FRMRC flood risk management research consortium

Stability Criterion for a Flooded Human Body Under Various Ground Slopes

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Introduction

- Overview research in modelling flooding - elevations and inundation extent - for steep catchments and dyke failure
- Overview research into flood hazard levels for people and vehicles:
  - People studies based on literature review and analysis of scaled experiments undertaken for controlled conditions
  - Vehicles studies based on laboratory experiments and formulae development
- Model applications - with hazard formulae included - for two site specific studies:- (i) Glasgow & (ii) Boscastle

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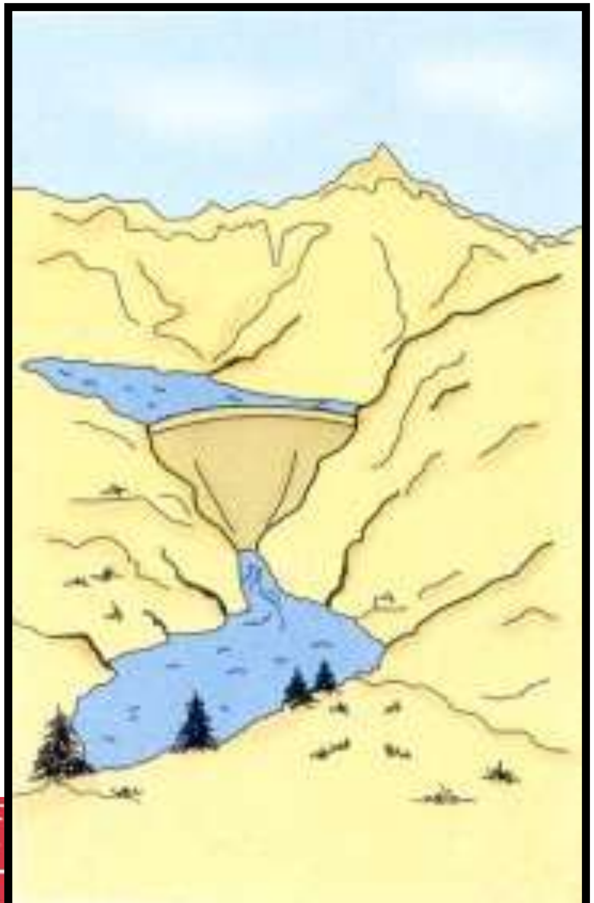
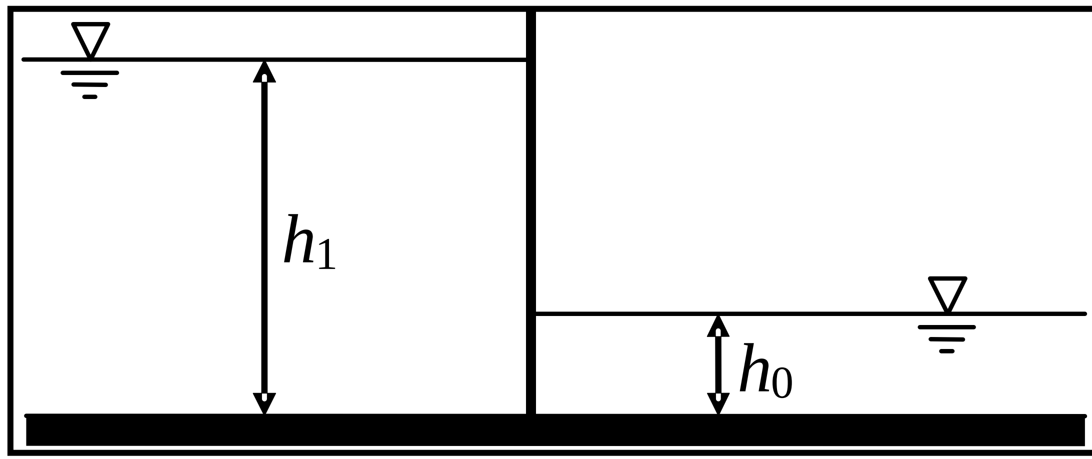
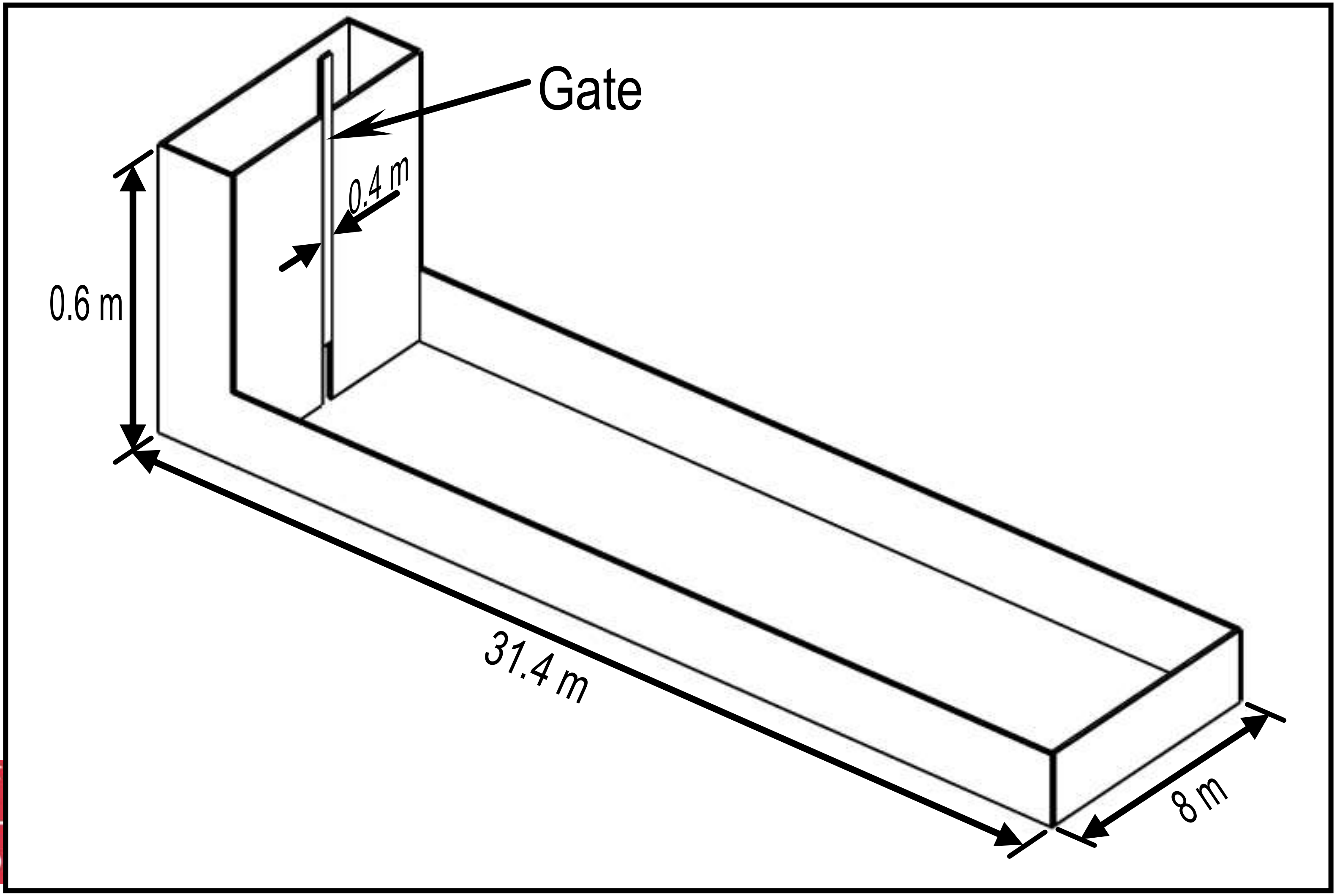
• Traditional vs. Supercritical Models

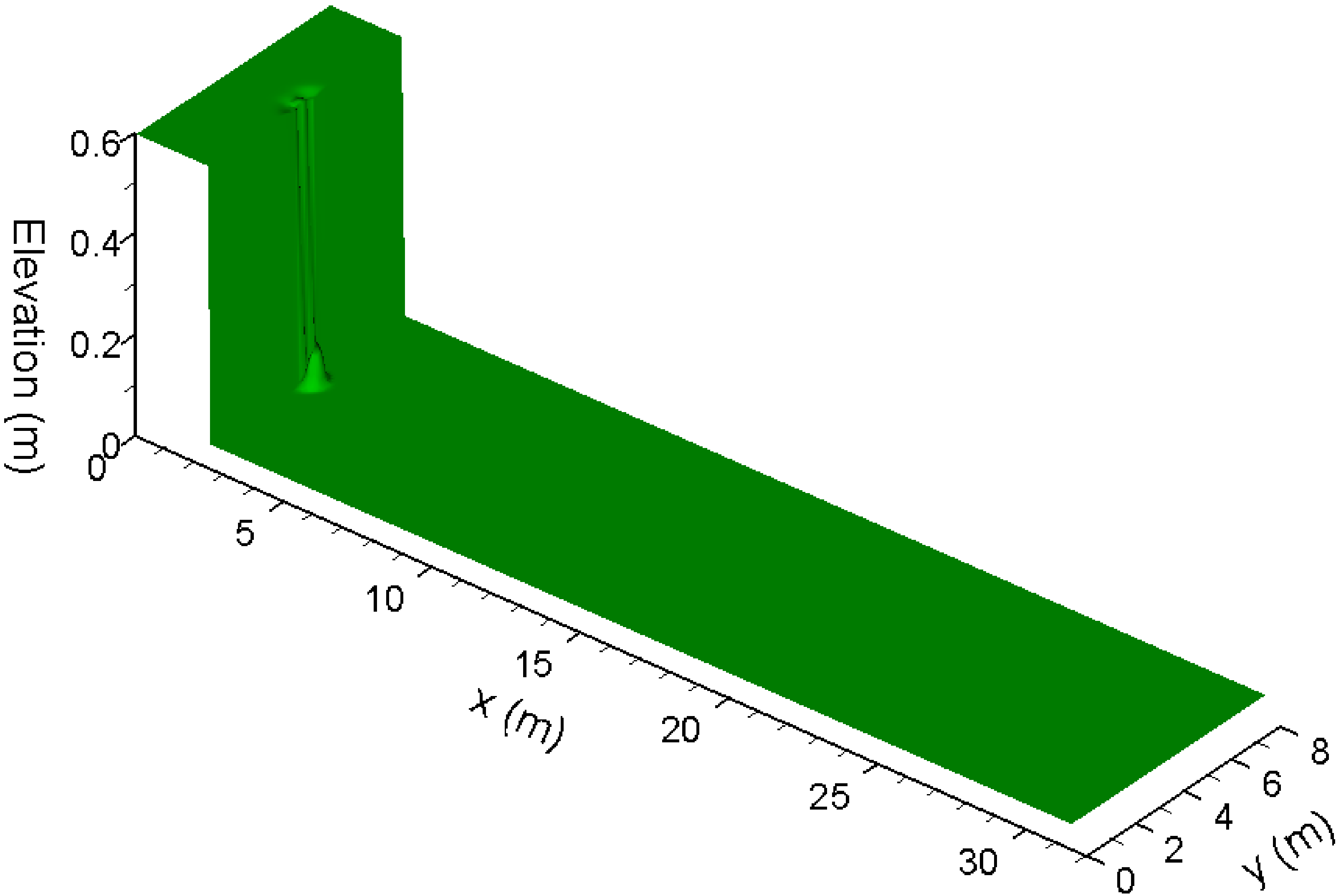
Dam-Break Problem





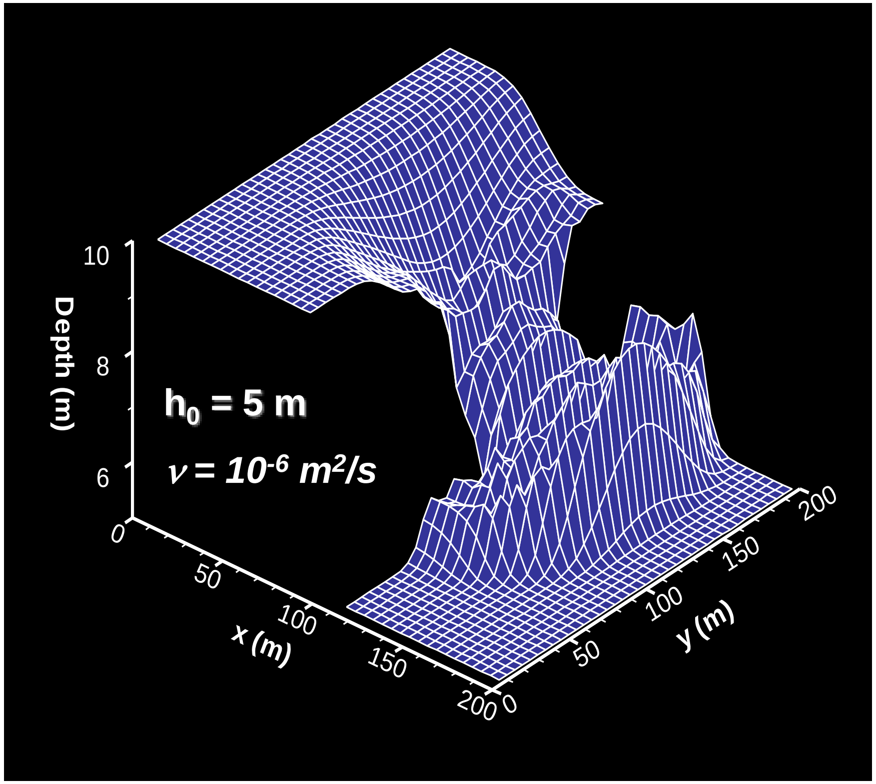
- Dyke Break Experiment (TU Delft)



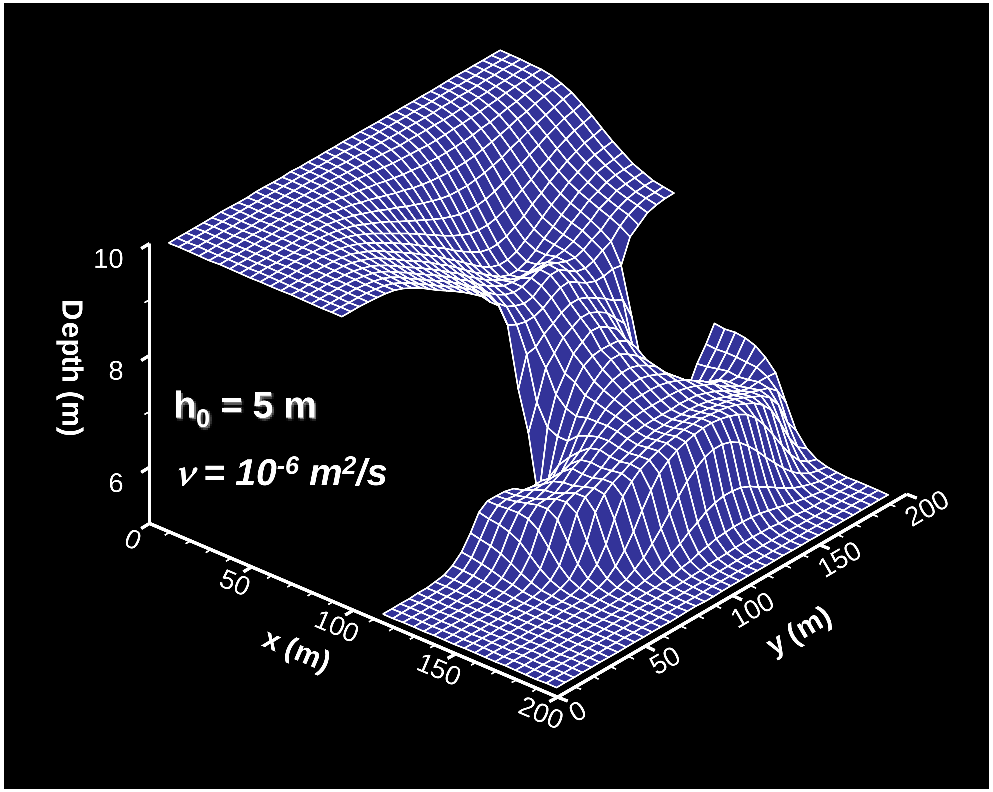


0.6
0.4
0.2
0
0
Elevation (m)
5
10
15
20
25
30
x (m)
0
2
4
6
8
y (m)

• DIVAST vs. DIVAST-TVD Models

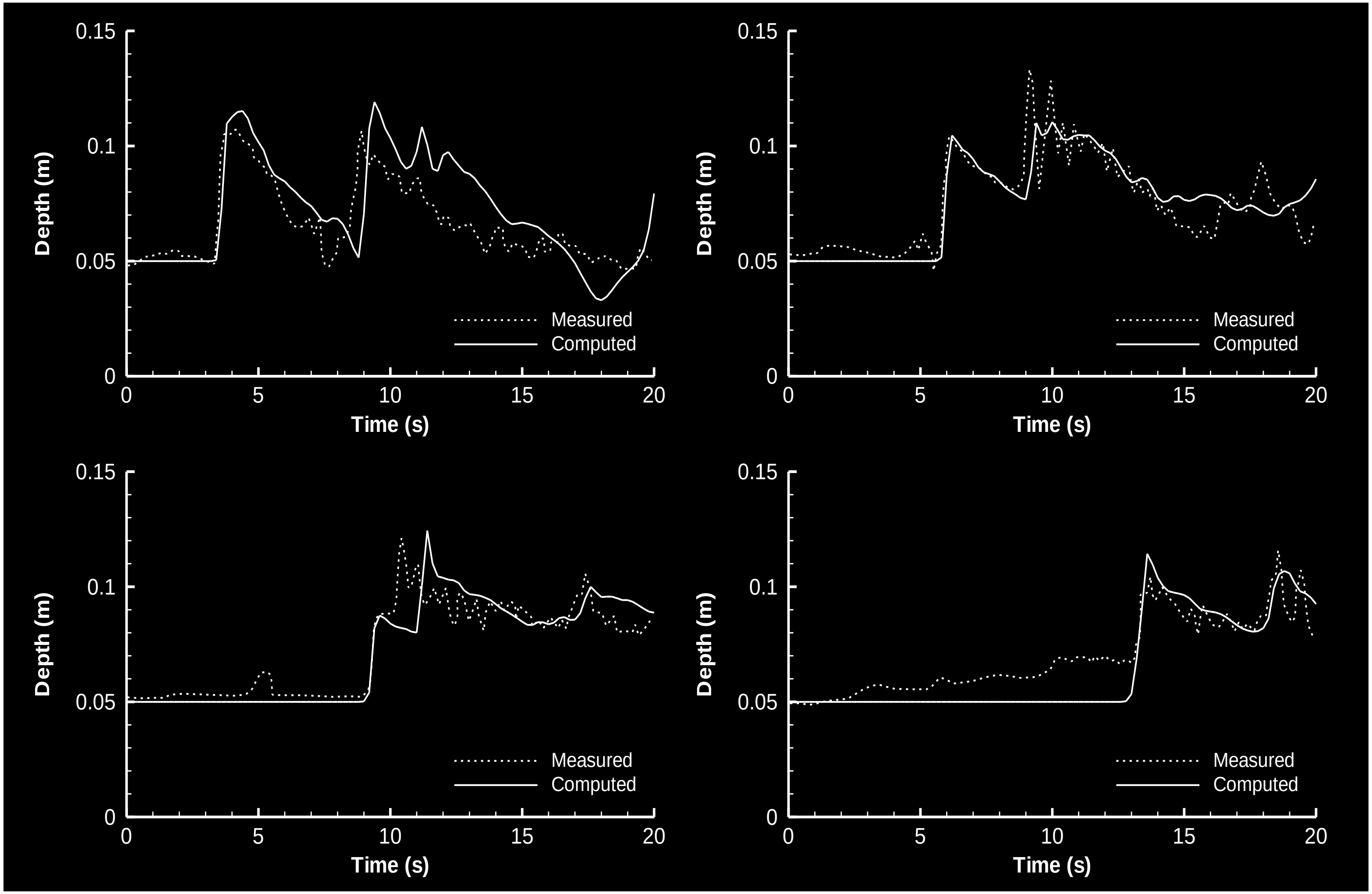


DIVAST



DIVAST-TVD

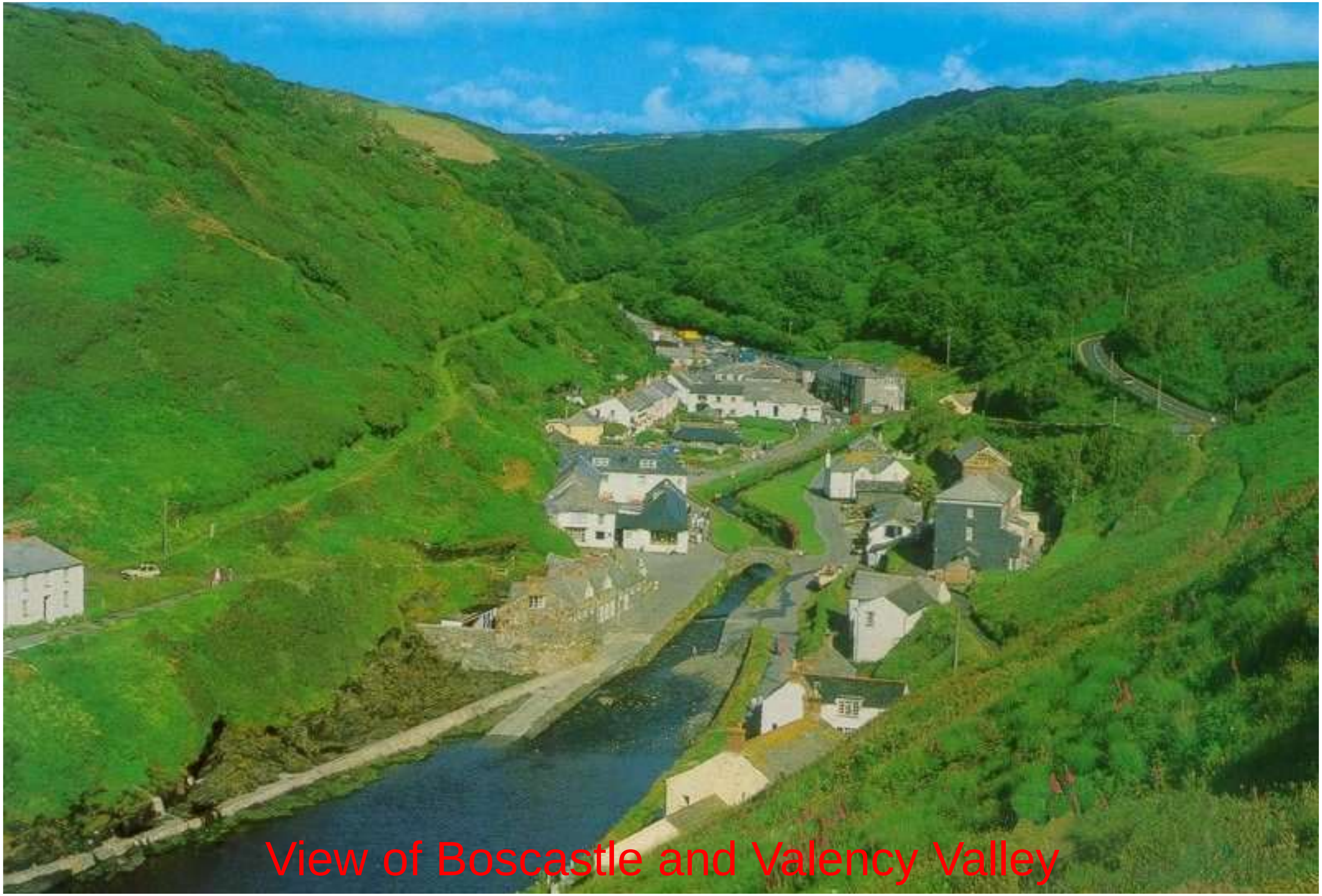
• Dyke Break Experiment



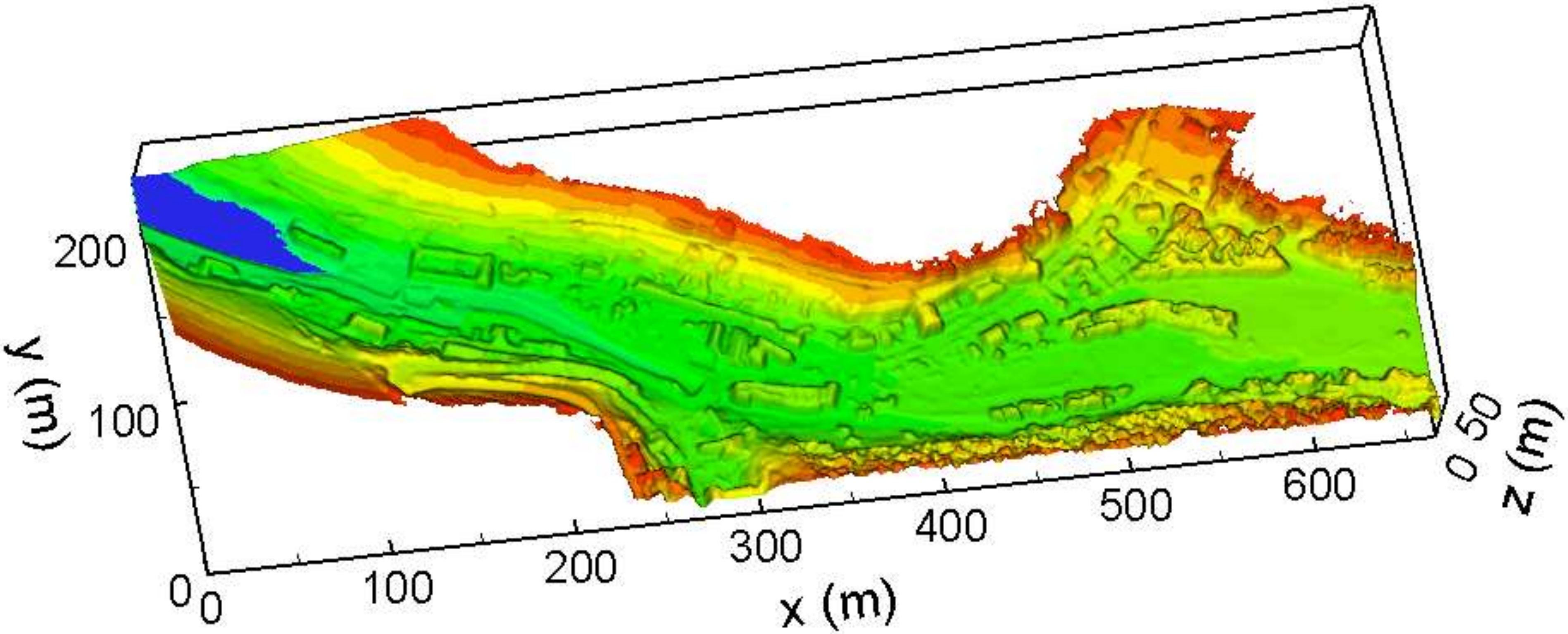
Wrong exit

Boscastle Flood 2004

- Small picturesque town in South West
- Short river basin reach with steep valley terrain – similar to many river basins in Wales
- Up to 200 mm rainfall fell in 5 hr and predicted to be 1 in 400 year return period
- Extensive damage to properties, bridges, highways and other infrastructure
- One of best recorded extreme flood events in UK with trans- and sub-critical flows

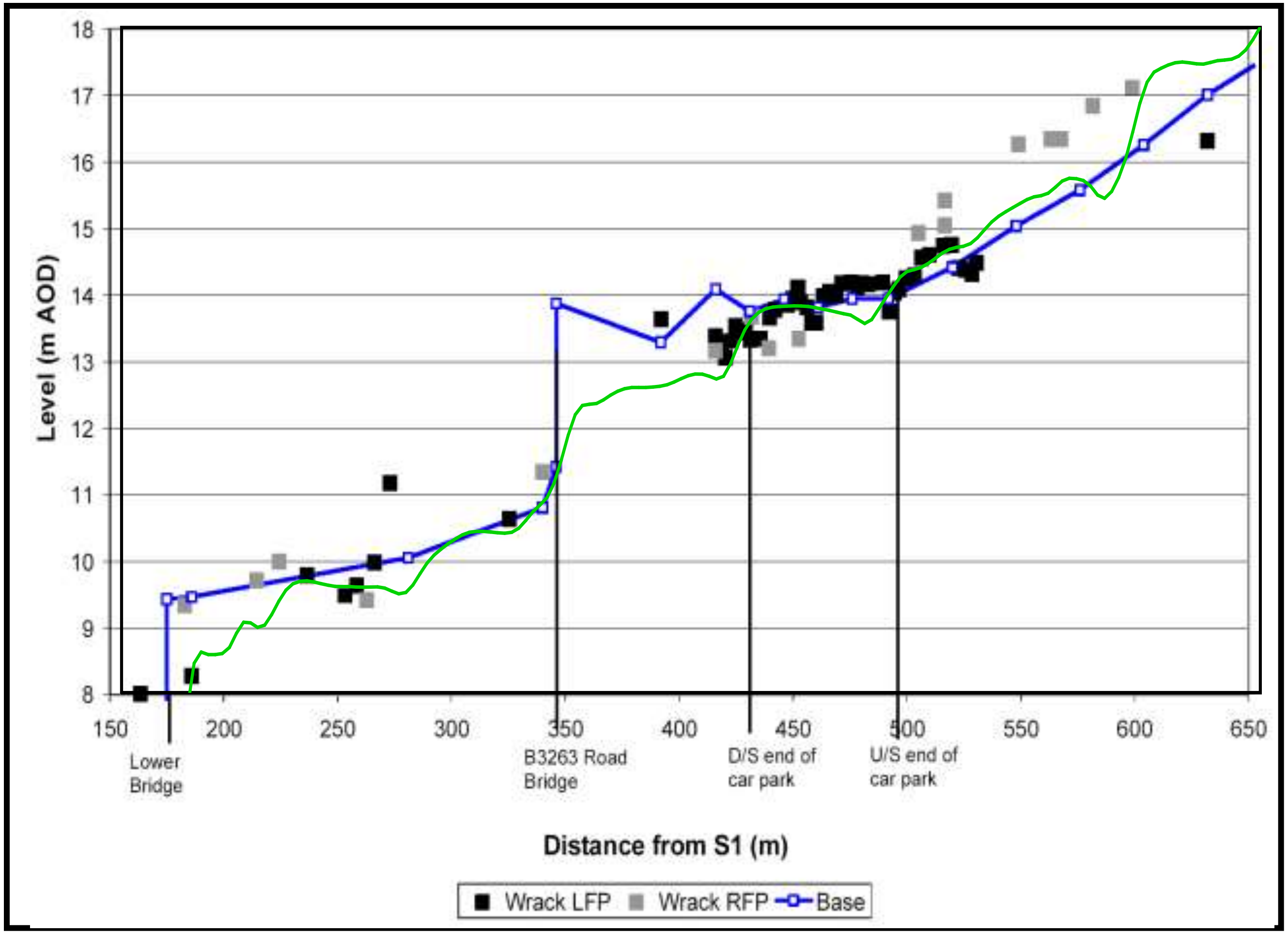

View of Boscastle and Valency Valley

- Predicted Flood Inundation



• Predicted Water Levels

Measured (symbols) and Predicted (green line)



Estimation of Incipient Velocity for Partially Submerged People in Floodwaters

- Previous study on the incipient velocity for vehicles
- Current study for partially submerged people

    Formula derivation

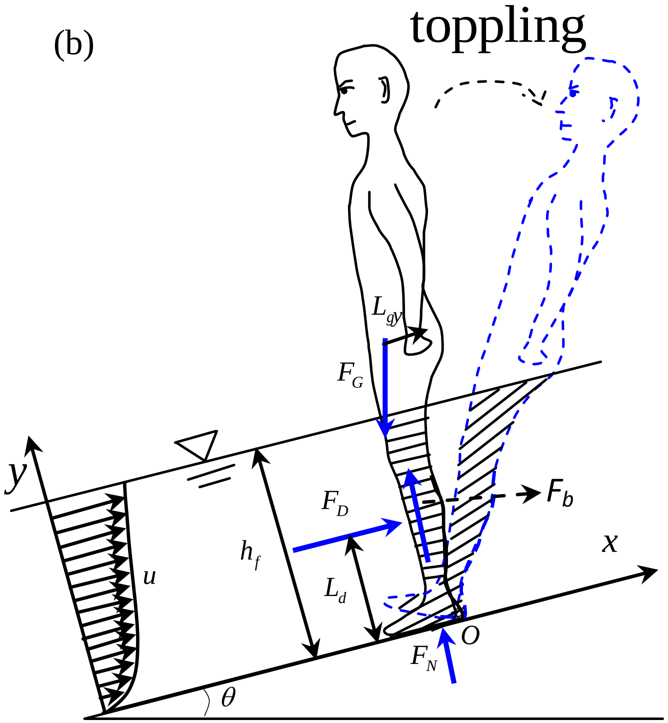
    Flume experiments following similarity laws

    Parameter determination and formula validation

    Estimation of incipient velocity for model people

• Formula derivation and 186 tests undertaken in China using 1:5.54 scaled models

Different forces acting on a partially submerged person



F_G : Effective weight

F_D: Drag force

F_b: Buoyancy force

F_N : Normal force

F_R: Frictional force

Critical condition for toppling instability, given by moment around pivot point O :

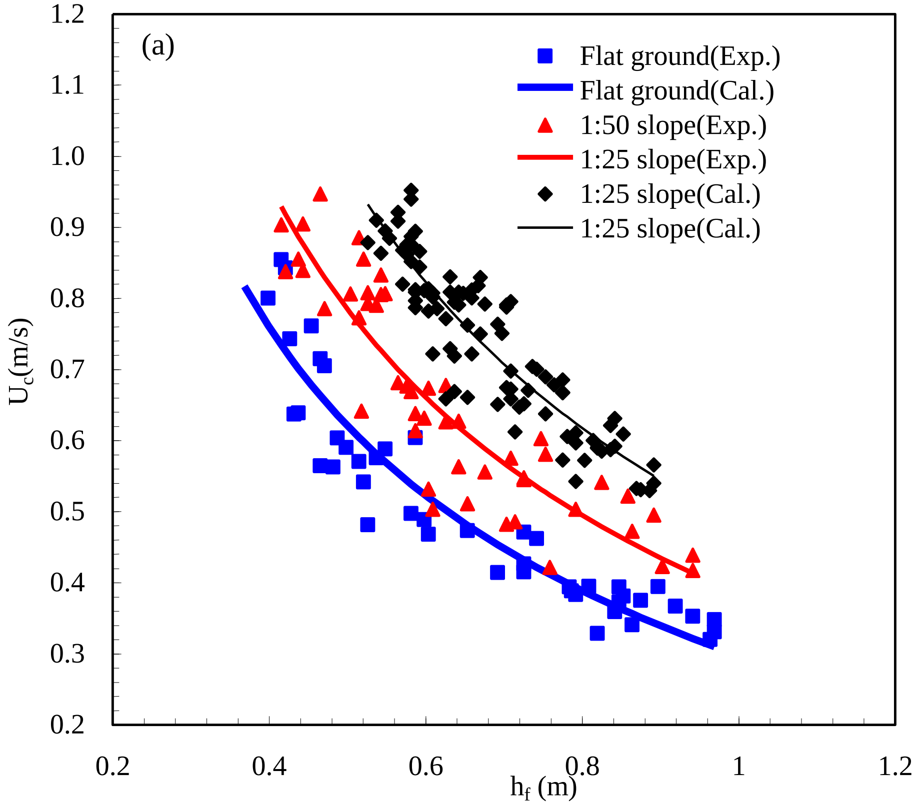
$$F_{Gy}L_{gy} + F_{Gx}L_{gx} - F_D L_d = 0$$

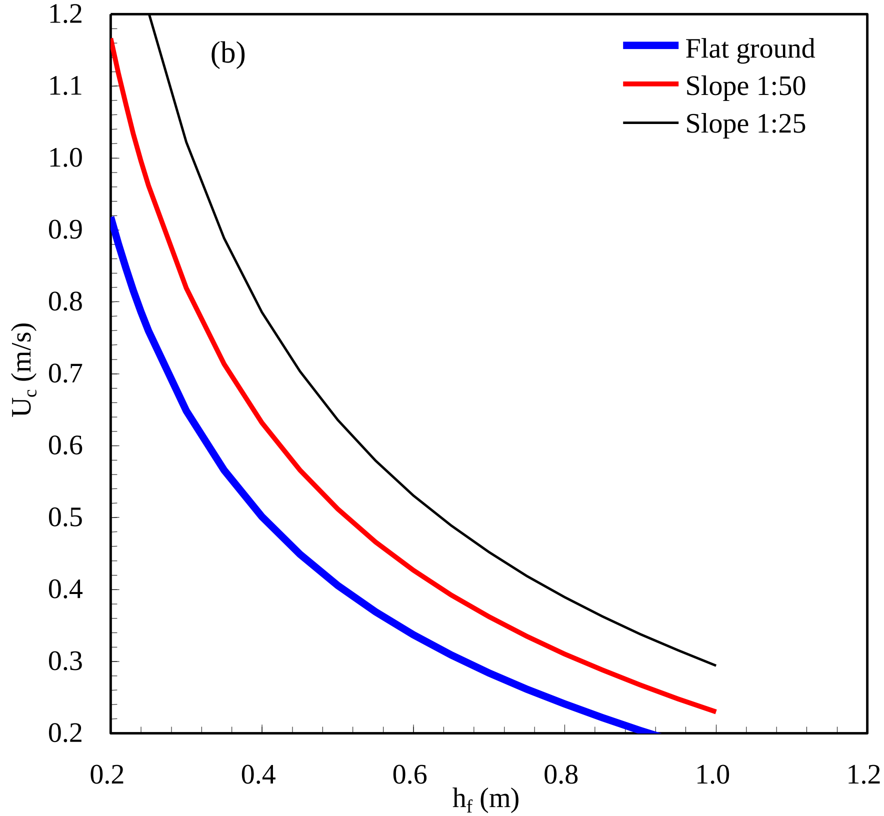
Giving for velocity v depth:

$$U = \alpha\left(\frac{h_f}{h_p}\right)^{\beta}\sqrt{\frac{m_p}{h_f^2\rho_f}(\cos\theta + \gamma\sin\theta) - \left(\frac{a_1}{h_p^2} + \frac{b_1}{h_f h_p}\right)(a_2 m_p + b_2)}$$

where: α, γ = coefficients (see paper), m_p = body mass,
h_p = body height, h_f = flow depth,
a_1, a_2, b_1, b_2 = body shape coefficients

- Scaled incipient velocity vs depth for: (a) adults and (b) children, for different bed slopes





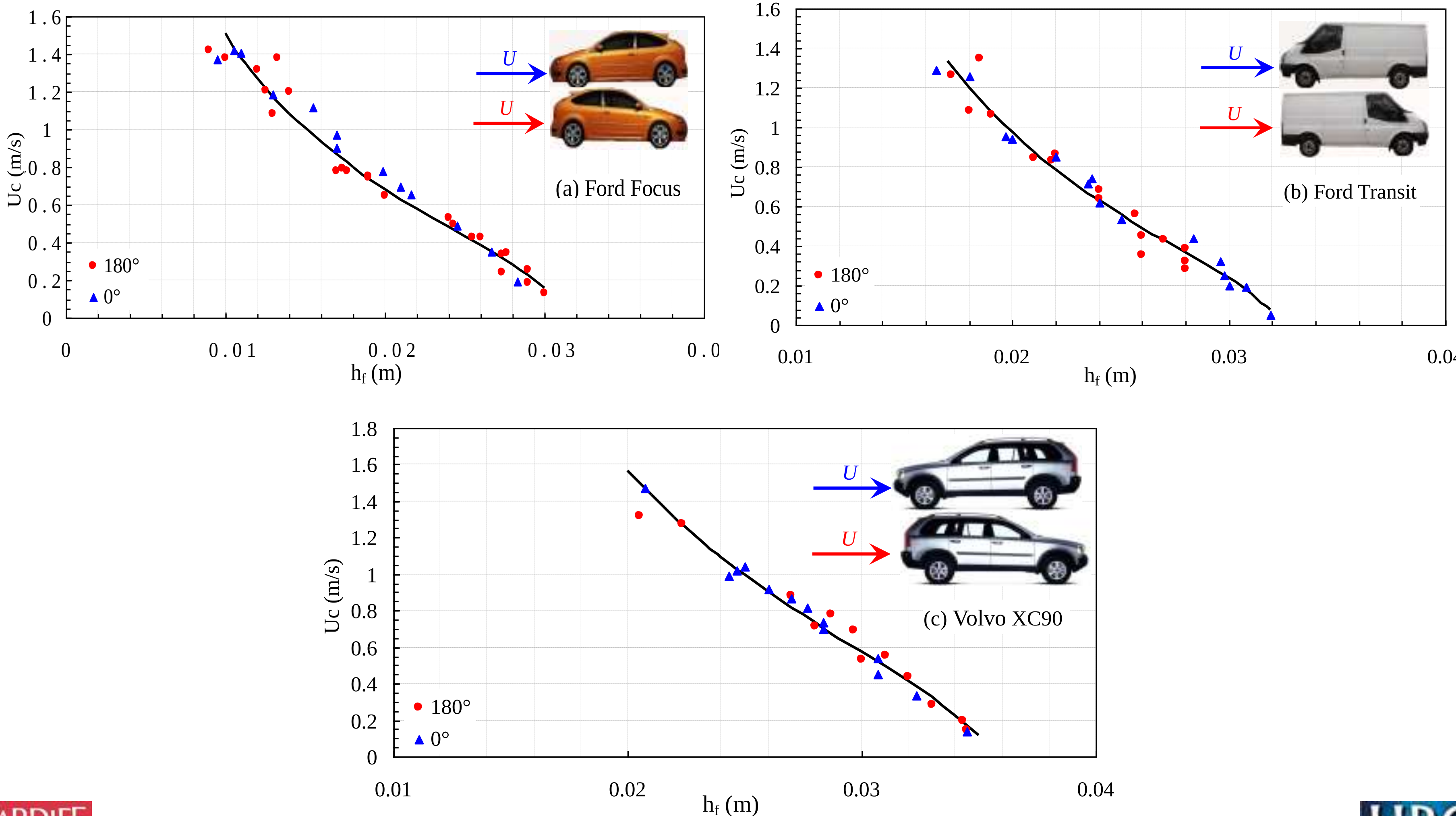
• Flume experiments for vehicle instability

Experiments conducted in flume at HRC at Cardiff University. Flume was 15 m long, 1.20 m wide and 1.00 m deep, with bed covered with plastic carpet and two glass sides.

To estimate critical conditions for prototype vehicles model vehicles and scale ratios were used, with three kinds of similarity laws used to design flume experiments.

Experimental test flume

Partially submerged vehicle test



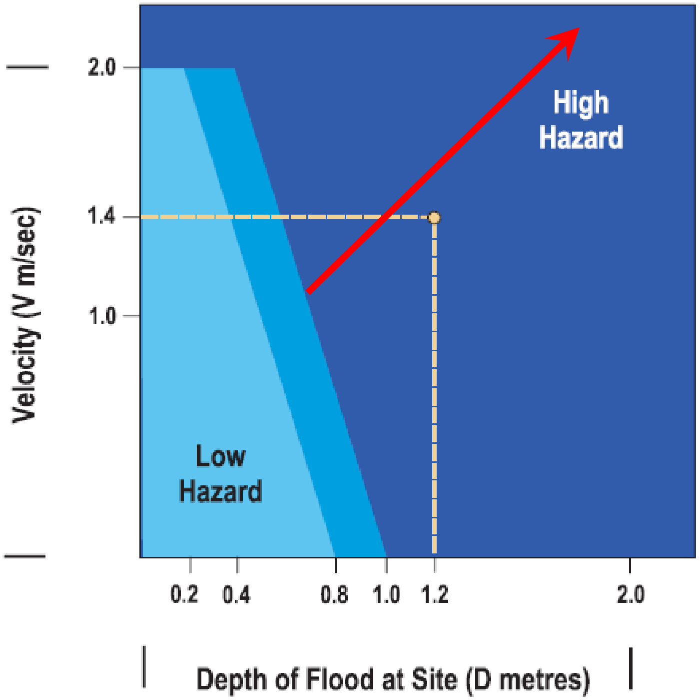
Depth-incipient velocity relationships for partially submerged model vehicles

• Empirical or semi-quantitative criteria

Defra (2003) use simple method to assess flood hazard based on velocity, depth and presence of debris:

$$HR = h \times (U + 1.5) + DF$$

HR = flood hazard rating;
H = depth of flooding (m);
U = velocity of floodwaters (m/s);
DF = debris factor (= 0, 1, 2 depending on probability that debris will lead to significantly greater hazard)



• Determination of Hazard degree

Incipient velocity formula from our studies used to assess people safety and vehicle curves from experiments and formulae to assess people and vehicle safety

Following expression used to determine degree of hazard:

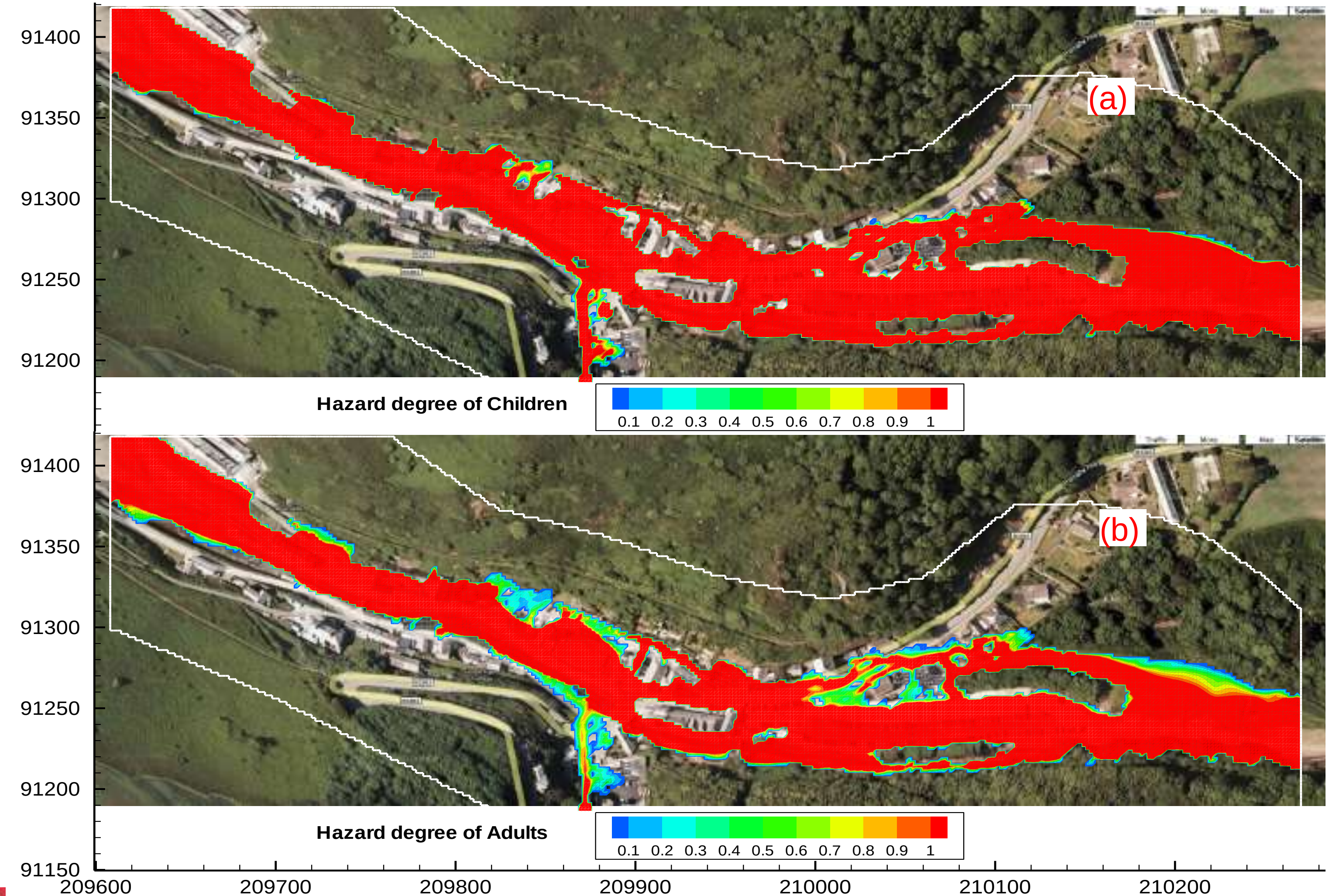
$$HD = \mathrm{Min}(1.0,\ U/U_c)$$

U = calculated depth-averaged velocity in a cell (m/s);
h = calculated flow depth in a cell (m);
U_c = critical velocity under depth (h) for vehicle or people instability (m/s);
HD = Hazard degree for vehicle or people in floodwaters

Safe if HD=0, Dangerous if HD =1.0

• Model Application - Boscastle flood, in UK

- Water depths on streets were more than 2 m with high velocities, carrying debris and cars. About 100 vehicles were washed away, but no fatalities were reported.



Distribution of hazard degree for people: (a) Children; (b) Adults

Conclusions

- Accurate modelling of flooding in steep catchments and levee breaches requires shock capturing models with DIVAST-TVD providing engine for ISIS-TVD
- Formulae developed for critical velocity v. depth for scaled people and vehicles under partially submerged conditions, verified using laboratory experimental data and video clips
- New Flood Hazard formula developed + traffic light display
- Models tested successfully for two sites predicting hazard levels for people and vehicles

Thank You

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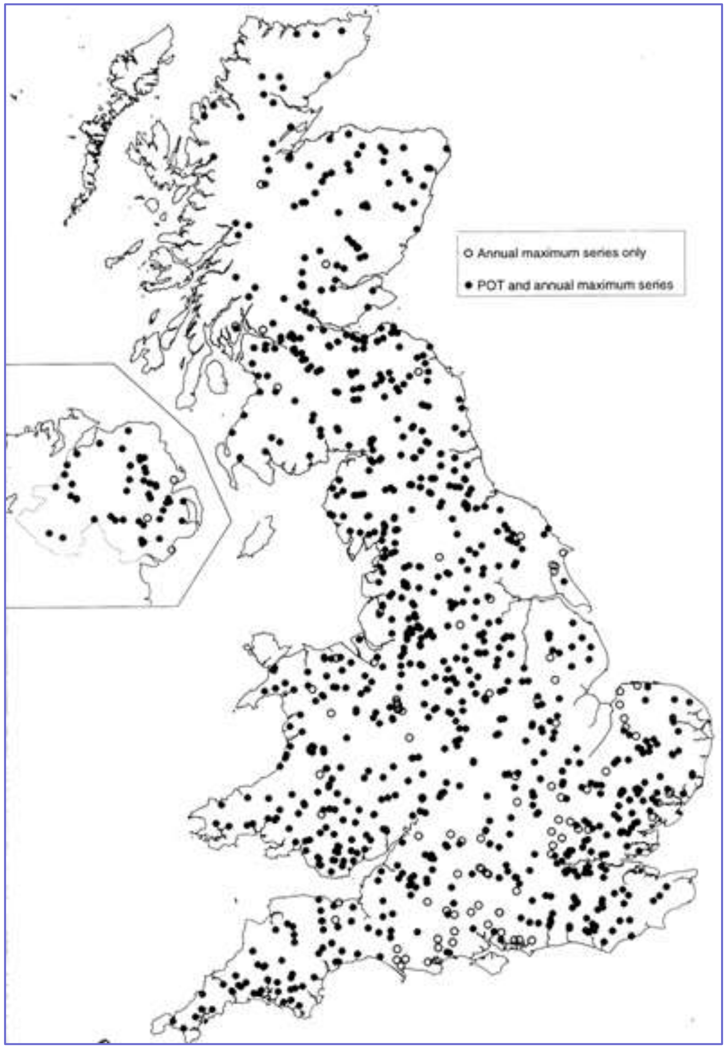


1000 river gauging stations

Environment Agency

living with the risk

The floods in Boscastle
and North Cornwall 16 August 2004

Actual flood peak 180 m^3/s

	Catchment Descriptors	Analogue sites	Rainfall runoff
QMED	6.8 m^3/s	3.998 m^3/s	
1000 year flood	16.6 m^3/s	10.4 m^3/s	35 m^3/s

Flooding in Boscastle and North Cornwall, August 2004, Phase 2 Report, EA/HR Wallinford, pp63

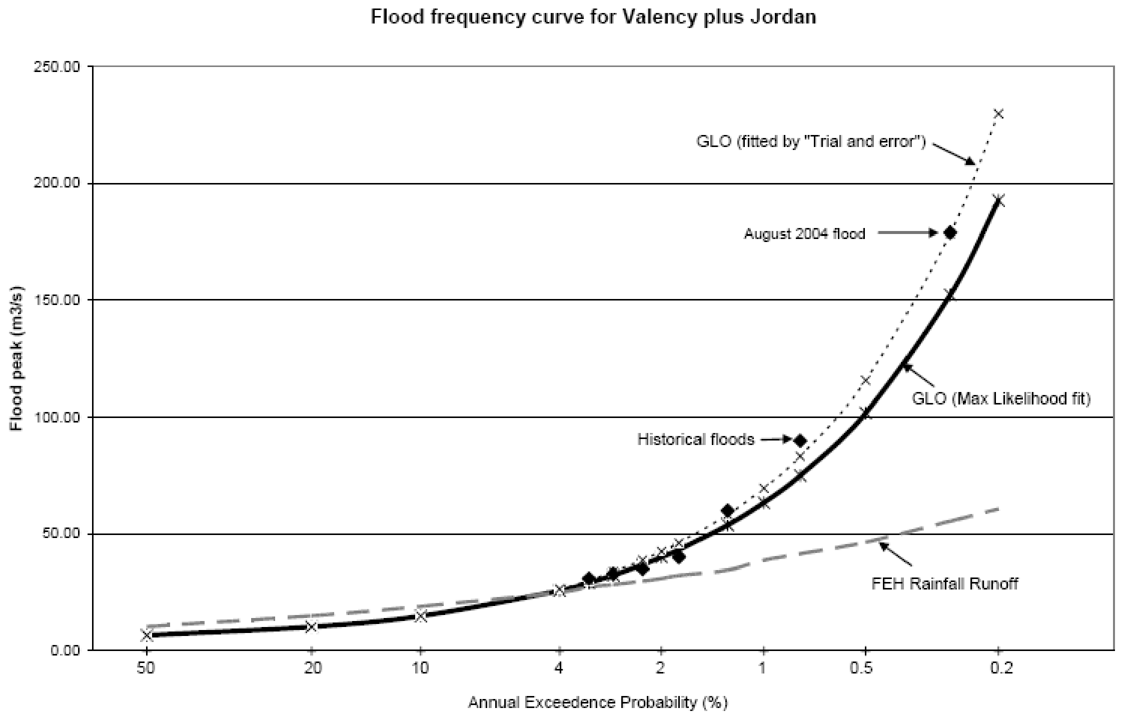


Figure 5.10 Estimated flood frequency curve for the Valency/Jordan catchment at Boscastle

The Official Report: “We believe, on balance, that the event had a 0.25% (1 in 400) chance of recurring in any one year.”

Flooding in Boscastle and North Cornwall, August 2004, Phase 2 Report, EA/HR Wallinford, pp63

- St Asaph North Wales

http://www.telegraph.co.uk/news/picturegalleries

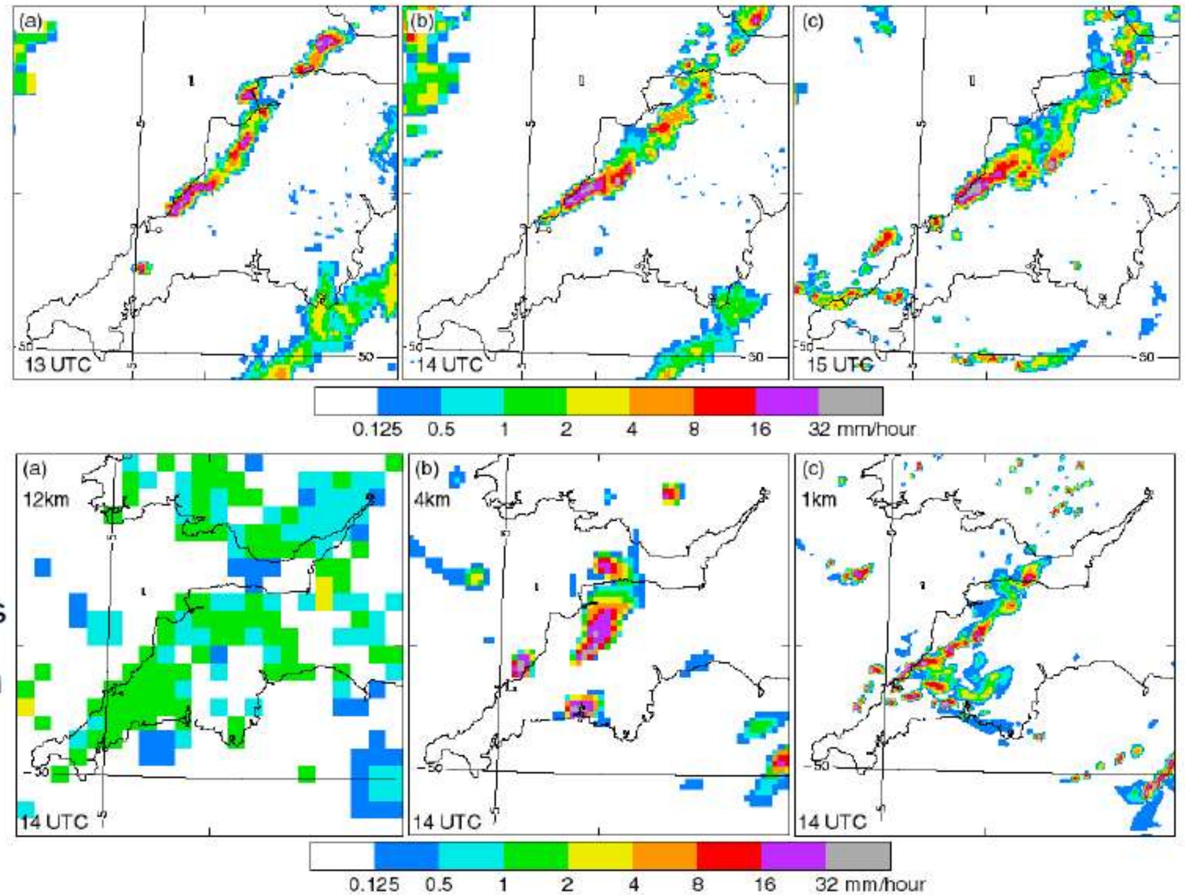
Benefits of very high resolution regional modelling

Met Office
Hadley Centre

Hourly rainfall rates from radar

Model forecasts

(a) 12km
(b) 4km
(c) 1km



Case study: Boscastle, 16th Aug 2004; Courtesy: Nigel Roberts

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- Aim:
  - Combine high resolution UKUM with hydrological model
  - Rainfall runoff modelling for steep short catchments
  - Improve understanding and representation of hydrological processes such as soil moisture deficient and land to atmosphere interactions ...
  - Improved runoff hydrograph for hydrodynamic river modelling.