wavin SPOTLIGHT

Whitepaper

The role of urban stormwater management in building a sustainable, climate-resilient city

wavin

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Executive summary

It takes a consortium of green, progressive thinkers to build a sustainable and climate-resilient city. From the municipality leaders, water authorities, and urban planners to the landscape architects, engineers, innovators and the private residents themselves – it is an immense, cooperative, and co-creative effort that requires commitment and considerable investment in time and money. A large part of such a transformative undertaking is the development of an integrated urban stormwater management infrastructure that will be resilient to the challenges of excessive and intense rainfall due to climate change. This whitepaper will examine how and why rain patterns in Europe are changing dramatically, underscoring the need for municipalities to identify the risk factors of heavy rainfall and develop best management practices (BMPs) to mitigate the risks.

Traditionally, stormwater management meant selecting an urban drainage solution, aiming simply at conveyance and discharge. It now extends far beyond that – to attenuation (below ground buffering) or infiltration, as well as retention (on surface facilities like ponds). All serve the purpose of delaying and storing stormwater runoff. This paper will demonstrate how engineering technology and innovation play a leading role in the design and development of sustainable stormwater management solutions, and why stormwater management is an integral part of urban planning.

Finally, we will come full circle – to the human-to-human connection. To develop an integrated and holistic municipal infrastructure, it takes an interactive partnership between key players: city managers, planners, developers, engineers, technology partners and thought leaders – and of course, the beneficiary communities. Essentially, it takes a movement to make a city climate-resilient. Europe is taking the lead in building resilient cities to tackle the effects of climate change. And Wavin, with its extensive knowledge and expertise in stormwater management, is a key player in this sustainable initiative. Without a doubt, the challenges are plentiful. But equally without doubt, the solutions are extremely viable, sustainable and worthy of a continent that cares about its people, its cities and the environment.

02

Introduction

Climate change is changing precipitation patterns across Europe and, indeed, throughout the globe. Each year, rainstorms and flooding events are increasing in both frequency and severity. In recent years, the end of May to early June marks the beginning of flood season. Europeans begin to brace for the inevitable: heavy rainstorms, flooding, and urban havoc (street closures, vehicle damage, power outages and more). In other words, it's the "new normal." With municipal water utilities already strained by decades of underinvestment and aging infrastructure, they now face a whole new spectrum of challenges, due to climate change, growing urban populations and legacy drainage and sewer systems which are inadequate for handling the rainfall levels we see today. Yet many communities are still failing to take these factors into account when planning for the future, and government policies aren't always being crafted with these risks in mind. More often than not, these policies, practices, and decisions are steeped in the past – relying on historical data and ignoring the threats posed by a rapidly warming climate. By contrast, careful climate-minded planning can make a city more resilient. In this context, the Intergovernmental Panel on Climate Change (IPCC) defines resilience as *"the ability of a city to pursue its social, ecological, and economic development and growth objectives, while managing its climate risks so as to create and maintain a sustainable city that is capable of not only adapting to climate change, but also circumventing it."* Resilience also has to do with the ability to recover and to ensure vital infrastucture to function during extreme events. These climate-resilient cities of the future will be determined by the engagement and decisions that municipal leaders, urban practitioners, innovators and community residents make today.

Urban flooding – the causes

Urban flooding occurs when water flows into a city or town faster than it can be drained, absorbed into the soil or moved to and stored in a man-made lake or reservoir. The four different causes of urban flooding are:

#1 **Pluvial flooding** – the accumulation of local rainfall runoff due to insufficient drainage and buffer capacity,

#2 **River floods** – overflowing rivers due to insufficient capacity of the rivers to discharge the rainfall or rapid snow melt in a catchment/river basin, which can spread as wide as a whole region or even across borders,

#3 **Coastal flooding** – storm surges induced by heavy storms, gale-force winds and hurricanes causing sea levels to rise and flood a city,

#4 **Groundwater** – water that collects or flows beneath the surface of the ground, filling the porous spaces in soil, sediment, and rocks – originating from rain, melting snow and ice.

In light of the dramatic rise in severe rainstorms throughout Europe, our focus will be on sustainable urban stormwater management as a means to mitigate the problem of extreme rainfall in urban areas and as a key part of the blueprint for building climate-resilient communities.

Best management practices – move beyond runoff and inundation objectives

BMPs can provide solutions to problems such as water quality, water resources, urban flooding and sustainable stormwater management in urban areas. In recent years, the choice of urban stormwater management measures has been problematic for urban planners whose selection criteria (based on flood volume) is no longer sufficient for determining which drainage solution to use. The time has come to move beyond runoff and inundation objectives and, instead, employ a more holistic set of criteria by which to evaluate and measure the sustainability of urban drainage projects. These comprise of non-structural and structural measures, such as green roofs, permeable pavements, infiltration trenches, bio retentions, detention ponds – as well as sustainable attenuation and infiltration boxes). The increase in urban flood events has prompted urban planners to take a closer look at 'resilience' as a gating factor to determine (and verify) the sustainability of BMP projects. The concepts of resilience and sustainability have become very much intertwined. The most significant contributor to climate resilience is the process of ensuring that communities become informed, engaged and empowered to take part in the urban planning process – so that they may spearhead effective blue-green initiatives that will be socio-economically beneficial for their communities.

Torrential rain in Paris

03

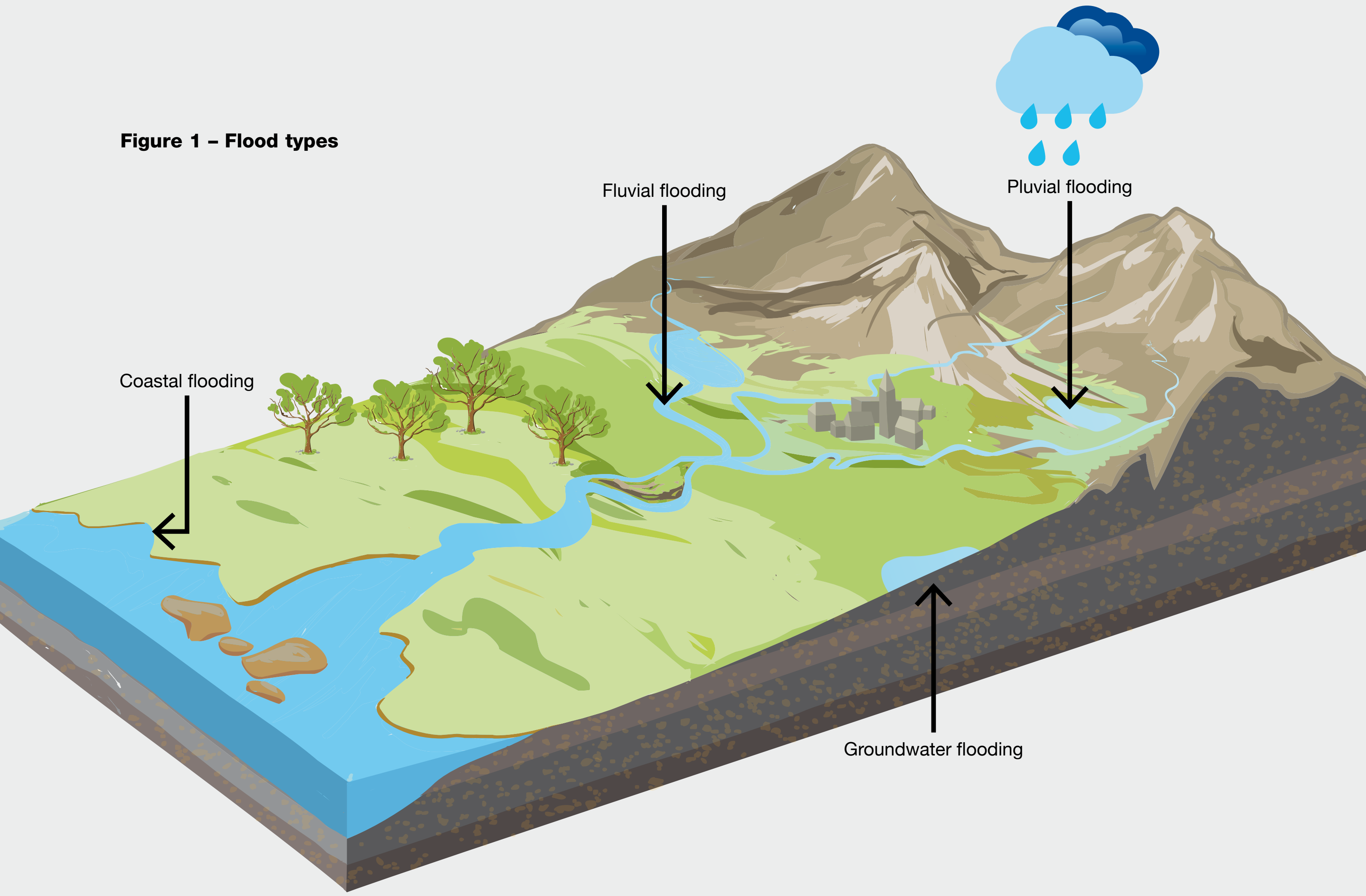
The challenges

Pluvial flooding has become an urban crisis

When stormwater runoff occurs, precipitation from rain or melted snow flows over the land surface. If stormwater does not soak into the ground – because of inhibitors like roads, driveways, parking lots, rooftops – the runoff will first flow into the drainage system (the sewers) which, if incapable of handling the volume, will then cause it to flood into the street and, worse, into buildings and homes. It will also flow down to the local streams, rivers, and lakes – causing flooding and erosion. This runoff becomes a health and an environmental hazard when it picks up the pollutants (like oil, grease, sediment, bacteria and pesticides) most often found on paved surfaces.

Urban flooding caused by heavy rainfall can quickly escalate into a full-scale urban crisis. Power outages, road gridlock, business disruption and unclean water are just a few of the problems that can wreak havoc in an urban community. The costs (damage to buildings, vehicles, furniture, infrastructure, lost business) become astronomical. To put things in perspective, 2012 was a record-breaking rain-soaked year in the UK – totaling 1,330.7 mm and costing the country's economy £600m. Agriculture was the hardest hit, costing a total of £1.3 billion, according to the National Farmer's Union (NFU). One year later, the UK was hit by severe winter storms from December 2013 to January 2014 – causing power outages and major disruption to transport. The heavy rain caused a flood phenomenon. Pluvial flooding was the least of their worries, as they were also hit by every other flood type: coastal, fluvial and groundwater (see the schematic, below).

Figure 1 – Flood types



A. Impact and extent of climate change on pluvial flooding in urban areas

Extreme weather events, such as heavy rainfall, can lead to increased flooding incidents and decreased water quality. In Europe, the impact and extent varies by region (see figure 2).

Increased pluvial flooding is projected to be one of the major consequences of climate change in Europe. According to the European Environment Agency (EEA), "Heavy precipitation events have become more intense and more frequent in Europe on average, but there are important differences across regions, seasons, time periods, heavy precipitation indices and underlying datasets." Overall, heavy rainfall has become more intense in northern and north-eastern Europe since the 1950s, and will continue to increase in frequency and intensity over the next many decades.

The EEA projects that global warming will lead to a higher intensity of rainfall and longer dry periods in Europe – with winter bearing the brunt of heavy daily precipitation throughout most of Europe "by up to 35% during the 21st century" and with a 30% increase in north-eastern Europe. Daily precipitation is also expected to increase during the summer months in most of Europe, although there will likely be a decrease for some regions in southern and south-western Europe.

Figure 2 – Regional impact of climate change (in Europe)

- Southern and central Europe are seeing more frequent heat waves, forest fires and droughts.
- The Meditarranean area is becoming drier, making it even more vulnerable to droughts and wildfires.
- Northern Europe is getting significantly wetter, and winter floods could become common.
- Urban areas, where 4 out of 5 Europeans now live, are exposed to heat waves, flooding or rising sea levels, but are often ill-equipped for adapting to climate change.

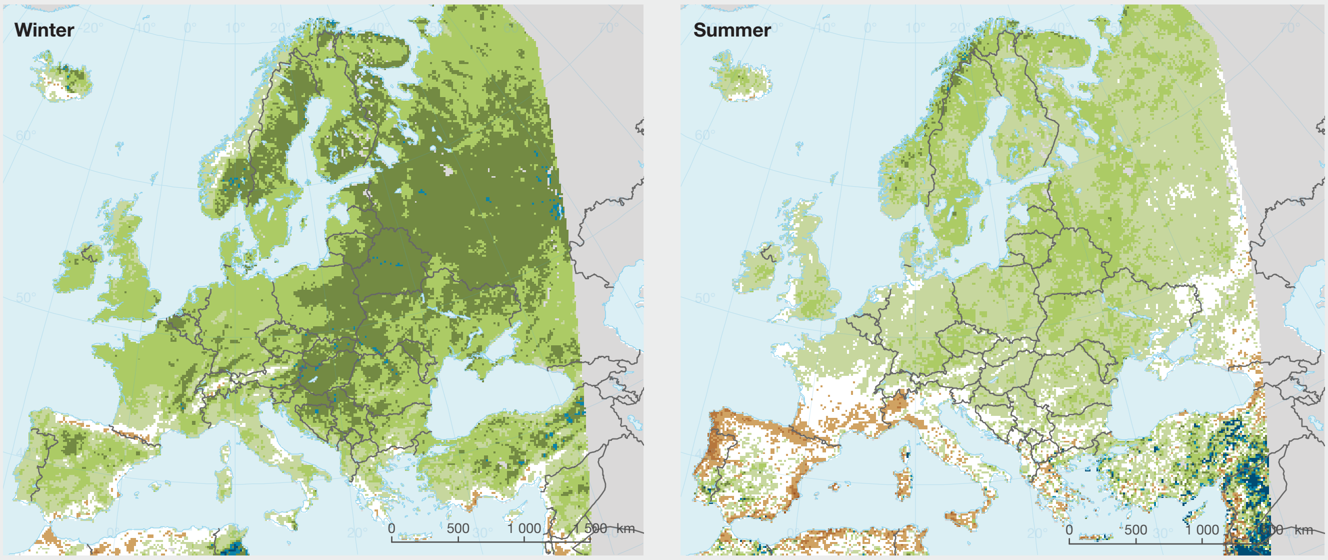
*(**Source**: European Commission (EC), Climate change consequences)*

Figure 3 – Potential flood risk for European cities from heavy rainfall events

Change in extreme precipitation
Cange in annual mean number of days with extreme precipitation (> 20 mm/day) for 2071-2100
-8.0 to -5.0 | -4.9 to -1.0 | -0.9 to 1.0 | 1.1 to 5.0 | 5.1 to 13.1

*(**Source** European Environment Agency, Data and Maps, last modified 6 April 2017)*

Figure 4 – Projected changes in heavy precipitation in winter and summer

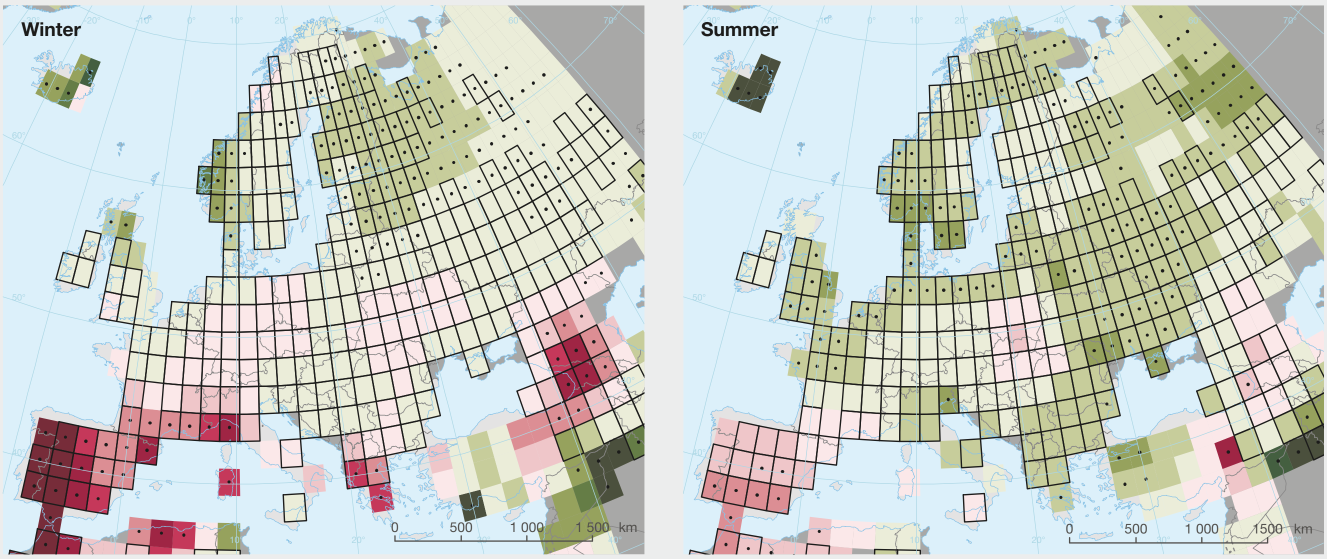


Heavy winter and summer precipitation change (%)

< – 25 | – 25 to -15 | -15 to -5 | -5 to 5 | 5 to 15 | 15 to 25 | 25 to 35 | 35 to 45 | > 45 | Outside coverage

(SOURCE: European Environment Agency, Data and Maps)

Figure 5 – Trends in maximum annual five-day consecutive precipitation/winter & summer



Trends in maximum of five–day consecutive precipitation for winter (left) and summer (right)

No data | Outside coverage

Rx5d (mm/decade): < – 5 | – 5 to -4 | -4 to -3 | -3 to -2 | -2 to -1 | -1 to 0 | 0 to 1 | 1 to 2 | 2 to 3 | 3 to 4 | 4 to 5 | >5

(SOURCE: European Environment Agency, Data and Maps)

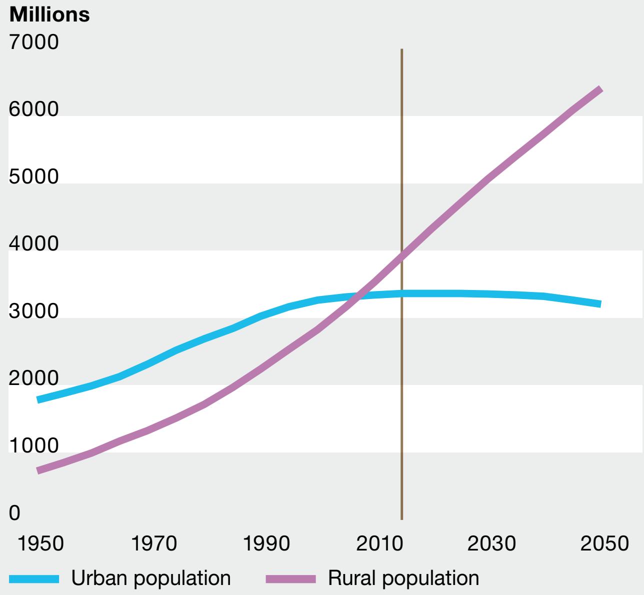
B. Impact and extent of urbanization on pluvial flood risk

Urban flooding problems due to excessive stormwater are increasing for a number of reasons – not the least of which is the rise in urbanization. People are flocking to the cities. In their 2014 Report on World Urbanization Prospects, the Department of Economic and Social Affairs of the United Nations states that 54% of the global population resides in urban areas. By 2050, two-thirds of the world's population will live in cities. In the mid-twentieth century, these statistics were reversed – with the global population being two-thirds rural and one-third urban.

With the exception of Africa and Asia, most countries have experienced a rise in urbanization – with the most highly urbanized countries being Belgium (98%), Japan (93%), Argentina (92%) and The Netherlands (90%). According to ESA, by 2050, *"89 countries are expected to become more than 80% urban."*

Urban areas are not only growing, they are also becoming denser – prompting (a) a drastic increase in the economic and social damage sensitivity per hectare urban area and (b) cities to adopt urban planning strategies which seek to reduce their negative, environmental impact and densification. Additionally, the limited proportion of permeable surfaces makes built-up land more susceptible to flooding. This vulnerability is evidenced by the rash of devastating torrential storms battered Europe for the past fifteen years – most notably in highly urbanized cities like Dresden and Prague (2002) Bern (2005), Copenhagen (2010, 2011 and 2014), Southwest England (2013-14) and the French Riviera (2015). From a cost perspective, it is estimated that flood damages cost Europe around 4.9 billion euros per year. This figure is expected to increase by 400% – to 23.5 billion euros in 2050.

Figure 6 – Urban and rural population of the world, 1950–2050



*(**Source** ESA, 2014 Report on World Urbanization Prospects, p.7)*

C. Inadequate and insufficient flood risk assessment and measurement

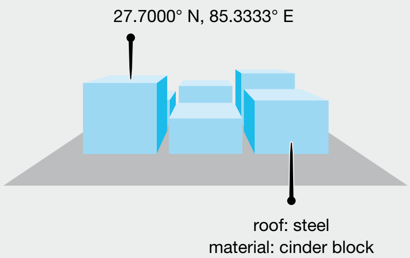
When assessing and measuring the risk of natural hazards, like pluvial flooding (and all other type of flooding), “risk” is defined as the probability that events of a given magnitude and a given loss will occur. Thus, the two key aspects of risk are “hazard” and “damage sensitivity” (someimes incorrectly called “vulnerability”). There are multiple ways of assessing, measuring and modeling risk – ranging from qualitative national risk assessment profiles for advocacy purposes to quantitative assessment for developing financial strategies to deal with the risk. Furthermore, risk can be assessed indeterministically – with a few to a single or few scenarios, and it can be assessed based on probability – meaning the likelihood that all scenarios will occur. The challenge, however, lies with the data that is used. In other words, according to the United Nations Office for Disaster Risk Reduction (UNISDR), although *“risk models are a representation of reality,”* they *“are only as good as the data used.”* We must also factor in human error into the equation – as well as the knowledge level of the individuals or groups who must read and analyze the models. A DRR practitioner, for example, may not understand the limitations of the models, whereas the experts who developed the models clearly do.

When measuring risk, there are many things that can go wrong or undetected. If, for example, not all risk sources or damage scenarios are identified, then this may result in biased decision-making. The list of scenarios may be incomplete in a flood risk analysis. Typical scenarios that are missed include: extreme events, secondary events and human error. In the case of extreme events, decision-makers and people at risk usually limit their analysis to events that are within their scope

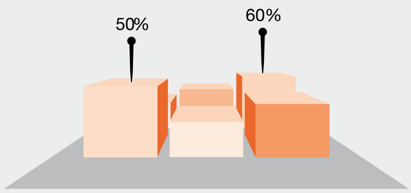
Figure 7 – The Components for Assessing Risk

Hazard
The likelihood, probability, or change of a potentially destructive phenomenon.

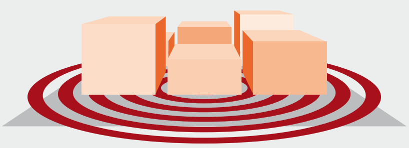
Exposure
The location, attributes, and values of assets that are important to communities.



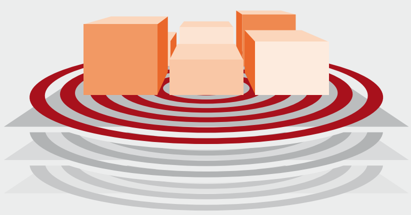
Vulnerability
The likelihoodthat assets will be damaged or destroyed when exposed to a hazard event.



Impact
For use in preparedness, an evaluation of what might happen to people and assets from a single event.



Risk
Is the composite of the impacts of ALL potential events (100’s or 1,000’s of models).



*(**Source**: UNISDR. Global Assessment Report 2015)*

of experience. Anything outside of that may possibly be missed and therefore, proactive measures to mitigate a potentially disastrous event may be overlooked or the flood defense system in place may not be sufficient to withstand such an extreme event. Secondary events like, for example, pollution or contamination from flood water may not always be identified as a possible scenario and therefore the community will be unprepared to deal with any damage control.

And finally, we revisit the problem of human error. More often than not, this may occur during the flood defense system planning and implementation phase, as well as the flood disaster management phase, where error may occur when a situation or scenario is not clearly understood or when, in disaster mode, everything (and everyone) is moving and reacting too quickly and frantically. As the saying goes, “cool heads must prevail.”

D. The perils of not being prepared for a stormwater floodeventuality

One of the greatest misconceptions about flood risk is that one must be located near a body of water to be at risk. If there’s any lesson to be learned from the annual occurrence of floods that have been battering urban areas throughout Europe, it’s that pluvial flooding can happen in any urban area, regardless of the elevation areas that lie above coastal and river flood plains.

Pluvial flooding does not come without its perils. When intense rain saturates an urban drainage system, the system becomes overwhelmed and water flows into the streets and nearby buildings and homes. This is especially noticeable when the drainage infrastructure is old and in need of repair or replacement – an expensive undertaking for many municipalities. And when the water flows (and rises) into the streets, it may cause property damage (to cars, homes, buildings). Additionally, there are the potential health hazards from flow velocity and possible pollutants contaminating the water or from downed power lines that may not be visible under the flood water (the potential fatal danger of electrocution if one inadvertently steps on a live wire that is wet). And then there are also the inconveniences, like power outages, business closures and disruption of transport services.

Although many cities try to be proactive by distributing flood preparedness pamphlets to their residents and by issuing storm warnings/alerts via television, radio, internet and smart phones, the fact remains that urban areas need to focus more on the root problem: the lack of resiliency in their drainage and sewer infrastructure and the need for progressive, sustainable alternatives for filtering, receiving and storing rainwater.

04

The solutions

How to make your city stormwater-resilient

Circular economy

A rising and increasingly dense urban population, combined with decades of unsustainable practices, has had an immense (and adverse) impact on the world's natural infrastructure. The depletion of our natural infrastructure has been caused by natural processes, negligence, and in recent decades, climate- and weather-related factors. Yes, climate change is real. And it's not going away any time soon. Our ecosystem is suffering. Water quality and accessibility is an issue that affects the rich countries just as much as the poor, developing countries. Affluent towns in Southern California have been experiencing severe drought conditions for many years now. Rainstorms have increased in intensity and urban flooding has become the rule, rather than the exception. The time has come to restore these resources to a condition that is ecologically sound and provides the resilience, materials and services that communities and businesses need to thrive – economically, socially and environmentally. In essence, what we need is a "circular economy" that would contribute to new technological, financial and environmental technology and innovation. And urban stormwater management and climate-resilience will play an important role in the circular economy continuum.

> "Through a transition from a linear usage of resources and waste production towards a sustainable management of urban resources with circular flows of resources, the sustainability of cities can be increased."
>
> – J.P. van der Hoek, A. Struker, and J.E.M. de Danschutter, Urban Water Journal Vol. 14, Issue 1, 2017.
> *"Amsterdam as a sustainable European metropolis: integration of water, energy and material flows"*

The contemporary challenges of a climate-resilient city call for improved collaborative urban stormwater management – a multi-disciplinary consortium of leaders and experts who share the same goal: the desire to create a resilient urban environment which functions sustainably and thrives on every level. From a stormwater management perspective, this means: flexible stormwater systems and solutions, energy use reduction, efficient land use, sensitivity to climate change impact, and securing critical infrastructure. Sustainable and resilient SWM needs be concerned about water supply access and security, public health protection (from water contaminants and pollutants), as well as flood protection in densely-built urban areas with many (and different) types of crucial urban infrastructure. Traditionally, resilient societies were perceived as communities that bounced back from devastation to the state they were in before. Not so. If we look at catastrophic events like Hurrican Katrina in New Orleans (back in 2005), it is obvious that they have recovered – although they are different from before. Thus, resilience – in the context of urban stormwater management – should be a flexible, adaptive process whereby communities learn to cope with changing economies, societal needs and a changing climate. In other words, prepare for the best, but also plan for the worst.

A. Engineering design – technology and innovation in rainwater management

Why, with everything we now know, do we still have flooding in the streets? The answer is quite simple. It's because we designed it that way. It's standard design.

So the question should be: "Is this standard design still applicable today?" Legacy systems and infrastructure are not able to withstand the stresses brought on by the excessive rainfalls that have been occurring across Europe. However, many cities are reluctant to invest in retrofitting or completely overhauling their drainage and sewer systems. And if they make the decision to allocate municipal funding for new or updated infrastructure, do they invest in increasing the urban drainage or underground storage capacity… or damage sensitivity of the urban environment? Improved drainage comes down to a choice of retaining water versus detaining water. Retention means that the water does not get discarded, but will be used for other purposes. Detention means that the water gets detained for a period of time (one hour, for example) and is then released slowly. As global warming continues to impact our urban communities, we will see more floods… and more droughts. Therefore, water retention makes sense, especially when cities need to keep the water and make it available for when there are dry spells – to irrigate gardens, and also for heat stress reduction.

There are many new and innovative approaches to stormwater management and they are not mutually exclusive. A city can opt to take a multi-tiered approach that suits their urban area. So, for example, stormwater attenuation and infiltration systems can be installed and also permeable pavements. The idea, after all, is to make urban areas as resilient and adaptive as possible. Innovative and climate-resilient stormwater management solutions are collected under the name **Environmental Site Design**. ESD effectively mimics natural systems along the whole stormwater flow path through combined application of a series of design principles throughout the development site. The objective is to replicate forest or natural hydrology and water quality. Each ESD practice reduces the volume of stormwater (incrementally) on its way to the stream, thereby reducing the amount of conventional stormwater infrastructure required. Some examples of this approach are the increasingly popular green rooftops and permeable pavements.

> "We have designed our sewer systems to fail every two years…"
>
> – Professor Frans van de Ven, Urban Water Management, Delft University (The Netherlands)


Green roof top

Green roofs/rooftop gardens

Roofs that are covered with vegetation, by their very nature, absorb rainwater and help to mitigate flooding. They have become very popular across Europe. The benefits, as they relate to water, are straightforward: for the building owner, it's a stormwater management tool; for the community, it reduces stormwater runoff; and for the environment, it prevents combined sewer overflow. Green roofs also contribute to the reduction of the urban heat island effect. The evaporation from the plants cools down the building and the city.


Permeable (grass) pavement

Permeable pavement, sidewalks and gardens

In some urban areas, green space is considered a luxury. On the ground and on rooftops, there is so much impermeable material. Concrete (or other materials like asphalt, brick, and bitumen) is simply not permeable. It cannot absorb rainwater. The concept of sustainable drainage makes perfect sense. As part of urban environmental initiatives that are underway in Europe and across the globe, the recommendation is that impermeable surfaces be replaced with permeable materials such as grass and gardens. This will allow the rainwater to drain into the soil. The process, known as infiltration, also serves to sustain the plant life.


Curbside stormwater drain receiving urban runoff

Separating rainwater from the sewage system

To improve water management and protect the sewage system from damage, cities are beginning to revamp their underground pipe and drainage systems – by separating rainwater from the sewage system. The separation enables the wastewater treatment plant to function properly, without it being overburdened by large quantities of stormwater. Meanwhile, the stormwater drains can often be integrated with the subsurface drainage system to control local groundwater levels.

Wavin Q-BIC Plus

A fully sustainable water infiltration and detention solution

The effects of climate change on rainfall levels and frequency have prompted urban planners and businesses to consider long term solutions for water infiltration and detention. Geocellular modular plastic units have been used for stormwater management throughout Europe since the 1980's. They are used to form underground structures which manage stormwater – by either allowing it to infiltrate back into the surrounding ground, or by attenuating it and then releasing a controlled rate into the existing drainage network. They help manage flood risk, as part of good SuDS design. To handle peak rainfall and masterfully control rainwater discharge, Wavin used this watertight technology to design attenuation and infiltration solutions like Q-Bic, Q-BB, AquaCell and the Q-Bic Plus. These modular plastic underground tanks are designed for use in locations where there are heavy traffic loads and where local groundwater levels are high. The Q-Bic Plus (shown above) is based on a modular concept that only uses side panels where they are really needed in an infiltration/attenuation tank. Made from virgin polypropylene, it is supremely robust and can withstand extreme loads. Additionally, these plastic crates are designed to last at least 50 years. Longevity equates to sustainability – an important factor for urban planners to keep in mind when building climate-resilient cities.


Hellwinkel

Case study
In northern Germany, the city of Wolfsburg is in the process of redeveloping an immense urban area in the district of Hellwinkel. Wavin Germany was asked to provide the sustainable rainwater solution that will eventually lead to the installation of more than 3000 Q-Bic Plus units. The vision behind sustainable urban development is to promote interconnected green spaces, a multi-modal transportation system, and mixed-use (residential/commercial) development. So, after careful consideration, the city of Wolfsburg put together a consortium of professionals (city officials, planners, architects, engineers, installers) and a company to provide the rainwater solution. Their common goal is to create sustainable and liveable communities that protect historic, cultural, and environmental resources. The area covers a span of 11 hectares and will encompass approximately 750 homes. The Hellwinkel Quarter is located near the Autostadt (owned by Volkswagen), and lies in between Reislinger Straße and the forest edge of Steimker Hills.

The objective for this urban housing project is to be nearly self-sufficient – on energy, water and infrastructure) and thus very sustainable. This district is hit by floods during heavy rainfalls and high ground water tables become an issue because there is no solution to manage the rainwater filtration. The Quarter's central point for rainwater management is the Wiesenterrasse, which consists of an upper and a lower part and is designed as a green area with stairs from a promenade that follow the terrain. Below this green area, they require large storage tanks to create the necessary capacity to buffer heavy rainfalls. Thus, the area needs a flexible stormwater solution that can work in a sloping terrain with a special stepped design and less disturbing gully covers.

Wiesenterrasse – rainwater solution:
It was decided that there would need to be rainwater attenuation below a nice, multifunctional green space. Wavin's sustainable stormwater concept centers upon three pillars or objectives:

- Evaporation via green areas;
- Reduced surface runoff by planted and green areas;
- Invisible below-ground water storage via Q-Bic Plus attenuation tank (from the top, water can filter into the tank but it will not go into the ground; instead, it will run off via flow control valves and chambers to the city of Wolfsburg's sewer system).

The products being used for this solution are the Wavin Q-Bic Plus (as infiltration/attenuation tank), and Wavin X-Stream (as rainwater pipe).

The installation of the first buffer tanks "UntereWiesenteresse" was finalized in August/September of 2016. 1500 Q-Bic Plus units were installed in 5 days. The overall project began in Q3 2015 and is scheduled to be completed sometime in 2018.

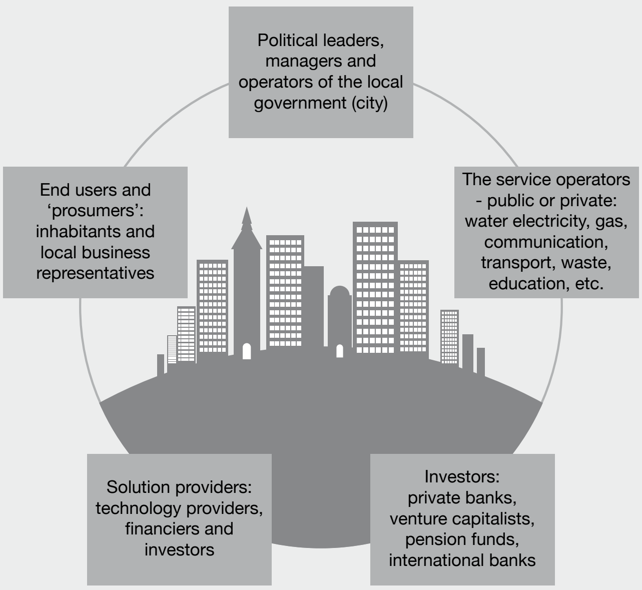
B. Planning – proactive urban stormwater management is key

Cities need to put stormwater management at the heart of urban planning – as part of an integrated and interactive process between planners, developers, engineers and beneficiary communities.

Measurement:
There are so many factors to take into account when measuring the state urban stormwater resilience – factors like geographical location, soil, paving, streams and gullies, separated sewer systems, and what measurement tools (software) to use.There is a wide spectrum of techniques available to help decision-makers analyze and measure flood risk and decide what stormwater management measures they should invest in.
One of the most commonly used is Cost-Benefit Analysis (CBA). Cost-benefit analysis is part of a more general procedure, known as Environmental Assessment and focuses on gathering information on all the environmental attributes, values and changes. In the context of flood risk reduction, CBA estimates the amount of flood losses expected in the future (without risk reduction), identifies possible risk reduction measures and their costs, estimates the benefits of such measures (i.e. liveability, attractiveness of the urban landscape, social cohesion effects, educational effects, sense of safety), and then calculates whether these measures will be economically feasible and efficient. Acceptance levels are also analyzed – issues like the acceptance (or not) of stormwater remaining on the streets and for what duration.

The players:
Essentially, an urban stormwater management task force (which would be a subset of the overall climate-resilience planning team) must be assembled. Stakeholders must be selected (usually municipal leaders, city and urban planners, landscape architects, engineers, industry leaders, community

Figure 8 – Stakeholders involved in shaping the city



(**Source:** *International Electro technical Commission (IEC), White Paper, Orchestrating Infrastructure for sustainable Smart Cities, p. 29)*

Figure 9 – Entry points for using decision-support tools to build flood resilience

Community selection	• Establishing community selection criteria • Defining aims, objectives, and approach jointly with communities
Project planning and implementation	• Baseline flood risk and risk perception assessment • Vulnerability and capacity assessment • Development of community flood resilience indicators • Identification of potential resilience-enhancing activities • Prioritization of flood resilience activities through risk-based CBA and other decision tools • Implementation and training
Ongoing resilience work	• Monitoring and evaluation • Learning • Dissemination of results

(**Source:** *Zurich Insurance Company, Risk Nexus, Making communities more flood resilient: the role of cost-benefit analysis and other decision-support tools, Sept 2014)*

leaders and select residents); stakeholder selection criteria must be clearly defined and understood. The team will then define the task force aims and objectives. They will also work with the community, to keep them engaged and involved. Sometimes these “urban task forces” will work or consult with adjoining municipalities who share similar issues, conditions and concerns.

Project planning and implementation:
Municipal planners and leaders must move from the traditional position where flood prevention (i.e. major river barriers and drainage infrastructure) is the only solution to the more forward-thinking flood resilience – a shift requiring an increase in responsibility for a variety of stakeholders (including property owners).

It should be noted that “risk” – in terms of stormwater management – is related to the recurrence of rainfall intensities and the location. For example, as low-lying areas accumulate rainfall runofff, they are prone to inundation. Whereas “flood risk” – in terms of all other types of floods, except pluvial – generally relates to the stability of the embankment and reliability and height of flood defense works.

C. Development – an integrated and holistic municipal infrastructure

It takes a team of progressive, community-minded stakeholders from across a wide spectrum of professions and disciplines to make an adaptive urban plan for climate-resiliency and stormwater management. And it takes that same team of green thinkers to see it through and to make sure that the plan is flexible enough to adapt to changing circumstances. Nothing stays the same. A holistic municipal infrastructure is one that synchronizes social, economic and environmental sustainability to become smart and resilient cities. Green environments tend to be more pleasant to live in and have an impact on the social quality of the environment, also contributing to the rise in home prices. These are cities where flood and water management assets function interoperably with other urban systems, including transport, energy, land use, and natural systems. The Wolfsburg case study is a fine example of a holistic municipal infrastructure.

05

Conclusions

We are standing at the precipice of change. The decisions we make now will determine how we live and thrive in the future. Will our cities be resilient? Will our socio-economic and environmental infrastructure withstand dramatic fluctuations in temperature and climate conditions?

Here's what we know for sure:

- Urbanization is on the rise,
- Cities are becoming more densely populated,
- Torrential rainfall is increasing in frequency and intensity,
- Urban pluvial flooding is becoming "the problem that won't go away,"
- Legacy stormwater management infrastructure is not equipped to convey rainwater runoff,
- Water quality is degrading,
- And climate change is real.

Throughout this whitepaper, we elaborated on the challenges and sustainable stormwater solutions related to urban pluvial flood resilience and expressed where and how urban stakeholders need to change their thinking – so that cities may achieve an integrated climate-resilient infrastructure that can efficiently contribute to socio-economic and environmental growth. The city should take the leading role in climate resilience – not just its leaders, but also its beneficiary stakeholders – the community. The stormwater management industry leaders like Wavin are taking a leading role in collecting information on how to do better, how to come up with smarter solutions – by designing forward-thinking solutions, testing their materials, and sharing this knowledge and expertise with cities and other stakeholders. Problems are merely opportunities in disguise. And sustainable urban stormwater management provides opportunities for harvesting other resources, like space, energy, water and nutrients. Industry innovators like Wavin are in a unique position to help guide urban communities towards the path to true resilience and sustainability – not only in stormwater management, but also in the ability to adapt to changing climate conditions and thriving in a circular city. So, to answer the first question – "Will we be resilient?" – Yes, we will.

06

The opportunity

Start an Urban Stormwater Resilience Movement in your city

Take action

We can't just leave it all up to the government, municipalities, environmentalists or urban planners to put an infrastructure in place to prevent urban flooding, and mitigate the problems of drought and heat stress. It has got to be a cooperative effort, as well as an individual effort. We – each of us – must make it our personal responsibility to adapt to climate change. Whether it's collecting rainwater or building a garden on top of our roofs, it's imperative that we take the steps necessary to be part of the stormwater management solution.

According to the European Environment Agency, "Annual flood losses can be expected to increase five-fold by 2050 and up to 17-fold by 2080." The EEA released a report on the need for climate change adaptation in Europe. The fact is that preventative measures need to be put into place sooner, rather than later. As for Wavin, we will continue to play a leading role in the development and production of forward-thinking, sustainable stormwater solutions – to diminish the challenges of urban flooding and do our part to adapt to the reality that is climate change.

For more information on how you can make your city or community climate-resilient, contact the stormwater project management team at Wavin and they will be happy to point you in the right direction.

Be a strong ambassador in your neighborhood. Attend city planning meetings. Most importantly, speak up and be heard.

For additional information and resources, please refer to the References/Resources section at the end of this whitepaper.

> "It's a collective endeavour, it's collective accountability and it may not be too late."
>
> – Christine Lagarde (Managing Director, IMF) on Climate Change

07

About wavin

Wavin is a leading supplier of plastic pipe systems and solutions. As one of the longest established names in this competitive and demanding market, Wavin built its reputation on 60 years of high quality and innovation.

We connect you to better solutions for above and below ground projects in the following application areas: water management, heating and cooling, water and gas distribution, waste water drainage and cable ducting.

The Wavin headquarters are located in Zwolle, the Netherlands. We have a direct presence in over 25 countries with 30+ manufacturing sites, mostly in Europe.

In 2012, Wavin became part of Mexichem, a global leader in plastic piping and one of the world's largest chemical and petrochemical companies. Mexichem serves a wide spectrum of industries through three main business groups: Fluent, Vinyl, and Fluor. Wavin operates in the Mexichem Fluent Business Group, which is comprised of several product categories: building and infrastructure, irrigation systems, geosynthetics and datacom systems.

Wavin's European leadership, local presence, commitment to innovation and technical support, all benefit our customers. We consistently achieve the highest sustainability standards and ensure total reliability of supply to support our customers to achieve their objectives.

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08

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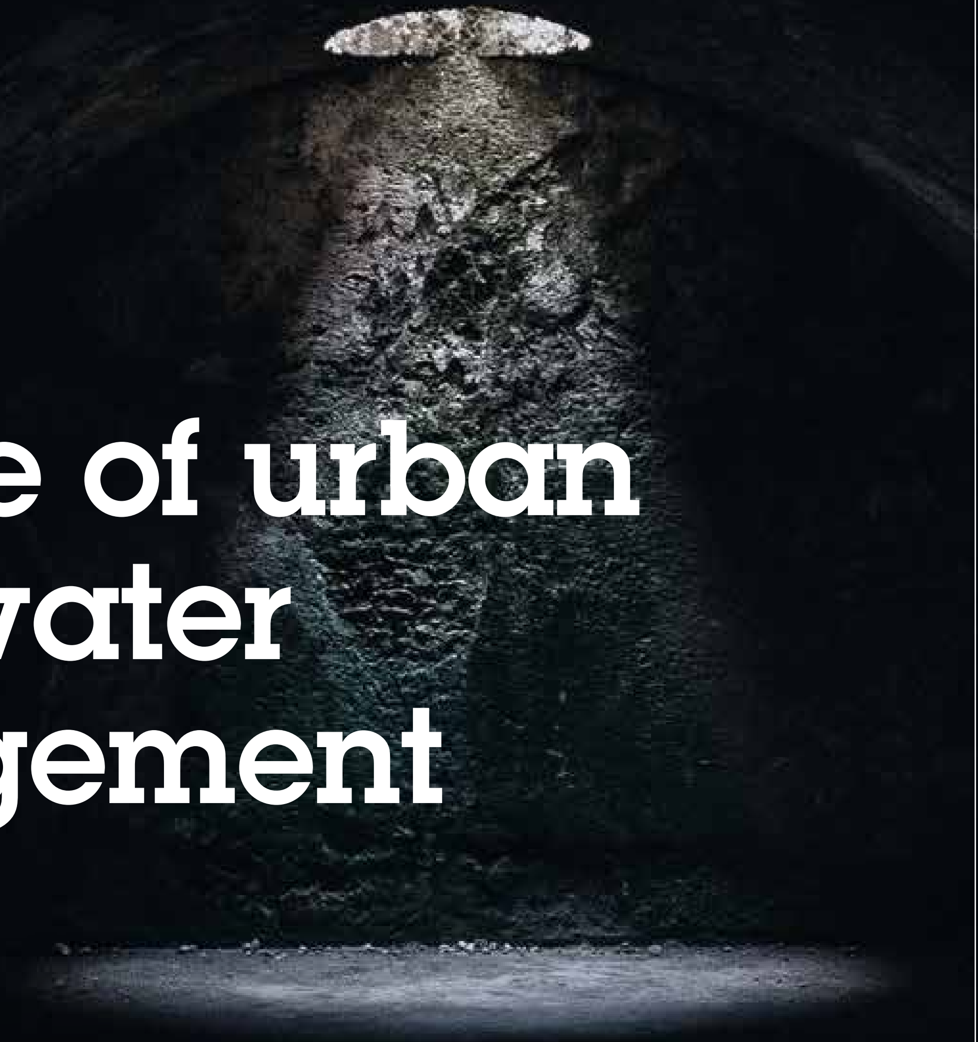
wavin SPOTLIGHT



the role of urban stormwater management

in building a sustainable, climate-resilient city

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