Flood frequency estimation in urban catchments

Thomas Kjeldsen,

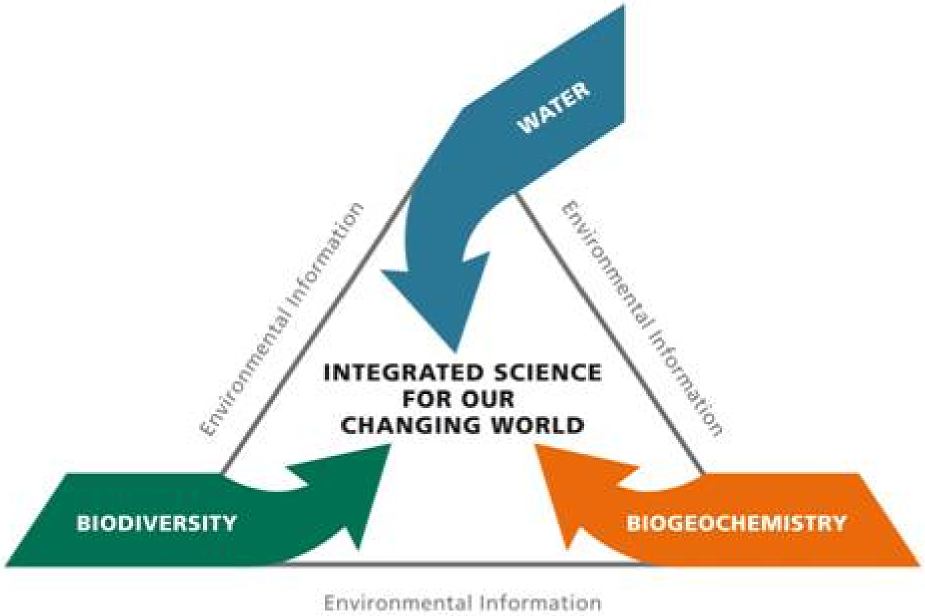
CEH Wallingford

Computational Intelligence in Water Engineering and Hydroinformatics, University of Birmingham, 18 February 2010

People & Sites

350 scientists, over 150 students & 130 support staff based across GB

Integration of Scientific Disciplines

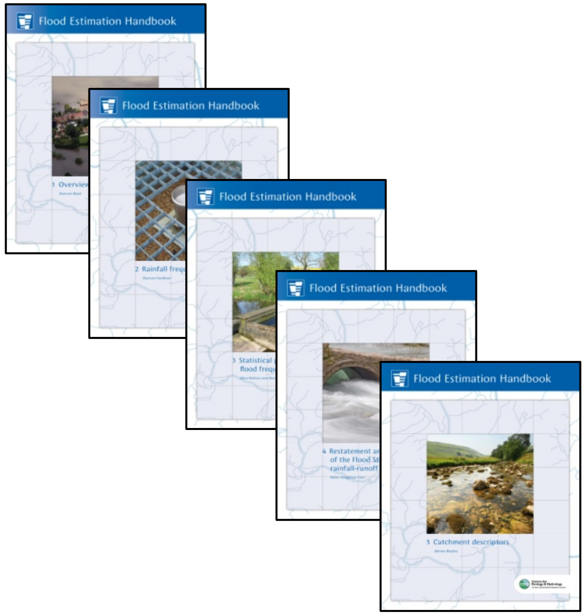


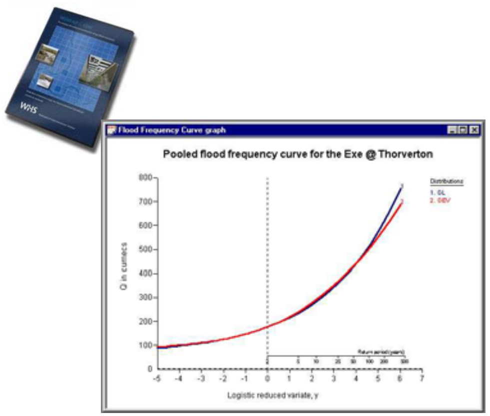
Scientific disciplines are integrated to develop practicable solutions for environmental sustainability

Daily Telegraph

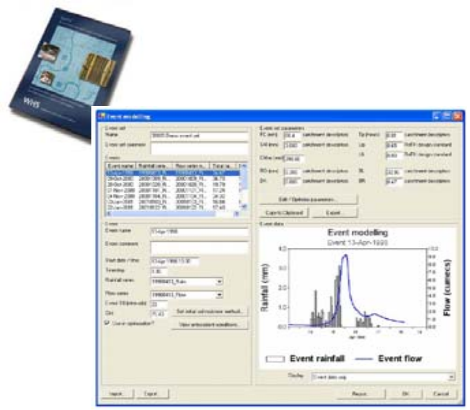
Flood Estimation Handbook

A unified set of procedures for rainfall and flood frequency estimation in the UK

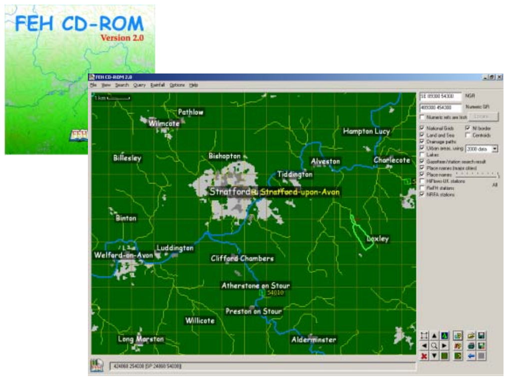




WINFAP-FEH v3



ReFH modelling

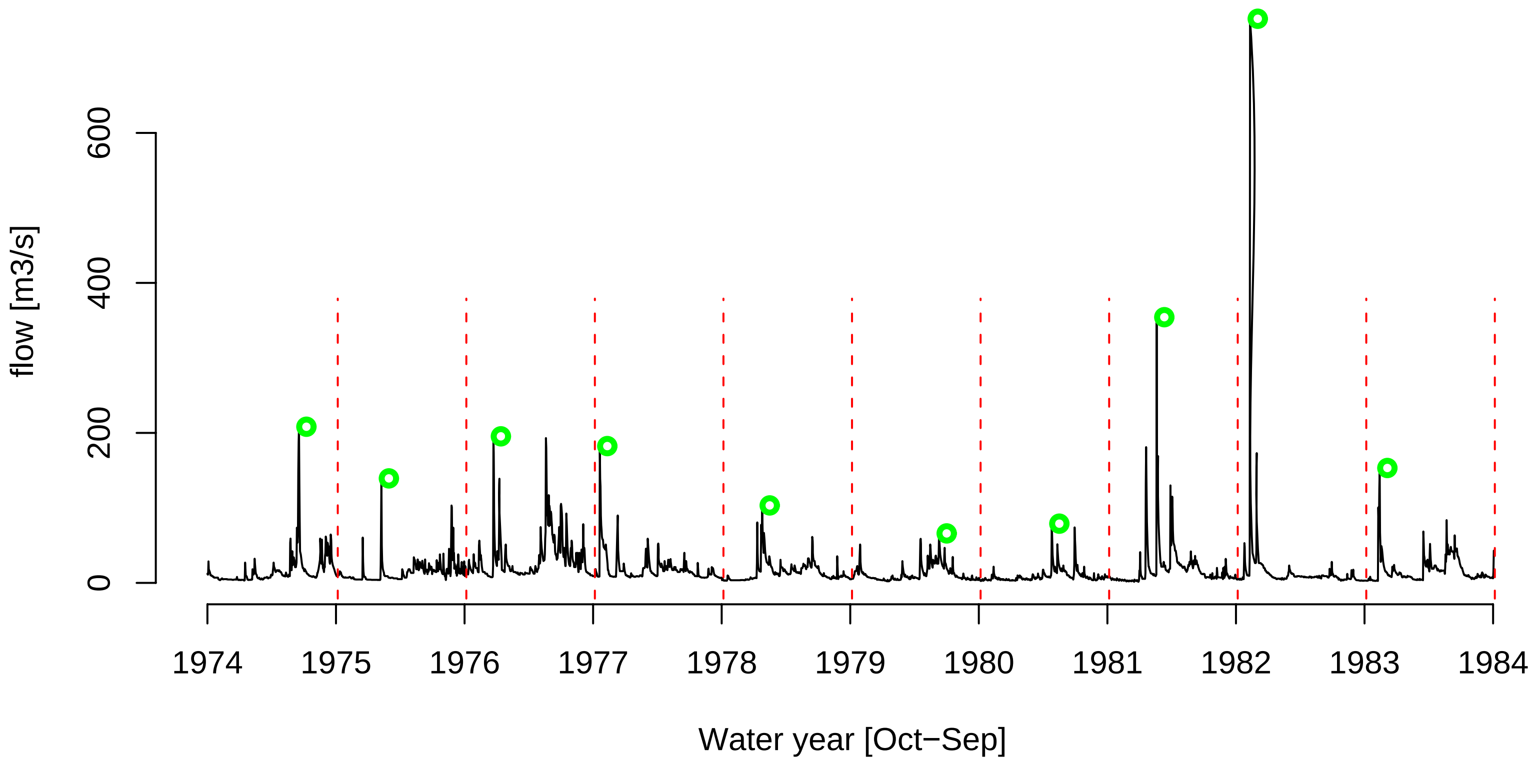


FEH CD-ROM v3

Data: observations

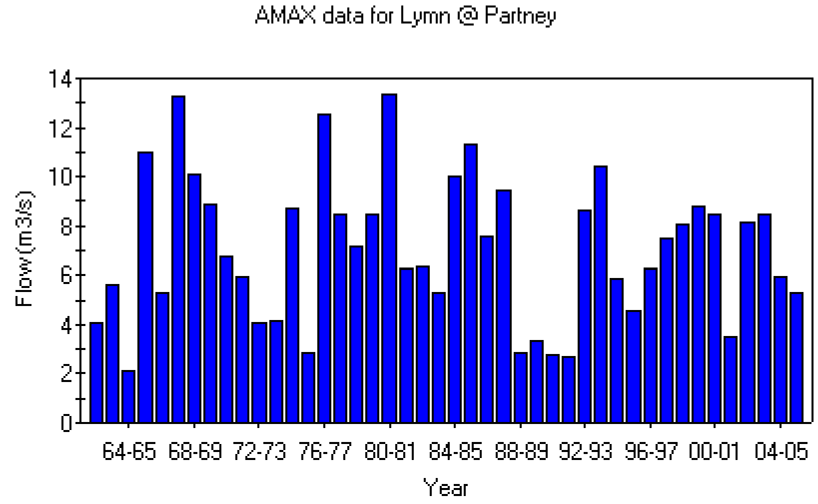
Time series → Extract flood peaks

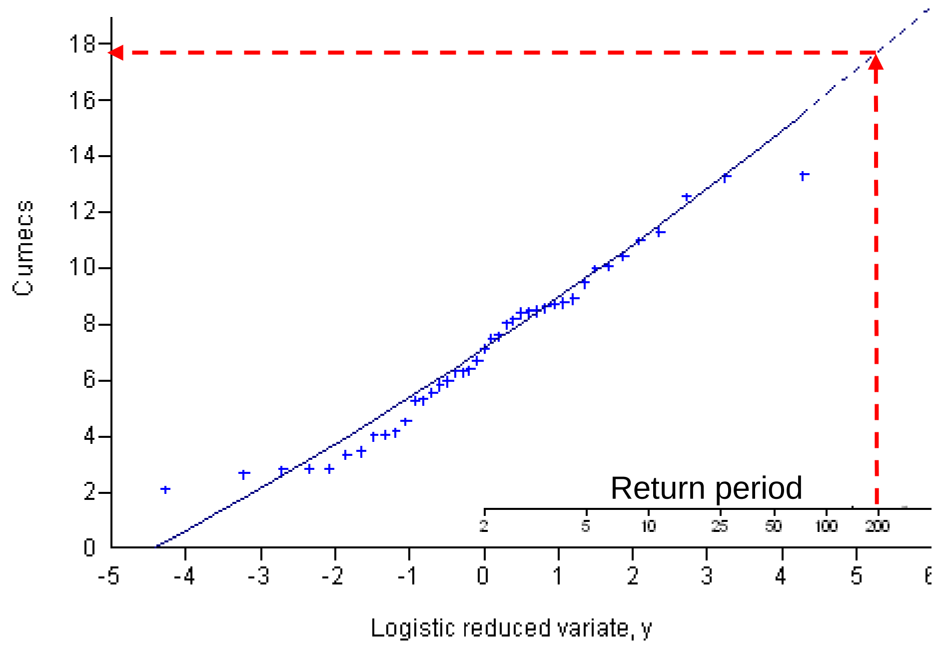
- E.g. Largest observed peak in hydrological year



Background:

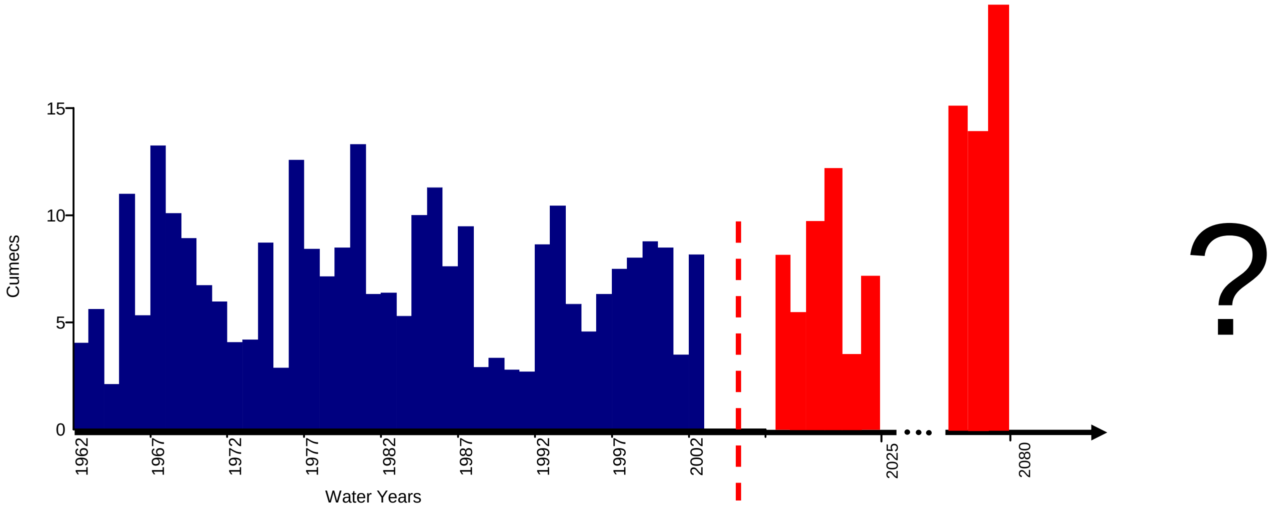
- **Statistical models of flood risk**
- **Methods developed for rural catchments (SC050050)**
- **Identify changes in flood characteristics**
- **Allow prediction in ungauged catchments**





- Reducing prediction uncertainty
- Get more information on extremes
- Environmental change
- New data sources
  - Identify
  - Incorporate

A non-stationary environment



Problems identifying trend from observed records

- **What are the causal factors of change?**
- **How long will trend be sustained?**
- **How are trend to be described analytically?**

In ungauged catchments, parameters estimated using catchment descriptors

$$QMED_{cds} = 8.3062 AREA^{0.8510} 0.1536^{\left(\frac{SAAR}{1000}\right)} FARL^{3.445} 0.0460^{BFIHOST^2}$$

602 rural catchment

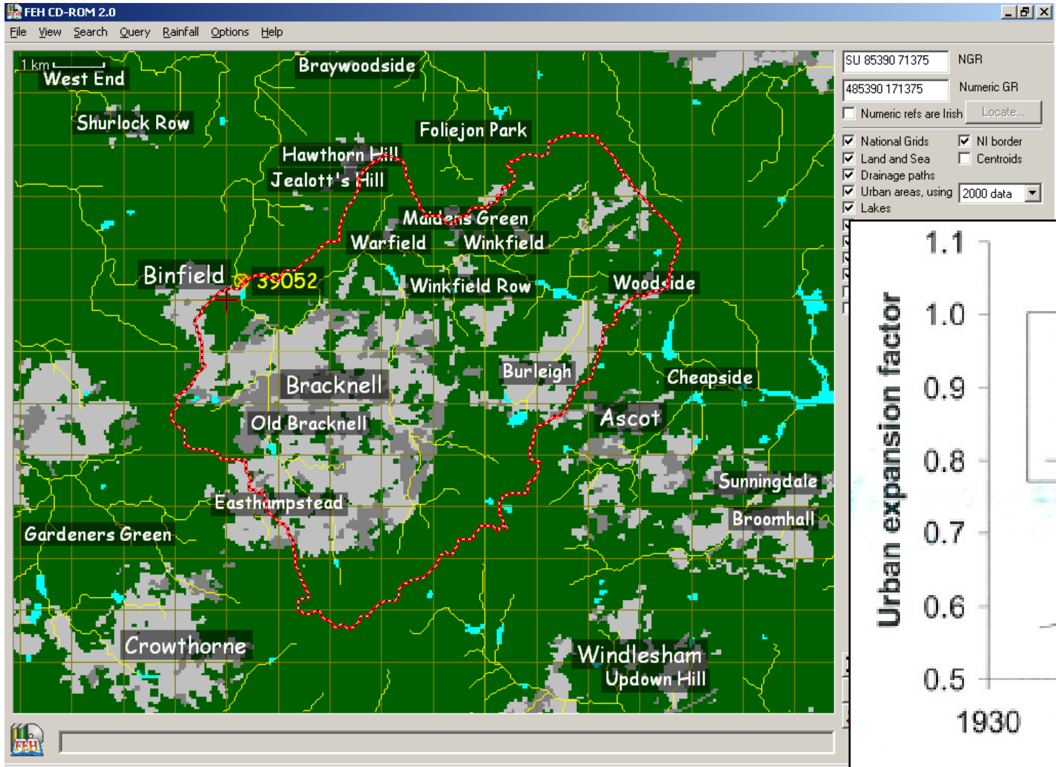
200 urban catchment:

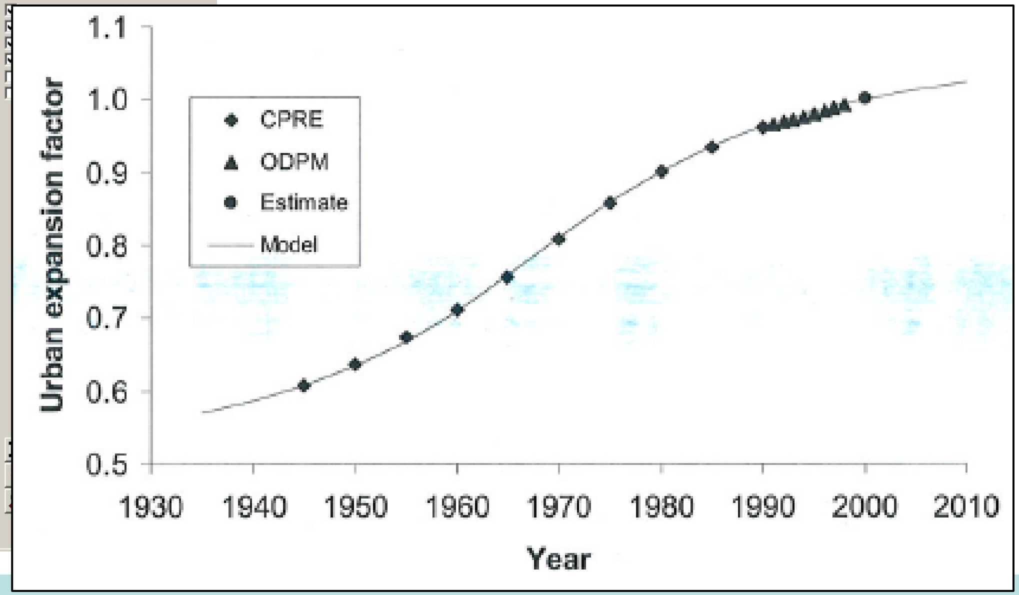
Explanatory variables describing urban area

$$\ln\left[QMED_{obs}^{(A-S)}\right] - \ln\left[QMED_{cds}^{(A-R)}\right] = \mathbf{X\theta} + \boldsymbol{\varepsilon}$$

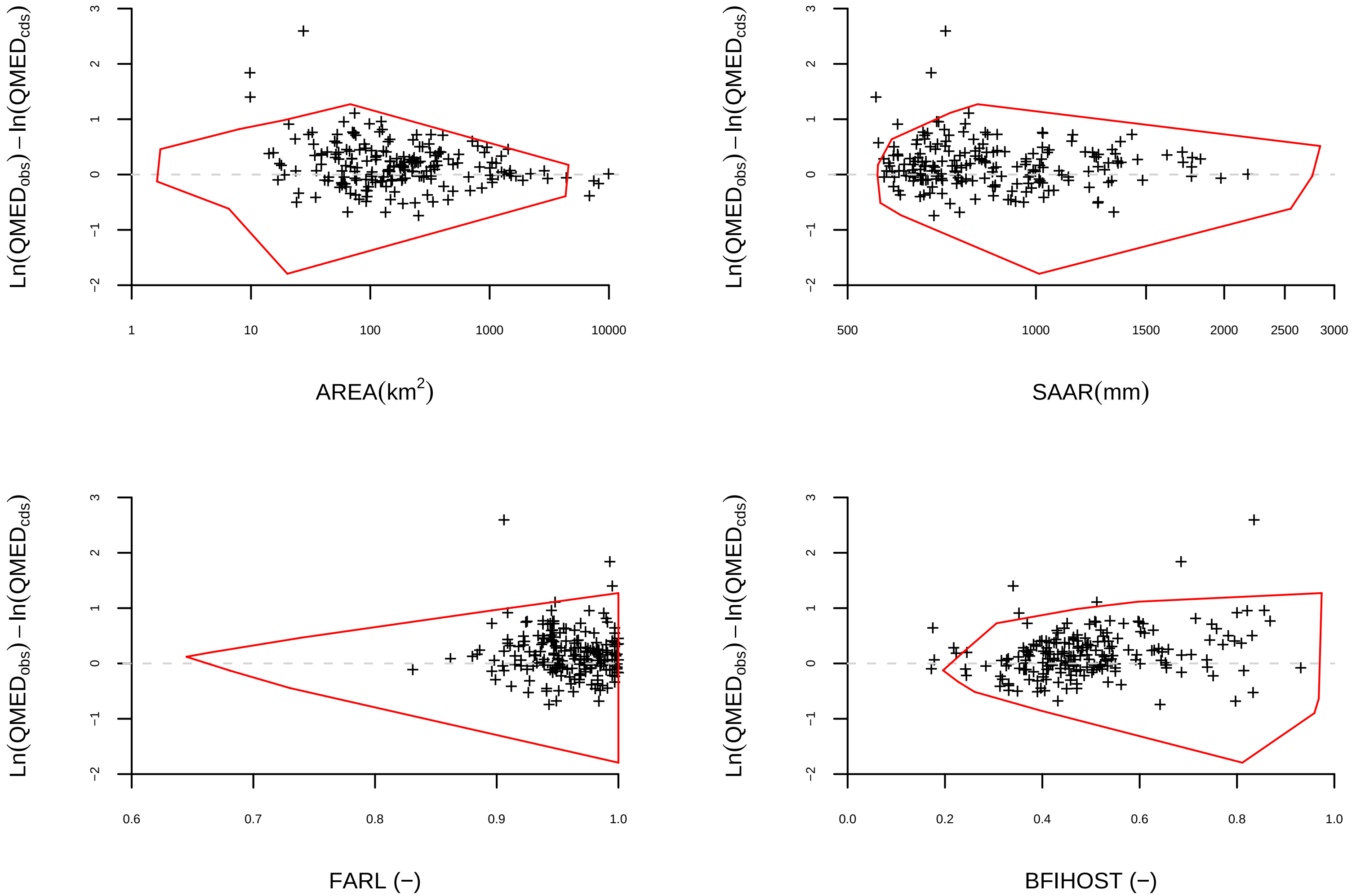
Observed (gauged)

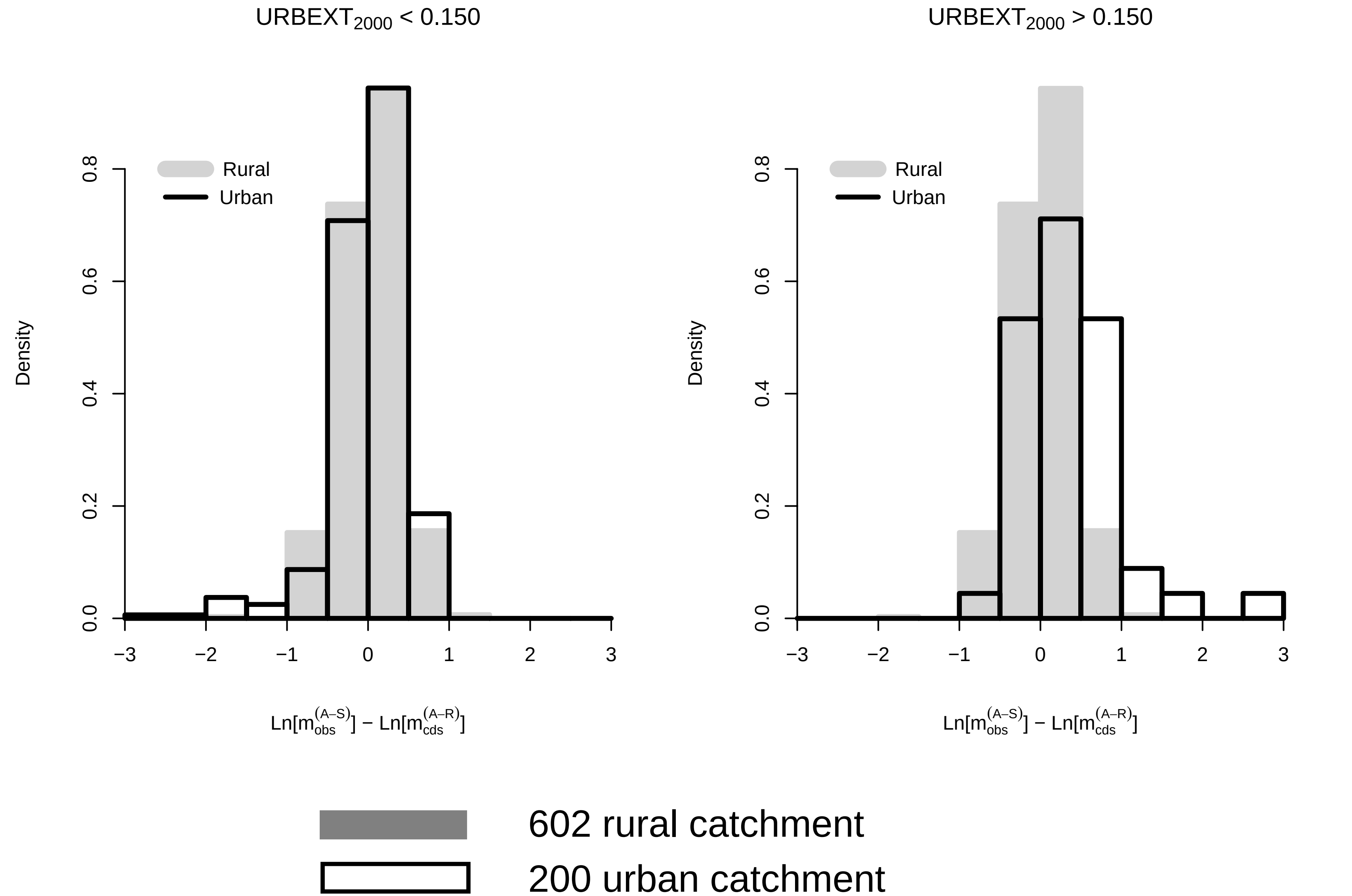
As-rural estimate (ungauged)

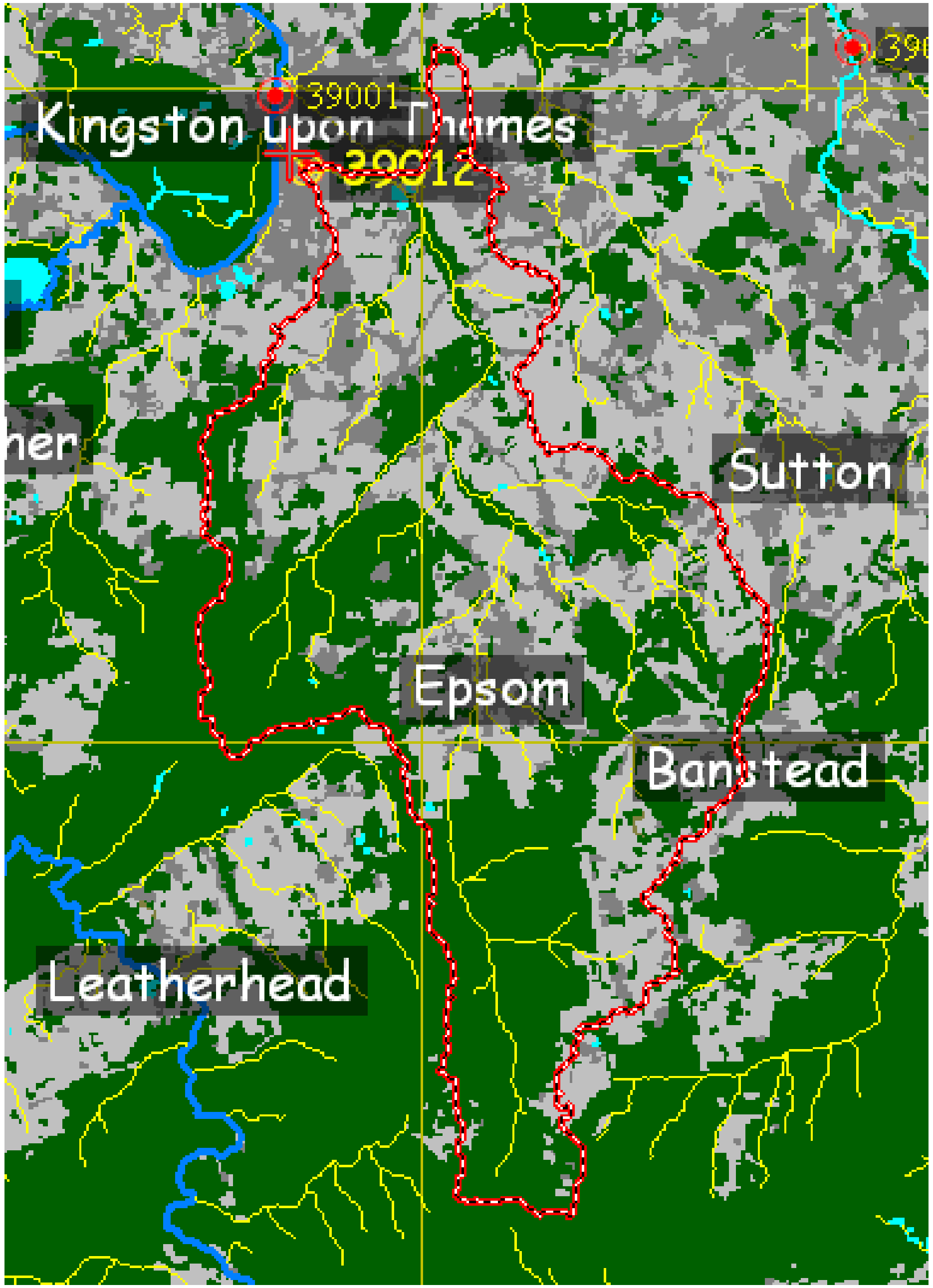




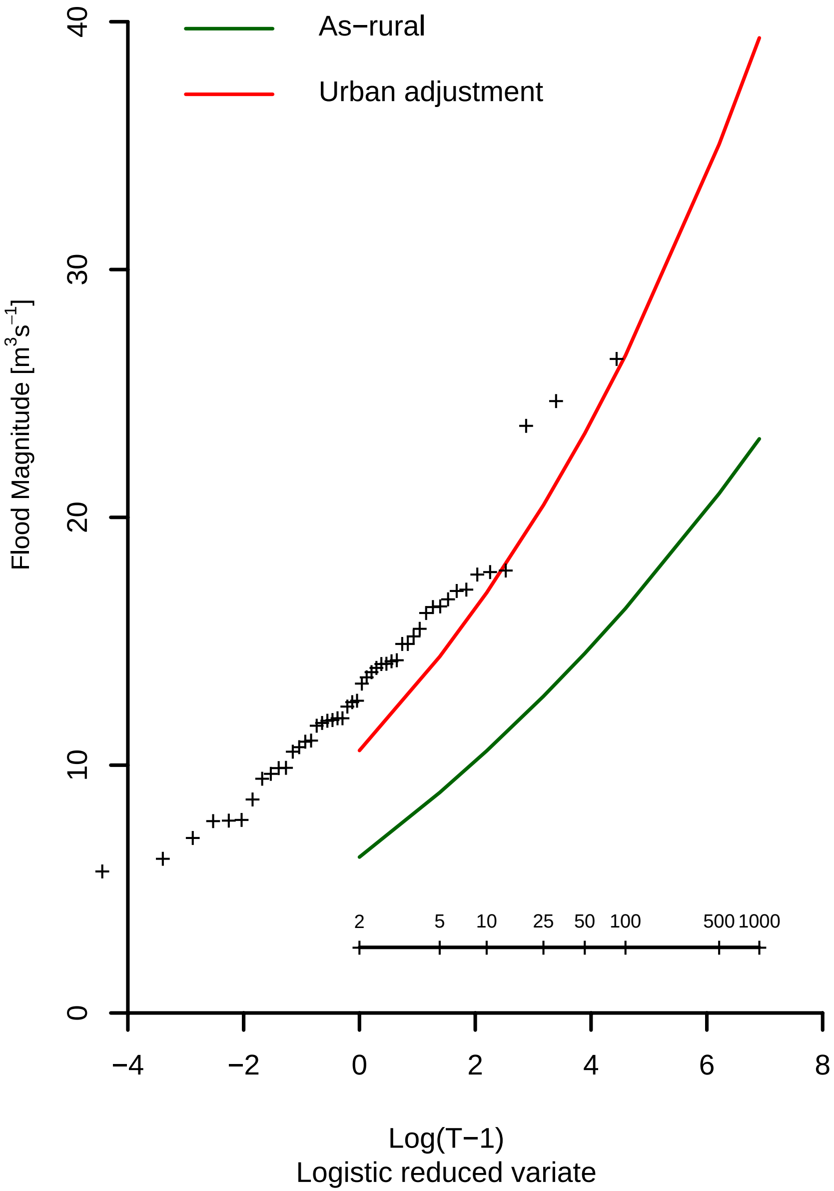
$$UEF = 0.7851 + 0.2124 \tan^{-1}\left(\frac{Year - 1967.5}{20.32}\right)$$


Ln(QMEDobs) − ln(QMEDcds)
AREA(km2)
1
10
100
1000
10000
SAAR(mm)
500
1000
1500
2000
2500
3000
FARL (−)
0.6
0.7
0.8
0.9
1.0
BFIHOST (−)
0.0
0.2
0.4
0.6
0.8
1.0
−2
−1
0
1
2
3


URBEXT2000 < 0.150
URBEXT2000 > 0.150
Rural
Urban
Density
0.0
0.2
0.4
0.6
0.8
−3
−2
−1
0
1
2
3
Ln[m(A–S)obs] − Ln[m(A–R)cds]
602 rural catchment
200 urban catchment



Hogsmill @ Kingston Upon Thames 39012
URBEXT2000=0.3072

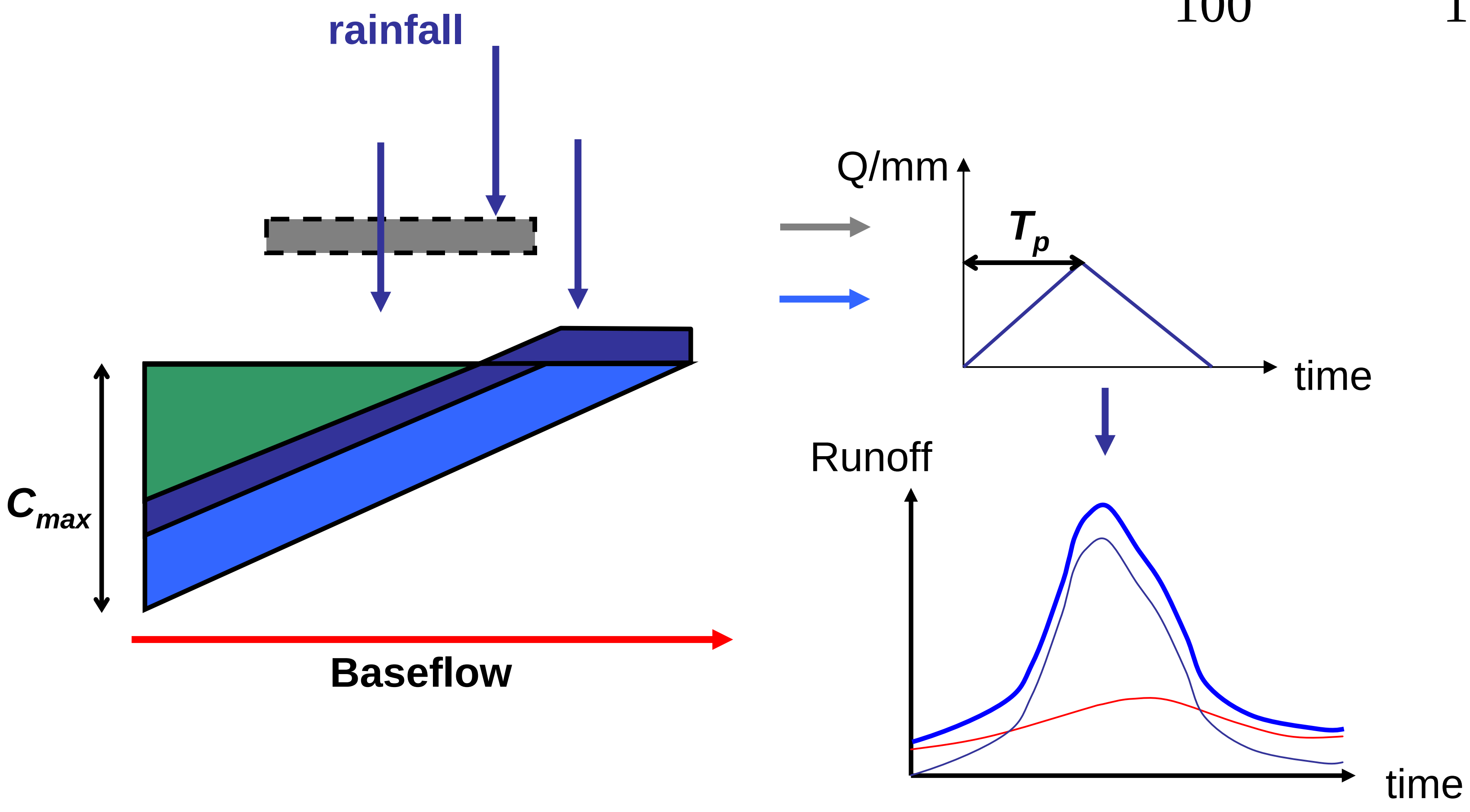


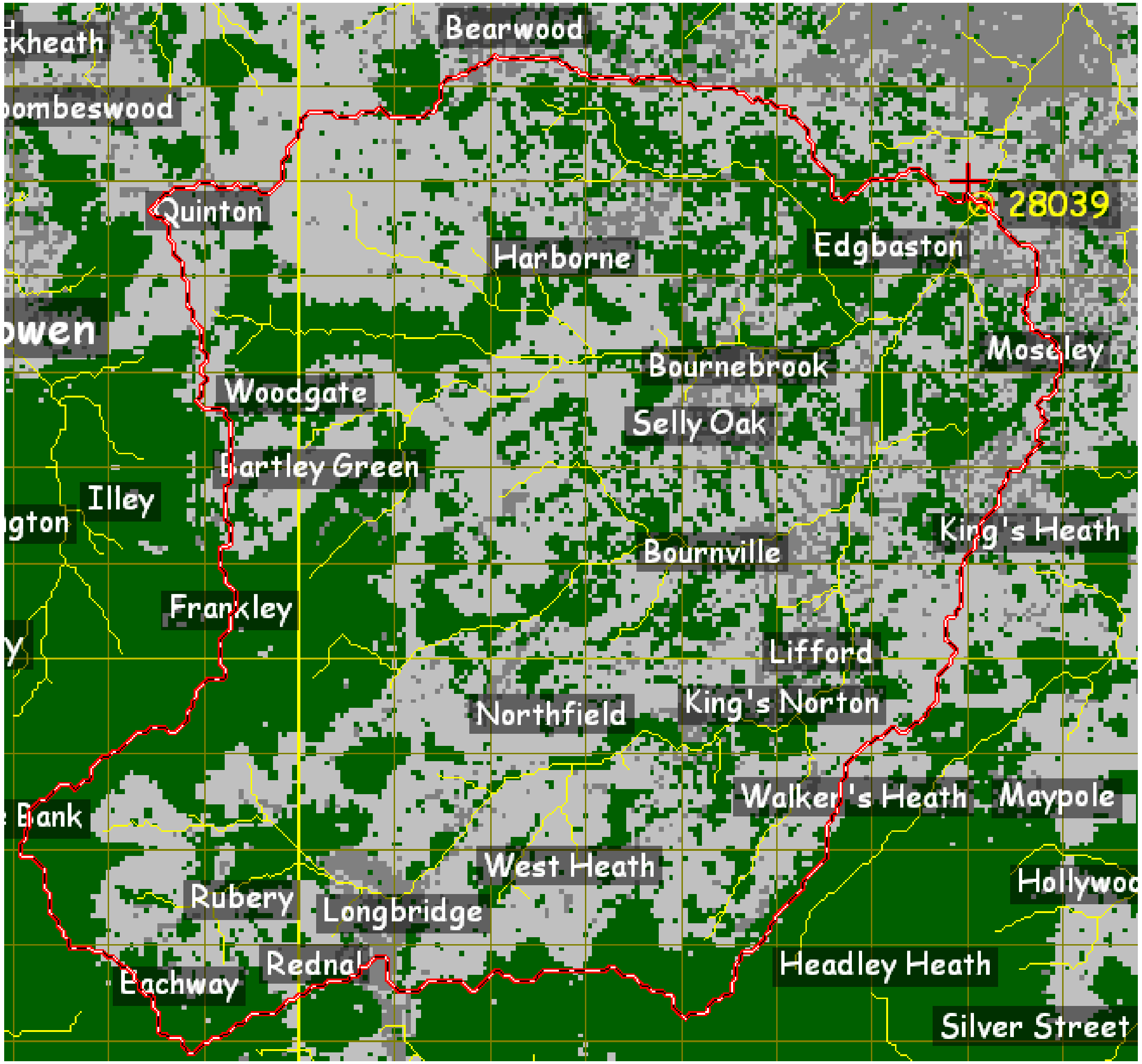
The Revitalised FEH/FSR rainfall-runoff model (ReFH)

I = overall percentage imperviousness

PR_u ~ 70% in UK

$$PR = PR_r \frac{100 - I}{100} + PR_u \frac{I}{100}$$





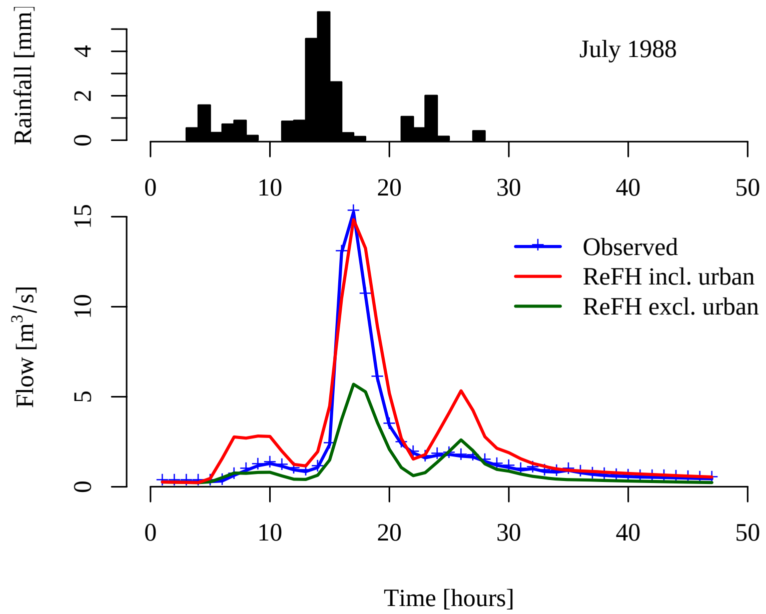
Urban extent from CEH land-cover map 1990

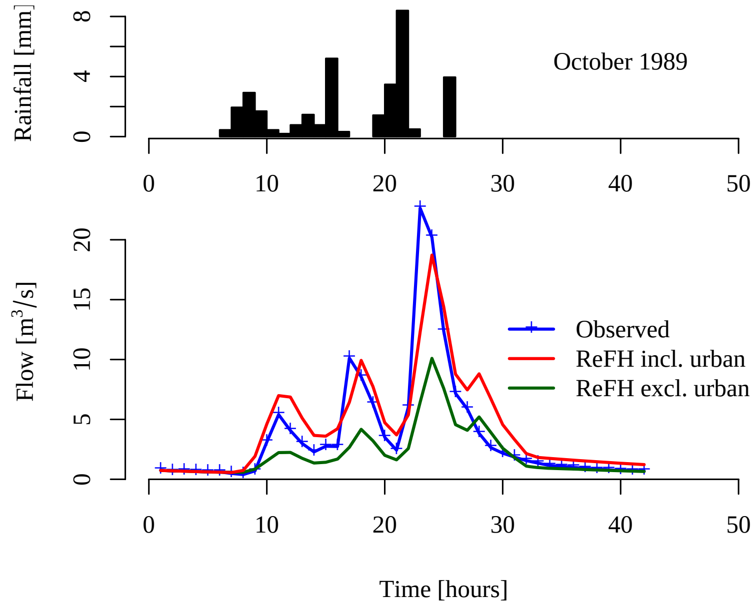
Catchment: 28039

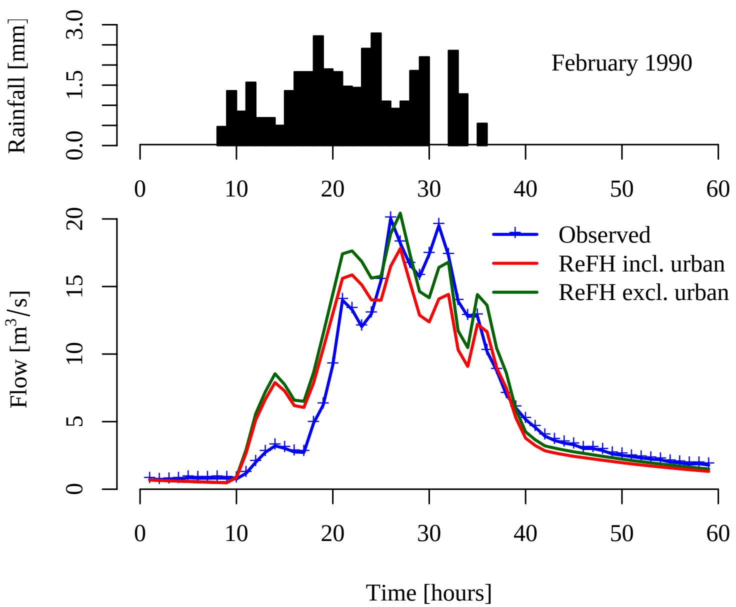
Area: 73.9 km²

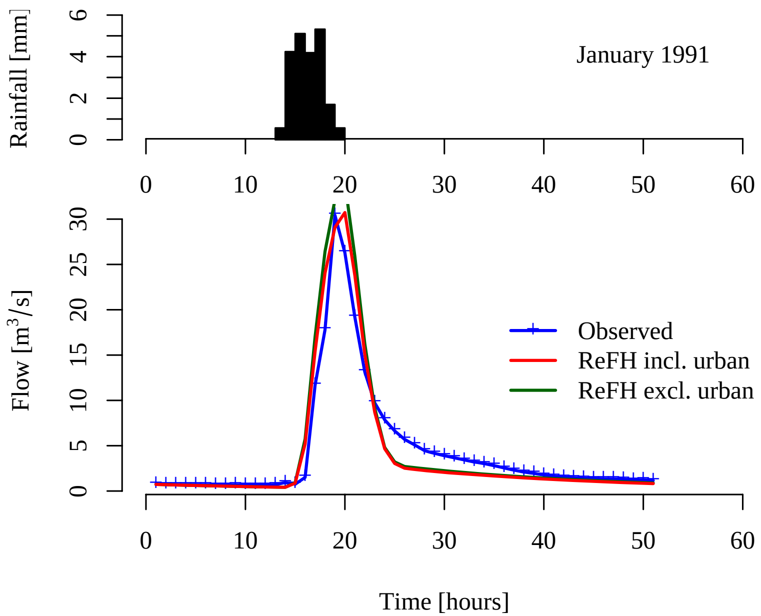
31 Flood events

1985 - 2000


July 1988
Rainfall [mm]
Flow [m3/s]
Observed
ReFH incl. urban
ReFH excl. urban
Time [hours]


October 1989
Rainfall [mm]
Flow [m3/s]
Observed
ReFH incl. urban
ReFH excl. urban
Time [hours]

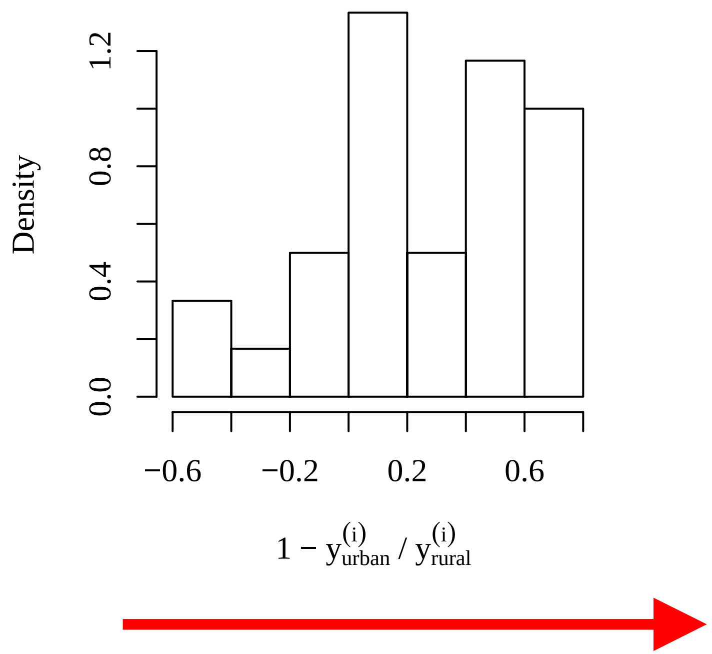

February 1990
Rainfall [mm]
Flow [m3/s]
Observed
ReFH incl. urban
ReFH excl. urban
Time [hours]


January 1991
Rainfall [mm]
Flow [m3/s]
Observed
ReFH incl. urban
ReFH excl. urban
Time [hours]

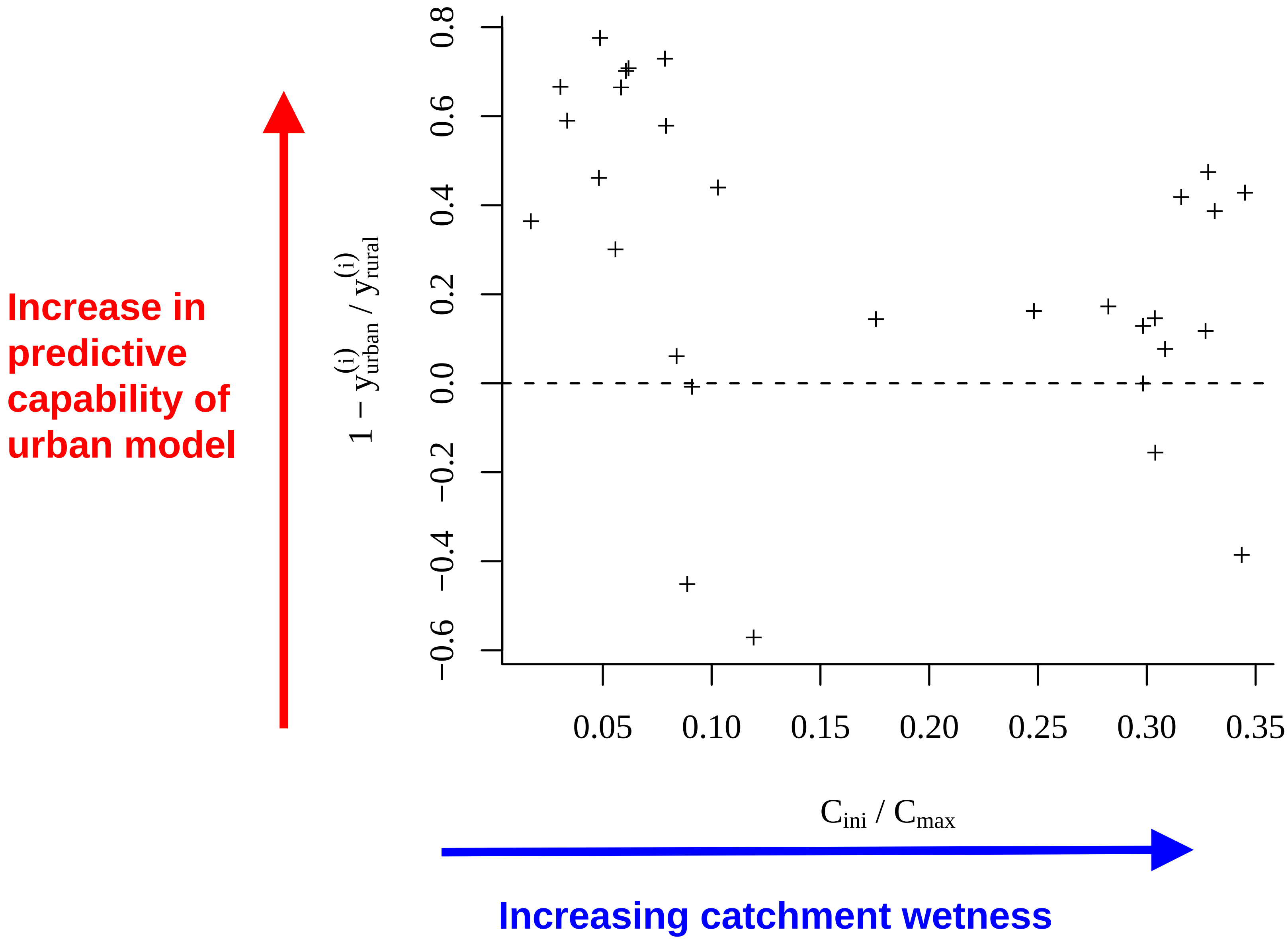
Predictive ability

$$y^{(i)} = \sum_{t=1}^{n_i} \left(Q_{obs,t}^{(i)} - Q_{sim,t}^{(-i)} \right)^2$$

$$\frac{y_{rural}^{(i)} - y_{urban}^{(i)}}{y_{rural}^{(i)}} = 1 - \frac{y_{urban}^{(i)}}{y_{rural}^{(i)}}$$



Increase in predictive capability of urban model


Increase in predictive capability of urban model
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
1 − y(i)urban / y(i)rural
0.05
0.10
0.15
0.20
0.25
0.30
0.35
Cini / Cmax
Increasing catchment wetness

Where next?

- More test beds
- More advanced hydrological models?
- Change vs. variability
- New data on land-use
  - More details
  - Temporal evolution of land-use
- Floods/droughts/…?