WHITEPAPER

Creating Sponge Cities to Tackle Surface Water Flooding

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FORWARD

Pluvial flooding, also known as urban flooding, is a rapidly escalating concern in cities and urbanised areas worldwide. Unlike fluvial flooding, which arises from overflowing rivers, pluvial floods result from intense rainfall overwhelming drainage systems. This white paper dives into the complexities of pluvial flooding, exploring its causes, its impacts, and potential mitigation strategies.

The widespread impact of pluvial flooding on communities and infrastructure can be devastating and highly disruptive—from damage to road, rail, and air transport, to domestic and commercial property loss, disruption to business, and even fatalities—making it a critical issue for everyone.

The paper draws on international expertise to provide guidance and best practices. It explores how the increasing frequency and severity of extreme precipitation events, attributed to climate change, are overwhelming ageing drainage infrastructure designed for historical rainfall patterns. It identifies the specific mechanisms of pluvial flooding, explaining how urbanisation contributes to the problem.

This paper will also discuss the multifaceted impacts of pluvial flooding, as well as explore the economic cost and societal costs, which include the disruption to communities, displacement of residents, and potential loss of life.

Crucially, the paper explores pluvial flood mitigation strategies and outlines various approaches, such as sustainable urban drainage systems (SuDS), improved drainage infrastructure, and green space development. These areas are of high importance for British Water, as demonstrated by our highly successful Sustainable Water Management (SuWM) Focus Group—a forum to provide manufacturers and suppliers with a route to monitor and promote SuWM design application.

Jo Bradley is the chair of the SuWM Focus Group. The group brings together everyone responsible for sustainable water management, from designers and manufacturers to regulators and academics, to discuss the evolution of sustainable water management, the barriers to implementation, and the future potential of nature-based and sustainable solutions to our water problems. Bradley said, "Sustainable water management has never been more important in the bid to reduce flooding and improve water quality. Recently, a primary focus has been on Schedule 3 of the Flood and Water Management Act 2010. We would like to see the incorporation of SuDS mandatory for new developments in England and will be seeking Defra's support for this to be enacted. Looking to the future, our focus is on the mitigation of road runoff pollution and how good sustainable water management can help overcome the effects of climate change."

This white paper is a valuable resource for:

- Policymakers seeking to develop effective flood risk management strategies.
- Urban planners and engineers designing sustainable drainage systems.
- Emergency responders preparing for and responding to pluvial flood events.
- Homeowners and businesses interested in protecting themselves from pluvial flood damage.

By exploring these strategies, the paper aims to equip stakeholders with the knowledge necessary to raise awareness of pluvial flooding and promote proactive mitigation strategies, helping us to build more resilient cities and communities prepared to face the challenges of a changing climate.

Lila Thompson, CEO of British Water

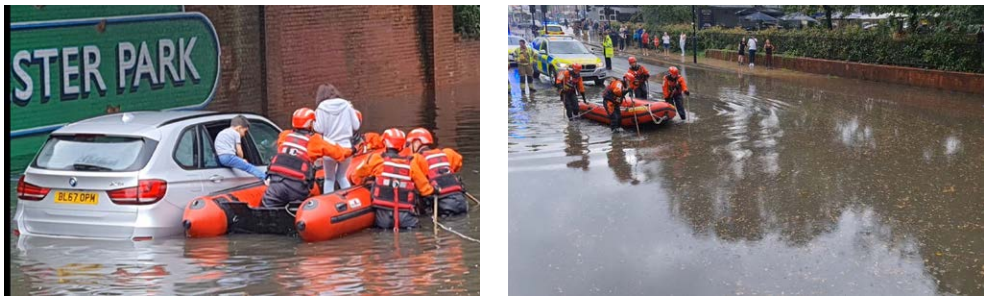
THE CHALLENGE

There is growing evidence that climate change is taking a toll on towns and cities.

In general, climate change is causing summers to be hotter and drier and winters to be wetter. However, there are very important exceptions to this rule.

It is the extremities of climate change that are inflicting the most damage on places and infrastructure. Many of the most extreme flooding events are taking place in the summer months, and there is also a trend towards the summer weather lasting longer, which increases the probability of extreme rainfall in the summer. This is because hot air can hold more moisture—for every one degree Celsius of warming, the atmosphere can hold 7% more moisture. Therefore, warmer air leads to more intense rainfall and increases the chances of flooding.

There are numerous examples of recent summer flood events that highlight how damaging intense rainfall can be. In July 2021, for example, London suffered surface water flooding from three extreme rainfall events in less than two weeks. The floods caused the closure of eight tube stations for a day and two hospitals, one of them being Whipps Cross Hospital, which had to evacuate 100 patients after a power failure. Dockland Light Rail station saw flood waters reach 40 to 50 centimetres deep. Sedgwick, one of the U.K.'s leading loss adjusters, received more than 2,000 flood claims during the two-week period. Meanwhile, the insurance data company, Perils, has estimated that insurance and reinsurance industry losses for the flooding between 12 to 14 July alone reached GBP 281 million.



Summer flooding in Worcester Park, London. Images courtesy of @mrbennbenn via X.

In August 2021, New York and eight other states in the U.S. were hit by Hurricane Ida. Its peak of 80 millimetres of precipitation per hour was almost double the 38 to 50 millimetres of rain per hour capacity that New York's sewer system can handle. CoreLogic estimated that Ida caused an estimated USD 16 billion to 24 billion in flooding damage in the northeastern United States, which includes New York, New Jersey, Pennsylvania, Maryland, and Connecticut. In New York City, the hurricane led to the deaths of 13 people, 11 of whom drowned from flooding in their basements.

One of Europe's worst surface flooding events took place in Copenhagen in 2011, where 150 millimetres of rain fell on the city in just two hours, leaving swathes of the city under up to a metre of water. The City of Copenhagen estimated that the cloudburst caused DKK 6 billion (USD 870 million or GBP 690 million) worth of damage. The incident also resulted in 90,644 insurance claims, with the value of the claims totalling DKK 4.88 billion and many smaller businesses wiped out permanently.

While floods are the world's most common natural disaster, this paper will focus exclusively on pluvial flooding rather than fluvial flooding and storm surges. Pluvial flooding is caused by heavy rainfall falling on impervious surfaces that cannot absorb or drain away the water quickly enough and/or from backflow from overloaded sewer systems.

Fluvial flooding occurs when the water level in a river, lake, or stream rises and overflows onto the neighbouring land, while storm surges are generated from high water levels along coastal areas and are often wind generated. Therefore, this paper does not cover major flood events, such as Hurricane Katrina and the impact on New Orleans.

This paper focuses on the ways to solve the growing damage being caused by surface water flooding as intense rainfall creates more flooding in urban city centres. To tackle this monumental task, we need to create sponge cities, which are cities capable of absorbing intense rainfall events. To understand the full picture, we interviewed global leaders at Ramboll, one the world's top ten environmental and sustainability consultancies, for this paper. The leaders at Ramboll have highlighted that surface water flooding currently accounts for most of their work on flood risk management.

This paper seeks to highlight some of the world-leading challenges and solutions for tackling surface water flooding.

HOW CAN WE SOLVE THIS?

In October 2018, the then-Chief Executive of the Environment Agency Sir James Bevan gave a speech at the Surface Water Management Conference, saying, "The 2007 summer floods were a wake-up call for all of us. They left 13 people dead, 44,600 homes flooded, and GBP 3 billion damage. The rescue effort was the biggest in peacetime Britain. That event led to the 2008 Pitt Review, which concluded that much of the flooding had arisen not from rivers over-topping, but from surface water pouring off the land."

Bevan continued: "Surface water flooding is a risk because of its reach. Of all the flood risks to which our rainy island is subject [to]—from coasts, rivers, groundwater, sewers, and surface water—it is surface water flooding which threatens more people and properties than any other form of flood risk. Over three million properties in England are at risk of surface water flooding, even more than those at risk from rivers and the sea (2.7 million)."

In June 2022, Steve Wilson, DwrCymru/Welsh Water's managing director of wastewater services, told a meeting of Swansea councillors and other public sector representatives that tackling surface water flooding was its biggest challenge in the coming years, as climate change led to periods of more intense rainfall that causes surface water flooding.

According to the National Infrastructure Commission's interpretation of Environment Agency flood risk maps for surface water flooding, around 325,000 properties in England are in areas that currently have a more than 60% chance of being affected by surface water flooding in the next 30 years (considered "high" risk). A further 500,000 properties are in areas that have a similar chance of being affected by surface water flooding in the next 100 years.

However, according to the National Infrastructure Commission's analysis, the number of properties in areas at high risk of surface water flooding is set to increase by 2055, including:

- An increase of 20,000 to 135,000 properties in areas at high risk due to the impacts of climate change, which will increase the intensity and frequency of heavy rainfall.
- An increase of around 35,000 to 95,000 properties due to new development putting more pressure on drainage systems.
- A further 50,000 to 65,000 properties that may be put in areas at high risk due to unplanned increases in impermeable surfaces.

There are other benefits to tackling surface water flooding. For example, England has a combined sewage system made up of hundreds of thousands of kilometres of sewers, some of which were built in the Victorian era. Having a combined sewage system means that clean rainwater and wastewater from toilets, bathrooms, and kitchens use the same pipes to travel to sewage treatment works. Combined sewer overflows (CSOs), also known as storm overflows, were developed as overflow valves to reduce flooding during heavy rainfall. In 2022, sewer overflows discharged a mix of raw sewage and rainwater into rivers and seas 301,091 times—or 825 times a day on average.

The U.K. government published its storm overflows discharge reduction plan in August 2022. Responding to this reduction plan would require water companies to spend GBP 56 billion between 2025 and 2050 to cut spills from CSOs that discharge into inland waterways and designated bathing waters. Attenuating surface water has the potential to significantly reduce combined sewer overflow (CSO) discharges.

WHY DO WE NEED TO CREATE SPONGE CITIES?

Copenhagen and New York City are at the forefront of the movement to absorb more water by becoming sponge cities, establishing cost-integrated systems solutions to solve surface water flooding.

Copenhagen began working on a plan to tackle surface water flooding in 2010 after successfully completing a project to improve the water quality in the city's harbour, which made the area safe for swimming again. The harbour's swimming pools are now used by more than 500,000 swimmers a year. However, the following year, they endured one of Europe's worst flooding events that caused the significant damage mentioned earlier in this paper.

For this British Water research paper, we spoke to Jan Rasmussen, Copenhagen's project director of the center for climate adaptation. Rasmussen was one of the authors of Copenhagen's Cloudburst Management Plan, and he has been working for Copenhagen Council on to engineer the city's flood defences for almost 35 years. The experienced engineer told us that Copenhagen's Cloudburst Management Plan includes more than 250 surface water flooding projects carried out across the city, more than 125 new pipes, and six new tunnels to handle stormwater.

The tunnel solutions were designed to be used in parts of the city with no opportunities for purely ground-level drainage solutions. The tunnels will function as basins for sewer overflow during "everyday" rain events. During larger cloudburst events, the new stormwater tunnels will also carry excess water out to sea.

In total, when combined, these solutions were designed to cover more than a million square metres of Copenhagen.

It had been estimated that the Cloudburst Management Plan will cost about DKK 11 billion or USD 1.6 billion and GBP 1.26 billion.

WHAT SOLUTIONS ARE COPENHAGEN PUTTING IN PLACE TO BECOME A SPONGE CITY?

Becoming a sponge city is not about solving surface water flooding in only one neighborhood or locality, but about solving it throughout the city. For Rasmussen, the most important element of the Cloudburst Management Plan is that it is a holistic, integrated citywide plan on how to better manage surface water flooding.

Rasmussen explained that it is "extremely important" to have a "detailed citywide plan because the plan requires the need for a lot of interconnected hydraulic calculations to better retain surface water flooding. Having a comprehensive view of the entire city means that making hydraulic changes to one area means we avoid accidentally flooding another area of Copenhagen, as we have calculated the impact stopping flooding in one area will have on other areas."

This practice will enable Copenhagen to become a true sponge city.

To tackle surface water flooding in Copenhagen, Rasmussen told us the engineers had to create new sustainable drainage (SuDs) "products," such as swales, rain gardens, and balancing ponds, which allow the city to cope with more stormwater and allow the water to be absorbed into the ground or drained away to the sea.

Rasmussen explained that many of the products serve multiple purposes and enable the city to tackle surface water flooding, while also creating new green spaces for residents to sit in and enjoy or use for exercise. These SuDs products improve the physical and mental health of Copenhagen residents, increase the public's use of spaces, and boost the value of surrounding properties.

Becoming a sponge city also creates more livable places by improving towns and cities with sustainable drainage solutions, as is being done in Mansfield, Copenhagen, and New York. One of the ways that designers and planners are creating more livable spaces that improve physical and mental health is through the creation of blue-green infrastructure.

According to the global engineering consultancy Ramboll, blue-green infrastructure refers to integrated engineering, architecture, and landscape designs that make use of green spaces—such as parks and recreational areas—to solve challenges related to water. Examples include a basketball court or skate park that can contain water during intense rainfall and protect drainage systems from being overloaded.

Engineers do not just have to use existing green spaces or sporting and community facilities to achieve this type of infrastructure. New facilities to help residents improve physical and mental health can be created from scratch.

To date, 19 SuDs products have been completed in Copenhagen, while three large tunnels have been laid. A further 63 SuDs projects have been started, as well as three tunnels and 17 pipes.

Rasmussen provided an overview of some of the SuDs products installed so far:

TAASINGE PLADS

Taasinge Plads was the first SuDs project undertaken as part of the Cloudburst Management Plan and saw a former car park transformed into a 1,000-square-metre urban park with a rain garden able to handle 500 cubic metres of stormwater. The project provides drainage for rainwater from local roofs and squares, diverting it from sewer systems and increasing Copenhagen's ability to withstand torrential rains of the future. Tasinge Plads, which was installed in 2014, also serves as a new meeting place for the neighbourhood's residents.

SANKT KJELDS PLADS

Just 100 metres away from Taasinge Plads, Sankt Kjelds Plads includes a large roundabout that has been transformed into a green oasis, creating a new public amenity that has made more people want to move to the area and dramatically increased rental values.

In total, seven roads converge at the roundabout. Areas of pavement in front of the buildings have been pulled forward and traffic has been discouraged. Additionally, the roundabout has been significantly reduced in size. The new areas are densely planted and have pathways curving through them with seating. Sunken areas were designed to be flooded when there are storms, acting as holding tanks, and the planting will cope with short periods of partial submersion.

In total, two-thirds of the asphalt have been ripped up and more than 600 trees of 100 different species have been planted.

The project has already received touring delegations from China, Brazil, Australia, and the New York City Council.

ENGHAVEPARKEN

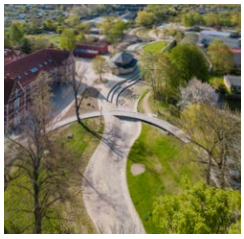
The historical Enghaveparken is currently the biggest surface climate project in Copenhagen and one of the city's best examples of blue-green infrastructure. Underneath the park, massive water reservoirs can retain 22,600 cubic metres of stormwater runoff. When there are normal volumes of rainfall, rainwater from nearby roofs is steered into park and into a new 2,000 cubic metre retention basin. Here, rainwater is stored so that it be used for watering a diverse range of plants and trees during dry spells. The water can even be transferred to municipal maintenance cars for cleaning city streets.

The neoclassicist structure of the park has been excavated to make room for 9,000 cubic metres of rainwater, with a low wall built around the perimeter of the park to hold a further 14,000 cubic meters of water.

The park features a multi-use sports pitch for a variety of urban sports, including skater hockey, basketball, and football. The pitch is up to 3.5 metres deep to retain stormwater runoff.

A mechanism that automatically pushes up the gates of the perimeter wall ensures that the climate-adaptive elements of the park function—even without electricity. In case of extreme rain, the automated gates will shut down the park to the public. Across the park, 220,000 bulbs have been planted, as well as 11,000 perennial plants, 950 roses, and 83 new trees.

KARENS MINDE



Once a swampy and neglected park, Karens Minde is now a modern green and blue space that features a stylish new playground for children, groundwater ponds, and raised paving for crossing the ponds. The park, which was transformed by the City of Copenhagen and the HOFOR water company, will provide storage for 15,000 cubic metres of rain in the event of a major storm. During intense rainfall, the new riverbed slows down the water and directs it to a small lake at the end of the park.

A rice field has also been created before the inlet to the permanent stormwater basin to handle excess rain. If the water gets too high, a large rain pipe drains the excess water into the sea.

Rasmussen told us that while 254 SuDs products are currently planned, this number could be reduced when they get into the detailed planning phase of each area.

The detailed planning phase might enable city engineers to deal with surface water in different ways and reduce the size of SuDs products or merge some SuDs products into one larger project.

Rasmussen said the long-term maintenance costs of the SuDs will be shared between the city council and the utility company. The utility company pays for water management while the city pays for greening of the urban space. However, the city council will look after most of the green interventions as part of their regular maintenance programme.

To add to the equation, Denmark's national government has issued new rules for how climate adaptation should be calculated. These calculations are based on an assessment of whether it is cheapest to prevent or restore flood damage. According to these new calculations, it is only worthwhile to protect the city against a 10-to-30-year flood rather than the one-in-100-year flood level that has been used to plan Copenhagen's Cloudburst management plan so far.

The new national rules mean that Copenhagen can continue to build its climate adaptation projects to a 100-year service level until 2027. However, after that, the projects must be adapted to the new, lower service level.

This situation is likely to inhibit Copenhagen's plan to become a sponge city, opening a new discussion of what it means for Copenhagen and Denmark to be climate-adapted. It will be a cause for debate in Copenhagen City Councils in the coming weeks and months.

How common is it for towns and cities across the world to be faced with these challenges on surface water flooding?

Christian Nyerup Nielsen, Ramboll's global division director for water infrastructure and climate adaptation, said, "Clearly, our main business is now on surface water flooding rather than the river flooding by far. Our business has probably shifted from 80/20 of our work being on river flooding to 80/20 on surface water flooding from rainfall.

"Globally it's on the surface water flooding side where all the interest is now, and many more of the major investments are going into that.

"This was what Copenhagen was able to show—that their biggest risk was from surface water flooding. Looking at the climate projections from 2030 to 2040, surface water flooding is expected to be overtaken by sea level rise and storm surges.

"But for now, their conclusion was that investments should go into surface water flooding from extreme rainfall, and we've seen the same also in other cities. This doesn't mean that we don't do rivers anymore—we are working on big river projects in Malaysia and other places—but much more of our work now is in surface water flooding."

WHAT IS HAPPENING IN THE U.K.?

Water supply company Severn Trent is investing GBP 76 million in a pioneering scheme to install hundreds of blue-green infrastructure interventions for a complete catchment approach to make Mansfield a sponge city by tackling surface water flooding, although Mansfield is officially designated as a town.

Mansfield Rain Garden

The two-and-a-half-year project is expected to reduce surface water flood risk for 90,000 people. It will see Severn Trent plant detention basins and bioswales, permeable paving, street planters, bioretention tree pits, verge rain gardens, and rainwater downpipe planters, covering 6.5 hectares of the catchment.

The Mansfield scheme will be capable of storing 30 million litres of rainwater during storms (30,000 cubic metres).

Severn Trent's plan was created as part of its post-pandemic green recovery bid. They observe over 200 locations in Mansfield, which they recorded on its hydraulic flooding risk register. About 160 of those locations are in residential areas, and an additional 60 locations would help to prevent highway flooding. When Severn Trent analysed its catchments to work out where they could have the most impact, the organisation learned that Mansfield was one of the most vulnerable catchments to surface water flooding in terms of the number of people affected.

We spoke to Adam Boucher, Severn Trent's programme lead for Mansfield, about the project. He told us the Mansfield scheme is the first time that a water company has effectively been allowed to build nature-based solutions of this type at this scale. Severn Trent has four main green blue interventions that will be installed in Mansfield: detention basins, bioswales, and two types of rain garden—one for the verge and one for the street.

"SUD's" installation Mansfield

Boucher told us that the long-term maintenance of the interventions takes a different approach to Copenhagen, as OFWAT allows Severn Trent to operate and maintain most of the interventions they have installed. A fifth intervention, permeable paving, is being operated and managed by the highways authority.

Boucher said, "We've developed proper SUDs standards, I think, for the first time in the U.K. We now have template designs for five interventions. When you look at each of those, they've all got different elements to them. But what we are doing is feeding surface water for the first time through an intervention so we're capturing water on the surface and feeding it through different layers of mulch, a grey medium filter layer, and then presenting clean water to the storage layer for the first time.

"We are always trying to find ways for water to infiltrate the ground rather than the sewer. Because we do proper SUDs, by the time the storage layer receives the water, it's clean water and you've got no blockage risk on the outlet. We'd normally put a 75-millimetre to 150-millimetre to 175-millimetre orifice in, but the fact that we've got surface water percolating through layers and presenting only clean water means that it has allowed us to develop a new control chamber with a 10-millimetre orifice in it."

In Mansfield, Severn Trent has been using Arup's digital software solution Terrain to help evaluate solutions for areas affected by flooding. Terrain creates a valuation volume calculation LiDAR topography data to determine how much water it could naturally hold.

Boucher said, "LiDAR also helps us estimate what intervention could be put into that area. Severn Trent then goes out into each area and does a ground truthing to make sure that it is the right intervention for that area. So, it helps to speed up selection of sites that are applicable for SUDs development and to calculate the amount of space available and the amount of water that it could hold.

"It helps to model interventions and the impact they have on each other, so we know whether we need to hold more water back to stop another street from getting flooded."

Severn Trent has also been working with the University of Sheffield to evaluate the porosity, conductivity, and hydraulic elements of Severn Trent's nature-based solution to calculate how water runs through it and determine the best mix of materials.

Nigel Dunnett, professor of planting design and urban horticulture in the Department of Landscape Architecture at the University of Sheffield and a collaborator on the project, developed the Grey to Green scheme in Sheffield. When it was constructed in 2014, it was the U.K.'s largest retrofit SuDS project, as well as the U.K.'s largest inner city green street.

Boucher said, "We're taking some of the learning of the Sheffield Grey to Green project and advancing that with the Mansfield project, trying to help the industry move forwards by making sure we're sharing the results with the University of Sheffield and helping with monitoring and testing."

Severn Trent will pay GBP 76 million to deliver the works in Mansfield, which accounts for 89% of the cost.

The water company has determined that it will cost them 11% more to deliver pioneering new sustainable drainage solutions in Mansfield, compared to just delivering more sewer capacity.

However, aboveground sustainable drainage solutions have other advantages as they prevent stormwater from reaching the sewers and mixing with sewage water. These solutions prevent dirty water from reaching rivers and other natural water courses while also reducing the amount of dirty water sent to Severn Trent's water treatment plants, saving energy and chemical use.

Delivering nature-based sustainable drainage solutions also helps to create more attractive towns and cities, making them more appealing for people to live, work, and visit. This view is shared by Andy Abrahams, the executive mayor of Mansfield, who said, "Severn Trent's rain gardens will help to alleviate the growing risk of flooding, as well as make Mansfield cleaner, greener, and, therefore, healthier.

The Court House Rain Garden, Mansfield

"The innovative Green Recovery programme fits perfectly with our own ambitious plans to make Mansfield more vibrant. Work will soon be starting on our own urban greening project to create attractive, environmentally friendly green spaces in the town centre.

"All these improvements will help make Mansfield more attractive and encourage people to spend more time and, therefore, money in the town centre for the benefit of the local economy, our residents, and visitors."

In October 2023, Ramboll and Rebuild by Design published a report that shows that New York City can expect a high return for investing in sustainable drainage solutions—up to USD 2.09 in socio-economic benefits for every dollar spent.

Ramboll Water's Nielsen said, "Our socio-economic analysis underscores that multifunctional blue-green infrastructure solutions can help big cities like New York manage water-related challenges in a cost-effective way. And these solutions also increase the quality of life for city residents, as places of leisure and community—an added value that we have now put into economic terms."

Amy Chester, managing director at Rebuild by Design, said, "Investing in Mother Nature is a win-win against climate change. The more that the city transforms from a concrete jungle to a sponge, the more that New Yorkers can use and enjoy their city and be sure to stay dry and safe during increased heavy rainfall."

Nielsen added, "When it comes to tackling surface water flooding, we always look for the green solutions first, and it's very, very often possible that these solutions can entirely fix the problem.

"When we started looking at preventing surface water flooding in Copenhagen in 2010, there was not so much focus on the climate footprint of the solutions being put forward. However, now there is. And if you look at it from that perspective, then it's even more obvious that this should be the way you would go.

"You will find examples of where the green solution is about 10% or 20% more expensive than the grey, and you would find the opposite as well, where it is 10% or 20% cheaper, and this varies from place to place and intervention to intervention. However, we expect to become much, much better at planning, designing, and implementing green solutions.

"Planners and engineers have had about 100 years of trying to be more efficient when installing grey infrastructure. We can still expect to see huge improvements and reductions in the cost of green solutions, so I would say to utility companies and water companies that they should be there to make these investments, knowing full well that in the beginning, they might be a little bit more expensive than the traditional ones. They should make those investments to be able to gain these efficiencies going forward."

Trine Stausgaard Munk, head of sustainability at Ramboll Water, said, "Too often, decisions come down to who's going to pay for it, who's going to maintain it. Now, we can put a monetary value on green solutions in terms of reduced pollution, better air quality, and the improved health of local people. But even if we couldn't put money on it, it's still the sound decision to install green solutions because you are creating something more people can benefit from.

"Nature-based solutions also attract talent. Clients, partners, and people come to me because they truly believe in designing with nature. But it's not just about installing 100,000 bioswales or putting in piping, it can also be about doing something much more community inspired, which attracts people to visit a place, as well as nature benefits.

"The benefits of a sustainable intervention don't have to be limited to that specific project site. Interventions can benefit people within several miles of an installation who now come to visit this site because it's a nice place to be."

In its business plan for AMP8, Severn Trent has included plans to deliver sustainable drainage catchment solutions in four further towns and cities in its region: Nottingham, Coventry, Gloucester, and Kidderminster.

Boucher said, "This is the first time anyone's done this in Britain on this scale and at this pace.

"Water companies are in the best position to deliver these kinds of catchment changes at pace, compared with traditional partnership and joint-funded schemes, and obviously, with that commitment around, looking after the asset afterwards.

"Having a water company lead alleviates risks to the local authorities around things like maintenance of sustainable drainage solutions and the scale of construction required.

"Councils are concerned about being asked to take the assets back after work is completed because of budget pressures they are under, so knowing we will take on the management of it is a big relief to them.

"These green spaces also deliver mental and physical health benefits for people in Mansfield."

NEW YORK CITY

In New York City, Mayor Adams has committed to invest USD 3.5 billion to build green infrastructure in sewered areas across all of the five boroughs to better manage the more intense rainfall and severe weather that climate change is bringing to the region. The scheme will also improve water quality in New York Harbor.

The socio-economic benefits of greener places are as applicable in Mansfield as they are in New York City. By implementing blue-green infrastructure in New York City, The Department of Environmental Protection (DEP) will save 20% on upgrading existing sewer to future service levels. Additionally, 151,000 new trees could be planted in the city with a positive blue-green infrastructure business case.

Severn Trent believes that future schemes will likely require less additional funding than the 11% that it has sought from partners for Mansfield, as Severn Trent learns more about delivering sustainable drainage solutions.

WHAT ARE OTHER PLACES IN THE U.K. DOING?

In the North West, United Utilities, Greater Manchester Combined Authority, and the Environment Agency have combined to create the U.K.'s first integrated water management plan. The plan aims to improve flood resilience, water neutrality, and water quality, as well as build in climate adaptation. Across a combined view of water and/or non-water investment locations, the plan has identified up to 300 locations to investigate where there is a predicted one-in-30-year flood risk.

Another place that has been badly affected by flooding is Kingston-Upon-Hull in the East Riding of Yorkshire. Hull was hit by flooding in 2007 and 2013, and almost 98% of Hull is considered to be at flood risk. This means that Hull has the second-highest number of properties at risk of flooding in an urban area in the U.K., second only to London.

On 5 December 2013, the east coast experienced a serious tidal surge, causing devastating flooding in Hull and communities along the banks of the Humber. The highest ever tide (5.8 metres) was recorded at the Hull Barrier.

In 2022, the Environment Agency announced a GBP 42 million investment called the Hull frontages flood defence scheme. The scheme, which will better protect 7 kilometres of shoreline, will provide greater protection to 113,000 homes and businesses, as well as develop local infrastructure and other public amenities.

The Hull frontages flood defence scheme is just one of a series of projects completed to help reduce flood risk in and around Hull, making communities more resilient to flooding. In June 2007, very heavy rainfall caused surface water flooding in Hull that damaged approximately 8,800 residential properties, 1,300 businesses, and 91 out of 99 schools. In Hull, 84% of surface water drains into the combined sewer network.

In 2018, Hull City Council, Yorkshire Water, East Riding of Yorkshire Council, the Environment Agency, and the University of Hull began working on its Living With Water Partnership. The resulting plan proposes a catchment scale approach for surface water management in Hull and the surrounding area. The plan estimates that there will need to be significant enhancements to the capacity of belowground and aboveground drainage infrastructure to reduce the risk of surface water flooding over the next 30 years. It also estimates that there will be three stages of implementation over a 25-year period with GBP 26.25 million of investment to be spent on blue-green solutions in AMP8 through 2030.

RECOMMENDATIONS

The cost of surface water flooding incidents in the U.K., Europe, and the U.S. shows that climate change is causing greater damage to towns and cities, providing an impetus to create more sponge cities.

Many councils are struggling financially with a 40% reduction in central government grants between 2009/10 and 2019/20. As a result, many councils are now spending more than half of their budget tackling adult and child social care. When surveyed by the Local Government Association in December 2023, one in five local authorities said that they are likely to go bankrupt. A study by Grant Thornton UK LLP found that two in five local authorities in England could see their reserves drop to less than 5% of their net revenue expenditure within the next five years. As a result of these financial difficulties, water companies have an opportunity to play more of a leading role in creating sponge cities by solving surface water flooding.

1. **Pace and Scale:** With plans to tackle surface water flooding in five urban areas over the next seven years, Severn Trent are showing that there is a way to deliver catchment-based solutions for towns and cities to tackle surface water flooding and, at the same time, tackle CSO overflows if water companies take more of a lead.

   This paper recommends that the Environment Agency initiate discussions with OFWAT and the Local Government Association to investigate whether water companies can take more of a lead to help flood authorities formulate and execute catchment-based plans to alleviate surface water flooding in towns and cities more quickly.

   This plan would require multi-agency dialogue, including discussions on helping water companies access more funding to deliver solutions to tackle surface water flooding.

2. **Water Management Act:** Schedule 3 of the Flood and Water Management Act 2010 had established proposals to make sustainable drainage systems a legal requirement for most new property developments and prevent the existing right of all new developments to connect to the existing public sewers.

Water companies are having to deal with an ever-increasing amount of foul water while mitigating costs, often not meeting the funding required to build the additional capacity required. However, the government decided not to implement Schedule 3 in England in 2012. In January 2023, The Department for Environment, Food & Rural Affairs (DEFRA) agreed to implement Schedule 3 and pledged to hold a public consultation later this year.

To date, this public consultation has not happened. This paper recommends that the consultation is launched as soon as possible, with the aim of developing a framework to manage the approval and adoption of drainage systems in the coming years. With housing developers now required to implement biodiversity net gain on all new property developments in a phased approach, it would make sense for Schedule 3 to be implemented quickly so that developers can begin to create biodiversity net gain units, which deliver sustainable drainage and help to alleviate surface water flooding.

3. **SuDs Manual:** The Construction Industry Research and Information Association (CIRIA) SuDS manual (C697) was first published in 2007, later revised in 2015. Since then, Severn Trent and other water companies have submitted information on how to deliver better sustainable drainage systems and how to build them in a modular fashion to be able to deploy them at scale more quickly.

   This paper welcomes an update of the CIRIA SuDs manual in 2024 to help water companies, flood authorities, and consultants and contractors share best practice and learn how to deliver better SuDs standard more quickly and cost-effectively.

4. **Outreach:** Today, one in four U.K. front gardens are completely paved over, and nearly one in three front gardens has no plants. This number increases to half of all front gardens in London.

   This paper recommends that planning authorities and water companies engage with schools, community groups, and households by submitting planning developments that encourage households to reduce paved surfaces and increase green spaces, helping to alleviate surface water flooding in their local community.

5. **The Importance of Integration:** Climate change is a rapidly evolving threat. In addition, as cities, infrastructure and the natural environment can grow, develop, change, or shrink, so can the locations at risk of hydraulic flooding.

   It is, therefore, essential that water management plans for towns and cities are integrated and deal with the coordinated development and management of water, land, and the built environment to best alleviate flooding, as well as improve the economic and social welfare of people and places.

   Data and digitisation are key to successfully developing, delivering, and updating integrated water management.

   The ability to run and update climate change models enables planners and designers to test the impact of different severities of climate change incidents in digital models, as well as analyse how the changing intensity and frequency of rainfall changes how towns and cities are affected. These models can identify bottlenecks of water and gaps which can cause surface water drainage solutions to break and fail. To create sponge cities, it is To create sponge cities, it is essential that planners and designers test these models in a digital environment to create truly integrated solutions that will stand the test of time and be refined when and where they are needed.