Water research and development

Investment review
2018 - 2019

ARUP

Foreword

Water is essential for life. As the global population increases, our demand for water intensifies pressure on finite water resources. By 2050, the global demand for water will increase by 55%, whilst half of the population will live in water scarce regions. Our most precious resource is at significant risk and we must act now. The digital revolution is transforming the water sector and technological developments open new possibilities, but it is an integrated approach that will secure the future of water.

At Arup, we've evolved our 'Design with Water' framework, which draws on our experiences of designing, implementing and maintaining water infrastructure around the world. 'Design with Water' is strongly underpinned by our research activities. It places an understanding of the local water cycle at the centre of responses to wider local issues, such as economic development, food and agriculture, community, and energy use.

In order to account for the whole water cycle, Arup conducts research into multiple aspects of water management. From Machine Learning assisted flood modelling to working with partners to better understand water resilience in cities, we are continuously broadening the expertise that enables us to assess risks and support our clients in taking a strategic approach to water usage and management.

To learn more about water at Arup, read our Global Water Annual Review on arup.com or download our Drivers of Change app.

Justin Abbott
Director, Arup Water Skills Leader

Research at Arup

Arup has been at the forefront of built environment planning and design for more than 70 years. Research has always been fundamental to how we think and how we do business, driving innovation and helping us to respond to the changing needs of our clients and the communities we serve.

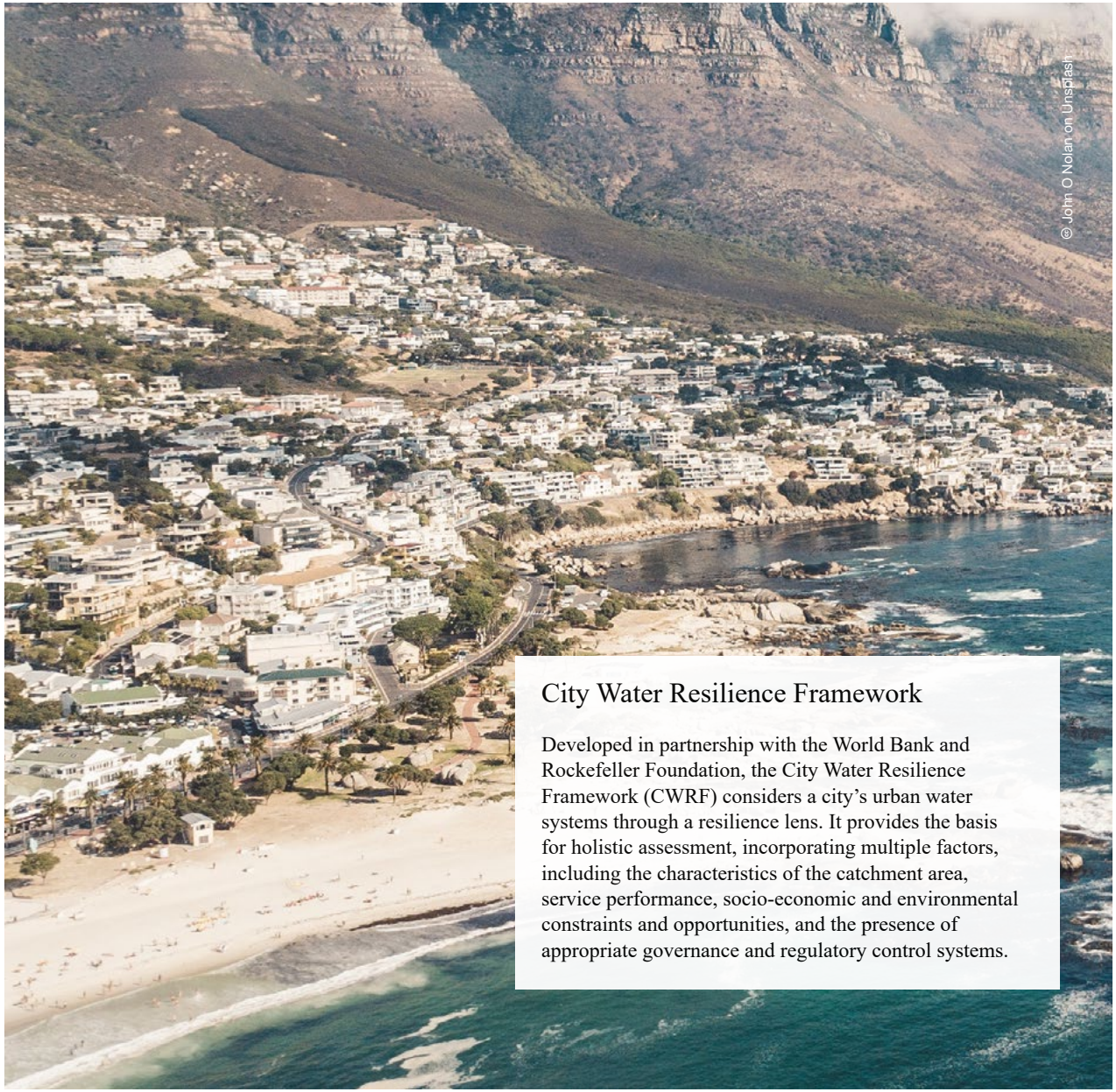
From ideas to application

We see design as an opportunity to rethink, reshape and redefine the world around us. Our research remit is broad, tackling everything from urban water systems and green infrastructure to Machine Learning assisted flood mitigation. With the support of a dedicated research team, Arup delivers ideas that help to solve complex challenges and are ready to be put into practice.

Working together for a better future

Research runs through our entire organisation, stimulating new thinking, encouraging collaboration and creating value through innovation. Our researchers work in partnership with academia and other businesses to bring together valuable combinations of disciplines in the pursuit of technical excellence. Every year we invite external parties to contribute to the Global Research Challenge, through which Arup funds the most promising and inspiring new ideas. We believe that open-minded collaboration builds legitimacy, ownership and accountability as we turn problems into potential solutions.

Find out more about our research at research.arup.com.



City Water Resilience Framework

Developed in partnership with the World Bank and Rockefeller Foundation, the City Water Resilience Framework (CWRF) considers a city's urban water systems through a resilience lens. It provides the basis for holistic assessment, incorporating multiple factors, including the characteristics of the catchment area, service performance, socio-economic and environmental constraints and opportunities, and the presence of appropriate governance and regulatory control systems.

Introduction

Rapid urbanisation and increasingly unpredictable climate changes across the world are causing strain on water infratructure and ecosystems. To tackle these complex challenges, a multidisciplinary approach to research is needed: one that considers the climate, geological, social, economic and environmental factors that affect water supply and use.

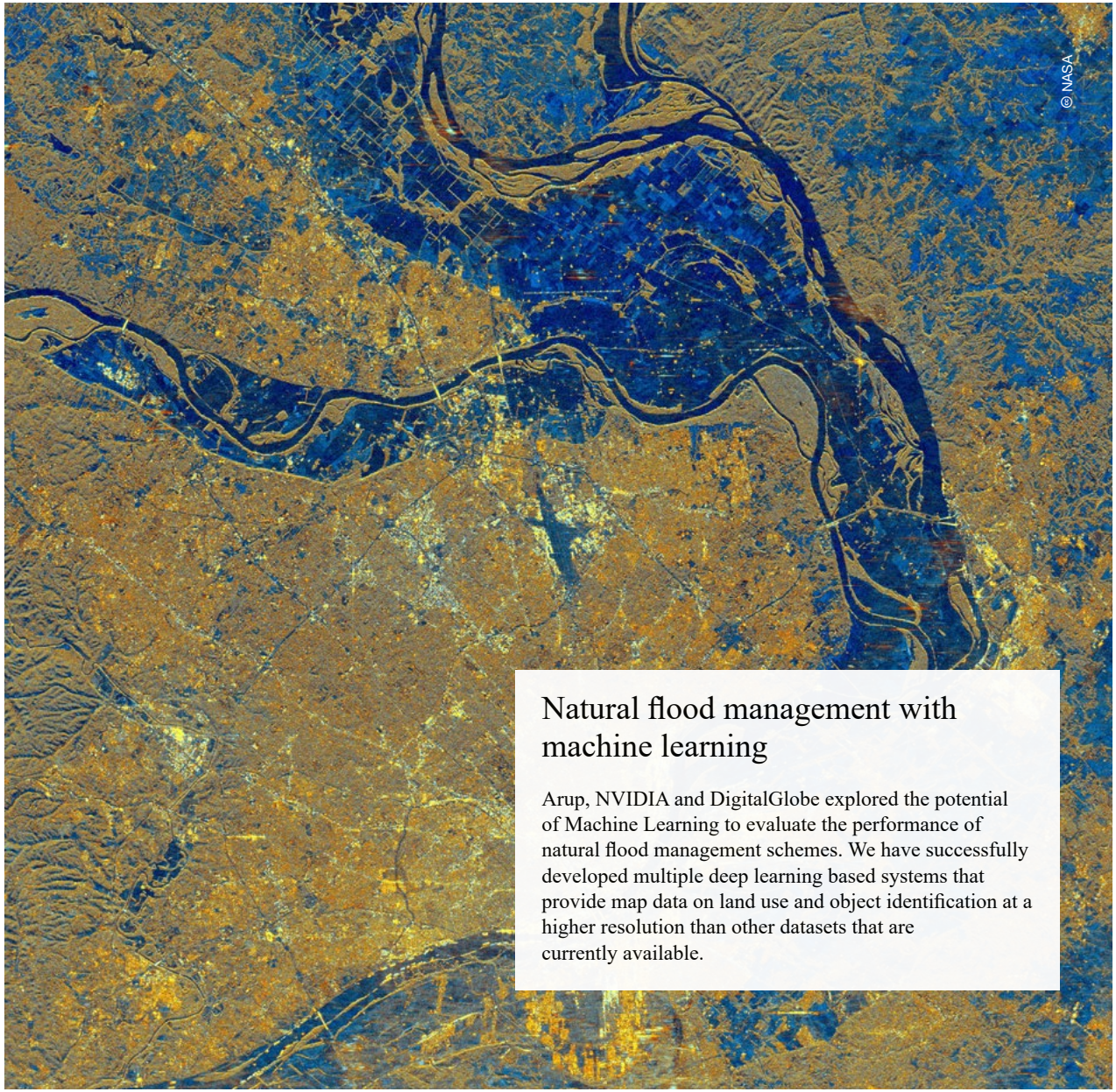
Arup continuously funds collaborative research, and this document provides an overview of the successful projects that we have invested in from 2016–2018. It highlights the breadth of water research initiatives across many related disciplines, our external partnerships and collaborations, as well as outlining our approach to both present and future challenges.

The 2016–2018 research and development programme supported numerous activities. These were linked to priority themes, which we defined as part of our strategic research agenda. Specifically, these themes were:

- Cities and demographics
- Decentralised water, recycling and reuse
- Resilient infrastructure
- Smart water and data
- Water and energy
- Water resources and ecosystem services

Applied research at Arup is facilitated through our internal investment system, Invest in Arup (IiA). This platform is instrumental in supporting research applications, seeking critical commentary from employees, and tracking progress and achievements.

We know that addressing the most complex water challenges cannot be done in isolation and we look to co-develop applied research with our clients and collaborators.



Natural flood management with machine learning

Arup, NVIDIA and DigitalGlobe explored the potential of Machine Learning to evaluate the performance of natural flood management schemes. We have successfully developed multiple deep learning based systems that provide map data on land use and object identification at a higher resolution than other datasets that are currently available.

Investment: funding trends and sources

The challenges facing the water sector have both global and local relevance, ranging from water demand to access to potable water. That is why, at Arup, we ensure our research is multidisciplinary and engages local teams, whilst being globally-transferrable as far as possible.

Over the last three years, Arup invested almost £2.2 million in 192 applied water research projects. The UKIMEA region is our major centre of excellence, with other regions also undertaking research initiatives on a regular basis. We worked alongside many experts, including advisory services, maritime engineering, planning, and environmental consulting and ecology. The last section of this document highlights a selection of our research projects, ranging from new and innovative flood risk management software to digital water masterplanning tools.

The anticipated impact of a digital revolution on our daily activities and the resilience of our systems is significant. Therefore, we have invested in digital initiatives to ensure we are able to provide cutting edge solutions and guide our clients through this exciting period of transition.

Our business is aligned to the United Nation's Sustainable Development Goals (SDGs). We understand the positive impact we can have on SDG6: Clean Water and Sanitation, and we also recognize the significant influence water will have on achieving all of the 17 SDGs. A number of the research projects presented here look to address these relationships whilst also directing research to explore the specific climate and water challenges facing the most vulnerable communities across the globe.

Figure 1: Distribution of Water research funding across regions (2016–2018)

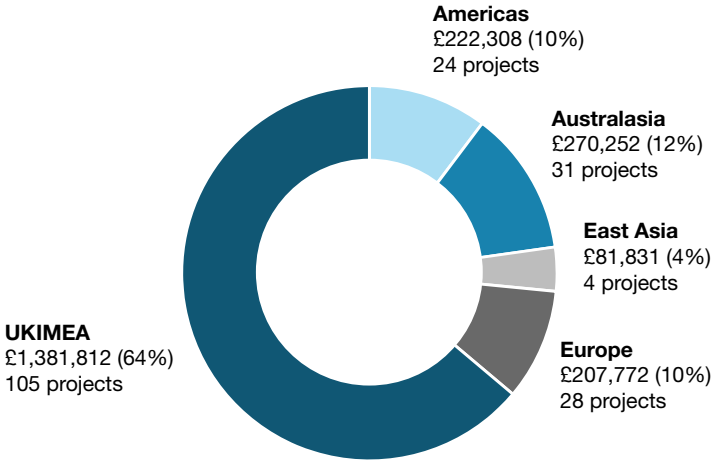
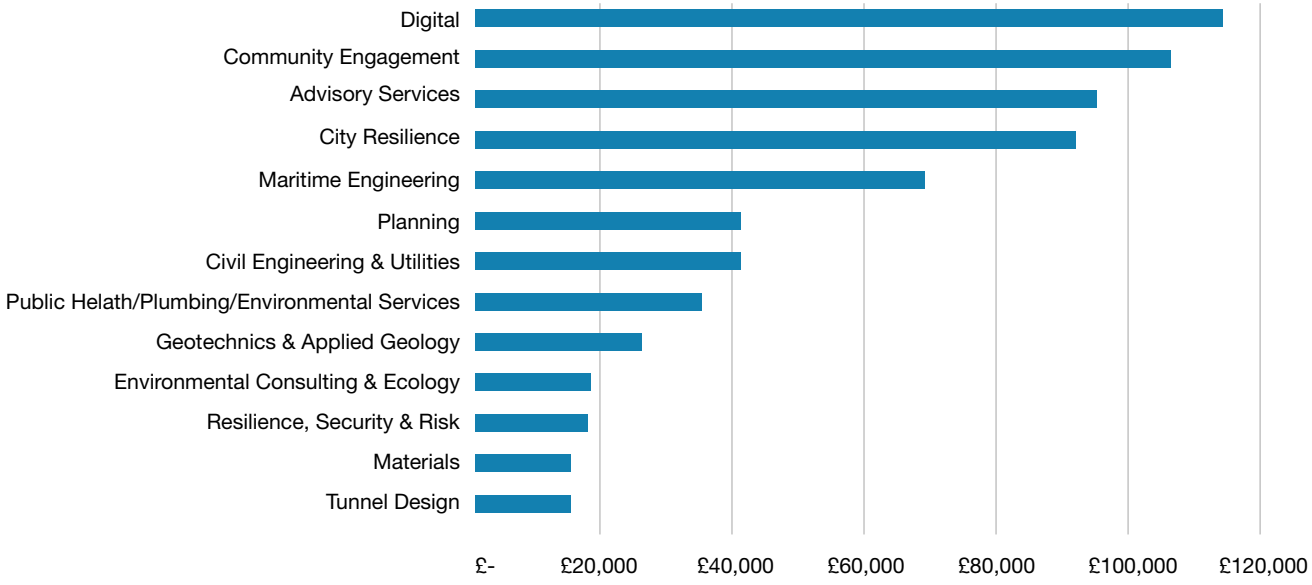


Figure 2: Other disciplines contributing to Water research projects at Arup (2016–2018)



Collaborations

At Arup, we believe that high quality, multidisciplinary research requires collaboration with the best in class, including academia, industry, public sector and NGOs. Only by working together can we really understand the challenges and leverage the value of new knowledge. We continuously search for opportunities to engage in joint research initiatives and we challenge ourselves to deliver at least 60% of research as a collaborative projects.

During 2016 to 2018, we significantly exceeded this target, with 71% of water research investment allocated to external collaboration projects. Of these projects, 43% were delivered by multi-discplinary teams across different sectors. This was followed closely by cooperation with academia and industry. We engaged with academic partners from different regions, including University of Leeds, Cambridge University, Virginia Tech, Delft University of Technology, and University College Cork.

Arup partnered on research projects with a number of industry organisations, including multiple water companies in the UK, Australia and Europe. To address some of the digital challenges, we established partnership with NVIDIA. We also worked with multiple NGOs, including the World Health Organisation (WHO), Engineers Without Borders, and the World Bank. A selection of our collaborations are included in the next section.

Figure 3: Allocation of Water research funding: internal versus external collaboration (2016–2018)

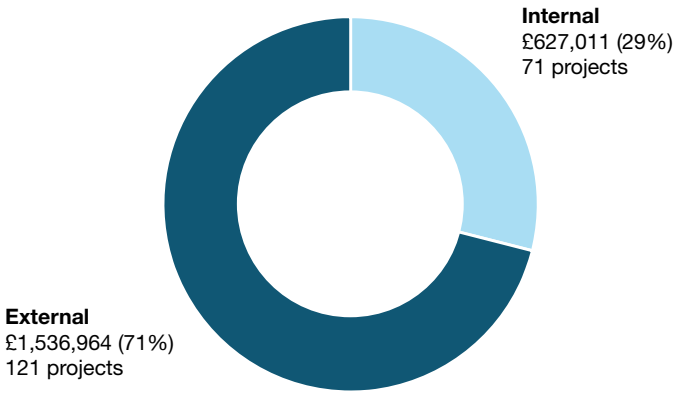
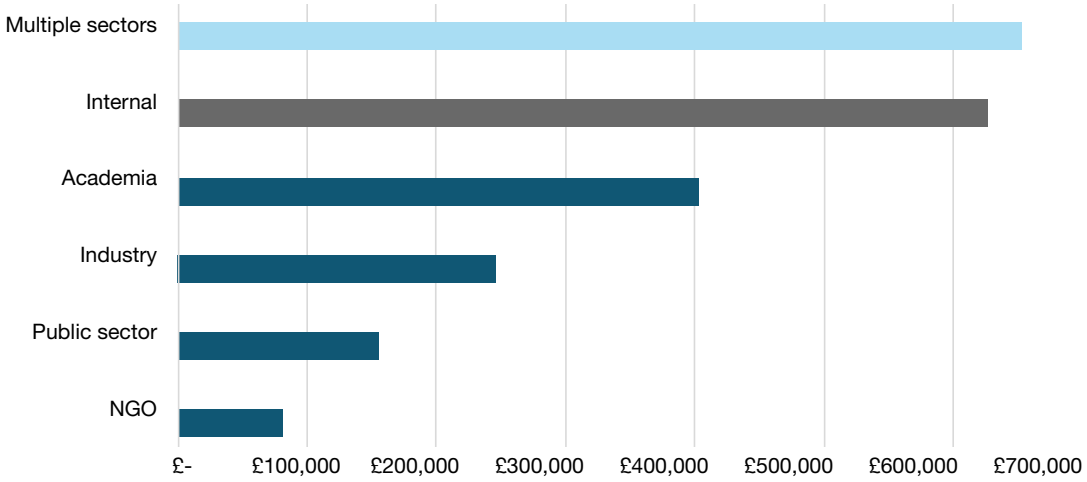


Figure 4: Allocation of Water research funding: type of external collaboration (2016–2018)



Collaborations

To accelerate innovation

Venturi: creating a global water technology community

Venturi is a partnership between Arup and WRc — two firms renowned for innovation. Together, we want to speed up innovation adoption in the water sector with a focus on creating a sustainable future and tackling real-world challenges. Our aim is to make innovation easier, faster, and increase its impact. Venturi helps innovative products and services — those with the potential to tackle the water sector's major challenges — get to market quickly.

To put resilience into practice

The Resilience Shift: Water Governance Global Toolkit

The Resilience Shift is a Lloyd's Register Foundation initiative delivered by Arup. It aims to shift the global approach to designing, delivering and operating critical infrastructure to make it, and the places that it serves, more resilient. Arup are working with SIWI's Water Governance Facility and We are Telescopic, a software developer, to spearhead the development of a global toolkit to help cities better govern their water to ensure their critical infrastructure is more resilient.

To tackle global challenges

Arup Global Challenge: WASH Basins, India

Through the Community Engagement Global Challenge Fund, Arup has committed £5 million over five years to projects which contribute towards achievement of the UN Sustainable Development Goals. As part of the WASH Basins project, Arup are working with FRANK Water and their local partners in India to develop an integrated water resource management (IWRM) toolkit for use by communities and district-level governments, to secure the provision of safe and clean drinking water and sanitation.

Collaborations

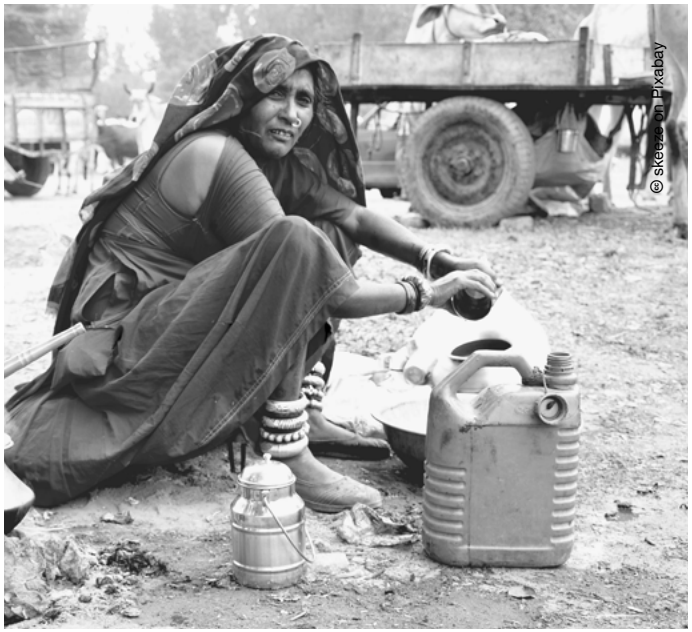
To tackle global challenges

Vulnerability of Pacific Island Nations to sea level rise

The world's climate is changing. Sea level rise in some areas of the Pacific Ocean is currently four times the global average. Many atolls in the Pacific are less than 5m above sea level and are home to thousands who feel connected with both their land and ocean. A changing climate will affect their physical environment, customs and culture. Arup has developed a vulnerability index to focus action and support to improve resilience of low lying Pacific Island Nations to sea level rise.

To tackle global challenges

FRANK Water Environmental Assessment Project



Since 2005, FRANK Water has been working with partners in India to improve the health and wellbeing of marginalised communities through improved access to safe drinking water, sanitation and hygiene education. Arup supported them in capturing the impact of the delivered projects by developing an environmental assessment framework. The framework enables NGOs in India to understand how their activities influence the environment and how to improve environmental sustainability where possible.

To tackle global challenges

A new hand-washing unit for communal latrines in emergency response

Diarrhoeal diseases and respiratory infections are a leading cause of preventable illness and death in humanitarian crises. Health threaths to people who are already exposed to stress conditions must be mitigated. Arup, together with British Red Cross, London School of Hygiene and Tropical Medicine (LSHTM) and Butyl Products are working on the design of a globally deployable hand washing unit, which will promote hand washing after the use of communal latrines. This intervention can potentially reduce the risk of diarrhoeal diseases by 50%.

Now, New, Next

Our portfolio of research must be well balanced to address the challenges presented by business as usual, whilst also exploring opportunities to push boundaries and develop new capabilities. To capture the scope, remit and potential impact of our applied water research, the classification of Now, New, Next has been applied to our portfolio of projects:

- Now — addresses business as usual to confirm often predictable outcomes and generate outputs that can be utilised immediately
- New — pushes disciplinary boundaries and explores transferable methodologies, often with predictable outcomes and outputs that can be applied in the near future
- Next — supports the development of new capabilities, often with unknown outcomes but generating outputs for medium to long-term application and benefit to the business.

In the last three years, Arup invested more than 60% of research funds into outward looking projects in the water sector. Our investment in projects with a medium to long-term application has been steadily increasing. This ensures our research explores emerging technologies and their long-term application, as well supporting our future ambitions to continue providing the highest quality, innovative solutions to our clients.

Figure 5: Short- and long-term investment: total for 2016–2018

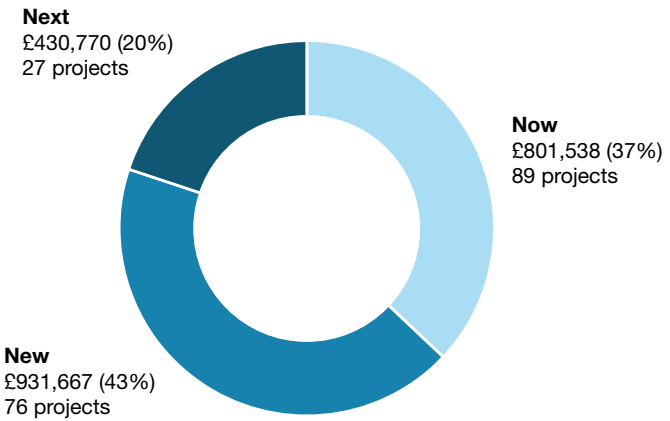
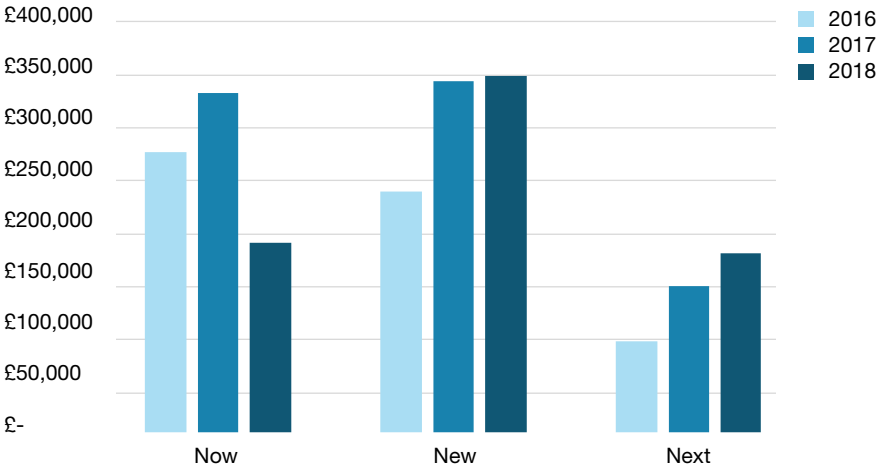


Figure 6: Short- and long-term investment: historical trends for 2016–2018



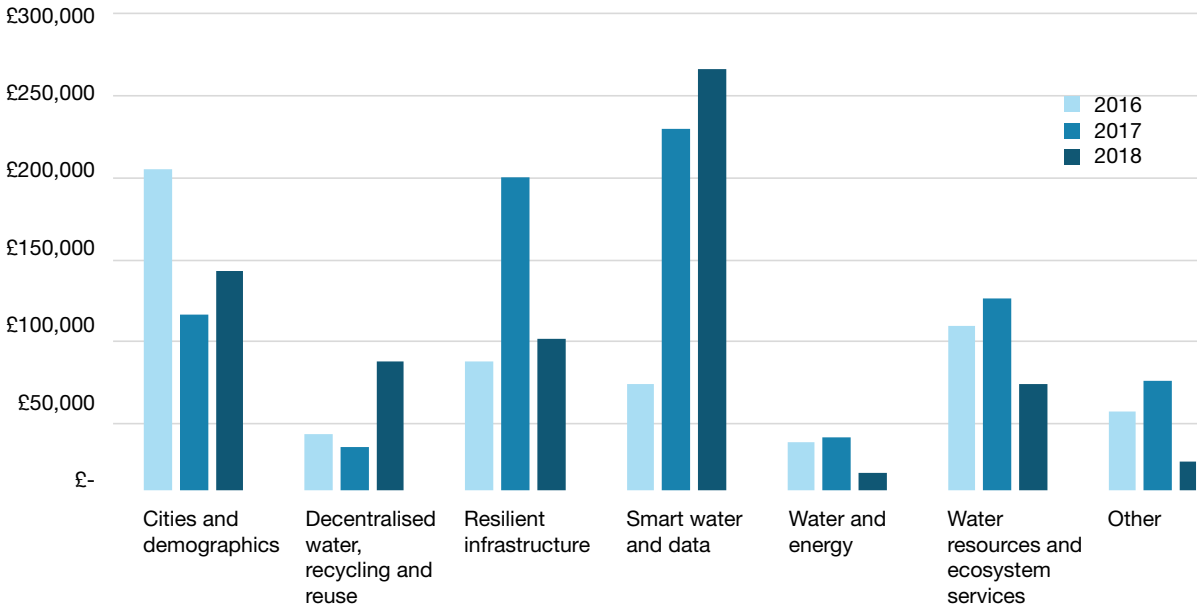
Themes

Applied research investments support our business strategy to further our commercial offering across resilient infrastructure, water resources and ecosystem services, water recycling and reuse. A significant part of our investment was directed towards addressing challenges related to cities and a growing population, especially relating to the impact of climate change and rising extreme weather events, such as floods.

The increasing focus on the realisation of the United Nation Sustainable Development Goals, especially Goal 6: Clean water and sanitation, is likely to increase our future research investment into emerging territories, such as novel water resources or strategies for increasing water efficiency and implementing Circular Economy principles. We will continue to explore how we can best harness the outputs of the digital revolution. Our research projects are already exploring how digital technology could transform the water sector, ranging from machine learning for flood protection to digital monitoring of water quality fluctuations.

Arup's applied research in the water sector will continue to explore new markets and opportunities to shape a better world. Research collaborations across our programme play an important role in maintaining a forward-looking perspective to direct our investments and prepare for the future.

Figure 7: Allocation of Water research funding against priority research themes 2016–2018



Research projects

Cities and demographics

Cities and sea level rise: flood hazard assessment and adaptation toolkits

Predicted sea level rise is a major factor in current and future planning for a city's resilience and prosperity. A comprehensive, delivery-focused methodology to assess coastal flood risks and potential damage was developed. The guide utilises global data sources to estimate sea level rise and uncertainty. It outlines the costs and benefits of a variety of approaches, ranging from protection to adaptation and retreat, and is able to identify best practice and key issues.

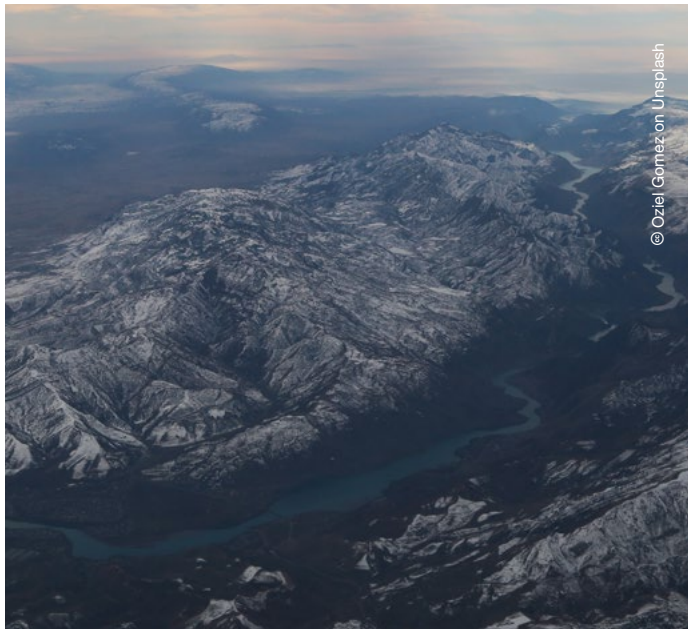
Cities and demographics

Re-thinking our coastal communities

Coastal communities are becoming home to more and more people. At the same time, threats to these locations from climate change induced sea level rise, erosion or coastal flooding are increasing. We researched best practices and identified strategic partners to team up with to create scenarios that will help us develop a range of prevention measures and interventions tailored to the needs and characteristics of specific communities.

Cities and demographics

Contribution of glaciers to flood hazard in mountainous regions in a warming world



The runoff from snowmelt and glacier melt to river flows creates potential flood hazards in mountainous areas. By evaluating the potential consequences of different climate change scenarios on the frequency and severity of flood hazards in mountainous regions, resilience strategies for vulnerable mountainous regions can be developed.

Research projects

Cities and demographics

Exploring a health-led approach to infrastructure

The availability and uninterrupted functioning of infrastructure, especially at times of extreme weather events, can have a major impact on the health and well-being of those affected. Current cost-benefit analyses of investment projects to improve the resilience of critical infrastructure do not include costs related to health services. Our research team worked alongside Public Health England and the Environment Agency to strengthen the economic approach in valuing health and well-being benefits.

Decentralised water, recycling and reuse

Biological systems for black wastewater purification into urban areas

There is a growing interest in the real estate market to integrate natural black waste water purification in building plans. We designed a controlled environment to test reed bed systems in practice, in cooperation with local administrative institutions and the supply industries in the Netherlands and Belgium. In all cases, rainwater harvesting formed part of the suggested alternative water scheme. Individual reed beds are more energy efficient and are able to remove and recycle micro pollutants and nutrients.

Decentralised water, recycling and reuse

Viability of ferric phosphate recovery

Regulations in the EU and UK regarding the purity of drinking water require removal of metaldehyde — a common component of traditional pesticides. This process is extrememly costly, complex and energy intensive. Our research team explored options to replace metaldehyde-based pesticides with ferric phosphate equivalents. We have also investigated options for ferric phosphate recovery from the sludge, with a view to developing a closed-loop process.

Research projects

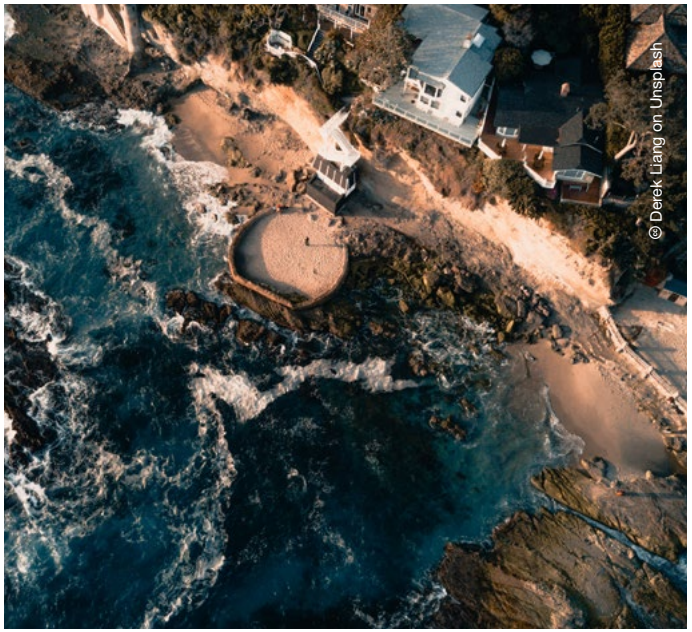
Resilient infrastructure

Resilient Engineering Design Initiative (REDi™) for floods

Flood risk reduction approaches are hindered by a lack of knowledge of the consequences of a code-based approach to flood design. By developing a framework for a resilience-based flood design, we were able to promote and incentivise flood resilience goals beyond code. REDi™ for flooding forms an additional assessment module that complements the established REDi™ seismic rating system, adding further rigour to the resilience-based design approach.

Resilient infrastructure

Improving the design of buildings and structures near the sea



Existing formulations for quantifying wave loads typically lead to over-conservative designs. Other than physical modelling, there is currently no recognised method to accurately determine the extent and forces of overtopping a breakwater. We developed a more accurate quantification method to measure the magnitude of wave overtopping forces acting on coastal structures. As a result, more efficient and cost-effective structure designs could be considered.

Resilient infrastructure

Individual property protection measures

Individual Property Protection (IPP) measures play a major role in the protection of residential and commercial properties from the ingress of flood water. In Ireland, IPP measures are currently the responsibility of the property owner. We investigated the feasibility and impact of introducing IPPs as part of a city-wide flood protection scheme. An outline design of IPP requirements for an urban area in Ireland was developed and a cost-benefit analysis of IPP introduction carried out.

Research projects

Resilient infrastructure

Visualising low probability high impact failures for resilience planning

Risk Assessment for Reservoirs (RARs) are used to inform key decision-making regarding dam improvements and risk management. However, since the available investment is usually limited, and engineering cannot entirely eliminate risk, the management strategy of so-called residual risk is required. Therefore, our dam engineering experts worked with the Resilience, Security and Risk team to examine how Arup's Holistic Integrity Test could be applied by dam operators.

Resilient infrastructure

Combined fluvial and groundwater flood risk management

Even though it is well known that ground water contributes to flooding events, there is not yet a method to account for this risk in flood modelling software. Arup attempted to address this gap by developing a model which incorporates ground water. Other factors beyond ground water have also been considered to improve the accuracy of flood modelling.

Smart water and data

Topup 2.0: rainwater harvesting analytics with GIS

The harvesting of rainwater is key to regional water supply and improves water resilience whilst reducing costs.
The largest cost item in medium to large-scale rainwater harvesting systems is the cistern or storage tank. Topup is a pioneering tool used for cistern sizing, which utilises GIS (Geographic Information System) to process large data sets in combination with a pragmatic approach to efficient cistern design.

Research projects

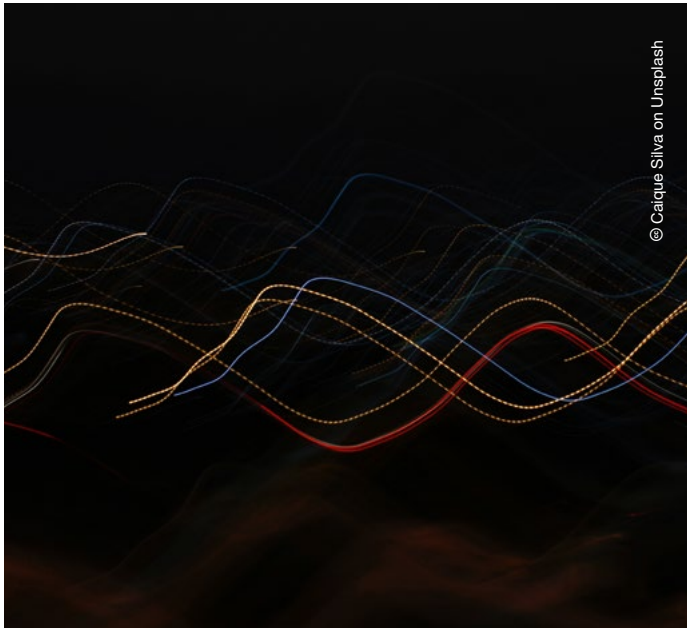
Smart water and data

Modelling water quality in disease prone areas

Poor water quality and the potential for spread of waterborne disease present significant risks to human health. The ability to model the conditions that support the development of waterborne diseases and to predict the spread of outbreaks can help mitigate these risks. We used a new generation of water modelling capabilities to develop a detailed water quality model that incorporates a range of key water quality parameters. The model was successfully validated using a South American city as a case study.

Smart water and data

Digital Tide: a 2050 vision of the water industry



Working with industry, academia and customers, we explored how digital technology can be applied to address current and future challenges in the water industry. Together, we gathered insights on the challenges of resilience, water supply, water quality and access to water supplies up to 2050. With this knowledge, industry leaders and practitioners are enabled to create strategies that harness digital opportunities to provide water supplies, essential to healthy, equitable, and sustainable economies.

Smart water and data

Machine Learning for river water level prediction and flood protection

The effective city-wide drainage strategy depends, among others, on the efficient management of urban rivers. It is therefore important that the river levels can be correctly predicted. Machine Learning could potentially facilitate this task. We explored the application of a neural network and big data analysis method for this purpose. Data from four monitoring stations and historical recordings of rainfall were used to train the developed software model.

Research projects

Smart water and data

Digital water master planning

The Digital Water Master Planning Tool (DWMPT) is intended to automate water supply and demand calculations for planned urban developments. The tool should significantly improve the efficiency of calculations and create an interactive platform for clients to explore the results. It will enable the rapid testing of different design ideas collaboratively, and enhance the decision making process.

Water and energy

Hydropower rapid assessment tool

Being able to predict expected energy yields is a key step during the investment analysis for a potential hydropower project. The efficiency of a hydropower plant depends on several factors, including available flow, presence and characteristics of a reservoir, capacity, and loss of a turbine. The modelling tool developed by Arup includes these and other criteria, allowing rapid assessment of the hydropower potential of a proposed scheme in a systematic and replicable way.

Water and energy

Fish stocking as mitigation for hydropower projects

Hydropower schemes provide numerous advantages, but can also have a significant impact on a river ecosystem. However, the traditional approach of mitigating it through fish stocking can contribute to biodiversity loss. Our team reviewed available research outputs and analysed their implications to inform Arup's position on this issue. We can provide advice to public bodies and potential investors, and suggest solutions that will satisfy the requirements of both parties.

Research projects

Water and energy

Determining the regional water-waste-energy balance

Addressing the waste-water-energy nexus is crucial to progressing the sustainable cities agenda. Combining wastewater treatment with energy generation can be achieved through anaerobic digestion (AD), but attention needs to be paid to the cost-benefit ratio. We investigated the factors impacting the economic feasibility of AD and developed a tool to assess economic benefits and costs over time, including the breakdown of energy, waste and other charges.

Water resouces and ecosystem services

Precision agriculture as a component of catchment management

Farming imposes significant stress on natural systems, and the aquatic environment in particular. The agricultural sector is currently undergoing a major transformation by applying digital technologies to improve the precision and control of farming activities. We investigated how technical solutions that are being adopted in farming are likely to influence the management of water resources, especially aspects related to water demand, water treatment and flood management.

Water resouces and ecosystem services

Working with nature to mitigate extreme hydrological events

Natural Flood Management (NFM) techniques complement a traditional approach to flood risk management and can play a big role as the policymakers are readily adopting and mandating catchment-based approaches. We investigated the case of Risca catchment to evaluate the potential of altering, restoring or using landscape features to reduce flood risk. The obtained results support the case for including NFM as part of a holistic approach to flood risk management.

Research projects

Water resouces and ecosystem services

Biological mechanisms of green infrastructure

The use of green infrastructure (GI) is a relatively new way to manage storm-water using soil, sand, mulch, stones and plants to infiltrate clean water while simultaneously capturing pollutants and solids. Best management practices must be supported with the knowledge of the performance of plant and soil types. Arup developed a guide to improve solution selection based on the specific nature of the project, and incorporating a number of parameters, such as climate, tributary area, native plant types or landscape design.

Water resouces and ecosystem services

Sustainable drainage systems in different climates

There are various Sustainable Drainage Systems (SuDS) currently proposed by experts. Yet there is a lack of criteria for matching the most suitable SuDS to different climate zones and landscape design. We categorised climate areas globally and examined the urban landscape constraints influencing the choice of the most appropriate solutions. A guide was produced that allows for the selection of adequate solutions at early stages of a project, and increases the efficiency of the design process.

Water resouces and ecosystem services

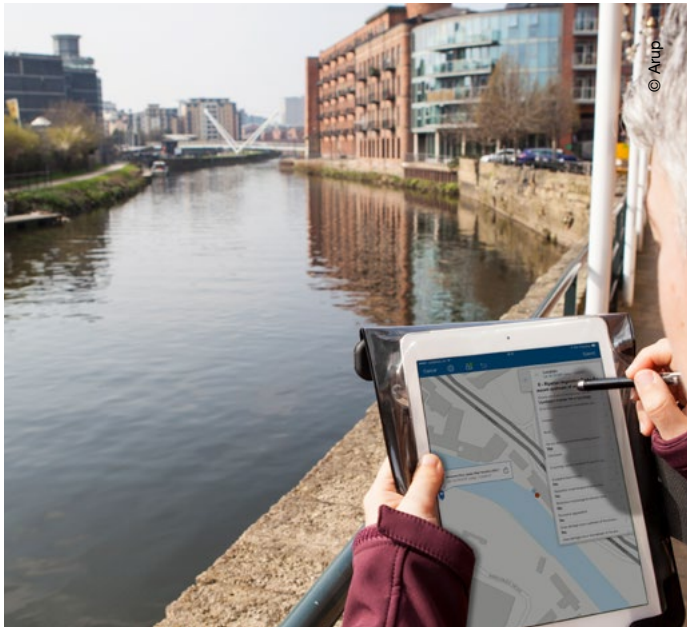
New approaches to financing city infrastructure

Traditional models for delivering green infrastructure (GI) are challenged by complexities around the questions of ‘who pays?’ versus ‘who benefits?’; understanding and quantifying the value of the wider long-term impacts of GI; incentives and enforcement; delivery within existing assets; and maintenance of GI. This project addressed these issues by identifying and piloting tangible design, funding, implementation and operating models that can be replicated, adapted and scaled internationally.

Research projects

Water resouces and ecosystem services

Bespoke river survey apps



The Arup team developed a GIS-based tool to record information in the field. A platform to digitally map elements and input relevant data and images in a digital form was created. The mobile app provides an efficient and effective medium for conducting field surveys, increasing accuracy and productivity. Further, the post-processing tools present and analyse the data to meet the client's preferred reporting format.

Water resouces and ecosystem services

Advancing building information modeling (BIM) for green infrastructure

Cities that are embracing green infrastructure are looking for the most effective ways to implement and maintain green infrastructure assets. We reviewed current maintenance management systems and determined the workflow required to feed designs into this system. We also considered utilising BIM to optimise the design process for non-standard, one-off green infrastructure assignments.

Water resouces and ecosystem services

Delivering green infrastructure along linear assets

Green infrastructure (GI) along linear assets can improve biodiversity and climate adaptation, as well as mitigate the impact of the development, such as water runoff, noise and air pollution. Together with CIRIA and major infrastructure providers, we reviewed a number of case studies, collated lessons learned and identified the critical success factors for effective management of GI.

Research projects

Water resouces and ecosystem services

River catchment modelling using Visual Basics for Applications (VBA)

Shifting the focus from areas at risk of flooding to the potential sources of flood risk upstream challenges traditional flood risk assessment methods, such as hydrological and hydraulic. Our research team worked on the development of a user-friendly tool to demonstrate impacts from catchment management interventions and their inclusion in the flood risk assessment.

Water resouces and ecosystem services

Emerging pollutants — keeping our water clean

New detection technologies facilitate the identification of contaminants in our water systems, including relatively new chemicals such as pharmaceuticals. A cross-disciplinary team of engineers from Australia and the UK singled out ten of the most pressing of these emerging pollutants and drew up a list of existing technologies to treat them. We grouped contaminants by category in order to highlight technologies that are able to treat more than one simultaneously.

Water resouces and ecosystem services

Suitability of sustainable drainage ponds as smooth newt habitat

Sustainable drainage systems support water management and can enhance biodiversity. We investigated the suitability of ponds that are created along linear infrastructure in Northern Ireland as a potential habitat for a smooth newt. Using the criteria defined by the National Amphibian and Reptile Recording Scheme (NARRS), our research team evaluated a number of locations, and produced guidelines on how to create more newt friendly environments.

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