Case Studies

on the integration of the gray and green infrastructure

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Foreword

With climate change making unwanted progress every day, business as usual is not an option in many sectors. The water sector is no exception. Increasing variability and uncertainty due to climate change are challenging water management and water-related disaster risk reduction. Not only the means, but also the basic concepts of water management need to be transformed to meet the challenges of climate and other global changes.

Since the dawn of human civilisation, societies have made investments in water to cope with the demands of climate and nature. Such human investments can even be seen in the heritage sites of the four great ancient civilisations - Egypt, Mesopotamia, Tigris-Euphrates and China - that were located along major rivers. Modern materials such as concrete and reinforced iron, and the technologies to use them, often in combination with natural materials such as earth and rock, have been developed, resulting in the construction of hundreds of thousands of 'grey' infrastructures that today support the lives and livelihoods of billions of people around the world. They have been seen and used as almost a panacea for water control. However, they are no longer versatile enough to meet the challenges of diverse demographic, industrial, social, financial and environmental conditions in a rapidly changing climate.

Green infrastructure is not new to the water sector. Its early traces can also be seen in historical heritage sites. Today, green infrastructure has re-emerged as another tool for water management. Newly developed science and technology, as well as growing local knowledge and experience, are demonstrating its multiple benefits for our societies and ecosystems, while serving the purposes of effective water management.

However, green infrastructure cannot replace grey infrastructure, at least not completely, and vice versa. The lesson is to combine the two appropriately. They differ in function, applicable scale, hydro-meteorological effectiveness, social and environmental impacts, and socio-economic costs and benefits. There are many cases where a grey or green structure added to an existing green or grey infrastructure dramatically increases its water benefits to people. Our challenge is to find the best "grey"-"green" combinations for the specific situations of our countries, cities and watersheds.

As green infrastructure re-emerges, its benefits, costs and conditions of use should be studied with grey infrastructure using our best scientific knowledge. We need to find the best combination and the most appropriate scale for planning and implementing investments. We also need to advance scientific and practical knowledge about effective practices and synergies with grey infrastructure.

The principles you will read in this document are guidelines for action that you can take as a decision-maker, coordinator, practitioner or any other stakeholder when dealing with green, grey and combined infrastructure for water management. They will help you to make informed choices about the best options to consider.

I sincerely hope that these principles will be useful to your country, community and people.

Dr. Han Seung-soo
Chair, High-level Experts and Leaders Panel on Water and Disasters (HELP)
Former Prime Minister of Republic of Korea

1 Case Studies on the integration of the green and grey infrastructure and nature-based solutions in the water-related infrastructure in Japan

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The Japanese government has long promoted nature-oriented river improvement and has implemented a number of infrastructure projects based on the struggle to find the appropriate balance between green and grey aspects of the projects. Through these experience in Japan, the authors introduce Japan's struggles to find the right balance between green and grey infrastructure in water management. Through the lessons learned from these examples, the authors highlight the importance of community and education.

1. Details of the project

In Japan, the river and freshwater network has been closely linked to people's daily lives, including transportation, domestic water supply and laundry. The development of infrastructure systems, including railways, motoways and water supply pipes, has forced the relationship between people and rivers, to be varied, and to be distant.

Historically, based on the experience of their long history, the Japanese have a lot of indigenous knowledge about how to deal with rivers and fresh water. However, most of them have been forgotten in the shadow of economic growth and infrastructure development.

In 1990, the Ministry of Construction (now the Ministry of Land, Infrastructure, Transport and Tourism) of Japan started the nature-oriented river improvement, which is similar to what we now call "nature-based solution", by issuing a document entitled "A guideline for promotion of nature-oriented river improvement". The guideline sets a fundamental value of "paying attention to the good habitat and nurturing environment for biological organisms that rivers naturally provide, while preserving or creating beautiful natural landscapes".

On the basis of this guideline and the following documents, Japan has developed nature-oriented or nature-based solutions based on an appropriate balance, which is not easy to determine, of the green and grey infrastructure.

In this chapter, the author presents several examples in Japan that consider the balance between green and grey infrastructure in the development of water-related infrastructure.

2. Cases

2.1. Riverside forest managed by local communities for more than 400 years (Fukushima, Japan)

The Arakawa River, a major tributary of the Abukuma River in Fukushima Prefecture, is characterised by very steep gradients and large amounts of sediment runoff due to the active volcano Mt. Agatsuma at its headwaters. The Arakawa River has long been the scene of frequent disasters, and records of disasters in the basin can be traced back to at least the 17th century. In the past, local communities have been involved in the protection of residential and farmland, the construction of open and non-contiguous levees, and the planting of flood protection forests in the riverside.

The idea of a flood protection forest was legislated in the amendment of the River Act of 1997. The forest around the Arakawa River was designated as a special forest area based on the amended River Act. This combination of forest and levee is still in place today and is still a source of protection for the city of Fukushima.

Fig. 1 Arakawa River Basin

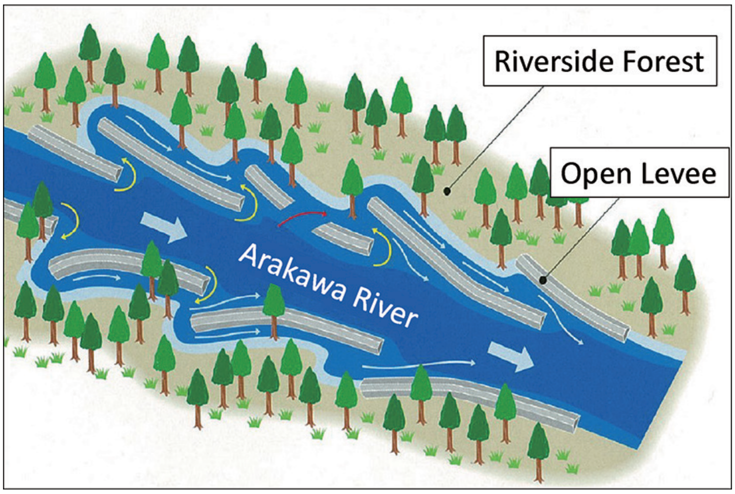

Fig. 2 Riveride flood protection forest and open levee system


Fig. 3 Riveride flood protection forest


Fig. 4 Open levee system in front of the flood protection forest

2.2. Moderation of farmland to co-benefit wetland park and flood storage (Shizuoka, Japan)

The Tomoe River basin, located in Shizuoka City of Japan, has historically experienced recurrent flooding due to the topographical features of gentle slopes and meandering channels and fragile geology in hilly areas.

Local communities have struggled with flooding for centuries. People in this basin have struggled to tackle the high frequency of flooding and have carried out various amounts of dredging and river improvement works.

The city has experienced rapid urbanisation since the 1950s, which has increased the speed and volume of flood discharges in the basin.

After a devastating flood in 1974, the Shizuoka Prefectural Government decided to promote comprehensive flood disaster risk reduction measures, including large-scale infrastructure such as the Oya Floodway, a diversion channel for the mainstream, the Asahata Flood Control Basin which is reported below, and community-based flood storage activities such as schoolyard flood storage, park flood storage and individual home flood storage.

The Asahata Flood Control Basin has been designed as a combination of green and grey infrastructure, including an urban park zone, a health promotion zone, a waterside recreation zone and a nature field zone. All these zones also have flood storage capacity and reduce flood discharge downstream.

In normal times, these zones play an important role as green infrastructure, providing citizens with nature-oriented activities and water-friendly habitats.

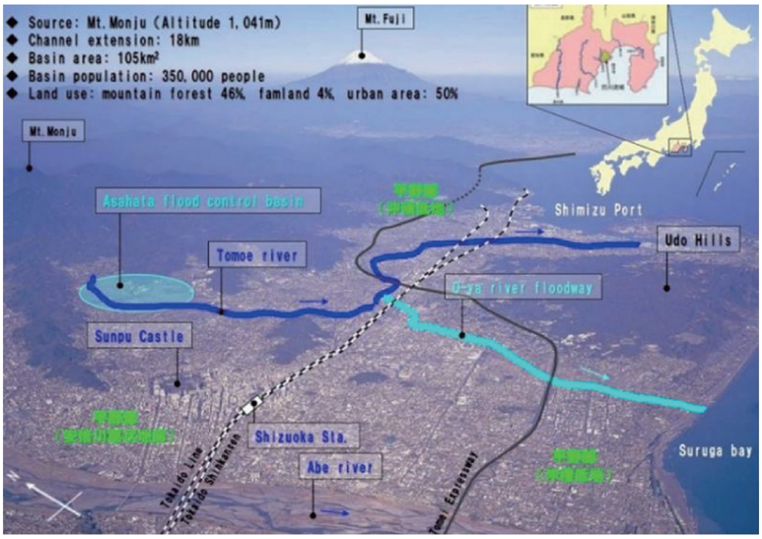

Fig. 5 Overview of the Tomoe River Basin (Source: Shizuoka Prefecture)

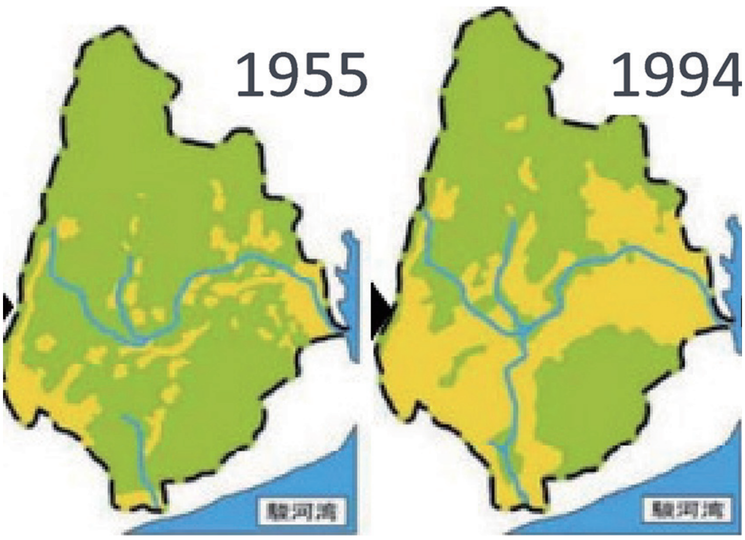

Fig. 6 Urbanization of the Tomoe River Basin (Source: Shizuoka Prefecture)

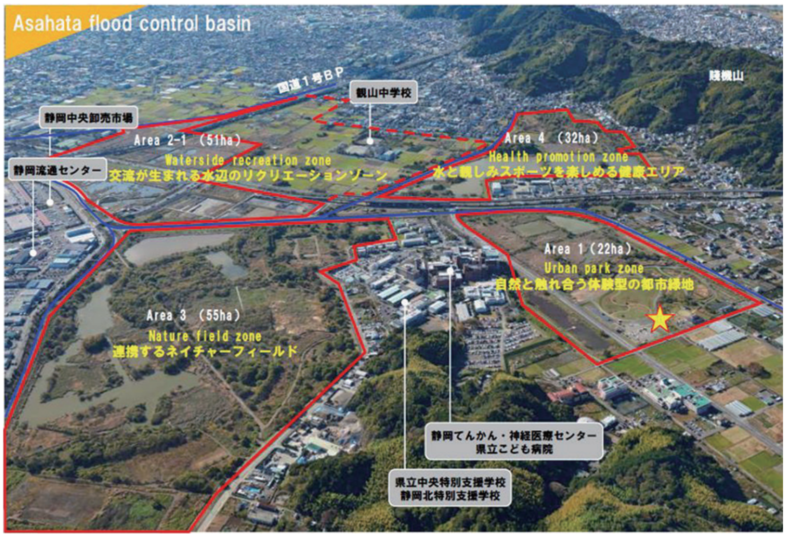

Fig. 7 Zoning of the Asahata Flood Control Basin (Source: Shizuoka Prefecture)

Fig. 8 Asahata Flood Control Basin storing floodwater in the 2022 flood (Source: Shizuoka Prefecture)

Fig. 9 Children's experience of rice planting in the Asahata Flood Control Basin (Source: Asahata Flood Control Basin Management Committee)

2.3. Great Forest Wall: Combination of multiple lines of tsunami defense facility based on the combination of green and grey infrastructure (Miyagi, Japan)

More than 15,000 people lost their lives and around 2,500 people are still missing in the devastating tsunami disaster caused by the tsunami caused by the Great East Japan Earthquake in 2011. In the aftermath of the tragedy, the Japanese government decided to build a comprehensive tsunami disaster risk reduction infrastructure along more than 400 km of the damaged coastline. The details of infrastructure development have been implemented through dialogues with local governments and local communities, which take years to reach a consensus.

Some areas have decided to plant coastal forests to reduce the risk of tsunami surges over the height of coastal levees. This comprehensive system, consisting of tsunami protection forests and levees with a reinforced surface, has been called the "Great Forest Wall".

This system is expected to provide persistent protection for coastal levees and contribute to the creation of a landscape that is integrated with the land behind it, preserving the natural environment and contributing to coastal use.

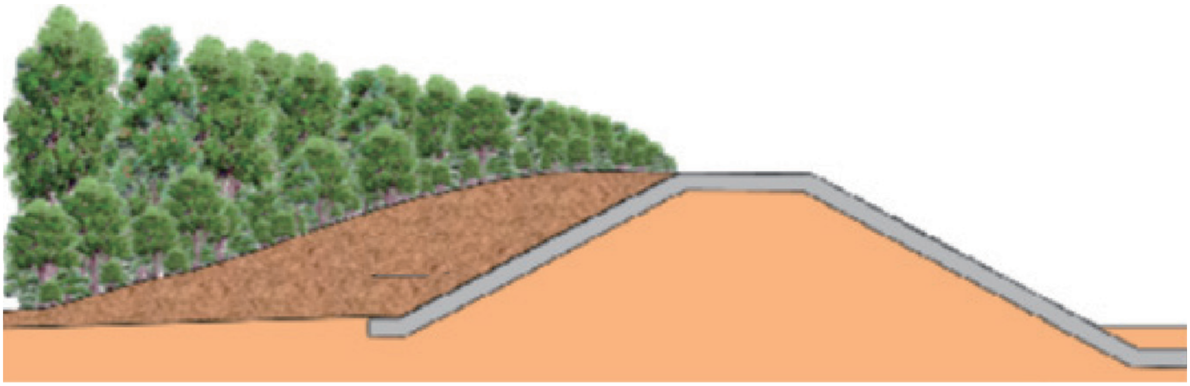

Fig. 10 Concept of the Great Forest Wall

Fig. 11 Implementation in Nakahama district

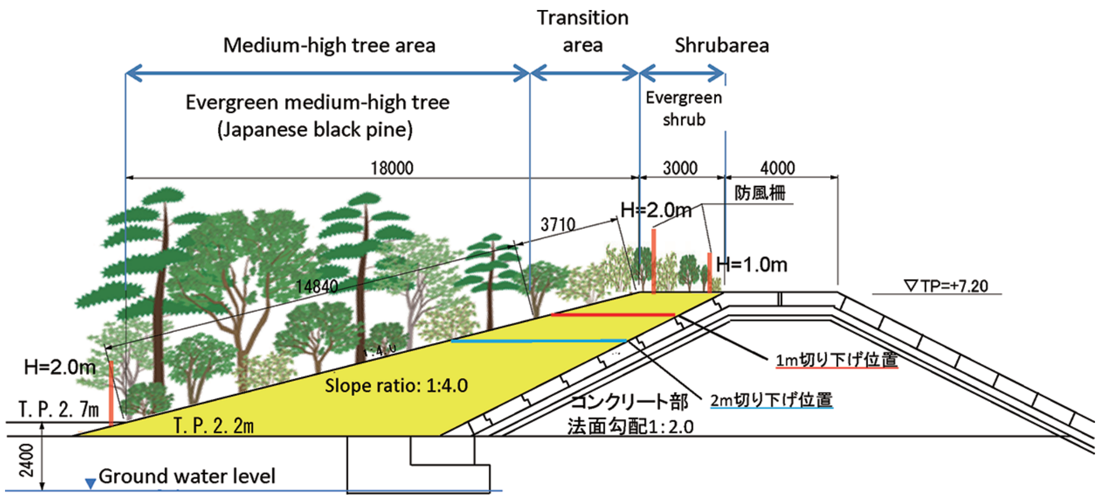

Fig. 12 Standard cross section of the levee

2.4. Kiso Sansen Park (Kiso three rivers park): The use of the river space as an urban recreation area and as a field for eco-hydrological education (Aichi, Gifu, Mie, Japan)

The Kiso River Basin is one of the most complex river basins in Japan, with a conjunction of three interrelated main rivers, the Kiso, the Ibi and the Nagara, which have complicated interactions with each other. Governors and people living in this basin have long struggled to manage the flood risks caused by the river.

In the Meiji era, from the late 19th century to the early 20th century, the Japanese government, assisted by engineers dispatched from the Netherlands on the basis of bilateral cooperation, carried out a huge river improvement plan that divided the river into three main streams to avoid complicated interrelationships between the basins.

As a result of this huge improvement work, a large amount of flat land has been created between and around the three main streams.

The Japanese government decided to utilise this space for the recreation and education of the citizens as the largest national park and named it "Kiso-Sansen Park", which means "Park of the Three Rivers". The park was inaugurated in 1987 and is divided into 13 areas, each with a different theme, such as the education of flowers and plants (area no. 1), water sports (area no. 7) or aquatic life (area no. 11).

Today, the park attracts more than 10 million people a year and more than 160 million people in total, contributing to the recreation and education of the people living around the basin, as well as tourists from all over the world.

Fig. 13 Standard cross section of the levee

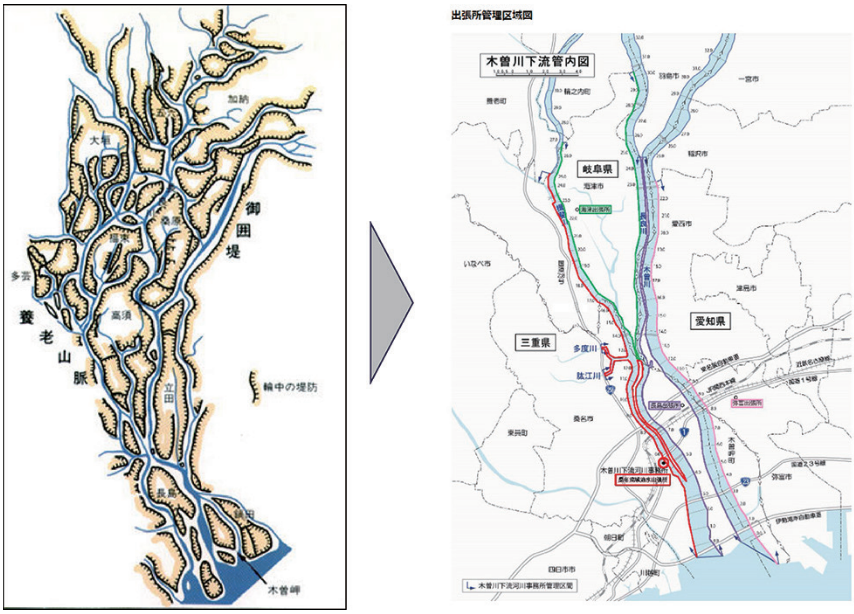

Fig. 14 Hisory of improvement of the Kiso River Basin (17c and now)

Fig. 15 A botanical garden in the flower park

Fig. 16 River environment educational park

Fig. 17 Historic river park at ancient battlefield

2.5. Nature-and-Culture-Oriented River Management (Gifu, Japan)

In the past, Japan's national land development, urbanisation and flood control measures, which did not take into account the river environment, have deteriorated the habitat, growth, breeding environment and landscape of living organisms, resulting in the disruption of the good relationship between people and rivers.

However, since the revision of the River Law in 1997, the concept of 'multi-nature river development' has been developed and applied to all rivers since 2006.

Specifically, the concept is to conserve the river's inherent habitat, growth and breeding environment for living organisms and diverse river landscapes, while taking into account the natural activities of the river as a whole and harmonising with local life, history and culture in all actions of survey, planning, design, construction and maintenance.

On the Itonuki River in Gifu Prefecture, the riverbed along the waterway and park were developed in an integrated manner. Through hydraulic analysis, the revetment was removed and the steps for approaching the waterfront were eliminated. An artificial babbling channel was created to guide people to the river.

This has encouraged children to enter the river to play.

Fig. 18 Itonuki River, before improvement

Fig. 19 Itonuki River, after completion

3. Key challenges and recommendations

Like other countries, Japan has struggled to find the right balance between green and grey infrastructure in water management. Although there are many lessons to be learned from the above activities, the authors would like to highlight the importance of community and education.

In general, green infrastructure should be well maintained to preserve its value in both infrastructure and ecosystem aspects. Community consensus and participation are essential for both purposes. In the case of the Arakawa River (2.1), the community has played a major role in maintaining both green and grey infrastructure for centuries. In the case of the Tomoe River (2.2) and the Great Forest Wall (2.3), the community has been carefully involved in the development and management of the entire infrastructure system from the very beginning, so that community members feel a sense of ownership of the infrastructure.

Education is also important, both in terms of eco-education and community involvement. In the cases of the Asahata Flood Control Basin (2.2) and the Kiso-Sansen Park (2.4), the ecosystem and biotope have been included in the curricula of local primary and/or secondary education programmes. The Itonuki River (2.5) encourages children to learn about the river. It obviously improves the quality of ecohydrological education and the commitment of the community members, who are also the grown children who have received this eco-education.

4. Conclusion

The Japanese government has long promoted nature-oriented river improvement and has implemented a number of infrastructure projects based on the struggle to find the appropriate balance between green and grey aspects of the projects. The author has presented several examples of such activities and emphasised the importance of community involvement and educational application as lessons from these experiences.

Japan will continue to improve and expand ecohydrological infrastructure development based on the balance between green and grey infrastructure, also in cooperation with the international community.

2 K-water's Integrated Gray and Green Infrastructure Development for Climate Change Response and Water Disaster Risk Reduction

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General Manager, K-water (Busan Eco Delta Smart City)

1. Summary of the article

The integration of green and gray infrastructure presents a future-oriented approach in sustainable water management by combining the advantages of nature-based solutions and engineering systems. At the forefront of these innovative efforts, Korea Water Resources Corporation (K-water) aims to showcase exemplary cases of green and gray infrastructure integration. The goal is to demonstrate how the synergy between these two types of infrastructure can address the complex challenges of water management faced by climate change and urbanization.

This case study explores two exemplary projects in Korea : the Sihwa Lake Tidal Power Plant and the Busan Eco Delta Smart City. These projects are not only at the forefront of sustainable water management in Korea but also serve as global benchmarks for utilizing and harmonizing the functions of natural and engineering systems.

the Busan Eco Delta Smart City embodies a future vision where green infrastructure is seamlessly integrated into urban planning. This smart city demonstrates how urban landscapes can collaborate with natural processes and merge with cutting-edge ICT technologies to promote efficient water management and enhance the quality of life for its residents.

On the other hand, The Sihwa Lake Tidal Power Plant, a marvel of gray infrastructure, utilizes natural tidal movements to produce electricity, marking a significant technical achievement in the renewable energy sector. Particularly, the integration with green strategies shows a successful balance between industrial development and ecological sustainability.

By reviewing these two projects, this case study aims to provide valuable insights into the potential of integrating environmentally friendly and gray infrastructure. It highlights how such integration can lead to more sustainable, resilient, and adaptable water management practices essential in the era of rapid urbanization and climate change. Moreover, as water-related disasters increase globally, this article is confident that it will serve as a useful reference for organizations, urban planners, and policymakers striving to implement sustainable water solutions.

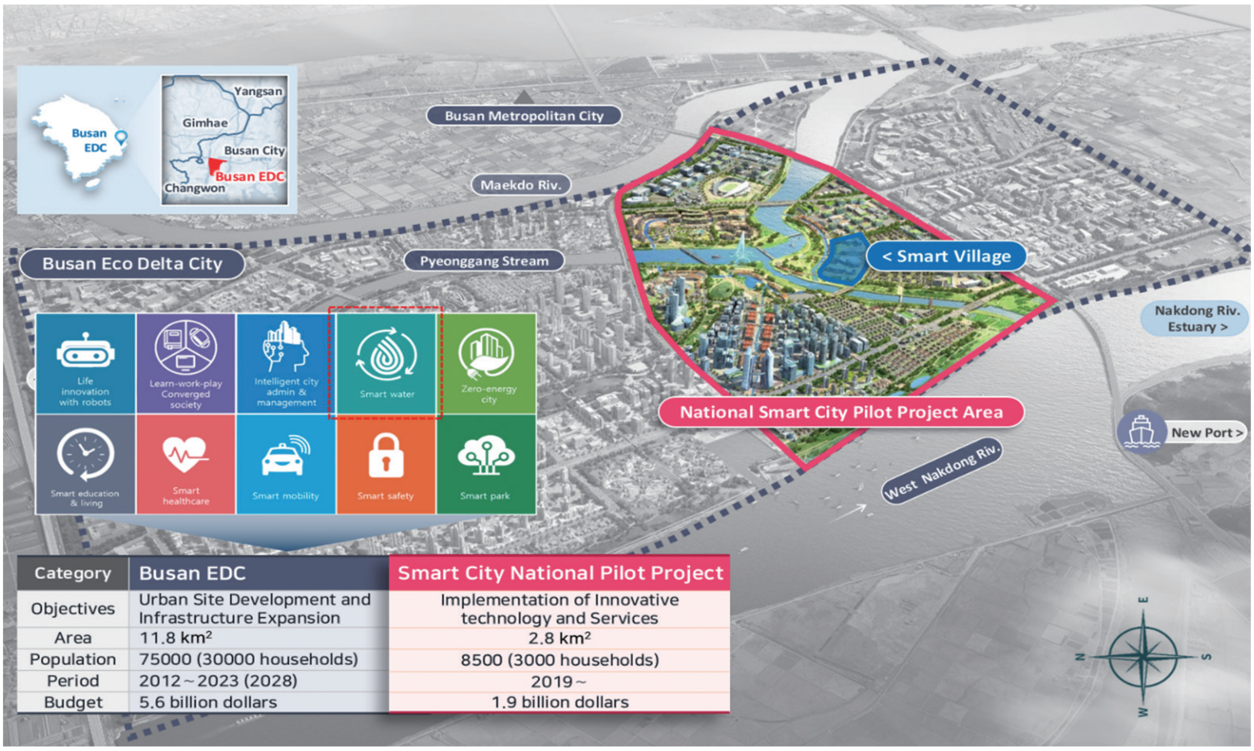
2. Details of the project

(1) Busan Eco Delta Smart City

First case is the Busan Eco Delta Smart City project. This project is part of South Korea's smart city pilot program aimed at incorporating Fourth Industrial Revolution technologies into urban development. Initiated in 2019, K-water is currently developing approximately 12 km² of urban area in the Gangseo District of Busan Metropolitan City, focusing on a central area of about 2.8 km² where ecological environments and key technologies of the Fourth Industrial Revolution converge to construct a smart city.

The project aims to implement smart technologies including smart healthcare services, smart education systems, smart transportation and safety, life innovations using robotics, intelligent urban administration and management, smart water, and a zero-energy city concept.

Notably, the city is flanked by the Nakdong River and the West Nakdong River, possessing rich water resources with three waterways at its heart, which positions it advantageously as an eco-friendly waterfront city. Based on specialized water management technologies, K-water is developing a smart water city platform that responds to climate change by applying advanced smart water management technologies and services throughout the entire urban water cycle (rainfall-river-water purification-sewage-reuse).



Category	Busan EDC	Smart City National Pilot Project
Objectives	Urban Site Development and Infrastructure Expansion	Implementation of Innovative technology and Services
Area	11.8 km²	2.8 km²
Population	75000 (30000 households)	8500 (3000 households)
Period	2012 ~ 2023 (2028)	2019 ~
Budget	5.6 billion dollars	1.9 billion dollars

< View of Busan Eco Delta Smart City>

(2) Sihwa Lake Tidal Power Plant

The second case, the Sihwa Lake Tidal Power Plant, is located on the west coast near Ansan city in Gyeonggi Province, South Korea. It is part of the development plan for the Sihwa District, which surrounds Sihwa Lake. The project involved constructing a dike and land reclamation to collect fresh water from nearby rivers and turn it into a lake. Construction of the dike began in April 1987, extending from Daebudo in Ansan to Oido in Siheung, covering five sections and 12.7 km. By January 1994, approximately seven years later, the construction of Asia's longest dike, with a water surface area of 48.98 km² and a total storage capacity of 330 million tons, was completed.Tidal power generation harnesses energy from the changes in sea levels caused by tidal forces. The west coast of Korea, where tidal range differences are particularly significant—reaching up to 10.3 meters in tidal range and 7.5 meters per second in maximum flow velocity—provides favorable conditions for tidal power.

The Sihwa Lake Tidal Power Plant was built into sections of the dike blocking Sihwa Lake, with construction spanning from 2004 to 2011. It features ten 20MW Kaplan turbines, each with a rotor diameter of 14 meters and a blade length of 7.5 meters. These turbines generate a total of 254 MWh per day, which annually adds up to 552 GWh—enough to supply electricity to 500,000 people for a year.

Additionally, the natural environment adjacent to the sea has been utilized to develop renewable energy sources such as solar and wind power. The Sihwa Lake area now hosts a renewable energy cluster equipped with facilities for solar, wind, and hydrogen energy demonstration. Around the power plant, solar and wind power plants, an offshore solar power demonstration site, and energy storage systems (ESS) have been established, and there are ongoing initiatives to utilize sea thermal energy.

Category	Sihwa Lake Tidal Power Plant
Facility Capacity	254MW (10 turbine-generator)
Annual Generation	552GWh
Generation Type	Single Tide-cycle System
Period	2004~2011
Budget	0.46 billion dollars

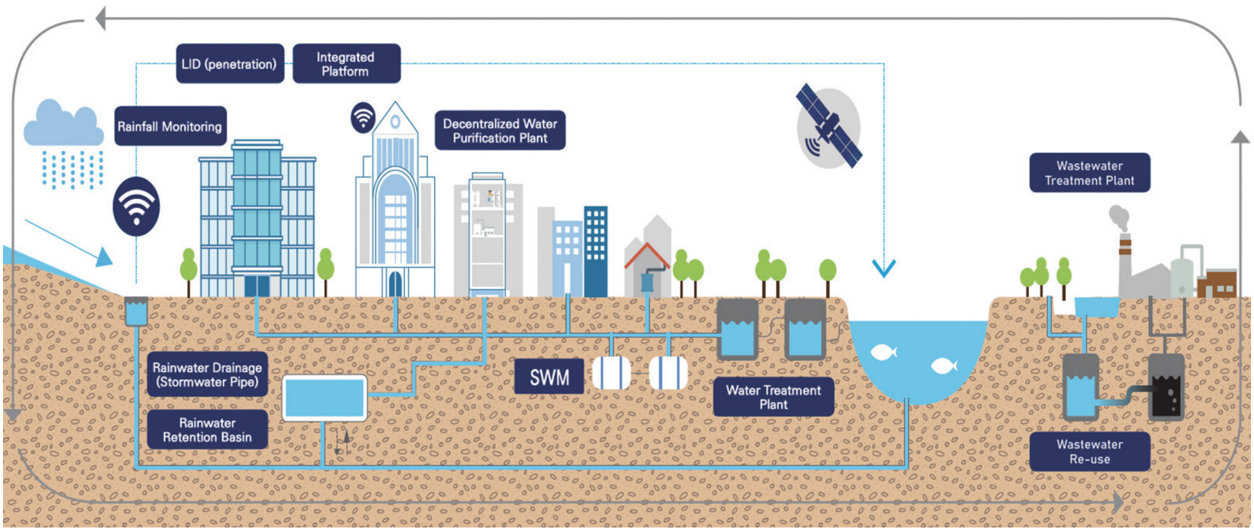
< View of Sihwa Lake Tidal Power Plant >

3. Cases

(1) Busan Eco Delta Smart City

Introduction of Specialized Water Technologies for Green Infrastructure Development and Climate Change Response

Busan Eco Delta Smart City applies advanced technologies such as Information and Communication Technology (ICT), Artificial Intelligence (AI), big data, and smart grids across the entire urban water cycle, from water sources to individual household taps. This approach enables precise management of both water quantity and quality. As a result, the city is transitioning into a sustainable water-specialized platform. Rather than merely producing, transporting, and treating water through traditional methods, this system integrates various sensors and controllers within the water movement process, creating a data-driven foundation for urban water management.



<concept of urban water circulation>

The smart water management technologies to be introduced in Busan Eco Delta Smart City include:

① Advanced Urban Flood Response System: Building a system equipped with small-scale rainfall radars and a real-time urban flood management system.

② Low Impact Development (LID): Introduction of LID practices to reduce the environmental impact of urban development.

③ Urban Stream Water Quality Improvement (Eco-filtering): Implementing eco-filtering techniques to enhance water quality in urban streams.

④ Smart Water Treatment Plants: Upgrading water treatment facilities with smart technologies for enhanced efficiency and control.

⑤ Smart Water Network Management (SWNM): Utilizing advanced monitoring and management systems to optimize water distribution and usage.

⑥ Sewage Reuse: Implementing systems to treat and reuse wastewater for various non-potable purposes.

⑦ Thermal Energy: Harnessing thermal energy from water sources for heating and cooling applications.

These technologies will be integrated throughout the entire urban water cycle to enhance the management and sustainability of water resources in the city.

Advanced Urban Flood Response System (Small-Scale Rainfall Radar, Real-Time Urban Flood Management System)

Due to the increasing trend of urban flooding and water-related disasters, there is a critical need for demonstrative rainfall observation technologies and operational techniques that can respond to localized heavy rainfall at the city level. The Busan Eco Delta Smart City is implementing state-of-the-art, high-precision small-scale rainfall radars to analyze the amount of rainfall locally and in real-time, allowing for the prediction and proactive response to potential flooding. Additionally, an urban water disaster system linked to an urban inundation prediction model based on surface terrain and network information is planned to be established.

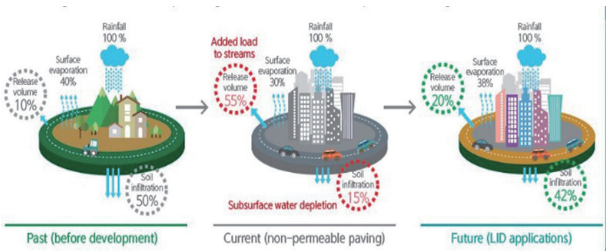
Furthermore, these high-precision small-scale rainfall radars will be installed in a central observatory within the city to create a foundation capable of responding to sudden local floods. The city plans to develop an urban flood prediction analysis model using hydrometric data, river flood information, and detailed urban flood data obtained through the rainfall radar, aiming to transform Busan into a city free from water disaster concerns.

Low Impact Development (LID)

Busan Eco Delta Smart City is currently being developed as a testbed for Low Impact Development (LID) technologies to improve the city's distorted water circulation system and enable various measures such as disaster prevention, microclimate regulation, and the health of aquatic ecosystems. Particularly, within the smart city, custom-sized green infrastructure is being constructed by applying rooftop greening, vegetative swales, rain gardens, and permeable pavements to roads, parks, and other public spaces.

Drawing from the retrospective application of LID technologies, the city plans to use a two-dimensional grid-based urban runoff model from the planning stage to analyze the quantitative effects of structural and non-structural methods. This analysis will guide the ICT-based construction and maintenance, leading to a Smart Water Balance tailored to the lifecycle of the city. Moving away from projects centered on single techniques, the city is advancing towards an integrated, multifaceted project approach to enhance urban water circulation. Ultimately, this initiative aims to contribute to the restoration of water circulation health in the Nakdong River basin and improve the quality of life for its citizens, establishing a K-water style water circulation city brand harmonized among citizens, the city, and rivers.

< ① Advanced Urban Flood Response System >



< ② Low Impact Development >

Urban Stream Water Quality Improvement (Eco-Filtering)

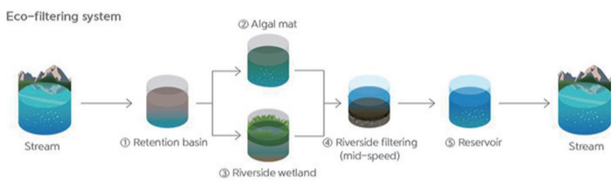
An eco-filtering system, a nature-based water purification process, is being developed along the Pyeonggangcheon and Maekdocheon rivers running through the city center to improve their water quality. This system allows water to flow naturally along the riverbanks where it is cleansed. Test beds have been operated to determine the appropriate technology and scale, including retention areas, algae mats, riparian wetlands, and riparian filtration areas. The capacity and size of the facilities have now been finalized, and installation is underway.

Smart Water Treatment Plants

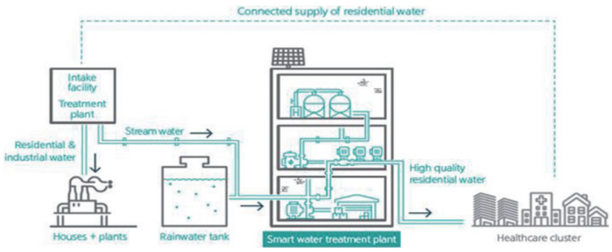
The current water supply system delivers treated water from large-scale treatment plants located near water sources to the end consumers. However, there have been several issues in the past, including leaks and water contamination during the distribution process.

To address these issues, the city has moved away from the traditional centralized, supplier-focused supply system. It has introduced consumer-centric smart water treatment plants located closer to consumers within the urban area. These plants allow residents to drink freshly treated water directly.

The plants have a capacity of approximately 1,100 cubic meters per day and utilize local water sources available in the urban area, such as rainwater, groundwater, and river water, processed through ultrafiltration methods. Additionally, the city has implemented compact vertical water treatment facilities that consider both functionality and aesthetic aspects of urban design. In the future, an automated supply system based on big data and integrated with ICT technologies is planned to enhance the efficiency and reliability of water supply.



< ③ Urban Stream Water Quality Improvement >



< ④ Smart Water Treatment Plants >

Smart Water Network Management (SWNM)

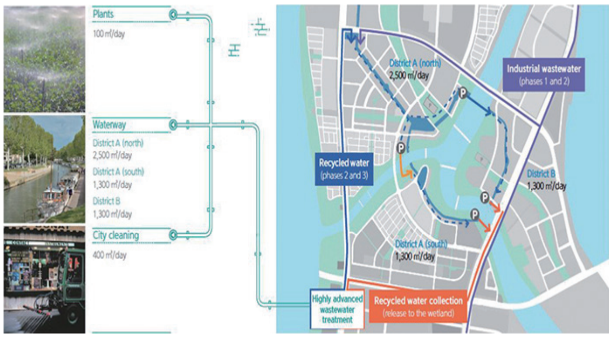
Smart Water Network Management (SWNM) is being implemented in the city, integrating Information and Communication Technology (ICT) throughout the entire process of water supply, from source to tap. This system allows for scientific management of water quantity and quality, providing real-time water quality information so that citizens can safely consume the water. For efficient network management, over 700 advanced sensing infrastructures are being installed, along with automatic drain facilities and inspection units to minimize leakage within the pipelines. Additionally, three water quality display boards are planned for installation to provide water quality information. Smart meters are also being installed in each household to provide continuous usage data, and services that detect activity patterns of vulnerable groups for enhanced living security.

Water Reuse System Development

As urban development accelerates and industrialization intensifies, the demand for domestic and industrial water is increasing, while water quality pollution and depletion of water resources are emerging as critical issues. The city of Busan plans to become a fully water-sufficient city that reuses 100% of its used water. A state-of-the-art sewage treatment plant (41,000 m³/d) is being installed underground, along with facilities for sewage reuse.

The treated water, which goes through an advanced treatment process and is of good quality, will be used as an alternative water resource for landscaping, urban water cleaning, and supplying waterways within the city for recreational water activities.

< ⑤ Smart Water Network Management >

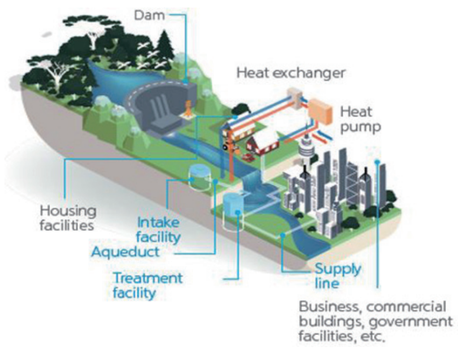


< ⑥ Water Reuse System >

Hydrothermal Energy

Busan Eco Delta Smart City is on its way to becoming an energy self-sufficient city through the establishment of a 60MW hydrogen fuel cell power plant (capable of supporting 24,500 households for a year) and the introduction of thermal energy using river water, a first in South Korea. Particularly, the city is utilizing the abundant water resources surrounding it to harness hydrothermal energy from the temperature differences between water and air, supplying this energy for heating and cooling within the city. This initiative reduces the reliance on fossil fuels and contributes to creating an environmentally friendly energy city.

Most cities in South Korea have inadequately utilized water resources as a source of energy, previously operating energy systems focused on individual buildings using tap water and seawater. However, Busan Eco Delta Smart City is the first in the nation to introduce a district-level heating and cooling system, which brings efficient energy use benefits directly to its citizens.

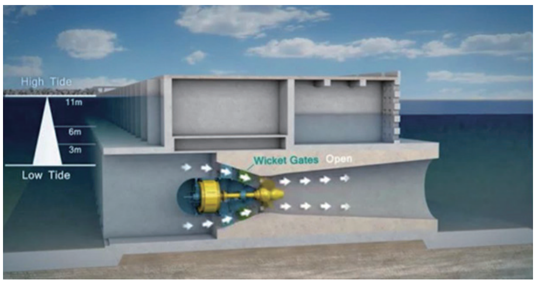


< ⑦ Hydrothermal Energy >

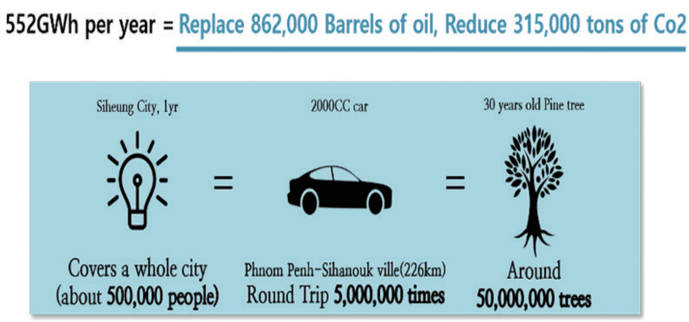
(2) Sihwa Lake Tidal Power Plant

Value as a Tidal Power Generation and Green Infrastructure Facility

Tidal power generation harnesses potential energy created by the differences in water levels during tides. Compared to solar and wind power, tidal energy is considered a more cost-effective and large-scale production option that is less affected by weather conditions, making it a reliable source of clean energy. South Korea has pledged to reduce its greenhouse gas emissions by 37% relative to its 2030 Business as Usual (BAU) projections. Through the Sihwa Lake Tidal Power Plant, K-water produces approximately 552 GWh of clean electrical energy annually, which prevents the emission of about 315,000 tons of carbon dioxide (CO2). This significant contribution to reducing greenhouse gas emissions underscores the growing importance of the Sihwa Lake Tidal Power Plant's role.



< Principles of Tidal Power Generation >



< Greenhouse Gas Reduction Effects >

Tidal Power Plant as a Hub for Renewable Energy Clusters

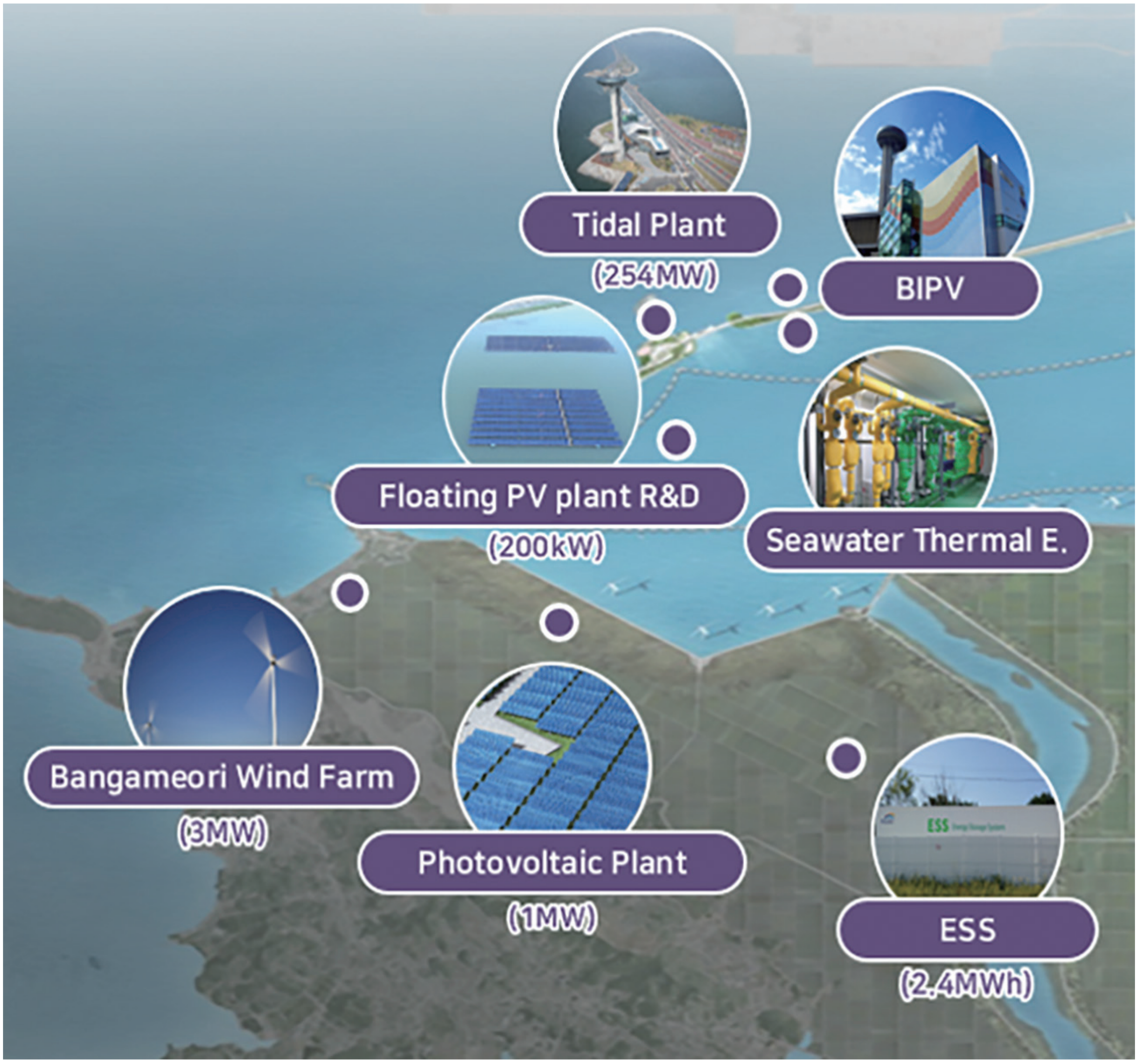
The Sihwa Lake Tidal Power Plant serves as a prime example of success in the renewable energy sector, establishing itself as a hub for renewable energy generation projects. The Sihwa Lake area boasts optimal geographic conditions for establishing a global-level self-sufficient renewable energy supply. Located adjacent to the sea, it efficiently utilizes water (tidal and seawater thermal energy), sunlight, and wind, which are abundant natural and marine resources. Geographically, its proximity to the metropolitan area also provides advantageous conditions for energy supply.

The "Bangamori Solar Power" facility, which began operation in 2016, has an installation capacity of 1MW and generates about 1.2 GWh annually. The "Bangamori Wind Power," which started in 2010, has a total capacity of 3MW and produces approximately 5.8 GWh annually. Additionally, there is an Energy Storage System (ESS) with a capacity of 2.4 MWh that can store 2.2 MWh of solar energy and 0.2 MWh of wind energy. A consortium including K-water is also conducting offshore solar R&D with an installation capacity of 200kW.

Within the management buildings of the Sihwa Lake Tidal Power Plant, a seawater thermal heating and cooling demonstration system and Building-Integrated Photovoltaics (BIPV) are being developed. The seawater thermal device uses the temperature difference of seawater, similar to hydrothermal energy, to provide heating and cooling for the facilities, currently setting up a system with a capacity of 20RT. BIPV serves dual purposes of building functionality and power generation, with plans to use solar panels installed on the exterior of the power plant building to operate heat exchangers and heat pumps during seawater heating and cooling. This system has a capacity of 27kW, with a project budget of 320 million KRW.

Furthermore, K-water plans to build a hydrogen infrastructure facility at Sihwa Bangamori in collaboration with the city of Ansan. This facility will use the 3MW from Bangamori wind power and 1MW from solar power to produce green hydrogen through water electrolysis, supplying hydrogen at a scale of 240 kg/day for experimental research and providing 300 kg/day of hydrogen to fuel 60 cars at a hydrogen refueling station, along with a carbon-neutral education and promotion center.

An expansion of the Sihwa Lake Tidal Power Plant is also under consideration. The plan includes adding four turbines and six sluice gates to increase the power generation by 112 GWh (25% increase) and enhance the seawater flow by 12.7 billion tons (26% increase), which is expected to further reduce carbon dioxide emissions by an additional 51,000 tons (25% increase).



< Overview of the Sihwa Renewable Energy Cluster >

Exemplary Case of Eco-Friendly Growth

As we enter an era of energy transition aimed at carbon neutrality, the Sihwa Lake Tidal Power Plant is being recognized as a symbol of eco-friendly renewable energy. The plant significantly contributes to the improvement of water quality and the restoration of the ecological health of Sihwa Lake by circulating 14.7 million tons of seawater daily. This activity not only helps restore the aquatic ecosystem directly and indirectly but also generates significant economic impacts, inducing production worth KRW 1.3 trillion and creating approximately 10,000 jobs, serving as a model for eco-friendly growth.

The Sihwa Lake Tidal Power Plant is at the forefront of integrating Fourth Industrial Revolution technologies and leading the Digital New Deal policies. K-water, which manages the operation of the tidal power plant, is driving change by incorporating Information and Communication Technology (ICT) into the Sihwa Lake area. They are creating a "data dam" using infinite resources and data, and advancing the application of Fourth Industrial Revolution technologies such as digital twins and artificial intelligence (AI).

A notable digital twin technology at the Sihwa Lake Tidal Power Plant is the 'K-TOP' (Tidal Power Operation Program), developed and completed in 2018. 'K-TOP' is a digital program designed to calculate the power generation under the same conditions as the actual generators installed, providing a power generation schedule that maximizes output considering the constantly changing tides. It includes features for calculating the power generation of bidirectional generation methods, which can be utilized in future tidal power constructions both domestically and internationally. Additionally, the 'Real-time Automatic Sluice Operation AI' incorporates an algorithm that predicts changes in sea level in real time, designed to automatically open gates and drain water from Sihwa Lake as needed.

4. Key challenges and recommendations

Major Challenges

Due to climate change and rapid urbanization, complex water management issues arise that demand innovative approaches. These issues are challenging to address with traditional water management methods alone, necessitating a sustainable and resilient water management system.

The integration of modern infrastructure with nature-based solutions is crucial to balance technological achievements and environmental conservation. For instance, the Sihwa Lake Tidal Power Plant simultaneously pursues renewable energy production and environmental restoration, seeking this balance. Additionally, as seen in the Busan Eco Delta Smart City project, there is a need to integrate smart technologies with water management to establish a more efficient and intelligent water circulation system. This approach optimizes water quantity and quality management and promotes water resource reuse and recycling.

Recommendations

To achieve sustainable water management and reduce water disasters, a forward-thinking approach that blends the benefits of nature-based solutions and engineering infrastructure should be adopted. This approach can respond to climate change and enhance ecological sustainability in urban environments.

Advanced technologies such as Artificial Intelligence (AI), big data, and smart grids should be integrated into water management strategies to proactively address predictable environmental changes and strengthen the capacity for disaster prevention and management.

Furthermore, engaging the community and fostering close collaboration with policymakers are essential to develop and implement sustainable water management policies. This ensures broad stakeholder participation and mobilizes a variety of perspectives and resources.

5. Conclusion

The integration of green and gray infrastructure presents a crucial solution for reducing water-related disasters, and this approach can evolve into a more effective strategy when combined with advanced water management technologies such as artificial intelligence and digital twins. As seen in the cases of Busan Eco Delta Smart City and Sihwa Lake Tidal Power Plant, this technological integration is essential to address the increasing water management challenges posed by climate change and urbanization.

Busan Eco Delta Smart City, currently being developed by K-water, applies water management solutions throughout the entire urban water cycle. This enables the city to autonomously prevent and adapt to climate change, creating an optimized urban model for eco-friendly energy production and circulation. This model is expected to enhance the city’s resilience to climate change effectively.

The Sihwa Lake Tidal Power Plant has been redeveloped from its original embankment construction to incorporate environmental values into a new infrastructure facility. As the world's largest tidal power plant, it has been reborn as a structure that combines various renewable energy facilities including tidal power, solar energy, marine thermal energy, and wind power.

In conclusion, combining the ecological benefits of green infrastructure with the structural strengths of gray infrastructure and cutting-edge technology plays a vital role in maximizing the efficiency of water management, enhancing urban resilience to extreme weather events, and protecting and restoring urban aquatic ecosystems. This integrated approach is essential for building a sustainable and resilient water management system and needs to be applied more broadly worldwide to reduce water-related disasters.

3 Green solutions for disaster risk reduction and climate change adaptation in the Netherlands

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1. Introduction

The Netherlands has over 1000 years of history of water resources management and protection against floods from rivers and the North Sea. Over the centuries the Dutch have shaped the Rhine-Meuse delta by building infrastructure to manage the water, to protect land against flooding and to reclaim land from the water. This resulted in highly complex water systems consisting of a network of rivers, streams, lakes, aquifers, canals, ditches, and related infrastructure such as sluices, dams, weirs, pumps, groynes, embankments and levees. As 10 million people of the Netherlands are living in areas prone to flooding from either the sea or river and 70% of its economy located in these areas, the main priority in water management is flood protection. Flood defenses, such as dikes, dams and storm surge barriers are the most important measures in the Dutch flood safety system, providing high safety standards varying between 1/100 to 1/100,000 per year, depending on the region.

Increasingly confronted with the current and expected effects of climate change, as well as the societal changes and priorities, there is a growing awareness to include nature-based solutions in building resilience to climate change. The flooding problems of the 1990's have considerably influenced the way in which the Netherlands deals with flooding risks. Consequently, the discourse gradually changed from merely constructing grey infrastructure as flood defense (dikes, storm surges, barriers) to approaches that include building upon natural processes. Such nature-based solutions are considered to be an effective strategy to build resilience to climate change and provide a more flexible and future-proof approach to flood risk management as the ability of natural flood defenses to adapt to sea level rise reduce risks of lock-in situations that might arise from grey infrastructure solutions.

Climate change and sea level rise will have an increasing impact on flood protection and the availability of freshwater resources and the resulting implications for society, economy and biodiversity. The Dutch Delta Program was initiated to tackle the new challenges through a holistic and integrated approach to water management and to keep the Netherlands the safest the delta in the world. Recognizing that the impacts of climate change will unfold over decades, the Delta Program has a long-term perspective on building resilience through its water infrastructure to protect the Netherlands from flooding, ensuring a sufficient supply of freshwater and adapting to the impact of climate change (Van Alphen, 2015; Van den Aarsen, 2023).

This chapter presents several cases in the Netherlands where nature-based solutions are strengthening the existing flood protection infrastructure along the rivers and North Sea coast. Nature-based solutions are also implemented as a strategy to build resilience to a changing climate in rural areas (e.g., natural water retention measures as a combined floods and drought risk management strategy) and urban areas (e.g., building resilience to heat stress and extreme rain fall).

2. Nature-based solutions

In the past decades the concept of nature-based solutions ("ecosystem-based adaptation", "eco-DRR" or "green infrastructure") has developed into an alternative or complement to traditional gray infrastructure approaches (World Bank, 2017; EEA, 2021; Bridges et al., 2021b). These interventions can be completely "green" (i.e. consisting of only ecosystem elements) or "hybrid" (i.e. a combination of ecosystem elements and hard engineering approaches). Nature-based solutions are actions to protect, conserve, restore, sustainably use and manage natural or modified terrestrial, freshwater, coastal and marine ecosystems, which address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services and resilience and biodiversity benefits (UNEA, 2022). Nature-based solutions are increasingly seen as important to mitigate the risks associated with water related disasters and reduce the impacts of climate change in combination with their ability to provide ecosystem services and biodiversity benefits (Figure 1). The growing scientific evidence demonstrates the full opportunity of nature-based solutions for disaster risk reduction and climate change adaptation (World Bank, 2017; Timboe et al., 2022; DeWit et al., 2022). Nature-based solutions are applicable in catchments and streams, large rivers, urban areas and coastal areas. In each domain the type of specific nature-based solutions might be different, but their overarching characteristics and objectives are the same, reducing the risks and impacts of water-related extreme events and additionally providing a multitude of co-benefits for society and nature. Nature-based solutions can play a key role in flood protection in river catchments (Opperman & Galloway, 2022). Nature-based coastal protection is increasingly recognized as a potentially sustainable and cost-effective solution to reduce coastal flood risk. It uses coastal ecosystems such as mangrove forests, salt marshes and seagrass beds to create resilient designs for coastal flood protection (World Bank, 2017; Van Hespen et al., 2023). In addition, nature-based solutions can also help mitigate droughts, erosion and landslide, forest fires and heath waves. The multiple benefits from nature-based solutions for disaster risk reduction and climate change adaptation are summarized in Figure 1. Nature-based solutions may also create multiple benefits to the environment and local communities. These include sustaining livelihoods, increasing biodiversity, improving food security, and sequestering carbon (Anisha et al., 2020; DeWit et al., 2022). Such solutions can be applied to river basins (e.g., riparian wetlands and floodplain forests), coastal zones (e.g., mangroves and coastal wetlands), and cities (e.g., urban parks).

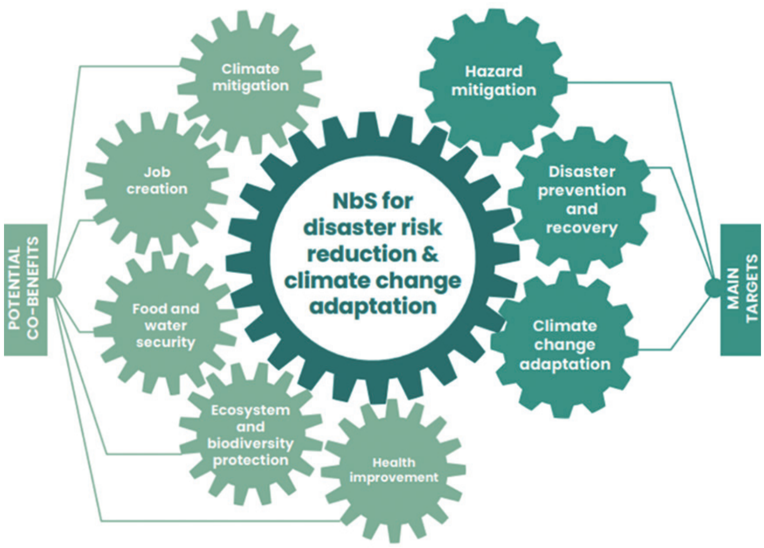

Figure 1: Multiple co-benefits from nature-based solutions for disaster risk reduction and climate change adaptation. From: DeWit et al., 2022.

3. Case studies

Green solutions for flood risk reduction need to be adapted to the ecosystem they are placed in. Consequently, different sets of potential green solutions for flood protections are available in rivers, coastal areas, and estuaries. This paragraph gives an overview of implemented large-scale green solutions for flood protection in different water-systems in the Netherlands. More and more, nature-based solutions are implemented to reduce the risks on droughts and pluvial flooding. Those solutions will be briefly introduced in paragraph 4.

3.1. Room for the river: the Meuse bordering the Netherlands and Belgium

The awareness of restoring ecological values of the main rivers Rhine and Meuse was growing in the late 1980's in the Netherlands (Van Looy & Kurstjens, 2022). Consequently, the rivers Rhine and Meuse and their floodplains were recognized as the backbone of the ecological main infrastructure in the Netherlands. This resulted in strategies and plans for ecological rehabilitation of floodplains by creating room for the rivers through lowering of floodplains, constructing lateral channels and widening of the main channel. The extreme flood events of 1993 and 1995 created strong political momentum to improve the flood resilience of the Dutch river systems and river management authorities emphasized the need for a flood risk management strategy based on increasing the discharge capacity on the one hand and improving the ecological and landscape values on the other hand (Pedroli & Dijkman, 1998; Smits et al., 2000; Duel et al., 2002). This resulted in the acceptance of creating room for the rivers as a cost-effective method to protect against floods while enhancing ecological values. A flagship room for the river project that simultaneously provide environmental, social and economic benefits and helps to build resilience is the Grensmaas project (Figure 2). The Grensmaas is a 45 km free flowing stretch of the river Meuse bordering the Netherlands and Belgium. The Grensmaas is the only gravel river in the Netherlands. Room for the river measures are implemented at both sides of the river, making this a transboundary project. The floodplain lowering of the Grensmaas is being combined with commercial gravel and sand mining. When the room for the river Grensmaas project will be fully implemented in 2027, a total volume of 54 million tons of gravel and 10 million tons of sand will have been extracted (Rijkswaterstaat, 2018). The room for the Grensmaas river project is largely funded through the commercial gravel extraction. Although not all the measures are fully implemented yet, the room for the river approach has demonstrated already its values, both in terms of flood projection and ecological restoration. The villages alongside the Grensmaas were not flooded during the flood event in summer 2021, despite the flood event of the river Meuse in summer 2021 was bigger than then the floods in 1993 and 1995.

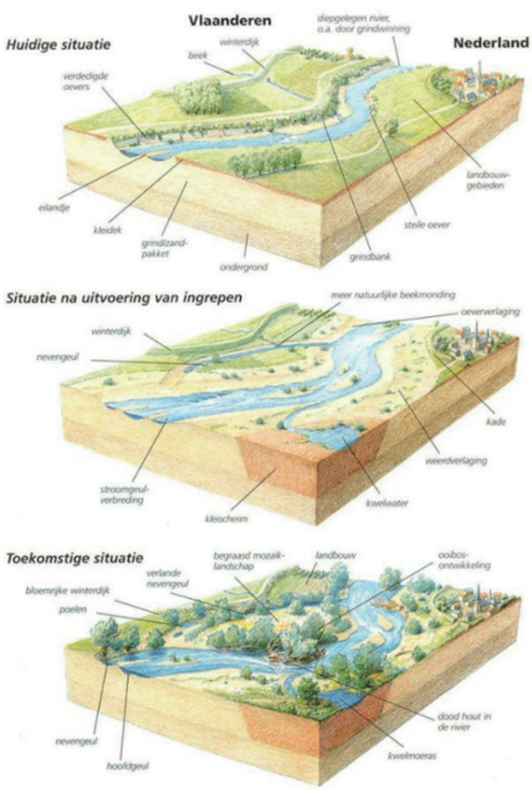

Figure 2: The Living Grensmaas concept: situation before implementing room for the river measures (above), after lowering the floodplains and creating lateral channels (middle) and in near future due to ecological processes (below). Source: Bureau Stroming[1]

[1] *https://www.stroming.nl/nl/overzicht/levende-grensmaas*

The room for the river measures also restore river ecosystems and providing habitats for endangered riverine flora and fauna. As a result, the Grensmaas is a dynamic, braided river landscape with a wide variety of habitats, instream complexes of riffles and pools habitats, sand and gravel bars, lateral channels, varied shorelines, and complexes of floodplain habitats, such as marshes, grasslands, and floodplain forests (Van Looy & Kurstjens, 2022).

3.2. The Sand Motor at the North Sea Coast

The Dutch North Sea coast consists mainly of sandy beaches and dunes. The beaches and dunes are a natural flood defense and protecting the Netherlands from coastal flooding. The beaches and dunes are also important for nature and recreation. Large parts of the Dutch shoreline is permanently eroding due to the prevailing currents in the system. To safeguard the hinterland of the Dutch coast, regular large scale sand nourishment is needed. A total volume of about 12 million m3 of sand is yearly needed to project and maintain the sandy shoreline, distributed over several sites that are sensitive for sand erosion (Brand et al., 2022). A traditional sand nourishment at a site contains a volume of 2-5 million m3 (Huisman et al., 2021). The lifespan of the nourishment is typically in the order of 5 years. This means that every 5 years the nourishment needs to be repeated, resulting in a frequent disturbance of the coastal ecosystem.

To explore alternative solutions for frequent sand nourishments along the shore, the Sand Motor Pilot Project was initiated in 2011. The Sand Motor is a mega-nourishment that supplied a much larger volume of sand in one specific location. After that, natural processes due to wind, currents and waves are redistributing the sand from the Sand Motor along the coast and towards the dunes. The mega-nourishment started as a hook-shaped peninsula of about 21.5 million m3 of sand, 1 km into the sea and 2 km alongshore (Huisman et al., 2021). The sand was dredged 10 kilometers off the coast and deposited nearshore to construct the hook-shaped peninsula. Long term detailed monitoring of the developments of the Sand Motor was carried out to better understand the dynamics and effectiveness of this mega-nourishment and showed that the concept was effective (Figure 3).

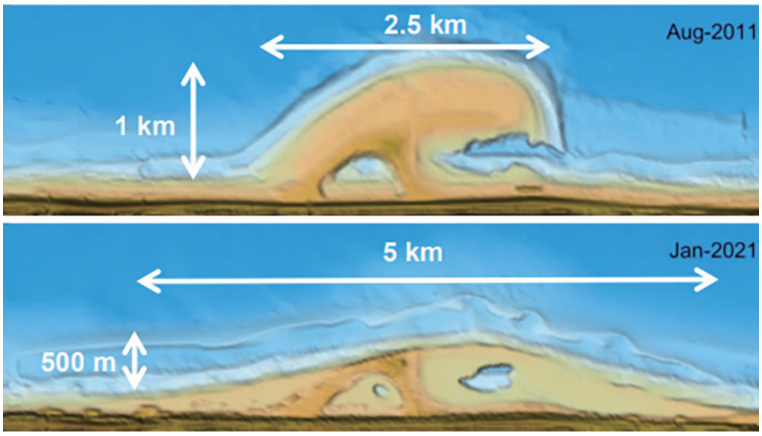

Figure 3: The development of the Sand Motor between 2011 and 2021 (Huisman et al., 2023).

This innovative approach of maintaining the shoreline limits the disturbance of local ecosystems while providing new opportunities for nature and recreation. The evaluation of 10 years of the Sand Motor showed that this innovative approach of large-scale coastal measure is very successful in terms of maintenance of the natural flood defense, ecological values and benefits for recreation. After 10 years the coastline has widened (Figure 4), and the dunes are growing well and therefore improve coastal protection. The Sand Motor will continue to develop in the years to come. The more sand spreads towards the dunes and beach, the less will remain of the original sandbank. The Sand Motor will become more and more elongated on the longer term as a result of alongshore redistribution of sediment (Luijendijk et al., 2019). The cross-shore width of the Sand Motor will decrease, while the beaches become wider. These changes will, however, take many years, meaning that the Sand Motor will be recognizable for another ten to twenty years as a seaward protrusion of the Delfland coast. Dune formation is expected to increase further in the coming years (Huisman et al., 2023). The Sand Motor has also created a wide range of habitats for species that are depending highly on the coastal ecosystems, including birds, macro-invertebrates and dune plants. Leisure visitors are valuing the landscape.

The concept of the Sand Motor demonstrates the value of large-scale coastal measures for protecting sandy shorelines and let natural processes do the work for building natural flood defenses. Additional pilots have been set up along the Dutch coast, but also internationally such as UK and Egypt.

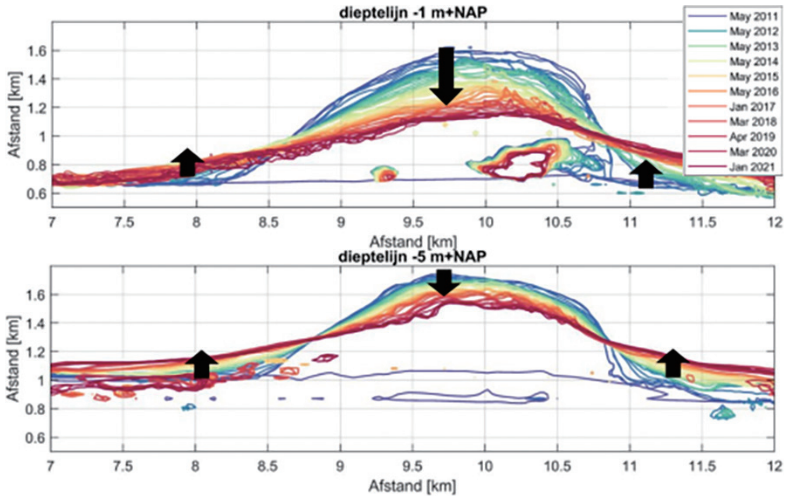

Figure 4: Coastline changes at the 1 and 5 meter depth contour (dieptelijn) of the Sand Motor between 2011 and 2021, distances (afstand) in km (Huisman et al., 2023).

3.3. Flood protection through reinforcing coastal dikes with salt marsh development

The Wadden Sea is the largest intertidal ecosystem in the world. The Wadden Sea is a large, temperate, relatively flat coastal wetland environment, formed by the intricate interactions between physical and biological factors that have given rise to a multitude of transitional habitats with tidal channels, sandy shoals, sea-grass meadows, mussel beds, sandbars, mudflats, salt marshes, estuaries, beaches and dunes. The Wadden Sea is protected by international agreements and is a designated UNESCO World Heritage site.

This case presents a pilot to improve the coastal protection through reinforcing an existing sea wall of the Wadden Sea coast near the city of Delfzijl in the Northeast of the Netherlands by artificially constructing new salt marshes (Figure 5). Coastal wetlands play important role in flood protection due to their capacity to reduce the impacts of waves (Baptist et al., 2021). The project was initiated by the municipality to explore the potential of improving coastal protection by combining nature-based solutions with reinforcing the existing grey infrastructure, while creating opportunities for enhancing ecological values and improving the water quality. The aim of the project was to investigate the best way to restore and construct salt marshes by reusing sediment from the port of Delfzijl and the Ems-Dollard estuary that is meeting the requirements for improving coastal protection while enhancing the ecological values. In total of 28 hectares of artificial salt marshes were constructed. The design of the marshes was a result of intensive stakeholder engagement processes resulting into an integrated design that was containing elements that were relevant and interesting for all parties involved, including experimental plots to better understand which initial construction choices would best stimulate the establishment of the saltmarsh. The strong stakeholder involvement has proved to be essential for the implementation and success of the project. The project was monitored between 2018 and 2020 to collect information on the morphological and ecological development of the marshes and lessons learned will be used to prepare guidance for design, construct and monitor salt marshes and use the salt marshes' ecosystem services.

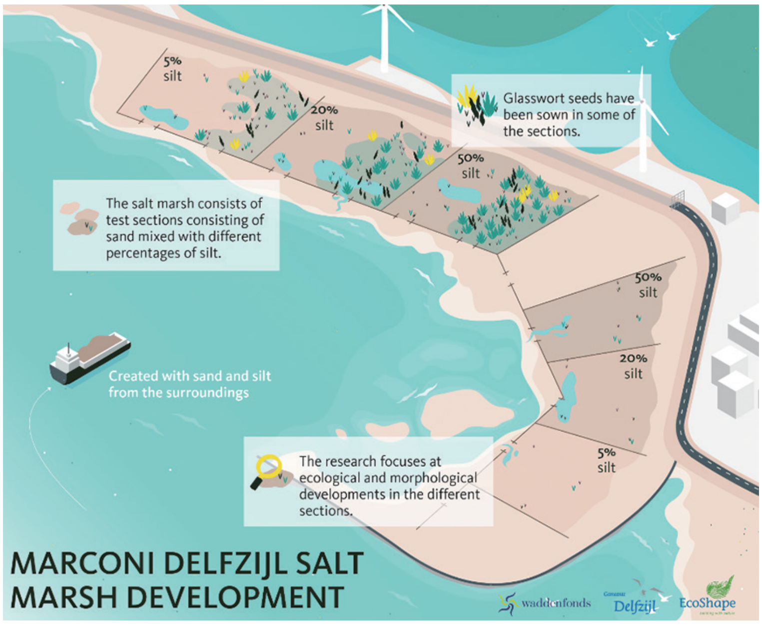

Figure 5: Design of the artificial salt marsh at Marconi near the city Delfzijl, the Netherlands (source Ecoshape)[2]

The presence of a wave attenuating salt marsh in combination with an alongshore dam forms a hybrid flood defense and provides a good basis to protect part of the town center of Delfzijl (Baptist et al., 2022). Model calculations showed that the presence of the salt marsh leads to a reduction of the significant wave height of 25% for wave overtopping over the dike at a flood level of 7 m above mean sea level and of 60% reduction at a flood level of 4 m above mean sea level, when compared to the original situation without the salt marsh (Van Lente & Vuik, 2020; Baptist et al., 2022).

Besides increasing coastal flood protection, the nature-based coastal defense is supporting nature and its biodiversity and can secure ecosystem services for human wellbeing. The Marconi constructed saltwater marshes demonstrates how large-scale natural coastal defenses can build back. To boost vegetation cover and species richness balanced mixing sand with mud is essential. Strong stakeholder engagement with key actors greatly enhances successful project implementation.

[2] *https://www.ecoshape.org/en/cases/marconi-salt-marsh-development*

The pilot salt marsh in September 2020, about two years after construction (Source Ecoshape)[3].

3.4. Wide Green - Grey Infrastructure alongside the Ems-Estuary

The fourth case presented in this chapter also combines nature-based solutions with existing grey infrastructure. Traditionally, coastal sea dikes have a sand core which is covered, on the seaward side, by a layer of clay and grass at the crest. The middle and lower part on the seaward side is covered by a revetment of stones or concrete blocks protecting the toe of the dike and sometimes a foreland adjacent to the dike (Figure 6). This cover of rocks, concrete, clay and grass protects the outer slopes against wave impact (Van Loon-Steensma & Schelfhout, 2017). The coastal sea dikes usually have steep slopes of 1:3 to 1:4. The Wide Green Dike is an innovative dike design concept to reinforce the existing traditional dikes along the Dutch Wadden Sea coast to meet current safety standards and prepare for the effects of climate change, as well as to enhance the nature and landscape values of the Wadden region. A Wide Green Dike has a grass-covered mildly sloping seaward face with a slope of around 1:7 and merges smoothly into the adjacent salt marsh. The combination of forelands (salt marshes) and gentle seaward slope of the Wide Green Dike are very effective in reducing wave impacts.

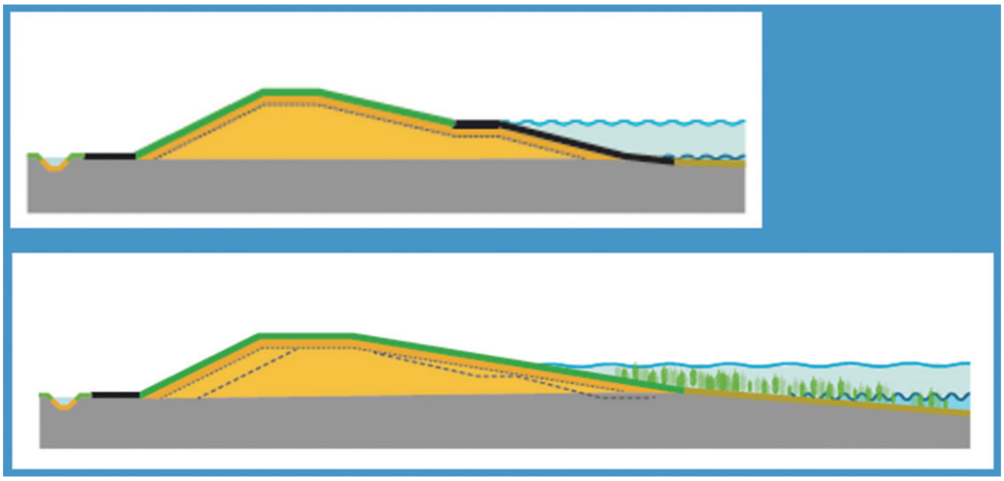

Figure 6: A traditional dike (above) and a wide green dike (below). From: Huiskens, 2016.

[3] *https://www.ecoshape.org/en/cases/marconi-salt-marsh-development/*

Alongside the Ems estuary a pilot project was started to reinforce existing embankments by reusing soft sediments (silt) from the estuary to implement to Wide Green Dike concept. This project is a collaboration between governments, environmental organisations and private sector with the aim to improve flood protection while strengthen both the economic and ecological development of the estuary. To maintain the Ems estuary large amounts of sediment are dredged yearly. To make dredged material from the estuary suitable for reinforcement clay ripening and maturation is needed. This process was taken place in specially designed clay ripening areas ("kleirijperij") to contribute to large-scale silt extraction in a cost-effective way. In 2022, the waterboard Hunze & Aa's has strengthened 750 meters of a flood protection dike, using 70,000 m3 of matured clay. Currently, the pilot is monitored to assess the robustness of this solution and to design guidelines for future use in dike reinforcement projects.

The reinforcement of existing coastal dikes by applying the Wide Green Dike concept are an innovative approach to meet all mandated engineering criteria for withstanding extreme conditions in the current climate, while offering additional advantages, such as greater robustness under extreme conditions in a future climate, more flexibility for adaptation and enhanced nature and landscape values. A Wide Green Dike merges smoothly into the Wadden Sea coastal landscape, which is characterized by a shallow tidal sea, sand flats and mudflats, and extensive semi-natural salt marsh along the coastline (Van Loon-Steensma & Schelfhout, 2017). The reuse of the sediments of Ems estuary offers a cost-effective approach to reinforce the dikes along the Ems estuary through the Wide Green Dike concept. In this case, the wide, gently sloping grass-covered dike is cheaper to build than a traditional steep dike with a revetment made of concrete or stones. Moreover, cyclic harvesting of sediment for periodic dike reinforcement appeared to be a sustainable option for adapting to future sea level rise.

4. Challenges for mainstreaming

The Sendai Framework for Disaster Risk Reduction (SFDRR) recognises the role of ecosystems and environment as a cross-cutting issue in disaster risk reduction, emphasising that ecosystems need to be considered in undertaking risk assessments, risk governance and investing in resilience (UNDRR, 2015). The SFDRR clearly refers to climate change adaptation and disaster risk reduction and supports the uptake of nature-based solutions: (i) 'to enable policy and planning for the implementation ecosystem-based approaches' in order 'to build resilience and reduce disaster risk', and (b) 'to strengthen the sustainable use and management of ecosystems and implement integrated environmental and natural resource management approaches that incorporate disaster risk reduction'. In addition, nature-based solutions support the implementation of the Sustainable Development Goals and the Water Action Agenda 2030 referring to the services they provide and the resilience they offer to society. Moreover, nature-based solutions are increasingly recognized to offer great potential to enhance urban resilience to climate change while bring more and more diverse nature into cities (Naumann & Davis, 2020).

Although adaptation to water-related climate risks and impacts makes up the majority of adaptation efforts worldwide (Timboe et al., 2022), well-functioning ecosystems provide important biodiversity and ecosystem services, such as flood protection, water storage, water flow and water purification. As ecosystems are also depending on water, water is also a solution for building resilience to climate change.

Successful implementation of large-scale nature-based solutions requires a systematic approach, comprehensive assessment, co-creation process with all relevant stakeholders, and carefully designed implementation processes. In the Netherlands, the concept of nature-based solutions has been applied to coastal protection and mitigation of flood risks from the large rivers Rhine and Meuse. In addition, there are also examples of nature-based solutions to mitigate floods and droughts in rural landscapes and to mitigate extreme weather events in urban areas.

In the Netherlands, more and more cities are developing green infrastructure as an approach to build resilience to climate change. The City of Rotterdam is one of the pioneers in developing innovative green infrastructure to transform pluvial flooding risk and heath stress challenges into solutions that provides communities safe, climate-resilient green spaces and at the same time boosts the local economic development through the creation of green jobs. Green urban infrastructure includes amongst other green solutions, green parks with water retention ponds, roof parks, rain gardens, urban wetlands, and green corridors for water infiltration (Tillie & Van der Heijden, 2016). The green infrastructure is also advancing social resilience, not only through protecting residents against the changing climate, but also bringing employment and providing opportunities to recreational activities and many more activities.

Nature-based solutions aiming to restore the sponge characteristics of landscapes will improve the resilience of rural areas against hydrological extreme events and reduce the vulnerability to both droughts and floods (Penning et al., 2023). Natural water retention measures to enhance the water storage potential of landscapes, soils and aquifers and foster ecosystem services for mitigating the impacts of floods and droughts have been implemented across the rural landscapes in the Netherlands in the past decades.

Despite the demonstrated values of nature-based solutions, mainstreaming these solutions is still hampered. Recently, the Netherlands has implemented a spatial planning policy that promotes natural processes of water and soil as a guiding principle for future urban development and land use and that stimulates climate resilience at a catchment level combining different types of nature-based measures into overarching strategies (Figure 7). In addition, the Government of the Netherlands has made a large fund available for piloting nature-based solutions as a strategy for building resilience to climate changing called NL2120[4].

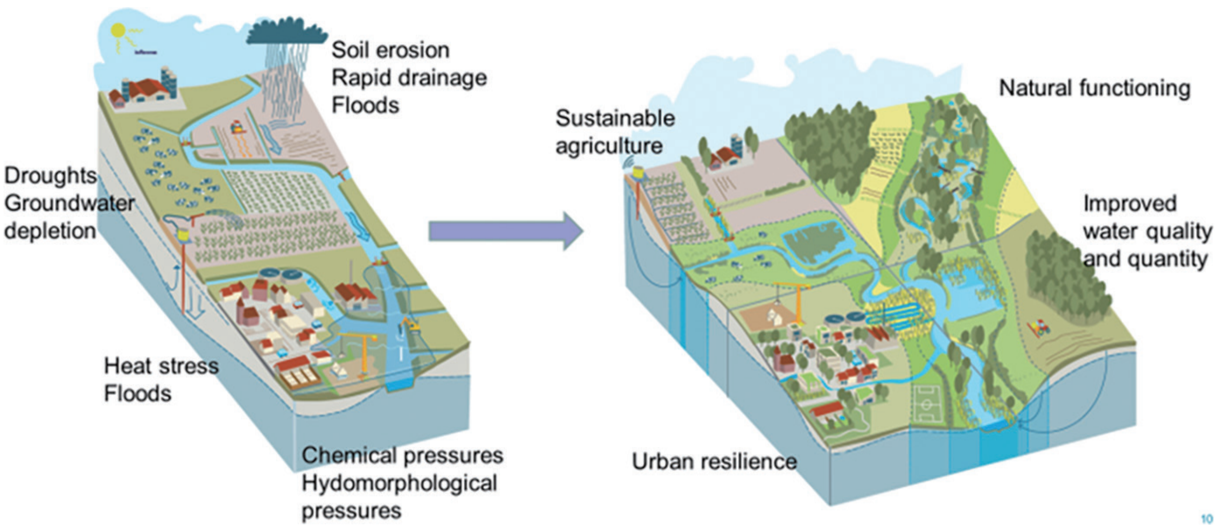

Figure 7. Nature-based solutions for climate resilient catchments (adapted from STOWA)[5]

[4] *https://www.nationaalgroeifonds.nl/overzicht-lopende-projecten/thema-landbouw-voedsel-en-land-en-watergebruik/nl2120-het-groene-verdienvermogen-van-nederland*

[5] *https://www.stowa.nl/publicaties/praatplaat-naar-een-klimaatbestendig-beekdallandschap*

Technical advancements in support of nature-based solutions are increasingly the subject of peer reviewed and other technical literature. Best practices of nature-based solutions in the Netherlands are frequently illustrating international guidance documents to inform program level action and technical practice for implementing nature based solutions (e.g., World Bank, 2017; Van Eekelen & Bouw, 2020; Bridges et al., 2021a, 2021b).

5. Conclusions

Nature-based solutions for climate change adaptation and disaster risk reduction are actions that work with and enhance nature to restore and protect ecosystems and to help society adapt to the impacts of climate change and slow further warming, while providing multiple additional benefits.

The Dutch main water systems face pressing environmental, economic and societal challenges due to climatic changes and increased human pressure. There is an increasing momentum for the use of nature-based solutions as part of resilience-building strategies, sustainable adaptation, and disaster risk management portfolios in the Netherlands. Nature-based solutions are not replacing gray infrastructure, on the contrary: combining nature-based solutions with (existing) gray infrastructure can offer additional robustness and flexibility in risk management and adaptation as illustrated by the cases in the Netherlands. Nature-based solutions are preferred where possible and grey infrastructure solutions are chosen when necessary.

Stakeholder involvement, dialogue and co-design of tools and measures are key to increase awareness, to tackle potential stakeholders' conflicts more effectively and to create social acceptance and demand for nature-based solutions. Awareness at governments, spatial planners, water managers, environmental agencies and organisations, economic sectors, society at large is growing that nature-based solutions provide cost-effective solutions for disaster risk reduction and climate change adaptation and simultaneously provide environmental, social and economic benefits and help building resilience.

Despite the showcases of large-scale nature-based solutions for mitigation flood risks from sea and main rivers, mainstreaming large-scale nature-based solutions has not used its full potential in the Netherlands yet. Key factors that will contribute to further effective application of nature-based solutions to mitigate water-related extreme events include:

- Fitting nature-based solutions into the landscape context and aligning them with natural (ecological) processes and seeking synergies across sectors is essential.
- Design of nature-based solutions is to be based on evidence of their functioning under normal and extreme conditions and knowledge of their development over time, considering the long-term perspective of changing climate.
- Integrating nature-based solutions with complementary existing grey infrastructure can provide robust future-proof solutions especially in locations where fully green options are not feasible due to e.g. a lack of space.
- Stakeholder engagement through co-designing and co-developing nature-based solutions will facilitate effective uptake and implementation of nature-based solutions.
- Strong institutional embedding through policies and regulation frameworks is requisite to support uptake and upscale nature-based solutions and requires coherence across policy domains and sectors.
- Fit-for-purpose financial instruments and approaches for implementation and maintenance of large-scale nature-based solutions help provide sound business cases.
- Nature-based solutions are based on inclusive, transparent, and empowering governance processes, where capacity building of the people involved is essential.

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4 Central and Eastern Europe: Natural small water retention measures for flood and drought management

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(1) Summary of the article

Natural small water retention measures (NSWRM), can greatly contribute to flood and drought management through improving water retention in the landscape. They present in addition multiple benefits including filtration of pollutants and biodiversity. Noting that awareness of these measures, methods and tools, and uptake, remained yet limited in the CEE region, GWP CEE started collaborating with partners in the early 2010s to advance these solutions. GWP has since supported a broad range of measures, including demonstration projects, knowledge products, stakeholder engagement, policy level work, and partnership development to support uptake of NSWRM.

(2) Details of the project

Central and Eastern Europe is increasingly vulnerable to the impacts of flood and droughts. Climate changes have resulted in an increase in the frequency and impacts of extreme climate events, including floods and droughts. At the same time, the intensification of agriculture, the unification of natural habitats, the construction of drainage systems, and urbanisation, have caused changes in the soil cover and water cycle, with more limited retention in catchments and a quicker water circulation. The population's exposure has also risen as ever more people live in flood-prone areas. Climate change models further point to a decrease of precipitation during summers, and an increase of precipitation during winters in Europe, further aggravating the cycle. Some monitoring systems and management measures are in place, but they are insufficient to protect people, infrastructure and nature.

NSWRM are taken with the aim to restore the natural water retention capacity of catchments.

- Technical Measures. Most hydro-technical and drainage works, aiming at the retardation of surface water runoff can be included in this group like construction of small water reservoirs, damming of lakes and water courses, construction of ditches and channels etc.
- Non-Technical measures (planning methods). Proper spatial planning of the catchment can play an important role in water management. This measure focuses on the creation of spatial planning that can limit the accelerated runoff of rain and snow melting waters.
- Non-Technical measures (agro-technical), often labelled now as Nature Base Solutions (NBS) These are the measures that depended on the way of land use, including the use of proper methods of arable field's cultivation in the river catchment.

All the NSWRM have positive social, economic and environmental effects. The most important benefits are:

- Changes in water outflow structure in the river, decrease of the flood wave and, in some cases, improvement of low flow conditions;

- satisfying the needs of water dependent forest and swamp ecosystems, as well as the improvement of the state of environment as a result of elevation of groundwater tables;
- increase of groundwater aquifers alimentation, which causes the increase of groundwater resources;
- fulfilling some of economic demands, for example, water reservoirs can be used as water intakes for firefighters, bathing resorts, fish ponds, water intakes for irrigation or watering holes for wild animals;
- improvement of natural values of environment, improvement of biodiversity of agricultural landscape by the restoration of wetlands, small ponds, creation of natural aquatic fauna and flora enclaves, creation of human friendly micro climate;
- protection of surface water quality, retention of suspended matter, cleaning of rainwater from nutrients (nitrogen and phosphorous).

Despite their benefits, NSWRM still have a limited uptake, with important challenges related in particular to awareness, knowledge, methods and tools, and expertise.

(3) Cases

GWP CEE took a pro-active approach to support the uptake of NSWRM, supporting demonstration projects, knowledge products, stakeholder engagement, policy level work, and partnership development.

As GWP CEE launched the regional Integrated Drought Management Programme (IDMP)[1] in 2013, it identified NSWRM among the measures to be supported for drought management in the Region. Within the IDMP, a specific project on Natural Small Water Retention Measures (NSWRM)2 was implemented by a group of experts from four CEE countries: Poland, Slovakia, Hungary, and Slovenia. The activities carried out included a compilation of case studies as well as the preparation of first Guidelines on Natural Small Water Retention Measures, published in 2015. During the course of the project, the experts identified the need to create a modern and effective tool for delivering knowledge on NSWRM. Consequently, GWP CEE collaborated with partners to develop a video lecture series on NSWRM.

An important milestone for advancing NSWRM came with the FramWat project[3], implemented over 2017 – 2020 with the support of INTERREG's Central Europe Programme. The project coordinated by Warsaw University of Life Sciences aimed at strengthening the regional common framework for floods, droughts, and pollution mitigation by increasing the buffer capacity of the landscape through NSWRM.

The starting point for the project was that the majority of water management and flood protection measures lack innovation and follow more traditional approaches, including large scale grey infrastructure investment programs or capital projects.

Within the scope of the project, GWP CEE supported stakeholder engagement, policy dialogues, development of the synthesis guidelines of the project as well as the preparation of 6 action plans for NSWRM in each of the project pilot catchments. A series of national and regional policy dialogues was conducted in 6 countries – Austria, Croatia, Hungary, Poland, Slovakia and Slovenia.

The project integrated the stakeholders most affected by droughts and floods (municipalities, forest districts,

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[1] https://www.gwp.org/en/GWP-CEE/WE-ACT/Projects/IDMPCEE/
[2] https://www.gwp.org/en/GWP-CEE/WE-ACT/Projects/IDMPCEE/Demonstration-projects/Small-retention-measures/
[3] https://programme2014-20.interreg-central.eu/Content.Node/FramWat.html

representatives of agriculture, nature protection agencies) with each other and experts, and facilitated creating ideas for in mitigating their effects. Problems and possible solutions were identified (Action plan), and tools (DSS planner) were provided to support stakeholders in the process of implementing activities (i.e. legal and technical guidelines).

In addition, national trainings were organized by project partners in 6 pilot river basins to familiarise stakeholders, particular target groups and associated partners with developed methods and to train them how to apply methodologies in river basins. Their purpose was to discuss and test the methodologies and train participants on how to use the developed GIS based assessment tool/s. National trainings were organized during the preparation of the concept plan and testing models. After creating the prototype of GIS Tool (FroGIS[4]), training of its use was conducted for all partners. Additionally, the materials from the training course of GIS tool was developed into an e-learning system. In 2018 the training was organized for several WULS students and several function demonstrations at meetings with stakeholders in various countries.

FRAMWAT tools were adapted in the next project where GWP and partners were involved (TEACHER[5]). Focus of further work was on down streaming the tools to the municipalities or regions. From the tool's perspective, the overarching platform TEACHER toolbox was created. It contained except FroGis also heavy rain assessments and mapping, flood modelling including impact of Climate Change on drinking water availability, assessment of forests vulnerability to CC as well as LocalAdapt tool supporting the local communities for CC adaptation., drought risk mapping and few tools related to River Basin Management practices. Number of activities including individual and partners training were undertaken in Poland, Hungary, Slovenia, Germany, Czech Republic and Italy. The project was led by GWP CEE partner University of Ljubljana.

At the moment FroGis is further developed and implemented on EU scale by SpongeScape[6] (2023-2027) program Horizon Europe project, which focuses on increasing the European resilience against floods and droughts by NBS retention measures and upscaling individual restoration projects. Project is implemented in Netherland, Great Britan, Poland, Slovenia, France, Germany and Greece.

The work continues also other EU project Optimal strategies to retain water and nutrients (OPTAIN)[7] funded by Horizon 2020 over 2020 – 2025 and coordinated by Helmholtz Centre for Environmental Research (UFZ, Germany). OPTAIN proposes a social and scientific journey towards the increasing and better understanding of the multiple benefits of NSWRM. In this project GWP co-leads the work package on Communication and Dissemination, aiming to be a bridge between researchers and end users/farmers.

(4) Key challenges and recommendations

FramWat developed a new set of tools for choosing the best location to improve water quality and better balance its quantity. It provided GIS-based tools and guidelines for the water authorities and decision-makers to critically approach and assess the effectiveness of nature-based small water retention measures in the river basin management context. FramWat increased the skills and capacities of water authorities and related stakeholders for sustainable use of landscape, and for better and climate-proof water resources management.

[4] https://programme2014-20.interreg-central.eu/Content.Node/FroGIS.html
[5] https://programme2014-20.interreg-central.eu/Content.Node/TEACHER-CE.html
[6] https://cordis.europa.eu/project/id/101112738
[7] https://www.optain.eu/

Partners developed innovative methods:

(1) Identifying locations in a river basin where N(S)WRM would be needed as a consequence of topological, hydrological, meteorological conditions.

(2) Supporting the evaluation of cumulative effectiveness of N(S)WRM at river basin scales.

(3) Improving understanding of small retention measures and a part of NBS for water management improvement

(4) enhancing upscaling of individual restoration and/or retention measures to the catchment scale

(5) Providing guidelines for implementation of N(S)WRM with policy options and cost analysis to mitigate negative effects of floods and droughts and prevent water pollution to preserve natural heritage in Europe.

Moreover, the methodology provided decision makers with appropriate tools to incorporate N(S)WRM into the next cycle of River Basin Management Plans and gave guidance and raise awareness about the importance of horizontal integration of different planning frameworks. All of the activities were carried out with a strong stakeholder engagement process, policy-level dialogues, and trainings, ensuring co-development and appropriation of the tools for uptake.

(5) Conclusion

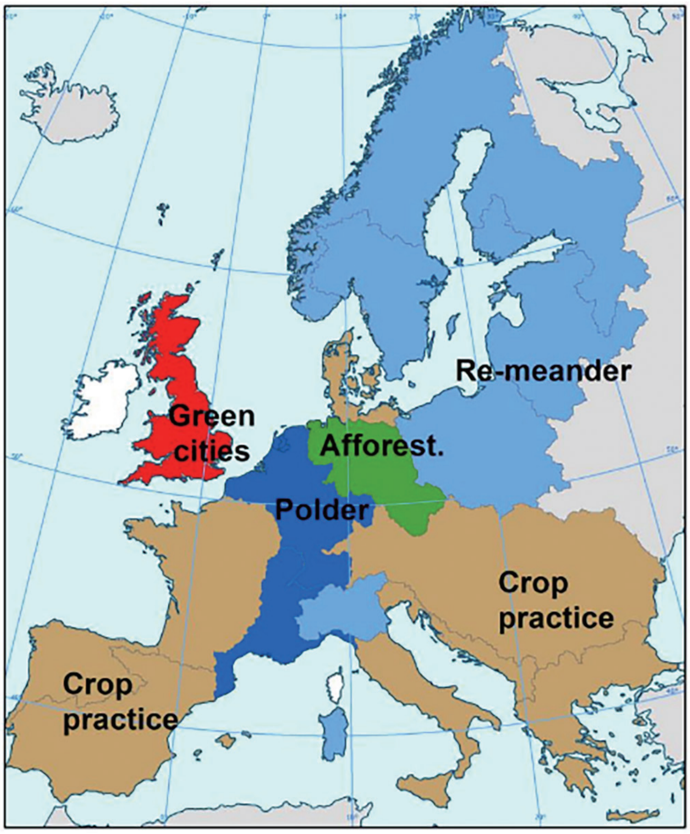
An intervention combining development of new tools and methods directly applicable by decision makers and river basin in management planners can greatly facilitate their uptake. When supported by national water management authorities, the measures can be included in river basin management planning and possibly replicated in other basins.

Table: Potential benefits expected from selected examples of NWRM

NWRM	Description	Potential primary benefits
Reconnection of oxbow lakes 	The historic straightening or canalisation of rivers resulted in the disconnection of meanders and formation of oxbow lakes. The re-connection of oxbow lakes to the main channel will restore the natural river flow conditions.	Enhanced water storage, attenuation of peak runoff, restoration of river continuity, diversifying flows and habitats, groundwater recharge
Conservation tillage 	By leaving crop residue on the soil surface, conservation tillage improves water infiltration into the soil and reduces soil erosion.	Water quality improvement, decreased runoff, soil conservation, increased infiltration potential
Installation of green roofs 	Coverage of a top of a building or structure with vegetation planted over a waterproof membrane.	Retain precipitation, provide insulation to buildings, new habitats for wildlife in urban environments, reduce peak flows, water quality improvement, soften extreme temperatures in cities, amenity space

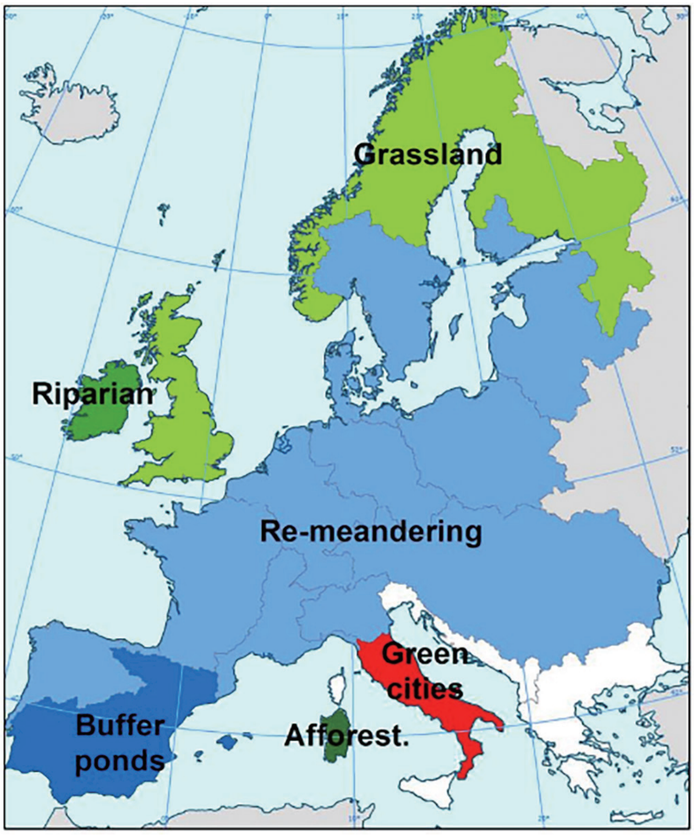
Source: 11309347 (europa.eu)

Map: Most effective regional measures to reduce flood peaks (here: 20 year return period)



Source: [Evaluation of the effectiveness of natural water retention measures - Publications Office of the EU (europa.eu)]

Map: Most effective measures to increase low flow per region (here: 10% flow)

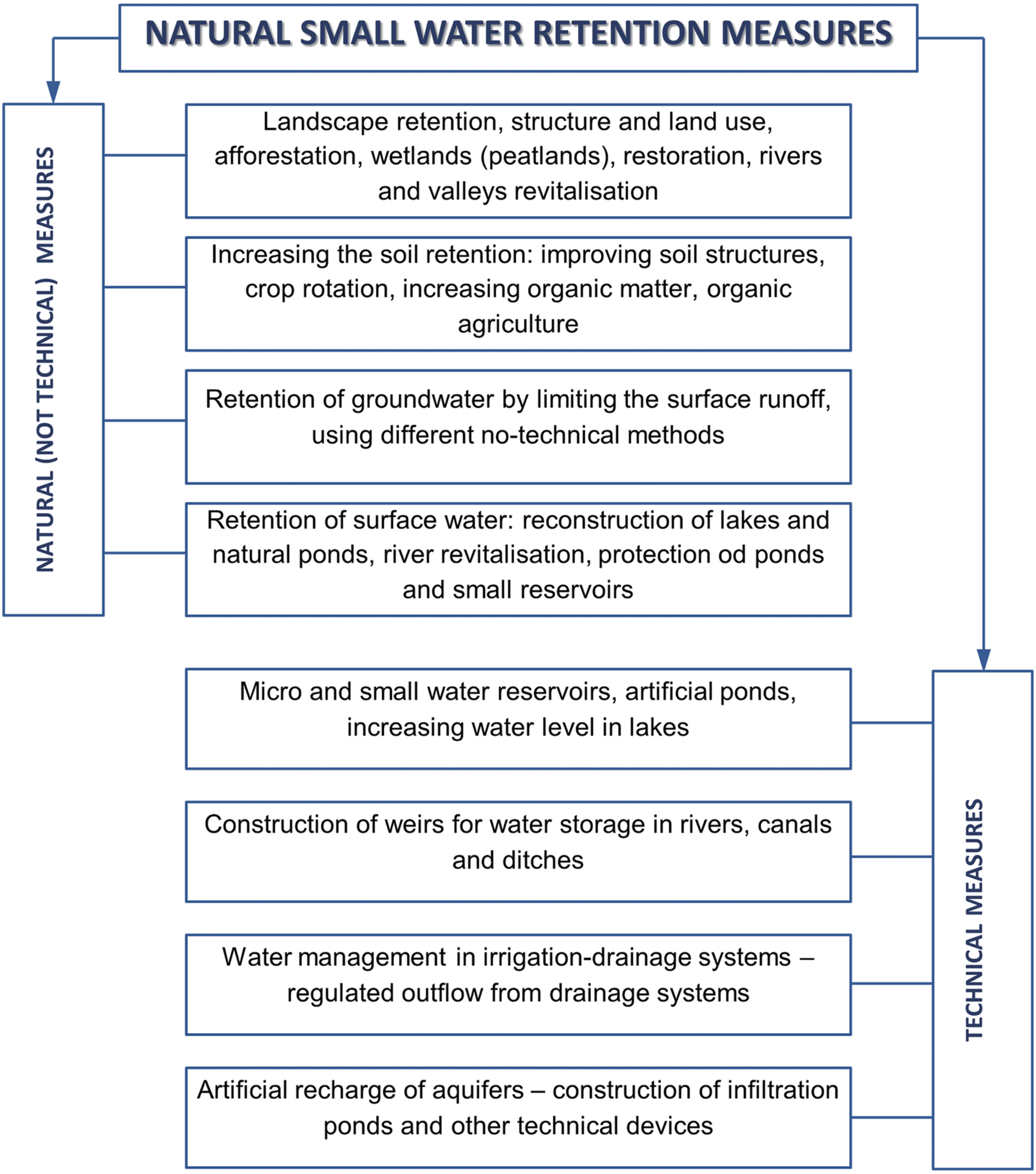


Source: [Evaluation of the effectiveness of natural water retention measures - Publications Office of the EU (europa.eu)]

Figure: Sava in Zagreb. On top: Current situation, i.e. before river restoration; below: Illustration of Sava after river restoration. Instead of monotonous reinforced banks and foothills or - even worse - planned hydropower impoundments, restoration could provide attractive recreation areas

Source: [01_SavaWhite Book Study.pdf (balkanrivers.net)]

Fig: Natural Small Water Retention Measures.



Source: idmp-nswrm-final-pdf-small.pdf (gwp.org)

Table: Evaluation of the impact of small retention measures on water resources and environment

Name of the indicator	Impact on water resources			Impact on			Threats
	Surface water	Soil retention	Groundwater	Landscape	Biodiversity	Water quality	
Afforestation of agricultural lands (poorly permeable soils, hummocky area, presence of snow melting floods)	++	+/–	+/–	+++	+++	++	Disappearance of certain plants (weeds)
Afforestation of agricultural lands (permeable soils – sands, presence of snow melting floods)	+	+/–	+/–	++	+++	++	Decrease of alimentation of groundwater aquifers
Agrotechnics (soil structure improvement) – poorly permeable soils	++	+++	++	+	+	++	Excessive intensification of agriculture
Agrotechnics (soil structure improvement) – permeable soils	+++	+++	++	+	+	++	Decrease of alimentation of groundwater
Agrotechnics-field water harvesting (small dikes around field edges)	+++	+++	+++	+/-	++	+++	large impact on the loss of deposits on the floodplain valley
Buffer zones along water courses and reservoirs lands (poorly permeable soils, hummocky area)	+	+	+	++	++	+++	Decrease of the area of grasslands and arable lands
Regulated outflow from drainage systems	+	++	+++	+	+	+++	Excessive humidity of arable lands, soil degradation (reduction processes)
Active water management on a drainage system (river valleys)	+++	+++	+	+	+	+	Intensification of agriculture
Construction of micro reservoirs on ditches	+++	++	++	++	+++	++	Excessive humidity of arable lands
Infiltration reservoirs and ditches	+	+	+++	+	+	++	Pollution of groundwater
Dry reservoirs/flood polders (river valleys used for agricultural purposes)	+++	++	+	+	++	+	Periodic destruction of crops yields, excessive humidity/drying
Construction of reservoirs on outflows from drainage systems	++	+	+	++	++	+++	Loss of the area for agricultural production
Old meanders/side reservoirs on rivers (retaining water during high spring flow)	++	+	++	++	++	+	
Construction of small reservoirs on rivers (dammed reservoirs)	+++	++	++	+	++	++	Destruction of valuable ecosystem, problems with fish migration
Dug ponds in local terrain denivelations	+	++	+	+	++	+	Destruction of valuable ecosystems
Small ponds (restoration)	++	++	+	++	+++	+++	Conversion of the ecosystem into less valuable
Water course restoration (meandering)	+++	++	+	+++	+++	++	Flooding of agricultural lands
Swamps restoration (peatlands)	+++	+++	++	+++	+++	++	Excessive limitation of water courses alimentation
Anti-erosion measures (various)	++	+	++	++	++	++	Changes in ecosystems

Scale: +++ meaningful impact, ++ medium impact, + small impact, +/– negative or no impact

Source: idmp-nswrm-final-pdf-small.pdf (gwp.org)

5 Environmental protection initiatives in the Japan Water Agency.

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Background

Japan Water Agency (JWA) has a large inventory of water resources development facilities today in Japan (Fig-1) and is working to reduce the damage caused by abnormal floods and droughts due to climate change, the management of ageing facilities to extend their service lifespan through dam rehabilitation, upgrading and advanced maintenance management, using new technologies. JWA is also working hard to decarbonize its operations, as Japan as a whole has set a target of reducing greenhouse gas emissions by 46% in 2030, with the ambitious goal of actually reaching a higher target of 50%.

This report focuses on JWA's efforts to reduce the burden on the natural environment and to contribute to global environmental protection in its water resources development and management operations.

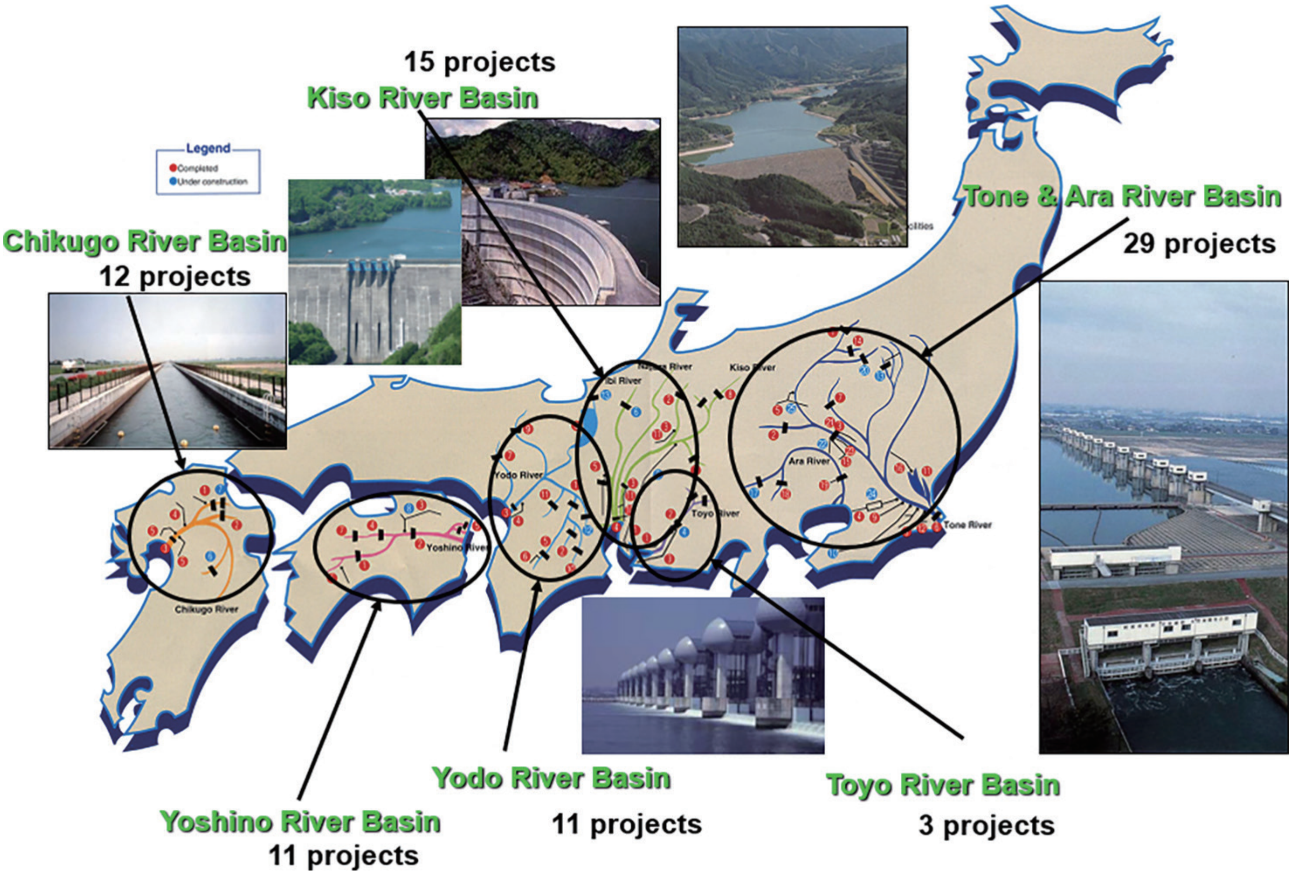


Figure- 1 JWA's project implementation area

1. Japan Water Agency's environmental conservation efforts in the implementation of its projects.

JWA has implemented big projects of water resources development. In particular, the dam projects are located in mountainous areas rich in nature and require large-scale changes to the natural environment due to the construction of the dam and ancillary facilities, the extraction of embankment materials necessary for the construction, the installation of various temporary facilities, and the replacement of existing roads submerged in the reservoirs. Therefore, it is necessary to address the implementation of construction projects, through conducting a careful environmental survey and the environmental impact assessment procedures required by the law with the occasional advice from experts in advance, in order to avoid or reduce the impact on the natural environment as much as possible. It is also necessary to maximize the utility of the project while minimizing natural resources and energy consumption during the management and operation phase after completion of the construction project.

1-1 Five basic perceptions

JWA believes that it is its social responsibility to contribute to building a society that ensures sustainable development with less environmental impact and to global environmental protection. Therefore, JWA has set the following five basic perceptions and specific action items under these perceptions to address the implementation of its projects:

① Basic Perception 1: To promote initiatives that take into account environmental protection

To ensure the appropriate environment conservation in and around the project area, comprehensive efforts will be made to ensure the design, construction and management with due consideration to environmental conservation.

- Action Item 1: Implementation of natural environmental surveys and environmental impact forecasts, and environmental conservation measures
- Action Item 2: Improvement of the river environment downstream of dams, etc.
- Action Item 3: Daily understanding of information on water quality through water surface patrols, and water quality surveys, etc.

② Basic Perception 2: Promotion of initiatives to reduce environmental load

Promotion of the control and recycling of construction by-products as well as that of greenhouse gas reduction initiatives.

- Action Item 4: Effective use of renewable energy
- Action Item 5: Reduction of electricity and fuel consumption, etc.
- Action Item 6: Reduction of paper consumption and office waste
- Action Item 7: Effective use of biomass such as driftwood and mown grass
- Action Item 8: Promotion of construction by-product recycling
- Action Item 9: Procurement of environmental goods, etc., and promotion of contracts based on Act on Promotion of Contracts of the State and Other Entities, Which Show Consideration for Reduction of Emissions of Greenhouse Gases, etc.

③ Basic Perception 3: Raising awareness of environmental protection

Raise environmental awareness and advance knowledge through environmental education and other means, so that each JWA staff member is actively involved in environmental protection.

- Action Item 10: Implementation of seminars and trainings on the environment

④ Basic Perception 4: Communication with society

Actively publicize JWA's environmental protection initiatives and environment-related information. In addition, as a member of the local community, communicate with society by participating in and cooperating with local environmental protection activities.

- Action Item 11: Dissemination of environmental information through public relations magazines, websites, events, etc.
- Action Item 12: Development of landscape-friendly facilities
- Action Item 13: Environmental conservation activities in cooperation with dam reservoir areas, etc.

⑤ Basic Perception 5: Compliance with environmental laws and regulations.

Comply with environmental laws, regulations and the guidelines set by JWA to prevent environmental pollution, and to preserve and create good environment

- Action Item 14: Compliance with relevant laws, regulations and guidelines set by JWA

1-2 Implementation of an environmental management system (W-EMS).

Furthermore, in order to convert the Basic Perceptions into practical and continuous approaches to environmental conservation, JWA established its own environmental management system (W-EMS), which has been in company-wide operation since 2016, each year managing and continuously improving environmental conservation targets through the PDCA cycle, the name being the acronym of“Plan”, “Do”, “Check” and “Act”.

W-EMS is a unique system that JWA created based on the know-how cultivated through the company-wide operation of International Standard ISO 14001 and certificate acquisition of it up to 2012 W-EMS was also developed with ensuring the same quality as the original Standard and restructured and improved in line with JWA’s business operations. Through this system, JWA can continuously monitor, evaluate and reduce the impact of the administrative and business activities on the environment, and comply with environment-related laws and regulations to bring about the conservation and creation of a good environment.

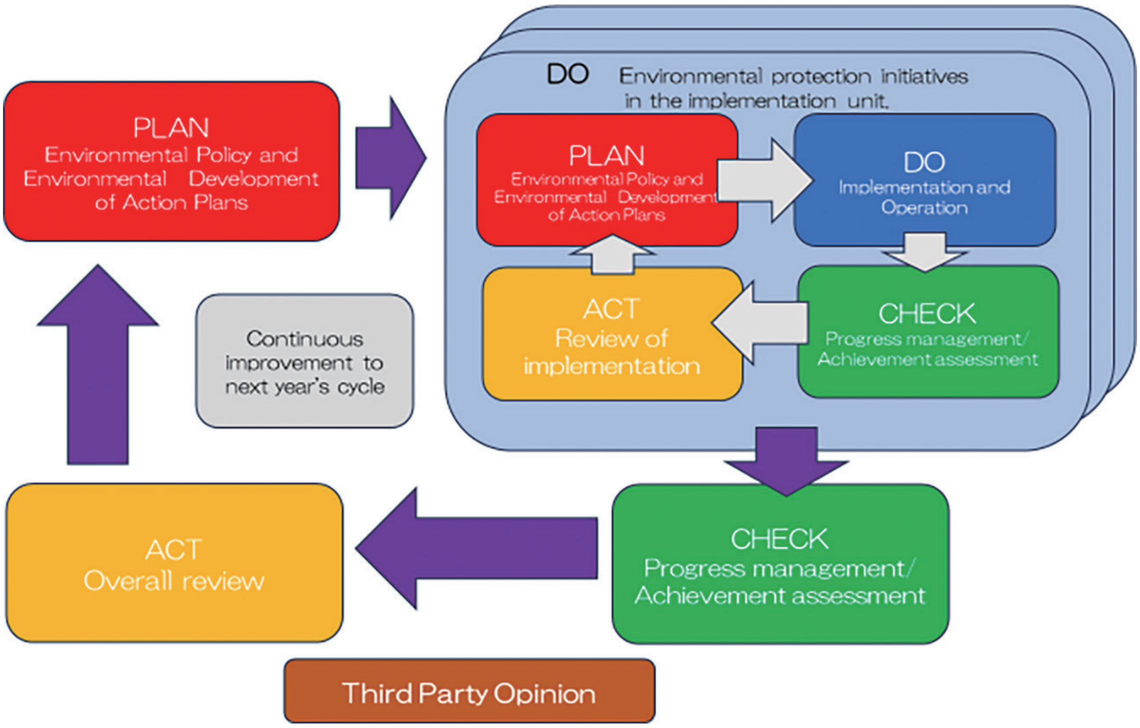


Figure- 2 Implementation of environmental protection measures through the W-EMS

1-3 Implementation system

In terms of the implementation system, the Chief Engineer, who is the chief technical officer at the head office, is responsible for overall JWA environmental management through the W-EMS as the 'Responsible Officer for Environmental Management (ROEM)', while the divisions in the head office and branch offices, and the individual construction offices and management offices are the 'Implementation Units (IUs)' for environmental conservation measures (ECM). Furthermore, each IU assigns a staff member in charge of each of the above-mentioned Action Items 1-14 to implement ECM. At the same time, 'Environmental Conservation Measures Promoter' is designated for each IU, and the staff member in charge assesses the progress and results of ECM. If any inadequacies are found, ROEM eventually instructs the relevant IU to make improvements for the following year, and sets new targets for further environmental improvements throughout JWA.

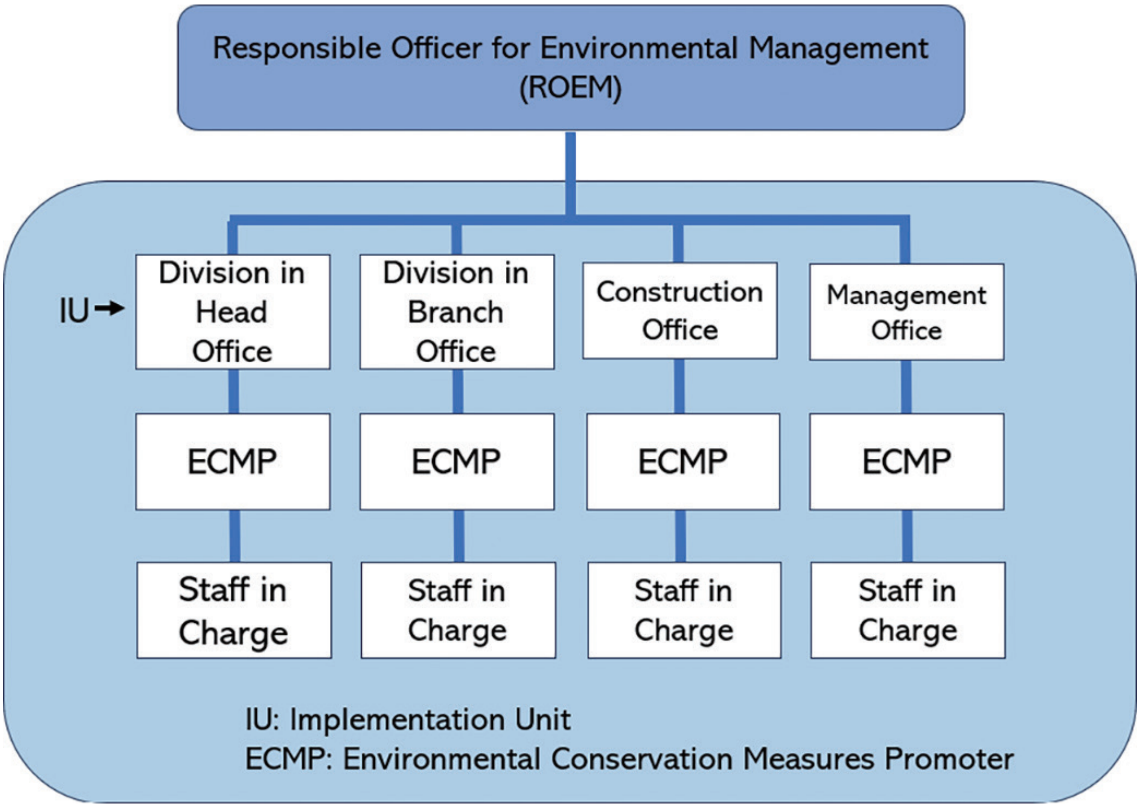


Figure- 3 Implementation system

2. Specific cases of initiatives

2-1 Natural environment studies, impact forecasts and protection measures

To protect the natural environment, natural environment studies and impact forecasts are carried out, and environmental protection measures are developed and implemented based on the results of these studies, etc.

① Conservation of Falconiformes

In general, Falconiformes are at the top of the food chain in the ecosystem. Therefore, the number is so small that the ecology is largely unknown. However, many species of hawk and eagle live in the upstream river basins of dams and planned reservoir site. JWA focuses on the mountain hawk-eagle as a rare species among Falconiformes and assumes that if its habitat can be maintained throughout the pre- and post-dam construction period by avoiding the impact of the project on its population as much as possible, the overall natural environment of the area will have been conserved.

In the research phase, the activity areas of the breeding pairs of the mountain hawk-eagles are clarified by means of fixed-point surveys. Based on the results of the surveys, nesting and hunting sites, etc. are estimated from flight density and the vegetation environment of the forest area, and these are identified as particularly important areas within the activity area of the breeding pairs.

In the stage of planning conservation measures, the particularly important areas are superimposed on the facility layout and construction scheme plans, and consequently, changes to and adjustments, including restriction of construction work during the egg-laying and nestling periods of the plans are made to avoid alteration of and less impact on these areas

After the completion of the construction, the behavior of the breeding pairs is to be monitored on a regular basis. If breeding activities are taking place or especially fledglings are confirmed around July or August, the effectiveness of the conservation measures can be proven.

Picture-1 Mountain hawk-eagle

Picture-2 Point survey

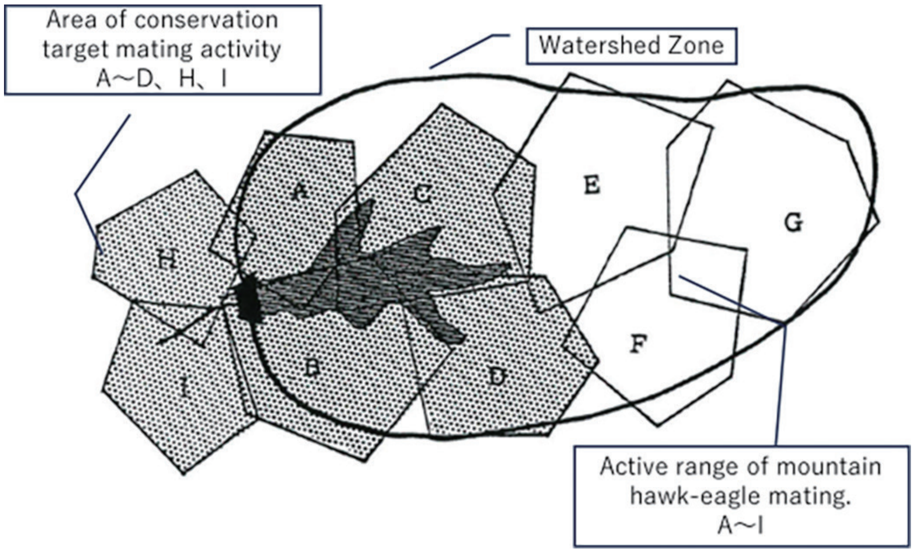


Figure-4 Distribution of the mountain hawk-eagle mating activity area.(Image.)

Multiple pairs of the mountain hawk-eagles grow at most of the dams of JWA, and in many cases, the pairs; have their activity areas without any spaces between them. In the case of the Tokuyama Dam of JWA, which reservoir is the largest in Japan, there are a total of 17 pairs around the dam site and its reservoir, all have continued to live there since the dam construction started and its reservoir was impounded after completion, and some fledglings have been observed.

② Conservation of giant salamanders

In the Kawakami Dam construction project, the conservation measures of giant salamanders have been implemented since 2016, which is to relocate them at the planned dam site and reservoir area to upstream river of the reservoir. The giant salamander is designated as the National Special Natural Monument, then it is necessary to get a permission from the Agency for Cultural Affairs for implementation of the conservation measures. In April 2018, a number of salamanders inhabiting the section in a diversion tunnel due to be constructed at the dam site were captured and released upstream.

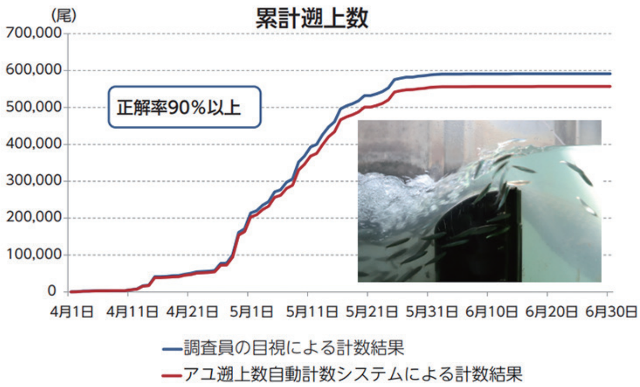
Picture-3 Giant salamander capture operation

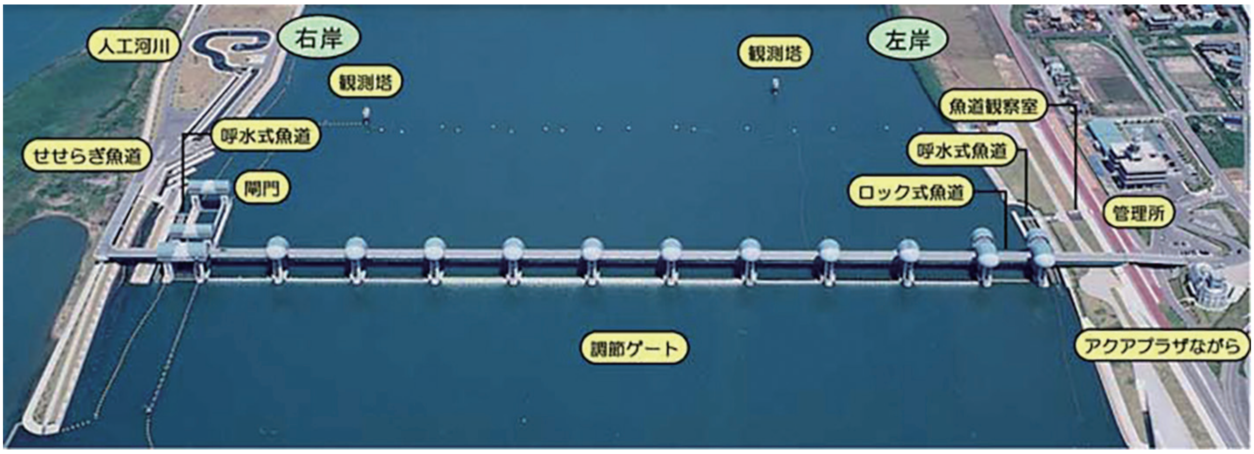
Picture-4 Captive giant salamanders.

③　Monitoring upstream migration of fish

In certain facilities such as those in estuary weirs, fish passages are installed and gates are operated to guide fish to the passages, taking into account the fish migrations, and monitoring surveys are conducted to confirm effect of these measures. At the Nagaragawa River Estuary Barrage of JWA, five fish passages of three types (Guide-flow type, Lock type and Brook type fishway) have been installed on the left and right banks of the Barrage, and fish run surveys have been conducted. JWA has established an AI-based automatic counting system, which was used to verify the upstream migrations of 590,000 young ayu, sweetfish in early spring 2019. An observation window onto the fish passage was installed in the Barrage facility, and live video footage of young ayu running upstream through the passage is streamed on the website during their migration period, among other initiatives, so that the public can see what is going on in the fish passage.

左岸呼び水式魚道　稚アユの群れ





Picture-5 Panoramic view of the Nagara River estuary weir

2-2 Promotion of initiatives to reduce environmental impact

①　Recycling of construction by-products

Based on the target values for recycling rates, etc. in the Construction Recycling Promotion Plan 2014, developed by the Ministry of Land, Infrastructure, Transport and Tourism, JWA has set the target values and been promoteing the recycling of construction by-products. In 2018, target values were achieved in all items as follows (Table-1).

Table-1 Promotion of recycling of construction by-products in 2018.

Construction By-products Target Items (Recycling rate)	Recycling rate (%) Actual / Target	Off-site emissions (t)	Recycled amount (t)
Asphalt and Concrete mass	100% / 99%以上	5,776	5,774
Concrete mass	100% / 99%以上	34,409	34,375
Construction By-products Target Items (Recycling - Reduction rate)	Recycling - Reduction rate (%) Actual / Target	Off-site emissions (t)	Recycled amount, etc. (t)
Construction generated lumber	100% / 96%以上	11,561	11,551
Construction sludge	100% / 90%以上	24,684	24,598
Mixed construction waste	98% / 60%以上	1,201	1,161
Total construction waste	100% / 96%以上	81,693	81,455
Construction By-products Target Items (Effective Utilization Rate)	Effective Utilization Rate (%) Actual / Target	Embankment backfills (m3)	Embankment peat volume other than new material (m3)
Construction soil	99% / 80%以上	10,431,737	10,350,250
Construction By-products Target Items (Emission Rate)	Emission Rate (%) Actual / Target	Annual emission (t)	Recycled amount (t)
Mixed construction waste	1.5% / 3.5% 以下	1,201	1,161

② Curb Greenhouse gas emissions from energy use

Some of JWA O&M offices generate hydrolectricity for their facility management in addition to the hydropower generated by the power generator utility. Over FY2013-17, JWA introduced and enhanced small hydropower and solar power generation facilities to further utilize the potential of the dams, canals, and other facilities. In FY2018, the effective use of these renewable energies contributed to the reduction of greenhouse gas emissions by 22,062 t-CO2.

- Actual performance of hydropower generation by O&M offices in 2018

  48,546 MWh of hydro-electricity was generated by 17 hydropower generation facilities. Of this, 5,168 MWh was used for facility management, thereby reducing JWA's greenhouse gas emissions by 2,547 t-CO2. In addition, 43,378 MWh of surplus electricity was sold to the power companies, which reduced costs and contributed to a reduction in greenhouse gas emissions by 21,371 t-CO2. In addition, 43,378 MWh of surplus electricity was sold to the power companies, which reduced costs and contributed to a reduction in greenhouse gas emissions of 21,371 t-CO2.

- Actual performance of solar photovoltaic power in 2018

  38 photovoltaic installations generated 1,435 MWh of electricity and this reduced greenhouse gas emissions by 6t-CO2, and contribut to a reduction of 691t-CO2.

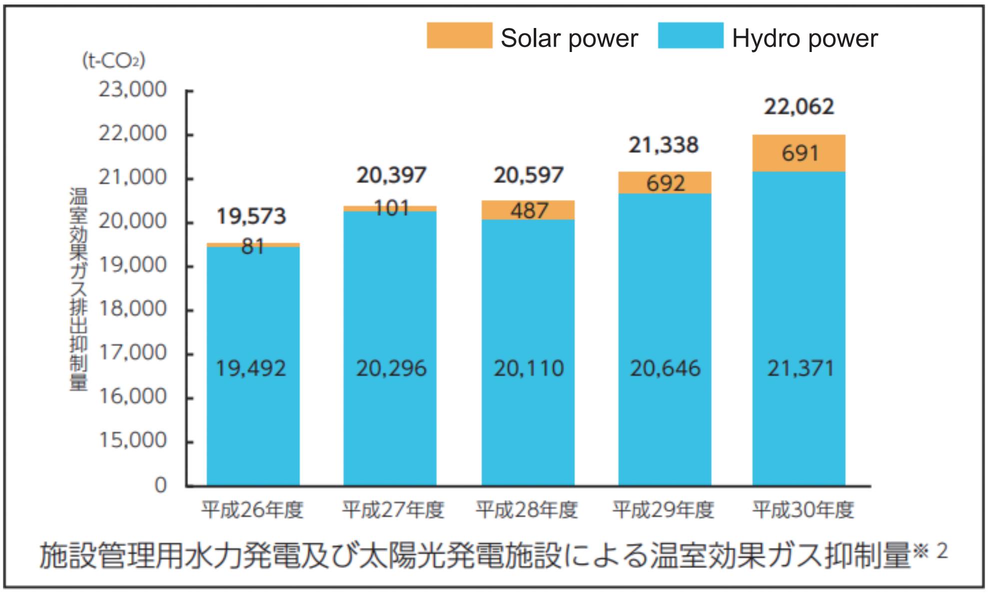


Figure- 6 Reduction of Greenhouse gas emissions by hydropower and photovoltaic facilities in O&M offices.

2-3 Communication with society Forest improvement

As a member of a local community, JWA participates in forest maintenance activities, community - in-river clean-up activities and environmental awareness-raising activities, together with local authorities and relevant organizations. The planting of broadleaved trees and thinning of cedar and cypress plantation forests in the mountains of river basins help mitigate floods and droughts, improve sediment run-off prevention functions and the growth and habitat of plants and animals. Municipalities in the basin carry out forest maintenance in cooperation with NPOs and other relevant organizations, and the Water Resources Agency also actively participates in these activities. The Tokuyama Dam office carries out a plan of protecting and nurturing the natural environment in the upper basin of the dam with local residents, by growing beech, konara (Quercus serrata), mizunara (Quercus mongolica var. crispula), chestnut and walnut trees from seeds into small seedlings, which are then donated to elementary and junior high schools (sapling home-stay activities), where the children and students grow them into large seedlings, which they later plant on mountain areas upstream of the Tokuyama Dam.

Picture-6 Planting of saplings

Picture-7 Installing posts to protect against winter snow.

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Case Studies on the integration of the gray and green infrastructure

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