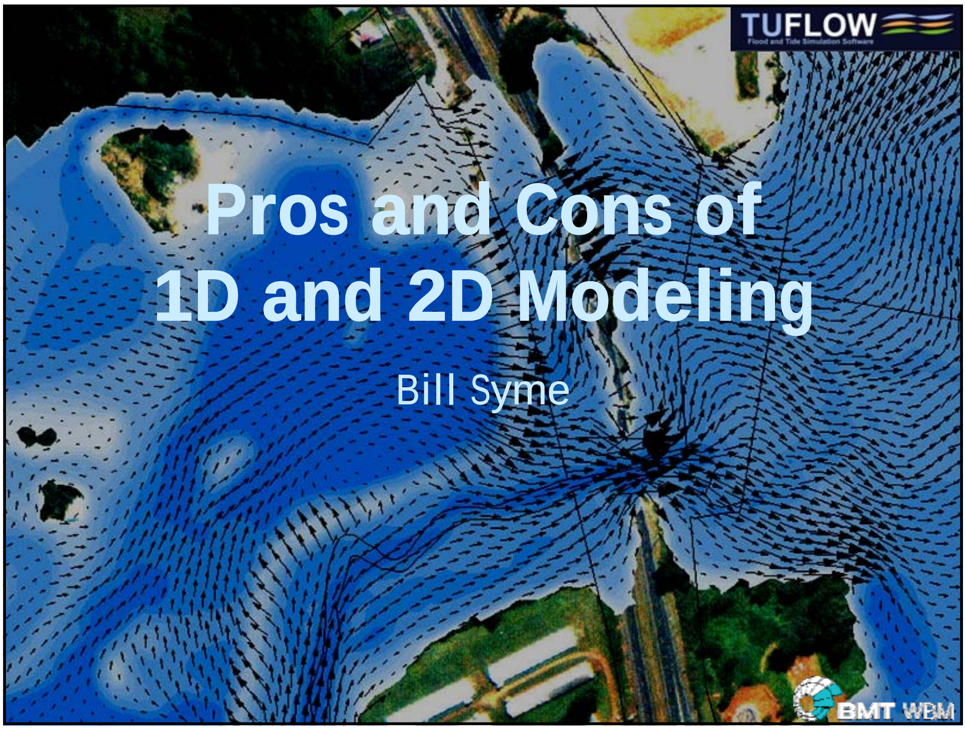
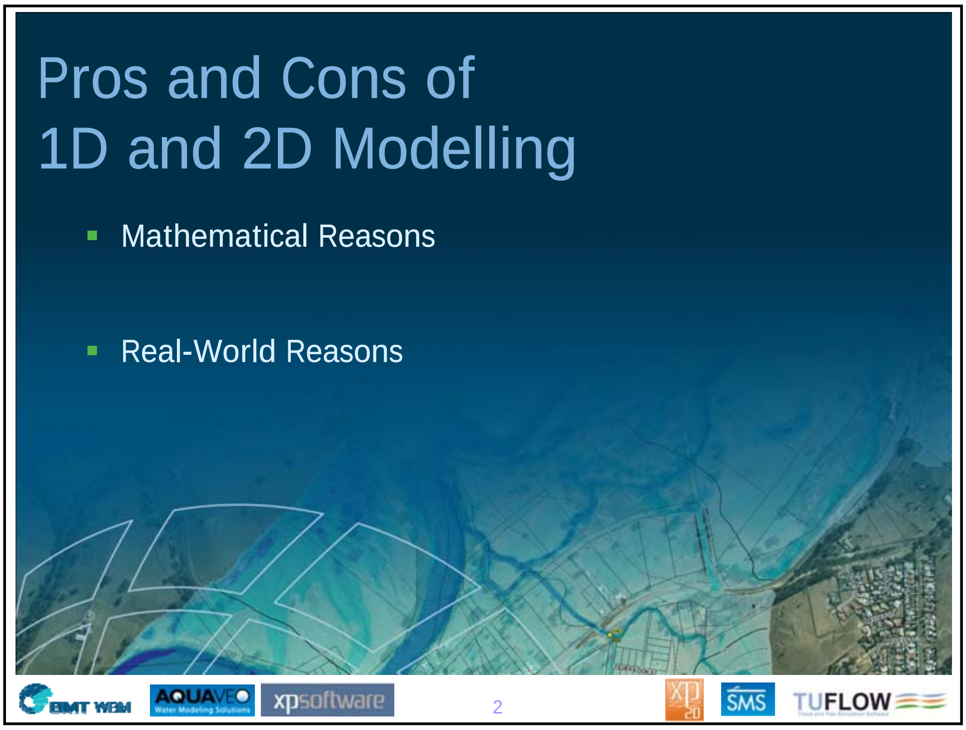
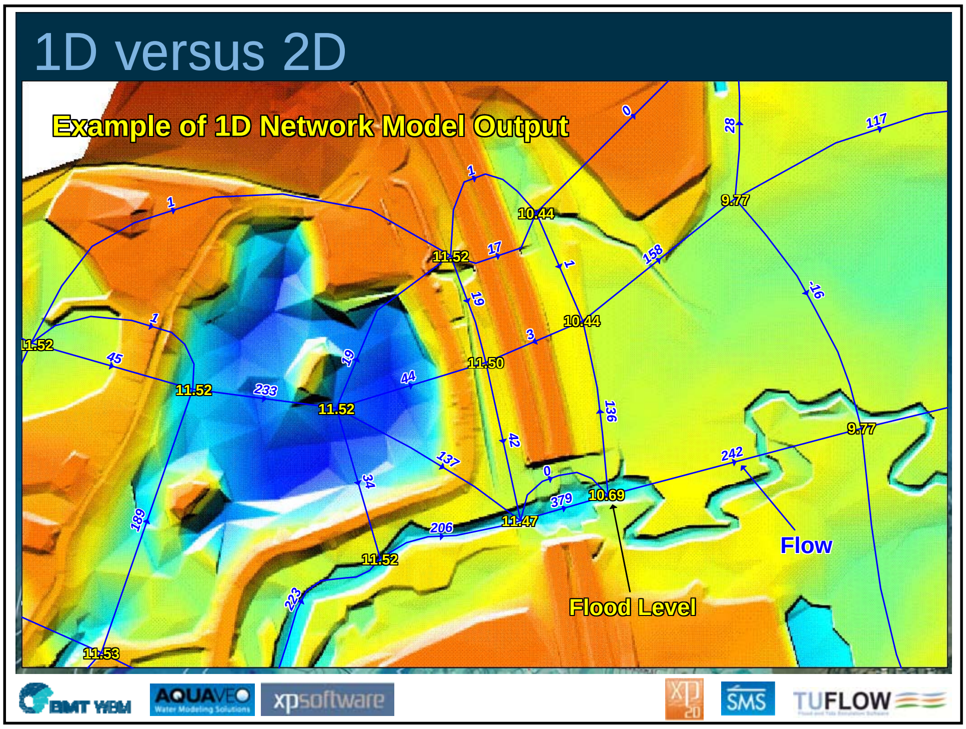
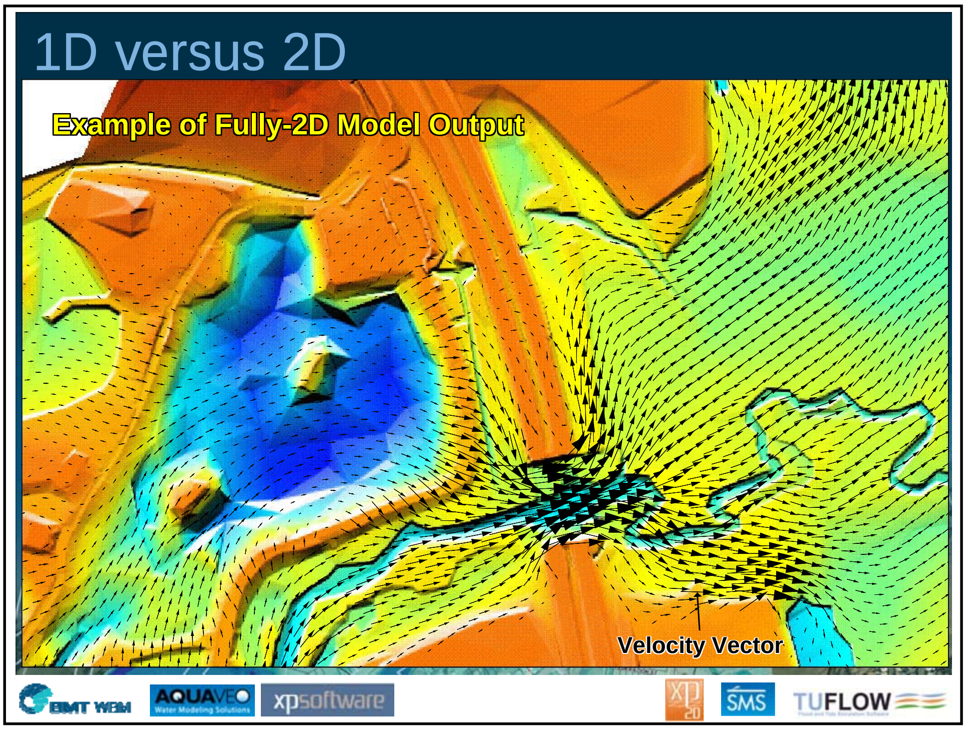
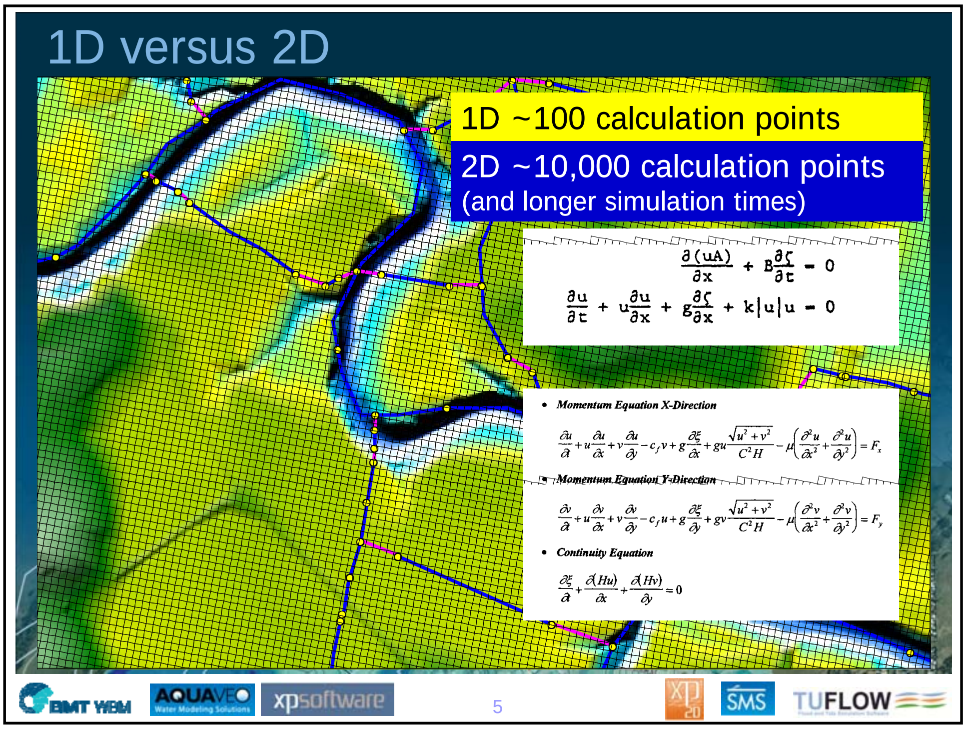
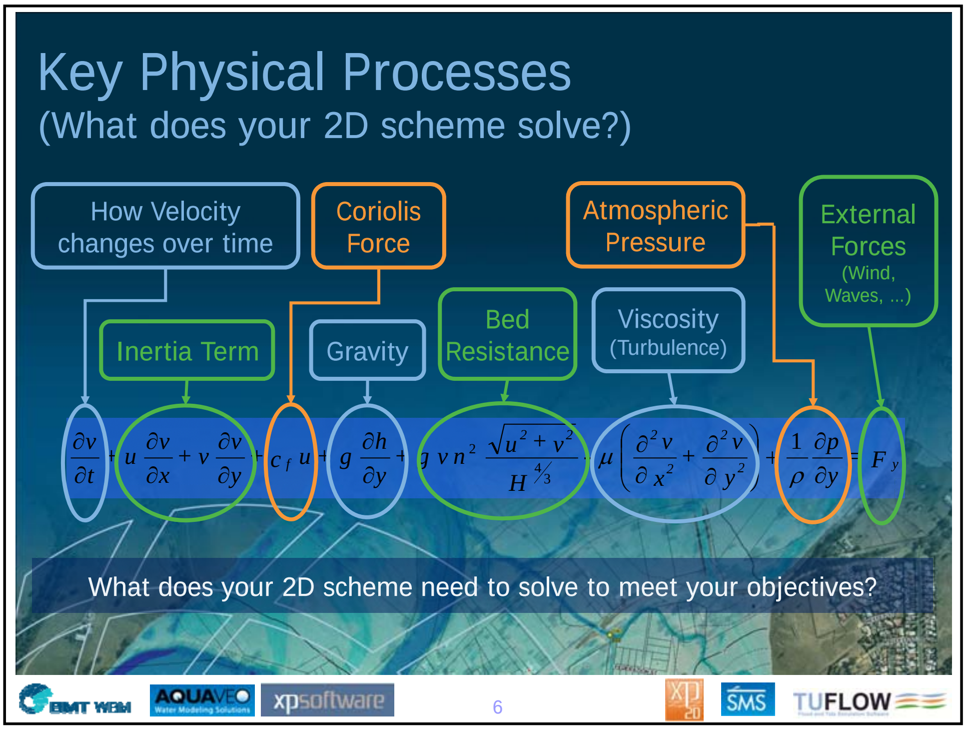

TUFLOW
Pros and Cons of
1D and 2D Modeling
Bill Syme
BMT WBM


Pros and Cons of
1D and 2D Modelling
Mathematical Reasons
Real-World Reasons
BMT WBM
AQUAVEO
xpsoftware
2
SMS
TUFLOW


1D versus 2D
Example of 1D Network Model Output
Flow
Flood Level
BMT WBM
AQUAVEO
xpsoftware
SMS
TUFLOW


1D versus 2D
Example of Fully-2D Model Output
Velocity Vector
BMT WBM
AQUAVEO
xpsoftware
SMS
TUFLOW


1D versus 2D
1D ~100 calculation points
2D ~10,000 calculation points
(and longer simulation times)
Momentum Equation X-Direction
Momentum Equation Y-Direction
Continuity Equation
BMT WBM
AQUAVEO
xpsoftware
5
SMS
TUFLOW


Key Physical Processes
(What does your 2D scheme solve?)
How Velocity changes over time
Coriolis Force
Atmospheric Pressure
External Forces
(Wind, Waves, ...)
Inertia Term
Gravity
Bed Resistance
Viscosity
(Turbulence)
What does your 2D scheme need to solve to meet your objectives?
BMT WBM
AQUAVEO
xpsoftware
6
SMS
TUFLOW

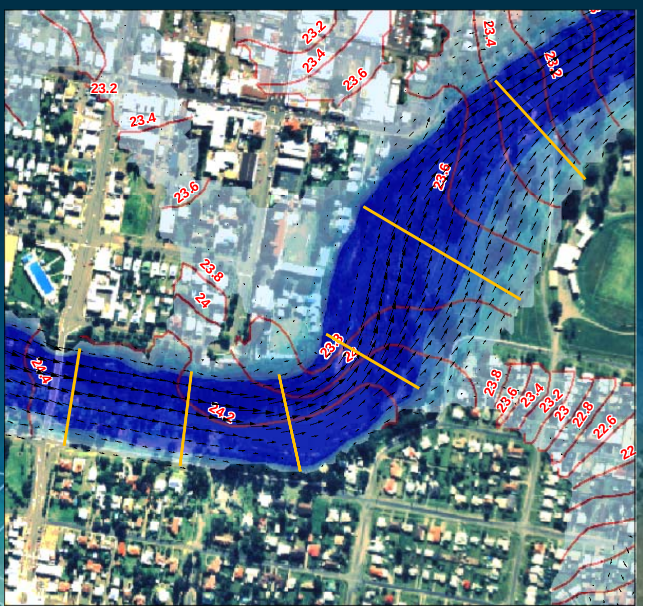
Bed Resistance

- Manning's equation most commonly used
- Bed resistance dominant term where n is high
- Compared with 1D
  - 2D n values should be very similar for straight uniform flow (can be slightly higher due to no side friction)
  - based on calibrated 2D models 2D n values are similar or lower (lower where 1D n values are artificially high due to sharp bends, etc)

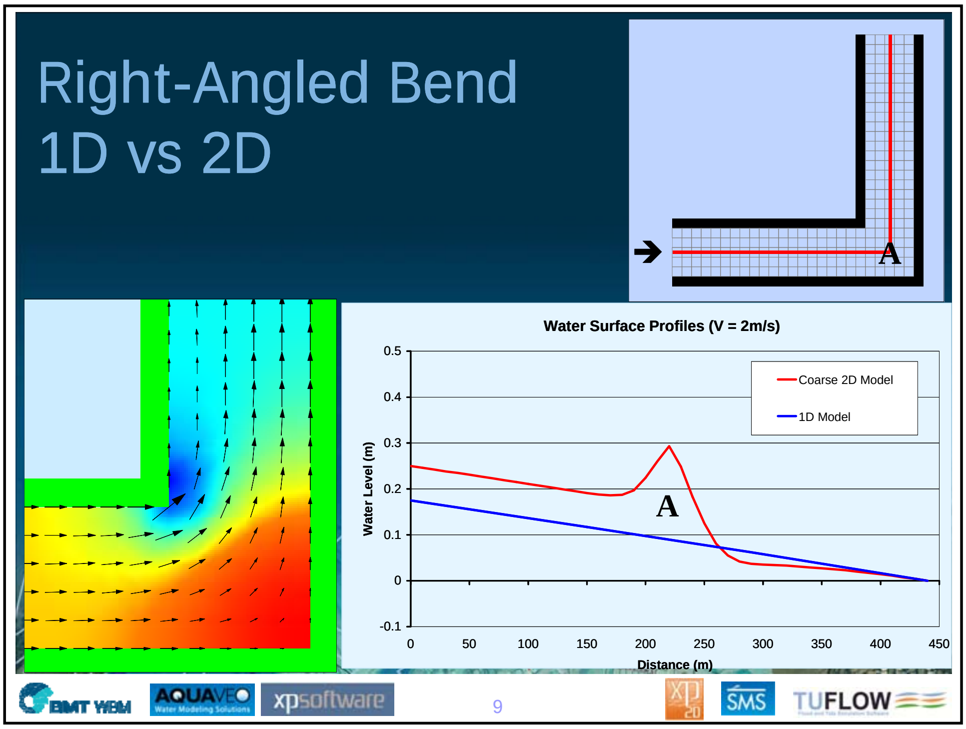
7

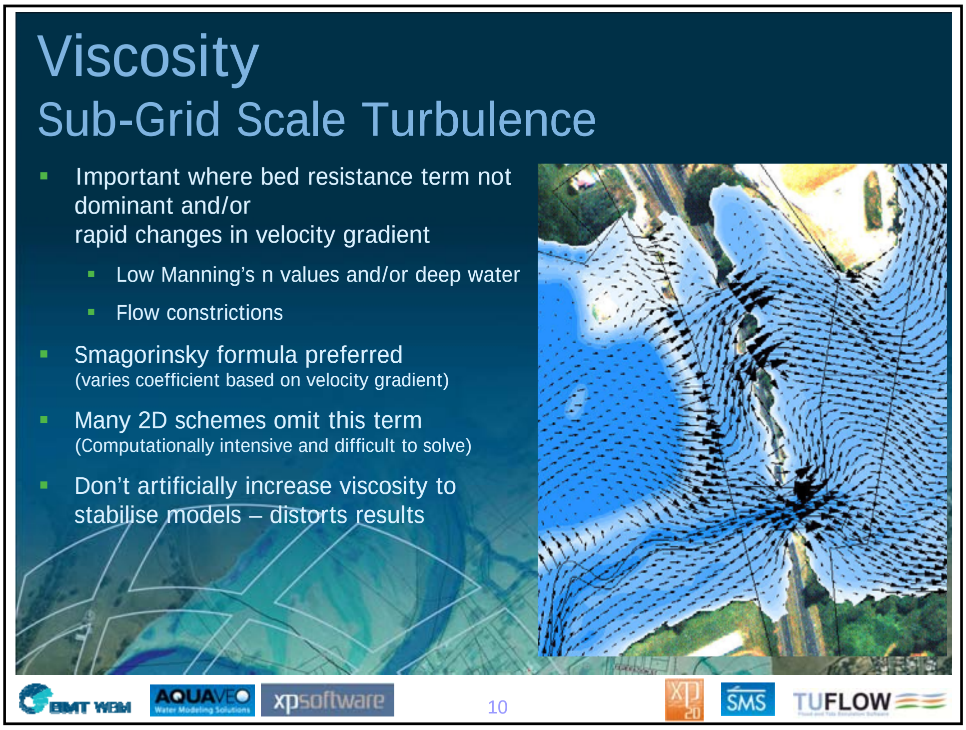
Inertia

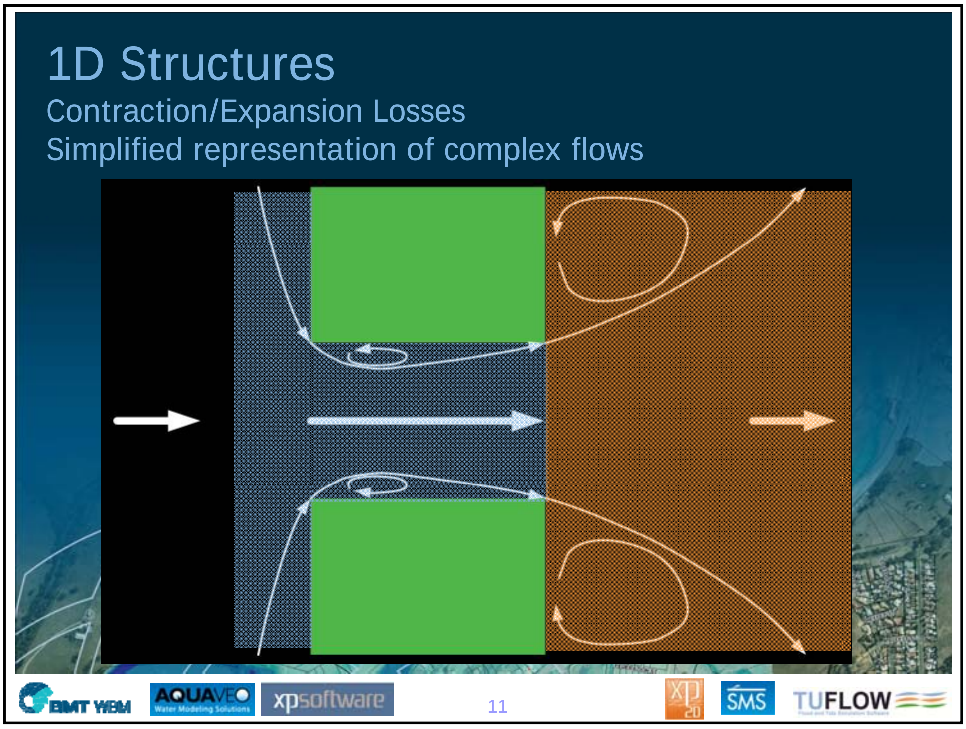
- 4 m/s
- 20 m deep
- 0.4m superelevation
- 1D:
  - Need additional losses (eg. higher n)
  - No superelevation

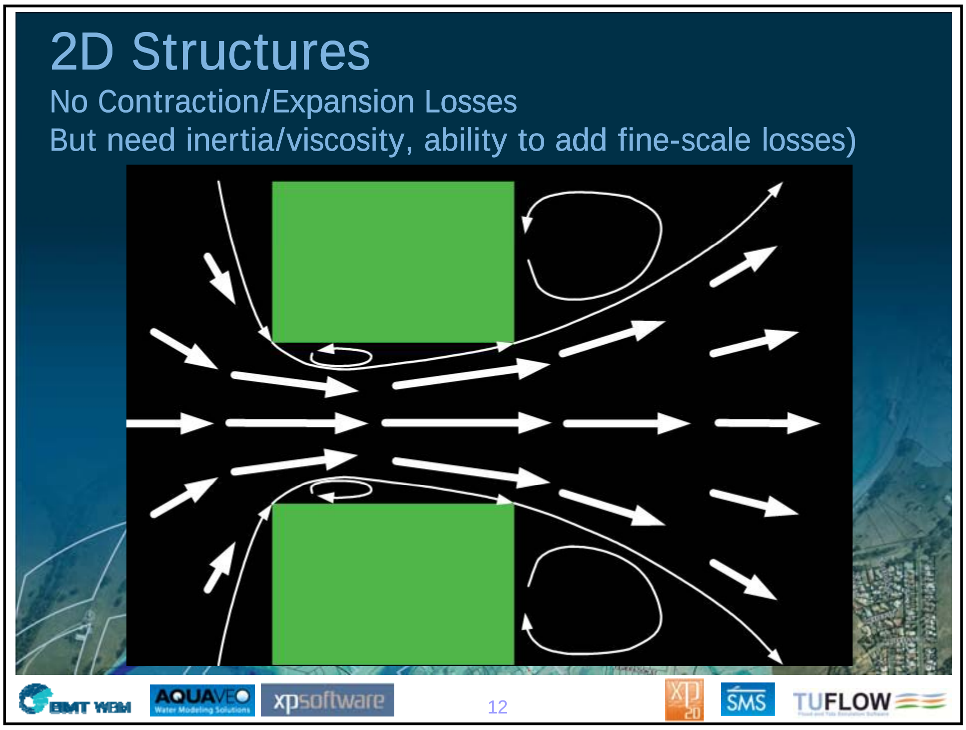


8


Right-Angled Bend
1D vs 2D
A
Water Surface Profiles (V = 2m/s)
Coarse 2D Model
1D Model
Water Level (m)
Distance (m)
A
0.5
0.4
0.3
0.2
0.1
0
-0.1
0
50
100
150
200
250
300
350
400
450
BMT WBM
AQUAVEO
xpsoftware
9
SMS
TUFLOW


Viscosity
Sub-Grid Scale Turbulence
Important where bed resistance term not dominant and/or rapid changes in velocity gradient
Low Manning's n values and/or deep water
Flow constrictions
Smagorinsky formula preferred
(varies coefficient based on velocity gradient)
Many 2D schemes omit this term
(Computationally intensive and difficult to solve)
Don't artificially increase viscosity to stabilise models – distorts results
BMT WBM
AQUAVEO
xpsoftware
10
SMS
TUFLOW


1D Structures
Contraction/Expansion Losses
Simplified representation of complex flows
11


2D Structures
No Contraction/Expansion Losses
But need inertia/viscosity, ability to add fine-scale losses)
12

Eudlo Creek Hydraulic Investigations, Qld, 1998-2003

Which Model?

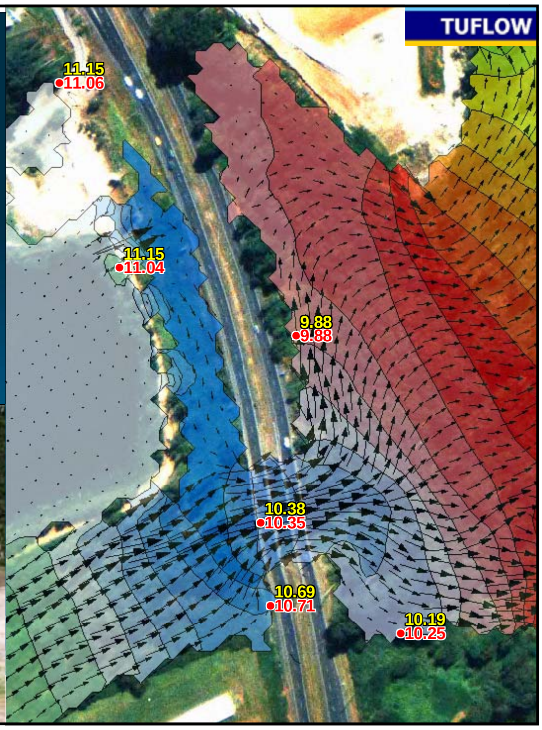
- Exhaustive Investigation
- $4m damages claim
- Physical Model (1:30 scale)
- Four 1D Models
  - HEC-RAS
  - MIKE 11
  - Rubicon
  - TUFLOW 1D
- Three 2D Models
  - FESWMS
  - MIKE 21
  - TUFLOW

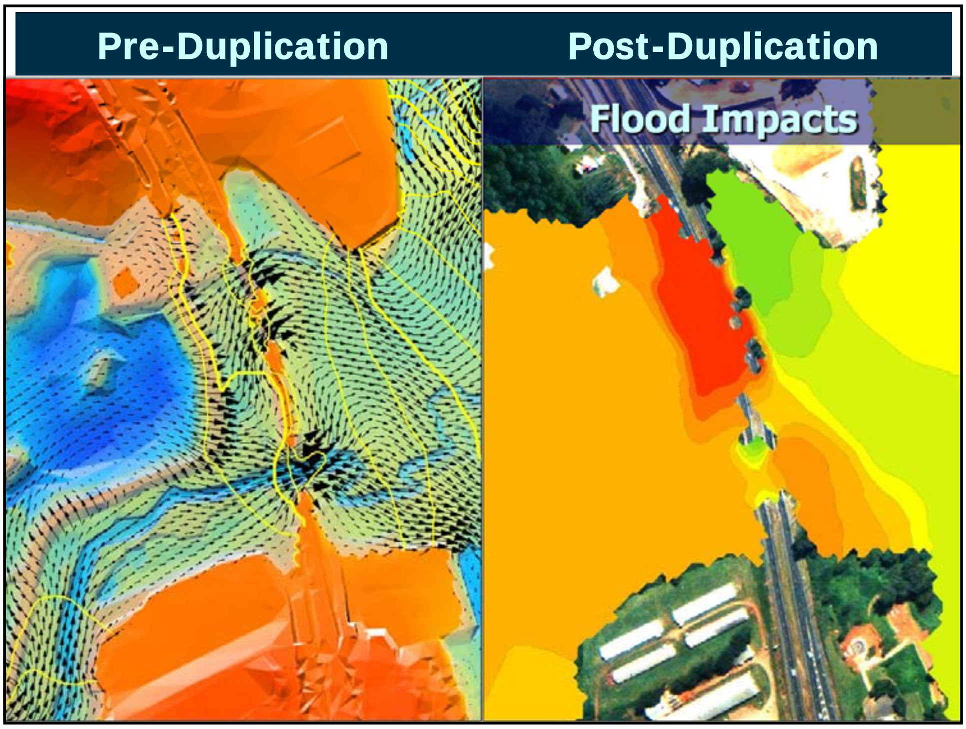
13

Eudlo Creek, Qld, 1998-2003

Calibration

- Three floods
  - 1983, 1992, 1999
  - One during study
- Good data sets

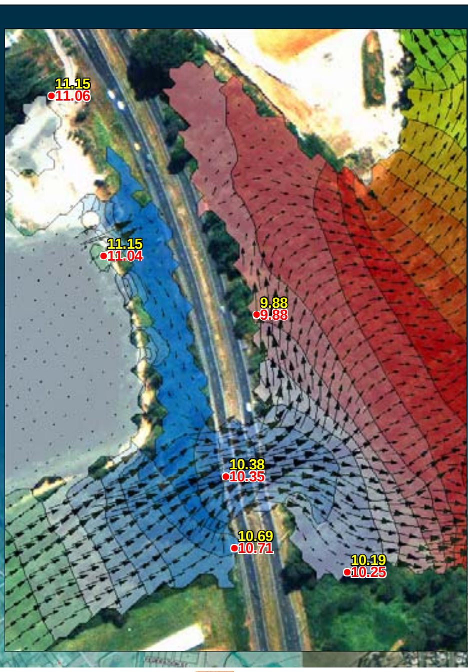




Eudlo Creek, Qld, 1998-2003

Key Findings

- Calibration
  (using standard parameters)
  - 1D models poor
    (Could only reproduce recorded affluxes for the 3 calibration events using non-standard parameters – did not dissipate enough energy at bridge)
  - 2D models performed well
    (only minor fine-tuning of parameters)
  - Physical model ?
    (once “rough” enough calibrated well)

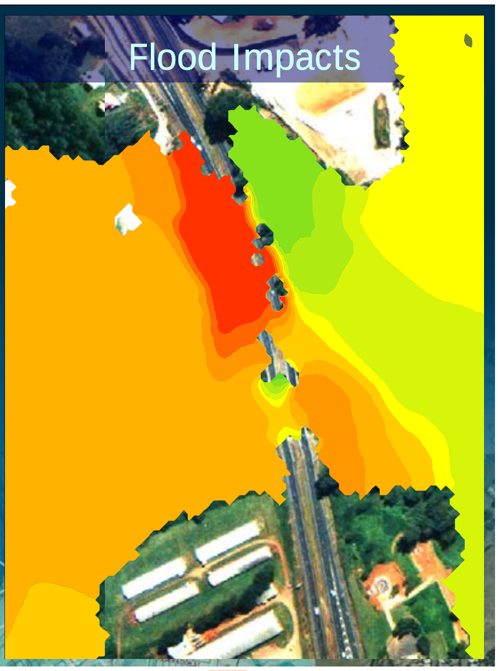


BMT WBM AQUAVEO xpsoftware 16 SMS TUFLOW

Eudlo Creek, Qld, 1998-2003

Key Findings

- Performance in meeting objectives
  - 1D models poor
    - Low confidence in results
  - 2D models excellent
    - Slow to run (back then)
    - FESWMS: problematic
    - MIKE 21: limited 2D structure representation
    - TUFLOW: numerous enhancements
  - Physical model good
    - Expensive
    - Very very slow turnover



BMT WBM AQUAVEO xpsoftware 17 XP2D SMS TUFLOW

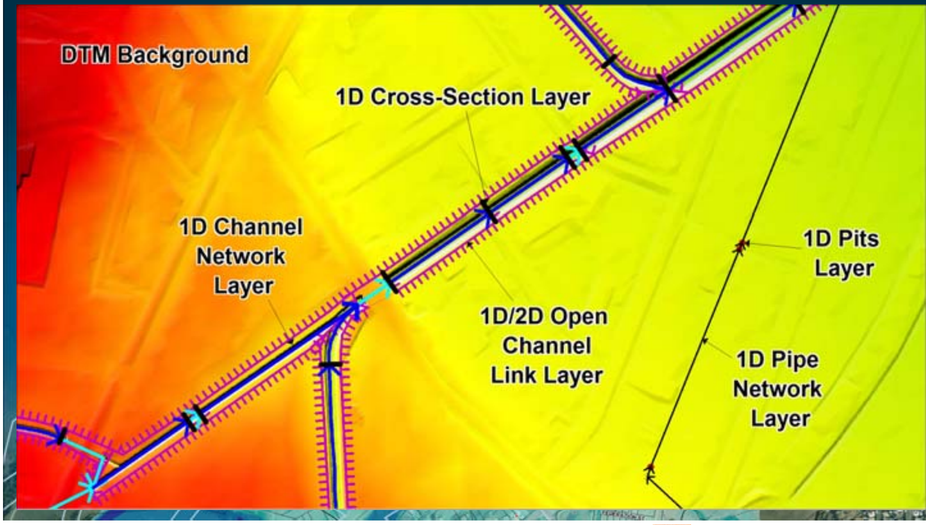
Throsby Creek Newcastle (2006)

- 1D
  - Sub and super critical flow
  - 700 structures
  - 1,000 pipes, pits and manholes
- 2D
  - Complex overland flows
- Excellent calibration events

BMT WBM AQUAVEO xpsoftware 18 XP2D SMS TUFLOW

Throsby Creek, NSW, 2006 - 2007

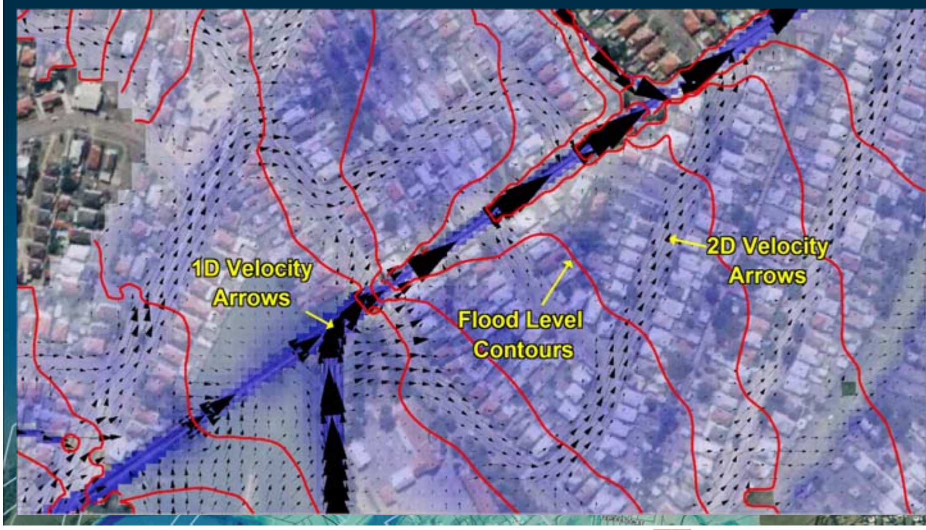
1D/2D Model Development



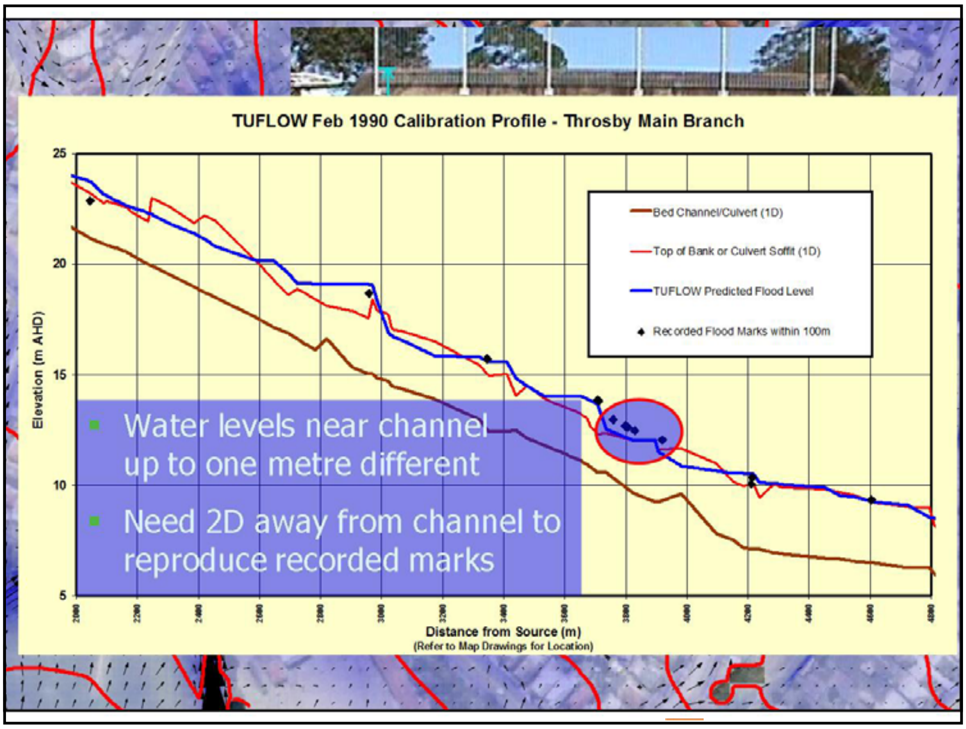
19

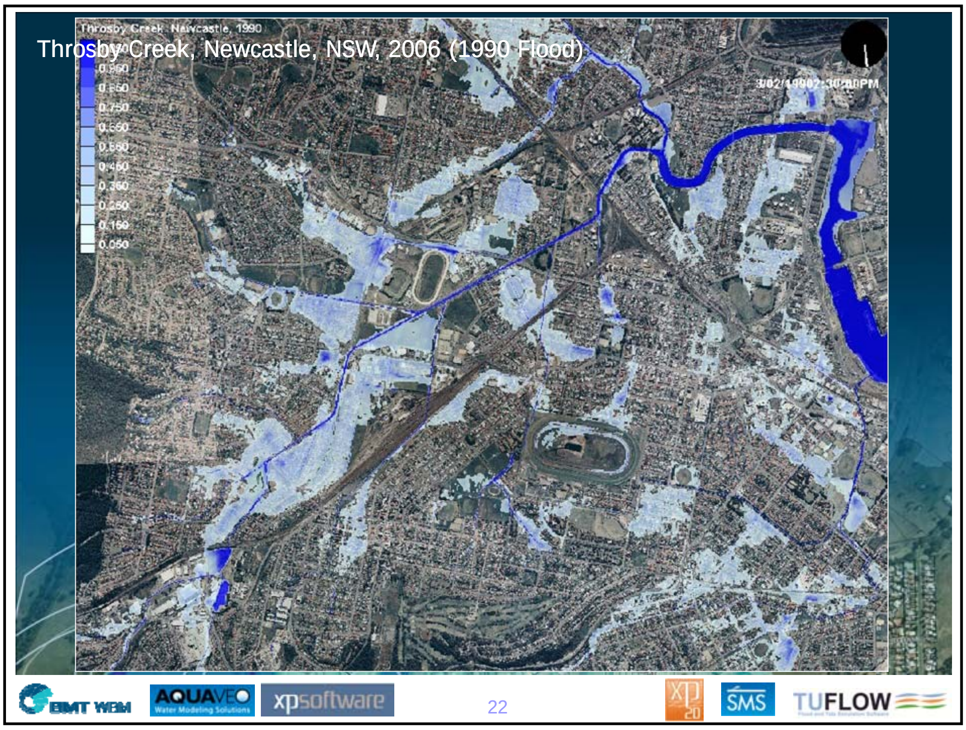
Throsby Creek, NSW, 2006 - 2007

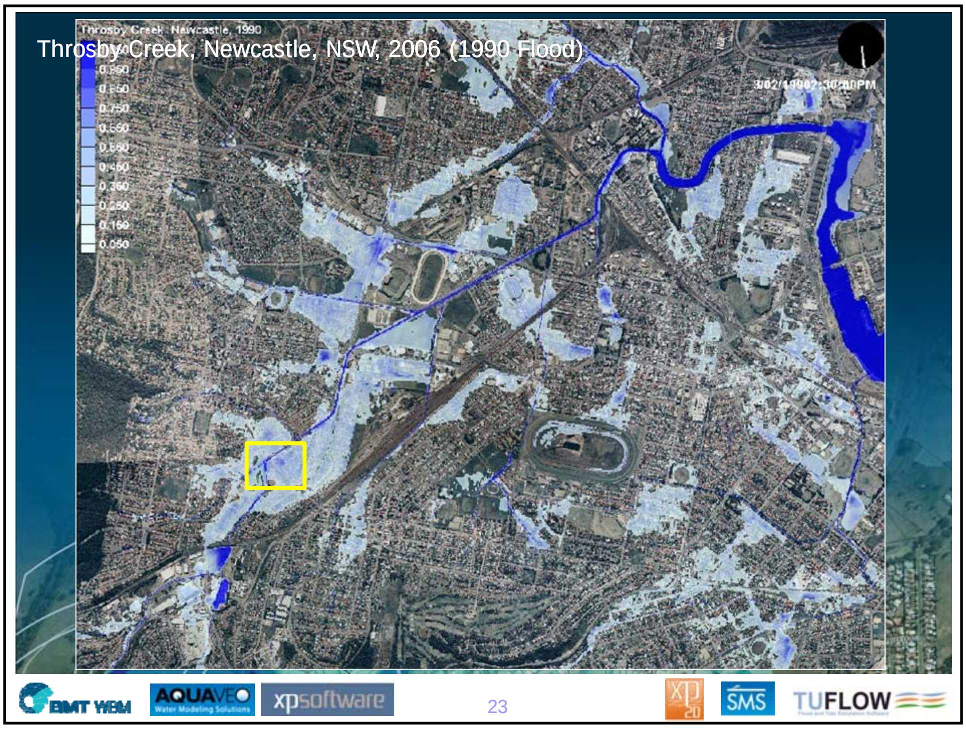
1D/2D Model Results

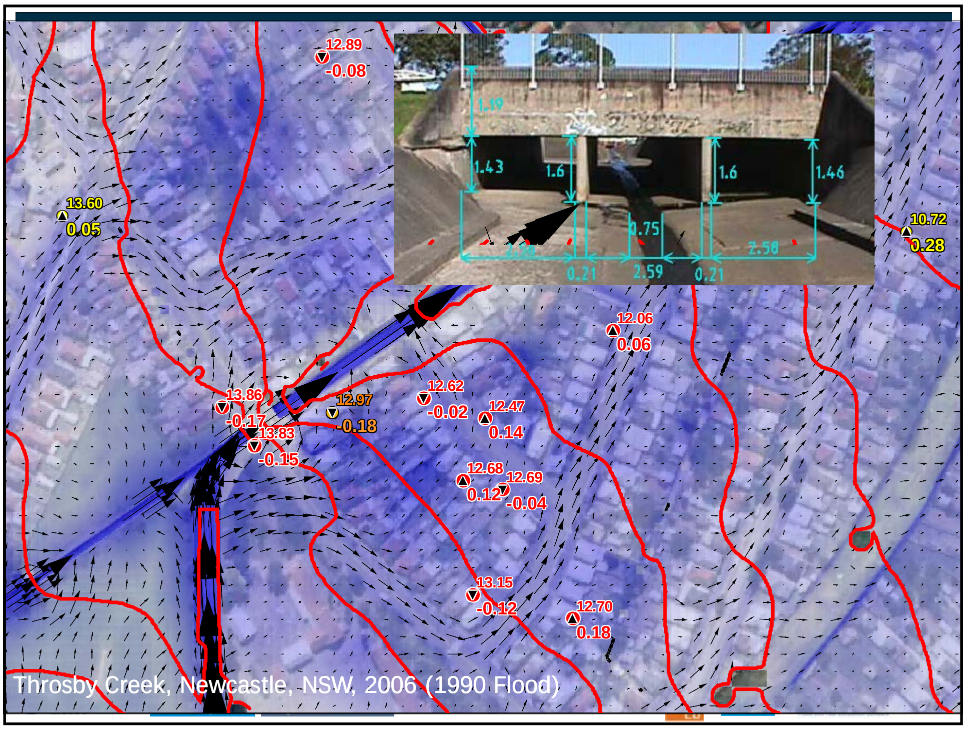


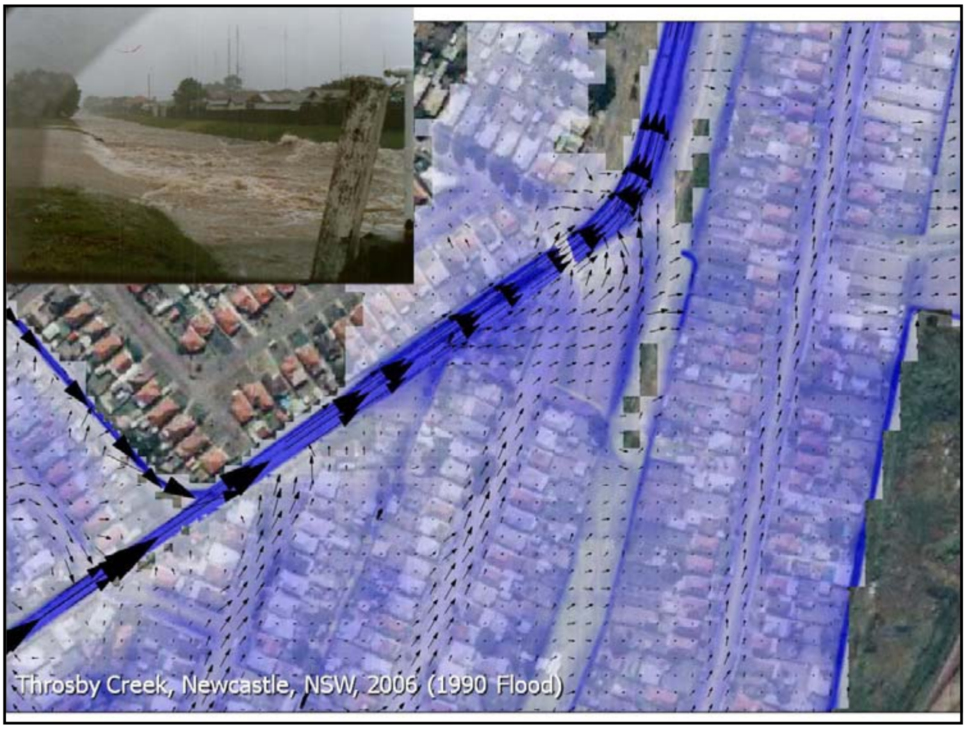
20

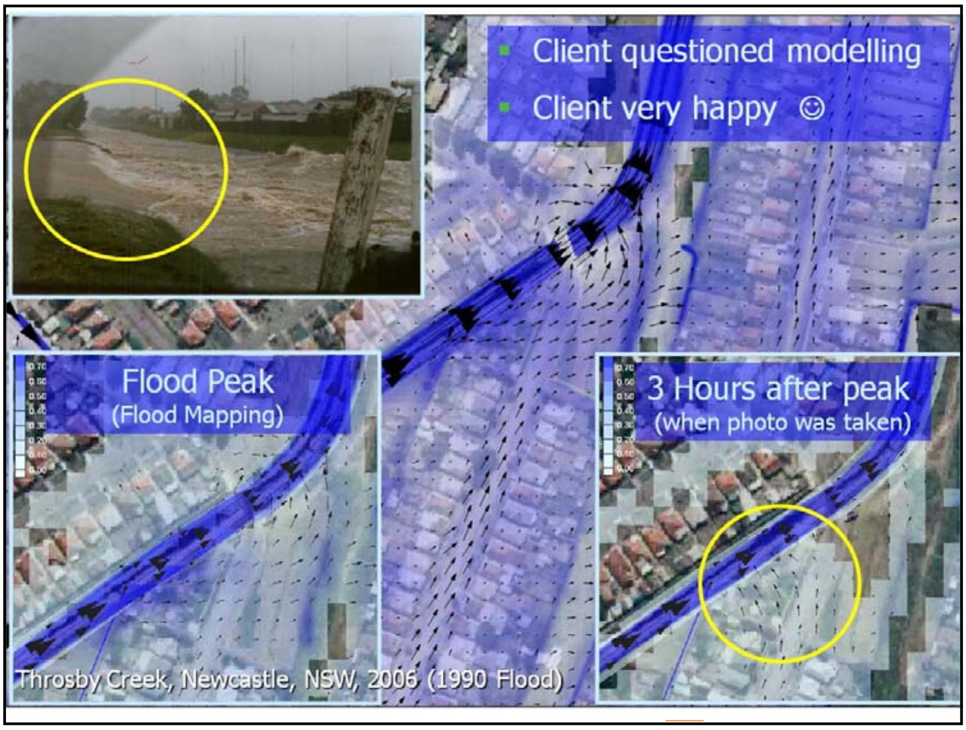

TUFLOW Feb 1990 Calibration Profile - Throsby Main Branch
Bed Channel/Culvert (1D)
Top of Bank or Culvert Soffit (1D)
TUFLOW Predicted Flood Level
Recorded Flood Marks within 100m
Elevation (m AHD)
25
20
15
10
5
Distance from Source (m)
(Refer to Map Drawings for Location)
Water levels near channel up to one metre different
Need 2D away from channel to reproduce recorded marks


Throsby Creek, Newcastle, NSW, 2006 (1990 Flood)
22


Throsby Creek, Newcastle, NSW, 2006 (1990 Flood)
23


12.89
-0.08
13.60
0.05
10.72
0.28
1.43
1.6
1.6
1.46
0.75
2.58
0.21
2.59
0.21
12.06
0.06
13.86
-0.17
13.83
-0.15
12.97
-0.18
12.62
-0.02
12.47
0.14
12.68
0.12
12.69
-0.04
13.15
-0.12
12.70
0.18
Throsby Creek, Newcastle, NSW, 2006 (1990 Flood)


Throsby Creek, Newcastle, NSW, 2006 (1990 Flood)


Client questioned modelling
Client very happy ☺
Flood Peak
(Flood Mapping)
3 Hours after peak
(when photo was taken)
Throsby Creek, Newcastle, NSW, 2006 (1990 Flood)

Throsby Creek, NSW, 2006 – 2007

June 2007

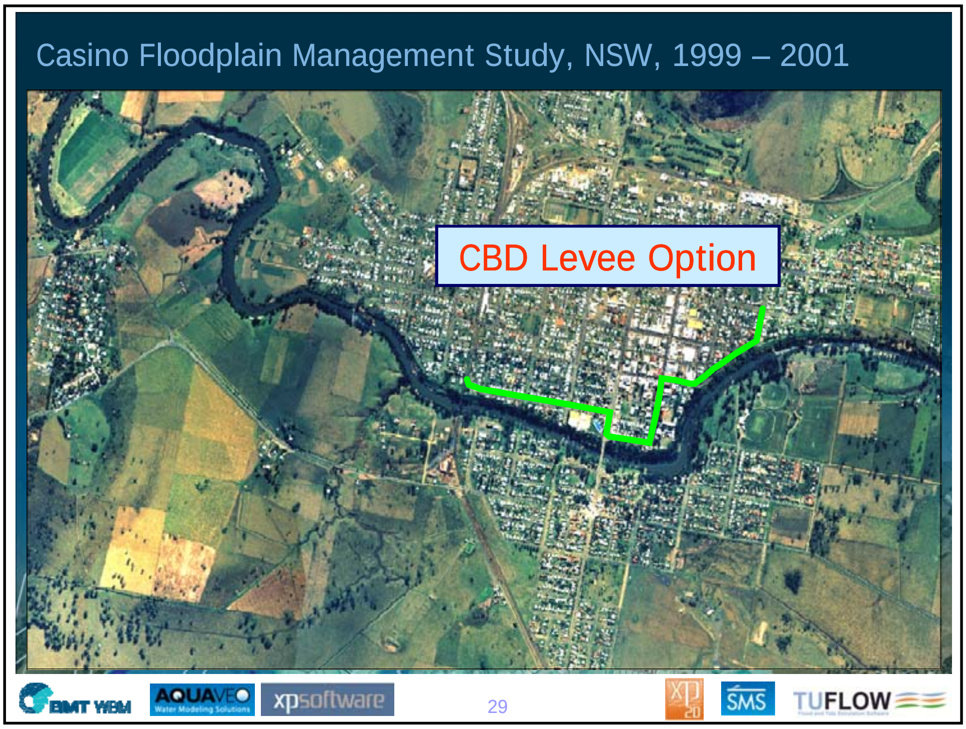
- ~100 year flood
  (1 week after submitting 100 year flood maps!)
- $700 million in damages
- 5,000 cars written off
- Thousands of homes inundated
- >1,200 flood marks to verify model!
- Field observations indicate an excellent comparison with modelling except…

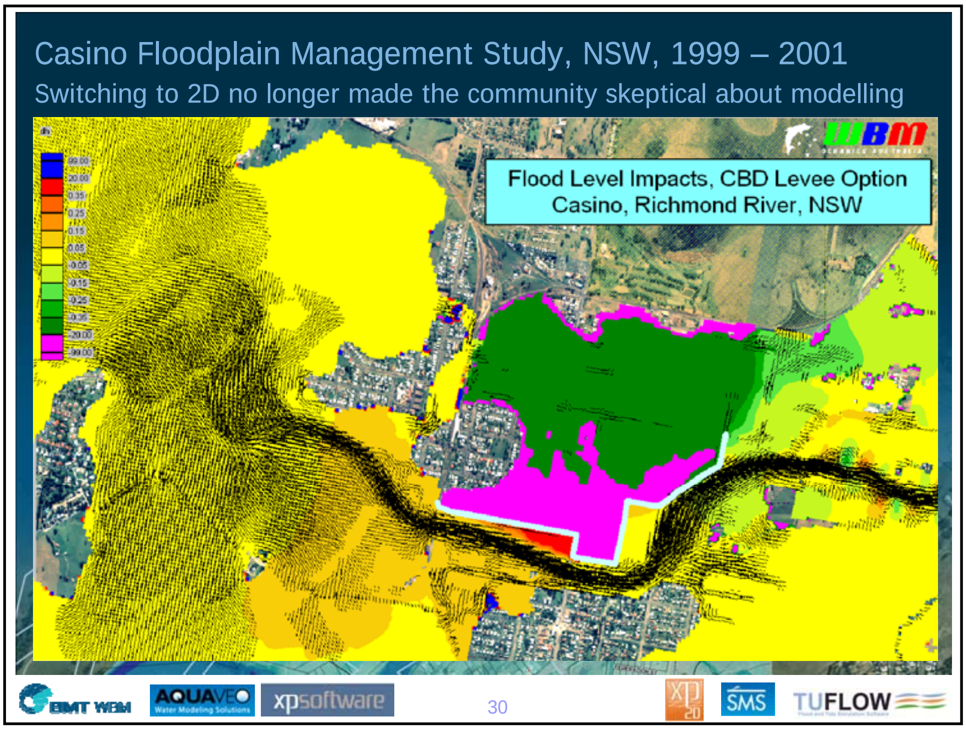
BMT WBM | AQUAVEO | xpsoftware | 27 | XP2D | SMS | TUFLOW

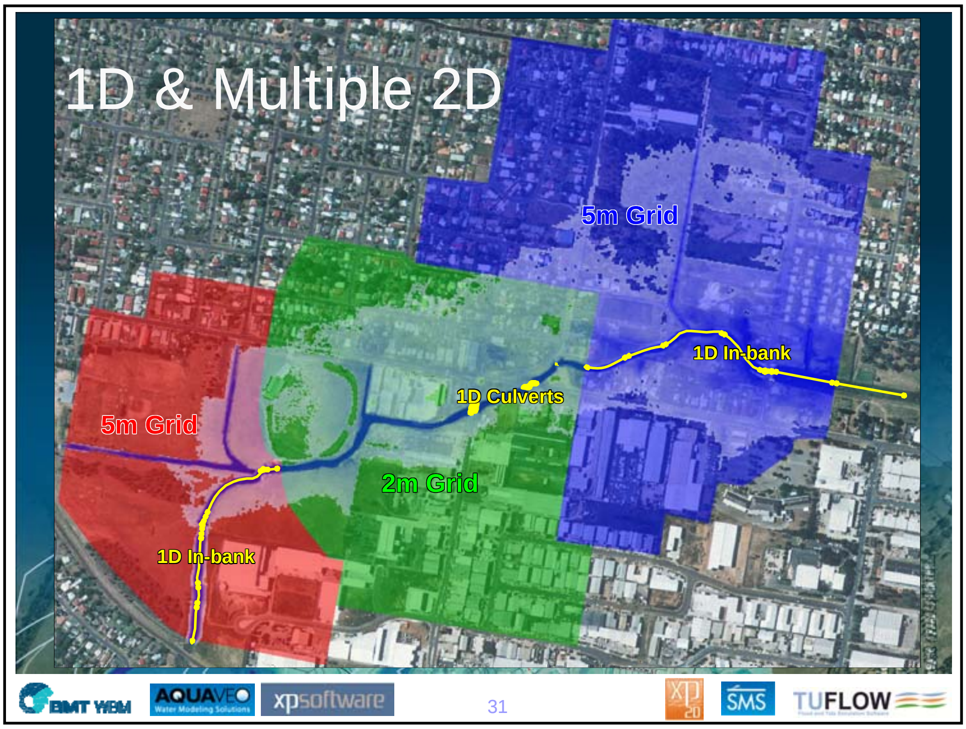
June 2007 Throsby Creek Flood

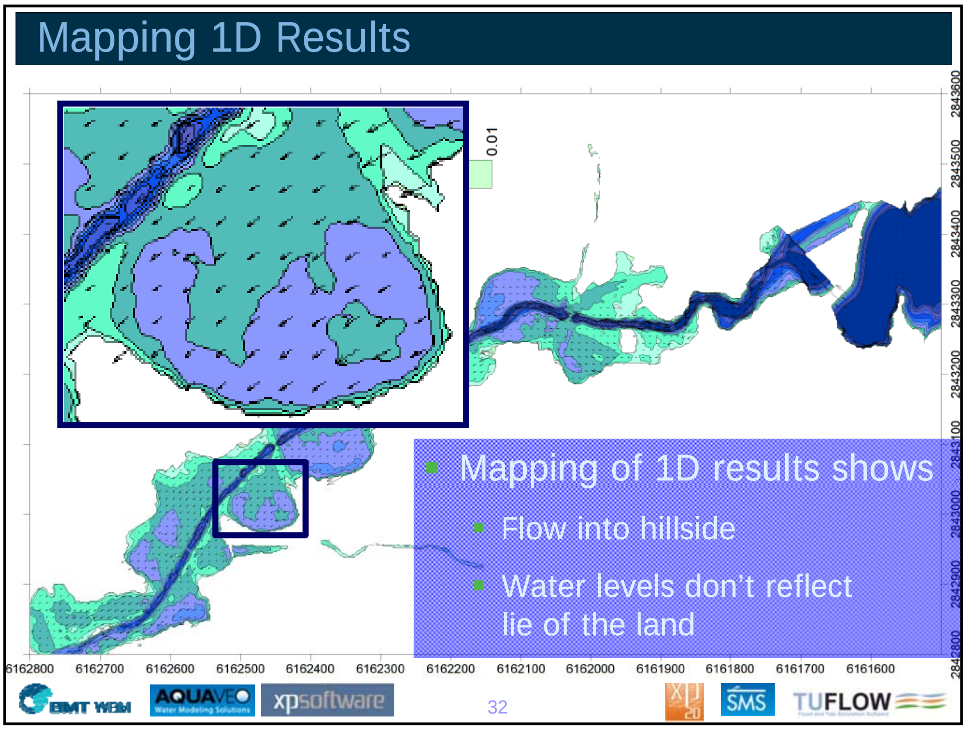
- Newcastle CBD
  - 1m deep – should be dry!
  - Outlet to harbour blocked by shipping container
- New housing estate flooded
  - Should be dry
  - Two cars blocked main drain d/s
- When blockages modelled, excellent comparisons resulted

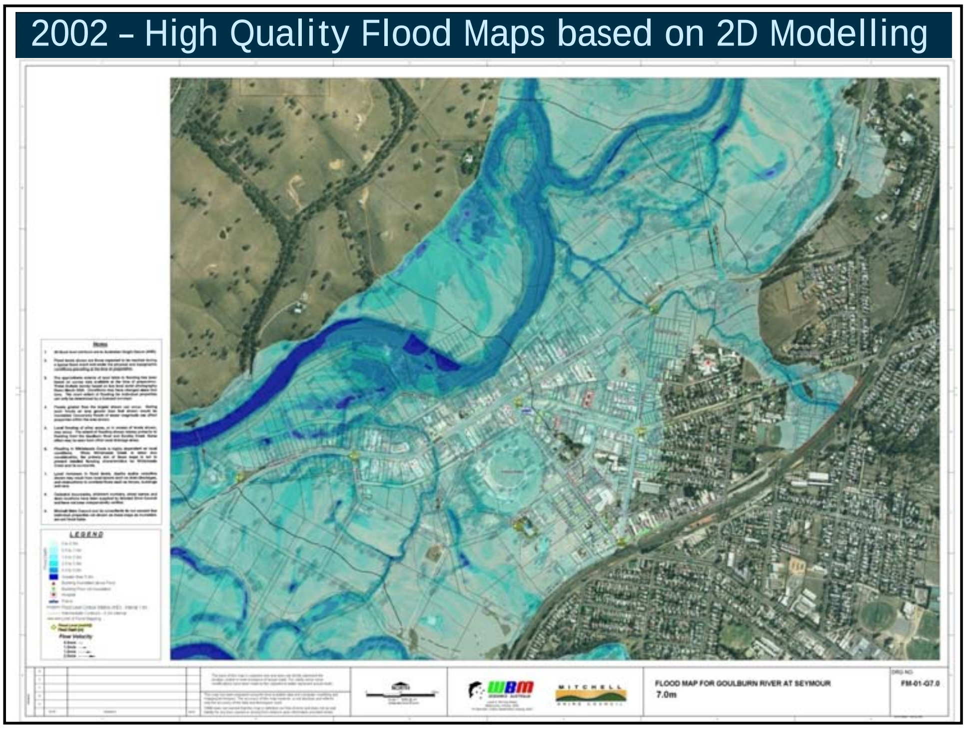
BMT WBM | AQUAVEO | xpsoftware | 28 | XP2D | SMS | TUFLOW

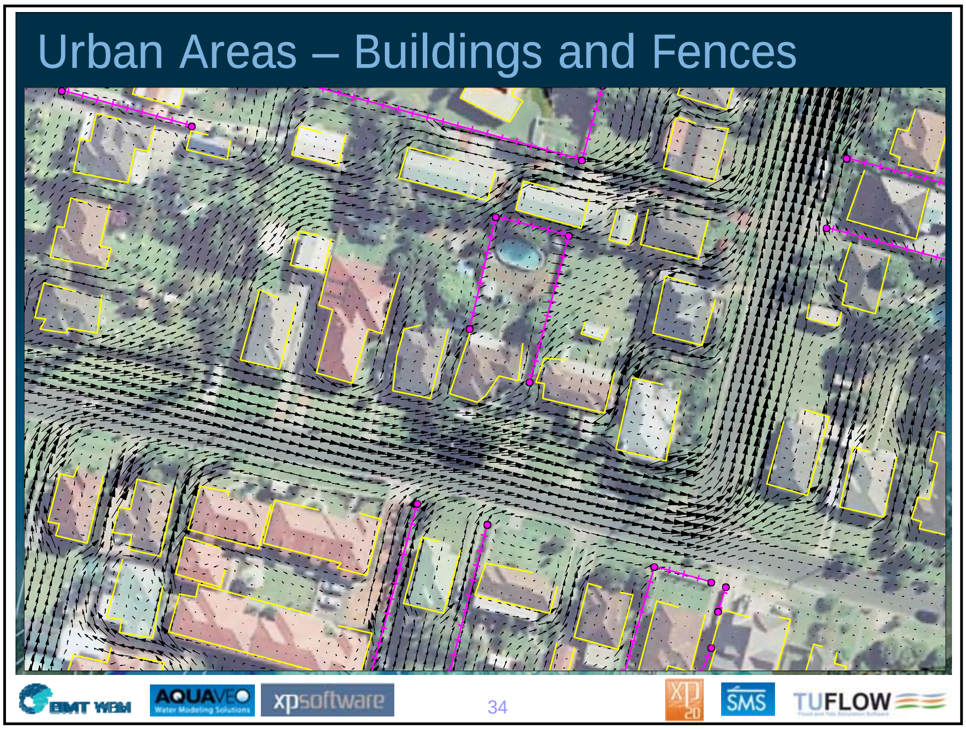

Casino Floodplain Management Study, NSW, 1999 – 2001
CBD Levee Option
29
TUFLOW


Casino Floodplain Management Study, NSW, 1999 – 2001
Switching to 2D no longer made the community skeptical about modelling
Flood Level Impacts, CBD Levee Option
Casino, Richmond River, NSW
30
TUFLOW


1D & Multiple 2D
5m Grid
1D In-bank
1D Culverts
5m Grid
2m Grid
1D In-bank
BMT WBM
AQUAVEO
xpsoftware
31
SMS
TUFLOW

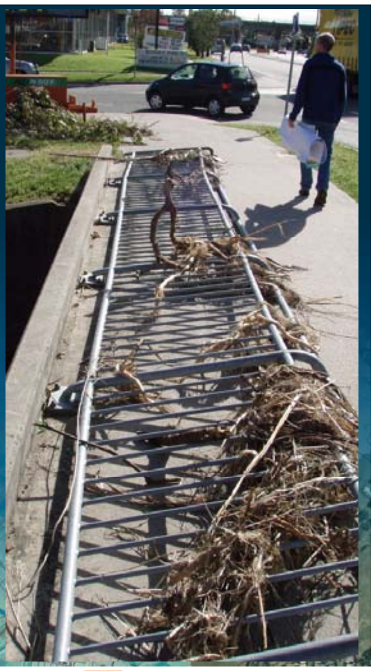

Mapping 1D Results
0.01
Mapping of 1D results shows
Flow into hillside
Water levels don't reflect lie of the land
6162800 6162700 6162600 6162500 6162400 6162300 6162200 6162100 6162000 6161900 6161800 6161700 6161600
BMT WBM
AQUAVEO
xpsoftware
32
SMS
TUFLOW


2002 – High Quality Flood Maps based on 2D Modelling
FLOOD MAP FOR GOULBURN RIVER AT SEYMOUR
7.0m


Urban Areas – Buildings and Fences
34

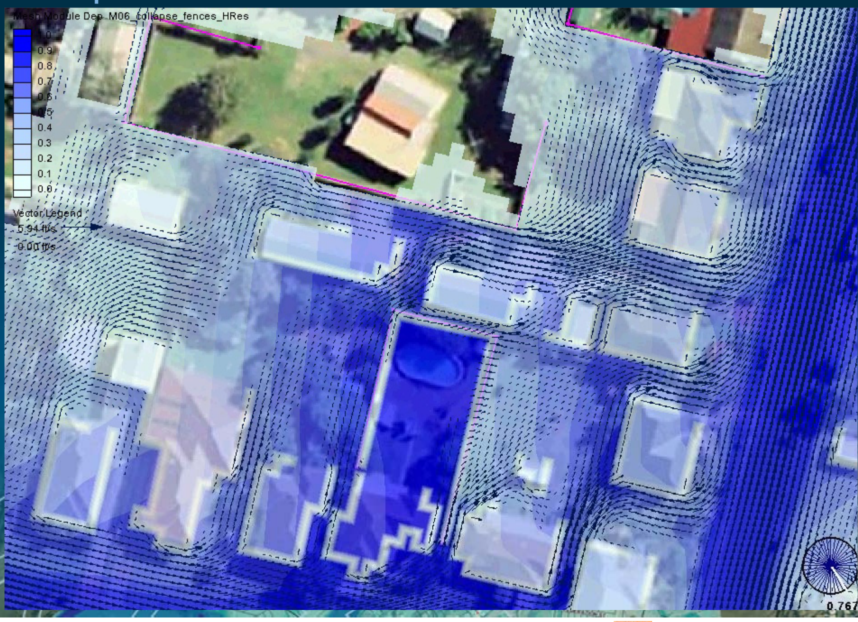
Modelling Fences!

- Able to raise element sides
- Element sides wet and dry
- Layered parameters
  - eg. vary blockage and losses with height
- Collapse element sides
- Switch between u/s and d/s controlled weir flow

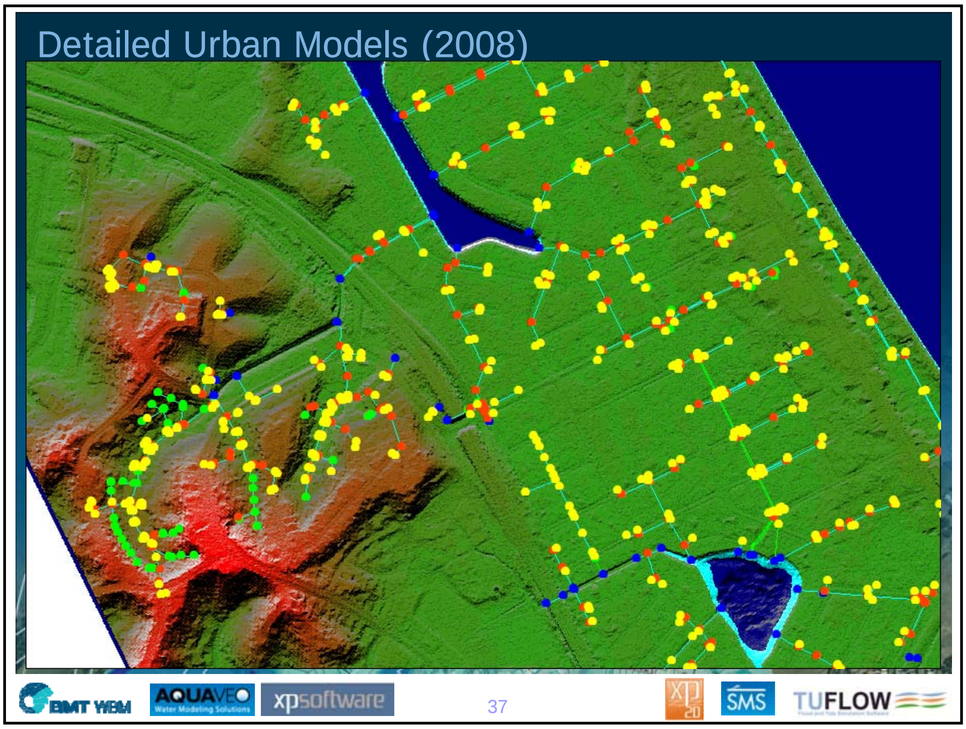


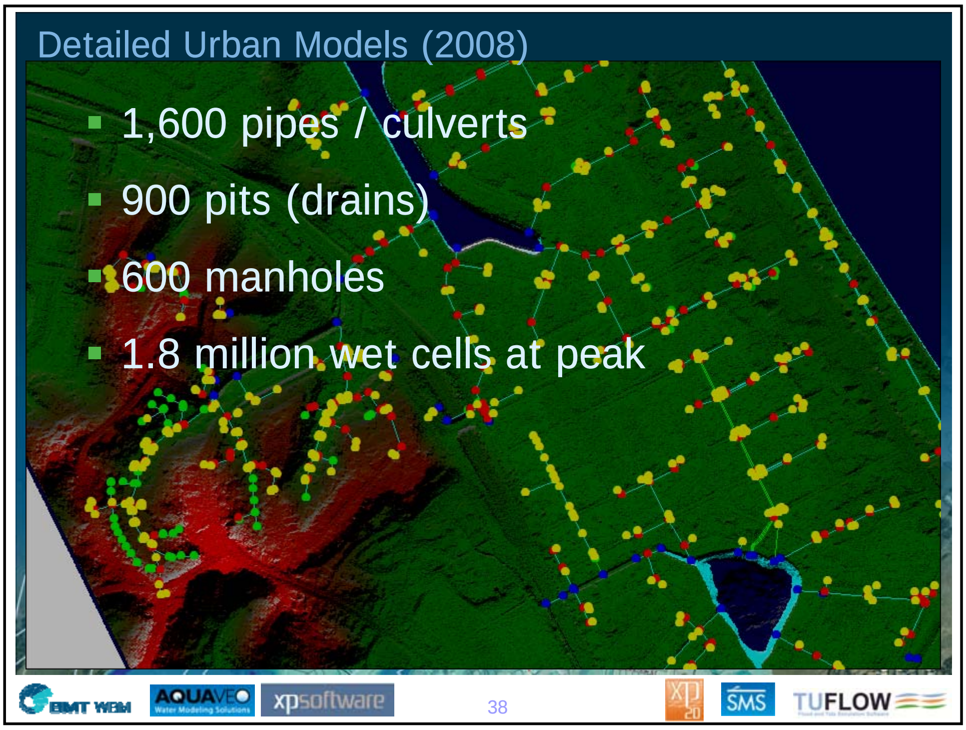
35

Collapsible Fences Animation



36


Detailed Urban Models (2008)
37

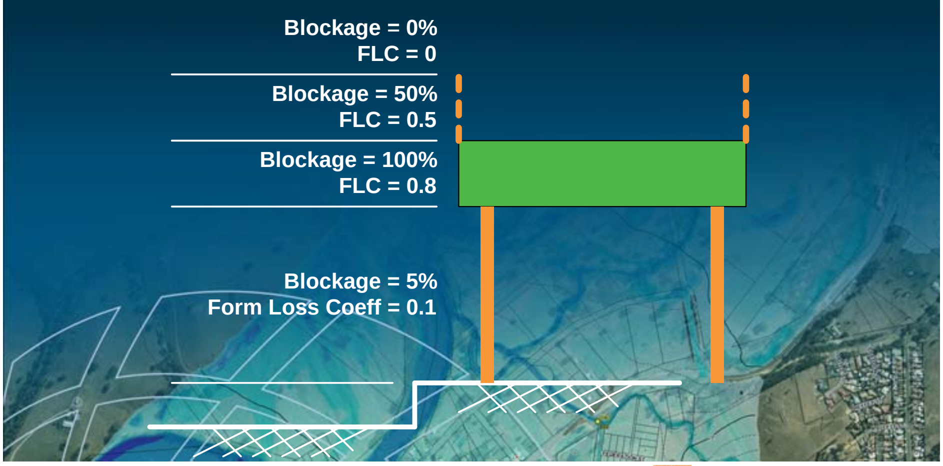

Detailed Urban Models (2008)
1,600 pipes / culverts
900 pits (drains)
600 manholes
1.8 million wet cells at peak
38

Modelling Blockages!?

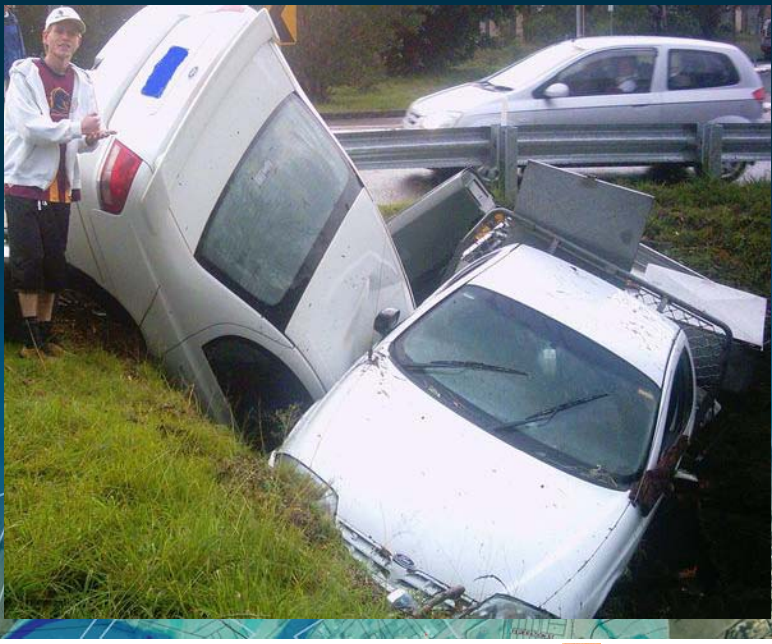
(These rails are recommended because they don't collect debris…)

39

TUFLOW 2D Layered Adjustments



40

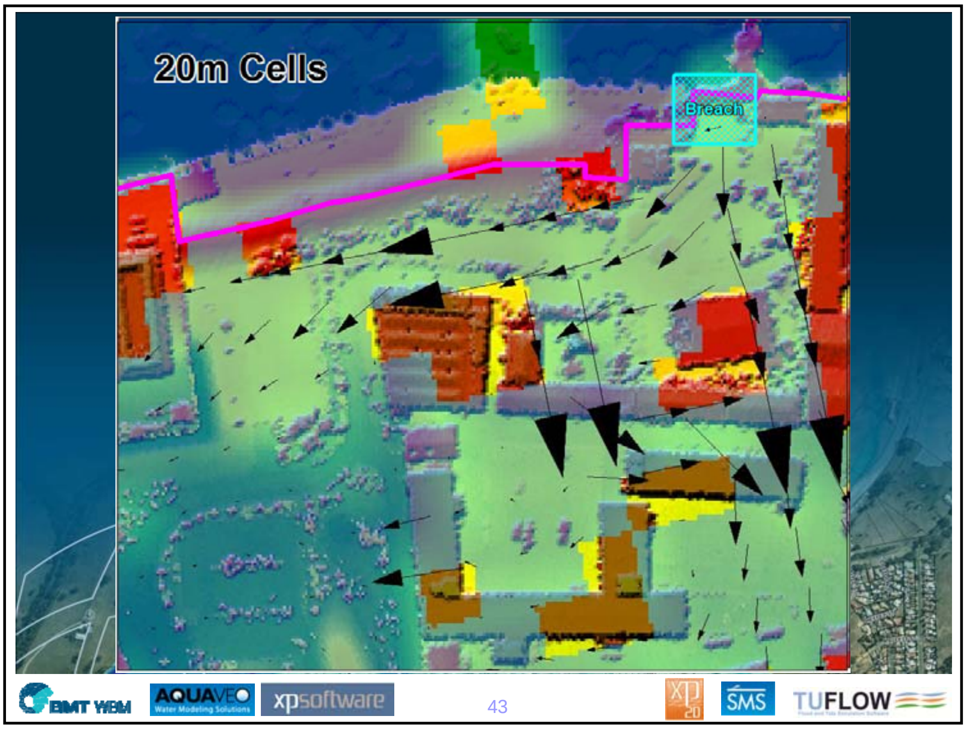


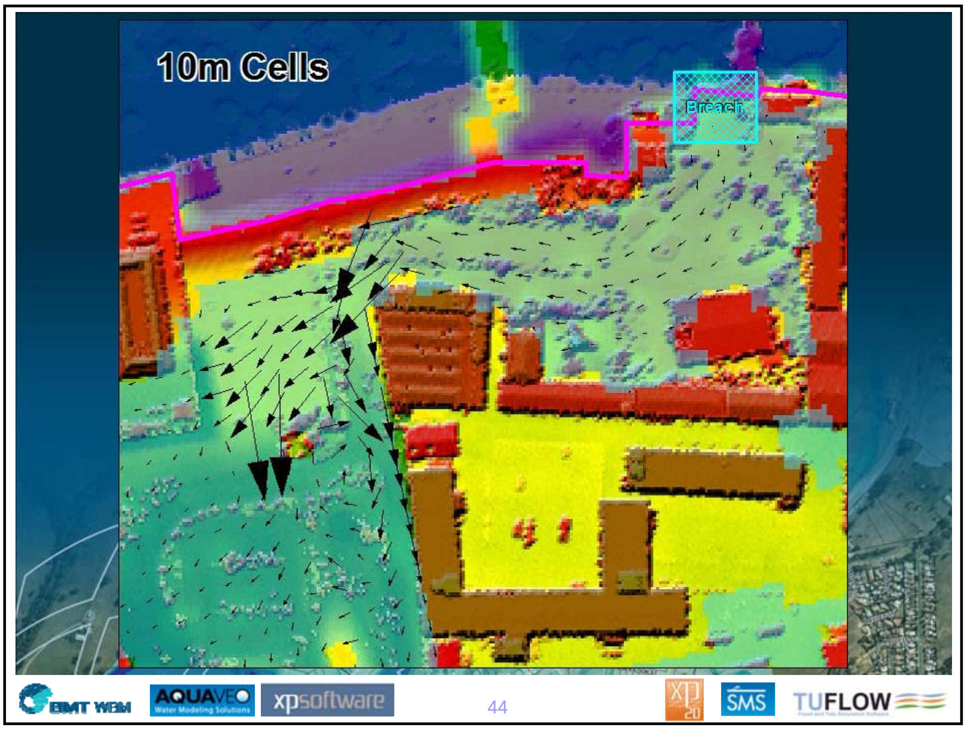
41

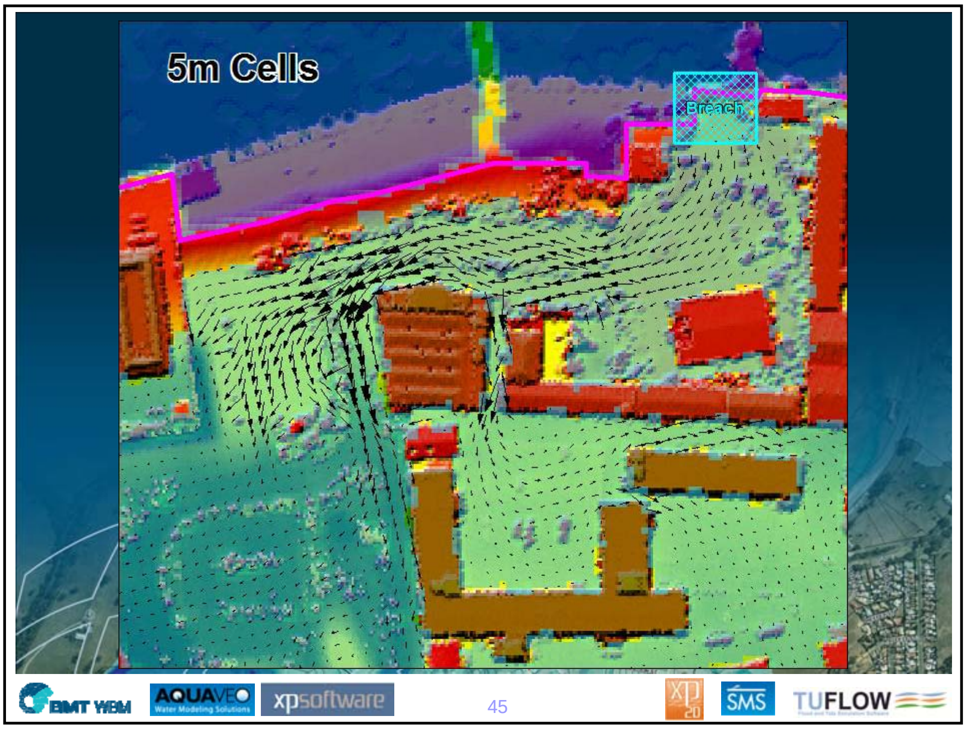
Influence of Cell Size

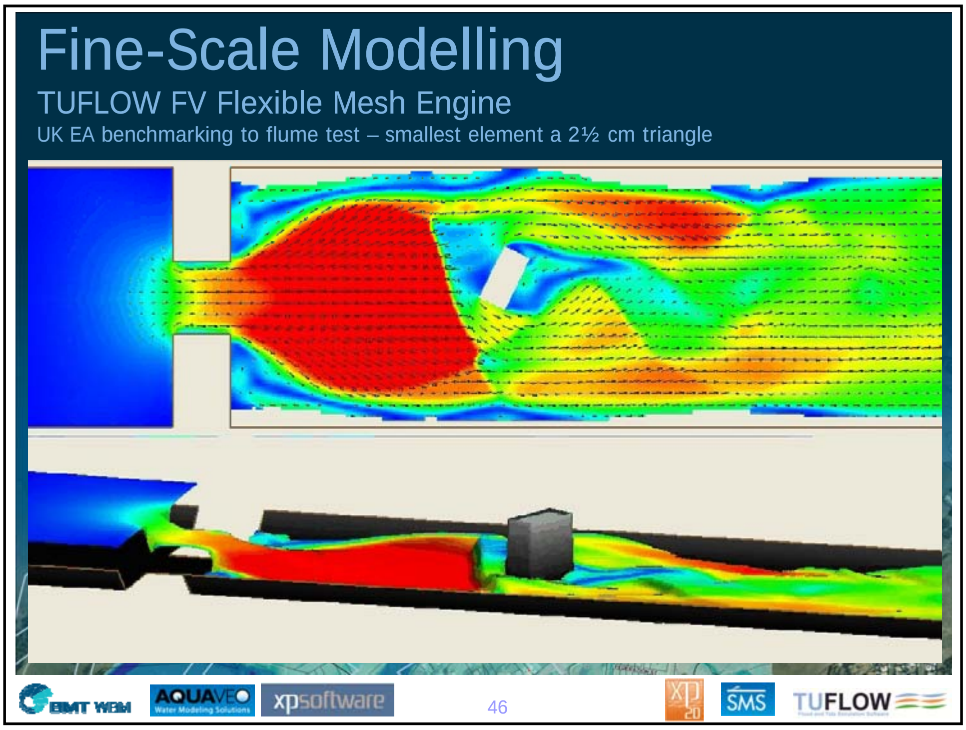
- Cell/Element Size(s)
  - Small enough to meet hydraulic objectives
  - Large enough to minimise run-times
  - Coarser than DEM
- For a fixed grid model halving the cell size increases run-times by a factor of eight (8) – keep this in mind!

42

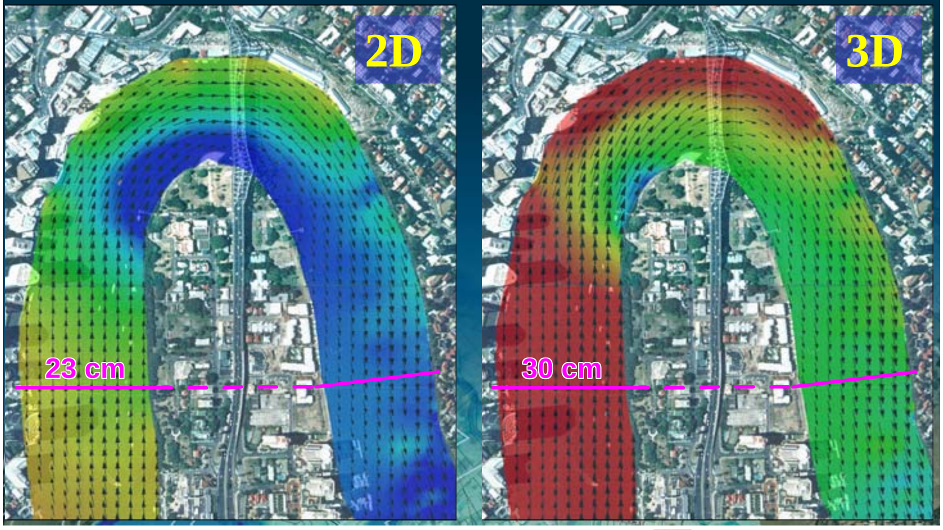

20m Cells
Breach
BMT WBM
AQUAVEO
xpsoftware
43
SMS
TUFLOW


10m Cells
Breach
BMT WBM
AQUAVEO
xpsoftware
44
SMS
TUFLOW


5m Cells
Breach
45


Fine-Scale Modelling
TUFLOW FV Flexible Mesh Engine
UK EA benchmarking to flume test – smallest element a 2½ cm triangle
46

2D or 3D?



47

Conclusions

- 1D models offer a better solution
  - where 2D resolution is too coarse
  - for pipes, manholes and small structures
- 1D requires more judgment
  (therefore greater uncertainty)
- 1D solutions vary (eg. steady vs unsteady)
- 1D solutions are
  - very fast
  - a poor approximation of complex (non-unidirectional) flows

48

Conclusions

- 2D or 1D/2D models offer significant gains
  - in accuracy of flood modeling, risk and flood impact predictions
  - in stakeholder understanding and acceptance
  - but are slow in comparison to 1D only
- Understand your software
  - Different 2D solutions vary significantly in performance
  - Make sure your 2D scheme solves the key physical processes needed
- Models still need to be
  - Calibrated where possible
  - Quality Controlled: Garbage In / Garbage Out

49