ENHANCEMENT OF A RIVER ISLAND IN PUNE

MASTERS OF LANDSCAPE ARCHITECTURE

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2015MLA009

SCHOOL OF PLANNING AND ARCHITECTURE, BHOPAL

NEELBAD ROAD, BHAURI, BHOPAL - 462030

MAY, 2017

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ACKNOWLEDGEMENTS

The writing of this thesis report has been one of the most significant academic challenges I had to face. Without the support, patience and guidance of the following people, this study would not have been completed. It is to them that I owe my deepest gratitude:

- Ar. Sonal Tiwari (Thesis Guide), who under took the act of my advisor despite his many other academic and professional commitments. Her wisdom, knowledge and commitment to the highest standards inspired and motivated me.
- Ar. Saurabh Popli (Program Co-ordinator), whose guidance and valuable words were instrumental in my perceiving things in a logical manner and formulating the direction for this study.
- Prof. Savita Raje, Ar. Varsha Gavande, whose inspirational words were instrumental in guiding my thoughts and ideas towards completion.
- My friends Steffi Sharma, Nazeem Shaikh and other batch mates, who despite working on their thesis, were present to motivate and push me forward during times when completing my thesis seemed far-fetched.
- My parents for their encouragement and profound understanding.

UNDERTAKING

I "*Manavraaj Yadav, 2015MLA009, Masters of Landscape Architecture*" have prepared a report titled "*Enhancement of a River Island in Pune*" under the guidance of "*Ar. Sonal Tiwari*" for the purpose of in partial fulfillment of condition of masters of landscape architecture program at School of Planning and Architecture, Bhopal.

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ABSTRACT

Most of the ancient cities in India grew along rivers, seeking proximity to a perennial source of clean water. Early agrarian based societies and trading societies needed this close proximity for irrigation of crops standing on fields and navigation of boats and barges ferrying goods along the river ways. Water was celebrated; represented in social, cultural and religious symbolism.

The river bank seems to have been forgotten by the citizens at large, seen as a smelly stinky part of the city. The horizontal gradient and geology of the river bank creates the phenomenon of annual flooding during the monsoons (rainy season) and also the ever present risk of flash floods. The unwanted and the forgotten river bank is the shelter for the poor and disadvantaged sections of the society. The river banks come alive only on the occasion of the festival of Ganesh Chaturthi.

Naik Environment Research Institute Ltd. (NERIL), a professionally managed progressive firm providing services in environmental conservation, water resource management, environmental impact assessment, preparation of environmental management plans, ecotourism, preparation of diversion of forestland proposals.
The NERIL plan proposes channelization of the river bed to achieve stable and constant water flows (accounting for seasonal variations in rainy Monsoon and dry summer months). This plan is linked with the existing attempts by the municipality under the National Urban Regeneration Scheme, which shall be financed partially by Central and partly by State government funds.

सार

भारत के अधिकांश प्राचीन शहरों में नदियों के साथ बढ़ते हुए, स्वच्छ पानी के एक बारहमासी स्रोत की निकटता की तलाश में। प्रारंभिक कृषि आधारित समाजों और व्यापारिक समाजों को खेतों पर खड़े फसलों के सिंचाई के लिए निकटता की जरूरत थी और नौकाओं और नदी के किनारों पर सामानों को लेकर जहाजों की नौवहन की आवश्यकता थी। जल मनाया गया; सामाजिक, सांस्कृतिक और धार्मिक प्रतीकात्मकता में प्रतिनिधित्व

लगता है कि नदी के किनारे बड़े पैमाने पर नागरिकों द्वारा भूल गए हैं, जो शहर के बदबूदार बदबूदार भाग के रूप में देखा गया है। नदी बैंक के क्षैतिज ढाल और भूविज्ञान मॉनसून (बरसात के मौसम) के दौरान वार्षिक बाढ़ की घटना और भी बाढ़ के बाढ़ के वर्तमान खतरे को बनाता है। अवांछित और भूल नदी बैंक समाज के गरीब और वंचित वर्गों के लिए आश्रय है। नदी के किनारे केवल त्योहार गणेश चतुर्थी के अवसर पर ही नदी के किनारे आते हैं।

नाइक पर्यावरण अनुसंधान संस्थान लिमिटेड (एनईआरआईएल), पर्यावरण संरक्षण, जल संसाधन प्रबंधन, पर्यावरणीय प्रभाव निर्धारण, पर्यावरण प्रबंधन योजनाओं की तैयारी, इकोटोरिज्म, वनभूमि प्रस्तावों के मोड़ की तैयारी में सेवाएं देने वाली एक पेशेवर प्रबंधन वाली प्रगतिशील फर्म है। NERIL योजना स्थिर और निरंतर जल प्रवाह (बारिश मानसून और शुष्क गर्मी के महीनों में मौसमी विविधताओं के लिए लेखांकन) प्राप्त करने के लिए नदी के बिस्तर के चैनलकरण का प्रस्ताव है। इस योजना को राष्ट्रीय शहरी पुनर्जनन योजना के अंतर्गत नगरपालिका के मौजूदा प्रयासों से जोड़ा गया है, जिसका आंशिक रूप से केंद्रीय और आंशिक रूप से राज्य सरकार के निधियों द्वारा वित्तपोषित किया जाएगा।

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1. INTRODUCTION

1.1. A PHENOMENON CALLED RIVER POLLUTION

Water pollution is an acute problem in all the major rivers. Dirty water is the biggest health risk and continues to threaten both quality of life and public health. Water is known to contain a large numbers of chemical elements. The interactions of both the physical and chemical properties of water play a significant role in composition, distribution and abundance of aquatic organisms. In the wake up increasing urbanization and industrialization, the pollution of river giving momentum day by day.

With growing urbanization and industrialization India faces the challenges of providing clean and safe water to all citizens. In the name of economy growth, most rivers and streams are turning into sewers. As more and more rivers are getting polluted, the municipalities are finding it difficult to treat river water to safe levels of consumption

Fig 1: The Sources of River Pollution.

and supply it to the citizens.

Source: "Water Pollution. Cuyahoga River 1952 Point sources"

An alarming 80% of India's surface water is polluted, a latest assessment by WaterAid, an international organization working for water sanitation and hygiene, shows. The report, based on latest data from the ministry of urban development (2013), census 2011 and Central Pollution Control Board, estimates that 75-80% of water pollution by

volume is from domestic sewerage, while untreated sewerage flowing into water bodies including rivers have almost doubled in recent years.

Between 1991 and 2008, the latest period for which data is available, flow of untreated sewerage has doubled from around 12,000 million litres per day to 24,000 million litres per day in Class I and II towns.[1]

1.2. NEED & JUSTIFICATION OF THE STUDY

Water was celebrated; represented in social, cultural and religious symbolism. This physical, mental and spiritual interaction has lost its way through the times.

The need for such a study is of utmost importance in reclaiming our dwindling wetlands. The years of human abuse and carelessness has taken a toll on the water bodies leading to degradation on a rapid scale. Along with the decrease in the water table, the situation has worsened ecologically. Hence a proposal is required to generate awareness amongst the people by creating spaces where they can experience a better environment first-hand.

A riparian ecosystem is a perfect option for restoring wetlands in a natural way. Man-made alternatives for restoration projects can only do so much before failing in the long run. The outcomes of the findings from the literature studies would help in understanding the basic functioning of such ecosystems and how they can be modified according to the Indian context.

The study of the Mula Mutha river is required to understand the extent of degradation of the water quality, the reasons behind the degradation, how it has

[1] '80% of India's surface water may be polluted, report by international body says', Sushma Dey, Times of India, June 28, 2015.

affected the ecosystem around it and what all measures can be taken to reclaim this landscape.

1.3. AIMS

Following are the aims hoped to be achieved during the course of this study:

- To understand the concept and working of a riparian ecosystem, along with the relevant terminologies, functions and its participating components.
- To implement such a concept in a design proposal for a small portion of a degraded river ecosystem.

1.4. OBJECTIVES

Following are the main objectives of this thesis study:

- To understand what riparian ecosystems are along with its components, the factors which are important in sustaining such an environment and also the benefits of having such ecosystems.
- To study the parameters of assessment of healthy riparian edges in context to the delineated study region, as well as successful restoration projects as case studies.
- To identify the factors which have led to degradation of the Mula Mutha River and study in context with observations from quantitative/scientific studies.
- To study the delineated site with respects to its surroundings and identifying its strengths and weaknesses.
- To propose a design solution for the same.

1.5. METHODOLOGY

a) Identify the prospective sites with need/potential for interventions and select a suitable site along the river system. Then study about the general overview of the region the site resides in.
b) Study the extent of degradation of the river system with respect to its surroundings and participants through already conducted studies.
c) Conduct a visual study on the site and identify its key points via SWOT analysis.
d) Study examples with similar scenarios as case studies and implement important ideas as concepts for design interventions.
e) Develop a detailed design for the site with complementing suitable interventions.

2. STUDY BACKGROUND

2.1. RIPARIAN ECOSYSTEMS

'A *riparian ecosystem can be defined as the stream channel between the low- and high-water marks plus the terrestrial landscape above the high-water mark (where vegetation may be influenced by elevated water tables or extreme flooding and by the ability of the soils to hold water'* - Naiman et al. 1993.

Riparian ecosystems are found on the margins of rivers, streams, lakes, marshes, as well as the floodplains of large rivers and small streams, and in gullies. In these areas, moist soils support plant communities that are quite distinct from those of the surrounding upland areas. Riparian ecosystems can vary in width from just a few metres next to small streams with steep banks, to more than 100 metres near large rivers.

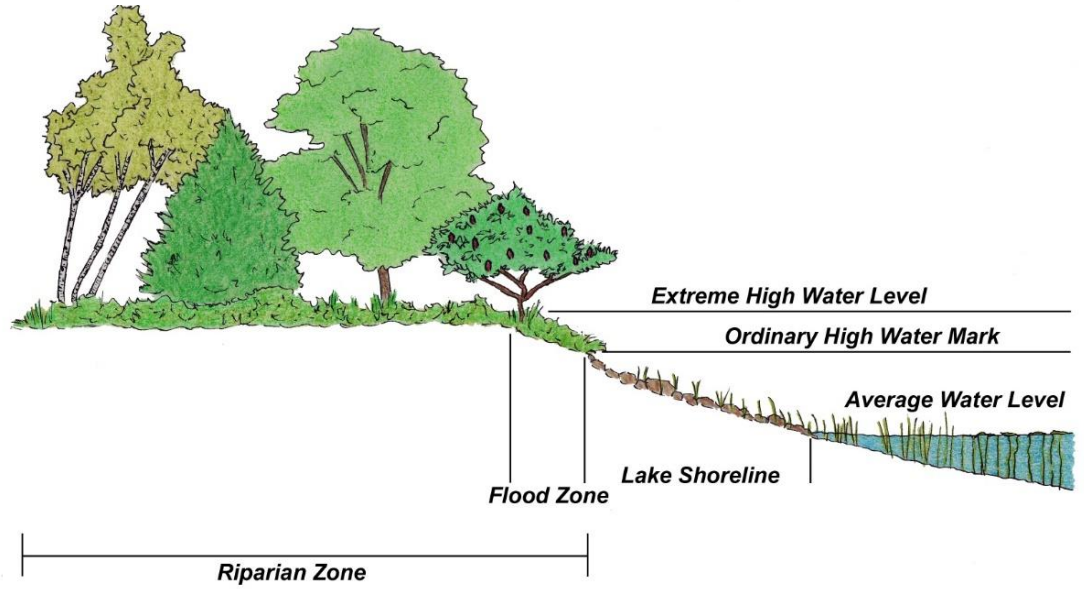
Riparian ecosystems are highly dynamic. Natural disturbances such as periodic flooding, blowdown of shallow-rooted trees and channel shifts that undercut the banks, combine to create a variety of habitat types that contribute to high levels of biodiversity. In mature riparian ecosystems, tree growth is rapid and the understorey lush and diverse.

Riparian ecosystems vary enormously. They can be divided into different 'structural stages' according to the age and form of the vegetation, ranging from gravel bars with almost no vegetation (stage 1) to old forests (stage 7).[2]

[2] A Review of the Efficiency of Buffer Strips for the Maintenance and Enhancement of Riparian Ecosystems, *By M. Brian C. Hickey and Bruce Doran*

The structural stage changes over time, as gravel bars are gradually invaded by herbs and grasses, then shrubs, and finally trees that are tolerant of seasonal inundation and flood scouring – unless a major flood removes the vegetation, leaving a bare gravel bar once more.

Fig 2: A general section of a Riparian edge.



Source: A landowner stewardship guide for species at risk in Nova Scotia.

Riparian ecosystems are important because of the following reasons:

- Riparian ecosystems boast an exceptionally high number of species for the area that they occupy. This is because they include the three critical habitat components for wildlife – water, cover and food – together with a variety of habitats found in snags, fallen logs and dense cover.

- The rich insect life provides food for birds, mammals, amphibians, reptiles and fish. In addition, the elongated shape of most riparian ecosystems maximises the amount of 'edge' habitat that creates diverse and productive environments for many species.

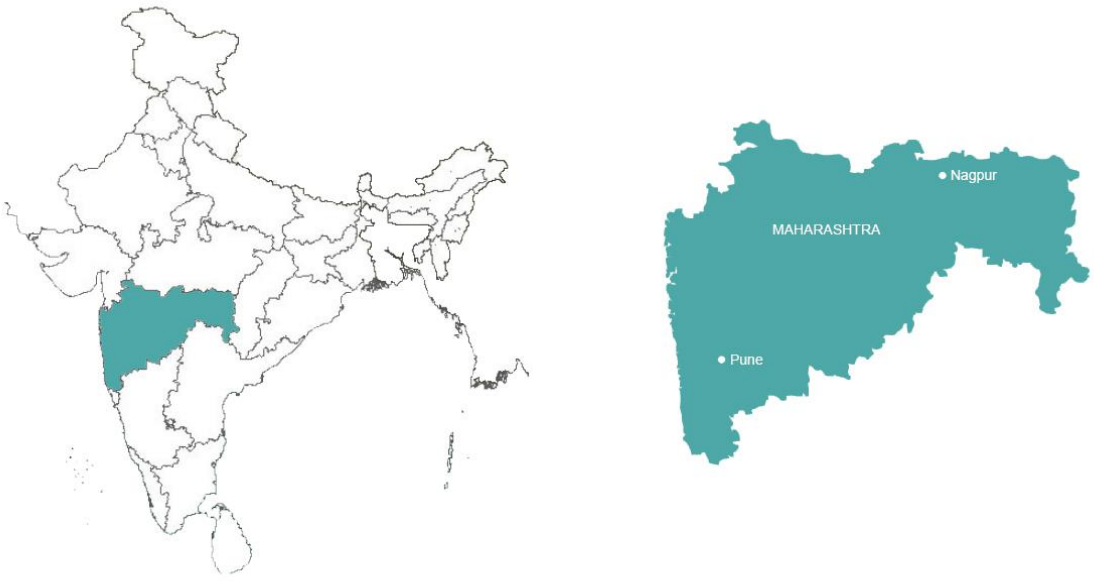
- Riparian areas help to regulate the flow of water, reducing peak storm flows by slowing or storing run-off.

2.2. CITY BACKGROUND

Pune is the ninth largest metropolis in India, and the second largest in the state of Maharashtra, after Mumbai (Bombay). Once the capital of the Maratha Empire, Pune is the administrative capital of Pune district. Pune is known by many epithets like the 'City of Virtues' in the ancient times, 'Queen of Deccan' due to its scenic beauty and rich natural resources, 'Monsoon Capital' of Bombay presidency during British Rule, 'Pensioner's Paradise' for its salubrious weather and laid back lifestyle, 'Oxford of the East' with more than a hundred educational institutes and nine universities.[3]

Pune has a growing industrial hinterland, with many information technology and automotive companies setting up factories in Pune district, and hence also called the 'IT City' and 'Detroit of India'. Pune is known for various cultural activities like classical music, spirituality, drama, sports, and literature and also called as the 'Cultural capital of Maharashtra'.

Fig.3: Pune District in context to the administrative boundaries of India.



Source: Wikipedia.org

[3] Reclaim the River, *Master of Design Thesis (MP DSD), Abhinav Gaurav (2010).*

The population of the Pune city is 3,124,458 and Pune Urban Agglomeration (Pune Metropolitan Area) is 5,057,709 as of the 2011 census. The same was about 4,485,000 in 2005. The migrating population rose from 43,900 in 2001 to 88,200 in 2005. The estimated population in 2016 for the Pune metro region is 6,226,959. According to the Pune Municipal Corporation, 40% of the population lived in slums in 2001. The sharp increase in censorial decade of 1991–2001 can be attributed to the absorption of 38 fringe villages into the city.

The average literacy rate of Pune was 86.15 in 2011 compared to 80.45 in 2001. Marathi is the official and most widely spoken language, while English and Hindi are understood by a significant part of the population. Since Pune is a major industrial metropolis, it has attracted migrants from all parts of India to come and settle here

2.3. CITY GEOGRAPHY

Pune is located 560 m (1,840 ft) above sea level on the western margin of the Deccan plateau. It is situated on the leeward side of the Sahyadri mountain range (the Western Ghats), which separate it from the Arabian Sea. It is a relatively hilly city, with its tallest hill, Vetal Hill, rising to 800 metres (2,600 ft) above sea level. Central Pune is located at the confluence of the Mula and Mutha rivers. The Pavana and Indrayani rivers, tributaries of the Bhima River, traverse the northwestern outskirts of metropolitan Pune.

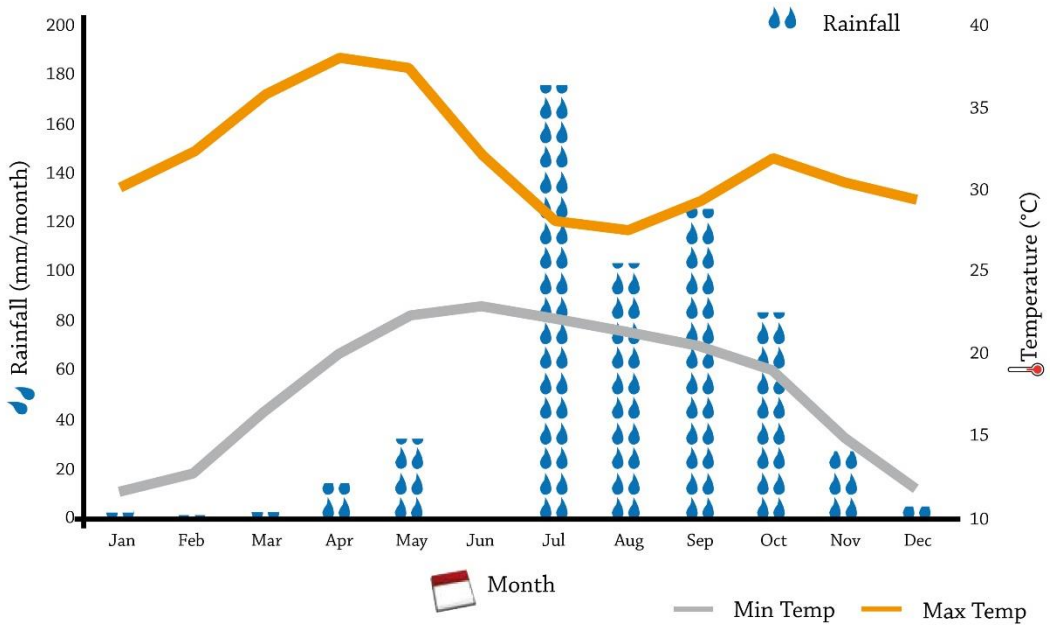
Pune lies very close to the seismically active zone around Koyna Dam, about 100 km (62 mi) south of the city, and has been rated in Zone 3 (on a scale of 2 to 5, with 5 being the most prone to earthquakes) by the India Meteorological Department. Pune has experienced some moderate- and many low-intensity earthquakes in its history.[4]

[4] Reclaim the River, *Master of Design Thesis (MP DSD), Abhinav Gaurav (2010).*

2.4. CITY CLIMATE

Pune has a tropical wet and dry climate with average temperatures ranging between 20 to 28 °C. Pune experiences three distinct seasons: summer, monsoon and winter. Typical summer months are from March to May. Even during the hottest months, the nights are usually cool due to Pune's high altitude. The monsoon lasts from June to October, with moderate rainfall and temperatures. Most of the 722 mm of annual rainfall in the city fall between June and September, and July is the wettest month of the year.

Fig.4: Mean Annual Cycles of Rainfall and Temperature at Pune



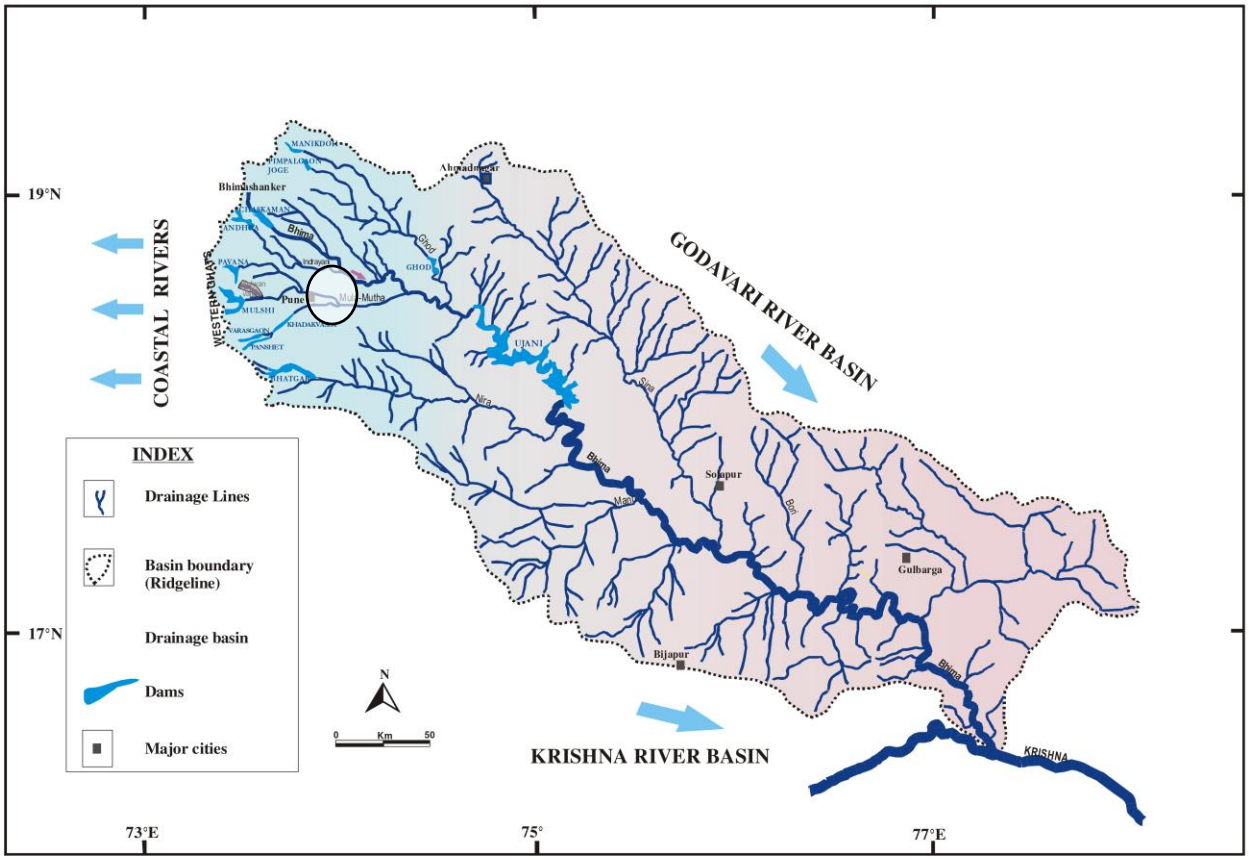
Source: Reclaim the River 2010, Chalmer's Institute of Technology, Sweden

2.5. THE CITY'S RIVER

The rivers Mula and Mutha form an integral part of the city's existence and identity. Like all the cities which grew along the river, Pune too developed from a small agricultural settlement Punnaka sometime around the 8th century AD. [5]

[5] https://en.wikipedia.org/wiki/Pune

Fig.5: The Bhima sub-basin which is a part of the Krishna River basin.



Source: WRIS Report for Bhima Basin.

The origins of both the rivers are separate, as Mula originates from the overflow of the Mulshi Lake, whereas the Mutha originates from Khadakwasla Reservoir. The rivers meet to form the Mula-Mutha near Sangamwadi and flow as one to meet the river Bhima towards east. Bhima in turn flows ahead to meet the river Krishna.

2.6. EXTENT OF DEGRADATION

Over the past decades, the biota of the region has deteriorated due to the pollution loads from the domestic, agricultural and industrial sources. Studies enumerating the floral species show a decline of 244 species in the last four decades. Simultaneously there has been an increase in Pollution tolerant bio indicator hydrophytes are present e.g. *Eichornia crassipes* (Water hyacinth), *Typha latifolia* (Broadleaf cattail) and *Ipomea carnea* (Besharam).

Studies enumerating the avifauna; birds along the rivers, streams and lakes; show a decline of 25 species in the last two decades. Aquatic fauna studies indicate that the total number of fish species observed in 1964 were 110. In 1995, they were reduced to 83. By 2002, they were 65 (23 were abundant, 31 common, 6 occasional, 5 rare) and 18 had become extinct. Increased presence of pollution tolerant birds like little cormorant (*Phalacrocorax niger*) and black winged stilt (*Himantopus himantopus*). Bivalve species preferring unpolluted water are now being replaced by pollution tolerant snail, *Bellamya bengalensis*.

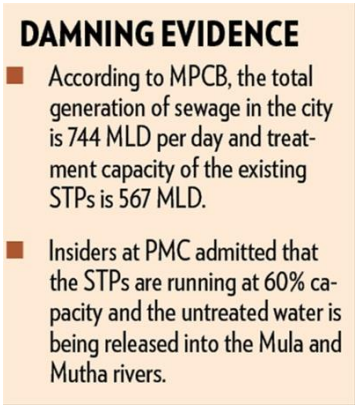
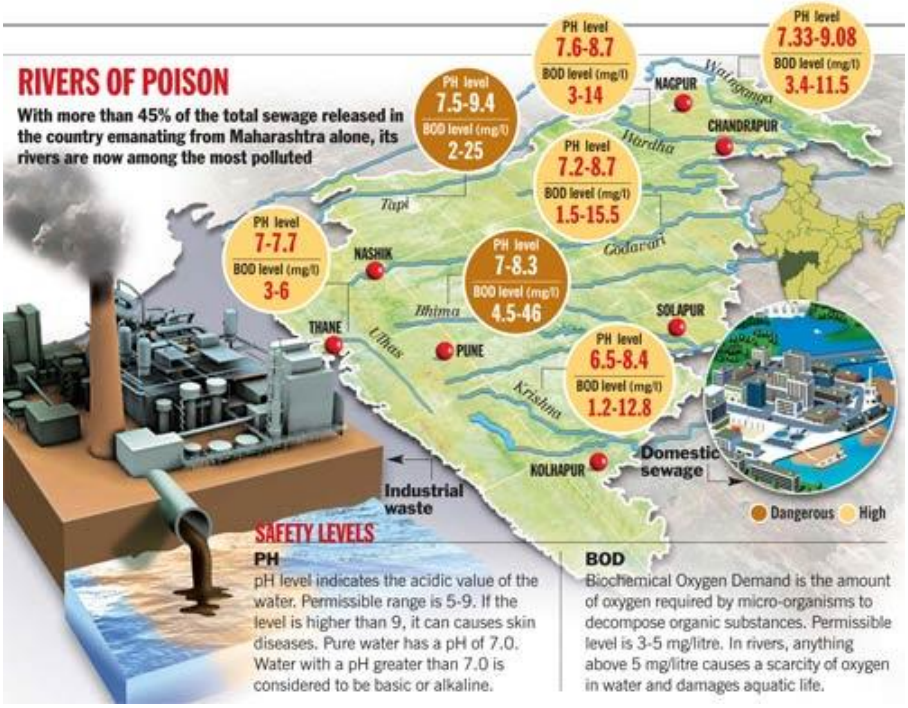


Fig 6: Local newspaper articles citing the adverse effects of pollution in the city as well the entire state.

Source: Hindustan Times



2.7. SITE SELECTION/ STUDY AREA

The area chosen for the study is a pair of river islands, where river Mula meets the river Mutha. The island is roughly 1 km. by 400 mts. at the longest and the widest ends respectively, making the site area roughly around 46 acres. The northern end of the site is occupied by the Rajiv Gandhi Nagar Slum, while the southern and south-eastern sides

are dominated by Institutional complexes. The northern end is reserved for agricultural purposes as per the 1978 PMC development plan. As per the Draft Development Plan for

Fig 7: An overview of the island with respect to the surrounding urban fabric.

Source: GIS

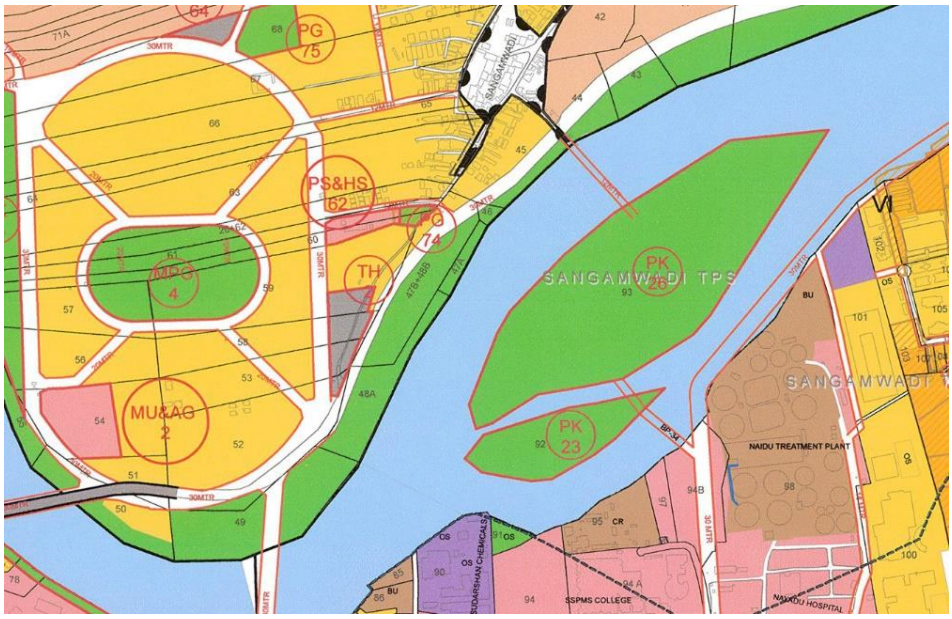


Fig 8: A blow-up of the proposed land-use map of Pune with the island designated as a recreation zone.

Source: PMC Draft Development Plan of 2007-2027.

the duration of 20 years, the islands are demarcated for recreational purposes. At present, the agricultural lands in the northern end of the site are proposed for residential development. This, along with the catchment area (judging from the surrounding land-use pattern) makes it an ideal spot for proposing a ‘nature trail park’, where people can come and unwind on a daily basis.

3. LITERATURE STUDIES

STUDY 1: A REVIEW OF THE EFFICIENCY OF BUFFER STRIPS FOR THE MAINTENANCE AND ENHANCEMENT OF RIPARIAN ECOSYSTEMS

By M. Brian C. Hickey and Bruce Doran

AIM: To understand and synthesize available literature about the effectiveness of the buffer strips.
OBJECTIVE: The authors want to convey that despite being intuitively appealing, most studies show significant nutrient removal in buffer zones undertaken in riparian buffers greater than 30 m wide.

SUMMARY:

- Buffer strips along shorelines are a central component of most non-point source pollution programs in North America. Vegetated buffer strips can mitigate the effects of agricultural and forestry activities by acting as a physical barrier to sediment, nutrients and pesticides being carried into streams.
- a buffer strip is defined as any strip of vegetation between a river, stream or creek and an adjacent upland land use activity, that is maintained for the purposes of protecting or improving water quality, or enhancing the movement of wildlife among habitat patches.
- Nitrogen can be removed by uptake into growing plants or by conversion of nitrate to nitrogen gases (NO, N2 and NO2) by denitrifying micro-organisms. Sediment-bound nitrogen can be effectively removed when riparian vegetation physically slows the movement of water allowing increased sedimentation rates.
- In contrast to the situation for nitrogen, there is no mechanism to remove phosphorus to the atmosphere (Cooper and Gilliam 1987). Phosphorus in agricultural runoff can be removed by sorption onto soil particles, by sedimentation, or through uptake by plants (Cooper and Gillian 1987).

- Buffer strips can assist in the retention of sediments, thereby reducing sediment loads to rivers and streams. Buffer strips can assist in the retention of sediments, thereby reducing sediment loads to rivers and streams.
- Studies have documented increases in stream temperatures associated with removing riparian forest. The proportion of the stream bank that is buffered by vegetation is more important than buffer width in determining effects on stream temperature (Barton et al. 1985).
- Riparian buffers may serve as corridors for dispersal among larger patches of forest habitat (Rich et al. 1994). For many area-sensitive species, buffer widths of at least 100 m are required to maintain breeding populations.

THE NEED:

Narrow buffers may reduce non-point source pollution in some situations, and even narrow buffer strips are sufficient to provide other benefits such as shading streams, thereby reducing water temperature, which is critical for some fish species.

Farmers who remove valuable land from production to establish protective buffer strips may incur significant economic losses. In order to justify these losses, more research needs to be devoted to demonstrating the efficacy of buffers of a width likely to be achieved in an agricultural setting.

STUDY 2: IMPACTS OF RIPARIAN VEGETATION ON HYDROLOGICAL PROCESSES

By Eric Tabacchi, Luc Lambs, HeÂ leÁne Guilloy, Anne-Marie Planty-Tabacchi, Etienne Muller and Henri DeÂcamps

AIM: To understand how riparian vegetation have adverse effects on hydrological processes of river channels.

OBJECTIVE: The authors study the influence of riparian vegetation on processes contributing to the water cycle in order to address theoretical and methodological difficulties in scaling up from local to regional environments.

SUMMARY:

- The main impacts of riparian vegetation on hydrological processes are briefly reviewed in order to highlight needs and perspectives for research and management goals. This review is based upon three distinct influences of riparian vegetation on hydrological processes:
    a) the control of runoff, i.e. the physical impact of living and dead plants on hydraulics
    b) the impact of plant physiology on water uptake, storage and return to the atmosphere
    c) The impact of riparian vegetation functioning on water quality.
    d) Riparian vegetation influences runoff trough complex hydraulic interactions during base flows as well as overbank flows. The contribution of fine vegetation structures to landscape hydrological roughness needs to be considered in relation to the spatial complexity (patchiness, vertical stratification, and rhizosphere) and temporal variability (phenology, succession) of plant communities.
- With the exception of some woody species, the uptake, storage and return of water to the atmosphere is poorly known for riparian communities, and therefore the assessment of the regional hydrological importance of the riparian corridor remains difficult to estimate. Although better understood than the above two influences of riparian vegetation on hydrological processes, there are still a number of unresolved issues concerning the role of riparian vegetation in controlling water quality. In particular, little is known about the coupling of microbial and vegetation functions in nutrient cycling and the dynamics of carbon release from coarse and fine plant debris.

- The influence of vegetation complexity and plant diversity on both qualitative and quantitative aspects of water cycling remains an important area for future research. Fundamental and management issues are identified in relation to the use of riparian vegetation as a model and as a tool.
- Following questions remain unanswered:
    a) The coupling between microbial and vegetation activity for nutrient filtering with respect to local groundwater pathways, to plant phenology and competition, and to local `external' factors such as the climatic setting and the level of interaction between river and groundwater.
    b) The release of organic matter to the stream from living and dead plants.
    c) The role of plant diversity in the control of nutrient dynamics at the river floodplain interface.

NEED:

The data collected helps in understanding that riparian ecosystems do decide the condition of the hydrological processes.

STUDY 3: ALTERATIONS TO RIPARIAN ECOSYSTEMS CAUSED BY RIVER REGULATION

By Christer Nilsson and Kajsa Berggren

AIM: To understand how river regulation methods alter riparian ecosystems.

OBJECTIVE: Dam operations have caused global scale ecological changes in riparian ecosystems. How to protect river environments and human needs of rivers remains one of the many important questions, which the Author wants to answer.

SUMMARY:

- A riparian ecosystem can be defined as the stream channel between the low- and high-water marks plus the terrestrial landscape above the high-water mark (where

vegetation may be influenced by elevated water tables or extreme flooding and by the ability of the soils to hold water; Naiman et al. 1993.

- Riparian ecosystems offer habitats for many species, function as filters between land and water, and serve as pathways for dispersing and migrating organisms (Naiman and Décamps 1997).
- Many environmental effects of dams are immediate and obvious. For example, dams obstruct migration pathways for fish, and reservoirs trap waterborne sediment. Other environmental effects are gradual and subtle, making them difficult to predict.

The main effects of dams on river ecosystems seem to be as follows:

- Upstream Effects:
    a) Inundation of habitats
    b) Creation of new riparian zones
- Downstream Effects:
    a) Altered hydrology and geomorphology
    b) Importance of flooding to riparian communities
    c) Salinization of the floodplains
    d) Invasion by exotic species
    e) Effects on linkages of the river

STUDY 4: STANDARDS FOR ECOLOGICALLY SUCCESSFUL RIVER RESTORATION

By M.A. Palmer, E.S. Bernhardt, J. D. Allan, P.S. Lake, G. Alexander, S. Brooks, J. Carr, S. Clayton, C. N. Dahm, J. Follstad Shah, D. L. Galat, S. G. Loss, P. Goodwin, D.D. Hart, B. Hassett, R. Jenkinson, G.M. Kondolf, R. Lave, J.L. Meyer, T.K. O'Donnell, L. Pagano and E. Sudduth.

AIM: To understand how to verify whether the river restoration projects are successful ecologically.

OBJECTIVE: The authors want to study the methods by which the past, on-going and future river restoration projects can be assessed to make them more ecologically sound in all aspects.

SUMMARY:

- Success of a restoration project is evaluated in many different ways. Cost effectiveness, stakeholder satisfaction, aesthetic pleasure, protection of important infrastructure, increase in recreation opportunities and community education about rivers, advancement in restoration science, are just some of the various parameters available throughout. However, a project must also be judged on whether the restoration is an ecological success. The 5 criteria for assessment are:
    a) **Have a Guiding Image/Statement of Objectives:** The first step in river restoration should be articulation of a guiding image that describes the dynamic, ecologically healthy river that could exist at a given site.
    b) **Ecosystems are improved:** Ecologically successful restoration will induce measurable changes in physicochemical and biological components of the target river or stream that move towards the agreed upon guiding image.
    c) **Resilience is increased:** Ecologically successful river restoration creates hydrological, geomorphological and ecological conditions that allow the restored river to be a resilient self-sustainable system, one that has the capacity for recovery from rapid change and stress.
    d) **No lasting harm:** Restoration is an intervention that causes impacts to the system, which may be extreme (e.g. channel reconfigurations). Even in such situations, an ecologically successful restoration minimizes the long-term impacts to the river.
    e) **Ecological assessment is completed:** Ecological goals for project should be clearly specified, with evidence available that post-restoration information or data were collected on the ecosystem variables of interest.
    f) The list provided is not comprehensive. The effort, cost and complexity of the evaluation process should be commensurate with the ecological risk, cost and

societal concern. Meeting these five criteria allows a restoration project to be labelled as ‘ecological restoration’.

- The process criteria can be viewed through a distinction between process and form. A restoration project is more likely to be successful if its design is based on an understanding of geomorphological and ecological processes rather than an imitation of channel forms believed to be suitable or prescribed by adherence to a classification scheme.

THE NEED:

Billions of dollars are currently spent restoring streams and rivers, yet to date there are no agreed upon standards for what constitutes ecologically beneficial stream and river restoration. Standards are needed because progress in the science and practice of river restoration has been hampered by the lack of agreed criteria for judging ecological success.

4. CASE STUDIES

The case studies aim at studying the successfully completed projects in the same context of the conducted thesis project with respect to the prevailing conditions on the respective sites and the changes after the applied interventions. Following are the case studies referred:

4.1. SHANGHAI HOUTAN PARK

Location: Huang Po River, Shanghai

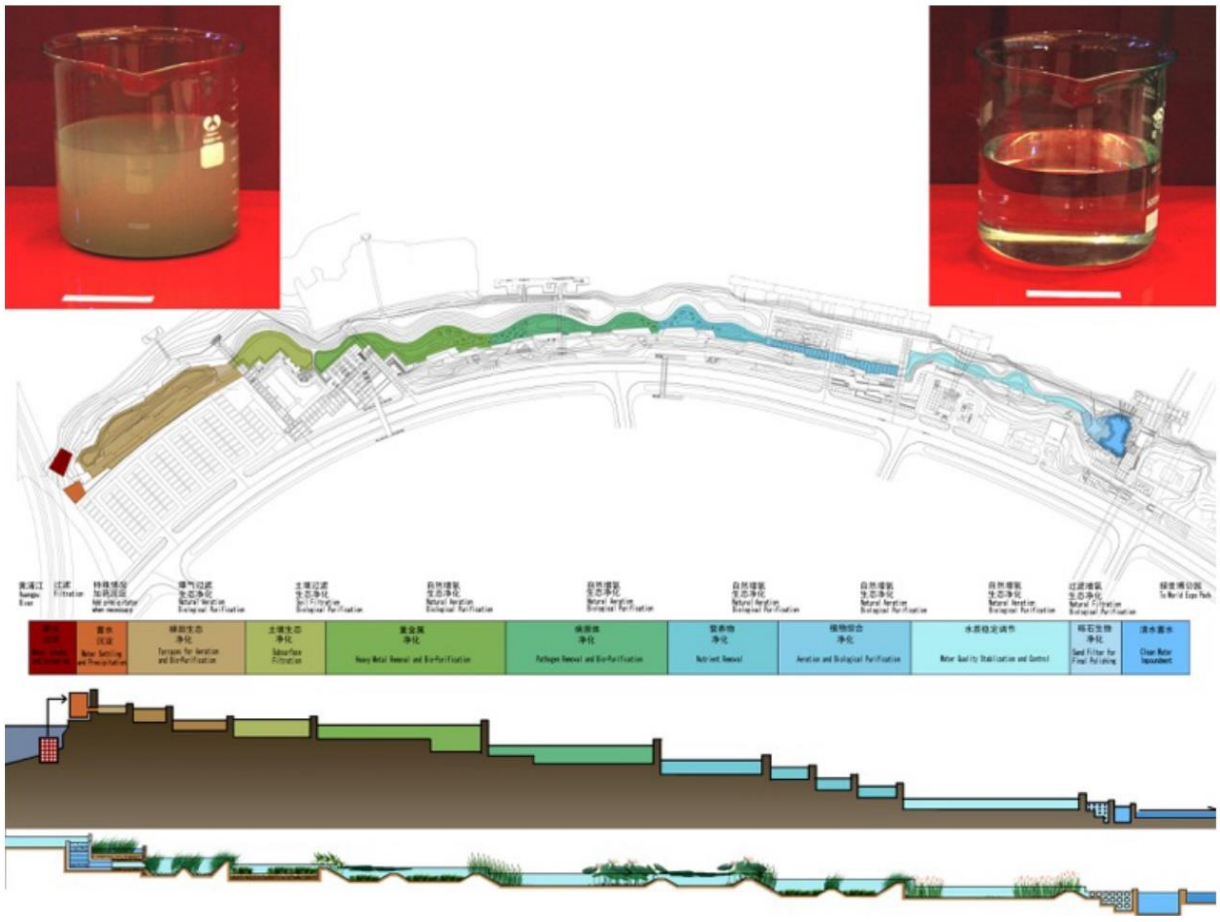
Size: 14 hectares

Timeline of Completion: 2010-15

Client: Shanghai World Expo Land Development Co., Ltd.

Landscape Architect: Turenscape

Fig 9: An overview of project with respect to the layout of the constructed wetland.



Source: www.turenscape.com

The conditions prevalent:

The site was a brownfield littered with industrial and construction debris both on the surface and buried throughout the site. The water of Huangpu River was highly polluted with a national water quality ranking of Lower Grade V, the lowest grade on a scale of I-V and is considered unsafe for swimming and recreation and devoid of aquatic life.

The existing concrete floodwall was designed to protect against a 1,000-year flood event with a top elevation of 6.7 meters, but it seemed rigid and lifeless. The 2.1 meter daily tidal fluctuation created a muddy and littered shoreline and which was inaccessible to the public.

The interventions undertaken:

The park was designed to create a green Expo that demonstrates green technologies in flood control, water treatment, and park design. Through the center of the park, a linear constructed wetland, 1.7 kilometers long and 5-30 meters wide was designed to create a reinvigorated waterfront as a living machine to treat contaminated water from the Huangpu River. Different species of wetland plants were selected and designed to absorb different pollutants from the water. Field testing indicates that 2,400 cubic meters per day of water can be treated from Lower Grade V to Grade III.[6]

The wetland also acts as a flood protection buffer between the 20 and 1000 year flood control levees. The existing concrete floodwall was replaced by a more habitat friendly

Fig 10: An overview of project with respect to the circulation and edge interaction.

Source: www.turenscape.com

[6] http://www.archdaily.com/131747/shanghai-houtan-park-turenscape

riprap that allows native species to grow along the riverbank while protecting the shoreline from erosion.

The project successfully demonstrated state-of-the-art design and construction techniques, resulting in 8 national design patents and 20-30 subsequent ecological water purification projects that employ the techniques created for Houtan Park.

Overlapped in the matrix of ecologically regenerated landscape are layers of agricultural and industrial past of the site and future of the post-industrial eco-civilization. Inspired by the fields of Chinese agricultural landscape, terraces were created to break down the 3-5 meter elevation change from the water's edge to the road, and to slow the runoff directed to the stream in the constructed wetland. These terraces are reminiscent of Shanghai's agricultural heritage prior to industrial development of the neighborhood in the mid-20th century.

4.2. BISHAN PARK

Location: Kallang River, Singapore
Size: 62 hectares
Timeline of Completion: 2009-2012
Client: PUB, Singapore's National Water Board
Landscape Architect: Atelier Dreiseitl

The conditions prevalent:

For the city state of Singapore, water autonomy is a top priority and the driver behind an island wide urban water management strategy. A tropical rainforest climate provides plenty of water, however this falls in fierce downpours which create a challenging situation in terms of flood management and water quality. The fact remains that Singapore has no other water source. The city is also densely inhabited, and the quality of urban space directly effects quality of life. Engineering of the past could be seen in the form of a utilitarian concrete channel. [7]These hard engineering systems created physical barriers

[7] http://worldlandscapearchitect.com/kallang-river-bishan-park-singapore-atelier-dreiseitl

disruptive to local communities and ecological wastelands, depriving citizens of recreational space and wasting much needed fresh water.

Fig 11: Layout of the project in context to the zoning of activities on the site.

Source: http://worldlandscapearchitect.com/kallang-river-bishan-park-singapore-atelier-dreiseitl

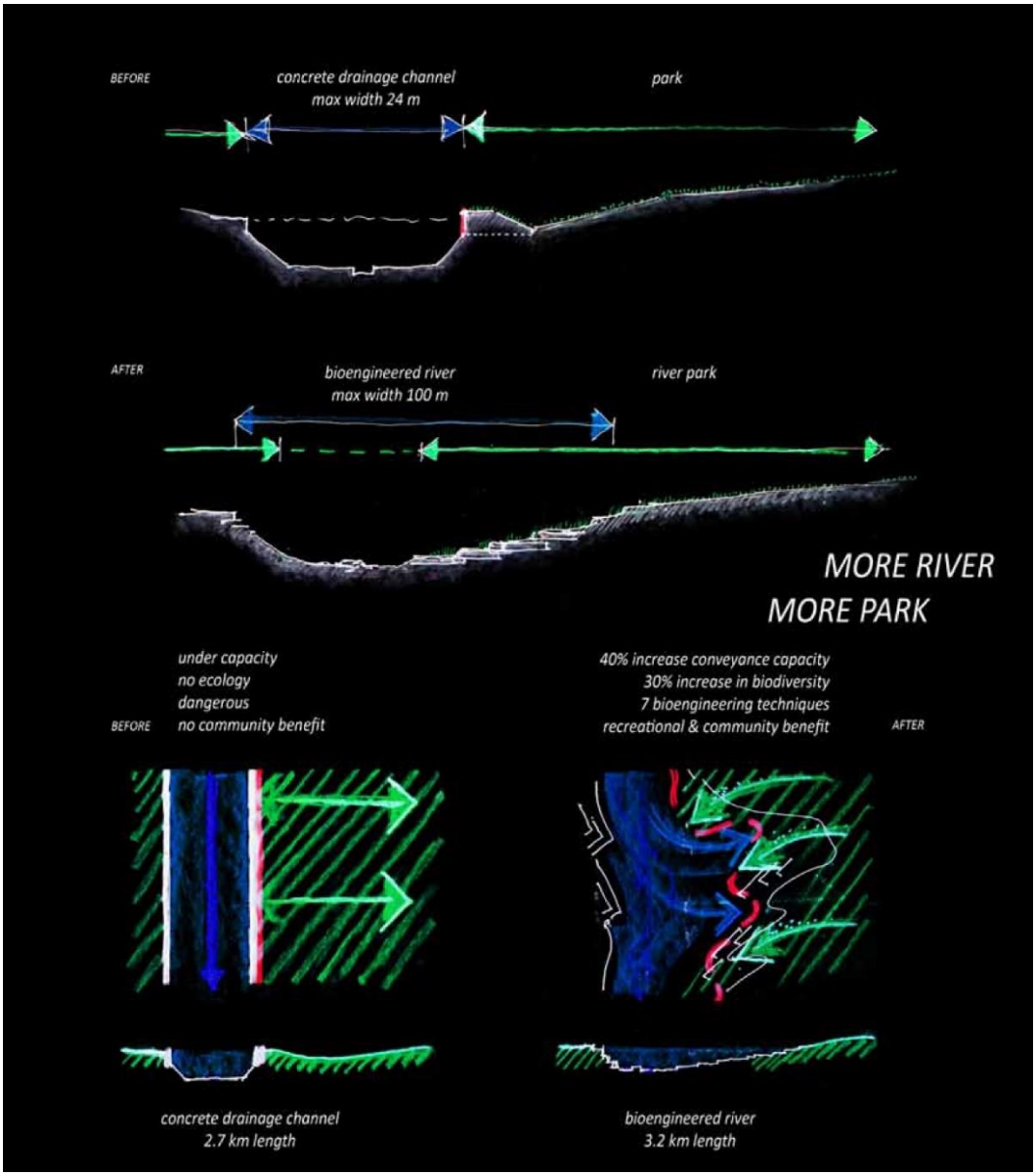
The interventions undertaken:

At Bishan Park, a 2.7 km long straight concrete drainage channel has been restored into a sinuous, natural river 3.2 km long, that meanders through the park. Sixty-two hectares of park space has been tastefully redesigned to accommodate the dynamic process of a river system which includes fluctuating water levels, while providing maximum benefit for park users.

Three playgrounds, restaurants, a new look out point constructed using the recycled walls of the old concrete channel, and plenty of open green spaces complement the natural wonder of an ecologically restored river in the heartlands of the city.

No wildlife was introduced to the park but the introduction of the naturalized river into the park has seen the park's biodiversity increase by 30%. 66 species of wildflower, 59 species of birds and 22 species of dragonfly have been identified in Bishan Park.

Fig 12: Change in cross-section cites the importance of interaction with water.



Source: http://worldlandscapearchitect.com/kallang-river-bishan-park-singapore-atelier-dreiseitl

4.3. SCHÖNEBERGER SÜDGELÄNDE PARK

Location: Berlin, Germany

Size: 18 hectares

Timeline of Completion: 2008-2009

Client: Berlin Senate, Allianz Environmental Foundation

Implemented by: Group Odious

The conditions prevalent:

For more than 70 years, the Schöneerger Südgelände was a switchyard and home to a Reichsbahn railway workshop. As a consequence of Berlin's political situation after the Second World War, rail operations were gradually suspended and then shut down for good in 1952. The land lay fallow for decades and nature gradually took over.

Nature produced an abundance and variety that astonished even nature conservationists and scientists.

In the early 1980s, however, plans were made to sacrifice the area to a new freight station and switchyard. Years of resistance mounted by citizens' groups, as well as expert appraisals attesting to the ecological value of the property, eventually won over political leaders and the administration, and the idea of a nature park was born.

Fig 13: An overview of the site.

Source: Natur-Park Südgelände: Linking Conservation and Recreation in an Abandoned Railyard, Berlin.

The interventions undertaken:

The natural forest that was able to develop here undisturbed holds a fascination of its own. The initially sparse stock of trees has become a densely wooded area with

undergrowth, and climbing vines give it the character of a primeval forest. Now the forest covers two thirds of the terrain.

The Südgelände Nature Park is characterized by an intriguing combination of nature, railway artifacts, and art. Visitors are led along walkways and paths that follow the course of the former tracks. An artists' group ODIOUS was responsible for the creative construction of the walkway. Art objects placed at special accents and enhance the grounds.

Fig 14: Boardwalks and look-outs make the site less invasive from the human visitors.

Source: Natur-Park Südgelände: Linking Conservation and Recreation in an Abandoned Railyard, Berlin.

4.4. INFERENCES FROM THE CASE STUDIES

Following are the inferences/ ideas that can be put to test in the design proposal from the conducted case studies:

a) Use of natural methods of treating water, such as constructed wetlands and floating reed beds, instead of artificial, 'life-less' STPs.

b) Constructing concrete walls along the river banks for protection against floods leads to a non-interactive edge which is harmful to the aquatic / riparian ecosystems.

c) The river island, being an ecologically sensitive area, should be subjected to minimal intervention, maybe through the use of elevated pathways/ boardwalks. Many openings can be exploited to suit visitors' needs to observe the residing avi-fauna from a safe distance.

5. SITE ANALYSIS

5.1. GEOLOGY AND GEOMORPHOLOGY

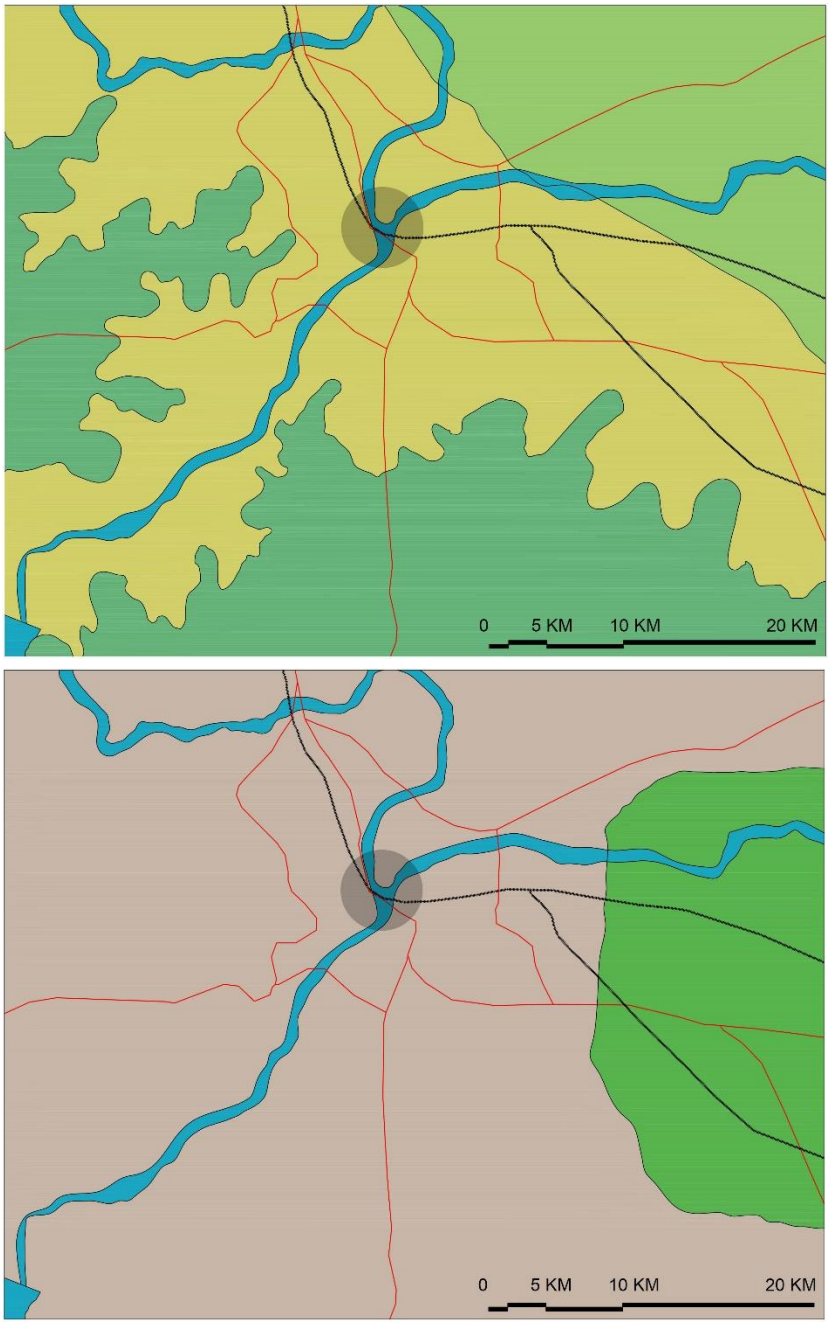


Fig 15: Geology (above) and Geomorphology (below) Maps of the City region.

Source: GIS

As according to the geological mapping of the region by GSI, most of the city as well the prospective site falls under 'compound *pahoehoe* basaltic lava flows' i.e. lava flows which are hard and compact in nature. They are fractured and jointed at places. The total

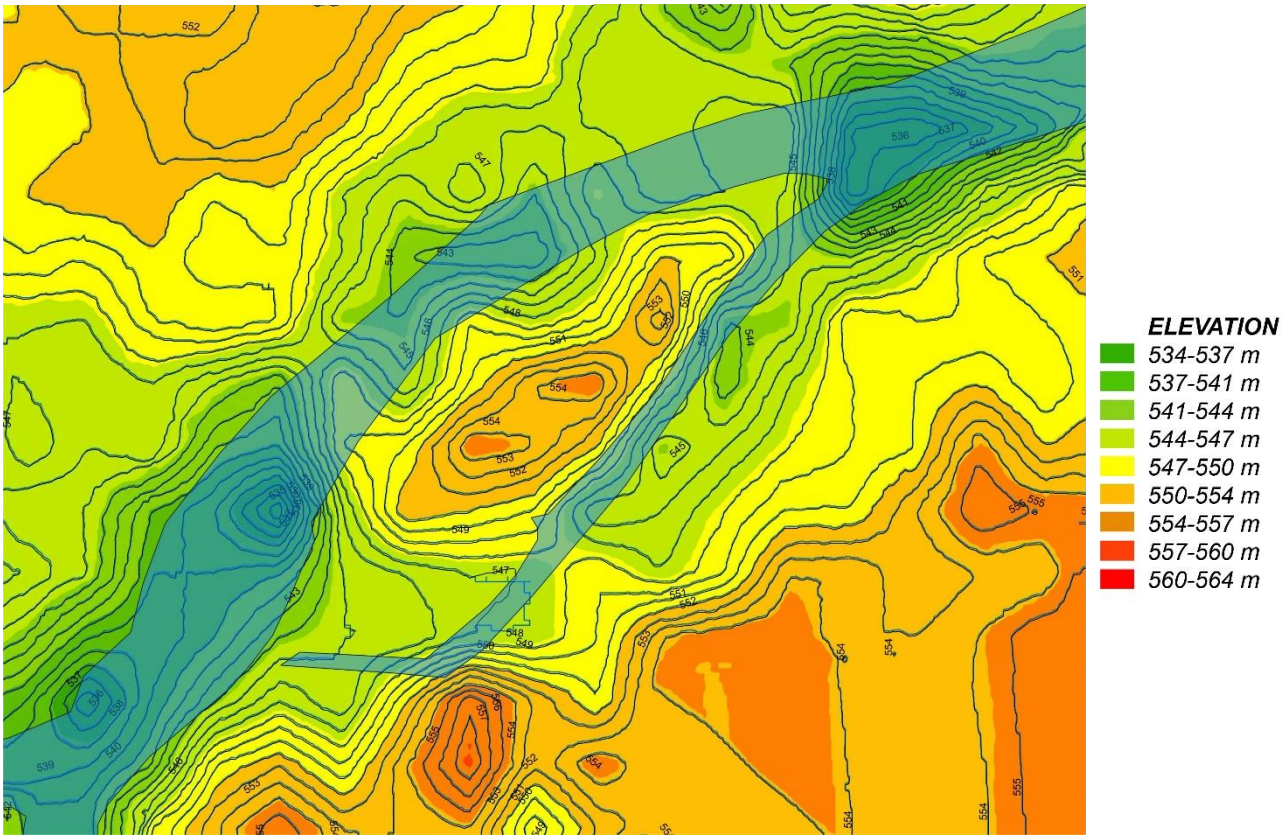
thickness of these flows as observed in and around the city of Pune is of the order of 130 m. However, at places it varies appreciably. The *Pahoehoe* flows are of compound type and individual flows cannot be traced for long distances.[8]

As per the geomorphological mapping of the region by the GSI, the average terrain of the city region is flat in comparison to the hilly region to the west of the city, with the elevation ranging from 550m to 900m, as one moves away from the city core towards the hills on the west.

5.2. ELEVATION AND SLOPE STUDY

In contrast to the geological and geomorphological studies of the city region, the elevation and the slope study was done on a smaller scale i.e. with respect to the island.

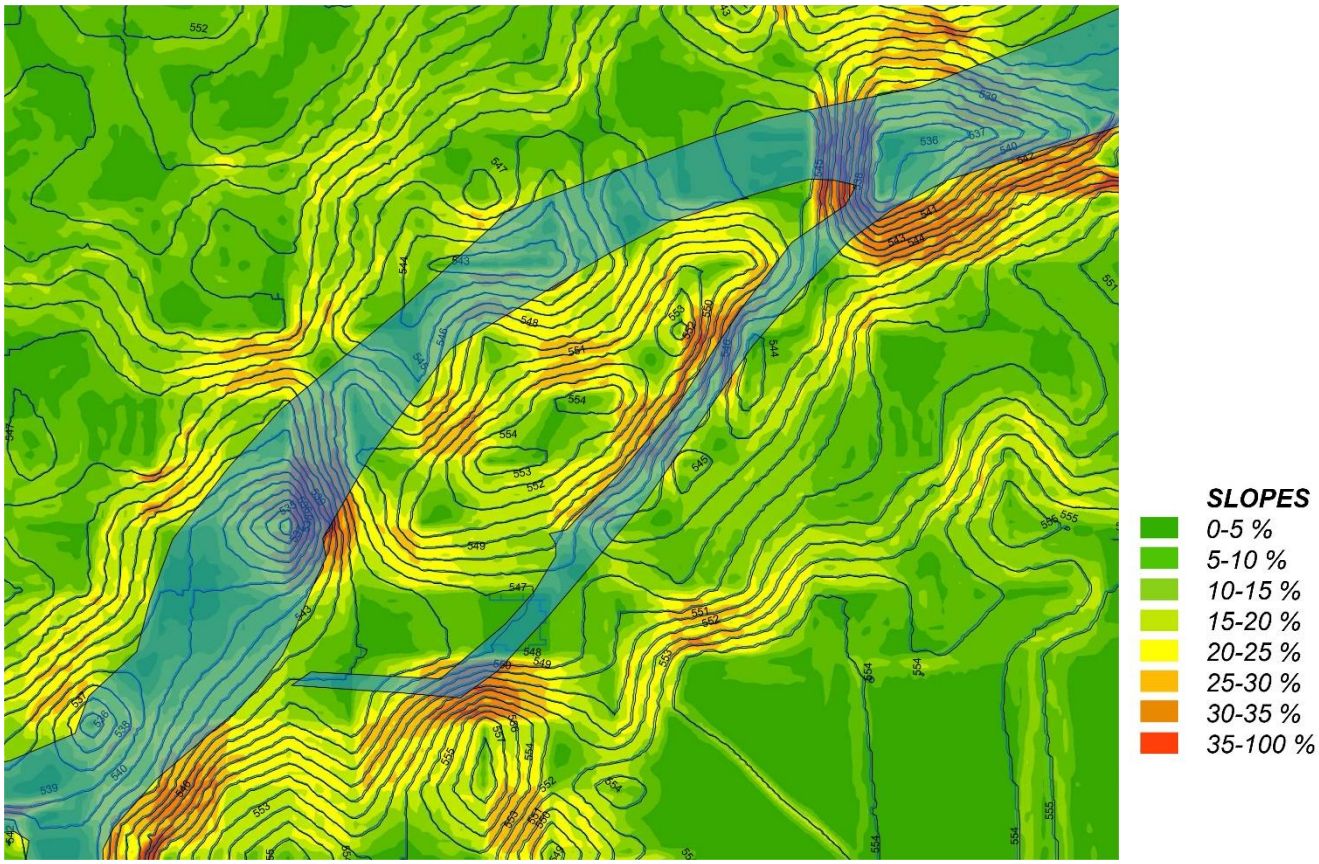
Fig 16: Elevation Map of the City region.



Source: GIS

[8] https://en.wikipedia.org/wiki/Lava

Fig 17: Slope Map of the City region.



Source: GIS

In comparison, the general elevation of Pune is around 560m from the mean sea level. The elevation study led to a conclusion that the terrain of the site majorly plain with gradual slopes. The highest point on the island is at 554m whereas the lowest point of the river bed is at 536m.

The map also provides us with the knowledge that general slope of the site ranges from 5% to 20%.

5.3. VEGETATION STUDY

Vegetation in the city:

The forest types found in Pune region is mainly dry deciduous type that is seen in various stages. It receives 900 to 1,500 mm (35 to 59 in) of rain annually. The dry deciduous

forests receive most of their rainfall with the June–September southwest monsoon, and are characterized by tall trees that drop their leaves during the dry winter and spring months. Much of the forest has been degraded through over-use, and thorn forests and shrub thickets are common.

These forests have three stories, with an upper canopy at 15–25 m (49–82 ft), an understory at 10–15 m (33–49 ft), and undergrowth at 3–5 m (9.8–16.4 ft). Trees are draped in lianas in denser, mature forests. Common species are *Acacia catechu, Albizia amara, Anogeissus latifolia, Boswellia serrata, Cassia fistula, Chloroxylon swietenia, Dalbergia latifolia, Diospyros montana, Hardwickia binata, Pterocarpus marsupium, Shorea talura, Sterospermum personatum, Terminalia belirica, Terminalia paniculata,* and *Terminalia tomentosa.*

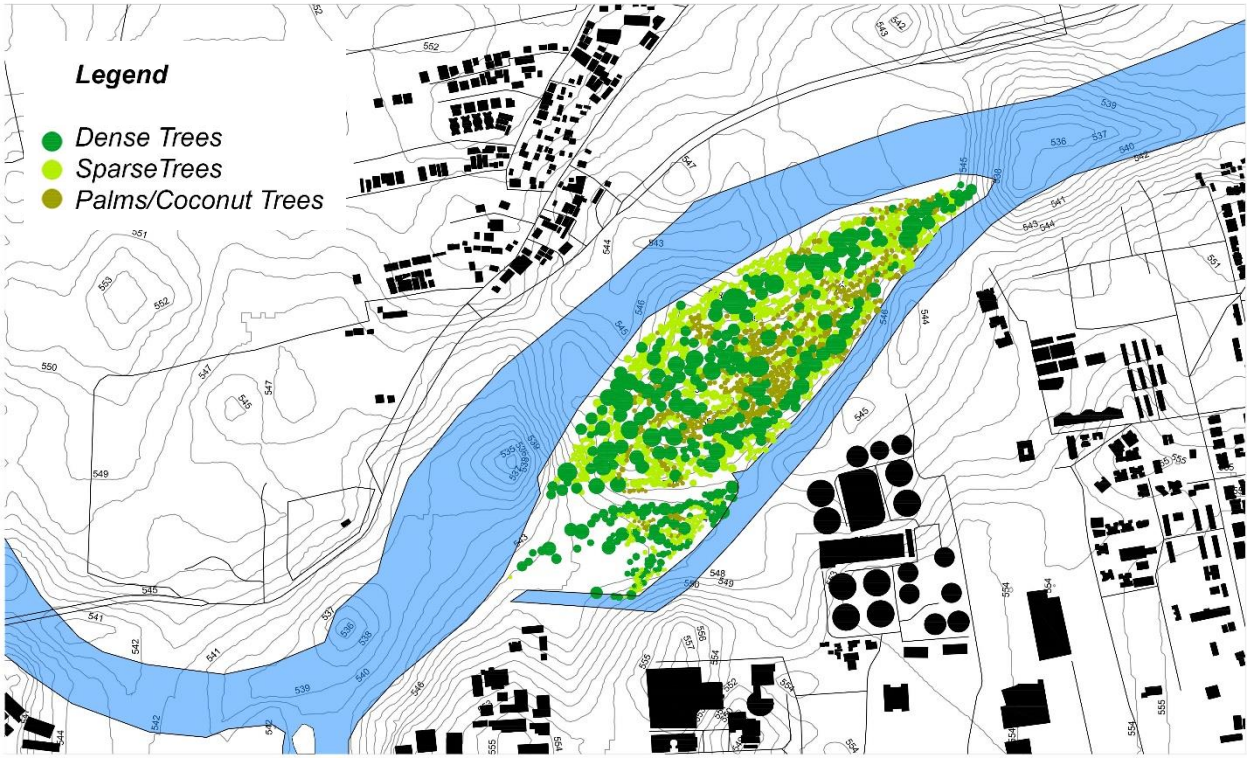
There are extensive open grass lands around Pune at Katraj, Talegaon, Shirur, but mainly in rainy season grass lasts till about January. They serve as pastures.

Vegetation on the island:

Already existing trails were noticed with trees, planted in a linear fashion on both sides. There is diversity in ‘plantation’, leading to speculations the ownership status of these river islands. Prominent vegetation includes:

a) Jungle Jalebi
b) Asoka
c) Rain tree
d) Karanj
e) Coconut
f) Peepal
g) Bamboos
h) Babool
i) Shindi

Fig 18 (above): The variety of vegetation on the island along the naturally existing trail.
Fig 19 (below): Vegetation mapping of the Island via Google Earth.



5.4. FISHES OF THE CITY

Some species were recorded from these water bodies nearly 150 years ago by Sykes during 1839-41. It appears that these species are not yet affected by pollution and associated changes in water quality. Some of the species described by Sykes are: *Garra mullya, Rohtee ogilbii, Nemachilichthys ruppelli, Proeutropiichthys takree* and *Labeo boggut* and these are still quite common in Mula Mutha.

The 'lost' 18 include large fishes like *Tor khudree, Silonia childreni, Anguilla bengalensis,*

Barilius barna, Schismatorhynchos nukta, Salmostoma clupeoides, Labeo fimbriatus, Labeo potail, Ompok pabo, Mystus gulio, Glyptothorax conirostrae poonaensis, G. lonah, and *Oreonectes evezardi.* Thus, out of a list of 62 fishes from Mula and Mutha rivers, about 30% of the fish species reported in 1940s by Hora and Misra, and Suter were not found during a survey. The current list of 62 fishes also includes 19 species that were not known in 1940s (though some of these were reported later by others). Fishes like *Rhinomugil corsula* and *Pseudosphromenus cupanus*, however, were reported for the first time.

Fig 20: (Below from left to right): **Species not affected by pollution.**
Garra mullya, Labeo boggut, Rohtee ogibii, Nemachilichthys ruppelli, Pseudotropius taakree.

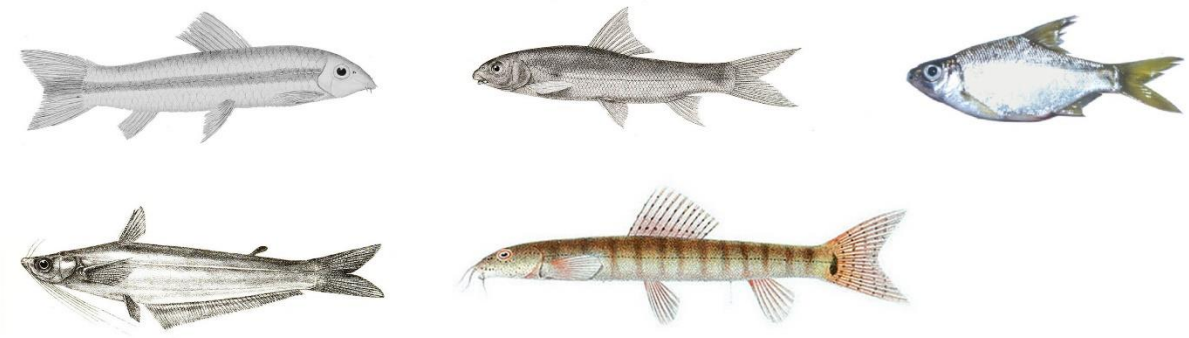
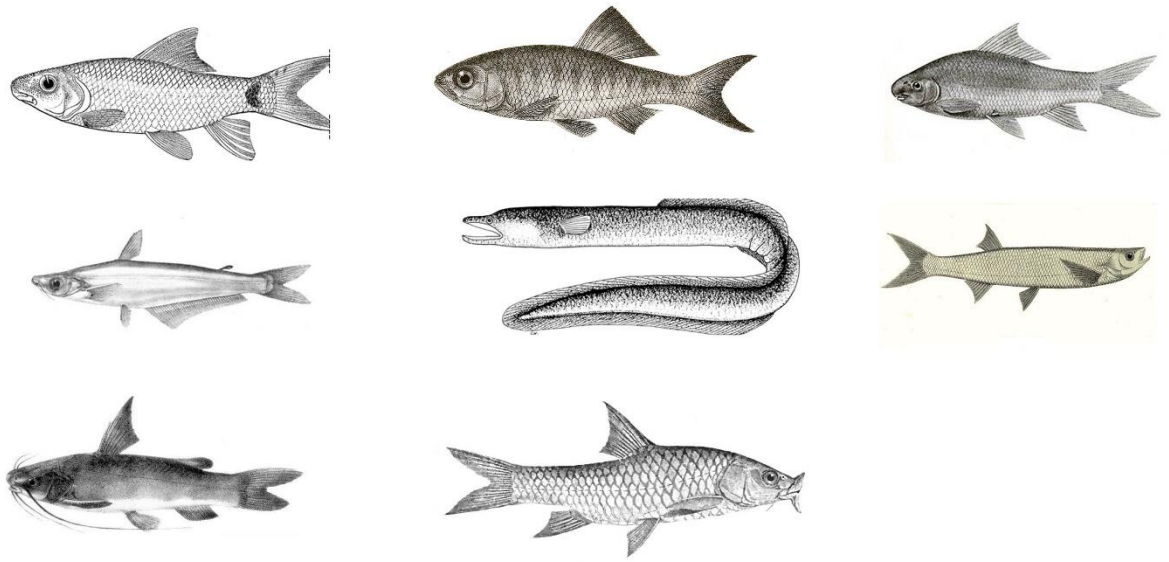


Fig 21: (Below from left to right): **Species lost.**
Labeo fimbriatus, Barilius barna, Labeo potail, Silonia childreni, Anguilla bengalensis, Salmostoma clupeoides, Mystus gulio, Tor khudree.



The main reason for this change (loss of some fish species and hence fish diversity) could be due to massive sewage and industrial pollution released into these rivers. River Mutha is so much loaded with sewage that, except during heavy monsoon rains, the flowing water is almost raw sewage. The area of the confluence of the two rivers is practically choked with decaying organic matter.

Fig 22: (Below from left to right): **Species introduced.**
Rhinomugil corsula, Pseudosphromenus cupanus, Oreochromis.

Source: Fishes of Mula and Mutha, G.K Wagh and H.V Ghate, 2002

On the other hand, river Mula passes through industrial and densely populated surroundings. As a result it is polluted with industrial effluents as well as civic wastes. Though not frequently, fish kills have been observed at many places in this river during 1976-84 (Ghate, pers. obser.).

The researchers also found the presence of vegetation such as *Hydrilla verticillata, Potamogeton* and *Vallisneria natans* choking the river.[9]

5.5. AMPHIBIANS OF THE CITY

Following is a list of the observed species in the city:

A: Bufonidae

1) Bufo melanostictus

2) Bufo microtympanum

[9] Freshwater Fish Fauna of Mula and Mutha, Pune, Maharashtra, *Case report, Zoo's Print Journal (2003).*

3) Bufo parietalis

4) Bufo stomaticus

B: Microhylidae

5) Microhyla ornata

6) Uperodon globulosus

C: Ranidae

7) Hoplobatrachus tigerinus

8) Occidozyga cyanophlyctis

9) O. hexadactyla

10) Limnonectes Limnocharis

11) Tomopterna breviceps

**12) Tomopterne sp.*

**13) Rana malabarica*

**14) Nyctibatrachus humayuni*

D: Rhacophoridae

15) Philautus bombayensis

**16) Polypedates maculatus*

Fig 23: (Below from left to right): **Species identified.**
Bufo melanostictus, Bufo parietalis, Uperodon globulosus, Microhyla ornata, Rana malabarica, Limnonectes limnocharis, Tomopterna breviceps, Hoplobatrachus tigerinus, Polypedates maculatus, Nyctibatrachus humayuni.

Source: Impact of urbanization on Amphibians of Pune, H.V Ghate and A.D Padhye, 1996

Of these enlisted amphibians, *H. tigerinus, O. cyanophlyctis, B. melanostictus* and *M. ornata* are the commonly found species. With the exception of M. ornata, the above frogs are seen practically throughout the year in suitable marshy habitats.

During the hotter period of summer, *H. tigerinus* often congregate in the moist or semi-moist beds of nullahs and streams. Unfortunately, now such areas are very few. There is a dense growth of algal mats or aquatic macrophytes like *Pistia* and *Eichhomia*. These growths have been observed to steadily reduce amphibian breeding over the last 10 years.

In a few isolated cases people have released fish species such as *Gambusia* and *Tilapia* in water bodies. These fishes have either selectively or generally eliminated amphibian eggs or tadpoles. In the case where there is only *Gambusia*, we have observed that *M. ornata* suffered the most while ranids and bufonids, continued to breed.[10]

[10] Impact of Urbanization on Amphibians of Pune, ***Zoo's Print Journal (1996).***

5.6. ODONATA IN THE CITY

A total of 287 individuals belonging to 32 species was recorded from urban areas. *Brachythemis contaminata* (Fabricius, 1793) was the dominant species with 25% of individuals followed by *Pantala flavescens* and *Orthetrum sabina* with 19% and 7% of individuals respectively. Species such as *Orthetrum glaucum* (Brauer, 1865) and *Pseudagrion decorum* (Rambur, 1842) were recorded only once.

The researchers found that across three land use types, there was a difference between the species composition and, in terms of species richness, urban habitats were the most diverse followed by forest and agricultural lands.

Fig 24: (Below from left to right): **Species identified.**
Pseudagrion rubriceps, Brachythemis contaminata, Orthetrum sabina, Trithemis aurora, Pantala flavescens, Rhyothemis variegata.

Source: Habitat and seasonal distribution of Odonata (Insecta) of Mula and Mutha river basins, Maharashtra, India, Aboli S. Kulkarni & K.A. Subramanian, 2013.

As per the researchers, following are the major odonata species found along the stream edges:

a) Pseudogrion rubriceps

b) Brachythemis contaminate

c) Orthetrum Sabina

d) Pantala flavescens

e) Rhyothemis variegate

f) Trithemis aurora

5.7. AVI-FAUNA IN THE CITY

As per the avid bird watchers of Pune, waders along rivers and streams have declined significantly. There, has not been much change in the population Egrets and common Ducks. It is suggested that rapid colonization of the riverbank and lakeshores could be the possible reason. The Little Comorant, considered to be an uncommon bird in the past, has become numerous along the banks of the river Mula-Mutha. The Blackwinged Stilt has also become numerous, especially around those spots where sewage water enters the river system. The Pied Kingfisher has declined in number, particularly along the much polluted stretch of the Mula-Mutha, where the turbid waters prevent it from fishing. The carpets of water hyacinths has also forced this species of kingfisher to move and establish its habitat elsewhere.[11]

As per the researcher's sources, the following species of avifauna are hunted and poached:

1. Herons
2. Waterhens
3. Grebes
4. Shanks
5. Flamingoes
6. Storks
7. Cranes

[11] Bird Diversity changes of Pune Urban Area, *Journal of Ecological Society, Vol.13-14(2000-2001).*

Fig 25: (below from left to right): **Species identified.**
Actitis hypoleucos, Gallinago gallinago, Ceryle rudis, Egretta garzetta, Microcarbo niger, Ardea cinerea, Ciconia episcopus, Amaurornis phoenicurus, Alcedo atthis.

Source: Bird Diversity changes of Pune, S. Nalavade and S. Dhole, Journal of Ecological Society, 2000-2001.

5.8. PHYSIO-CHEMICAL ANALYSIS OF THE RIVER

The pollution load into river Mula-Mutha has been increased due to rapid growth of Pune city both in urban and industrial areas. The Pavana River carries waste materials like sewage and industrial waste from Pimpri-Chinchwad Municipal Corporation. Industrial area is having industries like Hindustan antibiotics, Telco, Bajaj auto, Paper mills and others hundreds of small scale industries. The Mula River carries wastes from the west part of Pune city and both rivers confluence at Dapodi. Mutha River and its tributaries like Ambilvoda are more polluted than the Mula River, carrying waste material from remaining part of the city. Thereafter, these two rivers were confluence at Shivajinagar. [12]

[12] The Seasonal Fluctuation of Physico-Chemical parameters of River Mula- Mutha at Pune, India and their Impact on Fish Biodiversity, *Research Journal of Animal, Veterinary and Fishery Sciences, Vol. 1(1), 11-16, February (2013)*

Table 1: Physiochemical composition of the river Mula-Mutha.

Physico-chemical characteristics of water of Mula-Mutha at various sampling stations in year- 2004

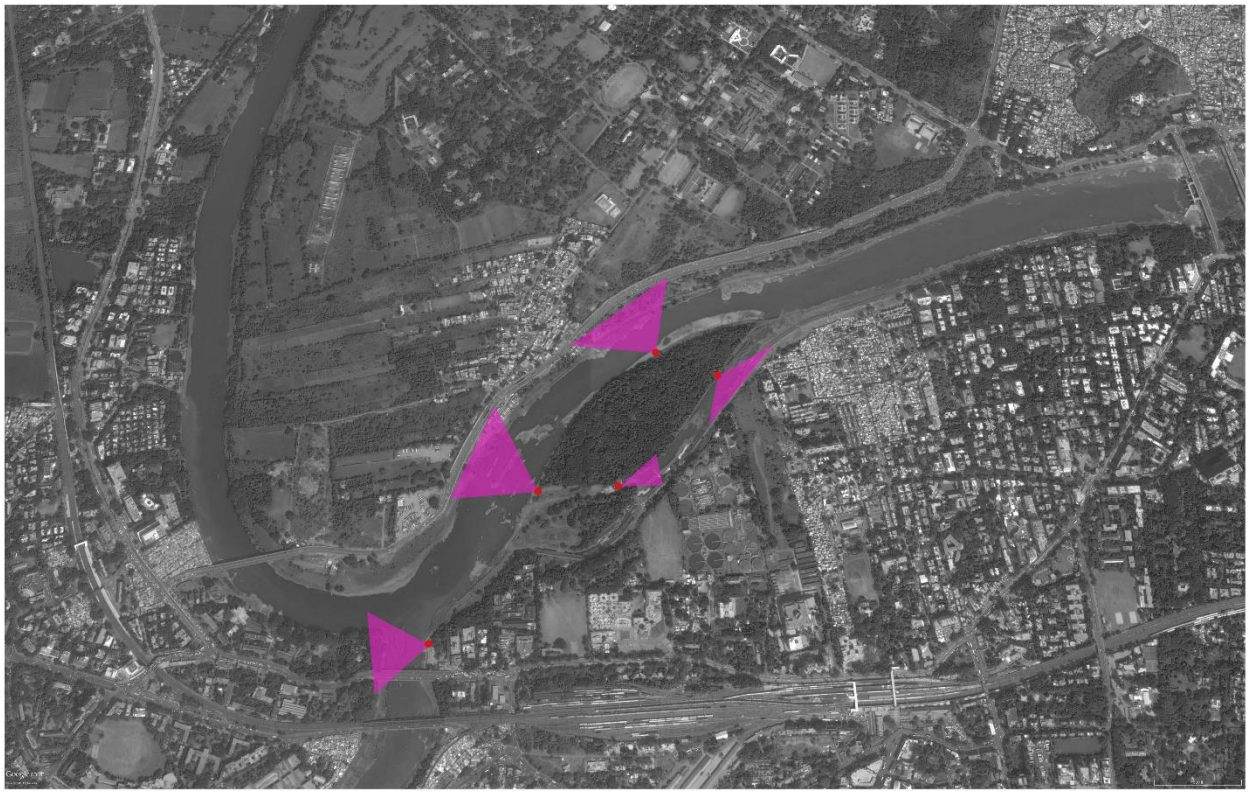
Parameters	Unit	Seasons	Sampling Stations		
			Station-A	Station-B	Station-C
Temperature	(^{o}C)	M	28.5	28.0	29
		W	23.4	22.3	24.6
		S	31	31.5	30
pH		M	7.1	7.28	7.06
		W	7.6	7.92	7.5
		S	6.8	6.98	6.73
Total Dissolved Solids	Mg/litre	M	586	608	585
		W	385	406	404
		S	271	262	288
Dissolved Oxygen	Mg/litre	M	4.1	5.6	4.3
		W	2.5	3.4	1.0
		S	0.8	1.2	0.5
Free CO_2	Mg/litre	M	9.0	8.3	8.76
		W	11.6	10.2	14.9
		S	19.2	16.5	24.3
Acidity	Mg/litre	M	213	156	264
		W	300	250	385
		S	163	210	250
Total Alkalinity	Mg/litre	M	190	320	175
		W	250	350	150
		S	358	400	360
Biological Oxygen Demand	Mg/litre	M	3.5	3.6	4.2
		W	20	21	38
		S	47	42	59
Chemical Oxygen demand	Mg/litre	M	76.608	40.32	88.704
		W	72	149.184	134
		S	168	190	172
Chlorides	Mg/litre	M	40.5326	38.5696	45.9385
		W	43.7099	55.6274	48.5665
		S	58.2798	60.48	58.212
Nitrates	Mg/litre	M	0.34	0.282	0.22
		W	0.20	0.114	0.17
		S	0.197	0.17	0.085
Phosphates	Mg/litre	M	98.0	85.0	123
		W	130	118	139
		S	148	125	154

M: Monsoon, W: Winter, S- Summer.

Source: *Courtesy: Research Journal of Animal, Veterinary and Fishery Sciences, February (2013).*

6. VISUAL ANALYSIS OF THE SITE

Fig 26: An overview of the Viewsheds around the site edges.



THE GHAT: The religious complex is 2 storeys (approx. 6-7 mts.) lower than than the main road. It houses a temple, a Ganpati Visarjan pool, public convenience facilities and a large congregational space adorned by 2 beautiful mature trees (figs.2 & 3).

Being maintained by the civic authorities, garbage is collected in compost pits, built along

Fig 26.1: The river island on the far side with the Ghat in immediate view; as visible from the Sangamwadi Bridge.

the river bank, till the crematorium.

Fig 26.2 & 26.3: The Ghat, which is situated at the junction where the rivers meet, is mostly used during Ganpati Puja and is a backdoor entry for the trail to the island.

THE SITE: The present access to the river islands is through a crematorium. As we move towards the junction where the 2 islands meet, we notice an algae bloom and garbage littered river bank. The litter is suggestive of the fact that it is deposited when the river flow is substantial during peak monsoons (figs.4 & 5).

THE EDGES: The island edges are littered with debris and garbage disposed of from regions upstream and small pockets of slum dwellers. There are small deposited sediment beds of water tolerant plants as well as water hyacinths over the water surface. Also proximity of the settlements (as seen in fig.B) from the river edges seem to play a major role in garbage disposal.

As one moves through the site, extensive erosion is noticed on the island junction (fig.7). A unique palette of vegetation on the island noticed and the transition from deciduous to riparian happens over a short distance (fig.8 & 9). The ‘treated’ water released from the sewage treatment plant (fig.10).

Fig 26.8, 26.9 & 26.10: The causes of degradation of the site is not only through man-made means, nature too has taken a toll.

6.1. SWOT ANALYSIS

Following are the key points about the site noticed during the visit:

STRENGTHS:

a) Home to one of the oldest surviving groves of Karanj and Shindi, in addition to the variety of other vegetation.
b) The site is a safe haven for the dwindling aquatic avi-fauna.
c) Being an island, it provides an excellent noise and visual barrier.

WEAKNESSES:

a) The island edges are pervious to erosion during monsoons.
b) Being an island, is has limited connectivity from the opposite river edges.
c) The site has become a dumping ground for the wastes carried by both the rivers.
d) High oxygen content in the water.

OPPORTUNITIES:

a) Ideal opportunity for the proposal of a trail park as the site in sensitive towards human intervention.
b) The island is already demarcated for recreational purposes, making it an ideal place for such a design proposal.

THREATS:

a) The site remains unattended and hence at risk from visits from wood cutters.
b) The site might become a haven for petty criminals too.

7. PROPOSALS AND INTERVENTIONS

7.1. PROPOSALS FOR THE SITE

Following are the principals of design decided for the intervention on the site:

a) Protect features and functions of a natural river.
b) Buffer sensitive natural areas.
c) Restore riparian and in-stream habitats.
d) Use non-structural alternatives to manage water resources.
e) Reduce hardscapes.
f) Manage storm water on site and use non-structural approaches.
g) Balance recreational and public access targets with river protection.
h) Incorporate information about the river's natural resources and cultural history into design of riverfront features, public art and interpretive signs.

In terms of introduction of new methods of river clean up, following mechanisms can be introduced:

I. LOCUS:

The concept of LOCUS is based upon a microbial fuel cell (MFC is a bio-electrochemical system that drives a current by mimicking bacterial interactions found in nature). The biocell is designed to have a capacity of 50 cubic metres as it takes care of 50,000 litres of raw sewage. The fleet of barges in total can be assumed to have 1000 biocells onboard. The total projected demand for sewage for the year 2009 was 115 MLD (million litres daily); of raw

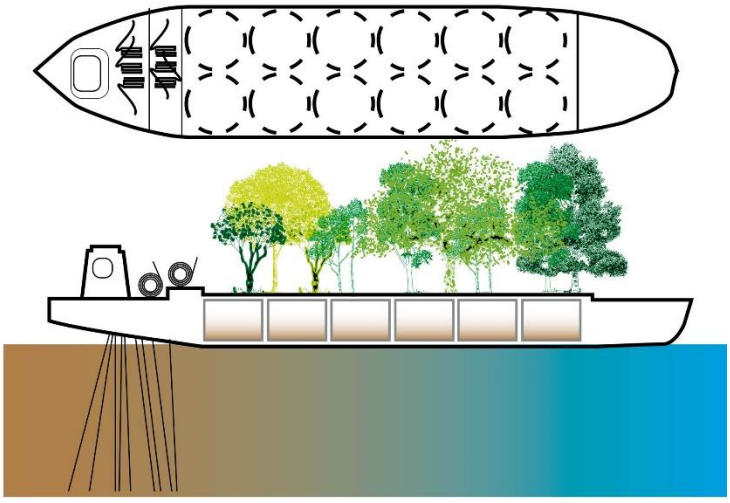


Fig 27: Schematic Representation of the LOCUS Barge.

sewage production. The bio cell has a processing period of 14 days, the sewage remains on the barge before being released as fertilizer-ish sludge for growing vegetables and trees on top of this and other floating barges. This means that one would need 115,000,000 X 14 = 16610000000 litre capacity. The bio cell could be assumed to be a 10m radii cylinder and 17.5 m high with a volume of around 4500 cu m, and there would be 12 of these on each barge: the dimension of the barge would be 22 m wide and 70m long. A fleet of 30 such barges to do the job till the year 2047.

II. GARBAGE COLLECTING BARGES:

Trash collecting barges known as *Mr. Trash Wheels* are solar- and hydro-powered trash interceptors based in Baltimore's Inner Harbor, which help in clearing debris before it enters the Chesapeake Bay. Over a million pounds of trash has been pulled out of the water by since it was installed in May 2014.

The contraption works by drawing power from solar panels and the current of Jones Falls River to turn a waterwheel, which in turn powers a conveyer belt. Containment booms direct the trash towards the conveyer belt, which then drops the debris into a waiting Dumpster. That bin sits on its own platform and can be floated out when it’s time to change it.

In context to the rivers Mula and Mutha in Pune, a fleet of approx. 5 such trash

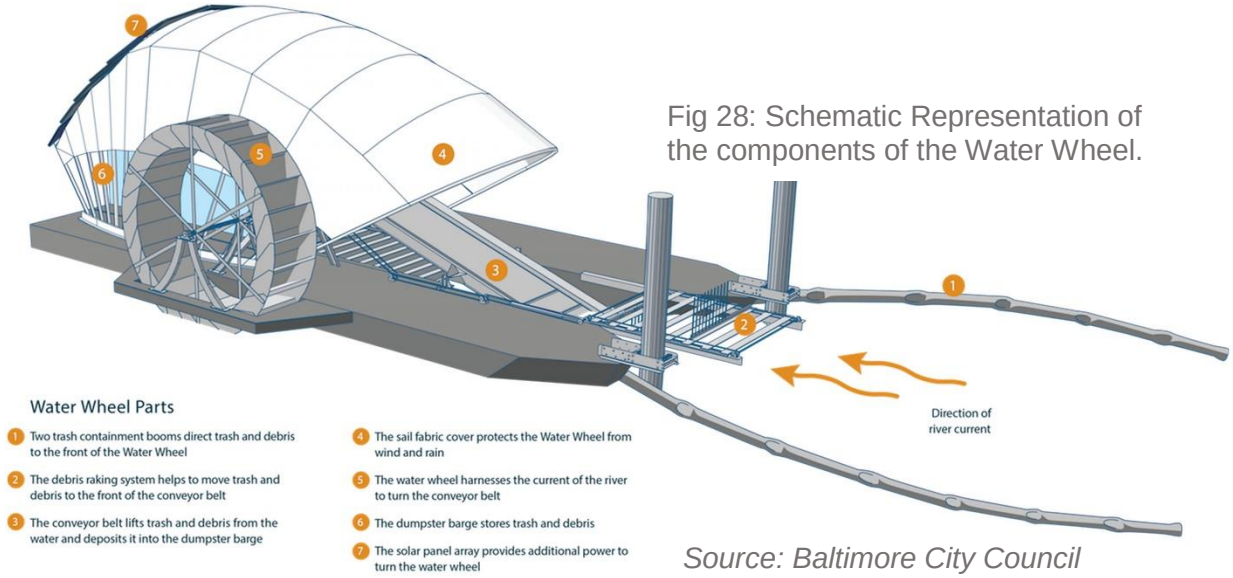


Fig 28: Schematic Representation of the components of the Water Wheel.

Source: Baltimore City Council

interceptors can be used to collect the discharged sold wastes in short amounts of time.

III. PHYTOREMEDIATION BEDS:

As per the U.S. Environmental Protection Agency, Phytoremediation is an emerging technology that uses various plants to degrade, extract, contain, or immobilize contaminants from soil and water. This technology has been receiving attention lately as an innovative, cost-effective alternative to the more established treatment methods used at hazardous waste sites.

In India, aquatic vascular plants like *Hydrilla verticillata, Spirodela polyrrhiza, Bacopa monnierii, Phragmites karka* and *Scirpus lacustris* can be planted along the river edges effectively to absorb unwanted dissolved organic as well as industrial affluents in the water. Along with proper planting & soil binding techniques, such vegetation can help in improving the water quality.

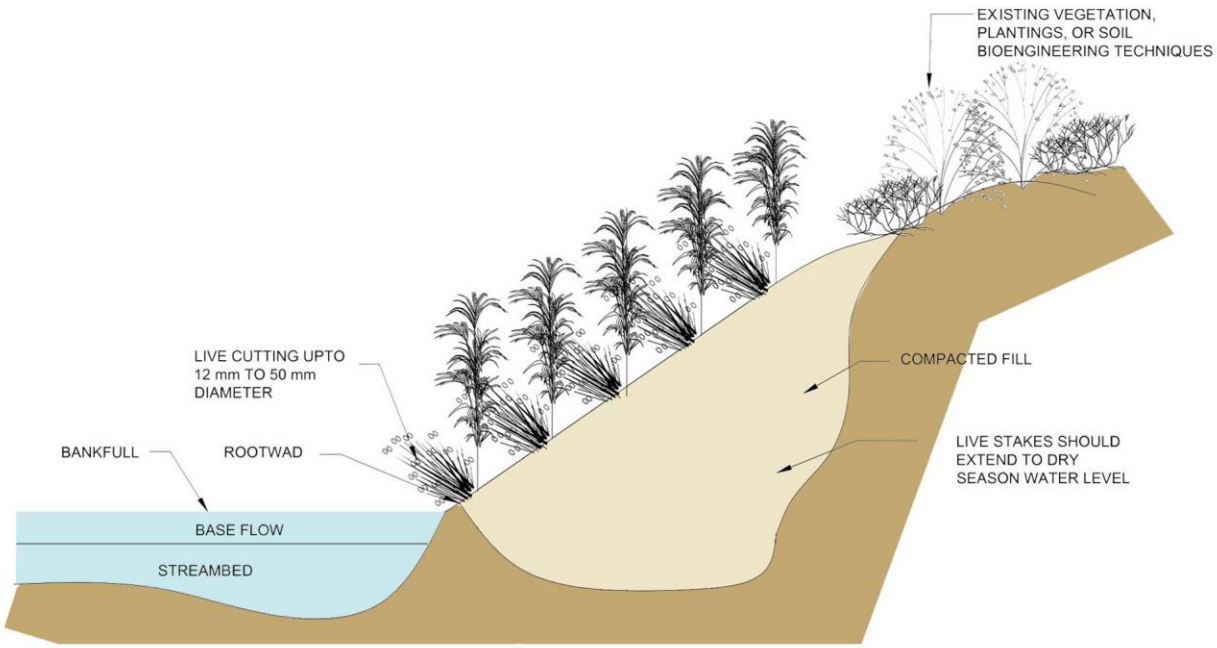
Fig 29: (From Left) Species for Phytoremediation Bed
Scirpus lacustris, Bacopa monnieri, phragmites karka, Hydrilla verticillata.

Source: www. Wikipedia.org

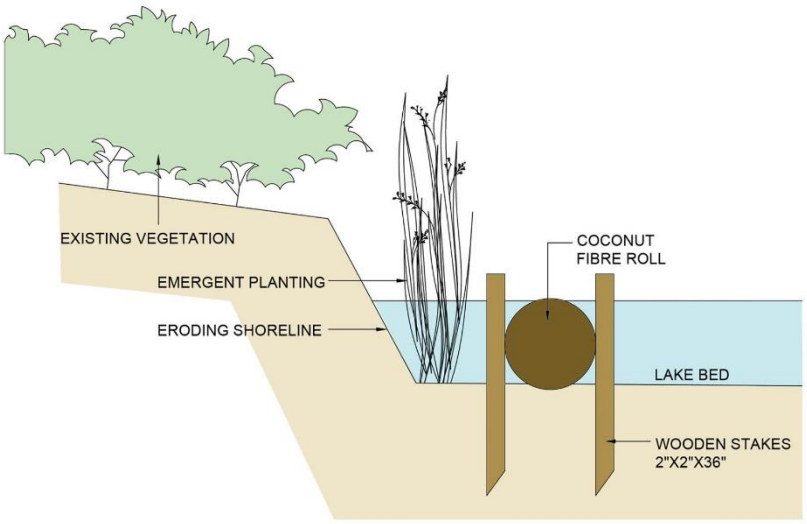
IV. BIOENGINEERING TECHNIQUES:

Instead of building concrete channels along the river edges, an array of bioengineering techniques can be used to mitigate the effects of erosion through rising and dropping flood levels of the river. Following are the main techniques which can be incorporated into the design:

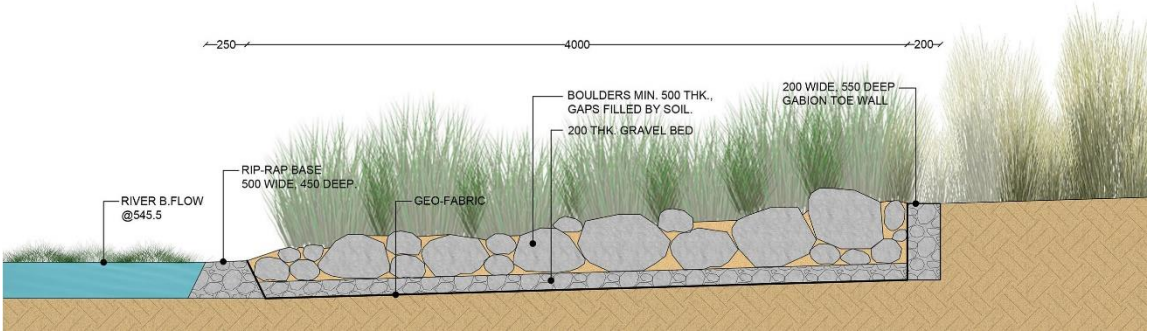
a) Brush Layering



b) Bio-Log



c) Rip-Rap



7.2. DESIGN INTERVENTIONS ON THE SITE

The entire set of interventions aim at making the visitors experience wilderness in the heart of the city. Creating such an experience is hard to gain in an urban setting. Hence the river island provides a perfect opportunity for the residing inhabitants as well as the incoming tourists to indulge in the experience on a weekly to bi-weekly basis.

The other great aspect of the experience is the presence of one of the oldest surviving groves of Karanj, Shindi and Babool. Along with the groves, there is a rather distinct variety of vegetation present on the short expanse of the site.
Being a river island, it provides a safe haven for the dwindling aquatic bird species of the region, where the growing urbanization of the city is already putting a toll on the natural water quality of the rivers and the streams.

In such a case, circulation on the island becomes an important aspect of the intervention. An ideal solution for minimizing the footfall per area and at the same time reducing the hardscapes, is the use of elevated stilt-pathways or boardwalks. There is also the need to incorporate functional amenities and services which blend in with the theme of the project.

Arriving to the main aspect of the intervention, which is the circulation pattern on the site. Mapping the density of vegetation on the site would lead to identification open spaces which might be of use for gathering spots.

Fig 29: Boardwalks, an ideal solution to roam in a 'forest' without disturbing the surrounding land.

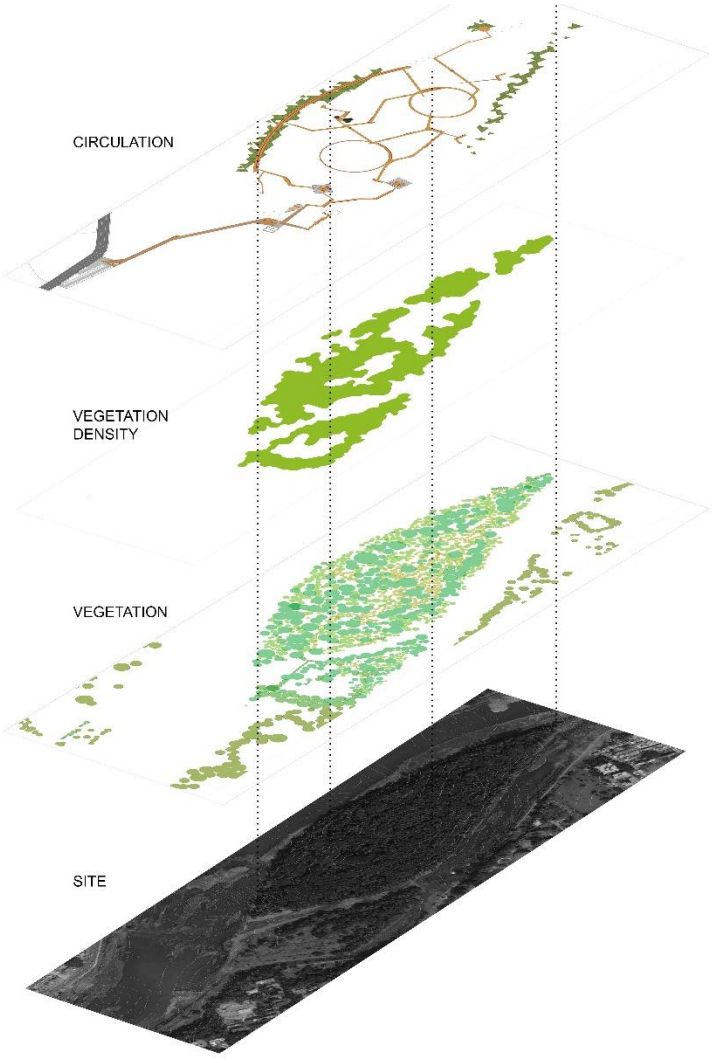
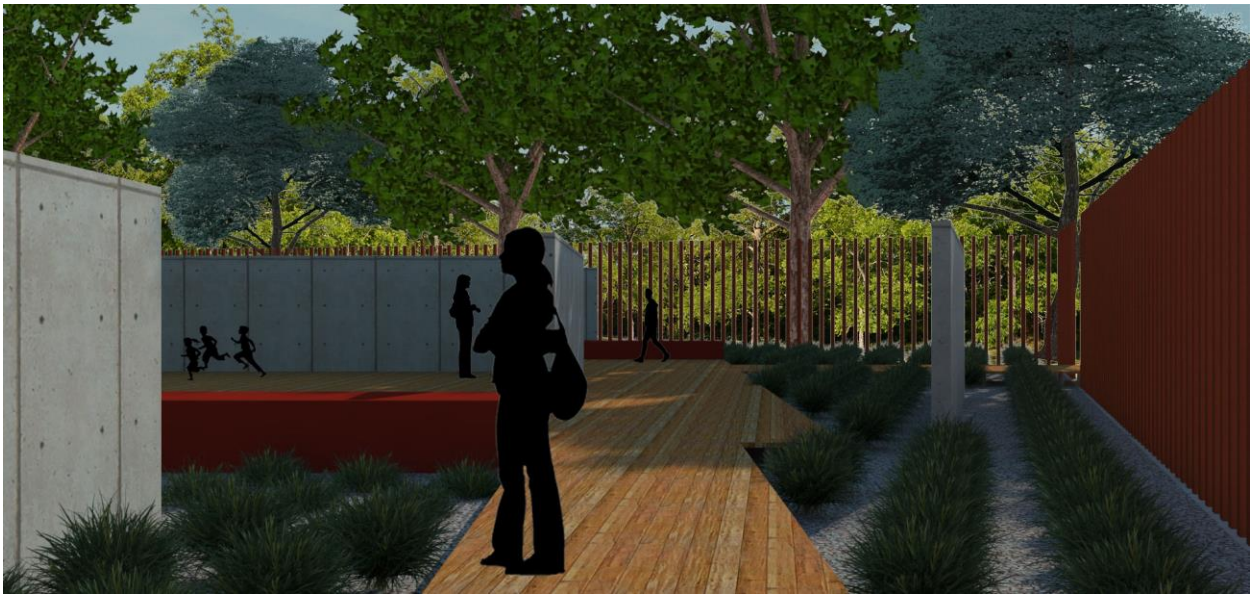
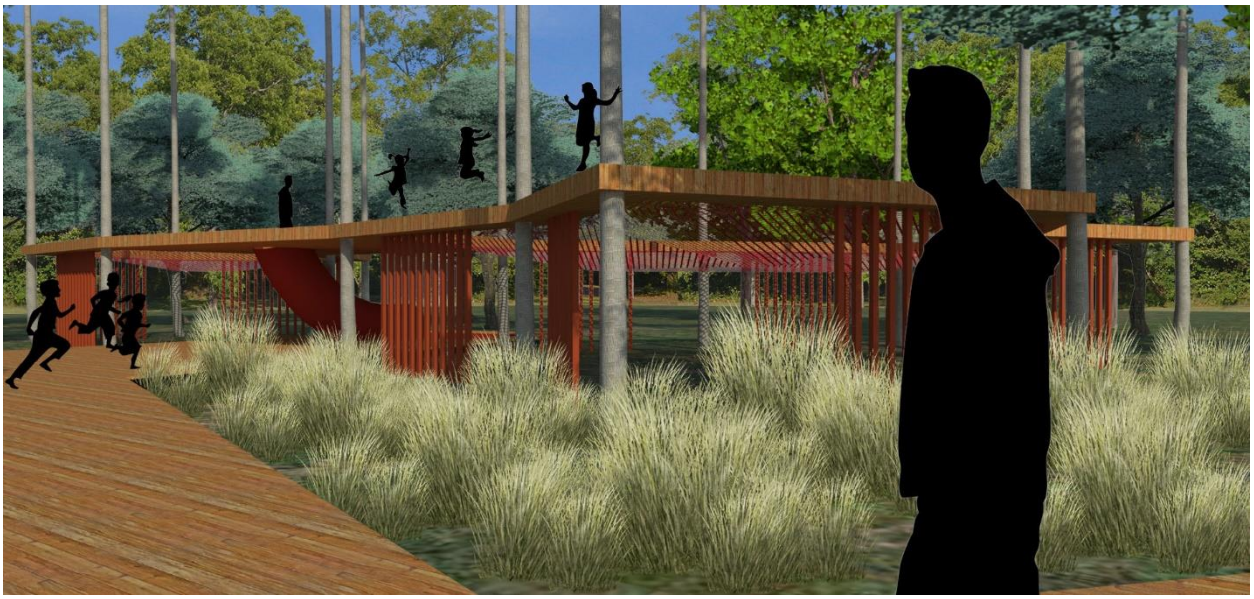


Fig 30: Isometric Blow-up of the evolution of the circulation pattern on the site.

The elements and spaces are designed keeping in mind that the site is sensitive to human interference and this interaction with the nature is to be kept to a minimum. Hence the visitors are made to travel through the site on elevated boardwalks. These boardwalks make the visitors experience the available interplay of the vistas offered by the site by travelling through a network of open spaces.

From the entrance to the island core, the aim of attracting attention of the visitors has been the main driving force behind the design and development of the features.





The island has the opportunity to become a place for learning as well as enjoying the lush and serene environment, away from the hustle of the city life.

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