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A Landscape Design Framework for the Ecological Remediation and Community Revitalization of an Industrially Degraded Urban Lake

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Abstract-*An extreme example of urban lake degradation is Shivapura Lake in the Peenya Industrial Area of Bengaluru, one of Asia's largest industrial clusters. BOD, COD, heavy metals and coliforms (KSPCB, 2023) with water quality significantly above CPCB Class D standards by factors of 10 to 80; Invasive species have now colonised 68% of the lake periphery (ATREE, 2020); and effective water spread has been decreased from 38.6 hectares to around 8.3 hectares through encroachment. This paper proposes a landscape design for ecological remediation and community revitalization of Shivapura Lake. The study is based on secondary data from published institutional and peer reviewed sources. The design framework comprises thirteen spatially defined zones in a Comprehensive Landscape Development Plan (CLDP), including a constructed wetland and ETP treatment system, phytoremediation belt, northern habitat lake, biodiversity park, community gathering plazas, a bio-retention step well reinterpreting the traditional Indian vav, rain garden and bioswale networks, and urban farming plots. A planting plan specifies 25 species across four communities. Lake edge cross-sections establish the technical construction logic for naturalized edges. The framework is structured as a replicable model applicable to the 181 similarly degraded industrial-edge lakes documented within BBMP limits.*

Key Words: Urban lake remediation, Constructed wetlands, Phytoremediation, Blue-green infrastructure, Bio-retention step well, Community revitalization, Peenya Industrial Area Bengaluru, Landscape design

1. INTRODUCTION

Bengaluru's historic identity was defined by more than 1,000 interlinked lakes locally known as kere , engineered as a complex rainwater harvesting and aquifer recharge network (Lakshmana Murthy, 1975) [9]. Between 1973 and 2018, the city lost 79% of its lake surface area (Nagendra & Mundoli, 2019) [10] as of 2024, only 81 of an estimated 262 lakes within BBMP limits are functionally ecological (BBMP Lake Portal, 2024) [2] Ramachandra and Setturu (2012)[15] reported a 340% increase in surface runoff and a 67% decrease in groundwater recharge in the Hebbal Valley sub-watershed over three decades.

Shivapura Lake is an industrial landscape setting which is a typical example of a lake affected by nearby industries. Shivapura Lake exemplifies severe industrial pollution, with BOD exceeding CPCB limits by over 80-fold, heavy metals surpassing permissible thresholds by factors of 48–86, invasive species dominating 68% of its periphery, and complete loss of sensitive taxa of all persisting despite multiple regulatory mandates and absent an integrated restoration framework.

2. RESEARCH METHOD AND DESIGN CHOICES

In this study, the main approach is based on design-led research. Site characterization draws entirely from published secondary sources: KSPCB Annual Water Quality Monitoring Reports (2023) [8]; BBMP land use and lake boundary records; Ramachandra and Setturu's (2012, 2020) [15] satellite imagery analysis; ATREE ecological survey data (2020) [1] and Census of India 2021 demographic data. The design process operated in three phases. The process was divided into three stages. The design process operated in three phases. Phase A compiled secondary data to characterize site conditions, pollution gradients, and catchment hydrology. Phase B reviewed four national and international lake remediation precedents using a structured comparative framework. Phase C developed the landscape design: a CLDP at 1:1000; a planting plan with species schedule; lake edge construction sections at 1:50; and detailed drawings for the bio-retention step well plaza.

3. SITE CONTEXT AND PROBLEM DESCRIPTION

Fig -1: Satellite imagery and Phase Structure of the Shivapura Lake Intervention Boundary

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Shivapura Lake is twelve kilometers northwest of central Bengaluru. This lake is surrounded by a lot of factories and workshops not by trees or green spaces. You can find places that work with metal, chemical plants and fabric dyeing units as well as smaller shops that make things and they are all located right next to the water, at Shivapura Lake. As noted in the 2018 report by the Karnataka Heath Systems Research and Development Agency on health concerns facing people living within 1.5 km from the water body, there is a direct association between distance from the lakes and the prevalence and incidence of skin disease, gastrointestinal diseases, and respiratory diseases among 1.2 lakh residents living within 1.5 km (Census of India, 2021).

Table -1 Shivapura Lake water quality parameters. Source: KSPCB (2023); CPCB freshwater classification guidelines.

Parameter	Shivapura Range (KSPCB 2023)	CPCB Class D Limit
BOD (mg/L)	78–248	< 3
COD (mg/L)	185–610	< 10
Dissolved Oxygen (mg/L)	0.2–1.6	> 4
Chromium (mg/L)	0.08–2.4	< 0.05
Lead (mg/L)	0.12–0.86	< 0.01
Coliform (MPN/100 mL)	2,400–24,000	< 500
TDS (mg/L)	1,840–4,200	< 2,100

Chromium and Lead concentrations exceed permissible limits by factors of 48 and 86 respectively, requiring chemical pre-treatment before constructed wetland treatment is viable (Pavlineri et al., 2017; Kadlec & Wallace, 2009) [13]. ATREE's (2020) [1] ecological survey confirms that the lake has crossed a tipping point of total absence of sensitive indicator species, dominance of pollution-tolerant generalists, and complete invasive cover of the terrestrial-aquatic transition zone of requiring active intervention.The design plan uses the buffer land allowed by the KLDA Act (2014), which separates two zones: a 30-meter primary buffer and a 60-meter secondary buffer.

4. THEORETICAL AND TECHNICAL BASIS

The design is informed by Waldheim's (2006) landscape urbanism framework of understanding landscape as active ecological infrastructure that reorganizes urban fabric through process and performance. Corner's (1999)[5] concept of landscape as living systems positions the lake not as a bounded water body to be 'cleaned' but as a system whose restoration reorganizes the surrounding industrial and residential fabric. Benedict and McMahon's (2006)[4] blue-green infrastructure (BGI) paradigm supports the co-design of constructed wetlands, bioswales, and riparian buffers with pedestrian movement and community programme. Kadlec and Wallace (2009)[6] provide the technical foundation for the water treatment strategy: sequential surface flow (SF) to subsurface flow (SSF) to deep polishing pond configurations achieve 85–95% BOD reduction and 90–98% TSS reduction within 18–36 months in tropical climates. Species selection draws on published tropical wetland performance data of Typha latifolia and Phragmites australis as primary emergent macrophytes; Canna indica for Chromium and Lead absorption; Vallisneria spiralis and Hydrilla verticillata for submerged aquatic oxygenation.

5. THE DESIGN FRAMEWORK: COMPREHENSIVE LANDSCAPE DEVELOPMENT PLAN

The CLDP comprises thirteen zones across the Shivapura Lake site, developed at 1:1000 scale (Figure 1). Each zone performs both an ecological treatment function and a community or habitat programme function.

Fig -2: Comprehensive Landscape Development Plan (CLDP), Shivapura Lake, Peenya. 1:1000. Zones 1–13 shown with material legend and zone key notes.

Table -2: CLDP 13-Zone Structure with ecological and programme functions.

Zone	Name	Function
1	Northern Lake and Habitat	Designed habitat lake; submerged macrophytes; floating pavilion; minimal public access
2	Biodiversity / Ecological Park	Low-disturbance native planting; avifaunal and invertebrate recovery
3	Community Gathering Plaza	Active civic space at ecological-community interface; shade trees; seating
4	Sports and Community Zone	Active recreation; perimeter bioswale; permeable paving
5	Parking and Entry Plaza	200-car/100-bike/50-cycle parking; permeable paving; shaded pedestrian walkway
6	Main Lake and Wetland Edge	Primary public-lake interface; emergent macrophyte edge; boardwalk
7	Phytoremediation Belt	Typha, Phragmites, Canna indica, Cyperus; pollutant uptake; edge stabilization
8	Boardwalk and Deck	Main jetty at +0.15m; lake-surface access; interpretation nodes
9	Rain Garden and Bioswale	Fresh water inlet; rain garden; bioswale pre-treatment; recharge zone
10	ETP and Constructed Wetland	Heavy metal and BOD pre-treatment at eastern sewage inlet
11 – 12	Future Development / Non-Built	Green buffer; ecological recovery; stormwater retention reserve
13	Bio-Retention Step Well	16m × 17m vav reinterpretation; stormwater capture; open gym integration

The material palette specifies permeable paving throughout active community zones to reduce impervious surface area and improve stormwater infiltration. Softscape integrates native meadows, amenity turf, and bioswales with five graded lake-edge planting zones, transitioning from terrestrial buffers through emergent macrophytes to submerged aquatic communities.

6. PLANTING DESIGN

These plants fall under four categories: terrestrial (land), which helps remove the air toxins. aquatic (on/in water), floating and submerged. Each group of plants serves an important function. Canna indica and Cyperus remove metal contaminants from the water; Lotus and Water Lily enrich the lake's habitat for fauna and enhance both water and air quality.

7. LAKE EDGE TECHNICAL SECTIONS

Two lake edge cross-sections establish the construction logic under two conditions: the phytoremediation bund section AA' (primary eastern edge facing the industrial zone), and the bio-remediation wetland edge section BB' (northern habitat lake).

7.1 Lake Edge Phytoremediation Section

- Zone 1- Bund Crown 3.0m with PICP surface to 80mm over 100mm open-graded crushed rock and geotextile filter fabric for pedestrian use and water filtration;
- Zone 2- Bio-Engineered Incline 6.0m with coir geotextile matting 50mm, root-zone growth matrix 250mm at 1:1.5 slope planted with Vetiver and Typha;
- Zone 3- Maintenance and Silt Bench 2.0m with semi-aquatic plants with 1:50 inward back-fall with filter drain;
- Zone 4- Littoral Macrophyte Slope 5.52m with Vetiver and Typha at 1:2 slope with seasonal water level variation of ±6.8m to ±4.8m;
- Zone 5- Rock Rip-Rap Toe Anchor 1.0m with 300-450mm boulders to stabilize toe of lake bed against scour.

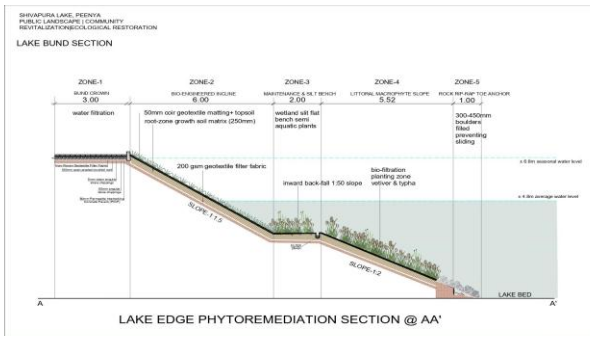

Fig -3: Lake Edge Phytoremediation Section AA'. Five-zone construction detail at 1:50. Primary eastern edge of Shivapura Lake.

7.2 Lake Bio-Remediation Wetland Edge

The BB' section (northern habitat lake, Zone 1) employs three zones with a shallower, more naturalistic profile: Zone 1- Bund Crown, 3.0m, with 700 gsm coir mesh, Vetiver stabilization, and PICP surface; Zone 2- Shallow Littoral Shelf, 2.0m, with Canna indica and Typha at 1:3 slope and seasonal water level ±2.5m to ±2.0m, creating marginal habitat for amphibious species and wading bird foraging; Zone 3- Lake Bed Zone, 4.0m each side, with 300mm organic mud and 200mm bentonite clay liner for independent water level management. The two sections demonstrate a consistent design principle: different edge conditions require different technical responses, but all edges replace concrete with graduated ecological transitions performing both water quality and biodiversity functions simultaneously.

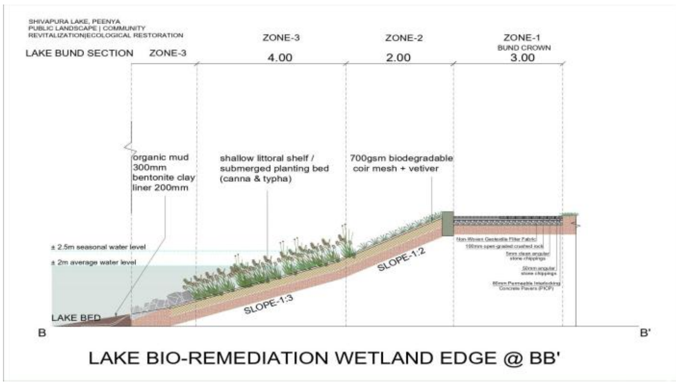

Fig -4: Lake Bio-Remediation Wetland Edge BB'. Three-zone construction detail at 1:50. Northern habitat lake edge of Shivapura Lake.

8. BIO-RETENTION STEP WELL PLAZA

The bio-retention step well plaza (Zone 13) represents the cultural ecological synthesis at the heart of the Shivapura proposal. The traditional Indian vav combined functional water storage with civic programmes of its descending steps creating a gradient between the urban ground plane and the water body. The Shivapura plaza reinterprets this typology at 16m × 17m (Figure 4): descending stone tread steps lead inward to a central catchment pond; bioretention planting pockets and permeable gravel paths minimize hard runoff surfaces; ADA-accessible ramps at 1:12 slope ensure universal access.

Fig -5: Bio-Retention Step Well Plaza (Zone 13). Plan and spatial strategy. 16m x 17m. Reinterpretation of traditional Indian vav as contemporary stormwater infrastructure.

When it rains a lot of water flows over the ground that is made to absorb it and it all goes to a tank in the middle. The water then goes through the dirt and the plants that are from here and they help make the water clean before it goes into the ground or comes out slowly through special pipes. When it is not raining the area is really quiet and nice so people can go there to think or have parties with their community. The design embodies the dual mandate of the proposal of measurable stormwater management performance and democratic public space for surrounding industrial worker communities currently without comparable open space within walkable distance.

9. PRECEDENT ANALYSIS

Table -3: Precedent analysis of design influence and key technical transfer to Shivapura CLDP.

Precedent	Design Influence	Key Transfer to Shivapura
Jakkur Lake, Bengaluru (40%)	STP + wetland + community fisheries in tropical urban context	15 MLD STP; wetland entry-point filtration; fish harvesting for biomass control
Erhai Lake, Yunnan, China (25%)	900 ha wetlands remove 1.16M kg COD/yr; multi-stage riparian buffer	3-stage buffer: 30m agricultural → 50m wetland → 20m lakeshore
Flushing Meadows, USA (20%)	Multi-stage filtration; Typha/Phragmites phytoremediation	Settling basin → gravel/reed bed → wetland absorption → lake entry
Al Qudra Lakes,	TSE water source; lined	Lined habitat lake (BB'); aeration; eco-

Precedent	Design Influence	Key Transfer to Shivapura
Dubai (15%)	lakes; reed-bed flocculants; nanobubble aeration	tourism maintenance model

Shivapura's combined industrial heavy-metal and high-fecal-coliform profile most closely resembles Jakkur Lake, confirming the Jakkur STP-wetland model as the primary technical reference. Habitat function targets encoded in the CLDP zone sizing are drawn from the Erhai and Flushing Meadows precedents: 20,000 sqm edge habitat area, 60% optimal open water ratio, and 18% wetland cover.

10. DISCUSSION

10.1 The Design as Spatial Knowledge

The central argument of this paper is that a rigorously developed landscape design proposal constitutes a legitimate and necessary form of knowledge production in urban ecological restoration. The gap in the literature on Indian industrial urban lake remediation is not primarily analytical of the ecological crisis is well-documented. It is spatial and technical: the translation of policy mandate and ecological science into a spatially explicit, constructible design that resolves the specific conflicts between industrial contamination, community programme, governance, and ecological habitat at a real site.

The Shivapura CLDP makes this translation explicit. Locating the ETP plant at the eastern sewage inlet reflects the contamination gradient analysis, available buffer land, and vehicle access requirements. Siting the bio-retention step well at the fresh water inlet reflects both hydraulic logic and the cultural logic of creating civic water infrastructure at the point of clean water entry of decisions that no ecological engineering or policy document alone would generate.

10.2 REPLICABILITY AND LIMITATIONS

The 13-zone CLDP is designed for modularity. For the majority of Bengaluru's 181 severely degraded lakes of where domestic sewage rather than industrial effluent is the primary contamination source of the ETP pre-treatment cell (Zone 10) can be replaced with a simpler STP-wetland integration on the Jakkur model. The phytoremediation belt, rain garden and bioswale network, bio-retention step well, and community programme zones are transferable to virtually any degraded urban lake in peninsular India with minimal site-specific modification. The 25-species planting palette uses only native or naturalized tropical species widely available in Karnataka.

This paper presents a design proposal grounded in secondary data. Primary ecological baseline surveys and hydraulic loading calculations for the ETP and constructed wetland have not been conducted and are required before implementation. Future research directions include primary ecological baseline survey; hydraulic modelling for the treatment wetland system; structured community engagement; and longitudinal monitoring of comparable Bengaluru lake restorations.

11. CONCLUSION

This paper has presented a 13-zone Comprehensive Landscape Development Plan for the ecological remediation and community revitalization of Shivapura Lake in Peenya Industrial Area, Bengaluru. Grounded in published secondary ecological data, engineering precedents, and four case studies, the proposal demonstrates how landscape architecture can serve as the primary instrument of ecological repair and democratic public space creation in a severely degraded industrial urban context.

The design's three most significant contributions are: first, the integration of ETP pre-treatment and constructed wetland cells at the sewage inlet as the non-negotiable first intervention; second, the 25-species native planting strategy establishing five distinct zones from terrestrial buffer through emergent macrophyte to submerged aquatic; and third, the bio-retention step well plaza reinterpreting the traditional Indian vav as contemporary stormwater infrastructure of combining measurable ecological performance with democratic civic space in a single design element. The spatial knowledge embodied in this design of and the replicable framework it offers of is the primary contribution this paper makes to the literature on urban degraded lakes in an industrial landscape setting.

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