Ecolgical Guidelines and Recommendations

for Mula-Mutha Riverfront Development

Ecological Society

Ecological Guidelines
and
Recommendations
For
Mula-Mutha Riverfront Development

Prepared by

Dr. Swati Gole
Revati Gindi
Dhruvang Hingmire
Sneha Ghate
Aditi Deodhar
Armuta Pradhan
Dr. Gurudas Nulkar

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Ecological Society
B-2, Jayanti Apartments, Near Ratna Hospital,
Senapati Bapat Road, Pune 411 016. India.
Telephone - 020-25677312
Mail - ecological.society@gmail.com
Website www.ecological-society.org

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Executive Summary

Over a period of three months, the Ecological Society undertook an in-depth study of nearly 15 km of river stretches in Pune city. We reviewed past studies and reports, met experts who have been associated with the rivers and conducted a workshop for NGOs and experts in Pune. There was a team of seven persons working on this project. A structured methodology was employed and at the end we prepared the guidelines and recommendation plan for the riverfront development of the Mula and Mutha. A short summary of this report follows.

Geological records reveal that the Mula and Mutha rivers are nearly 200,000 years old. Their continuous ecological functions and processes have crafted the neighboring landscape. We made several visits to collect data and photographs from nearly 15 km stretch. We split this stretch into 5 zones, based on the nature of the river and cross section of the channel.

For each zone we undertook a quantitative and qualitative assessment, recorded ecological and cultural hotspots, identified the interventions and threats and examined the opportunities. Based on this analysis, we classified the zones into three grades and recommend broad strategies for each grade. The rivers are an integral part of Pune city, its history and the culture of its people. Keeping this in mind, we identified 12 types of culturally and ecologically important spots and marked them on the zone maps. These are special ecological features like Rocky banks, Mouths of Feeder streams, Alluvial surfaces, Grassy patches, Riparian habitats, Faunal hotspots, and cultural feature like Ghats, Places of worship, Memorials and Heritage structures.

Grade 1: Zone 5 (Babasaheb Ambedkar Bridge to Aga Khan Bridge) and Zone 4 (Mula-Mutha Sangam to Ambedkar Bridge(Bund Garden)) are classified as the relatively best zones. Here the flow and character of the river are good, there are hotspots and these zones have minimum interventions.
The overall strategy for this zone should be one of no intervention and benign neglect.

Grade 2: Zone 1.1 (1Warje Bridge on Pune-Mumbai Highway to Rajaram Bridge) and Zone 1.2 Rajaram Bridge to Mhatre Bridge) have a relatively moderate ecological and cultural value. The broad strategy for this grade is one of partial intervention.

Grade 3: Zone 3 (Baba Bhide Bridge to Mula-Mutha Sangam) and Zone 2 (Mhatre bridge to Baba Bhide Bridge) have the least ecological value and severe interventions. For this grade we recommend substantial interventions and monitoring.

Besides these broad strategies that we recommend, we prepared guidelines and recommendations for the entire stretch. This was followed by specific recommendations for each zone. Furthermore, by studying riverfront projects in other nations, we make recommendations for design strategies.

1 | Project Introduction

The location of Pune city, towards the eastern end of the Western Ghats, has bestowed upon it an abundant supply of fresh water. The Western Ghats receive the highest rainfall in the state of Maharashtra, due to which, most of the large peninsular rivers originate here and drain towards the east. The Mula and Mutha rivers, emerge in the Western Ghats and flow through Pune. Since ancient times, aesthetic considerations have driven human beings to modify natural ecosystems to suit our ideas of beauty. The upcoming riverfront development program of the twin rivers of Mula and Mutha is intended to beautify the rivers, and expected offer citizen a place to relax and rejuvenate.

Many large cities in the world have undertaken such projects in the past, and there are lessons to be learnt for us. There are instances where excessive construction has overpowered the natural characteristics of the river. In other cases, the beautification has harmed the natural functions of the river to the extent that the flora and fauna has changed dramatically. However, such problems can be

avoided, even when improving the look and surroundings of the river. The main objective of this project was to conduct a detailed study of the current state of the river and make ecological guidelines and recommendations for the riverfront development project. The Ecological Society (ES) conducted a holistic, but rapid, study the Mula-Mutha to formulate these guidelines and recommendations. This report is intended to offer critical inputs to the planners and executors of the planned riverfront development project. Moreover, they can serve as a guide for managing the part of the river which flows through Pune.

Our aerial scope of the study is approximately 22 Km long stretch of river Mula-Mutha flowing through the Municipal boundaries of the city. This included following parts of the rivers-

- Mutha from Warje bridge to Mula - Mutha confluence
- Mula-Mutha from confluence to Agakhan Bridge

The study and this report is prepared for the Center for Environmental Education (CEE), who commissioned it. With the brief given by CEE and the discussions had with the CEE team, we prioritized the following objectives-

1. To assess the current status of the river as an ecosystem and identify the stresses on it related to its functioning.
2. To document the habitats and biodiversity in the defined stretches
3. To understand the functioning and processes of river ecosystem in its historic and present forms
4. To identify ecological hotspots and effects on ecosystem of the interventions previously undertaken; and to make recommendations for their conservation and restoration.
5. Propose a set of guidelines and recommendations based on ecological principles

Consequently, the report focuses on ecological values, biodiversity conservation, ecologically important areas, and makes recommendations from an ecological perspective for riverfront development project being considered for Pune city.

The river is a continuum. A complete understanding of the river ecosystem is possible only when it is studied from its origin to the point it merges into the sea. This requires a study of the upstream catchment and downstream journey. The present study is restricted to the stretches flowing through the city of Pune and hence has limitations to it. Moreover, due to time constraints, we undertook a rapid

biodiversity survey and could not record seasonal changes in flora and fauna. We have tried to overcome these shortcomings by using indicator species to access the ecological value of the river ecosystem.

Geological history of the river

Geological records reveal that the Mula and Mutha are nearly 200,000 years old (Dr. S. N. Rajguru, Deccan College). Over time, the continuous forces and processes of the rivers have resulted in the evolution of the surrounding landscape. The present day geomorphic features like the channel slope and width, river network, alluvial filled surfaces along the banks, riparian zones, instream sedimentation and erosion are a result of the processes of erosion and deposition. One study done by the Deccan College reveals that Mutha and its tributaries were flowing vigorously around 25 thousand years ago. However, around 18 thousand years ago, their flows reduced due to climate change and decreasing rainfall. It regained its vigorous flow between 10 thousand and 5 thousand years before the present (Dr.S.N.Rajguru).

The southern tributaries of the Mutha originate at Katraj. The Ambil Odha and Nagzari Odha are significant contributors to the flow of Mutha. Moreover, they recharge aquifers and increase the ground water availability.

Pune river in the bygone era.

2 | Methodology

The methodology employed for this study is depicted in figure 1. The study was divided into three phases. The first phase was a review of published literature, previous surveys and anecdotal observations. We studied recent history to understand the changing relation between river and citizens, its cultural, socio-economic importance and changing trends of water utilization. Previous studies on flora and fauna were reviewed. This helped understand the biological status of river ecosystem.

In the second phase, we planned the primary data collection with appropriate techniques and its techniques, analysis and the timeline for the study. We consulted experts from various backgrounds, related directly or indirectly to the river. This included archaeologists, geologists, ecologists, scientists and biodiversity experts, hydrologists and lawyers. For over two months, we studied the changes in stresses on the river and its impacts. Over the next two months, we undertook field visits to assess the current stresses, document the interventions, identify ecologically important areas and make an

inventory of the flora and fauna. At the end of this phase, we presented our findings to various NGOs, experts and bodies, who have worked with water resources of Pune city. The third phase was data analysis. We compiled, edited and analyzed the data and went on to discuss and debate the recommendation plan.

Field Observations

For the field observations, the entire length of the river from Warje Bridge to Yerawada Bridge was divided into sections/ zones of approximately 15 kilometres. Every observed zone shows many common features with other zones, however there are also some marked differences. The zones were created by taking into account nature of the river and crosssectional character of the channel.

There are five zones, comprising the area as follows:

Zone 1: This was further divided into two parts

Zone 1.1: Warje Bridge (on Pune-Mumbai Highway) to Rajaram Bridge

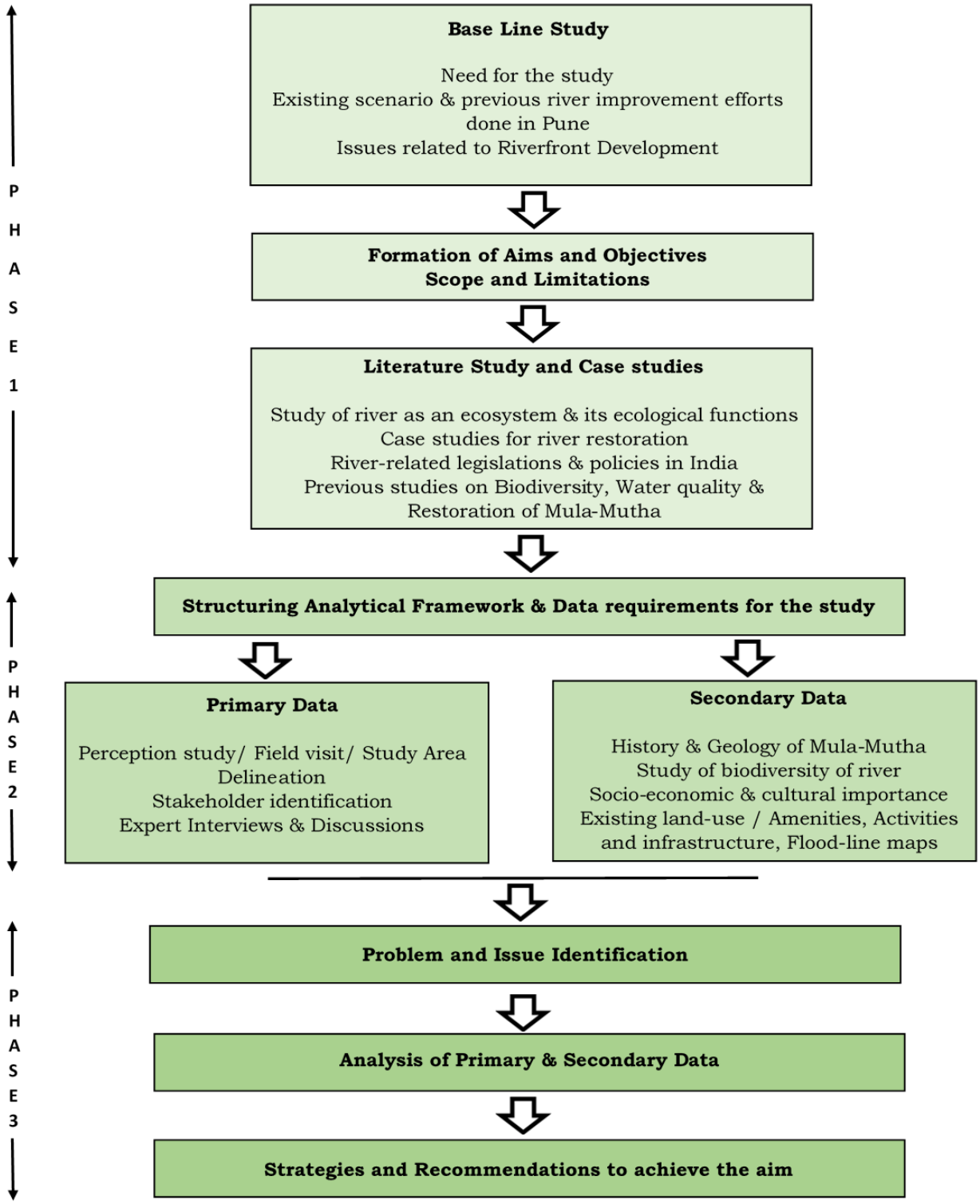
Zone 1.2: Rajaram Bridge to Mhatre Bridge

Zone 2: Mhatre Bridge to Baba Bhide Bridge

Zone 3: Baba Bhide Bridge to Mula-Mutha Sangam

Zone 4: Mula-Mutha Sangam to Ambedkar Bridge (Bund Garden)

Zone 5: Babasaheb Ambedkar Bridge to Aga Khan Bridge (Yerwada)


PHASE 1
Base Line Study
Need for the study
Existing scenario & previous river improvement efforts done in Pune
Issues related to Riverfront Development
Formation of Aims and Objectives
Scope and Limitations
Literature Study and Case studies
Study of river as an ecosystem & its ecological functions
Case studies for river restoration
River-related legislations & policies in India
Previous studies on Biodiversity, Water quality & Restoration of Mula-Mutha
PHASE 2
Structuring Analytical Framework & Data requirements for the study
Primary Data
Perception study/ Field visit/ Study Area Delineation
Stakeholder identification
Expert Interviews & Discussions
Secondary Data
History & Geology of Mula-Mutha
Study of biodiversity of river
Socio-economic & cultural importance
Existing land-use / Amenities, Activities and infrastructure, Flood-line maps
PHASE 3
Problem and Issue Identification
Analysis of Primary & Secondary Data
Strategies and Recommendations to achieve the aim

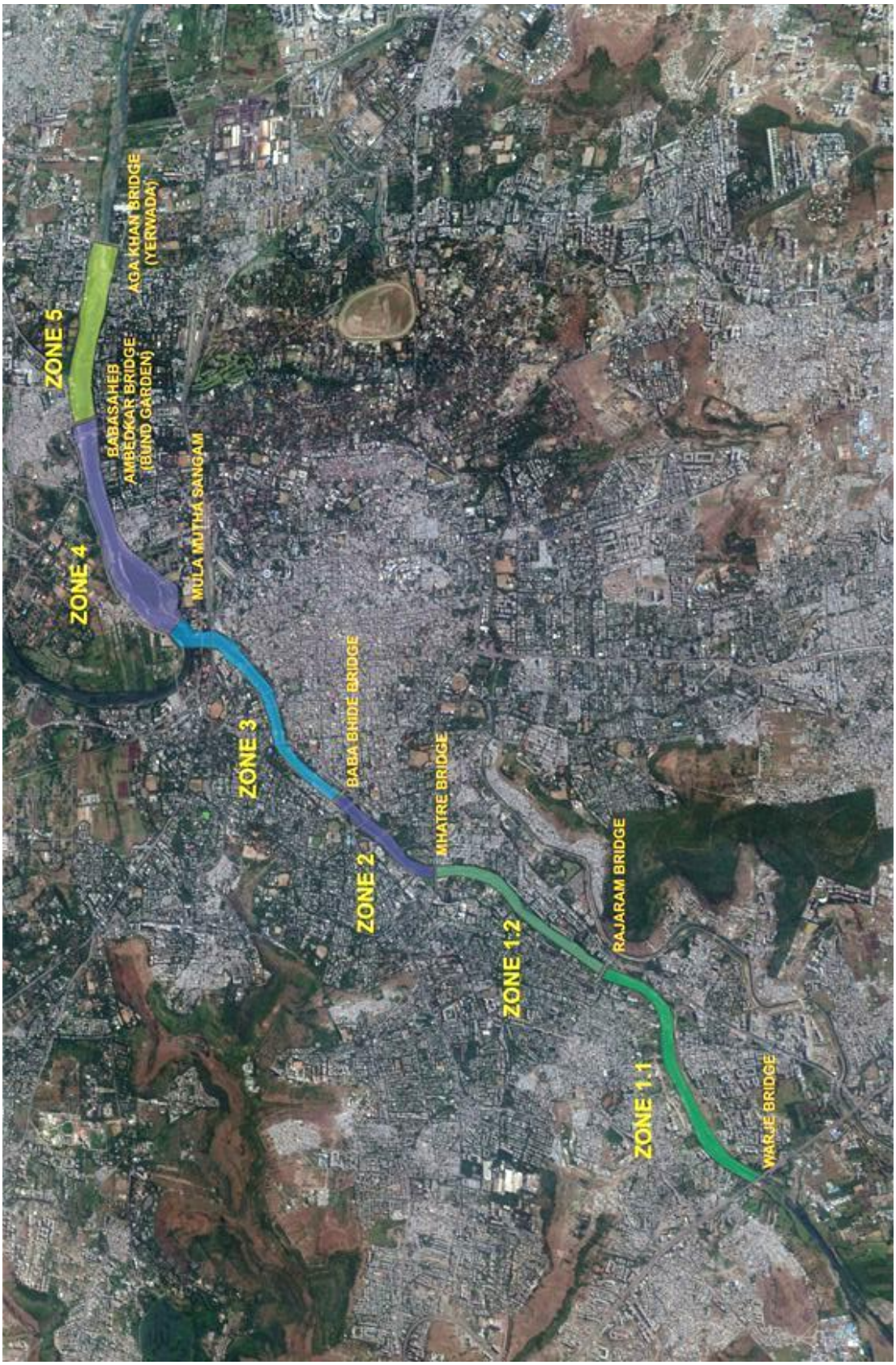
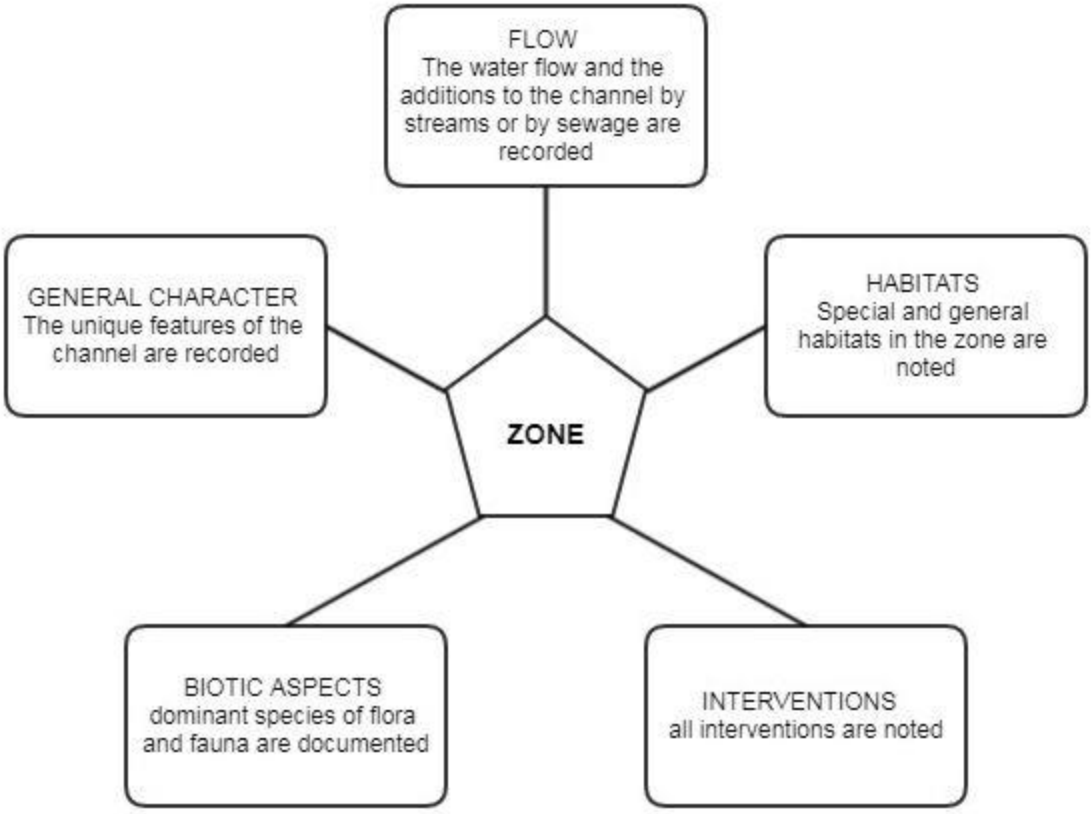


Figure 1 : Zones created in the study stretch

3 | Observations

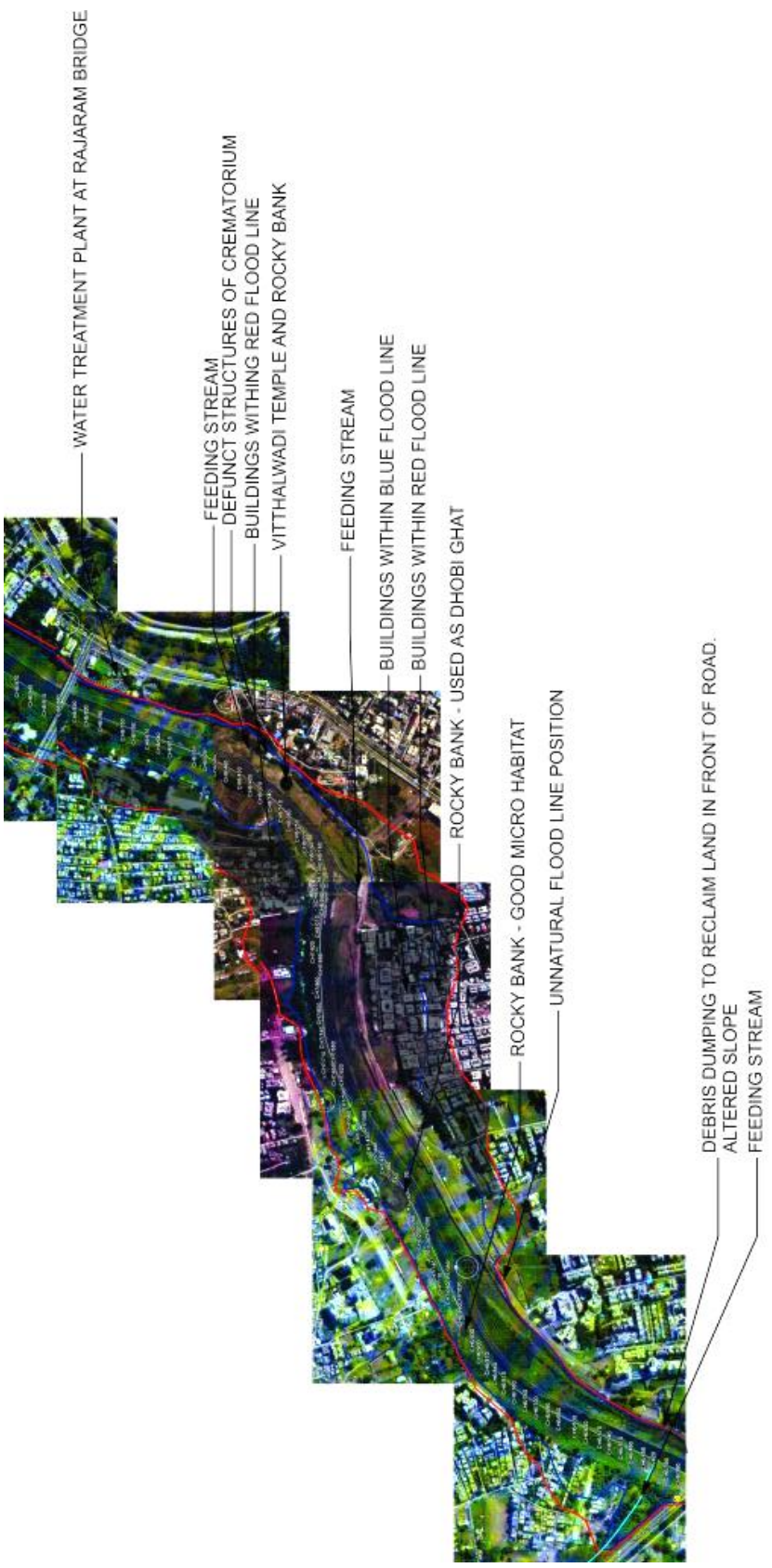
The zones were studied in detail. The data was noted, and photographic records are maintained. For studying the zones, the methodology depicted in figure was employed.



Studies conducted on each Zone

Our observations are presented by the zones. All sections and references are oriented in the direction of the river flow, ie from South-West to North-East. Accordingly, the banks are referred to as Left and Right banks. For each zone, the observations are then presented in the following sequence:

a. General character of the channel
b. Flow
c. Habitats
d. Biotic aspects
e. Interventions



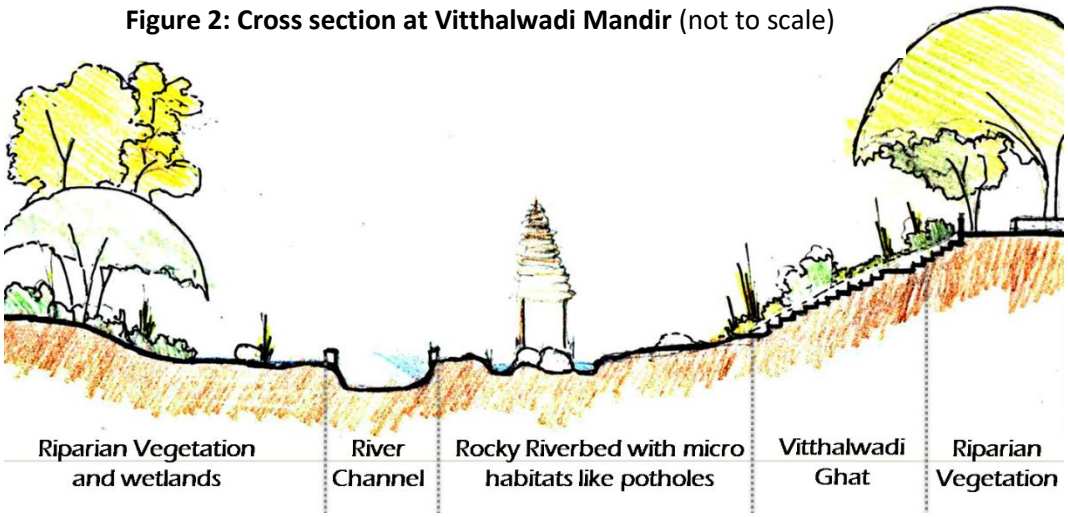
ZONE 1.1: WARJE BRIDGE TO RAJARAM BRIDGE

Zone 1.1: Warje Bridge to Rajaram Bridge

A. General Character of the Channel

The channel in this zone is sinuous. There is a prominent bend to the west of Vitthalwadi Mandir. The meander has several potholes, which make a special habitat. The function of erosion and deposition is evident here. The Channel cross section shows that the right bank channel wall is gentler than the left bank. The channel bed is composed of exposed bedrock and very small patches of sediment deposits.

Figure 2: Cross section at Vitthalwadi Mandir (not to scale)



There is a constructed Ghat near the Vitthalwadi Mandir and the opposite bank has a gentle and a steep slope. There is debris dumped near the slopes. The road built between Warje Bridge and Vithalwadi is now being removed. There is a good layer of soil below the road, which looks like an old alluvial filled surface. Moreover, near the Vitthal Mandir and on both the banks near Warje Bridge there are small patches of riparian vegetation.

B. Flow

The river flow is constricted by the walls, which makes it rapid. A channelized stream joins near the Vithal Mandir to the built channel of the river Mutha and adds sewage to the flow. The river flow is within the walls. While the rest of the channel has various habitats, they receive water only during floods or short seasonal pulses created by rainfall in the surrounding area. There is also a "press event" where during monsoon large quantities of water are released from the Khadakwasala dam. Many of the flora and fauna cannot adjust to such erratic flooding. Of special interest is the spring which flows

through a constructed “Gomukh" and discharges clean water into the river. We recommend that the springshed region for this spring be identified and protected.

The report “Survey of the rivers in the Pune city based on ecological factors in order to prepare an Eco-development plan to improve the river fronts of Pune” by Prakash Gole, talks about the flow *“Once over the rocky outcrop the stream at Vithalwadi flows sluggishly (240 mtrs/hour), eddying softly over submerged rocks and lapping against small inlets in Basalt which at places are sufficiently broad to make sheltered coves and bays.”* These unique places are today under threat, because of construction interventions which have are taking place near the Mandir.

C. Habitats

Stretch of river between Warje and Vithalwadi hosts various types of habitats such as exposed rocks in riverbed, potholes, crevices on exposed rocks, marshy areas, open grassy patches, deep pools, feeding streams, small riparian patches, meander related riffles and pools etc. This is a good diversity of habitats.

D. Biotic Aspects

In the biotic aspects the focus was on the birds as they are good indicators of the health of the river ecosystem. Detaied survey of flora at species level was carried out. We did not record microbial fauna and aquatic species, which may be available with Agharkar Research Institute, Pune.
Flora - The habitat diversity here supports vegetation like Colocasia, Typha, Canna, Ludwigia, Hygrophila etc. Riparian habitats include stunted growth of *Ficus racemosa, Acacia, Syzygium, Pongamia* spp. Associated with shrubs like Lantana, Eupatorium etc. Herbaceous growth like *Leucas biflora*, *Cleome* spp. associated with few grasses were observed in rock crevices. Along the edges of feeding streams observed typical vegetation like *Ficus racemosa, Phyllanthus reticulatus, Persicaria, Colocasia*, etc. We recorded pure formations of Xanthium in open patches occasionally and few open patches dominated by grass species. This is a non-native vegetation and invasive.

In river bed water hyacinth is found in patches. It is an aggressive species and needs to be managed. Of the six zones, this stretch has the maximum floral diversity. Eutrophication is a key reason for the rampant spread of this vegetation.

Fauna - In small riparian patches and dense shrubbery areas, birds like Prinia, Drongos, Sunbirds, Bush chats, Indian robin, and swallows, wagtails were observed. In open patches Yellow wattled lapwings were in large numbers. This is occasionally found, and an important species in terms of diversity. Roosting as well as nesting was sighted.

In river bed Spotbill ducks, Pond Herons, Black winged stilts were observed. White breasted kingfisher was seen using habitats like flowing water, riparian and channel walls. Presence of Black winged stilts and Pond heron indicates highly polluted water. Sighting of Red Munia indicate good marshy areas with Typha providing their Roosting places and open grassy patches. A rare sighting of the Cinnamon bittern indicates good marshy habitats in those areas. Wooly necked stork, Painted stork observed in open grassy patches.

Scavengers birds like Crows, Black kites, were observed in large numbers because there is solid waste dumping at many places in the channel bed.

As shared by the people catching fish on the left bank, near Vitthal mandir, Fish species like “Maral” which feeds on sewage is present in the river. This is a non-native, introduced species, which is now rampant in the river.

E. Interventions

This stretch has several interventions.

- Dumping and burning of Garbage
- Construction debris.
- Bank scraping
- Marking of flood lines incorrect
- Construction within flood lines and Encroachment
- Dumping in Feeding Streams
- Channelization of the river flow
- Defunct structures in riverbed.

ZONE 1.2: RAJARAM BRIDGE TO MHATRE BRIDGE

Zone 1.2: Rajaram Bridge to Mhatre Bridge

A. General Character of the Channel

River is channelized right from the Warje Bridge. This constructed channel flow continuous even beyond Vithalwadi till Rajaram Bridge. Beyond Rajaram Bridge two tributary streams join the main Mutha river. These two streams also separately flow in constructed channel and there are bunch of three constructed channels looking like a braided river is seen in this area. The Natural channel floor is very wide in this

Example of a braided river (Source : Greg O'Beirne, Wikipedia under CC license)

zone. Riparian vegetation is observed along both the banks. River channel is braided in this zone. Residential land use is prominent along the right bank, whereas party lawns, private, public open spaces and residential land use present along the left bank. Many micro habitats and wetlands are formed along the channel created by sewage water coming from the above mentioned commercial area.

B. Flow

Outflow of sewage treatment plant (STP) near Mhatre Bridge enters from the left bank and feeds the stream. We identified a spring in this zone near Hanamghar Ghat, which contributes meagre water to the Mutha River. Because channel slope is gentle, velocity of water is less.

C.Habitats

Habitats in this zone include Riparian Zones, pools, Marshy areas, open grassy patches, in stream boulders, Upland vegetation patches.

D. Biotic Aspects

Flora - Both banks have good riparian patches and a lining of tree canopy in upland vegetation. Trees like *Acacia, Pongamia, Phoenix, Holoptelea, Singapore Cherry, Sterculia foetida,* Rain trees and weeds *like Lantana, Ricinus, Parthenium* are observed here.

In stagnant pools growth of *Azolla, Lemna, Pistia* and marshy areas dominated with *Typha, Ludwigia, Cyperus* species.

At the edges of channel walls and at the base of boulders few herbs and shrubs like *Phyllanthus reticulatus Persicaria, Ludwigia* are found associated with *Cyperus* spp.

At places in open patches found pure formations of Xanthium. In wet grassy patches observed luxuriant growth of *Cynodon-Cyperus-Polygonum* community associated with typical herbs like *Eclipta, Persicaria, and Hygrophila.*

Where the streams join the main river, there are no channels and growth of dense vegetation of *Acacia nilotica,Ficus racemosa,Ficus hispida* has created good riparian zone. There are number of marshy areas, dominated by typical community *Polygonum-Typha-Colocasia associated* with *Hygrophila*.

In the river channel along the channel walls, dense growths of aggressive weed *Alternanthera philoxeroides* observed in patches.

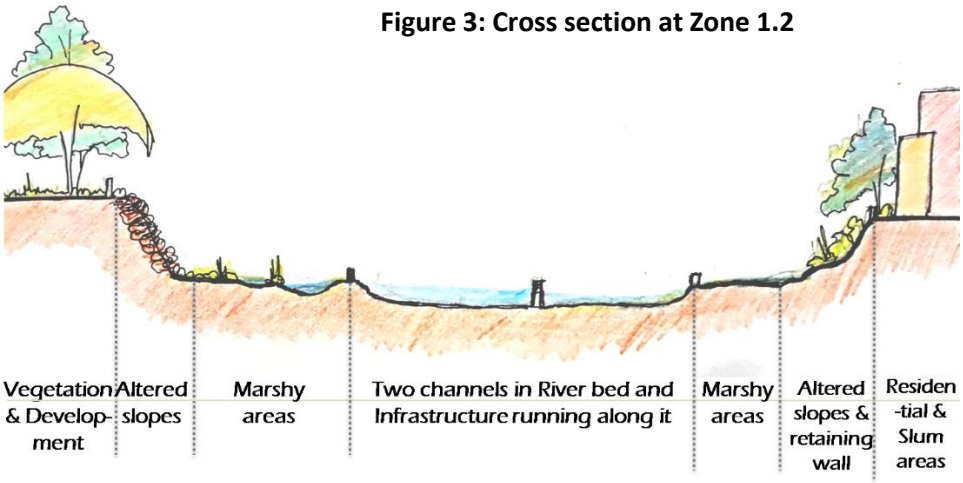
Fauna-Night heron, Cattle Egret, River turn, Painted stork, Black naped Ibis etc observed in this area indicating existence of wetland sites in that area.

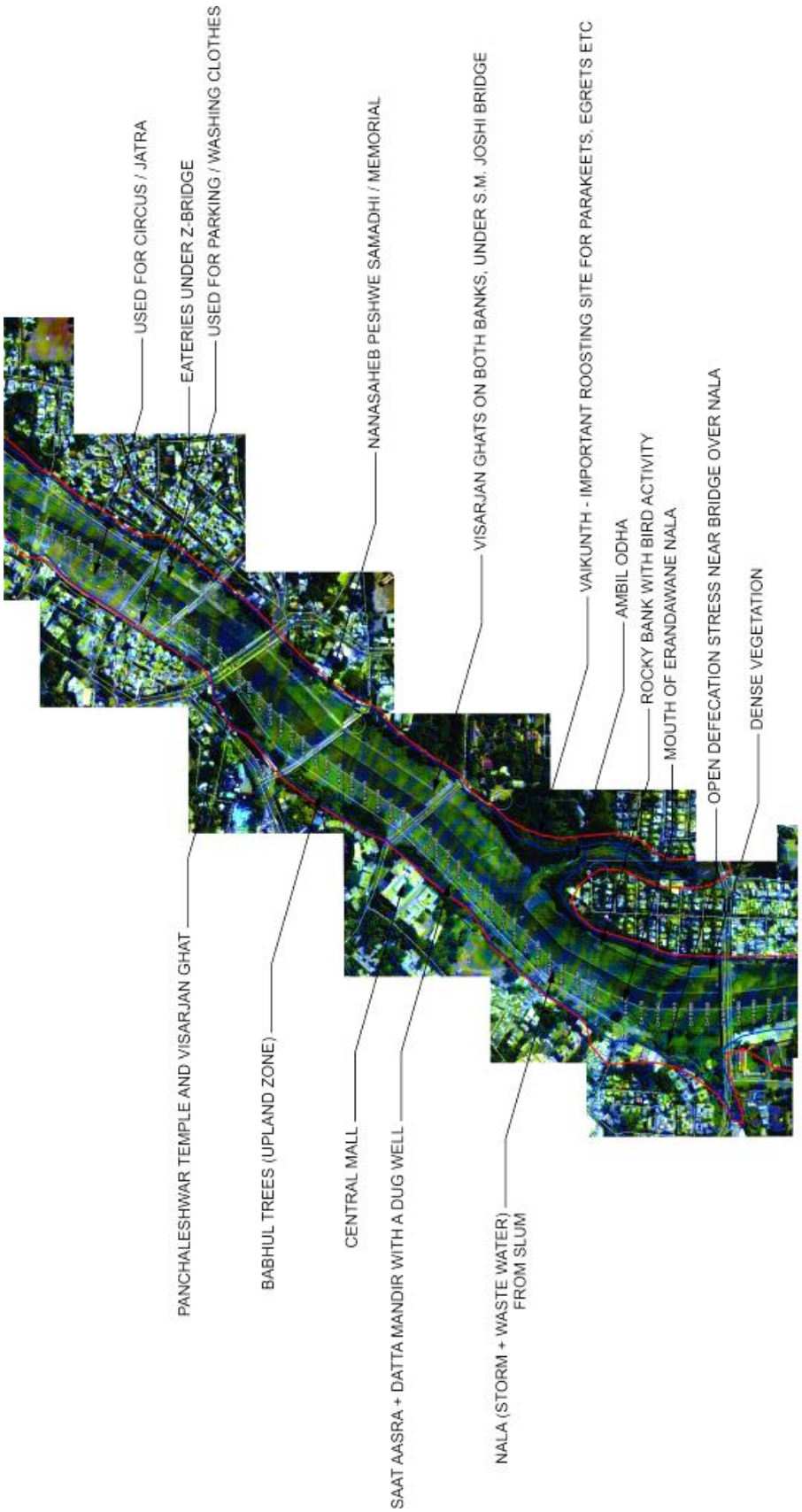
E. Interventions

- Dumping of Garbage and Construction debris from lawn side.
- Encroachments.

- Dumping in Feeding Streams.
- Dhobi Ghat and washing.
- Channelization
- Alteration in topography and natural drainage pattern.

Figure 3: Cross section at Zone 1.2





ZONE 2: MHATRE BRIDGE TO BABA BHIDE BRIDGE

Zone 2: Mhatre Bridge to Baba Bhide Bridge

A. General Character of the Channel

In this zone, the width of the river increases. Two major feeding streams join Mutha River here. Erandwane nala from left bank and Ambil Odha from the right Bank of the river. The river is channelized and has braided channels. There are alterations to the natural topography under the S.M. Joshi Bridge. A major level difference is created to accommodate riverside road. On the right bank, some pockets of rich riparian vegetation are present at some places like near mouth of Ambil odha and even along the riverside road.

B. Flow

The flow here is rapid. In stream rocks near S. M. Joshi Bridge create some turbulence. Ambil odha, a major feeder stream of Mutha drains into river in this stretch which brings in a lot of silt from Vaikunth crematorium and solid waste. This creates muddy stagnant patch with anaerobic conditions at the confluence.

C. Habitats

Habitat includes Riparian zones, In stream boulders, Small island, Marshy areas, open grassy areas, Upland vegetation patches, Rocky patches etc.

D. Biotic Aspects

Flora-Upland vegetation patches having good canopy cover of old growth Rain Trees lined at the backside of Vaikuntha and patch of trees like *Acacia, Pongamia* observed near Shri Shri Ravishankar School on right bank. Good riparian patches now isolated by road on left bank supports some plantation of *Gliricidia, Subabul* associated with few naturally grown trees like *Acacia* in good numbers.

At places dense canopy cover is also created by old growth *Ficus* trees.

Open patches are dominated with grass cover associated with clusters of *Ricinus, Phyllanthus* etc.

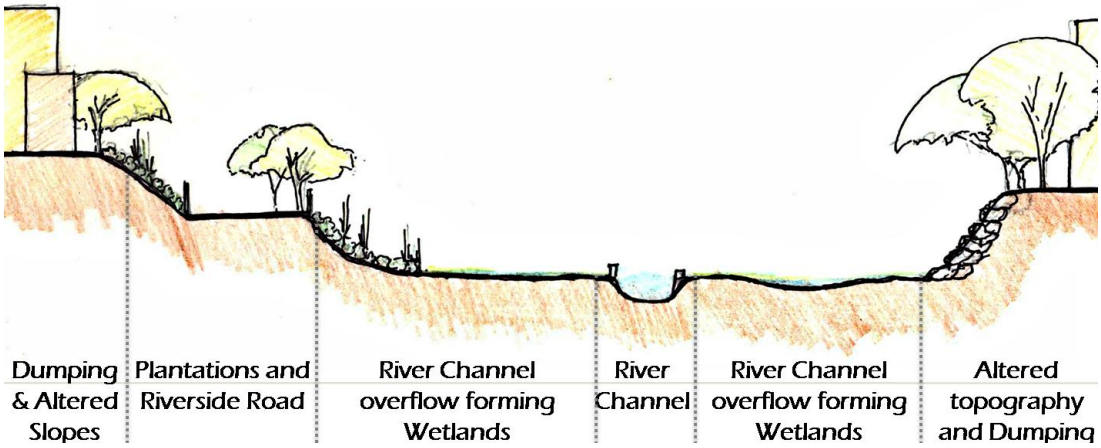
A marshy area near stream mouth supports typical community of *Colocasia, Hygrophila,* and *Ludwigia* with few *Cyperus* spp.

One Salix tree near Garware Collage, below Chavan Bridge is the remnant of riparian vegetation indicating good quality riparian vegetation in that area, in the past.

Fauna- Birds-In open areas we observed Munia, Ashy Prinia, Bee eaters, Swallows in shrubby growth, Pond Heron, Common sandpiper in good numbers indicating polluted water and Yellow wattled lapwings in open grassy rocky patches.

Rain trees on the right bank, near S. M. Joshi bridge serve as roosting places for various birds and hence is an important habitat

Figure 4: Cross section at Zone 2



E. Interventions

- Channelization
- Significant alterations in topography and natural drainage pattern are done for river side road.
- Dumping of Garbage in river and Feeding streams.
- Encroachments.
- Open Defecation near Slum and feeding Streams.
- Unorganized and Haphazard infrastructure.
- Mixing of Storm water and wastewater.

- Unplanned visarjan tank structures.
- Nirmalya is thrown in river near religious places.
- Solid Waste dumping in river near eateries under z-bridge.
- Hardscapes in riverbed to create parking lot.

ZONE 3: BABA BHIDEBRIDGE TO MULA MUTHA SANGAM

Zone 3: Baba Bhide Bridge to Mula-Mutha Sangam

A. General Character of the Channel

In this zone there is meandering near Balgandharva Bridge. The gradient is low and width of the river bed is large. Some channels are braided. Nagzari, a major feeding stream, joins the river from the right bank near Juna bazaar. Important historical and religious places like Omkareshwar temple, Siddheshwar Temple, Panchaleshwar temple, and ghats are present along the river and open public spaces like Vartak garden and Sambhaji garden are located along the river in this stretch. Towards Sangam, Width and depth of river corridor increases. We can observe the major level difference between riverbed and surrounding areas. In this stretch, the river is accessible at few points only. Retaining wall is constructed along the river bank starting from PMC to Mula-Mutha Sangam. A water spring known as “Bapucha Zara” is on the right bank at the back side of Omkareshwar Temple.

B. Flow

River is channelized, and the bed is wide. Flow is comparatively slow. Causeway near Sidheshwar ghat, channel is shallow, and water is stagnant. Bubbles formed by escaping methane gas are observed here, indicating anaerobic conditions. The place has a foul odour.

C. Habitats

In this zone observed habitats like Boulders in river channel, Lining of dense upland vegetation at the backside Sambhaji garden, Vartak Garden and Nana-Nani Park. Open grassy patches, Marshy areas, few riparian patches are found in this zone.

C. Biotic Aspects

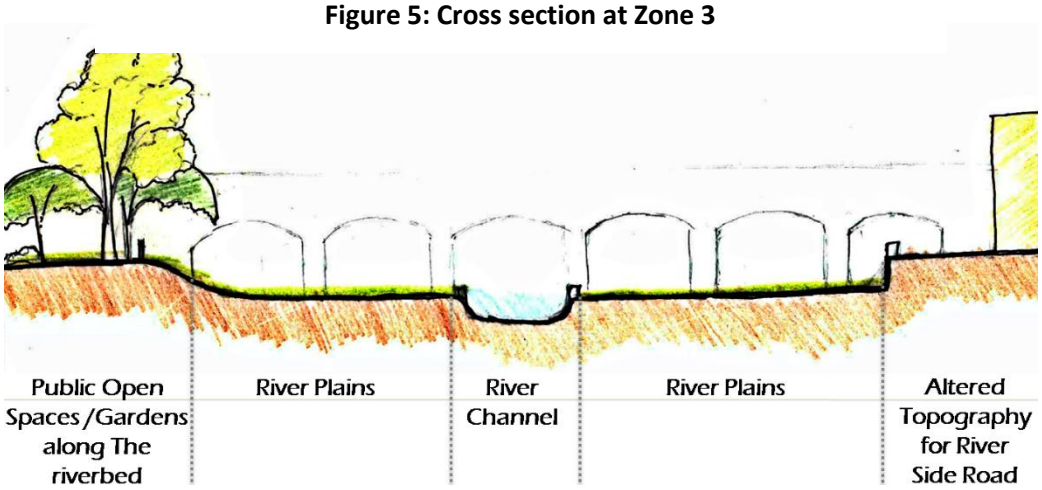
Flora-Upland vegetation includes dense canopy cover of Rain Trees and *Terminalia arjuna*. (At the back side of Sambhaji park and Nana-Nani Park area, etc.).

Large open patches are dominated with grass cover like *Cynodon* associated with herbs like *Xanthium*, *Ludwigia*, *Croton* etc.

Along the channel wall, in small patches observed shrubby growth of *Ricinus, Phyllanthus reticulatus* associated with few herbs like *Xanthium* indicating wasteland. Some marshy areas near Sidheshwar Ghat are dominated by vegetation like *Hygrophila, Colocasia, Persicaria* etc. Also, some grasses and *Cyperus* is seen here. In the riparian patch below Juna pul where Nagzari meets the river channel dense vegetation supports trees like *Acacia, Pongamia* associated with shrubs like *Lantana, Phyllanthus*, herbs like *Persicaria, Ludwigia* etc. At places individual growth of *Ficus racemosa* is observed e.g. near Bapucha zara. Water hyacinth is seen in few patches where water is shallow and stagnant.

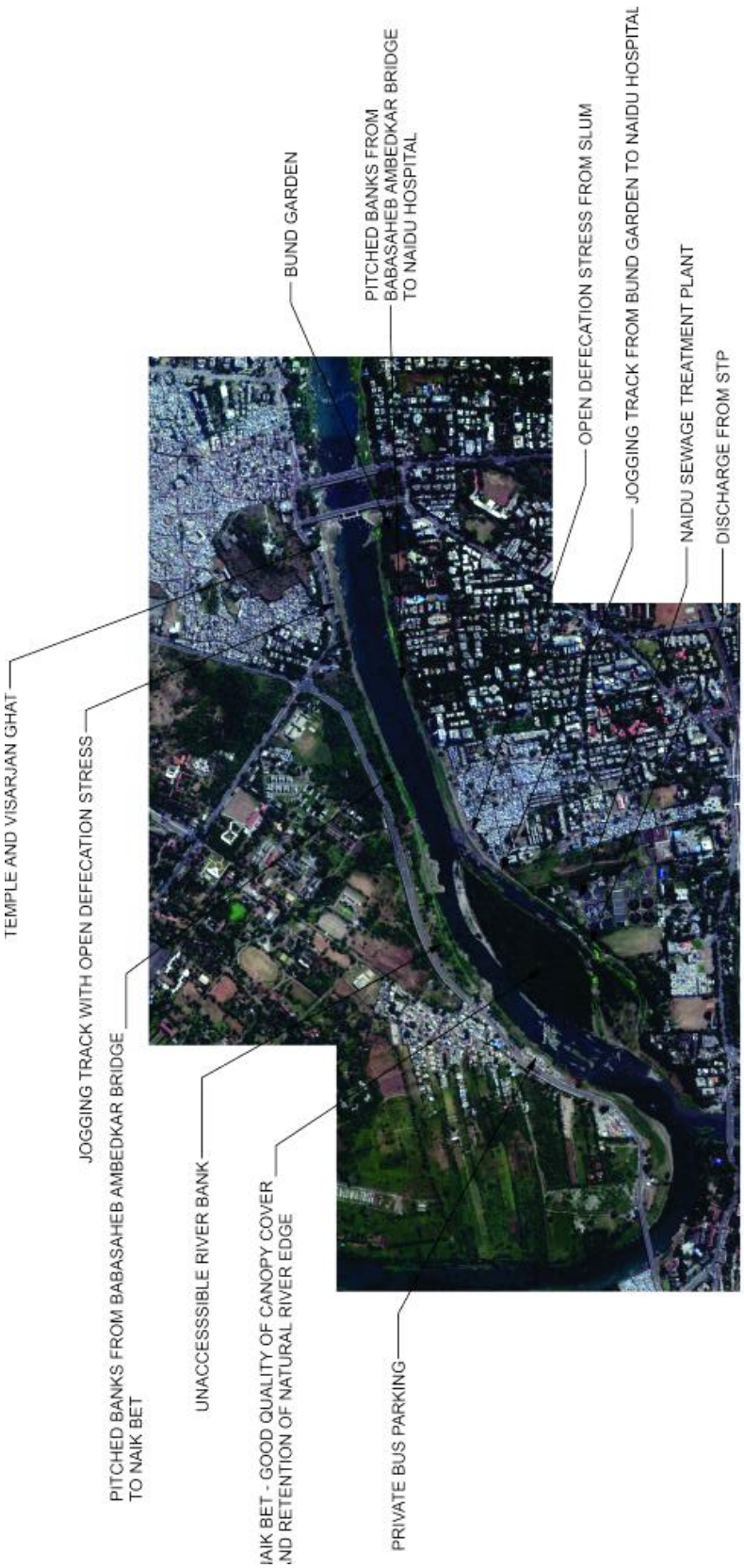
Fauna- Scavenging birds like crows, Black Kites, Pond Herons and Rock pigeons are dominant here indicating highly polluted water.

Figure 5: Cross section at Zone 3



D. Interventions

- Channelization
- Alterations in topography to construct road and infrastructure.
- Major Level difference between river and road. Limited access to river near areas like Juna Bazar, corporation.
- Dumping of Garbage in river and Feeding streams.
- Defunct Structures and remains of old causeway in riverbed.
- Grazing, clothes and Vehicle washing in riverbed.
- Open Defecation near Slum and feeding Streams.
- Unorganized and Haphazard infrastructure.
- All feeding streams are polluted.



ZONE 4: MULA MUTHA SANGAM TO BABASAHEB AMBEDKAR BRIDGE (BUND GARDEN)

Zone 4: Mula-Mutha Sangam To Babasaheb Ambedkar Bridge

A. General Character of the Channel

From Mula-Mutha sangam to Baba saheb Ambedkar Bridge, river has natural banks. The width of the river corridor increases significantly with good riparian vegetation present along both the banks. In this zone, the flow is divided by Naik Island. This Island is covered with a dense tree canopy. The island is isolated from the mainland during monsoon, but in summer, there is a pathway to walk across. Mula River is relatively deep, and flows are more to facilitate the Boat Club located here. Very high density residential areas and slum pockets are located along the river in this stretch. Open spaces are converted into parking spaces on the left bank. A walking trail is constructed from Bund garden upto the Naidu STP. Between the confluence and up to Bund Garden Bridge, there is pitching done intermittently. This makes the channel less natural. The intention of the pitching is not clear. In this zone the general character of the channel is changed completely by human interventions and hardly any natural character of the river is observed.

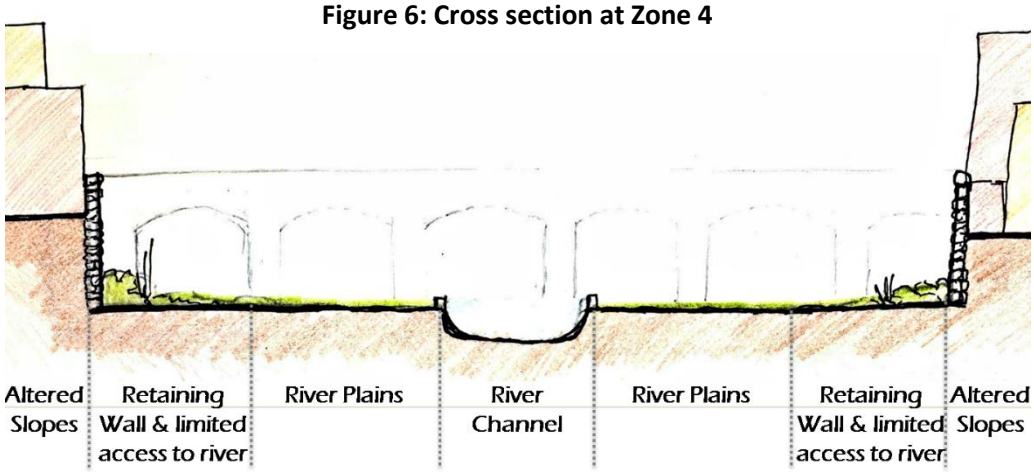
B. Flow

The Sangam is the confluence of the river Mula and Mutha. The flow of Mula is faster than the Mutha and this leads to sedimentation which has created an incipient island. This pops up during low water level. The mixing of two different flows changes the general pattern of stream flow and creates new habitats. The width and depth of the river channel is relatively more here. Water from the Naidu STP flows through the river with high velocity which is white and foamy probably polluted is seen near Naik Island.

C. Habitats

Habitats observed in this zone are: Open grassy patches, Riparian vegetation, Marshy areas, Upland vegetation and Prominent feature of this zone is island i.e Naik Island with dense vegetation.

Figure 6: Cross section at Zone 4



D. Biotic Aspects

Flora- Naik Island has dense and luxuriant vegetation. The 1958 study of Dr.V.D.Vartak recorded that *"Being in the mid stream the area receives new deposits of fertile soil every year, thus vegetation is thick and luxuriant. The perimeter of the island is covered with thickets of Syzygium, Phoenix and Pongamia trees along with the groves of Mango, Coconut and Santalum also shows the luxuriant growth. In the interior, the land is used for fruit orchard and for raising the crops like sugar-cane and other vegetables".* (V.D.Vartak, 1958). We could not visit the island due to high water level. However,we observed the vegetation from the left bank.

Near Mula-Mutha confluence, on the right bank at the back side of Ghat, riparian vegetation is dense and in tall canopy. Trees like *Pongamia, Syzygium*, associated with lianas like *Combretum ovalifolium (Piluki)* and climbers like *Argyreia nervosa (Samudrashok)* helping in forming a dense canopy cover. We observed vegetable farming in river bed by local people. Open patches along the trail are like protected areas (as this area is not used by people) supports good vegetation growth like *Abutilon, Ricinus, Ficus,* associated with grasses and herbs like *Alysicarpus, Indigofera, Crotalaria* etc. There are several host and nectar plants for butterflies and we observed good butterfly activity in this zone.

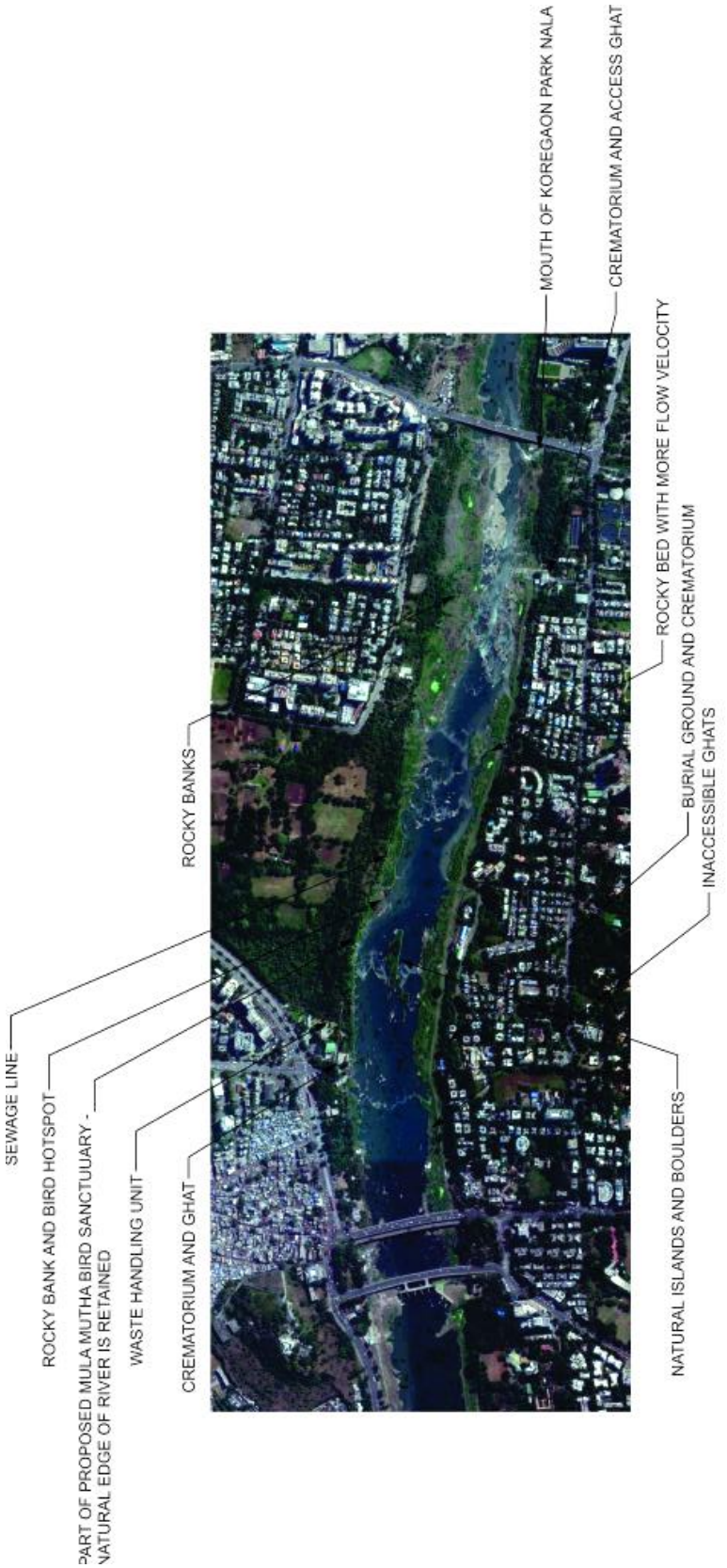
Fauna- The birds observed in this stretch are as follows-Painted stork, Pied Kingfisher, Black Ibis, Glossy Ibis, Cormorant, Red wattled lapwings, River Tern, Common Kingfisher, Purple heron, Wagtails, Woolly necked stork, Spot billed ducks, Coots and scavengers like Crows, intermittently Pariah kites, Rock pigeons and Mayna. This is a good diversity of birds. They represent various habitats, e.g. Glossy ibis, Black ibis, Purple heron, and Woolly necked stork use grasslands along the river bank. Pied Kingfisher,

Common Kingfisher shows the flow is sufficiently deep. Wagtails on the banks close to water and Red wattled Lapwings on the bank on the margin of grassland and open areas.

Scavengers like Crows, Pariah kites in large numbers near Sangam ghat indicate presence of biotic waste. Scavengers like Crows, Pariah kites in large numbers near Sangam ghat indicate presence of biotic waste.

D. Interventions

- Channelization
- Alterations in topography and there is a significant Level difference between river and road hence limited access to river.
- Pitching on both the banks of the river from Ambedkar Bridge to Naik bet.
- Dumping of Garbage in river and Feeding streams.
- Untreated sewage is released in river.
- Open defecation.
- Grazing, clothes and Vehicle washing in riverbed.
- Parking areas along the river near sangam.
- Unorganized and Haphazard infrastructure.
- All-important feeding streams and other fresh water streams are polluted.



ZONE 5: BABASAHEB AMBEDKAR BRIDGE TO AGA KHAN BRIDGE (YERAWADA)

Zone 5: Babasaheb Ambedkar Bridge to Aga Khan Bridge (Yerwada)

A. General Character of the Channel

Here the channel bed is very broad and braided. There are several islands which divide the flow. The stretch is characterized by rocky substratum and the river edge is in natural condition. There are big boulders in the main channel, rocky outcrops on the edges of the channel and the upland also consists of rocky substratum. Rocky outcrops on the edges and the upland provide resting places for some birds like the Pratincoles.

B. Flow

The gradient and velocity of the river increases as it flows towards Aga Khan Bridge from Bund Garden Bridge. This is because in the braided channel depth of water increases resulting in higher velocity.

C. Habitat

Habitats like Islands, boulders in the bed, riparian patches, open grassy patches, marshy areas, wetlands, rocky peninsulas, plantation area in upland zone, old growth trees are observed in this zone. We observed the greatest habitat diversity here. This was also the site selected by the late Shri Prakash Gole, founder of Ecological Society, for the Mula-Mutha Bird Sanctuary. A unique project which, when completed, will be a feather in the cap of Pune city.

D. Biotic Aspects

Flora - Island with dense vegetation supports *Syzygium, Pongamia* community associated with shrubs and herbs *like Phyllanthus reticulatus, Ricinus, Colocasia* etc.

Edges of riverbed observed growth of *Pongamia, Ficus racemosa* which indicates typical riparian community. At places also observed Salix and *Syzygium heyneanum* which indicator of good riparian vegetation.

In open patches, opposite Ghat, area is covered with grassy patches and stunted growth of trees like Acacia with few shrubs.

In rocky outcrops we see herbaceous vegetation like Evolvulus, Boerhavia associated with few grasses like Cynodon, Chloris etc.

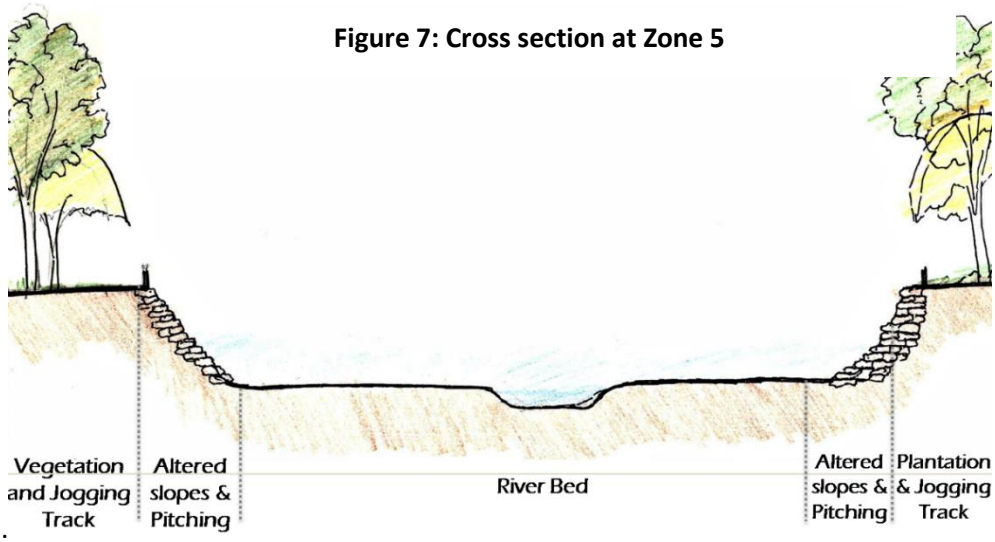
Upland plantation area having few old growth *Ficus* and trees like *Baobab, Acacia, and Dalbergia* etc. were seen. In the river bed we observed growth of *Eichornia* in patches where flow is gentle and water is stagnant.

Fauna-

The water-birds observed in the stream are as follows -Eurasian Coots, Spotbill ducks, kingfisher, River Tern, Gray Heron, Night Heron, Pied Kingfisher, Common Kingfisher, White breasted Kingfisher, Ruddy Shelduck, Cormorants, Pond Heron, Juvenile greater flamingo. On the edge of the water - White breasted water-hen, Purple moorhen. Gray heron, Open bills, night heron were observed.

In riparian zone-Ashy Prinia, Sunbirds, Green Bee Eater were seen. In the grassy patches there were Painted storks, Glossy ibis, Yellow Wagtail, Large pied wagtail, White browed wagtail. This area has greatest diversity of birds and very great congregation makes this zone special from the avifaunal point of view.

Figure 7: Cross section at Zone 5



E. Interventions

- Dumping of Garbage in river and Feeding streams.
- Waste handling units are located near the river
- Untreated sewage is released in river.
- Open defecation.

- Grazing, clothes and Vehicle washing in riverbed.
- Construction of sewage pipeline and inspection chambers are along the river bank.This construction is so high above the ground so that connection between upland and the riverbed is totally lost.
- Feeding stream on the right bank, opposite sanctuary area polluted, channelized and width of the stream is affected due to encroachment.

As is evident, many of the problems, issues and challenges repeat throughout the five zones. Similarly, the flora too repeats over the zones. It is the fauna which changes in the zones, depending on the quality of the habitat and the human disturbances.

Impacts of Interventions

The flow of river Mutha in the city area is not natural since the series of dams are constructed in the catchment area. These dams and the recent interventions such as channelization, roads, pitching, encroachment and others, affect river ecosystem. Here we note the effects of these and other interventions.

1. Effect of Dams

The minimum environmental flow required to sustain the river ecosystem is not being maintained in the river. Two important characteristics of the river are flow and flood. The “flood pulse” in tropical monsoon fed rivers is periodic. Life in the river adjusts to the flood pulse events. On the other hand, the press events are not natural events. Water released from the dam into the river channel is not periodic or rhythmic. Its quantity and duration are decided by human needs. Dams change the physical and biological rhythm of the rivers and organisms in the riverine ecosystem find it tough to adjust to the changes.

2. *Effect of Pollution and water quality*

STPs are installed along the river to treat the city sewage. This is then discharged into the river. However, the output quality of the STP needs to be studied. Furthermore, there is a significant addition of untreated sewage to the river. Due to this sewage, the ratio of fresh water to sewage water is very

low. Consequently, the river emits a foul smell and water is turbid. These problems have been identified by the PMC on their website.

From the data taken from PMC websites, we observe that average values of DO in Mutha and Mula-Mutha River has been below 4mg/l in last six years. Very few species of aquatic fauna can survive below 4mg/l and areas where DO is below 2mg/L, there is no possibility of aquatic life as the conditions are anaerobic. This indicates a highly degraded state of the river. This state can improve during monsoon, but this is a temporary state which does not lead to sustainable fauna in the river.

3. Effect of channelization

Till recently, the river flow was natural as several streams added freshwater into the river. The Kirkatwadi Odha, Nagzari odha, Ambil odha added a significant quantity of water to the river Mutha. For example, Kirkatwadi Odha was a main source to supply drinking water along with water from Mulshi dam to Pune during the crisis of 1962 Panshet dam disaster. (Deluge in Poona - Aftermath and Rehabilitation, Brahme & Gole, 1966). There was no significant change in the quality and quantity of water discharged by these feeder streams up to 1982. (Survey of the Rivers in Pune City based on Ecological factors to prepare an eco-development plan to improve the River-Fronts of Pune, Gole, 1983). However, post 1980's the river as well as the feeder streams were channelized. This affected the flow and water quality. Moreover, the ratio of sewage water to fresh water carried by the streams drastically increased.

Due to channelization, the flow is restricted to a small section of the river bed. Rest of the river bed remains dry and deprived of water; which makes the existing habitats defunct and adversely affects the species diversity. *"Because channelization disrupts the horizontal sinuosity of the stream channel, the types and functions of the species change as the habitat become more homogenous. Because of channelization of tributary streams, bank vegetation cover is eliminated. So, the amount of allochthonous organic input in this stream is diminished"*[1]. (Allochthonous material - something imported into an ecosystem from outside of it).

[1] Newhold, 1981, Strategy of Stream ecosystem recovery, In stress effects on Natural Ecosystem

Channelization also affects ability of the channel to migrate. This in turn hampers the regeneration dynamics of the channel bed vegetation. Lateral channel movement creates point bars (riffles) and Pools, which are suitable surfaces for plant generation[2]. As discussed by Newhold (1981), in the Mutha, its sineous course was observed near Vithalwadi and behind Garware College. The channelization in these areas resulted in loss of pools, riffle and island habitats.

4. Effect of pitching

A river's cross sections are dynamic. After every small or big flood it changes, there is fresh erosion and deposition. This is dependent on the force of flow, sediment load and other factors. When channel edge is stabilized by pitching the flexibility of processes is lost and it may erode or deposit excessively at other unpredictable places.

We observed extensive pitching constructed between Mula-Mutha confluence till Bund-Garden Bridge intermittently. Below this section is the ecologically important area for the `Mula-Mutha Bird Santuary`, as mentioned in the earlier section. This zone may get affected badly by excessive erosion or deposition.

5. Effect of roads and encroachment

The most significant intervention is the construction of road within the river channel. This intervention has many impacts

- Affects function of channel processes
- Destruction of channel topography
- Destruction and disturbance in habitats
- Loss of habitats and their biodiversity
- Loss of recharge and discharge zones

Road affects entire functioning of river ecosystem. It is not advisable to construct roads in the river channel or the riparian zone.

[2] Shankman, 1993, Channel migration and Vegetation pattern in the south eastern Coastal plain, Conservation Biology 7, pp 176-183; Shankman and Drake, 1990, Channel migration and regeneration of bald cypress in Western Tennessee, Physical Geography, ch 11, pp 343- 352

4 | Qualitative Assessment of Zones

The physical and biological aspects observed in the five zones were significantly different from each other. For an effective recommendation plan, we had to bring them on a common assessment platform. We did this by assessing the ecological quality of the zones, based on various parameters. We marked each zone based on nine characteristics and rated them on a scale of 0 to 5. High marks representing a higher value. The maximum marks possible for each zone is 38 and the total score of each zone was computed. Based on the scored percentage, each zone could be graded into three grades. The table ahead shows the assessment.

Zone-wise Quality Assessment							
		Zone 1.1	**Zone 1.2**	**Zone 2**	**Zone 3**	**Zone 4**	**Zone 5**
Channel	Range 0-5	3	2	0	1	4	5
Flow	Range 0-5	3	2	0	1	4	5
Habitat diversity	Range 0-5	4	2	1	0	3	5
Floral diversity	Range 0-5	4	2	1	0	5	3
Bird diversity	Range 0-5	3	2	1	0	4	5
Solid waste dumping	Yes=0, No=1	0	0	0	0	0	1
Encroachment	Yes=0, No=1	0	0	1	1	1	1
Human disturbance	Range 0-5	3	2	0	1	4	5
Roads/intervention in channel	No=1; Yes=0	0	0	0	1	1	1
Total Marks per Zone	**38**	**20**	**12**	**4**	**5**	**26**	**31**
Percent score		**52.63**	**31.58**	**10.53**	**13.16**	**68.42**	**81.58**

Table 1: Qualitative assessment of the Zones

Based on this quality assessment of each zone, we divided the zones into three grades, Grade 1 being the best and Grade 3 being the relatively poor zones.

The water quality is consistently poor throughout the zones, hence was excluded as an assessment criterion.

GRADE 1 Zones with relatively high ecological value Score > 66%	**GRADE 2** Zones with a relatively medium ecological value Score between 30-65%	**GRADE 3** Zones with the least relative ecological value Score < 33%
Zone 5	**Zone 1.2**	**Zone 3**
A. Strengths 1. Channel character and flow 2. Habitat diversity and bird diversity 3. Minimum solid waste dumping, encroachment, human disturbance and roads / interventions in channel. B. Opportunities 1. Floral diversity quality can be improved. C. Weakness 1. Nothing significant	A. Strengths 1. Habitat and floral diversity B. Opportunities 1. Channel character, Flow, Bird diversity and moderate human disturbance C. Weaknesses 1. Solid waste dumping, encroachment and roads in river channel.	A. Strength 1. Minimum roads / interventions in channel B. Weaknesses 1. Channel, flow, encroachment, Human disturbance C. Threats 1. Poor biodiversity and solid waste dumping.
Zone 4	**Zone 1.1**	**Zone 2**
A. Strengths 1. Floral diversity is the best 2. Minimum disturbance and encroachment 3. Naik island 4. Channel character, Flow, Biodiversity are strengths. B. Opportunities 1. Solid waste dumping to be stopped, protection of habitats from stresses induced due to grazing and open defecation. C. Weakness 1. Nothing significant	A. Strengths 1. Nothing significant. B. Opportunities 1. Channel, flow, habitat diversity, floral diversity, bird diversity, moderate human disturbance C. Weaknesses 1. Solid waste dumping, encroachments and roads / interventions in river channel	A. Strengths 1. No encroachments B. Weaknesses 1. Poor biodiversity C. Threats 1. Channel characters, flow, solid waste dumping, human disturbance and roads / intervention in channel.

Table 2: Grading scheme for zones

Strategy for Zones

Based on the qualitative assessment and grading done in the previous section, we propose a broad strategy for each grade. These strategies should be broadly followed for zones in the specific grades.

1. GRADE 1 Zones 4 and 5 : No interventions and a benign neglect

In these zones active restoration could be unnecessary and sometimes detrimental. We recommend no interventions and allow an undisturbed recovery. These zones have a potential to recover by benign neglect. It is necessary to take help of experts and the following steps are sufficient for the revival of this zone. These zones have a potential to recover.

1. Conservation of aquifer discharge areas (natural springs).
2. Conservation of heritage sites such as ghats, places of worship, samadhis and memorials.
3. Conservation of all habitats like instream, rocky banks, potholes, ponds, islands, upland zones, Riparian zones.
4. Identification and conservation of sediment deposits that indicate climatic history through geological time.
5. Conservation of faunal hotspots like roosting and nesting sites.
6. Restriction of human and cattle access by designing barriers

2. GRADE 2 Zones 1.2 and 1.1: Partial intervention

For zones in this grade, we propose some interventions which are important for assisted recovery. In these zones the stream corridor has the potential to recover. In such a case, action may facilitate natural processes already occurring.

1. Improvement of existing habitats
2. Removal of existing interventions that affect functioning of river / stream ecosystem.
3. Creation of public amenities and open spaces such as jogging tracks, gardens, public toilets, access points.

3. GRADE 3 Zones 3 and 2: Substantial intervention

Zones in this grade are in a relatively poor ecological state and require substantial intervention for a managed recovery. In these zones the recovery of desired functions is nearly beyond repair capacity of the ecosystem and thus active restoration measures are required.

1. Measures for bank stability, enhancement of drainage patterns and upland topography etc.
2. Structures for Water quality improvement measures
3. Habitat creation - Instream, bank, upland.
4. Removal of existing interventions that affect functioning of river / stream ecosystem.
5. Removal of encroachments / waste and debris dumping.
6. Creation of aquifer recharge areas
7. Creation of extensive Riparian zones.

Ecological and cultural hotspots in the stretch

A Biodiversity hotspot according to the Botanical Survey of India is "Hotspot is a biogeographic region that is both a significant reservoir of biodiversity and is threatened with distraction." Given the history of the river, the entire stretch has many important ecological and cultural features. These are critically important part of the legacy of the city and make for a case in immediate conservation. These places are highly vulnerable and irreplaceable. We identified 12 types of such hotspots. There is an urgent need to protect and conserve them. Where biodiversity is significant, but threatened, in case of surveyed stretch of river Mutha was identified.

The following hotspots were identified:

1. Ecological hotspots
    a. Rocky banks
    b. Feeder stream mouths
    c. Alluvial filled surfaces
    d. Grassy patches
    e. Riparian habitats
    f. Faunal hotspots
2. Cultural hotspots
    a. Ghats
    b. Places of worship
    c. Memorials
    d. Heritage structures

These hotspots in each zone are shown on the following maps.

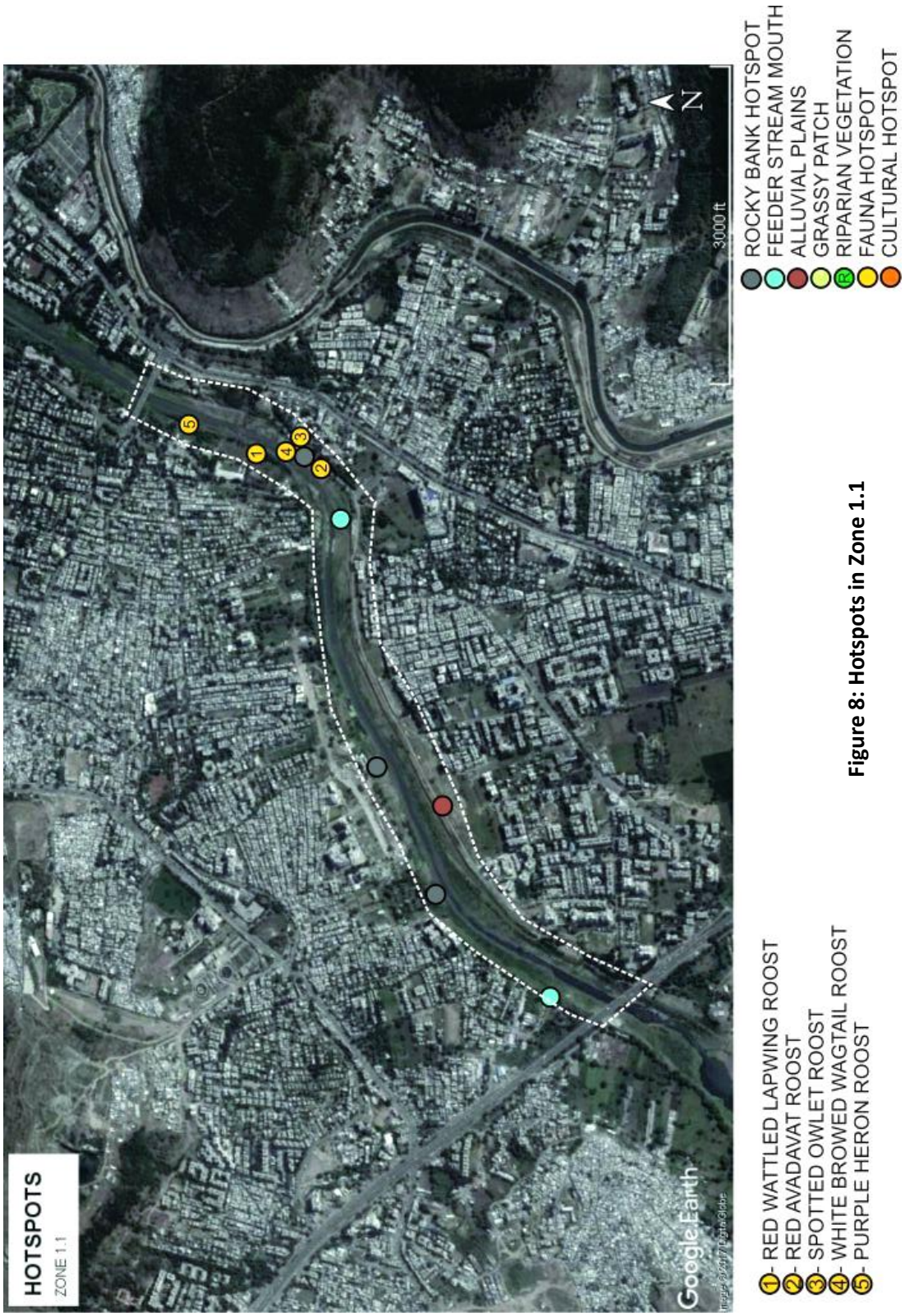


Figure 8: Hotspots in Zone 1.1

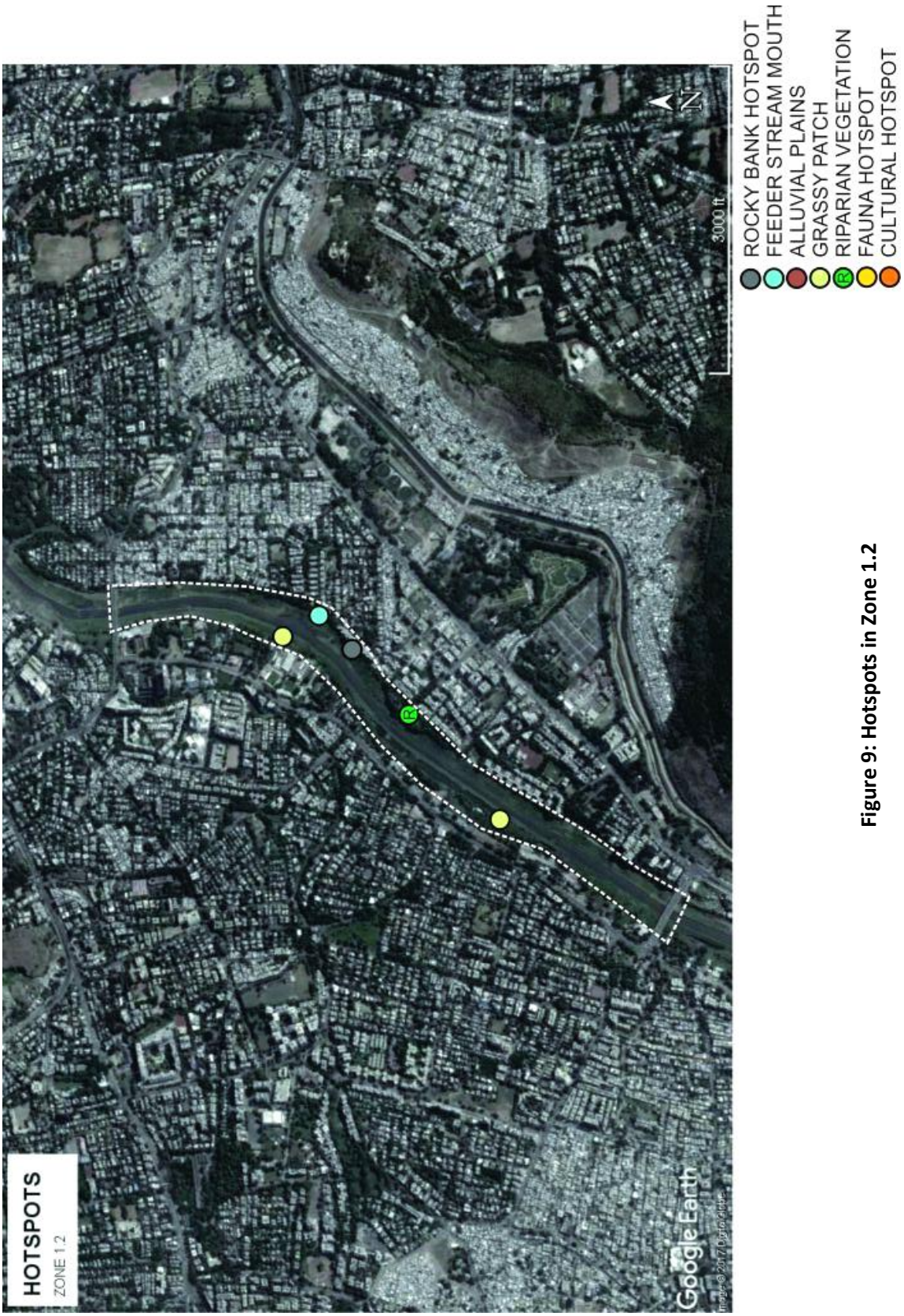


Figure 9: Hotspots in Zone 1.2

Figure 10: Hotspots in Zone 2

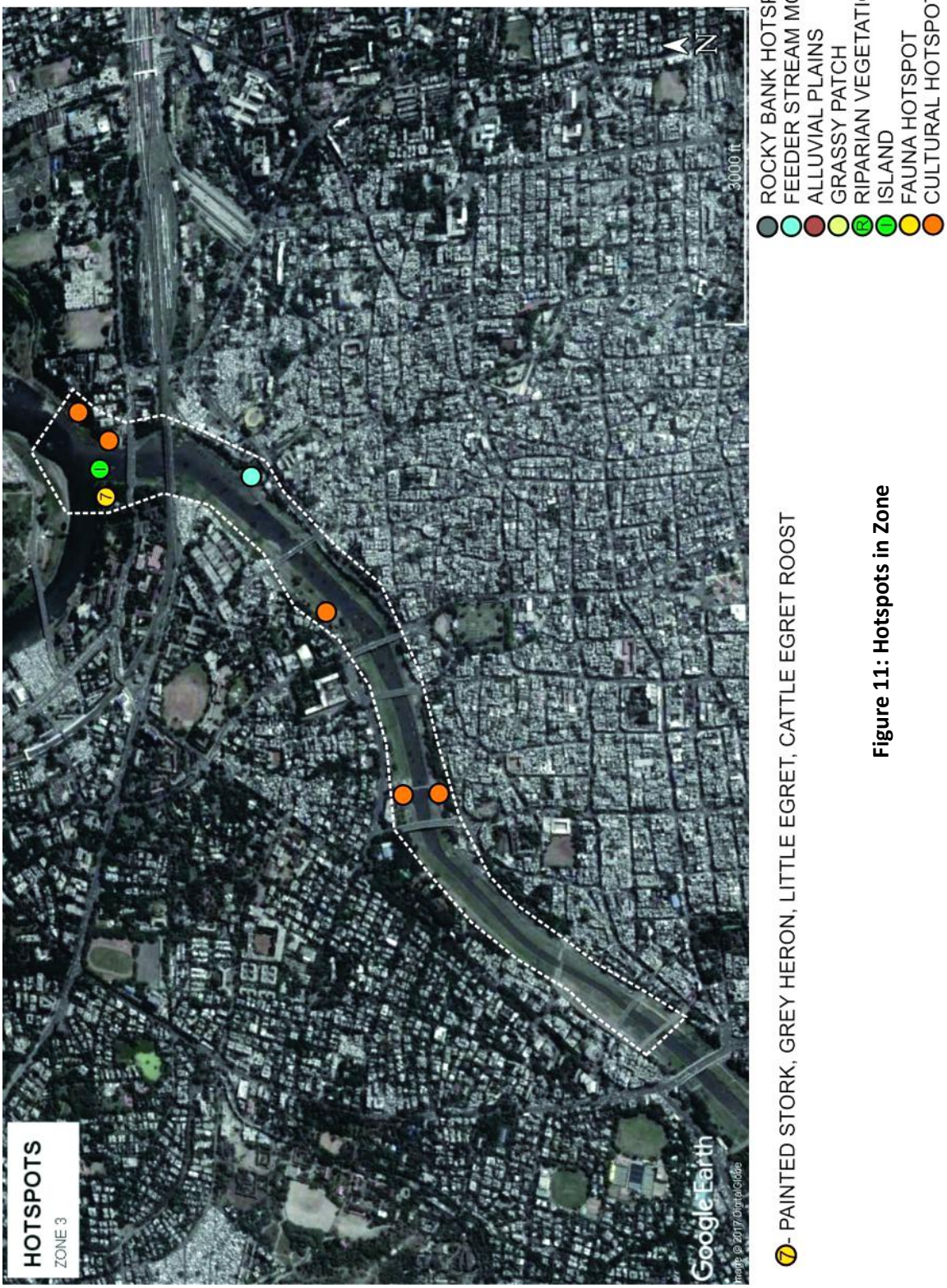


Figure 11: Hotspots in Zone

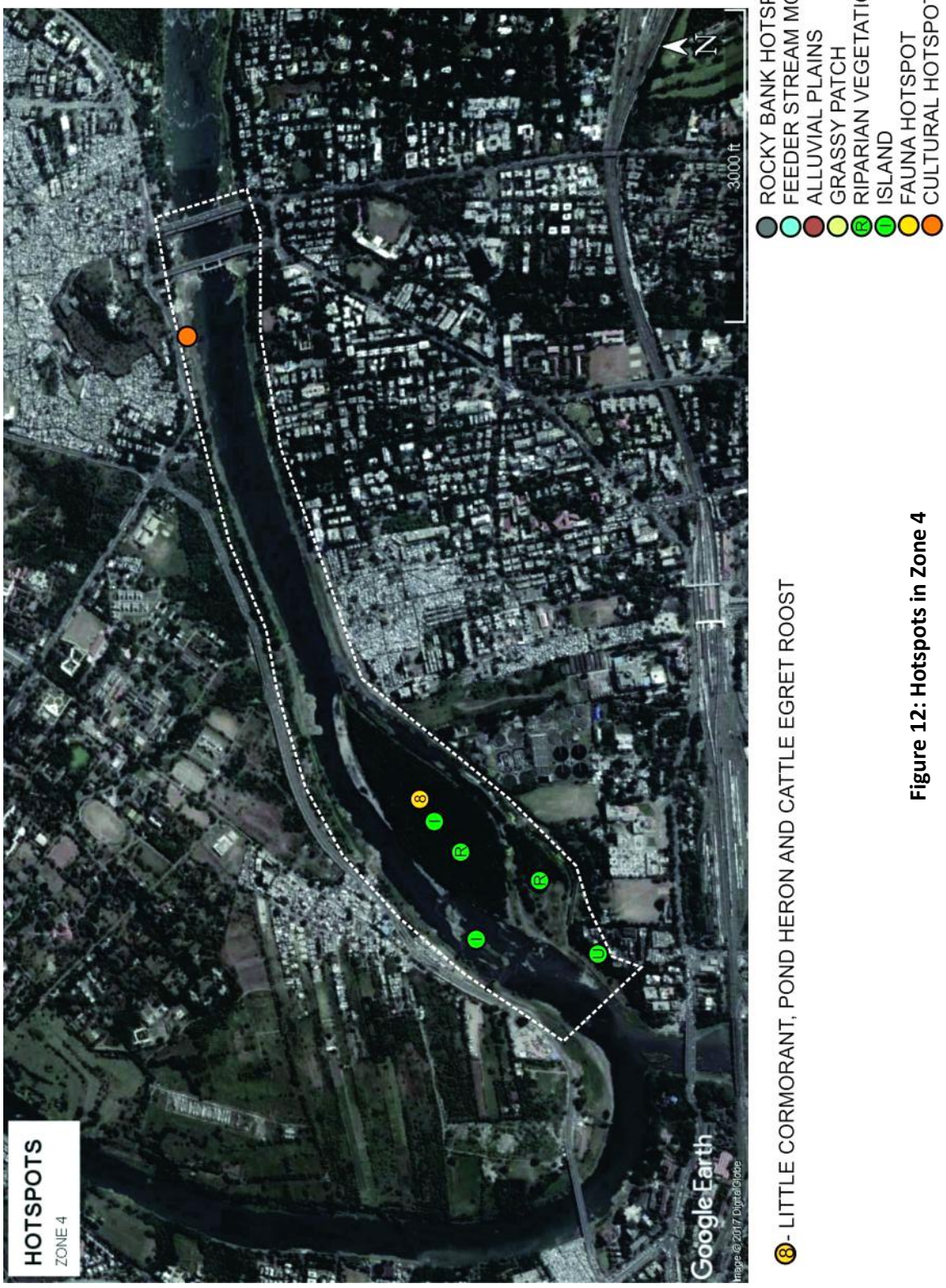


Figure 12: Hotspots in Zone 4

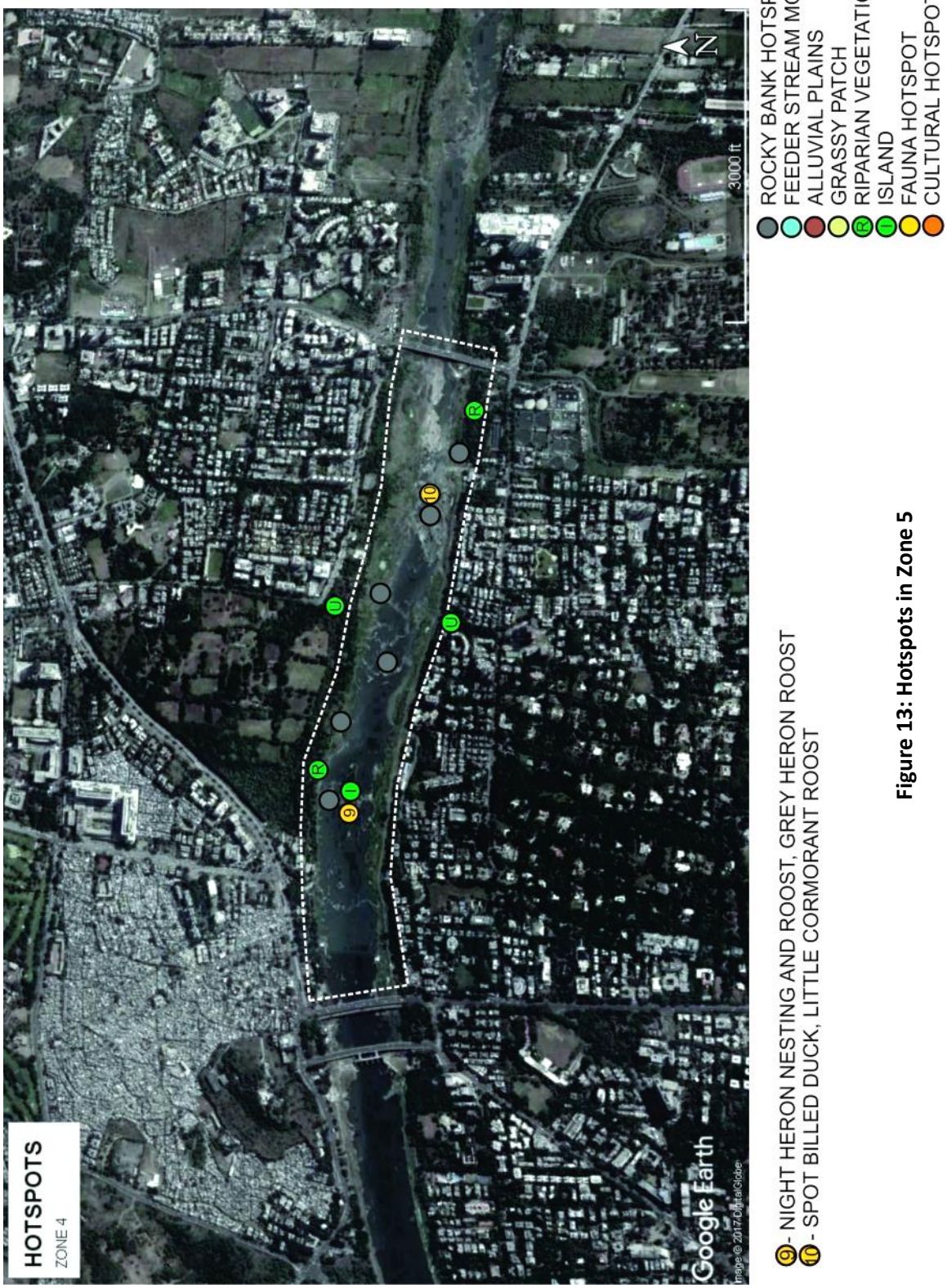


Figure 13: Hotspots in Zone 5

5 | Ecological guidelines and recommendations

Vision for the rejuvenation of Mula - Mutha river ecosystem

"There is a phenomenal resiliency in the mechanisms of the earth. A river or lake is almost never dead. If you give it the slightest chance… then nature usually comes back."[3] -.

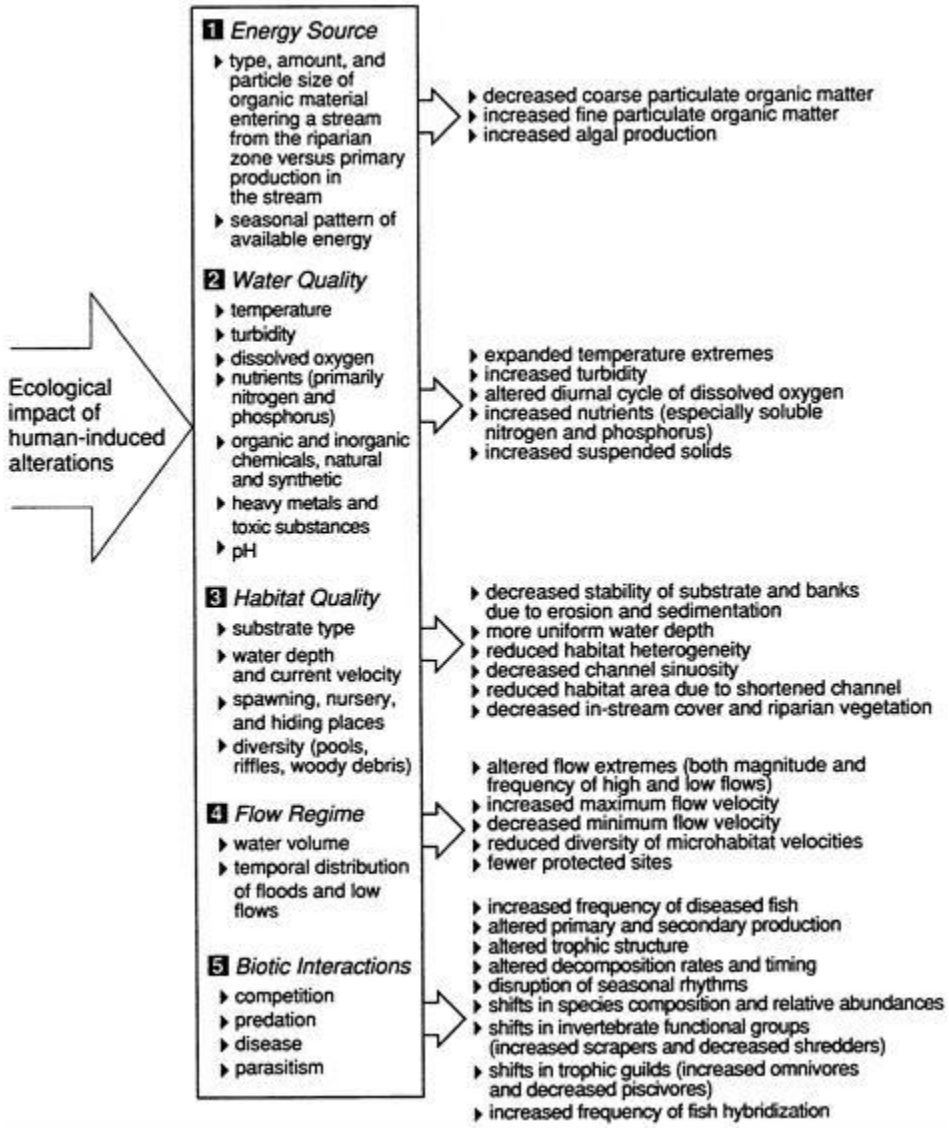
"Each stream is a whole greater than the sum of its geologic, climatic, hydrologic and biologic parts. Those who would save the rivers must first see each river whole, as a separate, vital and unique group of elements and energies that constantly seeks its own dynamic equilibrium." [4]

For the riverfront Development of the Mula - Mutha, it is essential to address not just the immediate banks of the river, but the river and stream corridor in entirety. These are complex ecosystems with

[3] Rene Dubos, 1981
[4] Nick Lyons, Foreword to Better Trout Habitat: A Guide to Stream Restoration and Management; Hunter, 1991

biodiversity and a network of streams. They perform critical ecological functions like modulating streamflow, storing water, removing pollutants from water and providing various habitat which hosts a rich biodiversity. River and stream corridors have vegetation and soil characteristics distinctly different from surrounding uplands and support higher levels of species diversity, species densities, and rates of biological productivity than most other landscape elements.

The five major classes of environmental factors that affect aquatic biota are shown in the figure. Arrows indicate the effects that can be expected from human activities, in this case the alteration of headwater streams, excluding small impoundments. Source: Karr et al., 1986 Illinois Natural History Survey, Champaign, III



Therefore, we consider that the vision for a holistic improvement in the river rejuvenation must address the following:

A. Conservation of the river as a natural entity.

The river is a vibrant ecosystem which bestows numerous ecological functions like recharge and discharge, erosion and deposition, storm water drainage etc. It is of critical importance to retain these natural functions and processes. This necessitates that the ecological value must be prioritized over the economic utility arising from the river. The proposed interventions must respond to this natural context sensitively, and not cause any major deviations to these functions.

We recommend that utmost importance be given to the restoration of the natural design of the river, over a human-centric built designs. This would not only make the project unique but also contribute to the ecological value accrued by the city.

B. Restoration of natural zones along the river

Ecological restoration is the process of returning an ecosystem as closely as possible to pre-disturbance conditions and functions. The restoration process includes rejuvenation of the structure, function and self-sustaining behavior of the ecosystem. Following restoration strategies must be applied in stages and corresponding to the ecological status of each zone.

1. Substantial intervention for managed recovery
2. Partial intervention for assisted recovery
3. Nonintervention and undisturbed recovery

C. Maintaining environmental flow and carrying capacity

For a natural state and to protect the habitats, it is essential to maintain the minimum and maximum levels attained by the river water naturally.

“Environmental flows is a system for managing the quantity, timing, and quality of water flows below a dam, with the goal of sustaining freshwater and estuarine ecosystems and the human livelihoods that depend on them. The most ecologically important aspects of a river’s flow are extreme low flows, low flows, high flow pulses, small floods, and large floods. Environmental flows can be designed to restore

any of these, with the goal of improving water quality, restoring sediment deposition, addressing the life-cycle needs of fish and wildlife, and restoring the livelihoods of river-based communities." [5]

"Most Indian rivers have gone sick primarily due to excessive diversion of their flows. It is said that diversions have been planned and executed without taking into consideration the survival need of the nature and its riparian communities. To make pollution abatement measures effective in the form of infrastructure development may not go long way to improve the health of the rivers unless survival need of the river system is an integral factor in our river planning." [6]Thus, it is of prime importance to maintain the minimum requirement of environmental flow for the Mula-Mutha for sustenance of the river ecosystem along with its functions and services. In Mula-Mutha the river flow is erratic and environmental flow is many times absent causing the loss of habitats and biodiversity.

D. Decentralized approach to river rejuvenation

Feeding streams are the most important feature of the Mula - Mutha ecosystem. Historically, the southern tributaries like Ambil, Nagzari contributed large quantities of water to the river. Today, these tributaries are enchroched upon and this has resulted into limited recharge of groundwater aquifers, reduction in the natural flow and large contribution of sewage water through these streams to the main stream. Therefore, restoration of the feeding streams is essential in the planning. If issues such as those relating to dumping of debris, solid waste, sewage and others, are addressed at the catchment level, they can lead to a sustainable solution.

E. Restoration for utility and aesthetic value

Restoration of the river ecosystem shall not only contribute to the ecological utility of the river, but also complement the beautification of the riverfront. Maintaining water quality is important for enhancing visual appeal of the riverfront. This will help the river to host macro and micro habitats for a wide array of flora and fauna. This in turn shall spawn biodiversity. There is an immense potential for research and scientific activities like birdwatching, insect trails, herpetology studies along the river banks. Conservation of Ghats and historical monuments, gardens is essential and its design should be

[5] https://www.internationalrivers.org/environmental-flows

[6] Source - NGT verdict for Yamuna River 2012

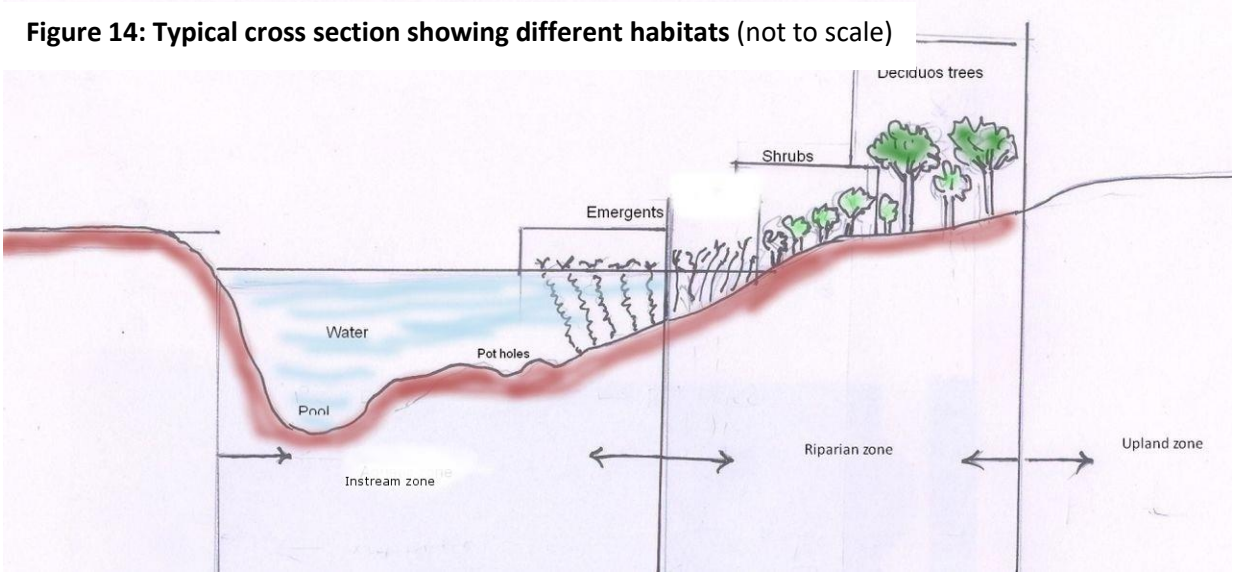
complementary to nature. Furthermore, identification of physical characteristics and improving them so that they will contribute to improvement in the biological characteristics, must be planned.

General guidelines and recommendations

While considering the stretch of the Mula - Mutha in the project area, some broad recommendations come to the fore. These address the river as a single entity, and aim at resolution of issues that are observed to be common along the entire stretch of the project area. These general guidelines and recommendations are as under:

1. Flora and Fauna

Figure 14: Typical cross section showing different habitats (not to scale)



In 1957, 400 species of 72 families were reported by Dr. V.D.Vartak. In 1981 there were 133 aquatic plant species belonging to 97 genera in 41 families (Dr. Vinaya Ghate). In 1983 Prakash Gole recorded 159 plants excluding ephemerals, in a six months study. Our study recorded 208 plants of 63 families. In 1958 aquatic species like *Ceratophyllum, Ottelia,Crinum, Najas, Eulophia, Potamogeton* were recorded. They are indicators of a good riverine ecosystem. Our study shows decline in purely aquatic plants and occurrence and dominance of weeds like *Eichornia* and *Pistia*. Most of the species are common and generalist plants species, including aggressive weeds. This indicates deterioration in quality of aquatic vegetation of Mula-Mutha.

Flowing water through the channel bed alters the shape of stream bed and the processes of erosion, deposition; creating variety of habitats like pools, riffles, riparian zone, islands, rocky patches, open grassy areas, sandy areas, etc. This habitat supports typical vegetation according to its microclimate, substratum, water availability, flow, its location etc.

This vegetation plays major role in functioning of riverine ecosystem. These habitats and its vegetation associated with its fauna is disturbed by absence of lack of environmental flow, polluted water, channelization, encroachments, dumping, roads, etc. Once these habitat conditions are improved, the vegetation will revive itself as seed bank is already exists in the river bed and its surrounding area. Only then faunal species which depends on this vegetation will establish their occurrence for food availability, roosting and nesting purpose. "Hydrophytes are important in restoring the ecological balance in the polluted environment"[7].

Growth of aquatic vegetation depends on the availability of oxygen, light, temperature, strata, flow, amount of water, etc. Availability of light and temperature are the key factors which depends on the depth of water. So the type of aquatic plants varies with the increase in depth of water. Different water levels create different zones in river bed i.e. aquatic, riparian and upland. These zones support growth of specific type of plants, e.g. Like *Ceratophyllum, Azolla, Wolffia* in aquatic zone, Amphibious plants like *Pongamia pinnata, Ficus racemosa, Commelina, Polygonum, Cyperus* spp. etc. in riparian zone and trees like *Phoenix sylvestris, Bombax ceiba* in upland vegetation. We observed aggressive weeds like water *hyacinth, Alternanthera* at many places which is a major threat for river. While restoring the habitats care should be taken for selection of plant species and its location. Plantation can be done only in riparian zone and in upland area. But for selection of plant species in more details, The study of the flora of the Mutha River-Bed near Poona by V.D.Vartak (1958) and Studies on the Aquatic flowering Plants from greater Pune Area: part I Enumeration by Vinaya Ghate and V.D.Vartak (1981) is very useful and study the same for Mula-Mutha rejuvenation purpose.

We observed aggressive weeds like water hyacinth, *Alternanthera* at many places which is the major threat for riverine ecosystem of Mula-Mutha. A periodic management is necessary for complete removal of these weeds for revival of habitats and its vegetation. We have recommended vegetation species for riparian and upland vegetation in the annexure.

[7] Ghate 1981

If any plantation of vegetation is to be proposed as a part of the Riverfront / Rejuvenation Project, the flora native to these respective habitats alone must be considered. Plantation of non-native species of flora and introduction of non-native faunal species must be strictly avoided. A list of flora and fauna corresponding to the above habitats is attached in the Appendix and can be referred to for plantation.

2. Habitat Creation

The flow and flood rhythm of rivers create micro physical features such as, exposed rocky surfaces in the stream bed, alluvial filled surfaces on the banks, pot holes, sandy surfaces on the river bed and boulder piles, etc. These riverine features are habitats for various kinds of organisms both plants, animals and microbial organisms. Oxygenation of river water takes place when it flows over exposed rocky surfaces. Several years of alluvial deposition creates riparian zones. These zones perform important functions like nutrient cycling, absorbing and releasing flood waters, maintaining fish and wild life habitats. The riparian zone is a series of aquatic and terrestrial vegetation bands or eco tones through which matter and water exchange takes place. Similarly, grassy patches, pot holes, sand flats etc. habitats play important role in biological functions. The biotic component of the river filters contaminants in the flow. We recommend: (i) Creation of instream habitats such as pile of boulders in the streams, creation of sand flats, conservation of potholes and creation of riparian zone by plantation (ii)Protection of existing riparian zone vegetation.

3. Construction activities

It is important that utmost care be taken to conserve the ecosystem along with its habitats, during the construction of any interventions as a part of the Riverfront Project. We do not recommend any construction in the river bed, other than pillars, which are ecologically designed.

i. The natural topography and drainage patterns of the river banks and river bed must be conserved during construction.
ii. The natural proportion of hardscape (impervious cover) and softs cape (soil, natural vegetation) must be maintained during construction. Adequate provision of recharge or discharge of aquifers must be kept at the time of planning any development work.
iii. Use of natural materials such as stone, mud, mud bricks, lime, local species of timber and bamboo must be encouraged for construction activity. Use of cement should be kept to a minimum.

iv. Care must be taken that surrounding natural physical features, habitats and biodiversity is not disturbed during the construction process. Earth moving machines cause large scale destruction of habitats and are best avoided around the hotspots. Manual labour must be given priority over these machines when possible.

v. Material like mud, silt, stone and sand shall not be procured from the river bed, banks, alluvial terraces or upland zones adjoining the river.

vi. Vehicular circulation for carrying the construction materials to the site must be planned and demarcated before commencement of the construction activity.

4. Water Quality

Presently, there is more sewage than fresh water in the river. We suggest the following measures:

i. No untreated sewage must be added to the river. It is critical that adequate STPs, commensurate to the growing population, are fully functioning. They must be monitored.

ii. STPs are not a long term sustainable solution as they are unable to treat all pollutants. Alternate sewage management systems are available and should be evaluated. A pilot testing is recommended before any large-scale implementation.

iii. All construction debris dumped within the red and blue flood lines to be immediately removed. This adds to the pollution and is a flood safety hazard.

iv. All encroachment within the red and blue flood lines to be demolished. Besides being a flood hazard, this is a major source of untreated sewage.

v. All the access points from which solid waste dumping happens into the river to be identified and mapped and appropriate design / planning solutions to be suggested to prevent the same.

vi. Water quality of the river must be maintained as per international / tropical standards (8PPM DO).

vii. Non-toxic and natural alternatives to chemical domestic products such as soaps, shampoos, detergents to be identified and promoted by the State. Policy level deterrent to the manufacturers / distributors of these products must be imposed under the “Polluter pays” principle.

5. Channelization

The channels in the river adversely affect the river ecosystem. All channels must be removed immediately. In the following monsoon cycle, detailed studies must be conducted to ascertain the natural character of the river before preparing the Riverfront Development Plan.

6. Aquifers and Hydrology

The hydrology of the urban stretch of the Mula - Mutha has undergone massive changes. Significant amount of the stream's flow is delivered as storm water runoff rather than baseflow. Depending on the degree of watershed impervious cover, the annual volume of storm water runoff can increase by up to 16 times that for natural areas (Schueler, 1995). In addition, since impervious cover prevents rainfall from infiltrating into the soil, less flow is available to recharge ground water. Therefore, during extended periods without rainfall, base levels are reduced.

i. We recommend a detailed study to maintain the ratio of natural vegetation. For this the impervious cover must be restricted to restore the base flow.
ii. A detailed map of the aquifers must be prepared. This should be referred to during the riverfront project. Furthermore, identify recharge zones of springs.
iii. Advice from hydrologists must be taken to ascertain the recharge and discharge zones of aquifers in the river.
iv. Natural springs in the catchment of the river and feeding streams must be conserved suitably and there must be no obstruction in their flow.
v. To arrange the recharge of aquifers.

7. Archaeology and Geology

i. The rocky banks and the alluvial terraces along the river must be identified with the help of geologists and archaeologists and suitably conserved.
ii. Access to be given to geologists / archaeologists to any construction site along the river to study the geomorphology and document it.

8. Human Activities

The river ecosystem has the capacity to provide for essential human utility such as water for domestic use, nutrients, wild vegetables, fishes etc. However, one needs to understand that there is an intrinsic

limit to the types of activities and their scale that a river ecosystem can sustain. This is termed as the "carrying capacity" of the river.

8.1 Domestic

NGT verdict on Yamuna river e-flow cites the example of water supply system for London city. *"City of London in UK manages its water supplies in form of off-river distributed reservoirs created on the bank of river Thames and river Lea. Water from river Thames / Lea during high flows in winter months is collected for later use."* (Source - NGT verdict for Yanuma River 2012) It goes on to suggest that the same can be applied to the river Yamuna. Shri. Prakash Gole has made a similar recommendation under the concept of "Retention / detention basins". this strategy can be effectively applied in the case of the Mula-Mutha. Open areas that would function like reservoirs / retention – detention basins must be identifies within the Municipal area of Pune as well as in the upstream areas (Source of 1983 report). These will not only act as decentralized sources of water that shall be filled during the press and pulse events during the monsoon, but also act as effective flood control measures in cases of emergencies. They can turn into riparian habitats which provide functional open spaces.

i. Carrying capacity of the river must be calculated to maintain minimum environmental flow that needs to be retained throughout the year. Accordingly, water quantity to be provided per head can be calculated.
ii. Wastewater from residential, commercial and industrial properties must be treated for physical and chemical pollutants at source or decentralised at society / ward level.
iii. Waste water quality must be maintained as per recommendations in the above "Water quality" section.

8.2 Grazing

i. At no point shall cattle roam freely in the river bed / banks. Habitat destruction by grazing / trampling must be strictly prevented.
ii. Fine to be imposed for illegal grazing
iii. There shall be no animal sheds in the river corridor. (cattle, pigs, horses etc)

8.3 Fishing

i. Fishing can be permitted only after water quality and habitats are restored.
ii. Devise a permit system to regulate fishing activity. This will prevent the over exploitation.
iii. No large nets, motor boats or hi-tech equipment shall be allowed for fishing
iv. No fishing allowed in the breeding periods
v. Hotspots like rocky banks and mudflats that act as spawning areas must be protected from fishing

8.4 Dhobi Ghats

i. Dhobi ghats can be retained in the Riverfront development Project.
ii. Discharge water to be treated
iii. Chemical detergents should not be used.

8.5 Vehicle washing

i. No vehicle washing to be allowed in the river.
ii. Where the road side storm water gutters meet nallas, streams or river, suitable treatment for suspended solids and oils shall be provided.

8.6 Rituals

i. Dumping of any solid waste into the river under the pretext of religion / tradition must be stopped immediately.
ii. Water must not be released from the dam for any religious / cultural reasons.

8.7 Eateries

i. Ban on plastic bags, containers, disposable cutlery in eateries around the river.
ii. Area for eateries must be restricted. Cannot be in the physical proximity of the river.

8.8 Recreation

i. Recreational activities which do not impact the river can be allowed on river banks.
ii. No changes be made within the riverbed for boating or any water sports.
iii. No pollutants of any kind be released through any recreational activity.

8.9 Heritage

i. The Heritage structures along the river must be identified and restored.
ii. A Heritage walk connecting these structures along the river can be planned. The objective of this walk is to revive the bond between the people and the river, and showcase the history.

8.10 Nature trails - Birds / Insects / Flora walks

i. Restoration of the river ecosystem will boost the flora and fauna along the river. Thus, trails can be planned for studying plants, birds, insects, fishes etc.
ii. Care must be taken to not disturb the hotspots while planning these trails.

9. Environmental flow

In NGT ruling of Pusha Saini Vs. Ministry of Environment, Forest & Climate Change & Ors., about the environmental flow of all rivers in India, the Court says *"…we direct that all the rivers in the Country shall maintain minimum 15 % to 20% of the average lean season flow of that river. However, whichever State is unable to adhere to this average percentage, in that event we grant liberty to that State Government to move the Secretary, Ministry of Environment, Forest and Climate Change (MoEFCC) who shall in consultation with the Ministry of Water Resources examine such a representation and if it is desirable to fix any lower percentage than the percentage aforestated, then it will pass appropriate order. The order should be reasoned and thereafter it would be left to the discretion of the State concerned to follow the directions of the Ministry in accordance with law. We also grant liberty to the Applicant to move MoEFCC if it has material with them in respect of any river of the country, which should have minimum environment flow in excess of 20%. If such representation is moved the same shall be disposed of by the Committee headed by Secretary in the Ministry of Environment, Forest and Climate Change in accordance with law."*

Based on this ruling by the NGT, we recommend that minimum E-flow of 15% to 20% must be released for Mula-Mutha. Furthermore, a detailed study regarding the actual requirement of e-flow for the river must be carried out to decide the actual E-flow requirement for the Mula-Mutha river.

10. Flood control and encroachments

i. The flood lines must be corrected and revised after a detailed study is carried out. Safety measures considering a worst-case scenario of structural damage or breakage the three upstream dams must be considered for the same.
ii. A policy level intervention banning any development in the area demarcated for riparian habitat development along the river, must be made.
iii. All illegal construction and debris dumped within the red and blue flood lines must be removed.
iv. Natural measures such as development of Riparian habitats at appropriate locations along the river must be employed for flood risk control.
v. Retention/detention basins to be made. Experts to be identified for consultation.

11. Studies and documentation

We recommend that the following studies be carried out before proposing a Riverfront Development / River Rejuvenation project:

i. Aquifer mapping
ii. Biodiversity assessment
iii. Habitat mapping
iv. Old growth trees, Riparian zone mapping
i. Water quality assessment
v. Feeding Stream mapping
vi. Drainage and topography studies

12. Upstream and Downstream policies

12.1 Upstream

i. Detailed recommendations and policy level interventions for monitoring and maintaining water quality upstream of Pune city to be prepared immediately.
ii. Identify and remove waste dumps from near the river banks. Eg - Kirkatwadi.
iii. Rejuvenation plan for feeding streams upstream of Pune must be given importance.
iv. Payment for Ecosystem Services (PES) Model can be adopted, and these funds may be used for conservation and restoration of ecologically important areas upstream of the city, especially around the source of the Mula and Mutha rivers.

12.2 Downstream

i. Water quality monitoring at regular time intervals, downstream of Pune city must be carried out.
ii. Polluter pays principle may be applied in case of bad water quality downstream. This fund may be used for water quality improvement and river restoration downstream.

13. Wind corridor

River provides an important service of temperature regulation. It acts as a wind corridor allowing a continuous passage of air. This passage helps in regulating temperature of the surrounding area. Considering specific case of Mutha river - *"Fortunately, the Mutha river flows from west to east through the city and provides a corridor for fresh air that blows from hills to the west and south-west. Through these corridors the fresh and cool winds enter the densely populated areas much to the relief of the residents.*

Tall buildings along the river-front interfere with the free flow of fresh air. Also, broad roads while they may relieve the traffic congestion in some parts may give rise to air pollution if heavy vehicular traffic is allowed on such roads. The fumes generated by the vehicles will be blown into city's congested areas by the winds blowing from the west and further foul the atmosphere there. It is therefore, advisable to avoid heavy traffic on roads proposed to be built at the edge of the river basin and allow the winds to flow freely." (Survey of the rivers in Pune city, based on ecological factors in order to prepare an eco-development plan to improve the river-fronts of Pune, Gole)

We strongly recommend that the policy level development control regulations must be framed along the river banks to protect this ecological function of the river.

14. Agriculture

Following is an extract from the NGT hearing on the Yamuna E-Flow: *"Agricultural practices shall be mandatorily made water efficient in terms of cropping and water use. Use of fresh water from rivers for irrigation purposes shall be discouraged and the use of treated sewage from the urban centres shall be encouraged and rewarded. Current practice of indiscriminate extraction of the ground water to meet cash crop agricultural needs shall also be curtailed by law… It is a fact that presently around 70-80 % of*

water for irrigation both during the Rabi and the Kharif season is being sourced from the underground sources and the canal irrigation is meeting only around 30% of the irrigation need of the farmer. This dependence on ground water is more pronounced during the Kharif season (Dec – Feb) which is also the lean season for the river. Fortunately, water needs during the Kharif season is far less than during the Rabi season (June – August). Thus, any measure that would augment the ground water would be helpful for the farmer. This is exactly what a flowing river does and hence the provision of e flow in river Yamuna is going to be helpful to the farmer. As regards increased water needs during the Rabi sowing, it being the monsoon season, there already is enough water available in the canals to meet the canal fed irrigation needs. In addition, it is suggested that during the high flows let there be water collected in various relict channels of the river which are to be easily found spread all over in close vicinity of the WYC. This water can then be used to augment irrigation needs during the Kharif season."

This policy of making agricultural practices water efficient and of connecting the cropping patterns to the flow regime of the Mula-Mutha should be applied upstream as well as downstream of Pune city. This will ensure provision of adequate amount of water to the city.

15. Maintenance

i. Before the Riverfront Development project is commenced, it is of prime importance to propose a plan for its maintenance.
ii. A fund to be set up for the maintenance and upkeep of the project and the recommendations in this report.
iii. Involvement of local communities and other stakeholders must be encouraged in the maintenance of project, and conservation of hotspots.

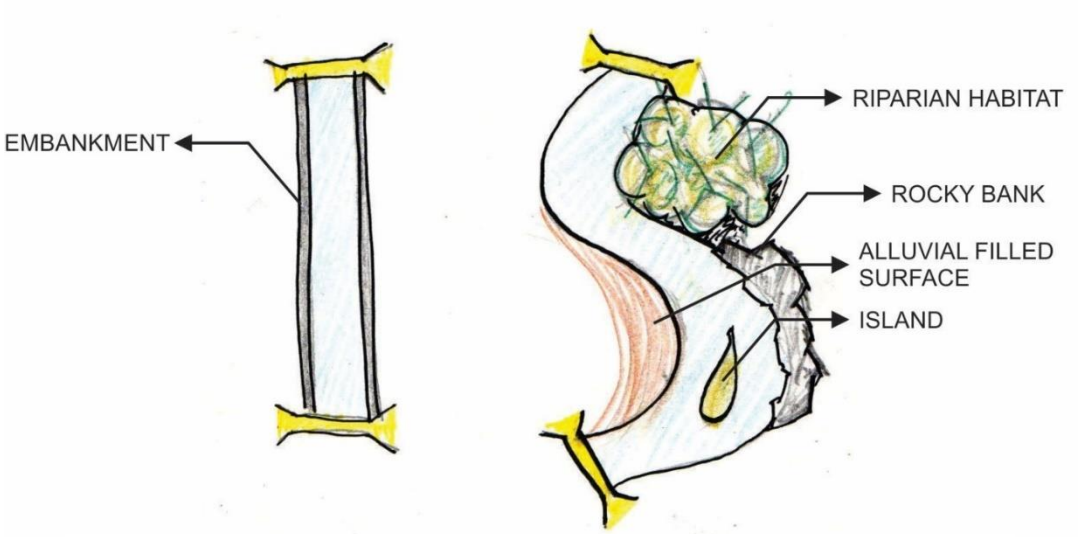
16. Compensation

In case of any proposal that can potentially damage the ecosystem, its habitats, flora, fauna, aquifer recharge and discharge zones, the work shall not commence before an appropriate compensation of the ecological features or services are provided.

Recommendations for design interventions

1. Maintaining a balance between built interventions vs restoration / conservation

An ecologically sensitive approach to Riverfront Development of the Mula-Mutha river must have the right balance between the built interventions and stretches where the river is retained as a natural entity. It is highly unlikely that the river can keep its natural form in an urban context. Since the river itself is one of the chief reasons for the human settlements to develop in a particular place, and eventually growing into a city; it is important to have a physical connect between the city and the river. However, one must also consider that restoring the natural ecological functions and services of the river ecosystem will also contribute to and complement the built interventions. It is necessary to not look at "Development" and "Conservation" as opposing ideals, but as ideals complementing each other.



A. Channelized Canal B. Chanelized canal- natural course

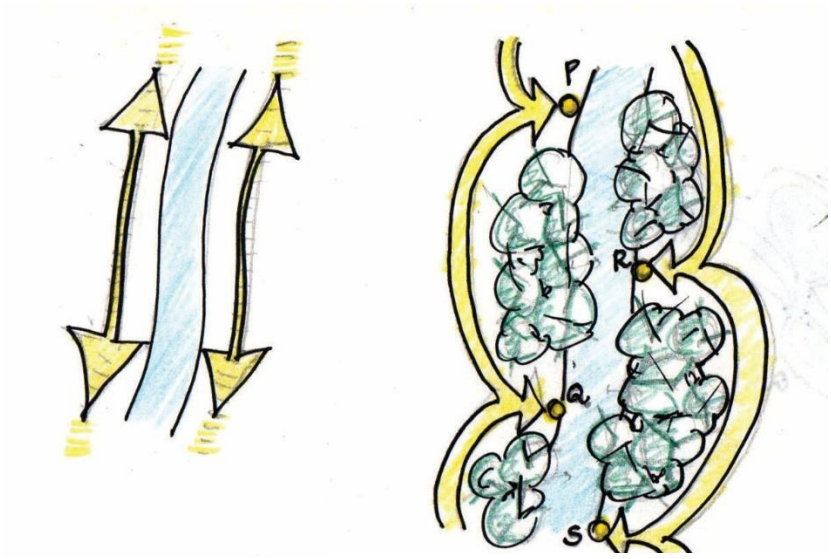
The above image schematically illustrates the difference between the river as a canal and in its natural form. Ecologically as well as aesthetically, a natural river is qualitatively richer than a channelized river.

2. Access at points, not along entire stretch of the river

When there is free access along the stretch of the river there are various stresses induced to the river ecosystem. These include air, water and noise pollution, trampling and disturbance of important habitats and hotspots. On the other hand, when access is allowed at fixed points, the space in between

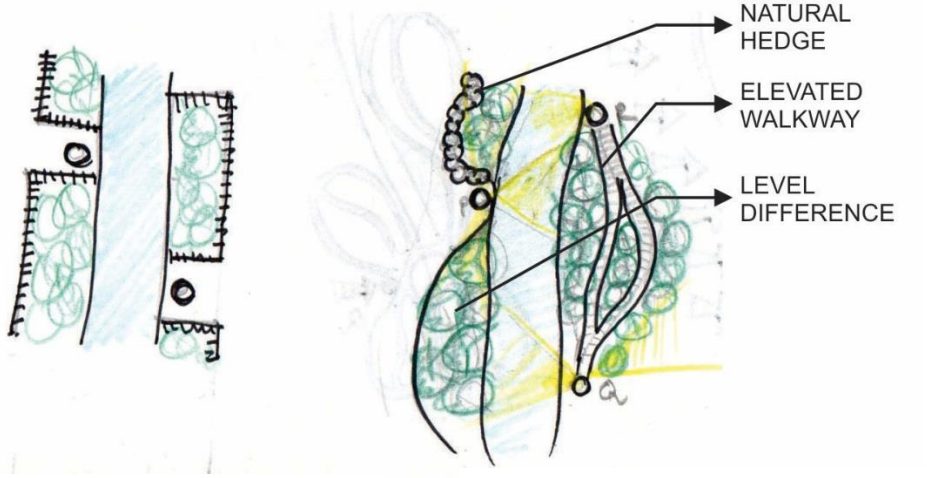
two access points can be used for habitat creation, restoration and conservation of the river's ecological functions and services. This will enhance the water quality as well as aesthetic appeal of the interventions defined as a part of the Riverfront Development Project.

We do not suggest raising barriers and depriving the citizens of the space. Barrier designs must allow a visual access to the river and its banks. For example, when a jogging track is to be provided for some distance, parallel to the river, it can be a raised walkway that provides a continuous view of the river but causes minimum disturbance to the habitat below.



A. Continuous access corridor **B. Fixed access points interspersed with natural patches**

In the above illustration, the access restriction need not be with tall barriers as shown on the left. This can be achieved through natural hedges, level differences or raised pathways.

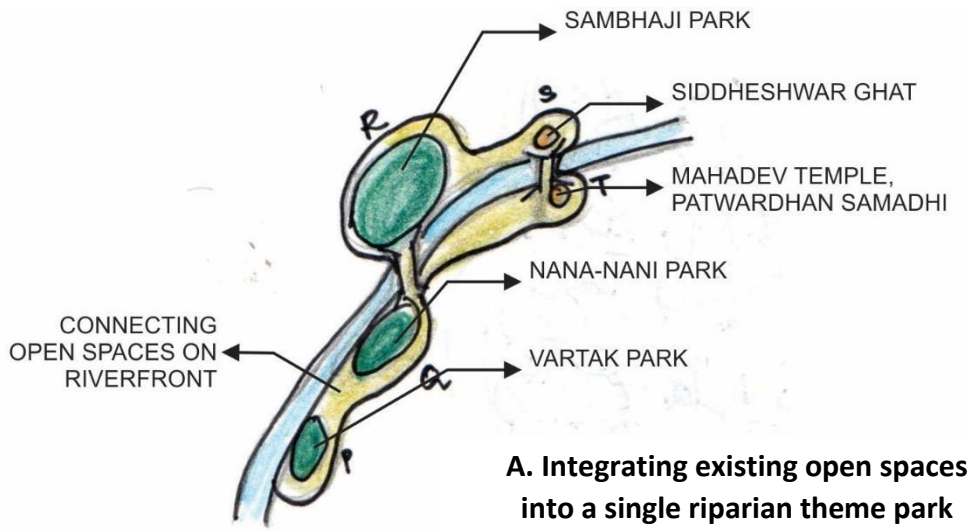


A. Visual and access barriers for protection of natural patches

B. Access barriers ensuring visual connectivity

3. Integrating open spaces along the river

Several open public spaces like parks, jogging tracks and heritage structures exist on both banks of the rivers. They are fragmented and distributed at different points along the river. The ecological principle that a whole, is greater than the sum of its parts, must be applied here. For example, a single huge open space will be more ecologically significant than many small open spaces, of the same area. So, these small and fragmented patches need to be connected and integrated.



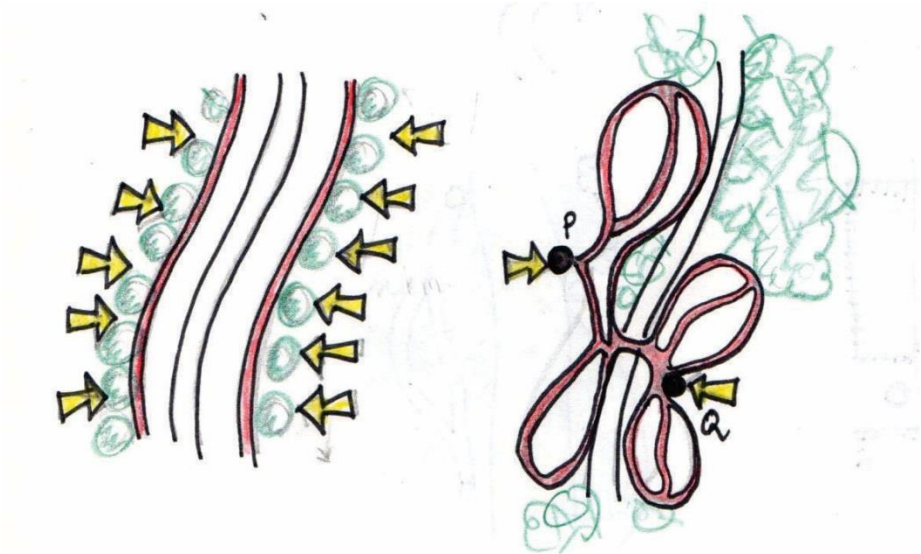
A. Integrating existing open spaces into a single riparian theme park

While connecting these open spaces to form one single open space, it is essential to develop a Riparian habitat themed garden. This way, it will also add to the ecological quality of the river in this stretch.

4. Effective planning of circulation

It is important to plan the circulation of vehicles, pedestrians, cyclists effectively in the riverfront design. A limited number of entry and exit points must be provided to the riverfront. With this, it is possible to restrict the entry of plastic and other polluting material in the river. Similarly, effective design measures must be employed to disallow solid waste dumping from bridges / causeways.

Instead of planning a linear pathway along the river, the same length of pathway can be designed while controlling the entry and exit points, as shown in the figure. This not only achieves the goal of restricting public movement and therefore the chances of pollution of the river / banks, but also provides variety in the experience of travel along the pathway. For example, in figure A, the experience at any point on the pathway will be similar. As opposed to that, in figure B, there will be multiple experiences depending on the nature of canopy cover and vistas / avenues created along the path. Car parking can be planned only at such limited entry / exit points.



A. Access along the entire stretch **B. Access at limited points**

In the above image, to the left is an example of a continuous path parallel to the stream flow, along the river. Here, there are multiple entry and exit points. Even if they are regulated, the experiences and the view from any points along the path will be similar. In contrast, for a pedestrian walking along the paths in the example to the right, there will be only two entry / exit points - P and Q. It will thus be simpler to make sure no plastic / waste enters the area. Also, one will have many options to choose from while walking on this path, where there will be varying experiences.

Specific recommendations for each zone

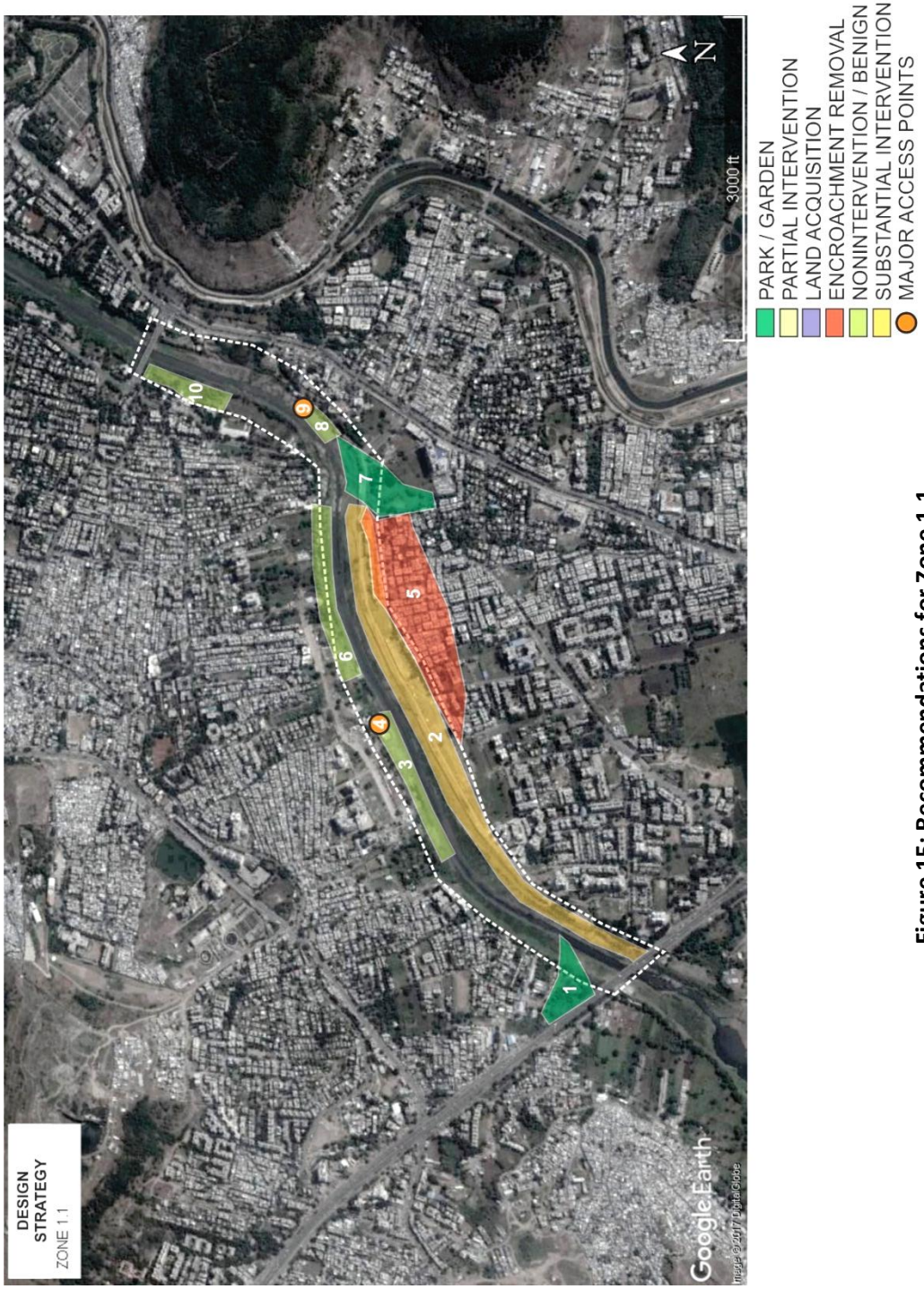


Figure 15: Recommendations for Zone 1.1

A. Zone 1.1 (Refer to the figure 15)

For this zone a partial Intervention strategy is recommended. The various patches in the zone need specific management

1. Patch 1

   This is the mouth of a feeder stream that meets the river on the left bank. The slope to the left is a gradual one, and there is a lot of area available around the mouth of this nala. Moreover, the flow velocity of the stream being slow, developing a Nala park in this area will be the most effective design strategy.
2. Patch 2

   This is the stretch wherein a road was constructed illegally. After the NGT verdict, the work of removing the construction material that was dumped for the road is currently in progress. However, due to the constant movement of heavy earth moving vehicles in this patch, the natural ecosystem is damaged to a large extent. Thus, substantial intervention in terms of habitat creation, plantation and maintenance is required here. Naturally, alluvial field deposits may have been located here. Thus efforts must be made to restore this type of ecosystem here.
3. Patch 3 and Patch 6

   These patches comprise largely of rocky banks. However, the water no longer reaches these rocks due to the concrete channels constructed in the river bed. These channels must be removed, and the changes must be observed for one seasonal cycle. Accordingly, assisted recovery of habitats in this rocky patch must be attempted.
4. Point 4

   This is an access point, used as a dhobi ghat. While water from the river is not actually used for washing clothes, it was observed that the wastewater from washing goes directly into the river. Also, the rocks are used to dry clothes. It is important to retain this activity, as it shows a connect of the people to the river, in their daily routine. However, the activity must be restructured so that the river pollution is prevented. Natural detergents such as Ritha must be encouraged and ones having chemical pollutants must be banned at this spot. Also, the wastewater may be passed through root zone filter beds before being let out into the river.
5. Patch 5

   One can see numerous structures built within the red and blue flood lines here. It is important for the sake of safety, river ecology as well as law enforcement that these be removed urgently.

6. Patch 7

   This is the mouth of a nala that joins the right bank of the river, before Vitthalwadi. It emerges from a settlement nearby and passes under a bridge before joining the river. The area between the nala and the settlement is already cordoned off. Thus, it will be easy to develop a Nala Park here that will be responsible for a decentralised treatment of the water entering the river. It will also act as a usable open space / garden area for the settlement.

7. Patch 8

   This is a rocky patch adjoining the Mahadev temple at Vitthalwadi. It contains nascent stages of potholes. Also, once the channels are demolished, the rocky habitats should be observed, developed and conserved.

8. Point 9

   Access point 9 is the Mahadev temple at Vitthalwadi. It experiences peak rush during Ekadashi and Ganpati visarjan. It is essential to control the stress on the rocky habitats nearby during these festivals. Also, circulation must be planned such that there is no disturbance to the hotspots nearby.

9. Patch 10

   This is a patch in front of the crematorium in Vitthalwadi. Once the access is restricted, it will be an ideal location for developing Riparian vegetation.

Figure 16: Recommendations for Zone 1.2

B. Zone 1.2 (Refer to Figure 16)

1. Patches 1, 2 and 5

   These patches include grassy as well as marshy vegetation. However, one can observe stresses due to illegal dumping of solid waste and debris from the wedding lawns located in the upland zone.

2. Patch 3

   This is a marshy patch that is a good habitat for birds, due to absence of channelization. This patch must be protected in its natural state.

3. Patch 4

   This is the mouth of a nala, which is actually the discharge from the Parvati water treatment plant. One can observe that a sizeable amount of water is carried into the river, with great velocity here. The nala and the area around it is cordoned off with a fence. It is ideal to make a stroll garden themed Nala Park.

4. Point 6

   This is the Dattawadi visarjan Ghat. Clothes and utensil washing activity takes place here in the morning. It can be treated the same way like Point 4 in Zone 1.1. Access must be limited to the ghat itself, and people as well as cattle must not be allowed to roam from the ghat to the adjacent patches 5 and 3.

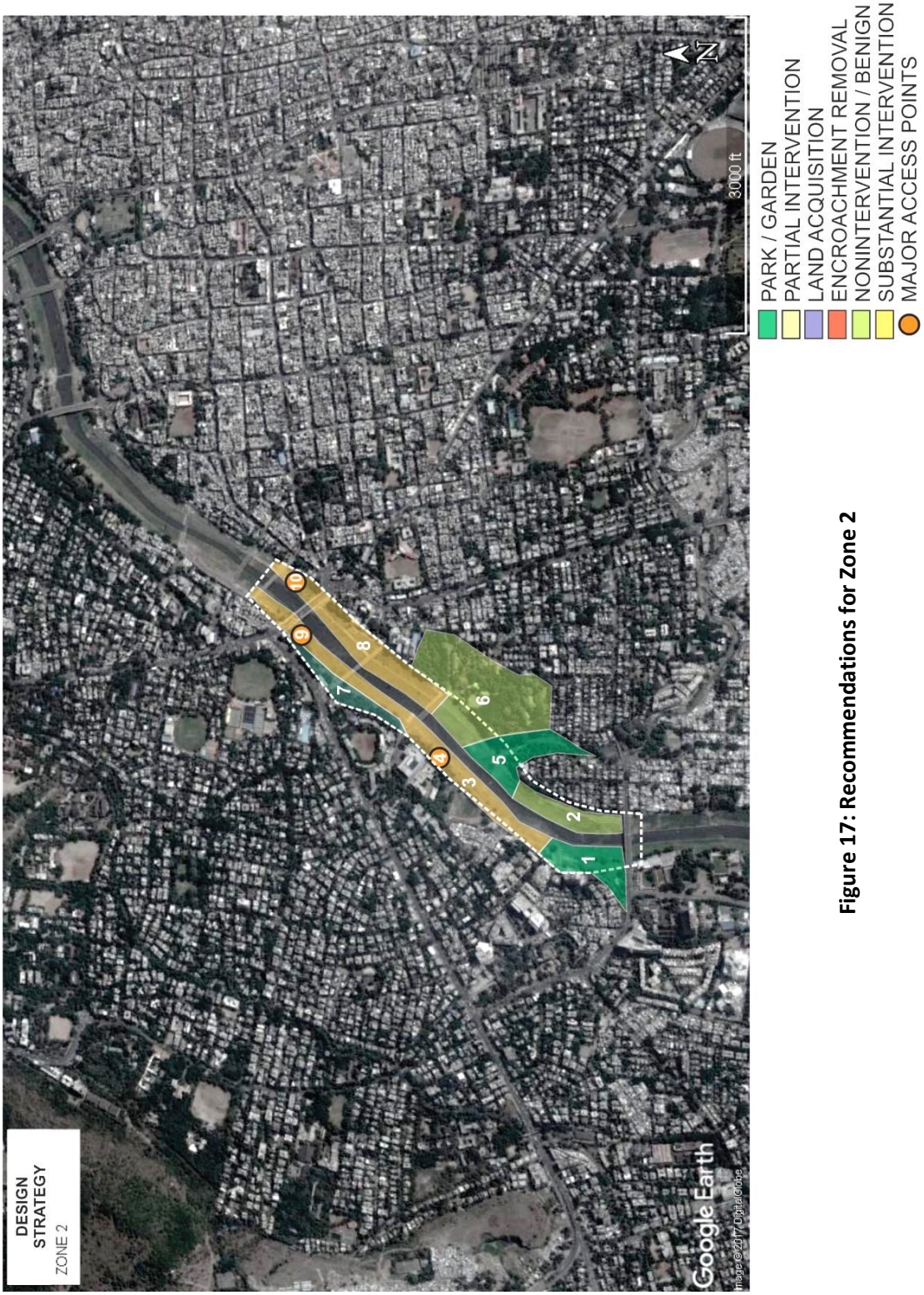


Figure 17: Recommendations for Zone 2

C. Zone 2 (Refer to Figure 17)

1. Patch 1

   This is the mouth of the Erandawane feeder stream that meets the Mutha river on its left bank. A significant flow volume and velocity can be observed here. It must be noted that the Erandawane stream is a tertiary feeder stream and hence, its catchment is sizeable. Moreover, the outlet from the STP near Mhatre bridge is also let out into this stream. It was observed that this water possessed a foul odour. Also, the stream is acting like a canal due to completely channelised banks.A nala park can be developed here, from the location of the STP to the mouth of the nala. This will not only act as a natural treatment zone but will also provide a much-needed open space to the locality. Access may be provided from Mhatre bridge.
2. Patch 2

   There are remnants of good Riparian vegetation were found. It is essential to protect this patch by restricting entry of cattle.
3. Patches 3 and 8

   These are the site of the current riverside road that is open to two-wheelers. Removal of this road, intensive plantation and habitat creation strategies should be employed here. Also, the natural topography and drainage patterns that were disturbed due to the road should be restored on both banks. A narrower pedestrian path / jogging track may be proposed in place of the road, after restoration of the bank vegetation and habitats.
4. Point 4

   This is an old place of worship called *Saat Aasra* that was originally located on the rocky bank. It also is a site for a dug well. This area should be conserved and developed as a sacred grove.
5. Patch 5

   This is the mouth of Ambil odha, a feeder stream meeting the Mutha river on the right bank. It is one of the most important feeder streams of the Mutha and therefore needs to be conserved. Nala park can be designed here from the mouth of the stream up to Indradhanushya hall.
6. Patch 6

   This is part of Vaikunth crematorium. It consists of many old growth trees that harbour many important bird and bat roosting sites. It is of utmost importance to conserve and protect this patch.

7. Patch 7

   This contains many Babhul trees which can potentially be a good upland zone. Intermediate level of intervention with a few plantations and protection should be the strategy employed here.

8. Points 9 and 10

   The Panchaleshwar temple and Nanasaheb Peshwe memorial are important cultural hotspots. Their conservation can be integrated with the riparian landscape in the surroundings.

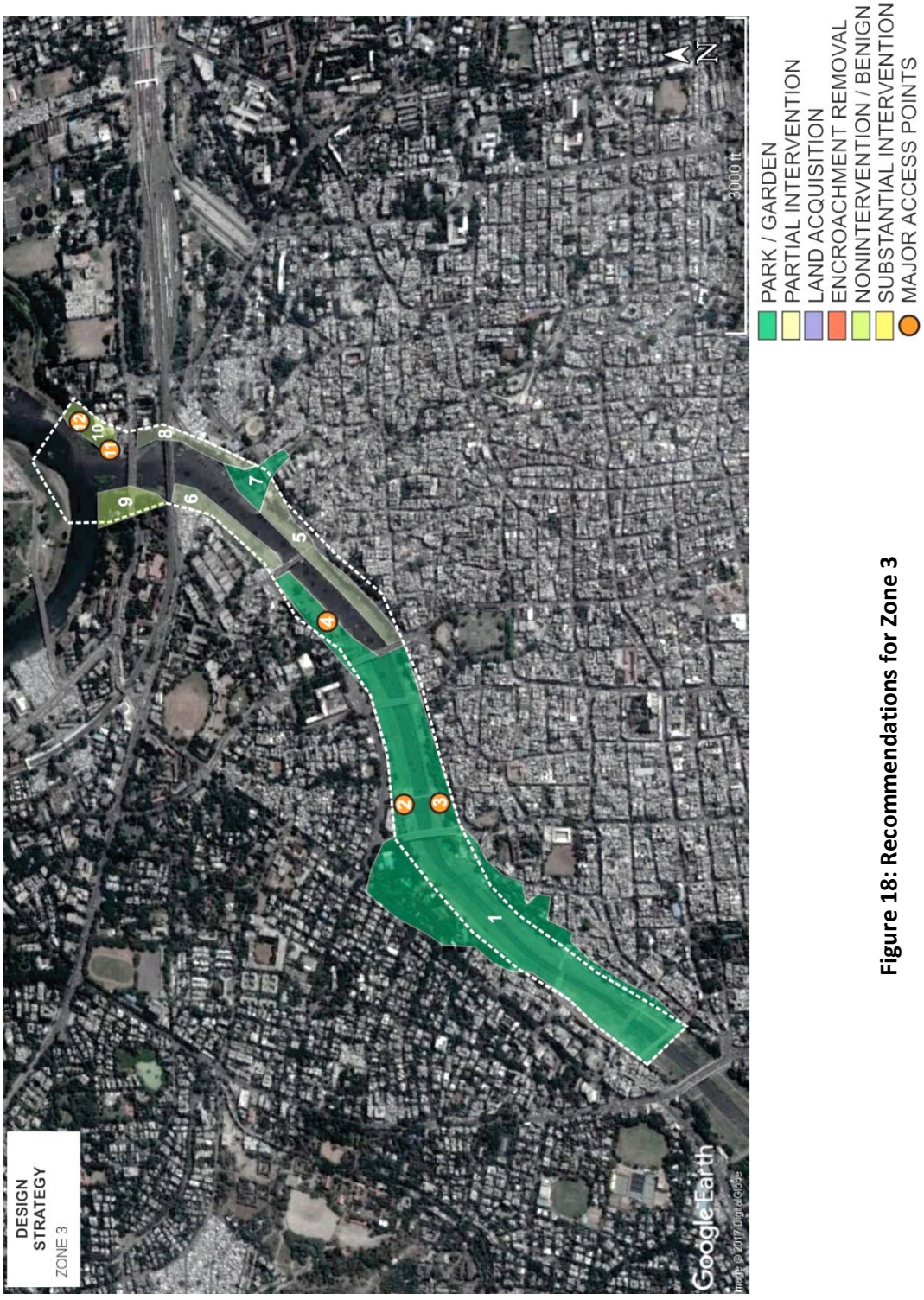


Figure 18: Recommendations for Zone 3

D. Zone 3 (Refer to Figure 18)

1. Patch 1

   There are three parks here - Sambhaji park, Vartak park and Nana-Nani park. It can be designed as one integrated open space to be connected to each other. These parks can be designed as a Riparian themed habitat, with avenues and vistas opening out to the river banks.

2. Points 2, 3 and 4

   This zone can be a heritage precinct, where these points are ancient ghats, places of worship and memorials. They may be connected to each other to form a heritage trail that intertwines with the Riparian parks. Such a concept of a public space having heritage structures and public parks can be developed on the lines of Lodhi Garden, New Delhi ut on a smaller scale.

3. Patches 5, 6 and 8

   These are predominantly wide open / grassy patches in the river channel that are separated from the adjoining roads by a level difference and retaining walls. They have a potential to be developed into a riparian habitat that acts like a buffer between the city and the river; and harbours biodiversity. Partial interventions in terms of fencing, plantations and habitat creation should be proposed here.

4. Patch 7

   This is the mouth of the Nagzari nala that enters the Mutha river on the right bank, from the Juna Bazaar area. This can be developed into a nala park.

5. Patch 9

   This is an important roosting and nesting site for many bird species and must be protected.

6. Patch 10

   This is the stretch from the Ghat at Mula Mutha Sangam to the Gosavi temple nearby. It is a relatively undisturbed upland zone, and must be protected by minimum intervention and restriction of cattle and human access.

7. Point 11

   This is the visarjan ghat at the Mula-Mutha confluence. It is one of the most important visarjan ghats during Ganesh festival, and also a crematorium. It can be planned as an important cultural hotspot.

8. Point 12

   This is the Gosavi temple near Mula-Mutha sangam.

Figure 19: Recommendations for Zone 4

E. Zone 4 (Refer to Figure 19)

1. Patch 1 This is patch includes the Naik Bet, which is one of the most well-conserved island and floral hotspot in the project area. The banks and the island edges are retained in their natural form. The character of this patch must be conserved with utmost priority, with the channel character and biodiversity acting as a reference palette for restoration works in other zones.
2. Patches 2 and 3 These patches comprise of a jogging track that is largely defunct. Stresses of open defecation and solid waste dumping must be dealt with. The jogging tracks will function as excellent flora-fauna trails if given a good access. Also, a buffer needs to be developed between the river and the upland zones here. Tracks can be developed here and connected to each other, integrated with Bund garden.
3. Point 4 This is a temple at the start of the jogging track near the Bund garden bridge, on the left bank of the Mula-Mutha. It also has a visarjan ghat. This place can be developed into an important access point to the river.

Figure 20: Recommendations for Zone 5

F. Zone 5 (Refer to Figure 20)

1. Patch 1

   This patch is part of the proposed Mula-Mutha bird sanctuary. The river has a braided channel. The channels are relatively shallow and rocky. Rocks are jut out at many places and large rocky surfaces are present along the upland. They form excellent habitats for water birds. This area therefore harbours a rich and bird population especially during winter. The importance and uniqueness of this place was identified by Late Shri. Prakash Gole, founder of Ecological Society. He made efforts to promote a water bird sanctuary along this stretch. The habitats needed to be protected and plantation of native species to replace exotic plantations must be undertaken. There is a waste handling unit at the entrance of this patch, that needs to be shifted away from the river, to avoid pollution and accidental dumping of this waste in the river during the monsoon. A trail / track should be planned while designing variations in canopy cover and vistas, to harbour different types of habitats for floral and faunal species.

   There is no example of a bird sanctuary within any Indian city, and this is a great opportunity to make Pune the first city to have one.

2. Patch 2

   This is a privately-owned land. For the sanctuary to function effectively, it needs some width to create and maintain a buffer between the important habitats and the city. Therefore, it is essential to acquire this land as a part of the Mula-Mutha Bird Sanctuary.

3. Patch 3

   This is a small patch around the crematorium ghat on the right bank. A limited area around the ghat should be designed for public use, while creating barriers between the rest of the sanctuary area and the crematorium.

4. Point 4

   This is the crematorium and a ghat. It was observed that habitat around the ghat was disturbed greatly during construction time. Therefore, restoring this rocky bank should be given high priority.

DON'T's - General recommendations on what to avoid

1. No channelization of the river. This is a well-studied aspect of river ecosystems and there are ample references which support the free flow of river in its own channel. This is clearly the most important DON'T for Mula-Mutha.
2. No concrete / tar / paver block or roads on any of the river banks, streams, riparian zones and springs. They must be retained in their natural state. This retains the character of the river and make it look like a river and not a canal.
3. No high-rise buildings on the banks. This is to allow an unrestricted view of the river. Within a bustling city, a natural river has the potential to be a place of natural beauty. This must be preserved at all times. As there are hardly any open spaces left for Pune citizen, this is a good opportunity.
4. No eateries/ restaurants / take-aways on the banks and in the river bed. We have identified these as a significant source of pollution and intervention to the natural processes on the banks. Moreover, the eateries today are in the zone where riparian vegetation is possible to be nurtured.
5. Do not use excessive lighting in the river bed. No flood lights or any other forms of excessively bright lights. This is detrimental to insects and nocturnal fauna. We recommend a separate study of lighting for the river zone.
6. No construction / structure in any of the identified ecologically important hotspots. This is critical to the restoration of flora and fauna in the river ecosystem. We have identified many stretches where riverfront development structures can be made.
7. Do not use any non-native species of vegetation for any kind of plantation in the river bed and on its banks. All plantations must only be of native species, relevant to this region of the country and habitat. We have provided a list of such vegetation.
8. Do not allow any untreated water or sewage to enter the river. This is critically important when we are trying to revive aquatic life.
9. Do not allow activities like large gatherings, weddings, circus, exhibitions, political rallies, Dandiya, etc. in the river bed (Refer to the NGT ruling in the case of Art of Living World Culture festival case).

Conclusion

The city of Pune is blessed with two rivers flowing within it and their confluence. In this age where cities are turning similar with undifferentiated architectural structures, it is critical to preserve a naturally endowed character of the city. A well-maintained river is not just a source of charm for its citizen, but also a provider of vital environmental services that every city needs for healthy functioning. It is this aspect of the river that we strongly recommend being conserved and nurtured, in the riverfront development project. Our recommendations are prioritized on ecological and cultural aspects and employ a holistic perspective of looking at the river as a continuum and a living ecosystem. We are aware that this report has limitations, but we hope that the project designers and planners will find the guidelines worthy of consideration. We would be glad to initiate further discussions to the stakeholders.

"Design needs to shift from a paradigm of transforming nature to one of transforming society; by improving the quality of life and relationships between all living things and the built environment"
Prakash Gole, Understanding Reality.

Acknowledgements

The Ecological Society is grateful to the Center for Environmental Education and the Pune Municipal Corporation for funding the project. We are indebted to the many experts who patiently gave us time to offer deep insights in the history and culture of the river. A special thanks to all the participants of the workshop that we conducted to discuss the river issues. The insights from them were most useful in preparing this report.

6 | Annexures

1. Experts views and recommendations
2. Full Checklist of Flora of Mula-Mutha
3. Checklist of Flora by Zones
4. Checklist of recommended flora for plantations, by habitats
5. Summary of the brainstorming output during River Restoration Workshop held on 29 September 2017
6. Case studies
7. Nala Park
8. Sabarmati Riverfront
9. Mula-Mutha Riverfront Concept

Annexure 1 | Expert Speak

Dr. Himanshu Kulkarni, ACWADAM

His research led him to believe that it is a mistake to consider the river as a recharge zone. More often, large patches of a river are places that experience groundwater discharge in the form of springs. “Count the number of Shiva temples along the Mutha in Pune. Those are the minimum number of natural springs; and besides these there might even be more!

The water table in Pune is largely feeding the river. This is responsible for diluting the polluted waters of the river. Pouring concrete over the river banks and stopping this groundwater from entering the river will only magnify the pollution problem.

He recommends the following studies to be done before conceptualizing the riverfront project:

- Aquifer mapping
- Details of catchment hydrology:
  1) AVERAGE yearly surface **WATER (**discharge)
  2) AVERAGE yearly groundwater contribution.
  3) ARTIFICIALLY regulated discharge pattern

Dr. S.N. Rajguru, Retired Professor, Deccan College, Pune

Now River banks and its main channel is completely changed by channelization, sand extraction, encroachment, polluting water by adding sewage Etc. We are changing the pattern of the river/streams and its flow. Mutha River is meandering because it's channel bed slope/ thalweg is gentle. It results in unique feature of alluvial field surfaces along the river Mutha. If you modify this tendency by channelization it will disturb the processes of flow regime and sediment discharge. Even Flow/flood regime is totally changed because of dam constructions in the upper catchment areas. There is very little natural base flow in the channel. This pathetic situation of the Mutha River is very dangerous in exceptional flood conditions.

The base flow is the main source of water especially during non- rainy season. This base flow comes from numerous springs along the river channel. Every Shivmandir along the course of Mutha is situated near such spring. This shows innumerable springs contribute to River Mutha. Some of the springs are still in use by citizens. Many sites of such springs are now not visible due to heavy construction along the river. There is a need to survey and document these aquifers/springs which are contributing water to the river channel as the new interventions are on its way.

Now the trend is to modify river course with the help of advance technology without consideration of natural processes happening in river functioning. Concretization of the river banks is the major threat for the functioning of natural processes.

Interdisciplinary experts' team (archaeologist, geography, biology, hydrology, engineers etc.) should include in the planning process to avoid further loss.

Dr. Priyadarshini Karve, Samuchit Enviro Tech, Pune

1. Mapping the actual and future requirement of water in the city.
2. Scientific assessment for rainwater harvesting potential in Pune should be conducted which will give an idea of how much water should be taken from the river.
3. Care should be taken to assess the river banks for ecological sensitivity. Certain patches in the river bank areas that have naturally developed into wetlands having clear water and good bird diversity.
4. Identifying such patches and demarcating them as natural heritage sites or reserved sites would help.
5. Such areas should be cordoned off and monitored to keep away from human contact; these areas should be left to develop on their own. Such areas can then act as small nature trails amidst the crowded urban areas.
6. There are many natural streams draining into the river in Pune. It has been observed through the Environment status reports that these streams have turned into nalas due to the discharge of untreated sewage, other effluents as well as solid wastes. Such streams can be harnessed for developing into recharge zones since these streams were earlier rainfed and not perennial. Hence, only during the monsoons they would drain the excess water into the rivers and there was no flooding. However, the additional inflow of untreated sewage due to improper or no sewerage system has led the rainfed streams turn into perennial nalas.
7. While conducting a socio-economic study along one such natural stream Ambil showed that the streams have natural springs at various locations if these are studied from a hydrological and geological perspective may provide an insight on recharge zones along the stream.
8. If all the streams are restored Pune will have ample decentralized source of water reducing the dependency on dams for water supply.
9. There are existing cultural heritage sites along the riverbank apart from these some recreation spaces can be developed for creating a bond with the river, however these should be limited to certain areas only.
10. Legal, political and educational solutions need to be explored to mitigate the pollution of the river through cultural practices.
11. Concept of adopting a stretch an initiative by Jeevitnadi can be a good effort towards building capacity and awareness among the citizens on river conservation. Motivated citizens can act as safeguards of the river.
12. Study and understand the existing trend of encroachments and domestic activities that people undertake like defecation, wastes dumping and washing clothes as well as cattle. Need to provide them with alternatives.
13. Collaborative arrangements can be explored between active NGOs working in the field of river restoration and riverfront development authorities.
14. Existing structures on the riverbanks such as ghats, important places of worship, monuments of historical significance, etc. should be restored/rehabilitated if required or should be left untouched.

Dr. Hemant Ghate, Retired Professor, Modern College, Pune

During late 1960s and early 70s we could see large beds of FW sponges near Vitthalwadi and also in slightly upper stretches. Today all this area is grossly silted, and no sponge exists. In fact, sponges are now absent from a long stretch of river and we find those only in unpolluted dam waters. Same is true of a moderate size FW prawn *Macrobrachium kistnensis* and a fish called *Aplocheilus.* Since 1980s these two animals are very rarely found in Mutha except in dam area. *Gambusia* and *Lebistes* (so called guppy) are abundant and have directly lead to disappearance of Aplocheilus. Yet another fish, commonly known as Tilapia, is now so abundant that 6-7 out of 10 fishes you collect are Tilapia. Many common fishes which were once abundant (species of Labeo, Puntius, Osteobrama, etc.) are not seen at all. We wrote several papers on fishes of Mula mutha and recorded the changing scenario, but the situation has not changed. It is worsening day by day. To treat the sewage waste generated by enormous population is beyond the capacity of PMC now and the river flowing thru' the city is almost an open sewage canal. Fishermen now mostly go to upper stretches or dam areas of Ujani and in Bhima as here we only get Tilapia. Dams were used to cultivate fishes, but I doubt if the practice continues for Panshet or Khadakwasla.

The bacterial count is very high at all places. Sewage fungus (as assemblage of true fungi, bacterial and some ciliates) is growing everywhere. Tubificid worms (aquatic Annelida) as well as Chironomidae (Diptera, relatives of mosquito) larvae are abundant in sewage polluted stretches. Their presence itself signifies dirty state of water. These two (often called blood worms as these are red colored due to hemoglobin. These feed on food provided by sewage and their populations are enormous.

Bivalves (Mollusca) have also vanished from these parts of river. There were at least 3 different species of bivalves in our river (Corbicula, Parreysia and Lamellidens) but none can be seen…while some snails have increased in number.

Aquatic insects, except some bugs that respire aerial oxygen are seen at places, are also affected.

River is choking with plants: Hydrilla, Eichhornia, Vallisneria are abundant; in Mutha Eichhornia is relatively less but in Mutha it is abundant and stagnating water (in effect providing breeding ground for some insects). The vegetation is clearly due to abundant phosphates and nitrates in river (legacy of sewage and detergents). Vegetation cannot be controlled unless these pollutants are controlled. It is also affecting fish population, so something must be done.

There is no true assessment of toxic pollutants in our rivers, esp Mula which received waste water from scores of industries. In the past 25 years no quantitative analysis has been done for pollutants. As a result, people are using water and fish caught in such waters and we do not know what health problems these people are suffering from. Both BOD and COD are so high at places that aquatic organisms just cannot survive. We do not have sensitive instruments to analyse all chemicals, but general toxicity of water must be routinely tested, but I doubt if it is done.

Detergent usage is high, and we find foam at places like Bundgarden. The detergents are also having many toxic chemicals, but people are unaware of their effects on aquatic organisms. Most planktonic

microscopic animals and plants have simply vanished from large parts of river and the situation is very bad.

The sad thing is that the same problems were faced by all developed nations during their industrial growth. They have documented all these effects and have also controlled all that now. We have ignored these reports and information and, so we are facing these problems. Scientific outlook is totally lacking, and we are repeating the mistakes of those developed nations.

Dr. Vinaya Ghate, Scientist Agharkar Research Institute, Pune

Dr. Vinaya Ghate talked about the changes in floristics of the Mutha river. This is summarized below:

1. **Floristic studies undertaken in Pune**
    a. Vartak (1957) in Flora of Mutha river bed reported occurrence of 327 species in Pune.
    b. Ghate Vinaya (1978) enumerated 133 aquatic plants from Mutha River. (submerged species, floating species, species in marshy/water logged areas and wet land species)
    c. Ghate and Sane (2000) Reported changes in riverine flora in Urban plant diversity at the cross road of conservation v/s development: a case study of Pune metropolitan area
    d. Wagh (2000) Reported changes in flora and fauna due to pollution impact
2. **Changes in Flora of Mutha River**
    a. Factors affecting Diversity mainly include reduced water flow throughout the year, increased water pollution and river development project.
    b. Riverside flora has been studied periodically by number of workers and significant changes have been recorded in flora and vegetation.
    c. There is significant decline in population of pollution sensitive aquatic and marshy communities like Ceratophyllum, Crinum, Equisetum Eulophia, Hydrilla, Marselia, Najas, Ottelia, Potamogeton, Vallisneria, and Zeuxine .
    d. Increased population of pollution resistant species such as Azolla, Alternanthera (Recorded Ist time in Maharashtra from Mutha river in 2000), Echhornia, Pistia.
3. **Suggestions for revival of riparian ecosystem**
    a. Today there is not at all freshwater flow through dams. Flushing of pollution by increasing fresh water flow. At least once in a month is needed for dilution of pollution.
    b. Launching natural pollution treatment plants at number of places, particularly at starting points. Variety of models is now available for such treatments. Such experiments already have been adapted in Pune e.g. Osho garden, Bagul Udyan
    c. Natural flora will revive of its own if conditions change.

Annexure 2 | Full Check-list of Flora of Mula-Mutha

Plant Checklist OF Mula-Mutha River

No.	Trees			
	Scientific Names	***Common Name***	***Family***	***Occurrence***
1	*Acacia auriculiformis Benth.*	Australian Babhul	Leguminosae	Occasional
2	*Acacia chundra (Rottler) Willd.*	Khair	Leguminosae	Occasional
3	*Acacia nilotica (L.) Delile*	Babhul	Leguminosae	Common
4	*Acacia polyacantha Willd.*	Pandhra Khair	Leguminosae	Occasional
5	*Adansonia digitata L.*	Baobab	Malvaceae	Occasional
6	*Aegle marmelos (L.) Corrêa*	Bel	Rutaceae	Occasional
7	*Ailanthus excelsa Roxb.*	Maharukh	Simaroubaceae	Rare
8	*Albizia lebbeck (L.) Benth.*	Shirish	Leguminosae	Occasional
9	*Albizia saman (Jacq.) Merr.*	Rain tree	Leguminosae	Occasional
10	*Alstonia scholaris (L.) R.Br.*	Satvin	Apocynaceae	Common
11	*Annona squamosa L*	Sitaphal	Annonaceae	Occasional
12	*Azadirachta indica A.Juss.*	Kadunimb	Meliaceae	Occasional
13	*Bauhinia purpurea L.*	Kanchan	Leguminosae	Occasional
14	*Bombax ceiba L.*	Katesawar	Malvaceae	Occasional
15	*Broussonetia papyrifera (L.) Vent*	Paper Mulberry	Moraceae	Common
16	*Capparris grandis L.f.*	Pachunda	Capparaceae	Occasional
17	*Carica papaya L.*	Papai	Caricaceae	Occasional
18	*Cocos nucifera L.*	Naral	Arecaceae	Occasional
19	*Cordia dichotoma G.Forst.*	Bhokar	Boraginaceae	Occasional
20	*Couroupita guianensis Aubl.*	Kailaspati	Lecythidaceae	Occasional
21	*Dalbergia sissoo DC.*	Shisav	Leguminosae	Common
22	*Delonix regia (Hook.) Raf.*	Gulmohor	Leguminosae	Occasional
23	*Eucalyptus globulus Labill.*	Nilgiri	Myrtaceae	Common
24	*Ficus benghalensis L.*	Wad	Moraceae	Occasional
25	*Ficus hispida L. f.*	Dhedumbar	Moraceae	Occasional
26	*Ficus racemosa L.*	Umbar	Moraceae	Occasional
27	*Ficus religiosa L.*	Pimpal	Moraceae	Occasional
28	*Gliricidia sepium (Jacq.) Walp.*	Undirmari	Leguminosae	Common
29	*Gmelina arborea Roxb.*	Shivan	Lamiaceae	Occasional
30	*Grewia tiliifolia Vahl*	Dhaman	Malvaceae	Occasional
31	*Holoptelea integrifolia Planch.*	Waval	Ulmaceae	Occasional
32	*Leucaena leucocephala (Lam.) de Wit*	Subabhul	Leguminosae	Common
33	*Limonia acidissima Groff*	Kavath	Rutaceae	Occasional
34	*Mangifera indica L*	Amba	Anacardiaceae	Occasional
35	*Millingtonia hortensis L.fil.*	Booch	Bignoniaceae	Common
36	*Mimusops elengi L.*	Bakul	Sapotaceae	Occasional
37	*Morinda pubescens Sm.*	Bartondi	Rubiaceae	Occasional
38	*Moringa oleifera Lam.*	Shewaga	Moringaceae	Occasional

39	*Muntingia calabura L.*	Singapore cherry	Muntingiaceae	Occasional
40	*Neolamarckia cadamba (Roxb.) Bosser*	Kadamb	Rubiaceae	Occasional
41	*Peltoforum pterocarpum Auct. non K.Heyne*	Tambadsheng	Leguminosae	Common
42	*Phoenix sylvestris (L.) Roxb.*	Shindi	Arecaceae	Occasional
43	*Pithecellobium dulce (Roxb.)Benth.*	Vilayati Chinch	Leguminosae	Common
44	*Polyalthia longifolia (Sonn.) Thwaites*	Ashok	Annonaceae	Common
45	*Pongamia pinnata (L.) Pierre*	Karanj	Leguminosae	Occasional
46	*Prosopis juliflora (Sw.) DC*	Wedi babhul	Leguminosae	Common
47	*Psidium guajava L.*	Peru	Myrtaceae	Occasional
48	*Pterospermum acerifolium (L.) Willd.*	Muchkund	Malvaceae	Occasional
49	*Putranjiva roxburghii Wall.*	Putranjiva	Putranjivaceae	Occasional
50	*Salix tetrasperma Roxb.*	Walunj	Salicaceae	Rare
51	*Santalum album L.*	Chandan	Santalaceae	Occasional
52	*Senna siamea (Lam.) H.S.Irwin & Barneby*	Kashid	Leguminosae	Occasional
53	*Solanum nigrum L.*		Solanaceae	Occasional
54	*Spathodea campanulata Beauv*	Pichkari	Bignoniaceae	Common
55	*Spathodea campanulata P.Beauv.*	Pichkari	Bignoniaceae	Occasional
56	*Sterculia foetida L.*	Punai	Malvaceae	Occasional
57	*Syzygium cumini (L.) Skeels*	Jambhul	Myrtaceae	Occasional
58	*Syzygium heyneanum (Duthie)Wall.ex Gamble*	Panjambhul	Myrtaceae	Rare
59	*Tamarindus indica L.*	Chinch	Leguminosae	Occasional
60	*Terminalia arjuna (Roxb. ex DC.) Wight & Arn.*	Arjun	Combretaceae	Occasional
61	*Terminalia catappa L.*	Badam	Combretaceae	Occasional
62	*Terminalia cuneata Roth*	Arjun	Combretaceae	Occasional
63	*Trema orientalis (L.) Blume*	Ghol	Cannabaceae	Occasional
64	*Zizipus mauritiana Lamk.*	Bor	Rhamnaceae	Occasional
		Herbs		
1	*Abutilon indicum (L.) Sweet*	Mudra	Malvaceae	Common
2	*Acalypha ciliata Forssk.*		Euphorbiaceae	Common
3	*Achyranthes aspera L.*	Aaghada	Amaranthaceae	Common
4	*Aeschynomene indica L.*		Leguminosae	Common
5	*Ageratum conyzoides (L.) L.*		Compositae	Common
6	*Alternanthera philoxeroides (Mart.) Griseb.*	Alligator weed	Amaranthaceae	Abundant
7	*Alternanthera pungens Kunth*		Amaranthaceae	Occasional
8	*Alternanthera sessilis (L.) R.Br. ex DC.*	Chabuk kata	Amaranthaceae	Abundant
9	*Alysicarpus tetragonolobus Edgew.*		Leguminosae	Occasional
10	*Amaranthus spinosus L.*	Katemath	Amaranthaceae	Common
11	*Amaranthus viridis L.*	Math	Amaranthaceae	Common
12	*Ammannia baccifera L.*		Lythraceae	Rare

13	*Apluda mutica L.*		Poaceae	Common
14	*Argemone mexicana L.*	Pivala dhotra	Papaveraceae	Common
15	*Asclepias curassavica L.*	Haladi Kunku	Apocynaceae	Common
16	*Azolla pinnata R. Br.*		Salviniaceae	Abundant
17	*Bacopa monnieri (L.) Wettst.*	Neerbrahmi	Plantaginaceae	Occasional
18	*Bambusa vulgaris Schrad.*	Yellow Bamboo	Poaceae	Occasional
19	*Bidens biternata (Lour.) Merr. & Sherff*		Compositae	Occasional
20	*Boerhavia diffusa L.*	Punarnava	Nyctaginaceae	Occasional
21	*Brassica juncea (L.) Czern.*	Mohori	Brassicaceae	Occasional
22	*Canna indica L.*	Kardal	Cannaceae	Occasional
23	*Canscora diffusa (Vahl) R.Br. ex Roem. & Schult.*	Kilwar	Gentianaceae	Occasional
24	*Celosia argentea L.*	Kurdu	Amaranthaceae	Common
25	*Centella asiatica (L.) Urb.*	Mandukparni	Apiaceae	Occasional
26	*Chloris virgata Sw.*		Poaceae	Common
27	*Chromolaena odorata (L.) R.M.King & H.Rob.*	Ranmari	Compositae	Abundant
28	*Cleome rutidosperma DC.*		Cleomaceae	Rare
29	*Cleome viscosa L.*	Pivali Tilwan	Cleomaceae	Occasional
30	*Colocassia esculenta (L.) Scott*	Ran-alu	Araceae	Common
31	*Commelina benghalensis L.*	Keni	Commelinaceae	Common
32	*Commelina caroliniana Walter*		Commelinaceae	Common
33	*Corchorus sp.*	Chunch		Common
34	*Cosmos sulphureus Cav.*	Cosmos	Compositae	Common
35	*Croton bonplandianus Baill.*		Euphorbiaceae	Occasional
36	*Cullen corylifolium (L.) Medik.*	Bavachi	Leguminosae	Common
37	*Cyanotis fasciculata (B.Heyne ex Roth) Schult. & Schult.f.*	Nilwanti	Commelinaceae	Common
38	*Cyanthillium cinereum (L.) H.Rob.*	Sahdevi	Compositae	Common
39	*Cynodon dactylon (L.) Pers.*	Harali	Poaceae	Common
40	*Cyperus scariosus R.Br.*	Lavhale	Cyperaceae	Occasional
41	*Dactyloctenium aegyptium (L.) Willd.*		Poaceae	Common
42	*Datura innoxia Mill.*	Dhotara	Solanaceae	Occasional
43	*Datura metel L.*	Dhotara	Solanaceae	Rare
44	*Desmodium tortuosum (Sw.) DC.*		Leguminosae	Common
45	*Digitaria ciliaris (Retz.) Koeler*		Poaceae	Common
46	*Dinebra retroflexa (Vahl) Panz.*		Poaceae	Common
47	*Echinochloa colona (L.) Link*		Poaceae	Common
48	*Eclipta prostrata (L.) L.*	Maka	Compositae	Occasional
49	*Eichhornia crassipes (Mart.) Solms*	Jalparni	Pontederiaceae	Abundant
50	*Emilia sonchifolia (L.) DC. ex DC.*		Compositae	Occasional
51	*Euphorbia heterophylla L.*	Dudhi	Euphorbiaceae	Common
52	*Euphorbia hypericifolia L.*	Dudhi	Euphorbiaceae	Common

53	*Exacum pedunculatum L.*		Gentianaceae	Occasional
54	*Glinus lotoides L.*		Molluginaceae	Common
55	*Gomphrena sp.*		Amaranthaceae	Occasional
56	*Grangea maderaspatana (L.) Poir.*	Mashpatri	Asteraceae	Common
57	*Gynandropsis pentaphylla (L.)*		Capparaceae	Common
58	*Heliotropium indicum L.*	Bhurundi	Boraginaceae	Occasional
59	*Hibiscus sp.*		Malvaceae	Occasional
60	*Hygrophila auriculata (Schumach.) Heine*	Talimkhana	Acanthaceae	Abundant
61	*Hyptis suaveolens (L.) Poit.*	Darptulas	Lamiaceae	Occasional
62	*Indigofera glandulosa Wendl.*	Borpudi	Leguminosae	Rare
63	*Ipomoea aquatica Forssk.*	Nalichi Bhaji	Convolvulaceae	Abundant
64	*Lagascea mollis Cav.*		Compositae	Occasional
65	*Launaea procumbens (Roxb.) Ramayya & Rajagopal*		Compositae	Occasional
66	*Lemna gibba L.*		Araceae	Abundant
67	*Leonotis nepetifolia (L.) R.Br.*	Deepmal	Lamiaceae	Occasional
68	*Leucas biflora (Vahl) Sm.*		Lamiaceae	Rare
69	*Leucas longifolia Benth.*		Lamiaceae	Common
70	*Ludwigia octovalvis (Jacq.) P.H.Raven*	Panlawang	Onagraceae	Common
71	*Martynia annua L.*	Vinchawi	Martyniaceae	Occasional
72	*Mollugo pentaphylla L.*		Molluginaceae	Common
73	*Ocimum gratissimum L.*	Tulas	Lamiaceae	Occasional
74	*Oldenlandia corymbosa L.*		Rubiaceae	Common
75	*Oxalis corniculata L.*	Amboshi	Oxalidaceae	Common
76	*Parthenium hysterophorus L.*	Gajar Gavat	Compositae	Abundant
77	*Persicaria glabra (Willd.) M.Gómez*	Sheral	Polygonaceae	Abundant
78	*Phyla nodiflora (L.) Greene*	Neerbrahmi	Verbenaceae	Occasional
79	*Phyllanthus niruri L.*	Bhuiawali	Phyllanthaceae	Common
80	*Physalis minima L.*	Popati	Solanaceae	Abundant
81	*Pistia stratiotes L.*		Araceae	Occasional
82	*Plumbago zeylanica L.*	Chitrak	Plumbaginaceae	Occasional
83	*Portulaca oleracea L.*	Gholu	Portulacaceae	Common
84	*Ruelia tuberosa L*		Acanthaceae	Occasional
85	*Senna sophera (L.) Roxb.*		Leguminosae	Occasional
86	*Senna tora (L.) Roxb.*	Takala	Leguminosae	Abundant
87	*Senna uniflora (Mill.) H.S.Irwin & Barneby*			Abundant
88	*Sesamum orientale L.*	Rantil	Pedaliaceae	Occasional
89	*Setaria pumila (Poir.) Roem. & Schult.*		Poaceae	Common
90	*Sida acuta Burm.f.*	Bala	Malvaceae	Occasional
91	*Solanum lycopersicum L.*	Tomato	Solanaceae	Occasional
92	*Solanum virginianum L.*	Katerigani	Solanaceae	Occasional
93	*Spermacoce pusilla Wall.*		Rubiaceae	Common
94	*Spilanthes acmella (L.) L.*		Compositae	Occasional

95	*Spirodela polyrrhiza (L.) Schleid.*	Tikali	Araceae	Abundant
96	*Synedrella nodiflora (L.) Gaertn.*		Compositae	Abundant
97	*Themeda quadrivalvis (L.) Kuntze*		Poaceae	Common
98	*Tithonia rotundifolia (Mill.) S.F.Blake*		Compositae	Common
99	*Trianthema portulacastrum L.*		Aizoaceae	Occasional
100	*Tridax procumbens (L.) L.*	Ekdandi	Compositae	Common
101	*Triumfetta rhomboidea Jacq.*		Malvaceae	Common
102	*Typha angustifolia L.*	Ramban/Pankanis	Typhaceae	Common
103	*Urena lobata L.*		Malvaceae	Occasional
104	*Verbascum chinense (L.) Santapau*	Kutaki	Scrophulariaceae	Occasional
105	*Wedelia triloba (L.) Hitchc.*	Wedelia	Compositae	Occasional
106	*Withania somnifera (L.) Dunal.*	Ashwagndha	Solanaceae	Common
107	*Xanthium strumarium L.*	Shankeshwar	Compositae	Common
		Shrubs		
1	*Calotropis gigantea (L.) Dryand.*	Rui	Apocynaceae	Occasional
2	*Chrozophora rottleri (Geiseler) A.Juss. ex Spreng.*	Suryvarti	Euphorbiaceae	Common
3	*Dalbergia melanoxylon Guill. & Perr.*	Patangi	Leguminosae	Common
4	*Grewia hirsuta Vahl*		Malvaceae	Rare
5	*Homonoia riparia Lour.*	Sherani	Euphorbiaceae	Occasional
6	*Ipomoea carnea Jacq.*	Besharam	Convolvulaceae	Common
7	*Lantana camara L.*	Tantani	Verbanaceae	Common
8	*Phyllanthus reticulatus Poir.*	Panjuli	Phyllanthaceae	Common
9	*Pluchea ovalis (Pers.) DC.*		Compositae	Occasional
10	*Pseudarthria viscida (L.) Wight & Arn.*		Leguminosae	Common
11	*Ricinus communis L.*	Erand	Euphorbiaceae	Common
12	*Sesbania sesban (L.) Merr.*	Shevari	Leguminosae	Common
13	*Solanum torvum Sw.*	Kutri	Solanaceae	Occasional
14	*Vitex negundo L.*	Nirgudi	Lamiaceae	Occasional
15	*Woodfordia fruticosa (L.) Kurz*	Dhayati	Lythraceae	Occasional
		Climbers		
1	*Argyreia nervosa (Burm. f.) Bojer*	Samusrashok	Convolvulaceae	Occasional
2	*Capparis zeylanica L.*	Govindi	Capparaceae	Occasional
3	*Cardiospermum halicacabum L.*		Sapindaceae	Occasional
4	*Celastrus paniculatus Willd.*	Malkangoni	Celastraceae	Occasional
5	*Coccinea grandis (L.)Voigt*	Tondali	Cucurbitaceae	Common
6	*Cocculus hirsutus (L.) W.Theob.*	Vasanwel	Menispermaceae	Common
7	*Combretum ovalifolium Roxb.*	Piluki	Combretaceae	Occasional
8	*Cryptolepis dubia (Burm.f.) M.R.Almeida*	Kavali	Apocynaceae	Occasional
9	*Cryptostegia grandiflora Roxb. ex R.Br.*		Apocynaceae	Occasional
10	*Diplocyclos palmatus (L.) Jeffrey.*	Shivlingi	Cucurbitaceae	Occasional
11	*Ipomoea cairica (L.) Sweet*	Railway creeper.Garwel	Convolvulaceae	Common

12	*Ipomoea nil (L.) Roth*		Convolvulaceae	Occasional
13	*Ipomoea obscura (L.) Ker Gawl.*		Convolvulaceae	Occasional
14	*Ipomoea triloba L.*		Convolvulaceae	Common
15	*Macroptilium atropurpureum (DC.) Urb.*		Leguminosae	Occasional
16	*Mukia maderaspatana (L.)M.Roem.*	Chirati	Cucurbitaceae	Occasional
17	*Passiflora foetida L*	Welghani	Passifloraceae	Common
18	*Pergularia daemia (Forsskal) Chiov.*	Utran	Apocynaceae	Occasional
19	*Teramnus labialis (L.f.) Spreng.*		Leguminosae	Occasional
20	*Tinospora cordifolia(willd.)Miers.*	Gulwel	Menispermaceae	Common
21	*Vigna radiata (L.) R.Wilczek*	Moong	Leguminosae	Occasional
22	*Ziziphus oenopolia (L.) Mill.*		Rhamnaceae	Occasional

Annexure 3 | Checklist of Flora by Zones

(Refer to Figure 14)

		Zones					
No	**Botanical name**	**1.1**	**1.2**	**2**	**3**	**4**	**5**
1	*Abutilon indicum (L.) Sweet*	√		√	√	√	√
2	*Acacia auriculiformis Benth.*	√	√	√		√	√
3	*Acacia chundra (Rottler) Willd.*					√	√
4	*Acacia nilotica (L.) Delile*	√	√	√	√	√	√
5	*Acacia polyacantha Willd.*	√		√			√
6	*Acalypha ciliata Forssk.*	√	√	√	√	√	√
7	*Achyranthes aspera L.*	√	√	√	√	√	√
8	*Adansonia digitata L.*						√
9	*Aegle marmelos (L.) Corrêa*						√
10	*Aeschynomene indica L.*	√	√	√		√	√
11	*Ageratum conyzoides (L.) L.*	√	√	√	√	√	√
12	*Albizia lebbeck (L.) Benth.*	√		√		√	√
13	*Ailanthus excelsa Roxb.*					√	
14	*Albizia saman (Jacq.) Merr.*	√	√	√	√	√	√
15	*Alstonia scholaris (L.) R.Br.*		√	√		√	√
16	*Alternanthera philoxeroides (Mart.) Griseb.*	√	√	√	√	√	√
17	*Alternanthera pungens Kunth*		√				√
18	*Alternanthera sessilis (L.) R.Br. ex DC.*	√	√	√	√	√	√
19	*Alysicarpus tetragonolobus Edgew.*	√		√		√	√
20	*Amaranthus spinosus L.*	√	√	√	√	√	√
21	*Amaranthus viridis L.*	√	√	√	√	√	√
22	*Ammannia baccifera L.*	√				√	
23	*Annona squamosa L*	√	√				√
24	*Apluda mutica L.*	√				√	√
25	*Argemone mexicana L.*	√	√	√	√	√	√
26	*Argyreia nervosa (Burm. f.) Bojer*	√				√	√
27	*Asclepias curassavica L.*	√	√	√	√	√	√
28	*Azadirachta indica A.Juss.*	√	√	√	√	√	√
29	*Azolla pinnata R. Br.*	√	√			√	√
30	*Bacopa monnieri (L.) Wettst.*	√					√
31	*Bambusa vulgaris Schrad.*	√		√			
32	*Bauhinia purpurea L.*	√			√	√	
33	*Bidens biternata (Lour.) Merr. & Sherff*	√	√	√		√	√
34	*Boerhavia diffusa L.*	√		√		√	√
35	*Bombax ceiba L.*	√		√		√	√
36	*Brassica juncea (L.) Czern.*	√	√	√	√	√	
37	*Broussonetia papyrifera (L.) Vent*	√	√			√	

		Zones					
No	**Botanical name**	**1.1**	**1.2**	**2**	**3**	**4**	**5**
38	*Calotropis gigantea (L.) Dryand.*	√	√	√	√	√	√
39	*Canna indica L.*	√			√	√	
40	*Carica papaya L.*	√				√	
41	*Canscora diffusa (Vahl) R.Br. ex Roem. & Schult.*	√		√		√	
42	*Capparis zeylanica L.*	√				√	
43	*Capparris grandis L.f.*		√	√	√	√	√
44	*Cardiospermum halicacabum L.*	√	√	√			√
45	*Celastrus paniculatus Willd.*	√				√	
46	*Celosia argentea L.*	√		√	√	√	√
47	*Centella asiatica (L.) Urb.*	√					
48	*Chloris virgata Sw.*	√	√	√	√	√	√
49	*Chromolaena odorata (L.) R.M.King & H.Rob.*	√	√	√	√	√	√
50	*Chrozophora rottleri (Geiseler) A.Juss. ex Spreng.*	√	√	√	√		√
51	*Cleome rutidosperma DC.*	√					
52	*Cleome viscosa L.*	√				√	√
53	*Coccinea grandis (L.)Voigt*	√	√	√	√	√	√
54	*Cocculus hirsutus (L.) W.Theob.*	√	√	√	√	√	√
55	*Cocos nucifera L.*	√	√		√	√	
56	*Colocassia esculenta (L.) Scott*	√		√	√	√	
57	*Combretum ovalifolium Roxb.*	√	√	√		√	√
58	*Commelina benghalensis L.*	√	√	√		√	√
59	*Commelina caroliniana Walter*	√				√	√
60	*Corchorus sp.*	√	√	√		√	√
61	*Cordia dichotoma G.Forst.*	√	√	√		√	
62	*Cosmos sulphureus Cav.*	√	√			√	
63	*Couroupita guianensis Aubl.*			√		√	
64	*Croton bonplandianus Baill.*		√			√	√
65	*Cryptolepis dubia (Burm.f.) M.R.Almeida*	√	√	√		√	√
66	*Cryptostegia grandiflora Roxb. ex R.Br.*	√	√	√		√	√
67	*Cullen corylifolium (L.) Medik.*	√			√	√	
68	*Cyanotis fasciculata (B.Heyne ex Roth) Schult. & Schult.f.*	√					√
69	*Cyanthillium cinereum (L.) H.Rob.*	√	√	√		√	√
70	*Cynodon dactylon (L.) Pers.*	√	√	√	√	√	√
71	*Cyperus scariosus R.Br.*	√	√				√
72	*Dactyloctenium aegyptium (L.) Willd.*	√	√	√		√	√
73	*Dalbergia melanoxylon Guill. & Perr.*						√
74	*Dalbergia sissoo DC.*		√	√			√
75	*Datura innoxia Mill.*	√	√	√	√	√	√

		Zones					
No	**Botanical name**	**1.1**	**1.2**	**2**	**3**	**4**	**5**
76	*Datura metel L.*				√		
77	*Delonix regia (Hook.) Raf.*				√		√
78	*Desmodium tortuosum (Sw.) DC.*	√	√				√
79	*Digitaria ciliaris (Retz.) Koeler*		√	√		√	√
80	*Dinebra retroflexa (Vahl) Panz.*	√	√			√	√
81	*Diplocyclos palmatus (L.) Jeffrey.*	√			√	√	√
82	*Echinochloa colona (L.) Link*	√	√	√		√	√
83	*Eclipta prostrata (L.) L.*	√	√	√		√	
84	*Eichhornia crassipes (Mart.) Solms*	√	√	√	√	√	√
85	*Emilia sonchifolia (L.) DC. ex DC.*	√	√				√
86	*Eucalyptus globulus Labill.*		√	√		√	√
87	*Euphorbia heterophylla L.*	√	√	√	√	√	√
88	*Euphorbia hypericifolia L.*	√					
89	*Exacum pedunculatum L.*	√					
90	*Ficus benghalensis L.*	√		√		√	√
91	*Ficus hispida L. f.*	√		√	√	√	√
92	*Ficus racemosa L.*	√	√	√	√	√	√
93	*Ficus religiosa L.*	√	√	√	√	√	√
94	*Gliricidia sepium (Jacq.) Walp.*	√	√	√	√	√	√
95	*Glinus lotoides L.*	√					
96	*Gmelina arborea Roxb.*						
97	*Gomphrena sp.*	√					
98	*Grangea maderaspatana (L.) Poir.*	√	√				
99	*Grewia hirsuta Vahl*	√					
100	*Grewia tilifolia Vahl.*	√				√	√
101	*Gynandropsis pentaphylla (L.)*			√		√	
102	*Heliotropium indicum L.*	√	√			√	√
103	*Hibiscus sp.*		√	√			
104	*Holoptelea integrifolia Planch.*	√	√	√	√	√	√
105	*Homonoia riparia Lour.*	√					√
106	*Hygrophila auriculata (Schumach.) Heine*	√	√	√		√	√
107	*Hyptis suaveolens (L.) Poit.*	√	√	√		√	√
108	*Indigofera glandulosa Wendl.*	√					
109	*Ipomoea aquatica Forssk.*	√	√				
110	*Ipomoea cairica (L.) Sweet*	√	√		√	√	√
111	*Ipomoea carnea Jacq.*	√	√	√	√	√	√
112	*Ipomoea obscura (L.) Ker Gawl.*	√					
113	*Ipomoea triloba L.*	√	√	√		√	√

		Zones					
No	**Botanical name**	**1.1**	**1.2**	**2**	**3**	**4**	**5**
114	*Ipomoea nil (L.) Roth*					√	√
115	*Lagascea mollis Cav.*	√					
116	*Lantana camara L.*	√	√	√	√	√	√
117	*Launaea procumbens (Roxb.) Ramayya & Rajagopal*		√	√		√	√
118	*Lemna gibba L.*	√	√		√	√	√
119	*Leucaena leucocephala (Lam.) de Wit*	√	√	√	√	√	√
120	*Leucas biflora (Vahl) Sm.*	√					√
121	*Leucas longifolia Benth.*	√	√	√		√	
122	*Limonia acidissima Groff*	√					
123	*Ludwigia octovalvis (Jacq.) P.H.Raven*	√	√	√	√	√	√
124	*Leonotis nepetifolia (L.) R.Br.*	√				√	√
125	*Macroptilium atropurpureum (DC.) Urb.*	√					
126	*Mangifera indica L*	√	√	√		√	
127	*Martynia annua L.*	√	√	√		√	
128	*Millingtonia hortensis L.fil.*	√	√	√			√
129	*Mimusops elengi L.*			√			√
130	*Mollugo pentaphylla L.*	√					
131	*Morinda pubescens Sm.*	√	√	√		√	√
132	*Moringa oleifera Lam.*	√			√	√	
133	*Mukia maderaspatana (L.)M.Roem.*	√	√	√			
134	*Muntingia calabura L.*	√	√	√		√	√
135	*Neolamarckia cadamba (Roxb.) Bosser*	√	√	√			
136	*Ocimum gratissimum L.*	√					
137	*Oldenlandia corymbosa L.*	√					√
138	*Oxalis corniculata L.*	√	√	√	√	√	√
139	*Parthenium hysterophorus L.*	√	√	√	√	√	√
140	*Passiflora foetida L*	√	√	√		√	√
141	*Peltoforum pterocarpum Auct. non K.Heyne*		√	√	√	√	√
142	*Pergularia daemia (Forsskal) Chiov.*	√				√	√
143	*Persicaria glabra (Willd.) M.Gómez*	√	√	√	√	√	√
144	*Phoenix sylvestris (L.) Roxb.*	√	√			√	√
145	*Phyla nodiflora (L.) Greene*	√					√
146	*Phyllanthus niruri L.*	√	√		√	√	√
147	*Phyllanthus reticulatus Poir.*	√	√	√		√	√
148	*Physalis minima L.*	√	√				
149	*Pistia stratiotes L.*	√	√	√	√	√	√
150	*Pithecellobium dulce (Roxb.)Benth.*	√	√	√	√	√	√
151	*Pluchea ovalis (Pers.) DC.*	√		√		√	

		Zones					
No	**Botanical name**	**1.1**	**1.2**	**2**	**3**	**4**	**5**
152	*Plumbago zeylanica L.*	√	√	√	√		√
153	*Polyalthia longifolia (Sonn.) Thwaites*		√	√	√		
154	*Pongamia pinnata (L.) Pierre*	√	√		√	√	√
155	*Portulaca oleracea L.*	√	√	√	√		
156	*Prosopis juliflora (Sw.) DC*	√	√	√	√	√	√
157	*Pseudarthria viscida (L.) Wight & Arn.*	√	√				
158	*Psidium guajava L.*	√	√				√
159	*Pterospermum acerifolium (L.) Willd.*			√			√
160	*Putranjiva roxburghii Wall.*			√		√	
161	*Ricinus communis L.*	√	√	√	√	√	√
162	*Ruelia tuberosa L*				√		√
163	*Salix tetrasperma Roxb.*					√	√
164	*Santalum album L.*	√	√			√	√
165	*Senna siamea (Lam.) H.S.Irwin & Barneby*	√	√	√	√	√	√
166	*Senna sophera (L.) Roxb.*			√		√	
167	*Senna tora (L.) Roxb.*	√	√	√	√	√	√
168	*Senna uniflora (Mill.) H.S.Irwin & Barneby*	√	√	√	√	√	√
169	*Sesamum orientale L.*	√			√		√
170	*Sesbania sesban (L.) Merr.*	√		√			
171	*Setaria viridis (L.) P.Beauv.*	√	√	√	√	√	√
172	*Sida acuta Burm.f.*	√	√	√	√	√	√
173	*Solanum lycopersicum L.*	√	√		√		√
174	*Solanum nigrum L.*	√					√
175	*Solanum torvum Sw.*	√	√	√	√	√	√
176	*Solanum virginianum L.*	√	√		√		
177	*Sonchus oleraceus (L.) L.*	√	√	√			√
178	*Spathodea campanulata P.Beauv.*	√	√	√			√
179	*Spermacoce pusilla Wall.*	√	√	√			√
180	*Spilanthes acmella (L.) L.*	√				√	√
181	*Spirodela polyrrhiza (L.) Schleid.*	√	√				
182	*Sterculia foetida L.*		√	√	√		√
183	*Synedrella nodiflora (L.) Gaertn.*	√	√	√	√	√	√
184	*Syzygium cumini (L.) Skeels*	√	√			√	√
185	*Syzygium heyneanum (Duthie)Wall.ex Gamble*						√
186	*Tamarindus indica L.*	√	√			√	√
187	*Teramnus labialis (L.f.) Spreng.*	√	√				√
188	*Terminalia arjuna (Roxb. ex DC.) Wight & Arn.*	√	√		√		
189	*Terminalia catappa L.*		√	√	√	√	√

		Zones					
No	**Botanical name**	**1.1**	**1.2**	**2**	**3**	**4**	**5**
190	*Terminalia cuneata Roth*						
191	*Themeda quadrivalvis (L.) Kuntze*						√
192	*Tinospora cordifolia(willd.)Miers.*	√		√			√
193	*Tithonia rotundifolia (Mill.) S.F.Blake*	√					√
194	*Trema orientalis (L.) Blume*	√	√	√	√	√	√
195	*Trianthema portulacastrum L.*	√					√
196	*Tridax procumbens (L.) L.*	√	√	√	√	√	√
197	*Triumfetta rhomboidea Jacq.*	√	√				√
198	*Typha angustifolia L.*	√	√			√	√
199	*Urena lobata L.*	√	√			√	√
200	*Verbascum chinense (L.) Santapau*	√	√	√		√	
201	*Vigna radiata (L.) R.Wilczek*	√					
202	*Vitex negundo L.*	√	√	√			√
203	*Wedelia triloba (L.) Hitchc.*	√				√	
204	*Withania somnifera (L.) Dunal.*	√	√	√	√	√	√
205	*Woodfordia fruticosa (L.) Kurz*	√					
206	*Xanthium strumarium L.*	√	√	√	√	√	√
207	*Ziziphus oenopolia (L.) Mill.*	√				√	√
208	*Zizipus mauritiana Lamk.*	√	√		√	√	√

Annexure 3 | Checklist of recommended flora for plantations, by habitats

(Refer Figure 14 for habitats)

Native trees and their habitats http://oikos.in/html/newckfinder/userfiles/files/Grow_Natives_booklet.pdf

Plantation Guidelines refer to http://oikos.in/html/newckfinder/userfiles/files/PlantationsGuidelines.pdf

For Riparian Zone

Sr.No.	*Botanical Name*	*Local name*
	Trees	
1	*Ficus racemosa*	Umbar
2	*Pongamia pinnata*	Karanj
3	*Salix tetrasperma*	Walunj
4	*Syzygium cumini*	Jambhul
5	*Syzygium heyneanum*	Panjambhul
6	*Lagerstroemia speciosa*	Tamhan
7	*Terminalia arjuna*	Arjun
8	*Neolamarckia cadamba*	Kadamb
9	*Acacia nilotica*	Babhul
10	*Crataeva adansonii*	Varun
	Shrubs	
1	*Vitex negundo*	Nirgudi
2	*Phyllanthus retuculatus*	Panjuli
3	*Homonoia riparia*	Sherani
4	*Tamarix ericoides*	Kadesherani
5	*Glycomsis pentaphylla*	Kirmira
6	*Woodfordia fruticosa*	Dhayati
	Herbs	
1	*Canna indica*	Kardal
2	*Coix lacryma-jobi L.*	Kashed
3	*Crinum viviparum*	Nagdamani
4	*Cyperus difformis*	Lavhale
5	*Hygrophila auriculata*	Talimkhana
6	*Persicaria glabra*	Paral
7	*Saccharum spontaneum*	Ranus/Kamis
8	*Typha angustata*	Ramban/Pankanis
9	*Centella asiatica*	Mandukparni
10	*Phyla nodiflora*	Jalpimpali
11	*Baccopa moneri*	Neerbrahmi
	Climbers	
1	*Tinospora cordifolia*	Gulwel
2	*Combratum ovalifolium*	Piluki
3	*Argyreia nervosa*	Samudraskok

For Upland habitat

	Trees	
1	*Alangium salvifolium*	Ankol
2	*Albizia lebbeck*	Shirish
3	*Bauhinia acuminata*	Pandhara Kanchan
4	*Bauhinia tomentosa*	Pivala Kanchan
5	*Bombax ceiba*	Katesawar
6	*Butea Monosperma*	Palas
7	*Capparis grandis*	Pachunda
7	*Cassia fistula*	Bahava
8	*Cordia dichotoma*	Bhokar
9	*Crataeva adansonii*	Varun
10	*Dichrostachy cinerea*	Sigamkathi / Durangi Babhul
11	*Dillenia pentagyna*	Karmal
12	*Erythrina suberosa*	Buch pangara
13	*Ficus microcarpa*	Nandruk
14	*Gmelina arborea*	Shivan
15	*Madhuca latifolia*	Moh
16	*Magnolia champca*	Chapha
17	*Mimusops elengi*	Bakul
18	*Mitragyna parvifolia*	Kalam
19	*Morinda pubescens*	Bartondi
20	*Murraya paniculata*	Kunti
21	*Neolamarckia cadamba*	kadamb
22	*Nyctanthes arbor-tristis*	Parijatak
23	*Oroxylum indicum*	Tetu
24	*Phoenix sylvestris*	Shindi
25	*Pongamia pinnata*	karanj
26	*Pterocarpus marsupium*	Beeja
27	*Pterospermum acerifolium*	Muchkund
28	*Saraca asoca*	Seeta Askok
29	*Schleichera oleosa*	Kusum
30	*Sesbania grandiflora*	Agasti
31	*Tamilnadia uliginosa*	Pendhra
32	*Terminalia bellirica*	Beheda
33	*Wrightia arborea*	Tambada Kuda
34	*Wrightia tinctoria*	Kala Kuda
	Shrubs	
	Capparis decidua	Nepati
2	Carrisa congesta	Karvand
3	Clerodendrum phlomids	Arni
4	*Helicteres isora*	Murudsheng
5	*Justicia adhatoda*	Adhulasa
6	*Pavetta crassicaulis*	Phapat
7	Vitex nigundo	Nirgudi
8	Woodfordia fruticosa	Dhayati

	Climbers	
1	*Argyreia nervosa*	Samudrashok
2	*Aristolochia sp.*	Badakwel
3	*Asparagus racemosus*	Shatawari
4	*Caesalpinia bonduc*	
5	*Cissus quadrangularis*	Hadjodi
6	*Clematis gouriana*	Ranjai
7	*Gloriosa superba*	Kal-lawi
8	*Hiptage benghalensis*	Madhumalati
9	*Oxystelma esculentum*	Dudhani
10	*Piper longan*	Pimpali
	Herbs	
1	*Bambusa arundinacea*	Kalak(Bamboo)
2	*Dendrocalamus strictus*	Mes(Bamboo)

Annexure 4 | References

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Annexure 4 | Summary of the brainstorming output during River Restoration Workshop held on 29 September 2017

Introduction

An approach paper on River Restoration in Pune is being developed through a collaborative process anchored by Ecological Society and Centre for Environment Education. Ecological Society has carried out surveys of the river channel and ecosystem over May-August 2017, and compiled past studies. The findings were presented to the multi-disciplinary group assembled on 29 September. Inputs were sought from the group on the ecosystem benefits from the rivers in Pune, what contributes to these functionalities and what detracts or impairs these functionalities.

Ecosystem Benefits from rivers / river systems include:
- Provision of fresh water
- Regulation of water drainage and erosion
- Cultural (cultural, recreation, ecotourism, educational)
- Supporting functions e.g. soil formation, nutrient and water cycling, as habitat

Regulatory Function of Water Drainage and Erosion	**Provisioning role**	**Supporting Functions of River as a Habitat/ Ecosystem**	**River as a Place of Cultural Value**
Is a sink / conveyor of flood waters, deposits sediments along the flood plains/ banks **What contributes to the role** • Natural water shed, which recharges aquifers and maintains base flow • Recharge areas within watershed • Network of natural feeding streams • Wetlands • Natural spring	The Mula Mutha river system provides water for domestic, commercial, irrigation use for Pune, and the upstream and downstream areas; Helps in maintaining groundwater; Fish and vegetable harvests; Small cultivation patches, Dhobi ghats are present along the river River channel is an air corridor Whether harvest of fish and vegetables, farming, and dhobi ghats are appropriate uses was	Nutrient and water cycling, soil formation, as habitat **What contributes to the role** • Bank character, Riparian zone, Wetlands, Islands • Meandering character • Exposed rocks and potholes • Open spaces along the river banks • Springs hyporheic zone • Oxygen carrying capacity (DO 8 ppm)	Education, recreation, cultural activities **What contributes to the role** • Natural habitats along the river channel (pools, fish, birds, bird watching/ butterfly watching, recreation/ education) • Natural state of river (clean and pure water) • Temple locations, which are at sources of spring (revival recommended)

• Vegetation along the river bank • Efforts like Sangrun model • Increasing awareness about river • Studies already done on various themes about river and river ecosystem **What is impairing or limiting this function** • Recharge zones are not protected; increased paving and hardscapes; impermeability in the river catchment; Land Development activities in upstream • Natural streams are blocked; deteriorated quality of feeding streams; Diversion of streams • Topography is modified during land development • Constructions, pitching, retaining walls; River bank damage; Channelization of river; Violation of red and blue lines • Solid waste and construction debris • Causeways and other bridges in river	discussed. It is felt that such activities are small-scale, they increase the connection of people to the river, and can be carried out in an 'ecosystem-integrated' manner. **What contributes to the role** • The quality of the watershed upstream and within city, permeability • Aquifers • The dam systems retain and provide water; however, the quantum of water that is drawn should be reduced by recycling and demand management • Slopes, riparian zone, and riverine habitat help in improving water quality • Gharkool lawns, Ramnadi, Mul-Mutha sanctuary are harvesting sites for wild vegetables **What is impairing this function** • Hardscapes in the watershed; Non-recognition of the water catchment function of the Pune city area, which has led to wells being closed/ not properly managed	• In-stream habitation and biodiversity; Preservation of indigenous species • Migratory bird roosts (eg proposed Mula Mutha Bird Sanctuary) • Nesting and roosting sites (of birds, insects, etc.) • Waders habitat / muddy banks • Microhabitats (eg behind Gharkul Lawns) • Riverbed vegetation • Maintaining the Base flow • STP social / third party audit • Public hearing of projects related to river basin **What is impairing this function** • Dams • Unplanned development in the upstream or watershed; Loss of recharge areas • Plantation of inappropriate species and modifications of the south-west bank of Khadakwasla reservoir is destroying the upstream habitat • Canalisation of river, nalas • Encroachment; Road; Bunds, barrages, dams • Excavation	• Educational activities, research, academic • Recreational activities, such as bird watching, story-telling sessions along ghats, open space (river as a large open area acting as wind corridor, aesthetic (visual connectivity), jogging tracks, eateries, etc • Cultural activities, such as Ganesh visarjan, last rites, nirmalya, activities along ghats • Existing Nadi Seva projects in the city (from jan-jagruti to shrama-jagruti) **What is impairing this function** • Disturbed ecosystems/ habitats • Scale of built up/ hardscapes/ human activities • Lack of awareness, of criticality • Cultural practices need to be evaluated by public • Wrong planning – temples, religious places; Historical importance of temple placement is lost • How, where and to what extent to have development activities • Lack of implementation / enforcement of laws • Lack of better alternatives • Springs are being blocked

• Lack of understanding of trends over the years in water drainage in river system • Climate change and it's impacts • Lack of long term studies, monitoring, research and planning • Lack of mapping of drainage system, aquifers etc • Lack of planning considering ecological aspects; Lack of disaster management planning • Lack of implementation of rules and regulation about wetlands; Lack of awareness about wetlands;	• Lack of regulation for groundwater extraction; changes in topography impacting recharge; destruction of aquifers by construction • Destruction of physical structures of stream and rivers, including by extraction of soil, rock, and concretization / channelization of streams • Untreated sewage, dumping of waste debris, oils and other pollutants from vehicle washing • Introduction of alien fish exotic vegetation • Fertilizers and pesticides used in agricultural activities in the upstream region may be affecting river water quality • Water usage and farming in the region downstream of Pune is adversely impacted due to pollution load contributed by Pune • Mismanagement of supply and demand of water Future approach may be Payment for Ecosystem Services (PES) for protecting upstream watershed	• Insufficient and nonfunctional STPs; STP outflows; Untreated sewage; Waste dumping, MSW, C&DW • Cultural and entertainment practices • Aquatic weeds/ invasive species • Haphazard plantation; Planned gardens • Absence of river basin vision • Lack of long term studies, monitoring, research and planning • Gap regarding no guidelines of development in the red and blue zones • Lack of ecological perspective in planners, bureaucrats, elected representatives • Awareness about details of ecosystem and it's principles; awareness about river in host city; Water navigation plans • Increase in water demand, the growth of the city	• Disposal method for nirmalya

"There is phenomenal resilience in the mechanisms of the earth. A river or lake is almost never dead. If you give it the slightest chance....then nature usually comes back" Rene Dubos

Ecological Society undertook an indepth study of the stretch of Mula-Mutha passing through Pune city. This report is based on these studies and offers guidelines and recommendations for the riverfront development program of the twin rivers. The recommendations are based on ecological and cultural aspects and employ a holistic approach to the river as a living ecosystem.

"...design needs to shift from a paradigm of transforming nature to one of transforming society; by improving the quality of life and the relationships between all living beings and the built environment" Prakash Gole