Project Inception Report

Urban Flood Resilience in an Uncertain Future

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1. INTRODUCTION

1.1. Context

In March 2015 House of Commons Commission of Inquiry into flood resilience highlighted the challenge of dealing with increasingly frequent and severe floods, stating, "*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* (House of Commons, 2015)." The Commission's statement immediately followed a prolonged period of severe and widespread coastal, river, surface water and groundwater flooding between December 2013 and 2014 (Thorne, 2014). It was, in turn followed by intense, prolonged rainfall and catastrophic flooding in December 2015 that provided an unwelcome but powerful endorsement of that statement. The Environment Agency estimate 5.2 million properties in England are at risk of flooding and the Adaptation Sub-Committee (ASC) of the Committee on Climate Change reported in October 2015 that significant additional investment and adaptation action will be needed to counter the increase in UK flood risk expected under global warming of 2°C (Sayers et al., 2015). Key infrastructure will also be at significantly increased risk, with numbers of assets exposed to flooding by a 1:75-year event increasing by 30%. The ASC stress that the most significant contribution to risk reduction will stem from a whole system approach to adaptation, recognising interdependencies with other urban systems, including transport, energy and land-use.

The aim of this engineering-led, multidisciplinary proposal is to conduct research necessary to make *urban flood resilience*[1] achievable nationally, by making transformative change possible through adoption of the whole systems approach to urban flood and water management advocated by the ASC. The central research question to be addressed is how planning, design, operation and organisation of both existing and new urban water systems (including flood risk management, waste/stormwater management and water security) should be re-envisaged and transformed to:

- ensure satisfactory service delivery under flood, normal and drought condition states;
- enhance and extend the useful lives of ageing grey assets by supplementing and integrating them with multi-functional Blue/Green infrastructure and urban green spaces.

This aligns with priorities set by Defra/EA and the Living with Environmental Change (LWEC) partnership, which recognise adaptable infrastructure, working with natural processes and effective stakeholder engagement as key to achieving multiple benefits. It is also central to the growing investment in water engineering in the current EPSRC portfolio, specifically in ways which see the key challenge of dealing with flooding and water scarcity as a single inter-connected problem.

Our approach will lever recent findings from the successful EPSRC Consortium 'Delivering and Evaluating Multiple Flood-risk Benefits in Blue-Green Cities' (EP/K013661, www.bluegreencitires.ac.uk), which has worked in partnership with stakeholders through a Learning and Alliance (LAA) to deliver methods for evaluating the multi-functional benefits of Blue/Green approaches to sustainable urban flood risk management that incorporate Sustainable Drainage System (SuDS).

In addressing urban flood and water resilience, three distinct research themes are identified:

1. Engineering Design of the spatially-integrated treatment trains of the Blue/Green and Grey (B/G+G) infrastructure needed to permit resilient management of urban water quantity and quality

1 We define *urban flood resilience* in terms of a city's capacity to maintain future flood risk at tolerable levels by preventing deaths and injuries, minimising damage and disruption during floods, and recovering quickly afterwards, while ensuring social equity and protecting the city's cultural identity and economic vitality.

in an uncertain future. i.e. coupling models for urban hydrology, hydrodynamics, stormwater storage and water quality to enhance continuous *service delivery*;

2. Engineering Development of Urban Flood Risk Management (UFRM) and water assets that function inter-operably with other urban systems including transport, energy, land-use and natural systems. i.e. integrating systemic infrastructure interdependencies to reduce disruption during floods and enrich *water resource utilisation*;

3. Conception of new approaches that put UFRM at the heart of urban planning, i.e. focusing on the interfaces between planners, developers, engineers and *beneficiary communities*.

1.2. Research Team

The names, affiliations and research interests of the Consortium Team are listed overleaf in Table 1. Short biographies of team members may be found in Annex I.

Table 1 Urban Flood Resilience Research Team

Team member	**University and home page**	**Research areas in Urban Flood Resilience Project**
Colin Thorne	Nottingham: http://www.nottingham.ac.uk/geography/people/colin.thorne	Urban flooding, geomorphology and sustainable flood risk management
Emily O'Donnell	Nottingham: http://www.nottingham.ac.uk/geography/people/emily.o'donnell	Learning and Action Alliances, overcoming barriers to sustainable Blue-Green flood risk management, flooding
Lindsey Air	Nottingham	Consortium Administrator
Nigel Wright	De Montfort: http://www.dmu.ac.uk/about-dmu/university-governance/executive-board/nigel-wright.aspx	Urban flood modelling (surface water, river flooding and coincident flooding events)
David Dawson	Leeds: https://engineering.leeds.ac.uk/staff/572/Dr_David_Dawson	Infrastructure adaptations and evaluation
Leeds RA	To start in Year 2	TBC
Richard Fenner	Cambridge: http://www-csd.eng.cam.ac.uk/people/staff/fenner	Urban drainage systems, multi-criteria analysis of flood risk management benefits. Stormwater as a resource.
Leon Kapetas	Cambridge: http://www-csd.eng.cam.ac.uk/people/staff/leon-kapetas	Urban drainage systems, multi-criteria analysis of flood risk management benefits. Stormwater as a resource.
Chris Kilsby	Newcastle: http://www.ncl.ac.uk/ceg/role/profile/chriskilsby.html#background	Urban inundation modelling (coupled surface and sub-surface systems)
Vassilis Glenis	Newcastle: http://www.ncl.ac.uk/ceg/role/profile/vassilisglenis.html	Urban inundation modelling (coupled surface and sub-surface systems), CityCAT development
Greg O'Donnell	Newcastle: http://www.ncl.ac.uk/ceg/role/profile/gmodonnell.html#background	Hydrological modelling, model coupling (e.g. combining CityCAT and SHETRAN models)
Jessica Lamond	University of the West of England: http://people.uwe.ac.uk/Pages/person.aspx?accountname=campus%5Cje-lamond	Citizen and stakeholder attitudes and behaviours with respect to flood risk management
Glyn Everett	University of the West of England: http://people.uwe.ac.uk/Pages/person.aspx?accountname=campus\gd-everett	Processes of social inclusion/exclusion as they relate to and affect citizen and stakeholder engagement in flood risk management.
Scott Arthur	Heriot-Watt: http://www.sbe.hw.ac.uk/staff-directory/scott-arthur.htm	Risks of blockage at structures in urban watercourses due to sediment and/or debris

Heather Haynes	Heriot-Watt: http://www.sbe.hw.ac.uk/staff-directory/heather-haynes.htm	Sediment dynamics, geomorphology, habitats and ecosystems in urban watercourses
Deonie Allen	Heriot-Watt: http://www.sbe.hw.ac.uk/staff-directory/deonie-allen.htm	Sediment and debris dynamics, blockage risks, and geomorphology in urban watercourses
Heriot-Watt RA	To start in Year 3	TBC
Karen Potter	Open University: http://www.open.ac.uk/people/kp6973	Planning and flood risk management, use of social science theory in understanding and overcoming barriers to innovation
Tudor Vilcan	Open University: TBC http://www.open.ac.uk/people/tv655	Resilience, land-use and flood risk management, use of social science theory in understanding and overcoming barriers to innovation
David Butler	Exeter: http://emps.exeter.ac.uk/engineering/staff/db242	Water engineering, integrated modelling of urban water systems, urban drainage and water efficiency
Zoran Kapelan	Exeter: http://emps.exeter.ac.uk/engineering/staff/zkapelan	Water engineering, flexible design/Real Options, metabolism based methodology for long-term planning of urban water systems
Sangaralingam Ahilan	Exeter: TBC http://emps.exeter.ac.uk/engineering/staff/sa632	Sustainability and integrated modelling of urban water systems, urban drainage and water efficiency

1.3. Aims, Objectives and Outcomes

To enable the coordinated planning, design and operation of closely coupled urban water systems necessary to achieve transformative change in urban flood risk and water management, we must answer the following specific research questions:

- How can urban flood and water quality treatment infrastructure be adapted to meet the challenges posed by changes in;
  a) climate,
  b) flood and water governance,
  c) economic development,
  d) society, and
  e) environmental values

  that are undeniable and unavoidable, but highly uncertain?

- How can currently discrete urban inundation models, infrastructure data and community exposure/vulnerability information be combined to support local, regional and national assessment of the potential for integrated systems of B/G+G infrastructure to meet the challenges of climate change, urban growth, social and neighbourhood inequality and environmental deterioration in UK core cities?

- How can engineered systems be better aligned with natural processes to:
  a) realise the resource potential of all forms of urban water, with opportunities for storage, recovery and reuse being taken at every stage of the urban water cycle, and
  b) become increasingly inter-operable with other urban systems (e.g. transport, land-use, energy)?

- How can engineering, scientific and vernacular knowledges be:
  a) co-produced by urban water professionals, academics and beneficiary communities, and
  b) applied to design adaptive flood and water infrastructure that provides safe, healthy and attractive Blue-Green urban spaces that are intensively used and highly valued by citizens and communities?

- How must interactions between:
  a) responsible authorities, and
  b) stakeholders (ranging from the planners and developers responsible for wider urban forms, to the engineers and scientists who design optimal solutions for specific locations and the communities at risk of flooding)

  evolve to enable cities to achieve flood resilience and water security that in ways that are sustainable, reliable and enduring?

In seeking answers to these research questions we will pursue **objectives** intended to:

1. develop urban flood and water management systems with the adaptive capacity essential to keep flood risk at acceptable levels however climate changes [WP1a].
2. produce a GIS-based tool to support comparative evaluation of the costs and benefits of alternative UFRM solutions and the potential for integrated B/G+G systems to deliver affordable urban flood resilience at the city, regional and national scales [WP1b].
3. design integrated stormwater treatment trains capable of;
   a) enhancing service provision 24/7 +365,
   b) improving asset performance, and
   c) delivering enhanced ecosystem services through integrated management of water quantity and quality that treats and values stormwater as a resource as well as a hazard [WP2].

4. enhance inter-operability of UFRM assets with other systems including:
   a) transport,
   b) energy, and
   c) land-use to expand the capacity of integrated systems of B/G+G infrastructure to contribute to wider urban resilience to climate change [WP3].

5. create connectivity in urban flood and water planning and management systems to support multiple functions while balancing trade-offs and facilitating positive interactions between:
   a) engineered assets,
   b) advances in water technology,
   c) natural processes in restored urban streams and drainage systems, and
   d) the preferences and behaviours of the citizens and communities that benefit from systems of B/G+G infrastructure [WP4 and WP5].

6. make the objectives of multi-objective planning policies deliverable in practice by bringing together engineers, stakeholders and Local Authorities in partnership working [WP5].

The following **deliverables** will be significant outcomes of the project:

Theme 1: *Engineering design to enhance service delivery*

- Next generation flood and water management models that bridge the interfaces between urban/rural and engineered/natural hydrological systems, making them capable of: simulating urban floods, droughts and water cycles within their wider catchment and metropolitan contexts to deliver acceptable service provision 24 hours a day, 365 days a year [WP1a].
- The steps necessary to design, implement and operate coupled B/G+G stormwater treatment trains through development of adaptation designs and pathways that are appropriate to their location, community and scale [WP1a].
- GIS toolbox for a National Assessment based on:
  a) identifying appropriate location-specific B/G+G infrastructure combinations,
  b) considering catchment and urban water resources and their variability,
  c) location-specific flood risk assessment (especially from coincident flooding),
  d) sewer condition and capacity, and
  e) stormwater resource potential for UK cities,
  under present and future climates [WP1b].

Theme 2: *Engineering Development for resource use across the flood-drought spectrum*

- Enhanced design methods that co-optimise management of urban runoff simultaneously to mitigate flood hazards *and* capture the benefits of treating stormwater as a valuable, though under-utilised, resource, leading to practical solutions for stormwater recovery, recycling and reuse [WP2].
- Improved integration of UFRM and water, energy and transport infrastructure leading to expanded inter-operability of urban 'systems-of-systems' [WP3].

Theme 3: *Putting UFRM at the heart of urban planning, at multiple scales*

- Characterisation of citizens' behaviours and decision-making concerning flooding and urban water use, and the means of informing those decisions through improved appreciation of flood risk and water literacy [WP4].

- New protocols for placing flood and water management decision making at the heart of urban planning, as recommended by Pitt (2008) and legislated for in the Flood and Water Management Act (2010) [WP5].

- Case studies demonstrating Blue-Green approaches to flood and water management that are innovative, inclusive, resilient and suitable for application in the contexts of:
  a) retrofit/urban renewal, and
  b) new build/new town applications [WP5].

Taken together and explored practically in the case study cities these carefully inter-woven models, tools and implementation approaches have the potential to co-produce the necessary understanding needed for coupling blue, green, grey and smart infrastructure in new and context specific ways, so that excess water quantities and poor water qualities can be dealt with using the integrated treatment trains required to achieve the modern paradigm of a *water-sensitive city*.

1.4. Approach and Methodology

The research takes a radical approach based on methods and models that are locally-defined (making them applicable), but spatially-linked through the 'stormwater cascade' (Figure 1), making them transferrable and suitable for up-scaling, regionally and nationally.

The engineering core of this project couples an array of carefully selected, physics-based models to support investigation of how stormwater cascades through a city's drainage system, accounting for the dynamics of not just water, but also sediment, debris, natural solutes and contaminants carried by urban runoff. Based on the capability of this suite of models to simulate water flow, storage and quality within an urban system, we will investigate how the performance of grey systems (e.g. lined drainage conduits/channels/ditches, underground pipes and detention tanks) can be improved by adding Blue-Green Infrastructure (BGI) and SuDS, to create integrated treatment trains designed to manage both the *quantity* and *quality* of urban runoff. Models and design solutions will be developed and tested in the contexts of retro-fit (as part of urban renewal and uplift in Newcastle-upon-Tyne) and new build (as part of creation of a 'garden city' in Ebbsfleet, Kent). Our intent is to work out and demonstrate how resilience to floods and droughts can be achieved using integrated systems of B/G+G assets, no matter how the climate changes in future, assuring continuous, long term service delivery.

The research will adopt a *whole systems perspective* that recognises interdependencies with other urban systems, including transport, energy and land-use. This will identify new opportunities for managing stormwater as a resource that will then be explored. This will add to the multi-functional benefits of using BGI to manage flood risk by increasing water security. Possibilities range from non-potable uses in homes or commercial buildings (based on RainWater Harvesting (RWH)) to irrigating green infrastructure (e.g. street trees), managing subsidence in clay soils, soil moisture enhancement and groundwater recharge. Wider benefits may extend to local energy generation using drainage infrastructure (i.e. micro-hydropower) and enhancement of urban watercourses and ecosystem services.

In short, the models and protocols developed will form the basis for assessment of the potential for the optimised combinations of B/G+G and smart infrastructure to deliver multiple-benefits in UK cities nationwide.

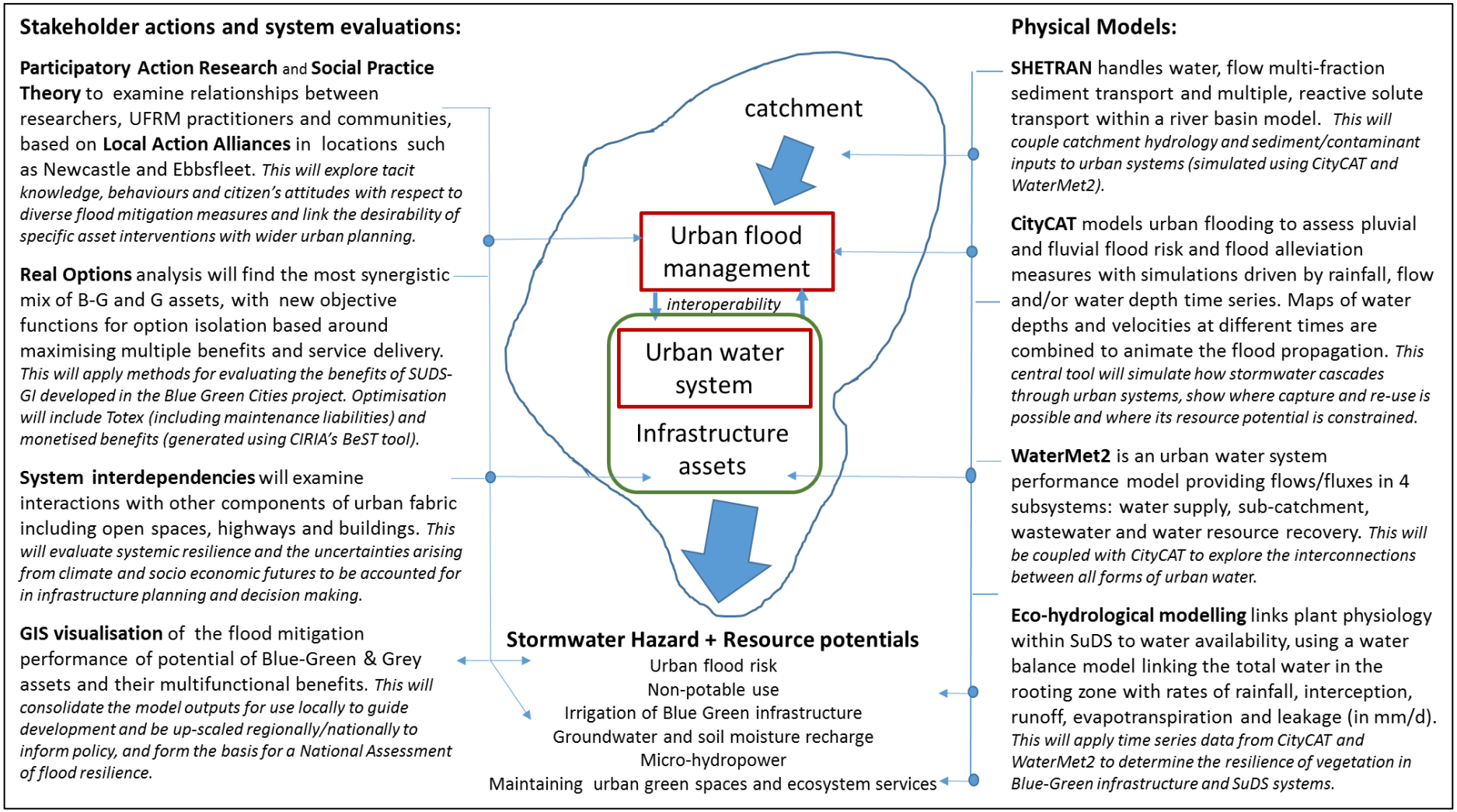

Figure 1 The scope of this project covers the entire 'stormwater cascade' from when water enters to when it leaves the urban area (centre panel), employing a suite of linked research methods and models to simulate physical and bio-chemical processes, and cross-tabulating with water governance, planning/development and stakeholder attitudes, preferences and actions at every stage

However, the goal of optimising urban flood and water management can only be achieved through a deep understanding of citizen and community preferences with respect to managing flood risk. This will be addressed using Participatory Action Research (PAR) and Social Practice Theory (SPT) to examine the attitudes and responses of citizens and communities to innovation in flood and water management. Moreover, engineering solutions must be better informed by and explicitly accounted for in urban planning and development at all spatial scales. For this reason, our research will extend to investigation of the socio-political planning, development and organisational context and how this impacts the collaborative governance of UFRM. This aspect of the work is essential to underpin and enable implementation of the engineering analyses and solutions identified in the core research outlined above.

The mechanism for bringing together engineering, social and planning components of the project will be co-location research by the entire project team in Newcastle-upon-Tyne, Tyne and Wear, and Ebbsfleet, Kent. Team research in these case study cities will establish how barriers to innovation can be overcome despite uncertainties in future urban climates, land-use, development and political leadership. Critical engagement with planners, developers and land-owners throughout the project will feed back and inform the core engineering focus of the work, building on the current trend towards the development of urban infrastructure observatories to explore responses to the innovative changes needed to achieve urban flood resilience.

1.5. Project Duration

The Project commenced at the University of Nottingham, De Montfort University, Open University, University of Leeds and University of Exeter on 1st October 2016. University of the West of England started on 1st September 2016. University of Cambridge started on 1st November 2016, and Heriot-Watt University started on 1st December 2016. Research at each institution is scheduled to be completed 36 months after the start date.

2. RESEARCH PROGRAMME

2.1. Research Structure and Schedule

The project will be performed as an integrated and sequenced set of five Work Packages (WPs) and within the contexts of Key Themes and Pressures (Figure 2). WP boundaries will be permeable. WPs and activities within them are scheduled to supply outputs needed to support progress in other WPs, and test applications in the case study cities, at the appropriate times (Figure 3). Project dissemination will increase in intensity in years 2 and 3.

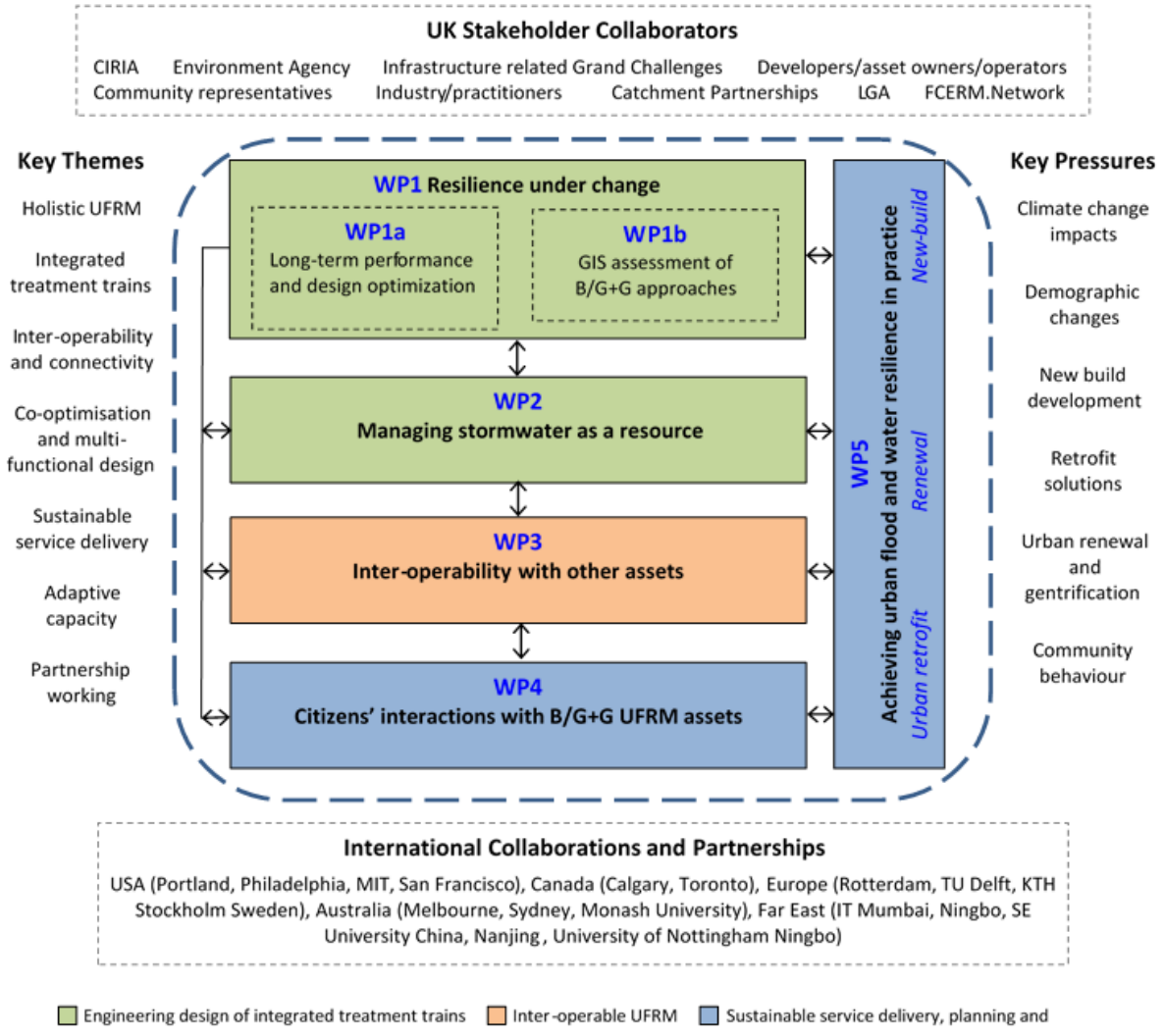

Figure 2 Project Structure

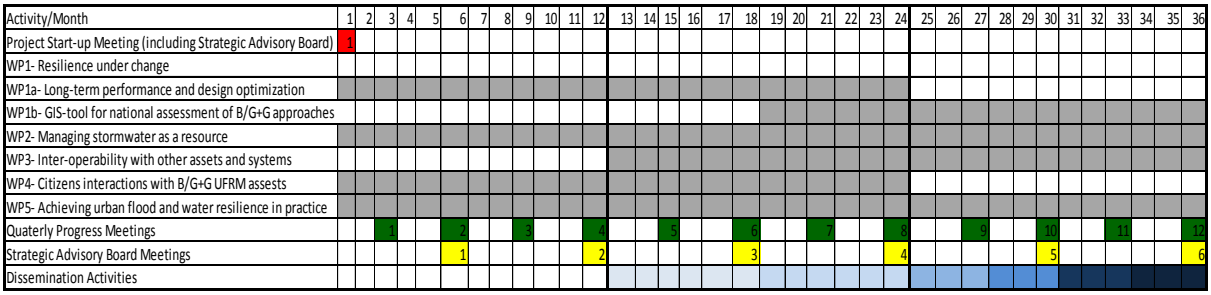

Figure 3 Project time chart

2.2. Work Packages (WPs)

2.2.1. WP1. Resilience under change

WP1 is divided into two sub-WPs;

1) WP1a studies and models specific systems
2) WP1b generalises the findings regionally and nationally

- **Aims and Objectives**

WP1 will investigate co-optimisation of BGI and traditional systems under Flood Foresight-style future scenarios for climate and socio-economic change, using the fully coupled surface/sub-surface urban drainage model CityCAT (Glenis et al., 2010) used in WP2, in conjunction with new models for sediment and pollutant dynamics developed by the Blue-Green Cities Research Consortium (e.g. Allen et al., 2016). The aim of WP1 is to establish how integrated surface/sub-surface water management systems can deliver service provision that is resilient to increased climatic variability.

We will replace the design of coupled piped and surface systems based on a single 'design flood' with a whole systems approach based on coordinated management of the 'stormwater cascade' [WP2] that makes the best possible use of urban water cycles, green spaces and green corridors in the case study cities [WP5]. This approach supports design of UFRM systems that deal with water quantity and quality, unlocking the potential for using stormwater as a resource [WP2].

- **Work Package Team**

WP1 will be led by Scott Arthur (Heriot Watt University). The research team also includes:

- Heriot Watt University: Heather Haynes, Deonie Allen and RA (Yr 3 only) (WP1a1, WP1a2 and WP1b)
- University of Exeter: David Butler, Zoran Kapelan and Sangaralingam Ahilan (WP1a2)
- Newcastle University: Chris Kilsby, Vassilis Glenis and Greg O'Donnell (WP1a1)
- University of Cambridge: Richard Fenner and Leon Kapetas (WP1a2)
- De Montfort University: Nigel Wright

- **Study Approach and Methods**

WP1a involves three tasks:

1. Quantify performance of BGI systems using our newly-tested and proven methods (Allen et al., 2016) to trace flows, debris, sediments and pollutants from source to sink, while paying close attention to B/G+G interfaces with other systems [WP3]. We will use tracer and monitoring results to develop next generation debris/sediment/pollutant models for forecasting long-term flood and water quality performance in the context of UKCP09 climate change forecasts.
2. Evaluate how innovative SuDS devices (e.g. planters and biofilters) inter-operate with BGI and traditional assets. We will identify opportunities and challenges to installing these devices in the case study cities [WP5].
3. Optimise design solutions for future flood resilience. A 'flexible design' approach (Woodward et al., 2014) will be adopted in developing adaptation decision pathways for an uncertain future that employ specially developed resilience and regret-avoidance based performance metrics [WP3].

WP1b will take up the outcomes of WP1a and, in consultation with end-users [WP5], build a GIS Toolbox to support comparative evaluation of the costs and benefits of alternative UFRM solutions.

The GIS Toolbox will be integrated with CityCAT (Glenis et al., 2010) and SHETRAN (e.g. Ewen et al., 2000) outputs with wider benefits [WPs 2 and 3] and integrate these with regional climate change and rainfall-runoff layers, UFRM treatment train performance indicators [WPs1a, 2], and damage/disruption reductions gained through improving inter-operability between water and other urban systems [WP3], employing a summative approach to assess current and future service delivery.

Recent advances in evaluating flood risk and multiple benefits of SuDS (CIRIA, 2015) and BGI (Hoang et al., 2016; Morgan and Fenner, *in press*) make it feasible to build up-scalable tools to assess the potential for such systems to deliver flood resilience regionally and nationally. Hence, the GIS Toolbox will help guide urban planning and development, while informing regional and national policy.

- **Links to other WPs and Contribution to Consortium Outcomes**

Developing the GIS Toolbox with involve integrating research outputs from WP1 and all other WPs in the project (Figure 4).

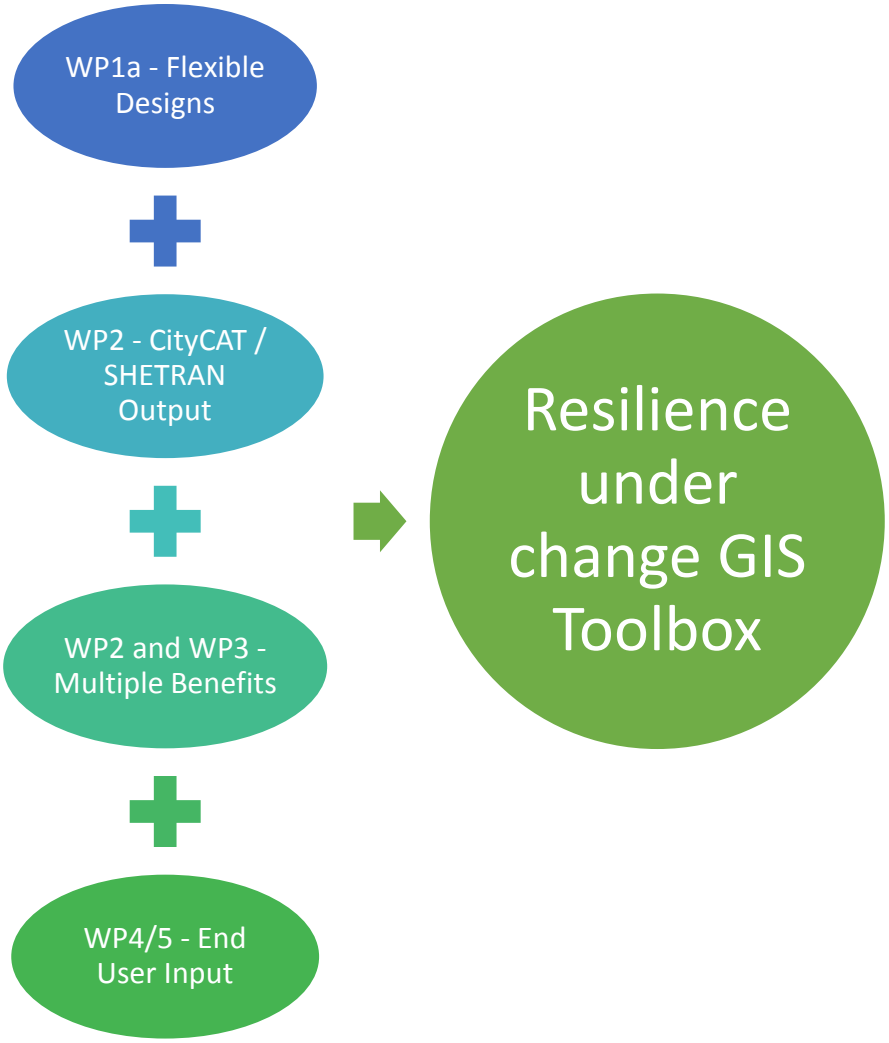

Figure 4 Inputs to the WP2 'Resilience under change GIS Toolbox'

2.2.2. WP2. Managing stormwater as a resource

- **Aims and Objectives**

Stormwater is frequently considered a hazard leading to a focus on extreme events at one end of the hydrological spectrum which can cause catastrophic flooding, property damage and potentially loss of life. As we enter a more uncertain climate the need to retain and utilise stormwater as a vital water resource comes more sharply into focus. This WP will examine these options and how they interact with the urban system both in the short and long term, and the benefits that can be secured both directly and indirectly (Figure 5).

In the first phase the viability of these applications will be assessed individually by the respective Consortium members as identified below. This will involve location specific example analysis of hydrological patterns in the case study cities (and elsewhere) to identify the relative potential for each application.

A second phase will consider how stormwater may be balanced through multiple uses as it cascades through the urban system, and will develop coupling between existing models to link hydrodynamic, sediment and eco-hydrological factors to understand both critical interactions and limits on capacity.

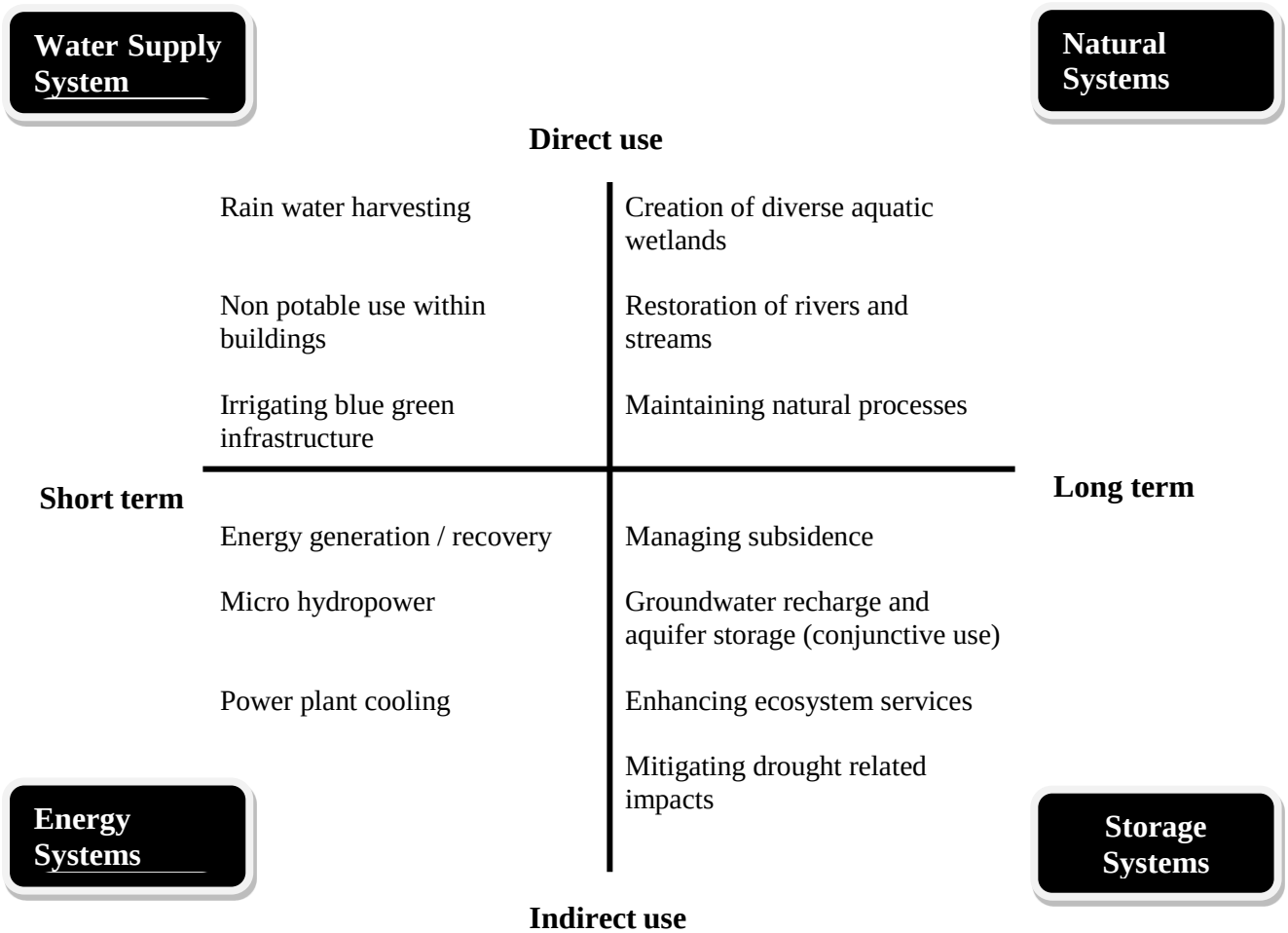

Figure 5 Options for stormwater reuse

- **Key Research Questions**

How can engineered systems for stormwater management be better aligned with natural processes and other physical infrastructure to:

a) realise the resource potential of all forms of urban water, with opportunities for storage, recovery and reuse being taken at every stage of the urban water cycle, and
b) provide reliable quantities as required so stormwater management becomes increasingly inter-operable with other urban systems (esp. transport, land-use and energy) (WP3)?

The objectives that will be addressed are to:

1. To develop procedures and design methods to derive greater benefit from the management of the urban water environment under flood, normal and drought conditions states through utilisation of stormwater resources.
2. To examine ways of coupling models for urban hydrology, hydrodynamics, stormwater storage and water quality for the purposes of establishing the potential for both direct and indirect use of stormwater in the short and long term.
3. To develop concepts of the ‘stormwater cascade’ where captured stormwater may be utilised multiple times as it moves through urban catchments.

- **Work Package Team**

WP2 will be led by Richard Fenner. Research will be delivered by four Consortium partners, with specific responsibilities as shown below:

- Richard Fenner and Leon Kapetas (University of Cambridge): Micro hydropower, groundwater recharge and urban landscapes
- David Butler, Zoran Kapelan and Sangaralingam Ahilan (University of Exeter): Non-potable use in buildings/Rain-Water Harvesting
- Chris Kilsby and Vassilis Glenis (Newcastle University): Surface and sub-surface interactions
- Heather Haynes, Deonie Allen, Chris Kilsby and Greg O'Donnell (Heriot-Watt and Newcastle University): Urban stream restoration

- **Study Approach and Methods**

WP2 will adopt a range of modelling approaches and where appropriate seek coupling between them.

University of Cambridge

New integrated management strategies will be investigated drawing on existing work related to the water – energy nexus through the WHOLESEM project. Extending the work of Ramos et al., (2013) and Bailey and Bass (2009) the feasibility of using micro-hydropower (such as at the outfall of storage ponds) will be examined, for example in the case study cities (WP5). This will involve appraising alternative technical designs by assessing the power generating capacity at specific urban catchment locations based on the routing of different storm profiles and return periods through the system. A multi criteria appraisal based on the Analytical Hierarchy Procedure (AHP) will examine the feasibility of such installations based on the extent of power output potential (from different designs), capital costs of installation and maintenance, and ecological impacts from required flow diversions. In addition, recent work has highlighted constraints on the power generating capacity of the UK with respect to the availability of adequate fresh water for cooling purposes (Byers et al., 2014; Konadu et al., 2015; Murrant et al., 2015). Issues which need to be resolved if stormwater is utilised include volumes, timing and availability of stormwater, water quality requirements and location of source relative to the point of use. On site sources, although producing small volumes, can be used without treatment in flue gas desulphurization systems, ash systems and cooling towers in coal-fired plants, and in cooling towers in combined cycle oil/gas and nuclear plants (EPRI, 2010). Assessment of using stormwater cooling in both the current and potential future fleet of thermal power stations in the UK will be explored at site specific locations with particular hydrological characteristics.

The use of artificial (e.g. infiltration trenches) and natural (e.g. swales) infiltration to enhance groundwater recharge will be modelled to determine the additional storage capacity that can be achieved locally in urban environments, which can be utilised during dry periods for applications such as irrigation of public green space. Risks of potential aquifer contamination from stormwater quality and pollution loads will be assessed, and adverse impacts on future flood risk explored. The potential for enhancing groundwater levels in urban areas constrained by different building densities and land-use will be established. The work will draw from recent experience in Australia and California where, driven by recent lengthy droughts, such practices are under active development (Dillon et al, 2014, California Water Board, 2015)

The use of patch and ecological network analysis will be used to examine the wider connectivity of BGI with wider urban green spaces, to establish potential for creating recreational and habitat corridors. Opportunities for improving the landscape connectivity index (Pascual-Hortla and Saura, 2006) through the selective siting of BGI/SuDS will be examined in a set of case study sites that evaluate the relationship of existing SuDS installations to their wider environment, as well as potential sites where SuDS can add value to the wider urban form.

University of Exeter

The provision of RWH in buildings has historically been driven by water efficiency considerations such as those imposed under building regulations or suggested by guidance schemes such as the Code for Sustainable Homes. Even then, water demand management measures such as dual flush toilets, low flow taps and waterless urinals are often used in preference, with RWH rejected on financial grounds when a whole life cost assessment is undertaken (Roebuck et al., 2013). However, researchers and practitioners have suggested that further investigation of the stormwater source control benefits of RWH is warranted, for example their role as sustainable drainage systems (Melville-Shreeve et al., 2016). When considered together, these dual benefits of resource reuse and stormwater management could enhance the uptake of residential systems especially if system design could be formalised for both (mutually conflicting) objectives and include the implications for future climate change.

In this WP, we will build on a continuous simulation tool (probabilistic tank-sizing tool, PTST) that uses an integrated BS (British Standards) 8515: 2009 Intermediate and Detailed Approach to design, combined with a large sample of probabilistic rainfall data from the UKCP09 Weather Generator, for the sizing of RWH system storage tanks (Lash et al., 2014). The tool has been used to size system storage for water saving applications only and in particular to determine the tank volume required under current climate parameters to meet the same level of non-potable demand under projected climate change scenarios. Due to the expected lifetime of both the building and the RWH tank, the 2080s (2069–2099) time horizon has been adopted. We will extend the model to be able to determine suitable storage volumes solely for stormwater attenuation purposes. This will use a range of available rainfall data including single design storms, superstorms, continuously monitored data and also the probabilistically-based UKCP09 weather data. We will apply the same principles to design of storage-based B/G+G and SuDS infrastructure and investigate the validity and benefits of this approach in their design.

In principle, RWH tanks should ideally be full in terms of resource recovery and empty for stormwater management. This is a classic trade-off situation and PTST will be further developed to include multi-objective optimisation with objectives including maximisation of water saving, minimisation of stormwater outflow and cost. Finally the tool will be generalised to allow application in the case study cities (WP5) and elsewhere.

The final element of WP2 is to generate a set of new performance relationships for dual-purpose RWH systems and incorporate them into the Urban Water Metabolism model WaterMet^2 (Behzadian and Kapelan, 2015) to calculate the overall water development balance and assess their long-term resource potential. Additional work will be carried out to explore the feasibility of coupling models (e.g. WaterMet^2 and CityCat) particularly to more readily capture temporal and spatial dynamics.

Newcastle University

Conventional analysis and simulation of urban water systems has addressed the hydraulic (surface and pipe-network) domain separately to the hydrologic (soils, vegetation, groundwater) domain. In addition, conventional hydraulic models (largely dealing with lateral flows) have not coupled pipe and surface flows adequately, have largely ignored the effects of buildings, and operate on short, typically 1-hour event, time-scales. On the other hand, hydrologic processes (largely dealing with vertical flows), must address longer time-scales incorporating seasonal and annual variability, and deal with updating and budgeting over months rather than hours. In order to deal with city-wide water systems, from urban trees, RWH, through to combined sewers, urban groundwater and on to large sewage treatment inflows, water utilities and Local Authorities need to account for both hydrologic and hydraulic processes on a continuous and long term basis.

We will therefore develop and apply a new comprehensive model of urban hydrosystems providing an enabling framework for the integrated study of fully coupled urban hydrology and hydrodynamics, on the surface, in the soil, and in the sub-surface pipe networks and groundwater. This will build on the integration of the existing hydrodynamic model (CityCAT) (Glenis et al, 2010) and hydrological model

(SHETRAN) to provide a 24/7, 365-days-per-year representation of continuous as well as event-based rainfall, water-storage, flow and soil-moisture.

Priority aspects to be analysed include:

a) local up to city-wide surface and pipe routing for design and operation of RWH, Blue-Green storage and flood-risk-management schemes;
b) city-wide shallow groundwater and soil moisture simulation for a range of issues including tree-health, seepage, groundwater flooding and pipe damage/ingress and geothermal heat recovery;
c) city-wide continuous estimation and modelling of inflows to waste-water treatment plants.

The system will be developed in the case study city of Newcastle (WP5), using existing models as well as new observational data from the Urban Observatory rain gauge and radar network.

Heriot-Watt University

More natural urban hydrology achieved using B/G+G infrastructure can also help restore rivers and streams previously degraded by flashy and polluted urban runoff. To assess this, the cumulative effects of B/G+G and SuDS treatment trains on downstream channel forms and processes will be investigated using the physics-based, spatially-distributed hydrological model SHETRAN (Elliot et al., 2012).

Consortium members at Heriot-Watt University will support Newcastle University with SHETRAN modelling by:

a) providing relevant field data on rainfall, flow, sediment transport within SuDS assets/treatment trains to validate the CityCAT and SHETRAN modelling appropriate to scenario testing;
b) assisting in development/refinement of sediment transport modules in existing software, as required;
c) reviewing and providing regional climate change data as required, and
d) potentially, providing field data for rivers downstream of urban BGI/SuDS

- **Research Plan and Schedule**

- University of Cambridge (9 months + 3 months application in WP5)
- University of Exeter (15 months + 3 months application in WP5)
- Newcastle University (14 months + 3 months application in WP5)
- Herriot-Watt University (10 months + 3 months application in WP5)

0-12 months The first phase of the study will focus on the discrete re-use options shown in Figure 5, to appraise (and model) the physical barriers and opportunities for stormwater resources

12-24 months As feasible approaches emerge, the second phase will assemble a wider typology of urban stormwater reuse to establish how stormwater resources can be cascaded through the urban system and identify where options are reinforcing or mutually exclusive, based on metabolic understanding of quantities and opportunities for balancing stormwater through multiple uses

0-36 months Running concurrently, as location specific opportunities emerge, appropriate coupling of models will be tested so that hitherto discrete models can be aligned to simulate translation of the stormwater hydrograph through the 'stormwater cascade', capturing dynamic responses in flows and storages at all stages (e.g. RWH storage → CityCat →Water Met2)

- **Links to other WPs and Contribution to Consortium Outcomes**

The work will inter-relate with;

WP1: by informing concepts of the water cascade with quantification of stormwater outflows and attenuation from installations such as RWH, and to identify opportunities for resource use within the GIS Toolbox

WP3: by identifying the wider interdependencies with other aspects of the urban systems, including establishing opportunities and constraints

WP4: exploring acceptability of viable re-use options with end users and other stakeholders

WP5: examining specific potential for resource recovery and reuse in the case study sites focussing on feasibility of retrofit solutions in Newcastle and new build in Ebbsfleet

Overall this WP contributes to Theme 2 of the proposal: Engineering Development for resource Use – across the drought flood spectrum.

2.2.3. WP3. Inter-operability with other systems

- **Rationale, Aims, and Objectives**

Under increasing pressures from the environment and society, urban systems now need to work harder than ever before. In flood risk management this need to 'do more with less' has led to a growth of innovations and defence schemes that have multiple purposes. Developing from the concept of multifunctionality (i.e. assets that have multiple purposes), we consider inter-operability of systems (i.e. systems and assets structures that can transfer their function/service directly to another system). A brief conceptualisation of inter-operability for two systems is illustrated below (Figure 6). Consider a piped drainage network (A) and field (B), these systems may have multiple functions, however, in the case of system A, storm water storage capacity may be its primary function (x), whereas crop yields may be the primary function of the field (y). If we want to assess the inter-operability of these systems it is intuitive to ask: what is the inter-operability of x and y for both systems? Or simply, what is the capability of the drainage network to grow crops, and what is the capability of a field to store storm water. Clearly, in this example inter-operability is only capable in one direction, however, the added capacity of the field to temporarily store storm water is a potential solution that could be considered in the evaluation of approaches to improving the resilience to flood risk.

Technological advancements in monitoring systems have opened up the potential for infrastructure systems to 'communicate' with one another, and the idea of inter-operable infrastructure systems that can interoperate to ultimately reduce flood risk, or share and enhance flood benefits, could be potentially beneficial. Building on inter-operability within intelligent systems and the concept of multi-functional assets, the core aim of this work package is to investigate the inter-operability of UFRM assets with other systems (e.g. transport, energy, land-use) to expand the capacity of integrated systems of Blue/Green+Grey infrastructure to contribute to wider urban resilience to climate change. Understanding the inter-operability between systems is key element of this.

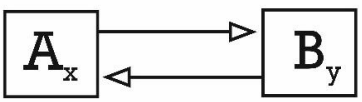

Figure 6 Simple inter-operability between two systems and there functions. System A and function x and system B and function y. See text for explanation.

However, adaptation in flood risk management is traditionally dominated by economic and technical solutions and approaches that raise challenges for more innovative UFRM. Recent improvements in system assessment tools have advanced the combination of key domains (e.g. socio-technical, socio-economic, enviro-economic) however the combination of all domains in assessing the value of resilience improvements of flood adaptation pathways remains a key methodological challenge. This work package will enhance UFRM solutions, support design methods and decision support tools that co-optimise inter-operability of the urban flood risk and water management systems with other urban systems including transport, energy and land-use. WP3 will examine where inter-operable designs could potentially benefit the system, and in order to do so we must evaluate and appraise the improvements of these solutions across multiple infrastructure systems and across domains (technical, social, economic and environmental – see Figure 7) in order to promote systemic resilience in UFRM.

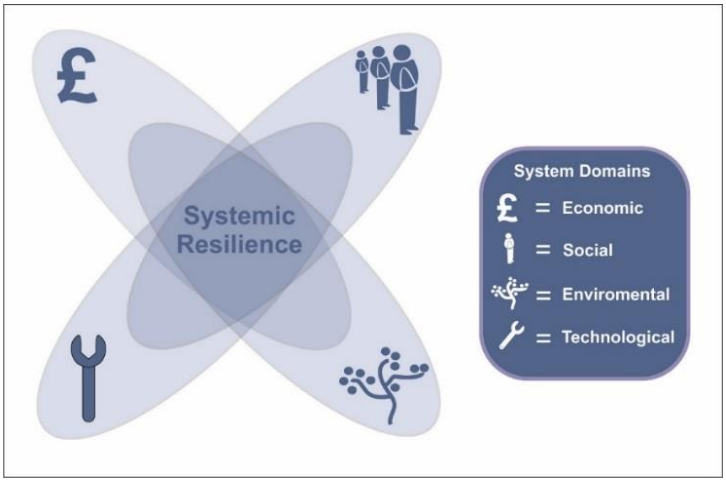

Figure 7 Key system domains: each domain can be categorised by multiple dimensions of value that can have a positive or negative impact on the system under study.

- **Objectives**

    - Conceptualise inter-operability in the context of UFRM and investigate the potential for enhancing Blue-Green and Grey infrastructure with existing assets and systems (drainage and transport networks, green space, etc.) that promote increased capacity and reduced flood risk
    - Review the effectiveness of impact and value capture of existing evaluation frameworks and metrics in the context of inter-operable systems
    - Demonstrate and evaluate inter-operable designs alongside other work package outputs at case study localities and by extension wider urban environments nationally

- **Work Package Team**

The knowledge needed for implementing inter-operable and multifunctional flood designs spans engineering, economics, environment and social science, and policy making; the selected work package team has this capacity. The team comprises David Dawson (WP lead), Nigel Wright, Chris Kilsby, Richard Fenner and their researchers. Collectively, they have extensive interdisciplinary capacity in the field of flood management and resilience. Specific expertise of the team includes flood simulation/modelling, hazard analysis, evaluation of flood benefits, climate change, adaptation economics, urban and infrastructure resilience, and system approaches to flood risk. In year two a research assistant will be appointed and their role will be to integrate system evaluation tools and multi-value benefits of inter-operable flood schemes across different infrastructure sectors.

- **Study Approach and Methods**

WP3 is integrated with other work streams in the project, developing and utilising their outputs along with providing outputs of its own (see below). The proposed overall approach of the work package is illustrated in Figure 8.

Inter-operability within the system: In order to operationalise this concept, we need to determine three components:

- **Physical capability of systems**: what is the capacity of each system, and what is the capacity of each system to take on another function (i.e. multifunctionality)?
- **Interface:** how is the transfer of the function achieved, e.g. a simple overflow pipe or new piece of connecting infrastructure?
- **Control:** what informational procedures (e.g. sensors, monitoring, decision frameworks, etc.) are in place to determine the timing and transfer of functions between systems?

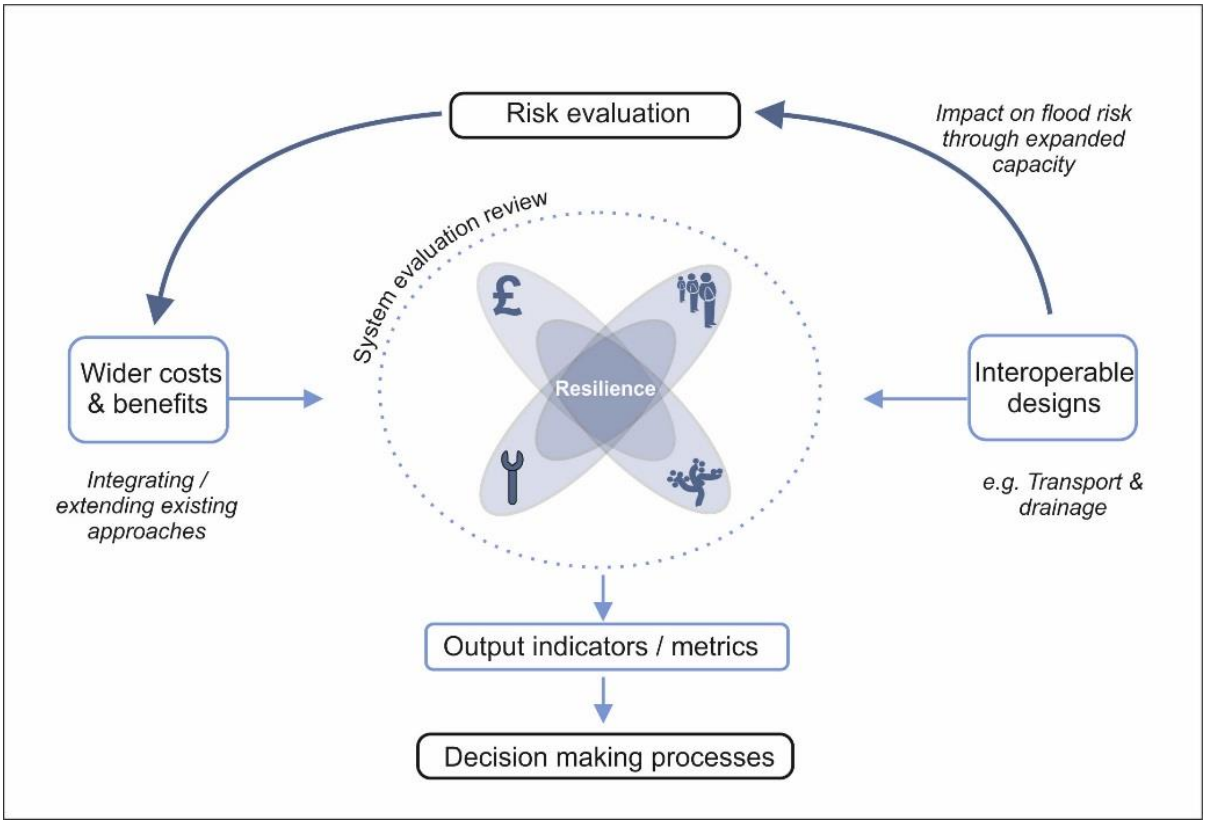

Figure 8 Overview of the WP3 approach

We will use these three components as our framework for investigating the potential for inter-operable systems at our case study sites. A document will be produced to conceptualise the approach further. This will be used to engage with practioners and planners to gauge their response and generate new ideas. This will also be complemented by taking the techniques used in drainage area planning with GIS-based asset mapping and utilising model simulations from CityCAT and WaterMet2 [WPs 1a, 2] to identify potential *physical capabilities* between existing infrastructure systems (i.e. drainage, waste water, transport and energy networks, environmental infrastructure and land uses) and there resulting impact on flood resilience (i.e. risk). *Interfaces* will be identified or determined and potential control systems outlined. Enhancing inter-operability without transferring the risk from one location to another is crucial consideration. Finally, using discussion with key stakeholders the control aspect of these

systems will be determined. With examples generated, the evaluation of the solutions can be carried out.

System evaluation review:

In assessing infrastructure risk across systems which necessitates valuation across systems. Using in-depth literature reviews and targeted interviews a full review of the evaluation frameworks and metric used in FRM will be conducted. Gaps will be identified and considered in evaluation of the inter-operable solutions proposed.

- **Research Plan and Schedule**

0-12 months: WP3 is scheduled to start in full in year two of the project. The first 12 months of the project will therefore be spent planning the approach and gathering evidence of inter-operable design solutions using the conceptual design document. The nature and extent of integration with; WP1a: regarding quantification of technical improvements in the system; WP2: regarding stormwater reuse and recovery; WP4: value of interventions to citizens and communities, and; WP5: case study sites, will also be determined. Finally, recruitment of the research assistant will take place in year one and they will start work in year two of the project.

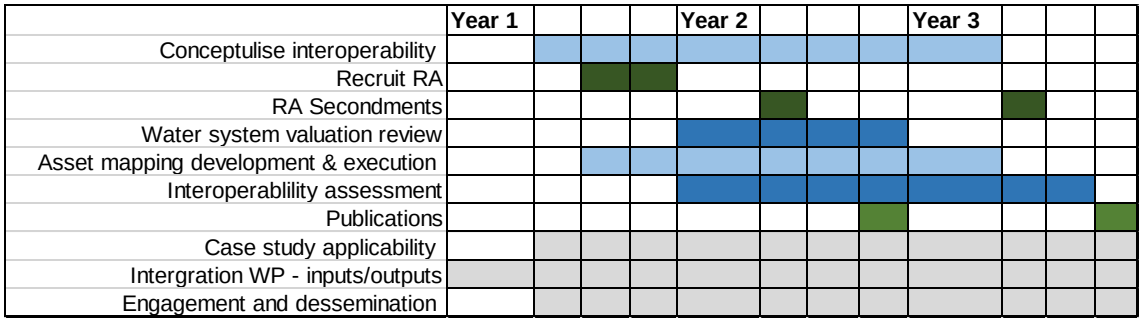

Figure 9 Proposed WP3 schedule

12-36 months: With a RA in post the work package can increase its attention to the objectives outlined earlier. The plan broadly follows these steps:

- Conceptualise inter-operability of the urban system: accounting for capturing dimensions of value from technical, economic, social, and environmental domains
- Determine the physical system boundaries, interfaces and controls: asset mapping of infrastructure systems at risk from case study sites: identify connections, interdependencies and propagation of flood impacts
- Test new designs and evaluate adaptation options under future climate and socio-economic scenarios
- Networking, engagement and dissemination activities both internally and externally

- **Links to other WPs and Contribution to Consortium Outcomes:**

The approach will allow system wide resilience evaluation of multiple, inter-operable B/G+G infrastructure design solutions. In doing so it could provide additional metrics for the GIS-toolbox [WP1b, Year 3], and help evaluate the resulting benefits of inter-operable designs solutions and valuations for *Real Options* analysis [WP1a, Year 2]. Feedback on the acceptability and utility of the new design approaches will help inform and steer the societal and stakeholder research as it progresses [WP4] and the outputs will contribute directly to the project's case studies in Newcastle and Ebbsfleet

[WP5]. Equally, system performance improvements and benefits from using stormwater as a resource (WP2) and citizen interaction (WP4) could provide added metrics for system evaluations. Peoples' perspectives of interventions; acceptance of disruptions, irrationality in decision making, health benefits – financial decision making may also help us explore the notion of risk transfer i.e. flooding fields to save cities.

2.2.4. WP4. Citizens' interactions with B/G+G infrastructure

- **Aims and Objectives**

Aim: The aim of WP4 is to develop our understanding of how attitude and behaviour change amongst flood professionals and urban residents might be achieved, to encourage greater co-development of B/G+G infrastructure such that devices put in place are more appreciated over the longer-term. This should in turn hopefully improve *felt* amenity benefits, behaviour and people's willingness to get involved with voluntary lay-maintenance and clearing. This should improve functioning and reduce maintenance costs to developers and Local Authorities, making devices more sustainable.

Objective 1: Establish baseline data. WP4 will need to first understand who the communities living around and using (or not using) devices are, what their feelings about the B/G+G devices are and whether or not they feel they achieve what they are intended to, in terms of both reducing flood risk and providing multiple benefits. WP4 can then look to understand the strengths and weaknesses of contemporary modes of engagement, how well communities and professionals feel these have worked in raising awareness, encouraging engagement and improving behaviour.

Objective 2: Understand community preferences. Beyond the preferences of a core group of participants, WP4 will need to gather data more widely from communities around the B/G+G devices. WP4 will also need to try to get beyond people providing what they perceive to be the more 'socially acceptable' answer of 'liking' all green infrastructure, using contemporary social psychology tools. WP4 will work alongside the core group to co-develop processes and means of effectively engaging wider communities, to gather their views.

Objective 3: Evaluate and assess the effectiveness of different interventions. WP4 will work with the core group to develop and implement interventions to affect community awareness, engagement and behaviour. WP4 and participants will be positioned to assess the efficacy of these different tools in context.

Objective 4: Develop transferable principles of B/G+G FRM community engagement. Lessons learnt from established B/G+G infrastructure and communities will be transferable to future developments. For this reason, case studies from each site (detailed in following section) will be developed to demonstrate how citizens' priorities and the reality of their lifestyles, communities, and neighbourhoods shape their understanding, preferences and behaviour in ways that will impact upon the ongoing costs and sustainability of B/G+G devices.

The specific objectives of WP4 in relation to the wider programme are therefore to:

1. Gain access to a core group of local concerned communities to gain an understanding of their feelings about B/G+G devices and the means by which they have been engaged by authorities previously;
2. Work with the core group to develop the means by which to survey community preferences more widely. Develop and test a tablet/phone app and use of social media, to inform the work undertaken in WP5;
3. Co-develop and trial a range of different community interventions to try and improve awareness, preferences and behaviour;

4. Build transferable principles of community engagement and produce case studies for use by professionals.

- **Work Package Team**

Dr Jessica Lamond (UWE) will lead WP4 with input from Karen Potter (OU) and Colin Thorne (Nottingham) supported by Glyn Everett (UWE), Emily O'Donnell (Nottingham) and Tudor Vilcan (OU). UWE will lead on the analysis of existing data and design of engagement tools with the support of Nottingham and OU. UWE and OU RAs will focus on the engagement activities in situ in Bristol and Milton Keynes with Nottingham RA focussing on IAT (Implicit-Association Test) and social media engagement activities.

- **Study Approach and Methods**

WP4 will look to extend and deepen public involvement through a Critical Communicative Methodology, encouraging understandings and approaches to the research to be developed with 'the researched' (Gómez et al., 2013; Rodríguez et al., 2013; Flecha and Soler 2014). In this way, WP4 will pursue a Participatory Action Research (PAR) approach to community engagement (Brydon-Miller et al., 2003), looking to facilitate the empowerment of communities and develop their voices within the city.

This might in turn help to encourage behaviour change, hopefully cultivating 'cultures of enthusiasm' (Geoghegan, 2012) whereby the development of interests and skills work in tandem, with and through local communities, to encourage people taking ownership of B/G+G devices within their area.

The aim will be mutual awareness-raising, for all (researchers, professionals and community members) to engage and learn from their involvement, sharing knowledge and understanding, upskilling participants and making maximum use of both lay and professional knowledge, skills and capacities.

PAR emphasises equal-standing and collaboration between 'researchers' and 'the researched', combining research with action and looking to make a tangible difference to participant's lives (social change) as well as producing useful and transferable knowledge. To this end, specific research questions will remain necessarily under-defined at the beginning of the project, because community input may change the focus; questions will emerge from conversations.

Engagement could include: raising awareness of flood-risk and different possible means to counter this, and discovering different community priorities and preferences around a portfolio of B/G+G strategies. A further stage of engagement would involve learning about and reflecting upon helpful and unhelpful behaviours in the wider community, and reflecting upon opportunities for encouraging behaviour-change that might enable the better performance of B/G+G infrastructure.

Three sites will be chosen around Bristol and one in Milton Keynes; the Bristol sites will be selected following conversations with Bristol City Council and South Gloucestershire Council (current thinking is around Emersons Green, Hanham Hall, the ongoing Southmead SuDS development work, and/or the Dings).

- **Research Plan**

<u>Stage One</u>

- The first stage in the research will involve gathering lay community participants (10) and interest group representatives (2) for each of the B/G+G asset types (ponds, swales, rain-gardens and permeable paving), as well as flood professional practitioners (5).

- Initial conversations around research focus and methods will take place, to finalise details of the approach to be adopted and alter these through discussions with participants, to optimise engagement.

- At this stage, specific research questions for the wider community will be developed. The Implicit-Association Test (IAT), a social psychology tool, will be worked with in developing a short and clear survey that can be used with the wider populace.

- Community members will also receive training in social research methods (observation, asking and recording questions, and gaining consent) and use of Data-Gathering Technology (DGT, e.g. tablet computers).

Stage Two

- In the second stage of the research, participants will be invited to gather data in their own time in their locales, to feed back for group discussion. Participants will use DGT to answer IAT questions, recording the preferences of those they know and people in their wider community. They will also be invited to passively observe and record behaviours in their community around the B/G+G devices under review. As data is gathered, researchers will continue to meet with participants and professionals to discuss and move towards findings.

- The research will propose a Social Practice Theory (SPT) analytical lens (Shove et al., 2012), for thinking through how B/G+G devices might interact with and be impacted by contemporary community practices and preferences. Theories of Social Practice look to move beyond rationalistic individualism and deterministic structuralism, adopting a both/and approach in considering the (series of) practices of (groups of) individuals, shared behavioural routines that are co-constitutive of individuals and wider social groupings (Reckwitz 2002). Individuals retain their agency in a contextualised fashion, both reproducing practices and contributing to their development, but the set of social practices is the unit of analysis rather than individual actors (Spaargaren, 2011).
- Residents and professionals may or may not wish to adapt the lens, and differences of opinion will be negotiated in producing a workable mode of analysis that gathers maximum support.

    - These discussions will open up conversation and reflection around interventions felt to encourage positive shifts in behaviour. A variety of interventions will be proposed, and the groups will co-develop those they feel would be most effective in their locale.

    - A phone/tablet app and social media platforms will be discussed and developed with the core group for use at the intervention stage as well as for rollout in WP5.

Stage Three

- In the third stage, interventions will be implemented and participants will continue observations, to track changes in awareness, perceptions and behaviour.

    - The format of one intervention will be pre-set, although participants can co-develop the content; communication and learning methods suited to interaction with large numbers of city dwellers (mobile apps, social media, crowdsourcing and crowd-testing, as mentioned above).

    - Online communications will be used to study changing attitudes, perceptions and opinions, and test bespoke communication/feedback approaches. Later, these online systems will be used to canvass and potentially shift citizens' and professionals' attitudes and behaviours with respect to B/G+G assets in the case study cities (WP5).

Possible Interventions

These would be for discussion and development with participants, so remain under-defined at present. However, some first suggestions of possibly productive interventions might be:

- Information signs

These have previously been criticised by some for being passive and static, however others have expressed appreciation and, if well co-designed with local participants, might feel more relevant to the local area and so receive better feedback

- Litter-picks

Littering is a commonly-known problem that presumably all can connect with. Inviting local community members to get involved with clearing litter might draw in participants with little previous connection to the area other than passing through. Team-leaders could then inform group-members about the area's functions and potential multiple benefits

- Open-invite activities and education days

Informal, conversational and fun activities days might draw in new interest if suitably publicised; activities could be framed around the area's potential multiple benefits, an educational or activities day, and/or a chance for people to voice what they like, don't like and what they feel could be improved

- Signing up 'Friends of' groups

For spaces that do not already have them, WP4 could work with local participants to establish 'Friends of' groups to begin promoting the area in their communities and doing voluntary work to help with maintenance and clearing

- Smartphone Apps

Developing apps could enable the public to engage in different ways: monitoring flora and fauna; recording activities; recording problems and complaints with visual records, social networking and commenting upon positive features of sites as they develop. This different means of engaging might bring in new audiences, connect people and help them feel that they have voice in the development and maintenance of 'their' area, as well as opening up a space for two-way communication between site-managers and users

- Bioblitz
    - Bioblitzes, 'an intense period of biological surveying in an attempt to record all the living species within a designated area'[2] can, when well-run, function as public-engagement, educational and awareness-raising exercises that produce reputable data for later use by professionals (Silvertown 2009; Roy et al., 2012).

- **Research Schedule (see also Figure 10)**

Sept 2016 – Mar 2017
- Conduct literature review, map out issues and develop methodological thinking
- Develop research programme and research potential study sites
- Finalise study sites through discussions with Bristol City Council, South Gloucestershire Council and others involved in OU studies

Apr 2017 – Sep 2017
- Establish contact with communities, gather participants
- Conduct initial observations

[2] https://en.wikipedia.org/wiki/BioBlitz

- Develop understanding of relevant community groups, engagement methods experienced and impressions of these
- Participants receive training and discussions to finalise research questions-in-practice
- Develop IAT
- Scope design for prototype digital and online communications tools (app, online survey, social media interactions)

Oct 2017 – Mar 2018
- Data-gathering and discussion of findings
- Design prototype digital and online communications tools, conduct IAT
- Develop and roll out app and social media platform
- Develop interventions

Apr 2018 – Sep 2018
- Begin implementation of interventions, with adaptation following feedback, continue conducting IAT
- Discussion and feedback with regard to progress and felt barriers
- Provide app and social media materials for transference to WP5

Oct 2018 – Mar 2019
- Continue interventions and IAT, monitoring any attitude and behaviour change
- Ongoing discussion and feedback with core group
- Continue monitoring and discussion of social media platforms

Mar 2019 – Sep 2019
- Conclusion of monitoring and intervention, discussion of findings with core group
- Planning re. sustainability of effective interventions and other outputs/findings

	Oct 2016 – Mar 2017	Apr – Sep 2017	Oct 2017 – Mar 2018	Apr – Sep 2018	Oct 2018 – Mar 2019	Apr – Sep 2019
Literature review and methodology						
Develop research programme, select and finalise study sites						
Establish contact with communities, gather participants						
Develop understanding of engagement methods experienced and impressions						
Train participants in social research, develop and finalise research questions						
Develop IAT test						
Scope design for digital media tools						
Data-gathering and discussion of findings						
Design and roll-out digital and online communication tools and social media platform						
Conduct IAT						
Develop and implement interventions, monitor attitude and behaviour change						
Discussion and feedback re progress, barriers and sustainability						
Provide materials for transference to WP5						

Figure 10 WP4 Gantt chart

- **Links to other WPs and Contribution to Consortium Outcomes**

WP4 will engage in productive conversations and knowledge-exchange with other WPs throughout the programme.

- Findings from WP1a and WP1b (design optimization and GIS assessment of B/G+G approaches) can feed into conversations with the core group, and the IAT, to explore lay citizens' perceptions of benefits and barriers
- Discussions with WP2 and WP3 will develop thinking around un/productive uses of, and potential for developing, citizen engagement regarding data collection around stormwater management and inter-operability of B/G+G assets
- WP4 will have a close and ongoing relationship with WP5, developing tools for data-collection and analytics as well as strategies for engagement, and learning from case study city LAA feedback to continue developing the WP4 research focus

2.2.5. WP5. Achieving urban flood and water resilience in practice

WP5 is divided into two linked sub-WPs;

1) Putting flood risk management at the heart of planning, and
2) Demonstration case studies.

2.2.5.1. WP5.1. Putting flood risk management at the heart of planning

Research will extend to investigation of the socio-political context of the urban land-use planning system and this system's impact on the governance arrangements of water management. A clear conclusion from the Blue-Green Cities research project was that reducing scientific uncertainties alone is insufficient in unlocking the potential for widespread uptake of BGI; stronger cross-sector integration and partnership working being key to overcoming the barriers (Thorne et al., 2015; O'Donnell et al., *in press*). The need for more sharply targeted planning policy instruments to affect future urban flood risk including renewal of existing urban spaces, new urban forms, new densities of development and more green space has indeed been recognised for decades, from the European Sustainable Cities and Towns Convention in Aalborg, 1994, through the Future Foresight Flooding analyses (Evans et al., 2004) and the Pitt Review (2008). The requirement to work in partnership with engineers/hydrologists and facilitate the delivery of integrated sustainable water management sits on the planner's priority list alongside a plethora of other environmental, social and economic issues and concerns – the majority of these issues and concerns being as complex and convoluted as the delivery of integrated water management (Potter et al., 2011). More fundamentally, it is alleged that sustainable flood risk management is not a task for which planning is constitutionally well equipped; political and economic forces have powerfully shaped the profession from the push for the development in the 1960s and through ongoing decades against which planners have struggled to mainstream what is often fundamentally 'aspirational' policy regarding sustainable development (Howard, 2009, Potter et al., 2016).

To meet the overall aim of this multidisciplinary proposal to make urban flood resilience achievable nationally, it has been recognised by the Consortium that further research is required to target the ongoing restricted connectivity between land-use planning and sustainable water management policy. Through an action research orientated approach, WP5.1 will work closely with practitioners to deepen the understanding and affect change at a practice level - how planners engage in a collaborative process with flood risk managers and other water-sector stakeholders, to develop integrated policy and strategies to broaden the uptake of B/G+G infrastructure.

- **Work Package Team**

This section of WP5 will be led by Karen Potter and Tudor Vilcan, and assisted by Colin Thorne, Jessica Lamond, Emily O'Donnell and Glyn Everett.

- **Aim**

To examine how the collaborative planning and decision-making process must evolve between responsible authorities and stakeholders (e.g. planners and developers responsible for urban form, engineers and scientists who design optimal water management solutions for specific locations and the communities at risk of flooding) to enable cities to achieve sustainable flood resilience and water security.

- **Objectives**

1) To identify, and 2) interpret the institutional barriers to innovation within the planning process, to further understand the socio-economic context, in which planners must operationalise policy and take planning decisions that affects the sustainable flood resilience of cities

3) To feed understanding of the planning and development context through to the case study cities and Learning and Action Alliances (LAA) (WP5.2), through action research and participatory knowledge mapping, develop shared problem definitions and compromises on a resolution of how the barriers could be overcome, for practitioners to modify their approaches and gain traction in delivering innovation

4) To investigate how planners may play the crucial collaborative role and achieve consensus in strategic land-use decisions on B/G+G with and against various other planning objectives and other institutions policies, whilst maintaining land values and enhanced development opportunities

- **Study Approach and Methods**

Action research should be, as asserted by Somekh (2005), the approach of choice for social science researchers focusing on innovation, due to its capacity to deepen understanding on the barriers and enablers to change – in this case, the barriers within the planning and development process. Action research can be particularly pertinent when a new phenomenon is introduced to bring about improvement (e.g. BGI), but because of the socio-economic and institutional complexity, attempts at change and implementing novel policy can often be frustrating and frequently not possible to implement as originally planned or intended. The Action Research methodology integrates social science inquiry with participants' own practical action aimed at dealing with real world problems and issues. Through the adoption of this approach, the research will seek to bring about change in an iterative, cyclical process of 1) data collection on the topic under investigation, 2) analysis and interpretation of the data, 3) planning and introduction of strategies to bring about change with 4) further evaluation of these attempts at change through the collection of further data. Whilst much research can claim to be applied and driven by real world problems, the important characteristic of action research is this linking of knowledge first generated by researchers being applied by practitioners, with a view to altering practices in a beneficial way (Denscombe, 2012).

Stage 1

The first stage of the research will essentially seek to understand what is happening already in the collaborative planning process between responsible authorities and stakeholders. Through the process of data gathering, the institutional, socio-political and procedural (including gaps in knowledge and data) barriers to UFRM innovation will be identified, through: a) a critical interpretative review of the academic and practitioner literature relating to the barriers in the planning and water management domain; b) a secondary analysis of the data and findings from the Blue-Green Cities project that also identified socio-political barriers to the implementation of BGI, c) interviews and observation in relevant planning meetings with the case study stakeholders, participatory observation and *Participatory Knowledge Mapping*[3] with the LAAs in Ebbsfleet and Newcastle, and d) complemented with exploratory discussions and interviews with key national participants in the flooding policy field.

Stage 2

It is important that the first stage of the research does not merely empathise with participants and offer up a mirror to their experience, as is alleged of much 'qualitative' research (Silverman, 1993). 'Theory', as defined by Silverman (1993), is a set of explanatory concepts offering ways of looking at the world and which are essential in defining the research problem, to shed light and add insight to the meaning of the social processes witnessed in the planning and flood risk management domain. For example, the theory of Collaborative Governance is a practice based theory about the management of collaborations, structured in themes representing issues identified repeatedly by practitioners, e.g. differences in the

[3]*Participatory Knowledge Mapping* is used to determine where the necessary knowledge resources are held and their state of "health" as regards to a task or organisation.

operational and decision making procedures of an organisation, the misunderstandings and tensions created through the different values and language of a profession or discipline (Vangen and Huxham, 2012). The second stage of the research will seek to interpret the barriers to innovation – in an iterative process, comparing the initial data and observations with previously developed theory to develop an analytical framework; further collection and coding of data based on this framework and lastly, a return to the literature to refine the research concerns and theory.

Stage 3

Action research seeks to go beyond merely describing a situation, analysing and theorising social practices – it also seeks to work in partnership with stakeholders to reconstruct and transform certain practices (Somekh, 2005). This will be operationalised through the LAAs in the case study cities (WP5.2). The general aim of innovation is to produce some form of change and to do things differently through the adoption and implementation of new ideas and policy (Hartley, 2014; Sørensen and Torfing, 2011 in Diamond and Vangen, 2017). Again, there is a rich body of literature providing theory and insight into transformative change. Although there are complex institutional and socio-economic factors and rigid structures and processes, working in collaboration provides important opportunities for public sector practitioners to lever opportunities that can emerge from working across sector boundaries, recombining concepts and practices from different disciplines to develop new learning and approaches. Practical information/data needs for enhanced decision making will be identified and methods by which they can best be addressed will be determined, e.g. through data analytics (Krioukov et al., 2011), meta-learning or data mining (Spielman and Thill, 2008). Through the process of *Cognitive Modelling*[4] systematic diagrams of aspects of the decision making process will allow for design of decision support systems that bring together the required data and knowledge. Comparative research will also be undertaken in other contexts to understand and demonstrate how identified barriers have been overcome.

Three major qualitative methods will be triangulated within the research stages above to reconstruct both the discursive and organisational aspects of the planning and flood risk management policy arrangement: through an analysis of documentation (e.g. planning policy and strategy, minutes of meetings); observation/participatory observation; and interviews and/or focus groups. Participant observation allows the distinctive opportunity to perceive reality from the viewpoint of someone 'inside' the case study, or as phrased by Silverman (1993), sharing in people's lives whilst attempting to learn and understand their world. Interviews are considered one of the main data collection tools in capturing the perceptions of actors and generating data which gives an authentic insight into people's experiences (Silverman, 1993). One of the hallmarks of focus groups is the explicit use of the group interaction to produce data and insights that would otherwise be less accessible without such interaction found in a group, stimulating participants in making explicit their views, perceptions, motives and reasons (Punch, 2005). The overall characteristic of qualitative research is that it is naturalistic and fundamentally depends upon watching and studying people and events in their territory and natural settings (Punch, 2005). Action research as a particular strategy works within the system, but also engages participants/stakeholders to own the problem, issue or concern and be involved with the research process – to be collaborators in the research rather than be watched and studied (Denscombe, 2012).

- **Research Plan and Schedule**

Stage 1 and 2 will commence in January 2017 to be completed within one year. The ensuing research plan and precise schedule will be refined and updated following the increased understanding gained in stage 1 and 2. The action research strategy, plan and schedule will be developed in collaboration with the LAA practitioners and in conjunction with WP5.2.

[4]*Cognitive Modelling* is a process that attempts to create systematic diagrams of aspects of the decision making process, again to identify where the gaps in understanding or data might be but also to allow for design of decision support systems that bring together the required data and knowledge.

- **Links to other WPs and Contribution to Consortium Outcomes**

WP5.1 will develop the interdisciplinary capability of the project, to increase not only the planning practitioner's understanding, but also the water manager's understanding of the complexity of policy fields and sectors outside their own. The increased understanding will be fed back to the team through WPs 1-4 to consider the systemic implications of the planning and development process when developing the scientific and engineering capacity for change. Planners must also take into account citizen and community preferences with respect to managing flood risk, and hence, the implications of WP4 will be fed through into the WP5.1 action research setting. The LAA will also participate in knowledge mapping to identify the gaps and possible misconceptions in knowledge relevant to planning and flood risk management.

2.2.5.2. WP5.2. Demonstration case studies

This section of WP5 is based in our two case study cities. The first case study will build on foundations laid and substantial progress already achieved by the Blue-Green Cities Consortium in Newcastle. Specifically, the Newcastle study will investigate how urban flood resilience can be achieved in practice in the contexts of urban renewal and expansion (i.e. through retro-fit, redevelopment and new build in developments at the urban fringe). The Ebbsfleet study will investigate how urban flood resilience can be achieved in the context of planning and developing an entirely new 'garden city'. Both cities were named in the successful proposal, submitting letters of support for that proposal and are committed to collaborating with the Consortium throughout its 3-year lifespan.

Newcastle

Newcastle is a natural choice for the first case study. In their letter of support, Newcastle City Council noted that, across the world, the co-benefits of natural flood risk management approaches, such as green infrastructure are being realised and the frameworks to drive activity are being created, citing as an example how the European Commission's Covenant of Mayors on Sustainable Energy and its 'Mayors Adapt' scheme - of which Newcastle was one of the first signatories - are being brought together.

During the Blue-Green Cities project, key stakeholders in Newcastle developed tools and governance structures that built confidence that re-imagination of the City's existing approaches to flood risk and water management was *possible*. Crucial in this process was the Learning and Action Alliance (LAA), which the Blue-Green Consortium established. The LAA provided a safe forum to explore advanced UFRM modelling and best practice in flood risk management, as mentioned in the Local Flood Risk Management Plan (Newcastle City Council, 2016). The LAA also helped develop consensus on the options available and appropriate to implementing innovation and change, as well as beginning to broaden horizons with respect to inter-operating urban water systems with other urban systems, such as transportation.

The potential for transformative change in Newcastle already existed prior to establishment of the LAA through individual contacts and networks between stakeholders, including, crucially, Northumbrian Water Ltd., Newcastle University, the Environment Agency and the City's primary water contractors, Arup and Royal HaskoningDHV. Having a dedicated forum where these and other institutional stakeholders could learn, unlocked the potential to turn those informal networks into an advocacy coalition that could move from envisioning a better water future for the city to implementing the first steps necessary to realising the latent ambition to make Newcastle a 'Blue-Green City'. For example, flood researchers at Newcastle University had already developed ideas for how road junctions and profiles could be modified to improve surface water drainage and reduce the vulnerability of the urban transport system to paralysis during heavy rain events like the 2012 'Toon Monsoon', which brought traffic to a halt just 35 minutes into the downpour. When academics from Newcastle University and other partners brought to the LAA ideas on how BGI could be incorporated into the streets of Newcastle they found a receptive group of like-minded professionals amongst the stakeholders in the LAA.

The LAA process culminated at the Blue-Green Cities Primary Knowledge Exchange and Research Dissemination Event at Newcastle's Centre for Life on 18th February, 2016, when key stakeholders signed a pledge setting out their shared intention to make a 'Blue-Green City' (Figure 11).

Collaborative research will continue in Newcastle between now and 2019, as the City moves forward with 'Blue-Green' approaches, align its actions with the work Arup and Newcastle University are currently undertaking on a global review of financing green infrastructure, to help move the City forward in realising its ambition to become a 'Blue-Green City'. In this continued cooperation, it is hoped that the geographical scope of the work will be expanded to the wider metropolitan area by bringing into play the North East Combined Authority's Green Economy working group as a mechanism for broadening learning and spreading it more widely.

The vehicle for participatory research in Newcastle will be a continuation of the Newcastle LAA, but with a reshaping of the vision, strategic objectives and stakeholder group, to be determined at early meetings of the LAA in 2017.

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 Warneford
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

Figure 11 Newcastle Declaration signed on 18th February 2016

Ebbsfleet

Ebbsfleet Development Corporation (EDC) welcomed the Consortium's invitation to partner with us, particularly because the role and use of landscape to support a wide range of environmental, social and economic outcomes is a defining aspect of the emerging vision for Ebbsfleet as a 21st century Garden City (the EDC are charged with delivery up to 15,000 new homes in North Kent in the next few years).

The aims and objectives of EDC's strategy for delivering the Garden City align closely with aspects of the Consortium's activities and intended outcomes, and it is clear that their involvement in the research will add to our understanding of how planning and development can be re-envisioned to navigate the Blue-Green Cities approach and ensure flood and water resilience in Ebbsfleet despite uncertainties that cloud our view of the UK's climate and socio-economic futures.

The geography and terrain of the locale guarantee challenges to flood and water security that provide a testing context for the creation of integrated B/G+G treatment trains and SuDS. The area to be developed features large, abandoned quarries (some with open water bodies), a massive landfill, a heavily impacted and incised watercourse (the River Ebbsfleet), an unintentionally flooded, but richly biodiverse marsh (created by water leaking from a former cement works) and a range of other former industrial sites interspersed with patches of farm land and relatively undisturbed countryside. The area slated for development is bordered by the existing communities of Swanscombe, Greenhithe and Northfleet, which have their own Local Authorities – each with its own planning agenda.

This back drop will not only challenge but inspire us to support EDC in achieving its goal of bringing forward, "high quality housing with smart, sustainable and renewable technologies".

It was agreed when members of the WP5 research team visited Ebbsfleet for a start-up meeting with representatives of EDC that the initial approach in Ebbsfleet will be to establish a LAA. EDC are perfectly placed to assist with this as they are already networked with landowners, developers, builders, utility providers and statutory partners in delivering the Garden City. EDC are happy to facilitate contact and dialogue with key stakeholders through their existing channels and working groups with a view to inviting them to join and participate in the LAA (with an initial meeting of interested parties scheduled for early 2017). They are also willing to share the results of their own baseline studies – which will provide a useful starting point for our research and have offered to commission additional explorative work where this would be mutually beneficial in moving the programme forward.

- **Work Package Team**

This section of WP5 will be led by Colin Thorne and Emily O'Donnell. Karen Potter, Tudor Vilcan, Jessica Lamond and Glyn Everett will also be involved in setting up the LAAs and performing aspects of the cooperative research.

In addition to specific inputs planned from staff at Nottingham, the OU and UWE, this part of WP5 is founded on *co-location research* by the whole Consortium Team. While details of the work will emerge as the project progresses, the breakdown of staff resources includes time for each RA to work in the case study cities for substantial periods. Also, the Nottingham budget covers RA and co-I travel and accommodation expenses related to their work in Newcastle and Ebbsfleet (see Annex II).

- **Aim**

The demonstration case studies research in Newcastle and Ebbsfleet will inform, take-up and apply research in WPs 1-4 to establish, within the project's lifetime;

a) how resilient UFRM service delivery can be put at the heart of urban planning, and

b) how barriers to innovation can be overcome despite uncertainties in future urban climates, land-uses, development patterns/trajectories and political leadership.

- **Objectives**

1. Make the aspirations of multi-objective planning policies deliverable in mainstream practice by bringing together engineers, stakeholders and Local Authorities with an enhanced understanding of collaborative partnership working (LAAs), linking with WP5.1.

2. Create connectivity in urban flood and water planning and management systems to support multiple functions while balancing trade-offs and facilitating positive interactions between:

    a) engineered assets;
    b) advances in water technology;
    c) natural processes in restored urban streams and drainage systems, and;
    d) the preferences and behaviours of the citizens and communities that benefit from systems of B/G+G infrastructure.

- **Study Approach and Methods:**

The demonstration case studies will present an opportunity for continuous knowledge exchange with WPs1-4 concerning challenges such as technology lock-in, maintenance concerns, institutional silos with differing goals, leadership concerns, and financial limitations. By participating in WP5, researchers and practitioners will co-produce knowledge to modify their approaches and gain traction in delivering innovation. For instance, GIS visualisation of the flood mitigation performance of the potential of B/G+G assets and their multifunctional benefits will be presented to LAA members by the WP1 team. *This will consolidate the model outputs for use locally to guide development and be up-scaled regionally/nationally to inform policy, and form the basis for a National Assessment of flood resilience.*

In addition, WP5 will use *Action Research* (Gómez et al., 2013) that engages researchers in the urban planning process as this has been demonstrated to accelerate uptake of innovation (Potter et al., 2011; Cettner et al., 2013). *Action Research* will start through the LAA approach, which represents current best practice (Newman et al., 2011; van Herk et al., 2011; Ashley et al., 2012; O'Donnell et al., *in prep*). LAAs are open arrangements where participants with a shared interest in innovation and implementing change create a joint understanding of a problem and its possible solutions based on rational criticism and discussion (Ashley et al., 2012). LAAs promote cooperation between diverse stakeholders from different disciplines and backgrounds. They aim to break down barriers to both horizontal and vertical information sharing and accelerate the identification, adaptation and uptake of new information (Batchelor and Butterworth, 2008). They encourage stakeholders to bring their knowledge and expertise and talk freely outside the constraints of existing formal institutional settings. An atmosphere of trust and mutual ownership facilitates the identification of innovative ideas for the solution of complex socio-technical problems.

The Newcastle LAA will build on but differ from that set up in 2014 as part of the Blue-Green Cities research project. This is necessary as some members of the old LAA have left their posts, while the scope and purpose of the new LAA differs sufficiently from that of its predecessor that it requires a complete reformulation. Specifically, LAA membership will be widened to include land-owners and developers - powerful interest groups hitherto relatively neglected in UFRM research.

The Ebbsfleet LAA will have at its core the network already established by EDC, but it will benefit from the inclusion of other stakeholders suggested by Consortium researchers on the basis of social theory and the specifics of the Garden City, its constituents, citizens and their neighbours in the adjacent, established communities of Swanscombe, Greenhithe and Northfleet.

Once the LAAs are up and running, Participatory Action Research (Parkes and Panelli, 2001) and Social Practice Theory (Hargreaves, 2011) will be employed to examine relationships between researchers, UFRM practitioners and communities. This will explore tacit knowledge, behaviours and citizen's attitudes with respect to diverse flood mitigation measures and link the desirability of specific asset interventions with wider urban planning.

- **Research Plan and Schedule**

The start-up meeting for Ebbsfleet took place on 17th November 2016 and was highly encouraging. The Consortium were represented by Colin Thorne, Karen Potter and Emily O'Donnell. Simon Harrison and Paul Boughton from the EDC were in attendance. The next meeting in Ebbsfleet (to identify LAA members) will be in early 2017.

The start-up meeting in Newcastle took place on 14th December 2016. Colin Thorne, Chris Kilsby, Karen Potter, Emily O'Donnell, Vassilis Glenis, Glyn Everett and Greg O'Donnell represented the Consortium. John Robinson, Kelly Graham, Darren Varley and Justin McLaughlan attended on behalf of Newcastle City Council.

Initial meetings of core members of the Newcastle and Ebbsfleet LAAs will meet in the first quarter of 2017. Subsequently, both LAAs will meet about every 8-10 weeks, although meeting frequency will be determined by LAA members at the early LAA meetings.

RAs and Co-Is from WPs 1-4 will attend LAA meetings as appropriate to meetings themes and the specific topics to be discussed. Consortium members will describe and present the interim results of their research to date and outline the next steps, as relevant to the case study location. They will receive feedback from LAA members concerning the utility of their research in the context of challenges faced by the case study cities. This will help ensure that the research outcomes are relevant to a range of practitioners, in addition to generating excellent science.

- **Links to other WPs and Contribution to Consortium Outcomes**

Research findings and practitioner feedback will align, and periodically re-align, research in WPs1-4 with end-user needs in the case study cities, throughout the project. In this context, distinguishing features of the case studies element of WP5 include:

a) responsiveness to practitioner needs,
b) a focus on empowering local champions,
c) co-production of new knowledge needed to meet technical challenges and overcome social, institutional and political barriers to innovation in sustainable urban flood and water management,
d) delivering urban flood and water resilience in practice, in the contexts of retro-fit, redevelopment and peripheral development in a core city and new build in a Garden City on overcoming barriers to innovation.

3. PROJECT MANAGEMENT

3.1. Management Structure

The project is coordinated and managed at the University of Nottingham by Colin Thorne, with assistance from Nigel Wright, Richard Fenner and Emily O'Donnell. Administrative support is provided by the Consortium Administrator, Lindsey Air.

Progress meetings (Quarterly Progress Meetings) are held at three monthly intervals, alternating between virtual and round-the-table formats.

The Strategic Advisory Board (SAB) provides oversight, inter-acting formally with the Research Consortium at bi-annual, strategic review and feedback meetings and, occasionally, through correspondence at other times – as appropriate.

Dissemination activities will be assisted by the Construction Industry Research and Information Association (CIRIA) and the UK River Restoration Centre (RRC) and will include professional publications and a programme of domestic and international knowledge exchange and dissemination workshops and events.

The Consortium will itself organize additional stakeholder workshops on selected topics in sustainable urban flood risk and water management, some of which will be held in Northern Ireland, Scotland and Wales. In all aspects of project management and dissemination, the project team will make best use of experience gained from the PI's leadership roles in Flood Foresight, FRMRC and the Blue-Green Cities research projects, together with the wide experience of the co-Is and RAs, and advice gained from the SAB and our project partners.

3.2. Financial Management

Each University will be responsible for administering their own grant under the terms of their Award Letter and the Consortium Agreement (Annex IV). As part of WP5, the University of Nottingham will fund activities by the co-Is and RAs in the two demonstration case study cities, as detailed in Annex II.

Any issues that arise concerning the budgets of each University will be discussed at project meetings with appropriate actions being agreed at that meeting. Where actions are agreed, these will be completed and reported back to the Consortium Administrator in advance of the next Quarterly Progress Meeting.

3.3. Dissemination

Dissemination will be led by the University of Nottingham (Colin Thorne and Emily O'Donnell), supported by the Consortium Administrator and with the assistance of Paul Shaffer (CIRIA), Marc Naura (RRC) and Jenny Mant (Ricardo), who are contracted to provide such support. Assistance with dissemination will also be provided on an 'On Call' basis at Nottingham and Newcastle Universities by designated Dissemination Officers.

3.4. Strategic Advisory Board (SAB)

The membership of the SAB is listed in Table 2. The Terms of Reference of the SAB may be found in Annex III.

Table 2 Membership of the SAB

Name	**Organisation**
Adam Baylis (Chair)	Environment Agency
Angie Bone	Public Health England
Bridget Woods-Ballard	HR Wallingford
Chris Digman	MWH
Dave Gowans	sweco
David Wilkes	Arup
Fola Ogunyoye	Royal HaskoningDHV
Hans Jensen	UKWIR
John Robinson	Newcastle City Council
Kit England*	SNIFFER
Mark Stranaghan	Department for Infrastructure, NI
Martin Buckle	RTPI and Independent Planning Consultant
Martin Kennedy	Northumbrian Water
Peter Drake	Water Industry Forum
Simon Harrison	Ebbsfleet Development Consortium
Simon Spooner*	Atkins

*corresponding member

3.5. Research Collaboration (National)

The Consortium will engage with current UK research projects on urban flood, water and infrastructure management, such as iBUILD (Infrastructure BUsiness models, valuation and Innovation for Local Delivery), ICIF (International Centre For Infrastructure Futures), and MISTRAL, phase two of the Infrastructure Transitions Research Consortium (ITRC).

Two of the Consortium Universities (Cambridge and Newcastle) are partners in UKcric (UK Collabatorium for Research on Infrastructure and Cities) and, through development of these themes in Newcastle and Ebbsfleet this research will build on UKcric's vision of developing urban infrastructure observatories, with specific interaction envisaged with the Newcastle Water Hub.

Further links exist (through Exeter and Newcastle) with EPSRC's recently launched Twenty 65 project, which is addressing population growth, ageing infrastructure and climate change, by tailoring solutions in the water sector to fit local circumstances.

These (and other) links offer clear opportunities for synergistic collaboration with related research groups.

3.6. Research Collaboration (International)

Cities and stakeholders in Europe (e.g. Rotterdam, TU Delft, KTH Stockholm Sweden), North America (e.g. Portland, MIT, San Francisco), Canada (e.g. Calgary), Australia (e.g. Melbourne, Sydney, Monash University), and the Far East (e.g. IT Mumbai, Ningbo China, SE University China, Nanjing) are also addressing the challenges addressed in this research programme.

Links will be developed with the authorities and academics in these locations to identify and share best practice as well as with bodies such as the International Water Association (IWA, Cities of the Future Programme), ICLEI Canada (Livable Cities Forum), the Resilient Cities Leaders Forum, and European

Programmes (e.g. Financialisation, Economy, Society and Sustainable Development, FESSUD, Delft Flood Resilience Group).

Academic institutions with whom dialogue will be established include Monash University's Centre for Water Sensitive Cities, UNESCO-IHE Flood Resilience Group, and the MIT Department of Urban Studies and Planning (Co-LAB).

3.7. Engagement with Related Projects

There will be a two-way exchange between the Urban Flood Resilience Research Consortium and similar research at national and international levels. A list will be added to the Urban Flood Resilience website for reference by the Consortium. This will be regularly updated as new research, reports and blogs are created.

4. REPORTING

4.1. Internal Monitoring and Reporting

Internal monitoring and reporting will be handled through Quarterly Progress Meetings, with the minutes being posted on the Consortium website.

4.1.1. Scientific Progress Reporting

Copies of all scientific and technical outputs will be submitted to the Consortium Administrator for recording. Scientific progress will be reported to and reviewed by the SAB at bi-annual meetings and reported to the EPSRC in line with the terms and conditions of the Award Letters (see Annex IV).

4.1.2. Financial Reporting

Financial reports will be prepared at each University by the relevant administrator, with assistance from the respective co-I, and in accordance with the terms of their Award Letter.

4.2. Strategic Advisory Board

The Strategic Advisory Board (SAB) will report their comments and advice in a short written report submitted to the Consortium Administrator following each of its six formal meetings. In addition, the SAB will (with assistance from the PI and lead RA) assess the practical relevance of the Consortium's research in an applications-oriented science audit at the end of Years 1, 2 and 3.

4.3. Reporting to EPSRC

Reports to the EPSRC will be prepared and submitted as required under the terms and conditions of the Award Letters.

All relevant outputs must be entered annually into 'Researchfish'. As the EPSRC funding is in the form of a joint award, each partner university is responsible for its own entry in Researchfish. Nottingham will investigate whether it is possible for all outputs to be linked to the Consortium within Researchfish in order that it can easily be accessed and assessed as a whole, rather than the outcomes being spread across nine separate entries.

5. ANTICIPATED PROJECT OUTCOMES AND IMPACTS

5.1. Consortium Impact

This project has the potential to enable a step change in protecting UK cities and the national economy against risks due to increased storminess caused by climate change, without constraining urban renewal and development. It can do so by envisioning and making deliverable a different water future: one based on resilient cities where flood and water management is planned, developed, designed and operated in ways that are truly sustainable. Our international networks and profiles mean that, as our new science emerges, it will be brought to the attention of the city leaders and populations not only in the UK, but worldwide.

The new science and knowledge created through our research will be of direct utility to academics, practitioners and organisations engaged in UFRM worldwide. Achieving the project aim will certainly help make the case study cities (Newcastle and Ebbsfleet) resilient to future floods despite uncertainties concerning climate and socio-economic changes. Our research also has the potential to help make cities throughout the UK more resilient and liveable; better able to manage future extremes of both flood and drought. The same is true for cities worldwide that are receptive to innovations needed to deliver integrated B/G+G and SuDS systems. Our research has the potential to inform public debates on urban planning, development and flood risk, to empower practitioners who recognise the need for transformative change and to increase confidence among UFRM decision makers.

Knowledge, insights and understanding of urban flood resilience generated by the Consortium will be useful not only to organisations and practitioners responsible for urban flood risk management, but also people living and working in cities throughout the UK and beyond, including Councillors, voters who elect them, tax payers who fund flood risk management and people and communities at risk of flooding.

We are committed to conveying our findings in ways accessible to professionals and decision makers, as well as the people and communities they serve. Specific impact groups and outcomes include:

SOCIAL IMPACTS

Civic society and governance:
Enhanced planning policy
Sustainable urban growth and development
Improved public health and well-being
Wider stakeholder engagement in city
Planning and governance

Citizens and Communities:
Urban renewal
Reduced flood anxiety
Neighbourhood uplift
Increases in flood and water literacy
Flood and water citizenship
Improved quality of life

ECONOMIC AND ENVIRONMENTAL IMPACTS

Urban economies:
Reduced flood losses and business disruption
Multiple benefits between floods from B/G+G spaces and corridors
Increased water security
More productive workforces

Competitive edge over rival cities that are not flood resilient, regionally, nationally and globally

Urban environments:
More urban green spaces and corridors
Managed flooding during extreme events that exceed capacity of piped/surface drainage system
Improved water quality
Improved air quality
Reduced urban heat island effects
Improved soil and soil water quality
Higher resilience to floods and drought

From the outset, impacts will extend outside academia because policy makers, planners, developers, engineers and communities in Bristol, Newcastle and Ebbsfleet will be actively engaged in our research. Our website and use of social networks, plus blogs, webinars, press briefings and appearances on the broadcast media will:

a) reduce the lag between production of new knowledge and impact outside academia, and
b) enable us to inform debate in real time on how to make cities flood resilient places where people live better and work more productively.

ACADEMIC OUTPUTS

Consortium members all have stellar records of scholarly publication and speaking at academic and practitioner conferences. They will certainly write journal papers, including papers in The Journal of Flood Risk Management, ICE Water Management, Urban Water Journal and Environmental Science and Policy, conference papers, reports and book chapters based on their findings.

PUBLIC OUTPUTS

Factsheets will be produced showcasing the key research findings from each WP, in a non-technical manor suitable for widespread public dissemination. Research findings will also be presented on the Urban Flood Resilience Website (www.urbanfloodresilience.ac.uk) and social media outlets, e.g. Twitter (Urban Flood Resilience @BlueGreenCites) and LinkedIn (Urban Flood Resilience Group).

OTHER OUTPUTS

The novel engagement with and involvement of end-users throughout the project will lead to the RA's gaining experience in ensuring impact at the early stages of their research careers that they will carry through to future projects, perpetuating pathways to impact established herein.

5.2. Work Package Outputs

5.2.1. WP1. Resilience under change

- **Academic Outputs**

The peer reviewed academic outputs will underpin the practitioner outputs outlined in the next section.

- **Practitioner Outputs**

a) Estimates for long-term BGI flood and water quality performance in the context of UKCP09 climate change forecasts.

b) Understanding of the feasibility of BGI and SuDS retrofit in residential, commercial and industrial areas

c) Model of the technical performance of key retrofit asset types

d) A GIS Toolbox which supports the comparative evaluation of the costs and benefits of alternative UFRM solutions

e) An approach to evaluate urban drainage system resilience and the effect of multi-functional enhancement strategies which take into account the optimum mix of design options over time and under uncertainty.

5.2.2. WP2. Managing stormwater as a resource

- **Academic Outputs**

We will present work at national and international conferences such as the 14th IWA/IAHR International Conference on Urban Drainage (Prague 2017). In the later stages of the project we will publish in appropriate, peer-reviewed international journals, such as the Journal of Flood Risk Management, ICE Water Management Journal, the Urban Water Journal and Water Research.

- **Practitioner Outputs**

a) Practical and efficient solutions for recovery, recycling and re-use of stormwater as a resource to increase water security in a future characterised by more intense and frequent storms and longer more stressful droughts

b) Enhanced design tools for sizing recovery systems and models to appraise their performance on the management of stormwater flows and quantification of benefits from each recovery option

c) Open source tools such as the enhanced RWH tool will be made available in the public domain to all relevant stakeholders

- **Public Outputs**

a) Dialogue with stakeholder groups about perceptions of stormwater re-use and mitigation of concerns

b) Dialogue with other utility operators (e.g. electricity sector) for joint (co-ordinated) action across the water-energy nexus

c) Practical pathways for potential enhancement and maintenance of urban green spaces

- **Other Outputs**

Through interactions with representatives on the SAB (including the Environment Agency, Public Health England, and drainage authorities, see section 3.4) the research outputs will be co-ordinated and implemented across responsible organisations.

5.2.3. WP3. Inter-operability with other systems

- **Interactions with other work packages**

a) Inter-operable designs solutions for urban systems

b) Contribution to improved 'system' impact estimation (direct and indirect)

c) Framework and approach capable of providing monetary and wider system valuation of FRM and adaptation decisions for use in optimisation and future pathway analysis

d) Bespoke impact profiles for case Newcastle and Ebbsfleet sites, including wider impacts of flood events

e) Contribute to academic impact of the project through engagement activities and dissemination of high quality research

- **Academic Outputs**

WP3 will produce two journal papers. The initial paper will be based on the conceptualisation and review of existing boundaries in flood evaluation for inter-operable design solutions in the UK. Some extended analysis of international approaches (with Consortia engagement) will help increase the international aspect of the work The second journal paper will be based on the practical application of the approach and techniques developed. Targeted journals include: Journal of Flood Risk Management, Climatic Change, Ecological Economics, and Applied Geography.

- **Practitioner Outputs**

a) WP3 will demonstrate what is achievable by extending existing approaches and outline pathways for future work which can be developed for wider urban roll out

b) Recommendations towards design and evaluation of more integrated approaches

c) Applying new Government guidance for valuing systemic resilience and infrastructure valuation theory (e.g. real options) on urban flood and water cycle management systems

- **Public Outputs**

a) Better value flood defence schemes (using inter-operable designs)

b) Improved evaluation of the flood management schemes and a framework to better capture value at all levels local-regional

c) Progress towards more sustainable flood management approaches (e.g. better living spaces, multifunctional defences, etc.) that will improve the 'liveability' in and around urban flood risk areas

- **Other Outputs**

The approach developed could be tailored to fit with adaptation of other infrastructure systems in the future (although this is beyond the scope of WP3).

5.2.4. WP4. Citizens' interactions with B/G+G infrastructure

- **Interactions with other work packages**

a) From the work of WP4 with local communities, models of best practice for community engagement and effective knowledge exchange will be developed that will be shared with WP5, to try to ensure that local voices are listened to throughout the planning process

b) WP4 will provide the tools to collect the citizen data that will be required for WP5 data analytics. Through ongoing knowledge exchange and discussion, WP4 will both learn from WP5 thinking and contribute to the development and implementation of the WP5 programme

c) The WP4 data analytics work will further help to embed community perceptions, values and behaviours into thinking around:

   i. More innovative, adaptable and sustainable UFRM designs [WP1a]: with an improved understanding of what people need and want (in terms of dealing with excessive water flows, keeping spaces hydrated, providing cleaner water and amenity values through the provision of green spaces, recreation, relaxation and flora and fauna), designs of UFRM will be able to be tailored more specifically to the particular exigencies of different communities
   ii. What local residents want to know about B/G+G functions and how this interest might be utilised in studies [WP2 and 3]; through conversation with residents and WP-leaders, possibilities for citizen science engagement will be explored

d) WP4 case studies will offer information to professionals on what forms of engagement are and are not felt to work with different communities (WP5)

e) WP4 will supply key inputs to WP5, while benefitting from feedback from case study city LAA members that will help align and re-align research in WP4 as it progresses

- **Academic Outputs**

WP4 will produce at least three publications (refereed journal articles, book chapters and/or conference-related publications); at least one book contribution and four conference presentations.

- **Practitioner Outputs**

WP4 will produce a range of outputs for different practitioners, format depending upon feedback as to what would be most useful. Possibilities include:

a) A CIRIA guide on B/G+G devices and community engagement

b) A Local Authority guide to community engagement strategies around B/G+G devices

c) An app, for use by professionals in engaging communities as well as gathering data

d) A Digital Testimonials resource toolkit for professional development purposes and wider engagement around effective approaches to engagement

- **Public Outputs**

a) Social media platforms for engagement around devices in people's local community (Facebook, Twitter, Instagram, etc.)

b) An app, to provide local residents with voice and open up more immediate communication around likes, dislikes and issues

- **Other Outputs**

The app and social media platforms that WP4 produces, and the public-facing elements of the data gathered by these, will provide an evidence-backed model for translation and transference to a wide range of issues and locations by a number of parties (governmental, non-governmental, voluntary, etc.).

5.2.5. WP5. Achieving urban flood and water resilience in practice

New protocols will be developed as part of WP5.1 for placing flood and water management decision making at the heart of urban planning as recommended by Pitt (2008) and legislated for in the Flood and Water Management Act (2010). As practitioners are often only concerned with achieving progress with the subject matter of the collaboration (flood risk management) rather than the collaboration process per se, hence the outputs will also pay attention to the collaboration process, including overcoming issues and tensions.

The primary outputs from WP5.2 are case studies demonstrating how urban flood and water resilience can be achieved using:

a) integrated treatment trains of B/G+G infrastructure, coupled with;
b) planned use of urban green spaces and corridors to convey and/or store surface water during events that exceed the capacity of the cities drainage system, in ways that;
c) minimise disruption to other urban systems (energy, transport etc.) while providing;
d) multiple economic, social and environmental co-benefits that matched to,
e) the needs and preferences of communities and stakeholders, within the contexts of:
f) retrofit, urban renewal, new build/new town applications.

Taken together and explored practically in the case study cities, the carefully selected and inter-woven models, tools and governance/planning/engagement/implementation approaches developed in WPs 1 to 4 have the potential to co-produce the necessary understanding needed for coupling blue, green, grey and smart infrastructure in new and context-specific ways, so that excess water quantities and poor water qualities can be managed as required to achieve the modern paradigm of a *water-sensitive, flood-resilient city*.

- **Interactions with other work packages**

WP1: information on urban water cycles, green spaces and green corridors in the case study cities (to inform coordinated management of the stormwater cascade (WP2)); insight into the opportunities and challenges to installing SuDS in the case study cities, and opportunity to interact with end-users to consult with WP1 to help build a GIS Toolbox to support comparative evaluation of the costs and benefits of alternative UFRM solutions

WP2: opportunities for assessing the resource value of stormwater in the case study cities

WP3: information on confidence, uncertainty and decision-making relating to infrastructure interdependencies

WP4: opportunities to test on-line systems to canvass and potentially shift citizens' and professionals' attitudes and behaviours with respect to B/G+G assets in the case study cities, and; provision of citizen data from case study cities needed for data analytics that embed community perceptions, values and behaviours into innovative and adaptable UFRM designs

- **Academic Outputs**

We will publish research in peer reviewed journals, such as the Journal of Flood Risk Management, Environmental Science and Policy, and ICE Water Management, and present our research at international and national conferences, including Flood and Coast 2017 and the International Conference on Flood Management 2017.

- **Practitioner Outputs**

Demonstration case studies research will offer recommendations to enhance planning policy and guidance, widen stakeholder engagement in city, and begin to transform planning and governance in Newcastle and Ebbsfleet, and potentially other Core Cities.

- **Public Outputs**

Public outputs in the case study cities (Newcastle and Ebbsfleet) include evidence to support:

a) Sustainable urban redevelopment, renewal, growth and development
b) Improved public health and well-being
c) Wider stakeholder engagement
d) Reduced flood anxiety
e) Neighbourhood uplift
f) Improved quality of life
g) Multiple co-benefits between floods from Blue-Green infrastructure, spaces and corridors

- **Other Outputs**

Our research into the benefits and impacts of multifunctional B/G+G infrastructure will generate knowledge to help stakeholders in Newcastle and Ebbsfleet to:

a) Reduce flood losses and business disruption
b) Increase water security
c) Produce a more productive workforce
d) Generate a competitive edge over rival cities that are not flood resilient, regionally, nationally and globally
e) Create more urban green spaces and corridors
f) Manage flooding during extreme events that exceed capacity of piped/surface drainage system
g) Improve water quality
h) Improve air quality
i) Reduce urban heat island effects
j) Improve soil and soil water quality
k) Create a higher resilience to drought

5.3. Dissemination Plan

Managing the risks of urban flooding to individuals, communities, businesses, property, infrastructure, commerce and the environment in cities, lies at the heart of this project. The project objectives include studies of the impact on, and feedback from, stakeholders including not only UFRM planners and decision-makers, but also individual citizens, community leaders, and businesses. In this respect, co-production of knowledge is integral to the research and the dissemination of our findings will begin on day 1. For example, the objectives of the project include to:

"*Make the objectives of multi-objective planning policies deliverable in practice by bringing together engineers, stakeholders and Local Authorities in partnership working*"

and,

"*Create connectivity in urban flood and water planning and management systems to facilitate positive interactions between: engineered assets; advances in water technology; natural processes in restored urban streams and drainage systems; and the preferences and behaviours of the citizens and communities that benefit from systems of B/G+G infrastructure*"

Further, case studies are central to this research and engagement with practitioners and communities throughout the project using *Participatory Action Research* provides an ideal pathway for dissemination of co-produced knowledge, data, analyses and methods. This will be led by WP5 who will align research in WPs 1-4 with end-user needs based on practitioner feedback on research findings at regular LAA meetings. This will enhance the reliability of the project outputs, ensure user buy-in and uptake of the project's user-focused deliverables.

In addition to engaging with end-users in co-production of knowledge and outcomes through WP5, further steps to ensuring impact through dissemination include:

1. Engagement with key stakeholders beyond those involved directly in the project through fieldwork, meetings and workshops that will include:
    a) Statutory authorities such as the DEFRA, EA for England and Wales, SEPA, and the Northern Ireland Department for Infrastructure (DfI), based on links that already exist between the team and these bodies and as well as new contacts;
    b) Built environment professionals such as architects, civil engineers, urban planners, transport and highways bodies and their professional institutions;
    c) Local Authorities in the case study cities (Newcastle and Ebbsfleet);
    d) Citizens through engagement with Non-Governmental Organisations (NGOs) such as the Rivers Trusts, National Flood Forum and appropriate local social enterprises.

2. Research in the project has started by drawing on the procedures already adopted by practitioners in designing urban fabrics, spaces and green corridors including, amongst others, the SuDS Manual, the RRC Manual, FRA Channel Design Options, Foundation for Water Research FR/R0014, Defra FD2619 and relevant CIRIA Reports. This means that the project's outputs will be set in a framework that is readily usable by practitioners. For example, CIRIA (Paul Shaffer) and RRC (Mark Naura and Jenny Mant (Ricardo)) have been contracted to provide dissemination support through their networks and will help with planning, advertising and organising delivery of the impact activities and outputs.

3. We have put in place a SAB made up of senior professionals in UFRM including representatives of the Environment Agency, Water Companies, consultants, City Councils, Public Health England and UKWIR (Table 2).

4. Each RA will spend at least two weeks at the beginning and end of the project on secondment to relevant organisations in one of the case study cities. The initial secondment will embed the project with stakeholders (e.g. Local Authorities, Water Companies, Environment Agency, Development Corporations), give RAs insights regarding barriers/opportunities for building flood resilience, and establish communications with practitioners. The final secondment will facilitate knowledge exchange and encourage uptake of project deliverables designed to help practitioners overcome challenges and implement innovation needed to achieve flood resilience

5. We will engage with professional associations such as the IWA and ICLEI internationally and CIRIA, the RTPI and TCPA nationally.

6. We will present work at national and international conferences such as the biennial International Conference on Flood Management (ICFM). In the later stages of the project we will publish in

appropriate, peer-reviewed international journals, such as the Journal of Flood Risk Management.

7. Internationally, we are engaging with other projects such as the Delft Flood Resilience Group (www.floodresiliencegroup.org), ICLEI and the Resilient Cities Leaders Forum (http://resilientcities2016.iclei.org/), and Ceres: Building Climate Resilient Cities (https://www.ceres.org/). International dissemination will culminate with a closing workshop held at the Royal Society of London (as was highly effective for FRMRC II).
8. Research outcomes of immediate relevance to practitioners will be published by CIRIA with assistance from the RRC. Production of four CIRIA reports will be guided by our SAB. Paul Shaffer (CIRIA), Mark Naura (RRC) and Jenny Mant (Ricardo) will assist the team in matching the content to the needs of practitioners (as they have done for reports by FRMRC and Blue-Green Cities). RRC involvement will extend our reach to professionals in the restoration of urban streams and wetlands, assuring wide dissemination, uptake and impact.

9. We will communicate the research on an on-going basis through internet-based tools including a project website, Twitter feed and LinkedIn group maintained by Emily O'Donnell.

The team all have prior experience of working with end-users in other projects. In particular Colin Thorne and Nigel Wright have been involved in generating user-focused research outputs in FRMRC. In this context, Colin Thorne was deputy Chair (Dissemination) for the FRMRC and he chaired FRMRC's Dissemination Committee. The University of Nottingham were responsible for the two user-focused deliverables produced during FRMRC I and have been involved in producing three of four CIRIA Reports coming out of FRMRC II. In this respect, the professional and stakeholder networks already developed under FRMRC will bring a large group of end-users to this project.

In addition, Colin Thorne and Emily O'Donnell were responsible for dissemination of user-focused research outputs from the Blue-Green Cities project, which included a successful website (45,977 views by 35,609 unique visitors), social media (168 LinkedIn Group members, 1325 Twitter followers), project blog (7490 views by 6139 unique visitors), Wikipedia page (over 16,000 views) and project factsheets (850 views of 16 factsheets) (statistics from 04.01.17). The Blue-Green Cities project culminated in a dissemination event in the demonstration city of Newcastle in February 2016 where the 'Newcastle declaration on Blue and Green Infrastructure' that was launched by Newcastle City Council (http://www.bluegreencities.ac.uk/bluegreencities/documents/blue-green-declaration-signed.pdf). The declaration was signed by six major public and private organisations actively involved in flood and water management and committed signatories to; the prioritisation of BGI in managing flood risk; the importance of changing working practices towards greater collaboration; working with developers to maximise BGI in new developments; raising awareness and building capacity amongst communities to develop and maintain BGI; and piloting new way of working to realise the multiple benefits of BGI. It is our ambition in the new Consortium to use experience gained during the Blue-Green Cities project to increase the number of people outside academia that engage and interact with us by at least one order of magnitude.

Other co-investigators are involved in a variety of related, funded projects (EU, Research Councils, etc.) both in the UK and internationally that will ensure two-way engagement with this project.

5.4. Key Performance Indicators (KPIs)

The performance of the Consortium will be monitored by the PI in relation to key performance indicators (KPIs). Each of the Project's WPs have their own time line, milestones and outputs, which will be used to gauge and assess the successful and timely completion of each element of the research programme. Comparison between research progress and the agreed timelines will alert the PI if any tasks are late so that timely corrective action can be taken. The need for and, when necessary, the nature of changes to the work programme will be identified and fully documented. Indicators of progress and success within the WPs that may be used by the management committee include:

- Manuscripts submitted to peer reviewed journals
- Conference papers
- Technical reports
- New collaborations
- Interactions with stakeholders and users
- Interactions with elected representatives and other decision makers
- Interactions with the international research community
- Generation of additional, related research funding
- Outreach activities

Additional KPIs to be monitored by the PI include:

- Interest in the Consortium website (e.g. number of hits and queries/contacts)
- Interest expressed in urban flood resilience more generally, for example through interest in other websites
- Highlights on wider societal and/or ethical components of the project, such as public outreach activities
- Collaboration and data exchanges with groups and organisations outside of the UK
- Overall quality and efficiency of the "external" communication strategy of the Consortium and level of European and International recognition of the Project's research, as evidenced by co-citation, referencing, requests for information received by Project Administrator, invitations received by the Partners, etc.
- Management of intellectual property and commercialisation of research output: as evidenced by management reporting
- Capacity of the Consortium to meet financial targets and to deliver results on time and on budget: as formally reported to the EPSRC
- Progress towards delivering the stated outputs and outcomes

5.5. Science Audit

The quality of the science being developed by the Consortium within the project will be assessed using standard EPSRC peer review procedures. The international relevance of the work will be assessed with the help of the SAB which will provide written feedback and recommendations after each SAB meeting and full science audit at the end of Year 3.

6. MANAGEMENT OF RESULTS AND OF INTELLECTUAL PROPERTY RIGHTS (IPR)

The obligations resulting from the Award Letters and Consortium Agreement (Annex IV) are binding for each University participating in the Consortium.

The EPSRC can request access to information held by any of the universities in the Consortium and the EPSRC requires them to comply with the Freedom of Information Act 2000 and the Environmental Information regulations.

The EPSRC must be informed of any major changes to the research project including in particular any failure to gain access to planned research facilities and services which will affect the deliverables. The EPSRC can request revised proposals and can decide to issue a new grant.

The ownership of intellectual property and responsibility for its exploitation rests with the research institutions. The research institutions have granted EPSRC licence to use the Results and Foreground IPR and the EPSRC may sub-licence each of the Funders.

Consortium universities and their researchers must ensure that all valuable results are protected and exploited and that they produce a suitable return. If the researchers do not intend to protect or exploit the results, the Funders have the option to have the IPR assigned to them at no charge. At their own expense a Funder(s) may protect or exploit those results. In such cases the researchers will not be entitled to a share of any income generated.

The Consortium universities must ensure that all those associated with the research are aware of, and have accepted the arrangements for exploitation of research findings as set out in the Consortium Agreement.

All results from the project (information and intellectual property rights resulting from the performance of the project) are the property of the university that has generated them. Ownership of information and intellectual property rights which pre-date the Consortium and/or are generated independently of the Consortium is not affected by the Consortium.

Each university owns the results it has generated or conceived. Commercial exploitation of the Results is required in accordance with the EPSRC Award Letters and universities should share the revenues resulting from the exploitation of joint results in proportion to their respective contributions and effort.

All decisions concerning the protection of IPR should be made by the university(s) generating the results and they should pay the resulting costs (in the case of joint results in proportion to their share of the ownership). The universities undertake to provide reasonable assistance in connection with proceedings involving any patent filed in connection with any results from the project.

The universities are entitled to publish and to present papers based on Consortium research, but are requested to provide copies to the Consortium Administrator for recording and archiving. In cases were IPR protection is being pursued, publication may be delayed to allow IPR protection to be put in place.

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8. LIST OF ACRONYMS AND ABBREVIATIONS

AHP	Analytical Hierarchy Procedure
ASC	Adaptation Sub-Committee
B/G+G	Blue/Green and Grey
BGI	Blue-Green Infrastructure
BS	British Standards
CBA	Cost-benefit analysis
CEDR	Centre for Effective Dispute Resolution
CIRIA	Construction Industry Research and Information Association
Co-I	Co-Investigator
Defra	Department for Environment, Food and Rural Affairs
DfI	Northern Ireland Department for Infrastructure
DGT	Data-Gathering Technology
EA	Environment Agency
EDC	Ebbsfleet Development Corporation
EPSRC	Engineering and Physical Science Research Council
FRMRC	Flood Risk Management Research Consortium
FESSUD	Financialisation, Economy, Society and Sustainable Development
GIS	Geographical Information Systems
IAT	Implicit-Association Test
iBUILD	Infrastructure BUsiness models, valuation and Innovation for Local Delivery
ICFM	International Conference on Flood Management
ICIF	International Centre For Infrastructure Futures
IPR	Intellectual Property Rights
ITRC	Infrastructure Transitions Research Consortium
IWA	International Water Association
LAA	Learning and Action Alliance
LWEC	Living with Environmental Change
NGO	Non-Governmental Organisations
PAR	Participatory Action Research
PI	Principal Investigator
PTST	Probabilistic tank-sizing tool
RA	Research Associate/Fellow
RRC	River Restoration Centre
RTPI	Royal Town Planning Institute
RWH	RainWater Harvesting
SEPA	Scottish Environmental Protection Agency
SuDS	Sustainable Urban Drainage Systems
SPT	Social Practice Theory
TCPA	Town and Country Planning Association
UFRM	Urban Flood Risk Management
UKcric	UK Collabatorium for Research on Infrastructure and Cities
UKWIR	UK Water Industry Research

9. ANNEXES

Annex I. Consortium Team Biographies

Prof Colin Thorne (PI) is Chair of Physical Geography at Nottingham. He has nearly 200 refereed papers/chapters and nine books, with nearly eight thousand citations. During a career spanning four decades, he has held posts with the universities of East Anglia, Colorado State, London, Canterbury (NZ) and Nottingham. He has led/co-led inter-disciplinary flood research consortia including: Flood Foresight, FRMRC, and the China-UK Taihu Basin Joint Flood Study, and has £17M+ of grant income. He led the Blue-Green Cities Research Consortium (http://www.bluegreencities.ac.uk).

Prof Nigel Wright (co-I) is PVC/Dean of Technology at De Montfort University having until recently been Professor of Water and Environmental Engineering at Leeds. He has over 120 peer-reviewed journal and conference papers and over £4M of grant income. Award of an EPSRC Discipline Hop Grant led to his research broadening to include vulnerability assessment. He was a co-I in the FRMRC and is currently a co-I in the SESAME, Blue-Green Cities and EU Climate Adaption (www.base-adaption.eu) projects. His international experience includes leading Masters' education at UNESCO-IHE, Delft and a Visiting Post at the Chinese Academy of Sciences Institute for Mountain Hazard and Environment, Chengdu. With co-authors, he won the 2009 IAHR Harold Schoemaker Award.

Dr David Dawson (co-I) is in Leeds University's Institute for Resilient Infrastructure. His research focuses on development of infrastructure systems that can adapt to changes in the social and physical environments within which systems are financed, created, used and managed. He has developed methods to assess infrastructure materials, values, appraisals and futures (EPJ005576; JSPS FFI/423; EP/K012398/1; EP/K503526/1). He was recently awarded a Leverhulme Early Career Research Fellowship investigating the challenges facing the adaptation of UK transport and infrastructure networks to future climate and weather impacts (ECF/2014/144), and funding for a secondment at the Department for Transport to co-write their response to the Transport Resilience Review (R29834/CN002).

Dr Richard Fenner (co-I) is a Reader in the Department of Engineering Centre for Sustainable Development at Cambridge University. He has published more than 100 papers, books and chapters. Richard is a Chartered Civil Engineer and CIWEM Fellow specialising in water, sanitation and sustainability issues in developed and developing countries, with a focus on urban drainage and water asset maintenance, e.g. Project Neptune (EPSRC EP/E003192/1). He is currently a co-I on 3 RCUK projects (Blue-Green Cities; Water interactions for whole energy systems modelling in the UK (Wholesem), (EPSRC: EP/K039326/1), and; A hidden crisis: unravelling current failures for future success in rural groundwater supply (NERC: NE/M008606/1). He is the recipient of several awards from the ICE including the George Stephenson Gold Medal, R A Carr Prize and James Watt Medal.

Prof Chris Kilsby (co-I) is Professor of Hydrology and Climate Change in Civil Engineering and Geosciences at Newcastle. He led the Defra commissioned, UKCP09 climate projections Weather Generator programme and subsequently simulated weather hazards for built environments through EPSRC projects valued at £4.4M. He was co-I of Flood Modelling for Cities using Cloud Computing, (EP/I034351/1), and is currently PI of the EPSRC FloodMemory project (EP/K013513/1), and co-I of Blue Green Cities (EP/K013661/1). He is co-I of EPSRC Resilient Electricity Networks for Great Britain (EP/I035781/1) and Senior Academic with the Willis Research Network on collective flood risk for the insurance industry.

Assoc. Prof Jessica Lamond (co-I) is in the Centre for Floods Communities and Resilience at UWE. She has over 130 peer-reviewed papers, books and chapters. She researches multiple aspects of urban flood risk, including development of novel understandings of barriers, and stakeholder/community engagement in flood adaptation, mitigation, recovery and insurance. Projects include Retrofit of SuDS in Central Business Districts (Royal Institute of Chartered Surveyors); a World Bank sourcebook for climate adaptation in Latin America, and Defra Pathfinder evaluations for Liverpool and Calderdale Councils. She was a co-I on the Blue Green Cities and FloodMemory projects, leads theme D (Urban

land-use planning and governance) of the Urbanisation Research Nigeria programme (DFID AC/201433), and manages the Supporting delivery of low cost resilience project (Defra FD2682).

Dr Karen Potter (co-I) is a Research Fellow in Collaborative Governance at the Open University. She is a former Local Authority planning practitioner with experience in cross-sector partnerships in water management and urban regeneration. Her research focuses on shifts in governance at the interfaces between science, policy and practice. She was PI of the NERC/TSB/WG Knowledge Transfer Partnership on Mainstreaming Natural Approaches to Flood Risk Management (KTP009107) and a co-I on the EU Interreg projects Celtic Seas and 'Pure Hubs' - creating urban-rural land-use connections. She is a member of the Defra/EA Thematic Advisory Group for Policy, Strategy and Investment; Deputy Chair of the RTPI Wales Policy and Research Forum, and represents the WaterCore Action Group European Innovation Partnership on regional water governance.

Dr Scott Arthur (co-I) is an Associate Professor at Heriot-Watt University. His research addresses all aspects of urban drainage, from roof systems to urban watercourses and sewer networks. Building on internationally leading work on the formation of blockages in sewers (GR/S17512/01), research undertaken in FRMRC II (EP/F020511/1) and SAWA has established Heriot-Watt as leaders in understanding debris-related flood risks. The key research outcome has been to link land-use to generation of natural and/or anthropogenic debris and which types of trash screen are most likely to block. Practical outputs are reported a high impact CIRIA Technical Note, which will be incorporated in UK culvert design guidance. He was a co-I the EPSRC Blue Green Cities project (EP/K013661/1), leading research on the movement of sediment and debris through urban drainage systems.

Dr Heather Haynes (co-I) is an Associate Professor in Heriot-Watt University's Water Academy. She is a Chartered Geographer and Fellow of the Royal Geographical Society (FRGS). Her research combines expertise in field monitoring and computational modelling to advance flood risk, water quality and eco-geomorphology research in natural and engineered watercourses. She was co-I on three RCUK projects: FloodMEMORY (EPSRC: EP/K013513); Blue-green cities (EPSRC: EP/K013661/1) and the Flood and Coastal Erosion Risk Management (FCERM) Network (EPSRC: EP/L000180). She has authored around 20 papers and book chapters and is an elected member of the Royal Society of Edinburgh's inaugural Young Academy.

Prof David Butler (co-I) is professor of water engineering and co-director of CWS at Exeter University. He specialises in sustainable and resilient urban water management, integrated modelling of urban water systems, urban drainage and flooding, and water efficiency. He has over 150 refereed journal papers and 15 books/reports. He currently holds an established career research fellowship (Safe and SuRe: Towards a New Paradigm for Urban Water Management, EP/K006924/1), is co-I of the STREAM Industrial Doctorate Centre (EP/G037094/1) and the WISE Centre for Doctoral Training in Water Informatics: Science and Engineering (EP/L016214/1). He has been a recipient of 2 consecutive EPSRC platform grants (GR/N22847, GR/S86846) and over 20 other EPSRC grants, plus many EU grants and industrial contracts. He is editor-in-chief of the Urban Water Journal.

Prof Zoran Kapelan (co-I) is professor of water systems engineering and an Academic Lead for the Water and Environment Group at Exeter. He has over 90 refereed journal papers and more than 200 other publications. He is or has been PI/co-I on >25 EPSRC, EU and industrial contracts worth over £4M. He is currently co-I and manager of the WISE Centre for Doctoral Training in Water Informatics: Science and Engineering (EP/L016214/1). His recent research focuses on a metabolism based methodology for long-term planning of urban water systems (developed as part of EU FP7 Transition to Urban Water Services of Tomorrow (TRUST) project) and work on adaptive/flexible flood risk management using Real Options, developed as part of KTP with HR Wallingford and EA's FCERM project (Brisley et al 2013).

Dr Emily O'Donnell (RA) is a Research Fellow in flood risk management at the University of Nottingham. She was the lead researcher and project coordinator on the Blue-Green Cities Research Project (EPSRC: EP/K013661/1) and Clean Water for All initiative. Her current research focuses on

identifying the uncertainties and challenges that act as barriers to the widespread implementation of Blue-Green sustainable flood risk management solutions, the evaluation of the multiple social and environmental benefits of BGI using GIS, and stakeholder engagement practices. She coordinated the Newcastle Learning and Action Alliance (2014-2016) and was fundamental in establishing the Newcastle declaration on blue and green infrastructure. She has a growing publication record (peer reviewed journals, book chapters and reports) and has presented her research at many national and international conferences and events. Emily also has expertise in water chemistry and glaciology gained through her PhD and post-doctoral research into glacier biogeochemistry.

Dr Glyn Everett (RA) is a Research Fellow at the University of the West of England in the Centre for Floods, Communities and Resilience; he has worked on social science projects around education, natural history and flooding for over ten years. Having previously worked on the EPSRC project Delivering and Evaluating Multiple Flood Risk Benefits in Blue-Green Cities, Glyn will now pursue qualitative social research in WP4 and WP5. Glyn's work focusses on the importance of involving public voice in flood risk management, both to gain from local knowledge and to ensure that B/G+G devices satisfy local preferences, thereby hopefully encouraging greater public engagement, understanding and behaviour change. As a wheelchair-user, Glyn is also interested in exploring the position of disabled people with regard to the possible benefits and barriers stemming from B/G+G devices, and emergencies in the built environment.

Mrs Deonie Allen (RA) is a Research Associate with the Water Academy, part of the Heriot-Watt University School of Energy, Geoscience, Infrastructure and Society. With a focus in flood risk, stormwater management (quality and quantity), fluvial geomorphology and sediment transport, her most recent research has been as part of the EPSRC Blue-Green Cities Consortium (WP2b) focusing on stormwater quality, sediment and debris transport through the urban environment. She has also been part of transforming the EPSRC FloodMEMORY cluster flooding impact on flood risk blue skies research findings into practice (SEPA Impact Acceleration Project) and extending this research towards fluvial geomorphological considerations of cluster flooding on flood risk. Deonie has +10yrs of industry experience, working within environmental engineering consultancies undertaking flood risk analysis, EIA /EMP and managing development projects for water quantity/quality compliance.

Mr Vassilis Glenis (RA) is a researcher in the School of Civil Engineering and Geosciences at Newcastle University. His research has been founded on two major technical capabilities: firstly, numerical modelling skills for hydrodynamic applications including urban flooding and drainage networks and secondly, advanced programming skills including object oriented languages, parallel programming, databases and the Cloud. He has developed the detailed hydrodynamic model CityCat for modelling and analysis of high resolution, pluvial, fluvial and tidal surge flooding. A fully-coupled subsurface drainage component has been developed recently. The model promises a paradigm shift in capability and use for not just flood risk assessment but also for design by incorporating Blue-Green infrastructure in urban areas. CityCat has been applied in the UK (e.g. London, Newcastle, Leeds), Australia (Melbourne), Belgium (Antwerp), Argentina (Cordoba) and across 571 European cities.

Dr Greg O'Donnell (RA) is a Senior Research Associate in the Department of Civil Engineering and Geosciences, Newcastle University. He has worked on several RCUK projects to investigate natural hazard impacts on natural, built and socioeconomic systems (e.g. SINATRA NE/K008781/1; FREE NE/F001134/1; FRMRC2 EP/F020511/1). A major theme of his research is the development, application and validation of state of the art hydrological models to solve science questions. In particular, his research has concerned predicting the impacts of anthropogenic changes on catchment and continental scale hydrological fluxes.

Dr Leon Kapetas (RA) is a Research Associate at the Centre for Sustainable Development, Department of Engineering of the University of Cambridge. He holds a Master's Degree in hydrology from Imperial College London and earned his PhD at the University of Edinburgh researching the reactive co-transport of microorganisms and heavy metals in the subsurface. Leon has worked in different research and consulting roles across different countries. He has worked as an urban resilience consultant for the "100

Resilient Cities" in Greece focusing on challenges in the areas of the natural and built environment. As a hydrogeologist in Peru he developed GIS-based groundwater flow and reactive transport models for aquifers in mining environments to support decision making in integrated water resource management. He has also worked as a postdoctoral researcher on multi-phase subsurface flow problems at Delft University of Technology, and the Weizmann Institute of Science, Israel.

Dr Tudor Vilcan (RA) is a Research Associate in the Department for Public Leadership and Social Enterprise at the Open University. He has been recently awarded a PhD from the University of Southampton. Using approaches from social and political science, Tudor's PhD thesis investigated the implementation of resilience policies in practice in the area of flood risk management. In addition to resilience, he is interested in planning, especially in relation to water management. Other research interests revolved around community participation and empowerment and the engagement of individuals with structures of governance. Tudor will be working mainly on WP5 which investigates the barriers to innovation in collaborative governance. Through action research and participatory knowledge, WP5 will look to engage stakeholders in order to overcome these barriers and broaden the uptake of B/G+G infrastructure.

Dr Sangaralingam Ahilan (RA) is a Research Fellow at the University of Exeter in the College of Engineering, Mathematics and Physical Sciences. He has a civil engineering background with research experience in river hydraulics, hydrology, flood and sediment modelling, and sustainability of urban water systems. He has worked on a number of water and environmental engineering projects in Ireland and the UK. In Ireland, he was involved in the Irish National Flood Studies update programme, the EU Water project (e.g., HYDROFOR, SILTFLUX) and the Bathing Water Directive project (e.g., Smart Coasts). In the UK, he took part in two EPSRC Sandpit projects: SESAME EP/KO12770/1 and Blue-Green Cities EP/K013661/1 on sustainable urban risk flood management. In the SESAME project, he contributed to the development of the Agent-Based Model to understand the behaviour of small businesses and associated organisations during and immediately after a flood. In the Blue-Green Cities project, he carried out long-term hydro-morphodynamic modelling to investigate flow and sediment interaction in sustainable drainage systems and their effects on hydraulic performance.

Annex II. Funding for demonstration city activities, secondments and progress meetings

Covered by University of Nottingham

- Accommodation, dinner (£30 pp) and lunch/refreshments (£10 pp) for all members of the team and SAB (32 people in total) for 6 progress meetings (plus travel for SAB)

- Travel to case study cities for 7 RAs (Heriot-Watt x2, Exeter, Newcastle, Cambridge, Leeds, UWE) over the 3 years - 4 LAA meetings per year (12 over 3 years, 6 in Newcastle and 6 in Ebbsfleet), plus 6 additional trips per RA to Ebbsfleet and 6 additional trip to Newcastle for their own case study research. 12 nights' accommodation per RA over the 3 years is also included in the budget

- Travel to case study cities for Nottingham and OU RAs (21 meeting in both Newcastle and Ebbsfleet, plus 12 night's accommodation for each RA over the 3 years)

- Research in retrofit case study (Newcastle):
    - 1000 postal questionnaires (WP4?)
    - 50 hours of interview transcription (WP5)
    - £2.5K for surveying drainage pathways (WP1)
    - £2K for demographic data on citizens (WP4)

- Research in new build case study (Ebbsfleet)
    - 1000 postal questionnaires (WP4?)
    - 50 hours of interview transcription (WP5)
    - £2.5K for surveying drainage pathways (WP1)
    - £2K for demographic data on citizens (WP4)

- Travel for Nottingham PI to case study cities (3 trips to each case study city (6 trips per year, 12 trips in total))

- RA living costs during two-week secondments. £500 per week per RA, for 8 RAs at the start of the project (Nottingham, OU, Heriot-Watt, Exeter, Newcastle x2, Cambridge, UWE) and for 9 RAs at the end of the project (Nottingham, OU, Exeter, Heriot-Watt, Newcastle x2, Cambridge, UWE, Leeds

What each institution will cover

- Travel for Co-Is and RAs to 6 progress meetings – this can be funded by the £8K travel allowance per co-I (over the 3 years)

- Each institution also has £3.3K for travel to case study cities in years 2 and 3. This comprises 3 trips to each case study city (6 trips per year, 12 trips in total). This is for the Co-Is only (Nottingham covers RA travel – see above)

Annex III. Terms of Reference for Strategic Advisory Board (SAB)

EPSRC Urban Flood Resilience Project SAB

TERMS OF REFERENCE

1. To provide independent advice to the Urban Flood Resilience Research Consortium on the quality of the science undertaken by the Consortium and the extent that it fulfils the objectives as set out in the Inception Report.

2. To perform a science audit of each of the Work Packages and report findings and recommendations to the Project Team.

3. To provide an independent source of informed advice to the Project Team and EPSRC as the need arises.

4. To receive and comment upon bi-annual progress reports produced by the Consortium and provide a critical oversight of the dissemination activities it conducts.

5. To advise the Principal Investigator on leading the project to a successful outcome that maximises its potential for impact on urban flood risk management and resilience practices nationally and internationally.

6. To meet as an Advisory Board in June and December/January, these meetings to coincide with quarterly project progress meetings.

7. No fees or stipend are payable to members of the SAB, but reasonable travel and accommodation costs will be refunded against receipts and registration fees for Consortium dissemination events will be waived.

8. Corresponding members will provide advice and steer to the Research Consortium, fulfilling points 1-5 above, and will communicate via email with the SAB chair (Adam Baylis) or Principal Investigator and Nottingham RA (Colin Thorne and Emily O'Donnell). They will not be expected to attend all meetings.

Annex IV. Consortium Agreement

The University of Nottingham

UNITED KINGDOM · CHINA · MALAYSIA

ACADEMIC COLLABORATION AGREEMENT

Dated: 17 November 2016

(1) **University of Nottingham**

(2) **De Montfort University**

(3) **University of Leeds**

(4) **The Chancellor, Masters and Scholars of the University of Cambridge**

(5) **University of Newcastle upon Tyne**

(6) **University of the West of England, Bristol**

(7) **The Open University**

(8) **Heriot-Watt University**

(9) **University of Exeter**

CONTENTS

CLAUSE

SCHEDULE

ACADEMIC COLLABORATION AGREEMENT BETWEEN:

1. **The University of Nottingham** of University Park, Nottingham NG7 2RD, United Kingdom ("**Nottingham**"); and

2. **De Montfort University** whose administrative address is at The Gateway, Leicester LE1 9BH ("**DMU**"); and

3. **The University of Leeds** of Leeds, LS2 9JT ("**Leeds**"); and

4. **The Chancellor, Masters and Scholars of the University of Cambridge** of The Old Schools, Trinity Lane, Cambridge, CB2 1TN ("**Cambridge**"); and

5. **University of Newcastle upon Tyne** a charitable organisation established under the Universities of Durham and Newcastle upon Tyne Act 1963, a statute of England, whose address for service is King's Gate, Newcastle upon Tyne, NE1 7RU, UK ("**Newcastle**"); and

6. **University of the West of England, Bristol** of Frenchay Campus, Coldharbour Lane, Bristol, BS16 1QY ("**UWE**"); and

7. **The Open University,** a body created by Royal Charter (Number RC 000391), an exempt charity in England and Wales, a registered charity in Scotland (Number SC 038302), with its registered address at Walton Hill, Milton Keynes, MK7 6AA, UK ("**Open University**"); and

8. **Heriot-Watt University,** a charitable body registered in Scotland under registration number SC000278, and having its main administrative offices at Riccarton, Edinburgh, EH14 4AS ("**Heriot-Watt**"); and

9. **University of Exeter** of Northcote House, The Queen's Drive, Exeter, EX4 4QJ ("**Exeter**").

Hereinafter, each a "**Party**" and collectively the **"Parties".**

BACKGROUND

The Parties submitted joint proposals to the Engineering and Physical Sciences Research Council (the "**Sponsor**") for an award of funding for the research programme entitled *"Urban Flood Resilience in an Uncertain Future"* (Nottingham Ref: EP/P004180/1) ("the **Project**"), which is set out at Schedule 1 to this Agreement.

Each Party has received a separate award of funding from the Sponsor for the performance of its part of the Project. The Parties' award letters from the Sponsor are attached hereto at Schedule 2 (the "**Offer**"). The Project Partners have agreed to make Contributions to the Project detailed in Nottingham's Offer letter at Schedule 2.

The purpose of this Collaboration Agreement is for the Parties to define their respective rights and obligations with respect such collaborative activities and it is hereby agreed between the Parties as follows.

AGREED TERMS

1. INTERPRETATION

1.1 The definitions and rules of interpretation in this clause apply in this agreement.

"Background Intellectual Property"	means intellectual property already owned by a Party prior to the commencement of the Project or developed or acquired outside the scope of the Project by a Party and introduced into the Project by such Party, including any modifications, improvements, derivatives or progeny thereof.
"Co-Investigators"	means Professor Nigel Wright at DMU; Dr David Dawson at Leeds; Dr Richard Fenner at Cambridge; Professor Chris Kilsby at Newcastle; Associate Professor Jessica Lamond at UWE; Dr Karen Potter at the Open University; Dr Scott Arthur and Dr Heather Haynes at Heriot-Watt; Professor David Butler and Professor Zoran Kapelan at Exeter.
"Confidential Information"	means all information of whatever nature or form that is disclosed by a Party ("**the Disclosing Party**") to another Party ("**the Receiving Party**") and which is either clearly marked as confidential or if disclosed orally or visually, but was, at the time of disclosure indicated to be confidential.
"Contribution"	means the financial or non-financial contribution (including, without limitation, the provision of human resources, materials, facilities and equipment) to be made by a Party or a Project Partner to the Project, as set out in Schedules 1 and 2.
"Foreground Intellectual Property"	means such intellectual property that is created, devised, developed or made in the course of work on the Project excluding any Background Intellectual Property.
"Intellectual Property"	means all inventions, patents, copyrights, work of authorship, design rights, trade names, trade marks, service marks, slogans (whether any of the same are registered or unregistered), know-how, data base rights (including the copyright of software in any code), and any other industrial or intellectual property and related rights anywhere in the world including applications for the foregoing.

"Joint Intellectual Property"	means individually and collectively all Foreground Intellectual Property which is generated collaboratively by two or more Parties in performance of the Project under this Agreement.
"Participating Associates"	means any contractor, subcontractor or service provider of a Party.
"Principal Investigator"	means Professor Colin Thorne at Nottingham.
"Project Partners"	means the Project Partners as set out in Nottingham's Offer Letter at Schedule 2, namely Environment Agency, Atkins Global, UK Water Industry Research Limited and Water Industry Forum.
"Results"	means any data recorded in any form resulting from experimental research, reports, statistical or mathematical tools, computer programs and algorithms developed in the course of work on the Project
"Sponsor"	means the Engineering and Physical Sciences Research Council

1.2 In this Agreement, unless otherwise expressly provided or unless the context otherwise requires:-

(a) References to the singular include the plural and vice versa.

(b) References to words denoting any gender shall include all genders.

(c) References to persons include companies, government departments and agencies and all other forms of body corporate or unincorporated.

(d) References to Clauses and Schedules are to Clauses of, and Schedules to, this Agreement.

(e) References to laws and statutory provisions shall include reference to any subordinate legislation made pursuant thereto and shall be construed as referring to those laws, provisions and subordinate legislation as respectively amended or re-enacted from time to time.

(f) The headings of this Agreement are for ease of reference only and are not part of this Agreement for the purposes of construction.

(g) Any undertaking by a Party not to do an act or thing shall be deemed to include an undertaking not to permit or suffer such act or thing to be done by another person.

(h) References to the Parties include their respective successors in title, permitted assigns and authorised legal representatives.

1.3 The Schedules form part of this Agreement and shall have effect as if set out in full in the body of this Agreement and accordingly any reference to this Agreement includes the Schedules.

1.4 In the event of any conflict between the terms of this Agreement and the terms of the Offer then the terms of the Offer will prevail. Subject to the foregoing, this Agreement shall take precedence over any other agreement signed between the parties relating to the subject matter hereof and over any other documents referred to herein.

2. PURPOSE AND SCOPE

2.1 The Project shall be undertaken at all times by the Parties in accordance with the terms of the Offer. Each Party undertakes that it will not knowingly do anything to place another Party in breach of that Party's respective funding Offer from the Sponsor.

2.2 Subject to Clause 2.1, the terms of this Agreement shall govern the rights and obligations of the Parties. These obligations include their respective Contributions, the management structure and all other terms of collaboration to be complied with in connection with the Project.

3. MEETINGS

3.1 The Parties undertake to have regular discussions (the timings of which to be mutually agreed) on the Project progress and to meet at least twice per year over the Project duration to discuss all matters pertaining to the research work and Results of the Project.

4. PROJECT MANAGEMENT

4.1 The overall management of the Project shall be the responsibility of Nottingham through the Principal Investigator who shall be the primary contact for and with the Sponsor and whose principal duties are listed in this Clause 4.

4.2 Nottingham shall manage the Project in accordance with the terms of this Agreement and the Offer. Nottingham shall use all reasonable efforts to ensure that the Parties do everything that is requisite to enable the terms of the Offer to be fulfilled.

4.3 A project board will be set up and will consist of the Co-Investigator(s) of each Party and chaired by the Principal Investigator (the "Project Board"). Each Co-Investigator shall be responsible for managing that Party's responsibilities in the Project and liaising with the Principal Investigator.

4.4 The Project Board will meet at least twice per year over the duration of the Project either in person or via teleconference facilities. If necessary, a Co-Investigator may delegate their attendance at a meeting to an appropriately qualified member of their Project research group. The Project Board will be responsible for managing the Project in accordance with the requirements of this Agreement and the regulations of the Sponsor.

4.5 The quorum for a meeting of the Project Board shall be no less than 80% of its members or their proxies, except Project Board decisions relating to a withdrawing Party or a defaulting Party where such meetings shall be quorate if held by the non-withdrawing or non-defaulting Parties. Each Party shall, through its representative on the Project Board, have one vote in Project Board decisions. Approval for any decisions shall require the support of a minimum of 80% of the members.

5. FINANCIAL MANAGEMENT

5.1 Each Party is funded separately by the Sponsor for its part of the Project, and each is responsible to the Sponsor for carrying out its part of the Project in accordance with its allocated budget. No Party is responsible for managing the budget of any other Party except itself. The Parties agree that no funds are payable by one Party to another for any work to be performed in the Project. Any costs incurred by a Party in performance of the Project or its obligations under this Agreement shall be borne by that Party itself.

5.2 The Sponsor's funding will be committed to the support of the Project, as set out in the Offers made to each of the Parties by the Sponsor under the EPSRC joint award. Each Party will manage the funding it receives from the Sponsor in accordance with that Party's respective Offer. Each Party will ensure that it does not overspend or otherwise misuse the funds allocated to it by the Sponsor. In the event that the Sponsor requires the reimbursement of any sums paid to a Party, each Party agrees that the sole responsibility for the reimbursement of such sums to the Sponsor will rest with the Party to whom the reimbursement request has been made by the Sponsor.

5.3 Each Party agrees to provide such information and supporting documentation as may be reasonably required by a particular Party to comply with the terms of a Party's Offer from the Sponsor under the EPSRC joint award.

6. CONTRIBUTIONS BY THE PARTIES

6.1 Each of the Parties undertakes to each of the others to:

(a) make its Contribution to the Project as set out in Schedule 1;

(b) comply with its obligations under, and the conditions of, its respective Sponsor's Offer;

(c) notify each of the other Parties, in accordance with Clause 1616, immediately if it receives any notice or request from the Sponsor;

(d) use all reasonable endeavours to obtain all regulatory and ethical licences, consents and approvals necessary to allow it to make its Contribution to the Project; and

(e) ensure that its employees and students (if any) involved in the Project: observe the conditions attaching to any regulatory and ethical licences, consents and approvals; and keep complete and accurate records of all research, development and other work carried out in connection with the Project and of all Results and observations.

6.2 Although each of the Parties will use reasonable endeavours to carry out the Project in accordance with Schedule 1, no Party undertakes that any research will lead to a particular result, nor does it guarantee a successful outcome to the Project.

6.3 The Project Partners have agreed to make the Contributions to the Project as set out in Nottingham's Offer letter at Schedule 2.

6.4 The Project, as described in Schedule 1, is formed of five (5) work packages (each a "**Work Package**"). Where any Work Package requires the involvement of one or more Project Partners, the Party with the lead responsibility for delivering the Work Package will use all reasonable endeavours to execute an agreement with the Project Partner, which adequately reflects the Contribution to be made by the Project Partner to the Project, each Party's respective interests, as well as the provisions of this Agreement, including, without limitation, Clause 7 (Confidentiality and Publication) and Clause 8 (Intellectual Property and Exploitation).

6.5 In the event of any conflict between the terms of this Agreement, the terms of the Offer and the agreement as described in Clause 6.4, the Parties agree that the terms of the Offer will prevail, followed by the terms of this Agreement.

7. CONFIDENTIALITY AND PUBLICATION

7.1 Subject to the provisions of Clause 7.2 and 7.3 regarding publication, all Confidential Information exchanged between the Parties or learned during the course of this Agreement shall, for a period of five (5) years from the date of receipt of such Confidential Information, be treated by the Receiving Party and its Participating Associates as confidential and shall not be disclosed to third parties by the receiving Party without express prior authorization from the Disclosing Party. Confidential Information of a Disclosing Party shall not be used by the Receiving Party except for the purpose of fulfilling its obligations of this Agreement unless otherwise agreed in writing by the Disclosing Party.

7.2 In accordance with normal academic freedom and the regulations of the Sponsor, the Results should be published for the general public and other relevant beneficiaries with an acknowledgement of the support received from the Sponsor. Such publication shall not include any of the Parties' Confidential Information. For the avoidance of doubt,

publication shall include, but not be limited to, publication in scientific journals, conferences and poster presentations.

7.3 In recognition of the Parties' mutual contributions to the Project each shall be given the opportunity to review any proposed publications arising from the Results prior to publication to comment and if necessary require amendment to protect their Confidential Information and/or Intellectual Property Rights. The Party intending to publish (the "**Proposing Party**") shall inform the Principal Investigator and the Project Board of any such intended publication in writing with a copy of the proposed publication arising from the Project at least 30 days prior to the intended submission or publication date. In the event that the Project Board identifies any Confidential Information and/or Intellectual Property Rights it wishes to be protected it shall inform the Proposing Party in writing accordingly. If no written reply is received within 30 days of receipt of the proposed publication then the proposing Party shall deem that the Project Board has not identified any such Confidential Information and/or Intellectual Property Rights and publication will proceed in the form disclosed to the Project Board. In no event shall permission for publication be unreasonably withheld.

7.4 The Parties agree that any publication must acknowledge the support received from the Sponsor and the contributions received from the Project Partners. The Parties agree that as a minimum acknowledgement, any publication shall carry the following statement: *"This research was performed as part of interdisciplinary research undertaken by the Flood Resilient Cities Research Consortium, which is funded by the UK Engineering and Physical Sciences Research Council."*

7.5 The obligations in this Clause 7 shall not apply to information which:

(a) can be evidenced in writing as having been known to the receiving Party before the commencement date of the Project, and not impressed already with any obligation of confidentiality to the disclosing Party; or

(b) is or becomes publicly known without fault on the part of the receiving Party; or

(c) is obtained by the receiving Party from a third party in circumstances where the recipient has no reason to believe that there has been a breach of an obligation of confidentiality owed to the disclosing Party; or

(d) is independently developed by the receiving Party; or

(e) is approved for release in writing by an authorised representative of disclosing Party; or

(f) the receiving Party is specifically required to disclose pursuant to an order of any Court of competent jurisdiction in order to fulfil the Court Order; or

(g) is required to be disclosed by law or regulation (including any requests under the Freedom of Information Act 2000, the Freedom of Information (Scotland) Act 2002 or Environmental Information Regulations 2004) or by order of a competent authority (including any regulatory or governmental body or

securities exchange), provided that the Disclosing Party is given as much as possible advance notice of the intended disclosure by the Receiving Party intending to make such disclosure and the Receiving Party consults with the Disclosing Party and gives due consideration to the Disclosing Party's comments.

8. INTELLECTUAL PROPERTY AND EXPLOITATION

8.1 The ownership of Background Intellectual Property will not be affected by this Agreement and ownership will remain vested in the Party to which it belongs. No transfer of such Background Intellectual Property to any other Party shall occur hereunder and none of the provisions of this Agreement shall be construed as such a transfer. However, where legally free to do so, the Parties shall grant to the other Parties a non-exclusive, royalty free licence of their Background Intellectual Property for the term of this Agreement and only to the extent that such a licence is required to enable a Party to fulfil its obligations hereunder.

8.2 Each Party grants to the other Parties an irrevocable, non-exclusive, non-transferable, royalty-free licence to use all Foreground Intellectual Property generated in the course of the Project for academic and non-commercial research purposes, including research involving projects funded by third parties provided that those parties gain or claim no rights to such Foreground Intellectual Property. Nothing in this Agreement grants any Party any right to use any of the trademarks, service marks or trade names of any other Party, directly or indirectly, in conjunction with any product, service, promotion, publication or publicity without the prior written approval of such other Party or of the appropriate trade mark or trade name owner.

8.3 Notwithstanding any other provisions of this Agreement, ownership of any Foreground Intellectual Property shall be vested in the Party or Parties generating such Foreground Intellectual Property, who shall be responsible for securing ownership of such Foreground Intellectual Property from their employees, students and other Participating Associates. Subject to the terms of this Agreement, the Party owning any Foreground Intellectual Property shall be entitled to use and exploit such Foreground Intellectual Property as that Party sees fit, and subject always to Clause 8.6.

8.4 The Parties shall make reasonable endeavours to keep each other fully informed on a confidential basis of all Foreground Intellectual Property generated by the Project, and shall be responsible for protecting and exploiting any such Foreground Intellectual Property at the owning Party's, or Parties', expense. In the event the owning Party or Parties are unable or unwilling to comply with its obligation to protect and exploit Foreground Intellectual Property, the Project Board shall consider how best to deal with such Foreground Intellectual Property and shall have the option to require an assignment of such Foreground Intellectual Property to another Party to enable prosecution and maintenance of such Foreground Intellectual Property by that other Party at its own cost. In the event that any Party wishes to exploit commercially any Foreground Intellectual Property assigned pursuant to this Clause 8.4, that Party shall

pay to the assigning Party a royalty and/or other appropriate form of remuneration which is fair and reasonable taking into consideration the factors set out under Clause 8.6.

8.5 All Joint Intellectual Property will be jointly owned by the relevant Parties and shall be apportioned according to respective inventive contribution. The detailed arrangements for handling the protection and exploitation arrangements for Joint Intellectual Property shall be made by the relevant owning Parties under separate written agreement between them, which shall include cost sharing in relation to the internal and external costs (official fees) for the drafting, filing, prosecuting and maintenance of such Joint Intellectual Property; and which Party shall be named as co-applicant, is best placed to take the responsibility for the filing and prosecution on behalf of the co-applicants and in their joint names of applications for registration, and the maintenance and renewal of any registrations, in such countries as the co-applicants agree to obtain protection of such Joint Intellectual Property, subject to the other co-applicant(s) co-operating in the provision of all necessary assistance, information and instructions, with respect to the same. Each such joint owner or joint applicant shall have the right to use Joint Intellectual Property by itself solely for academic and non-commercial internal research and development purposes only without recourse to the other joint owning Party or Parties.

8.6 Should any Party require access rights to any Foreground Intellectual Property vested solely in another Party for commercial exploitation of its own Results arising from the Project or for commercial exploitation of Joint Intellectual Property it owns with another Party, then reasonable endeavours shall be employed in negotiating terms of a separate specific written Agreement between the applicable negotiating Parties which shall include reasonable commercial terms (to include the payment of royalties or other forms of revenue) for the type of rights involved taking into account the respective Party's financial and non-financial contributions under this Agreement also taking into account the respective contributions of the Parties to such exploitation determined on a case-by-case basis. Any access rights to a Party's Background Intellectual Property shall be restricted to the extent to which such access may be legally permitted and shall be subject to negotiated fair and reasonable commercial terms.

9. TERM

9.1 This Agreement shall come into effect on 1 August 2016 and terminate on 31 October 2019 unless an extension to this term is agreed in writing by all the Parties. If this Agreement is entered into after 1 August 2016, it will apply retrospectively to work carried out in relation to the Project on or after 1 August 2016.

10. ADDITION OF NEW PARTIES

10.1 New Parties may join the Project subject to the unanimous agreement of the Project Board and the Sponsor, and subject to Clause 10.2.

10.2 New Parties shall be bound by the terms of this Agreement and such other conditions as the Project Board may specify.

11. WITHDRAWAL

11.1 Any Party (the "**Withdrawing Party**") may withdraw from the Project upon written notice to the Project Board and subject to such conditions as the Project Board and/or Sponsor may decide.

11.2 In the event of withdrawal of a Party the remaining Parties will make all reasonable attempts to reallocate the obligations of the Withdrawing Party under this Agreement between themselves or to a third party acceptable to the Sponsor, provided that any such third party agrees to be bound by the terms of this Agreement.

11.3 The Withdrawing Party shall not be entitled to recover any of its costs incurred after the date of withdrawal in connection with the Project and shall comply with all conditions imposed pursuant to Clause 11.1 which shall include (without limitation):

(a) rights granted to the other Party in respect of the Withdrawing Party's Background Intellectual Property shall continue for the duration of the Project subject to the restrictions contained in this Agreement;

(b) to the extent that exploitation of any other Party's Foreground Intellectual Property is dependent on the Withdrawing Party's Background Intellectual Property, then the Withdrawing Party shall, subject to any existing third party obligations, grant to the other Parties a non-exclusive licence to such Background Intellectual Property on fair and reasonable terms to be agreed;

(c) the Withdrawing Party shall grant to the other Party a non-exclusive, royalty-free licence to use the Withdrawing Party's Foreground Intellectual Property for the purposes of carrying out the Project. For the avoidance of doubt any exploitation of such Withdrawing Party's Foreground Intellectual Property will be dealt with in accordance with Clause 8; and

(d) all rights acquired by the Withdrawing Party to the Background and Foreground Intellectual Property of the other Parties shall cease immediately other than in respect of the Withdrawing Party's interest in any Joint Intellectual Property.

12. TERMINATION

12.1 In addition to the remedies contained in Clause 11 (Withdrawals); in the event that any Party shall commit any breach of or default in any terms or conditions of this Agreement, the remaining Parties may serve written notice of such breach or default on the defaulting Party. In the event that such defaulting Party fails to remedy such default or breach within sixty (60) days after receipt of such written notice any of the Parties may, at their option and in addition to any other remedies which they may have at law or equity, remove the defaulting Party and continue with the Agreement or terminate their involvement in this Agreement by sending notice of termination in writing

to the other Parties to such effect. Any removal of the defaulting Party shall be effective as of the date of the receipt of such notice whereupon the provisions of Clause 11.3 shall apply to the defaulting Party.

12.2 If any Party (a) materially breaches any provisions of this Agreement; or (b) passes a resolution for its winding-up; or if (c) a court of competent jurisdiction makes an order for that Party's winding-up or dissolution; or makes an administration order in relation to that Party; or if any Party (e) appoints a receiver over, or an encumbrancer takes possession of or sells an asset of, that Party; or (f) makes an arrangement or composition with its creditors generally; or (g) makes an application to a court of competent jurisdiction for protection from its creditors generally; the remaining Party's shall meet to either suspend or terminate that Party's involvement in the Project. Any removal of the defaulting Party shall be effective as of the date of the receipt of such notice whereupon the provisions of Clause 11.3 shall apply to the defaulting Party.

12.3 In the event that it is agreed by all the Parties that there are no longer valid reasons for continuing with the Project, the Project Board may decide by unanimous vote to terminate this Agreement by sending notice of termination in writing to all the Parties to that effect.

13. CONSEQUENCES OF TERMINATION

13.1 Options or licences granted by a Party to the defaulting Party shall terminate with cessation of all activities enjoyed pursuant to Clause 7 hereinbefore including the return of all Confidential Information and Background Intellectual Property upon demand by the owning Party.

13.2 Rights granted to other Party in respect of the defaulting Party's Background Intellectual Property made available for use in the Project or necessary to exploit the Results for the duration of the Project shall continue as set out in Clause 8.1.

13.3 All rights acquired by the defaulting Party to Results and Background Intellectual Property of the other Parties shall cease and be void from the date of termination of the defaulting Party's involvement in the Project.

13.4 In the event of termination of the Agreement at expiration of the Term and pursuant to the provisions of Clause 12.3 where the Parties agree there are no longer valid reasons for continuing with the Project, all rights to Background and Foreground Intellectual Property shall cease immediately except in the case of a Party's interest in any Joint Intellectual Property licences granted under Clause 8.2 and any agreements concluded pursuant to Clause 8.6.

14. DISPUTE RESOLUTION

14.1 The Parties shall use good faith efforts to resolve any dispute, claim or proceeding arising out of or relating to the subject matter of this Agreement via the Project Board.

In the event that any disputes cannot be resolved at this level then the senior executives of the relevant Parties who have authority to settle the same shall use good faith efforts to resolve the same. The concerned Parties may instead elect unanimously to resolve by mediation any dispute or difference arising in connection with this Agreement, which cannot be settled amicably.

14.2 If the matter is not resolved through negotiation within twenty eight (28) days, the parties may attempt to settle it by mediation in accordance with the Centre for Effective Dispute Resolution ("CEDR") Model Mediation Procedure. Unless otherwise agreed between the disputing Parties, the mediator will be nominated by CEDR.

14.3 To initiate mediation a Party must give notice in writing ("ADR Notice") to the other Party to the dispute requesting mediation in accordance with Clause 14.2 above. A copy of any such request should be sent to CEDR. The mediation will start no later than 30 days after the ADR Notice.

15. THIRD PARTIES

15.1 The Contracts (Rights of Third Parties) Act 1999 shall not apply to this Agreement and no person or persons other than Parties to this Agreement shall have any rights under it, nor shall it be enforceable under that Act by any person other than the Parties to it.

16. NOTICES

16.1 Any notices should be addressed in the case of **Nottingham** to:

Research, Enterprise and Graduate Services
University of Nottingham
Kings Meadow Campus
Lenton Lane
Nottingham, NG7 2NR
Attention: Head of Research Contracts

Any notices in the case of **DMU** to:

Legal Services Office
De Montfort University
The Gateway
Leicester
LE1 9BH
Attention: Head of Legal Services

Any notices in the case of **Leeds** to:

Research and Innovation Service

Level 11 Worsley Building
University of Leeds
Clarendon Way
Leeds
LS2 9NL
Attention: Director of Commercialisation

Any notices in the case of **Cambridge** to:

Research Operations Office
University of Cambridge
Greenwich House
Madingley Road
Cambridge
CB3 0TX
Attention: The Assistant Director, School of Technology

Any notices in the case of **Newcastle** to:

IP and Legal Team
Research and Enterprise Services
Research Beehive
Old Library Building
Newcastle University
Newcastle upon Tyne
NE1 7RU
Attention: Head of Intellectual Property

Any notices in the case of **UWE** to:

University of the West of England, Bristol
Frenchay Campus
Coldharbour Lane
Bristol
BS16 1QY
Attention: Pro Vice-Chancellor: Commercial Director and Corporation Secretary

Any notices in the case of the **Open University** to:

Legal Notices:
Joanne Vango
Commercial Legal Services Manager

The Open University
Commercial Legal Services
Walton Hall
MK7 6AA
email: finance-comm-legal@open.ac.uk
Attention: Joanne Vango, Commercial Legal Services Manager

Project Notices:
Ivana Lickova
Senior Manager
The Open University
The Faculty of Business and Law
Walton Hall
MK7 6AA
Email: ivana.lickova@open.ac.uk

Attention: Ivana Lickova, Senior Manager

Any notices in the case of **Heriot-Watt** to:

Heriot-Watt University
Riccarton
Edinburgh
EH14 4AS
Attention: Director, Research & Enterprise Services

Any notices in the case of **Exeter** to:

Legal Services
The University of Exeter
Lafrowda House
St. German's Road
Exeter
EX4 6TL
Attention: Head of Legal

17. LIABILITY

17.1 In respect of information or materials supplied by one Party to another hereunder, the supplying Party shall be under no obligation or liability (other than as stated in this Clause 17), and no warranty condition or representation of any kind is made by, given by or to be implied against any Party as to the sufficiency, accuracy or fitness for purpose of any such information or materials, or the absence of any infringement of any proprietary rights of third parties (including without limitation intellectual property rights, trade secret rights and rights over Confidential Information) by the use of such information and materials; and the recipient Party shall in any case be entirely

responsible for the use to which it puts such information and materials. Each Party represents and warrants that it has the full right and power to grant the licences granted hereunder, and that there are no outstanding agreements, assignments or encumbrances inconsistent with the provisions of any said licence or with any other provision of this Agreement. No Party makes any other representation or warranty, express or implied, neither shall any Party have any liability, in respect of any infringement of patents or other rights of third parties owing to any other Party's operation under any licence granted hereunder. Subject always to such other undertakings and warranties as are provided for in this Agreement, each Party shall be solely liable for any loss, damage or injury to third parties resulting from the carrying out by it of its parts of the Project and from its use of the Results.

18. LIABILITY LIMITATIONS

18.1 The aggregate liability of each Party under this Agreement to all of the other Parties collectively in respect of any and all claims shall not exceed the amount payable to that Party by the Sponsor.

18.2 Nothing in this Agreement limits or excludes either Party's liability for:

(a) death or personal injury caused by negligence; or

(b) Any fraud or liability that, by law, cannot be limited or excluded.

18.3 The liability of any Party for any breach of this Agreement, or arising in any other way out of the subject matter of this Agreement, will not extend to loss of business or profit, or to any indirect or consequential damages or losses.

19. RESPONSIBILITIES TO EACH OTHER

19.1 Each Party shall use all reasonable endeavours to ensure the accuracy of any information or materials it supplies hereunder.

20. NO PARTNERSHIP OR AGENCY

20.1 Nothing in this Agreement shall create any partnership or agency between the Parties.

21. NO IMPLIED LICENCE

21.1 Except as explicitly granted herein, no license, immunity, or other right is granted or assigned under this Agreement, either directly or indirectly, by implication, estoppel or otherwise, to any Party with respect to any Intellectual Property Right of any other Party.

22. ENFORCEMENT OF INTELLECTUAL PROPERTY RIGHTS

22.1 No Party shall have any obligation under this Agreement to institute any action or suit against any third party for infringement of any Intellectual Property Rights to which it

has granted a licence hereunder, or to defend any action or suit brought by any third party, which challenges or concerns the validity of any such Intellectual Property Rights. In addition, no Party to which any other Party has granted such a licence hereunder shall have any right to institute any action or suit against third parties for infringement of any such Intellectual Property Right.

23. ASSIGNMENT

23.1 Except as otherwise provided under this Agreement, no Party shall, without the prior written consent of the other Party assign or otherwise transfer partially or totally any of its rights and obligations under this Agreement.

24. GOVERNING LAW

24.1 This Agreement shall be subject to the laws of England and the Parties agree to the exclusive jurisdiction of the courts of England with regard to any dispute arising from it or its subject matter.

25. COUNTERPARTS

25.1 This Agreement may be executed in any number of counterparts, and by the Parties on separate counterparts, each of which so executed and delivered shall constitute one and the same instrument.

25.2 No counterpart shall be deemed as validly executed until each Party has signed a corresponding counterpart agreement.

25.3 A notice given under or in connection with this agreement is not valid if sent by e-mail.

26. MISCELLANEOUS

26.1 If any part or any provision of this Agreement shall to any extent prove invalid or unenforceable in law, the remainder of such provision and all other provisions of this Agreement shall remain valid and enforceable to the fullest extent permissible by law, and such provision shall be deemed to be omitted from this Agreement to the extent of such invalidity or unenforceability. The remainder of this Agreement shall continue in full force and effect and the Parties shall negotiate in good faith to replace the invalid or unenforceable provision with a valid, legal and enforceable provision which has an effect as close as possible to the provision or terms being replaced.

26.2 No failure to exercise or delay in the exercise of any right or remedy which any Party may have under this Agreement or in connection with this Agreement shall operate as a waiver thereof, and nor shall any single or partial exercise of any such right or remedy prevent any further or other exercise thereof or of any other such right or remedy.

27. CONTINUING OBLIGATIONS

27.1 The provisions of Clauses 7 (Confidentiality and Publication), 8 (Intellectual Property and Exploitation), 12 (Termination), 14 (Dispute Resolution), 17-18 (Liability), 22 (Governing Law), and 26 (Miscellaneous) shall survive termination or expiry of this Agreement (howsoever caused) for a period of five (5) years.

Signed by an authorised representative of University of Nottingham

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Name:
Title:
Date:

UNIVERSITY OF NOTTINGHAM
RYAN KEYWORTH

17 NOV 2016

DIRECTOR OF
FINANCIAL MANAGEMENT

Signed by an authorised representative of De Montfort University

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Name:
Title:
Date:

Signed by an authorised representative of the University of Leeds

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Name:
Title:
Date:

Signed by an authorised representative of The Chancellor, Masters and Scholars of the University of Cambridge

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Name:
Title:
Date:

Signed by an authorised representative of University of Nottingham

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Name:
Title:
Date:

Signed by an authorised representative of De Montfort University

Name: Nigel Wright
Title: Pro Vice-Chancellor
Date: 11/11/16

Signed by an authorised representative of the University of Leeds

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Name:
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Signed by an authorised representative of The Chancellor, Masters and Scholars of the University of Cambridge

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Signed by an authorised representative of the University of Leeds

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Name: CERI WILLIAMS
Title: DIRECTOR R&I DEVELOPMENT
Date: ~~9/11/16~~ 9/11/16

Signed by an authorised representative of The Chancellor, Masters and Scholars of the University of Cambridge

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Name:
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Signed by an authorised representative of The Chancellor, Masters and Scholars of the University of Cambridge

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Name: D. HOLLANDER
Title: SENIOR CONTRACTS MANAGER
Date: 9TH NOVEMBER 2016

Signed by an authorised representative of University of Newcastle upon Tyne

Christine Masterson

Name: Dr Christine Masterson
Title: Grants and Contracts Manager
Date: 9 November 2016

Signed by an authorised representative of University of the West of England, Bristol

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Signed by an authorised representative of the Open University

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Signed by an authorised representative of Heriot-Watt University

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Signed by an authorised representative of the University of Exeter

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Signed by an authorised representative of University of Newcastle upon Tyne

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Signed by an authorised representative of University of the West of England, Bristol

Name: L A RAWLINSON
Title: HEAD OF CONTRACTS
Date: 10/11/2016

Signed by an authorised representative of the Open University

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Signed by an authorised representative of Heriot-Watt University

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Name:
Title:
Date:

Signed by an authorised representative of the Open University

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Name: Joanne Vango
Title: Commercial Legal Services Manager
Date: 16/11/16

Signed by an authorised representative of Heriot-Watt University

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Signed by an authorised representative of the University of Exeter

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Date:

Signed by an authorised representative of Heriot-Watt University

Lynne Raventós

Name: LYNNE RAVENTÓS
Title: ADVISOR, IP & CONTRACTS
Date: 9 NOVEMBER 2016.

HW REF:
76571 / D15R105.37
EP/P003982/1

Signed by an authorised representative of the University of Exeter

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Signed by an authorised representative of Heriot-Watt University

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Name:
Title:
Date:

Signed by an authorised representative of the University of Exeter

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Name: CHARSTEN COLE
Title: INTERIM HEAD OF LEGAL SERVICES
Date: 15.11.2016

Schedule 1 : Project

Schedule 2: Offer Letters