Modelling the influence of flood event clustering on catchment scale bank erosion

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Outline

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- SHETRAN model
- Importance of bank erosion
- Modification of bank erosion within SHETRAN
- Application – Eden catchment, Cumbria
- Results – Hydrology and sediment
- Validation of bank erosion component
- Conclusions

EPSRC
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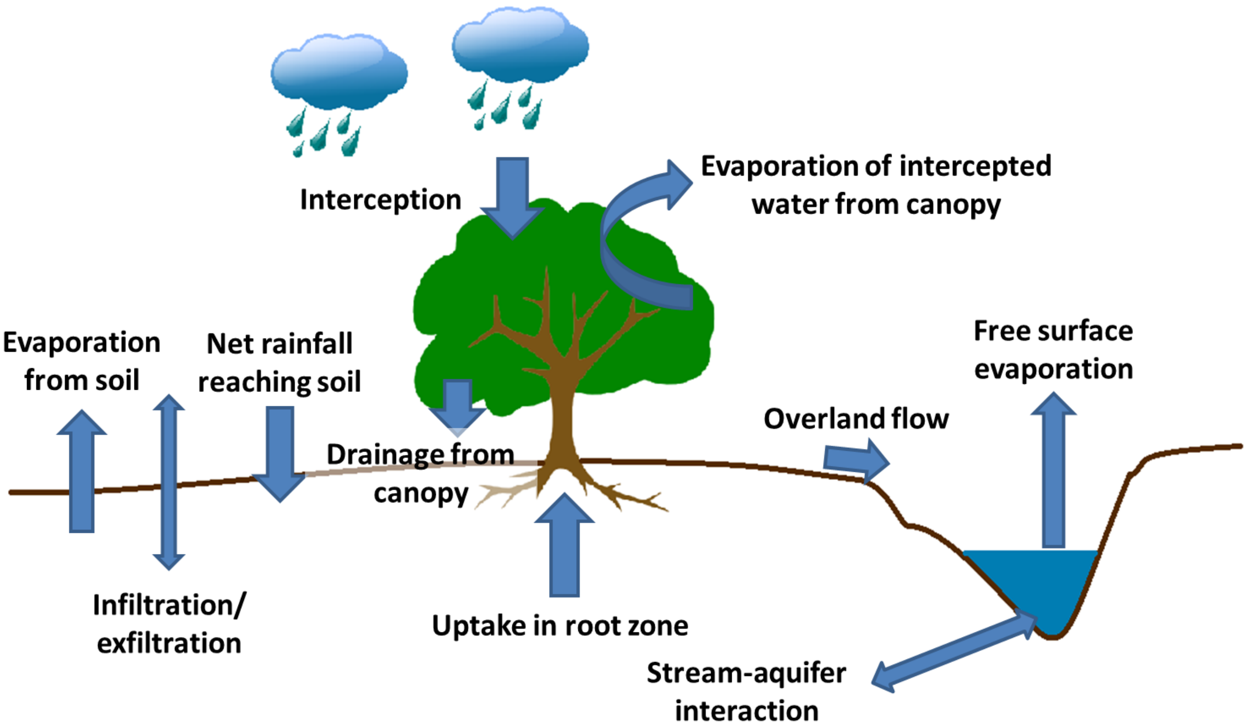
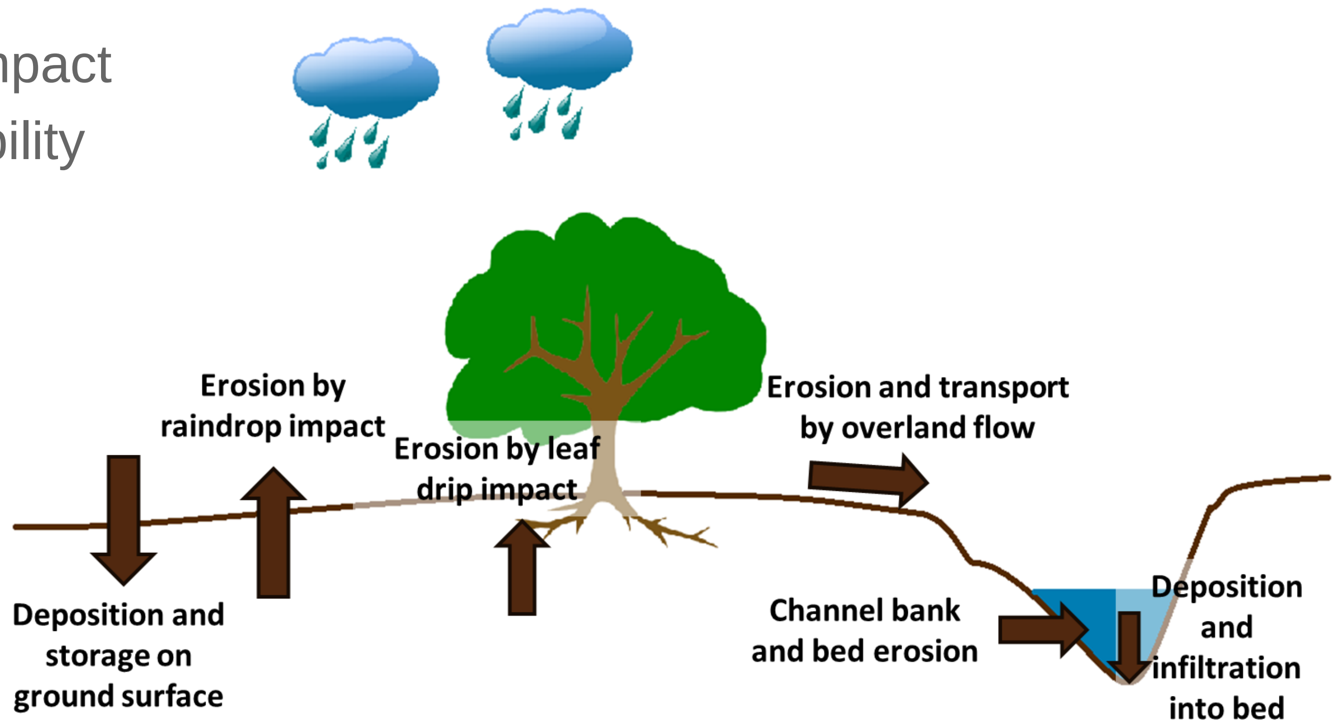
SHETRAN model

- Système Hydrologique Européen TRANsport
- Physically-based distributed model
- Spatial resolution from 0.1 km^2, temporal max 1 or 2 hours



SHETRAN model

- 7 sediment size fractions
- Overland flow transport – Engelund-Hansen
- Erodibility parameters
  - Overland
  - Raindrop impact
  - Bank erodibility



Bank erosion within SHETRAN

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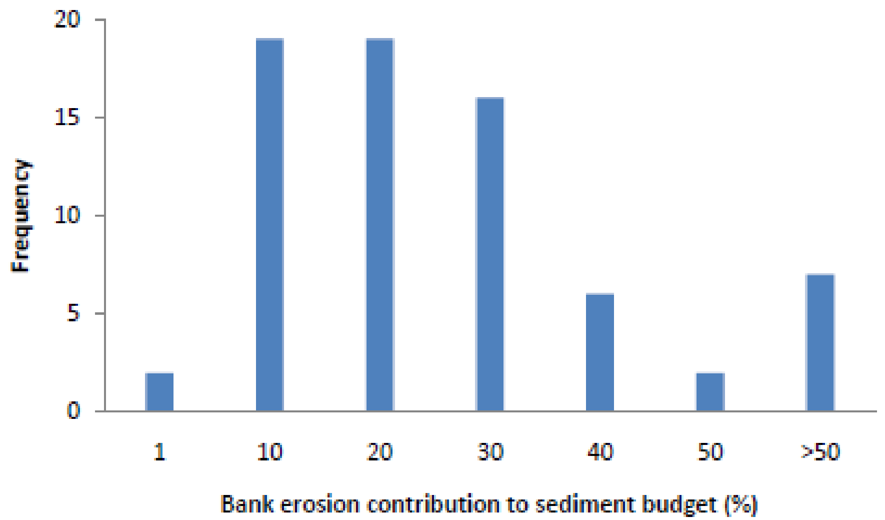
- Existing bank erosion component in SHETRAN:

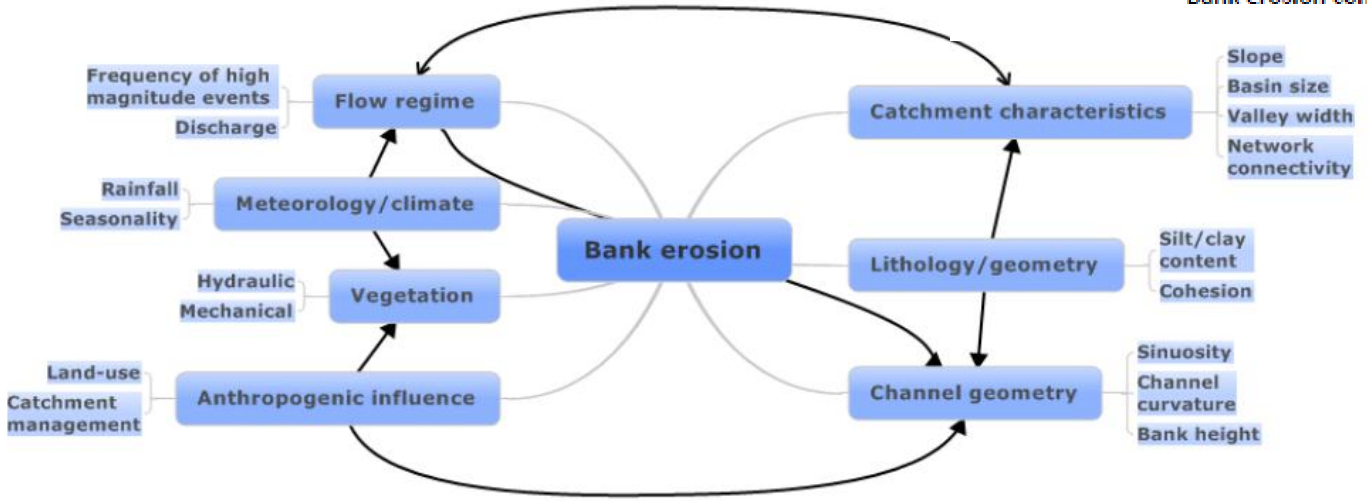
$$E_b = BKB\left(\frac{\tau_b}{\tau_{bc}} - 1\right)$$

- τ_b is function of width to depth ratio and flow shear stress and τ_{bc} obtained from Shields curve/dependant on silt clay content.
- BKB is erodibility coefficient – spatially and temporally constant
- No additional factors…

Importance of bank erosion

- Bank erosion = 4-40% suspended sediment budget in UK (Walling, 2005)
- Variability both within and between catchments





Modified bank erosion within SHETRAN

$$E_b = BKB.\left(\frac{\tau_b}{\tau_{bc}} - 1\right) \ where \ \tau_b > \tau_{bc}$$

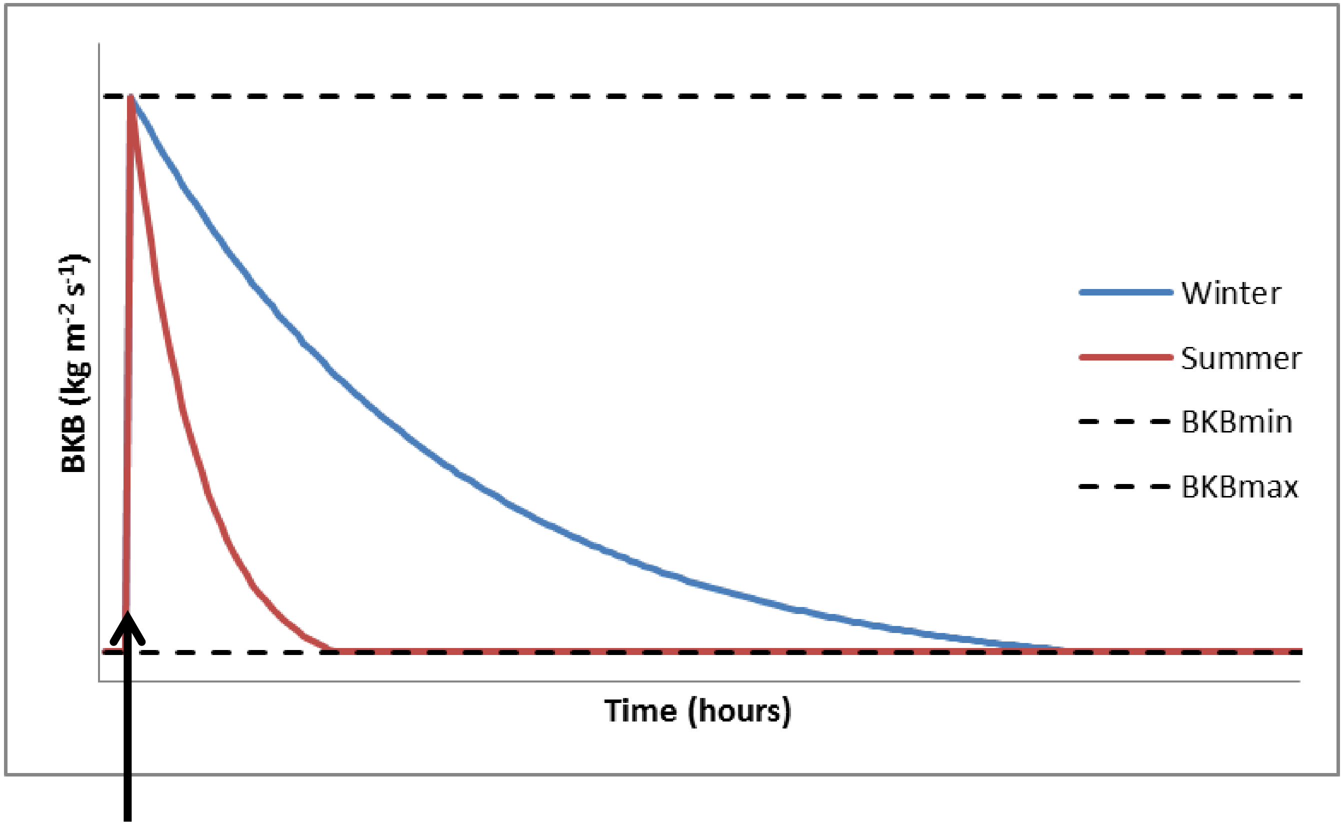
- Erodibility now SPATIALLY and TEMPORALLY variable
- Temporal variability:
  - Increased erodibility after high flow events (vegetation removal)
  - Recovery linked to potential evapotranspiration (vegetation re-growth)

$$BKB_t = BKB_{t-1}.R$$

$$R = 1 - \left(k.\delta t.\frac{PE_{obs}}{PEmax}\right)$$

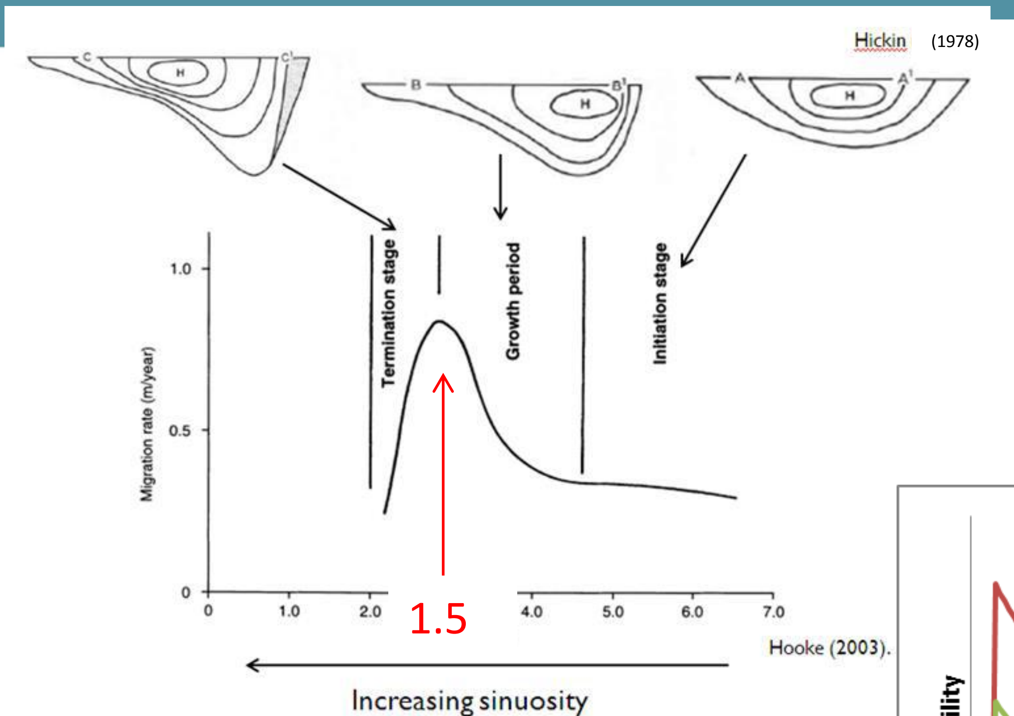
- New parameters: BKBmin, BKBmax, PEmax, *k*, and Qthresh
  - K controls recovery time

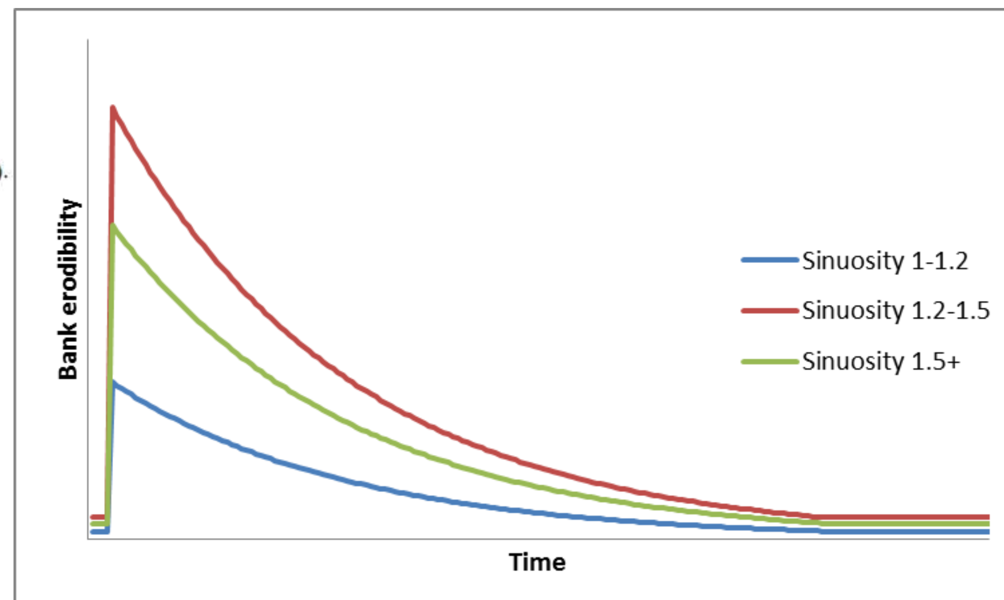
Modified bank erosion within SHETRAN



QThresh exceeded

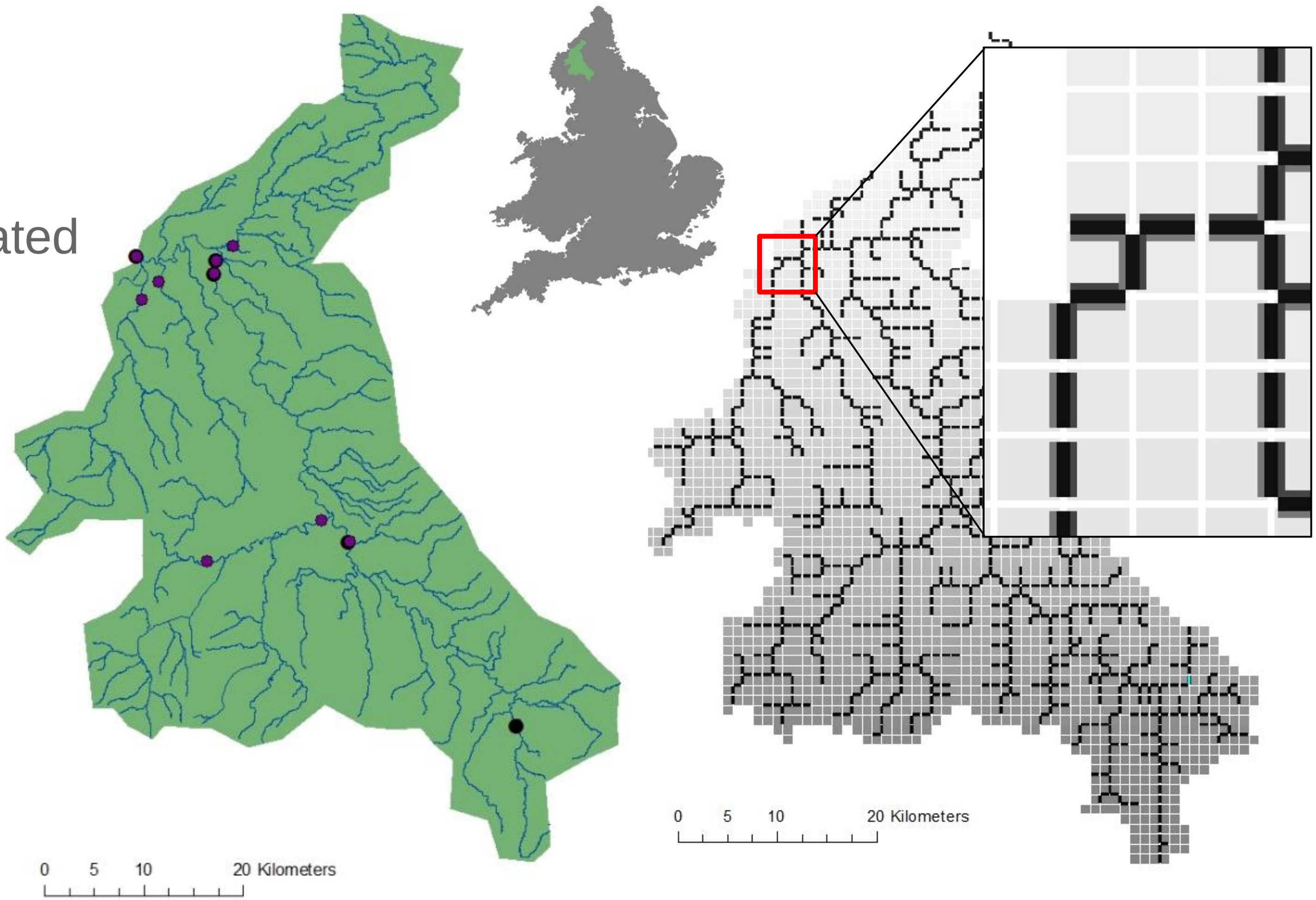
Modified bank erosion within SHETRAN





Application within Eden catchment, Cumbria

- 1975-2007
- Simulations with bank module
- Calibrated/validated using NRFA/ Hi-flows data



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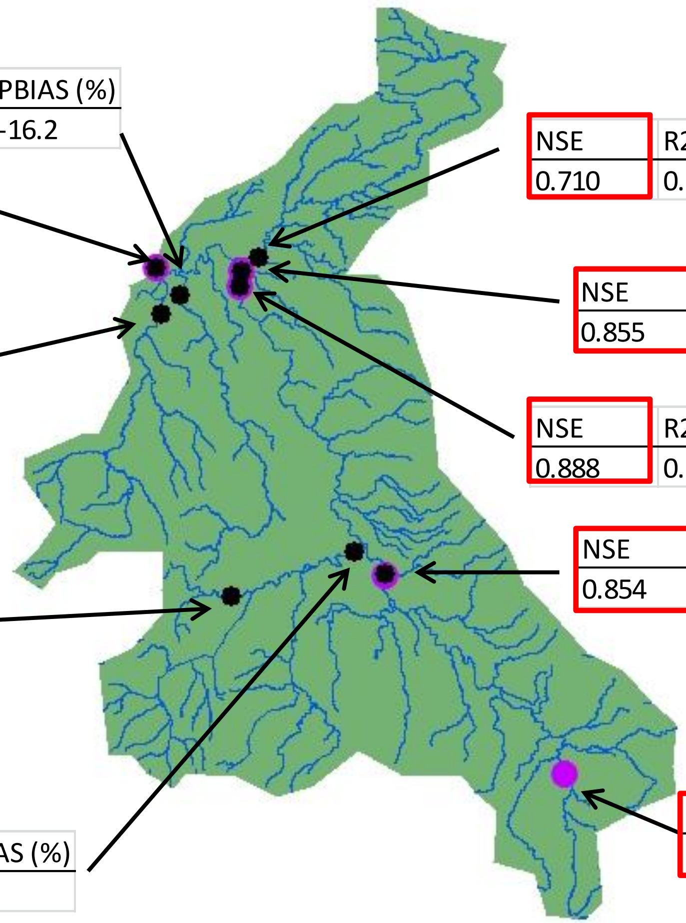
Results - Hydrology



NSE	R2	R	PBIAS (%)
0.645	0.865	0.930	-16.2

NSE	R2	R	PBIAS (%)
0.887	0.905	0.951	1.9

NSE	R2	R	PBIAS (%)
0.848	0.852	0.923	7.7

NSE	R2	R	PBIAS (%)
0.702	0.762	0.873	7.7

NSE	R2	R	PBIAS (%)
0.558	0.775	0.881	-5.3

NSE	R2	R	PBIAS (%)
0.710	0.790	0.889	10.7

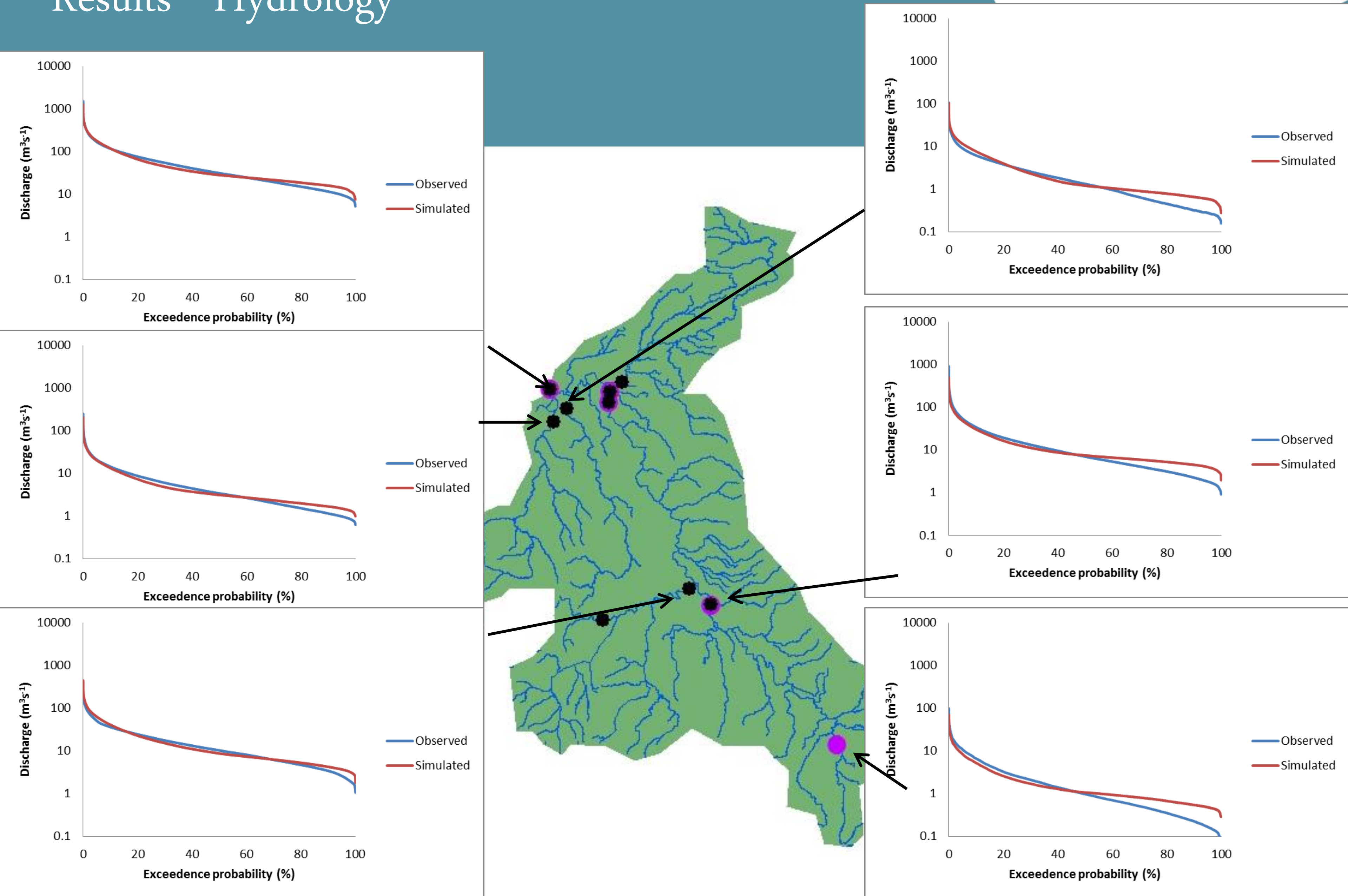
NSE	R2	R	PBIAS (%)
0.855	0.893	0.945	-1.5

NSE	R2	R	PBIAS (%)
0.888	0.903	0.95	2.1

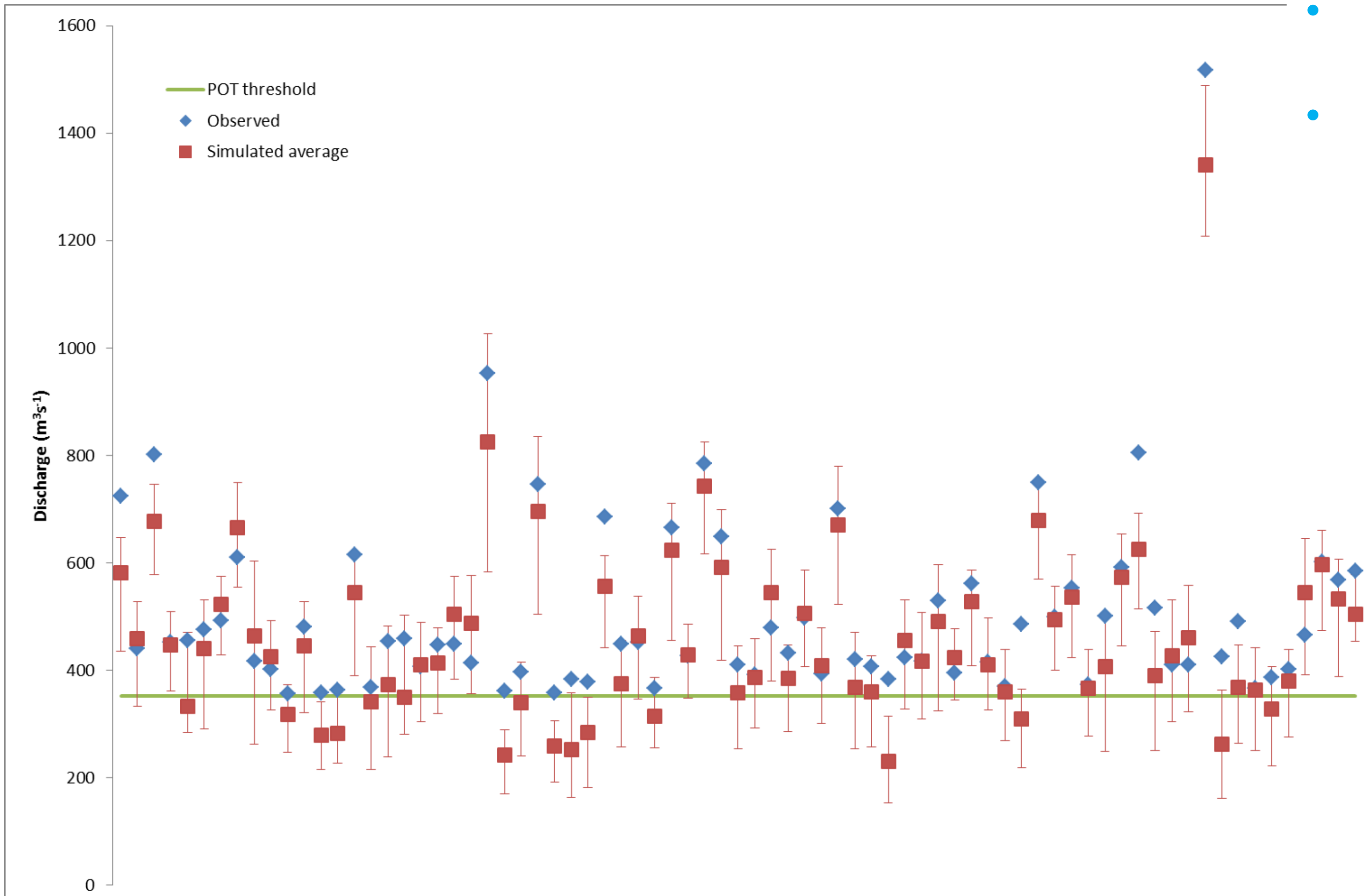
NSE	R2	R	PBIAS (%)
0.854	0.861	0.928	6.5

NSE	R2	R	PBIAS (%)
0.881	0.896	0.947	12.1

Results - Hydrology



Results - Hydrology



- Sheepmount
- 77% of POT events within simulated range

Results - Sediment

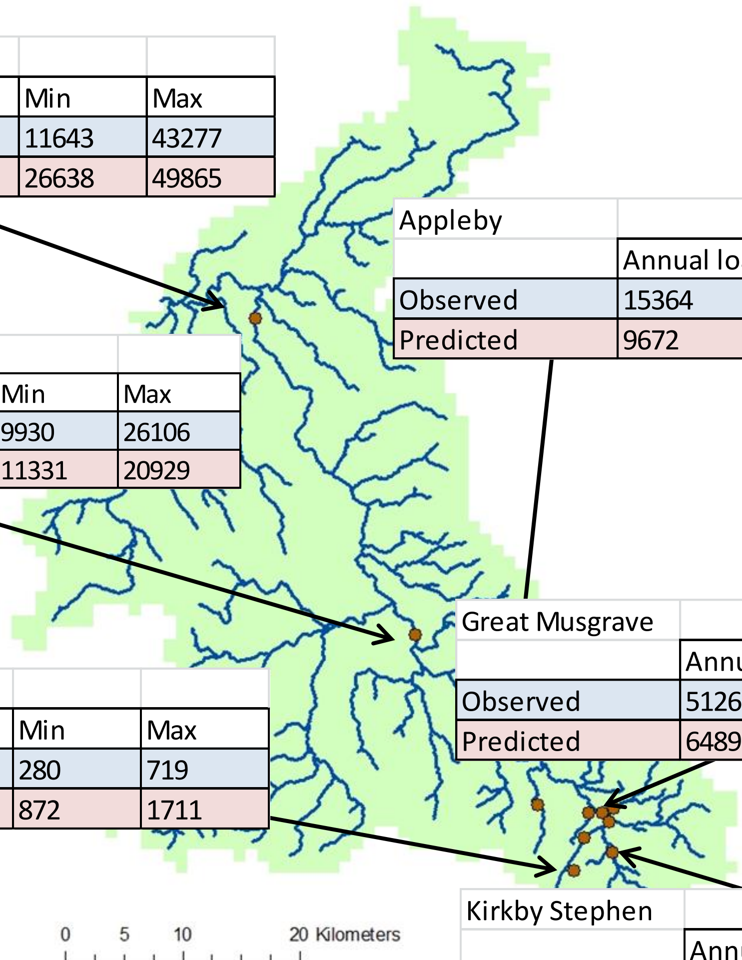
Great Corby			
	Annual load average (t yr-1)	Min	Max
Observed	21968	11643	43277
Predicted	34811	26638	49865

Appleby			
	Annual load average (t yr-1)	Min	Max
Observed	15364	14135	16747
Predicted	9672	7140	13316

Temple Sowerby			
	Annual load average (t yr-1)	Min	Max
Observed	16016	9930	26106
Predicted	14802	11331	20929

Great Musgrave			
	Annual load average (t yr-1)	Min	Max
Observed	5126	3332	7945
Predicted	6489	5199	9895

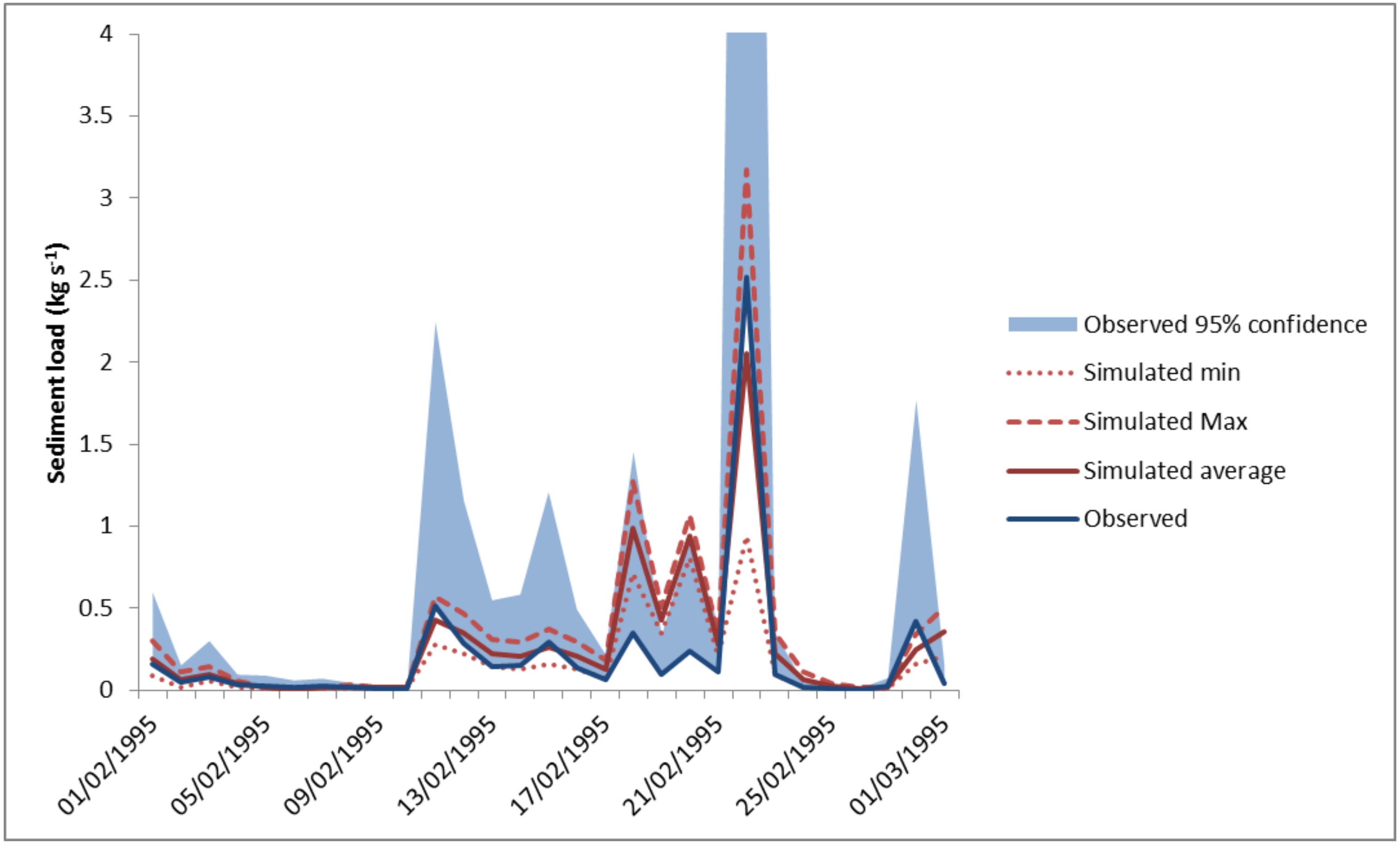
Smardale			
	Annual load average (t yr-1)	Min	Max
Observed	444	280	719
Predicted	1024	872	1711



Kirkby Stephen			
	Annual load average (t yr-1)	Min	Max
Observed	1794	1058	3086
Predicted	2191	1815	3611

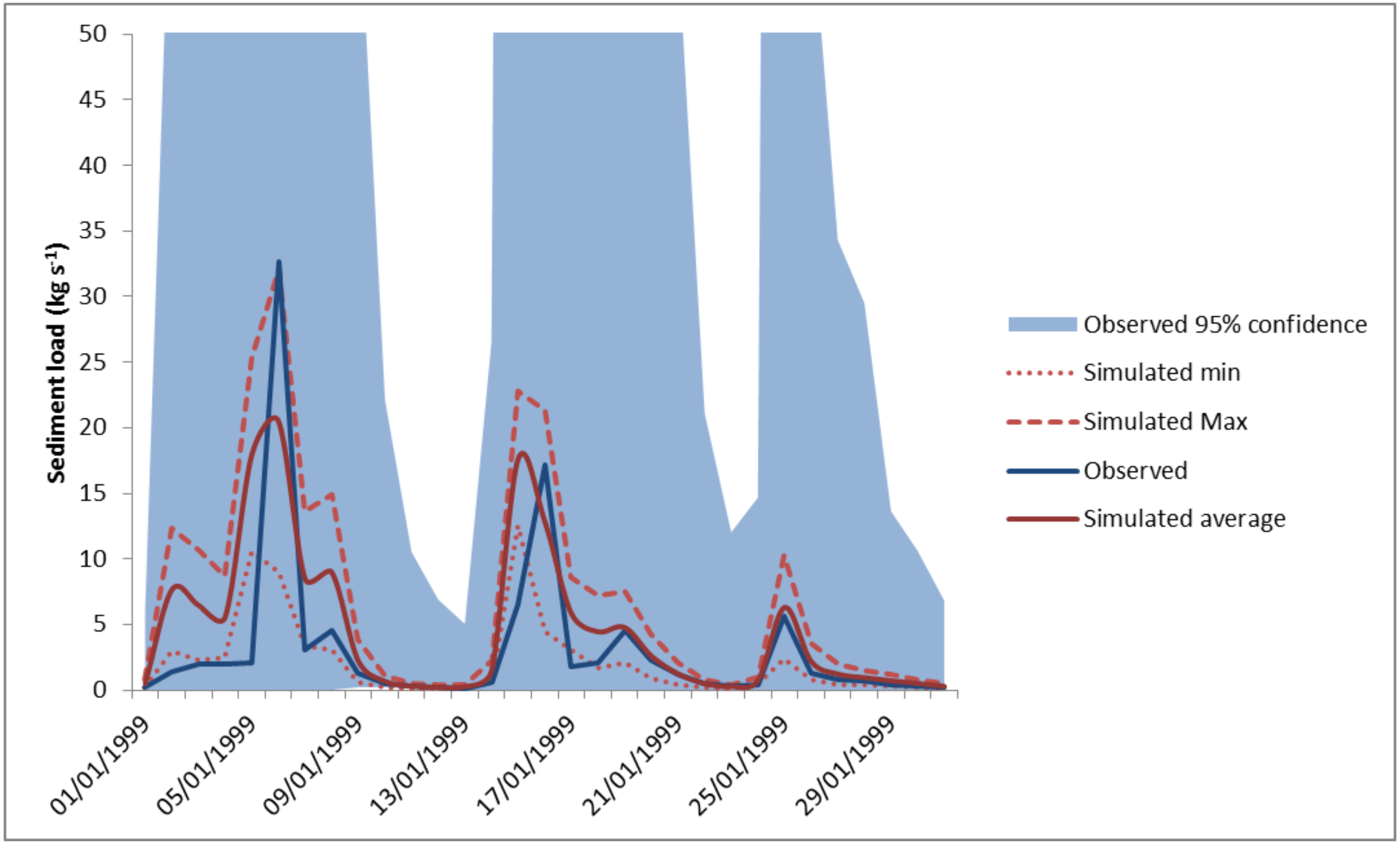
Results – Sediment

- Kirkby Stephen



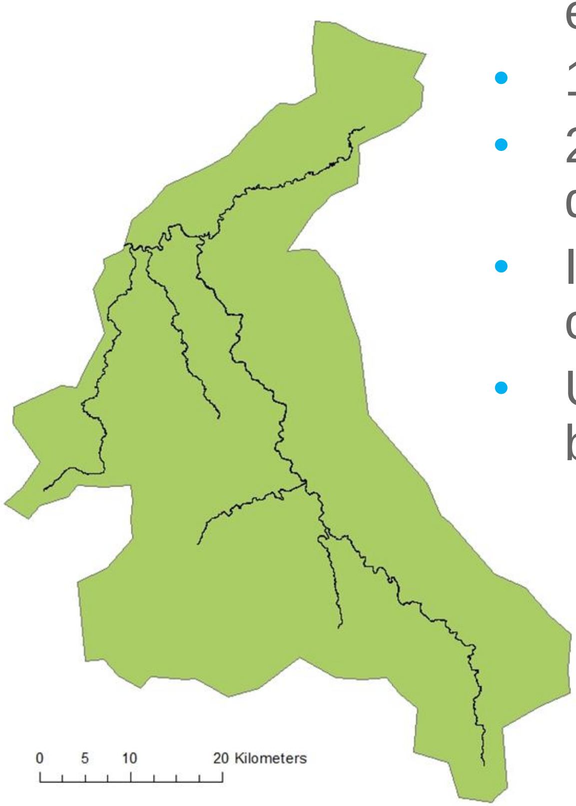
Results – Sediment

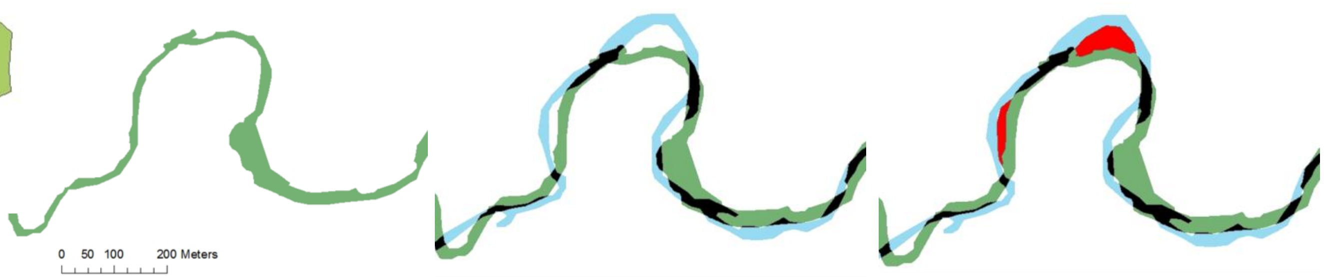
- Great Corby



Validation of bank erosion

- Polygon overlay analysis (Gurnell et al, 1994) = mass of bank eroded sediment
- 1880, 1901, 1956, 1970, 2010
- 211-4426 t yr^{-1} bank eroded sediment (includes re-deposited material)
- Indicates sections of channel actively eroding – comparison with model
- Used to validate both magnitude and spatial variability of bank erosion





Section of River Irthing 1970

1970 (with buffer) and 2012

1970-2012 With erosion 'islands'

Conclusions

- SHETRAN applied to Eden catchment, Cumbria
  - Both hydrology and sediment components validated against observational data
- Bank erosion is an important source of sediment within catchments
  - Highly spatially and temporally variable due to numerous controlling factors
- Bank erosion component within SHETRAN modified to represent spatial and temporal variability of bank erosion rates
  - Representation of sensitivity of bank erosion to flood event clustering
  - Bank erosion data GIS used to validate bank erosion component

Questions

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