Challenge 1: A risk-based analysis of small scale distributed nature based FRM measures deployed on river networks

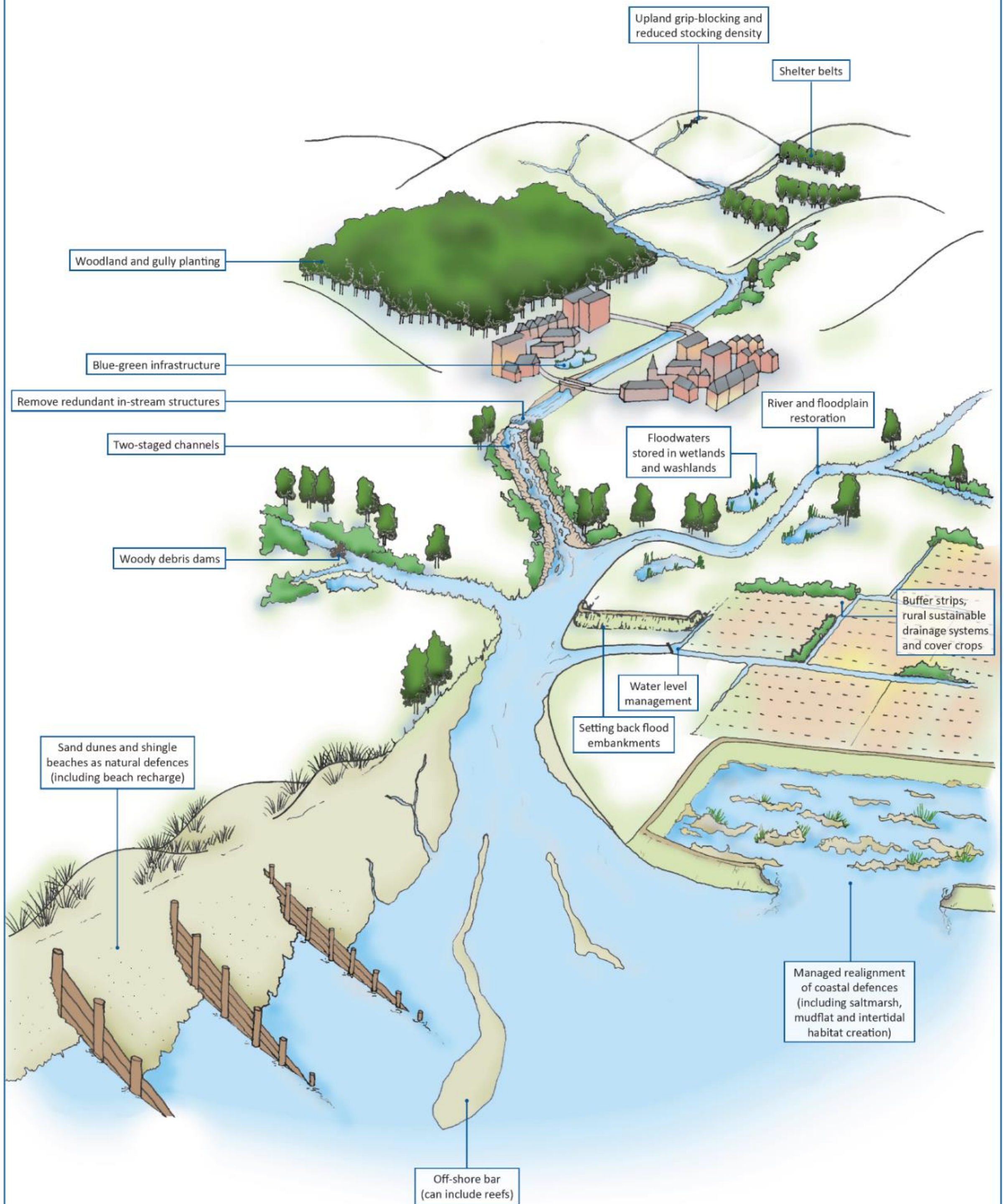
Barry Hankin, Rob Lamb

Contents

- Definition of Working with Natural Processes
- Some Background to JBA involvement in NFM
- A practical network problem
- The challenge
- Effectiveness and performance
- 2d modelling – any strategies?
- Downstream risk
- Spatially variable inputs

Nature Based Solutions: WWNP NFM NWRM

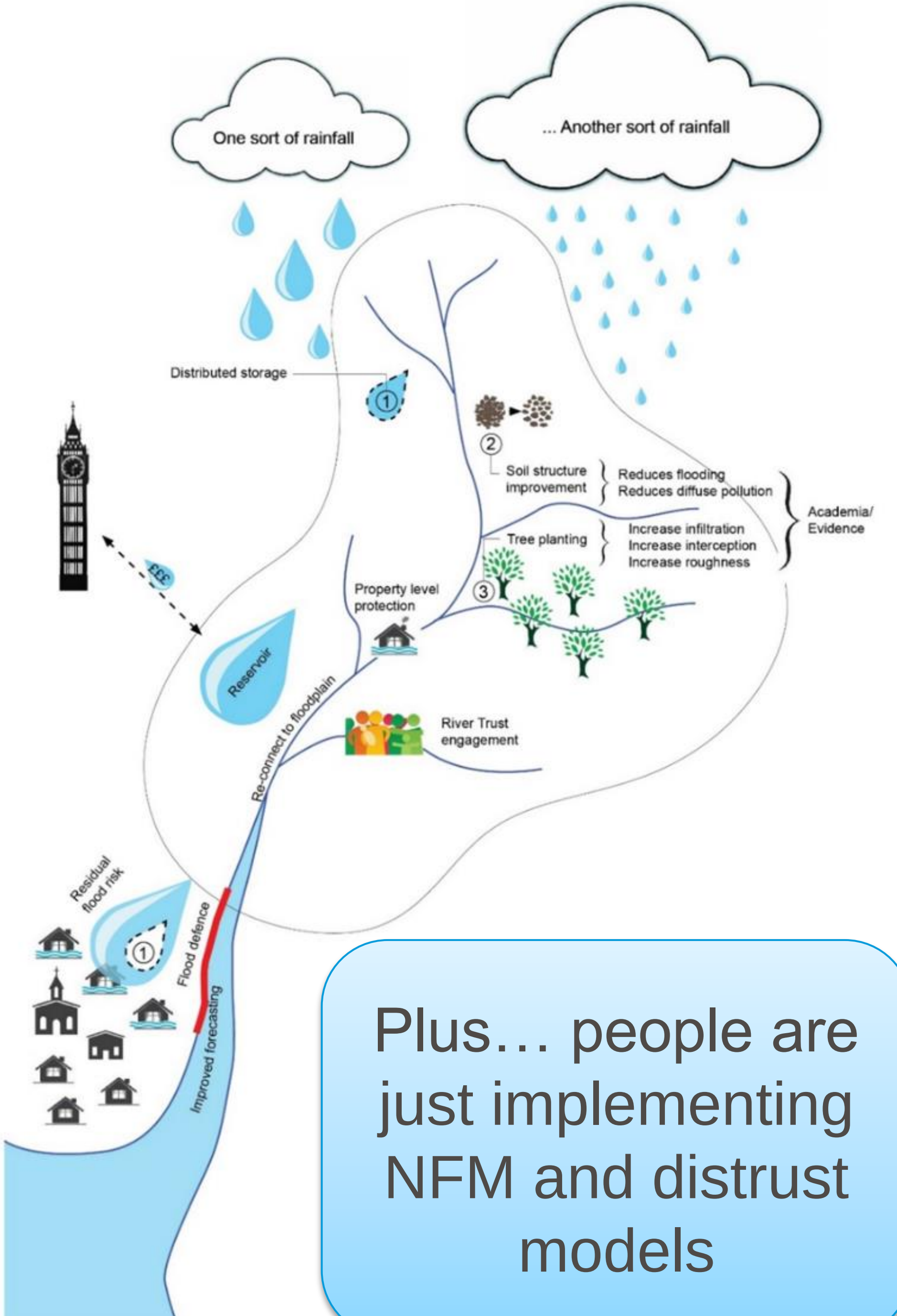
‘Working with natural processes means taking action to manage fluvial and coastal flood and coastal erosion risk by protecting, restoring and emulating the natural regulating function of catchments, rivers, floodplains and coasts’



JBA trust

NFM ‘risk management’

- NFM is different to established FRM
  - *Highly distributed measures impacting multiple processes, for which evidence is fuzzy*
  - We have developed better modelling of ‘whole catchment’ and tried to assess effectiveness robustly
- Event set modelling
  - *Where can we get best multiple benefits across most events?*
- Uncertainty framework
- **….But are there better strategies?**



Plus… people are just implementing NFM and distrust models

Previous projects

…bit of background

Some previous projects….
How to model and map NFM…?

JBA trust

Department for Environment Food & Rural Affairs

Cyfoeth Naturiol Cymru Natural Resources Wales

Llywodraeth Cymru Welsh Government

Environment Agency

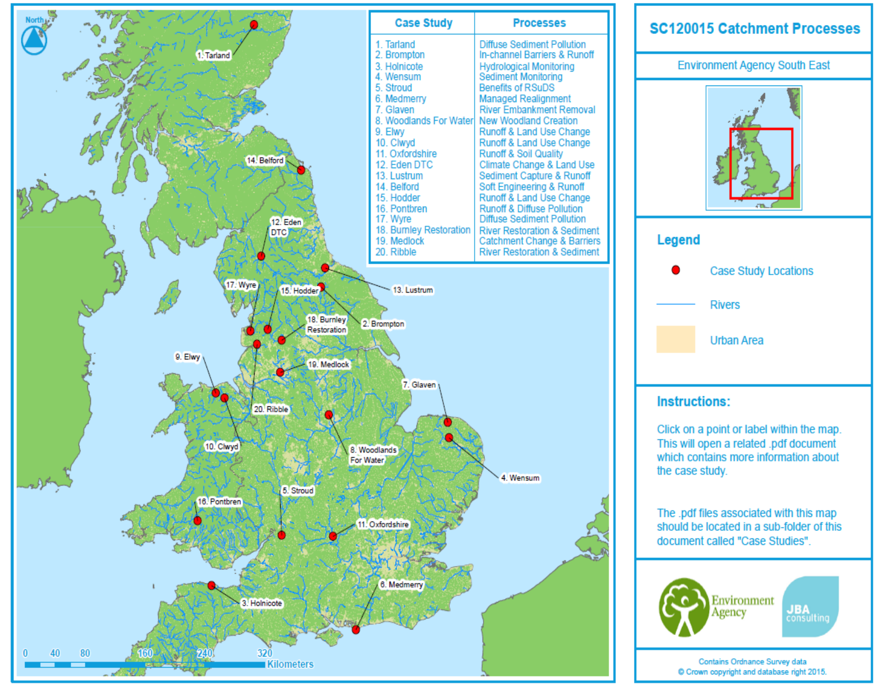
Flood and Coastal Erosion Risk Management R&D

JBA consulting

The James Hutton Institute
Science connecting land and people

Lancaster Environment Centre | Lancaster University

Newcastle University



- Report and outputs on GOV.UK, contains:
  - Advice on modelling and mapping each process in an FCERM context
  - 20 case studies developed
  - A library of tools developed

Project 2: Evidence Base for NFM…. Gaps?

Working with natural processes (WWNP) involves:

'*taking action to manage fluvial and coastal flood and coastal erosion risk by protecting, restoring and emulating the natural regulating function of catchments, rivers, floodplains and coasts*' (Environment Agency 2012)

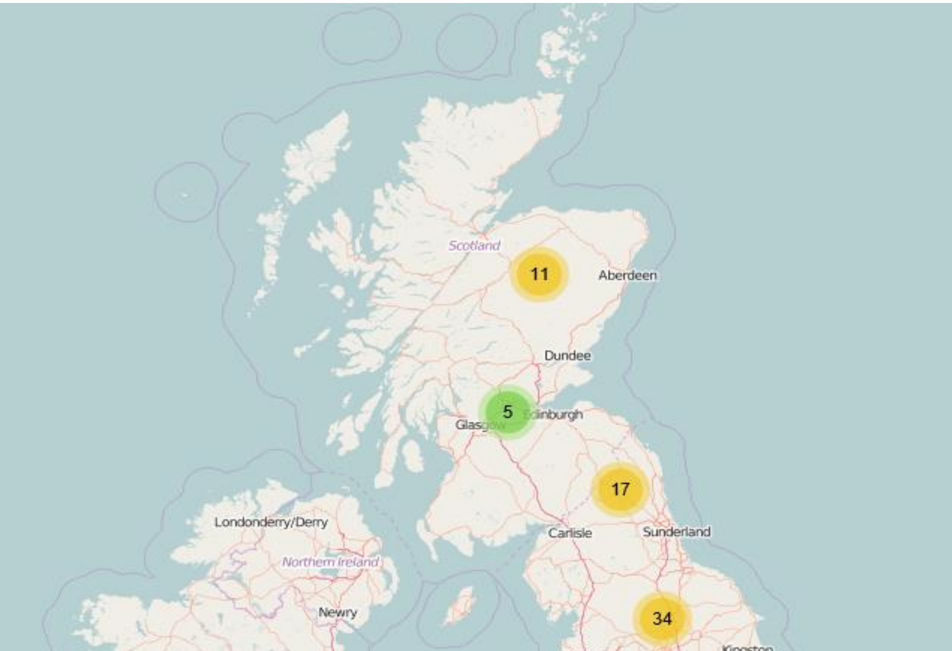
This Evidence Base will provide the foundation to providing technical guidance and tools needed by flood and coastal risk management authorities to help them understand, justify, develop and implement FCERM schemes which include WWNP to reduce flood risk.

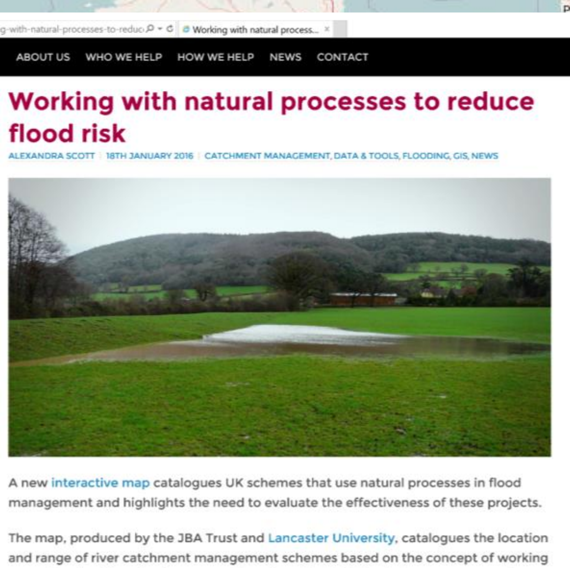
The Evidence base will identify gaps in our knowledge, and 'catchment laboratories' will be set up regionally to attempt to fill these knowledge gaps.

Flood and Coastal Erosion Risk Management R&D

Interactive Map on WWNP.

http://naturalprocesses.jbahosting.com/

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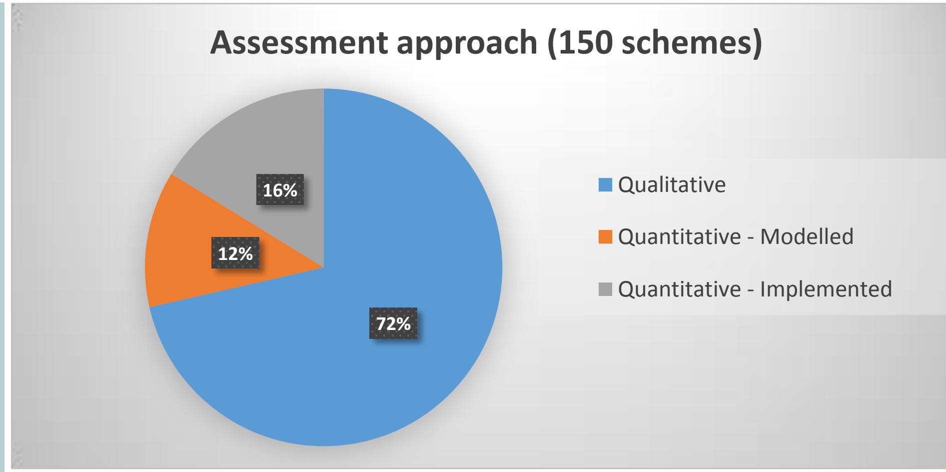
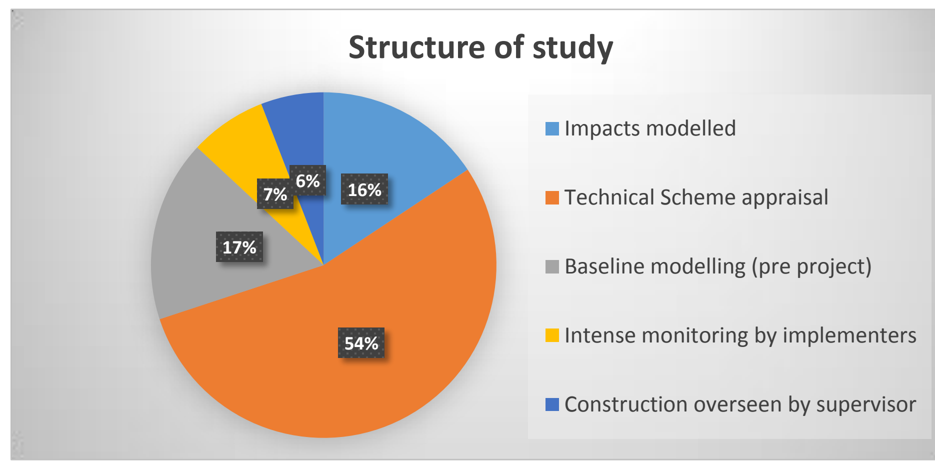
Working with natural processes to reduce flood risk

ALEXANDRA SCOTT | 18TH JANUARY 2016 | CATCHMENT MANAGEMENT, DATA & TOOLS, FLOODING, GIS, NEWS

A new interactive map catalogues UK schemes that use natural processes in flood management and highlights the need to evaluate the effectiveness of these projects.

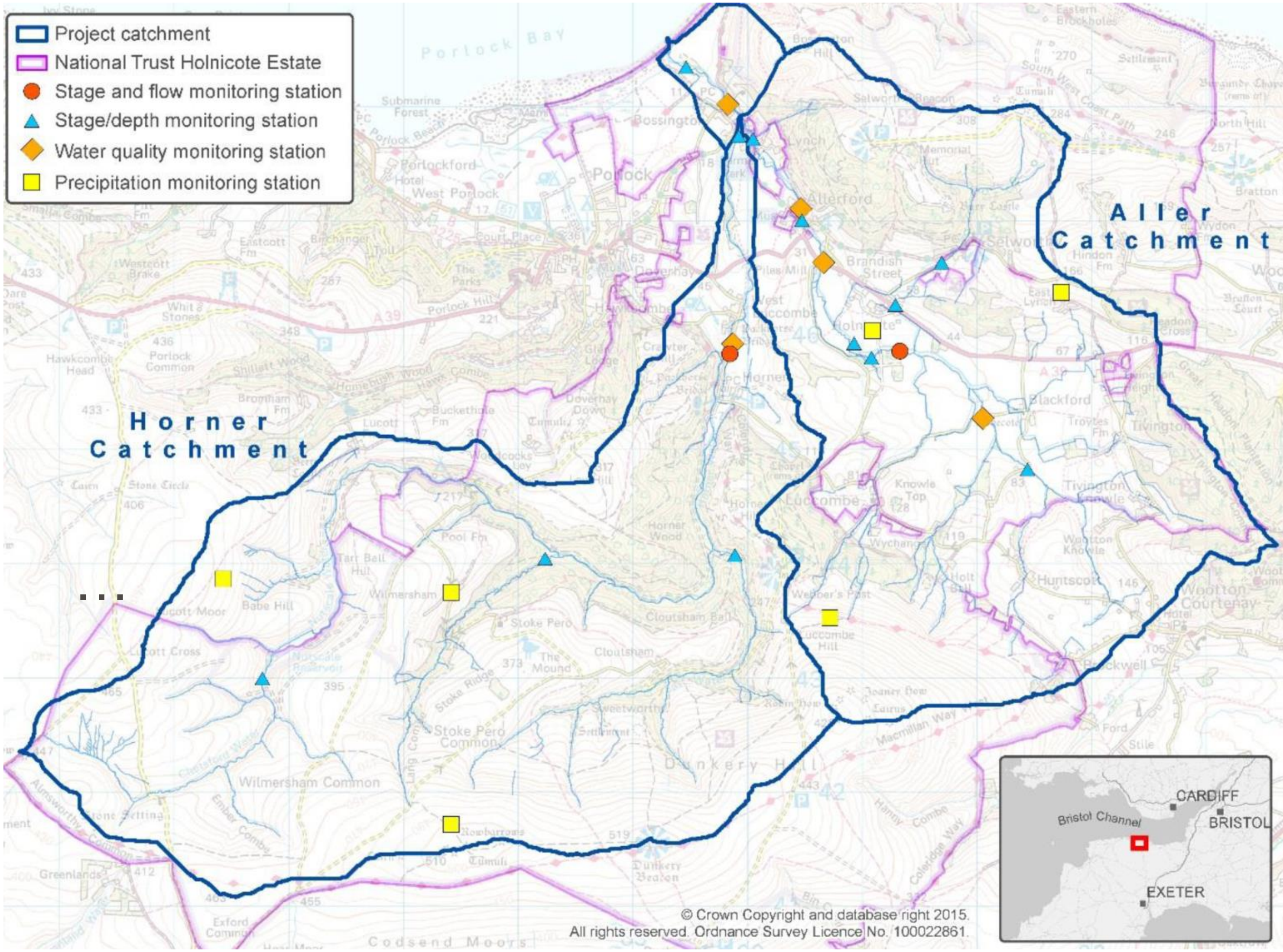
The map, produced by the JBA Trust and Lancaster University, catalogues the location and range of river catchment management schemes based on the concept of working





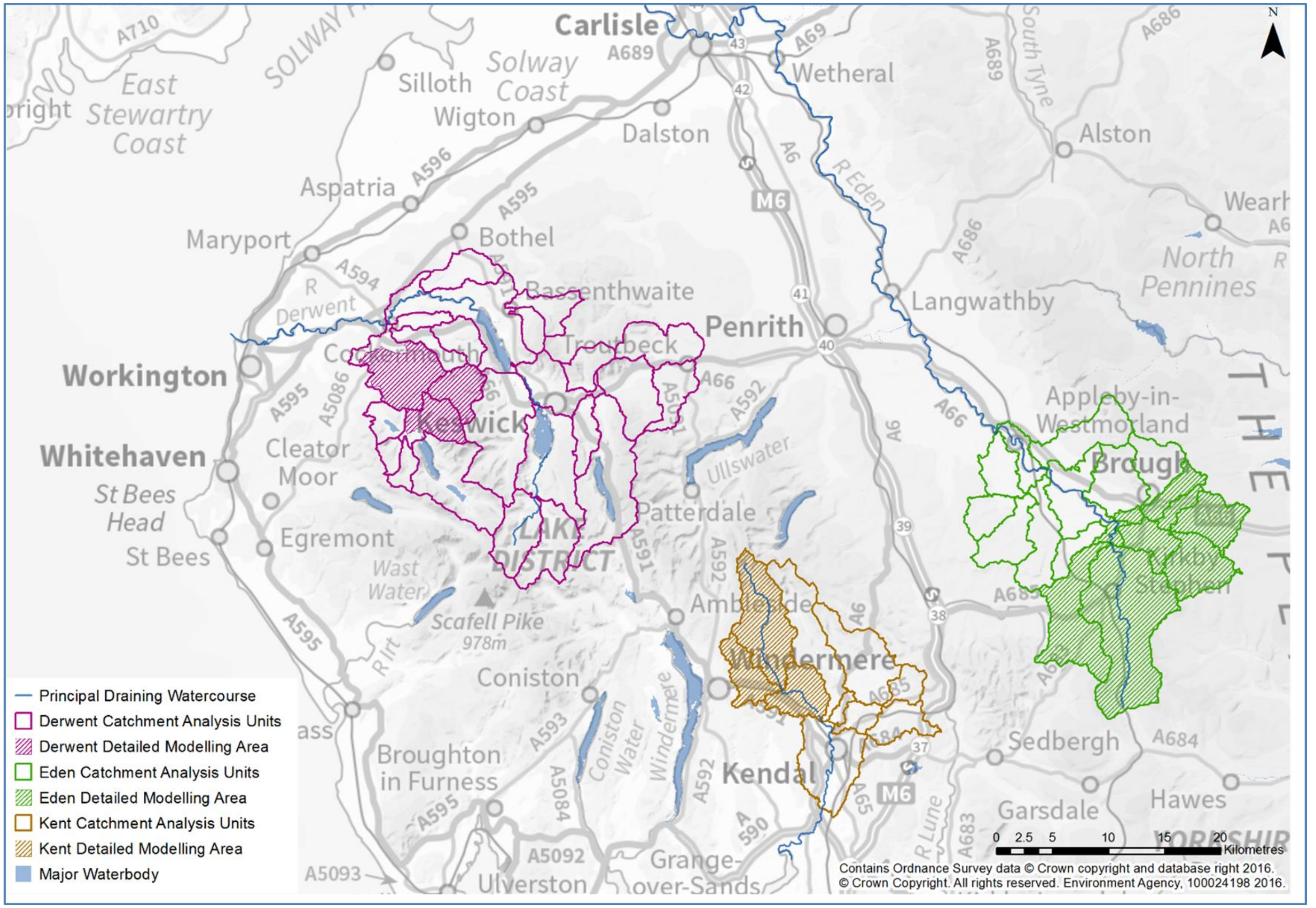
Environment Centre | Lancaster University

Holnicote: Detecting change from NFM?



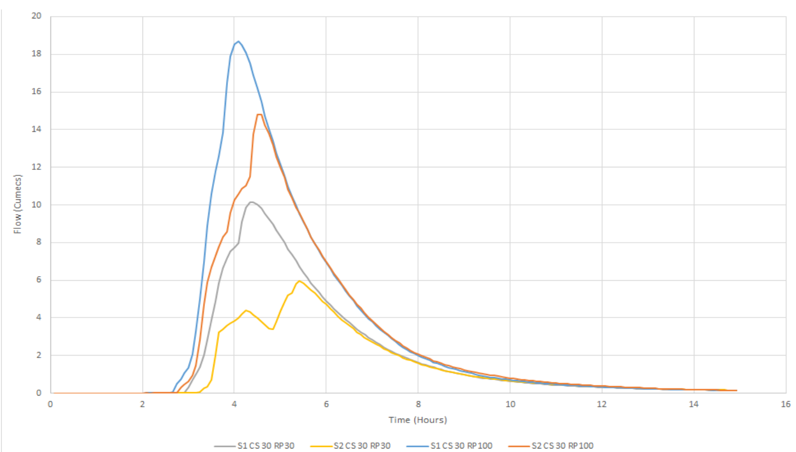
Life-IP Targeting of NFM Distributed modelling

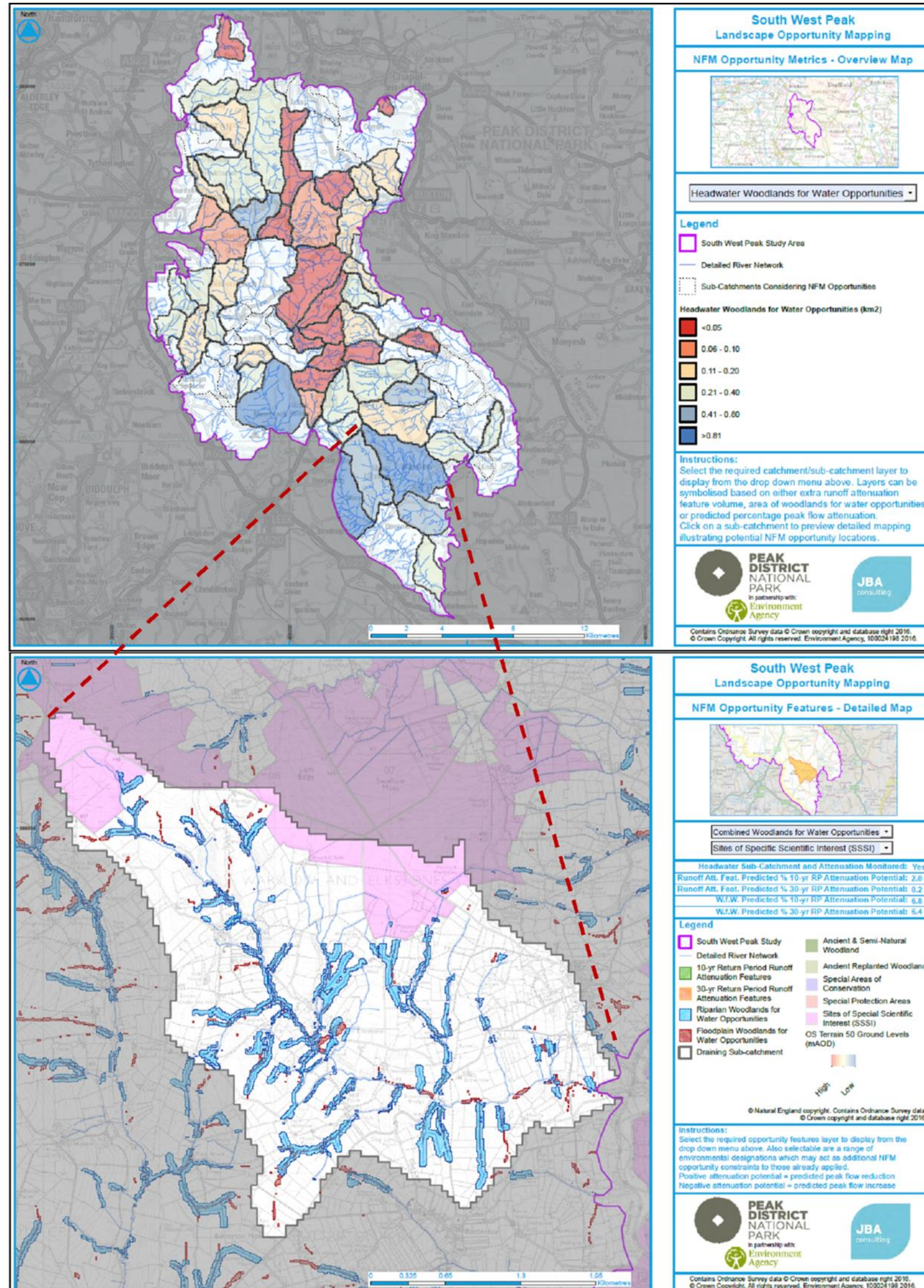
- Strategic modelling
- Engagement + refinement
- Interactive Maps
- Uncertainties



…Targeting

- Benefit and opportunity maps
- Opportunities: e.g. Woodlands for Water
- Benefits: the peak flow reduction or change to timing





Network problem for leaky barrier

Creating extra instream storage during flood events

Introduction

- Growing interest in the use of “nature-based” flood risk management measures, which include:
  - Small-scale runoff attenuation features (RAFs), which are typically “leaky” dams or barriers made from wood that allow low flows to pass through, but that hold back high flows, thus providing temporary storage of flood water.
  - The hope is that a large collection of such RAFs deployed in small stream channels may hold back enough flood water so as to mitigate flood risk downstream, where communities and people are at risk.

Brompton 1d network example
(Peter Metcalfe / Lancaster Environment Centre)

- Routing within Dynamic Topmodel
- Calibrated against real events
- Built in open software

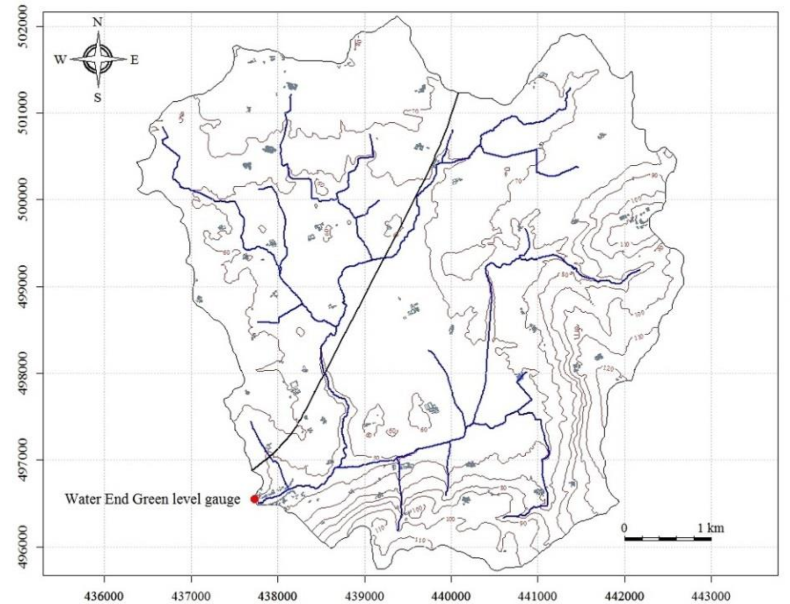
<u>Brompton case study</u>

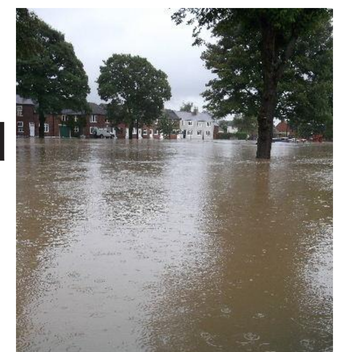
Agricultural catchment North Yorkshire, UK, ~ 26km²

History of severe flooding, most recently in 2012

Intensive arable farming: heavily modified channel network, extensive subsurface drainage; high land-channel connectivity

Apply Natural Flood Management to mitigate flood risk w/o hard-engineered structures?





Regulatory, land-use and access constraints = **in-channel features only allowed, in one sub-catchment**

Testing model response

Double-peaked storm event November 2012

Hydrological parameters calibrated against discharges reconstructed from stage gauge at outlet.

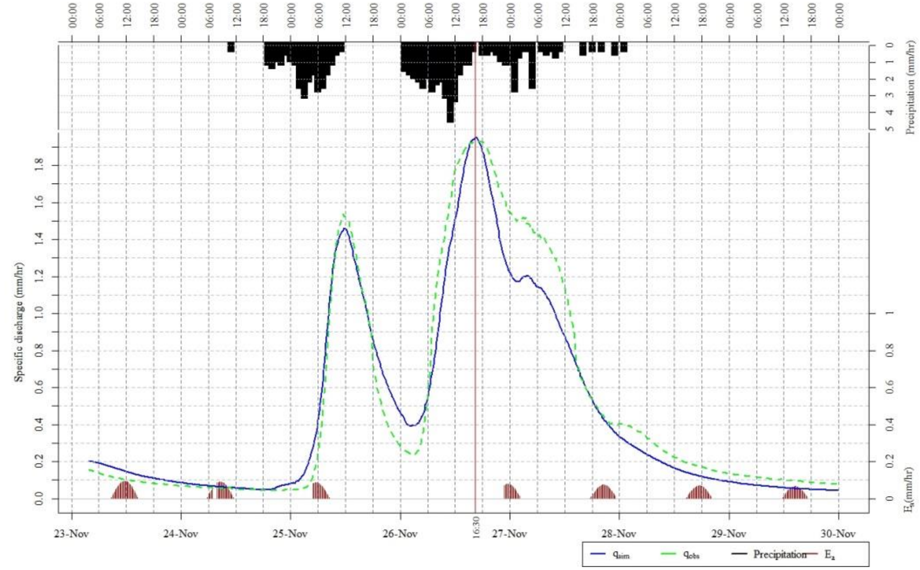
Hydraulic parameters calibrated to match observed timings and magnitudes of flood peaks:

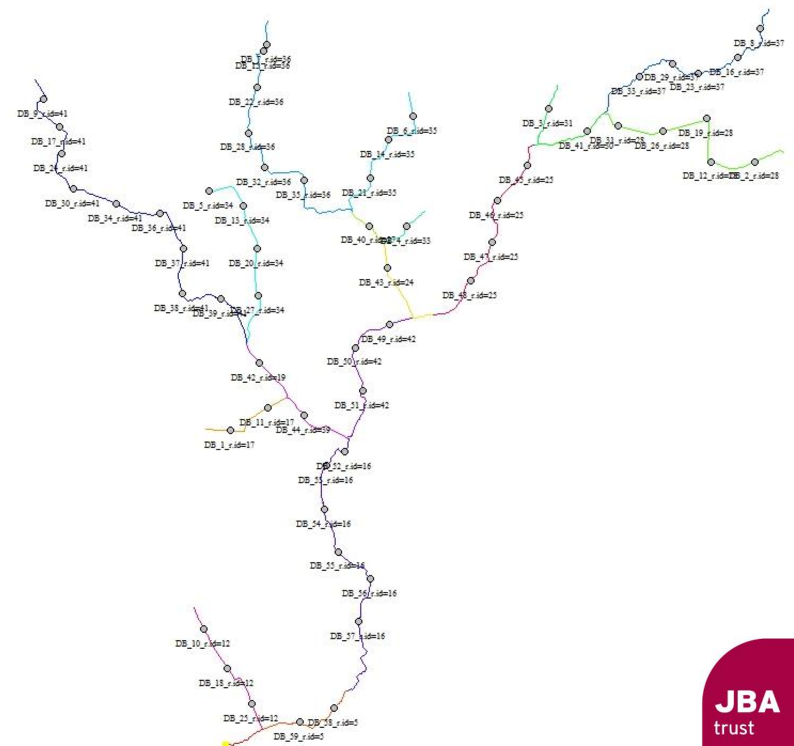
Performance measure

NSE > 0.9

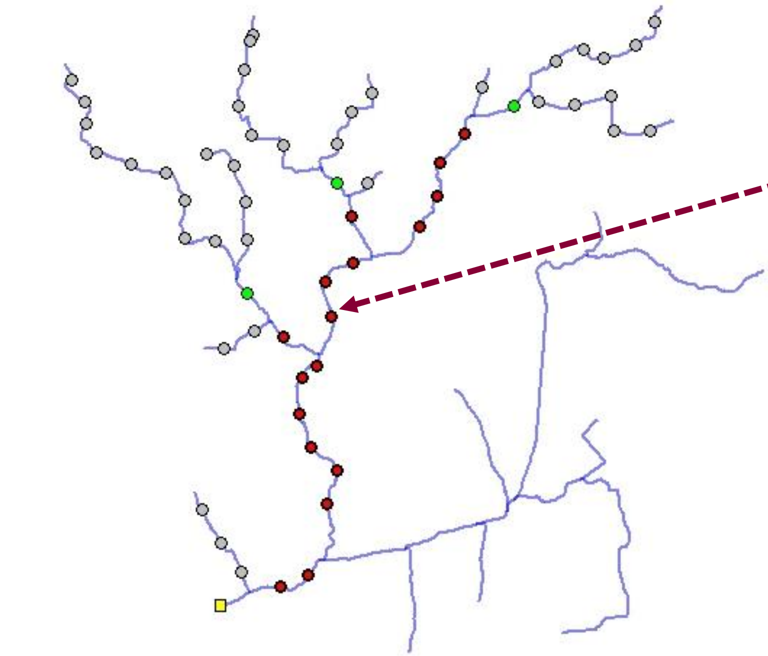
Underflow barriers applied in batches from highest reaches downstream until network filled

Examine effect on flood wave timing and attenuation



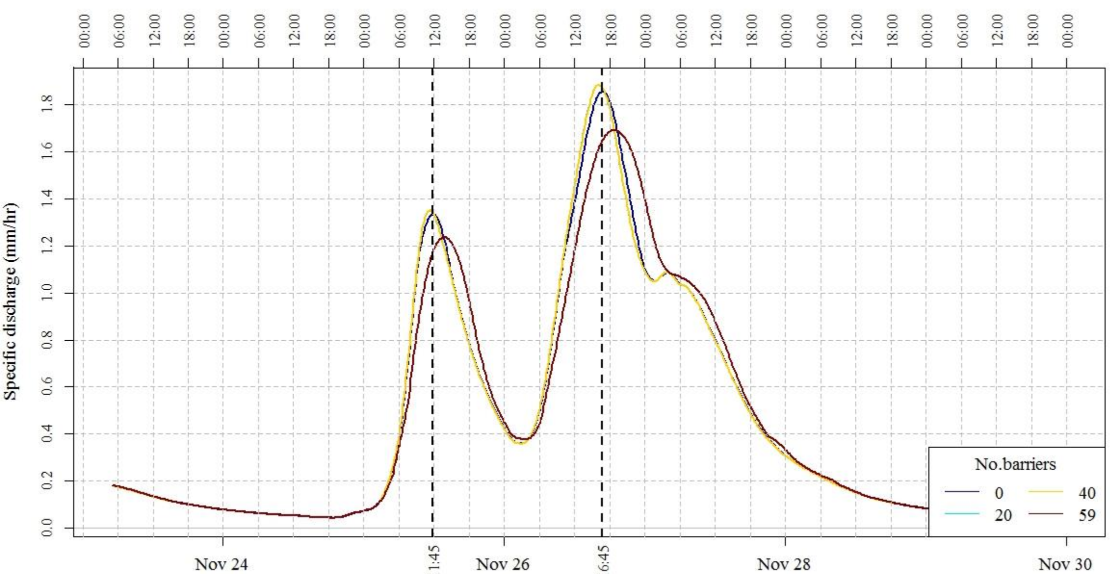


Results & Animation



Inactive
Activated
Overtopped

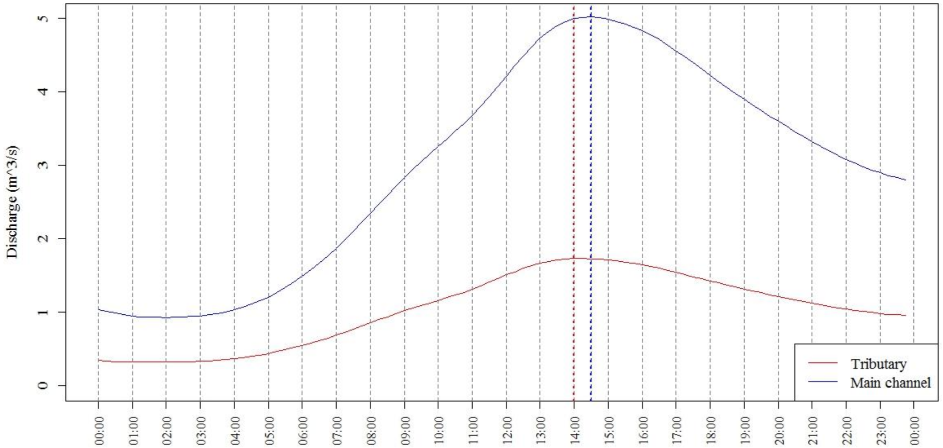
Most barriers in upper reaches never used….



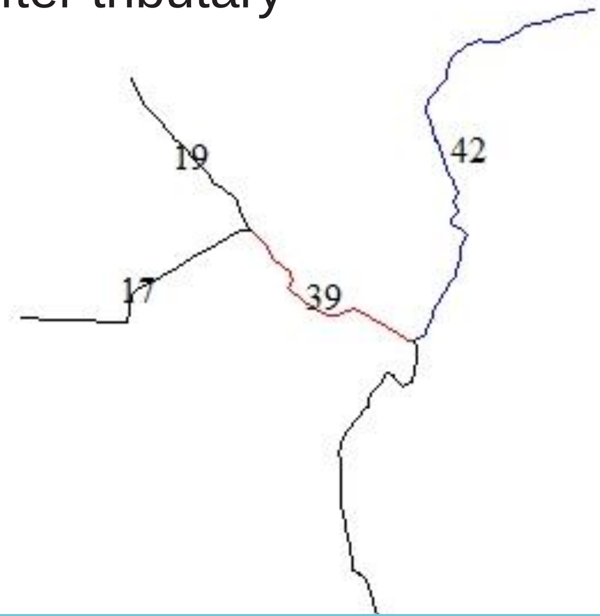
... whilst many of those further downstream are overflowing.

Benefits of detailed model

Consider confluence of un-named tributary with main channel of Ing Beck



Before: Main channel peak arrives after tributary



After: Adding 40 barriers has synchronised the flood peaks!

…we must be careful/strategic

The Challenge

A risk-based analysis of small scale distributed nature based FRM measures deployed on river networks

The challenge

- The challenge is in understanding the performance and optimization of a system comprising a collection of individual RAFs, distributed spatially throughout a connected stream network in a river catchment.

- This is a difficult problem that JBA Trust has been involved in tackling in recent work (see, for example http://www.jbatrust.org/news/reducing-flood-risk-by-working-with-nature/).

- Within a network analysis, we wish to generalise each RAF as an object that intercepts runoff within a flow pathway, and then releases the flow more slowly. Such features can be envisaged in hydrological models as conceptual storage elements or slow-pass filters (where the flood flow is a “signal” that is attenuated by the RAF).

The crux

- The crux of our challenge lies in representing arbitrary collections of RAFs as a whole system, within a stream network analysis.
- Ultimately, we wish to account for the performance and potential failure modes of a system of RAFs, including issues such as:
  - propagation of flood “waves” (i.e. peaks in runoff) through the network,
  - possible synchronization or de-synchronization of peak flows,
  - cascade-like failure modes (i.e. a collapse of one RAF triggers further collapses downstream)
  - dynamic utilization of the potential storage created by RAFs (i.e. testing whether the system of RAFs operates optimally over the network, versus situations where only a few RAFs are effective and others are redundant)
- A network analysis should prove useful in future to support optimization of deployment and maintenance strategies.

Insight for real systems

- We want to bring in some of the complexity of a real system
  - Although some level of abstraction may be required, the network should be characterized by realistic data such as variable stream slopes, flood wave speeds, friction and “inflow” boundaries.
- We are seeking to explore whether there is a mathematical strategy to give insight (and basic rules) into assessing the effectiveness and resilience of many small-scale nature-based flood risk management interventions in complex river networks.
- This will help us to describe distinctive deployment and maintenance strategies, e.g. concentrated on headwaters, concentrated on lower reaches, maintain every 1/2/10/50 years etc. (leading to different performance profiles through time).

For discussion

- More detailed issues for discussion could include:
  - Optimizing spatial distribution of nature based flood risk management interventions considering:
  - Synchronization issues (superposition of flood waves from different stream being made worse)
  - Under-utilization issues (storage uptake before flood peak)
  - Failure of in-stream storage features such as leaky dams
  - Cascade failure of in-stream features
  - Spatially variable rainfall fields inputs (different inflow conditions)
  - Can the model be generalized to a treatment of 2d surface runoff from a complex terrain, where blanket rainfall is used to expose network pathways

Conditioning / catchment complexity

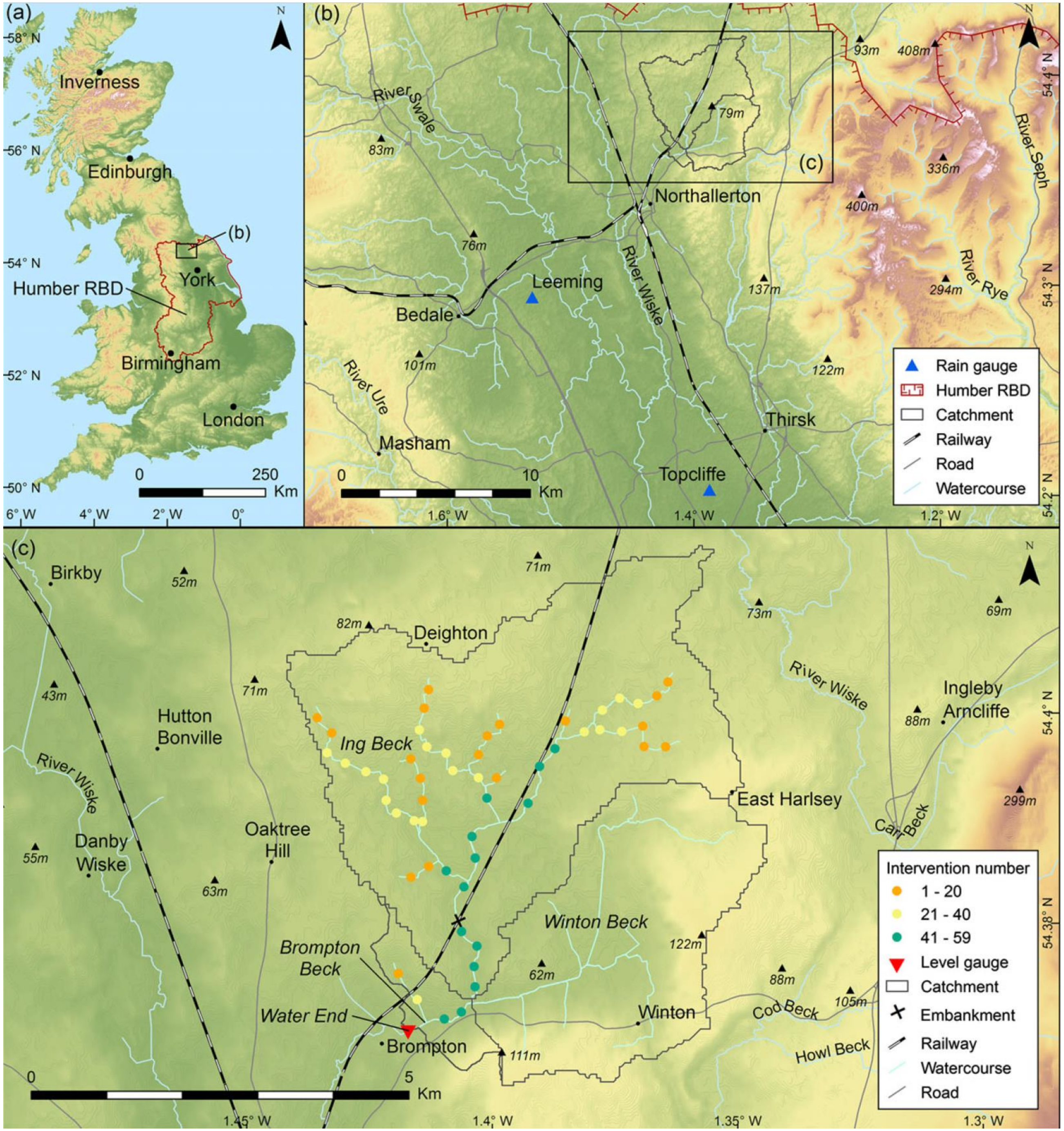
- Inflow boundary conditions. Spatially and temporally and variable.
- Slope of river reaches leading to different celerities.
  - Minimum of 2 slope classes with corresponding wave speeds.
- Length of river reaches, leading to time of travel with above.
  - 2 length classes.
- Friction of channel.
  - Minimum of 2 classes.
- Failure of leaky barrier in relation to maintenance strategy
- Example Data:
- JBA Trust will provide example stream network data, (for example from Brompton, N Yorkshire, where RAFs are being trialled) and flood flow measurements/simulations

Brompton Data

Thanks to Peter Metcalfe

Brompton

- Flooding 2012
- 19.2m3/s
- Need to reduce by 20%
- Peak at Winton thought to arrive 30 mins before Ing beck
- Target 54 in stream leaky barriers around Ing beck

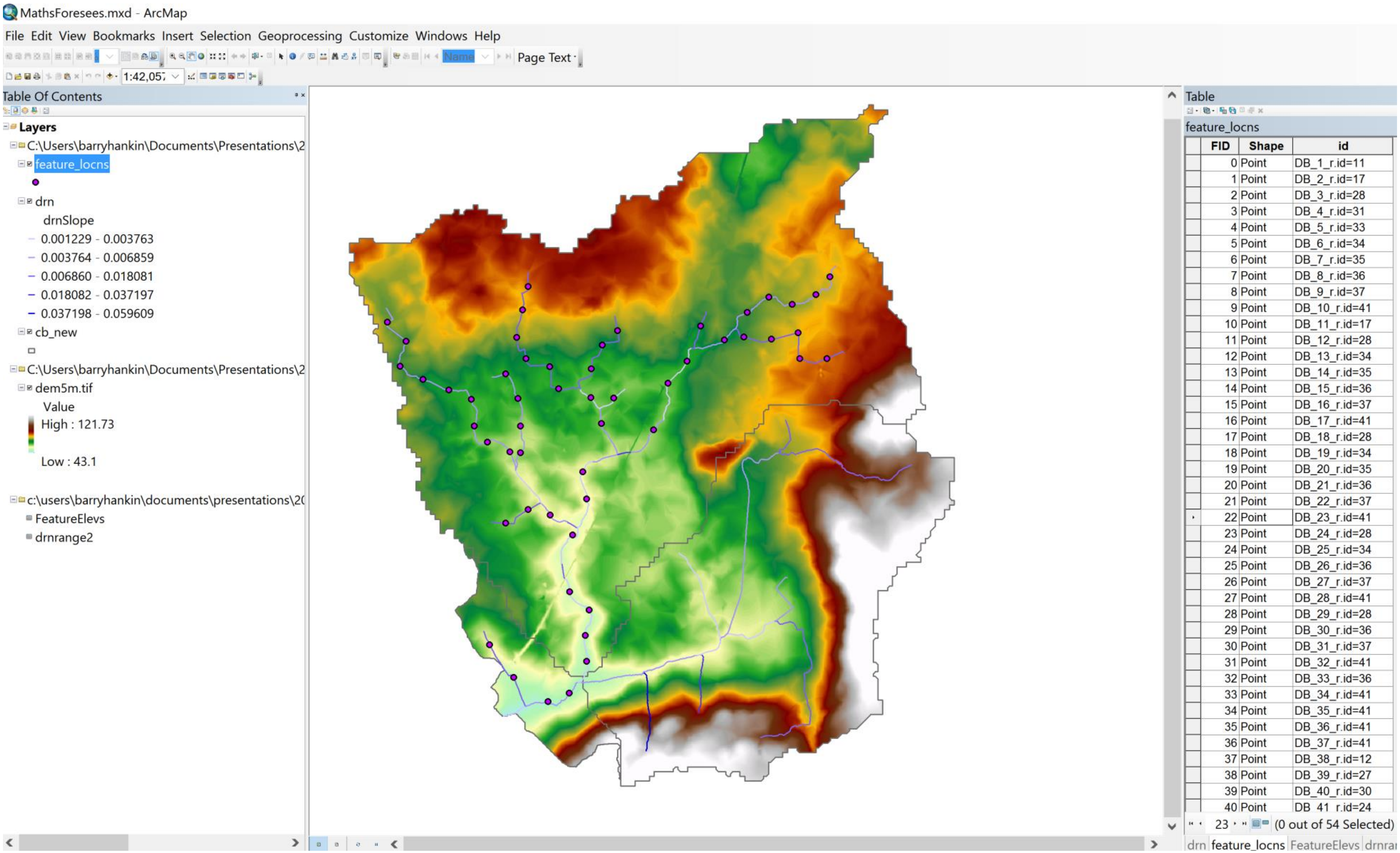


Data

- Addition of up to 54 leaky barriers.
- Node data with elevations
- River Segments attributed with slope
- Flows for model at main confluence near base of network

Additional channel and floodplain storage of approximately 70,000 m^3 is seen with a reduction of around 11% in peak discharge.
This might be sufficient to reduce flooding in moderate events, it is inadequate to prevent flooding in the double-peaked storm of the magnitude that caused damage within the catchment in 2012.

Spatial data



FID	Shape	id
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1	Point	DB_2_r.id=17
2	Point	DB_3_r.id=28
3	Point	DB_4_r.id=31
4	Point	DB_5_r.id=33
5	Point	DB_6_r.id=34
6	Point	DB_7_r.id=35
7	Point	DB_8_r.id=36
8	Point	DB_9_r.id=37
9	Point	DB_10_r.id=41
10	Point	DB_11_r.id=17
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37	Point	DB_38_r.id=12
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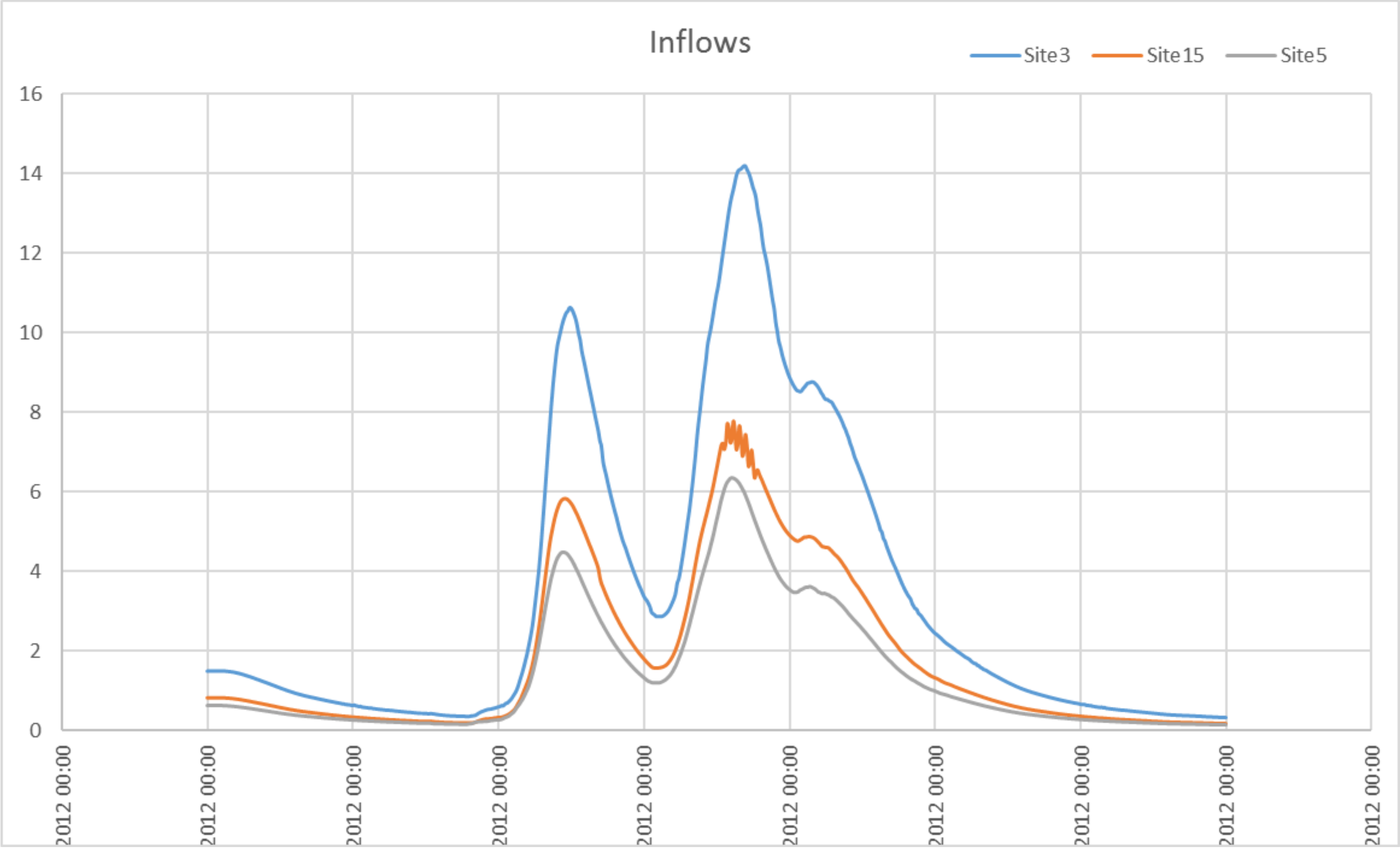
Data

- Outflows for two main tribs, an d following confluence



Discussion slides

…..Further things to consider

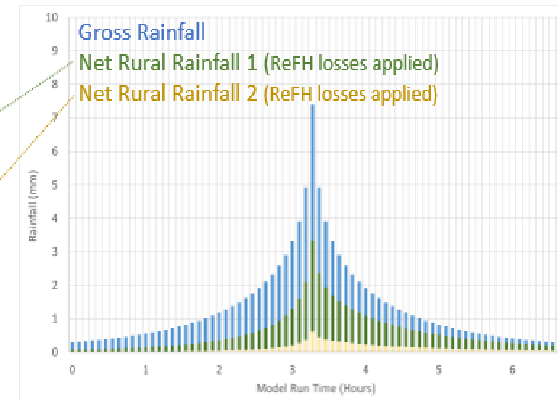
2d problem

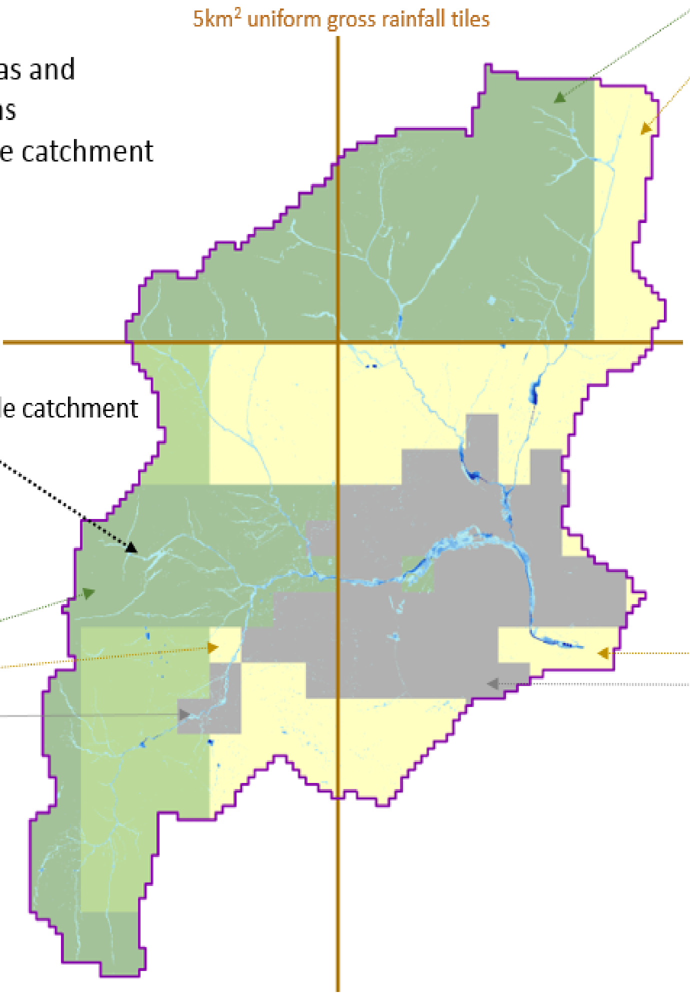
Highly complex pathways – similar strategies?

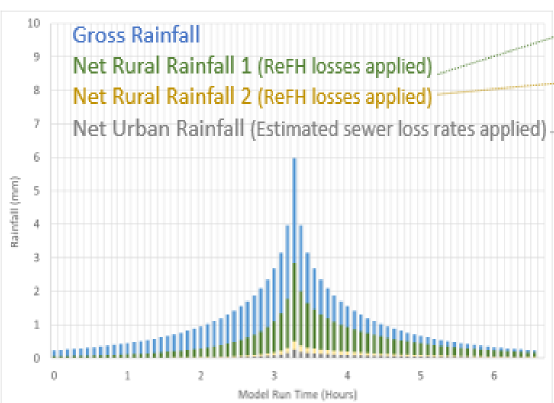
JFLOW modelling undertaken using whole catchment rainfall + losses model

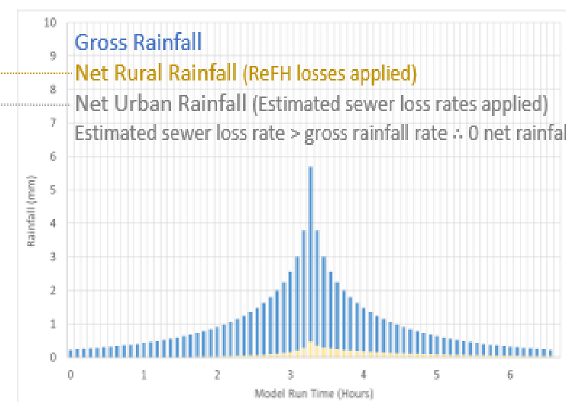
Whole Catchment Surface Water Runoff Simulation

- Schematic of inputs across a whole catchment
- Gross uniform rainfall input within each 5km² tile (varying across the catchment)
- Spatially varying ReFH losses in rural areas and estimated sewer loss rates in urban areas
- Surface water runoff output across whole catchment

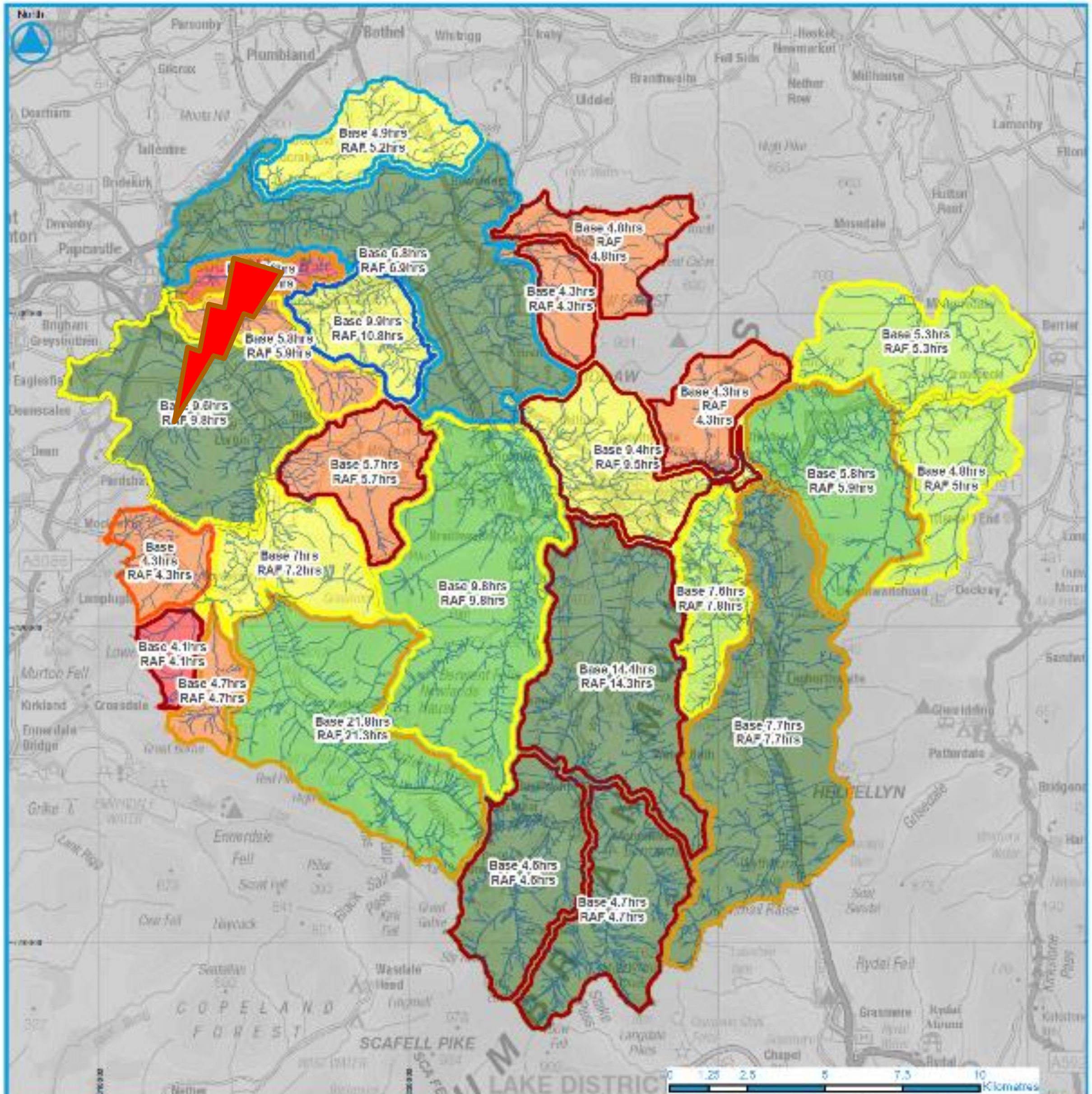








Derwent catchment – timing strategy?



Derwent Catchment

Working With Natural Processes Opportunity Mapping

Overview Map

Select layer to display from drop-down menu:

100-yr Return Period Runoff Attenuation Features

— Detailed River Network

Runoff Attenuation Features - 1% AEP Percentage Peak Flow Reduction (%)	1% AEP Runoff Attenuation Features Storage Area (m2)
≤ 1	< 25,000
> 1 and ≤ 2	25,001 - 50,000
> 2 and ≤ 5	50,001 - 100,000
> 5 and ≤ 10	100,001 - 150,000
> 10 and ≤ 15	150,001 - 200,000
> 15 and ≤ 25	200,001 - 379,258

Summary:

The catchment has been divided into sub-catchment analysis units based on the WFD waterbody catchments. The colour fill represents the area of each WWNP opportunity within each unit. The outline represents the potential percentage attenuation monitored within each unit.

The simulated time of peak flow for each unit are annotated for baseline and WWNP scenarios.

NOTE: Opportunity areas are summed within each unit whilst potential attenuation is representative of all upstream areas draining to unit outlet.

Opportunity locations are displayed on separate detailed maps accessed by clicking on a specific sub-catchment.

THE RIVERS TRUST

where there's water there's life

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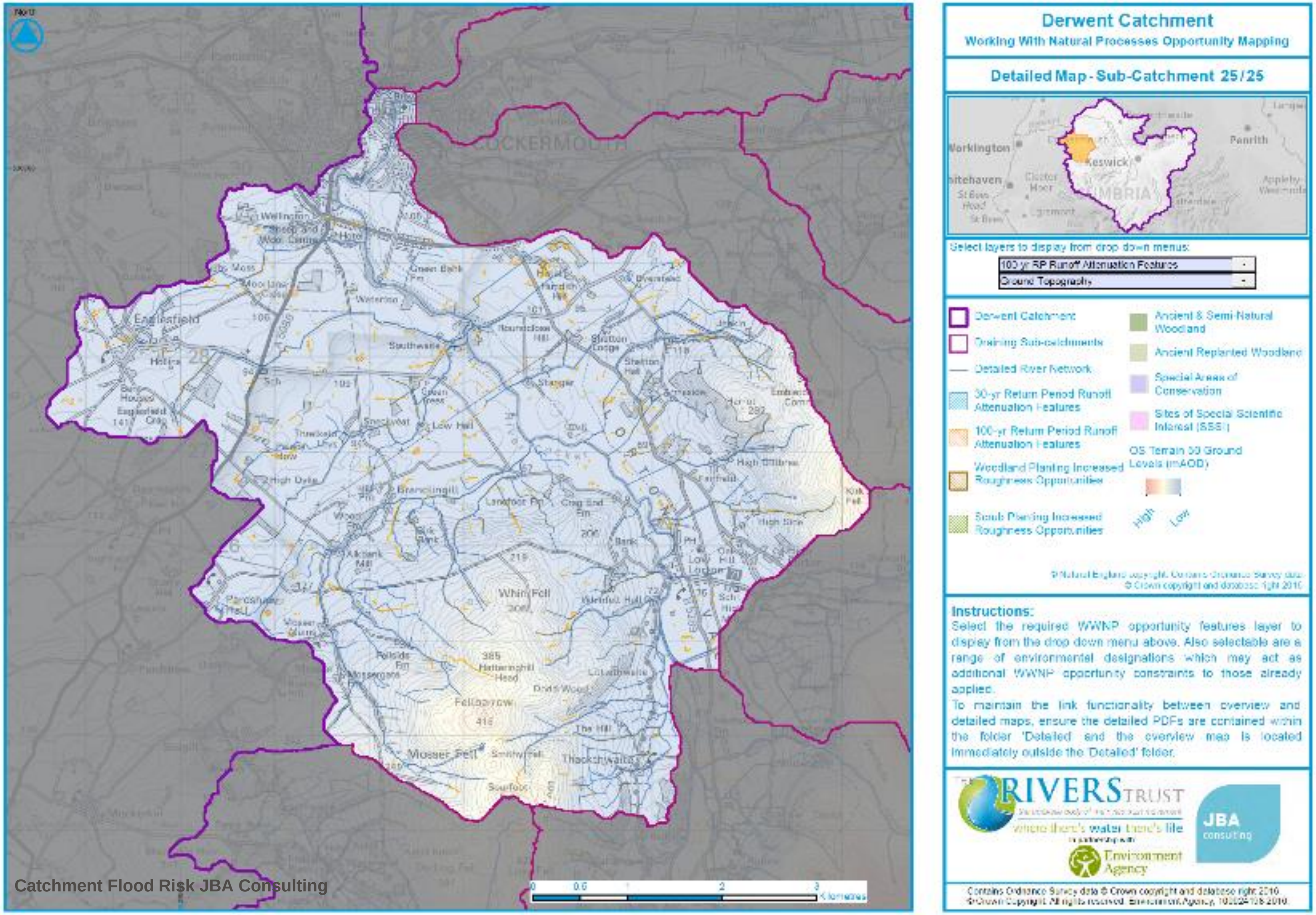
Environment Agency

JBA consulting

Derwent – Many Runoff Attenuation Features

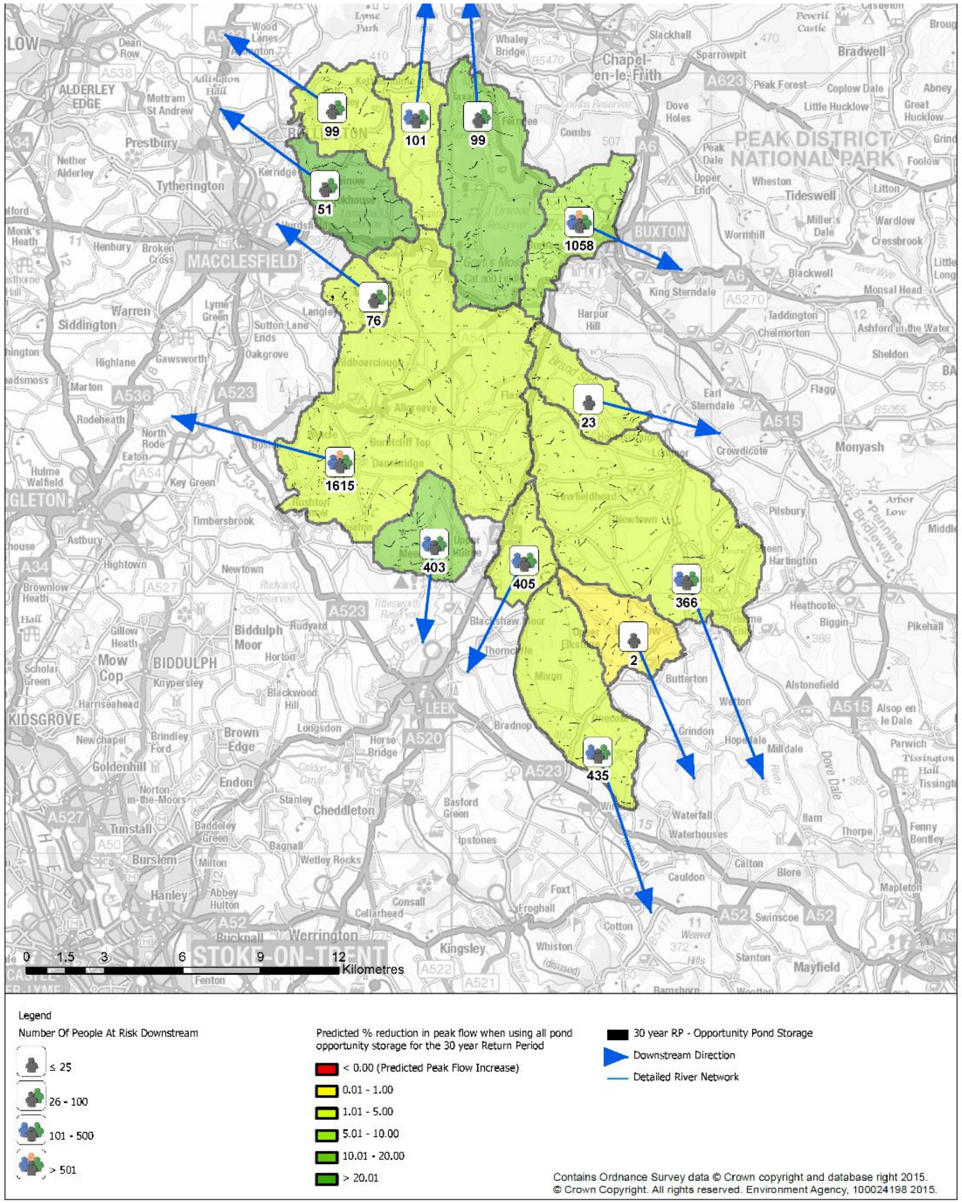
…JFLOW estimates between 5-10% peak SW runoff reduction for this catchment

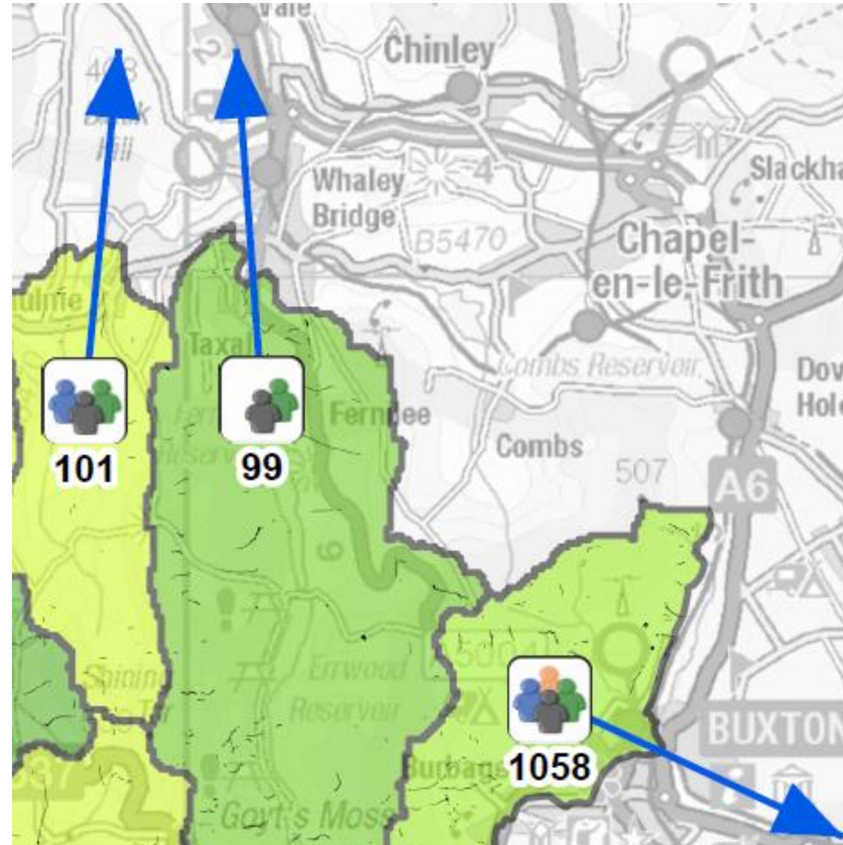


Catchment Flood Risk JBA Consulting

Downstream Risk

Communities at risk





Predicted % reduction in peak flow when using all opportunity storage for the 30 year Return Period

- < 0.00 (Predicted Peak Flow Increase)
- 0.01 - 1.00
- 1.01 - 5.00
- 5.01 - 10.00
- 10.01 - 20.00
- > 20.01

Variable boundary conditions

Different spatial distributions of rainfall

Rainfall spatial gradient (based on events sets from spatial joint probability modelling)