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REIA NO. 21 DIC.2024

ISSN: 2340-9851

www.reia.es

Water–sensitive neighborhoods: Sustainable water management as a strategy for urban regeneration in times of climate emergency.

// Barrios sensibles al agua: Gestión sostenible del agua como estrategia de regeneración urbana en tiempos de emergencia climática.

En el contexto de emergencia climática, gestionar las aguas pluviales y escorrentías urbanas plantea retos que requieren la implementación de soluciones sostenibles y resilientes. El proceso de "impermeabilización" de las ciudades resalta la urgencia de repensar los modelos de crecimiento urbano y su impacto en los ecosistemas hídricos. Este artículo analiza el diseño sensible al agua, promoviendo una sinergia entre el ciclo hidrológico y la planificación urbana bajo el concepto de Water Sensitive Cities. A través de los casos de Kronsberg en Hannover y Augustenborg en Malmö, se evidencia cómo la gestión integrada de aguas pluviales y la adaptación de la morfología urbana al ciclo hidrológico ofrecen soluciones viables, apoyadas tanto institucional como académicamente. En este artículo, se exploran soluciones de manejo integrado de aguas pluviales que combinan beneficios recreativos, funcionales y estéticos, evidenciando que estas estrategias no solo mejoran la estructura urbana, sino que crean entornos atractivos y seguros para la comunidad.

In the context of the climate emergency, managing urban stormwater and runoff presents challenges that demand the implementation of sustainable and resilient solutions. The "impermeabilization" of cities highlights the urgent need to rethink urban growth models and their impact on hydrological ecosystems. This article examines water-sensitive design, fostering a synergy between the hydrological cycle and urban planning under the concept of Water Sensitive Cities. Through the case studies of Kronsberg in Hannover and Augustenborg in Malmö, it is demonstrated how integrated stormwater management and the adaptation of urban morphology to the hydrological cycle provide viable solutions, supported both institutionally and academically. This article explores integrated stormwater management strategies that combine recreational, functional, and aesthetic benefits, showing that such approaches not only enhance urban structure but also create attractive and safe environments for the community.

Ciudades sensibles al agua, gestión de aguas pluviales, cambio climático, resiliencia, regeneración urbana

Water sensitive Cities, stormwater management, climate change, resilience, urban Regeneration

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Water–sensitive neighborhoods: Sustainable water management as a strategy for urban regeneration in times of climate emergency.

Introduction

In his book Nature and City, Ian McHarg states that urban planning must respond to the form of natural processes, and water is a crucial component of urban systems. This suggests that the way cities are built should derive from natural processes, with the hydrological cycle serving as a fundamental process that provides basic conditions for shaping urban morphology (McHarg, 1998, p. 18-19). In the context of a climate emergency, significant new challenges arise in urban water management, requiring adjustments that not only mitigate risks but also promote a new water culture based on sustainability and urban resilience (Soto & Herrera, 2019). Certain dynamics converge to increase vulnerability to these phenomena.

On the one hand, cities have experienced in recent stages a growing process of "impermeabilization." By the late 17th century, cities began to undergo notable growth, further intensified by rural exodus throughout the 20th century. The mass migration to urban areas caused an imbalance between the rate of land-use change from rural to urban and the rate of demographic growth, with the latter being significantly higher. The urgent need to urbanize streets led to adaptations such as soil sealing and water channeling. Climate change and rapid urban expansion have generated various issues related to water use and management, including the urban heat island effect, water pollution, and urban flooding

On the other hand, recent studies indicate a current global trend towards the concentration of the population in urban areas. Among these, the UN-Habitat report *"World Cities"* (UNhabitat, 2022, p. 39) reveals that in the 1950s, approximately 33% of the global population lived in cities. Seventy years later, this figure had increased to 56%, and it is expected that by 2050, cities will house 68% of the global population. This process of demographic concentration in urban environments occurs alongside the increase in the number of people living in flood-prone areas. In this regard, the study *"Resilient Cities for the World"* by C40 Cities estimates that by 2050, 7.4 million people in high-risk areas will face flooding (C40 Cities 2024:4). Additionally, the United Nations World Water Development Report predicts that the urban population suffering from water scarcity will double, from 930 million in 2016 to between 1.7 billion and 2.4 billion people by 2050 (UNESCO 2024: 14) The significance of this phenomenon led the European Environment Agency (EEA) to establish a research group in 2012 to study the impact of soil sealing* and propose guidelines and preventive policies for improvement and compensation (SWD 101, 2012).

**Soil Sealing: The paving of soil with non-porous materials, such as asphalt or concrete, restricts the soil's natural ability to infiltrate water. This use of impermeable materials impacts the water cycle, biodiversity, and urban ecosystems.*

All of this underscores the importance of discussing current urban growth models and their impact on water ecosystems, as well as the interaction of inhabitants with supply and sanitation services. It highlights the need for synergy between the hydrological cycle and urban planning, promoting reflection on the concept of Water Sensitive Cities (Georgi, 2024, p. 14-18), originated in Australia and internationally adopted. (Molina & Villegas, 2015).

In the European context, the Water Framework Directive and other derived sectoral legislations outline new challenges in urban environments that require the application of unconventional water management strategies and a reformulation of urban design (European Parliament, 2007, p 27-29). These measures demand a regulatory, legislative, and socioeconomic framework at the state, regional, and local levels, based on citizen participation, influencing urban planning and socioeconomic policies, and ensuring the viability of the measures to be implemented.

In summary, the objectives of this article are, first, to describe and analyze the principles of water-sensitive design, focusing on how the urban ecosystem is configured to create a complex and restorative network of pedestrian-oriented outdoor spaces that encourage daily social interaction. This is based on the study of two specific cases with institutionally and academically validated positive outcomes**: Kronsberg in Hannover, Germany, and Augustenborg in Malmö, Sweden. Second, this article aims to serve as a foundation for future academic and practical work and to support decision-making in response to new urban dynamics and climate challenges, emphasizing decisions grounded in the incorporation of natural processes into the design of urban structures.

***There is abundant information on the monitoring of these cases. The bibliographic references include significant examples of this accumulation of knowledge.*

The methodology of this study is based on a review of the literature and theoretical references, as well as the analysis of two practical case studies. The conclusions are derived from the study of the information gathered and the results of the theoretical references, as well as the synthesis of the two case studies: Kronsberg in Hannover and Augustenborg in Malmö, which have successfully addressed the integrated management of stormwater and the adaptation of urban morphology to the hydrological cycle as a natural process. Let's look at these two cases.

1*

Integration of the Water Cycle into Urban Structure Design.

Kronsberg, Hannover, Germany.

Basic Information

The Kronsberg neighborhood emerged as a result of the World Expo "Hannover Plan 2000," as part of the program "City and Region as Exhibition." This exposition was inspired by the theme "Man-Nature-Technology," and the Kronsberg eco-neighborhood project was presented under the name "Ecological Optimization Kronsberg," where water was highlighted as one of the key natural resources in the design. Today, Kronsberg is a model of a sustainable neighborhood that demonstrates a holistic vision in integrating actions with social, environmental, and technological impacts.

The neighborhood was developed over an area of 140 hectares to accommodate up to 15,000 residents. Previous studies showed that a conventional development in this location would irreversibly harm the natural water cycle, causing flooding issues. For this reason, the design focused on an integrated approach aimed at minimizing the impact on the pre-existing hydrological process. Groundwater recharge, as well as surface and subsurface runoff, was required to follow its natural course, as it did prior to urban development.

The Urban Structure and Its Adaptability to Flooding: Retain to Infiltrate.

In Kronsberg, an urban model was proposed that prioritizes the on-site retention and infiltration of rainwater, maximizing groundwater recharge. At the same time, new spaces for urban vitality were created, such as tree-lined and shaded streets, pathways connecting green spaces, and recreational rain gardens*** within residential blocks. The surface water management system in the neighborhood preserves and enhances natural drainage sources, preventing complications from flooding. Based on these design principles, some key data can be presented.

The amount of permeable land in the neighborhood reaches 61% of its total surface area. Parking lots and residential access areas were constructed using stone pavers, while permeable materials were used on plots, preserving green spaces. These strategies were implemented to promote the natural processes of evaporation and groundwater recharge. For instance, the installation of green roofs as a primary rainwater retention system aimed to reduce runoff velocity and enhance evapotranspiration. However, green roofs account for less than 30% of the total, as they were only required for roofs with a slope of less than 20%. (See Figure 3).

****Rain Garden: A green area designed to capture, retain, and naturally infiltrate rainwater, often integrated into a larger green infrastructure network. They reduce the percentage of surface runoff, help restore the water cycle and decrease the risk of flooding.*

FIGURE 01 & 02» By the author based on (Eckert, Schottkowski-Bähre & Kastner, 2000, p. 16). Urban structure plan of Kronsberg & Landscape plan + ecology.

The "Ecological Optimization Kronsberg" project was based on the idea of creating a decentralized and semi-decentralized stormwater management system. This system includes underground components such as conduits, reservoirs, and absorption and drainage boxes, as well as surface elements like channels, rain gardens, bioswales, and open ponds. These systems were implemented on both public and private plots.

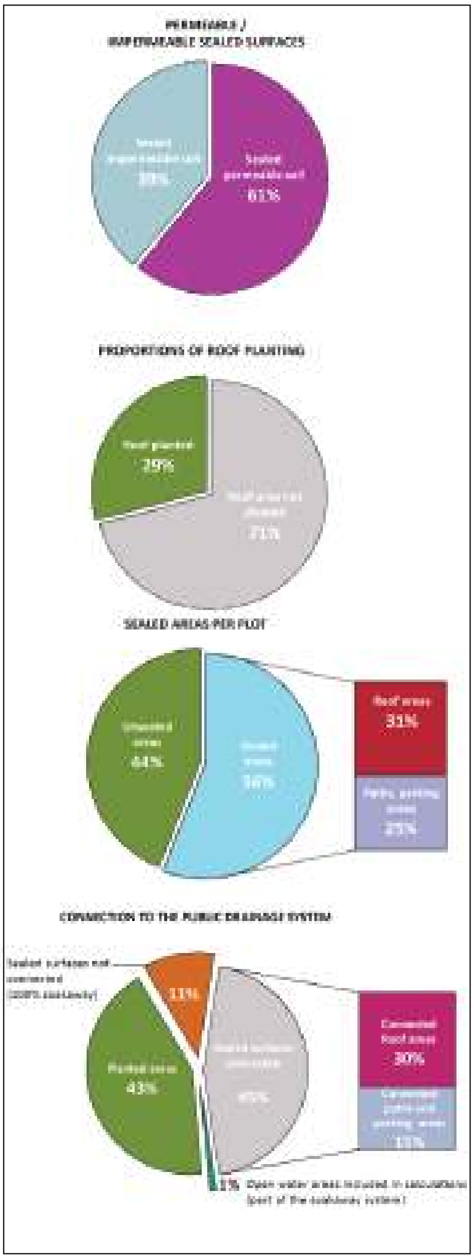
Stormwater management is achieved through regulated discharge and gradual drainage, which slows down the flow and prevents soil saturation during heavy rainfall (See Figures 1 and 3). Less than 50% of rainwater from green areas and impervious surfaces is directed to the sanitation system (See Figure 3). This decentralized approach to stormwater management alleviates the burden on the public network, relying on strategies that increase and preserve permeable soils, allow water to enter and exit, and retain or channel bodies of water, creating floodable areas.

Open ponds temporarily retain rainwater, raising their water level. Subsequently, the water drains through open grass channels containing bioswales with the Mulden–Rigolen system*. A sluice gate controls the flow of rainwater until it reaches the public retention ponds and basins. These water retention areas, which are part of the urban and recreational design of the neighborhood, naturally drain the water or overflow the excess into the sanitation network.

** Urban stormwater management approach that involves the use of detention basins (Mulden) and infiltration systems (Rigolen) to manage and control the flow of rainwater in urban areas.*

The design includes numerous gardens within the blocks, sidewalks, and bike lanes, accompanied by shaded tree-lined axes, playgrounds, and a network of paths with permeable pavements that connect access to residential areas, common spaces, and two rain boulevards. This urban design approach, sensitive to natural processes, not only preserves the ecosystem's balance but also benefits the physical and mental health as well as the social life of the residents, especially children and the elderly, by providing comfortable recreational spaces. Water and nature are integrated as key elements in the design of public spaces, linking surface water systems as recreational settings and incorporating a diversity of uses. This enhances urban vitality and improves the quality of public space.

FIGURE 03 » Graphs of Percentage of Permeable and Impermeable Sealed surfaces and connection to the public drainage system. (Source: Water Concept Krosnberg, 2000)



Intervention, Social and Urban Impact: The Proposed Urban Model as an Activator of Vitality. The Role of Water.

The intervention and social and urban impact of the stormwater control systems are classified according to the public or private nature of the plots. For example, on public plots between parking areas and sidewalks, rainwater is filtered through bioswales (Mulden-Rigolen system), and approximately every 10-12 meters, a native tree with large foliage is planted to provide shade along the sidewalk, inviting pedestrians and encouraging urban life and social interaction.

Additionally, two boulevards were constructed, one to the north and the other to the south (see Figure 2), starting from the hill park in the east and ending at the tramline in the west of the neighborhood. Both green-blue corridors are part of the pedestrian route and serve as central axes for the public space, along which various services and amenities are located.

These boulevards were designed as infrastructures for the retention and transport of rainwater, equipped with vegetation, pathways, urban furniture, small-scale clearings, gravel streams, water play areas, and spaces for contemplation, encouraging children's curiosity and play.

The diversity of activities and the promotion of social use that it implies inspires the design of Kronsberg, where the main axes for the retention and transport of rainwater are complemented by a network of services, uses, and diverse activities. This encourages the regular use of the space at different times of the day, for various purposes, and by different people, strengthening the identity of the place and ensuring its urban vitality.

In the private areas, each block of collective housing has interior parks at the center of the plot, surrounded by large residential blocks.

FIGURE 04 & 05 » By the author based on research and consulted sources. (Eckert, Schottkowski-Bähre & Kastner, 2000). Water system plan and aquatic landscape plan.

These permeable ground spaces include areas for free play and systems for the onsite collection and filtration of rainwater. The required percentage of trees and vegetation was specified to contribute to evapotranspiration and water infiltration, ensuring that the interior gardens have an environmental quality comparable to that of a park.

The design of the interior gardens required the approval of multiple stakeholders, including the municipal water authority of Hannover and the residents themselves. To comply with water retention regulations and landscape goals, strategies such as channels, ditches, ponds, and cisterns were implemented for onsite water retention. Each block of housing uses the floodable areas as opportunities to create free play spaces for children and social interaction areas for adults. During rainfall, the water is visible, and in its absence, these areas become green spaces. (See Figures 4 and 5).

The design of Kronsberg has turned the constant rainfall into a positive feature of the neighborhood's identity. Currently, the district is mainly home to young families with small children, attracted by the quality of the public space and the play opportunities offered by the water-sensitive urban design. It is common to see children playing in the interior parks of each block, riding bikes along the bike lanes, running through the network of landscaped paths that wind between the blocks, and enjoying the boulevards. Therefore, it can be said that water management in the neighborhood not only represents an approach to a more circular urban metabolism that aims to mitigate environmental impacts but has also become one of the key elements of its residents' identity. (Coats, 2009)

2*

Integration of the Water Cycle into Urban Structure Design.

Augustenborg, Malmö. Sweden

Basic Information

The Augustenborg neighborhood, covering an area of 32 hectares, was one of the first social housing developments in Malmö, built and delivered in the early 1950s. Initially, the neighborhood thrived, but the sanitation system, designed according to the standards of that time, proved inadequate. This combined system collected both wastewater and rainwater, causing system failures during heavy rainfall, leading to flooding in basements, garages, and ground floors.

Over time, Augustenborg experienced a marked economic decline, along with the associated social problems. The neighborhood became one of the most vulnerable in Sweden, with high unemployment rates and low purchasing power. Many homes were in poor condition, with moisture issues and poor insulation. The situation worsened with health problems among residents due to the diversion of sewage into water bodies during floods.

Urban Regeneration Process and Citizen Participation

In 1998, an inclusive ecological urban regeneration project called Eco-City Augustenborg was launched. The main objective of this project was to adapt to climate change and address the flooding issues of the neighborhood. Various environmental improvement measures were adopted, including CO2 reduction, waste management, sustainable mobility, energy efficiency, as well as social programs. These proposals were well received by the community, as they were seen as opportunities to create new jobs within the neighborhood.

The Eco-City Augustenborg project was a collaboration between private and public actors, the city of Malmö, and the active participation of Augustenborg residents. Community workshops, informational, social, and cultural events, talks, and community organizations were held. Funding came from both local and international European sources. However, the Sustainable Urban Drainage System (SUDS) was implemented by MKB, the water management department of the City of Malmö.

In 2010, Augustenborg was awarded the UN Habitat World Habitat Award in recognition of its pioneering climate resilience, efficient water management, and remarkable social transformation. The achievement of the Eco-City Augustenborg project underscores the importance of cooperation between government, citizens, and other key stakeholders to address current urban challenges, with a special focus on climate change adaptation and the promotion of social justice.

Urban Structure and Its Adaptability to Flooding: Local Open Rainwater System

In Augustenborg, the residential buildings had an invasive tendency in the landscape, which led to the need to rethink the relationship between the built and natural environments. Through the creation of "green axes, green roofs, and blue axes," a fusion between the natural and artificial habitat was achieved. The management and introduction of water into public spaces and green areas acted as an effective solution to mitigate the negative impacts of urbanization, such as soil pollution and the increasing risk of flooding due to rainfall. This approach aimed not only to adapt to the challenges of climate change but also to utilize water flows to enrich the urban landscape. The goal was to foster spaces that would serve as meeting points in proximity to water, strengthening the resilient identity of the neighborhood, while the green areas adjacent to water bodies would become urban landmarks.

Specifically, four fundamental strategies are implemented for the retention and delay of runoff: 1) the installation of green roofs and drains that direct water from the rooftops to channels or permeable soils; 2) storage in small ponds; 3) channeling through slow-moving flows in gutters and ditches; and 4) the creation of large infiltration surfaces. Let's examine this further.

The global relationship of the neighborhood shows that 58% of the soil is permeable. The incorporation of 2,100 m² of green roofs on buildings in the neighborhood and 10,000 m² of botanical garden on the rooftop of the industrial complex, inaugurated in 2001, helped to sustainably and efficiently counteract the flooding effect by gradually collecting, evaporating, and filtering rainwater through moss on the roofs or redirecting it towards downspouts (see Figure 8). Ninety percent of the rainwater from rooftops (non-gardened) and hard surfaces is channeled into the open water system, consisting of ditches that end in wetlands and ponds. In this way, green roofs helped reduce runoff by approximately 50% through increased evaporation and retention, enabling a better water balance.

FIGURE 06 & 07 » By the author based on research and consulted sources. (Mansson, Persson, 2024, p. 20). Urban structure plan of Augustenborg & Landscape plan + ecology.

Seventy percent of the rainwater that falls on green roofs is retained on the roof. Additionally, the green roofs have contributed to improving the thermal insulation of buildings and increasing urban biodiversity, serving as habitats for birds and other species, while also enhancing the overall landscape image of the neighborhood and increasing the green area of the neighborhood by 50% (see Figure 7).

Additionally, the urban drainage system proposed to solve the flooding problem was designed as a decentralized, integrated drainage system in two stages. In Stage 1, the rainwater flows from east to west, and in the second stage, the section runs along Lönngatan Street and ends in the northwest with the drainage of excess rainwater into the municipal network. Gardens in each of the residential blocks were adapted with a 6 km network of open-water channels that run throughout the neighborhood, leading to 10 retention ponds distributed across the area. This way, the runoff flows slowly, preventing peak flows. Thanks to these strategies, the project managed and delayed the water to avoid potential flooding, reducing the volume of water entering the sewage system and providing a local water balance in the neighborhood (see Figures 9 and 10).

The actions implemented for runoff management in Augustenborg are based on the availability of adequate permeable areas for the infiltration and storage of rainwater, as this increases the effectiveness of flood mitigation. In this regard, Augustenborg could be considered an example of the approach presented by the author Michael Hough in his book *Nature and the City*, where he argues that the percentage of collected water depends on the physical characteristics of the soil, topography, and vegetation. Therefore, the larger the infiltration areas, the greater the volume of water collected. (McHarg, 1998, p. 33- 35).

In Augustenborg, the water management systems are multifunctional. They provide recreational, functional, and aesthetic value. Space is not solely material, but also a setting where social action arises (Leal, 1997). The ditches that flow into wetlands and ponds not only collect and infiltrate water, but also create recreational spaces, urban attractors, and new microecosystems. The children's play areas and green spaces in the residential parks are designed to manage and temporarily store rainwater during heavy precipitation events. Additionally, a rainwater gutter was constructed along a bicycle path, efficiently integrating sustainable solutions into the urban mobility infrastructure.

The green and blue infrastructure planned for the neighborhood successfully provided safe recreational spaces for its inhabitants. The parks and play areas, designed to temporarily store water during rain, become leisure spaces when they are not flooded. These green spaces not only improve the quality of life by offering places for recreation, but also enhance urban safety by transforming

FIGURE 08 » By the author based on research and consulted sources. Graphs of Percentage of Permeable and Impermeable Sealed surfaces.

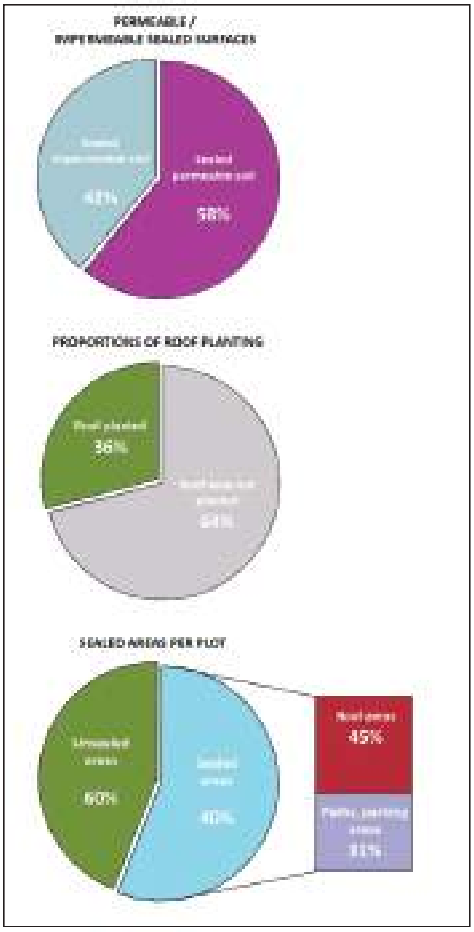


FIGURE 09 & 10 » By the author based on research and consulted sources. (Mansson, Persson, 2024, p. 206-211). Water system plan and aquatic landscape plan.

potentially problematic areas into active places, monitored by the community. (See figure 17).

For example, the neighborhood has a total of 30 gardens as spaces for dispersal and play, which foster social diversity and the accomplishment of multiple activities. Each housing block plot has an average of 60% permeable soil (See figure 8). The variety of uses for the public gardens ranges from children's play areas and benches to pathways and bike lanes, promoting generational and cultural diversity, and ensuring social interaction and exchange. This diversity of uses and users contributes to greater social cohesion, neighborhood security, and strengthens the neighborhood's identity. Encouraging informal surveillance and reducing isolation through various activities in public spaces enhances security, as increased foot traffic allows for natural supervision of the residential area (Michaud, 2002, p. 55).

The constant presence of green spaces and quality bodies of water activates urban life, encouraging residents to spend time outdoors and engage in community activities and initiatives. The microecosystems created by wetlands and ponds not only provide microclimates and enrich local biodiversity, but also educate and raise awareness among the community about the importance of sustainability and the management and care of water as a limited resource.

The implementation of these water management systems has been fundamental in the urban regeneration of Augustenborg. The transformation of the neighborhood from a decaying area to a model of resilience and sustainability has significantly improved living conditions and attracted new families, especially young families with small children, who seek a quiet, safe, and dynamic environment. Residents have been able to dignify their quality of life, and the results of this urban intervention had a significant socioeconomic impact on the families in the neighborhood. It demonstrates that stormwater management directly influences the structure of the neighborhood and that the combination of recreational, functional, and aesthetic benefits creates a balanced and safe environment, which not only meets the residents' needs but also serves as a model for sustainable urban planning.

Conclusion

The neighborhood of Augustenborg, in decline, faced multiple challenges: frequent flooding, high unemployment rates, constant immigration, and some of the lowest income levels in the city. Additionally, the saturation and poor management of sanitation networks caused severe public health issues. To address this situation, a collective participation process was implemented, involving a variety of stakeholders, from neighborhood residents to technical experts. Community-guided action plans were developed, focusing on both the specific needs of residents, because, as Attili and Sandercock (2005) point out, when a group organizes and acts upon its environment, it begins to perceive itself as a subject rather than an object.

The global design framework for the action plans focused on the development of an amphibious system that integrated a control cycle for rainwater. This system allowed for the gradual absorption of floods, transforming recurrent flooding into a design opportunity. Therefore, the neighborhood transformation design was inherently linked to the rain gardens, which facilitated controlled flood levels and provided spaces for dispersion and recreation. Additionally, as observed in the detailed analysis plans of the neighborhood, each water management system implemented in the Augustenborg project was simultaneously realized through the integration of technical infrastructures and public spaces. Thanks to greater urban complexity (Aquilué & Ruiz,2021, p 8), Augustenborg became an example of successful resilience, strengthening the sense of belonging and rootedness among its residents. It is a true case of social transformation.

Kronsberg, on the other hand, was an urban planning strategy that took advantage of the city's expansion as an opportunity to reimagine the traditional approach to the design and management of stormwater. Rather than treating water as a problem to be solved, it was decided to integrate it as a key element of the urban landscape. The approach was to manage rainwater on the surface, allowing it to filter slowly into the ground and creating dynamic and resilient landscapes that evolve over time.

Additionally, a "blue urbanism" approach was adopted, transforming Kronsberg into a garden neighborhood with permeable soil parks between the plots. These green spaces formed a network of biotopes, including wetlands and native vegetation, which promoted biodiversity. This redesign of the urban landscape not only solved flooding problems but also contributed to the protection of underground aquifers, establishing Kronsberg as an example of sustainable planning.

The success of Kronsberg lies not only in its ecological design but also in the diversity of uses and activities that connect the different elements of the aquatic landscape. The proximity between amenities, workplaces, homes, and services is key to fostering an active and vibrant urban life. The appropriate population density, with people occupying the streets for different reasons and at different times of the day, ensures the neighborhood's vitality and safety. This balance between urban functions, connectivity with the natural landscape, and social diversity has been fundamental in consolidating a safe and dynamic environment.

The analysis of these two case studies identified three main design principles organized within a controlled flooding system, which includes: 1. Rainwater capture, 2. Runoff channeling, and 3. Water storage. Additionally, these design principles are complemented by a flexible urban structure, composed of: 1. Rain gardens, 2. Axes formed by ditches, and 3. Nodes, such as ponds or reservoirs, which shape recreational public spaces. The final result is neighborhoods designed under an amphibious system that sustainably manages and utilizes water. Therefore, in the context of urban hydrological processes, it is essential to ensure the continuity of the water cycle within urban environments through a systemic vision that aligns with the network of services, uses, and activities. The integration of these natural processes into urban design acts as a catalyst for diversity, vitality, and urban comple

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