RIVER & COMMUNITIES

alternative scenarios

Sujana Devabhaktuni

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MASTER OF LANDSCAPE ARCHITECTURE

Department of Landscape Architecture
Faculty of Architecture
University of Manitoba,
Winnipeg, Manitoba

"Each species, even though it may seem insignificant, has a role to play in this tapestry of life. Every single individual matters, every single individual makes some impact on the planet every single day, and we have a choice as to what kind of difference we are going to make." – Jane Goodall (Earth Day, 2018)


Andhra Pradesh, India

Abstract

For thousands of years, rivers and forests have supported earth's civilizations and survive several natural calamities. However, these waters and woodlands are now under threat due to exponential impacts of humans' ecological footprints. This threat continues to increase due to the choices we make. Urbanization, sporadic growth patterns, poor development strategies, and lack of awareness have contributed to the demise of river and water bodies in India.

This practicum focuses on potential strategies to improve ecological conditions of Tammileru River in Andhra Pradesh and Telangana states by incorporating vernacular practices and refining policies for future development and management.

The current conditions of the river along its course are analyzed and ways in which it is being affected by the agricultural practices, structures and changing the lifestyle of communities living along the river are identified. Based on this analysis, design strategies are developed to re-establish relations between communities and the river, and by doing this, not only improve water quality but also helping recover groundwater levels to support the communities' daily needs.

◀ **Figure 1.0** *Study area in global context.*


Telangana
Andhra Pradesh
STUDY AREA

Acknowledgments

To my Committee Chair and Advisor Brenda Brown, I could not thank you enough for your support throughout my practicum and my time at the university. You have been a great inspiration to me. Thank you for everything.

To my Committee Examiners Ted McLachlan and Chip Sullivan, thank you for exploring Tammileru with me. Your thoughtful advice, guidance, and encouragement in the consideration and development of my work are constructive.

To my Uncle, thank you for driving me everywhere in pursuit of this practicum. You will be missed.

To my husband, you have been very thoughtful, caring and patient. Thank you for always being there for me, I would not have done this without you.

To my brother, cousin, mamaya garu, and family I couldn't have completed my research without your support. Thank you for your unconditional love, support, and patience.

◀ **Figure 1.1** *Location of Watershed within the states of Andhra Pradesh and Telangana.*

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▲ **Figure 1.2** *Deccan landscapes*

Typical landscape of Andhra Pradesh and Telangana states consists of farmland marked by tall coconut and palm trees. Rivers and streams flowing from Deccan plateaus are diverted into culverts that supply water for irrigation.

01 Introduction

Humans and wildlife survive by adapting to changing conditions. In some circumstances, people adapt and create healthier environments; in other scenarios, they surrender to counteracting the societal pressures, feel helpless and unintentionally harm the environment in efforts to resolve issues they face every day. The latter is witnessed in India, as in several other developing countries. Natural resources such as minerals, rivers, forests, and fertile lands have been squandered for development over the past fifty years and continue to be threatened by urbanization, unplanned growth and extensive agriculture and industries.

India, which once supported its people and flourished due to abundant water resources, is now at the brim of a water crisis (Mehta & Mehta, 2013). Rivers, lakes and water bodies are under tremendous stress throughout the country. Rapid uncontrolled growth and development have resulted in infringement of river beds and water bodies while lack of infrastructure, sanitation facilities and growing agricultural lands are major factors in the rivers' ecological deterioration and depleted groundwater resources in both urban and rural areas. In either scenario, the water resources India depends on for 65% of daily needs (Isha Foundation, 201-) has been critically affected by human actions throughout the countries development since the 1990s. In 1990, a total of 552 billion cubic meters (bcm) of surface water (66%) and groundwater (34%) was withdrawn, out of which 89% was used for irrigation – this is 10% higher than the global average (Chellaney, 2011, p. 32) (Sinha, et al., 2015, p. 2). 5% for domestic use, 3.5% for energy generation and 2.5% for industries (2015, p. 2). This water consumption rate increased to 750 bcm in 2015, and the total water demand is projected to reach 1050 bcm by 2025 -- almost equal to all available water resources (p. 2). International Water Management Institute (IWMI) and Food and Agriculture Organization (FAO) data shows that despite limited freshwater resources in South Asia, agriculture has continued to expand over the past thirty years resulting in severe groundwater depletion (Chellaney, 2011).

Yet, this is not a complete picture. In 2015, 275 rivers and streams in the country were declared polluted by the Central Pollution Control Board. This has doubled since 2010 (Burke, 2015). Improper collection, transportation, treatment and disposal of domestic and industrial waste into rivers and water bodies has led to the rise pollution levels in urban areas so high that the water can easily catch fire (Sinha, et al., 2015). According to the Central Pollution Control Board, 40 percent of India's water resources are considered unsuitable for use due to pollution and various other factors (2015). These conditions also affect how people interreact with water. Rivers once worshipped are now either dry or highly polluted, straining the relationship people have with water. These conditions if left unaddressed will change the waterbodies and rivers into greywater channels.

To better understand the reasons for river pollution and depleting groundwater resources, this practicum focuses on Tammileru River located in Telangana, and Andhra Pradesh states in southeast India, where I spend my childhood summers along Tammileru River in Vijayarai, Andhra Pradesh. There I witnessed the local community interacted with the river. Looking down the memory lane, time and again I go back to the same place when I think of my experience with this river. I remember my family and cousins visiting my grandparents every year from the time I was five. Living in close proximity to the river, we strolled into the shimmering sandy banks of the river every morning and spent time chasing small fish in the crystal-clear fresh water. The river bank was knit with massive evergreen trees on one end while the other bank had tall palm plantations and farms with several fruit trees, including mangoes, guava and cashews, that attracted a wide range of wildlife. The river edge was lively with people, animals and birds through the day. Such conditions along the river drastically changed over a decade. Similar to other rivers across India, Tammileru River has been dry, polluted and exploited for its resources and is now subjected to water stress, biodiversity loss and land degradation.

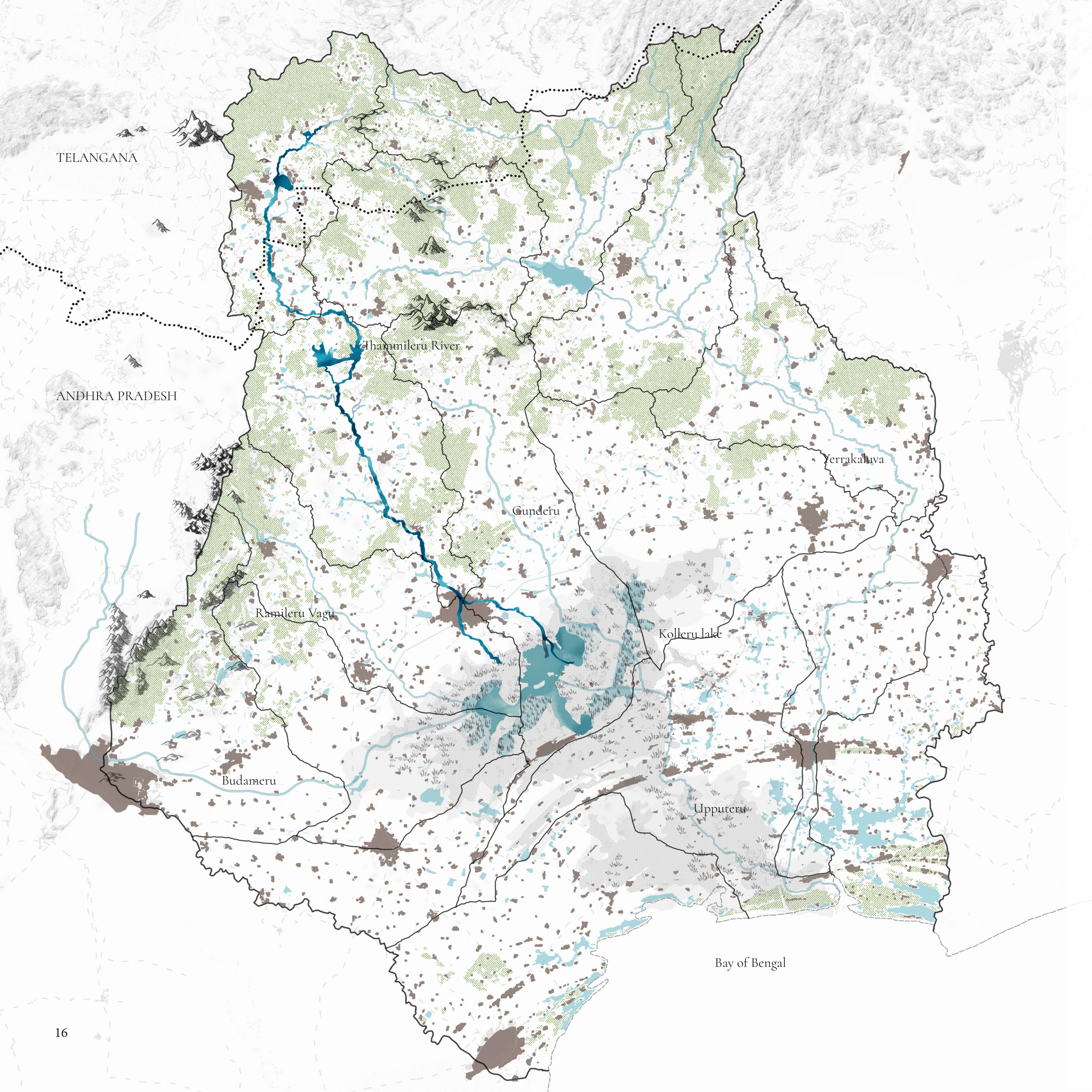
My research for this practicum began from these memories. The initial analysis of Vijayarai done for Landscape Topics course made me realize the need to look beyond this village to develop a comprehensive understanding of the issue faced by the river and other communities depend on it. I began research to develop an understanding of the relationship between people and river and how the changing conditions affected cultural interactions along Tammileru River. As there is minimal documentation on the river and the adjacent communities, I relied on personal observations, interviews and oral histories. With approval of the University of Manitoba Joint Faculty Research Ethics Board, personal interviews were conducted at several villages along the river with questions focused on individual engagement with the river in the past and present; fond memories; biodiversity and plant species; effects of changing conditions on day to day life, and visions for the future. These interviews are analyzed to draw attention to emerging conflicts, sinking groundwater levels, agricultural impacts on water stress and pollution concentrations downstream. This study helped establish the context of the river over time and the principle elements responsible for the changes in the communities in relation to the river. Changing the relationship between people and their surroundings is a primary focus in the document's graphics.

The goal is to achieve ecological resilience by emphasizing human and nature relationships and engaging community members as stewards of the land. Through designing and planning, I have sought to rejuvenate Tammileru River water systems with an ecological approach that not only supports the river but also promotes cultural interactions and contributes to the development of healthier regional ecosystems.

This river and community relationship is explored at two scales. At a small scale, the design interventions are developed to addressed issues faced at Vijayarai - They are intended to establish visual and physical connections between the community and the river whilst improving water quality by establishing wetlands in looping with existing landforms. It is intended that the design principles used at Vijayarai, could be adopted and applied to other communities along this river and would form a basis for the regional application. At the regional level, policies are proposed to protect the river ecosystem and improve groundwater levels through careful planning and utilization of rainwater. This combined effort by people and the government at local and regional levels will aid in the rejuvenation process of the river. Analogously, I hope the approach to this watershed can be translated to other places.

▶ **Figure 1.3** *Personnel experiences at Tammileru River at Vijayarai*


Yummy..
mangoes
Those are my mangoes.
Fisheeee..ee


TELANGANA
ANDHRA PRADESH
Thammileru River
Gunderu
Yerrakaluva
Ramileru Vagu
Kolleru lake
Budameru
Upputeru
Bay of Bengal

02 Context

◀ **Figure 2.0** *East flowing rivers between Godavari and Krishna*
Map is developed based on Water Resources Information System. Tammileru, Errakalva, Uppeteru, Gunderu and Bhudimeru are the five rivers in the watershed that flow into Bay of Bengal. These rainfed rivers are the primary source of water for irrigation.

East flowing rivers Watershed
Tammileru River - Study Area
Other rivers and streams in the watershed
Regional boundary
Transportation network
Coastal boundary - Bay of Bengal
Natural springs
Perennial dry
Swamp
Seasonally flooded marsh
Kolleru wetland
Plantations (only available data)
Forest
Hills
Settlements
Fisheries

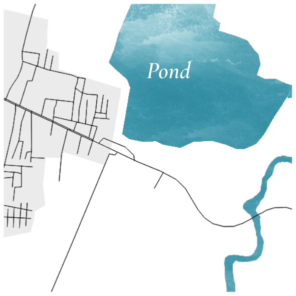
0 10km
N

Location

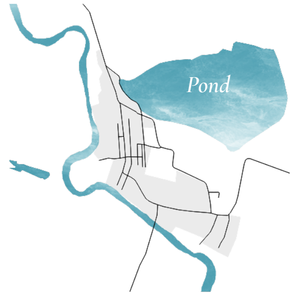
Situated in the Deccan plateau, east flowing rivers between Godavari and Krishna watersheds spread across three districts covering an area of 12,289 square kilometres. Five independent rivers, Errakaluva, Tammileru, Gunderu, Ramileru, and Budameru, flow into Kolleru Lake (WRIS, n.d.). Reflecting the predominant occupations in the region, the landscape of the watershed is comprised of 63% agricultural lands, 14.5% water bodies, 17.5% forests and 5% populated zones (n.d.).

The study area, Tammileru River originates in the hilly regions in the state of Telangana and quickly travels into Andhra Pradesh where it demarcates Krishna and West Godavari districts, travelling approximately 110 kilometres abutting a vast expanse of agricultural fields, and over 25 villages and small towns. At Eluru, the river splits into two and flows into Kolleru Lake where it joins Upputeru River before entering the sea. Historically, the river was an active space that attracted people and supported their day to day activates. These conditions have changed over the past few decades due to exponential growth in population and intensive agriculture and aquaculture activities (Prasad, et al., 2017). Today the river is dry most of the year.

Seetharampuram 1,247



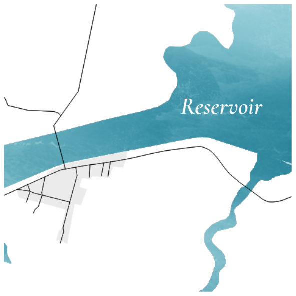
Sathupally (T) 12,504



Diddipudi nd

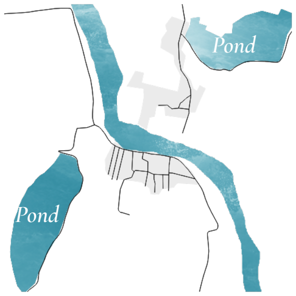

Chinnampeta 3,446


Kotapadu 5,874



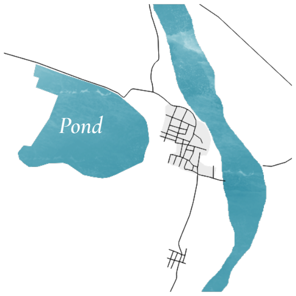
Mankollu 689


Yerravarigudem nd



Gullapudi 5,459


Valasapalli nd



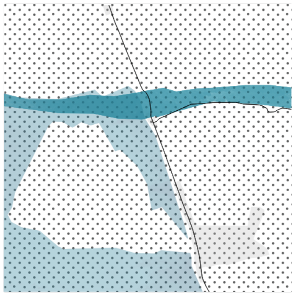
Ellapuram 1,173


Balive 1,798


Vijayarai 4,038


Eluru (M) 275,596

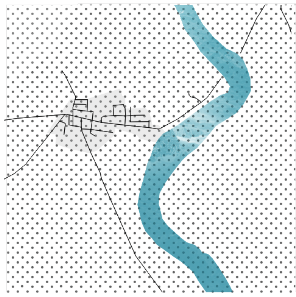

Gudivakalanka 5,308

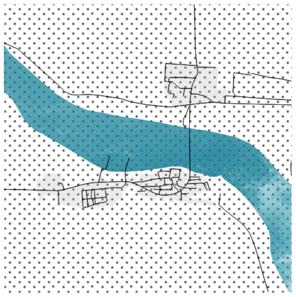

Kolletikota 21,292

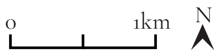

Siddapuram 7,171

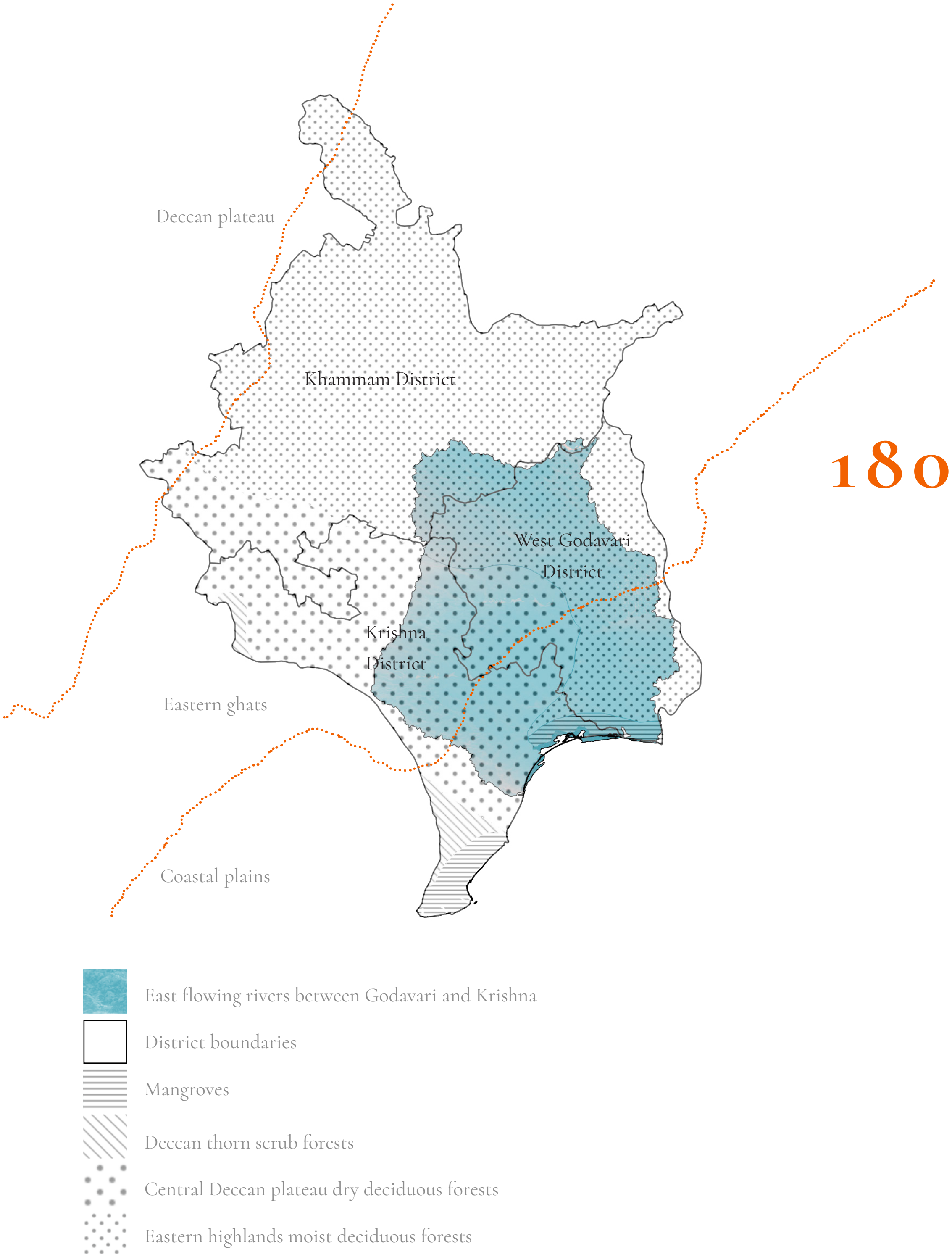

Akividu 27,641


Elurupadu 2,675


Mattagunta nd


Losarigutlapadu 22,831





Tammileru catchment
1587 sq.km

Population density
180- 20,000 / sq.km

Population along river
412,470

Farming dependent population
138,578

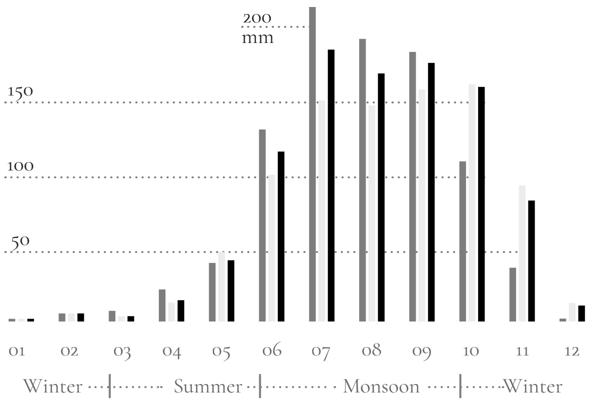
Agriculture
approx. **1000** sq.km

Literacy **42** %

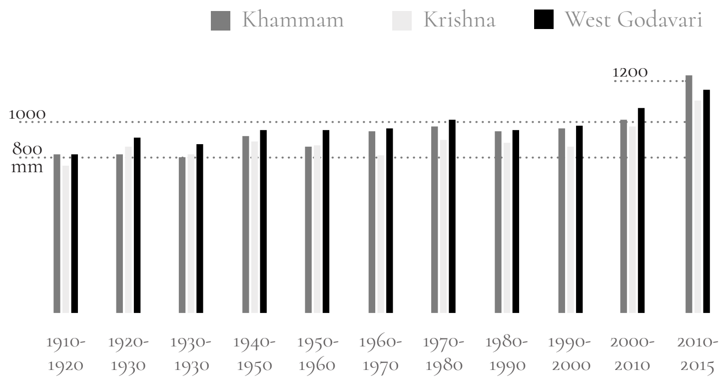
◀ **Figure 2.1** *Settlement patterns and population along Tammileru River*

▲ **Figure 2.2** *District, Ecozone and Physical features*

▶ **Figure 2.3** *Tammileru Watershed Statistics (Government of India, 2011)*



Average monthly rainfall (1910-2015)



Average annual rainfall (1910-2015)

Climate

Tammileru watershed is spread across Deccan Plateau, the Eastern Ghats and Coastal Plains. The climate changes from hot-dry to hot-humid as the river travels towards the sea. May is the hottest month with daily temperature ranging from 45ºC to 32ºC and coldest in January with daily temperature from 32ºC to 15ºC (World Weather Online, 2018).

July receives most rainfall. In the past 100 years, the volume of precipitation has increased as seen in the above graph. In the past century, regions in the watershed received an average precipitation of 672 millimeters annually in 1910 to an average of 965 millimeters in 2015 (India Meterological Department, 2018). Though the precipitation amounts seem to rise, water shortage continues to occur across the watershed resulting in changing agricultural patterns.

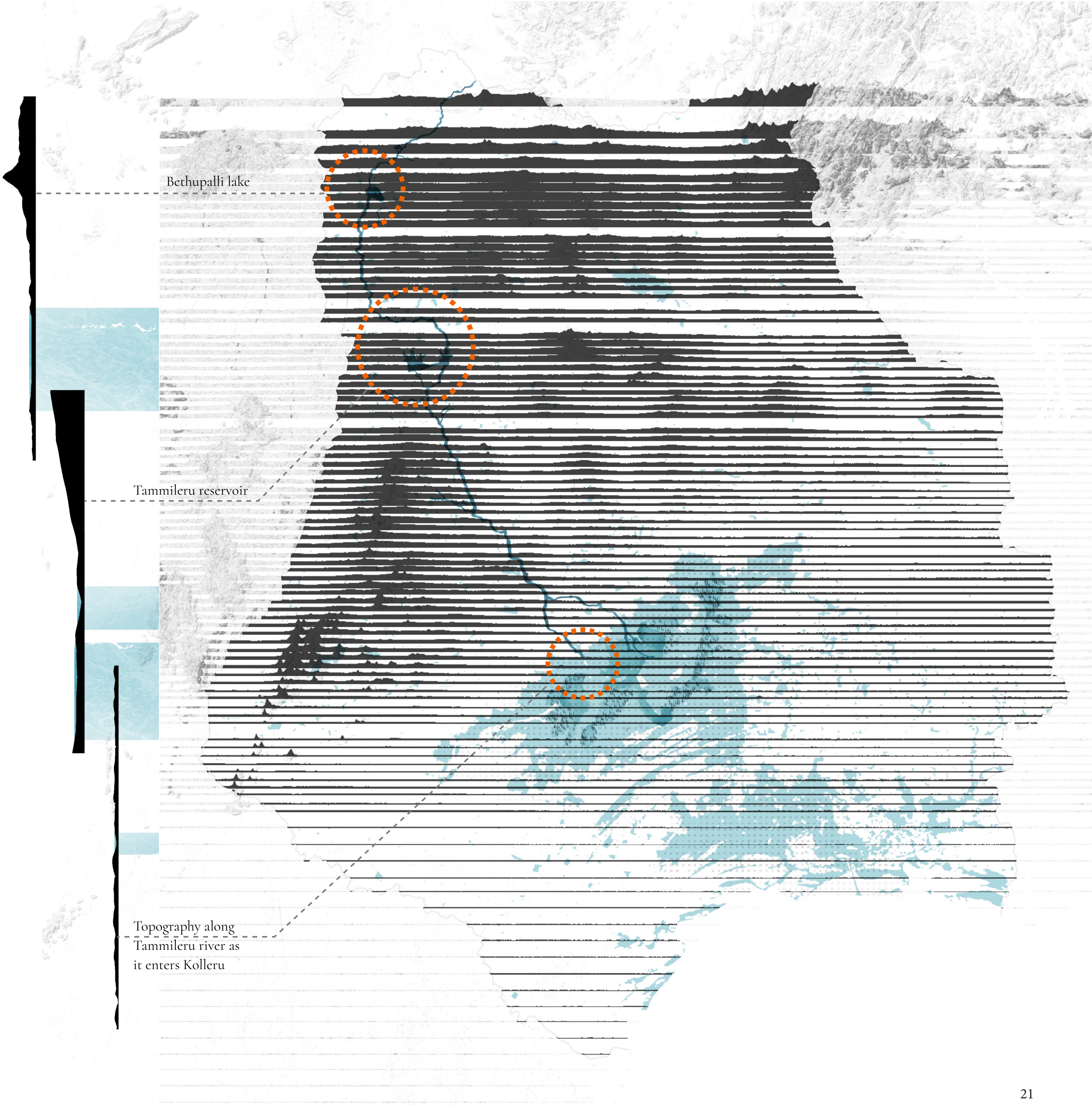
Topography

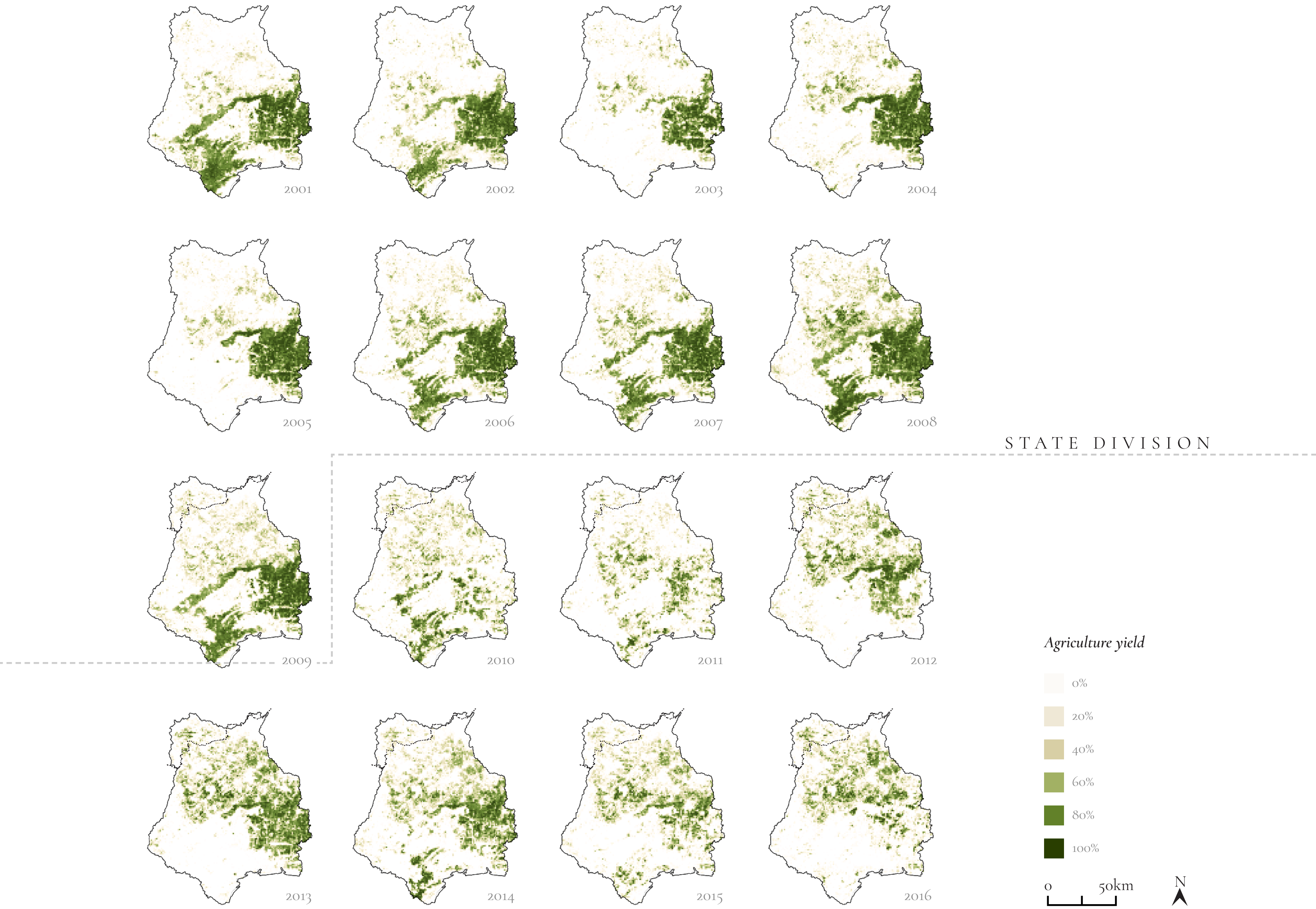
The watershed is predominately a plateau with small hills between 500-750m dotted across the north. The land gently slopes towards the coastal plateaus with maximum elevation of 5m above sea level. Based on topography, Tammileru reservoir was constructed in the northeastern part of the watershed to create a catchment of 576.60 square kilometers catering to seasonal flooding and overflow from Bethupally Lake (SE Irrigation circle, 2016).

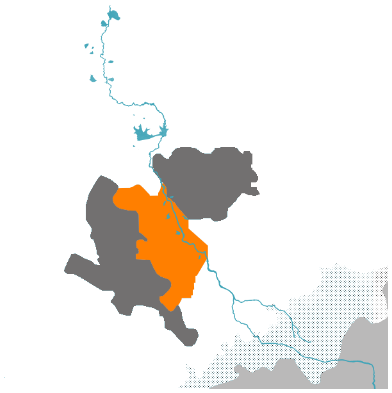
◀ **Figure 2.4** *Average monthly rainfall between 1910-2015*

▲ **Figure 2.5** *Average annual rainfall between 1910-2015*

▶ **Figure 2.6** *Topography*

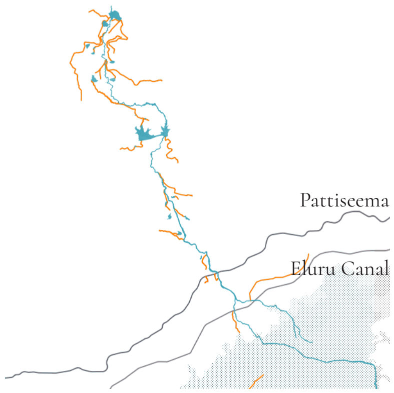

Bethupalli lake
Tammileru reservoir
Topography along
Tammileru river as
it enters Kolleru


2001
2002
2003
2004
2005
2006
2007
2008
STATE DIVISION
2009
2010
2011
2012
Agriculture yield
0%
20%
40%
60%
80%
100%
2013
2014
2015
2016
0
50km
N



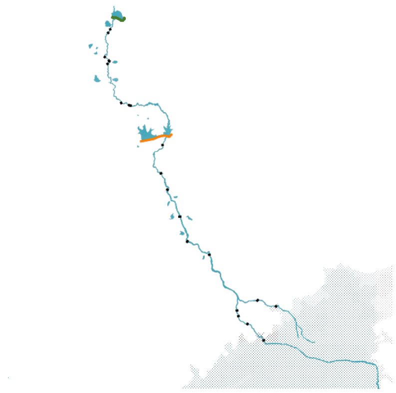
Ground water levels

Critical | Semi-critical | Saline



Irrigation Canals

Canals | Major diversion projects



Reservoirs, dams and anicuts

Reservoir | Minor reservoir | Anicut

“We grew corn, maize, paddy and had few coconut trees in the farmland. Due to the lack of water in recent years, we changed the crop land into cacao plantations. These plants required less water compared to the crops we cultivated in the past, so, water from the borewell is sufficient to water this plantation regularly. These forgiving plants, survive through water shortage periods in the summer.” (Resident of Munipalli, age 49).

◀ **Figure 2.7** *Changing agricultural trends (Jain, et al., 2017)*

▲ **Figure 2.8** *Groundwater levels (WRIS., 200?)*

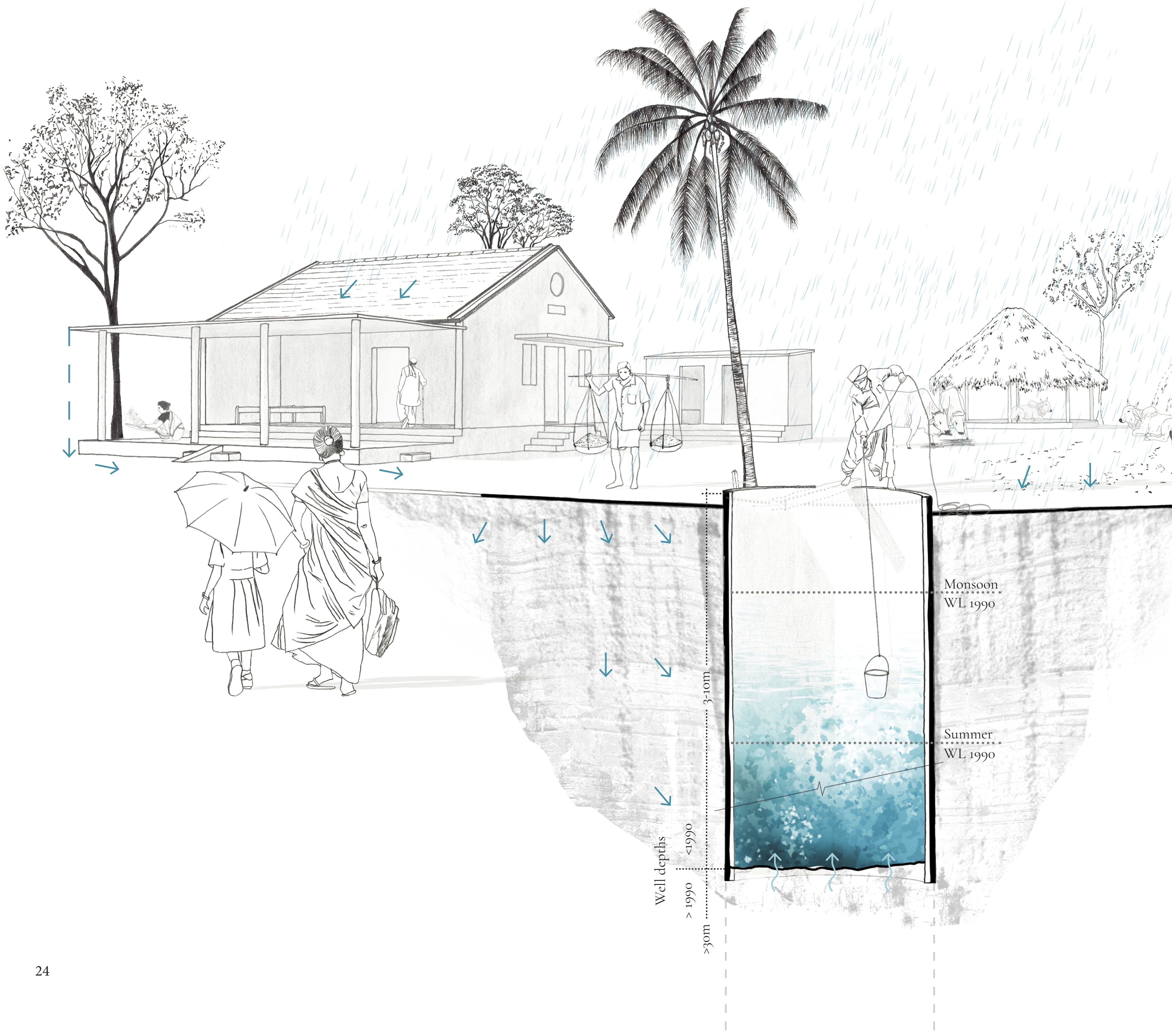
▲ **Figure 2.9** *Irrigation canals (2017)*

▲ **Figure 2.10** *Reservoir, dams and anicuts (2017)*

Agricultural patterns

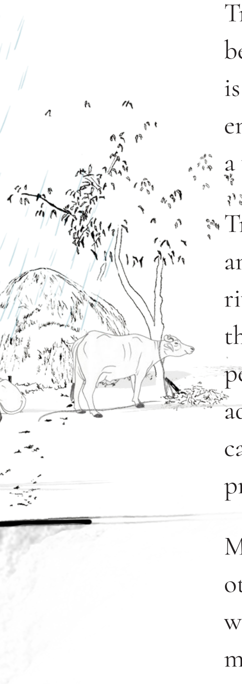
Irrigation was traditionally done based on “run-of-the-river schemes”, – a system that allowed water levels to rise at a barrage or a dam and be diverted into canals. The water level of the channels is maintained based on the available water and irrigation needs (Varshney, 2015). However, due to water storage requirements, growing irrigation demands, or low-interest crop loans and other agricultural incentives, farmers began to depend on groundwater resources (FAO, 2016). Over 2500 borewells are sanctioned in Krishna and West Godavari districts every year (ESRI India, 2018).

This trend, however successful in its initial phase, has contributed to aquifer depletion in Tammileru Watershed. A nationwide assessment survey indicates a 21% increase in groundwater exploitation between 1994 and 2004 (Arghyam, 2015). Studies of crop patterns between 2001 and 2016 clearly show a growing yield in the state of Telangana and diminishing yield in Andhra Pradesh since 2009 (Jain, et al., 2017), coinciding with the Andhra Pradesh state division.


Monsoon
WL 1990
Summer
WL 1990
3-10m
Well depths
<1990
> 1990
>30m

Traditional village life

People of Andhra Pradesh and Telangana speak Telugu and live in harmony with one another despite religious differences. Traditional houses in rural areas are small with one or two bedrooms with detached washrooms and kitchen. The house is coved with hay or terracotta roof tiles and set within a large enclosure with fruit yielding trees, plants, domestic animals and a well.



Traditionally, water from wells was used for domestic purposes, and drinking water brought from freshwater springs on the sandy river bank. Greywater from kitchen and bath were routed to the plant beds where it slowly infiltrated the ground. Rainwater percolated into the ground through a similar process aiding in aquifer recharge. Leftovers from the kitchen were fed to chicken, cattle and other domestic animals, while manure was used to produce cooking gas and agriculture compost.

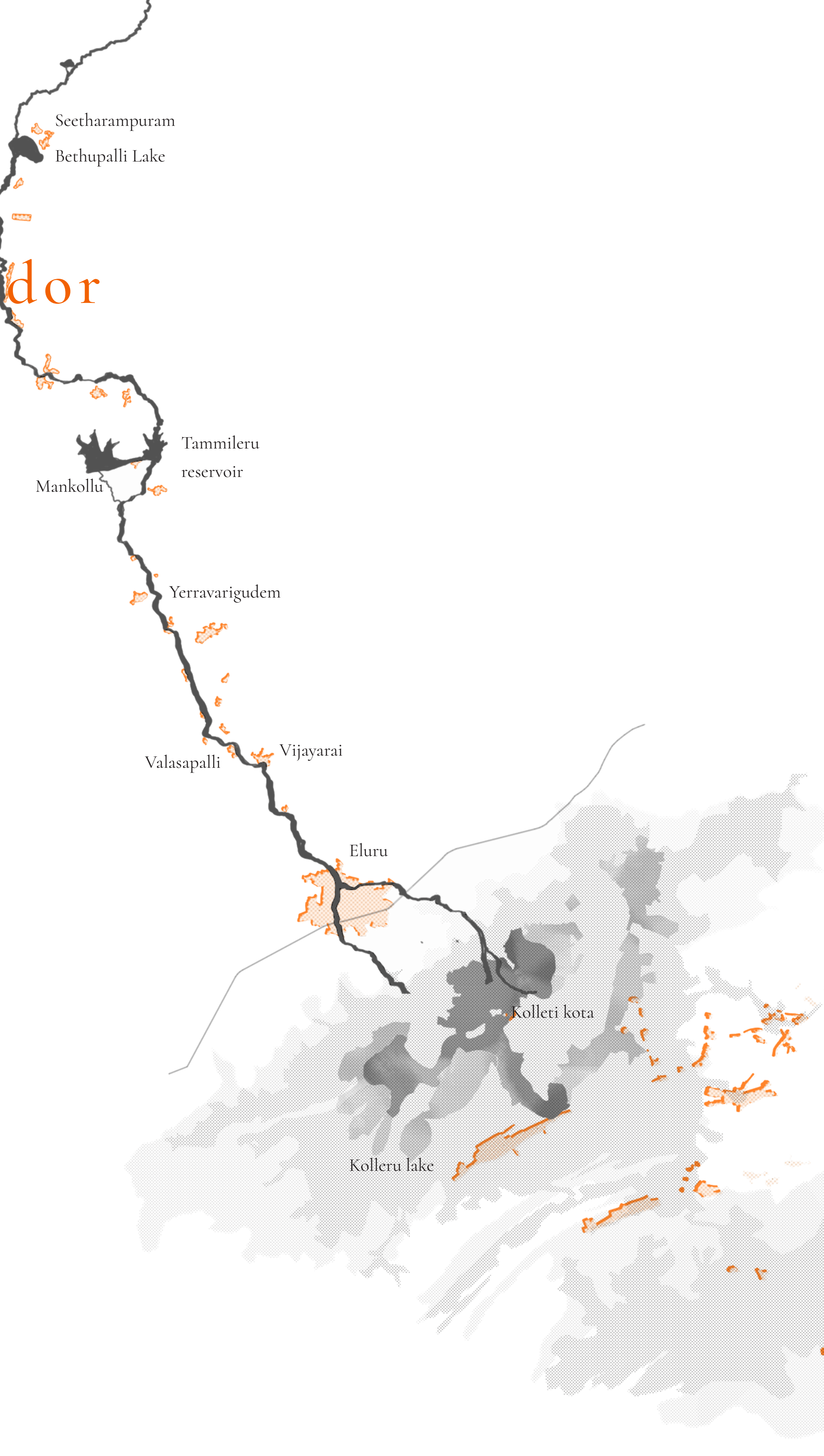
Most vegetables were grown in home gardens and farmlands while other food products were purchased at local markets. Goods were wrapped in old newspapers and carried in hand-woven baskets made with jute, bamboo, palm leaves or hard plastic which lasted up to five years.

Social gatherings and celebrations were a major part of life. On these occasions, food was served in plates made from broadleaf – typically from Shorea robusta, Ficus benghalensis and Musa species. Stainless steel tumblers were used to drink water, which were washed and reused. Excess food was served to the less privileged people in the community. This simple lifestyle was highly sustainable.

These conditions changed over the past decade due to shifting cultural influences and introduction to an easy way of living. The fertile agriculture lands attracted people from surrounding areas and the housing density increased. Plots became smaller with the flat-roofed house surrounded with hard paved surfaces, wells became inoperable due to depleted groundwater levels and were replaced with municipal water connections. Since the late nineties, new materials and products introduced in the markets have further affected this previously sustainable lifestyle. Paper and handmade baskets have been replaced with thin plastic bags, leaf plates and stainless steel glasses with single-use plastic materials that are hard to recycle – ultimately increasing communities waste production.

◀ **Figure 2.11** *Water levels in rural communities before 1990*
Traditional housing and lifestyle typically seen in rural Andhra Pradesh.

03 River Corridor



In the past decade, the river has remained completely dry throughout the year due to controlled water releases into the river and channelizations at the dam. This led to ecological changes along the river and left the riverbed exposed to exploitation and pollution. Along settlement edges, the exposed riverbed is often treated as a waste dump; at agricultural fields, it became a resource mine. Despite "official regulations" prohibiting people from extracting resources from the dry riverbed, representatives of the government along with some residents continue to break the law.

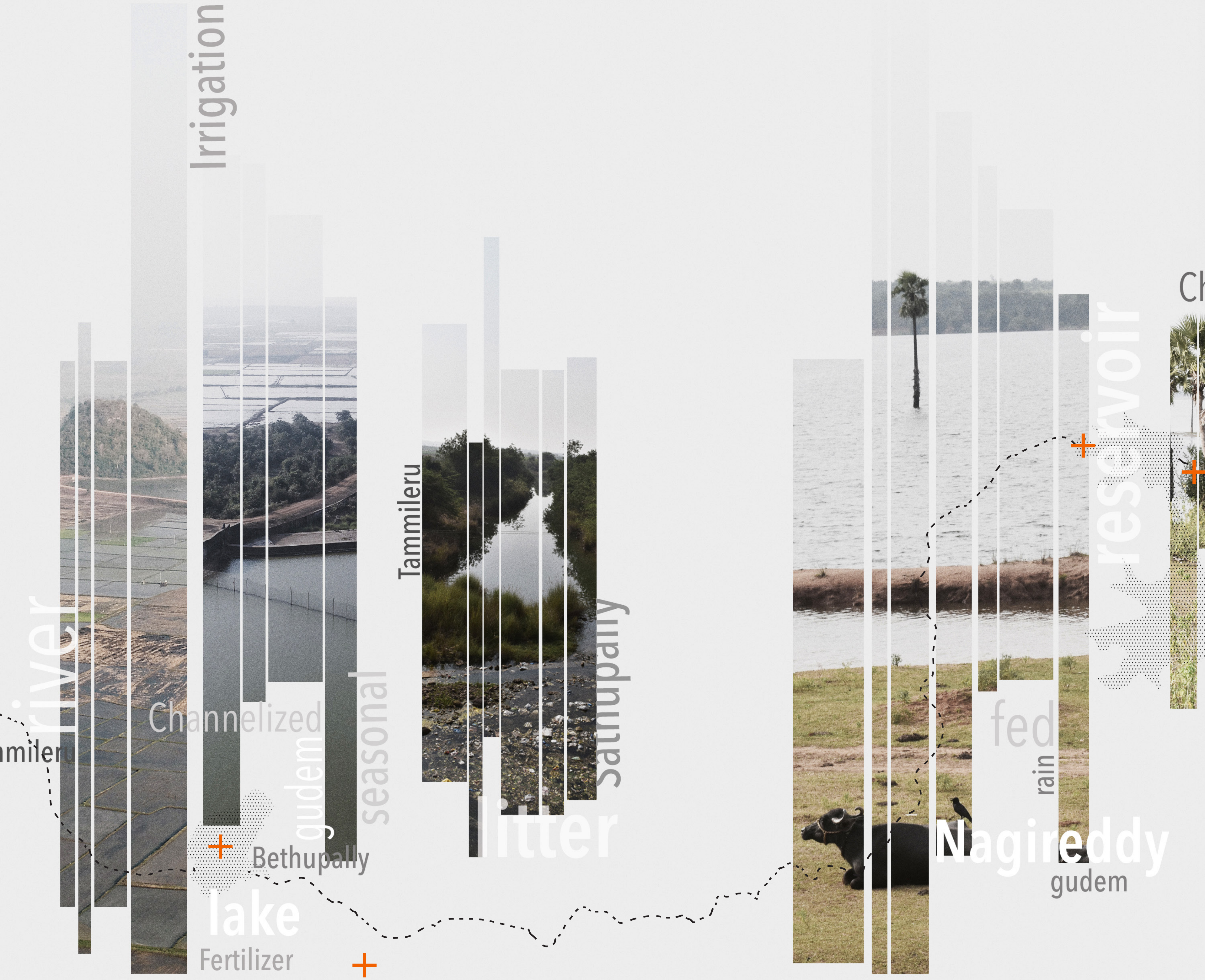
This sections gives a brief overview of how the river is being affected by adjacent settlements. As we travel downstream, the photocollage show a striking difference in the issues and the extent of river pollution.

▶ **Figure 3.0** *Villages visited along the river*

▶▶ **Figure 3.1** *Freshwater spring at Valasapalli*

Residents of Valasapalli collectively stood against the sand mining and protected the riverbed from exploitation. This is the only stretch between Mankollu and Eluru where mining is inactive. Despite having a municipal water supply, the inhabitants continue the traditional practice of acquiring drinking water from freshwater spring at the river.

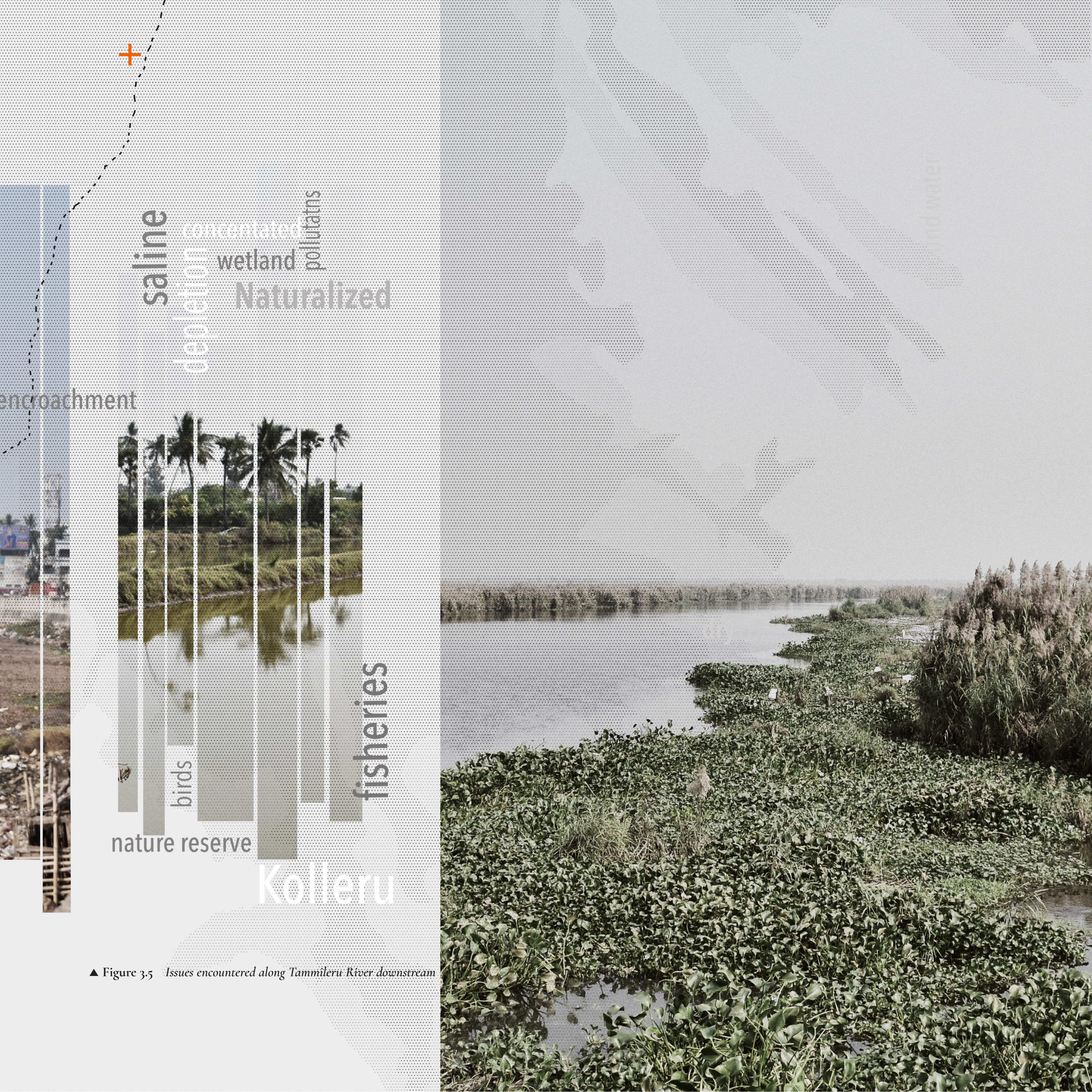
▲ **Figure 3.2** *Aerial view of Bethupalli lake and adjacent farmlands*


Irrigation
river
Channelized
gudem
seasonal
lake
Bethupally
Fertilizer
Tammileru
Satnupally
litter
reservoir
fed
rain
Nagireddy
gudem

◀ **Figure 3.3** *Issues encountered along Tammileru River upstream*

▲ **Figure 3.4** *Tammileru reservoir*
Water flow is terminated to increase storage capacities at the reservoir. Due to dry condition, plant growth can be seen all along the exposed river bed downstream of the reservoir.


high density
debris
open defecation
Tammileru
sarkar tumma
illicit
weed
Prosopis juliflora
sand
extration
litter
Vijayarai
sewage
untreated
fed
Eluru
Eichhornia crassipes

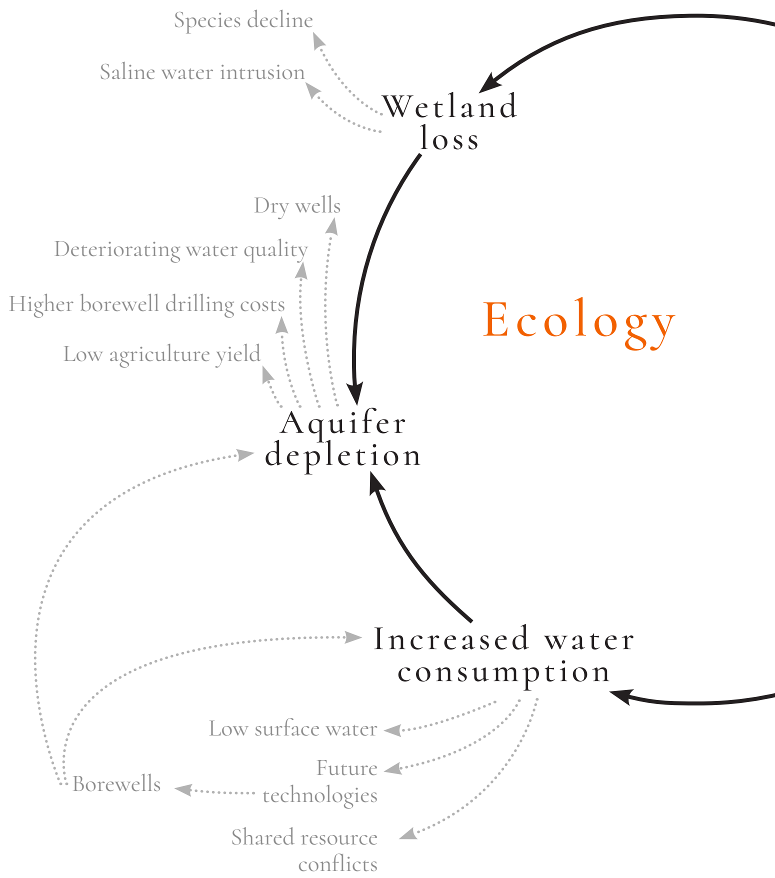


▲ Figure 3.5 *Issues encountered along Tammileru River downstream*

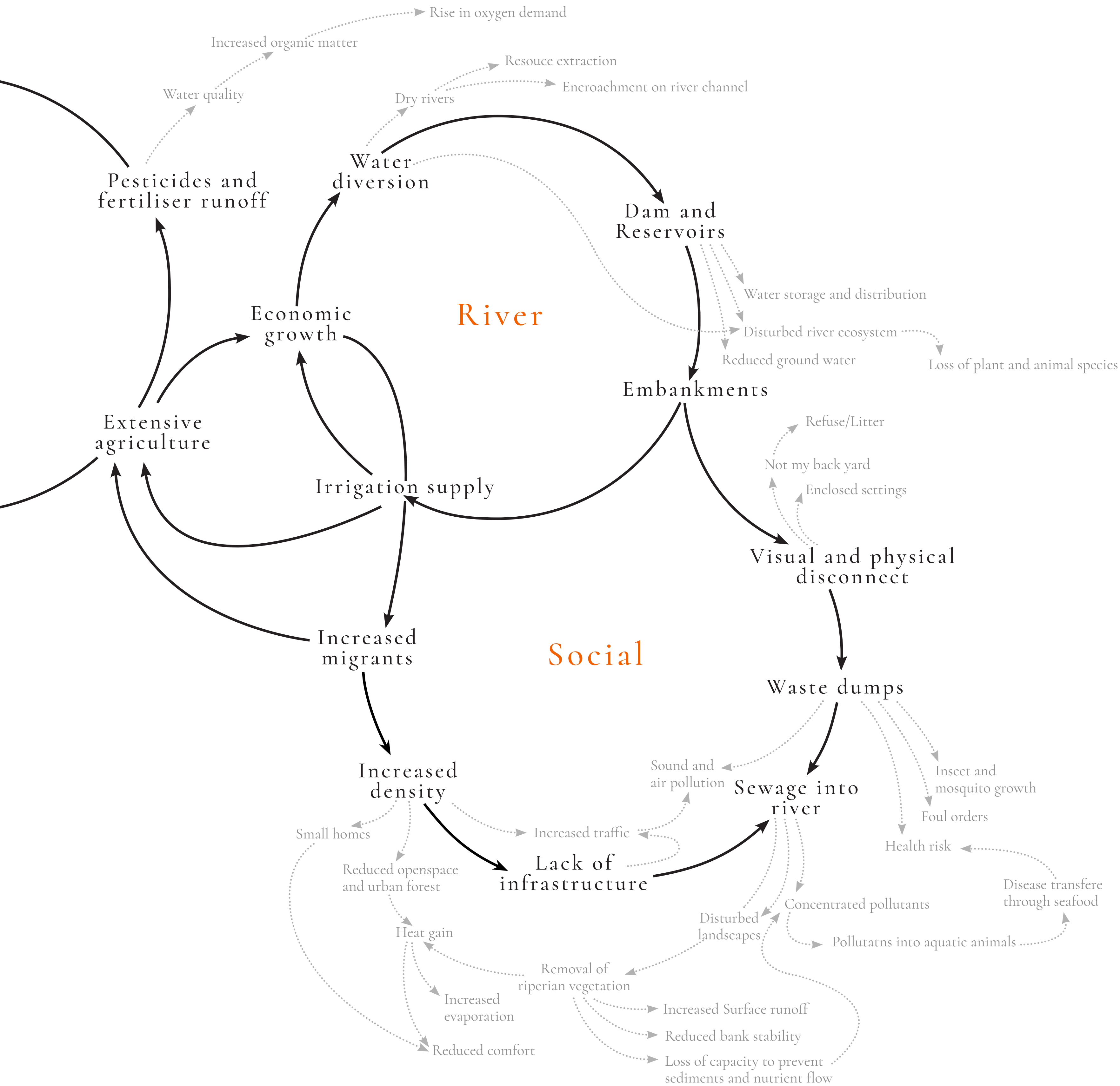
04 Regional study

The social and cultural practices combined with water ecosystems create a complex landscape that changes at every level due to individual interactions. Crop lands, small and large settlements on the river banks, along with growing water stress have changed the way people interacted with their surroundings over the past decade.

Once a respected resource and worshipped entity, water is now scarce. Over the years this has influenced how people see the landscape. With no water in the river for several years, the riverbed is perceived as a place of free resources and once the resources are exhausted, it became a wasteland. Aquifer depletion, contaminations of existing water resources, pollution and disconnection between people and their natural surroundings are among the major issues observed along the river. These conditions will be discussed in detail in this chapter at both regional and village levels.



▶ **Figure 4.0** *Major concerns along Tammileru River*



Rise in oxygen demand
Increased organic matter
Water quality
Resouce extraction
Encroachment on river channel
Dry rivers
Water diversion
Pesticides and fertiliser runoff
Dam and Reservoirs
Water storage and distribution
Disturbed river ecosystem
Loss of plant and animal species
Reduced ground water
River
Economic growth
Embankments
Extensive agriculture
Refuse/Litter
Not my back yard
Enclosed settings
Irrigation supply
Visual and physical disconnect
Increased migrants
Social
Waste dumps
Increased density
Sound and air pollution
Sewage into river
Insect and mosquito growth
Foul orders
Health risk
Small homes
Increased traffic
Lack of infrastructure
Reduced openspace and urban forest
Disease transfere through seafood
Concentrated pollutants
Disturbed landscapes
Heat gain
Pollutatns into aquatic animals
Removal of riperian vegetation
Increased evaporation
Increased Surface runoff
Reduced bank stability
Reduced comfort
Loss of capacity to prevent sediments and nutrient flow

Political barriers

Tammileru's headwaters are in Khammam district in Telangana state, while Bethupally Lake is the first place on the river where a large body of water can be seen. Over the years, an embankment has been built along the perimeter of the lake to increase water storage capacity to support irrigation. It thus becomes the first anicut on the river.

The anicut controls the water flow downstream and feeds into irrigation channels to several hectares of agricultural land in Telangana. Due to lake's limited capacity, water is released downstream during monsoon season and feeds into Tammileru reservoir in Andhra Pradesh.

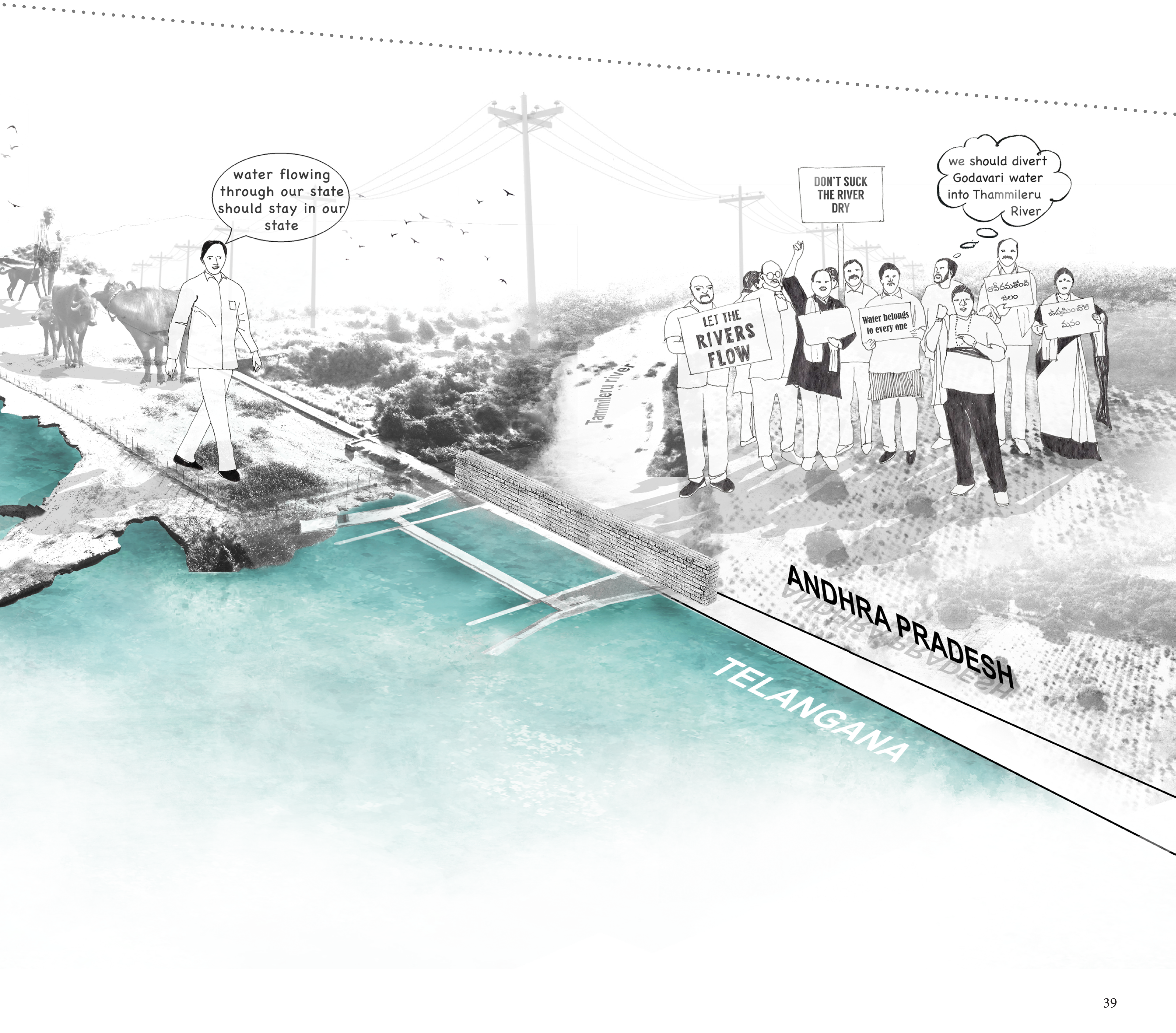
Spread across thirty-seven square kilometers, Tammileru reservoir was built in 1982 to store approximately 105 million cubic meters of water of which 33.9 million cubic meters of water is used for irrigation, and 42.4 million cubic meters for flood detention water (Maraka, 2017). Since the state division in 2009, Tammileru reservoir has never reached its full capacity, and the river downstream continues to remain dry throughout the year.

These conditions combined with the excessive extraction of groundwater, are major factors in the regio's water stress.

"My elders say that the river flourished for 100 years and never dried. This river [was] called "Jeevanadhi" which means perennial river till 1960. I lived in Vijayarai for over 60 years and experienced severe floods four times. Accessing the farms during this time was not possible, but the village was never flooded. However, both transportation and houses in Eluru, a town downstream, were severely affected by the floods." (Former resident of Vijayarai, age 82, 2017)

"Since the construction of Tammileru reservoir 160-200 square kilometers of land became highly productive. In my childhood, during sivaratri (Indian festival celebrated in March) we were terrified to cross the river due to high water levels. Now they pump water from wells to conduct the rituals during the festival. Recently till 2008, shallow spots where we cross the river had at least 500 millimeters deep water, these conditions changed since the state division." (Resident of Dharmajigudem, age 40, 2017)

▶ **Figure 4.1** *Water conflicts affecting downstream waterflow*


water flowing through our state should stay in our state
DON'T SUCK THE RIVER DRY
we should divert Godavari water into Thammileru River
LET THE RIVERS FLOW
Water belongs to every one
Tammileru river
ANDHRA PRADESH
TELANGANA

Exploited riverbed

For a long time, sand from the riverbed has been used by residents in the construction of houses in the villages adjacent to Tammileru River. When the river started to have prolonged dry periods, sand extraction turned into a significant business and sand was transported to other communities. As the demand for sand increased, illegal river sand mining boosted along the river. Though residents of Valsapalli collectively stood against mining activates and protected the riverbed, many villages between Mankollu and Eluru surrendered to political pressures and financial benefits.

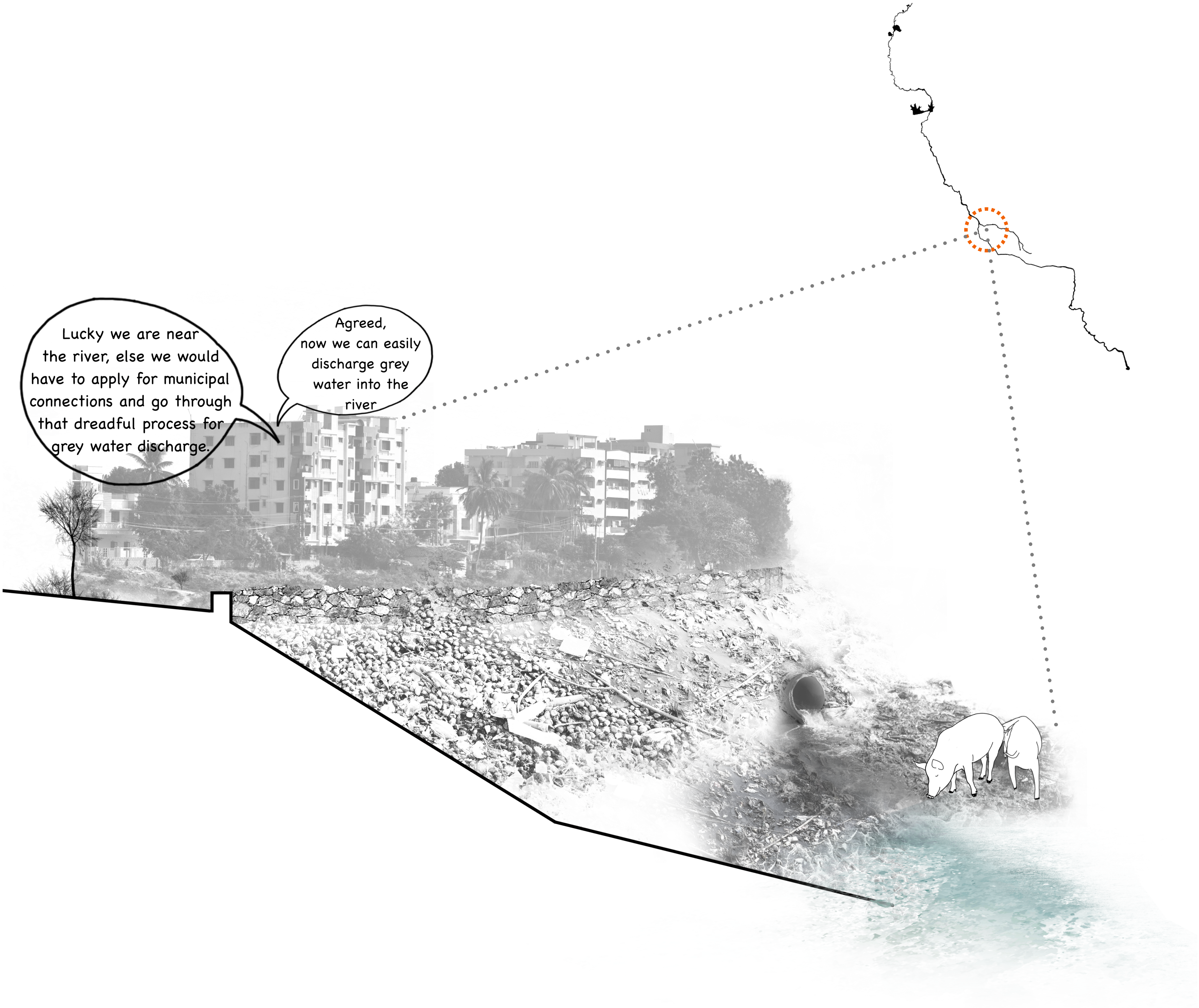
"People traveled from other places to spend time on the sandy shore of this river. Everything changed in the past ten years; there is neither water to swim nor sand in the river. Ten to fifteen feet (3-4 meters) of sand is extracted from the river in the past four years. We will soon see the ground. Sand mining is the main reason we do not have sufficient groundwater. Mining should stop to improve groundwater levels." (Resident of Vijayarai, age 47, 2017)

"As a kid, my friends and I spent a lot of time along the river, the fresh breeze was very refreshing, and the river felt like a beach. Groundwater levels reduced considerably in this region. We accessed water at 1.5 meters during my childhood, and now we have to drill over 15 meters. It is turning out to be very expensive. So farmers adjacent to the river dig wells on the riverbed where water can be easily accessed." (Resident of Venkatapuram, age 22, 2017)

▲ **Figure 4.2** *Activities on Tammileru River*
Current river activities and the conflicting perspectives.

With an inadequate supply of water for irrigation and advancing technology to extract groundwater, farmers adapted borewells for irrigation. With over 2500 wells sanctioned every year in each district (ESRI India, 2018), farmers enjoyed seemingly unlimited supply of water for years. However, over-exploitation of this limited resource affected the groundwater table in the region. This led the farmers to explore new water sources along the river.

Soon, wells were dug in the riverbed with several connections to supply water to farmlands. Once the water source is exhausted, the well is abandoned, and new wells are excavated. This over-extraction is not only depleting the aquifers at an alarming rate but sand mining pits pose a threat to people crossing the river during monsoon.



▲ **Figure 4.3** *Eluru towns refuse display*

▶ **Figure 4.4** *Waste discharge sources*

Density and pollution

The river bifurcates into east Tammileru and West Tammileru at Eluru. This densely populated town spreads over eleven square kilometres, on either side of Tammileru River with over 275 million inhabitants. Eluru is the largest urban area in the district and houses industries spread over one square kilometre across the town ((MSME, n.d.).

In Eluru, the river conditions are drastically different from other settlements. Houses built on the edge of the river bank discharge greywater into the river. Litter and organic waste from the market and small businesses are illegally dumped on the river banks, and untreated effluents from residential zones and industries, biological waste from markets, plastics and other solid waste are discharged into the river every day.

These effluents increase nitrogen concentration, promoting aquatic weed growth in the river. The municipal corporation, instead of addressing water pollution issues, focuses on beautification of the river banks and hope flood water will carry effluents downstream.

"Tammileru collects town's grey [possible black water], at Eluru. Here the river resembles a sewage system than a natural freshwater system." (Resident of Eluru, age 55)

Wetland

Kolleru freshwater lake/wetland is situated in the alluvial plains covering an area of 6121 square kilometres across Krishna and West Godavari districts(Azeez, et al., 2011, p. 16). The lake was a coastal lagoon around 6000 BP and now has receded 35km inland from the shoreline (p. 17). Five rivers, Tammileru, Yerrakaluva, Gunderu, Ramileru, and Budameru, along with several small drains, discharge into Kolleru. Maximum depth of the lake is ten meters and the average depth is between 0.5 to 2.0 meters; water levels vary between 1 to 1.5m throughout the year and can increase up to 5m during floods. Though the lake is mostly freshwater, seasonally, brackish water enters the lake along the coast due to low water levels. The lake offers excellent bird habitats and several species of migratory birds come every year. In 1999, the 308 square kilometres of the lake falling below the one-and-a-half-meter contour in Kolleru Lake was designated as a wildlife sanctuary and noted to be a vital birding area (p. 72). In 2002, the entire Kolleru lake was designated as Ramsar site (p. 89). Ramsar provides a framework for action plans for protection, conservation, and wise used of wetlands through an intergovernmental treaty (Ramsar; Corp 13, 2014). 148 rural settlements are spread across Kolleru lake, 50 settlements on the primary lake area, including 66875 households in the designated sanctuary zone (p. 20). Aquaculture, agriculture and duckery are the primary occupations. Over the years, agriculture lands have been converted into fisheries.

Throughout the 1980's, aquaculture in Kolleru developed extensively and spread across the lake. Between 1999 and 2001, fisheries production increased by 24% in West Godavari district and 56% in Krishna. In 2006, it was estimated that the annual income of fisheries was INR 200 crores (CAD 375,460,000). This attracted large investors to Kolleru and increased livelihood opportunities for the residents (p. 24). Over 85% of wetlands have been converted into aquaculture farms (Prasad, et al., 2017).

Water pollutants from Tammileru and other upstream rivers, paper, sugar, milk, distillery, pulp and chemical industrial discharge into the lake. Eluru municipality alone discharges twenty-four million litres of untreated sewage every day (Azeez, et al., 2011, p. 56). Organic-rich wastes affect the water quality of the lake leading to bacterial contamination, fish kills and increase waterborne diseases that affect the residents (p. 54).

Changes since the early 1900s have had significant effects on the lake's ecosystem. Extensive development of large-scale fisheries, unrestricted use of fertilizers, increasing chlorine levels, effluent discharge from upstream rivers into the lake have threatened the protected habitats, and humans socio-economic, health and political conditions. Data collected by the Andhra Pradesh state pollution control board between 2002 and 2009 indicated that the lake is contaminated with the bio-degradable organic matter, and high amounts of phosphate, chloride, nitrogenous fertilizers and sewage (p. 32).

* "Ramsar conservation is an intergovernmental treaty that provides the framework for conservation and wise use of wetlands and their resources." (Ramsar, 2018)

> *"Government sanctioned lands for aquaculture in 1976, ever since, our livelihoods have been dependent on fisheries. This part of the lake is now recognized as protected site. We are solely dependent on fishing and have nowhere else to go" (Group of residents from Kolletikota, 2017)*

▶ **Figure 4.5** *Livelihood and conservation conflicts, Kolleru*
The Kolleru protected zone status has several restrictions on conventional fishing practices as they are harmful to the habitats. Land use changes are also discouraged so, fisherman are threatened by the rules imposed on them and are in constant conflict with conservation practices.

"I am a fisherman and my family lived here for generations. Twenty years ago, water levels were over two and a half meters here, now its reduced by half, resulting in sea water entering the fisheries. Additionally, pollutants from five upstream rivers flow into Kolleru. Native fish species are lost due to a high concentration of pollution and sea water; we now import larvae from other places. These changing conditions are incurring financial losses resulting in people migrating to cities in pursuit of a better life." (Resident of Kolletikota, age 60, 2017)

Water quality

Tammileru River is a valuable resource for human and wildlife. From its headwater to mouth, the river passes through several urban and rural environments and has been drastically affected by the changes over the past few decades. Tammileru River is now mostly dry but has rainwater stagnated between the village and anicut at Vijayarai, and a few tributaries feed into the river at Eluru. From the site study, it can be noted that these two places are primary contamination sources to the river before it flows into Kolleru lake. At Vallasapalli, villages prefer to drink from a freshwater spring on the riverbed, which may be contaminated by agricultural runoff during monsoon season.

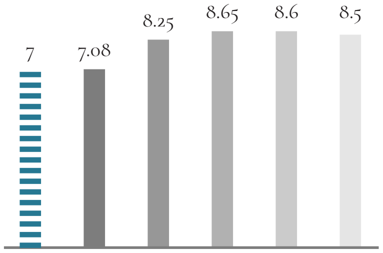
Water samples were collected at five sites – Vallasapalli freshwater spring, Vijayarai village, Vijayara anicut, at Eluru town north entrance and Eluru marker area (Figure 4.8) to test the water for its purity, and determine whether or not the water supports aquatic life. Water parameters such as pH, electrical conductivity (EC), dissolved oxygen (DO), biological oxygen demand (BOD), total dissolved solids (TDS) and chlorides are considered in this test. The results are then compared with drinking water and river water standards.

Results (pg 46-47) indicate that water from the springs at Vallasapalli is marginally above drinking water standards. At Vijayarai and Eluru sites, electronic conductivity levels exceed over 10,000 µs - levels that make water umsuitable for human, livestock or irrigation needs (MRCCC, n.d.). Dissolved oxygen levels are above the minimum level which indicates that fish and other invertebrates can survive (Fondriest Environmental, Inc, 2013). Biological oxygen demand levels are over nine parts per million, water exceeding this level is considered somewhat polluted due to the presence of organic matter (CIESE, n.d.). Total dissolved solids indicate that water is from a freshwater source (Fondriest Environmental, Inc, 2014). Chloride levels at Vijayarai village and Eluru market area are over the maximum range indicating that the water is not suitable for aquatic life (WHO, 2003).

◀ **Figure 4.6** *Fresh water springs on riverbed*
Typical countryside activities up to the 1990's are illustrated. Although this is a rare sight in 2018, residents of Vallasapalli follow the tradition of drinking water from freshwater springs.

Water quality tests

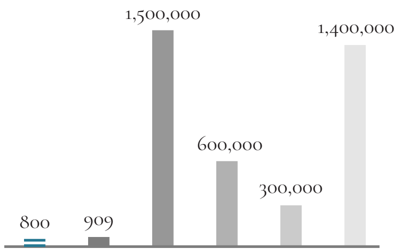
Drinking water standards



pH

pH is a measure of acidity and alkalinity of water. Drinking water should have a neutral pH. Water pH between 6.5-9 is suitable for aquatic life, values outside this range affect growth and productivity. Contaminants from external sources affect pH which intern increases aquatic plant growth (Fondriest Environmental, Inc, 2013).

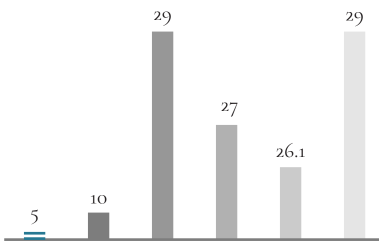
Valasapalli drinking water pond 0 0.1km



Electrical conductivity (µs/cm)

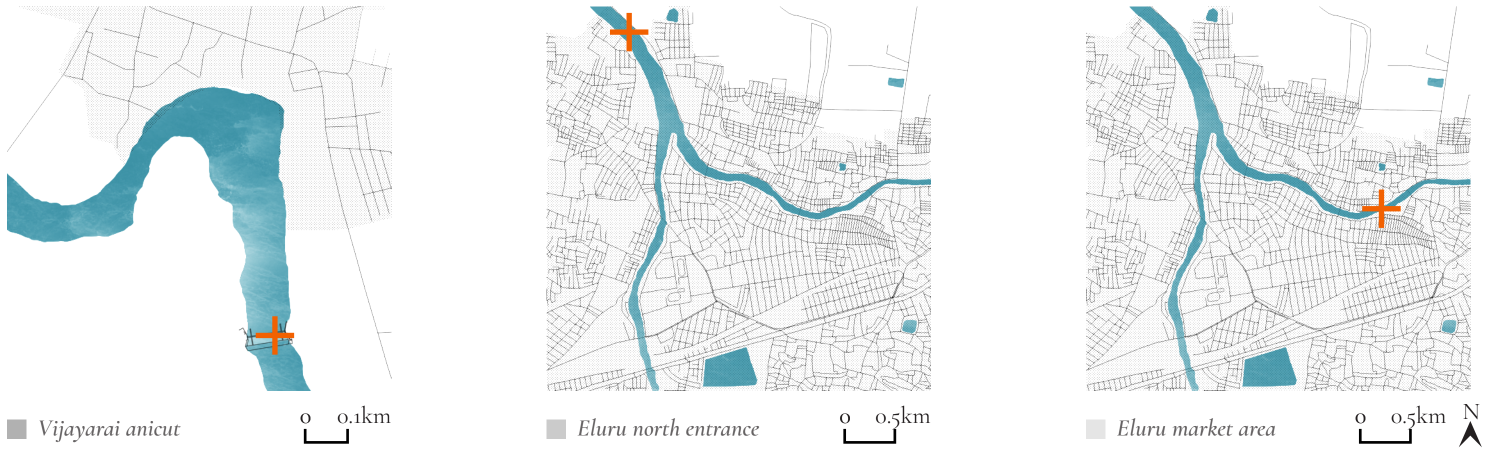
EC is a measure of liquid capacity to conduct electric charge and indicates water salinity levels. EC in freshwater is between 0-1500 µs/cm and should be between 0-800 µs/cm for drinking water. EC over 10,000 µs/cm is not suitable for consumption or irrigation (MRCCC, n.d.).

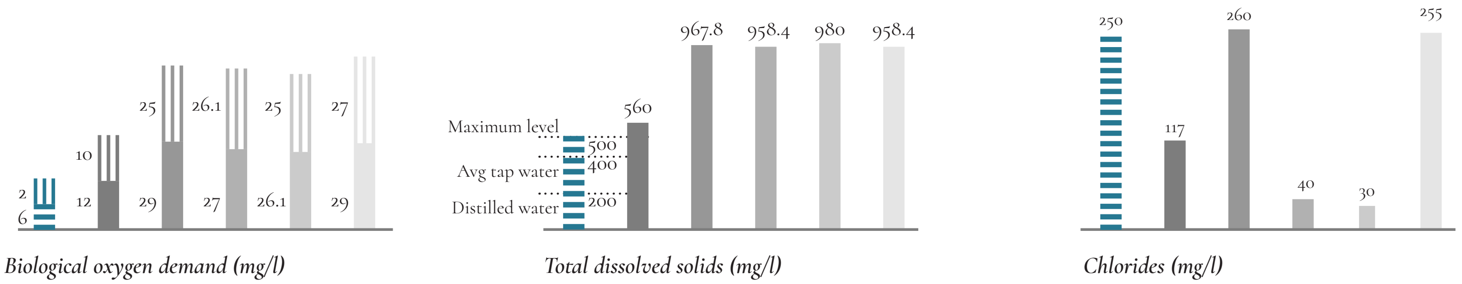
Vijayarai village area 0 0.1km



Dissolved Oxygen (mg/l)

DO influences organisms living in a water body and can have adverse effects on aquatic life if the levels are too high or too low. Organisms such as crabs, worms and bottom feeders can survive with minimum amount of oxygen (1-6 mg/l), however, a minimum of 5 mg/l is required for the survival of fish (Fondriest Environmental, Inc, 2013).





BOD is a measure of oxygen used by microorganisms to decompose organic matter or waste in water. Higher BOD levels indicate presence of more bacteria, which increases demand for DO. BOD levels of 6-9 mg/l are considered slightly polluted and levels over 100 mg/l is considered highly polluted with organic waste (CIESE, n.d.).

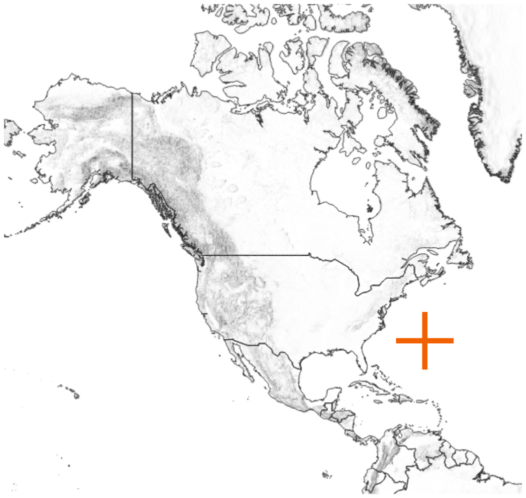
TDS is the sum of all ion particles that are smaller than 2 microns. TDS helps maintain cell density balance in aquatic life. In freshwater TDS can go upto 2000 mg/l however, it reduces fish productivity when the values range over 2200-3500 mg/l. TDS should be below 500 mg/l for drinking purposes (Fondriest Environmental, Inc, 2014).

Natural sources and external sources such as industrial discharge, sewage, urban and agricultural runoff are sources of chlorides in water. Health based guidelines suggest that concentration of chlorides should not exceed over 250 mg/l in drinking water. Higher concentration of chlorides in freshwater is not suitable for aquatic life (WHO, 2003).

Figure 4.7 *Test site locations*
Figure 4.8 *Water quality results*

05 Precedents

Water management and planning are the core issue along Tammileru River. Along with inputs from residents, design strategies, planning and practices from these selected studies have been influential in this practicum. Issues identified along Tammileru River are unique to their Indian context, and successful research projects related to these specific issues were not found. The selected case studies however different they may seem, do present successful strategies that help mitigating water management issues and helped inspire design approaches in this practicum.



Isle of Bermuda

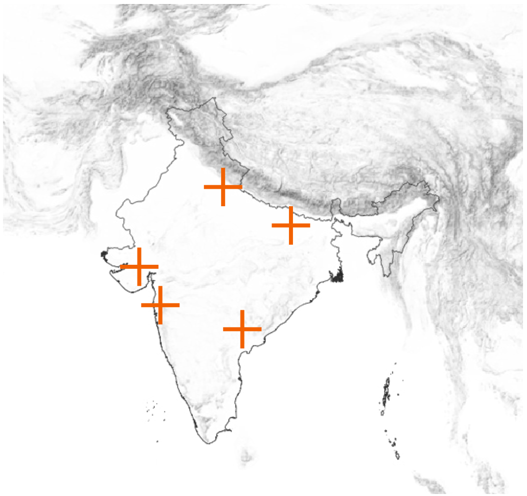
Location : North Atlantic Ocean
Type : Water harvesting
Area : 53.2 sq.km
Population : approx. 65,000

The Isle of Bermuda depends on the weather for water and is well known for its traditional water harvesting techniques. These strategies are unusual in their widespread local adoption.

Bermuda has no freshwater resources nor does it have easy access to groundwater, so, rainwater is the primary source of drinking water (Smith, et al., 2017, p. 8). Early colonizers adapted indigenous materials in their buildings to capture rainwater. With the local limestone, vernacular buildings were designed to slow down rainwater runoff from roofs and terraces. Water is directed from rooftops into furrows that channel it into underground storage tanks (Institute for International Urban Development, n.d.). This process caters to 50%-70% of freshwater used in households per year which is approximately 30 gallons per day (Glennie-Holmes, 2017).

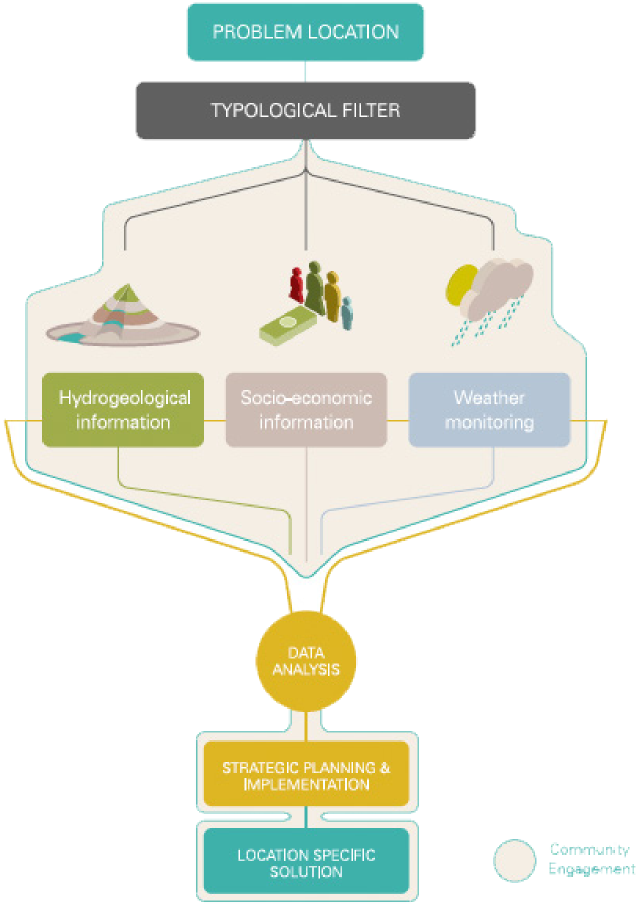
This practice has evolved over 350 years. It is mandatory for any construction ever since to convert 80% of the roof into a catchment area or must have catchment area on the ground for the same capacity to storage at least 400 liters for every 10 square feet of the catchment area (Smith, et al., 2017, p. 8). This process can be adopted in areas where annual rainfall exceeds 400mm/year (2017).

▶ **Figure 5.0** *Hamilton, Bermuda.*
▲ **Figure 5.1** *Traditional roof (Elbow Beach Cycles, 2016)*
Terraced roofs to slow down the water flow, and capture and direct water into underground storage tanks.



Participatory approach, India

Location : Bihar, Maharashtra, Gujarat, Telangana
Type : Educational and groundwater management
Area : approx. 8000 sq.m and above
Population : 2 or more



Since the green revolution in 1970, drilling technologies are introduced and widely adopted in India for agricultural, industrial and domestic needs (Arghyam, 2015). However, over-extraction of the water has exhausted aquifers in several regions across India. Arghyam and partner NGOs across the country in collaboration with the Advanced Center for Watershed Resources Development and Management, Arid Communities and Technologies, Peoples Science Institute, Watershed Support Services and Activities Network, and Megh Pyne Abhiyan built a sustainable model for groundwater management that focuses on scientific understanding of available resource, building capacities of local farmers and defining usage priorities (2015).

Participatory groundwater management (PGWM) program works on location-specific issues by adopting a three process approach - Action research, Capacity building and Advocacy (2015) . Action research allows the team to investigate target issue and derive at a solution that caters to socio-economic needs. Capacity building engages community and collaborators in discussing the issue and builds knowledge on both scientific and vernacular approaches. Farmers are then trained and educated about the fundamental hydrological condition of the area for best utilization of groundwater for drinking, household and agricultural purposes (2015). This approach to problem-solving is applied to resolve water-related problems at several locations across India.

▼ **Figure 5.2** *Project locations across India.*

▲ **Figure 5.3** *Participatory ground water management on the ground: the action research (Arghyam, 2015)*

[Guidelines]

In Himachal Pradesh; Luhali, Dhyali, Sattar-Bhadon, Thanakasoga and Dandor villages are faced with water shortage, bacterial and chemical contamination issues. A survey conducted to identify the source of contamination revealed an aquifer shared by all five communities in the valley. With the aid of PGWM, Water Management Committee and Water User Groups (WUG), social regulations were put together delegating villagers responsibility for cleaning, recharging and protecting the aquifer commonly shared by the villages. Over the course of the intervention, groundwater recharge works by PGWM improved the discharge levels of the springs and the bacterial and chemical contaminations decreased (2015, p. 14).

[Strategy]

In Telangana, farmers dependent on groundwater resources are suffering from reduced aquifer levels and struggling to pay expensive loans for drilling deeper borewells. Through the drought shield program, PGWM conducted an experiment on lands of five farmers within a watershed. With a concept of borewell pooling, farmers with borewells shared water with farmer without borewells by establishing a pipeline network to reduce evaporation and water seepage. This system efficiently distributed water between the farmland, conserved available water resource and reduced financial burdens benefited farmers with and without borewells (2015, p. 16).

[Educational]

In Gujarat, PGWM focused on capacity building and educating locals in the hydrological process in three years. People from government, local youth, staff from local non-government organization and decision making officials are chosen and trained on how to make groundwater and aquifer maps, decision-making processes, considerations for works on groundwater management. This training process educated the over 1800 people and helped them to make informed decisions concerning water management in the region (2015, p. 15).

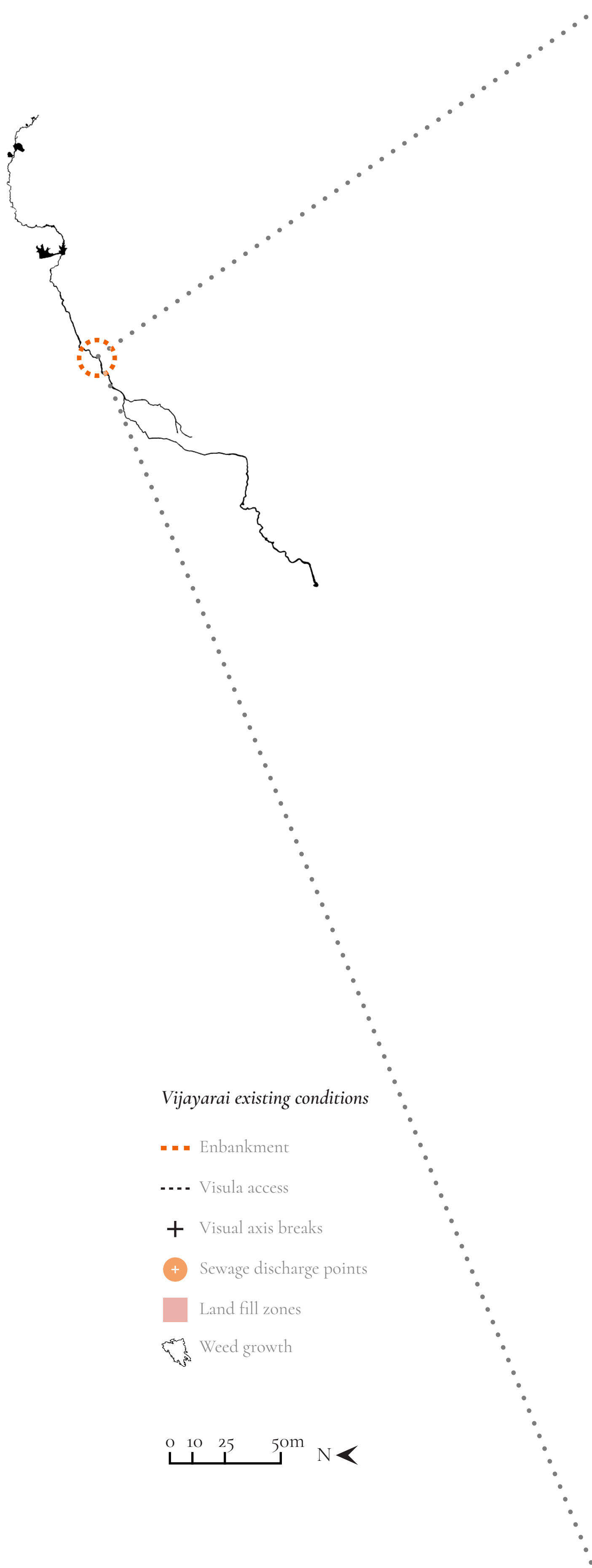
Each strategy and problem-solving approach employed by PGWM and water conservation policy in the Island of Bermuda, prove that with proper training and establishing appropriate plan and guidelines, water conservation and water quality can be improved by encouraging and involving people to protect and replenish the water resources within their neighbourhood. A similar approach could potentially help, localities along Tammileru River to conserve water and improve the water quality of the river.

06 Site Analysis

Vijayarai detail study

Vijayarai is a small village along the river where I spent most of my childhood summers. The community is spread across one square kilometer on the east side of the river bank with farmlands surrounding the community and the river. When I was growing up, the river was the heart of the village; people used it for entertainment, sports, and farming and the fresh water springs on the sand banks were the primary source of drinking water.

In 2000, an anicut (a small dam to control water flow) was built on the river downstream, at the end of the village. Subsequently, an embankment was constructed along the village edge to improve water storage capacity at the anicut. This, along with changing water flow patterns from upstream reservoirs led to several ecological changes along the river and changed the way people used it.



▶ **Figure 6.0** *Current state of Vijayarai settlement in relation to the river*


Settlement
Tammileru river
Farmlands
Anicut


Embankment
Line of sight

Connectvity

The embankment along the river provided a single access point northeast of the village and blocked all existing entry points from the streets. The five meter high embankment visually disconnected the village, river and the farms. Physical barriers forced people to take a longer router to the river, making it harder for users to carry water pots for longer durations. The barriers, steadily affected traditional river edge activities and discouraged people from accessing the river.

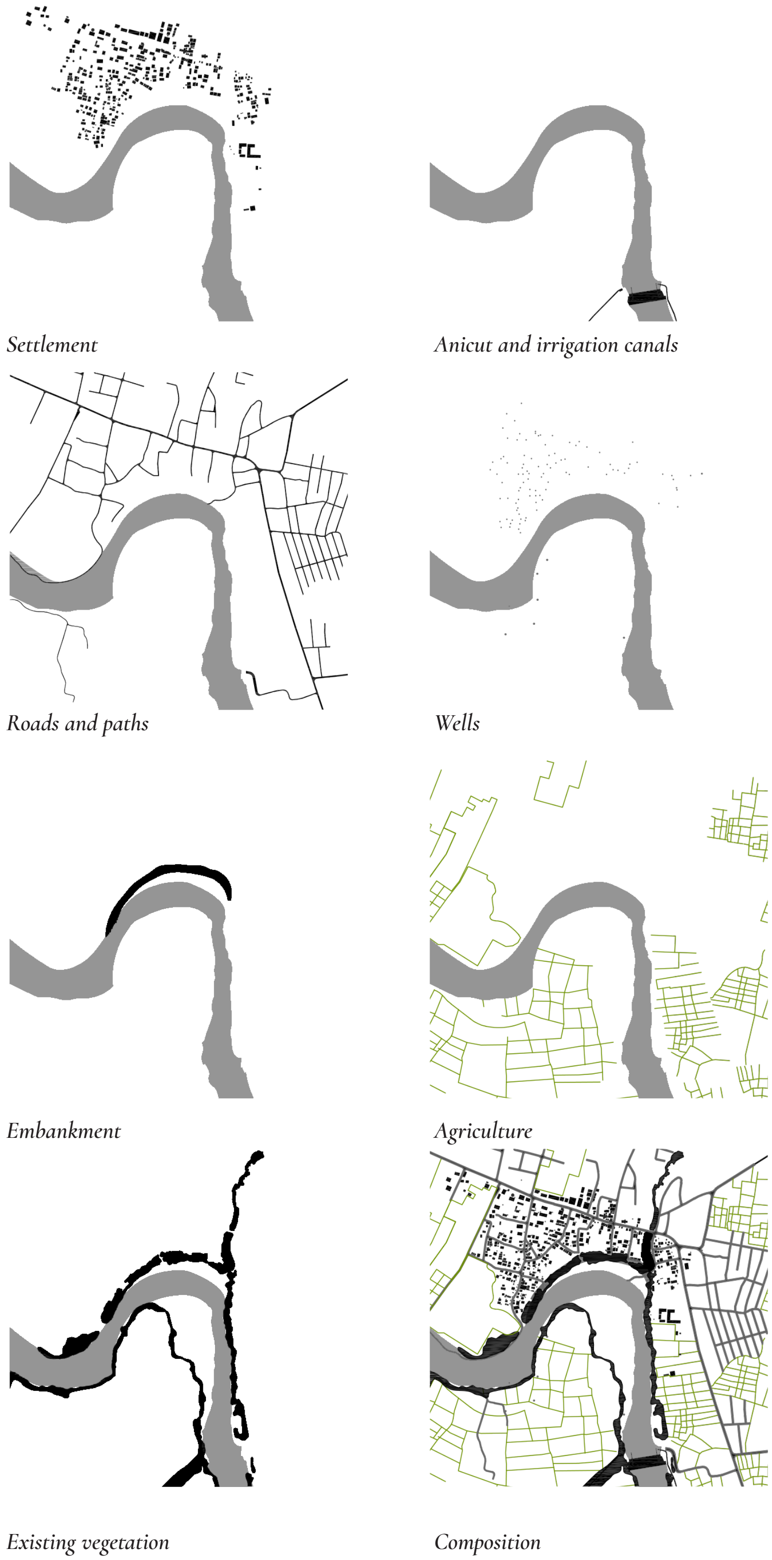
This physical and visual cessations, created a dead zone that cannot be accessed or seen easily. The community repurposed this dead zone into a wasteland which ultimately transformed the quality of the river ecology and the riparian edge.

◀ **Figure 6.1** *Vijayarai Anicut and river downstream*

The river has suffered from low water levels due to upstream water control systems and over extraction of available resources for irrigation. At this village, the river has been dry most of the year for the past five years with large water puddles formed from the rains at the deeper zones. The shallow stagnated water has become breeding grounds for bacteria, and mosquitoes.

In addition to this, the natural terrain of the village slopes towards the river, allowing unmonitored greywater for river-edge houses to drain into the river. The existing drainage infrastructure also follows the natural terrain of the land and slopes towards the river. The narrow swale like drainage system installed along a few streets collects greywater from the residences which is directed into a larger drain pipes with outfalls into the river.

Open defecation on the riverbed, refuse dumps from the village, unfiltered greywater from the rivers, and over extraction of ground water has left the village with polluted surface water and aquifers that are at high risk.

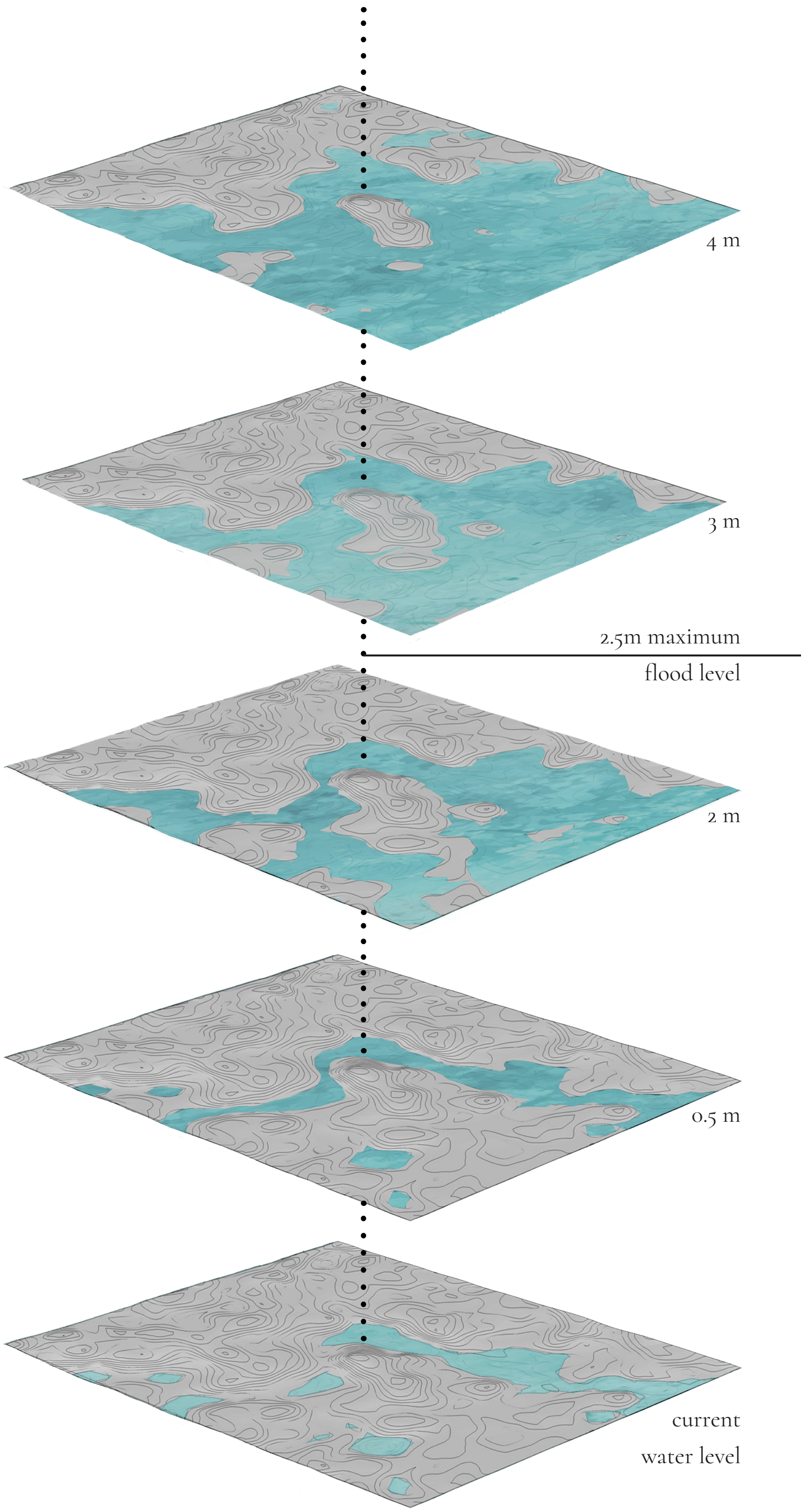


▶ **Figure 6.2** *Vijayarai village settlement in relation to the river*

▶▶ **Figure 6.3** *Progressively declining river edge conditions at Vijayarai*





Water flow analysis

The high embankment creating a physical and visual barrier has been identified a primary cause of behavioural changes in the community and its perceptions of the river. Despite the initial attempts to increase the water storage capacity of the anicut, the embankment has never served its intended purpose due to controlled and reduced water flow from upstream reservoirs. The anicut is not well maintained by the government has failed in its original purpose and is now used by the residents as a swimming pool.

Taking a step back, I would like to understand the water flow patterns at Vijayarai, to determine whether an embankment is required and if so, the appropriate height for this levee that serves the community and the anicut.

Based on the flood analysis study done using Geographic Information System, Global Mapper and Rhinoceros programs, it can be inferred that agricultural lands are most primary affected by raised water levels; they have minimal effect on the community. This clearly shows a potential to reduce the embankments height.

The water flow graphics are generated based on the high and low terrain points and indicate surface runoff patterns. The study indicates two major types of flow patterns; one drains directly into the river and the other into the stream that eventually flows into the river. A similar pattern is expected for grey water runoffs from houses. Places, where water flow is interrupted by the embankment, are identified as a potential site for constructed wetlands, where greywater and surface runoff can be filtered before releasing it into the river.

Legend

Contours 1m interval — Water flow papperns

Flooding pattern — River profile, stream, embankment and anicut

◀ **Figure 6.4** *Flooding pattern prior to the construction of embankment*

▶ **Figure 6.5** *Water movement at Vijayarai*

Vegetation characteristics

Azadirachta indica
Neem tree
Vepa chettu

Borassus flabellifer
Asian palmyra palm
Tati munja

Ficus racemosa
Indian fig tree

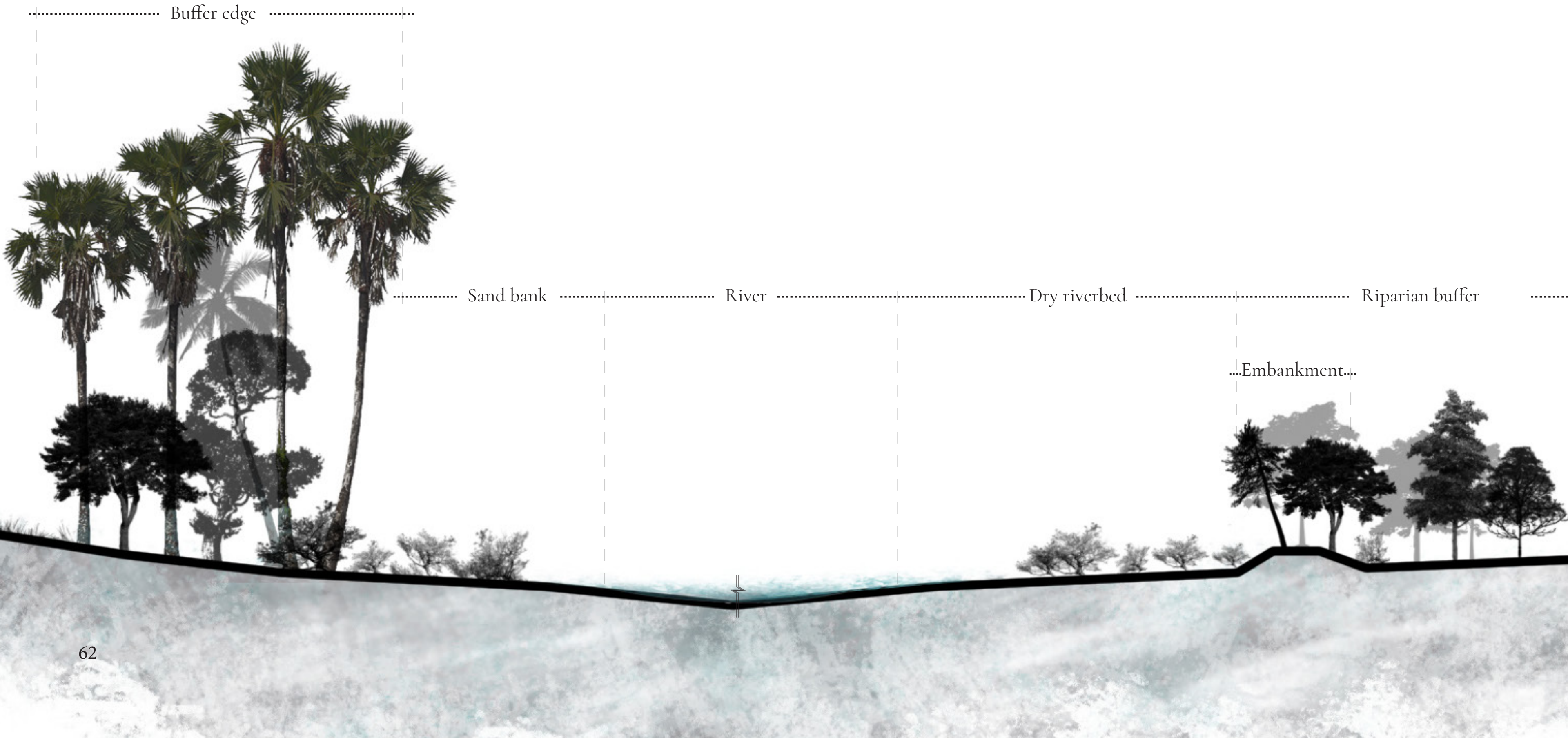
Phoenix sylvestris
Wild date palm
Eetha chettu

Pithecellobium dulce
Madras thorn
Seema chintachettu

Prosopis juliflora
Sarkar tumma
Tumma chettu

Syzygium cumini
Jamun tree
Neredu chettu

Terminalia arjuna
Arjuna tree
Thella maddi



Due to dry conditions of the river and sand mining, the subsurface soil layer are exposed at several location on the river bed, encouraged plant growth in the river. *Prosopis juliflora* (Tumma chettu), an invasive weed commonly seen in the degraded habitats, occupied the river banks. This shrub like species, is well adapted to wet and dry conditions and can rapidly colonize where moisture is available, out-compete other vegetation (Naudiyal & Schmerbeck, 2016). As the plant infringes on the riparian buffers, growth of the native species declined and species gradually disappeared affecting both biodiversity along the river (Pasiecznik, 2017). *Prosopis* species are known to effect soil water and reduce water table (2017). This species should be eradicated from the riverbed.

Summary

Vijayarai faces several ecological issues simply because of the indifference people have developed towards their surroundings since the construction of the high mound. Each problem is interlinked with the other to create a larger situation that cannot be ignored any longer. To be able to sustain the river and its life, people should change their practices and take control of the quality of life by improving the surroundings.

Once we understand the issues faced by the Vijayarai neighbourhood, the next step is to explore design strategies to that will work well in the context of this village. Aiming to address significant issues affecting both community and river, the design focuses on controlling water pollution and connecting people with the surroundings and at the same time engage the community to resolve issues related to weed growth and landfills.

▼ **Figure 6.6** *Existing riparian plant species*

◀◀ **Figure 6.7** *Plant characteristics along the riparian edge*

◀ **Figure 6.8** *Extent of native and invasive species*

07

Proposal

Central to the concept is to re-establish connections between the river and the community and enhance the river ecosystem by engaging the community as stewards of the land. Addressing the issues identified in the site analysis, the design focuses on improving water quality by reducing pollutants entering the river, re-establishing river access, improving native vegetation in the riparian edge and educating the community about simple sustainable ideas that could be incorporated in the day to day activities.

The overall goal is to improve the water quality of the river as it travels downstream along the settlements. Ideally, the design will set a precedent for other places facing similar issues, as well as help improve river conditions, water levels and create more diverse and resilient ecological river edges.

Based on the analysis of the riverfront at Vijayarai, the design will be executed at several phases. The community will be engaged in activities such as clearing riverbed landfill areas, removing invasive species and creating and constructing a native plant nursery throughout the construction phase. The objective is to engage the community in activities that will encourage them to care for their surroundings and strengthen their relationship with the land.

▶ **Figure 7.0** *Dry riverbed, Vijayarai*

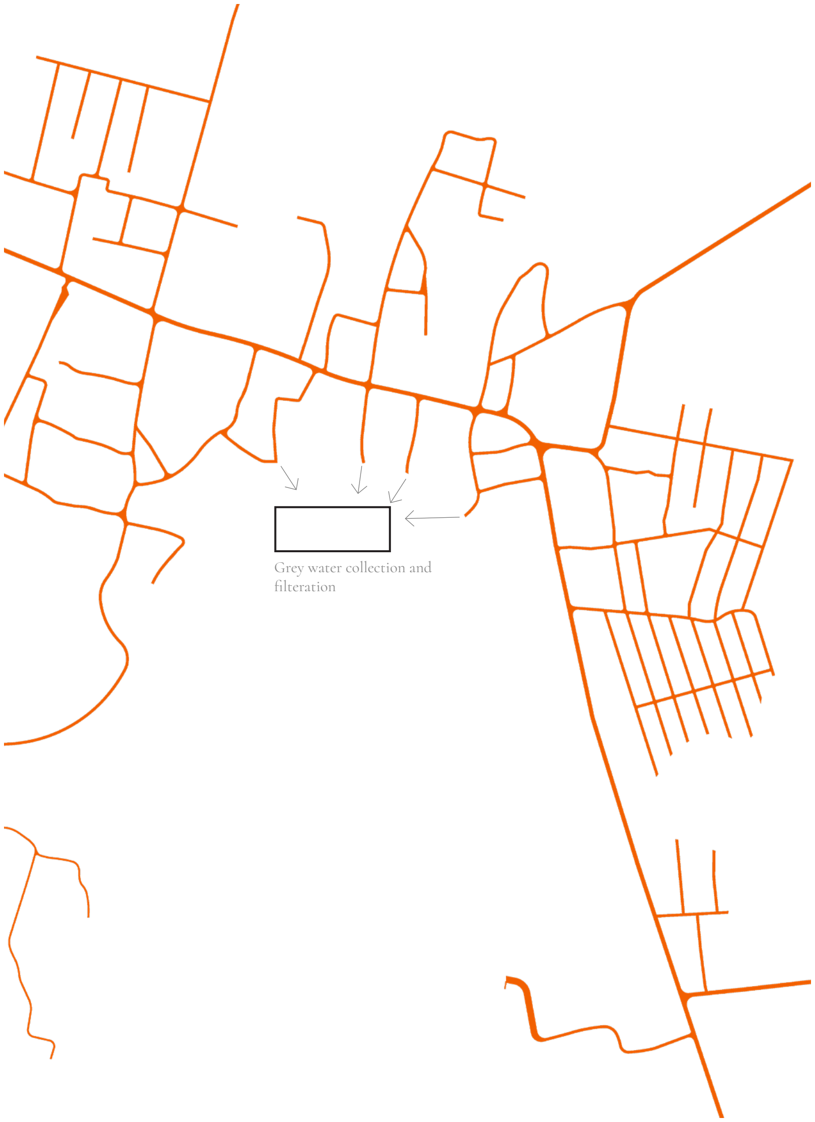
Phase 1

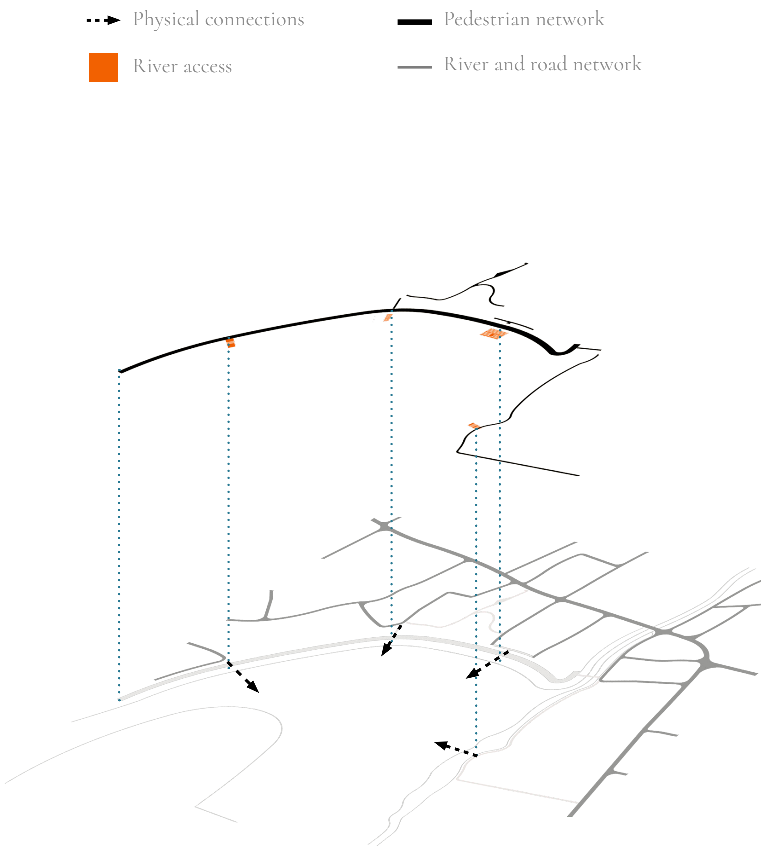
The first phase is focused on engaging the community to clear landfill along the river and improving the village's waste collection network. Clearly marked waste collection points on the streets would encourage people to properly dispose of waste. Refuse from individual units would be transferred to the treatment facility located northwest corner of the village, to be sorted and properly disposed.

▲ **Figure 7.1** *Water collection infrastructure development*
▼ **Figure 7.2** *Extend of invasive species along the riverbed*

Phase 2

Studies show that Prosopis species are hard to eradicate. However, it is imperative to control the growth of this species as it depletes groundwater resources. In moist conditions, a combination of mechanical and chemical treatments can be used to effectively control its spread. Mechanical clearing involves, uprooting the tree to sever roots below ground in areas that are neither too wet or too dry (Pasiecznik, et al., 2001). Ammonium sulfamate chemical treatment and fire can be used in other zones every five years to eradicate Prosopis species from the river (2001, p. 125).





Phase 3

Drainage infrastructure should be improved to control greywater surface runoff that flows into the river. This can be achieved by adding closed drainage along existing roads so that greywater can be effectively directed to a central location where it can be filtered before entering the river.

▲ **Figure 7.3** *Grey water infrastructure network*

Phase 4

Phase 4 focuses on re-establishing connections between the river and community by creating access points along the embankment. River access points are spaced across the levee to maintain five minute walking commutes between entry points. This connects with the pedestrian network linking the main street, and so people are drawn to the river edge.

▲ **Figure 7.4** *Proposed pedestrian network*


Temple
1
2
3
4
5
6
7
8
9
10
11

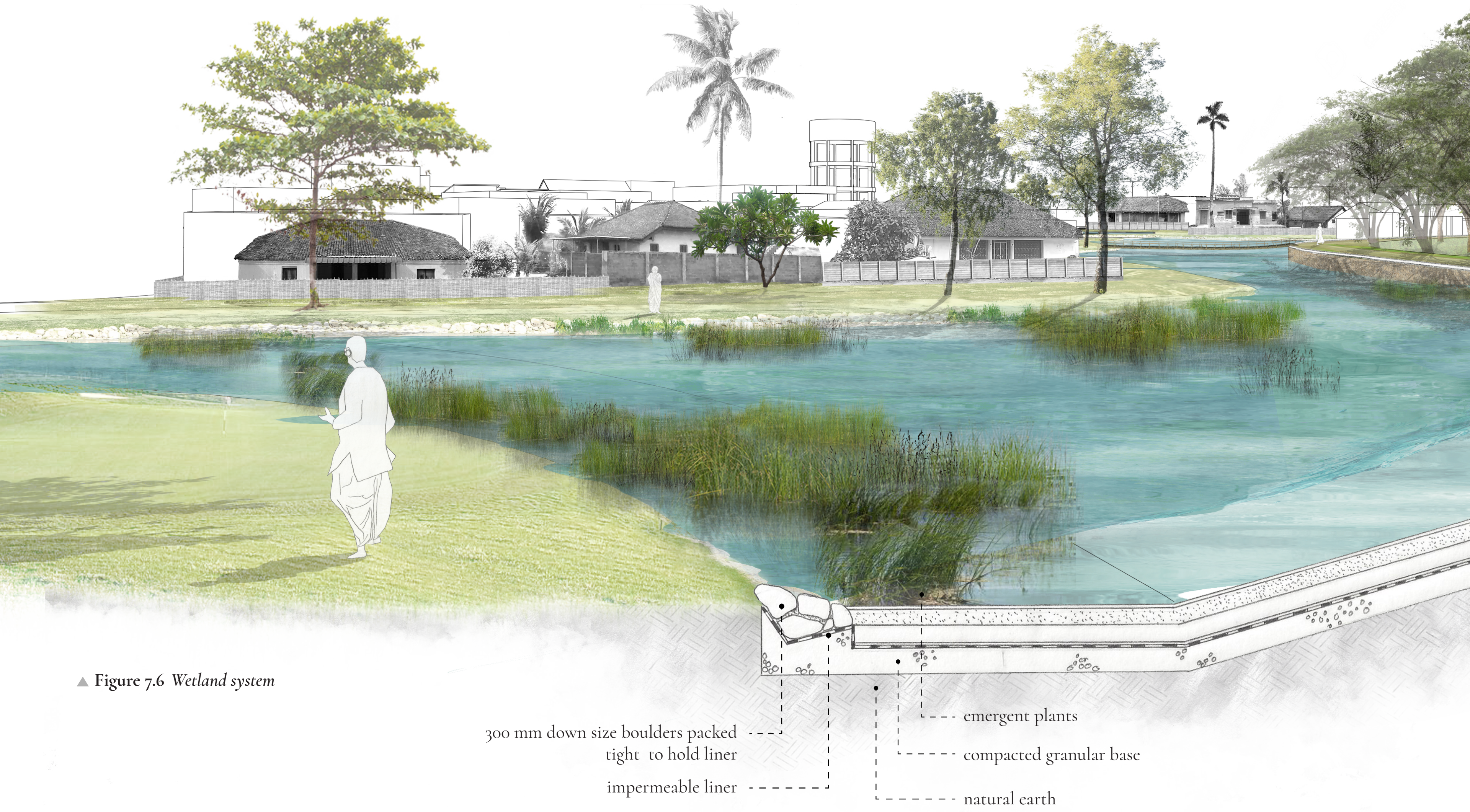
Design

The proposal envisions an ecological edge that offers recreational opportunities for the neighbourhood and bringing life to an otherwise disturbed landscape. Through design, the project aims to initiate a dialogue between the people and the natural surroundings by engaging them in solving environmental issues. The pedestrian networks and riparian buffer draw people towards the river edges from the busy main street. The pathways and decks through the wetland allow people to immerse themselves in the surroundings while revealing the wetland's functions through storyboards. The long walks along the embankment open into niches for community engagement, recreation, leisure and learning thus emphasizing human water interface.

◀ **Figure 7.5** *Vijayarai ecological edge*

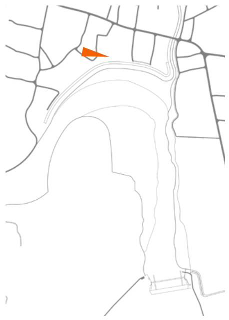
1. Farmlands
2. Restored sand bank
3. Riverwalk
4. Embankment
5. Wetland
6. Boardwalk
7. Wetland spillway
8. Wetland walk
9. Orchard grove
10. Learning corner
11. Ceremonial ghat
12. Stream / Marsh
13. Footbridge
14. Pathway
15. Lookout
16. Community retreat
17. Recreational area
18. River access
19. School

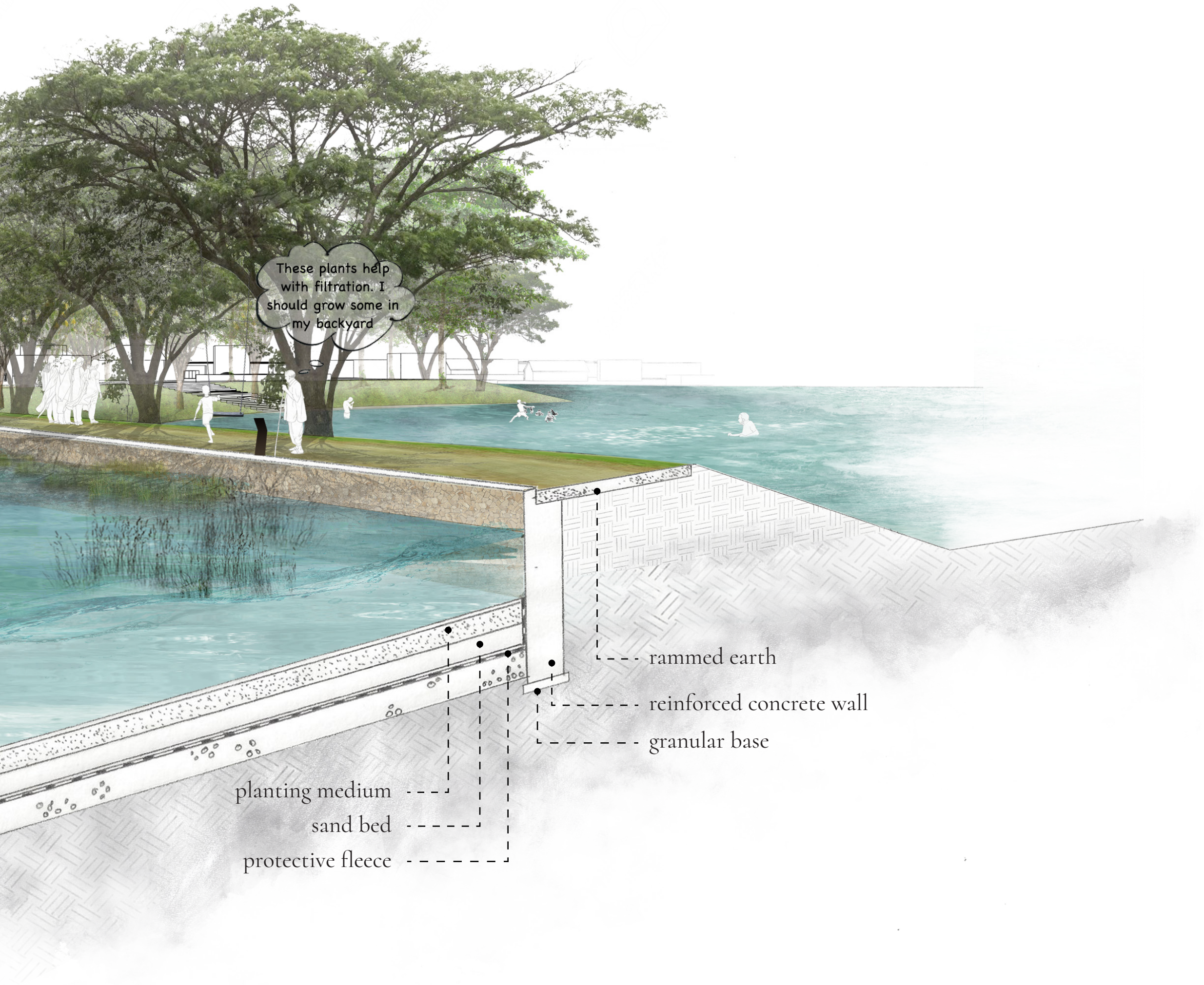
0 10km N



▲ **Figure 7.6** *Wetland system*

Water treatment system





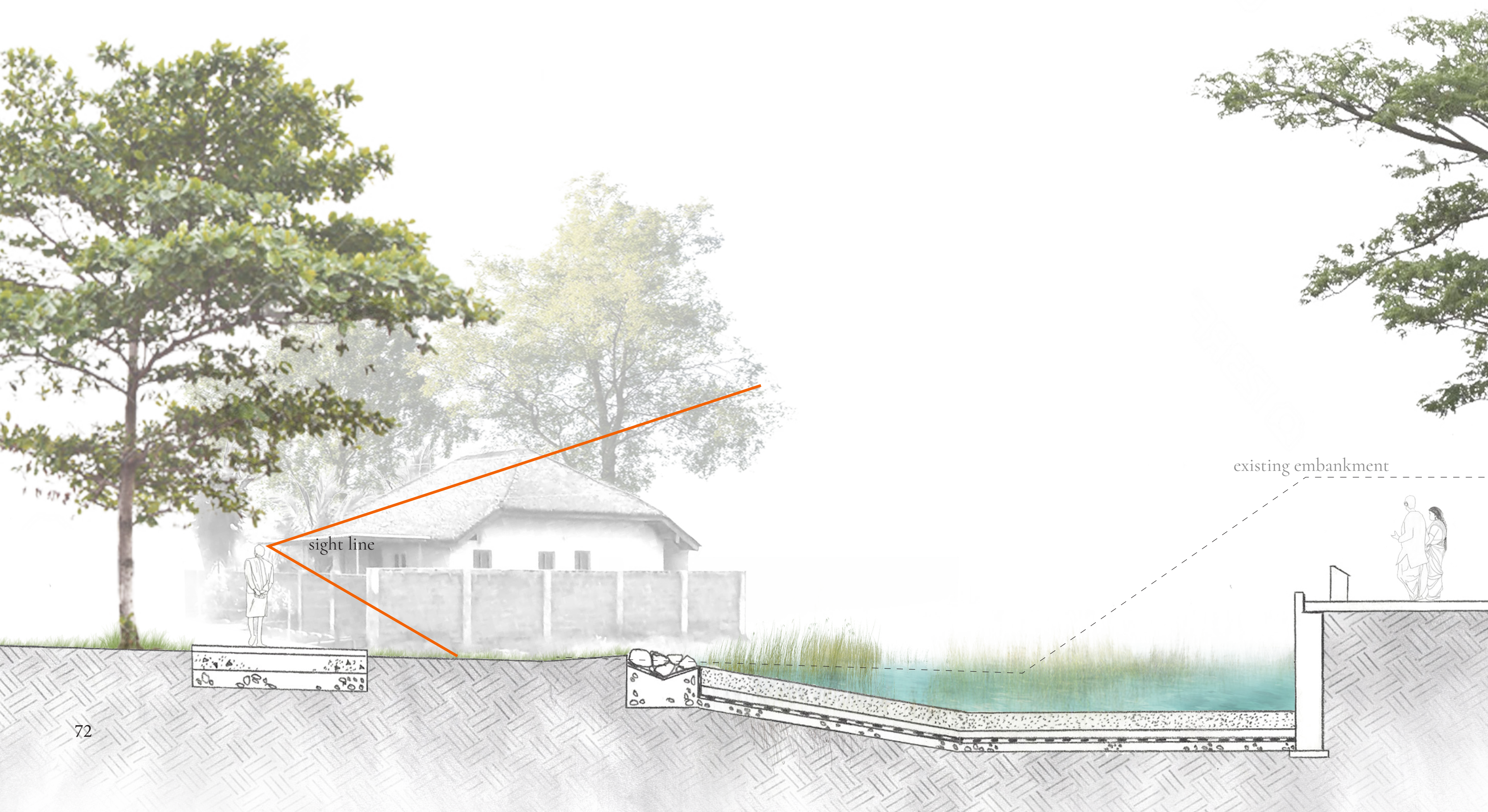
The wetland adjacent to the embankment is designed to treat grey water and improve water quality with emergent and submergent plants before it flows into the river. Grey water treatment is sequenced in three stages allowing settlement of solid waste and suspended particles, and breakdown of any chemical pollutant that come in contact with wetland plants while improving aesthetics of the surroundings.

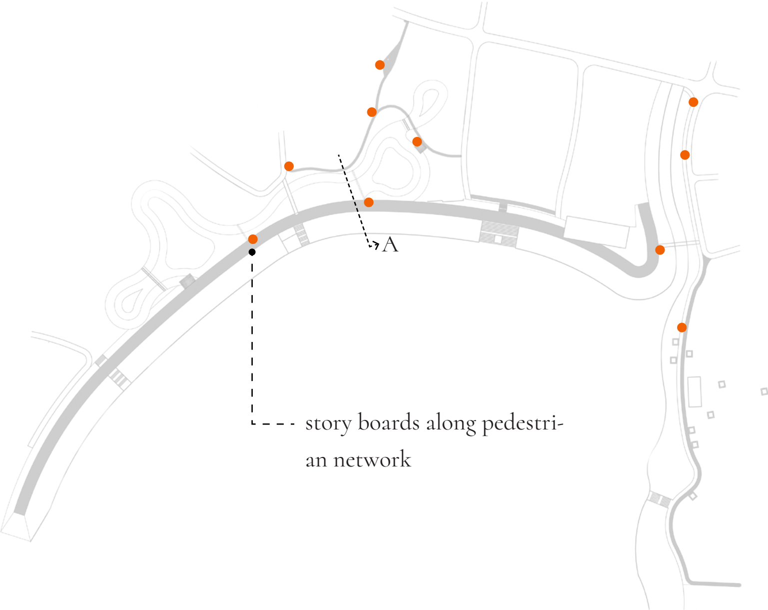
Visual links

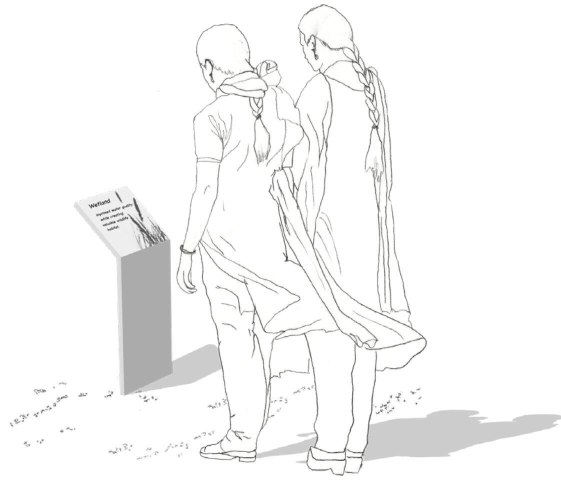
Embankment height is reduced by two meters, opening up the community to the river and farmlands. The pathways along the edge of the wetland connect neighbourhood streets and the levee through a series of boardwalks, paths and steps as well as providing access to the river.

Storyboards dotted along the pedestrian network, educate users about the importance of the wetland system, the pants used and their ecological benefits and significance. Thus, encouraging users to live in harmony with their surroundings.

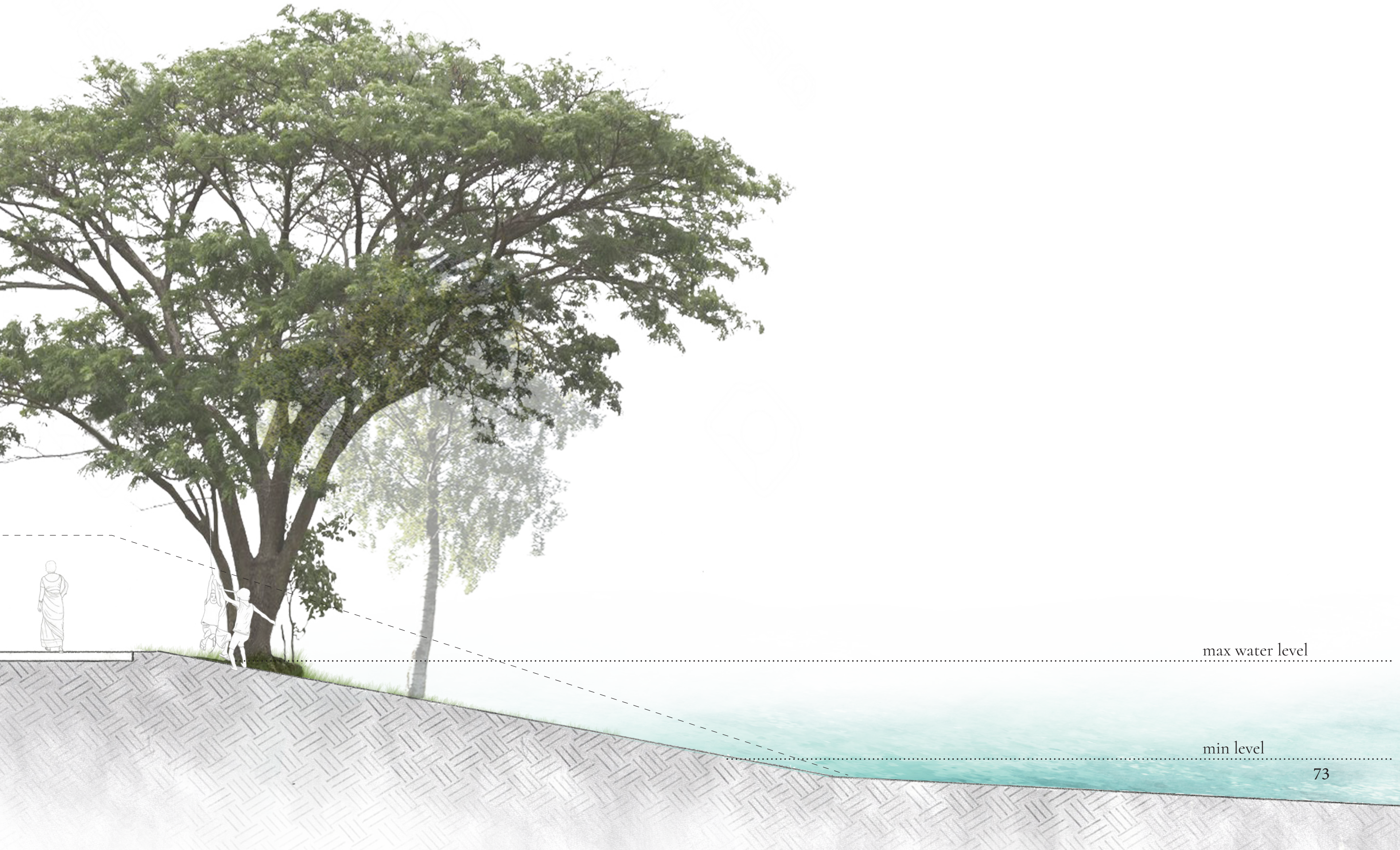
▼ **Figure 7.7** *Embankment and wetland edge (A).*

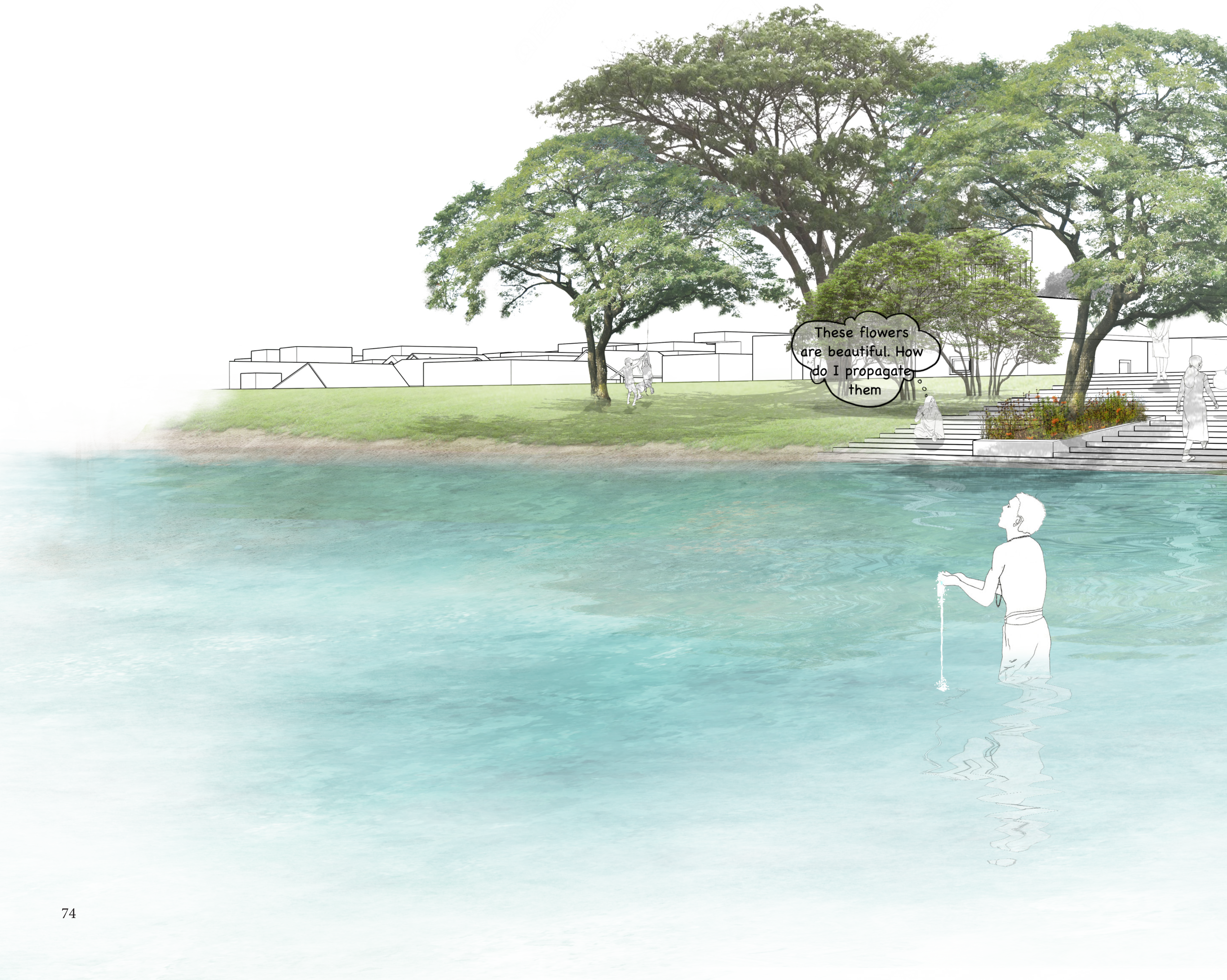


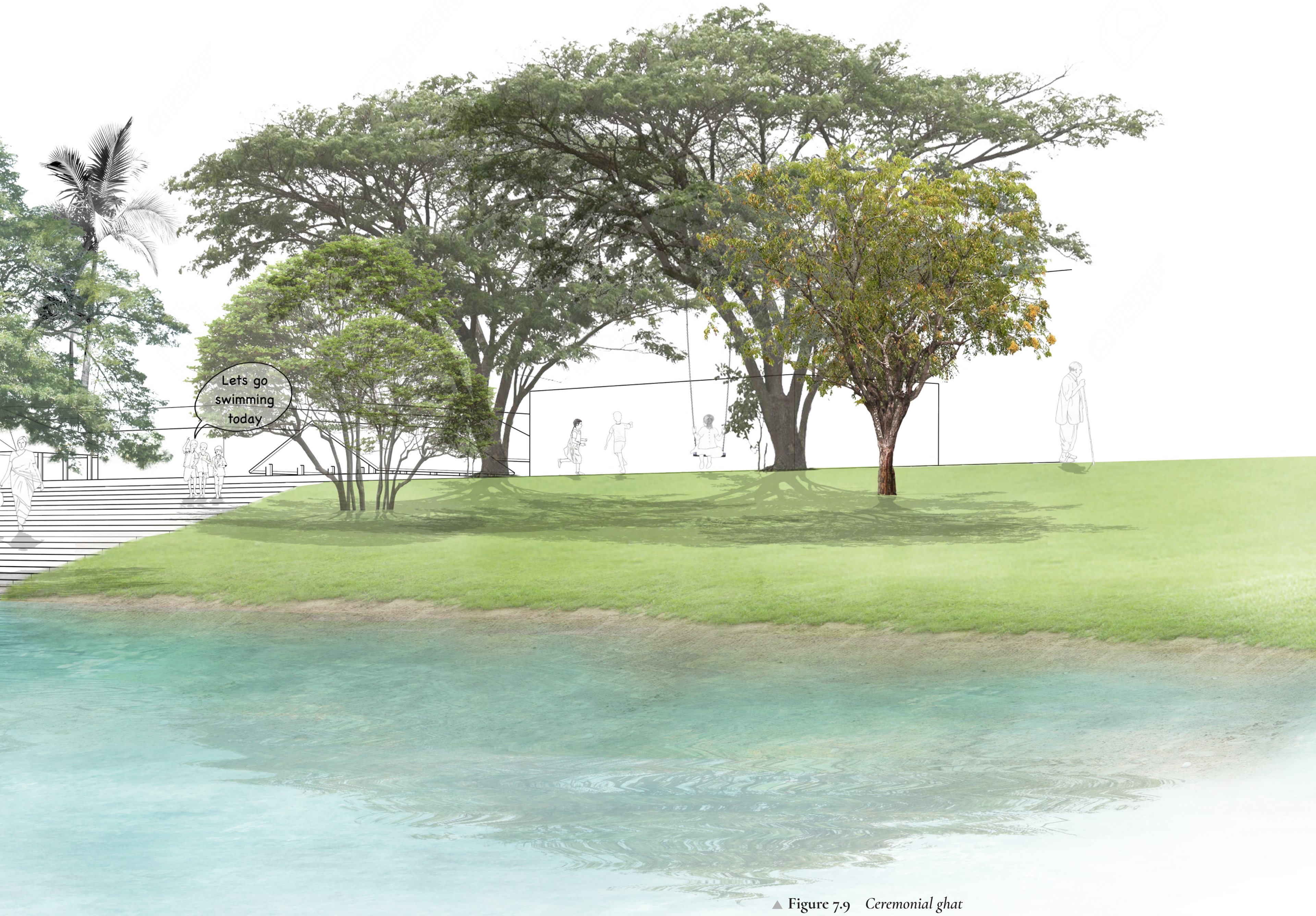




▲ **Figure 7.8** *Storyboard along pedestrian network.*




These flowers are beautiful. How do I propagate them

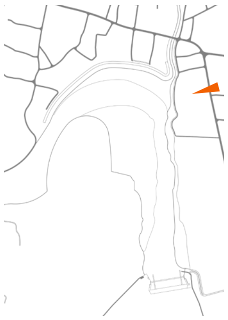


▲ **Figure 7.9** *Ceremonial ghat*

The stepped plaza is located in close proximity to the temple, providing direct access between place of worship and the river. It provides large open space for religious ceremonies and acts as a stepped resting area the rest of the time.

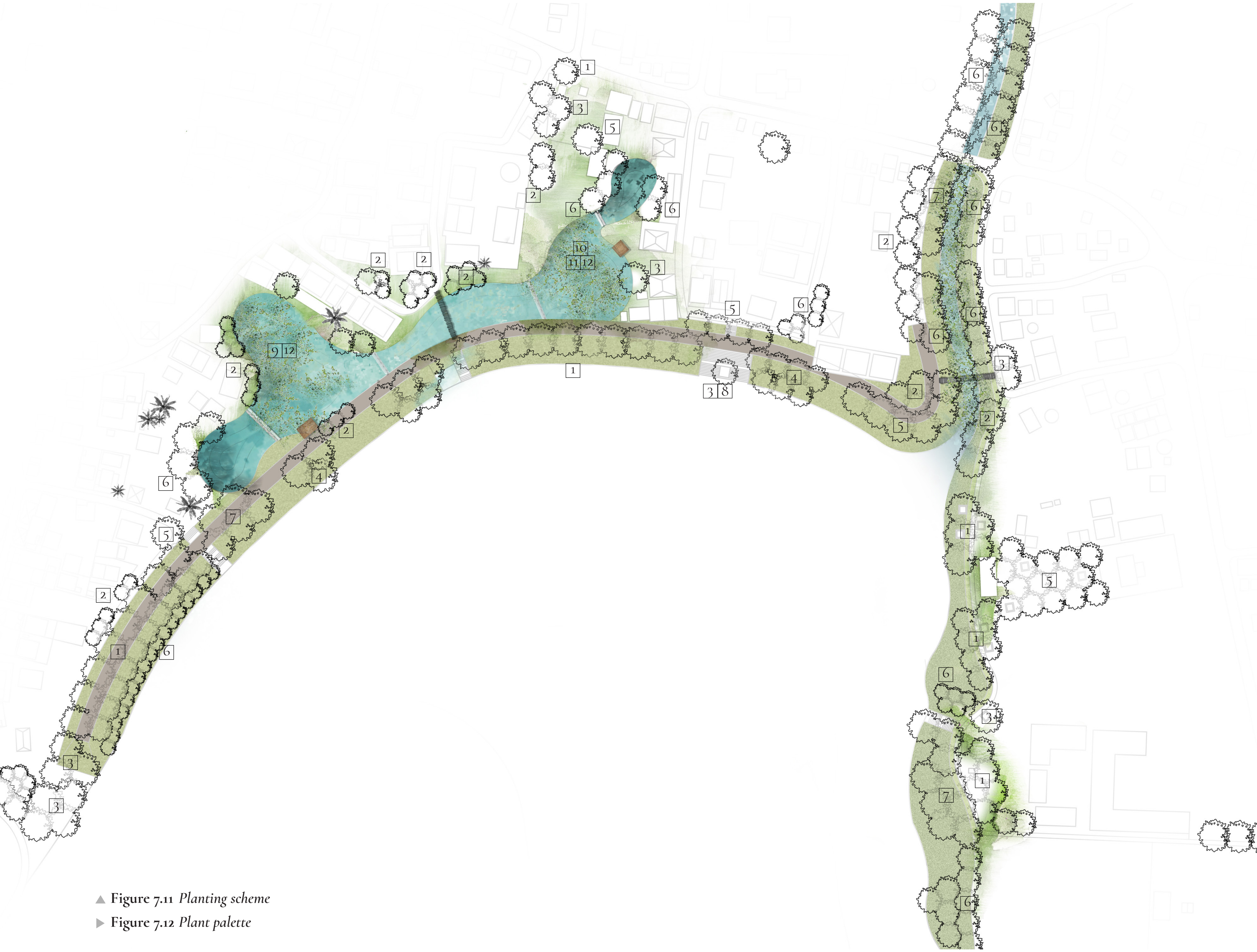
Community retreat

This treed courtyard on the south bank is a key amenity that brings the community together. With views overlooking the river and play area, this space can function as an outdoor classroom for skill development during school hours and as a shaded viewing gallery during games. It can also extend into the open field for occasional evening folk plays and entertainment.



▲ **Figure 7.10** *Community retreat and gathering place*

Planting

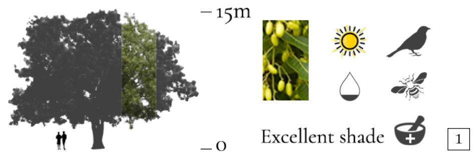


▲ **Figure 7.11** *Planting scheme*

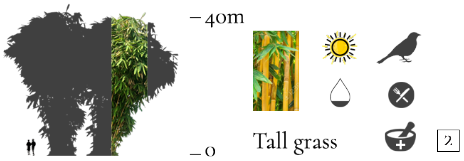
▶ **Figure 7.12** *Plant palette*

Plant selection

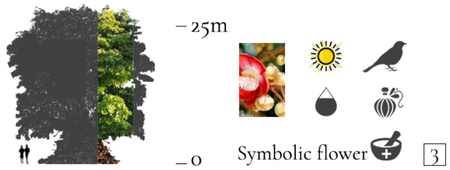
Azadirachta indica
Neem tree
Vepa chettu



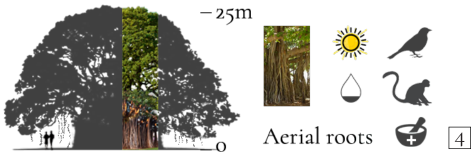
Bambus vulgais
Bamboo
Veduru



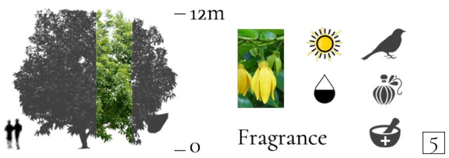
Couroupita guianensis
Cannonball tree
Nagamalli



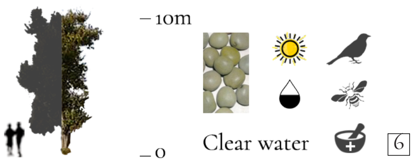
Ficus benghalensis
Banyan tree
Marri Chettu



Magnolia champaca
Champa
Sampangi

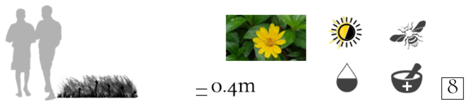


Strychnos potatorum linn
Clearing nut tree
Chillaginga

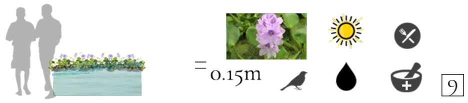


Syzygium cumini
Jamun
Neradu chettu

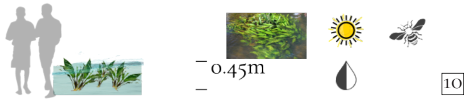
Sphagneticola trilobata
Wedelia
Guntagalagara



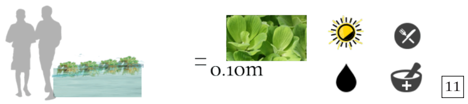
Eichhornia crassipes
Water Hyacinth
Jammu



Lagenandra toxicaria
Andavazha



Pistia stratiotes
Water Lettuce
Akasatamara



Typha domingensis
Reed mace
Dabbu jambu

Planting is designed to bring back native riparian species that have been lost over the years. Species in the plant palette have medicinal properties, religious significance and attract wildlife. The large trees have dense, wide crowns, offer ample shade and provide comfortable microclimate along the river. Emergent, submergent and edge species are spaced to create interesting elevations changes while breaking down heavy metals, chemical and other pollutants.

Potential regional applications

The principles applied in Vijayarai can be adopted at other locations with similar concerns. Waste collection and disposal systems, and drainage infrastructure should be improved in all urban and rural areas in close proximity to the river and any water sources to reduce, control and monitor pollutants entering surface and groundwater. Healthies river edges should be created by re-introducing native trees and opening the riverbanks to the community. Newly created spaces and paths make community part of the living edges, thus engendering a greater responsibility. In addition to these, the following areas need to studies and implement across the watershed to improve the condition of Tammileru River.

Water management

Over extraction of water, including construction of wells in dry riverbed is one of the bases for depleting ground water levels. The rates of withdrawal is higher than the annual precipitation and aquifers are not replenished quick enough to support human needs. Instead, as extracting ground water, farmers should be encouraged to localize recharge zones by capture rainwater for irrigation through retention and detention ponds. As seen in Isle of Bermuda, rain water surface runoff in each farm can be captured in a retention pond and used as the primary water source for agricultural needs. Simultaneously, detention ponds can be strategically located along the buffer zones of river banks (based on the runoff patterns) to capture and temporarily store water. This will reduce the peak rate of runoff allow water to infiltrate into the ground and recharge aquifers while preventing local flooding.

Contours 1m interval
Water flow pappern
Detention pond
Retention pond

Ecological edges

On reaching the ground, rainwater is dispersed -- absorbed by vegetation, absorbed by soil, and temporarily stored in shallow pockets and depressions. The rest flows into other water bodies and eventually into rivers (Marsh, 2010, p. 168). The surface runoff is low¬ in forested areas and high in barren lands, lightly vegetated land, farms, and urban area with impermeable surfaces. ¬Surface overflow is especially low in woodland with flat terrain. Taking advantage of the flat slopes along Tammileru River, dense native trees should be planted along the river to maximize groundwater infiltration and reduce evaporation. In the clay soil condition downstream, a combination of wetland and woodlands should be used to reduce runoff. This improves aquifer storage and slowly feed the river through subsurface sources.

River protection

As seen in the Regional Study of Chapter 4, Tammileru River is exploited by sand pirates and farmers in the upstream and highly polluted by urban users as it travels downstream. At Vijayarai village, river contaminations have led to increased biological oxygen demand and anaerobic conditions, total suspended solids and organic matter. This has affected fish populations, and also increased the transfer of disease to humans who eat them.

To make the river viable to support future civilization, it should be protected from contamination and exploitation. This can be successfully done only by making the community part of the restoration and protection process and introducing laws and regulations like the Clean Water Act to prevent and control the amount of sewage discharge into the river. People need to be reminded of the river's cultural significance, recreational use and changing flora and fauna, to allow them a glimpse of how a future clean river could benefit the neighbourhood. On the other hand, cities and villages should be held responsible for maintaining clean rivers, and failing to do so should have high financial implications. Funds raised through this process can be used to cleaning river and improve area infrastructure.

Built form on Rivers

Despite strenuous efforts, Mississippi River flooding has increased since 1900. Marsh uses this as an example of how local engineering solutions have failed to address watershed-wide issues. We need to look beyond the engineering solutions to address issues when dealing with water (Marsh, 2010, p. 210).

We do not yet have a comprehensive understanding of the hydrology of rivers and still try to manipulate their natural flow through dams, reservoirs, diversions channels and linking different rivers. The Tammileru River is not unique. I acknowledge the fact that we need water for our daily needs, however, attempting to solve a problem for short-term goals or political benefits is not the solution.

India's river protection and planning policies should be amended to accommodate feasibility studies

- To analyze ecological, environmental, physical, cultural and socio-economic aspects for all proposals related to water.
- To test the assumptions, theories and proposals, using simulation models to analyze and assess long-term effects on the health of the river, its flow and dependent communities both human or otherwise.
- To include an assessment by at least two organizations independent of each other, comprising of a professional team of Environmentalist, Geologist, Hydrologist, Landscape Architect, Architecture, Civil engineer.

This would help control, the number of structures built on the river and inform decisions that could protect the river and the environment.

◀ **Figure 7.13** *Potential locations for Detention and Retention ponds*

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Figure 1
Devabhaktuni, S., 2018. *Study area in global context*. nts. Data layer: Map Surfer ASTER GDEM-SRTM Hillshade [Quick map services]. Georeference. Winnipeg: Devabhaktuni, S; Using: Quantum GIS Geographic Information System [QGIS]. Version 3.0.1-Girona. Open Source Geospatial Foundation Project. Adobe Photoshop CC 2018 19.1.3. [Accessed May 2018].

Figure 1.1
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Figure 1.2
Devabhaktuni, S., 2018. *Deccan landscapes*. [pen and ink + digital]

Figure 1.3
Devabhaktuni, S., 2018. *Personnel experiences at Tammileru River at Vijayarai.* [pen and ink + digital]

Figure 2.0
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Figure 7.7
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