CLARE
CLIMATE ADAPTATION & RESILIENCE

UK International Development
Partnership | Progress | Prosperity

IDRC · CRDI
Canada

ICLEI
Local Governments for Sustainability
SOUTH ASIA

Nature based Solutions for Waterbody Restoration

Authors: Monalisa Sen and Rinku Singh

Editor: Saira Kurup

Designer: Sasi Madambi

Year of Publication: 2026

About the authors

This compendium was written by Monalisa Sen and Rinku Singh from ICLEI-Local Governments for Sustainability, South Asia. Dr. Monalisa Sen holds a doctoral degree in Environmental Studies In her capacity as Associate Director (Biodiversity), she presently coordinates the work on urban biodiversity and nature-based solutions at ICLEI- Local Governments for Sustainability, South Asia. Dr Rinku Singh holds a doctoral degree in Environmental Sciences and has been active in the fields of natural resource management, biodiversity and nature-based solutions.

Acknowledgements

The contributions from all case study reviewers which was instrumental in developing the case studies in the compendium is duly acknowledged. The authors would also like to thank the funding support through the CLARE Research for Impact (R4I) Opportunities Fund. CLARE is a flagship research programme on climate adaptation and resilience, funded mostly (about 90%) by UK Aid through the Foreign Commonwealth and Development Office (FCDO), and co-funded by the International Development Research Centre (IDRC), Canada. CLARE is bridging critical gaps between science and action by championing Southern leadership to enable socially inclusive and sustainable action to build resilience to climate change and natural hazards.

Contents

List of Abbreviations

%	Percentage
°C	degree Celsius
APP	Permanent Preservation Area
BDL	Below Detection Level
BDT	Bangladeshi Taka
BIS	Bureau of Indian Standards
BOD	Biological Oxygen Demand
CBD	Convention on Biological Diversity
CEMDE	Centre for Environmental Management of Degraded Ecosystems
CEO	Chief Executive Officer
CO2	Carbon di-oxide
CSMC	Chhatrapati Sambhajinagar Municipal Corporation
CSR	Corporate Social Responsibility
CWS	Constructed Wetland System
DDA	Delhi Development Authority
DO	Dissolved Oxygen
DRR	Disaster Risk Reduction
e.g.	Example
EC	European Commission
ESSVA	Ecosystem Service Shared Value Assessment
GDP	Gross Domestic Product
GVP	Garbage Vulnerable Point
GWC	Guandu Watershed Committee
HVCA	Hazard, Vulnerability and Capacity Analysis
IISc	Indian Institute of Science
IISD	International Institute for Sustainable Development
IMC	Indore Municipal Corporation
INR	Indian Rupee
IUCN	International Union for Conservation of Nature
km	Kilometre
km^2	Square kilometer
LGED	Local Government Engineering Department
MAR	Managed Aquifer Treatment
MEA	Millenium Ecosystem Assessment
Mg/l	Milligrams/litre
MGSP	Municipal Governance and Services Project
MLD	Million Litres per day
mm	Millimetre
NbS	Nature based Solutions

NCC	Narayanganj Municipal Corporation
PAF	The Water and Forest Producers Project
PES	Payment for Ecosystem Services
R&D	Research and Development
RCA	River City Alliance
SAT	Soil Aquifer Treatment
SDC	Swiss Agency for Development and Cooperation
SUNCASA	Scaling Urban Nature-based Solutions for Climate Adaptation in Sub-Saharan Africa
TSS	Total Suspended Solid
UHI	Urban Heat Island
UNCED	United Nations Conference on Environment and Development
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
URMP	Urban River Management Plan
USA	United States of America
USD	United States Dollar
WMAPSB	Water Management Association of the Paraiba do Sul River basin
WRI	World Resources Institute
WTP	Water Treatment Plant

Introduction

Since the industrial revolution, human activities have disrupted nature and natural processes. This has spiralled into an environmental crisis. Anthropogenic activities like urbanisation and industrialization have led to environmental degradation, the same reaching a sort of peak now. This has been exacerbated by climate change, the biggest crisis of the 21st century. Anthropogenic activities and climate change have thus created a condition of extreme biodiversity loss and degradation of ecosystem health and services.

Human induced global warming, at the current rate is projected to increase the temperature by 1.5°C by the year 2040[1]. Nature based Solutions offer holistic solutions to address this temperature rise and climate change and build climate resilience.

Origin of NbS

The formation of the United Nations Framework Convention on Climate Change (UNFCCC) and adoption of the Convention on Biological Diversity (CBD) at the United Nations conference on Environment and Development (UNCED), also known as the Earth Summit, held in Rio de Janeiro in 1992, emphasised on the need for mainstreaming sustainability into natural resource management. The findings of the Millenium Ecosystem Assessment (MEA)[2] made it evident that human actions have altered the functioning of natural ecosystems and significant policy level changes are needed to reverse the trend. Apart from familiarising the term ecosystem services, the MEA also highlighted the adverse impacts of indiscriminate use of ecosystem services by humans and emphasised on the need for taking adequate action against the harming trends. In the Paris agreement parties have been advised to achieve 'a balance between anthropogenic emissions from sources and removal of sinks of greenhouse gases in the second half of this century, advancing the need for use of nature to mitigate the effects of climate change.

NbS- Defining the Term

The concept of NbS was formulated by the International Union for Conservation of Nature (IUCN), and other organisations like the World bank and the European Commission (EC) in the late 2000s. In simple terms, NbS encompasses a large group of practices that are natural- implemented by harnessing the potential of nature and aim to protect the Earth's ecosystems. IUCN defines NbS as 'actions to protect, sustainably manage and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits'. Apart from protecting the natural environment, NbS are meant to provide sustainable solutions to communities and help reduce vulnerability to the drastic effects of climate change and other environmental threats.

The EC defines NbS as ´solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systematic interventions'. This definition was updated in 2020 to include that NbS must enhance the flow of ecosystem services and support biodiversity[3].

1. IPCC. Global warming of 1.50C. An IPCC Special Report on the impacts of global warming of 1.50C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threats of climate changes. 2018.
2. UN.2005. Millenium Ecosystem Assessment- Ecosystems and Human Well-being. Island Press. Washington DC.
3. Wild. T., Freitas. T., and Vandewoestijine, S. 2020. Nature based Solutions- State of the Art in EU- funded Projects.

NbS - The Principles

The conceptual framework of NbS considers the linkage between biodiversity and human well-being. IUCN has laid down 8 principles for the implementation of NbS. These are:

1. Embrace nature conservation norms (and principles)
2. Can be implemented alone or in an integrated manner with other solutions to address societal challenges (e.g., technological and engineering solutions)
3. Are determined by site-specific natural and cultural contexts that include traditional, local and scientific knowledge
4. Produce societal benefits in a fair and equitable way, in a manner that promote transparency and broad participation
5. Maintain biological and cultural diversity and the ability of ecosystems to evolve over time
6. Are applied at a landscape scale
7. Recognize and address the trade-offs between the production of a few immediate economic benefits for development, and future options for the production of the full range of ecosystem services, and
8. Are an integral part of the overall design of policies, and measures or actions, to address a specific challenge

NbS Approaches

Nature-based solutions are an 'umbrella concept' that can be implemented under the scope of a range of approaches[4]. To ensure effective NbS implementation, approaches have been properly defined by the IUCN. NbS approaches, also referred to as ecosystem-related approaches are segregated into five categories, which further comprises of specific sub-categories that are meant to refine the overall concept of NbS and its applications. It should be noted that this compendium follows the IUCN-based categorization of NbS approaches and their definitions. The different NbS approaches and their definitions as considered by the IUCN are summarised in the Table 1 below.

Table 1: NbS Approaches

NbS Approach	Type
Ecosystem restoration approach	Ecological restoration
	Ecological engineering
	Forest landscape restoration
Issue specific ecosystem-related approach	Ecosystem-based adaptation
	Ecosystem-based mitigation
	Ecosystem-based disaster risk reduction
Infrastructure-related approach	Natural infrastructure
	Green infrastructure
Ecosystem based management approach	Integrated coastal zone management
	Integrated water resource management

4. Cohen-Shacham, E., Walters, G., Janzen, C., and Maginnis, S. (eds.). 2016. Nature-based solutions to address global societal challenges. Gland. Switzerland. Doi: 10.2305/iucn.ch.2016.13.en.

NbS Approach	Type
Ecosystem protection approach	Area-based conservation approach including protected area management

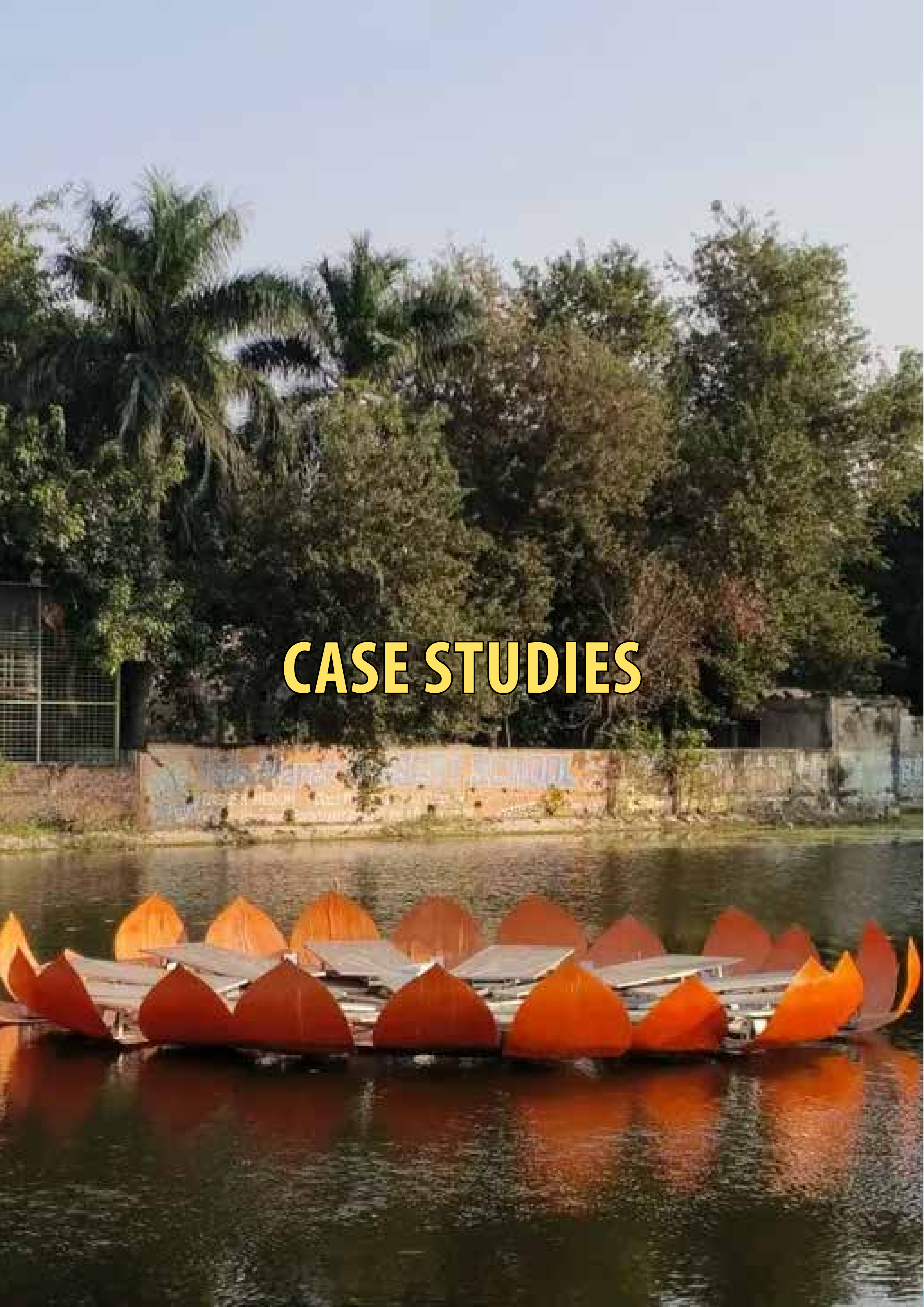
About this Compendium

This compendium focusses on water body restoration using Nature based Solutions. The compendium show cases 10 case studies on the same, from across the globe. The case studies provide a background of the situation, the issue, what NbS was used and the results of the same. Each case study also has a section on who can be contacted for more details. The case studies provided in the compendium are summarised in Table 2.

Table 2: Case Studies in the Compendium

S. No.	Name of the initiative	City	Country	Date started	Date completed
1.	Rejuvenating Annapurna Lake	Indore	India	2019	Ongoing
2.	Baburail Canal Restoration Project- A Holistic NbS Model	Narayanganj	Bangladesh	2017	2020
3	Treated Used Water for Indirect Potable Use Project, Devanahalli	Devanahalli	India	2017	Ongoing
4	Cache la Poudre River Restoration – Using NbS to support DRR	Fort Collins	USA	2010	2015
5	Kham River Restoration Mission: Bringing Alive a Dead River	Chhatrapati Sambhajinagar	India	2016	Ongoing
6	Neela Hauz Biodiversity Park- Restoring and Transforming a Wetland into a Biodiversity Park	Delhi	India	2015	2016
7	Ancash, Cusco and Lima Regions, Peru- Glaciares+ Project: Sustainable Watershed Management	Ancash, Cusco and Lima	Peru	2011	2019
8.	Rio Clare, Brazil: PES as a Nature based Solution for Watershed Restoration	Rio Claro	Brazil	2009	Ongoing
9.	Scaling Urban Nature-based Solutions for Climate Adaptation	Johannesburg	South Africa	2024	Ongoing
10.	Tampara Wetland: Ecosystem-based Disaster Risk Reduction based Restoration	Chatrapur	India	2019	2022

CASE STUDIES



CASE STUDY

Photo Credit: Clean Water

Rejuvenating Annapurna Lake

Indore, India

City Profile and Key Information

Local Government Name (in English)	Indore Municipal Corporation (IMC)
Official Name (in original language)	Indore Nagar Nigam
Country	India
State/Province	Madhya Pradesh
Population (two adjacent fields: numerical field + year field) + if available: Population growth (annual %)	1,964,086 (2011); 3.3% (annual population growth)
Total Area	530 km^2
Main geography type: India	Coastal, Dryland, **Highland**, Lowland, Mega delta, Small island

Overview

Indore, the largest city in the state of Madhya Pradesh in central India, sits on the Malwa plateau at an average elevation of 553 metres[5]. With a population of 1.96 million in 2011 and sustained annual growth of approximately 3.3%, the city has undergone rapid spatial expansion and industrialisation over the past two decades. The terrain is largely flat, with scattered hillocks, and the climate ranges from humid subtropical to tropical wet-and-dry conditions, with strong seasonal variations.

While Indore has gained national recognition for its solid waste management, its urban water systems have been under increasing stress. Untreated sewage inflows, waste dumping, encroachment, and nutrient loading have degraded several lakes and rivers, including the Kanh and Saraswati rivers. Rising temperatures and irregular rainfall patterns further compound water insecurity and ecological stress.

In this context, restoring degraded waterbodies in the city is not only an environmental priority but also a climate resilience and public health imperative. Annapurna Lake emerged as a critical test case for whether small urban lakes could be rehabilitated through integrated, cost-effective approaches.

5. NIC (2025). About District. District Indore. National Informatics Centre, Ministry of Electronics & Information Technology, Government of India. https://indore.nic.in/en/about-district/. Accessed on 31 December 2025.

Problem Statement

Located near the Annapurna Temple, the 2.5-acre Annapurna Lake had experienced prolonged degradation due to untreated sewage entering the lake through two active inflow channels, while domestic waste and religious offerings accumulated from daily activities around the temple.

Nutrient-rich inflows caused eutrophication and the rapid spread of invasive aquatic plants, particularly water hyacinth, on the lake's surface, blocking sunlight, and disrupting aquatic life. As decomposition intensified, Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) increased, further depleting dissolved oxygen (DO) and destabilising the aquatic ecosystem.

By 2023, the water quality had deteriorated sharply, with DO levels falling to about 2.3 mg/l, far below the levels required to sustain aquatic life. BOD and COD increased to about 20 mg/l and 68 mg/l, respectively, indicating severe organic pollution and oxygen depletion. Approximately 70,000 fish died in a mass mortality event, and the lake emitted persistent foul odours.

The lake's degradation led to biodiversity loss, reduced the recreational use and aesthetic value of the lake-temple precinct, and increased the risk of downstream contamination.[6] All these challenges highlighted the need for urgent intervention to revive the lake's ecosystem.

Objectives

The Annapurna Lake restoration initiative was conceived as a demonstration of how hybrid nature-based solutions (NbS), supported by targeted technology, could reverse ecological degradation in small urban lakes.

NbS, such as floating wetlands, aeration systems, and microbial remediation, offer cost-effective and sustainable alternatives to conventional engineering by working with natural processes to restore water quality, ecological balance, and ecosystem services.

The Annapurna Lake initiative adopted this integrated NbS approach to improve the lake's water quality, revive aquatic ecosystems, enhance its social and environmental value, moderate microclimatic conditions, and raise awareness among people about the importance of water conservation and management.[7]

The objective was to restore ecological function while keeping long-term operational costs manageable.

Implementation Architecture

The intervention strategy was based on three assumptions: nutrient and organic load reduction would stabilise DO levels; improved oxygenation would enable the recovery of aquatic biodiversity; and ecological recovery would restore social, cultural, and microclimatic functions of the lake.

---

6. Tiwari, C. (2024). From pollution to preservation: Reviving Indore's Annapurna Lake. https://www.groundreport.in/water/from-pollution-to-preservation-reviving-indores-annapurna-lake-7603811/. Accessed on 7 January 2026.

7. Clean Water (2025). Annapurna Lake-Project Report-by Clean Water. https://clean-water.co.in/wp-content/uploads/2025/03/Annapurna-Lake-Project-Report.pdf. Accessed on 14 July 2025.

Following a baseline assessment, the project deployed five floating islands, four floating aerators, one floating lotus-shaped solar aerator, and regular dosing of beneficial microbial cultures[8].

- Floating wetlands were installed as biofiltration systems. Planted with wetland vegetation, these buoyant platforms facilitated phytoremediation and provided surfaces for microbial communities that metabolise organic pollutants. By absorbing nitrogen and phosphorus, the wetlands addressed nutrient overloading at its source[9].
- Mechanical aeration systems were deployed to immediately increase DO levels. Four floating aerators were complemented by a lotus-shaped solar-powered aerator equipped with an 18-panel solar array. The solar-powered system reduced dependence on grid electricity, mitigated operational risks such as cable theft, and integrated renewable energy into ecological infrastructure. By combining oxygenation with decentralised energy supply, the design improved operational reliability.
- Beneficial microbial cultures were introduced to accelerate the breakdown of organic matter and sludge accumulation. These microbial cultures competed with algae for nutrients, thereby limiting further eutrophication.

Complementary measures were taken to address the risk of re-pollution in the future. Boundary walls of the water body were raised to prevent encroachments and waste dumping; sewage bar screens were installed to block the entry of solid waste; water hyacinth was removed to maintain the lake's aesthetic value and ecosystem health; and educational posters on responsible waste disposal were developed.

Figure 1: Lotus shaped solar aerator in Annapurna Lake (Photo Credit: Clean Water)

8. Clean Water (2025). Annapurna Lake-Project Report-by Clean Water. https://clean-water.co.in/wp-content/uploads/2025/03/Annapurna-Lake-Project-Report.pdf. Accessed on 14 July 2025.
9. Arivukkarasu, D., & Sathyanathan, R. (2023). Floating wetland treatment an ecological approach for the treatment of water and wastewater-A review. Materials Today: Proceedings, 77, 176-181.

Governance and Partnerships

The restoration of Annapurna Lake was implemented through a collaborative governance structure that combined private innovation, academic expertise, municipal facilitation and corporate social responsibility financing. Approximately INR 4 million (approximately USD 44000) was mobilised through Indian Institutes of Technology at Kanpur and Ropar under corporate social responsibility initiatives supported by Citi Bank and HDFC Bank (Parivartan initiative).

The project's institutional architecture is summarised below.

Table 3: Institutional Roles in the Annapurna Lake Restoration

Stakeholder	Role
Clean Water (Sustainable Water Technologies Pvt. Ltd.)	Project design and on-ground implementation of floating wetlands, aerators and microbial treatment
IIT Kanpur and IIT Ropar	Technical guidance, R&D support and performance validation
Indore Municipal Corporation	Institutional facilitation, alignment with city priorities and Smart City framework
Citi Bank & HDFC Bank (CSR initiatives)	Project Financing
NABL-accredited laboratories	Independent water quality testing and verification

The partnership structure enabled technical oversight, secured external financing, and ensured alignment with municipal priorities.

Outcomes and Impact

The Annapurna Lake rejuvenation delivered clear outcomes that demonstrated the effectiveness of NbS for urban waterbody restoration.

Ecological outcomes: The table below summarises laboratory results recorded two months after implementation in 2023.

Monitoring during the first three months recorded a reduction of 0.175 tonnes of methane emissions, equivalent to approximately 5 tonnes of CO_2.

The project evaluated results through a combination of water quality, ecological and social indicators. Water transparency also improved as higher Secchi measurements confirmed, while the disappearance of foul odours indicated qualitative recovery. Fish and bird populations returned, indicating restoration of ecological functions. Local residents resumed recreational use of the lake and demonstrated stronger community stewardship.

The table below shows the water quality parameters measured two months after the implementation of NbS.

Table 4: Results of Water Quality Assessment two months after implementation of NbS[10]

Parameter	Safe limits	Test results
Nitrate as NO_3 (mg/l)	<45	BDL
Nitrite as NO_2 (mg/l)	<30	BDL
Total Suspended Solid (TSS) (mg/l)	<500	26
Biochemical Oxygen Demand (mg/l)	<10	2.5
Dissolved Oxygen (mg/l)	>5	6.7
Phosphorous (mg/l)	<4.5	BDL

Note: BDL = Below Detection Level

Environmental and socio-economic impacts: The project created short-term livelihood opportunities linked to installation, maintenance and associated activities, supporting approximately 50 local families.

Improved water clarity and elimination of foul odours restored the lake's usability as a public space within a dense residential neighbourhood adjoining the Annapurna Temple complex. The improved environmental conditions reinstated the lake's cultural and recreational function.

While long-term socio-economic effects require further monitoring, the initiative shows that targeted ecological restoration can improve environmental conditions in dense urban neighbourhoods.

The visible recovery of the lake increased local interest in maintaining the site. Local awareness campaigns were followed by improved waste management practices around the lake perimeter.

For its efforts to restore Annapurna Lake and other lakes, the Ministry of Jal Shakti, Government of India, awarded Clean Water the title of "Water Hero".

Figure 2: Annapura Lake- before and after restoration (Photo Credit: Clean Water)

10. Clean Water (2025). Annapurna Lake-Project Report-by Clean Water. https://clean-water.co.in/wp-content/uploads/2025/03/Annapurna-Lake-Project-Report.pdf. Accessed on 14 July 2025.

Challenges and Gaps

Despite improvements in water quality and ecological recovery, several structural gaps remain. The project did not institutionalise structured capacity-building programmes for municipal staff or local stakeholders, which may continue in the long term. No formal ecosystem service valuation was conducted before or after restoration, limiting assessment of long-term economic and climate benefits.

Regular maintenance of aerators and floating islands, especially during extreme weather, was a challenge. Regulatory enforcement and interception measures need to be strengthened to control continued sewage inflows.

Future initiatives should institutionalise long-term monitoring to strengthen regulatory enforcement, include ecosystem service assessment, and integrate capacity-building to ensure sustainability.

Figure 3: Annapurna Lake before and after restoration (Photo Credit: Clean Water)

Lessons and Way Forward

The Annapurna Lake restoration shows that effective urban lake rejuvenation must address underlying biochemical drivers rather than relying solely on surface cleaning. Early baseline assessment of nutrient load and DO was critical for designing an effective lake rejuvenation plan.

The sequencing of hybrid interventions was important. Mechanical aeration provided rapid oxygen stabilisation, while floating wetlands and microbial cultures reduced nutrient loads and organic accumulation over time. This combination allowed visible improvement within months while supporting longer-term ecological recovery.

Independent laboratory verification increased technical credibility and improved decision-making.

Regular monitoring of water quality and biodiversity helped the team to track progress and adjust interventions where necessary. Engagement with the local community and awareness efforts encourage more responsible behaviour around the lake and increased community participation in protecting it.

The restoration of the lake's ecological balance through the planting of native vegetation supported biodiversity and expanded green cover. The combination of aeration for immediate oxygen recovery and floating wetlands for nutrient reduction enabled visible improvement within two months.

The model is particularly suited to small lentic waterbodies (2-5 acres) where nutrient loading and oxygen depletion are primary causes of degradation. Interventions should be adapted to local hydrological and pollution contexts rather than directly replicated. Replication requires site-specific baseline assessment, multidisciplinary technical expertise, and financing structures that incorporate long-term operation and maintenance.

Key Contacts

Name	Priyanshu Kumath, CEO and Founder
Organization	Clean Water
Address	"Clean-Water" 87, Aashirwad Villas, Opposite D-Mart, Indore, Madhya Pradesh-452010, India
Phone with international and national area code	+91 91 7999454226, 9769302930
Website	https://clean-water.co.in/
Email address (preferably not personal address)	priyanshu@clean-water.co.in

CASE STUDY


Photo Credit: Narayanganj Municipal Corporation

Baburail Canal Restoration Project – A Holistic NbS Model

Naryanganj, Bangladesh

City Profile and Key Information

Local Government Name (in English)	Narayanganj City Corporation (NCC)
Official Name (in original language)	নারায়ণগঞ্জ সিটি কর্পোরেশন
Country	Bangladesh
State/Province	Dhaka Division
Population (two adjacent fields: numerical field + year field) + if available: Population growth (annual %)	967,724 (2022); Annual population growth: 2.42%
Total Area	72.43 km^2
Main geography type: India	Coastal, Dryland, Highland, **Lowland**, Mega delta, Small island

Overview

Narayanganj, located approximately 17 km southeast of Dhaka, is an industrial city situated between the Shitalakshya and Buriganga Rivers, in Central Bangladesh. Covering 72.43 km^2 in area, and home to 967,724 people (2022 census), the city has experienced rapid industrialisation and high-density expansion.

Located on low alluvial terraces 1-10 metres above adjacent floodplains, and receiving about 2376 mm of rainfall annually, the city is highly exposed to monsoon flooding. Industrial growth, particularly in garments, textiles, rice, steel and engineering, aluminium, jute and sugar, combined with unplanned development, has led to encroachment of water bodies, conversion of wetlands, loss of green space and increased heat stress, exacerbated by climate change. Since 2011, large tracts of agricultural land, waterbodies and vegetation, particularly in Kadamrasul and Siddirganj areas, have been converted into industrial and residential establishments.

The Shitalakshya River forms a critical transport and trade corridor and is widely regarded as the city's lifeline. The city also has an extensive network of canals as well as low-lying swamps and marshes. Over time, sections of this canal network became degraded due to encroachment, sewage discharge and industrial effluents, reducing their drainage and ecological function.

Problem Statement

The Baburail Canal (also known as Baburail and Jhelepara Bangla Bazaar Canal), is a 2.8-km-long and 15-30 m-wide canal that historically connected the Shitalakhya River with the Dhaleshwari River in the west, and served as an important east-west waterway, with seasonal bidirectional flow. It also connected the Jimkhana Lake near the Shitalakhya River.

Over time, however, the canal's width narrowed due to unchecked siltation, waste dumping, and encroachment, and its connectivity with rivers was disrupted. As channel depth and width reduced, the canal's ability to convey stormwater reduced. Foul odours, mosquito breeding, waterlogging during monsoon and declining environmental quality affected adjacent neighbourhoods. Reduced conveyance capacity increased flood vulnerability in an already low-lying and climate-exposed urban area.

Rapid population growth, industrialisation, unplanned and rapid development and lack of governance further amplified the problem. Given Narayanganj's rapid urban growth and vulnerability to flooding and heat stress, restoring the Baburail Canal as a functional waterway and public space emerged as an urgent priority.

Objectives and Strategy

The Baburail Canal Restoration Project sought to:

- Restore hydrological connectivity between rivers;
- Improve stormwater drainage and reduce waterlogging ;
- Remove illegal encroachments and establishments;
- Improve environmental quality and biodiversity;
- Protect the city's historic waterway character.

Instead of treating the canal solely as drainage infrastructure, the project aimed to restore it as a functioning water corridor that could support hydrological, ecological and public space functions together. The intervention also provides a reference model for restoring degraded urban canals in comparable flood-prone cities.

Implementation

The project adopted a hybrid restoration strategy that combined engineering works and NbS. It focused first on restoring hydraulic capacity, then on stabilising the structure and finally on integrating public space.

Hydrological Recovery: Approximately 63,063 cubic metres of earth were excavated to restore the canal's depth and width along its 2.8 km stretch to improve water flow. Sluice gates were installed at both ends of the canal to regulate water levels and control flows during the monsoon.

Structural Stabilisation: To stabilise the slope and reinforce the structure, a combination of natural and conventional construction materials was employed. Soil-based treatments and geotextiles were used alongside concrete, stone, steel and piping systems to improve bank stability and permeability.

Encroachment removal: Encroached land was reclaimed and illegal structures were removed to restore the canal corridor. Adjacent roads and lanes were widened to improve accessibility and reduce pressure on the canal edge.

Public Space Improvements: Walkways were constructed along both banks, and seven pedestrian bridges and nine vehicular bridges enhanced cross-connectivity. Public amenities, including viewing decks, seating areas, lighting, toilets and drinking water facilities, were installed to encourage use of the space. Landscaping and the planting of 1,150 native trees at six-metre intervals increased shading and green cover. Stormwater drains were constructed to improve runoff management from adjacent areas. The canal was integrated into the broader drainage network, enabling it to function as a stormwater conveyance system.

Figure 4: Bird's eye view of Baburail Canal (Photo Credit: Narayanganj Municipal Corporation)

Governance and Partnerships

The Baburail Canal Restoration Project was implemented under the leadership of NCC, which held overall responsibility for planning, land management and execution. The initiative combined municipal authority, national technical oversight and international development financing to restore a strategically important urban waterway.

The project was financed by the International Development Association of the World Bank under the Municipal Governance and Services Project (MGSP), with a total investment of BDT 2,302,163,325.92 (approximately USD 21 million). The institutional roles are summarised below.

Table 5: Institutional Roles in the Baburail Canal Restoration

Stakeholder	Role
Narayanganj City Corporation	Project leadership, land recovery, planning and implementation
Local Government Engineering Department	Technical supervision under MGSP
International Development Association (World Bank)	Project financing
Vitti Sthapati Brindo Ltd.	Environmental and social safeguard studies (EIA, SIA, RAP) and design support
Local communities	Participation in consultations and resettlement processes

Outcomes and Impact

The restoration produced visible changes in hydraulic performance, environmental condition and public use of the canal corridor.

Ecological Outcomes: The restoration of 2.8 km of Baburail Canal reconnected it with the Shitalakhya and Dhaleshwari Rivers, re-establishing its hydrological function. Canal re-excavation and slope stabilisation increased channel depth and width, improved water flow and drainage capacity, and reduced waterlogging in adjacent areas, particularly during monsoon periods. While no hydrological modelling data is publicly available, municipal records indicate reduced seasonal waterlogging complaints in adjacent wards following restoration. The installation of sluice gates improved the regulation of seasonal flows.

Environmental conditions along the corridor improved visibly. Planting of 1,150 native trees at 6-metre intervals increased green cover. Improved flow and cleaner surroundings reduced foul odours and mosquito breeding.

Social and Community Outcomes: The restored canal corridor now has walkways, lighting, viewing decks and seating areas. Public amenities have increased accessibility, safety, and use throughout the day. Residents increasingly use the corridor for walking, jogging, leisure, and social interaction, improving neighbourhood liveability. Visible environmental improvements and consultation processes strengthened public awareness and contributed to improved civic behaviour related to waste disposal and canal protection.

Economic and Institutional Outcomes: Improved environmental quality and accessibility along the canal corridor stimulated local economic activity. NCC reported increased applications for business licenses in surrounding areas, along with rising property values near the canal. During implementation, the project generated temporary employment for local labourers and contractors.

A cost-benefit analysis of the project showed that the economic returns outweighed the costs.

Institutionally, the project strengthened coordination between NCC, LGED, and development partners and enhanced the NCC's capacity to plan and implement integrated urban waterway restoration projects. It received the Asian Townscape Jury Award in 2016 and the "Smart City, Smart Concept" Award in 2017, recognising its contribution to urban waterway restoration.

The project assessed performance using qualitative and quantitative indicators, including canal mapping, physical measurements of restored sections, documentation of plantation, cost-effectiveness analysis, stakeholder interactions, and community and media feedback. The intervention aligns with national water and climate planning frameworks and contributes to broader ecosystem restoration and urban resilience goals.

Figure 5: Restored Baburail Canal with walkway (Photo Credit: Narayanganj Municipal Corporation)

Gaps and Areas for Improvement

While the canal has been physically restored, long-term sustainability depends on continued management and enforcement.

Upstream waste discharge continues to pose risks. Without consistent enforcement and maintenance, there is potential for gradual re-pollution.

Dedicated budget provisions for operation and maintenance need to be secured over time.

Eviction and resettlement processes, though guided by safeguards, were socially sensitive. Future initiatives would benefit from stronger livelihood transition planning and earlier community engagement.

Systematic post-restoration monitoring of biodiversity, sedimentation and water quality has yet to be institutionalised, limiting the ability to track long-term ecological performance.

Lessons and Way Forward

The Baburail Canal restoration highlights several lessons relevant to canal recovery in dense, industrial cities.

Restoring the canal was not just an engineering task; it required governance authority and coordination. Without clear land control and administrative backing of the NCC, technical interventions alone would not have been sufficient.

The project also shows that canal restoration works best when structural repairs and nature-based elements are implemented together. Re-excavation and slope stabilisation quickly restored water flow and drainage capacity. At the same time, tree planting, landscaping and development of public spaces helped change how residents used the canal. The environmental improvements make the interventions visible and socially accepted.

Environmental improvements in drainage and public space also stimulated commercial activity, demonstrating that ecological investment can support economic objectives. Rising property values and increased business licence applications suggest that environmental upgrades can contribute to municipal revenue and local livelihoods.

However, long-term sustainability will depend on continued maintenance and monitoring. Without regular desiltation, waste management enforcement and upkeep of public amenities, physical improvements can gradually deteriorate. Dedicated budget allocations for maintenance need to be secured within municipal planning cycles.

Future canal restoration efforts in Narayanganj should prioritise three areas: institutionalised monitoring systems, secured maintenance financing, and deeper community participation in long-term management. Projects of similar scale typically require three to five years for planning, land clearance and stabilisation, and should integrate resettlement, environmental safeguards and stakeholder engagement from the outset.

Key Contacts

Name	Md. Asgor Hossain
Department	Superintending Engineer, Engineering Department
Organization	Narayanganj City Corporation
Address	10 BB Road, Nagar Bhavan, Narayanganj
Phone with International and National Area code	+880 1816-016924
Website	www.ncc.gov.bd
Email Address	se@ncc.gov.bd

CASE STUDY


PhotoCredit:https://youtu.be/uVNiX-zysTI?si=KuktU3lO3kpUSBWK

Treated Used Water for Indirect Potable Use Project

Devanahalli, India

City Profile and Key Information

Local Government Name (in English)	Devanahalli Town Municipal Council
Official Name (in original language)	Devanahalli Town Municipal Council
Country	India
State/Province	Karnataka
Population (two adjacent fields: numerical field + year field) + if available: Population growth (annual %)	28051 (2011); (annual population growth: NA)
Total Area	15.94 km^2 as per Census of 2011
Main geography type: India	Coastal, Dryland, **Highland**, Lowland, Mega delta, Small island

Overview

Devanahalli is a rapidly growing town, located about 35 km north of Bengaluru, one of India's fastest-growing metropolitan regions.[11] With a population currently estimated at 40,000, the town has expanded rapidly due to its proximity to major infrastructure corridors, including the Kempegowda International Airport.

The town lies in the Southern Maidan Region in Bengaluru Rural District, characterised by undulating terrain and mild to moderate drought conditions. With no perennial rivers, Devanahalli has historically depended on groundwater, lakes (keres), open wells and step wells (kalyanis) for domestic water supply. Two lakes, Sihineeru kere (Sweet Water Lake) and Doddadda ammani kere (Very Big Lake) form the backbone of this hydrological system.[12]

Over time, catchment degradation, reduced inflows into these water bodies, and urban expansion weakened their recharge function. With increasing groundwater abstraction, shallow aquifers declined and borewells were drilled deeper.

11. GoK (2026). Bengaluru Rural Countryside charm near Bengaluru city. Department of Tourism, Government of Karnataka (GoK). https://karnatakatourism.org/en/destinations/bengaluru-rural. Accessed on 12 January 2026.
12. BET (2026). Devanahalli and its water: Then and Now. Biome Environmental Trust (BET). https://biometrust.org/devanahalli-and-its-water-then-and-now/. Accessed on 13 Jan 2026.

Problem Statement

Devanahalli traditionally relied on about 100 old borewells, the depths of which increased from around 800 feet to more than 1500 feet – and in some cases 2000 feet -- within two decades. Water quality deteriorated, particularly due to high dissolved solids, leading many households to rely on private reverse-osmosis systems for drinking water. The reliability of the water supply declined, with some wards receiving water once every 10-15 days.

This supply model proved financially and environmentally unsustainable as deep groundwater extraction required high energy input, borewell yields declined, salinity increased, and water supply frequency was irregular.

Meanwhile, local lakes such as Sihineeru kere had lost much of their hydrological function due to catchment degradation and irregular inflows. The town was increasingly dependent on deep extraction while its traditional recharge systems remained underutilised.

The absence of a reliable surface water source and increasing aquifer stress necessitated a fundamentally different approach that focused on restoring local water bodies, recharging shallow aquifers, and reducing reliance on deep groundwater extraction.

Objectives

The Treated Used Water for Indirect Potable Use Project aimed to strengthen water security in Devanahalli by reusing treated wastewater to recharge shallow aquifers. The initiative was part of the larger Hebbal-Nagawara Valley (HNV) project, which diverts about 210 million litres per day (MLD) of treated wastewater from Bengaluru to replenish 65 lakes across Bengaluru Urban, Rural and Chikkaballapur districts.

Specifically, the Devanahalli project sought to: replenish shallow aquifers through Managed Aquifer Recharge (MAR) and Soil Aquifer Treatment (SAT); restore Sihineeru kere and associated open wells as functional recharge systems; reduce abstraction from deep borewells; provide a supplementary potable water source that meets the Bureau of India Standards (BIS) 10500 benchmark for safe drinking water; and demonstrate a safe model of indirect potable reuse for drought-prone, groundwater-dependent towns.

The initiative was not designed to replace conventional supply entirely, but to create a resilient buffer within the town's water system.

Implementation Approach

The project applies MAR combined with SAT to convert treated wastewater into a reliable domestic water source.

Under the initiative in Devanahalli, treated wastewater is:

- Pumped from a sewage treatment plant to Bagalur Lake for dilution with rainwater;
- Directed onward to Sihineeru kere in Devanahalli;
- Allowed to percolate through the lakebed and surrounding soil, naturally filtering through subsurface layers (SAT);

- Recovered from shallow aquifers via open wells and filter borewells; and
- Subjected to tertiary treatment (filtration, UV disinfection, chlorination) before supply.

Rather than direct potable reuse, the system introduces treated wastewater into the natural hydrological cycle, using the lake and aquifer as an intermediate buffer before engineered treatment.

The first steps were taken between 2017 and 2018, when Sihineeru kere was desilted. A significant shift occurred in 2021 when treated wastewater from the HNV project began entering the lake. As the lake refilled, shallow aquifers started to recover. In August 2021, a degraded open well was rejuvenated with the help of traditional well diggers from the Mannu Vaddar community, combining local craftsmanship with hydrogeological planning. Prior to potable use, the Indian Institute of Science, Bengaluru, tested the water quality to ensure its was free of heavy metals and pesticide contamination.

Only after these hydrological and quality safeguards were established did the system move into structured implementation phases.

Phase 1 (April 2023 – March 2024): Two filter borewells were installed to abstract recharged shallow groundwater. A water treatment plant (WTP) was established to provide tertiary treatment in compliance with BIS 10500. Initial supply reached approximately 250 kl per day.

Phase 2 (June 2024 – October 2024): Four additional filter borewells were integrated into the system. A higher-capacity WTP (20 m^3/hour) increased the total supply to 640 KL per day, meeting around 12% of the town's water demand.

Phase 3 (Ongoing): The model is being extended to Doddadda kere, with additional shallow borewells under development. Flow meters have been installed to monitor daily abstraction and ensure controlled extraction from recharged aquifers.

Governance and Partnerships

The Devanahalli initiative, led by Devanahalli Town Municipal Council, brought together civil society facilitation, scientific validation, treatment technology providers, philanthropic financing and traditional groundwater knowledge.

Biome Environmental Trust developed and coordinated the aquifer recharge and reuse strategy. Boson Whitewater provided tertiary treatment to meet BIS 10500 drinking water standards. The Indian Institute of Science (IISc), Bengaluru supported water quality validation prior to potable use. Traditional well diggers from the Mannu Vaddar community restored the degraded open well, contributing practical expertise in shallow aquifer systems.

Corporate Social Responsibility (CSR) and philanthropic partners supported implementation and research, while relevant state and district authorities provided regulatory oversight.

Figure 6: Bagalur Lake (Photo Credit: https://youtu.be/uVNiX-zysTI?si=KuktU3I03kpUSBWK)

Institutional Roles

Stakeholder	Role
Devanahalli TMC	Municipal lead and integration into supply system
Biome Environmental Trust	System design and facilitation
Boson Whitewater	Advanced treatment and potable compliance
IISc Bengaluru	Water quality testing and validation
EFI	Lake desiltation (early phase)
Mannu Vaddar well diggers	Open well restoration
CSR & research partners	Financial and research support

Outcomes and Impact

Hydrological and Ecological Outcomes: The revival of Sihineeru kere (17 acres) and the restoration of the adjacent open well reactivated Devanahalli's shallow aquifer system. Once treated wastewater under the HNV programme began entering the lake in 2021, lake storage stabilised and percolation into surrounding aquifers resumed. The recharge helped revive a degraded open well and enabled the installation of shallow filter borewells at 80- and 100-feet depth, which helped reduce reliance on deep borewells. By restoring shallow groundwater, the project reduced pressure on these stressed borewells and mitigated salinity risks.

Improved water retention in the lake supported the return of aquatic life and stabilised the ecological condition of the tank system, which had previously experienced seasonal drying.

Water Supply Outcomes: Following tertiary treatment (filtration, UV disinfection and chlorination) to BIS 10500 standards, the system now supplies approximately 640 kilolitres (KL) of potable water per day. During the initial operational period (189 days up to February 2024), 30,104 KL of treated water was supplied.

Source	Volume Supplied (KL)
Filter borewell (near lake)	5,348
Filter borewell (near old house)	6,637
Open well	18,119
Total	**30,104**

This accounts for roughly 12% of Devanahalli's daily demand. While it is not a complete replacement for existing sources, it provides a meaningful supplement to the municipal supply.

The impact on distribution reliability has been significant. Wards that earlier received water once every 10-15 days now receive a supply every 2-3 days. This has reduced household dependence on private tankers and RO systems, which had charged ₹5 per 20 litres due to high total dissolved solids in borewell water.

The shift from deep pumping to shallow aquifer abstraction also has energy implications. Extracting water from 80-100 feet requires considerably less energy than pumping from depths exceeding 1,500 feet, improving operational efficiency over time.

Institutional and Behavioural Outcomes: The initiative changed local perceptions of wastewater. Treated sewage is now treated as a managed input into the town's water cycle. Scientific validation by IISc Bengaluru and compliance with drinking water standards were central to building trust.

Devanahalli has become a demonstration site for indirect potable reuse through MAR and SAT methods. The model has attracted further research funding from the Department of Science and Technology to assess system performance and explore replication.

The project also strengthened collaboration between civil society, municipal authorities, scientific institutions, CSR partners and traditional well diggers, linking technical systems with local groundwater knowledge.

Gaps and Areas for Improvement

However, despite the gains, several gaps remain that should be addressed.

The intervention currently operates at a limited scale. Even at 640 kl/day, the system supplies only a fraction of municipal requirements. Scaling will require additional infrastructure, sustained financing and long-term institutional ownership.

The system depends on continued inflow of treated wastewater under the HNV programme. Any disruption in upstream treatment quality or supply volumes would affect the recharge function. This dependency needs to be formally recognised in long-term planning.

A detailed cost-benefit analysis was not undertaken prior to implementation. A systematic economic evaluation would strengthen the case for replication in other towns. Also, long-term financial sustainability has not yet been institutionalised within municipal budgeting.

While every effort is made to meet BIS standards, continuous and publicly accessible monitoring mechanisms should be established to strengthen transparency and public confidence.

Finally, incorporating ecological pre-treatment measures such as constructed wetlands may improve long-term system resilience.

The success of the project was measured through water quality monitoring, adherence to water quality standards such as BIS 10500, volume of treated water supplied to the residents of Devanahalli, number of beneficiaries, energy saved and cost-effectiveness of the initiative, reduced dependence on deep borewells and dimensions of waterbodies rejuvenated.

Figure 7: Tertiary treatment (Photo Credit: https://thebetterindia.com/373474/bengaluru-water-solutions-stp-treated-lake-rejuvenation-devanahalli-biome-environmental-trust-boson-whitewater/)

Lessons and Way Ahead

The Devanahalli project shows that restoring water security required reconnecting the town's lake, wells and shallow aquifers rather than continuing to deepen borewells. The revival of Sihineeru Lake led to aquifer recharge, enabling shallow water extraction.

The project also shows that natural filtration alone is not sufficient for potable use. Soil Aquifer Treatment improved water quality as water percolated through the lake bed and soil layers, but the drinking water supply was introduced only after tertiary treatment, laboratory testing and confirmation of compliance with BIS 10500 standards. Early testing by IISc to check for heavy metals and pesticides was important before scaling up the supply. Continuous monitoring and installation of flow meters helped build confidence in the system.

The restoration of the old open well highlights the role of traditional knowledge. The involvement of the Mannu Vaddar well-digging community supported practical decisions on siting and restoration, showing that older groundwater practices remain relevant in modern water supply systems.

Another clear lesson is that this type of intervention takes time. Initial desiltation took place in 2017–18. Recharge through HN Valley inflows began in 2021. Potable supply from shallow aquifers started in 2023 and expanded in 2024 to 640 kl per day. The gradual progression allowed water levels to stabilise, quality to be tested and infrastructure to be strengthened before increasing supply. Similar projects in other towns would need phased implementation and sustained technical oversight rather than one-time infrastructure installation.

Looking ahead, scaling up would require secure operation and maintenance funding, continued water quality monitoring, trained municipal staff, and additional recharge points. Reducing reliance on a single upstream inflow will also be important for long-term stability.

Overall, Devanahalli shows that groundwater-dependent towns can reduce pressure on deep borewells by restoring lakes, recharging shallow aquifers and combining natural processes with engineered treatment. The approach is feasible, but it depends on careful sequencing, monitoring and sustained municipal commitment.

Key Contacts

Name	Avinash Krishnamurthy
Department	Co-Founder and Director
Organization	Biome Environmental Trust
Address	264, 6th Main, 6th Block, BEL Layout, Vidyaranyapura, Bengaluru 560097, Karnataka, India
Phone with international and national area code	+91 80 4167 2790 / 2364 4690
Website	https://biometrust.org/
Email address (preferably not personal address)	avinash@biome-solutions.com; water@biome-solutions.com

CASE STUDY

Photo Credit: Colorado Riparian Association

Cache la Poudre River Restoration – Using NbS to support DRR

Fort Collins, Colorado, USA

City Profile and Key Information

Local Government Name (in English)	Fort Collins City Council
Official Name (in original language)	City of Fort Collins
Country	United States of America (USA)
State/Province	Colorado
Population	174,871 (2020)
Total Area	148.04 km^2
Main geography type: India	Coastal, Dryland, Highland, **Lowland**, Mega delta, Small island

Overview

Fort Collins is a mid-sized city in northern Colorado, located at the foothills of the Rocky Mountains along the Cache la Poudre River. With a population of approximately 174,871 (2020), the city serves as a regional economic hub supported by a diverse business base.

The city experiences a semi-arid to continental climate with relatively low annual precipitation and marked seasonal variability. The Cache la Poudre River is the primary surface water body flowing through Fort Collins, receiving water from snow melt and periodic intense rainfall events. These conditions make the river central not only to the city's water supply and ecology, but also to flood risk management.

The river has historically supported settlement, agriculture, and economic development in the region. However, over time, channel modification, gravel mining, and urbanisation significantly degraded the river. Steep artificial banks, abandoned diversion structures, and altered hydrology reduced the river's capacity to reduce flood flows, disrupted sediment transport, and degraded local ecosystems.

Fort Collins has an established institutional framework for managing natural assets. The City's Natural Areas Department oversees more than 2,000 acres of river-associated natural areas and adopted the Cache la Poudre River Natural Areas Management Plan in 2011 to guide long-term ecological restoration and floodplain management. As the city continued to grow, and remained exposed to flooding from snowmelt and stormwater, restoring sections of the river became a priority.

Problem Statement

Fort Collins has experienced steady growth, accompanied by land-use change, and increasing environmental pressures, including deforestation, flooding, air pollution, invasive species and extreme heat. The growth of the city has also significantly altered the banks and floodplain of the Poudre River, weakening its natural functions.

The Poudre River Zone, which includes 22 natural areas covering about 2,011 acres, plays an important role in maintaining river health and supporting habitat. Historically, the river followed a dynamic flow pattern, with seasonal flooding that sustained wetlands, side channels, and riparian vegetation. Over time, human activities, including gravel mining and urbanisation, changed the river's natural form deepened sections of it, and confined it within steep, artificial banks. These changes reduced its connection with the surrounding floodplain, limiting seasonal overflow into wetlands and side channels.

The McMurry and Sterling Pond areas were particularly affected. Gravel extraction pits disrupted groundwater movement and left behind isolated water bodies. Riverbanks became steep and unstable, with uneven sediment movement. What had once been a connected river-floodplain system became fragmented.

These physical changes affected ecological functions. Wetlands lost some of their original capacity to support native species. These disturbed areas also became vulnerable to invasive species. At the same time, rising water demand for agricultural and domestic use also affected river hydrology and ecology. The Josh Ames Diversion Dam, last used in 1985, disturbed the river flow and impeded fish movement.

Figure 8: Poudre River Zone (Photo Credit: Colorado Riparian Association)

Flood management was another concern. Fort Collins sees peak flows from snowmelt and intense rainfall. When a river loses access to its floodplain, it cannot slow, store and spread floodwaters. Altered channels and mined areas limited the landscape's natural buffering capacity.

As a result, the river's connection to its floodplain weakened, increasing the risk of flooding in adjacent areas, thus underscoring the need to restore the degraded section of the Cache la Poudre River.

Objectives

The main objective of the Cache la Poudre River restoration project was to remove high, artificial banks created during gravel mining operations, restore the river's ecological function and reduce the risk of flooding and urban heat islands in Fort Collins through NbS. Key objectives included reconnecting the river to its floodplain, improving riparian and wetland habitats, restoring natural flow regimes, and enhancing public safety and access.

The project focused on restoring river processes rather than constructing new hard infrastructure. At a broader level, the initiative demonstrates how urban river restoration using NbS can support climate adaptation, disaster risk reduction, and sustainable urban development, aligning with international goals for ecosystem restoration and biodiversity.

Implementation

The Poudre River restoration consisted of two site-based interventions: McMurry Natural Area and Sterling Pond. Both were implemented under the Cache la Poudre River Natural Areas Management Plan (2011) and addressed physical alterations caused by historic gravel mining and river modification.

The work focused on reshaping steep riverbanks, reconnecting the river with its floodplain, creating wetland habitat in former gravel pits, removing obsolete diversion infrastructure, and revegetating disturbed riparian areas.

The McMurry Natural Area (18 hectares) includes an 800-metre stretch of the Cache la Poudre River and two adjacent gravel ponds. Steep riverbanks were lowered to reconnect the river with its floodplain. Concrete and buried debris were removed from the banks, and the channel margins were regraded to widen the riparian corridor. Two acres of wetlands were established within the former gravel ponds.

The riparian area was replanted with native wetland species, floodplain trees, and shrubs. Five vegetation zones were created: emergent wetland, wet meadow, willow, cottonwood, and upland grassland.

Sterling Pond covers a 600-metre stretch of the river, adjacent to artificial ponds created through historic gravel mining. The elevated riverbank was lowered to reconnect the channel with its floodplain and expand the riparian zone. Five acres of new vegetated wetlands were created within the pond area.

The abandoned Josh Ames Dam was removed. Approximately 150 metres of the river channel were modified, and sediment that had accumulated behind the structure was excavated and reused for upstream bank stabilisation.

Governance and Partnerships

The restoration was led by the City of Fort Collins Natural Areas Department, which coordinated planning and implementation. The effort combined municipal leadership with nonprofit facilitation and technical expertise.

Sterling Pond restoration was financed through local funding and a USD 300,000 grant from the Colorado Water Trust secured through the Colorado Water Conservation Board.

Institutional Roles in the Cache la Poudre River Restoration

Stakeholder	Role
City of Fort Collins Natural Areas Department	Project leadership, planning and implementation
Colorado Water Trust	Project facilitation, fundraising support
Colorado Water Conservation Board	Financial support for dam removal
Tessara Water LLC	Engineering and water resource consulting
Biohabitats	Ecological assessment, design-build support, monitoring and outreach
Budhoe's Backhoe LLC	Construction support

Outcomes and Impact

The restoration of the Cache la Poudre River focused on reversing the physical alterations caused by gravel mining, channel modification, and abandoned infrastructure. The outcomes are most visible in changes to river structure, floodplain connectivity, and habitat condition.

Physical and Ecological Changes: Approximately two kilometres of the river corridor, including its banks, were restored. More than 1,500 m of the river were reconnected to its floodplain, allowing high flows to spread into adjacent areas, restoring sediment movement.

At McMurry Natural Area, five vegetated zones were established: emergent wetland, wet meadow, willow, cottonwood, and upland grassland. Over five hectares of riparian floodplain forest were created, along with several hectares of wetlands. This included the planting of 1,200 trees, 25,000 shrubs, and 60,000 wetland grass plugs.

At Sterling Pond, five acres of new wetlands were created within former gravel ponds. The lowering of the high bank between the river and pond improved floodplain access and supported the establishment of a cottonwood forest.

The removal of the abandoned Josh Ames diversion structure restored uninterrupted river flow, eliminated a barrier to fish passage, and reduced safety risks associated with recreational float boating.

Reconnecting sections of the river to its floodplain and expanding wetland areas increased the space available for water during snowmelt and intense rainfall events. While no quantified flood reduction figures are provided in the source material, the physical restoration of floodplain access and removal of flow barriers directly addressed confinement of the river channel.

Figure 9: Area after restoration (Photo Credit: Colorado Riparian Association)

Social and Recreational Outcomes: Restoration work improved access to the river and nearby natural areas. Trails, fishing access points, and safer entry areas were incorporated into the design. Lowered banks and removal of hazardous structures improved public safety, particularly for float boating.

The restored corridor has become a more active recreational space, supporting outdoor activities and local tourism. Short-term employment was generated during implementation. The improved environmental conditions in the corridor have strengthened its role as a public natural area within the city.

Gaps and Areas for Improvement

Although the restoration achieved visible physical improvements, several limitations remain.

Only limited sections of the river corridor were restored. Large portions of the Poudre River within the city remain outside the scope of these interventions.

Long-term monitoring of water quality, hydrology, and ecological performance is not described in detail. Without sustained monitoring, it is difficult to assess changes in flood behaviour, biodiversity recovery, or temperature moderation over time.

While the project improved recreational access and habitat structure, the documentation does not provide quantified data on biodiversity gains, flood reduction, or economic benefits.

The funding base relied significantly on specific grants and local support. Accessing a wider range of national and international financing mechanisms could improve the project's scalability and resilience.

Lessons and Way Forward

The experience in Fort Collins demonstrates several practical lessons grounded in implementation.

Restoring floodplain access is central to improving river function. Lowering artificial banks and reconnecting more than 1,500 m of river to its floodplain directly addressed channel confinement caused by historic gravel mining.

Removing obsolete infrastructure can have multiple benefits. The removal of the Josh Ames diversion structure restored flow continuity, enabled fish passage, improved sediment movement, and reduced safety risks.

Wetland creation within former gravel pits offers a practical way to transform degraded mining landscapes into functioning riparian systems. At both McMurry and Sterling sites, wetland establishment increased habitat diversity and water storage capacity.

The integration of ecological restoration with public access improvements helped ensure that river recovery did not exclude community use. Recreational improvements strengthened public support for the project.

From a governance perspective, the 2011 Natural Areas Management Plan provided a structured framework that allowed incremental site-based restoration over several years (2010–2015). Multi-institutional collaboration — particularly between the City of Fort Collins, Colorado Water Trust, Colorado Water Conservation Board, and technical partners — enabled the combination of ecological design, engineering works, and funding mobilisation.

For future work, expanding restoration beyond the currently treated reaches would require:

- Sustained financing mechanisms,
- Long-term ecological and hydrological monitoring,
- Continued coordination across agencies, and
- Phased implementation over multi-year timelines.

The Fort Collins case shows that river restoration in an urban context can be implemented incrementally under an existing planning framework, using established construction techniques and ecological design principles. Its replicability depends less on new technology and more on land availability, institutional continuity, and long-term management commitment.

Key Contacts

Name	Rick Bachand
Department	Environmental Program Manager
Organization	Natural Areas Department
Address	Natural Areas Department, 1745 Hoffman Mill Road, PO Box 580, Fort Collins, CO 80522.
Phone with international and national area code	970-416-2183
Website	fcgov.com/naturalareas
Email address (preferably not personal address)	rbachand@fcgov.com

CASE STUDY


Photo Credit: Eco Sattva

Kham River Restoration Mission: Bringing Alive a Dead River

Chhatrapati Sambhajinagar, Maharashtra, India

City Profile and Key Information

Local Government Name (in English)	Chhatrapati Sambhajinagar Municipal Corporation (CSMC)
Official Name (in original language)	छत्रपती संभाजीनगर
Country	India
State/Province	Maharashtra
Population (two adjacent fields: numerical field + year field) + if available: Population growth (annual %)	1,175,116 (2011); 3.45% (annual population growth)
Total Area	141 km² but 138.50 km² as per Census of 2011
Main geography type: India	Coastal, **Dryland**, Highland, Lowland, Mega delta, Small island

Overview

Chhatrapati Sambhajinagar (formerly Aurangabad) is a rapidly growing city located in a semi-arid drought-prone region on the Deccan Plateau in the state of Maharashtra, India. It is an important, administrative, industrial and tourism hub, and is known internationally for its proximity to UNESCO World Heritage sites such as the Ajanta and Ellora caves.

The city lies along the seasonal Kham River, a tributary of the Godavari River. With a population of 1,175,116 (2011 Census) and an annual growth of 3.45%, Sambhajinagar faces increasing pressure on its limited water resources. Groundwater availability is constrained by the area's location on hard basaltic rock, characterised by low porosity and poor groundwater recharge potential. The city faced dual water challenges of seasonal flooding during the monsoon and chronic water scarcity during the dry months.

Problem Statement

Historically, the Kham River served as a vital source of drinking water through stepwells and aqueduct systems (neher), and supported irrigation, biodiversity, and cultural life. Over the past two to three decades, the river had deteriorated into a sewage-carrying drain, losing both ecological function and public relevance. Untreated sewage and solid waste flows had also affected the Godavari downstream.

Encroachment on the Kham River's riparian zones and unregulated sand mining further degraded the riverine ecosystem. The 14 km-long stretch of the river flowing through the city was degraded, with 7.73 km highly degraded.[13]

The polluted river posed severe ecological and human health hazards. Residents described the river as a "nallah," or drain, reflecting its transformation from a natural river into a waste channel. Blocked river channels increased the risk of flooding in the monsoon season. The emission of foul odour and spread of waterborne diseases affected nearby local communities, and reduced the aesthetic value of the riparian landscape.

The decline of the Kham River also reflected broader urban challenges, including weak waste management systems, limited public open spaces, and insufficient coordination among agencies responsible for water, sanitation, and land use. Addressing river degradation, therefore, required a systemic approach rather than isolated clean-up actions.

Objectives

In 2016, Varroc Engineering Ltd launched the Kham River Restoration Mission to restore and revitalise the river , with an initial aim to improve the aesthetic and environmental conditions of this critical gateway. In 2019, EcoSattva, an environmental organisation, joined the mission and brought a research-driven and systems-based approach that aimed to:

- Restore ecological health and flow of the Kham River within the urban stretch
- Reduce pollution through improved solid and liquid waste management
- Enhance urban resilience to flooding and water stress
- Reconnect communities with the river through accessible public spaces, and
- Establish a replicable, low-cost model for urban river restoration.

Implementation

The restoration strategy, therefore, combined pollution control with floodplain stabilisation and groundwater recharge considerations. Nature-based solutions (NbS) were adopted as the core approach, as conventional grey infrastructure alone was insufficient to address the multiple ecological, social, and hydrological challenges associated with river degradation.

The NbS approach emphasised restoring natural river functions, improving waste management at source, and reconnecting communities with the river.

BOTRAM: The restoration strategy was guided by an integrated "cleaning, greening, and place-making" framework and operationalised through EcoSattva's BOTRAM approach (Baseline Assessment; Onboarding and Orientation; Training and Route Mapping; Resource Recovery; Awareness Campaigns and Monitoring

13. Shin, J., Shalunkhe, M., and Kustar, A. (2024). By Restoring India's Kham River, a City Revives Its Cultural Legacy. World Resource Institute (WRI). https://www.wri.org/insights/khamriver-restoration. Accessed on 21 July 2025

and Maintenance). The methodology is meant to overhaul and systematise solid waste management , and is also used for water body restoration and climate action planning. The framework seeks to ensure that ecological restoration is sustained by systems thinking and community will, not just infrastructure.

Figure 10: Kham river before restoration (Photo Credit: EcoSattva)

EcoSattva first analysed the river's status, conducted micro- and macro-level research, including orthophotography drone surveys, to map garbage-vulnerable points (GVPs) and flood lines along the Kham River. In 2020, it developed a strategy focused on waste cleanup and dredging and in 2021, it developed 'Unnati Waste Management Services,' a commercial service for waste management that employed and empowered Safai Saathis (waste pickers).These workers had received professional training and were inducted formally by the urban local body. Furthermore, the sanitation staff not only helped to reduce the amount of waste entering the river but also increased public awareness of waste management practices.

Native trees were planted along the riverbank. The Municipal Corporation developed infrastructure to keep the river clean, such as barriers to block dumping, garbage traps and connections to the city's formal sanitation system.

Core interventions included:

- **Solid waste management:** Closure of GVPs, source segregation, plastic traps, training of sanitation staff, and improved collection systems were implemented.[14]
- **Liquid waste interventions:** Included sewage interception and diversion; decentralised greywater treatment pilots, soak pit demonstrations, and awareness campaigns on household waste discharge.
- **Riverfront restoration:** Clean-ups, tree plantations, ecological landscaping, development of eco parks and pocket parks, riverbank pitching, and community events were undertaken.[15]

---

14. AU (2026). EcoSattva's Blueprint for Climate Resilient Cities: Local Actions, Global Impact. Ashoka University (AU). https://www.ashoka.edu.in/ecosattvas-blueprint-for-climateresilient-cities-local-actions-global-impact/. Accessed on 8 January 2026.

15. Dhagey, J. (2022). Apli Kham: Ecological river restoration as placemaking. Question of Cities. https://questionofcities.org/apli-kham-ecological-river-restoration-as-placemaking/. Accessed on 25 July 2025.

- **Behavioural changes and awareness:** Events for civic engagement, youth programs, and widespread media outreach was carried out using multiple platforms such as social media, print media, electronic media and offline events.
- **Governance:** Multi-departmental coordination and long-term operational planning were enforced. Collaboration between the sanitation, horticulture, engineering, and urban planning teams enabled better use of existing municipal resources.

Figure 11: Restoration work in progress (Photo Credit: Eco Sattva)

Low-cost, adaptable interventions such as floating plastic traps, soak pits, and decentralised greywater treatment plants were deployed for quick results, while remaining scalable and context-sensitive. Socially, the mission placed people's participation at the core, organizing 180+ public events, school campaigns, and riverfront activities to rebuild the social connect with the river.

Governance and Partnerships

The Mission was implemented through a multi-stakeholder structure:

Stakeholder	Role
EcoSattva	Baseline assessment, restoration design, BOTRAM framework application, monitoring oversight
Chhatrapati Sambhajinagar Municipal Corporation (CSMC)	Municipal ownership, infrastructure provision, staff mobilization, integration into city systems
Varroc Engineering Ltd.	CSR financing, initial convening, strategic support
Confederation of Indian Industry (CII)	Stakeholder coordination and industry outreach

Stakeholder	Role
Maharashtra Pollution Control Board (MPCB)	Water pollution regulation and compliance oversight
Local residents, youth groups, volunteers	Behavioural change, stewardship, riverfront engagement
State Climate Action Cell	Policy alignment and climate planning integration
River Cities Alliance	Knowledge exchange and national-level recognition

The initiative expanded from a four-party MoU to engagement with 12 stakeholders across municipal departments, civil society and industry.

The mission also led to the preparation of an Urban River Management Plan (URMP), making Chhatrapati Sambhajinagar the first city outside the Ganga basin to do so.

Outcomes

The restoration generated environmental, institutional, and social co-benefits beyond immediate river cleaning.

Physical and ecological changes: The Mission greened 50,776 m^2 by planting 1,03,851 native saplings. A total of 5.38 km of riverbank was stabilised through eco-sensitive pitching. Former garbage dumping sites were converted into ecological and pocket parks, including the 10.5-acre Kham Riverside Ecopark (1.25 km stretch) and smaller parks at Alamgir, Delhi Gate Sunset Park, and Rashi Van. These interventions altered the visible condition of the river corridor. Areas previously characterised by accumulated waste and stagnation were cleared and re-landscaped.

- An area of 1,24,261 m^2 was cleaned up,
- 171 GVPs were closed,
- Over 280 municipal staff were trained in solid waste management,
- Six plastic traps were installed in drains, and
- 24 bridges were barricaded to prevent solid waste dumping.

Waste system reform and operational impact: More than 0.3 million residents were integrated into an improved waste collection system. Over 280 municipal staff received training in solid waste management practices. The establishment of "Unnati Waste Management Services" formalised and trained Safai Saathis (waste pickers) to incorporate them into structured municipal systems. These reforms addressed upstream waste generation rather than focusing solely on riverfront clean-up.

The project progress was measured using a combination of different indicators and measures such as geo-tagged clean-up and plantation data, the length of riverbank pitched, decrease in visible litter and water stagnation, before and after photographs and drone imagery, mapping and closure of GVPs, dimensions of eco-park developed, reported increase in native biodiversity, number of municipal staff trained, total population covered under waste collection integration, and riverfront citizen engagements. The Municipal Corporation reported saving INR 2470 million through these efforts, as compared to the business-as-usual scenario.

Social and Civic Outcomes: The restoration effort reactivated the river as a public space. A total of 182 citizen engagement events were organised, involving over 22,000 participants, and the initiative received coverage through more than 200 media articles. The river, previously perceived as a drain, began to be referred to locally as "Aapli Kham" (Our Kham). While this represents a qualitative shift rather than a quantified ecological indicator, the scale of participation indicates that the Mission extended beyond engineering works into civic mobilisation.

In recognition of the Kham River restoration, Chhatrapati Sambhajinagar has been included in the 'River City Alliance (RCA)' under Namami Gange. The river's URMP catalysed other initiatives, including the revival of Kamal Talao, a city lake, and the initiation of a study to rejuvenate the Sukhna River in the Sambhajinagar district.

The mission led to an MoU with the State Climate Action Cell, laying the groundwork for a district-level Climate Action Plan anchored around waterbodies, a pioneering model for climate-integrated local governance. The initiative also won the St. Andrews Prize for the Environment in 2024.

Gaps and Areas for Improvement

The Kham River Restoration Mission highlights the significance of implementing integrated, adaptive management using low-cost, context-specific solutions; combining technology with nature-based interventions; strong inter-departmental coordination and continuous community engagement; use of tools such as the BOTRAM framework; and significance of sustainable waste management.

Figure 12: Before and after restoration (Photo Credit: Eco Sattva)

However, there were some key structural and strategic limitations:

- The Mission focused only on the urban stretches of the Kham River. Given that river systems function as continuous ecological corridors, untreated upstream inflows may limit long-term gains.
- While output indicators such as area cleaned, saplings planted, the staff trained are detailed, long-term ecological performance indicators are not clearly documented.
- It lacked a detailed cost-benefit analysis. Structured economic valuation of ecosystem services, health benefits, or avoided flood damages would strengthen the case for replication.
- Grey water management solutions at the household level also should have been introduced.
- Capacity building of riparian communities is essential for long-term sustainability of the river ecosystem.

- Arrangement of funding for long-term operations and maintenance of the river would be crucial.
- Strengthening regulations and their effective enforcement is central for reducing pollution in the Kham River.

Way Forward

The Kham River experience underscores that urban river restoration in water-scarce, rapidly growing cities requires systemic reform rather than isolated beautification.

One key lesson is that correcting the waste system must precede ecological restoration. Closing Garbage Vulnerable Points, improving collection coverage, and formalising sanitation workers addressed pollution at source. Without this shift, riverfront landscaping alone would not have produced durable outcomes.

Second, visible change along the river corridor played an important role in rebuilding civic engagement. The conversion of dumping sites into parks and the organisation of 182 public events demonstrate that river restoration can be both an environmental and a social process.

For other cities, the case highlights the importance of treating urban river restoration as a long-term governance and management process rather than a one-time project. Adaptation of this approach will require alignment with municipal systems, realistic timelines, and continued community involvement, rather than simply replicating specific interventions.

Key Contacts

Name	Gauri Mirashi
Department	Co - Founder and CEO
Organization	EcoSattva Environmental Solutions Pvt. Ltd.
Address	B-14, MIDC Railway Station, Chhatrapati Sambhajinagar- 431 001, Maharashtra, India
Phone with international and national area code	+91 95032 49494
Website	https://www.ecosattva.in/
Email address (preferably not personal address)	gauri@ecosattva.in

CASE STUDY

Neela Hauz Biodiversity Park – Restoring and Transforming a Wetland into a Biodiversity Park

Delhi, India, India

City Profile and Key Information

Local Government Name (in English)	Delhi Development Authority (DDA)
Official Name (in original language)	Dilli Vikas Pradhikaran
Country	India
State/Province	Delhi
Population (two adjacent fields: numerical field + year field) + if available: Population growth (annual %)	16.78 million (2011), 2.12 %
Total Area	1483 km² (2025)
Main geography type: India	Coastal, Dryland, Highland, **Lowland**, Mega delta, Small island

Overview

Delhi, located between the Yamuna River floodplain and the Aravalli range in Northern India, has undergone rapid urbanisation, significantly altering its hydrological systems. Historically, the city depended on a network of hauz (water reservoirs), baolis (stepwells), lakes, ponds, and small streams for freshwater supply and groundwater recharge. However, city expansion, extensive infrastructure development, encroachment and untreated wastewater discharge have degraded several of these important waterbodies.

The ecological decline of Neela Hauz Lake in South Delhi reflected this urban pattern. Once spread over more than 10 hectares and historically connected to Qila Rai Pithora, a medieval fortified complex in Delhi, the lake had shrunk into a heavily silted depression receiving untreated sewage from surrounding colonies. Its natural catchment had been disrupted, particularly after the construction of a flyover in 2009. The lake lost both its storage capacity and ecological function.

Problem Statement

By 2012, Neela Hauz had become a stagnant sewage-fed waterbody with almost no dissolved oxygen, incapable of supporting aquatic life. The degradation involved:

- Loss of natural drainage and catchment
- Continuous inflow of untreated sewage
- Solid waste dumping
- Decline in biodiversity
- Reduction in water storage capacity
- Loss of recreational and ecological value

In response to a Public Interest Litigation filed by local residents under the "Neela Hauz Citizens Group," the Delhi High Court ordered restoration of the lake in 2012.[16] The Delhi Development Authority, the primary urban planning and development body in the city, was tasked with implementing the restoration. The key challenge was to restore water quality and ecological function in a highly urbanised setting where natural hydrological inflows could not be fully re-established.

Objectives

The project aimed to revive the ecological functions of the severely degraded lake through nature-based solutions (NbS), while treating the untreated sewage inflow.

Specifically, the initiative aimed to:

- Treat approximately one million litres per day (MLD) of sewage through a zero-energy Constructed Wetland System (CWS)
- Improve lake water quality to functional standards
- Restore the lake basin and surrounding landscape through desilting and planting of native species
- Develop the site into a biodiversity park
- Demonstrate a replicable, low-energy urban wetland restoration model suitable for dense metropolitan contexts.

The project did not aim to recreate the historical hydrology, but to stabilise water quality and ecological function under existing urban conditions.

Implementation

Rationale for Nature-Based Solution

Rather than relying on conventional sewage treatment infrastructure, the project adopted a Constructed Wetland System (CWS) to:

- Treat sewage in situ using biological processes
- Operate with zero external energy input

16. Jacob, N (2012). Neela Hauz may turn blue soon. DDA and DJB to restore the south Delhi pond by 2013. DownToEarth.

- Reduce capital and operational costs
- Mimic natural wetland functions
- Enable water reuse to sustain lake levels

The approach relied on gravity flow, sedimentation, and plant–microbe interaction rather than mechanical aeration or energy-intensive systems.

Unlike conventional sewage treatment plants, which require continuous electricity and mechanical maintenance, the CWS relies on gravity, sedimentation, and plant-microbe interactions, significantly reducing lifecycle energy demand.

CWS mimics natural wetland processes and treats wastewater through bioremediation.

Technical Design and Implementation

The CWS comprises six major parts: two oxidation ponds of 3-feet depth each; a gradient channel with large pebbles; three physical filtration channels; a constructed wetland with planted furrows and gravel ridges; a cascade outlet with stones and pebbles; and a natural wetland zone.

Sewage water is stored in oxidation pond 1 for 24-48 hours, where aerobic bacteria break down all organic matter. It then moves to oxidation pond 2, where aquatic plants like Lemna absorb nitrates and phosphates. After passing through these two oxidation ponds, the biodegradable material is oxidised, and the bacterial biomass and other suspended solids settle.

The water then passes through the gradient channel, where large particulate matter is removed, followed by three physical treatment channels that remove particulate matter of all sizes.

Then the water flows to the CW comprising furrows and ridges. The microbes in the rhizosphere of aquatic plants help reduce biotoxins in the water. After physical treatment channels, the water passes through a cascade outlet that removes sludge and fine particulates. Finally, the water makes it way towards a natural wetland consisting of floating aquatic plants, which remove any remaining fine particulate and organic matter, before reaching the main lake.

The whole process takes less than 20 hours. For instance, sewage water with zero DO, and 80 mg/l BOD resulted in treated water with <4 mg/l BOD, and 8.5 mg/l DO after passing through the CWS established at Neela Hauz Lake.

The ecosystem around the lake was developed into a biodiversity park using NbS. The lake was desilted, and the desilted material was utilised for landscaping. Several native species were also planted around the lake landscape.

About 4000 students and locals extended support by planting nearly 10,000 native plant species. All these efforts led to the development of a three-hectare Neela Hauz Biodiversity Park.[17]

17. Babu, C. R., and Tiwari, R. K. (2021). Biodiversity Parks-Nature Reserves of Delhi. Delhi Development Authority (DDA). https://dda.gov.in/sites/default/files/e_bookbiodiversitypark.pdf. Accessed on 28 December 2025.

Figure 13: Constructed wetland at Neela Hauz (Photo Credit: https://lg.delhi.gov.in/image-gallery/9831)

Governance and Partnerships

The restoration was led by the Delhi Development Authority, following a High Court order. The total project cost was approximately USD 233,218, funded by DDA.

The institutional architecture is summarised below.

Stakeholder	Role
Delhi Development Authority	Project ownership, funding, implementation and long-term management
Centre for Environmental Management of Degraded Ecosystems, University of Delhi	Design and implementation of CWS; ecological restoration planning
Delhi High Court	Judicial mandate for restoration
Neela Hauz Citizens Group	PIL filing, advocacy and community mobilisation
Municipal Corporation of Delhi, Delhi Jal Board, Forest Department	Waste management coordination and regulatory support
Students and local residents	Plantation and stewardship

Figure 14: Oxidation pond at Neela Hauz (Photo Credit: https://lg.delhi.gov.in/image-gallery/9831)

Outcomes and Measurable Impact

The Neela Hauz Lake restoration model is considered the first example in the country of a lake revival project being integrated with the development of a biodiversity park. Its most significant outcome was the conversion of a stagnant, sewage-fed depression into a functioning treatment wetland and biodiversity site.

Ecological Outcomes: Before restoration, the lake was effectively anoxic (0 mg/l dissolved oxygen), with high BOD and COD levels that prevented aquatic life. Continuous inflow of untreated sewage had reduced the waterbody to a degraded basin with minimal ecological function. After the introduction of the Constructed Wetland System (CWS), approximately 1 million litres of sewage per day were treated biologically before entering the lake. Importantly, the CWS system operates without external energy input.

Monitoring data show measurable improvements:

- BOD reduced from 40 mg/l to 4 mg/l
- COD reduced from 80 mg/l to 0.7 mg/l
- Dissolved oxygen increased from 0 mg/l to 3.4 mg/l
- Phosphates reduced from 103 mg/l to 14 mg/l
- TDS reduced from 600 mg/l to 298 mg/l

These changes indicate not only pollutant reduction but a shift from oxygen-depleted conditions to water capable of sustaining aquatic organisms. The rise in dissolved oxygen is particularly significant, as it marks the restoration of basic ecological processes within the lake.

The lake now functions as a polishing wetland within an urban wastewater system. Although the original catchment hydrology has not been restored, the system has stabilised water quality under existing urban constraints.

Ecologically, the surrounding three-hectare site was restored through the planting of approximately 15,000 trees and shrubs representing over 100 native Aravalli species. The surrounding landscape now supports: 135 plant species; 135 bird species; over 40 butterfly species; and four mammal species. The intervention transformed a sewage-fed depression into a functioning wetland ecosystem capable of supporting diverse flora and fauna.

Socio-Economic and Recreational Outcomes: The Neela Hauz Biodiversity Park provides accessible open space in a densely built urban area, attracting visitors for walking, birdwatching, and environmental education. Schools and universities use the park as a field site for ecological learning and research, integrating it into academic curricula. The project generated employment during desilting, landscaping, and ongoing maintenance activities, although detailed long-term employment figures are not available.

Figure 15: The site is a haven for birds now (Photo Credit: Delhi Biodiversity Foundation)

Gaps and Areas for Improvement

The project's success was based on integrating ecological design, institutional leadership, and judicial mandate. However, the original hydrological catchment has not been reinstated, and the lake's water balance relies primarily on sewage treatment rather than natural recharge. The project could not restore or rejuvenate the lake's natural drainage system and catchment. Thus, reliance on wastewater to maintain the lake's water level limits the project's success.

The CWS at the biodiversity park effectively treated sewage water but continuous monitoring of physical, chemical, biological and hydrological parameters is important for ensuring long-term sustainability of the project. Better infrastructure development at the park, including basic amenities, signage, security, viewing towers, a canteen, and rest areas, would play a significant role in improving recreational and eco-tourism services.

Way Forward

The Neela Hauz initiative demonstrates that severely degraded urban lakes can be restored through low-energy, decentralised treatment systems when supported by institutional leadership and judicial mandate.

Key lessons include:

- Constructed wetlands can achieve measurable pollutant reduction without continuous energy input.
- Judicial intervention can catalyse stalled ecological restoration.
- Community participation strengthens local ownership.
- Biodiversity recovery is possible even in highly urban settings when water quality improves.

The model has been replicated at Kalindi Biodiversity Park along the Yamuna River in Delhi. Future strengthening would require continuous ecological and hydrological monitoring; partial restoration of natural drainage linkages where feasible; improved public infrastructure and interpretation facilities; and long-term maintenance planning.

Key Contacts

Name	Professor C.R. Babu
Department	Centre for Environmental Management of Degraded Ecosystems (CEMDE)
Organization	University of Delhi
Address	Neela Hauz Biodiversity Park, Near Sanjay Van, Aruna Asaf Ali Marg, Vasant Kunj, New Delhi-110067
Phone with international and national area code	+91- 9810586709
Website	delhibiodiversityparks.org
Email address (preferably not personal address)	crb26@hotmail.com, crbabu26@gmail.com

CASE STUDY


Photo Credit: Demerritt (2020)

Glaciares+ Project: Sustainable Watershed Management

Ancash, Cusco and Lima Regions, Peru

City Profile and Key Information

Local Government Name (in English)	Regional and Local Governments of Ancash, Cusco & Lima
Country	Peru
State/Province	Ancash, Cusco & Lima
Population (two adjacent fields: numerical field + year field) + if available: Population growth (annual %)	Population: 1083519 (Ancash); 1205527 (Cusco); and 839469 (Lima) Annual population growth (%): 0.18 (Ancash); 2.90 (Cusco); and 0.84 (Lima)
Total Area	35,914 km² (Ancash); 71,986 km² (Cusco); and 2,672 km² (Lima)
Main geography type: India	Coastal, Dryland, **Highland**, Lowland, Mega delta, Small island

Overview

Peru has approximately 71% of the world's tropical glaciers that are critical water sources for domestic use, agriculture, hydropower and ecosystems in the Andean Highlands. These glaciers make significant contributions to downstream river flows in the dry season in the Andean basin. For instance, the Cordillera Blanca in the Ancash region has 755 glaciers covering more than 470 km2. The Vilcanota Mountain Range of Cusco is home to 374 glaciers, covering more than 250 km² of glacial area; the Urubamba Mountain Range has 117 glaciers; and the Cordillera Central Mountain range is home to 174 glaciers, covering an area of about 50 km².

However, these glaciers have lost large areas of their glacial surfaces over the last 40 years due to global warming. The glacial surface of the Cordillera Blanca retreated by 34% between 1970 and 2012, while that of Vilcanota Mountain Range retreated by 33% between 1970 and 2009. The Urubamba and Cordillera ranges have lost 61% and 55% of their glacial surfaces, respectively, over about the same period.

The accelerating retreat of glaciers has altered seasonal water availability, increased the formation of unstable new glacial lakes, and heightened the risk of disasters such as flash floods and ice and rock landslides. It also reduced dry-season flows, creating water shortages in Peru's river basins, and severely impacting agriculture and hydropower production in the region.

Problem Statement

In the Santa, Vilcanota-Urubamba, and Cañete river basins, glacier retreat is increasing the risk of glacial lake outburst floods and reducing water availability in the dry season. Such ecological changes affect not just highland communities, but also the downstream urban centres and agricultural communities.

The disruption in water flow and quality caused by glacial melt is threatening flora and fauna that rely on freshwater ecosystems, and causing deadly flash floods that are destroying human settlements and displacing communities, with children, women, the poor, and indigenous communities being the most affected.

Additionally, in the Cusco district, several highland pasture areas have been degraded by overgrazing. Coupled with rising temperatures, this has increased evaporation rates in those areas, reducing water availability in the landscape. Water deficits, along with droughts resulting from glacier retreat, has worsened food security and threatened the livelihoods of Andean farmers and poor communities.

In this context, the Glaciares+ Project (Proyecto Glaciares+) was launched (2011-19) as a climate adaptation initiative integrating nature-based solutions (NbS), with measures for disaster risk reduction, water resources management and capacity building.

Objectives

The Glaciares+ Project aimed to strengthen climate adaptation and resilience in the glacier-dependent Santa River basin (Ancash), Vilcanota-Urubamba River basin (Cusco), and Cañete River basin (Lima) in Peru. Rather than attempting to reverse glacier retreat, the project aimed to reduce downstream vulnerability through integrated watershed management.

Its objectives were to:

1. Reduce disaster risk linked to unstable glacial lakes, glacier retreat, and hydrological instability.
2. Restore degraded wetlands and water bodies through measures for ecosystem-based restoration and the recovery of native vegetation.
3. Strengthen institutional and technical capacities for glacier monitoring, disaster risk management, and watershed governance.
4. Improve adaptive water management and promote sustainable agricultural practices in glacier-dependent basins.
5. Support climate-resilient livelihoods for vulnerable communities.

The approach framed glacier retreat as an irreversible trend requiring adaptation rather than mitigation at the basin scale.

Implementation and Approach

The project operated in three glacier-dependent basins -- Santa, Vilcanota-Urubamba, and Cañete.[18] It adopted cost-effective, nature-inspired, and community-based interventions for sustainable watershed management, climate change adaptation, disaster risk reduction and water security in glacial mountain ecosystems.

It was implemented in two phases. The first phase (2011-15) focused on strengthening technical and operational capacities in glacier monitoring and research to bring scientific knowledge to surrounding local communities to reduce vulnerability within the framework of climate change adaptation. The second phase, from 2015-2019, focused on building and strengthening capacities for climate change adaptation and risk reduction from glacier retreat, while taking advantage of opportunities for water resource management.

Nature-based solutions: The project adopted a blend of nature-based and technological solutions for sustainable watershed management of Peruvian glacial mountain ecosystems.

Key NbS interventions included:

- Watershed management of more than 200 naturally formed glacial lakes.
- Planting and replanting of native plants to restore wetlands and for stabilising banks.
- Fencing of tributaries to protect riparian vegetation from overgrazing and for the restoration of vegetation.
- Protection of grasslands and forests around important spring water resources.
- Training of smallholder farmers in adopting sustainable farming practices, including the sustainable use of water.

These were combined with:

- Construction of dams in periglacial lagoons for the storage of rainwater and the protection of wetlands.
- Development of hazard and evacuation maps.
- Installation of early warning systems.

Community-based adaptation: Community-based adaptation (CBA) was a key element of the project, combining traditional knowledge with innovative strategies to address current vulnerability, while strengthening adaptive capacity. The initiative integrated community-level data with a scientific understanding of climate risks in the climate vulnerability and capacity analysis of these areas. Interactions and surveys were conducted with local and indigenous people to identify potential issues and gather data to inform the sustainable watershed management plan.

The CBA process comprised:

- Supporting climate-resilient livelihoods by helping households diversify income and improve local planning and risk management;
- Implementing adaptation strategies to reduce the impact of hazards, specifically on vulnerable individuals and households;
- Building the capacity of civil society and local public institutions to support adaptation actions; and

18. Hou-Jones, X, Roe, D and Holland, E (2021) Nature-based Solutions in Action: Lessons from the Frontline. London. Bond.

- Conducting political advocacy and social mobilisation to tackle the root causes of vulnerability, including unequal control over resources, poor governance, and limited access to basic services.

Women were actively engaged in watershed management and local decision-making processes.

Stakeholder Roles and Governance Structure

The project fostered multi-institutional convergence, bringing together local, regional and national governments, communities, regional institutions and global organisations. Swiss Agency for Development and Cooperation (SDC) provided CHF 19 million (over USD 24 million) in funding for the project.

Stakeholder	Role
CARE Peru	Project implementation, community engagement, coordination
Swiss Agency for Development and Cooperation (SDC)	Financial support and strategic oversight
University of Zurich (with Meteodat, Centre for Research on Alpine Environment, Swiss Federal Technology Institute of Lausanne)	Glacier monitoring, hydrological modelling, technical design
National Water Authority (Glaciology Unit)	Glacier monitoring, water governance integration
Ministry of Environment	Policy alignment and environmental oversight
National Institute for Research on Glaciers and Mountain Ecosystems (INAIGEM)	National glacier research and institutional anchoring
Áncash, Cusco, Lima	Local implementation and coordination
National Institute of Civil Defence, National Centre for Estimation, Prevention, and Reduction of Disaster Risk	Risk assessment and emergency preparedness
Communities of Cusco and Nor Yauyos	Ecosystem restoration, adaptive agriculture, local stewardship

Outcomes and Impact

The Glaciares+ Project generated measurable environmental, institutional, and socio-economic outcomes across the Santa, Vilcanota-Urubamba, and Cañete basins.

Risk reduction outcomes

More than 200 glacial lakes were placed under structured watershed management planning. Wetland and spring restoration improved water retention in high-altitude zones.

The installation of a real-time early warning system — reported as the first glacier-related flood warning system in South America — covers areas where over 70,000 downstream residents are vulnerable to landslide and flash flood risks.

Before the intervention, glacier retreat had increased hazard exposure with no coordinated monitoring or risk communication mechanisms.

After implementation, hazard maps, evacuation planning, and early warning systems introduced better preparedness in high-risk zones.

Restoration of 143 hectares of wetlands and fencing of tributaries contributed to vegetation recovery, improving soil moisture retention and reducing erosion in upland catchments.

While glacier retreat continues, the project reduced immediate exposure to glacial lake-related disasters and strengthened local preparedness systems.

Figure 16: Overview of the region (Photo Credit: Demerritt (2020))

Water and Ecosystem Outcomes

Restoration of wetlands, springs, and periglacial lagoons improved local water regulation capacity.

In degraded high-altitude areas, where overgrazing and warming had reduced natural water storage capacity, fencing and revegetation allowed recovery of vegetation and improved protection of spring sources.

The creation and rehabilitation of rustic dams and lagoons increased water storage for agricultural use, particularly during dry seasons.

These interventions supported irrigation reliability for farmers, though long-term hydrological impacts require continued monitoring.

Livelihood and Capacity impacts

About 1000 small-scale farmers were trained in climate adaptation, DRR and management and integrated water resource management. Four women-owned and operated companies were created to sustainably produce and market products such as coffee, honey and granadilla.

The creation or strengthening of 34 water and sanitation service boards improved local governance.

Local communities participated in watershed planning and ecosystem restoration activities. The project contributed to irrigation water availability for farmers.

Schools in the region were inspired to include climate change adaptation and risk management in their curriculum.

Institutional Impacts

The project's institutional legacy lies in embedding glacier monitoring and watershed management within formal governance structures. It contributed to the creation of the National Institute for Research on Glaciers and Mountain Ecosystems. Coordination between ministries, departments and regional governments improved during implementation.

The initiative supported integration of glacier monitoring and watershed management within existing regulatory frameworks, including the Water Resources Law (2009).

Gaps and Areas for Improvement

The combined use of ecosystem restoration and monitoring systems in these glacial basins supported watershed management efforts to some extent. However, the glaciers continue to retreat at a rapid rate.

There is a need for enhanced community engagement involving all stakeholders, such as residents, local organisations, and business bodies, in project planning and implementation.

The project was delayed by several factors, including staff turnover, inadequate evaluation of the socio-political situation in the project areas and coordination challenges among multisectoral partners. A broader executing team with more diverse capacities could reduce some of these coordination gaps.

Monitoring and evaluation frameworks need strengthening for long-term tracking. Continued financial investment and exploration of local and national funding sources are necessary to sustain restoration and risk management activities.

Lessons and Way Forward

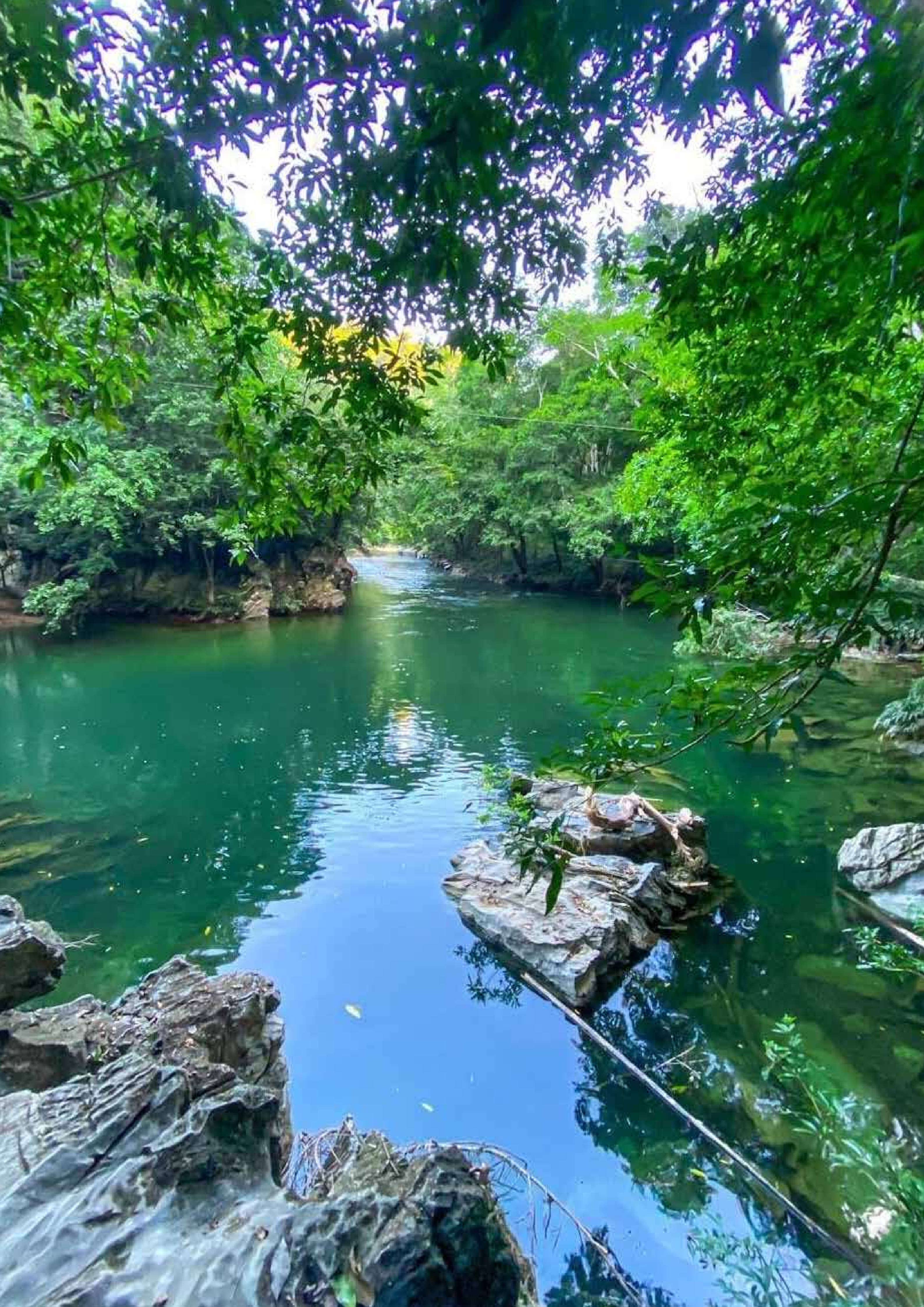
The Glaciares+ experience shows that NbS can play a meaningful role in managing water variability and reducing disaster risk in glacier-dependent basins. Wetland restoration, spring protection, and sustainable lake management strengthened watershed functions when integrated with monitoring and early warning systems.

However, the continued retreat of glaciers underscores that NbS alone cannot fully address long-term structural water scarcity. In high-altitude regions where hydrological regimes are rapidly changing, NbS are most effective when combined within broader governance frameworks and complemented, where necessary, by appropriate infrastructure measures.

For other mountain regions facing similar glacier loss, the relevance of NbS will depend on ecological conditions, institutional capacity, and long-term financing. Restoration of wetlands and high-altitude ecosystems can support water regulation and local livelihoods, but sustained monitoring and institutional coordination are important to maintain these gains over time.

Key Contacts

Name	Karen Price
Department	National Coordinator of the Glaciers +
Organization	CARE Peru
Address	67 Amador Merino Reyna Street, 9th floor, office 901, San Isidro, Lima, Peru
Phone with international and national area code	+51 (01) 6409393
Website	https://care.org.pe/
Email address (preferably not personal address)	kprice@care.org.pe



CASE STUDY


Photo Credit: NATWiP Project

PES as a Nature based Solution for Watershed Restoration

Rio Clare, Brazil

City Profile and Key Information

Local Government Name (in English)	City Hall of Rio Claro
Official Name (in original language)	Prefeitura Municipal de Rio Claro
Country	Brazil
State/Province	Rio de Janeiro
Population (two adjacent fields: numerical field + year field) + if available: Population growth (annual %)	17401 (2022)
Total Area	846. 80 km^2
Main geography type: India	Coastal, Dryland, Highland, **Lowland**, Mega delta, Small island

Overview

The municipality of Rio Claro, located in mountainous terrain in Rio de Janeiro province in southeastern Brazil, lies in the Guandu River Basin, a strategically important watershed in the country. The basin supplies drinking water to 12 million people in the Rio de Janeiro Metropolitan Area, and supports irrigation, hydropower generation and industrial uses.[19]

Rio Claro is located in the Atlantic Forest biome of the Paraíba do Sul River valley, a region that has undergone extensive deforestation since the late 18th century. The Paraíba do Sul River is hydraulically linked to the Guandu system. Initially driven by coffee cultivation and later by sugarcane expansion, charcoal production for the steel industry, agriculture, and urban growth, forest clearing intensified throughout the 19th and 20th centuries. From the mid-20th century onward, rapid industrialisation and rural-to-urban migration accelerated land-use change, resulting in forest fragmentation and the degradation of riparian zones.

These changes weakened watershed regulation functions by reducing infiltration, increasing surface runoff and sediment loads, and affecting dry-season flows in river basins. As urban water demand increased, the condition of upstream forests became directly linked to regional water security.

19. IWA (2025). Integrated management of Guandu basin for water supply in Rio de Janeiro State. The International Water Association (IWA). https://www.iwa-network.org/rio-dejaneiro-brazil. Accessed on 7 July 2025.

Despite retaining significant forest remnants, Rio Claro continues to experience land degradation associated with agricultural expansion, deforestation, settlements, infrastructure, logging, and wildfires. According to Global Forest Watch, between 2002 and 2024, Rio Claro lost approximately 337 hectares of humid primary forest.[20]

Considering the basin's regional importance, watershed degradation in upstream municipalities is not only a local ecological issue but also a metropolitan water security challenge.

Problem Statement

In Rio Claro, agricultural expansion and poorly managed pasturelands contributed to soil erosion, fragmentation of forest cover, and degradation of springs and riparian zones. As forest cover declined, the watershed's ability to regulate water flows weakened. Infiltration decreased, surface runoff increased, and sediment loads rose, affecting both water quality and dry-season water availability in the Guandu River Basin.

Brazil's Forest Code requires landowners to protect Permanent Preservation Areas (APPs) and maintain Legal Reserves. However, enforcement alone proved insufficient. Much of the remaining forest lies on privately owned land, and compliance often meant that farmers had to stop using productive land for agriculture or cattle grazing. Restoring or conserving forests meant giving up income that could otherwise be earned from milk production, crops, or pasture. These foregone earnings are referred to as "opportunity costs" — the income a landowner sacrifices by choosing conservation over agricultural production. For small and medium-sized landholders who depend on farming for their livelihoods, this loss can be significant.

The main challenge, therefore, was not simply ecological but institutional and economic: how to make forest conservation financially viable for private landowners. Without compensation, restoration would remain a financial burden. The project sought to address this gap by creating a mechanism that enables downstream water users to help offset the opportunity costs faced by upstream landholders, thereby aligning private incentives with public water security goals.

Objectives

The Water and Forest Producer Project (PAF) was launched in 2008 to:

- Protect and restore forest cover in critical headwater areas of the Guandu River Basin;
- Reduce erosion and sedimentation affecting water supply systems;
- Create economic incentives for rural landowners to conserve ecosystem services;
- Institutionalise a municipal-level Payment for Ecosystem Services (PES) mechanism supported by water user fees; and
- Strengthen governance coordination between municipal authorities, basin committees, and environmental agencies.

20. GFW (2025). Rio Claro, Rio de Janeiro, Brazil. Global Forest Watch (GFW). https://www.globalforestwatch.org/dashboards/country/BRA/19/65/?location=WyJjb3VudHJ5IiwiQlJBIiwiMTkiLCI2NSJd. Accessed on 6 July 2025.

Rather than treating watershed restoration as a one-time intervention, the project aimed to mainstream conservation into a recurring financial and institutional framework. Climate change mitigation through reforestation was perhaps the most important objective of the PES initiative.

Implementation

To achieve these objectives, the municipality adopted the PES mechanism as its core implementation instrument. Under this approach, beneficiaries or users of an ecosystem service provide payment to its provider.[21] For example, upstream communities in a watershed can adopt several sustainable land use practices in their fields such as agroforestry, block planting, and the creation of riparian buffers. These practices support improvement of water quality and quantity in a river.

PES is particularly useful where forests are on private land; downstream populations depend on upstream ecosystem services; enforcement of environmental laws alone is insufficient; and landowners need financial support to change land-use practices.

In Rio Carlo, downstream water users paid through water-use charges collected by the Guandu Watershed Committee. These funds were transferred to upstream landowners who conserved or restored forest areas. Payments were structured to compensate for:

- Opportunity costs of land-use change
- Restoration and maintenance activities
- Long-term conservation commitments

Rural landowners voluntarily enrolled in the programme and signed contracts committing to both active and passive restoration. Active restoration included tree planting, fire prevention, and fencing to prevent cattle intrusion into riparian zones. Passive restoration focused on protecting existing forest areas and allowing natural regeneration. In return, they received payments based on estimated opportunity costs and the ecological status of their land (i.e., whether the forest was in early or mid/advanced stages of recovery). Initially, contracts were signed for two years without any penalty for premature withdrawal. Historically preserved forest areas owned by landowners were designated as forests of an advanced stage. The project used Rio de Janeiro State Report on Milk Production to calculate the opportunity cost and projected a value of USD 7 / hectare/year.

PES is an important strategy that fosters socio-economic well-being and environmental sustainability, and integrates environmental goals with the socio-economic development of the area. PES effectively promotes nature conservation by enhancing compliance with environmental laws.[22]

Why is PES important?

Large-scale deforestation in the Atlantic Forest has already weakened water regulation in the basin. Continued degradation would further increase water treatment costs and water insecurity in the Rio de Janeiro Metropolitan Area.

At the same time, many landowners cannot afford to restore forests without compensation.

21. Mamedes, I., Guerra, A., Rodrigues, D. B., Garcia, L. C., de Faria Godoi, R., and Oliveira, P. T. S. (2023). Brazilian payment for environmental services programs emphasize water-related services. International Soil and Water Conservation Research, 11(2), 276-289.

22. Oliveira Fiorini, A. C., Swisher, M., and Putz, F. E. (2020). Payment for environment services to promote compliance with Brazil's forest code: the case of "Produtores de Água e Floresta". Sustainability, 12(19), 8138.

In this context, PES offers a practical mechanism:

- It links water users to water source protection.
- It reduces pressure on enforcement-only approaches.
- It supports both environmental recovery and rural livelihoods.

The project included specific reforestation targets, required participants to reforest a minimum of suitable areas, and utilised land-use mapping to identify suitable riparian areas for restoration.

While several other programmes in the country had focused on single ecosystem services such as carbon sequestration, the PAF Project promoted a wide range of ecosystem services based on healthy river basins and a forest biome. The project is one of the few initiatives that promote and strengthen the compliance with the Brazilian Forest Code, which mandates that landowners maintain natural vegetation cover on their property. Thus, the project supports existing laws and regulations on forest conservation.[23]

Currently, the project is being monitored by 70 rural landowners who are playing a key role in the conservation of about 4,562 ha, and the restoration of 564 ha. A cost-benefit analysis was performed prior to the PAF project at Rio Claro.

Figure 17: Community consultation (Photo Credit: NATWiP Project)

Governance Structure

The Water and Forest Producer Project (PAF) was structured around a clear upstream-downstream financial and governance link. The Rio Claro City Hall provided the legal foundation through Municipal Law No. 514/2010, which formally institutionalised PES and authorised payments to landowners. The Guandu Watershed Committee (GWC) collected water-use charges from downstream users in the Rio de

23. Santiago, T. M. O., Caviglia-Harris, J., and de Rezende, J. L. P. (2018). Carrots, sticks and the Brazilian Forest Code: the promising response of small landowners in the Amazon. Journal of Forest Economics, 30, 38-51.

Janeiro Metropolitan Area and used these revenues to finance PES contracts and operational costs. In this arrangement, downstream water users funded upstream conservation.

Programme implementation was coordinated by the Water Management Association of the Paraíba do Sul River Basin (WMAPSB), ensuring alignment with basin-level water management. The Nature Conservancy provided technical support and early-stage financing.

Institutional Roles in the Water and Forest Producer Project

Stakeholder	Role
Rio Claro City Hall	Legal framework; enacted Municipal Law 514/2010; authorised PES payments
Guandu Watershed Committee (GWC)	Collected water-use charges; financed PES contracts and operations
WMAPSB	Coordinated implementation; basin-level integration
The Nature Conservancy (TNC)	Technical studies and early-stage financial support
INEA	Monitoring of restoration financed through compensation funds
ITPA / TecnoGeo	Local technical implementation and landowner engagement
Rural Landowners	Forest conservation and restoration under PES contracts

Outcomes and Impact

The Water and Forest Producer Project generated measurable ecological, financial and governance outcomes.

Ecological and Land-use Outcomes

As of the most recent monitoring:

- 4,562 hectares of Atlantic Forest have been conserved under PES contracts.
- 564 hectares of degraded forest have been restored.
- Between 2010 and 2016, forest cover on participating properties increased by 136 hectares.
- 63 bird species were recorded in restored areas, representing a 91% increase compared to the 2013 assessment.
- A Bird Observation Centre was subsequently established, reflecting growing ecological value and local interest.

This increase in species richness suggests measurable ecological recovery in restored riparian areas. By improving vegetation cover in strategic upstream areas, the project aimed to enhance infiltration, reduce erosion, and stabilise watershed functions connected to the Guandu River Basin.

Hydrological Outcomes

Although basin-wide hydrological impacts are difficult to isolate, the programme targeted forest restoration in upstream areas, which is important for sediment control and water regulation. The intervention addressed the link between upstream land-use practices and downstream water security.

Figure 18: Increase in overall biodiversity (Photo Credit: NATWiP Project)

Economic and Institutional Outcomes

The programme established a functioning municipal PES mechanism anchored in water-use charges.

- 70 rural landowners are currently enrolled (approximately 14% of municipal landowners at peak participation).
- Between 2010 and 2016, USD 516,000 was paid in direct incentives to landowners.
- By 2016, total programme investment reached USD 4.48 million, of which 61% was allocated to active restoration.
- The Guandu Watershed Committee contributes approximately €68,000 annually to payments.

Payments were structured to compensate for opportunity costs, restoration activities and long-term conservation commitments. Water-use charges collected in the Guandu watershed were the primary source of funding, making downstream users the beneficiaries and upstream landowners service providers.

The initiative strengthened compliance with the Forest Code and demonstrated how economic incentives can complement regulatory frameworks. The experience contributed to broader national discussions on PES, preceding the adoption of Brazil's National PES Policy (Federal Law 14.119/2021).

The integration of land-use mapping, restoration targets, and contractual obligations introduced accountability mechanisms that strengthened programme credibility.

Figure 19: Restored Guandu river basin (Photo Credit: NATWiP Project)

Gaps and Areas for Improvement

Despite progress, several constraints remain:

- Participation is limited to private landowners; individuals without land cannot access PES incentives directly.
- Some landowners raised concerns about opportunity cost calculations and uneven enforcement between large and small properties.
- Hydrological improvements at the basin scale require long-term monitoring to establish causal attribution.
- Continued funding depends on stable water-use charge revenues and institutional commitment.

These gaps highlight the importance of sustained financing, transparent governance and robust ecological monitoring.

Lessons and Way Forward

The Rio Claro experience demonstrates that PES can function as a watershed governance instrument where upstream-downstream hydrological interdependence is clearly defined; a legal framework allows environmental service payments; a watershed institution can collect and manage water-use charges; land tenure is sufficiently formalised to allow contracting; and there is technical capacity for land-use mapping and ecological monitoring.

The model is particularly relevant in basins where forest cover directly influences water supply for large urban populations. However, replication requires adaptation to local institutional capacity, funding mechanisms, and ecological conditions. While it does not offer a universal template, the PAF experience shows how incentive-based forest restoration can complement environmental regulation and improve water security in urban areas.

Key Contacts

Name	Hendrik Mansur
Department	Specialist in Conservation
Organization	The Nature Conservancy Brasil
Address	Av. Paulista, 2439/91, Bela Vista 01311-300, São Paulo, Brazil
Phone with international and national area code	NA
Website	https://www.nature.org/en-us/
Email address (preferably not personal address)	hmansur@tnc.org

CASE STUDY

Scaling Urban Nature-based Solutions for Climate Adaptation

Johannesburg, South Africa

City Profile and Key Information

Local Government Name (in English)	City of Johannesburg
Official Name (in original language)	The City of Johannesburg Metropolitan Municipality
Country	South Africa
State/Province	Gauteng province
Population + if available: Population growth (annual %)	Population: 4803262 Annual population growth (%): 0.755
Total Area	1642.6 km^2
Main geography type: India	Coastal, Dryland, **Highland**, Lowland, Mega delta, Small island

Overview

Johannesburg is located on the Highveld plateau at approximately 1700 metres above sea level in Gauteng Province. With a population of over 4.8 million people (2022 Census), it is the largest metropolitan municipality in South Africa and contributes about 16% of the national GDP. Originally a mining town, the city now has a diversified economy centred on finance, services, trade and manufacturing.

Despite its economic prominence, Johannesburg faces mounting environmental pressures linked to rapid urbanisation, spatial inequality and ageing infrastructure. The Jukskei River catchment forms the city's primary drainage system. Over time, encroachment, industrial discharge, sewage inflows and solid waste dumping have degraded the river and its surrounding catchment.

As climate variability intensifies, the condition of the Jukskei catchment is directly linked to flood risk, water security and heat stress in vulnerable communities. Restoring the river system is therefore not only an ecological priority but a climate resilience imperative for the city.

Problem Statement

The Upper Jukskei River catchment reflected the cumulative impact of unmanaged urban growth and climate stress. The catchment has dense formal and informal residential areas, retail centres and agricultural zones. Invasive alien species, illegal dumping, sewage discharge and infrastructure constraints had degraded the area. The loss of vegetation and blockage of waterways had reduced the river's ability to absorb and regulate stormwater. Informal settlements along the riverbanks were highly exposed to flooding, leading to repeated property damage, health risks and livelihood disruption.

At the same time, densely built low-income neighbourhoods were seeing elevated temperatures due to limited tree cover and open space. Water scarcity and declining water quality further compounded vulnerability.

Although Johannesburg has climate and water security strategies in place, the degradation of the Jukskei catchment revealed a structural gap: conventional grey infrastructure alone was insufficient to address flood risk, biodiversity loss, urban heat and social vulnerability simultaneously.

A catchment-scale restoration approach was required — one capable of improving ecological function while strengthening community resilience.

Objectives

Launched on 22 May 2024, the three-year Scaling Urban Nature-based Solutions for Climate Adaptation in Sub-Saharan Africa (SUNCASA) project aims to revitalise the Upper Jukskei River catchment using NbS to:

- Reduce flood risk
- Improve water quality and water security
- Mitigate urban heat
- Restore degraded riverbanks
- Expand accessible green space
- Strengthen biodiversity
- Support local livelihoods

The initiative targets approximately 1.045 million residents and integrates gender equality and social inclusion into planning and implementation.

Implementation

In Johannesburg, the SUNCASA project is being implemented as an integrated river catchment revitalisation initiative. Work began with the identification of key ecological and socio-economic stressors, including:

- Proliferation of invasive alien species
- UHI effects in densely populated, low-income areas
- Flooding exacerbated by pollution and clogged waterways

- Degradation of riparian vegetation
- Solid waste dumping and sewage discharge
- Persistent water scarcity

Based on these challenges, the project adopted a structured NbS framework combining ecological restoration with social inclusion and local economic support.

Ecological Restoration

The interventions include:

- Removing invasive species
- Planting indigenous trees to rehabilitate riparian zones and stabilise soil
- Expanding green cover in densely populated neighbourhoods
- Supporting agroforestry activities linked to livelihoods
- Rehabilitating degraded riverbanks

These interventions aim to improve ecosystem functioning while delivering multiple co-benefits, including flood regulation, biodiversity recovery, and climate adaptation.

Waste Management and River Cleaning

Adaptable litter traps were installed to intercept solid waste and invasive logs before they worsened flooding downstream, along with systematic waste collection. A Litter Trap and Art component repurposed salvaged waste materials into functional installations and public sculptures. Local people and artisans reused materials such as water bottles, plastic bags, tree logs, papers, and bricks. This approach reduced debris, demonstrated circularity, and strengthened community engagement.

Community Engagement and Capacity Building

The project adopted a gender-responsive approach, ensuring that women and other underrepresented groups were actively engaged in planning, training, and decision-making processes. Key elements included:

- Community education and awareness-building on NbS and river management
- Gender equality and social inclusion training
- Support for women-led enterprises and local cooperatives
- Skills training, including macramé techniques used in adaptable litter trap construction

Local knowledge was combined with technical expertise, strengthening both the legitimacy and effectiveness of interventions.

Governance Structure

SUNCASA in Johannesburg was led by the International Institute for Sustainable Development (IISD) and the World Resources Institute (WRI), with USD 22 million in funding from Global Affairs Canada and governance support from the City of Johannesburg Metropolitan Municipality. The SUNCASA project was also implemented in Dire Dawa (Ethiopia), and Kigali (Rwanda).

Institutional Roles in SUNCASA

Stakeholder	Role
IISD & WRI	Project implementation and technical coordination
Global Affairs Canada	Project financing (under Partnering for Climate Programme)
City of Johannesburg	Municipal governance oversight and policy alignment
Johannesburg City Parks & Zoo	Ecological restoration support
GenderCC South Africa	Gender equality and inclusion mainstreaming
Water for the Future / Alexandra Water Warriors	Local mobilisation and river rehabilitation
Zutari	Technical advisory support
Local cooperatives and residents	Implementation support and stewardship

Figure 20: Community participation in solid waste removal (Photo Credit: World Resources Institute)

Outcomes and Impact

The project delivered measurable ecological restoration, climate resilience, and socio-economic outcomes.

Ecological outcomes:

- Rehabilitation of 469 hectares of riverbank
- Planting of 46,000 indigenous trees, including 13,000 in Alexandra Township
- Achievement of 80% of Johannesburg's 2024 urban greening target (6,324 trees planted in 2024)
- Removal of invasive alien species, including Kikuyu grass from 2 hectares
- Installation of adaptable litter traps

These measures helped to stabilise riverbanks, improve water flow, reduce debris blockages, enhance habitat quality, and strengthen natural flood regulation. The increase in tree cover reduced urban heat island effects, improved air quality, and supported groundwater recharge.

Climate and Flood Resilience Outcomes:

The restoration of riparian vegetation and improved waste management reduced flooding. By improving ecosystem integrity, the project strengthened water quality and contributed to increased water security.

Collectively, these interventions enhanced climate resilience for approximately 1.045 million residents, particularly in vulnerable communities.

Livelihood and Social Outcomes:

The project supported 14 local cooperatives, enabled the establishment of women-led tree nurseries, generated short-term employment for women, youth, and local artists and built technical skills in NbS implementation, monitoring, and adaptive litter-trap construction.

Community-led art installations constructed from salvaged waste reduced debris, raised awareness, and strengthened local connection to the river.

Project progress was monitored through ecological, social, and governance indicators, including area revitalised, number of indigenous trees planted, integration of gender-responsive NbS into local planning, improved solid waste management, gender equality and social inclusion, beneficiary population reached, and community participation.

Gaps and Areas for Improvement

While the project delivered measurable ecological restoration and strengthened community engagement, several challenges remain.

- Scaling NbS interventions beyond 469 hectares will require sustained financing, institutional continuity, and deeper integration into municipal planning instruments.
- While gender-responsive approaches were embedded in planning and implementation, tangible outcomes for women and other marginalised communities did not fully meet initial expectations. Broader societal perceptions of women's leadership in environmental initiatives did not change significantly within the project timeframe.
- Long-term institutionalisation of capacity building among stakeholders remains dependent on continued political commitment, funding, and policy mainstreaming.

Lessons and Way Forward

The SUNCASA project shows that restoring an urban river requires coordinated ecological, institutional, and community action. Key lessons include:

- Clearing invasive species improves biodiversity by clearing space for native species to grow.
- Waste management and flood mitigation can be combined through adaptive litter systems.
- Linking restoration to livelihood support increases participation.
- Gender inclusion requires sustained institutional embedding beyond project timelines.

Future efforts should prioritise:

- Expanding restoration across the wider catchment
- Securing diversified and long-term financing
- Integrating NbS into formal municipal planning instruments
- Strengthening monitoring systems for ecological and social outcomes
- The SUNCASA project demonstrates that urban river restoration in rapidly growing cities can reduce flood risk, address urban heat, and strengthen community resilience. But long-term success depends on sustained governance and financing beyond initial project periods.

Key Contacts

Figure 21: Undertaking plantations (Photo Credit: TheCityFix)

Name	Janina Schinck
Department	Economic Law and Policy Team
Organization	International Institute for Sustainable Development (IISD)
Address	111 Lombard Avenue, Suite 325, Winnipeg, Manitoba, Canada
Phone with international and national area code	+1 (204) 958 7700 (Canada)
Website	https://www.iisd.org/people/janina-schnick
Email address (preferably not personal address)	info@iisd.org; media@iisd.org

CASE STUDY


Photo Credit: Wetlands International South Asia

Tampara Wetland: Ecosystem-based Disaster Risk Reduction based Restoration

Odisha, India

City Profile and Key Information

Local Government Name (in English)	Chatrapur Notified Area Council
Country	India
State/Province	Odisha
Population (two adjacent fields: numerical field + year field) + if available: Population growth (annual %)	22027 (2011) ; 0.85% (Annual population growth)
Total Area	4.4 km^2
Main geography type: India	**Coastal** (highlighted); Dryland; Highland; Lowland; Mega delta; Small island

Overview

Tampara is a freshwater wetland located in Chatrapur block, Ganjam District, Odisha, within the Rushikulya River Basin along India's eastern coast.[24] The town lies near the Eastern Ghats mountains, and experiences a tropical monsoon climate zone. Its proximity to the Bay of Bengal makes the area highly exposed to cyclones, heavy rainfall, flooding and periodic drought.

Tampara Lake originated in the late 18th century when a depression formed near the Rushikulya River following a military event in 1766. Over time, the depression filled with rainwater and developed into a freshwater lake. A channel was later dredged to connect the lake with the river for the transport of goods, allowing periodic inflow of floodwaters and maintaining hydrological connectivity. Historically, this linkage enabled the wetland to function as a natural buffer during high-flow events.

The wetland supports fisheries, aquaculture, local transport, and tourism, and provides water to more than 10000 households. About 25,000 households depend on wetland-linked livelihoods, including fisheries, Kewra (*Pandanus odoratissimus L.*) flower collectors and water distilleries, and have 61 avian species, 23 fish species, and diverse flora and fauna.

---

24. MSME (2020). Brief Industrial Profile of Ganjam District (2019-20). Ministry of Micro, Small, and Medium Enterprises (MSME), Government of India. http://www.msmedicuttack.gov.in/press-release/kwjKvguABIPS-Ganjam%202019-20.pdf. Accessed on 12 July 2025.

Over time, however, rapid land-use change, agricultural expansion, construction activities and hydrological disruption changed the wetland's structure and functioning, reducing its ability to regulate floods and support livelihoods.

Problem Statement

Between 1988 and 2017, the wetland area shrank significantly, from 8,390 hectares to 2,433, respectively. Its hydrological connectivity with the Rushikulya River, which drains into the Bay of Bengal, was disrupted due to the diversion of inflowing streams and waste dumping. These and other anthropogenic activities such as intensifying agriculture, construction and encroachment, degraded the wetland ecosystem, reduced biodiversity, particularly fish diversity, and compromised water quality and flood buffering capacity.

The region's coastal location increases exposure to deadly cyclones such as Phailin (2013), Titli (2018) and Fani (2019). Recurrent flooding and extreme rainfall events have resulted in loss of property, livelihood disruption, and infrastructure damage. Wetland degradation directly increased community vulnerability by reducing flood absorption capacity, affecting fisheries and livelihoods, and weakening ecosystem services that earlier moderated flood impacts.

These combined ecological and socio-economic pressures prompted the Ecosystem-based Disaster Risk Reduction (Eco-DRR) restoration initiative in 2019.

Objectives, Local and Global Relevance

The project applied Eco-DRR, a NbS that restores ecosystem services to reduce disaster risks, while supporting the community's resilience and livelihoods.

The overall objective was to enhance the resilience of 12,000 households (approximately 60,000 people) to water-induced disaster risks.

Specific objectives included restoring wetland ecology and hydrological connectivity; reducing flood and cyclone-related risk; supporting climate-smart livelihoods; and mainstreaming Eco-DRR into local development planning.

The initiative aligns with the Sendai Framework for Disaster Risk Reduction, Ramsar Convention, the Post-2020 Global Biodiversity Framework, and national Wetland Conservation Rules.

Tampara Lake was designated a Ramsar Site in October 2021, recognising its international ecological importance at the international level.

Approach and Interventions

The model integrated ecosystem restoration, DRR and climate-smart livelihoods.[25] It was part of a larger participatory Eco-DRR project, implemented in Odisha, Bihar and Gujarat, focusing on the protection and restoration of wetlands, rejuvenation of village ponds, and conservation of waterbodies to strengthen disaster resilience.

In Tampara, community task forces were established across nine local village government units or panchayats to advance wetland conservation through awareness campaigns, sustainable livelihood practices, and indigenous knowledge. Stakeholders were trained in wetland conservation strategies and livelihood practices to strengthen their capacity for sustainable resource use and improve their livelihoods.

Ecological restoration actions included cleaning of 5.5 km of wetland channels, waterways, inlets and outlets; removal of water hyacinth; rejuvenation of 30 village ponds, restoration of 450 hectares of wetlands and common resources; monitoring of wetland health; and promotion of native species planting. Pond rejuvenation reduced extraction pressure on Tampara Lake and supported groundwater recharge.

Eleven Task Force Groups comprising about 150 local wetland champions were formed to support community outreach and monitoring. Indigenous and traditional practices such as making organic fishing gear and nets were promoted. Fisher communities were encouraged to discontinue the use of zero-size nets and adopt bamboo-based fishing gear, thereby reducing ecological stress on fish stocks. Awareness campaigns on Eco-DRR practices reached more than 18,000 community and CBO members in the basin.

Women actively participated in plantation and conservation activities, while community groups organised plastic waste collection drives to reduce pollution caused by tourists.

Scientific tools included the Hazard Vulnerability Capacity Assessment (HVCA) and the Ecosystem Services Shared Value Assessment (ESSVA), which informed restoration priorities.

Governance and Institutional Arrangement

Wetlands International South Asia led the project, with technical support from UNEP and collaboration from state, district, and local institutions.

At the local level, nine Gram Panchayats integrated Eco-DRR actions into their Gram Panchayat Development Plans, enabling convergence with public schemes such as the Mahatma Gandhi National Rural Employment Guarantee Scheme and the Odisha Livelihoods Mission. Community-based organisations, women's self-help groups, and Wetland Champion task forces supported on-ground implementation, monitoring, and awareness-building.

This multi-level arrangement enabled ecosystem restoration measures to move beyond project-based action and become embedded within formal planning and public financing systems.

---

25. UNEP (2022). Upscaling community resilience through Ecosystem-based Disaster Risk Reduction in India. United Nations Environment Programme (UNEP).

Institutional Roles in Project Implementation

Stakeholder	Role
UNEP; Wetlands International South Asia	Technical support and funding partnership
Chilika Development Authority	Scientific assessment, ecological oversight, and regulatory guidance
Ganjam District Administration	Integration with district disaster management planning
Gram Panchayats	Local planning integration and convergence with government schemes
Self-help Groups; Community-based Organisations; Wetland Champions	Community implementation, monitoring, and awareness generation

Outcomes and Impact

The Tampara Eco-DRR initiative resulted in measurable improvements in wetland condition, livelihood security, and flood risk management.

Ecological Outcomes: Approximately 450 hectares of wetlands and associated common-pool resources were restored. Cleaning 5.5 km of inlets and outlets improved water circulation and reduced obstructions that had previously intensified flood risk. The rejuvenation of 30 village ponds reduced extraction pressure on Tampara Lake and strengthened local water availability.

These actions contributed to improved water quality, partial restoration of hydrological connectivity, and recovery in fish diversity, indicating ecological stabilisation of the wetland system. The wetland was recognized for its unique characteristics and designated as a Ramsar Site in 2021.

Social and Livelihood Outcomes: More than 18000 community members were sensitized on Eco-DRR Practices, with 12000 households receiving resilience training in sustainable livelihood practices and wetland conservation approaches. For example, local fishermen adopted bamboo fish nets and discontinued zero-sized nets, reducing ecological stress on fish stocks.

Economic Outcomes: The cost-benefit analysis estimated total annual GDP in the project area at USD 18.68 million. Annual GDP losses avoided due to reduced disaster exposure were calculated at USD 373,651 (2% of annual GDP). The Net Present Value of the project's benefits was estimated at USD 2.7 million over 5 years and USD 14.2 million over 10 years.

Approximately 18,000 people and 4,500 properties were protected through improved flood regulation and ecosystem recovery.

Beyond quantitative results, the project improved the wetland's capacity to absorb floodwaters and regulate hydrological flows. Integration into Gram Panchayat Development Plans institutionalised ecosystem-based DRR, while Ramsar designation in 2021 strengthened conservation status and policy visibility.

Figure 22: Undertaking plantation activities (Photo Credit: Wetlands International South Asia)

Gaps and Areas for Improvement

Despite these gains, there were several institutional and technical gaps.

A comprehensive range of wetland-based ecosystem services and biodiversity values were not integrated into developmental planning like Gram Panchayat Development Plans. Cross-sectoral coordination among the water, agriculture, and fisheries sectors remains limited, hindering wider scaling.

Intensive advocacy and capacity building are needed to encourage local government institutions to own wetlands management. Mechanisms are needed to resolve resource-use conflicts between farmers and fishermen. Alternative and sustainable livelihood opportunities for wetland users are needed, supported by government schemes or programs.

Continued capacity development is necessary to enable panchayats and wetland user groups to plan and implement restoration activities. Demonstration activities are needed to show how Eco-DRR helps restore hydrological regimes in wetland basins.

Lessons and Way Forward

At Tampara, restoring water flows between the lake and its channels was central to reducing flood risk and improving wetland health. Cleaning and reopening inlets and outlets made it possible for the wetland's ecological functions to recover. The project experience highlights that restoring hydrological connectivity is fundamental to reducing water-related disaster risks in wetland systems.

Linking ecosystem restoration with public employment schemes improves financial sustainability and encourages local participation. The Eco-DRR project was integrated early into local planning frameworks, including Gram Panchayat Development Plans. Support from national and state schemes provided practical funding channels, reducing dependence on short-term project resources.

Community task forces and wetland champions played an active role in implementation and awareness efforts. Engagement with fishing communities led to changes in practice, including discontinuation of zero-size nets and greater use of bamboo-based nets.

The cost-benefit analysis provided concrete estimates of avoided losses and long-term economic returns, helping local authorities assess the value of restoration measures.

Going forward, better coordination across sectors, clearer documentation of hydrological changes at the basin level, and stronger integration of ecosystem considerations into development planning would support further progress.

Figure 23: Restored Tampara Wetland (Photo Credit: Wetlands International South Asia)

Key Contacts

Name	Dhruv Verma
Department	Wetlands Conservation
Organization	Wetlands International South Asia
Address	Module No. 003, Ground Floor, NSIC Business Park, Okhla Industrial Estate, New Delhi 110020, India
Phone with international and national area code	+91 11 46038906
Website	https://south-asia.wetlands.org/about-us/meet-our-team/
Email address (preferably not personal address)	dhruv.verma@wi-sa.org

NOTES

ICLEI - Local Governments for Sustainability, South Asia
C-3, Lower Ground Floor, Green Park Extension, New Delhi - 110016, India
Tel: +91 – 11 – 4974 7200; Fax: +91 - 11 - 4974 7201