Forty years of hydrological monitoring in UK catchments:

its evolution, challenges and needs

Nick Chappell, Lancaster University

Lancaster University

UKRI Natural Environment Research Council

British Hydrological Society

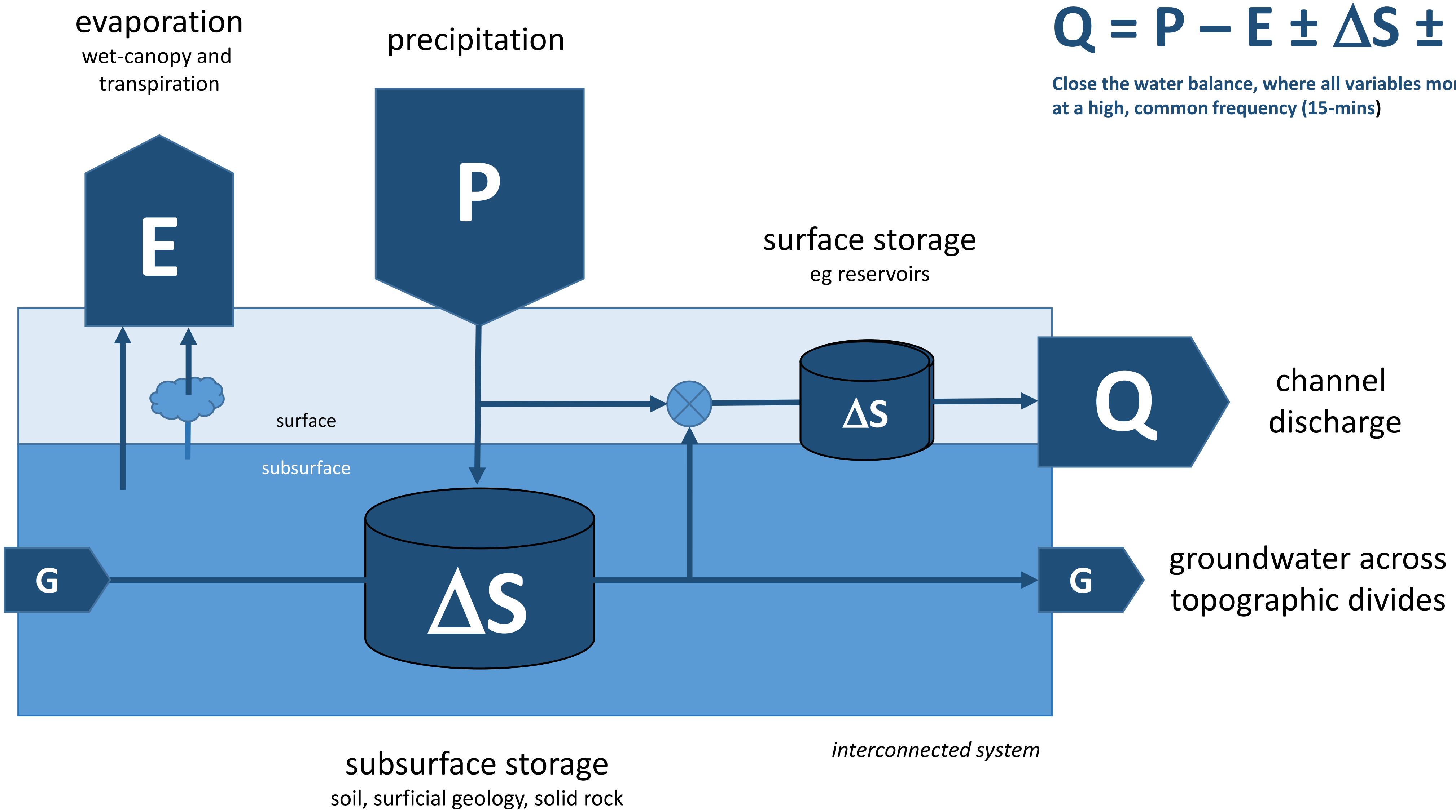
first BHS decade (1983-1992) vs current BHS decade (2014-2023)

focus on continuous monitoring within experimental catchments for discovery science

1. Technology
2. Basin scale
3. Network intensity
4. Comprehensiveness
5. Future prospects

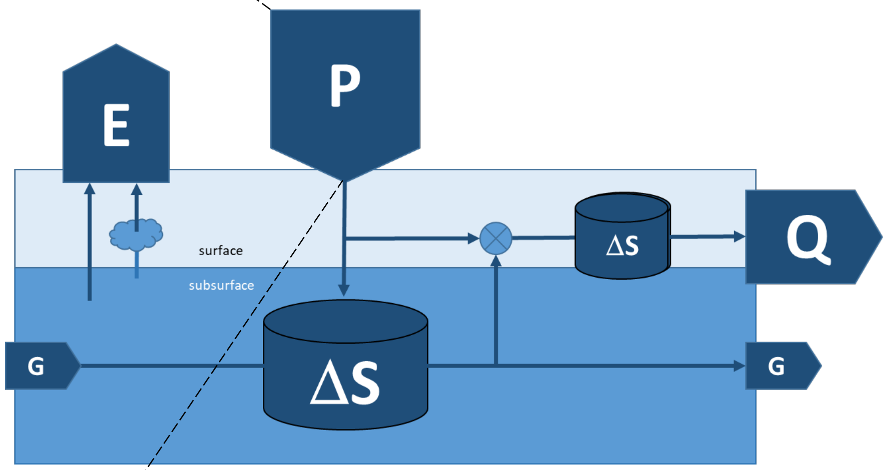
$$Q = P - E \pm \Delta S \pm G$$

Close the water balance, where all variables monitored at a high, common frequency (15-mins)



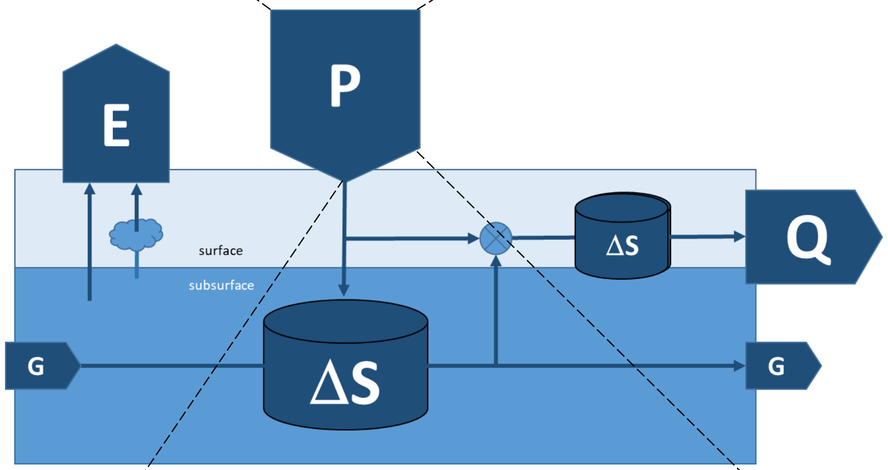
1. Technology

first BHS decade (1983-1992)



1. Technology

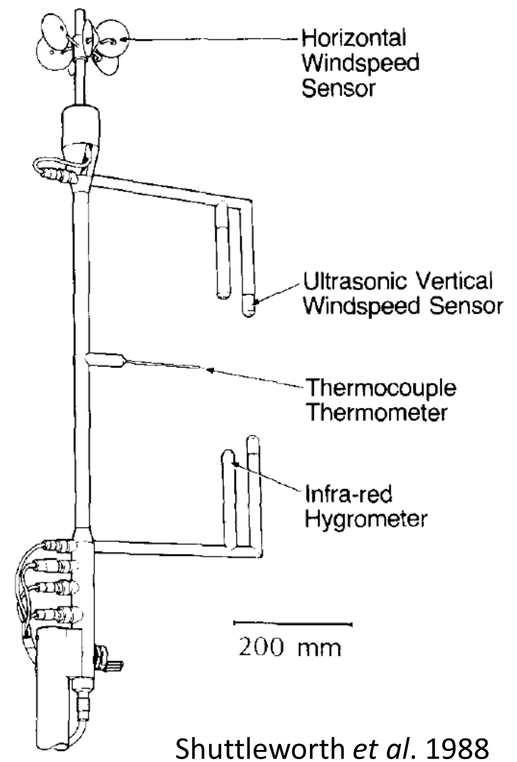
first BHS decade (1983-1992)



current BHS decade (2014-2023)

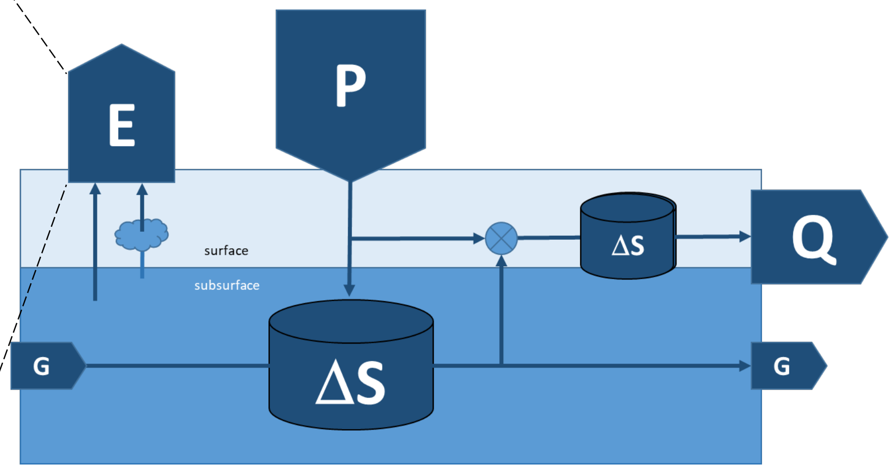
1. Technology

Hydra2



Shuttleworth *et al*. 1988
Agric. For. Meteorol.

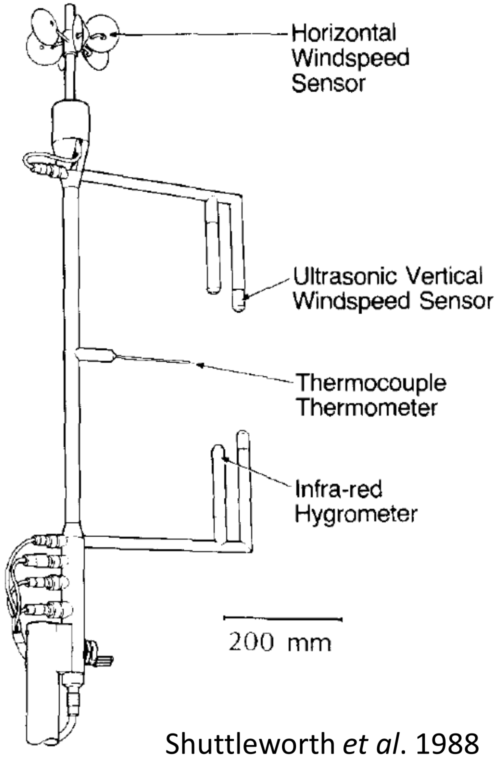
first BHS decade (1983-1992)



e.g., Eddy flux – researcher made

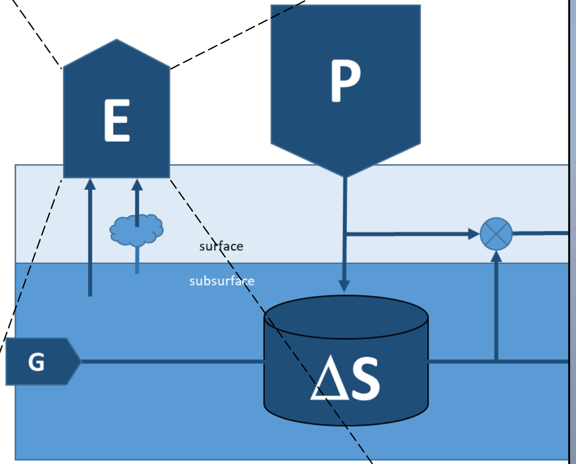
1. Technology

Hydra2



Shuttleworth *et al*. 1988
Agric. For. Meteorol.

first BHS decade (1983-1992)



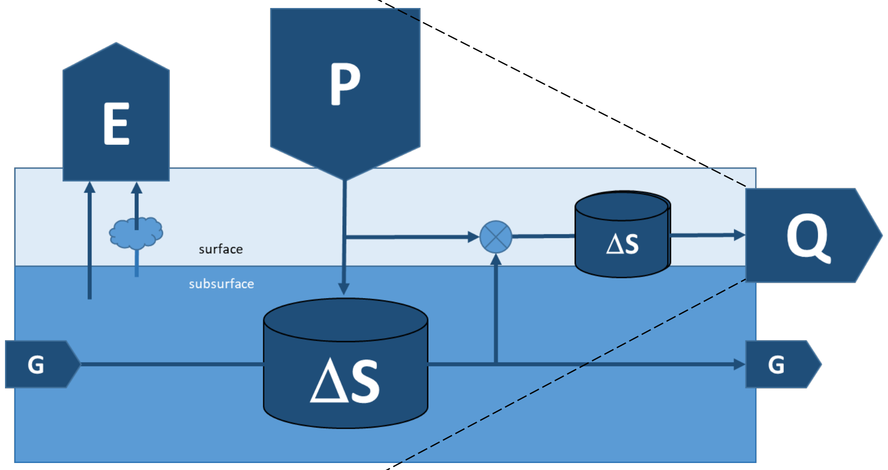
e.g., Eddy flux –
researcher made

current BHS decade (2014-2023)

commercially
available

1. Technology

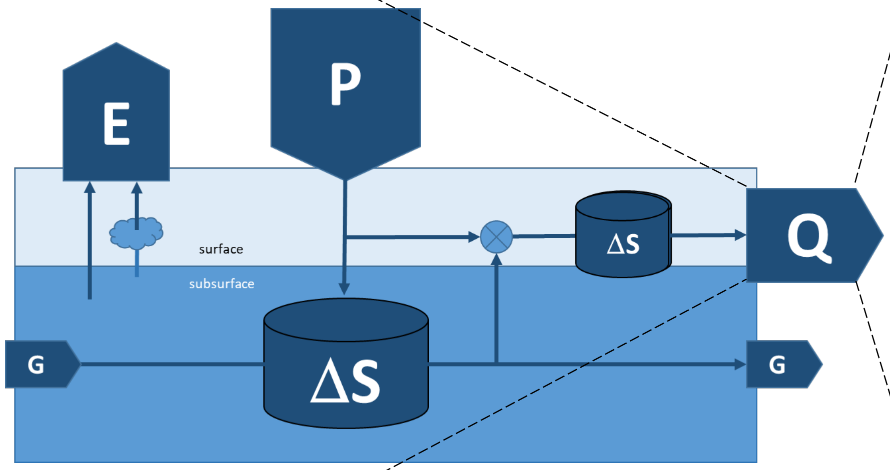
first BHS decade (1983-1992)



mostly manual
datalogger interrogation

1. Technology

first BHS decade (1983-1992)



mostly manual
datalogger interrogation

Telemetry loggers – easy to use
for researcher

current BHS decade (2014-2023)

1. Technology

benefits of telemetry

first BHS decade (1983-1992)

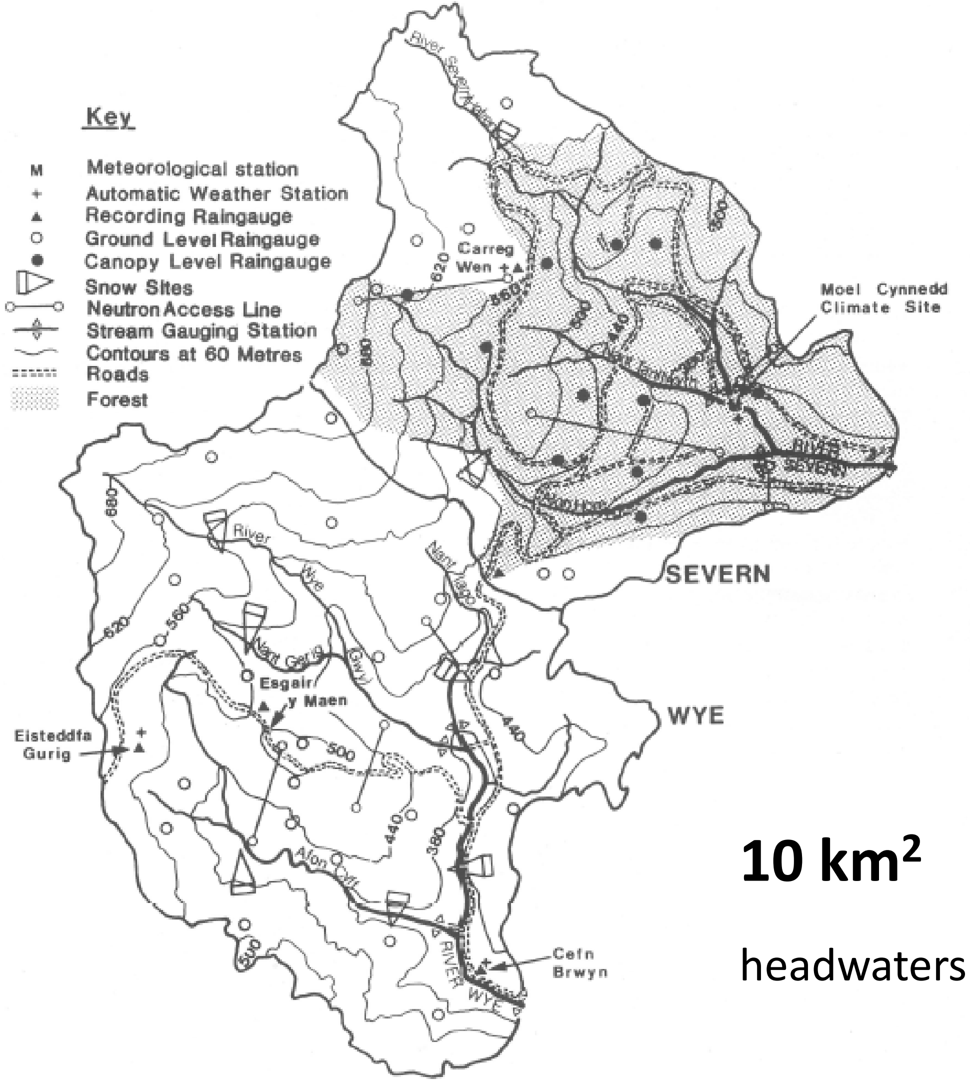
1/ Report error states – rectify with rapid field visit
2/ Auto concatenation of new data
3/ Show funder data collection live
4/ Show live data graphically – community/LLFA flood alerts
5/ API for real-time forecasting
6/ Easy data sharing for other end-users

Chappell & Mindham (2021) Research into methods of quantifying NFM effectiveness from direct observations in Cumbria (C-NFM): Lessons. Lancaster University Report to EA NFM programme

current BHS decade (2014-2023)

2. Basin scale

first BHS decade (1983-1992)



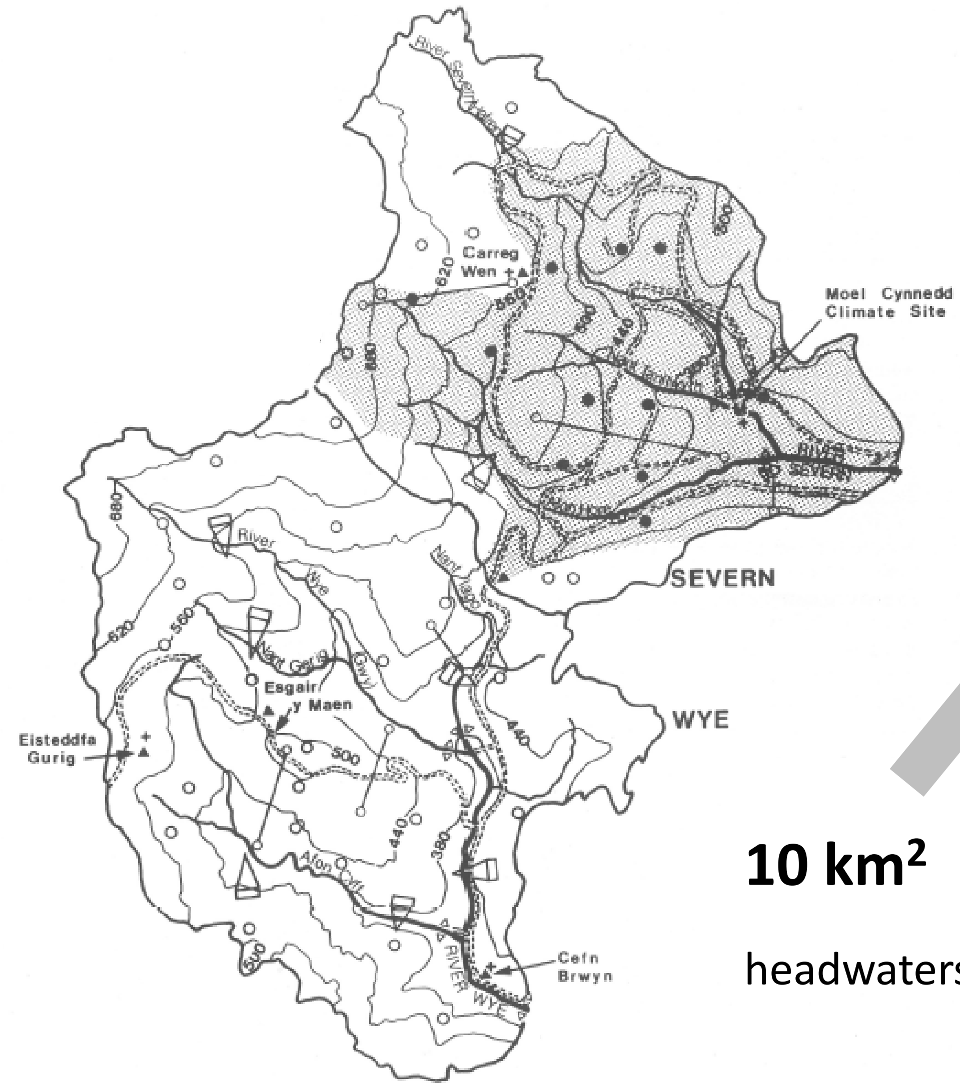
10 km²

headwaters

Kirby, Newson & Gilman 1991

2. Basin scale

first BHS decade (1983-1992) → current BHS decade (2014-2023)



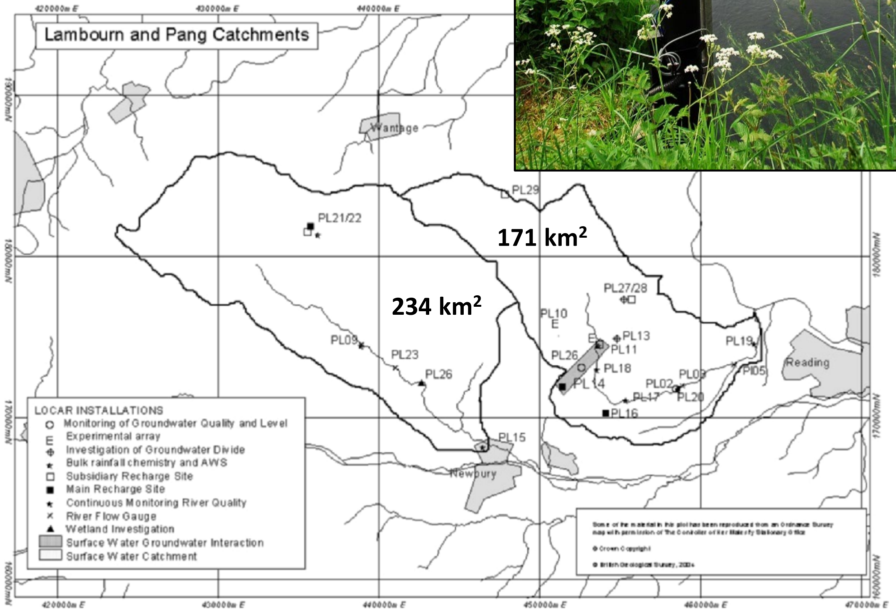
10 km^2

headwaters

100-200 km^2

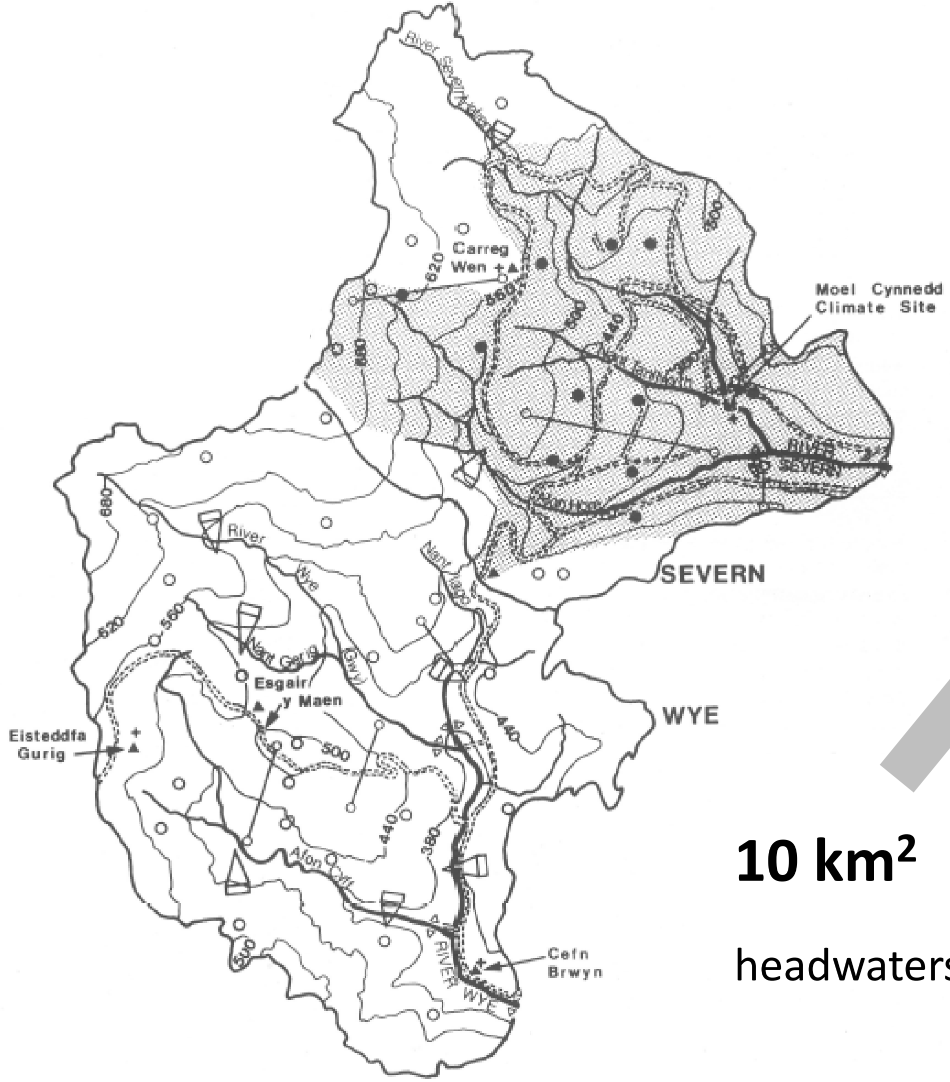
e.g., £10m LOCAR
2000-2006 (ended)

Wheater & Peach 2007
doi.org/10.1080/07900620420000248565



2. Basin scale

first BHS decade (1983-1992) → current BHS decade (2014-2023)



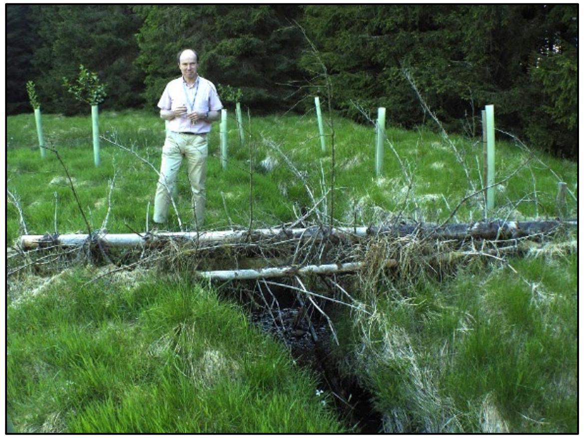
10 km²

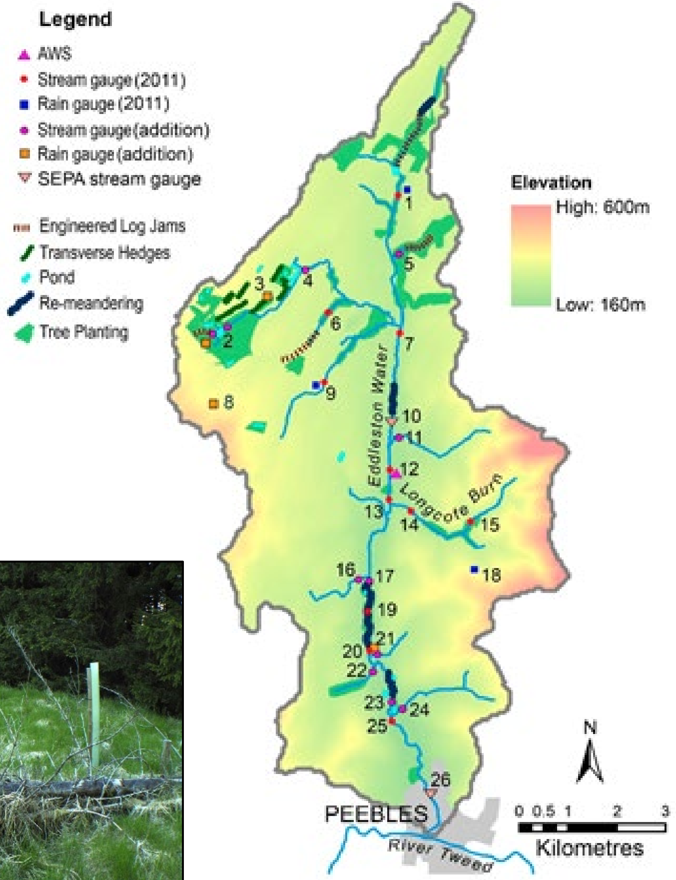
headwaters

100-200 km²

e.g., 69 km² Eddleston
2012-

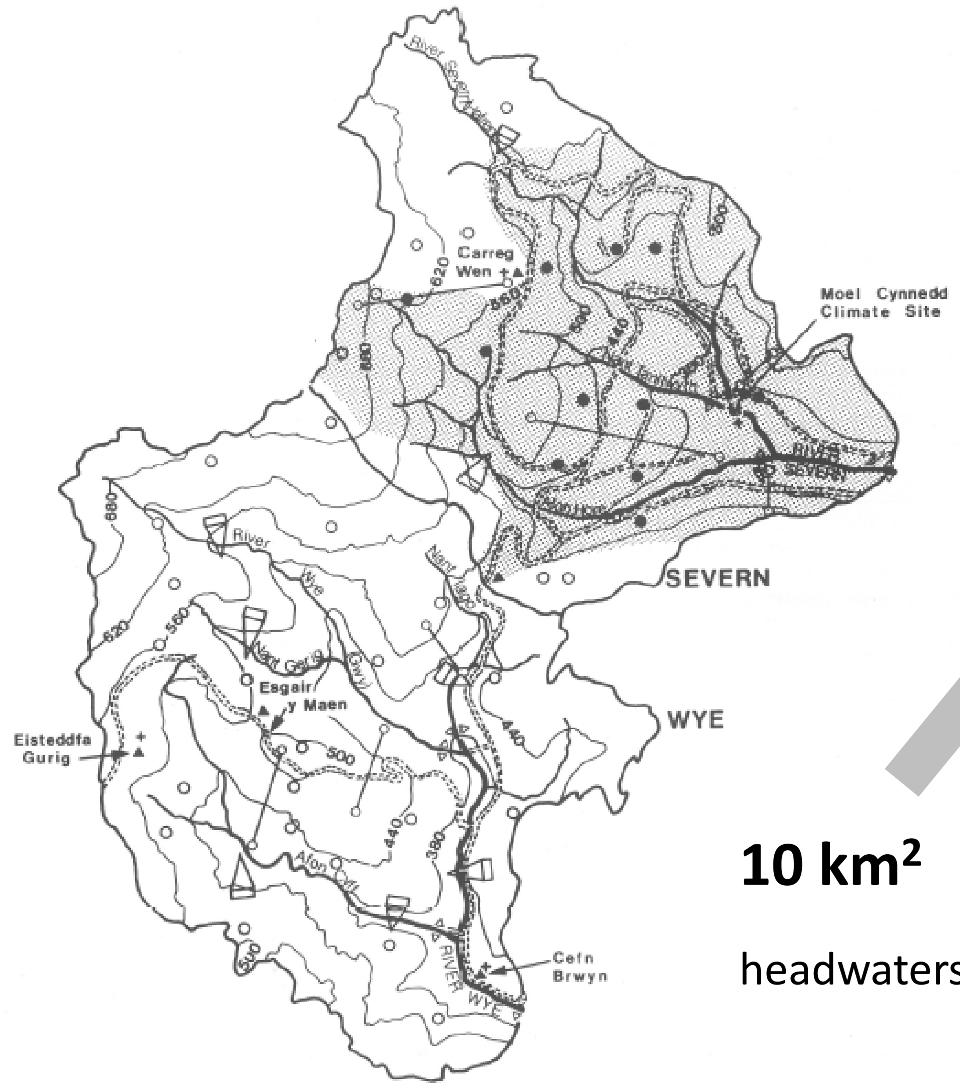
Spray et al 2022
doi.org/10.3390/w14152305





2. Basin scale

first BHS decade (1983-1992) → current BHS decade (2014-2023)



10 km²

headwaters

100-200 km²

need monitor intensively at 100-200 km² to incorporate

water supply interventions

(abstractions, reservoirs, treated sewage returns)

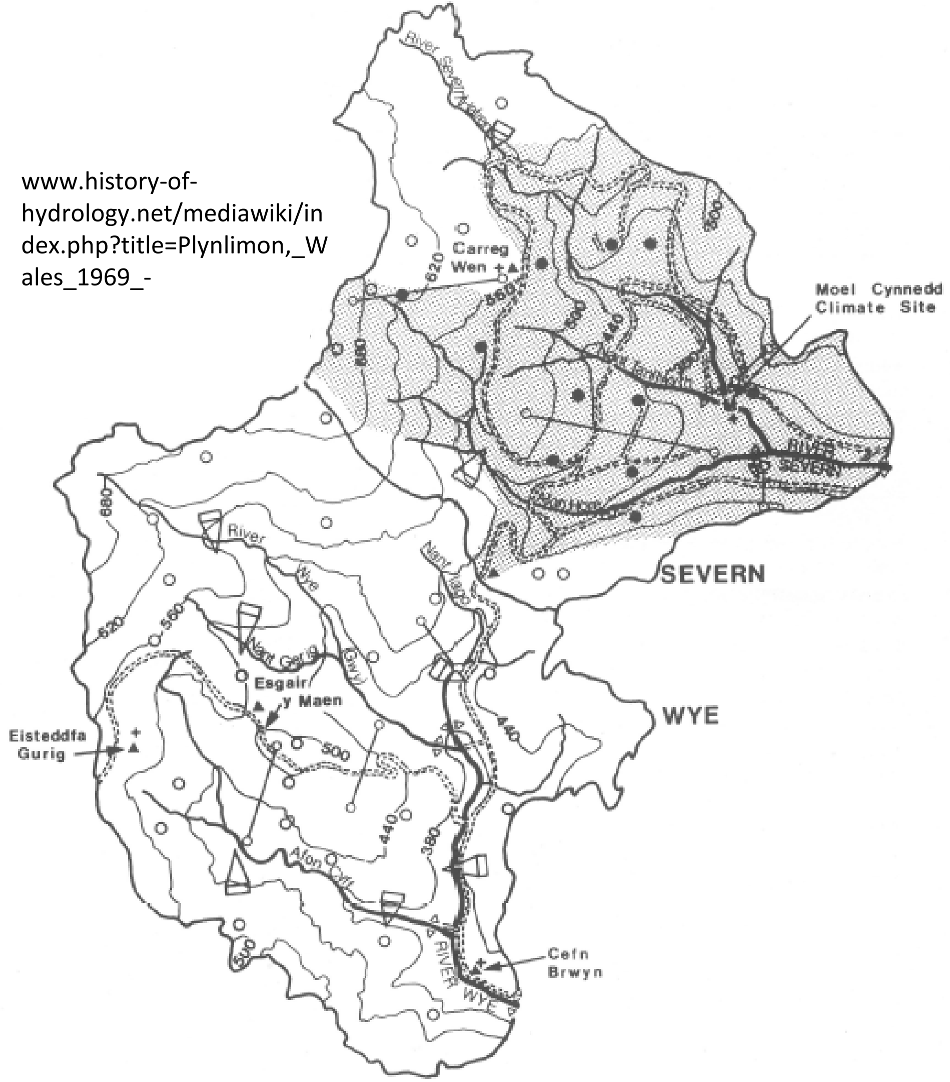
urban areas

large floodplains

3. Network intensity

first BHS decade (1983-1992)

www.history-of-hydrology.net/mediawiki/index.php?title=Plynlimon,_Wales_1969_-



e.g., Upper Hore flume 1985

Roberts & Crane 1997 Hydrol Earth Syst Sci 1: 477-482


L Hafren 1976


U Hafren 2004

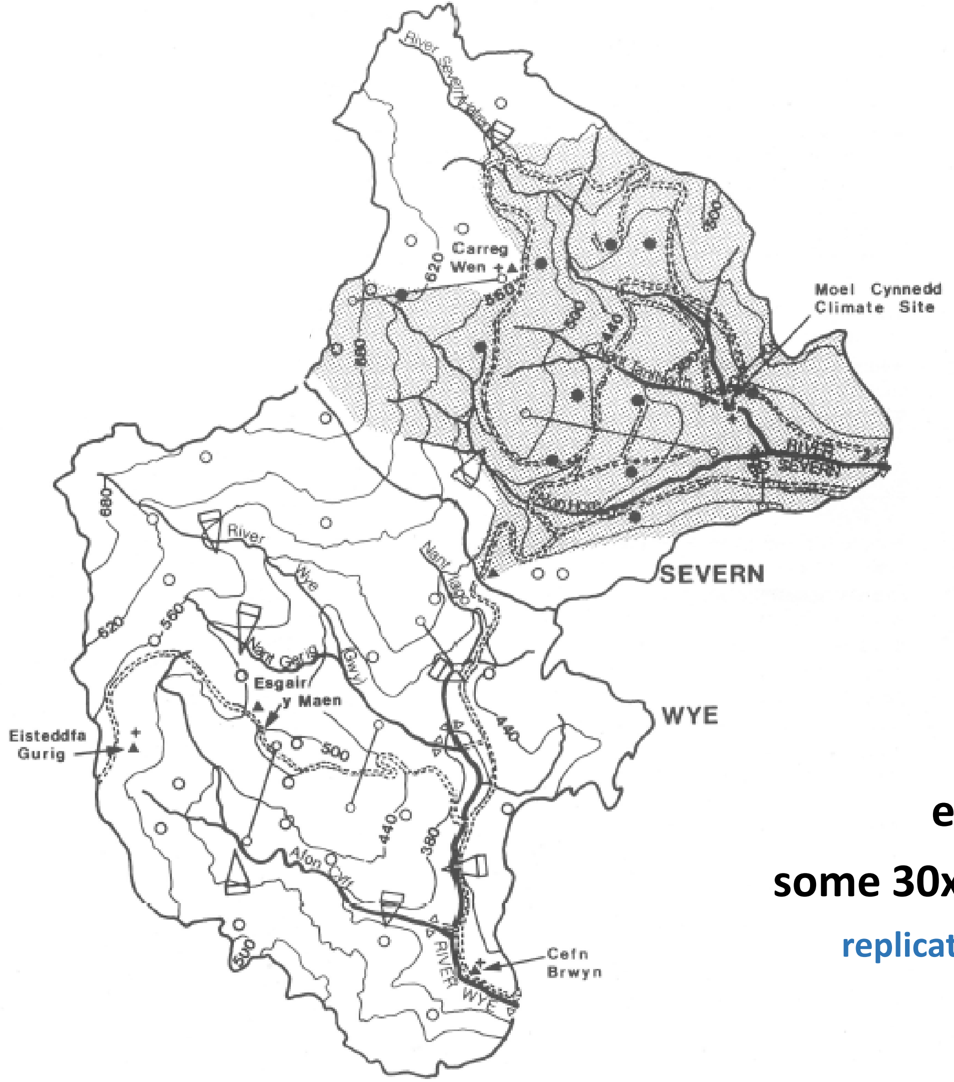
e.g., two Plynlimon experimental catchments

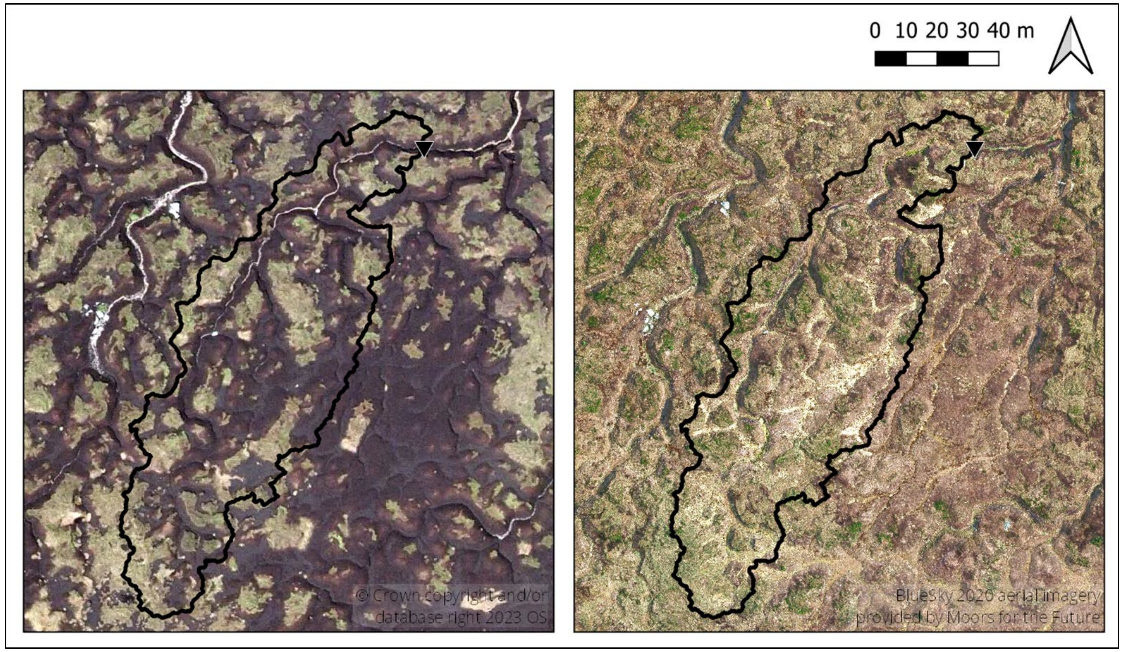
10 stream gauges over 19 km²

3. Network intensity

first BHS decade (1983-1992)

current BHS decade (2014-2023)





e.g., NERC Protect-NFM

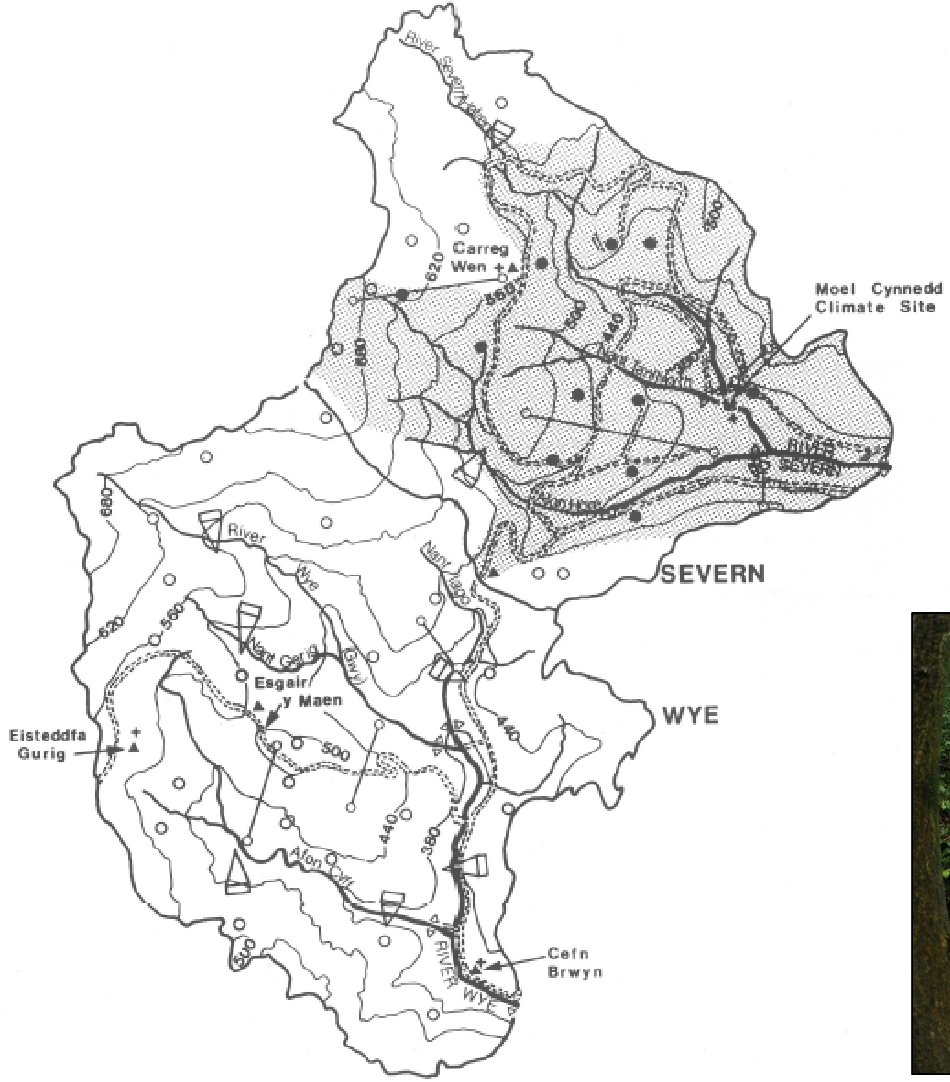
some 30x 0.1 km² 'nano-basins'

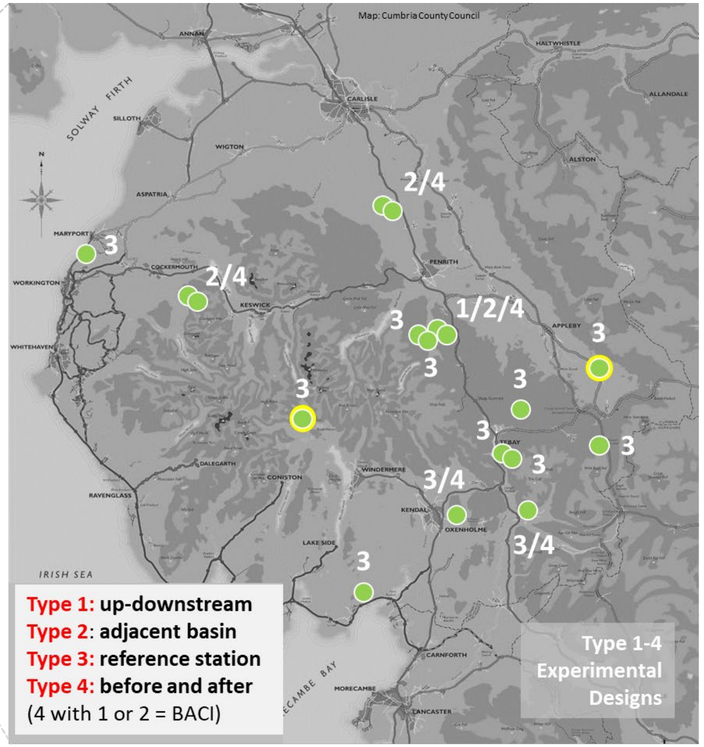
replicated peatland-restoration NFM

3. Network intensity

first BHS decade (1983-1992)

current BHS decade (2014-2023)





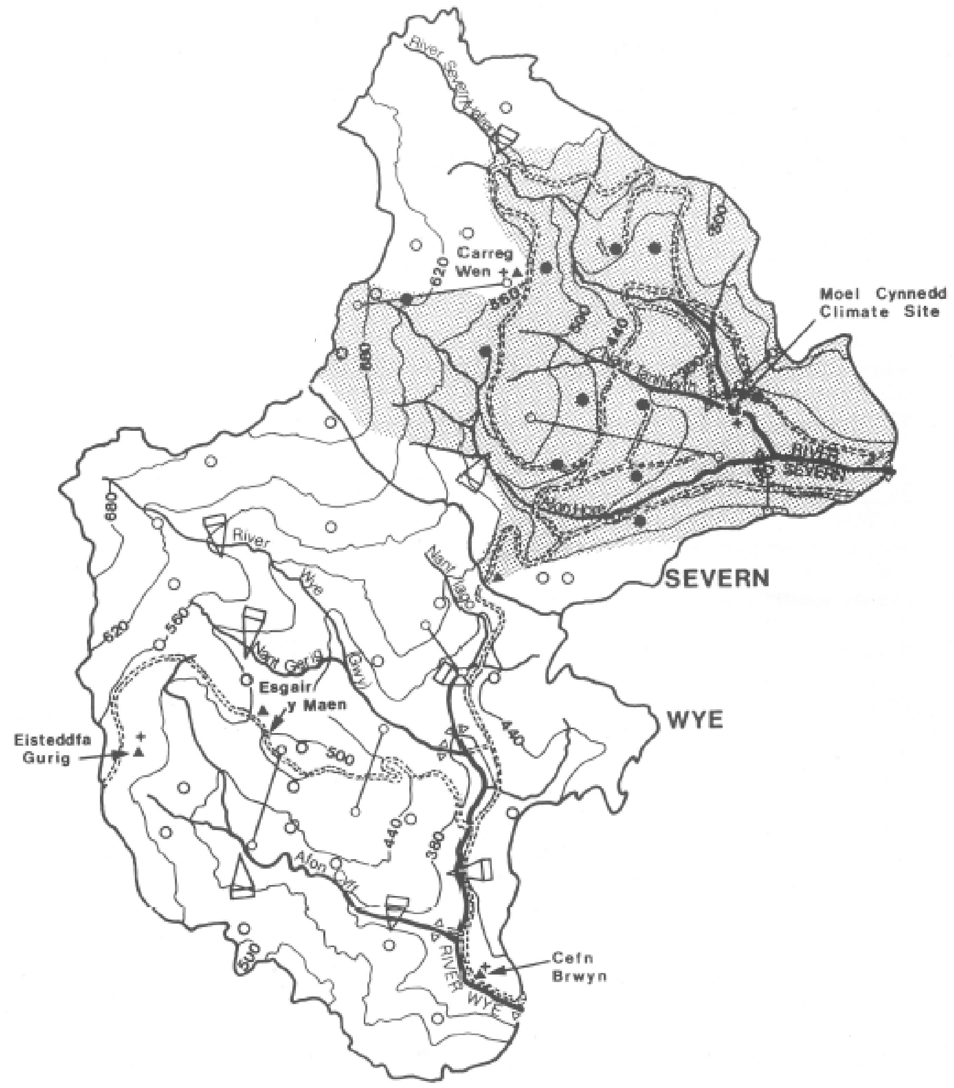
e.g., NERC Q-NFM

over 20x 1 km^2 micro-basin scale

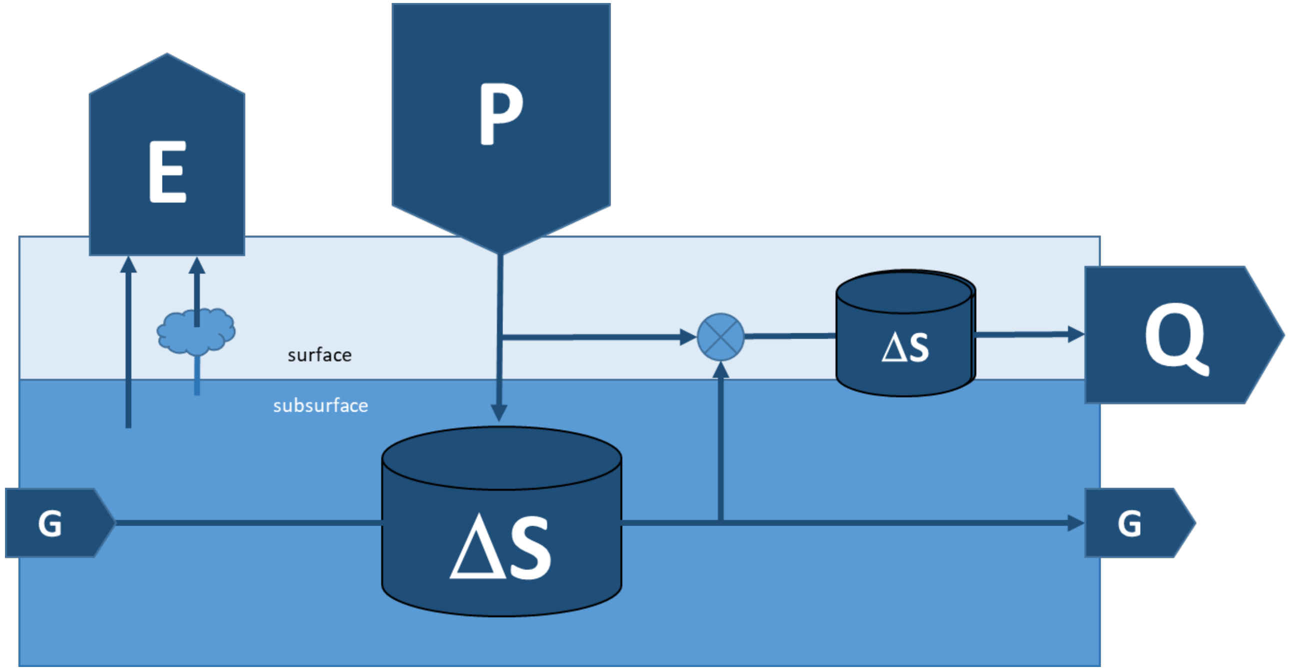
coverage of **diverse** NFM intervention types

4. Comprehensiveness

first BHS decade (1983-1992)



holistic catchment monitoring

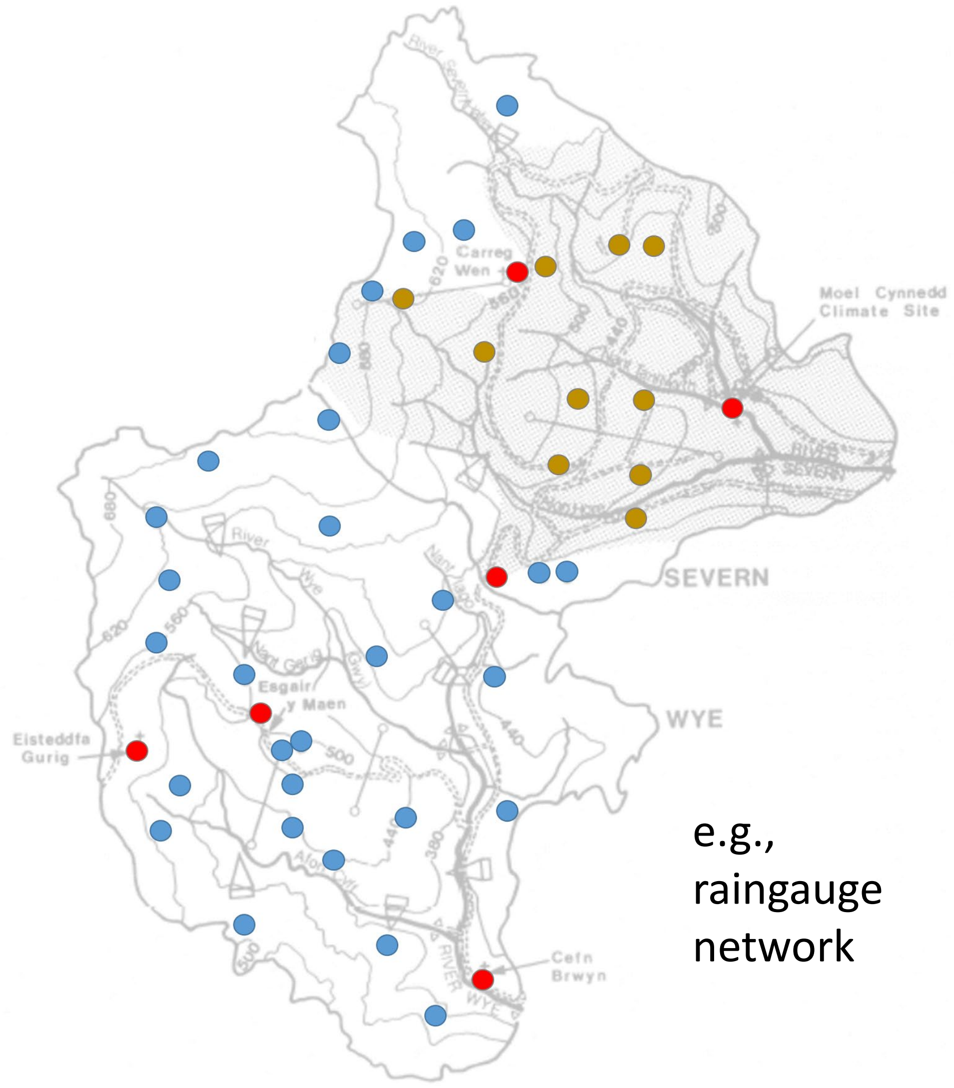


attempt to quantify all hydrological variables of interconnected system in ***sufficient detail*** *across whole instrumented basin*

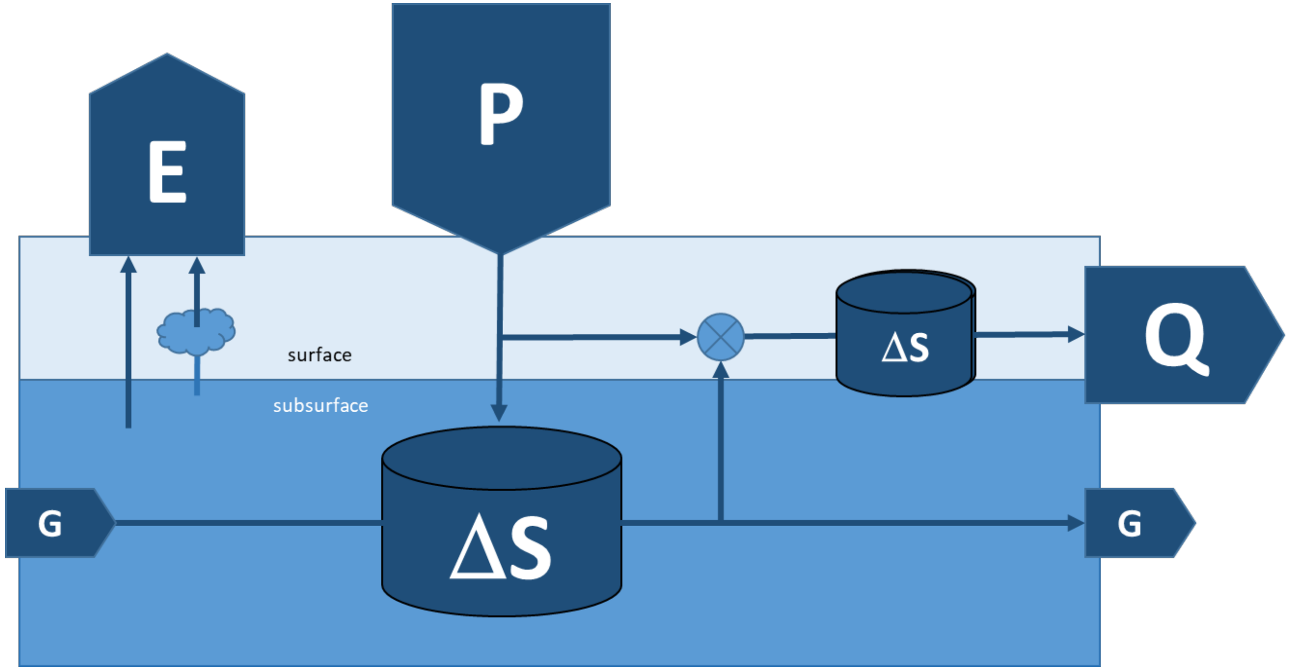
4. Comprehensiveness

first BHS decade (1983-1992)

holistic catchment monitoring



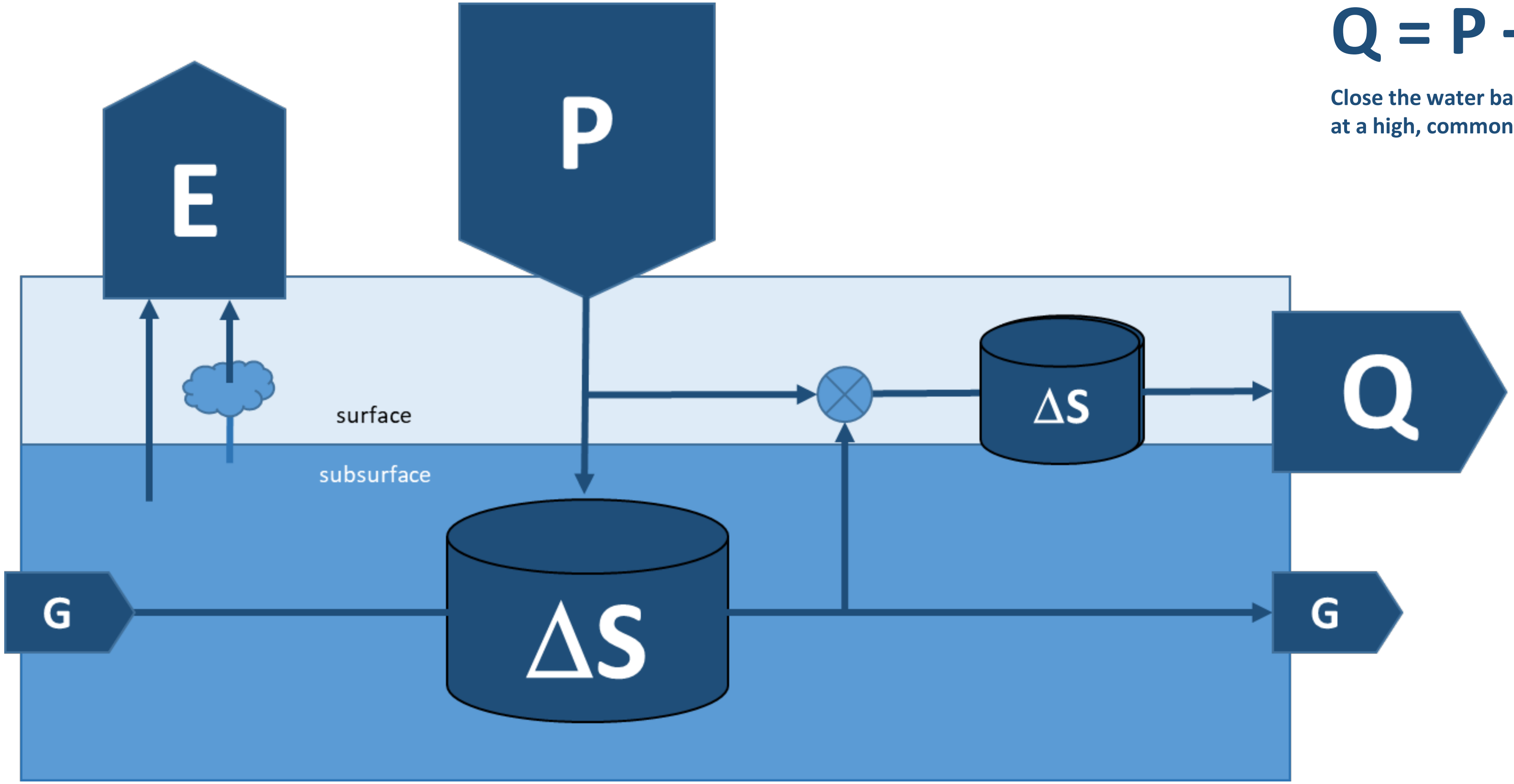
e.g., raingauge network



*attempt to quantify all hydrological variables of interconnected system in **sufficient detail** across whole instrumented basin*

4. Comprehensiveness

first BHS decade (1983-1992) → current BHS decade (2014-2023)



$$Q = P - E \pm \Delta S \pm G$$

Close the water balance, where all variables monitored at a high, common frequency (15-mins)

Are we doing that now?

4. Comprehensiveness

first BHS decade (1983-1992)

current BHS decade (2014-2023)

Received: 4 October 2019 | Accepted: 4 October 2019
DOI: 10.1002/hyp.13622

INVITED COMMENTARY

British Hydrological Society

Developing observational methods to drive future hydrological science: Can we make a start as a community?

Keith Beven[1] | Anita Asadullah[2] | Paul Bates[3] | Eleanor Blyth[4] | Nick Chappell[1] | Stewart Child[5] | Hannah Cloke[6] | Simon Dadson[4,7] | Nick Everard[2] | Hayley J. Fowler[8] | Jim Freer[3] | David M. Hannah[9] | Kate Heppell[10] | Joseph Holden[11] | Rob Lamb[12] | Huw Lewis[13] | Gerald Morgan[14] | Louise Parry[15] | Thorsten Wagener[16]

$$Q = P - E \pm \Delta S \pm G$$

Close the water balance, where all variables monitored at a high, common frequency (15-mins)

Are we doing that now?

*"...These knowledge gaps are illustrated by the fact that for many catchments we cannot close the water balance without **significant uncertainty**..."*

*"...This lack of water balance closure can also result from a lack of information about the influence of **water management** on water balance..."*

4. Comprehensiveness

first BHS decade (1983-1992) → current BHS decade (2014-2023)

Received: 4 October 2019 | Accepted: 4 October 2019
DOI: 10.1002/hyp.13622

INVITED COMMENTARY

British Hydrological Society

Developing observational methods to drive future hydrological science: Can we make a start as a community?

Keith Beven[1] | Anita Asadullah[2] | Paul Bates[3] | Eleanor Blyth[4] | Nick Chappell[1] | Stewart Child[5] | Hannah Cloke[6] | Simon Dadson[4,7] | Nick Everard[2] | Hayley J. Fowler[8] | Jim Freer[3] | David M. Hannah[9] | Kate Heppell[10] | Joseph Holden[11] | Rob Lamb[12] | Huw Lewis[13] | Gerald Morgan[14] | Louise Parry[15] | Thorsten Wagener[16]

$$Q = P - E \pm \Delta S \pm G$$

Close the water balance, where all variables monitored at a high, common frequency (15-mins)

Are we doing that now?

"...need to improve observations of __all__ the water balance components..."

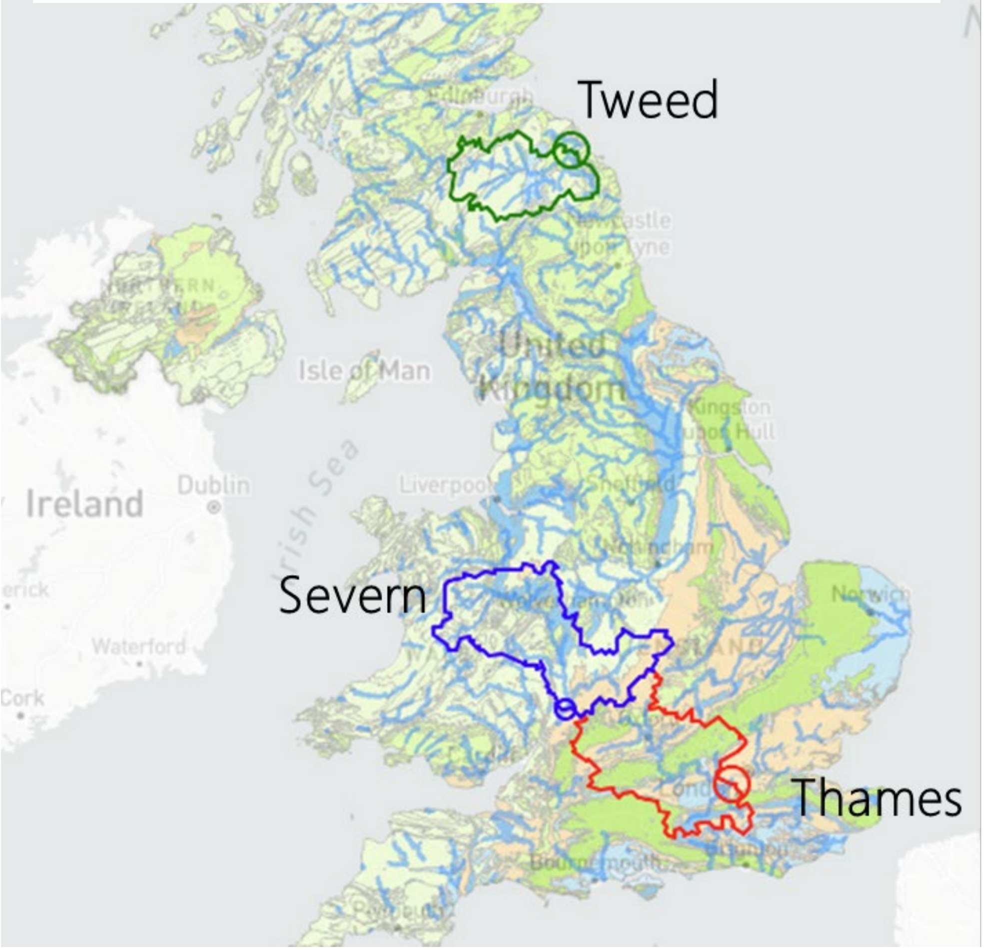
"...means better observational methods for all of the terms in the water balance equation as well as the __tracer and quality__ observations..."

5. Future prospects

FDRI
FLOODS & DROUGHTS RESEARCH INFRASTRUCTURE

Single UK Observatory

comprising of 3 comprehensively instrumented +100 km^2 sub-catch capturing UK **end-members** of hydrological behaviour



5. Future prospects

FDRI Delivery partners

UK Centre for Ecology & Hydrology

BGS

University of BRISTOL

Imperial College London

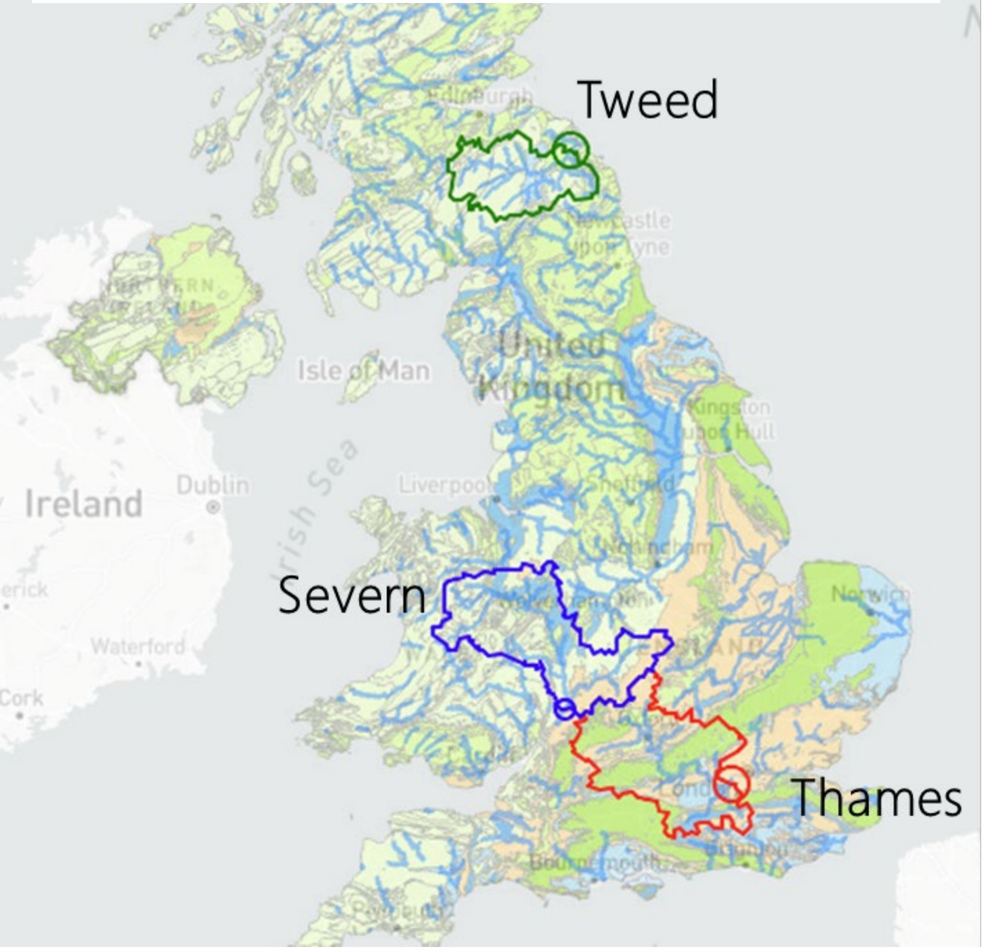
British Hydrological Society

Wagener *et al.*, 2019
Hydrol Processes

e.g., groundwater vs steep mountain dominated, also capturing West-East gradients and water quality contrasts

Single UK Observatory

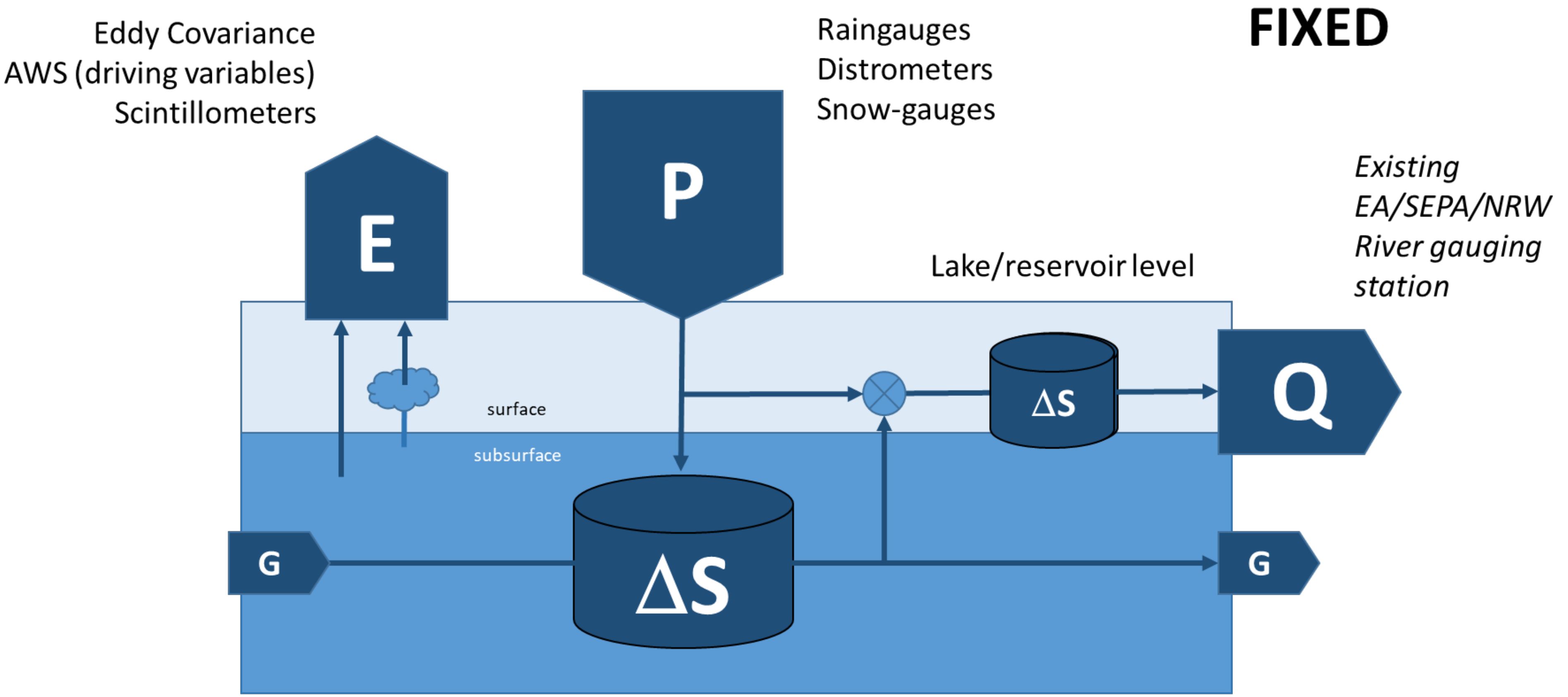
comprising of 3 comprehensively instrumented +100 km^2 sub-catch capturing UK **end-members** of hydrological behaviour



UKRI
Natural Environment Research Council

FDRI
FLOODS & DROUGHTS RESEARCH INFRASTRUCTURE

5. Future prospects

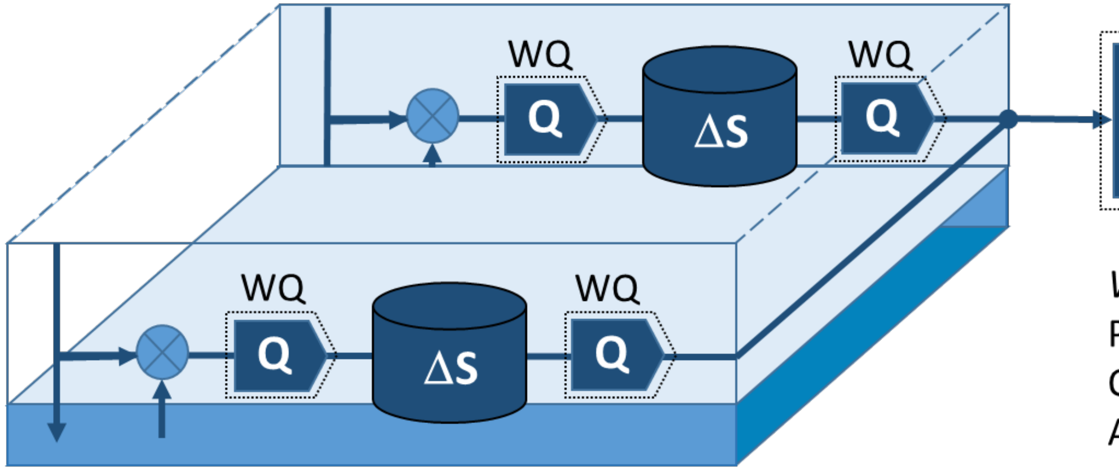


Shallow: Tensiometry; TDR; Cosmic Ray Neutron Sensing
Deep: Nested piezometers; Tensiometry; Electrical Resistance Tomography

5. Future prospects

FIXED

Water tracers:
Optical WQ
sondes



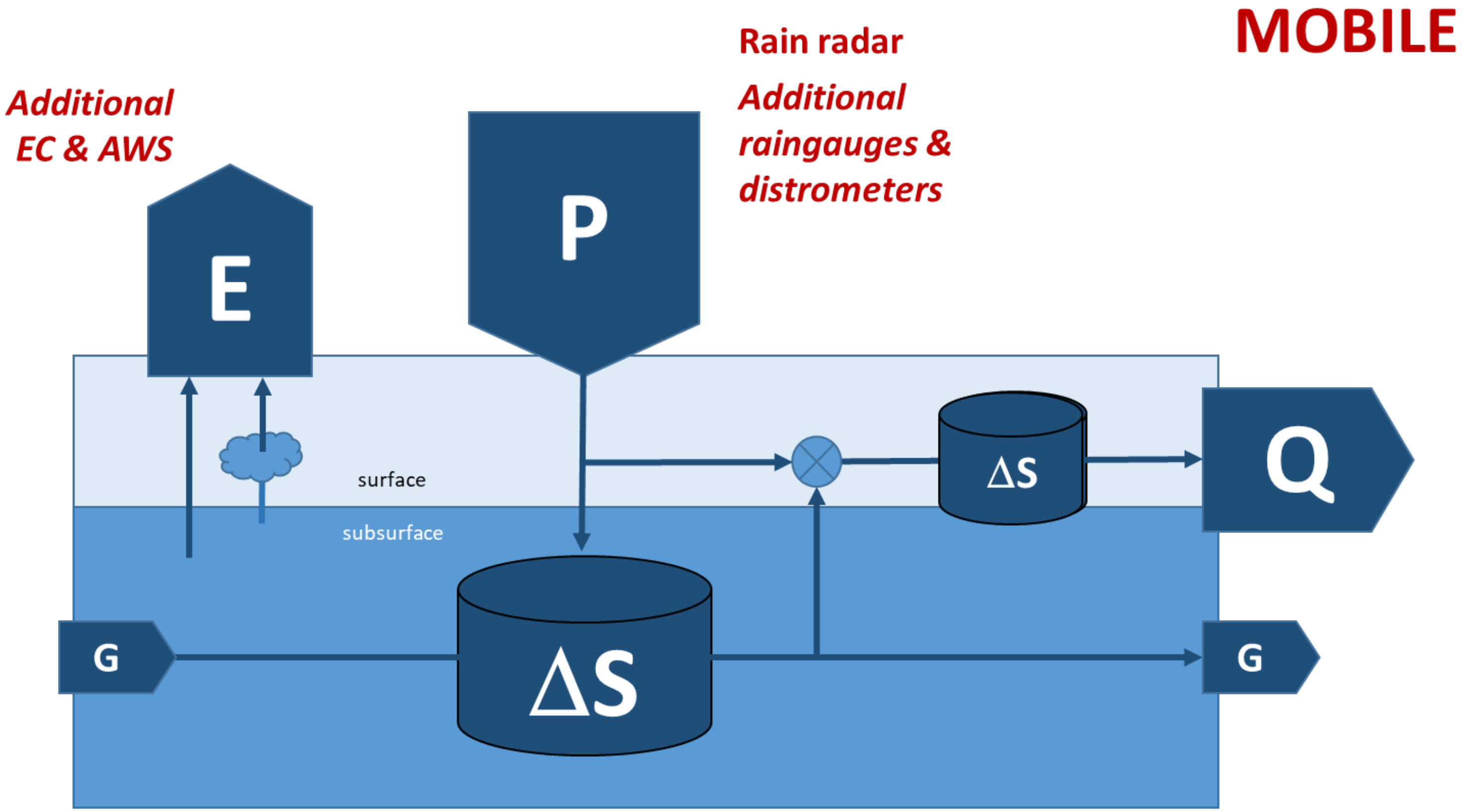
WQ

Water tracers:
PO_4-P, NO_3-N analysers
Optical WQ sondes
ALS (isotopes etc.)

Distributed discharge:
Gauging structures
Level sensors
SideADCP, radar, video, cont dilution

Water tracers:
Optical WQ sondes
ALS (isotopes etc.)
Temperature tracing

5. Future prospects



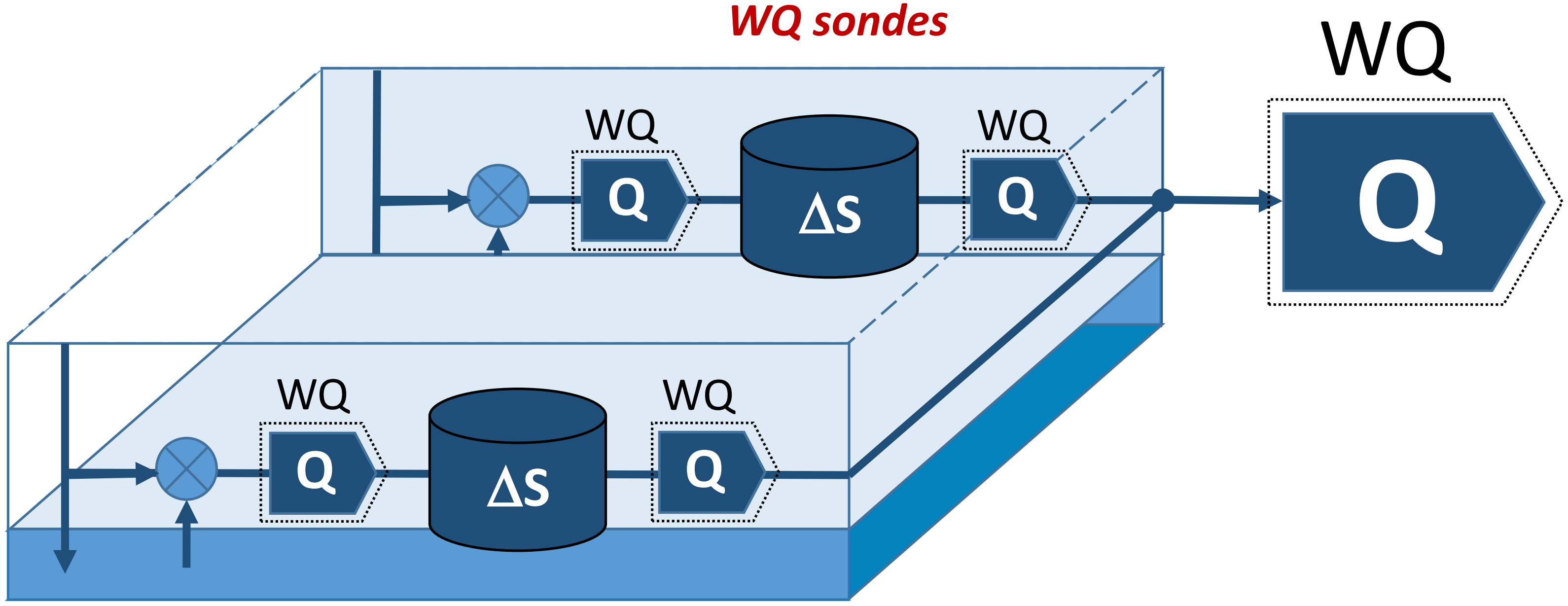
Drone L-band radar; Pump/packer test; water sampler / tracer test kit

Additional Tensiometry; TDR; Cosmic Ray Neutron Sensing

5. Future prospects

MOBILE

Additional water tracers: Optical WQ sondes



Drone LIDAR survey (channel bathymetry)
RTK GPS topo survey stations

Additional distributed discharge:
Gauging structures; Level sensors;
SideADCP, radar, video, cont dilution

Additional water tracers:
Optical WQ sondes
ALS (isotopes etc.)
Temperature tracing

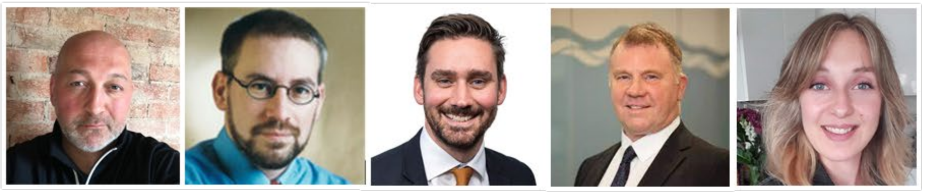
5. Future prospects

Community Advisory Group

FDRI FLOODS & DROUGHTS RESEARCH INFRASTRUCTURE

Nick Chappell	Hannah Cloke	Lindsay Beevers	Andrew Tyler	Isabelle Durance	Joseph Holden	David Hannah	Jamie Hannaford
Lancaster	Reading	Edinburgh	Stirling	Cardiff	Leeds	Birmingham	UKCEH

NERC have been preparing bid for £38M funding



Sean Longfield	Peter Singleton	Benn Kidd	Steve Kay	Imogen Barnsley
EA	SEPA	ARUP	UKWIR	JBA

Tom Griffin	Philip James
STFC	Newcastle

your interests represented

5. Future prospects

Now time for your engagement to finalise design & deliver UK monitoring platform

to enable UK hydrologists to deliver **next generation internationally-significant science** funded by NERC Thematic & other programmes

5. Future prospects

AGU PUBLICATIONS

Water Resources Research

REVIEW ARTICLE

10.1002/2014WR016839

Special Section:
The 50th Anniversary of Water Resources Research

Whither field hydrology? The need for discovery science and outrageous hydrological hypotheses

T. P. Burt[1] and J. J. McDonnell[2,3]

[1]Department of Geography, Durham University, Durham, UK, [2]Global Institute for Water Security, School of Environment and Sustainability, University of Saskatchewan, Saskatoon, Saskatchewan, Canada, [3]School of Geosciences, University of Aberdeen, Aberdeen, UK

Key Points:
- Reviews benchmark WRR on runoff generation
- Discusses the current lack of field work in hydrology
- Review is context for a vision for the future

Correspondence to:
T. P. Burt,
t.p.burt@durham.ac.uk

Citation:
Burt, T. P., and J. J. McDonnell (2015), Whither field hydrology? The need for discovery science and outrageous hydrological hypotheses, *Water Resour. Res.*, *51*, 5919–5928, doi:10.1002/2014WR016839.

Abstract Field hydrology is on the decline. Meanwhile, the need for new field-derived insight into the age, origin and pathway of water in the headwaters, where most runoff is generated, is more needed than ever. *Water Resources Research* (WRR) has included some of the most influential papers in field-based runoff process understanding, particularly in the formative years when the knowledge base was developing rapidly. Here we take advantage of this 50th anniversary of the journal to highlight a few of these important field-based papers and show how field scientists have posed strong and sometimes outrageous hypotheses—approaches so needed in an era of largely model-only research. We chronicle the decline in field work and note that it is not only the quantity of field work that is diminishing but its character is changing too: from discovery science to data collection for model parameterization. While the latter is a necessary activity, the loss of the former is a major concern if we are to advance the science of watershed hydrology. We outline a vision for field research to seek new fundamental understanding, new mechanistic explanations of how watershed systems work, particularly outside the regions of traditional focus.

THANK YOU!