Stress testing the impacts of climate change on water quality permitting across England

JBA Consulting: Barry Hankin, **Alex Garratt**[1], Changgui Wang and Paul Eccleston

Environment Agency: Tony Heaney, Paul Simmons & Jo Wybrow

[1]**Presenter**

Email: alex.garratt@jbaconsulting.com & barry.hankin@jbaconsulting.com

Introduction

Overall aim

Assess **nationally** the impacts to **water quality** from projected change in **flows** & **water temperature**, resulting from **climate change** at epoch **2060-80**

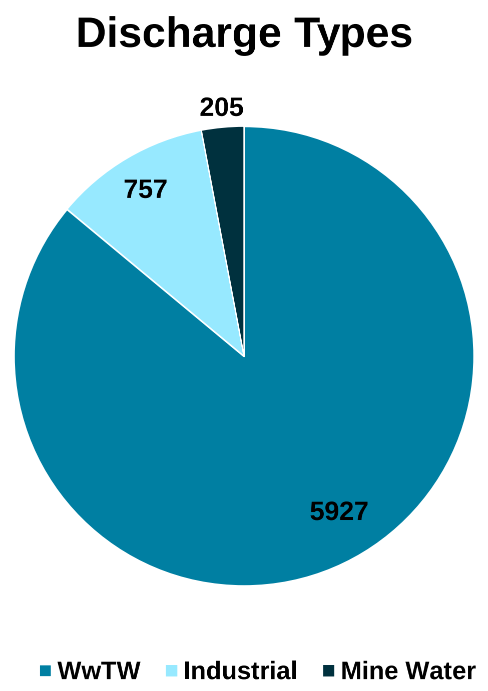
Objectives

1. The **number of discharges** that downstream WQ results in **failure** of WFD objectives due to **CC**.

2. The **change in length** of rivers failing objectives

3. Where **failure** to meet objectives is **projected in future**, assess whether **changing effluent quality** would result in meeting objectives.

Note - Results focus on 95% confidence of failure - as these drive water industry investment.



Introduction cont.

Why? What is the need for this work

- Feeds into the EA's permit planning
- What it means for existing discharges
- Cost of maintaining current quality
- Geographic risk
- Fundamental challenges: Standards & permitting

Model	Determinand	What is it?
Chemical	PFOS	surfactant e.g. fabric protector
	Cadmium	toxic metal
	Cypermethrin	insecticide
Sanitary	Phosphorus	nutrient
	Ammonia	nutrient
	DO	dissolved oxygen
	BOD	organic material

Introduction cont.

Key project facts:

- 17 SAGIS-SIMCAT regions covering England
- 146 Future Flows Hydrology gauges used
- Epoch: 2060 - 80
- 7 Python scripts written
- 6877 discharges analysed
- Length of watercourses modelled: 51,500 km
- 272 SIMCAT model runs completed
- Time limited programme (2.5 months)

Datasets:

- 17 Calibrated "Sanitary" SAGIS-SIMCAT models
- 17 Uncalibrated "Chemicals" SAGIS-SIMCAT models
- Future Flows Hydrology ensemble data
- UKWIR climate change sensitivity tool

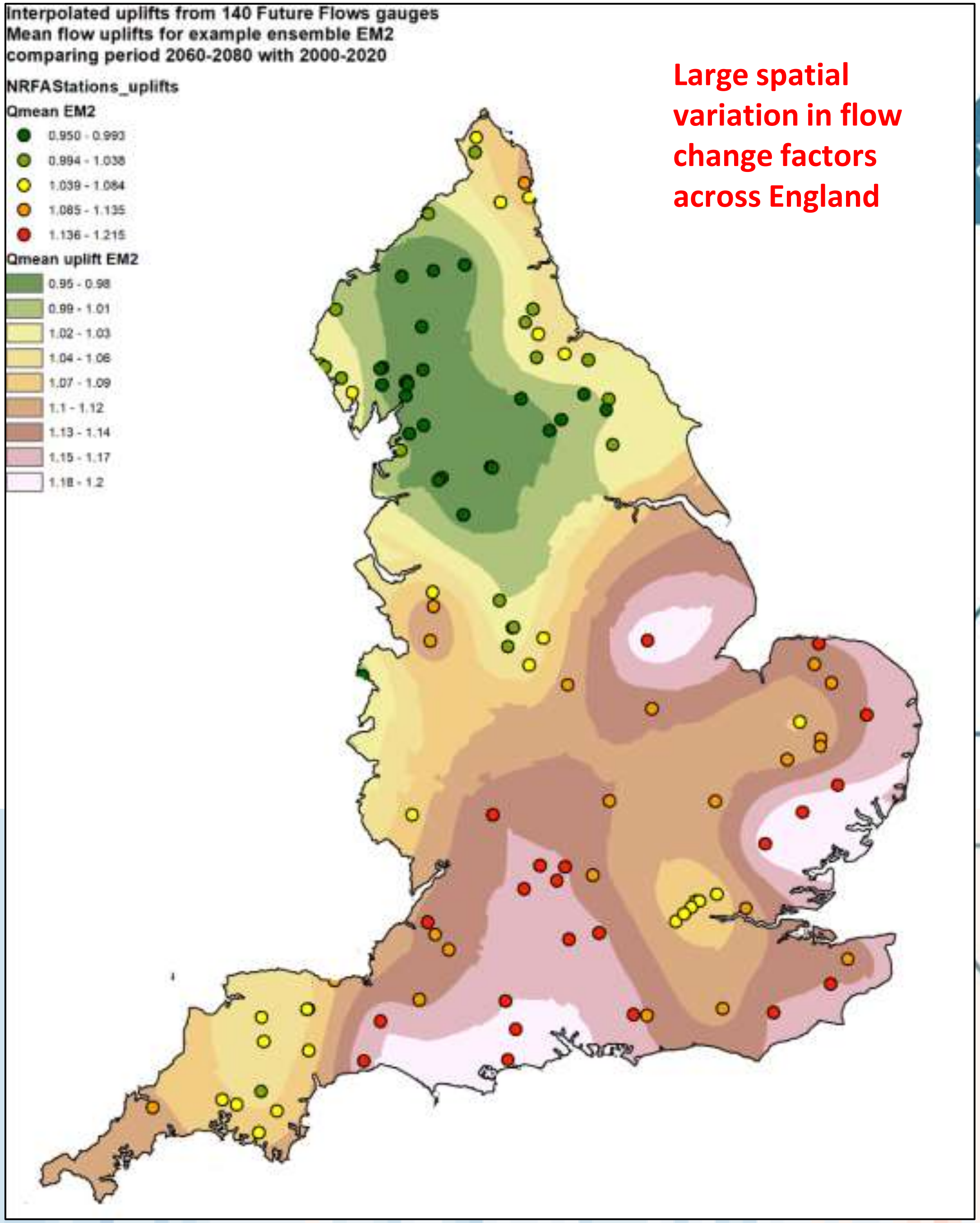
Limitations:

- SAGIS-SIMCAT is steady state
- SAGIS-SIMCAT is a Monte-Carlo mass balance statistical model
- Annual average model used for annual average permits

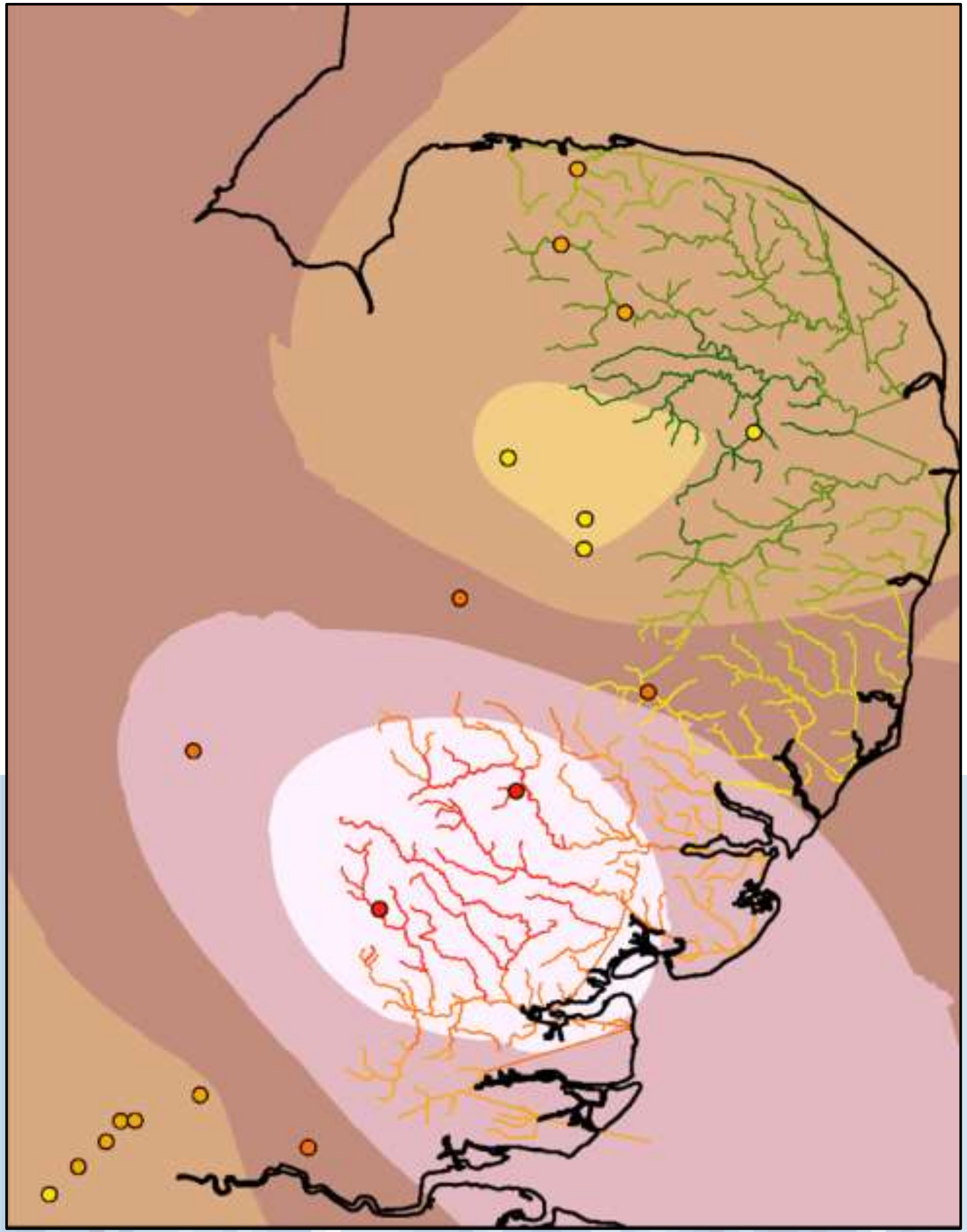
Methodology

Adjusting flow in future

- Calculate change factors from baseline FFH projections to epoch 2060 - 2080
- Mean and Q95 exceedance flow
- Total 11 members in the ensemble
- EA provided **3** members to use for each of 17 regions (roughly low, mid, high scenario)
- Time constraints – led to a reduced number of ensembles being used.
- Improvement could be using more ensembles in future work – to show full range of uncertainty.



Methodology – cont.



Quality control

- Transformation of Future Flows time series into flow change factors - gave the same result using Python and R script by 2 individuals
- Were change factors correctly brought into the UKWIR workbook
- Checking extraction and analysis of results using Python gave the same values as with a spreadsheet

Water temperature was raised by **+1°C** in the future scenarios
Sensitivity to temperature was explored up to **+ 2°C**

Summary of 3 stress tests

Stress test 1

Sanitary determinands → Drop-in class or >10% deterioration between baseline and future scenarios → Categorised into 4 possible outcomes →

Passed both tests
Failed only >10% deterioration
Failed only drop in class
Failed both tests

Chemical determinands → Two tests applied to baseline and future scenario results → **Test 1:** Downstream conc. is > (annual average EQS * 0.8) **Test 2:** If downstream conc. Is >= to (Upstream conc. + (1/2 the headroom) → Categorised into 4 possible outcomes →

Baseline pass & future pass
Baseline pass & future fail
Baseline fail & future pass
Baseline fail & future fail

Stress test 2

Difference in **failed length of river** between the baseline and future scenario.

Stress test 3

No threat to target
Target **met** by altering discharge
Target **not met** by altering discharge

→ Categorised into 9 possible outcomes →

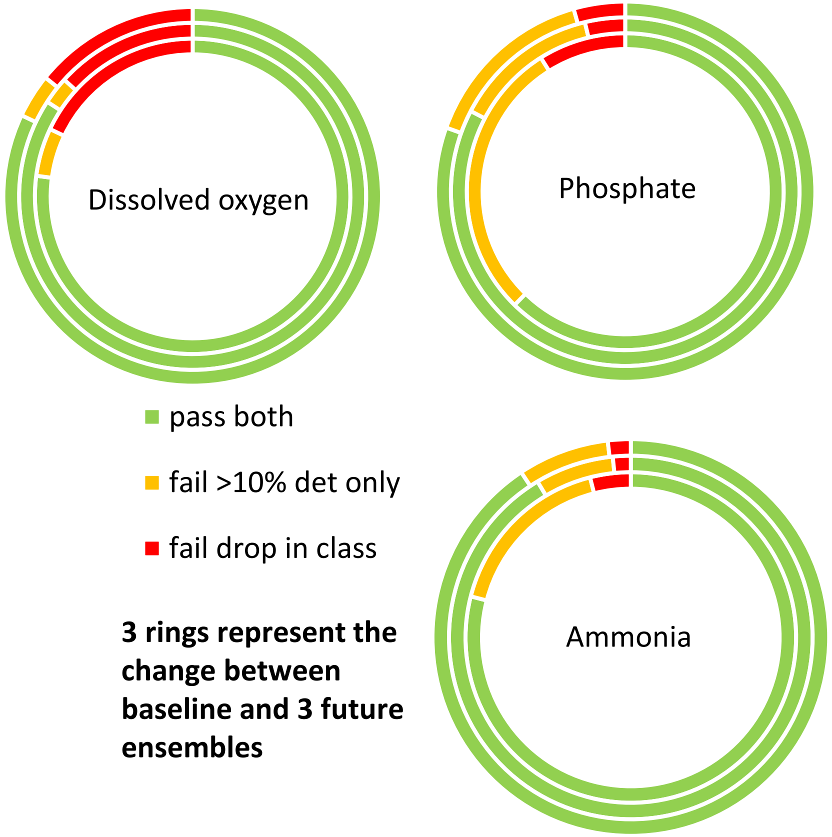
1	No change	No threat in baseline, no threat in future
2	Deterioration	No threat in baseline, target met in future
3	Deterioration – not met target	No threat in baseline, target not met in future
4	No change	Target met in baseline, target met in future
5	Deterioration – not met target	Target met in baseline, target not met in future
6	Improvement	Target met in baseline, no threat in future
7	No change	Target not met in baseline, target not met in future
8	Improvement	Target not met in baseline, target met in future
9	Improvement	Target not met in baseline, no threat in future

Results: Stress test 1 - change to downstream quality

Sanitary – DO

DO	Total discharges	Outcome category	EM1 No. of discharges	EM2 No. of discharges	EM3 No. of discharges	How failed
National	6877	0	5301	5789	5642	both tests passed
		1	339	176	259	failed >10% deterioration
		2	1155	904	948	failed drop in class
		3	82	8	28	failed both tests

High confidence – for 800 all 3 members failed

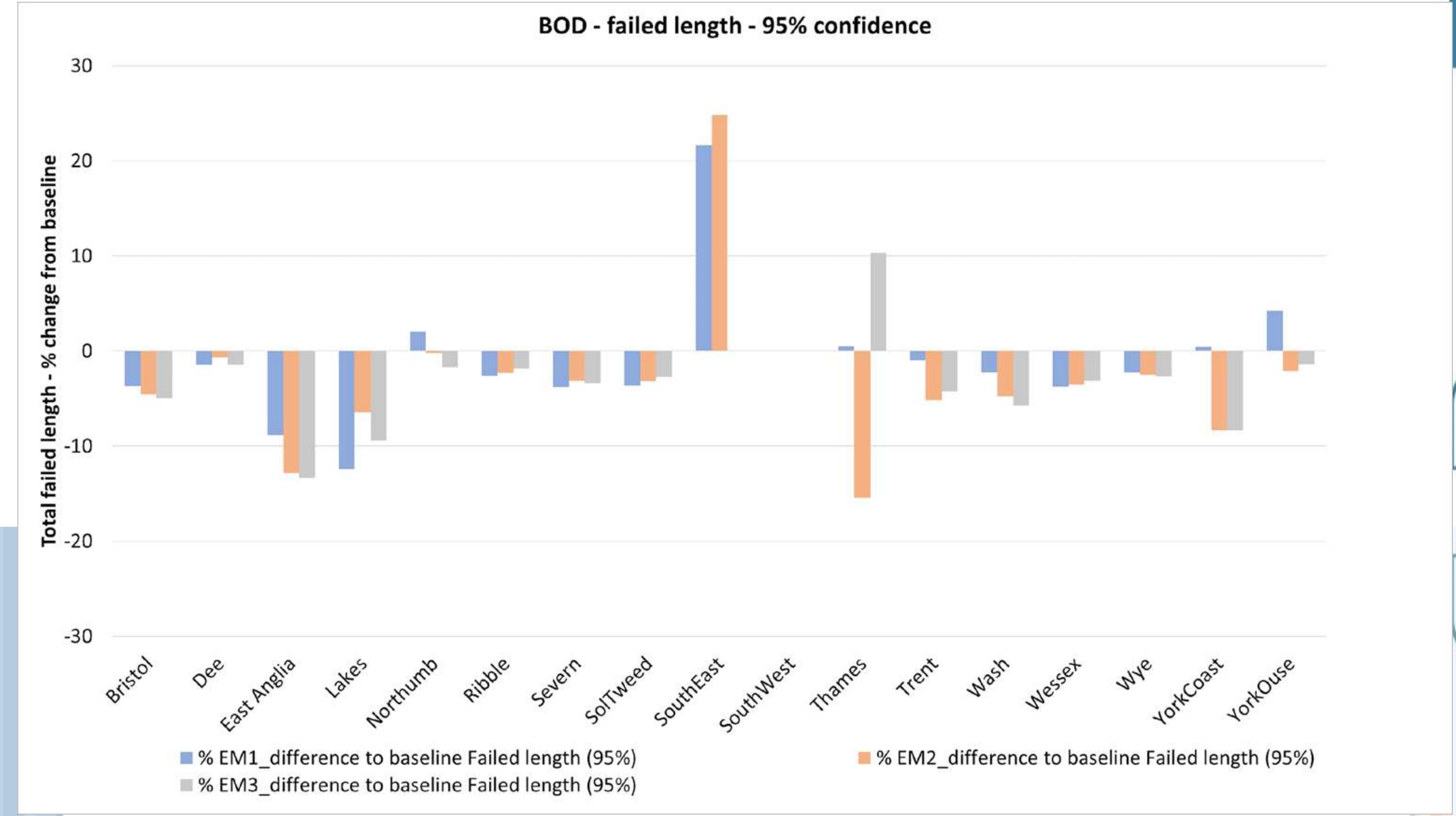


3 rings represent the change between baseline and 3 future ensembles

Chemical – Cadmium

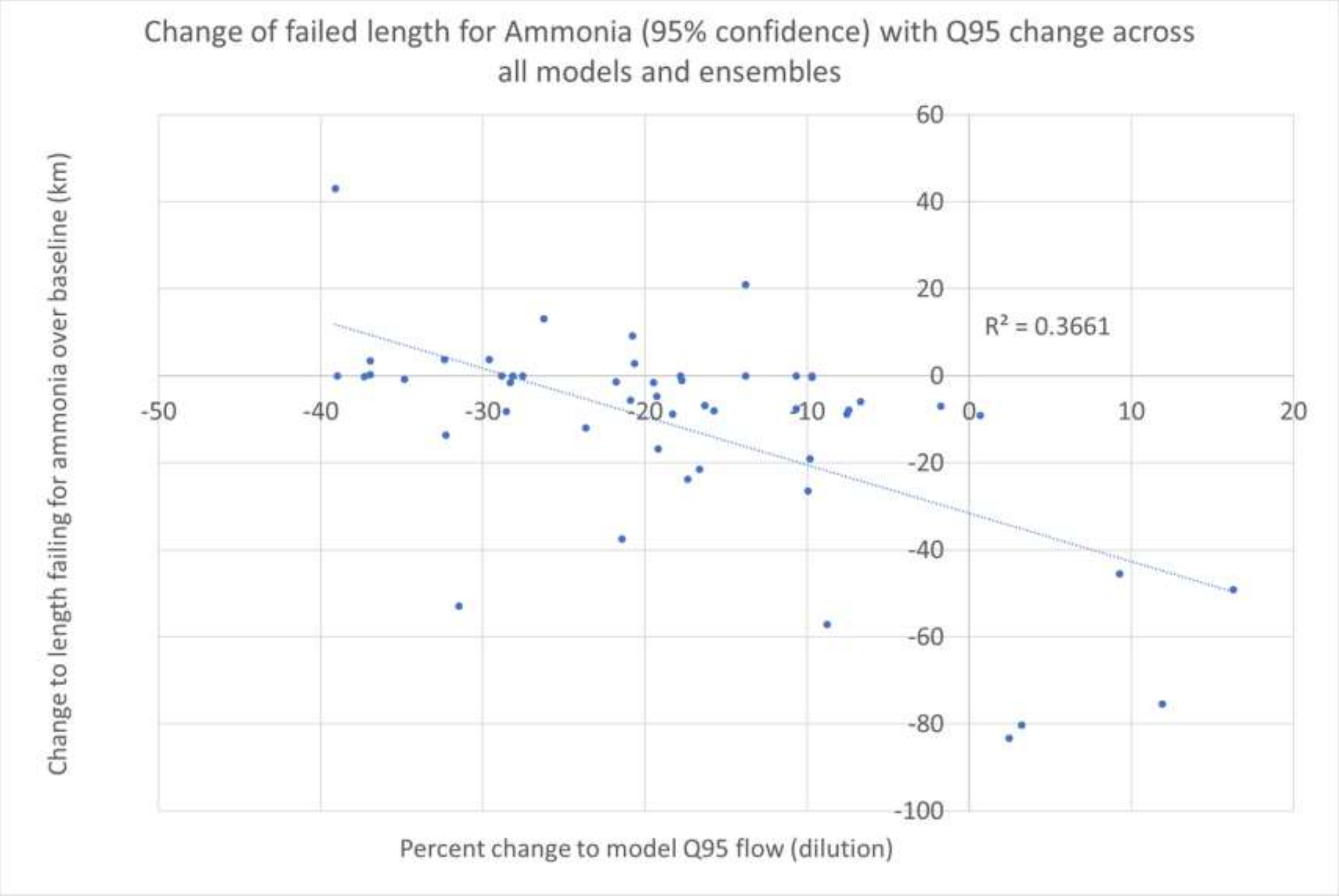
Cadmium	Total discharges	Result option	EM1 No. of discharges	EM2 No. of discharges	EM3 No. of discharges	Confidence	Result option key
National	6894	1	5276	5420	5399	6586	baseline pass, cc pass
		2	213	69	90		baseline pass, cc fail
		3	1	86	78		baseline fail, cc pass
		4	1404	1319	1327		baseline fail, cc fail

Results: Stress test 2 – change in length of river failing target

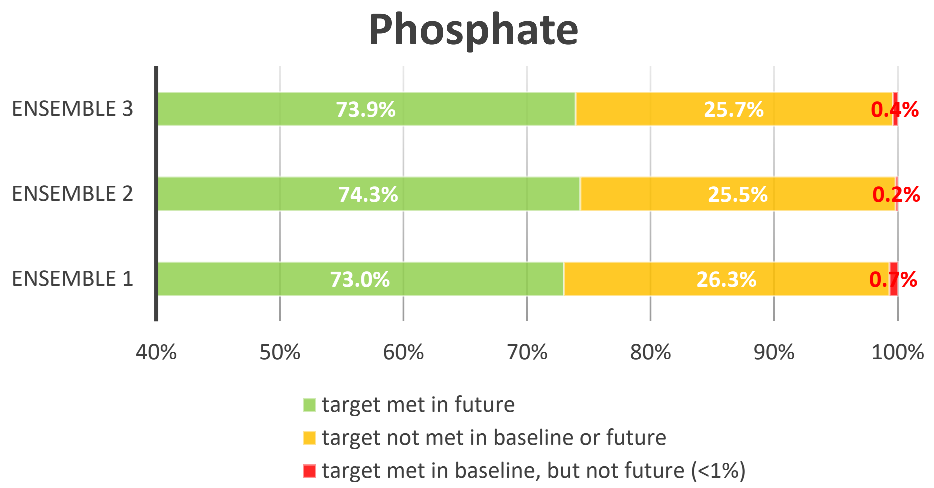


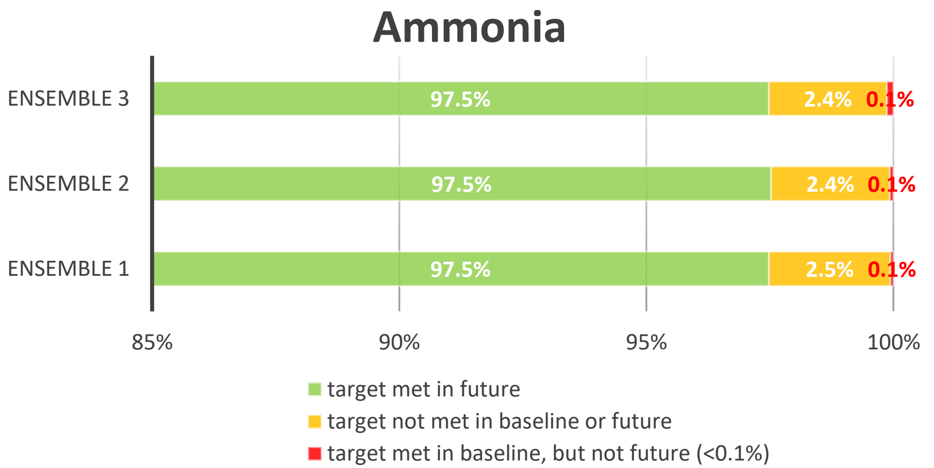
Results: Stress Test 2 - change to length failing target

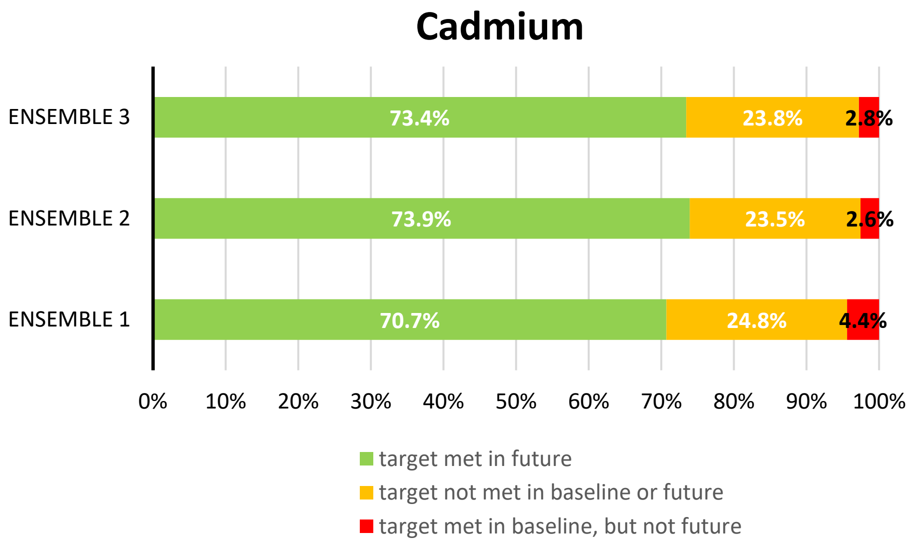
Ammonia – Correlation of future Q95 vs failed length

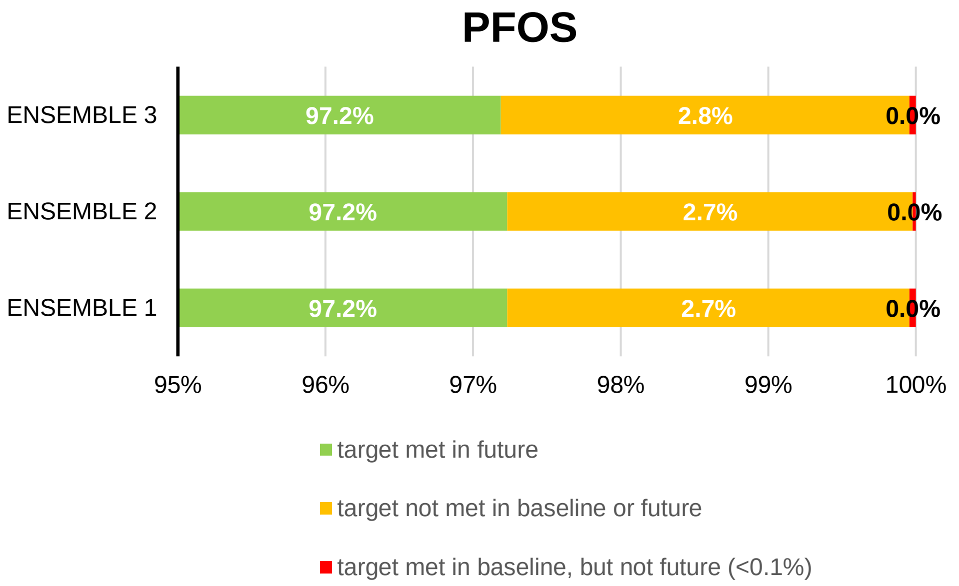


Results: Stress test 3 – altering discharge to meet targets



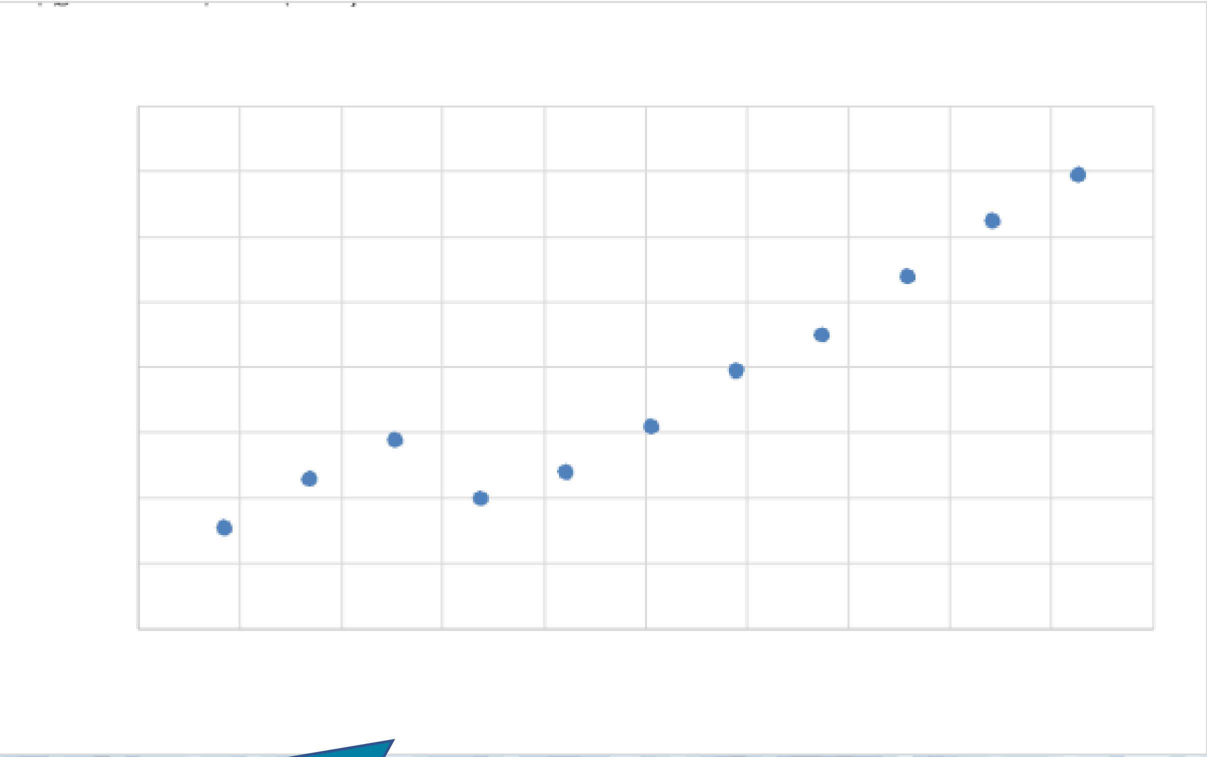




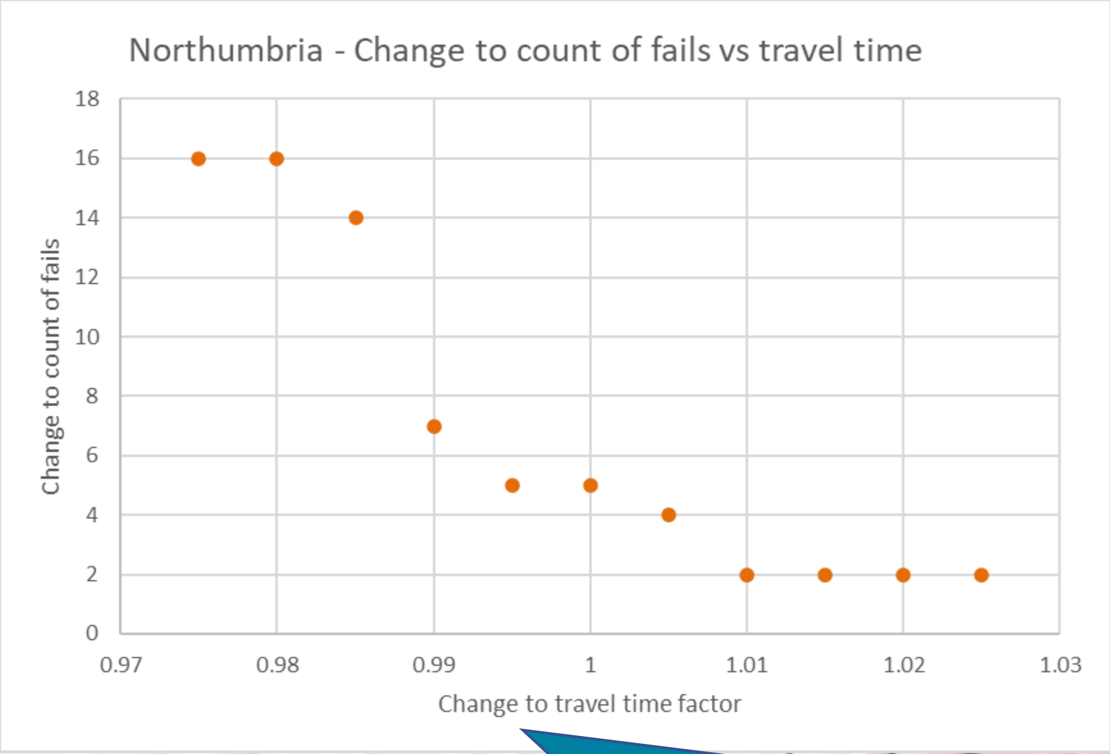


Sensitivity Analysis

Temperature - BOD



Travel time (α) - Cadmium



High temperature sensitivity so important to model projected water temperature more accurately in future.

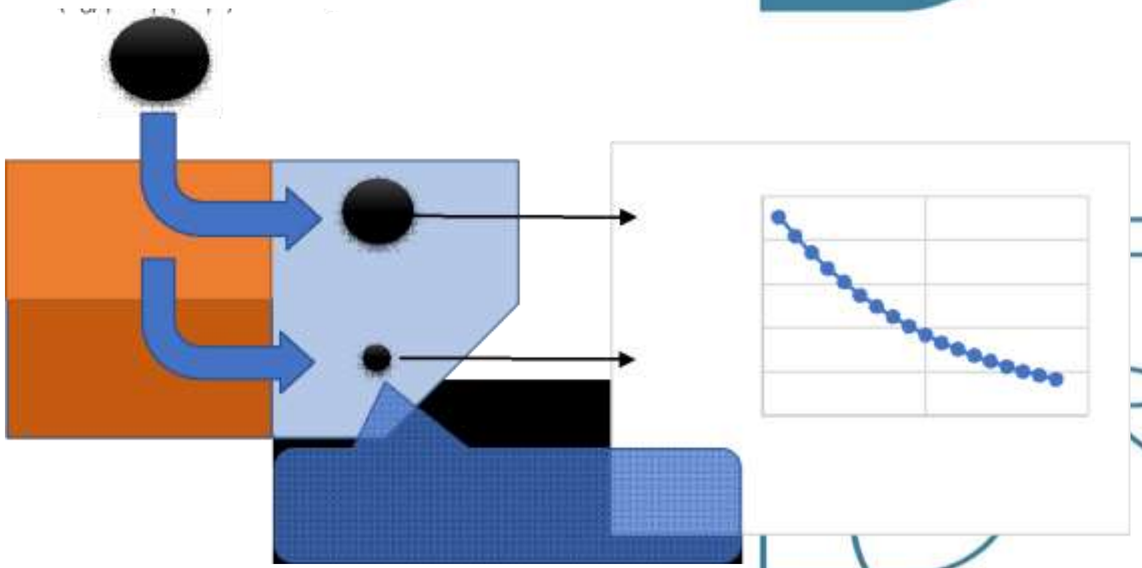
With reduced time of travel factor or reduced flow, failures are greater.

There is less time for decay for some substances so fails increase rapidly.

The nature of how travel time changes with increased rainfall has been explored with CSF-HYPE

We used the EA CSF-HYPE model* predicted ensemble mean changes to water quality by **month** for future epochs based on UKCP18 / RCP8.5

- The CSF-HYPE model for England has strong regional flow calibration across 777 flow gauges (NSE ~ 0.9; KGE ~ 0.69)
- Monthly uplift factors created for RCP8.5 climate change based on corrected high-resolution Met Office UKCP18 model (2.2km)
- Ensemble predictions show wetter winters (and drier summers) can lead to greater concentrations!
- Model results support idea that the faster runoff fractions are increasing disproportionately, and polluted runoff having reduced **residence time** to assimilate via faster pathways
- Tested in Eden focussing on two soil types – suggests that effect present for both, but that organic soils would be a little more resilient to climate change
  - Recent Natural Flood Management research (e.g. LANDWISE project, UK) makes strong correlation between porosity and organic content
- Further research is needed to ensure the assumptions on mixing rates of pollutants and residence times within soil layers are sensible



Climate change can generate pollution pathways with predominantly *much shorter residence times,* increasing concentrations and *not* diluting pollution

*International conference on land-use and water quality – Maastricht, September 2022: https://www.luwq2022.nl/

Conclusion of results

JBA group

Stress Test 1 - Sanitary

Dissolved oxygen and Phosphorus are most sensitive to climate changes, DO exhibits higher drop in class fails than phosphorus, followed by Ammonia.

Stress Test 1 - Chems

Cadmium poses the greatest risk, followed by PFOS and Cypermethrin.

Stress Test 2

Phosphorus poses the greatest risk for sanitary determinands and Cadmium/PFOS for chemical.

Stress Test 3

For test 3 Cadmium shows by far the highest counts of not being able to meet targets in future which are met in the present. Phosphorus has similar results but is less severe.

Recommendations for future

Monthly flow change factors – to include seasonal variability

Include a robust water temperature change in CC scenarios (especially important for temperature dependent sanitary determinands).

Include in future work changes to the travel time parameter

Considerations for future

Impact on WQ with meeting the DEFRA Storm overflow discharge reduction plan?

Sustainability reductions in abstractions from sensitive water bodies – 'increase' flows – and so increase dilution

Population change, demand management and future wastewater flows

Value of heat recovery from wastewater

Upcoming work in this area

JBA group

Phase 2 EA Climate change Stress Testing:

- Use **monthly** changes to flows to examine **seasonality** of low flows on WQ

- Use recent EA future surface **water temperature** work (**4000** sites) to refine model parameters

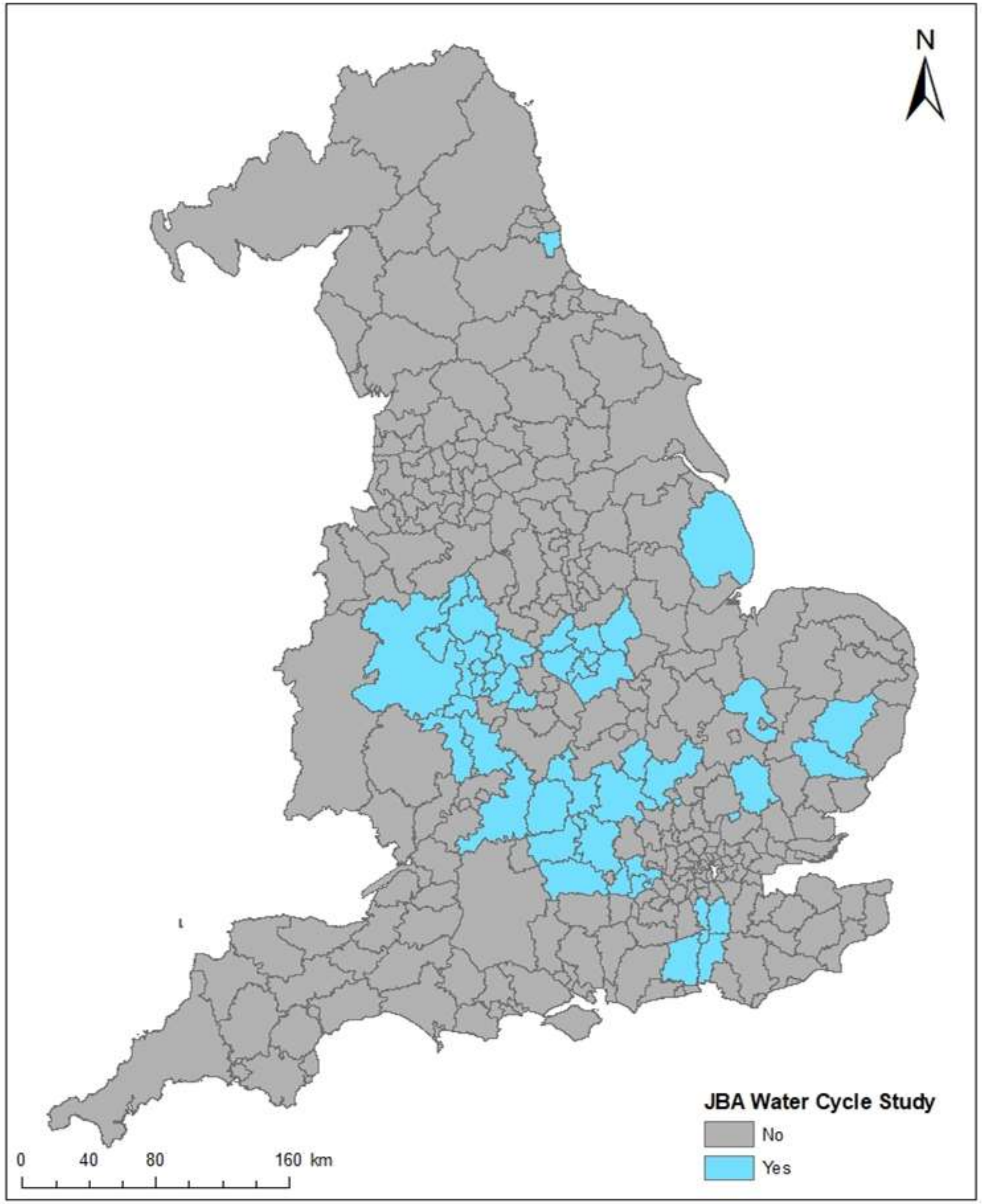
- A separate focus on change in **CSO spills** with climate change, using UKCP18 daily **rainfall** & **EDM** data, with SIMCAT and/or HYPE

HYPE by SMHI

CSO picture: Credit to Northeast Ohio Regional Sewer District
SMHI logo: Credit to SMHI

Water Cycle Studies

- We have worked for **40** local authorities in England, on **25** WCS projects
- Including modelling impact of planned **development** on in-river **water quality**
- Capability to include resilience to future **climate change** using this methodology



Thank you for listening

Email: alex.garratt@jbaconsulting.com & barry.hankin@jbaconsulting.com