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JOURNAL

PROJECT

GreenQuays - Urban River Regeneration through Nature Inclusive Quays

Breda, The Netherlands

TOPIC

Sustainable use of land and nature based solutions

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BY BIRGIT GEORGI, UIA EXPERT

The quays are prepared for nature to take over - Journal 4

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Breda's GreenQuays project served as a pioneering initiative to infuse more nature into the densely built medieval city centre by revitalising the river Mark and transforming its quays into green spaces. The primary challenge lays in greening these areas despite the scarcity of open space available and steep quay walls, while ensuring inclusivity for native flora and fauna to thrive. Officially inaugurated in September 2023, the GreenQuays are now in the process of ongoing natural greening, with the construction having laid the foundation for plant and animal colonization. This process will be closely monitored.

Significant insights have been gained on how to develop a nature-inclusive design that simultaneously ensures the stability of the quays and offers public spaces for people to enjoy, providing relief during heatwaves and serving as a buffer for excessive rainwater—both being challenges exacerbated by climate change. Elements of Nature-Inclusive Quays (NIQ) and the knowledge acquired have already influenced other construction projects. The GreenQuays serves as a blueprint for the transformation of further river sections, some of which are already under construction.

Furthermore, the project has yielded invaluable experience in successfully managing such projects, enabled by a

well-coordinated and innovative partnership, and fostered by an open-minded political and administrative culture. This approach has allowed for viewing partial setbacks as learning opportunities, driving continuous improvement and success.

The Project’s progress since it ended

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The project ended officially in late summer 2023, when the quays were constructed.The development of the GreenQuays is however ongoing as the plants and animals just started to invade the place. Nevertheless, the project site is already flourishing. Throughout the winter months, a lush carpet of moss has spontaneously covered the once bare walls, lending them a vibrant green hue.

Initially, the newly planted trees in the quay walls faced challenges as the process of watering and maintenance had not been optimal and required adjustment. They have not only persevered but thrived, demonstrating their resilience. Additionally, the lower quay terrasse, situated close to the water level, experienced flooding during the winter, as this has been anticipated. Yet, the design's durability has shone through, with no damage detected.

Though still in an early stage compared to their envisioned final state, the new quays have already become a beloved space for the community. People delight in strolling along the pathways and basking in the sun on the inviting stairs, embracing the rejuvenated waterfront.

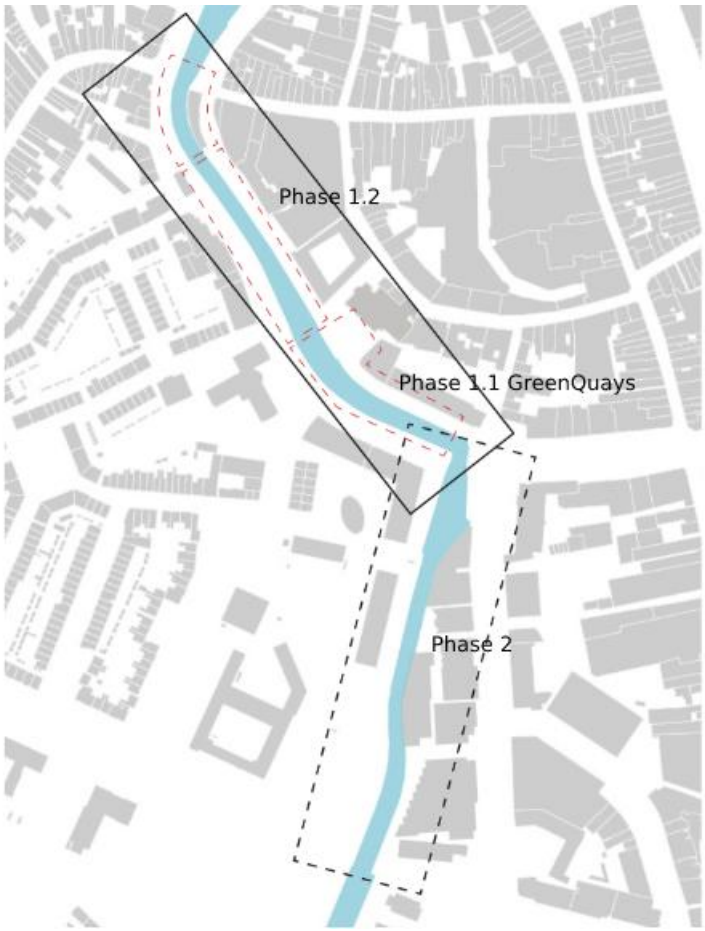
People enjoying the redesigned area. Image: Ton van Beek

The former small-scale pilot panels, where the wall design and tree integration have been tested, have been relocated to a new site but remain operational. This continuity allows for ongoing observation of their development, offering valuable insights due to their earlier installation. These panels have been established two and a half years prior to the completion of GreenQuays, providing an opportunity to gather data on plant growth for an already longer time span. Remarkably, the trees within their wall containers continue to exhibit robust vitality, underscoring the success of the design and planting methods employed.

The project’s plan for long-term sustainability

GreenQuays represent the inaugural phase (1.1) of the extensive river Mark redevelopment project in Breda's city centre. As the project's pioneering segment, they serve as a model for subsequent phases. Construction has

already commenced on phase 1.2, the next stretch of the river, with plans now underway to execute phases 2 and 3 concurrently in 2026/2027, ahead of the original schedule.



Phases of the river Mark project

Being seamlessly integrated into this broader development framework affords GreenQuays optimal conditions for long-term maintenance and adaptation. Their upkeep is seamlessly woven into Breda's regular green area maintenance routines. Moreover, the city has appointed a dedicated project manager tasked with overseeing their ongoing observation and refinement, acknowledging their innovative and pioneering nature.

Throughout the project, it became evident that measuring the success of the Nature-Inclusive Quay (NIQ) design requires ongoing monitoring, as the full development of vegetation and animal life takes years. The same challenge appears for measuring the related health benefits that depend of the development state of the quays. To ensure this, the city, some former project partners, and the regional health service GGD have agreed to continue monitoring, enabling the observation of the design's functionality and early detection of any shortcomings. This ongoing monitoring process will facilitate learning and refinement of the NIQ design and its management practices.

The insights gained from this monitoring effort will not only be pertinent to GreenQuays themselves but also hold significance for subsequent sections of the river Mark quays. Conversely, GreenQuays stands to benefit from future phases, as they will further open up the river and create a navigable waterway. This integration will foster connectivity between biodiversity hotspots and other areas within the city, enhancing the overall experience for residents and visitors alike.

Annual monitoring of insects, birds, and bats will primarily be carried out by volunteers supervised by the experts of the nature associations of Natuurplein de Baronie over the next 5 years. Professional fish monitoring will be conducted by RAVON in two rounds, scheduled for 2025 and 2028. Moreover, sensors are planned to be installed on trees and walls. Health and well-being will be monitored by BLASt in collaboration with GGD through two neighbourhood surveys. Additionally, partners have committed to convening 1-2 times per year over the next four years to discuss findings and engage in further knowledge-sharing activities.

Biodiversity monitoring. Image: Jacques Rovers

The GreenQuays and the broader river Mark development align seamlessly with Breda's vision, as articulated in the city's Environmental Strategy, to evolve into a city within a park by 2040. The quays not only embody this vision but also serve as a catalyst for inspiring similar initiatives in other areas that ensure dealing with nature more inclusively and allow their self-development while still enabling the multi-functionality of the areas. Their integration into Breda's long-term vision ensures their sustainability and continuity, firmly establishing them as an integral component of the city's environmental aspirations.

Generated Knowledge

The GreenQuays in spring 2024. Images: Veerle Hemerik

Nature-Inclusive Quays (NIQ) design

The project has successfully pioneered a novel and innovative design approach for quay areas known as Nature-Inclusive Quays (NIQ), revitalizing the once-buried river into a lively, navigable waterway. This endeavour not only restores the river's natural allure but also revitalizes the urban landscape, creating a more inviting environment for

both residents and visitors.

At the heart of the design philosophy lies the emulation of weathered, aged walls, fostering the spontaneous growth of wild plants and providing habitats for diverse wildlife. Central to this approach is a strong emphasis on native plants and animals and in parts a self-established wildlife, setting the project apart from conventional green wall designs following primarily an urban gardening perspective. Instead, the NIQ design incorporates a range of strategies to integrate greenery and natural elements into vertical structures, ensuring the promotion of self-established wildlife habitats. Features such as trees growing in walls, rough surfaces with niches for plants and animals, and underwater structures for fish all contribute to the richness of the design.

When developing the design, the team had to cope with several challenges. Combining modern quay structures with vegetation poses challenges. Wall flora, requiring space for roots and moisture, often emerges after decades of wear and tear. Organic material must accumulate in crevices for plants, mosses, and algae to thrive. Contemporary quay walls use steel sheet piling and impermeable surfaces, making them too dry for plants. Trees growing through walls can also cause structural issues. Aesthetic expectations may conflict with the needs of the natural environment. The final design has addressed these challenges and supports both strong, low-maintenance quay structures and flourishing wildlife.

NIQ wall design – the foundation for wildlife

The research journey towards developing an effective quay wall design unfolded through exploration across three distinct phases: laboratory research, small-scale pilot tests, and real-life verification. Within the laboratory phase, extensive research delved into the intricate interplay between brick and mortar-compositions, crucial for fostering a bioreceptive environment conducive to wall plant growth. Various bricks were scrutinized for their water absorption capacity and strength, with emphasis placed on identifying those most favourable for supporting plant life.

Simultaneously, mortar formulations underwent rigorous testing to ascertain their structural integrity and bioreceptivity. Novel approaches, including decorative pointing mortar, emerged as potential solutions to bolster the strength of joints while facilitating plant colonization. Critical to the success of the design was the evaluation of masonry strength and bonding, essential for withstanding external forces such as wind loads and boat collisions. Furthermore, exploration extended to the implementation of capillary substrate within cavities, aiming to optimize water absorption and support plant growth along the quay walls.

At the end, the research and testing led to the development of specialized pointing mortars designed to serve as bioreceptive substrates for plant colonization. Through iterative testing and refinement, mortar compositions were tailored to strike a balance between bioreceptivity and durability, ensuring long-term sustainability of the quay wall design. This laid the ground for a quay wall design that seamlessly integrates nature while fulfilling its functional requirements.

Plants sprouting out of the walls. Images: Birgit Georgi

Plant colonialisation of the walls

Several experiments were conducted on narrow strips of masonry of the small-scale pilot at varying heights, exploring different methods to encourage plant growth. Rainwater was directed to flow over the wall surface, and seeds such as of wallflower and wall snapdragon were affixed to joints using an adhesive made of maize. Small plugs of, e.g., wallflower and trailing bellflower were planted in gaps between stones at specific heights, while protruding stones with a frog were covered with a yogurt-moss mixture to promote moss growth. Some sections featured protruding mortar beds, and open butt joints were present at different heights. Additionally, one panel was equipped with sensors to measure mortar moisture independently.

Throughout the initial two-year trial, no structural mortar damage was observed, highlighting the resilience of the panels. The importance of capillary substrate behind the masonry became evident in maintaining wall surface moisture, particularly benefiting plants potted in recesses and germinated from seeds on joints. While traditional

mortar compositions supported modest plant growth, the panel with a bioreceptive pointing mortar, exhibited exceptional seedling development.

Excessive moisture in the masonry hindered plant growth, underscoring the importance of oxygen availability for plant roots. Subsequent observations revealed species preferences at different heights, with wallflowers thriving at higher elevations and wall snapdragon favouring moist conditions closer to the waterline. These findings inform future quay wall designs, emphasizing the need for tailored approaches to accommodate diverse plant species and optimize plant growth at various heights.

Trees growing out of the walls

An eye-catching feature of the GreenQuays design is the trees growing sideways out of the quay wall, providing a greener and more natural experience for residents and visitors. These quay wall trees, along with the vegetated quay wall, significantly contribute to the revitalized area. They have been planted in containers with substrate included in the walls.

In the laboratory phase of GreenQuays, the most suitable trees and shrubs for this unique growth pattern were identified. At the tree nursery, trees and shrubs had been tested in round air-pots with a diameter and height of 40 cm. These air-pots, with their limited growing space and perforated walls, encourage the development of a dense root ball with many fine hair roots, rather than long roots. The trees have been watered and their stems guided at right angles out of the pot along a round galvanized steel tube to shape them for growing through the quay wall holes. The testing found that Field Maple (Acer campestra), Grey Willow (Salix cinerea), and Fluttering Elm (Ulmus laevis) thrived under these conditions, as did Butterfly-bush (Buddleja davidii). However, Silver Birch (Betula pendula) struggled, and Black Alder (Alnus glutinosa) experienced stem burn.

Trees growing out of the quay walls. On the right side, the oldest trees in the test panels are still vital and grown up. Images: Erwin van Herwijnen

While the trees have been only planted in the quay walls by the end of 2023, results from the small-scale pilot that has been established in 2020 provide valuable insights into tree planting and substrate selection for vegetated quay walls. The pilot featured steel box structures with chambers formed by corrugated sheet piling, housing trees growing through circular portholes. Different substrate combinations were tested, with variations in organic content and grain size. Monitoring revealed that the mixture based on lava sand exhibited slightly higher moisture content compared to the sand mixture, with both substrates maintaining adequate oxygen levels. During the adjustment period, trees experienced leaf loss but regained full foliage, demonstrating healthy growth. The lava mixture was chosen for real-life verification due to its superior moisture retention properties.

Additionally, the study found that inserting one-year-old trees allowed them to form more naturally, while older trees required guidance and anchoring against wind. Accessibility to tree containers for maintenance was highlighted as essential, with recommendations for removable railings and additional aeration holes. Despite design constraints, such as the continuous brick frame edge, efforts were made to ensure optimal maintenance access through the porthole.

Enhancing fauna in the riverbed

Spatial structures underwater, such as aquatic plants, rocks, and dead wood, are of critical importance for fish habitat and biodiversity in the New Mark project area. While aquatic plants naturally provide essential structure underwater, navigability constraints necessitate exploring alternative options. However, limited space for aquatic

plants prompted investigations into alternative structures, including floating rafts, open concrete structures, and the introduction of dead wood.

From both practical and aesthetic standpoints, floating rafts were dismissed at the small-scale pilot, leading to the identification of gabions as the most promising solution. These structures, filled with wood, were selected for their compatibility with boat traffic and ability to provide habitat for target fish species, including young bindweed, bullhead, and eel.

A small-scale pilot study involving the installation of gabions filled with varying volumes of wood along the Mark River demonstrated positive outcomes. Five fish species were observed in the gabions, with increased fish presence compared to areas without gabions. While the project's duration has shown insufficient to determine optimal wood volumes, ongoing monitoring is expected to reveal the gradual decay of wood, fostering algae growth and macrofauna colonization, thereby enhancing fish habitat over time.

Climate-resilient design
The GreenQuays project, situated in an area prone to high heat loads in summer due to dense urban development and limited greenery, aimed to improve the climate resilience of the area and protection from too much over-heating. To address heat stress, a climate-responsive design strategy has been developed in collaboration with Wageningen University and the municipality of Breda. This strategy included spatial interventions to mitigate heat issues, focusing on creating cooling effects. The design measures were tested using simulations and were integrated into the project's implementation.

Nine urban design measures have been identified, each offering potential cooling effects. These measures were grouped based on their impact on urban climate, forming a toolbox for climate adaptation. The strategy for a climate-resilient design informed the design team's decisions, leading to interventions such as adding plants and trees along quays while keeping others open for better ventilation, incorporating water vaporization nozzles in quay walls, and replacing paved areas with vegetated surfaces.

The implementation of the climate-responsive interventions encountered also challenges. In particular, underground infrastructure and mobility request posed some issues hindering some measures that would have been more optimal from the climatic perspective. Nevertheless, the project provided valuable solutions and lessons learned categorised into spatial design and procedural aspects in developing a final design of the place with multiple stakeholders. This experience guides future efforts elsewhere in reducing urban heat stress and improving environmental sustainability in urban areas.

Spinn-offs
In addition to the original work and results achieved in GreenQuays, alternative applications of the project's solutions have been explored in other contexts.

GreenQuays has been instrumental in gathering crucial insights into the selection of appropriate substrates for tree growth, especially in constrained urban spaces where soil volumes are usually limited. The project's focus on growing trees out of walls necessitated the development of small containers with effective substrates capable of providing adequate water, nutrients, and oxygen to support tree health. The success of this approach has been validated through testing at Hanze University of Applied Sciences in Groningen, where tree sand combined with the Permavoid Capillary Irrigation System demonstrated remarkable resilience to fluctuating water levels. These findings have informed the design and implementation of similar solutions, such as the construction of the Grote Market square in Groningen, featuring a sophisticated underground structure with storage capacity and capillary systems to sustain tree growth amidst varying water conditions.

During the COVID-19 lockdown, partners form Delft University conducted experiments on various wall designs and materials, leading to the development of a dry-stacked system for walls built without mortar, deemed easy to assemble and reassemble. Although this concept emerged too late for incorporation into the GreenQuays project, it sparked new developments applicable to other wall constructions. Leveraging research from GreenQuays, the dry-stacked system was realized as the Quay Wall Garden in Delft in April 2022, facilitated by a small grant program from the Dutch government and collaboration with several companies.

Lessons learned

The GreenQuays project offers valuable insights into designing Nature-Inclusive Quays (NIQ) by striking a delicate balance between structural integrity and wildlife accommodation. Moreover, it provides a blueprint for developing multifunctional designs that bolster climate resilience and promote social cohesion. Beyond technical considerations, the project highlights the critical importance of effective management and inclusive engagement,

pivotal for both the construction phase and subsequent river sections.

The project's success owes much to its innovative approach, fostered by a diverse partnership encompassing research institutions, environmental organizations, NGOs, regional authorities, private enterprises, and the city of Breda as the lead partner. This collaborative model, though unconventional, proved indispensable for driving forward such a pioneering project, nurturing a culture of openness and mutual learning among stakeholders. Looking ahead, there's potential to expand collaboration with additional partners and departments within the Breda authority. The ongoing collaboration with the regional health services GGD has proven mutually beneficial and remains ongoing.

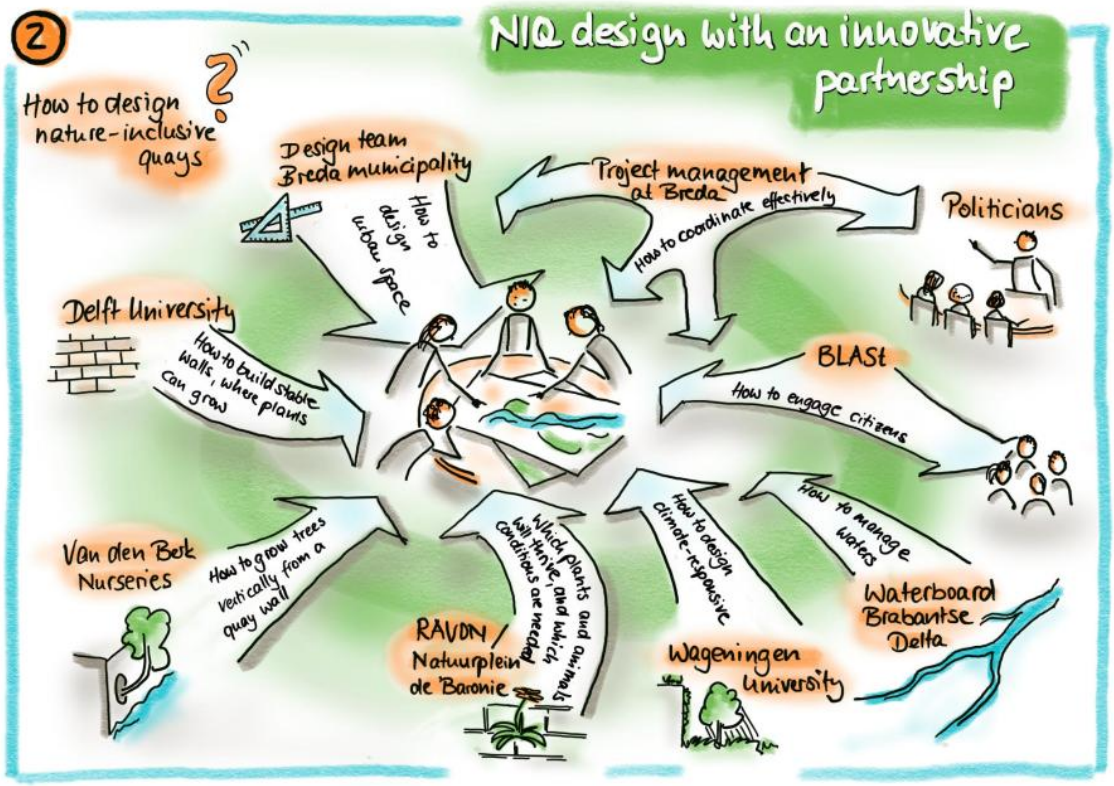


Image: Birgit Georgi

Robust project management played a pivotal role in providing guidance and facilitating cooperation among partners, ensuring clear delegation of responsibilities alongside regular communication and coordination.

The success of innovation within a significant infrastructure investment like GreenQuays was bolstered by Breda's longstanding culture of innovation and unwavering political support. Despite challenges such as escalating construction costs, the project remained aligned with Breda's vision of evolving into a 'City in the park', with political leaders viewing setbacks as opportunities for growth and refinement rather than barriers to progress.

> The strong collaboration between universities and the municipality, known for their open-mindedness and can-do attitude, was pivotal for the project's success. This partnership has flourished, leading to joint applications for new Dutch project funds, with Green Quays serving as a cornerstone of this fruitful collaboration.

Sanda Lenzholzer, Waageningen University and project partner of GreenQuays.

Recommendations to other urban authorities

These lessons are applicable to other cities embarking on similar projects. Establishing a diverse and innovative partnership that encompasses a range of knowledge and skills is crucial. Cultivating an open-minded and trusting cooperation, where each party assumes responsibility while fostering collaboration, is essential. For innovative projects like these, it's highly advisable to have a dedicated project manager with ample resources to facilitate communication and integration among partners and subjects.

Projects utilizing nature-based solutions face the challenge of proving their functionality once implemented. Nature and its ecosystem services are not fully developed at the end of the technical construction. Hence, adequate time for testing new solutions should be factored in to ensure the final design rests on a solid foundation. Furthermore, monitoring of these solutions should extend beyond the project's duration to provide

policymakers and planners with evidence of their efficacy and allow for necessary design adjustments.

Breda's solutions are well-documented in brochures available in both Dutch and English for other cities to follow the example. The NIQ design is being further applied in subsequent project stages scheduled until 2026/2027. There is then ample opportunity for others to draw inspiration from and study this example, contacting and engaging with experts on-site and adapting the technology to suit their own circumstances.

The knowledge is summarised in a set of brochures

Conclusions

The GreenQuays project has successfully implemented innovative quay designs despite encountering numerous challenges, including the COVID-19 pandemic disrupting participation and escalating material prices due to war in Ukraine threatening the project's further financing. Moreover, balancing the diverse and sometimes conflicting desires of various stakeholders, such as enhancing wildlife habitats, promoting urban greenery, and ensuring climate resilience, posed significant expenses.

Ultimately, while not all individual interests were fully met, all project partners take pride in the accomplishment. Moreover, citizens have already demonstrated their satisfaction by embracing the quays for recreational activities like walking, playing, and sunbathing.

A culture of mutual respect and active listening among stakeholders—project partners, construction company, and citizens—proved crucial to this success. This collaborative spirit, fostered by Breda's politically open-minded approach and its commitment to green development, laid also the ground for citizens' early involvement in the project, which actually had started already long before the GreenQuays project.

The seamless continuation of urban development using NIQ technology along further sections of the river, alongside ongoing collaboration among former project partners, demonstrates the enduring impact of the GreenQuays initiative.

The tangible example provided with the GreenQuays construction serves as a catalyst for the continued development of the River Mark and other areas within Breda, showcasing the benefits of nature-inclusive design for both citizens and the city as a whole. It is a testament to Breda's commitment to sustainability and innovation. As the city continues to explore new opportunities for urban greening, the lessons learned from this project will guide future undertakings. By fostering connections between nature and people, Breda sets an example for cities

around Europe and the world, demonstrating the potential of nature-inclusive urban planning to enrich the quality of life for residents and visitors alike.

Image: Birgit Georgi

Links

GreenQuays project website

Nature based solutions

See on UIA website