Quantifying and targeting the multiple benefits of Nature-based Solutions at the catchment scale

Jenny Broomby[1], **Barry Hankin[1] (P)**, Changgui Wang[1], Hannah Champion[1], Lucy Hyde[1], Paul Smith[1], Steve Maslen[1], Chris Gerrard[2]

[1]JBA Consulting

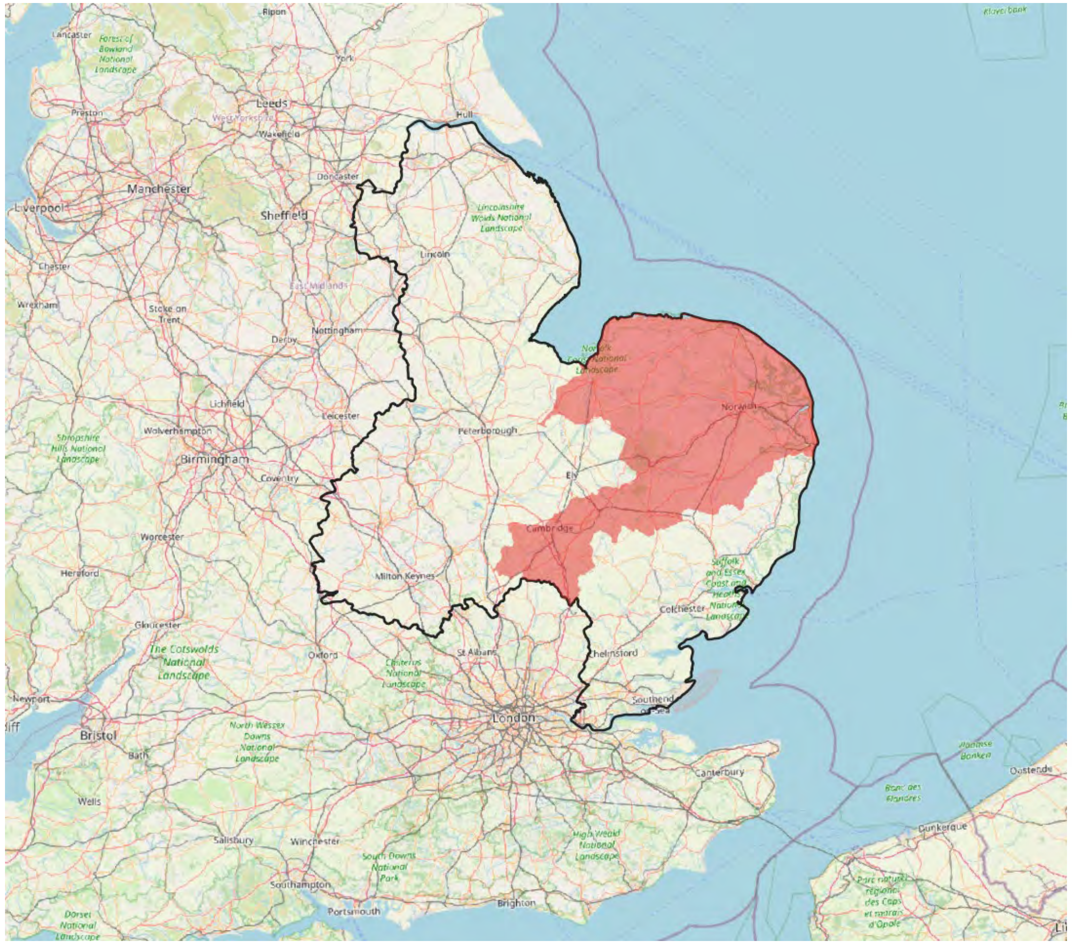
[2]Anglian Water

www.jbaconsulting.com

Nature-based Solutions (NbS) for diffuse pollution mitigation for Anglian Water

AIMS

- Modelling and mapping to help prioritise catchment and nature-based solutions (NbS) across the Anglian Region (shown) to achieve the greatest benefits for primary and secondary outcomes
- in ways that are not typically achievable through traditional asset-based investment, these comprise the primary drivers of:
  - **Reducing diffuse pollution**
  - **Improving low flows**
- Secondary drivers to deliver co-benefits to enhance:
  - Biodiversity
  - Recreation
  - Amenity

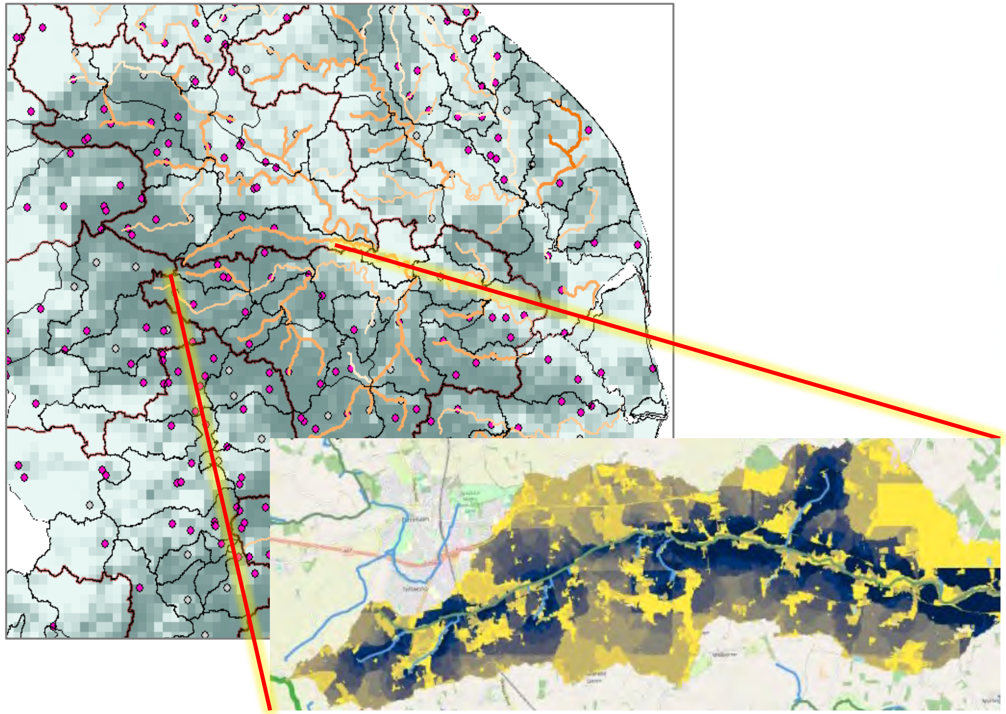


www.jbaconsulting.com

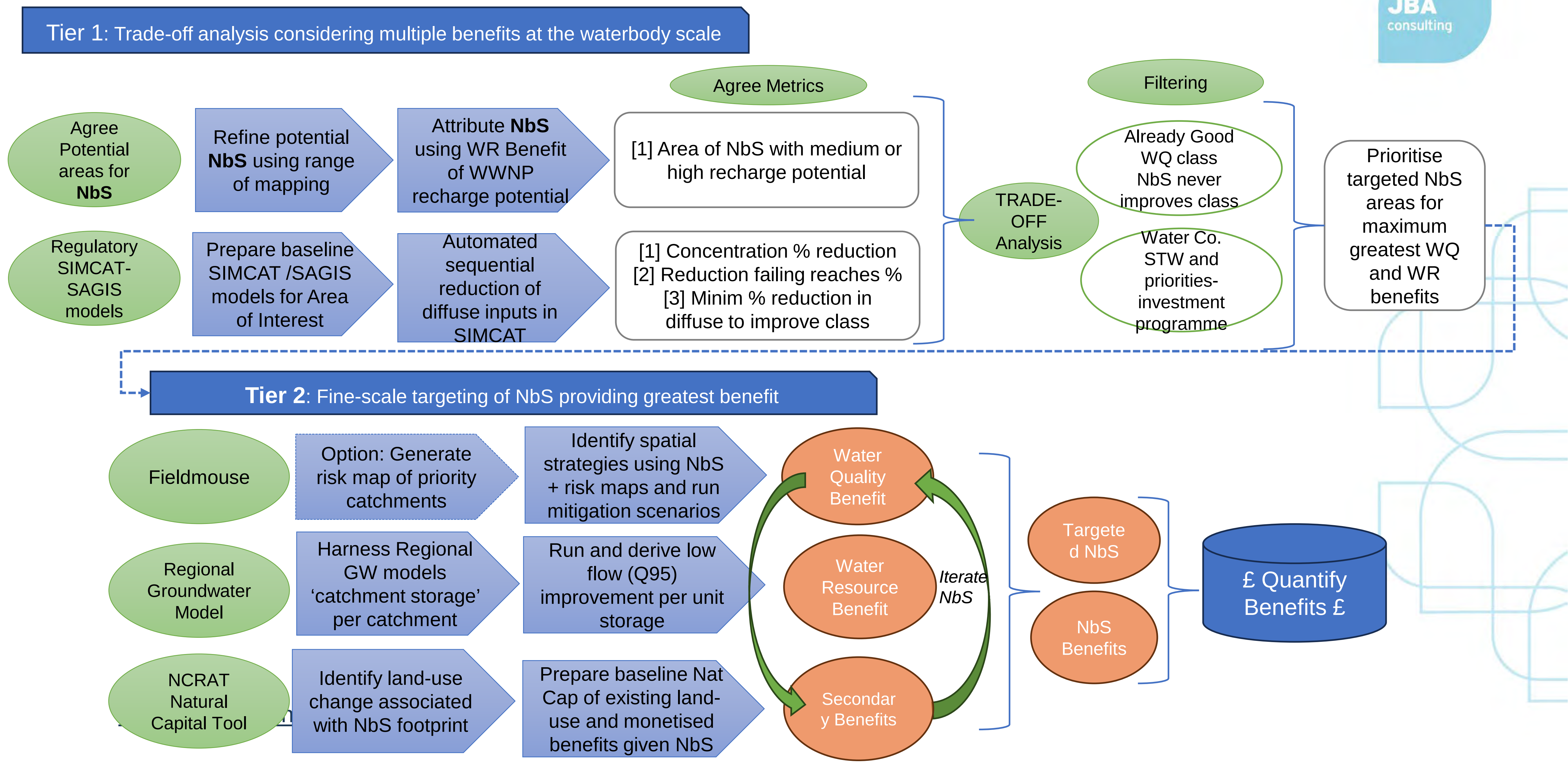
Tiered Modelling Approach

Two tiers of modelling:

- **Whole Region** – *Trade-off analysis for primary benefits* (Water Quality + Water Resources)
  - Create NbS maps (5 layers)
  - **SIMCAT** diffuse load analysis
  - Water Resource H/M/L classification
  - Trade-off analysis prioritising Waterbodies
- **Prioritised NbS Waterbodies** – *detailed analysis of where it matters*
  - **Fieldmouse:** travel-time grids; risk maps; NbS targeting within waterbodies / 10m res
  - Regional Groundwater modelling of low flow improvement potential from NbS
  - **NCRAT** – land-use change implications for]Secondary Benefits (Habitats, Carbon, etc)



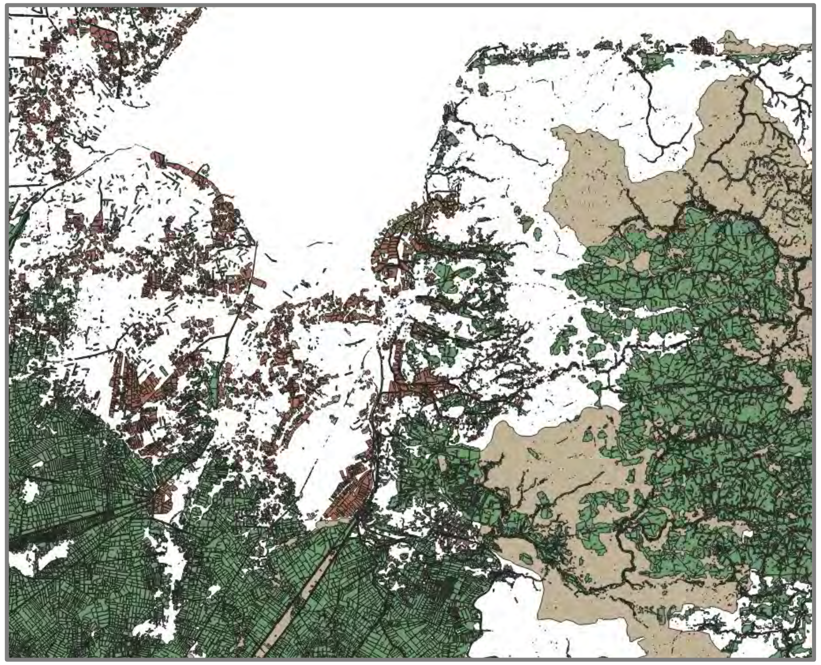
Tiered Approach for Quantifying & Targeting Multiple Benefits of Nature based Solutions



Regional NbS Mapping

JBA consulting

- NbS potential data sources:
  - Environment Agency 2016/17 potential areas for Working with Natural Processes (**WwNP**) maps – see: *https://naturalprocesses.jbahosting.com/Map*
  - Wildfowl & Wetland Trust maps for water quality:
  - *https://wetland-data-explorer.wwt.org.uk/pages/wwt-wetland-potential-data*
  - England Woodland Creation Offer - EWCO – Water Quality – Forestry Commission – Open Government Licence v3.0 - EWCO - Water Quality - data.gov.uk
  - (https://www.data.gov.uk/dataset/aeb1a104-8eed-4691-995d-a626805a1713/ewco-water-quality)
- Total area potential summarised at the WFD waterbody catchment units
- **Output:** 5 new data layers…



Preparation of NbS maps

- Five layers conducive meeting the primary drivers identified with spatial data:
  1. Wetlands for Water Quality
  2. Ponds / Runoff Attenuation Features
  3. Soil and Land use improvements (slowly permeable soils)
  4. Riparian and floodplain tree planting
  5. Floodplain Storage Enhancement

- A constraints layer for the region was produced using OS roads and rails (buffered by 10m), watercourses (buffered by 2m), OS buildings (buffered by 5m), and built-up areas (20m).

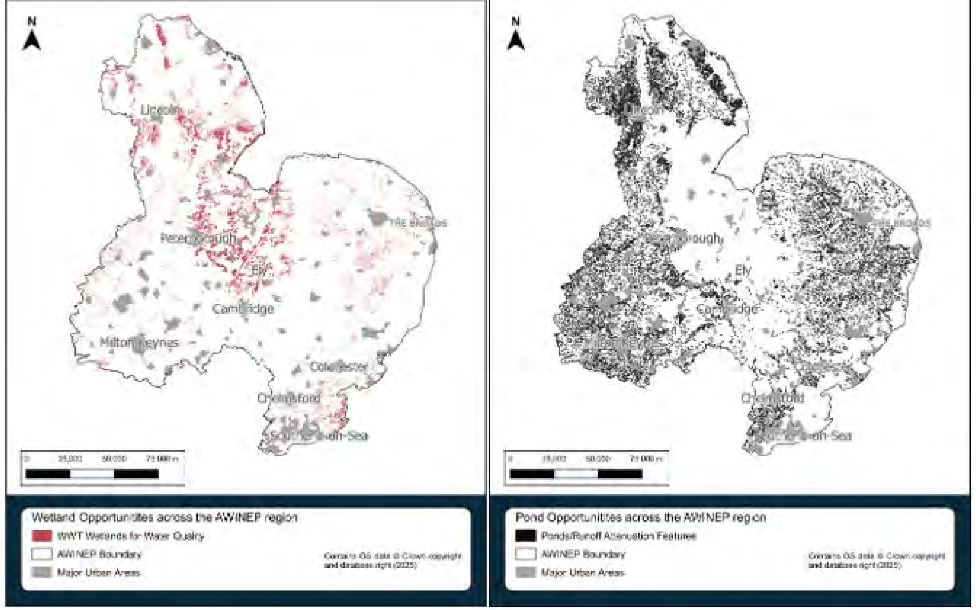


Figure 3-6: Wetland opportunities (left) and pond/RAF opportunities (right) across the AWINEP region.

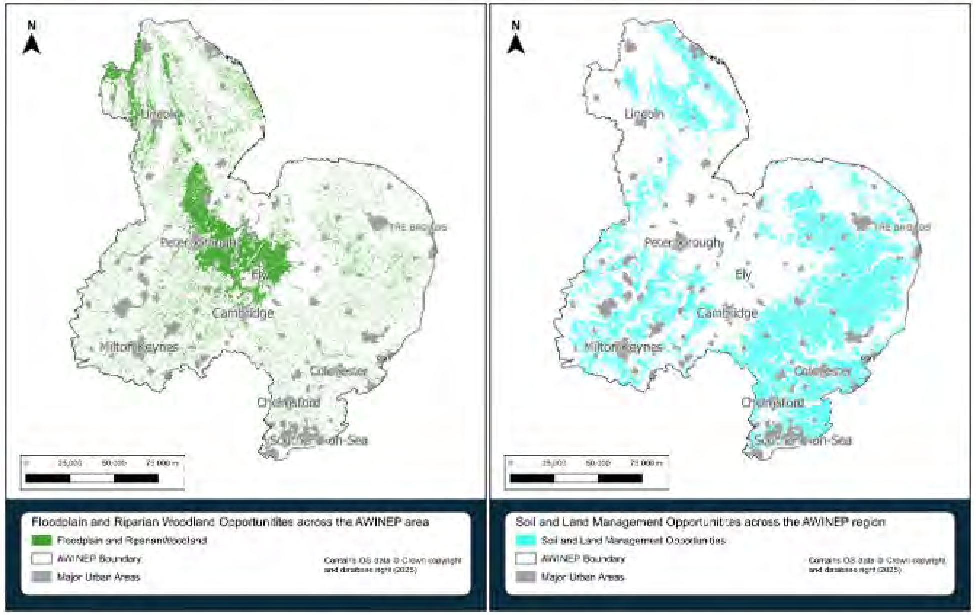


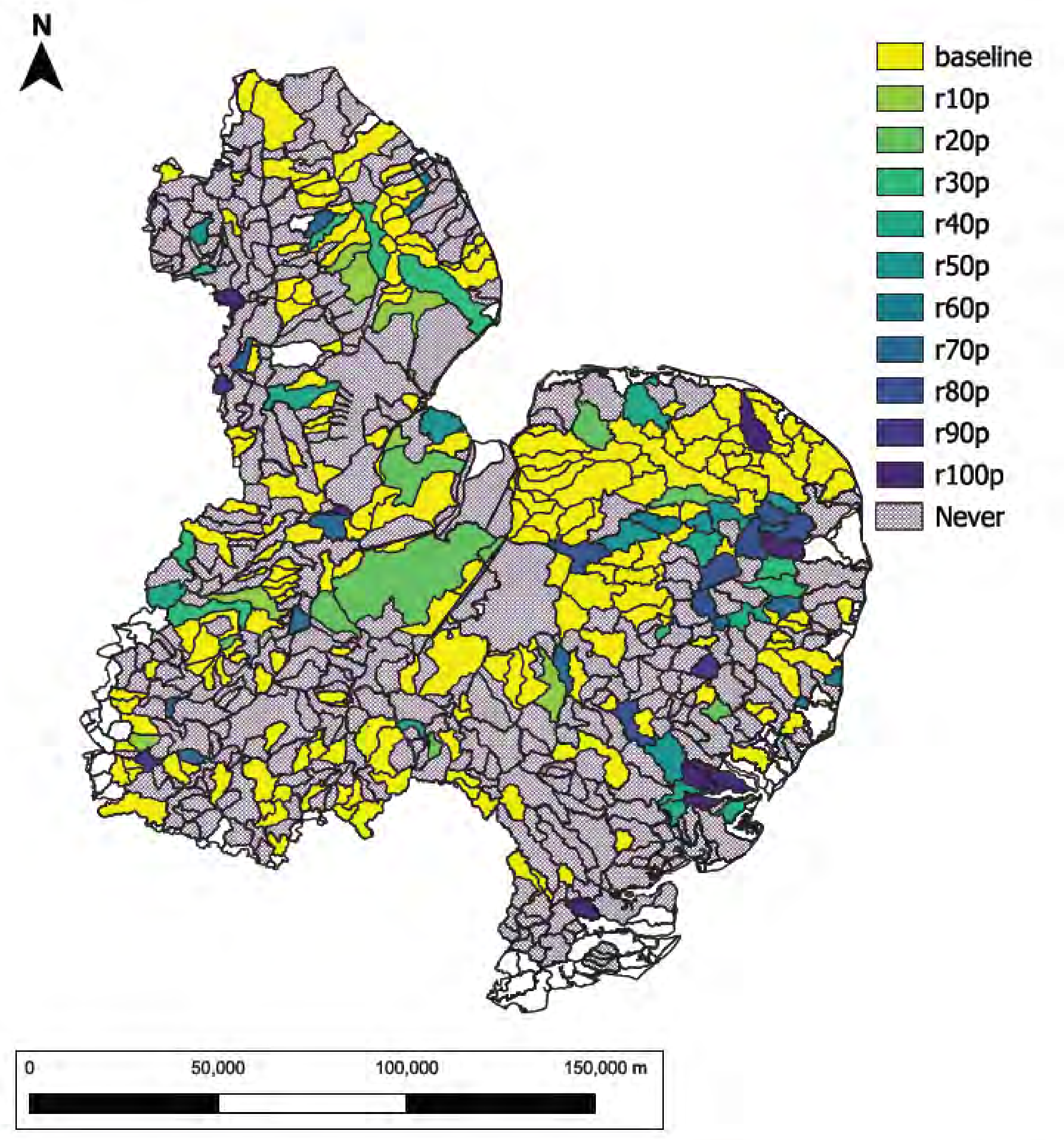
Figure 3-7: Floodplain and Riparian Woodland opportunities (left), and soil and land management opportunities (right) across the AWINEP region.

www.jbaconsulting.com

SAGIS / SIMCAT / Tier 1 Water Quality

- Sequentially reduced the diffuse agricultural load by 10%, 20%, …100%
- **Effort** to change class to “Good WQ”
- The map shows the effort required to get to GES (WQ) if possible:
    - **Grey** – Not possible
    - **Yellow** – Already Good
    - Lighter green shades:

      least effort required to get to GOOD WQ class



Reduction in diffuse Phosphate input required to produce a "Good" WQ class.

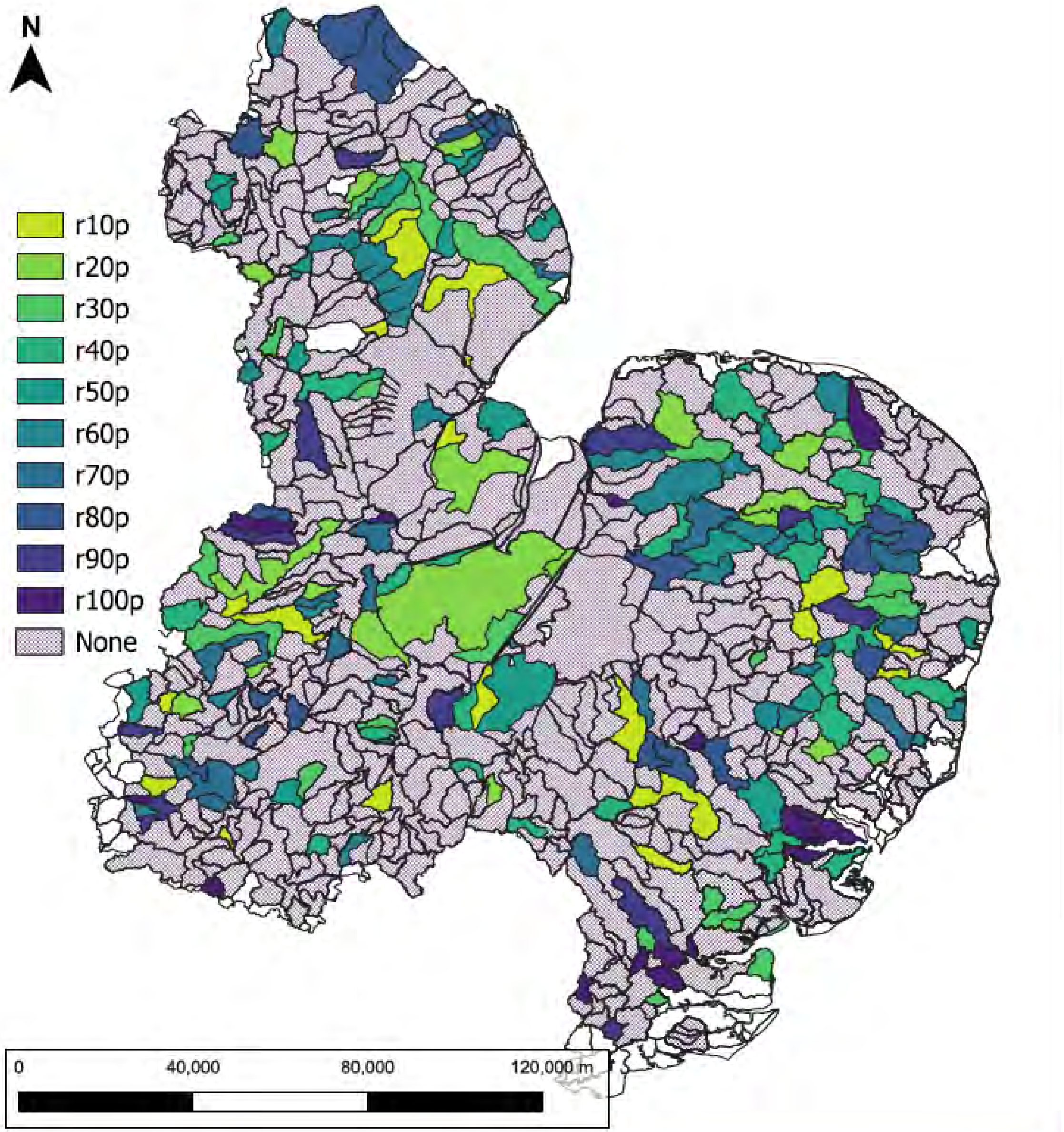
Contains OS data © Crown copyright and database right (2024)

JBA consulting

www.jbaconsulting.com

Other metrics

- Metrics reported:
  - Mean reduction in concentration downstream
  - Change in class (if at all)
  - Reduction in length of river failing at 95% confidence
- Regionally for 3 SAGIS/SIMCAT models + 10 scenarios (10%, 20%, …100%)
- Map shows the % reduction of diffuse agricultural loads required to make ANY improvement in class (not just GOOD)
- **Output:** Maps of least effort to improve

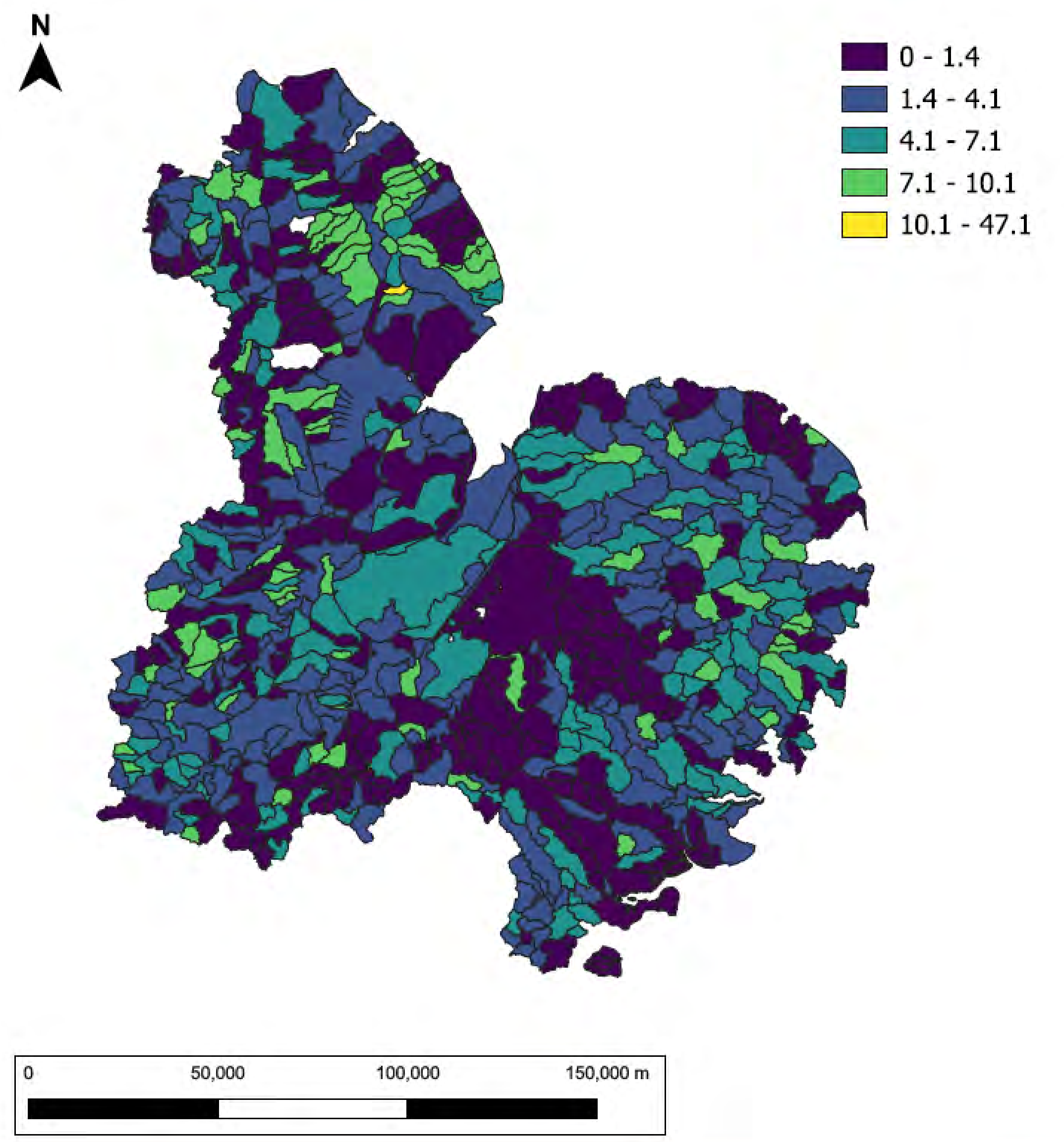


Reduction in diffuse Phosphate input required to produce a WQ class improvement.
None indicaste no improvement possible.

Contains OS data © Crown copyright and database right (2024)

Sensitivity to 10% Agri-load reduction

- A sensitivity test to 10% reduction in diffuse agricultural load
- Lighter green and yellow indicate where there would be the greatest reduction of Soluble Phosphorus



Percentage reduction in mean concentration with a 10% reduction in diffuse Phosphate input.

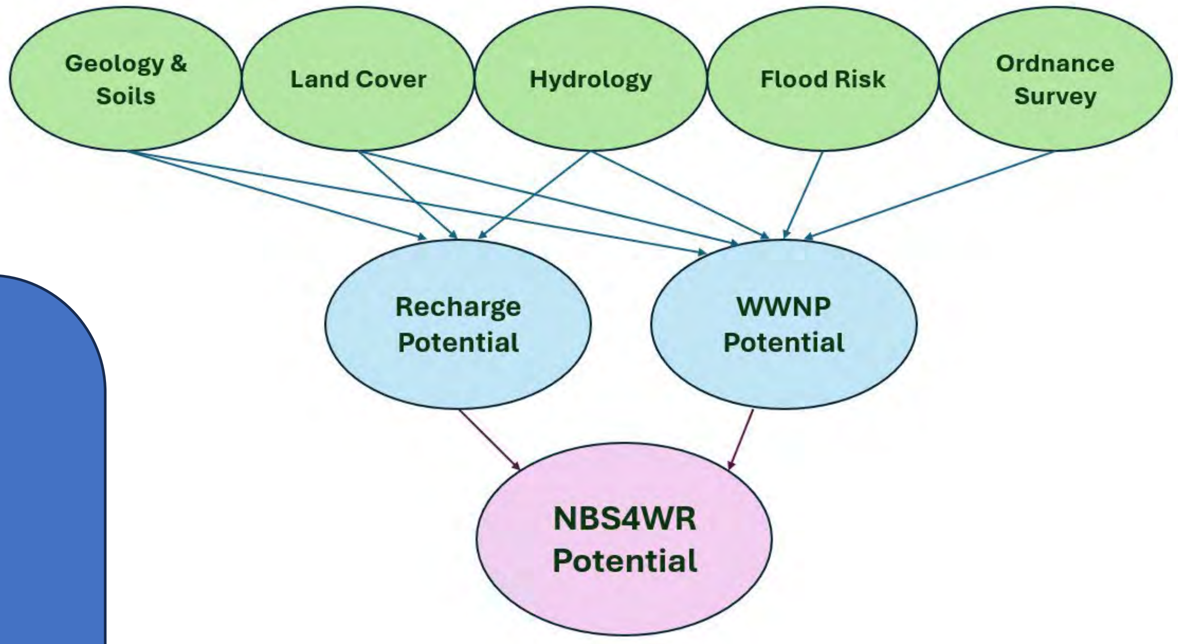
Contains OS data © Crown copyright and database right (2024)

Regional Water Resources Benefits of Nbs

- National methodology used based on Water Resource benefits of WWNP work
- Total area potential to be summarised at the WFD waterbody catchment units

The groundwater vulnerability map attributes below were combined with the following datasets which provided greater levels of aquifer and baseflow detail as well as soil information:

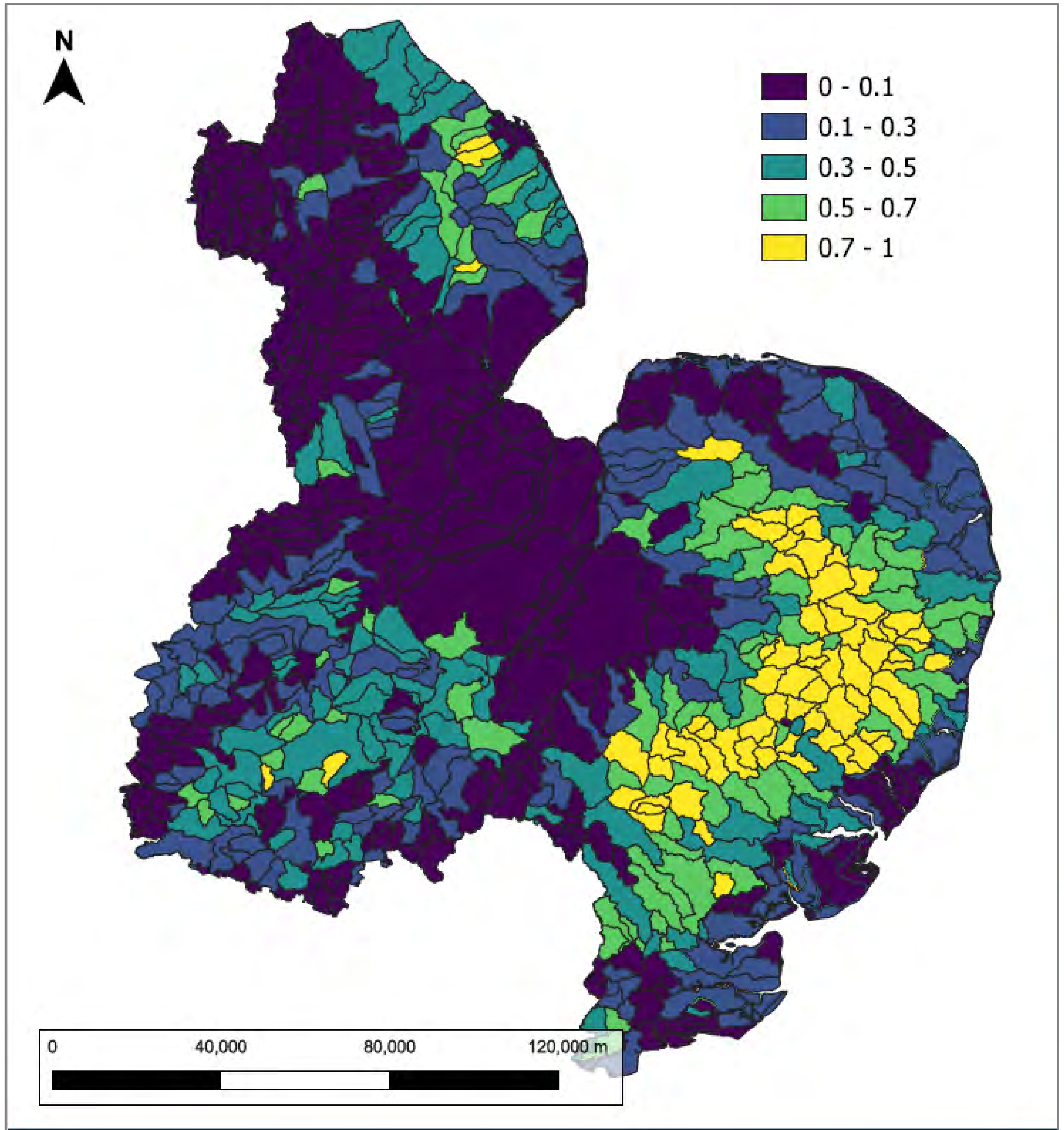
- Environment Agency Groundwater Vulnerability Map data sets used:
  - Drift patchiness/cover
  - Drift thickness
  - Superficial recharge potential/permeability
  - Bedrock flow type
- Environment Agency Aquifer Designation Map (Bedrock)
  - Aquifer designation
- Environment Agency Aquifer Designation Map (Superficial Deposits)
  - Aquifer designation
- 1km gridded BFIHOST data
  - BFI
- LandIS NATMAP Soilscapes data
  - Soil texture and drainage



https://catchmentbasedapproach.org/wp-content/uploads/2021/08/Idle-and-Torne-Working-With-Natural-Processes.pdf

Regional Water Resources Benefits of NbS / WR

- The area of NbS in each waterbody has been tagged as low, medium or high.
- Here we sum the areas of medium or high recharge potential as a fraction of waterbody area



Fraction of waterbody where interventions may produce a medium or high recharge.

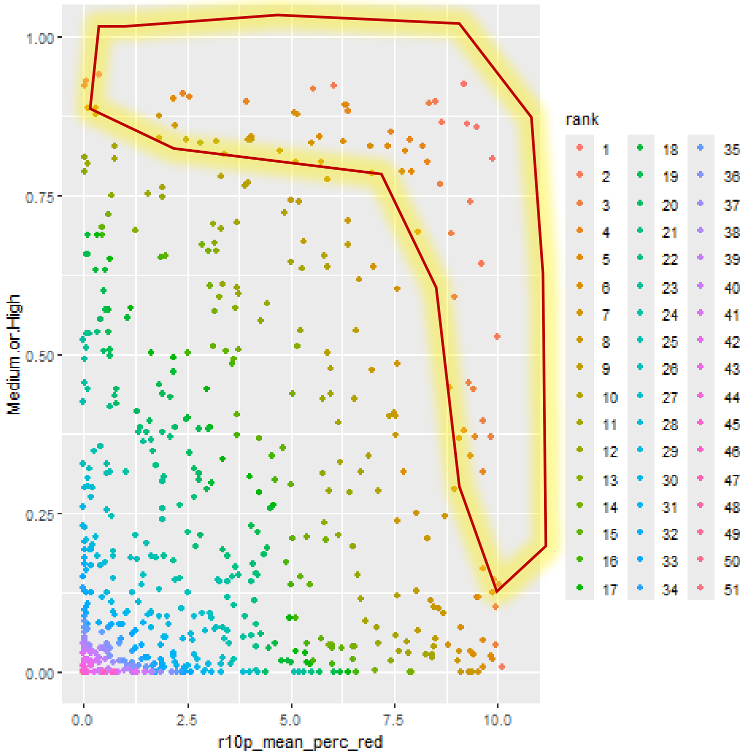
Contains OS data © Crown copyright and database right (2024)

JBA consulting

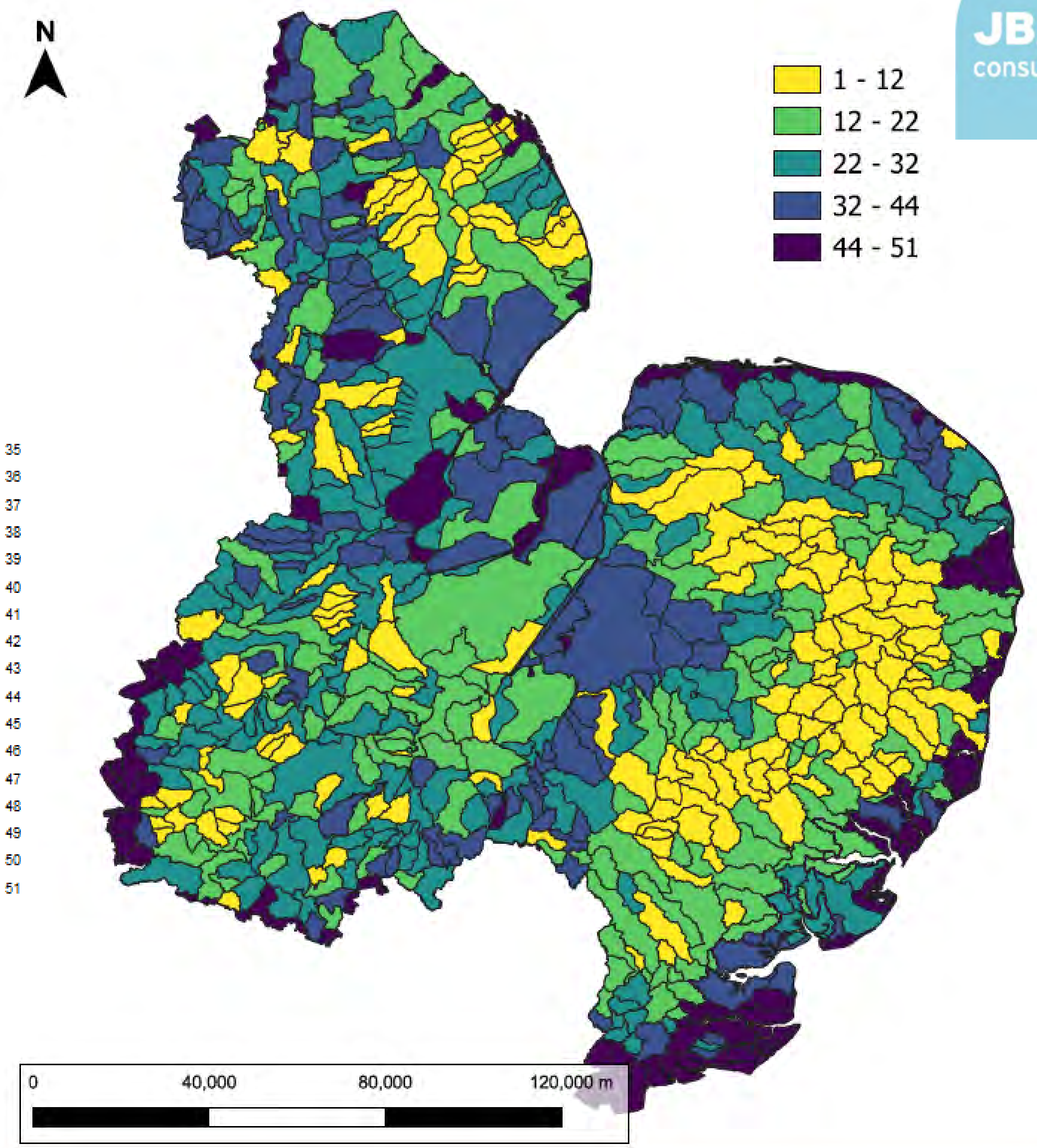
www.jbaconsulting.com

Trade-off of primary Ecosystem Services

- Trade-off Analysis of NbS benefit to
  - Water Quality (concentration reduction)
  - Water Resources (area high/medium recharge)
- Pareto-type analysis / non-dominant ranking
  - “Best set” in a pareto sense



Pareto ranking



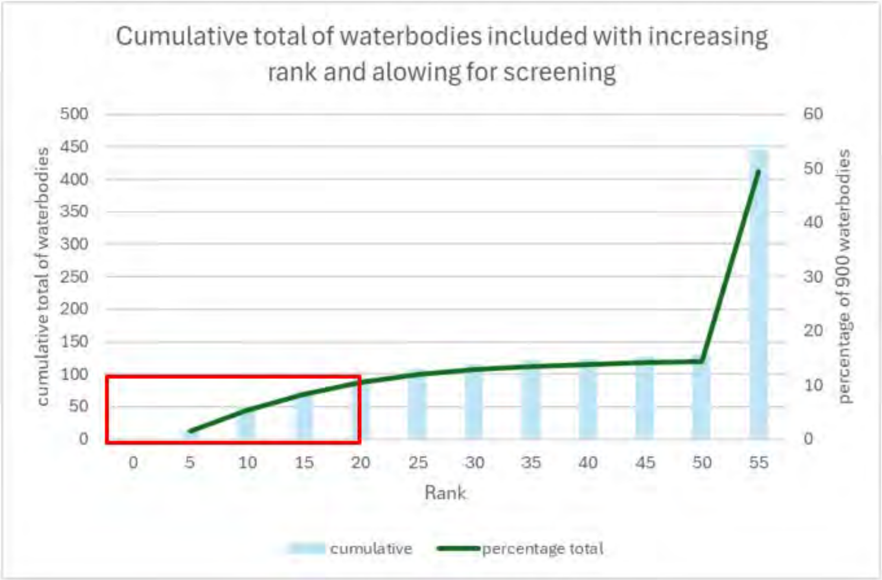
Priority ranking based on potential for medium or high recharge and reduction in mean soluable phosphorus concentration given a 10% reduction in diffuse agricultural input to SIMCAT.

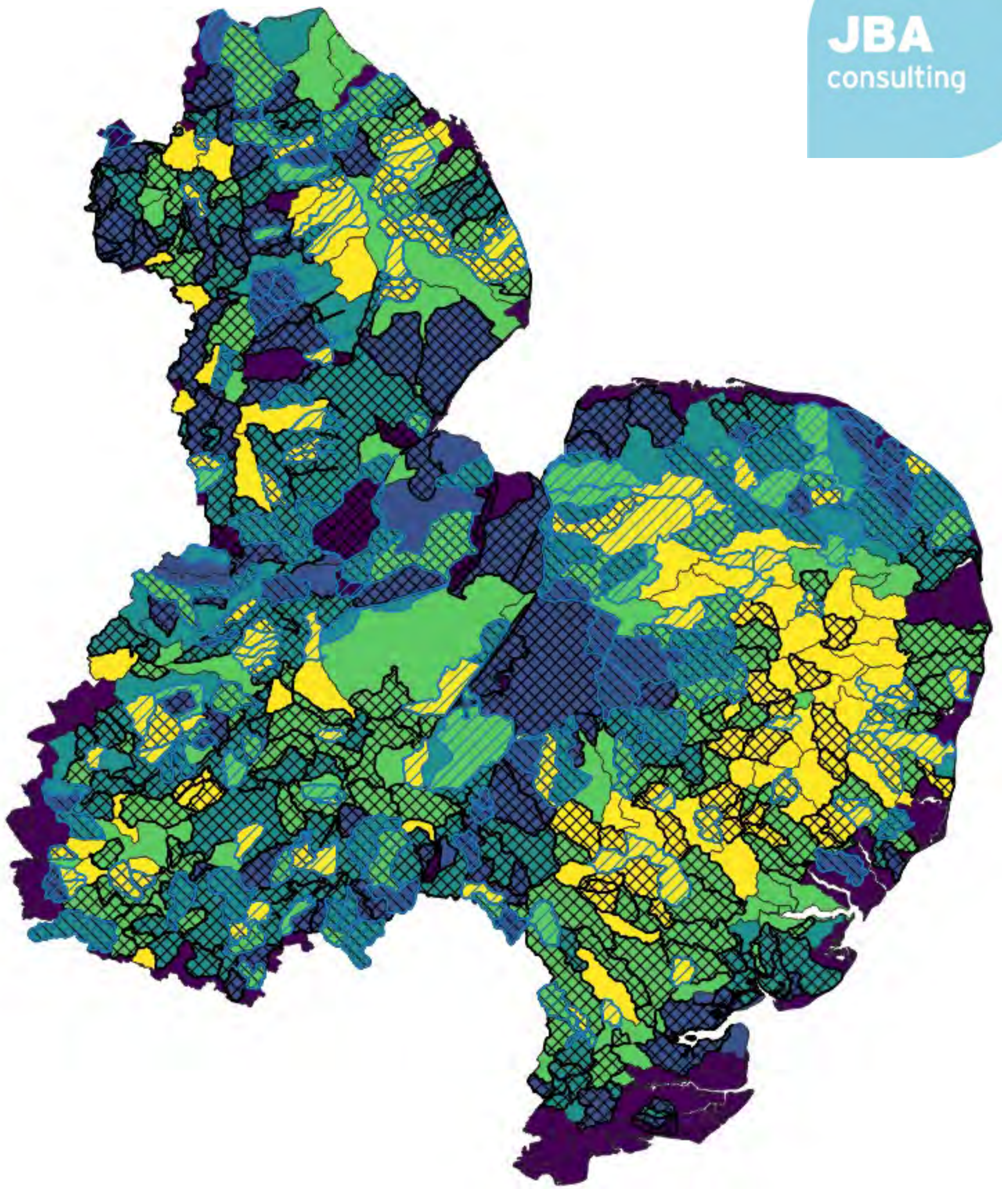
Contains OS data © Crown copyright and database right (2024)

Trade-off with screening

- Masking to avoid areas due to:
  - ‘Already Good’
  - ‘Will not achieve Good with NbS’
  - The remaining bright yellow waterbodies are those where to focus

Frequency histogram constructed from to explore a threshold of the rank for the priority waterbodies to take forwards for more detailed analysis.





www.jbaconsulting.com

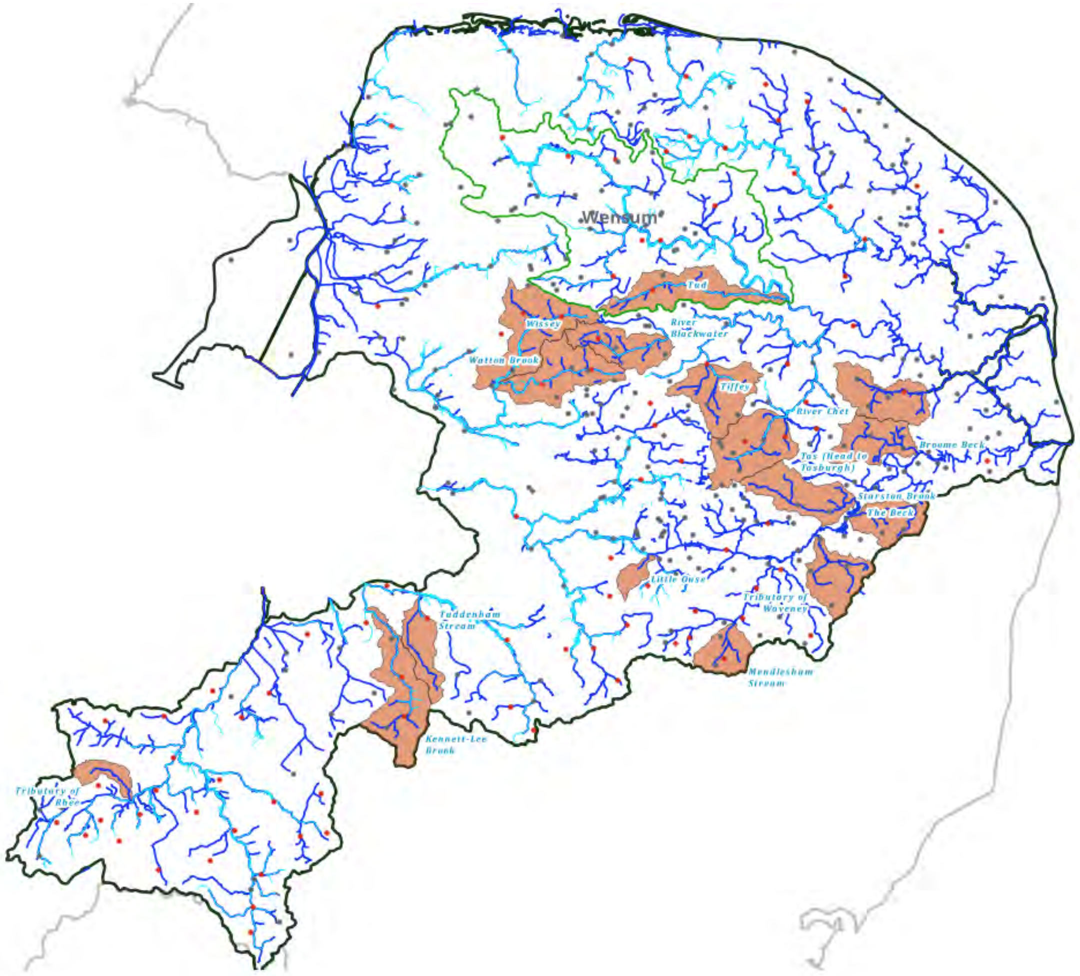
Focus on Advanced WINEP area

Priority / Whole Region

- All waterbodies that would result improvement to GOOD Water Quality Class (based on SP) but allowing between 10% to 40% diffuse pollution reduction in that same waterbody.

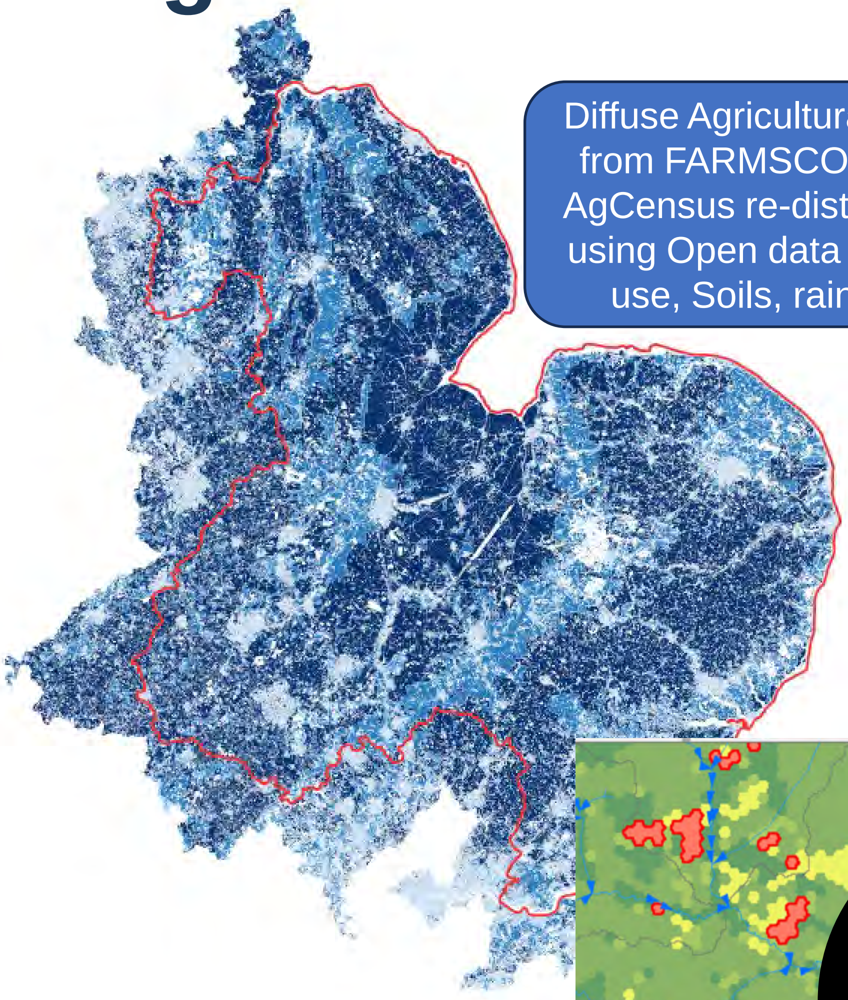
Advanced WINEP area

- This comprises same constraints as above but also checked there was:
- Approximately 50% of pipeline priorities on chalk streams
- At least one in the Wensum OWMC
    - 16 waterbodies for Tier 2 modelling

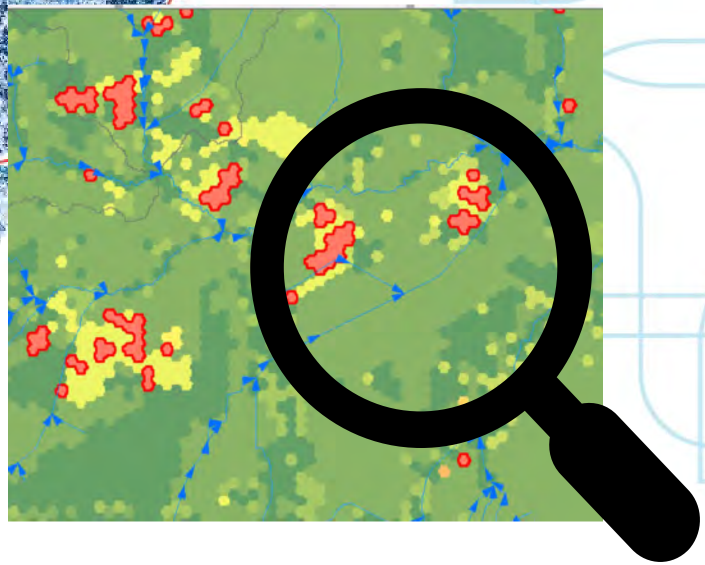


Tier 2 Water Quality modelling Fieldmouse

- *Fieldmouse simulates the transport +losses of pollution at the farm-scale via the physical landscape to understand the impacts on local watercourses, and enables the assessment of measures to improve farm management practices*
- It is a QGIS based model covering the whole catchment system:
- **Farm** **Landscape** **Water**
- **Source** **Pathway** **Receptor**
- For the **source** – it uses FARMSCOPER
- The **pathways** are modelled using a 10m DTM for the over-land transport and the Open River Network for the water transport
- It enables us to integrate land and water phases of transport and model diffuse pollution impacts on **water quality**



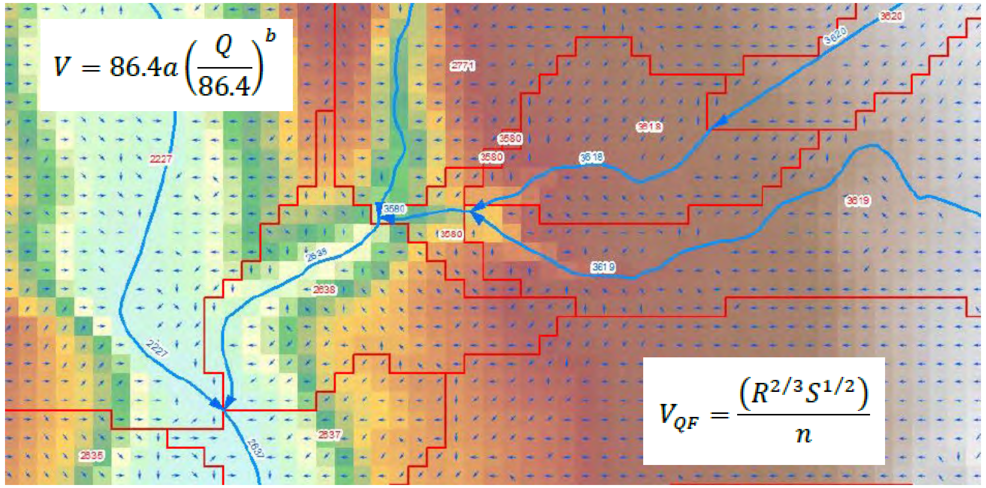
Diffuse Agricultural Data from FARMSCOPER / AgCensus re-distributed using Open data (Land-use, Soils, rainfall)

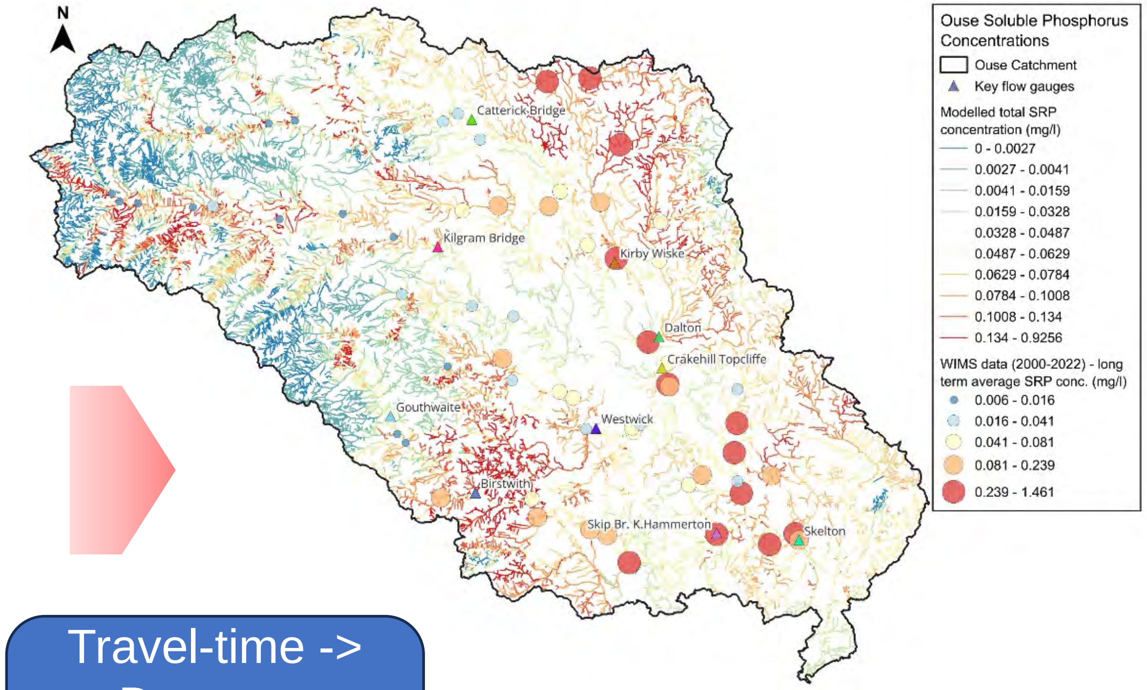


Loads accumulated and decayed along Open Rivers Network

Fieldmouse GIS model

- F1 Pollution concentration predictions for mean flow conditions
  - Overland / Quick-flow / slow-flow
  - Along river – empirical tracer regression





Travel-time -> Decay -> Load -> Concentration

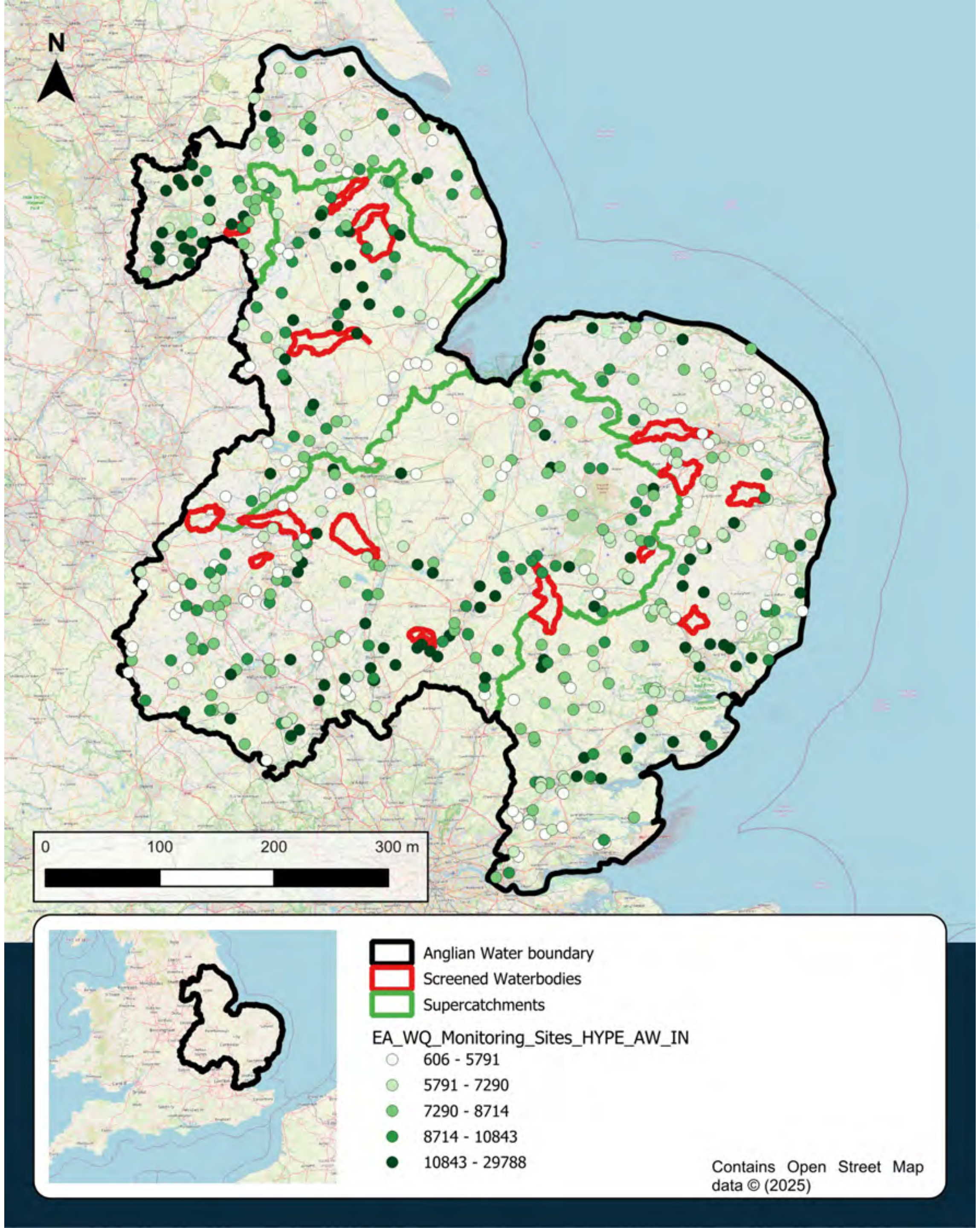
Fieldmouse

Calibration

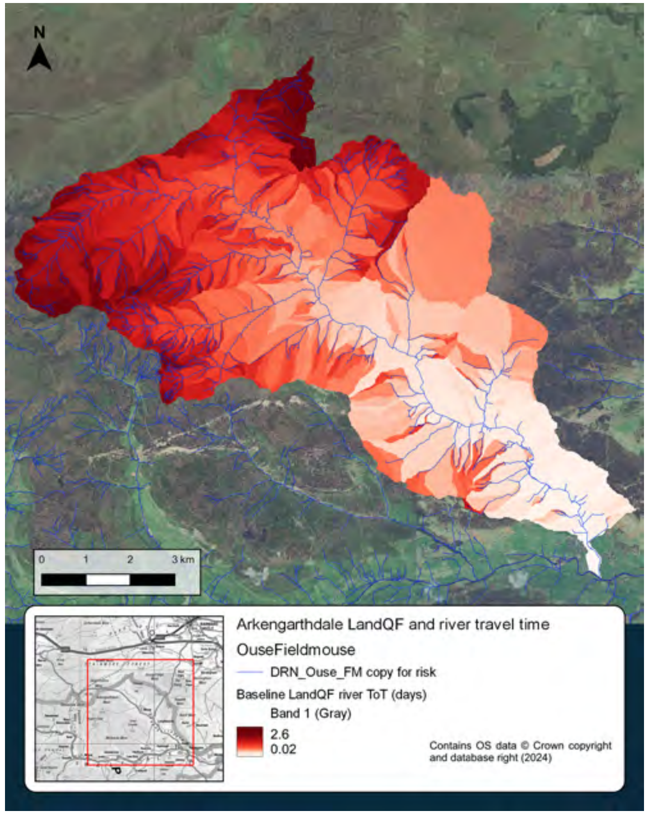
- **Flows**
  - NRFA flow gauges
  - Uplift to mean flows
- **WQ calibration**
  - Comparison of Fieldmouse average concentrations with long term averages at key WQ monitoring locations

Outputs

- **F1: River network themed with concentrations**
- **R1: Travel time rasters** are generated and combined with pollutant half-lives – the travel-time in days from any pixel to the outlet
- **R2: Importance rasters** - the relative importance of a unit pollution for:
  - Soluble Phosphorus (SP) / Nitrate (IN) / Suspended Solids (SS)
- **R3: Pollution Risk raster** is produced for each pollutant identifying where is greatest relative risk to the environment based on distributed load and connectivity



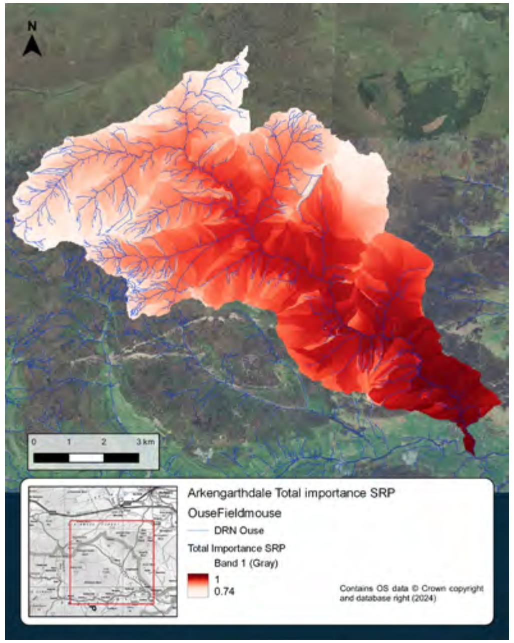
Travel Time → Importance → Risk



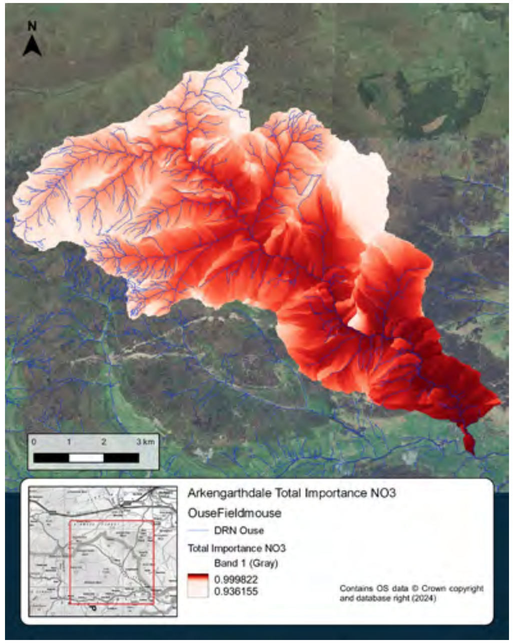
Travel Time grid

www.jbaconsulting.com

SP

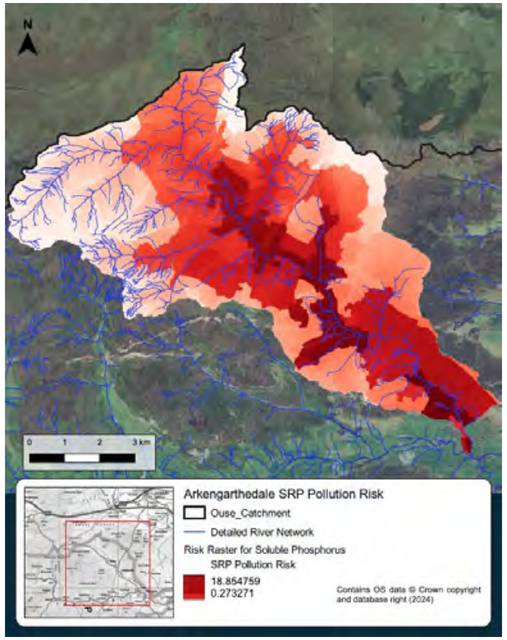


NO3

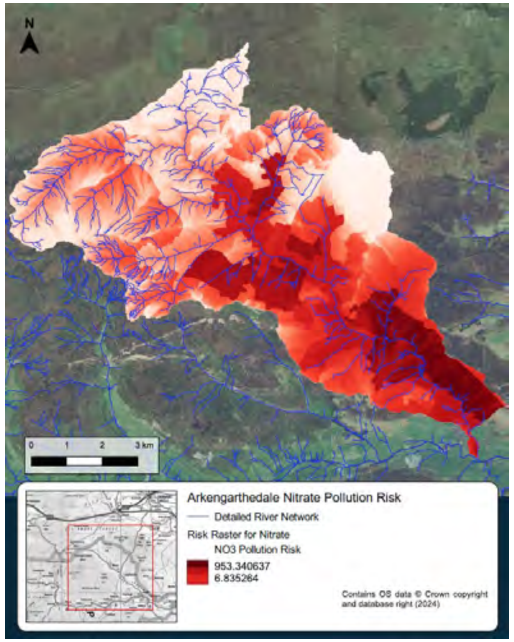


Importance Rasters

SP



NO3

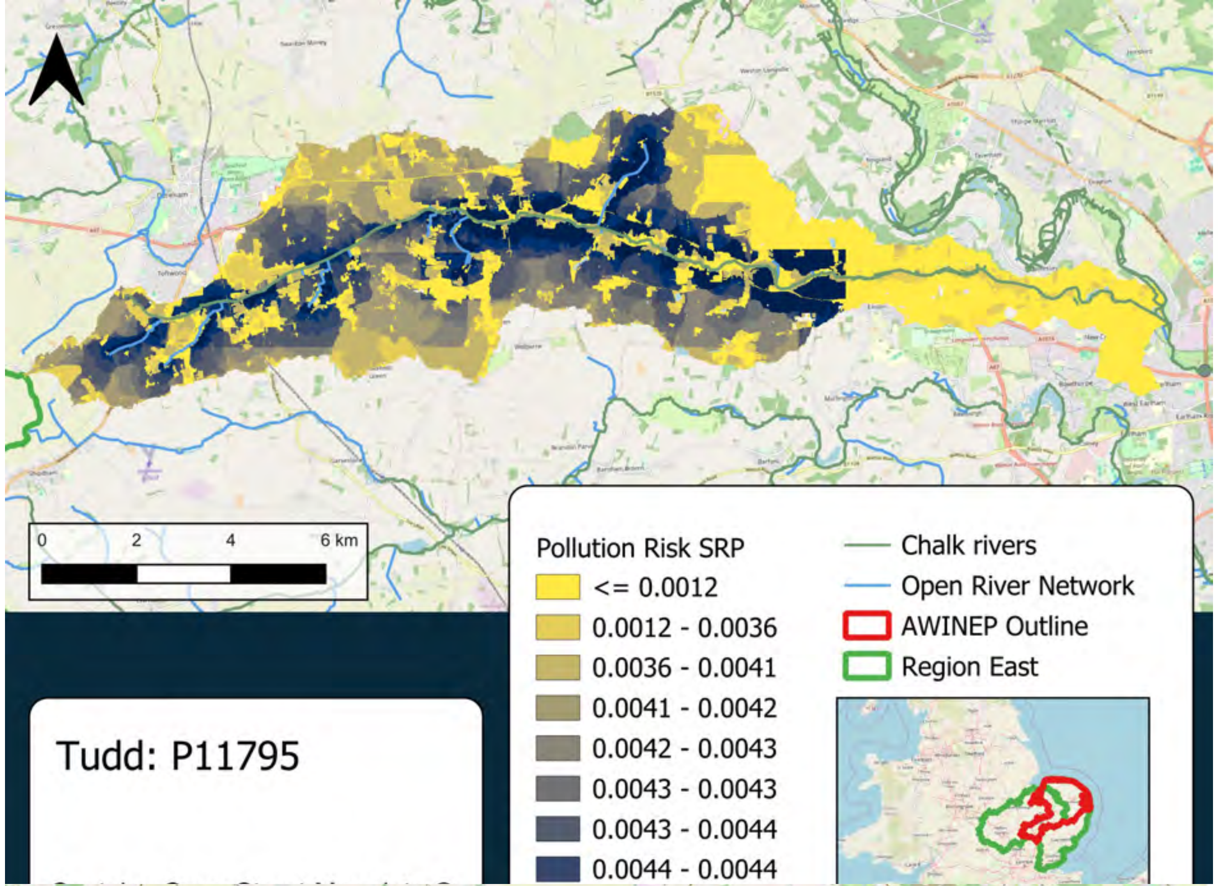


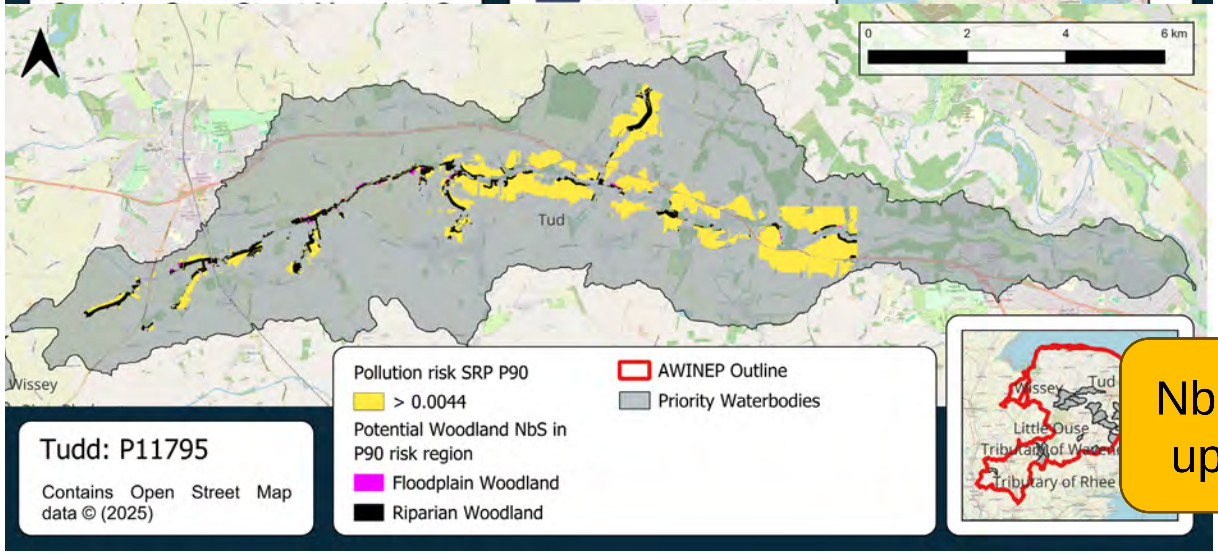
Risk Rasters

Tier 2 WQ model Fieldmouse

- Risk raster shown used to identify where NbS is likely to make a bigger difference
- It serves as a detailed targeting map without further mitigation modelling
- Mitigation modelling is then undertaken:
  - Assume uptake of NbS in e.g. upper 10 percentile of risk zone
  - Re-simulate having reduced loads from FARMSCOPER by an amount tabulated for e.g. riparian buffers or woodland
  - Approach is iterative and very dependent on landowner support for land use change
- Results based on frictional change only
  - Run 1 with riparian in upper 10% (1.22km2) led to only 0.4% reduction SRP
  - Run 2 with riparian in upper 10% led to only 0.5% reduction for SRP
  - Run 3 with 25% reduction in upper 10% led to SP reduction **1.2%-2.7%**
- *Awaiting* result based on reduced load due to land-use change – likely more significant

www.jbaconsulting.com

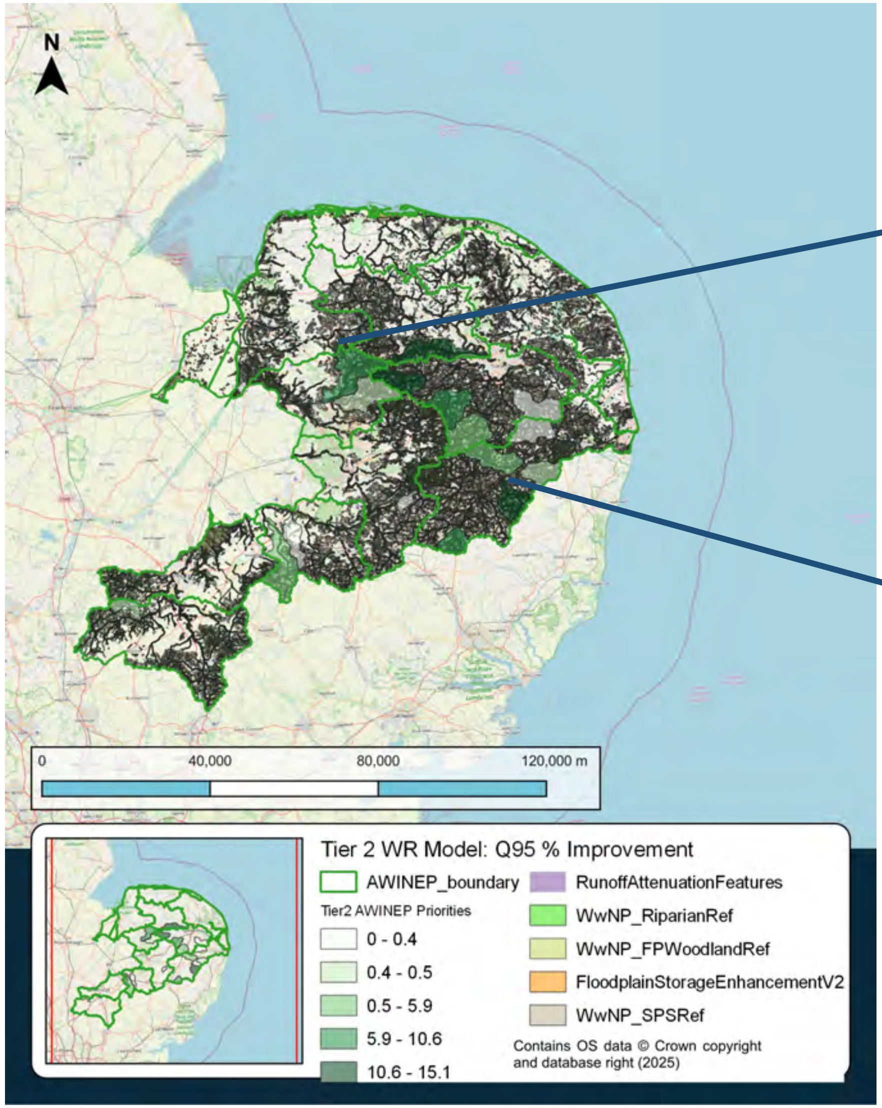


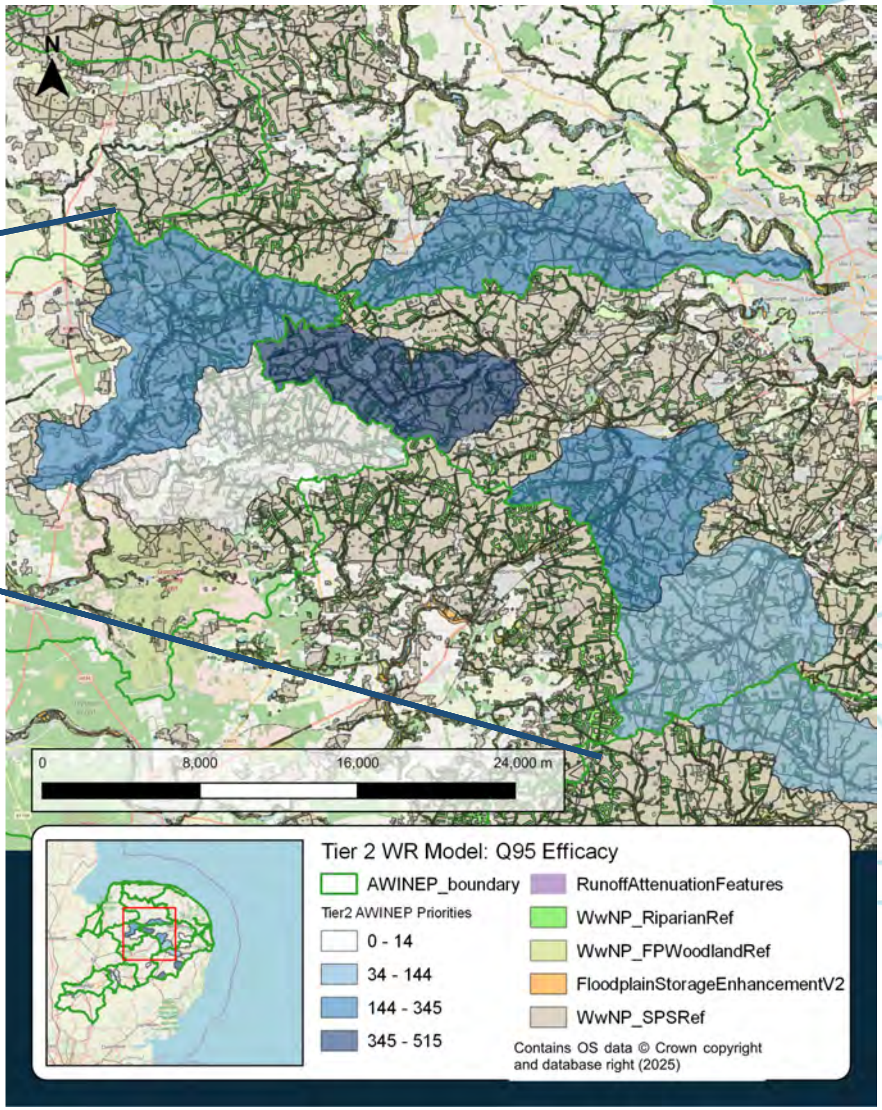


NbS intersecting upper 10% risk

Tier 2 Water Resource Modelling

- Groundwater model simulated with + without "catchment storage" from NbS
- Improvement to the low flows Q95 shown on left
- Efficacy measure on right:
  - Q95 increase / catchment storage
- For priority catchments:
  - Identify storage volume of NbS prioritised from Fieldmouse
  - Translating this to a Q95 improvement with the WR efficacy (next slide)
- This will be more associated with RAFs and Floodplain storage as opposed to woodland, but an equivalent extra storage is used here

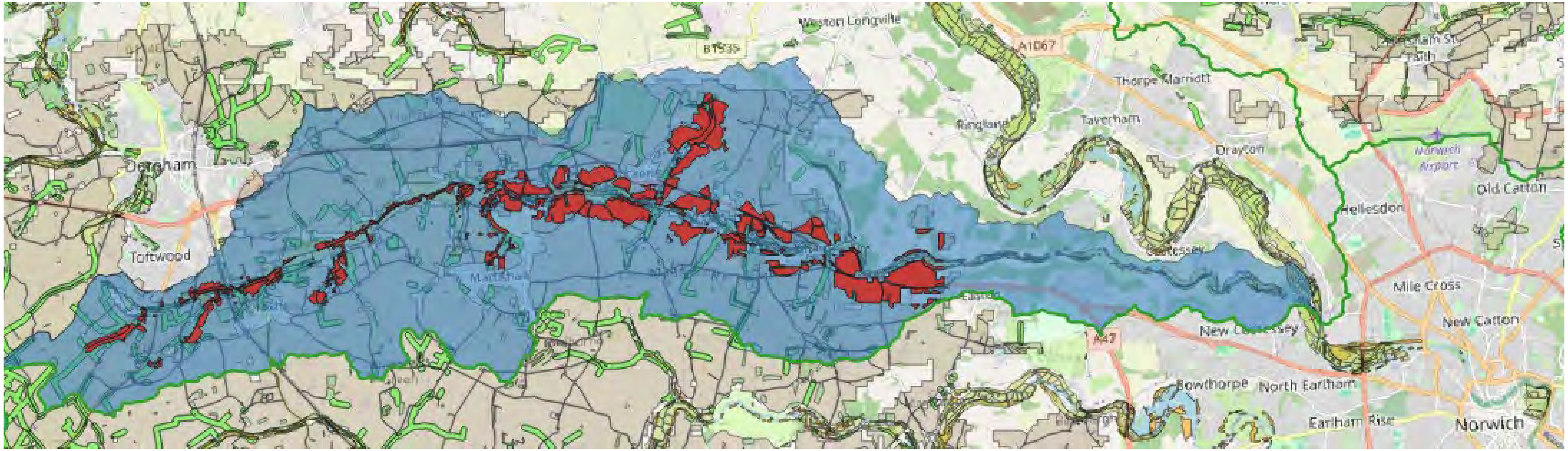




Tier 2 WR & secondary Ecosystem Services

JBA consulting

- For prioritised NbS identify Low flow benefit for WR
- Automate extraction of areas of change
  - Run 1 implies **1.22 km^2** land-use change to woodland
  - This implies a Q95 uplift of **4%** if the woodland results in 1cm extra storage
- Next use land-use change to populate NCRAT spreadsheet with the habitat change
- This will be used to estimate monetised benefits for the secondary ecosystem services such as habitat



Summary

Tiered analysis

- Tier 1 / Broad-scale analysis across 900 WFD waterbodies
  - NbS mapping
  - Water Resource Recharge potential
  - Water Quality diffuse load reduction
  - Trade-off + masking
  - Prioritisation of a pipeline of NbS
- Tier 2 detailed models
  - GW modelling – Quantified Q95 improvement per unit storage
  - Fieldmouse risk mapping – NbS targeting / quantification of concentration improvement
  - Further research needed…

Questions?

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