Quantifying catchment-scale coarse sediment dynamics in British rivers: Pre-fieldtrip briefing

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University of the West of England

EPSRC Grant: EP/FP202511/1

Outline…

1. Identification of the problem

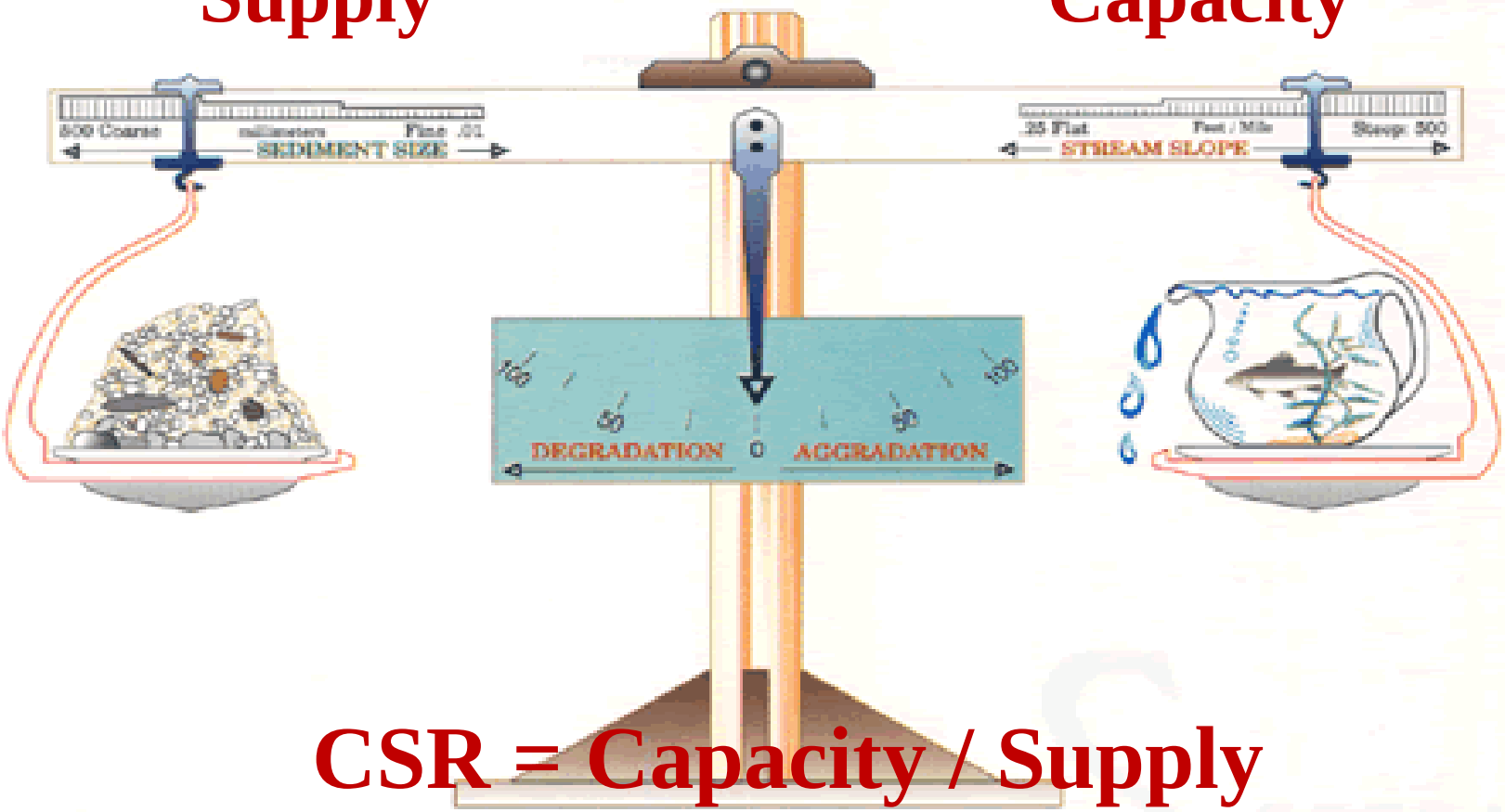
2. Development of a new approach

3. Assessing the new approach

1. Identification of the problem

Supply

Capacity



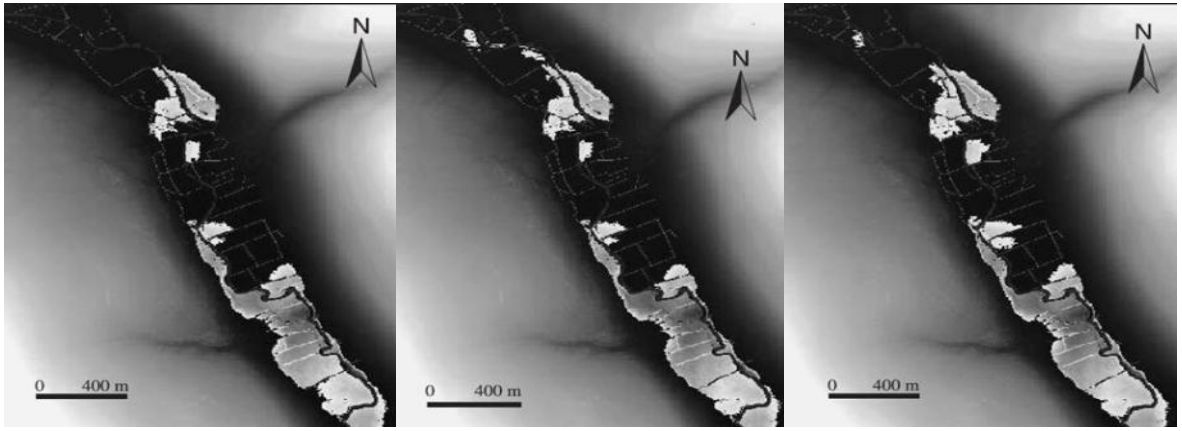
CSR = Capacity / Supply

(Sediment LOAD) x (Sediment SIZE) ✂ (Stream SLOPE) x (Stream DISCHARGE)

CSR<1 - Net sediment gain

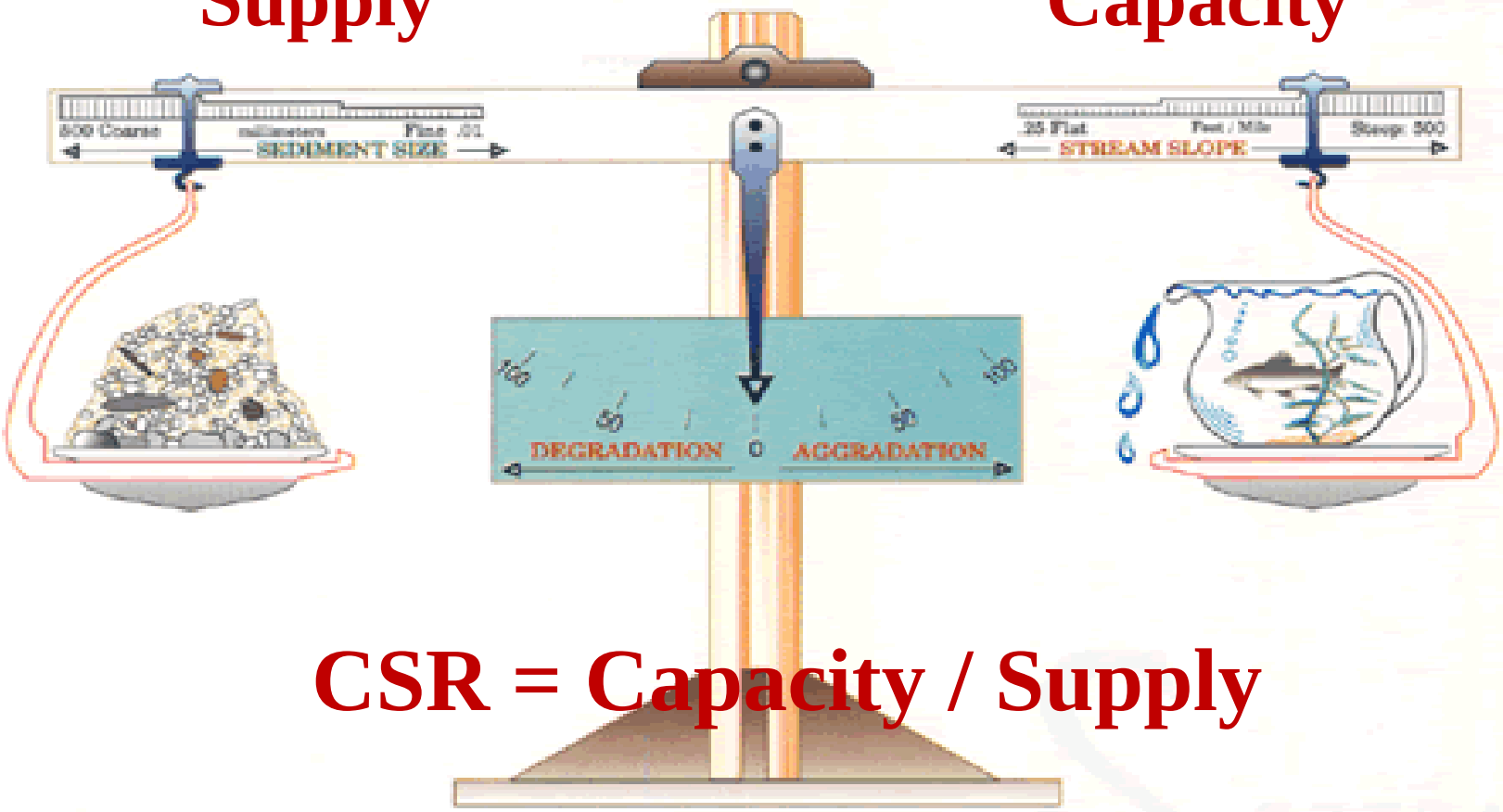
"…relatively short duration channel configuration changes, in this case over a 16-month period, can lead to substantial changes in inundated areas…the increase in inundated area was almost one-half of the increase in inundated area estimated as resulting from simulated climate change to the 2050s"

(Lane et al, 2007)



Supply

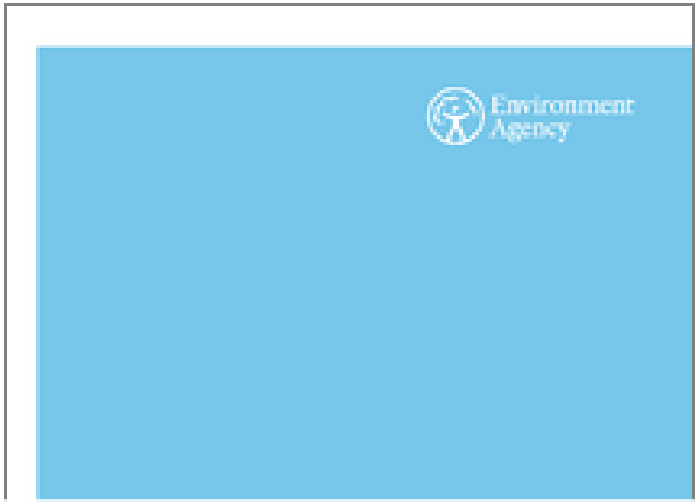
Capacity



CSR = Capacity / Supply

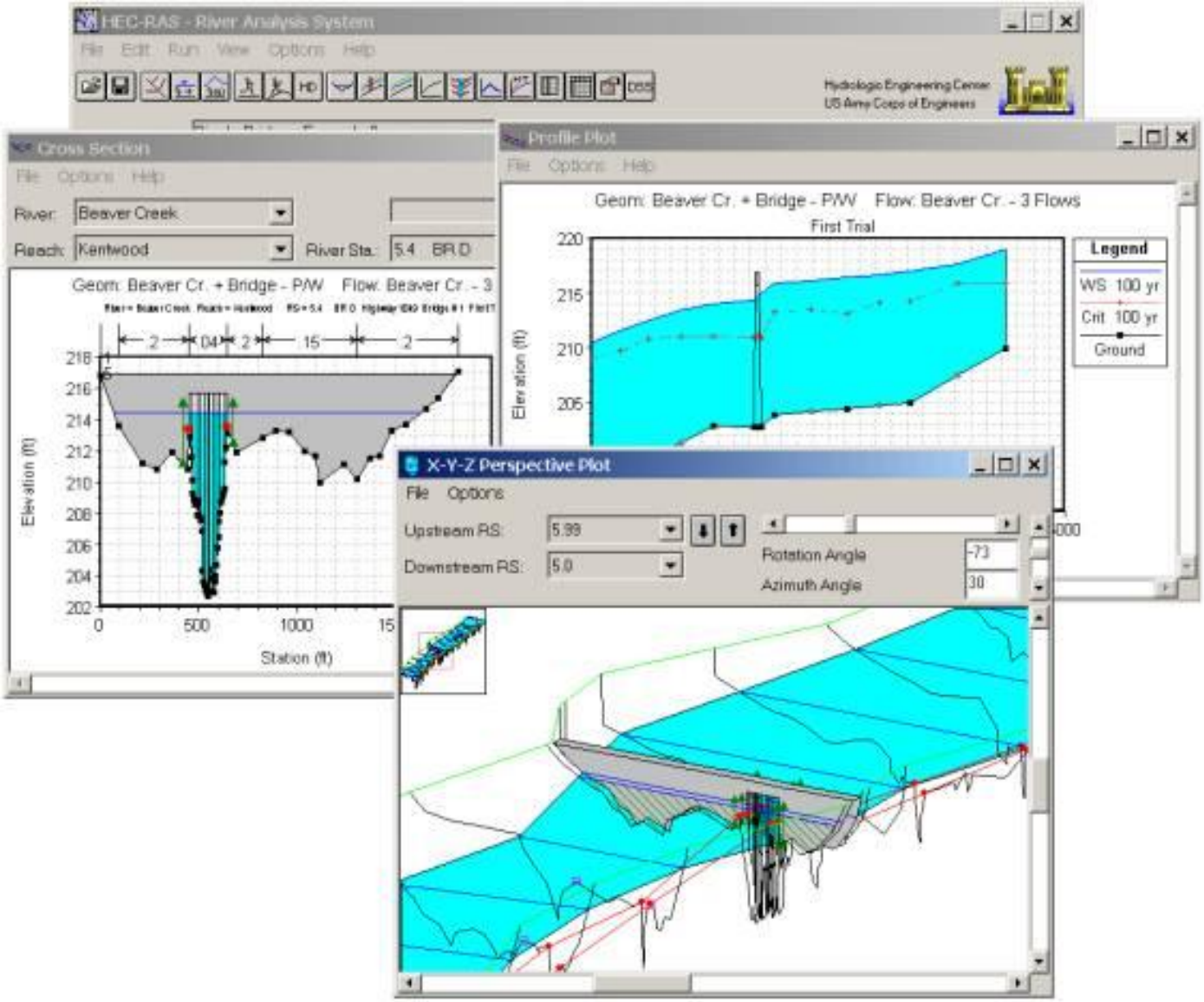
(Sediment LOAD) x (Sediment SIZE) ✂ (Stream SLOPE) x (Stream DISCHARGE)

CSR > 1 – Net Sediment Loss



"Sustainable catchment flood management policies will be based on an appropriate understanding of the catchment processes (particularly flood hydrology, flood routing, hydrogeology and ***geomorphology****) and an ability to predict the effects of flood defences, land use change and developments on such processes throughout the catchment."*

(DEFRA 2001)

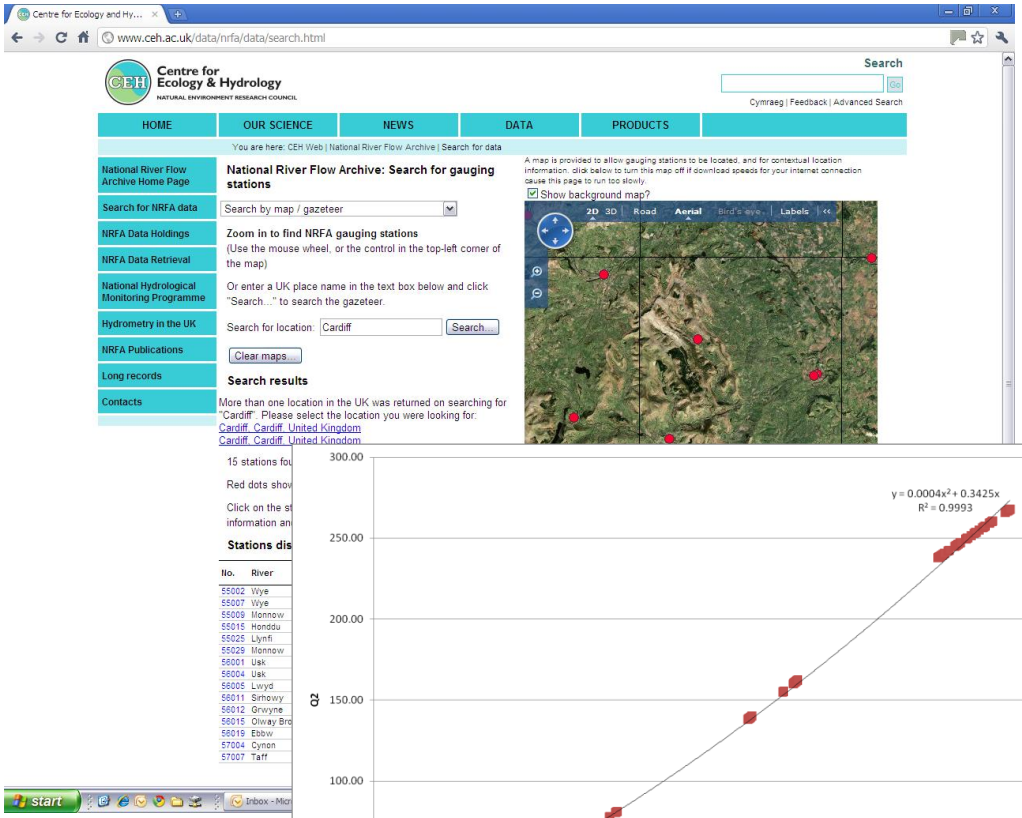

HEC-RAS - River Analysis System
File Edit Run View Options Help
Hydrologic Engineering Center
US Army Corps of Engineers
Cross Section
File Options Help
River: Beaver Creek
Reach: Kentwood
River Sta.: 5.4 BR D
Geom: Beaver Cr. + Bridge - P/W Flow: Beaver Cr. - 3
Elevation (ft)
Station (ft)
Profile Plot
File Options Help
Geom: Beaver Cr. + Bridge - P/W Flow: Beaver Cr. - 3 Flows
First Trial
Legend
WS 100 yr
Crit 100 yr
Ground
Elevation (ft)
X-Y-Z Perspective Plot
File Options
Upstream RS: 5.99
Downstream RS: 5.0
Rotation Angle -73
Azimuth Angle 30

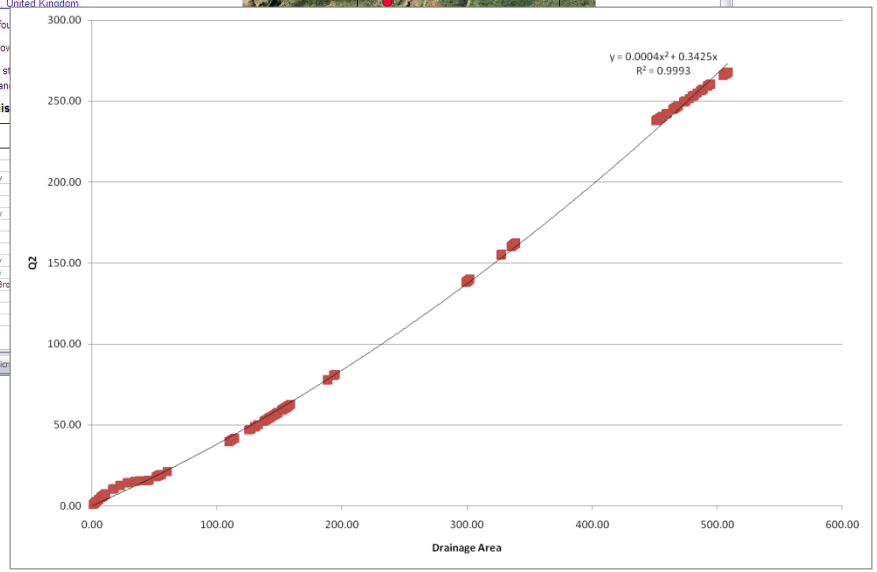
"In the majority of catchments, existing information [on geomorphology] may be limited or detailed only in specific locations, rather than being catchment wide"

(Environment Agency CFMP Guidance, 2006)

What data can we obtain at the catchment-scale?

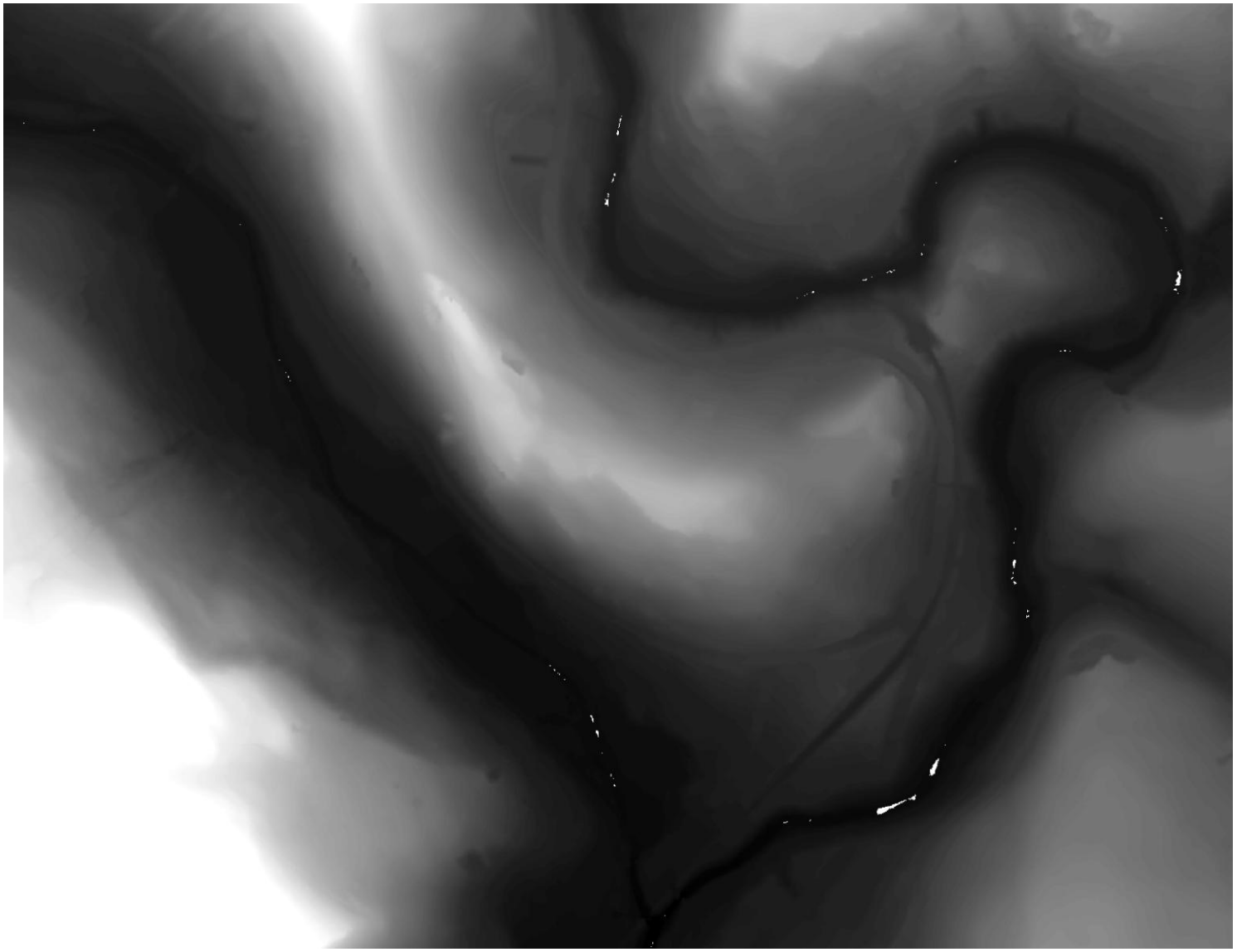
Discharge


www.ceh.ac.uk/data/nrfa/data/search.html
Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL
Search
HOME
OUR SCIENCE
NEWS
DATA
PRODUCTS
National River Flow Archive Home Page
Search for NRFA data
NRFA Data Holdings
NRFA Data Retrieval
National Hydrological Monitoring Programme
Hydrometry in the UK
NRFA Publications
Long records
Contacts
National River Flow Archive: Search for gauging stations
Search by map / gazeteer
Zoom in to find NRFA gauging stations
(Use the mouse wheel, or the control in the top-left corner of the map)
Or enter a UK place name in the text box below and click "Search..." to search the gazeteer.
Search for location: Cardiff
Search...
Clear maps...
Search results
Show background map?
Stations dis
No. River
55002 Wye
56007 Wye
55009 Monnow
55015 Honddu
55025 Llynfi
55029 Monnow
56001 Usk
56004 Usk
56005 Lwyd
56011 Sirhowy
56012 Grwyne
56015 Olway Bro
56019 Ebbw
57004 Cynon
57007 Taff

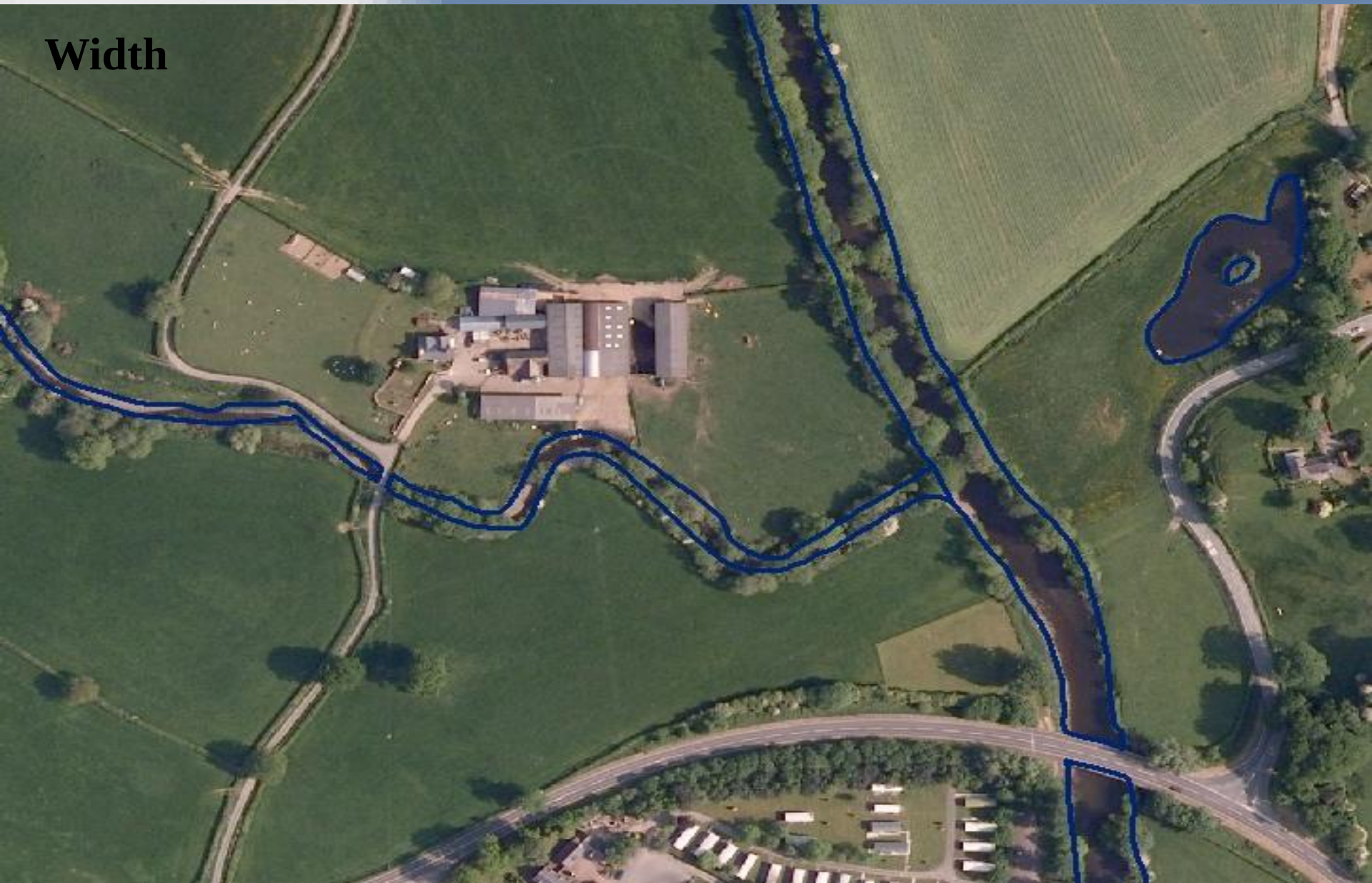

y = 0.0004x² + 0.3425x
R² = 0.9993
Q2
Drainage Area
0.00
50.00
100.00
150.00
200.00
250.00
300.00
400.00
500.00
600.00


WINFAP-FEH 3
WHS

Slope



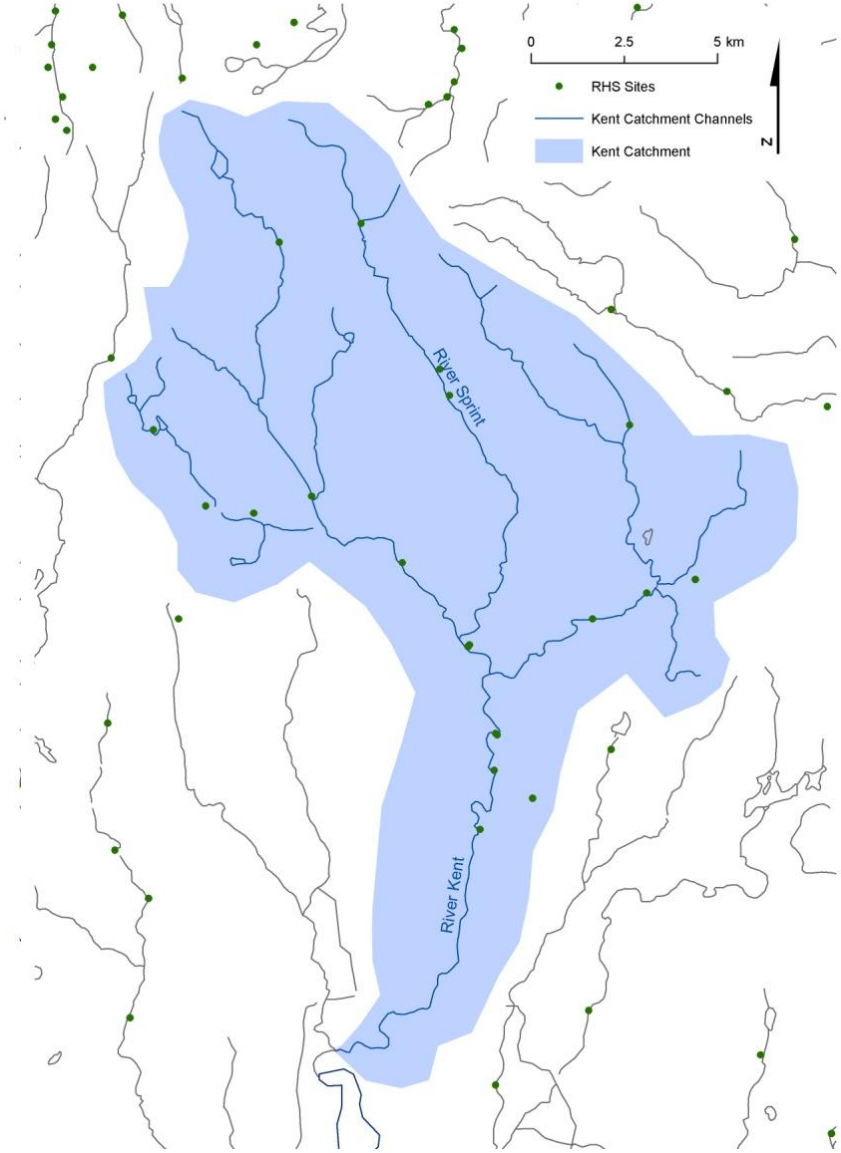
Width



Bed material size?

Channel shape?

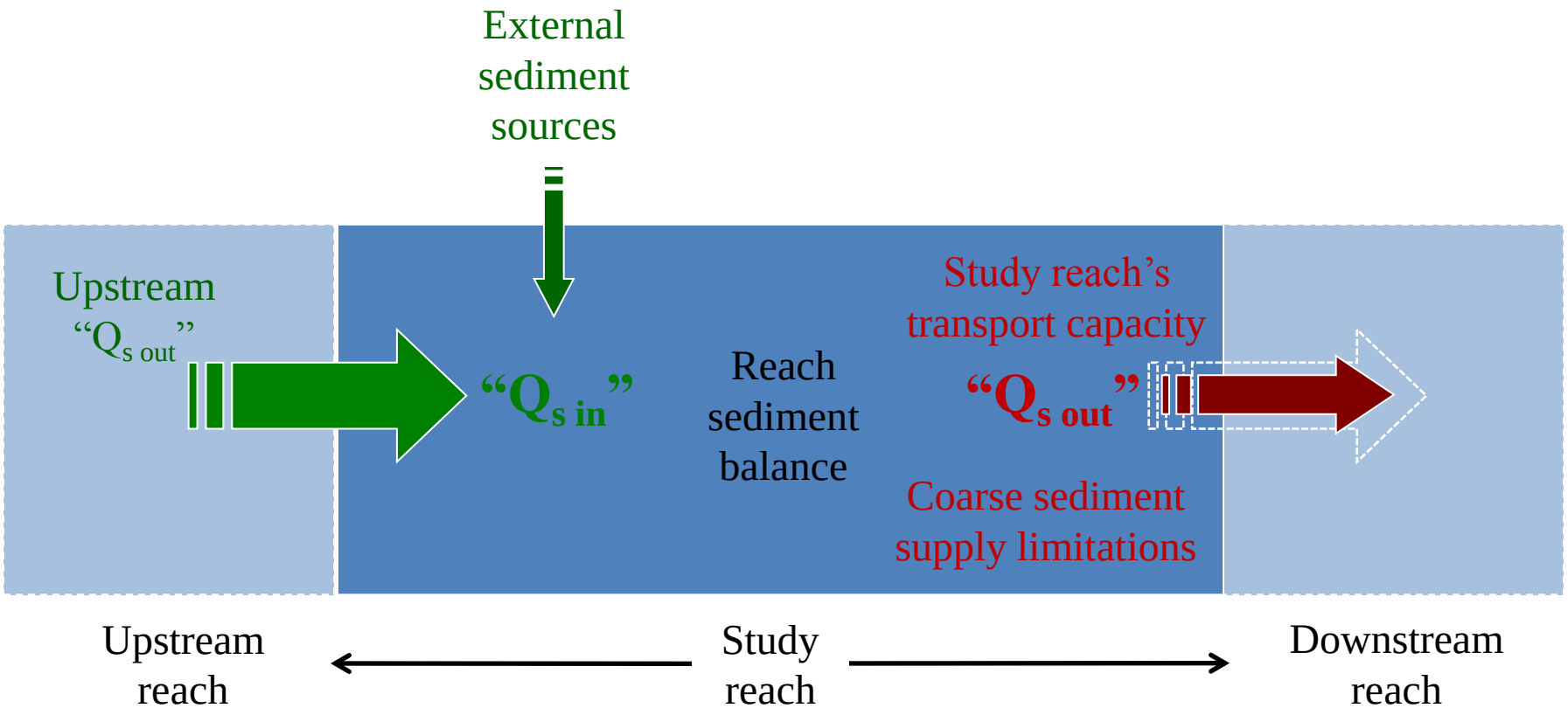
Conveyance / roughness?



1. **Identification of the problem:**
   We know that sediment dynamics need to be considered in the management of British rivers, and various analytical tools already exist. But their application remains limited due to data constraints. We can only parameterise discharge, slope and channel width widely at the catchment-scale.

2. Development of a solution:

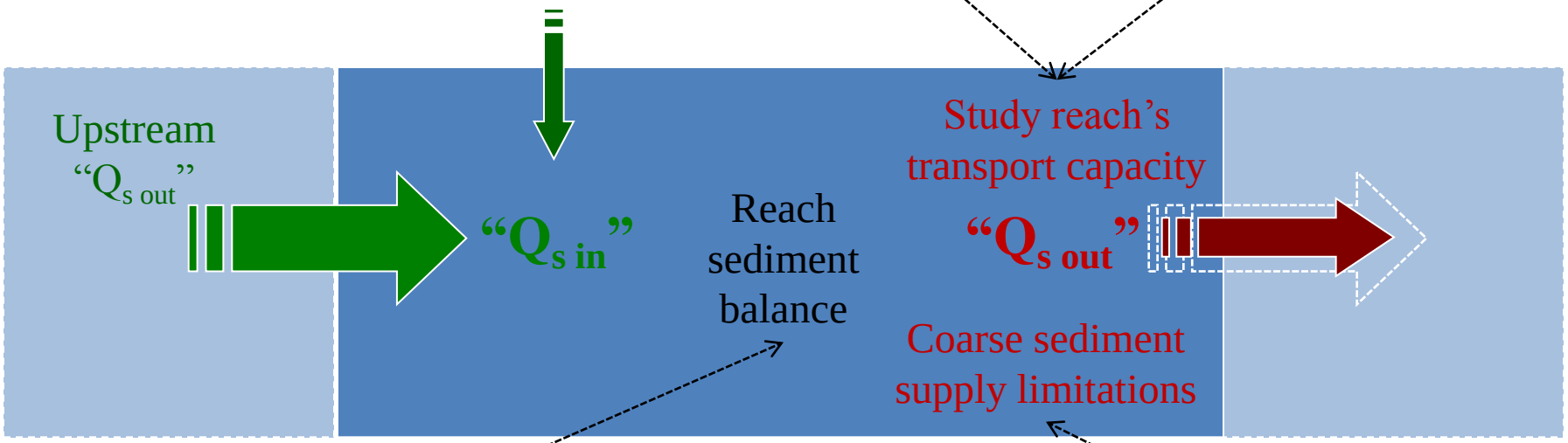
a) A reach-based sediment balance approach


External sediment sources
Upstream "Qs out"
"Qs in"
Reach sediment balance
Study reach's transport capacity
"Qs out"
Coarse sediment supply limitations
Upstream reach
Study reach
Downstream reach

How are external sediment sources accounted for?

What material sizes are accounted for?

How is a reach's transport capacity represented?



Upstream reach ← Study reach → Downstream reach

How should predicted reach sediment balance be represented?

Where are a reach's boundaries?

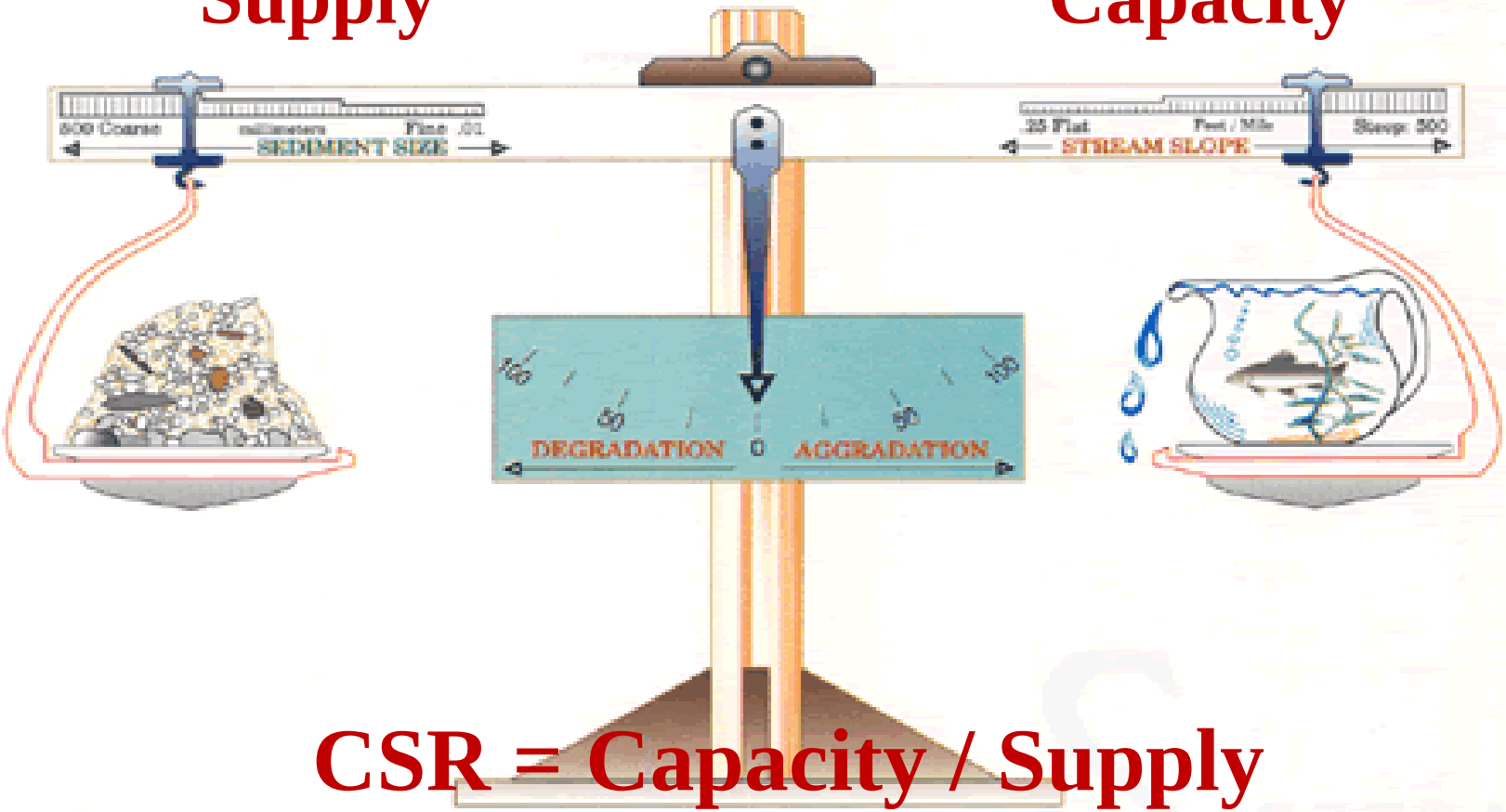
How are sediment supply limitations accounted for?

2. Developing a solution:

b) How to best represent the sediment balance of a reach (?)

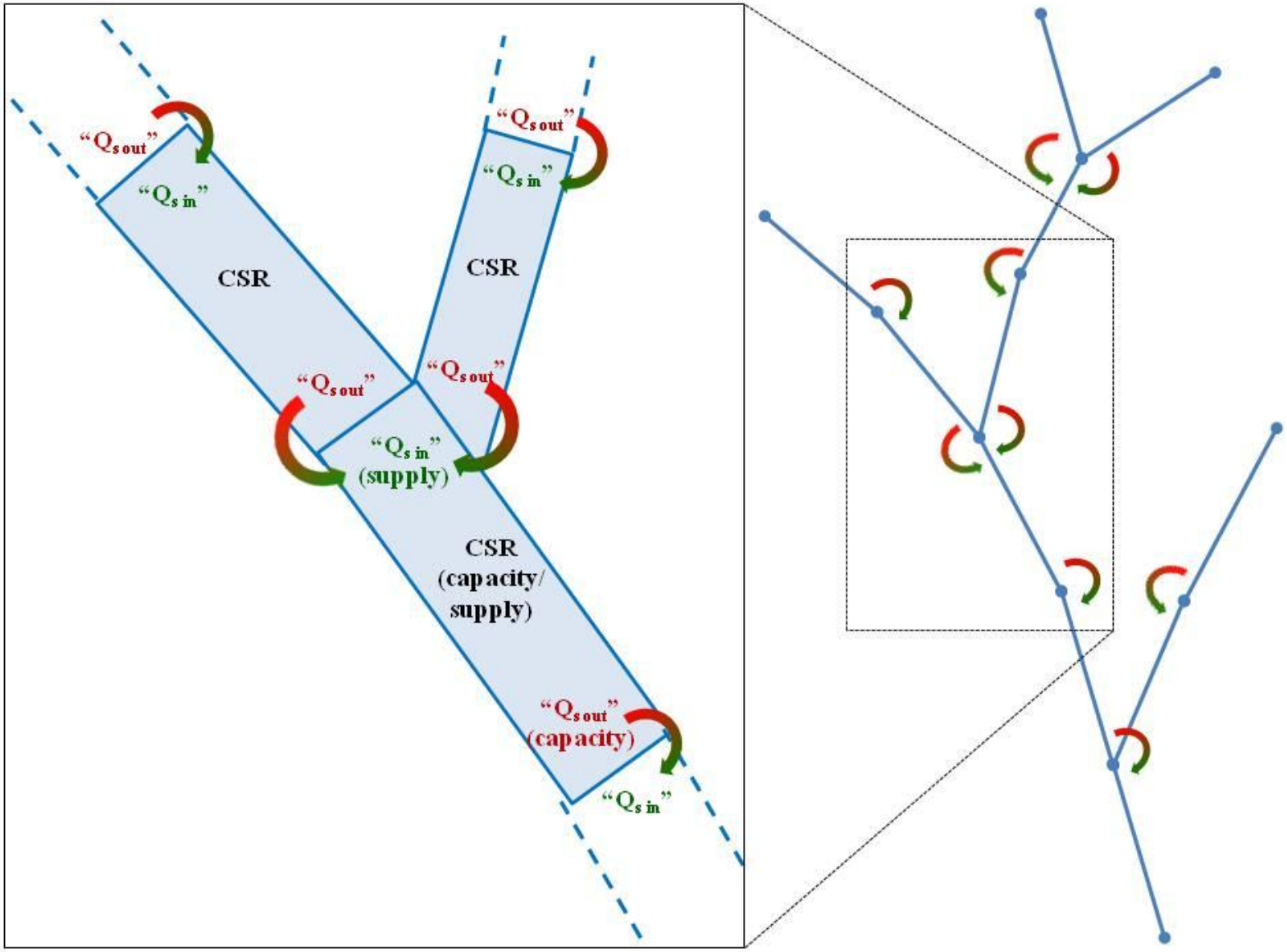
Supply

Capacity



CSR = Capacity / Supply

(Sediment LOAD) x (Sediment SIZE) ✂ (Stream SLOPE) x (Stream DISCHARGE)


"Qs out"
"Qs in"
CSR
"Qs out"
"Qs in"
CSR
"Qs out"
"Qs in"
(supply)
"Qs out"
CSR
(capacity/
supply)
"Qs out"
(capacity)
"Qs in"

2. Developing a solution:

c) How is a reach's transport capacity best represented ?

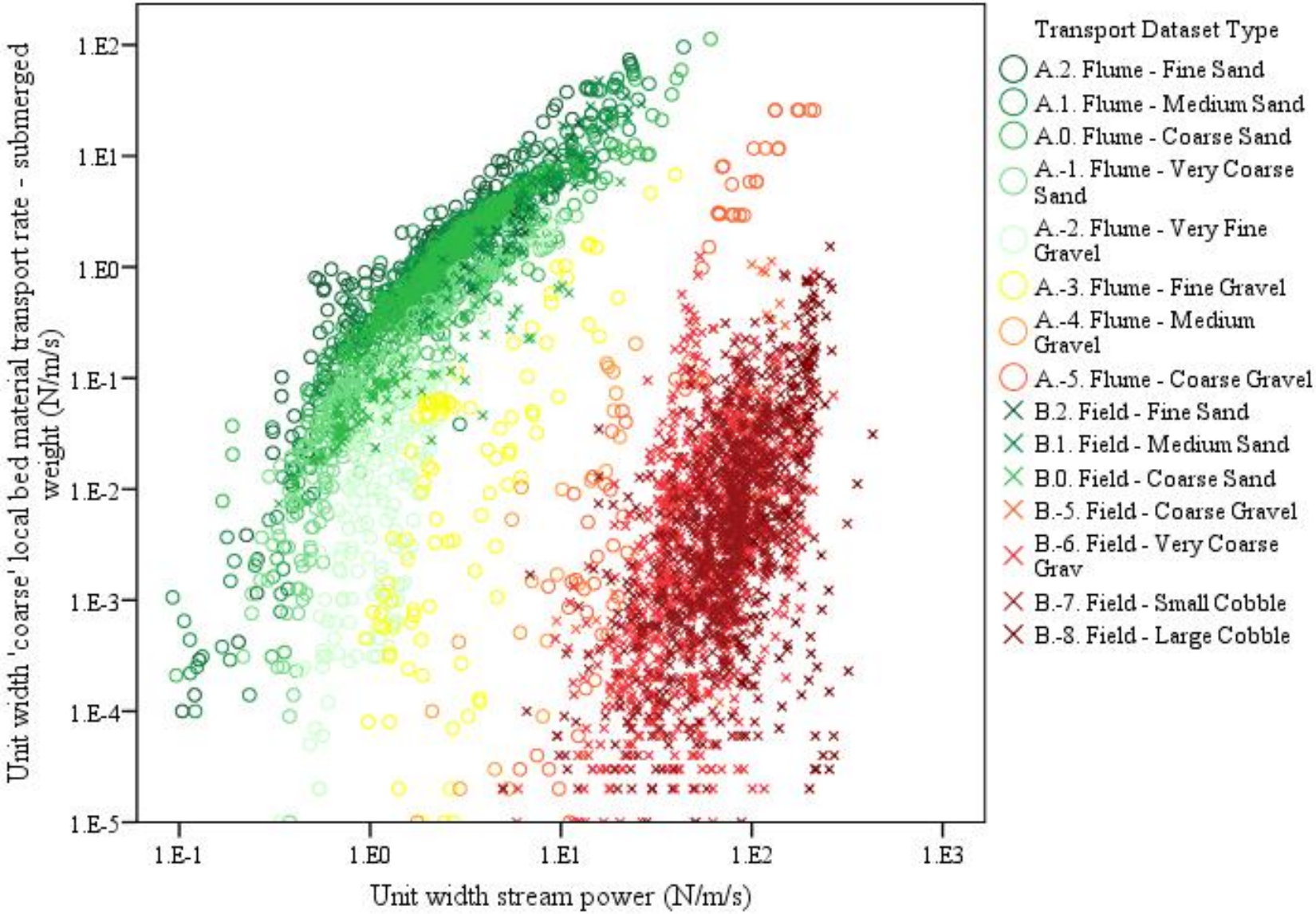
"The mechanics of sediment transport is so complex that it is extremely unlikely that a full understanding will ever be obtained…

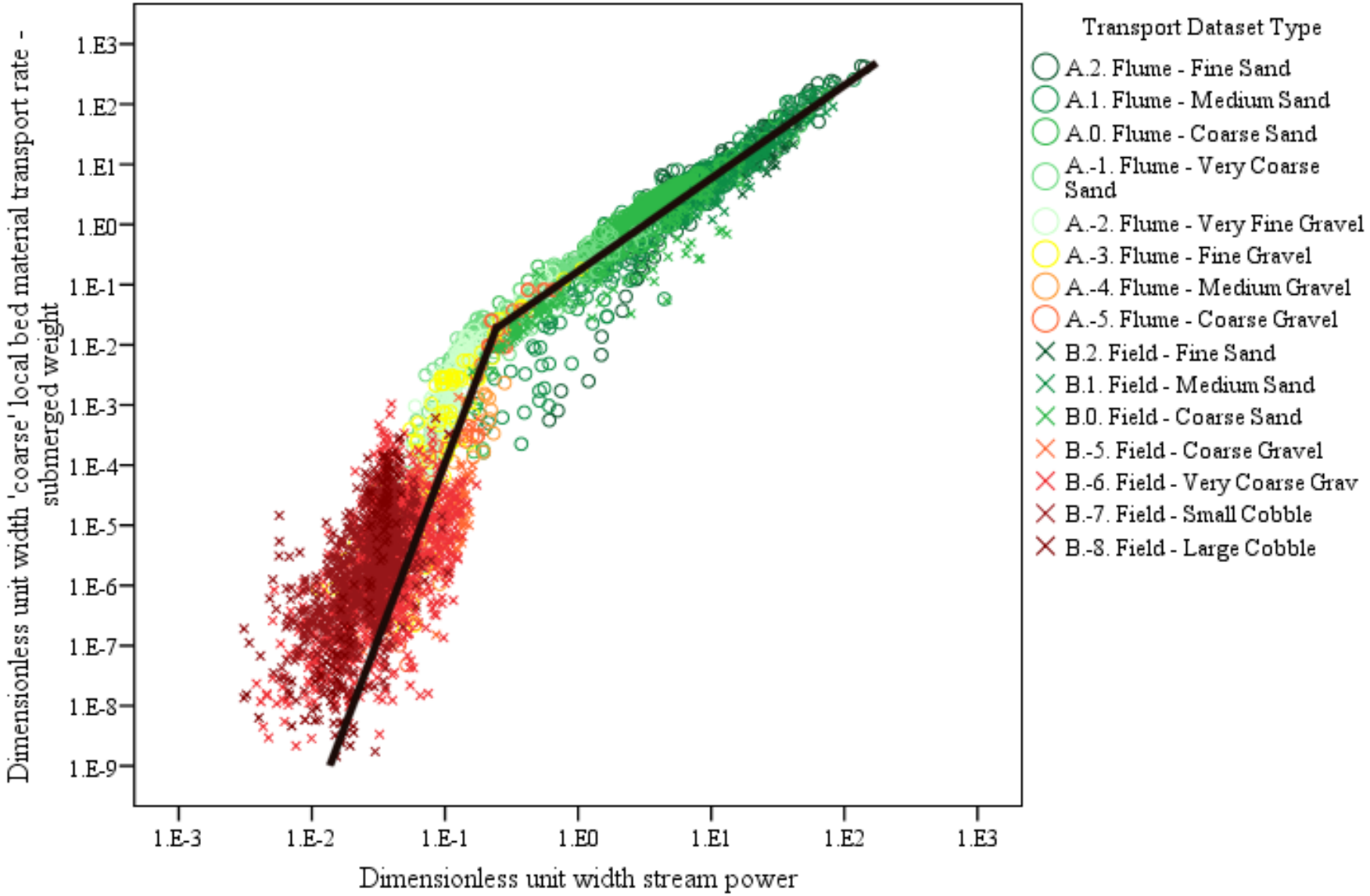
A "universal sediment transport equation" is not and may never be available."

(Simons and Senturk, 1992)

"The mechanics of sediment transport is so complex that it is extremely unlikely that a full **representation** will ever be achieved…

A **precise** "universal sediment transport equation" is not and may never be available."


Unit width 'coarse' local bed material transport rate - submerged weight (N/m/s)
1.E2
1.E1
1.E0
1.E-1
1.E-2
1.E-3
1.E-4
1.E-5
1.E-1
1.E0
1.E1
1.E2
1.E3
Unit width stream power (N/m/s)
Transport Dataset Type
A.2. Flume - Fine Sand
A.1. Flume - Medium Sand
A.0. Flume - Coarse Sand
A.-1. Flume - Very Coarse Sand
A.-2. Flume - Very Fine Gravel
A.-3. Flume - Fine Gravel
A.-4. Flume - Medium Gravel
A.-5. Flume - Coarse Gravel
B.2. Field - Fine Sand
B.1. Field - Medium Sand
B.0. Field - Coarse Sand
B.-5. Field - Coarse Gravel
B.-6. Field - Very Coarse Grav
B.-7. Field - Small Cobble
B.-8. Field - Large Cobble


Dimensionless unit width 'coarse' local bed material transport rate - submerged weight
1.E3
1.E2
1.E1
1.E0
1.E-1
1.E-2
1.E-3
1.E-4
1.E-5
1.E-6
1.E-7
1.E-8
1.E-9
1.E-3
1.E-2
1.E-1
1.E0
1.E1
1.E2
1.E3
Dimensionless unit width stream power
Transport Dataset Type
A.2. Flume - Fine Sand
A.1. Flume - Medium Sand
A.0. Flume - Coarse Sand
A.-1. Flume - Very Coarse Sand
A.-2. Flume - Very Fine Gravel
A.-3. Flume - Fine Gravel
A.-4. Flume - Medium Gravel
A.-5. Flume - Coarse Gravel
B.2. Field - Fine Sand
B.1. Field - Medium Sand
B.0. Field - Coarse Sand
B.-5. Field - Coarse Gravel
B.-6. Field - Very Coarse Grav
B.-7. Field - Small Cobble
B.-8. Field - Large Cobble

2. Developing a solution:

d) How to best represent a reach (?)

What is a reach?

- 10-20 channel widths

  (Montgomery and Buffington, 1997)
- 100-1000 channel widths

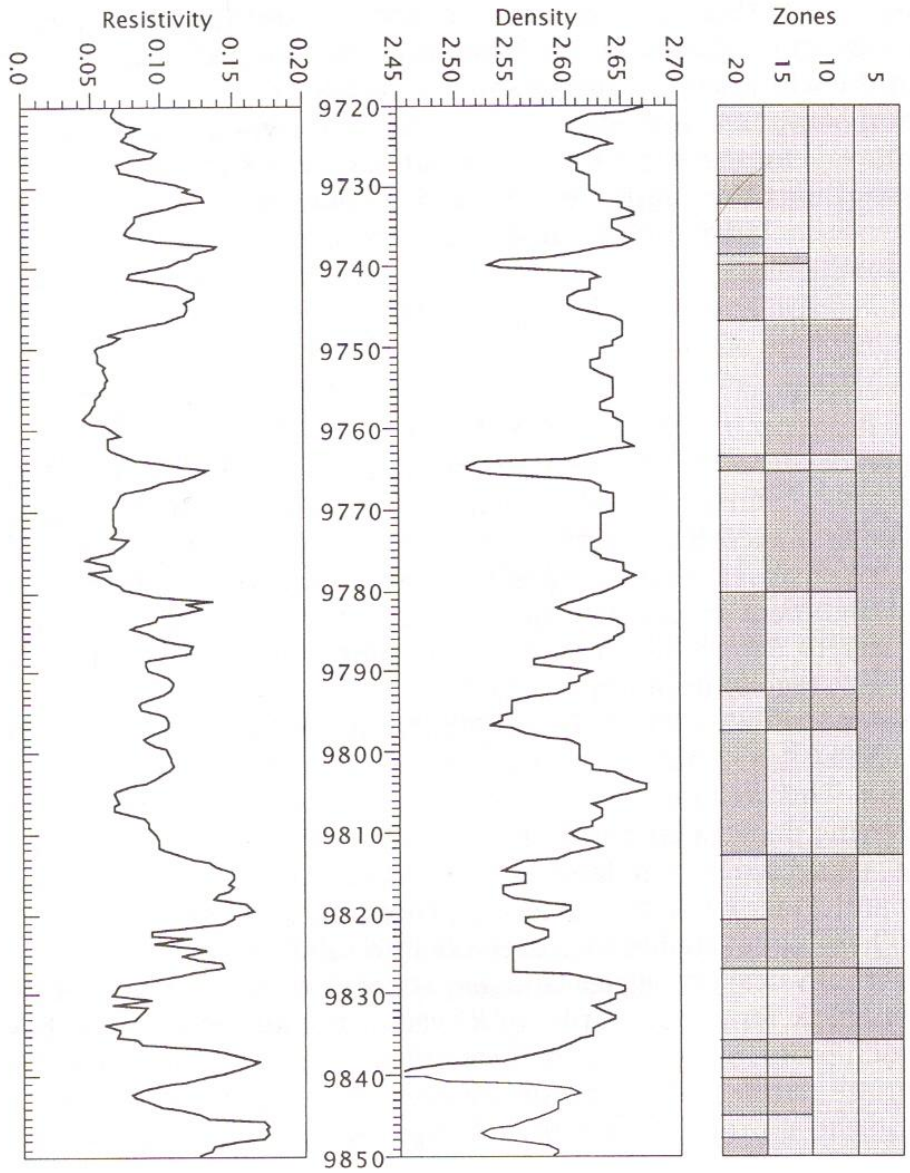
  (Grant et al., 1990)
- 500m

  (River Habitat Survey)
- Between tributary junctions and grid cell boundaries

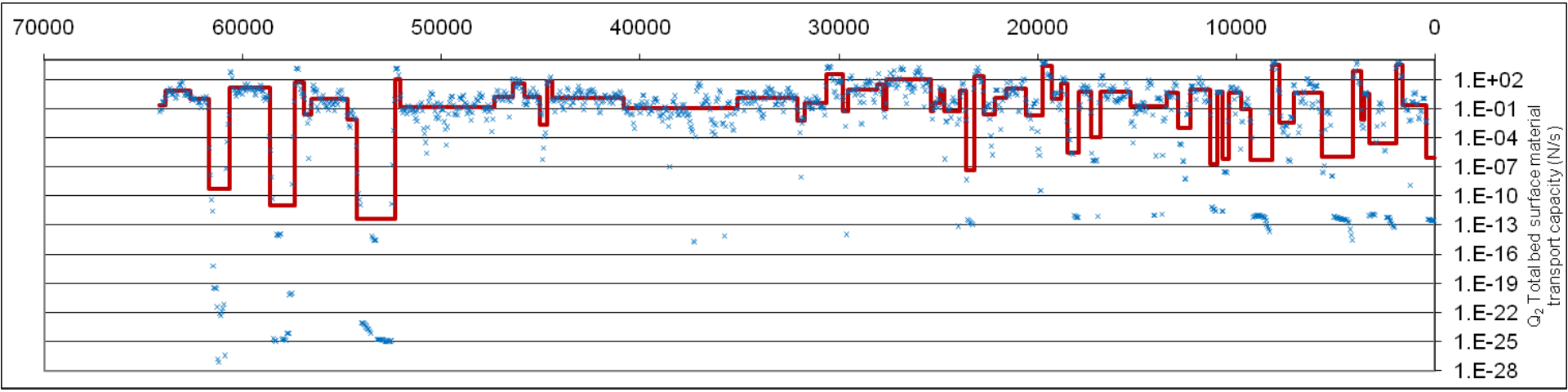
  (Benda and Dunne, 1997)
- Flow line between two hydrologic elements

  (Hellweger and Maidment, 1999)
- **A stretch of river composed of largely homogeneous geomorphological units**

  (Eyquem, 2007)


Zones
5
10
15
20
Density
2.70
2.65
2.60
2.55
2.50
2.45
Resistivity
0.20
0.15
0.10
0.05
0.0
9720
9730
9740
9750
9760
9770
9780
9790
9800
9810
9820
9830
9840
9850

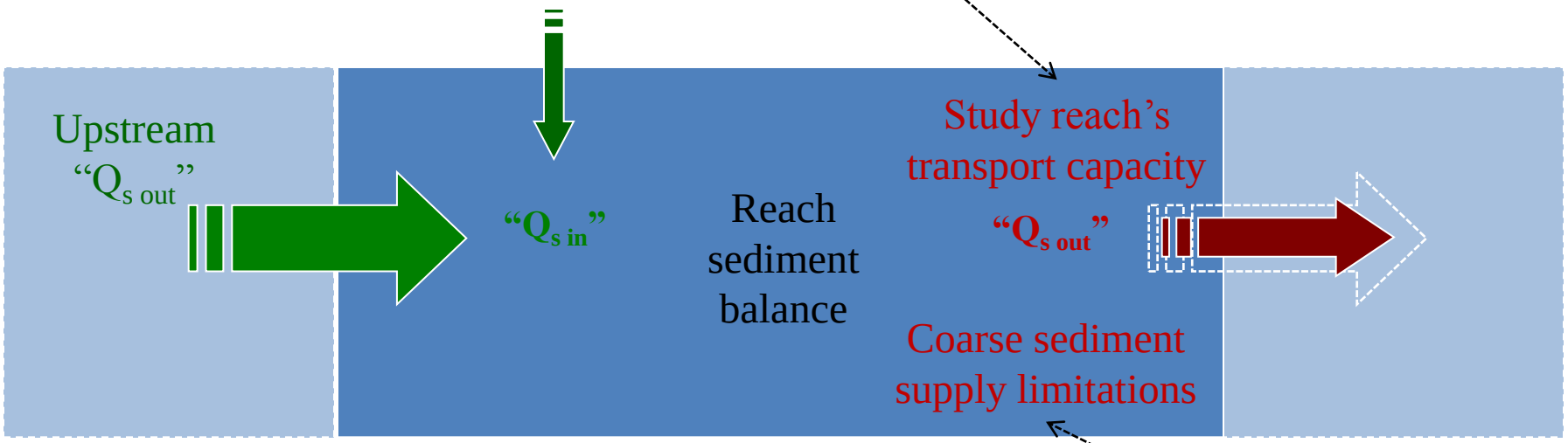
(Davis, 2002)



59% Explanation of variance

How are external sediment sources accounted for?

What material sizes are accounted for?



How are sediment supply limitations accounted for?

ST:REAM

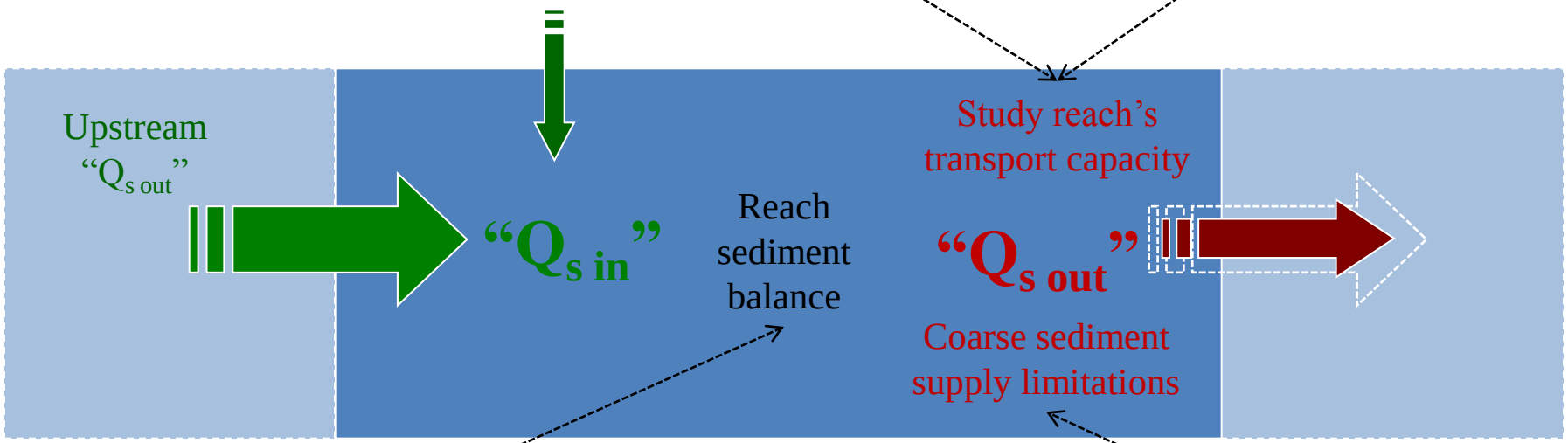
Sediment **T**ransport:

Reach **E**quilibrium **A**ssessment **M**ethod

Supply from tributaries is included, but not from banks or hillslopes

Bed material size is assumed to be uniform throughout the catchment

Reach transport capacity is predicted using a new general bed material transport relationship



Reach sediment status is represented by the predicted Capacity Supply Ratio

Functional reach boundaries are automatically identified using a zonation algorithm

Unless a reach's boundaries are completely non-erodible it is assumed that a reach fulfils its predicted transport capacity

Version6 - Taff, Cobble+Concrete, Q2a, 1%.xlsm - Microsoft Excel

Model Input

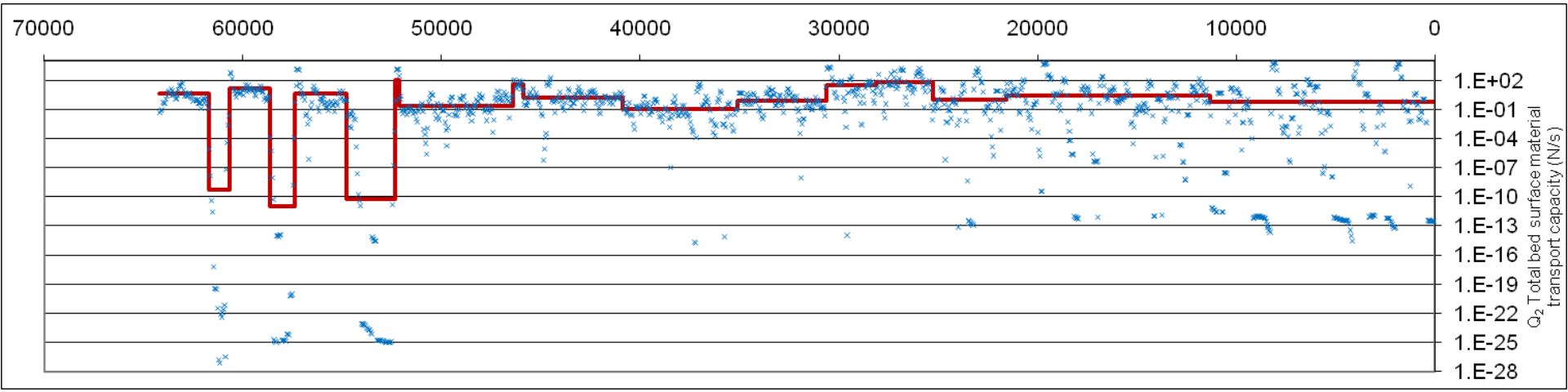
Clear Model Data

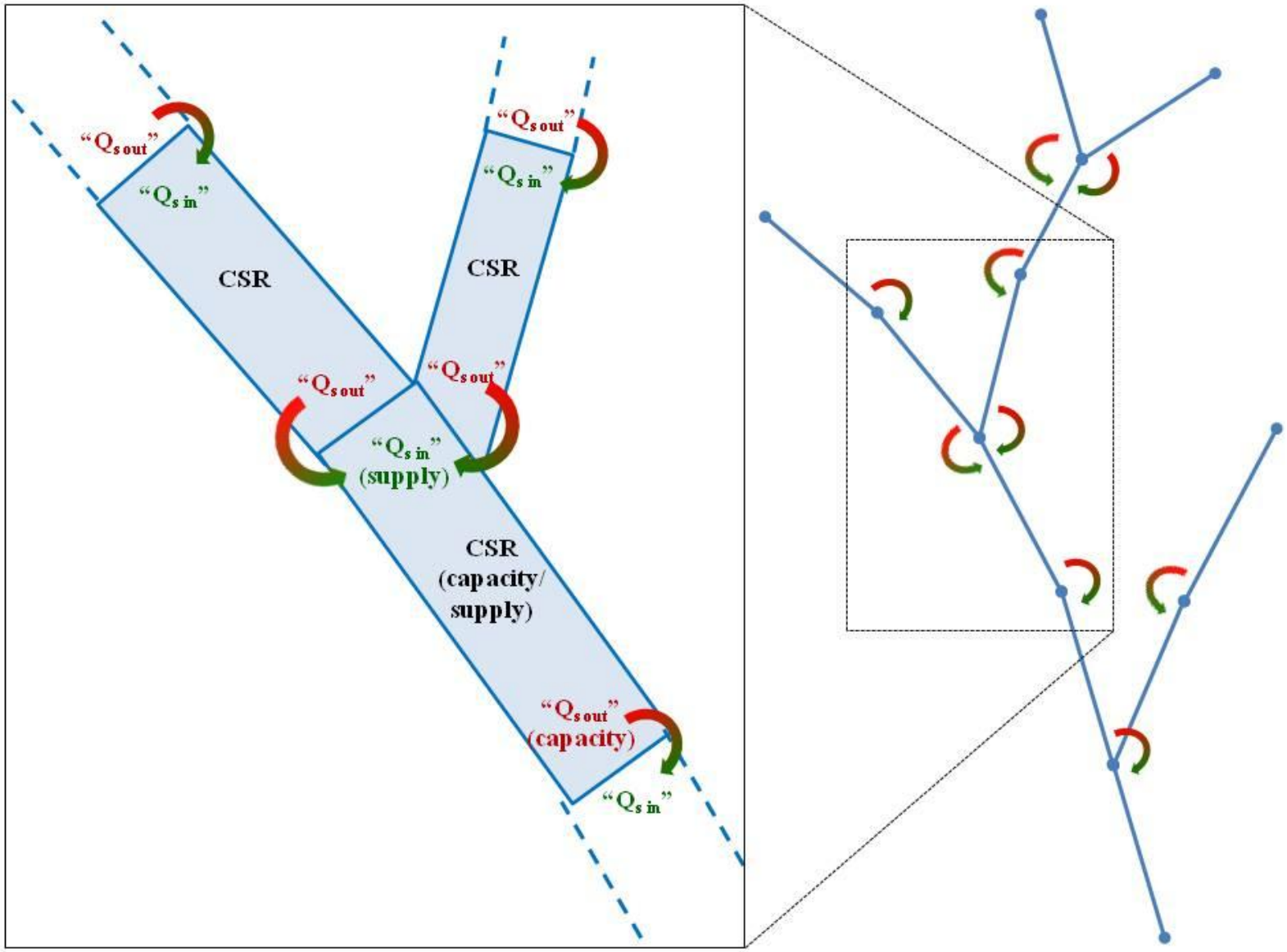
Set the catchment bed material size (m)... 0.1

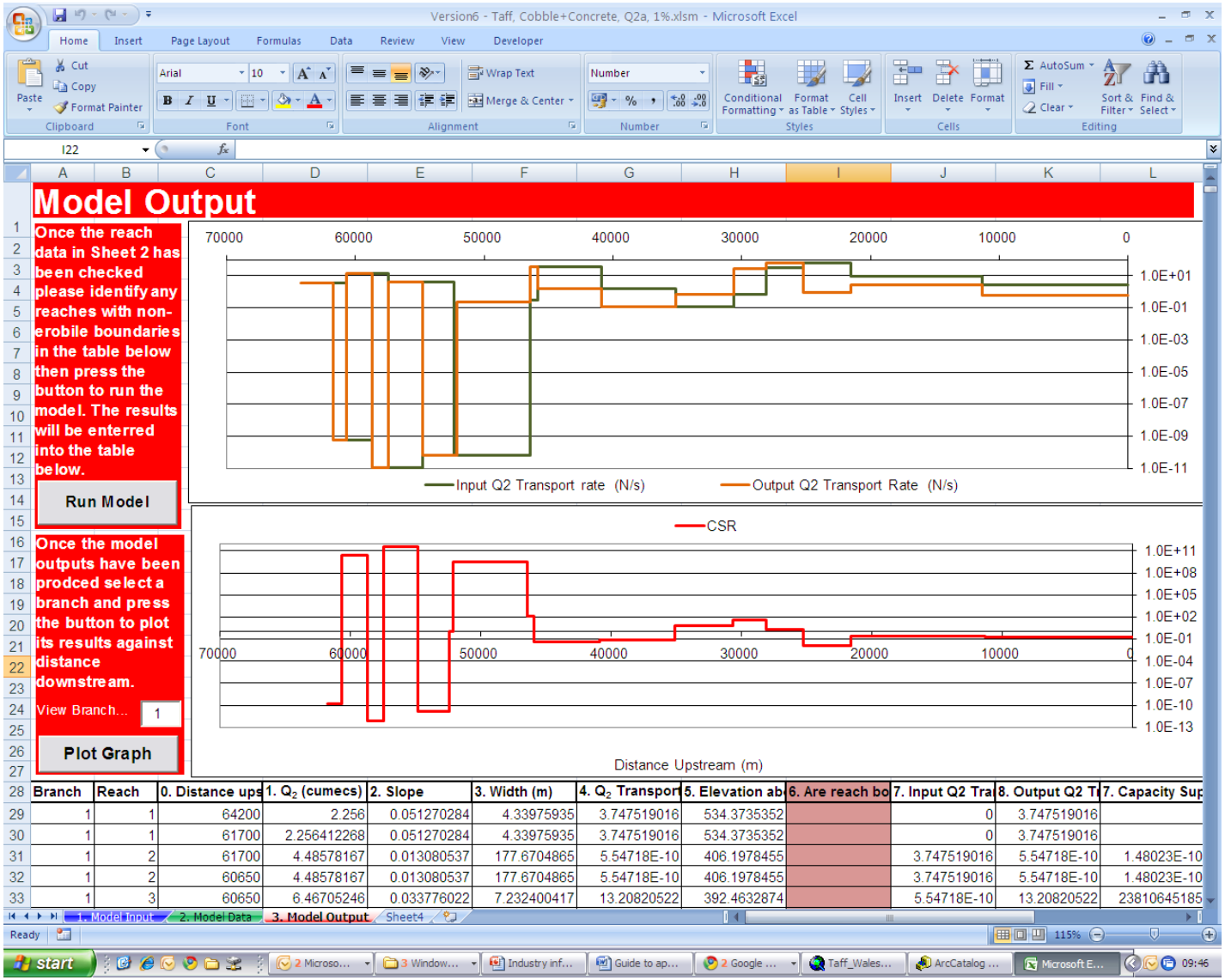
Adjust the sensitivity of the reach boundary algorithm ... 0.01

Input Model Data

	Branch	Segment	D/S Branch	D/S Segment	Length (m)	Q_2 (cumecs)	Slope (m/m)	Width (m)
3373	7	112			50	8.691800226	0.01615	6.8
3374	7	113			50	8.693044787	0.01615	6.7
3375	7	114			50	8.693044787	0.01409	6.6
3376	7	115			50	8.712969142	0.01228	6.6
3377	7	116			50	8.776475875	0.01052	6.7
3378	7	117			50	8.843720092	0.01523	6.5
3379	7	118			50	8.852436756	0.02059	6.6
3380	7	119			50	8.902246687	0.01885	6.6
3381	7	120			50	8.917189002	0.02034	6.4
3382	7	121			50	8.94832009	0.02082	6.6
3383	7	122			50	8.995639005	0.01642	6.6
3384	7	123			50	8.995639005	0.01471	6.4
3385	7	124			50	9.039222335	0.01431	6.4
3386	7	125			50	9.057902128	0.01413	6.6
3387	7	126			50	9.069108867	0.01296	6.5
3388	7	127			50	9.071598936	0.01465	6.7
3389	7	128			50	9.081561113	0.01268	6.8
3390	7	129			50	9.113936757	0.01176	6.7
3391	7	130			50	9.11767329	0.00867	6.9
3392	7	131			50	9.11767329	0.01351	6.8
3393	7	132			50	9.148804378	0.01178	6.6
3394	7	133			50	11.16360845	0.01522	6.7
3395	7	134			50	11.18228634	0.01262	7.0
3396	7	135			50	11.19972062	0.01614	7.0
3397	7	136			50	11.19972062	0.01146	7.3
3398	7	137			50	11.2034562	0.01425	7.8
3399	7	138			50	11.21964498	0.01263	8.0
3400	7	139			50	11.4375626	0.01240	8.1


70000
60000
50000
40000
30000
20000
10000
0
1.E+02
1.E-01
1.E-04
1.E-07
1.E-10
1.E-13
1.E-16
1.E-19
1.E-22
1.E-25
1.E-28
Q_2 Total bed surface material transport capacity (N/s)

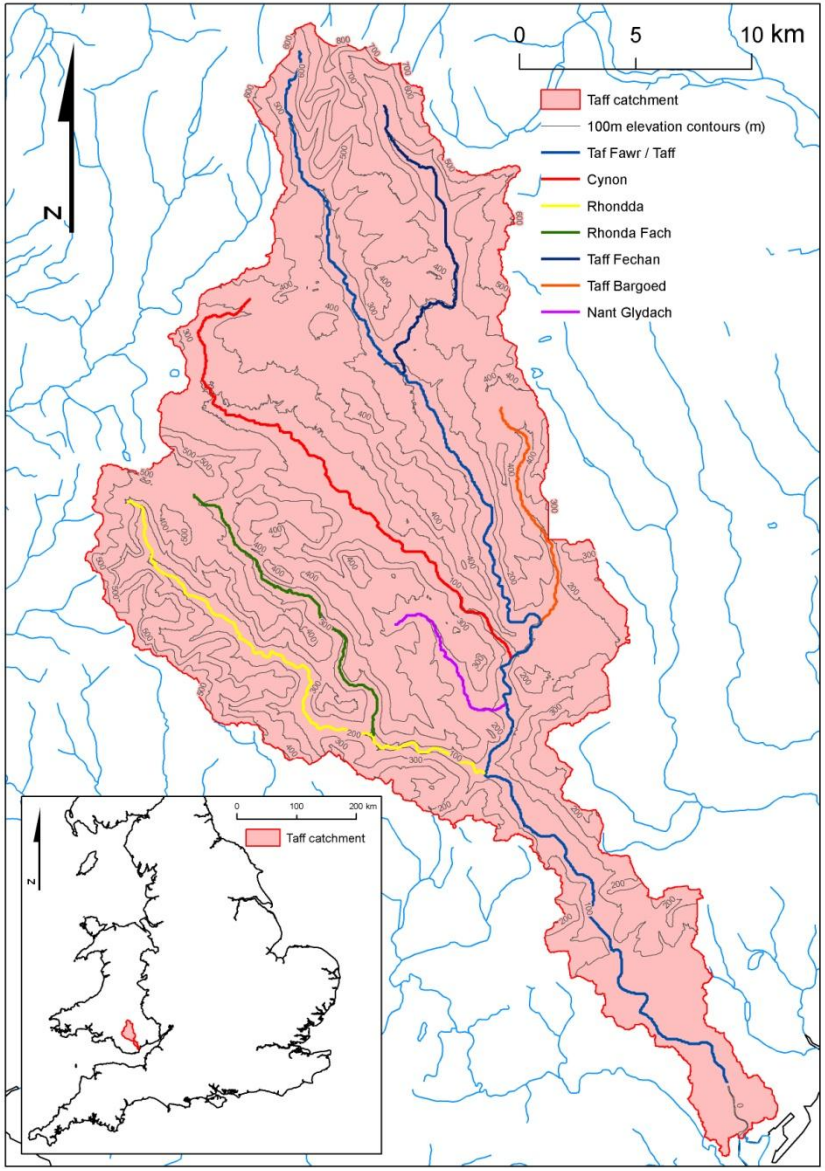

"Qs out"
"Qs in"
CSR
"Qs out"
"Qs in"
CSR
"Qs out"
"Qs out"
"Qs in"
(supply)
CSR
(capacity/
supply)
"Qs out"
(capacity)
"Qs in"

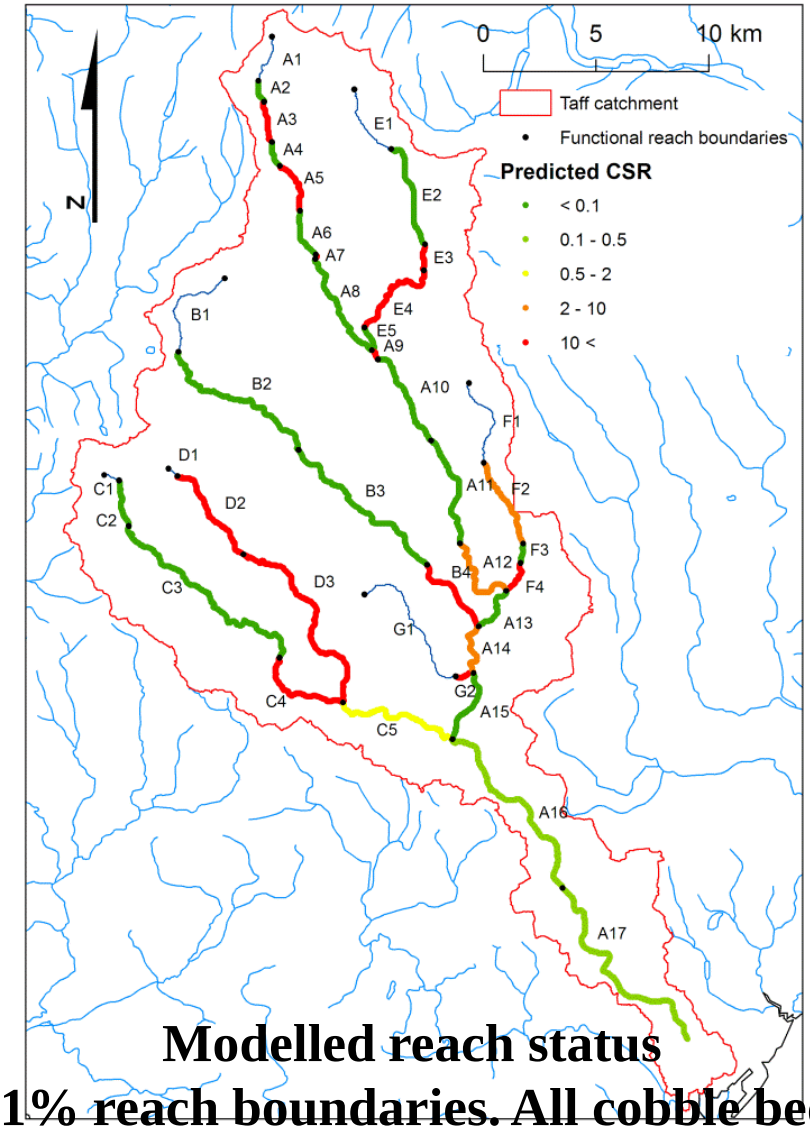


Branch	Reach	0. Distance ups	1. Q_2 (cumecs)	2. Slope	3. Width (m)	4. Q_2 Transport	5. Elevation ab	6. Are reach bo	7. Input Q2 Tra	8. Output Q2 T	7. Capacity Sup
1	1	64200	2.256	0.051270284	4.33975935	3.747519016	534.3735352		0	3.747519016	
1	1	61700	2.256412268	0.051270284	4.33975935	3.747519016	534.3735352		0	3.747519016	
1	2	61700	4.48578167	0.013080537	177.6704865	5.54718E-10	406.1978455		3.747519016	5.54718E-10	1.48023E-10
1	2	60650	4.48578167	0.013080537	177.6704865	5.54718E-10	406.1978455		3.747519016	5.54718E-10	1.48023E-10
1	3	60650	6.46705246	0.033776022	7.232400417	13.20820522	392.4632874		5.54718E-10	13.20820522	23810645185

3. Assessing the new approach

Fieldtrip to the River Taff, South Wales


0
5
10 km
N
Taff catchment
100m elevation contours (m)
Taf Fawr / Taff
Cynon
Rhondda
Rhonda Fach
Taff Fechan
Taff Bargoed
Nant Glydach
0
100
200 km
Taff catchment
N



Modelled reach status
(1% reach boundaries. All cobble bed)

FRMRC flood risk management research consortium

FRMRC flood risk management research consortium

FRMRC flood risk management research consortium

FRMRC flood risk management research consortium

FRMRC flood risk management research consortium

FRMRC flood risk management research consortium

FRMRC flood risk management research consortium

Topics for discussion...

- River Taff catchment context
- Assessment of ST:REAM performance against field observations
- Issues within reach-based sediment balance modelling:
    - Scale issues for reach-based sediment balance modelling
    - Suitability of ‘internally homogenous’ reaches for representing river channels
    - Relevance of using a single representative flow
    - Representation of hill-slope sediment supply
    - Accounting for non-erodible boundaries
- Management issues within a high energy river catchment
- Ease of visual identification of sediment balance/status during river reconnaissance
- Landscape and local controls over sediment delivery to reservoirs

Logistics...

- Leaving via coach at 9am, returning ~5pm
- Cost is included in the price of the conference
- Dress appropriately:
    - Sensible footwear
    - Waterproof / warm clothing
- Bring packed lunch – provided
- Eat a big breakfast!
- Please be respectful of the environment – both physical and human

- If you wish to run a ST:REAM model of the Taff catchment before the fieldtrip please upload a copy onto your laptop from the USB sticks provided and follow the instructions (see Chris Parker).

If you wish to apply ST:REAM within a catchment that you are working on at no cost then please get in contact at:

Chris2.Parker@uwe.ac.uk

Acknowledgement

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- **Engineering and Physical Sciences Research Council**
- **Department of Environment, Food and Rural Affairs/Environment Agency Joint Research Programme**
- **United Kingdom Water Industry Research**
- **Office of Public Works Dublin**
- **Northern Ireland Rivers Agency**

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