UK Reservoir Spillway Flood Hydrology

BHS/BDS national meeting, 7th March 2019, Institution of Civil Engineers

British Hydrological Society

The British Dam Society

Precision and accuracy of Unit Hydrograph parameters for gauged and ungauged basins: Can we do better?

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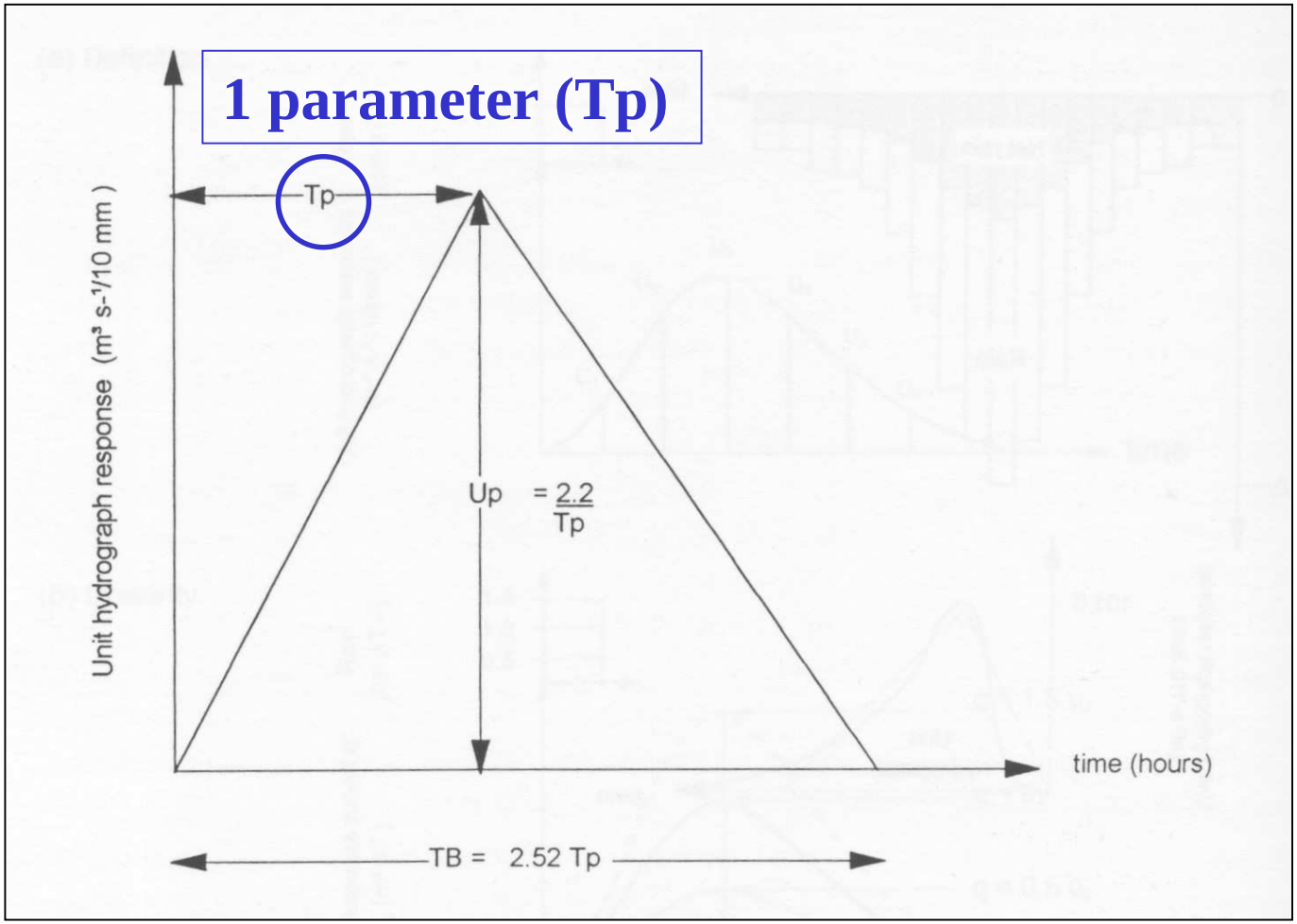
Outline ...

- Unit Hydrographs (UHs, gauged and ungauged basins)
  - FSR/FEH and ReFH
  - IHACRES

- Precision and accuracy of IHACRES UHs for the Wye at Cefn Brwyn (fairly typical of inflow basins to UK upland reservoirs)

- UHs for reservoir spillway hydrology
  – "Can we do better?"

The FSR/FEH triangular UH – for direct runoff (whatever that is) (1975/1999)

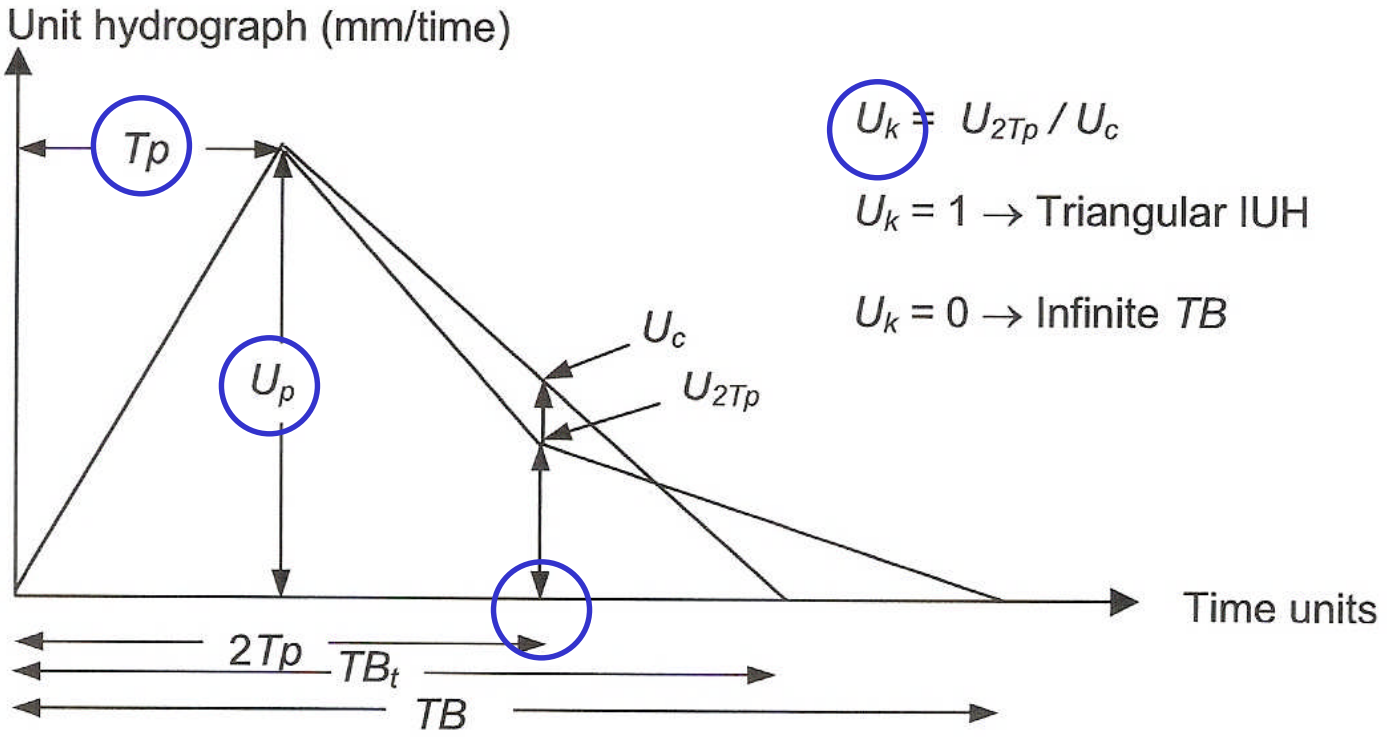


Revitalisation of the FSR/FEH rainfall runoff method

The ReFH (kinked) UH – for direct runoff (whatever that is) (2005)

1 (free) parameter (Tp)

U_k & U_p fixed (0.8 & 0.65 resp.)

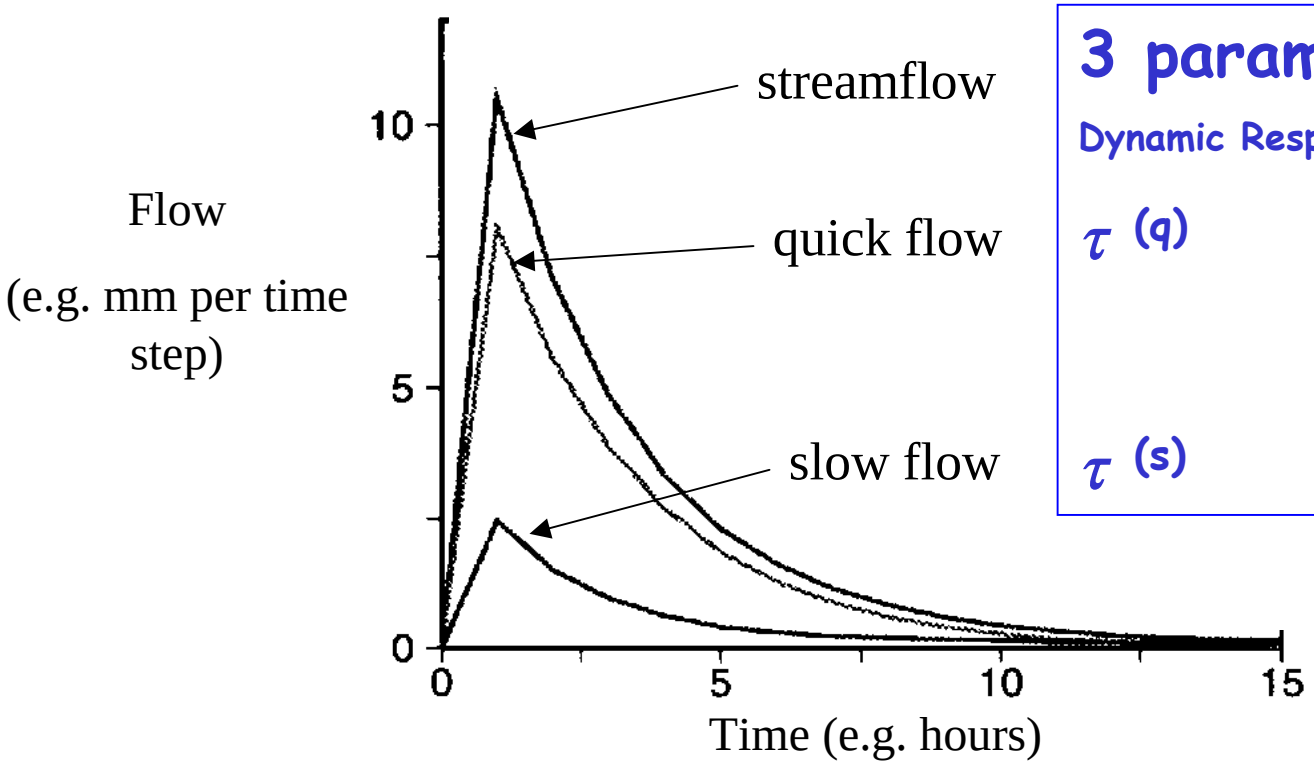


"Revitalisation of the FSR/FEH rainfall runoff method"

R&D Technical Report FD1913/TR (p15, 2005)

Unit Hydrographs for streamflow and its dominant quick- and slow-response components

IHACRES (1990)



3 parameters (DRCs)

Dynamic Response Characteristics ...

$\tau^{(q)}$

and SFI (cf. BFI)

$\tau^{(s)}$

Jakeman, Littlewood and Whitehead (1990). *J. Hydrol.*, 117, 275-300.

Qualitative comparison of UHs

Feature	FSR/FEH/ReFH	IHACRES
What is modelled?	Direct flow (non-measurable)	Streamflow (measurable)
High flows modelled?	Yes	Yes
Low flows modelled?	No	Yes
Event-based modelling?	Yes	Yes
Continuous streamflow simulation?	No	Yes
Prior hyetograph separation required?	Yes	No[1]
Prior hydrograph separation required?	Yes	No
Automated hydrograph separation provided?	No	Yes[2]
Smoothing, etc, of UHs identified from hydrometric data required?	Yes	No
UH parameters transferable to ungauged catchments?	Yes	Yes

Green - 'good'

Red - 'Not so good'

1. Done automatically using a parameter grid-search method within rainfall–streamflow model calibration.
2. Dominant quick- and slow-flow response components of streamflow.

Littlewood, I.G. (2008). Characterisation of river flow regimes for environmental and engineering hydrology: unit hydrographs for rainfall-streamflow modelling. *Folia Geographica: series Geographica-Physica*, XXXIX, 5-36.

$$Tp = \left[a(X_1)^b (X_2)^c (X_3)^d (X_4)^e \right] \times / \div fse$$

	Precision* (*fse* on *Tp*)	*n*
FSR (1975)	1.41	130
FSSR16 (1985)	1.48	175
FEH (1999)	1.85	204
ReFH (2005)	1.76	101

* values shown are not strictly comparable (*Tp* and $X_{i = 1 \text{ to } 4}$ not the same in all cases)

IHACRES calibrated to ~60 gauged basins (England and Wales) – ~20km^2 < A < ~1000km^2 – daily data

(Sefton and Howarth, 1998)

Coefficient of correlation

$\tau^{(q)}$	$\tau^{(s)}$	SFI
0.64	0.37	0.77

See also: Littlewood, I.G. (2004). Unit hydrographs and regionalisation of United Kingdom river flows: comments on some estimation uncertainties. 2nd Biennial conference of the International Environmental Modelling and Software Society, Osnabruck, Germany.1995.

For a preliminary analysis of DRCs for 8 Plynlimon basins – their statistical relationships to selected physical catchment descriptors (PCDs) – see Sefton et al. (1993, 1995).

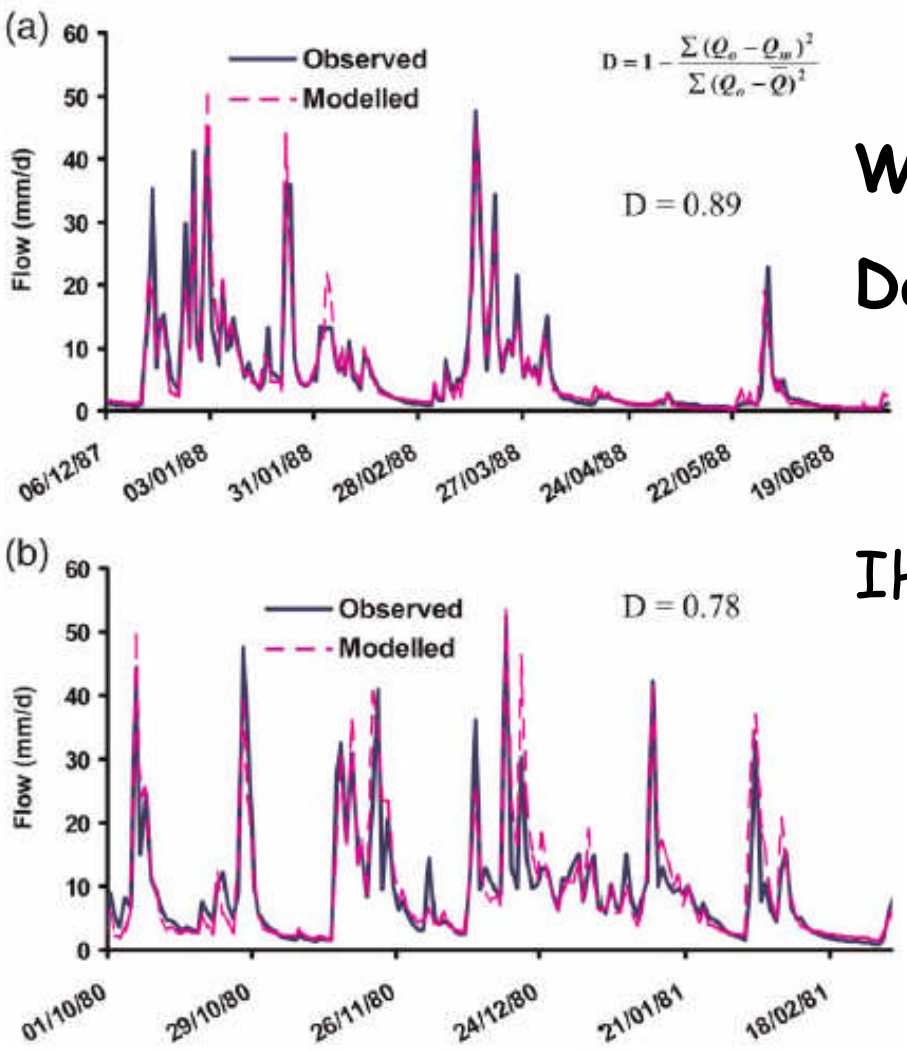


Figure 2 | Cefn Brwyn model fits: (a) calibration 6 December 1987–2 July 1988 and (b) simulation 1 October 1980–1 March 1981.

Wye at Cefn Brwyn, 10.6 km²

Daily data

IHACRES: calibration (top), simulation (bottom)

Littlewood and Croke (2013). *Hydrol. Res.*, 44(3), 430-440.

Coefficient of determination

IHACRES calibration 6 December 1987 – 2 July 1988

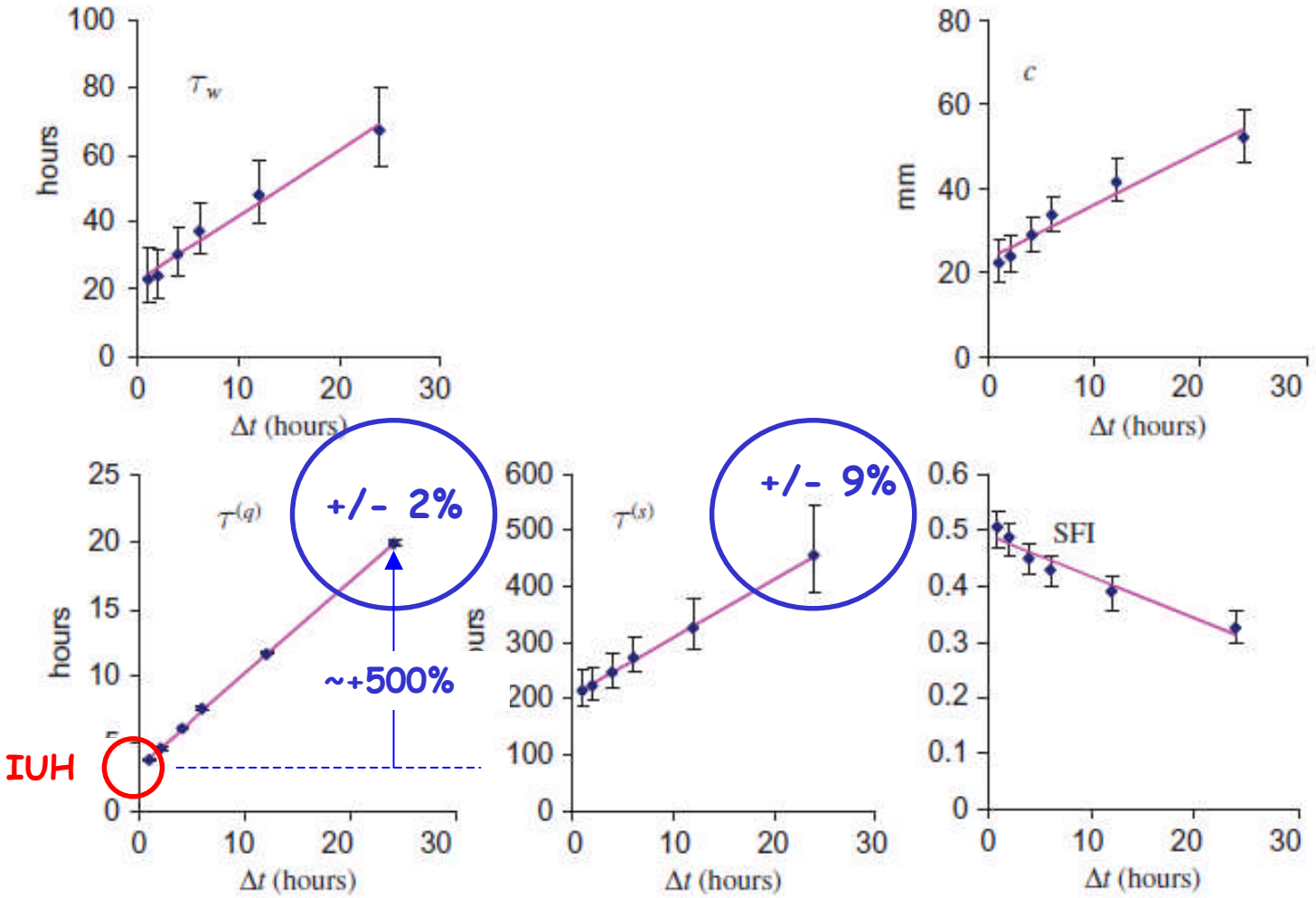
Δt (hours)	D
24	0.895
12	0.907
6	0.910
4	0.905
2	0.910
1	0.905

D ~0.9 for $1<\Delta t<24$ hours. However, it would be a big mistake to say there is nothing to choose between these calibrated models

Littlewood and Croke (2013). *Hydrol. Res.*, 44(3), 430-440.

Loss module DRCs

UH module DRCs



Littlewood, I.G., Croke, B.F.W. and Young, P.C. (2011). HSJ, 56(3), 521-524.

Summary:

- From 1990, UH-based rainfall–streamflow modelling ceased to be constrained to a conceptually-unrealistic triangular UH (with or without a kink in its recession) – or to event-based analysis – as used for reservoir spillway design flood hydrology

- Improved techniques for identifying UHs (e.g. IHACRES) have not been acknowledged by, or evaluated for, UK engineering flood hydrology

- **UK engineering design flood hydrology is 'stuck' – it is resistant to substantial improvement because it is too-heavily invested in conceptually unrealistic UH shapes (dating from 1975/1999, 2005)**

The 'flood hydrology road map' (EA) acknowledges that

- "Many of the methods we use are dated and based on approaches developed in the 1970s - 1990s"

and aims to

- "Develop a vision of flood hydrology 10-20 years from now"

Back to the title …

"Precision and accuracy of Unit Hydrograph parameters for gauged and ungauged basins: Can we do better?"

Gauged basins – YES

Ungauged basins – YES, probably – but there's work to do

Thank you