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EUROPEAN ASSOCIATION OF PUBLIC WATER OPERATORS

WORKING WITH NATURE TO RESTORE THE WATER CYCLE

Good practices from European Public Water Operators

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This document was authored by the Secretariat of Aqua Publica Europea, specifically by Milo Fiasconaro and Marine Boulard. The layout of this publication was designed by Liliana Baracova.

Any mistakes or inaccuracies remain entirely our own.

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AA – Appropriate Assessment

AIP – Autorità Idrica Pugliese

APE – Aqua Publica Europea

APUR – Atelier Parisien d'Urbanisme

AQP – Acquedotto Pugliese

ARS – Agence Régionale de Santé

ATO – Ambito Territoriale Ottimale

BCASA – Barcelona Cicle de l'Aigua

COPIL – Comité de Pilotage

COTECH – Comité Technique

CRU – Commission for Regulation of Utilities

DECLG – Department of Environment, Community and Local Government

EEA – European Environment Agency

EU – European Union

GEMAPI – Gestion des Milieux Aquatiques et Prévention des Inondations

GIS – Geographic Information System

ICW – Integrated Constructed Wetland

MAR – Managed Aquifer Recharge

NbS – Nature-based Solutions

PE – Population Equivalent

PFAS – Per- and Polyfluoroalkyl Substances

PLU – Plan Local d'Urbanisme

RISA – Rain Infrastructure Adaptation

SCI – Site of Community Importance

SDDEA – Syndicat Départemental Des Eaux de l'Aube

SDEA – Syndicat des Eaux et de l'Assainissement Alsace-Moselle

SPA – Special Protection Area

STRB(s) – Sludge Treatment Reed Beds

SuDS – Sustainable Urban Drainage Systems

TOC – Total Organic Carbon

WSSP – Water Sanitation Safety Plan

CONTRIBUTING MEMBERS

Acquedotto Pugliese

- Region of Puglia, Italy
- Population served 4.000.000

Barcelona Cicle de l'Aigua (BCASA)

- Municipality of Barcelona, Spain
- Population served 1.732.066

Brianzacque

- Province of Monza and Brianza, Italy
- Population served 937.790

Empresa Metropolitana de Abastecimiento y Saneamiento de Aguas de Sevilla (EMASESA)

- Sevilla, Spain
- Population served 1.078.869

Gruppo CAP

- Metropolitan City of Milan, Italy
- Population served 1.887.859

Hamburg Wasser

- City of Hamburg, Germany
- Population served 2.300.000

MM Spa

- Municipality of Milan, Italy
- Population served 1.400.000

Piave Servizi

- Provinces of Treviso and Venice, Italy
- Population served 340.729

Réseau 31

- Department of Haute-Garonne, France
- Population served 542.086

SDDEA

- Department of Aube, France
- Population served 346.346

Syndicat des Eaux et de l'Assainissement Alsace-Moselle (SDEA)

- Alsace and Moselle departments, France
- Population served 1.080.000

Sumarte

- Municipality of Arteixo, Spain
- Population served 34.038

Uisce Éireann

- Ireland
- Population served 4.400.000

Viacqua

- Vicenza, Italy
- Population served 544.579

Vienna Water

- Vienna, Austria
- Population served 1.900.000

Ville de Paris

- Paris, France
- Population served 2.113.705

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PREFACE FROM THE PRESIDENT

BERNARD VAN NUFFEL

President of Aqua Publica Europea

The importance of water needs little reminder: it sustains life and ecosystems, supports livelihoods, and shapes the relationship between societies and their territories. But its role goes even further. Water is also at the heart of Europe's competitiveness, as many industries, including those that are key to the green and digital transitions, rely on its availability.

At the same time, water resources and ecosystems are under mounting pressure. Climate change is intensifying droughts, floods, and extreme weather events, while human activities continue to deplete and degrade freshwater systems. According to the European Environment Agency (EEA)'s State of the Water report, 20% of Europe's land and 30% of its population experience water stress annually, a figure set to rise as climate change accelerates.

Against this backdrop, rethinking how we manage our finite water resources is imperative. Unlike other critical resources, water cannot be artificially created in any viable way. Instead, we must improve efficiency, strengthen resilience, and restore the ecosystems on which water depends.

This urgency is reflected in **the European Commission's Water Resilience Strategy**, published in June 2025. One of its core objectives is to repair the broken water cycle, an ambitious goal that recognises the interdependence between healthy ecosystems and water availability. Delivering on this ambition requires coordinated efforts across sectors and scales, with public water operators increasingly called upon to go beyond their traditional mandates and intervene directly in the hydrological system: protecting, managing, and even rehabilitating water-dependent ecosystems. However, this challenge is complex, involving trade-offs between competing demands, political choices, and broader societal well-being. In this context, it is highly relevant to consider how public water operators are rising to the challenge. Aqua Publica Europea (APE), which brings together more than 70 public operators serving around 90 million citizens across Europe, is at the forefront of these efforts. Our members are not only aware of the urgency of the crisis but are also pioneering innovative approaches to help repair the broken water cycle.

Among these approaches are nature-based and hybrid solutions. This publication presents a series of case studies showcasing such solutions implemented by APE members. It illustrates the growing role of public operators in addressing the water crisis, not only by ensuring reliable service delivery, but also by actively supporting ecosystem restoration and strengthening water security across Europe. These case studies show that Nature-based Solutions are efficient, cost-effective, and deliver numerous positive externalities, unlike "grey" solutions (such as stormwater basins, which emit high levels of CO_2). Moreover, they reinforce democratic control by involving local communities.

But for operators to fully assume this role, they must be supported by a conducive governance framework and adequate public funding. As APE, we are committed to contributing to this debate—especially at EU level—through the implementation of the Nature Restoration Law, the Commission's Integrated Framework for European Climate Resilience and Risk Management, and the negotiations on the next Multiannual Financial Framework (MFF). European support will remain essential, not only to enable wider adoption of these interventions but also to address disparities between regions in their capacity to design and implement them.

INTRODUCTION

Water is a resource under strong and growing pressure. In Europe, this is the result of the combined effects of demographic growth, the increasing needs of water-intensive industries, the intensification of agriculture, energy production, mining, navigation, and urban development. Together, these drivers exert significant strain on rivers, lakes, transitional and coastal waters, as well as groundwater bodies.[1] Climate change further exacerbates these challenges by disrupting the hydrological cycle, altering precipitation patterns, and increasing the frequency and severity of extreme weather events such as droughts, floods, and heatwaves.

Healthy aquatic ecosystems are essential for maintaining the water cycle. When these ecosystems degrade, the consequences are felt in both water quantity and quality. This is already happening, and the pressures outlined above are intensifying the damage, driving widespread degradation. As a result, the capacity of these ecosystems to sustain vital ecological functions is undermined and, in some cases, pushed to the point of collapse. In short, we are facing a broken water cycle.

Ensuring the resilience of aquatic ecosystems is therefore critical to safeguarding Europe's long-term water security and climate adaptation. Repairing the broken water cycle requires a fundamental shift in water management, one that confronts key questions: who is responsible for restoring degraded ecosystems? What does "repairing" mean in practice? And how can such interventions be effectively implemented when responsibilities are fragmented?

Traditionally, water operators have managed specific segments of the water cycle: abstracting and treating water for drinking purposes, and collecting and treating wastewater before releasing it back into the environment. Today, they are increasingly called upon to intervene in areas that fall outside their historical mandate, especially where ecosystem restoration is required. This shift demands adaptation as well as new skills and expertise. Operators are now exploring a wide variety of approaches that work with nature or combine natural and engineering methods, including Nature-based Solutions (NbS) and hybrid solutions.

For water operators, nature-based and hybrid solutions offer powerful and cost-effective tools to address a wide range of water-related challenges. Through NbS (such as wetlands or green urban infrastructure), or hybrid solution (combining "green" and "grey" infrastructures), operators can mitigate floods and droughts, improve water quality, and reduce long-term operational costs. These interventions also deliver broader co-benefits, including carbon sequestration, enhanced biodiversity, increased recreational and aesthetic value, and strengthened community resilience.

Yet integrating nature-based and hybrid solutions into traditional water management is far from straightforward. Their relative novelty, the complex governance arrangements they may require, and the absence of standardised assessment metrics can all hinder adoption. Moreover, although EU-level regulations referencing NbS exist—such as the Nature Restoration Law, the revised Urban Wastewater Treatment Directive, and the recast Drinking Water Directive—they have not yet translated into enabling governance frameworks on the ground in many contexts.

Despite these limitations, the uptake of NbS is growing. This publication aims to showcase best practices from Aqua Publica Europea members who are actively implementing both NbS and hybrid solutions (even though the boundary between the two is not always clear-cut) in response to concrete challenges. Through specific case studies, we illustrate how public operators are applying these approaches in real-world contexts. In addition to outlining the objectives and nature of each intervention, we also provide information on the governance architecture underpinning their implementation, as well as the funding mechanisms involved.

By presenting these examples, we aim to highlight not only the potential of nature-based and hybrid solutions, but also the challenges and complex arrangements they entail. Our goal is to foster peer learning within the public water sector and to contribute to the broader policy dialogue.

I. Working with nature

I. WORKING WITH NATURE

In this chapter, we present projects that aim to repair the broken water cycle, either by working with and through nature—via the restoration of freshwater ecosystems and the protection of water resources, or by applying green engineering solutions that mimic natural processes, such as Sustainable Urban Drainage Systems and nature-based approaches to wastewater treatment.

Ecosystem restoration

Ecosystem restoration is defined as "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed. Restoration involves active measures that seek to assist recovery of native ecosystems and ecosystem integrity. Restoration is therefore a deliberate process (that can involve a range of different activities), and the recovery of ecosystem integrity (i.e. ecosystem functions), the desired outcome. Restoration is a means by which socio-ecological resilience can be strengthened"[2].

For water operators, restoration efforts typically focus on aquatic ecosystems, especially rivers, wetlands, and riparian zones. These actions often involve restoring or re-naturalising riverbeds, improving flow regimes, or replanting vegetation along watercourses. In some cases, operators also take broader measures, such as revegetation and slope stabilisation, to help mitigate flood risks and combat soil erosion.

Restoring aquatic ecosystems offers operators a range of benefits: it improves upstream water quality, reducing the need for intensive treatment; it enhances flood management by increasing natural water retention; and it helps stabilise catchments, thereby lowering operational risks and long-term costs. Restoration also contributes to groundwater recharge, reduces sedimentation, and fosters biodiversity—all of which support more resilient and sustainable water services.

CASE STUDY

Renaturalisation of the Besòs River

(Barcelona Cicle de l'Aigua (BCASA), Spain)

Ajuntament de Barcelona | Barcelona Cicle de l'Aigua SA

Location

What it is about

The project aims to relieve human-induced pressures on the Besòs River ecosystem, restoring its natural functions and capacity for self-regulation.

Financing

Primarily funded by the EU through the Next Generation EU Funds – Recovery, Transformation, and Resilience Plan. Additional financial support is provided by the Diputació de Barcelona and the Ajuntament de Barcelona.

Parties involved

Collaboration between multiple stakeholders, including the City of Barcelona, local municipalities, environmental organisations, and scientific institutions. Various government bodies are responsible for different phases of the project.

The Besòs River flows through Catalonia, Spain, and ends in the Mediterranean Sea. It has been significantly affected by urbanisation, industrialisation, and human intervention, leading to habitat degradation, reduced biodiversity, and impaired ecosystem functions. This renaturalisation project seeks to restore the ecological integrity of one of Catalonia's most important waterways.

To achieve this, the initiative aims to reduce human-induced pressures on the Besòs River ecosystem, allowing it to function and self-regulate more naturally. It is structured into three phases, each targeting a different section of the river.

Phase 1 (2021–2022), covering the stretch from Pont Vell to Can Zam, focuses on improving ecological connectivity between the Collserola and Marina Mountain range natural parks, enhancing conditions for the European eel population, restoring lost wetland habitats, gradually eliminating exotic and invasive flora and fauna, and creating an educational space for citizen science and community outreach. Key actions include the creation of a river meadow with access to an educational lagoon, and the development of artificial lagoons serving as biodiversity reservoirs. As of January 2025, 65% of this phase has been completed, with finalisation expected by 15 March 2025, at a total cost of €806,298.17.

Phase 2 (2023–2025) focuses on establishing an ecological corridor between the Besòs River and Can Zam along both margins. The aim is to improve the continuity of natural habitats along the riverbanks, promote ecological connectivity between green spaces, enhance the river's natural capacity to filter pollutants, and provide safe, accessible pedestrian and cycling paths. Key interventions include the development of a pedestrian and cycling route and the creation of a biodiversity refuge. The estimated cost for this phase is €3,014,755.20, with work expected to begin in February or March 2025.

Phase 3 (2025–2027) will extend restoration efforts from Can Zam to Montcada i Reixac. The objective is to enhance climate resilience by improving the river's natural flood regulation capacity, while fostering long-term community stewardship of its ecosystems.

CASE STUDY

Restoration of the Souffel River

(Syndicat des Eaux et de l'Assainissement Alsace-Moselle (SDEA), France)

Location

What it is about

The project focuses on restoring the natural dynamics of the Souffel River by reversing decades of degradation, re-establishing ecological functions, and reducing flood risks.

Financing

Funded by SDEA, supplemented by an 80% subsidy from the Rhin-Meuse Agence de l'Eau (Water Agency).

Parties involved

Under the framework of the Souffel 2027 partnership programme: local elected authorities, farmers, citizens, the Chamber of Agriculture, the Rhin-Meuse Agence de l'Eau, departmental services. SDEA designed and delivered the restoration works.

The Souffel River is a 25-kilometre-long watercourse located in the Bas-Rhin department of the French Grand Est region. Over the years, it had become heavily degraded and artificially constrained due to historic land use, channelisation, and low flows, which had severely impacted its ecological and hydro-morphological integrity. To reverse this trend, the multi-partner Souffel 2027 programme was established in 2013 to coordinate restoration efforts across the basin.

The project pursued three main goals: improving water quality impaired by erosion and sedimentation, increasing ecological diversity by restoring natural river functions, and reducing flood risks by providing space for the river to expand naturally.

Restoration activities focused on rehabilitating the hydro-morphological dynamics of the Souffel by reintroducing natural meanders and reshaping the riverbed to restore flow variability. Riparian zones were replanted with native vegetation to stabilise banks, improve habitat connectivity, and foster biodiversity. Importantly, floodplain areas that had previously been used for intensive maize cultivation were transformed into meso-hygrophilous meadows—wet grasslands with plant species adapted to periodic flooding. These meadows serve as natural flood buffers, allowing the river to overflow safely during high-water events while also enhancing groundwater recharge and filtering sediments.

This transformation was undertaken in close collaboration with local farmers, ensuring that they were fully involved in and supportive of the project. Such collaboration was a key factor in the success of the restoration of the Souffel River, alongside the active participation of a wide range of stakeholders, including local authorities, citizens, and community organisations.

Restored section of the Souffel River showing remeandered channel, floodplain meadow, and vegetated buffer zones, designed to enhance biodiversity, improve water quality, and reduce flood risks.

CASE STUDY

LIFE ARTISAN Project – Combating Soil Erosion

(Syndicat des Eaux et de l'Assainissement Alsace-Moselle (SDEA), France)

Location

What it is about

The project tackles soil erosion and climate-related flood risks by restoring natural hydrological processes, promoting sustainable land use, and implementing NbS to protect water quality and agricultural resilience.

Financing

Funded under the EU's LIFE ARTISAN programme, which supports climate change adaptation through NbS. Co-financing is provided by the Agence de l'Eau (Water Agency) and local government entities.

Parties involved

Led by SDEA, in collaboration with local authorities, the Chamber of Agriculture of Alsace, local farmers, and scientific experts. Additional technical support is provided by other regional partners.

The LIFE ARTISAN project addresses the growing risks of soil erosion and water pollution linked to climate change in the Alsace region. Intensive agriculture, extreme weather events, and the disappearance of natural landscape barriers have accelerated mudslides, sediment runoff, and flooding, threatening local water quality and ecosystems.

To counter these challenges, the project implements a combination of landscape restoration and soft hydraulic engineering measures. A central objective is to restore natural hydrological cycles by reintroducing vegetation and structures that slow surface runoff, trap sediment, and stabilise soils. In Alsace, the dominance of spring crops such as maize and sugar beets leaves vast areas of farmland exposed during critical periods, increasing the risk of erosion. This vulnerability is exacerbated by traditional practices such as deep ploughing, which further reduce the soil's capacity to retain water.

The project therefore promotes sustainable land management techniques, including no-till farming, intercropping, and the use of buffer strips, all of which help retain soil moisture and prevent erosion. More than 62,000 native trees have been planted across strategic locations to form dense hedgerows and reforested zones that act as natural barriers against surface runoff. Species like Cornus sanguinea, Corylus avellana, and Prunus spinosa were selected for their ability to stabilise soil while also providing habitat for wildlife and pollinators. To ensure long-term success, dedicated maintenance programmes have been put into place, including regular weeding, selective pruning, and staggered trimming to maximise biodiversity benefits.

Beyond reforestation, the project integrates a range of soft hydraulic solutions. These include fascines (bundles of branches placed to slow the flow of water), sediment retention basins, and vegetated swales, all designed to help retain excess water upstream and to allow sediment to settle before runoff reaches rivers and urban areas. Wetland restoration has also been carried out in key flood-prone zones, further enhancing the landscape's capacity to absorb and regulate water flow.

Miscanthus hedge from 2020

Stakeholder engagement and governance are central to the project. Landowners, farmers, and municipal authorities are actively involved through structured governance bodies: steering committees (COPIL) and technical working groups (COTECH). Farmers receive tailored advice on sustainable practices, while municipal planners integrate project outcomes into wider regional climate adaptation strategies.

CASE STUDY

LIFE SORBA Project – Renaturalising the Sources of the Bacchiglione River

(VIACQUA, Italy)

Location

What it is about

The project restores the natural hydrology and biodiversity of the Bacchiglione River sources by rehabilitating former fish farming land within protected habitats, re-establishing wetland ecosystems, and creating ecological corridors to support species conservation and public awareness.

Financing

Originally funded by the EU, it now continues without EU funding.

Parties involved

The Province of Vicenza (lead partner), the Consorzio di Bonifica Alta Pianura Veneta (public water management consortium), the Regional Forestry Service, Veneto Agricoltura (Regional agency for agriculture), and the Municipalities of Dueville, Caldogno, and Villaverla (co-financiers). Acque Vicentine (now VIACQUA) was one of the project stakeholders.

Implemented between 2011 and 2013, the LIFE SORBA Project (LIFE09 NAT/IT/000213) restored the natural hydrological and ecological functions of the Bacchiglione River sources, one of Europe's most significant resurgence rivers. The initiative transformed 20 hectares of former fish farming land into a thriving natural ecosystem.

The intervention took place in a protected area near Dueville, in the Veneto region of northern Italy, within two Natura 2000 sites: a Special Protection Area (SPA) and a Site of Community Importance (SCI) under the EU Habitats Directive. Of the total area, 18.4 hectares had previously been dedicated to fish farming but were later abandoned. In 2010, the Provincial Administration of Vicenza purchased the site and launched a large-scale restoration project to recover key wetland and riparian habitats, including alder and ash-dominated alluvial forests, clear freshwater streams with submerged vegetation, and moist meadows.

Decades of fish farming had severely altered the environment. Numerous natural springs had been submerged, disrupting the local water balance, while over 20 hectares of wetlands were cemented, leading to a loss of hydrological diversity. These modifications caused a decline in biodiversity due to the destruction of critical wetland habitats and a significant release of nutrients and contaminants into the surrounding environment.

To reverse these impacts, the project undertook extensive restoration measures. The paleo-riverbed of the Bacchiglione River was reshaped, and long-obstructed spring heads were reopened. In addition, the Provincial Administration acquired 7.6 hectares of land outside the fish-farming area but still within the Natura 2000 site. This land was restored as an ecological corridor connecting to the 20-hectare Bosco del Centro Idrico di Novoledo biotope. The corridor was rehabilitated by reintroducing riparian wet woodlands, freshwater riverine habitats, and meso-hygrophilous meadows.

Targeted conservation measures supported key species, including the fish Cottus gobio, the amphibian Rana latastei, and bird species such as Alcedo atthis (Common Kingfisher), Nycticorax nycticorax (Black-crowned Night Heron), Egretta garzetta (Little Egret), and Circus aeruginosus (Western Marsh Harrier).

Alongside ecological restoration, the project strengthened scientific understanding of local vegetation and wildlife, while also raising public awareness. Educational trails were created to enable controlled public access, with a particular focus on engaging school groups.

Since 2022, under a formal management agreement with the Province of Vicenza, VIACQUA has been designated as the full manager of the restored area until 2036.

CASE STUDY

Arteixo River Restoration and Flood Mitigation Project

(SUMARTE, Spain)

Arteixo / Sumarte

Location

What it is about

The project addresses increasing urban flood risks in Arteixo by restoring natural river dynamics, enhancing water retention capacity, and integrating ecological and climate-resilient infrastructure into the urban landscape.

Financing

Publicly funded with a total investment of €1,568,398. The funding covers engineering works, ecological restoration, and long-term monitoring. Resources were allocated through municipal budgets, with additional support from regional water management programmes.

Parties involved

Led by the Municipality of Arteixo, which is responsible for planning, implementation, and long-term maintenance. Local environmental agencies and hydraulic engineering experts contributed technical knowledge on river restoration and hydrological modelling. The project also involves collaboration with landowners and engagement with local communities.

The municipality of Arteixo, located in the province of A Coruña in Galicia, northwestern Spain, has long faced recurrent flooding. Contributing factors include high urbanisation, inadequate drainage systems, and the alteration of natural river flows. With climate change intensifying extreme rainfall events, flood risks have increased significantly. To address these challenges, the Arteixo River Restoration and Flood Mitigation Project was launched to reintegrate natural water retention mechanisms, restore ecological functions, and strengthen flood resilience across the urban and peri-urban landscape.

Key actions included recreating natural floodplains, improving river connectivity, and integrating retention areas to absorb excess water gradually, reducing peak flows and preventing urban floods. Artificial barriers were removed, historic river channels reconnected, and stormwater retention basins constructed to store excess runoff and prevent urban drainage systems from being overwhelmed. These basins were designed to blend with the surrounding landscape, providing hydraulic benefits alongside habitats for wildlife and new public green spaces.

Riverbank restoration was another central measure of the project. Eroded sections were reinforced using native vegetation and bioengineering techniques to prevent further degradation and enhance water filtration. Vegetative buffer strips were planted to stabilise soil, reduce sediment transport, and improve water quality by filtering pollutants before they enter the main watercourse. Riparian ecosystems were rehabilitated along with native plant species to support biodiversity, strengthen carbon sequestration, and increase ecosystem resilience.

Within urban areas, sustainable drainage solutions were implemented, including permeable pavements and green corridors that improve infiltration and reduce surface runoff. Hydrological monitoring systems were also introduced to track water levels, sediment flows, and ecosystem recovery, enabling adaptive management over time.

The project is expected to significantly reduce flood risks in Arteixo by creating a coordinated network of flood retention areas and restored river sections. Beyond resilience and climate adaptation benefits, the creation of green public spaces along the river has improved urban liveability, offering recreational and educational opportunities for residents while reinforcing the cultural and environmental significance of Arteixo's waterways.

Existing dam

Key takeaways

As the examples above show, ecosystem restoration is becoming increasingly strategic for utilities facing the pressures of pollution, climate change, and urbanisation. Restored aquatic ecosystems can improve raw water quality, enhance natural water retention, and reduce the long-term costs of managing climate-related extremes. Restoration is a powerful tool for risk management that also delivers important benefits for nature.

However, implementing restoration projects is not without challenges. River restoration is a complex undertaking, and translating the science into practical, on-the-ground interventions requires new expertise and interdisciplinary partnerships. Notably, it demands early and sustained collaboration with landowners, local communities, and authorities—relationships that often need to be built from scratch and can be politically and logistically difficult to navigate.

There is also a deeper institutional challenge: restoration often falls outside the traditional perimeter of a water operator's responsibilities. Utilities typically focus on the abstraction, treatment, distribution, collection, and discharge of water. In contrast, reshaping rivers, restoring floodplains, or replanting riparian buffers sit upstream, is beyond their mandate. This has contributed to the more limited involvement of operators in large-scale restoration-oriented NbS, compared to more common urban-scale interventions such as Sustainable Urban Drainage Systems (SuDS).

What is often missing is a clear regulatory framework that enables and incentivises operators to engage in upstream restoration. In France, for example, the GEMAPI law has begun to redefine the perimeter of responsibility by assigning aquatic ecosystem management and flood prevention to local authorities, who may then delegate these tasks to their operators. Yet such enabling legislation remains the exception rather than the rule. For ecosystem restoration to become a fully integrated part of water management, operators must be empowered to act beyond their traditional mandates.

Ecosystem restoration offers significant potential to improve resilience, sustainability, and service efficiency. Realising this potential, however, will require a shift in how water services are defined, governed, and implemented. Moving upstream, literally, institutionally, and ecologically, will be essential to meet the challenges of the decades ahead.

Sustainable Urban Drainage Systems

Sustainable Urban Drainage Systems (SuDS) are defined as "approaches to manage surface water that take account of water quantity (flooding), water quality (pollution), biodiversity (wildlife and plants) and amenity. SuDS mimic nature and typically manage rainfall close to where it falls. SuDS can be designed to transport (convey) surface water, slow runoff down (attenuate) before it enters watercourses, they provide areas to store water in natural contours and can be used to allow water to soak (infiltrate) into the ground or evaporated from surface water and lost or transpired from vegetation (known as evapotranspiration)"[3].

In practical terms, SuDS are engineered solutions that replicate the natural water cycle within urban environments. They manage rainwater where it falls, slowing, storing, filtering, and infiltrating runoff rather than simply diverting it into sewers or watercourses. SuDS may include green roofs, permeable paving, swales, rain gardens, detention basins, etc. These elements are often designed to work in combination, addressing multiple stages of the runoff process.

For public water operators, SuDS offer a complementary approach to traditional grey infrastructure. Instead of relying solely on underground networks or storage tanks, SuDS integrate water management into the urban fabric, reducing peak flows, delaying discharges, and improving the quality of water entering the ground and surface bodies. They also reduce the burden on sewer networks, particularly during extreme rainfall events, thereby helping to prevent combined sewer overflows and reduce flood risks.

CASE STUDY

The Sponge Metropolitan City

(Gruppo CAP, Italy)

Location

What it is about

The project applies SuDS across Milan's metropolitan area to transform impermeable urban landscapes into sponges that manage stormwater, reduce flood risks, and enhance climate resilience.

Financing

Co-financed through the European Union's Recovery and Resilience Facility (Next Generation EU), with a total investment exceeding €50 million. A total of 90 site-specific interventions are planned across various municipalities.

Parties involved

Governance is shared between Gruppo CAP (the project operator) and the Metropolitan City of Milan. In addition, 32 municipalities within the metropolitan area are actively participating. The Italian Ministry of the Interior oversees compliance and funding, while regional authorities, urban planners, and local beneficiaries contribute to implementation and ongoing oversight.

The Sponge Metropolitan City project in Milan, Italy, is part of a broader initiative to address climate change and environmental degradation in urban areas. It aims to transform urban spaces from sources of pollution into resilient, environmentally friendly areas capable of absorbing environmental stressors and functioning as urban sponges. The project responds to pressing challenges in the Metropolitan Area of Milan, including natural resource degradation, land fragility, climate impacts, and rising production costs. Completion is expected by 2026.

At its core, the project focuses on implementing Sustainable Urban Drainage Systems (SuDS) to improve water management and sustainability across the metropolitan area. Bioretention areas will filter rainwater and remove pollutants before they enter the drainage system. Detention basins and permeable pavements will help prevent runoff, reduce surface water accumulation, and support groundwater recharge. Tree-lined filtration boxes will absorb water while also greening the urban landscape and improving aesthetics.

Additional measures include the development of green ditches, infiltration trenches, constructed wetlands, and phytoremediation areas, all designed to enhance natural water filtration, improve soil quality, and support biodiversity. Together, these interventions will create a more sustainable urban landscape, better equipped to manage floods and adapt to climate change.

Spanning 32 municipalities, the project features tailored interventions for each locality. Examples include the disconnection of the sewage networks in Varedo, the construction of a municipal car park in Paullo with integrated SuDS, and the creation of a water park in Paderno Dugnano to combine stormwater management with green infrastructure. Other actions involve urban de-impermeabilisation, expansion of non-potable water networks, and strengthening stormwater drainage systems.

By its completion, the project is expected to regenerate around 529,248 m² of urban space and disconnect or de-impermeabilise 344,239 m² of surfaces. This transformation will not only reduce runoff but also deliver significant energy savings with an estimated reduction of 125,775 kWh annually, equivalent to about 11 tonnes of oil.

CASE STUDY

SuDS for Flood Management and Pollution Prevention

Arteixo / Sumarte

(SUMARTE, Spain)

Location

What it is about

The pilot project applies SuDS to reduce flood risks, improve water quality, and create multifunctional green-blue infrastructure that supports biodiversity and urban resilience.

Financing

Funded through a public investment of €854,205, covering engineering design, construction, and long-term monitoring. Funds were allocated specifically to stormwater infrastructure improvements.

Parties involved

Led by the Ayuntamiento de Arteixo (Municipality of Arteixo), which oversees implementation and ensures compliance with urban planning guidelines. Local engineering firms contributed to the design of the retention systems, ensuring integration with existing infrastructure. Environmental agencies supported the project by assessing ecological impacts and ensuring alignment with water management regulations.

In the municipality of Arteixo (Galicia, Spain), uncontrolled stormwater runoff has increased flood risks and contributed to the pollution of local water bodies. Large volumes of rainwater from urbanised areas discharge directly into the Bolaños and Bidueiro rivers, while additional runoff enters the sewer system, placing heavy pressure on wastewater treatment plants. To address these challenges, the municipality launched an initiative to integrate Sustainable Urban Drainage Systems into its urban infrastructure. The project seeks to reduce surface runoff, enhance water infiltration, and create multifunctional spaces that support climate adaptation while improving urban liveability.

The project features a pilot implementation of SuDS across multiple locations in Arteixo, focusing on redirecting and managing stormwater from a 150,000 m² urban catchment area. Instead of flowing directly into rivers or sewers, stormwater is diverted into strategically located retention ponds, where it is naturally filtered and infiltrated into the soil. These ponds reduce flood risk, improve water quality, and provide aquatic habitats that strengthen urban biodiversity.

Five stormwater retention ponds were constructed to act as hydrological buffers, slowing runoff and allowing sediments and pollutants (such as hydrocarbons and other urban contaminants) to settle before reaching watercourses. Complementary measures include the creation of permeable surfaces and infiltration trenches in critical areas to enhance groundwater recharge and minimise runoff. The underground drainage system was also upgraded to manage excess water when retention ponds reach capacity, further easing the burden on wastewater treatment facilities.

Beyond flood control, the project delivers ecological and social co-benefits. The retention ponds serve as green-blue infrastructure, integrating ecological restoration with urban design. Vegetation planted around the ponds stabilises soil, reduces erosion, and aids in pollutant absorption. These features also improve aesthetic value, offer recreational opportunities, and enhance community well-being. The project includes community education initiatives to raise awareness of sustainable water management and the role of NbS in urban resilience.

The SuDS system is expected to significantly reduce peak stormwater flows, alleviating pressure on water bodies and urban sewer networks. By incorporating retention ponds, the project aims to capture and manage up to 2% of the runoff that would otherwise enter the municipal wastewater system, thereby improving overall efficiency, reducing treatment costs, and energy consumption. It will also provide direct flood protection for at least 300 residents in vulnerable areas.

Retention pound

CASE STUDY

Milan's First Sustainable Urban Drainage System for Resilience

(MM Spa, Italy)

Location

What it is about

The project marks Milan's first implementation of SuDS, transforming a degraded urban space into a multifunctional green corridor.

Financing

Total cost of the intervention was approximately €220,000–230,000, with most of the work funded through MM's Investment Plan. The provision of benches as part of the new green infrastructure was financed separately by the Municipality of Milan.

Parties involved

Design and implementation were carried out exclusively by MM. The request for these interventions was submitted jointly by MM and the Green and Environment Directorate of the Municipality of Milan.

In April 2023, Milan inaugurated its first Sustainable Urban Drainage System (SuDS) on Via Pacini, between Via Teodosio and Via Capranica. This street, located in a densely urbanised area, previously featured a central parterre that had been misused for parking, leaving the soil compacted and impermeable while damaging tree roots. The intervention sought to redevelop the area, prevent further degradation, and restore it as a green public space for the community.

The project widened the 200-metre-long, 10-metre-wide parterre, expanded pedestrian areas at crossings, and added new crossings to improve safety and accessibility. Alongside existing trees, new flower beds with diverse plant species were planted, and a pedestrian-cycling path was introduced. The site was further enhanced with benches, bicycle racks, and picnic tables, while also hosting Milan's first SuDS installation on a public road.

The SuDS system in Via Pacini consists of a dual-drainage approach. Given the high volume of traffic in the area, the initial runoff, which carries higher levels of pollutants, is directly diverted into the sewer system. Meanwhile, cleaner secondary rainwater is directed to bioretention areas—green depressions designed to filter and purify water through soil infiltration and plant-based phytoremediation. This system helps manage rainfall sustainably while reducing flood risk, enhancing biodiversity, and mitigating urban heat effects, in addition to serving as an aesthetic and functional urban feature.

To optimise water management, the new green areas were divided into three ecological zones based on water availability. The low zone (L) experiences frequent alternation between flooding and dry periods, the medium zone (M) undergoes occasional water fluctuations, and the high zone (H) remains dry with no significant water level changes. Around ten different plant species were selected to match the conditions of each zone. To ensure sustainable irrigation without excessive water consumption, a system was installed that can draw from existing groundwater wells, avoiding the use of drinking water.

The permeable pedestrian-cycling path facilitates access and maintenance of the SuDS. It is paved with permeable limestone over a stabilized limestone grit sub-base, allowing rainwater to infiltrate the ground directly and helping to de-pave a previously impermeable surface.

This project represents a significant milestone in Milan's urban sustainability agenda.

CASE STUDY

Integrated SuDS Programme Across the Monza and Brianza Province

(Brianzacque, Italy)

Location

What it is about

The multi-site initiative introduces SuDS across the Monza and Brianza province. Through the creation of parks, wetlands, and urban green spaces, the projects enhance stormwater management, reduce flood risks, and improve urban liveability while supporting biodiversity and climate resilience.

Financing

Jointly financed by Brianzacque and the Ambito Territoriale Ottimale (ATO)—a public administrative body responsible for managing integrated water services across a designated territory. In this case, the ATO coordinates planning and funding for water infrastructure within the province of Monza and Brianza. Additional support was provided by regional funding agencies through MM's Investment Plan. The provision of benches as part of the new green infrastructure was financed separately by the Municipality of Milan.

Parties involved

Planning and overall project management were handled by Brianzacque. Specialised design firms were hired for detailed planning, while Brianzacque took responsibility for the hydraulic components. Construction was awarded to external contractors overseen by Brianzacque. Operations were closely coordinated with local municipalities.

In recent years, Brianzacque, the public water utility serving the province of Monza and Brianza in Northern Italy, has led a series of green infrastructure projects across multiple municipalities. These initiatives aim to improve stormwater management, reduce flood risks, and alleviate pressure on ageing sewer systems. Beyond these technical objectives, the projects also enhance urban environmental quality by creating multifunctional green spaces that support biodiversity, provide recreational opportunities, and strengthen overall urban resilience.

Brianzacque's Sustainable Urban Drainage System projects are tailored to the specific hydrological and social conditions of each site. By combining engineering functionality with ecological design, these interventions transform underused or flood-prone urban areas into dynamic green-blue infrastructure.

Parco dell'Acqua di Arcore: located between Via Gran Sasso and Via Monte Bianco, this pilot project serves as a model for future green infrastructure in the region. It features a natural reservoir with a capacity of approximately 14,000 cubic meters, designed to capture and manage runoff from nearby watercourses. The basin is planted with hydrophilic vegetation to support natural filtration. The park also includes picnic areas, walking paths, and community gardens, making it both a functional and recreational space. Completed in September 2021, the project cost was approximately €708,000.

Parco dell'Acqua di Bernareggio-Carnate-Ronco Briantino: this project, located near the CTL3 sports complex, addresses irregular runoff in a region with heavy clay soils and limited drainage infrastructure. It features a 24,000 cubic meter open earth basin and a permanent wetland that regulates water flow and protects downstream sewer networks. In addition to flood mitigation, the park enhances local biodiversity through wetland habitat creation. The project, costing €2.3 million, was completed in December 2021 and inaugurated in September 2022.

Parco dell'Acqua di Bellusco: this project was developed to mitigate flooding from sudden, intense rainfall. It includes the restoration of old watercourses, the construction of new drainage ditches, and the conversion of an underused area into a public green space. The intervention, funded by local government resources, was implemented between 2021 and 2023 at a cost of approximately €800,000.

Bovisio Masciago: this project, located along Via Matteotti, features tree-lined planters, rain gardens, and pergolas designed to reduce flood risk, improve air quality, and enhance thermal comfort. The intervention includes 50 SuDS elements, 1,850 m² of bioretention areas, 60 trees, 100 shrubs, 2,000 m² of herbaceous plants, 1,700 m² of flowering meadows, and 9,000 plants selected for biodiversity support. A 770-meter cycle path integrates the site with broader mobility networks. Construction began in November 2022 and was completed in March 2023, with a total cost of approximately €1.3 million, funded by Regione Lombardia.

CASE STUDY

Barcelona's SuDS Strategy

(Barcelona Cicle de l'Aigua (BCASA), Spain)

Ajuntament de Barcelona | Barcelona Cicle de l'Aigua SA

Location

What it is about

Barcelona has developed a city-wide SuDS strategy to tackle urban flooding, water scarcity, and pollution by decentralising stormwater management.

Financing

Primarily financed through municipal budgets, with additional funding from regional and European programmes. To ensure long-term maintenance and system efficiency, the city established a dedicated SuDS maintenance contract, coordinated by BCASA, with an annual budget of €1,285,558. These funds support regular upkeep, monitoring, and the performance evaluation of installed systems across the city.

Parties involved

Led by the SuDS Commission of the Barcelona City Council, which brings together multiple municipal entities, including the Barcelona Water Cycle, the Parks and Gardens Institute, the Municipal Urbanism Institute, and the Public Health Agency, among others. The Commission is responsible for identifying and promoting best practices, managing project implementation, training municipal staff, and raising public awareness about the benefits and functions of SuDS.

Barcelona faces persistent challenges related to urban flooding, water scarcity, and environmental degradation, driven by high population density, extensive impervious surfaces, and a Mediterranean climate characterised by intense but irregular rainfall. The city's drainage system has historically struggled to cope with stormwater overflow, leading to increased flood risk and the pollution of local water bodies. In response, the Barcelona City Council launched a SuDS strategy to embed NbS into urban planning. This strategy focuses on decentralised water management, improving soil infiltration, reducing surface runoff, and treating rainwater as a valuable resource.

Barcelona began implementing SuDS in 2005, integrating decentralised rainwater management solutions into select urban development projects. The creation of the SuDS Commission in 2016 marked a turning point, allowing the city to scale up interventions and formally integrate SuDS into its climate resilience and urban planning strategies. The approach emphasises stormwater retention, water purification, and ecosystem enhancement, employing techniques such as permeable pavements, bioretention areas, infiltration basins, and rain gardens.

A key element of the strategy is the transformation of existing and newly designed public spaces into infrastructure that delivers both hydrological and social benefits. Examples include the redevelopment of Carrer de Cristòfol de Moura (street), where a large depavement programme replaced asphalt with structured soils and bioretention systems to improve infiltration and reduce surface runoff; in Parc de Joan Raventós (park), green infrastructure was introduced to enhance water retention, support local ecosystems, and create a more resilient landscape; at Marina del Prat Vermell (neighbourhood), green corridors were established to mimic natural hydrology, using rainwater-fed ecosystems to manage runoff. The Eixample Superblocks Initiative integrates bioretention areas, green infiltration zones, and underground infiltration tanks to regulate the urban water cycle while improving the quality of public space and encouraging sustainable mobility.

The Barcelona SuDS Master Plan is designed to manage approximately 5.71 million cubic meters of rainwater annually across 1,295 hectares. Interventions across streets, sidewalks, parks, and other public spaces capture, filter, and gradually release rainwater, while creating micro-habitats that enhance biodiversity. The city has also developed a Technical Guide for SuDS Design (2020) and a GIS-based inventory system to monitor performance, plan maintenance, and support decision-making with real-time spatial data.

The implementation of SuDS in Barcelona delivers multiple benefits: hydrologically, it reduces flood risks, increases groundwater recharge, and minimises combined sewer overflows; environmentally, it improves water quality, supports habitat creation, and contributes to carbon sequestration and urban cooling; socially, it enhances the usability, safety, and aesthetic appeal of public spaces while mitigating extreme heat and drought impacts.

CASE STUDY

The ParisPluie Plan

(Ville de Paris, France)

PARIS

Location

What it is about

ParisPluie is a city-wide strategy to manage rainwater at its source, aiming to reduce sewer overflows, flooding, and pollution of the Seine.

Financing

Grants are available through the Seine-Normandy Agence de l'Eau (Water Agency) for studies and interventions that reduce rainwater discharge into the sewer system and control pollution at the source. Additionally, the Île-de-France Region may provide financial assistance for projects incorporating vegetated techniques and NbS.

Parties involved

The City of Paris is responsible for implementing the plan. Various city departments, including those overseeing urban planning, sanitation, and environmental management, are involved in enforcing and monitoring its application. Additionally, partnerships have been formed with organisations such as the Atelier Parisien d'Urbanisme (APUR), which contributes to research and mapping efforts to support the plan's objectives.

Paris faces growing challenges in managing urban stormwater due to extensive soil sealing and increasing strain on its sanitation network. Traditionally, rainfall has been managed primarily through the sewer system, but climate change and urbanisation have made this approach unsustainable. The increasing frequency of intense rainfall events, coupled with aging infrastructure, has raised the risk of combined sewer overflows, localised flooding, and pollution of the Seine and other water bodies. In response, the City of Paris developed the ParisPluie Plan—a comprehensive rainwater management strategy that shifts focus from end-of-pipe drainage to localised management at the source. The plan aims to retain and infiltrate rainwater locally, reducing pressure on the sewer system and enhancing the city's resilience to extreme weather events.

Launched in 2019, the ParisPluie Plan introduces a rain zoning strategy tailored to Paris's diverse geological and infrastructural conditions. Its central objective is to disconnect the first millimetres of rainfall (most heavily loaded with pollutants) from the combined sewer system, particularly during rainfall events with a six-month return period. The strategy is guided by three principles: accounting for geological variations across the city, leveraging knowledge of the existing sanitation network, and prioritising localised rainwater management over reliance on sewer infrastructure.

To implement the strategy, a rain zoning regulation was enacted in March 2018 and incorporated into the Local Urbanisation Plan (PLU). Compliance is mandatory for property owners and developers. Under this regulation, any new construction or redevelopment project exceeding 20 m² for buildings, 500 m² for outdoor facilities, and 1,000 m² for public roads or green spaces must integrate rainwater management measures. This ensures that large-scale impermeable surfaces do not contribute excessive runoff to the sewer system.

To support the adoption of the ParisPluie Plan, the city developed a communication and support strategy for both professionals and the public. A dedicated visual identity was created to reinforce awareness, alongside educational videos, technical guides, public events, and municipal training sessions targeting departments responsible for roadways, housing, and environmental planning.

The plan also includes pilot projects and research initiatives. Rain gardens were installed to measure evapotranspiration, facade reservoirs tested rainwater retention on buildings, and a city-wide study with APUR was launched to identify areas for soil de-sealing to improve absorption and reduce runoff.

A communication plan and an identity for the rain zoning

CASE STUDY

RISA – The Rain Infrastructure Adaptation Project

(Hamburg Wasser, Germany)

HAMBURG WASSER

Location

What it is about

The RISA Project addresses stormwater challenges in Hamburg caused by rapid urban growth and climate change. It promotes integrated, water-sensitive urban design to reduce flooding and combined sewer overflows.

Financing

Financed primarily by the environmental agency, with some funding from Hamburg Wasser. Hamburg Wasser was responsible for the management of the project. Surveys, expert reports and pilot projects were mainly financed by the environmental agency.

Parties involved

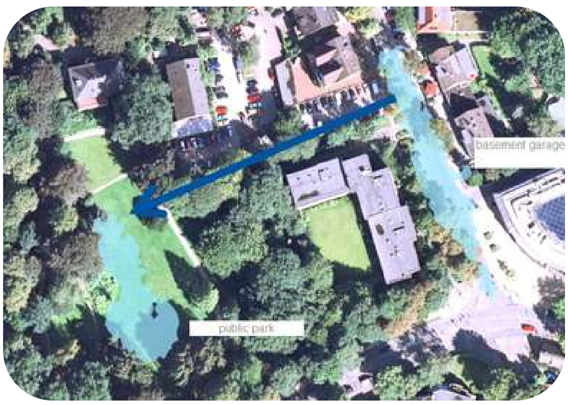
The State Ministry for Environment and Energy (Behörde für Umwelt und Energie - BUE) and Hamburg Wasser were the leading entities in the project. The initiative also involved collaborations with organisations such as Kompetenzzentrum Wasser Berlin GmbH and Atelier Dreiseitl, which contributed expertise in water management and urban planning.

Hamburg is a rapidly growing city, with approximately 1 km² of land sealed annually and projections for 10,000 new flats each year. This urban expansion has increased surface runoff and reduced infiltration and evaporation, contributing to higher summer temperatures and flood risks. Additionally, climate change has intensified extreme weather events, particularly cloudbursts, further straining the city's stormwater infrastructure. To address these challenges, Hamburg has adopted an integrated approach to stormwater management, focusing on reducing combined sewer overflows, mitigating flood risks, and promoting a near-natural water cycle through water-sensitive urban design. A central initiative within this strategy is the Rain Infrastructure Adaptation (RISA) Project, which develops sustainable solutions for urban rainwater management.

Launched as part of Hamburg's climate protection plan, the RISA Project officially ran from September 2009 to December 2015, though its initiatives continue. The project integrates sustainable stormwater management into urban planning, aiming to reduce combined sewer overflows through water protection programmes and structural sewer adaptations. Flood prevention is addressed by transforming urban spaces into multifunctional areas capable of retaining excess rainwater. Parks, playgrounds, and sports facilities have been designed as retention zones, enhancing flood resilience while improving public amenities.

The project also promotes a near-natural water cycle by incorporating water-sensitive urban design into city infrastructure. Measures include reducing sealed surfaces, replacing them with permeable materials, and introducing rain gardens, bioswales, and green roofs in schoolyards and along streets. These NbS alleviate pressure on drainage systems while providing environmental and social benefits.

Beyond physical interventions, RISA places a strong emphasis on developing technical guidelines and planning tools to support the long-term sustainability of rainwater management. Manuals and information resources were created to assist city planners, property owners, and other stakeholders in implementing effective drainage strategies.



Flood protection in Public Park

CASE STUDY

EMASESA’s Approach to Climate Adaptation

(EMASESA, Spain)

Location

What it is about

The project tackles Seville’s climate challenges by integrating SuDS, bioclimatic design, and water reuse into urban infrastructure. These interventions aim to improve flood management, reduce urban heat, enhance biodiversity, and promote public health.

Financing

Co-financed through a combination of municipal funds, EU programmes such as the LIFE Programme (LIFE18 CCA/ES/001122) and Urban Innovative Actions (UIA03-301), as well as partnerships with academic institutions and private entities.

Parties involved

EMASESA’s work is supported by a wide partnership network: the Seville City Council (urban planning alignment), the University of Seville (technical and scientific expertise), Gerencia de Urbanismo and PCT Cartuja (innovation in public space), CSIC Eduardo Torroja Institute and Innovarcilla Foundation (materials and passive cooling research), and private partners such as ALTEN and EFE Verde (public awareness and dissemination).

Seville, one of the warmest cities in Europe, is increasingly affected by heatwaves, prolonged droughts, and extreme rainfall events. These pressures have placed growing strain on urban water management systems, requiring new approaches to reduce flood risks, improve thermal comfort, and enhance water efficiency. In response, EMASESA, the municipal water utility of Sevilla, has developed and implemented a suite of climate adaptation projects that combine SuDS, bioclimatic design, and innovative water reuse techniques. Pilot interventions have tested permeable pavements, bioretention systems, infiltration wells, drainage ditches, and rainwater harvesting technologies.

One flagship initiative, the Healthy City Project – Avenida El Greco (2017), reimagined a busy commercial street as a climate-adapted corridor. It introduced permeable pavements, floodable green areas, and rainwater harvesting systems alongside cycle lanes, pedestrian zones, and energy-efficient lighting. Altogether, this project improved mobility, reduced urban temperatures, and enhanced air quality.

The Cartuja Qanat Project – Isla de la Cartuja (2022), applied ancient water management practices to develop low-energy cooling strategies. Inspired by traditional qanats (subterranean channels that transport and cool water), this project used underground water channels and evaporative cooling to lower ambient temperatures without mechanical systems, while revitalising public spaces such as an amphitheatre and marketplace. The project demonstrated how cultural heritage can inform innovative climate solutions.

The LIFE Watercool Project piloted water-based bioclimatic interventions, including shaded areas, reflective pavements, green roofs, and misting systems, all aimed at mitigating the urban heat island effect. It also developed a digital platform to help urban planners and private actors to model and replicate these solutions across the city.

Beyond these major initiatives, EMASESA has systematically integrated SuDS throughout Seville. Permeable pavements, bioretention areas, infiltration infrastructure, detention ponds, and lamination collectors have been deployed in streets, plazas, and parks, improving infiltration and water retention.

Together, these interventions have reshaped Seville’s approach to urban water management.

Key takeaways

The many examples of SuDS featured above—and the sheer diversity of their application—speak to both the growing interest and growing capacity of public water operators to implement them. SuDS are now firmly part of the toolbox that water operators use to enhance urban water resilience. They represent a versatile set of techniques to manage stormwater more sustainably. Their capacity to deliver multiple co-benefits, such as urban cooling, biodiversity enhancement, and improved public spaces, makes them particularly valuable in the face of intensifying climate pressures.

However, the implementation of SuDS also faces a number of institutional and operational challenges. Effective design requires early integration into urban development plans, demanding close coordination between water utilities, municipal departments, and urban planners. Long-term performance hinges on consistent maintenance, often necessitating new models of inter-agency collaboration and funding. Public acceptance can be another hurdle; repurposing grey infrastructure into green space involves reimagining how cities function, which may meet resistance from residents or other stakeholders.

Crucially, SuDS often fall within a grey zone of responsibility. While their benefits are clearly hydrological, their implementation tends to lie outside the traditional remit of water operators. Instead, they sit at the intersection of water management, urban planning, and public health, areas traditionally managed by different actors. This fragmentation can make it difficult for operators to take the lead or secure investment without an enabling legal or institutional framework. Moreover, as seen across the projects, financing these systems commonly relies on a mix of funding sources rather than a single, stable stream. This “financing engineering” mirrors the governance complexities involved, potentially hindering the wider uptake and scalability of SuDS.

Nonetheless, it is increasingly clear that SuDS will become a defining feature of the cities of tomorrow. With the right governance structures, policy support, and cross-sector collaboration, these systems can help shift urban water management towards a more sustainable, climate-adaptive model. This model not only manages risk but actively enhances the liveability and resilience of urban environments.

Catchment Protection

Catchment protection refers to “precautionary actions, procedures or installations undertaken to prevent or reduce harm to the environmental integrity of drainage areas used to catch water, such as reservoirs or basins”. [4] As climate change, pollution, and overuse place increasing pressure on freshwater resources, water operators are turning upstream to protect water at the source. Catchment protection involves a broad set of measures, including creating buffer zones around catchment areas, managing land use to prevent runoff and contamination, negotiating pollution controls with farmers or industries, and in some cases, acquiring land to ensure direct oversight of sensitive areas. These actions help safeguard both the quality and availability of water, reducing the burden on downstream treatment processes and enhancing long-term resilience. In essence, by protecting catchment areas, operators are investing in the most fundamental layer of water security.

CASE STUDY

Vienna's Catchment Protection Strategy

(Vienna Water, Austria)

City of Vienna

Location

What it is about

Vienna's Catchment Protection Strategy focuses on safeguarding the alpine spring water sources that supply most of the city's drinking water.

Financing

Primarily financed through water tariffs which support the overall water supply system, including the implementation of NbS. Federal subsidies occasionally complement these investments, particularly for infrastructure upgrades and conservation measures. Vienna Water has also accessed EU funds to support scientific research and innovation in water quality monitoring and protection.

Parties involved

The City of Vienna oversees water management through its municipal departments, with Vienna Water (MA 31) responsible for operating the public water supply system. The Viennese Forestry Department works in coordination with MA 31 to manage protected areas. Decision-making on NbS is guided by these departments together with city political leadership. At the federal level, the Ministry of Agriculture, Forestry, Regions, and Water Management defines water protection policies.

Vienna's drinking water supply relies almost entirely on high-quality alpine spring water, which provides around 90% of the water consumed by its 2 million residents. The springs, located in the North-Eastern Limestone Alps, are protected catchment areas, with water transported to the city via two large mains. Safeguarding these source areas is central to Vienna's long-term water security, and the city has developed a nature-based strategy centred on land conservation, sustainable forestry, and microbiological research. This approach ensures that Vienna's water requires only minimal treatment before distribution.

The city's strategy prioritises maintaining the natural state of its catchments while implementing targeted measures to optimise land use and mitigate risks to water quality. The city owns large portions of the catchment areas, which are legally designated as water protection zones, ensuring that land use remains strictly controlled. The primary objective is to subordinate all other land uses to water protection, meaning that activities such as forestry, pasture management, and tourism must be adapted to prevent any negative impact on water quality or quantity.

To manage potential conflicts between land use and water protection, Vienna Water and the Viennese Forestry Department developed a Spring-Protection Guideline, which applies to city-owned areas. This guideline outlines best practices for managing forestry, game populations, pasture activities, and tourism in ways that do not compromise water security. In privately owned sections of the catchment areas, similar principles are negotiated through legal proceedings to align external land use with Vienna's water protection priorities.

One of the key risks to Vienna's water quality is microbiological contamination, particularly in karst springs, which can rapidly transmit pollutants from the surface to groundwater. To address this, Vienna Water has invested in advanced monitoring systems and scientific research to understand the factors influencing microbiological water quality. Until recently, data on the microbiological characteristics of alpine karst springs were limited to routine surveillance, leaving significant gaps in knowledge. Since the early 2000s, intensive research efforts have been conducted in the Northern Calcareous Alps, providing new insights into the hydrogeological and microbiological behaviour of these springs.

Thanks to this comprehensive protection framework, Vienna's water requires only minimal treatment, consisting of UV disinfection and, in some cases, chlorination (applied near distribution points rather than at the source). Beyond operational measures, Vienna Water continues to expand the extent of protected land by purchasing additional plots in the catchment areas. Increasing public ownership of these areas allows for greater control over land use decisions, reinforcing the city's long-term commitment to natural water conservation.

CASE STUDY

Lough Guitane Riparian Woodland Afforestation Project

(Uisce Éireann, Ireland)

Location

What it is about

The Lough Guitane Riparian Woodland Afforestation Project creates native woodland buffers along a key drinking water lake in rural Ireland. The project protects water quality, supports biodiversity, and helps reduce nutrient runoff into the lake.

Financing

Funded through a grant (Woodlands for the Protection of Water) which is administered through the Forestry Service under the Department of Agriculture, Food and Marine in Ireland.

Parties involved

Uisce Éireann and the Professional Forestry Company are responsible for delivering the project, and the grant funding body for approving and financing the project. Uisce Eireann gives consent to progress the woodland grant application on their lands, and the Professional Forestry Company completes the application process and then plants and maintains the woodland to be able to claim the grant funding.

The Lough Guitane Riparian Woodland afforestation project is part of Uisce Éireann's broader strategy to protect water resources through Nature-based Solutions. Located in Gortdromakiery, County Kerry, the project establishes a native woodland buffer along the lakeshore of Lough Guitane, a key source of drinking water for the region. The site, covering approximately 5.27 hectares, lies adjacent to Killarney National Park, the MacGillycuddy Reeks, and the Caragh River Catchment SAC (000365), which makes biodiversity protection and ecological sensitivity central to project design.

The afforestation plan creates a native riparian woodland planted with species such as birch, alder, and willow, chosen for their suitability to local conditions and low vulnerability to deer browsing. The project integrates environmental safeguards identified through the Appropriate Assessment (AA) process under the EU Habitats Directive. These include a 15-metre unplanted setback from the lakeshore, the use of non-tensile A-frame deer fencing to prevent soil disturbance, and restrictions on machinery and chemical use.

Special care was taken to protect sensitive species, including otters and freshwater pearl mussels. Trees were pit-planted to prevent sediment mobilisation, scrub was retained to maintain habitat continuity, and no new drainage was permitted. All works were restricted to daylight hours to minimise wildlife disturbance.

Though small in scale, the project is strategically significant, both in its direct contribution to catchment protection and as a model for future water-forest integration projects. Once established, the woodland is expected to reduce nutrient runoff, provide shade to moderate water temperatures, and create a semi-natural habitat buffer to safeguard the water body from future land-use pressures.

Appropriate Assessment Determination made by the Minister for Agriculture, Food & the Marine, for Afforestation project CN85772, located at Gortdromakiery, Co. Kerry

CASE STUDY

Managing Seasonal Mosquito Proliferation in Northeastern France

(Syndicat Départemental Des Eaux de l'Aube (SDDEA), France)

SDDEA ET SA RÉGIE

Location

What it is about

The project addresses mosquito proliferation in the Seine and Aube Valley region through targeted larvicide treatments.

Financing

Financed through public service budgets, with contributions from the municipalities that have transferred their mosquito-control responsibilities to SDDEA.

Parties involved

Managed and implemented by SDDEA, in coordination with the Agence Régionale de Santé (ARS) Grand Est for vector surveillance, particularly regarding the tiger mosquito. Local municipalities collaborate by informing citizens, facilitating access to treatment areas, and encouraging public engagement in prevention measures.

The Seine and Aube valleys in northeastern France are prone to seasonal mosquito proliferation due to stagnant waters that form during periods of heavy rainfall. This creates favourable breeding grounds, particularly for Aedes rusticus, a mosquito species that emerges in spring and is responsible for large-scale nuisance. In 2018, the Communauté de Communes Seine et Aube transferred mosquito-control responsibilities to SDDEA, which now coordinates both preventative and curative measures across 111 communes.

SDDEA conducts an annual mosquito-control campaign, with interventions timed to the larval stage of Aedes rusticus. This species, well adapted to winter conditions, hatches in early spring, making February treatments decisive. The treatments target larval habitats, which include wooded wetlands, reedbeds, poplar groves, and marsh depressions flooded by the Seine and Aube rivers.

The intervention relies on larvicides based on Bacillus thuringiensis israelensis, a biocide authorised for organic farming. Until 2024, only liquid formulations (Vectobac 12AS) were applied, but in 2025 SDDEA began testing solid granule formulations (Vectobac G), which showed greater resilience under cold conditions and higher efficiency in post-treatment monitoring. Treatments are carried out by helicopter dispersal over hundreds of hectares and by hand in smaller or more sensitive sites.

The 2025 campaign covered approximately 657 hectares, combining 634 hectares treated by helicopter and 23 hectares treated on the ground. Monitoring indicated an 88% success rate for aerial treatments, with solid formulations proving more effective than liquid ones. The campaign's success also depended on weather and hydrological conditions, as floods and rainfall patterns directly influence larval development.

Complementing these technical measures, SDDEA also addresses vector control and public awareness. It deploys egg-trap devices to monitor the presence of Aedes albopictus (tiger mosquito), a potential disease vector, and runs awareness campaigns encouraging citizens to eliminate stagnant water containers (such as barrels, buckets, or tyres) around homes and gardens. Residents are also encouraged to support natural predators such as bats, birds, and aquatic insects.

A helicopter conducting aerial mosquito-control operations over wetlands in the Seine and Aube valleys.

Key takeaways

In a context of increasing pressure on water resources, from pollution to climate-driven scarcity, protecting water at its source is not merely a precaution; it is a fundamental responsibility for water operators. The long-term quality and availability of drinking water depend on the health of catchments that feed reservoirs, rivers, lakes, and springs. Investing in source protection stands out as one of the most effective measures water operators and authorities can take to secure supplies before costly treatment or emergency responses become necessary.

There is no one-size-fits-all approach. Source protection requires a complex mix of land use planning, legal frameworks, stakeholder engagement, and sustained monitoring. Negotiating with private landowners, balancing competing interests across sectors, and committing to permanent land management practices often demand strong political ownership and institutional coordination.

Wastewater Treatment

Wastewater treatment refers to the process of removing pollutants and contaminants from used water so that it can be safely discharged into the environment or reused. As wastewater becomes increasingly polluted—especially with nutrients like nitrogen and phosphorus, organic matter, micropollutants such as PFAS, and microplastics[5]—conventional treatment technologies have grown more complex and energy-intensive.

In that context, some water operators are exploring more natural, low-tech approaches for specific stages of the wastewater treatment process. These include systems that use vegetation and soil-based processes to treat sludge or wastewater in a more cost-effective and energy-efficient way. Though limited in scope, such approaches demonstrate how nature can still play a role even in highly technical parts of the water cycle.

CASE STUDY

Sludge Treatment Reed Beds

(Uisce Éireann, Ireland)

Uisce Éireann Irish Water

Location

What it is about

This pilot project explores a low-energy, nature-based alternative to mechanically dewatering alum sludge from drinking water treatment. The approach aims to cut carbon emissions, lower costs, and reduce the environmental impact of sludge management.

Financing

Funded by the Commission for Regulation of Utilities (CRU), it is the first project globally to investigate STRBs at this scale for dewatering alum sludge (as opposed to dewatering ferric sludge, ferric sulphate being more commonly used internationally).

Parties involved

Managed by Uisce Éireann and supported by a cross-disciplinary internal team from Infrastructure Delivery, Asset Management, and Operations.

In Ireland, aluminium sulphate is the primary coagulant used in over 90% of drinking water treatment processes; this creates a considerable volume of alum-based sludge. Managing this sludge traditionally requires energy-intensive mechanical dewatering systems, such as centrifuges or filter presses, which generate sludge cakes that must be transported off-site several times per week—adding further carbon and financial costs. To address these challenges, Uisce Éireann launched a pioneering project to test Sludge Treatment Reed Beds (STRBs) as a nature-based alternative for alum sludge dewatering. The project was deployed in response to growing environmental obligations, including the need to limit discharges of untreated sludge/supernatant and to reduce the overall carbon footprint of sludge management.

The STRB system consists of six oval-shaped concrete vessels, each with a capacity of 11 m³, filled with layers of sand and gravel media, and planted with Phragmites australis (common reed). Sludge is delivered weekly to a reception tank and then distributed to each reed bed at varying loading rates to evaluate optimal performance. The sludge has a dry solids content of 1.5–2% and originates from water treatment plants using aluminium-based coagulants.

The reed beds act as natural dewatering and filtration units, significantly reducing energy consumption compared to conventional methods. In addition, the process avoids sludge cake production and reduces the need for trucking, which brings savings in emissions and transport costs.

Phase 2 of the project was completed in 2024, marking the start of the operational phase. This phase centres around the loading and sampling of the reedbeds with alum-based sludge from water treatment plants. Uisce Éireann continues to load the beds during Q1 2025 to investigate the impact of winter conditions and assess the resilience and filtering capacity of the beds under frost. Phase 3, launched in 2025, focuses on documenting results, submitting reports to authorities, and preparing the groundwork to implement this technology as a standard alternative to conventional dewatering at other treatment sites.

A detailed table of pollutant removal efficiency collected during the operational phase demonstrates impressive results, with removal rates for aluminium, iron, manganese, suspended solids, turbidity, and TOC often exceeding 99%.

If successful, STRBs could become a low-cost, low-carbon alternative for managing alum sludge in Ireland. Over a 30-year lifecycle, the whole-life cost of STRBs is estimated to be 30–50% lower than mechanical dewatering systems. The approach holds promise not only for environmental compliance and sustainability goals but also for enhancing habitat biodiversity at treatment sites.

Reeds at early life stage

Key takeaways

Although wastewater treatment remains largely dominated by technical and energy-intensive processes, water operators are increasingly exploring nature-based alternatives to make sludge and wastewater management more sustainable, both in response to new regulatory requirements and shifting environmental realities. These approaches may not yet fully replace high-tech solutions, but they can serve as valuable complements, and perhaps one day become standalone solutions. Their success will depend on ongoing innovation, regulatory support, and robust monitoring to ensure they are well understood, thoroughly tested, refined, and scaled in a way that promotes replicability.

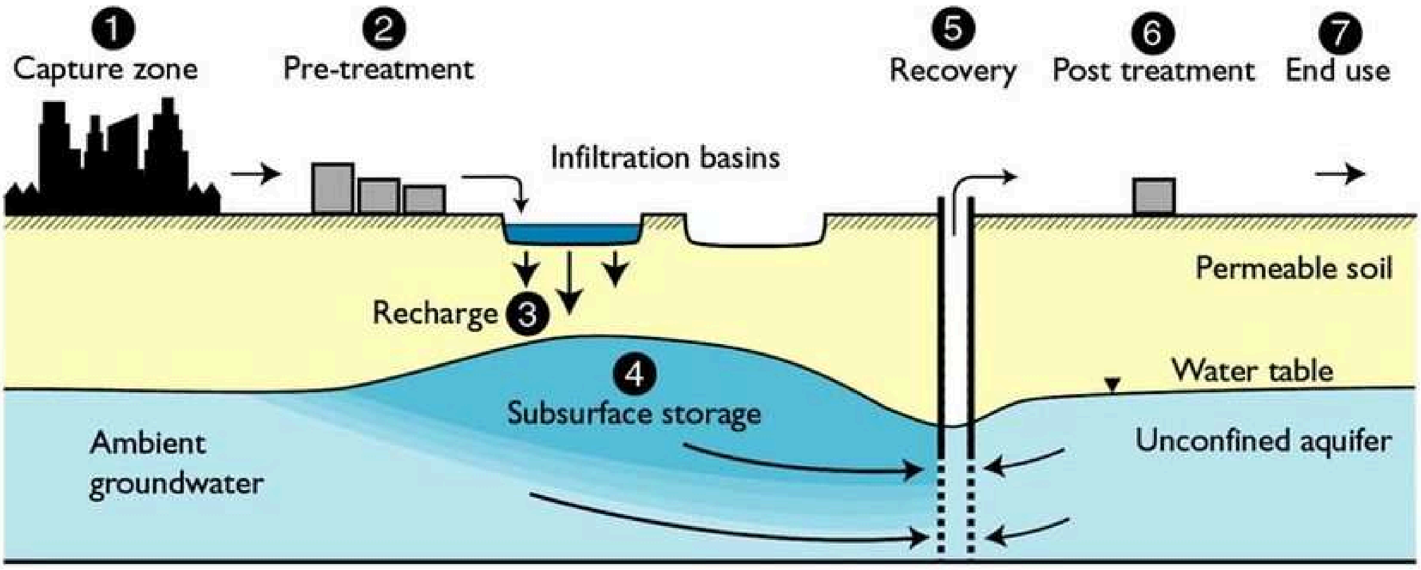
II. Hybrid Solutions

II. HYBRID SOLUTIONS

The previous chapter presented projects focused on restoring or mimicking the natural water cycle. In this chapter, we turn to initiatives that blend green and grey infrastructure, combining traditional engineering approaches with Nature-based Solutions. In particular, we will explore examples of Managed Aquifer Recharge and Constructed Wetlands that integrate these complementary strategies.

Managed Aquifer Recharge

Managed Aquifer Recharge (MAR) refers to “the purposeful recharge of water to aquifers for subsequent recovery and environmental benefit”[6]. It encompasses a wide range of techniques, such as aquifer storage and recovery, bank filtration, infiltration basins, and soil aquifer treatment [7], that aim to enhance groundwater availability and quality. MAR systems can draw on both surface water and treated wastewater. When the latter is used, careful consideration is required to manage risks associated with residual pollutants and to ensure the protection of groundwater resources. For water operators, MAR offers a powerful set of benefits. It increases the resilience of water supply systems to climate variability and drought, helps restore overexploited aquifers, and supports water quality improvement and ecosystem functions. When implemented effectively, MAR is both a buffer against scarcity and a long-term investment in water security.



CASE STUDY

Acquedotto Pugliese’s Managed Aquifer Recharge Strategy

(Acquedotto Pugliese (AQP), Italy)

Location

What it is about

Acquedotto Pugliese’s MAR strategy uses treated wastewater to replenish groundwater through trenches and soil infiltration systems near treatment plants. This approach helps address chronic water scarcity by boosting aquifer levels while also creating wetland habitats that support local biodiversity.

Financing

Rough indication of investment costs is €80-100 per population equivalent, net of the cost/value of the committed land.

Parties involved

The investment is authorized by the Ambit's Governing Body, in this case the Autorità Idrica Pugliese (AIP). This type of intervention was also included in the Apulia Region Water Protection Plan, prior to the approval of the AIP.

In southern Italy’s Apulia region, water scarcity is a long-standing challenge due to low rainfall and high demand for potable, agricultural, and industrial use. To address this, Acquedotto Pugliese (AQP) has made Managed Aquifer Recharge (MAR) a cornerstone of its climate resilience strategy, using treated wastewater to replenish groundwater reserves. By integrating MAR systems near treatment plants, where environmental and hydrological conditions support infiltration, AQP both strengthens water supply and enhances local ecosystems.

AQP’s primary objective is to secure sufficient resources to meet medium- and long-term needs in a region where aquifer recharge from natural rainfall is limited. To achieve this, AQP has implemented 26 draining trench projects and 3 soil spreading systems, designed to channel treated wastewater from 35 purification plants. These systems are designed as excavated basins adjacent to treatment facilities, allowing for the slow percolation of treated water into the subsurface. Their specifications, such as trench size, filtration layers, and infiltration rates, are adapted to local soil conditions to maximise recharge efficiency.

In 2023 alone, MAR interventions returned approximately 28 million cubic metres of water to the environment, representing a significant share of total groundwater extraction in the region. These measures not only strengthen water availability but also provide ecological co-benefits: several trench systems have evolved into thriving wetland habitats, supporting the breeding and feeding of both resident and migratory bird species. The sites near the Gioia del Colle and Casamassima wastewater treatment plants, for instance, are now recognised as key ecological areas.

To ensure durability and safety, the MAR systems are engineered with wide access ramps for maintenance, wooden fencing for safety, and measures that integrate them with the surrounding landscape. Regular maintenance supports both hydraulic performance and ecological value.

CASE STUDY

Réseau 31's Experimental Project on Managed Aquifer Recharge

(Réseau 31, France)

Location

What it is about

This experimental MAR project in southwestern France aims to boost water availability in the Garonne River basin by storing winter water underground and releasing it during summer low flows.

Financing

Total investment for the experimental phase is €1.83 million (excluding VAT), co-financed by: Agence de l'Eau Adour-Garonne, €923,520 (50%); Région Occitanie, €405,384 (22%); Département de la Haute-Garonne, €120,000 (6%); BRGM, €287,000 (16%); Réseau31, €119,096 (6%).

Parties involved

Réseau31 is the lead project owner (maître d'ouvrage), responsible for technical coordination, financing, permitting, and stakeholder engagement. The project is carried out in partnership with BRGM (France's geological survey agency), which leads the scientific, hydrogeological, and geophysical studies. Local authorities and citizen groups are engaged at each stage of the project.

In southwestern France, the Garonne River basin faces increasing water stress due to climate change, with projections indicating river flows could decline by up to 50% in the coming decades. To secure water availability during low-flow summer periods, Réseau31 has launched a large-scale experimental MAR project to recharge the Garonne's alluvial aquifer using water diverted from the Saint-Martory Canal in winter. The aim is to store water underground during times of abundance and release it back into the river during the summer, supporting environmental flows and helping the river withstand extreme droughts.

The project diverts gravity-fed water from the historic Saint-Martory Canal—normally supplied by the Garonne—into a nearby alluvial aquifer during the winter period. In summer, this stored water is intended to re-emerge into the Garonne, supporting its flow during critical drought conditions without relying solely on upstream reservoir releases. Following detailed site studies across a 100 km² area on the river's left bank (between Martres-Tolosane and Carbonne), a promising infiltration zone was identified, offering highly permeable soils, a deep unsaturated layer, minimal environmental risks, and compatibility with existing irrigation infrastructure.

The recharge system will use infiltration basins and repurposed irrigation ditches, capable of storing significant volumes of water underground. Modelling simulations suggest infiltration rates of around 560 litres per second over 4-6 months could substantially contribute to summer flow support.

As the first full-scale MAR experiment in France specifically designed for low-flow river support, the project introduces innovation on multiple levels: scientific (modelling karstic and alluvial aquifers), regulatory (atypical permitting for groundwater manipulation), and institutional (coordination across technical and political actors). It also highlights the difficulty of reconciling hydrogeological timelines with technical and political expectations.

Beyond its scientific objectives, the project places emphasis on transparency and public engagement. Since MAR infrastructure is largely invisible and results will take years to manifest, Réseau31 has prioritised communication with local communities and elected officials to build legitimacy and maintain trust. If successful, the project could serve as a replicable model for other areas of the Garonne basin and more broadly for water-stressed regions in France.

River Garonne at low water

CASE STUDY

AQUOR Project – Combating Groundwater Resource Decline

(Viacqua, Italy)

Location

What it is about

The AQUOR Project addresses groundwater depletion in Italy's Vicenza Upper Plain by implementing five pilot MAR systems. Using infiltration techniques such as forested areas, trenches, and wells, the project restores groundwater levels impacted by climate change and reduced natural recharge.

Financing

Co-financed by the European Union's LIFE+ Programme, with a total budget of €1,814,548. The European Commission provided €693,348, while the remaining €1,121,200 was covered by the Province of Vicenza and the participating stakeholders.

Parties involved

Viacqua (water operator), the Province of Vicenza, Acque Vicentine S.p.A., Alto Vicentino Servizi S.p.A., Consorzio di Bonifica Alta Pianura Veneta, Consorzio di Bonifica Pedemontano Brenta, Centro Idrico Novoledo, Veneto Agricoltura.

The AQUOR Project (LIFE+10/ENV/IT/000380, 2011–2014) was developed in response to the increasing depletion of groundwater resources in the Vicenza Upper Plain, a critical recharge area for northern Italy's aquifers. Over the past 60 years, the high Vicenza aquifer has experienced a net decrease in groundwater levels of over two meters, primarily due to declining natural recharge and increasing water withdrawals for municipal, industrial, and agricultural use. The situation has been exacerbated by climate change, which has resulted in more intense but less frequent rainfalls, reducing infiltration capacity. Additional pressures include soil sealing in the high plains and a shift from gravity-fed irrigation to more efficient but less infiltrative sprinkler systems. To counteract these trends, AQUOR introduced MAR techniques to restore a balance between groundwater inputs and withdrawals.

The project introduced five pilot groundwater recharge systems across the Vicenza Upper Plain, utilising different infiltration techniques suited to local hydrogeological conditions. These included forested infiltration areas, infiltration trenches, sub-surface infiltration fields, infiltration channels, and infiltration wells, each designed to capture and redirect surface water from irrigation channels into the aquifer.

- The Carmignano di Brenta site features a forested infiltration area, where a network of sinusoidal channels was constructed within a newly planted woodland.
- The Sarcedo site uses an infiltration trench, directing surplus water from the Verlata irrigation channel into the aquifer via a gravel-filled trench with a micro-perforated pipe system.
- The Rosà site implemented a sub-surface infiltration field, enabling groundwater recharge beneath an active agricultural area, ensuring continued land use while increasing infiltration.
- The Ancignano di Sandrigo site developed an infiltration channel, designed as a wildlife corridor to enhance biodiversity while facilitating water retention.
- Lastly, the Breganze site incorporates a series of infiltration wells, providing a vertical recharge system to transfer surface water into deeper aquifers.

Each site was designed with sediment traps and flow control systems to optimise infiltration rates while maintaining water quality. Monitoring stations equipped with multi-parameter probes were installed to continuously track water levels, conductivity, temperature, and other key indicators.

Following its initial implementation, the project encountered governance challenges regarding the long-term management of the MAR sites. Uncertainty over roles, responsibilities, and financial commitments led to a period of inactivity. However, in 2023, a new agreement was reached between Viacqua, the Consorzio di Bonifica, and AcegasApsAmga(multi-utility company operating in environmental and water services, and gas and electricity distribution), allowing the reactivation of three MAR sites. During the 2023-24 season, over 1.6 million cubic meters of water were infiltrated, and operations for 2024-25 began in November.

Key takeaways

Managed Aquifer Recharge is a promising approach for enhancing water security in the face of growing climatic uncertainty and declining groundwater levels. By storing water during periods of surplus and releasing it when needed, MAR not only enhances resilience to drought and scarcity but also supports the restoration of overexploited aquifers.

But the success of MAR hinges on more than good design. These are complex projects that operate on the timescales of nature—which often means waiting for seasonal cycles, conducting extended monitoring, and committing to long-term environmental stewardship. Projects must be credible, not only scientifically but also institutionally. Securing financing, earning public trust, and coordinating across scientific, technical, and political domains are as essential as the infrastructure itself.

A crucial aspect of deploying MAR projects is ensuring water quality and how to maintain it effectively. The European Commission has published guidelines to frame MAR practices, based on a risk-based approach. These guidelines emphasise focusing on the quality of the water used, not its source, and on building confidence in that quality.

Working with natural systems also requires a level of respect and responsibility. In practice, this means taking extra precautions, undertaking thorough environmental studies, and honouring commitments, something too often neglected in rushed projects. MAR requires not just know-how, but the capacity to lead a multidisciplinary process: aligning hydrology, engineering, land use, and local development in ways that are coherent, inclusive, and adaptable over time.

Constructed Wetlands

Constructed wetlands are "engineered systems that have been designed and constructed to utilise the natural processes involving wetland vegetation, soils, and their associated microbial assemblages to assist in treating wastewater. They are designed to take the advantage of many of the same processes that occur in natural wetlands but do so within a more controlled environment."[8] While they draw on the same biological and chemical mechanisms as natural wetlands, constructed wetlands are carefully tailored to meet specific water treatment objectives. For water operators, constructed wetlands offer a powerful and flexible tool. They can significantly improve wastewater quality by removing a broad spectrum of pollutants, including emerging contaminants such as pharmaceuticals. Their role in controlling stormwater overflow is increasingly relevant in a changing climate, helping to buffer extreme rainfall events and reduce pressure on conventional treatment infrastructure. But their value extends well beyond water quality. Constructed wetlands also deliver a range of co-benefits: they sequester carbon, enhance urban biodiversity, and contribute to the creation of multifunctional green spaces.

CASE STUDY

Constructed Wetlands for Water Quality Improvement

(Acquedotto Pugliese (AQP), Italy)

Location

What it is about

This project uses constructed wetlands in Puglia, Italy, to treat wastewater naturally and sustainably. These systems remove pollutants with aquatic plants, lowering energy use and costs.

Financing

Financed through European and national funding programmes, including PO FESR Puglia 2007-2013, regional development funds, and municipal investments. A rough indication of the investment costs is €80-100 per person equivalent, net of the cost/value of the committed land. The investment was authorised by the Autorità Idrica Pugliese (AIP).

Parties involved

Led by AQP, which oversees the design, operation, and maintenance of the constructed wetlands. Projects are developed in collaboration with the Apulia Region and local municipalities and embedded within broader regional environmental frameworks. Scientific institutions including the University of Salento and the University of Foggia contribute to performance monitoring and ecological research.

In the water-scarce region of Apulia, Acquedotto Pugliese (AQP) has turned to constructed wetlands—also known as phytodepuration systems—as a Nature-based Solution to treat wastewater in a low-energy, low-impact way. Facing mounting pressure from groundwater contamination, high seasonal water demand, and the need to decarbonise infrastructure, AQP is integrating wetland-based treatment into its broader strategy for sustainable water management. By harnessing the natural filtering capacity of vegetation and microbial activity, these systems remove pollutants that conventional plants often struggle to eliminate, while consuming a fraction of the energy.

AQP has implemented phytodepuration systems across several sites in the region. Two standout examples are located in Melendugno and Carmiano, where constructed wetlands use dense aquatic vegetation to naturally filter wastewater, removing pollutants before the treated water is discharged into the environment.

The Melendugno site, commissioned in 2010, covers 8 hectares—5 of which are active treatment basins—and processes approximately 9,000 cubic metres of wastewater per day. It receives inflow from the local wastewater treatment plant serving the municipalities of Melendugno, Calimera, and Martignano. The system is specifically designed to target persistent pollutants such as pharmaceuticals and pesticides, which are often not fully removed by conventional wastewater treatment plants.

A second facility in Carmiano, developed in 2014, consists of four constructed wetland basins covering 0.65 hectares, with a treatment capacity of 2,465 cubic metres per day. This system incorporates more than 22,000 plant rhizomes, which help to enhance biological filtration, accelerate pollutant breakdown, and promote water oxygenation.

The constructed wetlands function by guiding pre-treated wastewater through a series of shallow, vegetated basins planted with species such as Phragmites australis (Common Reed) and Typha latifolia (Cattail). These plants trap sediments, stimulate microbial activity, absorb excess nutrients, and filter out a wide range of contaminants. Beyond their wastewater treatment functions, constructed wetlands offer a range of environmental co-benefits. They create habitats for migratory birds and local wildlife, improve carbon sequestration, and help regulate local microclimates. The rich vegetation and steady water presence enhance biodiversity.

AQP also emphasises the economic and operational efficiency of phytodepuration systems. Compared to traditional wastewater treatment plants, constructed wetlands require less energy and fewer chemicals. Operating costs are significantly lower, €0.01 per cubic metre, compared to €0.12 per cubic metre for conventional systems. These projects also create local employment in areas such as wetland maintenance, plant cultivation, and ecological monitoring.

To safeguard long-term performance, AQP has established scientific monitoring programmes to assess pollutant removal rates, plant vitality, and overall ecosystem stability. These ongoing studies help refine and optimise the phytodepuration process.

CASE STUDY

MM's Phytodepuration System

(MM Spa, Italy)

Location

What it is about

The phytodepuration system treats stormwater overflows using a two-stage constructed wetland. By combining submerged- and free-flow wetlands, it reduces pollutants by at least 50%, supports biodiversity, and lowers treatment costs.

Financing

Financed as part of MM's infrastructure development programme.

Parties involved

Developed and managed by MM. The Municipality of Milan was involved in site selection and planning, ensuring that the project was well-integrated with the surrounding urban landscape. Technical experts from MM carried out feasibility studies, field surveys, and design optimisations to align with ecological and hydraulic requirements.

The Nosedo Wastewater Treatment Plant in Milan is central to managing urban water quality. As part of its broader infrastructure modernisation and sustainability strategy, MM implemented a phytodepuration system integrated with newly constructed rainwater retention tanks. The project aims to improve the treatment of stormwater overflows, particularly during heavy rainfall, and reduce pollutant loads entering local water bodies, aligning with Milan's broader sustainability goals by incorporating NbS into urban water management.

The phytodepuration system was built between the Vettabbia watercourse (southern part of Milan) and the Nosedo emissary, a site chosen to both maximise treatment efficiency and support the ecological fabric of the adjacent park. The system comprises two main components operating in sequence to treat stormwater: a submerged-flow constructed wetland followed by a free-flow constructed wetland.

The process begins with pre-treatment in rainwater retention tanks, where coarse solids are removed from wastewater through screening and sedimentation. This first step reduces the pollutant load and prepares the water for biological treatment. From there, the water is pumped into the submerged-flow phytodepuration system, made up of eight vertical-flow basins filled with gravel and planted with aquatic vegetation. This configuration supports filtration and microbial activity, which together help break down organic pollutants and reduce the overall contaminant load.

The treated water then passes into the free-flow phytodepuration system, which serves as the final polishing stage. This system includes a 5,400 m² wetland area designed to stabilise and further purify the water before its controlled release. The free-flow system plays an essential role in equalising flow rates, improving biodiversity, and reinforcing ecological corridors within the park.

The system as a whole is capable of intercepting at least 50% of the annual pollutant load from stormwater overflows. In addition to environmental benefits, the system contributes to operational efficiency. By intercepting and partially treating stormwater before it reaches the main treatment facility, it reduces energy consumption, lowers operational costs, and extends the capacity of existing infrastructure. Its integration within a public green space also creates visible co-benefits, from enhanced biodiversity to improved recreational amenities.

Areas identified in agreement with MM technicians and the Municipality of Milan for the construction of phytoremediation systems

CASE STUDY

Dunhill Integrated Constructed Wetlands

(Uisce Éireann, Ireland)

Location

What it is about

The Dunhill Integrated Constructed Wetlands treat all local wastewater and stormwater using natural wetland processes. Designed to mimic marsh ecosystems, the system improves water quality while supporting biodiversity and providing recreational and educational benefits to the community.

Financing

Financed by Waterford County Council with support from the Department of Environment, Community and Local Government (DECLG).

Parties involved

The initial wetland was designed and constructed by Waterford County Council (Ray O'Dwyer & Paul Carroll). The extension in 2012 was developed by environmental consultants Vesi Environmental Ltd. and Dr. Rory Harrington. The system is currently operated and managed by Uisce Éireann.

Located in the village of Dunhill, County Waterford, the Dunhill Integrated Constructed Wetland (ICW) treats all wastewater and stormwater generated by the local community. The initial system was constructed in 2000 to serve a population of about 100 people. As the village grew, a second ICW was added in 2012 to accommodate increased loads. This innovative system is part of a broader effort within the 2,500-hectare Dunhill–Annestown catchment, where 23 ICWs have been constructed since 1995 to treat a wide range of agricultural, commercial, and domestic wastewater.

The ICW system treats all wastewater from Dunhill village, with a design capacity estimated at around 200 population equivalent (PE). It features two phases of wetlands located on either side of the main village road. The full treatment site covers 4 hectares, with 1.3 hectares functioning as the primary treatment area. The system includes a septic tank, two settlement cells, and four multi-stage treatment cells. It also incorporates dedicated stormwater cells that manage surface runoff before combining with treated effluent and discharging into the Anne River.

Treatment occurs in both anaerobic and aerobic conditions through shallow, vegetated wetland cells designed to mimic natural marshes. Native plant species such as bulrush and cattail slow water flow, improve sedimentation, and support microbial activity necessary for the degradation of pollutants. The ICW also features a spring-fed reference pond, serving as a natural benchmark for effluent quality.

Beyond treatment, the ICW delivers significant environmental and social co-benefits. It contributes to local biodiversity, provides habitats for aquatic and terrestrial species, and plays an educational and recreational role in the community. The 2012 extension included the creation of a village amphitheatre and has since become integrated into the 5-kilometre Anne Valley Walk, a local greenway connecting Dunhill to the coastal village of Annestown.

In 2018-2019, Uisce Éireann conducted a year-long performance study, taking weekly samples to assess the treatment efficiency of each foul water cell. Results confirmed the ICW's high performance in reducing contaminants across all measured parameters, reinforcing the system's viability as a sustainable and low-energy solution to wastewater management.

Dunhill village integrated constructed wetland (ICW)

CASE STUDY

Reuse of Treated Effluents

(Piave Servizi, Italy)

Location

What it is about

The project uses treated wastewater to support forest health and sustainability. It aims to reduce freshwater use and boost carbon sequestration by irrigating a local forest with reclaimed water. The initiative integrates real-time monitoring and strict safety plans to ensure water quality, while promoting biodiversity and climate resilience.

Financing

Co-financed under the Piano Sviluppo e Coesione Veneto FSC 2021-2027, with resources allocated for research, development, and environmental monitoring.

Parties involved

Led by Piave Servizi in close collaboration with the Municipality of Meolo, which owns and manages the Belvedere Forest. Scientific support is provided by the Università Politecnica delle Marche. CO.RI.LA. assists with environmental studies related to water-ecosystem interactions. KANDO (BM Tecnologie Industriali) supplies real-time wastewater monitoring systems, and Hydroprogetti S.r.l. is responsible for the infrastructure design and engineering.

The Belvedere Forest project in Meolo, located in the Veneto region of Italy, and developed by Piave Servizi, explores the use of treated wastewater to support forest health and function. By assessing the quality of the effluents from the Meolo wastewater treatment plant and ensuring compliance with reuse regulations, the project aims to demonstrate how reclaimed water can improve tree growth, enhance biodiversity, and boost carbon sequestration. Real-time data is gathered through Tree Talker sensors installed throughout the forest, which monitor parameters such as sap flow, growth rate, and climate response.

One of the core objectives of the project is to determine whether the forest can serve as a carbon sink to offset CO_2 emissions from the Meolo wastewater treatment plant. Preliminary estimates suggest that the 18-hectare forest already sequesters more than 200 tons of CO_2 annually—a figure expected to increase if the forest benefits from consistent irrigation with reclaimed water.

To ensure water reuse is safe and sustainable, a Water Sanitation Safety Plan (WSSP) has been implemented. This plan outlines risk management procedures and incorporates stakeholder input from municipal authorities, environmental agencies, and local farmers. Special attention is given to the plant's sewage matrix, which includes significant industrial inflows. Monitoring has confirmed the high purification performance of the treatment plant, and targeted sampling has been conducted to verify compliance with reuse standards under the new European regulations.

The Municipality of Meolo plays a key role in enabling the project, as it owns the Belvedere Forest. The Forest is typically managed by a contracted operator, selected by the municipality, responsible for its maintenance, recreational use, and educational outreach. For environmental enhancement initiatives like this one, formal authorisation is required but typically supported enthusiastically by the local administration.

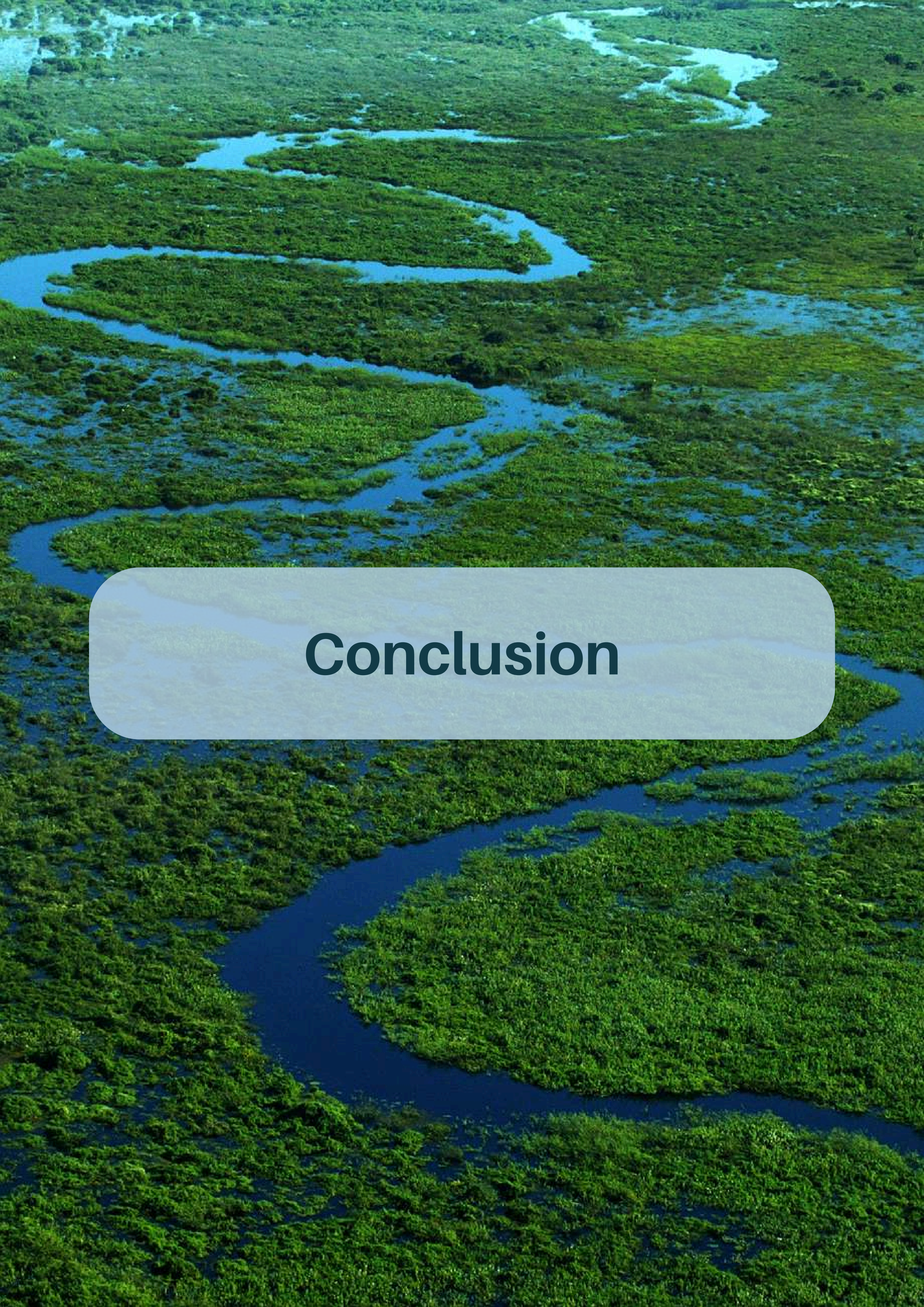
The project is divided into two phases. The first phase focuses on validating the effluent quality and ensuring that it meets reuse standards, especially given the presence of industrial sources in the sewage stream. The second phase explores ways to enhance the forest's ecological value, promote biodiversity, and refine methodologies for calculating CO_2 offsets.

If successful, the Belvedere Forest project will demonstrate how treated wastewater can be repurposed to support ecosystem health and climate action.

Key takeaways

Constructed wetlands are increasingly proving their value as practical solutions for treating wastewater and managing stormwater. As the cases above demonstrate, these systems are not only effective at removing pollutants, including emerging contaminants, but also deliver a range of ecological and social co-benefits, from enhancing biodiversity and sequestering carbon to improving microclimates and creating public green spaces. They also offer a reliable, low-energy, and low-cost complement to conventional treatment infrastructure. Yet, developing and operating constructed wetlands in practice requires highly specific knowledge—expertise that not all water operators may currently have at their disposal. Constructed wetlands are complex, living ecosystems, and their design and maintenance must be supported by robust monitoring frameworks, ecological expertise, and long-term investment planning. The selection of the sites, hydraulic performance, plant health, and seasonal dynamics all influence effectiveness.

In many ways, constructed wetlands sit at the crossroads of engineering and ecology. With the right expertise and institutional backing, they offer a scalable solution that water operators can integrate into their toolkit for improving wastewater quality and managing stormwater overflows.



Conclusion

CONCLUSION

Throughout this publication, we have highlighted examples of nature-based and hybrid solutions implemented by European public water operators, members of Aqua Publica Europea. The case studies presented are remarkably diverse, ranging from ecosystem restoration and sustainable urban drainage systems to catchment protection, wastewater treatment, aquifer recharge, and constructed wetlands. Similarly, the roles played by our members in these projects are varied, as are the financing mechanisms that make them possible.

One common characteristic, however, runs through all these measures: in addition to addressing water-related challenges, solutions that restore or mimic natural processes typically unlock a broader spectrum of co-benefits for society. These include enhanced biodiversity, greater resilience to the impacts of climate change, carbon sequestration, more liveable public spaces, and much more.

In short, Nature-based Solutions are not a silver bullet, but they can represent an important element in the toolbox of water operators to address the growing pressures threatening our environment and societies. Whether implemented as stand-alone measures or as part of hybrid systems, their flexibility allows them to complement, and in many cases, strengthen traditional engineering infrastructure.

Paradoxically, this very potential of NbS to deliver multiple benefits can also pose a challenge to their uptake. First, many of the benefits generated by NbS present the typical features of public goods (they cannot be appropriated by individuals). Moreover, these benefits often extend over a relatively wide geographical area, larger than the site where the NbS is implemented, and beyond the administrative boundaries of the authority that took the decision on their realisation. The combination of these two aspects may complicate the identification of viable financing mechanisms.

In addition, the multi-benefit and multi-scale nature of NbS, combined with the land-use changes they frequently entail, means that responsibilities for design and implementation are often distributed across several actors and institutions, making coordination and decision-making more complex.

Finally, while NbS are expected to have longer lifespans (and therefore produce benefits over longer periods) compared to traditional infrastructure, their long-term maintenance costs are not always well established. More generally, robust metrics to carry out cost-benefit analysis of NbS (against other options) are still partially missing. This is partly due to the time required to generate sufficient data and analytical framework enabling for a thorough assessment of NbS. But there is probably also an intrinsic complexity in evaluating NbS due to their multi-benefit nature mentioned above, and to the fact that costs and benefits may vary significantly depending on local contexts.

For all these reasons, a greater uptake of NbS will require[9]:

- The development of conducive policy frameworks to address the governance, financial, and knowledge barriers that still limit the deployment of NbS. Policies and regulations promoting more integrated land and water planning are particularly essential. In this regard, the requirement for "integrated stormwater management plans" in the revised Urban Wastewater Treatment Directive is a positive example, stepping in this direction.
- The development of dedicated financing mechanisms to support NbS. Relevant examples already exist, such as the ring-fenced tax introduced under the GEMAPI law in France (see page 17), or the stormwater fees calculated on some proxy of land-use such in Germany and in the Netherlands.
- Closing the knowledge gap in the sector. Further research on the long-term costs and benefits of NbS is needed, supported by sustained public funding. EU programmes such as Horizon and LIFE have already played an important role in advancing this knowledge, and it is important that similar funding streams remain available in future Multiannual Financial Frameworks.

We can transfer or clean water (and both activities require a significant amount of energy), but we cannot "produce" water (at least not in a way that is economically viable): only nature knows how to do it. As Europe strives to adapt to the impact of climate change and shift towards more sustainable economic models, nature-based and hybrid solutions will play a vital role in reshaping water management and our approaches to ensuring Europe's water security.

Public water operators are already demonstrating leadership in this field, implementing NbS and hybrid approaches whenever they provide effective responses to concrete local challenges. Their experience shows both the feasibility of these measures and their capacity to deliver multiple societal benefits.

The task ahead lies in strengthening the governance, financing, legislative, and knowledge frameworks that will allow such solutions deploy their full potential and that their uptake is not hindered by institutional bottlenecks.

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4. https://www.eea.europa.eu/help/glossary/gemet-environmental-thesaurus/water-catchment-protection
5. https://www.consilium.europa.eu/en/policies/wastewater-treatment/
6. https://www.nwrm.eu/concept/3853
7. Figure 8.2 Schematic types of managed aquifer recharge, where ASR: aquifer storage and recovery, ASTR: aquifer storage, transfer and recovery (Dillon, 2005), retrieved from https://circabc.europa.eu/sd/a/049c2aba-fe3e-481a-95f3-d956be4e52e4/RECLAIM_WATER_Policy_Brief_Final.pdf
8. https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/constructed-wetland
9. For more information, please refer to the strategy we have developed for the Water Supply and Sanitation Sector on how to mainstream NbS and increase their uptake, elaborated in the framework of our participation in the EU-funded project MERLIN: https://project-merlin.eu/files/merlin/downloads/sectoral_strategies/MERLIN_sectoral_strategy_Water_Supply_and_Sanitation_sector.pdf

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