FRAMEWORK FOR LAKE REJUVENATION

Prepared by

WELL Labs

Water, Environment, Land and Livelihoods (WELL) Labs is a research and innovation centre driving social impact in the field of water sustainability. Based in Bengaluru, it is part of the Institute for Financial Management and Research (IFMR) Society. WELL Labs co-creates science-backed solutions that improve people's lives and livelihoods and sustain nature. It works closely with multiple stakeholders such as governments, businesses, multilateral institutions and civil society groups.

Prepared by

Friends of Lakes

Friends of Lakes is a volunteer-led, non-registered, not-for-profit collective based in Bengaluru. With stewardship over more than 23 lakes, the group is dedicated to the rejuvenation and protection of urban water bodies through both scientific approaches and active citizen participation. Each lake is cared for by a team of local stakeholders, ensuring community-led conservation at core.

In collaboration wtih

GBA
(Greater Bengaluru Authority)

BCAC
(Bangalore Climate Action Cell)

NbS4India
(India Forum for Nature-based Solutions)

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International Centre for Clean Water

Bangalore University Water Institute

Advanced Centre for Integrated Water Resources Management (ACIWRM)

Federation of Bengaluru Lakes (FBL)

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Document Revision History

The Lake Rejuvenation Framework is a living document that will continue to evolve through contributions from partner organisations and field experts. The current Version 2.0 is an updated form of Version 1.0, incorporating insights and recommendations from various practitioners.

Version	Release Date	Incorporated Changes
Version 1.0	March 2025	
Version 2.0	May 2026	- Added General Characteristics to the advanced survey methodology - Incorporated inputs into hydrology, biology, and chemistry parameters - Implemented scientific revisions to visualisations - Integrated structural inputs into a few asset designs

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Foreword

Dr. Veena Srinivasan
Executive Director
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"Urban and peri-urban lakes are vital ecological assets in Indian cities. They provide flood protection, help with groundwater recharge, create biodiversity habitat, and alleviate heat stress. But beyond these, they are important community spaces. For many urban residents, lakes are the only large public natural spaces to which they have access. The benefits of such spaces on mental health and physical fitness are well-documented. They also improve property values.

Today, many urban lakes in India face severe pressures from urbanisation, pollution, and encroachment. Not surprisingly, there has been considerable interest in 'lake rejuvenation' both by Urban Local Bodies and citizen groups funded by CSR donors.

Many lake rejuvenation efforts have remained piecemeal despite significant investments, with outcomes often falling short of expectations. In some cases, rejuvenation efforts have been ineffective or actually worsened flooding. This has resulted in accusations and counter accusations between civil society groups and government agencies. Agencies have become wary of approving lake rejuvenation projects by third parties even though they lack the funds to undertake projects on their own. Civil society organisations and resident welfare associations on the other hand have raised issues of contractor incompetence.

Nonetheless, the CSR law in India presents a huge opportunity for civil society organisations to engage in lake rejuvenation and shape their own neighbourhoods. Recent experience shows that approval and oversight by public agencies are necessary to ensure technical specifications are met. However, this must occur through a streamlined process that accounts for the limits of the capacity of agency staff as well as the lack of trust between agencies and community groups.

This framework emerges as a response to the lake rejuvenation challenge. It offers a structured, science-backed, and community-informed roadmap for lake rejuvenation. The goal is to move beyond ad-hoc interventions toward integrated processes that align ecological functions with social aspirations.

The framework has been co-created through collaboration among research institutions, civil society organizations, government agencies, and citizen groups. It breaks down a complex process into accessible steps from diagnosis and visioning, through design and implementation, to monitoring and evaluation.

It is intended to serve as both a technical reference and a practical tool for policymakers, practitioners, funders, and communities committed to restoring and sustaining lakes. This is more than a manual for lake management. It represents a collective vision for how India's lakes can be rejuvenated as living community spaces."

Messages from our leaders

Preeti Gehlot
Special commissioner
Bruhat Bengaluru Mahanagara Palike

The Lakes Department of BBMP has worked with WELL Labs, among other partners, to co-create a framework for lake rejuvenation. This has been integrated into the Bengaluru Climate Action Plan's Standard Operating Procedures for its Blue-Green Infrastructure Network.

WELL Labs blends science with insights from the ground to tackle urban water issues effectively. The department appreciates their skill of simplifying technical ideas into clear visuals and actionable plans.

Punati Sridhar
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Former ED , JSYS (Jala Samvardhane Yojana Sangha)

Lakes are vital common property resources that sustain the States' water security, biodiversity, and quality of life. Over the past decades, rapid urbanisation, pollution, and neglect have degraded many of these lakes, resulting in flooding, loss of groundwater recharge, and ecological imbalance.

Lake rejuvenation must therefore be treated as a shared responsibility. Citizens have an inherent right over these commons, and their active participation is essential in every stage — from planning and monitoring to maintenance and protection. Government agencies must provide the policy framework, technical expertise, and enforcement against encroachments, while citizens and civil society should ensure vigilance, stewardship, and community ownership.

Karnataka has already demonstrated a successful participatory model. Under the Jala Samvardhane Yojana Sangha, a government society, more than 3,700 lakes were rejuvenated through Tank User Groups (TUGs). The project was self-sustaining.

Regrettably, this proven model was later shelved for reasons best known to the government, though the federation of TUGs remains active. Reviving and strengthening this approach is critical for the protection, biodiversity, development, and productivity of our lakes. With scientific management and people's participation, every rejuvenated lake can once again become a thriving ecosystem and a sustainable water source for generations to come.

Table of Contents:

** Stages 3 (Implementation) and 4 (Operation and Maintenance) are currently being undertaken through ongoing projects. Insights from these processes will inform and further strengthen these sections in subsequent iterations of the Framework document.*

How to navigate the document

Component 1: The diagnosis and visioning stage helps conduct a risk analysis at both the catchment and lake levels, mapping stakeholder activities, and engaging communities to capture their aspirations. This collaborative process results in a shared vision, clear priorities, and actionable guidance to steer the lake rejuvenation efforts effectively.

Component 2: The design stage helps conduct detailed baseline studies to understand lake characteristics, prioritising interventions and developing scientifically informed design guidelines for lake assets. These assets are planned to be code-compliant and tailored to site-specific needs, ensuring ecological and functional integration.

Component 3: The implementation stage ensures assets are constructed as per design specifications. It includes key checks across pre-, during-, and post-implementation phases to ensure quality, compliance, and long-term performance.

Component 4: The operation and maintenance stage ensures assets function at desired levels. It includes implementation timelines, routine checks, and material tests to maintain quality and performance over time.

Component 5: The monitoring and evaluation stage helps track the lake's progress toward set targets. It includes checklists for conducting an asset survey, a lake health survey, and comparing the current versus desired state across lake hydrology, biology, and chemistry

Chapter name - Indicates the stage/component of the framework

Component marker - A colour coded marker that indicates the stage in the overall framework.

Current step marker - A highlighted colour coded marker that indicates the current step within the selected component.

Step marker - A faded, colour coded marker showing all other steps within the selected component.

1

1.1

1.2

1.3

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List of abbreviations

No.	Abbreviation	Full form
1	AAQ	Availability, Accessibility, and Quality
2	ABR	Anaerobic Baffled Reactors
3	AF	Anaerobic Filter
4	ASP	Activated Sludge Process- Extended Aeration
5	BOD	Biological Oxygen Demand
6	CCP	Critical Control Points
7	CPCB	Central Pollution Control Board
8	CGWB	Central Ground Water Board
9	COD	Chemical Oxygen Demand
10	CPHEEO	Central Public Health & Environmental Engineering Organisation
11	CSR	Corporate Social Responsibility
12	DO	Dissolved Oxygen
13	DPR	Detailed Project Report
14	EC	Electrical Conductivity
15	EWL	Ecological Water Level
16	FTL	Full Tank level
17	GIS	Geographic Information System
18	HFL	High Flood Level
19	HRAP	High Rate Algal Pond
20	HDL	Hydraulic Design Load
21	HRT	Hydraulic Retention Time
22	IS	Indian Standard
23	KPI	Key Performance Indicator

No.	Abbreviation	Full form
24	LBL	Lake Bed Level
25	M&E	Monitoring and Evaluation
26	MBBR	Moving Bed Biofilm Reactors
27	MBR	Membrane Bioreactors
28	MLD	Million Liters per Day
29	MPN	Most Probable Number
30	MWL	Maximum Water level
31	NGO	Non-Governmental Organization
32	NRSC	National Remote Sensing Centre
33	O&M	Operation and Maintenance
34	OSM	Open Street Map
35	PMU	Project Management Units
36	SAR	Sodium Absorption Rate
37	SBR	Sequencing Batch Reactors
38	SPCB	State Pollution Control Board
39	STP	Sewage Treatment Plant
40	TBL	Tank Bund Level
41	TN	Total Nitrogen
42	TOC	Total Organic Carbon
43	TSI	Trophic State Index
44	TSS	Total Suspended Solids
45	UASB	Upflow Anaerobic Sludge Blanket
46	µmhos/cm	micromhos per centimetre

List of abbreviations

No.	Abbreviation	Full form
47	°C	degree celsius
48	mg/L	milligrams per litre
49	MPN/100 mL	Most Probable Number per 100 millilitres
50	mg/g	milligrams per gram

Definitions

No.	Term	Definition
1	Trophic state	The trophic state of a water body is a relative expression of a lake's biological productivity.
2	Oligotrophic state	Lakes that have scant nutrients and are minimally productive. These lakes exhibit clear water with good visibility but may not provide the necessary nutrients and algae to maintain a healthy environment for fish and wildlife.
3	Mesotrophic state	Lakes that have a moderate amount of nutrients and are reasonably productive; they generally support a fair amount of algae, aquatic plants, birds, fish, insects and other wildlife.
4	Eutrophic state	Lakes that have good or sufficient nutrients and have fairly high productivity; they are able to support an abundance of algae,aquatic plants, birds, fish, insects and other wildlife.
5	Hypereutrophic state	Lakes that have an overabundance of nutrients an dare the most productive trophic class of lakes. These water bodies have the greatest potential for widely ranging dissolved oxygen conditions, which can have a detrimental effect on native plants and animals.
6	Custodian	An individual, community group, institution, or government agency that is responsible for the care, management, and protection of the lake and its surrounding ecosystem.
7	Detailed Project Report (DPR)	An in-depth technical and financial document that provides a full description of a project, covering its objectives, scope, design, feasibility, implementation strategy, cost estimates, expected benefits, and risk management plan. It acts as the primary referencedocument for project approval, funding, and monitoring.
8	Dry season	The part of the year when rainfall is minimal or absent. Evaporation often exceeds precipitation, leading to lower stream flows, shrinking water bodies, and stressed ecosystems. Typically during January–May (with occasional pre-monsoon showers).
9	Wet season	The part of the year characterized by heavy or frequent rainfall and corresponds to the monsoon or rainy period. Typically during June–December (Southwest and Northeast monsoons).

No.	Term	Definition
10	Full Tank Level (FTL)	The designed storage level of a lake/tank/reservoir, marking the point at which the water body is considered full under normal conditions. Once the water level reaches FTL, any additional inflow overflows through the surplus weir/spillway.
11	Maximum Water Level (MWL)	The highest level of water the tank/lake/reservoir can reach under extreme conditions (e.g. floods) before the embankment is overtopped.
12	Ecological Water Level (EWL)	The minimum water level in a lake or reservoir thatmust be maintained to support its ecological functions.
13	Lake Bed Level	The lowest elevation (or bottom level) of the lake basin, that is, the ground level where the lake stores water
14	Tank Bund Level (TBL)	The elevation of the crest (top surface) of the tank lake embankment or bund. It represents the highest structural level of the bund.
15	Freeboard	The vertical distance between the Maximum Water Level and the Tank Bund Level.
16	Littoral zone	The shallow, near-shore region of a lake where sunlight penetrates to the lake bottom, enabling the growth of rooted aquatic plants. It extends from the shoreline to the maximum depth at which sufficient light reaches the bottom for rooted plants to grow. This zone is typically the most biologically productive part of the lake, supporting high biodiversity, including fish spawning grounds, aquatic plants, amphibians, insects, and birds.
17	Pelagic zone	The open-water region of the lake away from the shore, extending from the surface down to the depth where light can still penetrate. It is dominated by free-floating organisms like phytoplankton and zooplankton.
18	Permeability	The ability of a soil, rock, or surface to allow water (or other fluids) to pass through it. It depends on the size and connectivity of pores or spaces within the material and plays a key role in groundwater recharge and stormwater infiltration.

No.	Term	Definition
19	Benthic zone	The bottom of the lake (lake bed), including sediment and the organisms living in or on it. It is characterised by low oxygen, and is, inhabited by decomposers (bacteria, fungi) and bottom-dwelling organisms (worms, crustaceans).
20	Invasive organisms	Plants, animals, or microorganisms that are introduced (intentionally or accidentally) into an ecosystem where they are not native, and that spread rapidly, often outcompeting or displacing native species.
21	Catchment	A catchment (or drainage basin) is the area of land where all rainfall and surface water naturally drain into a common waterbody, such as a lake, river, or reservoir. It defines the lake's water inflow region, influenced by topography, land use, and ecological characteristics.
22	Upstream	The areas or sections of a river, drain, or catchment that are located closer to the source (higher elevation) and contribute water flow toward a lake or river.
23	Downstream	The areas or sections of a river, drain, or catchment that lie after the lake or confluence, receiving the water that flows out from it.

Need for a framework

Lake rejuvenation refers to the process of improving the condition and functioning of a lake so that it can achieve target functions that are both scientifically feasible and aligned with community priorities. The target functions for urban and peri-urban lakes include flood mitigation, recharge, storage for indirect potable reuse, and ecological or social services.

MISMATCH BETWEEN OUTPUT AND OUTCOMES

Interventions often focus on outputs, such as installation of flood control infrastructure in a lake, rather than prioritizing outcomes, like the flood control function performed by the lake.

LACK OF CONSENSUS IN GOAL SETTING

Often, there is a lack of consensus among stakeholders about the goals, with scientific objectives taking precedence certain times, and community perspectives being prioritised at other times.

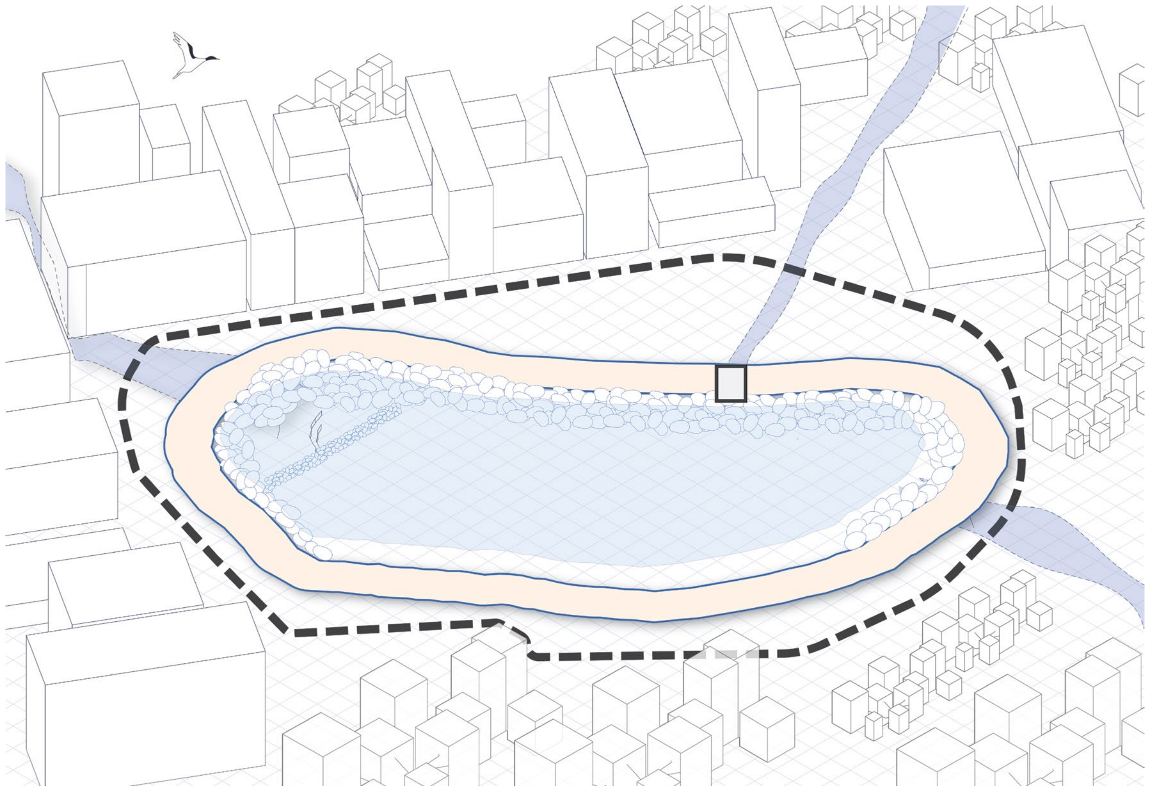
LACK OF STANDARDS FOR DESIGN AND OPERATIONS

Lack of design, construction, and operational standards leads to a range of undesired consequences. Though water quality is assessed using a discrete system, varying use cases require a continuous scale to reflect increasing sensitivity and to ensure consistent evaluation across lake water uses.

ATTRIBUTION ISSUES

Fragmented planning, unclear responsibility, and a lack of understanding of cause-effect relationships between management actions and changes in the lake make it challenging to connect specific lake interventions to observed outcomes.

Scope of the framework



This framework particularly focuses on **urban and peri-urban, tropical shallow lakes**. It specifically addresses **freshwater lakes** in peninsular India. Their maximum **depth is 6 meters** (Pisano et al., 2020), so light can potentially penetrate to the bottom. These lakes, therefore, are non-stratifying; that is, they lack vertical density segregation (Padisák & Reynolds, 2003).

These dynamic systems are often located in densely populated areas, where human impact is significant. They face pressures from domestic and municipal sources of pollution. The framework specifically **excludes** lakes receiving **industrial sources of pollution** because such contamination involves complex chemical pollutants and heavy metals. These require specialized, often costly, remediation techniques that differ significantly from the nutrient and organic matter management approaches.

Stakeholders of the Lake Rejuvenation Framework

Successful lake rejuvenation demands the coordinated efforts of multiple stakeholders, each bringing unique priorities, expertise, and responsibilities. The Lake Rejuvenation Framework creates a platform where government officials, funders, technical experts, and local communities can align towards shared goals. While officials focus on resource efficiency and risk mitigation, funders ensure transparency and accountability. Similarly, experts bring in scientific rigor, and citizens contribute local knowledge and ownership. Together, these diverse voices enable inclusive, efficient, and sustainable restoration outcomes.

Government officials

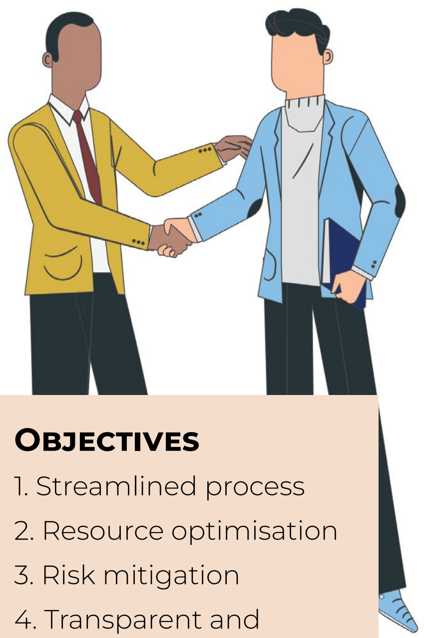
Project Management Units (PMU), Department heads, etc.

Objectives

1. Objective evaluation and approvals of DPRs
2. Resource optimisation
3. Risk mitigation
4. Streamlined process

Donors/Funders

Grantees, CSR donors, etc.



Objectives

1. Streamlined process
2. Resource optimisation
3. Risk mitigation
4. Transparent and objective evaluation of the rejuvenation process

Technical Experts

Consultants, Architects, Engineers, etc.

Objectives

1. Streamlined process
2. Scientific approach

Citizen groups & Communities

People in and around the catchment, Lake groups, etc.

Objectives

1. Inclusive and transparent operation and planning
2. Empowered community
3. Sense of ownership
4. Risk mitigation

Components of the Lake Rejuvenation Framework

A STRUCTURED APPROACH TO REJUVENATION

Reviving urban lakes requires more than just physical restoration. It demands a comprehensive, science backed, and community-informed process. The Lake Rejuvenation Framework provides a clear, five-step roadmap that guides efforts towards lake rejuvenation, from initial diagnosis to long-term sustainability. Each component, from visioning to evaluation, ensures that ecological, functional, and social outcomes are aligned and continuously improved. This version of the framework (Version 2.0) covers Stage 1 (Diagnosis and Visioning), Stage 2 (Design), and Stage 5 (Monitoring and Evaluation). Stages 3 (Implementation) and 4 (Operation and Maintenance) are currently being undertaken through ongoing projects. Insights from these processes will inform and strengthen these sections in subsequent iterations. Furthermore, many lake rejuvenation efforts do not adequately invest resources in Stages 1, 2, and 5. This document, therefore, focuses on these critical phases in detail.

1. Diagnosis and Visioning

This process helps determine the function and purpose of the lake from both scientific and community lenses.

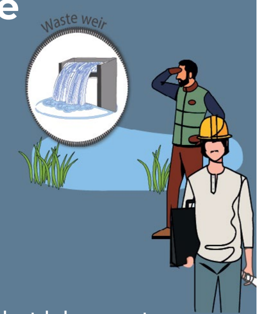
2. Design

This process ensures that assets are scientifically designed according to established codes and categorised by function, enabling the achievement of the targets set for the lake.

3. Implementation

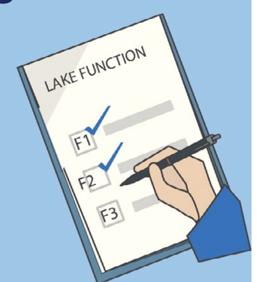
This process ensures that assets are developed in alignment withthe design specifications.

4. Operation and Maintenance



This process ensures that lake assets are consistently operated at their intended performance levels over time.

5. Monitoring and Evaluation



This process helps determine the lake's progress in achieving it's target function(s).

Concepts and approaches used in the framework

a) ASSETISATION

Lake rejuvenation is an inherently complex and multifaceted challenge, often surrounded by diverse stakeholder perspectives and competing priorities. Typically, people tend to focus on a single aspect of the problem, such as ecological, recreational, cultural, or hydrological, which results in a fragmented vision that lacks comprehensiveness. Moreover, no single funder can finance all the interventions needed to rejuvenate a lake fully.

To navigate these challenges, we have adopted an assetisation framework. This approach offers multiple advantages:

Decomposition of Complexity: By unbundling the lake into individual assets (eg: wetland, channel, bund, etc.), we simplify a highly complex system into manageable parts. This helps clarify what specific interventions would be required for each component.

Asset Baselining: Establishing an asset baseline provides a snapshot of the current state. This serves as a reference for ongoing operations, maintenance, and evaluation. This enables adaptive management and progress tracking.

Standardisation of Asset Designs: Defining clear standards (design and operational) for each asset ensures that interventions help meet the target function. This promotes quality control and facilitates consistent design and maintenance practices.

Financialisation and Ease of Attribution: Viewing engineered lake components (e.g. channels, bunds, inlets, and outlets) as assets makes it easier to attribute costs, benefits, and responsibilities. This can improve transparency and accountability in governance.

Better Governance And Community Engagement: Asset-level delineation facilitates inclusive decision-making by allowing different stakeholder groups to focus on assets relevant to their interests and expertise. It also fosters clearer roles, responsibilities, and incentives.

b) CHECKLIST

Throughout the framework, we have deliberately adopted a checklist approach for each component. The intention is to break down complex technical concepts and processes into simple and understandable steps. By translating detailed scientific or engineering requirements into concise checklists, the framework helps ensure that the rejuvenation process can be readily followed, implemented, and verified by a wide range of stakeholders. This method has multiple benefits:

Simplification of Process: Checklists allow complex tasks to be broken down into clear, manageable actions, making it easier for all stakeholders to understand and follow the progress.

Multi-agency Coordination: Since various agencies are involved at different stages, checklists help ensure that no steps are overlooked.

Transparency and Accountability: The checklist records the decision-making process and the rationale behind each action. This increases clarity and accountability throughout the project lifecycle.

Accessibility: In contrast with lengthy reports that are often dense, difficult to read, and sometimes skipped entirely by stakeholders, checklists provide a concise summary that is accessible and easily interpretable by all participants.

Monitoring and Evaluation: Checklists serve as practical tools for ongoing monitoring, helping track completed tasks and identify pending or incomplete steps, thereby enabling timely interventions.

1. Lake Diagnosis and Visioning

This component offers a guide to developing a holistic and inclusive Lake Vision Document. It captures a lake's context, risks, opportunities, community aspirations, and constraints to define a clear vision, set priorities, and guide action. Ultimately, it forms the basis for the preparation and implementation of Detailed Project Reports (DPRs).

Diagnosis and Visioning

OVERVIEW

Lake Diagnosis and Visioning is a collaborative, data-driven approach that combines scientific assessment with community input to guide effective lake restoration. This essential first step ensures a comprehensive understanding of the lake's condition and aligns restoration efforts with both ecological needs and local priorities.

Historically, local communities acted as custodians of lakes, maintaining these water bodies through collective ownership, management, and care, forming a closely connected social-ecological system (Nagendra & Ostrom, 2014). Subsequently, the process of lake rejuvenation had shifted to government departments. However, over time, the emphasis has shifted back to citizen groups, now formally assigned day-to-day responsibilities such as security, gardening, and solid waste management. This transfer of stewardship enables community action and sustained engagement, reinforcing local ownership and accountability (Srinivasan & Apoorva, 2020).

Why is lake visioning important?

A lake visioning exercise is crucial because it bridges scientific understanding with community priorities. On one hand, risk analysis and assessment of inherent lake characteristics reveal what functions a lake can physically and environmentally support. On the other hand, communities and stakeholders living around the lake have unique dependencies, knowledge, and aspirations involving the lake, such as livelihoods (fishing, farming, grazing), recreation, and cultural practices.

Visioning provides a structured, participatory way to:

1. Share scientific findings on risks and lake potential with the stakeholders.

2. Map out ongoing stakeholder activities and historical uses.

3. Facilitate community discussions, so local perspectives inform priorities.

4. Negotiate and co-develop a realistic, prioritised list of functions for which the lake should be managed.

Step-by-step process of lake diagnosis and visioning

Prior to the initiation of any rejuvenation efforts, it is essential to understand the lake's context, capacity, and stakeholder expectations. This step-by-step guide helps establish a strong foundation by systematically diagnosing catchment risks, assessing the lake's potential, and aligning community aspirations with ecological functions. This process enables informed and inclusive decision-making, ensuring that each lake's restoration is purpose-driven and context-specific.

1 Risk analysis

Risk assessment identifies priority lake functions by evaluating catchment-wide and lake-specific characteristics.

2 Factors that influence lake function

Key inherent factors that constrain or aid the ability of the selected lake to play a function, such as flood control or groundwater recharge.

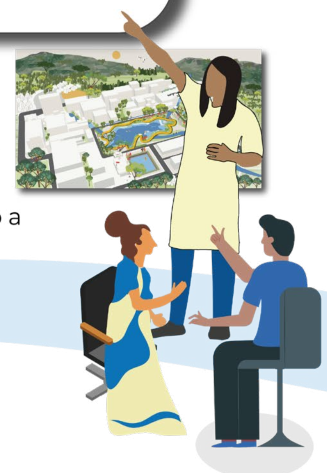
3 Stakeholder and activity mapping

Map stakeholders and activities to assess their impact on the lake and support inclusive decision-making.

4 Lake visioning

Bring together all stakeholders, present scientific findings, and facilitate open discussions on prioritising lake functions.

LAKE VISION DOCUMENT



5 Lake vision document

Finalise the lake vision through stakeholder consultations, building on the analysis conducted in the previous step, and synthesize it into a lake visioning document.

Functions a lake can perform

In urban and peri-urban spaces, lakes can play singular or multiple critical roles. They recharge groundwater, mitigate floods, support biodiversity and ecological health, enable indirect potable reuse, and provide socio-cultural and recreational spaces for communities. The functions a lake serves depend both on the needs of the surrounding communities and on the lake's inherent characteristics.

Groundwater Recharge

Lakes help replenish underground aquifers by allowing water to percolate through the soil, especially during monsoon and high-flow periods.

Flood Control

By storing excess rainwater during heavy rainfall, lakes reduce surface runoff and help prevent urban flooding downstream.

Indirect Potable Reuse

With adequate treatment, lake water can be reused to supplement drinking water sources, improving water security in cities.

Ecological Functions

Lakes support diverse habitats for aquatic and terrestrial species, contributing to urban biodiversity and ecological resilience.

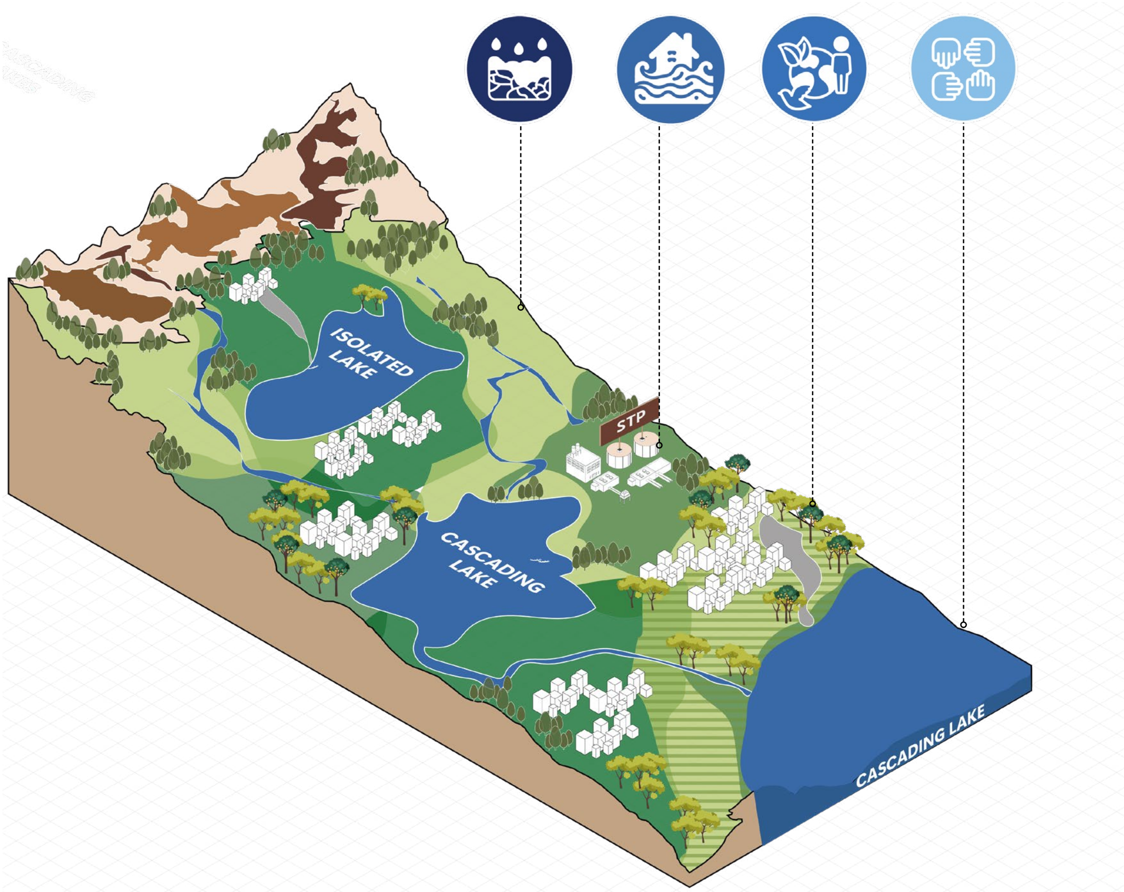
Socio-Cultural Functions

Lakes offer open spaces for recreation, cultural events, and community gatherings, strengthening social bonds and improving well-being.

1.1. Risk analysis

1.1.1. Understanding catchment level risks

A lake does not exist in isolation; it is part of a larger water catchment system that can encounter multiple challenges. Furthermore, the area and the people around the lake could experience different problems. For instance, people might face frequent or occasional flooding; there might be a scarcity of drinking water, especially groundwater, a source on which numerous urban residents depend; the area could be losing its remaining biodiversity; or the area could lack meaningful public and social spaces.



The purpose of the risk analysis at this stage is to **systematically identify** and **evaluate** the **key risks** present at both the **catchment** and **lake levels**. This assessment helps us understand not only the existing risks but also the potential of the lake to reduce these risks.

Since this analysis is conducted at the very beginning of the rejuvenation process, before even before the beginning of any intervention, we have designed it as a practical, resource-conscious screening exercise. Recognising that there may be constraints regarding time, funding, and access to detailed data at this stage, our approach focuses on making the process simple.

We have intentionally selected indicators that can be assessed using publicly available secondary data sources, as well as straightforward, rapid primary surveys, if needed.

The results from the indicators are synthesised into a risk matrix, allowing for risks to be classified as low, medium, or high. This classification helps prioritise the risks the lake can realistically address, and helps guide decisions about what functions the rejuvenated lake should be designed to serve.

While a standard set of indicators is provided, the framework is adaptable. If more accurate or locally relevant data sources are available, users are encouraged to substitute or supplement indicators accordingly.

We have selected the following indicators for the easy identification of different risk levels:

Flood vulnerability

Secondary datasets:

The National Remote Sensing Centre (NRSC) provides a Flood Vulnerability Assessment System that combines data on maximum rainfall and runoff potential to classify areas according to flood vulnerability, ranging from very low to very high. This dataset offers a broad-scale, spatial overview of flood risk that can be used for initial screening (NRSC-ISRO, 2025).

Primary datasets:

To complement this, a localised survey is conducted to gather ground-level information on the typical depth of water inundation and the frequency of flood events experienced by the community. This primary data helps refine the risk classification by capturing actual flood impacts on the ground (Moya Quiroga, et al., 2018).

Water scarcity

Secondary datasets:

The Central Ground Water Board's assessment methodology classifies each block based on the balance between groundwater extraction and recharge. Blocks are categorised as safe, semi-critical, critical, or over-exploited, providing an objective index of water scarcity risk at the regional level (Central Ground Water Board, 2023).

Water scarcity

Primary datasets:

On-the-ground surveys are used to understand community dependency on borewells, including its functioning through the year. These surveys would capture perceptions of access: for instance, whether borewells fail during summer or function year-round, and whether reliance is seasonal or constant. This provides localised insights that complement the broader groundwater status data, enabling finer classification of water scarcity risk.

Nutrient enrichment

Secondary datasets:

The Central Pollution Control Board (CPCB) or State Pollution Control Boards (SPCB) routinely monitor and publish water quality data for lakes, including measurements of Total Nitrogen (TN) in mg/L (Karnataka State Pollution Control Board, n.d.).. Using these TN values, the Trophic State Index (TSI) for nitrogen can be calculated with the formula:

$TSI(TN) = 54.45 + 14.43 \times \ln(TN)$

This TSI score classifies the water body's trophic status as follows:

30–40: Oligotrophic (low productivity)

40–50: Mesotrophic (moderate productivity)

50–70: Eutrophic (high productivity, elevated risk)

>70: Hypereutrophic (very high productivity; high risk of algal blooms and oxygen depletion)

Nutrient enrichment

This approach provides an objective, quantitative basis for assessing nutrient enrichment risk using readily available, standardised data sources (Carlson & Simpson, 1996).

Primary datasets:

Field observations are used to complement the secondary data. These include visual assessments of the presence or absence of algal blooms, dense macrophyte growth, and floating scum, either across the lake or in localised sections. Such on-the-ground evidence helps validate or refine the risk category derived from TSI calculations, particularly in cases where recent conditions diverge from collected data.

Habitat loss

Secondary datasets:

The eBird platform compiles extensive observations on water birds through participatory research. By analysing reports of water bird species such as the frequency and diversity of sigh species, including the frequency and diversity of their sightings, as well as the occurrence (or absence) of rare or vulnerable species over the past year, this dataset serves as a useful proxy for evaluating the quality and extent of habitat actually available for wildlife at the lake. Lower diversity or absence of typical or rare water birds can signal significant habitat degradation.

Primary datasets:

Direct field observations are used to assess habitat pressures. This includes documenting the spread and dominance of invasive plant species across the lake, as well as noting visible shoreline modifications (such as concrete embankments, excessive dumping, or filling) that indicate disturbance to natural habitats and barriers to native species' movement and habitat use.

Restricted public spaces

Secondary datasets:

Using the Availability, Accessibility, Quality (AAQ) framework, spatial datasets such as OpenStreetMap (OSM), satellite imagery, and land use plans can help assess:

Availability: The number, size, and distribution of public spaces within the lake catchment.

Accessibility: GIS analysis of proximity to residences, walkability, presence of physical barriers (e.g. highways, walls), and connected street networks.

Quality: Proxy indicators from street-level imagery (e.g. Google Street View, Mapillary) and satellite data (e.g. presence of vegetation cover, shade structures, lighting) that can indicate usability and maintenance. Cadastral maps can reveal legal ownership, encroachments, or potential threats to public use.

These datasets allow for preliminary spatial diagnostics that highlight gaps or inefficiencies in the public space network.

Primary datasets:

On-ground surveys and participatory tools deepen the AAQ assessment by capturing:

Availability: Residents' awareness of existing public spaces, including informal or seasonal gathering areas.

Accessibility: Perceived ease of access, safety, inclusiveness (especially for women, older adults, or marginalised groups), and socio-cultural barriers.

Quality: User experiences related to cleanliness, maintenance, availability of amenities (benches, play areas), safety (lighting, policing), and suitability for recreation, livelihoods, or community events.

Community engagement methods, like focus groups or participatory mapping, can also highlight the required demands of the residents.

1.1.2. Risk analysis tool

This table synthesises multiple indicators into a structured risk matrix, helping assess the feasibility of a lake performing key functions. Each function is evaluated through relevant threat metrics, using both secondary and primary data.

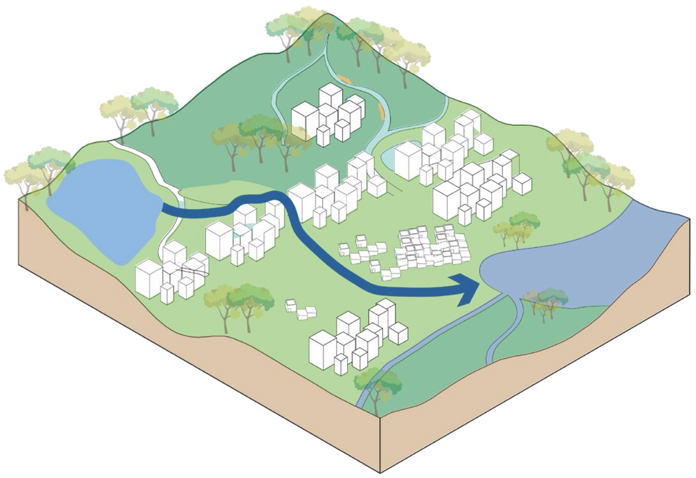
Each indicator is rated on a scale from low to high risk, allowing practitioners to classify the severity of risks associated with each function. This classification helps determine which risks are manageable through lake rejuvenation; what functions of the lake should be prioritised; and whether the lake's current condition supports or limits certain uses.

Functions	Risk metrics	Secondary analysis			Primary data analysis			Severity of risk
Flood control	Flood vulnerability	Very high vulnerability to flooding	Medium vulnerability to flooding	Low vulnerability to flooding	Every year: Water depth >0.5m Every 5 years: Water depth >1m Lake is breaching	Every year: Water depth <0.5m Every 5 years: Water depth 0.5–1m Every 10 years: Water depth >10m	Every 10 years: Water depth <1m	High/low
Ground water recharge or Indirect potable reuse	Water scarcity	Over exploited/ critical block	Semi critical block	Safe block	You depend on borewells throughout the year / or your borewells do not function during summers.	You depend on borewells only during some months / and your borewells function throughout the year.	You are not dependent on borewells or tankers.	High/low
	Nutrient enrichment	Hyper eutrophic/ eutrophic	Mesotrophic	Oligotrophic	Presence of algal blooms / floating macrophytes / scum in a major portion of the lake?	Presence of algal blooms / floating macrophytes / scum in some parts of the lake?	Absence of algal blooms/ floating macrophytes / scum?	High/low
Ecological	Habitat loss	Does eBird report no sighting of waterbirds in the past year?	Does eBird list waterbirds as rarely sighted in the past year?	Does eBird list waterbirds as commonly sighted in the past year?	Widespread invasive species dominance / major shoreline modifications.	Increased presence of invasive species / moderate shoreline modifications.	Minimal or no presence of invasive species / minor shoreline modifications.	High/low
Socio-cultural	Restricted public spaces	Availability: The neighbourhood/ catchment area does not have any public spaces within a 15-minute walking radius.	Availability: The neighbourhood / catchment area has limited public spaces within a 15-minute walking radius.	Availability: The neighbourhood/ catchment area has sufficient public spaces within a 15-minute walking radius.	Accessibility/quality: The neighbourhood lacks accessible public spaces or dedicated livelihood spaces.	Accessibility/quality:The neighbourhood has limited accessible public spaces or dedicated livelihood spaces.	Accessibility/quality: The neighbourhood has sufficient accessible public spaces and dedicated livelihood spaces available.	High/low

1.2. Factors influencing lake functions

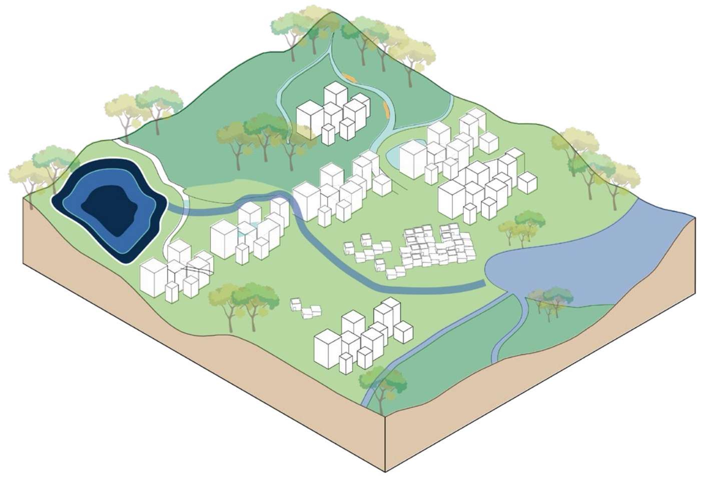
1.2.1. Understanding the factors

Lakes play multiple functions, but not every lake is equipped to perform all of them. A lake's ability to deliver specific benefits depends on factors such as its location, catchment dynamics, water quality, and surrounding land use. While all lakes have certain inherent characteristics, it is the presence or absence of key ecological and physical features that determines their suitability for particular roles. Recognising this, a site-specific assessment is crucial to identify which functions a lake can realistically and sustainably support.



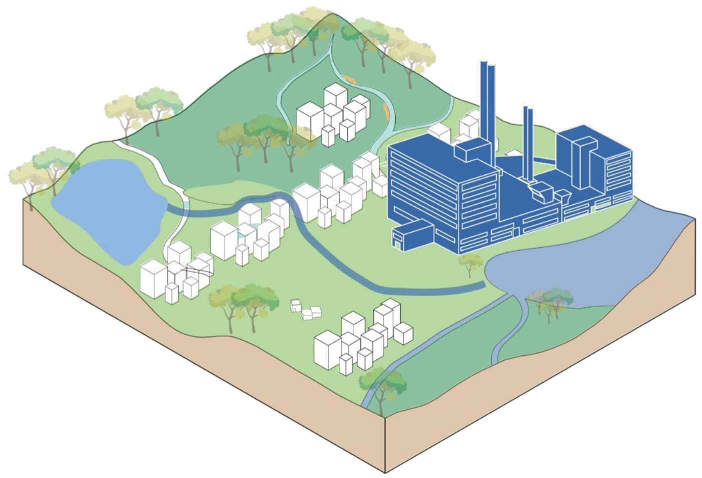
Inlet/outlet connection

Assessing the condition of inlets and outlets reveals if water can flow as intended, ensuring hydrological connectivity. This exchange supports water, nutrient, and aquatic life movement. In floodplain lakes, it allows flood buffering by absorbing and gradually releasing stormwater. Without it, floodwaters bypass the lake, increasing downstream flood risk.



Located in recharge zone

Whether a lake can effectively recharge groundwater depends whether it can capture enough runoff, the soil permeability, and the difference in water level between the lake and groundwater table.



Control over water quality

Polluting land uses like industries releasing heavy metals or pharmaceuticals can cause long-term water quality issues beyond the reach of typical treatments. Land use assessment helps decide if interventions within the framework are sufficient.

1.2.2. Influencing factors tool

This scientific tool helps identify the key factors that constrain or support the lake's function.

Input: No input from previous step.

Functions

Factors influencing the lake's ability to play a function	Catchment connectivity	Located in recharge zone	Control over water quality
Groundwater recharge		●	●
Flood control	●		
Indirect potable reuse		●	●
Ecological			●
Socio cultural			◒

● Critical criteria ◒ Desired criteria

It helps identify the key functions a lake can play keeping in mind the external factors influencing it.

Input: Severity of threat from step 1 (Risk analysis) and external factors constraining lake function from step 2, as well as other supporting inherent conditions that restrict or aid the lakes' ability to perform a function.

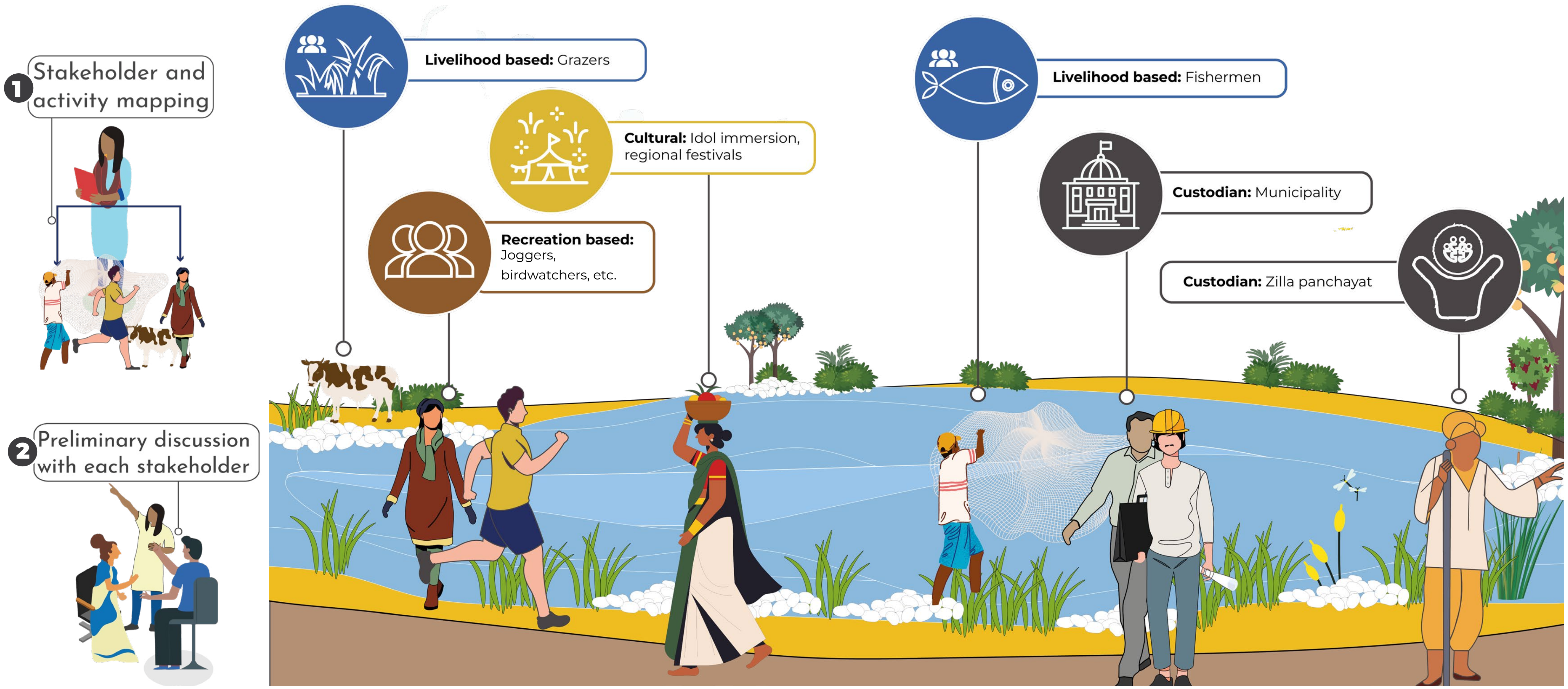
Risks	Severity of risk	Factors influencing lake function		Status of function the lake can play
Groundwater scarcity	Low/high	Located in recharge zone	YES/NO	Can/cannot play groundwater recharge function
		Control over water quality	YES/NO	
Flood control	Low/high	Hydrological connections	YES/NO	Can/cannot play flood control function
Nutrient enrichment and habitat loss	Low/high	Control over quality	YES/NO	Can/cannot play ecological function
Socio cultural	Low/high	Presence of underutilised spaces	YES/NO	Can/cannot play socio cultural function

1.3. Stakeholder identification and activity mapping

1.3.1. Need for stakeholder participation

Stakeholder and activity mapping is a key step in understanding how different groups interact with the lake and its surroundings. This includes livelihood-based users, such as grazers and fishermen; recreation-based users, like joggers and bird watchers; cultural users engaged in idol immersion or local festivals; and custodians, such as the municipality or the zilla panchayat.

Mapping these stakeholders helps identify overlapping or conflicting uses, while preliminary discussions with each group highlight their specific needs and concerns. This participatory approach ensures that the rejuvenation plans are inclusive, context-sensitive, and aligned with the lived experiences of those most connected to the lake.



1.3.2. Stakeholder identification tool

The Stakeholder Identification Tool offers a structured way to map and understand the diverse user groups that interact with the lake. It categorises stakeholders into four types: livelihood-based/resource users, cultural users, recreational users, and custodians. For each type, it identifies the role they play, as well as their specific activities (e.g. fishing, idol immersion, jogging), and links these to the lake's ecological and socio-cultural functions.

The tool also captures whether these activities are seasonal or year-round, estimates the number of people involved, and evaluates whether or not current practices are supported by the lake. This framework enables a clear understanding of both usage pressures and the potential for inclusive lake management by projecting the future state of each activity and its impact, and whether it should it be supported or restricted.

User type	Role played	Activity	Lake function	Is the activity seasonal or throughout the year	If seasonal then: Months	No. of people involved	Future state	If supported, improvements required
 **Livelihood based / resource user**	Dependency on the lake's resources for their income and daily sustenance	E.g.: Fishing, grazing, washing clothes	Ecological/ socio-cultural ▼	Seasonal/ Yearly ▼			Supported/ not supported ▼	
 **Cultural user**	Engagement with the lake for traditional, religious, or community practices	E.g: Idol immersion, water sports, etc.	Ecological/ socio-cultural ▼	Seasonal/ Yearly ▼			Supported/ not supported ▼	
 **Recreational user**	Engagement with the lake for leisure activities	E.g: Jogging, birdwatching, swimming, etc.	Ecological/ socio-cultural ▼	Seasonal/ Yearly ▼			Supported/ not supported ▼	
 **Custodians**	Responsible for the ownership, upkeep, and long-term maintenance of the lake		Ecological/ socio-cultural ▼	Seasonal/ Yearly ▼			Supported/ not supported ▼	

1.4. Lake visioning

1.4.1. Process of lake visioning

The lake visioning process combines risk analysis, ecological and contextual lake factors, and stakeholder activity mapping to identify and prioritise the lake's future functions. First, risk analysis helps understand the severity and urgency of threats like flooding, pollution, or habitat loss. Next, lake-specific factors, such as hydrological connectivity, urban pressures, land use, and ecological constraints, determine the limitations and opportunities for interventions. Finally, stakeholder activity mapping, which captures what people currently do or aspire to do around the lake, including livelihood, recreational, or cultural uses, is conducted. Together, these inputs help generate an output matrix of **prioritised lake functions** based on urgency and stakeholder relevance, guiding focused and inclusive rejuvenation efforts.

1. Preparatory Steps

Identify and analyse risks at the catchment and lake level; identify the lake's inherent characteristics, including hydrological connectivity, recharge potential, and land use; and map existing stakeholder activities and ongoing uses of the lake.

2. Community Engagement

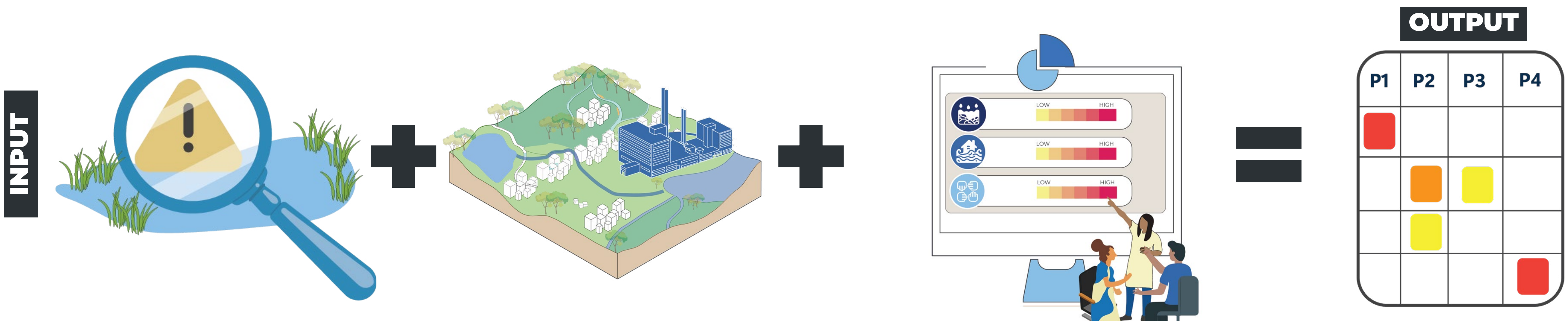
Initiate early conversations and conduct field visits in the catchment and adjacent communities; document community needs, expectations, and existing vulnerabilities (e.g. water, sanitation, and livelihood); and identify formal and informal user groups (e.g. farmers, fisherfolk, youth, and NGOs).

3. Visioning Workshop

Organise an accessible, inclusive meeting within the lake catchment area for maximum participation; present scientific and community findings in an understandable format; facilitate open discussions on priorities, challenges, and lake functions; and enable negotiation between what is biophysically feasible and locally desirable.

4. Co-development of Vision

Arrive at a consensus or develop a prioritised list of functions for the rejuvenated lake; and record and share the outcomes through a Lake Visioning Document.



Catchment risk analysis:

Severity of catchment risks gives the requirement

Lake factors:

Limitation and scope based on setting of lake

Stakeholder activity mapping:

List of activities that stakeholders perform or wish to perform.

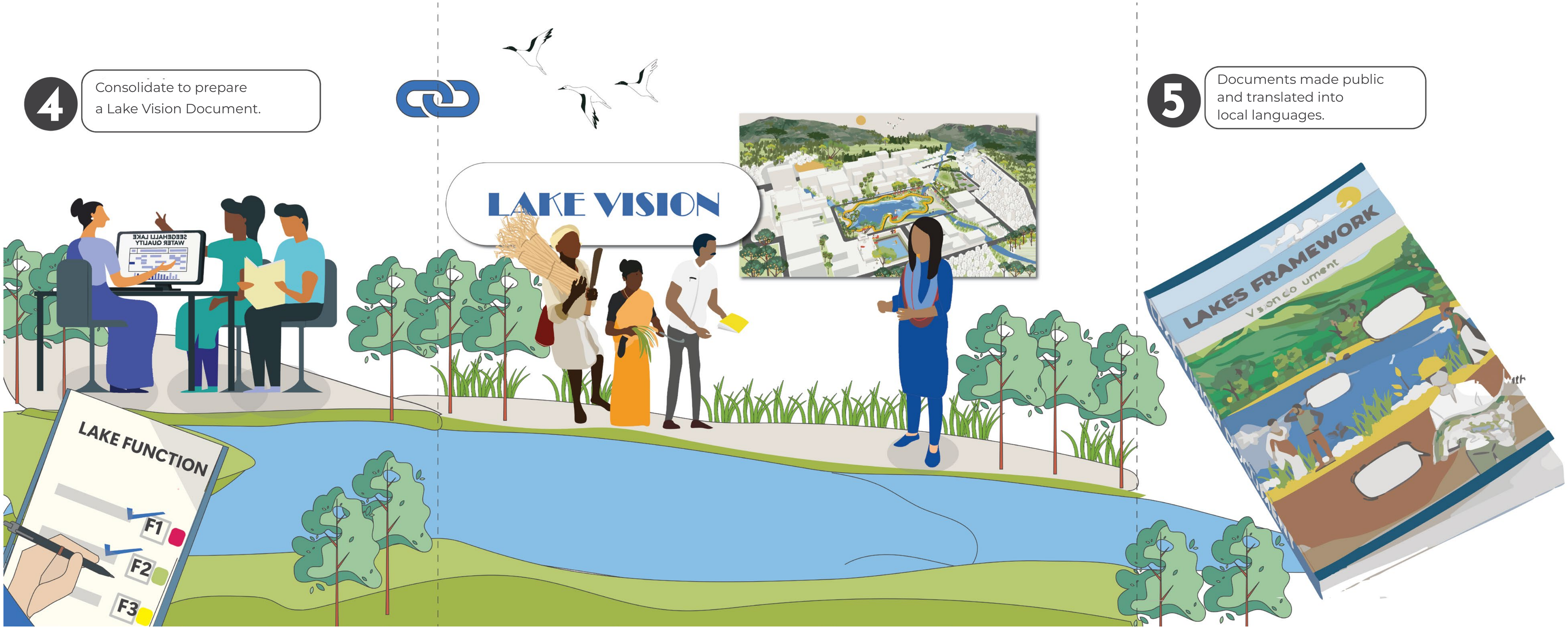
Prioritised functions the lake should perform based on urgency and stakeholder inputs

1.5. Lake vision document

1.5.1. Overview

In the final step of the lake visioning process, all findings from the preceding assessments, such as risks, external lake factors, lake conditions, functions, and stakeholder aspirations, are consolidated using structured checklists to create a comprehensive Lake Vision Document.

This document outlines the prioritised functions of the lake, supported by ecological and social evidence, and reflects the shared aspirations of diverse community members. Once prepared, it is made publicly accessible and translated into local languages to ensure inclusivity and ownership. The Lake Vision Document serves as a **guiding blueprint** for lake rejuvenation, enabling coordinated action and long-term stewardship.



1.5.2. Lake vision document tool

This is a decision-making checklist that helps translate technical assessments and stakeholder inputs into actionable priorities for lake rejuvenation. It evaluates each potential lake function across three key parameters: severity of risk, functional feasibility (based on factor mapping), and stakeholder priorities (aspiration mapping).

Based on this multi-criteria analysis, each function is then ranked on a scale of 1 to 10, guiding the formulation of a site-specific, evidence-based lake vision. This tool ensures that the final vision is grounded in both scientific rationale and community aspirations.

Function	How severe is the risk? (Risk assesment) Input 1 option	Can the lake perform the function based on factor mapping?	Stakeholder views on the function? (Stakeholder aspiration mapping) Input 1 option	Final prioritised functions Input 1 option
Flood control	High/medium/low	Can/cannot play flood control function	High priority/ medium priority/ low priority	Ranking 1-10 ______ *1-High, 10-Low*
Ground-water recharge	High/medium/low	Can play/ cannot play groundwater recharge function	High priority/ medium priority/ low priority	Ranking 1-10 ______ *1-High, 10-Low*
Indirect potable reuse	High/medium/low	Can play/ cannot play indirect potable reuse function	High priority/ medium priority/ low priority	Ranking 1-10 ______ *1-High, 10-Low*
Ecological	High/medium/low	Can play/ cannot play ecological function	High priority/ medium priority/ low priority	Ranking 1-10 ______ *1-High, 10-Low*
Socio-cultural	High/medium/low	Can play/ cannot play socio-cultural function	High priority/ medium priority/ low priority	Ranking 1-10 ______ *1-High, 10-Low*

1.5.3. Lake vision document structure

1. Overview of the lake

This section provides a general introduction to the lake, including its location, size, historical significance, ecological characteristics, and current usage. It also highlights key environmental and socio-economic roles the lake plays in the community.

2. Risk analysis

A comprehensive assessment of risks affecting the lake at the catchment level, considering natural and human-induced threats. This includes land-use changes, deforestation, urbanisation, industrial activities, and climate change, which collectively impact water inflow, quality, and ecosystem balance.

2.1 Secondary data analysis

2.2 Primary data analysis

3. Factors influencing lake functions

4. Ability of the lake to play the function

5. Stakeholder activity mapping

A visual or descriptive analysis of different stakeholders interacting with the lake, their level of influence, and the type of activities they engage in. This helps in understanding competing interests and in identifying potential collaboration opportunities for lake management.

5.1 Types of stakeholders

5.2 Types of activities around the lake

7. Lake visioning workshop

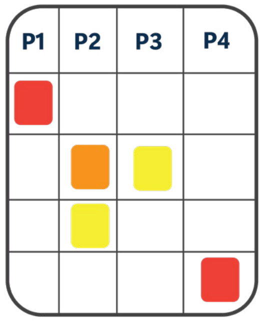
7.1 Key takeaways from the workshops

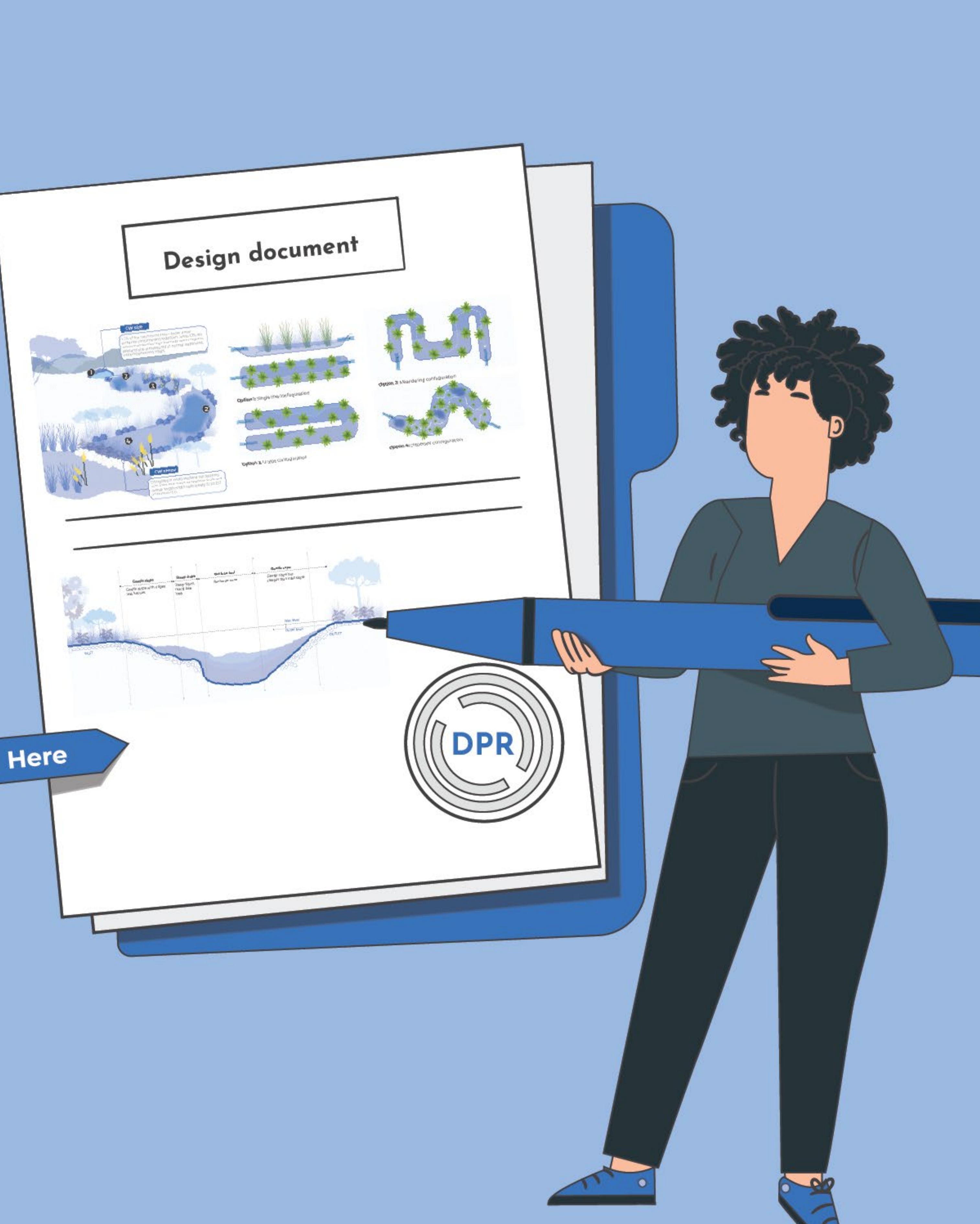
Summary of the most important insights from discussions, including shared concerns, knowledge gaps, community expectations, and potential solutions proposed by stakeholders.

7.2 Prioritised functions of the lake

FINAL OUTPUT/CHECKLIST EXAMPLE:

Function	From step 1 **How severe is the risk? (Risk assessment)** Input 1 option	From step 2 **Can the lake perform the function based on factor mapping?**	From step 3 **What are stakeholders' views on the function?(Stakeholder aspiration mapping)** Input 1 option	From step 4 **Final prioritised functions** Input 1 option
Flood control	Low	Cannot play flood control function	Low priority	*Ranking 1-10* 1
Groundwater recharge	High	Can play groundwater recharge function	High priority	*Ranking 1-10* 2
Indirect potable reuse	Low	Can play indirect potable reuse function	Medium priority	*Ranking 1-10* 4
Ecological	Low	Cannot play ecological function	Low priority	*Ranking 1-10* NA
Socio-cultural	Low			*Ranking 1-10* 3
Jogging		Can play these socio-cultural functions	High priority	3a
Gathering				3b
Idol immersion			Low priority	3d
Boating				3e
Swimming		Cannot play this function		NA
Livelihood				
Fishing		Can play these socio cultural functions	Medium priority	3c
Grazing				3c





2. Design

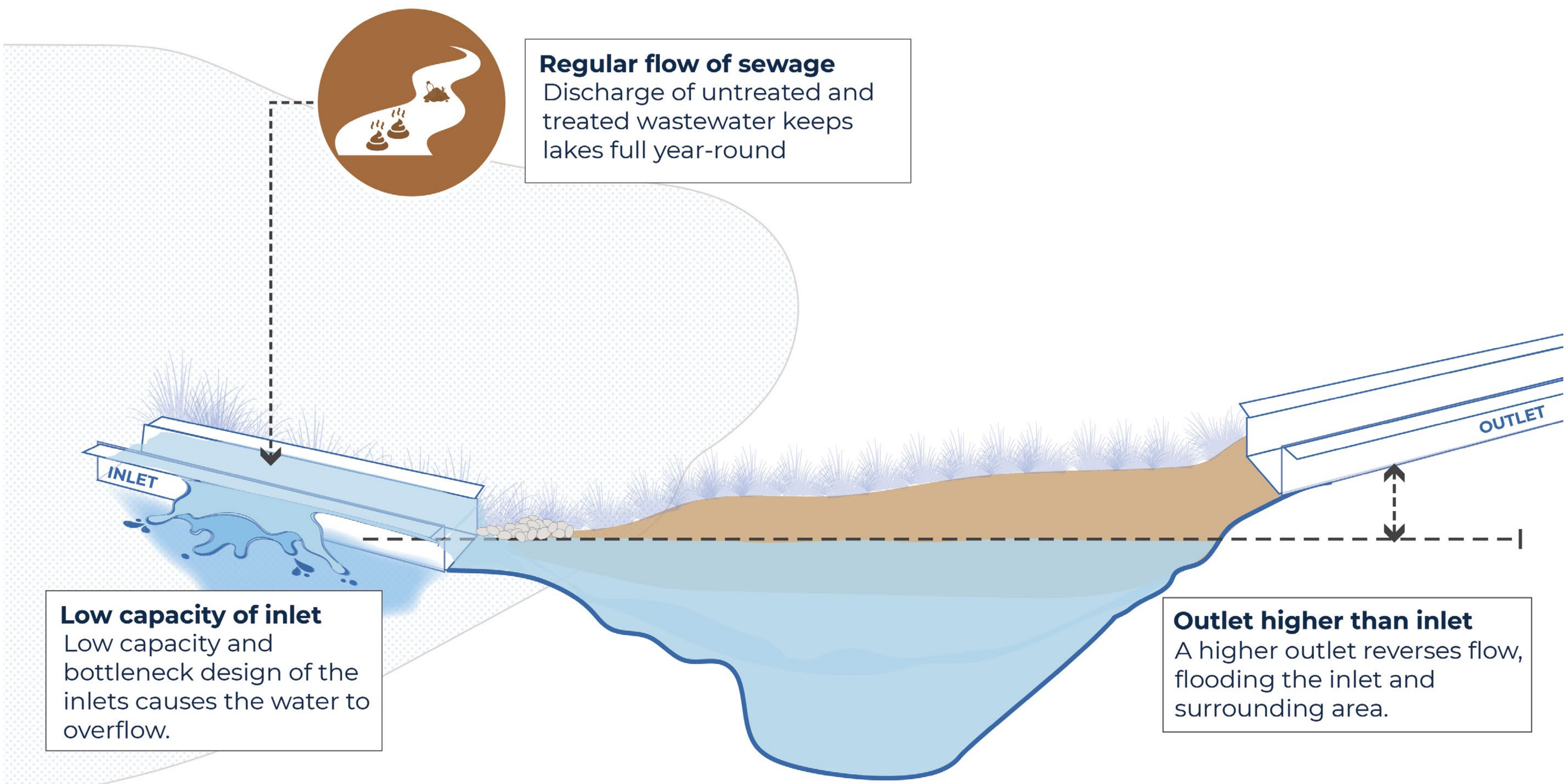
This component serves as a comprehensive guide for developing a holistic and inclusive Lake Rejuvenation Detailed Project Report (DPR). It outlines key design principles, provides an in-depth understanding of lake characteristics, and provides a detail drawing of assets. Additionally, it presents the necessary baseline studies required for asset prioritiation and concludes with detailed design guidelines for various lake assets.

Design

OVERVIEW

The Design Section focuses on developing a scientific lake design to ensure it can perform its target functions while supporting sustainable rejuvenation. It serves as a comprehensive guide for preparing a holistic and inclusive Lake Rejuvenation DPR. The section outlines key design principles rooted in lake characteristics and asset designs, explains how these factors influence lake functions, and translates these insights into detailed design guidelines. It also specifies the baseline studies required to support informed planning and asset prioritisation.

A common challenge in lake rejuvenation is the lack of clear standards for the design and placement of different lake components, as well as limited understanding of how each asset contributes to overall lake function. By standardising both the design and location of assets, the section ensures that each intervention supports the lake's intended ecological and hydrological roles, offers durability, and represents a meaningful investment, moving beyond simple beautification towards long-term functionality and resilience.



Enhancing lakes' ability to deliver key functions

In the design stage, we bring together two essential components:

Lake Characteristics – We first understand the lake's natural profile: the inflow and outflow of water, its natural self-purification capacity, and the diversity of aquatic life it supports. These inherent qualities form the foundation of the lake's functioning.

Built Assets – We then design targeted interventions, such as infrastructure for water treatment, flood management features, or ecological enhancements that can be integrated into the lake and its surrounding landscape. These assets complement and strengthen the lake's natural capabilities.

When these two elements work together, they significantly enhance the lake's ability to deliver **key functions more efficiently.**

Why keep these separate?

In this framework, lake characteristics and lake assets are deliberately considered as distinct components because they serve different, albeit complementary, roles in lake management and rejuvenation.

Clarity of Assessment: Separating the two enables us to distinguish between what can be monitored (natural processes) and what can actually be managed (man-made interventions).

Effective Targeting: This separation allows stakeholders to focus resources and efforts on assets, where real change is possible, while monitoring characteristics to gauge effectiveness and track progress.

Integrated Management: Together, both aspects provide a comprehensive picture: lake characteristics indicate how the system is functioning, while assets provide the levers for moving towards desired outcomes.

Step-by-step process for lake redesign

The step-by-step process helps transform the Lake Vision Document into a detailed, actionable plan. First, we identify the lake's unique characteristics and manageable assets. Then, we list the assets that align with the lake's intended functions. Subsequently, we design assets to meet specific criteria, such as relevant Indian Standard codes, regulatory guidelines, and established design guidelines.

Second, we establish a baseline of current asset conditions to guide effective operation, maintenance, and monitoring. The process culminates in a Lake Rejuvenation DPR, ensuring that the redesign is precise, function-oriented, and ready for implementation.

2.1. Lake characteristics

2.1.1. What biophysical natural laws govern lake function?

The characteristics of a lake are the result of the biophysical natural laws and processes that govern the lake's functions. These are inherent qualities shaped by both environmental and historical forces, and are grouped into three main categories:

Lake Hydrology

Water movement, distribution, and processes in lakes, including inflow, outflow, and catchment interactions

Lake Biology

Native and invasive species in lakes, including their populations, interactions, and habitats

Lake Chemistry

Composition of lake water, including nutrient and pathogen levels, pH, Dissolved Oxygen (DO), and how these factors affect the ecosystem health

2.1.2. How do lake characteristics influence different functions?

Lake functions are governed by the interplay of hydrology, biology, and chemistry. Each function depends on a specific combination of these categories. For instance, groundwater recharge relies on hydrology and chemistry, as water movement and quality influence recharge potential. Flood control is mainly driven by hydrology, through inflow, outflow, and storage. Indirect potable reuse requires both hydrology and chemistry to ensure adequate supply and safe quality. Ecological functions depend on all three: water flow, nutrient balance, and species interactions.

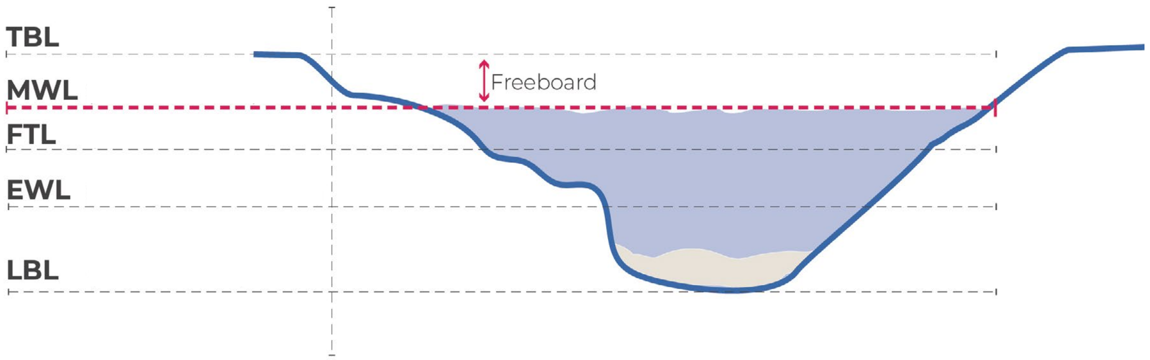
Functions	Factors influencing the lakes' ability to perform a function	Lake hydrology	Lake biology	Lake chemistry
	Groundwater recharge	●		●
	Flood control	●		
	Indirect potable reuse	●		●
	Ecological	●	●	●
	Socio-cultural		●	●

● Critical criteria

2.1.3. Lake hydrology

Can the lake hold water temporarily during an extreme rainfall event to prevent damage to the surrounding areas or the lake itself?

To answer this, it is essential to understand the various water level thresholds within the lake. These include: the minimum level required to sustain aquatic life; the maximum level before overflow or flooding occurs; and the maximum level needed to maintain the lake's structural integrity. Measuring and monitoring these levels helps assess the lake's capacity to buffer extreme rainfall events and protect surrounding areas from damage.



Note:

TBL- Tank bund level

MWL- Max water level

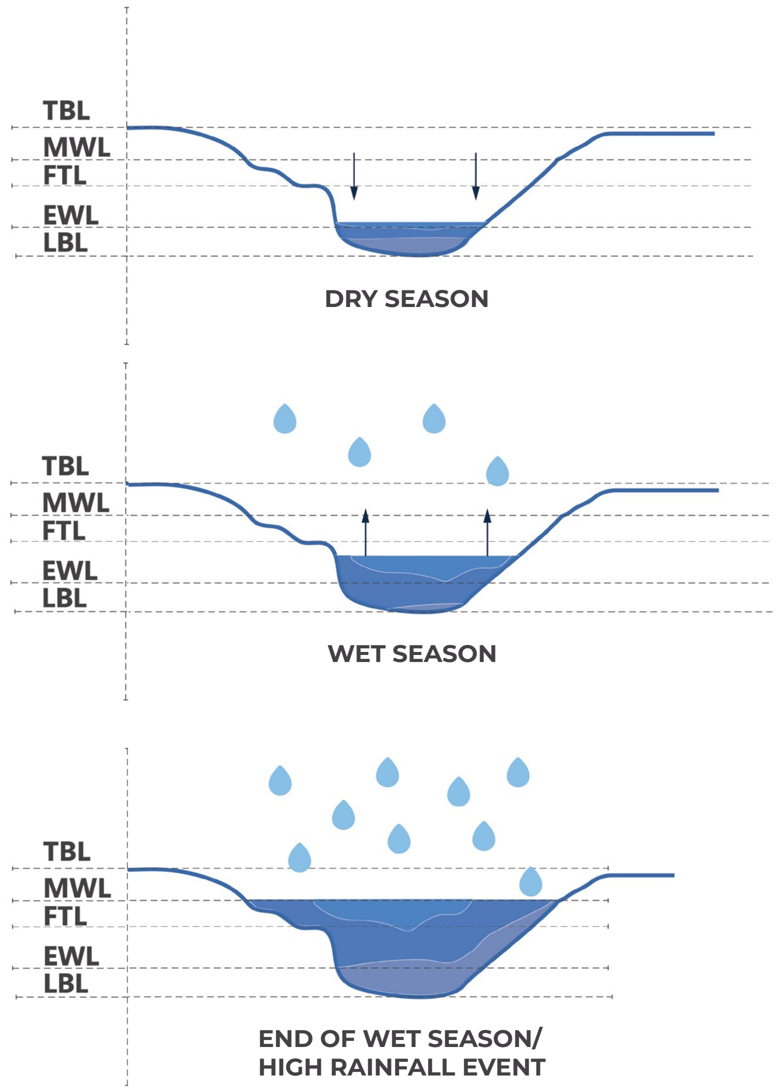
FTL- Full tank level

EWL- Ecological water level

LBL- Lake bed level

Does the lake receive sufficient inflow throughout the year?

To evaluate this, it is crucial to understand the seasonal variation in water levels. During dry seasons, water levels should not drop below the Ecological Water Level, which supports ecosystem health. With the onset of monsoons or heavy rainfall events, lake levels should rise accordingly and, if necessary, overflow without exceeding the Maximum Water Level to prevent flooding or damage. This balance indicates a healthy and sustainable inflow pattern throughout the year.



How to survey lake's general characteristics

Surveying the general characteristics of lakes is crucial as it establishes a foundation for future restoration, conservation, or management efforts. This can be done through reconnaissance surveys and GIS-based analysis, which can help document both the lake's location and catchment features. This includes recording lake details such as name, coordinates, jurisdictional authority, and surrounding settlements, as well as catchment attributes like size, land-use ratio, population, and nearby industries. Upstream and downstream linkages, maximum water spread area, and elevation profiles are also mapped to understand the lake's broader hydrological context. These parameters provide baseline information essential for planning, monitoring, and managing the lake system, ensuring interventions are aligned with its physical, social, and ecological settings.

Baseline studies - General

Key questions	Data type	Mode of measurement	Parameters	Unit
Where is the lake located and what are the catchment characteristics?	Lake details	Reconnaissance survey	Lake name	-
			Name of village/ town	-
			Coordinates	-
			Name of the department / agency which has jurisdiction over the lake/ custodian	-
	Catchment characteristics	GIS	Catchment size	-
			Urban : Non urban area ratio	-
			Location and type of industry in the lake surrounding area	-
			Population	-
	Upstream and downstream details		Upstream lakes(s)	-
			Downstream lake(s)	-
	Lake extent		Maximum water spread area	Ha
	Lake assets position		Lake and asset elevation profile	Degrees

How to survey lake hydrology

To survey lake hydrology, it is essential to systematically assess water quantity, movement, and connectivity through a combination of topographical, bathymetric, hydrological, and GIS-based methods. This process involves measuring parameters such as lake extent, water levels, inflow and outflow volumes, catchment characteristics, and depth profiles.

By addressing critical questions like the lake's capacity to temporarily store water during extreme rainfall or maintain consistent inflows throughout the year, the hydrological survey establishes a robust baseline for understanding the lake's hydrological functioning and response to seasonal and extreme events.

Baseline studies - Lake hydrology

Key questions	Data type	Parameters	Unit	Current state	Desired state
Can the lake hold water temporarily during an extreme rainfall event to prevent damage to the surrounding areas or the lake itself?	Extent of the lake	Current water spread area	Ha		-
	Full Tank Level	Full Tank Level	m		
	Maximum Water Level	Maximum Water Level	m		
	Volume	Maximum volume	Million Litres		
	Depth	Area volume relationship			
		Maximum depth	m		
	Inflows	Number of inlets			
		Peak inflow (volume of catchment runoff) at each inlet	Cubic m/sec		
		Average inflow at each inlet	Cubic m/sec		
	Outflows	Number of outlets			
		Evaporation losses	Cubic m/day		
		Infiltration losses	Cubic m/day		
		Average flow at each outlet	Cubic m/sec		
Does the lake receive sufficient inflow throughout the year?	Catchment characteristics	Volume of treated and untreated sewage	Ha		
	Upstream and downstream details	Volume of flow from upstream Lakes	Cubic m/day		

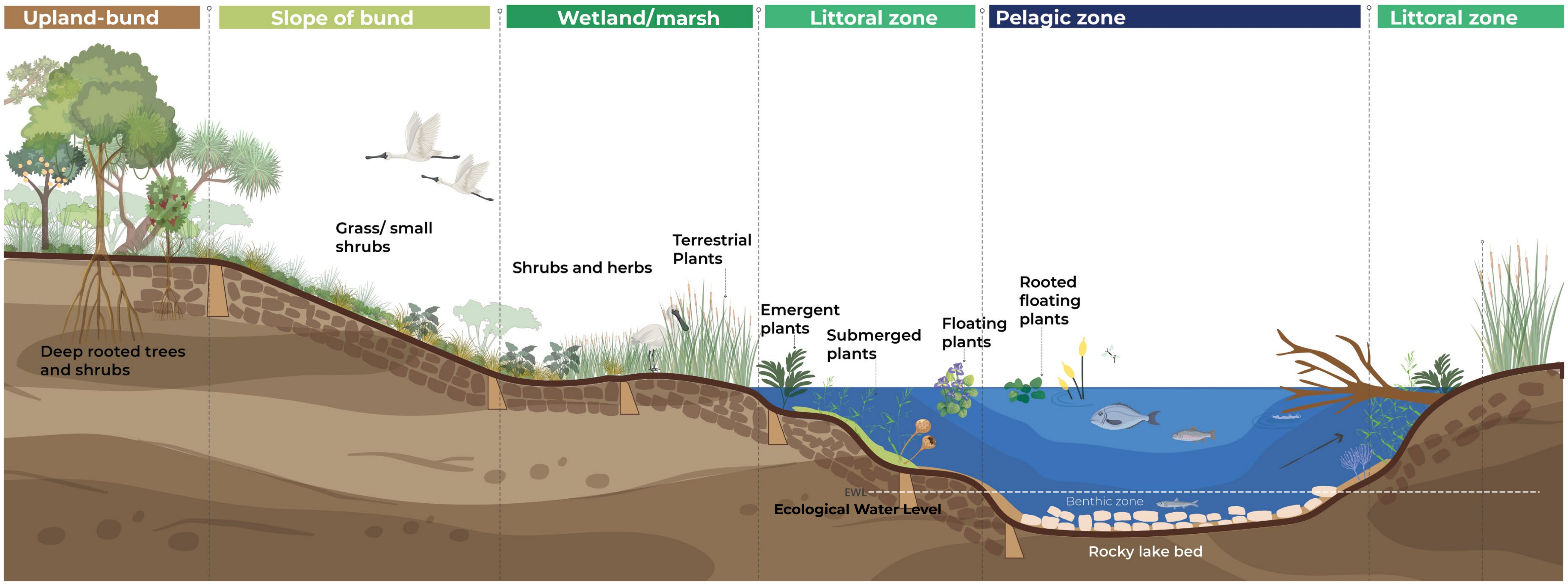
2.1.4. Lake biology

Is the lake appropriately zoned based on function?

It is important to determine whether the lake is divided into distinct zones, from the bund to the open water body, as each zone provides varied habitats essential for different plant and animal species that play vital roles in maintaining the lake's overall ecological health. Plant selection in these zones can enhance biodiversity, stabilise soil, purify water, and strengthen the lake's structure. Refer to *Annexure 1* for suitable plants by zone and function.

Does the lake have nesting and roosting sites for large and small birds, and amphibians?

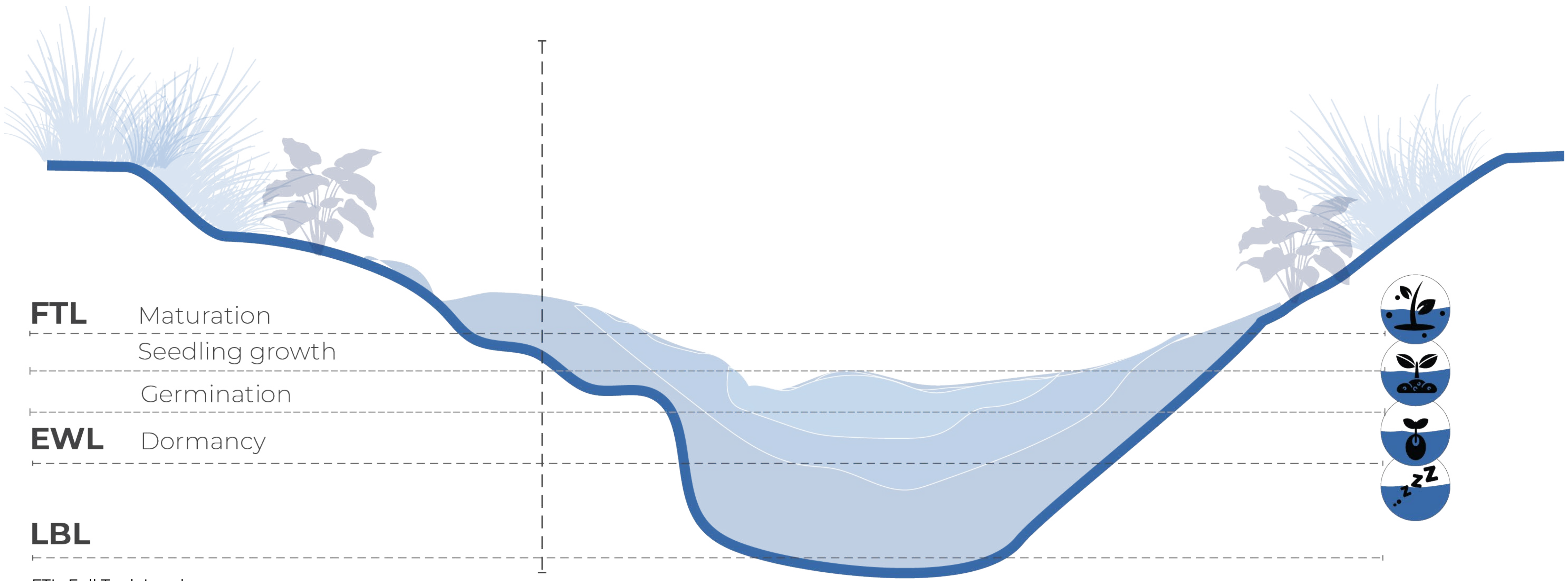
To support healthy populations of birds and amphibians, it is crucial to assess whether the lake provides sufficient nesting and roosting sites for them, along with the availability of abundant food and dedicated undisturbed areas free from human interference. These essential conditions can help ensure the continued presence and survival of diverse fauna within the lake ecosystem.



Does lake filling support the growth of macrophytes?

Many aquatic plants have growth cycles that depend on or coincide with the lake's filling and water level fluctuations. Understanding whether the lake filling occurs as expected is important to ensure that diverse macrophyte species can thrive. This supports overall biodiversity and ecological balance within the lake.

Macrophyte: Macrophytes have growth cycles adapted to seasonal or periodic water level changes. Rising water levels trigger seed germination and seedling establishment by providing necessary moisture and submersion conditions. Stable or receding levels allow for maturation and flowering phases. These water-level fluctuations influence nutrient availability, light penetration, and habitat space, which together regulate macrophyte growth and sustain biodiversity.



FTL: Full Tank Level
EWL: Ecological Water Level
LBL: Lake Bed Level

How to survey lake biology

To survey lake biology, it is important to systematically document both plant and animal species within and around the lake. This involves assessing native and invasive species populations, evaluating the extent of invasive macrophytes, and recording habitat use by key fauna. Surveys should also track the presence of migratory birds, nesting and roosting sites, and the diversity of macroinvertebrates, fish, amphibians, reptiles, and mammals.

Baseline studies - Lake biology

Key questions	Data type	Parameters	Unit	Current state	Desired state
Is the lake appropriately zoned based on function? **Does lake filling support the growth of macrophytes?** **Does the lake have nesting and roosting sites for large and small birds, and amphibians?**	Flora	Native plant population and species count			
		Invasive plant population and species count			
		Area under invasive macrophytes			
	Fauna	Habitat use by key species			
		Native animal population and species count (macroinvertebrates, fish, anurans, reptiles, mammals and birds)			
		Invasive animal population and species count			
		Number of migratory birds using the lake as a habitat/breeding site			

2.1.5. Lake chemistry

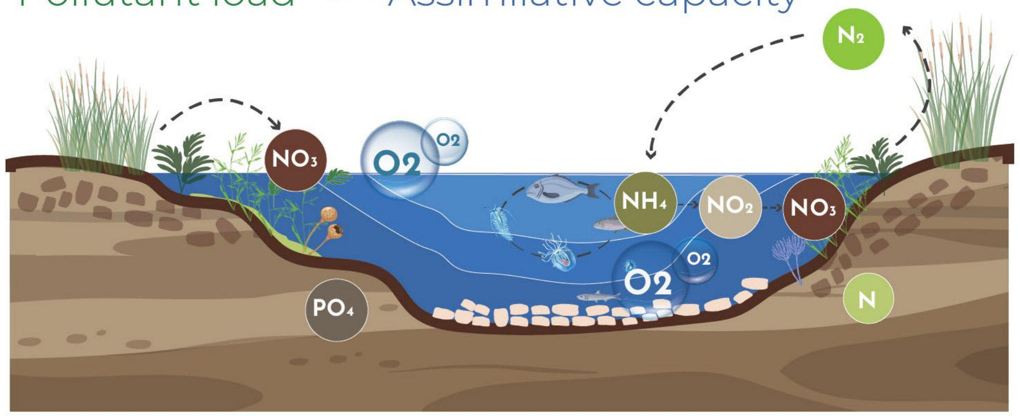
What is flowing into the lake and how does this affect the lake's ability to perform different functions?

It is essential to understand that the type and volume of inflows vary both temporally and spatially, influencing the kinds of loads entering the lake. Knowing these inflow characteristics is critical for diagnosing current impacts and making informed management decisions and interventions.

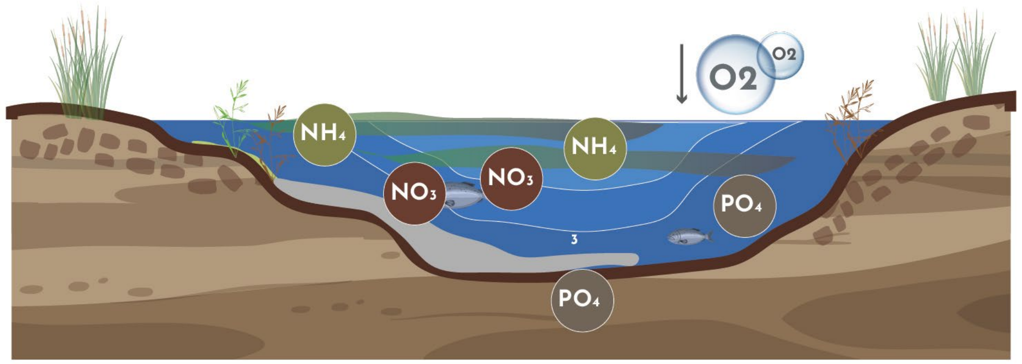
What is retained in the lake, and how does this affect the lake's ability to perform different functions?

Determining the lake's natural assimilation capacity, that is, how much load it can absorb without ecological degradation, is crucial. This knowledge can help identify the extent of retention, and guide the design of interventions necessary to meet the desired ecological and functional outcomes.

Pollutant load <= Assimilative capacity



Pollutant load > Assimilative capacity



How to survey lake chemistry

To survey lake chemistry, it is crucial to comprehensively assess water and sediment quality to understand what flows into and what remains in the lake. This involves recording catchment characteristics, as well as sources of solid waste and wastewater, and measuring key parameters, such as pH level, nutrients, dissolved oxygen, contaminants, and sediment composition.

These measurements clarify how inflows, pollutants, and retention of materials affect the lake's ecological health and ability to perform various functions.

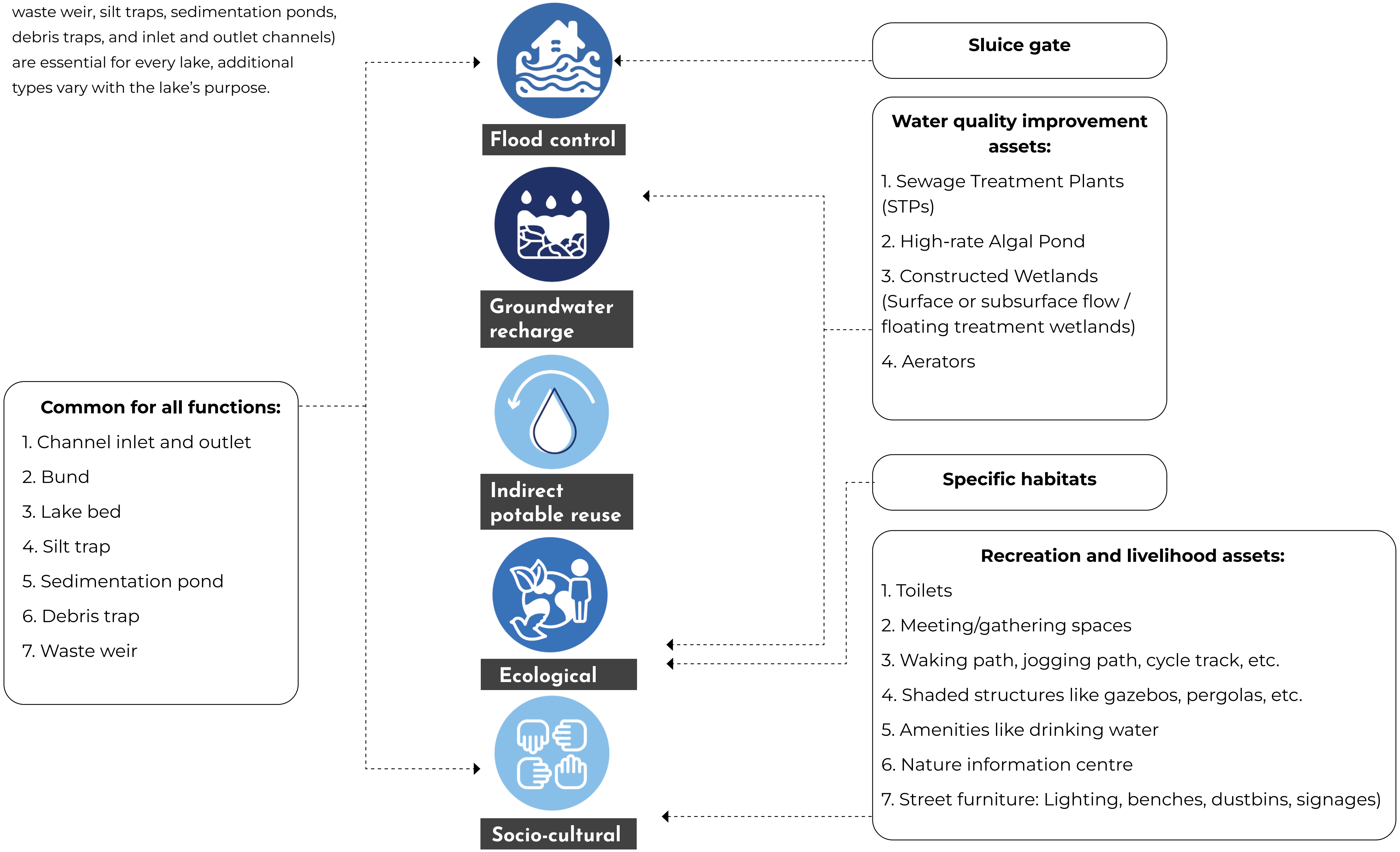
Baseline studies - Lake chemistry					
Key questions	**Data type**	**Data type**	**Unit**	**Current state**	**Desired state**
What is flowing into the lake and how does this affect the lake's ability to perform different functions?	Catchment characteristics	Location and type of industries in catchment area	Degrees		-
		Population			
	Solid waste	Solid waste /garbage points	Degrees		
	Wastewater outfalls	Location of wastewater outfalls	Degrees		-
What is flowing into the lake and how does this affect the lake's ability to perform different functions? **What is being retained, and how does this affect the lake's ability to perform different functions?**	Water quality	Colour, odour	-		
		pH	-		
		Electrical conductivity	µmhos/cm		
		Temperature	°C		
		Total suspended solids	mg/L		
		Total alkalinity	mg/L		
		Dissolved oxygen	mg/L		
		Biochemical oxygen demand	mg/L		
		Chemical oxygen demand	mg/L		
		Total nitrogen, nitrate, ammonium	mg/L		
		Total phosphorus	mg/L		
		Orthophosphate	mg/L		
		Fecal coliforms	MPN/100 mL		
		E. coli	MPN/100 mL		
What is being retained, and how does this affect the lake's ability to perform different functions?	Sediment quality	Total phosphorus	mg/g		
		Total nitrogen	mg/g		
		Total organic carbon (TOC)	mg/g		

2.2. Asset listing

2.2.1. List of assets to achieve target functions

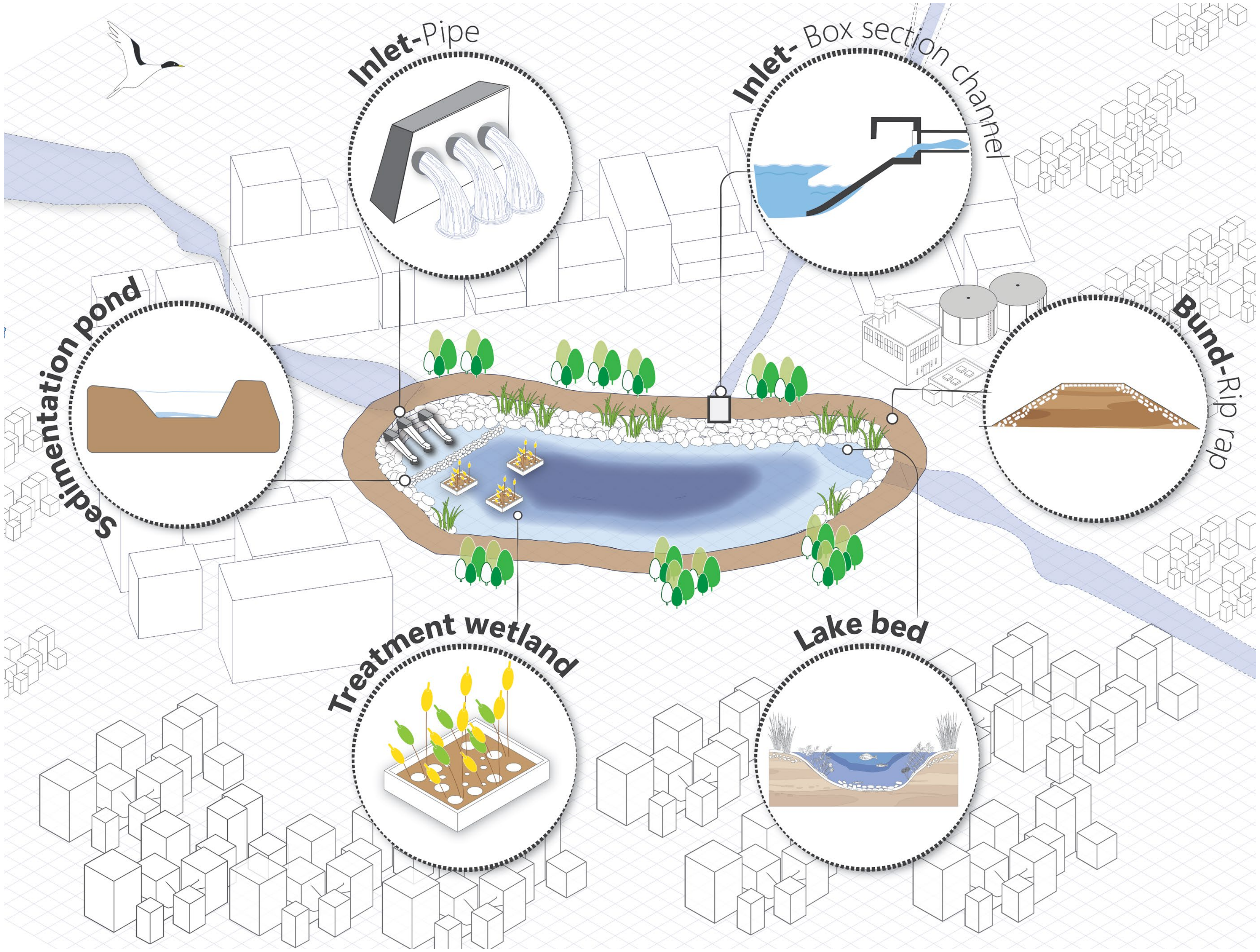
The assets required for a lake depend on the functions it is expected to serve. While some core assets (such as bunds, lake bed, waste weir, silt traps, sedimentation ponds, debris traps, and inlet and outlet channels) are essential for every lake, additional types vary with the lake's purpose.

For example, if flood control is a priority, a sluice gate is necessary. If the focus is on groundwater recharge, indirect potable reuse, or ecological enhancement, assets such as water-quality treatment systems and designated habitat zones are required. Similarly, if the lake is meant to support socio-cultural functions, recreational features, such as walking paths and open spaces, should be included. This chart is designed to guide the selection of appropriate assets based on the intended functions of the lake.



2.2.2. Location of assets in and around the lake bed

The diagram illustrates the different types of assets located in and around the lake bed, along with the specific roles and functions each asset is intended to serve.



Inlet: Directs water into the lake.

Bund: Retains water within the lake.

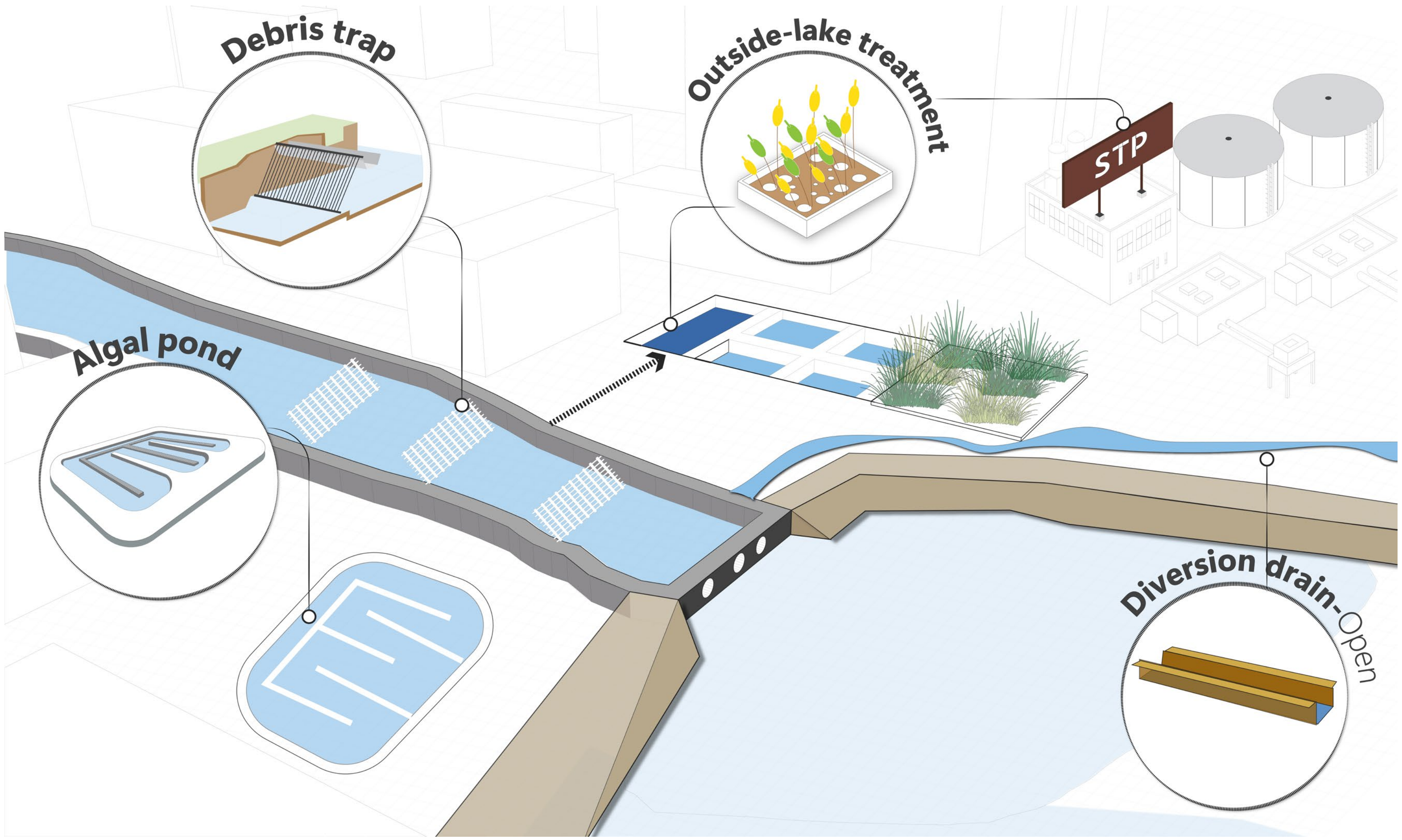
Lake bed: Supports water storage, recharge, and ecological functions.

Inlake treatment: Floating wetlands that enhance lake water quality by absorbing dissolved phosphorous/ nitrogen via roots, while boosting habitat and biodiversity.

Sedimentation pond: Slows flow post silt-trap to settle finer particles and adsorbed pollutants, clarifying water before it enters the lake.

2.2.3. Location of assets in and around inlets

Various configurations of assets located outside the lake can effectively manage lake inflows by sequencing them to progressively treat pollutants, adapted to site-specific conditions, such as inflow volume, pollutant types, and land availability.



Diversion drain: Diversion drain" should be deleted and "Interception and diversion drain:" should be bolded.

Interception and diversion drain: Channels polluted inflows away from the lake towards treatment assets, preventing direct dumping and enabling controlled inflow management.

Sewage treatment plant (STP): Removes pollutants from domestic wastewater using physical, chemical, and biological processes, to produce treated water and biosolids suitable for safe discharge or reuse.

Inlake treatment: Enhances water quality by filtering pollutants and supporting biodiversity.

Silt trap: Captures suspended sediments from surface runoff, reducing turbidity and lake siltation.

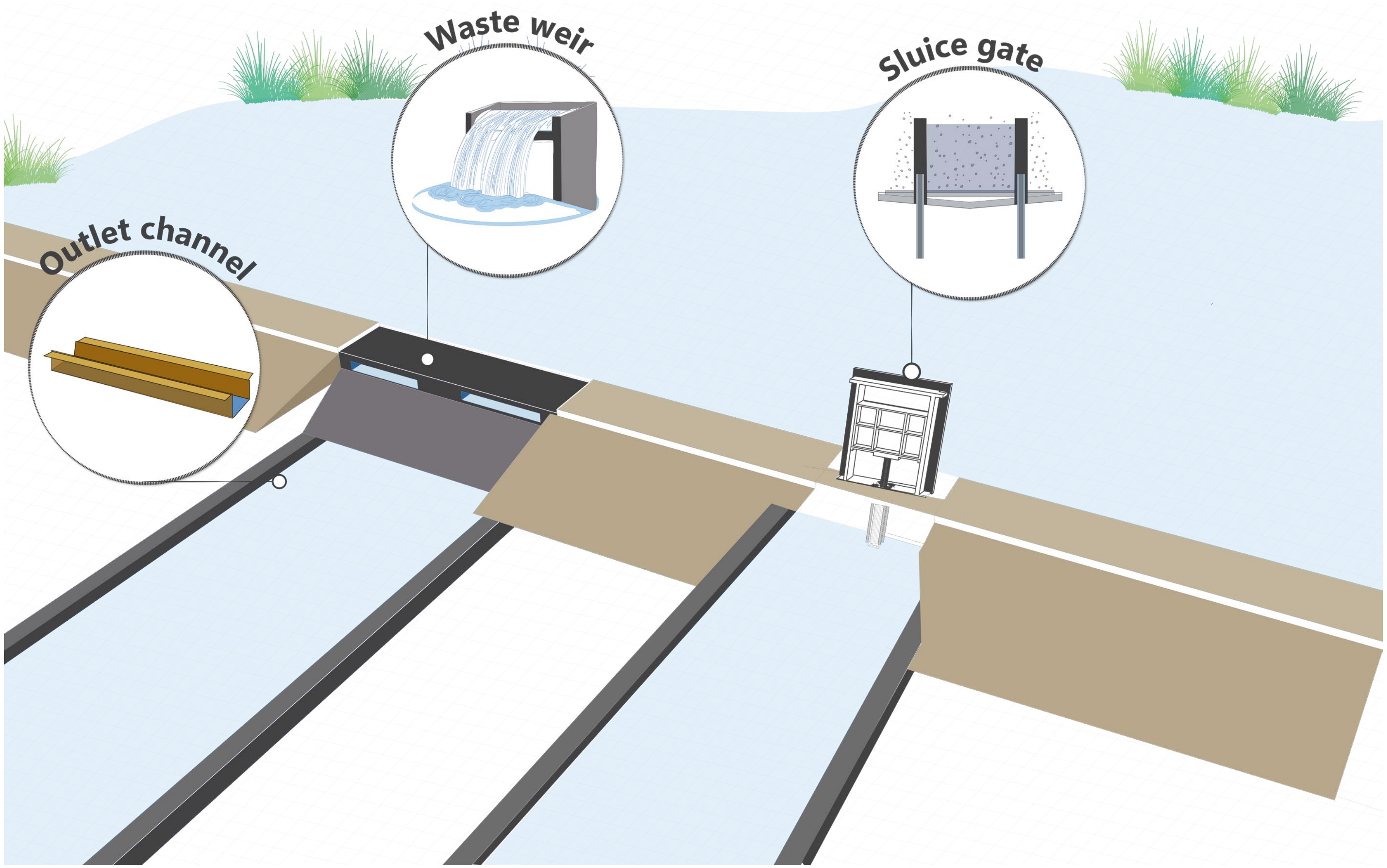
Debris trap: Screens out floating materials, solid waste, and vegetation, protecting lake aesthetics and reducing blockages in downstream systems.

High-rate algal pond: Accelerates algal growth in shallow raceway ponds to uptake excess nutrients rapidly through biomass harvesting, acting as a biological polisher for secondary-treated effluent.

Outside-lake treatment: Constructed wetland that filters remaining pollutants via plant roots, microbial biofilms, and sedimentation; and excels at denitrification and pathogen die-off for tertiary treatment before lake inflow.

2.2.4. Location of assets in and around outlets

The diagram illustrates the different types of assets located in and around the outlet, along with the specific roles and functions each asset is intended to serve.



Outlet channel: Drains excess water from the lake.

Waste weir: Safely discharges excess water during storm events to prevent overtopping.

Sluice gate : Controls the release of water.

2.3. Asset design

2.3.1. The need for design codification

Codification of designs is essential to ensure that all lake assets are built to established standards. This enhances transparency, accountability, and long-term functionality. By systematically reviewing relevant Indian Standard (IS) codes, literature, and expert inputs, the design standards for every asset have been consolidated and translated into a practical checklist.

This approach addresses several issues commonly observed in infrastructure projects. Significant resources are often spent on designing, redesigning, and modifying structures. Yet, the checks and balances typically reside solely with the consultant preparing the Detailed Project Report (DPR). A standard checklist provides a straightforward, accessible tool that can help verify design compliance, identify deviations, and determine which specific design aspects may be causing an asset or the lake itself to underperform.

By codifying designs into checklists, stakeholders from diverse backgrounds can quickly assess asset quality and raise constructive questions. It removes the dependency on technical expertise or exclusive access to detailed blueprints. This democratises the review process, ensuring all assets are constructed following standardised procedures. It also reduces the risks of oversight or substandard implementation.

Common assets and flood control

Indian Standard Code

Most nationally recognised design standards (Indian Standard Codes) have been developed for reservoirs. In this framework, we have adapted these standards to the scale of lakes, considering asset requirements at the smallest appropriate sizing. Below are the few standards we have used in the framework:

IS 12169-1987

IS 6966-1989

IS 10430-2000

IS 11527 (1985)

IS 8237 (1985)

Water quality assets

National and international codes and guidelines for design have been referenced for specifying the design of water quality improvement assets, including:

Central Public Health & Environmental Engineering Organisation (CPHEEO). (2013). *Manual on sewerage and sewage treatment systems.* Ministry of Urban Development New Delhi.

National Mission for Clean Ganga. (2018). *Guidelines for preparation of DPRs for works of interception and diversion of drains and sewage treatment plants.* Government of India.

Government of South Australia. (2020). *High rate algal pond (HRAP) design guideline.*

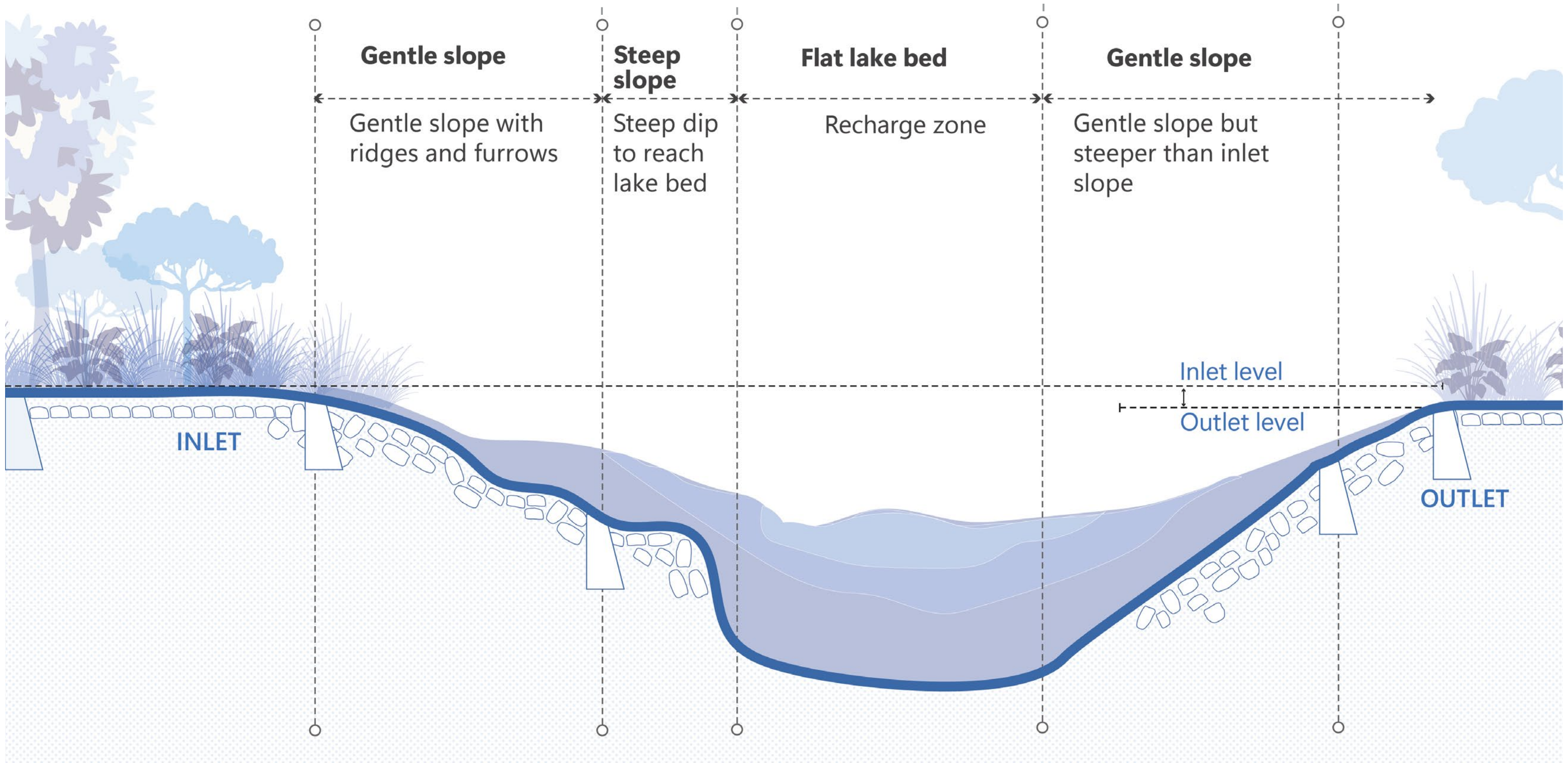
Department of Biotechnology & Central Pollution Control Board, Government of India. (2019). *Manual on constructed wetland as an alternative technology for sewage treatment in India.*

Tilley, E., Ulrich, L., Lüthi, C., Reymond, P., Schertenleib, R., & Zurbrügg, C. (2014). *Compendium of sanitation systems and technologies.* Eawag; UN-HABITAT

2.3.2. Lake bed design

The slope and depth of the lake bed directly influence its functions. However, during lake rejuvenation, the lake bed profile is often altered without regard for the lake's ecological and hydrological characteristics. This framework, therefore, treats the lake bed profile as an asset. This recognition helps make design choices that can balance ecological function, recharge potential, and storage, while making trade-offs between competing objectives (such as sediment trapping and ease of desilting versus total storage capacity; or water storage and recharge potential versus the maintenance of ecologically suitable habitats) explicit.

ECOLOGICAL FUNCTION	40%	10%	40%	10%
FLOOD CONTROL / RECHARGE	10%	10%	70%	10%



1.1. Lake bed profile (Not to scale)

DESIGN CONSIDERATIONS:

Slope of the lake bed depends on the function

Gentle slope - towards inlet: Supports ecological function

Flat lake bed: Supports recharge

Depth of the lake: Supports storage function

Level of inlet to be higher than outlet

TRADE OFFS:

Gentle slope at inlet.

PROS

1. Allows silt to be trapped, conserving recharge function in lake-bed.

2. Aids dry-season desilting.

CONS

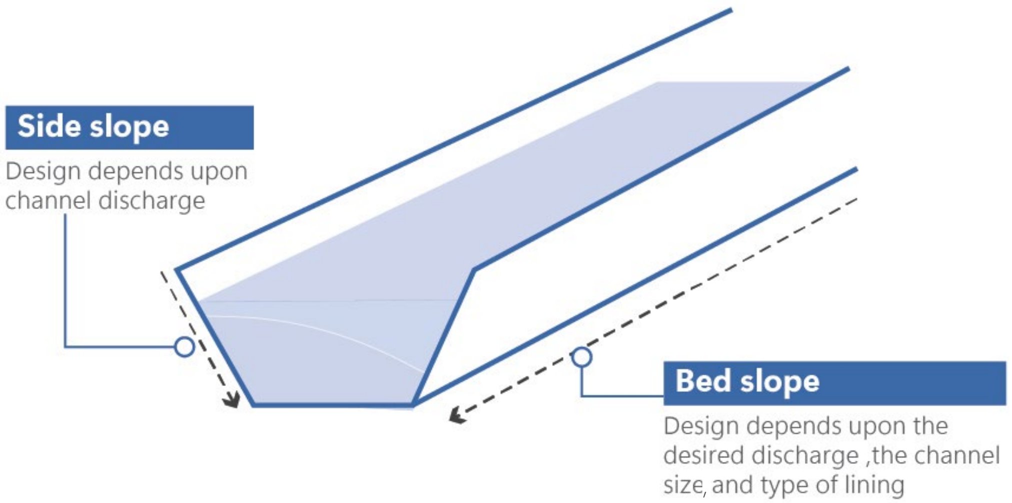
1. Reduces the overall storage of the lake.

DEPTH	Ecological Zone: 1-2 m Recharge/ Storage zone: 2-6m
PERCENTAGE AREA	Gentle slope- 40% Steep slope- 10% Flat lake bed- 40% Gentle slope- 10%

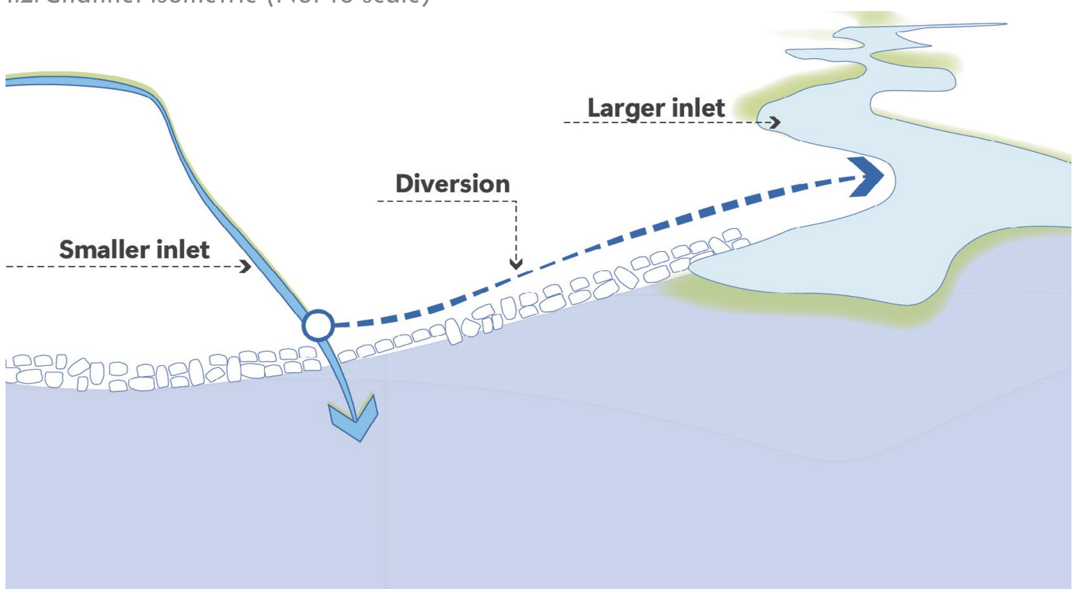
QUANTITY ASSETS

2.3.3. Channels

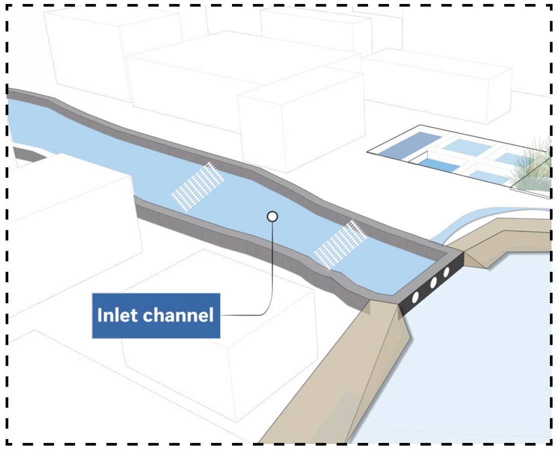
Inlet and outlet channels are integral to the functioning of a cascading lake system. Much like the veins of a watershed, they connect upstream flows to downstream waters. These channels may be natural or man-made, but their placement and design determine how effectively the lake can receive, store, and release water. By treating inlet and outlet channels as assets, their design supports both hydraulic efficiency and lake health, while reducing risks of erosion, sedimentation, or overflow.

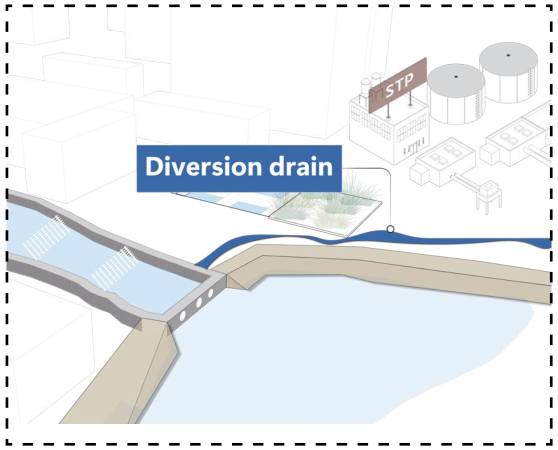


1.2. Channel isometric (Not to scale)



1.3. Diversion drain (Not to scale)





INLET/OUTLET CHANNEL

ASSET LOCATION:

Depends on natural gradient for efficient water flow

DESIGN CONSIDERATIONS:

Desired discharge refers to the safe conveyance of water, without causing erosion or sedimentation

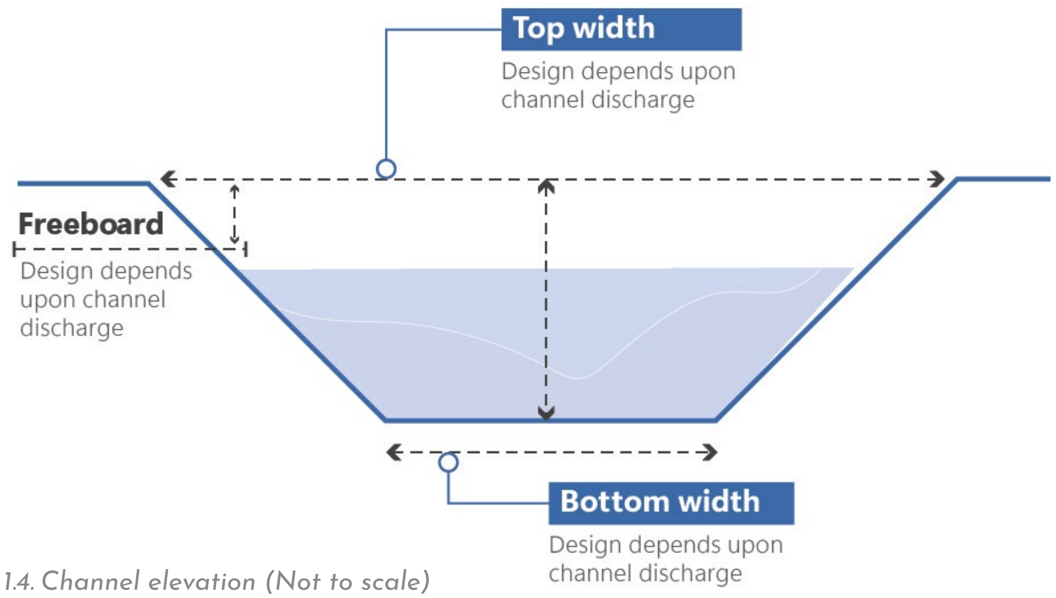
It depends on the expected peak flow from a catchment area during a storm event

DIVERSION DRAIN:

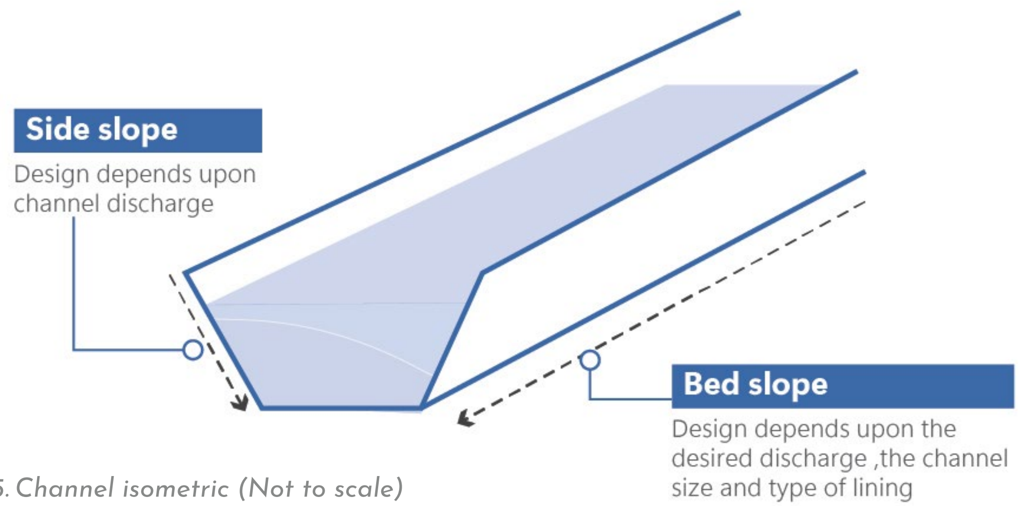
ASSET LOCATION:

If one of the inlet is small/low capacity, it can be diverted to a larger inlets.

Inlet/outlet channels



1.4. Channel elevation (Not to scale)



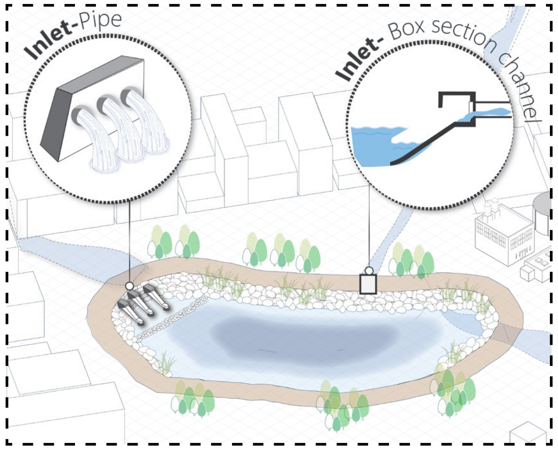
1.5. Channel isometric (Not to scale)

Side slope	**Type of soil**	Side slope (Horizontal: Vertical)
	Very light loose sand	2:1 to 3:1
	Sandy loam	1.5:1 to 2:1 (in cutting) 2:1 (in embankment)
	Sandy gravel/ murum	1.5:1 (in cutting) 1.5:1 to 2:1 (in embankment)
	Black cotton	1.5:1 to 2.5:1 (in cutting) 2:1 to 3.5:1 (in embankment)
	Clayey soil	1.5:1 to 2:1 (in cutting) 1.5:1 to 2.5:1 (in embankment)
	Rock	0.25:1 to 0.5:1
Channel bed slope	1-5% to control velocity of water to avoid erosion and sedimentation	
Freeboard	**Canal discharge (cumecs)**	Freeboard(m)
	>10	0.75
	3-10	0.6
	1-3	0.5
	<1	0.3
	<0.1	0.15m
Permissible velocity	**Material**	**Velocity(m/s)**
	Stone pitched lining	1.5
	Burnt clay tile or brick lining	1.8
	Cement concrete lining	2.7

2.3.4. Inlet box culvert

The inlet culvert serves as the gateway through which water from inlets or upstream drainage channels enters the lake. Its design not only determines how effectively the lake captures stormwater but also how well it can prevent erosion, sedimentation, and structural damage.

By viewing the inlet culvert as an asset, it can be designed for hydraulic efficiency, as well as for long-term ecological and structural stability of the lake.



ASSET LOCATION:

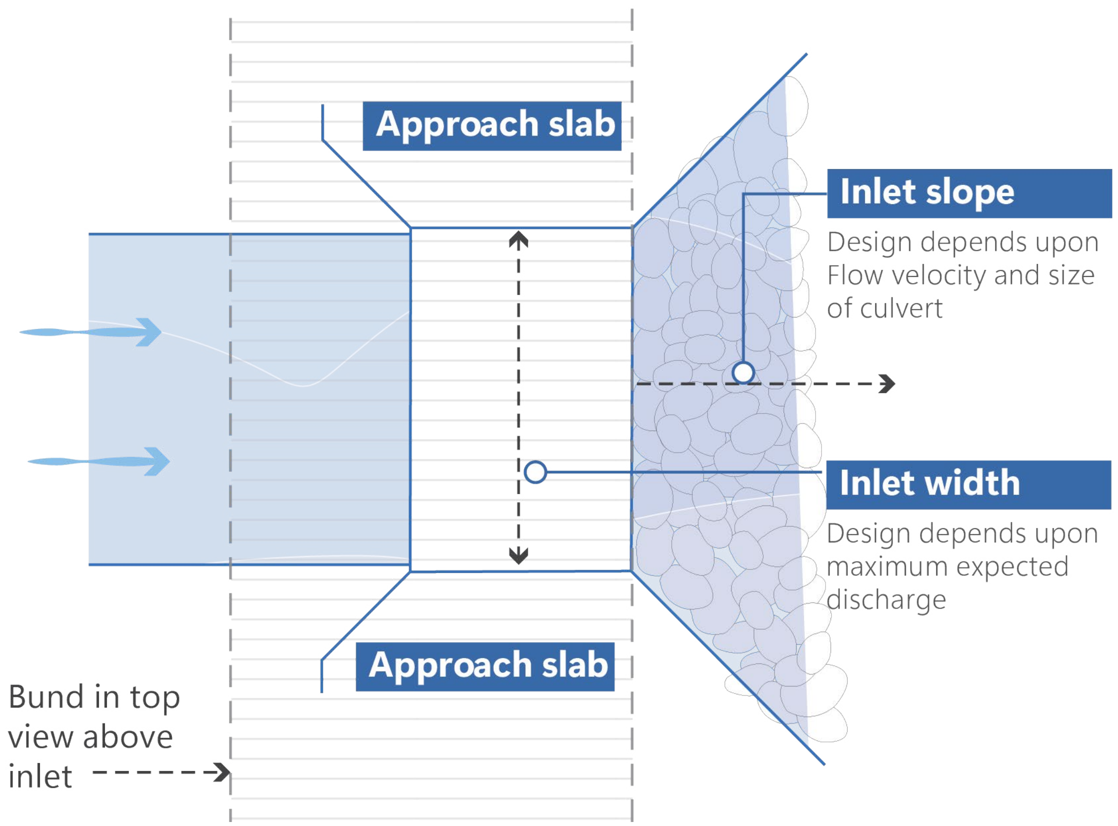
Depends on alignment with natural drainage channel

Location should ideally maximises water collection efficiency.

DESIGN CONSIDERATIONS:

Desired discharge refers to safe conveyance of water. It depends on the expected peak flow from a catchment during a storm event.

Depends on the expected peak flow from a catchment area during a storm event

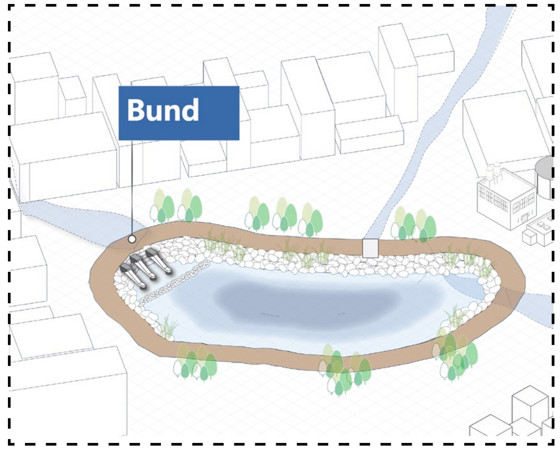


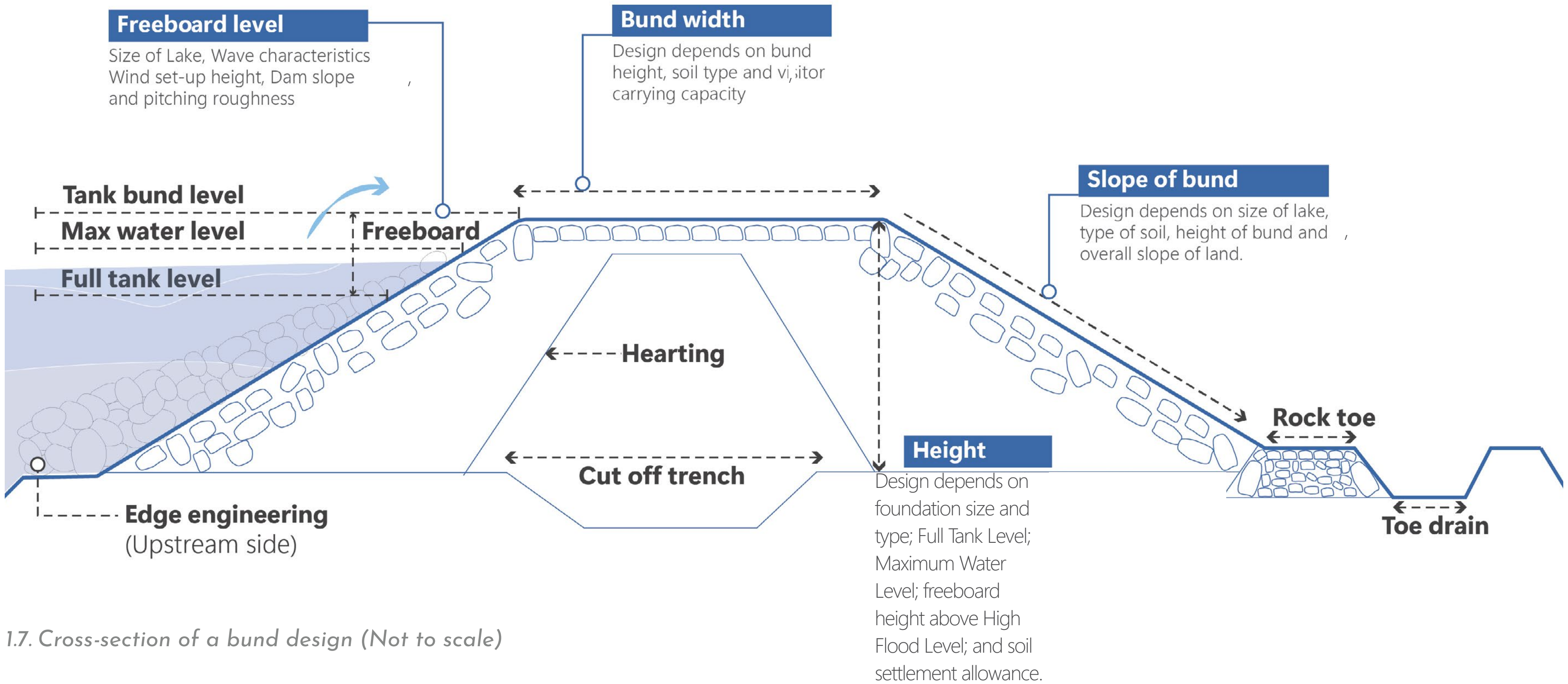
1.6. Plan of an inlet (Not to scale)

2.3.5. Bund

The lake bund is the earthen embankment that defines the lake boundary and retains stored water. It is one of the most critical structural assets in the lake system, ensuring both water security and safety of surrounding areas. Beyond its hydraulic role, the bund often doubles as a walking path or promenade, becoming a vital community space that connects people with the lake.

By treating the bund as both an engineering structure and a community space, its design helps balance structural stability, water retention, ecological value, and social use.





1.7. Cross-section of a bund design (Not to scale)

ASSET LOCATION:

Depends on topography and contour levels to ensure effective water retention and minimal structural stress

DESIGN CONSIDERATIONS:

Size of the lake determines the amount of water the bund must retain and, subsequently, influences the size of the bund.

Soil type and compaction determine the bund's stability and structural strength.

TRADE OFFS:

Adding trees on the bund might improve ecological function but could reduce bund strength.

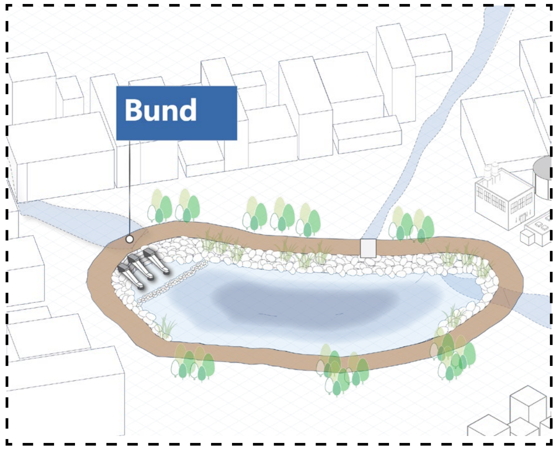
Free-board (m)	Bund width (m)	FTL(m)	Bund Height (m)
0.9	1.2	1.5-3.0	= FTL+ Freeboard
1.2	1.5	3.0-4.5	
1.5	1.8	4.5-6.0	
1.8	2.7	>6.0	
NOTE:	Rock toe height: Not necessary up to 3 m bund height; for bunds >3 m, provide 1 m rock toe height.		

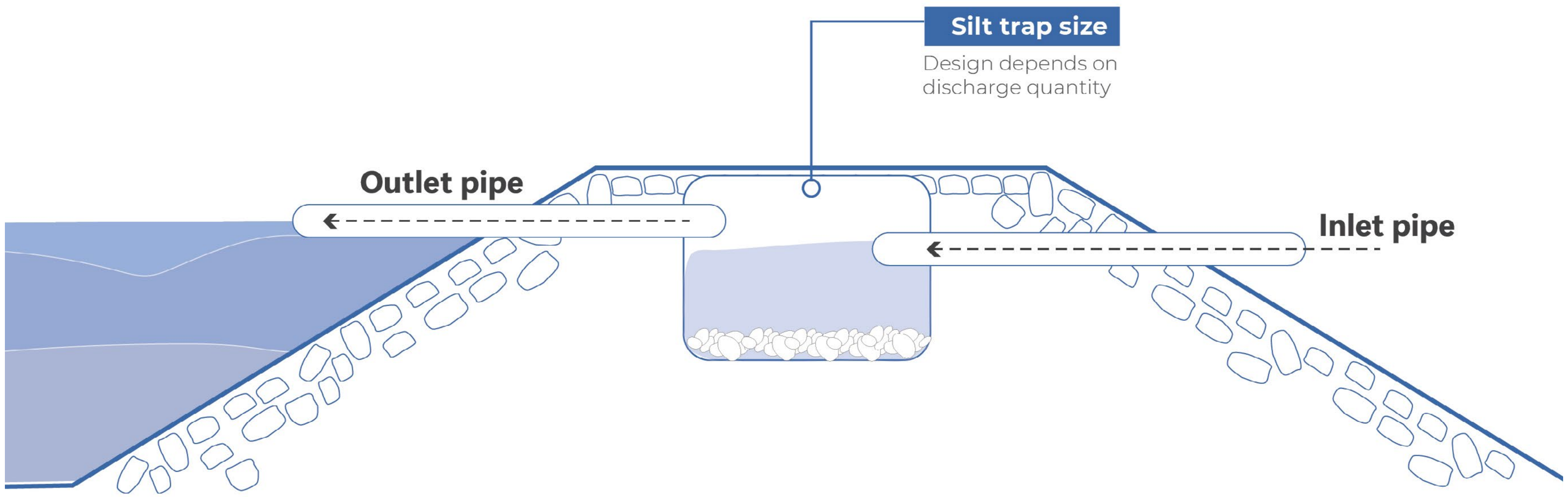
Soil Type	Upstream Slope(H:V)	Down-stream Slope (H:V)
Coarse grained (GW, GP, SW, SP)	Not suitable	2:1
Coarse grained (GC, GM, SC, SM)	2:1	
Fine grained (CL, ML, CI, MI)		
Fine grained (CH, MH)		

2.3.6. Silt trap

A silt trap is a small structure built near the lake's inlet to capture sediments, debris, and other suspended solids before water enters the lake. By preventing excessive siltation, it safeguards the lake's storage capacity, water quality, and ecological health.

By treating the silt trap as an asset, it becomes a first line of defence that protects the lake's hydrological and ecological functions while reducing long-term maintenance burdens.





1.8. Cross-section of a silt trap under bund (Not to scale)

ASSET LOCATION:

Always positioned near the inlet culvert, where incoming flows can be intercepted before entering the main water body.

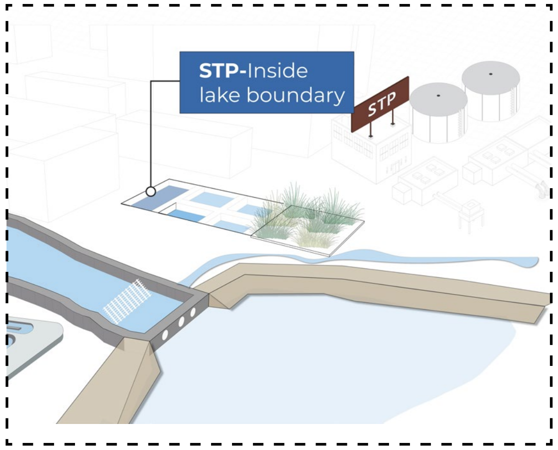
DESIGN PARAMETERS:

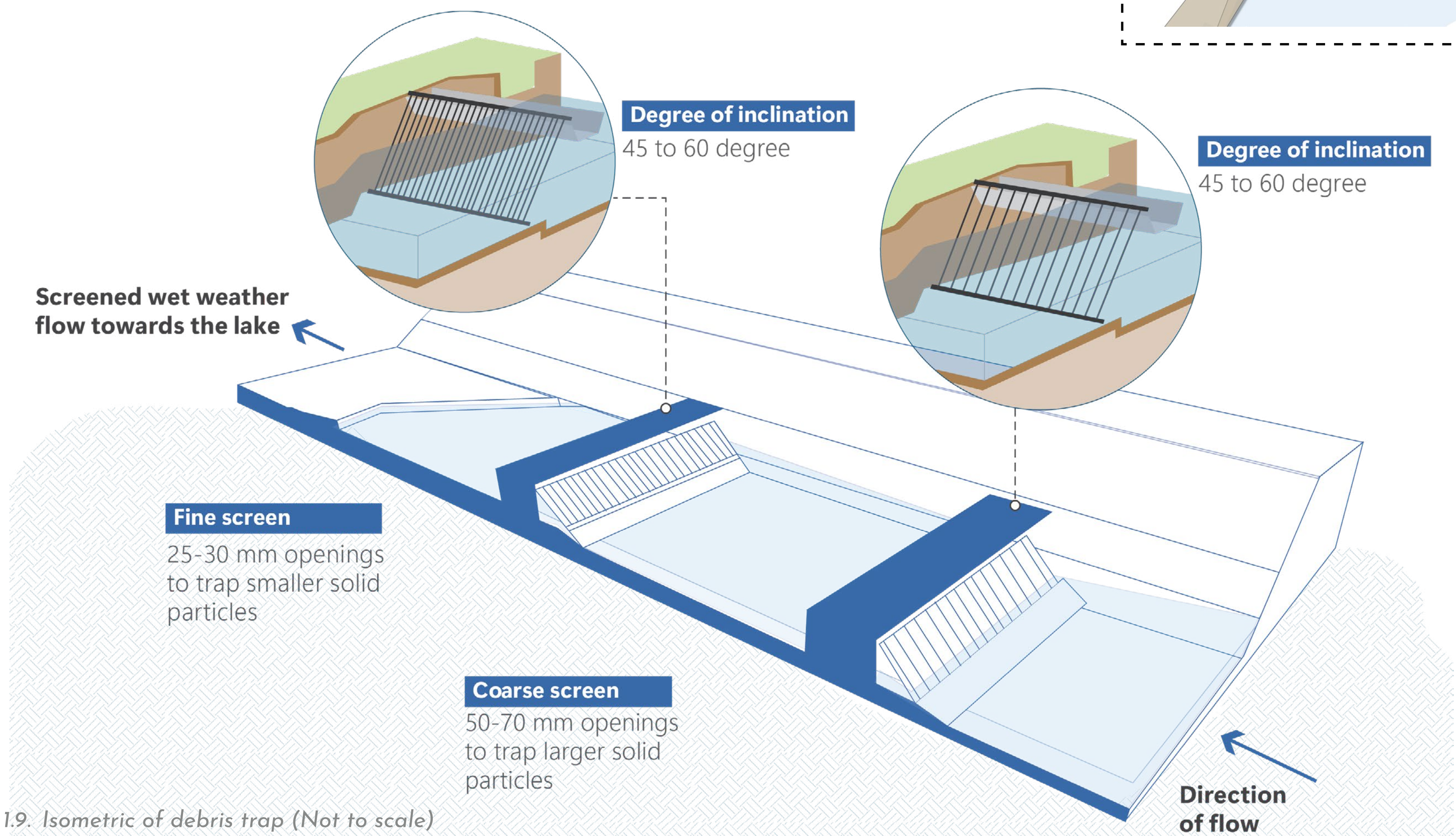
Determined by the expected sediment load from the catchment and the desired water quality within the lake. Size, depth, and retention time are adjusted to optimise sediment settling while maintaining hydraulic efficiency.

2.3.7. Debris trap

A debris trap is a screening structure located at the lake's inlets to intercept solid waste, floating debris, and larger particles before they enter the main water body. It serves as the first barrier, protecting the lake's hydraulic and ecological functions.

By treating debris traps as assets, they function as an essential first line of defence in lake rejuvenation, improving water inflow quality and protecting subsequent infrastructure.





1.9. Isometric of debris trap (Not to scale)

ASSET LOCATION:

Installed inside the inlet channel where wet-weather flow enters the lake.

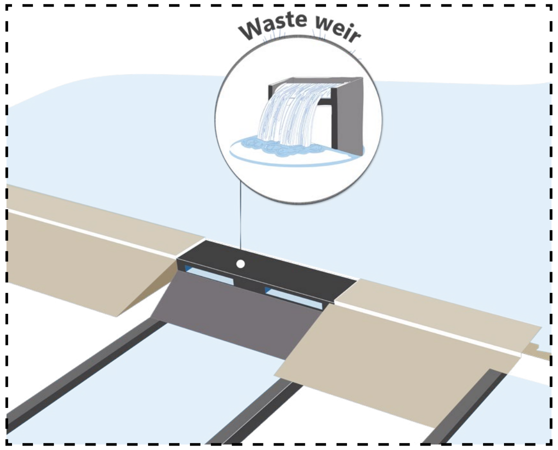
DESIGN PARAMETERS:

Coarse screen (50–70 mm openings) is placed first in the direction of flow to trap larger debris such as plastics, branches, and other floating waste.
Fine screen (25–30 mm openings) is placed next, capturing smaller solids and finer waste material.
Screens are typically installed at an inclination of 45°–60°, which allows water to pass through while enabling easy removal of trapped waste.
Dry-weather flow may be diverted to a separate treatment facility to avoid unnecessary load on the lake.

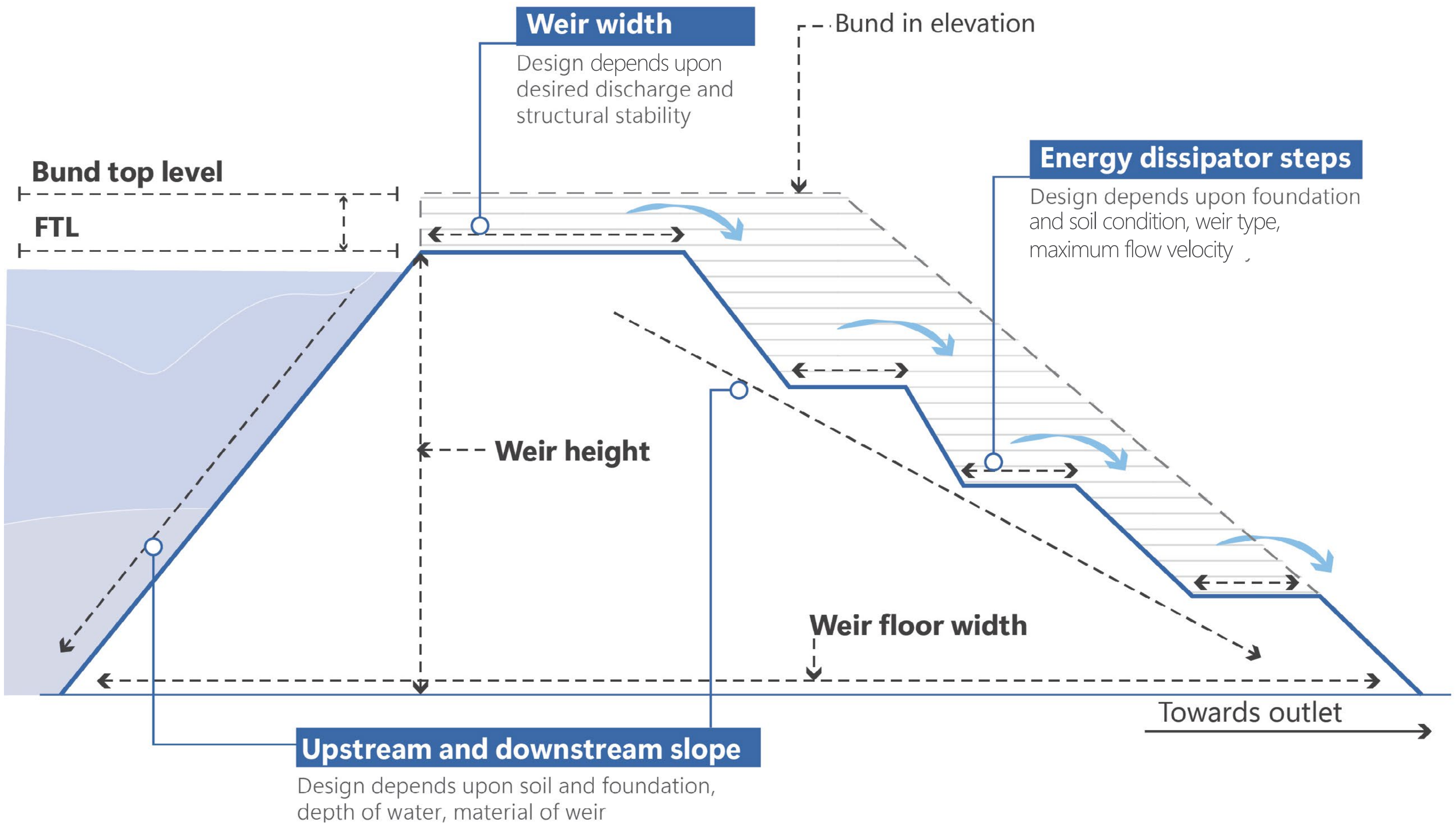
2.3.8. Waste weir

Waste weir (or surplus weir) is a critical safety structure that allows excess water to exit the lake during heavy rainfall or storm events. It prevents overtopping of the bund and protects surrounding areas from flooding, acting as the lake's controlled spillway.

By treating waste weir as an asset, it is recognised not merely as a discharge point but as a safety valve of the lake system, balancing water retention with flood resilience.



1.10. *Cross-section of a waste weir (Not to scale)*



ASSET LOCATION:

Positioned where the build-up of storage above ground level is minimal, ensuring stability. It should not be aligned directly against the main stream-flow, to avoid excessive hydraulic stress. Not located directly against the flow of the stream.

DESIGN PARAMETERS:

Desired discharge refers to safe conveyance of water. It depends on the expected peak flow from a catchment during a storm event.

-The size, stability, and structural strength depend on both the material used and the total volume of water stored in the lake.

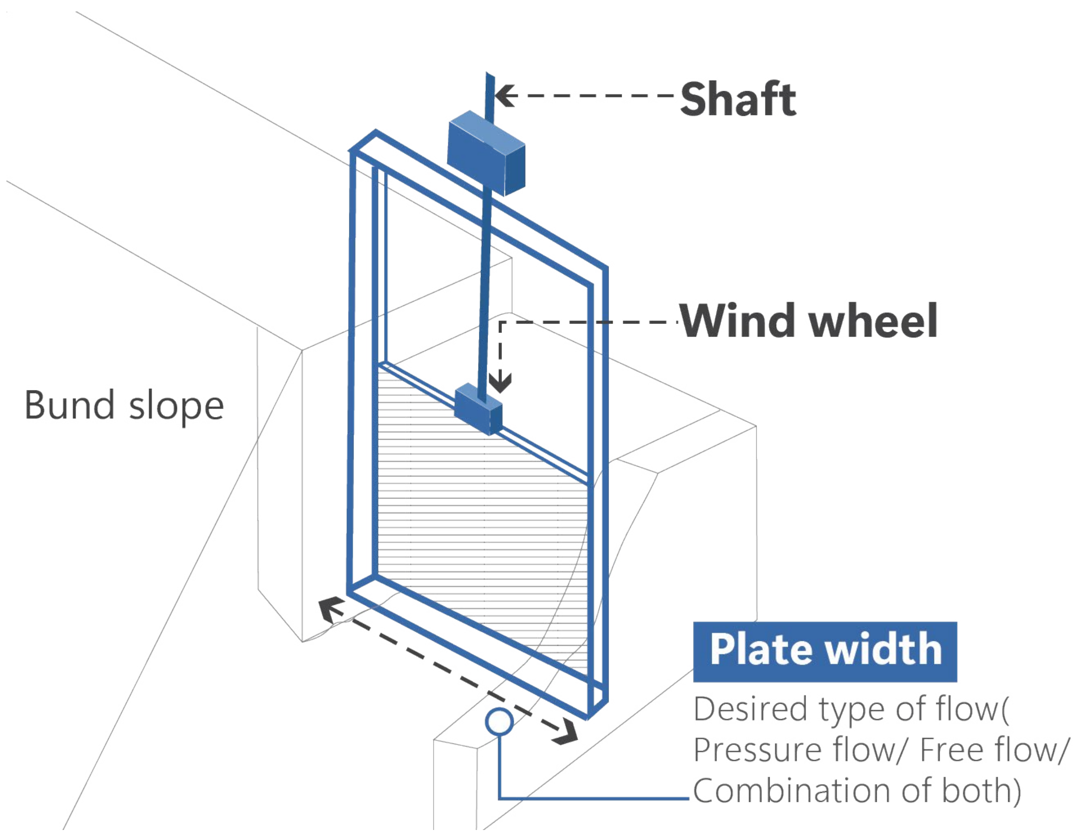
-Energy-dissipating features, such as stilling basins and steps, may be incorporated to prevent downstream erosion.

Location	Locate the waste weir where storage build-up above ground level is minimal, avoiding direct alignment with the stream flow.
Height	Height= Full Tank Level
Weir width	Upto 2m
Weir floor width	Minimum width of the horizontal floor = 2(D + H) D= Height of Weir H= Maximum water head over the wall (MWL - FTL)
Length	Weir length (L) should be designed to safely pass peak discharge without exceeding MWL.
Slope	Upstream slope- 2:1 or 3:1 (depending on the ground condition) Downstream slope- 3:1
Note	FTL- Full Tank Level

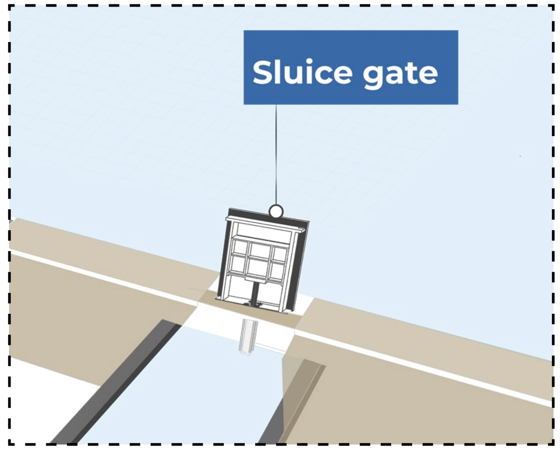
2.3.9. Sluice gate

The sluice gate is a controlled outlet structure that regulates the flow of water released from the lake. Unlike the waste weir, which acts as a passive safety spillway, the sluice gate provides active management of water levels, particularly during storm events, to prevent flooding and protect downstream areas.

By treating the sluice gate as an asset, it is seen not just as an outlet, but also as a key flood-control tool, enabling active management of the lake's hydrology and downstream safety.



1.11. Isometric drawing of sluice gate



ASSET LOCATION:

Positioned near the outlet of the lake, usually integrated within or alongside the bund.

DESIGN PARAMETERS:

Desired discharge refers to safe conveyance of water.

Capacity is designed to safely convey expected peak flows. Operations (manual or automated) should be carried out only after mapping and assessing functioning capacity of downstream drains, to prevent flooding. This is particularly important because designed drain capacity can be reduced due to encroachments or illegal sewer line connections.

Operability (manual or automated) determines how precisely water levels can be regulated.
Structural strength and durability depend on the materials used (e.g. steel gates, reinforced concrete frames) and the volume of water retained.

Number of sluice gates to be installed	Dependent on the number of directions the land will slope into
Size (width*length)	Discharge capacity

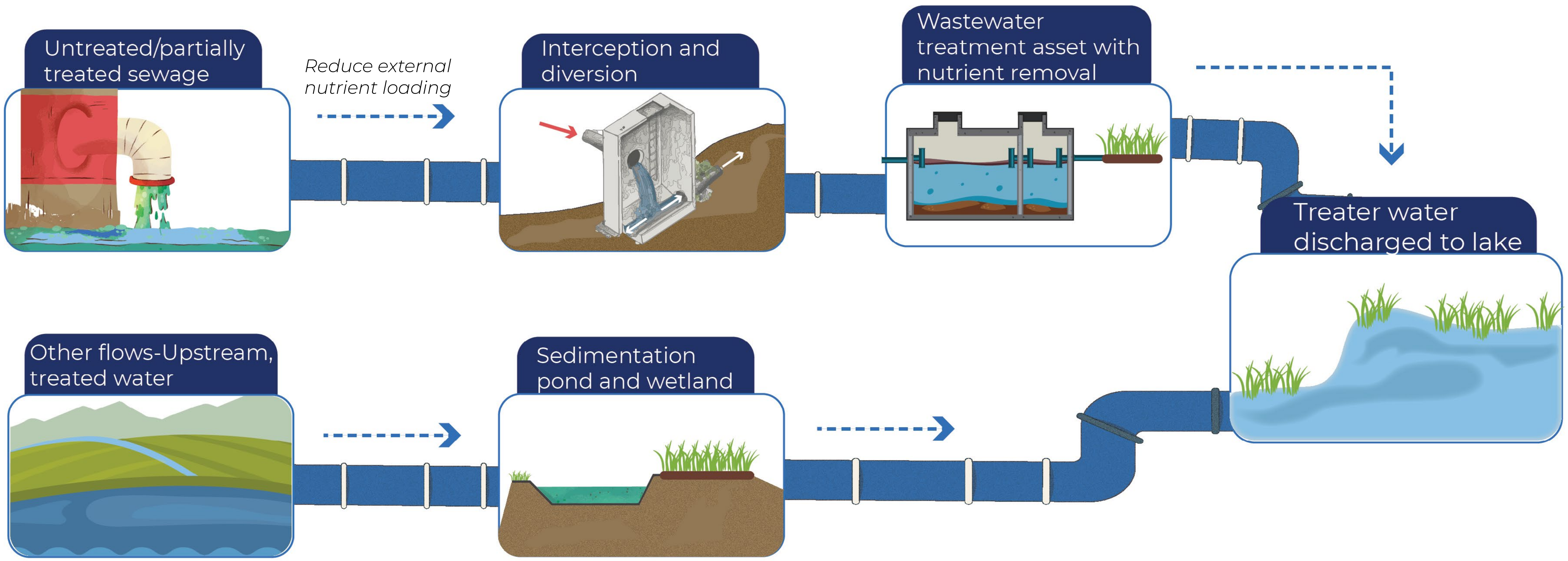
QUALITY ASSETS

Recommended approach for lake water quality management

Based on catchment land use and location, lakes receive inflows from various sources, each with different pollutant loads. These inflows may be continuous (such as treated water from decentralised or centralised sewage treatment plants, greywater or septic tank effluents, and untreated sewage), or intermittent (occurring during rain events). The inflows may come via stormwater drains, combined sewers, or as overflow from upstream lakes. Both inflows represent external sources of pollution; phosphorus-rich lake sediments constitute internal sources.

For different types of lake inflows, a two-fold water quality management approach should be followed.

First, high external loads, such as untreated or partially treated sewage, should be intercepted and diverted to treatment facilities that remove organic matter and nutrients. Only after adequate treatment should the water enter the lake. This would protect ecosystems from nutrient enrichment. Second, lower-load inflows, often from rainfall, should be treated via sedimentation ponds and in-lake wetlands. This would allow sediment settling and nutrient uptake before discharge.



1.12. *Recommended process diagram for lake quality management (Not to scale)*

Asset selection for water quality improvement

Based on the functions prioritised during the Diagnosis and Visioning component and after establishing the baseline characteristics of the lake, appropriate water quality improvement assets can be selected to bridge the gap between the current (baseline) and the desired state of the lake. Selection of treatment technologies, whether in series or parallel, necessitates the consideration of the required treatment level, land availability, and budgets for both the Implementation as well as Operation and Maintenance components.

For example, if the inflow consists of untreated blackwater, an appropriately sized STP can be installed to remove organic matter and suspended solids. Conversely, if the inflow comprises STP-treated water, with nutrient removal being the main concern, High-rate Algal Ponds or Constructed Wetlands would be the more suitable options, with the discharged effluents controlling the lake's nutrient levels.

The Table below classifies typical inflow types alongside water quality improvement assets, treatment levels attained, purposes, and the rationale behind each choice.

Inflow Type	Water Quality Improvement Asset	Treatment level (Secondary / Tertiary)	Purpose	Rationale for Choice
Untreated black and greywater, septic tank effluent, combined sewer overflows	Sewage Treatment Plants	Secondary or Tertiary (depending on treatment train)	Biological degradation of organic matter and suspended solids	Chosen for effectively handling and reducing heavy organic and sewage pollution loads with reliable performance under continuous inflow.
Combined sewer overflows, surface run-off, STP treated water	High-rate Algal Ponds	Secondary	Biological nutrient uptake and organic matter reduction	Useful for polishing nutrient-rich water where biological nutrient uptake is desired with relatively low operational cost.
Greywater / septic tank effluent, surface run-off, STP treated water, upstream lake overflows	Constructed Wetlands	Tertiary	Polishing step for nutrient removal and ecological restoration	Preferred when nutrient removal and ecological restoration are goals, and sufficient land is available for natural treatment processes.
Upstream lake overflows	Aerators	Tertiary	Oxygenation and enhancement of water quality, supporting biological processes	Selected to promptly improve oxygen levels and reduce BOD in lakes with low DO but lower pollution loads.

2.3.10. For STPs inside the lake boundary with treatment capacity < 1 MLD

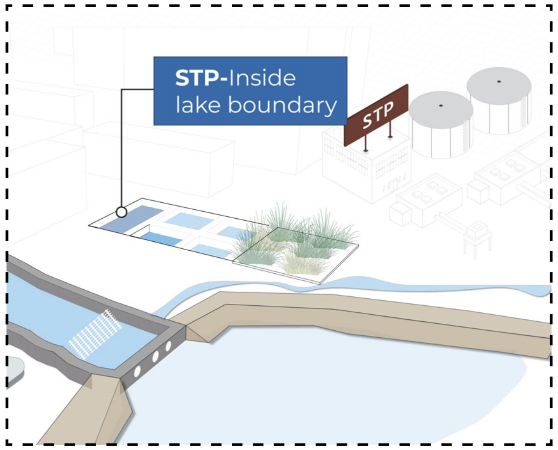
An STP removes organic matter, suspended solids, nutrients, and pathogens from sewage before the water enters a lake. For local-scale sewage treatment with minimal footprint and operational complexity, a system with a treatment capacity of less than 1 million litres per day (MLD) is ideal. Its compact design is particularly suitable for areas with limited land availability near the lake.

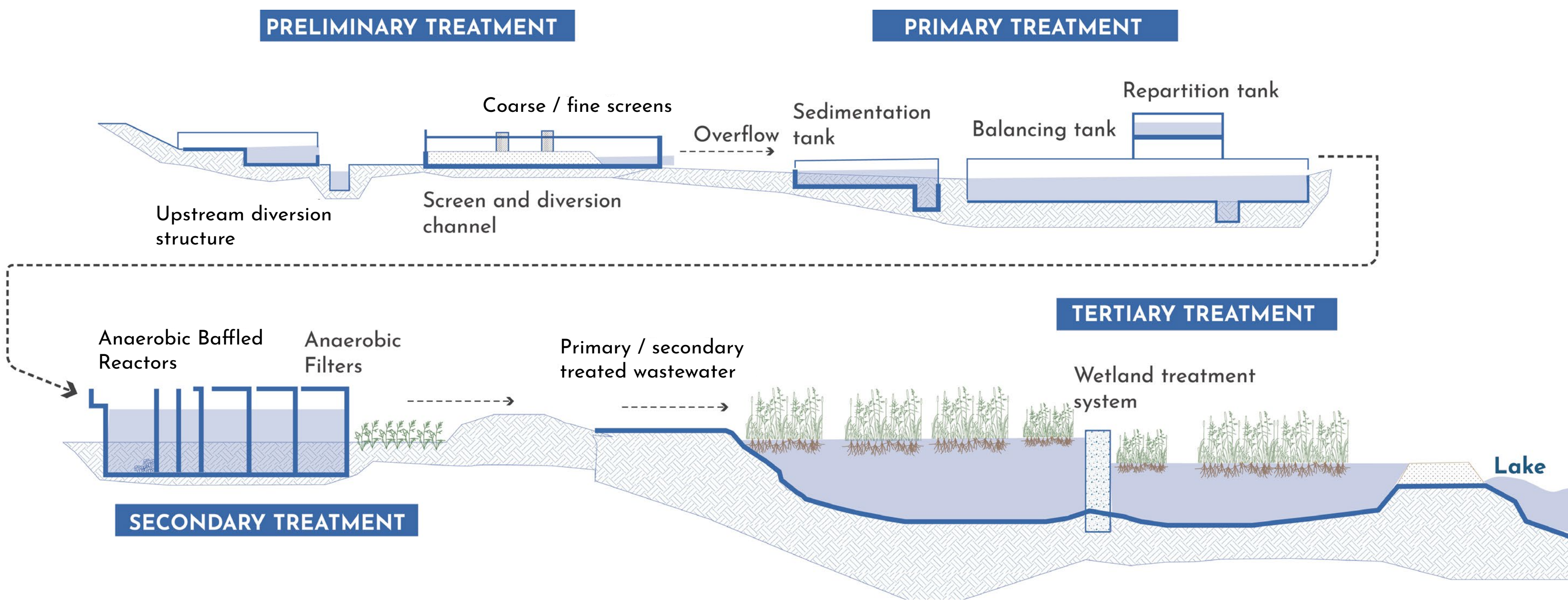
For this treatment scale, high-rate anaerobic treatment systems are recommended, involving the following steps:

First, pre-primary and primary treatments using screens, oil and grease traps (if necessary), and sedimentation tanks are essential to remove large solids and substances that could hinder subsequent treatment.

Second, high-rate anaerobic reactors, such as Anaerobic Baffled Reactors (ABR) and Anaerobic Filters (AF), are commonly employed, especially in India. Their high biomass retention and effective organic matter removal work well together to provide efficient treatment.

Finally, tertiary treatment using constructed wetlands is recommended as a polishing step. Positioned near the lake's inlets, these wetlands further reduce nutrients and pathogens before the treated water is discharged into the lake.





1.13. *Cross-section of an STP<1MLD (Not to scale)*

ASSET LOCATION:

Located near the lake inlet.

DESIGN PARAMETERS:

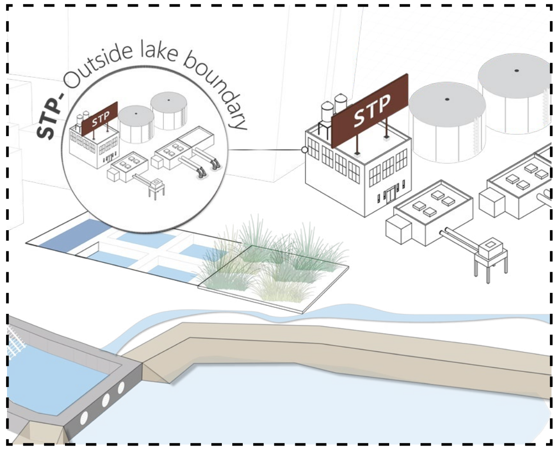
Desired discharge refers to safe conveyance of water.

Depends on the expected peak flow from a catchment during a storm event.

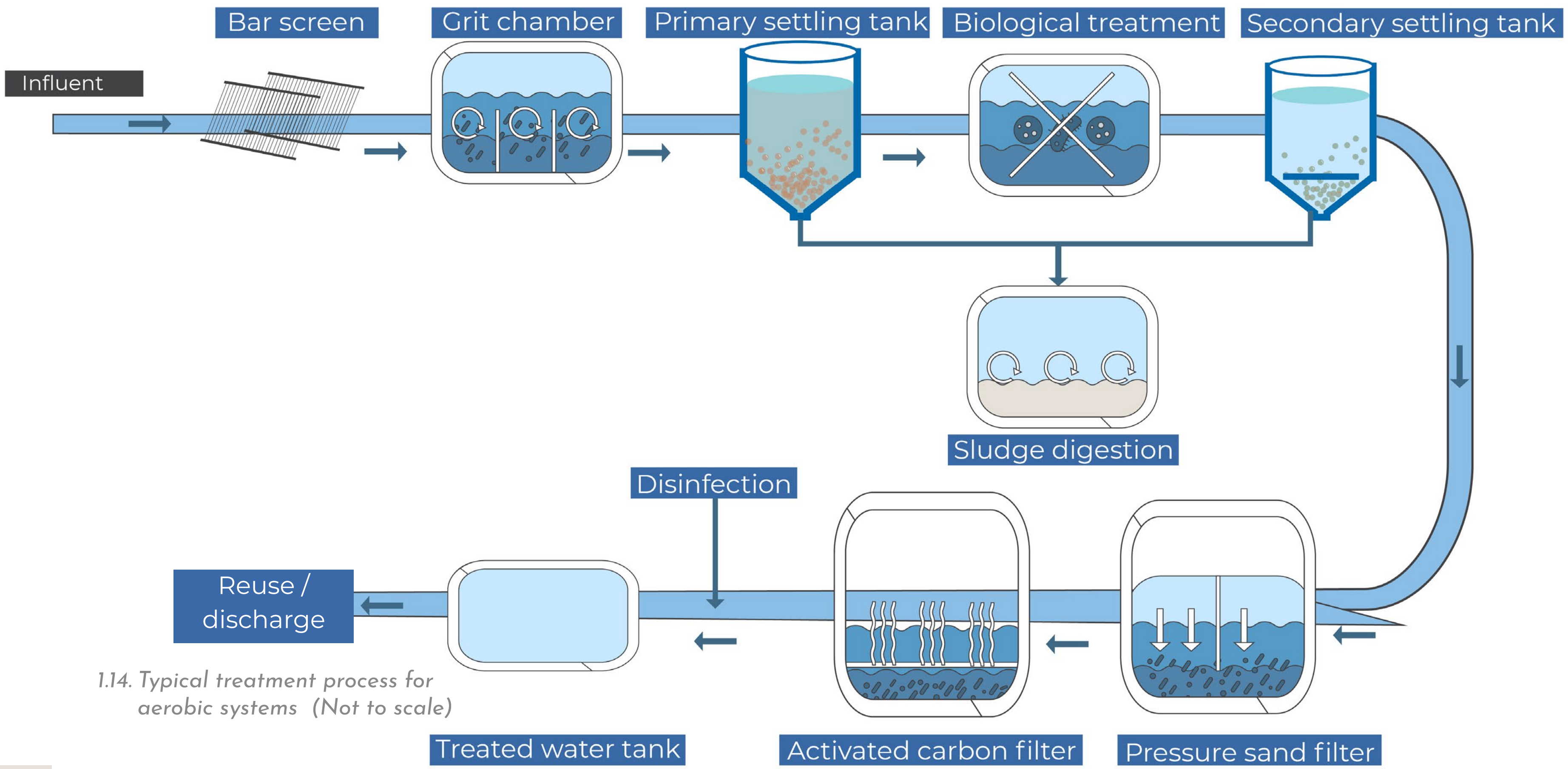
Parameter	Criteria
Anaerobic Baffled Reactor (ABR)	
Hydraulic retention time	48-72 hrs
Upflow velocity	< 0.6 m/h
Number of upflow chambers	3-6
Anaerobic Filter (AF)	
Hydraulic retention time	12-36 hrs
Surface area	90-300 m2 per m3 of occupied reactor volume
Filter material sizes	12-55 mm diameter
Water level covering media	> 0.3 m
Materials	Gravel, crushed rocks or bricks, cinder, pumice, or specially formed plastic pieces, depending on local availability.

2.3.11. STP > 1 MLD: Aerobic treatment systems outside lake boundary

In this setup, influent sewage first passes through a bar screen and grit chamber, that removes large debris and sand. It then passes through a primary settling tank for sedimentation. Biological treatment breaks down organic matter, after which a secondary settling tank clarifies the effluent; sludge from both stages can be treated anaerobically. For tertiary treatment, activated carbon and pressure sand filters are used to remove residual chemicals and fine particles, producing high-quality treated water suitable for reuse or discharge. Aerobic STPs are best suited for wastewater with relatively low to medium organic strength (low Biological Oxygen Demand/Chemical Oxygen Demand), when higher removal efficiencies are required. Aerobic systems are ideal when energy availability is not a constraint, and faster treatment with better polishing is needed.



Common aerobic treatment processes include the activated sludge process and its modifications, such as sequencing batch reactors (SBR), oxidation ditches, extended aeration (ASP-EA), moving bed biofilm reactors (MBBR), and membrane bioreactors (MBR).



1.14. Typical treatment process for aerobic systems (Not to scale)

ASSET LOCATION:

Located near the lake inlet.

DESIGN PARAMETERS:

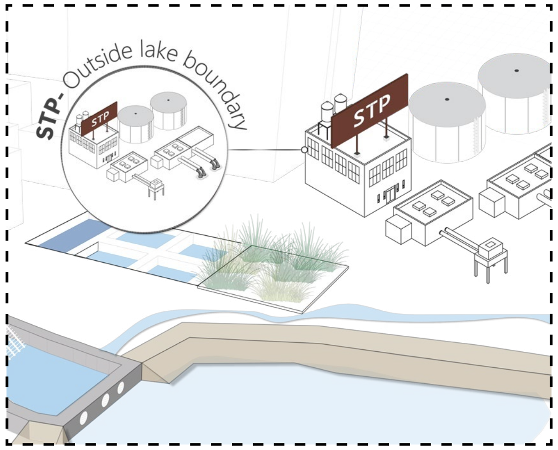
Aerobic systems treat wastewater with low–to-moderate Biological Oxygen Demand (<2,000 mg/L). They need oxygen, and remove nitrogen and phosphorus effectively. However, they produce more sludge and incur higher aeration costs, making them common in urban areas.

Large STPs often pair them with anaerobic units; anaerobic treatment reduces organic matter and generates biogas, while aerobic treatment polishes the water quality to meet established standards.

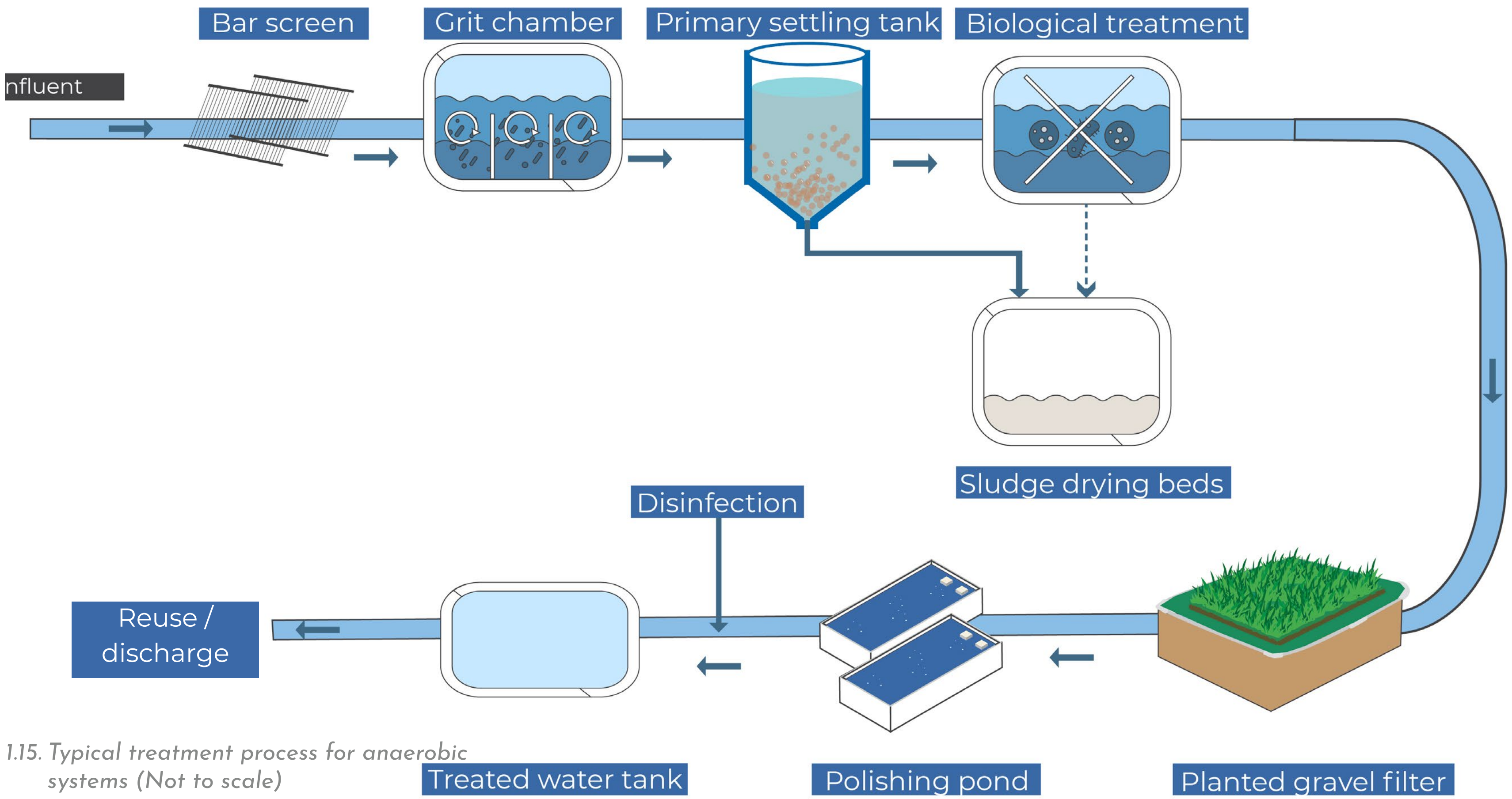
Parameter	Activated Sludge Process (ASP)
Hydraulic retention time	4–10 hours
Organic loading rate	0.2–0.5 kg "Biological Oxygen Demand/" /kg MLSS/day
Biomass concentration	2000–5000 mg/L Mixed Liquor Suspended Solids
Aeration	Required (DO 2–4 mg/L)
Temperature range	10–30 °C
Sludge retention time	5–10 days
Sludge recycling	Yes (return activated sludge)
Upflow Velocity	Not applicable
Effluent quality	High Biological Oxygen Demand and Total Suspended Solids removal

2.3.12. STP > MLD: Anaerobic treatment system outside lake boundary

This system follows an initial sequence similar to that of aerobic treatment system. Sewage first enters through a bar screen and grit chamber, after which it passes through a primary settling tank. This is followed by a high-rate anaerobic treatment, and sludge from the process is dried in drying beds. For the tertiary treatment, a polishing pond and a planted gravel filter, a natural purification method that further removes nutrients and contaminants, are used. Anaerobic STPs are preferred for producing high-strength wastewater that have high organic loads (high Biological Oxygen Demand/Chemical Oxygen Demand). They are more energy-efficient, produce less sludge, and can generate biogas (though the biogas is often vented due to low volume). Anaerobic systems also typically require longer retention times and often need a post-treatment step for polishing effluent quality.



Common high-rate anaerobic treatment processes include Upflow Anaerobic Sludge Blanket (UASB) reactor, Anaerobic Baffled Reactor (ABR) and Anaerobic Filter (AF).



1.15. Typical treatment process for anaerobic systems (Not to scale)

ASSET LOCATION:

Located near the lake inlet

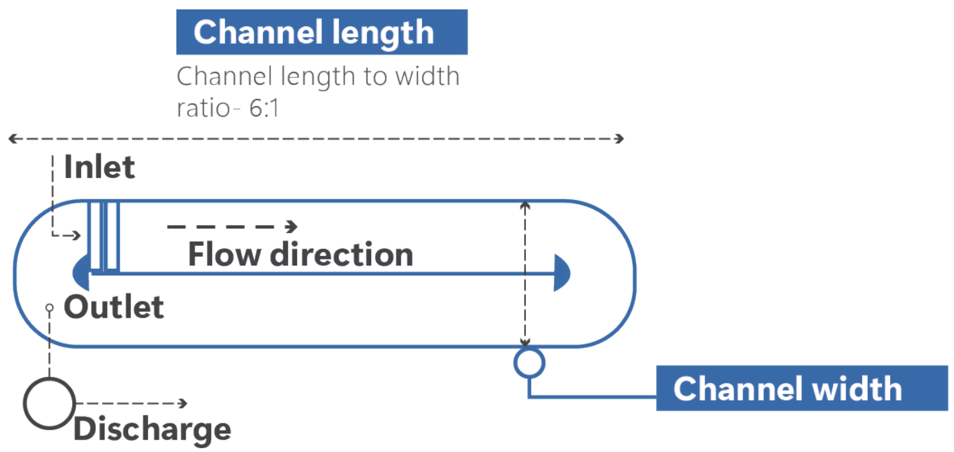
DESIGN PARAMETERS:

Anaerobic systems suit wastewater with high Biological Oxygen Demand. Operating without oxygen, they cut energy costs and generate methane for recovery. They need longer retention times and strict temperature/pH control. Usually, anaerobic treatment is the first step for producing high-strength wastewater, followed by aerobic polishing to meet discharge standards. Large STPs combine both: anaerobic units lower organic load and produce biogas, while aerobic units provide secondary treatment and polishing.

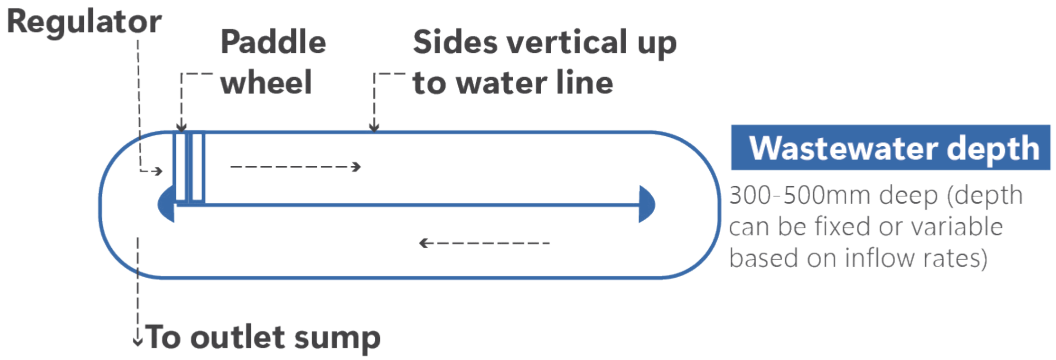
Parameter	UASB Reactor
Hydraulic retention time	8–12 HOURS
Organic loading rate	2–4 kg Chemical Oxygen Demand/ m^3·day
Biomass concentration	40–100 kg Total Suspended Solids/ m^3 sludge blanket
Aeration	No aeration; biogas produced
Temperature range	>/= 20 °C
Sludge retention time	120–150 days
Sludge recycling	No recycling
Upflow Velocity	0.5–1.0 m/hr
Effluent quality	Moderate removal, suited for high-strength wastes

2.3.13. High Rate Algal Pond

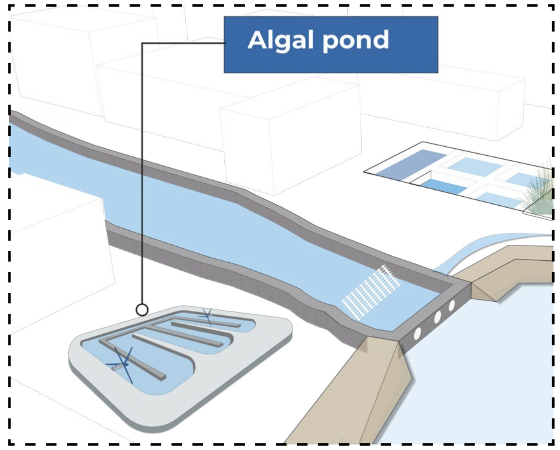
A High Rate Algal Pond (HRAP) removes organic matter, nutrients, and pathogens from wastewater through algae-bacteria interactions and oxygenation. It is a shallow, elongated channel system equipped with paddle wheels to maintain steady water movement and enhance algal treatment. Its design focuses on maximising surface area and controlling depth to provide optimal conditions for both wastewater treatment and algal growth. Depending on flow requirements, channels can be arranged in a single loop or a series of loops to allow flexibility in configuration (governed by the land shape, area available and grade across the site) and capacity of the pond. Its dimensions, loop configuration, and consistent surface levels work together to improve efficiency and treatment outcomes for lake management. Multiple HRAPs can also be chosen to cater to peak flows.

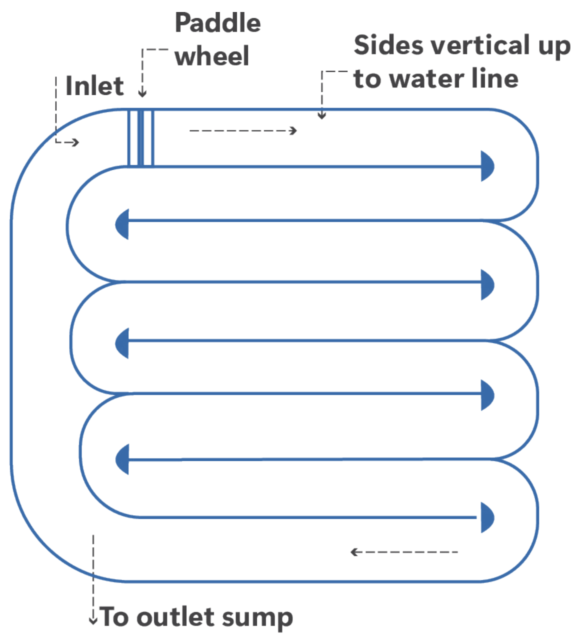


1.16. *Channel aspect ratio(Not to scale)*



1.17. *HRAP configuration showing single loop (Not to scale)*





1.18. *HRAP configuration series loop (Not to scale)*

ASSET LOCATION:

Located near the inlet

DESIGN PARAMETERS:

Inflow: Treats septic tank / partially treated STP effluent; pretreatment options: anaerobic lagoons, Imhoff tanks, large septic tanks and anaerobic digesters with screening.

Flow rate: Keep uniform; avoid batch flows (use buffer storage if needed). If not, design flow rate ≤ Hydraulic Design Load (HDL) over 5 hours.

Critical control points (CCPs):

Wastewater depth: 300-500mm (fixed/variable based on inflow).

Detention time and volume: HRAP volume (combined, if series) < 10 days at HDL.

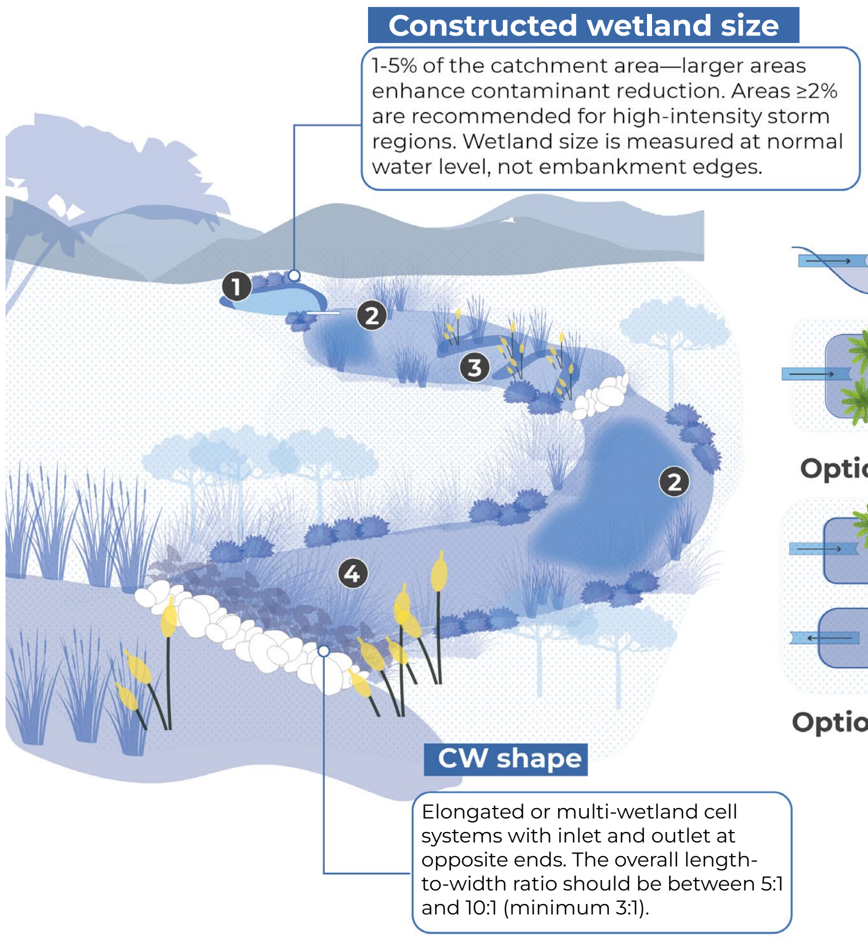
Mean surface flow velocity: > 0.2 m/s.

Channel ratio: Length to width > 6:1 (single loop).

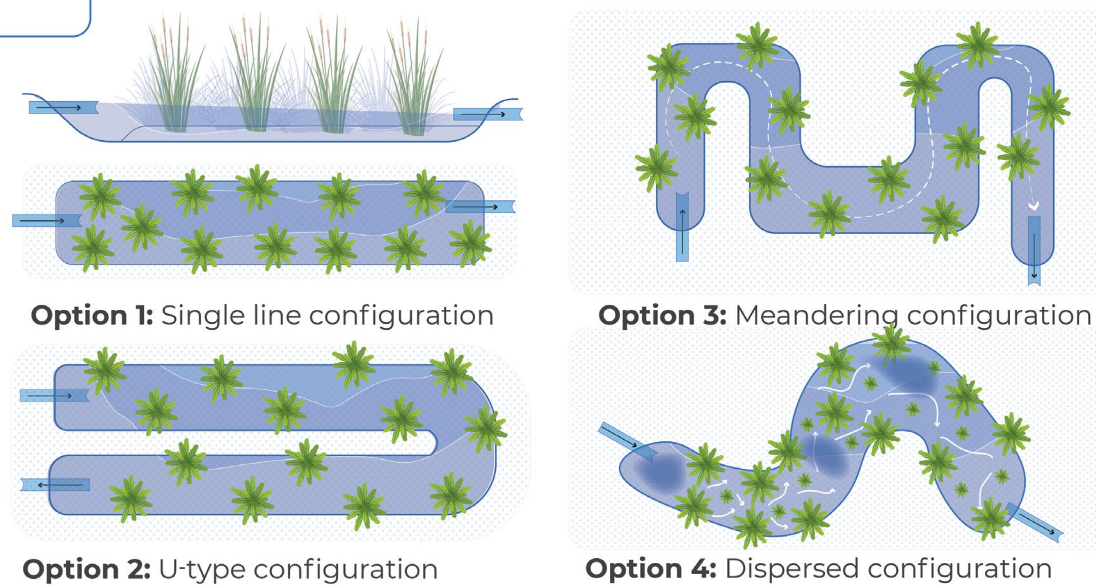
Freeboard: Min. 300mm for HRAP channels.

2.3.14. Constructed wetland

A constructed wetland is engineered near the lake inlet to maximise treatment and contaminant reduction. It typically features a combination of deep sedimentation zones, open water channels, and extensive shallow, densely vegetated areas. The wetland's size is selected to cover a portion of the catchment area, with design favoring elongated or multi-cell shapes for effective water flow. Different layout options, including single line, U-type, meandering, or dispersed configurations, allow for flexibility in choosing the design according to site conditions and treatment needs. This natural system supports filtration, nutrient uptake, and habitat creation, improving overall water quality before it enters the lake.



1.19. 1. Deep sedimentation pond, 2. Deep water inlet zone, 3. Shallow vegetated zone, 4. Outlet zone



ASSET LOCATION:

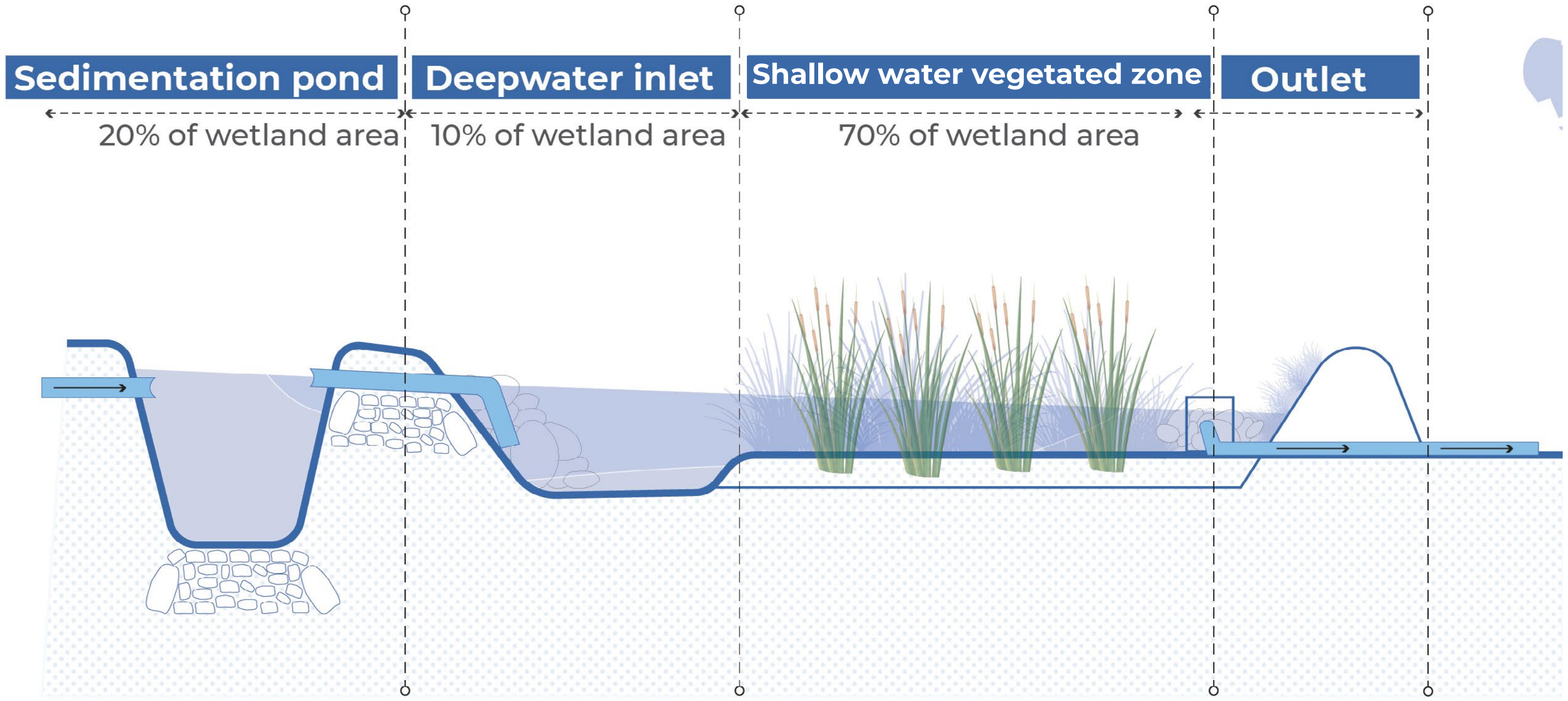
Located near the inlet

DESIGN PARAMETERS:

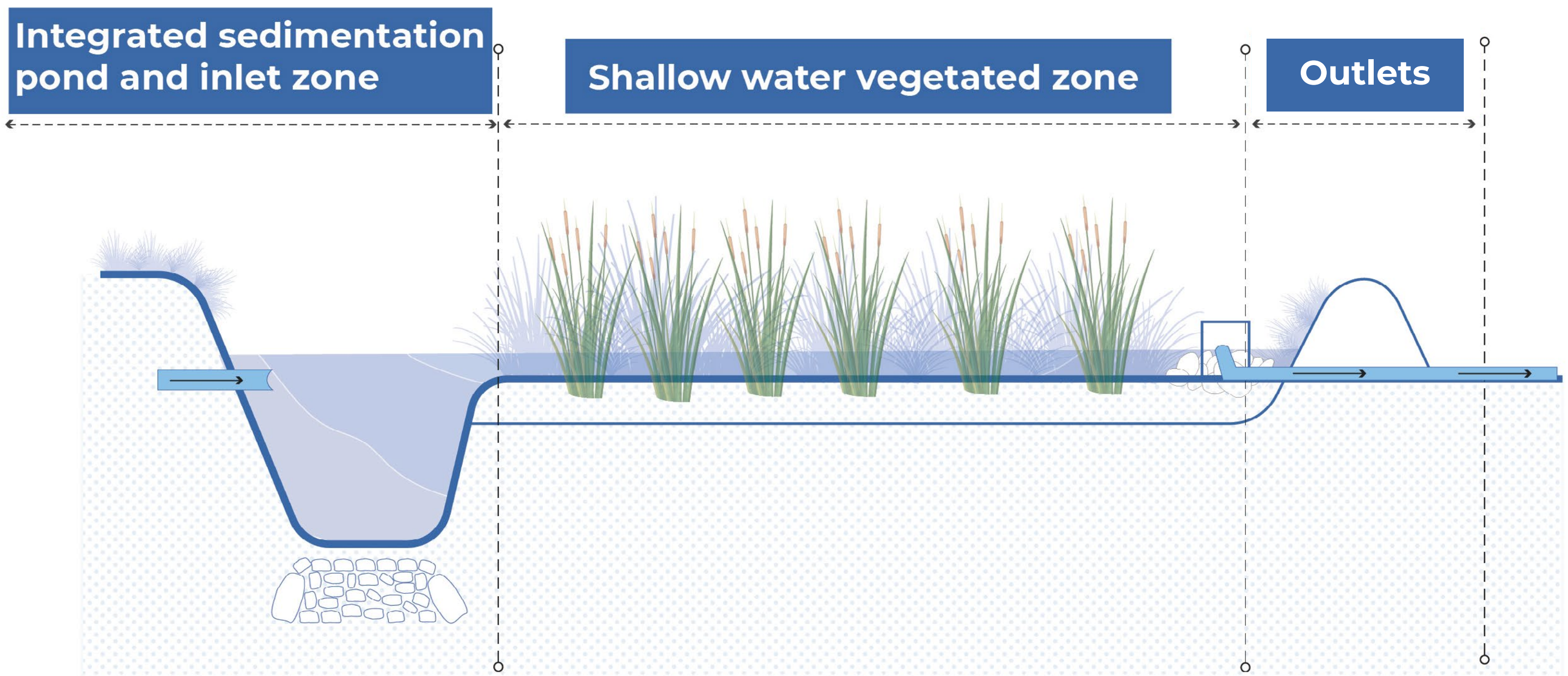
Initial deep sedimentation pond (>1.5 m depth): Size up to 20% of the wetland area, taking account of expected peak flows based on local rainfall intensity.

Deep (>0.5m) open water dispersion zone at inlet: Up to 20% of the wetland size located at the inlet of each vegetated wetland zone, and up to 30% of the total wetland area can be deep zones.

Shallow (average 0.3 m depth) densely vegetated zone: At least 70% of wetland area. This is to reduce the impacts of disturbance and faecal inputs by waterflow.



Option A: A separate sedimentation pond, deepwater inlet and shallow treatement basin



Option B: An integrated single inlet sedimentation pond, deep dive inlet and shallow basin

Option A is most appropriate when site space and configuration allow distinct physical separation of treatment stages to optimise sediment capture and vegetative treatment efficiency.

Option B reduces system footprint and complexity by consolidating hydraulic structures. It is suitable for sites with space constraints or where hydraulic control structures favor combining sedimentation and inlet functions without compromising treatment efficiency.

Sizing	Volume dependent
System sizing and performance estimation	P-k-C model
Hydraulic retention time	2-3 days per cell
Vegetation porosity	0.65-0.75
Water depth	0.1-0.6 m
Length to width ratio	2:1 TO 5:1

P-k-C model: Tanks-Kinetic-Concentration

2.4. Asset baselining

2.4.1. Need and process for asset baselining

Before the start of any rejuvenation work, establishing a clear baseline of the lake's assets is crucial. Asset baselining involves assessing the current state of each asset against its intended design standards and functions. This process helps us understand what exists on the ground; whether the asset continues to function as required; and what gaps or issues need to be addressed. In doing so, we ensure that the interventions are evidence-based rather than ad hoc, and that resources are directed towards the most urgent needs.

The process begins with the identification of all the assets in and around the lake, such as sluice gates, bunds, channels, weirs, wetlands, silt traps, and debris traps. First, whether the assets are present is checked. Those that are present are then evaluated for their current state, whether they are damaged, dysfunctional, oversized, or simply in need of cleaning. The observed condition is compared with the design standards to determine if the asset is fulfilling its intended purpose, such as safe discharge, filtration, storage, or water quality improvement. Based on this evaluation, recommendations are made for the next steps, which may involve routine maintenance, structural repairs, redesign, or new asset planning if an element is absent altogether.

Through this process, asset baselining provides a comprehensive understanding of the lake system, creates a benchmark for future monitoring, and ensures that all subsequent interventions are aligned with the lake's ecological and functional requirements.

Current state	Recommendation
Damaged	Structural repair
Dysfunctional	Maintenance
Partially functional	Functional optimisation
Not cleaned	Maintenance
Undersized/Oversized	Asset redesign
Good condition	Maintenance

1.20. *Damaged waste weir*

1.21. *Broken channel*

1.22. *Not cleaned wetland*

2.4.2. Asset baseline checklist

If the asset is present, select its condition from the options under Current State. Based on the selected condition, refer to the corresponding action under Proposed Work to guide necessary interventions. If the asset is absent, go to the Asset Planning step.

		Based on visual observations				Based on asset design	
Asset	Purpose of asset	Is the asset Required to meet The function?	Is the asset Present?	Current state	Observed issues	If present, does it Fulfill the design Criteria?	Proposed work
Sluice gate	Controls the release of water.	YES/NO	YES/NO	Damaged		YES/NO	Structural repair
Channel	Drains excess water from the lake.	YES/NO	YES/NO	Oversized		YES/NO	Asset redesign
Bund	Contains and protects stored water while preventing flooding.	YES/NO	YES/NO	Damaged		YES/NO	Maintenance
Waste weir	Safely discharges excess water during storm event to prevent overtopping.	YES/NO	YES/NO	Not cleaned		YES/NO	Cleaning
Lake bed	Supports water storage, recharge, and ecological functions.	YES/NO	YES/NO	Dysfunctional		YES/NO	Asset redesign
Constructed wetland	Enhances water quality by filtering pollutants and supporting biodiversity.	YES/NO	YES/NO			YES/NO	Cleaning
STP	Treats water.	YES/NO	YES/NO			YES/NO	Structural repair
Algal pond	Treats water.	YES/NO	YES/NO			YES/NO	Cleaning
Silt trap	Captures sediment before it enters the lake, reducing siltation.	YES/NO	YES/NO			YES/NO	Asset planning
Debris trap	Prevents large floating materials from entering and clogging the lake system.	YES/NO	YES/NO			YES/NO	Asset planning
Inlet box culvert	Directs water into the lake	YES/NO	YES/NO			YES/NO	Cleaning

2.5. Detailed Project Report structure

2.5.1. Components of a Detailed Project Report

1. Introduction and Project Background

Overview of the lake (location, historical significance, and current condition).

Objectives of the project (e.g. water conservation, biodiversity restoration, pollution control)

Approach and methodology

2. Baseline Assessment and Site Analysis

Topographical survey; total station survey; geotechnical and hydrological study; water quality analysis; ecological assessment, including flora, fauna, aquatic life, biodiversity mapping; and pollution and encroachment study, including sources of sewage, industrial discharge, and waste dumping.

3. Lake vision

Stakeholder engagement and community participation plan: Involving local communities, NGOs, and environmental groups; and conducting awareness programs, citizen science initiatives, and participatory monitoring.

Lake functions: Primary and secondary

4. Legal and Regulatory Compliance

Applicable environmental laws and policies (e.g. Wetland Protection Act, Pollution Control Norms).

Permissions required from government agencies (municipal corporation, water resources department, environmental bodies).

Land ownership details and any encroachment clearance requirements.

5. Environmental and social impact assessment

6. Project Scope and Design

Lake Desiltation Plan – Removing excess silt, sludge, and waste materials..

Embankment Strengthening – Preventing erosion using natural and engineered solutions.

Stormwater Management Plan – Redesigning drains, inlets, and outlets for efficient water flow.

Biodiversity Restoration Plan – Planting native aquatic vegetation, restoring fish populations, and supporting wetland ecosystems.

Pollution Mitigation Measures – Constructed wetlands, bio-filtration zones, aeration systems.

Community & Recreational Space Development – Walking paths, eco-parks, boating zones, educational signages.

7. Implementation Strategy and Work Plan

Phase-wise execution plan (short-term, mid-term, long-term interventions).

Methodology for construction of assets, dredging, water treatment, and plantation.

Timeline and milestones for completion.

8. Cost Estimates and Budgeting

Detailed cost breakup for various components (e.g. civil works, electrical, and landscaping).

9. Financial plan

Funding sources (government grants, CSR funding, public-private partnerships, NGOs).

Revenue generation plan for upkeep of the lake.

10. Monitoring and Evaluation Framework

Periodic water quality testing and ecological assessments.

Maintenance schedule for embankments, plantations, and infrastructure.

Performance indicators (e.g. improved water quality, biodiversity, and community involvement).

Annexures (Supporting Documents)

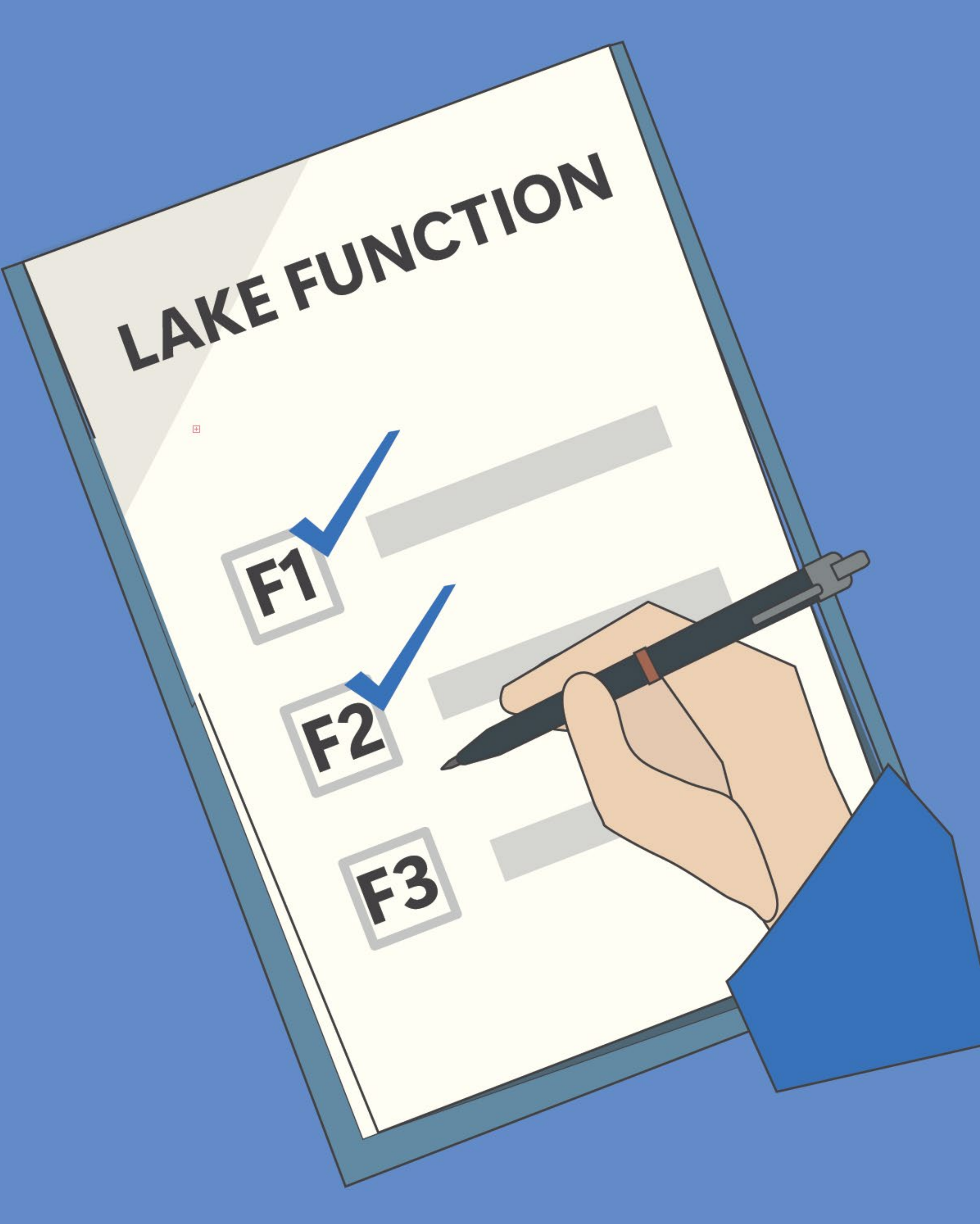
Maps and survey reports (topography, hydrology, and biodiversity mapping).

Water quality test reports (pre-rejuvenation analysis).

Government approvals and environmental clearances.

Detailed cost estimation sheets.

Technical drawings and designs (lake sections, embankments, and wetland filtration systems).



5. Monitoring and Evaluation

The monitoring and evaluation stage helps track the lake's progress toward set targets. It includes conducting an asset survey, a lake health survey, and comparing the current versus desired state across lake hydrology, biology, and chemistry

Monitoring and Evaluation

OVERVIEW

Monitoring and Evaluation (M&E) is an ongoing management process that tracks whether a lake rejuvenation project is meeting its intended goals. It identifies bottlenecks and detects unexpected outcomes (positive or negative) arising from implementation and activities. In the context of lake rejuvenation, M&E encompasses parameters related to both lake characteristics (such as water chemistry, hydrology, and biology) and assets (the condition and function of installed structures).

A strong M&E framework enables stakeholders to use a common set of quantifiable metrics to track progress, making it easier to evaluate whether project objectives are being achieved. It also supports the identification of both external and internal influences on the water body, assessing management effectiveness and facilitating evidence-based decision-making. Regular tracking of parameters enables adaptive management, allowing interventions to be adjusted according to changing conditions.

Importantly, the parameters selected for monitoring are closely aligned with those established in the baseline study, focusing on all mutable factors. This helps ensure direct comparability between the initial state and subsequent measurements, providing a clear measure of change and progress.

The M&E framework is designed to assess the current state of the lake function and project outcomes against desired targets, and to define measurement frequencies.

The framework supports two levels of monitoring: basic and advanced. Basic monitoring uses visual observations accessible to non-experts for early issue detection and community engagement. Advanced monitoring, by contrast, requires specialised personnel, equipment, and laboratory analysis for detailed diagnostics and for guiding targeted technical interventions.

For evaluation, we developed a score card with Key Performance Indicators (KPI) for lake health. These indicators capture both outcomes and operational performance. While volumetric benefits are typically reported post lake rejuvenation, benefits in terms of water quality improvements have not been captured. The newly developed KPIs fill this gap.

Together, these approaches ensure that monitoring is both inclusive and technically robust, supporting continuous improvement in lake management.

PROCESS FOR MONITORING

Citizens can use simple checklists to observe and document the current condition of lake infrastructure and health. If any visible issue is identified, whether relating to lake assets or ecosystem stress, it can be reported to custodians, who can then initiate advanced monitoring and targeted action, as needed.

BASIC MONITORING- Citizen science with field test kits

Asset survey
Survey the physical condition and operation of the assets.
Frequency: Bi-yearly

Lake health
Assess early warning indicators of the lake's health.
Frequency: Bi-yearly

ADVANCED MONITORING- Trained personnel with laboratory facilities

Lake hydrology
Monitor water quantity, levels, and flow.
Frequency: Seasonally

Lake chemistry
Measure key water and sediment quality parameters .
Frequency: Quarterly

Lake biology
Monitor species diversity, habitat quality, and ecological interactions.
Frequency: Bi-yearly

5.1. Basic monitoring

5.1.1. Asset survey

This tool enables citizens to visually check the current condition of lake assets and flag issues that are clearly visible. It helps identify whether an asset is functioning properly or if there are concerns worth reporting for further action.

Asset	Purpose of asset	Current state	Observed issues
Sluice gate	Controls the release of water.	Damaged	
Channel	Drains excess water from the lake.	Oversized	
Bund	Contains and protects stored water while preventing flooding.	Damaged	
Waste weir	Safely discharges excess water during storm event to prevent overtopping.	Not cleaned	
Lake bed	Supports water storage, recharge, and ecological functions.	Dysfunctional	
Constructed wetland	Enhances water quality by filtering pollutants and supporting biodiversity.		
STP	Helps in water treatment.		
Algal pond	Helps in water treatment.		
Silt trap	Captures sediment before it enters the lake, reducing siltation.		
Debris trap	Prevents large floating materials from entering and clogging the lake system.		
Inlet box culvert	Directs water into the lake.		

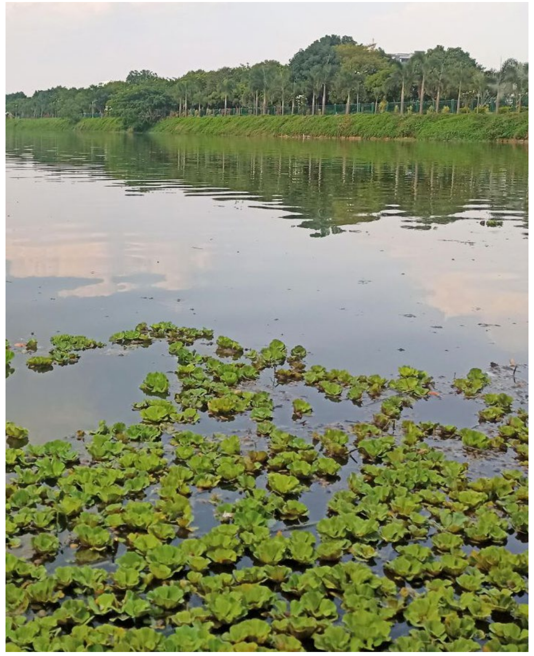
5.1.2. Lake health

This tool allows citizens to visually observe and flag any apparent changes or problems in lake health, such as unusual growths or visible pollution.

Parameter	Frequency	Current state	Desired state
Algal bloom	Monthly		No / Minimal presence
Macrophyte bloom	Monthly		No / Minimal presence
Scum	Monthly		No / Minimal presence
Debris/ Garbage	Monthly		No / Minimal presence
Fish kill	Event-based		No / Minimal presence
Bird kill	Event-based		No / Minimal presence

Site images from **Yellamallapachetty Lake**

1.23. Algal bloom in the lake



1.25. Macrophyte in the lake

1.24. Garbage in Lake

1.26. Froth near the lake outlet

5.2. Advanced monitoring

OVERVIEW

Advanced monitoring is conducted in the field using specialised instruments, probes, and sensors, or by collecting samples for laboratory analysis. The parameters tracked are consistent with those established during the baseline studies in the design phase, enabling direct comparison over time. Frequent data collection helps measure progress toward project goals, diagnose the causes behind current lake conditions, and validate issues observed during basic monitoring. This focused approach ensures that both routine and targeted parameters spanning lake hydrology, biology, and chemistry are regularly evaluated to inform effective management.

During advanced monitoring, the key questions and parameters established during the baseline study in the design phase are frequently monitored to capture any changes that occur in the current state. This measurement is checked against the desire state.

Once the extent of the issue is identified, the next steps to reduce the problem and optimise lake function(s) are taken.

5.2.1. Lake hydrology

The table contains hydrological parameters that should be regularly monitored to assess the quantity, movement, and distribution of water within the lake system. These measurements help evaluate water level fluctuations, inflow and outflow patterns, and overall hydrologic balance essential for lake health.

Monitoring- Lake Hydrology

Key questions	Data type	Parameters	Unit	Frequency	Current state	Desired state
Can the lake hold water temporarily during an extreme rainfall event to prevent damage to the surrounding areas or the lake itself?	Extent of the lake	Current water spread area	Ha	Seasonally		-
	Volume	Current volume	Million Litres			-
	Inflows	Average inflow at each inlet	Cubic m/sec	Daily/ Seasonally		
	Outflows	Evaporation losses	Cubic m/day	Seasonally		
		Infiltration losses	Cubic m/day			
		Average flow at each outlet	Cubic m/sec	Daily/ Seasonally		
Does the lake receive sufficient inflow throughout the year?	Catchment characteristics	Volume of treated and untreated sewage	Cubic m/day			-
	Upstream and downstream details	Volume of flow from upstream lakes	Cubic m/day			

*Seasons = Dry vs Wet

5.2.2. Lake chemistry

The table details the critical chemical parameters measured to evaluate the lake's water quality, including nutrient levels, dissolved oxygen, pH, and contaminants. These data inform assessments of the lake's capacity to support aquatic life and meet environmental standards.

Monitoring - Lake Chemistry

Key questions	Data type	Parameters	Unit	Frequency	Current state	Desired state
What is flowing into the lake and how does this affect the lake's ability to perform different functions?	Catchment characteristics	Location and type of industry in lake area	Degrees	Every 5 years		-
		Population				
	Solid waste	Solid waste /garbage points	Degrees	Yearly		
	Wastewater outfalls	Location of outfalls of wastewater	Degrees		-	-
What is flowing into the lake and how does this affect the lake's ability to perform different functions? **What is being retained, and how does this affect the lake's ability to perform different functions?**	Water quality	Colour, odour	-	Quarterly		
		pH	-			
		Electrical conductivity	µmhos/cm			
		Temperature	°C			
		Total suspended solids	mg/L			
		Total alkalinity	mg/L			
		Dissolved oxygen	mg/L			
		Biochemical oxygen demand	mg/L			
		Chemical oxygen demand	mg/L			
		Total nitrogen, nitrate, ammonium	mg/L			
		Total phosphorus	mg/L			
		Orthophosphate	mg/L			
		Fecal coliforms	MPN/100 mL			
		E. coli	MPN/100 mL			
What is being retained, and how does this affect the lake's ability to perform different functions?	Sediment quality	Total phosphorus	mg/g			
		Total nitrogen	mg/g			
		Total organic carbon	mg/g			

5.2.3. Lake biology

The table outlines the biological parameters tracked to understand the diversity, abundance, and health of aquatic and surrounding life forms, such as plants, fish, and birds. Monitoring these indicators helps evaluate ecosystem functions and biodiversity status over time.

Monitoring - Lake Biology

Key questions	Data type	Parameters	Unit	Frequency	Current state	Desired state
Is the lake appropriately zoned based on function? **Does lake filling support the growth of macrophytes?** **Does the lake have nesting and roosting sites for large and small birds, and amphibians?**	Flora	Native plant population and species count		Yearly		-
		Invasive plant population and species count				
		Area under invasive macrophytes				Minimal
	Fauna	Habitat use by key species				
		Native animal population and species count (macroinvertebrates, fish, anurans, reptiles, mammals, and birds)				-
		Invasive animal population and species count				Minimal
		Number of migratory birds using the lake as a habitat/breeding site				

5.2.4. Advanced monitoring tools

Instruments installation for monitoring and evaluation

This section presents examples of key lake characteristics and corresponding parameters that can be monitored in the field using various advanced instruments. These technologies enable continuous, accurate, and real-time data collection to provide detailed insights into hydrological, chemical, and biological conditions of the lake, supporting precise assessment and management.

Characteristics	Parameter	Purpose	Field instruments	Position
Lake Hydrology	Flows	Monitor flows in and out of the lake	Staff gauge Capacitance sensors	Inlet/ Outlets
	Rainfall	Monitor local rainfall that contributes to runoff	Automatic rain gauge	Catchment
	Infiltration	Measure the infiltration rate	Mini disk infiltrometer Double ring infiltrometer	Lake bed
	Groundwater level	Monitor groundwater level in shallow (open well) and deep aquifer (borewell)	Pressure transducer	Catchment
Lake Chemistry	pH	Monitor water quality changes	Handheld probe	Water body (near inlets, outlets and centre of the lake)
	Electrical conductivity			
	Temperature			
	Total suspended solids			
	Dissolved oxygen			
	Total alkalinity		Smartphone-based testing kits Field testing kits	
	Total nitrogen, nitrate, ammonium			
	Total phosphorus			
	Orthophosphate			

1.27. *Double ring infiltrometer*

1.28. *Handheld water quality probe*

1.29. *Automatic rain gauge*

5.3. Evaluation

5.3.1. OVERVIEW

Evaluation is the process of analysing monitoring data to assess the current condition of the lake, compare it against established targets or benchmarks, and guide decision-making. It helps determine whether management interventions are effective and if adjustments are needed to meet restoration goals.

Sl. No.	Water quality parameters	Unit	Class of water				
			E	D	C	B	A
1	**pH**	-	6.0-8.5	6.5-8.5	6.0-9.0	6.5-8.5	6.5-8.5
2	**Dissolved Oxygen (DO)**	mg/L		≥ 4	≥ 4	≥ 5	≥ 6
3	**Biochemical Oxygen Demand (BOD)**	mg/L			≤ 3	≤ 3	≤ 2
4	**Total Coliforms**	MPN/100 mL			≤ 5,000	≤ 500	≤ 50
5	**Free Ammonia (as N)**	mg/L		≤ 1.2			
6	**Electrical Conductivity (EC)**	µmhos/cm	< 2,250				
7	**Sodium Absorption Ratio (SAR)**	-	< 26				
8	**Boron (B)**	mg/L	< 2				

5.3.2. CPCB lake water quality targets

Currently, the Central Pollution Control Board (CPCB) Designated Best Use Criteria is used to assess surface water bodies (i.e. both river and lake water) quality. This system classifies lakes according to their current condition and matches them to a most suitable use, such as drinking, bathing, or irrigation, instead of enforcing one set standard for all uses. While these criteria are useful to classify lakes into broad, distinct categories, tracking incremental improvements or observing progress toward a target over time becomes challenging. The CPCB approach is like a broken ladder: the steps are uneven and some rungs are missing, making it harder to climb toward a goal. Some important parameters are included only in certain categories. For example, free ammonia is measured only for wildlife and fisheries, while dissolved oxygen is considered under classes A to D but not under E, preventing direct comparison and clear progress tracking across all uses.

To overcome these limitations, we developed a **water quality KPI scale** that addresses these gaps by providing **continuous scoring across all parameters and functions,** enabling better tracking of lake progress and targeted interventions.

Notes	
Class	**Surface water designated best use**
Class A	Drinking water source without conventional treatment but after disinfection
Class B	Outdoor bathing (organised)
Class C	Drinking water source after conventional treatment and disinfection
Class D	Propagation of wildlife and fisheries
Class E	Irrigation, industrial cooling, controlled waste disposal
Below E	Not meeting A, B, C, D and E criteria
	No standard prescribed

5.3.3. What are KPIs and why are they needed?

Key Performance Indicators (KPIs) are measurable, quantifiable metrics used to track progress towards specific project goals or benchmarks. In the context of lake rejuvenation, a KPI scale is created using various water quality and ecosystem parameters, with values ranging from worst to best conditions. These indicators assess both outcomes and operational performance. These process-focused KPIs help monitor the ongoing effectiveness of lake operations and management activities. They provide data-driven insights to evaluate whether investments and interventions are producing meaningful changes on the ground, and guiding the lake toward its desired state. By enabling stakeholders to objectively assess results, KPIs support continuous improvement, transparency, and accountability in project delivery.

5.3.4. Rationale behind the parameters chosen for creating the water quality score card

The parameters selected for the water quality scorecard cover key aspects of lake health. Physical indicators, like pH and total suspended solids, reflect basic water condition and clarity, which impact both aquatic life and usability. Chemical parameters, such as dissolved oxygen, biochemical and chemical oxygen demands, and nutrients (total nitrogen, nitrate, total phosphorus), are essential for tracking pollution, eutrophication, and water quality trends over time. Biological indicators, like fecal coliforms, help assess the safety of the water for human contact and are useful indicators to track sewage pollution.

The selection is based on widely accepted national guidelines (e.g. CPCB) and global best practices used for monitoring lakes worldwide. This ensures that each parameter included in the scorecard directly influences the lake's current status, its suitability for different uses, and its ability to meet targeted goals for rejuvenation.

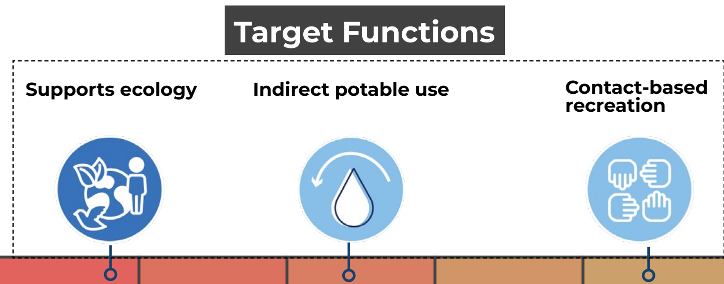
5.3.5. Proposed scale for water quality

Interpreting the score card and determining the interventions needed to reach set goals

The scorecard gives each water quality parameter a score, ranging from worst to best, and uses colors to represent the condition of the lake. Icons at the top help identify what the lake can be used for as water quality gets better: whether it supports ecology; can store water for indirect potable reuse; or is safe for contact-based recreation.

For each parameter, the observed measurement is matched to the closest value on the scorecard, and its corresponding score is recorded. Each parameter is given equal weighting.

To assess overall lake performance, the sum of parameter scores is calculated; this aggregate score indicates which target function(s) the lake can currently support. If the overall score falls below the threshold required for a specific function (for example, recreation/swimming), it signals the need for targeted interventions, such as installing new treatment assets or improving management, to move the score upward.



Sl. No.	Parameters		Unit	Worst										Best
1		**δpH**	-	**1**	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	**0**
2		**Total suspended solids**	mg/L	**200**	182	164	146	128	110	92	74	56	38	**20**
3		**Dissolved oxygen (before sunrise)**	mg/L	**3**	3.4	3.8	4.2	4.6	5	5.4	5.8	6.2	6.6	**7**
4		**Biochemical oxygen demand**	mg/L	**12**	11	10	9	8	7	6	5	4	3	**2**
5		**Chemical oxygen demand**	mg/L	**85**	80	75	70	65	60	55	50	45	40	**35**
6		**Total nitrogen**	mg/L	**15.00**	13.52	12.03	10.55	9.06	7.58	6.09	4.61	3.12	1.64	**0.15**
7		**Nitrate**	mg/L	**20.0**	18.2	16.4	14.6	12.8	11.0	9.2	7.4	5.6	3.8	**2**
8		**Total phosphorus**	mg/L	**1.00**	0.91	0.82	0.73	0.64	0.55	0.46	0.37	0.28	0.19	**0.10**
9		**Fecal coliforms**	MPN/100 mL	**1024**	512	256	128	64	32	16	8	4	2	**0**
Score				**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**

Note: Round off measured value to the next highest value δpH: deviation of the measured pH value from the neutral 7. pH value ~7 corresponds to δpH = 0 and the best score of 10

5.3.6. Feedback loops

When the current and desired states do not match

Once advanced monitoring data reveal that measured values do not align with desired target states, a systematic feedback loop is employed to diagnose the source of issues within the lake rejuvenation framework. The process begins by evaluating operations: Are all lake assets being operated and maintained at the desired level?

If operations are confirmed to be satisfactory, the design is assessed as the next step: Are the assets designed to meet the established standards and perform their intended functions? If design is not the limiting factor, the focus then shifts to implementation: Were the assets constructed and installed according to the specified standards? This iterative feedback process helps determine where corrective actions areneeded, whether in operation, design, or interventions, to optimise lake function and ensure project success.

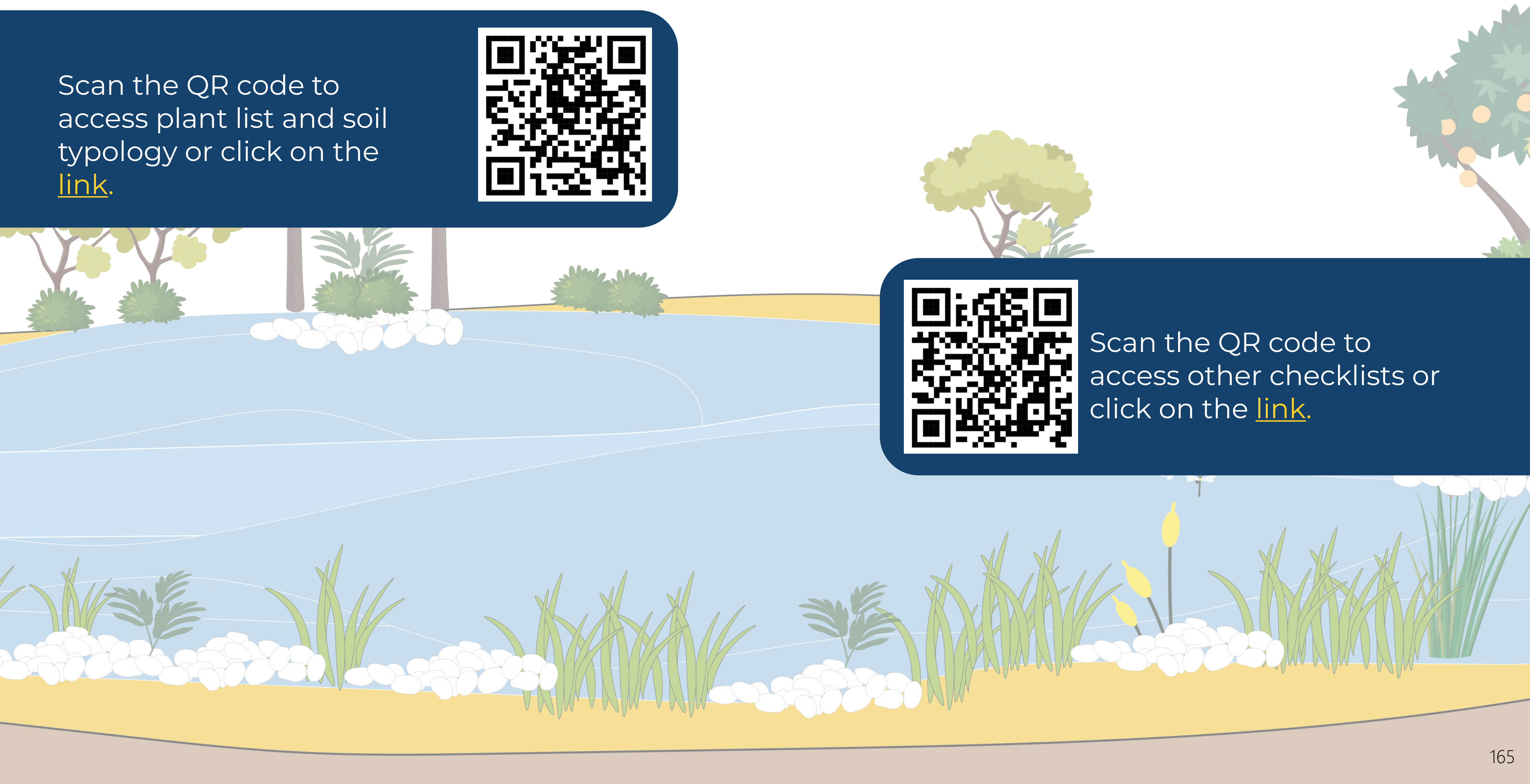

STP
Constructed wetland
Debris trap
Social (Open air gym)
Social (signages)
Sedimentation pond
Social (Walkway)
Social (Kalyani)

Annexures

Entails soil typologies, plant lists and excel files of checklists

Scan the QR code to access plant list and soil typology or click on the link.

Scan the QR code to access other checklists or click on the link.



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