

Integrating Nature-Based Solutions into Drainage and Irrigation Systems



This Technical Study on ***Integrating Nature-Based Solutions into Drainage and Irrigation Systems*** was developed by the Global Green Growth Institute (GGGI) and the National Drainage and Irrigation Authority (NDIA).

The study was led and authored by Michael Bak, Dr. Vairaj Arjune, and Nicholas Taylor. The authors extend sincere appreciation to the Ministry of Agriculture, the National Drainage and Irrigation Authority, and the many stakeholders interviewed throughout the process. Special acknowledgement is given to NDIA experts Christine Douglas; Rudolph Persaud, Orner Webster, and Marissa Persaud; the Deltares review team—Hans Gehrels and Lakshman Srikanth; and external consultant Dr. Justin VanderBerg for their valuable insights. We would like to thank Hansrajie Sukhdeo- GGGI Guyana Country Manager and Lionel Wordsworth, Chairman of NDIA, Ministry of Agriculture, for their oversight and guidance.

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Summary

Climate variability, sea-level rise, and rapid land-use change increasingly exceed the design capacity of ageing drainage and irrigation (D&I) infrastructure in Guyana, heightening risks of pluvial and coastal flooding, drought stress, and salt-water intrusion. This study evaluates how Nature-based Solutions (NbS) can augment and de-risk existing grey assets, drawing on global best practice and Guyana-specific evidence to inform the National Drainage and Irrigation Authority's (NDIA) strategic planning. The study seeks to (i) identify fit-for-purpose NbS and green-grey hybrids for priority D&I contexts, (ii) synthesize relevant international and regional best practices to derive design and implementation lessons for Guyana, (iii) assess performance and trade-offs of select NbS interventions, and (iv) propose a practical roadmap, monitoring framework, and financing options for scaled adoption.

The approach taken in the study is based on literature and policy review; screening of biophysical and land-use conditions; key informant interviews and a multi-stakeholder workshop to ground-truth feasibility; and modelling using the InVEST suite—Annual Water Yield (AWY), Sediment Delivery Ratio (SDR), and Nutrient Delivery Ratio (NDR). The modelling applied a Before–After Control–Impact (BACI) design to compare direction-of-change under a common baseline for four representative interventions—riparian buffers, detention ponds/check dams, constructed wetlands, and floodplains.

Key findings indicate that (a) detention ponds/check dams consistently attenuate peak flows per unit area and reduce downstream sediment pulses; (b) riparian buffers most effectively curb hillslope sediment and nutrient export at source; (c) constructed wetlands provide robust nutrient removal and flow equalization benefits while creating ecological co-benefits; and (d) floodplains reduces peak discharge and supports sediment/nutrient retention when land availability permits. The performance varies with soils, slope, drainage density, tidal/outfall controls, and O&M practices; hybridization with existing grey assets (canals, pumps, and sluices) is therefore recommended.

Systemic constraints such as fragmented governance, corridor encroachment, limited routine maintenance, and sparse monitoring data, currently limit optimization and scaling. Priority recommendations are to institutionalize NbS through NDIA design standards and SOPs; protect and restore drainage corridors and riparian buffers via land-use controls; embed cost-benefit appraisal that values ecosystem services to compare green, grey, and hybrid options; establish a results-oriented monitoring framework with hydrologic, water-quality, ecological, and socio-economic KPIs; mobilize financing through national programmes and adaptation/blue-carbon windows; and operationalize delivery via phased, region-led workplans with empowered WUAs and clear O&M responsibilities.



Mangroves along a muddy shoreline with rock revetment



A sluice gate structure used for managing water levels and drainage along the low-lying coastal plain, forming part of Guyana's flood control infrastructure.

1. Introduction

1.1 Purpose and Scope of this Study

Guyana's drainage and irrigation (D&I) system is a critical component of the country's agricultural and water management infrastructure. Relying on an interconnected network of canals, conservancies, and sluices, the system plays an essential role in mitigating flood risks, managing water resources, and supporting livelihoods. Image 1 depicts a sluice within the East Demerara Water Conservancy (EDWC) that serves as a critical drainage component in Region 4. This study examines relevant international cases of D&I systems—including the institutional frameworks governing these systems and the integration of nature-based solutions (NbS) to enhance performance and resilience—and seeks to identify lessons that can be applied to the development of Guyana's D&I system. It further explores the challenges involved in sustaining these systems and the actions required to address them, emphasizing the importance of a collaborative and integrated approach among all stakeholders to achieve long-term sustainability.

The study also highlights the growing relevance of nature-based solutions in addressing climate change related challenges. Strategic investment in NbS can complement traditional grey infrastructure by enhancing ecosystem services, reducing flood risks, and contributing to sustainable livelihoods. In many cases, NbS offer cost effective alternatives to the substantial financing required for rehabilitation and new installations, particularly in the context of climate adaptation. By outlining opportunities to integrate NbS into existing D&I infrastructure, the study aims to support the development of a more resilient, adaptive, and inclusive system—while underscoring the need for proactive maintenance, continuous monitoring, and collaborative governance to ensure long term effectiveness.

This study is intended to provide an evidence base for the updated Drainage and Irrigation Strategy currently being developed by the National Drainage and Irrigation

Authority (NDIA). It presents an assessment of the current governance structures, institutional frameworks, and policy context surrounding D&I in Guyana, and it identifies existing applications of NbS already in use across the country. These national experiences are benchmarked against global best practices from NbS interventions implemented in similarly vulnerable geographies with comparable objectives.

Beyond documenting case examples, the study examines climate related risks and social vulnerabilities that influence D&I system performance, proposing NbS interventions as part of a broader climate adaptation strategy. A typology of NbS is included, detailing the range of ecosystem services they provide—such as flood attenuation, water purification, and erosion control—and highlighting opportunities to scale their use in Guyana's coastal and inland regions.

Building on the GIS based spatial analysis carried out in the technical study on “Making the case for resilient drainage and irrigation systems in Guyana¹”, this study identifies priority flood risk hotspots along the coast where NbS can help mitigate impacts. This analysis is complemented by hydrological modelling that estimates the cost effectiveness and performance trade offs of selected interventions. Through this integrated approach, the study aims to equip NDIA engineers and planners with practical decision making tools for incorporating NbS into the D&I project lifecycle. It concludes with targeted recommendations for institutionalizing NbS within NDIA's project planning, infrastructure design, and long term investment framework.

1 As part of the project, a technical study on integrating resilience in the D&I system in Guyana was developed by Vairaj Arjune, Michael Bak, and Ronald Cumberbatch. The section on flood risk mapping in Guyana was used to inform the nature-based solution modeling in this study.

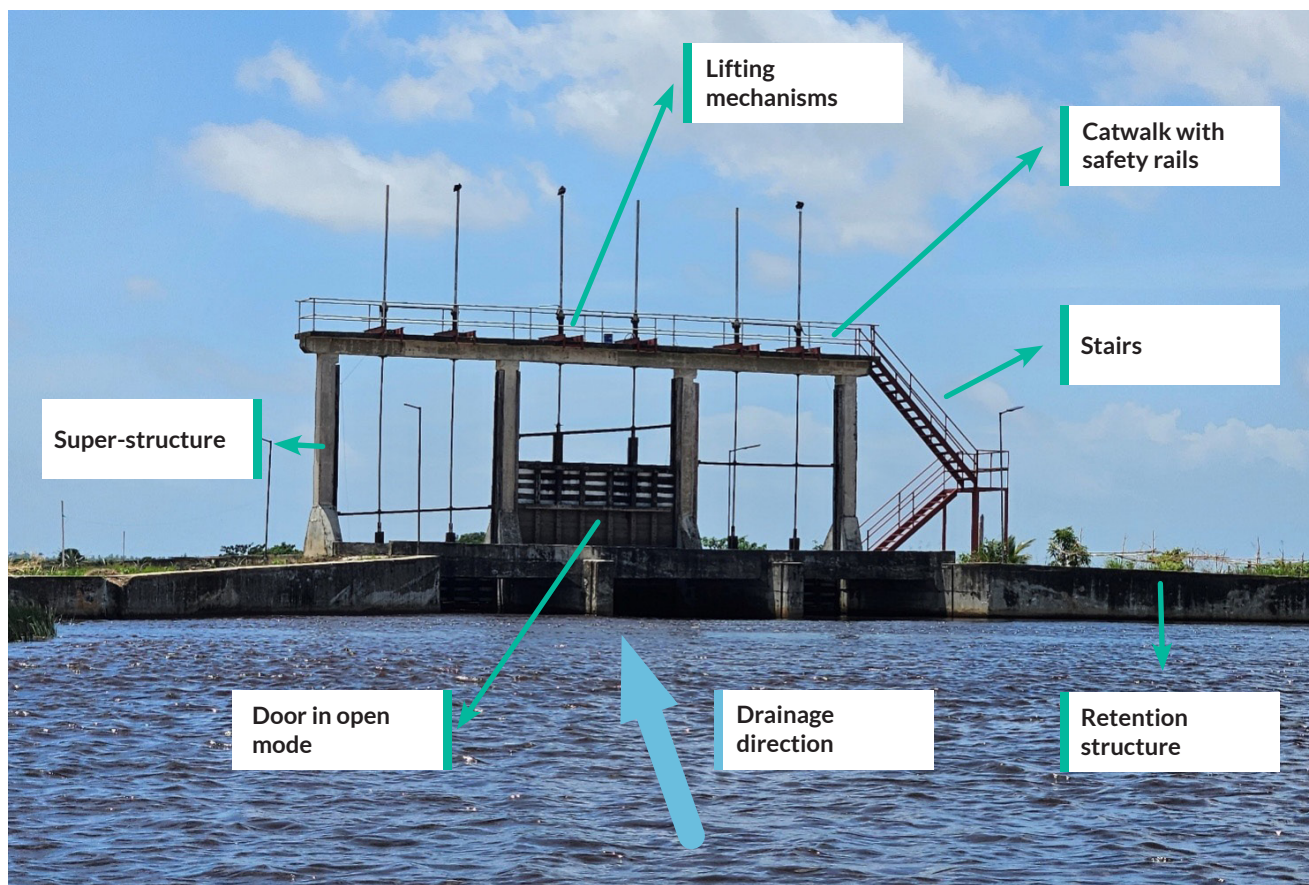


Image 1. Drainage and irrigation structure in Guyana

1.2 Alignment with National and Global Commitments

This study is closely aligned with Guyana’s national priorities for water resource management, sustainable agriculture, climate adaptation, and long-term development. Its objectives directly support major national policies and international frameworks, including the Low Carbon Development Strategy (LCDS) 2030, the Nationally Determined Contributions (NDCs), and key Sustainable Development Goals (SDGs).

Guyana’s water resources are highly seasonal and unevenly distributed, creating significant challenges for agriculture and rural livelihoods. The study responds to these challenges by promoting the integration of Nature-based Solutions (NbS) into drainage and irrigation systems to enhance water availability, stabilize agricultural production throughout the year, and reduce vulnerability to both droughts and floods. This approach strengthens national food security, improves rural livelihood resilience, and supports climate-resilient infrastructure development.

The study’s methodology reflects the LCDS 2030’s commitment to ecosystem-based, integrated water governance. It accounts for the hydrological, ecological, and social diversity across regions and emphasizes watershed-specific planning, participatory decision-making, and cross-sectoral coordination. Through regionally tailored Water Management Plans, routine assessments of surface and groundwater resources, and improved data-driven governance, the study addresses Guyana’s capacity to manage climate variability and development pressures. Moreover, the study aims to contribute to achieving SDGs, particularly SDG 2 (Zero Hunger), SDG 6 (Clean Water and Sanitation), SDG 13 (Climate Action), and SDG 15 (Life on Land). Overall, the study reinforces national policy priorities while advancing global sustainability commitments through integrated, resilient, and nature-based water management solutions.

1.3 Identifying Integration Opportunities for NbS

The D&I sector faces a number of systemic challenges, including insufficient hydrological data, fragmented institutional governance, and limited private sector investment in infrastructure rehabilitation. Structural failures, such as the malfunctioning of kokers and sluice gates, have already led to significant flooding, underscoring the urgency of action. In response, nature-based solutions (NbS) have emerged as one of the most effective strategies for enhancing the resilience, efficiency, and sustainability of D&I infrastructure. For example, mangroves currently shield approximately 60% of Guyana's coastline from flooding, serving as a critical natural defense for communities, businesses, and ecosystems². However, ongoing degradation and loss of mangrove forests have weakened these protections, leading to increased coastal flooding and saltwater intrusion into farmlands. This intrusion not only threatens agricultural productivity but also risks contaminating the

country's freshwater resources. Integrating NbS – such as mangrove restoration, floodplain zoning, and green infrastructure – into national D&I strategies can help improve drainage performance, enhance biodiversity, recharge groundwater, and provide long-term climate resilience.

In Guyana, where agriculture is concentrated in low-lying, flood-prone coastal regions, D&I systems are vital for managing water flows. However, as highlighted by the Dutch Risk Reduction Team, existing infrastructure is aging and under pressure from increasing urbanization and climate variability³. Integrating NbS, such as riparian buffers along drainage canals, reforestation in upland catchments, and managed aquifer recharge can alleviate pressure on these systems, reduce sedimentation, and extend their functional lifespan.

² Results from the Project: Nature-based solutions to protect Guyana from coastal flooding. Accessed from [Nature-based solutions to protect Guyana from coastal flooding](#) on 20th Feb, 2026.

³ Steijn, R., Westebring, F., & Klostermann, J. (2015). *Flood risk management in the northern coastline of Guyana, and Georgetown in particular*. Dutch Risk Reduction Team.



Sluice located at Viva-La-Force, West Bank, Demerara. This structure is part of the drainage system of a large sugar plantation.

Children of the families that worked on the plantation caught fish the old-fashioned way in the countryside using a cast net.

1.4 What are Nature-based Solutions?

According to the International Union for Conservation of Nature (IUCN)⁴, Nature-based Solutions (NbS) are defined as “actions to protect, sustainably manage, and restore natural or modified ecosystems that address societal challenges effectively and adaptively, while simultaneously

providing human well being and biodiversity benefits.” NbS use natural systems and processes to tackle major challenges such as climate change, biodiversity loss, water insecurity, and disaster risk—illustrated in **Figure 1**, Overview of Nature based Solutions for Addressing Climate Hazards.



Figure 1. Overview of Nature-based Solutions for Addressing Climate Hazards⁵

These approaches harness the functions of ecosystems—forests, wetlands, mangroves, grasslands, and others—to provide benefits for both people and nature. By restoring, conserving, and sustainably managing natural resources, NbS offer a holistic way to address environmental challenges while promoting human well being and supporting sustainable economic development. Examples include afforestation, wetland restoration, and climate smart or sustainable agriculture.

What differentiates NbS from traditional engineered (“grey”) infrastructure is that NbS work with natural

processes rather than attempting to control or override them. They recognize that healthy ecosystems can often deliver cost effective, resilient, and long lasting alternatives to built infrastructure⁶. For example, mangrove restoration provides coastal protection against storm surges while also supporting biodiversity and local fisheries. This dual functionality is why NbS are increasingly viewed as essential tools for achieving global climate goals, enhancing biodiversity, and building more resilient communities.

4 IUCN World Conservation Congress, 2016. Defining Nature-based Solutions. https://portals.iucn.org/library/sites/library/files/resrecfiles/WCC_2016_RES_069_EN.pdf

5 Source: Global Commission on Adaptation, *Adapt Now: A Global Call for Leadership on Climate Resilience* (Rotterdam and Washington, DC: Global Center on Adaptation, 2019), 32. <https://gca.org/reports/adapt-now-a-global-call-for-leadership-on-climate-resilience/>.

6 United Nations Environment Programme (UNEP). (2021). *Nature-Based Solutions for Climate Change Adaptation*.

In wet tropical climates, intense and prolonged rainfall frequently overwhelms conventional drainage infrastructure, resulting in repeated flooding, infrastructure damage, and economic losses. NbS can help reduce these risks by increasing the landscape's capacity to retain, slow, and infiltrate water. Ecosystems such as wetlands, riparian buffers, floodplains, and mangroves naturally absorb excess water and reduce downstream flood peaks.

Mangroves in particular provide significant protective benefits. They dissipate wave energy, reduce coastal erosion, and limit saline intrusion into freshwater systems—functions that are especially valuable in low lying coastal areas such as those found in Guyana⁷. By integrating these natural defenses into broader adaptation and development strategies, countries can improve climate resilience while preserving the ecosystems that underpin local livelihoods and biodiversity.

⁷ Sayers, P., Horritt, M., Penning-Rowsell, E., & Fieth, J. (2019). *Flood risk: Summary for the third UK Climate Change Risk Assessment*. Committee on Climate Change. <https://www.ukclimaterisk.org/wp-content/uploads/2020/07/Future-Flooding-CCC-2019-Sayers.pdf>



1.5 Typologies of Relevant NbS

While there are significant overlaps between the nature-based solutions (NbS) that can be implemented to enhance drainage systems and those designed primarily to support irrigation, this study considers these two functions separately while acknowledging their co-benefits. It is important to note that significant and diverse co-benefits are a defining characteristic of NbS. **Table 1** presents illustrative examples of NbS relevant to drainage systems. This list is not exhaustive—as NbS options are wide-ranging and often most effective when

tailored to local ecosystems and built-environment contexts—but it provides a representative sample of the types of interventions referred to in this study.

Global and regional databases on NbS are proliferating, which can provide a more detailed and extensive list of options such as the NbS Knowledge Database⁸ and the NbS Evidence Platform⁹, although many more exist focused on case studies and other specific uses.

Table 1. Nature-based Solutions for Drainage Systems.^{10 11 12}

NbS Type	Primary Function	Drainage Benefits	Co-Benefits
Vegetated Swales	Surface water conveyance	Slows runoff, increases infiltration, reduces peak flows	Improves water quality, enhances green space
Constructed Wetlands	Water filtration and temporary storage	Stores stormwater, filters sediments and pollutants	Enhances biodiversity, carbon sequestration
Riparian Buffers	Vegetative strips along water bodies	Reduces runoff velocity and erosion, buffers floodwaters	Habitat corridors, water purification
Retention/Detention Ponds	Stormwater capture and slow release	Reduces flood peaks, allows sediment settling	Can be used for irrigation, habitat creation
Green Roofs	Vegetative cover on buildings	Reduces runoff generation from rooftops	Urban cooling, insulation, aesthetic benefits
Permeable Pavements	Porous surfaces for walkways and roads	Allows water to infiltrate, reducing surface runoff	Urban heat reduction, groundwater recharge

8 NetworkNature. (n.d.). *Nature-based solutions knowledge database*. European Commission. <https://networknature.eu/nbs-knowledge-database>

9 Nature-based Solutions Initiative. (n.d.). *NbS evidence platform*. University of Oxford. <https://www.naturebasedsolutionsevidence.info>

10 Miralles-Wilhelm, F. (2021). *Nature-based solutions in agriculture: Sustainable management and conservation of land, water, and biodiversity*. Food and Agriculture Organization of the United Nations and The Nature Conservancy. <https://doi.org/10.4060/cb3140en>

11 World Bank. (2017). *Implementing nature-based flood protection: Principles and implementation guidance*. World Bank Group. <https://openknowledge.worldbank.org/handle/10986/28807>

12 UN Environment-DHI, UN Environment, & IUCN. (2018). *Nature-based solutions for water management: A primer*. https://www.unepdhi.org/wp-content/uploads/sites/2/2020/05/WEB_UNEP-DHI_NBS-PRIMER-2018-2.pdf

NbS Type	Primary Function	Drainage Benefits	Co-Benefits
Reforestation / Afforestation	Vegetative cover in upper catchments	Enhances infiltration, reduces overland flow and sedimentation	Improves water regulation, biodiversity, and air quality
Mangrove Restoration	Coastal vegetative buffer	Reduces storm surge and coastal flooding, protects outfalls	Supports fisheries, prevent saltwater intrusion
Agroforestry along canals	Trees and crops integrated along drainage canals	Reduces soil erosion and nutrient runoff	Provides food, fuel, and income
Grass-lined Channels	Vegetated open drainage channels	Slows water flow, stabilizes banks, reduces sediment transport	Aesthetic improvement, pollinator habitat
Check Dams / Vegetative Barriers	Small structures in channels	Slows flow, encourages sediment deposition	Recharges groundwater, reduces erosion
Floating Wetlands	Aquatic vegetation on rafts in water bodies	Improves water quality, absorbs excess nutrients	Can be used in canals, ponds, or lagoons

Most of the solutions listed in Table 1—such as retention ponds, check dams, vegetated channels, and wetlands—are not new to civil engineering; they have long been used in water resource management as components of stormwater systems and flood control infrastructure. What distinguishes the NbS paradigm is not the novelty of these structures, but rather the framework through which they are understood and evaluated. NbS encourages a shift from viewing these elements as solely functional infrastructure to recognizing them as multifunctional ecosystems that deliver a range of co-benefits—biodiversity support, water purification, urban cooling, and social amenities, among others. By incorporating ecosystem service valuation into planning and cost-benefit analyses, NbS offers a broader, more holistic assessment of effectiveness and sustainability compared to traditional grey infrastructure.¹³ This approach is especially valuable

in wet tropical contexts like Guyana, where hybridizing nature and engineering can optimize both ecological resilience and infrastructural performance in the face of intensifying climate risks.

Hydrological modeling conducted in flood-prone areas has demonstrated that integrating NbS such as reforestation¹⁴, floodplain restoration¹⁵, and vegetated drainage¹⁶ channels can substantially decrease surface runoff and delay peak flows. This leads to a reduction in flood frequency and severity, decreasing reliance on engineered solutions such as pumps and sluices. The 2021 FAO and The Nature Conservancy (TNC) report also notes that NbS provide redundancy and flexibility in systems, enhancing their ability to absorb shocks and adapt to future climate scenarios.¹⁷

Table 2 presents a range of NbS that can benefit irrigation

13 ibid

14 Kabeja, C., Li, R., Guo, J., Rwatangabo, D. E. R., Manyifika, M., Gao, Z., Wang, Y., & Zhang, Y. (2020). The Impact of Reforestation Induced Land Cover Change (1990–2017) on Flood Peak Discharge Using HEC-HMS Hydrological Model and Satellite Observations: A Study in Two Mountain Basins, China. *Water*, 12(5), 1347

15 Baida, M. E., Chourak, M., & Boushaba, F. (2024). Flood Mitigation and Water Resource Preservation: Hydrodynamic and SWMM Simulations of nature-based Solutions under Climate Change. *Water Resources Management*, 39(3), 1149–1176

16 Maurya, O. P., Nandi, K. K., & Dutta, S. (2025). Harnessing Vegetation as a Nature-Based solution for Integrated river corridor Management: a path towards harmonized Human–Nature synergy. *Ecohydrology*, 18(5)

17 Miralles-Wilhelm, F. (2021). *Nature-based solutions in agriculture: Sustainable management and conservation of land, water, and biodiversity*. Food and Agriculture Organization of the United Nations and The Nature Conservancy. <https://doi.org/10.4060/cb3140en>

systems—particularly those in conservancy and surface water-fed networks such as those found in Guyana. Although many interventions resemble those used in drainage systems, such as vegetated buffers, constructed wetlands, and check dams, their functionalities differ significantly. In drainage, NbS primarily aim to manage excess water and reduce flood risks by facilitating temporary storage, infiltration, and flow regulation. In contrast, NbS within irrigation systems focus on retaining, storing, and strategically distributing water to farmlands, particularly during dry periods. For example, wetlands that serve as floodwater buffers in drainage systems

act as pre-treatment zones and temporary reservoirs in irrigation systems, improving both water quality and availability. Likewise, vegetative buffers along irrigation canals stabilize banks and reduce sedimentation, thereby increasing flow efficiency and prolonging infrastructure life. Overall, irrigation-oriented NbS emphasize sustaining water availability, minimizing conveyance losses, and strengthening agricultural resilience—rather than promoting rapid water removal, as is typical in drainage contexts.

Table 2. Nature-Based Solutions for Irrigation Systems.^{18 19}

NbS Type	Primary Function	Irrigation Benefits	Co-Benefits
Riparian Buffers	Vegetative zones along irrigation canals	Reduces bank erosion and sedimentation, stabilizes canal edges	Improves water quality, supports biodiversity
Constructed Wetlands at Discharge Points	Intermediate filtration between conservancies and canals	Filters sediments and agrochemicals before water enters fields	Enhances water quality, provides habitat
Agroforestry on Irrigated Lands	Trees integrated into farming systems	Improves soil moisture retention and microclimate	Diversifies income, reduces evapotranspiration
Check Dams and Vegetative Barriers	Small structures along canals or within fields	Slows flow, promotes infiltration and sediment settling	Recharges groundwater, reduces canal erosion
Managed Aquifer Recharge Zones	Infiltration zones downstream of canals	Stores excess water during wet seasons for use in dry periods	Improves water security, mitigates salinity intrusion
Canal Revetment with Grasses or Vetiver	Bioengineered banks of canals	Stabilizes canal slopes, reduces maintenance costs	Aesthetic value, pollinator habitat

18 IUCN. (2020). *Nature-based solutions for agricultural water management and food security*. <https://www.iucn.org/resources/publication/nature-based-solutions-agricultural-water-management>

19 Miralles-Wilhelm, F. (2021). *Nature-based solutions in agriculture: Sustainable management and conservation of land, water, and biodiversity*. Food and Agriculture Organization of the United Nations and The Nature Conservancy. <https://doi.org/10.4060/cb3140en>

NbS Type	Primary Function	Irrigation Benefits	Co-Benefits
Retention Ponds in Field Systems	Small on-farm water storage	Captures water during canal overflow, extends water availability	Buffers flood/drought extremes, improves local irrigation timing
Cover Cropping in Irrigated Fields	Ground cover on fallow or between crop cycles	Improves soil structure, reduces runoff and nutrient loss	Enhances organic matter, supports soil microbial health
Reforestation in Upland Watersheds	Tree planting in upstream catchments	Enhances water retention and regulates inflows to conservancies	Reduces sediment inflow, carbon sequestration
Floating Vegetation	Vegetation mats placed in wide canals	Uptake of nutrients, stabilizes flow, prevents algal blooms	Improves ecosystem function, supports aquatic biodiversity

In wet tropical environments, where rainfall can be both excessive and unevenly distributed, NbS like those listed in Table 2 can offer adaptive strategies to manage excess water in the wet season and retain moisture during dry periods. This balance is crucial for rainfed agriculture as well as systems reliant on irrigation. The integration of NbS into farm-level planning also encourages community participation and knowledge sharing, ensuring that interventions are locally relevant and socially accepted.

Moreover, NbS have the potential to transform degraded agricultural landscapes into multifunctional systems that simultaneously support food production, water

regulation, and biodiversity. By aligning with landscape-level management approaches, NbS can foster synergies across sectors—bridging agricultural productivity with conservation and disaster risk reduction objectives. Ultimately, integrating NbS into agricultural water management aligns with the broader goals of climate-smart agriculture and sustainable development.²⁰

²⁰ Ibid

1.6 Global and Regional Case Studies: Comparative Overview

This section highlights case studies from Bangladesh, Pakistan, and India to demonstrate how climate-vulnerable regions are successfully integrating local knowledge, natural infrastructure, hydrological insights, and strong community participation to enhance resilience. Together, these examples show how different solutions ranging

from hybrid coastal engineering and large-scale mangrove restoration to community-led wastewater reuse, can improve water management, safeguard livelihoods, and strengthen climate adaptation.

1.6.1 Bangladesh: Enhancing Coastal Resilience in a Changing Climate

Project background

Bangladesh's coastal zone is home to over 40 million people and is characterized by its dynamic deltaic environment, shaped by rivers, tides, and frequent cyclones. While the country has made significant progress in reducing disaster fatalities, challenges persist from erosion, flooding, saline intrusion, and climate-induced hazards. Investments over five decades (~US\$10 billion) have led to structural defences, shelters, early warning

systems, and afforestation efforts, making Bangladesh a global leader in coastal climate resilience.

By combining geospatial risk mapping, stakeholder consultations, and technical field assessments, the three hotspot areas, Polder 35/1, Polder 48 (Kuakata), and Cox's Bazar Marine Drive (see Figure 2), were chosen based on their high exposure to erosion and flooding, critical socio-economic value, and suitability for implementing innovative, nature-based or hybrid coastal resilience solutions.

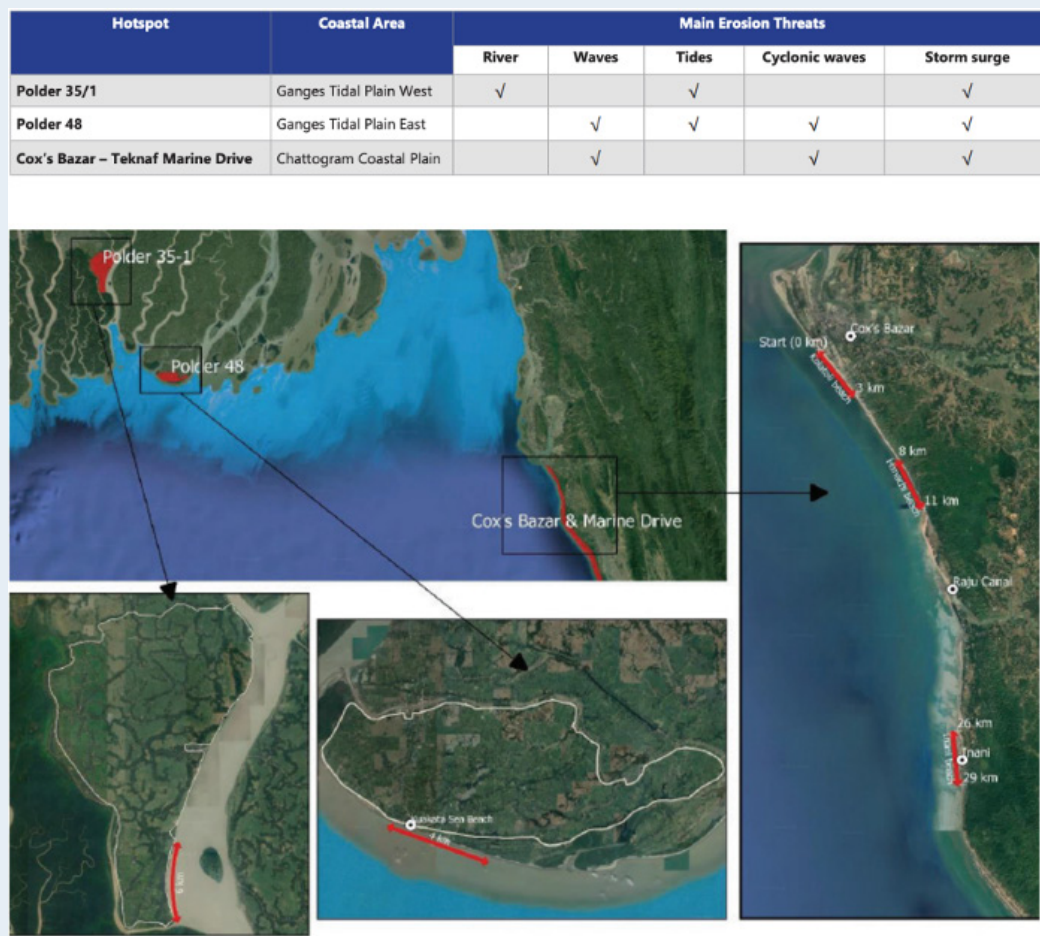


Figure 2. Overview of the Three Erosion Hotspot Locations for Detailed Analysis

Project Objective

The initiative aimed to:

- Enhance climate resilience in Bangladesh's coastal zone
- Provide data-driven and risk-informed recommendations
- Guide sustainable investments combining engineered infrastructure and nature-based solutions

Project Focus: Polder 35/1

Located in southwest Bangladesh, Polder 35/1 protects agricultural lands and villages from saline intrusion and tidal inundation caused by the Baleshwar River and the sea. However, over recent decades, severe bank erosion has accelerated, threatening embankments, farmland, and livelihoods as shown in Figure 3.

Traditional structural interventions, such as revetments and embankments, have had some success, but have not fully stemmed the ongoing losses or addressed the underlying river dynamics. In response, a hybrid and nature-based solution was proposed, integrating engineered elements with processes that work with natural sediment flows.

The core of this hybrid solution involves dredging an alternative river channel in the Baleshwar River to redirect hydraulic pressure away from erosion-prone areas. This intervention aims to reduce scouring and slow the lateral migration of the riverbank. At the same time, the design incorporates revetments using geotextile bags and grass turfing, which stabilize the embankment's slope while allowing some natural absorption of wave energy, as shown in Figure 4-6.



Figure 3. Land Use in Polder 35/1

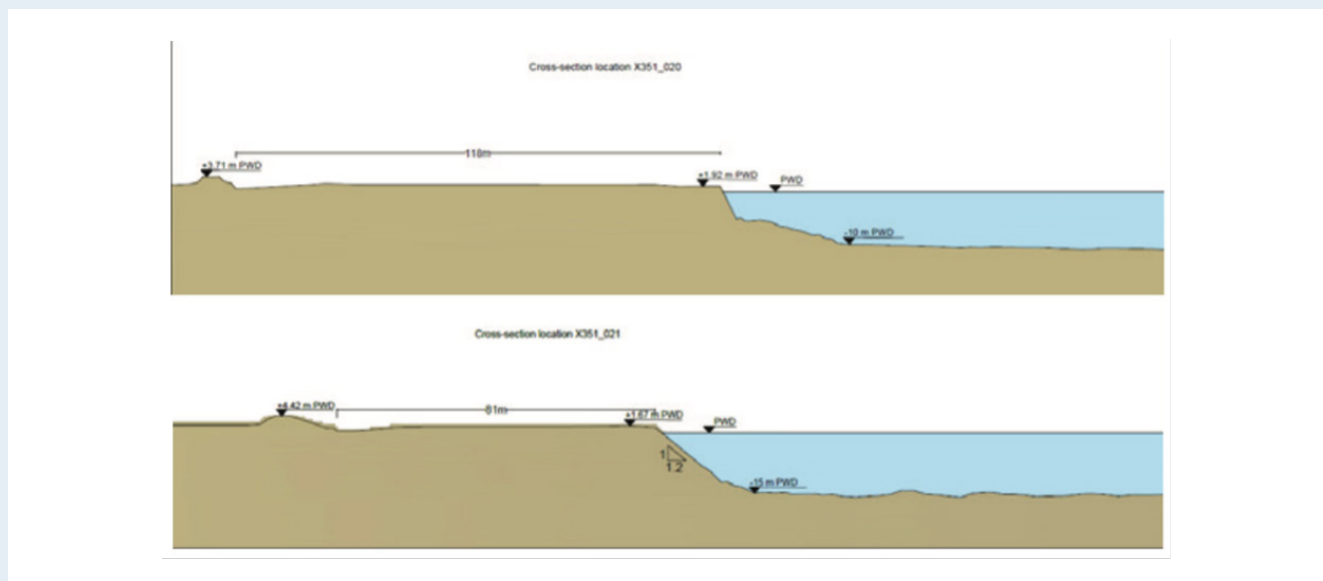


Figure 4. Schematic Representation of the Present Situation with Basic Dimensions in Two Cross Sections

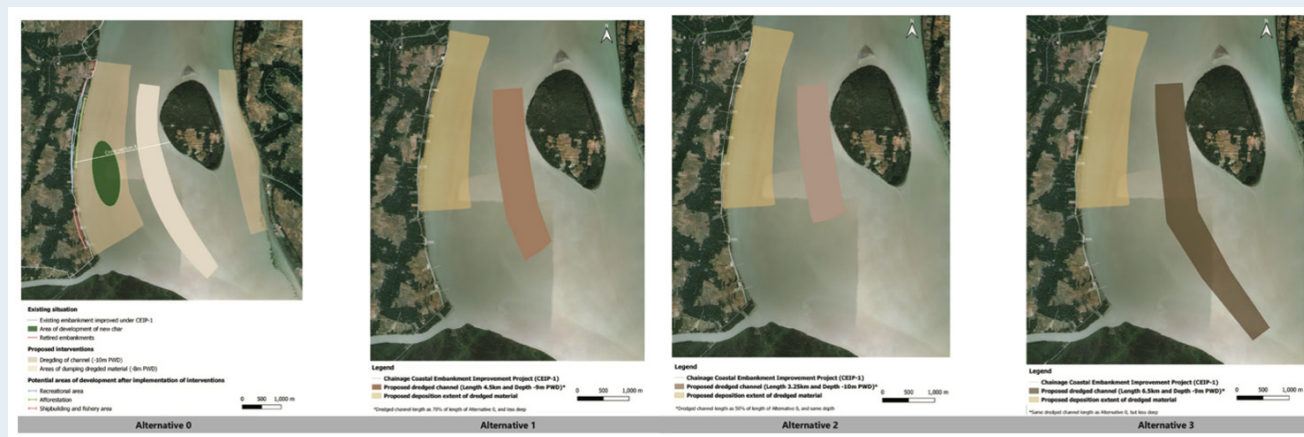


Figure 5. Proposed Dredging and Dumping Alternatives to Reduce Erosion at Polder 35/1



Figure 6. Artist Impressions: Birds-Eye View and Typical Cross Section of Proposed Hybrid Solution

Best practices for Guyana D&I

- Strengthening operation and maintenance (O&M) of existing drainage, irrigation, and sea defense infrastructure is critical for Guyana to ensure that past investments continue to deliver protection and productivity.
- Pairing traditional infrastructure with nature-based solutions (NbS), such as mangrove restoration and riparian buffer zones, can strengthen resilience and offer co-benefits like biodiversity and carbon sequestration.
- Guyana's future planning would also benefit from risk-sensitive land-use zoning, particularly in balancing development with ecosystem preservation along the coast. Ensuring inclusive community participation in the design and maintenance of adaptation efforts, especially among small farmers, women, and Indigenous groups, can enhance local ownership and long-term success.

1.6.2 Delta Blue Carbon ²¹

Project background

The Indus Delta Blue Carbon 1 (DBC1) Project is located in the Indus River Delta of southern Pakistan, within the Sindh province. This coastal delta region has long suffered from severe environmental degradation due to reduced freshwater inflows, saline intrusion, and coastal erosion, exacerbated by upstream damming and climate change. The local ecosystem, once dominated by dense mangrove forests, had been severely depleted, leading to the collapse

of fisheries, loss of livelihoods, and high vulnerability to cyclones and flooding (see **Figure 7**).

Launched as a large-scale nature-based adaptation initiative, the DBC1 project focuses on restoring degraded mangrove forests and safeguarding existing tidal wetlands, while engaging local communities in reforestation, monitoring, and sustainable resource use. It is recognized as the world's largest mangrove restoration project financed through blue carbon credits and is implemented through a public-private partnership model.

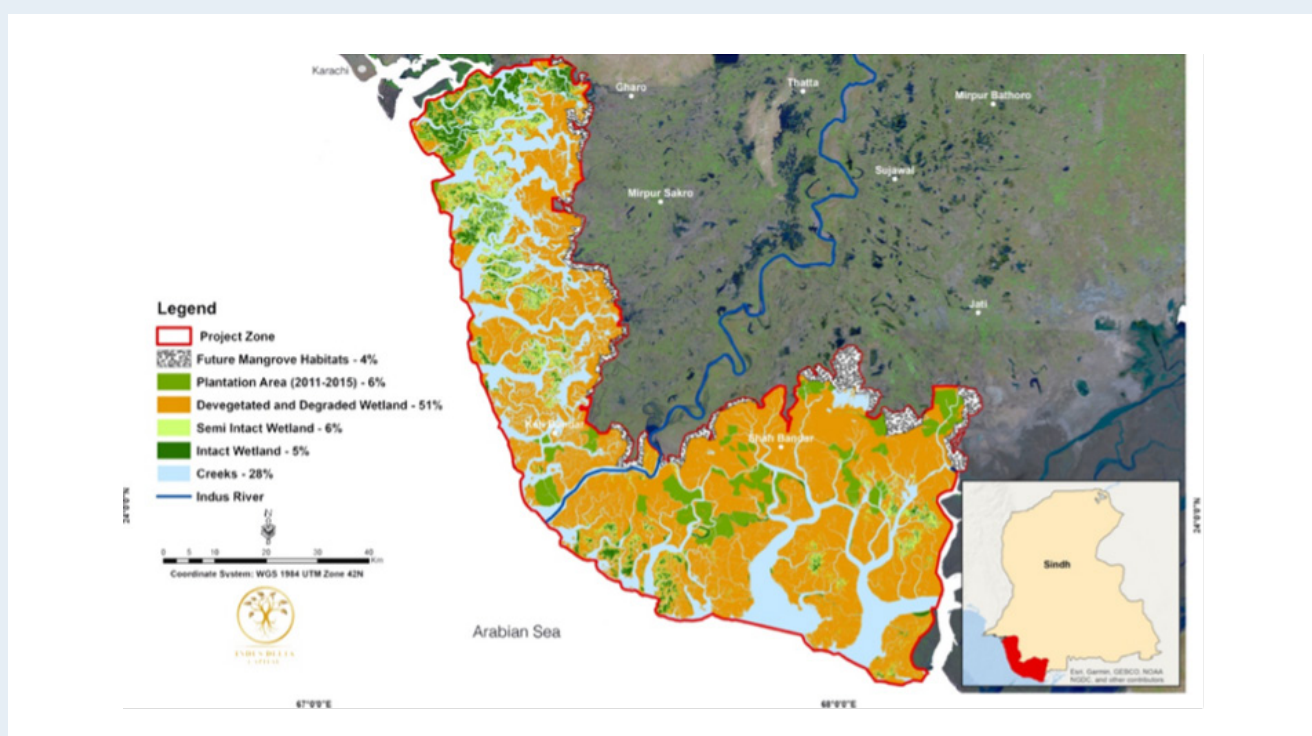


Figure 7. Project zone boundary and land cover

Project Objectives

The key objectives of the DBC1 project are to:

- Restore and conserve mangrove forests across over 350,000 hectares of degraded delta land
- Improve the climate and flood resilience of coastal communities
- Re-establish ecological functions such as sediment trapping, salinity control, and coastal drainage stabilization
- Provide sustainable livelihoods and economic benefits to local populations through job creation and ecosystem-based adaptation
- Leverage carbon financing (via blue carbon credits) to fund long-term restoration and protection

²¹ <https://drive.google.com/file/d/1gNyShWzjFCNRLWyLxwQjSWgQLtRD66qi/view>

Project Highlights

A cornerstone of the Indus Delta DBC1 Project has been the restoration of over 5,000 hectares of mangrove forests, with ambitions to restore 226,000 hectares and protect an additional 102,000 hectares. These mangroves act as living infrastructure, naturally buffering saline intrusion, stabilizing coastlines, and reducing sedimentation in canals and creeks—functions that are vital to maintaining healthy drainage and irrigation systems in coastal zones. Their root networks promote soil percolation and groundwater recharge, enhancing freshwater availability for irrigation.

As shown in **Figure 8**, as mangrove plantations mature, their total carbon stock (t C/ha) increases rapidly over the first 20-30 years before stabilizing. This growth trajectory not only illustrates enhanced ecosystem functioning over time but also suggests increasing soil stabilization and water management benefits as these forests age.

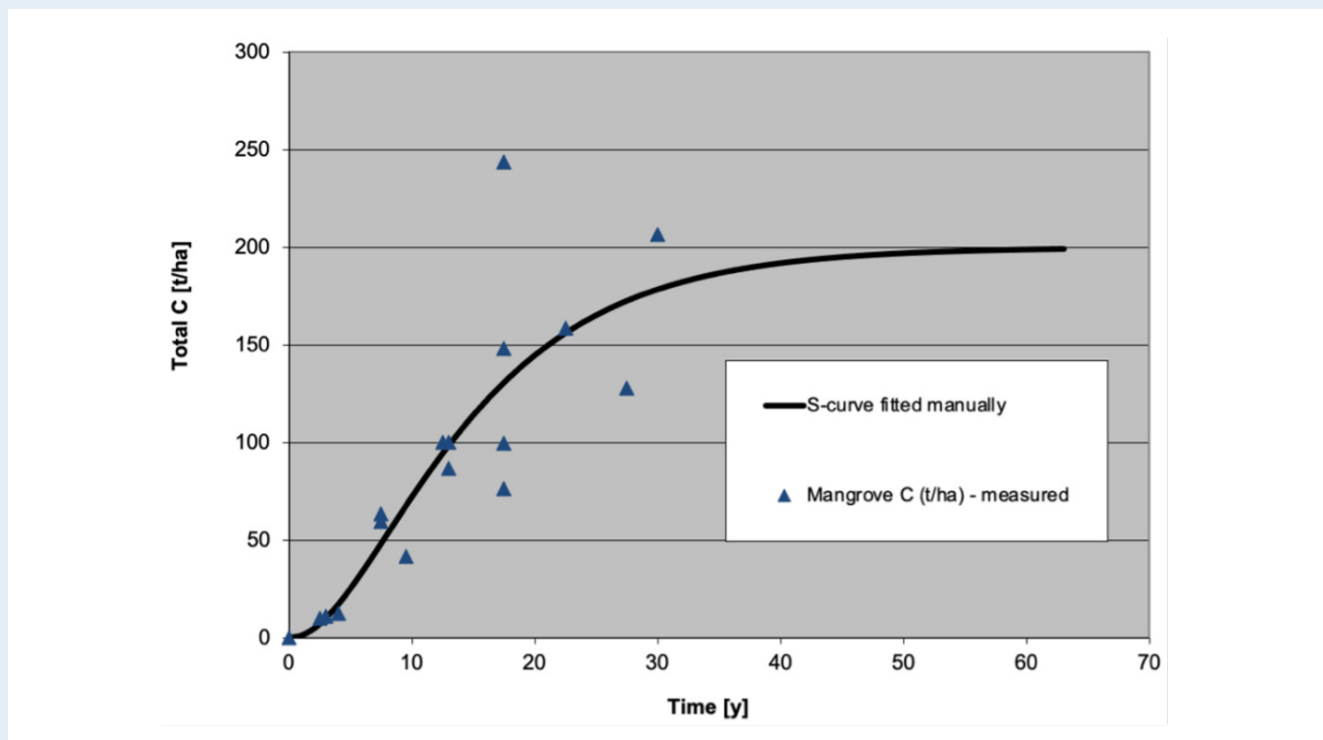


Figure 8. General growth model for mangrove plantations in the Indus Delta for ex-ante estimates of GHG removals, based on a sampled chronosequence

Further, **Figure 9** visualizes the project's holistic NbS framework, linking strategic actions, such as large-scale reforestation, law enforcement, community capacity building, and sustainable energy adoption, with critical outcomes like wetland restoration and mangrove conservation. These, in turn, lead to improved ecosystem services including natural drainage regulation, flood buffering, and saline control.

The project leveraged carbon financing mechanisms, generating verified blue carbon credits to fund restoration and management activities long-term. Over 21,000 green jobs were created in local communities, especially for women and marginalized groups.

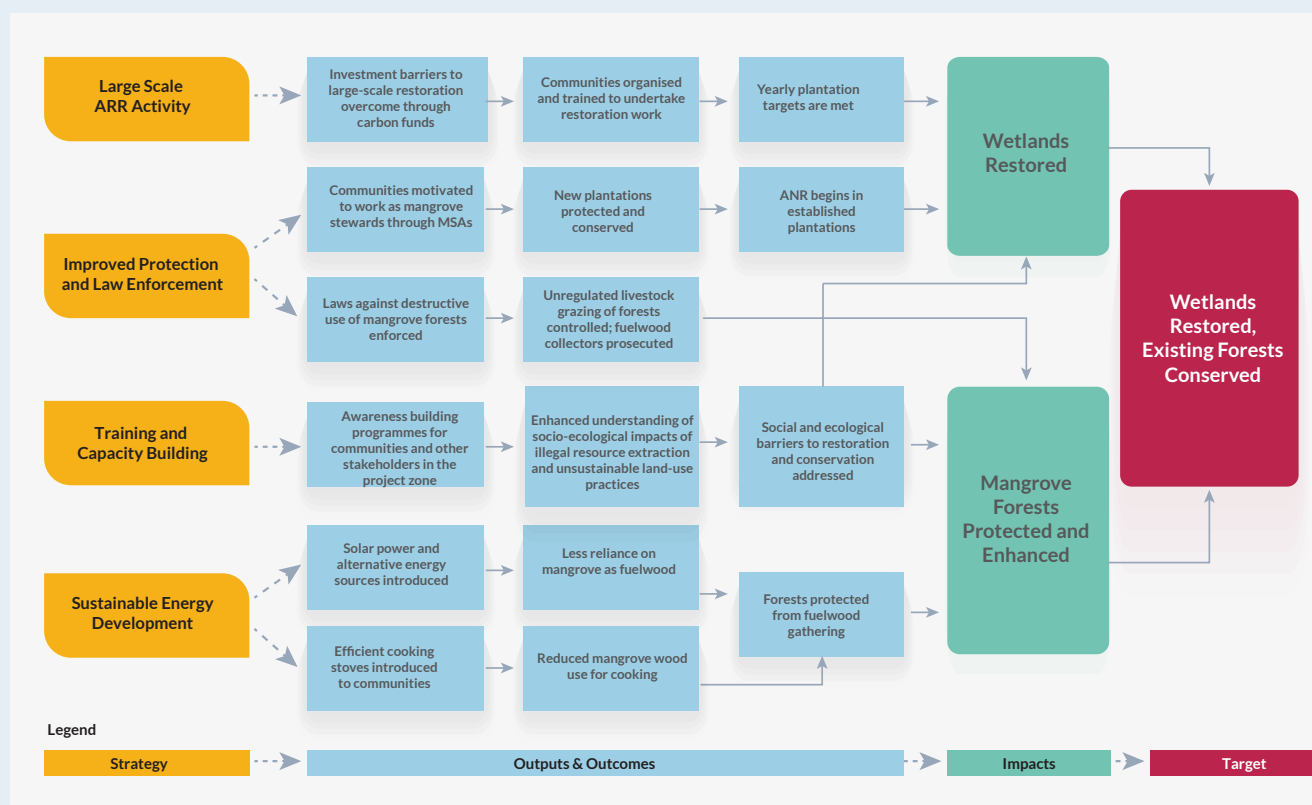


Figure 9. Result Chain: Restoration of Degraded Mangrove Areas and Conservation of Existing Mangroves

Best practices for Guyana D&I

- **Integrate mangroves as living infrastructure:** restored mangroves naturally regulate drainage, trap sediment, and reduce salinity in coastal irrigation systems. Extensive opportunities exist in Guyana for mangrove restoration and closer integration between drainage canals and mangrove systems.
- **Align drainage systems with natural hydrology:** designing canals based on tidal and seasonal flows improves water distribution and flood resilience. Starting with LIDAR surveys and detailed hydrologic mapping and modelling, understanding the natural hydrologic drainage and aligning canal systems more closely with it can enhance system resilience and efficiency.
- **Utilize blue carbon financing for infrastructure:** revenue from carbon credits can fund canal desilting, sluice repairs, and water monitoring systems.
- **Engage local communities in D&I maintenance:** community participation ensures long-term upkeep of canals and equitable water access. Integrating the community-based mangrove management systems of National Agricultural Research & Extension Institute (NAREI) with Water User Association systems of NDIA can help farmers and communities more efficiently play a role in infrastructural systems gaining more benefit from them while reducing upkeep costs.

1.6.3 East Kolkata Wetlands²²

Project background

The East Kolkata Wetlands (EKW), with an average rainfall of 1600 mm (90 % between June to October), spanning 12,500 hectares on the eastern edge of Kolkata, India, represent one of the world's largest and most successful examples of a community-led nature-based solution (NbS) for wastewater management, drainage, and food production, see **Figure 10**. Recognized as a Ramsar Site in 2002, the EKW system has evolved over a century to manage the city's sewage through an integrated network

of aquaculture ponds, agricultural fields, and marshes. This naturally functioning wetland receives over 910 million litres of sewage per day, around 65% of Kolkata's untreated waste, diverted from the city's sewerage system into shallow fishponds, where it is biologically treated before being reused for fish culture and agriculture. The system's functionality is deeply rooted in traditional knowledge, low-cost ecological processes, and decentralized community management.

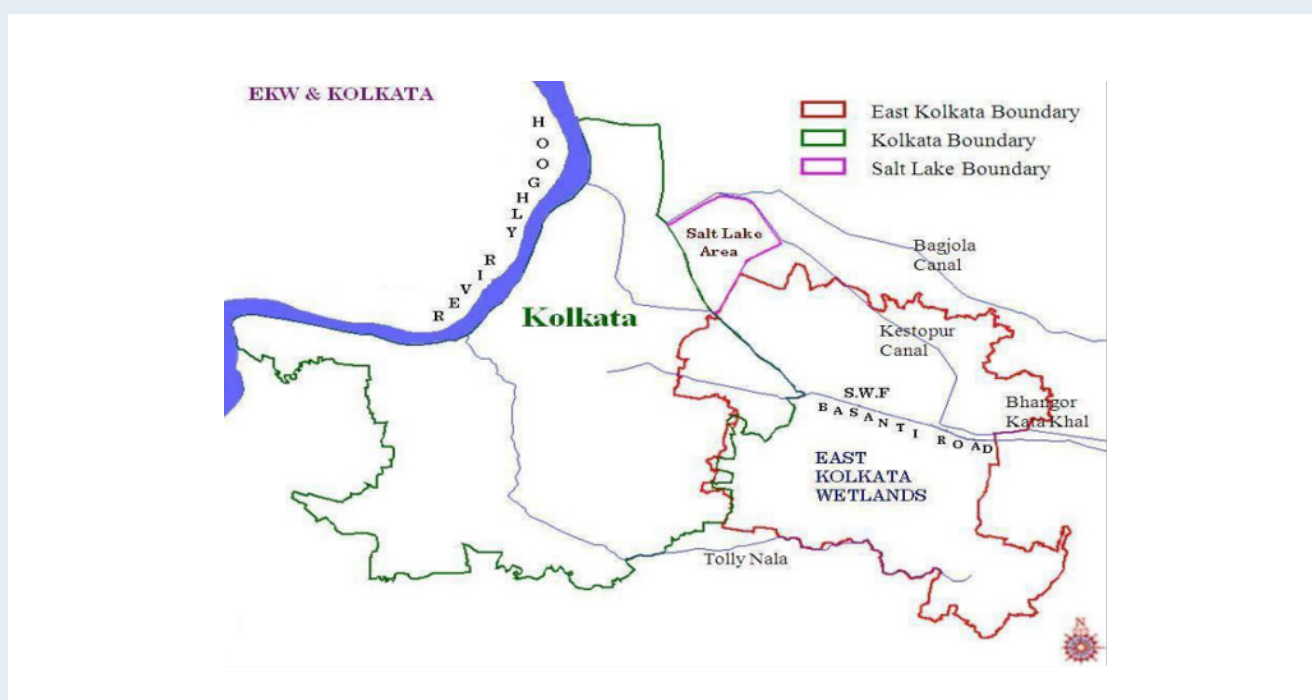


Figure 10. Project Location

²² <https://www.theclimategroup.org/our-work/publications/east-kolkata-wetlands-ekw-community-led-nature-based-solution-combat-climate>; https://www.unescap.org/sites/default/files/Session4a_KaushikGhosh.pdf

Project Overview

As shown in **Figure 11**, the EKW is a mosaic of landforms including predominantly water dominated areas to land centric usages for agriculture and horticulture. Settlements are interspersed between various land

uses. The use of sewage as the basis of aquaculture, agriculture and horticulture production systems provides the rationale for considering the entire area as a single management unit.

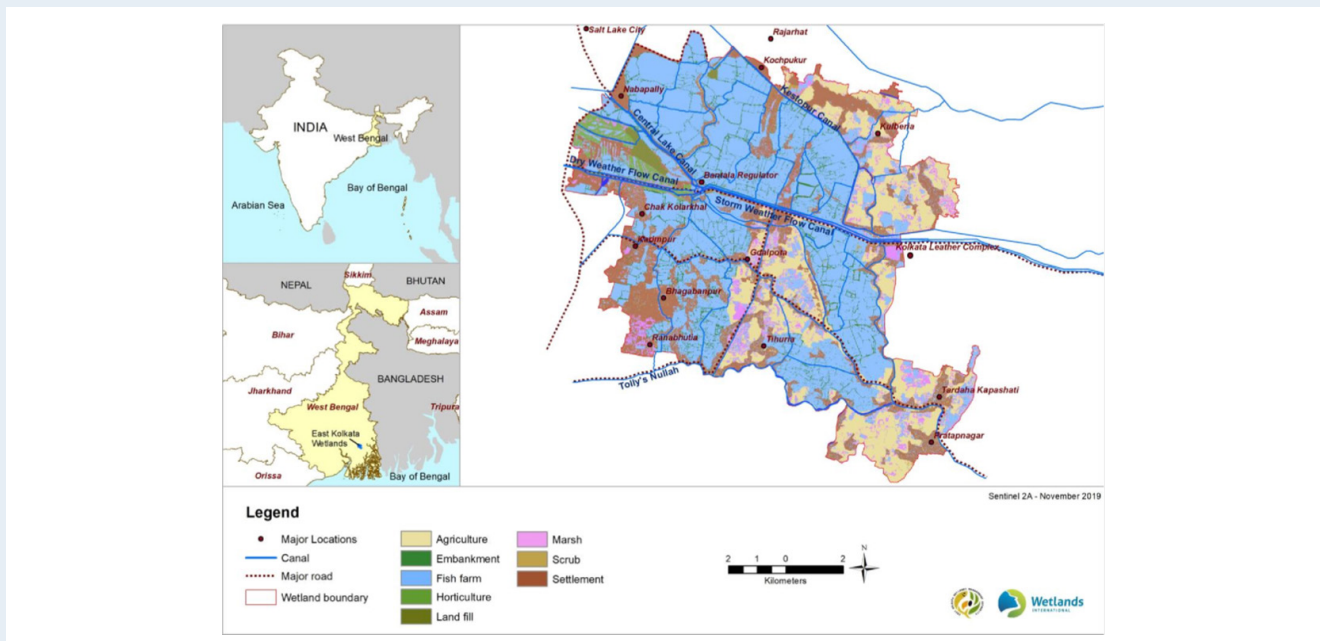


Figure 11. East Kolkata Wetlands

The main objective of the EKW system is to offer a low-cost, decentralized, and sustainable alternative for treating the wastewater of Kolkata. Simultaneously, it creates livelihoods for local communities through aquaculture and agriculture. The system uses urban sewage as a resource rather than waste, recycling it through natural biological processes to support sewage-fed fisheries and irrigated

farming systems. This integrated model is illustrated in **Figure 12**, which maps the flow of sewage from Kolkata City into fish farms and agricultural zones, benefiting both the environment and the community.

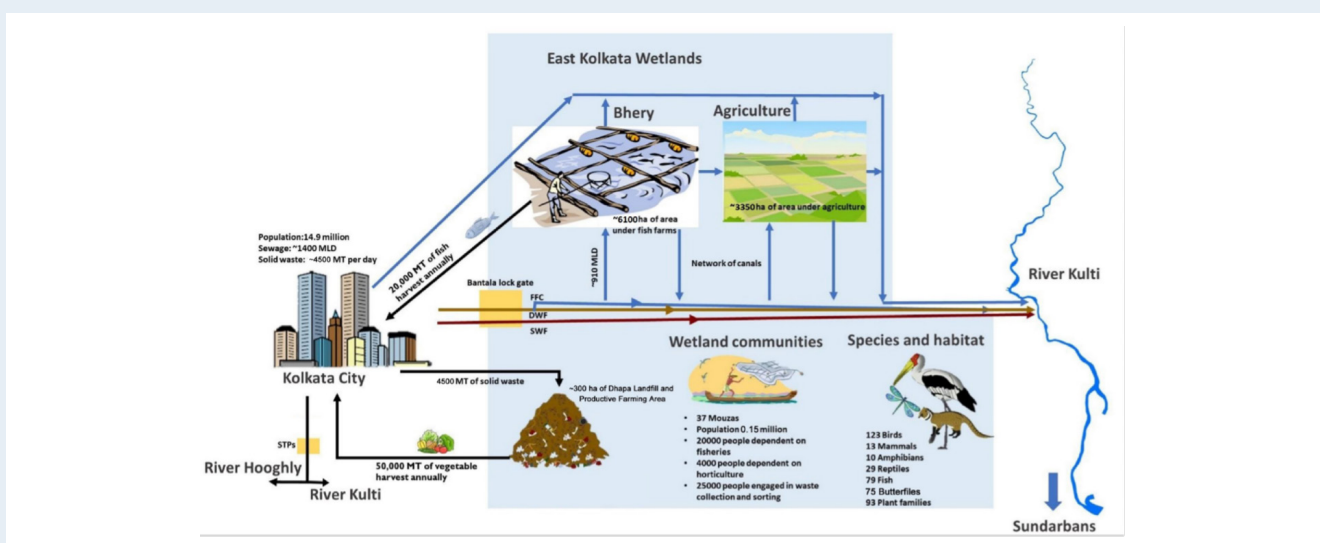


Figure 12. Schematic diagram of East Kolkata Wetlands resource recovery system

The wetlands currently treat approximately 910 million litres of sewage daily, delivering a natural, cost-free wastewater treatment service. This ecological function replaces the need for high-cost treatment plants and saves the city around ₹4,680 million annually. As wastewater moves through the fish farms and cultivation areas, it is progressively purified, with nutrients redirected into algal growth, fish production, and agriculture.

EKW supports substantial food production, generating over 20,000 metric tons of fish and 50,000 metric tons of vegetables annually. In addition, more than 2,850 hectares of paddy fields are irrigated using the nutrient-rich effluent, creating a model for circular economy in peri-urban wetland systems. These outputs are made possible through a traditional knowledge-based system that requires minimal external inputs.

Importantly, the wetlands are a major livelihood base for local communities. Nearly 150,000 people are directly dependent on the wetlands for employment through fisheries, farming, garbage farming, and related informal sectors. These communities have evolved symbiotically with the ecosystem and are central to the wetland’s functioning and protection.

To preserve and enhance the functioning of this system, the East Kolkata Wetlands Management Authority (EKWMA) has laid out a comprehensive set of interventions, shown in **Figure 13**. These include desilting of canals, controlling invasive species, bheri²³ rehabilitation, hatchery development, community health initiatives, zero-plastic zoning, and strengthened monitoring. This management plan aims to ensure long-term sustainability of ecosystem services, biodiversity conservation, and livelihood resilience for communities around the wetlands.

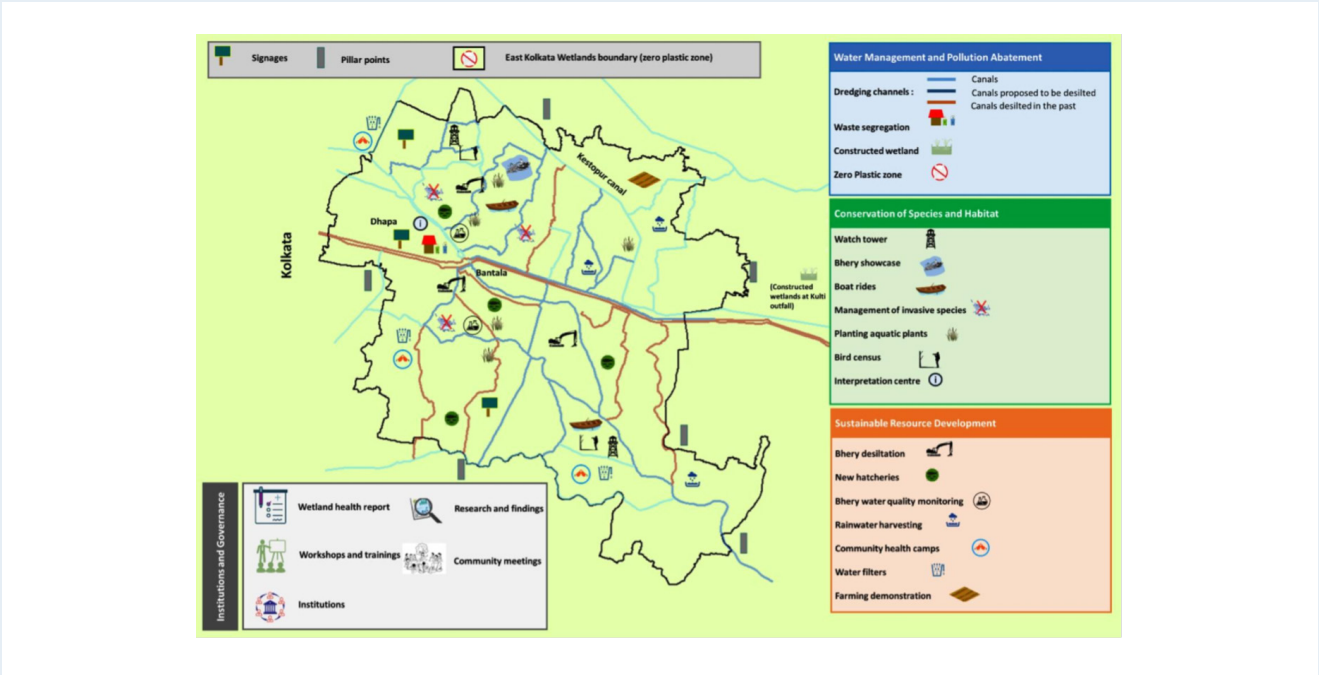


Figure 13. Management interventions proposed at East Kolkata Wetlands

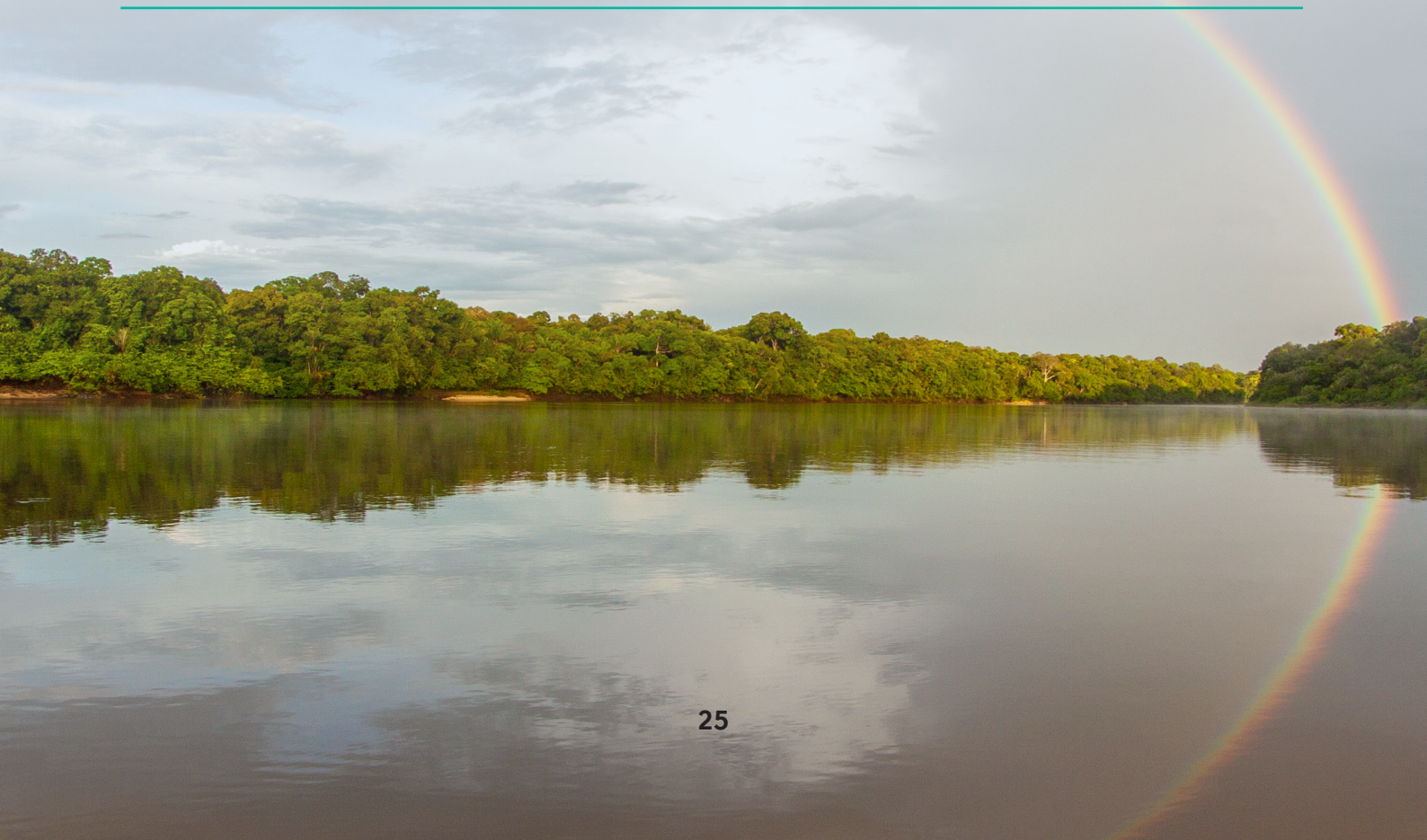
Outcomes

EKW has emerged as a cost-effective, low-emission, and socially inclusive alternative to conventional drainage and sewage treatment systems, as shown in **Figure 14**. It has successfully:

- Provided continuous food and income security to thousands of urban and peri-urban families
- Prevented urban flooding by functioning as a natural stormwater retention basin
- Recharged aquifers and preserved hydrological cycles through natural filtration and percolation
- Created a model for wastewater reuse in tropical developing cities with limited resources
- Maintained biodiversity in a highly urbanized setting, supporting birds, fish, and wetland flora.



Figure 14. A sewage inflow barrage gate at Bantala, EKW



2. Contextualization of Drainage, Irrigation, and Nature-based Solutions in Guyana

This section synthesizes empirical findings and secondary data to characterize the operational context of drainage and irrigation (D&I) systems in Guyana and to assess the applicability of Nature based Solutions (NbS) for flood management and irrigation enhancement. Flood prone zones with potential for NbS interventions were identified through a structured data collection process involving targeted interviews and technical consultations. A semi structured interview schedule (see annexure 1) was administered to engineering personnel from the National Drainage and Irrigation Authority (NDIA), including regional engineers, agricultural engineers, and mechanical engineers operating in Regions 2, 3, 4, 5, 6, 7, and 10. Additional inputs were obtained from the Regional Democratic Council (RDC) and the Mahaica, Mahaicony and Abary Authority (MMA) in Region 5. The instrument consisted of 22 technical questions designed to: a) evaluate existing D&I system vulnerabilities and operational constraints; b) assess opportunities for integrating or enhancing NbS to reduce flood impacts and stabilize irrigation supply; and c) identify institutional capacity gaps, including training requirements for implementing gender responsive D&I approaches.

A total of 13 technical experts participated, with the majority representing NDIA's Head Office and regional

engineering divisions. The sample included five regional engineers, two civil engineers, one agricultural engineer, and one field auditor; senior level technical officials from RDC and MMA provided additional operational insights. To complement the interviews, two focused group technical discussions were conducted with regional head engineers. These sessions were supported by a customized NbS explainer document (see annexure 2), which outlined relevant NbS typologies, functional mechanisms, and integration pathways within engineered D&I systems. The explainer served as a technical reference to facilitate informed decision making regarding site specific NbS applicability.

The first technical meeting, held in August 2024, presented engineers with geospatially defined flood risk hotspots and facilitated the selection of two to three priority locations per region for NbS design and deployment. The second meeting focused on aligning proposed NbS interventions with NDIA's existing and planned civil works programmes to ensure compatibility with hydraulic infrastructure, optimize system level performance, and support long term flood resilience objectives.

2.1 Guyana's Climate Hazards

2.1.1 Flood risks in Georgetown

One of the most significant flood events in recent history occurred in early 2005, affecting nearly 275,000 people (37% of the population) and causing an estimated economic loss of US\$ 465 million (60% of GDP)²⁴. The event resulted from a combination of unusually high rainfall in December 2004, which left the ground saturated, followed by some of the heaviest rainfall on record in January 2005, since records began in 1888. In some areas, standing water

reached 120-150 cm and persisted for several days. Region 4 was the hardest hit, suffering nearly 55% of the total damage, followed by Region 2 (23%) and Region 5 (19%)²⁵. The intense rainfall also led to a rise in water levels at the East Demerara Water Conservancy Dam (EDWC), approaching the critical breaching level of 59 feet, which could have resulted in the dam's failure.

24 Government of Guyana. (2022). Guyana's Low Carbon Development Strategy 2030. www.lcds.gov.gy

25 Forni, Marc S.; Ghesquiere, Francis; Hanmer, Lucia C.; Lopez Martinez, Patricia; Meier, Gerald E.; Peacock, Bill.

Guyana: Preliminary damage and needs assessment following the intense flooding of January 2005 (English). Washington, DC: World Bank.

Georgetown's drainage uses a system of irrigation channels connecting the East Demerara Water Conservancy to the Demerara River creating a gravity fed drainage system. Additionally, a secondary drainage system exists using roadside drains that connect to the primary irrigation channels channeling water to the Demerara River. A number of small pumps have been retrofitted to the system to increase conveyance throughout the system. The system is quite old and has several drawbacks (listed below). Further, flooding already regularly surpasses the system's design capacity. Urban development including illegal construction and filling of channels has further reduced the conveyance capacity of this system.

- » Water can only be released during low-tide, reducing the capacity of the system to drain water and increasing the risk of flooding during high-tide.
- » The river outflow is a manually operated sluiceway creating a potential bottleneck if damaged.
- » Gravity-fed outflows limit the capacity of drainage through the channels.
- » Channels are prone to sedimentation during flood events, further reducing their capacity.

A system conveyance capacity model was made in 2015 by a Dutch survey team using a number of estimates and assumptions such as a 75% efficiency of existing sluices and pumps at the time of the calculation. The overall conveyance of the system was estimated at 2,812,298m³ of water per day, or 101mm/day of rainfall over the Georgetown area. Looking at annual maximum rainfall series from 1886-2015, a 101mm/day event is expected to recur every 2-years²⁶. However, during the time of this study rainfall events of 186mm/day and 208mm/day had been seen in 2014 and 2015 respectively suggesting this magnitude of rainfall is more common than the 1886-2015 data series would suggest.

2.1.2 Flood risks in other regions

Outside of Georgetown, flood risk in Guyana remains a persistent and widespread challenge, particularly across coastal and riverine regions in Regions 2, 3, 5, and 6. These areas are highly vulnerable to pluvial flooding, driven by intense rainfall events that overwhelm aging drainage systems, and fluvial flooding, which results from river overflows during the wet season. In Region 2 (Pomeroon-Supenaam), floodwaters frequently affect agricultural lands and settlements due to poor outflow management in the Pomeroon River, creating backwater effects that trap excess water inland²⁷. In Region 3 (Essequibo Islands-West Demerara), low-lying communities along the Essequibo River are susceptible to tidal surges, often compounded by clogged or poorly maintained drainage channels that limit the effective discharge of stormwater²⁸. These compounding issues are particularly problematic during high tide events, when gravity-based drainage systems become ineffective and water remains trapped in residential and agricultural zones.

In Region 5 (Mahaica-Berbice), flooding is closely tied to the operations of the Mahaica-Mahaicony-Abary (MMA) conservancy system, where intense rainfall can exceed the system's storage and discharge capacity. When this occurs, excess water is released into rivers like the Mahaica and Abary, inundating downstream villages and farmland²⁹. Similarly, in Region 6 (East Berbice-Corentyne), the Canje and Berbice Rivers pose flood risks to urban areas and rice-growing regions, particularly when embankments are overtopped or compromised. Drainage networks in this region are often under-maintained and suffer from sedimentation and blockage, which limit their effectiveness during high-intensity rainfall events³⁰. These regional flood risks underscore the urgent need for integrated water management approaches—including the use of Nature-Based Solutions (NbS)—that can improve water retention, reduce sedimentation, and buffer communities against increasing climate extremes.

26 Delft University of Technology. (2016). Analysis of Drainage System in Georgetown, Guyana.

27 Stabroek News. (2022). *Renewed flooding of Pomeroon farmlands leaves residents in despair*. <https://www.stabroeknews.com/2022/02/27/news/guyana/renewed-flooding-of-pomeroon-farmlands-leaves-residents-in-despair/>

28 Caribbean Disaster Emergency Management Agency (CDEMA). (2015). *Flooding in Guyana: Situation Report #1*.

29 Guyana Energy Agency. (2019). *Sustainable Management of Natural Resources*. <https://gea.gov.gy/wp-content/uploads/2019/07/A3-Sustainable-Management-of-Natural-Resources.pdf>

30 Stabroek News. (2021). *Corentyne villages reeling from floodwater*. <https://www.stabroeknews.com/2021/05/31/news/guyana/corentyne-villages-reeling-from-floodwater/>

2.1.3 Drought and water scarcity-related risks

Drought and water scarcity are growing concerns in Guyana, particularly during the dry seasons that span from late August to November and from mid-January to April. While the country is typically associated with abundant rainfall, changing climate patterns and El Niño events have introduced increasing variability in rainfall distribution and intensity. This has resulted in extended dry periods that compromise the availability of surface water in conservancies and irrigation canals, especially in Regions 3, 4, 5, and 6, where agriculture is heavily reliant on consistent water supply. In times of low rainfall, water levels in the conservancy systems fall below operational thresholds, limiting their ability to support irrigation demand. This challenge is particularly acute for rice farmers, whose planting and harvesting cycles depend on timely water releases from conservancies and canal systems³¹.

The impacts of drought are exacerbated by inefficiencies in irrigation infrastructure and a lack of water storage mechanisms at the farm level. Traditional irrigation methods and open canal systems result in high conveyance losses due to seepage, evaporation, and unregulated withdrawals. Moreover, the lack of real-time monitoring and adaptive release systems in conservancies makes it difficult to manage water allocations effectively during low-flow periods. As climate projections for the Caribbean indicate a likely increase in the frequency and severity of drought events, it is crucial for Guyana to invest in adaptive water management strategies, including the use of Nature-Based Solutions (NbS) such as agroforestry, cover cropping, managed aquifer recharge, and the rehabilitation of wetlands. These approaches can enhance water retention in the landscape, reduce evaporation losses, and promote more efficient and equitable use of available water resources.

2.1.4 Sea-level rise, coastal flooding and saltwater intrusion

Sea level rise, coastal flooding, and saltwater intrusion represent converging threats to Guyana's densely populated and agriculturally critical coastal zone. With

over 90% of the country's population living on land that is at or below sea level, the coast is highly susceptible to tidal surges and storm-induced flooding. Guyana's defense infrastructure—including sea walls, kokers (sluices), and embankments—has historically protected settlements and farmlands, but these structures are increasingly under pressure from rising sea levels and more intense rainfall events. According to projections, sea levels along the Guyanese coast could rise between 0.26 and 0.82 meters by 2100, which would significantly increase the frequency and severity of coastal overtopping, permanent inundation in some areas, and the failure of gravity-based drainage systems during high tide³². The inability to release water through sluices when sea levels are high leads to prolonged inland flooding, particularly in regions such as West Coast Demerara, Mahaica, and the East Coast of Berbice, where drainage infrastructure is already overburdened.

This rise in sea level also facilitates saltwater intrusion into freshwater systems, including coastal aquifers, rivers, and irrigation canals. During the dry season or drought periods—when freshwater flows from conservancies and rivers are reduced—saltwater can advance inland through river mouths and into agricultural areas, especially along the Demerara, Essequibo, and Berbice Rivers. Damaging saline water compromise soil fertility, reduces crop yields, corrodes infrastructure, and makes freshwater sources unsuitable for drinking and domestic use. Nature-Based Solutions (NbS) can play a key role in responding to these threats. Mangrove restoration along the coastline and riverbanks acts as a natural barrier against storm surges and saline intrusion, while wetland conservation and riparian reforestation improve water quality and support the recharge of freshwater aquifers. These ecosystem-based approaches complement engineered defenses and provide flexibility and redundancy, making them critical components of an integrated coastal resilience strategy for Guyana.

31 FAO & The Nature Conservancy. (2021). *Nature-based solutions in agriculture: Sustainable management and conservation of land, water and biodiversity*. <https://doi.org/10.4060/cb3140en>

32 WWF. (2021). *Living with Sea Level Rise in the Caribbean: Policy Guide for Coastal Adaptation*. World Wildlife Fund. https://www.panda.org/wwf_news/?1928366/Living-with-Sea-Level-Rise-in-the-Caribbean

2.2 Policy Framework for Drainage & Irrigation

The overarching framework for drainage and irrigation is the National Strategy for Agriculture in Guyana 2013-2020, particularly Priority 3 and Priority 19. Priority 3 provides for water security and water management through building effective systems for water management and strengthening drainage and irrigation infrastructure, by emphasizing:

- Modernize and expand D&I infrastructure including the Hope-like structures, conservancies, and canals to address sedimentation challenges of poor river gradient flows
- Increasing investment for acquiring fixed and mobile drainage and irrigation pumps
- Strengthening maintenance and operation practices of D&I equipment under the ownership of NDIA, MMA and RDCs
- Supporting the development and inclusion of water users' association and farmers in D&I planning

Priority 19 supports the development of an Agriculture Risk Reduction and Disaster Management Program through adaptation initiatives such as nature-based solutions to prevent and manage floods and droughts, by emphasizing:

- Incorporating other kinds of disasters such as disease outbreaks
- Building data driven systems for early warning systems

- Building back better-response and rehabilitation

2.2.1 National Drainage and Irrigation Authority Act

The current D&I legislation that governs NDIA operations is the NDIA Act (2004). The primary mission stated in the Act is: "The National Drainage and Irrigation Authority functions as the Nation's apex organization dealing with all public matters pertaining to management, improvement, extension and provision of drainage, irrigation, and flood control infrastructure and services in declared areas of the country. While providing support and assistance to other public institutions dealing with connected activities, it shall also evolve mechanisms for improved water use with financial sustainability, equity, and efficiency as the guiding principles."

With the rapid unstructured increase in areas brought into farming, consideration must be placed on the improvement and management of both declared and undeclared D&I areas. In many areas, there is also no physical separation of the drainage system of residential and farming areas, which has now inadvertently become the responsibility of the NDIA.

2.2.2 NDIA Strategy 2017-2021

The NDIA Strategy was a strategic framework to guide the development, maintenance and improvement of drainage and irrigation systems in both declared and undeclared lands in Guyana. The specific strategic objectives of the strategy are listed in **Table 3**.

Table 3. NDIA strategy objectives 2017-2021

Strategic Objectives	Means
GIS Development	Improving data collection of D&I components to facilitate analysis, including the use of geographic information systems, to support informed decision-making and planning.
	Collecting reliable data to conduct thorough risk assessments for farming areas, thereby aiding the identification of vulnerabilities and the prioritization of interventions.
Hydraulic Infrastructure Enhancements	Developing hydraulic models of catchment areas to gain insights into the effects of planned changes and ensure optimal system performance.
	Increasing the discharge capacity of catchment areas to effectively handle a minimum of 3.5 inches of rainfall within 24 hours, resulting in better flood management and a 50% reduction in water-related crop losses.

Strategic Objectives	Means
Community Engagement	Involving local communities in the planning and management of D&I systems, which includes encouraging the creation of WUAs and cultivating a sense of shared responsibility.
	Engaging farmers to understand the importance of cost recovery and ensuring the long-term sustainability of financial sustainability and maintenance of the D&I systems
Capacity Building and Development	Providing training and capacity building programmes for NDIA Staff to enhance skills and knowledge in D&I planning and execution.
	Identifying and developing 5,000 acres annually for new or renewed cultivation, thus supporting agricultural expansion and contributing to food security.
Inter-agency coordination	Collaborating with various government agencies such as the GRDB, NAREI, GLDA, Hydromet, GMC and MMA/ADA to effectively manage data and implement the D&I strategy.

The D&I Strategy 2017-2021 was an essential step in Guyana's efforts to improve D&I infrastructure. It set the foundation for future initiatives focused on reliable data modelling to sustainably manage drainage and irrigation, reduce the vulnerabilities of climate change, and promote agriculture development.

2.2.3 NDIA Capital Works Strategy 2021-2025

This strategy emphasizes the importance of making capital investments to enhance the country's drainage and irrigations systems and build resilience to climate-related challenges. The key elements of the Strategy are listed in **Table 4**.

Table 4. Key elements of NDIA capital works strategy

Strategic Objectives	Means
Infrastructure Enhancement	Increase the discharge capacity of catchment areas to effectively handle a 15-year return period, which translates to an average of 3.5 inches of rainfall within a 24-hour period, thereby strengthening resilience against severe weather events.
	Fast-track the deployment of pumped drainage systems to enhance water management in low-lying areas and complement the existing gravity-based discharge.
	Prioritize the regular maintenance of sluice outfalls to ensure optimal functioning
	Adopt new technologies to enhance management of D&I infrastructure
Technology Integration and Mapping	Conduct detailed mapping of catchment areas and determine drainage coefficients

Strategic Objectives	Means
Community Engagement and Capacity Building	Foster community involvement through the formation of WUAs in DDIAAs and UDIAAs
	Implement comprehensive capacity building programmes for NDIA staff to enhance their expertise in managing D&I systems
Risk Assessment	Collect data to perform risk assessments of farming areas to identify vulnerabilities and prioritize mitigating measures
	Support agricultural expansion through the identification and development of 5,000 acres of land for new or renewed agricultural cultivation
Climate Adaptation	Improve road access to both existing and newly developed farmlands
	Implement strategies to reduce weather-related crop losses by 50%

With a strong emphasis on improving infrastructure, integrating technology, engaging communities and supporting agriculture, the strategy aims to a reliable and sustainable D&I system while enhancing resilience to the effects of climate change.

2.2.4 National Climate Adaptation and Resilience Frameworks

The National Climate Change Policy and Action Plan (NCCPAP) 2020–2030 outlines a structured approach to

climate action through nine policy directives categorized under adaptation, mitigation, and cross-cutting measures. In the adaptation category, the focus is on building and retrofitting climate-resilient infrastructure, reducing disaster risks, and integrating resilience into key sectors such as health, education, and agriculture. More details are shown in **Table 5**.

Table 5. Summary of policy directives in the NCCPAP 2020–2030

Category	Policy Directive	Policy Objectives
Adaptation	PD 1: Establish climate resilient infrastructure and physical development	1.1 Build and retrofit green towns, settlements, urban and rural centers and critical infrastructure
		1.2 Reduce disaster and hazard risks that jeopardize productivity and livelihoods
		1.3 Implement ‘climate proofing’ adaptation and resilience building technologies across all sectors
	PD 2: Sectoral Climate Change Mainstreaming for a Healthy, Educated Society	2.1 Promote a safe, healthy, socially secure climate resilient population
		2.2 Use education to generate shifts in the behaviors towards more climate-smart livelihoods and lifestyles
		2.3 Build agricultural resilience for national food and nutrition security

Category	Policy Directive	Policy Objectives
Mitigation	PD 3: The Implementation and Use of Green and Clean Technologies	3.1 Transition to renewable energy technologies and practices to reduce climate risk and carbon emissions
	PD 4: Build a diversified, climate-ready, low-carbon Guyanese economy	4.1 Mainstream climate change sensitivity across energy and extractive industries 4.2 Commit to large scale transition to cleaner production and service industries
	PD 5: Responsible Management and Utilization of Natural Resources	5.1 Maintain Guyana's forests as a major carbon sink 5.2 Responsible management of watersheds and freshwater resources for human and ecological benefits
Cross-cutting	PD 6: Promote Equitable Participation in National Decision-Making Processes	6.1 Drive social equity for vulnerable groups (women, youth, indigenous and aged) in national processes 6.2 Report to the people of Guyana on corporate climate responsibility, accountability, and transparency
	PD 7: Science-Based Climate Decision Making	7.1 Strengthen the technical capacity of national institutions for evidence-based decision-making 7.2 Invest in and support scientific data management and use for implementing climate actions
	PD 8: Finance and Resources for Climate Action	8.1 Increase domestic budget allocations for climate change programming
	PD 9: Public-Private Cooperation on Climate Action	9.1 Coordinate international climate finance and donor support 9.2 Promote low carbon economy employment and livelihoods 9.3 Support innovation and climate-ready micro, small, and medium enterprises

The Climate Resilience Strategy and Action Plan (CRSAP), as shown in **Figure 15**, serves as Guyana’s overarching resilience-building framework, offering a roadmap for identifying climate risks, prioritizing sector-specific adaptation measures, and integrating resilience into national development planning. It supports long-term sustainability by enhancing institutional capacity,

mainstreaming climate considerations into public policy, and promoting investment in adaptive infrastructure and ecosystem protection.

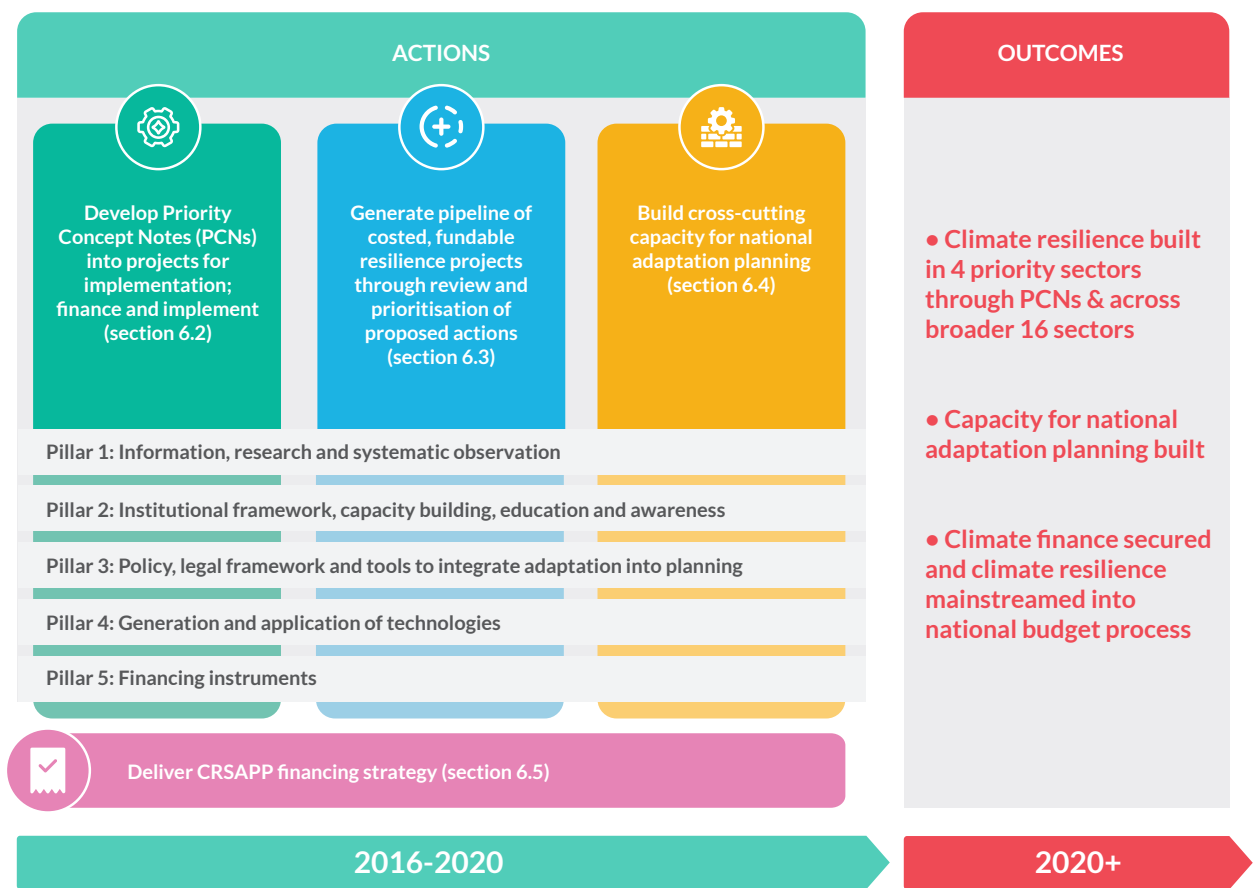


Figure 15. CRSAP Roadmap

2.3 Existing Examples of Nature-based Solutions and Green-Grey Infrastructure in Guyana

2.3.1 The East Demerara Water Conservancy & Other Conservancies

The conservancy system in Guyana represents a unique integration of natural hydrological features with engineered infrastructure and is central to the country’s drainage and irrigation (D&I) network. Major conservancies such as the East Demerara Water Conservancy (EDWC), Boerasirie, and Abary are large, shallow reservoirs that collect rainfall and upland runoff

during the wet season and release it for irrigation or flood control through a network of canals, sluices, and relief channels. These systems are especially important in Guyana’s low-lying coastal zones, where much of the population and agricultural activity is concentrated below sea level. The Dutch Risk Reduction team emphasized the critical role of conservancies in mitigating flood risk, particularly during intense rainfall events when gravity-based drainage is constrained by high tides³³.

33 Steijn, R., Westebring, F., & Klostermann, J. (2015). *Flood risk management in the northern coastline of Guyana, and Georgetown in particular*. Dutch Risk Reduction Team.

Viewed through the lens of Nature-Based Solutions (NbS), the conservancy system delivers multiple ecosystem services while reducing the need for extensive grey infrastructure. See **Figure 16**. The forested upper catchments that feed the conservancies facilitate infiltration, evapotranspiration, and sediment regulation, helping to moderate inflows and maintain water quality. Within the conservancies themselves, the large surface water bodies function similarly to natural wetlands by

attenuating peak flows, storing floodwaters, and allowing for sediment deposition before water is discharged to populated or cultivated areas. This multifunctionality supports both flood resilience and agricultural productivity. Such systems exemplify how NbS can enhance water resource management by harnessing ecological processes³⁴.

**Nature-based Solution example:
Ecosystem Service of Bioretention Areas**

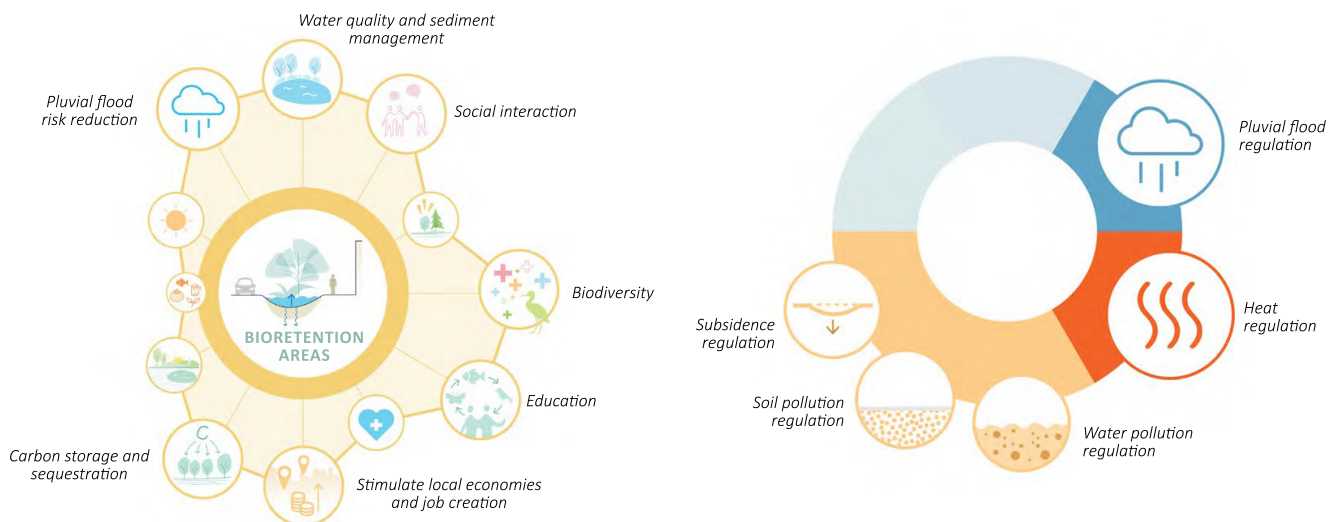


Figure 16. Overview of ecosystem services provided by bioretention ponds.³⁵

The conservancies represent large scale bioretention areas and agricultural check dams. Traditional engineering approaches look at the conservancies as: (1) a source of flood management through water retention and (2) a system for managing irrigation waters. Analyzing the same system with a NbS approach means incorporating these two key services while also assessing wider values the conservancies bring including (3) water quality and sediment regulation, (4) enhancing local biodiversity, (5) providing carbon storage, (6) groundwater recharge, and potentially more. Taking the example of ecosystem service (3), recently the East Demerara Water Conservancy is being used as a source of enhanced household water for

Georgetown. As natural wetland areas, the conservancies filter water and trap sediments that create turbidity in drinking water. By pumping water from the conservancies instead of groundwater or rivers, the costs associated with water treatment—particularly the cost of flocculants and energy from pumping—can be reduced. Simultaneously, by reducing the amount of groundwater being pumped in coastal areas like Georgetown this ‘nature-based solution’ can arrest coastal subsidence and saltwater intrusion exacerbated by over-pumping, reducing NDIA’s pumping costs and enhancing groundwater quality.

34 FAO & The Nature Conservancy. (2021). *Nature-based solutions in agriculture: Sustainable management and conservation of land, water and biodiversity*. <https://doi.org/10.4060/cb3140en>

35 World Bank. 2021. A Catalogue of Nature-based Solutions for Urban Resilience.

Opportunities exist to further apply NbS principles to reinforce the ecological integrity and performance of the conservancy system. Interventions such as reforestation in upstream watersheds, vegetated buffer zones along canals, sediment traps, and bioengineered slope stabilization along embankments can reduce erosion, extend storage capacity, and decrease maintenance costs by minimizing siltation. These improvements align with recommendations from UNEP-DHI and IUCN (2018), which advocate for integrating natural infrastructure into water management strategies, particularly in climate-vulnerable regions like Guyana³⁶. As the country continues to face increasing flood risk and water insecurity under changing climate conditions, the conservancy system offers a powerful, locally adapted model for hybrid infrastructure that embodies the principles and benefits of Nature-Based Solutions.

2.3.2 The Hope Canal and Hope-like Structures

The Hope Canal, officially known as the East Demerara Water Conservancy (EDWC) Northern Relief Channel, is one of Guyana's most significant drainage infrastructure projects (see **Figure 17**). Completed in 2013 at an estimated cost of GYD 3.6 billion, this 10.3 km canal connects the EDWC to the Atlantic Ocean via a three-door head regulator and an eight-door outfall sluice³⁷. Triggered by extreme flooding in 2005, which overwhelmed the EDWC dam and inundated much of the East Coast Demerara, the canal allows controlled drainage of excess conservancy water directly into the sea³⁸. Hydrological modeling during project planning showed that, during a 10,000-year rainfall event, water levels would remain safely below embankment overtopping thresholds thanks to the canal's discharge capacity³⁹.



Figure 17. The Hope Canal outfall sluice

36 UN Environment-DHI, UN Environment, & IUCN. (2018). *Nature-based solutions for water management: A primer*. https://www.unepdhi.org/wp-content/uploads/sites/2/2020/05/WEB_UNEP-DHI_NBS-PRIMER-2018-2.pdf

37 https://en.wikipedia.org/wiki/Hope_Canal

38 <https://reliefweb.int/report/guyana/guyana-tenders-hope-canal-structures-be-advertised-soon>

39 The World Bank. (2014). *Guyana Conservancy Adaptation Project: Implementation Completion and Results Report* (Report No. ICR3019). Retrieved from https://ewsdta.rightsindevelopment.org/files/documents/39/WB-P103539_itUXJWV.pdf

Since its commissioning, the Hope Canal has demonstrated measurable benefits. The 2021 floods spared much of the East Coast and Georgetown, largely due to the canal's ability to efficiently evacuate excess water⁴⁰. More recent assessment suggest that such relief channels can reduce regional flood risk by up to 60–70%⁴¹. As the largest sluice in Guyana, the canal has also supported improvements in land value by lowering flood risk and enhancing drainage and irrigation capacity.

Building on this success, the government has begun planning additional “Hope-like” canals across three regions⁴²:

- » The Canals Polder area, West Bank of Demerara, Region No. 3.
- » The Mahaica/Mahaicony/Abary (MMA) area, Region No. 5.
- » No. 19 Road to No. 65 Village, Corentyne, Region No. 6

The regions are characterized by flat and fertile lands, but while there is adequate irrigation water in the catchment, removing excess water from the land in a timely and

consistent manner remains a key challenge. During high intensity rainfall events these regions suffer from inundation, resulting in losses of crops, livestock, damage to properties and infrastructure and disruption to livelihood. The draft master plan for Region 3 is being developed and modified with initial plans for canal improvement and water storage that could benefit over 26,000 acres of land – rice cultivation, cash crop and residential lands. Similarly, rehabilitation and construction of new embankments along the Mahaica, Mahaicony and Abary area in Region 5 could benefit well over 200,000 acres of land - rice cultivation, cattle fields, and cash crops. Preparatory works in Region 6—covering areas like Bengal, Numbers 51/52, and Whim/Letter Kenny are underway as of early 2025⁴³. These relief channels are intended to channel excess conservancy and backland water directly to the Atlantic, mitigating flood risk and improving irrigation access (see **Figure 18** below). Estimates show that these canals will serve up to 430,000 acres of farmland across the three regions, with a projected investment of approximately GYD 26 billion, largely funded through Guyana’s Low Carbon Development Strategy carbon credit revenue⁴⁴.

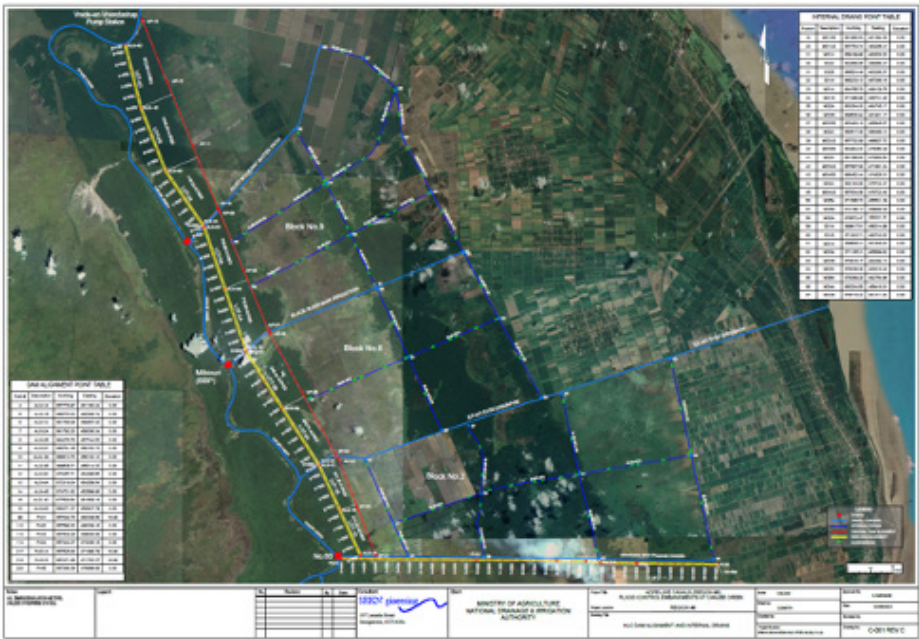


Figure 18. Master plan for drainage and irrigation improvement in Region 6

40 <https://guyanachronicle.com/2021/06/01/hope-canal-saves-coastland-from-major-floods/>
 41 <https://newsroom.gy/2024/03/10/new-hope-like-drainage-canal-in-reg-6-to-reduce-flooding-by-70/>
 42 <https://www.stabroeknews.com/2024/03/17/news/guyana/hope-like-canals-to-cut-risk-of-flooding-by-60-in-region-six-president/>
 43 <https://agriculture.gov.gy/2024/05/20/construction-of-region-six-hope-like-canals-to-begin-soon/>
 44 <https://guyanatimesgy.com/works-started-on-reg-6-hope-canal-replica-no-66-to-canje-embankment-completed-mustapha/>

2.3.3 Coastal mangroves and green-gray infrastructure

Coastal mangroves in Guyana have long served as a vital natural defense against erosion, tidal flooding, and saltwater intrusion, particularly in the low-lying coastal regions where most of the country's population and agriculture are concentrated. Over the past decade, Guyana has made significant strides in restoring and managing its mangrove forests, largely through the Guyana Mangrove Restoration Project (GMRP), led by NAREI. Since 2010, this initiative has re-established hundreds of hectares of mangroves along the Atlantic coast, especially in areas like Victoria, Mahaica, and Lusignan, using both community-based planting and natural regeneration techniques⁴⁵. These efforts have improved sediment retention, stabilized shorelines, and provided habitat for biodiversity. Mangroves also contribute to carbon sequestration and local livelihoods through eco-tourism and small-scale fisheries. However, challenges remain due to coastal erosion, illegal harvesting, and development pressure, which continue to threaten the long-term sustainability of these natural systems.

To enhance coastal protection and climate resilience, Guyana has increasingly embraced green-grey

infrastructure, combining traditional engineered solutions with Nature-Based Solutions (NbS) like mangrove belts and sediment trapping. One notable example is the use of geotextile tube groynes and bamboo brushwood structures to encourage natural sediment accretion, creating favorable conditions for mangrove colonization⁴⁶. These hybrid interventions have been piloted with promising results in areas like Mon Repos and Triumph, where coastal defenses have historically been vulnerable. By integrating these techniques into broader coastal engineering strategies—such as upgrading sea defenses and sluices—Guyana can build a more adaptive and cost-effective protection system. Moving forward, efforts can be strengthened by scaling successful pilot projects, improving monitoring and maintenance, and embedding NbS into national planning frameworks. Additionally, empowering communities through co-management arrangements and securing long-term financing for NbS maintenance will be critical to ensure that green-grey infrastructure solutions continue to evolve and deliver protection for coastal Guyana.

45 NAREI. (2020). *Guyana Mangrove Restoration Project: Project Summary and Achievements*. National Agricultural Research and Extension Institute.

46 Government of Guyana. (2021). *Low Carbon Development Strategy 2030*. <https://lcds.gov.gy>



3. Identifying Gaps and Opportunities for Integrating Nature-based Solutions in Guyana

3.1 Stakeholder Prioritization Workshop Overview

As part of the strategic planning process for integrating Nature-based Solutions (NbS) into Guyana's Drainage and Irrigation (D&I) systems, a two-day national workshop was convened on September 17–18, 2024, at Regency Suites Hotel in Georgetown. The event was organized jointly by the National Drainage and Irrigation Authority (NDIA) and the Global Green Growth Institute (GGGI), with financial support from the Coalition for Disaster Resilient Infrastructure (CDRI) under the Infrastructure for Resilient Island States (IRIS) initiative. The workshop aimed to support the development of a strategic, integrated, and sustainable national D&I strategy aligned with Guyana's Low Carbon Development Strategy (LCDS) 2030.

The objectives of the workshop were to:

1. Engage a wide range of D&I stakeholders in the strategic planning process;
2. Identify key challenges, risks, and institutional gaps related to D&I infrastructure and governance;
3. Explore opportunities for integrating Nature-based Solutions (NbS) and Gender Equality and Social Inclusion (GESI) into D&I planning;
4. Introduce global best practices on NbS for flood management and water security; and
5. Set a foundation for collaborative institutional mechanisms across ministries, agencies, and regional bodies.

The workshop brought together over 50 participants representing 15 institutions, including the Ministry of Agriculture, NDIA, Hydromet Service, GuySuCo, MMA, the Guyana Rice Development Board, the Central Housing and Planning Authority, the Ministry of Finance, civil society, academia, and development partners such as the World Bank and UNDP. Sessions included a mix of technical presentations, stakeholder dialogues, group mapping exercises, and interactive polling using tools such as Mentimeter.

Participants were guided through a structured challenge and opportunity mapping process (see Image 4), including the identification of critical institutional, technical, and climate vulnerabilities affecting D&I systems—particularly in Guyana's Coastal Regions 2, 3, 4, 5, and 6 where over 90% of the population reside. A key focus of the workshop was the co-development of NbS priorities, grounded in participants' lived experience, technical knowledge, and regional perspectives. This participatory approach was instrumental in surfacing both location-specific interventions—such as mangrove restoration, green corridors, and wetland expansion—and cross-cutting needs such as enhanced community monitoring, ecosystem service valuation, and capacity building within NDIA. The outputs of the workshop directly informed the spatial prioritization, modeling, and recommendations included in this study and will serve as a baseline for institutionalizing NbS within Guyana's D&I strategy moving forward.

Chapter 3 of this study builds off the findings of this workshop and incorporates additional information from literature review and conversations with NDIA staff to outline the gaps and opportunities for NbS integration in Guyana's D&I system. This section presents the challenges as described by stakeholders as well as the opportunities and priorities for potential NbS development based on a wide range of expert opinions.



Image 2. Challenge and opportunity mapping to identify critical gaps in D&I

Through a participatory workshop conducted with NDIA and key national stakeholders in combination with desk research and discussions with NDIA staff, a range of technical and institutional barriers were identified that currently constrain the effective integration of Nature-Based Solutions (NbS) into Guyana's Drainage and Irrigation (D&I) systems.

3.1.1 Challenges Prioritized to be Addressed In-Part by Nature-based Solutions

Based on review of secondary reports and publications along with insights from the Strategic Stakeholder workshop, this section maps the climate challenges (Figure 21) that can be addressed with NbS interventions.

• Pluvial, Coastal, and Seasonal Climate Risks

As outlined earlier in this study, the accelerating impacts of climate change are amplifying existing challenges in D&I management. Increasing pluvial flooding—caused by intense rainfall that exceeds drainage capacity—is now a regular occurrence in both rural and urban regions. Coastal flooding, driven by sea level rise and storm surges, places additional pressure on outfalls, pumps, and embankments, especially in low-lying coastal zones. Sea-Level Rise is causing particularly major challenges to Guyana's drainage system as higher tides are reducing the number of hours in the day where gravity-driven drainage into the sea is possible.

Additionally, prolonged dry seasons, which create periodic water scarcity that threatens agricultural output and household water supply. Increasingly extreme and unpredictable seasonality hydrologic systems is a major strain on D&I infrastructure across Guyana.

The multidimensional nature of these risks requires a shift from purely reactive engineering responses to a proactive system that incorporates NbS for water retention, flow regulation, and storm buffering. For example, mangrove restoration and inland wetland rehabilitation have been cited by stakeholders as high-impact interventions to reduce flood pressure and increase seasonal water storage capacity. However, implementing such solutions requires addressing the technical and institutional barriers outlined here.

• Illegal Construction and Unregulated Encroachment on Drainage

Illegal construction around drainage channels, conservancies, and critical water outfalls poses a growing threat to the functionality and sustainability of Guyana's D&I infrastructure. During the stakeholder workshop,

several regional engineers and planners emphasized that unregulated housing developments, informal settlements, and commercial structures are increasingly encroaching on buffer zones, drainage reserves, and embankments. In many cases, these structures obstruct natural and engineered water pathways, leading to localized flooding, reduced infiltration, and deterioration of drainage capacity. Additionally, construction on natural retention areas such as lowlands and wetlands removes important flood-buffering functions, undermining the effectiveness of existing D&I systems and limiting the feasibility of future NbS interventions.

The proliferation of unauthorized construction is linked to rapid urban expansion, weak enforcement of zoning laws, and limited coordination between agencies responsible for land use planning, housing, and water infrastructure. Without clear institutional mechanisms to monitor, regulate, and remove encroachments, NDIA and its partners struggle to implement both grey and green infrastructure effectively. This also limits the spatial availability for introducing NbS such as vegetated corridors, wetland restoration, or riverbank stabilization. Addressing this issue requires improved land governance, enforcement of spatial planning regulations, and coordinated efforts across ministries to protect drainage corridors and create legally recognized buffer zones for resilient infrastructure development.

3.1.2 Technical Gaps for NbS Integration

• Outdated Infrastructure and Inadequate Technology

Many core components of Guyana's D&I network—such as pumps, sluices, and canal linings—are outdated and increasingly prone to failure. Much of this infrastructure was installed decades ago and has not been upgraded to withstand current rainfall intensities or accommodate modern flow control technologies. For example, most canals are unlined and uncovered, which contributes to excessive water loss through evaporation and seepage, particularly during dry seasons. Additionally, limited automation or digitization across infrastructure systems means operators lack tools such as remote-controlled sluices or flood-responsive sensors, which are increasingly standard in climate-resilient water management systems.

The absence of modern infrastructure makes it difficult to incorporate hybrid or NbS-enhanced designs. For instance, integrating vegetated buffers, sediment traps, or constructed wetlands into existing drainage pathways requires that the infrastructure be adaptable and reliable—a condition that is not currently met in

many parts of the country. Without infrastructure modernization, NbS may either be underutilized or fail to function effectively when coupled with outdated grey systems.

● **Insufficient Real-Time Data and Monitoring**

Across all regions, the lack of consistent, real-time data emerged as a critical obstacle to both conventional and nature-based D&I management. Stakeholders reported an absence of live monitoring for key variables such as water levels, sediment loads, salinity, and flow rates. While some agencies—namely HYDROMET and NDIA—maintain basic data collection systems, these are inconsistently used and rarely integrated across regions or institutions. For example, flood alerts often rely on anecdotal evidence or delayed field reports rather than automated early warning systems. As early warning systems often require the same hydrologic data that is needed for modelling and planning D&I systems, enhancing these systems can represent a low-hanging fruit for addressing Guyana's climatologic challenges.

Moreover, key hydrological features such as groundwater recharge zones, wetland catchments, and inter-basin drainage linkages remain poorly mapped. This information deficit severely limits the capacity of NDIA engineers to design systems that are responsive to changing climatic conditions. Without strong baseline data and performance tracking, it becomes difficult to justify, monitor, or evaluate NbS interventions, especially those aimed at regulating flows, storing excess water, or mitigating salinity intrusion.

Presently, a lack of data makes it impossible to generate accurate hydrologic models in any major region of Guyana. This fact was evident during the preparation of this study as many assumptions were required to produce hydrologic models to inform NbS pilot design and impact assessments. The same lack of data hinders the work of NDIA to effectively model and plan all forms of D&I infrastructure.

● **Inefficient Water Use and Poor Irrigation Practices**

Guyana's agricultural sector continues to rely heavily on inefficient irrigation techniques—most notably flood irrigation—which contribute to substantial water loss and increased pressure on D&I systems. In the absence of infrastructure to support water-efficient practices (such as drip irrigation, field-level water recycling, groundwater recharge systems), a significant portion of irrigation water is lost before it reaches crops. Unlined canals and distribution channels also contribute to water losses through infiltration, and little has been done to

systematically pilot or scale interventions like vegetated canals or agroecological practices that enhance soil water retention. Stakeholders emphasized that these inefficiencies are further amplified by inadequate on-farm drainage, leading to localized flooding, soil degradation, and reduced agricultural productivity.

● **Unplanned and Inequitable Water Access**

Stakeholders highlighted that unauthorized water diversions and unregulated land development are common, particularly in rapidly urbanizing and hinterland areas. These actions often compromise the capacity and effectiveness of D&I systems, as water flows become fragmented and unpredictable. In some cases, informal settlements or agricultural expansions are constructed on or near natural drainage corridors, obstructing water pathways and reducing infiltration.

In addition to physical disruptions, the unplanned nature of D&I infrastructure expansion has created significant inequities in water access. Some communities, particularly those in remote or peri-urban areas, lack adequate drainage or irrigation coverage, while others receive disproportionate investment. These disparities not only increase vulnerability to flooding and drought but also pose social and political challenges that can undermine support for long-term NbS investments.

3.1.3 Institutional Gaps for NbS Integration

● **Coordination and Governance Deficiencies**

A consistent message from the stakeholder workshop was the fragmentation of responsibilities and weak coordination among institutions involved in water management. NDIA, Hydromet, the Environmental Protection Agency (EPA), and regional administrations often operate with limited inter-agency communication, leading to redundancies, gaps in service delivery, and conflicting project objectives. There is currently no centralized system for ranking D&I risks, sharing inspection data, or aligning infrastructure investments with climate and disaster planning frameworks.

This siloed governance structure makes it particularly challenging to integrate cross-sectoral tools like NbS, which often require cooperation across ministries of agriculture, housing, environment, and finance. Without improved coordination mechanisms and joint planning platforms, even well-designed NbS interventions risk being underutilized or poorly maintained.

● Capacity and Resource Limitations

A shortage of skilled technical personnel—particularly engineers, hydrologists, and environmental planners—was identified as a major bottleneck in both the planning and maintenance of D&I systems. Many regional offices operate with limited human and financial resources, which restricts their ability to plan, implement, and monitor complex projects. In most cases, NDIA's regional offices have only one staff engineer. This is insufficient to maintain existing infrastructure let alone plan and design the expansion of D&I infrastructure that is needed throughout Guyana. Routine maintenance, a cornerstone of infrastructure resilience, is often deferred due to lack of funds or logistical support.

This constraint also affects the adoption of innovative approaches like NbS. Without staff trained in ecosystem-based planning or hydrological modelling, and without sufficient operational budgets to pilot new interventions, agencies are likely to default to conventional grey infrastructure methods, even when more sustainable alternatives exist.

● Lack of Inclusive and Participatory Planning

Currently, the planning and decision-making processes for D&I infrastructure do not systematically include the voices of key stakeholders such as smallholder farmers, Indigenous groups, women, or youth. This lack of inclusivity undermines local ownership of infrastructure projects and weakens the sustainability of NbS interventions, which often rely on community-level stewardship and decentralized maintenance.

Water User Associations (WUAs) have been established in a limited way in Guyana through a 2004 program. While WUAs have potential to be a useful organ of water governance, in Guyana, WUAs are not widely adopted or systematically supported. Where they do exist, their roles often overlap with those of Neighbourhood Democratic Councils (NDCs), creating confusion around mandates for D&I infrastructure planning, maintenance, and conflict resolution. This institutional ambiguity reduces the effectiveness of both entities and can lead to fragmented decision-making, unclear accountability, and missed opportunities for community-driven maintenance and monitoring. Clarifying the role and democratic structure of WUAs and their roles relative to NDCs, and embedding them in regional D&I planning processes could significantly enhance inclusive governance and support the scaling of NbS interventions.

During the workshop, stakeholders emphasized that participatory approaches are essential for aligning NbS interventions with local knowledge, preferences, and capacity. For example, community-led mangrove management or localized monitoring of green infrastructure can significantly enhance performance, but only if local actors are engaged early and meaningfully in project design and implementation.

● Monitoring and Enforcement Gaps

Weak regulatory enforcement was identified as a major barrier to both infrastructure quality and environmental safeguards. Field reports from NDIA and regional engineers often go unaddressed due to institutional inertia or budget constraints.

For NbS, where performance is often harder to measure in the short term, robust monitoring systems are particularly important. Without effective enforcement mechanisms and performance tracking frameworks, it becomes difficult to ensure the sustainability and functionality of nature-based interventions over time.

● Lack of Climate Risk Integration

Perhaps the most cross-cutting technical and institutional barrier is the absence of climate risk integration into D&I planning processes. Current designs and infrastructure specifications do not account for projected changes in rainfall patterns, sea level rise, or drought intensity. As a result, systems may become rapidly obsolete or underperform under future conditions.

Integrating NbS requires forward-looking planning tools that factor in climate projections and long-term adaptation goals. Developing these tools—and embedding them into design protocols, cost-benefit analysis frameworks, and maintenance schedules—will be essential to building climate-resilient D&I infrastructure in Guyana.

Technical	Institutional
• Human-induced interference infrastructure and narrow drainage channels • Limited storage capacity • Deficient outfall structures • Siltation and blockages in drainage channels • Lack of integration with other infrastructure • In need of drainage technologies	• Lack of coordination and cooperation • Governance and regulation • Limited financial resources • Limited knowledge capacity and data collection • Limited public awareness and participation • Need to incorporating climate change scenarios

Figure 19. Comprehensive list of technical and institutional challenges identified in previous studies on D&I infrastructure in Guyana⁴⁷

47 MacDonald, D. (2003). Guyana Drainage and Irrigation Systems Rehabilitation Project. Ministry of Agriculture, Guyana; Delft University of Technology. (2016). Analysis of Drainage System in Georgetown, Guyana; Japan International Cooperation Agency. (2017). Data Collection Survey on Drainage Capacity in Georgetown in the Cooperative Republic of Guyana, National Drainage and Irrigation Authority, Ministry of Agriculture, Guyana.



3.1.4 Stakeholder Priorities for Nature-based Solutions for D&I in Coastal Regions

The NbS priorities listed below were assessed through an initial stakeholder workshop in September 2024 and serve as a foundational starting point for identifying interventions across regions 2-6. These interventions were selected based on their potential to enhance the functionality, resilience, and sustainability of D&I systems in Guyana, addressing key challenges such as sedimentation, flooding, and infrastructure maintenance. Further analysis, including GIS mapping and hydrological modeling, will help refine these priorities, ensuring that interventions are targeted to maximize their impact and align with regional needs and ecological conditions.

• Region 2 (Pomeroon-Supenaam):

Coastal Mangrove Restoration: Rehabilitating mangrove forests along the Pomeroon River and adjacent coastal areas to reduce storm surges and erosion. These mangroves help protect D&I outfalls by stabilizing coastal soils and reducing sediment accumulation in nearby waterways.

Stakeholder Engagement Plans: Developing inclusive strategies for NbS project implementation, emphasizing community-based monitoring and maintenance. Community involvement ensures timely debris clearing and regular maintenance of D&I infrastructure.

• Region 3 (Essequibo Islands-West Demerara):

Green Corridors: Establishing vegetative pathways along urban waterways such as the Boerasirie Conservancy drainage system. These corridors reduce runoff and debris inflow, helping maintain the functionality of D&I canals.

Urban Farming Expansion: Promoting rooftops and community farming in populated areas to manage stormwater runoff. Urban farming minimizes surface water flow into D&I systems, alleviating pressure on irrigation channels.

River and Stream Renaturation: Restoring sections of the Essequibo River's tributaries to improve natural flow and sediment management. This intervention reduces siltation in irrigation canals and improves water quality for agricultural use.

Green Building Solutions: Integrating water-retaining features in new urban developments to reduce runoff and urban heat stress. These features decrease the strain on D&I systems during heavy rainfall events.

Mangrove Restoration: Enhancing mangroves along the Essequibo River and coastal zones to protect communities from erosion. Mangroves stabilize riverbanks, preventing sediment from clogging nearby D&I structures.

Conservancy Capacity Expansion: Increasing storage and drainage capacity within the Boerasirie Conservancy through dredging and NbS such as sediment traps. These interventions improve the efficiency and lifespan of D&I infrastructure.

Community Collaboration: Strengthening local involvement in monitoring NbS and D&I systems. This collaboration enhances the timely identification of blockages and ensures proper functioning of infrastructure.

• Region 4 (East Bank Demerara):

Mangrove Restoration: Restoring mangroves along the Demerara River to reduce erosion and storm surge impacts. Mangroves prevent sedimentation at D&I outfalls, ensuring efficient water flow during high rainfall.

Green Corridors: Establishing vegetated pathways within Georgetown and along urban canals to manage runoff and mitigate urban heat. These corridors improve the effectiveness of D&I systems by reducing debris inflow and increasing infiltration.

Green Building Solutions: Promoting rooftop gardens and water-efficient construction in Georgetown to address runoff issues. These solutions reduce surface water accumulation, alleviating stress on urban D&I networks.

Open Green Space Protection: Preserving undeveloped land along the East Bank corridor to maintain infiltration and reduce surface water accumulation. Protected spaces enhance groundwater recharge and reduce the volume of water entering D&I infrastructure.

Conservancy Enhancements: Enhancing the East Demerara Conservancy with sediment traps and slope stabilization to prevent siltation and maintain storage capacity during extreme rainfall events. These enhancements ensure consistent irrigation supply and reduce maintenance needs.

Natural Wetland Protection: Protecting wetlands adjacent to the conservancy to maintain water filtration and habitat services. Wetlands regulate water inflows into D&I systems, preventing overflow and protecting downstream infrastructure.

Slope Stabilization: Using forested areas along the conservancy's periphery and upland regions to reduce

erosion risks. Stabilized slopes prevent sedimentation, preserving the integrity of D&I channels.

● **Region 4 (East Coast Demerara):**

Mangrove Restoration: Restoring mangroves along the coast east of the Demerara River to buffer storm surges and protect D&I systems. Restored mangroves prevent debris and sediment from entering coastal D&I infrastructure.

Green Corridors: Establishing vegetative pathways in urban areas such as Better Hope and Lusignan to reduce stormwater runoff. These corridors help maintain clear D&I canals by filtering debris and enhancing infiltration.

Green Building Solutions: Expanding urban farming and water-efficient buildings along the East Coast to address urban flooding. These buildings reduce surface runoff and improve D&I system performance during heavy rainfall.

Conservancy Enhancements: Strengthening the East Demerara Conservancy through slope stabilization, sediment management, and tree planting near key inflows. These interventions improve floodwater retention and ensure uninterrupted irrigation supply.

● **Region 5 (Mahaica-Berbice):**

Mangrove Restoration: Rehabilitating mangroves near the Mahaica and Abary rivers to protect agriculture and settlements along the coast. These mangroves reduce the inflow of sediment and debris into D&I channels, preserving their capacity.

Wetland Protection and Expansion: Supporting the Abary Conservancy with NbS such as wetland restoration to enhance water retention and sediment management. Improved wetlands stabilize water levels and protect D&I structures from siltation.

● **Region 6 (East Berbice-Corentyne):**

Targeted Mangrove Restoration: Restoring mangroves at the mouths of the Berbice and Canje rivers to reduce erosion and flooding. These mangroves stabilize riverbanks, protecting nearby D&I systems from sedimentation.

Wetland Protection and Expansion: Enhancing wetland systems linked to the Black Bush Polder to improve flood management and biodiversity. These wetlands regulate inflows into D&I canals and improve the reliability of irrigation systems during dry spells.

3.2 Nature based Solutions (NbS) Modelling

3.2.1 Tools for Assessing Nature-based Solutions

Effectively identifying and prioritizing opportunities for Nature-Based Solutions (NbS) requires a structured, interdisciplinary assessment approach that aligns ecological potential with social and economic needs. One leading tool in this space is the World Bank's NbS Opportunity Scan methodology, which provides a replicable, data-driven process to rapidly assess where NbS can have the greatest impact in reducing climate and disaster risk⁴⁸. The Opportunity Scan begins by mapping physical risk exposure (flooding, erosion, heat) and overlaying this with land use, ecosystem conditions, and socio-economic data to identify where ecosystems can be most functional. It is designed to work with existing planning processes and provides actionable spatial outputs that can be directly linked to investment planning, particularly in flood-prone and water-stressed environments. The Opportunity Scan framework is structured around three core questions:

- (1) Where can NbS reduce disaster or climate risk?
- (2) Where are NbS feasible to implement?
- (3) Where are NbS most cost-effective?

By combining risk analytics (such as flood hazard maps or storm surge models) with ecological assessments and implementation constraints (e.g. land availability, governance), the scan delivers "hotspot" maps where NbS are not only technically viable but also economically and socially desirable. It supports governments and development partners in moving beyond pilot projects toward portfolio-level planning for NbS investments. This methodology has already been applied in various contexts including Vietnam, Bangladesh, and parts of Latin America, and offers strong applicability to tropical, flood-prone countries like Guyana.

Other international organizations also propose structured

frameworks for NbS opportunity assessments. For example, the IUCN Global Standard for NbS outlines a criteria-based approach to determine whether proposed interventions are truly nature-based and aligned with sustainability and equity goals⁴⁹. The standard encourages assessments that include stakeholder engagement, ecosystem service valuation, and adaptive governance structures. Meanwhile, tools such as the Oppla Knowledge Marketplace⁵⁰, PANORAMA Solutions⁵¹, and the NetworkNature⁵² database allow for cross-comparison of existing NbS projects and best practices. These platforms are useful for benchmarking similar interventions in comparable climatic and geographic contexts and can support feasibility and design stages of NbS planning.

An additional layer of assessment comes from integrating ecosystem service modeling tools such as InVEST⁵³, ARIES⁵⁴, and Co\$ting Nature⁵⁵, which quantify the environmental and economic benefits of NbS interventions. These tools allow practitioners to simulate different scenarios—such as the impact of wetland restoration on flood risk or the value of riparian buffers for nutrient reduction—providing critical input for cost-benefit analyses and funding proposals. Combining tools like these with participatory mapping and local knowledge can ground-truth technical assessments and ensure community alignment. Together, these approaches provide a comprehensive framework for identifying, prioritizing, and operationalizing NbS in a way that is spatially targeted, socially inclusive, and financially sound.

3.2.2 Introduction to Modelling Approach

Guyana's low-lying coastal and riverine regions face perpetual water management challenges which have long been engaged through traditional management practices such as building channels, sluice gates, and pumps. These active approaches struggle to manage current water flows and will continue to struggle under increasing flows

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49 IUCN. (2020). *Global Standard for Nature-Based Solutions: A user-friendly framework for the verification, design and scaling up of NbS*. <https://www.iucn.org/theme/nature-based-solutions/resources/iucn-global-standard>

50 Oppla. (n.d.). *Nature-Based Solutions Knowledge Marketplace*. <https://oppla.eu>

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53 Natural Capital Project. (n.d.). *InVEST Tool*. <https://naturalcapitalproject.stanford.edu/software/invest>

54 ARIES. (n.d.). *Artificial Intelligence for Environment & Sustainability*. Integrated Modelling Partnership. <https://aries.integratedmodelling.org>

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under climate change. Nature-Based Solutions (NbS) offer an opportunity to support those active systems through the inclusion of passive ecological systems enhance water regulation and ecosystem resilience while delivering co-benefits for reduced sediment and nutrient loads, improved biodiversity, amongst others. This section evaluates the impacts of four NbS interventions—riparian buffers, detention ponds and check dams, wetland creation, and floodplain restoration—using the InVEST toolkit and its associated Annual Water Yield (AWY), Sediment Delivery Ratio (SDR), and Nutrient Delivery Ratio (NDR) models.

Nature-based Solutions offer an opportunity to re-engage natural processes in slowing upland water flows and allowing natural processes such as flooding, infiltration, and retention to delay the onset and peak flow rates of floodwaters, thereby enhancing ecological functions while also improving the anthropocentric benefits of natural processes. Utilizing NbS solutions may limit the overall amount of flood water and flood intensity in lower lying areas, allowing more time for in-place response systems to clear water and limit overall flood damages. However, NbS interventions require additional land be committed/returned to natural uses often at the expense of cropland that would otherwise be placed in productive use.

To directly compare the trade-offs between various NbS options, this assessment modelled the construction of four readily deployable NbS interventions across a representative watershed to understand to individual impacts of each option. The four options investigated were:

- Riparian buffers
- Wetlands creation/restoration
- Detention ponds/check dams
- Floodplain Restoration

The impacts and costs of each intervention were assessed using the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) toolkit. InVEST is a suite of open-source software models that map and value the goods and services from nature. Specifically, this assessment used the Annual Water Yield (AWY), Sediment Delivery Ratio (SDR), and Nutrient Delivery Ratio (NDR) components of the InVEST toolkit. AWY examines the total amount of water that falls on a landscape and models how much water is retained due to vegetation and soil characteristics of different land coverings, and estimates the total amount of water retained within a watershed. SDR examines

elevation, slope, soil composition, and land use to model the total amount of soil erosion and deposition that occurs within a landscape. NDR examines the slope, land use, and nutrient retention properties of agricultural areas to model the amount of nutrients that are retained or released into waterbodies.

The impacts directly attributable to each NbS option were quantified using a Before-After Control-Impact (BACI) experimental design. The BACI approach involves developing a baseline scenario, then comparing the differences of subsequent scenarios that represent each NbS option.

To initiate the model, a representative watershed was identified in Region 6, composed of a roughly equal mix of cropland, grassland, and barren areas with some forested areas. Due to limited data availability, global elevation and global land use land cover (LULC) datasets were used as a basis for this assessment, with manual modifications to align the data with locally observable water bodies and land uses. An artificial slope was added to the elevation data and a smoothing filter was applied to align with local characteristics (**Figure 20 - Left**). LULC data were corrected visually with attribute values taken from corresponding global datasets (**Figure 20 - Right**). This representative watershed formed the basis for all scenarios thus providing robust comparable outputs. The analysis scenarios included:

- **Scenario 0 – Baseline:** Land uses consisting of roughly equal areas of cropland, grass lands, and barren areas, with some forested areas.
- **Scenario 1 – Riparian buffer:** Same baseline land use with a 45m wide, 1000m long riparian area added to each side of the stream where treed areas replaced cropland.
- **Scenario 2 – Detention pond/check dam:** Same baseline land uses with placement of a 10 hectare detention pond where open water replaced cropland.
- **Scenario 3 – Wetland creation:** Same baseline land uses with placement of a 10 hectare wetland where wetlands replaced cropland.
- **Scenario 4 – Floodplain restoration:** Same baseline land uses with 100m of floodplain added to each of side of the river replacing croplands, barren areas, and grasslands.

For each scenario, each InVEST model (AWY, SDR, and NDR) were run using the same baseline inputs with the scenario-specific land use data (for additional details

including data sources, processing steps, and parameters, please see the Appendix). The results were aggregated to the watershed scale to provide a single metric representing the change directly attributable to each NbS Intervention.

3.2.3 Scenario 0 – Baseline

To establish a benchmark, the baseline scenario was developed using the modified elevation data and generalized land use patterns to illustrate representative conditions. The baseline scenario represents water,

sediment, and nutrient outputs under unchanged conditions, providing the benchmark for how this control landscape preforms in the modelling environment (**Table 6. Baseline values for InVEST Ecosystem Services.**).

Table 6. Baseline values for InVEST Ecosystem Services

	Scenario	Water Yield (m ³ /year)	Sediment Export (tons/yr)	Phosphorus export (kg/yr)	Nitrogen export (kg/yr)
0	Baseline	61,413,432	14,402	101.84	1,153.78

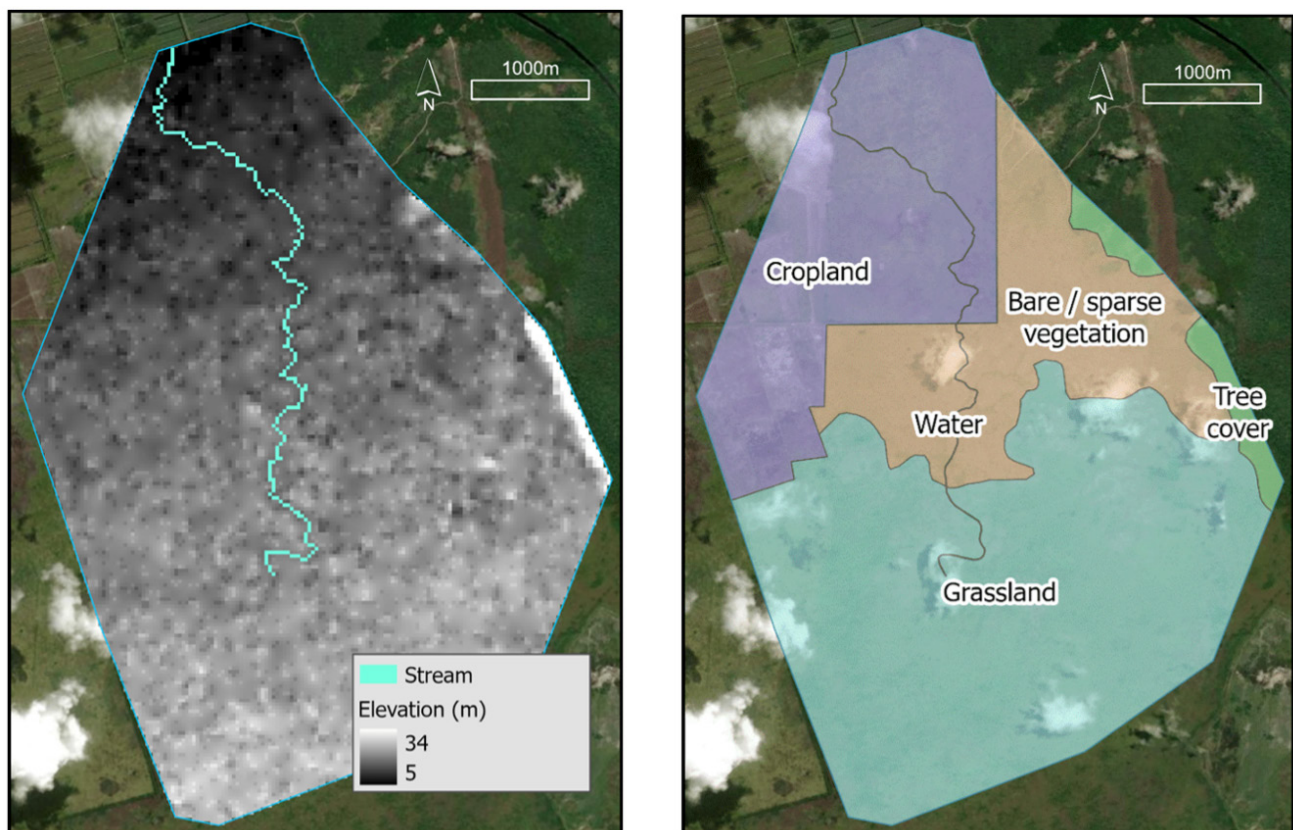


Figure 20. Representative Watershed (left) and baseline land use map (right)

3.2.4 NbS Intervention Scenarios

For each NbS intervention scenario, the land use dataset was modified to reflect the construction of a generalized representative NbS project. For scenario 1, a riparian buffer was simulated by replacing a 45m swath of cropland with tree cover, along 1000m of the stream bank on both sides of the river (**Figure 21a**. Land use allocations for each NbS Intervention (orange) scenario: 1) Riparian Buffer, 2) Detention pond/check dam, 3) Wetland, 4) Floodplain). This equated 9.6 hectares of land use changing from general agricultural areas to treed areas. For scenario 2, a check dam was simulated at a key point along the river

leading to a 10-hectare detention pond (21b - Due to the coarseness of the elevation data, actual flooding created by a check dam was unable to be simulated) converting 10 hectares of cropland to standing water. Scenario 3 used the same area of land use change as scenario 2, except it replaced cropland with 10 hectares of wetland (21c). Scenario 4 simulates a reconnected floodplain. The coarseness of elevation data prevented actual floodplain width to be determined, so this simulation transforms 100 metres swaths of land along each side of the river from its baseline use to floodplain (21d).

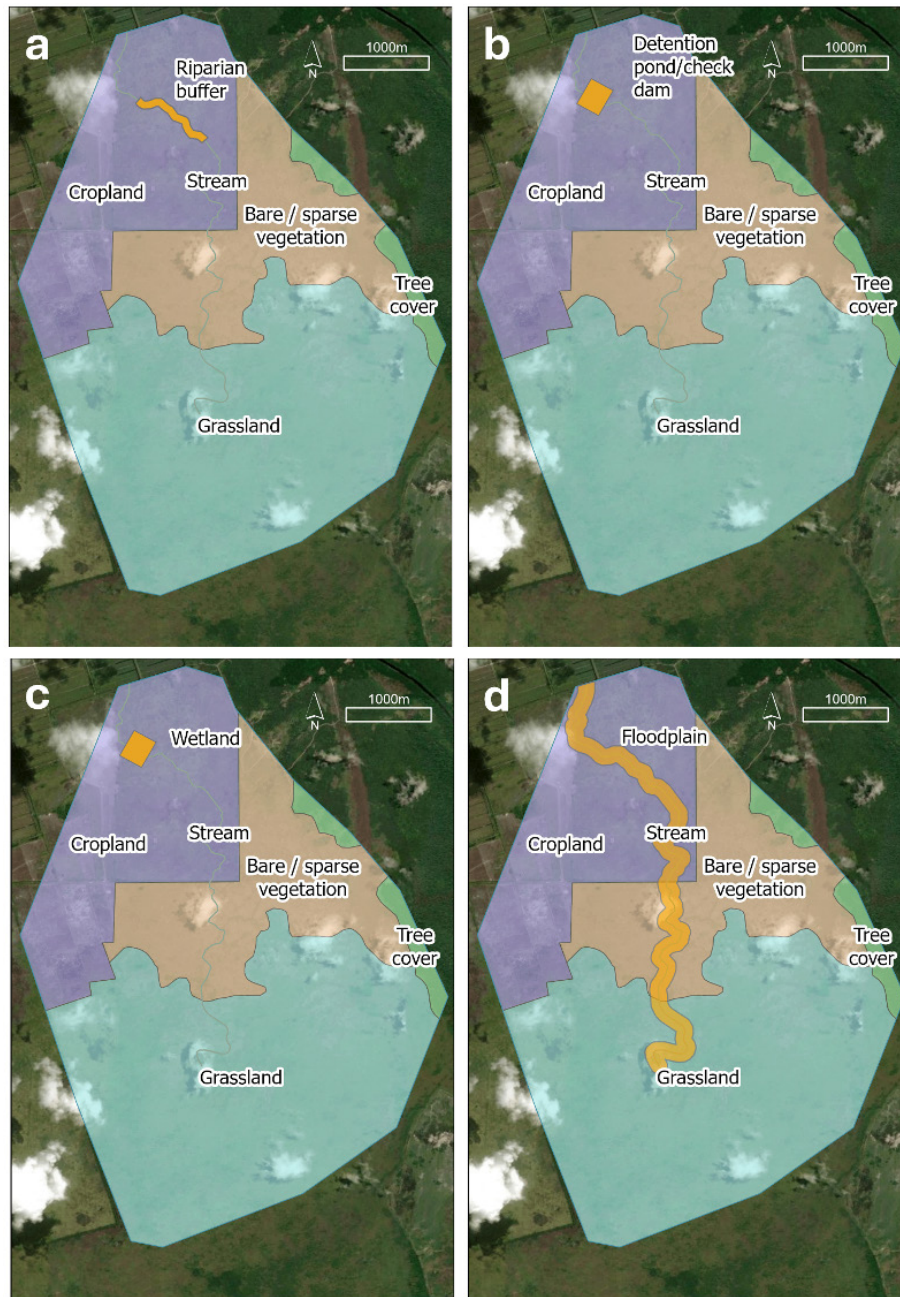


Figure 21. Land use allocations for each NbS Intervention (orange) scenario: 1) Riparian Buffer, 2) Detention pond/check dam, 3) Wetland, 4) Floodplain

3.2.5 Nature-based Solutions Modelled Benefits

The InVEST tool estimates the physical change in the ecological performance of the landscape. Converting these values into economic units for cost comparisons

depends on local contexts and markets. **Table 7** describes the range of potential valuations for each of the modelled outputs based on literature review.

Table 7. Source of economic benefit estimates for NbS options

Value of ecosystem services	Unit value (USD)	Source
Water Yield Reduction	1.03\$/m3/yr	Lin et al. (2024)
Sediment Export Reduction	26\$-8\$/ton/yr	De Jesus Crespo et al. (2023)
Nitrogen export reduction	777\$-15\$/kg/yr	Berg et al. (2016)
Phosphorus export reduction	233\$-73\$/kg/yr	Dodds et al. (2009)

3.2.6 Results

Utilizing the BACI experimental provides summary outputs of environmental conditions before, and after, the NbS intervention. Holding all parameters equal except for the changes in land use allows any change in output to be attributable to the NbS intervention. The results presented in Table 9 display the differences in values between each scenario and the control scenario, meaning that the presented values are the reductions caused per hectare of land dedicated to each intervention.

3.2.7 Scenario 1 – Riparian buffers

Using this approach, each hectare of riparian buffer placed between croplands and streams has the potential to reduce waterflow through the river system by 41 cubic metres per year. Additionally, riparian buffers also have the potential to prevent over 4 tons of sediment from reaching the watercourse, reducing congestion at downstream locations. In areas where fertilizers are used, riparian buffers are effective at reducing phosphorus and nitrogen loads in runoff. Riparian buffers also expand ecological habitats in key areas that support high degrees of biodiversity, often including pollinators that increase productivity for some crops, and other species that can lower pest loads for livestock.

Riparian buffers are relatively low cost NbS interventions, largely created by strategic planting of key species combined with letting land re-wild itself. The primary cost in constructing riparian buffers is the lost revenue from removing agricultural lands from productive use. Riparian

buffers are most appropriate where agricultural areas directly abut water courses, with moderate or shallow slopes.

3.2.8 Scenario 2 – Detention ponds and check dams

The simulated 10 ha detention pond and check dam was found to be more effective at reducing water yields than riparian buffers, but not as effective at reducing sediment yield. Each hectare of detention pond was shown to reduce water yields by over 100 cubic metres per year, and reduced sediment loads by more than 3 tons per year (Table 9). Detention ponds and check dams also reduced nutrient loads of both phosphorus and nitrogen.

Check dams can be built across a variety of land uses. In agricultural areas, this may require removing farmlands from productive use and may cause flooding in unexpected areas. Check dams and detention ponds also require specific elevation characteristics to be most effective, requiring some slope and constraining topography to 1) slow the flow of water, and 2) for the constrain water in a reasonable area without causing nearby flooding. Check dams are often ideal interventions in areas of higher slopes where higher water velocities can cause excessive erosion. Additionally, dams and ponding can substantially alter the ecological function of active streams and watersheds by limiting fish migration, and changing water temperatures and turbidity. Additional ecological assessments should be considered before building check dams and retention ponds.

3.2.9 Scenario 3 – Wetland construction

Within this modelling framework, detention ponds and wetlands are treated similarly both replacing a 10-hectare parcel of cropland. However, in scenario 3, this 10-hectare plot is replaced with an herbaceous wetland. Compared to detention ponds, wetlands retained slightly less water (109 cubic metres per year per hectare) and had a slightly lower sediment reduction (2.4 tons per year per hectare) (Table 9). Whereas check dams are designed to impede water flow creating a pond, wetlands look to expand and thereby slow the water courses that pass through it, maintaining slightly higher velocities which account for less water and sediment reduction. Nutrient retention is similar between both land uses.

Compared to detention ponds, however, wetlands offer a bounty of additional ecological benefits and fewer of the disruptions associated with dams and detention ponds. Namely, expanded habitats encourage biodiversity expansion. There is still the cost of lost productivity if croplands are to be replaced with wetlands, but wetlands can be built in more areas than check dams allowing less valuable lands to be converted.

3.2.10 Scenario 4 – Floodplain restoration

Results of floodplain restoration fell within the distribution of the other NbS interventions (**Table 8**). Floodplains were found to be more effective than riparian buffers at reducing water flows and sediment load, but not as effective as detention ponds and wetlands although they maintained similar levels of nutrient reduction.

In the model, floodplain restoration was represented by converting all areas along the stream to floodplain. While this was necessary due to the lack of precise elevation data requiring an estimated width of floodplain, actual floodplain restoration could be much more focused, obtaining most of the benefits with much less of the land use through a ‘string of pearls’ approach (Wohl, et al. 2018). The ‘string of pearls’ approach focuses on floodplain restoration at specific sites naturally suited to

floodplains, often at areas where stream slopes shallow rapidly near the exit of canyons or steep areas. Allowing floodplains to be restored in these areas would allow over bank flow which slows water velocities, encouraging water infiltration and sediment and nutrient deposition.

3.2.11 Summary results

In terms of water flow reduction, riparian buffers were the least impactful (Table 8). Detention ponds and wetlands achieved very similar levels of water reduction, with wetlands allowing some more water flow which is expected as they do not attempt to completely stop water flows. Floodplain restoration achieved a much more pronounced overall reduction in water flow, but less flow reduction than detention ponds and wetlands on a per-area basis.

In terms of sediment reduction, riparian buffers were the most effective solution as they provide a physical barrier to between sources of erosion and water courses. Check dams and detention ponds were second most effective as reducing sediment load, but they accomplish this through sediment infilling which decreases its effectiveness over time. Wetlands also reduce sediment load but because they do not stop water completely, they are not as effective at removing sediment. Floodplains, and their associated over bank flows, can be highly effective at removing sediment, with some areas being better suited to deposition than others.

In terms of nutrient reduction, riparian buffers were slightly worse than the other NbS options while detention ponds, wetlands, and floodplains performed similarly.

Table 8. Summary results of each NbS intervention normalized per hectare of land use

	Scenario	Water Yield Reduction (m3/ year/ha)	Sediment Export Reduction (tons/ yr/ha)	Phosphorus Export Reduction (kg/yr/ha)	Nitrogen Export Reduction (kg/yr/ ha)
1	Riparian buffer	41.19	4.36	0.18	1.84
2	Detention Pond/ check dam	110.47	3.33	0.23	2.53
3	Wetland construction	109.82	2.41	0.23	2.53
4	Floodplain restoration	58.03	2.75	0.23	2.41

Applying the estimated values of NbS benefits (Table 7) to the modelled outputs of interventions (Table 8) produces a range of quantified values for constructing each NbS. Per hectare, detention ponds and wetlands produce the best return on investment based on the estimated ecosystem service value provided in terms of reducing water flows,

sediment, and nutrients in the water stream, see **Figure 22**. However, when considering construction costs which are much higher per hectare, riparian buffers become the most economical, delivering slightly lower benefits but at much cheaper costs.

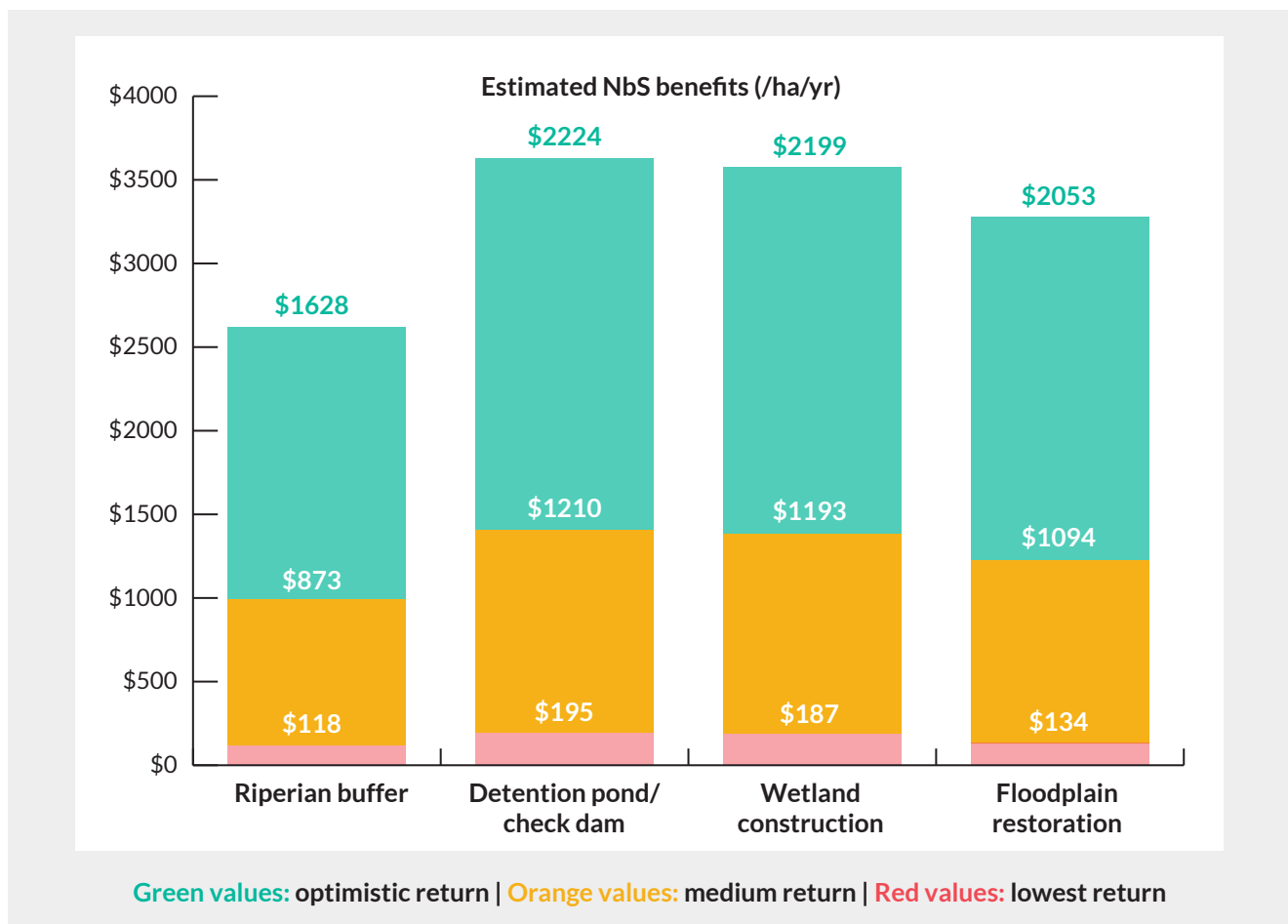


Figure 22. Total benefits per hectare per year for NbS projects

3.2.12 Assumptions and limitations

Modelling attempts to recreate re-world conditions to see how those conditions respond to various changes and inputs. Simplifying an infinitely complex natural world to a finite simulated world necessarily requires some generalizations. For baseline conditions, those assumptions have all been held constant to ensure robust comparability of outputs. However, assumptions within the differentiating parameters do influence the outcomes. All efforts have been made to ensure assumptions are grounded in literature or best practices within the InVEST modelling environment.

This modelling worked within the constraints of highly limited data. Namely, the global elevation, land use, and soil data are insufficient for accurate representation of on-the-ground conditions. Holding baseline conditions constant (where possible) between scenarios allowed for relative comparisons between the outputs, but absolute values will differ depending on real-world conditions.

As with all ecosystem services assessments, this work only includes the quantifiable economic benefits of ecosystem and fails to adequately capture the full breadth of benefits provided by natural ecosystems. Furthermore, qualitative social benefits are fully captured in this approach.



4. Strategic Recommendations for Enabling Nature-based Solutions

4.1 Recommendation 1: Develop Technical Guidelines and Standard Operating Procedures for NbS Integration

NDIA should establish a clear and practical framework for integrating NbS into its core D&I planning and operations. This study provides a starting point—offering an initial set of NbS typologies and site concepts—but for meaningful institutionalization, NDIA will need to develop its own technical guidelines and standard operating procedures (SOPs) that define how NbS are identified, designed, implemented, and maintained across different regions and infrastructure types.

The development of a basic taxonomy of NbS interventions—covering both natural and hybrid infrastructure—is an essential first step. This should be accompanied by guidance on functional performance measures, silting considerations, vegetation selection, and maintenance schedules. These SOPs should be developed in a way that is compatible with NDIA's current project

design and procurement processes, and flexible enough to be adapted over time as more data becomes available.

Having clear guidelines in place will also enable NDIA to make more consistent and transparent decisions about where and how to integrate NbS into ongoing works, whether in the design of Hope-like canals, the expansion of conservancy capacity, or the expansion of croplands. Over time, these guidelines can be built out with performance metrics and practical field experience, creating an internal knowledge base that supports scaling. The international examples referenced in this study offer useful templates that can be adapted to the Guyanese context, but the process of developing NDIA's own standards will ultimately need to be grounded in its operational realities and institutional mandate.

4.2 Recommendation 2: Institutionalize Nature-Based Solutions within NDIA's Cost-Benefit Analysis Frameworks

Mainstreaming Nature-based Solutions (NbS) within Guyana's D&I planning will require the establishment of a cost-benefit analysis (CBA) framework that adequately captures the full value of ecosystem services. NDIA should develop and adopt a supplemental CBA module that accounts for both direct and co-benefits of NbS—including flood risk reduction, sediment control, soil moisture retention, water quality enhancement, and avoided maintenance costs. Existing tools such as the World Bank's and IISD's guidelines on CBA for NbS can provide tested methodologies that can be adapted to Guyana's coastal and conservancy-fed systems.

This new CBA module should include practical guidance for NDIA engineers and economists on how to quantify key ecosystem service values, assess long-term system efficiency under climate stress scenarios, and compare grey, green, and hybrid infrastructure solutions. Piloting this framework through selected projects—such as Hope-like canals or sediment trap installations within conservancies—will be critical for refining the approach

and demonstrating its relevance.

Further, NDIA should work with the Ministry of Finance and the Office of Climate Change to ensure alignment of this methodology with national investment guidelines, enabling NbS-based projects to access funding streams such as LCDS 2030 revenues, the Green Climate Fund, or adaptation financing mechanisms. Integrating NbS into project appraisals is not simply about valuing environmental co-benefits; it is a necessary step toward ensuring that D&I infrastructure performs under the compounded pressures of climate change, land use shifts, and growing demand for water services.

This recommendation underpins many of the other strategic actions outlined in this study. Without a fit-for-purpose CBA system, NbS will continue to be undervalued, underfunded, and excluded from the infrastructure toolkit. With one in place, NDIA will be well-positioned to deliver infrastructure that is not only technically sound, but also economically resilient and ecologically adaptive.

4.3 Recommendation 3: Enhance Partnerships and Communication with Land Use and Planning Authorities

One of the persistent challenges raised throughout this study—and by NDIA regional staff during stakeholder consultations—is the encroachment of buildings and infrastructure into areas critical for flood management. Unauthorized or poorly planned development in drainage easements, floodplains, or near conservancy boundaries can not only compromise existing infrastructure but also severely limits the potential for integrating Nature-based Solutions (NbS) such as riparian buffers, flood detention ponds, or restored wetlands. As climate-related flood risks increase, the lack of coordinated land use management poses a growing systemic risk.

NDIA cannot address this challenge alone. Effective integration of NbS will require strengthened collaboration with land use management agencies, including the Central Housing and Planning Authority, the Guyana Lands and Surveys Commission, and regional and municipal governments. In particular, there is a need for joint

planning mechanisms that allow for early coordination on project siting, zoning enforcement, and land tenure arrangements. This coordination should aim to delineate and preserve functional flood zones, maintain vegetated buffers along key watercourses, and prevent further development in high-risk areas.

Strategic land use decisions—especially in rapidly urbanizing areas such as the East Bank and East Coast of Demerara—must reflect realistic hydrological data and forward-looking climate risk assessments. NDIA and partner agencies should work toward establishing flood-compatible zoning overlays and enforceable no-build areas, particularly around the conservancy system and major drainage channels.

4.4 Recommendation 4: Strengthen Public Communication and Awareness on NbS and D&I Resilience

Ensuring the maintenance of NbS and the value of investments will require strong public understanding and support. While NDIA and partner agencies bear responsibility for planning and maintaining D&I infrastructure, the long-term success of these systems depends on how communities interact with them. Poor waste management, informal construction, and the degradation of vegetated flood buffers often arise not from negligence, but from a lack of awareness of how these systems work and why they matter.

A focused and well-resourced public communication strategy is needed to increase public understanding of how natural systems—such as mangroves, wetlands, and floodplains—contribute directly to flood protection, infrastructure performance, and community safety. Property owners, developers, and local government officials should be able to clearly recognize that vegetated land adjacent to canals or conservancy boundaries is not “unused land,” but a critical part of the flood management system. Targeted communication should highlight the role that these areas play in absorbing excess water, reducing peak flows, and preventing downstream damage.

Communication also represents an opportunity to foster a groundswell of community-level stewardship around the maintenance and protection of D&I assets. Campaigns should not only raise awareness but actively encourage community participation in canal clearing, mangrove preservation, and the monitoring of NbS interventions. These campaigns can be linked to the LCDS 2030 and other efforts toward sustainable development of the GoG. This could be supported through school-based education, community workshops, signage near critical infrastructure, and collaborations with civil society and local media. In the long run, fostering a sense of shared responsibility for drainage systems—rooted in both knowledge and ownership—will reduce maintenance costs, improve system resilience, and strengthen the social foundation for scaling NbS across the country.

4.5 Recommendation 5: Build a System for Hydrologic and Ecosystem Data Collection and Monitoring

NDIA lacks a systematic approach for monitoring ecosystem health across its drainage corridors and conservancy systems, and real-time hydrologic data remains fragmented and limited in geographic coverage. These data gaps reduce NDIA's ability to plan, prioritize, and adaptively manage interventions, particularly in the face of more variable rainfall patterns, salinity risks, and increasing development pressures.

A coordinated ecosystem and hydrological monitoring system should be developed and institutionalized as part of NDIA's operational toolkit. This system should include both real-time and periodic data collection on key parameters such as water levels, flow velocities, canal sedimentation, wetland extent, vegetation health, and water quality (including salinity, turbidity, and pH). Monitoring efforts should be spatially linked to priority NbS sites and high-risk flood zones and aligned with climate-sensitive agricultural areas. Over time, this system should also incorporate land cover change and development encroachment data to support enforcement and land use planning.

Equally important is the diffusion of monitoring capabilities to the local level. Regional NDIA offices, WUAs, NDCs and community partners should be equipped to collect and interpret field data using standardized templates and low-cost tools like rain gauges and cell phone apps. Building this local capacity will enable early detection of blockages or ecological degradation and foster greater

ownership of system performance. Clear protocols should be developed to integrate this local data into a centralized platform accessible to planners, engineers, and policy makers at the national level.

Where possible, this effort should be implemented in partnership with the Hydrometeorological Service and the Guyana Water Authority. Both institutions bring critical technical expertise and existing infrastructure. A joint approach would enable cost-sharing, data harmonization, and cross-agency collaboration, while avoiding duplication of efforts. The goal should be to establish an umbrella system that supports D&I planning, climate adaptation, and water resource management under a unified monitoring architecture.

This monitoring system would serve not only to reduce flood and drought risk, but also to support agricultural productivity, particularly as NDIA explores ways to improve irrigation efficiency, manage salinity risks, and optimize water availability. A robust monitoring backbone will allow for adaptive management of conservancy releases, drainage gate operations, and seasonal planning cycles—all of which become increasingly important under shifting rainfall and sea level conditions.

4.6 Recommendation 6: Create Systems for Decentralized Planning and Implementation of NbS

NbS, by their very nature, are context specific. Unlike large-scale engineered infrastructure, which can often be designed centrally and replicated across sites, effective NbS interventions require close alignment with local hydrology, land use, community needs, and ecosystem conditions. This makes centralized planning of NbS challenging—and in many cases, counterproductive. To scale NbS across Guyana's D&I system, NDIA will need to enable more decentralized identification, planning, and implementation of these interventions.

Regional NDIA offices in collaboration with WUAs, NDCs and farmers are often best placed to identify specific sites where NbS—such as vegetated buffers, riparian corridor

restoration, sediment traps, or constructed wetlands—could support flood mitigation or improve irrigation performance. Many of these interventions are low-cost, low-risk, and reversible, making them well-suited to experimentation and local adaptation.

To address this, NDIA should establish decentralized planning mechanisms that allow regional and district teams to propose, evaluate, and implement NbS interventions with defined thresholds of autonomy. This could be structured through a set of eligibility criteria and pre-approved design templates for small-scale NbS, allowing quick deployment without waiting for national-level review. Dedicated budget lines for local

NbS experimentation and minor works should also be established within regional offices.

In parallel, NDIA should invest in capacity building and technical training for its field teams and regional engineers, focusing on how to identify suitable NbS sites, assess intervention feasibility, and align these with broader D&I functions. Field toolkits—derived from the technical guidance proposed earlier—should include simple

checklists, example designs, and O&M considerations tailored to lowland and coastal contexts. Partnering with local stakeholders, including Water User Associations and community-based organizations, can further support this decentralized model.

4.7 Recommendation 7: Enable Integration of NbS in Cropland Expansion Planning

As the Ministry of Agriculture advances national goals to expand agricultural production, there is a parallel opportunity to ensure that this expansion is done in a way that strengthens, rather than undermines, the resilience of Guyana's D&I system. The introduction of new cropland, particularly in flood-prone and poorly drained areas, can significantly increase surface runoff, reduce infiltration, and degrade riparian zones unless planned with water system dynamics in mind. From a D&I perspective, it will be far more efficient and cost-effective to incorporate NbS at the point of expansion, rather than retrofitting them into already converted or degraded agricultural land.

NDIA should proactively coordinate with other programs within the Ministry of Agriculture, NDCs, and local farmers to ensure that all new cropland expansion includes integrated hydrologic planning and NbS screening. This could include conducting basic hydrological assessments before clearing begins and mapping water retention areas, natural drainage corridors, and existing wetland features that should be maintained. Interventions such as riparian buffers, vegetated field margins, seasonal detention areas, and wetland set asides can be included from the outset to protect both farm productivity and downstream infrastructure.

This proactive approach would be supported by tools already proposed in this study—particularly the development of NbS-focused CBA frameworks and ecosystem risk mapping. NDIA, in partnership with the Guyana Lands and Surveys Commission and agricultural extension services, should create planning toolkits for land conversion, including guidance on siting, layout, waterway protection, and the integration of low-cost NbS. These resources should be shared with farmers and local government representatives as part of the permitting or promotional process for new cropland development.

Integrating NbS into cropland expansion offers a strategic entry point to scale NbS at lower cost and greater impact, particularly where large-scale conversion is ongoing. Rather than treating environmental safeguards as constraints, this approach positions them as core components of sustainable land development, helping to maximize the productive potential of land while minimizing flood risk, drainage congestion, and future rehabilitation needs. It also helps NDIA embed NbS into emerging agricultural landscapes from the outset, building long-term resilience into the country's food system and water infrastructure simultaneously.

4.8 Study Conclusion and Scope

This study provides a starting point for understanding the opportunities for the integration of NbS into Guyana's D&I systems. It offers an initial framework for identifying, prioritizing, and evaluating NbS interventions, and proposes a set of technical and institutional actions to support their uptake. However, the findings and recommendations presented here are not comprehensive nor prescriptive. The real challenge lies in translating these concepts into structured, operational systems that can be sustained across regions, projects, and institutions.

For NbS to be meaningfully adopted, they must be embedded within NDIA's core infrastructure planning and management systems—not treated as add-ons or special cases. This will require strategic decisions at the leadership level, as well as practical investments in technical guidance, monitoring, training, and cross-agency coordination. At the same time, enabling environments must also be built at the local level. Farmers, contractors, and community members all play direct roles in how land and water are used, and their understanding of the value

and function of NbS will be key to ensuring interventions are respected, maintained, and scaled. Without local ownership and routine reinforcement through education and engagement, even well-designed NbS risk being neglected or degraded.

Ultimately, NbS are not simply design features—they are part of a broader shift in how we view and manage hydrologic systems. They allow for a more decentralized, adaptive, and cost-effective approach to flood risk management and water allocation. But this potential can only be realized if there is a shared understanding of why hydrologic systems matter, how they are changing, and what role each actor plays in shaping their future. This study lays the groundwork, but the process of building resilient and inclusive water systems through NbS will require sustained commitment—from NDIA, partner agencies, and the communities whose lives and livelihoods depend on it.

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Annexures

ANNEXURE 1

LITERATURE SURVEY QUESTIONS

Background

1. What are the existing studies conducted on the state of D&I in Guyana?
2. What are the challenges and possible recommendations identified in the studies?
3. Are the studies comprehensive or only dealt with specific regions or locality?
4. Who are the stakeholders in these studies?

Technical

1. What are the technical challenges affecting D&I and how much of it has been documented?
2. Have previous studies modelled technical recommendations for D&I improvements?
3. What aspects of existing technical studies have been implemented in strategic documents of NDIA?
4. What are the new and emerging technical challenges facing D&I in terms of irrigation of farmland and drainage of excess water?

Institutional

1. Who are the stakeholders in D&I and what are their role?
2. What are the challenges at the institutional level both in terms of within agencies and across Ministries?

INTERVIEW SCHEDULE

PILLAR

1

OWNERSHIP

1. What is the structure of operation and maintenance when water mandates involve different ministries/agencies assets?
2. In the event of an emergency, where a key asset, for example, a koker/sluiice is damaged leading to flooding, what is the procedure, and do you see areas where the process can be improved?
3. Are WUAs users regularly trained in O&M procedures and how often do NDIA conduct oversights WUA practices?
4. What are the important vulnerabilities that you consider important in your region? For example, livestock, large farming areas, indigenous people, low-income, etc.
5. Are the D&I resources in the region adequate to address the vulnerabilities in your region?
6. Are women and youth able to voice their concerns on potential adaptation measures or in the conceptualization and design of D&I systems?
7. Which groups would you identify as vulnerable in the drainage & irrigation sector?
8. How do current drainage and irrigation projects consider the needs of vulnerable groups (e.g., women, low-income communities, indigenous groups)?
9. Are there any adjustments you've had to make to accommodate the needs of underrepresented groups in D&I infrastructure or maintenance?

PILLAR

2

OVERSIGHT AND COORDINATION

1. Are there guidelines to collaborate with other agencies and ministries in areas where D&I infrastructure is present? How often do you encounter challenges where different agencies/ authorized contractors impede drainage and irrigation systems. Can you give an example?
2. Previous reports have cited concretization of narrow drains and channels as leading causes of flooding. Are there guidelines for continuous monitoring of drainage channel construction by NDIA contractors?
3. Do you see D&I resilience planning being integrated in urban development planning, particularly with new housing projects and road construction?
4. How often are you involved in the planning process with other Ministries or agencies where their work involves or impacts D&I assets in your region?

PILLAR

3

INFRASTRUCTURE PLANNING AND MAINTENANCE

1. More capacity is required in the maintenance and operation of D&I assets. Who are the local stakeholders that could enhance capacity and strengthen efficiency?
2. Are there any predictive or warning systems of expected flooding to inform planning in the region. How do you disseminate this information?
3. How much of a challenge is sedimentation of D&I infrastructure? Are you able to keep up with dredging? Where are dredged sediments deposited?
4. Are there areas where sedimentation and/or water retention ponds could be constructed?
5. Are sluices often blocked up by debris? How is this generally managed?

PILLAR

4

DATA MONITORING SYSTEMS

1. With plans to propose stainless steel doors for kokers/sluices, how is the monitoring of the infrastructure operator managed? Should there be a real-time system of water level indication that automatically manages the sluice gate? How do you see such enhancement in flood management and creating confidence in communities?
2. What specific challenges do you encounter when integrating gender equality or social inclusion into project design or implementation?
3. How can the NDIA ensure that D&I projects are more inclusive in terms of both access and benefits to vulnerable communities?
4. What kind of training or capacity-building would help engineers better implement GESI-focused approaches in their work?

Open Discussion of possible pillars:

- Human Resources
- Technology in D&I



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