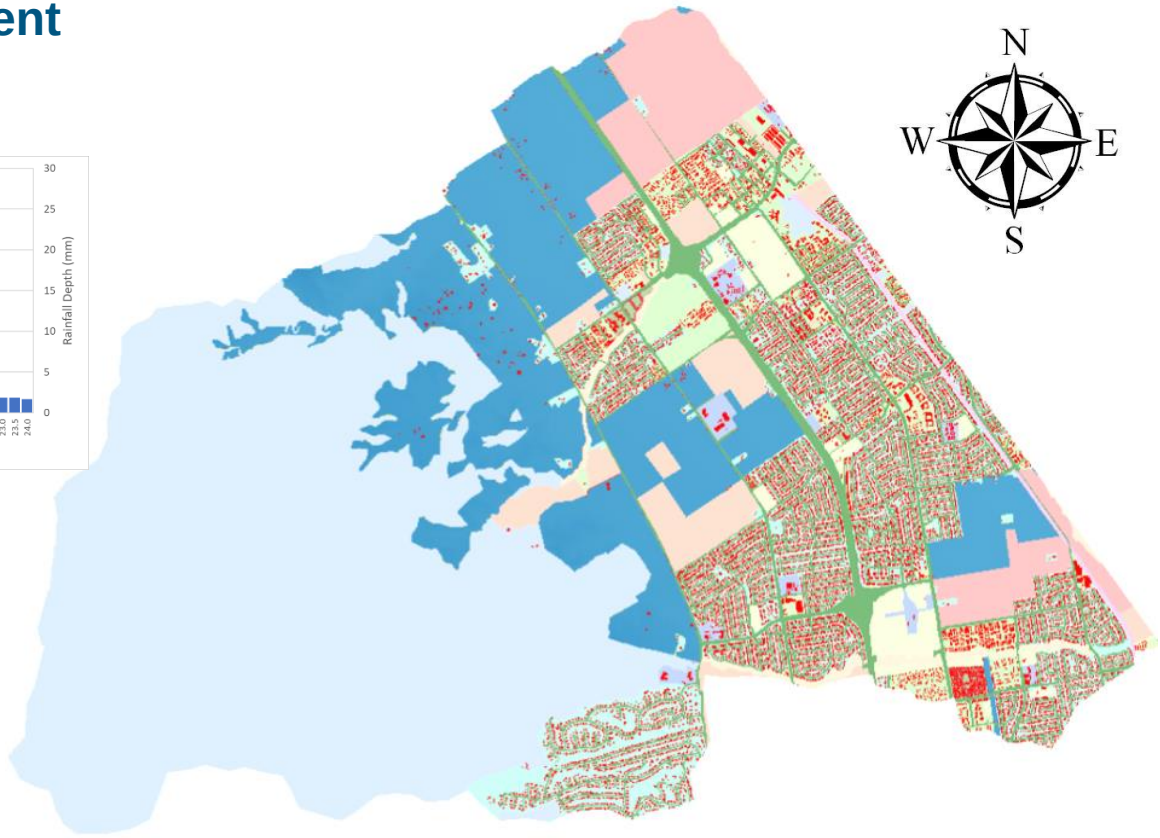
Urban Case Study

- 21^2 mile ($54km^2$) catchment
- Hypothetical 24hr storm



- Direct rainfall approach
- 2D overland
- 1D open channel
- 1D pipe



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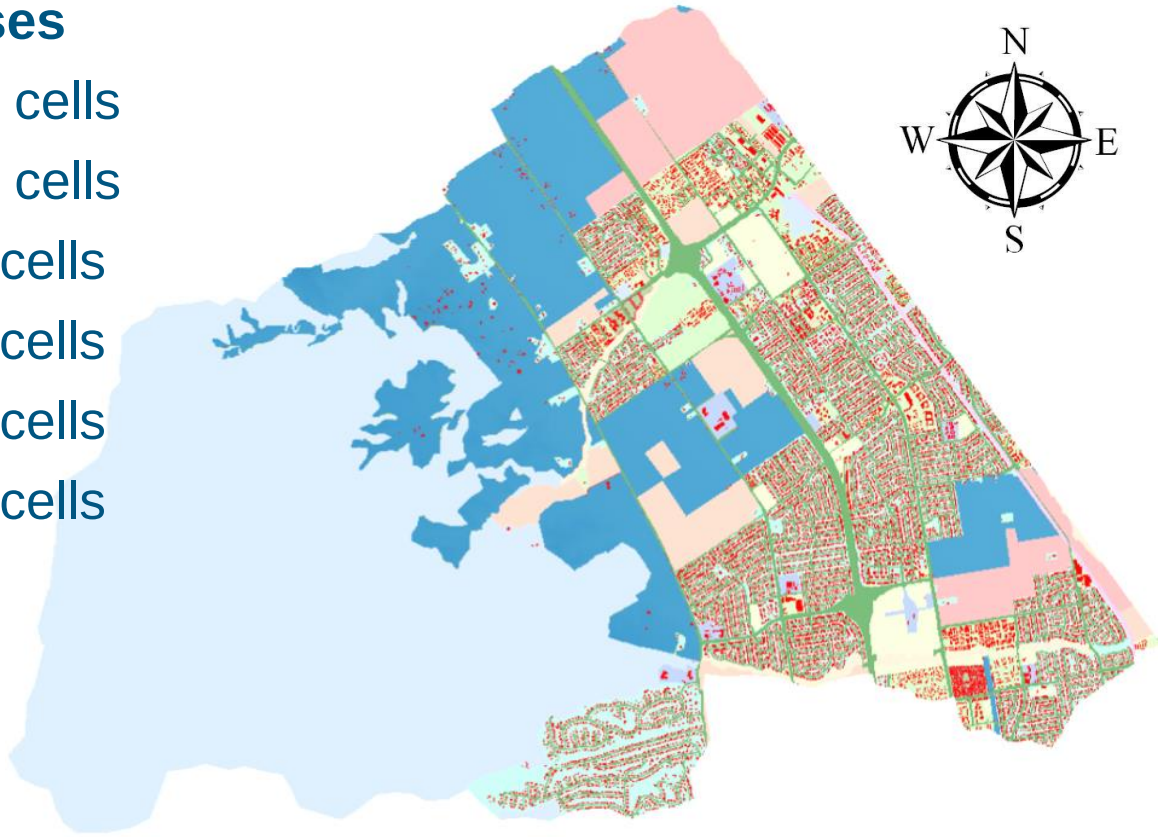
Urban Case Study

Cell Resolution Test Cases

1. 10ft (3m): 5,821,000 cells
2. 15ft (4.5m): 4,042,000 cells
3. 20ft (6m): 2,588,000 cells
4. 30ft (9m): 647,000 cells
5. 50ft (15m): 233,000 cells
6. 75ft (23m): 104,000 cells



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Results

- 9.2hr simulation
- 10ft case used as baseline for analysis of coarser resolution results

10ft (3m) Resolution
5,821,000 cells

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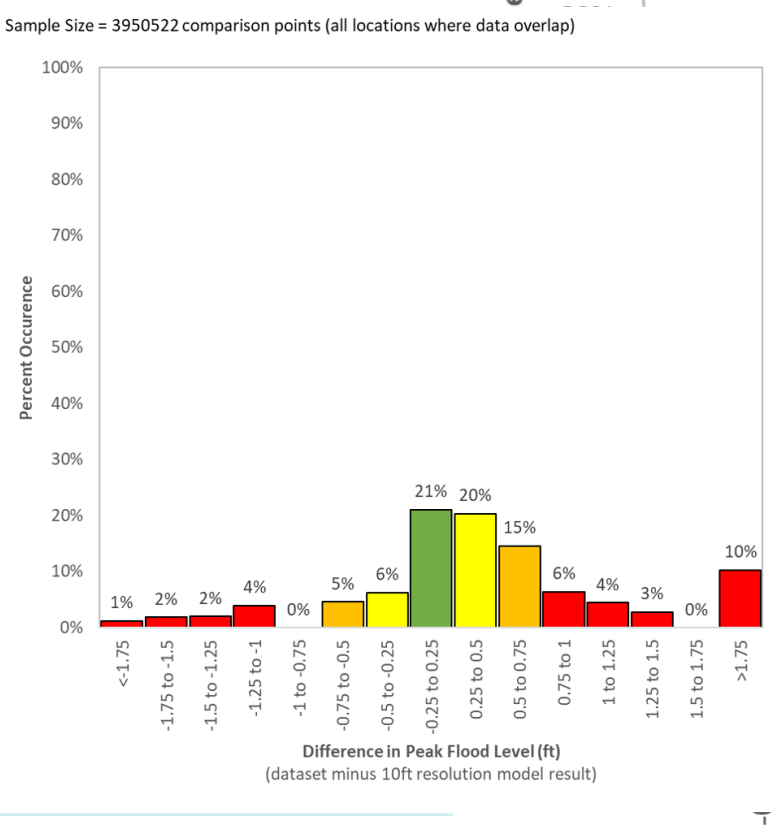
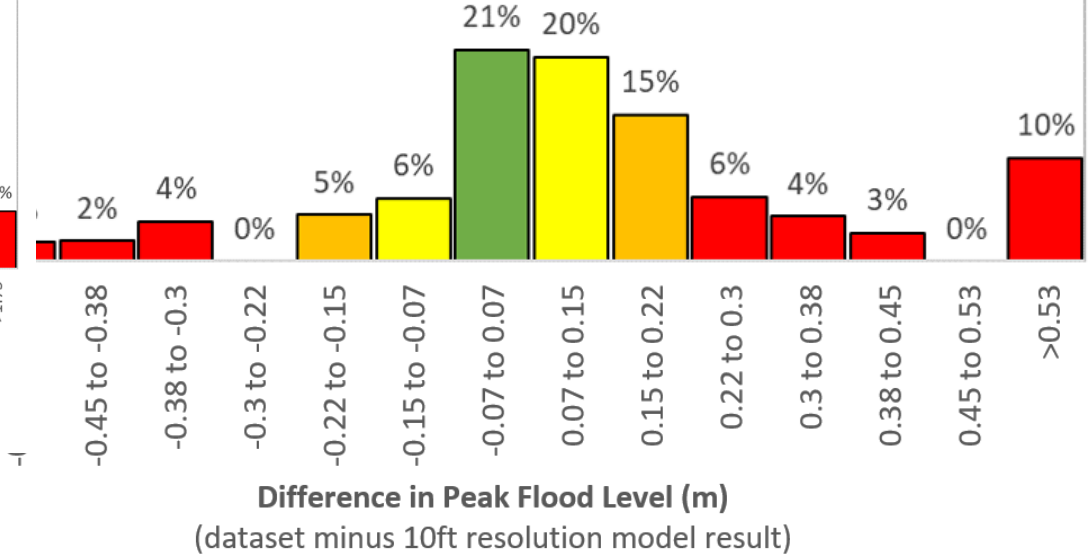
Results

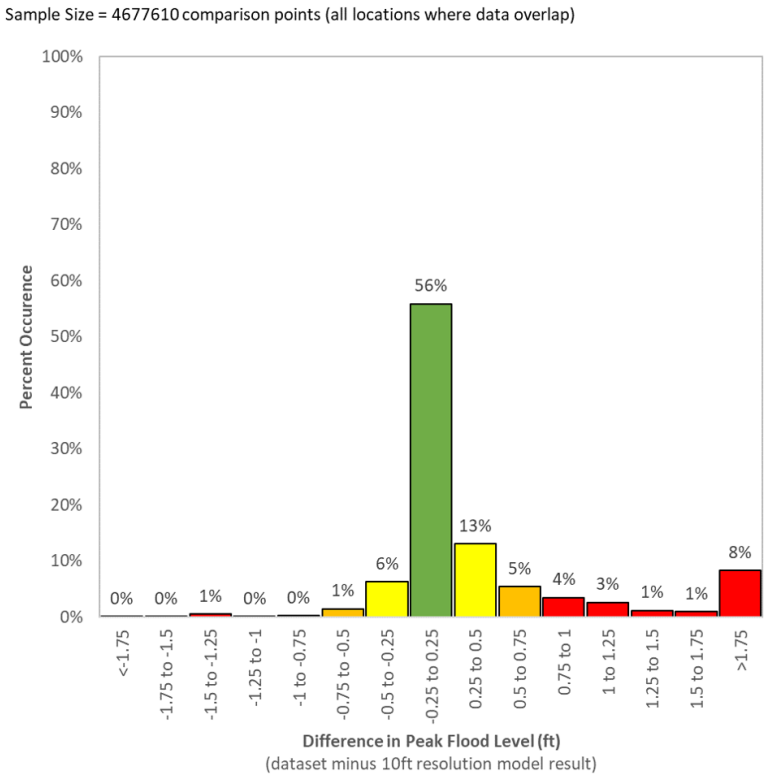
- 0.08hr simulation
- Convergence ✘





Results

- 0.23hr simulation
- Convergence ✘



50ft (15m) Resolution
233,000 cells

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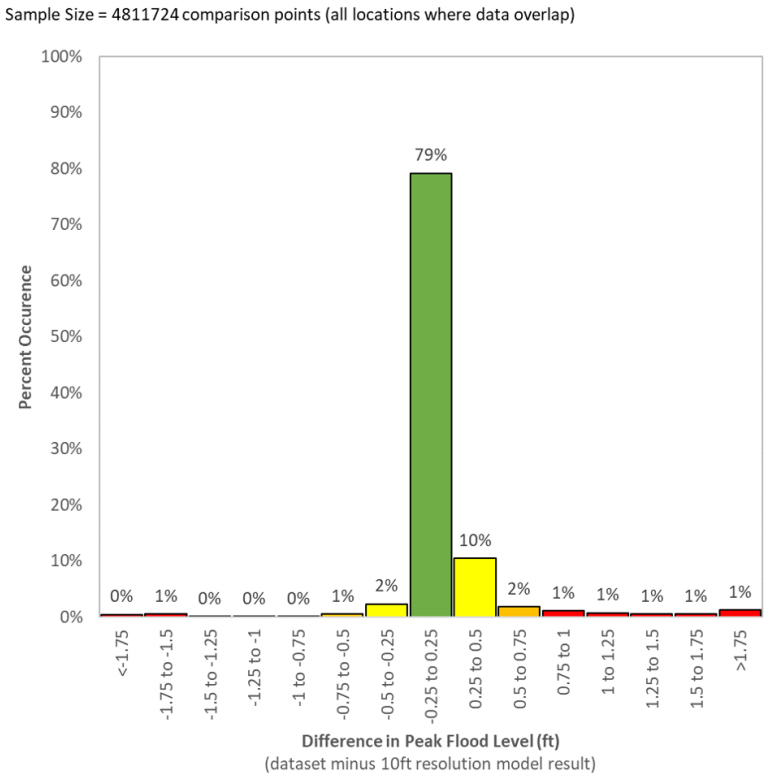
Results

- 0.65hr simulation
- Convergence ✘



30ft (9m) Resolution
647,000 cells

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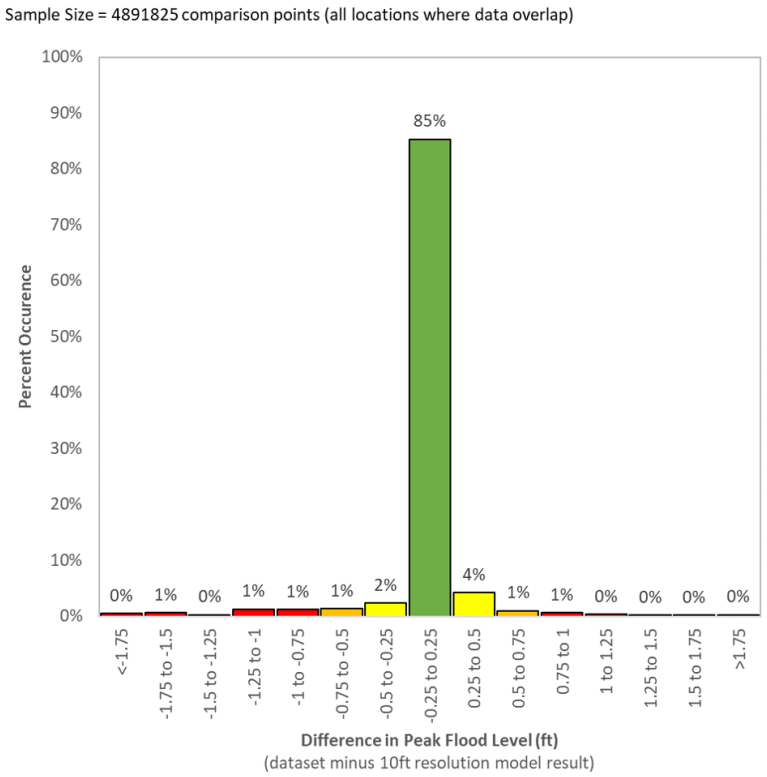
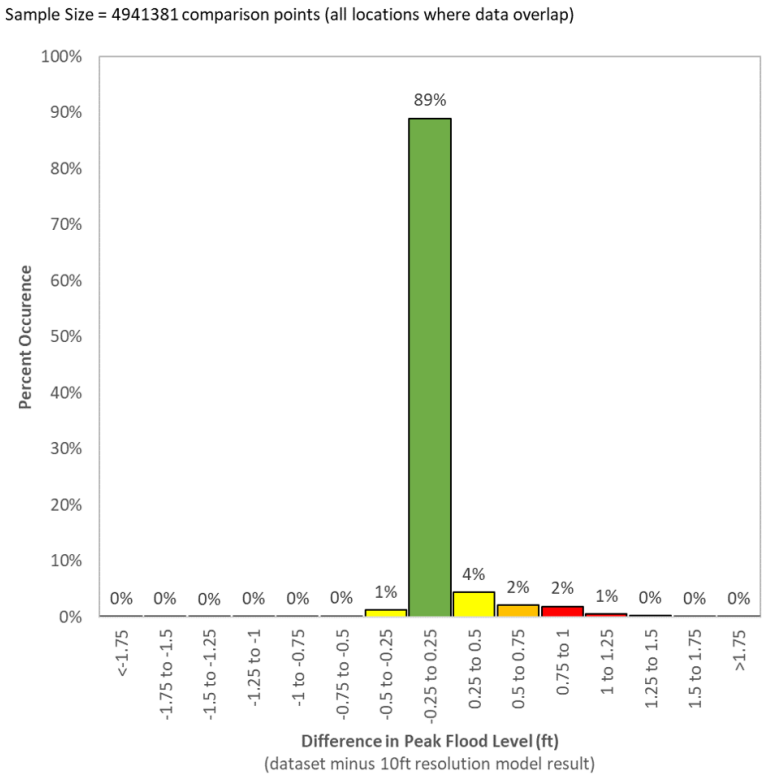
Results

- 1.8hr simulation
- Convergence ✓



Results

- 4.4hr simulation
- Convergence ✓



15ft (4.5) Resolution
4,042,000 cells

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Results

- 9.2hr simulation
- Target result for comparison

10ft (3m) Resolution
5,821,000 cells

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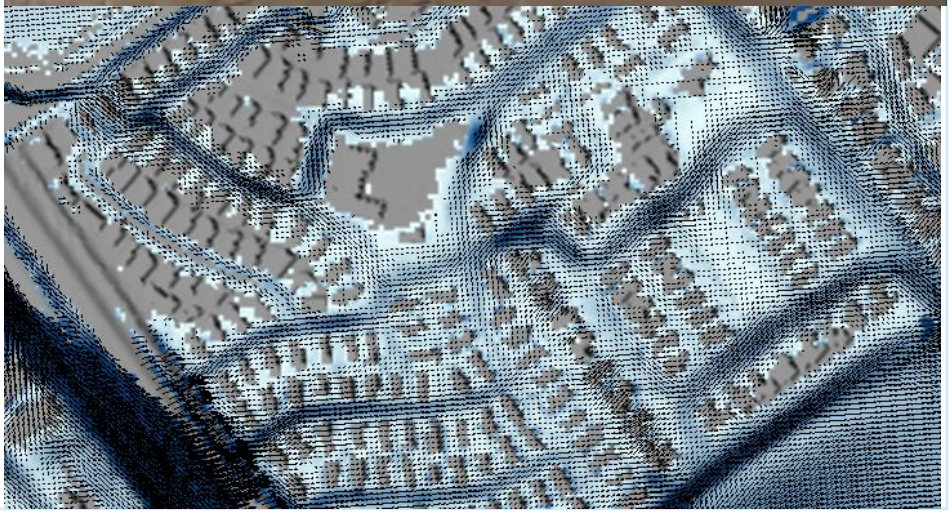
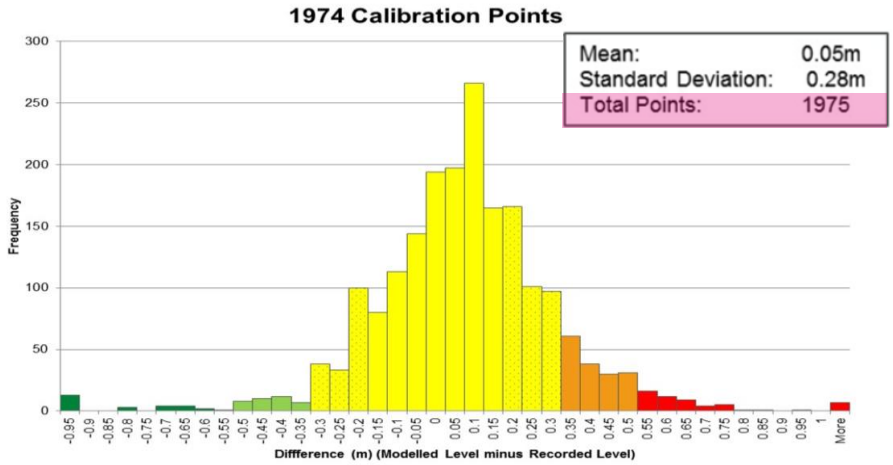
Result Discussion
Guideline Comparison

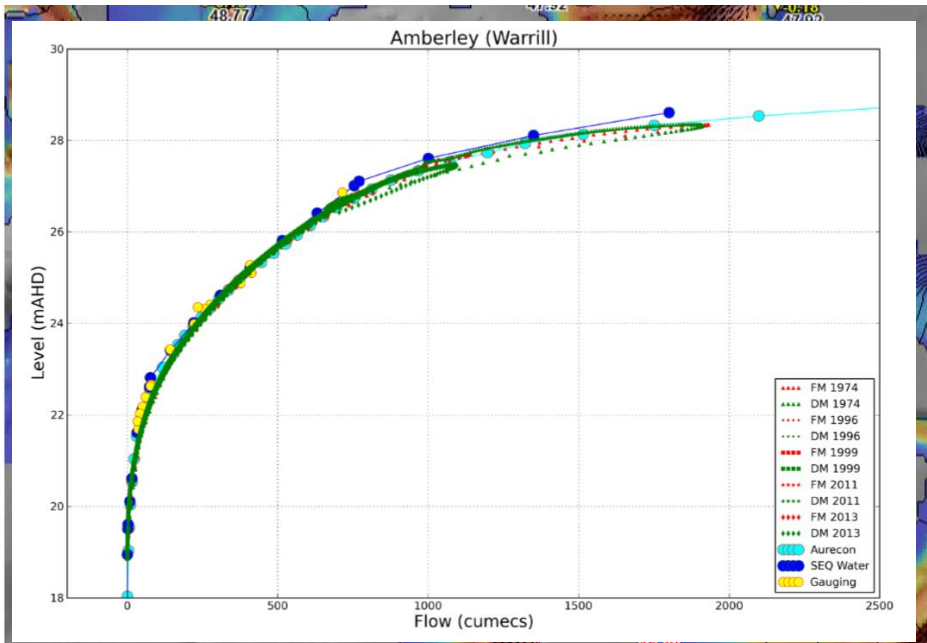
- **Resolution < 20ft (6m) is recommended**
- **Test results agree with the guideline recommendations**
- **Optimum resolution depends on modelling objectives**
- **Why is fine resolution necessary?**
  1. Urban areas characteristically have many abrupt obstructions
  2. Fine resolution is needed to accurately represent the high variations in flow behavior (level and velocity) near obstructions

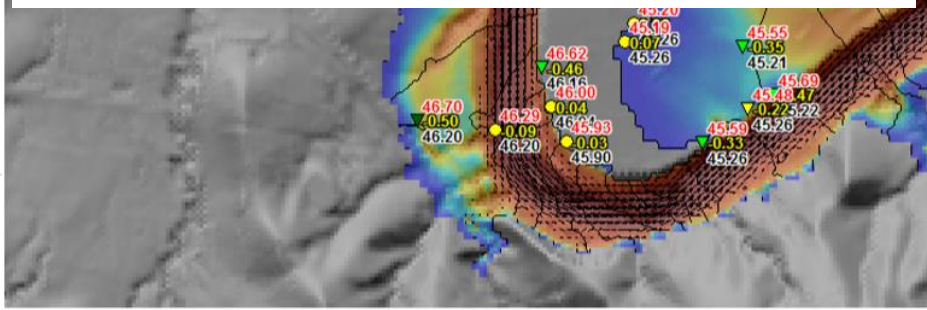


Presentation
General Discussion

- ARR2012 2D Modelling guideline recommendations have been confirmed valid
- Does mesh convergence guarantee model results will be correct?
- **NO!**
- All models should be calibrated to historic events.
- There is no other independent way to identify accidental data errors in input
- TBC in another presentation







Thank you for watching

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