

Urban Flood Resilience in an Uncertain Future: the Blue-Green Advantage



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www.bluegreencities.ac.uk

EPSRC
Pioneering research
and skills



www.urbanfloodresilience.ac.uk

Outline

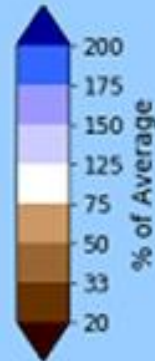
1. Recent UK flooding
2. Future floods & the Blue-Green Advantage
3. Delivering a Blue-Green Future
4. Conclusions and Closing Message
5. Achieving Urban Flood Resilience

1. Urban Floods in the UK

THE FLOODS ARE GETTING WORSE



June 2019
Rainfall Amount
% of 1981-2010 Average



June 2019 Rainfall Anomaly



Carlisle has been hit by 3 x 100-year storms in a decade

How can we manage flood risk sustainably and make our cities resilient to future floods?

A photograph of a forest path that has forked. On the left, a wide, smooth path made of grey gravel leads uphill. On the right, a narrower, more rugged path made of dirt and fallen branches leads uphill. The forest is dense with tall, thin trees and green undergrowth.

Continue on
our current
path

A different
Urban Flood Risk
Future

A Grey Future: *Bigger tanks, more tanks, huge pipes*



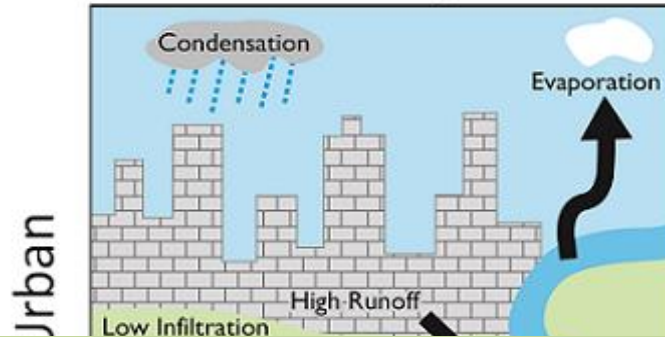
A Grey Future: *Higher walls and deeper channels*



2. Future Floods & the Blue-Green Path to Resilience

WHAT IS A BLUE-GREEN CITY?

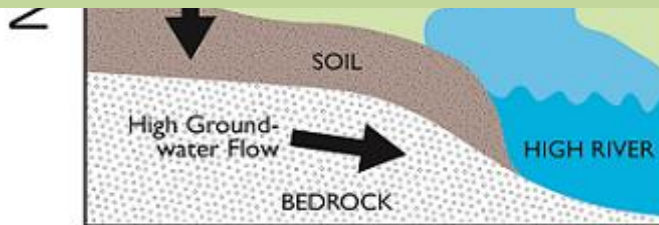
Water Cycle



Streetscape



Blue-Green Cities aim to recreate a naturally oriented water cycle while contributing to the amenity of the city by bringing together water management and green infrastructure¹.



BLUE

GREEN





J4M8,
Edinburgh



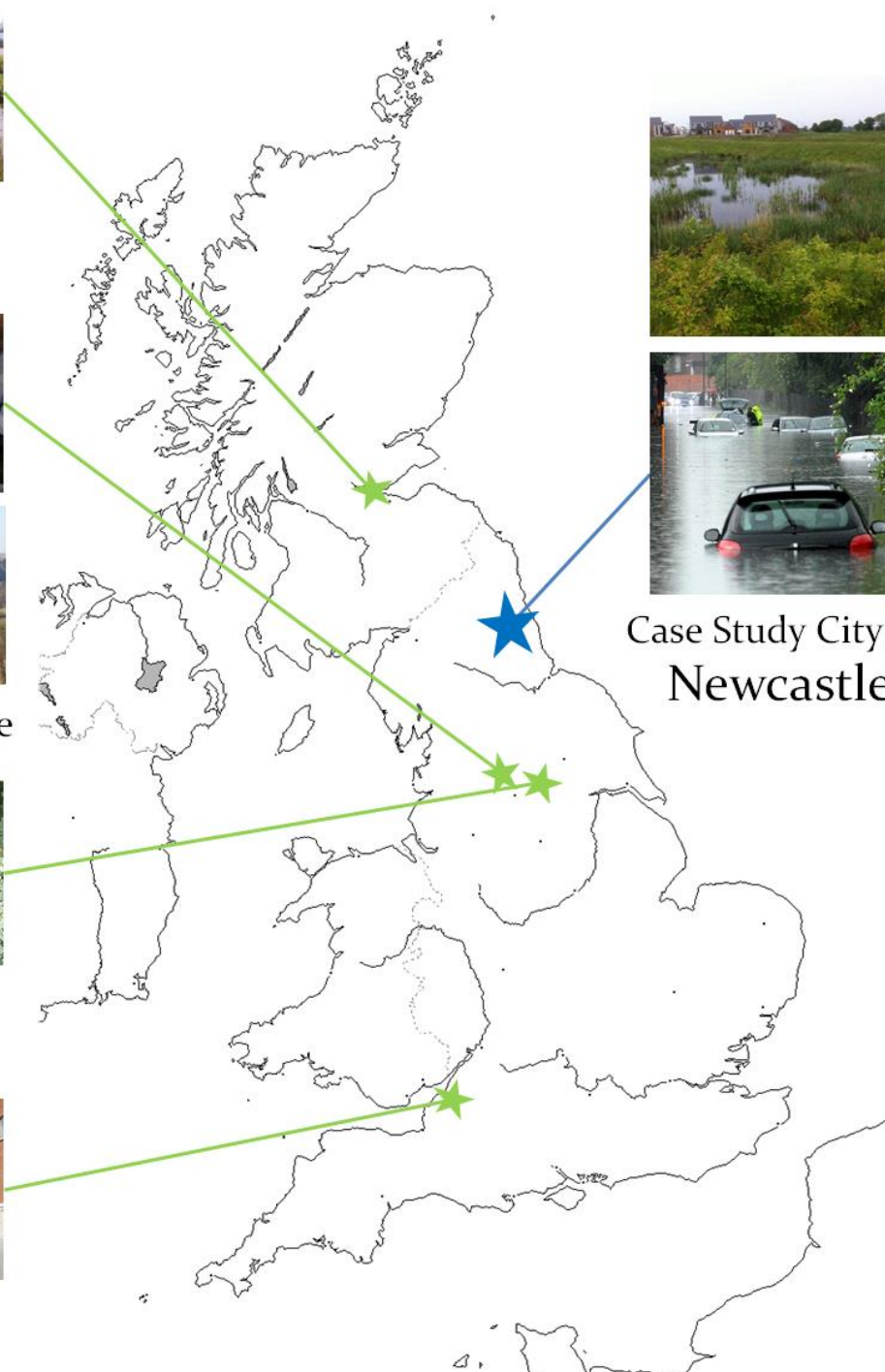
Hebden Bridge



Wortley Beck,
Leeds



The Dings,
Bristol



Case Study City:
Newcastle



International Collaborations



Portland, Oregon

Blue-Green Cities are working with:



Ningbo, China

Blue-Green Cities are working with Ningbo academics
James Griffiths, David Higgitt, Faith Chan and Odette Paramor



Blue-Green Cities Research Approach

Model Existing
& Future
Flood Risk
Management

Understand
Citizens'
Behaviours

Evaluate
Multiple Flood
Risk Benefits

City Authority
and Community
Communications

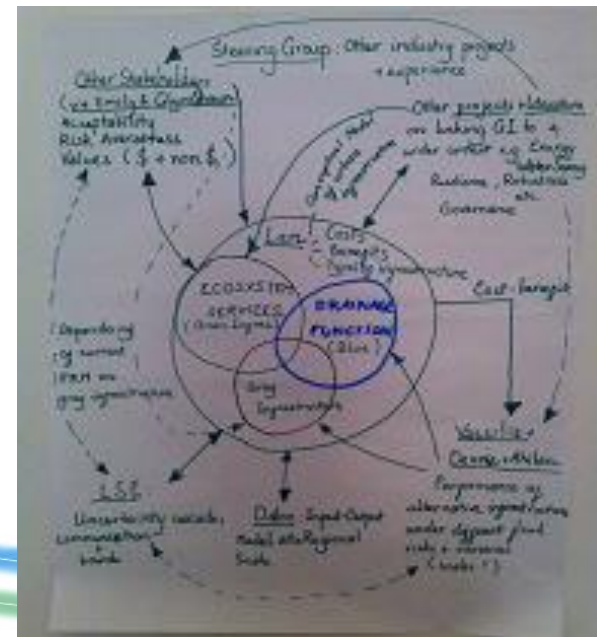
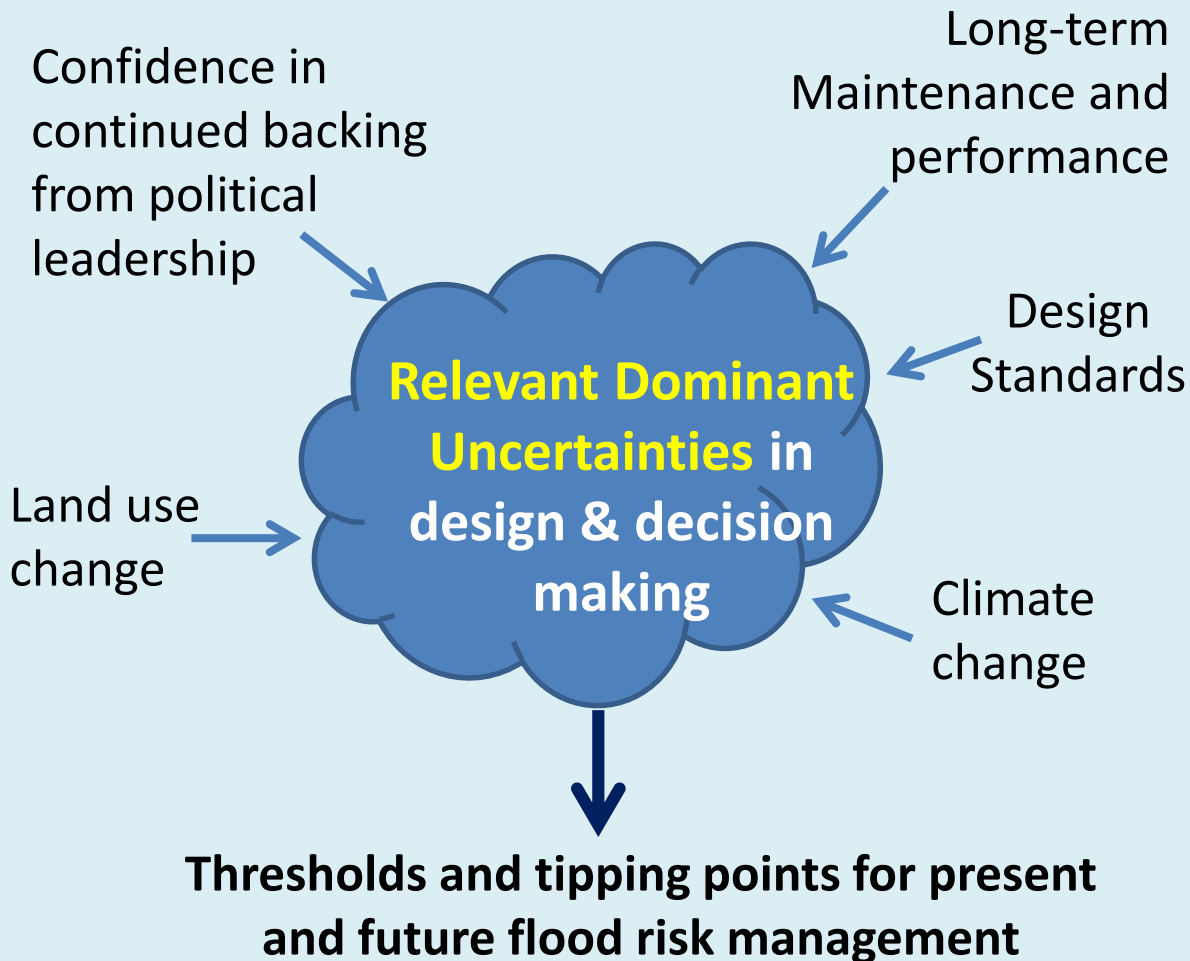
Options for
Grey+Green
Measures

Newcastle upon Tyne, UK
Portland, Oregon

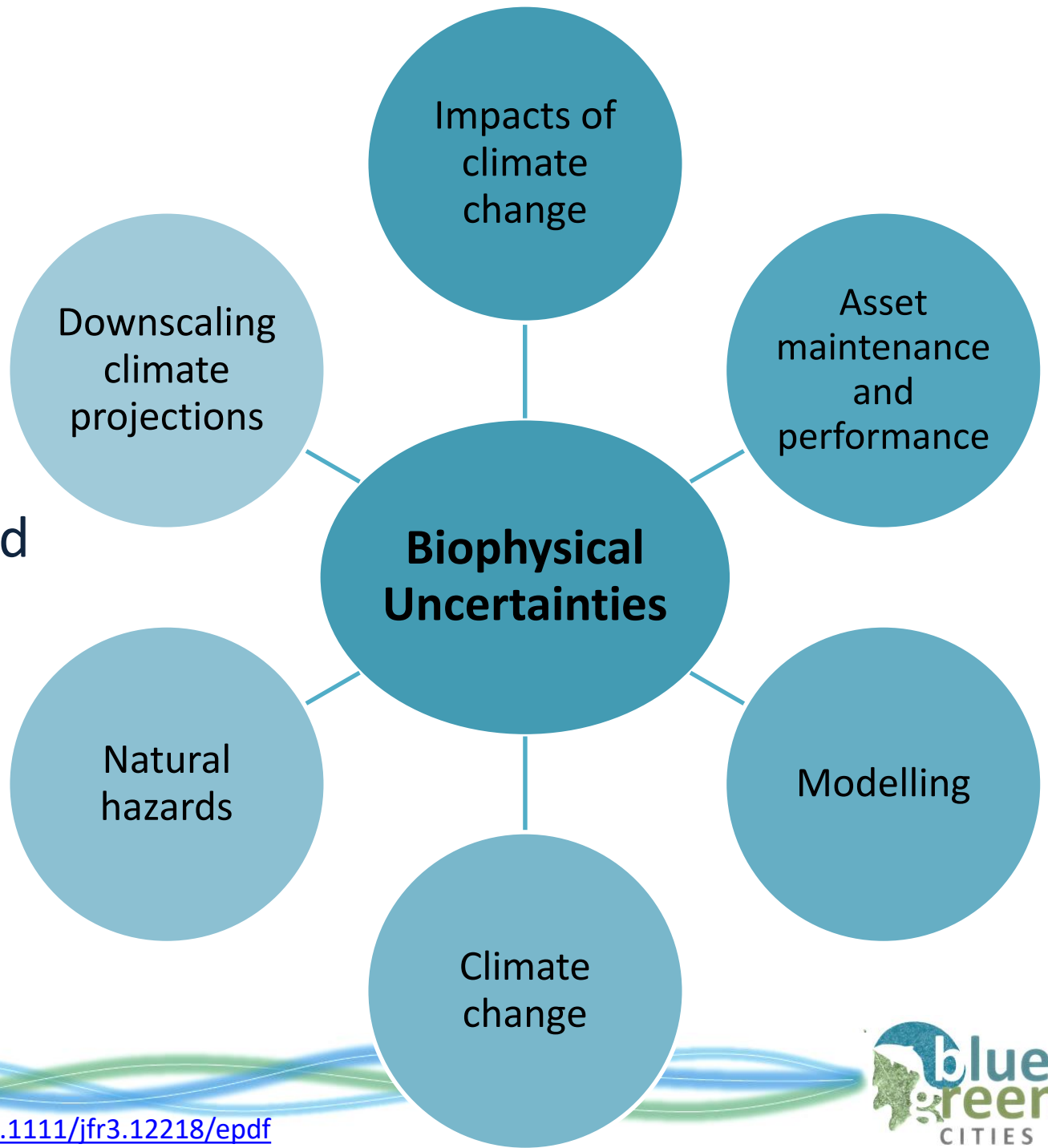


City Authority
and Community
Communications

Embracing Uncertainty



Research in
Portland identified
the dominant
biophysical
uncertainties



Multiple benefits of BGI

Response to CC impacts

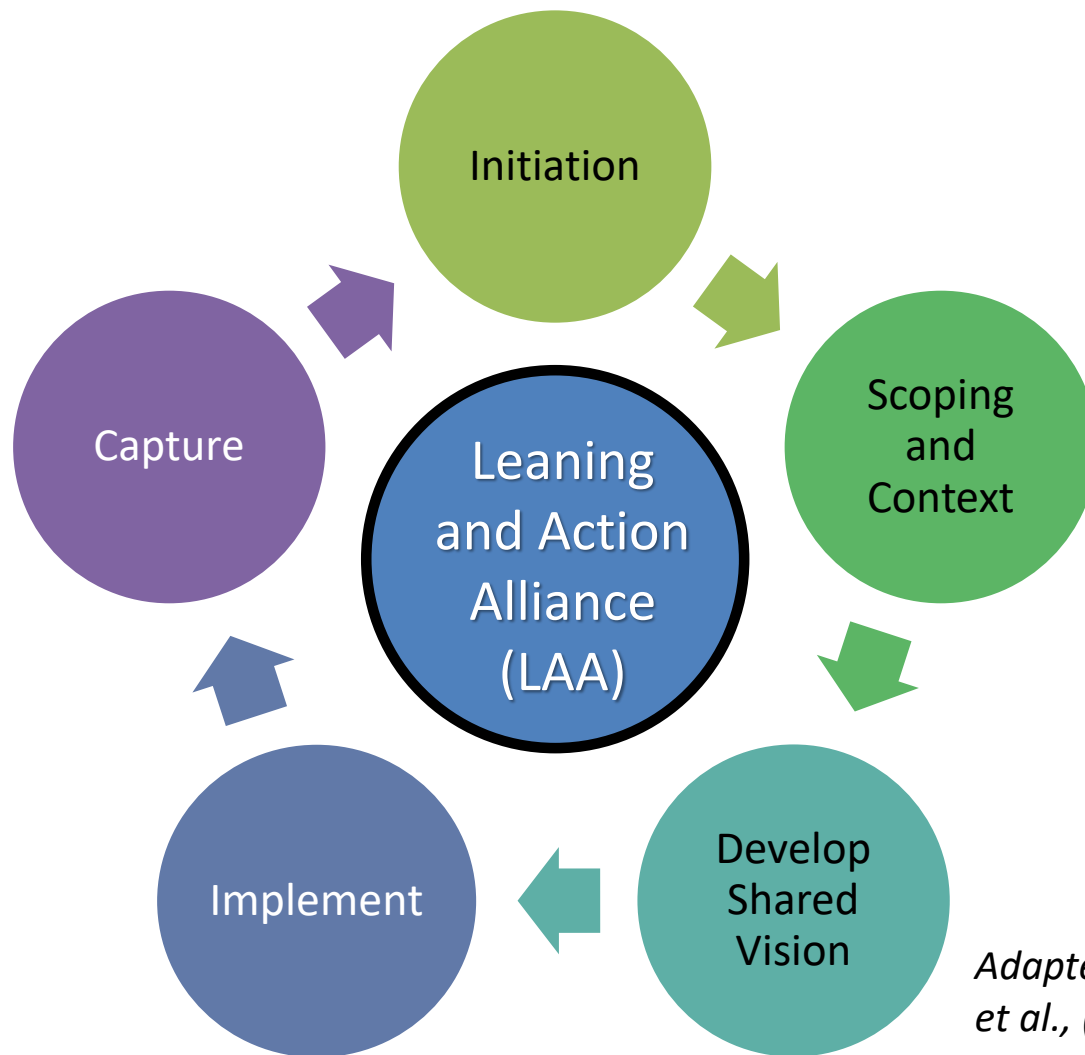
Public preferences

Socio-political uncertainties, esp. public preferences, stewardship and equitable delivery of BG assets, have a greater impact on decision making than biophysical uncertainties

Economic resilience to CC

Urban Growth

Working with stakeholders to identify and maximise the multiple benefits of BG



A LAA is usually an **open arrangement** where participants create a **Joint understanding** of a problem and its **possible solutions** based on rational criticism and coherence through **discussion**. It facilitates the identification of **innovative ideas** for the solution of complex (wicked) problems **outside the constraints of existing formal institutional settings**.

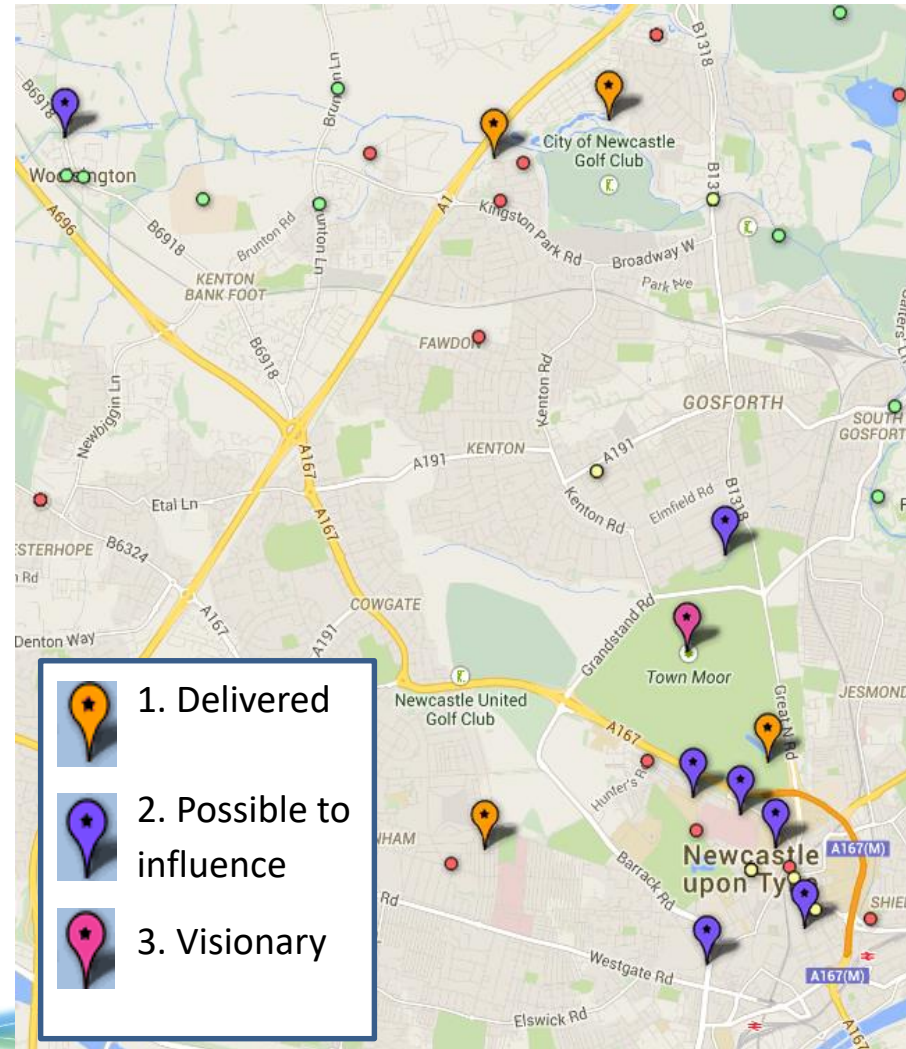
Adapted from Ashley et al., (2011)

Newcastle Learning and Action Alliance (LAA)

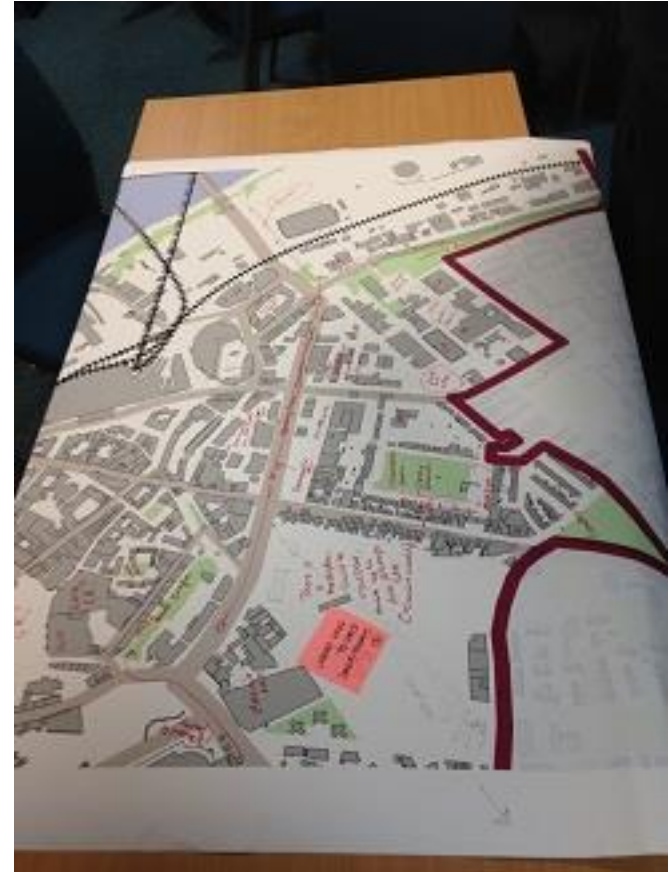
Objective: The LAA will promote the blue-green vision for Newcastle and realise it by recognising, and utilising, windows of opportunity for potentially influencing the strategies of decision makers



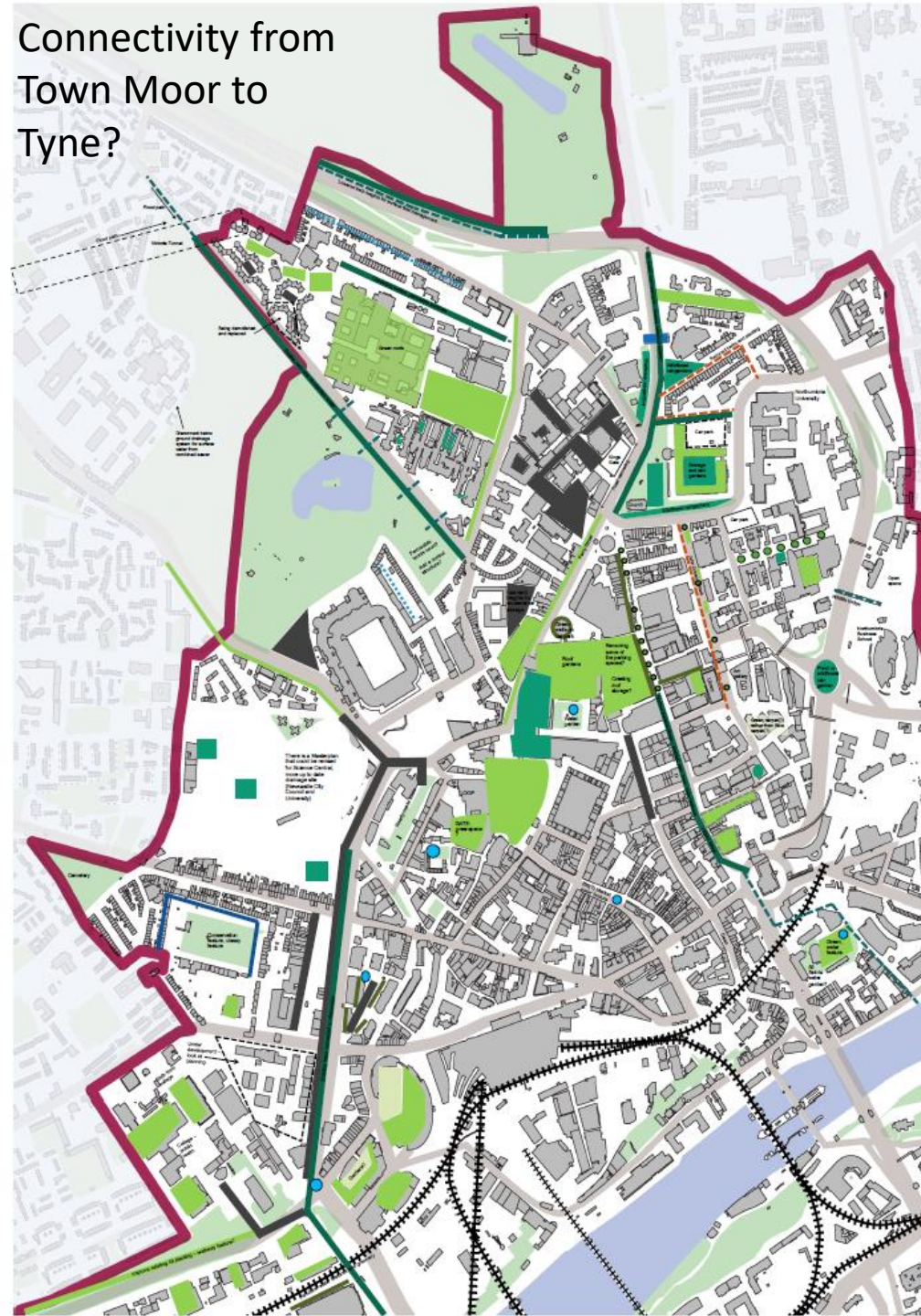
- Identifying Blue-Green/SuDS initiatives (built, planned and visionary) in Newcastle



Master-planning a Blue-Green urban core



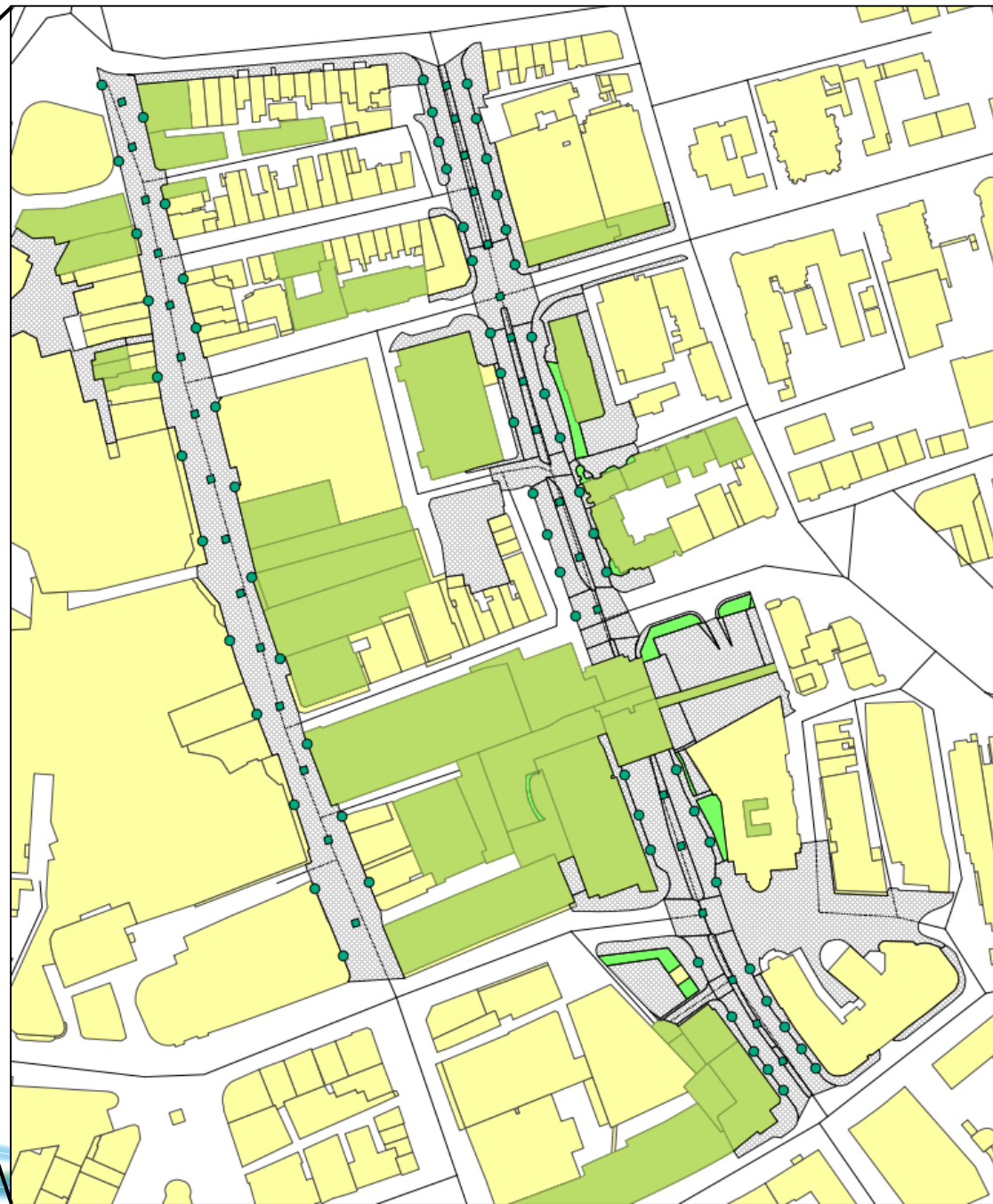
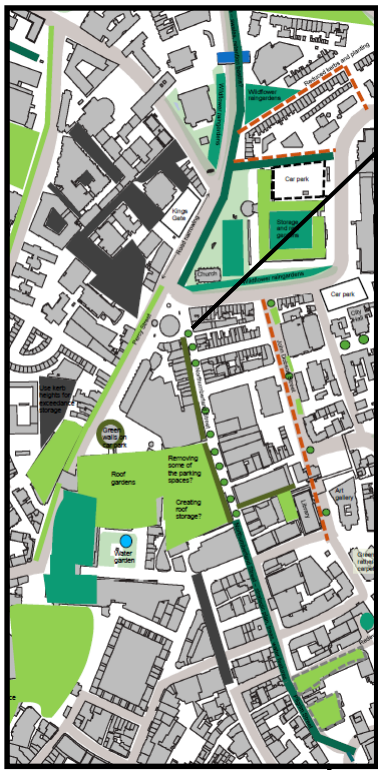
Connectivity from Town Moor to Tyne?



Newcastle Urban Core Blue-Green Future: legend

-  Possible greenspace/green roof/green features
-  SuDS
-  Permeable surface
-  Water feature, e.g. fountain
-  Permeable paving
-  Street trees
-  Rills, swales
-  Green walls
-  Downpipe disconnections
-  Above ground water flow and connected greenspace
-  New cycle route with green landscaping and pedestrian routes
-  Blue roof
-  Water butts
-  Grey water reuse





Northumberland
Street and John
Dobson Street:

- Green roofs
- Swales (2x2 m)
- Street trees
- Permeable paving

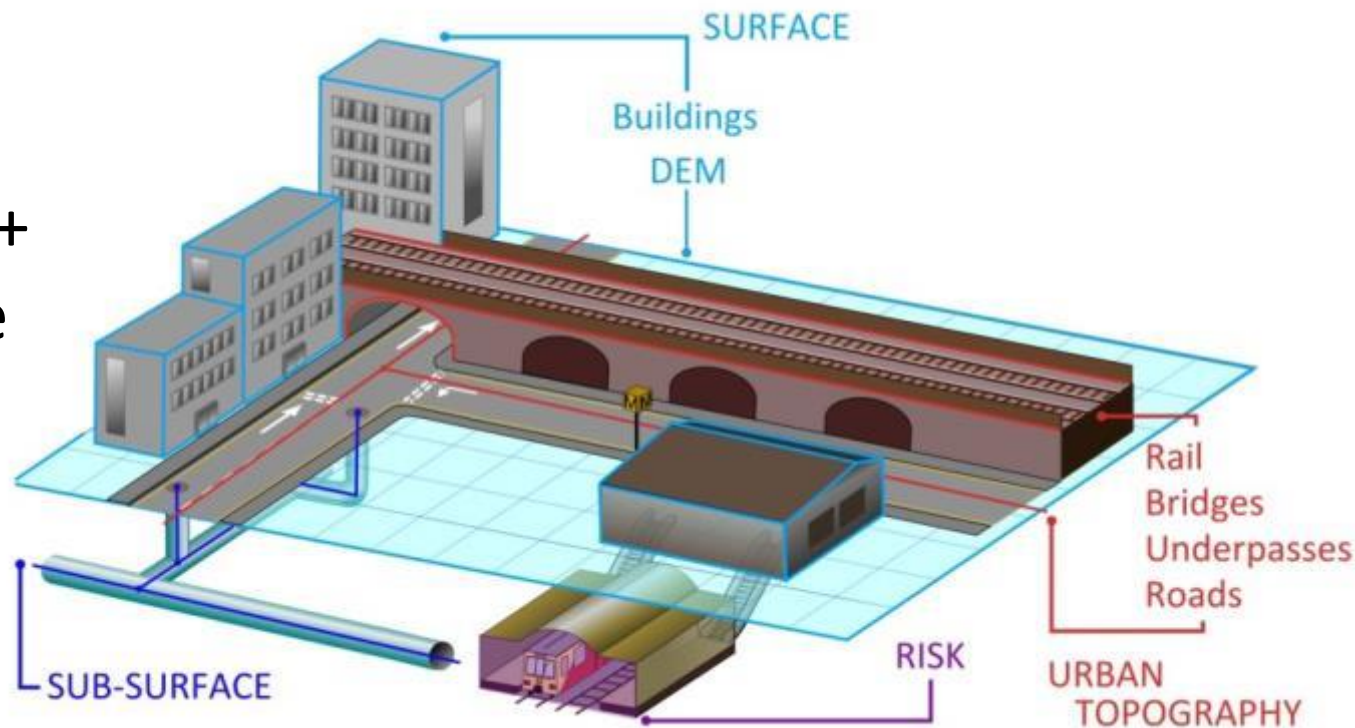
Model Existing and Future Flood Risk Management

Urban flood modelling: Combined sewer and surface water flood model

CityCAT couples surface + subsurface drainage networks

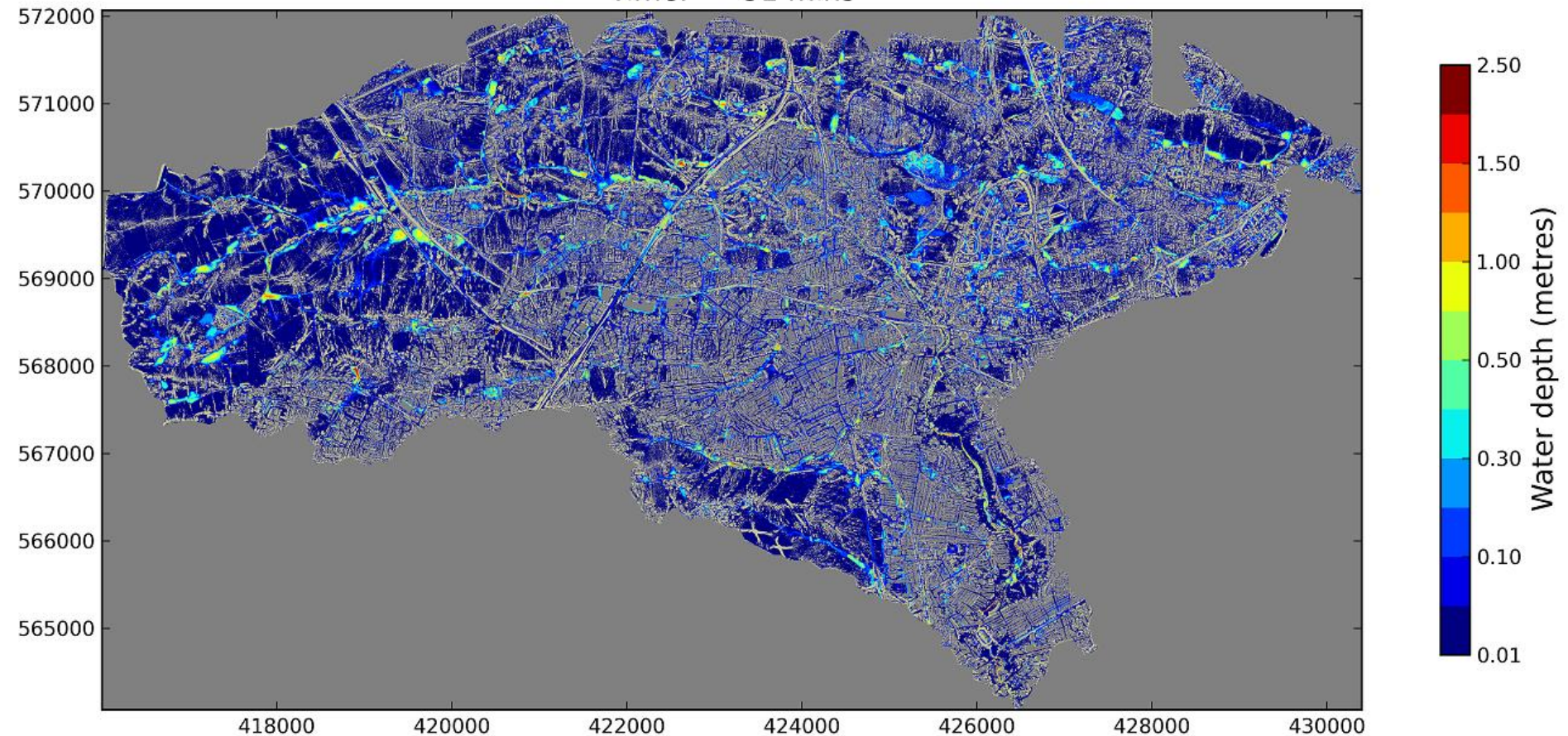
Model surface water flooding due to rainfall + blocked sewers + sewer surcharge

CityCAT models all possible flow types:
free surface
pressurised
mixed



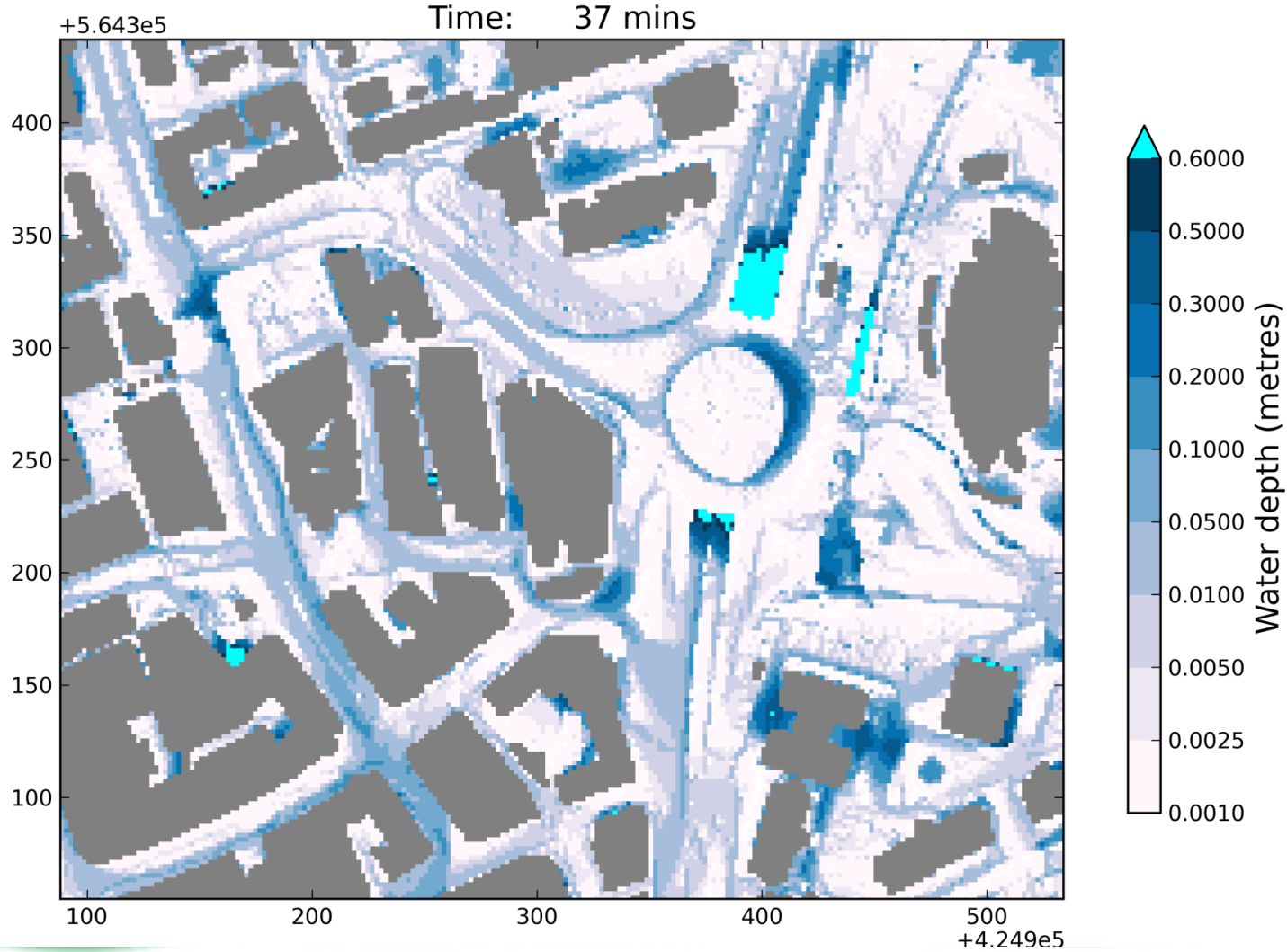
WP 2a Flood Inundation - CityCAT and Delft 3D

Time: 51 mins



Water depth map of **Ouseburn catchment** (area = 120km² , cell size = 2m, cells = 30million). Storm event = 60 minutes, 100-year return period

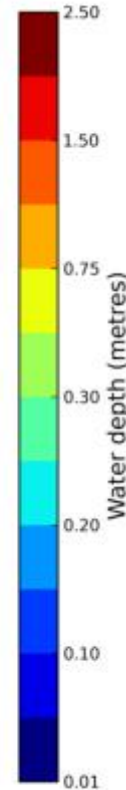
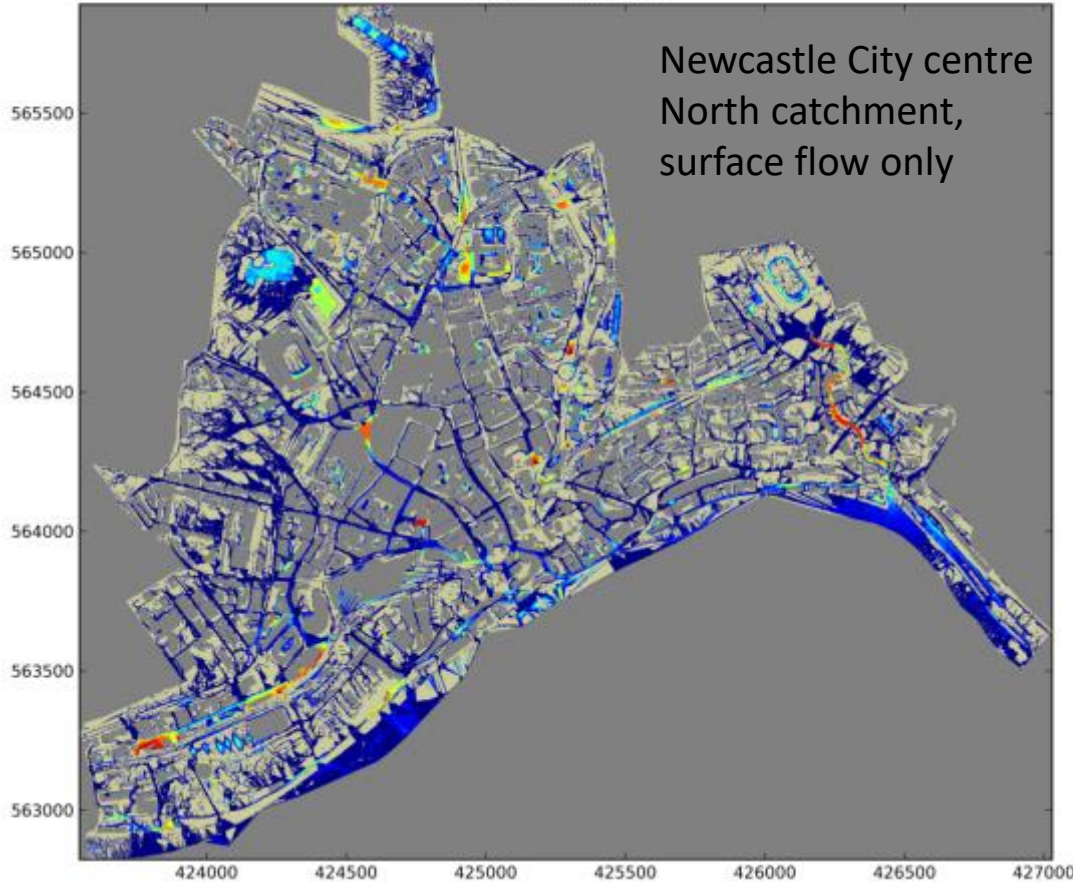
Preliminary results from the coupled model for the urban core area



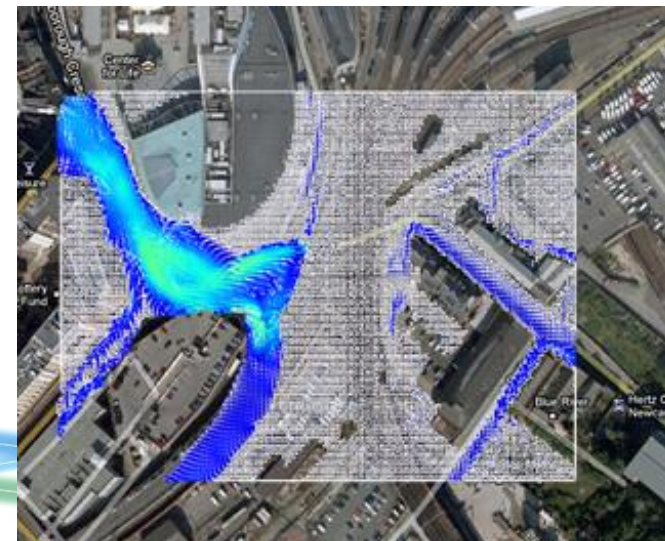
CityCAT hydrodynamic inundation model used to test options for Blue-Green solutions to urban flooding

Time: 110 mins

Newcastle City centre
North catchment,
surface flow only

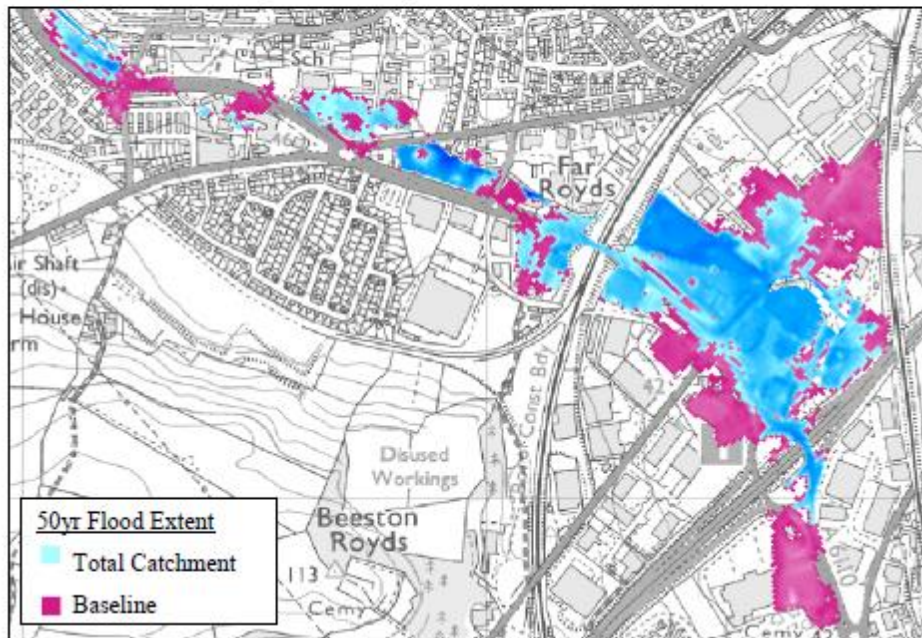
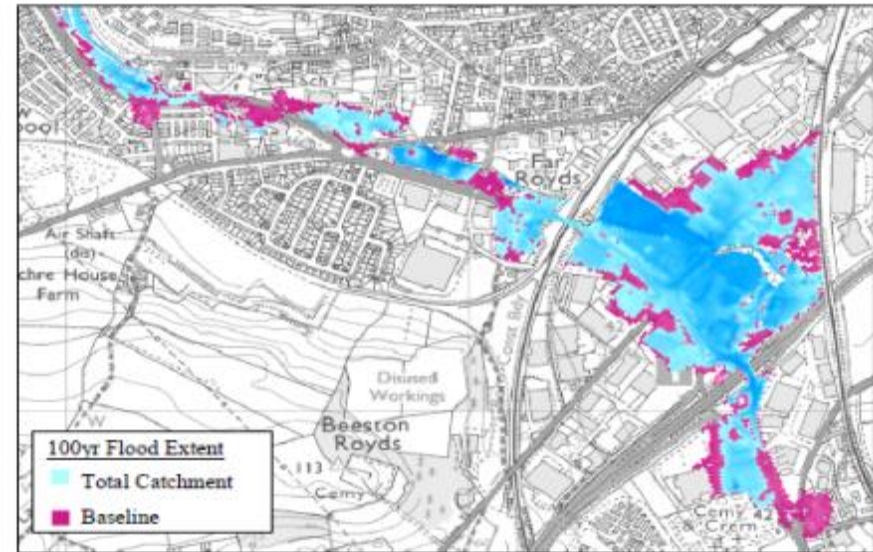
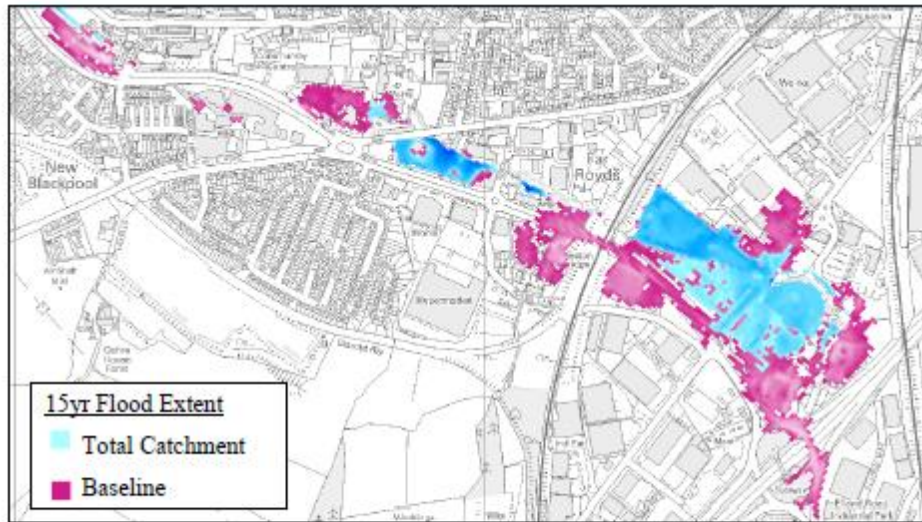


Subsurface network incl.
manholes and drains



Fully coupled surface-subsurface flood model produces excellent results for city centre

Urban river modelling with/without Blue-Green Infrastructure



Wortley Beck Catchment, Leeds

- B-G performs well for 10 and 25 yr return period floods
- Impacts on 50 and 100 yr return period floods are less significant

WP2b. Sediment, morphology, habitats

- Sediment transport & debris dynamics in urban drainage networks
- Sediment/Debris risks to **Grey** versus **Blue-Green** infrastructure
- Risks and Benefits of Stream Restoration in urban watercourses

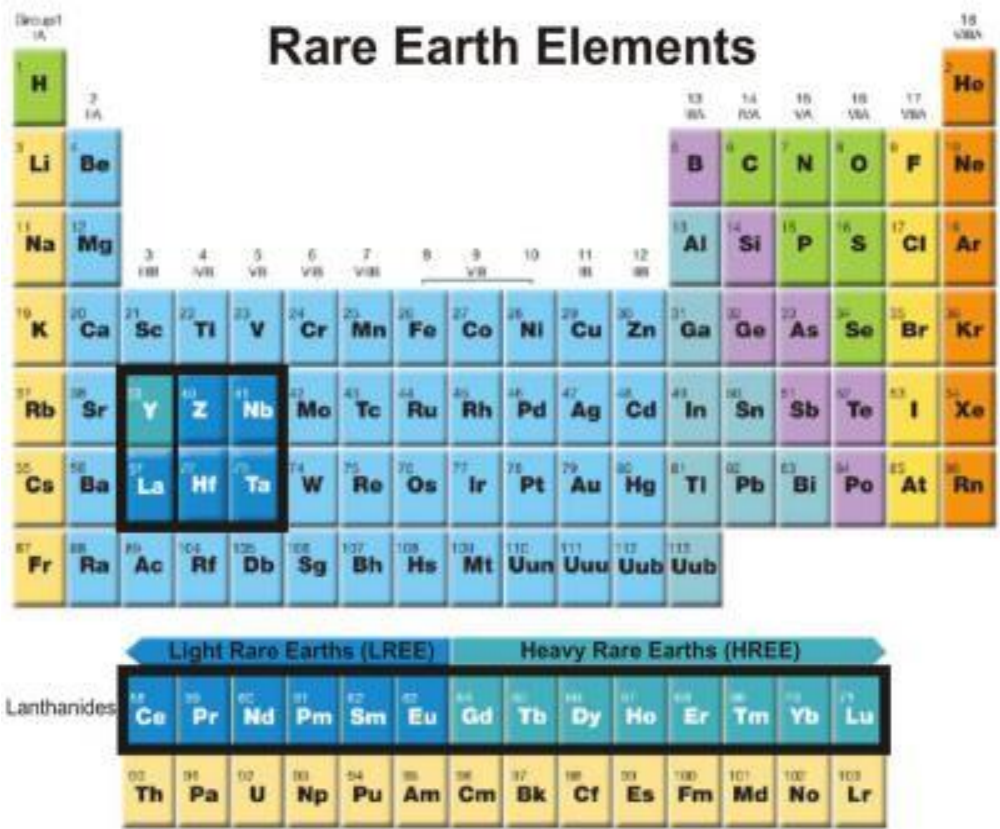


PIT
technology

Blue-Green sediment/water quality performance using Rare Earth Oxide (REO) to trace sediment

REO tracing method:

- 15 unique identifiers
- Monitor fine sediment transport/storage
- Ephemeral flows
- Long-term functionality
- Intra + inter event dynamics
- Understand pollutant concentration changes in Blue-Green treatment trains



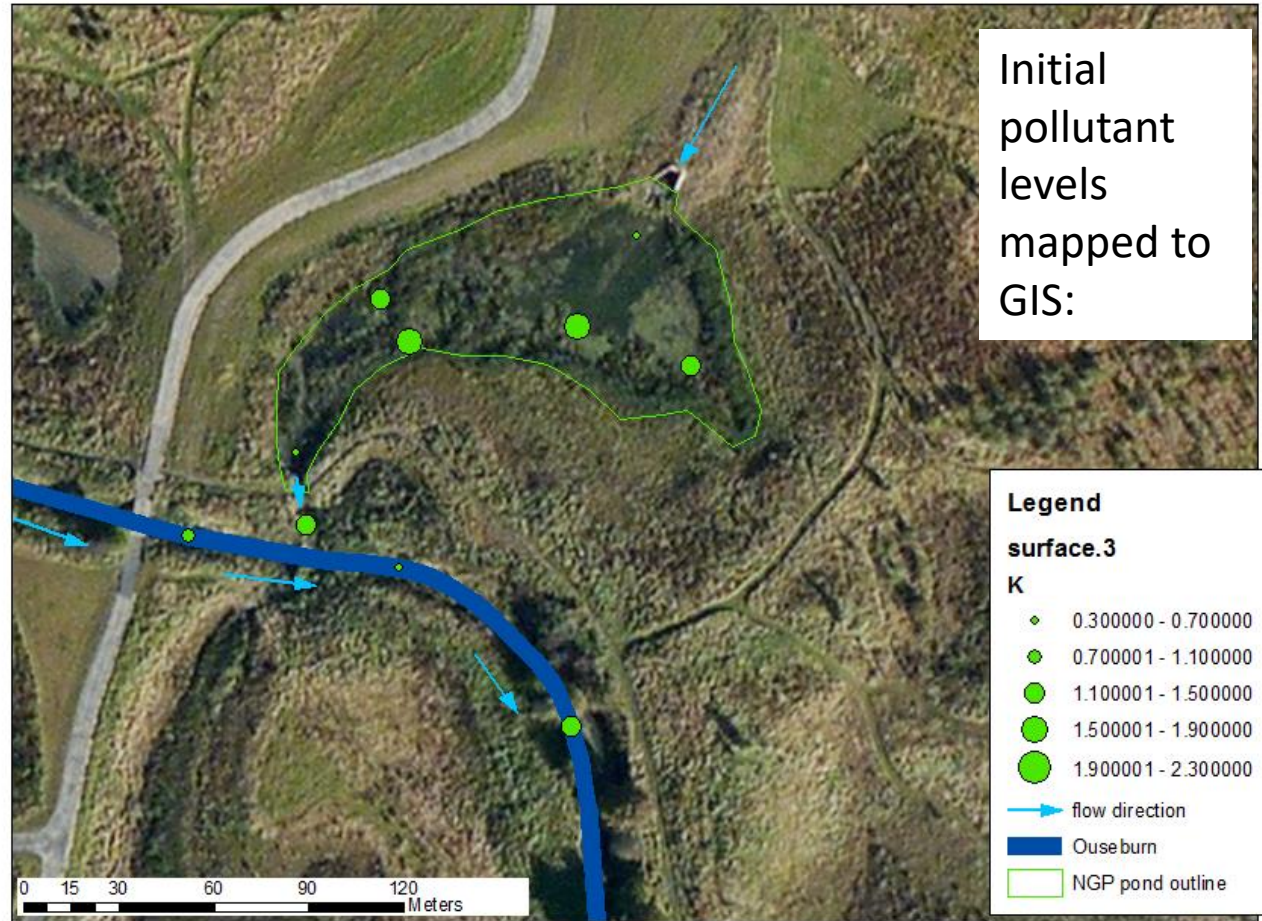
REM = rare earth metals
 REE = rare earth elements
 REO = rare earth oxides
 LREE = light rare earth elements (La-Sm)
 HREE = heavy rare earth elements (Eu-Lu)



WP2b. Sediment, debris, morphology and habitats

Field sampling of Newcastle Great Park case study site

- High fine sediment influx (upstream construction works)
- High fine sediment detention in pond
- HM+ pollutants in flow are within acceptable limits (except Fe, Mn, Al, Ca, Ni, Sn and P)
- Deposition (bed) sediment is generally below contaminated land use levels.
- K, Fe, Mn, Mg, Zn, Ca, Cu and P levels are moderate (require further analysis)
- Historic land use influence needs to be considered



Model Citizens' Behaviours

WP2c. Individual and Community Attitudes, Behaviours and Preferences



The Dings, Bristol (above), @Bristol (top-right), St Nicholas House, Bristol (bottom right)

Social perspectives, preferences and behaviours

Aims: Understanding citizens' views, beliefs and values

1. Residential: Wingrove neighbourhood:-
property-level installations, permeable paving, water barrels
2. Business: Central Business District:-
green roofs, green spaces, Blue-Green infrastructure



Outcomes: **quantified behavioural models** for agent-based modelling of citizen behaviours with respect to flooding

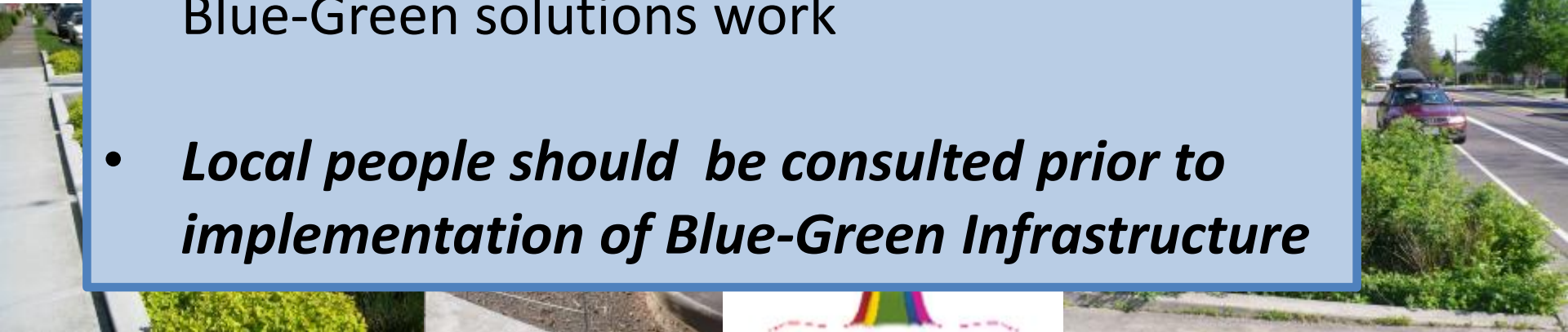


People's perceptions and behaviours with respect to

Way Forward:

- Local people are the Local experts
- Local people have useful local knowledge
- Local people must understand Blue-Green infrastructure in order to Value it
- Local people must cooperate to maintain BGI
- Local People need to feel ownership to make Blue-Green solutions work
- ***Local people should be consulted prior to implementation of Blue-Green Infrastructure***

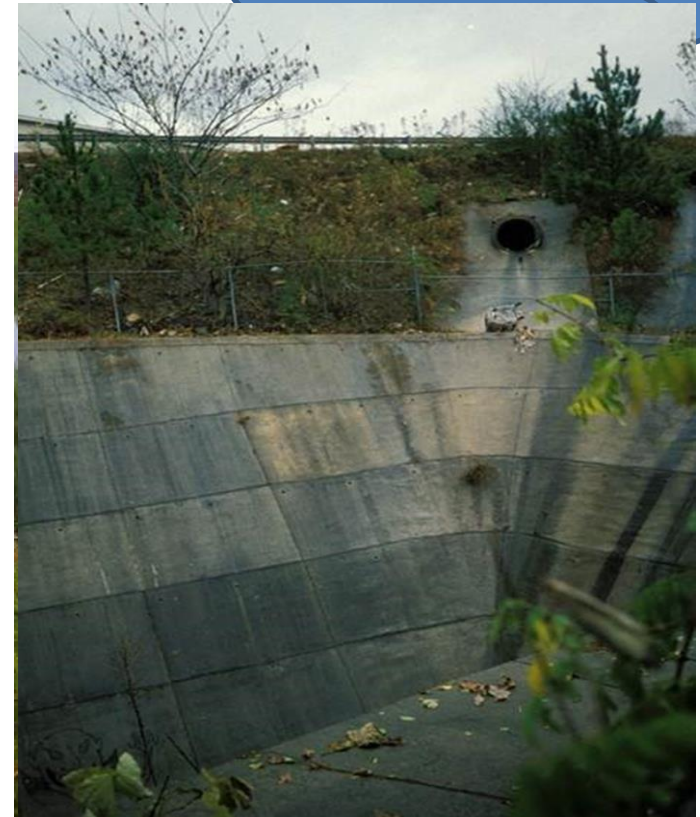
ture



Options for Hard/Soft Measures

Grey-Green Options: *Social performance*

resource



- Recreation
- Aesthetics
- Amenity
- Wellbeing and liveability (stress relief, restorative benefits)
- Encourages community cohesion, social interaction
- Physical and mental health

Blue-Green Options: *Environmental performance*



BRUNTON PARK FLOOD ALLEVIATION SCHEME - LANDSCAPE PROPOSALS
MMD-277630-L-DR-00-0001 P03



Common Reed
PROPOSED REEDBEDS



PROPOSED SPECIES RICH GRASSLAND



Hazel



Oak



Guelder Rose



Redcurrant

WET WOODLAND SPECIES



Marsh Marigold



Greater Pond Sedge



Bramble



Forget-me-not

PROPOSED MARGINAL SPECIES

Source www.nwl.co.uk



PROPOSED TREE SPECIES



Silver Birch

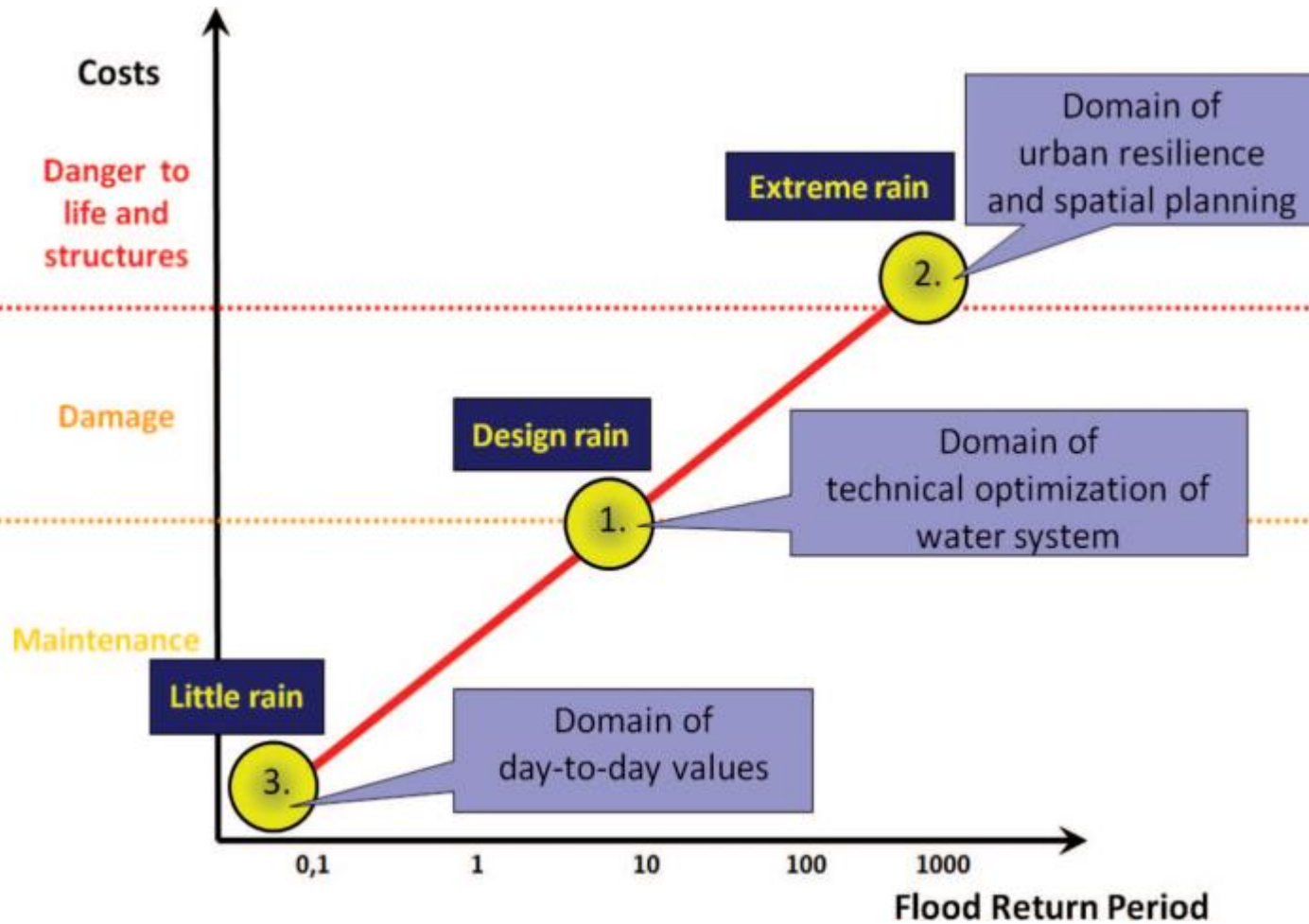


Bird Cherry



European Holly

Designing for exceedance: *Three point approach*



Blue Condition

2. *If extreme flooding occurs infrastructure facilitates managed urban conveyance and storage.*
1. *FRM infrastructure provides required level of service for flood defence.*
3. *Green infrastructure and spaces used on a daily basis by communities and ecosystems.*

Green Condition

Fratini et al.,(2012) Three Points Approach (3PA) for urban flood risk management.

Evaluate Multiple
Flood Risk
Benefits

WP4. Synthesis and Evaluation of benefits

QGIS-based multi-criteria analysis and evaluation of functions and benefits of Blue-Green infrastructure as part of integrated UFRM

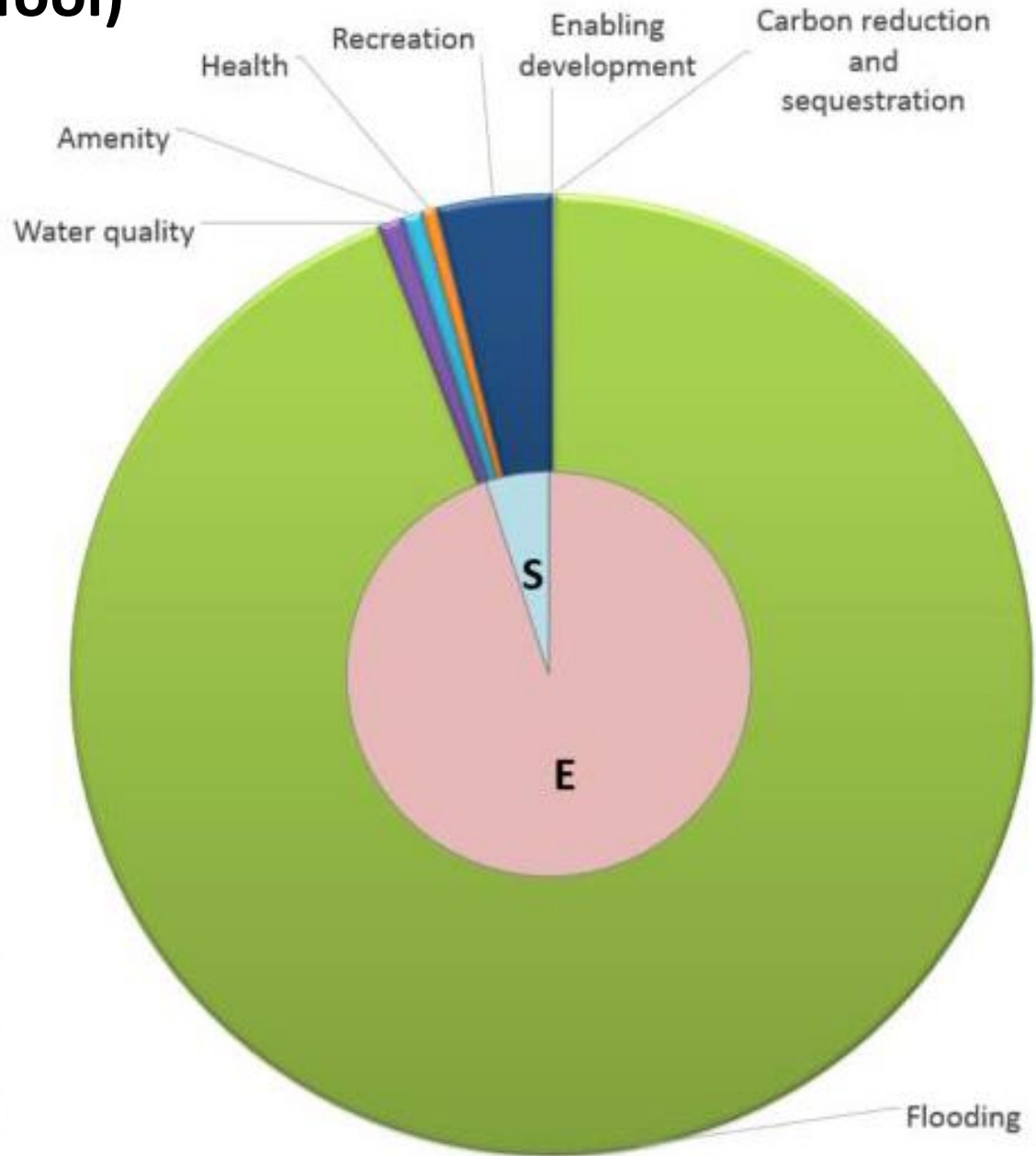


- **Integrated networks of Grey and Blue-Green** Infrastructure
- **Significance of benefits** is context specific – no single values
- **Ratings for Urban context and Stakeholder values & preferences**
- **Recommendations on design details** to enhance most significant flood and non-flood benefits
- Linked to **CIRIA Project RP993**

BeST(Benefits of SuDS Tool)

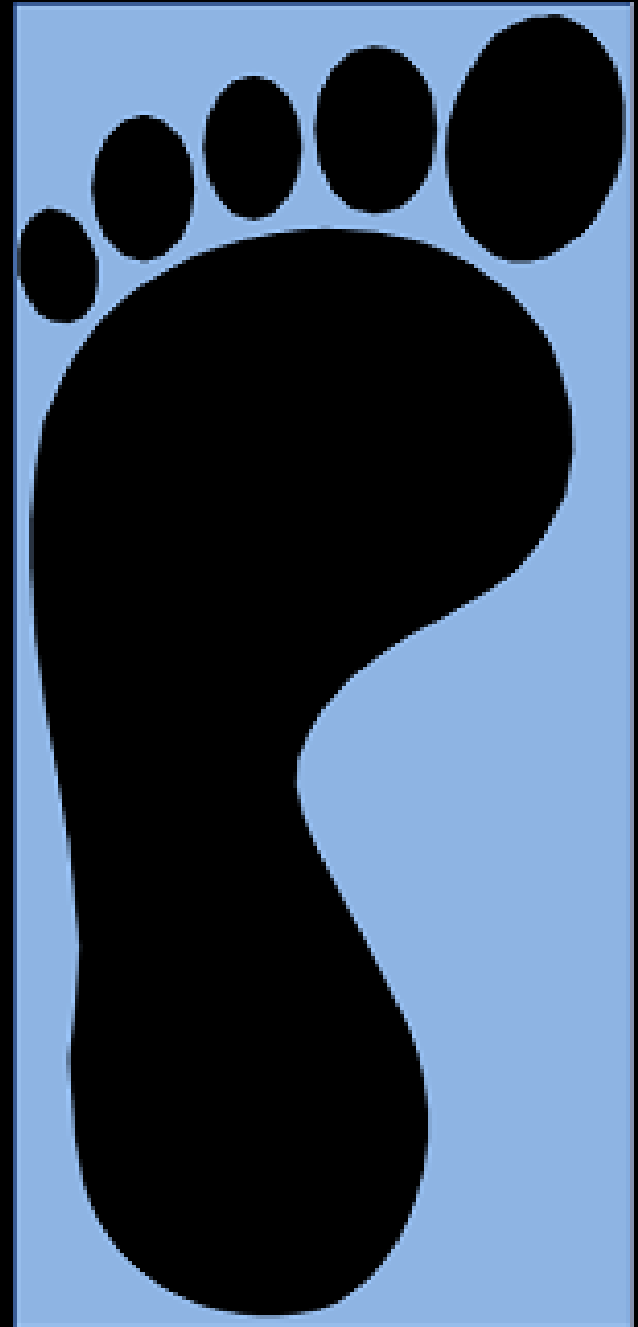
W045d BeST–User Manual

Release version
1 July 2015



The Flood Footprint

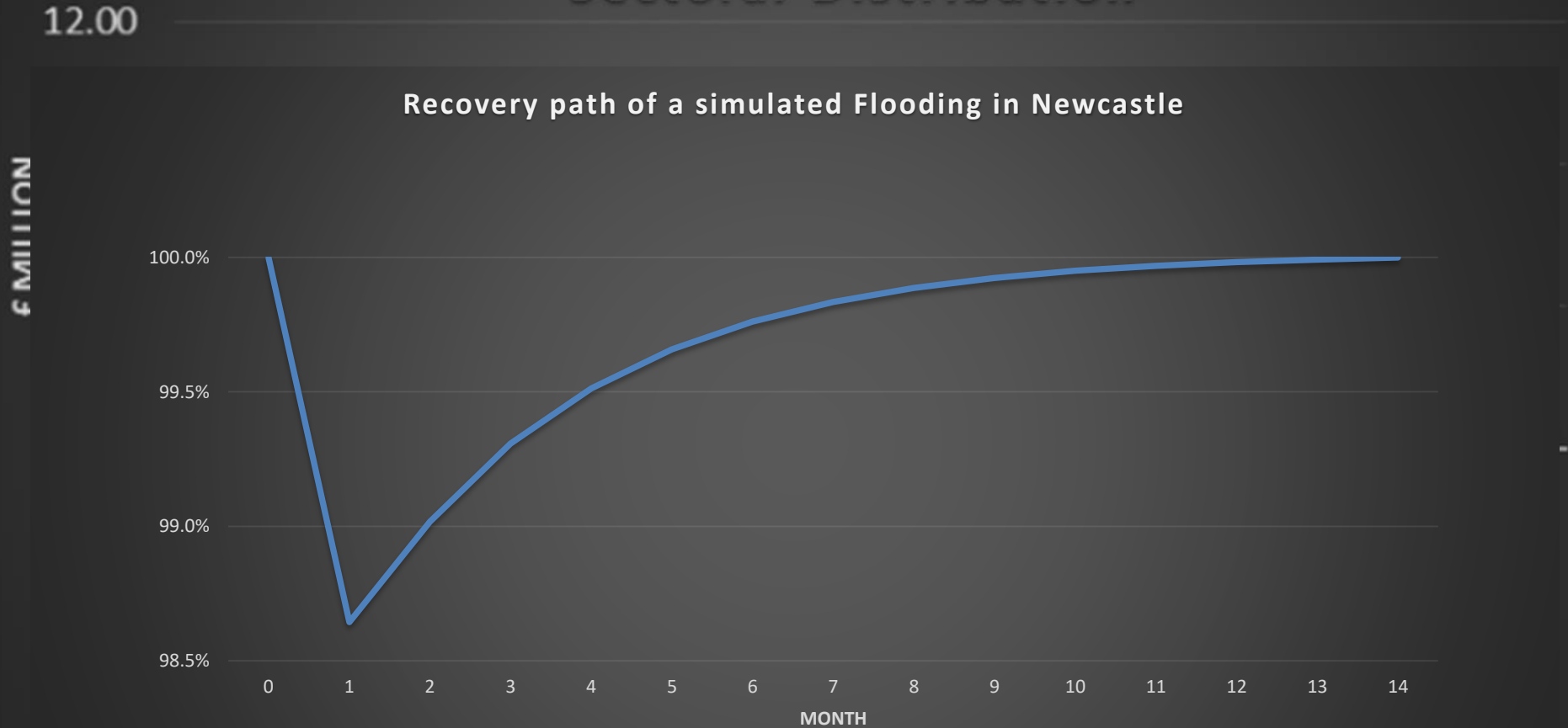
An accounting tool to measure the cascading economic impacts of flooding through multiple, coupled, economic sectors and systems



2012 Flood Footprint: Total damage = ~£78 million

Sectoral Distribution

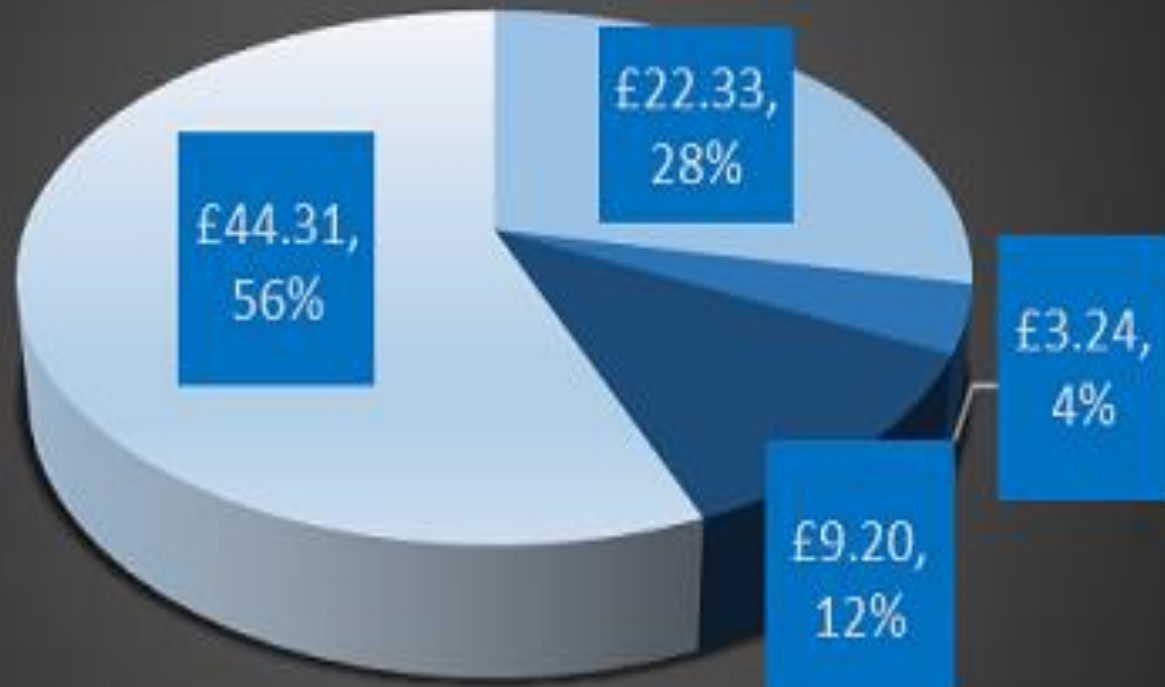
Recovery path of a simulated Flooding in Newcastle



Direct Damages = ~£34 M Indirect Damages = ~£44 M

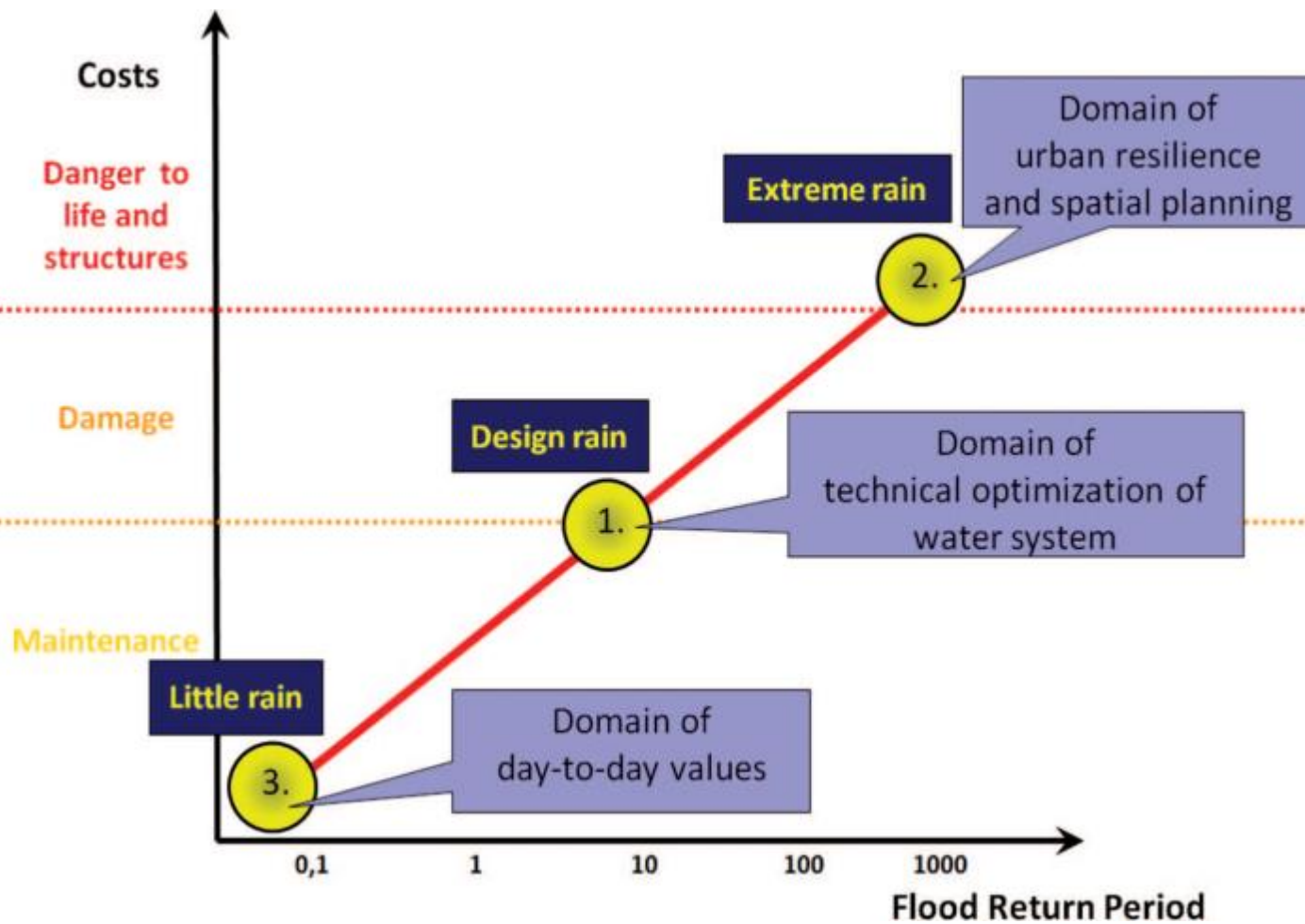
Manufacturing, Utilities and Business sectors most affected

Flood Footprint composition (£ million)



■ Direct Residential
■ Direct Infrastructure

■ Direct Industrial
■ Indirect damage



Blue Condition

2. *If extreme flooding occurs BGI facilitates managed urban conveyance and storage.*

1. *Blue-Green infrastructure provides required level of service for flood defence.*

3. *Green infrastructure and spaces used on a daily basis by communities and ecosystems.*

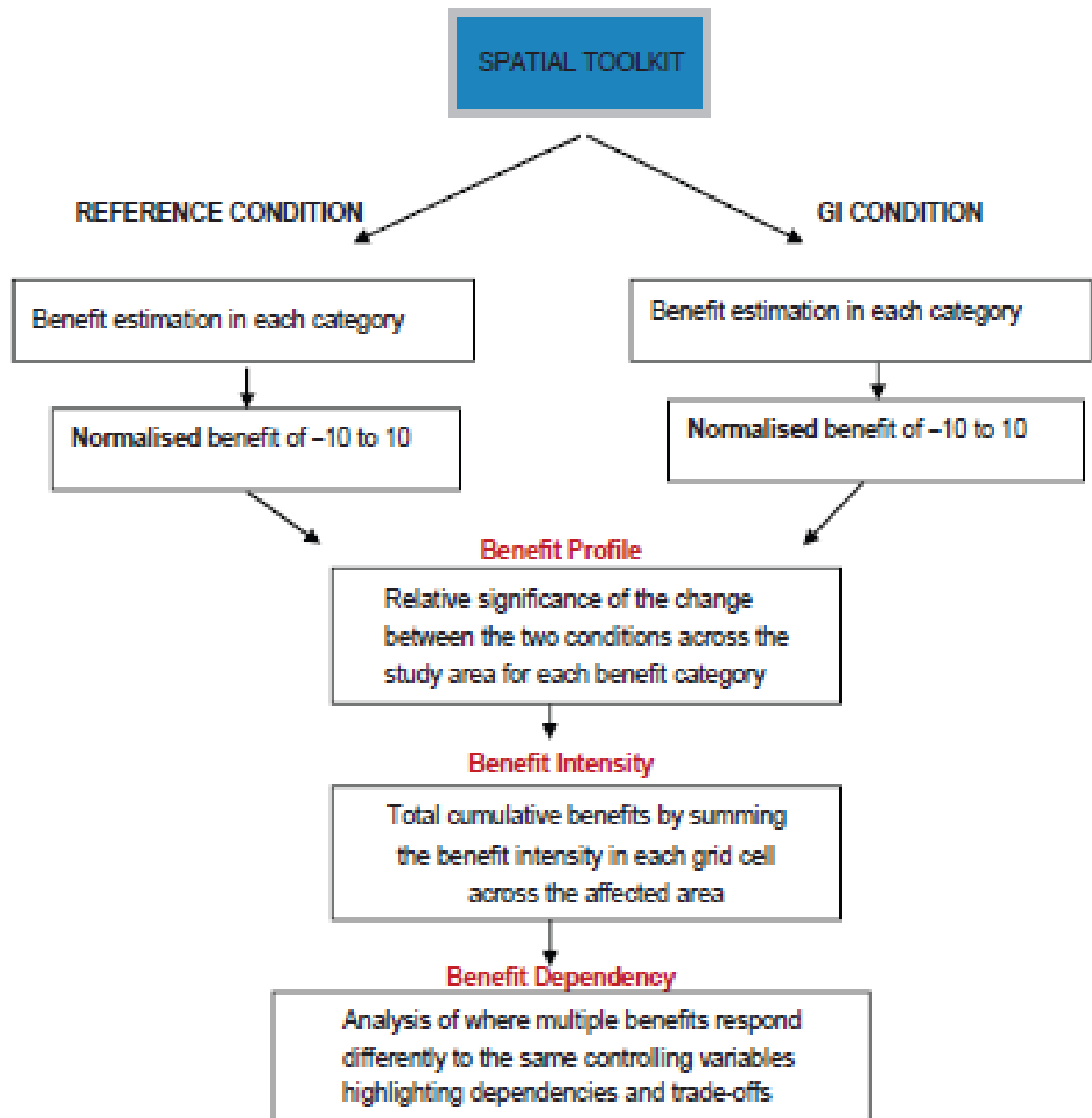
Green Condition

Designing for Exceedance + Designing for non-flood conditions

= Benefits 24/7, 365 days a year.....



Benefit analysis tool kit



GIS platform used to assess, quantify and value benefits of using Blue-Green infrastructure for sustainable urban flood risk management

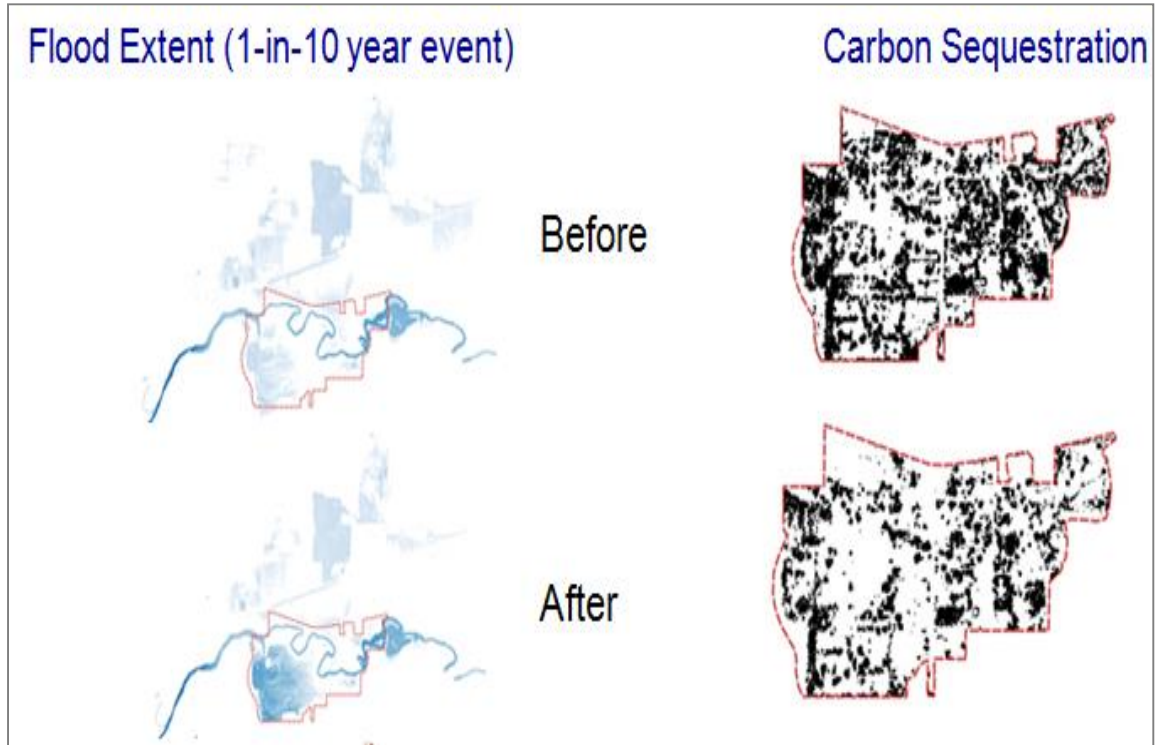
The GIS creates *benefit layers* based on:

Benefit profile:

normalised impacts and relative contribution

Benefit intensity: spatial extent and distribution

Benefit dependency: complimentary and exclusivity of impacts



Example: Distribution of flood mitigation and carbon sequestration benefits in a case study in Portland

Demonstration Case Studies

3. Delivering a Blue-Green Future

Portland, Oregon, USA



'Grey to Green' initiative (2008-2013)
32,200 new street trees, 867 green street planters, 398 eco-roofs, culvert removal, land acquisition, river and floodplain restoration

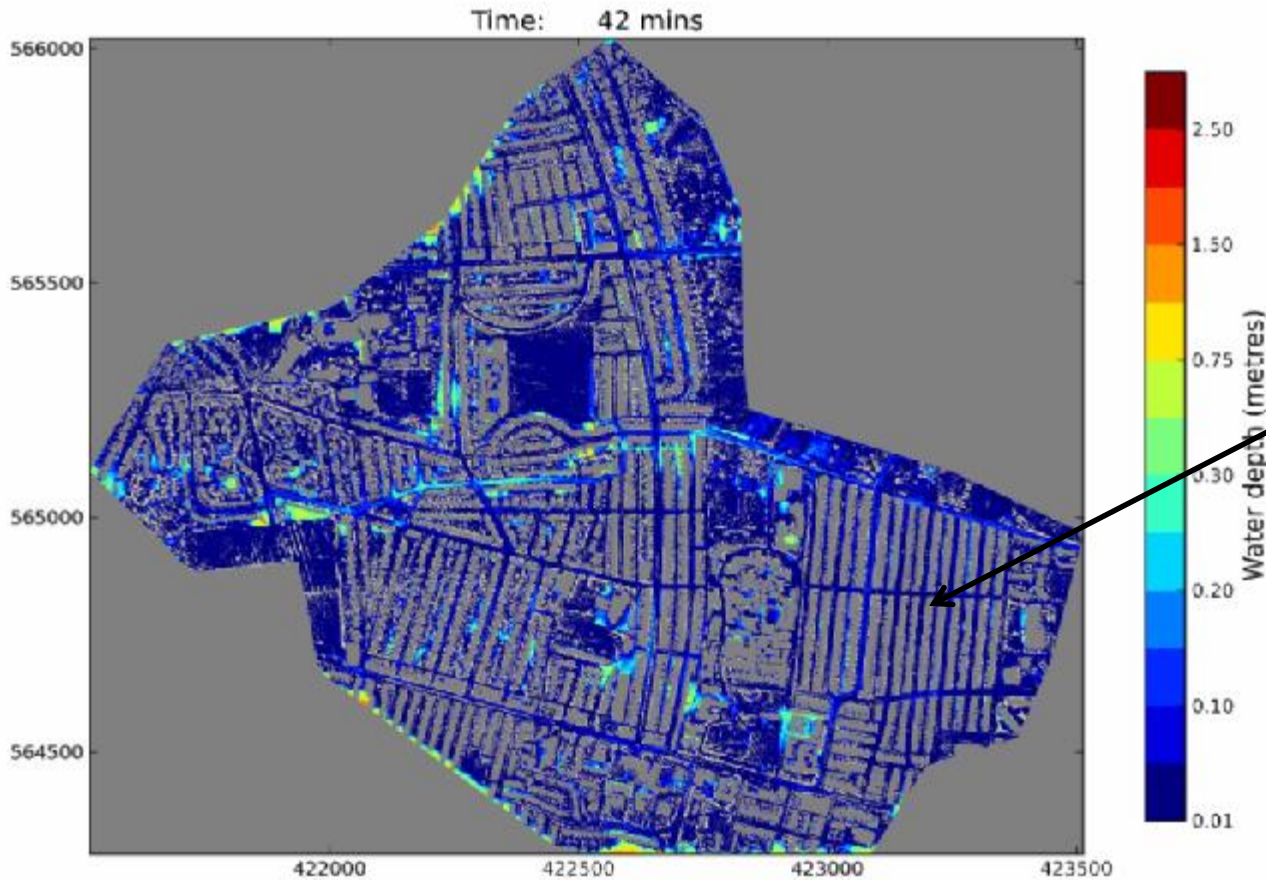
Newcastle, UK



SuDS as part of residential developments (NCC, EA, NWL), small scale examples from landowners

Blue-Greening the Wingrove residential area using - permeable paving, rain gardens, planters and blue-green roofs

Arthurs Hill, Wingrove



Blue-Green measures reduce local surface water flooding for frequent rainfall events

Blue-Green Benefit Mapping Tool: Benefit Potential



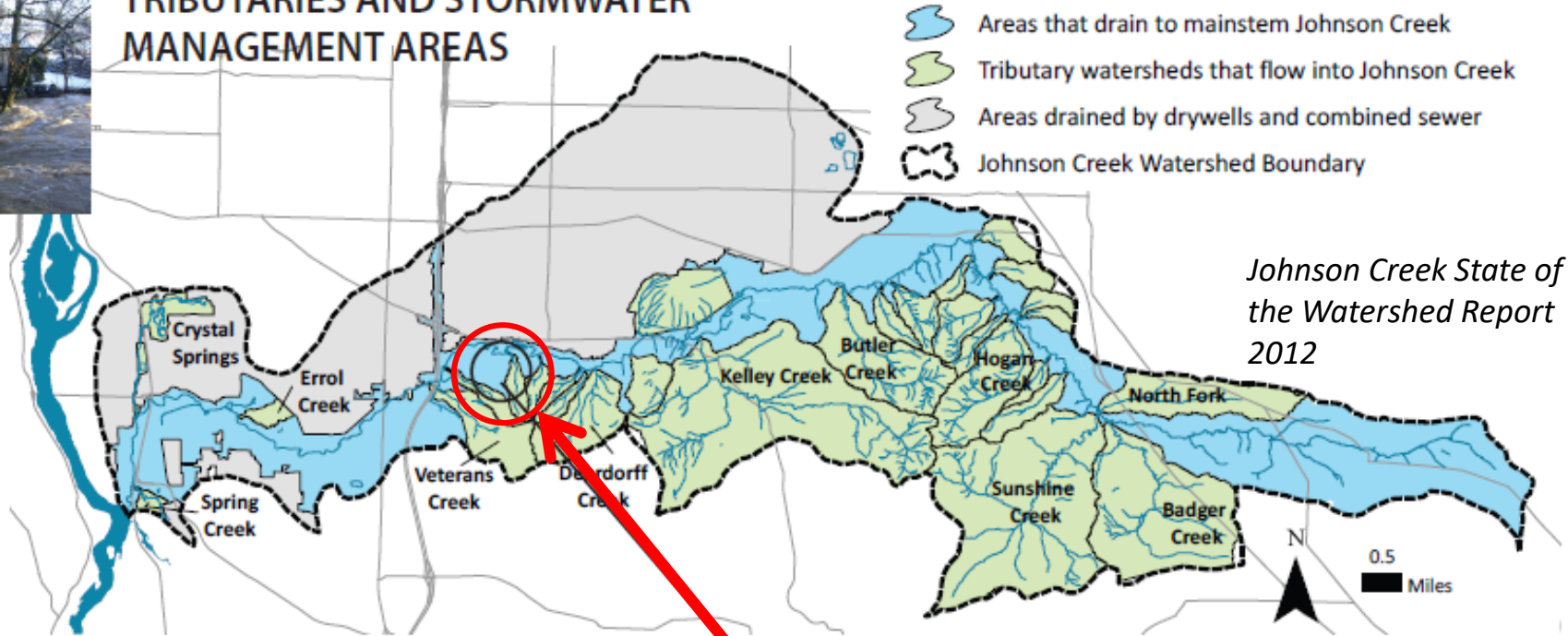
<http://www.bluegreencities.ac.uk/bluegreencities/publications/multiple-benefit-toolbox.aspx>

Flood Reduction and multiple co-benefits of
Blue-Green Infrastructure in Arthurs' Hill, Newcastle

East Lents, Johnson Creek



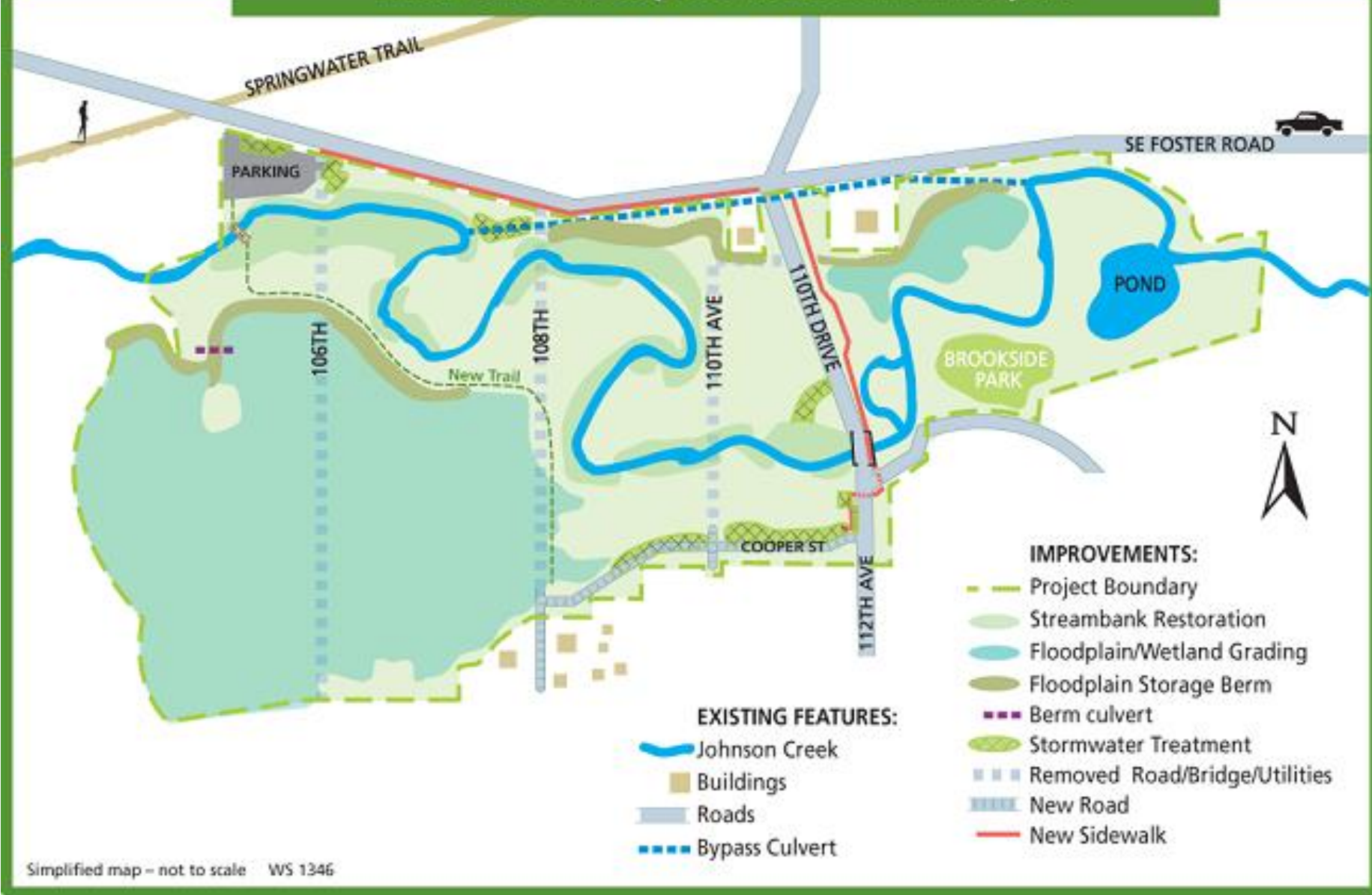
TRIBUTARIES AND STORMWATER MANAGEMENT AREAS



Frequent flooding in East Lents and Foster Road



East Lents Floodplain Restoration Project



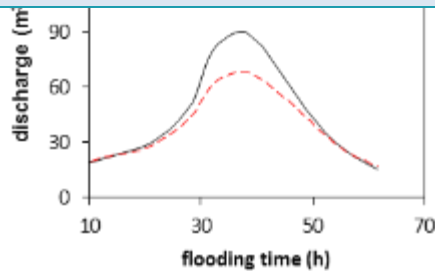
Simplified map - not to scale WS 1346

Flood Reduction Benefits of the East Lents Floodplain Restoration

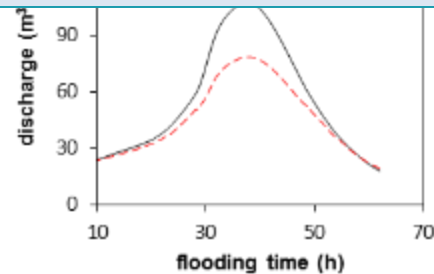
10 year

50 year

Flood peak reduction benefits are strong and **increase** for longer return period events

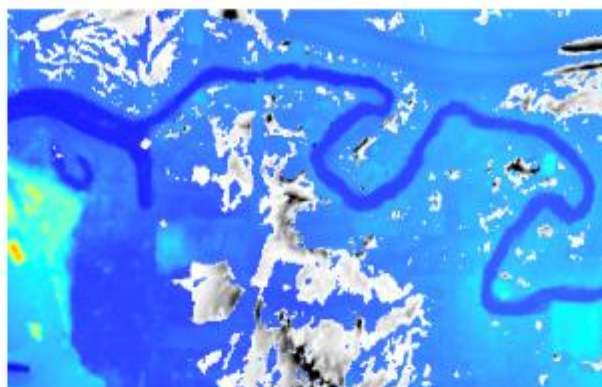
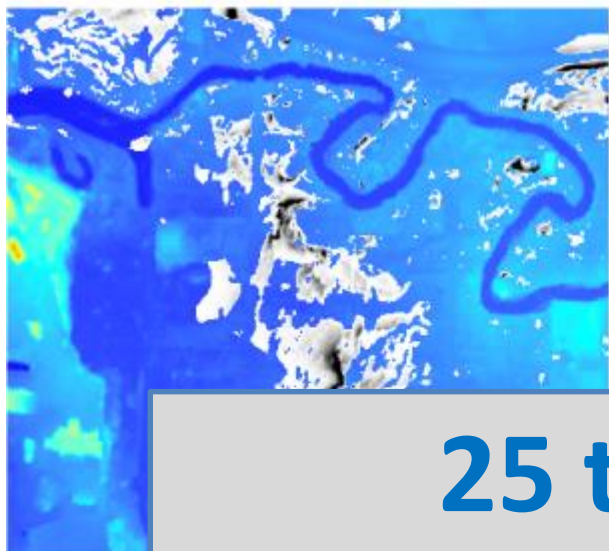


100 year



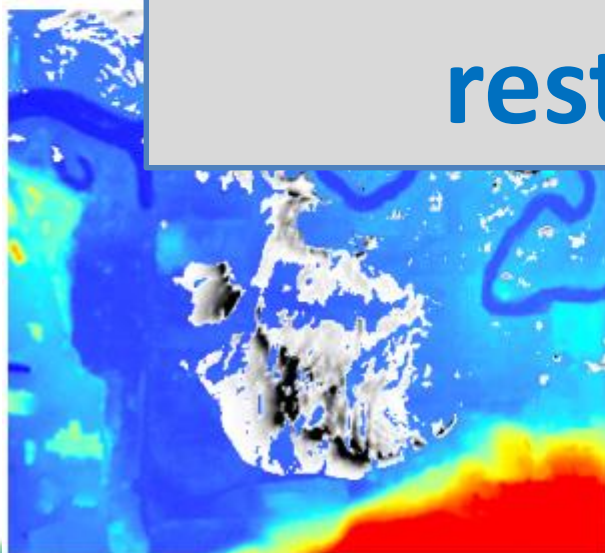
500 year

Sediment storage benefits in the East Lents flood basin

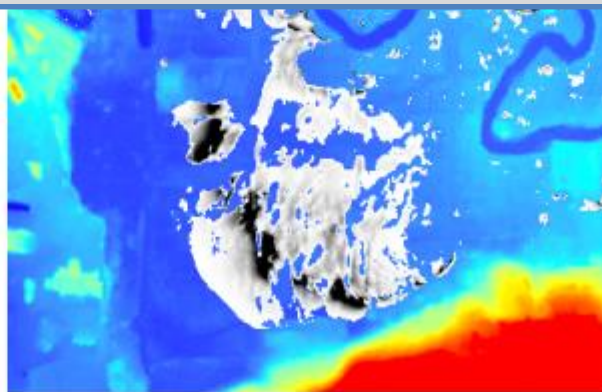


Sediment deposition

25 to 40% incoming sediment load is deposited in restored floodplain

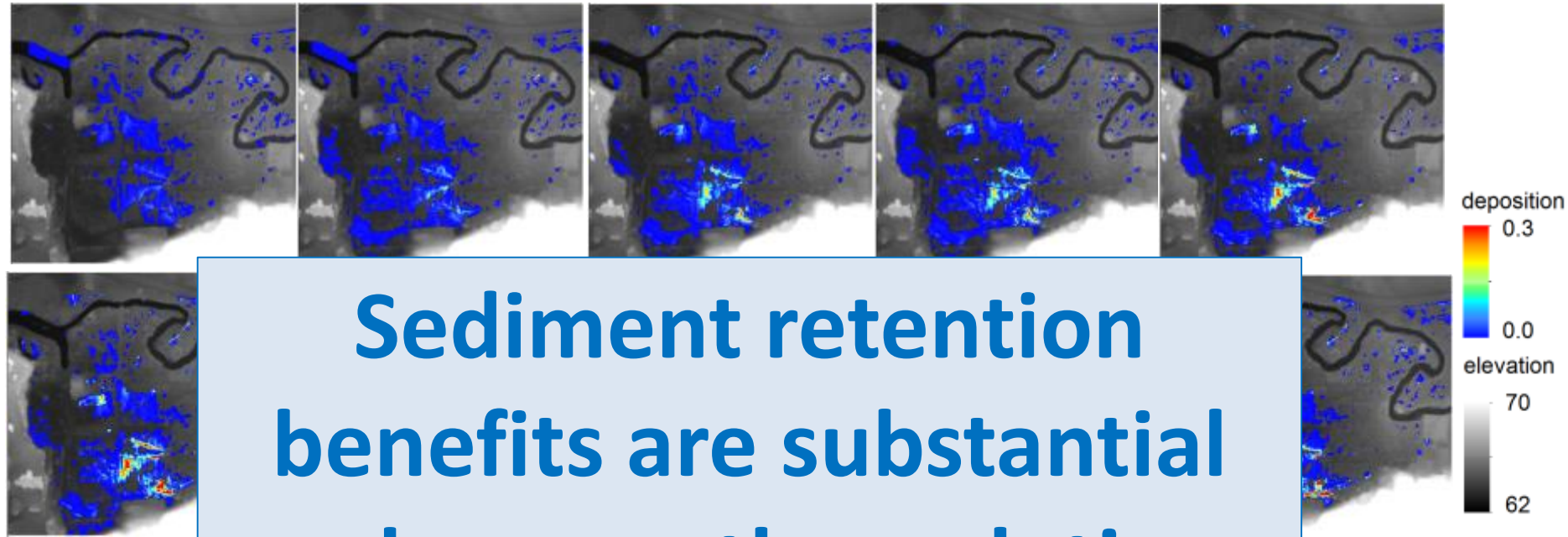


(c) deposition_100 year

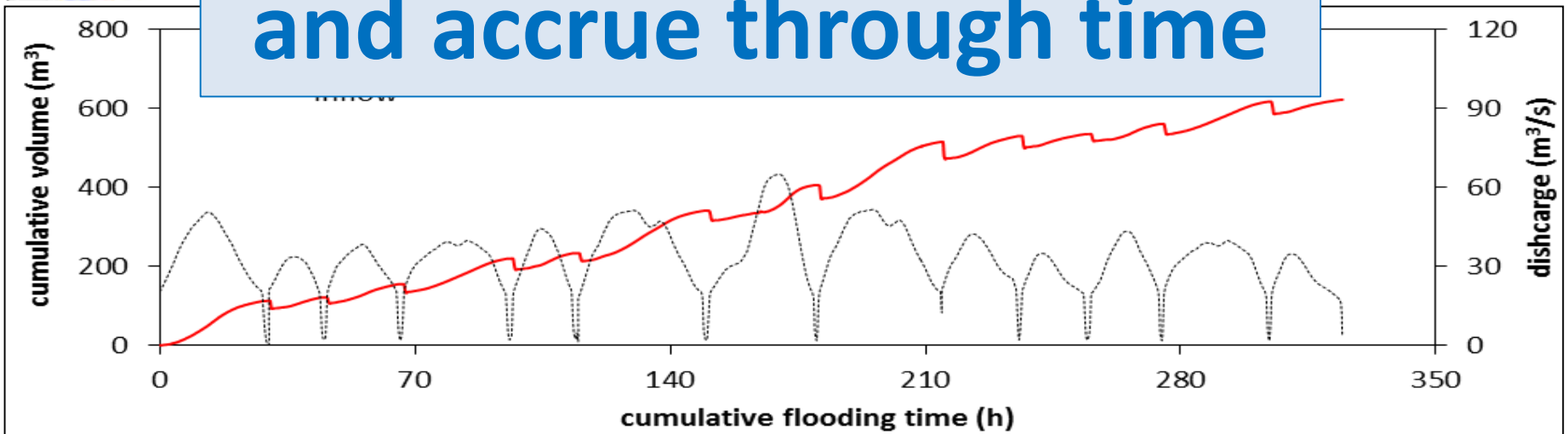


(d) deposition_500 year

Sediment accumulation through time



**Sediment retention
benefits are substantial
and accrue through time**



Evaluating multiple benefits of Flood Basin

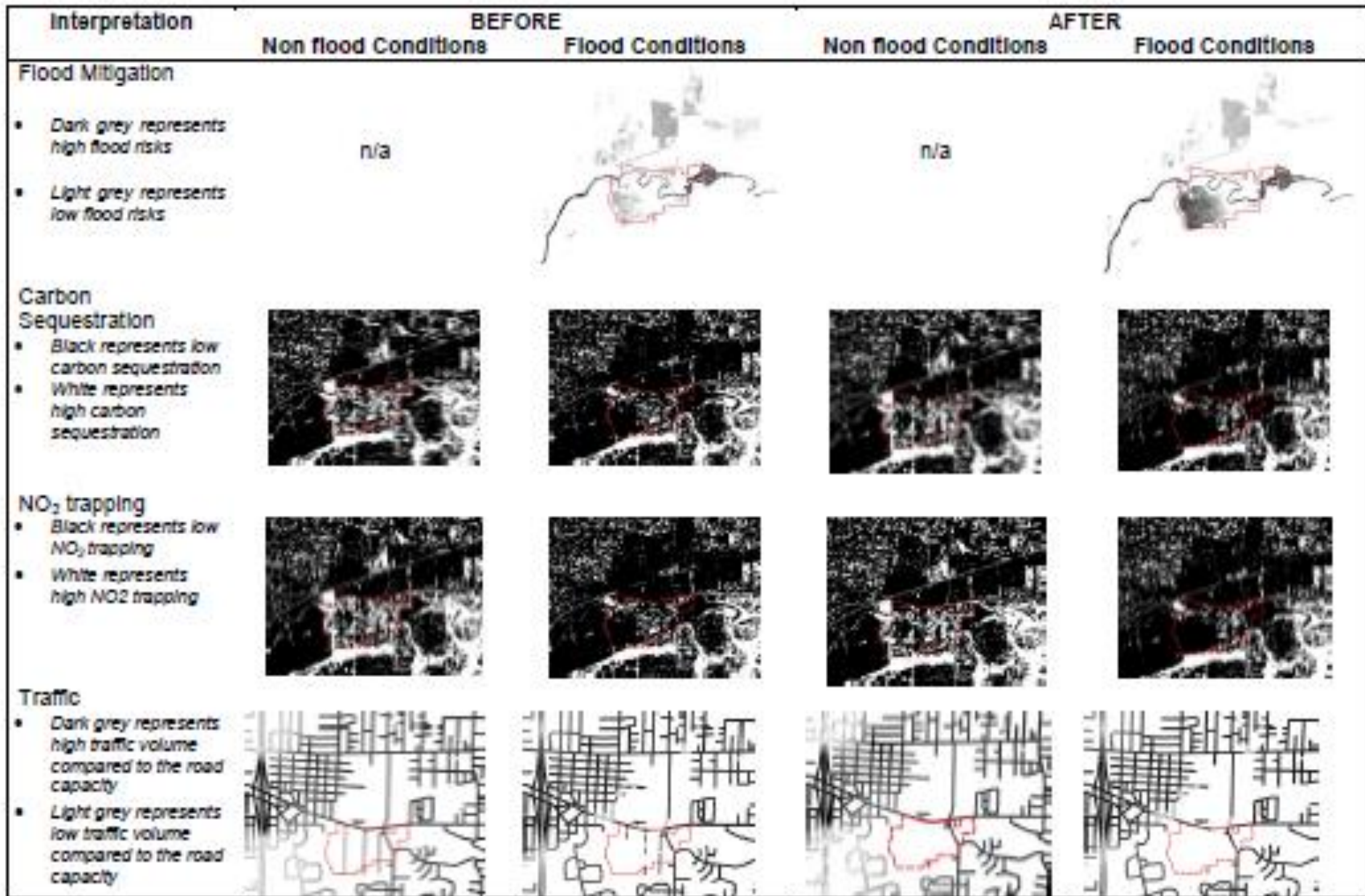


Figure 7. Benefit distribution under the non-flood and flood conditions of the East Lents area (continue next page)

Evaluating multiple benefits of Flood Basin

Reconstructing floodplain has resulted in some temporary disbenefits due mostly to loss of trees

But reconstructed floodplain yields net benefits when flooded, flooded beyond design capacity or not flooded at all.

Figure 7. Benefit distribution under the non-flood and flood conditions of the East Lents area

* Black-white: 0-10 depicting low to high benefit intensity e.g. 10  0

Portland - Building confidence, overcoming barriers

Community Engagement: Understanding and valuing the benefits of Blue-Green assets through Public access to information, Social Learning, Positive Experience of asset maintenance & performance



Image: Oregon Department
of Environmental Quality
2010.

Newcastle declaration on Blue and Green Infrastructure

Newcastle City Council, Northumbrian Water, Newcastle University, the Environment Agency, Arup and Royal HaskoningDHV confirm their commitment to expanding the amount of Blue and Green Infrastructure in towns and cities across the UK. In establishing the declaration, the signatories acknowledge that:

- Flooding has a significant effect on the quality of life of our residents and the performance of the North East economy;
- Without continued effort, climate change threatens to increase this;
- Proactive investment in preparing for it is considerably cheaper and more preferable than dealing with damages;
- Investment in blue and green infrastructure has a significant role to play in managing flood risk in urban areas; and that
- Deploying such infrastructure can also make a significant positive contribution to many other important areas of life, including physical and mental health and wellbeing, biodiversity, carbon emissions, culture, quality of life and the economy.

We therefore commit to the following:

- Providing local, regional and national leadership, encouraging and collaborating with others to increase the uptake of blue and green infrastructure
- Developing a supportive policy framework for new and retrofit projects
- Prioritising the use of green and blue infrastructure in managing flood risk wherever possible
- Assessing and increasing deployment within our own estates and activities
- Working with developers to maximise the amount of blue and green infrastructure in new development
- Piloting new ways of working, and new funding models which help to realise the multiple benefits of blue and green infrastructure
- Continuing to build and share data, knowledge and understanding needed to successfully implement such approaches
- Raising awareness and building capacity amongst communities to develop and maintain blue and green space, as part of wider resilience building initiatives

Signed:

Cllr Ged Bell
Cabinet Member for Investment
and Development
Newcastle City Council

Richard Warnford
Wastewater Director
Northumbrian Water

David Wilkes
Global Flood Resilience Leader
Arup

Marie Fallon
Area Manager for
Northumberland, Durham and
Tees, Environment Agency

Clare Rogers
Director of Estates
Newcastle University

Fola Ogunyoye
Leading Professional for Flood
Resilience
Royal HaskoningDHV

Newcastle declaration on Blue and Green infrastructure

Signed: 18th Feb 2016

Newcastle helps lead the way in blue-green cities move to combat flood risk

15:30, 19 FEB 2016 | BY [TONY HENDERSON](#)

More water storage and greening spaces in Newcastle are the basis for the city conference pledge at the Life Science Centre

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Witherspoon Photog

Blue-Green Cities conference line up, left to right, Fula Ogunyoye, Haskoning DHV; David Wilkes, Arup; Marie Fallon, Environment Agency; Clare Rogers, Newcastle University; Richard Warneford, Northumbrian Water; Coun Ged Bell, Newcastle City Council

Blue and green could rival black and white as key colours in the Newcastle of the future

WWT WATER & WASTEWATER TREATMENT

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HOME / NEWS / NEWCASTLE COMMITS TO BLUE-GREEN INFRASTRUCTURE PLAN

Newcastle commits to Blue-Green Infrastructure plan

19/02/2016

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Newcastle City Council has committed to implementing large scale blue-green infrastructure measures such as sustainable drainage, following research that showed the potential gains of the approach.



L-R: Fola Ogunyoye (Haskoning DHV), David Wilkes (Arup), Marie Fallon (Environment Agency), Clare Rogers (Newcastle University), Richard Warneford (Northumbrian Water), Cllr Ged Bell (Newcastle City Council).

The council has backed research from the Blue-Green Cities Consortium, led by the University of Nottingham, which found that increasing the amount of storage ponds, water channels, green roofs, green walls and green space (known as blue and green infrastructure) in Newcastle could make a significant contribution to reducing flood risk, as well as improving air quality and biodiversity.

It comes following estimates for the City Council which highlighted a £70m gap to keep flood risk on the Ouseburn and City Centre at current levels by 2030, accounting for growth, paving over open space.

MOST READ

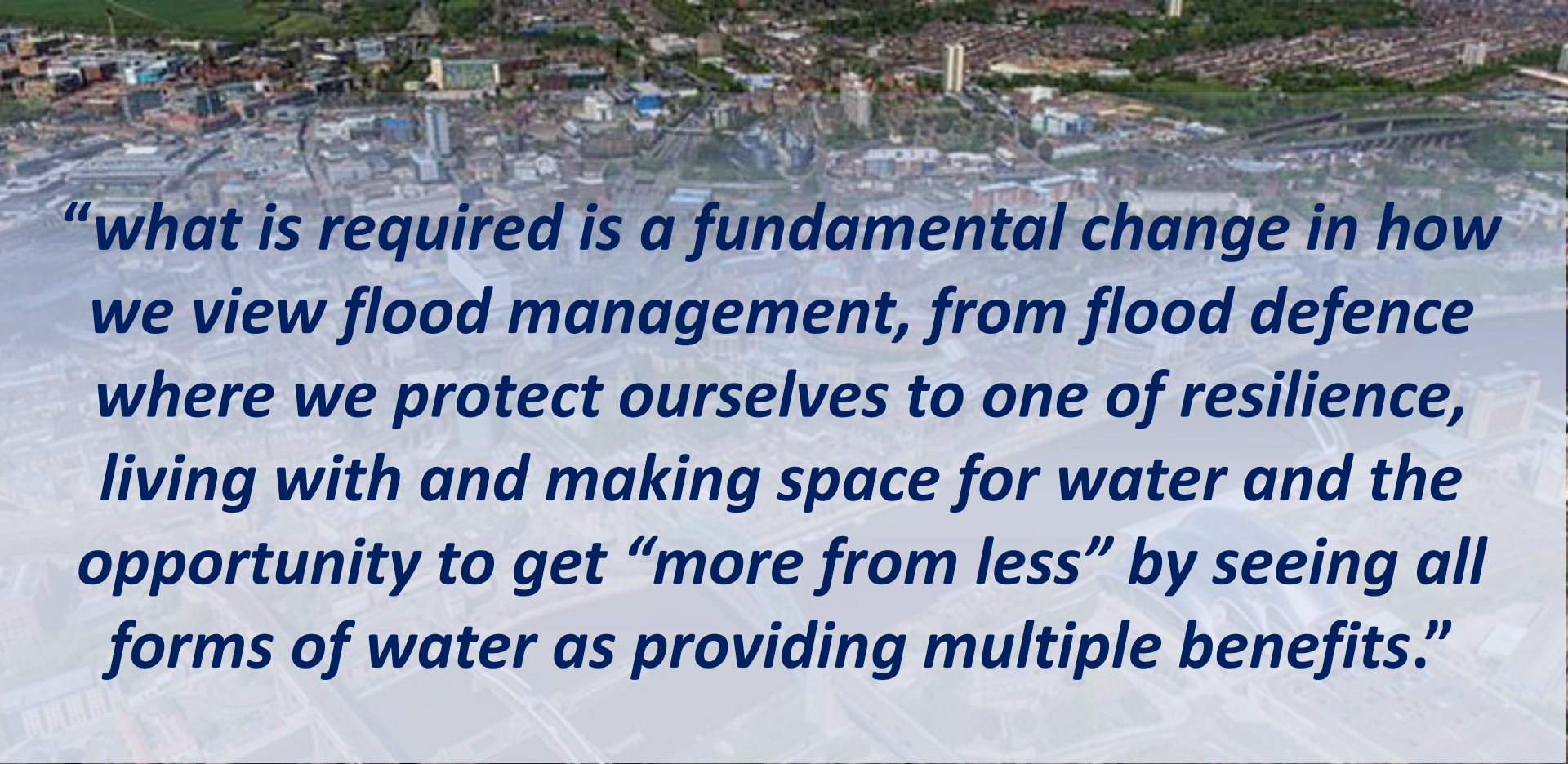
[UU and Severn Trent team up for non-domestic retail market](#)

[Newcastle commits to Blue-Green Infrastructure plan](#)

[Putting the focus on phosphorus](#)

Conclusions

- Flooding is the most serious natural hazard we face – not just in the UK or NZ, but globally.
- The magnitude and frequency of flood events are set to increase unacceptably.
- We can't prevent flooding but we can reduce flood damage and disruption through changes to urban planning + development.
- Flood risk can be kept at current levels if we adopt Blue/Green+Grey approaches and build urban flood resilience, but we must start *NOW!*



“what is required is a fundamental change in how we view flood management, from flood defence where we protect ourselves to one of resilience, living with and making space for water and the opportunity to get “more from less” by seeing all forms of water as providing multiple benefits.”

Closing Message

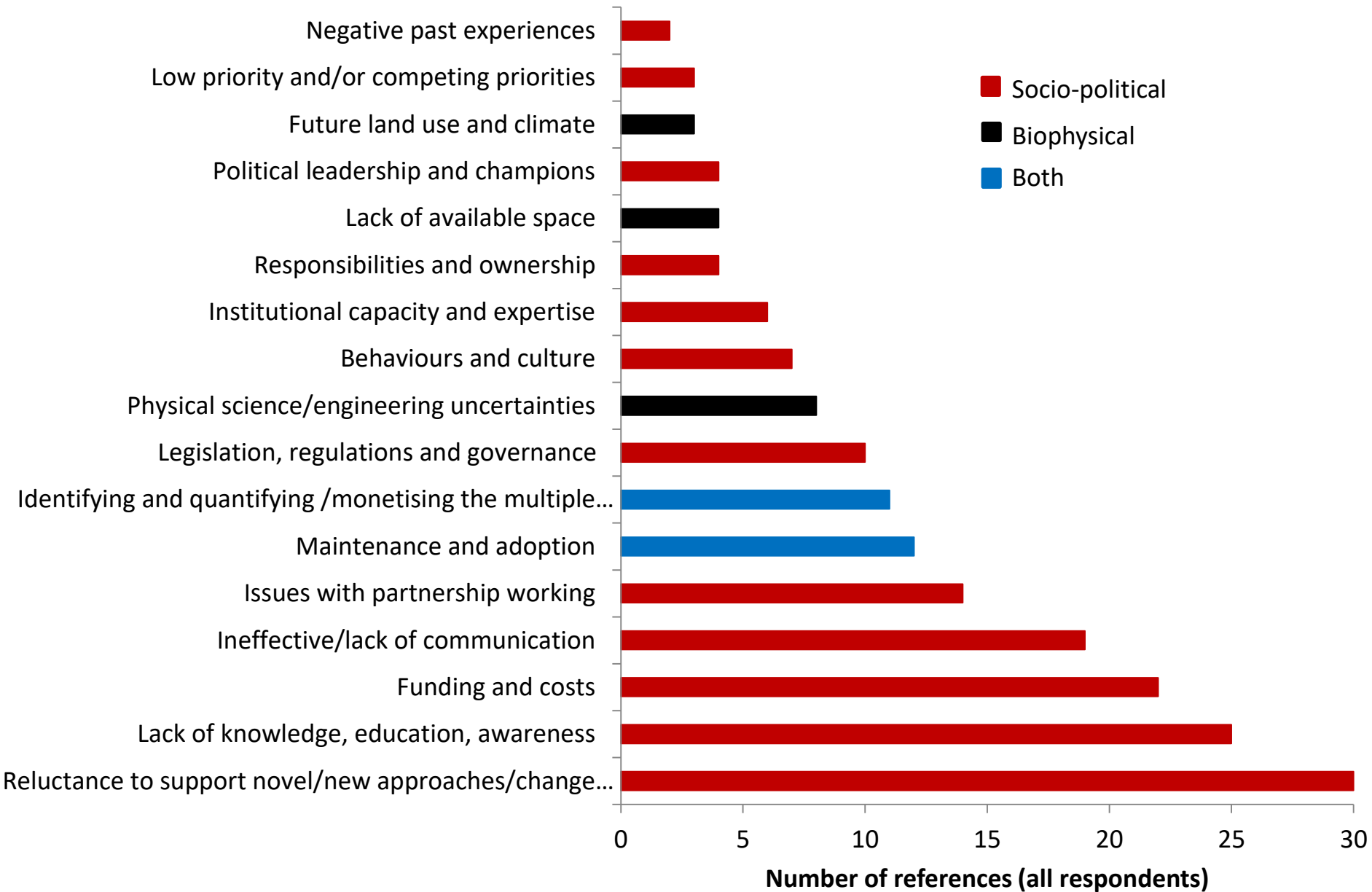
Commission of Inquiry into flood resilience of the future titled ‘Living with water’, March 2015. All Party Group for Excellence in the Built Environment, House of Commons, London SW1A 0AA: p. 32, para. 3.

The **Blue-Green** Cities Research Consortium was supported by:

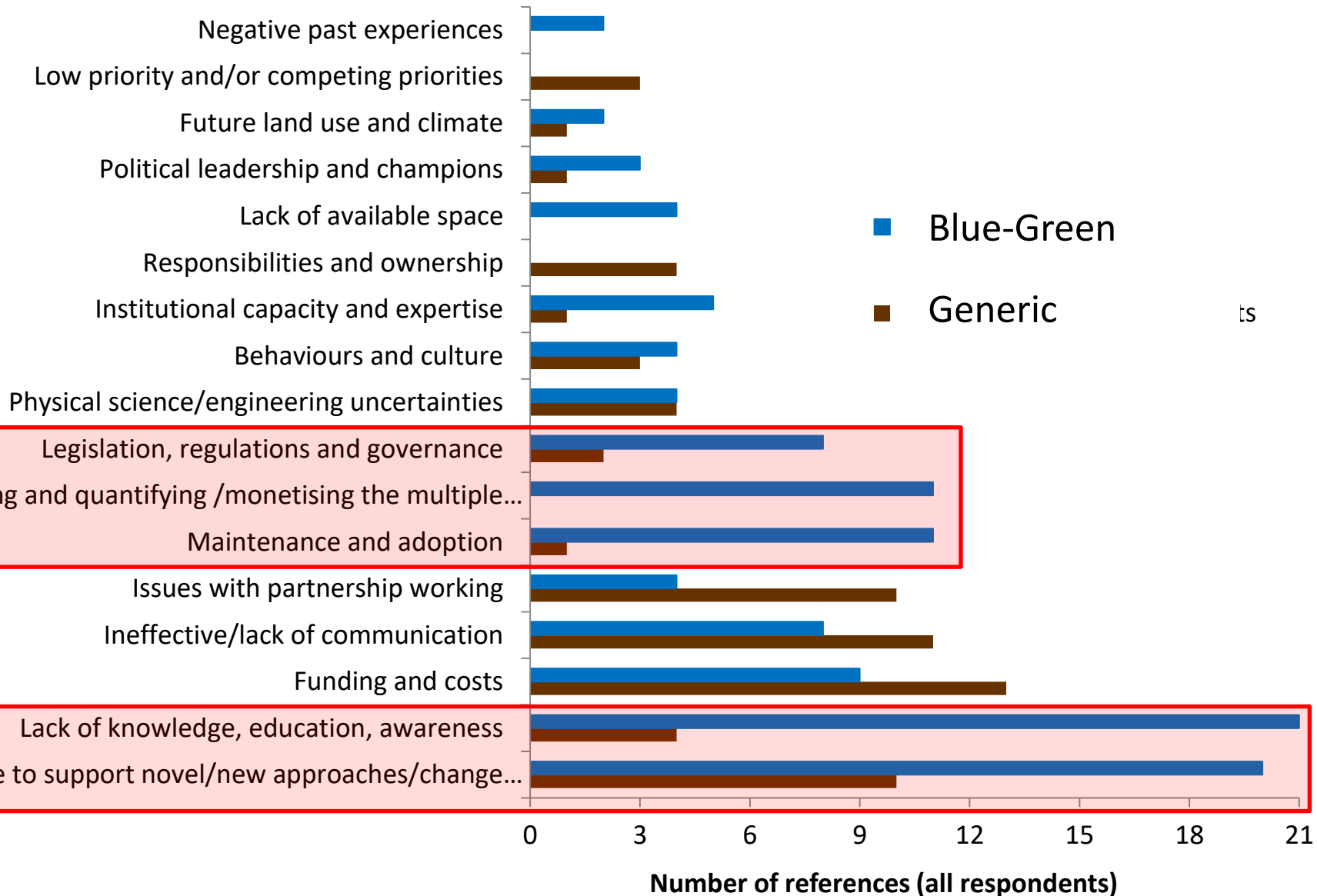
- **Engineering and Physical Sciences Research Council**
- **Northern Ireland Rivers Agency**
- **Environment Agency**
- **Newcastle City Council**
- **Northumbrian Water Limited**



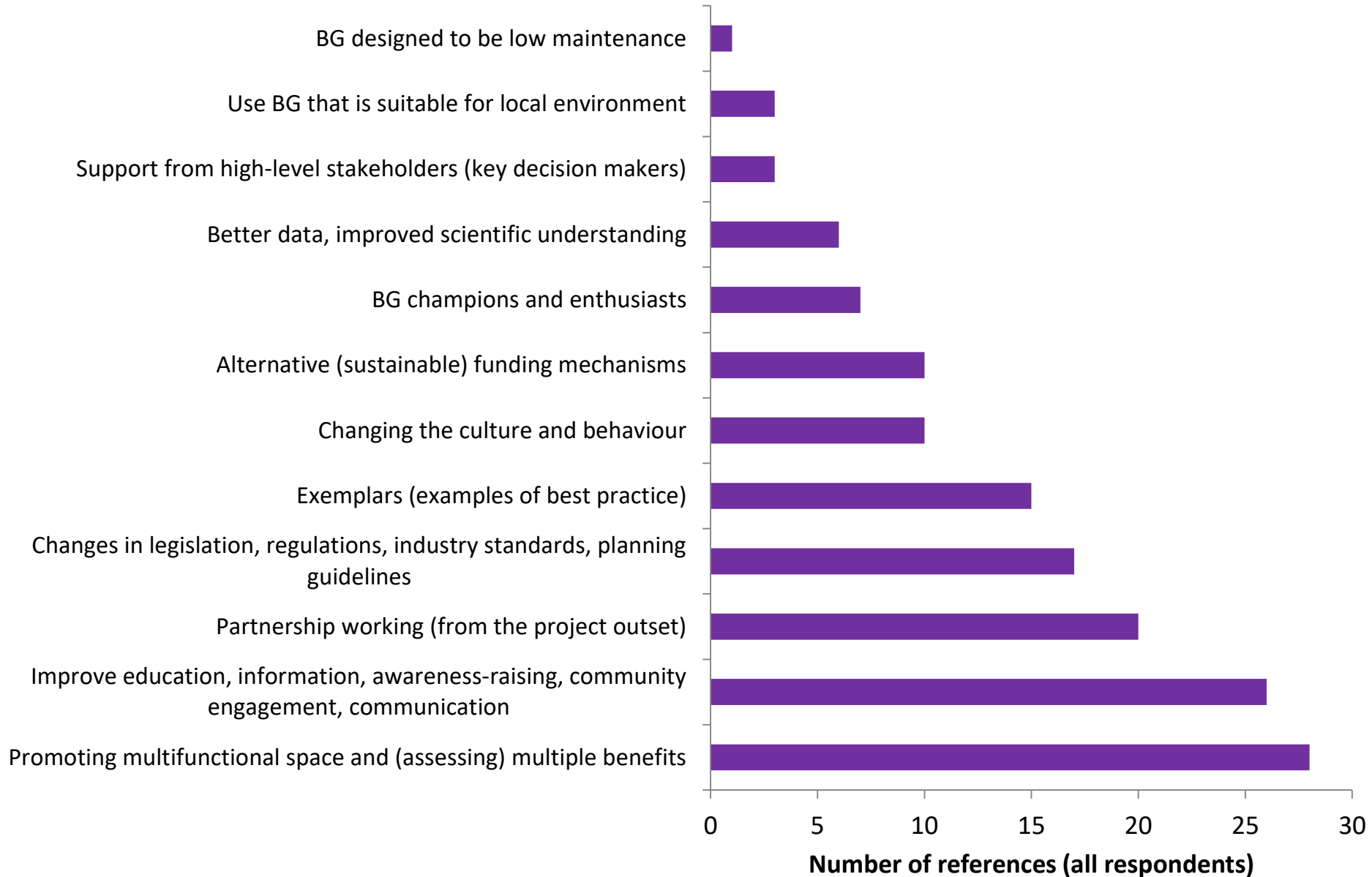
Newcastle barriers to Innovation



Newcastle Barriers to innovation – some are specific to Blue-Green, others are relevant to urban water in general



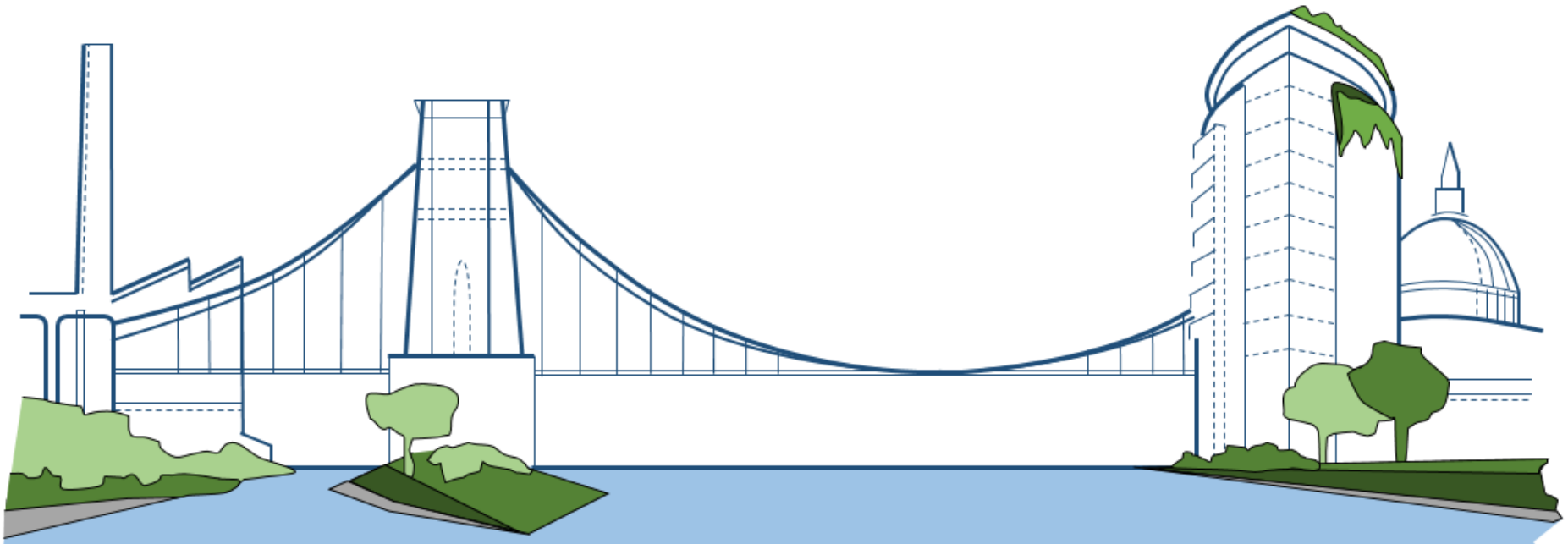
Newcastle strategies to overcome barriers to innovation



4. ACHIEVING FLOOD RESILIENCE

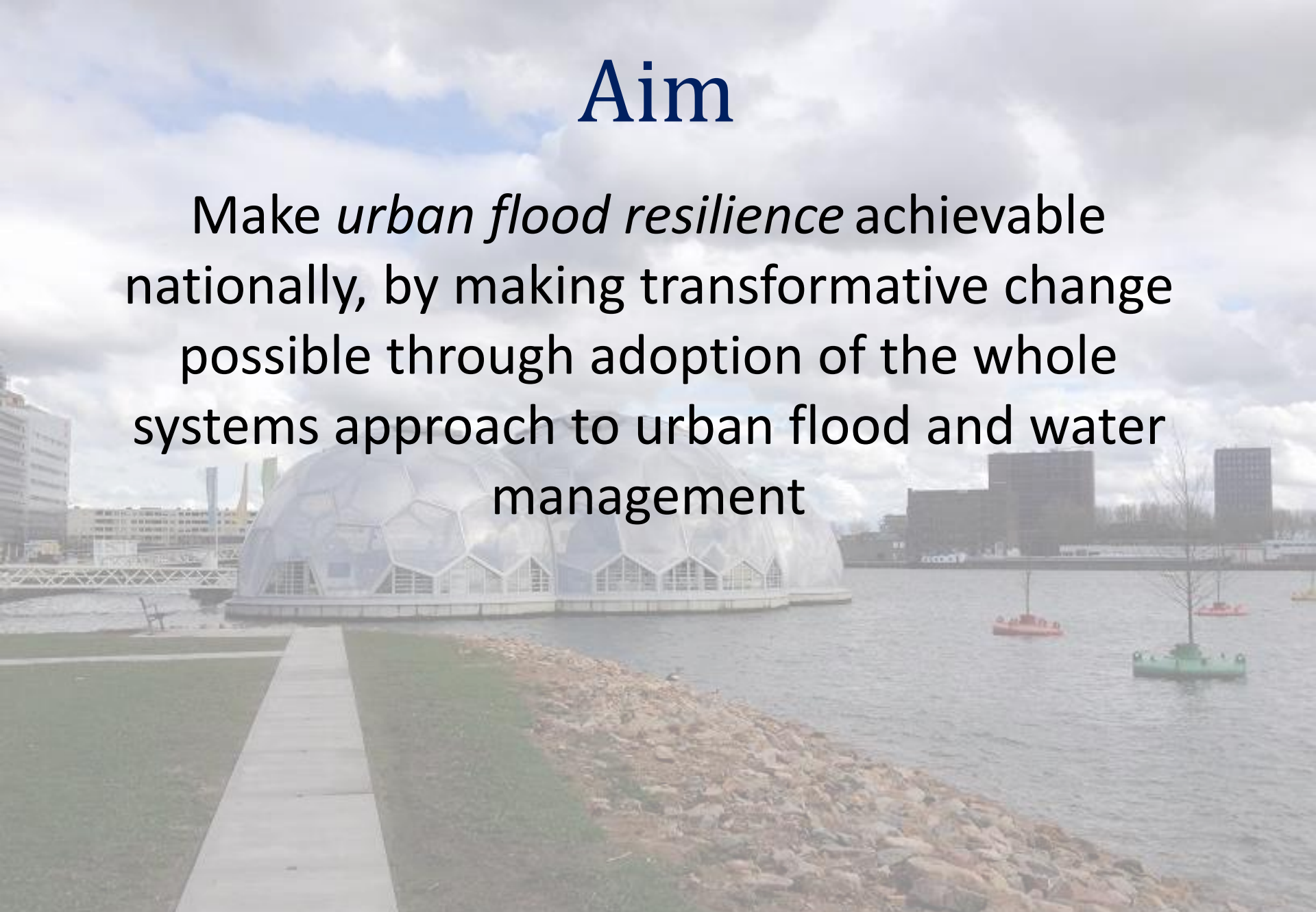
A new Research Consortium

Achieving Urban Flood Resilience in an Uncertain Future



Aim

Make *urban flood resilience* achievable nationally, by making transformative change possible through adoption of the whole systems approach to urban flood and water management

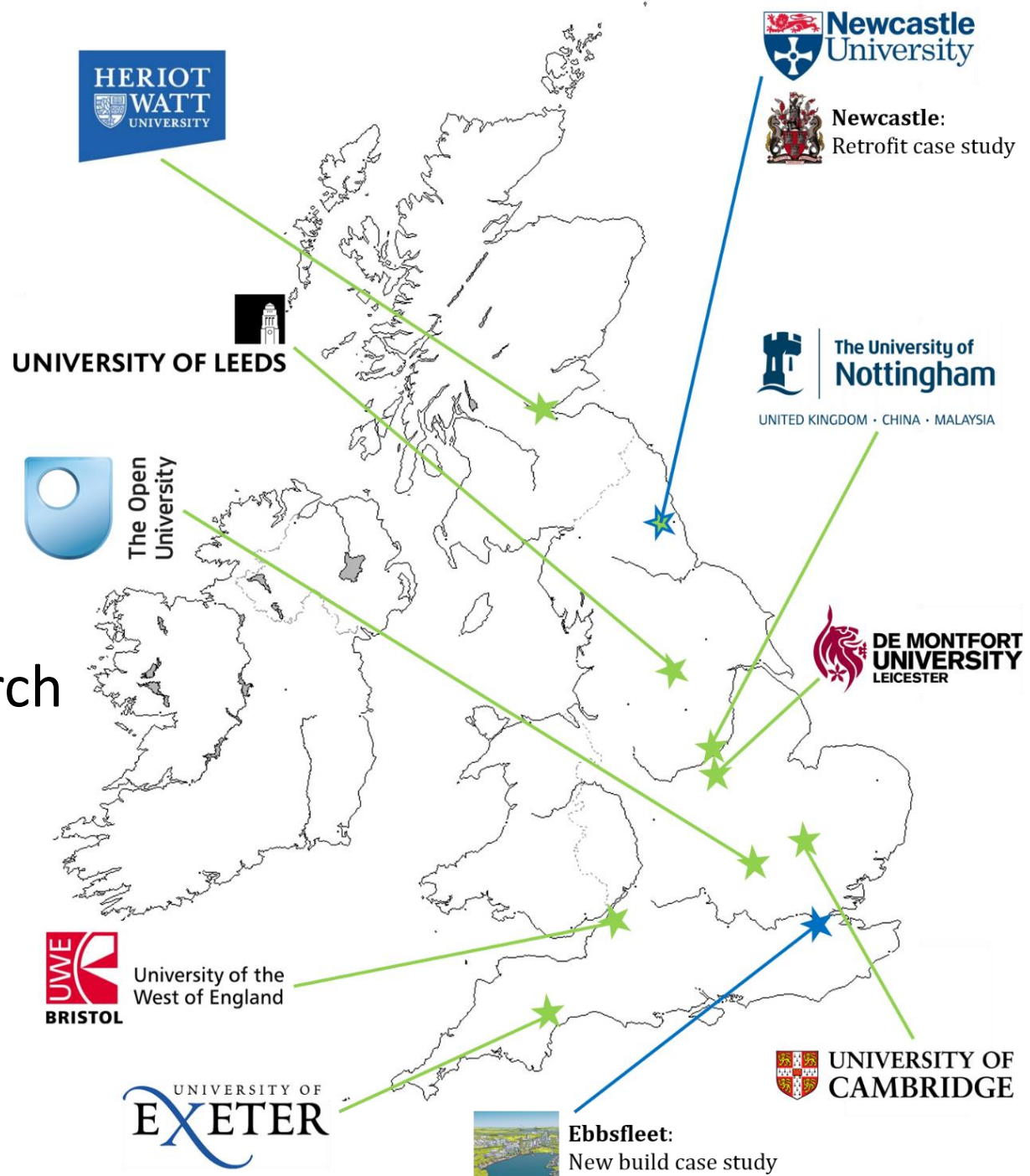


Urban Flood Resilience

A city's capacity to maintain future flood risk at acceptable levels by:


1. preventing deaths and injuries,
2. minimising damage and disruption during floods,
3. recovering quickly afterwards,
4. ensuring social equity,
5. protecting the city's cultural identity and economic vitality


UK Urban Flood Resilience Research Consortium

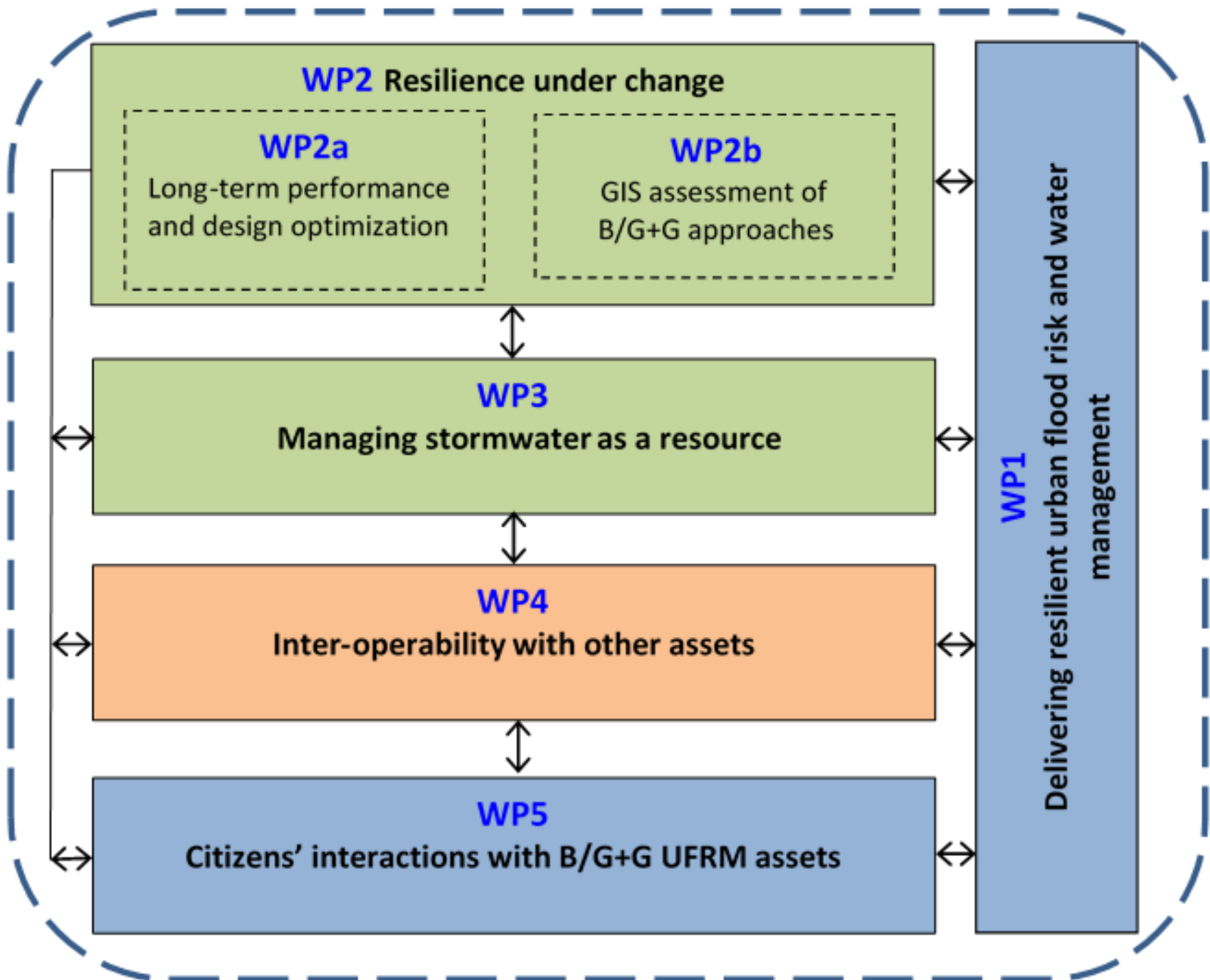


Urban Flood Resilience Research Themes

- 
- **Planning** that puts UFRM at the heart of urban planning & focuses on interfaces between planners, developers, engineers and *beneficiary communities*

- 
- **Engineering Design** of the integrated Blue/Green and Grey (**B/G+G**) treatment trains that support resilient management of both water quantity and quality

- 
- **(Re)Development** of flood and water management assets that function inter-operably with other urban systems: inc. transport, energy, land-use and natural systems



Case study sites



-  Houston Industrial Estate, Livingston
-  Edinburgh, Goreglen and Livingston
-  Newcastle upon Tyne
-  Ouseburn catchment, Newcastle
-  London Borough of Sutton
-  Greater London
-  Ebbfleet Garden City
-  England, Wales, Scotland and Northern Ireland¹
-  North West Cambridge Development
-  Bristol case studies: Hanham Hall eco-development, Embleton Road, Emersons Green

¹comparison of institutional barriers to SuDS

Urban Flood Resilience - Case Study Cities

Newcastle



Retrofit and urban renewal

Ebbsfleet



New build



EBBSFLEET GARDEN CITY

Where London meets
the Garden of England...

Welcome to Britain's first new
Garden City in 100 years.



Ebbsfleet
Development





EBBSFLEET
GARDEN CITY

It is made from high-quality
materials. It is made to last
and is designed to be
easy to maintain.

Connects Ebbsfleet
stations,
the transport
south-east

EBBS
GARDEN CITY

> Landscape infrastructure

Bringing in the green and the blue

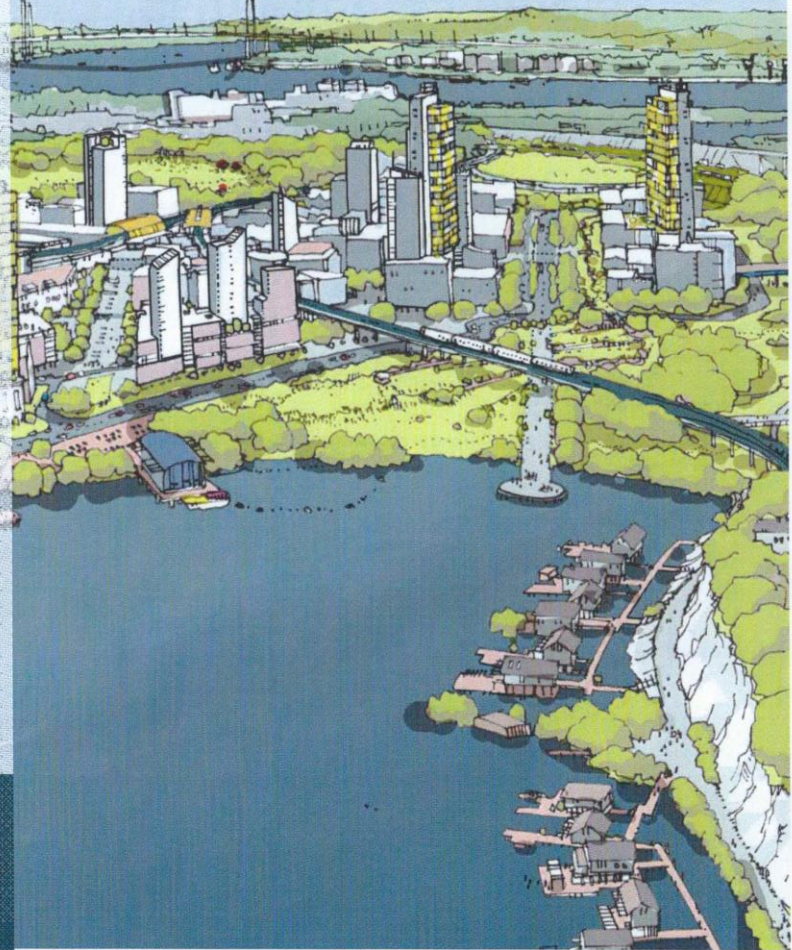
Garden grid establishes integrated green infrastructure network

- 7 new major City Parks
- A local neighbourhood park within 5 mins walk of all residents
- International Landscape competition to design and deliver world class innovative green corridors, parks, and play areas to get the community engaged and active
- Strategy exploit the natural features and topography of Ebbsfleet to create an active Ebbsfleet and become a centre for sports and leisure in Kent.

>Progress

1.2

Km of new cycle and footpaths under design and construction in 2016/2017.



Sheffield is the pilot core city in the new *National Flood Resilience Review*

The NFRR recommends transformative change to:

“unlock the economic, aesthetic and ecological value of the city’s water at the same time as making (Sheffield) an even nicer place to live.”

and NFRR will,

“be working with Sheffield to identify development that will beautify the city-scape, unlock opportunities for urban regeneration and fit with local priorities.

Our aim is for Sheffield, and thereafter the other Core Cities, to own and lead this resilient (re)development.”

(NFRR, p25).

Connswater Community Greenway Urban River Restoration

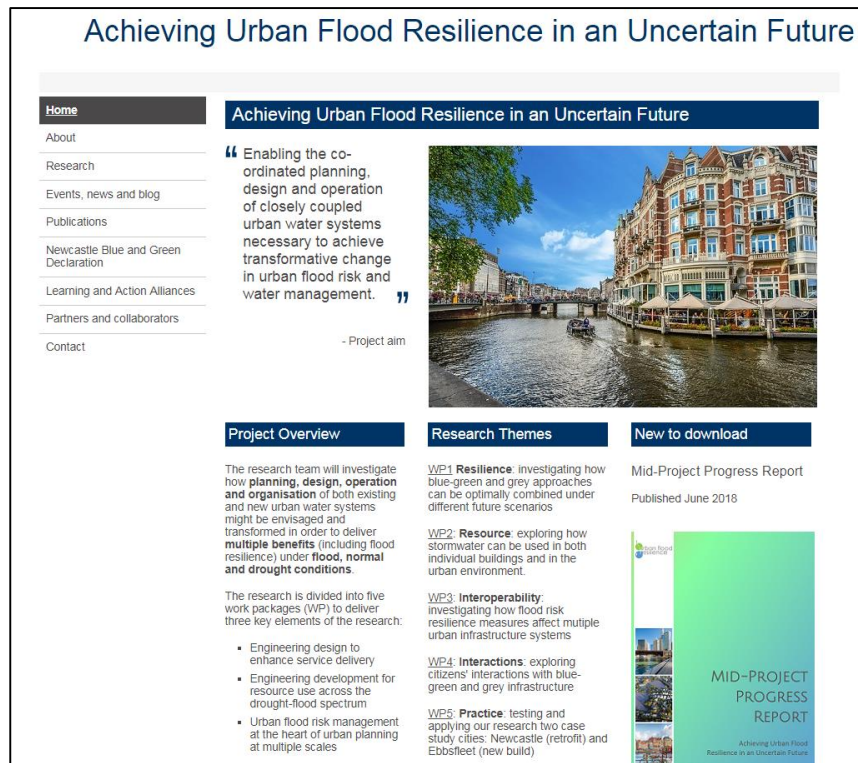


For more information:

➤ **Project blog:**
<http://blogs.nottingham.ac.uk/blue-greencities/>

➤ **Project website**
www.urbanfloodresilience.ac.uk

➤ 



Achieving Urban Flood Resilience in an Uncertain Future

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Newcastle Blue and Green Declaration
Learning and Action Alliances
Partners and collaborators
Contact

Achieving Urban Flood Resilience in an Uncertain Future

“ Enabling the co-ordinated planning, design and operation of closely coupled urban water systems necessary to achieve transformative change in urban flood risk and water management. ”

- Project aim

Project Overview
The research team will investigate how **planning, design, operation and organisation** of both existing and new urban water systems might be envisaged and transformed in order to deliver **multiple benefits** (including flood resilience) under **flood, normal and drought conditions**.

The research is divided into five work packages (WP) to deliver three key elements of the research:

- Engineering design to enhance service delivery
- Engineering development for resource use across the drought-flood spectrum
- Urban flood risk management at the heart of urban planning at multiple scales

Research Themes

WP1 Resilience: investigating how blue-green and grey approaches can be optimally combined under different future scenarios

WP2: Resource: exploring how stormwater can be used in both individual buildings and in the urban environment.

WP3: Interoperability: investigating how flood risk resilience measures affect multiple urban infrastructure systems

WP4: Interactions: exploring citizens' interactions with blue-green and grey infrastructure

WP5: Practice: testing and applying our research two case study cities: Newcastle (retrofit) and Ebbfleet (new build)

New to download
Mid-Project Progress Report
Published June 2018

MID-PROJECT PROGRESS REPORT
Achieving Urban Flood Resilience in an Uncertain Future



UrbanFloodResilience
@BlueGreenCities

Multi-institutional research project led by the University of Nottingham investigating urban flood resilience in an uncertain future. Tweets by Emily and Shaun.

Acknowledgement

The research presented in this presentation is being conducted as part of the Urban Flood Resilience Research Consortium with supported from:



5. CONCLUSIONS AND CLOSURE

Conclusions

- Flooding is the most serious natural hazard we face – not just in the UK or NZ, but globally.
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- Flood risk can be kept at current levels if we adopt Blue/Green+Grey approaches and build urban flood resilience, but we must start *NOW!*

Further Information

Geographical Journal

Thorne, C., 2014. Geographies of UK flooding in 2013/4. *The Geographical Journal*, Vol. 180(4), pages 297-309.

<http://onlinelibrary.wiley.com/doi/10.1111/geoj.12122/full>

Blue-Green Cities Research Consortium

<http://www.bluegreencities.ac.uk>

Urban Flood Resilience Research Consortium

www.urbanfloodresilience.ac.uk

Blue-Green+Grey *Treatment Trains* to manage the Rural - Urban Stormwater Cascade



- Manage water quantity and quality at every stage of the urban water cascade
- Make best use of urban green spaces and grey infrastructure to reduce flood and drought risks through integrated management
- Use stormwater as a resource wherever possible
- Make the water system inter-operable with other urban systems inc. energy, transport, public health, recreation, forestry and ecology.