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1. INTRODUCTION

1.1. Context

The collaborative research proposed is intended to contribute to research on urban water use (in the broadest sense) and flood risk management within the context of ensuring sustainability and resilience in water engineering. By bringing together leading academics from the UK and US, it is highly likely that the new knowledge generated will be of global significance. This is all the more so because the US counterparts of the UK team are specifically studying urban and environmental water issues in and around the City of Portland – which is recognized internationally as a World-leading city in sustainable and resilient use of water and green infrastructure. This is especially the case due to Portland's on-going 'Grey to Green Initiative', begun in 2008, and hence, because the collaborative research involves Portland, its wider significance is guaranteed.

The UK team represent the Blue-Green Cities (B-GC) Research Consortium that emerged from an EPSRC Sand Pit. A Blue-Green City aims to recreate a naturally-oriented water cycle while contributing to the amenity of the city by bringing water management and green infrastructure together (Hoyer et al. 2011). This is achieved by combining and protecting the hydrological and ecological values of the urban landscape while providing resilient and adaptive measures to deal with flood events. Key functions include protecting natural systems and restoring natural drainage channels, mimicking pre-development hydrology, reducing imperviousness, and increasing infiltration, surface storage and the use of water retentive plants (Novotny et al. 2010). B-GC Research aims to develop new strategies for managing urban flood risk as part of wider, integrated urban planning intended to achieve environmental enhancement and urban renewal in which multiple benefits of Blue-Green Cities are rigorously evaluated and understood. Research includes multiple topics of importance to: addressing key UK societal challenges (vulnerability to flooding, social equity in flood risk management, urban renewal that produces neighbourhood uplift but avoids gentrification); contributes to current or future UK economic success (reducing annual expected flood damages, enhancing the competitive edge of UK cities, improving quality of life for UK citizens), and; enables future development of key emerging green businesses and enterprises in urban areas. This collaboration adds value to the Consortium's research with regard to each and all of these challenges. Details can be found on the project website www.bluegreencities.ac.uk and personnel are listed in the Annexes.

The US partners have been chosen because the:

1. intellectual scope of the EPSRC project aligns precisely with socio-economic and natural science research at Portland State University (PSU), Oregon State University (OSU), Washington State University (WSU) and Reed College under the National Science Foundation (NSF) Portland-Vancouver ULTRA-Ex (PVU) project;

2. intensive, technical research on the dynamics of wood in rivers in Work Package 2b (sediment, debris and habitats, as part of the wider modelling work package) of the B-GC will benefit from collaboration with related, NSF-funded, engineering research at OSU;

3. research in all three projects falls within EPSRC's stated priority area of "water engineering within the context of Sustainability and Resilience" and coincides with topics mentioned in the 'Clean Water for All' call including: water reuse, storm water use, urban water sustainability, and resilience of water infrastructures.

The US team comprise several members of the NSF funded Portland-Vancouver ULTRA (Urban Long-term Research Area) project (or PVU), currently in its 4th year. The PVU project examines

the role of governance for a pair of cities, Portland, Oregon and Vancouver, Washington, which have developed over the past several decades under contrasting policy regimes at the state, regional, and local levels. The project seeks to find how differences in local and state levels of governance and policy affect the resilience of both social and ecological landscapes, and how monitoring ecosystem services may provide a usable feedback loop in urban socio-ecological systems. PVU investigators are assessing multiple pathways through which human actions, governance systems, and the built and social infrastructure affect ecosystem services provided by landscape vegetation pattern and regional water quality. Our approach features three cross-cutting activities (landscape scale development patterns, civic ecology and environmental education) that examine both natural system variables and social outcomes. We also have three focused projects (water quality, stormwater management and urban riparian greenspace conservation) that primarily examine effects of social patterns and governance on natural system characteristics. More recent funding has also been obtained to examine the effects of climate change on the vulnerability of urban water resources. Details can be found on the project website www.fsl.orst.edu/eco-p/ultra/ and personnel are listed in the Annexes.

These topics and approaches of PVU resonate with the B-GC, which includes Work Packages on:

1. Communications between scientists, institutional stakeholders and communities;
2. Modelling urban flood inundation, riparian conservation/restoration and citizens' attitudes and behaviours towards flood risk management and blue-green infrastructure;
3. Appraising structural/non-structural options for urban flood management, and;
4. Multi-criteria analysis to establish the true economic, social and ecological costs and benefits of blue-green versus grey urban flood risk management infrastructure.

At OSU Desiree Tullos and colleagues collect fine-resolution velocity measurements around engineered log jams in their NSF project to better understand the distribution of forces on, and velocities and turbulence around, wood in rivers. This is relevant to WP2b of the B-GC project, which is concerned with risks associated with wood in urban streams since the movement of wood is based primarily on the balance of forces (buoyancy, drag, weight, pressure, friction) on the wood.

As the US and UK projects share similar interests spanning the social and biophysical spectrum in urban areas and with a focus on water resources, expected benefits of collaborating are high. Collaboration will especially benefit UK researchers because the US projects are in the third of four years, meaning most of its data and results will be available for knowledge transfer in 2014.

1.2. Research Team

The names and affiliations of the academic UK and US members of the Project Team are listed overleaf in Tables 1 and 2.

Maggie Skenderian, Johnson Creek Watershed Manager, Bureau of Environmental Services (BES), City of Portland, Oregon. Maggie Skenderian will assist in the development of each Topic (Section 2.2) as appropriate to the context and application in the selected sub-watershed in Portland (Errol-Tideman), the location for focussed research during co-location working in Portland in May 2014. She will provide an overall steer in the direction of the collaborative research (Section 2.1.2) and ensure that the outcomes of each component are fully integrated and provide information that is useful and applicable to BES, the City of Portland, local practitioners and stakeholders. Maggie will join the team in Newcastle in March 2014 (Section 2.1.1) and provide input to all Topics and work closely with Colin Thorne and Emily Lawson (UK members of the Project Management Team, Section 2.2.1). Maggie will play a key role in Topic 5

and the evaluation of the wider benefits of Blue-Green infrastructure using multi-criteria analysis.

Other key members of the Team, or groups, who are based in Portland include;

Marie Walkiewicz, Johnson Creek Watershed, Watershed Services Group**,** BES, City of Portland, Oregon.

Members of **Johnson Creek Watershed Council** (www.jcwc.org), including;

Robin Jenkinson, Restoration Coordinator, Johnson Creek Watershed Council.

Table 1. Clean Water for All Research Project Team, UK members

Team member	**Role**	**Research Institution**	**Department**
Colin Thorne	P.I.	University of Nottingham	Geography
Dabo Guan	Co-I	Leeds University	Earth and Environment
Jessica Lamond	Co-I	University of the West of England (UWE)	Architecture and Built Environment
Jenny Mant	Co-I	Cranfield University	River Restoration Centre
Leonard Smith	Co-I	London School Economics	Centre for the Analysis of Time Series
Nigel Wright	Co-I	University of Leeds	Civil Engineering
Dick Fenner	Co-I	Cambridge University	Centre for Sustainable Development
Scott Arthur	Co-I	Heriot-Watt University	Built Environment
Chris Kilsby	Co-I	Newcastle University	Civil Engineering
Nick Mount	Co-I	University of Nottingham	Geography
Deonie Allen	RA	Heriot-Watt University	Built Environment
Glyn Everett	RA	UWE	Architecture and Built Environment
Vassilis Glenis	RA	Newcastle University	Civil Engineering
Lan Hoang	RA	Cambridge University	Centre for Sustainable Development
Emily Lawson	RA	University of Nottingham	Geography
Shaun Maskrey	PhD Student	University of Nottingham	Geography
Faith Chan	RA	University of Nottingham Ningbo China	Geographical Sciences
Sangaralingam Ahilan	RA	University of Leeds	Civil Engineering
David Mendoza	PhD Student	University of Leeds	Earth and Environment

Table 2. Clean Water for All Research Project Team, US members

Team Member	Role	Research Institution	Department
Alan Yeakley	Co-I	Portland State University	Environment
Heejun Chang	Co-I	Portland State University	Geography
Connie Ozawa	Co-I	Portland State University	Urban Studies and Planning
Anita Morzillo	Co-I	Oregon State University	Forestry
Noelwah Netusil	Co-I	Reed College	Economics
Jennifer Morse	Co-I	Portland State University	Environment
Desiree Tullos	Co-I	Oregon State University	Biological & Ecological Engineering
Zbigniew Grabowski	PhD Student	Portland State University	Environment
Denise Fisher de Leon	PhD Student	Portland State University	Environment
Marissa Matsler	PhD Student	Portland State University	Urban Studies and Planning
Samantha Hamlin	PhD Student	Portland State University	Geography
Will L'Hommedieu	PhD Student	Oregon State University	Water Resources Engineering
Maya Jarrad	UG Student	Reed College	Economics

1.3. Aim

Our aim is to build long-term, collaborative partnerships with American colleagues engaged in NSF-funded research that complements without duplicating that within the EPSRC's "Delivering and Evaluating Multiple Flood Risk Benefits in Blue-Green Cities".

1.4. Project Duration

The Project commenced on 1st January 2014 and is due to be completed within 12 months: i.e. by 31st December 2014.

2. RESEARCH PROGRAMME

Research will be performed as a closely integrated and carefully sequenced set of six Topics (detailed in Section 2.2) that will run in parallel. Essentially, effort will focus on developing the relationships between UK and US counterparts in early 2014 (Jan-April) and planning the collaborative research to be completed in Portland in May 2014. This will be aided by face-to-face contact when the Portland team visit the UK in March for a week. The research will be applied in a sub-watershed in Portland (Errol Tideman) during and after the UK visit in May, and disseminated in December 2014 at the University of Nottingham Ningbo Campus (UNNC), China.

2.1. Research schedule

The project will support collaborative activities with the following goals:

- initial exchange of information in UK as necessary to plan collaboration activities;
- co-production of knowledge, information and insights through intensive periods of co-location working in Portland, Oregon,
- joint Wrap-up Meeting and Stakeholder Dissemination Event to maximize stakeholder and international impact.

Bilateral contact is encouraged prior to the March Workshop to make introduction, exchange ideas and reprints of current research.

2.1.1. Initial Workshop (March 2014)

US academics will come to the UK for one-week to attend an initial workshop, exchange knowledge and plan further activities. The workshop will span three days (Monday-Wednesday) and will be hosted by Newcastle University. Newcastle is the chosen Demonstration City in the B-GC project and hence there will be opportunity for the US team to visit the area and experience some of the potential issues for implementation of blue-green vs. grey infrastructure for flood risk management. The timetable for the initial workshop is detailed in Table 3.

The workshop will include plenary sessions during which researchers will make presentations on their research Topic, methods, results and lessons learned, followed by extended questioning and discussion. Sessions will formulate common terms, metrics, approaches and models necessary to provide the basis for research applicable in both UK and US cities. Time will also be spent on detailed planning for collaborative research on six key Topics of mutual interest identified by UK and US academics during Skype, telephone and physical meetings held in preparing this proposal.

Following the workshop, teams will break out for concurrent knowledge exchange, development and research planning meetings specific to each of the Topics, and travel with the appropriate UK Co-I to their institution for two more days of work (Thursday and Friday). These will provide the basis for collaboration during co-location working in Portland.

Table 3. Timetable for Initial Workshop in the UK, March 2014

Day	**Activity**	**Location**
Sunday (16th)	US team arrive in the UK	UK
Sunday (16th)	US and UK team meet for dinner (ice-breaker), 5.30	Newcastle, Caledonian Hotel bar
Monday (17th)	Presentations from US (am) and UK (pm) teams on work completed to date (pm session doubles as BG-C March Quarterly Progress meeting). Introduction to BES from Maggie Skenderian. Evening reception with Newcastle stakeholders as part of ongoing Learning and Action Alliance	Newcastle University, Research Beehive, Seminar Room B 2.22. Caledonian Hotel
Tuesday (18th)	Field Trip (am); visit Newcastle SuDS Introduction to Errol Tideman catchment and Johnson Creek issues (Maggie Skenderian) Plan collaborative research on Topics 1 and 2 (pm) Early evening BG-C meeting to discuss WP application in Newcastle Dinner 7 pm	Newcastle Newcastle University, Research Beehive, Seminar Room B 2.22 Newcastle Pizza Express
Wednesday (19th)	Plan collaborative research on Topics 3, 4, 5 and 6 (finish at 2.30 pm) US team to travel to UK institution with relevant Co-I	Newcastle University, Research Beehive, Seminar Room B 2.22 UK institutions of choice
Thursday-Friday (20-21st)	Topic groups to research and develop specific Topics.	UK institutions of choice
Saturday/Sunday (22-23rd)	US team to return home	US

2.1.2. Co-location Research (May 2014)

Collaborative research will be performed in Portland, Oregon, during one-week visits by the academics and 30-day periods of targeted, intensive, collaborative research by their RAs and Students. The US-UK team will focus their research on the Errol Tideman sub-watershed, part of the Johnson Creek watershed, and designated by BES as top priority for improvement. The Errol Tideman sub-watershed contains an interesting mix of restored river reach, residential and commercial property, a large industrial plant, park and forest, and green space. Key issues are developing environmentally sound measures for bank stabilisation (bank erosion due to numerous outfalls into Johnson Creek) and improving water quality as the industrial plant is thought to discharge pollutants, e.g. PCBs, into Johnson Creek. The team will also look at the potential for diverting drainage from a pristine micro-watershed to the east of the industrial plant. At present there is no outlet for drainage from the micro-watershed and so outflow travels under the industrial plant in a pipe and later into Johnson Creek. Co-production of knowledge and research will also involve the key Portland stakeholders (detailed in Section 1.2), and specifically, Maggie Skenderian, Johnson Creek Watershed Manager, BES, who has been fundamental in designating the sub-watershed, sharing local contacts and making introductions. The UK team will be based in the BES offices throughout their stay.

Inter-action will occur prior to and following co-location working via Skype. It is anticipated that a jointly authored journal article or short communication will be produced for each Topic.

During the co-location research there will be opportunity to attend conferences, workshops and events being held in Oregon, including;

- 3rd Annual Symposium on Urbanization and Stream Ecology in Portland (SUSE) (15-17 May)
- Johnson Creek Watershed Council's (JCWC) Annual Celebration and evening dinner, Reed College, 22 May, Colin Thorne to give a presentation on the CWFA Project to highlight the similarities/differences between Johnson Creek and UK watersheds

2.1.3. Wrap up Meeting and Stakeholder Dissemination Event (UNNC, China, December 2014)

The final activity will be a one-day wrap-up meeting and stakeholder dissemination event to consolidate and showcase the outcomes of the collaboration and announce the planned next steps. This will be held at the UNNC, China, in December 2014. The UK team will be present physically. Attempts are being made to raise funds for the US team to travel to China, but should these prove unsuccessful, they will participate via the web. About 50 stakeholders will participate physically, while it will also be live-streamed to allow others to participate remotely. This format was used by the P.I. as dissemination officer for the FRMRC and it proved highly effective. The webinar format will maximize stakeholder and international impact.

2.2. Research structure and management

Research will be performed as a closely integrated and carefully sequenced set of six Topics, and order to fit with the sequence of B-GC Work Packages. The Topics and key researchers are detailed below.

<u>Topic 1.</u> Climate change and flood risk: communicating risk and uncertainty; vulnerability and adaptability of different communities.
UK: Thorne, Smith, Lawson, Chan
US: Ozawa, Hamlin

<u>Topic 2.</u> Modelling flows and water quality in the urban water cycle
UK: Wright, Kilsby, Ahilan, Glenis,
US: Chang, Grabowski

<u>Topic 3.</u> The influence of Green Streets, Blue-Green Infrastructure and river restoration on waterway health and water quality
UK: Mant, Thorne, Arthur, Allen
US: Yeakley, Morse, Fisher de Leon, Tullos, L'Hommedieu

<u>Topic 4.</u> Community perceptions of blue-green infrastructure in the urban environment: The Social Dynamic
UK: Lamond, Everett, Chan
US: Morzillo, Matsler

<u>Topic 5.</u> Wider system interactions and the generation of multiple benefits of Blue-Green infrastructure (inc. impact on house prices)
UK: Guan, Fenner, Arthur, Hoang, Mendoza
US: Netusil, Skenderian, Jarrad

<u>Topic 6</u>. Structuring and evaluating community priorities through participatory modelling
US: Skenderian
UK: Maskrey, Lawson, Thorne

2.2.1. Project Management

The project will be led by Colin Thorne (Nottingham), Alan Yeakley (PSU), Emily Lawson (Nottingham) and Maggie Skenderian (BES) (hereafter referred to as the Project Management Team). Their role will be to lead the co-location research in Newcastle and Portland while contributing to the six topics and providing constant input to facilitate the production of an integrated piece of research and ensure the research is fully interdisciplinary. The Project Management Team will be responsible for the allocation of resources and tasked with keeping the research to schedule. In addition, each member of the Project Management Team has specific interest and skills in different Topics and will contribute their knowledge and expertise while working with the Topic leaders. Colin Thorne will co-lead Topic 1 and Alan Yeakley will be the US lead of Topic 3. Emily Lawson has particular interests in Topics 1 and 5, and Maggie Skenderian has strong familiarities with Topics 1, 3, 4 and 5.

3. TOPIC PROPOSALS

The planned research for the six Topics is detailed below in the form of several short proposals.

3.1 Topic 1. Climate change and flood risk: communicating risk and uncertainty; vulnerability and adaptability of different communities

Over-arching goals and research questions

To develop a method for identifying the Relevant Dominant Uncertainties (RDU's) and the capacity of alternative strategies for stormwater management under different futures.

To investigate the thresholds of these strategies for absorbing different levels of rainfall and identify the tipping points between effective performance and failure.

We do not want to try and predict the future changes that will happen in the Errol-Tideman sub-watershed. Instead, we want to assess the ability of different methods to cope with a range of futures and communicate this choice to the local residents and institutions.

Scope acceptable

Topic 1 will be restricted in geographical scope and will focus on the unimproved streets in the Errol Tideman sub-watershed. This is an approximate 40 acre area with drainage from the streets, at present, feeding into a pipe that discharges into the ox bow lake section of Johnson Creek.

Study Approach

Topic 1 will conduct a series of sequential tasks with some iteration (see methods section). This includes a detailed background information and literature review, interviews with professionals working in different Bureaus of the City of Portland, identification and ranking of vulnerabilities and risks associated with the unimproved streets region, and assessing the ability of different strategies to cope with varying degrees of rainfall.

Topic 1 will also promote communication between the different Topics and directly link with several of the Topics, e.g. Topic 4 and the work of Shaun Maskrey, who will provide perceptions of local communities regarding different strategies to manage stormwater in the unimproved streets region and their willingness to pay, plus their level of commitment to future road improvements. Topic 1 will also link with Topic 5, who will assess some of the alternative strategies for road development and flood risk management in the Errol Tideman area and pass on the results of a cost/benefit analysis.

Methods, Techniques & Analysis

a. Interview experts to identify key vulnerabilities using the Delphi method. This will allow us to rank vulnerabilities to determine RDUs for each risk; current risks to system that will be addressed include:
   - Current condition of the unimproved streets
   - Existing piping system

- Roads
- Oxbow
- Johnson Creek.

b. Collate climate change data from the University of Washington. This is given in multiple ranges (1970-1999, 2000-2030, and 2040-2070). This will allow us to determine the future ranges in precipitation, estimated to be -5% to 14%).

c. Collect background data, e.g. www.portlandmaps.com. This will follow an iterative method including background research prior to interviews with experts to augment our understanding of local processes and vulnerabilities. More specifically, this will include reviews of documents, reports, archives, and previous interviews with residents from BES. We will produce a profile of the study area (socio-economics, demographics, place-affinity, climate predictions, land use plan, Bureau of Transportation's code for road improvements, have any improved streets suffered high levels of damage in the past?)

d. As part of the background data, we will identify current road conditions and how they affect the resource (water). This will link with the other Topic groups who will be examining the physical and ecological processes and problems associated with the drainage of the unimproved streets and downstream input into Johnson Creek.

e. Rank the vulnerabilities. This will help with the determination of the RDUs.

f. Identify alternatives to the Bureau of Transport's plan to develop the unimproved streets to meet City code (or not meet city code as this is probably unrealistic in the green streets area) and calculate the following (with substantial input from other groups):
   - Cost of installation
   - Cost of maintenance (over 5-10-20-50 years)
   - Expected performance under various rainfall scenarios (describe escalator of costs for levels of "protection")
   - Identify additional options and marginal benefits from additional actions that might occur on the property (Topic 5, Dick Fenner with Heejun Chang)
   - Clarify "adaptability" of each alternative – talk to experts about how hard is it to change (e.g. if twice/four times/eight times etc. as much water came through, what changes would be needed?), input from Topic 5 on multiple benefits
   - Also address how the current conditions (no improvements) would cope under future rainfall scenarios

g. Identify the thresholds and non-linearities in the capacity of the unimproved streets to cope with different future rainfall events; address the question "where are the step changes where a street changes from functioning to flooded/damaged beyond repair?"

h. Consider the costs of avoiding failure in line with critical RDUs.

i. Create a framework for how such analysis could be done in similar catchments

Staffing (minimum)

Emily Lawson arrives April 30th to attend May 1st stakeholder meeting in Errol Tideman, leaving May 24th.
Colin Thorne will be involved in the project for all of May, Emily and Colin will also be working with Maggie Skenderian on the project management
Lenny Smith - TBD

Connie Ozawa will be able to attend weekly progress meetings with some periodical support
Samantha Hamlin will able to attend weekly progress meetings, coordinate with Emily to interview experts, help conduct the background research and write/edit the final output

Schedule

Prior to research in Portland (May 2014);

- Gather background information, identify experts, Skype call to check on progress in early April
- Develop a set of milestones, share this information with the other groups (and get back similar information on milestones), determine critical paths and present to the team via a CWFA Gantt chart

Portland, May 2014

- Hold team and Topic 1 meetings in the first week of May
- Weekly progress meetings while Emily and Samantha do the research
- Prior to leaving Portland, have a debrief and decide next steps

Budget:

In addition to the budget assigned to Emily and Colin (from the EPSRC), we require a transcription service for recorded interviews. As a maximum, this will be 100 hours of transcription time x $20.00/hour = **$2,000.**

3.2 Topic 2. Modelling flows and water quality in the urban water cycle

Goals:

Deliver an improved evidence base to for planning, designing and implementing green infrastructure features in Johnson Creek. Increase capability of modelling and understanding certainty of service provision of green infrastructure elements.

How a feasible range of green infrastructure interventions retain sediments, pollutants and reduce flood risks at the target sub-catchment (within Errol-Tideman (~150 acre) study area – street improvement or local improvement district (LID) (50 acre) scale.

Questions in order of priority:

How do types of green infrastructure interventions at the street scale affect service provision of sediment retention and peak flow amelioration (restricted to unimproved roads – intervention options at single road scale)?

How does location and networked character of installations affect performance under different alternative scenarios (at the road scale for a defined set of installation types – TBD based on input from other groups)?

How do these interventions scale at the level of the LID (50 acre scale)?

Scope:

Intensive modelling exercise at street level scaling up to Errol-Tideman LID. Overall, to model likely impacts of different green infrastructure scenarios at the street and LID scale.

Using existing data sets at catchment scale to set boundary condition for main channel at Errol-Tideman mouth.

Study Approach:

To develop a street level model of hydrodynamics and morphodynamics. In particular to model sediment transport and relationships to flow. Utilizing this model we will study the existing (base) situation and proposed interventions. We will use this information to upscale the street level model to the road network within the LID area. Upscaling will include feasible range of impacts from the LID on main channel Johnson Creek at the outfall of study area in terms of sediment delivery and flow distribution

Methods, techniques and analysis

Apply existing hydro and morpho-dynamic model from Leeds/Newcastle team (Wright's code, CityCAT) utilizing data on flow and sediment relationships from Topic 3 at street scale. At street scale survey streets with high resolution GPS (Integrative Graduate Education and Research Traineeship (IGERT) unit) to obtain micro-topography. At study area scale, obtain high resolution topography from LIDAR data. Rainfall events defined from hourly data available from local stations. Soils data utilized from coarse USDA (US Department of Agriculture) maps, as well as stratified sampling at street level resolution. Will have land cover data at 30 m resolution, potentially using LIDAR-derived vegetation layer. Will require stream cross-section for up-scaling to LID.

Utilizing same base data set, and outputs from site level modelling, create pixel based model at 1m scale covering the LID area. Use model to identify sediment delivery and flow distribution at catchment mouth under scenarios developed at research group level.

Staffing minimum

Minimum staff for phase 1:

UK team (1 FTE/person) –
- Nigel – week 1,
- Ahilan – 3-4 weeks,
- Andy Sleigh – day ~5, 2 weeks - for surveys, program selection

US team (1 FTE/person)–
- Heejun - 1 week spread over month
- Z – 2 weeks over month
- Jen - .5 weeks, TBD

Staffing ideal

City support for surveying data collection – 2 people for 1 week

Budget min

Terrestrial LiDAR rental – ~$5,000

GIS Technician or Graduate Student Support for upscaling - .5 FTE for 3 months $3,600 + tuition ~$7,500 USD

Budget ideal

GIS Technician or Graduate Student Support for upscaling - .75 FTE for 3 summer months, .5 for 3 fall term months – $15,000

Schedule

Prior to May – identify potential study sites – check with Maggie Skenderian on data availability from BES/Intertwine

Month of May – data collection, QC – scenario development depending on input from other teams

Week 1 – site visits – identify study sites
Week 2 + 3 – site surveys and data collection, model initialization
Week 4 – Quality Check and time for site revisits and model refinement

Model Building and Running – Summer – Early Fall 2014

3.3 Topic 3. The influence of Green Streets, Blue-Green Infrastructure and river restoration on waterway health and water quality

Overall rationale:

The overarching aim of Topic 3 is to examine the influence of Green Streets, Blue-Green Infrastructure and river restoration on waterway health and water quality. These individual elements of a Blue-Green City are acknowledged to provide some water quality and habitat benefits, but may convey a greater or lesser influence within a network. Within this context, the aim of this research is to investigate the influence of upstream catchment stormwater management in conjunction with river restoration on the ecosystem health and water quality benefits provided to Johnston Creek.

Research Questions:

How does the implementation of green streets and Blue-Green Infrastructure within a catchment influence the receiving water quality, riparian habitat and river health?

What influence do river restoration activities (re-naturalising of a modified watercourse) have on water quality, riparian habitat and river health?

Objectives:

- Identify the extent, type and contamination of sedimentation adjacent to storm water outfalls draining a variety of catchments (water management, land use, topography & socioeconomic)
- Identify the strength of influence, correlation and relationship between a variety of catchment characteristics, habitat value and sediment characteristics (specifically the

implementation of green streets and BGI, the adoption and improvement of roads and local land use)
- Undertake a coordinated assessment of microbial health to define, in conjunction with modified river habitat assessments (RHA), habitat benefits across the outfall reaches.
- Compare the different land uses, implementation of stormwater improvement devices and river restoration activities on sediment deposition trends and sediment contamination
- Demonstrate whether natural or restored river reaches are more resilient to contamination and the potential impact of this on river habitat and health

Methods and design:

Site selection

An extensive mapping exercise will be completed, with the aid of GIS, to identify all potential stormwater outfalls to Johnston Creek. Outfalls will then be categorised into land use categories:

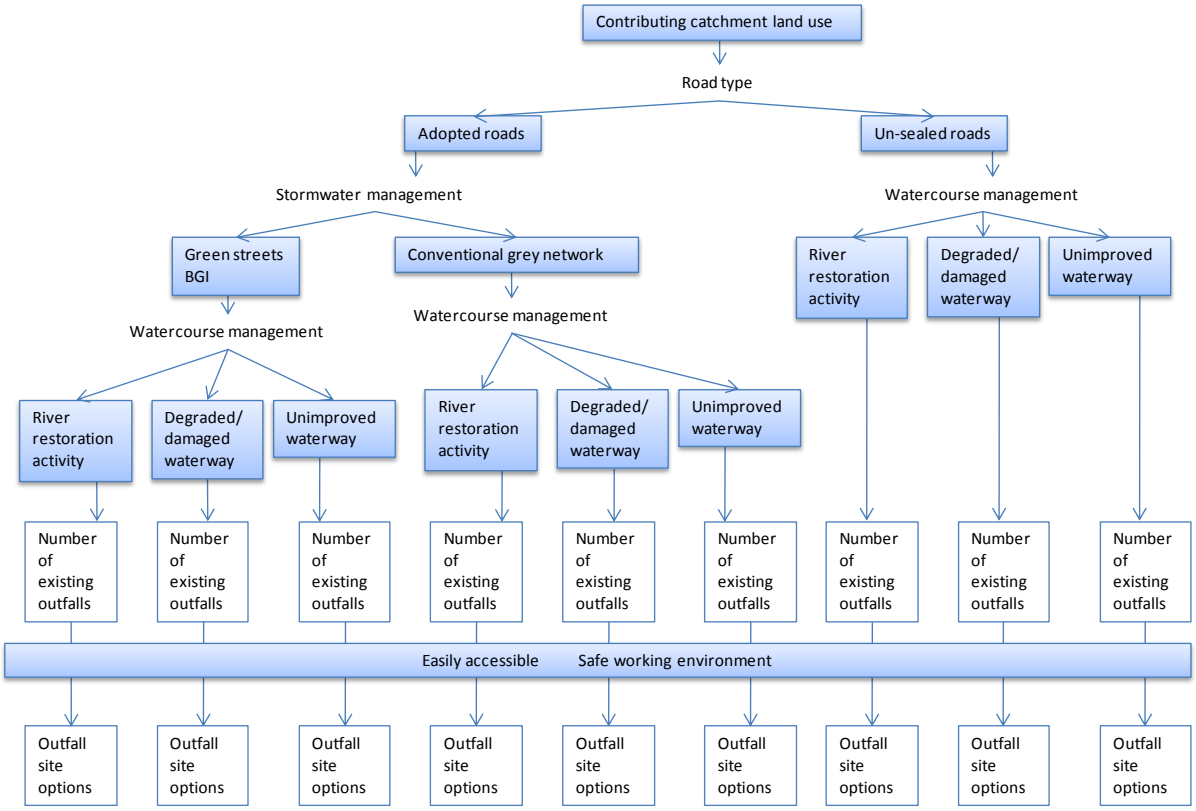
- rural and woodland
- arable and pasture land
- urban parkland and open green space
- commercial
- industrial
- low density urban residential
- high density urban residential

Within each land use category, each outfall will be classified as degraded/damaged, unimproved or improved in terms of water course management. One outfall from each sub category will be selected based on accessibility, resulting in a potential of up to 63 catchment-outfall sites to be assessed. A decision tree, similar to the one below, will be used to identify appropriate and effective outfall case study sites.

Rapid assessment of outfall impacts on sediment quality and habitats

A methodology to rapidly assess a high number of stormwater outfalls will be employed in the field. This will support maximum data gathering efficiency at a low level of complexity. To achieve a high site analysis throughput, a simple site analysis protocol will be used.

1. Cross section survey at outfall location where possible(where outlet and river flow and slope are available)
2. Sediment deposition survey on outfall bank, specifically within the 250 m upstream and downstream of the outfall location. Deposition survey is visual and by poling for deposition depth. Data will be recorded to GPS points.
3. Sediment core sampling within deposition areas, upstream, and the outfall and downstream of the outfall. Three core samples per outfall (upstream, downstream and at the outfall) supplemented by any significant sediment deposition zones found within the sample reach.
4. Water quality sampling (where water quality data does not exist – for TSS (total suspended solids), P and N and heavy metals) at the outfall, upstream and downstream within the waterway adjacent to the outfall.
5. Modified RHA for the 500 m reach
6. Physical habitat mapping of the same section as the sediment deposition surveys



Nested analysis

At three or four key sites detailed analysis will be undertaken. At these sites a greater detail of deposition assessment will occur, supporting a full suite of metals analysis, N and P potential analysis. Further detail of habitat mapping will be completed across these reaches to extend the rapid assessment trend analysis, providing greater detail and catchment management-restoration-waterway health linkage understanding.

Analysis and Outputs:

Field and laboratory analysis will consist of a dataset of modified RHA ratings, sediment deposition weightings, sediment contamination levels (heavy metals), microbial respiration potential, P and N potential and water quality levels (TSS, N, P, temperature etc.)

This database will be collated with catchment details, specifically land use, the extent of adopted roads and the quantity of green-blue infrastructure implemented. Empirical analysis will be completed to identify the influence of individual and cumulative catchment elements on river and habitat health.

Outputs from this research will include:

- A database of water and sediment quality analysis in conjunction with river habitat assessments for Johnston creek outfalls
- An established and proven methodology to examine green streets/BGI and river restoration project water quality improvement capability and treatment effectiveness
- Identification of effective and less effective catchment management scenarios and locations within the Johnson Creek watershed and how this affects habitat features
- One paper outlining the methodology and its effectiveness in catchment level BGI/Green Streets and river restoration assessment

- One paper outlining the linkage, trends and empirical relationships discovered through this research.

Staff requirements:

UK RA: 4 weeks (Deonie Allen, DA)
Field support for 3 weeks: (MSc from Cranfield)
UK Co-I 1 week (Scott Arthur, SA)
UK Co-I: 1 week (Jenny Mant, JMa)
Input from the PI's in the UK and USA for at least one week
Undergraduate summer work experience support
Lab technical support and sampling (respiration, P and N) (Jen Morse, JMo): 1+ weeks
Lab technical support and sampling (AAS analysis of sediment for metals (UK)) 1 week

Time scale

Time	Activity	Staff requirement
-2 week	Meeting with Robin Jenkinson to start acquiring and processing outfall options	CT (Colin Thorne, organiser) AY (Alan Yeakley), JMo, DF (Denisse Fisher de Leon)
Day 1	Meeting with Robin Jenkinson (RJ) and whole Topic 3 team to discuss outfall options	CT (organiser) AY, JMo, DF, SA, DA, RT, JMa (by Skype)
Day 1...	GIS mapping of available data Collaborative GIS working group data dissemination	DF
Day 2 and 3	Workshop and reconnaissance AIM: to check and implement outfall selection criteria, select outfall sites for the program	AY (organiser) AY, JMo, DF, SA, DA, All meeting notes emailed to JMa/RT for discussion
Day 4-8	Site sampling and survey	
Day 5	Review of methodology and revision of process and sites where/as necessary	AY (organiser) AY, JMo, DF, JMa, RT, DA, All meeting notes emailed to SA for discussion
Day 9-30	Site sampling and survey Weekly (Friday morning) check in contact with AY, JMo, JMa, SA to update on progress and discuss any issues arising (method to be agreed...possibly email?)	DA, RT
Day 9-30	Tuesday and Thursday MSc involvement on site CO2 lab analysis P and N potential analysis	JMo, JMo students, DA, RT, DF
Day 31	Wrap up	AY (organiser) AY, JMo, DF, DA, RT All meeting notes emailed to JMa and SA
Post field visit	Heavy Metals analysis of sediment samples from Johnson Creek	DA, RT

3.4 Topic 4. Community perceptions of Blue-Green infrastructure in the urban environment: The Social Dynamic

Research Objective

Describe attitudes and perceptions of residents in proximity to green streets facilities that have existed in locations for varying time periods since installation.

Scope

This research objective builds on current ULTRA work in three areas: 1) Tabor to River surveys; 2) Hedonic assessments of green streets facilities and property values; 3) Attitudes toward green streets facilities. Assessment will take place across several neighbourhoods that are part of the green streets program. The outcome of this research will be a preliminary evaluation and measurement tool for monitoring and assessment of resident perceptions of green streets facilities over time in different locations, and the benefits (and detriments) that they provide. It is expected that efforts will result in one peer-reviewed publication and provide the foundation for a comparative data collection in Newcastle.

Study Approach

A qualitative social science approach will be used for collection of values, attitudes, and perceptions data. Locations for data collection will be selected based on varying time since green streets installation, including pre-installation.

Methods, Techniques, and Analysis

Four locations will be identified based on time intervals since green streets installation for data collection. Anticipated time steps: pre-installation, recent installation (1-year since), and two less-recent installation (5- and 10-year since). Longer intervals are based on previous results suggesting that property values decline during first four-five years post-installation, and then increase; these intervals will allow us to capture before and after.

Semi-structured qualitative interviews will be used to collect data. BES will assist researchers with contacting potential subjects for interviews, such as through neighbourhood associations. The Errol Heights neighbourhood will be used as the pre-installation location. Locations for recent- and post-installation (5- and 10- year since) are TBD. It is expected that nine interviews will be completed for each location.

Sample variables of interest are currently in development, but are grounded in ULTRA work already completed. These will serve as a starting structure for interviews. Essentially, for example, we assume that we can anticipate some of the main and important themes that will be derived from interviews. However, opportunity exists to expand on-the-ground language within the context of equity, and learn from residents potential resolutions for stumbling blocks with implementation and maintenance of the green infrastructure program.

Initially, we focus on four* categories of variables:

1. Convenience – e.g., parking, accessibility to sidewalks
2. Liability – e.g., who is liable for accidents?
3. Aesthetics – e.g., improvement to air quality, habitat, collect garbage, attract vermin, pet waste, right outside house versus down the street, flooding

4. Monitoring and maintenance – e.g., paying for maintenance, cleaning, maintaining vegetation

Things to find out:

- Institutional Review Board (IRB), Faculty of Research Ethics Committee
- Can we revisit some people who were interviewed previously

*A fifth variable (Outreach) may be added after further discussion.

Staffing (minimum)

Glyn will be the main interviewer
Anita and Marissa will assist with logistics

Staffing (ideal)

Additional individual to complete transcription of interviews (professional-grade transcription)

Budget and Schedule

Expectation is to have a majority of interview contacts in place and preparatory work completed will take place before Glyn arrives (heavily dependent on input from BES). Specific interview schedule will be completed upon contact with potential subjects. IRB requirements TBD.

Budget items:

Transportation for Glyn (month)	31 days @ $5 per day	$ 100
Transcription costs	36 interviews @ $100 each	$ 3,600
Refreshments for interviews	36 interviews @ $15 each	$ 540
Incentive (gift card)	36 gift cards @ $20 each	$ 720
Colour printing for information leaflets	40 leaflets @ $1 each	$ 40
Publishing costs	1 manuscript @ $1,500	$ 1,500
TOTAL	$ 6,500	

3.5 Topic 5. Wider interactions of alternative surface water management

Overarching goals and research questions

To develop a framework to evaluate the temporal and spatial benefits of alternative surface water management options

Research question: How to test the significance of spatial and temporal benefits of a range of alternate surface water management options?

Scope

The broad theme of the work is to understand

- To examine the importance of connectivity
- To establish the significance of a range of ecosystem services and physical benefits
- To examine a range of temporal and spatial scale of each benefit

Also, to focus on Ecosystem Services and physical benefits

To coordinate with other topics, specifically with Topic 1 and 4, on linking interests and scenarios/alternatives/perceptions

Centred on the Street-by-street initiative in the Tideman-Johnson catchment but accepting the cascading benefits of the adjacent area

Study approach

Four step approach

i) Outline design for alternative surface water management ranging from grey to green (with regard to the feasibility of the alternatives in the study area), for example Business-as-usual, a grey solution and a green solution
ii) Evaluate the benefits based on an Ecosystem Services approach (qualitatively)
iii) Significance evaluation of incremental value added within a specific location
iv) Evaluating the benefit synergy through the development of a benefit footprint representing at a range of space and time

Methods, techniques and analysis

GIS approach to analyse the temporal and spatial overlay of benefits against existing physical and socio-economic context of the area, potentially utilizing existing tools
Therefore identify potential and changes affecting connectivity and benefit realization
Potential platforms: Netlogo and other GIS-based tools (ArcGIS, QGIS, i-Tree etc.)
Methods: binary benefit analysis, qualitative analysis and quantitative analysis

Staffing (min)

- US: Noelwah, Maya, Maggie
- UK: Dick, Scott, Lan

(Shaun: residents' priorities and views (without specifying options), detailed in Section 3.6 as a separate proposal)

Schedule

20th March: Meeting between Maggie and the Cambridge team; Noelwah and Maya and the Leeds team

1st week of May: UK team visit
Rest of May: RA and student team

June:
Finalising and delivering input
Deliverables: A framework to evaluate different benefits as a benefit footprint

3.6 Topic 6. Structuring and evaluating community priorities through participatory modelling

Goal

To use a participatory modelling approach and Bayesian networks techniques, to structure and evaluate community priorities in the Errol Tideman sub-watershed of Johnson Creek, Portland.

Research questions

- What are the community priorities in the Errol-Tideman sub-watershed relating to street improvements generally, and blue-green infrastructure in particular?
- To what extent do Bayesian networks provide a tool through which local knowledge and understanding can be structured in order that stakeholders view the system holistically;
- And come to consensus around their (potentially conflicting) priorities, such that they can be presented as recommendations for the future?

Scope

The study will be restricted to the group of unimproved streets that make up the north-eastern corner of the Errol Tideman sub-watershed. Workshop participants will be residents of those streets.

Study approach

The study will involve a workshop schedule (Figures below), supported by pre- and post-project discussions with approximately ten local residents.

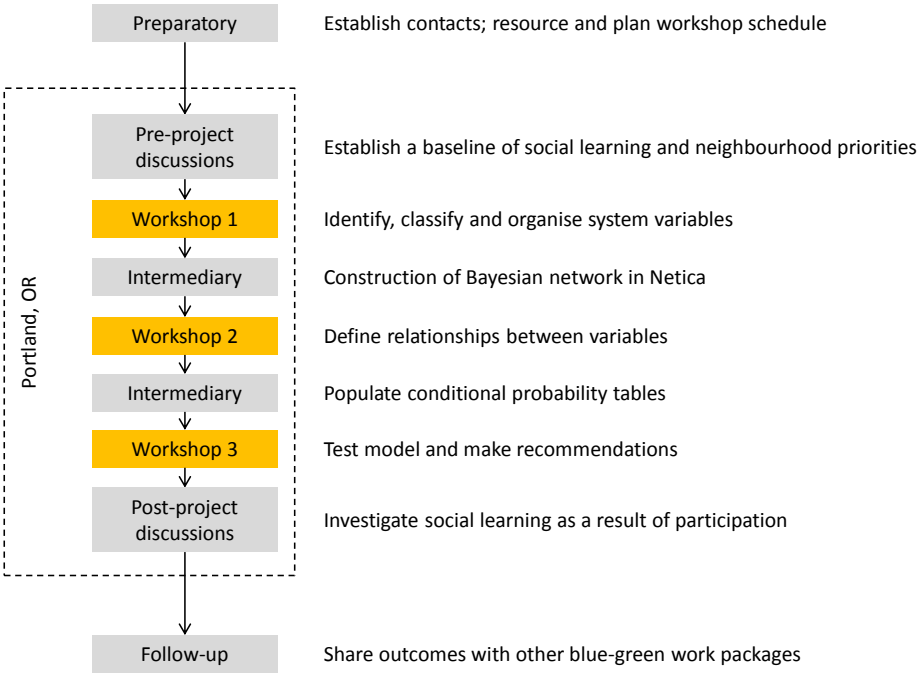


FIGURE: STUDY APPROACH

Methods, techniques and analysis

The study will involve three workshops, the first of which being an afternoon (four hours) and the second and third being evenings (two hours each). These will involve 8-12 participants

undertaking a series of participatory modelling activities to identify neighbourhood priorities (aka objectives), the interventions that could be implemented to achieve these, and lastly the factors affecting the probability of those interventions a) being implemented and b) being successful. Local expertise in these areas will be captured and structured in a conceptual model of the neighbourhood system as it relates to street improvements, using a Bayesian network built in Netica™. This model will be used to test out different future scenarios (in terms of governance, see later), and make recommendations for what the community identify as their priorities for street improvements. A workshop schedule is shown below.

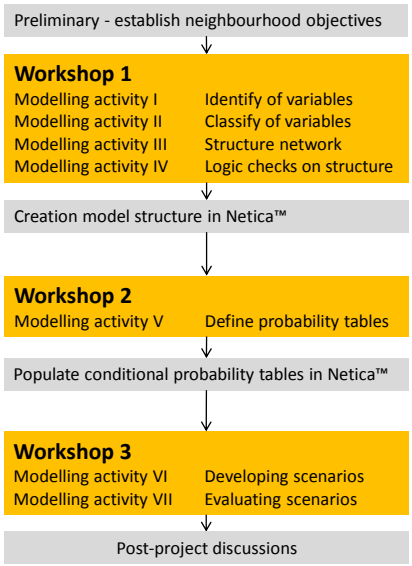


FIGURE: WORKSHOP SCHEDULE

Staffing

The study will be led by Shaun Maskrey with the assistance of Emily Lawson (workshop facilitation), for four weeks between 29.04.2014 and 26.05.2014 (see schedule for details). Maggie Skenderian (Bureau of Environment Services) will act as a key point of contact for gaining access to local residents and providing a logistical support for the workshops.

Schedule

Pre-Portland	Designing and resourcing of workshop schedule, making initial postal contact with residents, liaison with Maggie (participant access) and WP2c
Tues 29.04.2014	Arrive Portland
Thurs 01.05.2014	Community meeting – speak with members of the community to introduce the project and provide information on the upcoming workshops. Organise preliminary discussions.
Sat - Sun 03/04.05.2014	**Preliminary discussions with residents** Aims: identify initial neighbourhood objectives
Intermediary	Finalising list of objectives

Sun 11.05.2014	**13:00 – 17:00 Workshop One** Session 1: 13:00 – 15:00 Aims: identification and classification of system variables Session 2: 15:20 – 17:00 Aims: organise the variables into a logical network structure
Intermediary	Create model structure in Netica
Thursday 15.05.2014	**19:00 – 21:00 Workshop Two** Aims: define the relationships between variables
Intermediary	Populate conditional probability tables
Thursday 22.05.2014	**19:00 – 21:00 Workshop Three** Aims: test the model and make recommendations for future neighbourhood improvements
Intermediary	Write up outcomes, disseminate to stakeholders and other work packages
Sat - Sun 24/25.05.2014	**Post-project discussions with residents**
Mon 26.05.2014	Depart Portland

Budget

Catering:	$300

Workshop 1: four hours - hot and cold drinks at three intervals, afternoon tea at the interval
Workshops 2 and 3: two hours - tea and coffee at the start and cake at mid-session

Hire of venue:	$NIL – provided by city
US printing costs:	$75
Stationery/workshop resources:	$75
Total:	$450

4. PATHWAYS TO IMPACT

Pathways to Impact already in place for the B-GC Consortium Impact will be used as vehicles for disseminating the outcomes of this collaboration. Inclusion of research based in and around Portland will greatly enhance the impact of the B-GC project outcomes due to that city's very high global profile as a Blue-Green City.

Beyond this, further national and international impact will be assured through inclusion of a Stakeholder Dissemination Event, held as a physical meeting and webinar at the conclusion of this collaborative effort, in late 2014.

More generally, pathways to impacts will include; engagement with key stakeholders beyond those involved directly in the project through fieldwork (especially questionnaires and focus groups in Topic 5), meetings and workshops that will include:

- Statutory authorities such as the DEFRA, Environment Agency for England and Wales (EA), the Scottish Environmental Protection Agency (SEPA), and the Northern Ireland Rivers Authority, based on links that already exist between the Investigators and these bodies (especially those forged during the FRMRC) and as well as new contacts;
- Built environment professionals such as architects, civil engineers, urban planners, transport and highways bodies and their professional institutions;
- Local councils in the research study and B-GC Demonstration Cities (Newcastle). Newcastle was chosen in part due to the existing engagement of the Local Authority in developing a blue-green city;
- Citizens - through engagement with NGOs such as the Rivers Trusts, National Flood Forum and appropriate local social enterprises.

5. RESEARCH OPPORTUNITIES AND FUTURE COLLABORATION

The collaborative research brings together teams of researchers that include not only senior professors but also early career academics, researchers and postgraduate students. It is therefore highly likely that some of the academic links, relationships and friendships formed during initial collaboration in 2014 will endure through careers that will span the next two decades. It is, therefore, in the building of cooperative and mutually beneficial relationships that the best prospects of long-term collaboration reside.

Beyond the role of the collaborative research in providing enhanced opportunities for development of genuine partnerships between individuals and research groups lies the possibility of applying for follow-on funding to support further cooperative efforts. Based on the track records of the P.I. and Co-I's, this seems likely to happen. The senior academics are all adept at winning competitive grants and are more than capable of doing so in this context. What cannot be assured is their motivation. The chemistry between them and their US counterparts has to be right and that cannot be guaranteed *a priori*. That said, the UK team undertook a one-week mission to Portland in April, 2013, and the chemistry was excellent! That said, there is every prospect that the collaboration will move forward in 2015 (the last year of the B-GC) and beyond.

6. RESOURCES AND ACCOUNTING

6.1 Initial Workshop in the UK

This workshop is essential to allow the UK and US research teams to meet, exchange knowledge and initiate joint activities. It will also raise the profile of the EPSRC Consortium.

10 x US-UK airfares @ £800 = £8000, 10 x round trip airport transfers @ £200 = £2000, 10 x lodging for 6 nights @ £80 = 4,800, 10 x food x 7 x £25 = £1750, Workshop venue and catering (3-days, on Newcastle campus) = £900
Total Cost £17,450

EPSRC Contribution £13,960

% EPSRC Contribution (80%)

6.2 Collaboration: P/Co-I visits and RA/Student exchanges for co-location research at PSU/OSU

Maximizing benefits and building longer-term collaboration requires UK P/Co-Is to make one week visits and UK RAs/Students to fully engage with their American counterparts during 30-day exchange periods at PSU/OSU.

Total Cost
P/Co-I visits: 9 x UK-US airfares @ £800 = £7200, 9 x round trip airport transfers @ £100 = £900, 9 x 7 night's on campus accommodation @ £50 = £3150, 9 x 7 days food @ £25 = £1575 Total = 12,825
RA/Student exchanges: 6 x UK-US airfares @ £800 = £4,800, 6 x round trip airport transfers @ £100 = £600, £6 x 30 night's on campus accommodation @ £45 = 8,100, 6 x 30 days food @ £25 = 4,500 Total £18,000
Total Cost = £30,825

EPSRC Contribution £24,660

% EPSRC Contribution 80%

6.3 Wrap up meeting and stakeholder dissemination event, China (plus webinar)

This one-day event will consolidate and showcase the outcomes of the collaboration and announce the next steps. The webinar format (for the US team) avoids trans-Atlantic travel costs and maximizes stakeholder and international impact.

Total Cost
Travel for UK team 12 x £75 = £900, Catering for UK 60 participants @ £13 = £780
Total cost = 1680
EPSRC Contribution £1344

% EPSRC Contribution 80

10. Total Cost £49,955

10. EPSRC Contribution 39,964

10. % EPSRC Contribution 80

7. REFERENCES

Hoyer, J., Dickhaut, W., Kronawitter, L. and Weber B. 2011. *Water Sensitive Urban Design*. Jovis, University of Hamburg.

Novotny V., Ahern J. and Brown P. 2010. *Water Centric sustainable communities: planning, retrofitting and building the next urban environment.* John Wiley and Sons, New Jersey.

8. ANNEXES

Annex I. Contact details for UK and US collaborators

Contact details for the **UK team**:

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Annex II. Track record of UK Topic Leaders

Colin Thorne will lead the collaboration, coordinate activities across the Topics, and co-lead Topic 1. His research and experience in water-related projects and studentships funded by (amongst others) EPSRC, NERC, ESRC, EA, Defra, SEPA, FCO, Foresight and the UN build on his BSc and PhD degrees in Environmental Sciences (UEA) to equip him to provide leadership across the project.

Leonard Smith will co-lead Topic 1. He is a Fellow of Pembroke College, Oxford and Director LSE's Centre for the Analysis of Time Series (CATS). He is a member of the WMO's Expert Team on Forecast Verification (www.wmo.int/thorpex) and a consultant to the European Centre for Medium-range Weather Forecasts. He works within the Grantham Research Institute on Climate Change, the ESRC Centre for Climate Change Economics and Policy, and is P.I. on "Evaluating the Economics of Climate Risks and Opportunities in the Insurance Sector" for Munich Re and the NERC 'End-to-End Quantification of Uncertainty for Impacts Prediction' (EQUIP) project.

Nigel Wright will lead Topic 2. Nigel has an international reputation in hydrology, hydraulics, flood inundation, algorithm development, and model selection, speed-up, and uncertainty.

Jenny Mant will lead Topic 3. She has long experience in urban river management and restoration principles and processes, gained in working with stakeholders, consultants and public agencies across the UK in delivering best practice in flood alleviation projects. She currently provides advice to Defra/EA (FD1920/TR).

Jessica Lamond will lead Topic 4. Her research interests focus on managing the consequences of flooding through behavioural adaptation and flood insurance. She has 50+ publications on flooding and the urban environment, including a World Bank handbook for integrated urban flood management.

Dabo Guan and Dick Fenner will co-lead Topic 5. Dabo has worked on interdisciplinary projects assessing the contrasting socioeconomic impacts of flooding and climatic change in cities that are poor and vulnerable, and rich and with good adaptive capacities. He is a Lead Author for the IPCC AR5. Dick's research experience on sustainable urban drainage, the development of knowledge based systems for performance assessment and multi-scale modelling of integrated urban water systems (GR/K5158/01, EP/E003192/1, EP/E 003192/1) complement Dabo's expertise.

Scott Arthur will work on Topic 5. Scott is an expert in sustainable urban drainage with over 80 publications who has contributed to standards developed in the UK, EU and USA through research supported by the EPSRC, EU and Scottish Government, especially with regard to wood dynamics and blockage risks in urban streams.

Shaun Maskrey will lead Topic 6. This links with his PhD research (EPSRC studentship) into "Bayesian networks as a tool for involving stakeholders in the participatory modelling and management of flood risk".

ANNEX III. LIST OF ACRONYMS AND ABBREVIATIONS

BES	Bureau of Environmental Services
B-GC	Blue-Green Cities
CATS	Centre for the Analysis of Time Series
Co-I	Co-investigator
Defra	Department for Environment, Food and Rural Affairs
EA	Environment Agency for England and Wales
EPSRC	Engineering and Physical Sciences Research Council
EQUIP	End-to-End Quantification of Uncertainty for Impacts Prediction
ESRC	Economic and Social Research Council
FCO	Foreign and Commonwealth Office
FRMRC	Flood Risk Management Research Consortium
FTE	Full time equivalent
GIS	Geographical Information System
IGERT	Integrative Graduate Education and Research Traineeship
IPCC	Intergovernmental Panel on Climate Change
IRB	Institutional Review Board
JCWC	Johnson Creek Watershed Council's
LID	Local Improvement District
LSE	London School of Economics and Political Science
NERC	Natural Environment Research Council
NGO	Non-Governmental Organisation
NSF	National Science Foundation
OSU	Oregon State University
P.I.	Principal Investigator
PCB	Polychlorinated Biphenyls
PSU	Portland State University
PVU	Portland-Vancouver ULTRA-Ex project
RA	Research Associate
RDU	Relevant Dominant Uncertainties
RHA	River Habitat Assessments
RHESSys	Regional Hydro-Ecologic Simulation System
SEPA	Scottish Environmental Protection Agency
SuDS	Sustainable Urban Drainage Systems
SUSE	Symposium on Urbanization and Stream Ecology
TBD	To be decided
TSS	Total Suspended Solids
ULTRA-Ex	Urban Long Term Research Area
UNNC	University of Nottingham Ningbo Campus
USDA	US Department of Agriculture
WSU	Washington State University