National flow-dependent and local through-time source apportionment to help manage diffuse / point source pollution using the CSF-HYPE model for England

Barry Hankin[1], Sarah Warren[1], Nicola Wood[1], Elizabeth Wood[1], Johan Strömqvist[2], Chris Burgess[3], Tom Newton[3], Sharon May[3], Phil Smith[3], Hannah Champion[1], Andrew Binley[4]

[1]JBA Consulting, [2]SMHI, [3]Environment Agency, [4]Lancaster University

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Flood and coastal resilience innovation programme

Part of the £200m Flood and coastal innovation programmes

QUANTUM

Quantifying livestock impacts on freshwaters

CSF

Environment Agency

https://www.ousewem.co.uk/

QUANTUM NERC Grant: NE/X015807/1

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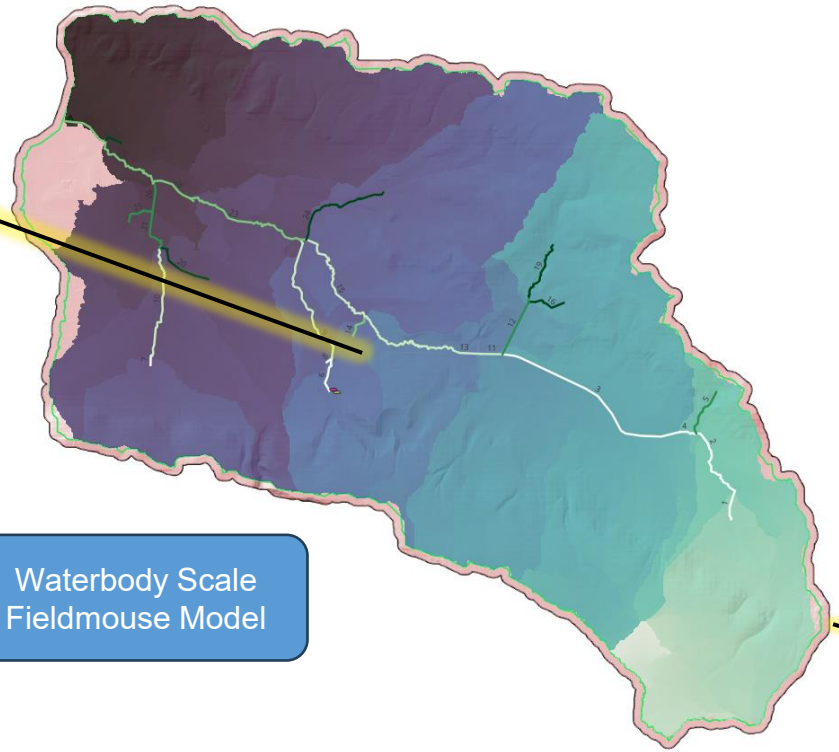
June 2025

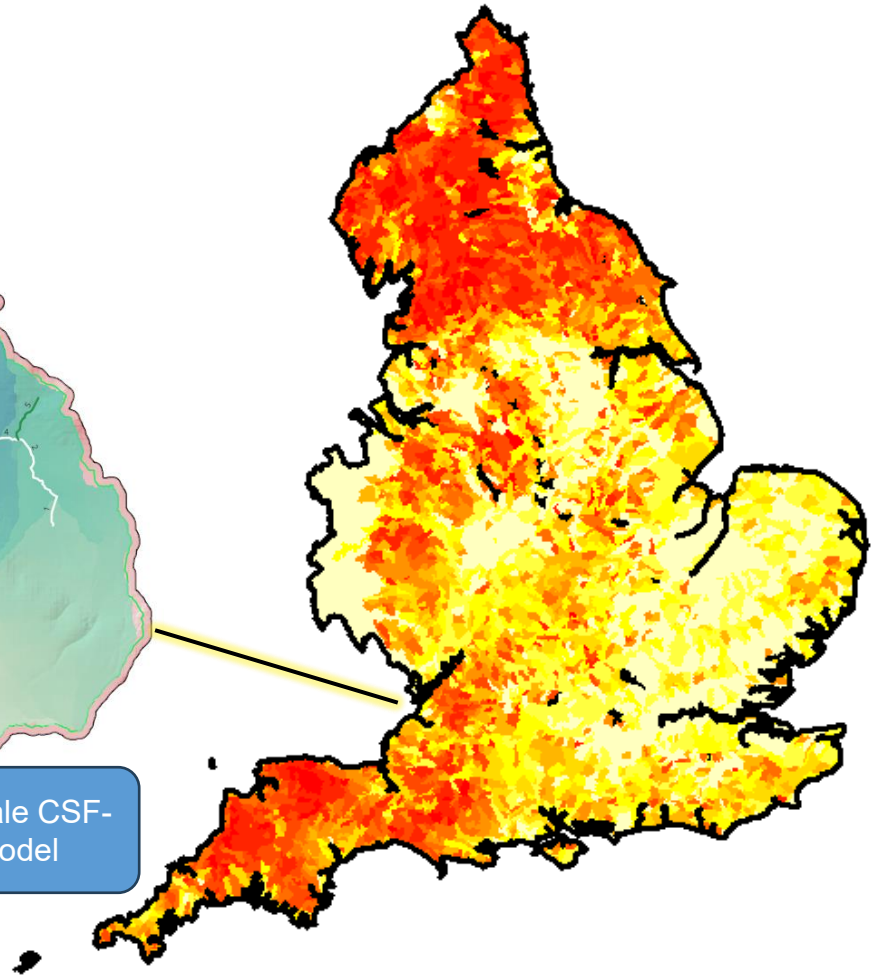
Pollution modelling at different scales and upscaling

- Modelling & Management of loads at multiple scales
- Upscaling field evidence?

Plot Scale
Particle Tracking



Waterbody Scale
Fieldmouse Model



National Scale CSF-HYPE Model

Commonality: Transport rates + half-lives of different pollutants

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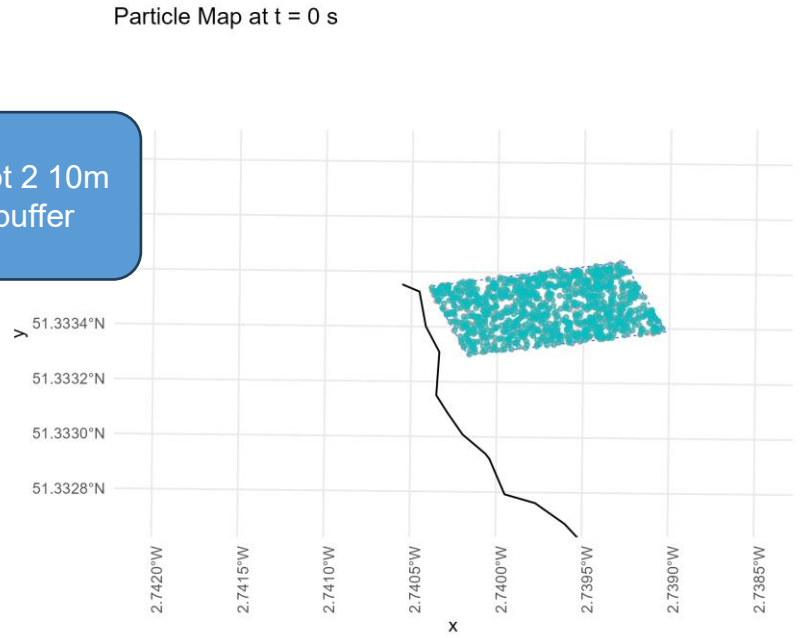
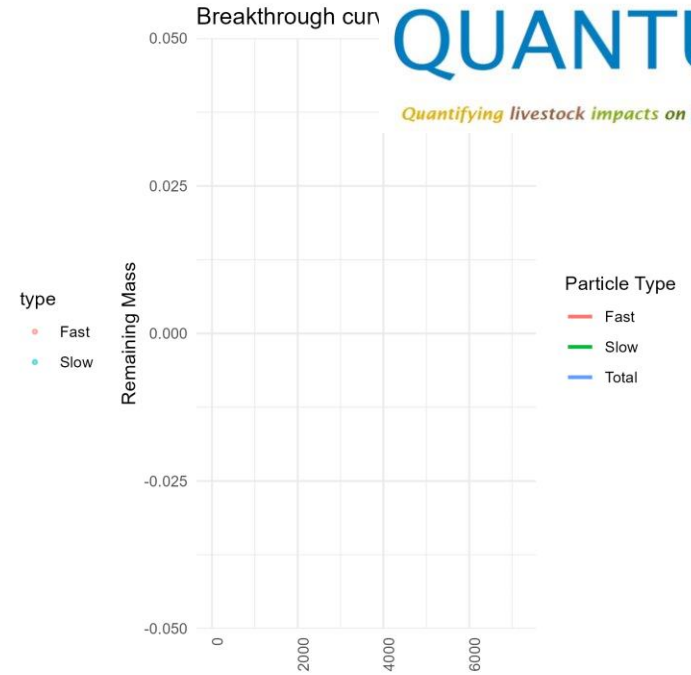
The plot-scale

Conceptualised dual-pathway particle tracking R script

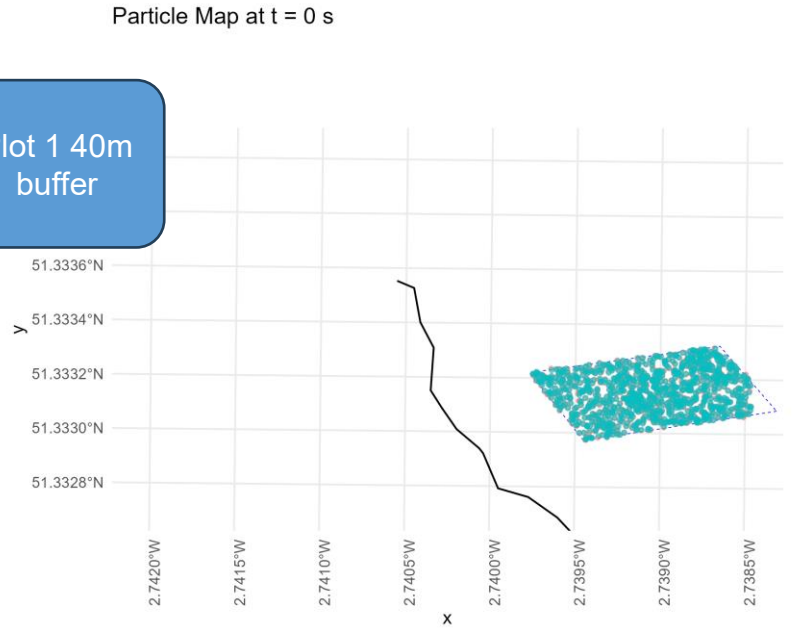
- JUMP model initiates thousands of particles of unit mass and advects 2 sets:
  - Fast using overland flow velocities plus diffusivity scaled by velocity
  - Slow – multiplier on surface velocities and diffusivity conceptualising through-soil (sped up here factor is only 0.1)
- Calibrate half-life for different classes of pollutant behaviours.

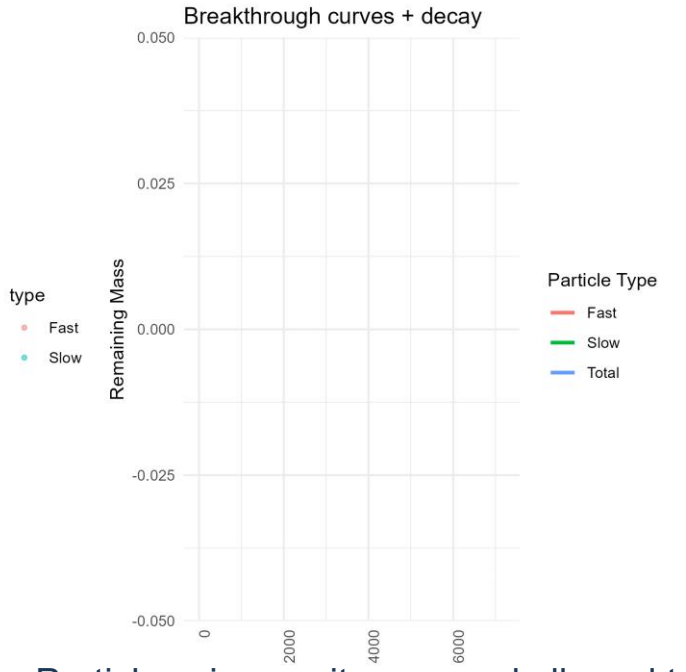
Plot 2 10m buffer





Plot 1 40m buffer





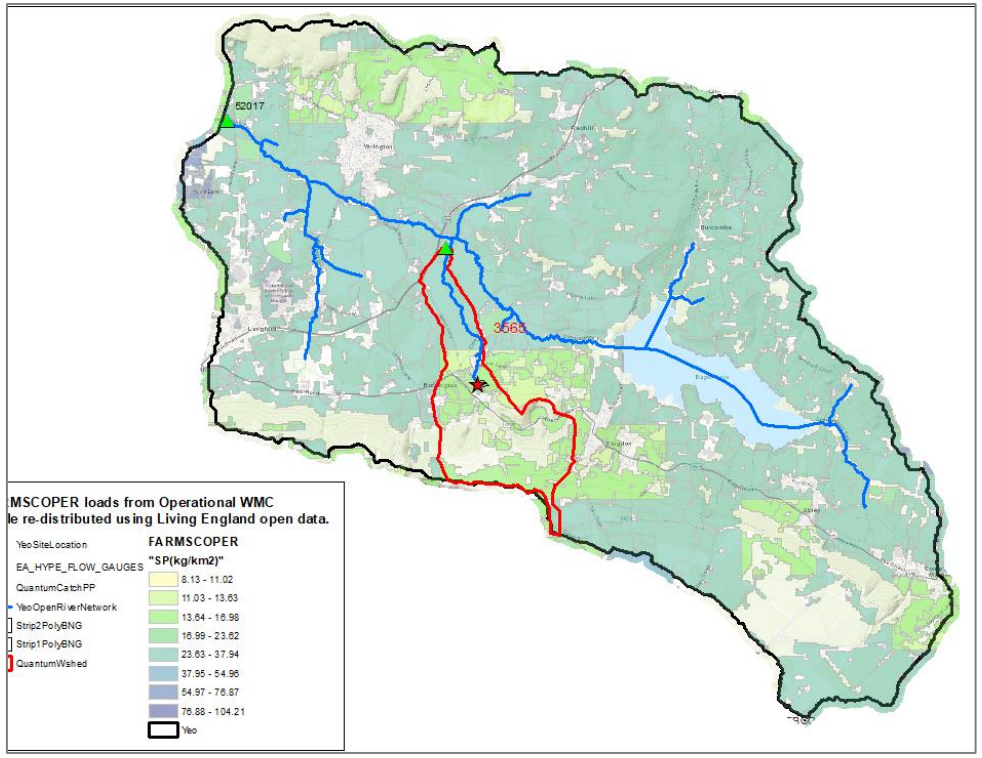
Particles given unit mass and allowed to decay

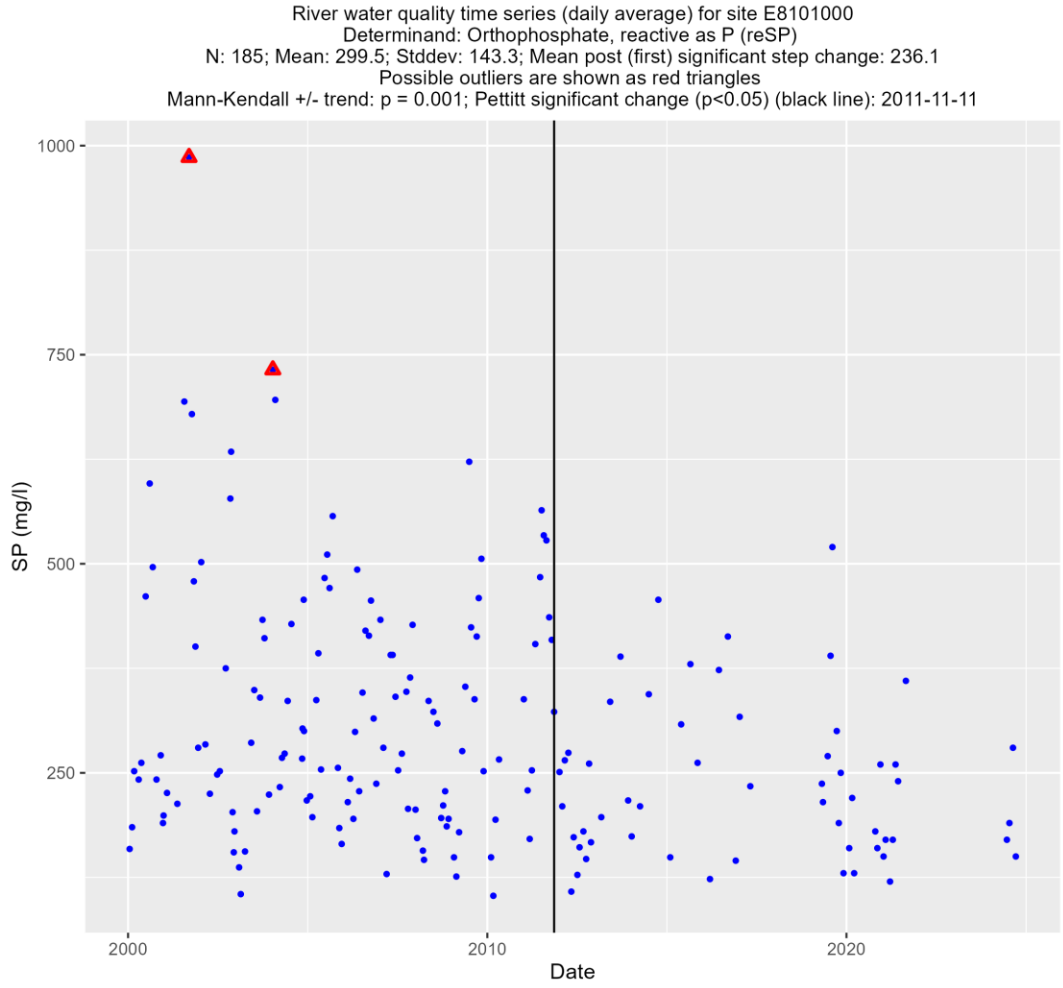
QUANTUM

Quantifying livestock impacts on freshwaters

The catchment Scale: Yeo

- Current WFD chemical class Poor
- Recent mean 0.236mg/l





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Site overview and open-data loads disaggregated

Long term monitoring data below outlet

Fieldmouse Risk (first run)

Accumulated mean flows adjusted to mean flow at NRFA flow gauge @ Congresbury:

[NRFA station data for 52017 - Congresbury Yeo at Iwood]

Station

52017 - Congresbury Yeo at Iwood

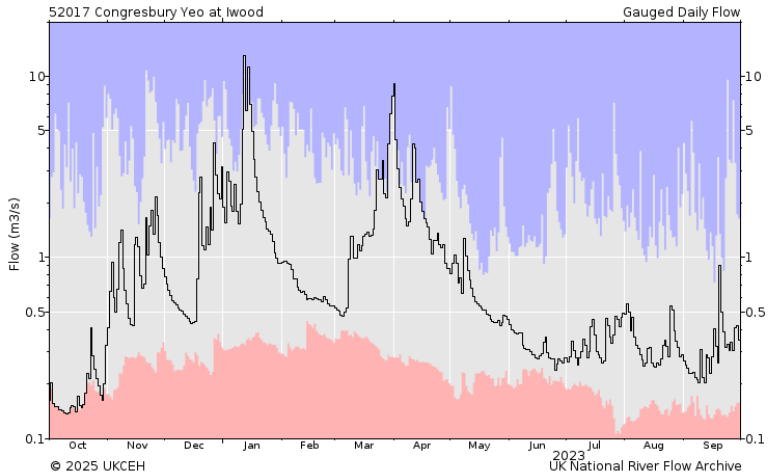
Station info | **Daily flow data** | Live data | Peak flow data | Catchment info | Photo gallery

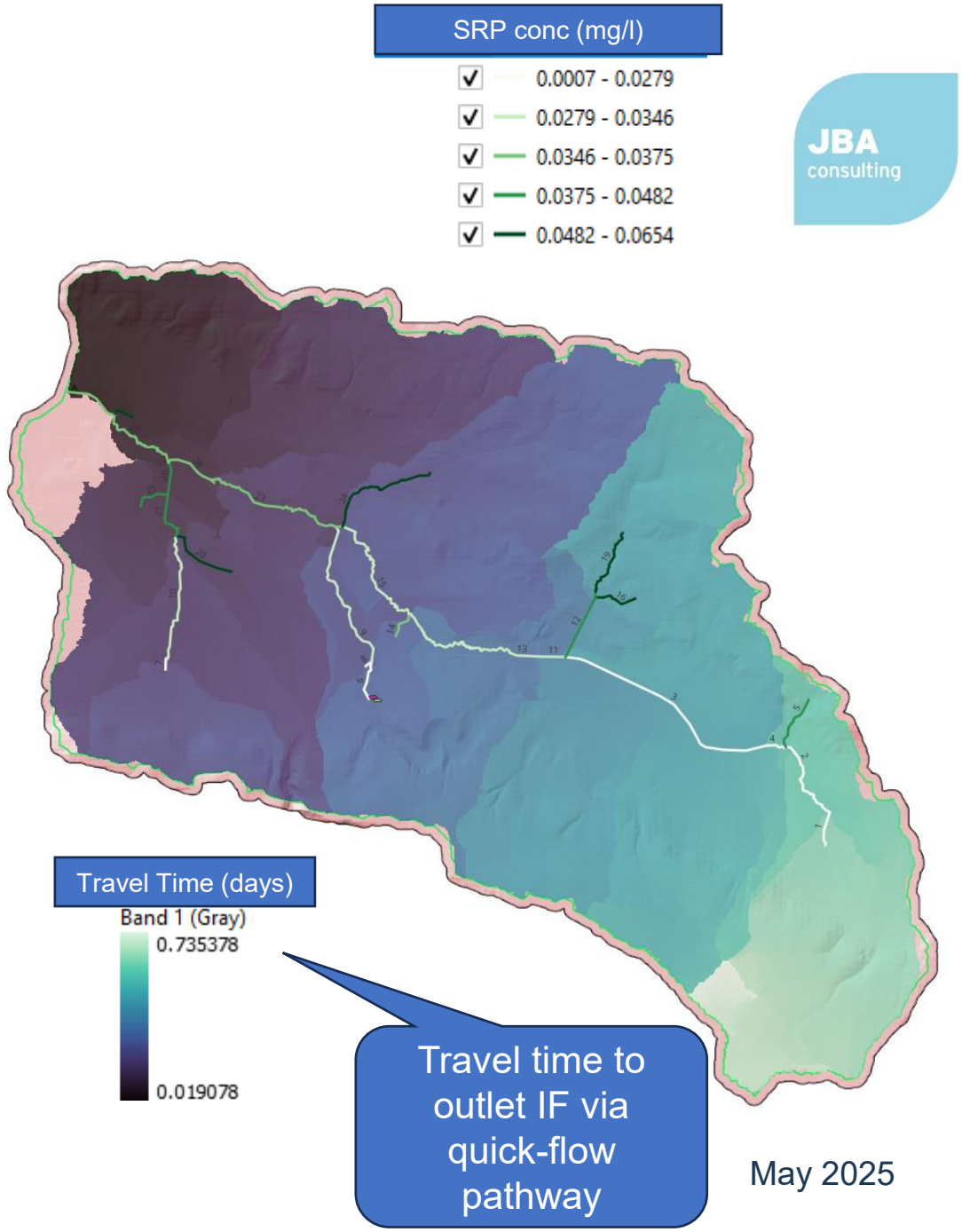
Data series: Gauged Daily Flow | Graph type: Annual hydrograph | Year: < 2023 > | Refresh

Period of record:	1973 – 2023
Percent complete:	77 %
Base flow index:	0.65
Mean flow:	0.784 m^3/s
95% exceedance (Q95):	0.211 m^3/s
70% exceedance (Q70):	0.33 m^3/s
50% exceedance (Q50):	0.484 m^3/s
10% exceedance (Q10):	1.629 m^3/s
5% exceedance (Q5):	2.286 m^3/s

Gauged daily flow (GDF) data is available for download for this station.

Download flow data





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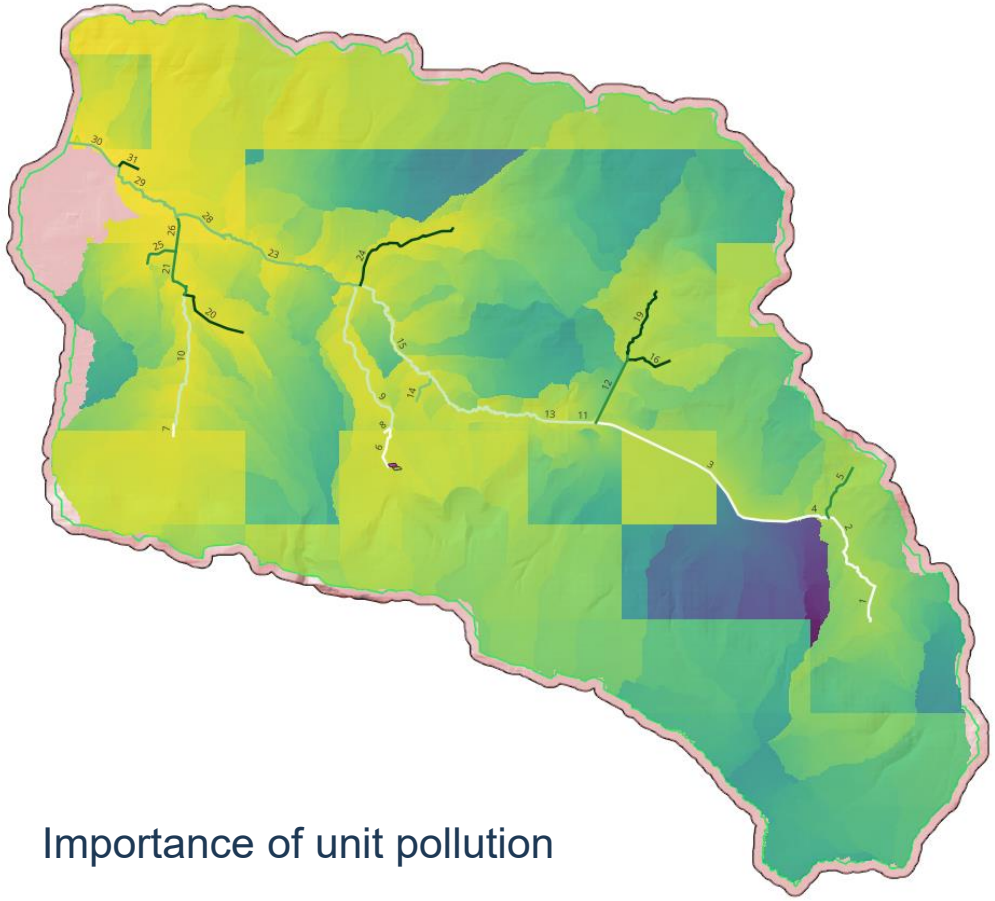
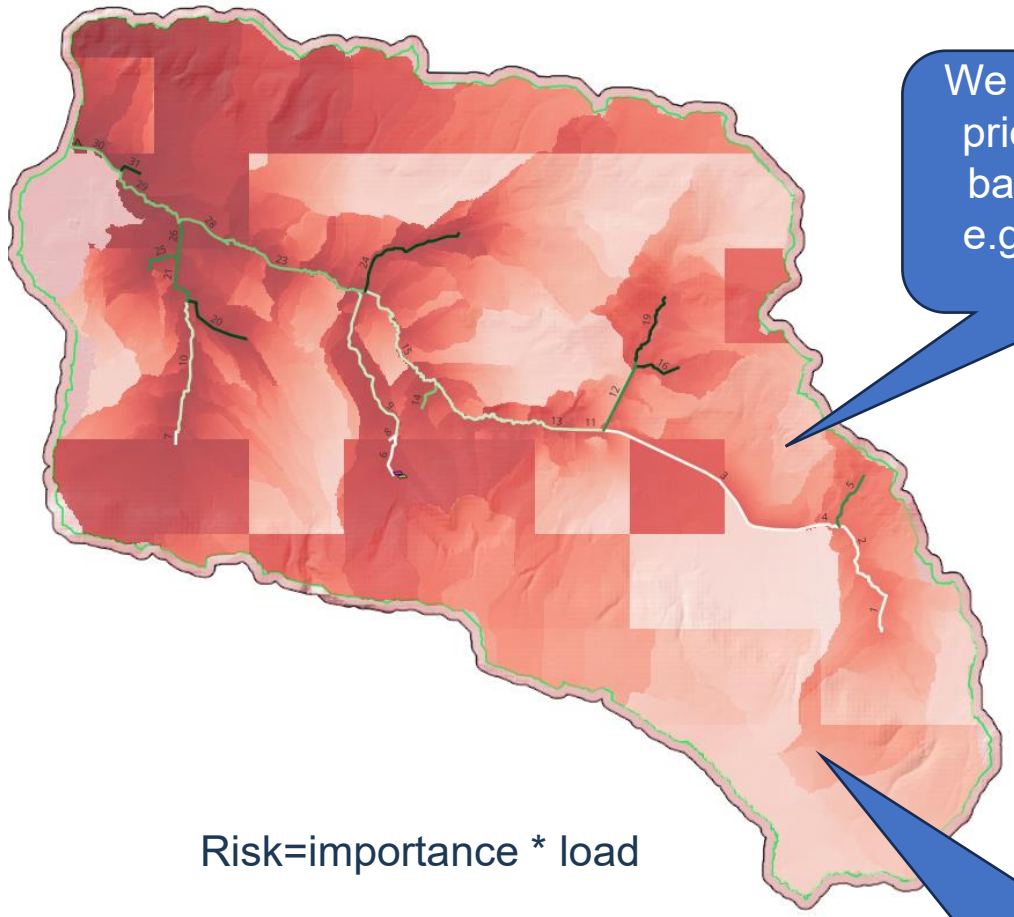
May 2025

Importance + Risk



Importance of unit pollution



Risk=importance * load

We can use this to prioritise Nature-based Solutions e.g. target upper 10%ile

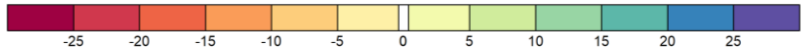
Artefacts from open soil + runoff data grid scales (to be improved)

The National Scale (England)

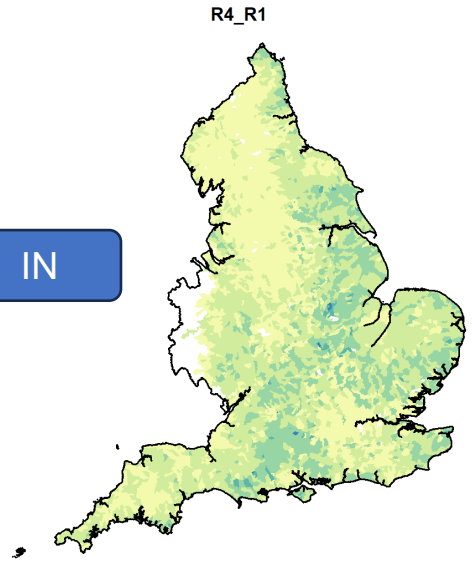
Looking at change using CSF-HYPE v 6.02

Percentage change considering all environmental stewardship, regulation and Catchment Sensitive Farming.

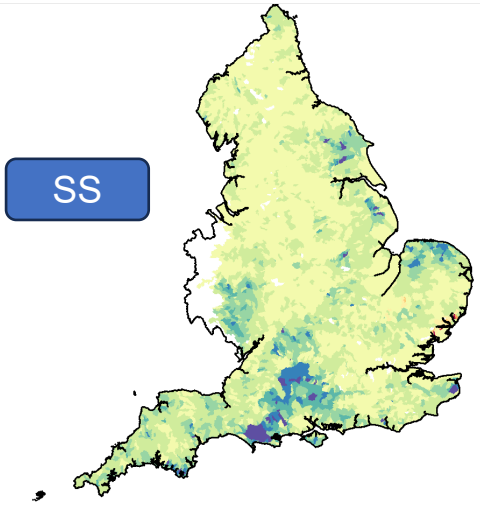
(note showing 2018-2022 longer period plots not available)



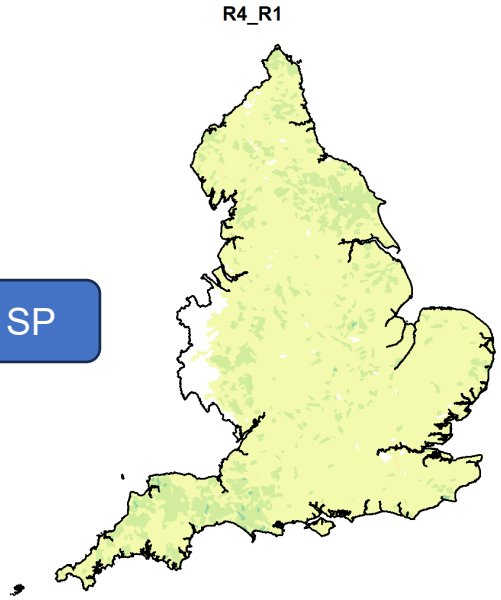
IN



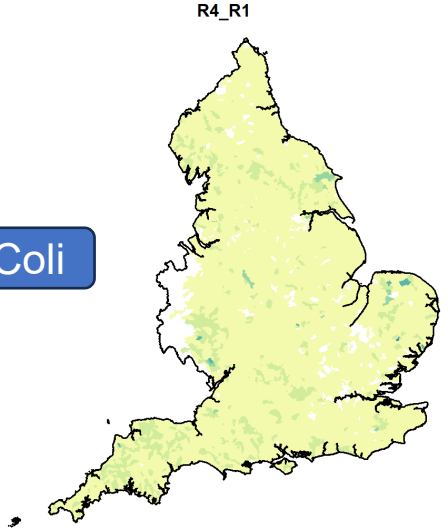
SS



SP



E.Coli



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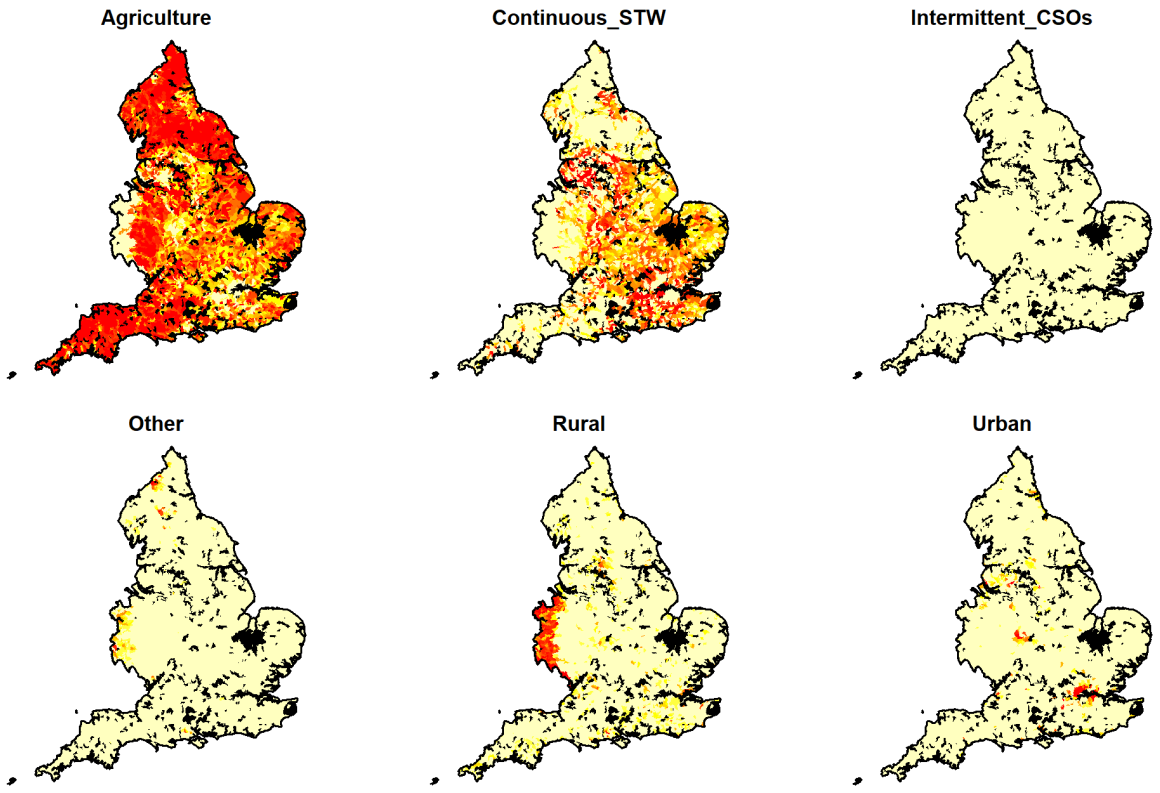
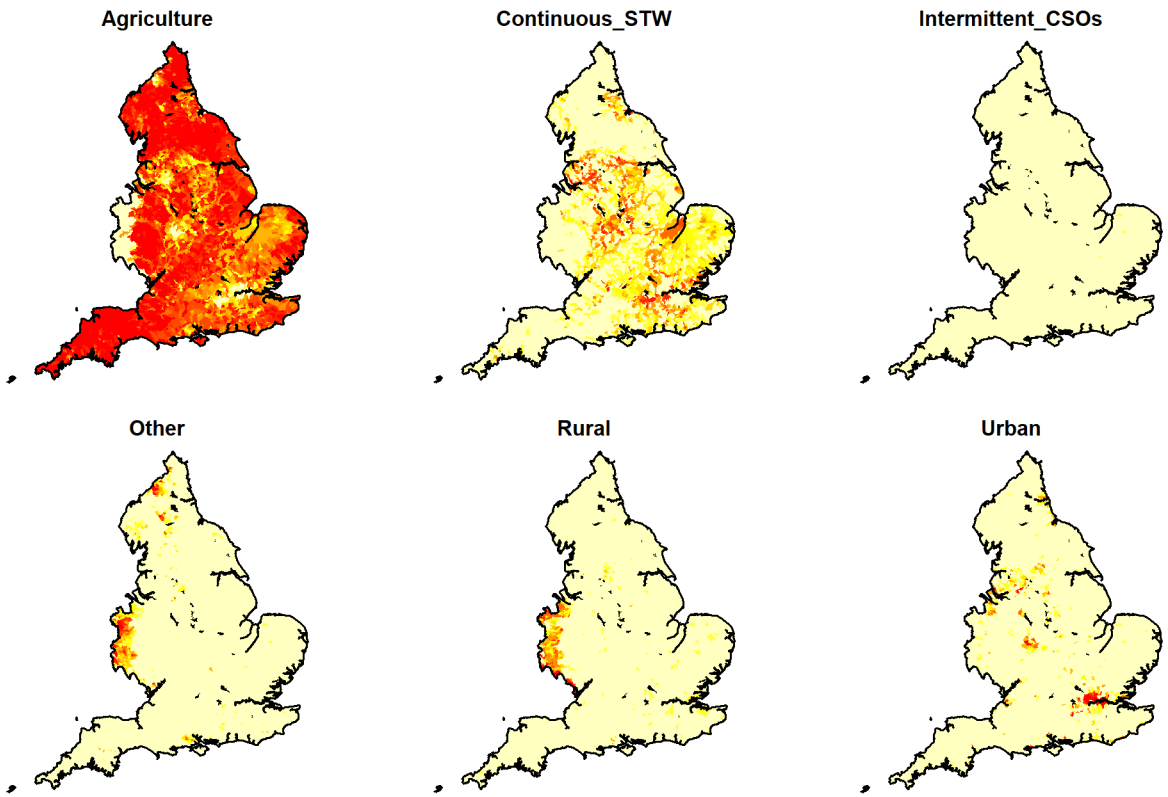
National Source Apportionment Heat maps under different flow conditions (Inorganic Nitrate)





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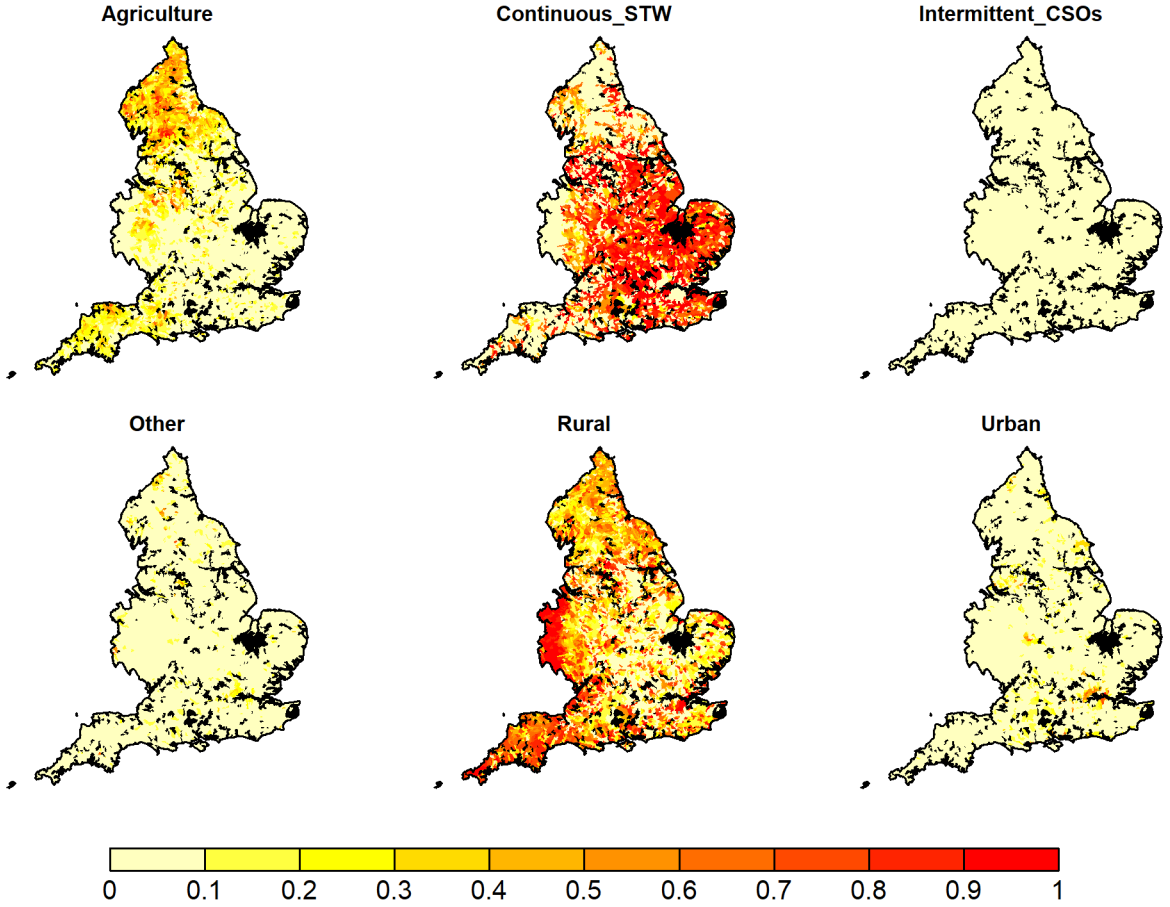
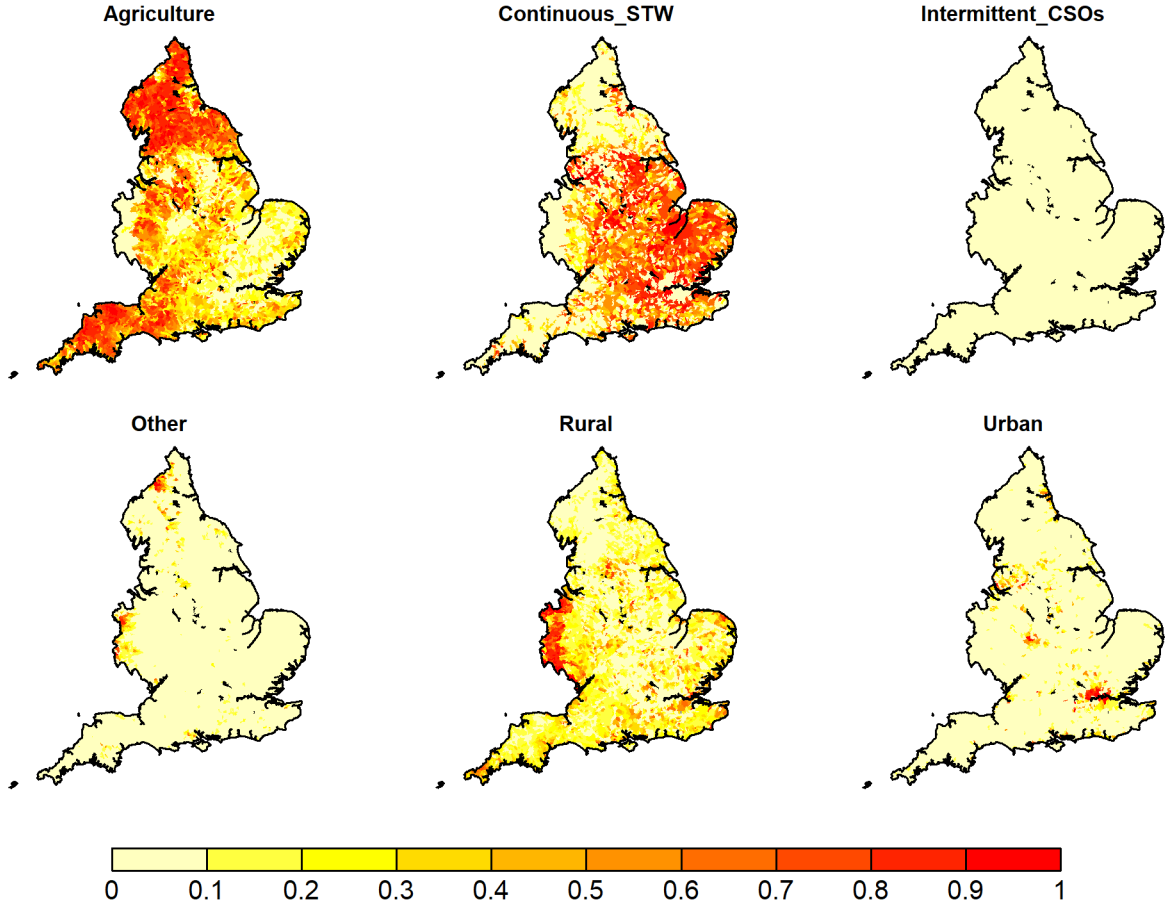
LOW Flows

Medium-High Flows

National Source Apportionment Heat Maps for Soluble Phosphorus under different flow conditions





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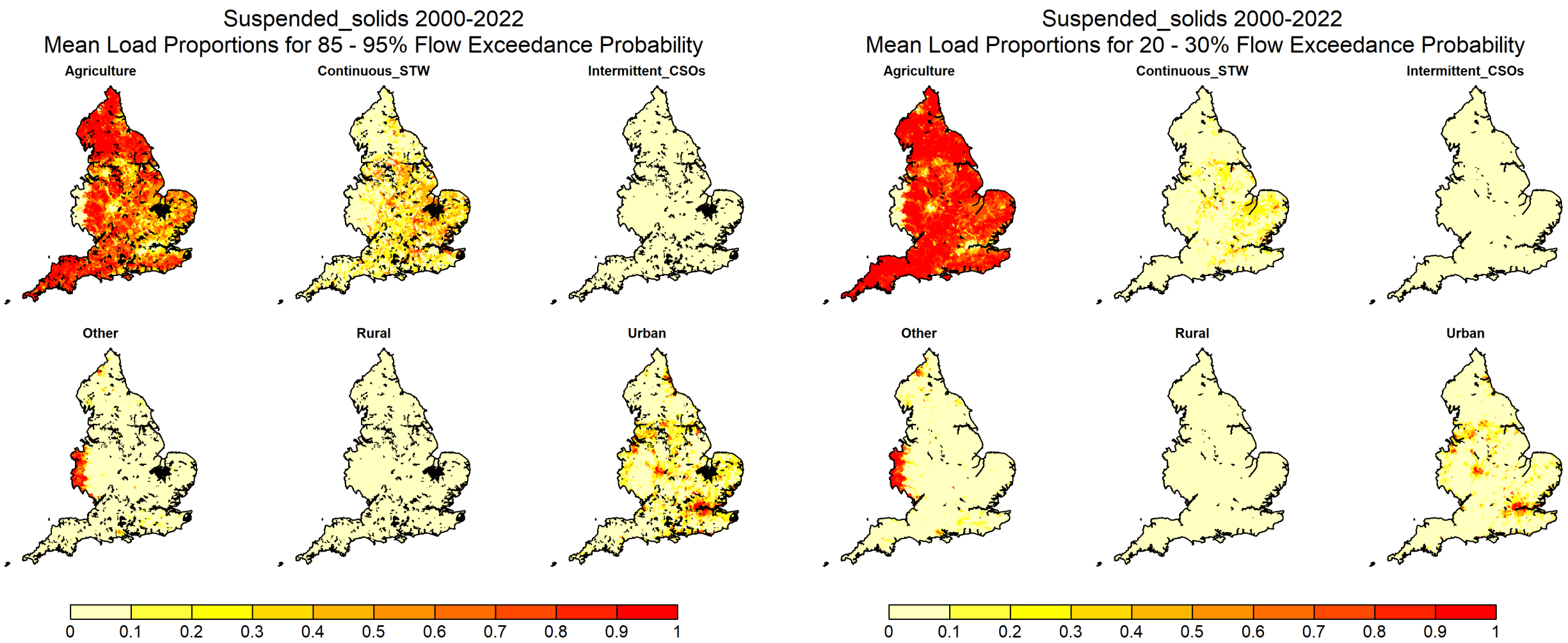
LOW Flows

Medium-High Flows

National Source Apportionment Heat Maps for SS under different flow conditions



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LOW Flows

Medium-High Flows

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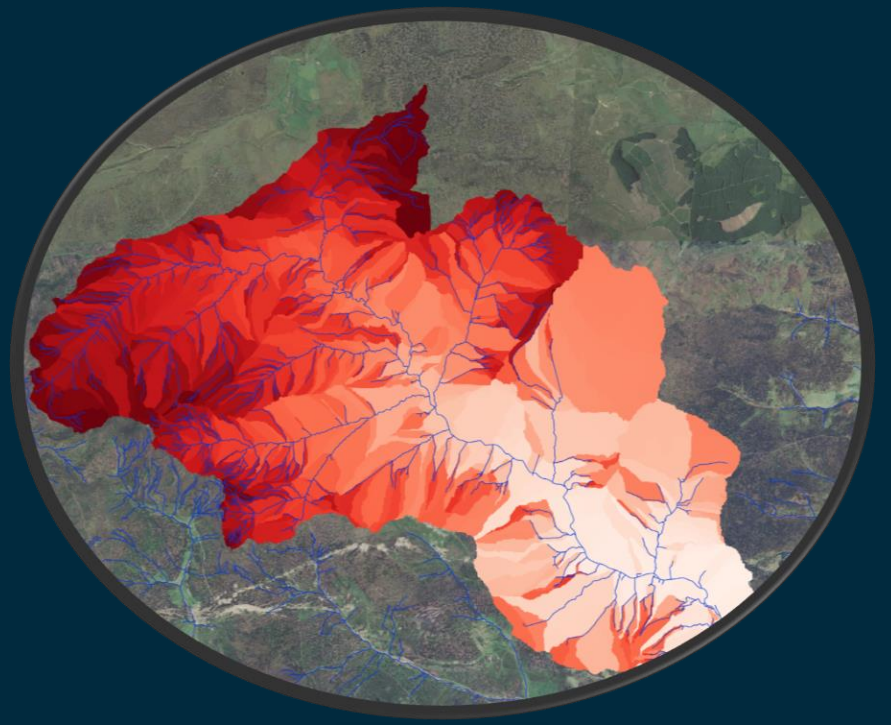
Fieldmouse + CSF-HYPE at a finer scale

Spatially and through-time



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Travel time from a 10m pixel in the landscape

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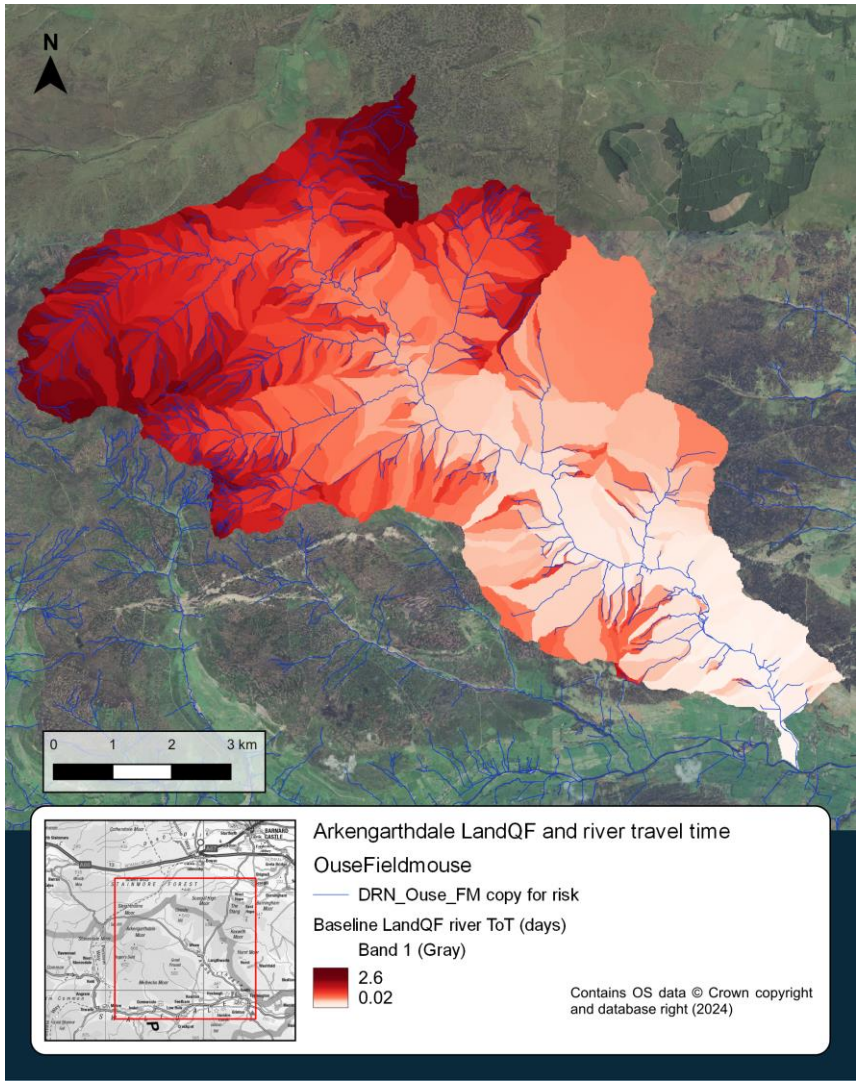

Time of Travel (ToT)

- Community scale: Arkengarthdale
  - Fieldmouse outputs a travel time map in units of ‘days’ from every pixel to the catchment outlet
  - This provides greater time for assimilation of pollutants in the environment
  - A unit of pollution on a filed in the headwaters here would take nearly 3 days to reach the outlet

Importance of a unit of pollution in a 10m pixel in the landscape

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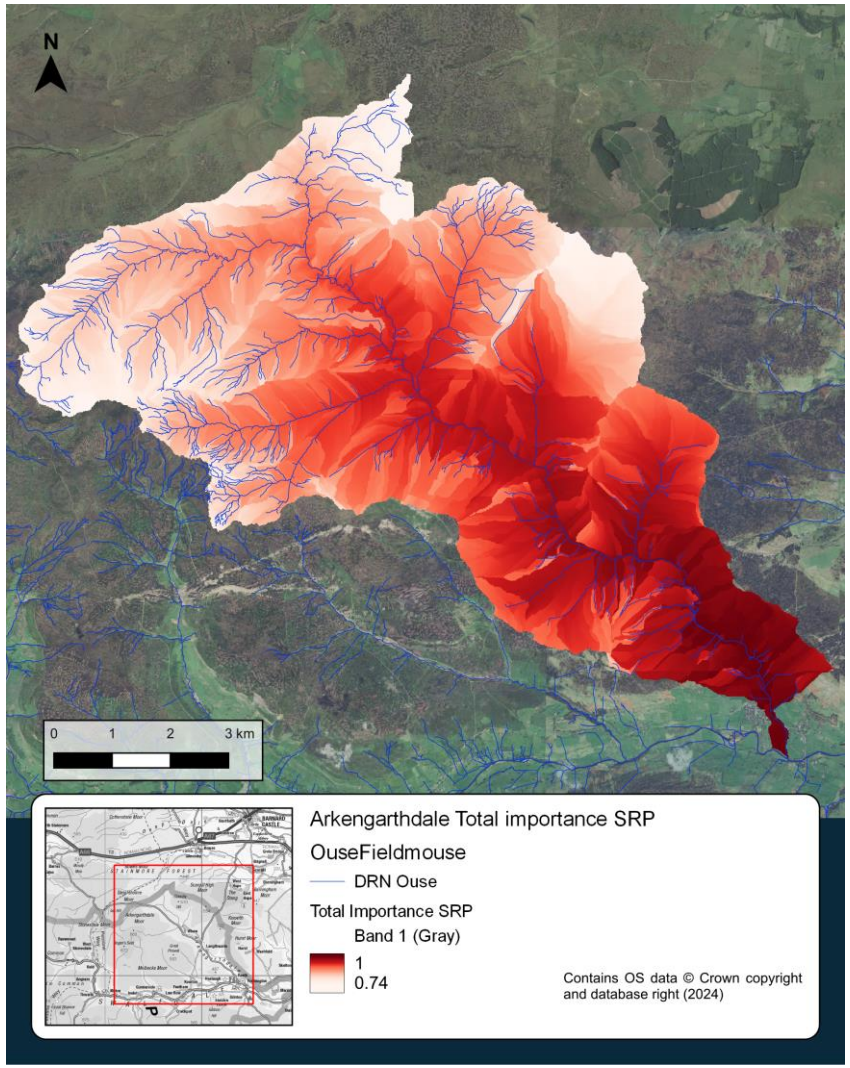
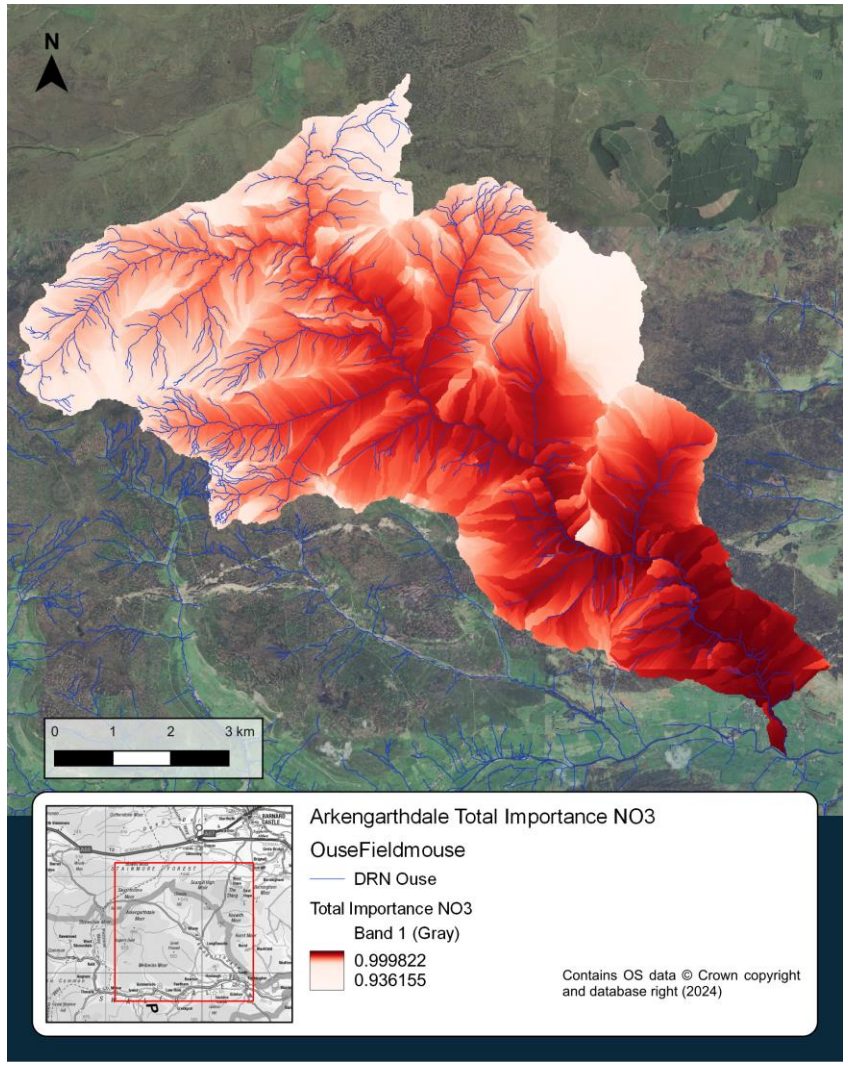


Soluble Phosphorus



Nitrate

- Importance Rasters
- Showing the relative importance of a unit of pollution in any 10m pixel have at the outlet

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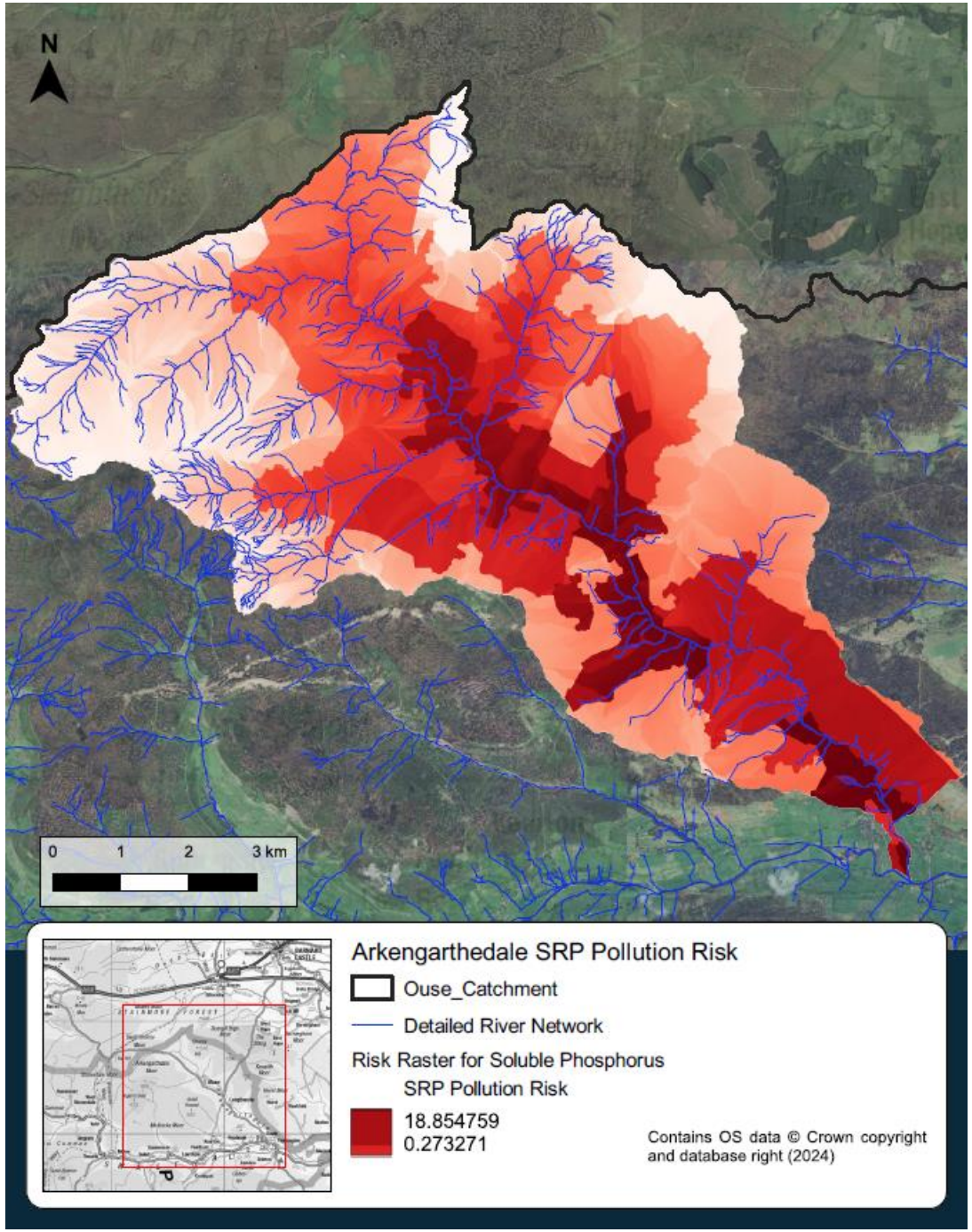
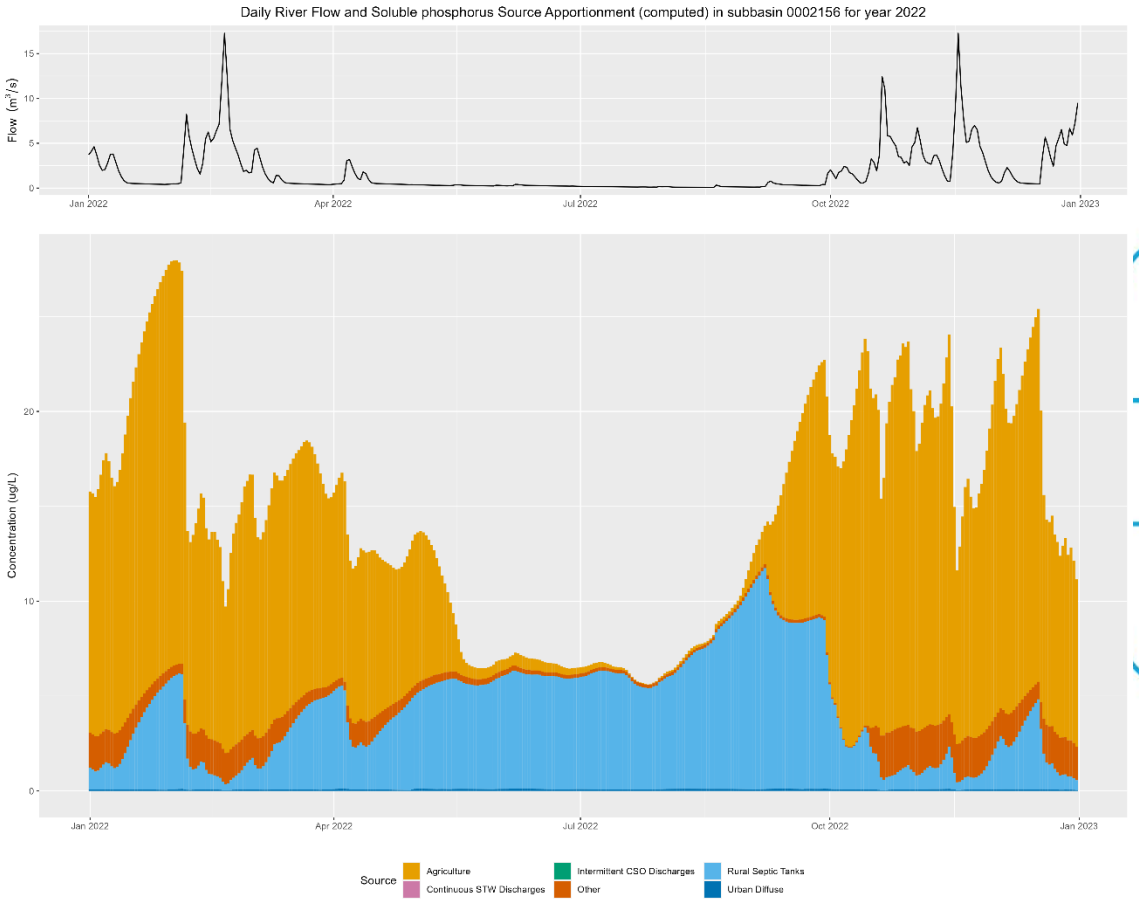
- Arkengarthdale – RISK raster for Phosphorus to help focus location for NbS





Event-driven agricultural SP loads using **CSF-HYPE**

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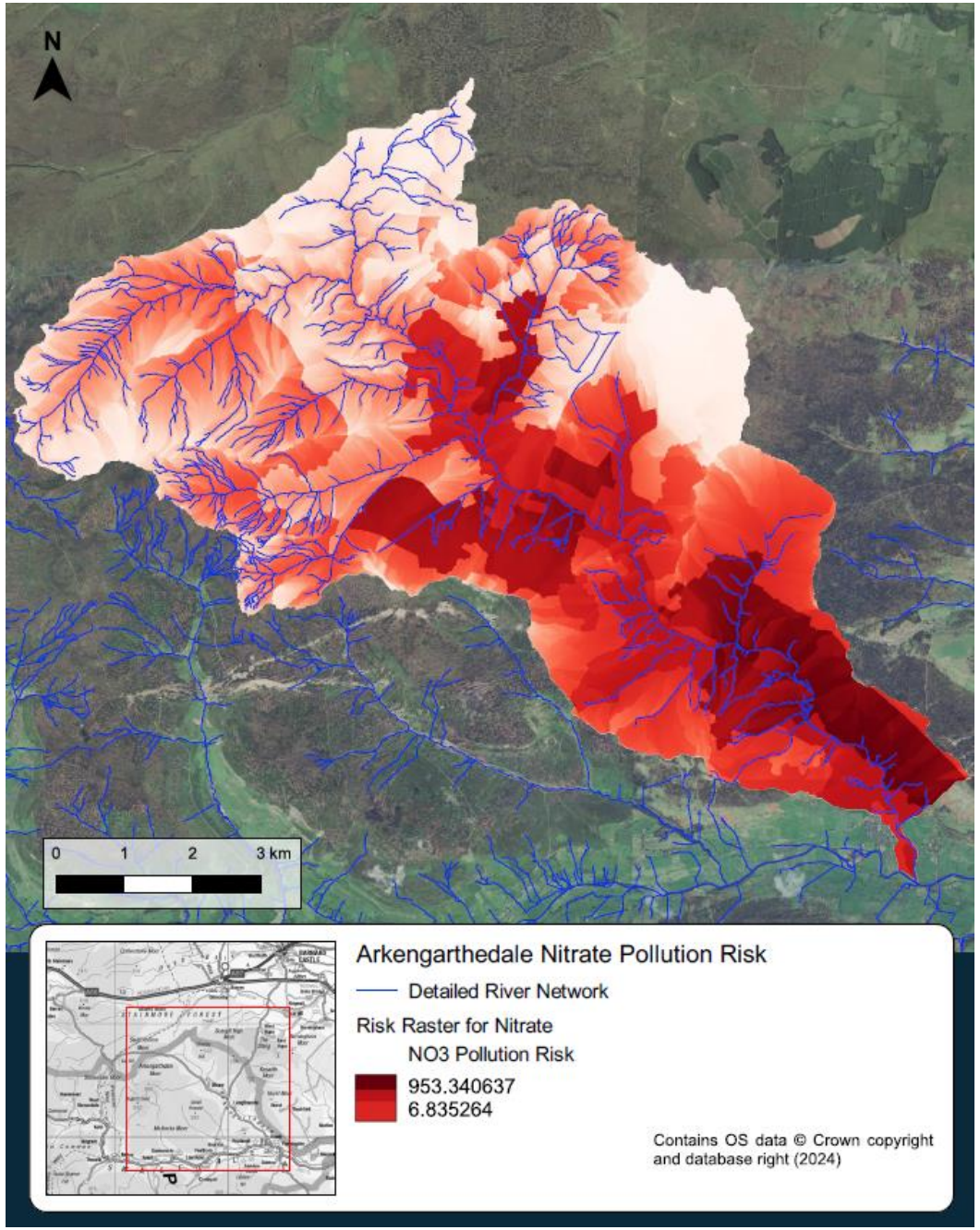
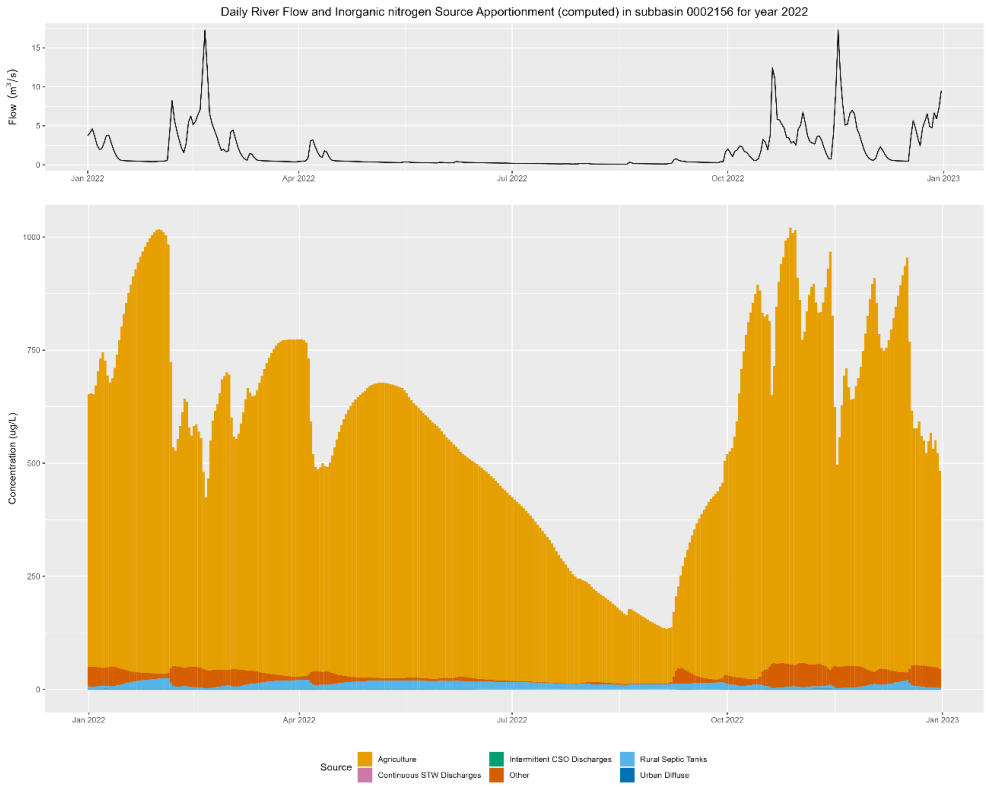
- Arkengarthdale – Risk Raster for Nitrate

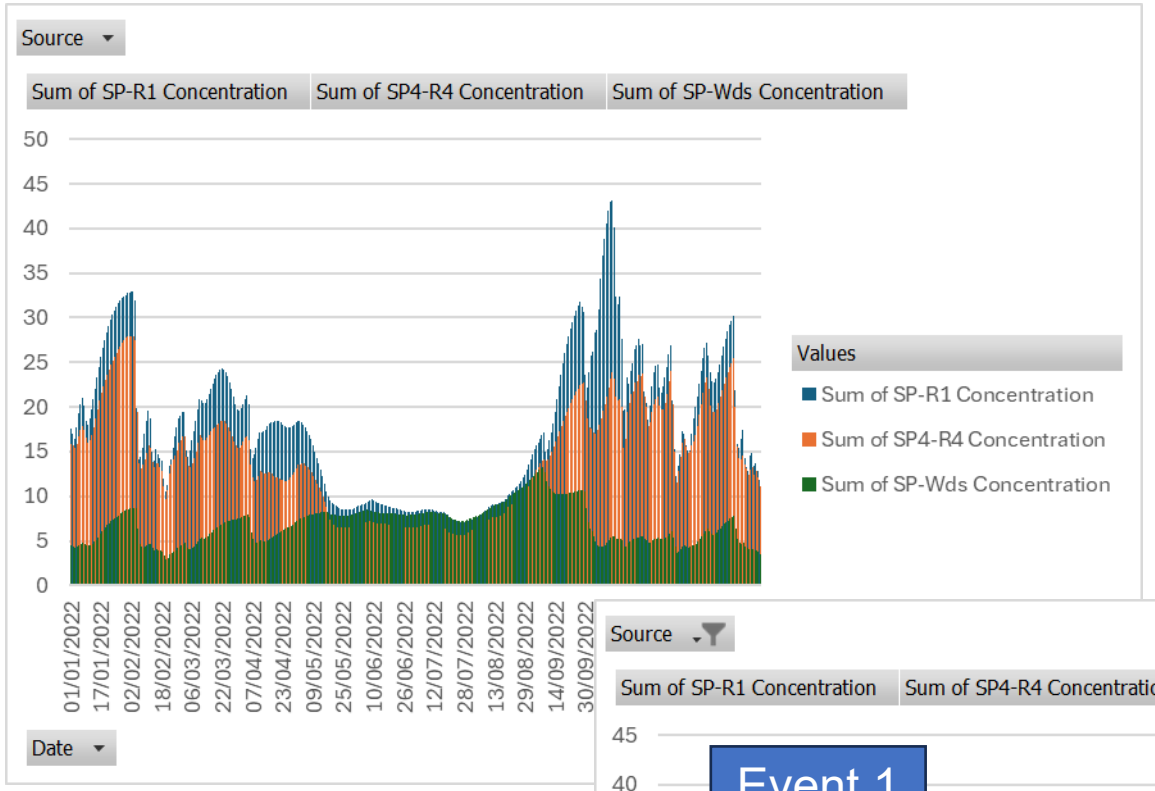




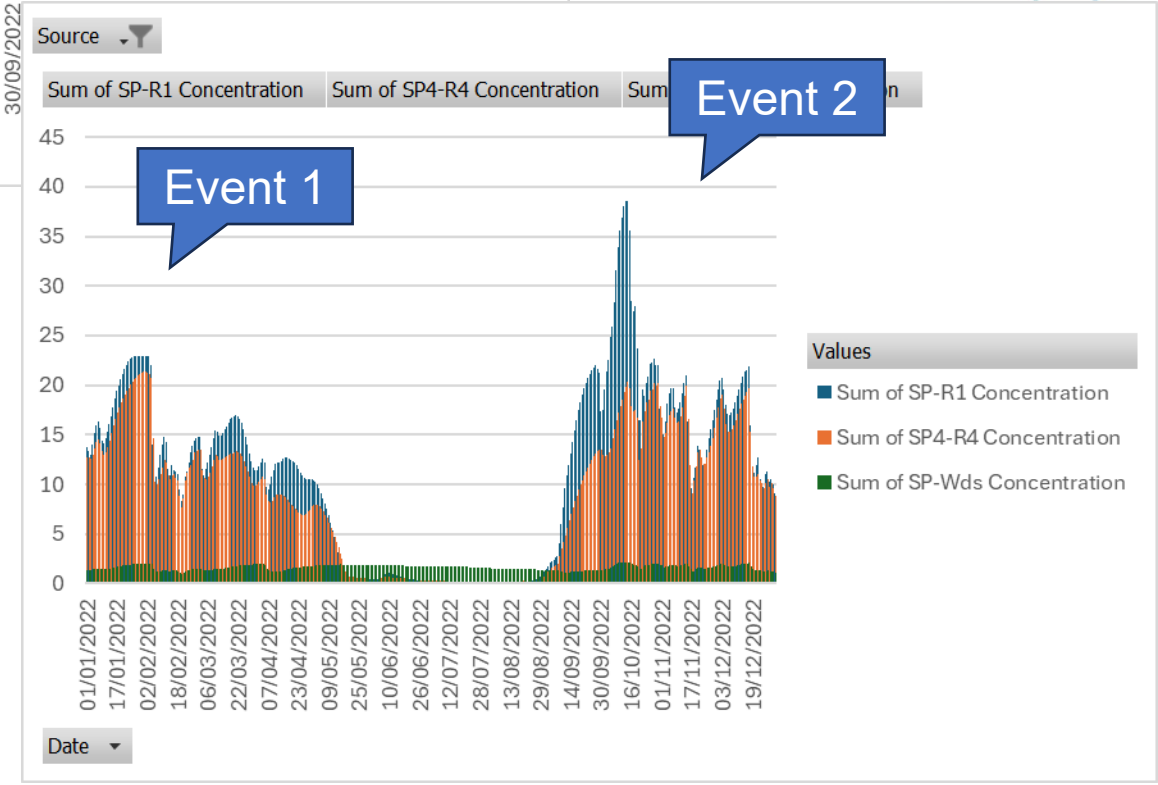
Even-driven agricultural IN loads using **CSF-HYPE**

Mass avoided (CSF-HYPE)

- Change scenarios:
  - Baseline R1
  - CSF + Env Stewardship R4
  - Change to riparian and floodplain planting
- Peak concentration reductions
  - Event 1
    - R4 - 7.6%
    - Woods: 91.3%
  - Event 2
    - R4 - 47.2%
    - Woods: 94.5%
- Mass avoided?



Change in total loads through time



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Efficacy of Nature-based Solutions

Peak Flow reduction from flood model

- UKRI/NERC programme research developed an efficacy measure based on the peak volume avoided
- See Chappell et al, 2023 https://doi.org/10.5281/zenodo.10361737)
- Footprint of woodland = 100ha
- Using **JFlow*** Peak flow reduction 5 year return period = 2.1%
- Volume avoided at peak = 2,177m^3
  - ~1 Olympic swimming pool
- Could express efficacy 21.8m^3 / ha

Similarly for loads

- What about loads avoided….
- Event 1
  - CSF: 11.4 Kg P
  - Woods: 59.4 Kg P / 945ha
- Event 2
  - CSF: 22.2 Kg P
  - Woods: 48.3 Kg P / 945ha

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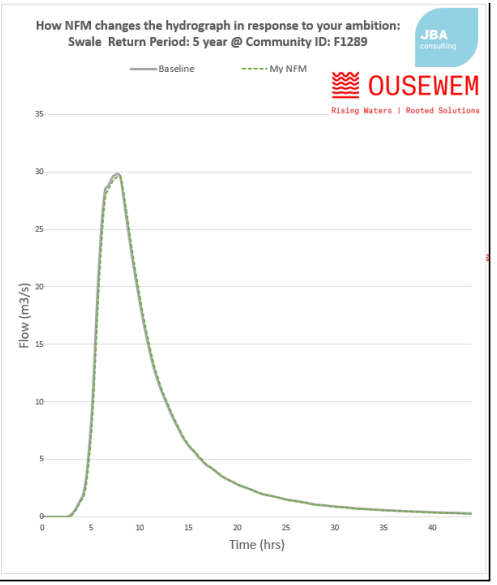
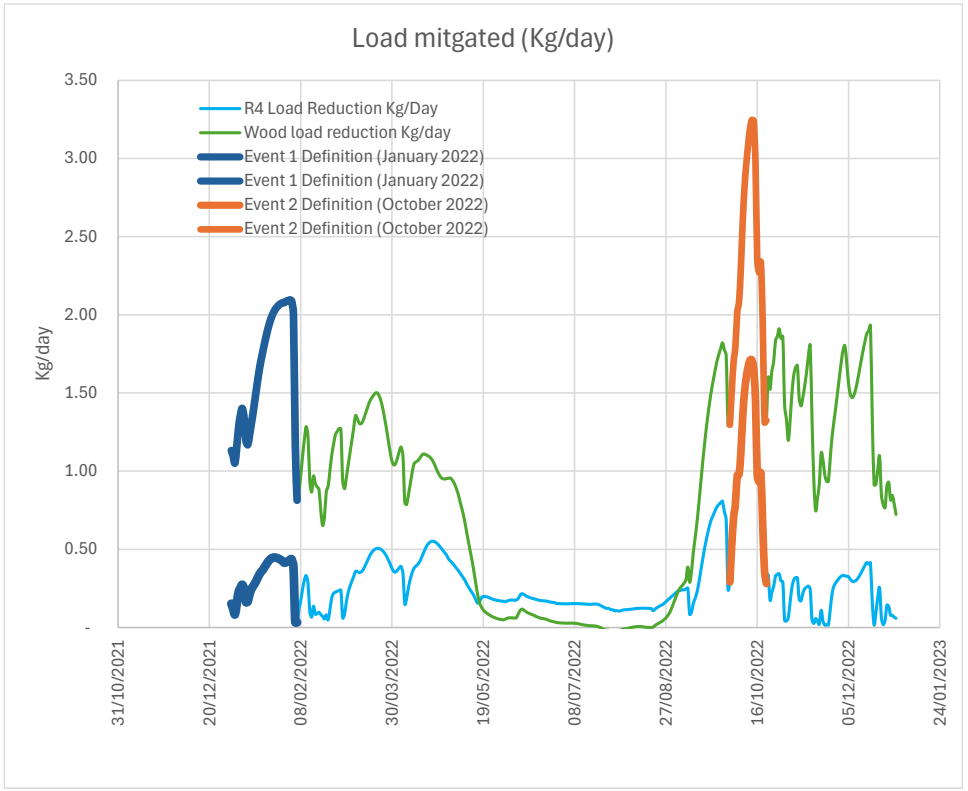
Ousewem HAT (Hydrological Assessment Tool) v4.9

1. Choose Catchment ->	Swale	Catchment Area (km2)	Recommended Duration
5. Choose Community ID ->	F1289	67.7	6
3. Choose Return Period ->	5 year	Claimable Area (km2)	6 hour
4. Choose Storm Duration ->	6 hour	14.4	
Your Ambition for Natural Flood Management		Gauge:	
5. Please choose the your ambition for the following 8 types of NFM as a % uptake of what was modelled:		Upstream NFM Area (ha) in Claimable	Proportion of claimable area
5.1 Catchment Woodland Expansion	0	0.0	0.0%
5.2 Riparian/Floodplain woodland	100	99.9	6.9%
5.3 Hedges	0	0.0	0.0%
5.4 Soil and Land Management	0	0.0	0.0%
5.5 RAFs	0	0.0	0.0%
5.6 Leaky Barriers	0	0.0	0.0%
5.7 Floodplain Reconnection	0	0.0	0.0%
5.8 Offline storage	0	0.0	0.0%
RESULTS	Total NFM (ha)->	99.9	
Peak flow reduction (%)	0.7%	Olympic pools	
Effective volume avoided from peak (m3) and Olympic Swimming Pools	2,177	0.9	
Catchment reduction Factor	0.21		
Efficiency (vol avoided per ha)	21.8	(m3 avoided per ha)	
Rural properties at risk locally	16	Total properties	
Urban properties at risk locally	-	16	
Downstream Community (XY)	404033, 499505	NZ0204	
Benefits of NFM (damages avoided in community)			
Total benefits			
please use effective volume until available			
Water Quality Score (1-10, 10 highest co-benefits)		8	





JFlow is a 2D flood inundation model

..So a slight reduction in peak flow and a strong reduction in peak load

Summary

- Trying to improve understanding of half-lives from field-scale using JUMP modelling and upscale using Fieldmouse + HYPE
- Systems based Fieldmouse model is providing new ways to help target and quantify where NbS might be best prioritised
- National scale source apportionment runs helpful to understand load contributions under different flow conditions
- Finer-scale
  - Risk maps providing strong tools for prioritisation to help identify NbS
  - Combined with opportunity maps proving a valuable source for e.g. WINEP programme
  - Through-time source apportionment is providing strong knowledge transfer about nature of event driven pollution
- We present a new way to measure the efficacy of different types of catchment measures, similar to peak flow avoided per measure, we use peak mass avoided

QUANTUM

Quantifying the nutrient enrichment, pathogenic, and ecotoxicological impacts of livestock farming on UK rivers

Penny Johnes, Ian Bull, Richard Evershed, Ana Castro-Castellon, Sydney Enns, Victoria Hussey (University of Bristol)
Davey Jones, Dave Chadwick, Dan Davies (Bangor University)
Barbara Kasprzyk-Hordern, Tolulope Lawrence (University of Bath)
Charles Tyler, Simona Frustaci, Anke Lange, Hannah Boote (University of Exeter)
Andrew Binley, John Ball (Lancaster University) collaborating with JBA Consulting

and our regulatory, industry and academic Project Partners and Stakeholders

Contact: penny.johnes@bristol.ac.uk