Regeneration of watercourses within urban areas. Some considerations on relevance, strategies, and design tools

Paola Sabbion
Department of Architecture and Design, University of Genoa, Italy
paola.sabbion@gmail.com

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Abstract

Water plays a crucial role in landscape design, offering opportunities to shape significant spaces while also enhancing ecological conditions. Regenerating rivers and streams, in particular, has proven to be an effective strategy for environmental recovery at various scales. These waterways are complex ecosystems, highly anthropized over time and revitalizing them in urban and peri-urban areas can yield multiple benefits such as biodiversity conservation, flood protection, and the creation of public spaces. A landscape-based approach to river restoration encompasses not just design but also considers the potential processes it can trigger and comprehends the interconnections within the entire system. The different projects mentioned represent examples of techniques capable of combining usability and ecological improvement, enabling the enhancement of water accessibility and contributing to environmental well-being through the use of diverse design strategies and tools.

L'acqua svolge un ruolo cruciale nella progettazione del paesaggio, offrendo l'opportunità di modellare spazi significativi e migliorando le condizioni ambientali ed ecologiche. La rigenerazione di fiumi e torrenti, in particolare, si è dimostrata una strategia efficace per il recupero ambientale alle diverse scale. I corsi d'acqua sono, infatti, ecosistemi complessi che hanno subito forti alterazioni antropiche nel tempo: la loro rigenerazione può apportare molteplici benefici in aree urbane e periurbane, contribuendo alla conservazione della biodiversità, alla protezione dalle esondazioni e alla creazione di spazio pubblico. Un approccio paesaggistico alla rigenerazione fluviale include una progettazione che consideri i potenziali processi innescati e le interconnessioni all'interno dell'intero sistema. I diversi progetti citati raccolgono esempi di tecniche in grado di coniugare fruibilità e miglioramento ecologico, consentendo una nuova accessibilità all'acqua e contribuendo al benessere ambientale attraverso l'utilizzo di diverse strategie e strumenti progettuali.

Keywords

Urban River, River Restoration, Water-sensitive cities, Nature-Based Solutions, Green Blue Infrastructure.

Fiumi urbani, Rigenerazione fluviale, Città sensibili all'acqua, Soluzioni naturali, Infrastrutture verdi e blu.

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Anthropogenic alterations to river systems

The effects of urbanisation on river ecosystems are well-known and have been identified as 'the urban stream syndrome' (Walsh et al., 2005). Both direct and indirect anthropogenic activities alter river environments, resulting in critical changes in watershed processes and habitat conditions, which cause the degradation of biological and even cultural diversity (Wantzen et al., 2016).

Alterations to river systems arise from various causes, including demands for water, energy production, urban growth, flood control, and agricultural, industrial, and navigation needs. Exploitation and pollution, dredging, changes in the flow regime, excessive fishing, vegetation removal, and the introduction of invasive species decrease the natural complexity of riverine landscapes and cause the loss of many ecological functions.

Intensive exploitation of rivers began over 500 years ago in the Western world, increasing significantly in the late 19th and 20th centuries. Rivers have suffered considerable harm to their natural environment, particularly since the dawn of the industrial era. As a result, nearly 80% of the world's population faces high levels of threats caused by water insecurity and degraded riverine habitats, which are also considered the main cause of extinction in aquatic ecosystems (Vörösmarty et al., 2010). Currently, only a small portion of the flood-prone areas that existed in the 19th century remain. More than half of the world's rivers are polluted or at risk of drying up and there is an increased risk of water pollution and pathogenic contamination due to flooding or higher pollutant concentrations during droughts. Moreover, the quality of water is expected to continue to deteriorate in the future, as a result of elevated water temperatures, reduced dissolved oxygen, and water's self-purifying ability (UN Water, 2020).

Direct anthropogenic alterations in riverine ecosystems involve watershed-scale processes such as erosion and nutrient delivery, which lead to imbalances in stream flow, water quality, and biological interactions. Construction of channel diversions or size reductions, dams, and flood control devices significantly reduce the transport and storage of organic matter, resulting in simplified habitats and biodiversity. Levee construction and bank armouring also reduce habitats and biological diversity by eliminating natural flood flows, bank erosion, channel migration, connectivity, and river-floodplain interactions that affect riparian ecosystem conditions (Roni and Beechie, 2012). Furthermore, human activities can indirectly cause variations due to changes in land use within the catchment area. Filling wetlands or removing riparian vegetation for agri-

culture, urban development, or construction of impervious surfaces impacts habitat diversity and biological capacity. Within the catchment area, subsurface flow intercepted by impervious surfaces rapidly runs into watercourses, increasing flood risk.
Increased impervious surface cover and road construction also increase sediment supply, delivering pollutants such as pesticides, urban and industrial waste, and agricultural land nutrients to streamflow, affecting riverine habitats and biota (Gravrilescu, 2021).
Regarding the aforementioned dynamics, it is essential to emphasize that, contrary to common planning practices of the last two centuries, rivers are not mere water collectors. They naturally fulfil a range of geomorphological, hydrological, and biological processes, including erosion and sediment transport, nutrients and organic matter distribution, providing vital conditions and habitats that are essential for ecosystem functions, including feeding and reproduction (Guimarães et al., 2021). In natural conditions, riverine landscapes continuously change due to normal habitat variation dynamics, such as discharge, bank erosion, bar deposition, and lateral channel migration (Harrison et al., 2015). All of these determine the biological diversity of floodplain habitats. Habitat and biological diversity are supported by specific riverbed forms and channel features such as depth, velocity, and roughness (McCabe, 2011). Environmental changes, channel structure, and floodplain interactions influence erosion, transport, and storage of inorganic and organic matter produced within streams and riparian areas (Harms et al., 2021); however, the pattern and distribution of habitat types remain substantially stable over time. Imbalances are due to anthropogenic activities (Gilvear et al., 2013), threatening river integrity and affecting the structure, flow, and quality of watercourses.

Relevance of process-based river restoration
The last century was characterized by a purely hydraulic and engineering approach to floods: many rivers across the world have been transformed into dystopian symbols just to respond to security concerns against the risk of flooding. One of the most significant examples of such intervention is the Los Angeles River, where, following the devastating 1938 flood, the federal Works Progress Administration and the Corps built a 60km concrete channel aimed at draining storm surges twenty thousand times higher than the river's dry season flow (Gandy, 2006; Gumprecht, 2006). The process of altering rivers for security reasons has created artificial channels that deprive aquifers, prevent replenishment, and contribute to the need to import massive quantities of drinking water. This overlooks the role of wetlands and floodplain ponds – which help to regulate ecological processes, reduce downstream floods, and contribute to slow flows (Moore and Richardson, 2012) – causing the loss of plant and wildlife species and hindering residents from contact with their natural environment.
Relying solely on engineering is now an outdated concept. The protection of high-quality habitats is gaining prominence in urban regeneration politics and practice, where water and vegetation are considered symbiotic agents, promoting an evolution from 'hard' to 'soft' engineering approaches (Plunz, 2017). Interest in river restoration – understood as a set of strategies for rehabilitation, enhancement, improvement, mitigation, and reclamation (Roni and Beechie, 2012) – has considerably increased in recent decades. This emphasizes the urgent need to mitigate the effects of climate change through adaptive solutions. Adaptation strategies aim to restore the natural water cycle and promote water-sensitive cities (Ward et al., 2012). Creating space for water and building resilience to flooding, as well as restoring rivers and catchments to a more natural state, are key strategies for improving the

quality of the environment and biodiversity (McBain et al., 2010). River restoration aims to achieve sustainable flood management, habitat quality and biodiversity restoration, pollution control and cultural awareness promotion. Examples of this approach include the ongoing restoration project of the previously mentioned L.A. River, which involves renovating a continuous riparian ecosystem along the River Corridor (LARRMP, 2007). Similarly, the latest government-led Namami Gange initiative in India aims to protect the Ganges and its tributaries, reforest parts of the basin, restore wildlife species, and promote sustainable farming. Another example is the Seine water improvement, made possible thanks to an important local government investment that aims to make the Seine a swimming river again by 2024 (in time for the next Summer Olympics in Paris). It is noteworthy that the European Commission's 2030 Biodiversity Strategy specifically targets the restoration of at least 25,000 km of rivers as part of the European Green Deal.

Effective international protection can be complex because many countries rely on their rivers for economic benefits. Despite the complexity involved in implementing environmental improvement processes, which are never separate from the economic and social context of an area, the concept of process-based river restoration has become increasingly significant in recent decades. To reduce anthropogenic interferences, there is a strong need to promote the natural processes of river and floodplain ecosystems, integrating different techniques to address the root causes of ecosystem degradation and establish a new balance between socioeconomic needs and sustainable management (Beechie et al., 2010). Process-based restoration methodology strategies promote the recovery of river-floodplain ecosystems over the short, medium, and long term (Gilvear et al., 2013). These strategies support the regulation of runoff, sediment supply, hydrology, as well as habitat and water quality improvement. By orienting regulatory frameworks and planning policies to reduce anthropogenic pressure on water bodies, greater results can be achieved, making the system self-sufficient without requiring human maintenance (Moore and Rutherfurd, 2017).

Implementing Nature-Based Solutions (NBS), a stormwater management approach that mimics natural hydrologic processes, by prioritizing multi-disciplinary landscape management of waterways is critical to achieving a sustainable regeneration strategy, especially in the long term. Restoration initiatives can contribute to increasing biodiversity in urban areas, but in a built environment, they can help also to integrate human presence as a significant part of a quality urban landscape. It is well-established that the shape of a watercourse can provide a pleasant space for city dwellers and visitors who can perceive the characteristics of a vital environment and rich ecology, translating it into positive signals for the psyche and health, with restorative and revitalizing effects on human beings.

To achieve this goal, multiple strategies are required: stormwater management, erosion and flood control, ecosystems and water quality rehabilitation, land use planning, and social opportunities development. Waterways should be managed with a holistic approach that considers "scenic and cultural values, wildlife resources, and recreational potential, as well as appropriate industrial, agricultural, and commercial development" (ASLA, 2020). Establishing greenways, blue ways, and trail linkages are tools that can help protect and promote watercourses. Promoting collaborations between landscape architects, urban planners, architects, ecologists, and hydraulic and hydrogeological experts is the best way to address the complex processes of waterways.

Effective techniques should be designed at different scales: at the reach scale, habitat improvement (e.g., channel re-meandering, planting, grazing removal) can be implemented, while at the watershed scale, connectivity restoration (e.g., barrier removal, levee setbacks, fish passage) or improvement of hydrological processes (e.g., stormwater runoff regulation, instream flow control) can be successfully executed. Long-term and short-term strategies should be combined to integrate initial benefits with the system's resilience capacity enhancement. Therefore, a landscape-based approach to river restoration should not be only intended as a design but essentially as a vision of the processes an intervention can initiate, both for the economic-social and environmental effects. A holistic approach considers the whole system and its interactions, rather than just the individual parts and is process-based rather than singular problem-solution oriented. Perceiving critical issues as opportunities to organize more suitable conditions for life can generate a vast field of interdisciplinary and interconnected strategies. In this framework, flood defence structures can encompass only one aspect of the multifaceted features of the riverine landscape: morphology, water quality and treatment, vegetation, and biodiversity can all contribute to restoring the aesthetics of a river or stream space.

Restoring connectivity within settled or urbanized areas

From a functional point of view, operating in settled areas means working on river connectivity. Connectivity restoration includes modifications to river channels, adjacent riparian zones, and inputs of water, sediment, and solutes to rivers (Wohl et al., 2015). Restoring connectivity in all its dimensions, longitudinal (upstream-downstream), lateral (floodplain-riparian area) and vertical (hyporheic zone-subsurface area), requires a reactivation of organic material, sediment, and nutrient transport and reconnection of lateral habitats. This involves reinstating a natural hydrologic regime through channel reconstruction and riparian planting (Roni and Beechie, 2012). Longitudinal connectivity can be restored by removing dams, culverts, and bridges. Lateral connectivity can be improved by restoring links between the river channel and its floodplain, increasing natural exchanges between surface and subsurface flow, natural erosional/sediment deposition, organic matter retention, and channel migration processes. Specific strategies include enhancing bank stability and instream conditions by restoring the natural sinuosity and creating structures (i.e., pools, riffles, new floodplain habitats) which can increase complexity and improve riparian habitat diversity. Removing bank armouring, when possible, can be an effective technique to restore channel migration and other floodplain processes. Ultimately, levee removal, lowering or setback allows the river to migrate or meander and connect to the adjacent floodplain to fulfil natural riverine functions (Roni et al., 2008; Duda et al. 2022).

Many restoration techniques are available to adjust channel morphology. Bioengineering techniques should be preferred, where possible, to stabilize banks reducing erosion while improving riparian habitat. This approach (which in Europe is in use since the beginning of the twentieth century) employs a combination of natural materials such as wood (e.g., logs, trees, fascines), living plants (live bush stakes, live branches, willow bundles, cuttings), rocks, and natural-fibre mats to stabilize non-cohesive riverbanks controlling erosion until riparian vegetation grows. However, not all of these techniques are always recommended in an urban environment: the suitability should be evaluated in relation to the context and place, avoiding standardized solutions.

Those interventions not only regard structural engineering but include other aspects of river management as long-time key strategies that focus on long-term improvements to river environments, habitats, water quality, river recreation, and livelihood (Basak et al., 2021). In heavily urbanised areas, where waterways have often been piped or buried to make space for urban settlements, there is a widespread need to uncover rivers and redesign their banks. Cement banks cause habitat loss, considering that within most urban contexts the instream habitat is poor, with decreased water quality (Reich and Lake, 2015). Thus, restoration practices focus mainly on naturalizing banks by eliminating hard structures and redesigning vegetated banks and meanders. Also, there is a strong need of promoting access to water and public space.

Urbanization, coupled with the negative effects of climate change, exacerbates the impact of impervious surfaces, leading to a significant rise in the frequency and magnitude of peak flows. Thus, it is imperative to manage frequent and extreme hydrological events in urban areas. Regenerating riverscapes can be truly effective by paying careful attention to the water cycle in all its phases, primarily through the sustainable management of rainwater. Streams cannot always repair problems created at large scales (Ernhardt and Palmer, 2011); hence, the focus should shift to stormwater runoff treatment and control to improve natural hydrology, balance sediment supply, and reduce pollutant levels. These goals can be achieved by reducing the number of impervious surfaces and filtering or treating stormwater to improve water quality in order to delay stormwater arrival into water bodies.

Blue-green approaches to flood risk management can be useful to shift from the idea of flood defence to water management with particular attention to biodiversity and cultural values (Wright et al., 2011). Green and Blue Infrastructure (GBI) implementation, reducing runoff and soil erosion and increasing infiltration through recharging the urban groundwater aquifer (Davis and McCuen, 2005) both in new settlements and in existing urban areas is a growing practice in many cities worldwide. Retrofitting existing urban developments with rain gardens and vegetated swales can reduce storm flows by up to 70% (Song, 2022). Furthermore, GBI implementation can contribute to creating an ecosystem which is more self-sustaining and resilient to perturbations. These kinds of NBS need to be conceptualized and shaped according to the site and adapt to climatic conditions and rainfall regimes, as well as to the specific architectural context of cities. This represents the possibility for further and interesting developments in landscape architecture.

It is worth noting that stream rehabilitation may seem to have little effect on natural processes and habitat within heavily urbanized areas, but it can help to radically change people's perception and experience of rivers. If complete long-term stream rehabilitation is not always feasible under urban constraints and river restoration plans and programs can only partially achieve all the objectives of naturalization, it is notable that local-based habitat improvement can achieve some ecological benefits (Walsh et al., 2005). On the other side, if the potential for ecological restoration is limited, social benefits can be a significant motivation for restoration. Those should be integrated within urban revitalization initiatives to enhance the urban landscape and reintegrate the river as part of it (Guimarães et al., 2021). Environmental projects such as the restoration of an urban river waterfront in low-income neighbourhoods are evaluated for their successful impact on the local community, particularly in the USA. Therefore, river restoration projects with quality, innovation, and social and environmental implications should be recognized, as they contribute to the community's well-being and integration. Not by chance the 2023 ASLA-NY Honor Award has just been awarded to a river restoration project (Ferry Point Park East Waterfront in Bronx, NYC), focusing on habitat creation, resiliency, and wetland restoration.

Design strategies and tools for urban-river regeneration within urbanized areas

In heavily urbanized areas, streams and river restoration offers the opportunity to integrate ecolog-

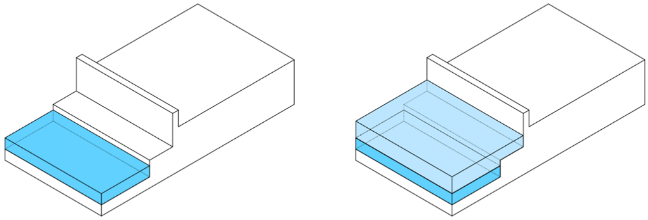


Fig. 1 – Submergible Riverside Paths. (Author's elaboration).

ical and social instances, biological and aesthetics needs with landscape design to achieve more sustainable territories and cities. A range of strategies can be implemented and combined to create space for water, while simultaneously enhancing ecological values and creating public space. The following projects serve as examples to clarify various techniques used to restore connectivity, improve accessibility to water, and provide flood protection while enhancing ecological conditions.

While the references provided are not all-encompassing solutions, they offer simple design tools

Fig. 2 – Allegheny River, Pittsburgh (Photo: 2008, flickr.com/photos/onasill/ | CC BY-NC-SA 2.0)

Fig. 3 – Access to Water through Ramps. (Author's elaboration).

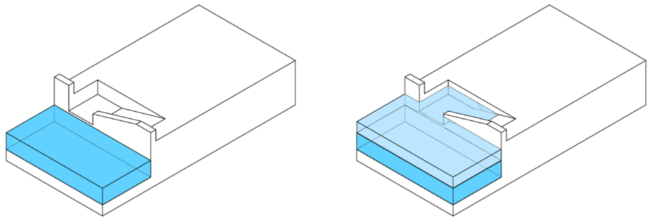
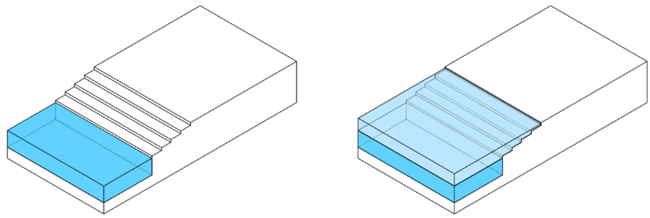


Fig. 4 – Terracing Riverbank Walls. (Author's elaboration).



that can be incorporated and integrated into the design process. They can be adapted to the site and used to create an integrative approach to different aspects, such as flood protection, improved ecological conditions, and amenity. The interventions and tools are presented here from the smallest to largest scales and from the least influential on morphodynamical processes to the most influential, taking into consideration the context of urban rivers where complete restoration of all natural processes may be difficult to achieve.

Firstly, to improve accessibility several measures can be implemented. The creation of submergible riverside paths, for example, can enable people to walk along a river's edge and enjoy access to water even if the banks are very steep and there is no riparian strip or available flood area (fig.1). These interventions have completely transformed the urban experience of rivers in heavily urbanized areas (e.g., Allegheny River in Pittsburgh, fig. 2).

As an alternative, continuous vertical limitations at the level of the banks can be interrupted only at select points by creating a few accesses to water through a ramp ending in a waterside area sloping towards the river (fig. 3). If it is possible to make space for a beach, it can serve as a small habitat for ecological diversity. This measure has been successfully implemented, for example, at Limmat River in Zurich, where a former canal has been reshaped to provide more natural access to water.

When there is enough space, it is possible to intervene by terracing the riverbank walls in certain sections (fig. 4). Terraces can offer a pleasant transition to water, providing opportunities for several different uses: access to the river, recreational areas, and space for plantings. Such interventions have been successfully implemented in cases such as the Rhône in Lyon, Spree in Berlin, and Rio Manzanares in Madrid (fig. 5,6,7). These interventions greatly improve the amenity of a riverine landscape, yet with a limited impact on the river morphodynamical processes.

To improve ecological conditions along the edge of a watercourse, a new substrate can be added and planted to make riverbanks suitable for plant colonization, creating a semi-natural riparian corridor

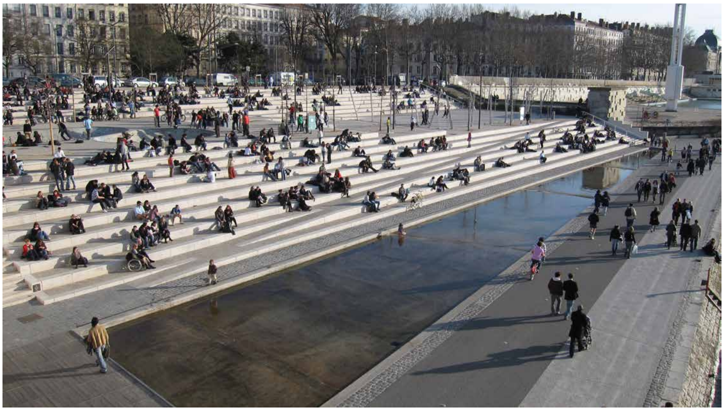
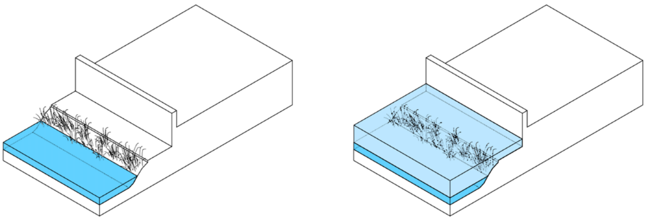


Fig. 5 – Rhône River, Lyon (Photo: 2009, flickr.com/photos/donna/ | CC BY-NC-SA 2.0) .

Fig. 6 – Spree River, Berlin (Photo: 2006, flickr.com/photos/gertrudk/ | CC BY-NC-SA 2.0).

Fig. 7 – Rio Manzanares, Madrid (Photo: 2011, flickr.com/photos/lacittavita/ | CC BY-NC-SA 2.0).

Fig. 8 – Implementing a Semi-Natural Riparian Corridor. (Author's elaboration).



(fig.8). This simple ecological connection creates stepping-stones for different species of amphibians and birds. Examples of this type of intervention at different scales include the Seine at Choisy le-Roi in Paris, where a submergible planting marginal area is located between the riverside and its boardwalk, and the Leutschenbach River in Zürich, where reinforced embankment-vegetated walls with pebbles have brought the canal back to a more natural appearance (Prominski et al., 2017).

In Zürich, a recent stream restoration project called the Zürich Stream Daylighting Program aims to reopen and 'daylight' as many streams as possible, with the goal of enhancing ecological and recreational values within the city's urban area (Loritz et al., 2016). De-culverting, or uncovering and daylighting, urban rivers is a multifaceted intervention that addresses the diversion and culverting of rivers for urban development purposes. It encompasses the process of exposing buried watercourses and restoring them to a more natural state. These projects can range from basic de-culverting by removing the concrete covering to more extensive reconstruction of river banks and beds (fig.9) (Wild et al., 2011). Alongside well-known examples like Cheonggyecheon in Seoul (fig.10), there are numerous instances of uncovered rivers in Western and Central Europe, such as Panke in Berlin, Soestbach in Soest, and Emscher (upper section) in Germany, Bièvre in Paris, Dyle in Leuven, Woluwe in Brussels, and Quaggy in London (Wantzen et al., 2022). Recently, a de-culverting strategy has been successfully implemented in the city of Oslo, focusing on major streams such as the rivers Akerselva, Alna, and Hovinbekken (fig. 11).

Reprofiling the dike section, if it is physically possible and safety has been ensured, is a crucial design tool that can yield multiple benefits, such as enhancing naturalness, creating public spaces and improving the landscape (fig. 12). With the aim to create flood areas that are also suitable for recreational purposes, the riparian landscape can ex-

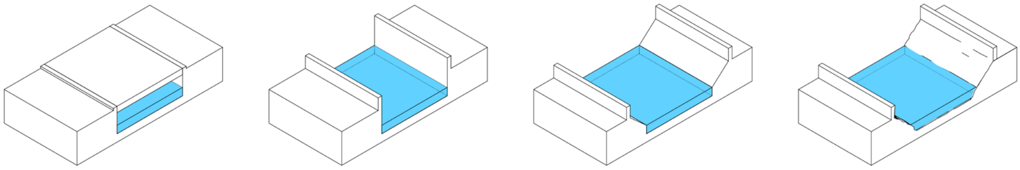


Fig. 9 – Deculvertisation: From Simple Removal of Overhead Structures to Regrading Banks and Profiling Channels. (Author's elaboration).

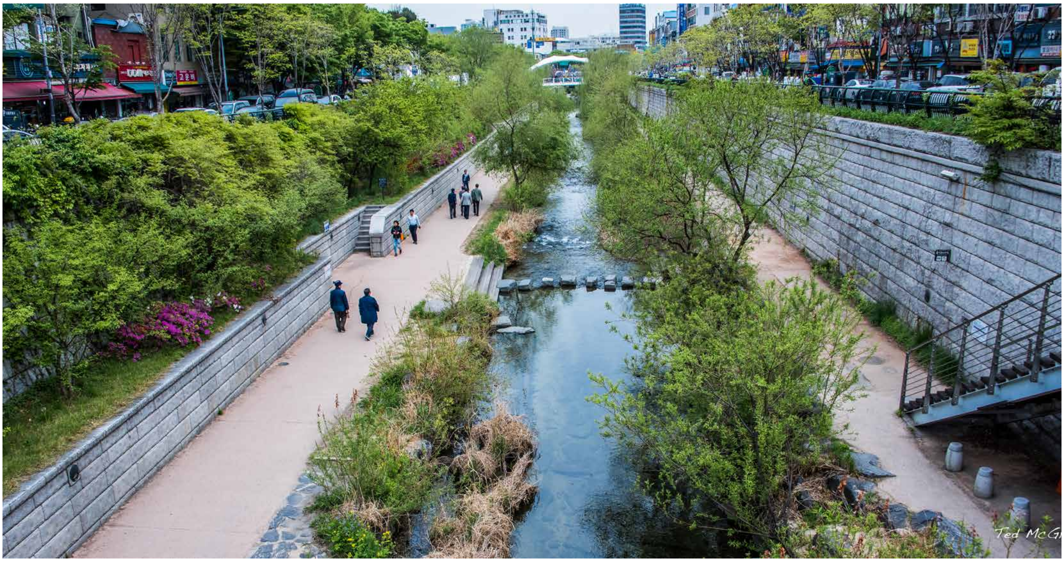


Fig. 10 – Cheonggyecheon Stream, Seoul
(Photo: 2017, flickr.com/photos/tedmcgrath/ | CC BY-NC-SA 2.0).

Fig. 11 – Hovinbekken River Park (Photo: 2022, hovinbekken.org).

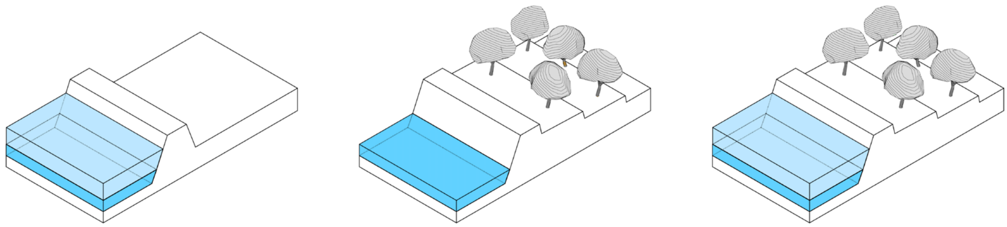


Fig. 12 – Reprofiling Dike Sections. (Author's elaboration).

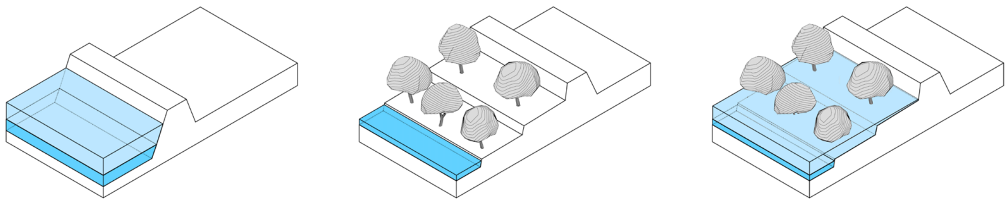


Fig. 13 – Creating Space for Flood Areas. (Author's elaboration).

pand, facilitating the recovery of dynamic morphological processes on a larger scale (fig. 13). Shaping the dike in such a way that it creates specific areas that experience seasonal flooding allows for land to be submerged during certain periods of the year, but also makes it possible to plan and utilize the land for public purposes when it is not flooded. Periodic flooding helps preserve natural processes and habitats and provides opportunities for recreational activities such as submersible meadows. In China, large-scale projects have been implemented incorporating submersible parks such as the Red Ribbon in Qinhuangdao, Minghu in Liupanshui, Houtan and Yangpu Riverside in Shanghai, and Yanweizhou in Jinhua City. These flood areas, designed wetlands, and Blue-Green infrastructures were established to address China's significant impact from climate change (Palazzo and Wang, 2022). Natural-based design solutions that focus on regenerating riverine ecosystems by integrating natural, agricultural, and urban landscapes are recently gaining attention likewise in highly degraded territories in the Nile Delta in Egypt (Fouad et al., 2022). Similarly, this approach was used to design Kallang River Park in Bishan, Singapore (fig. 14). Europe has several examples of parks provided with large flood plains, including the river parks of Ebro in Zaragoza, Turia in Valencia (fig. 15), Besòs in Barcelona, Rhine Koller Island Polder in Brühl, Neckar Green Ring in Ladenburg, and Parc de la Gironde in Coulaines.

The Elbe catchment represents a significant case study for large-scale river restoration within the European Union. Over the past decade, numerous interventions have been implemented to attain and maintain the good ecological status of water, as required by the Water Framework Directive for all surface water bodies by 2027 (European Commission, 2000). These interventions include floodplain restoration, the connection of oxbow lakes to rivers, transverse structure removal, and the reduc-

Fig. 14 – Kallang River, Bishan (Photo: 2013, flickr.com/photos/jan/ | CC BY-NC-SA 2.0).

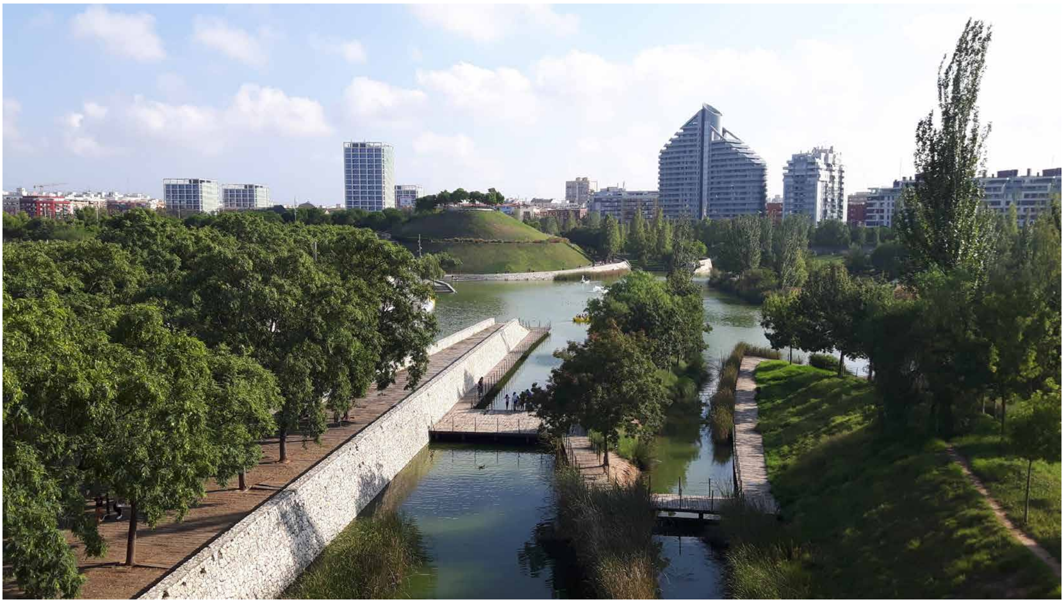


Fig. 15 – Turia River Park, Valencia (Photo: 2016, flickr.com/photos/borisdzhingarov/ | CC BY-NC-SA 2.0).

tion of nutrients and pollutants. As a result, the Elbe is now a rare European case of a free-flowing river along its 622 km main course, with many floodplains that are recognized as hotspots of biodiversity (Wachholz et al., 2022), and quality public space has been implemented in more urbanized areas such as HafenCity in Hamburg (fig. 16). Likewise, the River Thames is poised to become the next focal point for large-scale landscape restoration through the London Thames Gateway project. This initiative holds significant importance for sustainable development and growth in the capital, having been prioritized by the national government, beginning with the regeneration of the East London Olympics in 2012. Furthermore, when discussing significant river restoration projects, it is crucial to acknowledge the commendable efforts of the Netherlands. The Dutch government initiated the Room for the River Programme in 2007, with the objective of effectively managing rising water levels in rivers. This comprehensive program encompassed a multitude of measures, including the reduction of floodplain levels, construction of water reservoirs, relocation of levees, improvement of side channel depths, and establishment of flood bypasses. Spanning across 30 projects, the majority of them were successfully completed by the end of 2018. The overarching goal of the program was to establish sufficient room for the safe flooding of the four rivers, namely Rhine, Meuse, Waal, and IJssel, at over 30 locations. The implemented measures were also devised to enhance the overall quality of the surrounding areas.

Conclusions

Regenerating water systems in urban areas through river restoration interventions, GBI, and NBS offers an opportunity to enhance the cohesion of fragmented urban and peri-urban landscapes. By restoring connectivity, accessibility, and perception, these interventions can rehabilitate these areas and give rise to new centres of activity. These multifaceted processes necessitate careful consideration of urban, landscape, environmental, and ecological transformations, and may require significant interventions such as reorganizing infrastructure, production, and transportation systems.

Landscape design should consistently strive to enhance the ecological cycle, necessitating caution regarding standardized solutions. Instead, the landscape should be regarded as a strategic element, taking into account its impact on human perception. To foster public awareness of natural dynamics, designers can harness the essential processes of erosion and deposition that naturally occur along waterways. For instance, in the River Aire restoration project in Geneva, designed geometrical patterns in the riverbed demonstrate the natural process of water finding its way, highlighting the relevance of fluvial geomorphology. This is a key example of contemporary landscape design letting nature develop its forms without imposing a completely predictable plan. On the contrary, coastal regeneration practices are often regarded as icons intended to enhance standardized aesthetic values in cities, thereby carrying the inherent risk of uncritically adopting preconceived solutions, which could potentially lead to a widespread Westernization (Tort-Donada et al., 2020).

If the separation between soil and water could ultimately be considered a human abstract concept used to define an ecosystem that is neither strictly land nor water, but one that is characterized by ubiquitous wetness, where rain is held and transformed into life (Da Cunha, 2018), river restoration and design strategies should be examined in light of a comprehensive understanding of the role of human intervention. It would be appropriate to critically reconsider the ongoing debate and the most recent perspectives on landscape-based river restoration and management, particularly in relation

Fig. 16 – HafenCity, Hamburg (Photo: 2008, flickr.com/photos/m.prinkle/ | CC BY-NC-SA 2.0).

to the concept of Capitalocene (Moore, 2016). This controversial term finds the roots of the actual condition in the Western world starting from the sixteenth century, with the capitalist system systematically exploiting human and environmental resources. If, in this conceptual framework, river retrofitting could reproduce a nostalgic form of relationship that paradoxically reaffirms a nature-culture separation, awareness of this particular risk should inform the guiding principles of contemporary design. Therefore, according to the latest perspectives on river restoration and care, deconstruction emerges as a more pressing priority than retrofitting, with the process itself holding even greater significance than the final outcome. A thorough understanding of the environmental and cultural context can prevent design homogenization that fails to consider the unique characteristics of a site. Prioritizing the landscape as a means of restoring water resources is essential for addressing hydrological issues specific to an area without disregarding its formal and spatial dimensions. Landscape architecture, employing a process-oriented design approach and collaborating with ecological, geographical, economic, and social sciences, has the capacity to effectively manage the intricate interrelationships among rivers and the temporal dynamics of urban socio-ecological systems.

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