Blue–Green Cities

Blue–Green Cities

Integrating urban flood risk management with green infrastructure

Edited by Colin R Thorne
University of Nottingham

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About the editor

Colin R Thorne has worked on flooding and flood risk management for 30 years. Following the floods that devastated Bangladesh in 1987 and 1988, he contributed to the nation's Flood Action Plan (1990–2004), focusing on the management of flooding and related morphological changes along the Rivers Ganges and Brahmaputra. Back in the UK in 2000, the Millennium Floods convinced then Deputy Prime Minister John Prescott that climate change was real and would make future floods increasingly frequent and severe. When, in 2002, Sir David King (then the government's chief scientific adviser) set in motion the Flood Foresight Project (2002–2004) to provide the scientific evidence needed to support or refute Mr Prescott's prediction, he asked Colin to lead on the geomorphological aspects of river flooding and coordinate the qualitative assessment and ranking of the drivers of future flood risk. Between 2004 and 2012, Colin acted as the deputy director of the UKRC Flood Risk Management Research Consortium (funded by the UK Research Consortium), with particular responsibility for a super-work package on flood sediments and geomorphology. In parallel, he was part of the technical advisory panel for Sir Michael Pitt during his study of the summer floods of 2007, the director of the Flood Foresight Update study in 2008, and the principal investigator for the UN/NERC/Defra/FCO-funded China–UK Taihu Basin Flood Study (2008–2011), which applied the Flood Foresight approach to the city of Shanghai and its hinterland. Between 2013 and 2016, Colin was the principal investigator for the nine-university EPSRC Blue–Green Cities Research Project, which received additional support for collaborative research with colleagues in the USA and China, under the Clean Water for All initiative. Colin also has extensive experience in policy-related research. He advised the UK Government during and following the winter floods of 2013–2014, serving on the Scientific Advisory Group for Emergencies (SAGE), and has assisted the UK's Environment Agency on river sediments and habitats, natural flood management, working with natural processes and green infrastructure. He has, on various occasions, also undertaken research and consultancy on sustainable flood risk management in Alberta, Argentina, Ethiopia, India, Libya, Kazakhstan, Pakistan, Queensland, New Zealand, Russia and the USA. Colin's contribution to knowledge and its practical application was recognised in 2016, when he won the Royal Geographical Society's George Back Award for policy-related research. Colin is currently the principal investigator for the EPSRC research consortium Achieving Urban Flood Resilience in

an Uncertain Future. He divides his time between the UK and the Pacific Northwest, where he works with the US Army Corps of Engineers and the US Geological Survey on the sustainable management of sediment-related flood risks along the Toutle and Cowlitz Rivers, which remain problematic due to the elevated sediment loads that still emanate from Mount St Helens 40 years after the cataclysmic eruption of 1980.

About the contributors

Sangaralingam Ahilan is a research fellow in the Centre for Water Systems, University of Exeter, UK. He has a civil engineering background with research interests in river hydraulics, flood frequency analysis, flood and sediment modelling, urban sanitation, rainwater management and urban system modelling. He obtained a PhD from University College Dublin, Ireland, where he researched the influences of floodplains on flood estimation procedures in Ireland. Sangaralingam has worked in a number of water and environmental research projects in Ireland and the UK. As part of the EPSRC Blue–Green Cities Research Project, he investigated the long-term flow and sediment dynamics in blue–green infrastructure. His current research in the EPSRC Urban Flood Resilience project focuses on the potential of rainwater management systems on water supply augmentation and flood resilience, and urban metabolism modelling to explore sustainable urban water management strategies in Ebbsfleet Garden City, UK. Sangaralingam also serves as an editor for the *Journal of Water and Climate Change*.

Scott Arthur is a professor at Heriot-Watt University, UK. His research addresses all aspects of urban drainage, from roof systems to watercourses and sewer networks. Building on internationally leading work on the formation of blockages in sewers, research undertaken in the UK and the EU has established Heriot-Watt University as a leader in understanding debris-related flood risks. The key research outcome has been to link land use to the generation of natural and/or anthropogenic debris and which types of trash screen are most likely to block. Scott has also undertaken considerable field-based work looking at the movement of sediments in conventional and sustainable urban drainage systems. This ranges from sediment movement in sewers to pollutant trapping in ponds and the clogging of permeable pavements.

Robert Bertsch is a consulting engineer with DHI, based in Vienna, Austria, where he works on flood resilience design. He carried out his PhD research at Newcastle University, UK, and Scottish Water at the STREAM Centre for Doctoral Training, on exploring new technologies for simulation and analysis of urban flooding using the CityCAT model. His research has demonstrated the utility of detailed modelling with exact building and storm drain inlet information, coupled with a novel flood exposure analysis tool, for the rapid assessment of the flooding of buildings for entire cities.

Josh Burch manages stream restoration projects for the District of Columbia's Department of Energy and Environment (DOEE) in the USA. Josh has managed stream restoration projects in Columbia since 2009. Prior to his time at the DOEE, Josh led several job training programmes in Columbia focused on engaging youth in environmental stewardship work, and previously served as a Peace Corps Volunteer. The Alger Park Stream and Upland LID Project won the 2019 Best Urban BMP award, and Josh was the recipient of an Anacostia Hero Award from the Anacostia Watershed Society.

Christopher Digman is an expert and recognised technical leader in urban drainage, specialising in wastewater and stormwater management, sustainable drainage, flood risk management, pollution control and sewer solid movement. Chris's specialties are surface water management (planning, modelling, design and guidance writing); urban drainage (problem understanding, investigation, modelling, design and construction), smart networks, sewer solid modelling, and guidance writing (including flood risk solutions and water quality solutions).

Kit England is a chartered environmentalist, and has worked on climate adaptation and resilience for over 10 years. He currently works at the sustainability charity Sniffer, managing Climate Ready Clyde – a collaborative initiative of 15 public, private and voluntary organisations developing an adaptation strategy and action plan for the Glasgow city region in the UK. Prior to this, Kit led the climate adaptation approach for Newcastle upon Tyne and chaired the Core Cities Climate Resilience and Adaptation Working Group for over 5 years, comprising the UK's ten biggest cities outside London. Kit has also advised the Joseph Rowntree Foundation on climate adaptation and social vulnerability, and advised both UK Government and the European Commission on developing and implementing adaptation action. He is also a member of an ISO working group on climate change adaptation, and a contributing author for the third UK Climate Change Risk Assessment. He has also worked on research and capacity-building projects for the Scottish Government, Defra, the Association of Directors of Environment Planning and Transport (ADEPT) and the Committee on Climate Change, in partnership with some of the world's leading consultancies, including AECOM and ARUP.

Glyn Everett is a research fellow at the Centre for Architecture and Built Environment Research (CABER) at the University of the West of England. Glyn has worked on social science projects around education, natural history and flooding for over 15 years. Glyn's work focuses on the importance of learning about local preferences and involving public voices in flood risk management, both to gain from local expertise and to try to ensure that devices satisfy local preferences, in the hope that this will encourage greater public engagement, understanding and behaviour change. His current work looks at the potential value of employing social practice theory in approaching and analysing the potential for voluntary community stewardship of blue-green infrastructure.

Richard Fenner is a Chartered Engineer and a member of the Institution of Civil Engineers and a Fellow of the Chartered Institution of Water and Environmental Management. He is currently Professor of Engineering Sustainability in the Engineering Department, Cambridge University, UK. Richard's research interests are in water, sanitation and sustainability issues in both developed and developing countries, with a focus on urban drainage, UK water industry asset maintenance, and water, sanitation and health (WASH) issues in Africa. His research has included published work on the asset maintenance of sewerage infrastructure; developing scale laws for hydrodynamic separation; developing algorithms for leak detection in water mains; applying sensor arrays for monitoring sewage odour; modelling ultraviolet light disinfection of greywater and recycling for single home use; building a simplified climate impact assessment tool to evaluate the impact of climate change on water treatment plant operation; and examining the impacts of coupled resource management of water, energy and land on food security. He led the spatial analysis of multiple benefits from blue-green infrastructure for the Blue-Green cities Research Project. He is the co-author/joint editor of the books *Sustainable Infrastructure: Principles into Practice* (2014) and *Sustainable Water* (2016), and the subseries advisor for Springer's Sustainable Development Goals book series for *Goal 6: Clean Water and Sanitation*, and a member of the Editorial Advisory Panel for *Nature Sustainability*.

He has served on a number of steering groups and advisory panels for the UK's Environment Agency, the Construction Industry Research and Information Association (CIRIA), Thames Water and the Building Research Establishment (BRE). He is the recipient of several awards from the Institution of Civil Engineers, including the George Stephenson Gold Medal, the R A Carr Prize and the James Watt Medal, and the Senior Moulton Medal from the Institution of Chemical Engineers.

Vassilis Glenis is a lecturer in hydroinformatics at the School of Engineering, Newcastle University, UK. His research background is in hydrodynamic modelling, where he has developed advanced shock-capturing finite-volume methods and applied them using cloud computing. As the originator and main developer of the CityCAT hydrodynamic simulation software, his work has focused on flood modelling in urban environments, coupling the surface and pipe networks and incorporating blue–green interventions. He has also developed and applied stochastic weather generators for climate change impact assessments, notably for the UKCP09 national climate projections.

Dabo Guan is a distinguished professor at Tsinghua University, China, and a senior member of St Edmund's College, University of Cambridge, UK. He is a Fellow of the Academy of Social Sciences, UK. He specialises in environmental economics for international climate change mitigation, climate change adaptation, scenario analysis on environmental impacts, water resources accounting and management, and input–output modelling and their applications in both developed and developing countries. He was a lead author for the IPCC AR5. He was a Highly Cited Researcher in 2018 and 2019. He has authored over 150 publications, including over 40 articles published in *Science*, *Nature*, *Nature* research journals, and *Proceedings of the National Academy of Sciences of the USA (PNAS)*. He received the PNAS Cozzarelli Prize 2014, the Leontief Prize three times and the Philip Leverhulme Prize. His paper about climate change impact on beer consumption received the 2018 Altmetric Top 100 award.

Mingfu Guan is an assistant professor of water and environmental engineering who has 9-year research track record in water-related risk modelling. Prior to moving to Hong Kong in September 2018 he was awarded a prestigious EPSRC postdoctoral fellowship, tackling challenges in

achieving urban resilience to intense rainfall and flooding in a changing climate. He obtained his PhD in 2014 at the University of Leeds, UK. Since then, as a postdoctoral researcher, he has successfully worked on high-profile projects funded by UK and EU agencies, with a focus on Blue–Green Cities, urban stormwater and flood risk management. He also is a member of UK EPSRC associate peer review college and a grant reviewer for the UK Natural Environment Research Council. As a leading author, he has published 15 high-impact journal articles and served as an invited reviewer for 17 journals.

Chris Kilsby is a professor of hydrology and climate change at the School of Engineering, Newcastle University, UK. He worked in airborne atmospheric research at the UK Met Office Meteorological Research Flight before joining Newcastle University in 1991. At Newcastle University, his research and teaching has focused on hydrological extremes (floods and droughts) under present and future climates. He has championed the use of stochastic rainfall models with hydrological and hydraulic models for climate change impact assessments and adaptation design. His research using advanced computational modelling covers worldwide applications, including water resources, flooding, urban drainage, heatwave and infrastructure resilience.

Jessica Lamond is a professor in real estate and climate risk and a co-director of the Centre for Architecture and Built Environment Research, University of the West of England. She works on understanding structural and non-structural responses to flood risk in the built environment. Jessica has a background in decision science, and has research interests in barriers and drivers to delivering integrated flood management, including the long-term financial and economic implications of flooding and insurance. Recent projects include work on the EPSRC's Urban Flood Resilience, Flood MEMORY and Blue–Green Cities Research Project, and on projects on land use planning and climate adaptation in Nigeria for the UK Department for International Development. She is the co-author of several books in the area of flood risk management, including the World Bank handbook on integrated flood risk management.

Jenny Mant is a fluvial geomorphologist with 25 years' experience in river restoration and catchment management. Jenny has worked in all environments from source to sea, primarily in the UK, Europe and the USA, and has also

provided river restoration advice in China and Japan. Following Jenny's PhD on the evaluation of hydrology on ephemeral fluvial processes related to in-channel vegetation in southern Spain, Jenny joined the UK's River Restoration Centre as its technical manager. During her 15 years at the centre, she provided advice on river restoration across the whole of the UK. During that time, she was the communication lead for a 4-year EU funded project (RESTORE) on river restoration advice, where she carried out numerous technical and policy-maker workshops across Europe. During her career, Jenny has authored and co-authored a range of river restoration, catchment management, water quality, and natural flood management peer-reviewed papers. She has also authored, and been part of advisory panels related to, a range of technical advice, including the widely used *Manual of River Restoration Techniques* and associated monitoring guidance, both of which have been translated into a range of languages. Jenny is currently a technical director for Ricardo, and heads up the water team. She has responsibility for a range of water company frameworks related to environmental assessment and the benefits of different approaches to water management for society and ecology, and continues to provide technical advice on fluvial geomorphology and river restoration. Jenny is a trustee of the Wild Trout Trust, an organisation that engages with local groups and provides practical advice on river enhancements with the aim of making a difference to people and the aquatic environment.

Shaun Maskrey works for the UK's Environment Agency on the flood risk management of the River Thames. He works with local government and communities across Southeast England, providing advice on flood risk, partnership working and project management. Previously, he worked as a researcher at the University of Nottingham, UK, on projects exploring the multiple benefits of blue-green infrastructure in cities. He specialises in planning and running participatory sessions for multi-agency groups, championing greater use of local knowledge in flood risk decision-making.

David Mendoza-Tinoco is a lecturer in economics at the Faculty of Economics, Autonomous University of Coahuila, Mexico. He is member of the National Researchers System of the National Council of Science and Technology. He holds

a BA in economics from the Metropolitan Autonomous University, Mexico City, and an MA in economics from The College of Mexico. He obtained his PhD at the School of International Development at the University of East Anglia, UK. David specialises in ecological economics, climate change adaptation and input–output modelling.

Marc Naura is a geomorphologist, hydromorphologist and ecologist with 25 years' experience in environmental management, applied research and consultancy. He has worked both in marine and freshwater environments in consultancy, research and as part of a major government organisation. His work ranges from research and development and policy advice to river/catchment audits, training, geomorphological/ecological appraisals, ecological and hydromorphological modelling, impact assessment and river restoration. Marc has an interest in decision support and software development. He completed a PhD on designing software for prioritising rivers for habitat enhancement work. As part of his research, he studied the organisational and human factors that affect the uptake of science and technology in organisations, and developed software design methods to maximise user input. As an adviser to UK agencies on hydromorphology and Water Framework Directive (WFD) matters, he regularly participated in UK technical advisory groups dedicated to morphological and ecological issues. At the EU level, he was involved in the production and review of CEN standards on hydromorphology and the development of solutions to the implementation of the WFD. He now works for the River Restoration Centre as its science and technical manager, where he leads the development of tools, techniques and research for river restoration planning and catchment survey. He is a Chartered Environmentalist and a full member of the Chartered Institute of Ecology and Environmental Management and the British Society for Geomorphology.

Helen O'Brien works for Leicester City Council, UK, as a senior nature conservation officer within the Planning Department. She is responsible for advising on the Council's environmental policies, plans and strategies with particular relevance to biodiversity and promoting the multiple functions of blue–green infrastructure in the city and its environs.

To this end, she wrote Leicester's Green Infrastructure Strategy 2015–2025 and Biodiversity Action Plan 2011–2021 to provide an evidence base and actions to design and implement opportunities for such infrastructure in Leicester. Helen is also a practitioner, and is actively involved in helping to design and deliver a number of blue–green projects in Leicester, advocating partnership working at local, regional and national scales. She is also interested in the delivery of blue–green infrastructure at a catchment and/or landscape scale. She has worked closely with the Soar Catchment Partnership, the River Soar and Grand Union Canal Partnership, and the local wildlife trust to help achieve multiple aims and promote the funding and support of projects locally and in the wider catchment. Previously, Helen worked for Nottingham Trent University, UK, where both her research and projects involved natural flood management techniques and changes in land use to provide a sustainable means of reducing desiccation and erosion of peatlands while seeking to improve water quality and biodiversity. These principles are readily transferable to the green spaces of urban cities, and provide many benefits to local residents.

Emily O'Donnell is a research fellow in urban flood resilience at the University of Nottingham, UK, and leads the research on the EPSRC Urban Flood Resilience project that investigates transformative change in urban water systems. Emily helped lead the EPSRC Blue–Green Cities Research Project (2013–2016) that developed new methods and frameworks to robustly evaluate the multiple benefits of blue–green infrastructure. Her research specialises in urban flood resilience, flood risk and water management, blue–green infrastructure and stakeholder engagement. She is interested in how cities are addressing current and future urban water challenges associated with climate change, urbanisation and ageing infrastructure, and how visions may be developed for blue–green urban futures where multifunctional blue–green infrastructure creates environmental and societal co-benefits and is delivered by cross-organisational collaborations. Her current research focuses on identifying the uncertainties and challenges that act as barriers to the widespread implementation of blue–green infrastructure, and how these may be overcome through changes in practice and policy. Her research also uses novel toolkits to evaluate and monetise the social,

environmental and economic benefits of blue–green infrastructure (under flood and non-flood conditions), and identify the implicit and explicit perceptions of blue–green and grey infrastructure held by professionals and communities. She works closely with UK local government and industry stakeholders in Newcastle, Ebbsfleet and Nottingham to develop sustainable visions for urban water management *via* learning and action alliances. Emily is also exploring how blue–green futures may be developed as new forms of environmentally sustainable urban governance as part of a British Academy TUKIC (Tackling the UK’s International Challenges) grant, using case studies in Newcastle (UK), Portland (Oregon, USA), Ningbo (China) and Rotterdam (the Netherlands).

Maggie Skenderian has expertise in natural resource planning, restoration and communications. She has a BS in natural resources from the University of Vermont, USA, and an executive master’s degree in public administration from Portland State University, USA. She worked for the Portland Bureau of Environmental Services as the Johnson Creek watershed manager for over 20 years. There, she focused on implementing a comprehensive watershed restoration programme in Johnson Creek, with an emphasis on floodplain restoration, salmon habitat restoration and water quality improvements. Her work also included planning and implementing multifaceted green infrastructure and stormwater projects with a diverse set of stakeholders, and creating a methodology for assessing the value of green infrastructure through an asset management inventory. She is now the owner and principle of Upstream Consulting LLC.

Jonathan Vann is a Chartered Geographer, a Fellow of the Royal Geographical Society and the managing director of Riverscape Environmental Consultants, based in Leicestershire, UK, and specialising in the water environment. Previously, Jonathan worked for the UK’s Environment Agency in the Thames, Anglian and Midlands regions, most recently as a senior flood risk management advisor developing blue–green infrastructure schemes to reduce the risk of flooding by improving public open spaces. Jonathan also has a strong interest in river restoration and the role that this work can play in the long-term management of flood risk in urbanised areas.

Nigel Wright is the deputy vice-chancellor (research and innovation) at Nottingham Trent University, UK. From initial research on the use of computers to predict the movement of fluids in the natural and built environment, Nigel's research has expanded into the cross-disciplinary aspects of flood risk management and climate change adaptation. This has led to funding from the EPSRC, the Natural Environment Research Council and the Economic and Social Research Council, among others. Nigel's work has had a strong international focus. In addition to time spent working in the USA and the Netherlands, he has worked on collaborative projects in Ethiopia, Zimbabwe, Zambia, Mozambique, Argentina, China and India. He is currently a visiting professor of the Chinese Academy of Sciences.