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Working Together for Water Security:

NATURE-BASED AND GRAY INFRASTRUCTURE SOLUTIONS

DEEP DIVE

NOTE: This document is an accompanying resource to the Watershed Investment Program How-To Guide. Readers are strongly encouraged to review the guidance in its entirety before delving into any accompanying subject-matter "Deep Dives," including this document.

Document Objectives

Delivering resilient and robust solutions to water security challenges often requires a combination of 'green' and 'gray' solutions. While nature-based solutions (NbS) can help secure clean, reliable water for people and nature and mitigate against water-related climate disasters, while delivering on a number of co-benefits, water resources managers will continue to rely on built or 'gray' infrastructure to deliver water security objectives. Moreover, an existing installed base of conventional gray infrastructure is often present in watersheds, which can be complemented with green solutions to enhance water security impacts and/or reduce costs associated with infrastructure operations and maintenance.

This technical brief is intended to provide the reader with further insights into NbS and gray infrastructure by answering the following questions:

- What exactly is meant by green and gray infrastructure?
- How do NbS and gray infrastructure address water security challenges?
- How might they be combined to provide more robust and resilient solutions?
- What are some barriers to incorporating NbS into gray solution sets and how can we overcome them?
- Where can we find additional resources on this topic?

Defining Green and Gray Infrastructure

As a foundation, this brief will start with clarifying exactly what is meant by green and gray infrastructure in relation to water security outcomes.

Green infrastructure (also sometimes called natural infrastructure, or engineering with nature) intentionally and strategically preserves, enhances, or restores elements of a natural system, such as forests, agricultural land, floodplains, wetlands, coastal forests (such as mangroves), and riparian areas, among others. (*Browder et al 2019*)

Gray infrastructure refers to built structures and mechanical equipment, such as reservoirs, embankments, pipes, pumps, water treatment plants, and canals. These engineered solutions are embedded within watersheds or coastal ecosystems whose hydrological and environmental attributes profoundly affect the performance of the gray infrastructure. (*Browder et al 2019*)

For the purpose of this brief, given that it was developed to support technical guidance on developing nature-based solution programs for water security, the terms NbS and gray infrastructure will be used, with the assumption that NbS includes or is synonymous with green infrastructure. However, note that various organizations use the terms 'green infrastructure' and 'nature-based solutions' in slightly different ways. Some use these terms interchangeably, while others think about green infrastructure as a subset of NbS, especially those that are applied in urban settings or fall into the 'created' category of nature-based solutions. For example, the European Commission Communication on Green Infrastructure describes green infrastructure as *a tool for providing ecological, economic and social benefits through nature based solutions, for helping to understand the advantages nature offers human society, and for mobilizing investments that sustain and enhance these benefits*. Meanwhile, the Environmental and Energy Study Institute uses NbS as an umbrella term with green infrastructure and natural infrastructure being sub-categories of NbS.

While the terms 'green' and 'gray' infrastructure appear to be binary or opposed to one another, the reality is that there is a green-gray spectrum along which these NbS and gray infrastructure options exist (Figure 1). Different combinations of solutions along this spectrum can be assembled in a portfolio fashion to match the project objectives and local conditions regarding political, social, and natural environment conditions. Importantly, watershed conditions will always modify and impact the efficacy of grey infrastructure works, and hence holistically considering all options along the spectrum broadens the toolkit available to address water security concerns. The specific kinds of solutions generally depends on (1) project objectives, (2) desired performance and reliability characteristics, (3) relative cost characteristics, (4) local policy and regulations, (5) native ecosystems and existing watershed health, (6) land use patterns, and (7) social acceptance of proposed works.

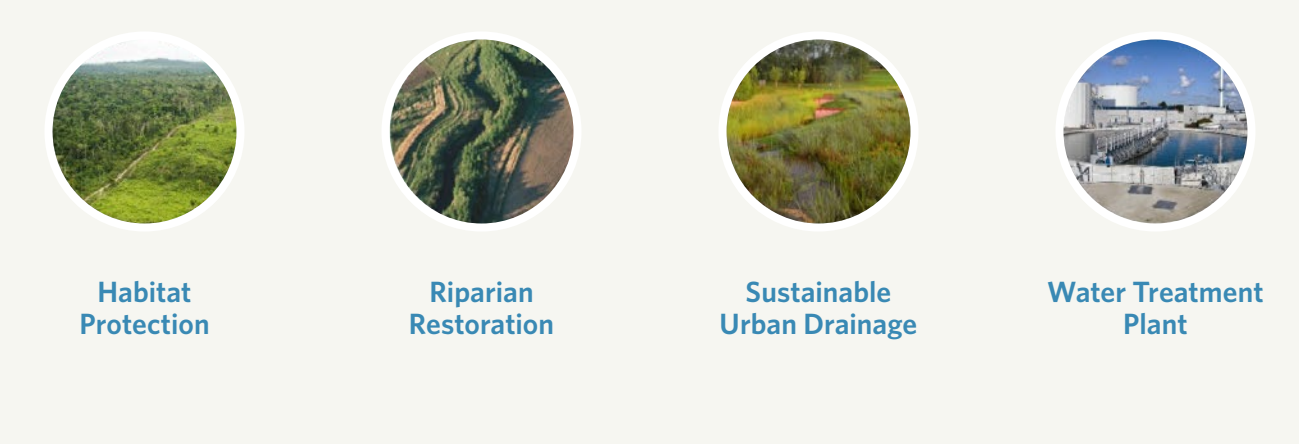

FIGURE 1. Green-gray infrastructure spectrum for water security outcomes (adapted from Green-Gray Community of Practice 2020)

Delivering on Water Security Outcomes

In the context of water management, both NbS and gray infrastructure can serve to deliver on a variety of outcomes, including supplying clean, reliable water to people and mitigating impacts of extreme events such as floods and droughts. Both types of infrastructure can also provide additional benefits to people and nature, although the types of benefits they typically are designed to deliver on differ. For example, NbS often are expected to provide benefits to ecosystems and/or biodiversity, while gray infrastructure is usually focused on one or more benefits to people, while working to minimize impacts on the environment.

Table 1 below provides examples of various green and gray infrastructure solutions that can address specific water management issues. For example, water purification can be achieved via vegetated systems such as riparian buffers or wetlands, or via a water treatment plant. As an additional reference, each of the NbS Technical Factsheets include a 'Relation to grey infrastructure' section detailing how the NbS category either acts as a complement or substitute to traditional grey infrastructure options.

TABLE 1. Examples of complimentary green and gray solutions to common water management issues (Cassin et al 2020)

WATER MANAGEMENT ISSUE (Primary service to be provided)		GREEN INFRASTRUCTURE SOLUTIONS	LOCATION				GREY INFRASTRUCTURE SOLUTIONS
			WATERSHED	FLOODPLAIN	URBAN	COASTAL	
Water supply regulation (including drought mitigation)		Re/afforestation and forest conservation	●				Dams, reservoirs, and groundwater pumping Water distribution system
		Reconnecting rivers to floodplains		●			
		Wetlands restoration/conservation	●	●	●		
		Constructing wetlands	●	●	●		
		Water harvesting	●	●	●		
		Green spaces (bioretention and infiltration)			●		
		Permeable pavements			●		
Water quality regulation	Water purification	Re/afforestation and forest conservation	●				Water treatment plant
		Riparian buffers		●			
		Reconnecting rivers to floodplains		●			
		Wetlands restoration/conservation	●	●	●		
		Constructing wetlands	●	●	●		
		Green spaces (bioretention and infiltration)			●		
		Permeable pavements			●		
	Erosion control	Re/afforestation and forest conservation	●				Reinforcement of slopes
		Riparian buffers		●			
		Reconnecting rivers to floodplains		●			
	Biological control	Re/afforestation and forest conservation	●				Water treatment plant
		Riparian buffers		●			
		Reconnecting rivers to floodplains		●			
		Wetlands restoration/conservation	●	●	●		
		Constructing wetlands	●	●	●		
Moderation of extreme events (floods)	Riverine flood control	Re/afforestation and forest conservation	●				Dams and levees
		Riparian buffers		●			
		Reconnecting rivers to floodplains		●			
		Wetlands restoration/conservation	●	●	●		
		Constructing wetlands	●	●	●		
		Establishing flood bypasses		●			
	Urban stormwater runoff	Green roofs			●		Urban stormwater infrastructure
		Green spaces (bioretention and infiltration)			●		
		Water harvesting	●	●	●		
		Permeable pavements			●		
	Coastal flood (storm)	Protecting/restoring mangroves, coastal marshes, and dunes				●	Sea walls
		Protecting/restoring reefs (coral/oyster)				●	

People have relied on both types of infrastructure to secure water for thousands of years and they will continue to do so. Even in a highly intact watershed, where vegetative cover filters water to high quality before it reaches a stream or lake, gray infrastructure components such as pumps, pipes and taps are needed to bring that water to people.

It is clear that focusing only on gray infrastructure solutions is not meeting water management needs, nor resulting in outcomes resilient to or capable of adapting to future climate pressures. Society's increasing disconnection from ecosystems has weakened our fundamental understanding that healthy ecosystems are foundational for human health and well-being and for long-term economic sustainability. Built infrastructure has been critical in meeting many human needs, including capturing and delivering safe drinking water, providing housing and transportation, and generating and supplying energy. However, with such a primary focus on gray solutions, many societies around the world have allowed ecosystems to be degraded, and accompanying this degradation is a huge loss in the foundational ecosystem services they provide, including those that tie into water sector management.

Intentionally combining green and gray infrastructure to lower costs and improve resiliency addresses both the looming financial and environmental crisis facing global infrastructure systems. With the right conditions, green infrastructure components can cost-effectively enhance service delivery, while also empowering communities and increasing infrastructure systems' resilience and flexibility in a changing climate (Browder et al 2019).

> **"... combining green and gray infrastructure to lower costs and improve resiliency addresses both the looming financial and environmental crisis facing global infrastructure systems."**

Green and Gray as Complimentary Solutions

For many water systems or watersheds, the most effective, robust and resilient way to meet the water needs of people and nature is through a combination of green and gray solutions. In fact, there are many ways the two types of infrastructure can be quite complimentary and improve the resilience and effectiveness of each individual solution.

In some cases, a cost-benefit analysis of the potential solutions to a specific water security challenge may result in selection of solely a gray or green solution. However, more often than not, a full cost accounting of all benefits will indicate that a set of integrated solutions will provide the most holistic way to address a water quantity and/or quality challenge. Table 2 below provides examples of gray solutions and complementary NbS to achieve specific water security objectives. For example, delivery of clean water to cities can be most cost-effectively provided in most cases by a combination of NbS in the water supply basin and gray infrastructure downstream that captures, conveys and treats the water. NbS in this case compliments the gray infrastructure by maintaining or restoring water quality at a consistent level and avoiding increased capital or operational costs.

TABLE 2. Examples of complimentary gray and green solutions to deliver water security outcomes (adapted from Browder et al 2019)

OBJECTIVE	GRAY SOLUTIONS	NbS	BENEFIT(S)
Deliver clean water to people	Reservoirs, pipes, water supply treatment	Protection or restoration of natural vegetated areas such as forests, grasslands, riparian areas, etc.	Reduce nutrient and sediment load to the system, extending the life of the system and reducing costs or avoiding upgrade to treatment system
		Agricultural BMPs	Reduce nutrient and pesticide to water treatment system; reduce sediment load to system
Treatment of wastewater	Wastewater treatment plant	Wetlands	Depending on make-up of effluent and downstream needs, reduce or eliminate the need for wastewater treatment
Hydropower	Dams, reservoirs and intakes	Protection or restoration of natural vegetated areas such as forests, grasslands, riparian areas, etc.	Reduce sediment load to the systems, extending the life of the system, reducing dredging costs
Urban stormwater	Drains, pipes, storage tanks	Green roofs, bioswales, urban wetlands	Slow down runoff and increase storage capacity which can reduce the need for system upgrades
River flooding	Levees, channeling	Protection, reconnection and restoration of floodplains	Increase ability of the system to store water, reducing flood peaks and decreasing risk of topping levees
Provide water for crops	Diversion, pipes, canals and irrigation systems	Agricultural BMPs that improve soil water holding capacity	Reduce the need for irrigation water by holding water longer in the soil for crops

In general, NbS are most cost-effective at addressing water security when deployed in the upper catchment—e.g., across large swaths of natural areas or working lands—while gray infrastructure is more often concentrated in areas where water supply and sanitation is provided to people and stormwater gathers due to development. There are many exceptions to this generalization, of course, for example with dams capturing and storing water in the upper catchment and urban green infrastructure helping to slow down and filter stormwater in a city.

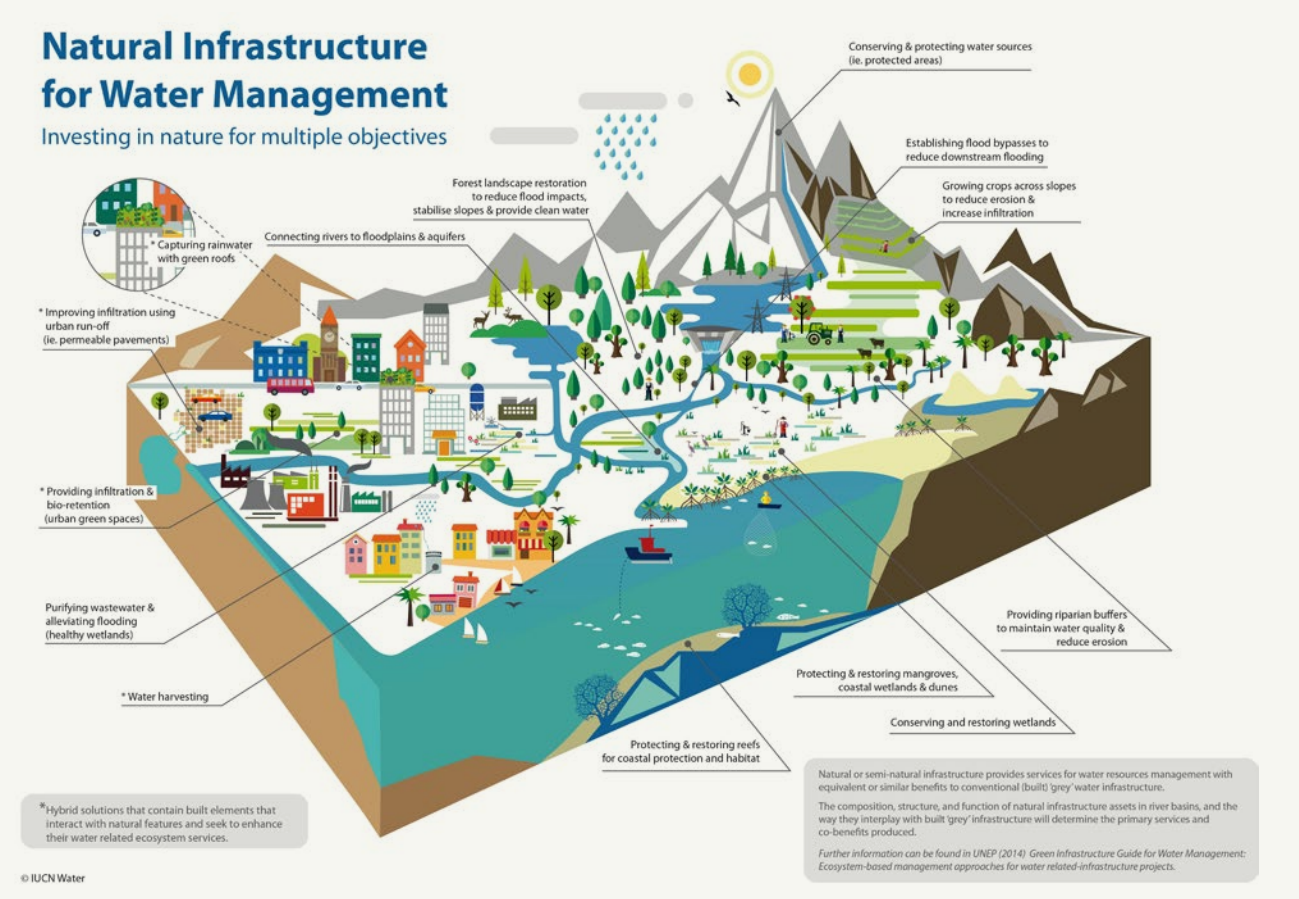

FIGURE XX. [Diagram watershed illustration showing how green and grey infrastructure can work together—e.g., NbS upstream (protection, revegetation), Ag BMPs midstream, gray infra (treatment plant)/SUDS downstream]

The most cost-effective and sustainable system for water management and delivery of water services likely requires a thoughtful combination of NbS and gray infrastructure, which necessitates integrating these concepts into water resource planning processes. The two pathways for integrating NbS into hybrid green-grey design as part of an integrated water management system include:

Option #1: NbS implementation as an add-on to an existing built system. In this case, NbS measures are meant to complement and enhance an already finalized set of grey infrastructure works. Reasons to do so include enhancing benefits delivery, refining inputs that enter into the water management system, and polish outputs. Furthermore, because NbS approaches are portfolio-based, they can be flexibly deployed to help water systems adapt to land use and climate change (as opposed to trigger large grey infrastructure capital expenditure requirements). Relevant examples include:

- Protecting or restoring watershed areas to promote water quality entering the water treatment system (e.g., via sediment or nitrogen reduction)
- Polishing the outputs of wastewater treatment plants via the addition of artificial wetland structures

Option #2: Intentional integrated planning for new or growing development. This option requires co-developing green and grey infrastructure elements early in project design with the aim of optimizing an overall blended portfolio to maximize water security and other co-benefits. Such an approach may also integrate into earlier water sector master planning efforts to ensure that NbS efforts are adequately represented and listed for consideration during project preparation phase. Relevant examples include:

- Combining gray irrigation infrastructure upgrades and agricultural best management practices (e.g., hedgerows) to help improve crop production in an underperforming agricultural area.

- Utilizing a combination of floodplain reconnection / restoration and levees to reduce negative impacts of riverine flooding for people, while maintaining critical habitat for fish and agricultural production in the area along the river.

Between these two options, the first option is by far the most common today; however there is an opportunity to change the way infrastructure is planned, designed and financed to more effectively address water management challenges with intentional integrated planning from the start.

Barriers to NbS and Integrating Hybrid Green-Gray Solutions

Despite the overwhelming benefits of integrated Nbs-gray portfolios, several barriers exist for the inclusion and funding of NbS as a solution to water security challenges. These include:

- Inexperience with planning, design and implementation of NbS by many entities tasked with the delivery of water security outcomes.
- Many government and private sector planning, design and funding processes are structured in a way that prioritize and incentivize gray solutions.
- Challenges in quantification of NbS and their predicted benefits, in part due to the lack of cost-benefit cases to draw from and inexperience in many institutions tasked with addressing water security challenges.
- Inadequate or inappropriate policies on supporting integration or implementation of NbS to address water security challenges.
- High transaction costs due to the nature of coordination and scale required for implementation.
- Time delay in delivery of benefits for many NbS, particularly those related to restoration.
- Lack of reported monitored outcomes of NbS interventions and related uncertainty of benefits delivery due to the complexity of the processes on which NbS depend.
- Limited standardization due to differences required by application in local contexts.
- Difficulty funding and financing NbS due to many of the points mentioned above.

Several resources discuss these barriers in more detail, including Nature Based Solutions and Water Security, the CEO Water Mandate's Benefit Accounting of Nature-based Solutions for Watersheds Landscape Assessment and UNEP's Green Infrastructure Guide for Water Management.

Addressing Key Barriers

The good news is that several efforts are underway to address and provide knowledge and capacity to overcome these barriers. A few of these include:

- The EU Horizon 2020 brings together many projects that are focused on addressing barriers to NbS and are managed through Nature-based Solutions Task Forces. The Task Forces include the following topics: Data and Knowledge Sharing, Integrated Assessment Framework, Governance, Business Models and Financial Mechanisms, NBS Communication, and Co-creation and Governance.
- The U.S. Army Corps of Engineers Engineering with Nature program works to better integrate NbS into engineering planning, design and implementation with these core elements in mind:
  - *Use science and engineering to produce operational efficiencies supporting sustainable delivery of project benefits.*

- *Use natural processes to maximum benefit, thereby reducing demands on limited resources, minimizing the environmental footprint of projects, and enhancing the quality of project benefits.*
- *Broaden and extend the base of benefits provided by projects to include substantiated economic, social, and environmental benefits.*
- *Use science-based collaboration to organize and focus interests, stakeholders, and partners to reduce social friction, resistance, and project delays while producing more broadly acceptable projects.*

Over the next several years the Engineering with Nature initiative will aim to further collaboration, help build capacity to further integrate natural solutions into projects and programs and support the growth in the number of green-gray projects and opportunities to communicate about them.

- The CEO Water Mandate has partnered with The Nature Conservancy, Danone and LimnoTech on an initiative to provide guidance and tools to help practitioners identify and quantify multiple benefits of NbS for water. By standardizing and clarifying approaches to identification and quantification of the full range of benefits of NbS for water, the initiative aims to strengthen the business case for NbS.
- Oxford's Nature-based Solutions Initiative aims to increase understanding of the potential for NbS to address critical global problems and to support the implementation of NbS around the world. The initiative achieves this through a combination of research, education and policy advising which tackle several of the barriers to NbS scaling.
- The Global Green-Gray Community of Practice, led by Conservation International, aims to scale up green-gray solutions to help address biodiversity loss and climate impacts. The group does this in four ways: innovate and pilot new green-gray approaches, expand science, engineering and policy activity in this area, increase awareness of green-gray approaches and build a community to increase uptake of green-gray solutions and ease access to financing of green-gray projects.

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References and Additional Resources

There are a growing number of reports and other resources that support growth of investment in integrated NbS-gray water security solutions. The following represent a handful of relevant resources that provide more details and guidance on this topic Moreover, a number of these resources (including Green-Gray Community of Practice, 2020; Browder et al 2019) include detailed case studies of green-gray projects that may serve as useful inspiration.

Brill, Gregg, Tien Shiao, Cora Kammeyer, Sarah Diringer, Kari Vigerstol, Naabia Ofosu-Amaah, Michael Matosich, Carla Müller-Zantop, Wendy Larson and Tim Dekker. (2021). Benefit Accounting of Nature-Based Solutions for Watersheds: Guide. United Nations CEO Water Mandate and Pacific Institute. Oakland, California. www.ceowatermandate.org/nbs/guide.

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Green-Gray Community of Practice. (2020). Practical Guide to Implementing Green-Gray Infrastructure. https://www.conservation.org/projects/global-green-gray-community-of-practice.

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United Nations Environment Programme. (2014). Green Infrastructure Guide for Water Management: Ecosystem-based management approaches for water-related infrastructure projects. https://www.unepdhi.org/green-infrastructure-guide-for-water-management/.

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