La voz del río

Landscape interventions to restore the river ecosystem
in Monterrey, Mexico

Eline Onih Holtes

Landscape Architecture
Master thesis, TU Delft

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Fig. 1: Illustration based on photo of Rio santa catarina la huasteca. Image credit: Aldo Davalos. Wikimedia Commons

Colophon

MSc Landscape Architecture
Thesis report

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Master Architecture, Urbanism, and Building Sciences

Master track Landscape Architecture

Flowscapes graduation studio

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KIVI
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I am thankful to my fellow landscape architecture students for their support and the memorable moments we shared throughout the year.

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Abstract

This thesis investigates the degradation of the river ecosystem in Monterrey, located in northeastern Mexico, with a focus on the Río Santa Catarina. Historically a free-flowing river from the Sierra Madre Oriental to the Gulf of Mexico, the Río Santa Catarina is now often dry except during heavy rains or hurricanes, when it poses flood risks to the city. Human interventions, including concrete reinforcement of riverbanks and the construction of roads, have disconnected the river from Monterrey's urban fabric and exacerbated water scarcity during dry seasons. These short-term flood control measures have degraded the river ecosystem, reflecting broader issues of biodiversity loss, climate change, desertification, and water scarcity.

Monterrey, situated in a semi-arid landscape and facing severe climate challenges, exemplifies the complex relationship between human societies and their natural environments. Historical changes have shifted the city's relationship with its landscape from symbiotic to exploitative, driven by industrialization and rapid urbanization. This shift has led to a narrative that views the natural landscape as a problem to be managed rather than a resource to be nurtured.

This thesis highlights the significant opportunity for Monterrey to transform its approach to river management. By reimagining the Río Santa Catarina as a natural river park, the city can enhance flood control, restore ecological integrity, and foster community engagement. The proposed solutions are based on the Urban Ecology Design Approach (Tillie, 2024), which considers the urban ecosystem level, urban habitat level and the species level of Monterrey. The solutions are integrated in the watershed of the Santa Catarina River based on the Watershed Approach (Hooijmeijer et al., 2021) and promotes strategies for upstream water retention, midstream space allocation, and controlled downstream flow. Three site-specific designs illustrate these strategies, aiming to restore the river's ecological balance and reconnect the community with the river.

While the issues faced by Monterrey's river ecosystem are context-specific, they reflect global challenges of balancing flood control with ecological resilience. The methods and strategies developed in this thesis are broadly applicable to other regions facing similar environmental pressures.

Keywords: urban ecology, river ecosystems, watershed, landscape architecture

Glossary

Ecology: all organisms are interdependent and they interact with one another and the physical environment.
Biodiversity: diversity of life- genetic, species, biotopes (habitats)
Urban ecology: the whole of interactions of organisms, built structures, and the physical environment, where people are concentrated (Forman, 2014).
Urban Ecology Design: Using design and urban ecology principles to create biodiverse, regenerative and resilient living environments (Tillie, 2024).

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1

Introduction

This chapter introduces the geographical, natural and cultural context of Monterrey, Mexico, and the posed problem, research question and research goal.

Biodiversity crisis and climate crisis

Globally, we confront the intertwined challenges of human-induced climate change and biodiversity loss. Given that our future is dependent on biodiversity and a stable climate, immediate action is crucial to safeguard the well-being of present and future generations.

The Living Planet Index assesses 32,000 populations of 5,230 animal species worldwide. In its most comprehensive study to date, spanning 50 years, the WWF and the ZSL (Zoological Society of London) Institute of Zoology report an alarming 69% decline in wildlife populations from 1970 to 2018, as depicted in figure 2.

The extent of decline varies among different regions and species. Latin America shows the most dramatic regional decline, with an average population abundance decrease of 94%. Freshwater species worldwide are experiencing the steepest overall decline at 83%, according to the report.

If global warming exceeds 1.5°C, climate change is likely to become the primary driver of biodiversity loss in the coming decades. Rising temperatures are already causing mass mortality events and the initial extinctions of entire species. Each additional degree of warming is expected to exacerbate these losses and their impact on people (Living Planet Report 2022, 2022).

Figure 3 illustrates the correlation between biodiversity loss and escalating global temperatures. The escalating percentage of species projected to perish due to climate unsuitability in specific regions heightens the risk to ecosystem integrity, functionality, and resilience to climate change. The colour gradient signifies the proportion of species forecasted to face locally endangered status, as per the International Union for Conservation of Nature (IUCN), and the elevated risk of local extinction within designated areas at varying levels of global warming.

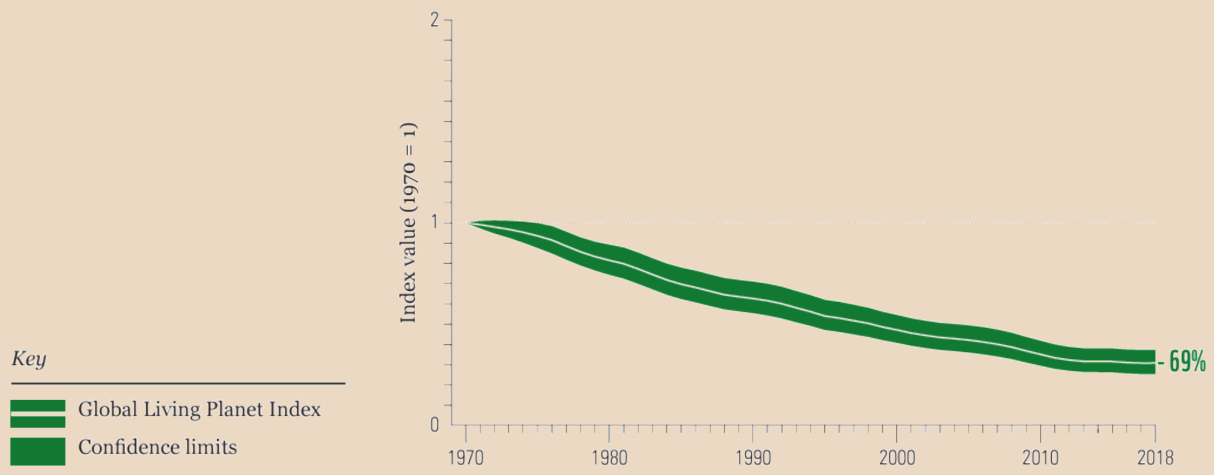


Fig. 2: *The global Living Planet Index (1970 to 2018)* Source: LPR 2022, WWF/ZSL (2022).

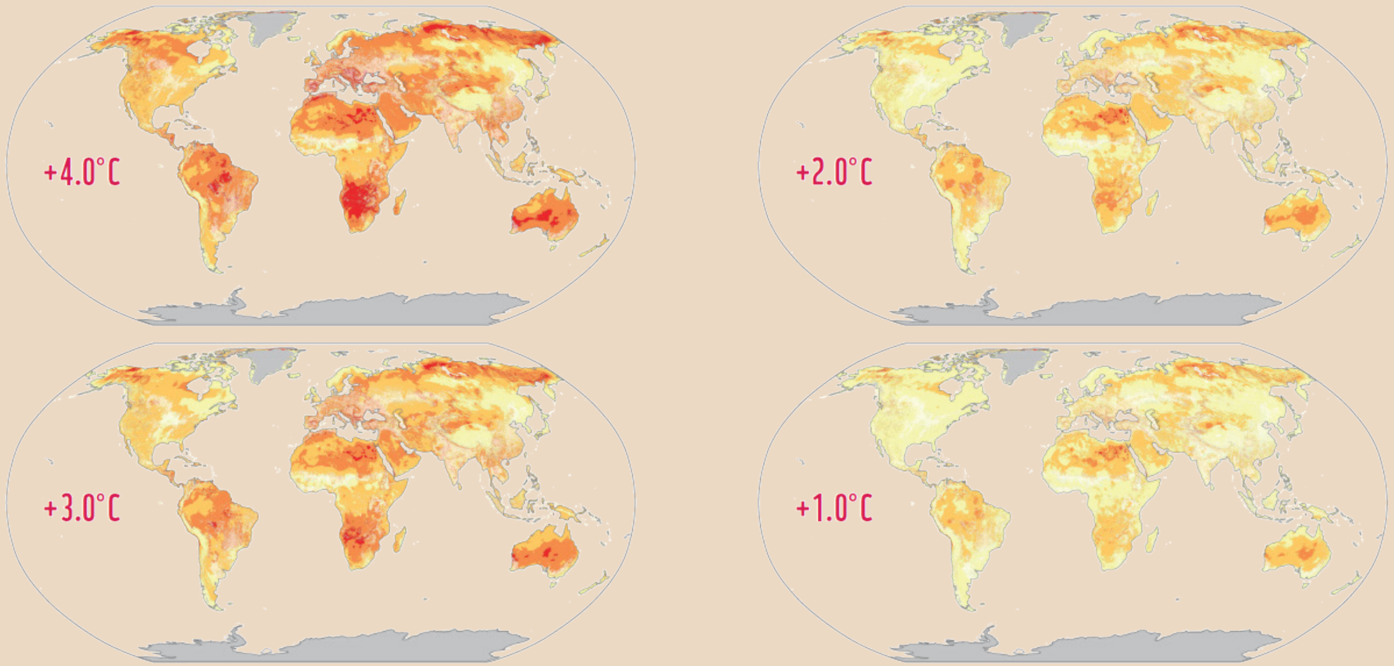


Fig. 3: Projected loss of terrestrial and freshwater biodiversity compared to pre-industrial period. Source: LPR 2022, Reprinted from Figure 2.6 in Parmesan et al. (2022) 11, based on data from Warren et al (2018) 178.

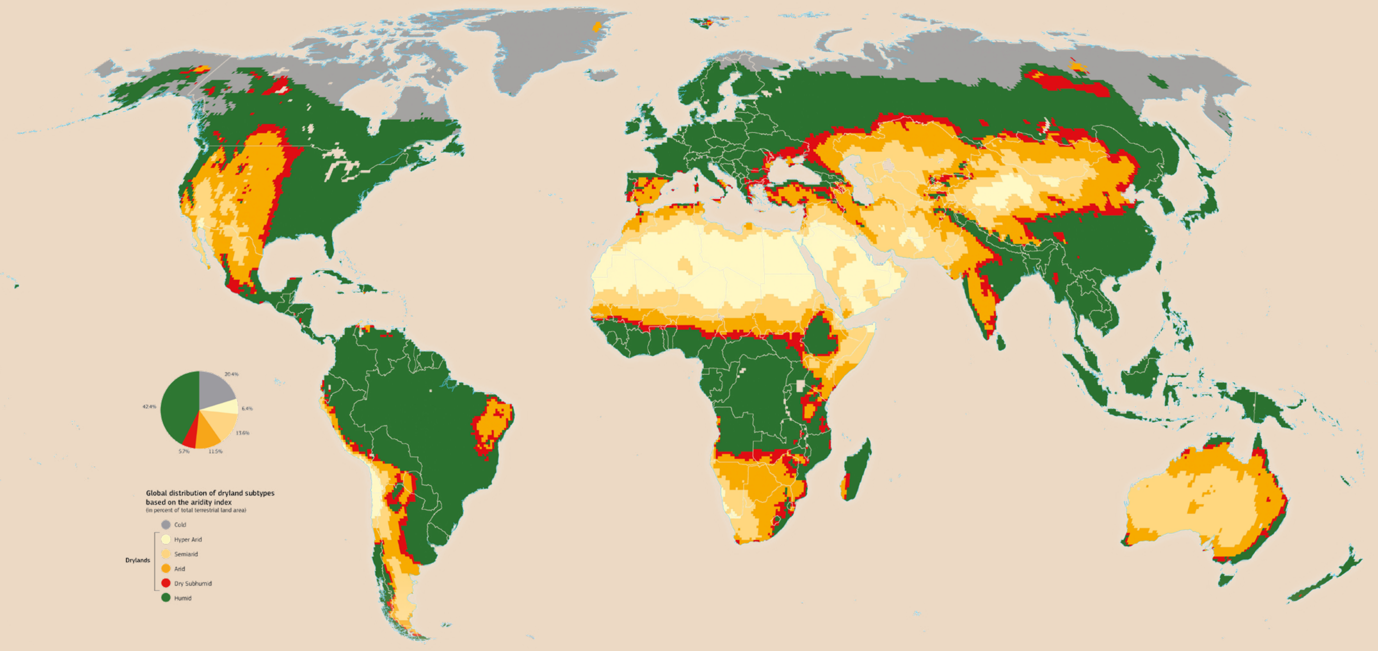


Fig. 4: ***Patterns of Aridity.*** Source: Global Precipitation Climatology Centre and potential evapotranspiration data from the Climate Research Unit of the University of East Anglia (CRUTSv3.20), WAD3-JRC, modified from Spinoni J. 2015 [AP]. https://wad.jrc.ec.europa.eu/patternsaridity

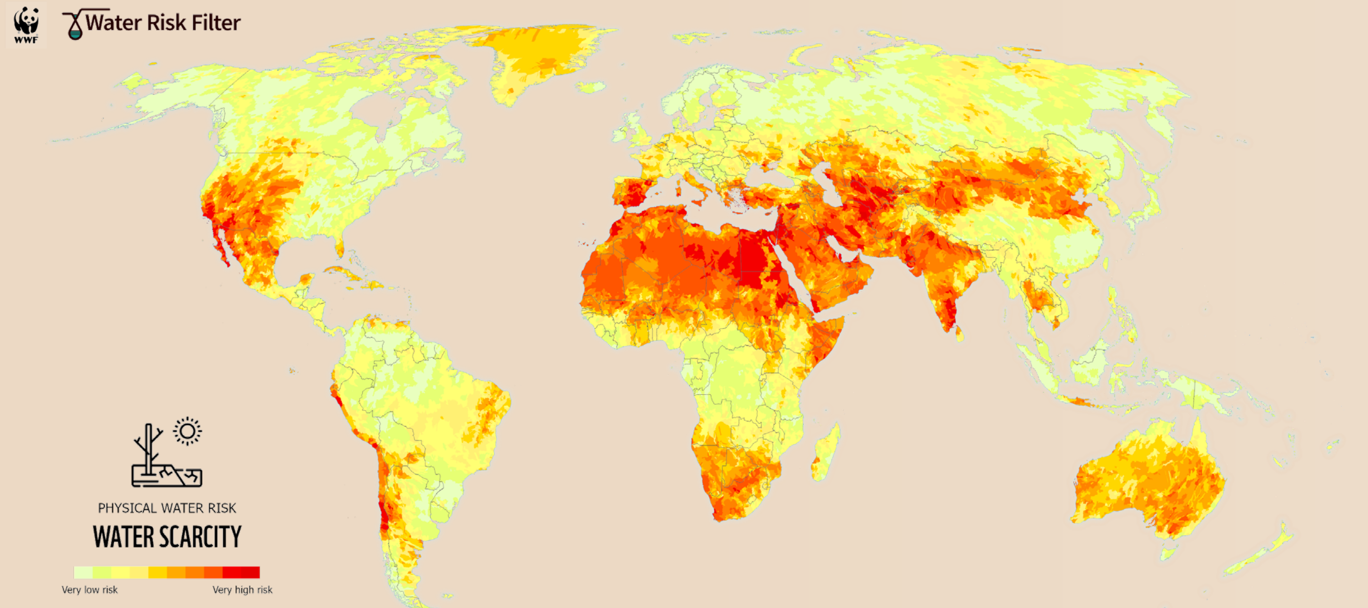


Fig. 5: ***Water scarcity***. Source: WWF Risk Filter Suite. Jan 2023. https://riskfilter.org/map-gallery.

Desertification and water scarcity

Aridity is a climatic condition marked by a deficiency of water. Drylands, ranging from dry subhumid to hyper-arid areas, are particularly vulnerable to the impacts of climate change compared to more humid regions. Consequently, the need to mitigate the effects of climate change is heightened in these areas.

Monterrey, located in northern part of Mexico, chosen as the research location for this project, exemplifies these challenges, situated within a region experiencing profound ecological decline, as evidenced by the stark decrease in average population abundance according to the Living Planet Index (94% decline in Latin America).

By focusing on Monterrey, this research aims to contribute to the understanding and mitigation of the global challenges posed by climate change challenges like desertification, water scarcity and biodiversity loss.

The need for Urban Ecology Design

Biodiversity loss, as highlighted in the Living Planet Report 2022 (LPR), is primarily attributed to land-use change, with human developments continually degrading and fragmenting natural habitats across terrestrial, freshwater, and marine ecosystems. This trend is exacerbated by rapid population growth, emphasizing importance to reshape our environments to promote nature preservation. Efforts must transcend mere compensation for biodiversity loss and focus on actively reversing this decline, as illustrated in figure 6.

Given my interest in Urban Ecology, I have chosen to pursue my studies at the Urban Ecology Design Lab, guided by Nico Tillie. The lab's mission is to establish a symbiotic relationship between human culture and the natural environment, creating habitats for both humans and other organisms within urban settings.

Through landscape planning and design, we endeavour to counteract the biodiversity loss induced by human development in urban environments. Aligned with the commitments of the Leaders' Pledge for Nature, our goal is to achieve nature positivity by 2030, fostering a harmonious coexistence between humanity and the natural world.

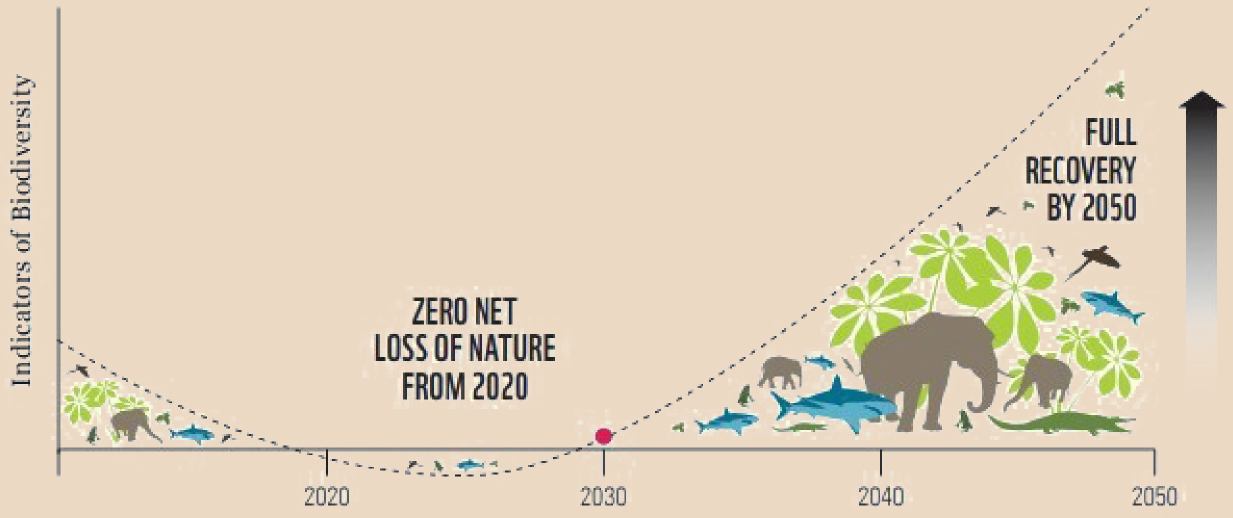


Fig. 6: *Nature Positive by 2030 A measurable global goal for nature. Source: Locke et al. (2021) 193.*

Fig. 7: *Urban Ecology Design Lab Logo. By Janine Schmeitz.*

Research location: Monterrey, Mexico

Fig 8: Holtes, E.O. (2024) *View on the Monterrey Metropolitan Area (MMA)* [photo]. Monterrey, Mexico

Research location

Continent: North America
Counrtry: Mexico

Country: Mexico
State: Nuevo León

State: Nuevo León
City: Monterrey

From left to right: fig. 9: North-America and Mexico, fig. 10: Mexico and Nuevo León, fig. 11: Nuevo Léon and Monterrey.

Research location

The site of this project is the Monterrey Metropolitan Area (MMA), located in the state of Nuevo León in the northern part of Mexico. The second largest metropolitan area of Mexico after Mexico-city. With an estimated population of about 5.5 million people as of 2020 and the second most productive metropolitan area in Mexico. A city known for the production and export of concrete, beer and glass.
The agglomeration is embedded at the edge of the Sierra Madre Oriental mountain ridge and therefore marks a transition between the sub-humid tropics and the desert. The site belongs to the Sierra Madre Forests & Mexican Drylands bioregion, a bioregion dominated by desert and dry shrublands, but the eastern and western ranges of the Sierra Madres are covered with subtropical pine and oak forests. It contains eight ecoregions.

Fig. 12: Monterrey, Satallite map. v

Fascination

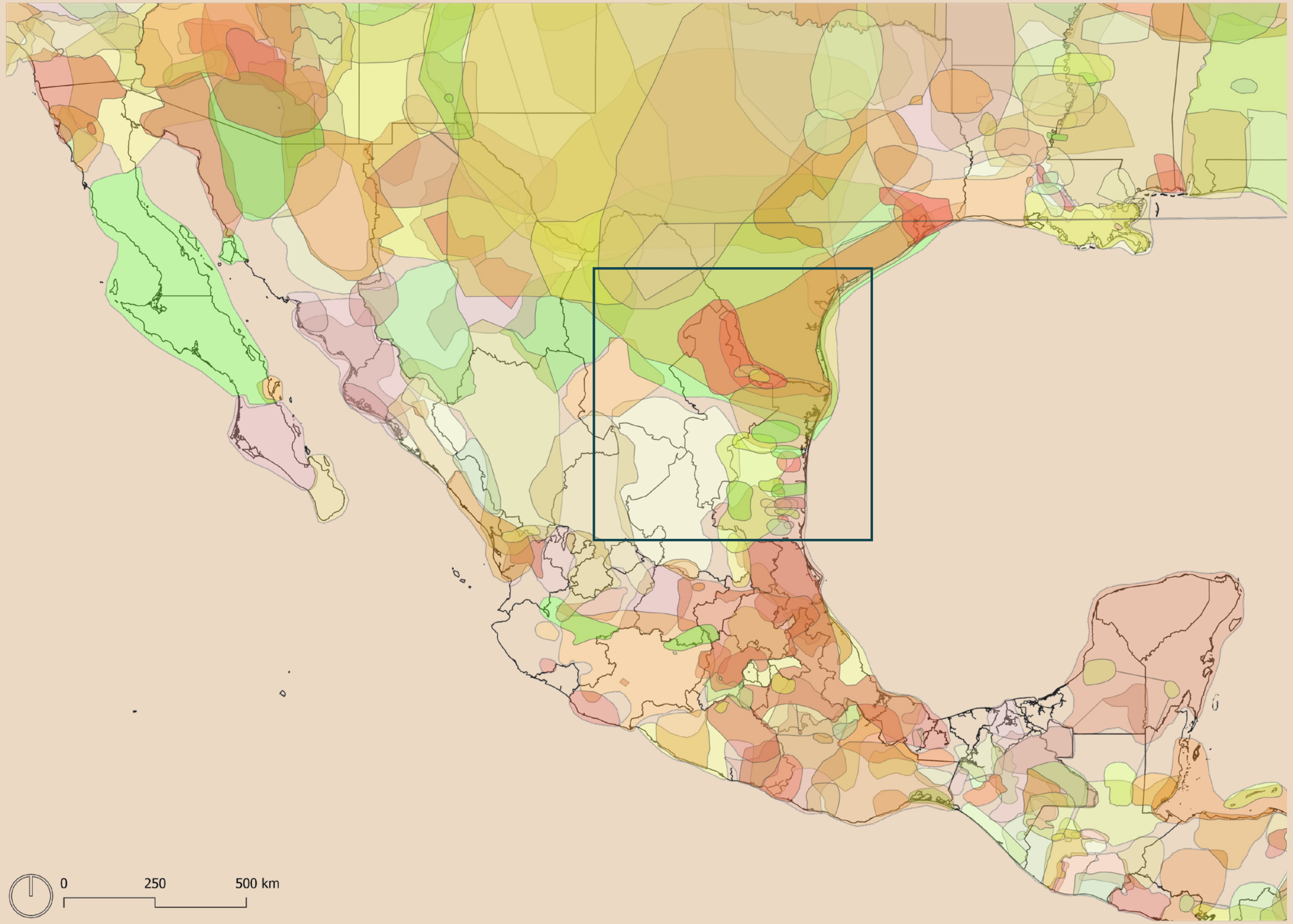
With a special interest in Urban Ecology, I chose to graduate at the Urban Ecology design lab, under the guidance of Nico Tillie. The aim for the design lab is to find a balance between human culture and the natural environment, to provide a habitat for humans and other organisms in the urban environment. In this way, we as landscape planners and designers, can contribute to reversing the biodiversity loss caused by human developments in urban surroundings.

At the invitation of Nico Tillie and Rob Roggema a couple of students were invited to start a collaboration between the TU Delft and the Técnologico de Monterrey by choosing Monterrey as our research location. This corresponded to my personal interest in doing research on a location with a different culture and a climate highly influenced by climate change.

The Monterrey Metropolitan Area (MMA) is characterized by a stony environment of about 5.5 million people. Home to a mix of indigenous, Spanish, Mexican and Texan culture. The landscape surrounding the agglomeration is characterized by fascinating natural sceneries of the Sierra Madre Oriental mountain range, and the diverse landscape types surrounding it.

Fig. 13: Eline during a hike in Monterrey. Image credit: Pieter van der Wel.

Historical exploration: Indigenous territories



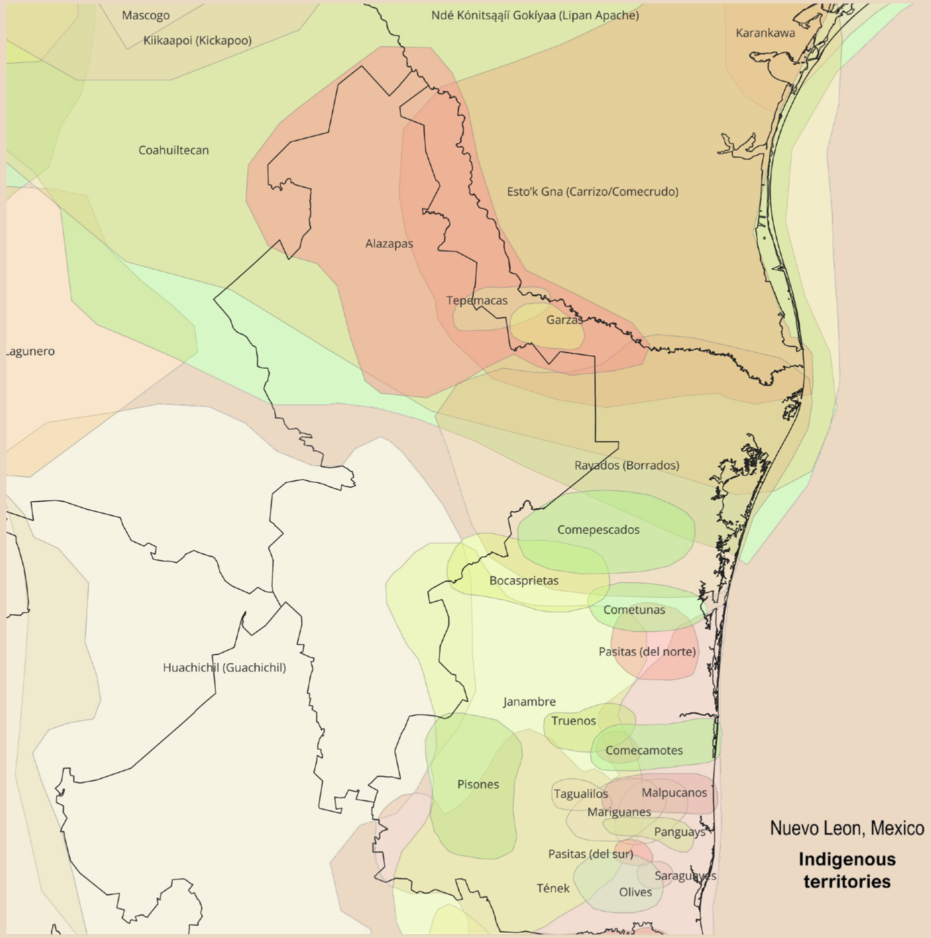


Fig. 14. and Fig 15: *Indigenous territories, compared to the current states of Mexico and the United states*. Based on data from: https://native-land.ca/.

North-America used to be home to indigenous tribes, varying from nomadic hunters and gatherers to semi-hunters and gatherers, depending on the landscape circumstances and the availability of resources. This resulted into larger indigenous territories in the desert like landscape in the north of Mexico, compared to the indigenous territories in the south, with a tropical climate. Meaning that they did not necessarily exist out of larger communities, but that they had to roam the landscape more often in search for resources (J. Byng, personal communication, October).

This was also true for the indigenous nomadic hunters and gatherers in Nuevo León before the arrival of the Spaniards. Initially, the colonizers referred to all inhabitants of northern Mexico as Chichimecas. However, these indigenous people were actually composed of several distinct linguistic groups. In Nuevo León, these included the Alazapas in the north, the Guachichiles in the south, the Borrados and Tamaulipec groups in the east, and the Coahuiltecans in the west (John Schmal, n.d.).

Historical exploration: Oasisamerica, Aridoamerica & Mesoamerica

Fig. 16:. ***Oasisamerica, Aridoamerica and Mesoamerica***. Based on source: https://www.unprofesor.com/ciencias-sociales/mesoamerica-aridoamerica-y-oasisamerica-mapa-y-caracteristicas-4818.html#anchor_1

Another culturally defined description of the landscape of the research location is Aridoamérica. Aridoamérica is a region in northern Mexico and the southwestern United States characterized by a dry and arid climate. Semi-nomadic cultures in Aridoamérica historically adapted to the challenging environmental conditions by practicing a combination of agriculture, hunting, gathering, and mobility. These cultures often moved seasonally in search of resources, following patterns of rainfall and the availability of food and water.

The main characteristics of Arid America:
They were semi-nomadic cultures due to the difficulties of living in such a dry area.
Hunting and gathering were their main economic activities, although they also engaged in trade with the Meso-Americans.
The people had to cope wild animals attacks.
The cultures of the region did not undergo significant progress, likely owing to the complexity of their situation.

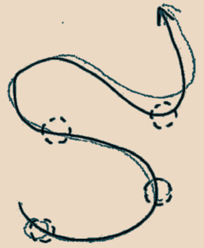
They had a significant religious influence, although not much information about their beliefs has been reached to this day (Eloy Aguirre, 2021).

Historical exploration: landscape biography

'Natural' landscape

"Pre-Columbian" era

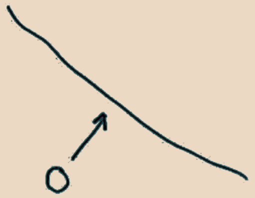
Nomadic and semi-nomadic tribes roamed through the land because of the limited resources in the desert like landscape.



Colonial landscape

16th century

Foundation of the city of Monterrey by the spanish settlers to protect the border of the Spanish empire.



Industrial Landscape

Industrial revolution

Rapid development of economy in the city because of the steel and beer industry. Connection with America through railways.

The overused landscape

Today

Rapid population and urban growth. The carrying capacity of the resources are exceeded.

Left to right: Fig. 17: Collage of the "pre-Columbian era in Monterrey. based on photo by Manny Lopez, Fig. 18: collage of the 16th century in Monterrey, Fig. 19: collage of the industrial revolution in Monterrey, Fig. 20: collage of Monterrey today. Based on a photo by Cesar Rodriguez, 2022.

Historical exploration: landscape biography

‘Natural’ landscape

‘Pre-Columbian” era

Before the arrival of the Spanish and Portuguese settles, the ‘’pre-Colombian’’ era, the relationship between the humans and the surrounding landscape of the current MMA can be described as symbiotic. Nomadic and semi-nomadic tribes roamed through the land because of the limited resources in the landscape. The first Spaniard and Portuguese settles described a fantastic landscape of rivers, creeks, large tree groups, dense forest on the hills and abundant wildlife (Zurita, 2024).

Fig. 17: Collage of the “pre-Columbian era in Monterrey. based on photo by Manny Lopez.

Colonial landscape

16th century

At the cost of the original inhabitants and their culture, the village of Monterrey was established by Spanish and Portuguese settlers to protect the border of the Spanish empire. But the village remained very small and non-important for about 250 years (Zurita, 2024).

Fig. 18: collage of the 16th century in Monterrey,

Historical exploration: landscape biography

Industrial Landscape

Industrial revolution

Because of the industrial revolution and the connection with America through railways, commerce and industry (steel and beer) began to flourish. Rapid economic growth required urban expansion, leading to deforestation and the loss of natural habitats for animals and other organisms.
'Suddenly, that lush and attractive description of a landscape that could be home to human life and settlements, shifted to descriptions of a poor nature, arid land with no beauty or value whatsoever.' Nature began to be tamed (Zurita, 2024).

Fig. 19: collage of the industrial revolution in Monterrey,

The overused landscape

20th century > today

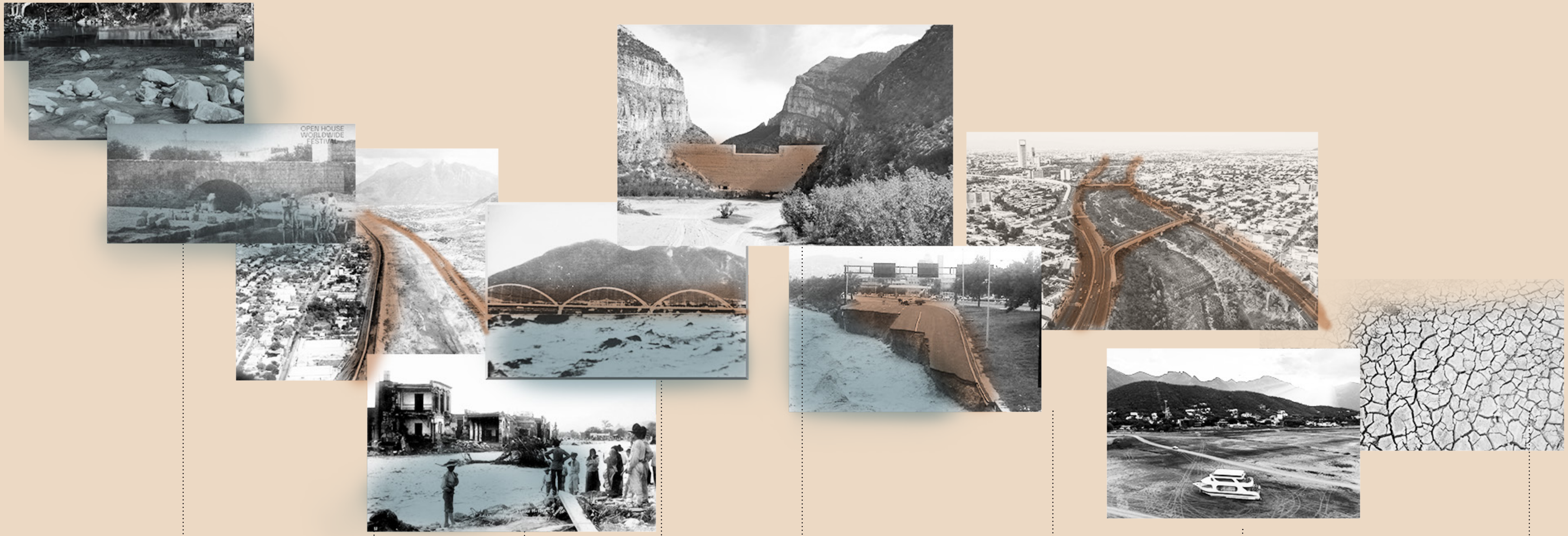
Because of rapid population and urban growth, the carrying capacity of the resources of the landscape are exceeded. Therefore, we can describe the current landscape as the overused landscape, were the people in the MMA take more than the landscape can provide. And nature began to be tamed, piped, managed and pushed back.

Fig. 20: collage of Monterrey today. Based on a photo by Cesar Rodriguez., 2022.

Historical exploration: The evolving relationship of water and society

Human interverence in the water system

River



19th century
Scientists recommended to embank the Santa Catarina River because of the spread of diseases.

Mid 20th century
Intubation of its waters. The river transformed into the "gutter" of the city.

1909
The city experienced its worst flooding in history, with an estimated 5,000 fatalities.

1988
Hurricane Gilbert

2004
Realisation of Dam

2005
Hurricane Emily (Category 5) and floods

2010
Hurricane Alex (category 2) and floods

2012
Severe Drought

2021
Hurricane Grace (Category 3) and floods

2022
Severe Drought

Fig. 21: ***Relationship between the people of Monterrey and water through time*** [collage]. Based on photos from : https://www.youtube.com/watch?v=sXsEtojmyBo, https://atlasmateriaprima.net/Presa-Rompepicos, by Cesar Rodriguez

Floods with high impact

Fig. 22: Screenshot of a film by Enrique Guadarrama. June 20, 2024.

Drought

Fig. 23: Drought. Photo by Mike Erskine on Unsplash.

Water scarcity

Fig. 24: Residents lining up to fill their containers with water in Monterrey, where the entire metropolitan area of about five million people is affected by drought. Photograph by Cesar Rodriguez., 2022.

Pollution

Fig. 25: Garbage in the Santa Catarina riverbed.

The evolving relationship of water and society

The relationship between the people of Monterrey and it's surrounded water's has changed over time. This evolution, depicted in (fig. 21), reflects the complex relationship between human activities and natural forces. Understanding these changes is crucial to cope with the challenges posed by the current water related issues in Monterrey.

Initially, Monterrey's inhabitants maintained a symbiotic relationship with their natural surroundings, adapting their way of life to the landscape's conditions. However, the industrial revolution marked an important shift. In the 19th century, the relationship with the river system began to change dramatically.

As industrialization surged, scientists advocated for the embankment and canalization of streams and rivers, citing concerns over the spread of diseases during seasonal low water. These interventions, while intended to mitigate health risks, distanced the city's residents from their rivers. The canalization of the river system turned streams into channels resembling gutters, mirroring how the populace began to perceive their rivers.

Over time, Monterrey's inhabitants came to view the river as a problem to be solved rather than a vital resource to be cherished. Moreover, the people began to see the seasonal dry riverbed as their property. The constriction of riverbanks exacerbated the damage caused by seasonal floods and hurricanes.

The economic growth caused rapid population growth and urban sprawl, with no to little green space development in the city. Leaving no change for water to infiltrate. Together with the significant degradation of the rivers, the city is built to get rid of the water as fast as possible.

Last summer, the drought was so intense that people had to wait for water trucks to provide them with water.

The evolving relationship between people and water in Monterrey serves as a reminder of the intricate connections between human societies and the natural world. As we confront the challenges of the 21st century, it is crucial that we learn from the lessons of the past and work towards a harmonious coexistence with our environment.

Degradation of the river ecosystem in Monterrey

Fig. 26: Holtes, E.O. (2024). *Modified riverbank* [photo]. Monterrey.

Fig. 27: Anuncia, S. ***Rompepicos dam***[photo]. Monterrey.

Green spaces (forest, shrubland, national parks)

Urban area

Rivers

Streams

Modified riverbanks

Dam

Fig. 28: River degradation in Monterrey. GIS data: Inegi.

The Monterrey Metropolitan Area (MMA) developed along the Santa Catarina River, which originates in the National Park de Cumbres and once meandered freely through the landscape. Today, however, the rivers of Monterrey have been extensively modified. The flow of the Santa Catarina and Pesquería rivers is heavily influenced by their channelization, reinforced with concrete slabs along their natural banks. The Santa Catarina River, the largest channelized river structure in the MMA, runs from east to west through the city. It has the widest riverbed in Monterrey but only becomes a significant flowing river during periods of heavy rainfall, such as hurricanes, which occur approximately every ten to fifteen years. These infrequent but severe events are often cited as justification for the river's separation from the city. Currently, the Santa Catarina River is not accessible to the public, confined within concrete channels and flanked by major highways.

Despite these modifications, the Santa Catarina River holds the potential to serve as a natural park, offering a valuable connection for the people of Monterrey. My graduation project aims to explore this untapped opportunity further.

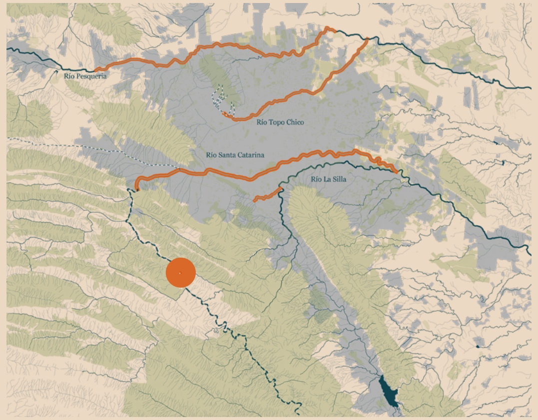
Figure XX illustrates how the Monterrey Metropolitan Area disrupts the larger ecosystem. The city sprawls across the valley between the mountains like a semi-liquid substance or blanket, effectively severing most natural and physical connections and hindering inhabitants from experiencing nearby natural processes firsthand. While the river segments upstream and downstream of the metropolitan area are surrounded by forests and national parks, the sections within the city have been heavily altered. This modification has led to biodiversity loss and ecological imbalance.

The Rompepicos dam

The Rompepicos Dam, located in the riverbed of the Santa Catarina River, was built primarily for flood control. Its purpose is to mitigate the impact of heavy rains and hurricanes on the Monterrey Metropolitan Area (MMA), which is prone to severe flooding. The dam helps regulate the flow of the Santa Catarina River, preventing sudden surges that can lead to catastrophic flooding downstream in Monterrey. Its design typically includes spillways to safely manage overflow during peak flood events. With increasing concerns about climate change and its impact on weather patterns, the role of the Rompepicos Dam in flood management remains critical.

Unlike other dams, the Rompepicos Dam has openings that allow people and animals to pass through when the riverbed is dry, which is most of the time. Nevertheless, the dam impacts the local ecosystem, particularly the Santa Catarina River. Efforts are made to balance flood control with environmental conservation.

Unfortunately, the government plans to build another dam in this protected natural reserve. Concerned citizens have organized an initiative named 'Unrioenelrio,' advocating for alternative flood risk management solutions through nature-based approaches.



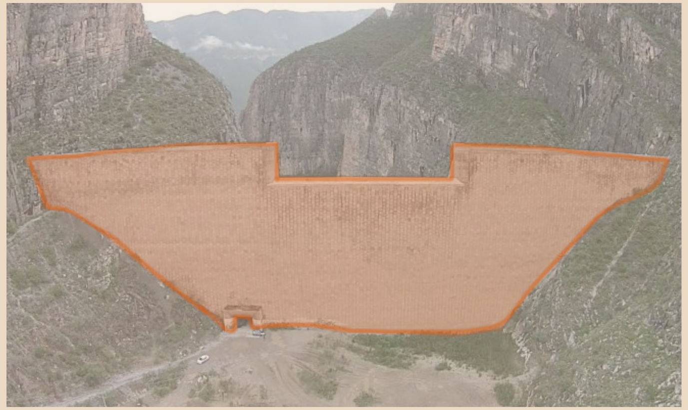


Fig. 29: Photoshop based on a photo by unkown. Dam during dry conditions.

Fig. 30: Photoshop based on a photo by unkown. Dam during a hurricane.

Fig. 31: Photoshop based on a photo by Castaneda, S. Dam during dry conditions.

Fig. 32: Photoshop based on a photo by unkown. Dam during a hurricane.

Fig. 33: Holtes, E.O. (2024). *Modified riverbank* [photo]. Monterrey.

Fig. 34: Holtes, E.O. (2024). *Six-lane road at the river edge of Santa Catarina*. [photo]. Monterrey.

Fig. 35: Holtes, E.O. (2024). *Piles of dumped trash in the Santa Catarina river*. [photo]. Monterrey.

Fig. 27: Anuncia, S. *Rompepicos dam*[photo]. Monterrey.

Problem statement

To conclude previous chapters, the challenges of biodiversity loss, climate change, desertification, and water scarcity are intrinsically interconnected and pose significant threats to the well-being of both current and future generations. The Living Planet Report 2022 underscores the severity of these challenges, revealing alarming declines in wildlife populations globally. Latin America, including the research site Monterrey in Mexico, faces particularly acute declines, with profound implications for ecosystem integrity and resilience(LIVING PLANET 2022, n.d.). Situated in a semi-arid landscape, Monterrey is more prone to these climate change challenges, compared to places with a cooler climate.

The profound alterations to its river systems, exemplifies the complex relationship between human societies and their natural environment. The historical exploration of Monterrey's landscape biography reveals a shifting dynamic, from a symbiotic relationship with nature to one marked by industrialization, rapid population growth and urbanization, exceeding the limits of the resources in the landscape.

The degradation of the rivers in Monterrey is also the cause of a shifting narrative, the once appreciated landscape being projected as a problem to solve, nature began to be tamed, piped, managed and pushed back.

Short term solutions to prevent possible floodings has led to long-term negative impact on the rivers ecosystems and natural habitats in the MMA.

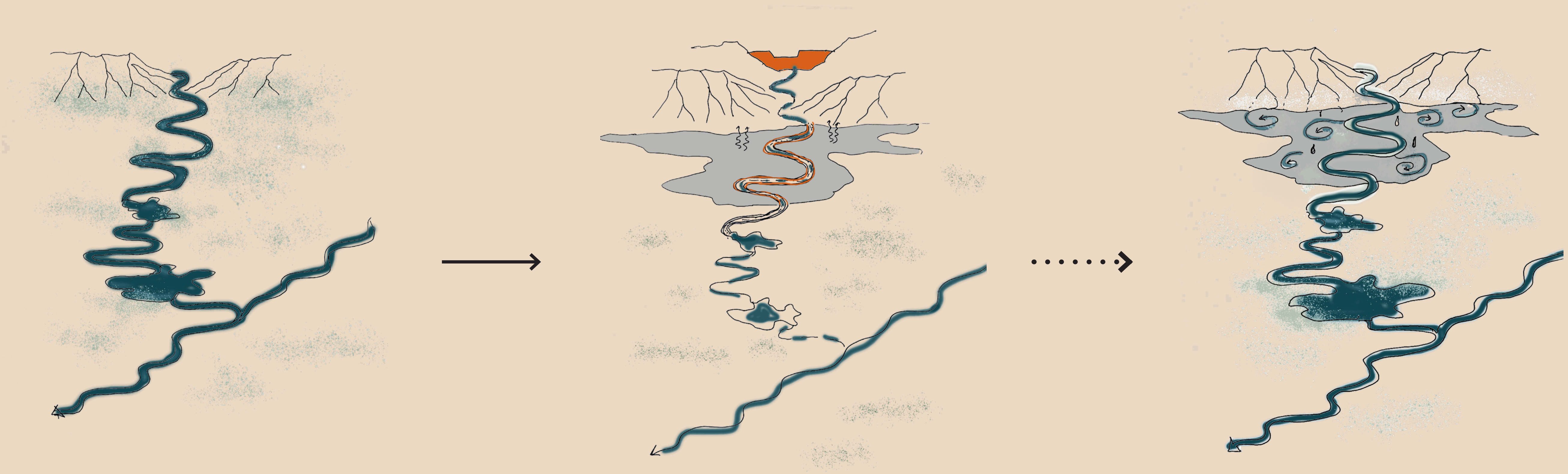
However, amidst these challenges lies untapped potential for transformative action. There is an opportunity to reshape urban environments in a manner that promotes biodiversity conservation, climate resilience, and sustainable water management. By reimagining Monterrey's river systems as natural park and reconnecting inhabitants with their surrounding ecosystems, we can foster a more harmonious coexistence between humanity and nature.
A transformation of the city and region narratives towards nature based, and landscape-driven solutions.

Research question

What landscape architectural interventions can be employed to restore the river ecosystem of Monterrey?

Research goal

Restoring the river ecosystem



Before

NATURAL LANDSCAPE

The water roamed freely from the mountain ranges, through the watershed of the Rio Grande, into the Gulf of Mexico

Now

OVERUSED LANDSCAPE

The water system is exploited by the great amount of people that live in the arid landscape of Monterrey.

Future

SYMBIOTIC LANDSCAPE

The research goal would be to move towards a symbiotic landscape were the city gives space to the river system and can contribute to the ecosystem of the river via
nature-based solutions.

Fig. 36: *illustration of research goal.*

2

Research *about* design

This chapter delves into the theoretical approaches in landscape architecture that have been instrumental in shaping this thesis. It concludes with a discussion of the methods and processes employed in the research.

The natural river ecosystem

Fig. 37: Holtes, E.O. (2024). *View on the Río La Silla* [photo]. Monterrey, Mexico.

Theoretical framework

The Urban Ecology Design Approach

The Urban Ecology Design Approach aims to improve ecological functioning within cities and its surrounding regions, from the urban core to the countryside (Tillie, 2024). It is a design practice to enhance the quality of space and life of all species within those areas. The three stepped urban ecology design approach takes the urban ecosystem level, urban habitat level and species level is taken into account when designing for urban ecology.

In this approach, **urban ecosystem level** is mainly defined by the environmental systems at the urban landscape or regional scales. Taking both the natural layers and the urban layers into account, with the elevation, water, soil, and landscape vegetation (or ecoregions) as the basis.

The **urban habitat level**. A habitat is the natural home or environment for organisms such as animals or plants. Although not exactly the same, this is also often referred to as a biotope.

The **species level** refers to the scale of the experience world of specific species. Through design we can improve the urban environment for specific species. In some cases, ecologist specify target species, or umbrella species for urban environments to focus on in urban development. If you design for their specific habitat requirements, you will automatically also invite other species.

Urban Ecosystem level: MMA

Habitat level: Tampaulipan matorral

Species level: Monarch butterfly

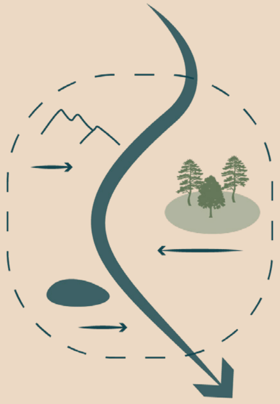
Fig. 38: Illustration of the three layers of The Urban Ecology Design. Approach.

The watershed approach

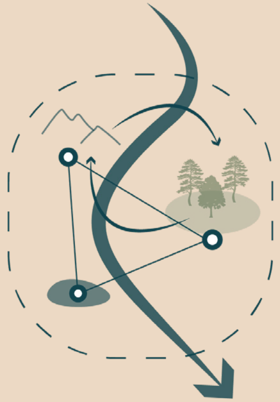
The watershed approach is a systematic methodology centred around the concept of a watershed, defined as the area of land that channels water to a common outlet such as a river, lake, or ocean. Encompassing all land, vegetation, and water bodies, a watershed is delineated by natural features such as topography, which dictate the flow of water (1).

This approach acknowledges the intricate interconnections and mutual influences within a specific watershed. Actions taken within the watershed, regardless of scale or location, reverberate across its entirety, highlighting the need for comprehensive management strategies (Hooijmeijer et al., 2021).

Recognizing that land use practices—such as agriculture, forestry, urbanization, and industrial activities—profoundly impact water quality, quantity, and ecosystem health, the watershed approach endeavours to enhance sustainable management and protection. It does so by integrating considerations of the complex interactions between land and water systems, engaging relevant stakeholders, and implementing adaptive management techniques. Effective watershed management hinges on collaborative efforts among all stakeholders, underscoring the importance of collective engagement in safeguarding the health and integrity of these vital ecosystems.



1. The watershed



2. The watershed as interconnected system

3. Upstream, midstream and downstream effect

Figure 39: illustration of the watershed approach.

Theoretical framework

Landscape ecology design principles

The configuration of urban habitats

Scientifically, the foundation of ecological networks was laid in two publications, the first of which dealt with the relationship between species number and size and degree of isolation on islands the so-called Island theory of MacArthur and Wilson from 1967.

In the second publication of Jared Diamond in the mid-seventies, (The island dilemma, lessons of modern biogeographic studies for the design of natural reserves). these research results were applied in rules for the design of nature reserves, in which he contrasted good solutions with bad solutions like:
1. Big is better than small
2. One whole is better than separated
3. Connected is better than separated
4. Close together is better than further apart

Diamond's scheme was further elaborated in the following years. The most important components of an ecological network are cores, steppingstones and corridors. In the city, the cores are often the large parks or lakes, the steppingstones are the small parks and natural ponds, and the corridors are the verges, roadsides and banks with waterways.

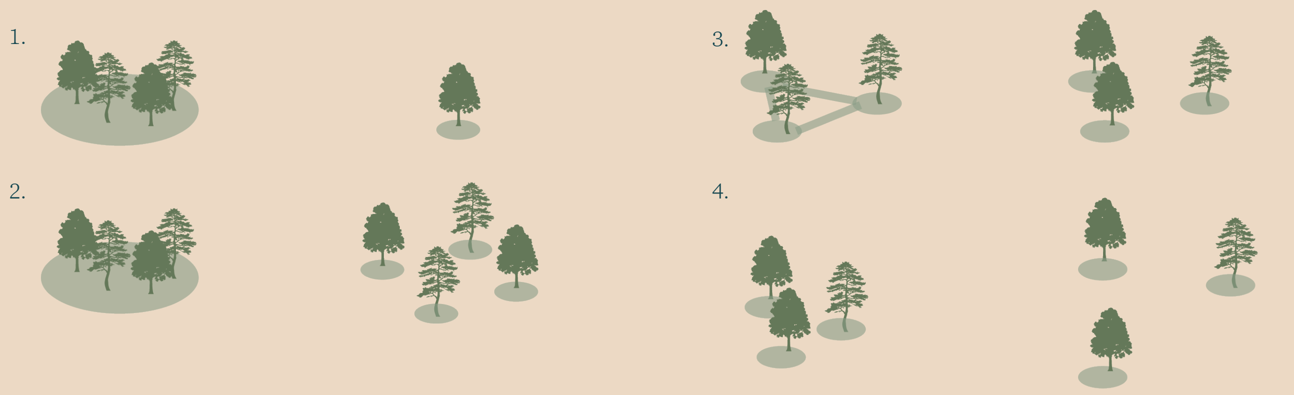


Fig. 40: Illustration of principles for urban habitat configuration.

Design principles for corridors

Research indicates that establishing high-quality connections between patches often fosters increased biodiversity, although effectiveness may vary. These connections, referred to as ecological corridors, play a pivotal role in facilitating the movement of species across fragmented landscapes. Notably, streams and rivers serve as corridors of exceptional significance, facilitating the movement of water-dependent species throughout the ecosystem. However, it's essential to acknowledge that corridors can also pose challenges to biodiversity. Human-made structures such as roads, railroads, and canals often act as barriers, disrupting natural connectivity and impeding the movement of wildlife.
In their work, Dramstad et al. (1996) outline several principles for optimizing the effectiveness of corridors. Key considerations include the width and connectivity of the corridor, with wider corridors and fewer interruptions generally proving more effective.

Additionally, maintaining a vegetation structure akin to that of larger patches along the corridor is crucial. For stream and river corridors, water quality plays a vital role, with vegetated banks serving as natural filters and providing habitat for diverse species. This transitional area between land and water, known as the riparian zone, is particularly rich in biodiversity.

Furthermore, corridors can still function effectively despite gaps, provided the gaps are not too large and the land use within them is not drastically different from that of the corridor itself. In cases where continuous corridors are not feasible, the establishment of stepping stones, comprising a series of small patches strategically placed, serves as a viable alternative. Even a single stepping stone, strategically positioned, can significantly enhance the effectiveness of such networks in facilitating species movement and maintaining biodiversity.

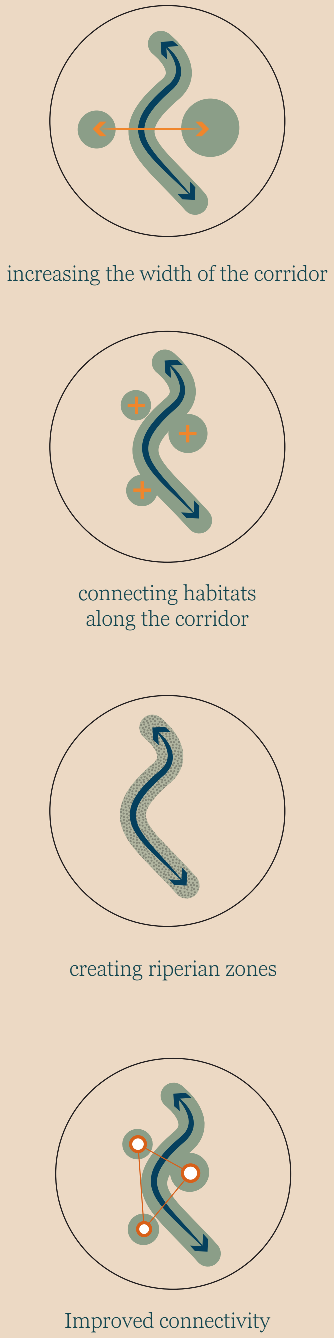


Fig. 41: Illustration of principles for corridors.

Theoretical framework

Landscape based approach

The landscape-based approach is a methodology that highlights the landscape as a complex system composed of both natural and human-made elements that shape the built environment. This approach utilizes the landscape as the foundational condition, encompassing physical features, ecosystems, cultural artifacts, and social structures, to inform and direct changes within a specific region or place. A critical aspect of this approach is the analysis of the landscape's specific context, which reveals its characteristics and dynamics and how they influence its current state. Mapping and drawing are valuable tools for communicating and representing visual thinking. The landscape-based approach adopts a holistic perspective, considering the landscape as an integrated whole and acknowledging the interconnectedness and interdependence of its various components (Nijhuis, 2022).

Method and process

The diagram on the right page illustrates the methodology applied to donduct this thesis.
The methodology is described via different phases in the process of design: understanding, finding solutions, design and reflection.

Research *for* design
Analysis // understanding,

To get a better understanding of the landscape and the challenges and opportunities that belong to it. Analysis were conducted on Urban Ecosystem level, Urban Habitat level and Species level, according to the Urban Ecology Design Approach, as described in the theoretical framework chapter.

To understand the bioregion of Monterrey the biotic, abiotic and anthropogenic layers need to be studied through mapping analysis, literature and data.

- To fully understand certain topics, like the water system, cycles will be studied and visualized.
- Drawing from the analysis and studied cycles the problem(s) can be stated.
- The main research question and sub questions are stated to address the identified problem(s).
- Location visits to get a better understanding of the landscape

Research *about* design
Design tools // solutions,

What landscape architectural design interventions could be used to restore the river ecosystem of Monterrey?

- Gathering knowledge about landscape design interventions made in arid to semi-arid around the world
- Constructing a toolbox with applicable landscape design interventions

Research *by* design
Design //
How to implement landscape architecture design to restore the river ecosystem of Monterrey?

- Making a vision and design principles based on the gained information.
- Proposing a Masterplan for the bioregion of Monterrey based on the vision,
- A design elaboration of the vision by (multiple) design elaborations on a smaller scale. Making the design principles site-specific and relatable to the human and non-human scale.

Reflect // reflection

- A check if the design outcomes and the written thesis give answer to the stated research question(s).
- Writing a conclusion with the most critical insights of the project
- Writing a reflection about the projects methodology, design content and social and moral aspects regarding it.

What landscape architectural interventions can be employed to restore the river ecosystems of Monterrey?

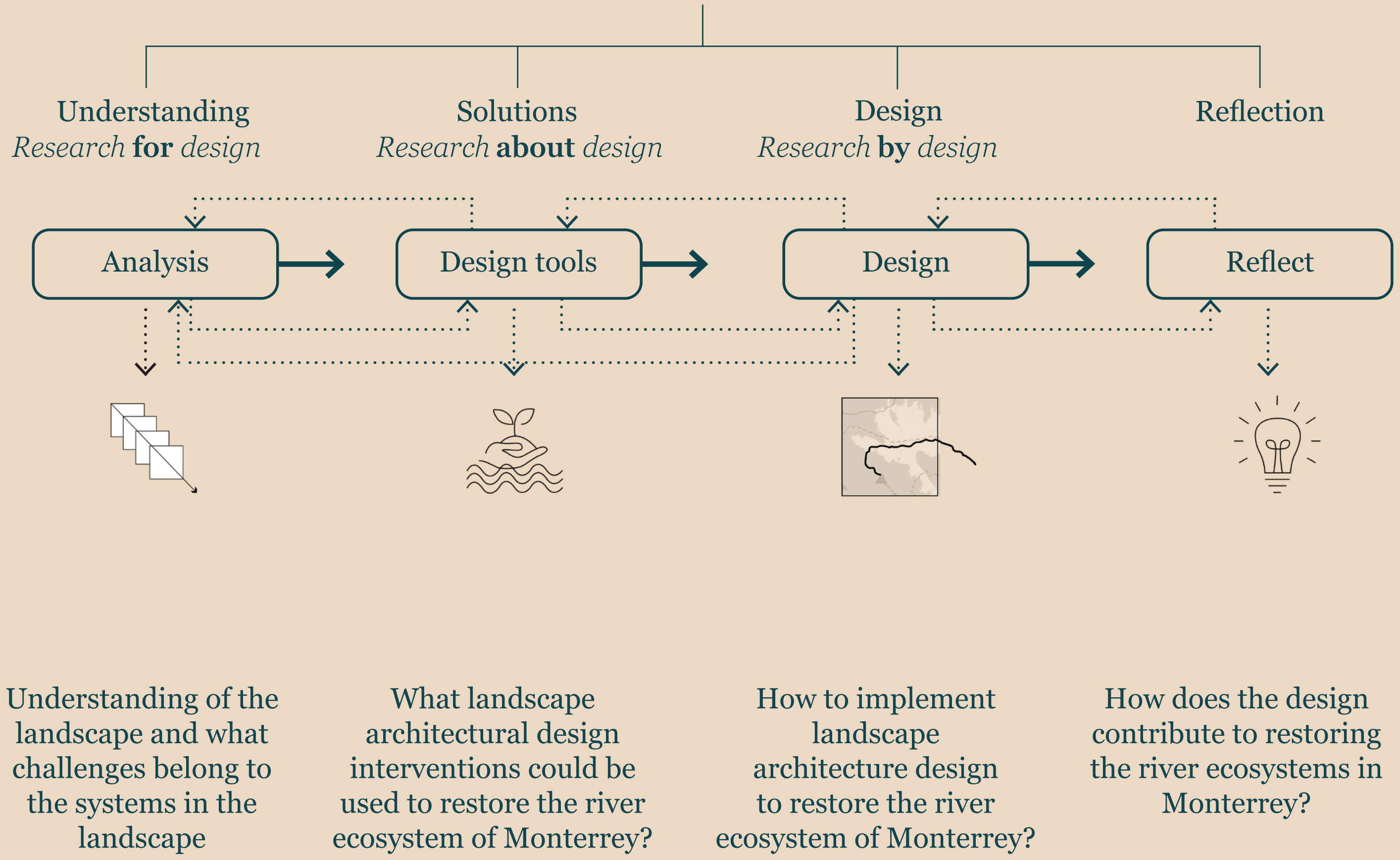


Fig. 42: Methodology diagram.

3

Research *for* design

The aim for this chapter is to provide a better understanding of the landscape of Monterrey and its complexities via the lens of the Urban Ecology Design Approach: by analysing the urban ecosystem level, urban habitat level and the species level of Monterrey.

The Urban Ecosystem level

Analysis of the ecosystem on the regional scale

Fig. 43: Holtes, E.O. (2024). *View on Monterrey* [photo]. Monterrey, Mexico.

Fig. 44: Nueco León. Topography and elevation. GIS data: Inegi, Google maps.

Topography, elevation and geomorphology

The agglomeration is situated at the edge of the Sierra Madre Oriental mountain ridge, marking a transition between the sub-humid tropics and the desert. The Sierra Madre Oriental, a segment of the Rocky Mountain System extending from Canada to the Isthmus of Tehuantepec, features large, often asymmetrical folds. South of Monterrey, these folds frequently overturn to the east and sometimes experience eastward thrusting. West and southwest of Monterrey, the folds often overturn to the north or both flanks, forming fan folding (see Fig. 45). In this region, anticlines—upward folds in the geological layers—create mountains, while synclines—downward folds—form valleys. The average elevation in the Sierra Madre is approximately 2,000 meters, with some peaks exceeding 3,000 meters (Weidie, 1961). The folding in the mountain ridge has, in some areas, positioned horizontal layers of soil vertically above ground (see Fig. 46).

Fig. 45: Holtes, E.O. (2024).View on the folds of the Sierra Madre Oriental.

Fig. 46: Holtes, E.O. (2024).View on the folds of the Sierra Madre Oriental.

The watershed

Watershed of the Río Grande

Rio Grande main course

Rio Grande secondairy course

Rio Grande watershed

San Juan river basin

State borders

Fig. 47: The Río Grande Watershed and its rivers. GIS data: Arcgis.

The Rio Grande, known as Río Bravo in Mexico (officially Río Bravo del Norte), traverses North America, originating in Colorado between the Sangre de Cristo Mountains and the San Juan Mountains. Its course extends southward through New Mexico and forms the border between the United States (Texas) and Mexico from Ciudad Juárez to El Paso, eventually emptying into the Gulf of Mexico at Brownsville. This vital waterway spans 3,034 kilometers.

The expansive Rio Grande watershed, covering an area of 472,000 square kilometers, is crucial for meeting the water needs of seven U.S. and Mexican states, especially in arid and semi-arid regions. Flowing through deserts and steppes, the Rio Grande irrigates fertile valleys and agricultural regions along its route to the Gulf of Mexico near Brownsville, Texas. However, the river's flow is heavily regulated by numerous dams and irrigation diversions, causing some sections of the Rio Grande to run dry. Despite this, the lower Rio Grande Valley, including the Rio Grande Delta, remains a significant agricultural hub due to extensive irrigation.

Since the mid-1990s, the river's flow has been drastically reduced, reaching only 20% of its natural volume due to extensive diversions, dam constructions, and water consumption by urban centers and agricultural lands (Olson & Lang, 2021).

The watershed of the Río Bravo also known as the 'Río Grande'

Fig. 48: Río Grande by Erich Schlegel.

The watershed

The Río Bravo-San Juan watershed

The Monterrey Metropolitan Area (MMA) comprises 12 municipalities, including Monterrey, the capital of the state of Nuevo León. Situated in the San Juan River basin, a sub-basin of the Rio Bravo/Río Grande which spans the border with the United States. According to the watershed approach (Hooijmeijer et al., 2021) , this signifies that the water system of the MMA not only impacts its immediate surroundings but also influences the broader Río Grande watershed further downstream, which ultimately drains into the Gulf of Mexico.

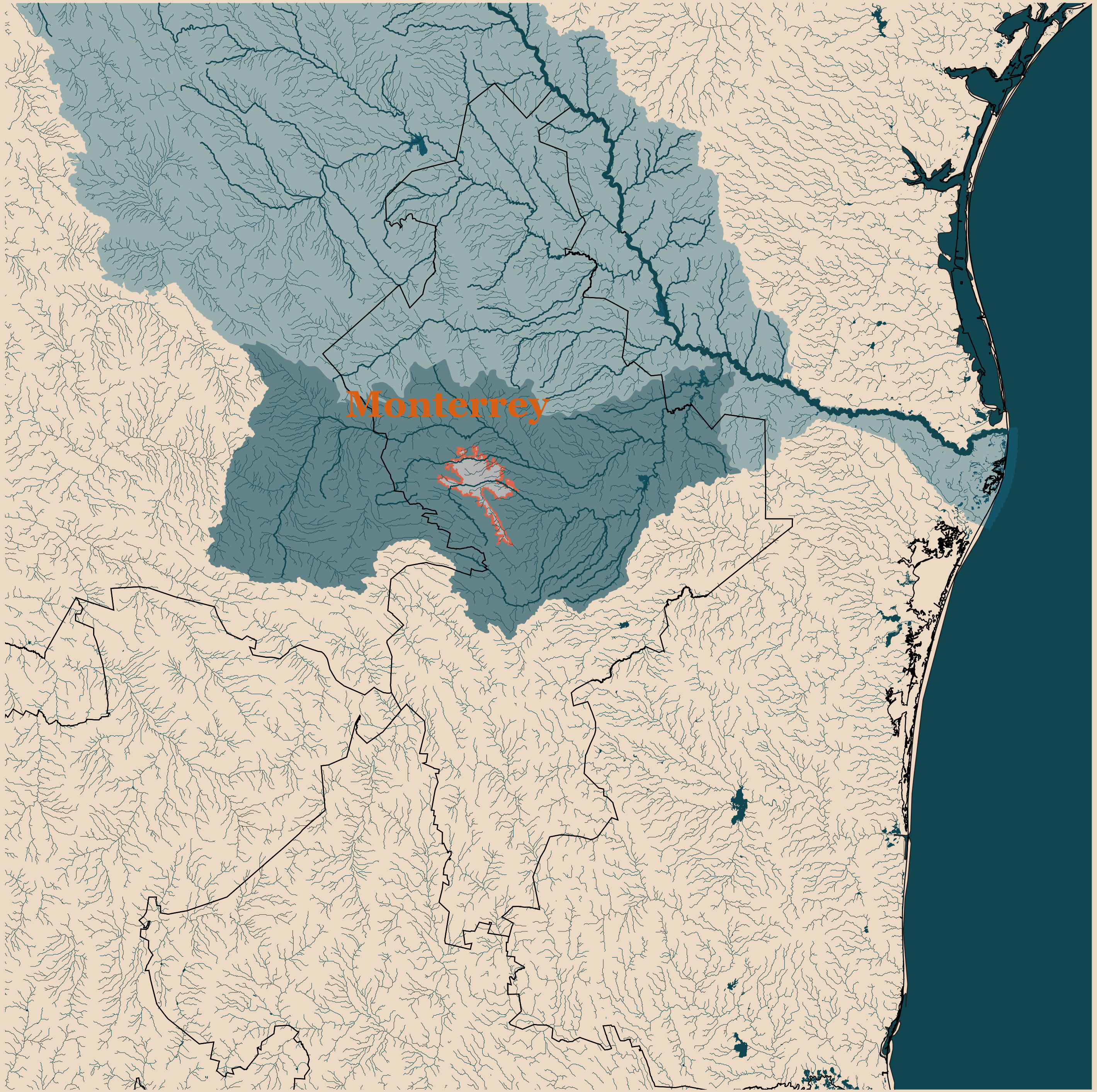


Fig. 49: The Río Grande and San Juan watershed and rivers.GIS data: Inegi.

Water cycle

Water vapor from the Gulf of Mexico evaporates into clouds, which, upon reaching the Sierra Madre Oriental mountain range, condense, giving rise to the region's rivers. However, the occurrence of forest fires contributes to soil runoff.

While water infiltrates the ground, replenishing groundwater aquifers crucial for Monterrey's water supply, overutilization leads to groundwater degradation.

The city's lack of vegetation exacerbates water-related challenges, impeding water infiltration and increasing evaporation rates. Moreover, industries discharge treated wastewater back into the river system without reusing it, further straining water resources.

The channelization of rivers and the absence of green spaces in the urban landscape accelerates water drainage from the city. This approach prioritizes rapid water removal over retention, despite Monterrey's semi-arid climate and limited water availability. As a result, the city faces ongoing challenges in managing its water resources sustainably.

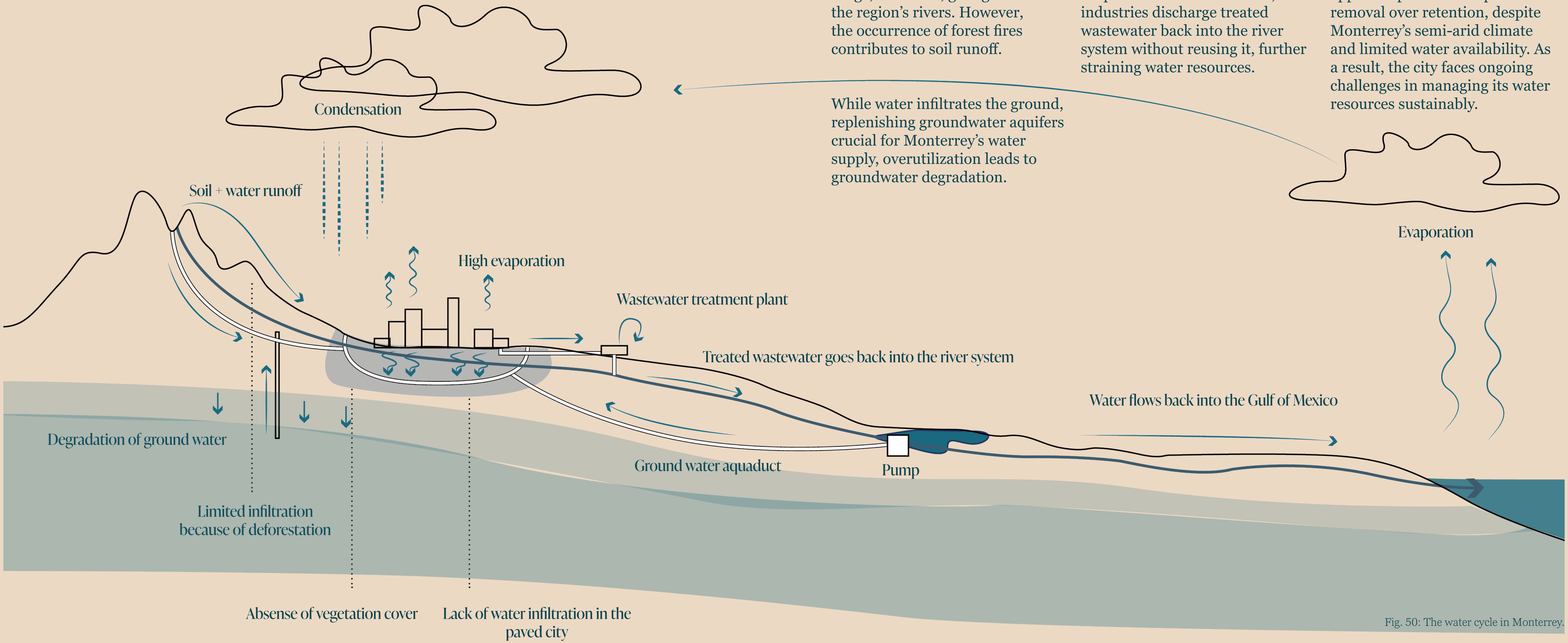


Fig. 50: The water cycle in Monterrey.

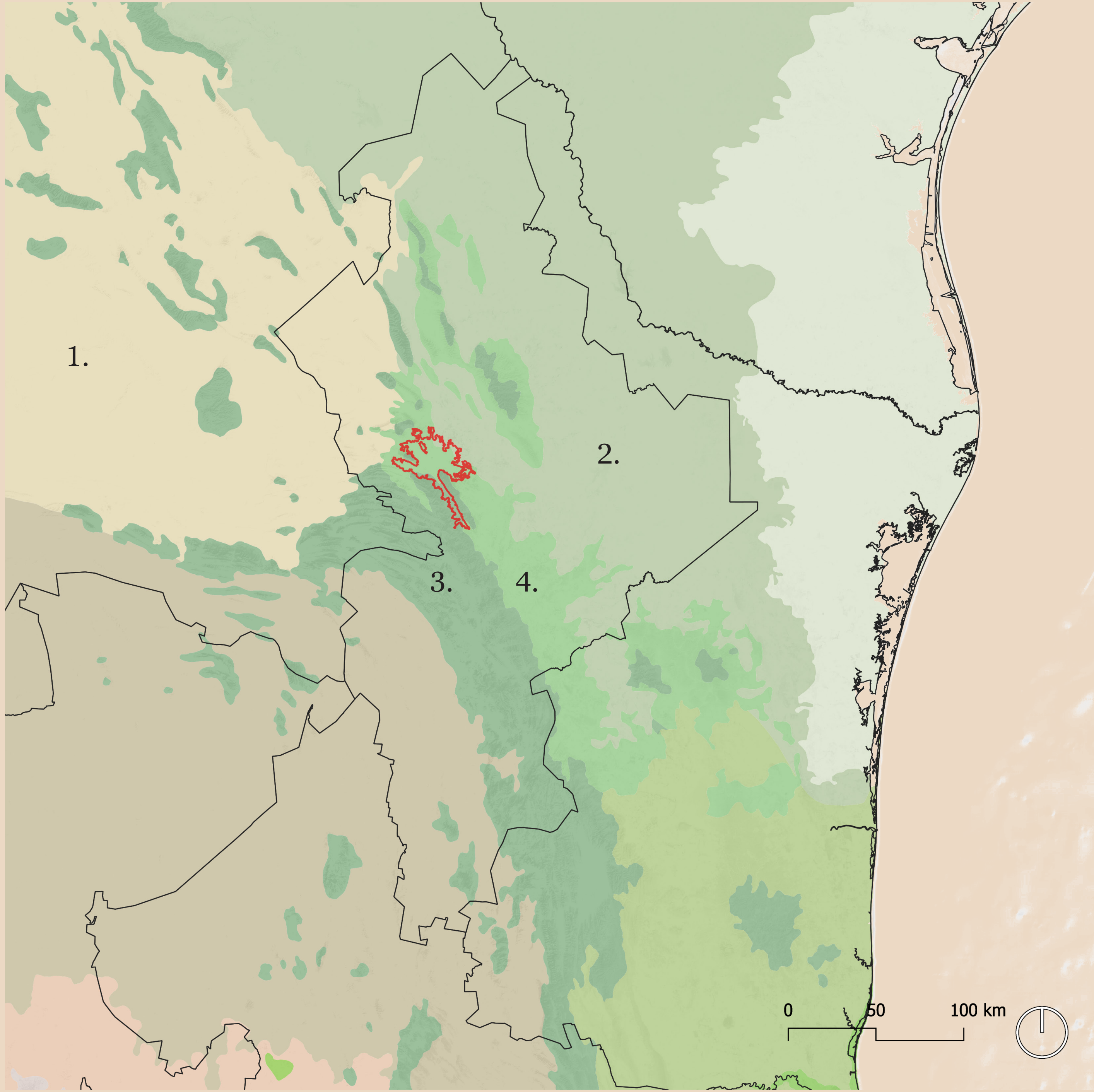
The bioregion

Fig. 51: The Mexican drylands bioregion. Source: https://www.oneearth.org/bioregions/

The agglomeration is embedded at the edge of the Sierra Madre Oriental mountain ridge and therefore marks a transition between the sub-humid tropics and the desert.

the Mexican drylands bioregion, a bioregion dominated by desert and dry shrublands, but the eastern and western ranges of the Sierra Madres are covered with subtropical pine and oak forests. It contains eight ecoregions (One Earth, n.d.).

Fig. 52: Holtes, E.O. The Mexican drylands.



The ecoregions

The ecoregions of the MMA region fall within the Mexican Drylands bioregion, as illustrated on the previous page. Nuevo León encompasses several distinct ecoregions, including parts of the Chihuahuan Desert, Tamaulipan Mezquital, Sierra Madre Oriental Pine-Oak Forests, and Tamaulipan Matorral.

1. Chihuahuan desert

Fig. 54: Fewings, N. Chihuahuan desert. On Unsplash.

2.Tamaulipan mezquital

Fig. 55: Tamaulipan mezquital.

3. Sierra Madre Oriental pine-oak forest

Fig. 56 Sierra Madre Oriental pine-oak forest.

4.Tamaulipan matorral

Fig. 57: Tamaulipan matorral.

Fig. 53: The ecoregions of the region GIS data: Inegi..

Natural reserves and vegetation

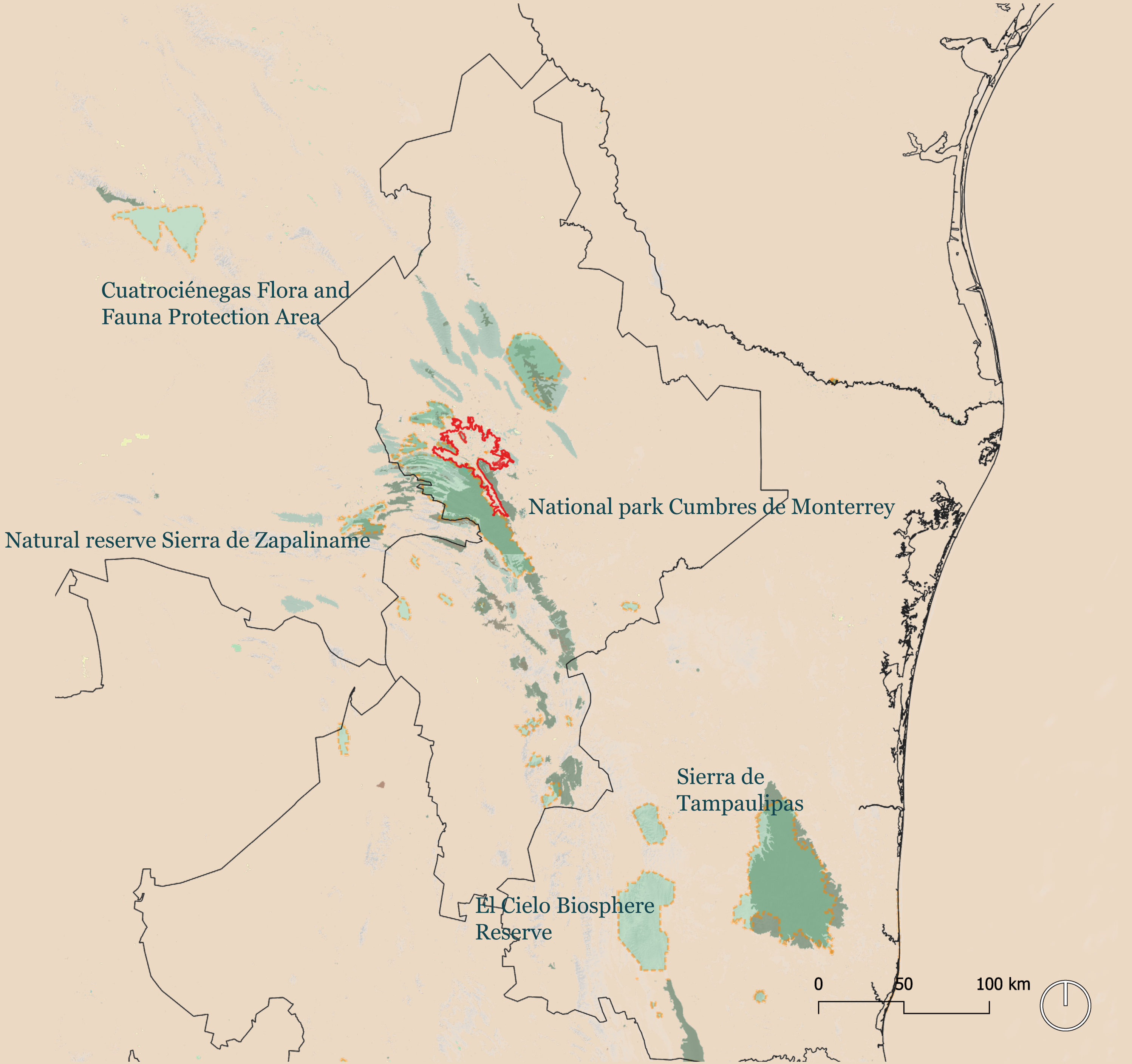


Fig. 58: Natural reserves and vegetation of the region.Gis data: Inegi

Fig. 59: Holtes, E.O. (2024). *National park de Cumbres de Monterrey.* [photo]. Monterrey, Mexico.

The region contains several natural reserves, some of them with a protected status like the National park Cumbres de Monterrey.

Most of these vegetated areas are located alongside of the Sierra Madre Oriental mountain ridge.

The (Urban) Habitat level

Analysis of the human and non-human habitats

Fig. 60: Holtes, E.O. (2024). *View on the Cerro la Silla mountain ridge* [photo]. Monterrey, Mexico.

Soils

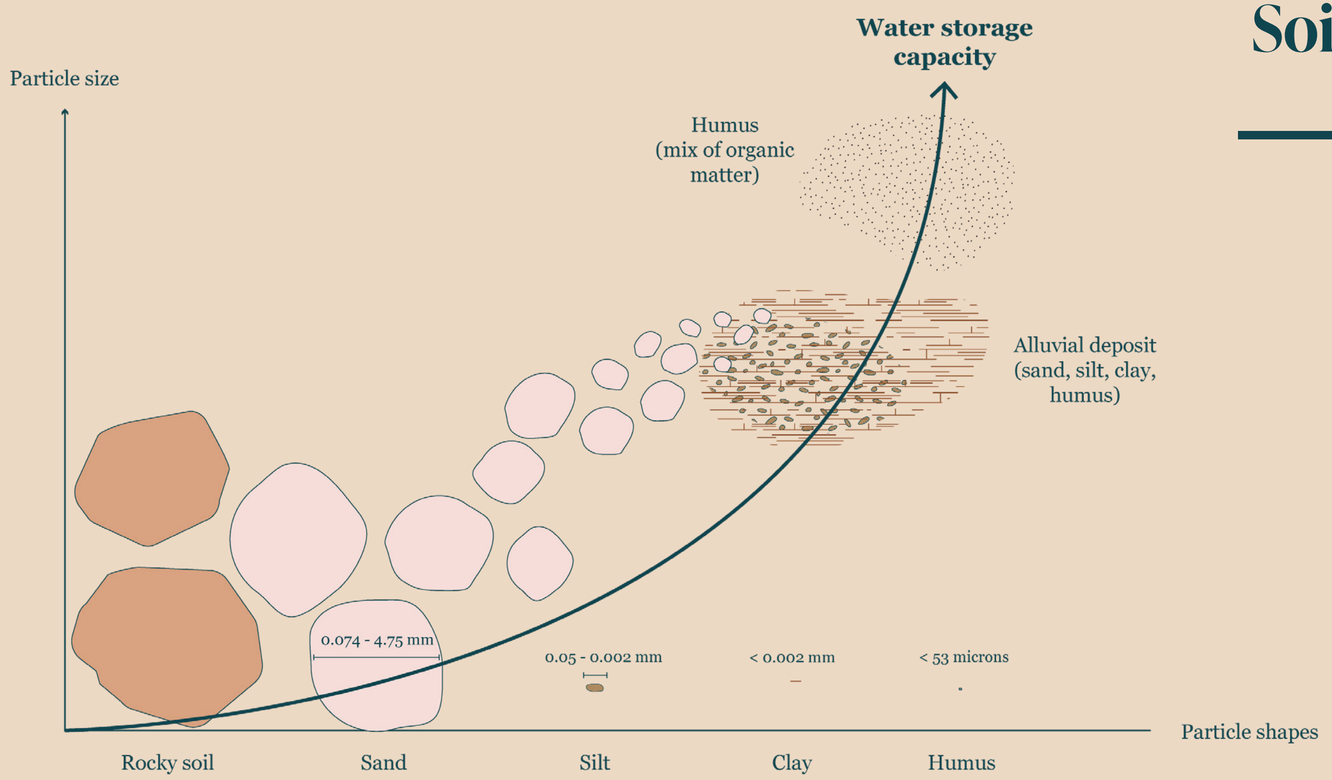
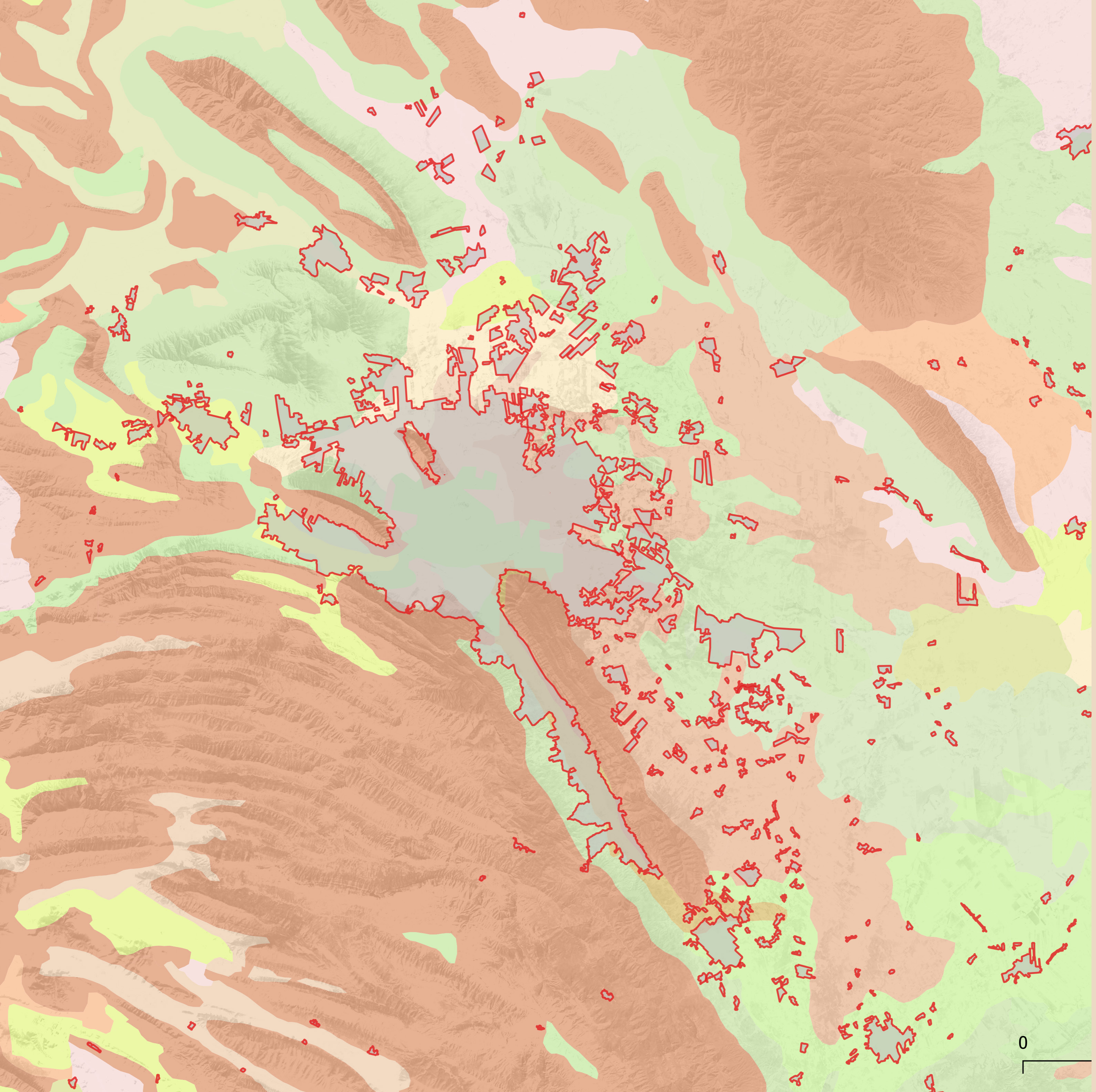


Fig. 61: Soil water capacity per soil type. Soil water capacity per soil type. Based on: https://nrcca.cals.cornell.edu/soil/CA2/CA0212.4.php#:~:text=The%20total%20soil%20water%20storage,70%20to%2085%25%20by%20volume and https://www.sciencelearn.org.nz/resources/957-soil-properties

The soils in the area of the MMA exhibit distinct characteristics across different regions. On the eastern side of the Sierra Madre Oriental, the soils are rich in humus, contributing to higher fertility and organic matter content. In contrast, the mountain ridge itself is dominated by rock fragments and calcareous soils, which are less fertile and more alkaline. On the western side, desert soils prevail, characterized by low organic content and limited water retention capacity. Within the city, the topsoil layer is primarily composed of sand, providing a foundation for construction.

The accompanying diagram illustrates the water storage capacity of each soil type. Total water storage capacity refers to the maximum amount of water that can be held when all soil pores or voids are saturated (Cornell University, 2010). Consequently, the rocky soils in the mountains have significantly lower water storage capacity compared to the more organic soils found in the southeast of Monterrey.



Litosol = rock fragments
Vertisol = calcareous soils
Rendzina = humus-rich shallow soils
Phaeozem = organic matter
Kastanozem = organic matter
Xerosols = soils of the deserts, sand

0 10 20 km

Fig. 62: soils in MMA. GIS data: municipality of Monterrey, http://www.conabio.gob.mx/informacion/gis, Inegi.

Water system of the MMA

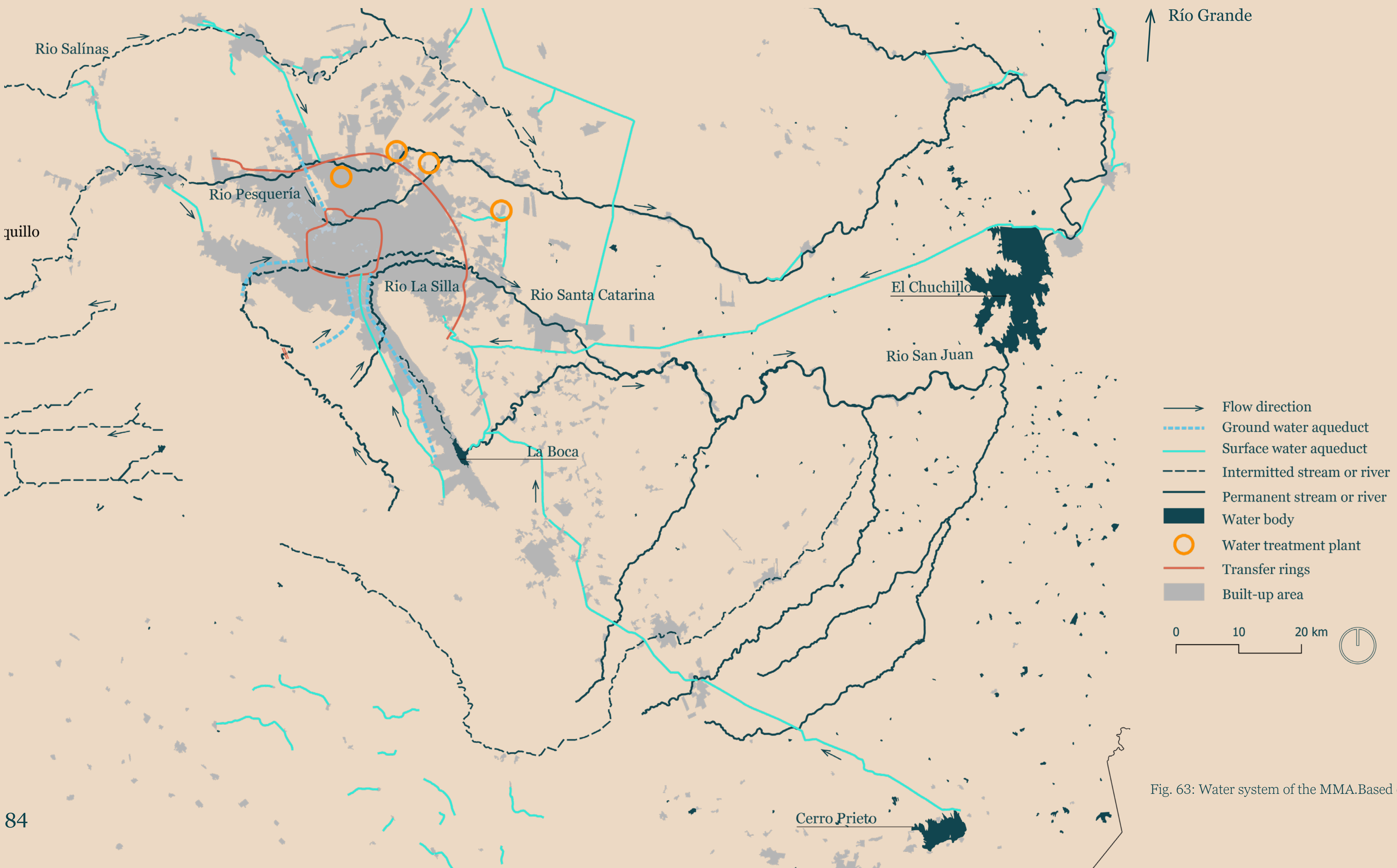


Fig. 63: Water system of the MMA.Based on info from Conagua and GIS data from Inegi.

The Monterrey Metropolitan Area (MMA) sources half of its water supply from three downstream reservoirs: El Cuchillo, Cerro Prieto, and La Boca (Fig. XX). According to the 1944 International Water Treaty, Mexico has exclusive rights over the waters of the San Juan River Basin. The water services authority, Servicios de Agua y Drenaje de Monterrey (SADM), manages the MMA's water supply.

The main rivers flowing through the MMA are the Río Pesquería, Río Santa Catarina, and Río La Silla, which descend from the mountains towards the El Cuchillo reservoir and the Río Grande basin. The city's water supply is pumped from these reservoirs up the mountains and distributed via a network of transfer rings.

Yearly rainfall and hazards

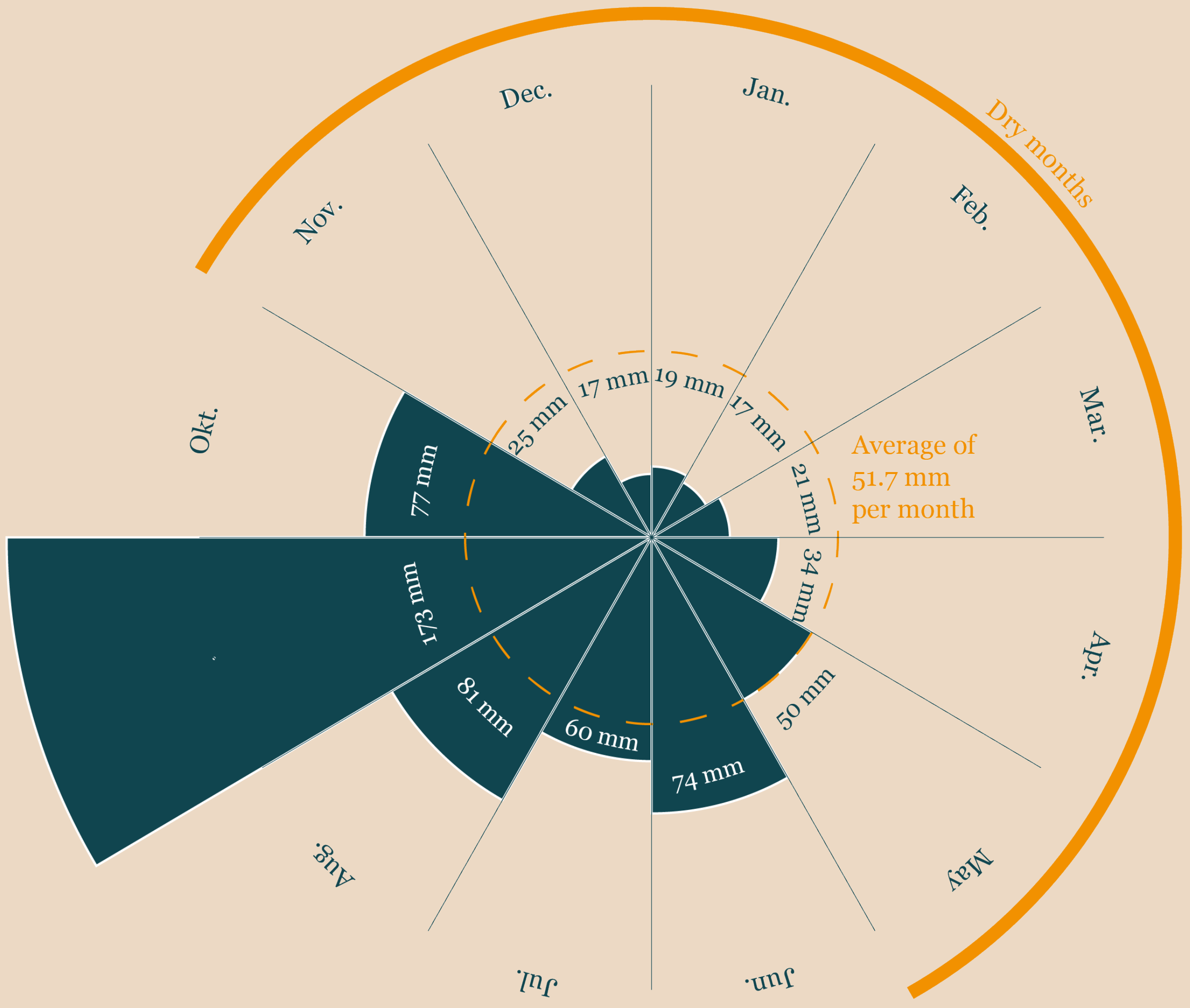


Fig. 64: Yearly rainfall in MMA. Based on data from Conagua.

The MMA receives only 600mm of rain per year on average and local creeks and rivers usually run dry or carry only minimal flows. The annual precipitation shows us a long period of drought, most of the years precipitation occurring in September (Ismael Aguilar Barajas & Aldo Iván Ramírez Orozco, n.d.). Nonetheless, every 3 or 4 years intense rain showers of 100mm or more within a 24 -h period (sometimes associated with named tropical storms, e.g. Ingrid in 2013) do occur. These downpours invariably overwhelm the city's storm drain-age system and cause localized, short duration problems particularly to transit.

The MMA's distance from the nearest coast (about 200 km) protects it from the direct onslaught of hurricanes, but its location at the foot of the Sierra Madre Oriental range exposes it to a significant flash flood hazard. Powerful hurricane remnants from the Gulf of Mexico occasionally reach the region and discharge large amounts of precipitation within a short period of time over critical catchment areas in the mountains high above the city. Three to four times per century, these events result in sudden and profuse surface flows notably in the Santa Catarina River, the MMA's principal watercourse which crosses the whole metropolitan area west to east.

Understanding Hydrological Dynamics in Flood Risk Management

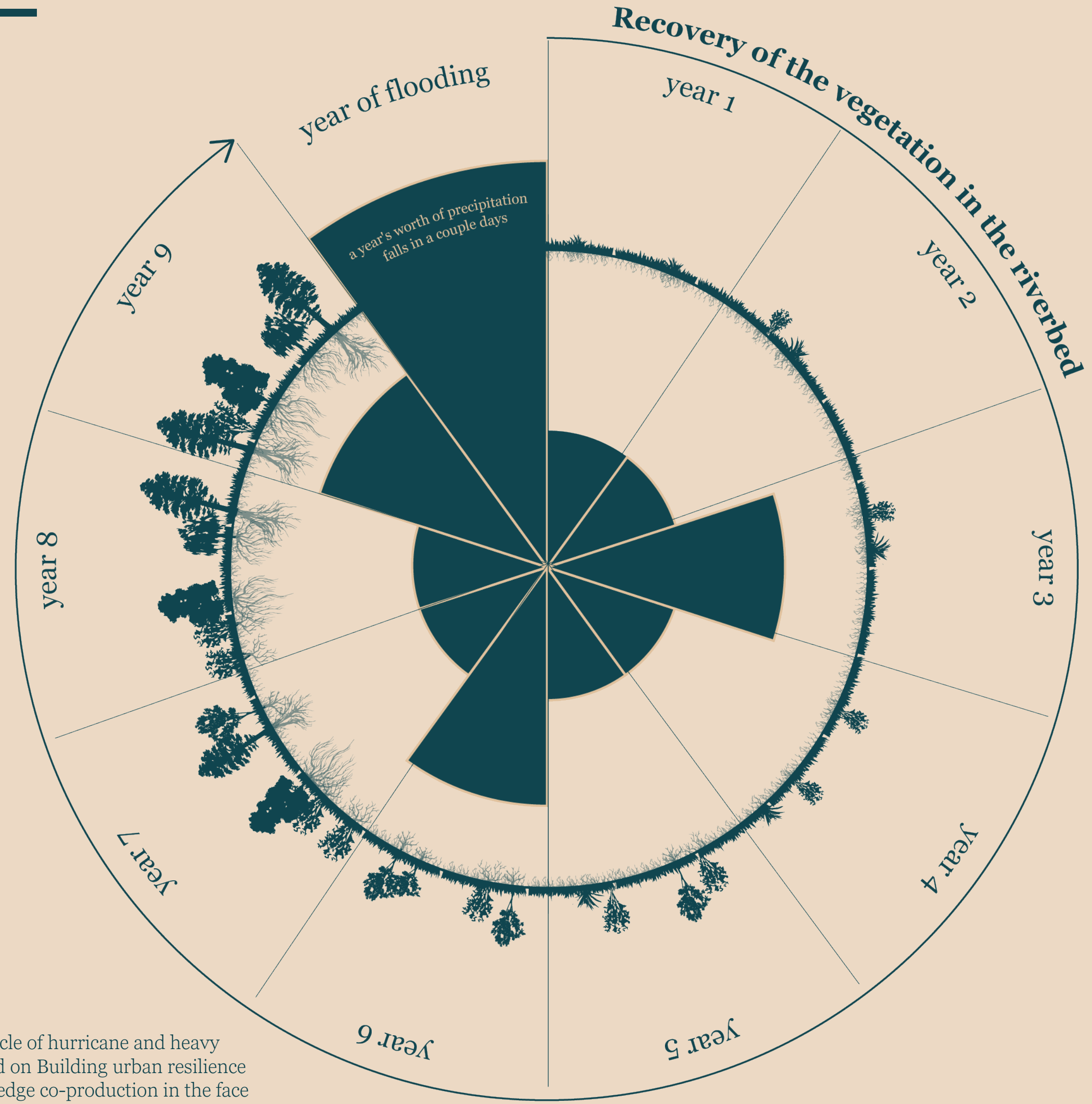


Fig. 65: Cycle of hurricane and heavy rains.Based on Building urban resilience and knowledge co-production in the face of weather hazards by Aguilar-Barajas, I., Sisto, N. P., Ramirez, A. I., & Magaña-Rueda, V. (2019).

In flood risk management, understanding the dynamics of the Santa Catarina River is crucial. Under typical conditions, the riverbed is dry, allowing for natural vegetation succession. However, intense rainfall events, occurring every 3-4 years, cause the river's water levels to rise significantly. The most substantial flows result from storms, like hurricanes, impacting the slopes of the Sierra Madre Oriental, which happen approximately every 10-15 years (Aguilar-Barajas et al., 2019).

As I am finishing this thesis, storm Alberto has moved inland over northeastern Mexico, bringing heavy rains and flooding. This storm has led to the Santa Catarina River overflowing, causing multiple casualties and prompting local authorities to move people to temporary shelters and suspend public activities (TecScience, 2024). Again, the river is showing its power and claiming its space.

Hurricanes disrupt the vegetation within the riverbed, as the rushing water sweeps away existing vegetation. After each hurricane, the vegetation growth cycle restarts, leading to the predominance of pioneer species in the riverbed. This cyclical process is depicted in the adjacent timeline diagram (N. Tillie, personal communication, March 15, 2024).

Consequently, the Santa Catarina River undergoes three distinct water level stages: dry seasons, heavy rain periods, and hurricane-induced flooding. Despite their unpredictable nature, these varying water levels must be factored into the design of structures and landscapes along the riverbank.

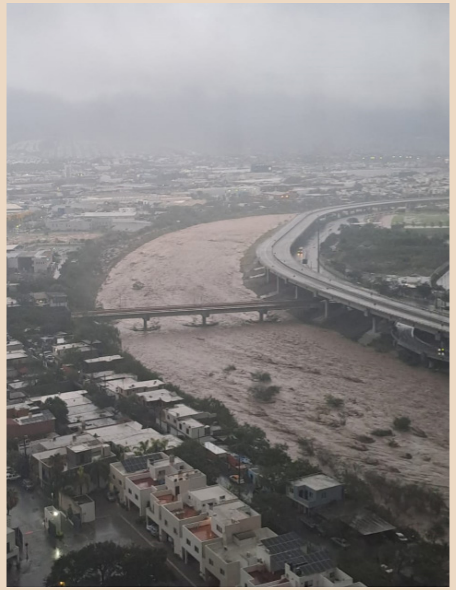
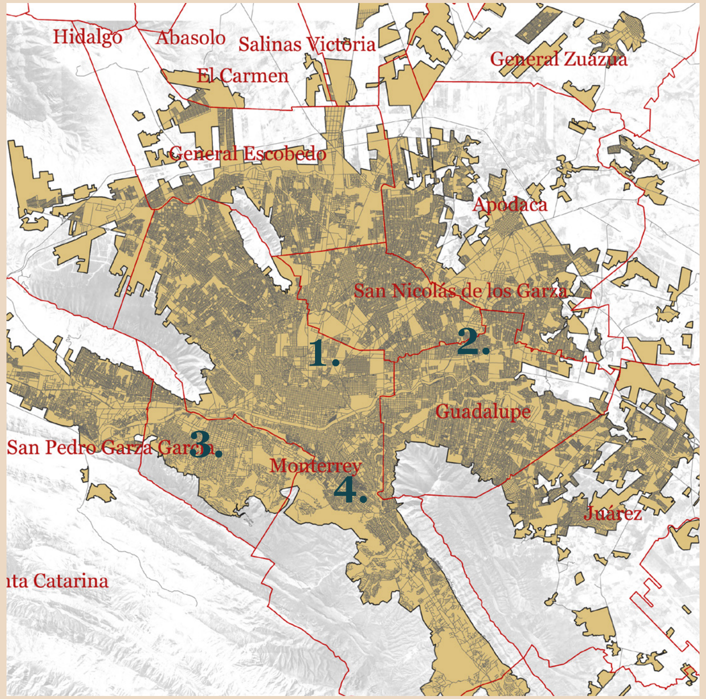


Fig. 66: Impact of storm Alberto. Photo by Rob Roggema, June 20, 2024.



Fig, 67: The different municipalities that belong to the MMA. GIS data: Gobierno de Monterrey.

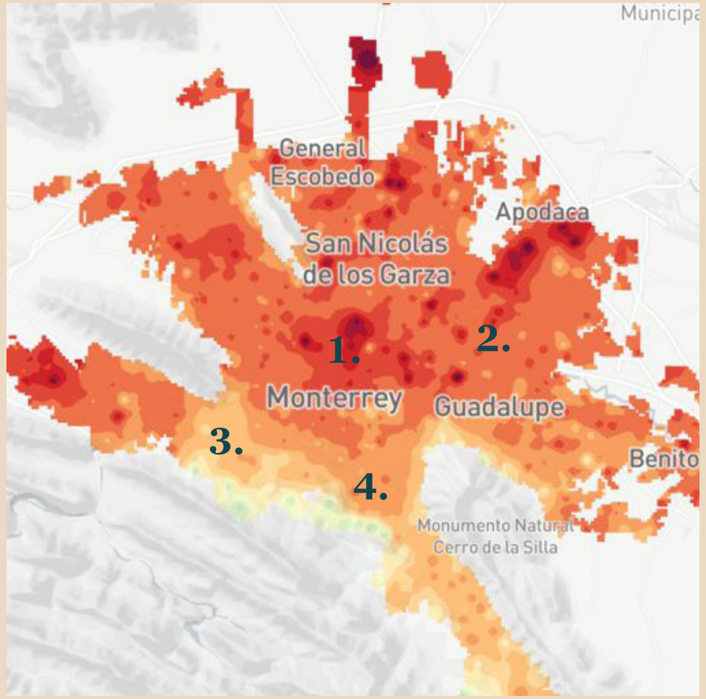
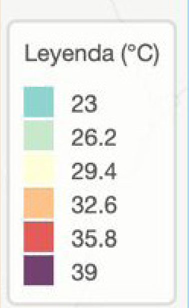


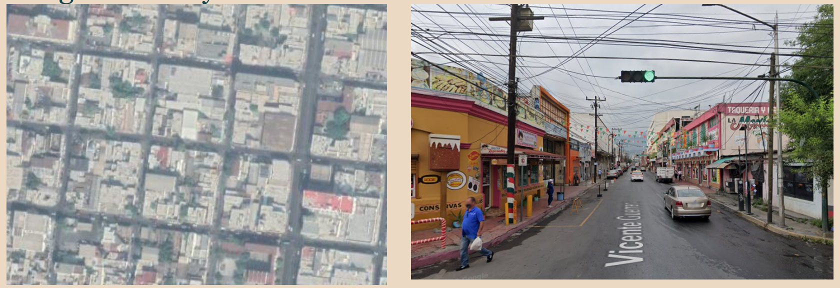
Fig. 68: Heat stress in MMA. Via Mapbox.



Urban habitats & heat stress

In Monterrey, various typologies of urban habitats can be distinguished, as illustrated by the satellite images on this page. These include large blocks in the city center, typical blocks on the outskirts, gated communities, and high-rise buildings on the affluent south side of the city. The paved and stony urban areas are associated with a high percentage of heat stress.

1.Big blocks city center



2. Outskirts

3. Gated communities

4. High rise

Fig. 69: Urban typologies. Collage conducted based on photo's from google earth.

Vegetation

The vegetation surrounding Monterrey is dominated by scrub vegetation and pine-oak forests on the mountain ridges. Within the city, smaller parks and squares provide some greenery, but there is a noticeable lack of larger green spaces and structures.

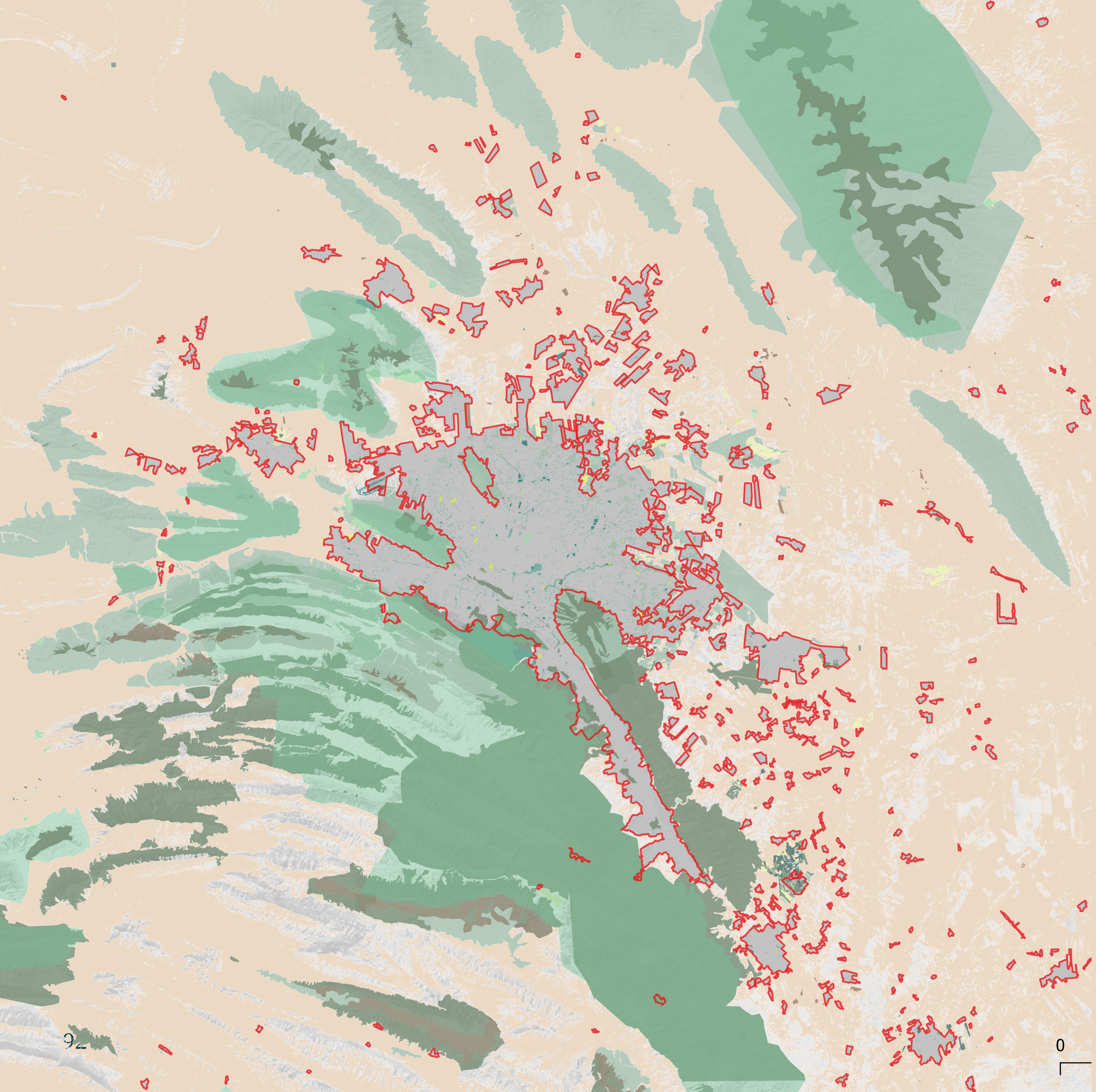


Fig. 70: Nature reserves and vegetation in the MMA. GIS data: Inegi.

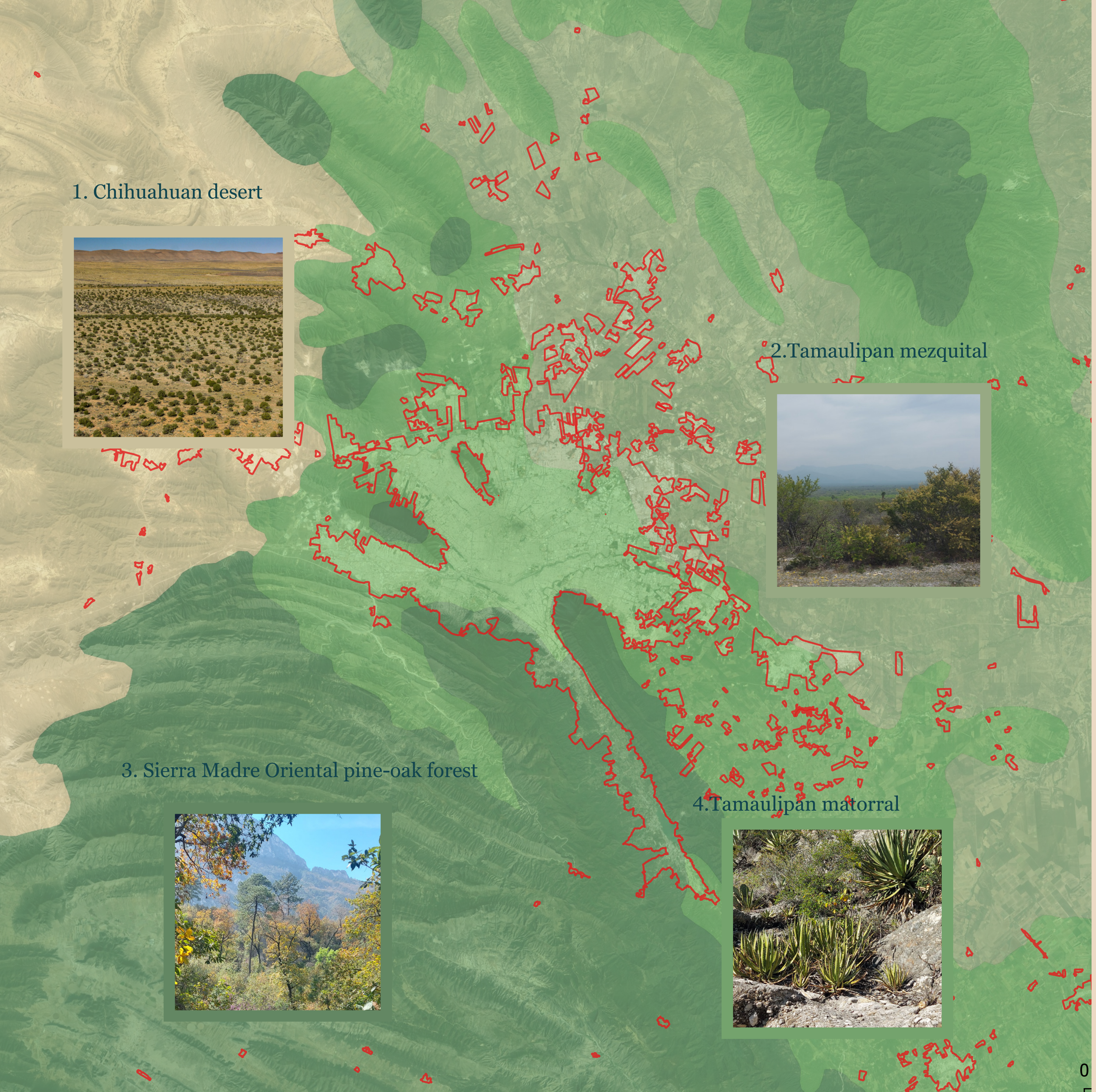
Fig. 57: Tamaulipan matorral.

Fig. 56 Sierra Madre Oriental pine-oak forest.

Species level

Analysis of the species per ecoregion

Fig. 71: Holtes, E.O. (2024). *Species of the Sierra madre oriental ecoregion* [photo]. Monterrey, Mexico.



Ecoregions

The Monterrey Metropolitan Area is surrounded by diverse ecoregions, each with unique characteristics. The Chihuahuan Desert, the largest and most biologically diverse desert in North America, spans southeastern Arizona, southern New Mexico, western Texas, and north-central Mexico. It is bordered by the Sonoran Desert, Arizona Mountain Forests, and Colorado Plateau Shrublands, forming an ecological crossroads with a rich variety of flora and fauna. The Sierra Madre Oriental Pine-Oak Forests ecoregion extends from isolated mountain ranges in the southwestern U.S. to several Mexican states, reaching the Trans-Mexican Volcanic Belt near Mexico City. This ecoregion, dominated by pine-oak forests at elevations between 1,000 and 3,500 meters, supports diverse plant and animal species, including endemic pine species and distinctive birds like the maroon-fronted parrot and Colima warbler.

The Tamaulipan Matorral ecoregion is characterized by low valleys and plateaus between the Sierra Madre Oriental and the Gulf Coastal Plain of Tamaulipas. It features sedimentary rocks of marine origin with abundant faults and folding due to tectonic activity and is largely dominated by desert shrub distinct from the Chihuahuan Desert or Central Plateau, hosting many endemic species. The Tamaulipan Mezquital ecoregion occupies the southwestern portion of the Gulf Coastal Plain in southern Texas and northeastern Mexico. Recognized as the 36th global biodiversity hotspot by the Critical Ecosystem Partnership Fund in 2016, this ecoregion extends from the western outskirts of San Antonio, Texas, south to near General Zaragoza, Tamaulipas, and northwest to the area west of the Amistad Reservoir on the Rio Grande River, entirely within the North American Coastal Plain.

In addition to these ecoregions, the Santa Catarina River itself can be considered a unique ecoregion due to its distinct conditions and habitats. Each of these ecoregions contributes to the rich biodiversity and ecological significance of the Monterrey Metropolitan Area.

Fig. 54: Fewings, N. Chihuahuan desert. On Unsplash.

Fig. 55: Tamaulipan mezquital.

Fig. 56 Sierra Madre Oriental pine-oak forest.

Fig. 57: Tamaulipan matorral.

Fig. 72: The ecoregions of the MMA. GIS data: Inegi, Satellite only by PDOK wms.

Ecoregion : Chihuahuan desert

Fig. 73: Pronghorn and lechuguilla. Image credit: Creative Commons.

Fig. 75: Yucca elata by Stan Shebs.

Fig. 76: Agave lechuguilla by Stan shebs.

Fig. 74: Creosote Larrea tridentata. Image credit: Creative Commons.

Fig. 77: bush muhly by Patrick Alexander.

Fig. 78: The flagship species of the Chihuahuan Desert ecoregion is the Mexican wolf. Image credit: Larry Lamsa, Creative Commons.

Ecoregion: Tampaulipan mattoral

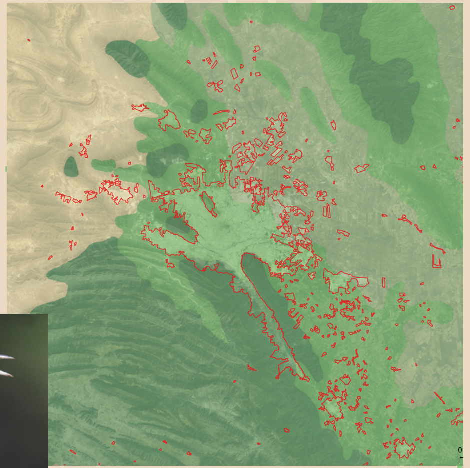


Fig. 79: Holtes, E.O. *Queen Victoria agave* [Photo].

Fig. 80: By unknown. *Eastern Meadowlark* [Photo]. Image credit: Creative Commons.

Fig. 81: Holtes, E.O. *Spanish dagger* [Photo].

Fig. 82: Aguascalientes, M. *Smooth mesquite* [Photo].

Fig. 83: Urieta, M. *Texas prickly pear* [Photo]. On Unsplash.

Fig. 84: Theiner, P. *Mexican prairie dog* [Photo]. Image credit: Creative Commons.

Ecoregion : Sierra Madre Oriental Pine-Oak forest

Fig. 85: Culbert, D. *Quercus castanea* [Photo].

Fig. 86: Ramsey, D. *Monarch butterfly* [Photo].

Fig. 87: Brundage, S. *Mexican pinyon pine* [Photo].

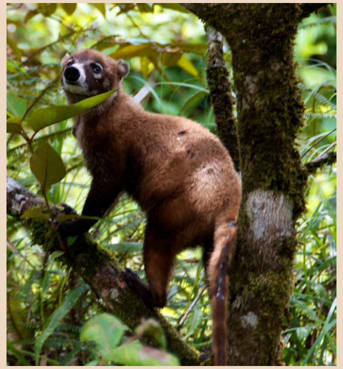


Fig. 88: Harlick, B. *White nosed coati* [Photo].

Fig. 89: González, R. *Maroon-fronted parrot* [Photo].

Fig. 90: cogdogblog on Flickr. Name unkown. *Alligator juniper* [photo].

Fig. 91: Image credit: Creative Commons. Name unknown. *Nelson's pine* [Photo].

Ecoregion: Tampaulipan Mezquital

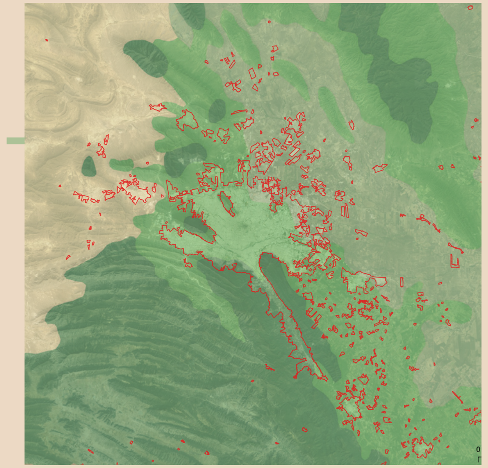


Fig. 92. By Mountain States Nursery. *Honey mesquite* [Photo].

Fig. 93. E, Castela. *Chaparro* [Photo].

Fig. 94. Kilby, E. *Ocelot* [Photo]. Creative Commons.

Fig. 95: Pfeiffer, M. *hook-billed kite* [Photo].

Fig. 96. Marcus, J. *Texas prickly pear* [Photo].

Fig. 97: By unkown. *Southern Plains wood rat* [Photo]. Image credit: Creative Commons.

The ecology of the MMA rivers

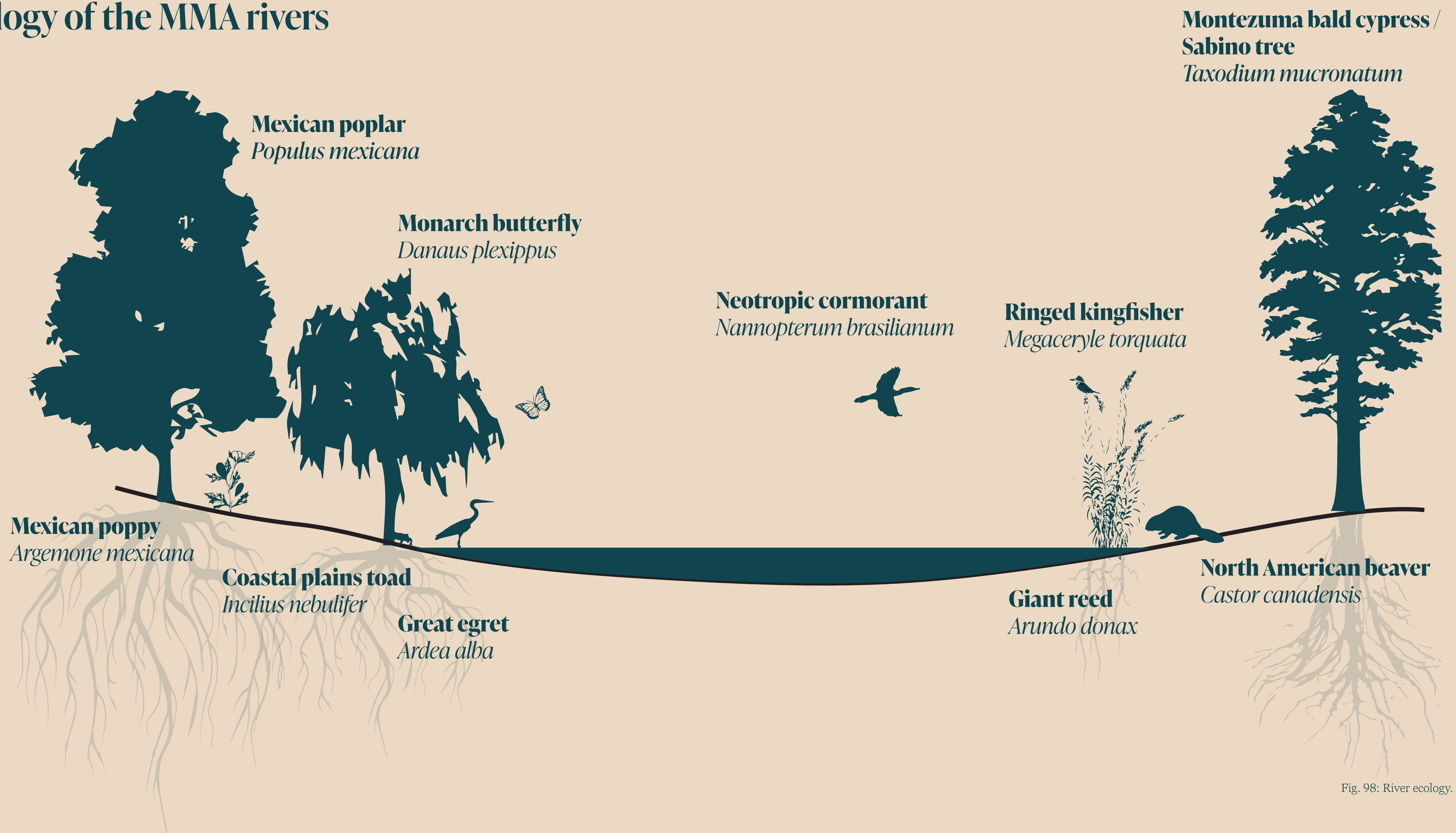


Fig. 98: River ecology.

Site visit

As landscape designers, it is essential to thoroughly understand the landscape you are designing for. This requires local research. Although a lot of preliminary analysis and research can be done based on literature, map data and existing information, it is crucial to visit the site for a more in-depth investigation. In addition, the available data and information about the location is limited, often incomplete or outdated.

Together with three other graduate students in the Urban Ecology Design Lab, Isa van der Bijl, Kim Handelé and Pieter van der Wel, we visited Monterrey, Mexico between February 11th and March 10th 2024. On site we stayed on the campus of the Monterrey Institute of Technology and Higher Education also known as Técnologico the Monterrey (TEC).

Under the guidance of experts such as Rob Roggema, other professors and fellow students from the Faculty of Architecture and Urban Planning, from TEC we visited various locations in and around the study area. The site visit of a month provided us to study the landscape through personal observation, capturing visual imagery, sketching, data collection, interviews and other relevant methods.

The main takeaways from my stay in Monterrey for my project were the invaluable contacts made and the firsthand observations of the Santa Catarina River. Throughout my stay, I had the opportunity to accompany professors from TEC Monterrey on excursions to various locations along the river. These visits, spanning from upstream to downstream, provided a comprehensive understanding of the river's current state and potential challenges. For instance, we discovered informal settlements and significant garbage dumping, revealing realities unseen on Google Maps.

The individuals I met in Monterrey, particularly Ericka Toledo and Roxana Fonseca from the Water Centre at TEC, played a crucial role in deepening my understanding of the watershed and its associated issues. Conversations with locals shed light on the contrasting perspectives, with some advocating for the river's protection while others prioritize short-term solutions, notably the government. Who were planning on creating a second dam in the protected natural reserve upstream.

These experiences have not only broadened my knowledge but also highlighted the complexities surrounding river conservation and management. They have prompted me to reconsider my approach and explore innovative solutions that balance short-term needs with long-term sustainability.

Fig. 99: Bijl, I.(2024).*Species of the Sierra madre oriental ecoregion* [photo]. Monterrey, Mexico.

4

Research *by* design

This chapter explores the vision for the Santa Catarina River in the Monterrey Metropolitan Area (MMA). It outlines key design principles and illustrates these principles through specific design interventions along the river's upstream, midstream, and downstream sections.

Río Santa Catarina

Fig. 100: Santa Catarina River in Monterrey (Eline Holtes, 2024)

Watershed zones of the Santa Catarina

The river Santa Catarina itself can be described as an ecoregion, because it entails its own unique conditions and ecology. Moreover, the river course of the Santa Catarina flows through different zones, we can determine by the difference in elevation, soil, climate, ecoregions, and the presence of water.

Upstream zone

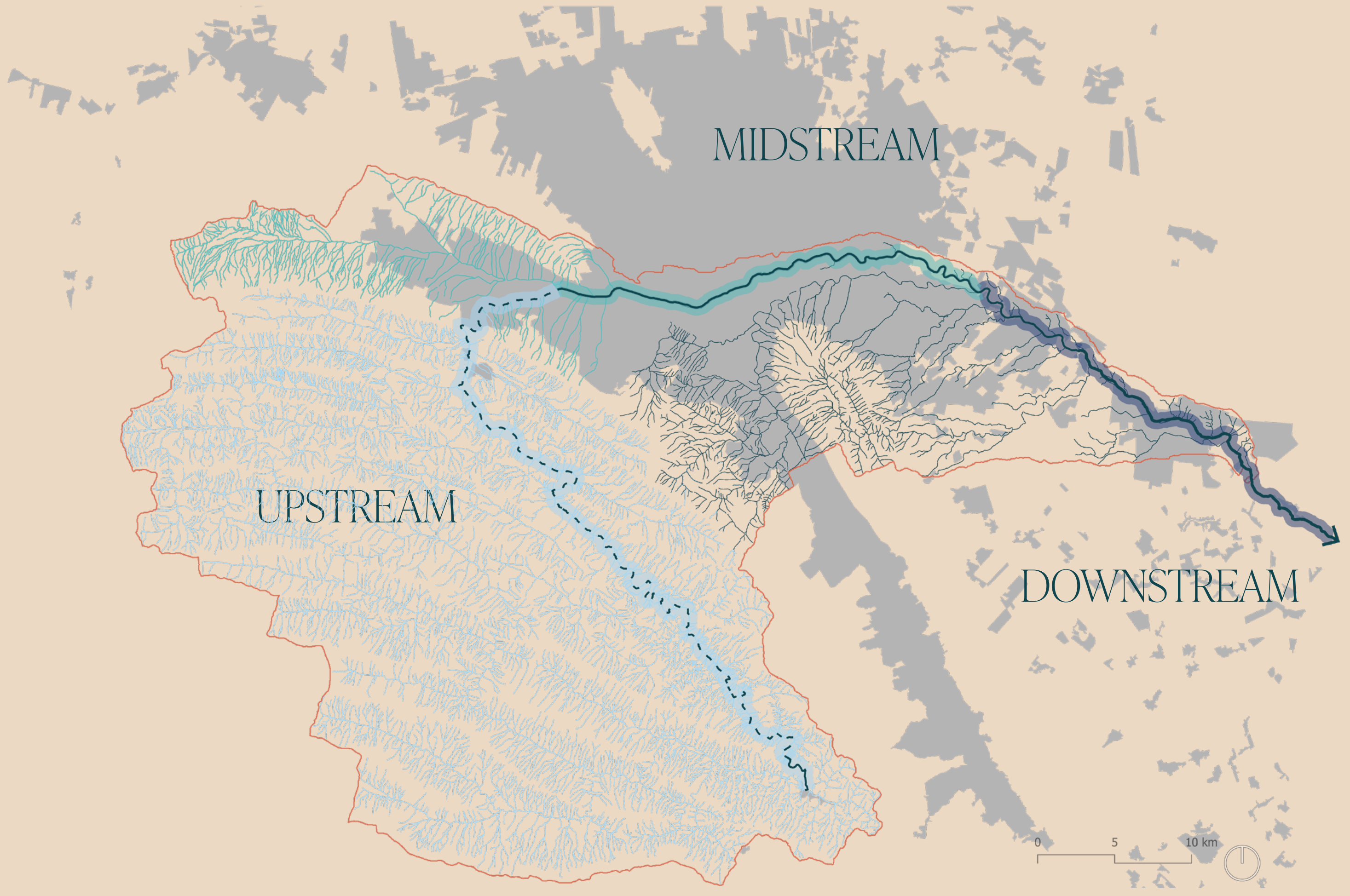
The first zone, referred to as the ''upstream zone'', is situated in the ecoregion of the Sierra Madre Oriental Pine-Oak forest and in the highest part of the watershed. Although this zone marks the origin of the river, it remains mostly dry due to a combination of factors: forest fires that reduce vegetation cover and therefore, a lack of infiltration into the ground water resevoirs, rocky soils that have a lower water storage capacity and the overuse of groundwater aquifers to supply water to the people and industries of Monterrey. This overuse contributes to the degradation of groundwater resources.

Midstream zone

The second zone, referred to as the ''midstream zone'' is located in the ecoregion of the Tamaulipan Matorral, located between the Sierra Madre Oriental and the Gulf Coastal Plain of Tamaulipas. The ecoregion is primarily desert shrub, but distinct from the vegetation of the Chihuahuan Desert or Central Plateau and with many endemic species (found nowhere else).
This zone of the Santa Catarina is located within the boundaries of the agglomeration of Monterrey. The presence of water in this midstream zone is limited because the stony environment is made to get rid of the water as quickly as possible via pipes and the canalized rivers.

Downstream

The third zone, referred to as the ''downstream'' zone is located in the ecoregion of the Tamaulipan Mezquital. Vegetation across the ecoregion is extremely variable, but the defining plant community is mesquite grassland dominated by honey mesquite and curly mesquite grass, with other common plants including chaparro and jazmincillo. The downstream zone is characterized by the constant presence of water and conditions that match most with the 'natural circumstances' of the river.
This part of the river is under pressure of the always expaning agglomeration of Monterrey, threatening the existance of the wide river profile in this zone.



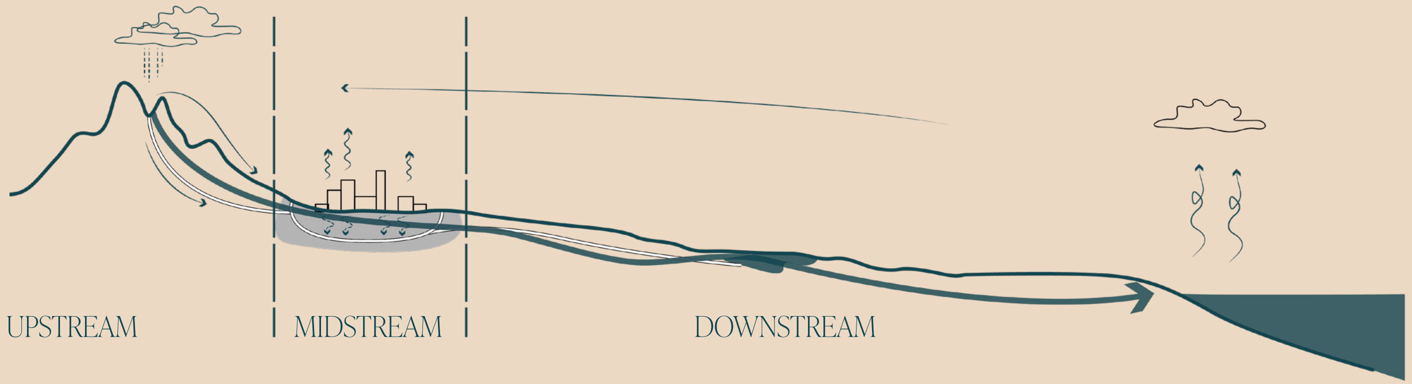


Fig. 101:Key map of the Santa Catarina Watershed. GIS data: Inegi, SIATL Fig. 102: Principle section watershed.

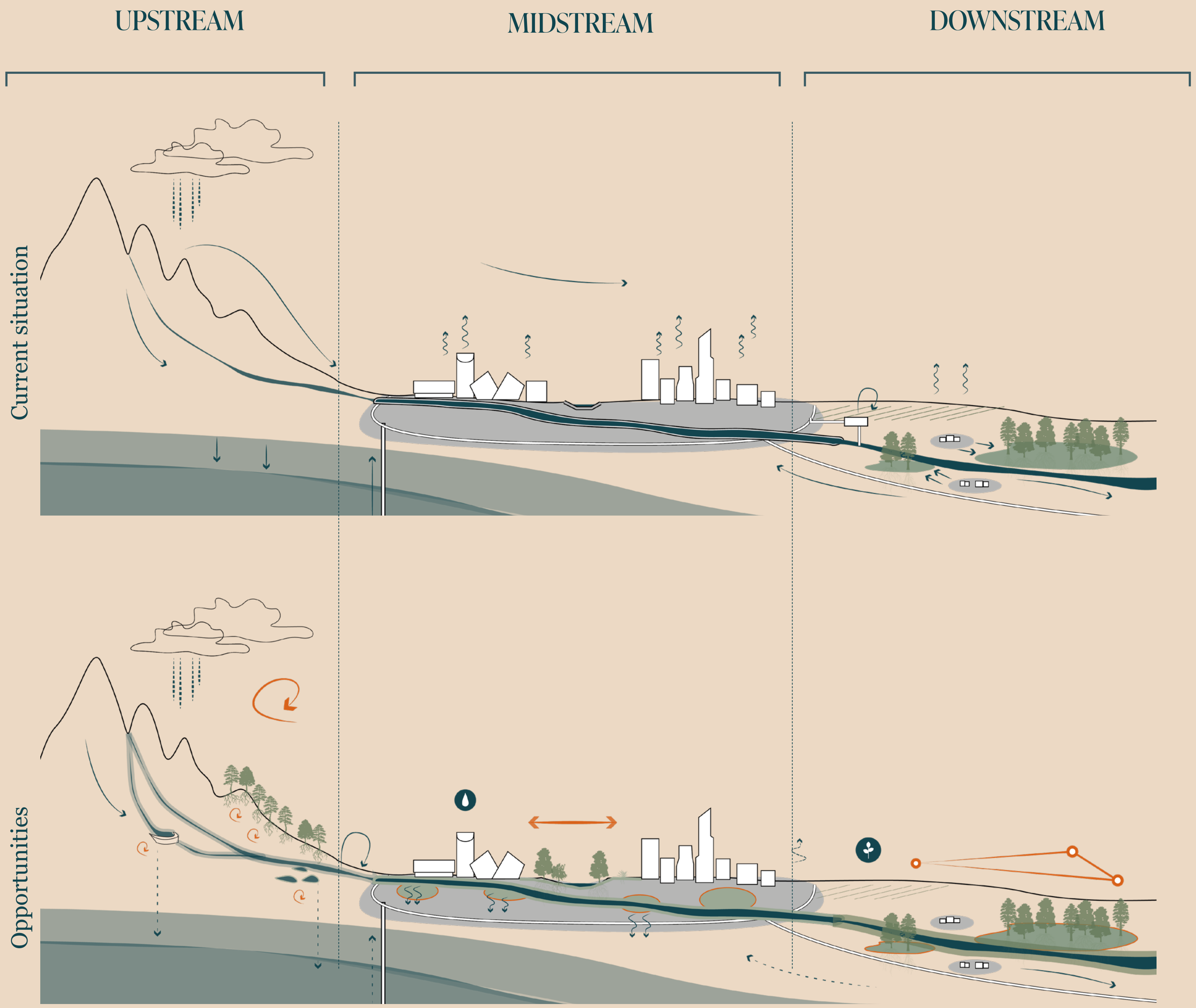


Fig. 103: Principle section of the current situation upstream, midstream and downstream.
Fig.. 104: Principle section of the proposed interventions upstream, midstream and downstream.

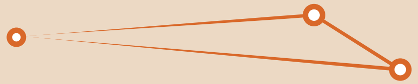
Opportunities in the water system

Upstream:
Water capture

The strategy for the upstream zone emphasizes capturing and retaining water to facilitate gradual soil infiltration, thereby enhancing groundwater recharge. Additionally, it includes efforts to restore the pine-oak forest in areas that were lost due to fires.

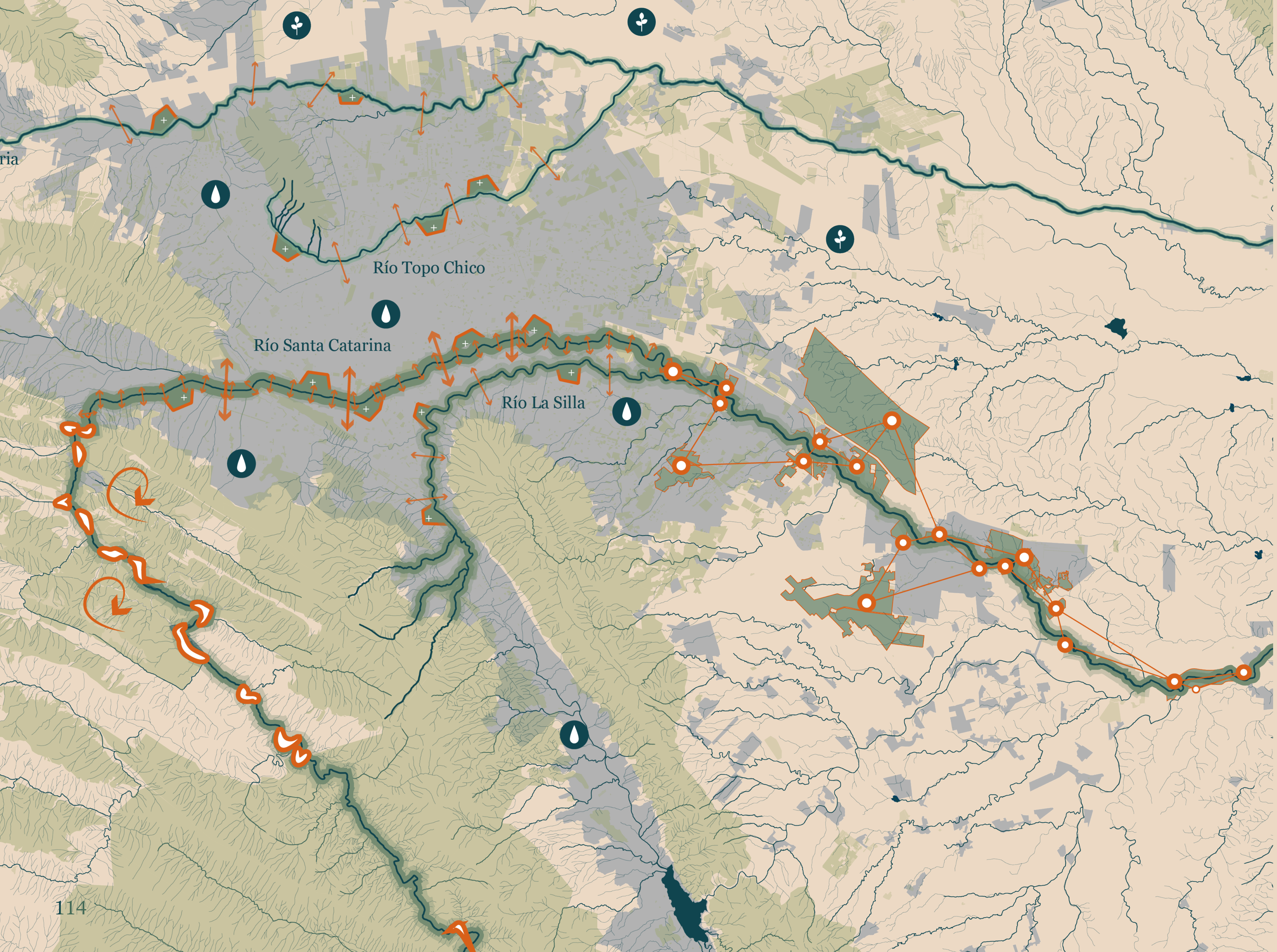
Midstream:
Giving space

The strategy for the midstream zone aims to allocate more space for the river, re-naturalize the riverbanks, and create new habitats along its course. Additionally, it focuses on enhancing river accessibility and creating valuable public spaces surrounding it.



Downstream:
Allowing the flow

The strategy for the downstream zone focuses on protecting the existing wide natural banks and river forests, as well as enhancing connectivity between these areas.



Vision for the MMA rivers

Restoring the river ecosystems

water saving agriculture

water saving measures in the city centre

giving space back to the river

connecting and protecting natural areas

water capture and retention

new green public spaces (habitats) along the river

river with wide, natural riverprofile

stream

protected river forests

green spaces

urban area

water body

0 10 20 km

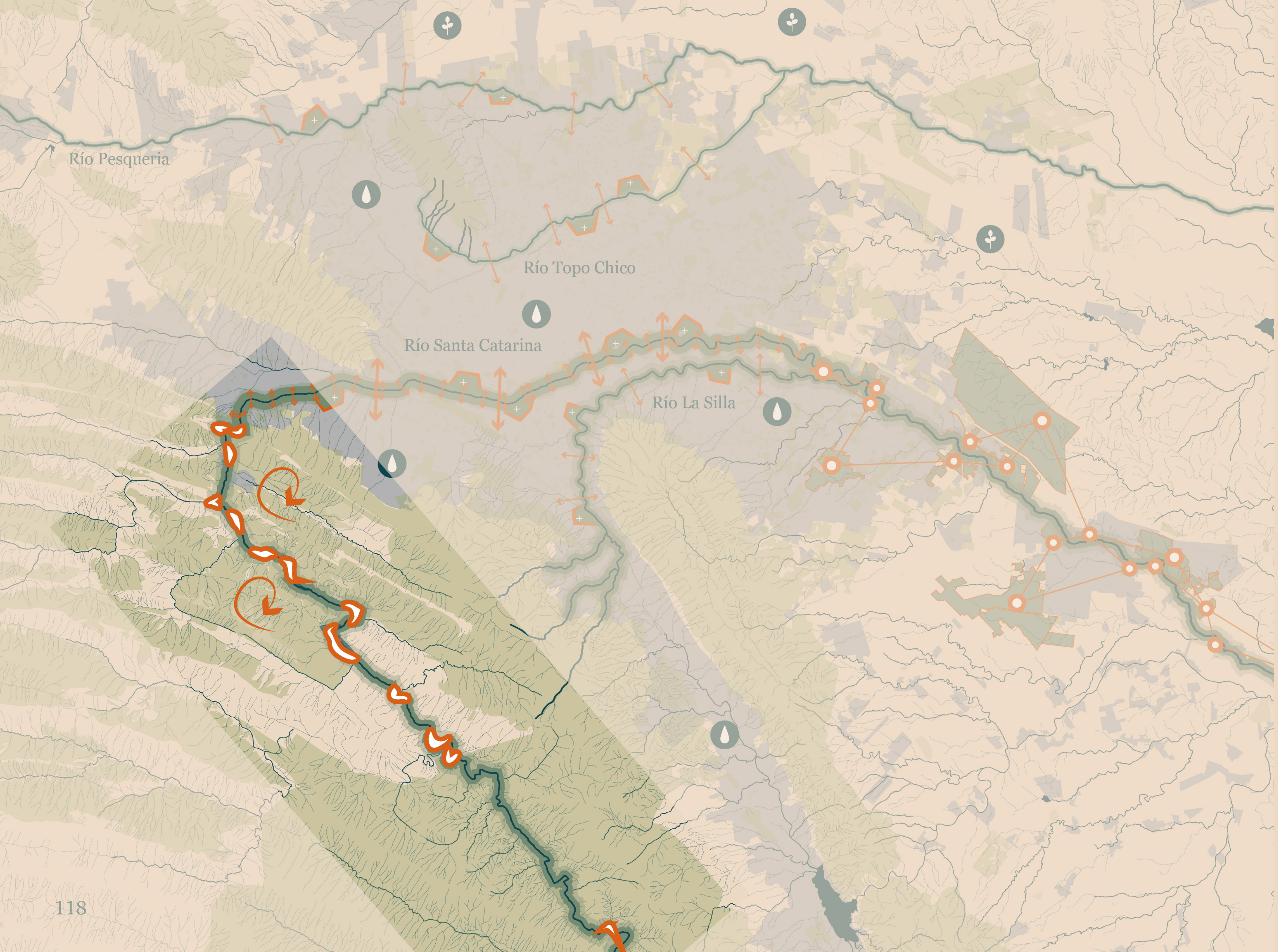
The vision map illustrates the implemented design interventions along the Santa Catarina River, encompassing upstream, midstream, and downstream sections. While the focus of this map is on the Santa Catarina River, the design interventions presented can be adapted and applied to other rivers, taking into account their unique conditions. This project adopts a comprehensive approach to restoring and enhancing the river system from its source to its mouth.

Fig. 121: Vision for the rivers in MMA.

The upstream zone

Fig. 122: Holtes, E.O. In the dry riverbed of the Santa Catarina River.

The upstream zone



water saving agriculture

water saving measures in the city centre

giving space back to the river

connecting and protecting natural areas

water capture and retention

new green public spaces (habitats) along the river

river with wide, natural riverprofile

stream

protected river forests

green spaces

urban area

water body

0 10 20 km

Fig. 120: Vision for the rivers in MMA.

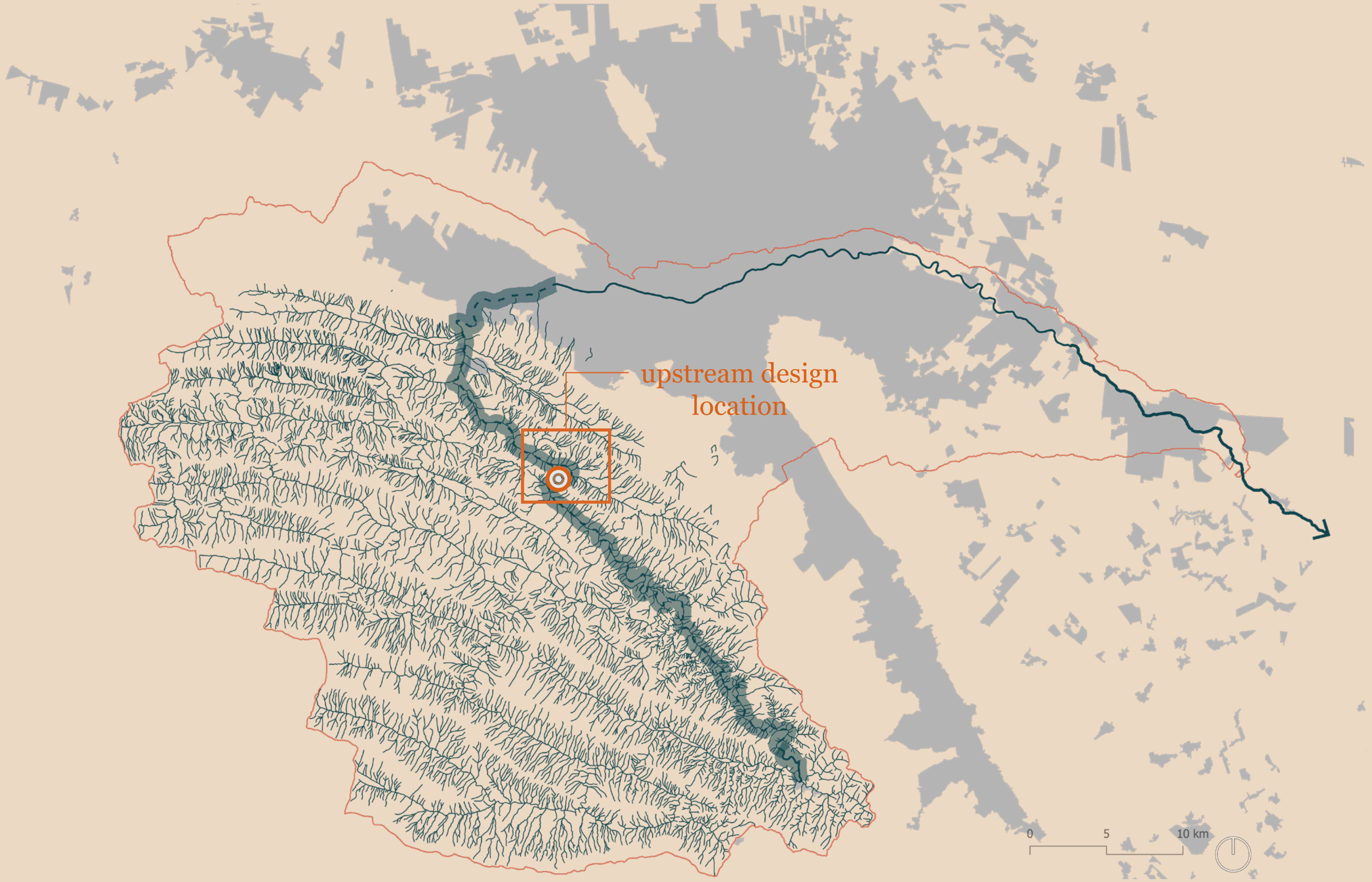


Fig 123: Streams in the upstream zone of the Santa Catarina Watershed.

Fig 124: Upstream zone in principle section: upstream.

Upstream conditions

The zone marking the origin of the river in the mountains, situated within the Sierra Madre Oriental Pine-Oak ecoregion, is referred to as the 'upstream zone.'

Despite being the river's origin, this zone remains mostly dry due to several factors: forest fires that reduce vegetation cover, leading to decreased groundwater infiltration; rocky soils with low water storage capacity; and the overuse of groundwater aquifers to supply water to Monterrey's population and industries.

This overuse exacerbates the degradation of groundwater resources.

Additionally, the large Rompepicos dam, located adjacent to the design site, significantly disrupts the ecosystem by interrupting the riverbank's function as an ecological corridor through the mountains.

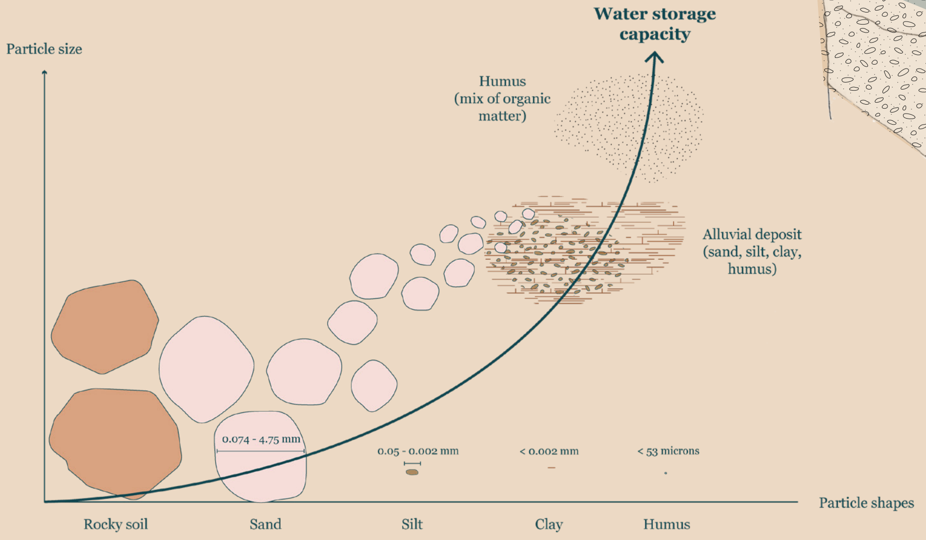


Fig. 125: Diagram of the water storage capacity per soil type.

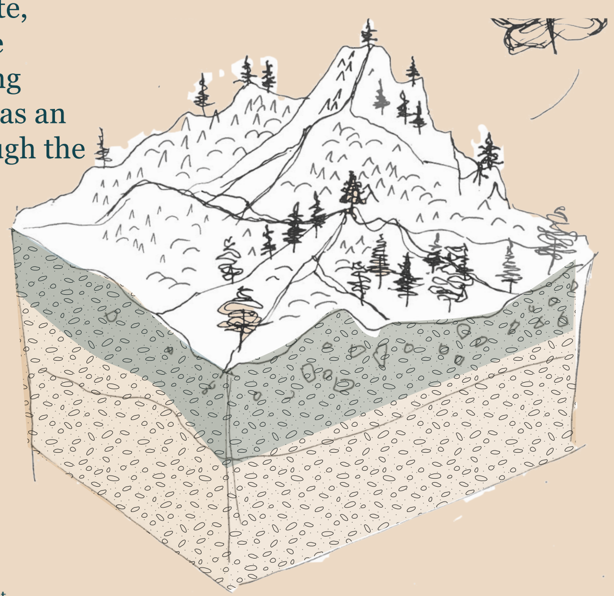


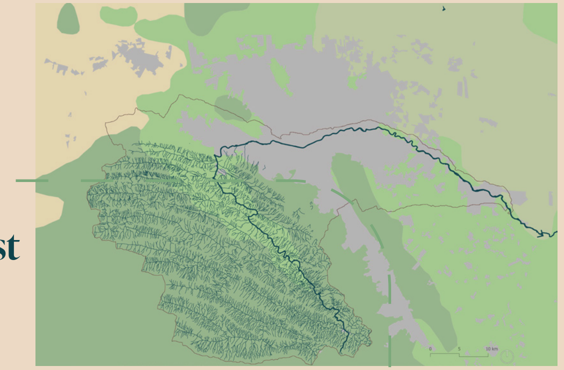
Fig. 126: Siera Made Oriental pin-oak forest ecoregion tile.

Ecology of the Upstream

The Sierra Madre Oriental Pine-Oak Forests ecoregion extends from isolated mountain ranges in the southwestern U.S., such as the Davis and Chisos Mountains, to southern New Mexico and several Mexican states, eventually transitioning into the Trans-Mexican Volcanic Belt Pine-Oak Forests near Mexico City. This ecoregion, dominated by pine-oak forests at elevations between 1,000 and 3,500 meters, features a diverse range of flora and fauna, including endemic pine species and distinctive birdlife like the maroon-fronted parrot and Colima warbler.

The dominant pine species in this ecoregion include Nelson's pinyon pine (endemic), Mexican pinyon pine, smooth-bark Mexican pine, Arizona pine, Mexican weeping pine, and the endemic Gregg's pine. Major oak species include Quercus castanea and Quercus affinis, both part of the red oak group. Mexican pinyon pine and alligator juniper thrive on wetter east-facing slopes, while more xeric west-facing slopes support the endemic weeping pinyon. This ecoregion, along with other Mexican pine-oak regions, is recognized as a global Endemic Bird Area, featuring endemic species such as the maroon-fronted parrot, bearded wood-partridge, Colima warbler (during the breeding season), and dwarf jay. Other notable birds include wild turkey, golden eagle, and peregrine falcon.

Characteristic mammals include mule deer, puma, jaguar, cliff chipmunk, collared peccary, and white-nosed coati. The pine-oak forests in Coahuila are crucial migratory corridors for monarch butterflies, which have their largest wintering populations in the Trans-Mexican Volcanic Belt Pine-Oak Forests. The Bravo River serves as a key biological corridor between northeast Coahuila and the Chisos Mountains in Texas, linking the biotas of the Chihuahuan and Tamaulipan deserts.



Ecoregion : Sierra Madre Oriental Pine-Oak forest

Fig. 127: Culbert, D. *Quercus castanea* [Photo].

Fig. 128: Ramsey, D. *Monarch butterfly* [Photo].

Fig. 129 Brundage, S. *Mexican pinyon pine* [Photo].

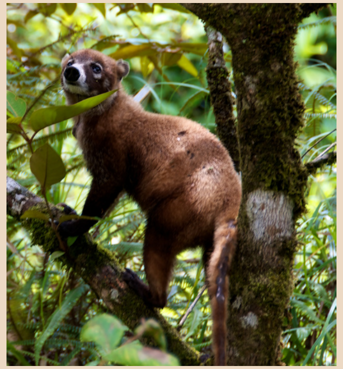


Fig. 130: Harlick, B. *White nosed coati* [Photo].

Fig. 131: González, R. *Maroon-fronted parrot* [Photo].

Fig. 132: cogdogblog on Flickr. Name unkown. *Alligator juniper* [photo].

Fig. 133: Image credit: Creative Commons. Name unknown. *Nelson's pine* [Photo].

Design interventions upstream

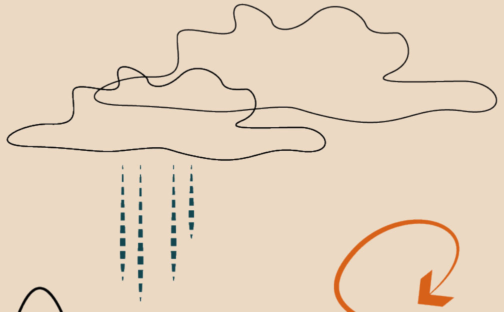
Water capture

The strategy for the upstream zone focuses on capturing and retaining water, allowing it to infiltrate the soil gradually. To achieve this, various interventions are proposed:

Reforesting the slopes of the mountain edge to restore vegetation cover and reduce soil erosion.

Capturing rainwater through the construction of water retention catchments.

Educational initiatives to increase understanding of the importance of river ecology.



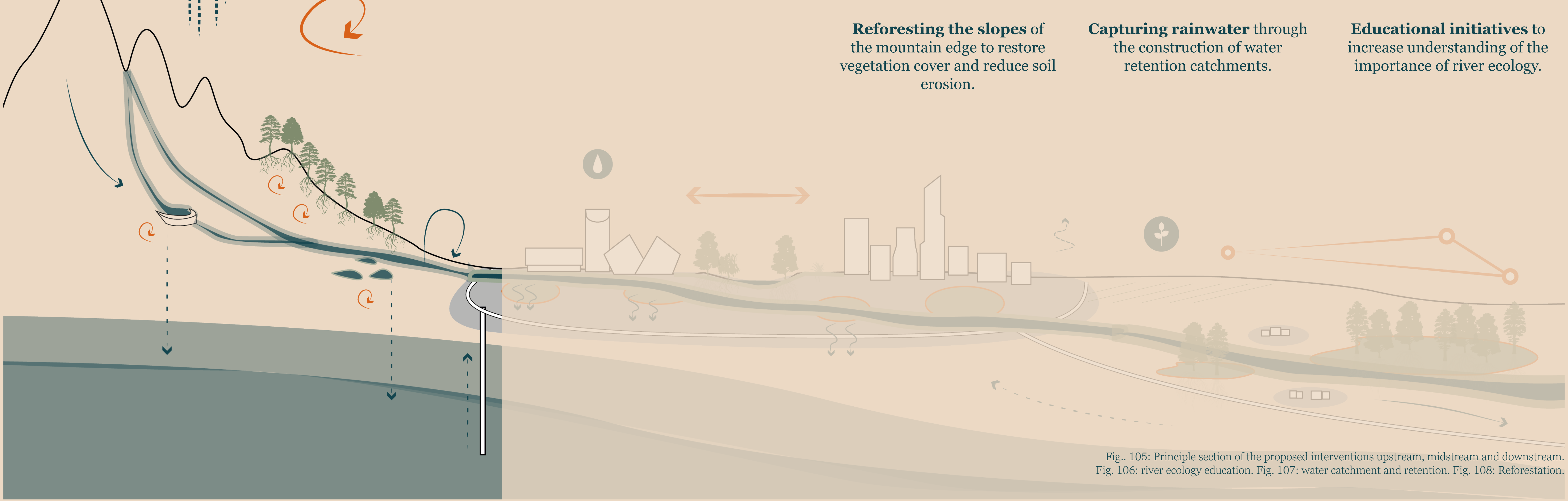


Fig.. 105: Principle section of the proposed interventions upstream, midstream and downstream.
Fig. 106: river ecology education. Fig. 107: water catchment and retention. Fig. 108: Reforestation.

Upstream design location : current situation

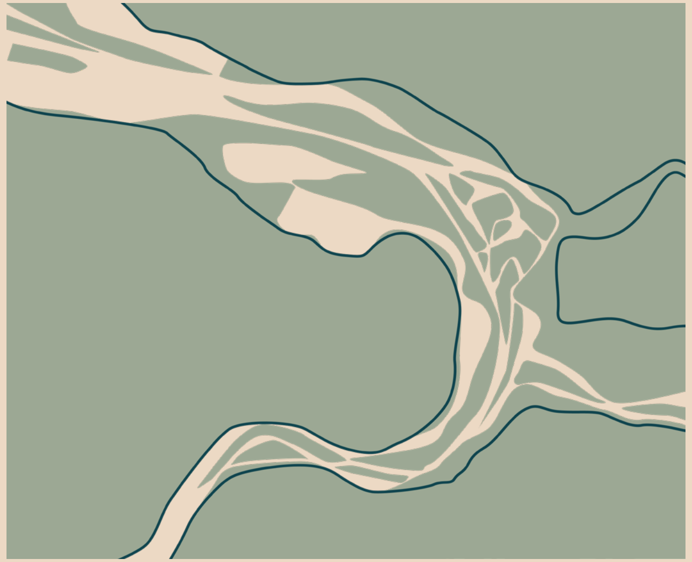


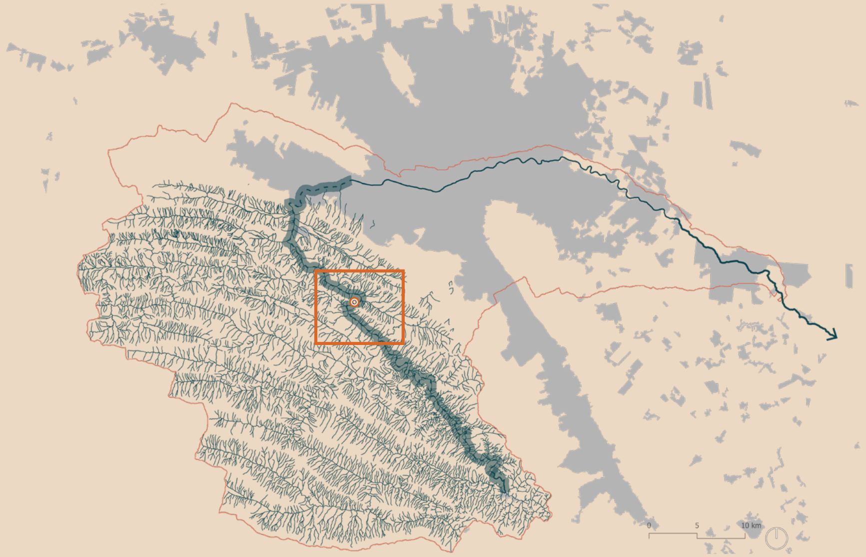
Fig. 134 Vegetation analysis map. Based on Google maps.

Fig. 135 Shrub vegetation. Screenshot taken from Google maps.

Fig. 136. Human activity analysis map. Based on Google maps.

Fig. 137. illegal settlements and agriculture

The upstream design location of the Santa Catarina is located close to the Rompepicos Dam. The spot is characterized by the steep slopes of the mountain ridges of the Sierra Madre Oriental. Forest fires are the cause of the dissapearence of pine-oak forest in the area. The slopes are covered with shrub vegetation. Altough there it is prohibited to built in this protected natural reserve, people have built homes here in the mountains.



shrubs

illegal settlements

road

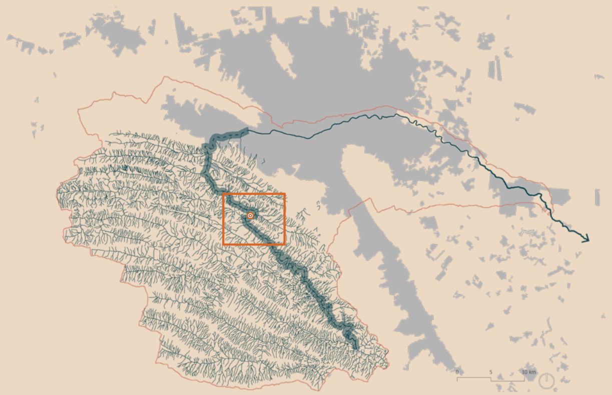
riverbed

dam Rompepicos

Fig. 138: design location satallite image. GIS data: Satellite only by PDOK wms.

0 50 100 150 200 250 m

Settlements in the riverbed of the upstream zone



Smaller communities have established residences in the upstream part of the Santa Catarina River, within the protected Cumbres de Monterrey National Park. Despite the park's protected status, which prohibits construction, self-built homes are present. These homes often lack proper sanitation, resulting in pollution that affects the river from upstream to downstream.

Furthermore, some houses are situated within the river's flood zone, posing significant risks during storms, such as Hurricane Alberto, which impact the slopes of the Sierra Madre Oriental. The accompanying photos on this page illustrate these conditions and the associated dangers.

Fig. 139: Collage of Screenshots of a film by Enrique Guadarrama. June 20, 2024.

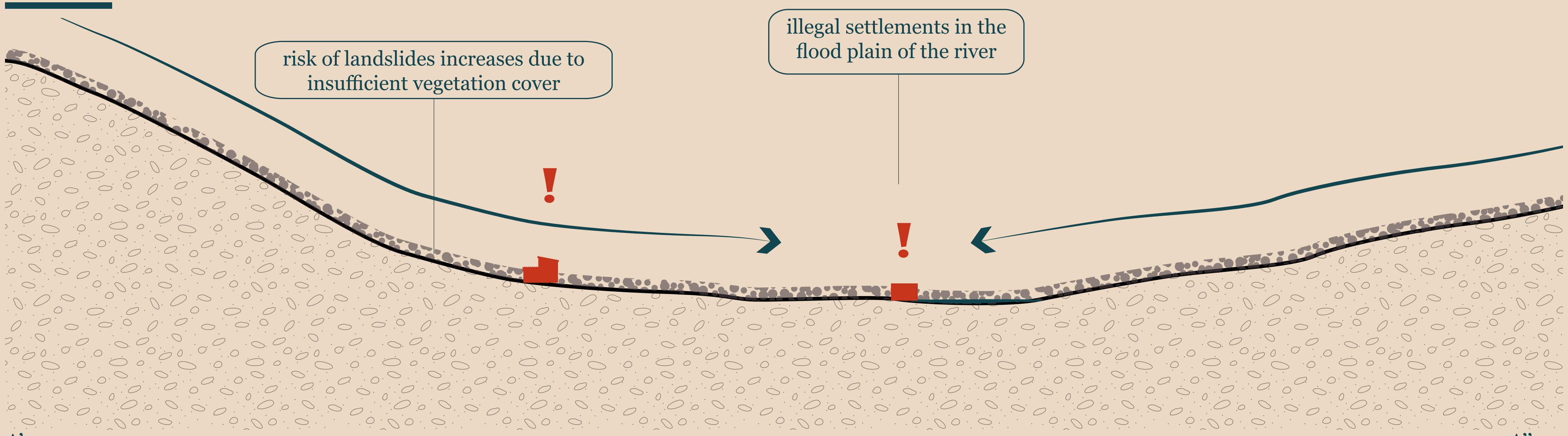
Upstream
Creating a safe living environment

Although building in the national park is illegal, these communities have established a sense of place and social cohesion in the valley. To improve their living conditions and safety, homes currently situated in the floodplain could be relocated to higher ground along the mountain ridges. This relocation should be accompanied by the provision of high-quality sanitation facilities to prevent river pollution and enhance the health of the residents in this zone.

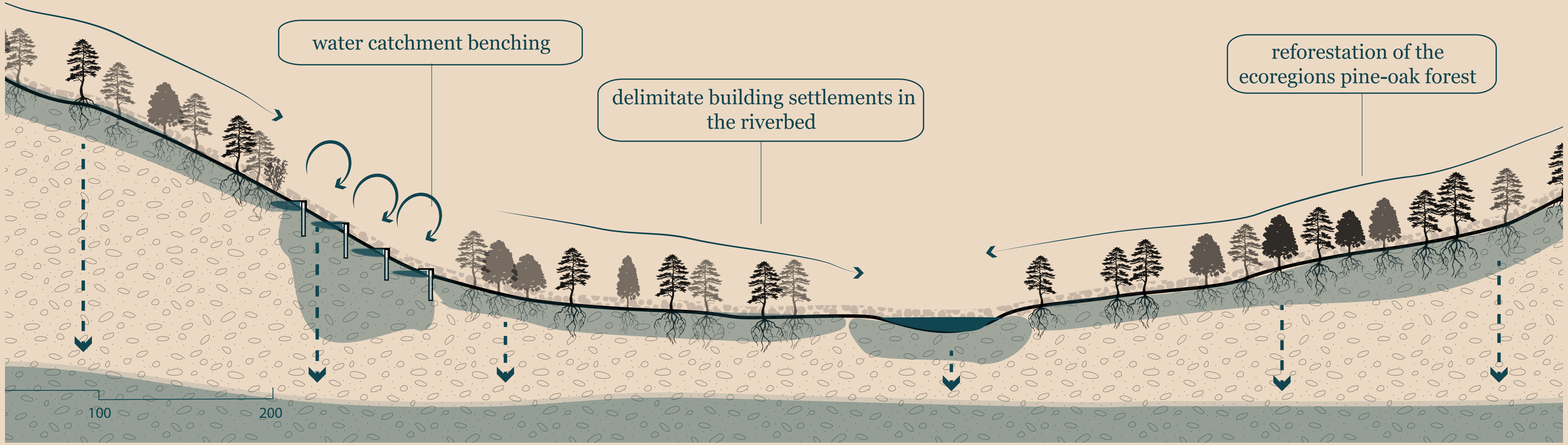
140: Screenshots of a film by Enrique Guadarrama. June 20, 2024.

Upstream design elaboration

Capturing the water



A' Fig. 141 Section of the upstream design site, current situation. A''



B' Fig. 142: Section of the upstream design site, with implemented design interventions. B''

Fig. 138: design location satallite image. GIS data: Satellite only by PDOK wms.

As outlined in the vision, the strategy for the upstream zone focuses on capturing and retaining water through reforestation of mountain slopes and constructing water retention catchments to facilitate slow infiltration and groundwater recharge.

In the design proposal, the riverbed and mountain slope edges are reforested. The roots of pine and oak trees will enhance water infiltration.

Catchment spots are created using the 'benching' technique, also known as 'terraced field or paddy terrace, to reduce runoff and its velocity, minimize soil erosion, and conserve soil moisture and fertility on the mountain slopes (USC School of Architecture, 2020). This approach captures and retains water, thereby replenishing the aquifers with rainwater.

Implementation of the ‘benching’ method

Trees of the Sierra Madre Oriental Pine-Oak forest

Mexican pinyon pine
Pinus cembroides
Quercus laceyi
Brundage, S.

Nelson’s pine
Pinus nelsonii
Creative Commons. Name unknown.

Alligator juniper
Pinus nelsonii
cogdogblog on Flickr. Name unkown.

Quercus castanea
Culbert, D.

This section illustrates the implementation of the ‘benching’ method. Concrete walls are strategically placed within the mountain ridge slopes to create smaller reservoirs that take advantage of the natural elevation. During heavy rains, these basins overflow sequentially, with excess water cascading from one basin to the next until it ultimately reaches the riverbed.

When filled with water during heavy rainfall, these reservoirs facilitate slow infiltration into the ground, aiding in groundwater recharge. Additionally, the slopes are reforested to restore the native pine-oak forest that belong to the ecoregion of the Sierra Madre Oriental. which includes species such as Nelson’s pinyon pine and Mexican pinyon pine.

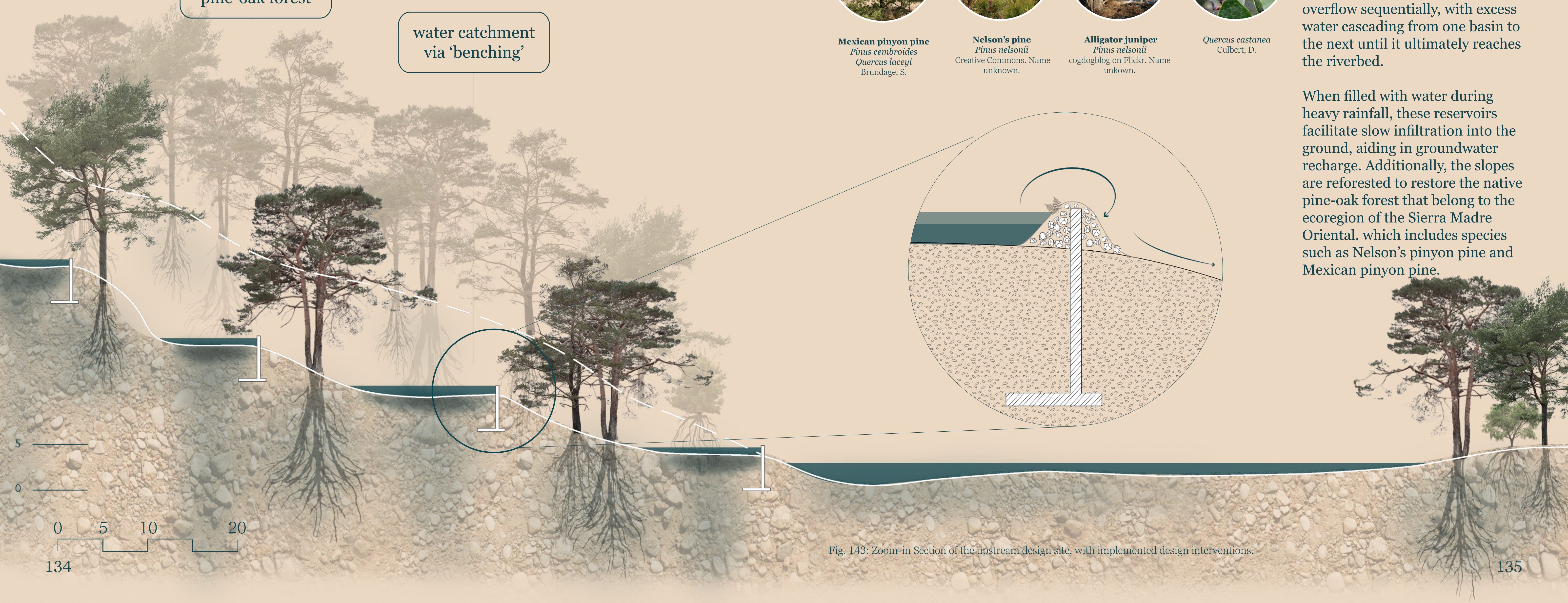


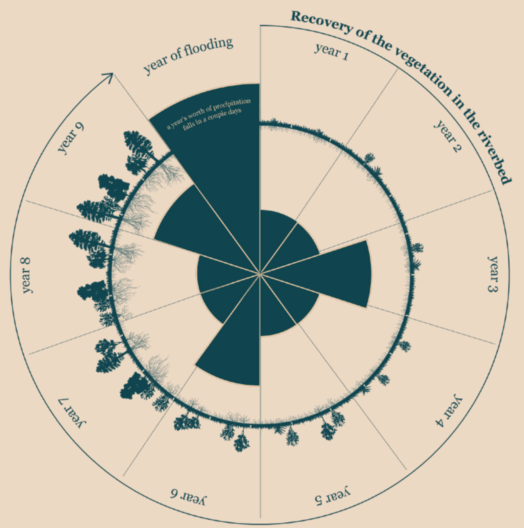
Fig. 143: Zoom-in Section of the upstream design site, with implemented design interventions.

Upstream design through time

The different hydrological circumstances

The design site experiences distinct conditions across the three stages of water levels. For most of the time, the riverbed remains dry, reflecting the typical arid conditions. However, during periods of heavy rain, a running stream appears within the riverbed, causing the benching water catchment basins to fill up and slowly infiltrate the ground. In the event of a hurricane, the entire riverbed will be inundated.

- Benching water catchment
- Elevation lines
- Shrub vegetation
- Reforestation
- Water body



Regular conditions

Fig. 144: *upstream design proposal during the "regular conditions" : dry.* GIS data: Satellite only by PDOK wms.

0 50 100 150 200 250 m

Heavy rains

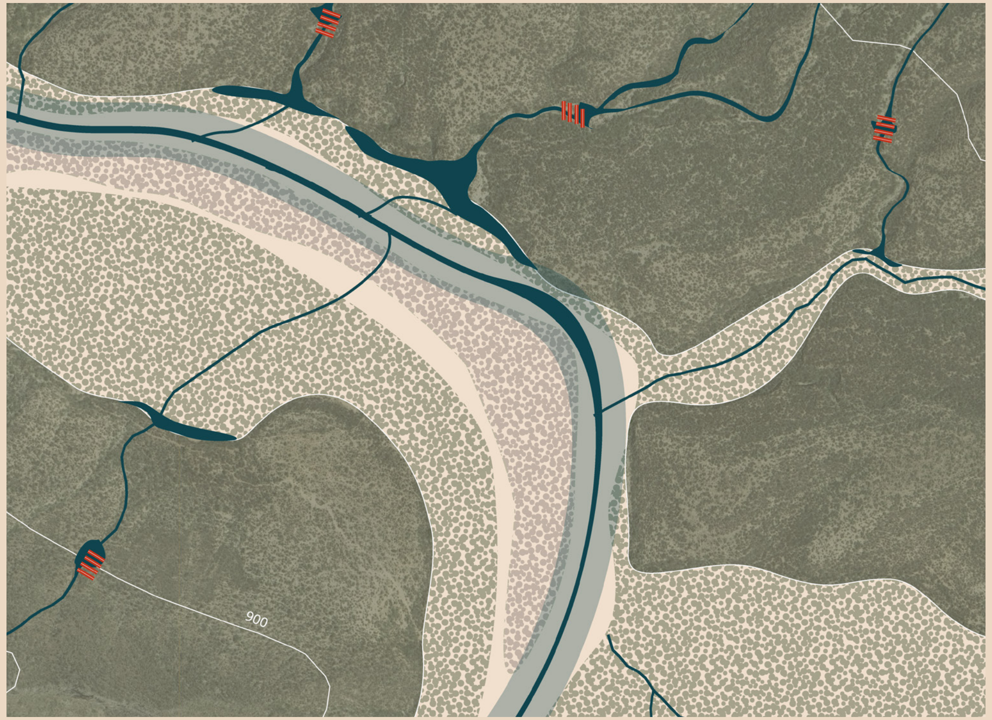


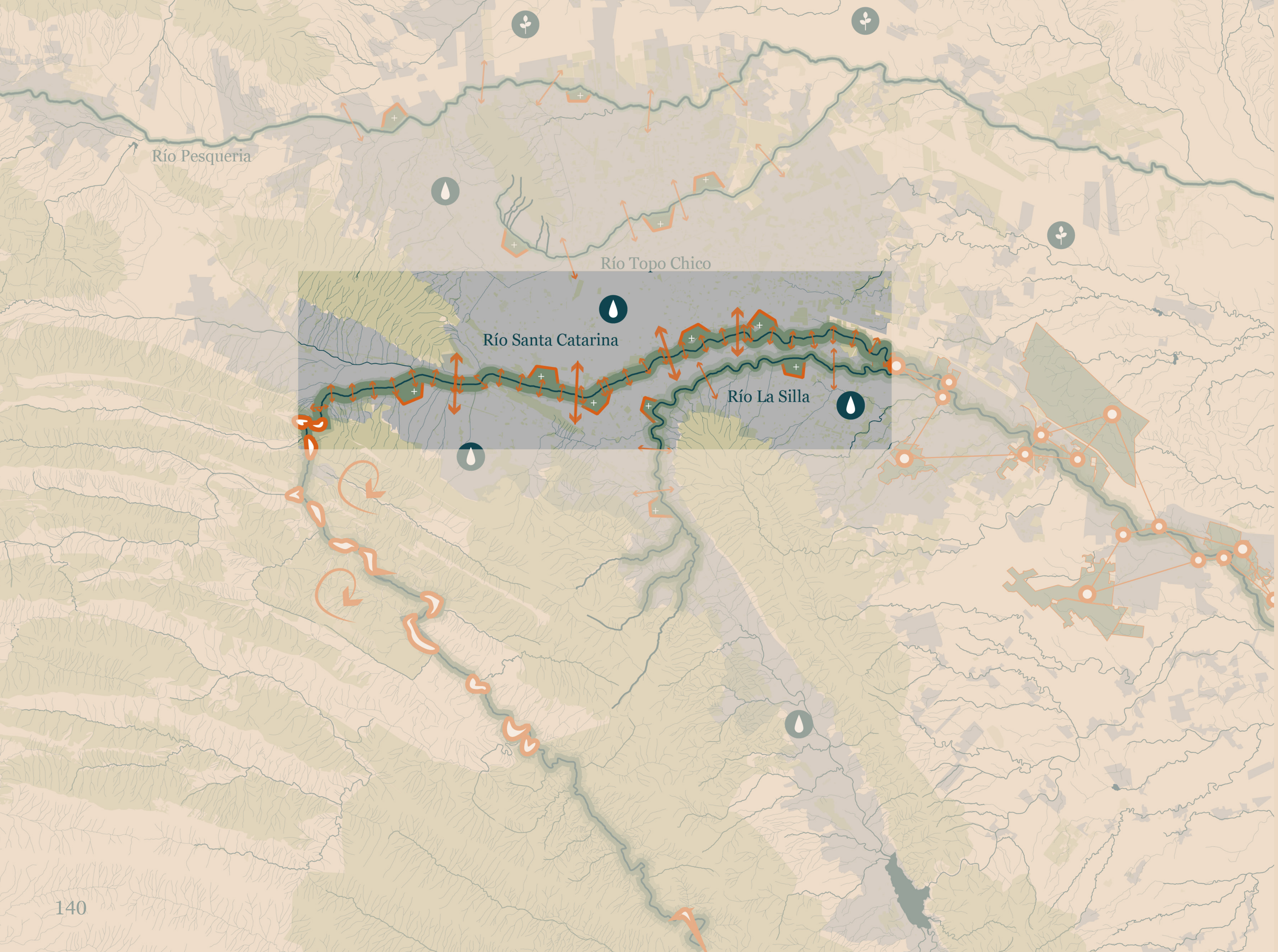
Fig. 145: *upstream design proposal during the occasional heavy rains.* GIS data: Satellite only by PDOK wms.

Hurricane

Fig. 146: *upstream design proposal during an occasional hurricane.* GIS data: Satellite only by PDOK wms.

The midstream zone

Fig. 147: Holtes, E.O. In the riverbed of the Santa Catarina River in Monterrey.



The midstream zone

water saving agriculture

water saving measures in the city centre

giving space back to the river

connecting and protecting natural areas

water capture and retention

new green public spaces (habitats) along the river

river with wide, natural riverprofile

stream

protected river forests

green spaces

urban area

water body

0 10 20 km

Fig. 120: Vision for the rivers in MMA.

Fig 148: Streams in the midstream zone of the Santa Catarina Watershed.

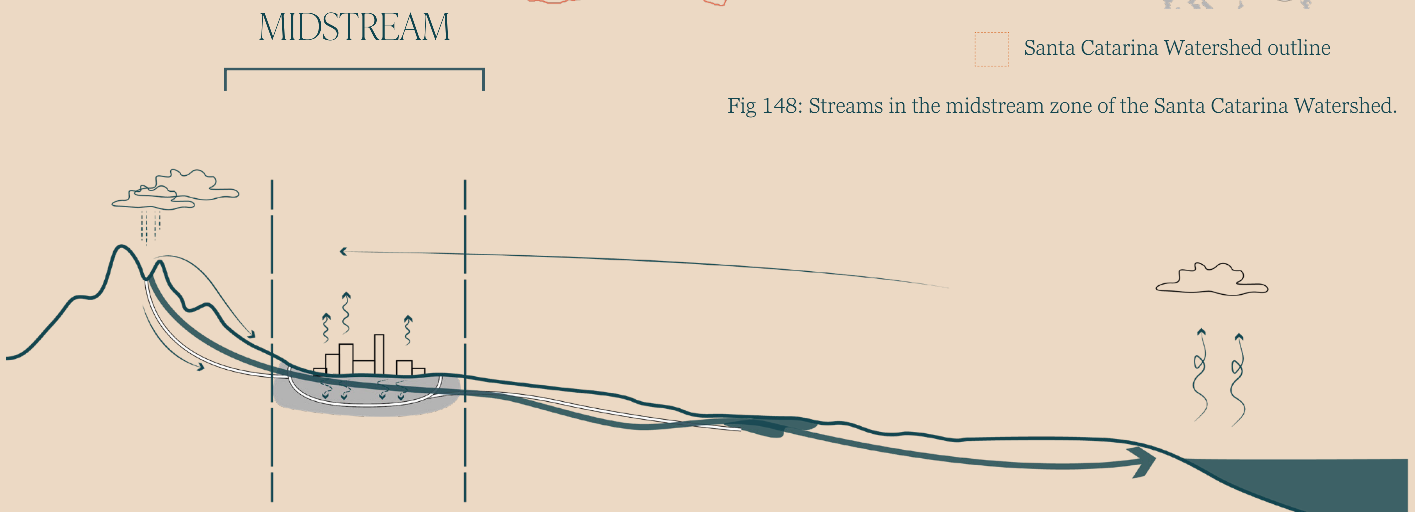


Fig 149: Midstream zone in principle section.

Midstream conditions

The midstream zone, situated within the ecoregion of the Tamaulipan Matorral and the boundaries of the Monterrey Metropolitan Area (MMA), presents unique characteristics. Notably, there are no visible streams in the city as they are concealed beneath the pavement, with water being drained through an extensive pipe system. Within this zone, the Santa Catarina River is channelized, contributing to its altered state. Additionally, the river suffers from significant pollution due to the prevalent practice of waste dumping by local residents. The Santa Catarina River is largely inaccessible to the people of Monterrey, further diminishing its presence and utility within the urban landscape.

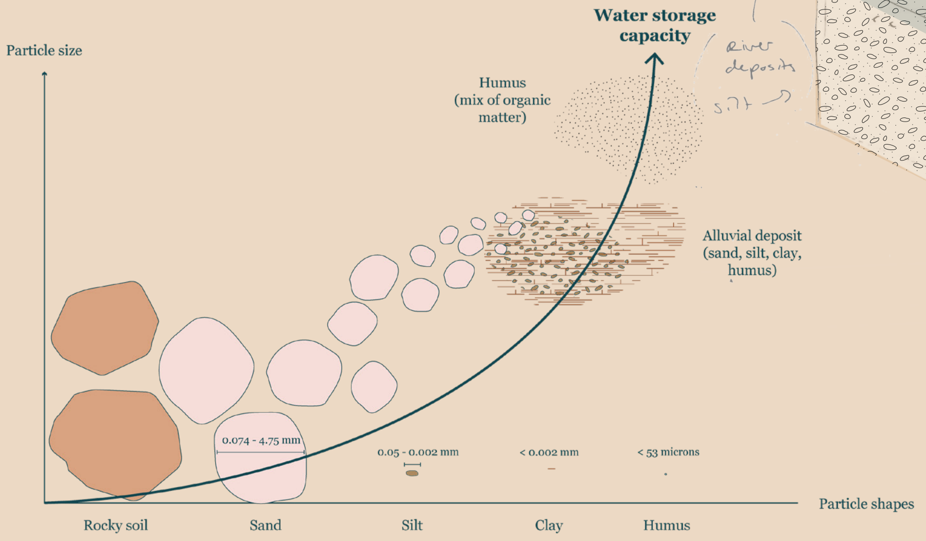


Fig. 150: Diagram of the water storage capacity per soil type.

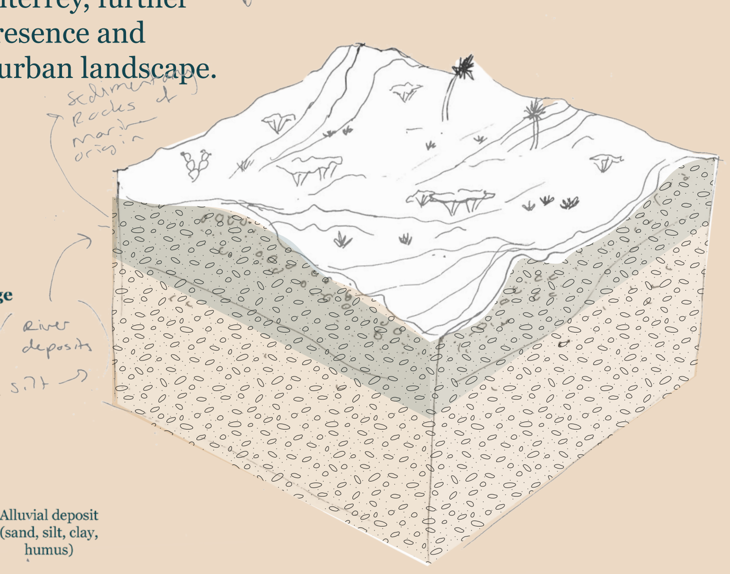


Fig. 151: Tamaulipan matorral ecoregion tile.

Ecology of the midstream

The Tamaulipan Matorral ecoregion is primarily characterized by low valleys and plateaus situated between the Sierra Madre Oriental and the Gulf Coastal Plain of Tamaulipas. The dominant bedrock consists of sedimentary rocks of marine origin, marked by abundant faults and folding due to tectonic activity. This ecoregion is largely desert shrub, distinct from the vegetation of the Chihuahuan Desert or Central Plateau, and hosts many endemic species.

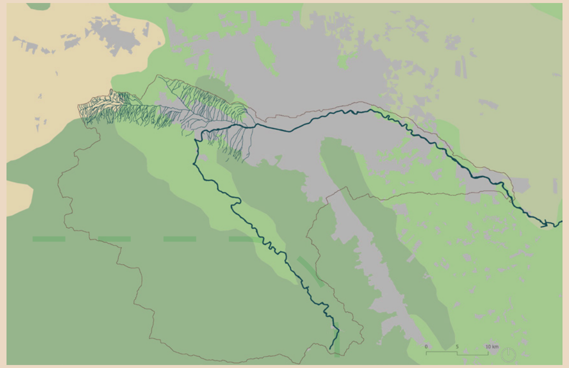
The climate of the Tamaulipan Matorral is arid to semiarid subtropical, with average annual precipitation less than 1000 mm. Dominant plant species include desert Christmas cactus, Texas prickly pear cactus, mesquite, smooth mesquite, Spanish dagger, shrubby blue sage, leatherstem, cenizo, Mammalaria cacti, tepeguaje (great leadtree), and catclaw mimosa, among others.

At the base of the Sierra Madre Oriental mountains, at elevations below 2,000 meters and with average annual precipitation between 450 and 900 mm, shallow soils support a unique community known as piedmont scrub. This community consists of shrubs 3–5 meters tall, with dominant plants such as baretta, palo estaca, and various acacia species. Montane chaparral at elevations above 1,700 meters in the Sierra Madre Oriental is dominated by oak species, accompanied by madrone, yuccas, mountain mahogany, Bauhinia, many legumes, and a species-rich herbaceous layer.

The ecoregion's high diversity of cactus species makes it a global priority for succulent conservation. It is a hotspot of evolution within the mint family and contains at least four endemic genera of woody plants. Endemic agaves are also abundant, such as the Queen Victoria agave, which has a significant portion of its range here.

Notable mammals in the ecoregion include the yellow-faced pocket gopher, Saussure's shrew, the narrow endemic Allen's squirrel, collared peccary, coyote, and the highly endangered Mexican prairie dog, which has been reduced to less than 4% of its native range due to poisoning by ranchers.

Characteristic birds include the burrowing owl, rose-throated becard, Tamaulipas crow, Chihuahuan raven, green jay, brown jay, long-billed thrasher, black-crested titmouse, hooded oriole, eastern meadowlark, Altamira yellowthroat, hooded yellowthroat, blue bunting, and olive sparrow.



Ecoregion: Tampaulipan matorral

Fig. 152: Holtes, E.O. *Queen Victoria agave* [Photo].

Fig. 153: By unknown. *Eastern Meadowlark* [Photo]. Image credit: Creative Commons.

Fig. 155: Holtes, E.O. *Spanish dagger* [Photo].

Fig. 154: Aguascalientes, M. *Smooth mesquite* [Photo].

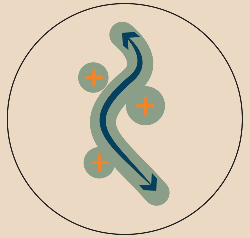
Fig. 156: Urieta, M. *Texas prickly pear* [Photo]. On Unsplash.

Fig. 157: Theiner, P. *Mexican prairie dog* [Photo]. Image credit: Creative Commons.

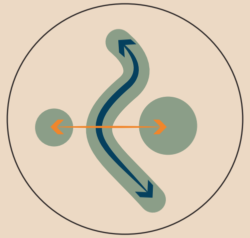
Design interventions midstream

Giving space

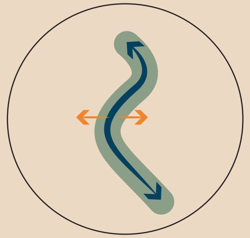
The strategy for the midstream zone focuses on providing more space for the river, re-naturalizing the riverbanks, and creating new habitats along the river. This will be achieved through the following proposed interventions:



Creating and connecting new habitats along the riverbed to foster biodiversity.



Establishing perpendicular connections between green areas north and south of the river to form ecological corridors.



Increasing the width of the riverbank and dechannelizing the river to accommodate natural river dynamics and enhance flood management.

Educational initiatives to increase understanding of the importance of river ecology.

Enhancing accessibility and adding recreational functions along the river to benefit the community.

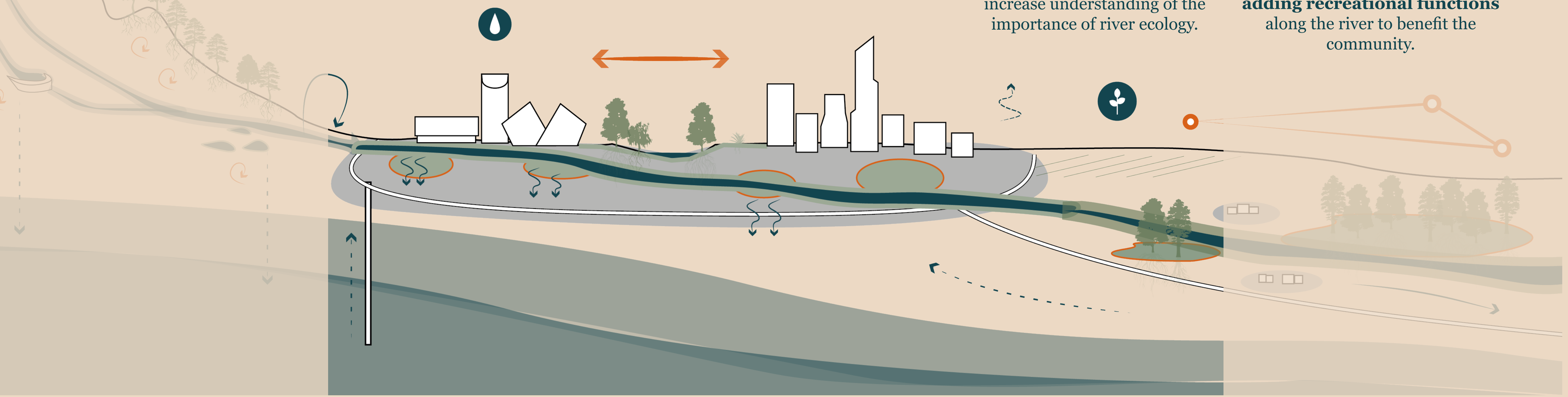


Fig.. 109: Principle section of the proposed interventions upstream, midstream and downstream, Fig. 110: river ecology education, Fig. 111: perpendicular connections, Fig. 112: increasing the width of the riverbank, Fig. 113: connecting + creating habitats along the river, Fig. 114: Adding accessibility and recreational functions to the river.

Midstream current situation

The midstream design location is situated in the heart of the city. Just behind Monterrey's central square, the Macroplaza. This public space, currently used as a parking lot and roundabout, lies at the edge of the riverbed and is adjacent to the Municipality, the Museum of Contemporary Art of Monterrey, and an event hall.

Presently, the 6-lane roads make the Santa Catarina River inaccessible from this location, creating a significant barrier. Revitalizing this public space can bridge the city centre, the Santa Catarina River, and the southern part of the city, offering substantial benefits. This revival can greatly enhance public space accessibility for the poorer communities on the north side of the river, fostering better connectivity and social integration.

Midstream design location

Fig. 158: Google earth screenshot of the upstream design location.

Midstream current situation

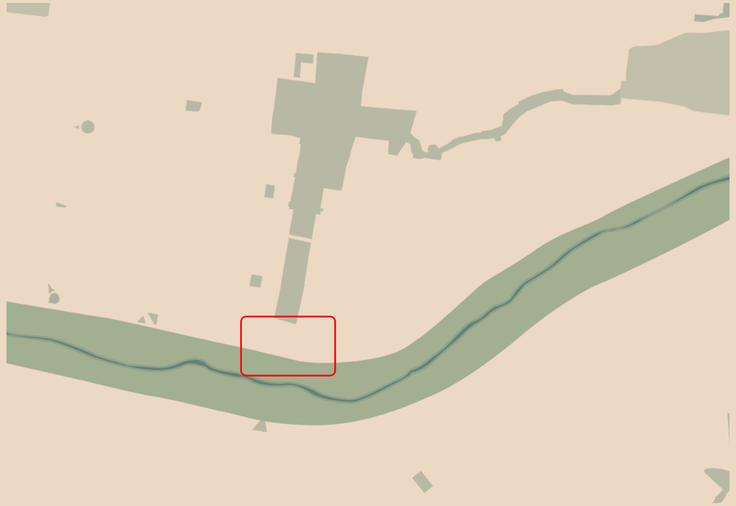


Fig. 159: midstream vegetation analysis map. Based on Google maps.

Fig. 160: Handelé, K. Site visit in the Santa Catarina river [Photo].

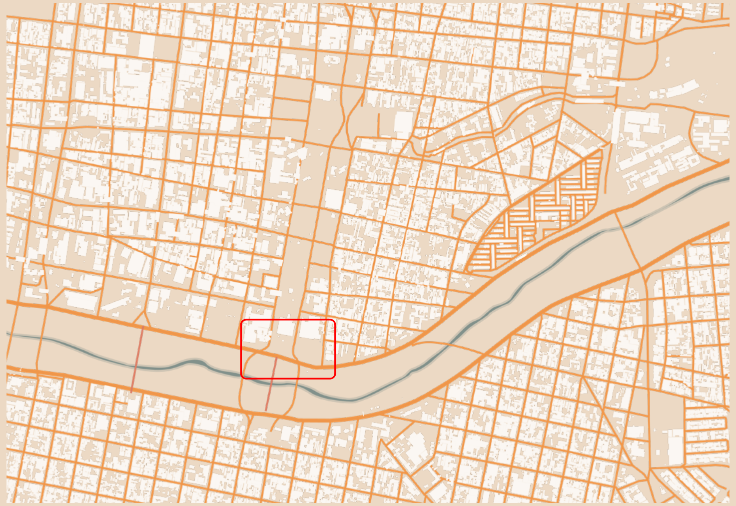


Fig. 161: midstream human activity analysis map. Based on Google maps.

Fig. 162: screenshot from Google Earth.

Fig. 163: Satallite image. Map conducted via QGIS.

- midstream design location
- city parks
- river ecology
- river
- road
- pedestrian bridge

Fig. 164: Holtes, E.O. (2024). *Modified riverbank* [photo]. Monterrey.

The midstream design location of the Santa Catarina River is characterized by an abundance of traffic and roads, facilitating connections between the north and south, as well as the east and west, of the Monterrey Metropolitan Area. However, this infrastructure largely bypasses any direct connection to the Santa Catarina River. In this zone of the watershed, the river is channelized by concrete walls, as depicted in Figure XX.

The vegetation analysis map reveals that, aside from the river ecology of the Santa Catarina River, the main plaza, and the man-made canal resembling Venice, there is limited green space available for the residents of Monterrey, especially considering the dry climate. Furthermore, this design location has the potential to serve as the missing link between the existing urban habitats.

Midstream vision implementation

Enhancing the Ecology of the Santa Catarina River

To enhance the ecology of this section of the Santa Catarina River, new habitats should be established along its banks to connect and improve the existing ecosystems, aligning with the river vision. Implementing this landscape intervention will result in the creation of new city parks. To illustrate the potential transformation, I focused on the design of the Plaza de Santa Catarina.

current situation

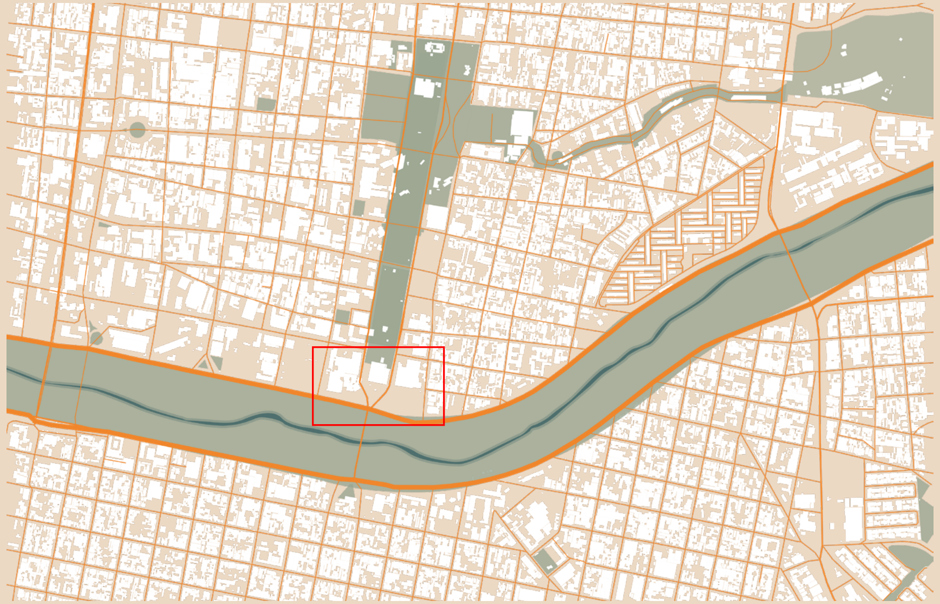
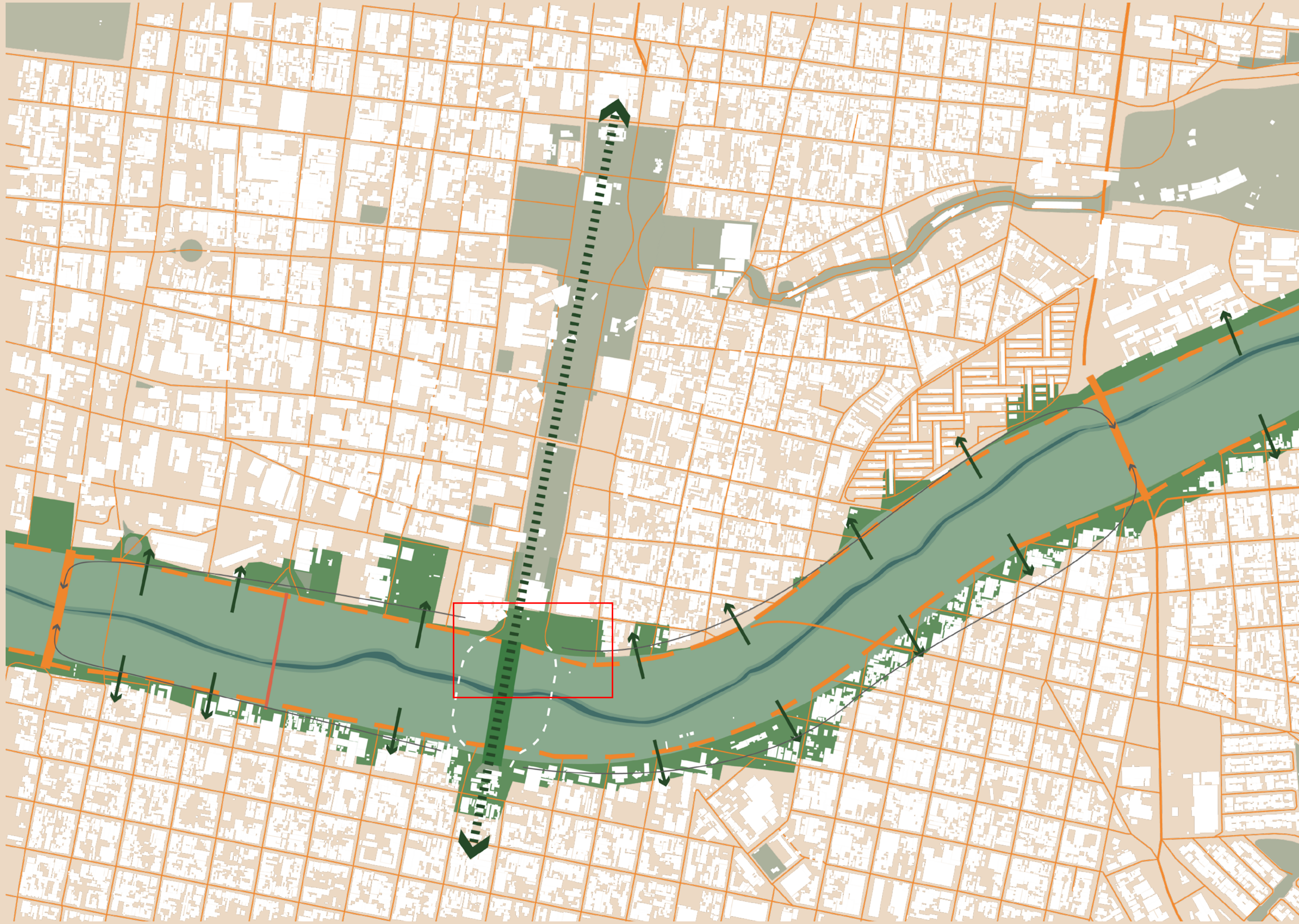


Fig. 165: Combined analysis map of the current situation from the midstream design location [Map].

design proposal



Midstream design location
Green public space connection
Widening of the river profile
Removal of bridge
Relocation of traffic
Pedestrian brdige
Roads
Road relocated underground
Buildings
River
Present green public space
New green public space along the river
River park

Fig. 166: Design proposal for the midstream design location [Map].

Proposed transformation of the midstream design location

Current Situation

Figure XX depicts the current situation of the midstream design location. Here, we can see the abundance of traffic and pavement dominating the public space.

Proposed Transformation

On the next pages (XX - XX), you can view the detailed transformation plan. This redesign illustrates how new habitats can be created while establishing valuable public areas along the Santa Catarina River. The square and pedestrian bridge will serve as crucial connectors between the city center, the river, and the southern part of the city, offering significant benefits. This revitalization will greatly improve public space accessibility for the impoverished communities on the north side of the river, promoting better connectivity and social integration.

Enhancing Connectivity and Public Engagement

The redesigned pedestrian bridge will enhance connectivity between the city center and the natural riverbed, helping to reestablish the relationship between the people and the river. Incorporating educational elements will foster a deeper understanding and appreciation of the Santa Catarina River among the local population.

Ecological Improvements

To improve the natural dynamics of the river and its water storage capacity, it is crucial to remove the concrete walls, allowing for the re-naturalization and enhancement of the riverbanks' ecology.

Flexible and Sustainable Design

Given the occurrence of floods during heavy rains or hurricanes, interventions in the river should be removable and flexible. For instance, markets and festivals could be held in the riverbed, with minimal cleanup required if a storm is forecast.

Fixed elements in the river should be constructed from natural materials so that their loss during floods is not damaging. For example, pathways could be made from wood chips sourced from willow trees within the river area.

Water Management

During the construction of the new square, integrated water management elements will be essential. Water infiltration crates will ensure adequate moisture levels in the soil, promoting healthy vegetation growth. Additionally, water outlets will channel rainwater towards the river, where helophyte filters will purify the water before it enters the river, thereby maintaining and increasing the river's water volume throughout the year

Fig. 167: *midstream design location* [Image]. Google Earth.

Fig. 168: *Design proposal for the midstream design location* [Photoshop].

Redevelopment of the pedestrian/
cyclist bridge
Plaza de Santa Catarina
Accessibility to the river
River ecology
education
Removal of the concrete slabs
Rain + grey water purification

Midstream design elaboration
Giving room back to the river

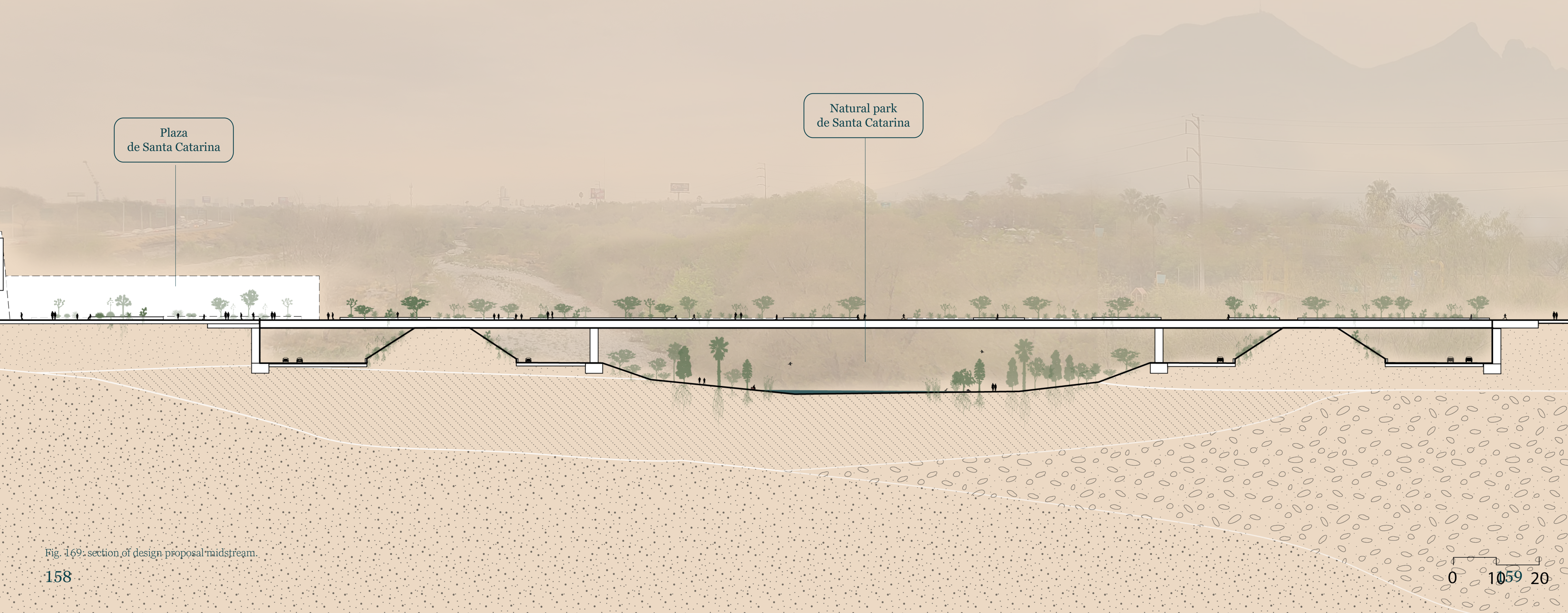
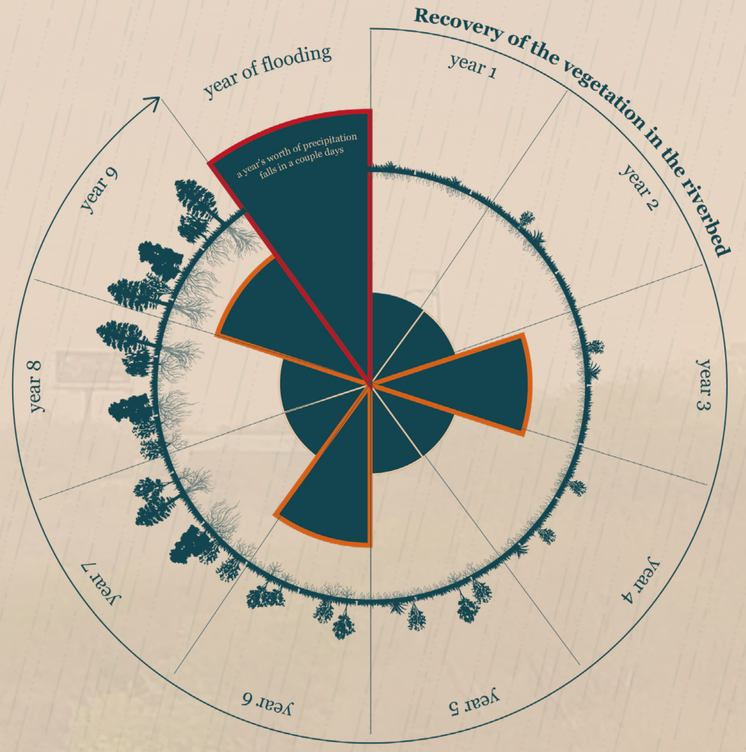


Fig. 169: section of design proposal midstream

Midstream design through time:
The different hydrological circumstances

The design site experiences distinct conditions across three stages of water levels. For most of the time, smaller streams run through the Santa Catarina riverbank. During heavy rainfall, these streams expand, potentially overflowing parts of the park. In the event of a hurricane, the riverbed will be fully flooded, and the force of the river will wash away the grown vegetation, restarting the process of pioneer growth in the river.

The section on this page illustrates how people would use the space during different hydrological events. The dotted water level lines represent the expected maximum water levels in each scenario. The black indicates 'regular conditions,' where it is safe to enter and recreate in the riverbed. The orange show conditions during heavy rains, advising caution when entering the river. The red represent conditions during a storm or hurricane, advising against entering the river while still allowing use of the plaza.



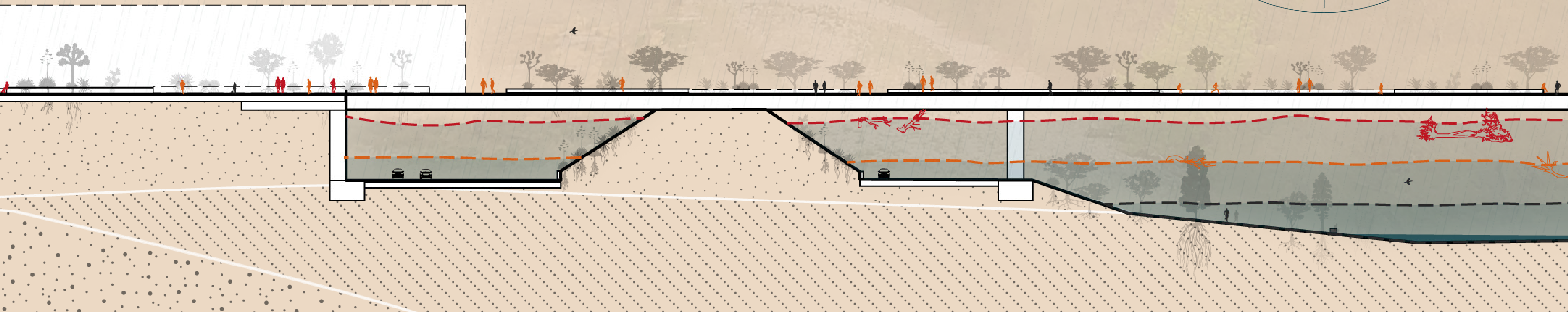


Fig. 170: section of design proposal midstream during the different hydrological circumstances

Plaza de Santa Catarina design

Fig. 171 Reference: University of New Mexico – Smith Plaza. By Blake Marvin.

Fig. 172: Reference of mexican garden.

Fig. 173: Reference of stairs towards the river.

The design for the Plaza de Santa Catarina aims to create a pleasant atmosphere, providing space for recreation and enjoyment of the river view.

The design shapes are inspired by Brazilian landscape architect Roberto Burle Marx and the redevelopment of the plaza on the University of New Mexico campus.

The planting plan for the Plaza de Santa Catarina draws inspiration from the Tamaulipan Matorral, the native ecoregion of this midstream design location.

On the following pages (166 - 167), you will see that the design style extends across the redeveloped bridge. This area allows people to stroll, sit, or run while enjoying the view of the Santa Catarina River.

Fig. 174: Map of the design proposal for the Plaza Santa Catarina.

Santa Catarina bridge

Tamaulipan matorral

Queen Victoria agave
Agave victoriae-reginae
© Holtes, E.O.

Smooth mesquite
Prosopis laevigata
by Aguascalientes, M.

Spanish dagger.
Yucca gloriosa
By Holtes, E.O

Texas prickly pear
Opuntia engelmannii
By Urieta, M.

+ Native trees

Lacey Oak
Quercus laceyi
© 2019 Leander Area Wholesale Nursery supply

Texas live oak
Quercus fusiformis
© Virtual Library of Phoenix Landscape Plants

Desert willow
Chilopsis
By Lukes, L

Sandpaper tree
Ehretia anacua
© 2012 Arizona Board of Regents

Fig. 174: Impression of the view from the Santa Catarina bridge.

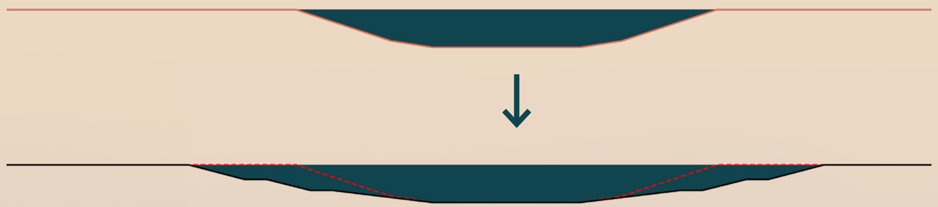
Future scenario
Giving room back to the river

Inspired by river development projects as the Madrid Río project, an example of bringing a big road structure along a river underground for the realisation of a riverfront park. A project by West8. I also want to showcase a scenario for the Santa Catarina river in Monterrey, where the road could be brought underground to widen the river profile.

By creating more room for the river, the rivers waterbody flow will increase. And therefore will have a better water carying capacity in case of heavy rains and the occacional hurricanes.

Fig. 104: Madrid Rio project. By West8.
https://www.west8.com/projects/madrid-rio/

Improved water carying capacity



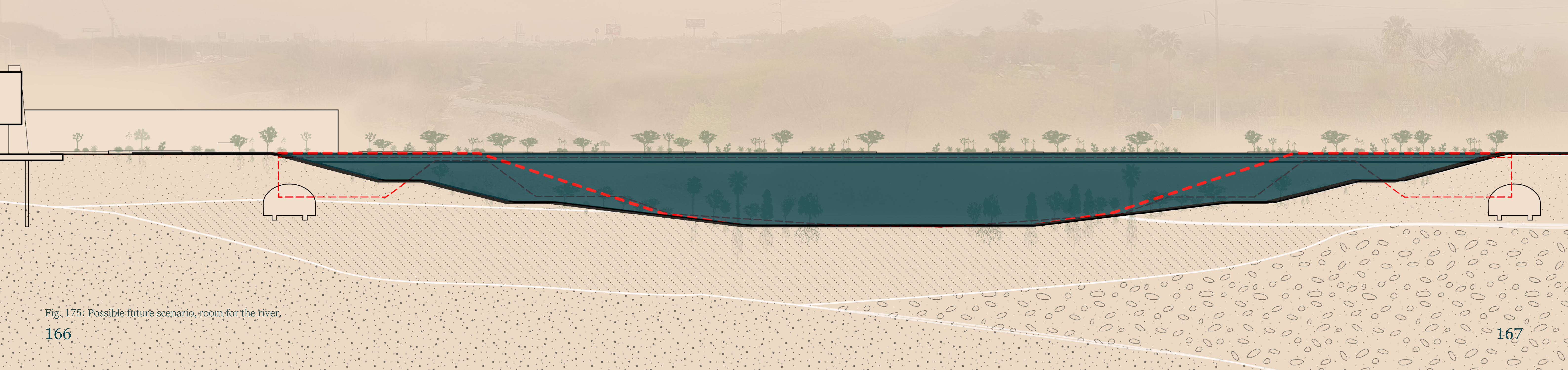
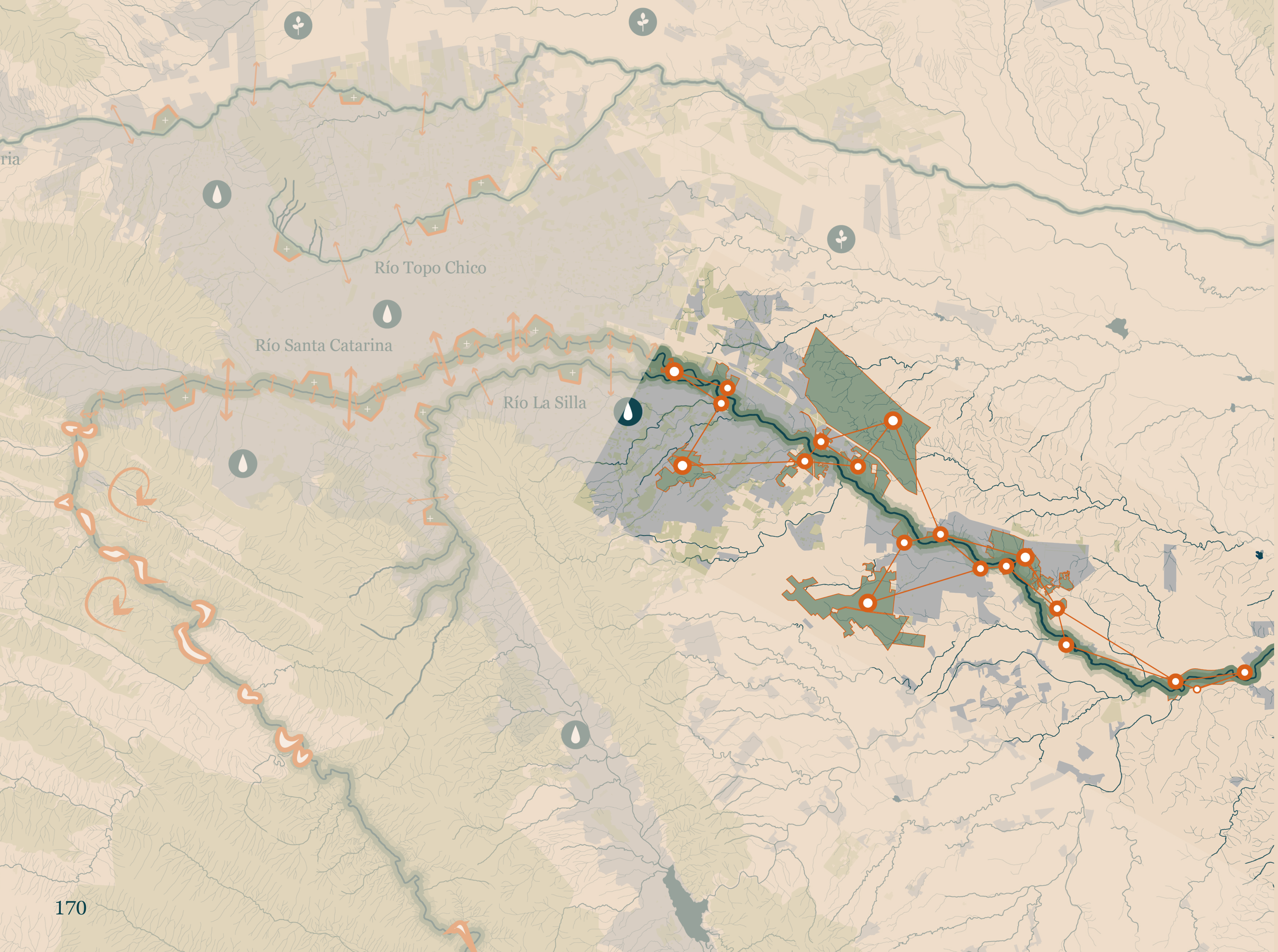


Fig. 175: Possible future scenario, room for the river.

The downstream zone

Fig. 176: Holtes, E.O. View on the riverbed of the Santa Catarina River in Monterrey.



The downstream zone

- water saving agriculture
- water saving measures in the city centre
- giving space back to the river
- connecting and protecting natural areas
- water capture and retention
- new green public spaces (habitats) along the river
- river with wide, natural riverprofile
- stream
- protected river forests
- green spaces
- urban area
- water body

0 10 20 km

Fig. 120: Vision for the rivers in MMA.

Downstream conditions

The third zone, referred to as the "downstream" zone, is located in the Tamaulipan Mezquital ecoregion. This downstream zone is characterized by the constant presence of water and conditions that most closely match the natural circumstances of the river.

The soil in this region is rich in humus and nutrients. In and around the riverbed, alluvial deposits are found, which have a very high water storage capacity.

However, this zone is under pressure from the ever-expanding Monterrey agglomeration, threatening the existence of the wide river profile. Additionally, garbage dumped in the upstream and midstream zones also affects the downstream area.

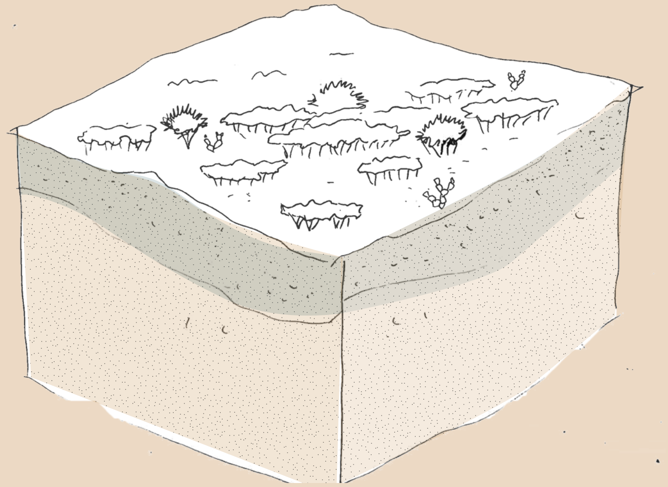


Fig. 178: Tamaulipan mezquital ecoregion tile.

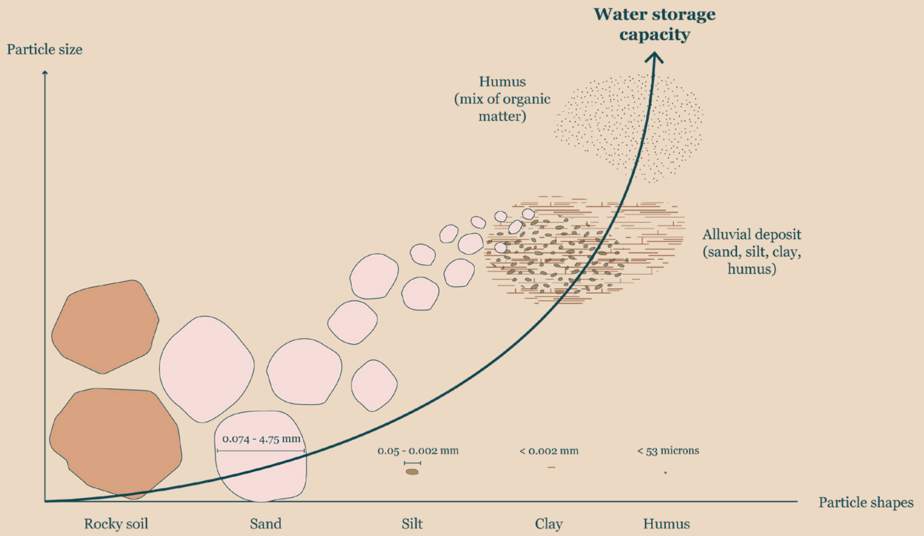


Fig. 179 Diagram of the water storage capacity per soil type.

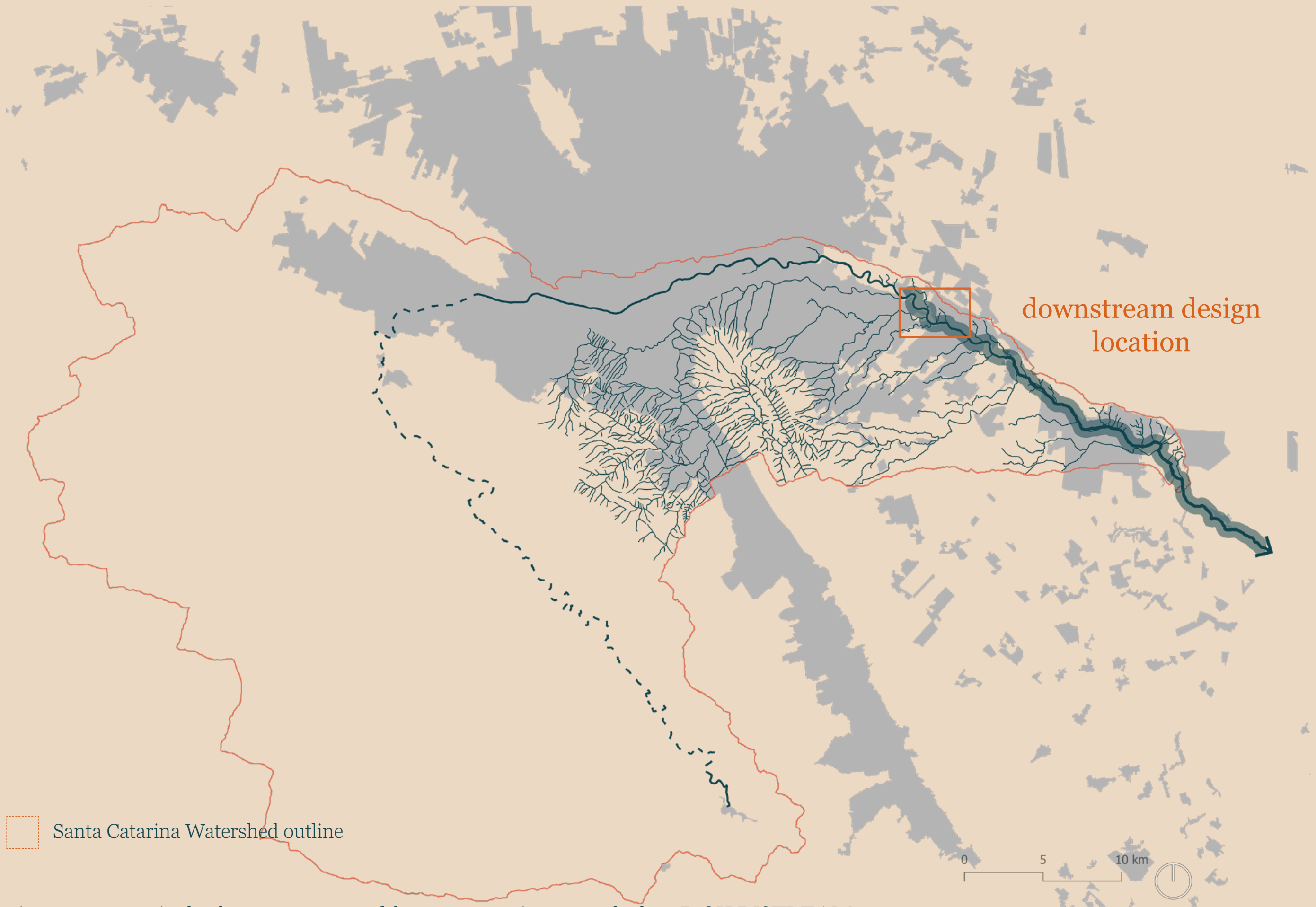


Fig 180: Streams in the downstreamzone of the Santa Catarina Watershed.

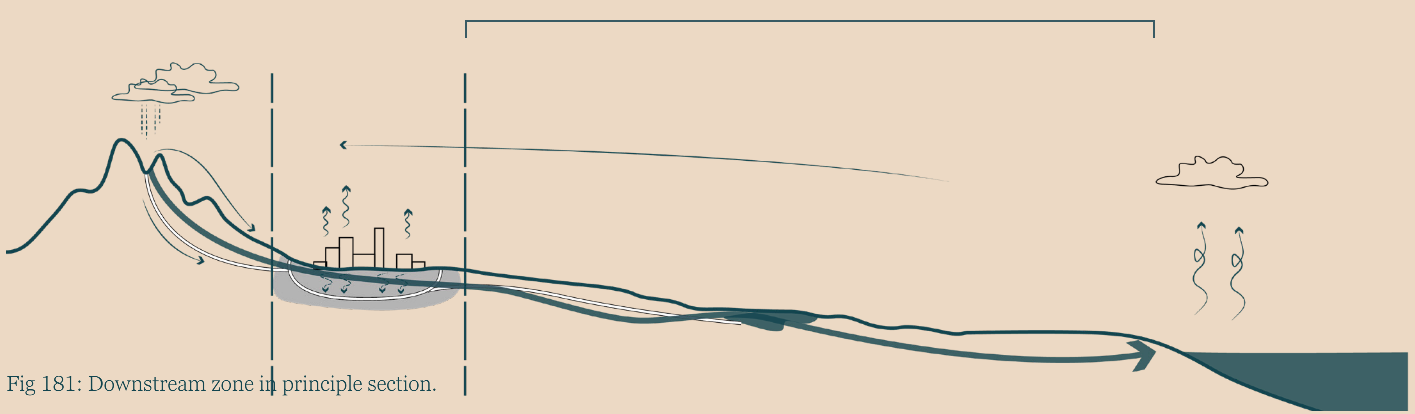


Fig 181: Downstream zone in principle section.

Downstream ecology
Tampaulipan Mezquital

The Tamaulipan Mezquital ecoregion occupies the southwestern portion of the Gulf Coastal Plain in southern Texas and northeastern Mexico. Entirely within the North American Coastal Plain, it was formally recognized as the 36th global biodiversity hotspot by the Critical Ecosystem Partnership Fund in 2016. This ecoregion extends from the western outskirts of San Antonio, Texas, south to the boundary between the Nearctic and Neotropic Realms near General Zaragoza, Tamaulipas, and northwest to the area west of the Amistad Reservoir on the Rio Grande River.

The Rio Grande flows through the middle of this ecoregion on its way to the Gulf of Mexico, serving as a natural border between the United States and Mexico. The Texas portion of this ecoregion is often referred to as the South Texas Brush Country. It is bordered by the Edwards Plateau ecoregion to the north, the Texas Blackland Prairies and East Central Texas Forests to the northeast, the Western Gulf Coastal Grasslands to the east, the Veracruz Moist Forests and Tamaulipan Matorral to the south and southwest, and the Chihuahuan Desert and Sierra Madre Oriental Pine-Oak Forests to the west.

Given its geographic position, the Tamaulipan Mezquital serves as an ecological crossroads between east and west, and subtropical and tropical zones, which contributes to its high biodiversity.

The climate of the Tamaulipan Mezquital is semiarid subtropical, with winds from the Gulf of Mexico keeping the region relatively humid for much of the year. Average annual precipitation ranges from 400 to 1000 mm. Vegetation across the ecoregion is highly variable, but the defining plant community is mesquite grassland, dominated by honey mesquite and curly mesquite grass, with other common plants including chaparro and jazmincillo.

There are also open woodlands of mesquite with a grassy understory of taller species such as hooded finger grass, over shorter grasses like grama grasses. Tamaulipan thornscrub features spiny shrubs and trees over grasses, forbs, and succulents. Higher, rocky sites with shallow soils support medium-stature shrubland with blackbrush, guajillo, cenizo, and other species. Lower, flatter sites with deeper soils feature mesquite and taller woody plants openly spaced over grasses, forming a savanna. Common plants in these areas include granjeno, lotebush, prickly-pear, and brasil.

Ecoregion: Tampaulipan Mezquital

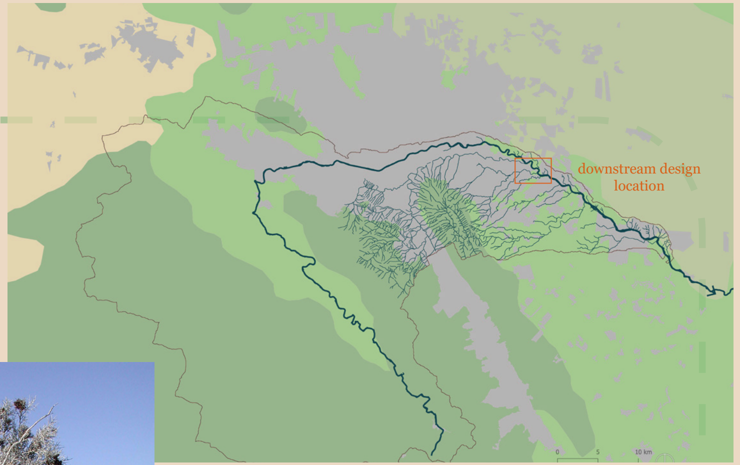


Fig. 183. By Mountain States Nursery. *Honey mesquite* [Photo].

Fig.184 E, Castela. *Chaparro* [Photo].

Fig. 185 Kilby, E. *Ocelot* [Photo]. Creative Commons.

Fig. 186 Pfeiffer, M. *hook-billed kite* [Photo].

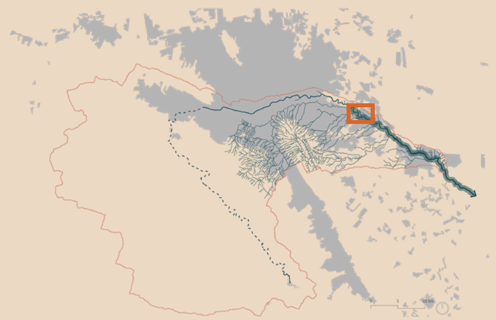
Fig. 187: Marcus, J. *Texas prickly pear* [Photo].

Fig. 188. By unkown. *Southern Plains wood rat* [Photo]. Image credit: Creative Commons.

Downstream ecology
River ecology

In addition to the ecoregions defined in the previous pages, the river itself can be distinguished as a unique ecoregion, given its specific conditions and habitats.

Under optimal conditions, the river ecology of the Santa Catarina River would include tree species such as willows, poplars, and the Sabino tree, Mexico's national tree. Recently, flagship species like the North American beaver have been spotted in the river, and each spring, the Monarch butterfly is observed along the riverbanks. Additionally, the Neotropic cormorant and the Great egret are commonly seen fishing in this ecoregion.



River ecology

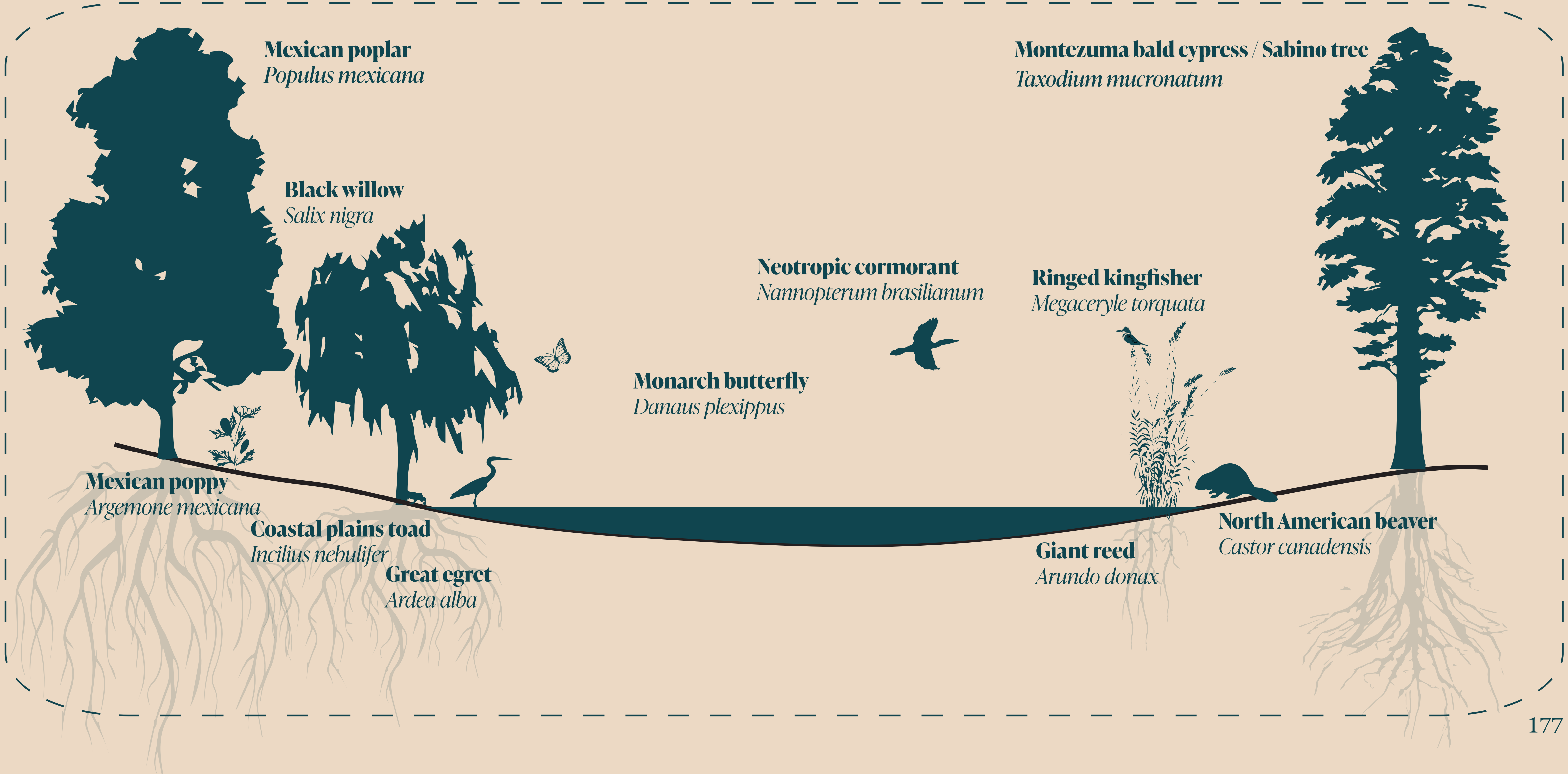


Fig. 189:Principle river ecology section.

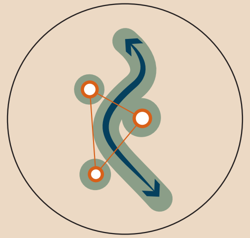
Design interventions downstream

Allowing the flow

The strategy for the downstream zone focuses on protecting the existing wide natural banks and river forests, as well as enhancing connectivity between these areas. The proposed interventions include:

Educational initiatives to increase understanding of the importance of river ecology.

Protecting the wide riverbanks and the river forests to preserve their natural state.



Maintaining and connecting habitats along the river to support ecological continuity.

Incorporating recreational functions to enhance community engagement with the river.

Promoting sustainable agriculture to reduce water demand from the most water-intensive sector.

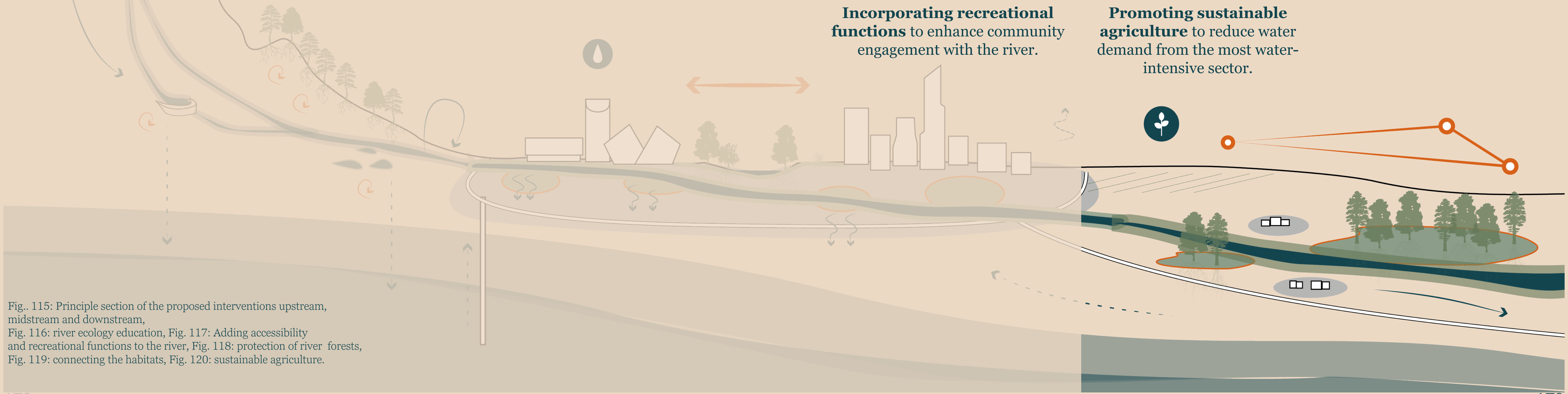


Fig.. 115: Principle section of the proposed interventions upstream, midstream and downstream,
Fig. 116: river ecology education, Fig. 117: Adding accessibility and recreational functions to the river, Fig. 118: protection of river forests,
Fig. 119: connecting the habitats, Fig. 120: sustainable agriculture.

Downstream current situation

Fig. 190: *Vegetation analysis* of the downstream design location [Map]. Based on Google maps.

Fig. 191: Holtes, E.O. *River ecology of the downstream zone* [Photo].

Fig. 192: *Human activity analysis* [Map]. Based on Google maps.

Fig. 193: *The surrounding neighbourhoods downstream* [Image]. Screenshot from Google maps streetview.

Because the river is not designated as a natural protected area, the downstream river ecology is endangered by urban expansion. If we do not intervene in this zone, it is highly likely that neighborhoods will be built right up to the edges of the riverbed, as illustrated in red on the map below. This will not only harm the existing river forest but also endanger residents by placing them in the floodplain zone.

Therefore, it is crucial to designate this part of the river as a protected area to preserve the wide river profile.

The neighborhoods surrounding the river are working-class areas. By addressing pollution in the upstream and midstream zones, the quality of the river ecology would improve, thereby enhancing the public spaces in these neighborhoods.

forest
shrub vegetation
riparian vegetation
river
working-class housing
sport facilities
road

Fig. 194 :*Current situation downstream design location*. [Map]. Based on a satallite map, conducted via QGIS.

Downstream vision implementation

Allowing the flow

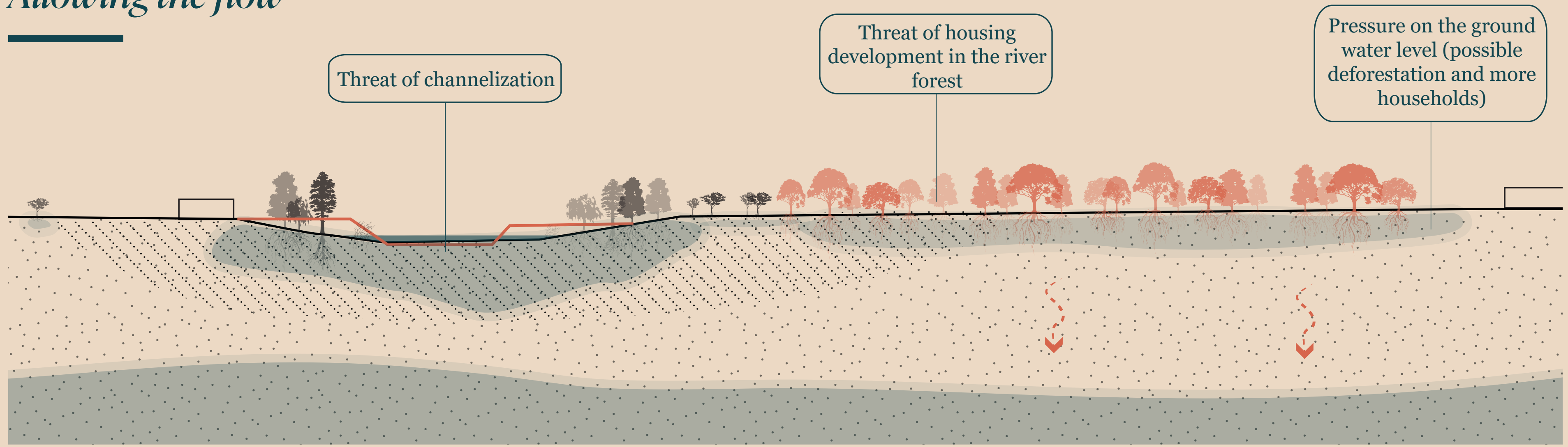


Fig.195: *downstream design location current situation in section.*

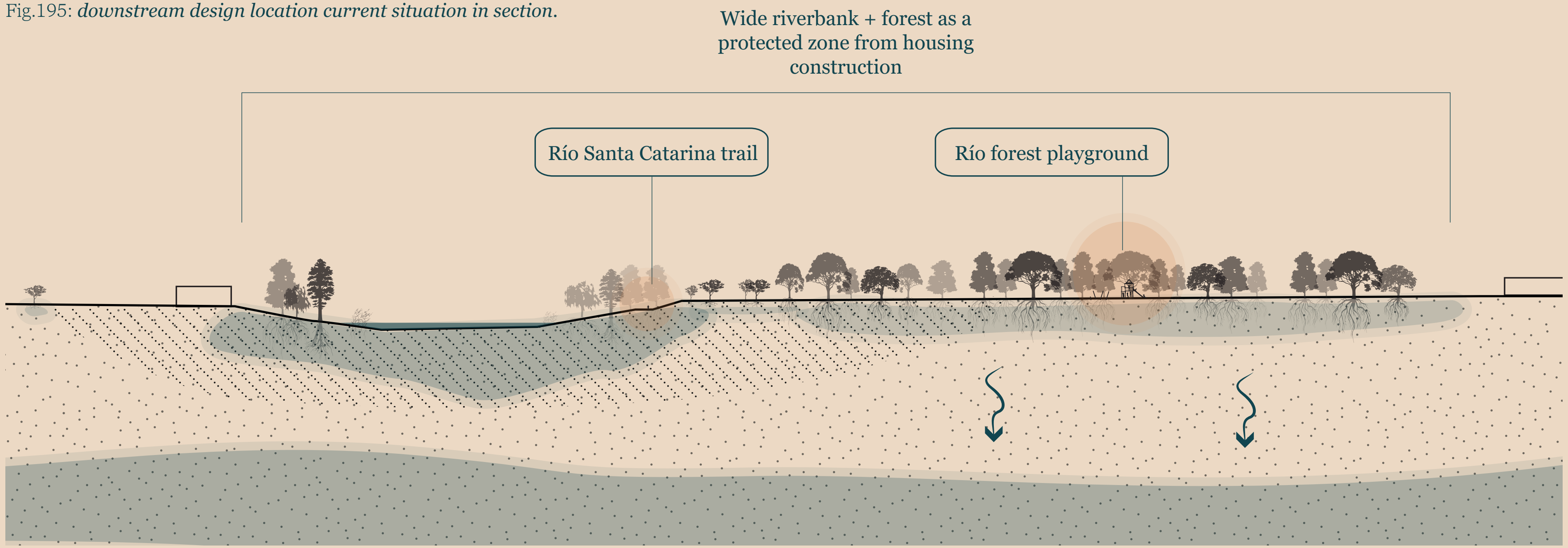


Fig. 196: *downstream design location with design proposal in section.*

Currently, there is a lack of connectivity between the river and the houses of the working-class community. To improve the quality of public spaces in the surrounding working-class neighborhoods, recreational functions will be incorporated into the river area. For instance, walking paths along the river and through the river forests can enhance the connection between the community and the river ecology.

In addition to recreational opportunities, the strategy includes educational initiatives to raise awareness about the importance of river ecology. This approach aims to foster a greater appreciation for the river, promoting a symbiotic relationship with its natural dynamics.

Downstream design through time

The different hydrological circumstances

The design site experiences distinct conditions across three stages of water levels. The downstream zone is characterized by a year-round flowing river. During heavy rains, water levels rise, and in the event of a hurricane, the river overflows its banks and inundates the flood zone.

These sequence of maps highlights the importance of granting protected status to the river's floodplain to ensure a healthy ecosystem and safeguard the surrounding communities.

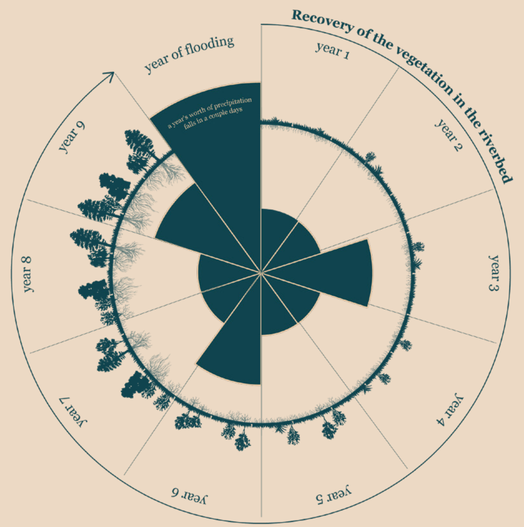


Fig. 197: *downstream design proposal during the "regular conditions" : dry.*

Fig. 198: *downstream design proposal during the occasional heavy rains.*

Fig. 199: *downstream design proposal during a hurricane.*

Downstream river forest

River ecology

Montezuma bald cypress / Sabino tree
Taxodium mucronatum
© Holtes, E.O.

Mexican poplar
Populus mexicana
By Rockefeller, A. - www.inaturalist.org

Black willow
Salix nigra
By Marlin, B. - Wikimedia commons

5

Conclusion & evaluation

Conclusion and discussion

Project results and relevance

This thesis identifies significant issues within Monterrey's river ecosystems, primarily due to short-term flood control measures that are only activated every 10-15 years. These measures result in habitat degradation, river channelization, limited accessibility, and a negative narrative towards nature. The short-term flood risk reduction strategies often undermine long-term river resilience. This study prioritizes long-term solutions, assessing the river from its origin to its terminus, with the landscape as a foundational element.

Utilizing the Urban Ecology Design Approach, which examines urban ecology at multiple levels—ecosystem, habitat, and species—the research provided a comprehensive analysis that informed the landscape design. Through a watershed approach, the project formulated solutions spanning the entire river, proposing strategies for water retention upstream, space allocation midstream, and controlled flow downstream.

Through the implementation of three site-specific designs, the project aimed to address ecological disturbances along the river. Notably, the strategies and designs were crafted with consideration of the river's three distinct water level stages, without neglecting the impact of hurricane discharge. Instead, the focus was on mitigating flows and enhancing river ecology through revision.

Transferability

While the Monterrey river ecosystem issues are context-specific, the broader problem of manipulated water systems to prevent disasters is common worldwide. Short-term safety measures and long-term river resilience often conflict. Although the solutions in this thesis are tailored to Monterrey, the fundamental strategies derived from the watershed and urban ecology design approaches are universally applicable.

Limitations

Several limitations were encountered during the project. The lack of precise spatial data necessitated reliance on global or continental GIS datasets, risking inaccuracies in detailed maps. The site visit to Monterrey, lasting a month, did not cover all intervention areas due to scale and accessibility issues.

Conducting a project for a city on another continent imposed physical constraints, leading to assumptions based on maps and photos for some design parts. Cultural differences posed another challenge. Despite efforts to understand the local context by engaging with Monterrey's residents, there remains a gap due to my own cultural framework. Additionally, some proposals are idealistic, assuming stakeholder cooperation that might encounter resistance in reality.

Ethical aspects

The thesis proposes improvements to the river ecosystem, which could impact vulnerable populations, such as those living in informal settlements along the riverbank of the Santa Catarina. Solutions like income from tourism, improved spatial quality, and flood risk prevention aim to benefit these communities. However, interventions such as increased protection of natural areas might still affect the most vulnerable. Therefore, implementing these strategies should include compensation plans and safe relocation options for affected communities.

Future recommendations

Future recommendations emphasize the applicability of the research principles and methods in similar contexts. Incorporating a participatory approach during the design process could address ethical issues, allowing for social input and fostering awareness. This participatory approach would enhance understanding and acceptance among inhabitants, facilitating a more harmonious relationship with the river ecosystem.

Reflection and recommendations

Position within the field of architecture

This thesis, as part of the landscape architecture graduation studio Flowscapes, focuses on the movement and flows within complex systems, specifically exploring the river ecosystems of Monterrey Metropolitan Area (MMA). It examines water flow, animal migration, and seasonal movements. The thesis envisions a symbiotic relationship between culture and nature, transforming rivers into ecological corridors, guided by the Urban Ecology Design Approach, which integrates urban habitats into broader ecological systems.

Reflecting on the method and process

The project employed various methods, including literature reviews, GIS mapping, site visits, and consultations with locals and experts. Each method provided unique insights, enriching the project's understanding and outcomes. The theoretical framework was particularly beneficial, guiding the research and problem-solving process. Site visits proved invaluable, offering first-hand experience of the landscape's atmosphere, dimensions, and dynamics. Despite desk research, the physical site visit to Monterrey revealed unexpected differences, underscoring the importance of on-site exploration in landscape architecture.

Collaboration with Monterrey's Technical University facilitated local engagement, although the inability to revisit the site multiple times presented a limitation. The iterative process of research and design, informed by continuous feedback from mentors and specialists, was crucial. Balancing diverse inputs and maintaining focus amid emerging issues and opportunities were challenging but necessary for the project's coherence.

Additionally, my involvement in the Urban Ecology Design Lab and the development of the Urban Ecology Design MOOC (massive open online course), broadened my understanding of urban ecology. Applying course assignments to my project site enriched both the course content and my research.

Final Reflections

The thesis project expanded my knowledge and skills in landscape architecture, particularly in working with large-scale, complex systems. The iterative research-design process, combined with on-site experiences and interdisciplinary collaboration, provided a comprehensive learning journey. This experience will inform and guide my future endeavours in landscape architecture, ensuring a balanced and context-sensitive approach to urban ecology design.

References

Aguilar-Barajas, I., Sisto, N. P., Ramirez, A. I., & Magaña-Rueda, V. (2019). Building urban resilience and knowledge co-production in the face of weather hazards: flash floods in the Monterrey Metropolitan Area (Mexico). Environmental Science and Policy, 99, 37–47. https://doi.org/10.1016/j.envsci.2019.05.021

Cornell University. (2010). Total Soil Water Storage Capacity. Https://Nrcca.Cals.Cornell.Edu/Soil/CA2/CA0212.4.Php#:~:Text=The%20total%20soil%20water%20storage,70%20to%2085%25%20by%20volume.

Eloy Aguirre. (2021, May 31). Mesoamérica, Aridoamérica y Oasisamérica: mapa y características. Https://Www.Unprofesor.Com/Ciencias-Sociales/Mesoamerica-Aridoamerica-y-Oasisamerica-Mapa-y-Caracteristicas-4818.Html#anchor_1.

Hooijmeijer, F., Bijlsma, L., Van Rijn, F., Bouwman, A., & Veerbeek, W. (2021). NBS in Vulnerable Geographies Applicability of NBS in socio-economic unequal urban/peri-urban contexts with water-related challenges.

Ismael Aguilar Barajas, & Aldo Iván Ramírez Orozco. (n.d.). Agua para Monterrey.

John Schmal. (n.d.). Indigenous Nuevo León: Land of the Coahuiltecans.

Living Planet Report 2022. (2022).

Nijhuis, S. (2022). Landscape-Based Urbanism: Cultivating urban landscapes through design. 249–277. https://doi.org/10.1007/978-3-030-97023-9_1

Olson, K. R., & Lang, J. M. (2021). Rio Grande an International Boundary River Is Drying up and in Need of Restoration. Open Journal of Soil Science, 11(12), 587–610. https://doi.org/10.4236/ojss.2021.1112029

One Earth. (n.d.). Sierra Madre Forests & Mexican Drylands Bioregion.

TecScience. (2024). Alberto, The First Named Storm, Marks The Start of a 'Highly Active Hurricane Season.' TecScience. https://tecscience.tec.mx/en/human-social/tropical-storm-alberto/
Tillie, N. (2024). Urban Ecology Design MOOC.
USC School of Architecture. (2020). ATLAS OF DRYLANDS DESIGN.
Zurita, O. (2024). Words of Oswaldo Zurita.

Tillie, N. (2024). Urban Ecology Design MOOC.

Zurita, O. (2024). Words of Oswaldo Zurita.

Figures

X Appendix

The Mexican adventure

Excursion guide site visit Monterrey, Mexico, Feb-March 2024

Isa van der Bijl, Kim Handelé, Eline Onih Holtes, and Pieter van der Wel

MA

12/2

Tecnológico Monterrey

Arrival day in Monterrey, Mexico. Rob Roggema and Rodrigo, his assistant, welcomed us for a tour of the Tecnológico de Monterrey (TEC) campus.

DI

13/2

Symposium

Attended a symposium in the library on campus where, among others, Professor Rob Roggema presented the projects under the La Ola Verde program, with the mission to green the city. Our graduation projects were briefly mentioned! Afterwards, we were able to study in the TEC library.

WOE

14/2

Excursion

Excursion to Ponte Verde, Parque España, Parque Fundidora, and Santa Catarina. We walked from the campus towards the Santa Catarina river. We crossed it via Ponte Verde, a new park bridge that connects the north and south of the city for pedestrians and cyclists (cycling here is only for recreation). On the south side of the bridge lies Parque España, a park focused on children, a bit of faded glory. But on the north side, you find a beautiful large park with old industrial buildings and elements: Parque Fundidora.

DO

15/2

Musea de Historia de Mexicana

Visit to the Museo de Historia Mexicana. The National History Museum covers the history of Mexico, from the conquest of Tenochtitlan to the Mexican Revolution. The rooms display a diversity of objects that are representative of four centuries of Mexican history.

VR

16/2

Workshop @TEC

We attended a lesson with presentation by Rob Roggema about the symbiotic landscape and participated in a workshop with students from TEC and the FAMM (Fondo Ambiental Metropolitano de Monterrey). We exchanged data and information about the landscape of the Monterrey Metropolis (MMA).

MA

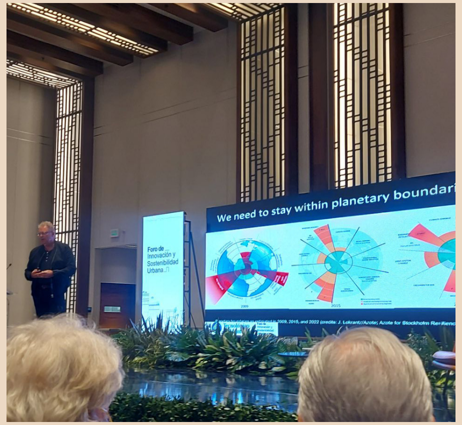
19/2

Excursion Parque la Huesteca

Together with Rob and his wife we took a hike through Parque la Huesteca, the mountain range where the Santa Catarina rises. Along the way we were amazed by the sometimes almost surreal landscape and plants.

DI

20/2

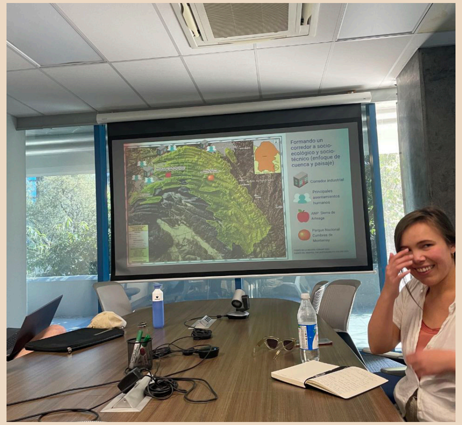


Conferention

Studying on campus and in the afternoon we went to the conference “Foro de Innovación y Sostenibilidad Urbana 2024” in a hotel in San Pedro (richest neighborhood in Latin America). Rob Roggema was one of the speakers here.

WOE

21/2



Water Centre, TEC

Study day in the campus library and a tour of the Water Center. We got to take a look behind the scenes and two enthusiastic ladies told us about the research center.

DO

22/2

The future of water, TEC

In the Water Center we presented our graduation projects and received feedback from various professors. Afterwards we could participate in a presentation about The future of water by Erika Toledo, an enthusiastic lady from the water center.

VR

23/2

Excursion Santa Catarina, El Salto

We drove through the mountains in a TEC van towards la Ciénega de González. From there we did a super nice hike towards the “waterfall” el Salto via the dry riverbed of the Santa Catarina.

Excursiegids locatiebezoek Monterrey, Mexico, feb-maart 2024
Isa van der Bijl, Kim Handelé, Eline Onih Holtes en Pieter van der Wel

MA

26/2

Museo De Arte Contemporáneo

Visited the Museo De Arte Contemporáneo. Super beautiful building, which is worth a visit in itself. And there just happened to be an exhibition of nature and landscape on display!

DI

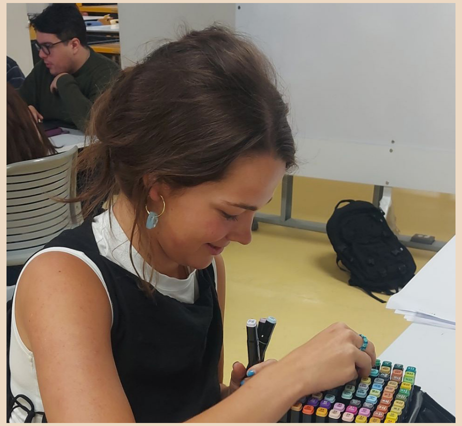
27/2

Parque Ecológico Chipinque

A great start to the week with a hike through Parque Ecológico Chipinque. What a paradise! Beautiful. In the park we made the climb to Meseta del Pinal. A viewpoint where we had an amazing view of the Monterrey Metropolis. Totally worth the elevation gain and sweat!

WOE

28/2

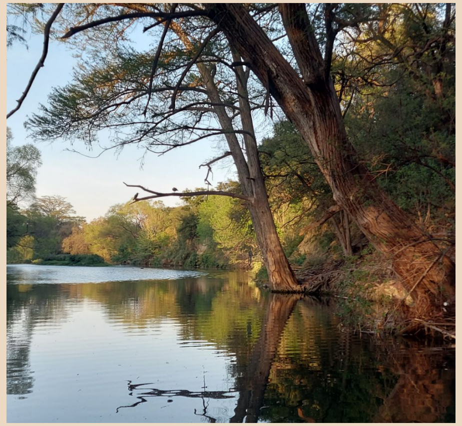


Workshop, TEC

During the day we participated in a workshop for a course that Rob teaches at TEC about the landscape of the future.

DO

29/2



Excursion to Río La Silla

Sheila, one of the students we met through TEC, and a friend of hers took us for a walk along the La Silla River. The only river in Monterrey that is not completely canalized. Here you will still find Sabino trees, the national tree of Mexico.

VR

1/3

Excursie Cerro La Silla

The most challenging hike yet. There was a path up, but the slope sometimes reached up to 40%. From the top at “Las Antenas” we had a magnificent view of the mountain ridge of Cerro La Silla. Along the way we encountered wildlife; the white-nosed coati and birds of prey.

MA

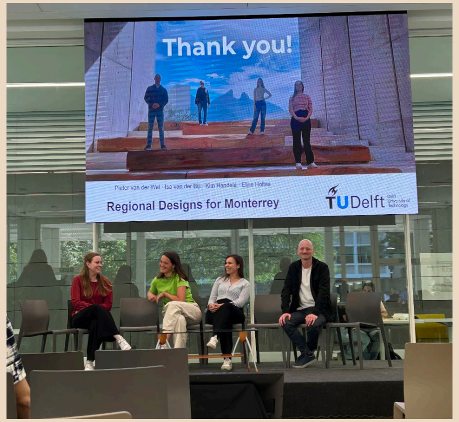
4/3

Visit to a water treatment plant

Visit to a water treatment plant at the Río Pesqueria. There they clean sewage water from the city and companies. Most of it goes back to the companies and some of the clean water is simply released into the (polluted!) river.
They are convinced that this will make the polluted river water cleaner.

DI

5/3



Regenerative Regions International Symposium day 1

Start of the Regenerative Regions International Symposium. A full program for two days with speakers from all over the world. We were scheduled for day 1 of the symposium in the afternoon! We had 5 minutes per person to pitch our graduation projects. And then a panel responded to our work. Only compliments for our work.

WOE

6/3

Regenerative Regions International Symposium day 2

Day 2 of the symposium featured a well-known speaker, Steffen Nijhuis; head of the landscape architecture track at TU Delft will give a presentation on Regional Design for Regenerative Urban Landscapes. The symposium ended with drawing on the map of Monterrey with those present. We were also put in the spotlight by Rob with a certificate of participation.

DO

7/3

Excursion to Río Santa Catarina

In the afternoon Fabian, one of the TEC professors, took us to visit Río Santa Catarina at several points. We started at one of the “informal settlements”, built in the riverbed. The mountains of waste, which are illegally dumped, are striking. The next stop you saw the result of locally removing vegetation in the river to promote the flow of water. At the last point we could see the results of 10 years of development without human interventions.

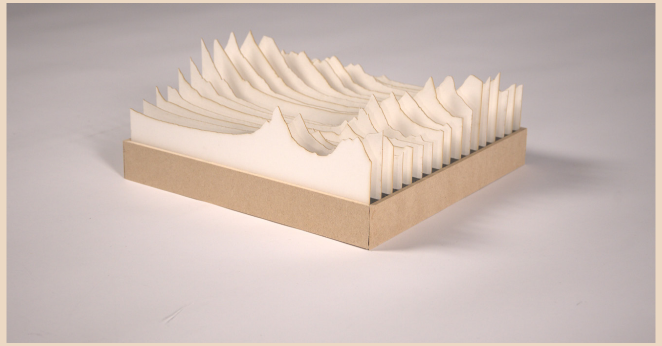
VR

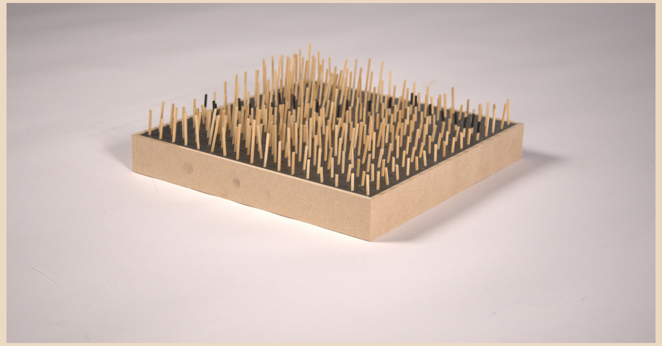
8/3

Excursie IDEAS

With a number of speakers from the symposium we went to Higueras, where Pedro started a sustainable project together with the community. IDEAS: Centro Interpretativo de Educacion Ambiental Sustenable.

Models





Principle model of the topography of the
Sierra Madre Oriental.

Principle models of the topography of the
design locations of several students.

Urban Ecology Design MOOC

During my graduation year I was also working as student assistant on the development and moderation of the Urban Ecology Design MOOC (massive open online course), together with Nico Tillie, Rosa de Wolf and Laura Fokkelman.

The work broadened my understanding of urban ecology. Applying course assignments to my project site enriched both the course content and my research.

Eline Onih Holtes