

Developing Skills in TUFLOW

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Workshop topics

1. Conceptualisation and schematisation in model building:
 - * Aims and objectives, project constraints
 - * Model suitability
 - * Model stability
 - * Grid sizing, model extent, boundary locations
 - * Simulation times (timestepping, data output)
2. Schematisation of TUFLOW boundary conditions
 - * Types of boundary
 - * 1D-2D linking (high level)
 - * Linkage to structures in the 1D domain

Conceptualisation and schematisation

- * Establish clear aims and objectives for your modelling study
- * Establish project budget (potentially impacts upon available time & data)
- * Develop an understanding of the study area hydraulics, with specific reference to study aims & objectives
- * What data is available?
- * Define areas to be modelled and approach to representing the relevant hydraulics in these areas
- * Simulation considerations (timing, number of simulations, available hardware)
- * Justify your chosen approach
- * Giving the above some thought at project startup is time well spent!

Define aims and objectives

- * Why has the study been commissioned? (Strategic level model, model requested to address concerns at a specific location, site specific FRA, update to FWA / ABD studies etc.)
- * What are the required outputs?
 - * Flood extents
 - * Hazard / depth / velocity mapping
 - * Visualisation of flooding
 - * Timing of inundation
 - * Impact comparisons
- * Be an intelligent modeller. Can the model do more? Where can we add value?

Study area hydraulics

- * Visit the study area (if at all possible)
- * Research observed relevant mechanisms of flooding
- * Refer to past studies, maps, LiDAR and other topographic datasets, aerial photography etc.
- * Understand the relevance of study reach hydraulics to your specific study aims

Available data

- * Previous modelling studies (BEWARE of legacy issues!). Check calibration / sensitivity / sensibility.
- * Topographic data (extent):
 - * LiDAR DTM
 - * Topographic surveys – sites, defences, key obstructions to flow
 - * DTMs from other sources – vertical accuracy?
- * Mapping data (OS MasterMap or other mapping in UK, aerial photography)

Define approach: 2D domain extent

- * Domain extent – establish suitable boundary locations for the model
- * Must capture all relevant hydraulics
- * These will be influenced by:
 - * Data constraints
 - * Locations which suitably capture hydraulics
 - * Number of wet cells in simulation / simulation times
- * 1D-2D linking provides flexibility in location of boundaries
- * Move uncertainty away from areas of interest

Define approach: 1D - 2D linking

- * 1D approaches may be better suited to representing clearly defined flow paths
- * Check for available data and relevant flow routes
- * 1D-2D linking allows boundaries to be moved upstream and downstream without significant impact on simulation times

Define approach: 2D grid sizing

- * Grid should be suitably sized so as to effectively represent key mechanisms of flooding
- * Aim for 3-4 cells across major flow paths
- * Must result in a workable simulation time (halving 2D cell size typically increases simulation time by a factor of eight - four times as many cells & half the timestep).
- * TUFLOW model builds are independent of grid size, so coarser grids can be used during model build before using the final grid size on final design simulations

Simulation Considerations

- * Model schematisation is important not only in capturing mechanisms of flooding, but also in:
 - * Stability of model
 - * Workable simulation times
 - * Delivery of project (timescales!)
- * Again, giving the above some thought at the beginning of projects is time well spent!

Simulation times and stability

- * TUFLOW offers an implicit solution of the full 2D free-surface wave equations
- * Solver based on the Stelling finite difference, alternating direction implicit (ADI) scheme
- * Courant number is a measure of stability
- * 2D implicit schemes stable when Courant numbers ≤ 10 (typically ~ 5)
- * Examples - timestep 5 secs, grid 10m:
 - * Depth 1m, Courant number = 2.2
 - * Depth 5m, Courant number = 5.0
- * 2D timestep as a rule of thumb should be between half to a quarter of grid size

Simulation times and stability

- * Time for simulation to complete depends on:
 - * Timestep
 - * Number of wet cells
 - * Storm duration
 - * Computer speed
 - * Frequency of writing output (and size of output files)
- * Bear in mind:
 - * Number of simulations required
 - * Project timescales

Simulation times and stability

- * AVOID the temptation to 'fix' an unstable model by reducing the timestep
- * If the Courant numbers are reasonable, instability is unlikely to be a timestep issue
- * Review 2D Courant numbers in _Cr.dat file (as of build 2008-08-AA) – specify as output in *.tcf or *.trd file
- * Reducing timestep can increase run times substantially, so...
- * Investigate the reason for instability (poor input data, schematisation errors etc.)
- * If model is operating at high Courant numbers, run simulations assessing the sensitivity of model output to smaller timesteps
- * Watch out for high MB errors as an indicator of too high a timestep (console window / *.tlf/) – aim for $\pm 10\%$ - output to _MB.csv files

Simulation Considerations

- * Simulation times can be LONG and will impact upon project delivery
- * Ideal run times:
 - * 2 to 3 hours, allows for review of 3 simulations per day, per core
 - * 6 to 7 hours – time for review of 2 simulations per day, per core
 - * > 7 hours – all day / overnight simulation – review of one simulation per day, per core

Model Output

- * Model outputs specified in the TUFLOW control file (*.tcf / *.trd)
- * Example output types:
 - * Water level, hazard, velocity, flow, depth
- * Frequency of output impacts upon simulation times (dependant on destination folder)
- * Frequency of output also influences output file size
 - * Large output files may soon fill up hard drive and server space
 - * Difficult to share

Justify your approach

- * Recap
- * Justify your chosen approach in relation to:
 - * Modelling study aims and objectives
 - * Project budget (can this be used as justification?)
 - * Study area hydraulics and perceived mechanisms of flooding
 - * Available data
 - * Simulation considerations
- * Demonstrate that a considered approach has been taken to modelling

Justify – (repeat slide)

Link back to:

- * Establish clear aims and objectives for your modelling study
- * Establish project budget (potentially impacts upon time & data)
- * Understand the hydraulics in the study area, with specific reference to study aims & objectives
- * Available data
- * Define areas to be modelled and approach to representing the relevant hydraulics in these areas
- * Simulation considerations
- * Justify your chosen approach
- * Giving the above some thought at the beginning of projects is time well spent!

Example: Boundary conditions

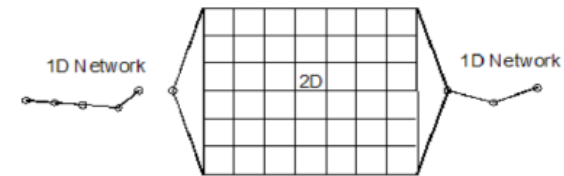
- * Boundary conditions and links to 1D and 2D domains are applied through 2d_bc GIS layers
- * Boundaries can be:
 - * Water level - 2D – 2D to 2D linking, HS (Tidal water level), HQ (head v flow), HT (head v time), HX (Head from an external source)
 - * Flows – QT (flow v time), QC (constant flow), VC (constant velocity), VT (velocity v time),
 - * Sources – RF (rainfall v time), SA (rainfall/flow v time over a specified area), SH (flows v head, pumps/abs), ST (Flow v time), SX (source from a linked 1D domain)
- * Boundaries may be applied directly to the 2D domain, or may involve 1D-2D linking

1D-2D Linking

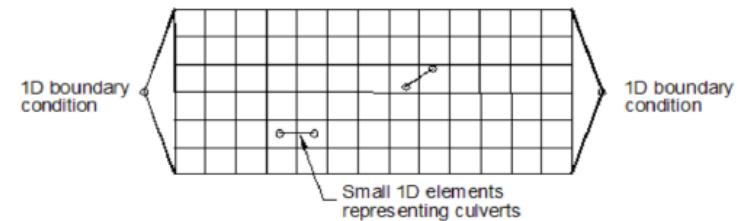
- * Two modes of linking:
 - * Level / HX
 - * 1D domain sends levels to the 2D domain
 - * 2D domain sends flows back
 - * Flow / SX
 - * 1D domain sends flow to 2D domain
 - * 2D domain sends levels back

1D-2D Linking

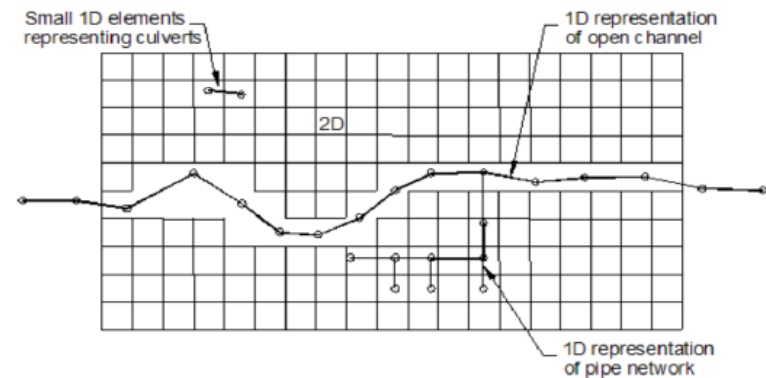
- * Both can be used inline, embedded or laterally
- * Inline – usual configuration is SX US boundary and HX DS boundary
- * Embedded – SX boundary link usually applied
- * Lateral – HX or SX appropriate, depending on bank / floodplain geometry



1a



1b

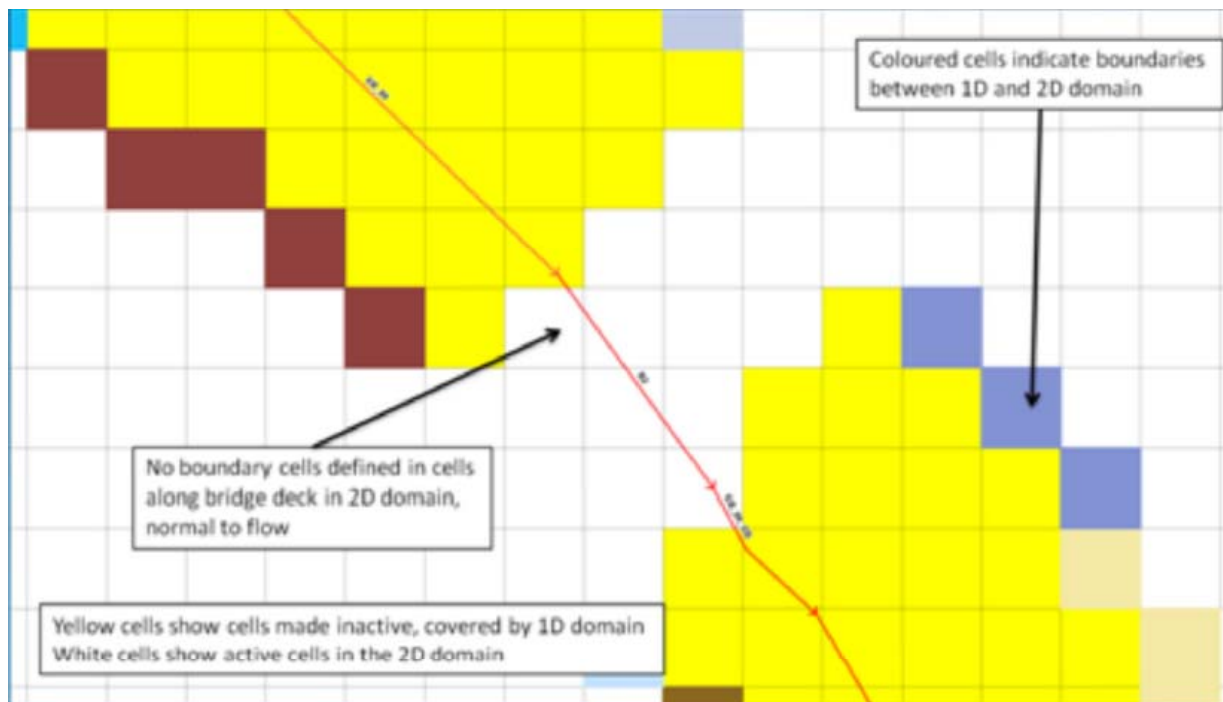


1c

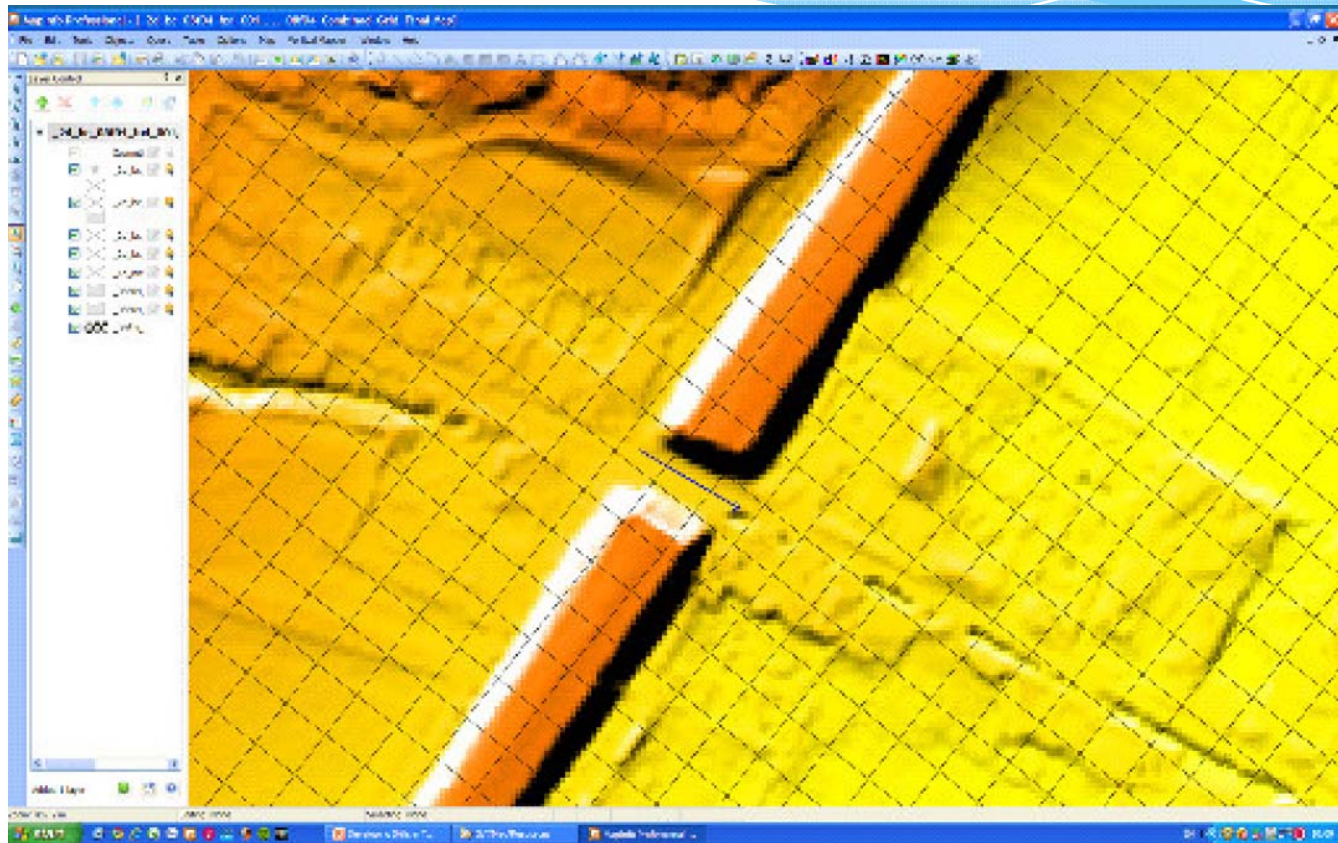
Linkage to structures in the 1D domain – structure decks

- * Common cause of problems in model reviews
- * Focus on linking structure decks represented in 2D domain to 1D domain (although representing decks in 1D domain as weir/spill unit is also valid)
- * Approach:
 - * 2D cells represent topography of structure deck i.e. Road
 - * 2D cells must be linked to the upstream and downstream faces of structure (HX boundary), with appropriate elevations applied (3D breaklines / Z shape layers)
 - * Important bank elevations upstream and downstream are also correctly applied

Linkage to structures in the 1D domain – bridge decks



ESTRY Culvert Example



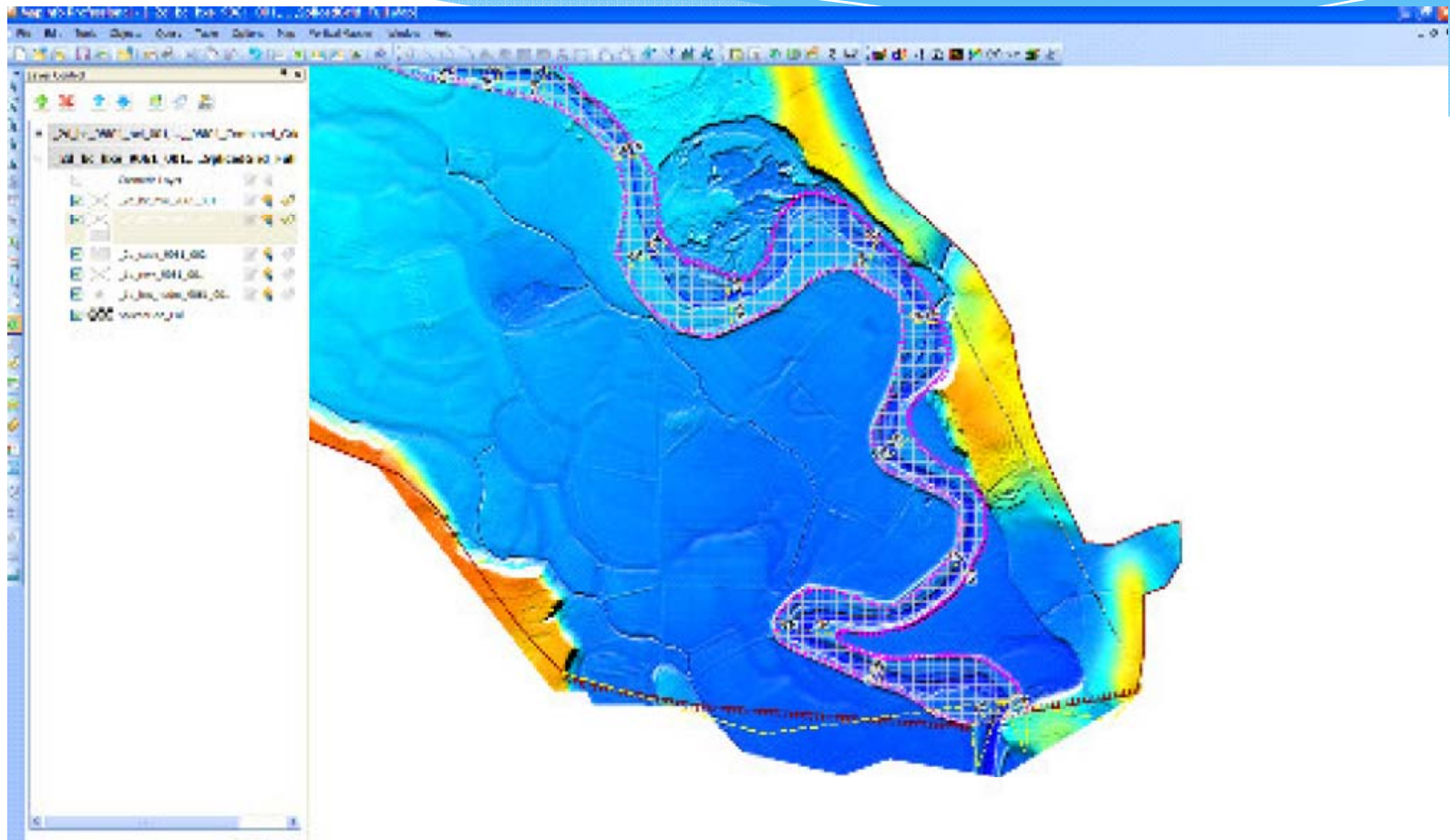
ESTRY Culvert Example

- * Common error is 2D boundary width
- * Culvert modelled in ESTRY (1d_nwk layer)
- * Linked to 2D domain using SX boundary (designated by SX point in 2d_bc layer)
- * Cell size = 20m
- * Structure width comparable or less than cell size, therefore 1 cell selected as boundary is suitable
- * Cell size selected must be comparable to structure geometry
- * In this example, should structure be 40m width, 2 cells should be highlighted as boundary cells

1D-2D Downstream Boundary Example

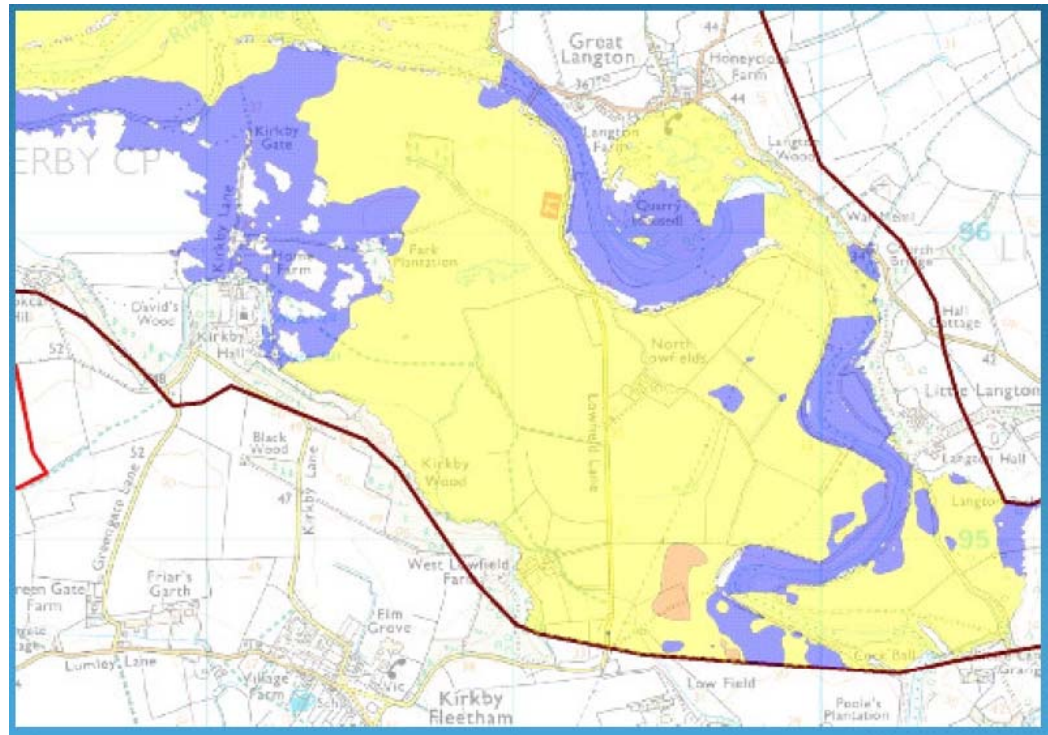
- * Example DS boundary error (surprisingly common)
- * 1D-2D linked reach
- * 1D domain represented in ISIS, linked to 2D domain via HX and CN lines in 2d_bc layer
- * DS boundary incorporates HX line along width of the floodplain linked to 1D domain 'collecting' flow from the 2D domain into the continuing 1D domain

1D-2D Downstream Boundary Example

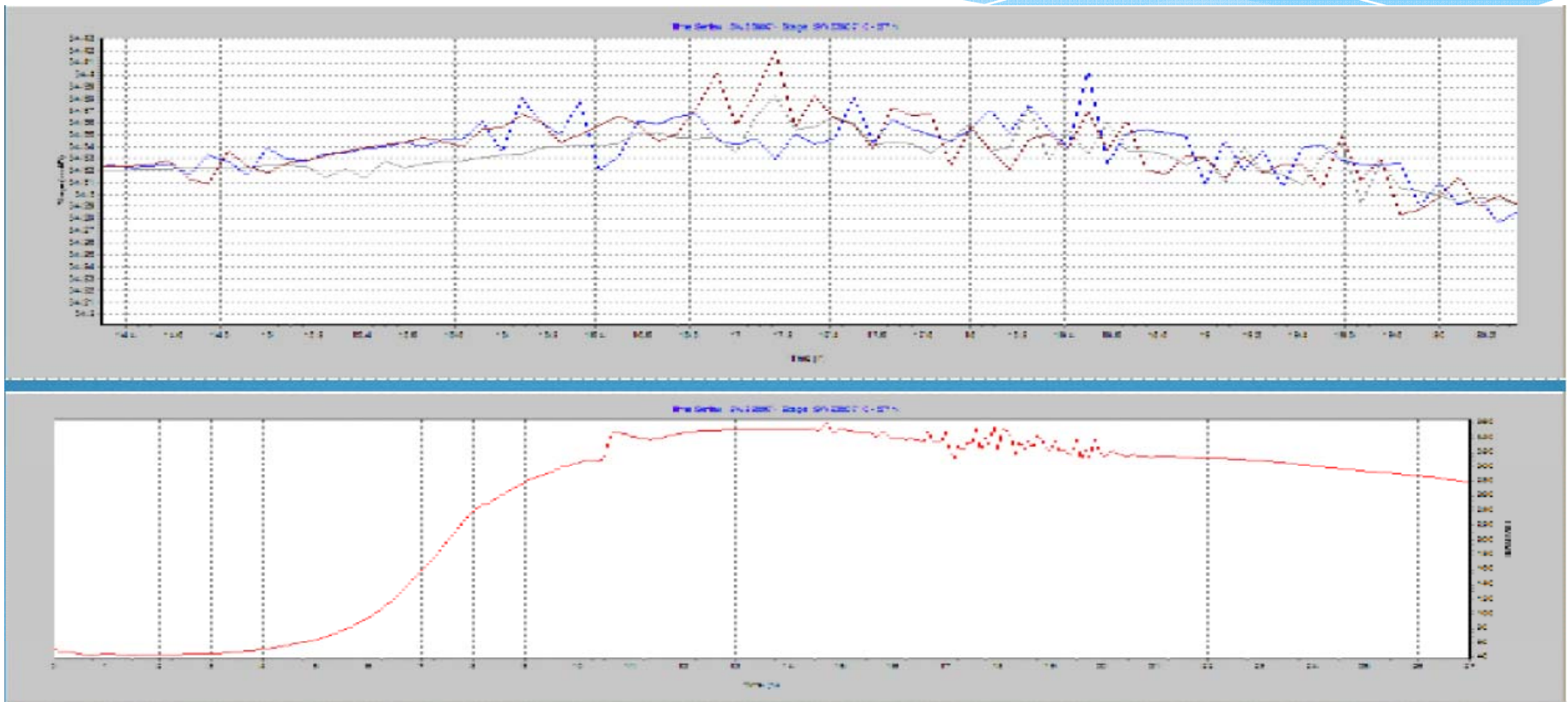


1D-2D Downstream Boundary Example

- * Baseline and proposed events modelled showing inclusion of new bridge structure US in model reach
- * Outputs show significant variation between 1000yr design event simulations
- * (Yellow indicates up to 0.25m increase in peak level 3km DS of bridge)
- * Does this look right?



1D-2D Downstream Boundary Example



Any Questions?