Adapting Urban Water Management to Climate Change:
Learning from Germany and the European Union

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Introduction

Around the world, cities are finding innovative solutions to respond to historic and emerging environmental problems, and in the process can learn from each other's successes and failures. New York City, for instance, has a history of working with the Dutch on issues related to coastal protection, even prior to Superstorm Sandy. The opportunities for international knowledge sharing on issues related to water management and climate adaptation, however, extend well beyond coastal protection. In particular, many large cities—including in the United States, United Kingdom, Netherlands, Denmark, and Germany—are increasingly focusing on the challenges posed by heavy rain events. This paper focuses on solutions developed by the largest urban populations in the Netherlands and Germany: Amsterdam, Rotterdam, the Emscher Valley, Hamburg, and Berlin.

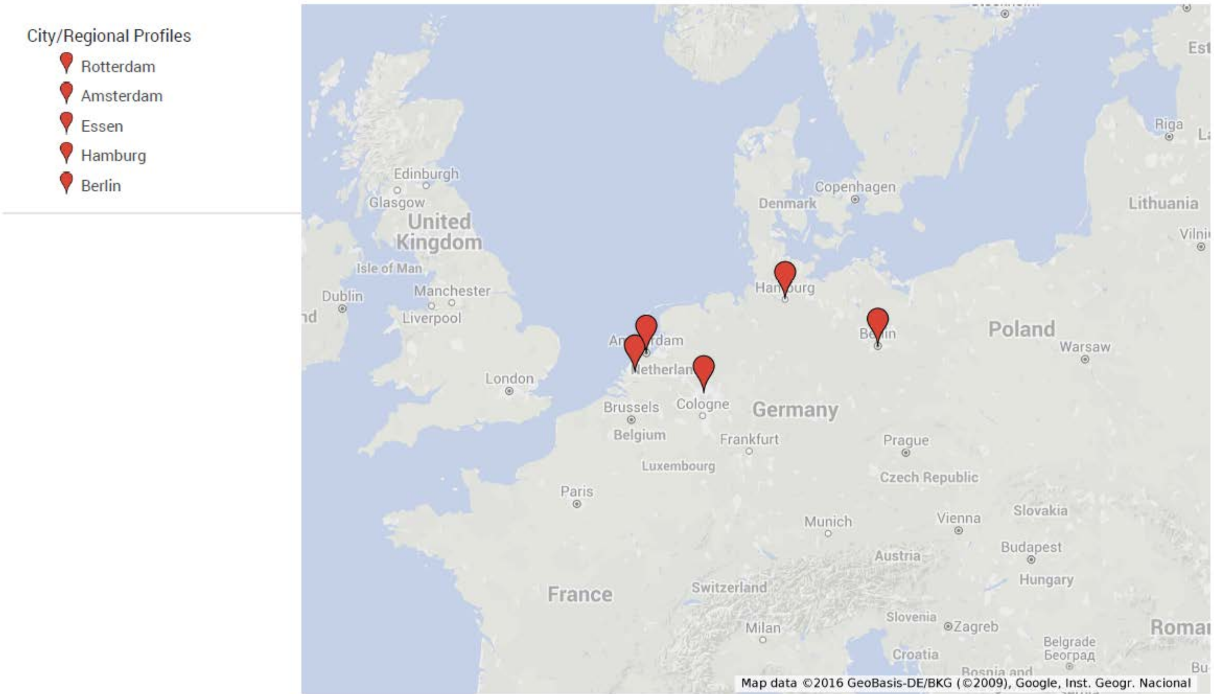
The motivation for developing innovative water management solutions is sometimes different, namely whether the activities are designed to solve for problems related to water quantity (i.e. flooding) versus water quality (i.e. combined sewer overflow and rain water runoff pollution). Having largely solved for storm surge through national coastal defenses, for instance, Rotterdam and Amsterdam are turning their attention to water quantity in low-lying areas where rain water pumping may not be sufficient for large rain events. In Germany—Berlin and the Emscher Valley in particular—have been focused primarily on water quality by reducing wastewater input to waterways. In many cases, the water solutions are based on slightly different approaches to green infrastructure implementation, and each city can maximize benefits and minimize mistakes by learning from each other. Whereas many cities in the United States are mostly trying to solve for water quality, adding an additional lens of water quantity can help form an approach that mitigates both issues.

Global Trends, Local Solutions

Climate change is a global issue, but its impacts are manifest locally. Sea level is rising across the world and the impacts are exacerbated where land is subsiding. While parts of the globe are likely to see a decrease in rainfall, New York and cities in northern Europe are likely to see an increase. Many locations will see similar impacts, but the solutions must be adapted for the specific local conditions, including the policy environment. For instance, regulatory requirements in the United States, such as the Clean Water Act, may prompt a different response than in the European United, which is governed by the Water Framework Directive.

Green infrastructure—an approach to water management that protects, restores, or mimics the natural water cycle—is a common solution despite these variations. Traditional solutions such as sewers, pumps, and berms, are designed for static conditions. As sea level rise and precipitation patterns change, it becomes more difficult for these systems to cope. Therefore, an additional layer of green infrastructure provides a buffer to climate change. Several examples of these approaches and its multiple interpretations are shown in the city and regional profiles that follow.

City and Regional Profiles



City/Region	Population	Area	Featured Project
Rotterdam	619,879	126 sq mi	Rotterdam Climate Proof
Amsterdam	840,486	85 sq mi	Amsterdam Rainproof
Emscher Valley (Ruhr Metropolitan Region)	Approx. 2.2M	334 sq mi	Emscher Conversion
Hamburg	1,774,242	292 sq mi	Rain Infrastructure Adaptation (RISA)
Berlin	3,562,166	344 sq mi	Concepts for Urban Stormwater Management and Sewage Systems (KURAS)

Figure 1. The Floating Pavilion showcases Rotterdam's climate adaptation efforts as a technological and marketing pursuit.

Rotterdam

Rotterdam is an internationally recognized leader in climate adaptation. The city's climate policy, known as Rotterdam Climate Proof, aims to ensure that Rotterdam is fully climate resilient by 2025.

Rotterdam has water on all sides and 80-90 % of the city lies below sea level. Just like in New York, heavy downpours cause flooding of streets, basements, and sewer overflows. Berms, storm surge barriers, and pumping systems are being adapted for sea level rise and heavy rain, but there is also a recognition that these systems have their limits and additional layers are needed for climate resilience.

Adaptation generally involving wide-scale application of small-scale measures, an additional layer of measures on top of the traditional solutions. Where possible, this involves multifunctional spaces, such as parking garages in which the lowest level can be left vacant ahead of a storm to accept excess flood water. Often times, these types of projects can piggyback on other capital investments. Near Rotterdam's central train station, for example, water storage has been created on top of a new parking garage. Modular 'Water Shells' provide over 600,000 gallons of water storage.

Another example of adaptation in Rotterdam is the simple allocation of space for existing waterways to flood. An area surrounding a canal in the center of Rotterdam has a setback that is used as a path when dry, but which can also flood safely. Probably the most iconic example of a passive flooding area in Rotterdam, however, is the Water Square. The Water Square has the capacity to store 475,000 gallons of rain water in three basins—two shallow basins receive water every time it rains, while one deeper basin only floods during heavy rain events. The design process involved the surrounding neighborhood, including several schools and a church. Most days, the Water Square is used by the schools for recreation. On Sundays, it is sometimes used as an outdoor service area for the church, which even uses rain water collected on site for baptisms. During a heavy rain event, however, the deep basins fills with water and assumes a new identity, and aesthetic value, as a pond.

Rotterdam strongly demonstrates the opportunity to use climate resilient development to promote the economy, research, and even tourism. The city is actively promoting itself as a center for water and climate change expertise. An example is the Floating Pavilion, right in the middle of the city, a visitor center and a concept for a floating space that will be resilient to climate change.

One key aspect of the strategy is to raise awareness so that people realize what changes are necessary in their city to support for resiliency measures. Many of the measures, such as the Water Square, also require that citizens accept that public spaces may flood from time to time. Another aspect is to create new businesses, jobs, and research programs. Rotterdam has about 20-25 delegations visit each year to see the city's approach to climate adaptation, and estimates that there are approximately 3600 jobs in the region which are directly linked to climate adaptation.

Figure 2. Rotterdam's Water Square is a recreational space during dry weather, but fills up with water during heavy rain.

Figure 3. Amsterdam Rainproof demonstrates the capacity of green infrastructure (here, a green wall) to absorb rainfall.

Amsterdam

Just as in New York, where Superstorm Sandy promoted much more interest in resiliency, many other cities have had extreme events that have created similar momentum. In many European cities, these have been large rain events, otherwise known as cloudbursts. Amsterdam experienced a large cloudburst in July 2014 which closed parts of the highway, canceled flights at the airport, and turned streets into canals. The rainfall total was between 2-3.5 inches, but what really exacerbated the flooding was the intensity—in some places, half an inch fell in just five minutes, a rate that corresponds to 5 inches per hour.

Amsterdam Rainproof, formed as a spinoff of the water utility Waternet, is a program that promotes a grassroots network of public and private partners which all take a role in mainstreaming green infrastructure to reduce the flood risks from cloudbursts. Fifty-six partners from government, community groups, academia, design, and consulting groups work together to leverage opportunities to implement green infrastructure as part of development and redevelopment. They also target “wet spots” for focused intervention to reduce flooding. In contrast to Rotterdam and its large projects like the Water Square, Amsterdam Rainproof is more focused on public engagement and smaller projects. It concentrates its resources primarily on public engagement and technical assistance.

Amsterdam Rainproof helps create awareness that there are many straightforward ways to manage the impacts of climate change. A sign on a public display reads, "And how to we defend ourselves against excess water caused by climate change? The solutions, like the rain, are plentiful." One solution is called a 'polder roof,' based on the Dutch term for areas protected by dikes. Polder roofs resemble traditional green roofs, but below the planted rooftop is an additional water storage area that provides water storage beyond the capacity provided by the plants and soil alone.

Rainproof has also developed creative ways to promote public education. A converted shipping crate is used to display a green wall—when water comes out of a showerhead above, the green wall absorbs water whereas the brick wall besides it channels it directly from the gutter and onto grass and the pavement below. For the water that drains to the pavement, there is a set of hollow tiles used to demonstrate yet another way to absorb water before it makes its way to streets and sewers. Furthermore, inside the shipping crate there is an interactive exhibit that shows the impacts of flooding, including the July 2014 cloudburst, and ways that Amsterdam Rainproof is promoting resiliency to future events. A whiteboard encourages visitors to write what they are doing to make their city rainproof and to post it on social media.

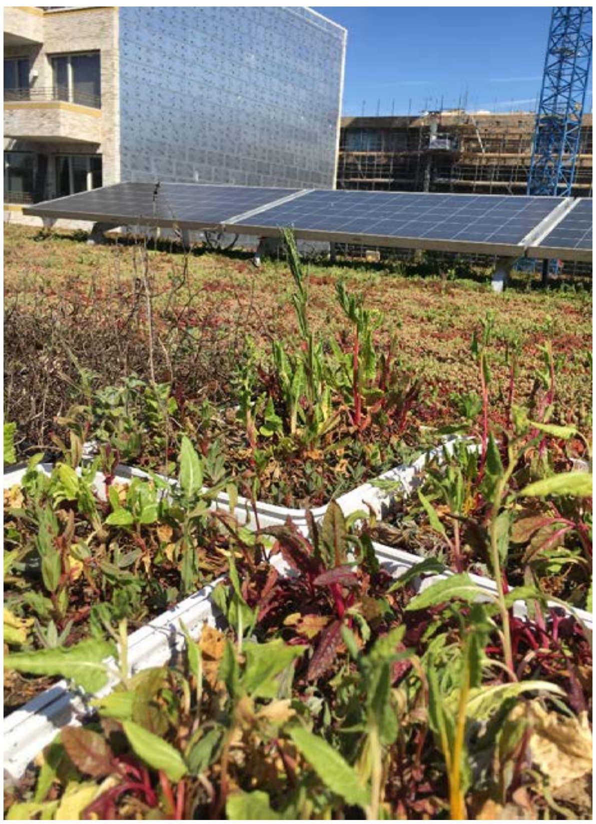


Figure 4. A 'polder roof' and set of hollow tiles demonstrate the capacity for ordinary spaces to hold rain water.

Figure 5. The Emscher River, which became an open sewer for mining and industry, is being restored to a more natural state.

Emscher Valley

The Emscher Valley in the Ruhr Metropolitan Region of Germany is an area of coal mining and heavy industry that began in the early 19^{th} century. Polluted rivers are a legacy of these activities, including the Emscher River which empties into the Rhine. Historically, these rivers were also prone to flooding, which created a serious health hazard. In response, in 1899 Germany's first water board, the Emschergenossenschaft or Emscher Water Management Associated, was founded. They developed a comprehensive management concept for regulating sewage disposal and treatment as well as drainage and flood protection. This, however, turned the Emscher River into an open sewer with high berms on both sides to control flooding. Today, the Emscher Conversion is a 50-mile restoration project to restore the Emscher to its natural state.

After the decline of the area's industry and the pollution it left in its wake, the water board was faced with two decisions to prepare for the future—a traditional approach which would use traditional engineering solutions including berms, pumping, and larger sewers, or a more flexible, nature-based solution. The nature-based solutions, which was now possible after the industrial decline and the closure of the mines in the late 20^{th} century, became the preferred alternative. The approach channels wastewater into closed sewers and uses green infrastructure to manage rain water. The local state and municipalities have committed to decoupling rain water drainage from the sewer system by 15% over 15 years.

In practice, this translates to new developments that integrate sustainable rain water management with architecture and design. A local zoo, for example, was landscaped to resemble an African lake and serves as a retention basin with a volume of over 40 million gallons of water upstream of a watercourse that feeds into the Emscher. Even the old mines have been repurposed; there are several locations that have been turned into parks, with old sewage canals turned into clean wetlands and old treatment tanks turned into ponds, complete with water lilies.

The Emscher has been largely restored and the green spaces along the river have now become desirable recreation areas and bicycling paths. Where the Emscher meets the Rhine, a weir was built so that wastewater would also empty into the Rhine, even during high water levels. Now the Emscher is so clean that the weir is being removed, and the Rhine and Emscher will be able to once again mix, allowing fish to return into the Emscher for the first time in over a century. In addition, a new floodplain is being created where the two rivers meet, creating new wetlands and wildlife habitat in the process.

Figure 6. A weir (top) used to maintain one-way flow from the Emscher into the Rhine is being removed to make way for a floodplain (bottom) where the two rivers will mix for the first time in over a century.

Figure 7. Hafencity, outside the berms that protect inner Hamburg, has been elevated to withstand flooding from the River Elbe.

Hamburg

While not below sea level like Rotterdam and Amsterdam, Hamburg is also prone to regular flooding from the River Elbe. This lead to the development of large berms to protect the inner city, whereas areas outside the berms have been elevated, with signs posted at street level to warn the population what to do in the event of a flood. Like the other cities described above, rain water management is critical in Hamburg. The Rain Infrastructure Adaptation project, or RISA, focuses on the multiple objectives to integrated water management in Hamburg: to restore a near-natural water balance through infiltration, retention, and evaporation; to protect open waterbodies through reduction of pollutant loads; to protect urban areas from flooding; and to use rain water as a design element.

Hamburg Wasser, the local water utility, has taken an active role in communicating responsibilities for managing heavy rain events. Whereas the sewer system is designed for typical storms, more intense events require temporary use of traffic space and open areas to store and convey water, while extraordinary storms require protection of buildings to prevent damage from storms that exceed the capacity of both the sewers and above-ground flood management infrastructure. This holistic view of flood prevention requires assigning roles and responsibilities for rain water management to go beyond just the water utility to include road planners, urban planners, and homeowners.

The city of Hamburg, in collaboration with local universities, has created several manuals to guide this shared responsibility, including for multi-functional, water-sensitive school yards and streets. The city has also assessed inland flood risks and developed guidelines for systematic risk management in flood-prone areas. Like Rotterdam, Hamburg also has their examples of multi-functional spaces, such as a rain water playground where children are encouraged to use the area in both dry and wet weather. Hamburg is also looking to cities like Rotterdam for inspiration, visualizing how ordinary plazas could be transformed into water squares.

Figure 8. Water management was central to the design of Hamburg's first rain water playground.

Figure 9. The redevelopment of Potzdamer Platz included on-site water treatment and storage in the form of an artificial lake.

Berlin

Water management has been central to much of the redevelopment that has occurred since the reunification of Berlin. Near the city's center in Potzdamer Platz, for example, a large artificial lake complete with wetlands on its perimeter, mixes form and function. Rain water from the development is collected and treated, while the location gains the aesthetic and cooling benefits of a water feature. A large sculpture protrudes from the water, further enhancing the area as a destination. What is not so clear when visiting the area is that a road runs beneath it—arriving on the other side of the lake, one finds that cars disappear under it into a tunnel.

On the outskirts of the city center, there is even more space for creative uses of water. A large artificial wetland has been built specially to filter rain water before discharging it to nearby waterways—a much cheaper and more environmentally-friendly alternative to more traditional treatment. Nearby at the Technische Universität Berlin, water that falls as rain supports plants growing along the façade of the building. Various species of plants are being tested for water demand and for their potential to cool buildings. The results are impressive, with evaporation and associated evaporative cooling serving to both manage water that would otherwise require a sewer system, and to reduce the energy required to cool the building.

Berlin seems to embrace sustainable water management. A new development near the Spree River was required to manage all rain water onsite in order to avoid any added pollution. Where sewer overflows do occur, one community activist has constructed a large, floating pipe system, with wetlands and trees above it. Although flooding is not a concern due to damming of the river, the water quality of the Spree is a major driver for new development in Berlin.

Using Berlin as an example, Concepts for Urban Stormwater Management and Sewage Systems (KURAS) is a network of partners from research and industry as well as local decision makers, that highlights how water management can improve city life. Like Amsterdam Rainproof or Hamburg's RISA program, these interdisciplinary teams advance research and showcase the best available water technologies.

Figure 10. A greened façade at the Technische Universität Berlin is being monitored for its water and energy benefits.

Commonly Observed Themes

Key elements of adaptive rain water management approaches are summarized below, based on the examples cited in the city and regional profiles.

Setting a standard: Traditional engineering criteria has been used to define the level of service provided by drainage systems, for instance the "5-year storm," or a rain intensity with a 20 percent chance of occurring in any one year. Many cities are revisiting these criteria to prepare for larger volumes of rain water through a mix of sewer improvements and surface solutions like green infrastructure. Amsterdam, for instance, sets a numeric criteria of managing 2.4 inches of rainfall in 1 hour, but for branding purpose the criteria is "Rainproof"—setting the expectation that property owners can help safeguard the city to its numeric criteria and beyond.

Developing a toolbox: Just as engineered solutions typically consisted of pipes, tunnels, tanks, and pumps, innovative solutions are emerging to manage rain water. Managing larger storms involves a distribution of responsibilities including private property owners, parks, and transportation agencies. Cities can help foster the development of these technologies and a shared sense of responsibility by promoting new technologies and incentivizing their development through technical and financial assistance. Some examples of these technologies include green roofs and rain gardens, permeable pavement, underground and above-ground storage, and beneficial reuse.

Engaging the public: As much of the urban landscape is comprised of private property, it is essential to enlist developers in the process of creating climate-resilient cities. The developers alone are not sufficient, however—there must also be a demand, which must be created through outreach and education, as well as expertise in the design and consultant communities.

Developing and piloting opportunity areas: Getting new technologies off the ground often requires smaller scale testbeds. "Showcase" projects can be found in many cities and have become the basis for monitoring the effectiveness of these systems, improving upon them, and advertising what is possible to other property owners and other cities.

Financing and implementation: Paying for new projects can be achieved in a variety of ways, from incorporating subtle changes into other urban activities such as street design, to grassroots projects developed by the community and benefactors through crowdsourcing and crowdfunding.

Economic development and partnerships: Adaptive rain water management has a large role in promoting revitalization of communities and can add co-benefits such as greening and cooling, and can also be aligned with other community projects like bicycle lanes. Furthermore, cities that have been successful in applying these sustainable development approaches locally have been able to showcase their projects to visitors and export their expertise to other cities.

Figure 11. An ordinary plaza in Hamburg is reimagined as a multifunctional space fashioned after Rotterdam's Water Square.

Conclusion

Historically, cities have tried to keep water out by building sewers, dikes and barriers, but that culture is beginning to shift and cities are seeking ways to live with water, removing barriers and shifting runoff patterns to mimic natural flow patterns. The future holds a mostly untapped potential for water management as means to enhance urban livability. Moreover, climate change may require that used water, and runoff that has traditionally been seen as waste, be recovered to offset potable water demand and enhance resiliency to drought.

Peer-to-peer networks of professionals, particularly at the city level, can work together to exchange information about approaches to very similar challenges—particularly, how to maximize funds to achieve multiple environmental benefits, while building systems that are robust in the face of climate change. Cities that have established themselves as leaders in this capacity, including the locations described in this report, are already seeing the benefits of their efforts, while new examples will likely emerge that build and improve upon the models that have already been established.