SUSTAINABLE LAKE RESTORATION AND MANAGEMENT

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Causes of Lake pollution and degradation

- Most lake pollution problems are caused by nutrients, contaminants, and sediments due to erosion or sinking and decomposition of dead species and plankton.
- These pollutants could be external which are carried into lake from diffusive/nonpoint sources as; a) using of agricultural fertilizers, herbicides and pesticides in lake catchment area, b) runoff and what it could carry to lake body, c) atmospheric fallout e.g. acid rain precipitation or a point source as in case of pumping sewage.
- While the internal loading usually refers to recycling of nutrients from sediments, primarily through redox reactions at the sediment–water interface and decomposition of settling organic matter.
- Encroachment into the Lake zone, thereby shrinking the lake and altering the rate and volume of runoff (flows) making them non potable, impairing their absorption capacity, deteriorating water quality, disturbing aquatic biodiversity and finally resulting in the water body vanishing.

Significant lake stress factors, causes and ecosystem consequences

Lake stress factors	Main reasons	Ecosystem consequences
Water level decline	Overuse of the drawn water from the lake itself. Decrease in feeding water amount. Increase outflow from the lake.	Increase the salt concentration Temporary advance of eutrophication
Eutrophication	Nutrient load from both point or diffuse sources	Unwanted high plant growth, algae blooms and fish kills
Saprobization and microbial infection	Organic matterload as a BOD from: anthropogenic sources natural sources autochthonous biomass	Oxygen depletion and fish kills
Acidification	Acid rain with SO_2 and NO_x geogenic sulfur acidification from pyrite oxidation	Low pH, metal load, absence of hydrogen carbonate, low species diversity
Salinization	Transpiration losses by irrigation and the surface connections to salt layers	Decressing of lake's size and throughflow, in addition to meromixis occurrence.
Contamination	Hazardous substances: industrial wastes; nitrate or pesticides from agriculture	O_2-depletion and obstructing lake's self-purification process

STEPS IN SUSTAINABLE LAKE MANAGEMENT (as per UNEP)

1. Baseline assessment (Lake brief): Prior to planning any lake recovery project, an assessment of the baseline ecological, cultural and socioeconomic conditions is needed to

- Characterization of the lake and its basin - Biophysical, chemical, biotic information; Management and policy information
- Identify degradation and underlying causes of degradation
- Define restoration vision and targets during planning
- Provide a benchmark for measuring change following implementation
- Stakeholder engagement -Women, minorities, right holders and experts in lake degradation and restoration
- Consider wider socio-economic and political considerations – are key to achieving desired restoration outcomes
- Incorporate all kinds of knowledge and information -Traditional or indigenous knowledge and modern science
- **Assess state of six pillars of lake basin governance and Strategize improvements for these six pillars**

Ten principles of Ecological restoration – to be integrated with the six pillars of ILBM

PRINCIPLE 1:

Ecosystem restoration contributes to the UN Sustainable Development Goals and the goals of the Rio Conventions.

PRINCIPLE 2:

Ecosystem restoration promotes inclusive and participatory governance, social fairness and equity from the start and throughout the process and outcomes.

PRINCIPLE 3:

Ecosystem restoration includes a continuum of restorative activities.

PRINCIPLE 4:

Ecosystem restoration aims to achieve the highest level of recovery for biodiversity, ecosystem health and integrity, and human well-being.

PRINCIPLE 5:

Ecosystem restoration addresses the direct and indirect causes of ecosystem degradation.

PRINCIPLE 6:

Ecosystem restoration incorporates all types of knowledge and promotes their exchange and integration throughout the process.

PRINCIPLE 7:

Ecosystem restoration is based on well-defined short-, medium- and long-term ecological, cultural and socioeconomic objectives and goals.

PRINCIPLE 8:

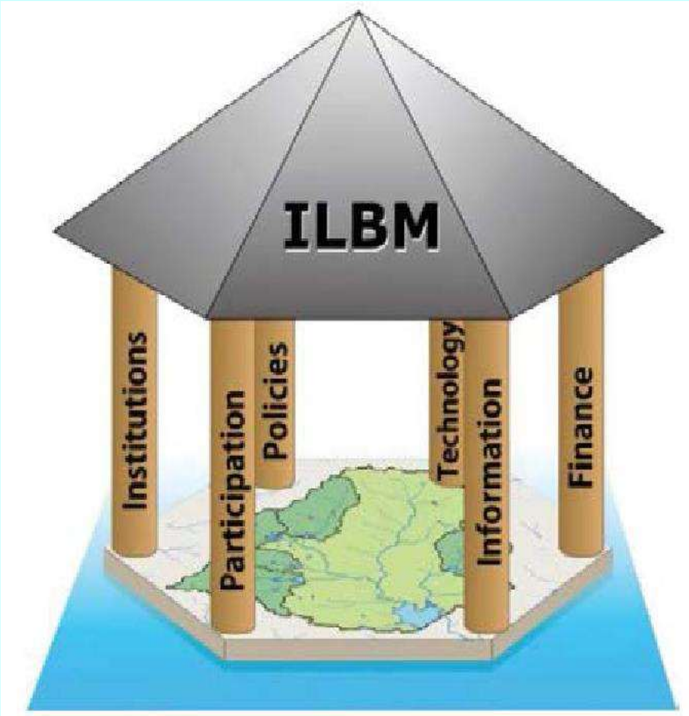
Ecosystem restoration is tailored to the local ecological, cultural and socioeconomic contexts, while considering the larger landscape or seascape.

PRINCIPLE 9:

Ecosystem restoration includes monitoring, evaluation and adaptive management throughout and beyond the lifetime of the project or programme.

PRINCIPLE 10:

Ecosystem restoration is enabled by policies and measures that promote its long-term progress, fostering replication and scaling-up.



STEPS IN SUSTAINABLE LAKE MANAGEMENT (as per UNEP)

2. Making a Lake Recovery Plan (Components of Lake Recovery Plan):

1) Define a vision, targets and recovery goals -Develop a shared vision, restoration targets and specific goals and objectives with key stakeholders; Specific indicators for ecological and social attributes; Include timelines for implementation, management and monitoring; Risk assessment and appropriate risk management

2) Define a reference model (reference site) - Six key ecosystem attributes can be used to describe the reference model

3. Monitoring and Evaluation (Steps):

Determine resource availability; Identify relevant time frames for monitoring progress; Identify most important actions; Identify indicators and targets; Prioritize which indicators will be monitored; Identify responsible parties; Establish the timeframe for completing the monitoring; Define quality control standards, reporting frameworks and data distribution methods; Report results to stakeholders; Periodically review progress and modify plan; Introduce Nature based Solutions (NbS) with proper selection

4. Institutions, Policies, Stake holders engagement and participation are integral to SLM

5. Technology, Information and Finance are the other 3 pillars of Integrated Lake Basin Management (ILBM). Integrate all the 6 ILBM pillars with the 10 principles of Ecological restoration.

STEPS IN SUSTAINABLE LAKE MANAGEMENT (as per UNEP)

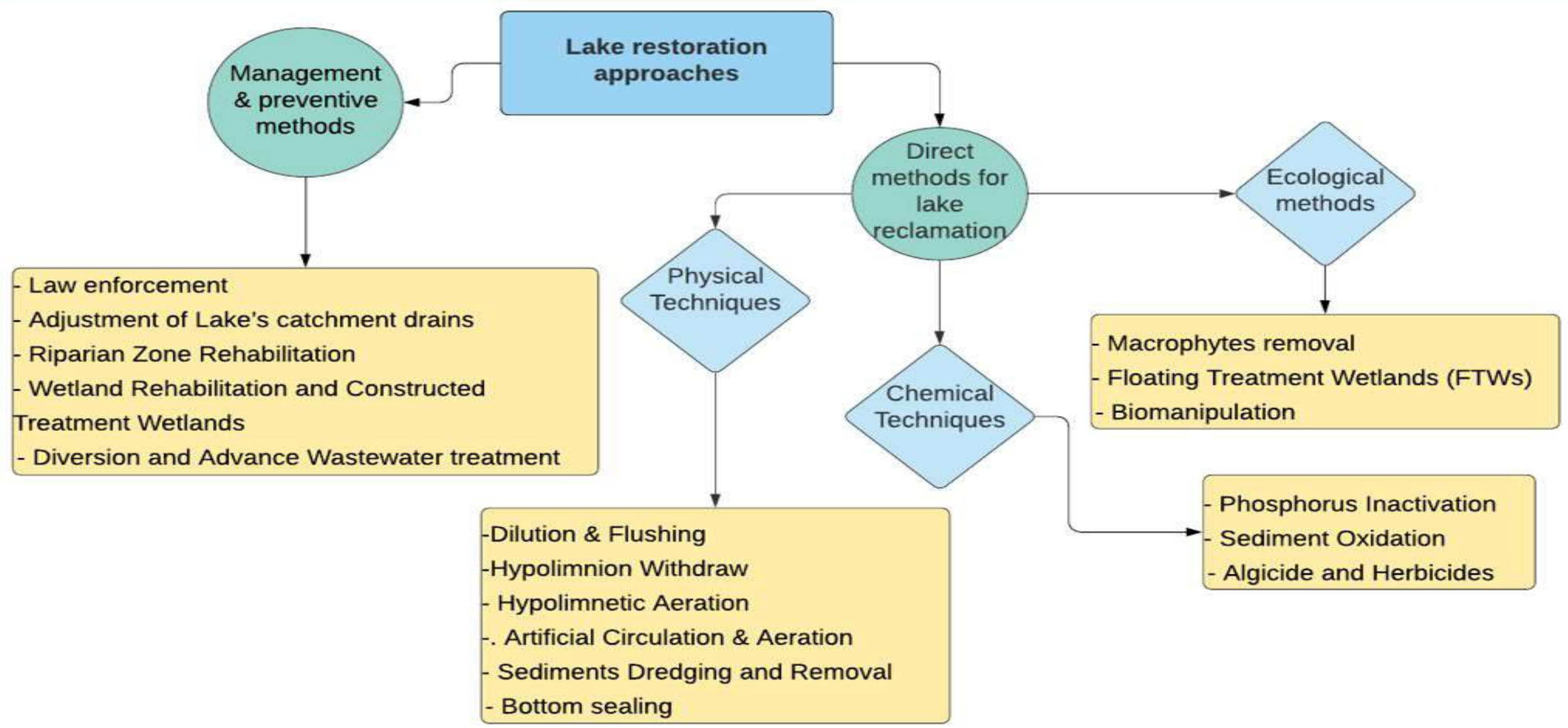
6. Implementing SLM Process: Is a cyclic process comprising the following steps

- Acknowledge state of lake basin
- Identify issues, needs and challenges
- Seek ways to strengthen the governance pillars
- Assess the governance improvements through monitoring and evaluation
- Continue effort, eventually to reach the long-term goal by Re-visiting the lake brief and Routine inspection of project site

Implementing SLM: Key points :

- Where ecological restoration is inappropriate or not viable, SLM should aim for the highest possible recovery level (includes biodiversity)
- Small and ongoing improvements can be cumulative at larger scales
- How well the core partnership (the governmental and private sectors, NGOs, other civil society, resource users and stakeholder groups) works together determines ultimate success
- SLM plans must align with regional and national plans to be viable in the long-run
- Planning and governance must work together because SLM Implementing SLM involves a large number of stakeholders with multiple sector interests, making the implementation of the plans and programs complex; and Requires the peoples' understanding and proactive involvement across the entire lake basin over long time, requiring government agencies to play a suitable facilitating role and implement individual plans and programs.

Activities related to lake restoration processes



Lake Management and protection methods

MANAGEMENT & PREVENTIVE METHODS:

- Law enforcement
- Adjustment of lake's catchment drains
- Riparian zone rehabilitation
- Wetland rehabilitation and constructed treatment wetlands
- Diversion and advance wastewater treatment

ECOLOGICAL METHODS:

- Macrophytes removal
- Floating treatment wetlands (FTW)
- Biomanipulation

PHYSICAL TECHNIQUES:

- Dilution and flushing
- Bottom sealing
- Hypolimnetic aeration
- Artificial circulation and aeration
- Sediments removal
- Hypolimnion withdrawal

CHEMICAL TECHNIQUES:

- Phosphorus inactivation
- Sediment Oxidation
- Algicide and Herbicides

Lake Restoration and Management initiatives

- Clearance of illegal encroachments along the lake boundaries
- Lake boundaries should be demarcated clearly and garland roads and fencing should be laid to prevent further encroachment of the lakebed
- Total ban on dumping of garbage and building rubble
- Stopping any further pollution is the first prerequisite for the restoration of any lake. Total ban on sewage dumping; Divert sewage drains joining the water bodies
- Control eutrophication and the factors causing increase of nutrient load, including phosphorus elimination. Curbing the nutrient import into a lake; Increasing the nutrient export; Increasing the P-sedimentation and preventing its re-dissolution; Hypolimnetic withdrawal
- Desilting of lakebed and periphery of the lake during summers, increase the storage capacity of the lake
- Control of organic load (Saprobization); Control of acidification; Detoxification
- Set up Sewage treatment plant (STP)

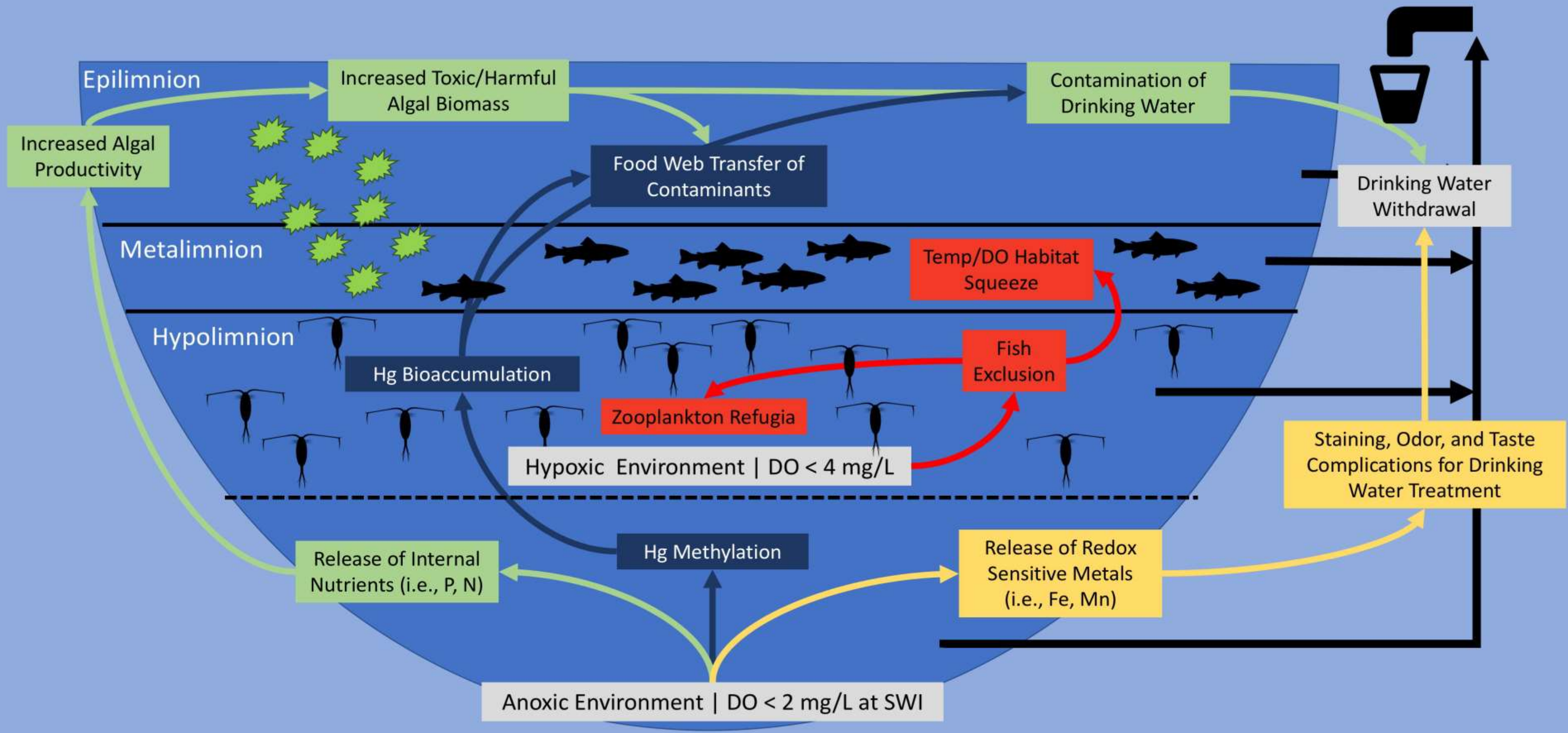
Lake Restoration and Management initiatives

- Continuous Water quality monitoring
- Restore/ introduce the weirs of the water bodies
- Maintain full tank level (FTL)
- Strengthening lake-bunds and create islands (nesting islands)
- Develop Green belt (Ecological restoration) along the lake periphery and surroundings of the lake with native species and removal of invasive and exotic species (Macrophytes); Biomanipulation (Food-web manipulation)
- Explore developing fisheries culture
- Incentivize Rag-pickers to remove plastics and other wastes from the surroundings of the lake
- Introducing value additions – develop lake fronts with park, amphitheater, meditation zones, walking/ cycling track, boating
- Stake-holders participation and community involvement
- Governance, Monitoring and Budget provision

Individual in-lake measures

Method	Conditions influencing effectiveness
Sediment removal	Potentially suitable for small and shallow lakes. It may be most effective as it removes a source of internal P and N loading from the lake ecosystem.
Hypolimnetic withdrawal	Withdrawal should focus on periods with maximum nutrient accumulation in the hypolimnion. Requires that the water volume (inflow to waterbody) is sufficient for continuous removal. The method slowly removes nutrients from the ecosystem.
Aeration	May control sediment P release at the sediment water interface by activating an iron-P trap under oxidizing conditions, depending on the presence of sulphide and the oxygen supply rate. Can facilitate N removal via coupled nitrification–denitrification.
Binding P to minerals and clays (Al/Fe/Ca salts, lanthanum-modified bentonite)	Effectiveness depends on the character of the P-binding agent and its sensitivity to environmental conditions (pH, redox, sediment resuspension).
Biomanipulation by removal of planktivorous and bottom feeding fish	Most successful in lakes in which the external nutrient load has been reduced to a level allowing a shift to a long-term clear state.
Other biomass removal (e.g., aquatic macrophytes, cyanobacteria)	Lakes with mass occurrence of nuisance macrophytes (e.g., dominant species are invasive) or removable phytoplankton.

Conceptual diagram of Hypolimnetic oxygenation control on nutrients, metals, phytoplankton, fish, and zooplankton



THANK YOU