DHARA

Directing Flows in Mumbai through Landscape

Ayesha Mahiira Hussain

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DHARA

Directing Flows in Mumbai through Landscape

A resilient blue-green landscape framework towards hydrological,
ecological and communal reinstation for the Mumbai Estuarine Urbanscape

Dhara - "A steady, continuous flowing movement"
Collins Dictionary

Ayesha Mahiira Hussain

5244889 | a.m.hussain@student.tudelft.nl

Mentors : Steffen Nijhuis and Daniele Cannatella

MSc Landscape Architecture | Faculty of Architecture and the Built Environment

Delft University of Technology

TU Delft

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ACKNOWLEDGMENT

This thesis is a reflection of my time spent learning about land and unland. Understanding crises and finding method and solace in landscape architecture has driven this product.

Thank you to my mentor Steffen who supported me greatly in this process and ensured I made it to the other side smoothly. His patience, trust and assurance was the ultimate motivator. He streamlined my thoughts and often prodded me on in difficult times. He inspired me with his infinite ideas and directed approach.

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Thank you to my home, canal and blue balcony.

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ABSTRACT

From 1700 onwards the natural coastal landscape of Mumbai has gone through drastic changes and has become the highly urbanized metropolis we see today. The natural landscape was that of a forest to estuarine topographical gradient. This transformation of the land has had a major impact on the city's resiliency, impacting water systems, green cover and communities. The natural systems have been built over with sea walls, causeways, railways and other such infrastructure elements that have become barriers, hampering the natural processes and flows. With urbanization, the local fishing communities that were initial inhibitors of Mumbai have been pushed to the fringes, now residing in the most vulnerable parts of the city. These problems, and the added pressure of climate change, has resulted in a very vulnerable system prone to flooding and consisting of compromised ecosystems and marginalized communities.

Considering the city as an interception within nature, it is important to look at the recovery of these elements via a nature based approach. Blue green infrastructure is a tool to deploy nature based solutions in complex urban environments. They work with landscape as infrastructure and infrastructure as landscape, creating an intertwined urban and natural system. Therefore the objective of this thesis is to explore the potentials of a blue green landscape framework that will provide conditions for hydro-morphological recovery, ecological restoration and communal requalification for the urbanized estuarine landscape of the Greater Mumbai Region. The thesis focuses on three design assignments, coastal protection, restoration of flows and communal safety. This in turn would impact the liveability of the city and raise awareness of the importance of natural systems and processes in urban environments.

Design research and research by design provide the methods to direct this research where analysis and setting up of design principles are components of design research and the testing of design principles is part of research by design.

This research is conducted at three scales, examining the potentials of the blue green landscape framework at the regional scale, analysing a watershed system boundary and a detailed design for the coastal region with elaborations related to mangroves, infrastructure and informal settlements. The research concludes with a reflection on the process and outcomes and their relevance for other geographical locations where similar threats are experienced.

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1.4 Relevance
1.5 Outline of the Research

Image - Kartik Chandramouli/Mongabay.

Natural System

Urban Transformation

Top - Flickr - Mr. OppenHeimerR
Bottom - Flickr - Climate Group

01 | INTRODUCTION TO THE URBANIZED ESTUARY

1.1 | FROM ESTUARY TO URBANSCAPE - MUMBAI

An estuary is a transition zone between river environments and maritime environments. This defines an ecotone where freshwater and saline water interact. Mathur and DaCunha, in their documentation Soak, defined an estuary as “allowing the sea in” differentiating it from a delta where rivers reach out to sea. This implies that in an ideal situation the transitional zone of an estuary would be of gradients where the sea is allowed inland and rivers have room to spread, creating a region of wetness along the coast.

In tropical coastal areas where the monsoon is an annual occurrence and is synonymous with rainstorms, this wetness is the enemy. These storms along with the tidal changes create a dynamic environment that is often difficult to inhabit. Therefore, while keeping the sea out has become the primary agenda, with it comes the mentality that rainwater should be channelled away from land as quickly as possible as well. In doing so, a landscape of gradients that is critical to the functioning of an estuary, is endangered, making such areas extremely vulnerable and susceptible to flooding.

Mumbai, the present day financial capital of India and the most populous metropolis in the country is built on one such tropical estuarine landscape, that ranges from the higher altitude inland region down to the estuarine landscape. From 1662 onwards, the natural landscape was modified through a series of reclamation projects, where landfills, sea walls, causeways and other such construction projects were implemented to keep the sea out, and accommodate the influx of population that wanted to maximize the economic potential of the region. Over time, a high density urban metropolis developed and the natural landscape system is buried under sprawl, infrastructure and waste. In Mumbai, people have homes, but water has no place to go.

The city is now against water, not for it.

2005 - The maximum rainfall recorded - 944mm
Deaths attributed to flooding - 1094

India, T. O. (2022, February 17). mumbai flood. The Times of India. https://timesofindia.indiatimes.com/topic/mumbai-flood

2021 - A city where people have learned to adapt momentarily but are unaware of the challenges that are brewing and still to come.

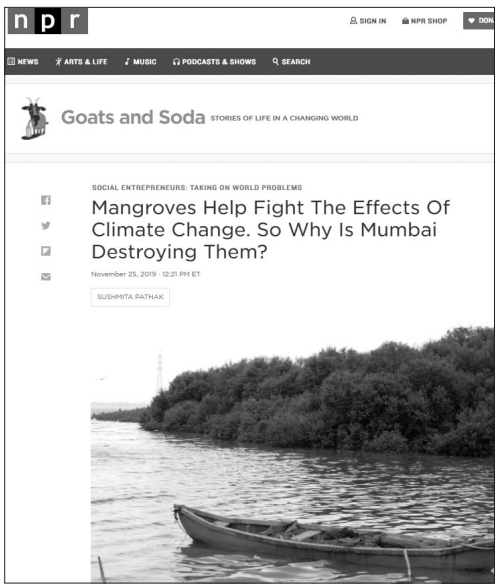
Desk, T. H. N. (2021, June 9). In pictures | Monsoon season begins in Mumbai. The Hindu. https://www.thehindu.com/news/cities/mumbai/in-pictures-monsoon-season-begins-in-mumbai/article34769110.ece/photo/7/

Informal settlements in the monsoon

Indranil Mukheerjeee /AFP via Getty Images

LIVING WITH VULNERABILITY

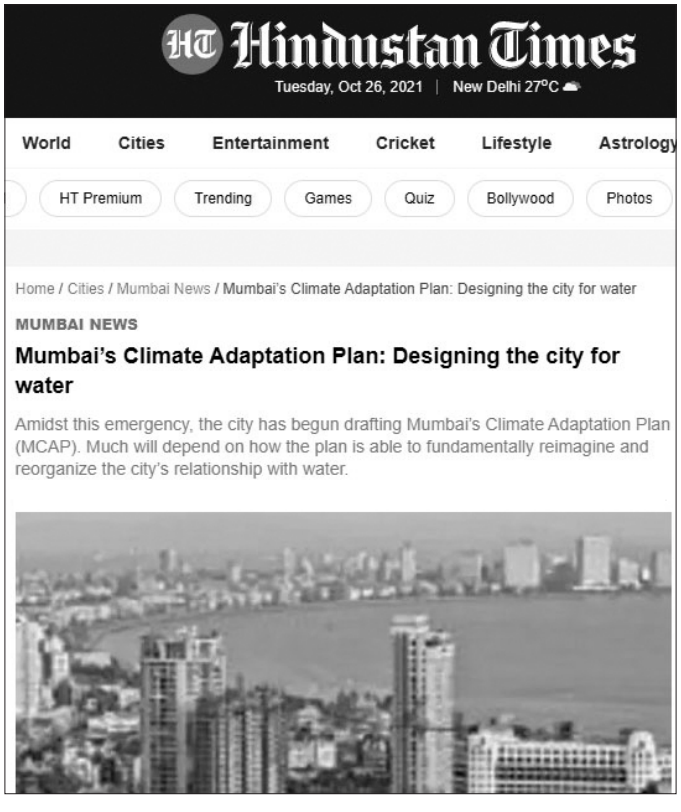
On 26th July 2005, Mumbai came to a standstill. The city experienced severe flooding recording a 24-hour rainfall figure of 944 mm which attributed to 1094 deaths, major human suffering and economic damage. This rainfall resulted in large scale inundation of the city. The drainage system proved inadequate for the volume of runoff, and the rivers and reservoirs within the city overflowed. (Malini et al, 2008) The climate crisis is contributing to changes in rainfall patterns and with rapid unplanned urbanization and a grave modification of natural systems, these floods are likely to cause more damage in the future. While the inhabitants of the city have learned to adapt momentarily by clearing the lower floors of their homes and workplaces during the monsoon, they continue to live with vulnerability. This particularly impacts the marginalized communities that have been pushed to the low lying areas of the city where the impact of flooding is the greatest. Here the high urban density, lack of space improper waste and water management systems causes the greatest damage.



Depleting Mangroves

Local communities impacted by urban pressure

Depleting Forest



Climate Crisis

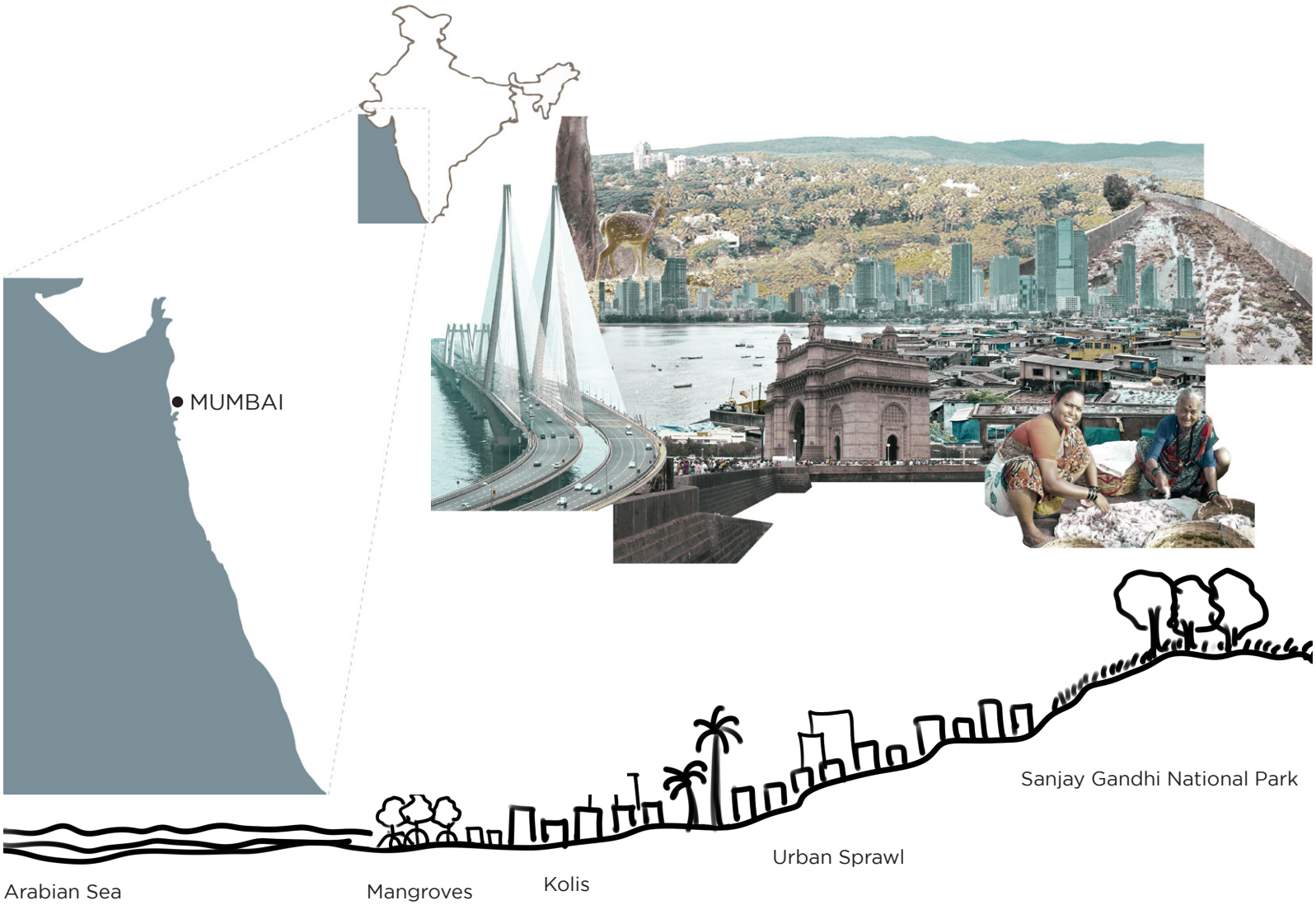
Published material of the challenges faced by the city

The Landscape Perspective - Soak - Mathur DaCunha

Source: Soak. (2009). Mathur / Da Cunha. https://www.mathurdacunha.com/soak

CALL FOR ACTION

Since the 2005 floods, there has been much debate on future plans for Mumbai, with small steps being taken to increase its resiliency against future weather events. Many articles have been published bringing this urgency to the forefront, discussing the importance of a well functioning water management system, sewage system, mangroves, urban green etc, however most commentary has been urban centric and governance related. In 2009, through their publication and exhibition, Soak, Mathur and DaCunha were the first to shed light on the importance of a landscape perspective to addressing Mumbai's problems. More recently, on 27 September 2021, the city began to draft a Climate Adaptation Plan to reimagine and reorganize Mumbai's relationship with water wherein a need to integrate landscape architecture perspectives that consider the relations of different waters, air and land use systemically is highlighted (Anand, 2021). As can be attested by recent discussions, this issue requires an integrated landscape approach, using nature based solutions to create a framework for future resiliency that can become a basis for any further urbanization.

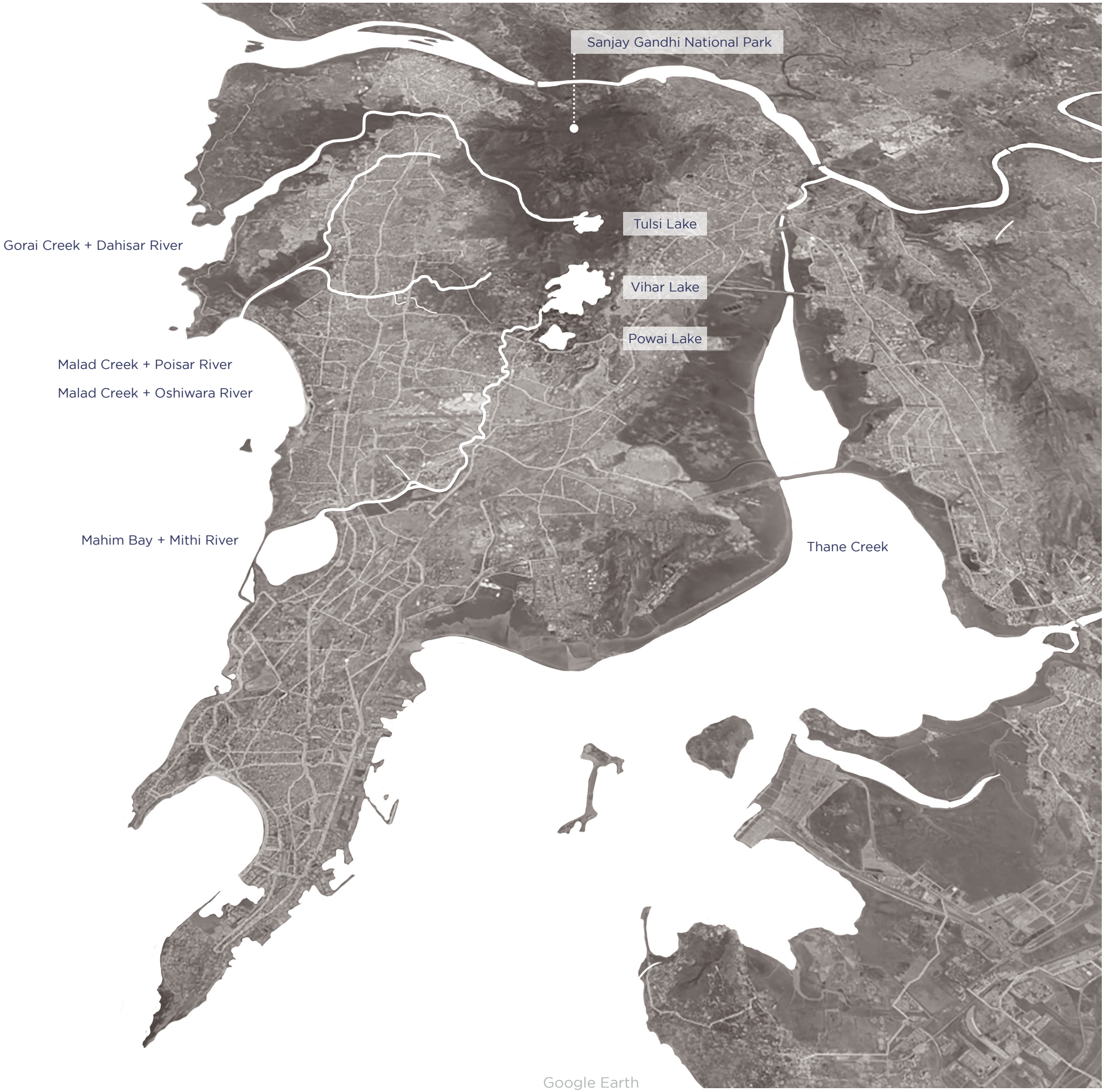


THE JUXTAPOSITIONS OF MUMBAI

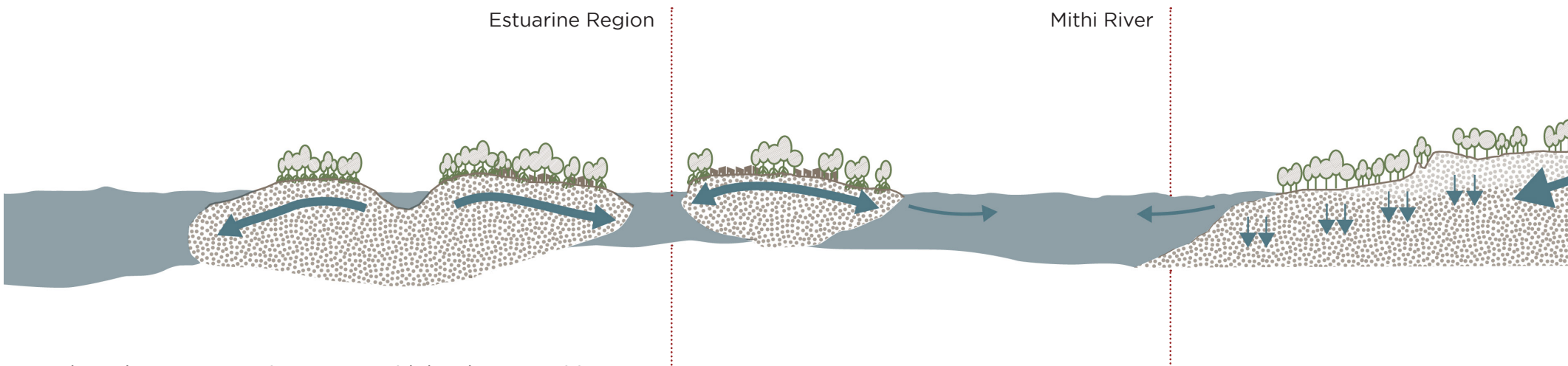
The study area of this research, Mumbai, is an amalgamation of diverse landscape types, urban structures and cultures. The city is located on the western coast of the Indian peninsula, bound by the Arabian Sea, and south of the Tropic of Cancer. It is the 4th most populous city in the world, home to 20.6 million residents. Since the 1600s under the British rule, the area transformed dramatically, setting the foundations for the metropolis that it is today.

The area that the region covers is 603 km2, starting from the coast and extending towards the higher Sanjay Gandhi National Park at an elevation of 400m. There are many ecosystems that exist within this range, from coastal mangroves and mudflats, to inland plains and highland forests. There is a juxtaposition of elements, high and low, rich and poor, wet and dry that play important roles in the dynamic quality of this city that have attracted many settlers through the ages.

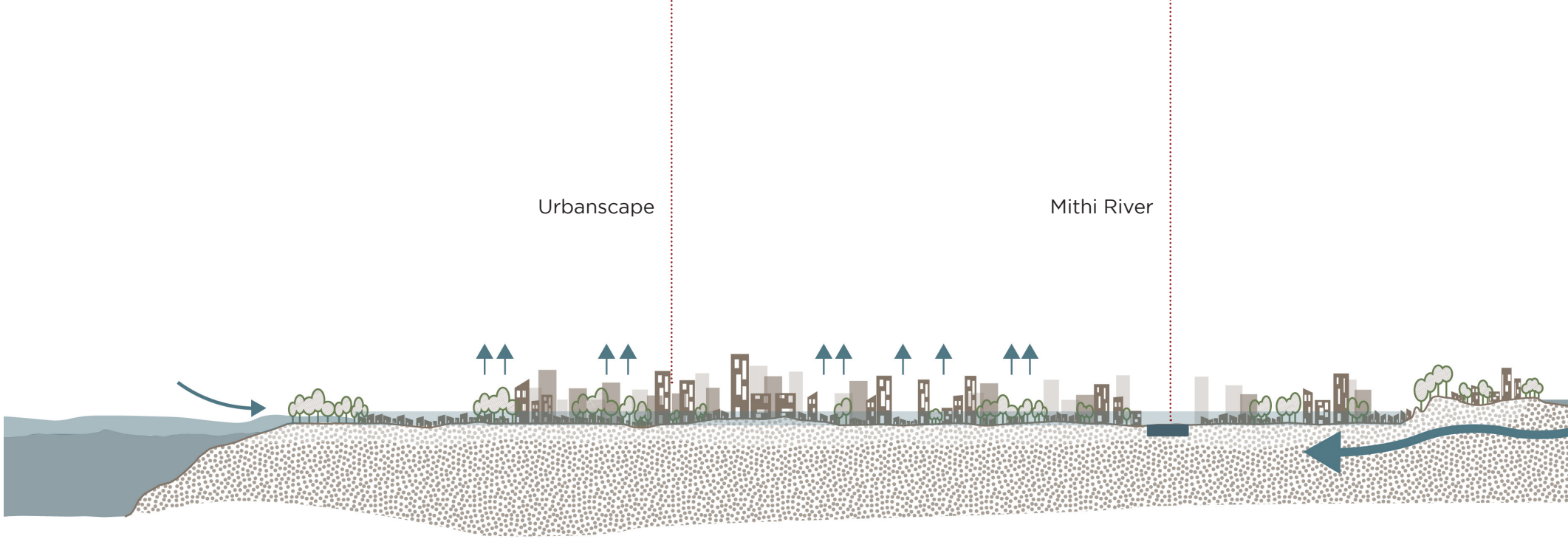
Presently, the natural landscape is hardly visible. The cultural landscape boasts of highly engineered contemporary infrastructure, highrises and historic forts but is also home to the now marginalized fishing communities, the Kolis, that were the first inhibitors of the region. Initially thriving on water related activities, the city now relies on other industries and has turned its back against water, always finding new ways to curtail it. The four main rivers have been canalized into nalas or drains, reservoirs have been constructed along their course to supply fresh water to the residents, and the forests both inland and coastal are being destroyed constantly to make room for new development.



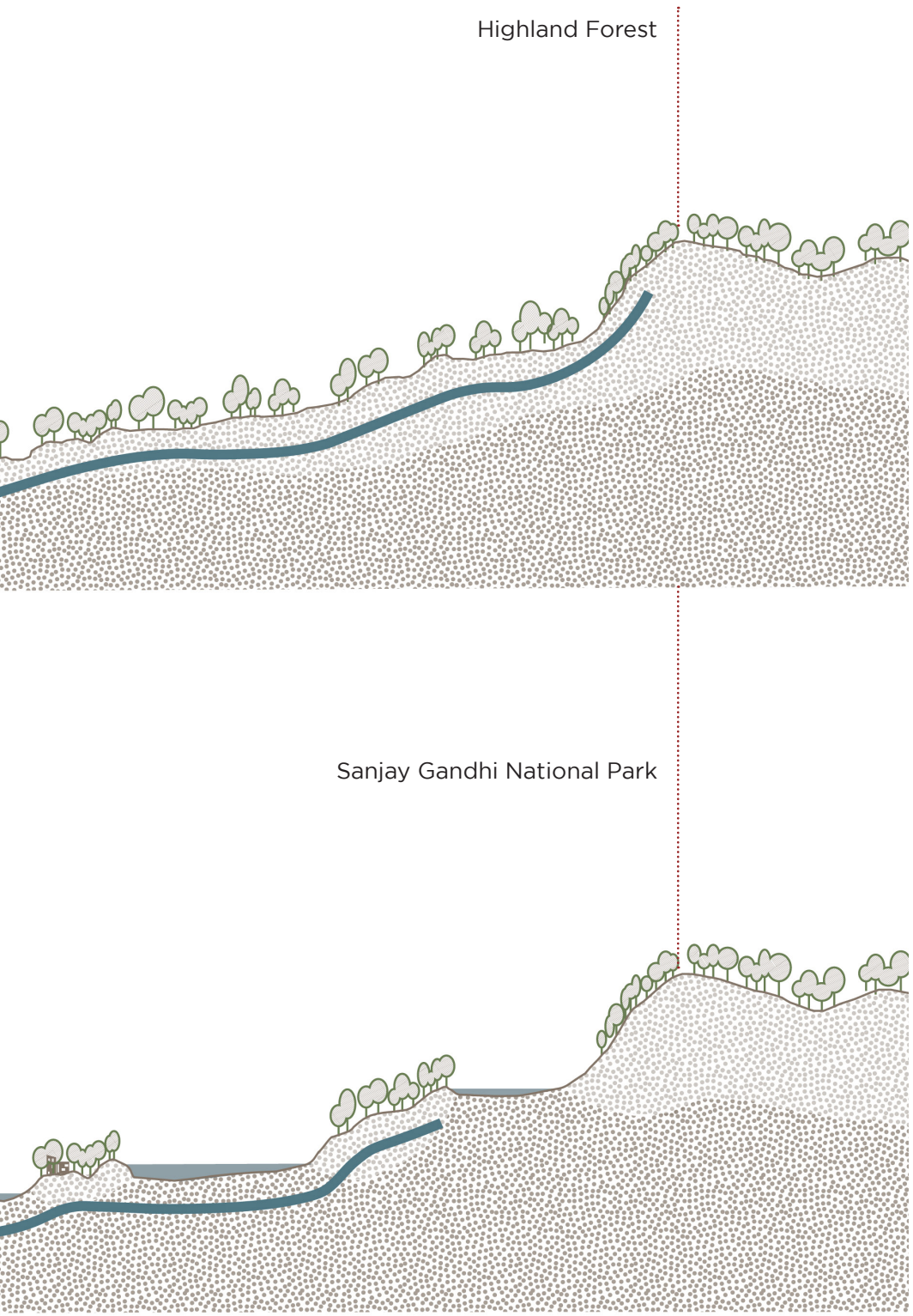
Google Earth



Natural Landscape - Estuarine system with local communities



Current Landscape - Dense, highly urbanized city



1.2 | THE PROBLEM

ERASURE OF THE NATURAL LANDSCAPE

CAUSE
URBANIZATION - Modifying the Natural System

EFFECT
LOSS OF BLUE-GREEN ELEMENTS - Flooding, Compromised Ecosystem, Loss of Quality of Life

THREAT
CLIMATE CHANGE - Sea Level Rise, Increased Flash Floods, Urban Heat Island

Not only has there been a physical erasure of the natural system, there is also the added pressure of lack of quality of the remaining systems. What is left of waterways is polluted, clogged with solid, industrial and plastic waste. There is no difference between the sewage and stormwater systems. Open spaces are isolated, unconnected and often encroached upon or paved for “beautification”. The green and blue elements are undervalued and neglected, with focus on the grey elements or built environment. This also impacts the mentality of the residents, making them believe that hard infrastructure is a sign of advancement and progress.

There are serious consequences that come with modifications to natural systems, that all contribute to the flooding that the city experiences, and with the threat of climate change – increased storms and rising sea levels, these problems are likely to get worse. Because of depleting green cover, the city is unable to retain, detain and discharge water adequately, which is critical to its future resiliency. Because of the loss of mangroves, the city’s natural defense against the sea is compromised. With the lack of green cover, comes the loss of biodiversity which impacts quality of life – clean air and water and a wide range of other ecosystem services. Another big consequence of this urbanization is the marginalization of communities that rely on water related activities, rendering them most vulnerable to the impacts of flooding, and leaving them with inadequate living conditions.

Rivers as Drains

Informal Settlements in vulnerable areas

FLYING OVER MUMBAI (DHARAVI) 4K Aerial Film. (2019, July 27). YouTube. https://www.youtube.com/watch?v=uFEq-CB0Ev8&ab_channel=DannyMcgee

1.3 | RESEARCH OBJECTIVE AND QUESTIONS

With the impending climatic challenges, and the past and continued reclamation and urbanization of Mumbai the estuary, there is a clear need to reassess the approach towards water, ecology and community. By adopting a “landscape first approach” one can hope to transition to a sustainable and resilient living environment, as strong structures such as the natural elements and processes should become the driver for future urban development. Nijhuis (2022) writes that “landscape-based urbanism identifies and guides urban development towards the most advantageous places, functions, scales and inter-relationships, through the development of robust landscape structures” An adaptable framework helps guide urban transformation through design explorations that utilize the knowledge of the natural and social context, providing possible solutions to a spatial problem. (Nijhuis, 2022) This results improved water management, biodiversity, community safety, cultural identity and in turn economic development.

However to deploy a landscape based approach, it is essential to understand the past and current landscape, how the city turned its back against water, and how a strategic framework can help direct the city towards living with water, restore the functioning of the natural systems and along with it generate user safety and experience that allows the residents to be FOR water and not against it.

RESEARCH OBJECTIVE

To explore the potentials of a blue green landscape framework that will provide conditions for hydro-morphological recovery, ecological restoration and communal requalification for the urbanized estuarine landscape of the Greater Mumbai Region.

Hydro-morphological Recovery | Storage and movement of water

Ecological Recovery | A landscape of gradients and habitats

Communal Requalification | Safety and improvement of quality of life

RESEARCH QUESTIONS

UNDERSTANDING - How does the present day Mumbai landscape system function, how did it change over time and what are the challenges related to its transformation?

FRAMEWORK - How can blue-green structures help to mitigate these challenges and be transformed into spatial design principles to restore natural systems, drive community safety and guide future urban development?

APPLICATION - What are the spatial possibilities of the framework at the local scale that can create conditions to help re-establish hydro-morphology, ecology and community to make the region flood resilient and climate proof?

RELEVANCE - What are the lessons learned from using blue green landscape framework as a basis for design in Mumbai, that are applicable in similar geographical regions with similar challenges?

1.4 | RELEVANCE

SOCIETAL RELEVANCE

This study aims at creating awareness of the various types of waters that a city engages with. It aims to create an educative landscape system that brings citizens closer to water - that the city once used to thrive on. It will focus on empowering communities by providing habitats for both economic and environmental upliftment. Thus far, the city's relationship with water has been hostile, the aim of this thesis is to restore that relationship. Every region along the course of a river has its own identity, biodiversity and habitats, this thesis hopes to create relationships between them and create a sustainable living system that while dealing with environmental issues, also addresses liveability, education and perception of the landscape.

SCIENTIFIC RELEVANCE

This study is scientifically relevant because it aims to contribute towards an understanding of the impact of urbanization on coastal areas and how urban structure can start becoming a part of the blue green network of a city. It explores adaptable strategies that can help navigate problems related to urbanization – water vulnerability, loss of biodiversity and cultural identity through nature based solutions. This study will also explore cultural programming in the city as an educative tool to understand its landscape importance, and enforce positive relationships between people and the landscape they inhabit.

PROFESSIONAL RELEVANCE

On 27 September 2021, the city began to draft a Climate Adaptation Plan to reimagine and reorganize Mumbai's relationship with water wherein a need to integrate landscape architecture perspectives that consider the relations of different waters, air and land use systemically is highlighted (Anand, 2021). Hence the issue at hand requires considerable attention, and also requires a nature based approach. Presently most of the research has been about stopping the water, walling the rivers, and ensuring that the water moves out of the city efficiently. However, an integrated nature based design strategy can help develop a system where water can be stored, delayed and recharge within the urbanscape. This graduation project will address spatial design based systems for that, and therefore will provide a different perspective towards water management that can be referenced by the professional community.

1.5 | OUTLINE OF THE RESEARCH

INTRODUCTION TO THE URBANIZED ESTUARY

This chapter introduces the estuarine landscape, and Mumbai as an example of one such landscape. It addresses the problems that the city faces and the need for a landscape approach to mitigate these problems. It concludes with the research goal, questions and the societal, scientific and professional relevance of this research.

TOWARDS A LANDSCAPE APPROACH

This chapter addresses the research approach, the theoretical framework and the method that is applied through the research to answer the posed questions.

AN UNDERSTANDING THROUGH SCALES

This chapter investigates Mumbai's landscape system, historic and present. It outlines the challenges and potentials of the region and concludes with the design assignment.

THE BLUE-GREEN VISION

This chapters looks at blue green landscape based case studies that are relevant for the context of Mumbai and extracts design principles from the same that can be applied in spatial design both at the regional and local scale

REINSTATING THE DYNAMIC

This chapter shows the result of the research through design. A strategic masterplan for the coastal region is designed and two focus areas are elaborated upon.

DISCUSSION & CONCLUSION
This chapter concludes the research via an evaluation of results and its implications and limitations.

02

TOWARDS A LANDSCAPE APPROACH

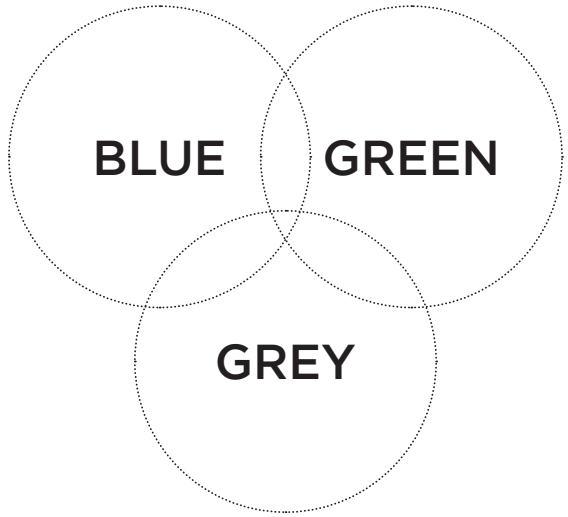
2.1 Theoretical Framework

2. 2 Method

Image - Flickr

LANDSCAPE APPROACH

ONE SYSTEM



LANDSCAPE AS INFRASTRUCTURE AND
INFRASTRUCTURE AS LANDSCAPE

BLUE GREEN LANDSCAPE FRAMEWORK

that is CULTURE and CONTEXT specific for MUMBAI

02 | APPROACH

2.1 | THEORETICAL FRAMEWORK

TOWARDS A LANDSCAPE APPROACH
The landscape approach as proposed, implies that urban development is based on a proper understanding of the natural system, where “the city is in fact part of nature” (Sprin, 1985) or gravely dependent on it. Since the city is the human driven transformation of a natural system, it is imperative to understand the underlying system on which the urban layer is imposed. For Mumbai, most of the urban development is situated in an estuarine region, therefore water and water related ecologies play a key role in the safe and liveable functioning of the system. The reclamation projects and the continual urban expansion has left little room for nature and natural processes, but it important to find a way to reinstate these systems in the new urban context, where the urban form that is experienced is “a visible manifestation of underlying organization” (Lyle, 1991).

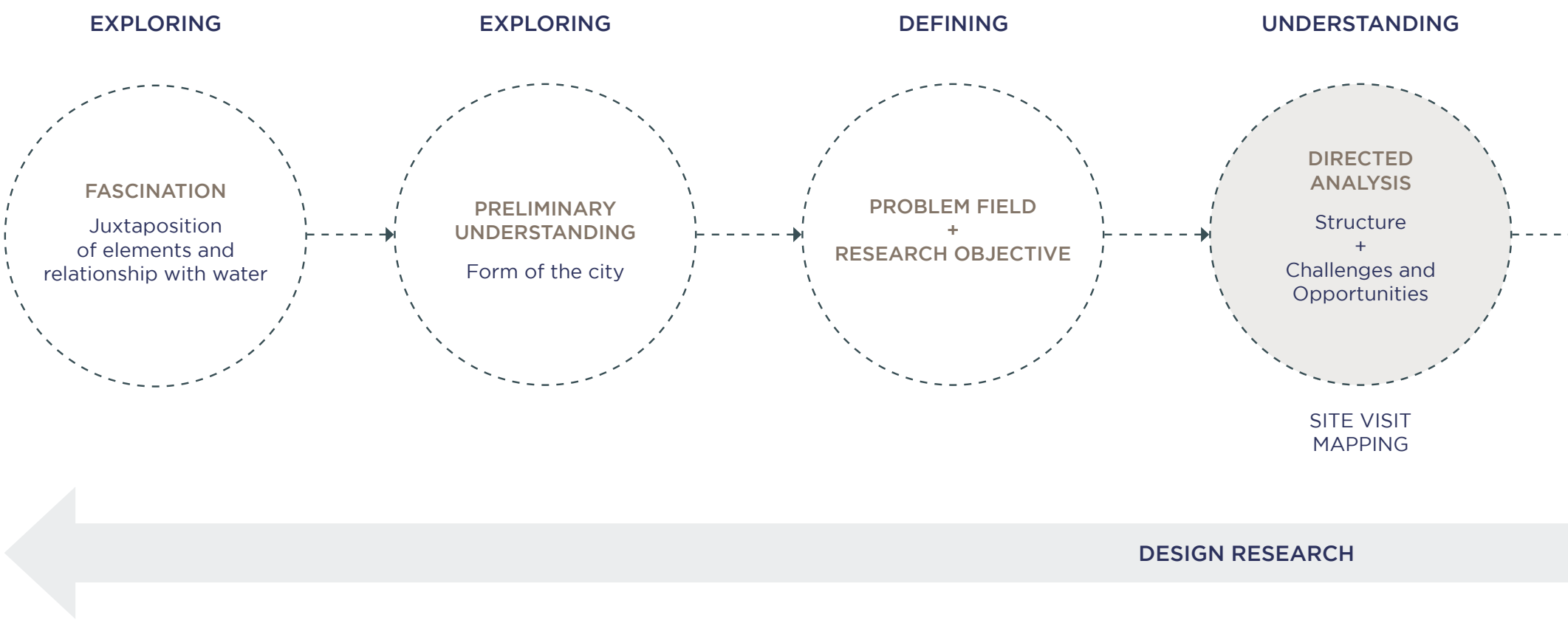
TOWARDS A BLUE GREEN LANDSCAPE FRAMEWORK
The natural context is made up of relief, water, soil, geological substructure and climate, together with the corresponding ecosystems. In short, it consists of blue and green elements and their processes, that have been adapted for human settlement through reclamation and urbanization. Water, a vital structuring element, poses a challenge for the urban environment during extreme weather events such as heavy rainfall and tidal processes. Green spaces are critical for many ecosystem services as well as for increasing the sponge capacity of a region.

Urban landscapes can be understood as complex systems composed of subsystems each with their own dynamics and speed of change (Otto, 2011; Portugali et al 2012, Batty, 2013, as cited in Nijhuis, 2015). A landscape framework based on the strong structures that have a slower rate of change, can assist in making the natural system operational again in the new urban context. Infrastructure can be seen as a type of landscape and landscape as a type of infrastructure. (Nijhuis, 2015) The hybridization of the two can result in the a restoration of flows.

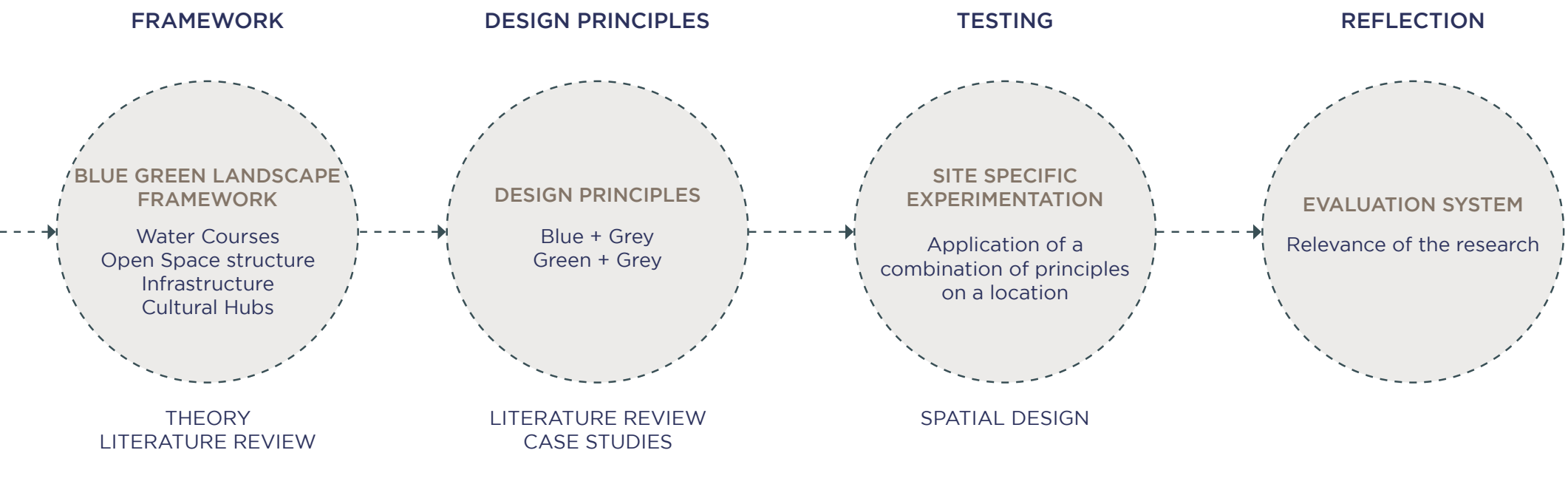
With an increase in population of urban areas, a grey infrastructure (the connective tissue) has developed as barriers to the natural system that usually leaves minimal scope for blue and green flows and processes, potentially resulting in mismanagement of stormwater and flooding issues. (Ahmed et al., 2019)

Blue green infrastructure is “an interconnected network of natural and designed landscape components, including water bodies and green and open spaces, which provide multiple functions such as: (i) flood control, (ii) water storage for irrigation and industry use, (iii) wetland areas for wildlife habitat or water purification, among many others.” (Ghofrani, 2016)

CONTEXTUALIZING THE FRAMEWORK
The development of a blue green framework that is adaptable to a context and is the basis for future development. A Blue green landscape framework needs to be contextualized to the environment it is applied to. Each landscape has its own distinguishing features and is differentiated by its own specific character, therefore landscape authenticity becomes important and contributes to spatial quality and identity. We can understand landscape authenticity by looking at the landscape as an integrated whole: as a living system, history and spatial experience, particularly through the natural, human made and cultural layers and their relationships that constitute the landscape system. (Nijhuis, 2020) Rapid urban development and functional change can compromise the layering and legibility of the landscape and there is a danger that the cultural identity will disappear. Landscape authenticity is also about context and culture. It is about peoples perceptions of the places they inhabit. (Stobbelaar & Pedroli, 2011). The strategies need to express the identity of a place, and work with layers of history, cultures and the people that inhabit the place, to remain legible and become part of an expression that makes people respect and contribute to the land that they inhabit. These strategies also need to make room for unempowered communities that are the most endangered if we look at a landscape first approach.



Structure of the Research - While the process is not necessarily linear it follows a system that is divided into two components - Design Research and Research by Design.



2.2 | METHOD

The theoretical framework is applied via two main domains of research. The first domain is “design research and consists of analyzing and developing the toolkit. The second domain is “research by design which is experimentation through design (Nijhuis and Bobbink, 2012). For landscape design it important that the research traverses through scales, as actions at the local scale can impact the regional vision and vice versa.

The “understanding” research question is answered by examining the natural and urban processes in the area. The layer analysis contributes to an understanding of the elements the city is comprised of. Site visits and mapping are also part of developing this understanding. The challenges and opportunities that emerge lead to the design assignment. The “framework” question is answered by analyzing relevant case studies that use the BGI framework as a tool. This contributes to guiding design principles – concepts or strategies, that are applicable in the context of Mumbai. These are the components of design research. The “application” question is part of the “research by design” domain. Here experimentation and testing is conducted using a relevant combination of principles on identified locations that are derived from the challenges and opportunities outlined in the analysis, but at the local scale. This contextualizes the framework and leads to the result which is the design and its evaluation.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03

AN UNDERSTANDING THROUGH SCALES

3.1 Structure of the City
3.2 Challenges and Potentials
3.3 Design Assignment

Image - Flickr - Climate Group

Urban Structure of Mumabi

Urban Built - Formal and Informal Settlements

Natural Systems - Mangroves and Rivers

03 | AN UNDERSTANDING THROUGH SCALES

3.1 | STRUCTURE OF THE CITY

STRUCTURAL ELEMENTS
Present day Mumbai can be divided into 4 structural elements, the urban area, surface water, natural green, and urban green.

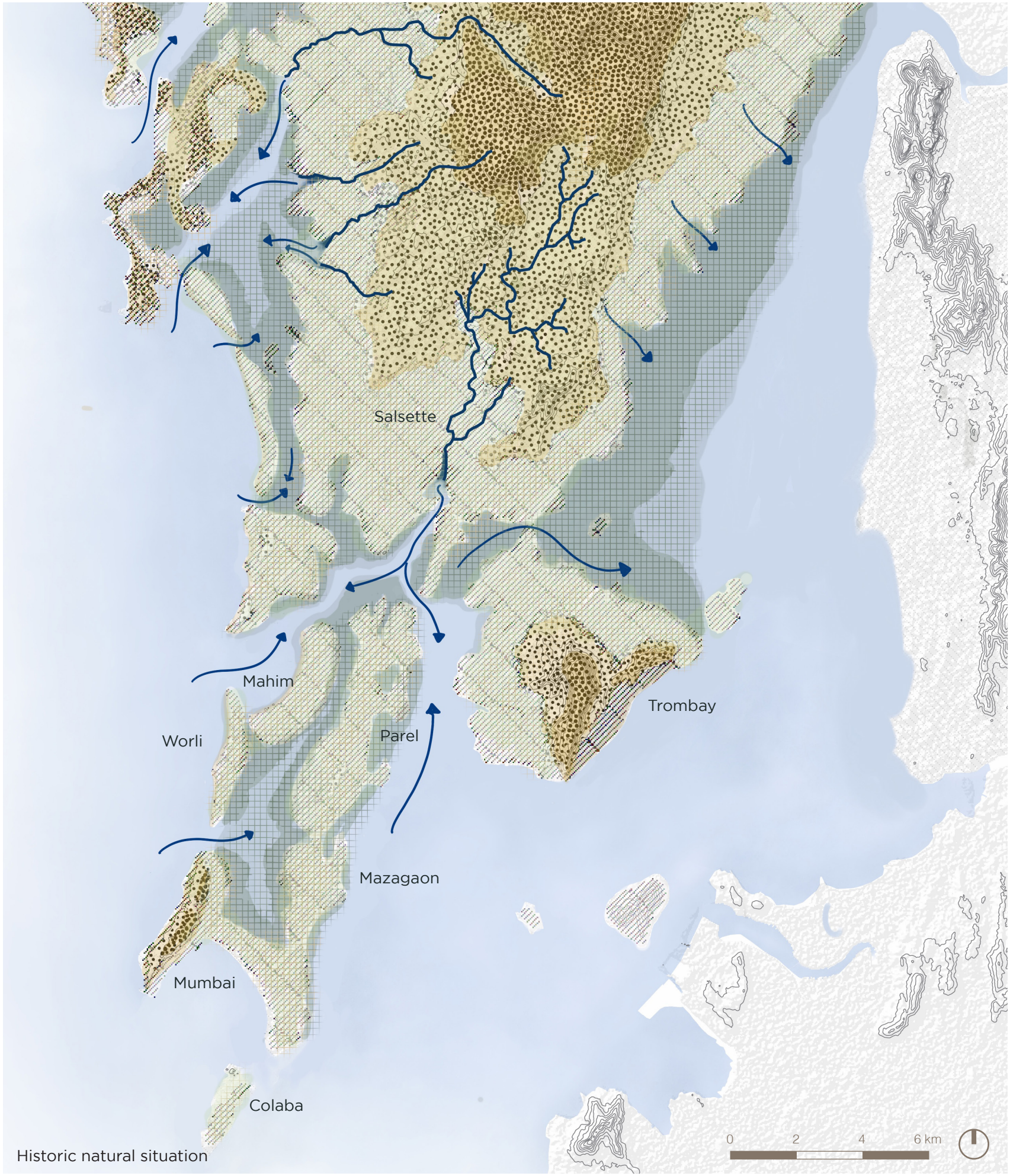
THE URBAN AREA
The urban area constitutes of the maximum surface area of the city. It consists of the built environment, infrastructure lines of roadways and railways, and informal settlements, the fishing villages and slums that are situated in the low lying area of the city. Additionally within this dense urban fabric there are historic structures – forts and caves scattered through the city.

NATURAL LANDSCAPE
The natural areas are situated along the coast and in the upper reaches. The main natural landscape along the coast is the mudflats and mangroves with a few beaches. At a higher altitude, the Sanjay Gandhi National park is situated which is a protected forest region.

SURFACE WATER
The surface water is comprised of three reservoirs – Powai, Vihar and Tulsi, built to supply drinking water to the city, situated in the upper forested area, and four rivers emerging from this region – Mithi, Oshiwara, Poisar and Dahisar.

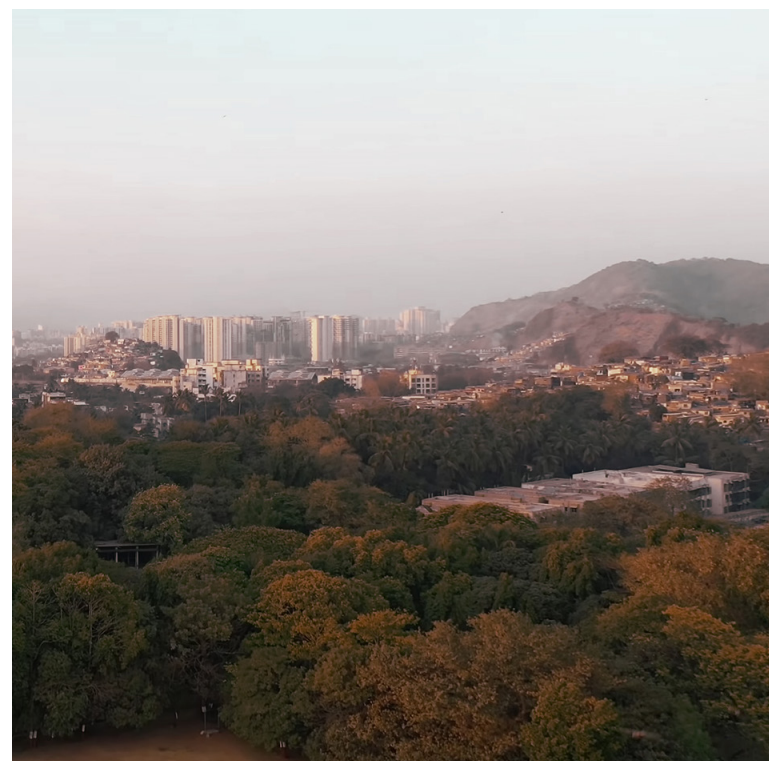
URBAN GREEN
The urban green structure is limited to a few pocket parks scattered through the city's highly dense urban environment.

Images: FLYING OVER MUMBAI (DHARAVI) 4K Aerial Film. (2019, July 27). YouTube. https://www.youtube.com/watch?v=uFEq-CB0Ev8&ab_channel=DannyMcgee



Historic natural situation

Mangroves and Mudflats



Highland Forested Areas

NATURAL LANDSCAPE - THE UNDERLAY

The natural underlay of Mumbai is characterized landscape consisted the estuarine region, and forested higher ground. The structuring elements of the estuarine region were the sea, beaches, rivers, tidal flats, mangroves and wetlands. The higher ground consisted of plains and forested land, and is often referred to as the seven historic islands that constitute Mumbai. However, simply put these areas were just higher ground in an otherwise largely wetscape. The system of this natural landscape relied on the interaction of salt and fresh water where the mangrove and mudflat ecology developed. These regions were either below sea level or just above. The wetlands were areas were areas where storm water would collect that emerged from the higher regions of the city. The inland area of higher altitude, which is the present day Sanjay Gandhi National Park had numerous waterways emerging from it and the slight changes in topography created a web of surface water flows. The first known inhabitats of the islands were the Koli community, or fishermen, who are still residing in parts of Mumbai today who relied on the water system for their livelihood.

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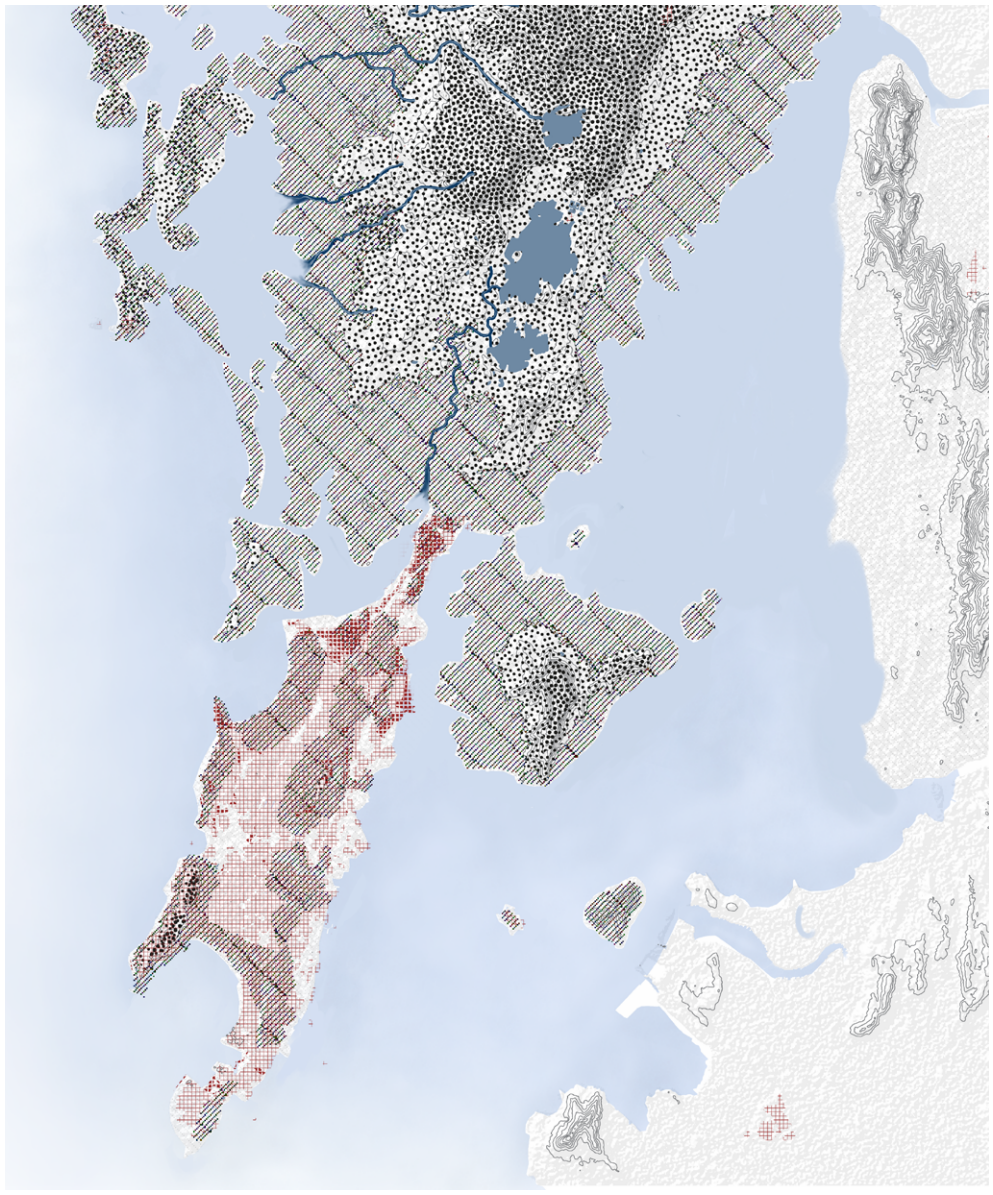
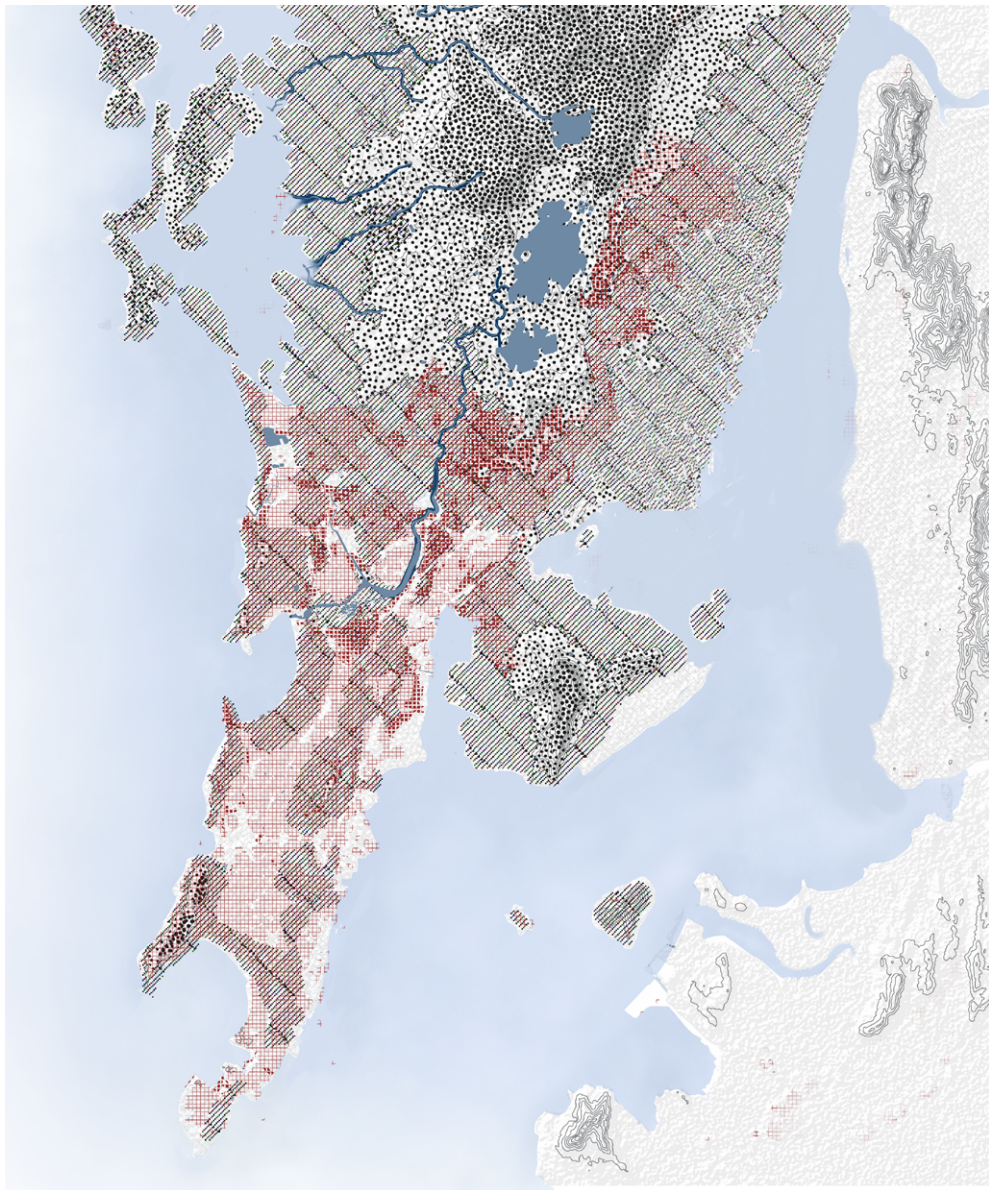


Water around islands reclaimed to form Mumbai
Reservoirs created to provide water to the city
Mahim Creek separating the city from Salsette Island
Population - 1,244,934

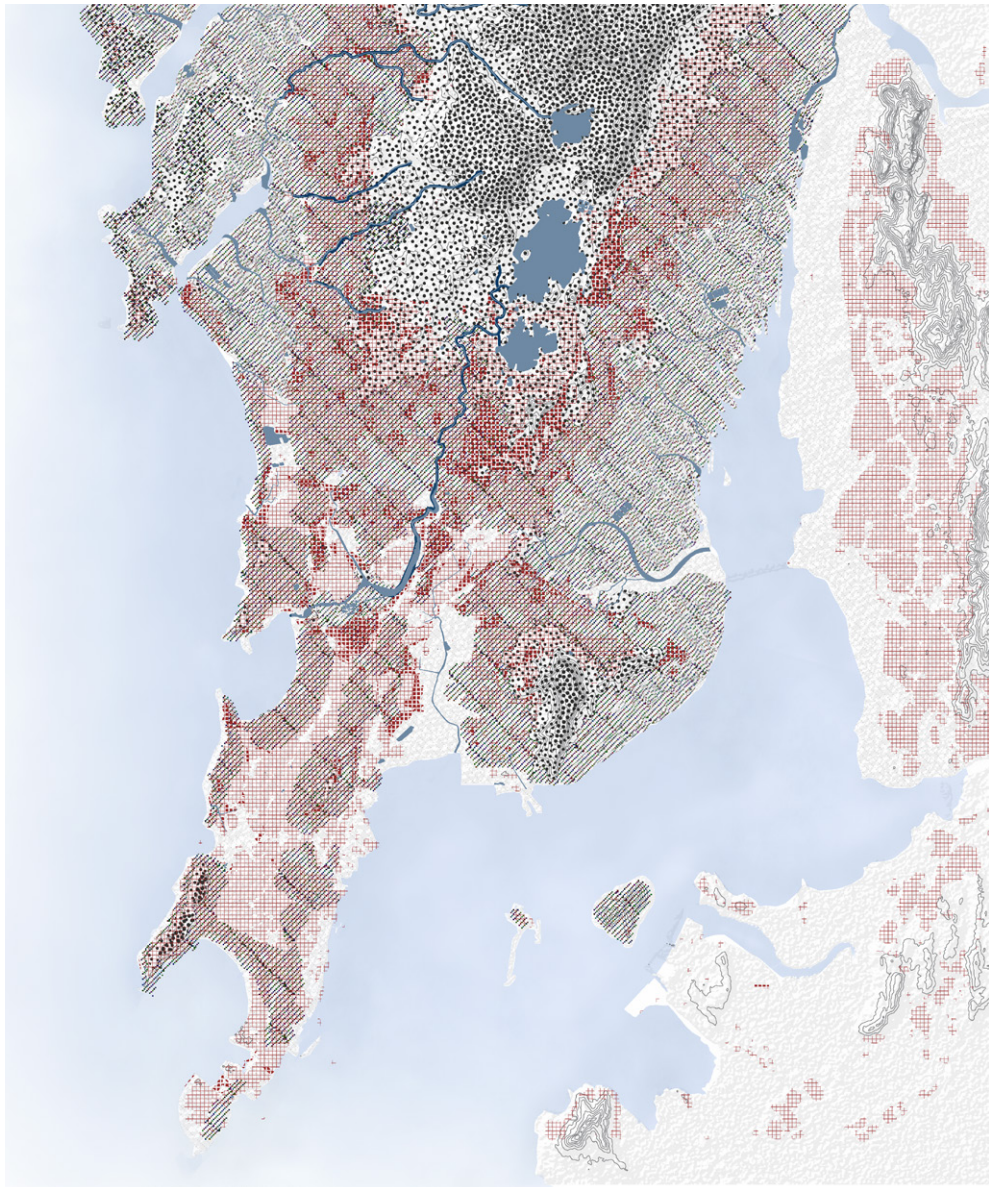
1850



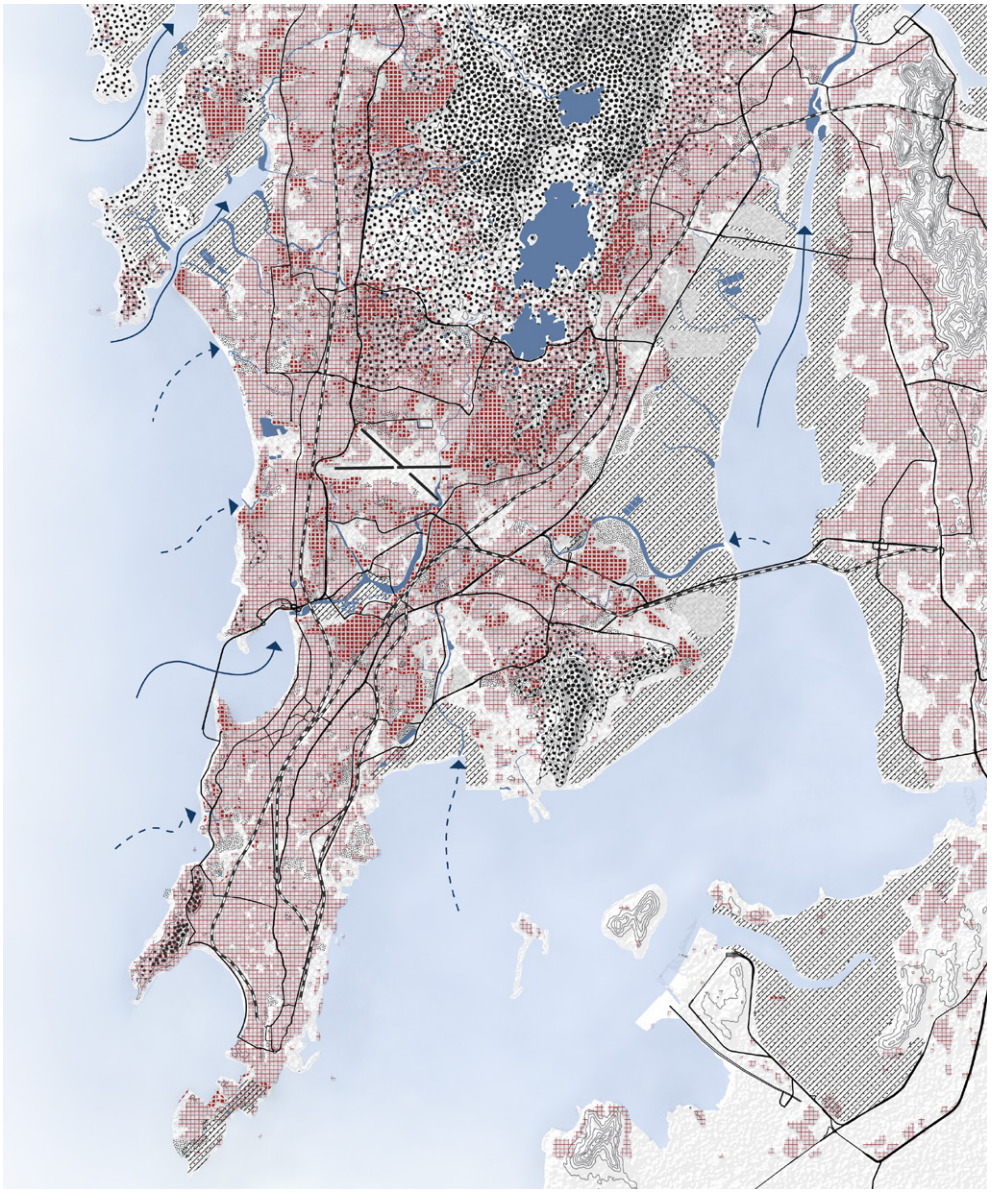
Mahim Creek reclaimed to expand city
City expanded to connect Mumbai to Thane
Expansion on Trombay
Population - 2,966,902

Based on Esri, DeLorme, NAVTEQ, 2013

1900



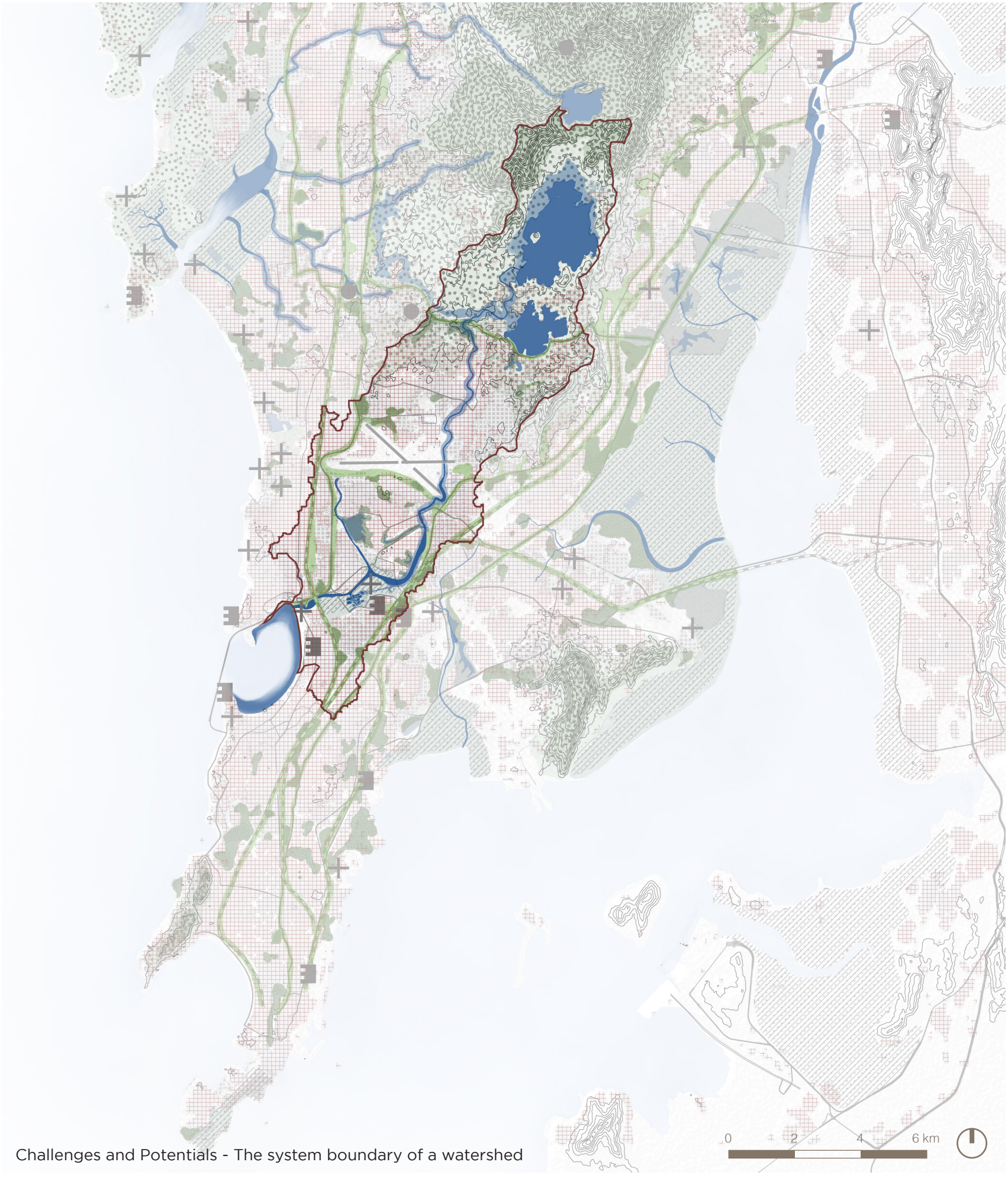
1950



Urban expansion on Salsette Island
Reclamation of mangroves and salt pans
Rivers reduced to lines
Population - 5,970,575

THE RECLAMATION PROJECTS

From 1700 onwards a series of reclamation projects were initiated under the British Rule where the natural landscape was converted to the urbanscape we see today. The strategic location of the islands made it a prime port for trade with the Indian subcontinent, and a population influx was initiated as the prosperity of the region increased. In this This process of unification of the estuary as initiated by the British resulted in the marginalization of communities that had been living there previously. The kolis were pushed towards the wet marshy grounds that remained and established their slum communities there.



Challenges and Potentials - The system boundary of a watershed

3.2 | CHALLENGES AND POTENTIALS

While the unification of these islands made the city a global hub in today's context, this came at a cost of a series of problems. What is left of the natural landscape is limited to depleting mangroves, depleting forest cover, a canalization of rivers to drains, and the expulsion of the local communities from safe land to land that is often water logged and unfit to build upon. The problems can be characterized into three main components - Hydro-morphological, ecological and communal - which can be seen and analyzed through a system boundary of a watershed. The Mithi watershed is the largest in the region where these elements come together.

HYDRO-MORPHOLOGICAL PROBLEMS

With the changes in natural water systems, discharge capacity and tidal dynamics are affected. Due to the construction of sea walls and causeways the sea doesn't have room to penetrate inwards. With the conversion of rivers into canalized drains, there is no room for stormwater that travels from the higher altitude regions. Additionally with all the hard surfaces that are introduced, the absorption capacity of the city is greatly lowered. However, the water system is a great potential as well. By restoring flows the vulnerabilities can be reduced.

ECOLOGICAL PROBLEMS

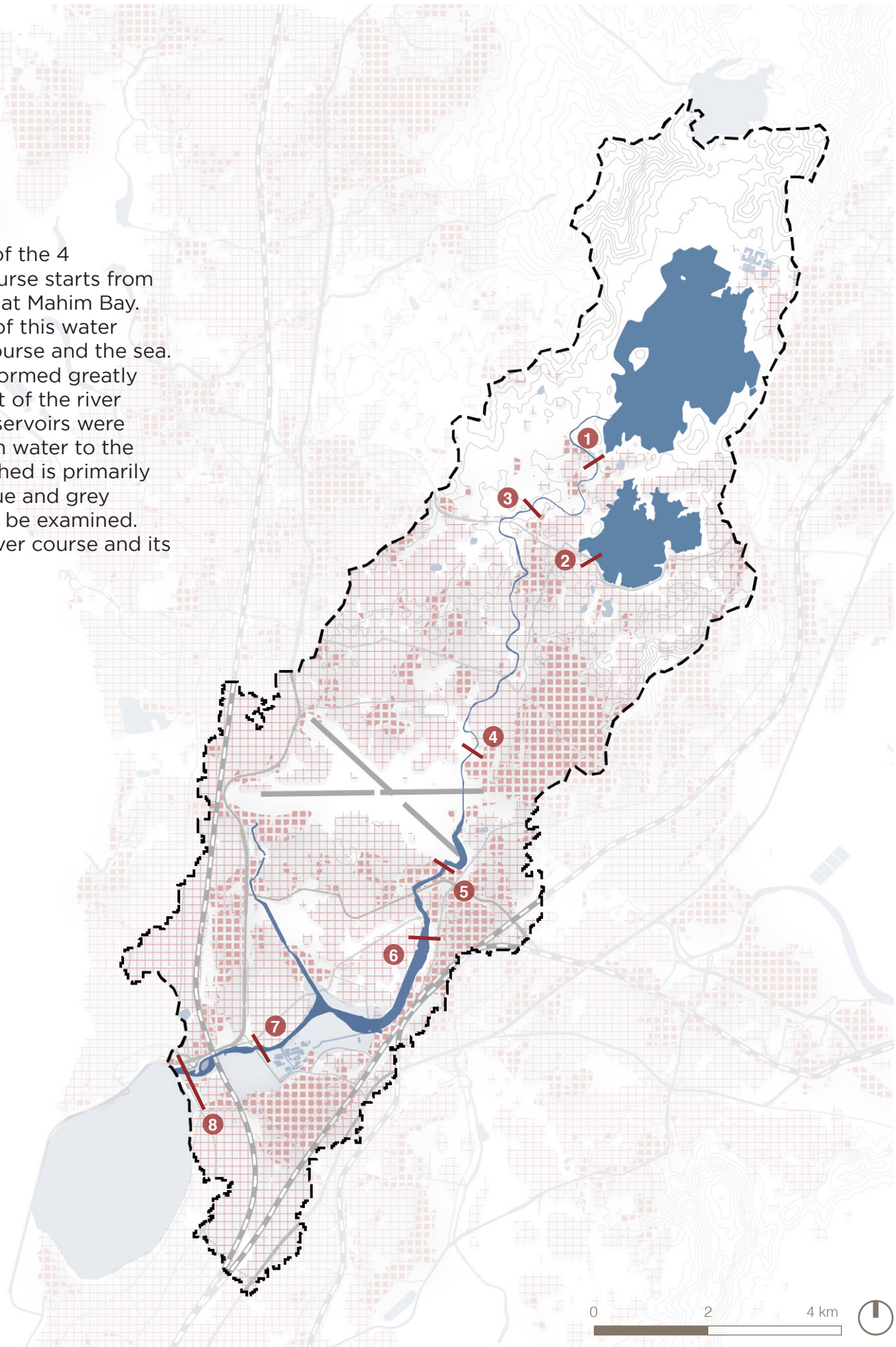
The various ecotones that existed in the natural landscape are compromised affecting biodiversity greatly. The system of flows and natural processes is stopped by urban infrastructure and buildings. The mangrove habitats are being encroached upon to make room for the ever increasing population. What is left of them, while protected is greatly endangered as they are bound by hard edges, not being able to get the required conditions of water and sediment to thrive. Additionally the forests fringes are also being encroached upon, as the urban sprawl of the city increases. However, open space system can be developed into a network and the infrastructure lines can act as connectors.

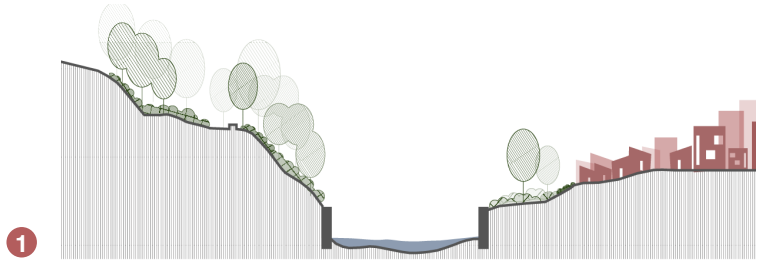
COMMUNITY VULNERABILITY

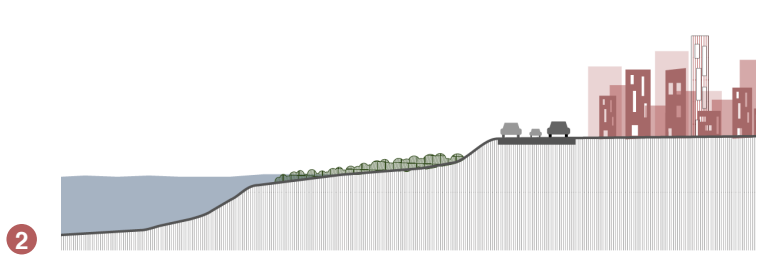
With urban sprawl, also comes the problem of community vulnerability. The locals have been marginalized and forced to establish residence in the most vulnerable low lying parts of the city. These areas are also where it is critical for natural systems to exist. Hence the pressure of urbanization, and now the need to re-establish natural systems is threatening their homes. While the density in these areas is high, engaging the communities where the vulnerability is most is a potential. Developing a public space system for these communities can be both socially and ecologically beneficial.

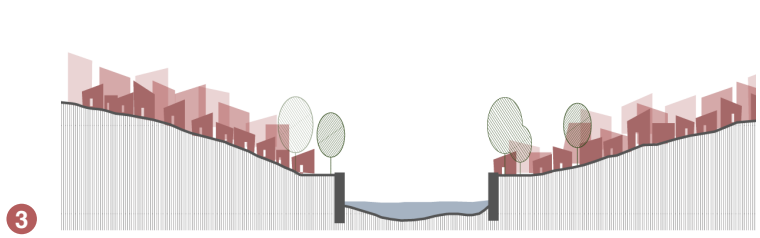
WATER SYSTEM

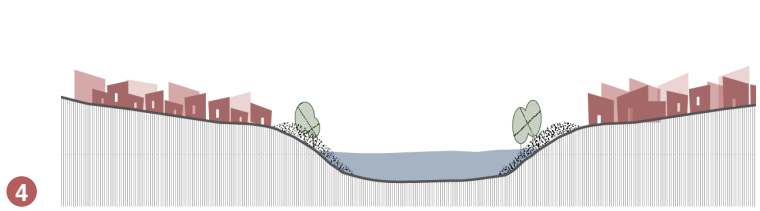
The Mithi watershed is the largest of the 4 watersheds in the city. The river course starts from the upper areas and meets the sea at Mahim Bay. There are three main components of this water system – the reservoirs, the river course and the sea. The natural river system was transformed greatly in the process of urbanization. Most of the river is bound by concrete walls. Two reservoirs were created in its course to supply fresh water to the city. The urban fabric of the watershed is primarily informal settlements. Hence the blue and grey infrastructure relationship needs to be examined. This series of sections shows the river course and its edges.

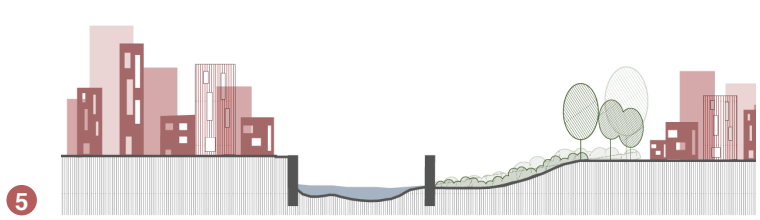


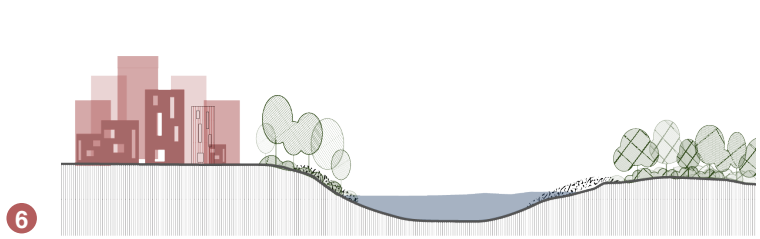


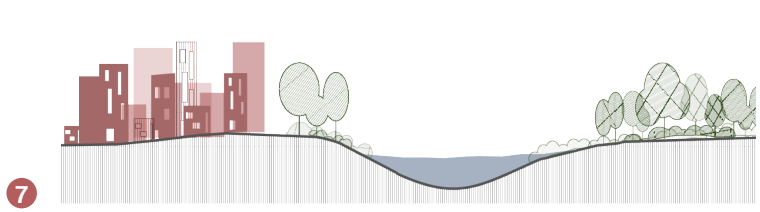


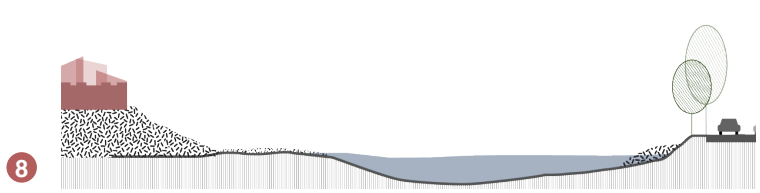












300 m

Origins. Concretized edges, narrow river.

Reservoirs: Urban development causing polluted reservoirs.

Informal settlement: Concrete edges result in urban density along banks.

Informal settlement: Sloping banks result in trash deposit along banks.

Urbanized areas: Concretized river, free standing walls that form unnecessary barriers.

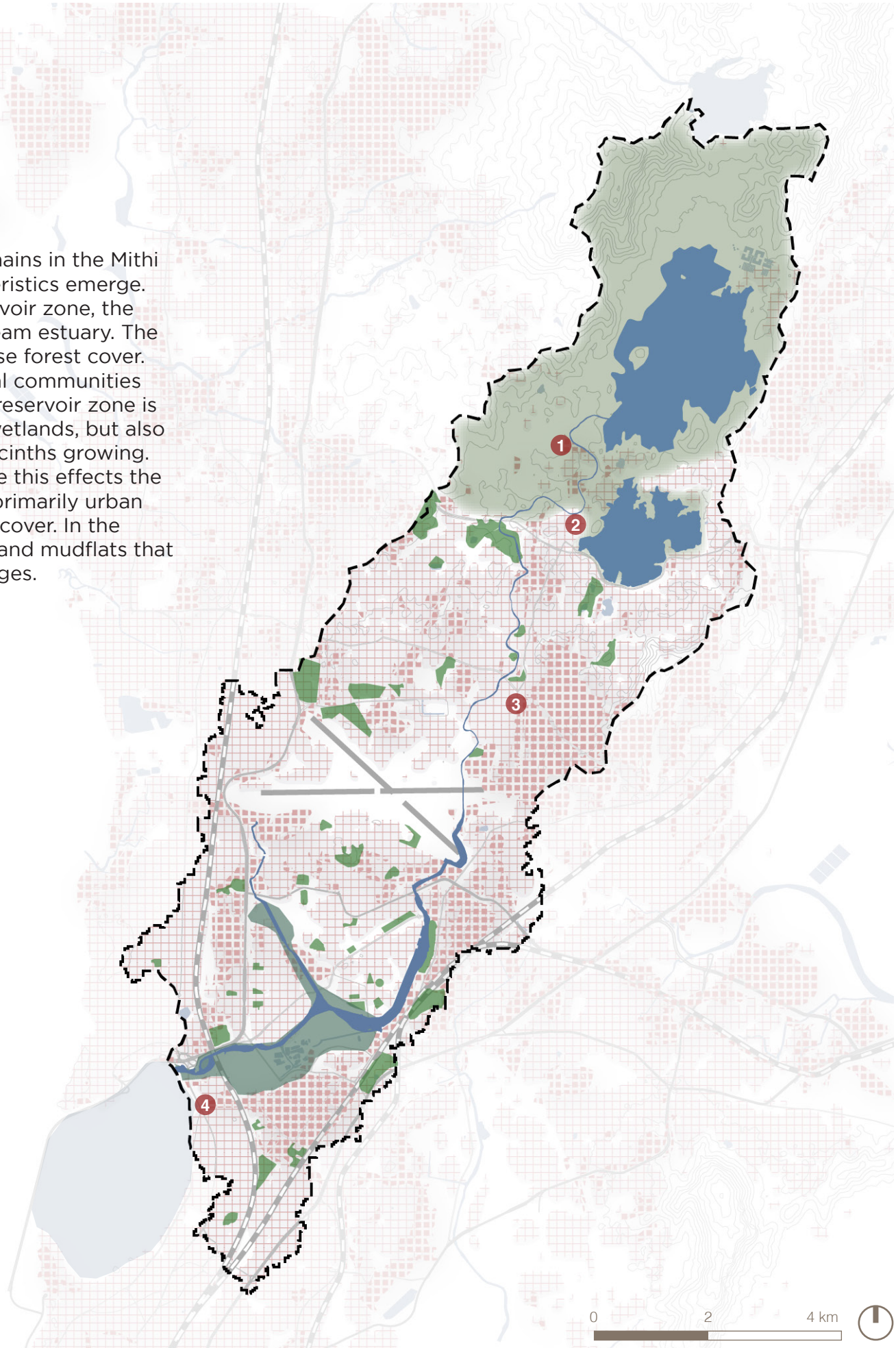
Mudflats: Coastal protection

Mangroves: Coastal protection

Estaury mouth: Historic forts, polluted beach and mudflats.

OPEN SPACE SYSTEM

Analyzing the green cover that remains in the Mithi watershed area, four main characteristics emerge. The upstream forest area, the reservoir zone, the midstream plains and the downstream estuary. The upper area is characterized by dense forest cover. However along the river edges local communities have established their homes. The reservoir zone is characterized by open water and wetlands, but also have parasitic plants like water hyacinths growing. The water quality is poor and hence this effects the ecology. The midstream stretch is primarily urban development with scattered green cover. In the coastal zone, there are mangroves and mudflats that are polluted and bound by hard edges.



Nature reserve

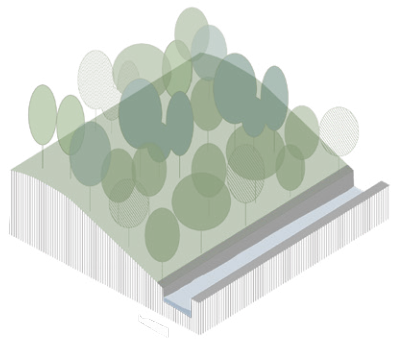
Forest

Wetlands

Urban green

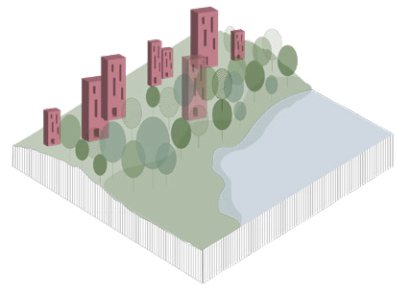
Mangroves

Mudflats



1

Upstream : Hardwood forest with nature reserve

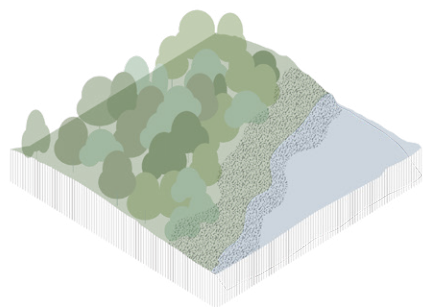


2

Upstream: Polluted water resulting in parasitic plants like water hyacinth

3

Midstream: Sparse urban green within dense urban fabric, segregated by constructed walls.

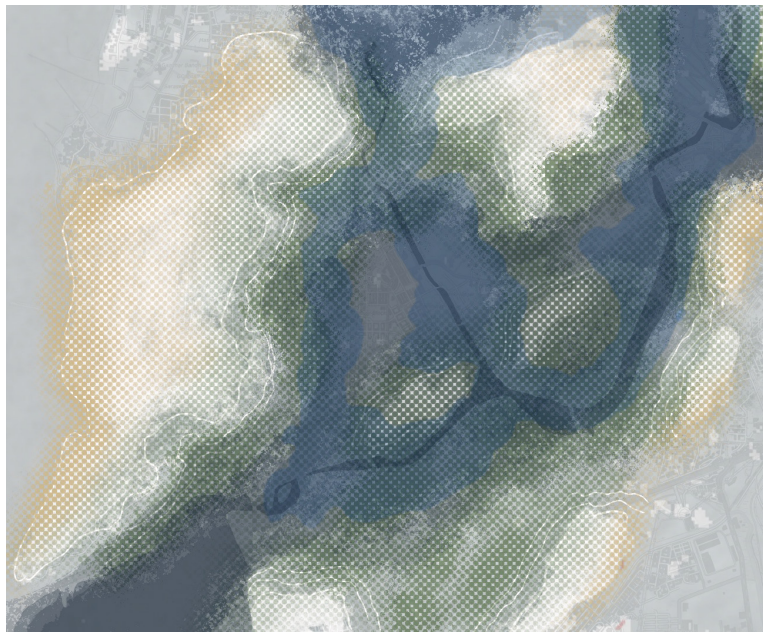


4

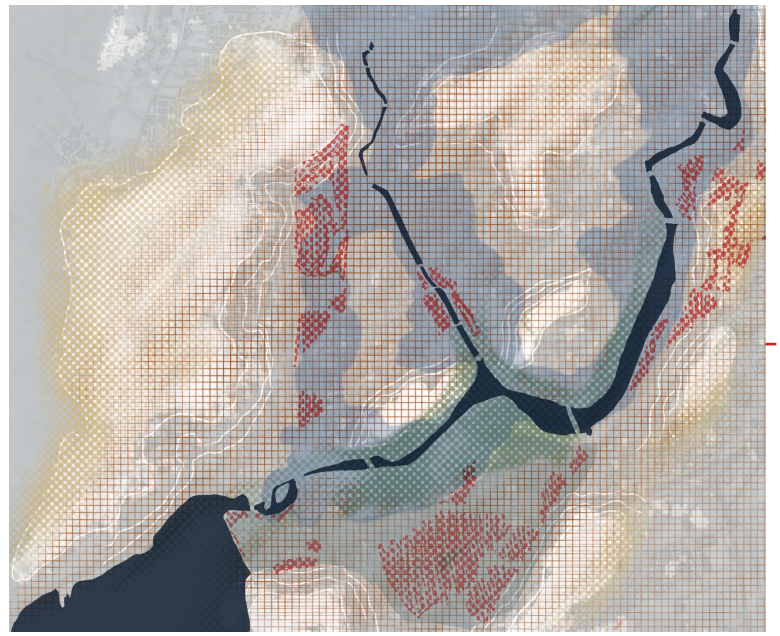
Downstream: Depleting mangroves and mudflats threatened by pollution and urban development.

VULNERABILITIES

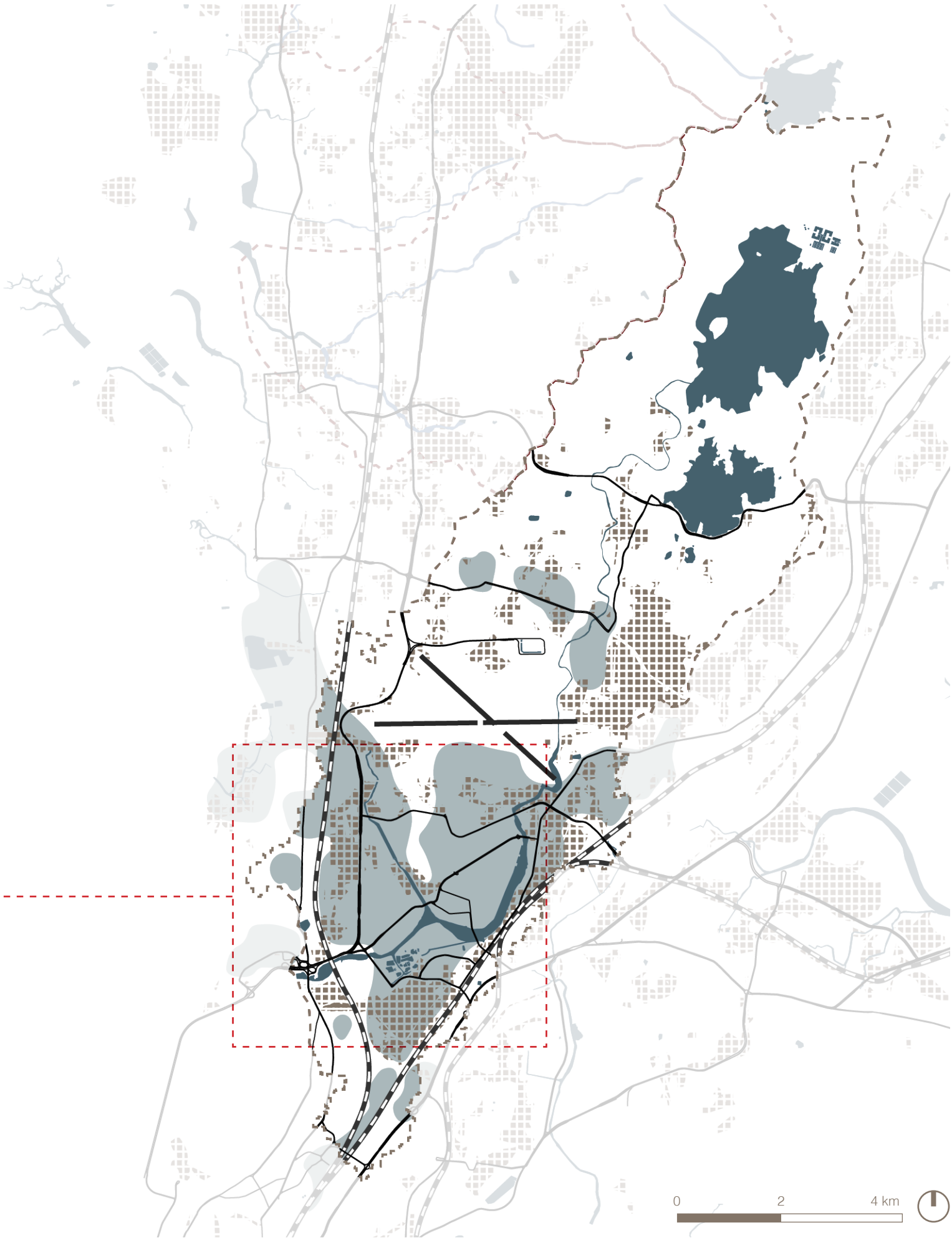
By previously analysing the urban transformation of Mumbai and the Mithi watershed blue-green system, one could see that the greatest transformation took place at the estuary where Mithi meets the sea. By looking at the topography and recreating the natural landscape for this region it can be seen that a wetscape of gradients existed. The natural landscape consisted of the sea, river, tidal flats, mangroves, wetlands and higher ground. A significant portion of it was reclaimed to connect various higher areas that would be convenient to inhabit. This created zones of low lying areas bound by infrastructure lines. These areas were unfit to build on and therefore have been occupied by informal settlements for a long time. This region is therefore important to address because it was initially composed of the natural flood defense system for the city, but was modified greatly and therefore experiences severe flooding.



Natural situation



Informal Settlements situated in vulnerable areas

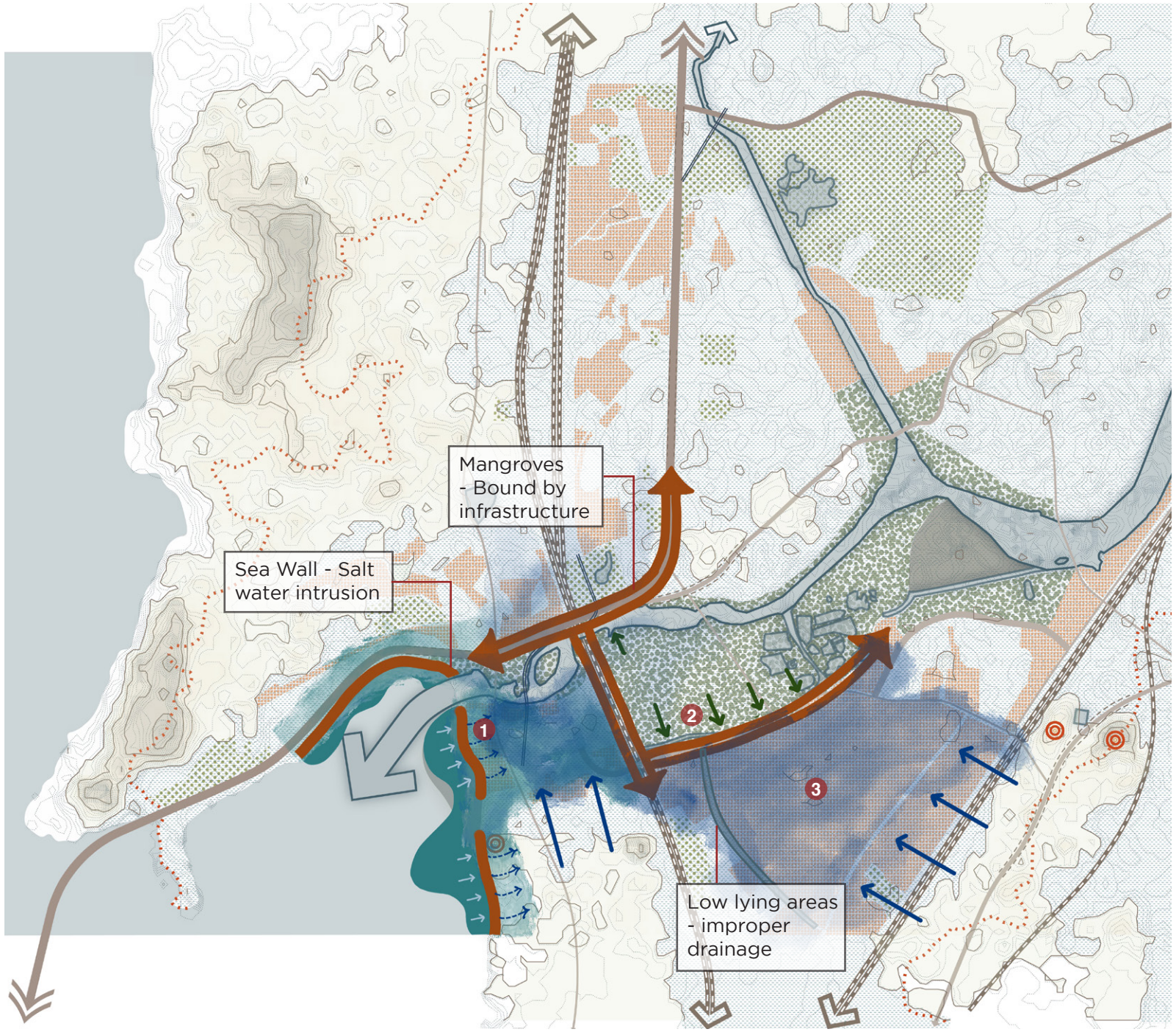


Highest flood impact zone

Largest concentration of informal settlements

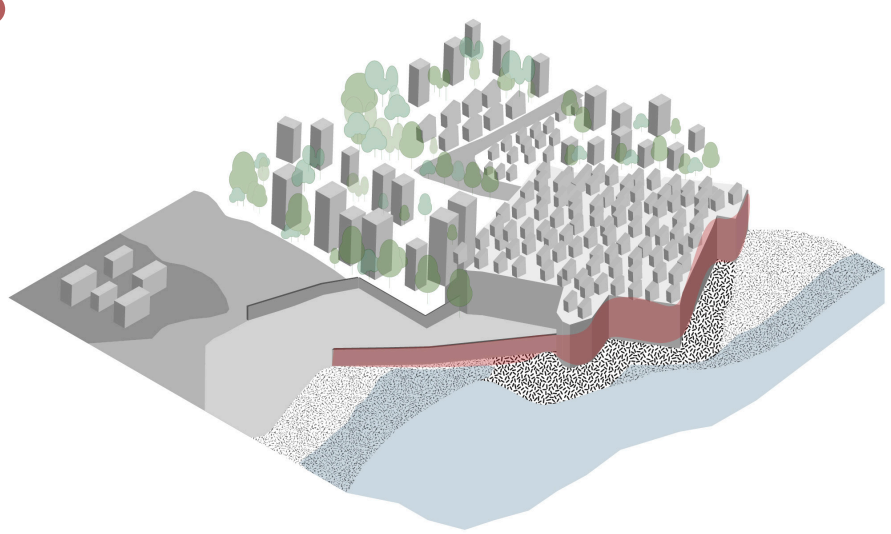
Infrastructure Barriers

Natural Flood Defense system - Mangroves

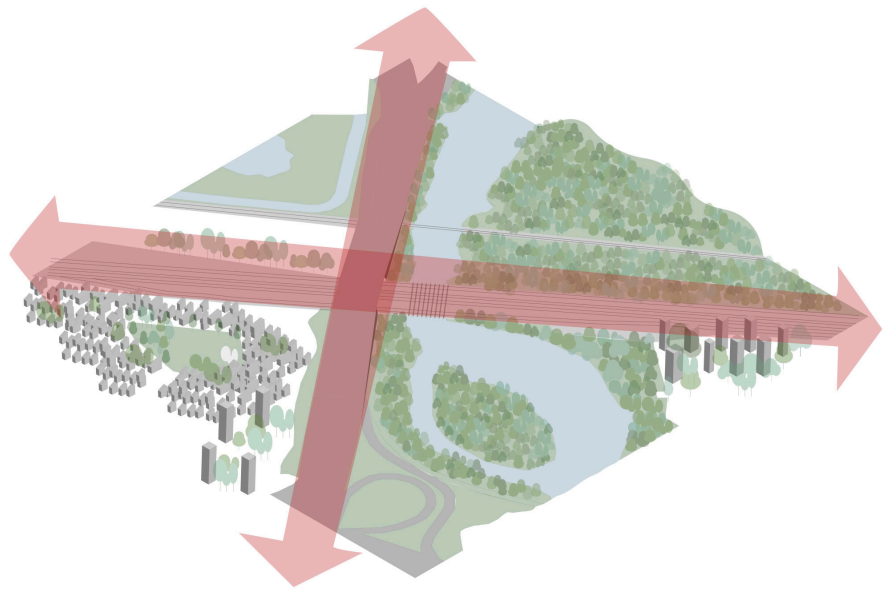


Challenges and Potentials of the Mithi Estuarine Zone

1



2



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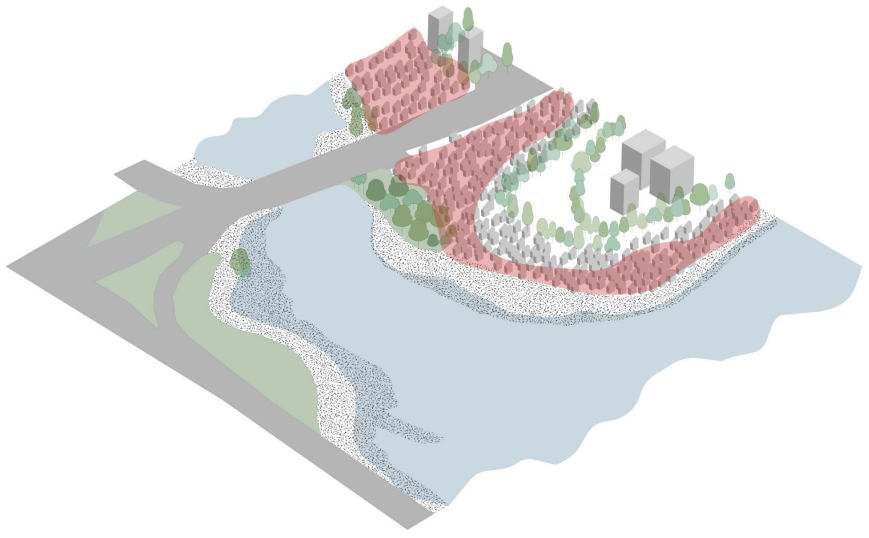


CONSEQUENCES

CURTAILING THE SEA
The river course has been narrowed with urban development on both banks. There is only one outlet for discharge to the bay. The area has a sea wall that removes the gradient needed for the sea to swell and results in salt water intrusion. There is an opportunity to increase discharge and inflow by penetrating the sea wall.

BINDING OF MANGROVES
The mangroves that remain are inwards away from the coastline and bound by the river on one side and the largest informal settlement in the world on the other. There are many infrastructural crossings that pass through them, roads, railways and even the freshwater pipelines. These barriers disturb the balance of water and sediment that is required for the mangroves to thrive, thereby endangering them.

IMPROPER WATER MANAGEMENT IN WETLANDS
The wetlands in this area are inhabited by informal settlements. Insufficient drainage systems result in flooding of these areas. Few drainage canals exist and paved surfaces result in a lack of percolation of water.

BLUE | Hydromorphology compromised - Sea Walls resulting in rise of ground water level with salt water intrusion

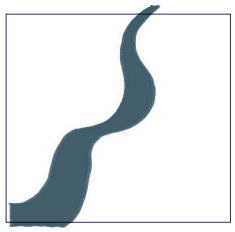
GREEN | Ecology compromised - Unhealthy mangrove landscape with infrastructure acting as a barriers

GREY | Community compromised - Informal Settlements prone to flooding - not enough room for water

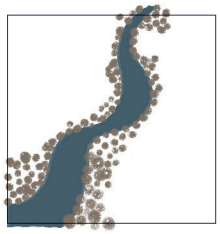
3.3 | DESIGN ASSIGNMENT

The understanding of the structure of Mumbai and the identification of challenges and potentials of the region provides direction for where intervention is necessary and what types of interventions can help address the challenges the city faces. In doing so a design assignment emerges that has the potential to contribute towards a healthy functioning city. Therefore based on the three systems - the blue green and grey - three challenges emerge - hydro-morphological recovery, ecological restoration and communal reinstation. From this potential systems are identified - the mangroves, the infrastructure lines and the informal settlements. Subsequently the design assignment is identified as coastal protection, restoration of flows and community safety.

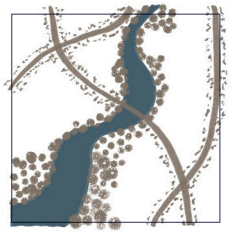
SYSTEMS



Blue

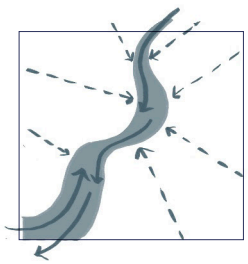


Green

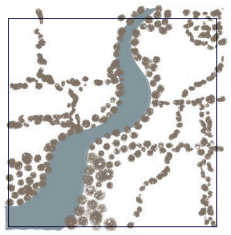


Grey

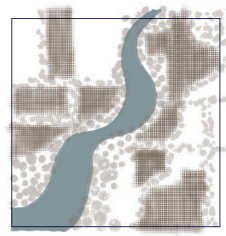
CHALLENGES



Hydro morphological Recovery

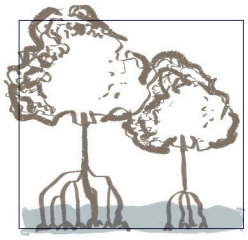


Ecological Restoration

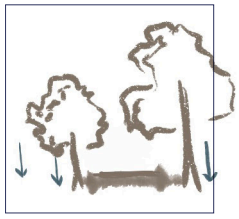


Communal Requalification

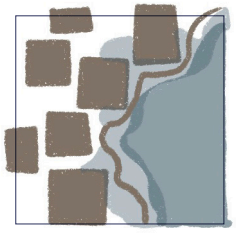
POTENTIALS



Mangroves

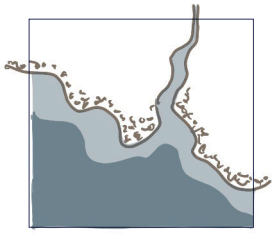


Infrastructure Lines

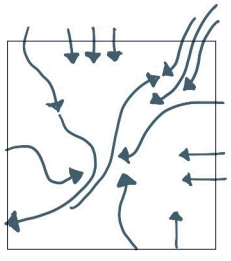


Informal Settlements

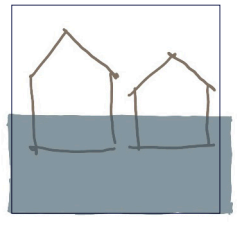
DESIGN



Coastal Protection



Restoring Flows



Community Safety

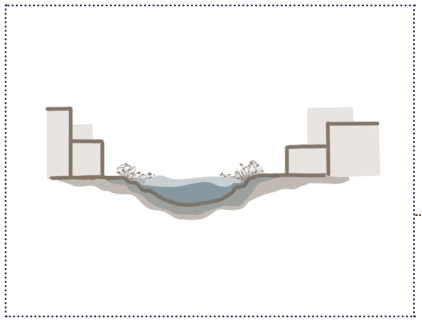
04

THE BLUE-GREEN VISION

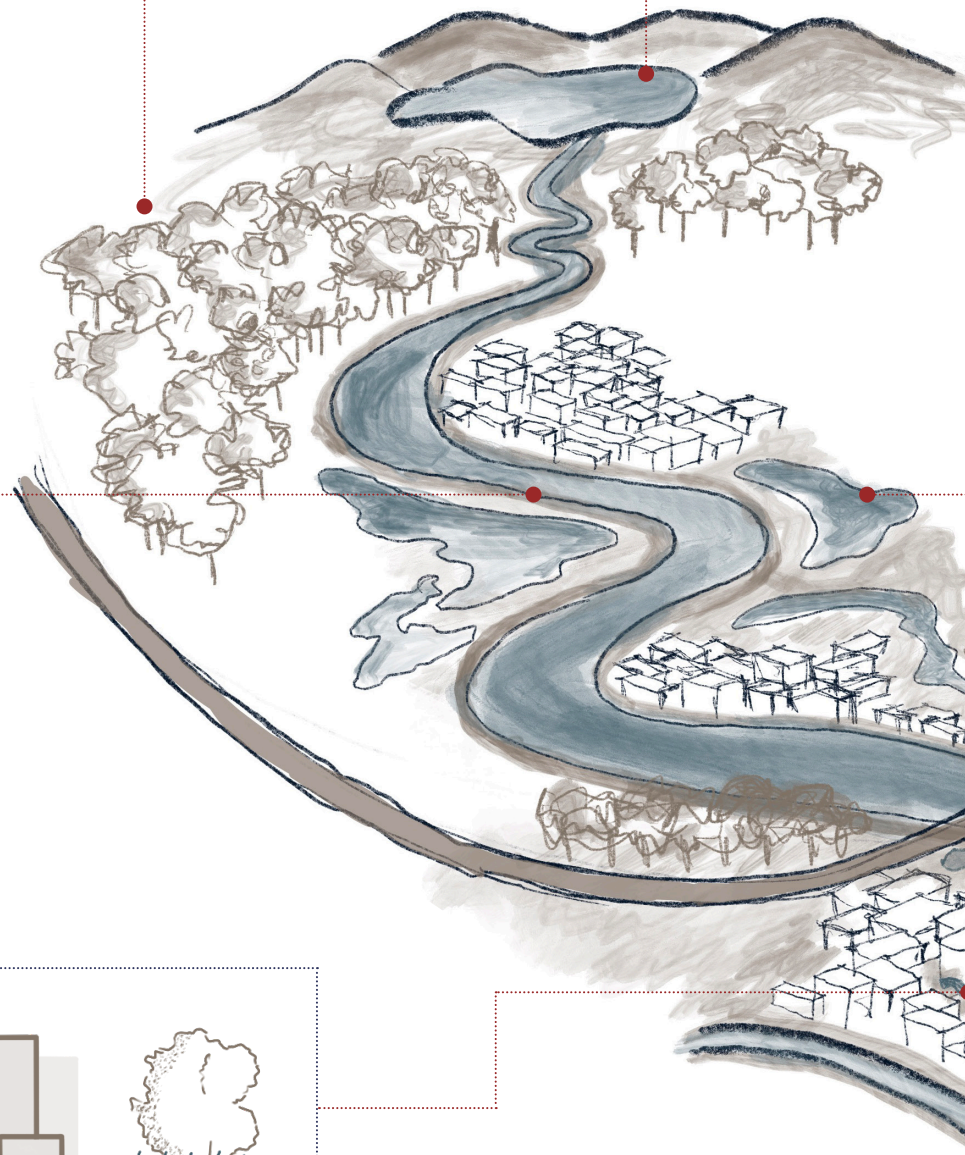
4.1 Introduction to the Vision
4.2 Design Principles
4.3 Case Studies
4.4 A blue-green Landscape Framework for Mumbai
4.5 One System

Image - Author

Urban Forests
Terracing
Natural gabions
Phytoremidiation



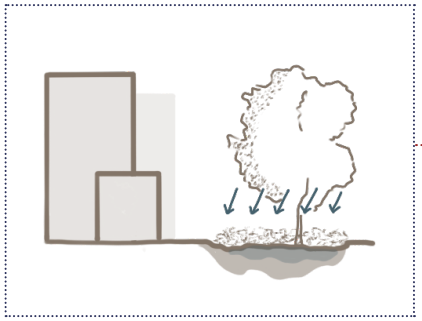
River Course Naturalization
Bank naturalization and stabilization
Oxbows
Dynamic edges



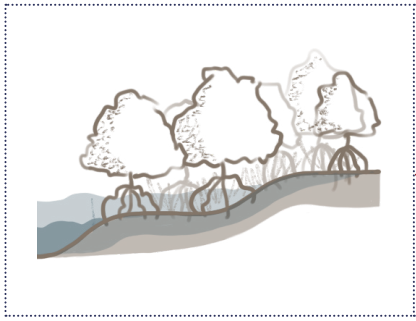
04 | THE BLUE GREEN VISION

From the analysis of Mumbai through scales, the design assignment that is identified involves three main components – coastal protection, restoring flows, and community safety. Zooming back to the scale of the watershed, many projects emerge where the blue-green systems can be activated. Nature based solutions (NBS) rely on blue and green infrastructure (BGI) that are capable of providing multiple functions and ecosystem services (Hamel, 2021). This chapter explores the possibilities for the design assignment by outlining design principles that can be applied in various combinations to create conditions for the blue-green system to be reactivated. The principles are derived via an understanding of the natural landscape and via case studies that use BGI as a tool. A regional blue green framework is presented as a conclusion for this chapter.

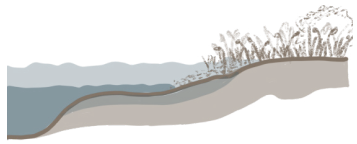
The research question addressed here is –
How can blue-green structures help to mitigate these challenges and be transformed into spatial design principles to restore natural systems, drive community safety and guide future urban development?



Permeable Surfaces
Pocket parks
Residential gardens
Rain gardens
Detention Ponds

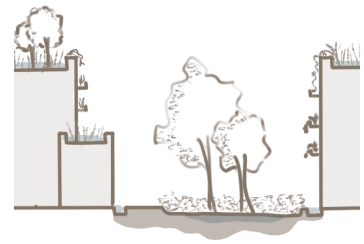


Mangrove Restoration
Ecosystem
Mudflats and beach safety

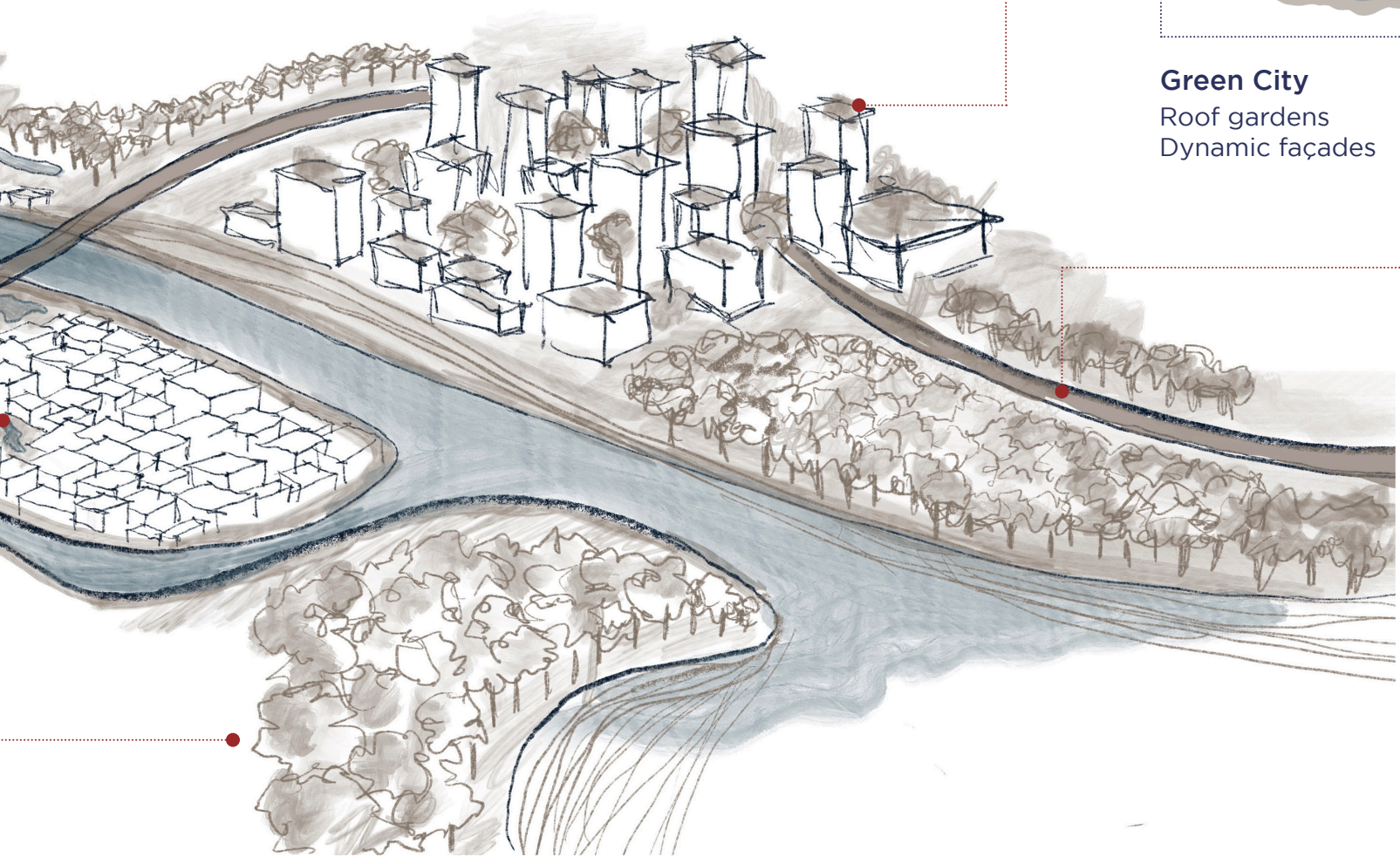


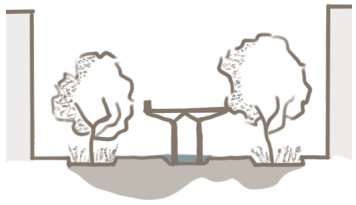
Reservoir retention
Increasing capacity for retention
Purifying plants for water quality
Recharge Soil

Wetland Reconstruction
Water filtration
Room for the river



Green City
Roof gardens
Dynamic façades



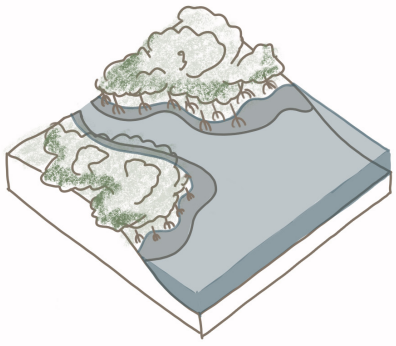


Ecological Corridors
Green avenues
Impervious surfaces
Drain channels
Shaded streets

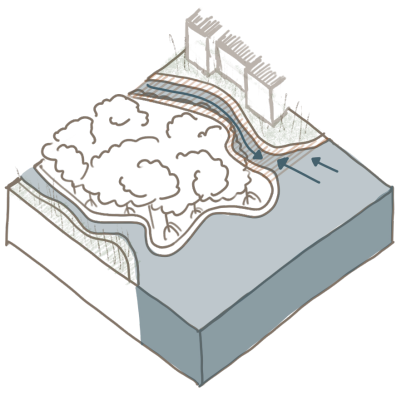
4.1 | DESIGN PRINCIPLES

Spatial principles derived from the natural landscape as well as precedent studies are highlighted below. These principles are directed towards the blue green vision and can provide conditions for improving the water system, ecology, and community of Mumbai. They can be categorized based on the elements in the landscape - the coast, the open water, public space and mobility. An application of a combination of principles leads to the local scale interventions.

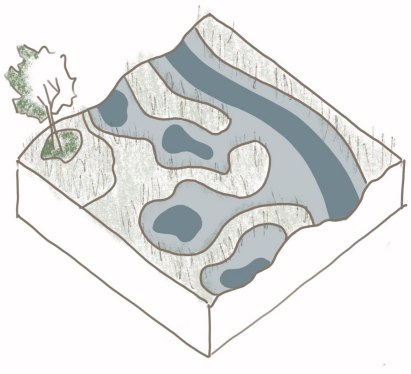
COASTAL



MANGROVES
Protection and restoration of the mangrove system to enable flood safety, shrimp production and river mouth ecology.

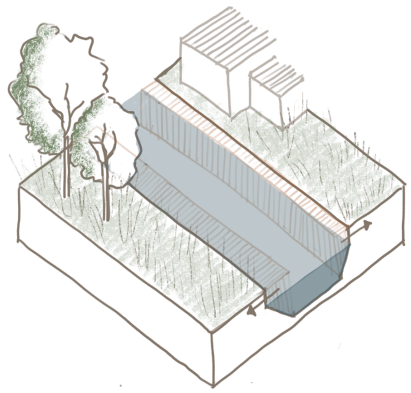


NEW CONNECTIONS
Allowing controlled inlet and outlet of water for increased discharge as well as to improve mangrove health by creating tidal dynamics.

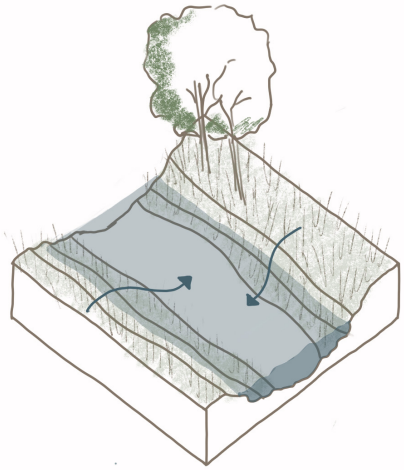


FILTRATION AND RETENTION
Connecting rivers to wetlands and restoring movement of water to ensure filtration through halophyte planting.

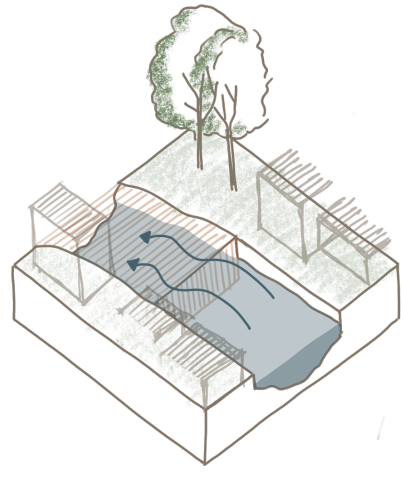
OPEN WATER



WIDENING EDGES
Making room for the river to increase capacity. Adjusting edges where possible

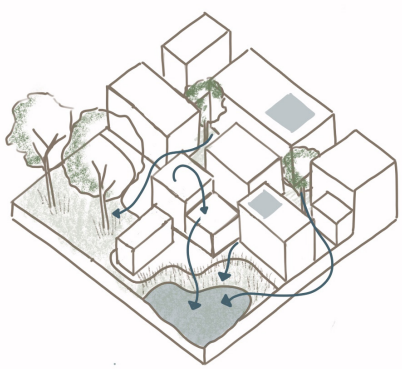


GRADIENTS
Where possible naturalizing the river banks to allow natural dynamics of the river and flood protection. This will also allow for new riparian ecology.



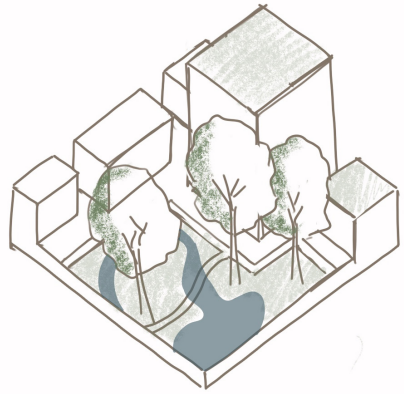
EXTENSIONS
Where possible recreating natural systems where water used to flow. Extending streams that have been reduced or erased.

PUBLIC SPACE



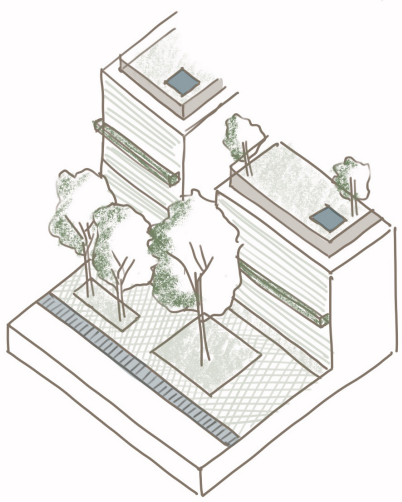
PERMEABLE SURFACES

Water flows and retention systems. Rearranging settlement to allow for absorption zones.



WATER STORAGE

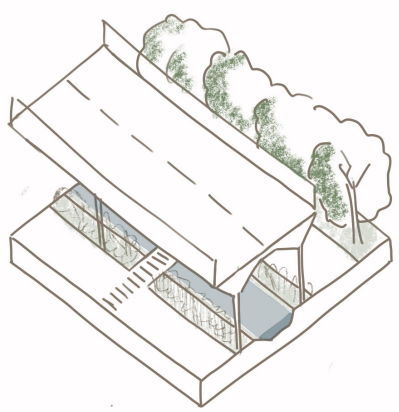
Urban areas where there is open space to be reorganized with green pockets and water ponds allowing groundwater recharge through rain gardens, detention ponds and water squares.



GREEN BUILDING

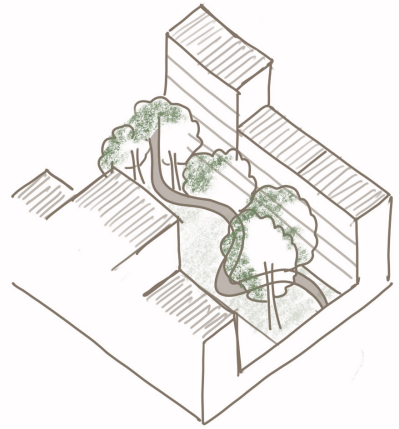
Building systems with a network of green roofs, rain water harvesting, green façades, shaded streets, drainage channels and impervious pavements.

MOBILITY



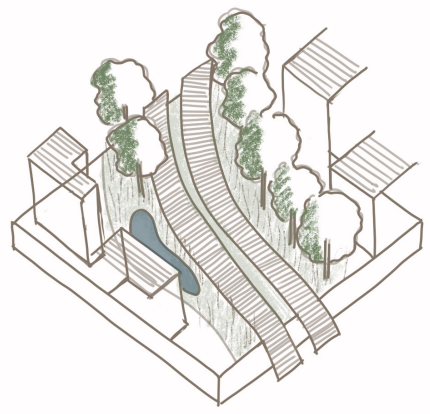
HIGHWAY AVENUES

Using the areas under highways as drainage routes. Linking urban green pockets.



CONNECTIONS

Creating a network of slow mobility that impacts both ecology and public space.



ECOLOGICAL CORRIDORS

Using train line as nature only zones allowing ecology to develop. Can be used as water management areas and slow moving traffic zones.

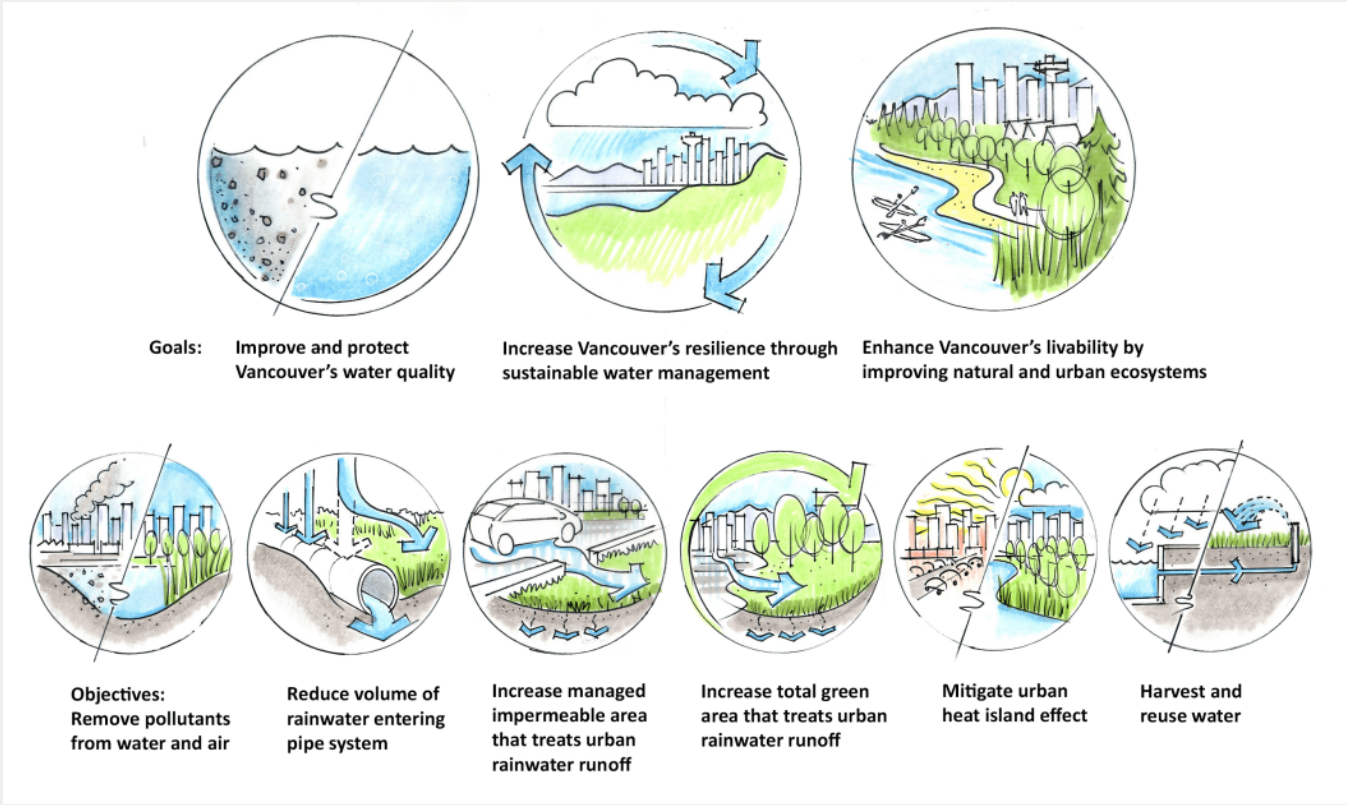


Image - vancouver.ca, Rain City Strategy

CASE STUDY 1
Rain City Strategy: A green rainwater infrastructure and rainwater management initiative
City of Vancouver

The Rain City Strategy re imagines the design of Vancouver's public space structure to include a holistic rain water management system. This research aims at improving and protecting the city's water quality, increasing its resilience through sustainable water management and Enhance its liveability by improving natural and urban ecosystems. It introduces Green Rainwater Infrastructure (GRI) that uses "both engineered and ecosystem based practices to protect, restore and mimic the natural water cycle and considers it a drainage infrastructure tool as well as an approach to water management and natural systems. (Vancouver, 2019) The plan highlights the importance of infrastructure in reducing discharge to pipe systems through onsite actions using streets and public space, buildings and parks and beaches. GRI implementation can contribute to climate adaptation and reduce the risk of flooding.

The main strategy for this project is to manage rainwater as close to where it lands. For Mumbai's context bioretention, resilient roofs, rainwater tree trenches, subsurface infiltration, absorbent landscapes and permeable pavements are some of the ways this can be achieved. While densification is essential, this research highlights the need for absorbent landscape areas. It also mentions the importance of separating sewer and drainage systems.

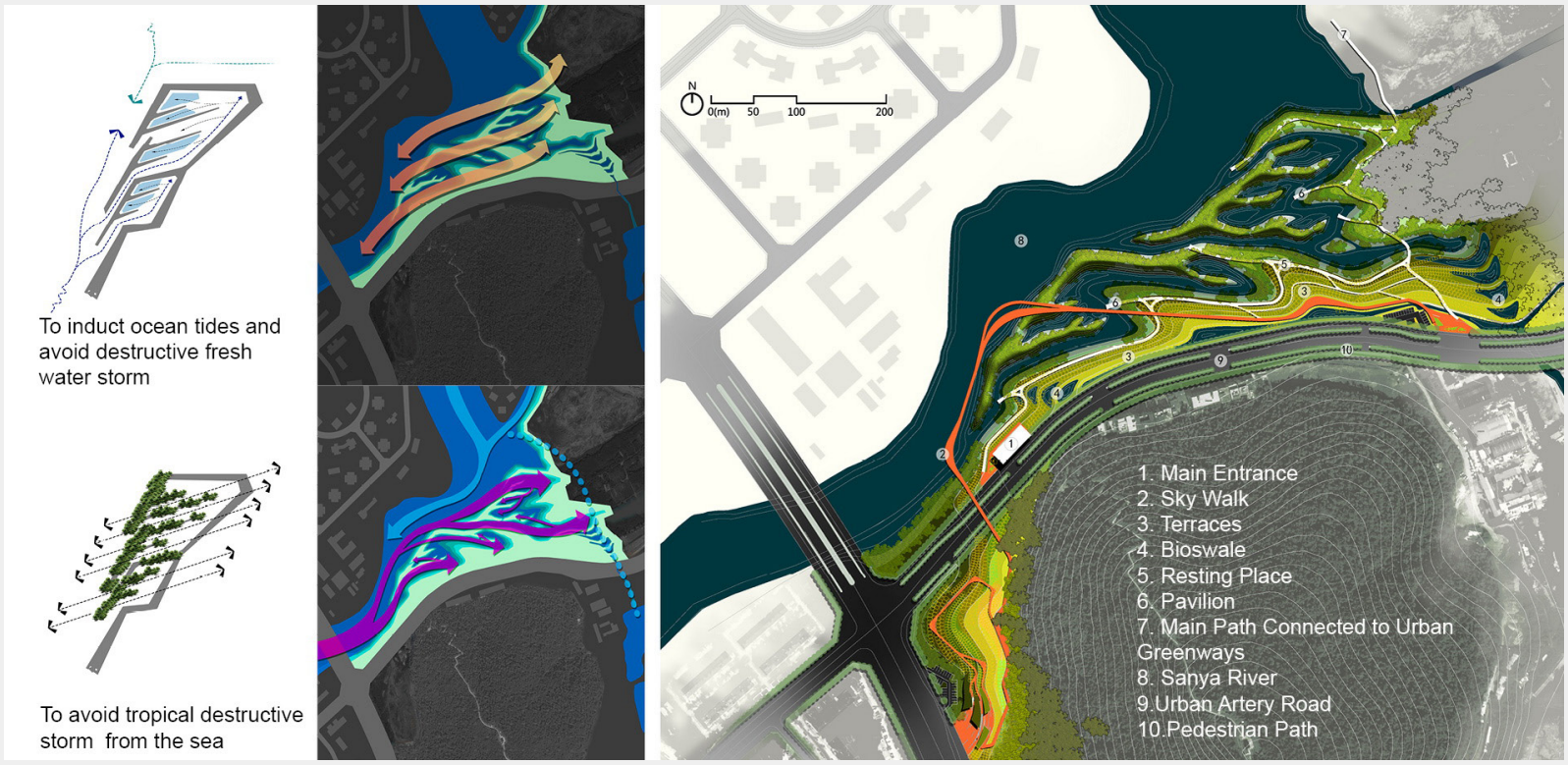


Image - vancouver.ca, Rain City Strategy

CASE STUDY 2
Sanya Mangrove Park
Turenscape

China's Hainan Island is vulnerable to flooding. This project aims at restoring the mangroves that disappeared, contributing to the safety of the area. The area that has been transformed into the mangrove park had polluted waterways and concrete flood wall. The new design creates the required tidal and stormwater dynamic that is needed to support mangrove growth. This project demonstrates the success of a design strategy based on ecological processes. The concrete flood walls killed the existing mangroves, wiped out the riparian habitats, blocked tides from the sea and storm water from the upper land causing flooding.

The strategies that are relevant for the context of Mumbai are the interlocked form that was created allowed the tide inwards but prevent the tropical storm surges from flooding the region. Terraces and bioswales were created to catch the stormwater from the urban pavement and road, creating different elevations of water. Additionally pedestrian passageways follow the new geometry making the mangrove park accessible. The success of this project makes it a relevant case study because the coastal area of Mumbai is also lined with mangroves that are deteriorating and need rehabilitation. Because this area is now a habitat for fish and birds as well as a place for leisure, this project shows that ecological restoration can benefit the environment as well as the community.

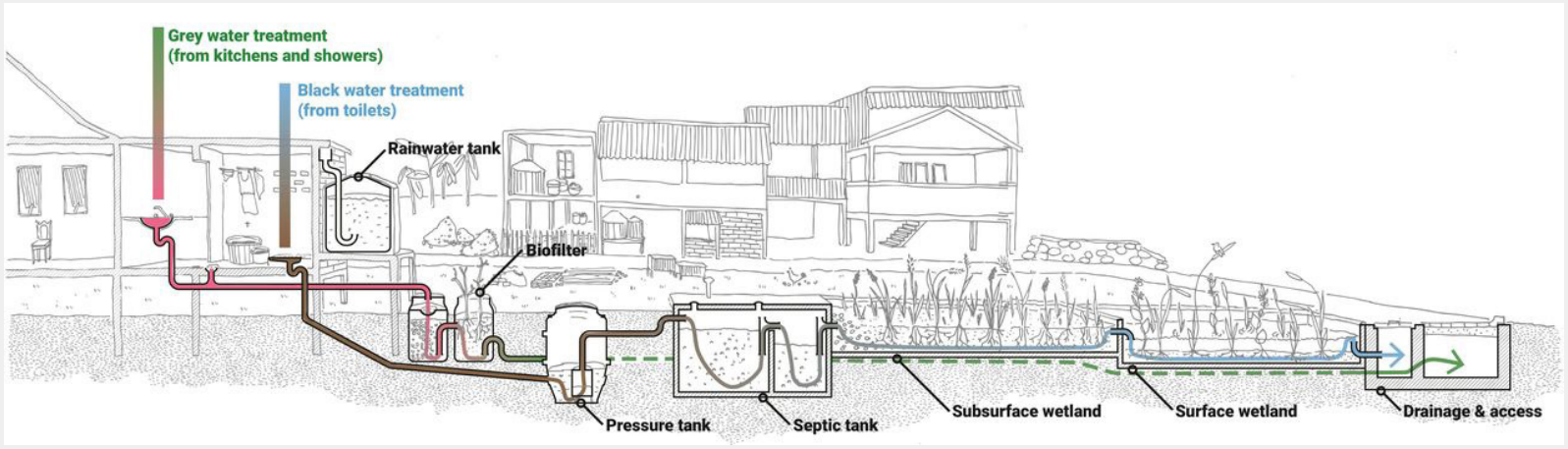


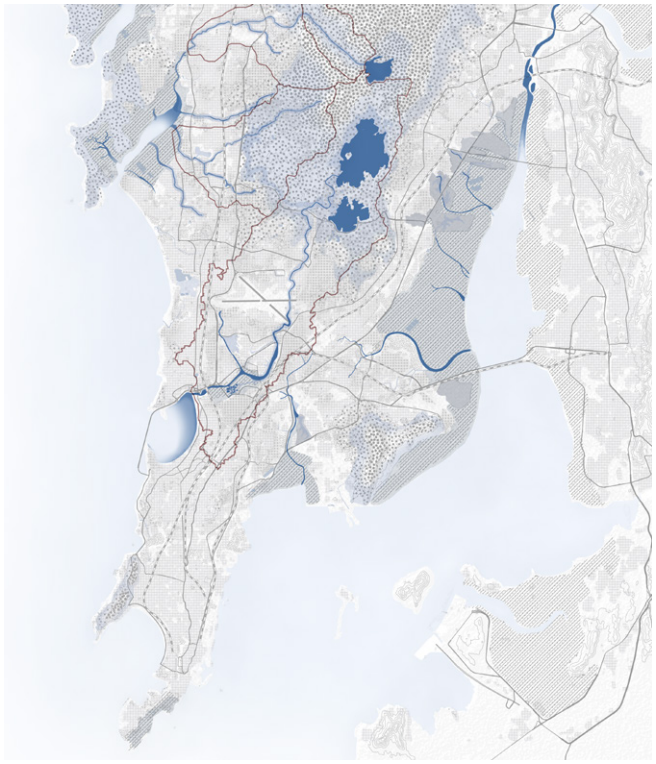
Image - RISE, Leder, 2021b

CASE STUDY 3

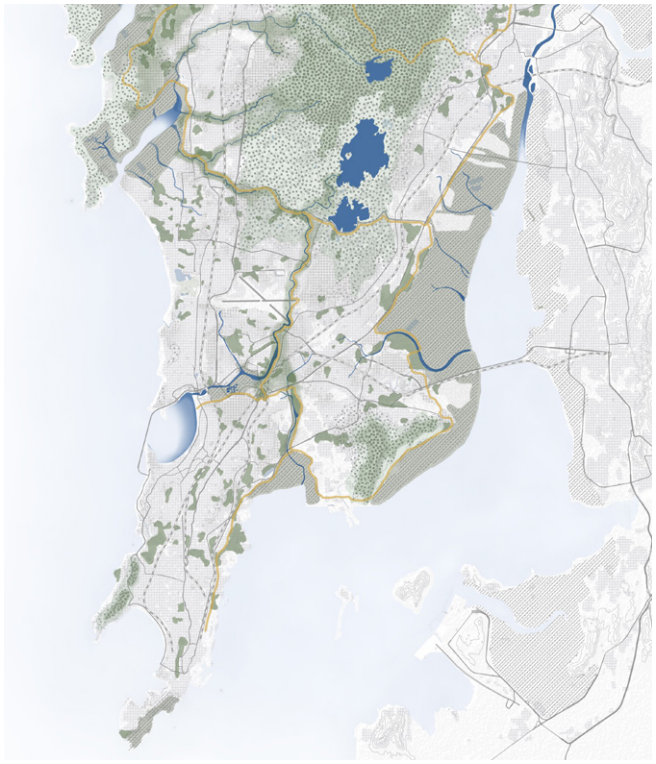
Study design, rationale and methods of the Revitalizing Informal Settlements and their Environments (RISE) study: a cluster randomised controlled trial to evaluate environmental and human health impacts of a water sensitive intervention in informal settlements in Indonesia and Fiji
RISE

This RISE research focuses water management systems in informal settlements. The main goals are limiting community exposure to environmental pollutants, improve water cycle management, diversifying water source supplies and attend to water drainage and flood management. (Leder, 2021) This study deploys an urban design approach to water management where wastewater and stormwater quality is improved prior to reuse or discharge. The solutions also include the decentralization of water infrastructure to prevent the sewage and greywater to be released into the environment.

The strategies deployed that are relevant to the case of Mumbai are constructed wastewater treatment wetlands with biofilters and biofilter drains for grey water. The existing drains are reprofiled or resized as per requirements. Swales, rain gardens and permeable paving is suggested. For water supply, rainwater collection tanks can be created. These strategies can be deployed within the informal settlements in Mumbai to ensure a system of natural water filtration, so that water can be reused and purified before it is pushed out to sea.



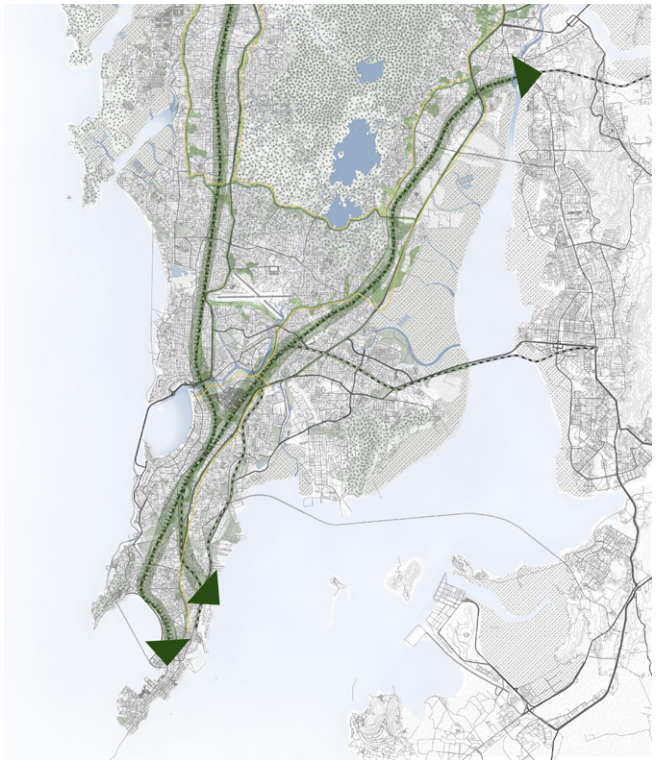
Increasing Retention
Increasing Discharge Capacity
Restoring tidal dynamics
Protecting and enhancing the coast
Systems for delay, filtration and reuse



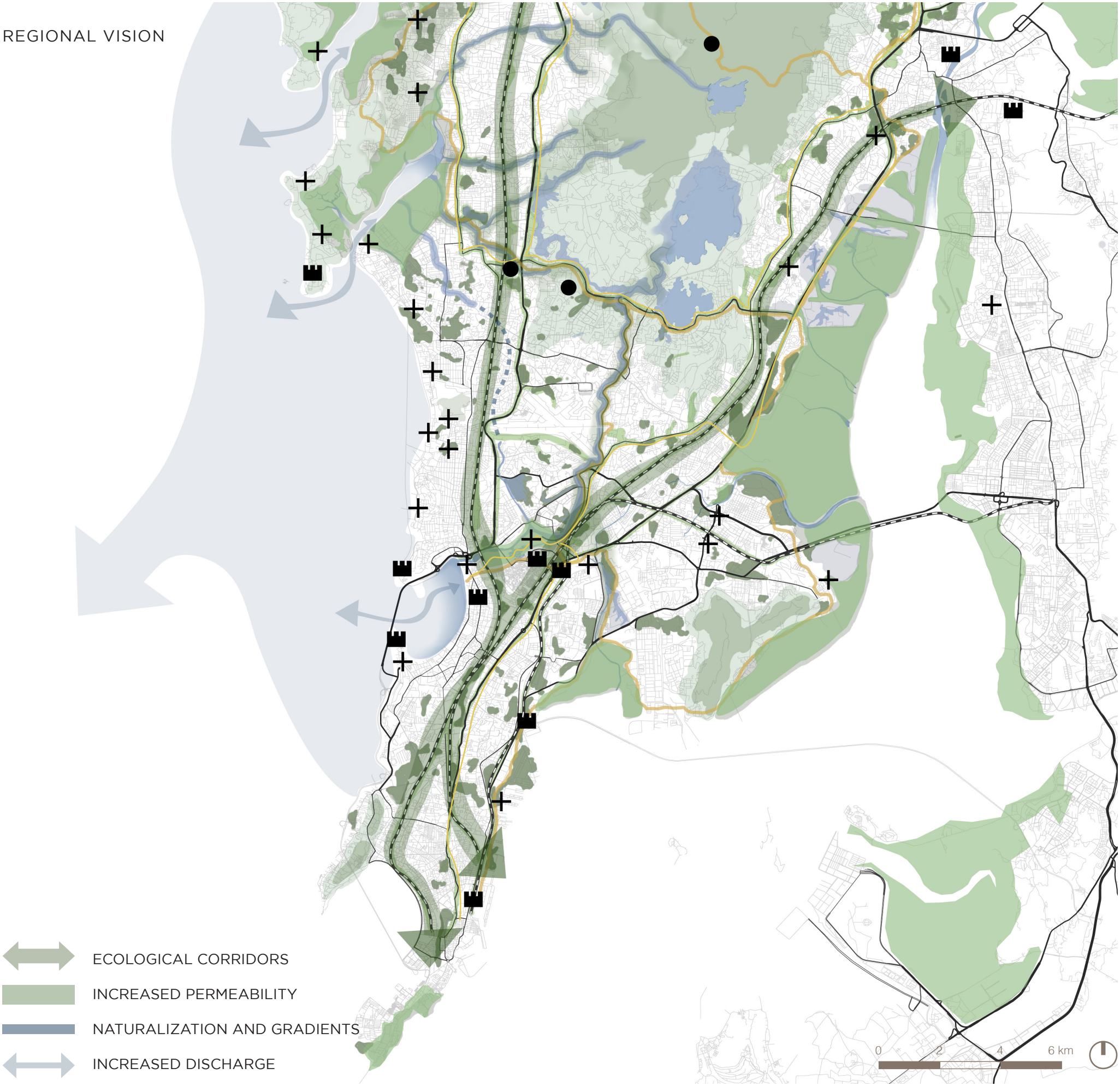
Sponge Capacity
Biodiversity
Connecting open urban green spaces
Integrating agriculture into the green network

4.3 | A BLUE-GREEN LANDSCAPE FRAMEWORK FOR MUMBAI

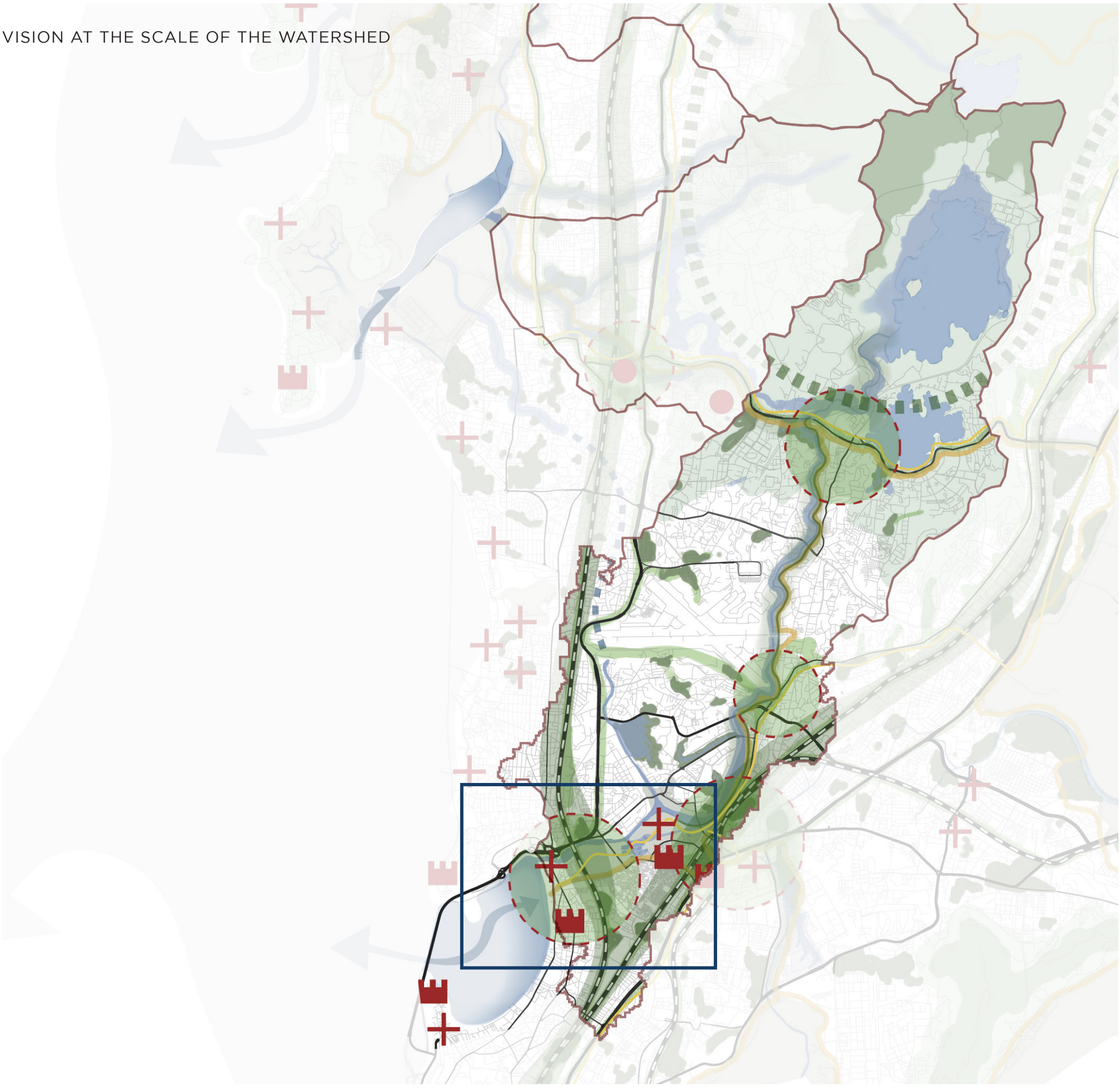
In the theoretical framework previously discussed, blue-green infrastructure (BGI) is defined as “an interconnected network of natural and designed landscape components, including water bodies and green and open spaces, which provide multiple functions such as: (i) flood control, (ii) water storage for irrigation and industry use, (iii) wetland areas for wildlife habitat or water purification, among many others.” (Ghofrani, 2016). Additionally, infrastructure can be seen as a type of a landscape, and landscape as type of infrastructure. (Nijhuis, 2015) This forms the basis of a blue green infrastructure network for the city, which involves not only blue and green elements but also grey elements. The smaller maps show the blue green and grey elements and highlight the services they can provide. The map on the right shows the composite vision for the region.

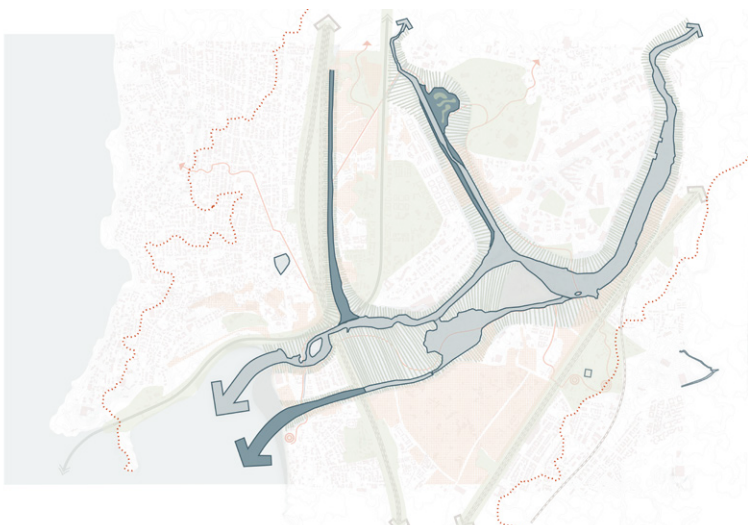


Ecological corridors
Using crossings
Slow mobility
Connecting urban green


ECOLOGICAL CORRIDORS
INCREASED PERMEABILITY
NATURALIZATION AND GRADIENTS
INCREASED DISCHARGE
0
2
4
6 km

VISION AT THE SCALE OF THE WATERSHED

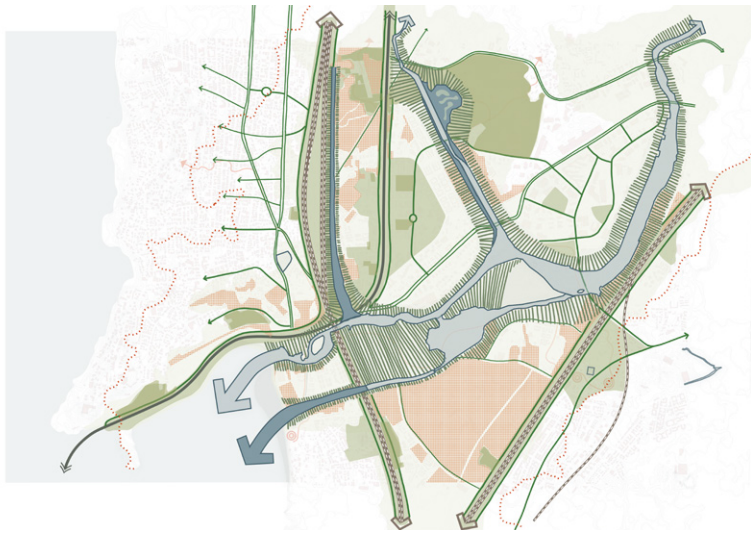




ACTION - RESTORING FLOWS
Reconfiguring the water system to increase discharge and improve tidal dynamics

IMPACT - MANGROVE RESTORATION
Flood Safety
New ecologies
Community relationship with natural system

ACTION - REINTRODUCING GRADIENTS
Reducing hard edges, connecting green spaces and making room for soft surfaces within urban fabric.



IMPACT - SOFT CITY
Increased sponge capacity
New ecologies
Infrastructure as connector not barrier

4.4 | ONE SYSTEM

Previously the Blue-green Landscape framework addressed the regional and watershed scales. In this section, the blue green framework is applied more locally, at the scale of the Mithi Estuarine Region. The concept for this area addresses two major actions – restoring flows, and reintroducing gradients. Here landscape is seen as infrastructure and infrastructure as landscape. By performing two large scale actions – there are impacts.

RESTORING FLOWS
By reconfiguring the water system to increase retention, filtration, discharge – stormwater is managed. To allow the sea in, as an estuary would normally do, new course connections are added. This results in a restored saline and stormwater dynamic and improved water quality that allows for the functioning of a healthy mangrove system, catalyzing the growth of new mangroves as well as restoration of the existing ones. Being the natural defense system from the sea, the mangroves provide flood safety. Additionally the ecological value of the mangrove system is manifold allowing for brakish water flora and fauna to thrive. The third benefit the restored connection between communities and the natural environment.

REINTRODUCING GRADIENTS
By reducing the hardness of the region through connecting urban green spaces via infrastructure lines and introducing more permeable surfaces, a network of diverse green spaces is created, that impacts the sponge capacity of the city. This results in increase sponge capacity and helps transform the infrastructure lines from barriers to corridors. This improves urban ecology and increases the ability of the low lying regions to manage and channel water. In doing so, community safety is improved and inclusiveness is generated via new connections.

MITHI ESTUARINE ZONE VISION

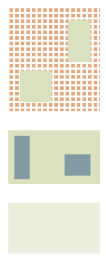
The Mithi estuarine zone is a layered urbanscape with the natural system buried under mobility and infrastructure. By looking at the urban estuarine landscape as a collective system with restored structures, processes, gradients and contributors the rehabilitation of the region is commenced. Via a detailed elaboration at the mouth of the estuary the system is further explained. This area focuses on the mangrove system and infrastructure lines, and their interaction with informal settlements.

New Course Connections

- New connections towards the sea to allow inlet and discharge
- Making room for the river
- Extending streams to recreate natural system

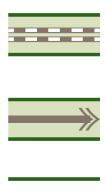
River ecology

- Mangrove protection and restoration
- Gradient bank naturalization
- Water storage and filtration through wetlands



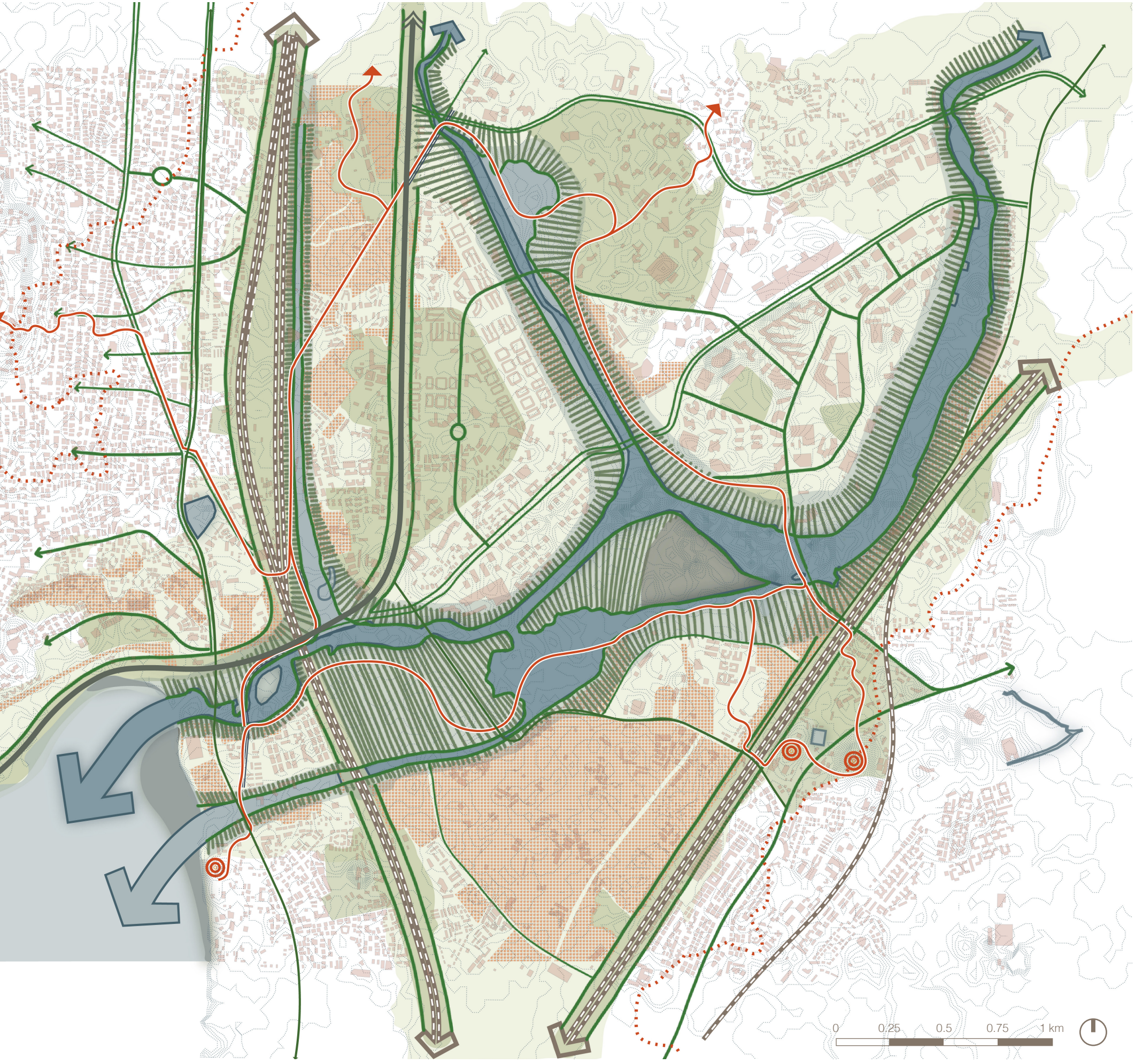
Urban Green

- Informal settlement safety through water retention
- Groundwater recharge through water Squares, rain gardens, detention ponds
- Climate adaptive city systems



Corridors

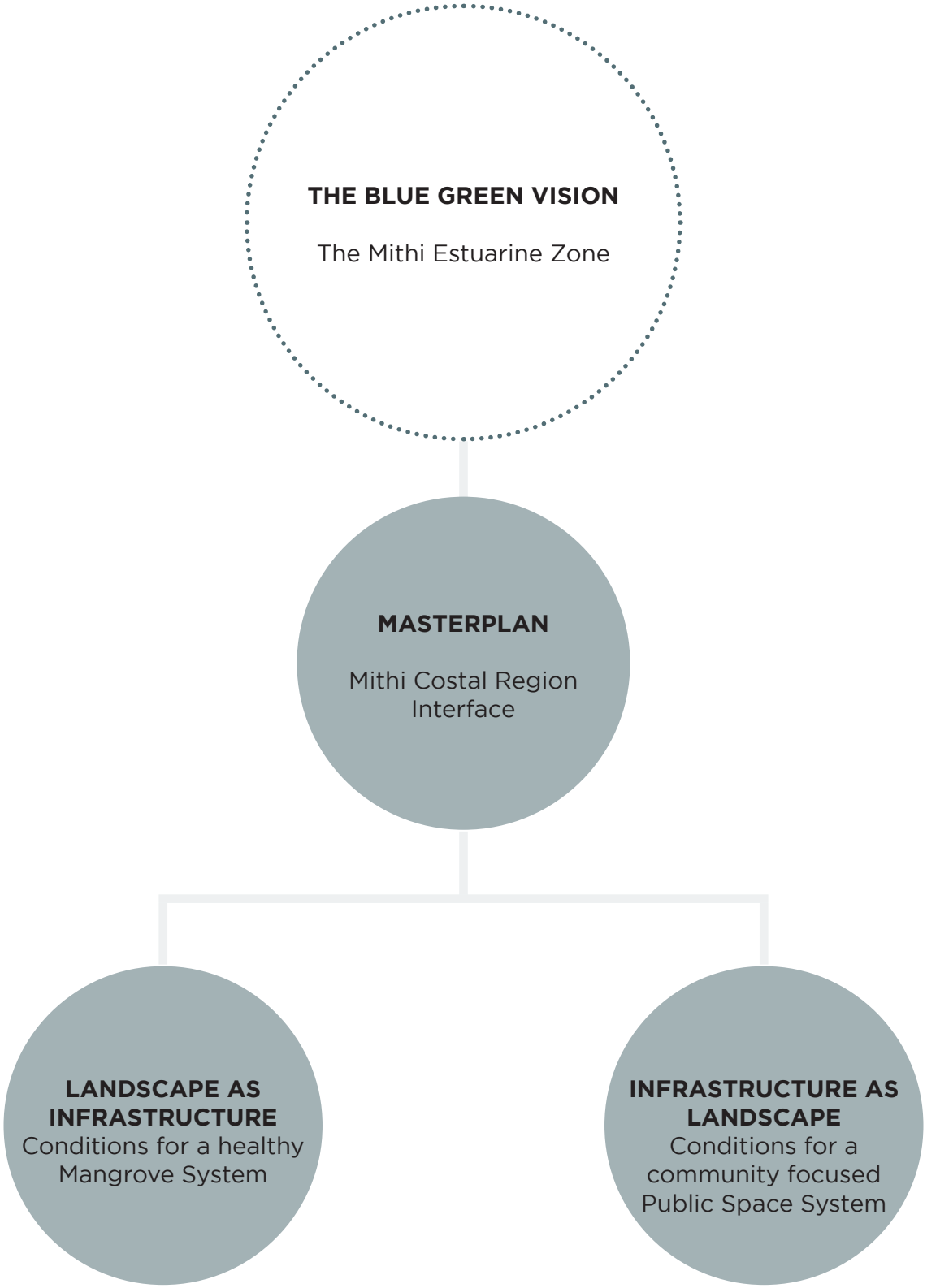
- Ecological corridors to link habitats
- Green avenues and streets for increased sponge capacity


0
0.25
0.5
0.75
1 km

05

REINSTATING THE DYNAMIC

Image - Author



Research by Design - Application of the Principles

Informal Settlements

Infrastructure Barriers

Natural Landscape

Image 1 - Wikipedia
Image 2 & 3 - Author

05 | REINSTATING THE DYNAMIC

This chapter showcases the application of a combination of design principles outlined previously, at three scales. The blue-green vision plan addressed in the previous chapter shows some of the larger strategic interventions at the scale of a region. The plan for the Mithi-Mahim-Dharavi area addresses a more local scale, where the community, nature and infrastructure are all addressed collectively. Here the focus is on increasing sponge capacity, increasing discharge capacity, and allowing room for tide. The two elaborations highlight how community and the natural landscape work together and how community and infrastructure work together.

The research question addressed here is –
What are the spatial possibilities of the framework at the local scale that can create conditions to help re-establish hydro-morphology, ecology and community to make the region flood resilient and climate proof?

5.1 | MITHI COASTAL REGION INTERFACE

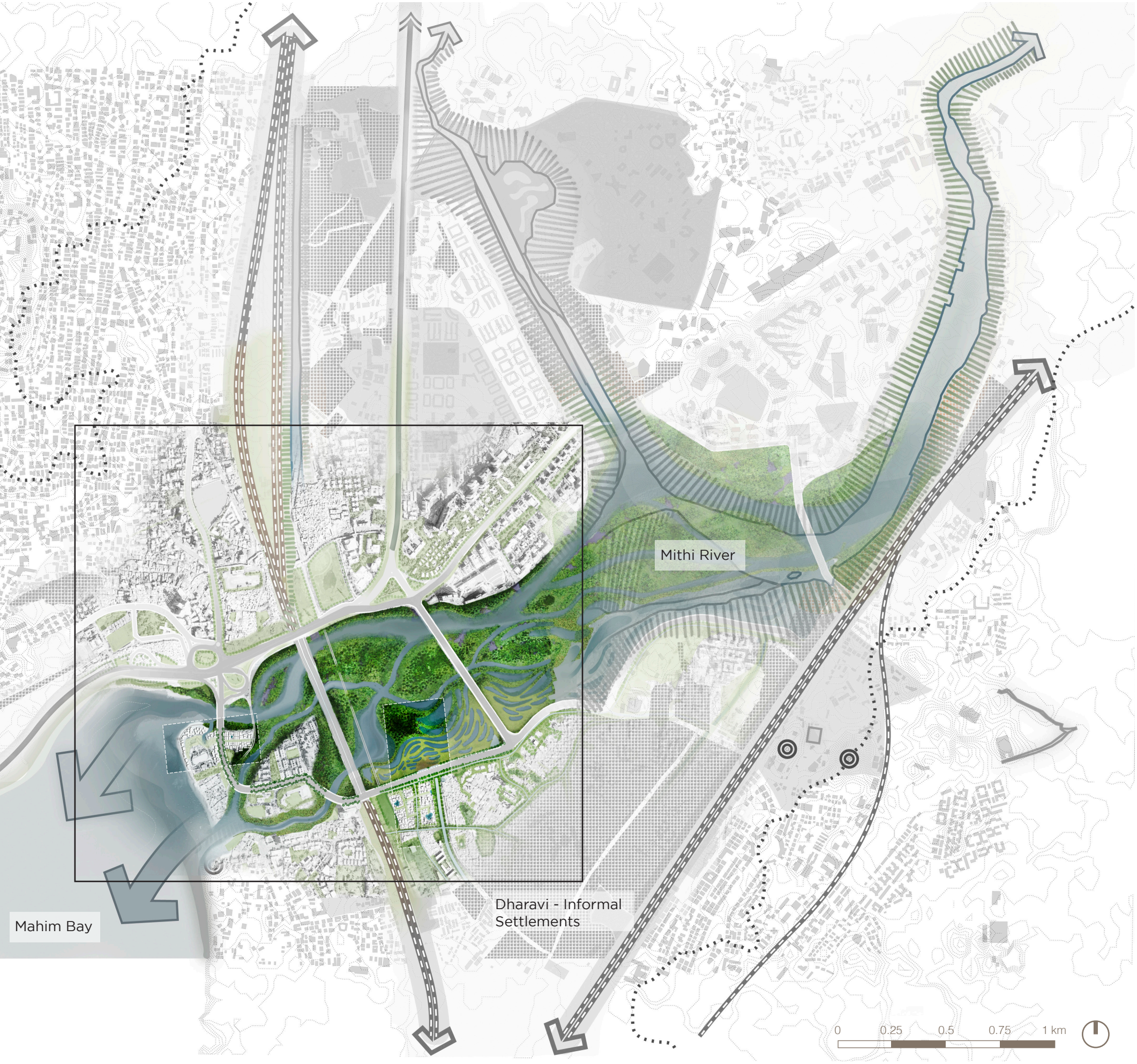
The previous chapter addressed the development of a blue-green vision for the Mithi Estuarine Zone. That strategy plan can be seen as an underlay and a basis for local scale interventions. At the coast where the Mithi River meets the Mahim Bay, a mangrove system exists. This design intervention explores the recreation of a braided river system that supports flows in this region. It also explores the potential of urban infrastructure as a channels for landscape continuity.

Current Situation - The Bay Interface

Current Situation - Infrastructure Barriers

Mithi Estuarine Zone - Blue-green vision as an actionable masterplan

Image 1 & 2 - Author


Mithi River
Mahim Bay
Dharavi - Informal
Settlements
0
0.25
0.5
0.75
1 km

Mithi-Mahim-Dharavi Masterplan

0 100 200 400m

5.2 | MITHI-MAHIM-DHARAVI MASTERPLAN

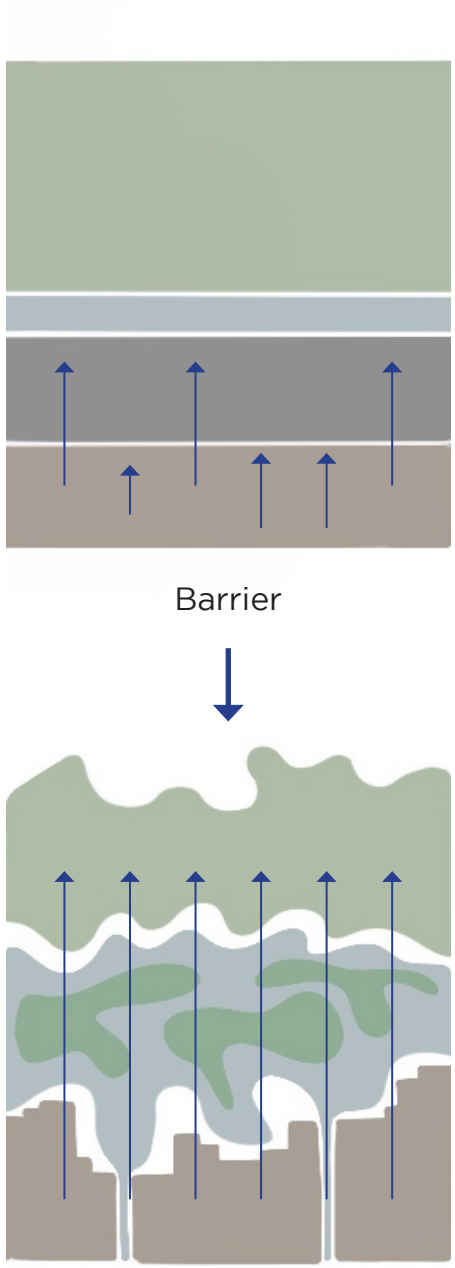
The Mithi-Mahim-Daravi area is representative of the challenges the city faces presently. The natural landscape is buried under infrastructural elements that act as barriers, constantly interrupting flows. Within the informal settlements there isn't adequate infrastructure to manage water rendering them vulnerable to inundation. Principles from the blue green landscape framework are applied to the region, recreating the estuarine conditions that existed but within the new urban context.

Largely, the intervention involves a change in water system that becomes a catalyst for the blue green framework to develop. Many projects can be highlighted within this system, some of which are marked on the map. However, to begin, some of the critical projects are discussed.

At the interface of the sea, new connections are added that allow the sea to swell inland and stormwater to be discharged outward. The braided river system is designed to be representative of the natural estuarine formation. The remaining mangroves in this region are presently bound by hard edges which greatly impacts their health. Wetland transition zones between the informal settlements and the mangroves are created, that generate the required sedimentation and flow for the mangrove to become healthier.

In the low lying regions water storage and discharge is increased by converting grey infrastructure lines into ecological corridors. By increasing the permeability of these elements the barriers are softened increasing retention and biodiversity. The informal settlements benefit from an improved urban environment, creating space for recycling of wastewater, storage of stormwater for reuse in the recycling and leather industries prevalent in the region.

1. Revitalization of Existing Mithi Connection
2. Public Space project for Fishing Community
3. New River Connection at Mahim Beach
4. Fort City Project - Revitalization of historic forts
5. Terraced Wetlands Project
6. Urban Water Management in Dharavi
7. Ecological Corridor of Mumbai Local Railway
8. BKC Wetland Park
9. Mangrove Restoration Project
10. BKC Soft city Project



Barrier

Flow

LANDSCAPE AS INFRASTRUCTURE
Informal Settlements
Mangroves

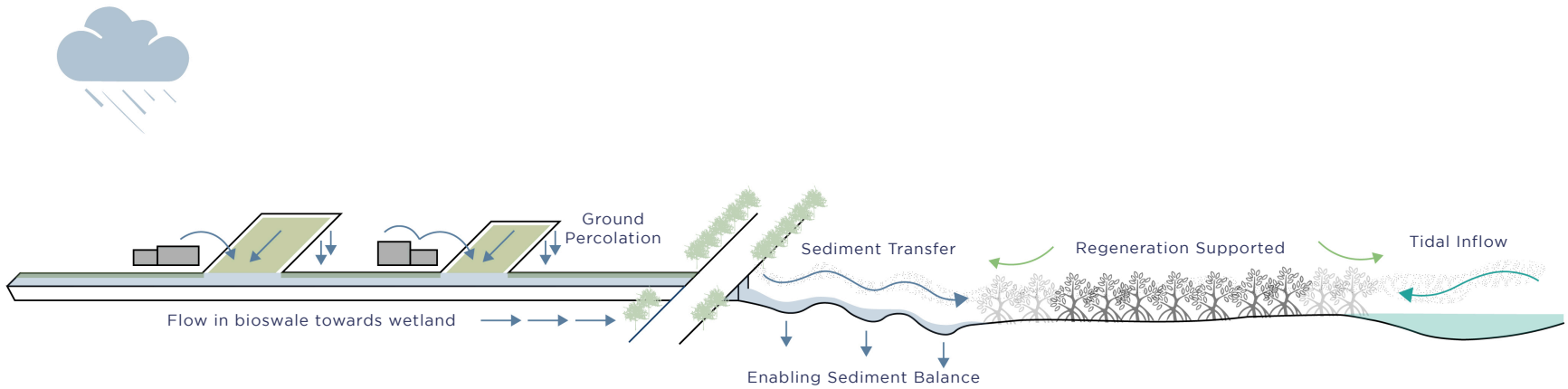
Create transition zone of

WETLANDS
between MANGROVES and INFORMAL SETTLEMENT

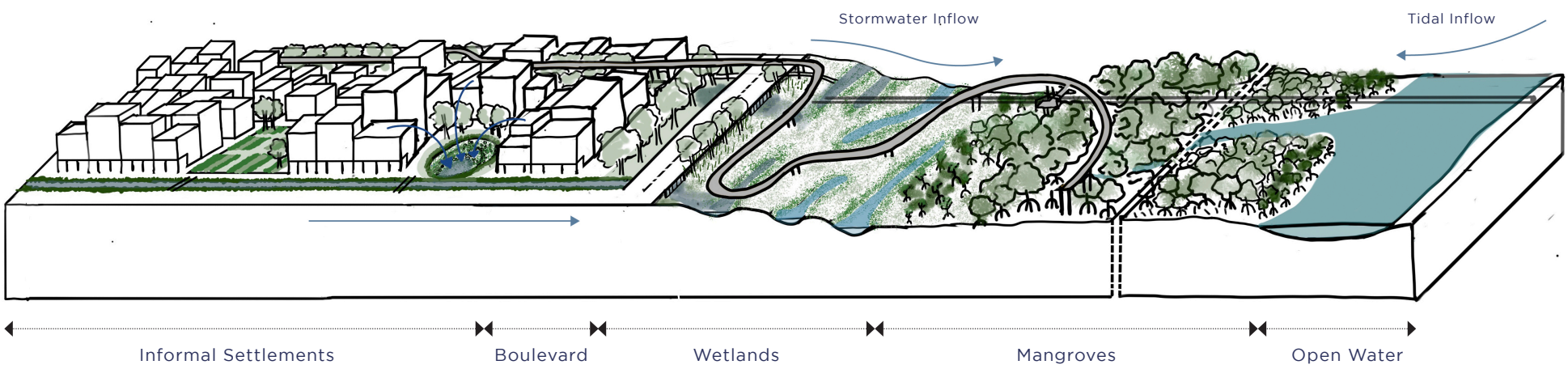
5.3 | LANDSCAPE AS INFRASTRUCTURE

This focus area is characterized by three primary elements – the mangroves, a motorway and informal settlements. The concept diagram above shows the transformation of the existing hard boundaries to gradients. The mangrove landscape is completely enclosed, and the informal settlements have taken the place of the wetland. The existing section shows how the informal settlements have hardly any open spaces and the road becomes a divider between them and the mangroves. One single water canal is responsible for stormwater drainage for this region. The mangrove forest is deteriorating, and if these conditions remain, it will slowly disappear.

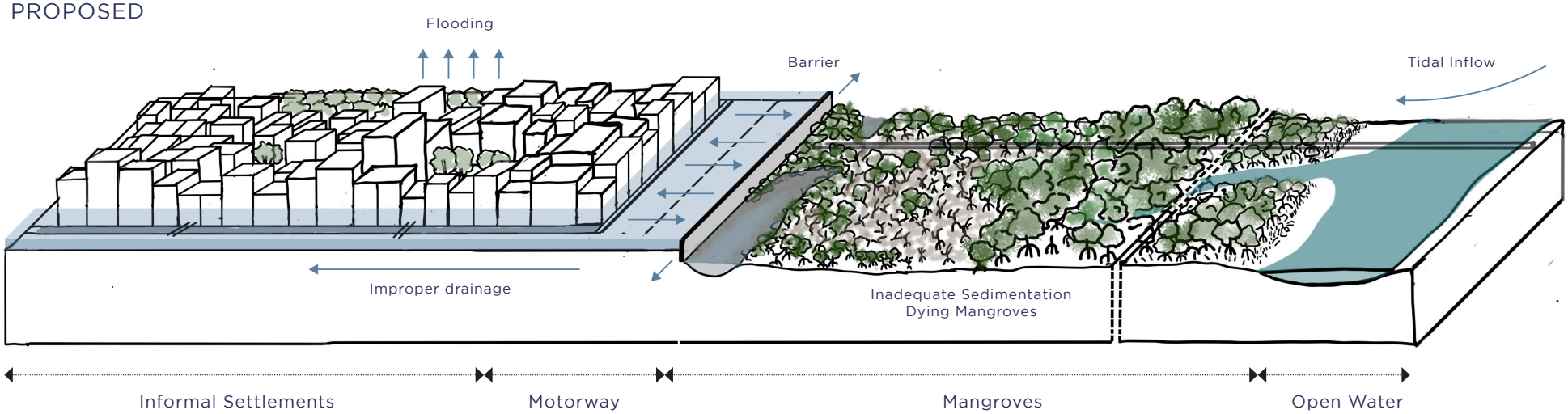
To rehabilitate the conditions for the mangrove forest, fresh water flows need to be created. A part of the mangrove forest is removed and converted into a wetland. Here stormwater is stored and filtered before entering the mangroves, and offers the opportunity to engage the community in related maintenance activities. The fishing communities benefit from the improved water quality and mangrove health which attracts aquatic life that thrives in brackish conditions. Within the informal settlements, rain gardens and permeable surfaces are introduced, to temporarily detain water. The canal that runs perpendicular to the mangrove is converted into a stream with soft edges, and a level difference ensures excess water gradually enters the wetland.



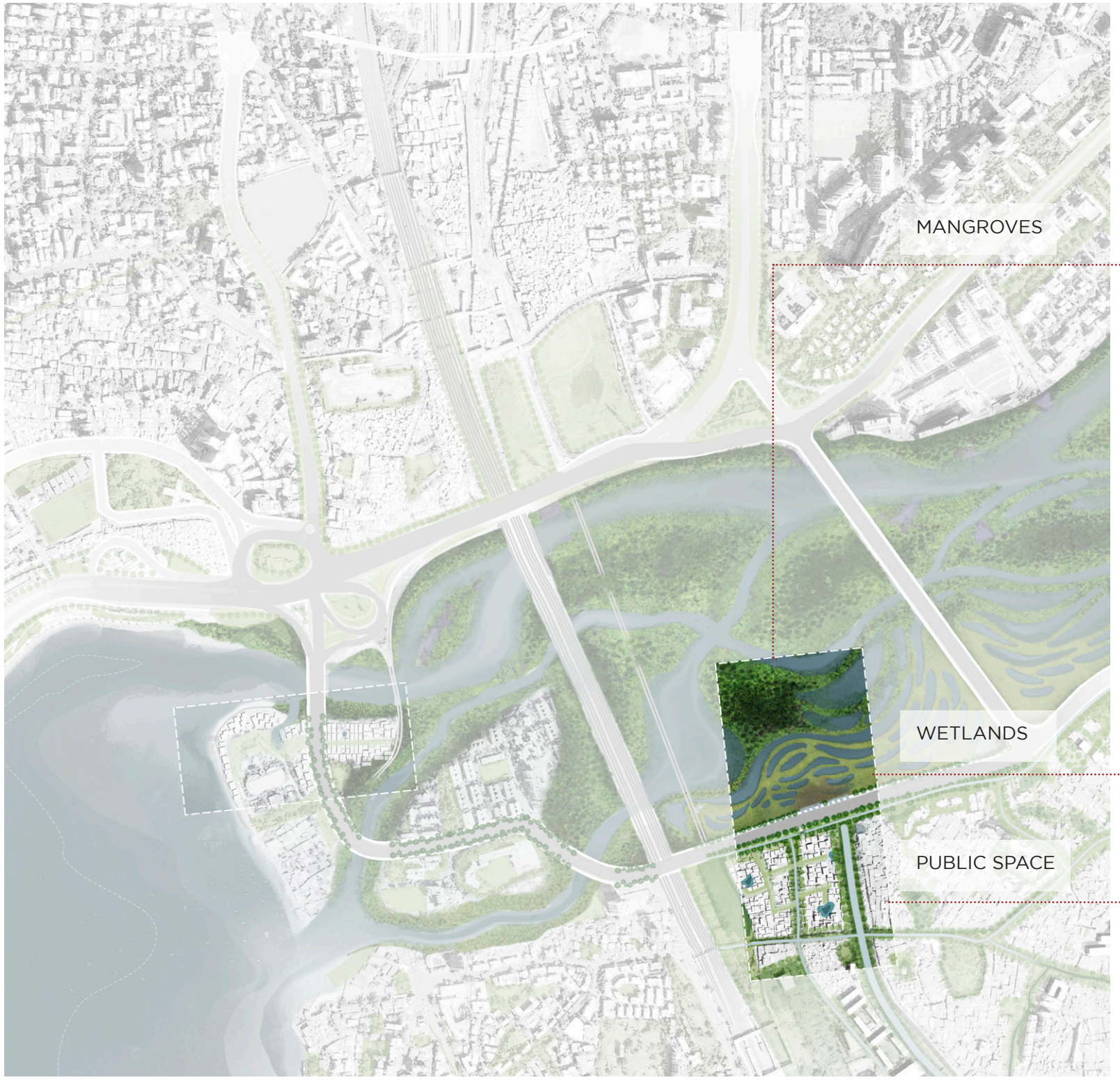
SYSTEM



PROPOSED



EXISTING

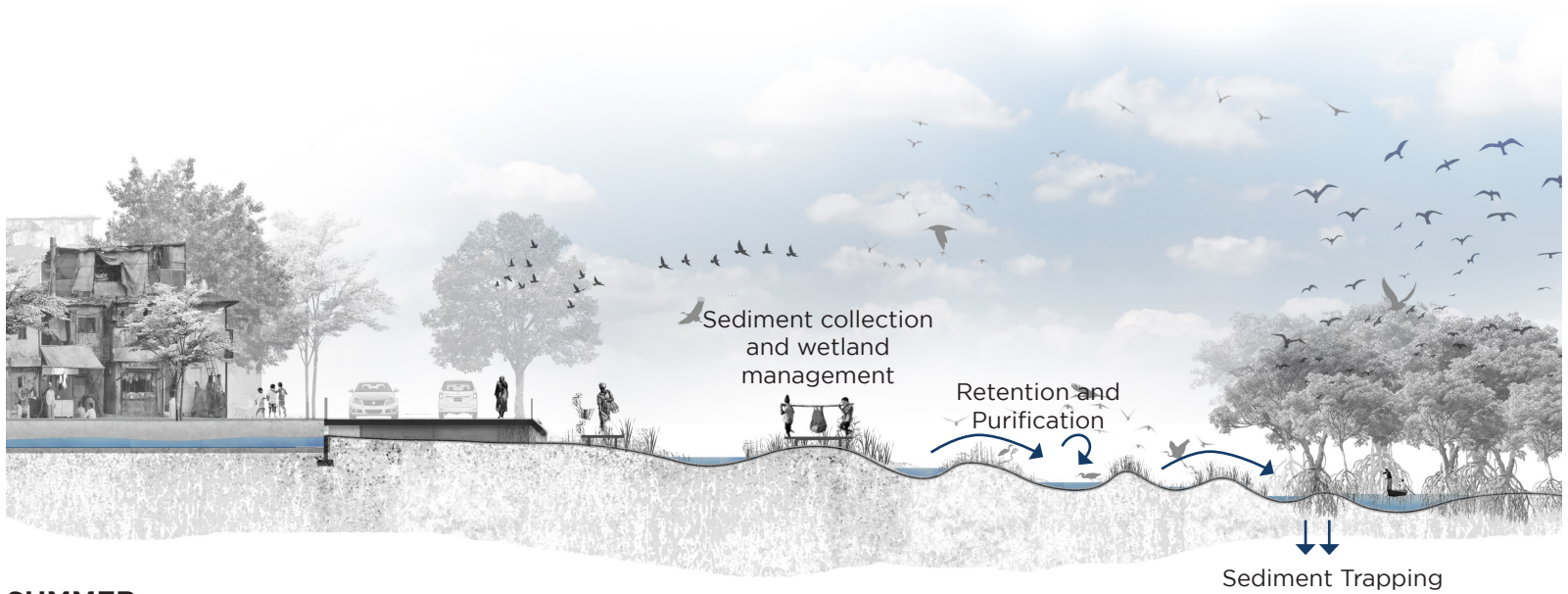


Landscape as Infrastructure

WATER SYSTEM
Water from the rooftops is channelized into rain gardens or public open spaces. Some of it penetrates while the excess moves into the canal network. The main canal, now lined with naturalized edges, opens towards the wetland allowing a transfer of water and sediment. The wetland regulates the amount of sediment that enters the mangrove system, providing the necessary sediment balance for the mangroves. This system also reduces the risk of flooding in the urban fabric.

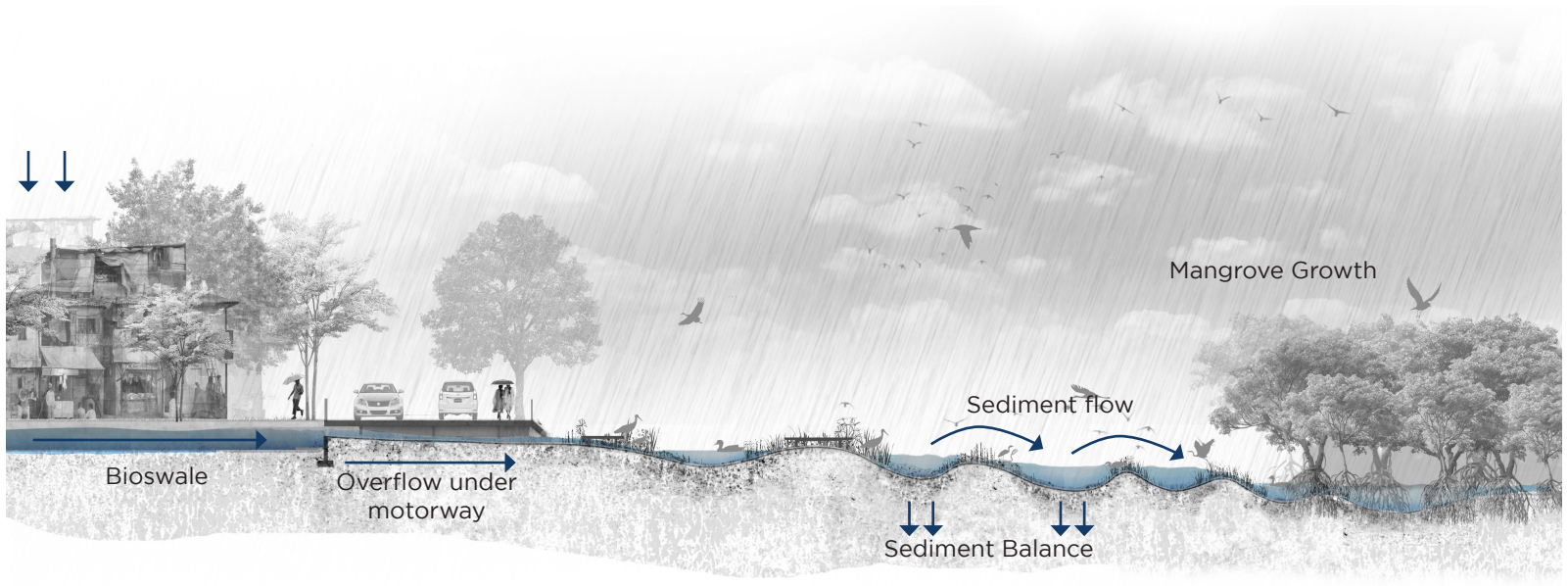
ECOLOGY
A network of public space with permeable surfaces is created. This increases the sponge capacity of the region. The road barrier is narrowed and lined with trees. The wetland with its halophyte planting becomes a habitat for birds. The mangroves are home to fish and shrimp that thrive in brakish conditions.

COMMUNITY
The public spaces can be used for recreation, urban farming or water storage. Since the primary occupation of the people living in this area is recycling of plastics, leather and metal, a part of the process is also cleaning these scraps which contaminate the water. Hence these public spaces can be used for waste water filtration as well. The construction and maintenance of the wetland becomes another industry where sedimentation collection, mangrove berm building, and tourism are employment opportunities.



SUMMER

Even the small ponds that have hardly any water can be a magnet for wetland life. Maintenance of the wetland is an employment opportunity.



MONSOON

The indented areas fill up with runoff from the informal settlements. Excess sediment is trapped in the indents allowing for a balance of sediment for the mangrove.

Naturalized edges for canal to create bio-swale. The edges can be used for reed plantation, washing of clothes etc. It also creates a front face for the houses along the water, as opposed to the previous drain. Solid waste can be trapped at various points allowing for clean up to take place.

The wetland itself helps maintain flows, resulting in improved water quality. This results in the creation of an ecological habitat for many birds, fish and insects. A cut and fill process can be used to create the changes in elevation and develop the wetland. Its maintenance is an employment opportunity for the locals.

The mangrove park is a place to see the mangroves thrive with the introduction of the new water system. It becomes an indicator of the possibilities of natural systems and their importance.

Barrier

Flow

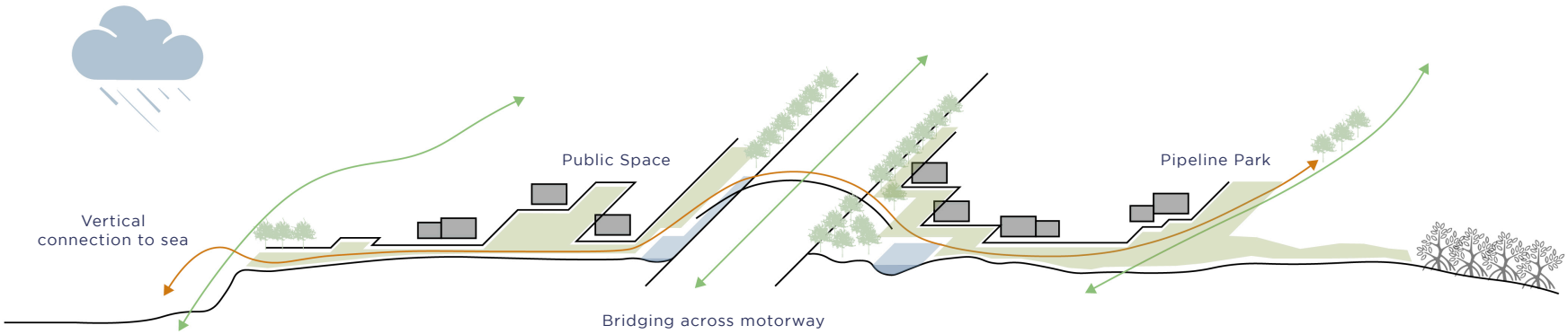
INFRASTRUCTURE AS LANDSCAPE
Informal Settlements
Infrastructure Lines

Create continuous
PUBLIC SPACE STRUCTURE
using various
INFRASTRUCTURE BARRIERS
within
INFORMAL SETTLEMENT

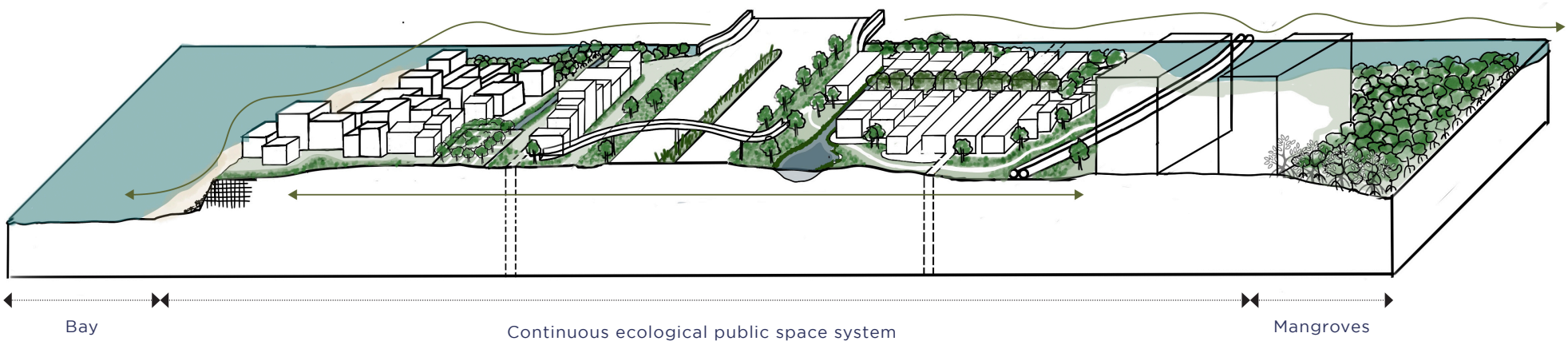
5.4 | INFRASTRUCTURE AS LANDSCAPE

This focus area is characterized by three distinct infrastructural elements – the sea wall, the highway and the fresh water supply pipeline, all intertwined within a sprawl of informal settlements. The highway and the pipeline run perpendicular to the river course crossing. The concept diagram shows the transformation from hard surfaces into a softscape. The existing section shows how the informal settlements (fishing communities) are situated on the seawall, detached from the sea. It shows the highway as a barrier that segregates the communities on either side as well as interrupts the flow of water. The fresh water pipeline runs on ground and concrete infrastructure is created to support it. The hard surfaces result in the inability of this region to absorb water.

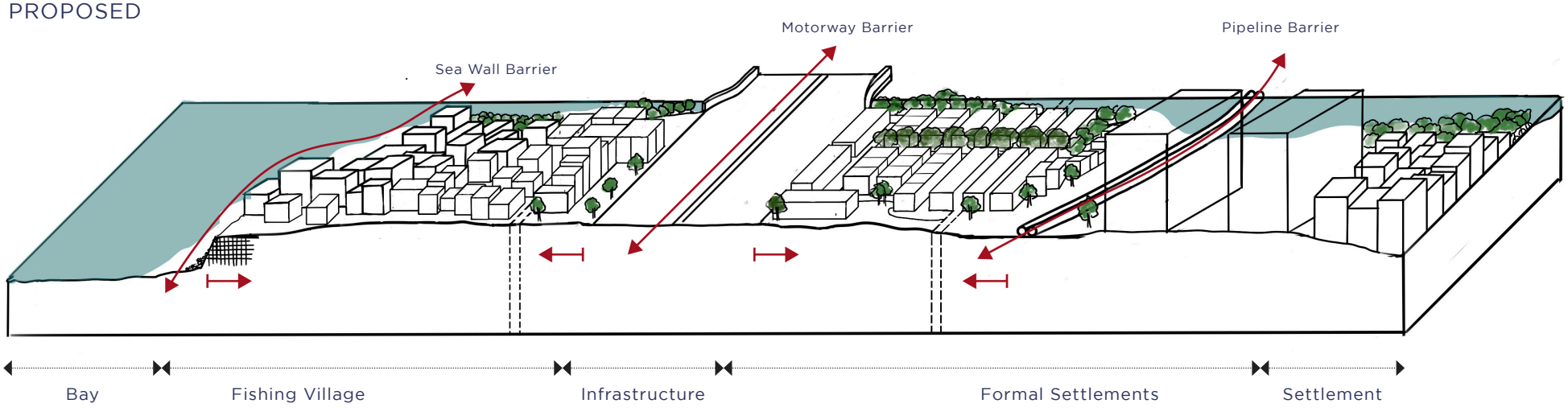
To rehabilitate this region, a network of soft surfaces is introduced that not only impacts absorption capacity but also contributes to urban ecology creating habitats for flora and fauna, as well as promotes communal inclusivity through a connective public space structure. Since this area is higher, situated on the sea wall, it becomes a place where stormwater can be collected and detained momentarily. By increasing the permeability of the surfaces and adding water squares and gardens within the informal settlements, the runoff is slowed down, and flooding can be prevented.



SYSTEM



PROPOSED



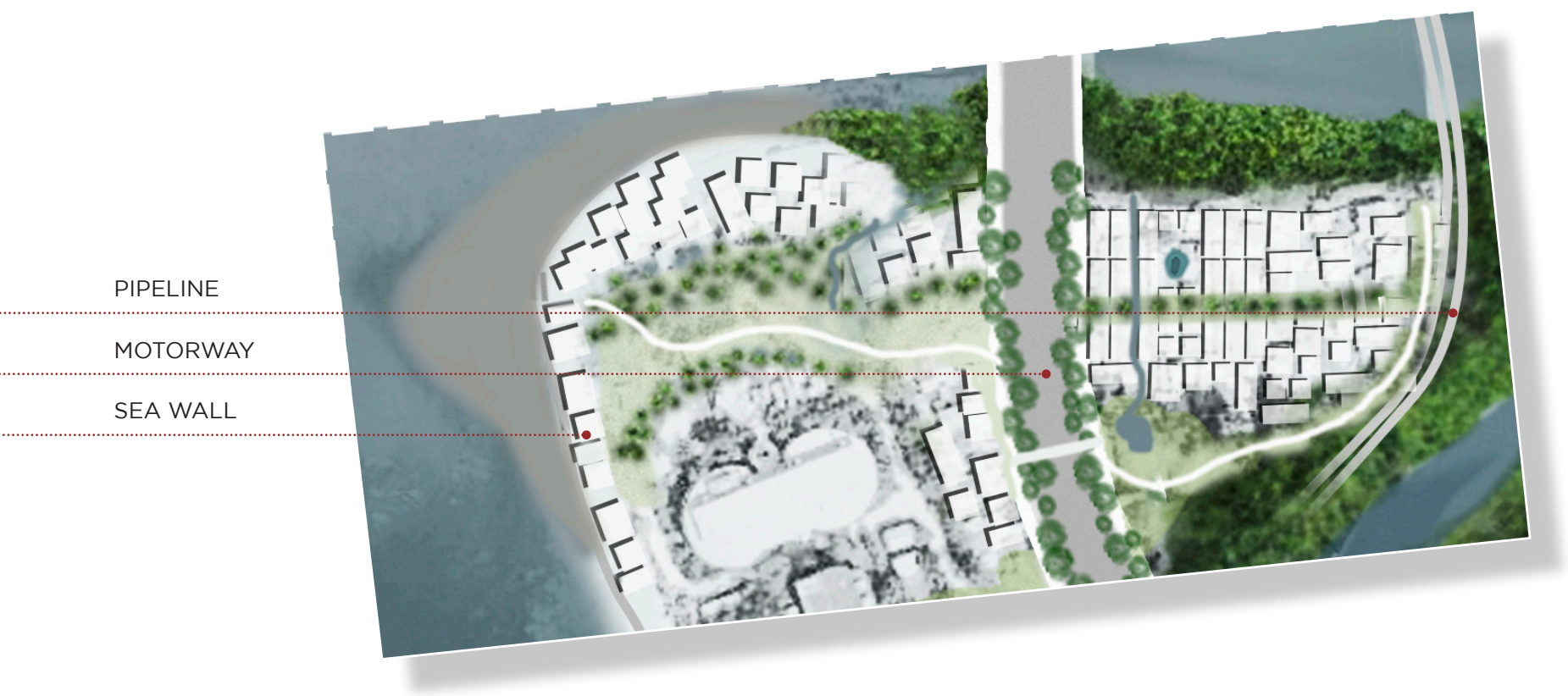
EXISTING

Landscape as Infrastructure

SEA WALL
Presently the beach area at the interface of the sea wall and the sea is neglected. While normally sea facing areas are valued as prime residential location, the fishing village that sits perched on the sea wall has turned its back to the sea. The waste generated in the village is thrown off the sea wall polluting the area below. With minimal intervention a stepped pathway is created towards the sea that sits lightly on the rocky wall. This creates a connection between the higher ground and the sea, reenergizing the sea face and encouraging the community to value the bay. This also improves the accessibility of the fisherman that go out to sea dangerously climbing down the rocks. A space for the fish market is created within the urban fabric.

MOTORWAY
Continuing inwards from the informal settlements along the bay, this softscape approaches the highway. The street profile is modulated to create accessible public space and make room for slow moving traffic. A water outlet is introduced along the highway that improves the drainage of the fishing village. The sidewalk and the motorway are separated by permeable areas which are designed for holding water in times of heavy rain, and can otherwise be used as areas of rest. The basket weavers, fish vendors and potters can use the public space along the highway to set up their shops. A pedestrian bridge connects the two sides of the highway that leads from the fishing village to the pipeline park.

PIPELINE
The pipeline park is an area that is bound on both sides by residential development. It is where the fresh water supply pipes cross the city, above ground. Presently, it is already designed as a public space but towards the river it deteriorates in quality. This region is revitalized by minimal intervention, converting the hard paved surfaces to softer edges, increasing permeability. This becomes an active public space that engages visitors and also is educational to understand how the water system functions within the city.



SUMMER
Small scale wetscapes such as rain gardens are created on either side of the motorway to allow for increased percolation. Storage areas are created as water squares within the urban development.

MONSOON
In the monsoon the rain gardens have the ability to hold water. The water squares can be used by the community to wash clothes etc.

The motorway is transformed into a boulevard with slow moving infrastructure and public space on either side. The car lanes are reduced and a setback is created. That space can be used to set up local markets for the street vendors. The materiality of this space allows permeability, which increases the sponge capacity for the area.

The pipeline park is a place for meeting. Since this is easily accessible and tells the story of the water of Mumbai, it can become a public space for people to understand the systems present in the city. This linear park connects to the mangroves at the Mithi river - and hence becomes a continuous permeable system leading to the sea. There is potential to develop educational facilities like schools along the pipeline park.

At the sea wall, subtle interventions are created that improve accessibility for the fishing community. Presently it is challenging for the fishermen to walk downwards to the sea, they have to climb over big rocks. Vertical connections in the form of light stairs are designed to improve the flow.

5.5 | THE VISION, IMAGINED

The two local scale interventions are derived using a combination of principles outlined previously. Similarly, more projects that were outlined within this region can be realized. With that, what emerges is the blue-green vision for the Mahim-Mithi-Dharavi region, which can further be translated up the course of the Mithi River and other watersheds in Mumbai. This vision contains various water sensitive strategies that help transform Mumbai's coast into a more ecological and socially inclusive landscape.

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06

DISCUSSION AND CONCLUSION

6.1 Research Findings
6.2 Lessons Learned
6.3 Limitations and Recommendations

DISCUSSION AND CONCLUSION

6.1 | RESEARCH FINDINGS

The disappearance of the natural landscape makes Mumbai susceptible to extreme flooding, particularly during the monsoon combined with high tide. Climate change is only going to impact this further, with the increase in rainstorms and sea level rise.

The built up urban tissue compromises natural processes, both water and ecology related, and are interrupted or erased to make room for urbanization. While the natural system is affected, this also affects the people living in the city, particularly in the vulnerable low lying areas. Often these areas are home to marginalized communities, as they are considered unsuitable for construction.

This research aimed to find a landscape architecture approach to address these challenges and find context specific ways to reintroduce the landscape system into the urban context to provide conditions for both environmental and communal upliftment for the city. Hence the goal was to explore the potential of a blue green landscape framework to provide conditions for hydro-morphological recovery, ecological restoration and communal requalification for the urbanized estuarine landscape of the Greater Mumbai Region. While reducing flood risk, this blue green framework creates new ecologies, as well as a better standard of living for Mumbai's residents. Four research questions have been answered in the process of navigating this goal.

UNDERSTANDING
The now urban landscape of Mumbai consisted of three main elements, the estuarine landscape, the flows of the rivers and valleys and the upland forest of higher altitude. However each of these ecosystems are compromised due to the urban built environment. The landscape can only function optimally when these elements are thriving, and their systems are working in tandem with each other. However, the urban infrastructures have become barriers, impacting the functioning of this system. The ability of the city to retain, detain and discharge water has reduced and the basic function of the estuary to allow the sea to swell has been hindered. This causes a plethora of problems, - flooding, loss of habitats, and an unsafe place to live overall. Analysing a system boundary of a watershed, the Mithi river watershed, one can see that these challenges exist at many scales, in the larger system and down to the local scale. By making room for water, increasing the unbuilt surface area by developing a landscape of gradients, these flows and processes can be restored, greatly impacting the resiliency of the region.

FRAMEWORK
From the understanding of the natural system, and how it has changed over time, and from best practices seen in other projects, we learned that a blue green landscape framework that is context adaptable can restore natural processes allowing them to function optimally. This framework considers the urban infrastructure as landscape infrastructure and also the landscape as infrastructure essential to the functioning of a system. This blue-green framework can create suitable conditions for rehabilitation of water, ecology and community. Design principles can emerge based on the interaction of the blue, green and grey fabric in the city. Because of the urban density, it is often critical that for restoration of the system, the existing urban built environment needs to be modified. The dynamics between saline and fresh water need to be restored, the barriers need to become corridors or connectors restoring flows, the built infrastructure needs to be come softer allowing for absorption, the hard edges need to be transformed into gradients and the community needs to be involved in the restoration of these processes to ensure their function over time and also provide them with a safe and enjoyable living environment.

APPLICATION
The application focuses on the estuarine region of the Mithi watershed, where blue green and grey elements interact, and where the vulnerability is the highest, based on topography. It is seen that by the application of a combination of relevant principles to this zone some of the original flows can re-emerge. The elaboration of two focus areas shows two distinct systems. The first is the restoration of flows for the functioning of a healthy mangrove system that is the natural coastal defense for the region. In this design elaboration, a wetland is introduced between the informal settlements and mangroves, allowing for retention, sedimentation and filtration of the storm water entering the mangrove forest, impacting its health and increasing its ability to grow naturally. The local people engaged in activities related to the maintenance of the wetland and mangroves thereby also impacting their livelihood in a positive way.

The second design elaboration focuses on softening the city. Here via the process of minimal intervention the urban environment is adjusted to create increased permeability, both socially and environmentally. Barriers are converted to corridors, hard edges are modified into gradients and communal connectivity is increased. This improves sponge capacity, biodiversity and communal integration.

REFLECTION
A landscape architectural approach deployed through scales can contribute to a better functioning urban environment that relies on natural processes for its resiliency. This can not only impact the current system, but can guide future development. Through the process of spatial design based on the blue green framework and associated design principles, it is seen that small scale strategies can have an impact on the regional scale. On first glance it feels that there is just not enough space to implement landscape based strategies in this dense urban context, but through the multiscale approach zooming into the local scale and applying a combination of design principles locally, conditions can be generated where there natural system can thrive. The regional vision is therefore translated into low intervention design strategies that contribute to the larger narrative of hydro-ecological and communal reinstation.

By restoring the functioning of the water system, the natural defense system of mangroves flourishes mitigating flooding in low lying areas, and the city as a whole. Ecologies, special flora and fauna that is unique to the estuarine landscape thrive, improving biodiversity, essential for improved air quality, waste water treatment, and other ecosystem services. Additionally, the local communities benefit from new economies related to preserving and enhancing the natural landscape. Social inclusivity of the informal settlements is increased by improving the quality of spaces within these areas, while also providing ecological value. Through this design, the communities that originally functioned on a water based economy, now return to interacting with water and not fighting against it. Additionally the indispensable qualities of the landscape are brought to the forefront, creating an awareness towards the importance of the natural environment.

6.2 | LESSONS LEARNED

The result of this research is an intervention at the coastal end of a watershed system, and two elaborations within this region. The two elaborations focus on infrastructure as landscape and landscape as infrastructure respectively and can be relevant for other high density urban environments, where the two are almost always considered separate entities. The two relationships highlighted are the interaction of informal settlement with the natural landscape and infrastructure system. In tropical regions prevalent with mangrove coastlines that are at a risk of flooding, the strategies related to mangrove health, and how communities and natural landscape interact become relevant. For densely populated cities with a lot of hard infrastructure, the strategies identified in the second elaboration related to softening, corridors and connections become relevant.

The method of design research and research by design used in this research is a helpful tool to delineate strategies and then test them in strategic locations. The design research process of analysing the natural landscape and its transformation, selective mapping and drawing are indispensable tools to understand and work with a landscape. For strategies establishing a framework is helpful to develop a directed toolkit to deal with the analysed challenges. Subsequently the combining of principles and testing process to arrive at a result is the process of research by design that shows how theoretical knowledge can be applied contextually.

6.3 | LIMITATIONS AND RECOMMENDATIONS

Overall it was a challenge to deal with and research on the three relationships of water, community and ecology, however this research sheds some light on how conditions can be created to integrate these elements to generate flows within a city. More attention could have been paid on the community aspect and particularly the interaction of people with the landscape, leaving room for more research on the same. Further multidisciplinary research could contribute towards researching the societal aspects– particularly those of sanitation, sewage and sold waste management. Further ecological research on mangrove types and habitats and hydrological research on water dynamics could all contribute to a more detailed design. Additionally a scenario study of the effects of the design over time keeping in mind climatic changes would be greatly beneficial. All in all, this research forms a starting point for implementing a blue green infrastructure related landscape design the Mumbai region with a long way to go.

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DHARA

Ayesha Mahiira Hussain