Improving Groundwater Recharge Using Nature-Based Solutions

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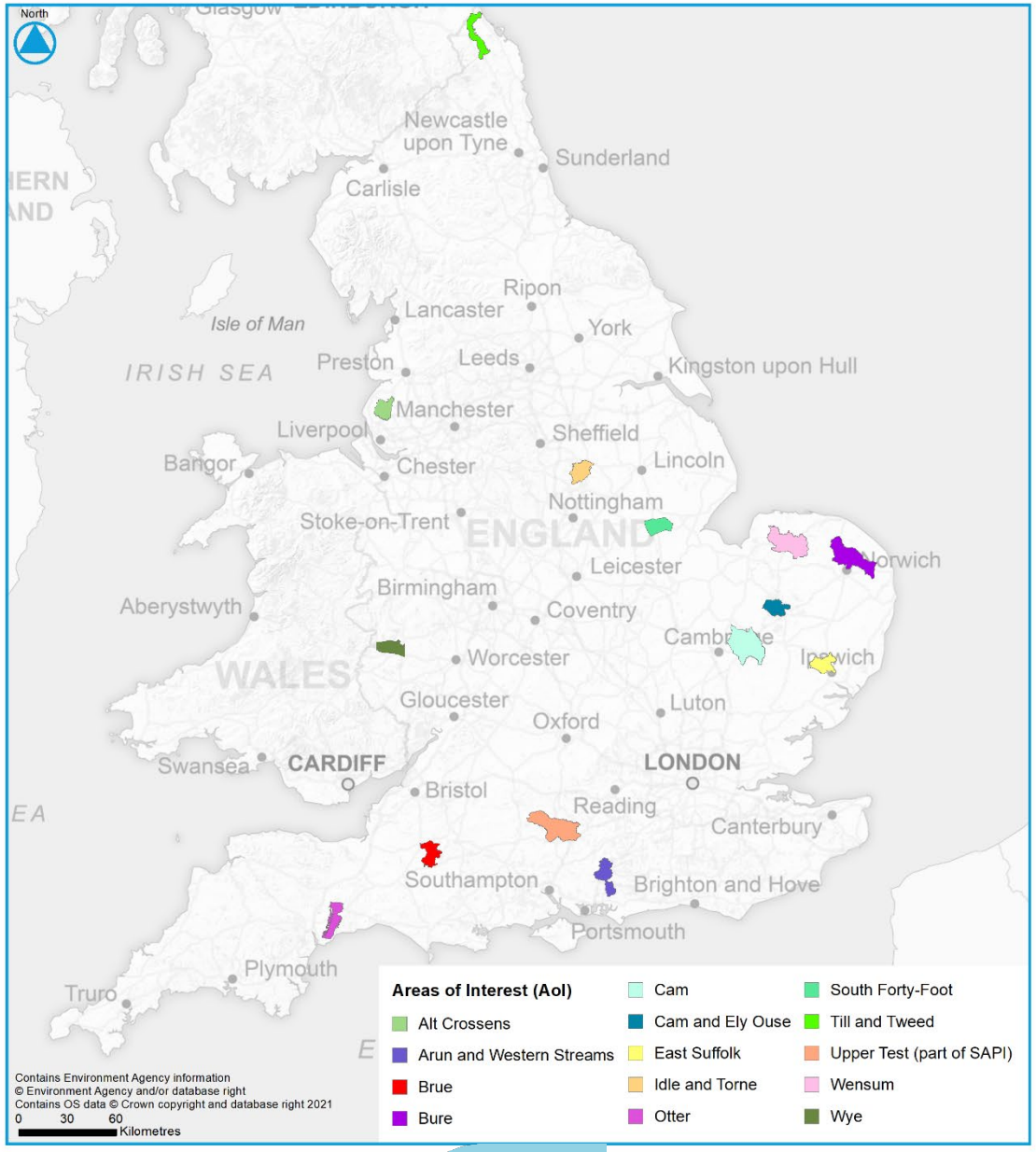
Project Aims:

- Investigate the evidence and potential of Nature Based Solutions (NBS) across catchments with differing geology for:
  - increasing recharge to groundwater,
  - capturing runoff (holding water back), and
  - maintaining baseflow in rivers
- Recommend measures favourable to groundwater recharge
- Aims to be part of a wider package of cross-catchment work to achieve sustainable abstraction and more resilient water resources management



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Project Structure

- Literature review Summary matrix of measures
- Conceptualisation 10 Water Resources priority catchments
- Mapping
- Modelling

Matrix of WWNP measures

Priority catchments WWNP reports

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Literature Review

- Focused on Woodland Creation, runoff attenuation features, Soil and Land Use Management
- Summarised literature review outputs in an NBS Evidence Matrix that shows –
  - Measure Group and Types
  - Water Resource Benefit Indicator
  - Potential Water Resource **Benefit** and **Evidence**
  - Potential Water Resource **Disbenefit** and **Evidence**
  - **Multiple Benefits**
  - **Areas to Avoid**
- An extensive pre-existing data review was also performed

NBS Evidence Matrix

WWNP Measure Group	WWNP Measure Types	Project WWNP GIS Categories	WRB	Funding Scale	Potential Water Resource Benefits	Evidence	Potential Water Resource Dis-Benefits	Evidence	Multiple benefits	Areas to avoid
Upper Catchment Land and Runoff Management	Runoff attenuation storage features on hillslopes including ponds, bunds, infiltration trenches and swales	WWNP RAF WWNP CS		Small-scale capital construction	1. Improves water storage, promotes infiltration and groundwater recharge where sited over permeable geology	1. Larson and Safferman, 2008 1. Hankin et al., 2018 1. Zhao et al., 2016	1. Reservoir Act 1975 regulates areas of significant storage volume and this threshold may reduce in future 2. Sedimentation can develop over time and result in clogging reducing infiltration 3. Surface ponding can result in poor soil aeration and restrict infiltration	1. GOV.UK, 2010 2. Larson and Safferman, 2008 3. USDA & NRCS, ND	Slow and attenuate surface runoff for flood risk reduction and delayed recharge Capture and filter sediment loads Capture and filter diffuse pollutants Improved biodiversity and habitat creation	In close proximity to contaminated land which may mobilise pollutants In close proximity to abstractions sensitive to groundwater quality eg. SPZs Generating storage volume >10,000m3
	Peatbog restoration including grip blocking and vegetation restoration	WWNP RAF WWNP CS		Land management	1. Sustains groundwater level and raises water table 2. Kinder Plateau, Derbyshire- water tables increased by 35mm over a 3-year period 3. Water tables raised by 20mm in Lake Vrynwy catchment, Wales	1. Krause et al., 2007 2. Pilkington et al., 2015 3. Wilson et al., 2010			Slow and attenuate surface runoff for flood risk reduction and delayed recharge Capture and filter diffuse pollutants Improved biodiversity and habitat creation Carbon sequestration	Careful management around SSSIs
	Tillage/ploughing and sub-soiling management	WWNP SPS WWNP LCM		Farming Management	1. Conventional tillage can increase soil infiltration rates compared to no tillage 2. Sub-soiling can increase infiltration by 10% through enhanced porosity after 2-years 3. Slot mulch can increase infiltration and increase water storage by 41% 4. Contour ploughing can retain surface runoff for recharge	1. Lipiec et al., 2006 1. Gomez et al., 1999 2. Sojka et al., 1993 3. McConkey ND 4. Harris et al., 2004	1. Conventional tillage can reduce soil infiltration rates compared to no tillage 2. Modifies soil properties by decreasing porosity and lowering hydraulic conductivity.	1. Elliott & Efetha, 1999 2. Carter and Colwick 1971	Conservation tillage can reduce soil erosion and diffuse pollution rates	Avoid conventional tillage in areas of fragile and erodible soils, particularly on steep hillslope gradients
	Peatbog drainage			Land management	1. Short-term initial drainage increases near-surface water storage capacity	1. Rogger et al., 2017	1. Increased soil moisture deficit reducing groundwater recharge and oxidation of peat will lower water tables and reduce peat thickness and reduce water storage	1. Rogger et al., 2017		Careful management around SSSIs
	Land and in-field drainage features	WWNP SPS WWNP LCM		Farming Management	1. Reduces local water table improving soil storage capacity Can divert surface water to more permeable areas	1. Blanc et al., 2012	1. Can promote rapid surface runoff and exacerbate diffuse pollution	1. Blanc et al., 2012	Improved crop yield	Areas susceptible to surface water flood risk or flashy fluvial flooding
	Arable land management including cover crop, crop choice, reduced intensification, grass seeding, hedgerow planting	WWNP SPS WWNP LCM		Farming Management	1. Application of crops with reduced water demand to reduce impact on water balance and resulting recharge 2. Cover crops can reduce surface runoff and increase soil water capacity. 3. Reduced intensification of managed grassland can increase soil water capacity Crop rotation can increase soil hydraulic properties	1. Defra, 2013 1. Wheater and Evans, 2009 2. Petto et al., 1979 3. Puttock & Brazier, 2014	1. Maize fields left bare in early autumn increase hillslope and silt runoff, diverting potential recharge away from aquifers 2. Cover crop can increase soil moisture deficits in rain-scarce regions reducing recharge potential	1. Palmer & Smith, 2013 1. PWAG SouthWest, ND 2. Deasey et al., 2007	Slow and attenuate surface runoff for flood risk reduction and delayed recharge Soil retention Reduced diffuse pollution rates Enhanced soil organic matter content Improved biodiversity and habitat creation	Cover crop in rain-scarce regions which may reduce proportion of rainfall recharging into aquifers

Summary matrix of measures

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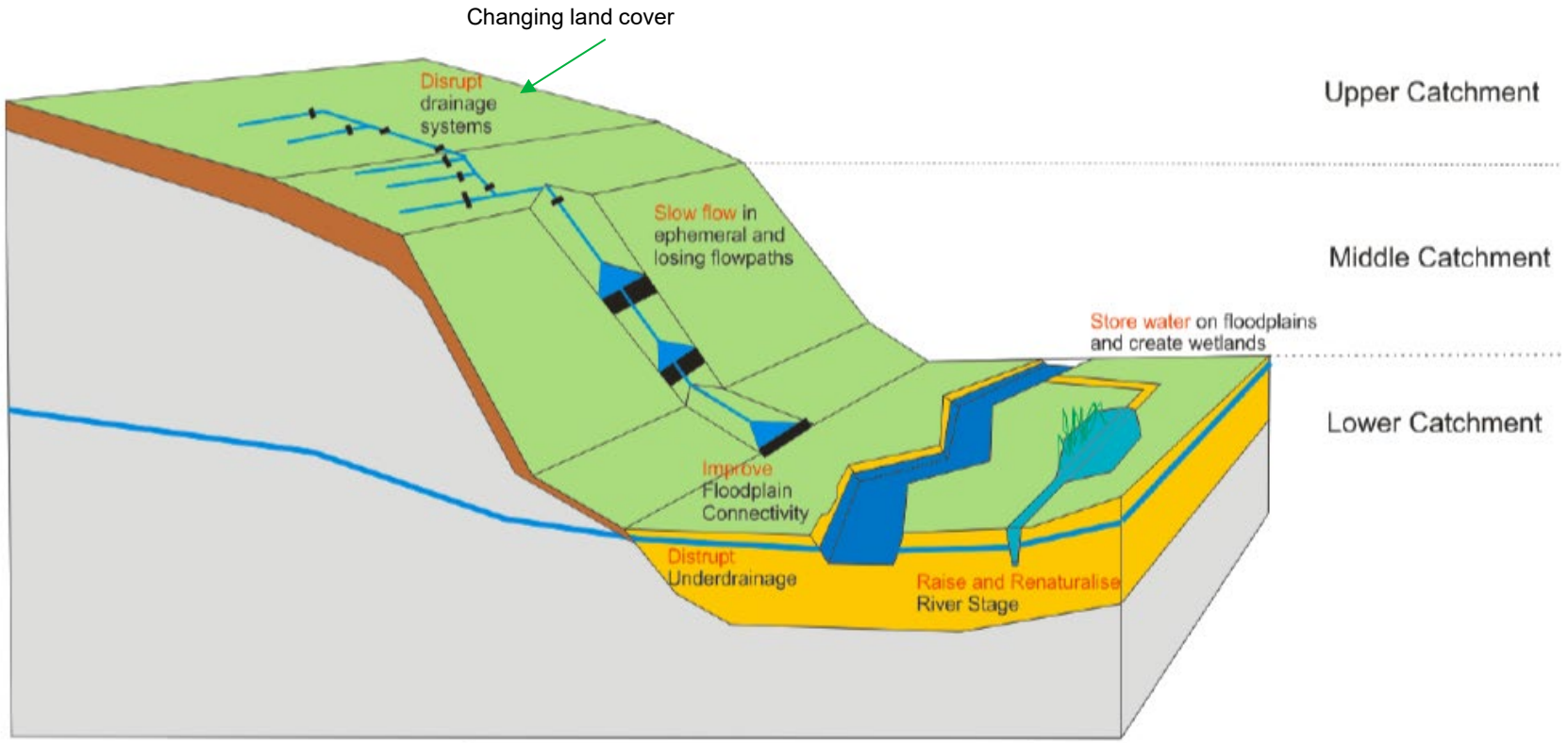
Generic Conceptualisation

- Focus on where NBS Interventions can affect groundwater resources,
- Catchment has been broken down into –
  - Upper
  - Middle
  - Lower



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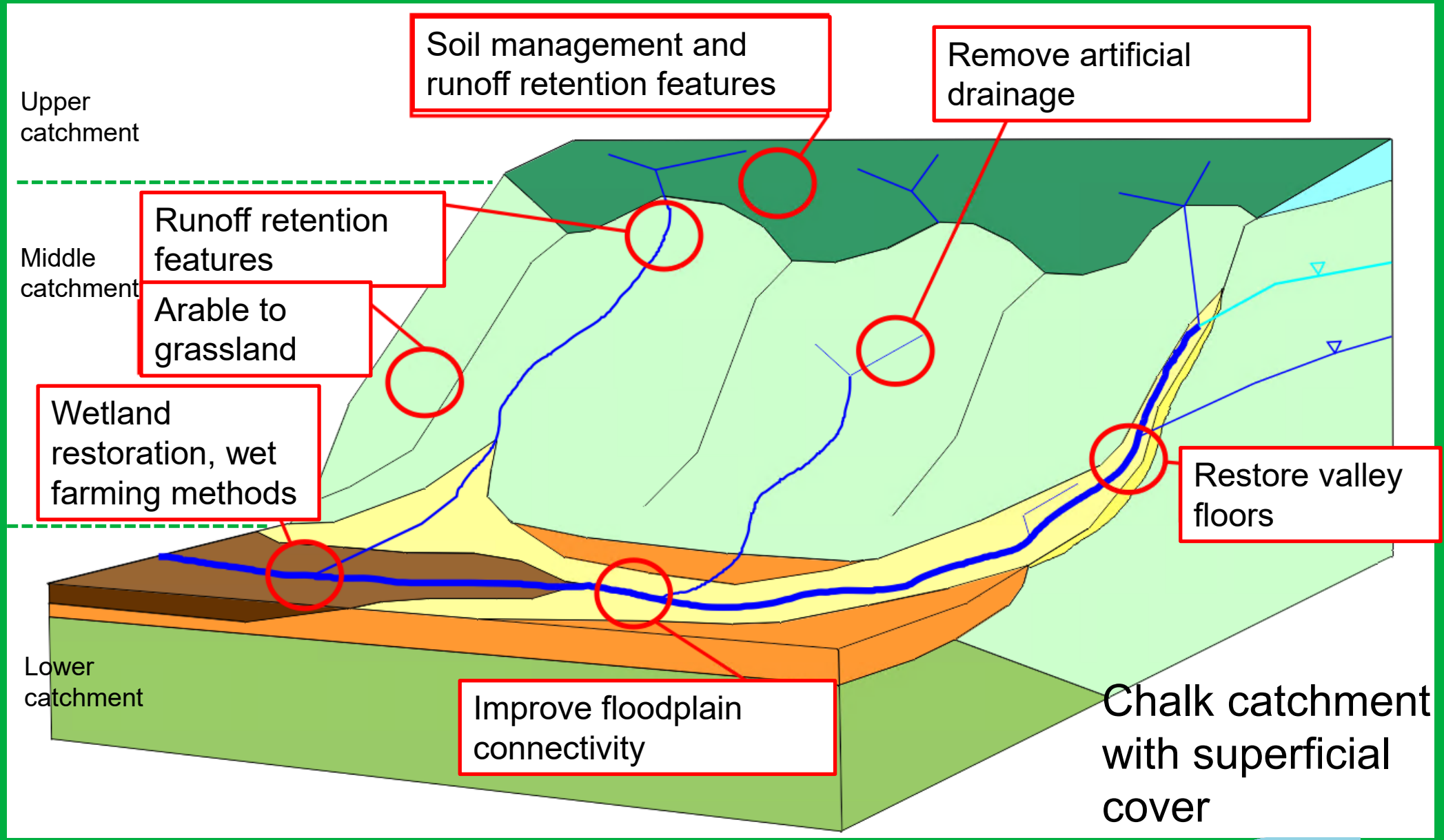

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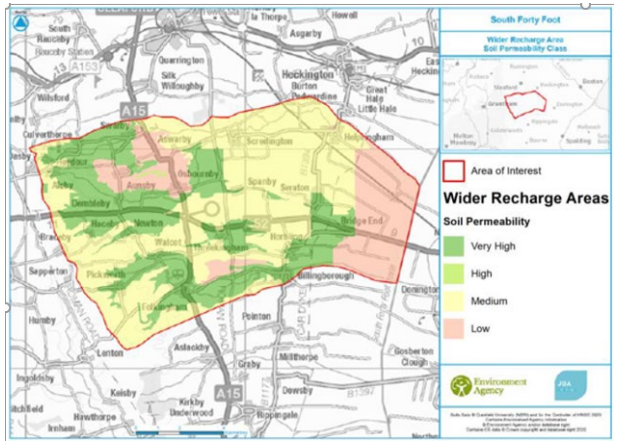
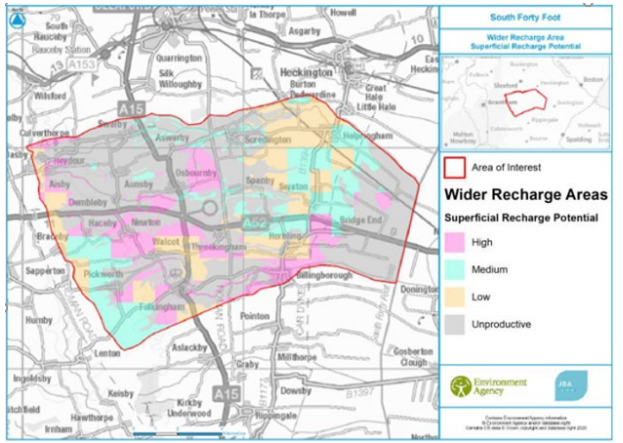
Mapping Recharge Potential

- Classify areas based on their:
  - Soil Drainage
  - Superficial Recharge Potential
  - Bedrock Recharge Potential
- Identify areas where water is most needed
- Key data sources:
  - Groundwater Vulnerability Mapping
  - Aquifer Designation
  - Baseflow index / soil category
  - Soils mapping

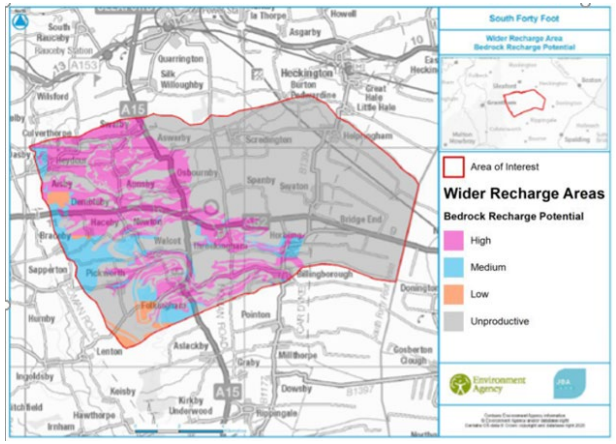
Soil Drainage



Superficial Recharge Potential

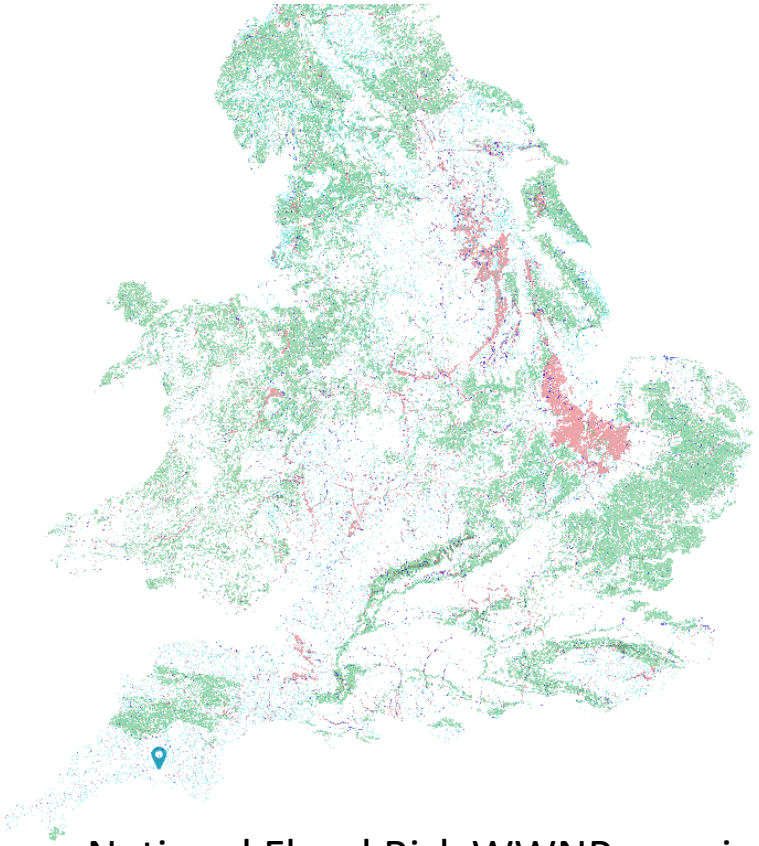


Bedrock Recharge Potential



NBS Measures

- Define a set of NBS features applicable to the local catchment and groundwater processes
- Define their recharge and multiple benefit potential and highlight any potential constraints
- This included initially adopted EA (Natural Flood Management) Evidence Base (2017) features:
    - Runoff attenuation features
    - Floodplain reconnection features
    - Tree planting features including riparian, floodplain and wider catchment
- Expanded to include soils improvement, wider surface water flood risk, arable and grassland land cover



National Flood Risk WWNP map is available on the JBA Trust website: https://naturalprocesses.jbahosting.com/Map

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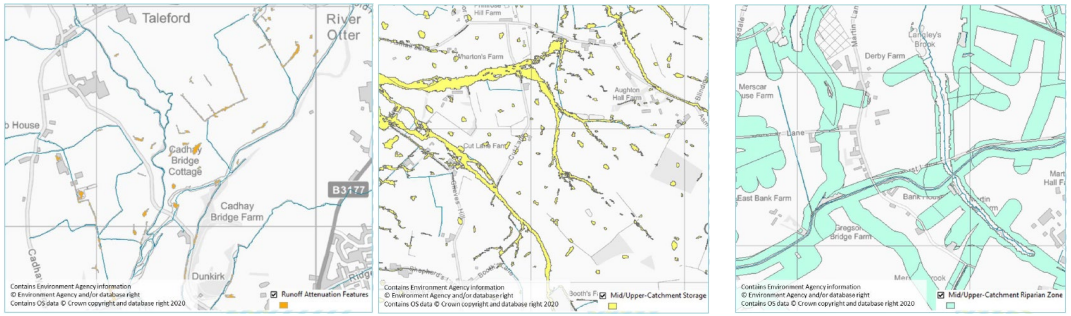
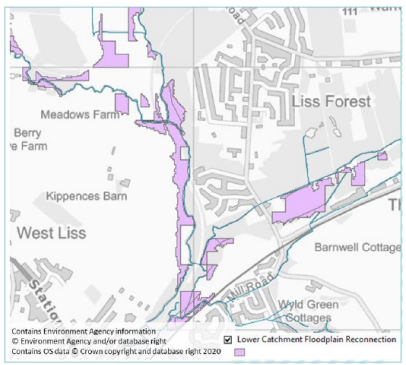
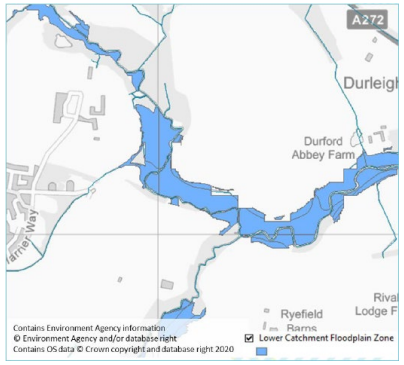
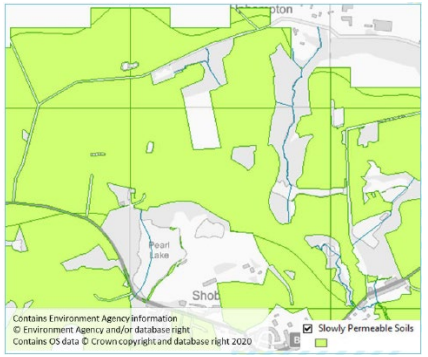
NBS Features - examples

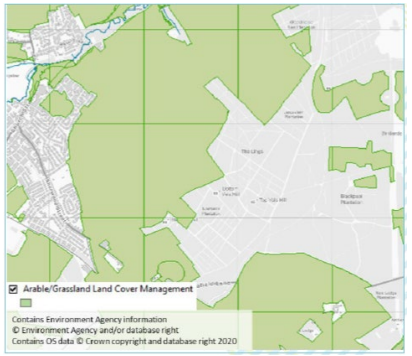
- Runoff attenuation features
- Upper / mid catchment storage
- Upper / mid catchment riparian zone
- Lower catchment floodplain re-connection
- Lower catchment floodplain zone
- Slowly permeable soils – increasing infiltration
- Arable and grassland land cover management







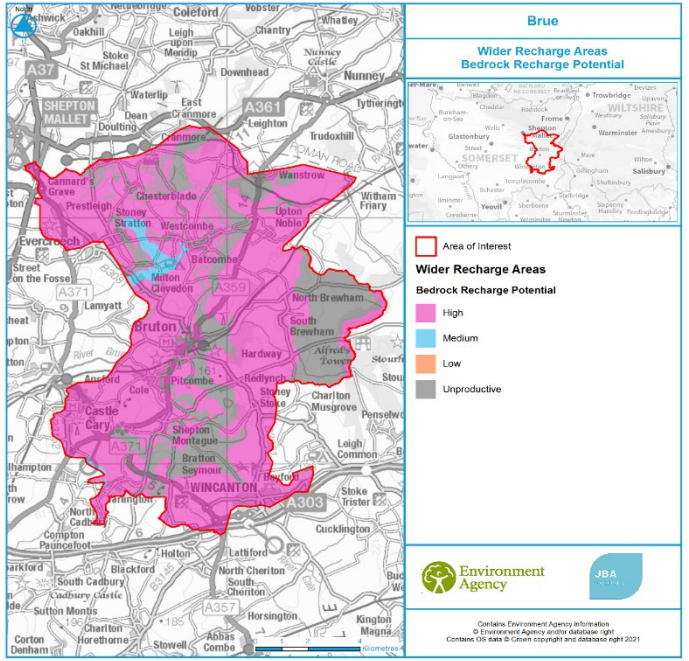




Nature-based Solutions (NBS) Attribution

- Bringing recharge potential and NBS features together
- Aims to define NBS recharge and multiple benefit potential and highlight potential constraints

Recharge potential



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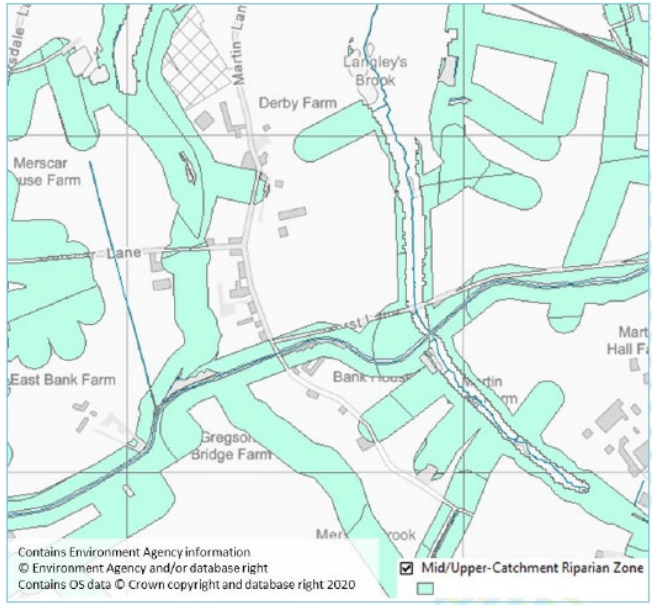
NBS features



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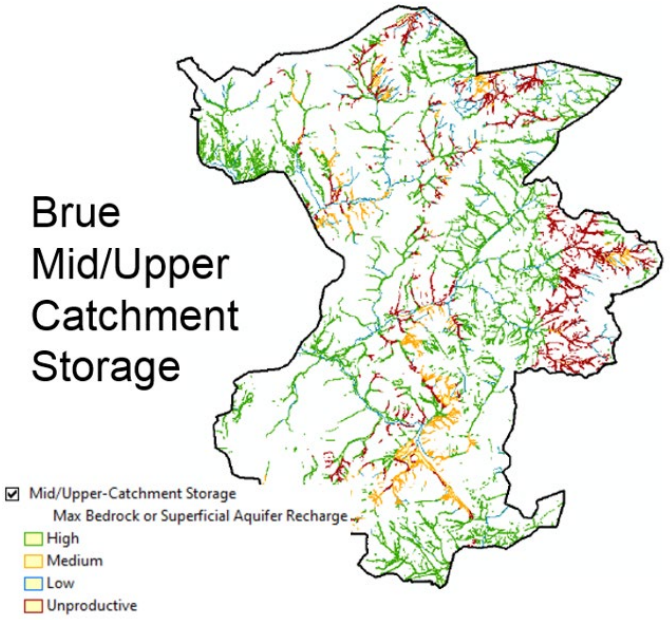
Potential Benefits of NBS



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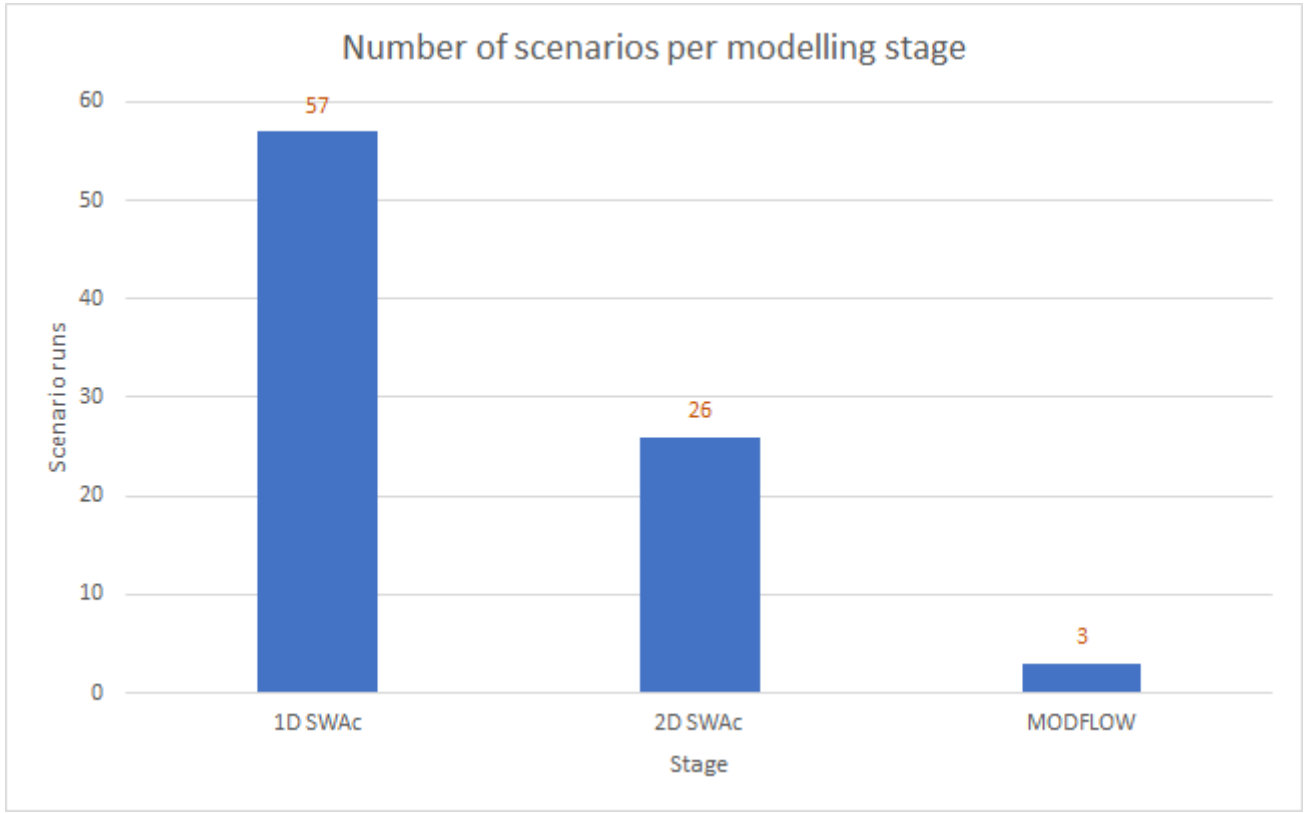
Modelling nature-based solutions

- Conceptual model review (adding missing processes e.g. canopy interception)
- Updated recharge model
- 1-D recharge modelling (SWAc – surface water accounting model)
- 2-D recharge modelling (SWAc)
- Groundwater modelling (MODFLOW)

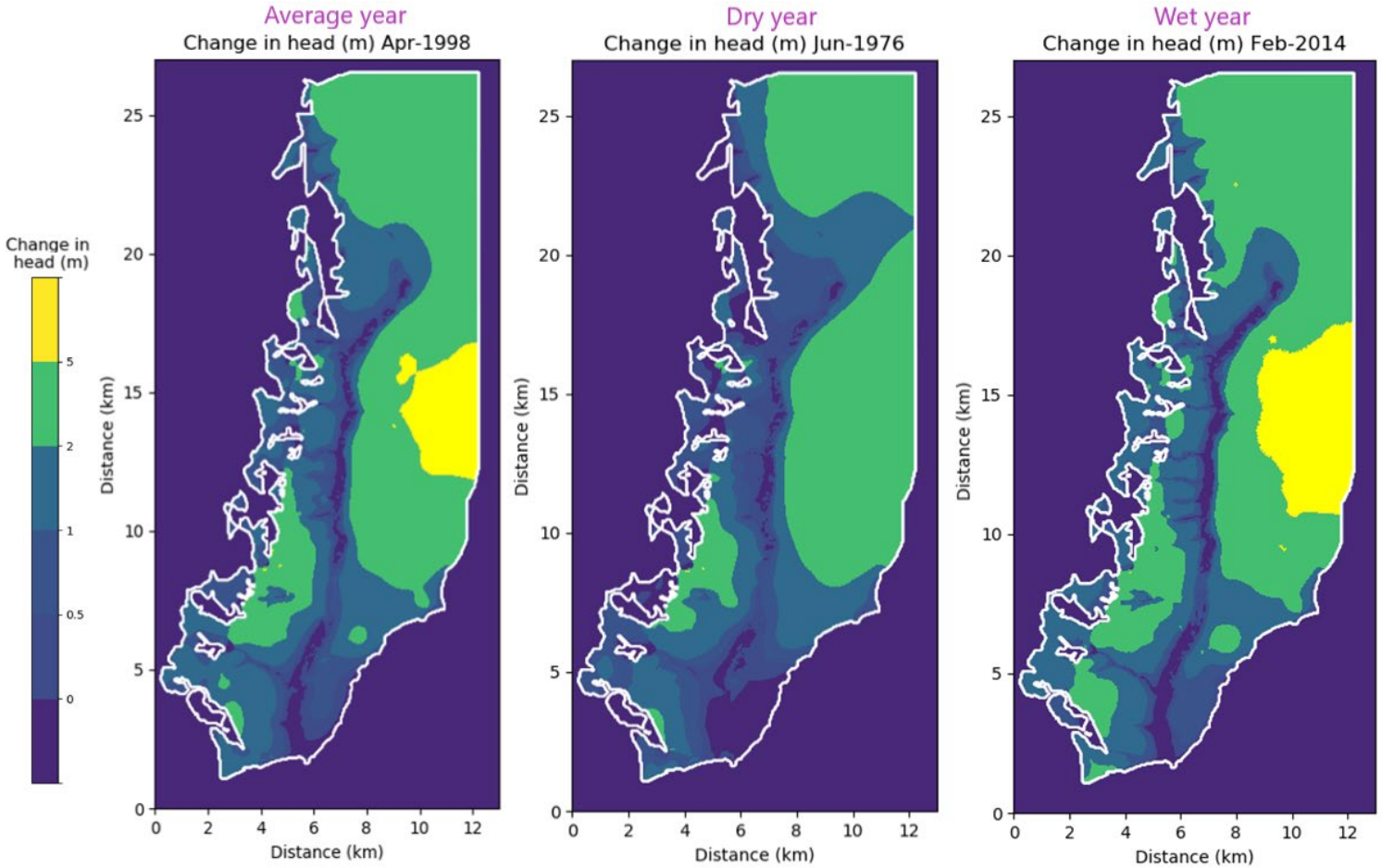
- Focused so far on runoff attenuation features, soils management and tree planting measures

- Results – 4% increase in recharge with soil improvement 50% coverage, 5% with 100% coverage (Otter sandstone catchment)

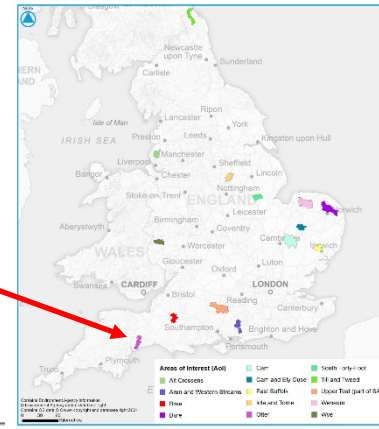


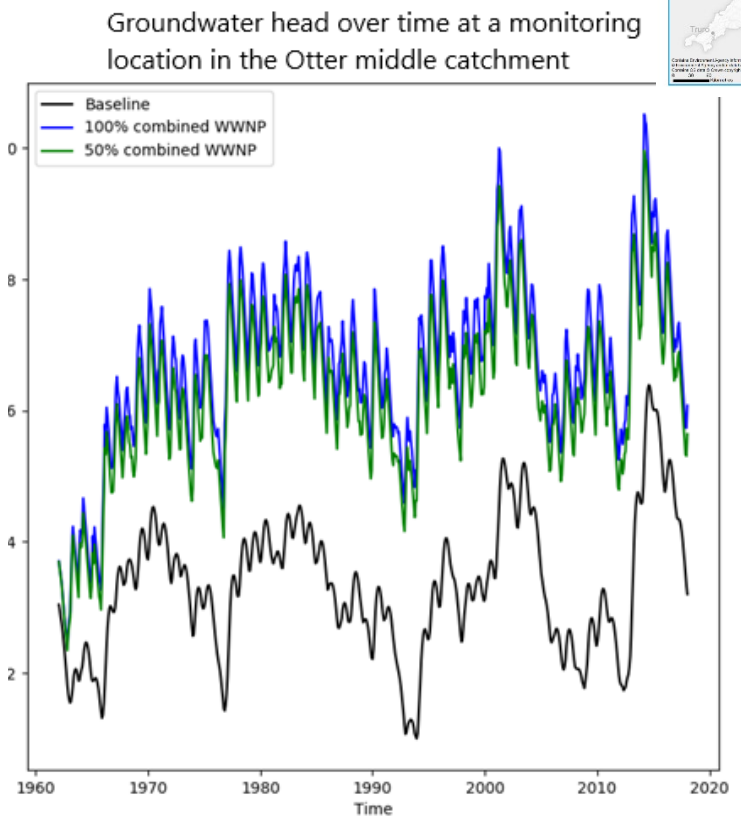
Scenarios per modelling stage

Modelling results



Location of Otter sandstone catchment





Most gains with 50% implementation scenario

Scenario groundwater head change:
Difference in groundwater head between baseline and 50/100% scenarios for average / dry and wet year

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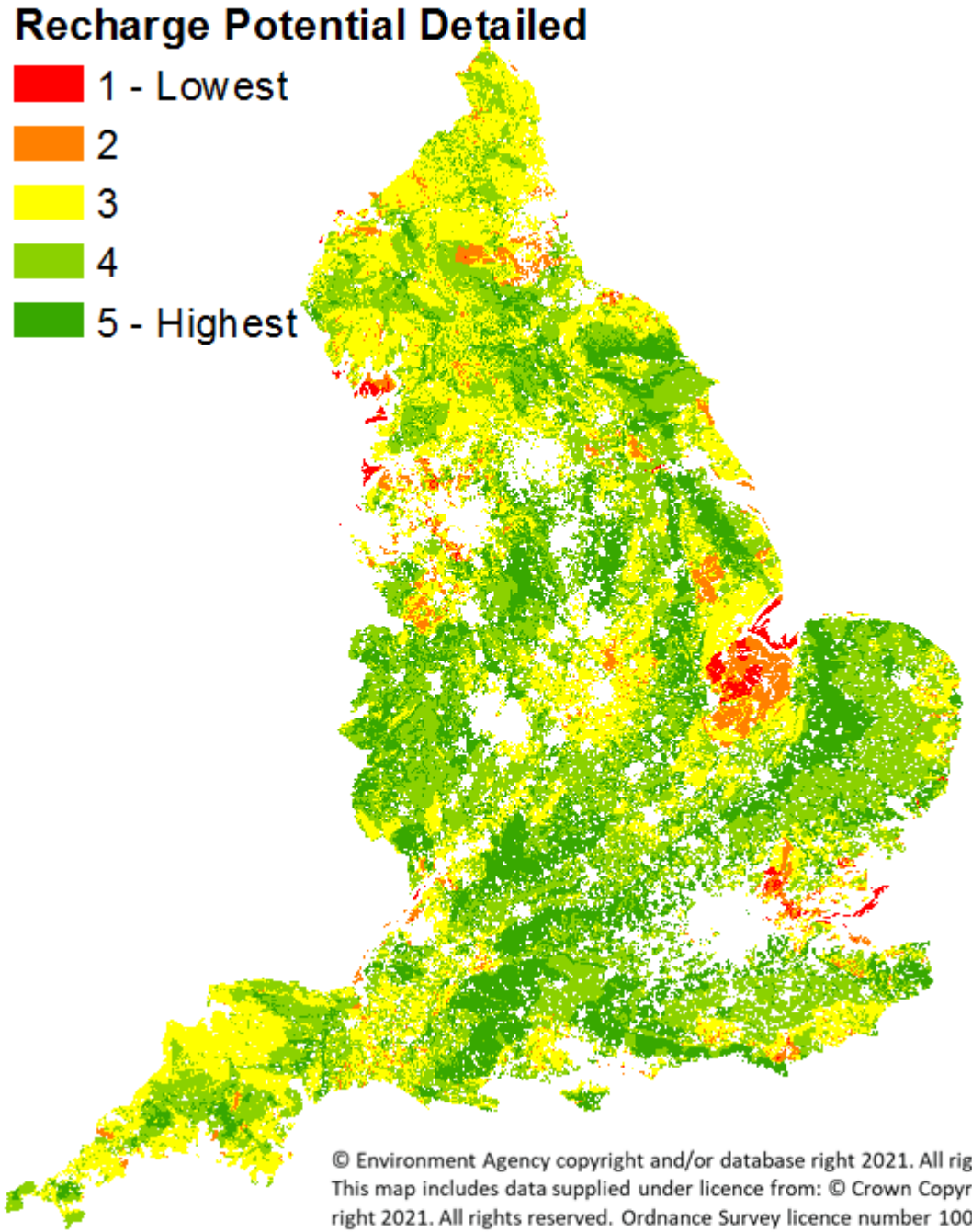

Prioritising action in the right locations

- Developing a national map of recharge potential to aid spatial prioritisation
- Intended outcome: increased ground and surface water resources
- Indicates potential effectiveness – for use as a starting point for local study/consultation
- Developed for Environmental Land Management Schemes but will be useful in other contexts

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What's next? – Future Work on NBS

- Groundwater modelling of NBS in Chalk catchments
- Adding missing processes to recharge models
- NBS and climate change modelling
- Integration of NBS with land management schemes
- Spatial mapping tool for water resources impacts of tree planting schemes

…long-term goal…NBS mapping for the whole of England as part of catchment management.

THANK YOU! MERCI! Any questions?

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