Approach to Waterbody Rejuvenation

A Perspective

Consortium for DEWATS Dissemination Society

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Approach to Waterbody Rejuvenation: A Perspective

Publication by: **Consortium for DEWATS Dissemination (CDD) Society**

'Waterbody Rejuvenation' for the purpose of this publication means rejuvenation of inland waterbodies that include lakes (natural, manmade, deep and shallow), reservoirs, tanks, and ponds located in urban and peri-urban areas; and to some extent, addresses the drains, streams and nallahs that discharge into these waterbodies. The rejuvenation of main river channels, their flood plains, creeks, estuaries and coastal waters is not addressed here and nor are rural waterbodies.

This publication is a knowledge document and emphasises CDD Society's perspective on the subject.

July 2019

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Kasavanahalli Lake, Bengaluru, Karnataka

Preface

Public health and environmental health are intricately linked; and, nothing signifies a healthy environment better than a waterbody full of life.

There is an old saying that **WATER IS LIFE** and this is generally interpreted as water is important for our survival i.e. to sustain human life on this planet, but what this statement also means is that ***water contains life*** and therefore, waterbodies are **LIVING SYSTEMS** – teeming with life. So, rejuvenating a waterbody is like healing an ailing person. There are quick fixes, and there are more sustainable approaches to well-being – more enduring, cheerful, wholesome and glorious! Rejuvenating a waterbody in a sustainable manner is about bringing life back into the water-body, enhancing and sustaining it.

Why did it fall sick in the first place? Humans are surely to be blamed. We have so savagely violated our waterbodies and in so many ways (solid waste, industrial pollution, domestic sewage pollution, encroachments, commercial fish farming, etc.) that the majority of them are either dead or on the brink of death. Urbanisation and industrialisation have increased the intensity of pollution to such an extent that the self-healing capacities of our waterbody ecosystems are no longer enough to counter these multiple onslaughts. Nothing is more urgent for restoring the environmental health of our country than rejuvenating our waterbodies. Doing so can have enormous positive impacts not only for the environment but also for human health, the economy and the nation's well-being.

While fixing the problems at their origin (source) is the ideal way forward, there is scope for intermediate relief in the form of fixes along the flow channels or addressing the problems in the terminal waterbodies. Fixing the problem at source is about altering human behaviour and helping citizens make the connection between their well-being and the health of the waterbodies that serve them. The intermediate relief approaches are also important in helping people get a glimpse of what well-being can look and feel like!

At CDD, we have attempted to build on our legacy of decentralised wastewater treatment (DEWATS) to come up with Nature Based Solutions (NBS) for rejuvenating waterbodies. To do so, we have taken a **holistic approach that looks at the multiple facets of a waterbody** – its role as a water storage and recharge structure in preserving and enhancing our water resources and thereby enhancing water security; its potential role as a cleanser i.e. its ability to remove carbon and nutrients from polluted waters; its role as a buffer in flood management; its role in supporting

life (biodiversity) and livelihoods (economy); not to mention, its additional roles as glorious public and religious spaces that heal the soul.

Well, taking a systems view is not easy. It calls for a way of thinking that is multi-disciplinary, inter-disciplinary and toggles between macro and micro perspectives. It is about seeing the interfaces, the sub-systems, the feedback loops, the delicate balance that exists within the system and the self-governing mechanisms at work. This includes a good understanding of the history, legacy systems, hydrology and hydro-geology, native biodiversity, catchment characteristics, pollution characteristics, social contexts around livelihoods and rights etc. **Solutions to rejuvenate a waterbody, then become highly contextual.**

A living system also requires a living and learning institution to nurture it. Although waterbodies have the capacity for self-healing, they do require some form of regular maintenance. Given the dynamic nature of the waterbody ecosystem, it is important to observe it regularly, *collect data on an ongoing basis and take necessary steps to keep the system well-tuned* (in good balance). Policy, regulation and institutional mechanisms to ensure adequate preservation, operations & maintenance and financial sustainability thus become critical pieces to sustain a rejuvenated waterbody. *Any such mechanism should have citizens at the centre of it* – who can play the role of custodians/trustees, given that they are also the natural beneficiaries of such rejuvenation efforts.

This publication is an attempt to unpack such an approach and provide a deeper insight into these perspectives. It suggests frameworks and methodologies that can be used to come up with holistic and sustainable solutions. While the emphasis is on technical solutions, the approach locates this in the context of a broader systems thinking framework.

I hope this publication is useful to all those who are passionate and enthusiastic about reviving, rejuvenating and preserving our waterbodies – government, citizens and service providers.

I would like to acknowledge key contributions of my colleagues who were instrumental in producing this document – *Ms. Sonal Kaushik* for steadfastly leading the effort and contributing to its development, *Andrews Jacob* and *Karthik Ravichandran* for their key contributions and support, *Gilles Boulicot, Tarika, Isha, Vrishali and Debisha* for their review, *Raphael Hannequin* for some wonderful illustrations and many others in CDD and its network whose body of work has shaped the ideas in this document.

While the current publication draws upon CDD's limited experience in this field, we hope to bring out more upgraded versions as our own experience in this domain continues to grow. We welcome feedback from readers and further insights/contributions to improve this document. We want to see this as a living and learning document.

Happy reading!!

GANAPATHY P.G.
Director of Programs

Kurichi Lake, Coimbatore, Tamil Nadu

01 | Urban Waterbodies Today
in a state of **abject decline**

Urbanisation has been rapidly increasing in the last few years in India, in terms of economic development, population and geographical boundaries. It is a global observation that all urban expansions have engulfed waterbodies in their territories and peripheral regions.

Waterbodies have been the backbone of resource sustainability in any urban conglomerate. They cater to different needs - drinking, washing, fishing and irrigation, they are an essential resource for industrial development, store water, serve as a retention mechanism that captures flash floods, help maintain ground water levels through recharge, support biodiversity and avian fauna, and influence a city's micro-climate. Apart from performing the above mentioned ecosystem services, waterbodies are natural carbon sinks that help in mitigating global warming and accumulation of greenhouse gas emissions, primarily originating from cities.

Today, the availability and quality of water resources are under considerable threat. Our waterbodies are being degraded in multiple ways. The many challenges being faced by urban waterbodies include –

01 | The **Solid Waste** Challenge

Solid waste creates a bigger challenge than any other issue as in many cities, waterbodies are treated as dump yards not only for municipal solid waste but also for construction & debris (C&D), biomedical waste, faecal sludge from septic tanks, industrial hazardous waste, food waste from hotels and restaurants – all of which have contributed to converting these waterbodies into cesspools. **Indiscriminate dumping of solid waste** results in increased organic load, toxic and inert waste, blockage of water flow, foul smell, and reduced aesthetics of these waterfronts.

Solid waste choking the outlet of **Kumaraswamy Lake**, Coimbatore

02 The **Wastewater Pollution** Challenge

Deterioration of water quality due to wastewater (municipal & industrial) discharged through storm drains and open nallahs into waterbodies is a common challenge. In peri-urban areas, agricultural runoff containing fertilizers and pesticides also deteriorates water quality. Activities like bathing, washing clothes, washing cattle, recreational activities like boating, and cultural activities like idol immersions also contribute to polluting waterbodies. This poses a major health hazard to those consuming these waters.

Inflow of wastewater into **Selvachintamani Lake**, Coimbatore

03 The **Weed & Silt** Challenge

Both point and non-point source flows bring silt, pollutants and nutrients into waterbodies, deteriorating the water quality and causing the **manifestation of water hyacinth leading to eutrophication**. Majority of urban waterbodies are overtaken by invasive species and heavily covered by weeds, especially during the monsoon. These species cover the entire water spread and disturb the waterbody ecosystem.

Increase in weeds (especially invasive species) and silt, in turn leads to **loss of habitat and decline in species** associated with the ecosystem. The resulting loss is not only a burden on the environment but also an economic and social burden on the public whose lives are directly dependent on the natural resource.

Weed infestation in **Hoskere Lake**, Bengaluru

04 | The **Drain & Infrastructure** Challenge

Lack of regular maintenance of inlet and outlet structures leads to their deterioration. Clogging conditions near the inlet and outlet structures, seepage at outlets, and breached bunds are commonly observed. In many cases, due to alteration of natural drainage channels and development of new urban infrastructure, including interception of drains in the upstream, the waterbodies are not refilled, and often go dry. On the other side, storm water having no alternate path, causes floods near the obstructed drains.

Deteriorated inlet structure of **Selvachintamani Lake**, Coimbatore

05 | The **Social** Challenge

Unauthorised squatters and large-scale **encroachments** by developers is another challenge facing urban waterbodies. These result in obstruction of stormwater flows, thus making the waterbodies defunct or dry for most of the year. Wastewater generated from these squatters also contributes to deterioration of water quality; as does open defecation.

Over the years, people have been disconnected from their water history, primarily because of a **lack of knowledge and sensitivity** towards the waterbody ecosystem. Citizens are not aware of the problems that dumping of solid waste, discharging of wastewater, open defecation, or encroachments, pose to these waterbodies. A general misconception among people is that keeping a city clean is the government's responsibility and not theirs.

Many **livelihoods are completely dependent on these waterbodies** and their decline poses a challenge for the communities to survive.

Encroachments along the outlet drain of **Kurichi Lake**, Coimbatore

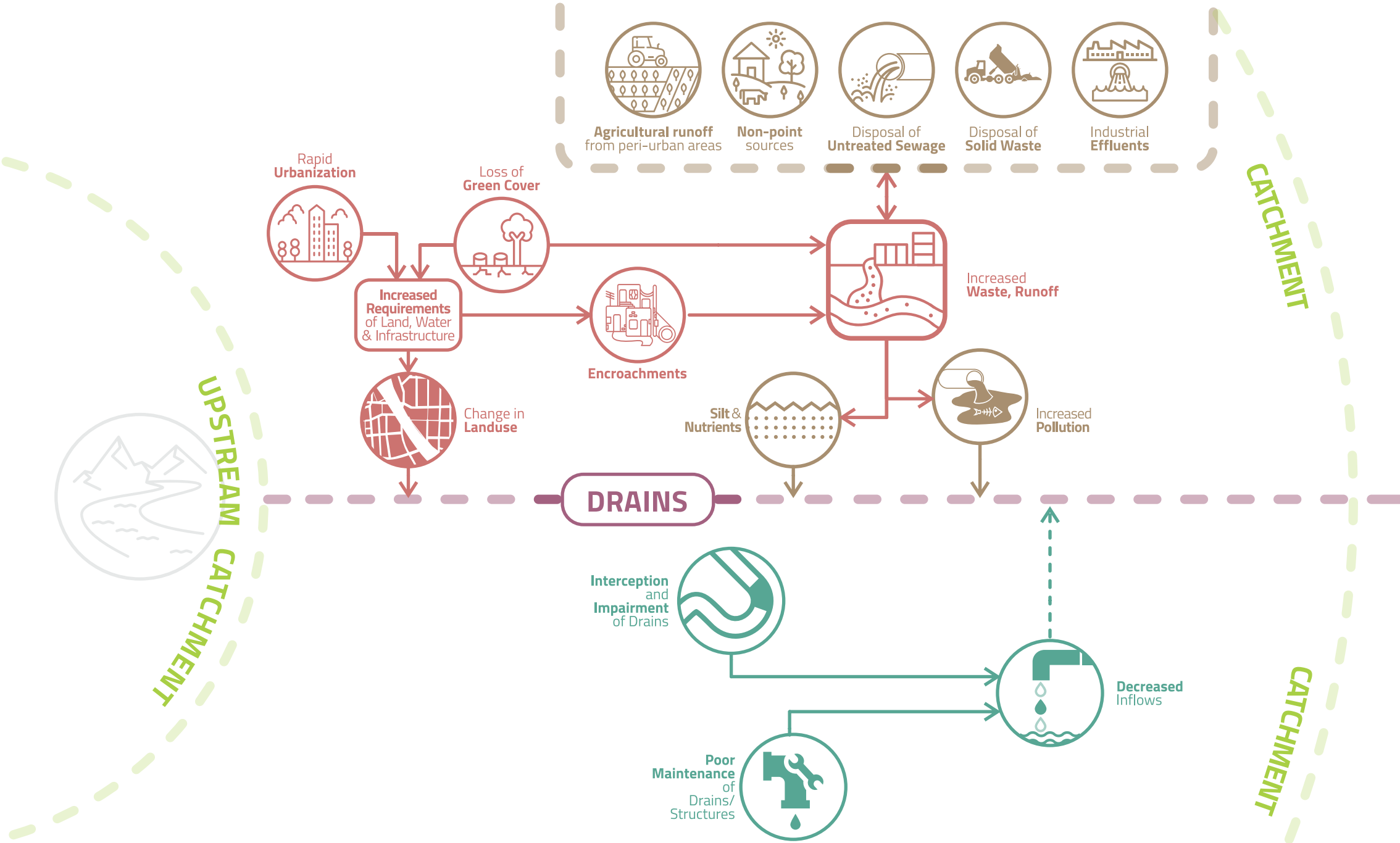
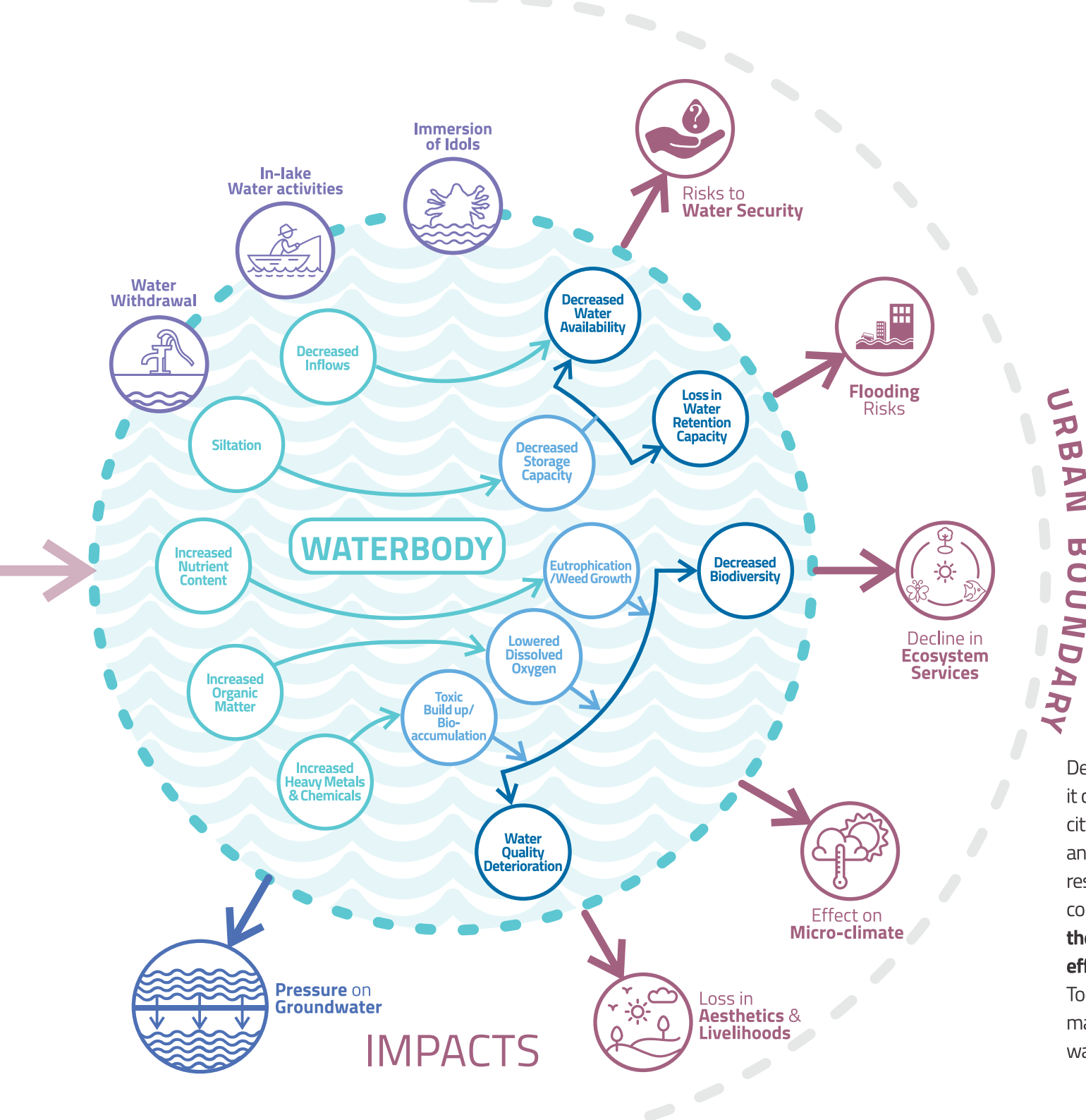


Figure 1: Impact of the Interconnections of Urban Activities on the Catchment, Drains and Waterbodies in Urban Areas

ISSUES / CHALLENGES



Despite the threat that urbanisation poses to waterbodies, it cannot be abruptly stopped – after all, it is needed for a city's future growth. Waterbodies are a critical feature of any urban landscape as they are an easily accessible resource for human use. However they have been continuously degraded over the years. **It is now time that their role is properly evaluated in the urban economy and effective actions are initiated for their rejuvenation.** Today, the need is to structure and implement effective management principles to preserve and restore waterbodies in urban localities.

Jakkur Lake, Bengaluru, Karnataka

02 | The Essence of Waterbody Rejuvenation
recognising the **interlinkages**

Waterbody rejuvenation encompasses the following –

- Restoring the wholesomeness of the waterbody to its original state
- Conserving and enhancing its biological diversity
- Conserving and preserving its ecosystem services
- Reviving the waterbody into a (new) live form, if deteriorated altogether (beyond repair) over time due to anthropogenic pressures
- Managing the waterbody within the context of sustainable development, while meeting the current and future demand without compromising on its ecological health/ character

The World Lake Vision developed by the International Lake Environmental Committee *(ILEC[1])*, Japan, has provided seven key principles for sustainable lake management (*refer* ***Box 1***). These align with the rejuvenation philosophy defined above as well as with the rejuvenation approach and process discussed further in this document.

Box 1

Principles for **Sustainable Lake Management**

Principle 1 : A harmonious relationship between humans and nature is essential for the sustainable use of lakes

Principle 2 : A lake drainage basin is the logical starting point for planning & management actions for sustainable lake use

Principle 3 : A long-term, preventive approach directed to preventing the causes of lake degradation is essential.

Principle 4 : Policy development and decision making for lake management should be based on sound science and the best available information.

Principle 5 : The management of lakes for their sustainable use requires the resolution of conflicts among competing users of lake resources, taking into account the needs of present and future generations.

Principle 6 : Citizens and other stakeholders should be encouraged to participate meaningfully in identifying and resolving critical lake problems.

Principle 7 : Good governance, based on fairness, transparency and empowerment of all stakeholders, is essential for sustainable lake use.

Source : Kodarkar MS, 2008

[1] ILEC is a non-governmental organisation established in 1987 by Japan's Environmental Agency and Ministry of Foreign Affairs, with the objective of advancing international cooperation for the conservation of lake environments and to promote environmentally sound management of lakes around the world, based on scientific knowledge gained through primary research.

Kaikondrahalli Lake, Bengaluru, Karnataka

03 | Unravelling the **Legal Framework**
good **intentions** - weak **enforcement**

"It is the duty of every citizen of India to protect and improve the natural environment including forests, lakes, rivers and wildlife, and to have passion for living creatures."

-Article 51 A of the Constitution of India

Although, the Constitution of India stresses on protecting and improving inland waterbodies such as lakes and rivers, they are currently not covered under any specific legal statute in India. Nevertheless, there are several legislations (*refer **Box 2***) enacted till date that have relevance and provisions for conservation of lakes. In addition, some states have individual state level legislations for the protection and conservation of their lakes and wetlands. India has also been a signatory to the Ramsar Convention on Wetlands since 1982 and is committed to conservation and wise use of all wetlands within its territory. Further, the National Green Tribunal (NGT) has also passed orders for the restoration of environmental zones around lakes and wetlands that are relevant for some cities/states.

The **key policy and rules** that need to be referred to with respect to management of waterbodies are –

- **The National Environment Policy (NEP), 2006**, which recognises the ecosystem services provided by wetlands and seeks to set up a legally enforceable regulatory mechanism for lakes and wetlands to prevent their degradation and enhance their conservation.
- **The Wetland (Conservation & Management) Rules, 2010**, amended in 2017, stress on the conservation and management of wetlands in accordance with the principle of 'wise use'. It aims to decentralise the management of wetlands to the state authority. It delineates the activities prohibited in notified wetlands.

Box 2
Existing **Legal Provisions**

The major legal provisions which have a bearing on inland waterbodies are:

- The Indian Fisheries Act, 1897
- The Wildlife Act, 1972,
- The Water (Prevention & Control of Pollution) Act, 1974
- The Forest Conservation Act, 1980
- The Environment (Protection) Act, 1986
- National Environment Policy (NEP), 2006
- Waste Management Rules, 2016
- Wetland (Conservation & Management) Rules, 2017

Other than the above, the **key programmes and schemes** rolled out by the Government of India for the conservation, restoration and rejuvenation of waterbodies are –

- The then Ministry of Environment & Forests (MoEF) came up with the ***National Wetlands Conservation Programme (NWCP)*** in 1985/86 for implementing management action plans for wetlands *with preservation of biodiversity at its core*. In 2001, the

National Lake Conservation Plan (NLCP) was introduced to address pollution issues in lakes situated in urban, peri-urban and semi-urban environments through interception, diversion and/or treatment of pollution loads. The Ministry in 2013 merged the two schemes into an integrated scheme named ***National Plan for Conservation of Aquatic Eco-systems (NPCA)***, considering the need for a common approach towards conservation and management of lakes and wetlands, despite certain differences in the goals and objectives (e.g. biodiversity, in the case of wetlands, and water quality, in the case of urban lakes) to enable the application of a uniform guideline, and promote an integrated and multi-disciplinary approach with a common regulatory framework.

- In 2009, the Ministry of Water Resources (MoWR) came up with a National scheme on ***Repair, Renovation and Restoration (RRR) of Waterbodies***. This scheme has provisions of being financed by either a state government or by external assistance (i.e. The World Bank).
- In December 2018, the Ministry of Housing Affairs issued ***Draft Sub-guidelines for Waterbody Rejuvenation under AMRUT (Atal Mission for Rejuvenation and Urban Transformation)***. The scheme is applicable to all cities under AMRUT, where two waterbodies can be taken up for rejuvenation to facilitate water supply and groundwater recharge in the city.

Box 3

Key Planning & Control Rules extracted from Legal & National Guidance Documents

- Every lake has unique hydrological and ecological characteristics. While planning restoration activities, these unique characteristics need to be considered.
- A buffer zone covering a certain distance around the waterbody should be declared as no-development zone or as an eco-sensitive area.
- Dumping of any solid waste into these eco-sensitive areas should be made a punishable offence.
- Any commercial use of the waterbody and its immediate surrounding areas should be assessed before permission is granted by relevant authorities.
- Measures to arrest first storm water load through bio-approach at the space prior to entry point, or at the entry-point should be evaluated.
- Catchment protection should be included in restoration activities.
- The shoreline of waterbodies should be properly fenced to protect from encroachment.
- Any outfall of wastewater into the waterbody should be prevented and only treated effluent, as per effluent standards of the State Pollution Control Board, may be allowed to be disposed into waterbodies.
- The water quality of waterbodies needs to be monitored, on a regular basis, by the relevant authorities.
- *Dredging should be avoided while Desilting can be considered*[2].
- Felling of trees for any development in or around the waterbody should be avoided.
- Stakeholder participation and capacity building must be used as important instruments for better planning and management of waterbodies.
- Ownership of waterbodies should be should be clearly defined, as most face indefinite sustenance due to multiplicity of administrative control and/or lack of specific action by a singular authority.
- Dovetailing of various government programmes and projects in the planning, for conversion of funds to be considered.

[2] Desilting involves the removal of accumulation of silt and sediments in order to restore the waterbody capacity. It does not involve widening or deepening the waterbody. Dredging goes further than desilting by enlarging the waterbody through deepening and widening.

Institutional Framework for Inland Waterbody Management

Inland waterbodies and lakes (or wetlands) are governed at three levels in India as illustrated in ***Figure 2***.

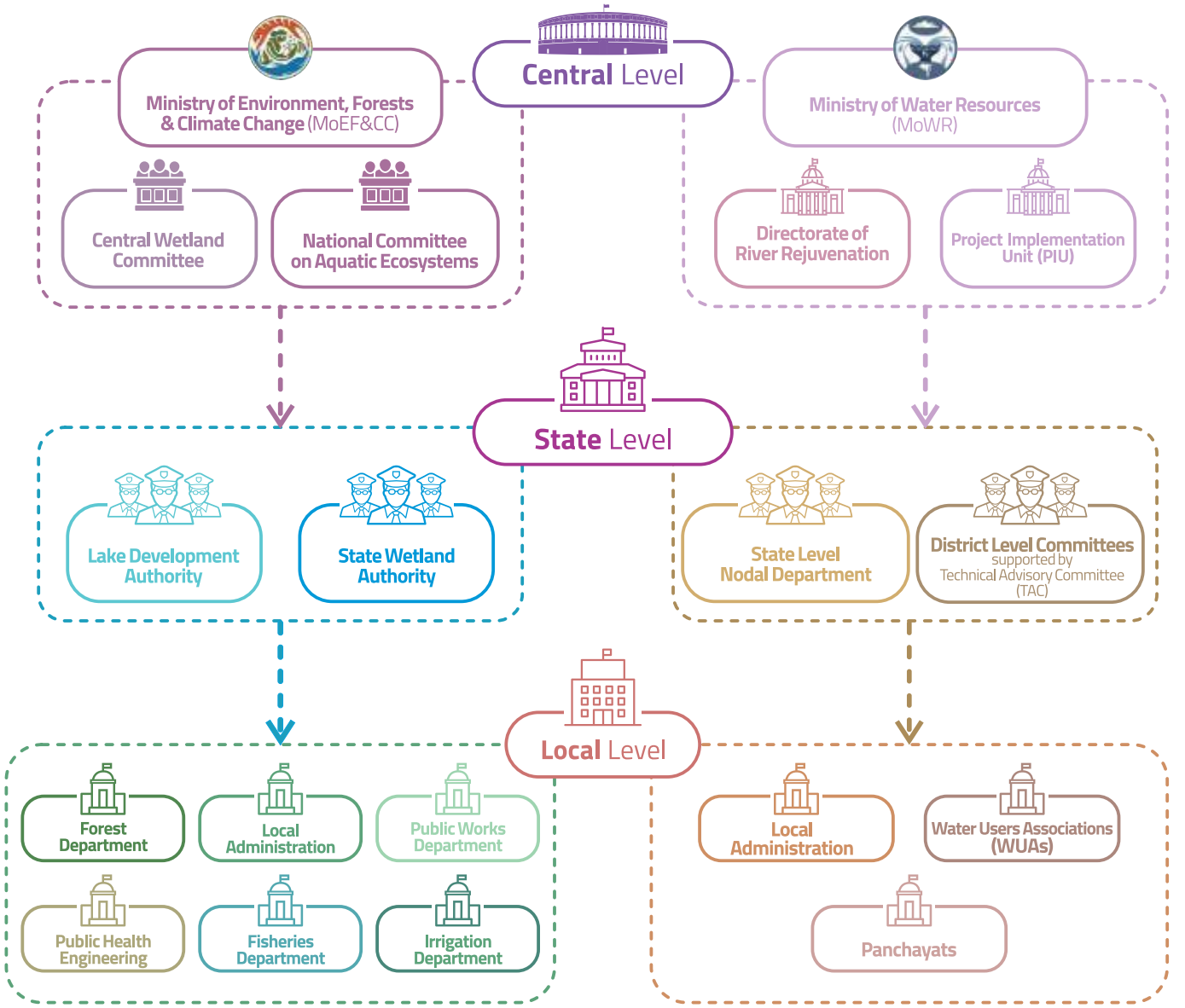


Figure 2: **Institutional Framework** for Management of Inland Waterbodies in India

The custodians of conservation programmes, such as NPCA and RRR of waterbodies, are Ministry of Environment, Forests & Climate Change (MoEFCC) and Ministry of Water Resources (MoWR) at the National level respectively, supported by State Nodal Authorities/ Agencies at the State level (which are either autonomous bodies or are housed in the Environment or Forest department).

At the local level, inland waterbodies are multiple use systems and therefore have many stakeholders. Quite often, the same waterbody is managed by several agencies/ departments with conflicting interests. The departments of Public Health Engineering, Water Supply, Fisheries, Irrigation, Urban Development, Local Administration, Tourism, and Environment & Forests are among the common ones responsible for maintaining waterbodies across different states. **The multiplicity of agencies involved in the use and management of the inland waterbodies is one of the key causes of their degradation.**

Limitations of the Current Legal Framework

01 | **Lake authorities** have limited success as they **lack enforcement powers**

- National or State level agencies/committees created for implementing conservation programmes have not been as effective because **their role is limited to approval** of Conservation Plans and they **do not have powers to enforce or penalise for non-compliance**.
- There is no specific institutional mechanism yet, which is a regulatory agency for Lake/Wetland Management, at the National or State level, with a well-defined monitoring and enforcement mechanism and that can act as a guide to states for sustainability of conservation programmes.
- The decentralisation of powers under the Wetland Rules 2017 is a good step towards management of wetlands and easing off the long institutional red-tape process. However, **the creation of State Wetland Authorities under an already existing State Department, loses its supremacy and power to enforce and regulate**.
- There were efforts in the State of Karnataka, where the Lake Conversation Authority Act was enacted with powers to regulate and enforce. However, the Act was repealed by the State government itself within a couple of years and housed the Lake Authority (now renamed Tank Development Authority) under Minor Irrigation department, thereby diluting its power of enforcement.

02 | **No legal norms** for inland urban waterbodies **smaller than 100 ha** or for those that are **not notified**

- No norms or guidance is provided in the legal framework for urban waterbodies less than 100 ha or those that are not notified by the government. The regulations, policies and programmes related to conservation & repair are applicable for notified waterbodies or for those which fall under their criteria (generally, large water bodies).
- Earlier, the NLCP could be referred to, for urban/ peri-urban waterbodies greater than 10 ha. However, with the introduction of NPCA 2013 guidelines (which supersede the NLCP 2008 guidelines), **small urban water bodies are not regulated by any legal instrument**. Though, in some cases, ecologically sensitive or important waterbodies in an urban area are regulated via State resolutions, there are no general guidelines at the national level.

03 | Though comprehensive, **NPCA guidelines have not yet been adopted** on the ground in its truest sense

- NPCA guidelines adopt the ecosystem approach with more emphasis on biodiversity conservation values. It also provides for sustainable utilization in a way that is compatible with maintenance of natural properties of the ecosystem. **The guidelines detail out all the key elements** required under planning, implementation, management and monitoring of any integrated management plan of wetlands/ lakes. However, **their adoption on the ground remains to be seen**. We are yet to see an example in India where the NCPA guidelines have been followed in their truest sense and as comprehensively as guided in the document.

04 Lack of operational level guidance for effective implementation & monitoring

- A key aspect missing in the NPCA guidelines are comprehensive details for each conservation activity proposed for repair or restoration of waterbodies. For example, the strategy for when to propose desilting operations is clearly laid out, however the operational guidance is missing, such as - how to plan and conduct desilting operations, different desilting/dredging technologies available, the machinery to be used for desilting, how to deal with dredged material etc. If such guidance for each conservation activity is defined and standard operating procedures are laid out, it will be easy for planners to prepare a robust plan as well as for regulators to monitor.

05 Lake Management Plans as per National Programmes **are prescriptive in nature and not sustainable**

- The management plans for waterbodies are mostly formulated, financed and implemented on annual cycles, and generally, these **are not based on comprehensive catchment-scale** management plans.
- Most **plans are prescriptive in nature and do not address the root causes of degradation** which may include changes in hydrological regimes, catchment characteristics, pollution levels or loss of biodiversity.
- Post project sustainability strategies are also not worked out. In only a few states, has allocation been made within their budgets for maintenance of aquatic ecosystems. Wherever such allocations are made, it is mostly for establishment expenses and not for supporting restoration activities or monitoring on field.
- Lake management plans that involve government approvals **stress on infrastructure development that can be quantified** and estimated following states' *SORs*[3]. **The softer aspects**, which include expert technical advice leading to better solutions, adoption of best practices, environmental monitoring, capacity building and public sensitization **are not considered or encouraged**. This leads to development of plans that are not sustainable in the long run.

[3] Schedule of Rates (SORs) is a rate list setting out the staff, labour and works related rates that a contractor will use for pricing cost reimbursable work. All the Governments/Departments every year prepare and update rates of normally used items/materials/works. Estimates have to be worked out based on those rates only. This enables the government to compare offers/quotes from different contractors.

Hoskere Lake, Bengaluru, Karnataka

04 | A **Suggested Approach** to Rejuvenation
holistic and **participatory**

The rejuvenation approach of waterbodies is multi-faceted, multi-dimensional and depends on the existing condition of the waterbody as well as the purpose of rejuvenation. A waterbody is a dynamic feature in a catchment - its variations are both spatial and temporal. Further, it is influenced by a human context determined by policy, institutional, financial and sociocultural elements. Hence, the rejuvenation process needs to consider all dimensions and be holistic.

Based on its recent experiences of waterbody rejuvenation, CDD Society has attempted a holistic framework for rejuvenation and the same is illustrated in ***Figure 3***.

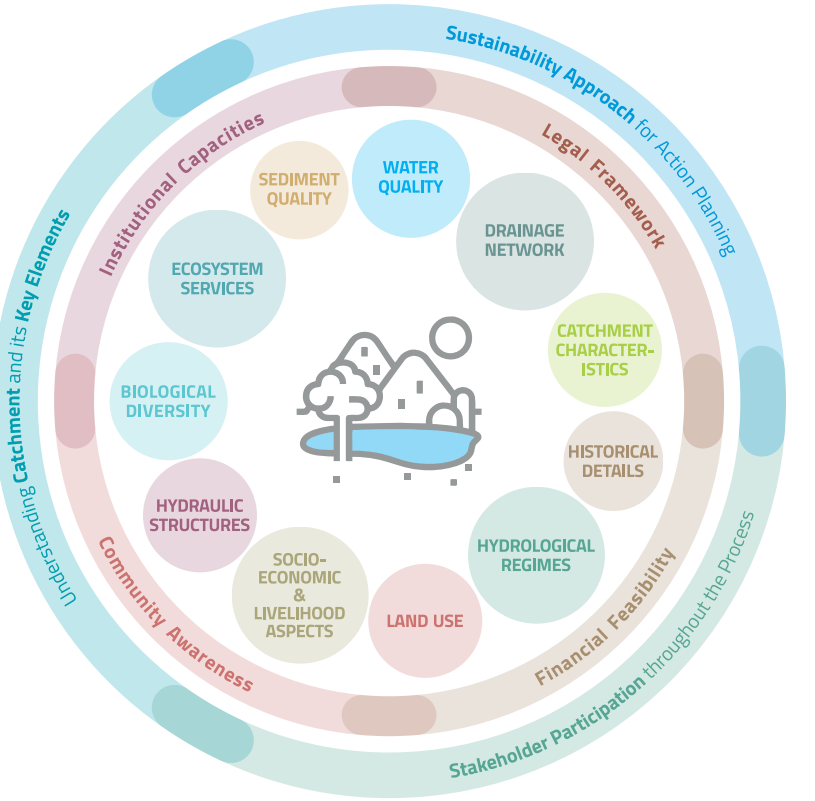


Figure 3 : Holistic Approach for Waterbody Rejuvenation

Understanding **Catchment** and its **Key Elements**

While designing a rejuvenation plan, **an understanding of the waterbody as a part of a bigger system is critical**. Land and water are ecologically linked in a natural system called a *catchment, drainage basin, or watershed*. A waterbody is a reflection of its watershed/ catchment; more specifically, it is influenced by the catchment's size, topography, geology, soil, land use and vegetation.

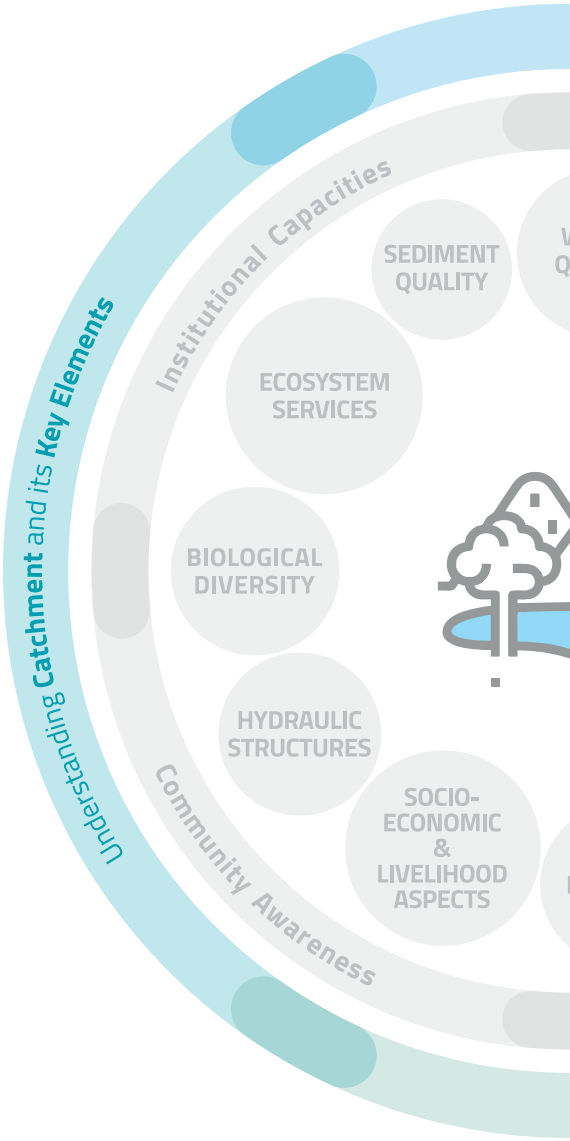
Adopting a catchment approach enables understanding of the hydrological regime of the basin, which governs the 'quantity' of water that reaches the waterbody. It also indicates the silt (from the upstream catchment) and nutrient load (from sewage and fertilizers from gardens and peri-urban agricultural fields) that the runoff may carry to the waterbody, thereby helping understand the 'quality' of water and 'source of pollution' reaching it.

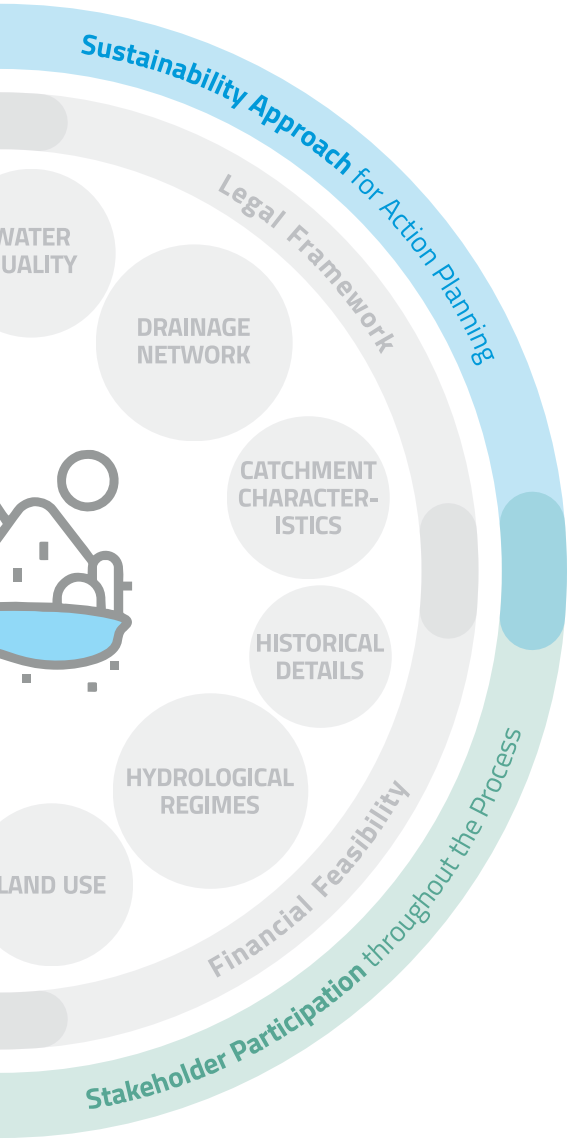
The approach **emphasises a cross-disciplinary understanding of water, land, people (community) and related elements** in a catchment, to comprehend the lake holistically and the key elements that influence it.

For instance, hydrological factors are important in accounting for the spatial and temporal variations in runoff quantity, quality, silt and nutrient loading in waterbodies. These factors include basin morphology, climatic factors, vegetation and land use, solid and drift geology, soils and anthropogenic activities. Other than the hydrological factors, limnological factors also contribute to spatial and temporal variations that have a direct influence on the aquatic ecosystem and the life it supports. These factors include water flow-rate, morphology, salinity, acidity, oxygen, biological diversity, light levels, depth and temperature.

Moreover, changing land use has an impact on the quantity and quality of water entering the waterbody. In urban areas, the high proportion of impervious area increases the runoff to waterbodies and at the same time, high intensity runoff carries silt and urban waste, deteriorating the water quality. Water infrastructure is another important element that regulates the inflows and outflows into the waterbody and also is the key to regulating floods. Another key aspect is the governance of the waterbody that informs about its ownership and the legal instrument by which it is regulated and maintained.

Therefore, while planning and developing any rejuvenation plan, it is essential to study all the key elements and interconnections that influence the waterbody. *Refer next section on **Key Elements** that influence the Waterbody (Page 23-25), that provides detailed information about these elements.*





Sustainability Approach for Action Planning

An important aspect of the rejuvenation approach is to assess and address existing and future demands that the waterbody is or will be servicing. Hence, while planning for future needs, **it is necessary that the rejuvenation plan respond equitably to the social, economic, environmental and regulatory imperatives**. And at the same time understand the interconnectedness and interdependence between these aspects while also considering institutional mechanisms responsible for its implementation and maintenance.

Further, **interventions may involve policy, plan, project and program level interventions that complement each other and result in sustainable solutions**. Most rejuvenation solutions are generally observed to be techno-centric and piecemeal, and not holistic; for example, sewage treatment plants (STPs) are seen as an immediate solution for pollution reduction of wastewaters being discharged into waterbodies. These STPs become defunct in a few years' time either due to operational, capacity, monitoring or financial issues. In these cases, if the action plan includes regular training programs to raise institutional capacities and policy level commitment on budgets for O&M to complement the STP project(s), then there are better chances of the rejuvenation plan being sustainable. Hence, for solutions to be sustainable, it is important to adopt a holistic and rounded approach while designing the interventions or action plan.

Stakeholder Participation throughout the Process

Water rejuvenation plans are always people's plans. **Stakeholder participation plays a significant role in triggering and sustaining the rejuvenation process.** The plan can be realised only if there is a buy-in and commitment from the general public. Even if thoughtful plans are created, their success over the years is certain if the general public is sensitized and committed towards helping the government to maintain the improved status of the waterbody. This will happen only when the citizens are involved in the planning process itself. Participation and involvement of people is to be sought at various stages of project development & implementation:

Planning Stage

- A maximum number of people should be informed about the problems affecting the waterbody, the rejuvenation plan and the expected outcomes
- The community/ individuals should be consulted for their views on issues which affect them. Consultation can be extended to include prioritization of issues and identification of interventions
- Key stakeholders with different capacities should participate in various activities in developing the plans. Some of them can participate in decision making.

Implementation & Operations Stage

- The community should take the lead in implementing, monitoring and creating a dynamic plan, as per their capacities and interests.
- Citizen groups and NGOs should get involved in keeping watch for any untoward action or happenings in and around the waterbody.

Rejuvenation of Kaikondrahalli lake in Bengaluru is discussed here as a successful case exemplifying local community participation *(refer **Case Study** overleaf)*.

Case Study: **Restoration of Kaikondrahalli Lake through people's participation**

Kaikondrahalli lake is located in the south east of Bengaluru. In 2000, the lake was filled with fresh water, surrounded by groves of fruiting trees, and frequented by birds, foxes, and snakes. By 2003, the lake had begun to dry up due to the incoming channels being blocked by construction and the dumping of debris and garbage. By 2007, the lake bed was a slushy malarial bed of sewage and waste.

In 2008, a local resident united a small core group of residents to take care of the waterbody. They invited members with technical expertise in specific aspects of planning, relevant to the rejuvenation, including ecologists and architects. They were aware of the local government BBMP's (Bruhat Bengaluru Mahanagara Palike) plan for rejuvenation of the lake. The group reviewed the detailed project report (DPR) by BBMP, from an ecological and social perspective and requested modification of the plan to fit local needs. This collaboration between the BBMP and the residents group was a key factor in enabling a robust and sustainable plan. The DPR was redesigned by the group, using inputs from a local architect.

The initial DPR included plans for an expensive, large garden landscaped with exotic flowering species. This group felt that this money could be much better utilized through other measures and got the plans modified to exclude the ornamental garden from the DPR. Local residents contributed funds and collected hundreds of saplings of native species for plantation in the lake premises. The original DPR also planned to convert large parts of the lake into wooded areas. The area around the lake is dependent on ground water; the group felt it was much more important to preserve the original water spread area of the lake, thus the DPR was redesigned to retain as much area under water as possible so as to enhance groundwater recharge.

The lake is now maintained by the BBMP and a local trust, Mahadevpura Parisara Samrakshane Mattu Abhivrudhi Samiti (MAPSAS), which plays a nodal role in the conduct of the activities for lake improvement.

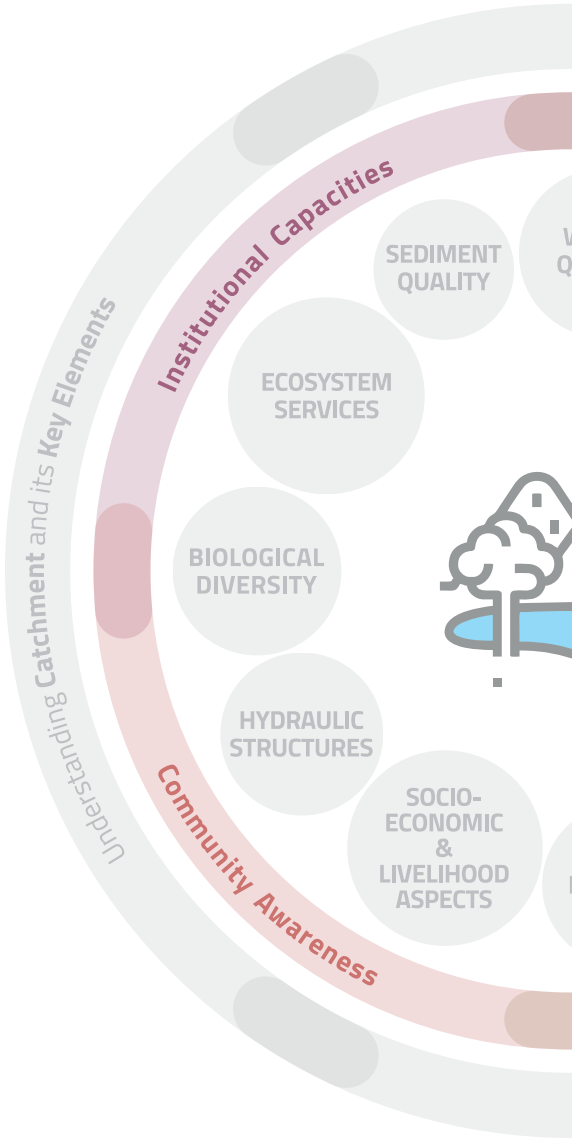
As a consequence of the group's efforts, the BBMP, which otherwise looked at restoration in a piecemeal manner, without taking into account the interconnectivity of lakes, initiated a program to restore a set of seven connected lakes (Kaikondrahalli being one of them). The rejuvenated lake is a collective node where people from the neighbourhood meet and organize to work on other local problems.

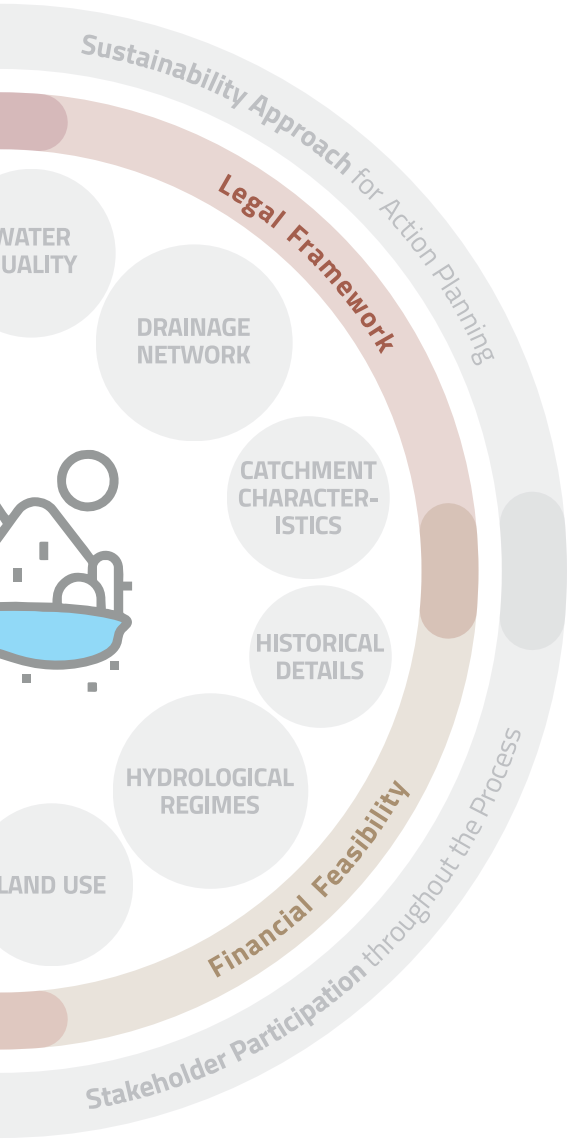
The process of people coming together in a city to work on an issue of public interest has its own challenges. While the group working on Kaikondrahalli lake has faced such issues, the overall output has been positive.

State of the lake in **2009 prior to restoration**

State of the lake in **2019 after restoration**

Source: Nagendra H., 2016





Key Elements
that influence the waterbody

As discussed previously, a holistic understanding of cross-disciplinary elements in a catchment is an important step for any rejuvenation plan. This section discusses these key elements, their significance and the information required to be collected for each element or aspect.

In practice, **it is difficult to gather all data and information**, as the data is either fragmented across different government departments and research institutions or not available. Nevertheless, **holistic assessments are important**, and efforts should be made to collect primary data where secondary data is not available.

These key elements can be categorised as follows -

- **Overarching elements** such as the legal framework, institutional capacities, financial feasibility etc. that need to be evaluated from an implementation perspective – to understand the workability and sustainability of the rejuvenation plan in the long term.
- **Technical elements** such as catchment characteristics, hydrology, ecosystem services, water quality etc. that are required to be assessed from planning perspective – to understand the 'quantity' and 'quality' of water reaching the waterbody and to plan for the services it can provide to the community in future.

Overarching Elements

Legal Framework

To understand the existing governance and institutional regime - both formal and informal governance administering the waterbody. Also, to understand rules and regulations applicable to the waterbody and its ownership details.

Institutional Capacities

To understand institutional capacities for planning, implementation and O&M of the rejuvenation activities. Also to identify overlapping responsibilities, compatibility between the institutions (Government or other agencies) and gaps in institutional arrangements. This is a crucial element for long term sustainability of the project and helps in formulating a capacity development plan integrated with the rejuvenation plan.

Financial Feasibility

To understand the fund flows – capital investment and operational costs. Rejuvenation activities are not sustainable if they are not financially feasible. It is crucial to plan these efforts in a way that initial capital expenditures and ongoing O&M costs are optimised in the best possible way. In addition, revenue earning mechanisms, such as user fees, taxes, development cess, lease rentals etc. can be evaluated to offset operational expenses.

Community Awareness

To understand if the community is sensitive and concerned about the existing problems faced by the waterbody and the future challenges that it will pose to their lives in the long-term. Also, to understand, if they are willing to participate in the rejuvenation activities. Involvement of the community is crucial for the sustainability of any rejuvenation plan.

Technical Elements and their Significance

HISTORICAL DETAILS

It provides the history and purpose for which the waterbody was created. Critical information on the history of the waterbody enable informed decisions for restoration.

Information requirements:

- Purpose of development in the past
- Ownership details
- Tank registers/memoirs:
  - Hydraulics including full tank levels, flood levels, sluice levels, holding capacity, discharge structures
  - Drains and canal system
  - Number of sluice gates, command area (if applicable)
- Biodiversity supported over time by the waterbody
- Evolution of water spread, lake boundary, existing drainage system
- Rectification works undertaken previously, including desilting, repair/retrofitting of hydraulic structures
- Any historical flood events, causes and remedial measures undertaken post floods

HYDRAULIC STRUCTURES

Assessment of existing infrastructure helps to evaluate if it can cater to demands of present and future urban changes of the city. Also, to evaluate if it can sustain intense inflows and reduce flood risks.

Information requirements:

- Existing infrastructure and its condition – bunds/embankments
- Type and condition of drains opening into the waterbody
- Details of inlet and outlet structures, such as surplus weir, sluice arrangement
- Pumping arrangement, if any
- Presence of other infrastructure in the water body, if any

CATCHMENT CHARACTERISTICS

Hydrological character of a catchment is highly dependent on its characteristics like topography, soil, vegetation, climate etc. These are interrelated, exerting variable influences on each other. Understanding these helps in identifying vulnerable areas, their characteristics and in estimating water inflows, quality and nutrient load.

Information requirements:

- Topography
- Geology & hydrogeology
- Soil characteristics
- Vegetation, green cover
- Climate parameters - temperature, precipitation, humidity, wind velocity, any exceptional events and their recurrence
- Land use and land cover

HYDROLOGICAL REGIMES

In the urban context, understanding the hydrological cycle is crucial, as over time, characteristics of the catchment change. Investigations of hydrological components inform about inflows and outflows, interrelationships between surface and ground water and trends of water availability over time in the waterbody.

Information requirements:

- Water inflow-outflow; specific inflow like wastewater and outflow like pumping or diversion
- Inundation pattern
- Infiltration rates
- Groundwater conditions
- Water usage within the basin
- Upstream infrastructure like dam, diversion channel, upstream water bodies, etc.
- Downstream infrastructure like drains, water bodies etc

LAND USE

Land use informs about the catchment area and eventual threats that can contribute silt, nutrients, pollutants and heavy metals into wastewaters.

Land use has an impact on quantity and quality of water entering a lake. In urban areas, the high proportion of impervious surfaces prevents seepage of rainwater into the soil, increasing the rate of surface water flow to the lake. High flushing rates from urban areas can increase erosion of the watershed area providing sufficient force to carry materials (minerals, solid waste etc.) along with the soil into the lake, affecting water quality.

Information requirements:

- Land use - residential, institutional, industrial, dumping sites, commercial spaces, major infrastructure (road, railway station, airport, harbour), green spaces, barren lands, water bodies, forest, agriculture, and encroachments around the waterbody

DRAINAGE NETWORK

Drainage network informs about the inflows and outflows to and from the waterbody, helps in identifying drains that have been encroached or altered over the time, as well as in identifying sources of pollution along these drains.

Information requirements:

- Drainage area delineation
- Drainage network, slope and geometry of the drains
- Stormwater network diversions and alteration
- Discharge capacity and flow
- Location of outfalls of wastewater into drains with quantification
- Underground sewer lines, water supply and wastewater management of the town or city
- Solid waste dropping sites along the drains with characteristics

WATER QUALITY

Water quality, a direct indicator of the ecological health of a waterbody, aids in understanding pollution status, type of pollutants, sources and sinks of pollution, so as to assess if the water is adequate for use by humans or to maintain aquatic biodiversity. It also helps determine adequate remediation measures in a water body and its upstream catchment.

Information requirements:

- Water quality with spatial and temporal variation inside the waterbody
- Water quality with spatial and temporal variation of inflows from drains and outfalls, but also from back flow if any.
- Groundwater quality in the vicinity of the waterbody
- Potentially polluting activities upstream of the water body with specifics

Water quality entails various parameters, such as Dissolved Oxygen (DO), Biochemical and Chemical Oxygen Demand (BOD & COD), temperature, electrical conductivity, nitrate, phosphorus, potassium, faecal coliform etc. Heavy metals, such as lead, chromium, iron and mercury are of special concern because they produce chronic poisoning in aquatic animals.

ECOSYSTEM SERVICES

Healthy waterbodies serve people and the environment enormously. These services include:

- Provisioning services (direct wetland products - food, fibre, water)
- Regulating services (regulate hydrological regimes, influence micro-climate, reduce disaster risk, groundwater recharge)
- Cultural services (recreational value, cultural-religious norms and beliefs)
- Supporting services (primary production and other functions to enable delivery of all the above)

Rejuvenation accounts for these services to recover and improve them.

Information requirements:

- Types of ecosystem services (as explained above) that the waterbody catered to or is catering to

SEDIMENT QUALITY

Sediments act as sinks or sources for trace pollutants, like heavy metals and persistent organics. In addition, they provide natural habitats for aquatic organisms. They play a very important role in physicochemical and ecological dynamics; any change in toxic concentrations of heavy metal residues on the sediments will affect the natural aquatic system. Sediment quality assessment helps to understand the ecological status of a waterbody, detect toxic constituents, and to control their fate and effect.

Information requirements:

- Sediment quality (heavy metals & persistent organics) from inside the waterbody

BIOLOGICAL DIVERSITY

Biological diversity reflects the health and balance of any ecosystem and its limitation in adjusting to changes and fluctuation. Its study helps to understand the significance of the habitats dependent on the waterbody, important conservation values associated with the area, and trends in conservation status of dependent species. It also informs about the invasion of species and contributing factors.

Information requirements:

- Existing biodiversity and trends – terrestrial, aquatic, avian, benthic
- Invasive and native species

SOCIO-ECONOMICS & LIVELIHOOD

Socio-economic data helps understand people's dependence on aquatic ecosystems for livelihoods - largely fishing, agriculture, fodder, gardening and small business around lakes that cater to tourists and visitors. These studies give insight into the cultural importance of the waterbody, livelihood vulnerability and its relation to changes in wetland resources and any resource-use conflicts.

Information requirements:

- Demographic details surrounding the waterbody
- Community's social, cultural, economic dependence on the waterbody
- Historical or archaeological sites, religious places or important common property structures in and around waterbodies

Waterbody Rejuvenation Planning – **Process Flow**

The methodology adopted in planning of the rejuvenation project is illustrated in ***Figure 4***. The holistic, participatory and sustainability approaches discussed above are intertwined in the process flow.

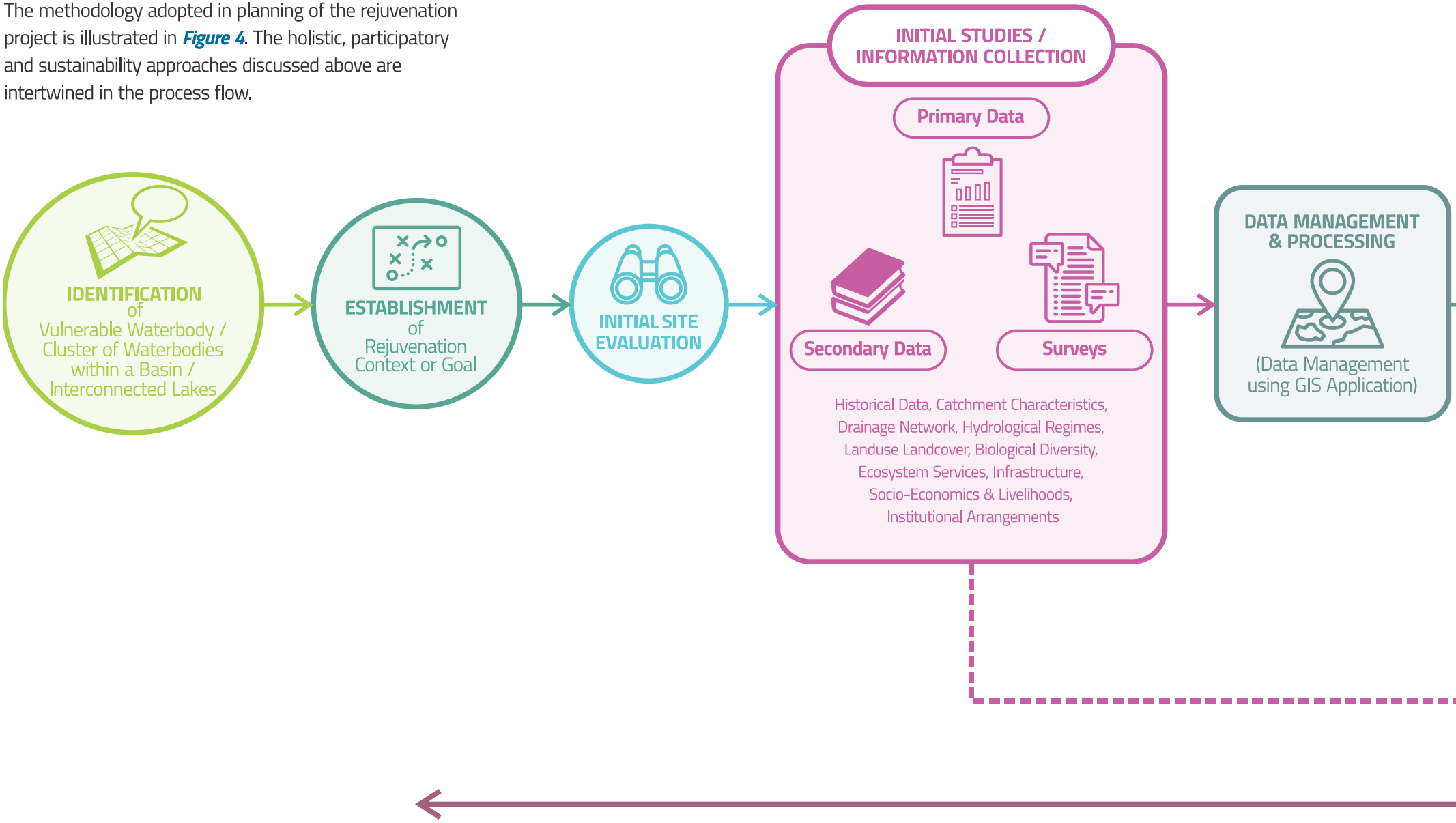
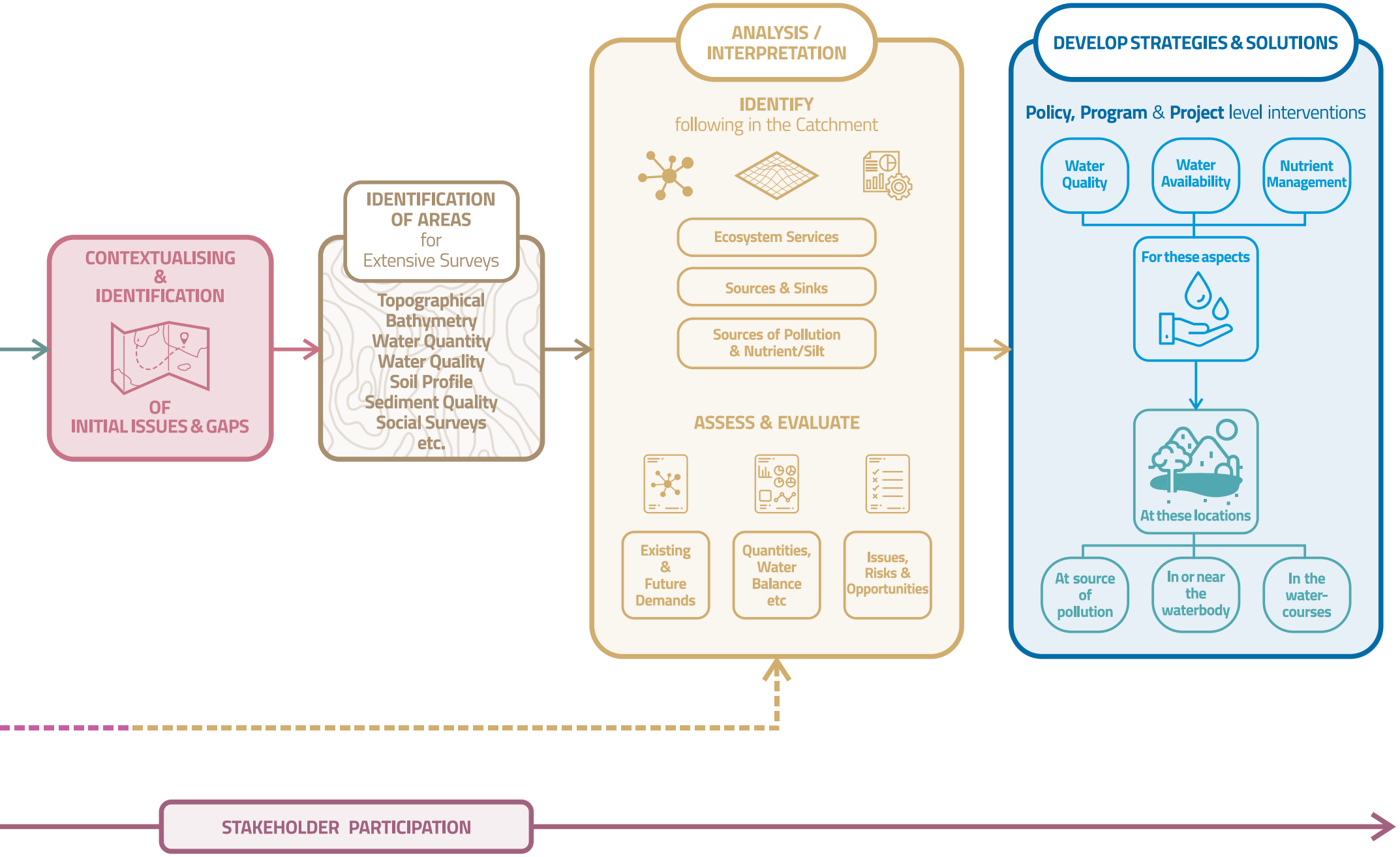


Figure 4: Process Methodology for Rejuvenation Planning


CONTEXTUALISING
&
IDENTIFICATION
OF
INITIAL ISSUES & GAPS
IDENTIFICATION
OF AREAS
for
Extensive Surveys
Topographical
Bathymetry
Water Quantity
Water Quality
Soil Profile
Sediment Quality
Social Surveys
etc.
ANALYSIS /
INTERPRETATION
IDENTIFY
following in the Catchment
Ecosystem Services
Sources & Sinks
Sources of Pollution
& Nutrient/Silt
ASSESS & EVALUATE
Existing
&
Future
Demands
Quantities,
Water
Balance
etc
Issues,
Risks &
Opportunities
DEVELOP STRATEGIES & SOLUTIONS
Policy, Program & Project level interventions
Water
Quality
Water
Availability
Nutrient
Management
For these aspects
At these locations
At source
of
pollution
In or near
the
waterbody
In the
water-
courses
STAKEHOLDER PARTICIPATION

A rejuvenation project can be conceptualised for an individual waterbody or a cluster of waterbodies. The next step is to understand the purpose and context for rejuvenation. This can be established by conducting an initial assessment of the waterbody and its catchment as well as discussions with different types of stakeholders that are directly or indirectly impacted by the degrading waterbody.

Initial assessment involves understanding the general condition of the waterbody, inlet and outlet structures, obstruction to flows; health and diversity of the fauna and flora; visual quality of the waterbody and the drains, this includes transparency, colour, over development of aquatic weeds; solid waste accumulation; soil excavation or dumping in past; status of encroachment, grazing animals, open defecation, immersion of idols and other socio-cultural uses of waterbody. This helps in identifying initial issues and gaps.

Holistic evaluation of all catchment characteristics, hydrological factors, limnological factors, land use, socio-economic aspects, institutional aspects are **required for understanding the waterbody**. *Refer section on **Key Elements** that influence the Waterbody (page 23-25) for detailed information.* This leads to understanding many facets of the waterbody and its changing characteristics over time; and helps in identifying the existing and future challenges in the changing urban context. It also helps in evaluating its behaviour for the context of rejuvenation planning (i.e. the purpose for which waterbody rejuvenation is being considered), which leads to identification of the detailed survey requirements. For example, addressing a pollution problem will require detailed water quality analysis; while assessing decline in storage capacity will require topography and bathymetry surveys with detailed water balance studies; evaluating heavy metal toxicity may require sediment quality analysis. *Refer **Box 4** for details of information collected in these surveys.*

This step, arguably, is the most important for assessment as it provides inputs for designs, and estimates quantities for further analysis and evaluation. It also requires commitment of time and funding to perform field monitoring, as it may require seasonal data throughout the year. Although the monitoring (or survey) cost can be substantial, it is often comparatively smaller to the cost of implementing an effective solution for a degraded waterbody.

Analysis of extensive surveys aids in identifying gaps as well as possible opportunities for repair and restoration. It also helps in evaluating potential interventions required for rejuvenating a waterbody. These interventions should be designed in a way that ensures water availability throughout the year, maintains water quality and addresses all other challenges that the waterbody faces due to catchment modifications. The strategy should be to first address the issues at source itself, then along the watercourse and finally at or around the waterfront.

As mentioned in the previous section, solutions leading to the rejuvenation action plan may involve policy, plan, project and program level interventions that complement each other and ensure sustainability. An illustration of sustainable and rounded action planning for constructed wetlands (one of the technology solutions to address water quality in a waterbody) is discussed in ***Figure 5***.

Box 4

Detailed Surveys

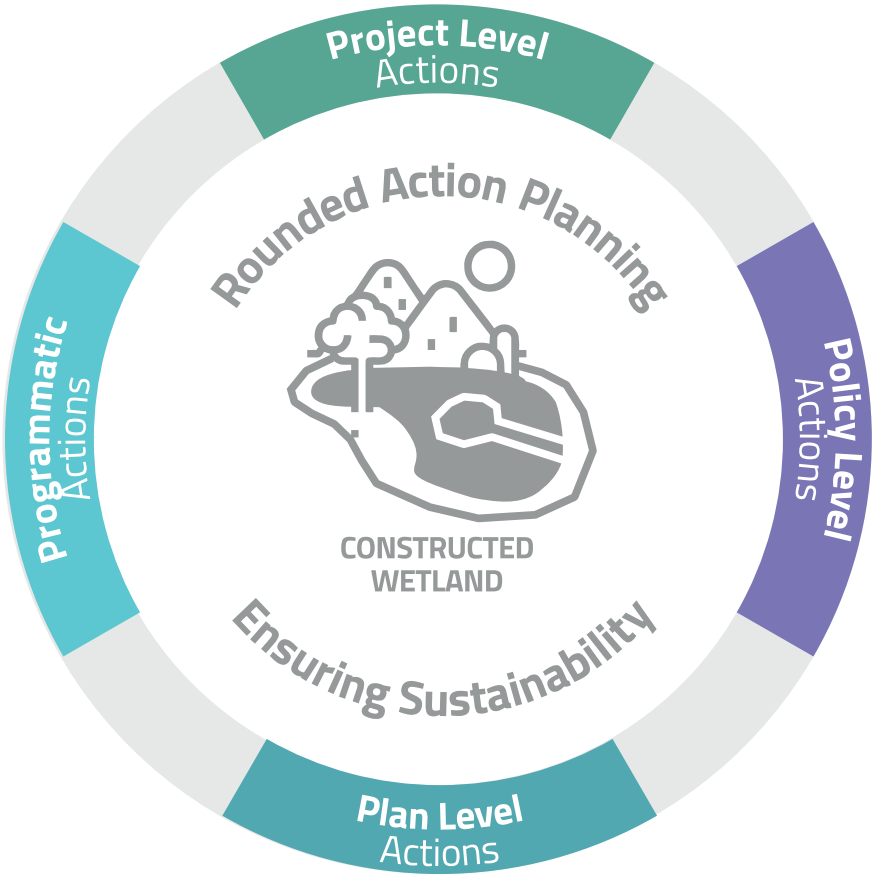
Topographical Surveys are conducted to learn physical features of the surrounding area and drains that show elevations and grading features. It also informs change due to encroachments with respect to historical data. Topographical Surveys help derive the following information –

- Elevation and dimensions of physical features with respect to a benchmark in the surrounding area
- Elevation and dimensions of various hydraulic structures - drain outfall levels, weirs, sluice arrangements, check dams in drains, embankments etc.
- Marking the boundary of the waterbody
- Creating contours of the catchment and nearby areas

Bathymetry Surveys provide the lake bed (contour) morphology required to understand volume and characteristics of a waterbody. It helps derive the following information –

- Elevation points underwater
- Depth of water
- Underwater features

Water Balance Studies informs the trends of water availability over a period of time and variability in seasons. It involves rainfall analysis, runoff analysis, percolation and evaporation losses, and measurement of drain carrying capacity.



Pilot Project for the Waterbody or Constructed Wetland – floating island or free water surface wetland

Screens Installed to remove debris and other solid waste entering the area where Constructed Wetlands are planned & installed

Specialized Training to relevant stakeholders responsible for constructing the artificial wetlands

Training Program for relevant stakeholders responsible for maintaining the constructed wetlands

Monitoring Plan for inlet and outlet water from Constructed Wetland with proper mention of responsibilities and institutions involved

Monitoring Plan with procedures for timely harvesting of the plants and regular maintenance of the Constructed Wetlands

Policy Advocacy for effective sustenance of Constructed Wetlands which includes

- Allowable norms of wastewater quality that is required
- Penalties drawn for indiscriminate dumping of solid waste in the drains
- Incentivising NGOs and People's Forum for regular cleaning of drains

Figure 5: Illustration of **Rounded Approach to Action Planning** for **Constructed Wetland** as an Intervention

Any rejuvenation plan, if supported by a demonstration project, a training program for its users, an awareness program to sensitize its stakeholders, and a policy to ensure the implementation, would help scale the plan to other waterbodies within the city or set an example for other cities to follow. Public awareness programs are critical tools to ensure participation of all stakeholders in implementation of any rejuvenation plan.

Generally, **quick fix solutions and approaches are expected** by regulators and other custodians of waterbodies. However, it is important to understand that **if the waterbody is degraded beyond repair, it takes a long time to revive it to its original form.** There are no quick transformation or rejuvenation solutions, because waterbodies have been neglected and degraded for many years - the healing process will now take time too.

Proposed **Free Water Surface Wetlands** in Periyakulam Lake, Coimbatore, Tamil Nadu

05 | Generic **Strategies & Interventions**
context-driven and **nature-based** solutions

Interventions need to be planned factoring in all aspects - technological, social, environmental, institutional etc.; so that each problem the waterbody is facing can be addressed comprehensively, while ensuring that proposed interventions are well anchored and able to achieve sustainable outcomes.

This section demonstrates different strategies and methods that can be applied to planning and implementing some of the interventions. Special emphasis has been placed on interventions that are generally implemented viz. wastewater treatment, desilting and deweeding. These interventions have been presented here encompassing strategies for implementation as well as focusing on nature-based technological solutions rather than conventional methods.

A few other interventions, such as urban placemaking, green shorelines, in-situ measures are discussed, to introduce eco-restorative and sustainable solutions that boost biological diversity, enhance ecosystem services and help in reviving a deteriorated waterbody.

This is not a complete set of solutions but a compilation of a few interventions that represent the essence of green and sustainable strategies.

01 | Pollution abatement via **decentralised solutions**

Treatment of wastewater is required before the water is discharged into any waterbody or wetland. There are legal norms that regulate water quality and emphasize that only treated water should get discharged into waterbodies. However, there are many nallahs/streams which contain municipal wastewater and sewage from the nearby habitations that open into waterbodies, that cannot be regulated and are slowly turning these waterbodies into cesspools.

For such cases, decentralized wastewater treatment is a viable solution, where the wastewater can be treated by three approaches:

- Wastewater treatment at the source
- Wastewater treatment along the drains
- Wastewater treatment at mouth of the inlet

Decentralized solutions are cost effective and have a lower environmental impact compared to centralized solutions. Primarily because the environmental and financial impact of just the construction of sewer infrastructure is more than the impact of construction and operation of a decentralized facility.

The choice of treatment technology for a decentralized system is conditioned by the pollution concentration and the site characteristics. Land availability is also one of the critical aspects for planning a decentralized system.

Treatment at Source

Treating the wastewater at source means implementing the decentralized wastewater treatment system at the source of pollution itself i.e. at individual houses/cluster level/industry and institution level. It is by far the most sustainable approach as it guarantees that the full catchment area from source to water body is maintained healthy and clean. Such systems can be DEWATS (nature-based technology), improved septic tanks for handling domestic wastewater and onsite effluent treatment for industrial discharges. Such an approach will ensure the wastewater at the source is treated to a certain level and then let out into the drains, thereby improving the quality of water reaching the waterbody.

Treatment along the Drains

If the pollution concentration is low, treatment along drains can be one of the options; where aquatic vegetation and training of the watercourse is integrated within the drains. This helps in removing nutrients and organics through a self-purification process. Meandering of flow ensures extra oxygen input and contact with *active edges*[4] and vegetation results in better water cleansing. If hydraulic conditions allow, it is also possible to implement treatment (floating) wetlands *(refer **Box 5**)* in the drain itself. However, the limitation of implementing any such system is that it may obstruct the stormwater flow. In certain cases, it is worth diverting part of the flow to a decentralized wastewater treatment plant before releasing back to the drain, thereby achieving both objectives of addressing the pollution as well as creating a dilution of the main flow.

Solid waste is usually accumulated all along the drain and creates obstacles along the course, hence it is necessary to install screens at judicious locations.

Screens at inlet of **Mahadevapura Lake**, Bengaluru

Treatment at the Mouth of the Inlet

Based on the quality and quantity of the wastewater flowing in the drain and based on the context of treatment (i.e. use of treated water or goal of rejuvenation), combinations for wastewater treatment can be proposed – pre-treatment, primary treatment, secondary and tertiary treatment. The selection of primary and secondary treatment is subject to the pollution load, the volume of wastewater and ease of operations of the technology where it is proposed. Post-secondary treated wastewater (or direct flow if the pollution is less) can be treated using constructed wetlands *(refer **Box 5**)* such as free water surface wetlands or floating wetlands created inside the waterbody. This not only treats water but also enhances biodiversity and aesthetics.

[4] *Refer **Box 6** for description on Active Edges*

Box 5

Treatment Wetlands or Constructed Wetlands

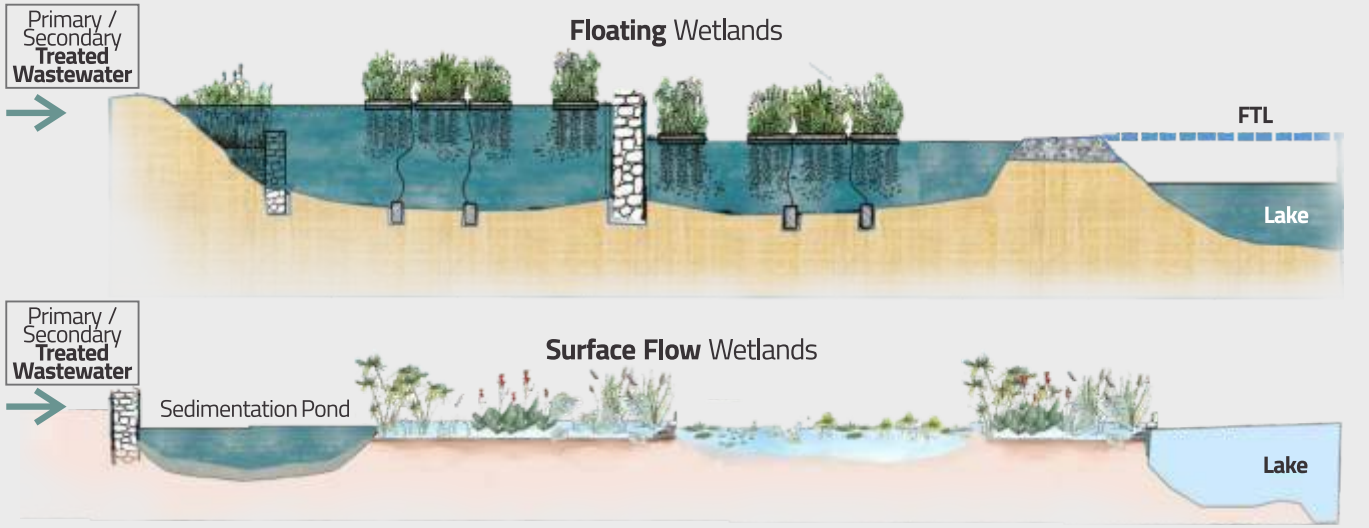
Constructed Wetlands (CWs) can be used as part of decentralised wastewater treatment systems or as stand-alone systems depending on the pollution load. They provide a natural way of removing nutrients and pollutants, mimicking natural wetland systems.

CWs are a proven, effective and "low tech" technology with low operational requirements. It does not require foundation or construction. They add beauty and diversity to a waterscape, attracting a greater range of niches within the system. An increase in botanical diversity enhances the uptake of nutrients and pollutants.

There are different types of CWs designed for a variety of wastewater types. For inland waterbodies two types of CWs are generally proposed - Floating Constructed Wetlands and Free Water Surface Flow Wetlands. Other types of CWs like vertical or horizontal subsurface flow constructed wetlands (of which some are planted filters, root zone systems, phyto reeds etc.) are less common in this context, being higher maintenance and cost intensive.

However, they can be chosen when pollution loads are high. The choice of free flow wetlands or floating wetlands is site specific and related to the water level and variation in the waterbody, part of aesthetical integration, availability of maintenance resources, vector and odour control measure.

In these artificial wetlands, the main treatment mechanism that occurs is biological conversion, physical and chemical adsorption, metabolising and fixation of nutrients, minerals and gases. Here plants are made to emerge from the water surface and are selected based on their ability to be partly submerged, to grow on wastewater, fix and metabolise pollutants and to have roots that can spread deep. While this happens, plants transport oxygen from the surface to the water through the roots and uptake nutrients and eventually pollutants from the water. The roots act as a carrier and provide symbiotic support for micro-organism growth that further enhances the treatment through the water column in the case of floating wetland or in the substrate or silt in the case of free flow wetland.



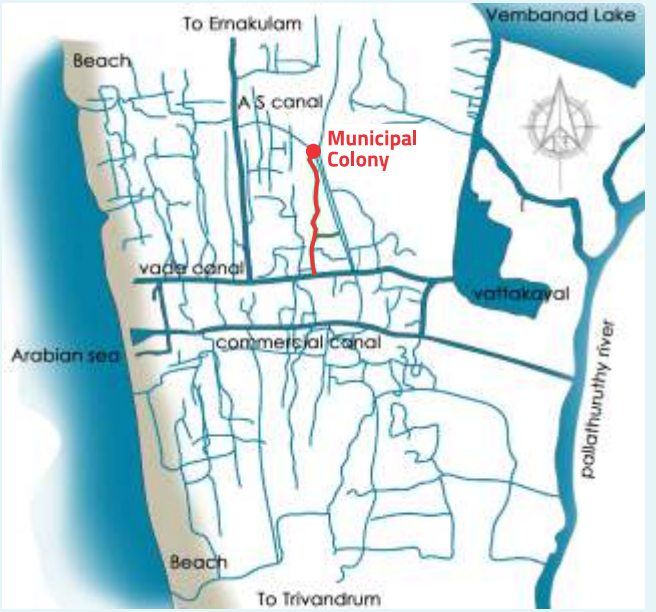
Schematic view of **Floating Wetlands** and **Freewater Surface Wetlands** for tertiary treatment in lakes

Case Study: **Decentralised Treatment**

Wastewater treatment close to source:
Alappuzha Canal Rejuvenation

Alappuzha is a Town Municipality located in Kerala, India. The oldest planned backwater town of Kerala, Alappuzha's main waterways which link the Arabian sea on the west to the Vembanad lake on the East - were once its nerve centres. Unfortunately, over the years, with Alappuzha port losing its commercial importance, road networks got more prominence, and the network of canals slowly started losing their purpose. Today they have been reduced to easy waste dumping spaces – a cause for major pollution, heavy eutrophication, health concerns and poor aesthetics.

The *Government of Kerala* along with *IIT Bombay, CDD Society, Bengaluru* and *Kochi based Inspiration*, planned to rejuvenate Vada Canal and Commercial Canal in Alappuzha town. As a part of this project, 375 m of downstream stretch of Municipal Colony canal – a sub canal flowing into Vada Canal was taken up as a pilot.



Project Location, Alappuzha, Kerala

It involved:

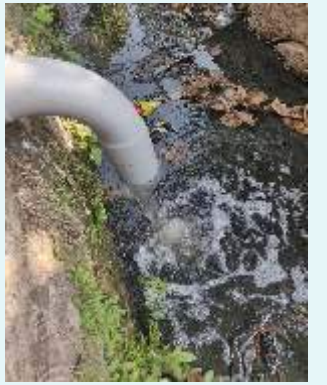
- implementation of decentralized treatment plants (DEWATS) for a group of households in the colony
- constructing toilets for individual households in the catchment
- piping all black and grey water to the DEWATS system

This ensured only treated water flowed into the sub-canal thereby improving the water quality of Vada Canal and also helped in minimising flooding or waterlogging inside the colony during heavy rains.

Wastewater from Municipal Colony

Toilets for Individual Households

DEWATS system installed at Municipal Colony



Treated Water from DEWATS

Case Study: **Decentralised Treatment**

Wastewater treatment along the drains:
Dwarka Drain Remediation (proposed)

Dwarka is one of the recently developed well-planned residential areas situated in South West Delhi District, India. Even though Dwarka is a well-planned sub city, sanitation is of major concern as all the wastewater from the surrounding unauthorized colonies is discharged directly into the stormwater drains. Most of the wastewater generated upstream of Dwarka district is directly discharged into 4 major storm drains, namely Palam Drain, Trunk Drain-2, Trunk Drain-4 and Trunk Drain-5, which flow through the different sectors of Dwarka, turning entire stretches of the drain into open sewers. Simultaneously, the lack of adequate solid waste management has resulted in large quantities of waste being dumped into the Palam drain. Therefore, the Palam drain which was originally meant for the seasonal discharge of storm water now carries a perennial flow of sewage and waste. It has become a major threat to public health and the environment.

The Delhi Development Authority (DDA) wishes to achieve a clear stream of water in these drains as part of a larger urban rejuvenation program to create a more livable city. With this vision in mind, the DDA engaged *Centre for Green Mobility Ahmedabad (CGM)* and *CDD Society*, to jointly address the rejuvenation of storm drains and induce their transformation into vibrant urban spaces.

Treatment wetlands and **meandering arrangements** planned for **Trunk Drain-5**

The 5 km length Trunk Drain-5 was taken for remediation by proposing 'greenways' along the drain. From quality and quantity investigations conducted at various points along the drain, it was found that the drain has advantages of both dilution and self-cleansing capacity which help in reduction of pollution load without any treatment facility. Treatment wetlands (mix of free flow water surface wetlands with active edge) are being planned along the edges of the drains. In addition, meandering arrangements will be artificially created along the flow in order to improve the quality of the water in the drain. The solution also included decentralized wastewater treatment systems (DEWATS) at the outfalls and surrounding parks that aid the dilution effect for the incoming wastewater.

Transformation of areas near **Trunk Drain-5** into a **vibrant green space**

The transformation of polluted channel into remediated and landscaped waterways, will not only bring back a healthy environment but also blend well with the surrounding environment and urban fabric. Such a space will inevitably add to the quality of urban life and enhance the potential and economic value of the area. It will also provide a scalable and sustainable method of remediating the polluted drains of cities.

Case Study: **Decentralised Treatment**

Wastewater treatment at the mouth of the waterbody:
Mahadevapura Lake, Bengaluru

Mahadevapura Lake is located along the Outer Ring Road, adjacent to the Bagmane Tech Park in the eastern fringes of Bengaluru city. The Lake is spread across an area of 26 acres. In an attempt to rejuvenate the lake, in 2016, Bruhat Bengaluru Mahanagara Palike (BBMP) constructed necessary hydraulic structures as well as a concrete box channel to divert wastewater entering the lake, enabling only storm flows into the lake during the monsoon. This diversion of wastewater protected the waterbody from pollution, but left it dry during summers as there was no other source of water.

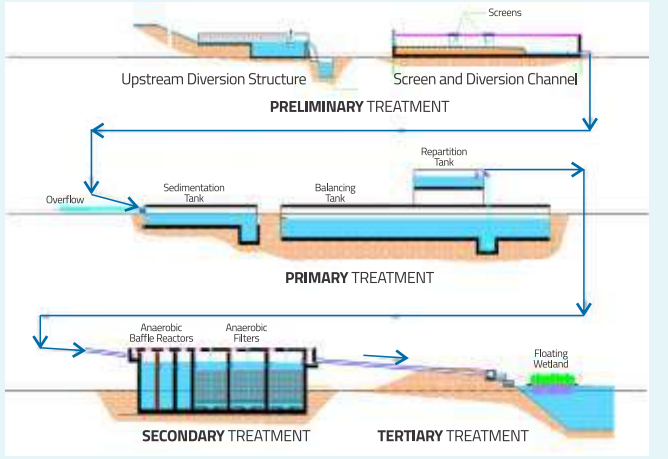
United Way Bengaluru (UWBe), an NGO brought together four IT firms (Mphasis, Amazon, HTC Global and DELL Technologies), to fund a solution to *replenish the lake with water throughout the year*, which will aid groundwater recharge and also enhance the micro-climate of the lake area. *UWBe* partnered with *CDD Society* to design a wastewater treatment solution that would replenish the lake.

CDD Society designed and implemented a **Decentralized Wastewater Treatment System (DEWATS), at the mouth of one of the inlets** – an anaerobic treatment system which mimics natural processes by providing the right conditions for microbial action. This ecofriendly treatment plant taps and treats 1MLD wastewater flowing in an inlet drain (open channel) and discharges the treated water into the lake every day. The treatment process is chemical free with minimum dependence on electricity and has been designed with minimum O&M requirements. This project has been recently commissioned in the month of June, 2019

The wastewater treatment system includes primary, secondary and tertiary treatment processes with the following modules that are designed based on the pollution load entering the selected drain.

- **Preliminary treatment**: Screen with grit collection structure and gate for wastewater diversion
- **Primary treatment**: Diversion channel with two stages of screening, sedimentation tank and balancing tank
- **Secondary treatment**: Integrated anaerobic baffle reactor with anaerobic filters
- **Tertiary treatment**: Combination of gabions followed by floating wetlands

Mahadevapura Lake Site



DEWATS System (treatment) established at the site

02 | **Green Infrastructure** to enhance biodiversity in waterbodies

Biodiversity is a vital component in waterbody rejuvenation, however, it is generally avoided in planning restoration activities as it takes time to build and maintain. In order to enhance biodiversity in and around waterbodies, *green infrastructure*[5] or shorelines, which serve as safe havens for flora and fauna, can be provided. It also greatly influences the ecological health and resilience of the waterbody.

Green infrastructure with respect to waterbodies includes:

- Green and active edges along the embankments
- Creation of wetlands inside the waterbody
- Artificial bird islands and creating ecozones (biodiversity sensitive zones) in the waterbody

While creating this green infrastructure, introduction of native species of flora and fauna helps revive and restore the ecosystem, and rejuvenate the abiotic components of the waterbody, such as dissolved oxygen, nutrients and minerals.

Green and Active Edges

Green and active edges in a waterbody is achieved by planting native species of plants on the embankments of the waterbody. These active edges restore biodiversity and ecosystem services. It also acts on the water quality by which accumulated pollutants in the water and sediment can be progressively fixed and removed. *Refer **Box 6** to know more about green and active edges and their benefits.*

To ensure the regeneration of biodiversity and the establishment of healthy lake ecosystems, all the sides of waterbody edges can be designed as active edges using rocks and plants and can be recalibrated to allow for gentler slopes that can be stabilized with these naturalized methods, to ensure a better and healthier ecosystem.

Creation of Artificial Wetlands in the Waterbody

While on average, natural wetlands have more species and support higher abundance, artificial wetlands have the potential to support similarly diverse communities. Overall, regardless of the type, larger wetlands, with shallower waters, tend to be more biodiverse. The combination of shallow water, nutrients (from receiving storm and wastewater), and high primary productivity (the amount of biomass produced) is ideal for the development of organisms/aquatic species. In addition to enhancing biodiversity, artificial wetlands regulate water purification, and protect the lake ecosystem from soil erosion and flooding. Creation of these wetlands with native species of flora and fauna in a degraded waterbody will revive it and restore all ecosystem services. Artificial wetlands can be created within the waterbody at different places, in accordance with the roles they can offer like pollution mitigation, ecosystem services, aesthetic value etc. These are similar to constructed wetlands (already discussed under decentralised treatment).

[5] Green infrastructure is a strategically planned network of high quality natural and semi-natural areas with other environmental features, designed and managed to deliver a wide range of ecosystem services, and protect biodiversity in urban settings. (Definition by European Commission, 2010)

Artificial Bird Islands and Creating Ecozones (biodiversity sensitive zones) within the Waterbody

Artifical bird island in a lake

Bird islands are similar to active and green edges, except they are built in isolation inside the waterbody, which then offer a protected habitat for aquatic life and birds. The same active green edge created along shorelines is also created here. Migratory birds find these islands safe as they are away from the areas of human activity.

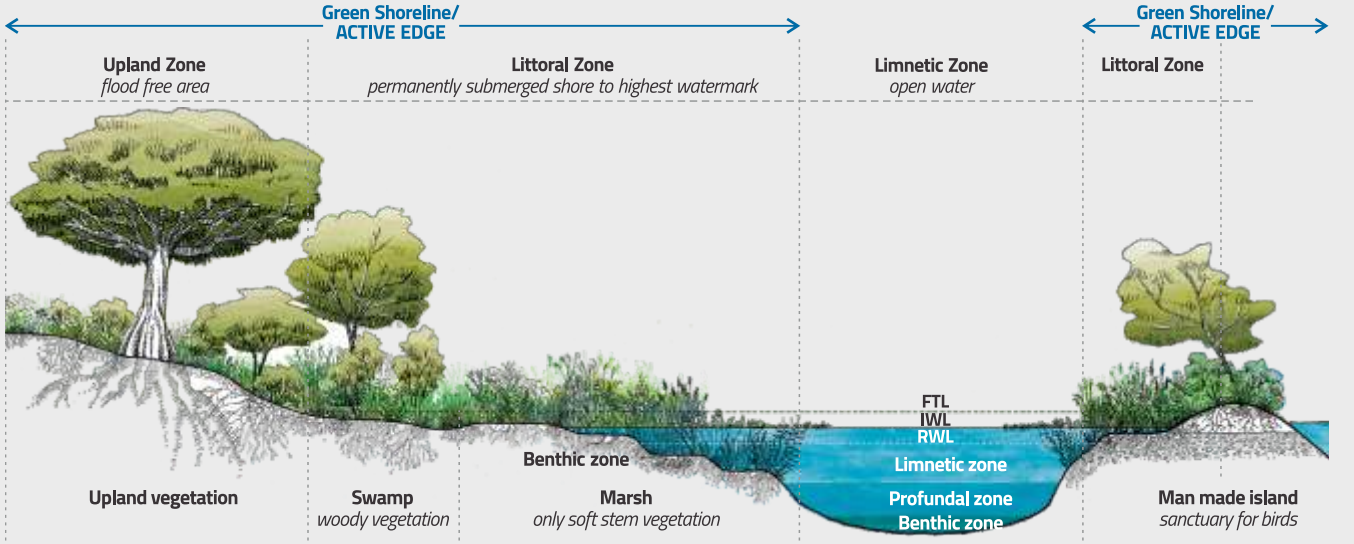
Designating ecological zones within a waterbody where human interventions are prohibited is another way to enhance biodiversity in a waterbody. Potential biodiverse areas can be identified, which can be conserved and designated as ecological zones. These areas can be identified by looking at the bathymetry profile (generally deeper sections of a waterbody), where disturbance is the least and where minimum water is available throughout the year, and which have a gentle slope and can be *stratified*[6].

Box 6

Active Edges

Green and active edges restore the *littoral zone*[7] in a waterbody. Development of active edges (also called slope bioengineering methods) closely replicate the natural state of the streambank or shoreline environment, providing hydrological, ecological, and aesthetic benefits that structural methods do not. Experts agree that re-vegetating lake shores with native vegetation is the best solution for water quality and long-term embankment stability. Vegetation plays an important role in protecting the shoreline from erosion, as plant roots also stabilize the soil. Vegetation filters pollutants and nutrients from the water, improving water quality. Plants also improve the shoreline environment by providing wildlife habitat and restoring the natural ecosystem.

Shoreline plants contribute to aquatic habitat in four important ways. First, vegetation provides diffused shade to the water's edge, creating conditions that help juvenile fish blend in with their surroundings. Secondly, they restore natural food web processes to the shoreline – plants are home to insects and other small organisms, which become food for fish when they fall into the water. Third, they provide twigs, branches and leaves, which create essential refuge from birds and bigger fish. Finally, planted strips protect water quality by filtering excess nutrients and other contaminants from stormwater. Rainwater flowing over lawns/green spaces carries fertilizer, pet faeces, gasoline, paint, heavy metals and pesticides into the waterbody, but selected shrubs and perennials can help fix and neutralize these contaminants.



Active Edges at Lake Embankment and around Artificial Island

[6] Stratified here means layering the lake shores using the natural contours of the waterbody and introducing the native plants therein. Seasonal waxing and waning of the lake water expose different levels of the shores/ lakebed, which is when the strata specific species are planted. Selected aquatic and semi aquatic plants can grow under variable water depths or soil wetness, based on which stratification is developed.

[7] A typical lake has three distinct zones (limnetic, littoral and the benthic zone) of biological communities linked to its physical structure. The littoral zone adjoins the shore (and is thus the home of rooted plants/ benthic plants) and extends down to the depth where photosynthesis takes place. Littoral zone is a home to many phytoplanktons and zooplanktons. The nekton of the littoral zone is often rich in species and numbers.

Case Study: **Biodiversity Enhancement**

Creating Ecozones:
8 Lakes Restoration Project, Coimbatore (proposed)

Coimbatore city lies in the foothills of one of the richest biodiversity hotspots, the Western Ghats. The consortium of *Oasis Designs Inc, New Delhi* and *CDD Society, Bengaluru* was selected as consultants for the eco-restoration of the 8 lakes in Coimbatore under the Smart City initiative by the local administration. The key principles followed for restoration included nature-based solutions with much emphasis on the revival of biodiversity.

During investigations, it was found that freshwater biodiversity in Coimbatore, especially of the lakes, is under stress due to the inconsistent inflow of fresh water, drying of lakes, sewage disposal, and dumping of solid waste. This is indicated by the poor biodiversity composition of these lakes. The frequent drying up of the lakes and introduction of invasive species has also resulted in diminishing native biodiversity over the years especially seen in aquatic plants, fish, birds and amphibians.

In order to restore the lakes and enhance their biodiversity, the following has been proposed:

- Re-introduction of native species that build up the community and make the waterbodies cleaner and more sustainable. Removal of all exotic/non-native/alien invasive species of plants and animals from the lake system by introducing systematic management measures.
- Designating a biodiversity zone in each of the 8 lakes. Stratified landscaping for creating niches for various native birds and plants in these zones.
- Reducing erosion and silt runoff by ensuring adequate natural breaks through native vegetation along the drains. It is recommended that native flora be planted up to 500 m from the lake in the inlet drains. The sluice gates at the entry of the lakes stop silt from flowing into the lake, which may be later dredged off to clear the pathway.
- Conducting awareness and behavioural change outreach programs on the importance of biodiversity-rich lakes for locals and other stakeholders. Employing awareness programs for shifting bio-resource practices, such as fishing of non-native to native stocks.

The above measures are being currently implemented in two lakes and tendered out for other lakes. Benefits of these measures will be observed in a year or two.

Designated ecological zone in Periyakulam lake

Migratory Birds at Periyakulam Lake in Coimbatore city

03 | Judicious **Desilting**

Desilting is seen as a recommended suggestion in many guidelines prepared on waterbody conservation and repair. Silt gets accumulated in waterbodies over the years, reducing their storage capacity. However, it should only be considered, if necessary, given the circumstances, and if planned and executed in a well assessed manner.

Desilting being carried out in **Narasamapthy Lake** during dry period

In India, generally desilting activities are carried out by using excavators (commonly known as JCBs after the company name) that may not have precision excavation mechanism installed. Desilting carried out by such excavators, includes chances that in addition to the deposited silt, the strata or original lake bed may also get dislodged. There is no specified boundary or visible difference between the deposited silt and the original soil of the lake bed. Thus, by desilting, sometimes the original lake bed gets disturbed, which has far reaching adverse effects on the performance of the lake. The most visible impact is the increased percolation rate resulting in seepage losses through the lake bed. The reason being that by massive digging the thin sealing layer of compacted silt deposited year after year of lake filling is disturbed and the joints of original strata get exposed. Another reason why desilting should be avoided is that it may result in release of nutrients from sediments, increased turbidity of water, destabilization of sediments, and all of this creates adverse impacts on the benthic population.

Desilting operations increase the storage capacity and average depth of the waterbody but it can be prohibitively expensive and impact the lake ecosystem. Hence, it is important to ascertain the objective of this action before undertaking it.

Desilting operations should be conducted only if necessary and in one or more of the following cases:

- If the contaminants in the sediments are at *'Severe Effect Level'*[8], it indicates detrimental impact to the majority of the sediment-dwelling organisms and their consumers
- Reduced storage capacity of the lakes and increased vulnerability to flood situations
- Suitable sites are available for desilted material
- Impacting recreational access to leisure boating
- Impacting fishing and thereby livelihoods

If desilting has to be carried out in a waterbody, it should only be conducted in certain areas ("spot" dredging) of the lake and not involve the entire lake. It will not only be less expensive but also less ecologically damaging; also a lesser area would be required for disposal of desilted sediments. Desilting should be supported by bathymetry of the waterbody and should maintain the gradual gradient aligning with bed contours.

Sediment disposal sites should be identified in advance and should not be located near the waterbody, in order to avoid removed sediments returning back to the system. Desilted soil should be tested for contamination before disposal; in case of contamination, it should be disposed of in a confined landfill; if non-contaminated, it can be beneficially utilized as soil conditioner in agricultural fields, or as a construction material.

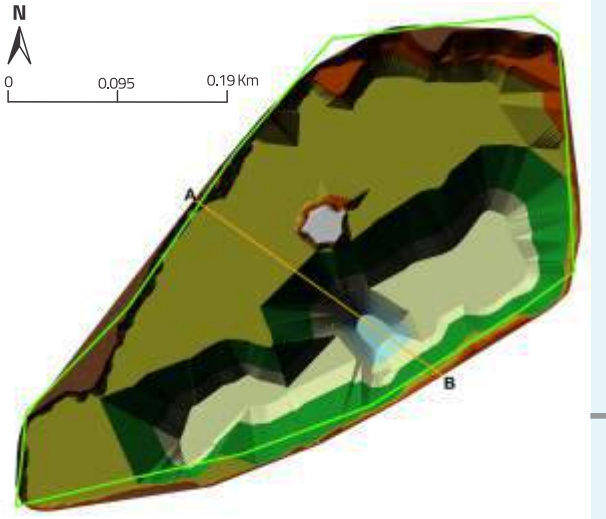
[8]The Severe Effect Level: At this level, the sediment is considered heavily polluted and likely to affect the health of sediment-dwelling organisms. If the level of contamination exceeds the Severe Effect Level then testing is required to determine whether or not the sediment is acutely toxic. At the Severe Effect Level a management plan may be required. The plan may include controlling the source of the contamination and removing the sediment.

Case Study: **Desilting**

Selective desilting:
Selvachintamani Lake, Coimbatore (proposed)

In the 8 Lakes Restoration project, Coimbatore, a passive approach to desilting was adopted by the consultants (*Oasis Designs Inc, New Delhi* and *CDD Society, Bengaluru*). As a strategy, it was decided to desilt only those lakes where storage capacity was severely compromised. Hence, desilting had been avoided in practically all the lakes, except Selvachintamani lake which had no *dead storage*[9]. Silt had reached up to the sill level of the overflow structure and had submerged the bottom of the sill. Hence, it was recommended to desilt the lake in the north-central area (where the lake bed is slightly raised) to the depth of 0.9 m and gradually reduce the depth of excavation towards the shores. As per pre-estimates, 34.3 thousand cubic metres of silt will be removed.

It is suggested that desilting be done when the lake is dry so that the effort of dewatering is reduced to a great extent. Desilted soil shall be managed and reused in the lake itself for bund strengthening or to create wetland habitats, reed beds and islands using native plants. In case of extra silt, Coimbatore Corporation will have to allocate land for dumping, preferably, a dumpsite with a layer of clay lining at the bottom to restrict undetected percolation of nutrients into the ground.



Bathymetry of the Lake

Spot Dredging planned in north-central area after examining bathymetry, maintaining gradient towards outlets

Proposed Plan for **Desilting** in **Selvachintamani Lake**, Coimbatore

[9] Dead or inactive storage refers to water in a waterbody that cannot be drained by gravity through outlet works or spillway, and can only be pumped out. Dead storage allows sediments to settle, which improves water quality and also creates an area for fish during low levels.

04 | Deweeding
a continuous activity under rejuvenation

Proliferation of water hyacinth, duckweed and water lettuce is a massive problem for urban waterbodies today. Every year, the government spends millions of rupees to get the weeds removed from these waterbodies. Disposal of hundreds of truckloads of these weeds is another problem the government needs to tackle.

Deweeding operations in canal of **Alappuzha** Town in Kerala

When lake weeds cover more than 25% of a lake's surface, it is considered dense growth. This can interfere with water-based recreation, such as fishing, boating, swimming and navigation. *Most importantly, dense weed growth can cause major fish kills by depleting oxygen in the water at night.*[10] Water hyacinth can alter water clarity and decrease phytoplankton production, dissolved oxygen, nitrogen, phosphorous, heavy metals and concentrations of other parameters. Hence, it is imperative to control weed manifestation.

[10] Source: Helfrich L.A. et al, 2009

Following are the various approaches for weed control and removal that can be employed:

Preventive Measures for Weed Control

Design alterations to reduce weed manifestation– Waterbodies with aquatic weeds proliferating should have steep bunds. Many species of lake weeds flourish when they can take root in underlying soil. This can be prevented by creating steep banks on the edge of the lake, that descend directly into deep waters. It is difficult for aquatic weeds to become established in deep waters. This strategy does not apply to waterbodies infested with algae or free-floating plants.

Create a buffer zone around the waterbody - Weed proliferation is usually caused by an overabundance of nutrients in the surrounding soil. Runoff underlain with fertilizers from nearby green areas/lawns, animal waste (from cattle grazing around the lakes), and sewage add to the nutrient content of the lake water; which feeds these weeds and causes them to grow in large numbers.

Creating a riparian buffer zone by planting native plants or trees around the waterbody and in the drains traps these nutrients.

Deweeding Methods

The most sustainable solution for controlling the proliferation of water hyacinth would be to adopt preventive measures as explained above; however, this may require extensive catchment scale land-use management, regulation, and enforcement.

Manual, mechanical, chemical and biological control methods are commonly used to control water hyacinth, but no one method is suitable for all situations. Each method has advantages and disadvantages, and ultimately the choice of a control method should be based on site-specific conditions, including the size and spatial configuration of the area to be controlled, seasonal weather patterns, designated uses of the waterbody and budget constraints.

Manual removal – This method is practical only for small quantities of weeds in lakes. It is wise to clear weeds on a regular, if possible weekly basis. Lake weeds need to be cut from their roots. They can be cut with a sickle or pulled up by hand, then removed from the water with rakes or hoes. Most weeds are perennials, meaning they will continue to sprout throughout the season due to underwater roots. Hence, such weeds must be removed from their underlying roots in order to properly stub their growth.

Controlling lake weeds by hand can be labour intensive and difficult, as these weeds usually grow back quickly.

Mechanical measures – For large areas under weed growth, aquatic weed cutters and harvesters are used (in India, generally, *JCBs*[11] are used). It is only suitable when immediate clearance is required because mechanical devices often leave cut-up weed fragments in the water and new weeds may grow from these pieces. Plant fragments left in water may deplete dissolved oxygen if they die and decompose. Often, they form roots and colonize new areas if they live. Mechanical harvesting presents disposal problems; and it is usually the most expensive weed control practice available.

Biological and Chemical methods – Biological method takes 3 to 5 years to be effective and needs intensive monitoring by experts. Different biological species like swans, grass carp and insects, which predate on the weeds, are introduced into lakes (lake sites). However, they can be treated as invasive species and are generally not recommended.

Chemical methods, involve spraying herbicides on the weeds. This method is very effective; however, their application is very sensitive, and like the Biological method, requires expert monitoring. Any fluctuation in their dose may cause fish kills and depletion of dissolved oxygen. Herbicides will need to be reapplied in subsequent years as underlying seeds are unaffected by the first application and will therefore emerge the next year despite initial treatment.

The combination of two or more weed control methods used together will provide more effective results at a lower cost than any of the methods used alone. To arrive at the best system for a specific situation in a waterbody, advice should be sought from an aquatic weed specialist.

Other than the selection of the deweeding methods, **the disposal strategy for weeds also needs to be planned** before commencing operations. There are many beneficial uses of water hyacinth that can be integrated into the rejuvenation plan as an alternative livelihood option for the dependent community.

[11] Earth excavators (commonly known as JCBs after the company name)

Case Study: **Deweeding**

Application of combination of Deweeding Methods:
Rankala Lake, Kolhapur

Rankala Lake situated in Kolhapur, Maharashtra has been polluted by wastewater, which has resulted in enormous weed growth, since 1996. Various initiatives have been undertaken by the municipality, local NGOs, industries and citizen groups to remove the weeds. In 2000, Kolhapur Municipality adopted mechanical and manual methods to remove the weeds. This was very effective in the beginning, but the weeds grew back in the next year itself.

Following these efforts, in 2001, Kolhapur Municipality adopted a biological weed control programme, where exotic weevils (insect) that control excess growth of water hyacinth, were used; in addition to manual and mechanical removal of the weeds. This process was operated with minimum cost and was found effective when implemented. But it brought with it some issues, such as - plants dying and adding to the organic load; and increase in mosquito breeding. Later, the hyacinth reappeared.

In 2009, under NLCP, Kolhapur Municipality carried out a combination of mechanical and manual removal of water hyacinth for the entire lake. The lake was completely cleared of weed infestation and was visibly clean immediately. However, this was not a long term solution and weeds spread over the entire lake in a year's time. The same manual and mechanical deweeding was repeated by the municipality after 3 years and the results were same as in 2009. The same year, the entire lake was filled with blue-green algae due to an increase in the nutrient inflow.

The learning was that the entire lake gets infested with weeds, if the method of removal is not scientifically adopted by the contractors. One method of deweeding is never effective - a combination of methods should be adopted for reducing infestation. Plus, it is important to understand that there are native bacteria, which under certain climatic conditions, reappear and trigger weed growth. The weed removal process is a continuous process and it takes years to reduce weed infestation. Controlling weeds and deweeding should be done scientifically under expert supervision.

Kolhapur Municipality understood these issues and worked hard for many years to cut off the source of nutrients (wastewater) that creates the weed problem, and achieved success to a certain extent.

Weed infested lake in **2009**

Lake in **2019** after repeated deweeding operations

(Photos courtesy: Aditya Velhal)

Source: Ghone A. *et al*, 2015

05 | Urban Placemaking
connecting people to waterbodies

People and waterbodies are connected. Urban placemaking, as part of waterbody rejuvenation, is a process for creating neighbourhoods that inculcate 'sense of place' and 'ownership' for city dwellers. Placemaking is concerned not only with the physical elements of a place (that lend it the functional value) but also how those elements create an ambience by enhancing the 'sense of place' (psychological value). 'Sense of Place', which is the objective for any placemaking exercise, is essential for community wellbeing as it generates feelings of security, safety, pride and ownership.

The current condition of urban waterbodies filled with sewage, weeds and solid waste discourages people from going near them. They smell and are aesthetically unappealing. Further, inaccessible waterbodies are currently used as sites for many illegal activities and people feel unsafe to go near them. This has disconnected people from waterbodies and ownership of these waterbodies is decreasing over time.

Urban placemaking, as part of waterbody rejuvenation, is a process for community buy-in. People in urban areas lack places for recreation and entertainment. Waterbodies play such roles extensively when they are in good condition. They also act as education centres for citizens and students as they exhibit ecosystem functions, water cycle, biodiversity of the area, and many other life related sciences. People are attracted to clean waterbodies for fresh air, sports and healthy activities.

Rejuvenation plans may include urban placemaking elements, such as walkways, cycle paths, green turfed areas, parks and children's playgrounds, benches, fountains/musical fountains within or near waterbodies, education/scientific centres, bird watching towers, public toilets, eating joints, active play areas, entertainment spaces etc.

Urban Placemaking at **Sankey Tank**, Bengaluru

The waterfront of most waterbodies should be planned as an accessible public space with promenades for walking and cycling. Depending on the character of each area, promenades can be designed as nature trails, or as urban plazas in areas abutting busy hubs in the city. Walking and cycling zones created around the waterbody allow people to reconnect to waterfronts and help in keeping encroachments at bay, apart from making the waterbody safe for people to use. Ecological areas can also be a part of waterfront development and can function as nature-trails allowing nature enthusiasts to access the ecological areas for bird-watching etc. Another design aspect of waterfront development is to transform open spaces near the waterbody into active play areas. The sports-oriented place-making approach directly addresses the shortage of green and open public spaces and helps bring people together to interact as a community.

A waterbody with clean water, a healthy environment and ecosystem along with such urban placemaking infrastructure, will always have people around it, which in itself goes a long way in maintaining the waterbody. Proper maintenance of such infrastructure brings people to participate and own these waterbodies. There is community pressure on the local administration to maintain these sites. Also, these vibrant spaces boost tourism and augment other economic activities.

Case Study: **Urban Placemaking**

Connecting People to Lakes: Mansagar Lake, Jaipur

Mansagar Lake is located on the northern outskirts of Jaipur City. This man-made reservoir, constructed 400 years ago, is flanked by hills. There is a palace built in the middle of the lake and a temple on its north-western end.

Since 1962, sewage from Jaipur city has been diverted into the lake as it was no longer used for recreation and the palace had been abandoned. This resulted in rapid silting, decreased water storage capacity and submergence of the palace by more than 3m.

In December 2002, Jaipur Development Authority (JDA), under National Lake Conservation Plan (NLCP), came forward to undertake ecological restoration of Mansagar Lake with the aim of restoring the lake as a potential tourist attraction site.

Given the nature and characteristics of the project, a public private partnership (PPP) was deemed desirable in order to sustain the lake's maintenance on an ongoing basis. The following activities have been implemented in the lake's precincts along with restoration:

- Promenade along the main road overlooking Palace
- Development of new restaurants, handicraft shopping complexes in the lake vicinity
- Development of amusement parks, children parks in the lake periphery areas
- Development of parking areas near the lake

It was perceived that the revenue generated from the above activities will be used for maintenance of the lake by the private partner, thereby ensuring sustainability. The management plan ensured gradual improvement of lake water quality, preventing future pollution. *The lake surroundings have been enhanced aesthetically, and the recreational facilities provide revenue for the management*[12]. However, due to public litigation, PPP model could not succeed in the spirit as planned.

[12] Source: Raina M., 2008

[13] Source: IL&FS Website

The site has now become a centre of attraction for tourists as well as locals. The project has contributed significantly to a decadal growth of 144% in domestic tourist and 22% growth in foreign tourist arrivals visiting Jaipur circle. *Through the multiplier impact of tourism on the economy, the project has also contributed in terms of increased revenues to government, promoting local businesses and products including handicrafts, providing livelihood to the local people, etc.*[13]

Before restoration (Photo courtesy: Down To Earth)

Promenade to view Jalmahal at Mansagar Lake, Jaipur

06 | Other Strategies under rejuvenation

Several technologies and methodologies can be employed to address various issues which often are not implemented judiciously due to lack of scientific knowledge. Some of these are:

- 'Aeration' to improve water quality
- Condition assessment of hydraulic infrastructure and repair

Aeration

The basic purpose of aeration is to increase the dissolved oxygen content of the water. Aeration can increase fish and other aquatic animal species, prevent fish kills, and improve water quality. In some cases, algal blooms can be reduced or a shift to less objectionable algae species can occur. It can also be advantageously combined with active edges or floating islands as described earlier, where it can greatly enhance the treatment efficiency. However, aeration is not a 'cure-all' for a lake's ills (refer ***Box 7***).

Surface Aerators to improve dissolved oxygen levels in the waterbody
Photo courtesy: Kasco Marine

Fountains and water aerators are commonly adopted for water purification and cleaning water in *anoxic condition*[14], which is often caused due to sewage and septage disposal, increased sediments in runoff, effluent discharge and solid waste dumping.

Artificial circulation or *Aeration* can be achieved through the infusion of air into the bottom of the waterbody or by surface agitation from a fountain or spray-like device to allow oxygen exchange at the surface.

Box 7:
Pros & Cons of **Aeration**

PROs

- Breaks down bottom organic sediments (muck)
- Eliminates odours
- Manages algal blooms
- Prevents fish deaths due to anoxic conditions
- Improves fish growth by maintaining oxygen at the bottom of the waterway

CONs

- Changes the communities of phytoplankton, zooplankton and other primary food sources that larval and juvenile fish species rely on
- Decreases the availability of still water to those species that need it
- Makes nutrients more available to phytoplankton and aquatic plants, increasing their rate of growth
- Increases temperature throughout the water column due to the downward mixing of warm surface water
- Not cost-effective as it requires high energy and O&M

[14] Anoxic waters - that are depleted of dissolved oxygen

Case Study: **Aeration**

Restoration through Aeration Technology: Bhopal Lake, Bhoj Wetland

Bhoj Wetland of Bhopal comprises of two lakes i.e. Upper and Lower Lakes. These wetlands are listed amongst the 25 lakes recognized by Ramsar (2007). The twin lakes have a total water spread area of 32.29 sq km and support a rich and diverse range of flora and fauna. With the help of a soft loan from the Japanese Bank for International Cooperation (JBIC), a comprehensive project called the Bhoj Wetland Project had been implemented for conservation and management of these twin lakes. The Upper Lake has been installed with floating fountain type of aeration units; while the Lower Lake has floating fountain, ozonizer and floating fountain cum ozonizer (dual system) types of aeration units. These units are successfully being used to allow oxygen exchange in the lakes thus benefiting its biodiversity.

On average, an increase of 40-60% in dissolved oxygen concentration was recorded during the operation of the aeration units, compared with values before. Similarly, reduction of 30-50% in BOD and COD was recorded. The increased biological stabilization of the waste material becomes particularly evident, considering the reduction in nutrient concentration, particularly of phosphates and nitrates.

Floating Fountain Aeration in **Bhopal Lake**

Source: The Free Library, 2008

Further, aeration is a short-term in-situ management strategy used to alleviate immediate water quality issues. It does not address the underlying causes of eutrophication. It may help decreasing the frequency and intensity of *algal blooms*, but the blooms are rarely eliminated. Some bacteria are native and blooms naturally occur under certain conditions. Aeration should always be considered in conjunction with other management interventions, if the algal blooms have to be completely eradicated.

Condition Assessment of Hydraulic Infrastructure

Hydraulic Infrastructure includes bunds/embankments, drains, inlet and outlet structures such as surplus weir, sluice arrangement etc. One of the main aspects in rejuvenation planning is condition assessment of these structures. Deteriorating structures hinder the success of planned rejuvenating activities as well as decrease the capacity of the waterbody to handle peak flows and floods.

There are many reasons for deteriorating structures –

- non-maintenance of these structures
- change in hydrological characteristics over time
- manipulation of structures over time to suit other infrastructure requirements of growing urban areas
  For example, the natural drainage of inlet or outlet drains sometimes gets modified due to road construction or laying of storm drains; and in some waterbodies, size of embankments get modified due to dumping of lake silt (during desilting operations) or by continuous disposal of C&D waste.

All the above reasons call for condition assessment and engineering investigation of all the water management and hydraulic structures. This involves checking the current flood handling capacity of the lake and drains, inspecting

and understanding the need for refurbishment and retrofitting of hydraulic structures, such as sluice gates, surplus weir, bunds/embankments.

In most rejuvenation projects, the focus on hydraulic infrastructure is not given much importance. Generally, it is observed, that *Planners/Architects* lack understanding of hydraulics and engineering structures, while *Engineers* do not give due importance to aesthetics. More so, sometimes the implementing agencies hired to realise the design drawings on field, do not understand the nuances of the design elements; nor do they employ best practices in construction. Further, there are some key hydraulic aspects such as Full Tank Level (FTL) that have been altered over a period of time, either due to modifications in the surrounding infrastructure, inlet-outlet structure levels or inside lakebed changes. There is a need to look at these types of issues in concurrence with historical data and the present situation to correct these aspects which play a key role in maintaining water in these waterbodies and avoiding flood situations upstream and downstream.

During the rejuvenation of the lake, extra emphasis is given to the lake but not to the drains that bring in water from the catchment. These drains are lined, encroached upon and diverted over the years. Drains are key elements of stormwater management and flood control in an urban area, a rejuvenation plan must include assessment of feeding and outlet drains as critical components.

Embankments/bunds that hold water get eroded over the years through wave action and non-maintenance. It has also been observed that in many lakes, the height of the bunds is raised by depositing silt on them during desilting operations without considering the strength and role of these bunds. This impacts the bund stability and water retention capacity. Hence, necessary bund strengthening measures have to be taken and the desired height of the bund must be maintained as per the provisions in the codes.

All the above challenges are very common but get missed out in planning and maintenance of rejuvenation works. Condition assessment is a very important aspect and hence needs to be integrated on all planning proposals.

Selvachintamani Lake, Coimbatore, Tamil Nadu

In Summary

*...There is a **Science** to the **Art** of Waterbody Rejuvenation*

One may wonder if healing a living system is an art or a science, and there is no straight answer to this question. When one is talking about restoring an ecosystem that has been destroyed and of re-establishing the balance to sustain it, while still allowing for some level of human activity to interfere with this system, **there are no fool proof solutions or answers**.

The approach would necessarily have an element of experimentation with measured or graded interventions in phases, combined with live monitoring and observations that would serve as a feedback loop to fine tune the intervention. **Nature-based solutions particularly, would exhibit a lead-lag effect** i.e. the results would take some time to manifest themselves. The effect of interventions on microbial flora and fauna are usually not immediate. But only an experienced mind would appropriately sense the lead-lag effects. The design of these systems (in many ways) would therefore be based more on empirical models rather than theoretical frameworks.

These empirical models can show a high degree of variations based on different contexts – temperature, climate, scale of the waterbody, rainfall patterns, hydrogeological profiles etc. Therefore, it is even more important that we take an experimental view on these rejuvenation efforts and **see them as a continuous process rather than a one-time fix**. The institutional models for ongoing O&M of these waterbodies are hence critical – because, they must provide for such ongoing observation, learning and modelling. It is therefore logical that **communities around a waterbody are made part of the institutional framework for management of the waterbody**. As direct beneficiaries of a healthy waterbody, they are likely to be more observant and diligent, and ensure that the knowledge of the system is not lost with the passage of time.

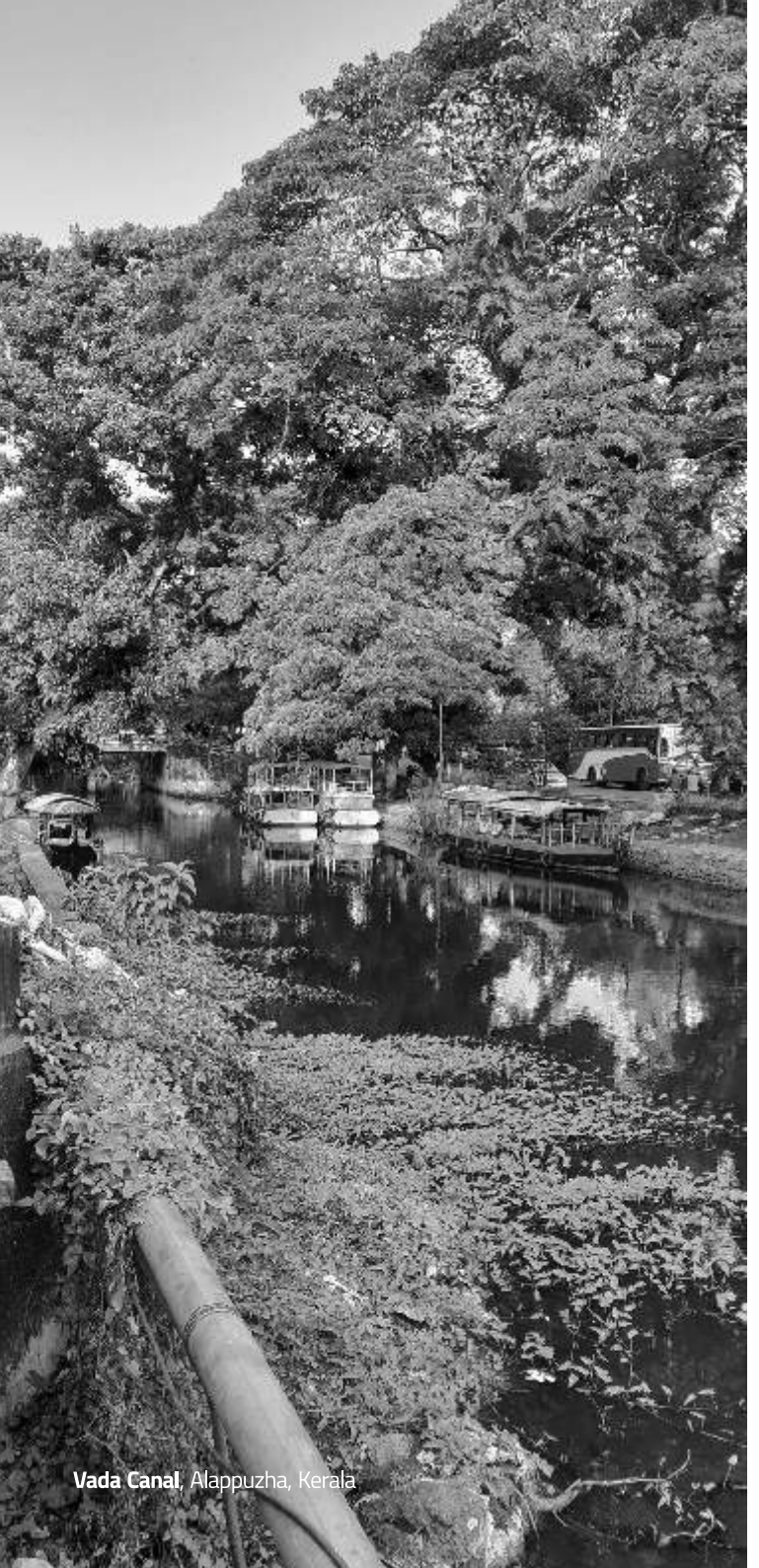
Urban waterbodies exist in a very dynamic context, given the fast pace of change in urban areas. The dry season flows, for instance, would significantly vary in quality and quantity over time, based on how the catchment changes in character. This has to be observed closely and course corrections made from time to time. Wet season flows are also very unpredictable, due to both - larger climate change effects and developments in the catchment areas. The O&M regime will need to keep pace with these dynamic contexts. And **this would only be possible by close monitoring, continuous learning and improvisation**.

Another challenge, particularly with nature-based solutions, is the **availability of skill sets to execute bio-engineering works**. With decades of emphasis on steel and concrete works, some traditional skills of earthen and masonry construction seem to have been forgotten. But **these forgotten techniques are important as they integrate ecology and structural functions** in a better manner.

In spite of the many challenges, there are some simple guidelines one can follow:

- **Address the solid waste challenge first**. If we can prevent solid waste from getting into the drains and lakes, addressing the liquid waste challenge becomes easier.
- Ensure that **wet season flows are not diverted away from waterbodies**. Ensure that they reach the waterbody – not in a hurry – but in a slow manner flowing through meandering drains, through weeds and grass, while also infiltrating into the soil.
- **Treat dry season flows, if any, through constructed wetlands** if the pollution load is low. But, if the pollution load is heavy, ensure that dry season flows are intercepted and treated before being let out into the waterbody. Over time, ensure that sources of pollution are addressed in a manner such that the pollution load in the drains and waterbodies are within the self-cleansing capacities of these systems.
- **Create livelihoods that synergise with the maintenance needs** of waterbodies. Or create celebrations and events that synergise with the needs of the waterbodies across seasons.
- **Connect people to waterbodies** – ensure that people take ownership of their waterbodies and benefit from them. Put the community at the centre of any institutional mechanism that is created for ongoing maintenance of the waterbody.
- In an urban context, practise **desilting only if there is a sustainable option to handle the desilted sediments**. Some level of compromise of storage capacity may not be a huge problem in an urban context. This must be viewed of course, in the context of the waterbody's role in flood management of the catchment.
- **Deweeding can be a regular activity** and is best achieved by making it an economically relevant activity by enhancing livelihoods from this activity.
- In the context of lakes, **ensure every lake has a surplus weir and a sluice gate** for maintenance. The sluice can even be handy for removing silt.
- **Pay attention to the edges of the waterbody**. Ensure the bunds have low gradients and have stratified active edges of native species planted on the inside edge.
- **Segregate urban and ecological edges** if possible. Treat them differently.
- Ensure that the lake has multiple grades, if possible **aesthetically designed**; so that, when water levels drop, the lake reveals itself in an aesthetic manner, and nurtures various kinds of bio-diversity across the seasons.

It is always important to have clarity on the goals of rejuvenation efforts – as they can be manifold – water security, biodiversity enhancement, aesthetics, recreation, livelihoods etc., and some of these objectives can be in some conflict with each other. In a country like India, and specifically in an urban context, **we see that improving water security can be an overarching goal** and having such clarity can point to the right kind of solutions and help make the right choices when there is a conflict in goals.



Vada Canal, Alappuzha, Kerala

Abbreviations

AMRUT	Atal Mission for Rejuvenation and Urban Transformation
BOD	Biological Oxygen Demand
BORDA	Bremen Overseas Research and Development Association
BBMP	Bruhat Bengaluru Mahanagara Palike
CPHEEO	Central Public Health and Environmental Engineering Organization
CGM	Centre for Green Mobility
COD	Chemical Oxygen Demand
CDD Society	Consortium for DEWATS Dissemination Society
CWs	Constructed Wetlands
DEWATS	Decentralized Wastewater Treatment system
DDA	Delhi Development Authority
DPR	Detailed Project Report
DO	Dissolved Oxygen
FTL	Full Tank Level
IIT	Indian Institute of Technology
ILEC	International Lake Environmental Committee
JBIC	Japanese Bank for International Cooperation
MAPSAS	Mahadevpura Parisara Samrakshane Mattu Abhivrudhi Samiti
MoEF	Ministry of Environment and Forests
MoEFCC	Ministry of Environment, Forest and Climate Change
MoWR	Ministry of Water Resources
NEP	National Environment Policy
NGT	National Green Tribunal
NLCP	National Lake Conservation Plan
NPCA	National Plan for Conservation of Aquatic Ecosystems
NWCP	National Wetlands Conservation Programme
O&M	Operation and Maintenance
PCB	Pollution Control Board
PWD	Public Works Department
RRR	Repair, Renovation and Restoration
SOR	Schedule of Rate
STP	Sewage Treatment Plant
UWBe	United Way Bengaluru

Doddanekundi Lake, Bengaluru, Karnataka

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Notes

Notes

Approach to Waterbody Rejuvenation
A Perspective

A **Knowledge** Document
by

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