

La voz del río

Landscape interventions to restore the river ecosystem
in Monterrey, Mexico

Eline Onih Holtes

Landscape Architecture
Master thesis, TU Delft



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

First mentor: Nico Tillie
Second mentor: James Byng
Delegate: Negar Sanaan Bensi

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We can restore the river ecosystem of Monterrey!

1

Introduction



Collaboration
Relevance
Location
Historical exploration
Problem statement
Research goal
Research question

Collaboration between TU Delft and Tecnológico de Monterrey

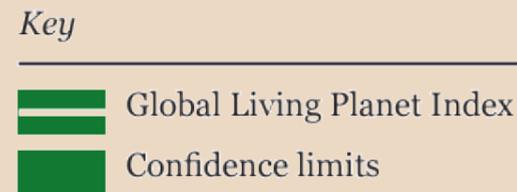
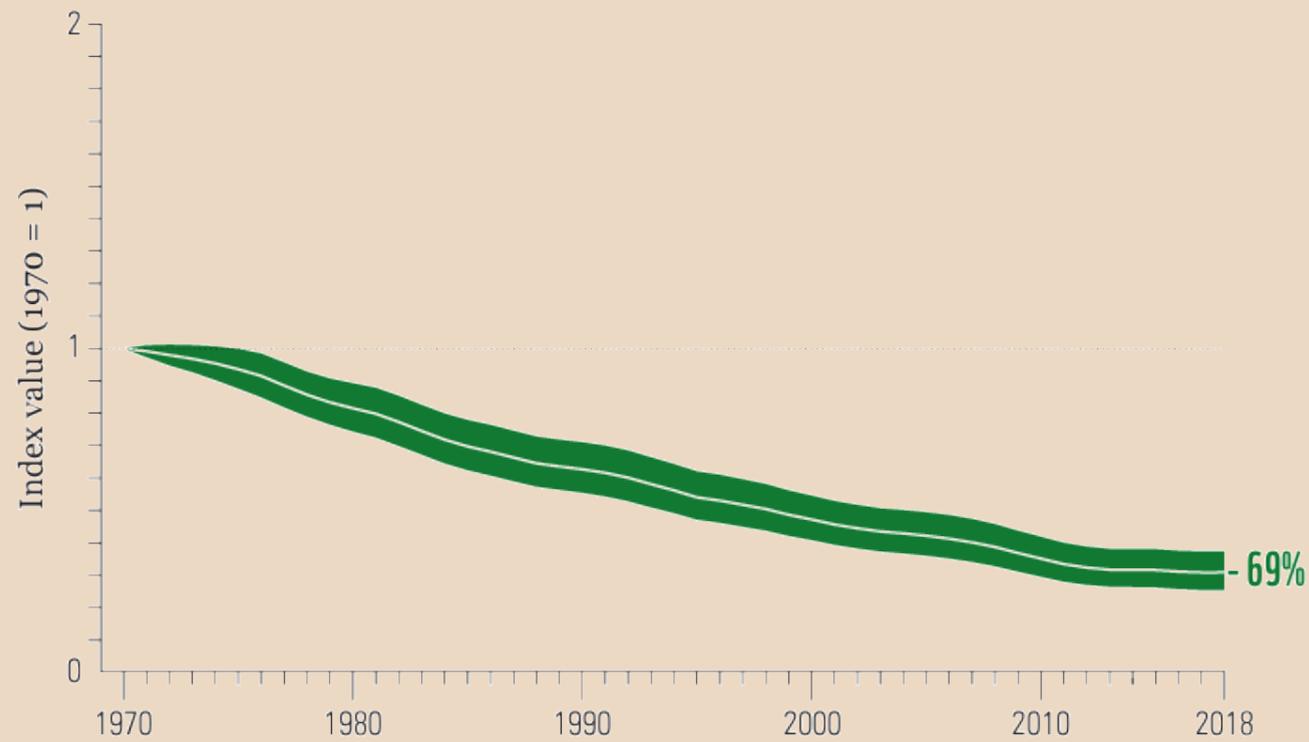


Photos by Pieter van der Wel, 2024.



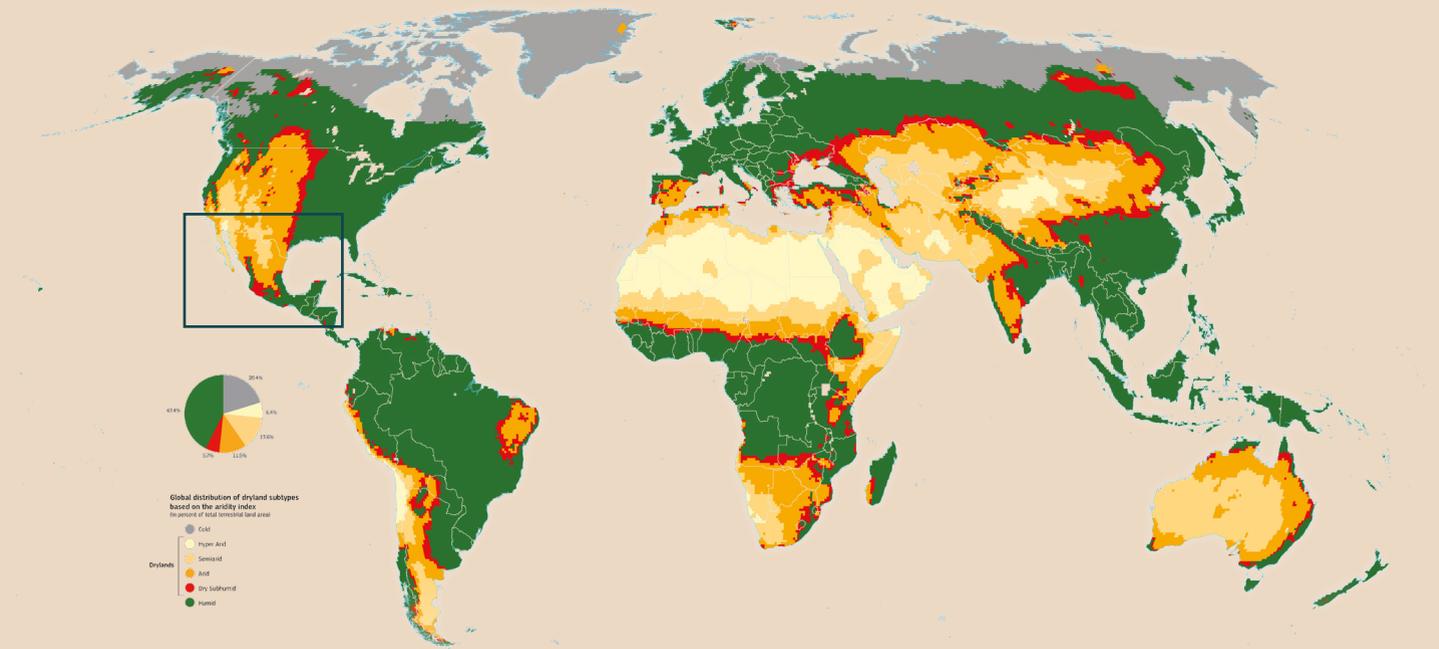
Relevance: a need for urban ecology design

The living planet index report an alarming 69% decline in wildlife populations worldwide.



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

Patterns of Aridity



Source: Global Precipitation Climatology Centre and potential evapotranspiration.

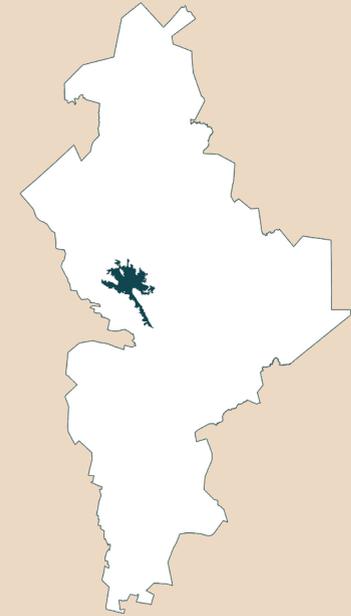
Research location



Continent: North America
Country: Mexico



Country: Mexico
State: Nuevo León



State: Nuevo León
City: Monterrey

Research location

Monterrey Metropolitan Area (MMA) , Mexico

Inhabitants MMA: 5.5 million

Altitude: 530m

Surface: 324,4km²



Hóltes, E.O. (2024). *View on the MMA from parque chipinque.*

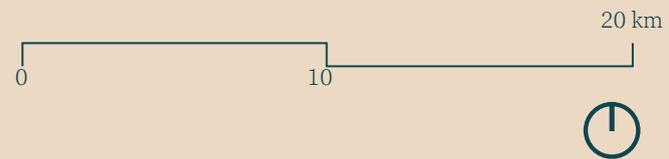
Research location



Holtes, E.O. (2024).

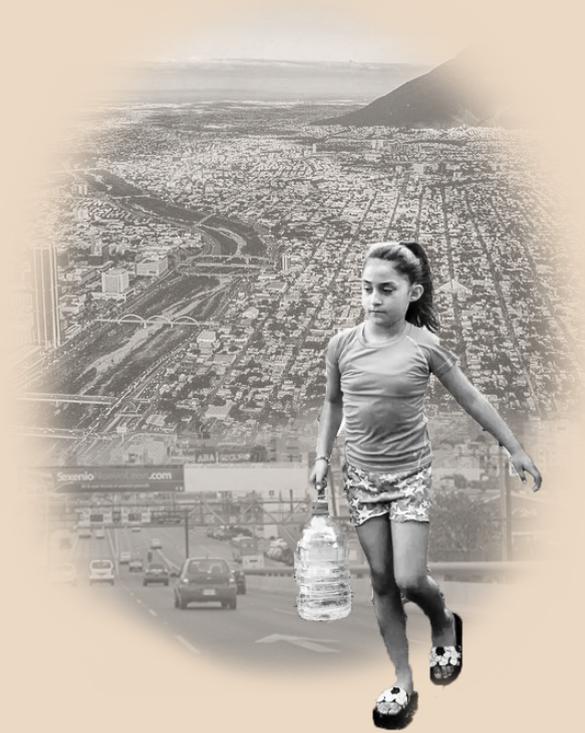
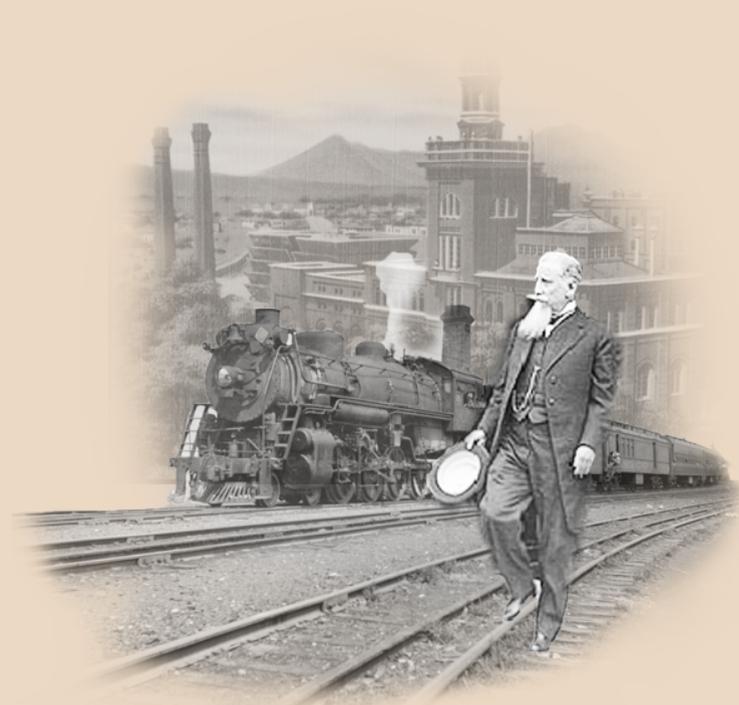
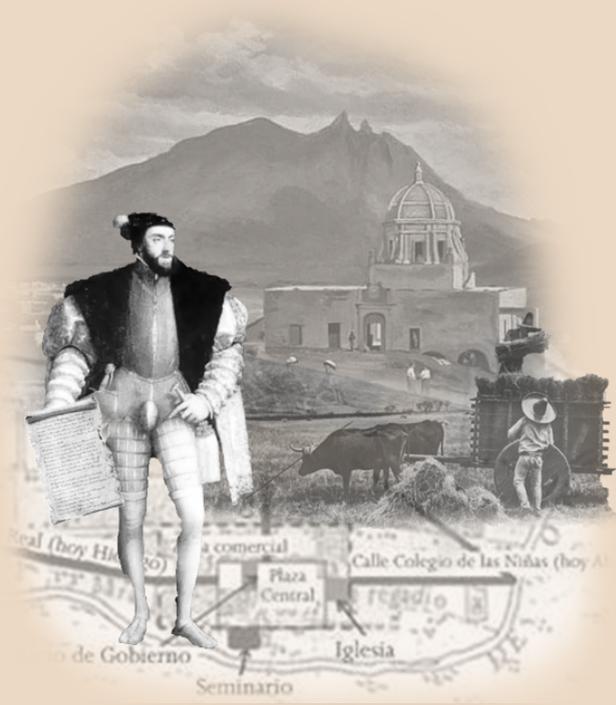


Holtes, E.O. (2024).



Map: Monterrey, Satallite map. GIS data: Satellite only by PDOK wms.

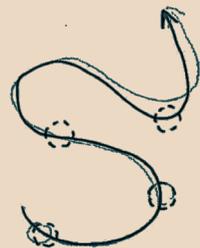
Landscape biography



NATURAL LANDSCAPE

“Pre-Columbian” era

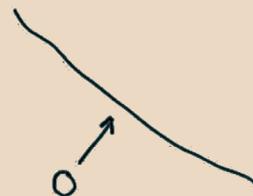
Nomadic and semi-nomadic tribes roamed through the land because of the limited resources in the desert like landscape.



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

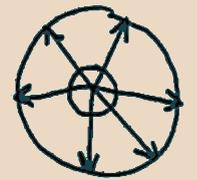
Rapid development of economy in the city because of the steel and beer industry. Connection with America through railways.



OVERUSED LANDSCAPE

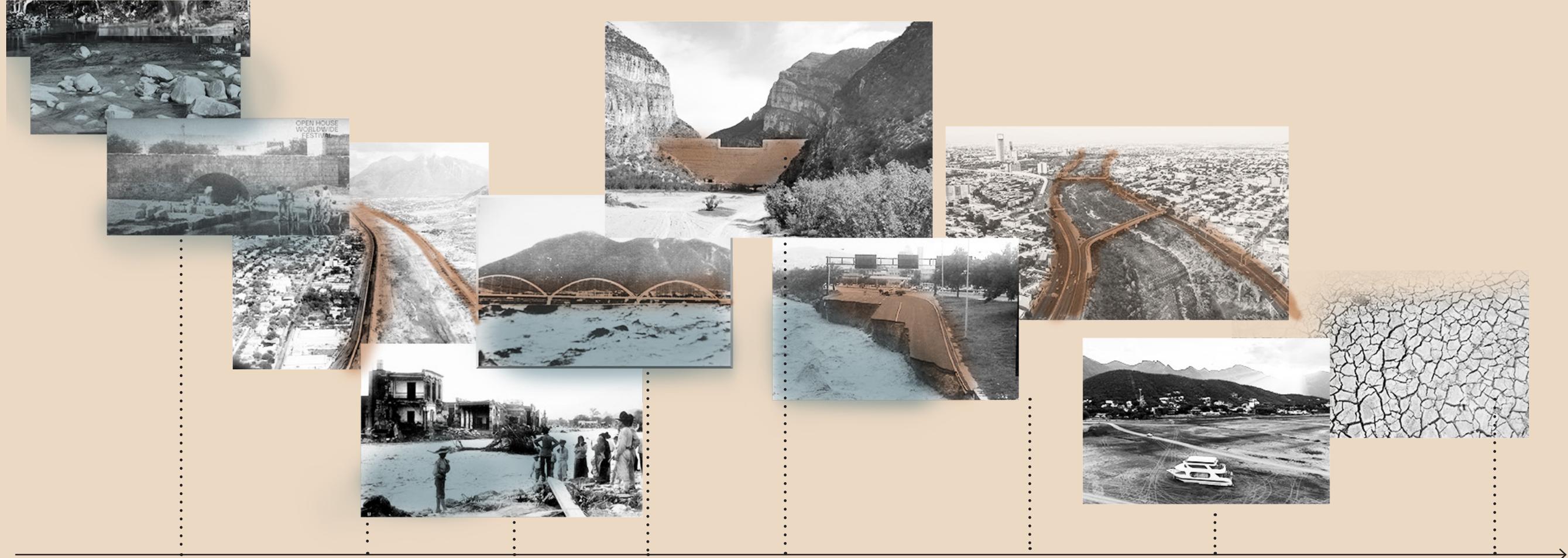
Today

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



The evolving relationship of water and society

■ Human interference 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

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/Presas-Rompepicos>, by Cesar Rodriguez

The natural river ecosystem



Degradation of the river ecosystem

Modified riverbank



Holtes, E.O.

Degradation of the river ecosystem

Garbage dumps



Holtes, E.O.

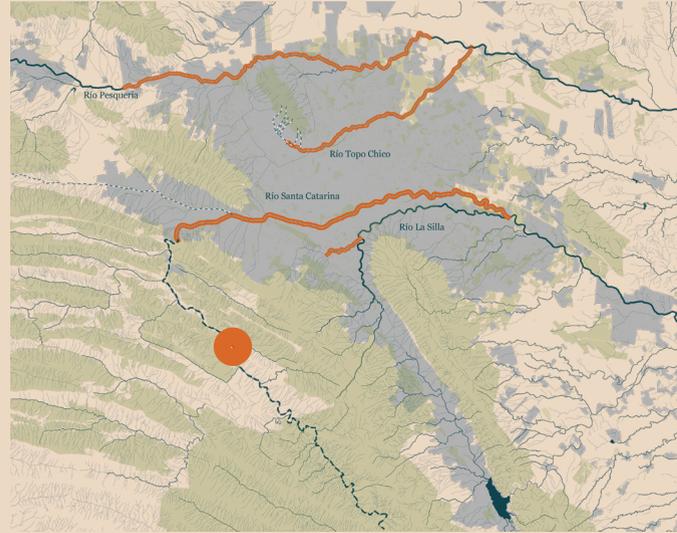
Degradation of the river ecosystem

Six-lane roads at the edge of the river



Holtes, E.O.

The Rompepicos dam



During a hurricane



During regular conditions



Photoshop based on a photo by unkown. Dam during a hurricane.

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

Degradation of the river ecosystem



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



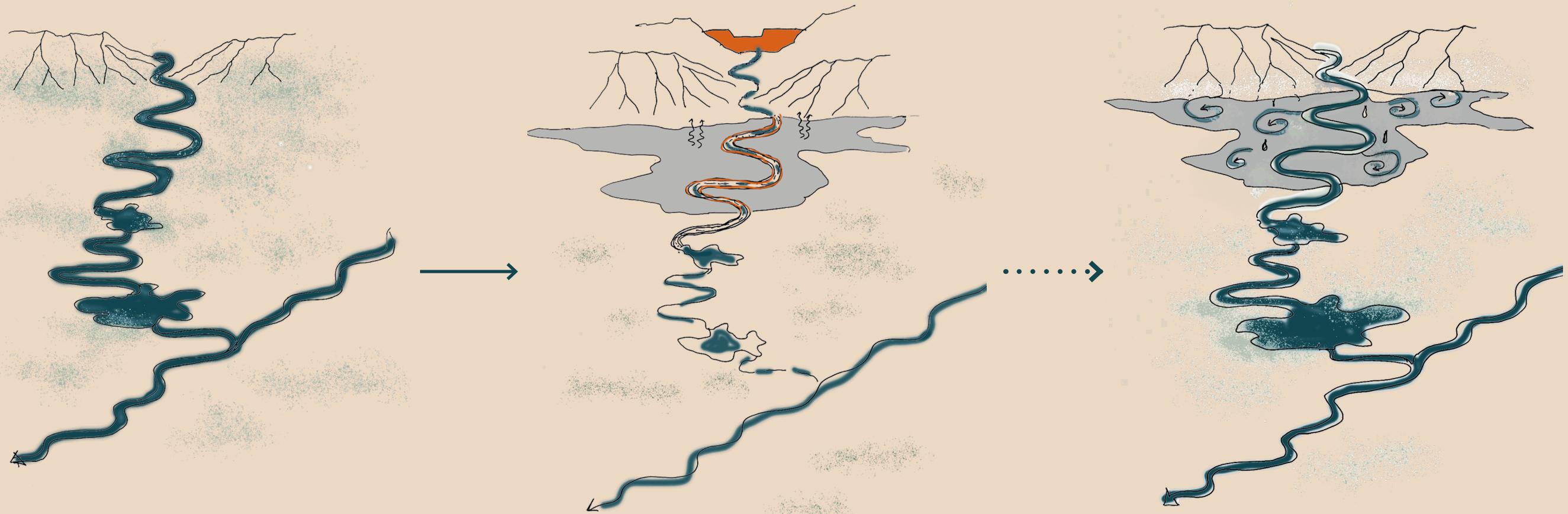
Anuncia, S. *Rompepicos dam* [photo]. Monterrey.



-  Green spaces (forest, shrubland, national parks)
-  Urban area
-  Rivers
-  Streams
-  Modified riverbanks
-  Dam

River degradation in Monterrey. GIS data: Inegi.

Research goal: restoring the river ecosystem



Before

Now

Future

NATURAL LANDSCAPE

OVERUSED LANDSCAPE

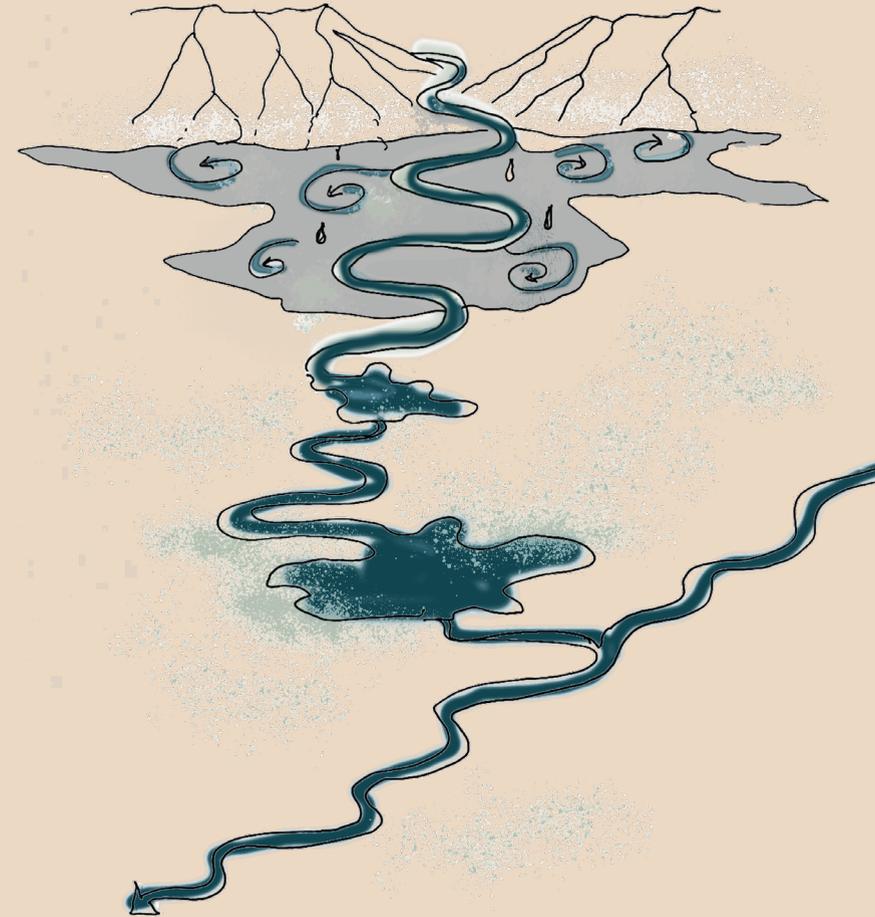
SYMBIOTIC LANDSCAPE

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

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

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.

Research question



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

2

Analysis



Ecosystem level analysis

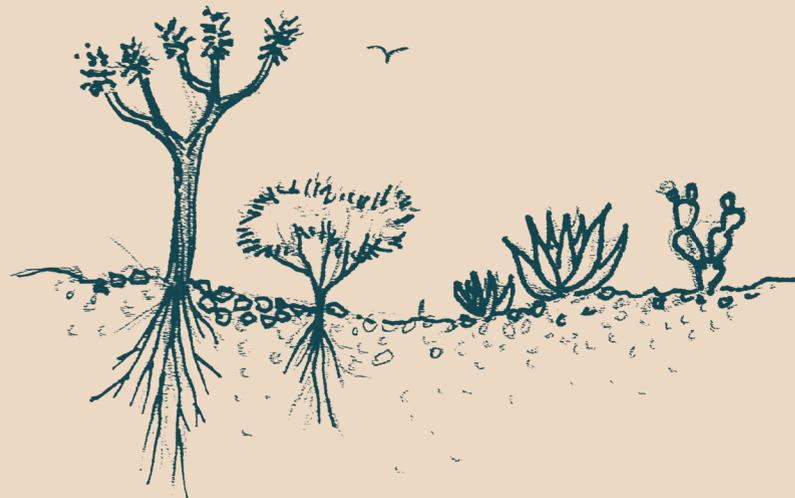
Habitat level analysis

Species level analysis

The Urban Ecology Design Approach

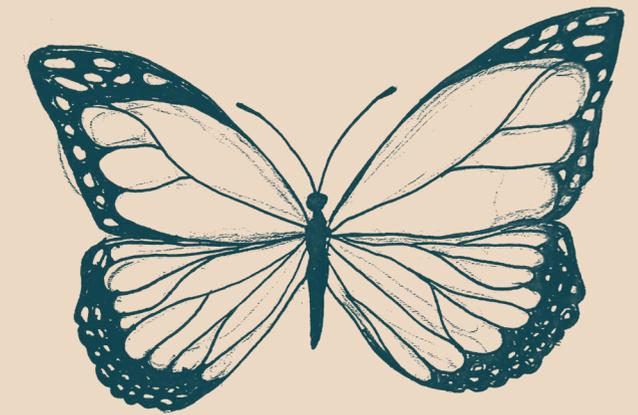


Urban ecosystem level



Urban habitat level

The human and non-human habitat:
the built environment and natural areas



Species level

Urban Ecology Design MOOC

TU Delft FIND COURSES LEARNING ONLINE FOR BUSINESS HELP & SUPPORT LOGIN Search...

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About this online course

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ENROLL ON EDX edX

<https://online-learning.tudelft.nl/courses/urban-ecology-design/>



Video recordings at the media center of Tecnológico de Monterrey photo by Ana Gabriela Perez Cantu.

The Urban Ecosystem level

Analysis of the ecosystem on the regional scale



Topography, elevation and geomorphology



Folds of the Sierra Madre Oriental: fan folding and vertically positioned layers of soil above ground.



Holtes, E.O. (2024).

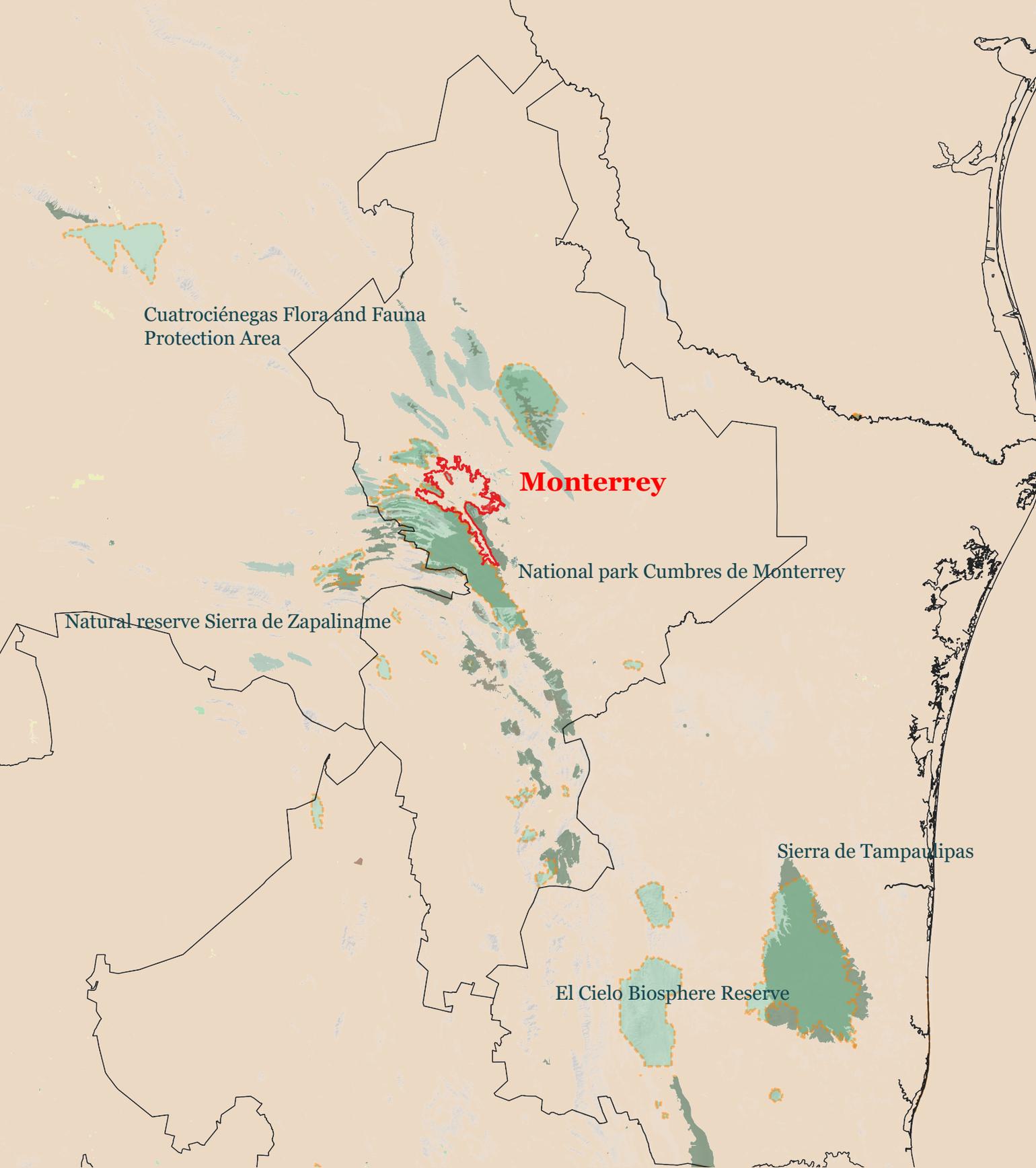


Holtes, E.O. (2024).

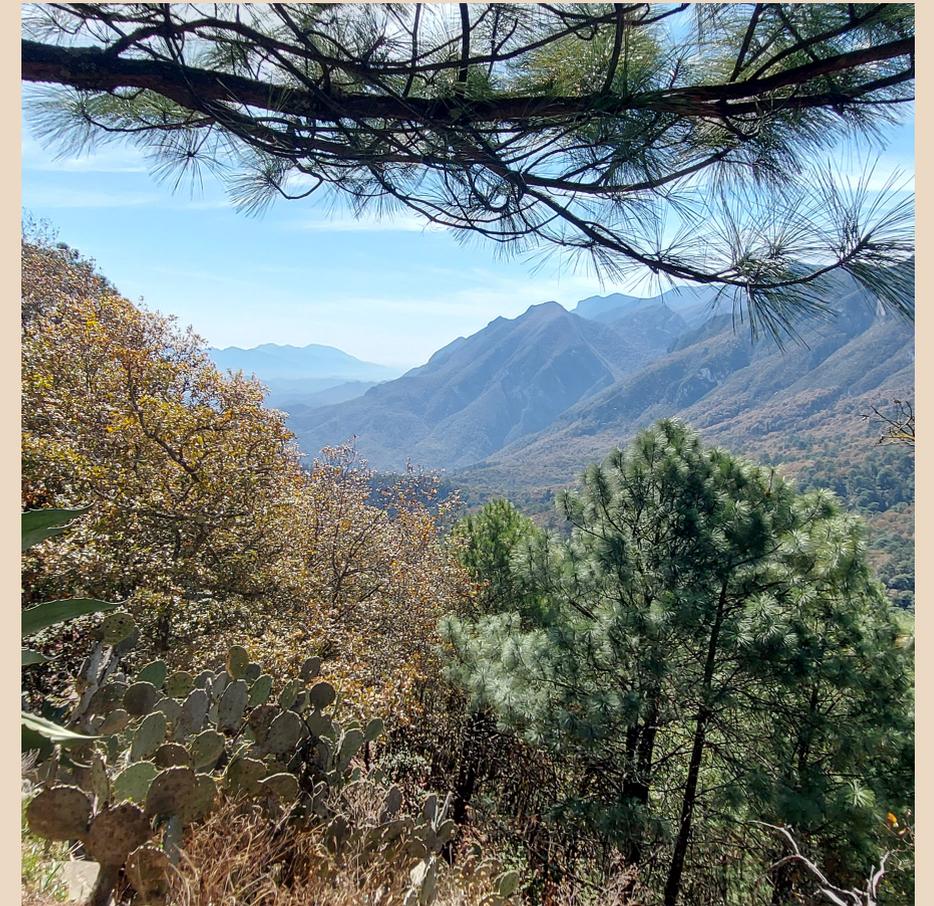


Nuevo León. Topography and elevation. GIS data: Inegi, Google maps.

Natural reserves and vegetation



National park de Cumbres de Monterrey



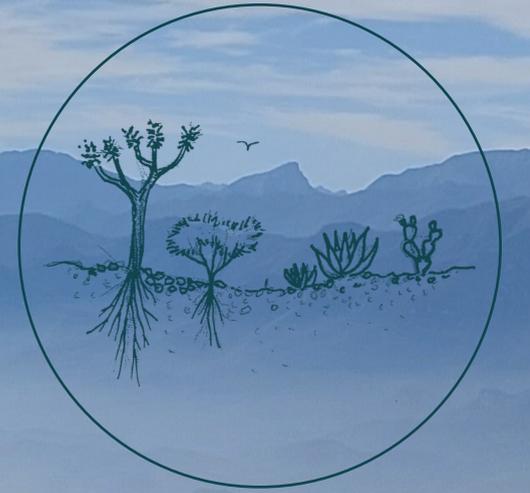
Holtes, E.O. (2024).



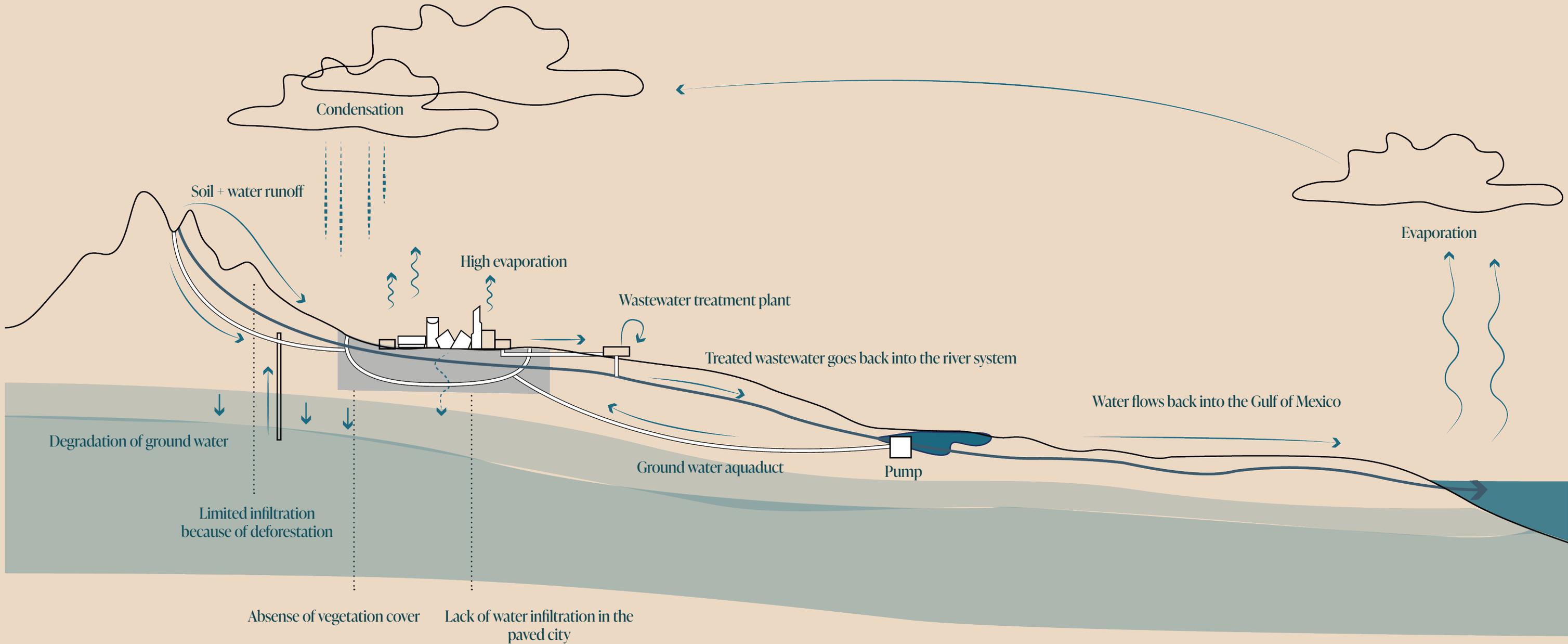
Natural reserves and vegetation of the region. Gis data: Inegi

The (Urban) Habitat level

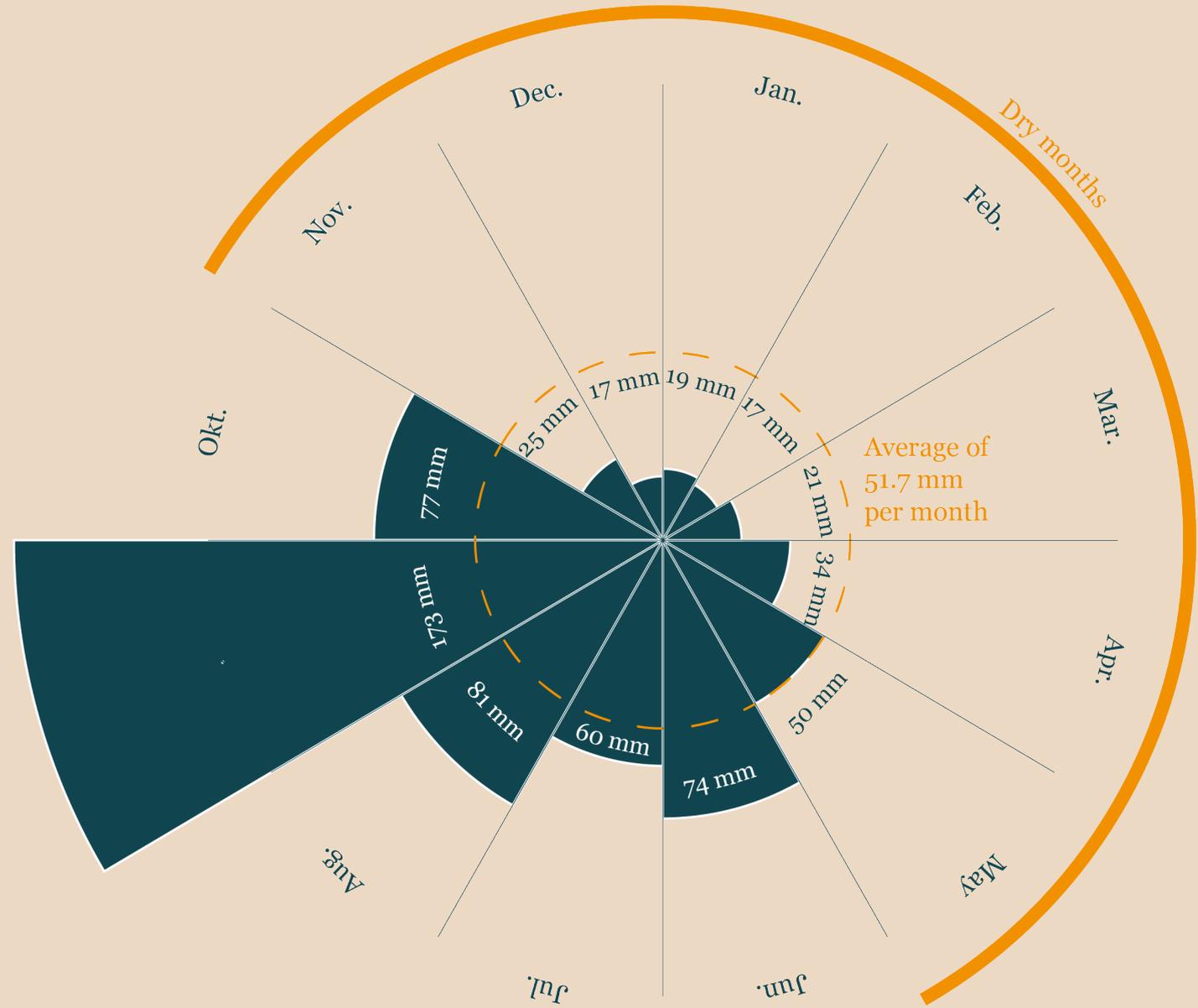
Analysis of the human and non-human habitats



Water system



Yearly rainfall



Yearly rainfall in MMA. Based on data from Conagua.

Species level
Analysis of the species per ecoregion



Ecoregions

Chihuahuan desert



Fewings, N. Chihuahuan desert. On Unsplash.

Sierra Madre Oriental pine-oak forest



Sierra Madre Oriental pine-oak forest.

Tamaulipan matorral



Tamaulipan matorral.

Tamaulipan mezquital



Tamaulipan mezquital.

3

Design



River vision

Upstream design elaboration

Midstream design elaboration

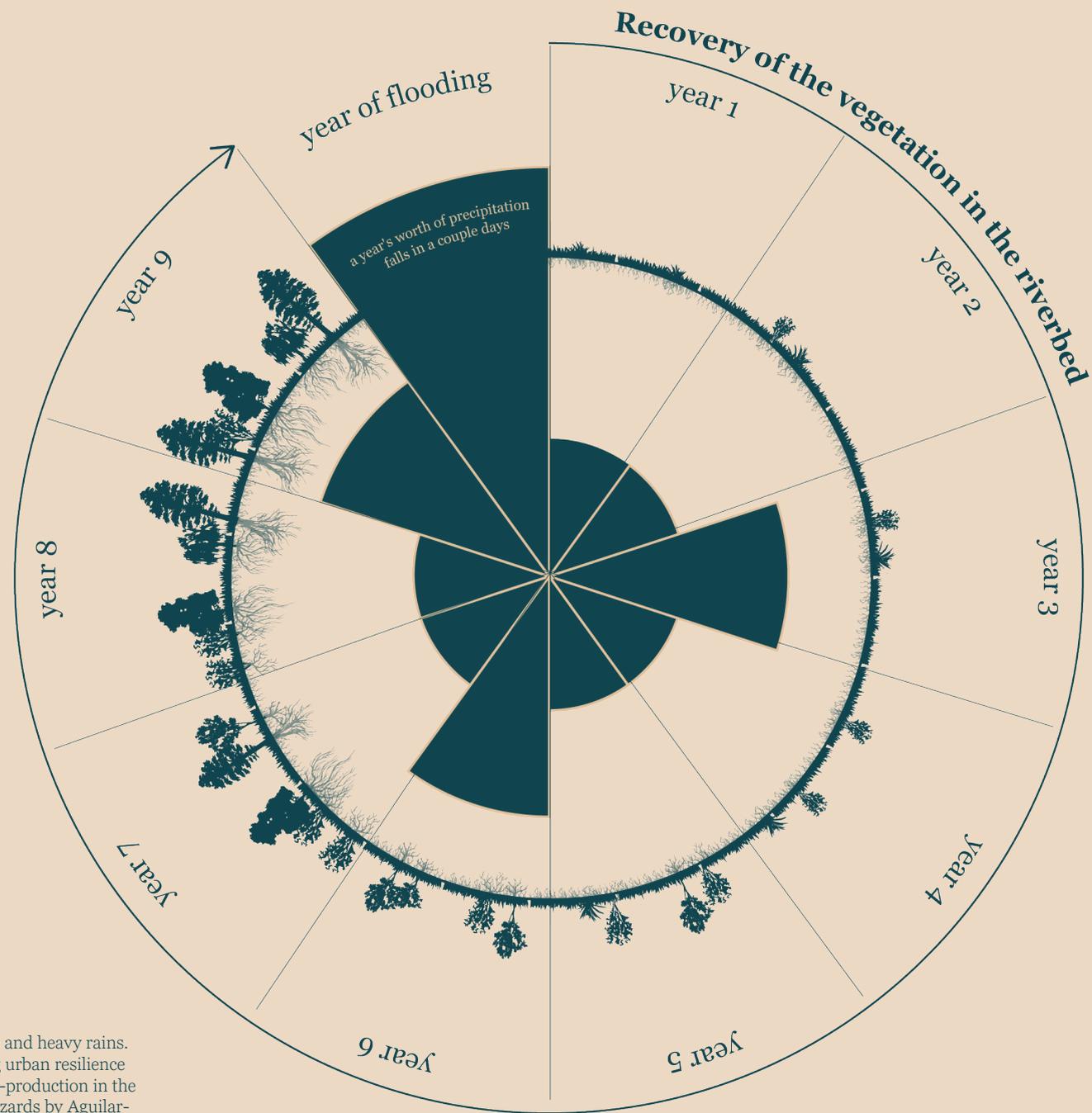
Downstream design elaboration

Río Santa Catarina



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

Occasional heavy rains and hurricanes

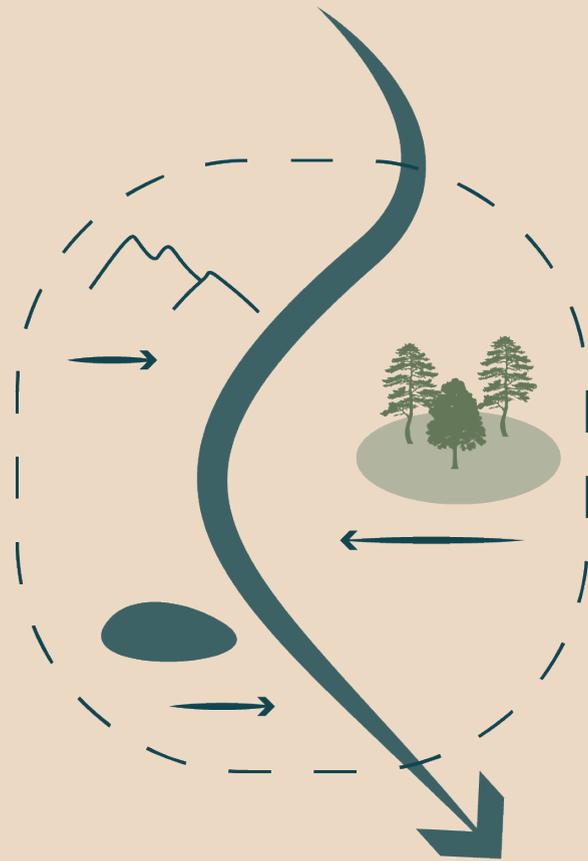


Cycle of hurricane and heavy rains. Based on Building urban resilience and knowledge co-production in the face of weather hazards by Aguilar-Barajas, I., Sisto, N. P., Ramirez, A. I., & Magaña-Rueda, V. (2019).

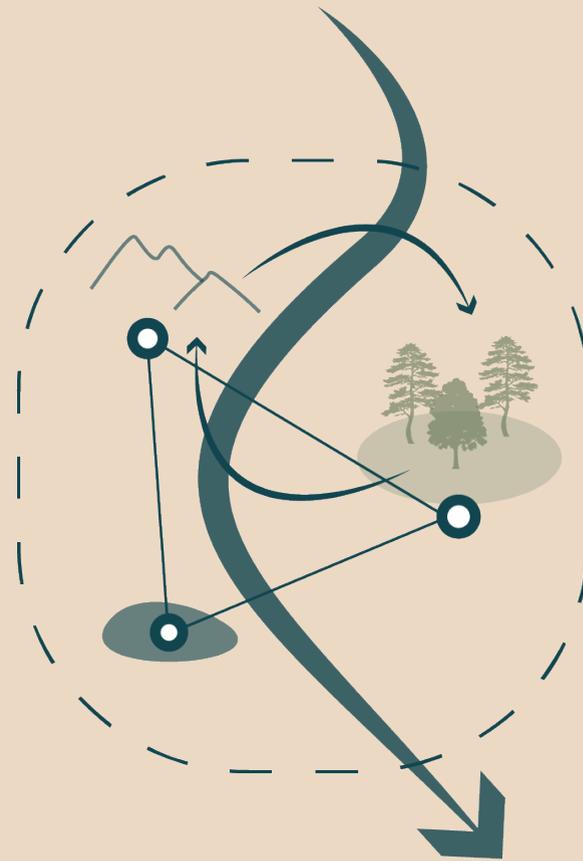


Impact of storm Alberto. Photo by Rob Roggema, June 20, 2024.

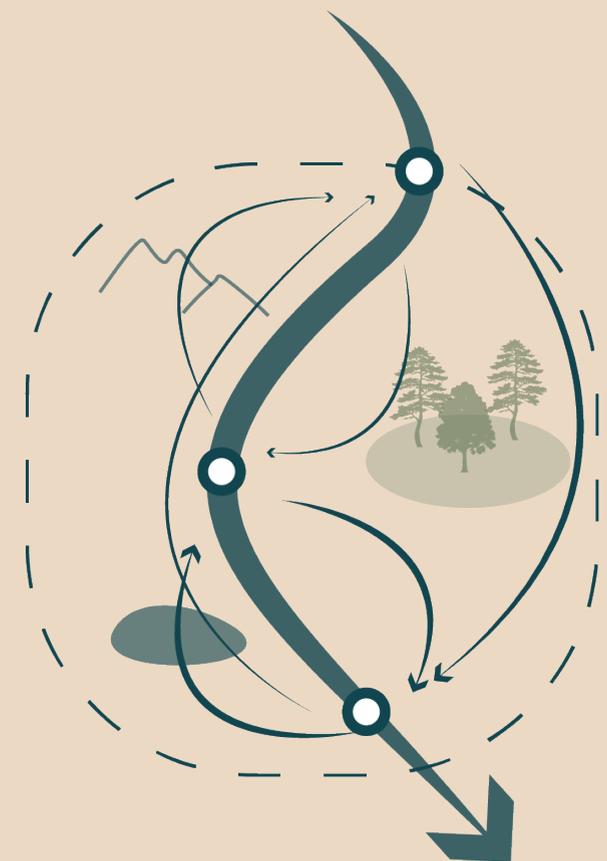
The watershed approach



1. The watershed



2. The watershed as interconnected system



3. Upstream, midstream and downstream effect

Illustrations based on the theory of 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.

The watershed of the Río Bravo



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

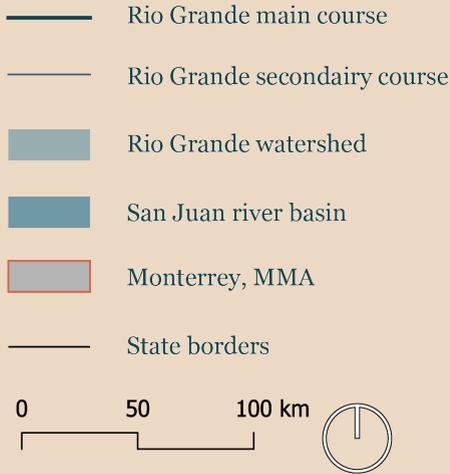
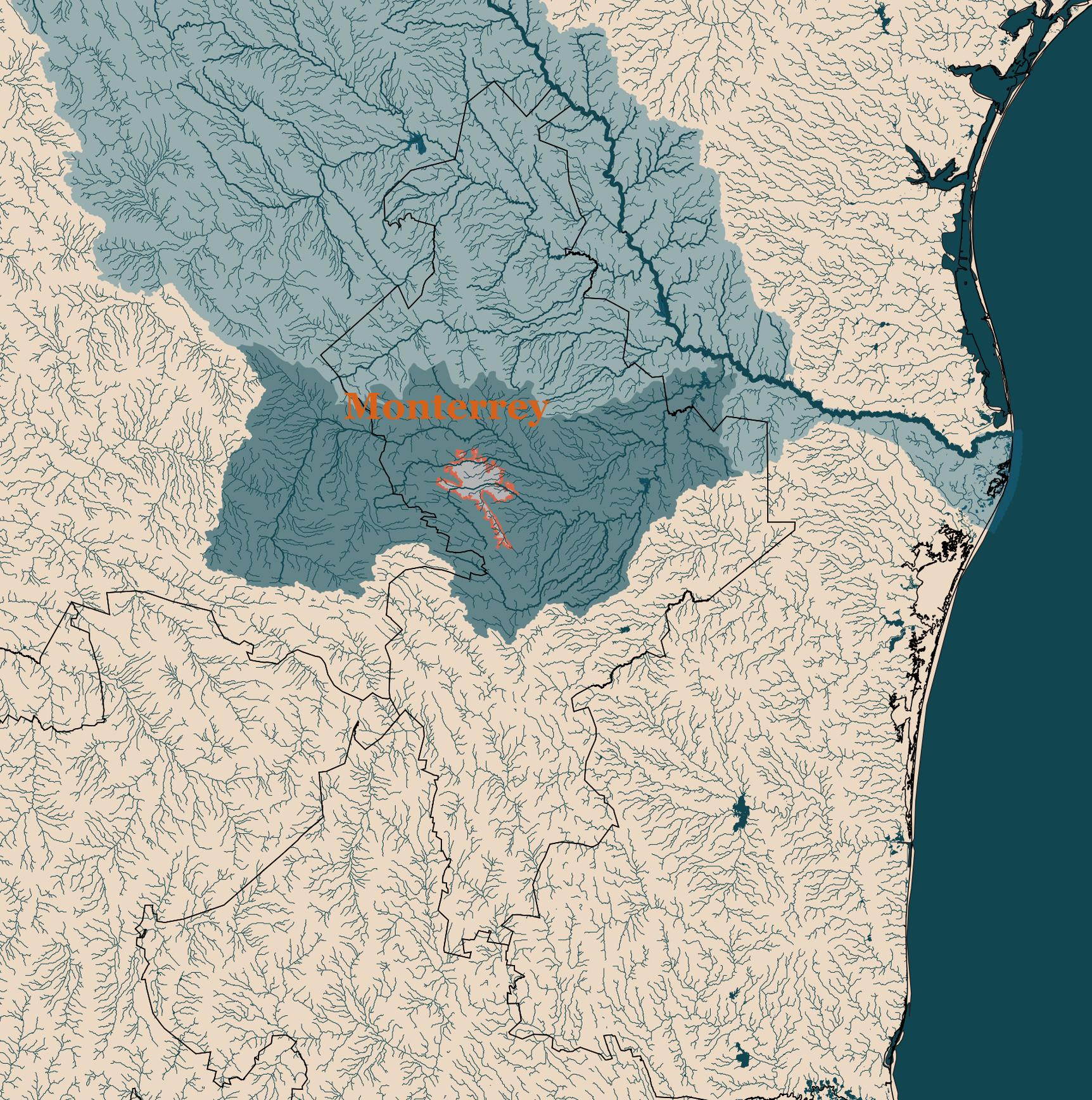


Río Grande by Erich Schlegel.

- Rio Grande main course
- Rio Grande secondary course
- Rio Grande watershed
- San Juan river basin
- State borders

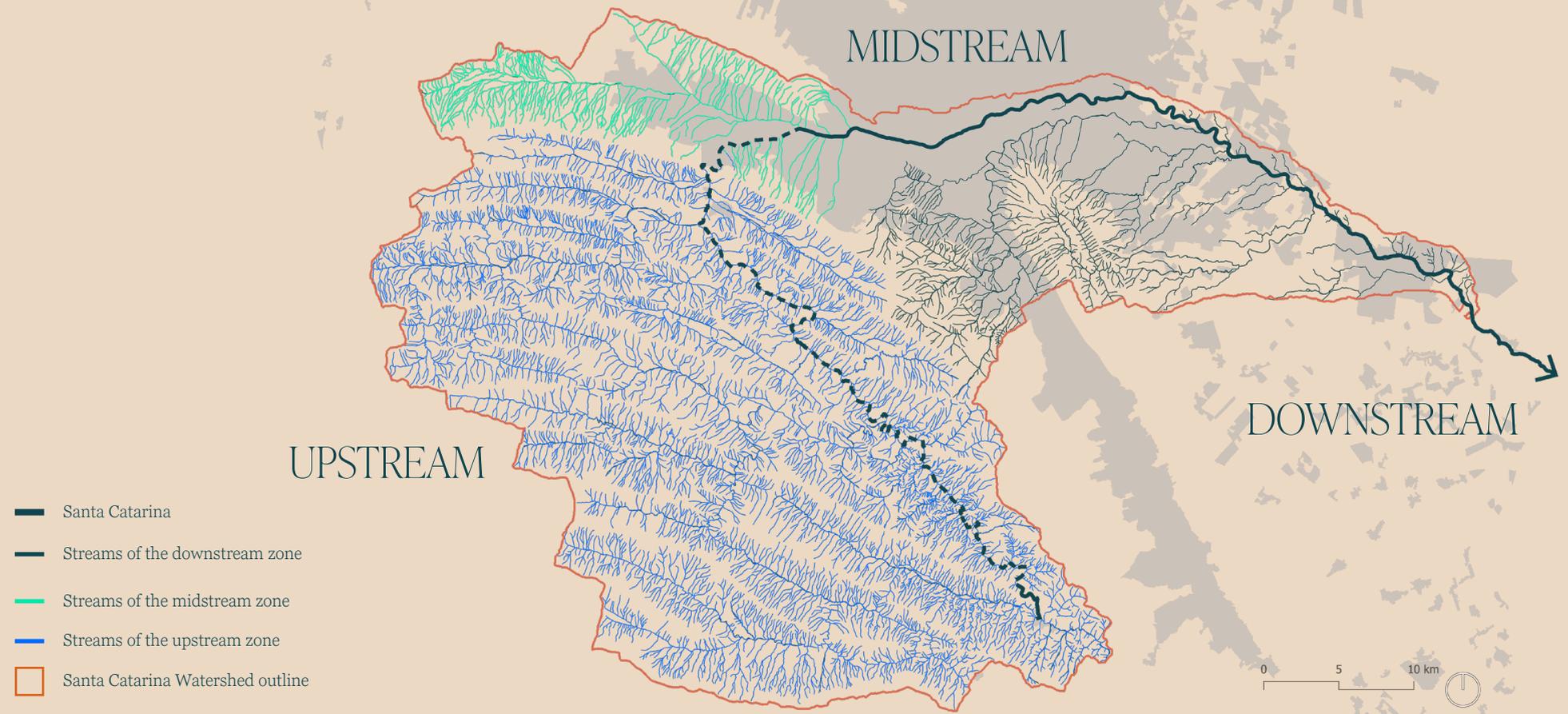
The Río Grande Watershed and its rivers. GIS data: Arcgis.

The Río Bravo-San Juan watershed

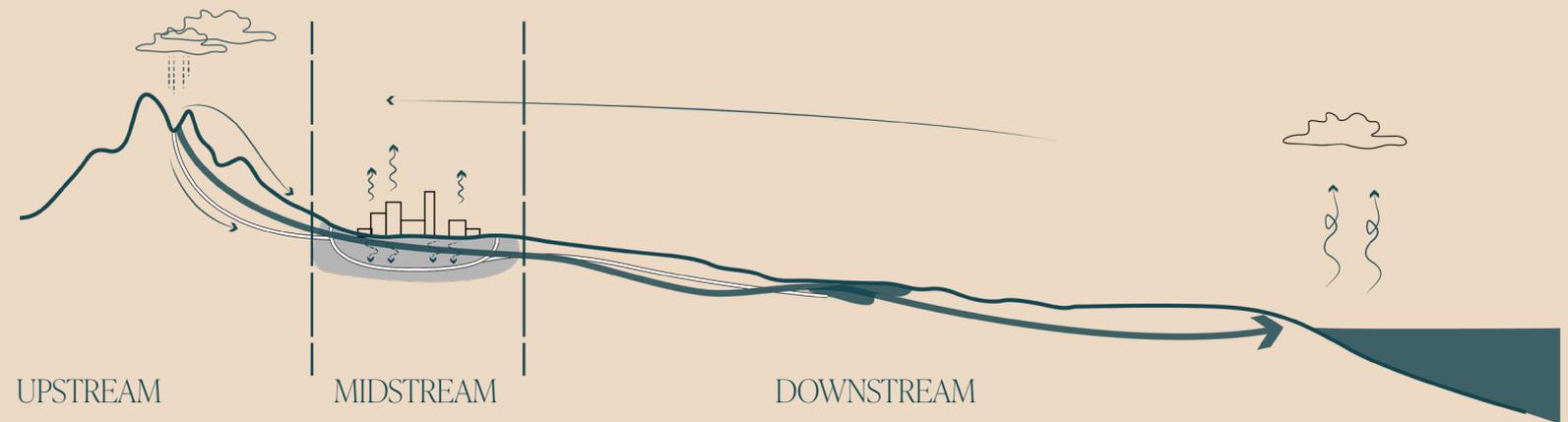


The Río Grande and San Juan watershed and rivers.GIS data: Inegi.

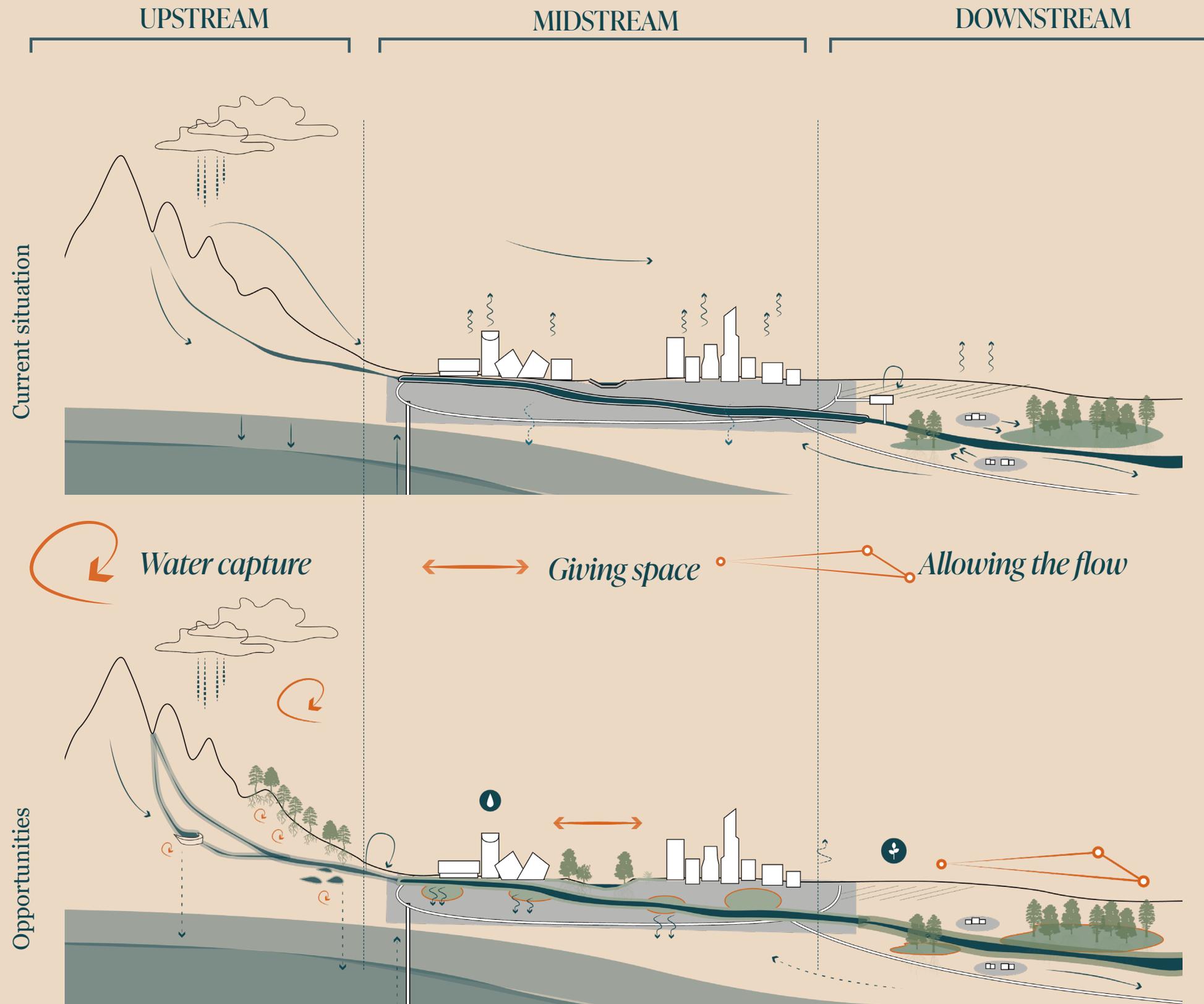
Watershed of the Santa Catarina



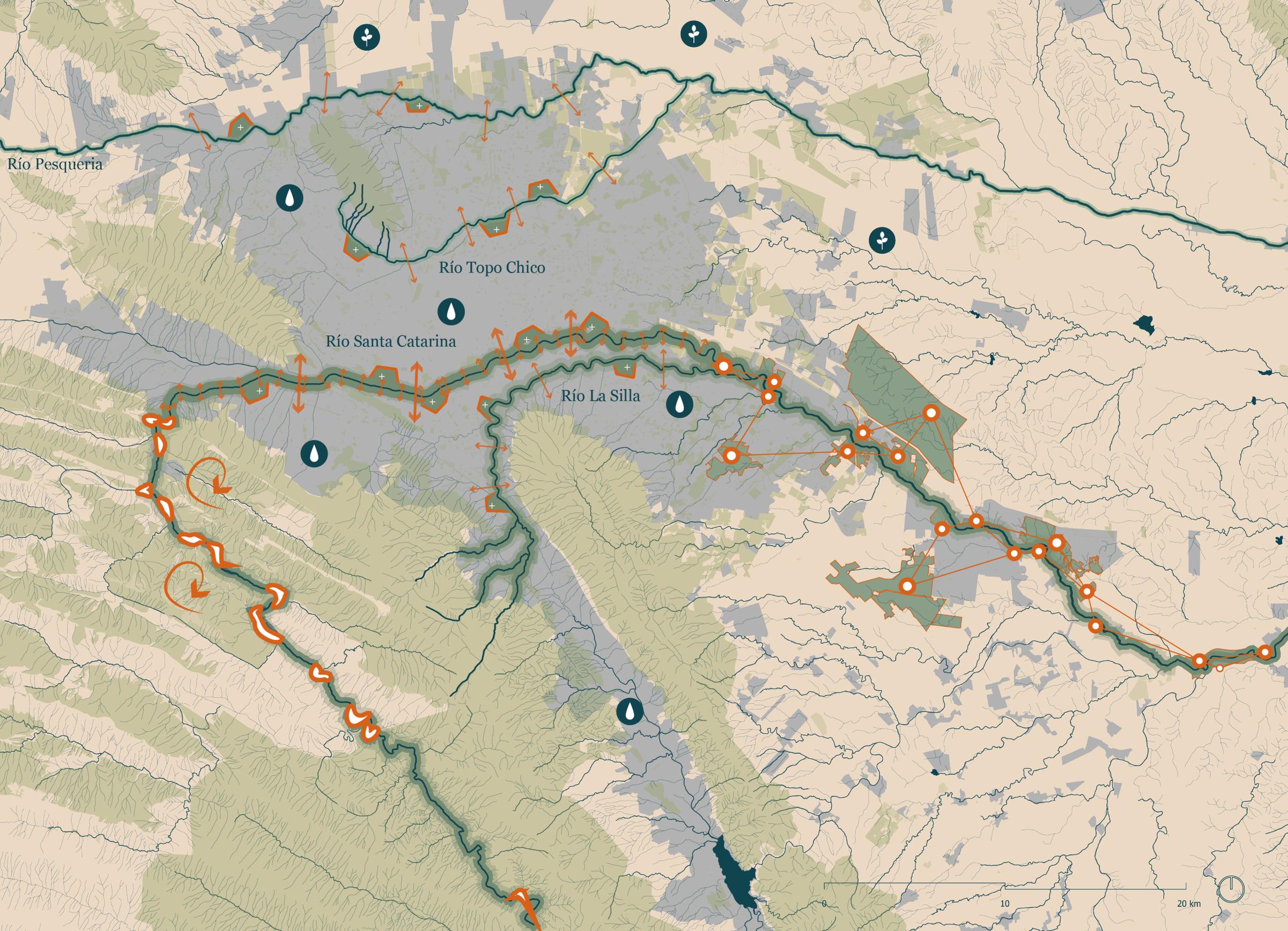
- Santa Catarina
- Streams of the downstream zone
- Streams of the midstream zone
- Streams of the upstream zone
- Santa Catarina Watershed outline



Opportunities



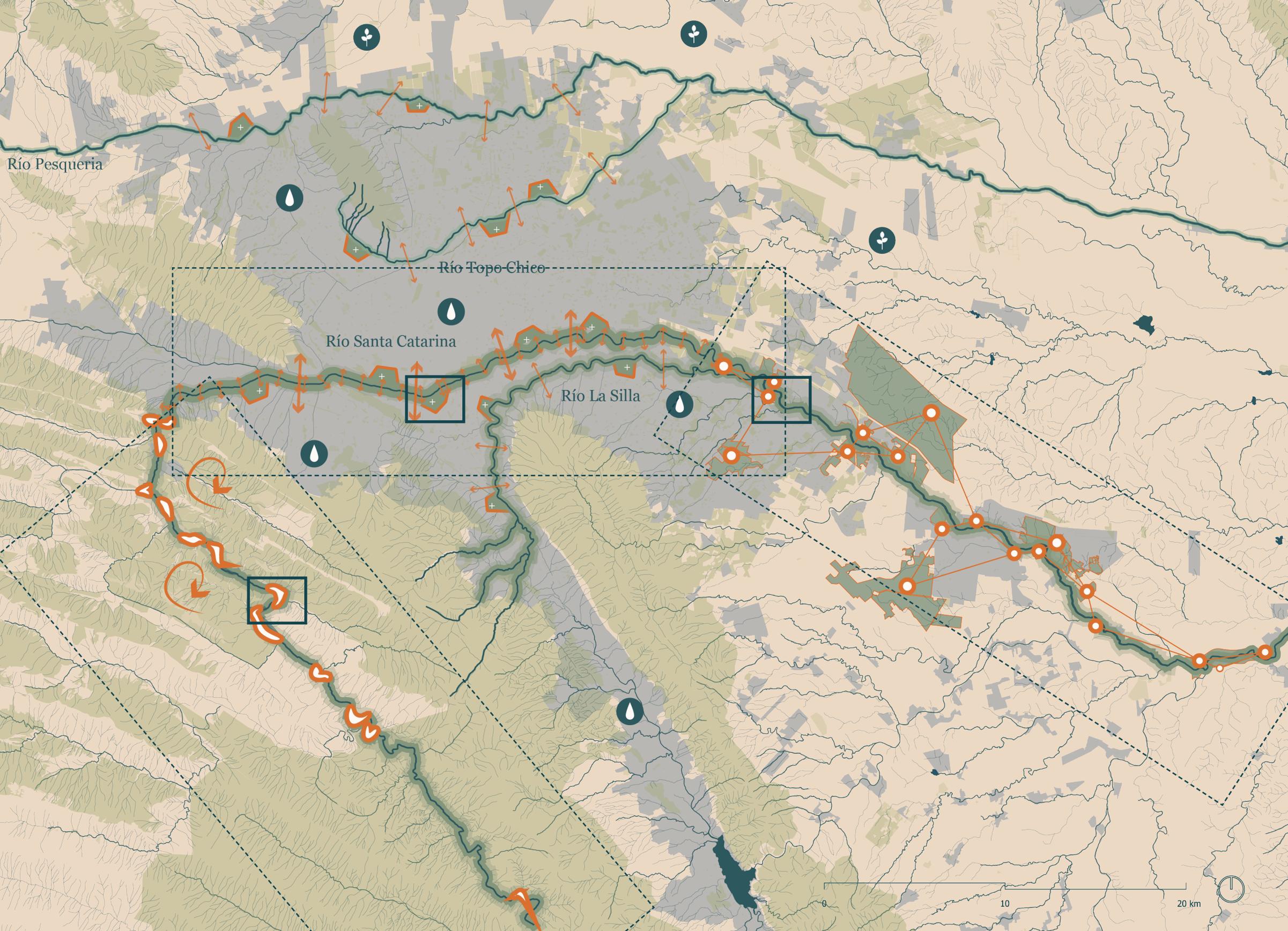
The river vision



- 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

Vision for the rivers in MMA.

The river vision

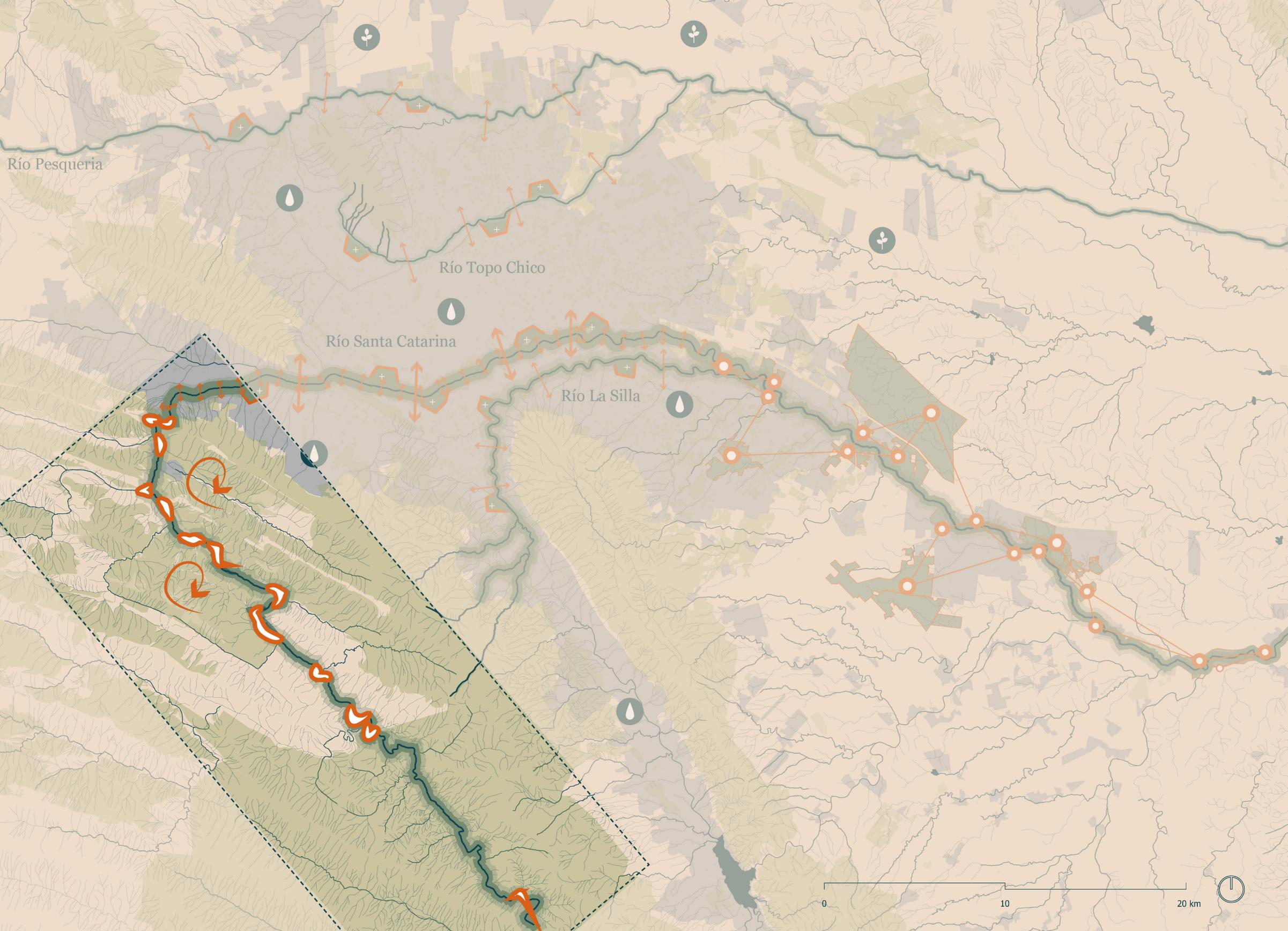


-  water saving agriculture
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-  new green public spaces (habitats) along the river
-  river with wide, natural riverprofile
-  stream
-  protected river forests
-  green spaces
-  urban area
-  water body

Vision for the rivers in MMA.

The upstream zone

Water capture



- 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
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- green spaces
- urban area
- water body

The upstream zone

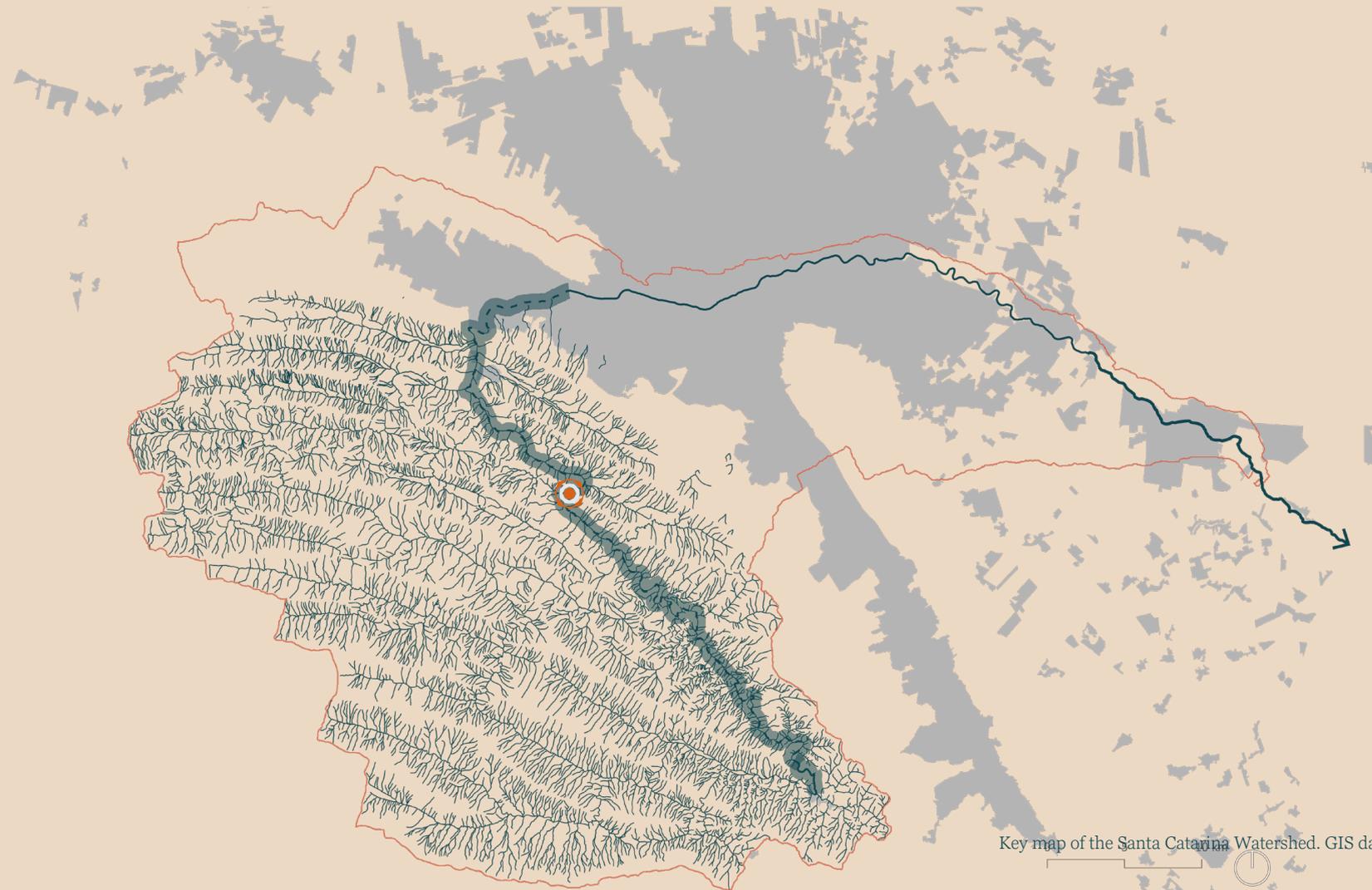


Holtes, E.O. In the dry riverbed of the Santa Catarina River.

Upstream conditions



Anuncia, S. Rompepicos dam[photo]. Monterrey.

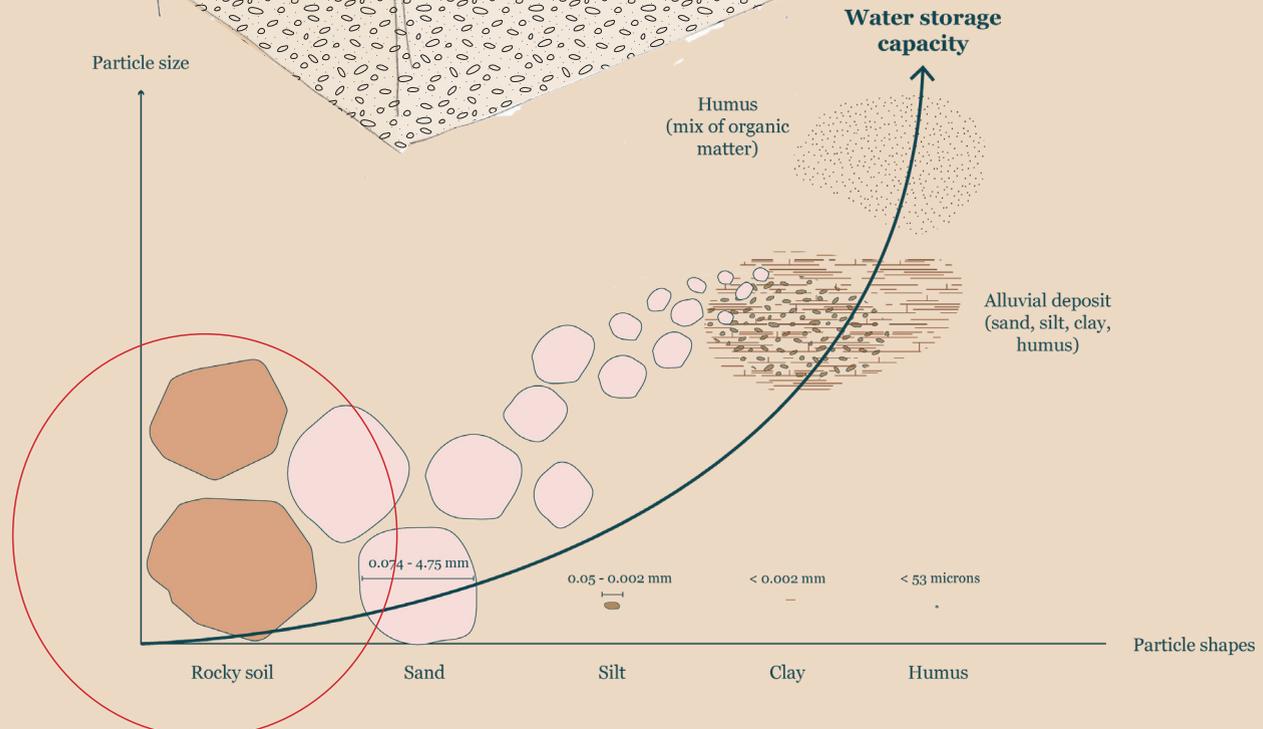
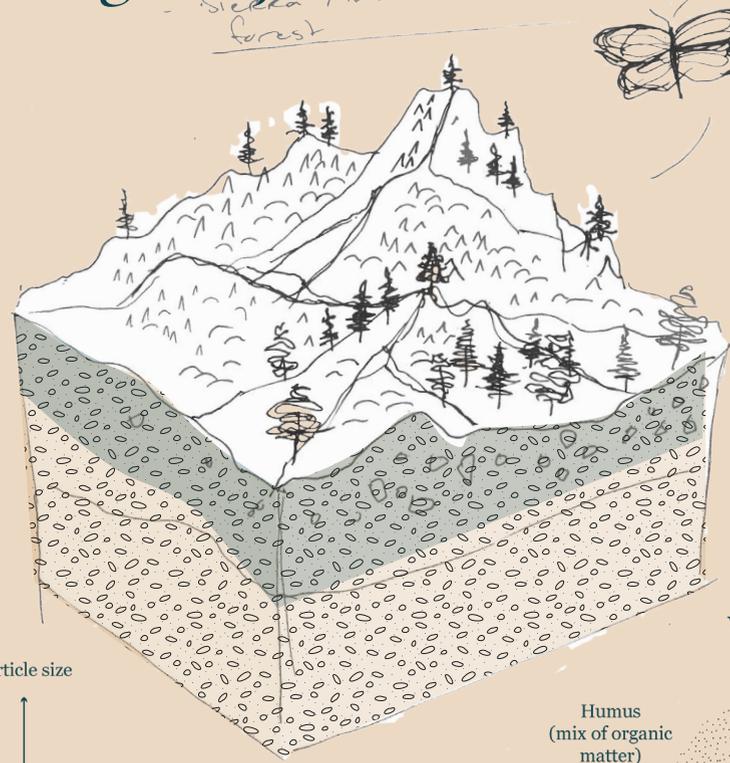
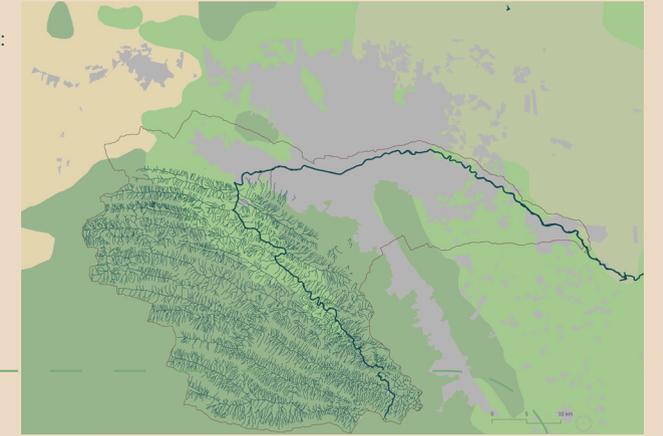


Key map of the Santa Catarina Watershed. GIS data: Inegi, SIATL

Upstream conditions

The ecoregion of the Sierra Madre Oriental Pine-Oak forest

The ecoregions of the MMA and the watershed of the Santa Catarina. GIS data: Inegi, SIATL



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>



Culbert, D. *Quercus castanea* [Photo].



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



Harlick, B. *White nosed coati* [Photo].



Ramsey, D. *Monarch butterfly* [Photo].



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



cogdogblog on Flickr. Name unknown. *Alligator juniper* [photo].

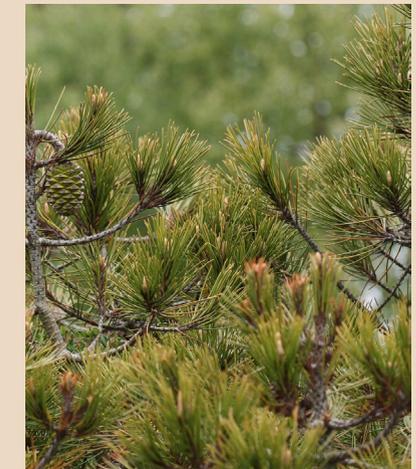


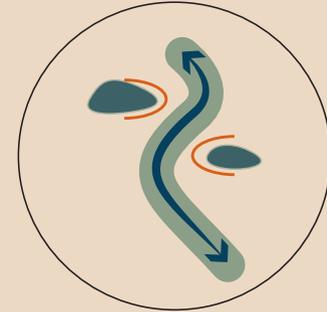
Image credit: Creative Commons. Name unknown. *Nelson's pine* [Photo].

Design interventions upstream

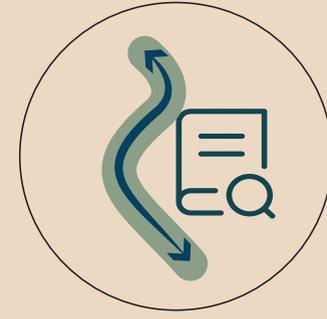
Water capture



Reforestation
to keep the water in the soil
+
reduction of landslides

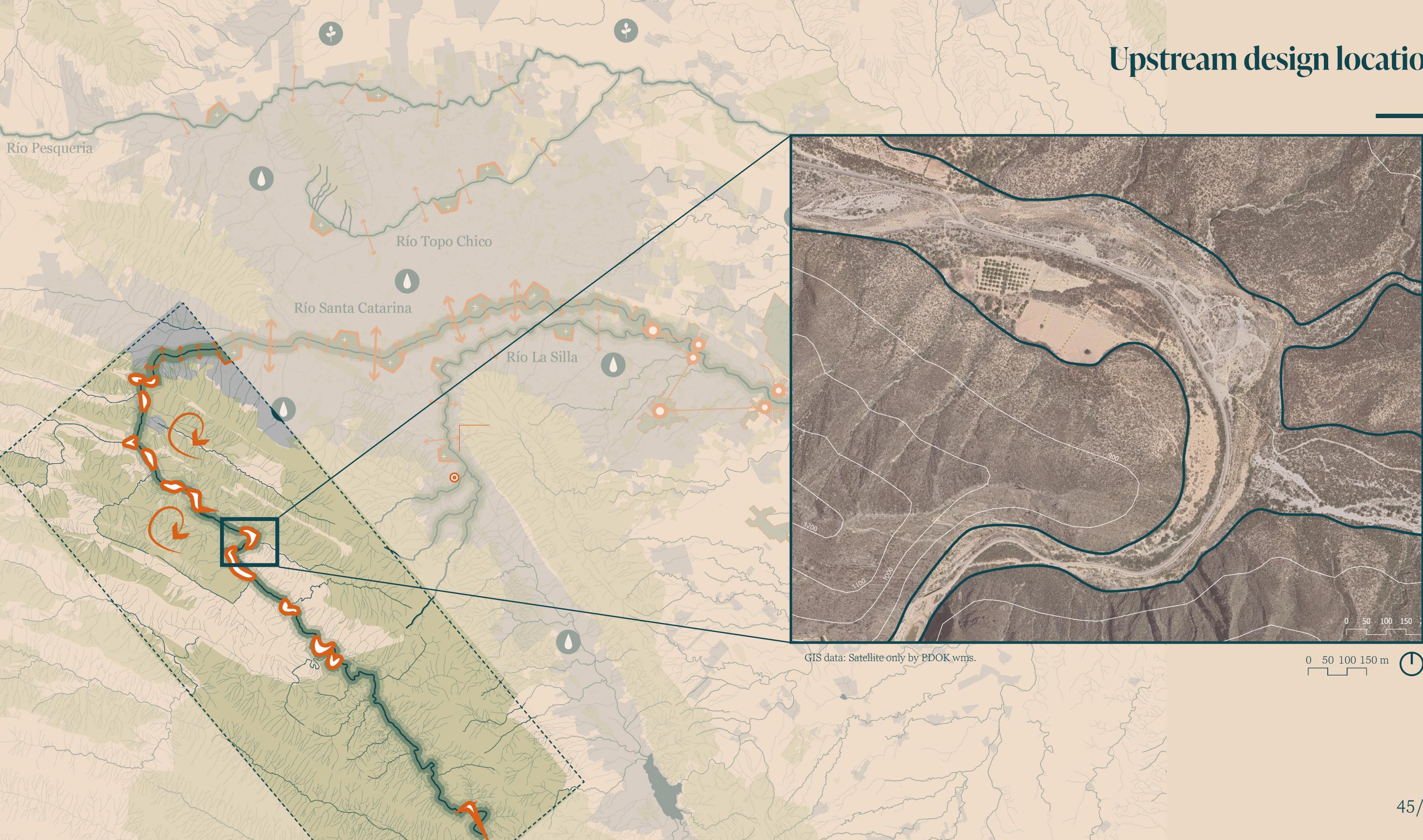


Water catchment and
retention



River ecology education

Upstream design location



GIS data: Satellite only by PDOK wms.

0 50 100 150 m

Upstream design location

Analysis of the current situation



GIS data: Satellite only by PDOK wms.

Vegetation



Vegetation analysis map. Based on Google maps.

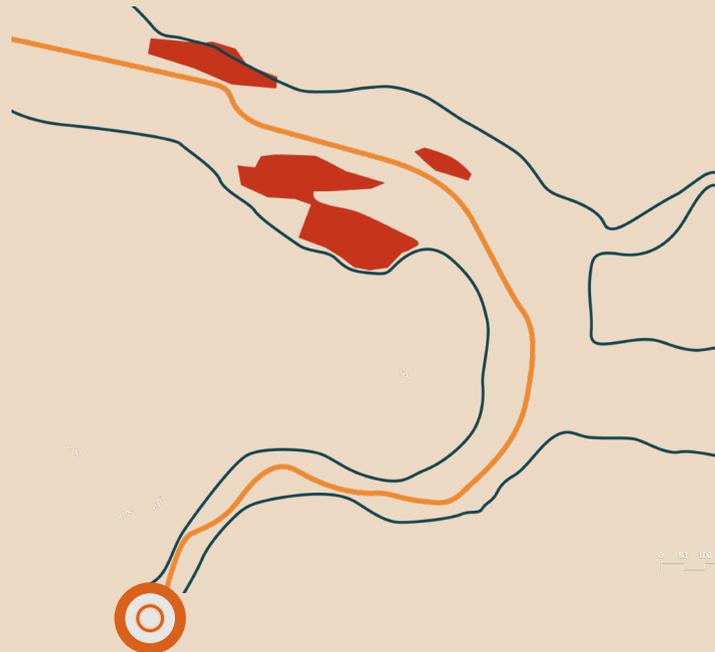


Shrub vegetation. Screenshot taken from Google maps.



- shrub vegetation
- illegal settlements
- road
- riverbed
- dam Rompepicos

Human activity



Human activity analysis map. Based on Google maps.



Illegal settlements and agriculture

Human activity in the Upstream zone

Settlements in the riverbed of the Santa Catarina



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

Upstream

Creating a safe living environment



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

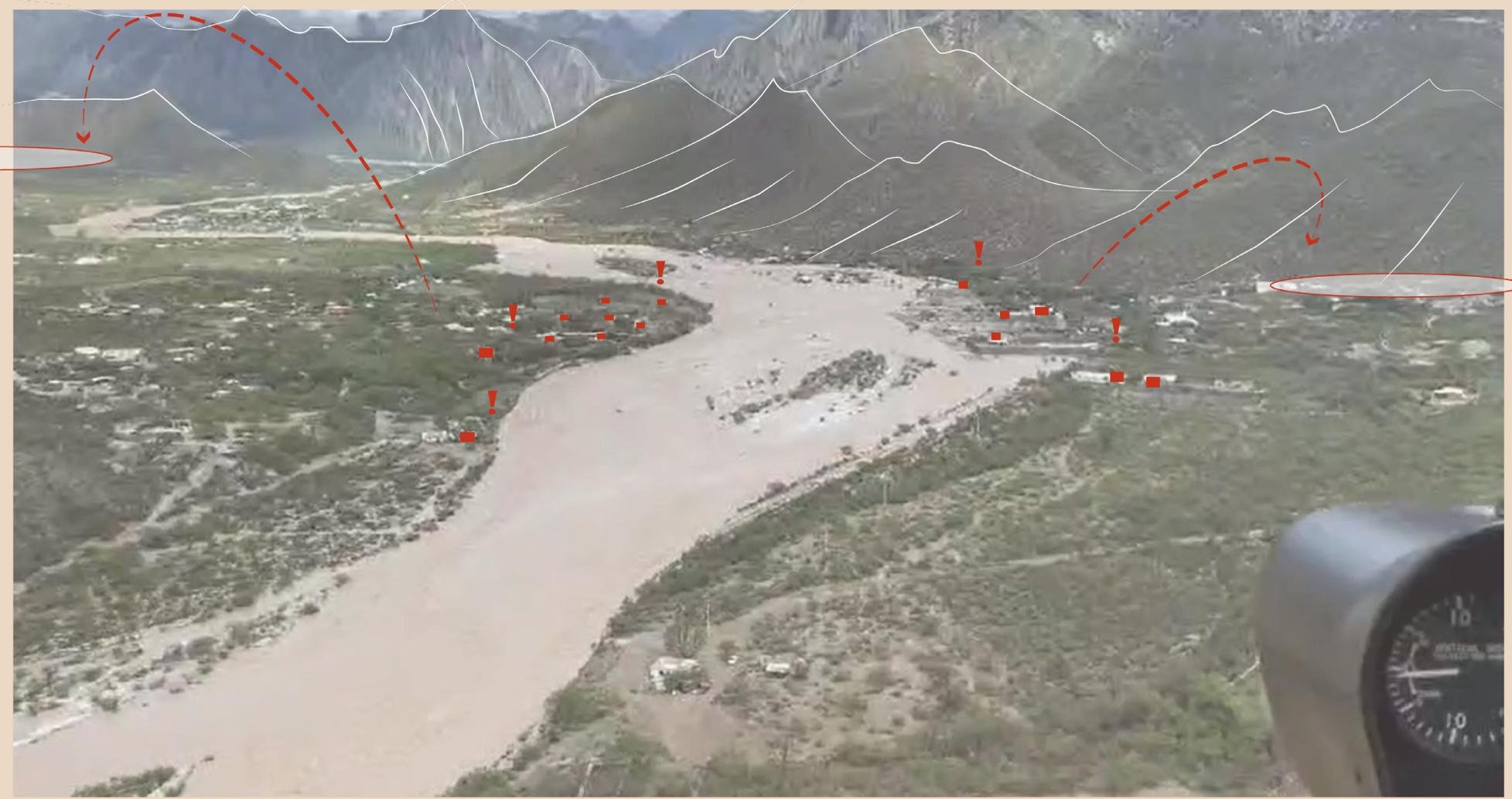


Illustration based on screenshots of a film by Enrique Guadarrama. June 20, 2024.

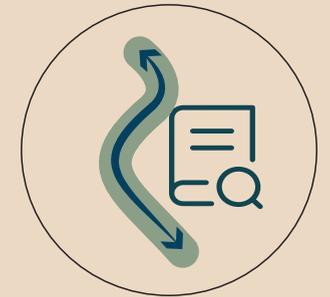
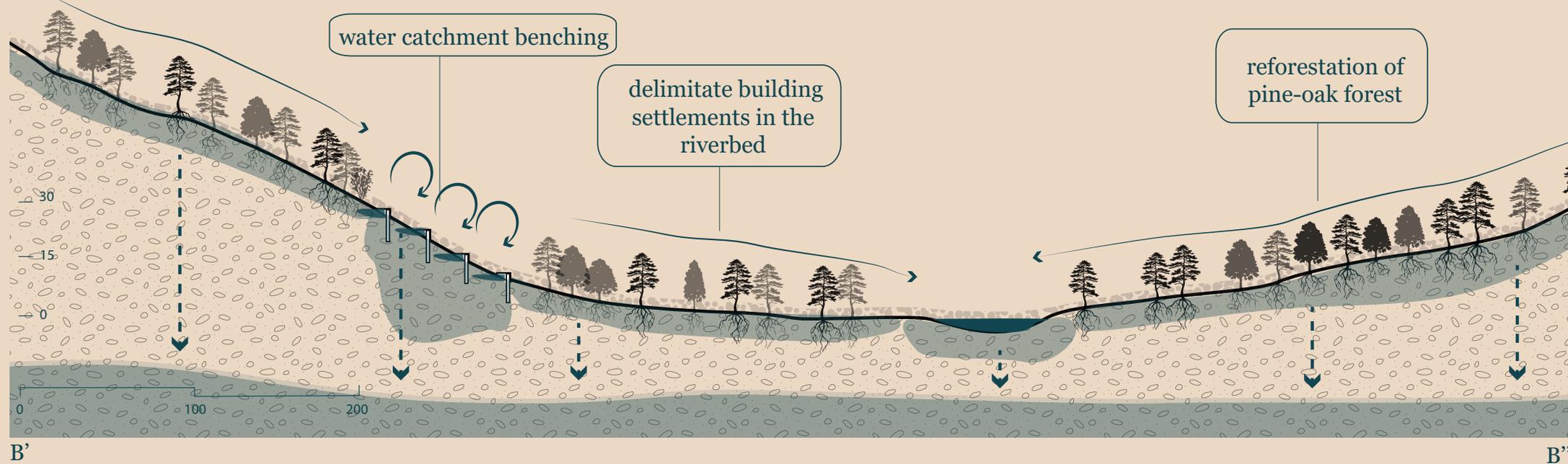
Upstream design elaboration

Capturing the water via reforestation and benching method

Current situation

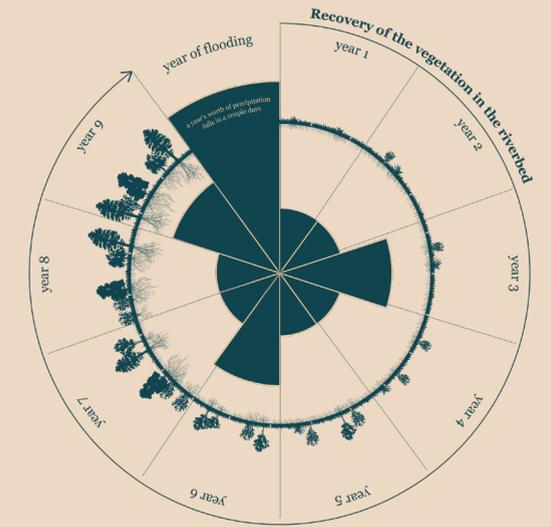


Implementation of interventions



Upstream design through time

The different hydrological circumstances



Regular conditions

Heavy rains

Hurricane



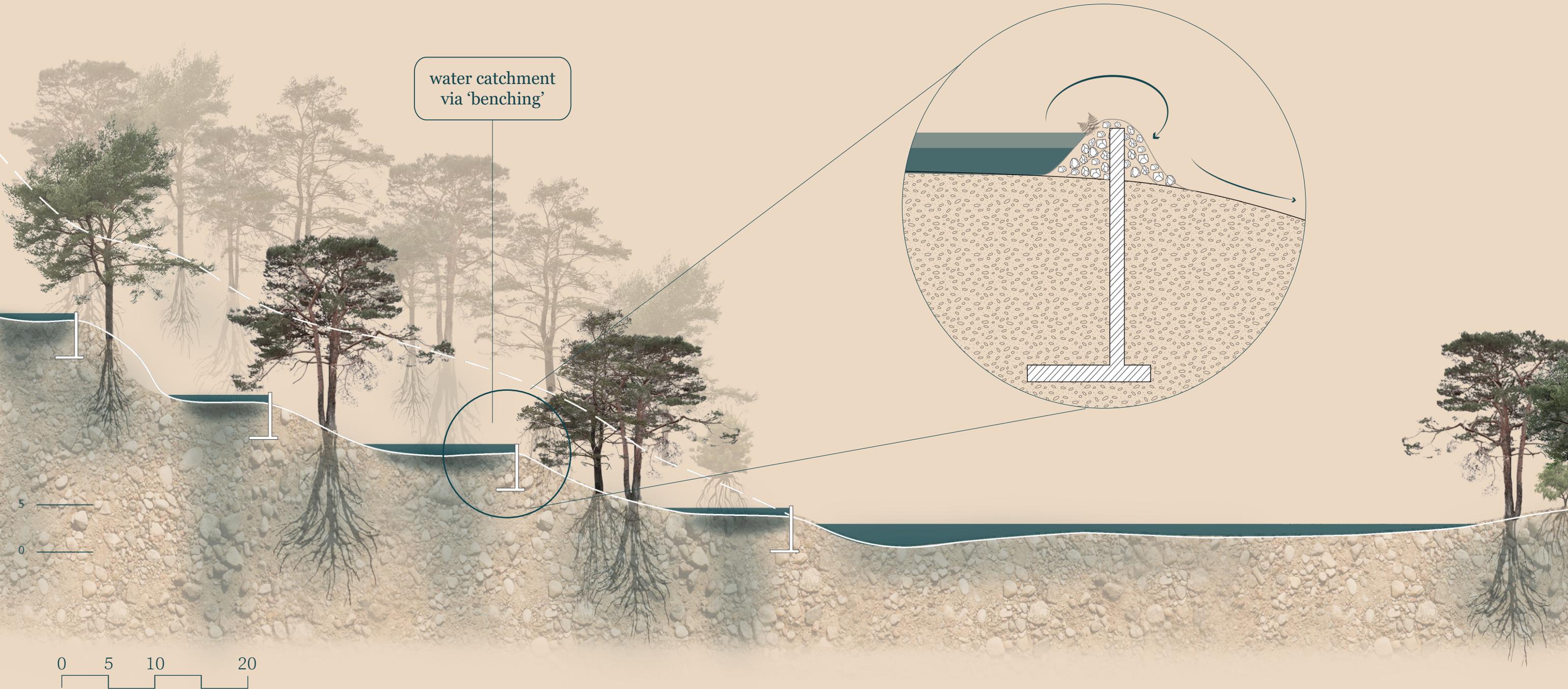
0 50 100 150 200 250 m



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

Upstream design elaboration

Implementation of the 'benching' method



Upstream design elaboration

Selection of species based on the ecoregion

Trees of the Sierra Madre Oriental Pine-Oak forest

reforestation of
pine-oak forest



Mexican pinyon pine
Pinus cembroides
Quercus laceyi
Brundage, S.



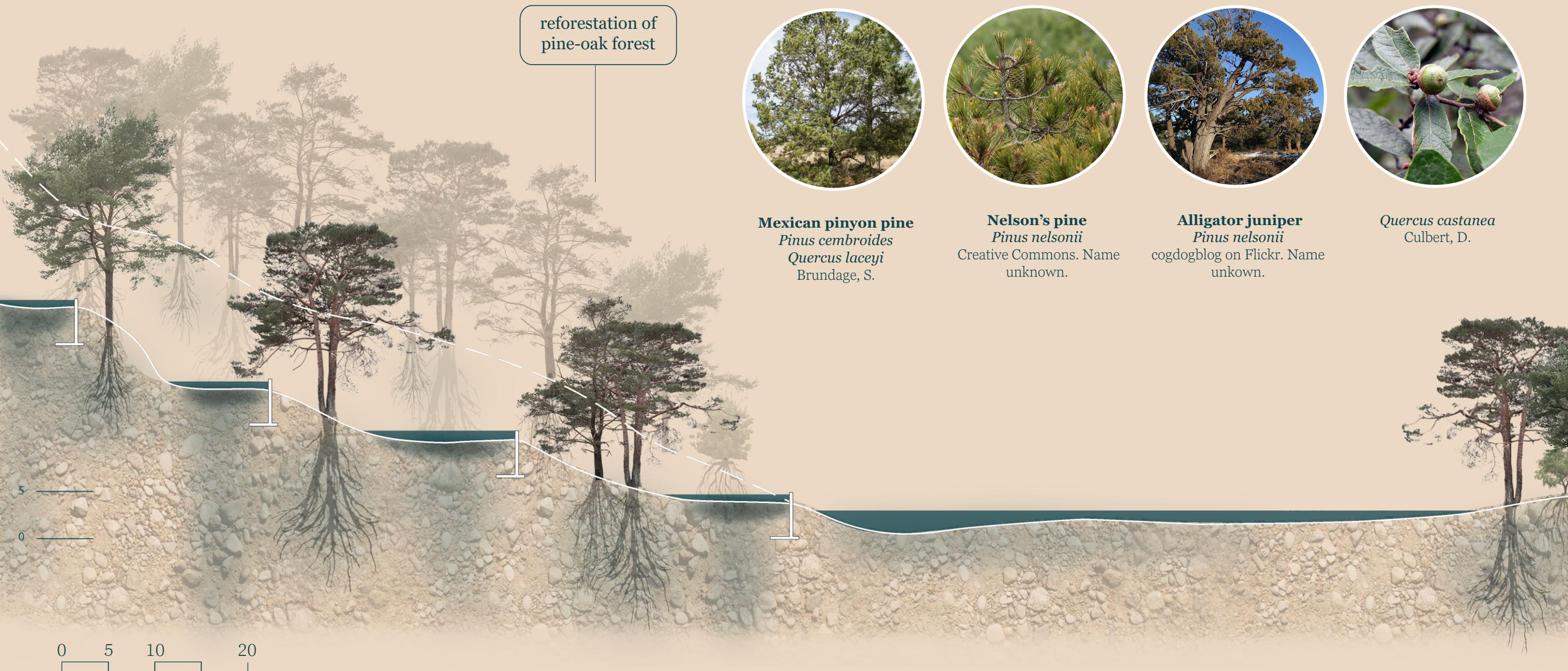
Nelson's pine
Pinus nelsonii
Creative Commons. Name
unknown.



Alligator juniper
Pinus nelsonii
cogdogblog on Flickr. Name
unknown.



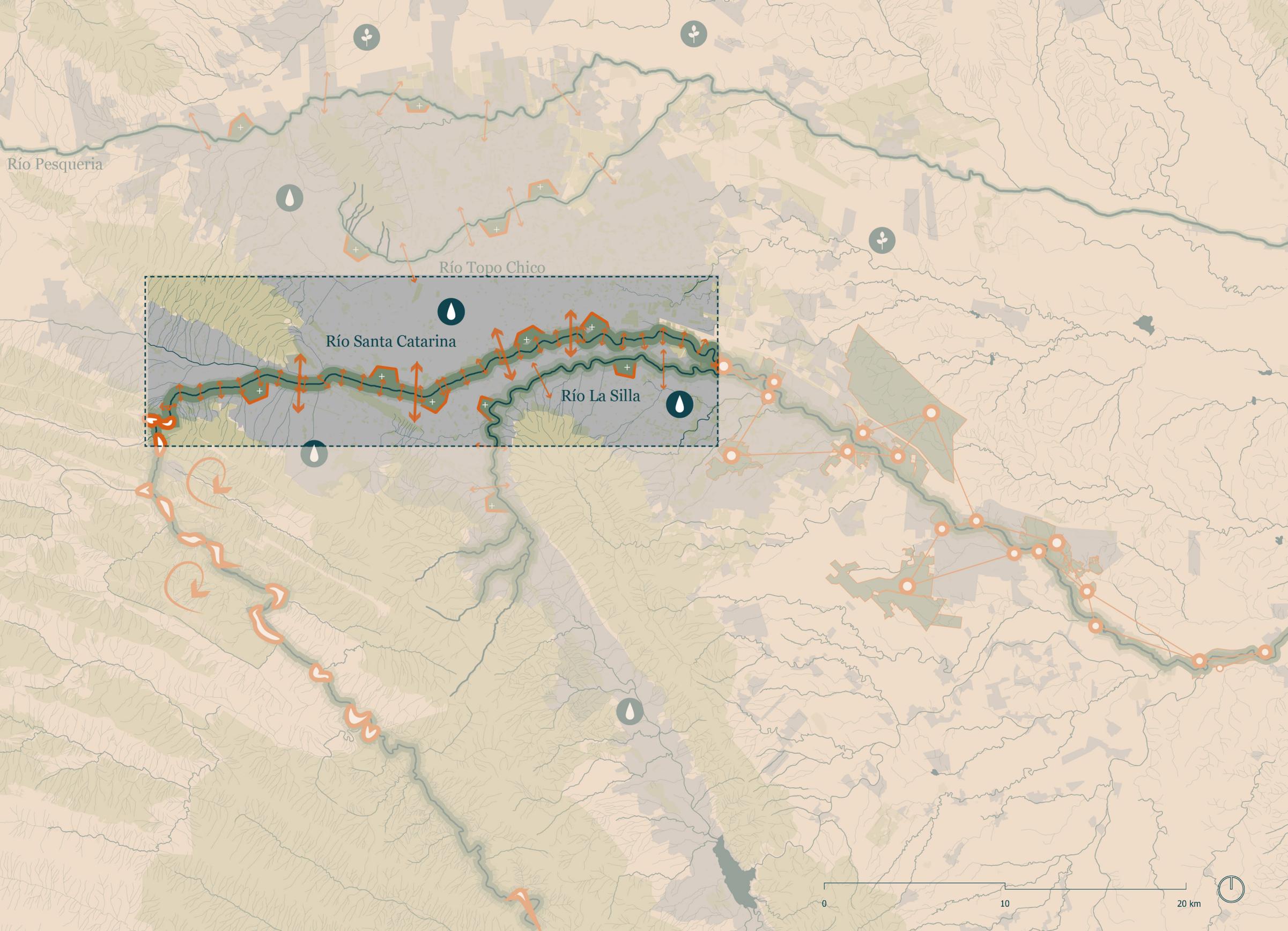
Quercus castanea
Culbert, D.



0 5 10 20

The midstream zone

Giving space



- 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
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- urban area
- water body

Vision for the rivers in MMA.



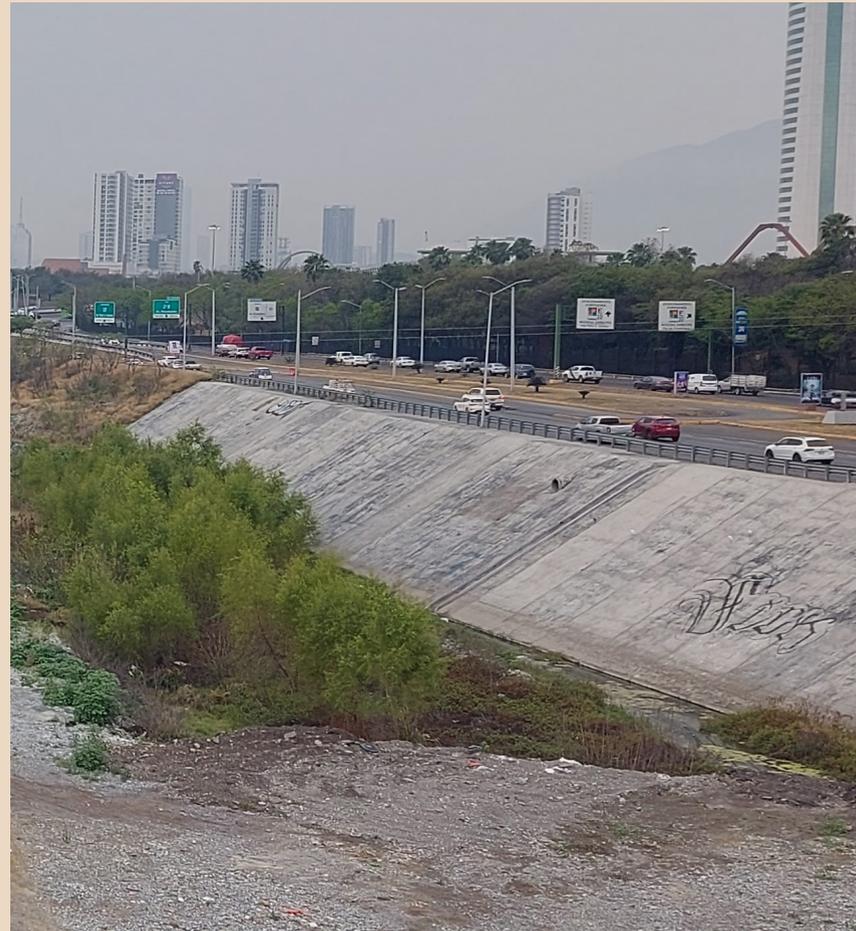
The midstream zone



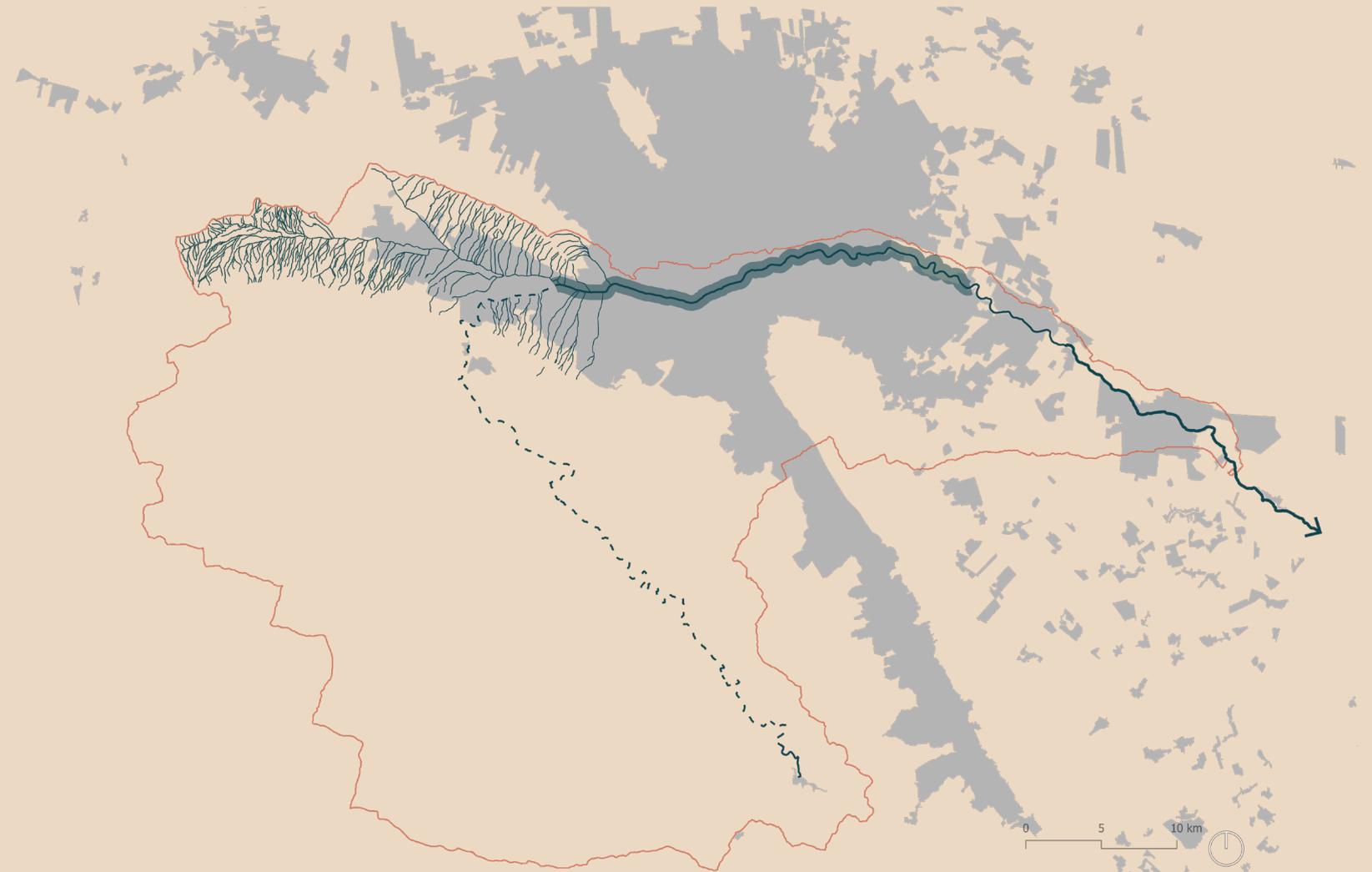
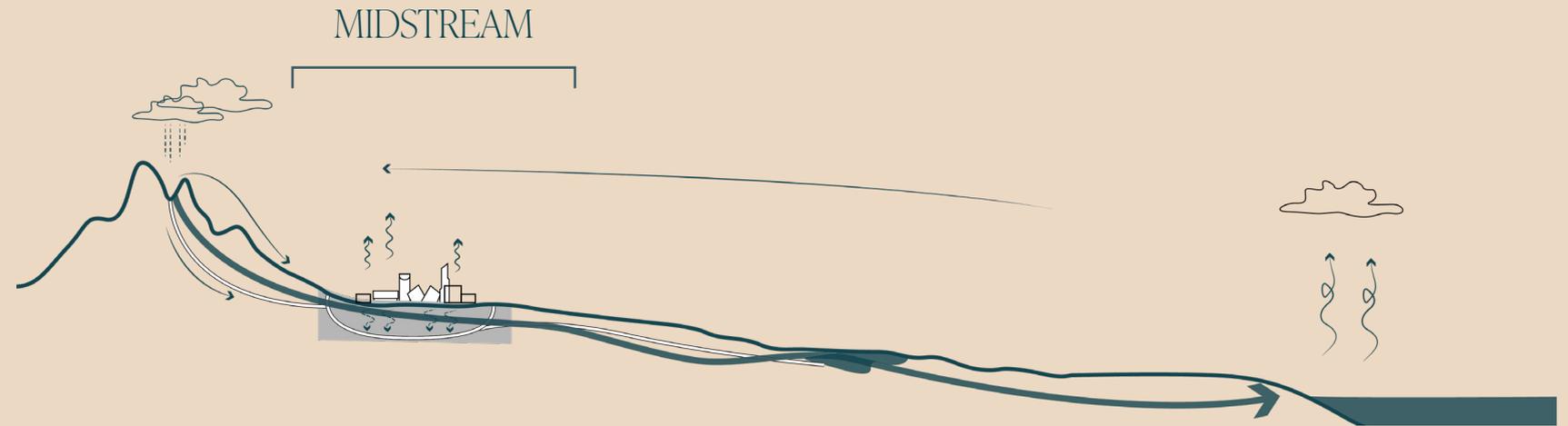
Holtes, E.O. In the riverbed of the Santa Catarina River in Monterrey.

Midstream conditions

Modified riverbank



Holtes, E.O.

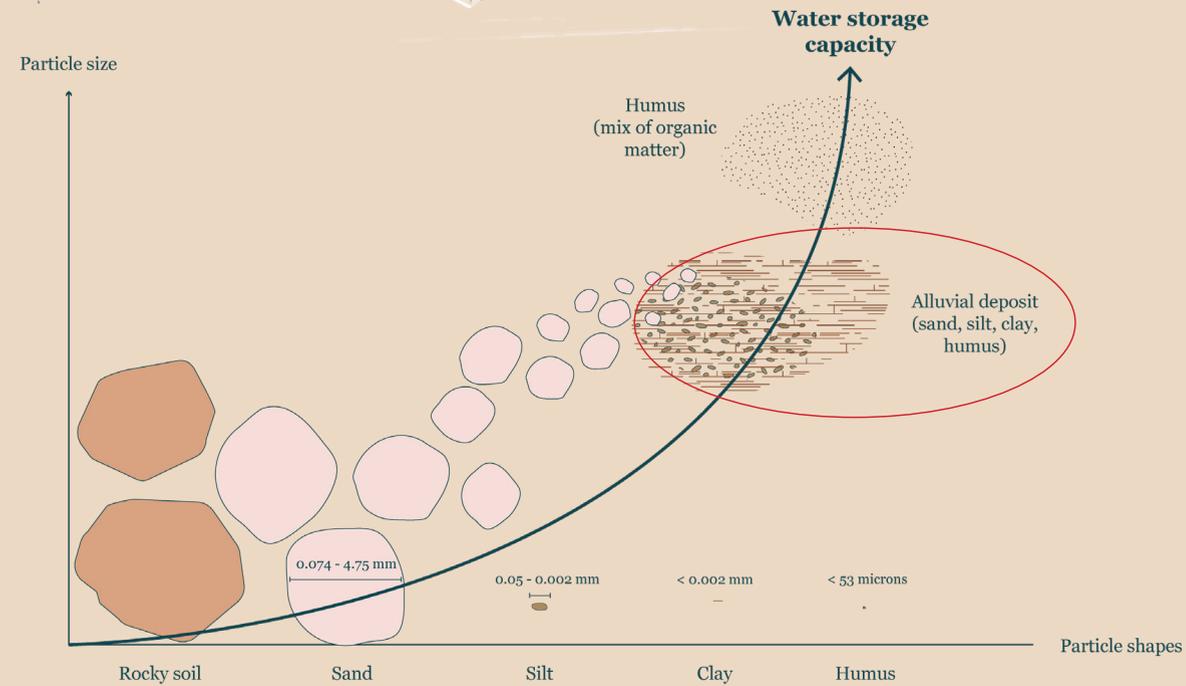
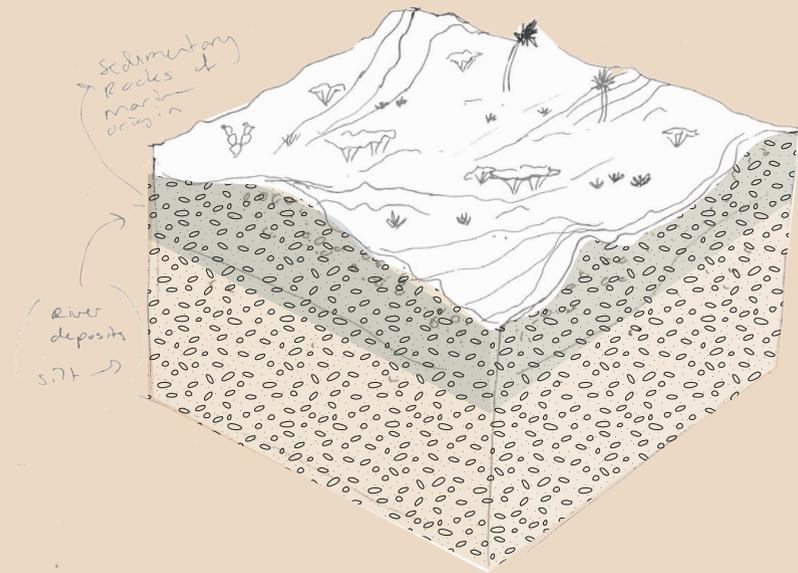
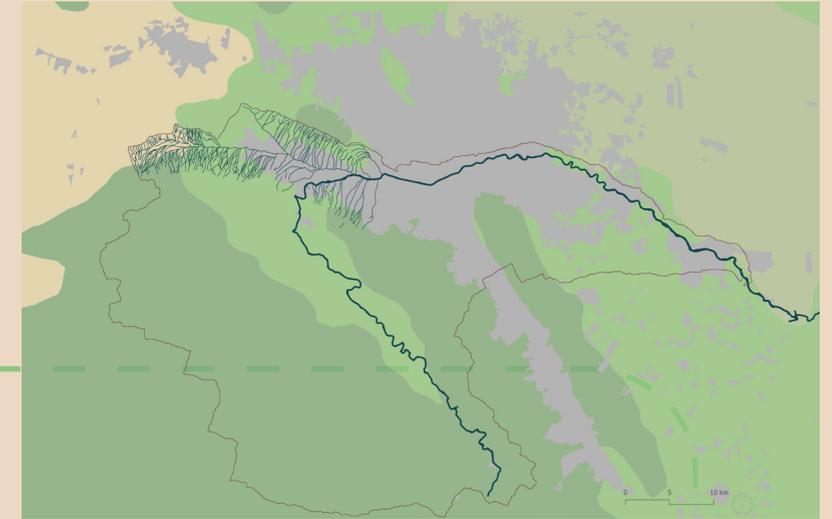


Streams in the midstream zone of the Santa Catarina Watershed GIS data: Inegi, SIATL.

Midstream conditions

The ecoregion of the Tamaulipan Matorral

The ecoregions of the MMA and the watershed of the Santa Catarina. GIS data: Inegi, SIATL



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>



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



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



Holtes, E.O. *Spanish dagger* [Photo].



Aguascalientes, M. *Smooth mesquite* [Photo].



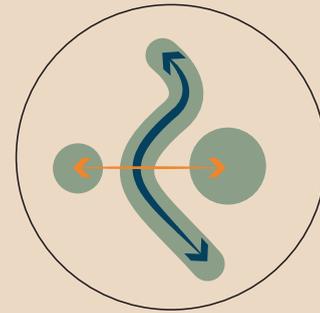
By unknown. *Eastern Meadowlark* [Photo]. Image credit: Creative Commons.



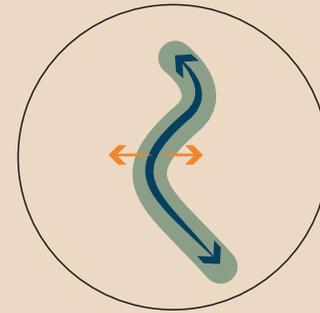
Theiner, P. *Mexican prairie dog* [Photo]. Image credit: Creative Commons.

Design interventions midstream

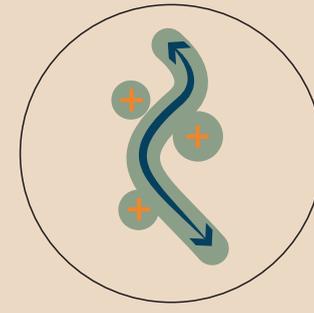
Giving space



Perpendicular connections



Increasing the width of the riverbank



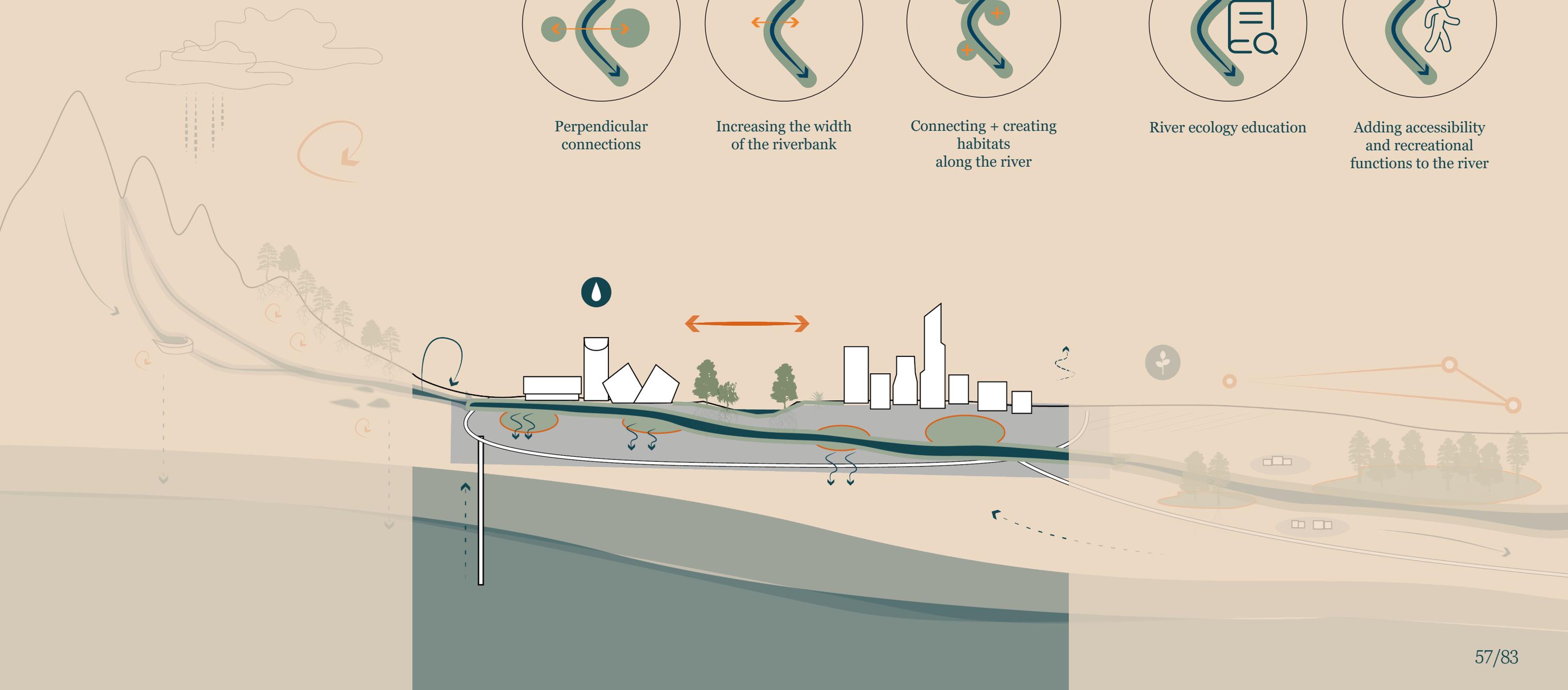
Connecting + creating habitats along the river



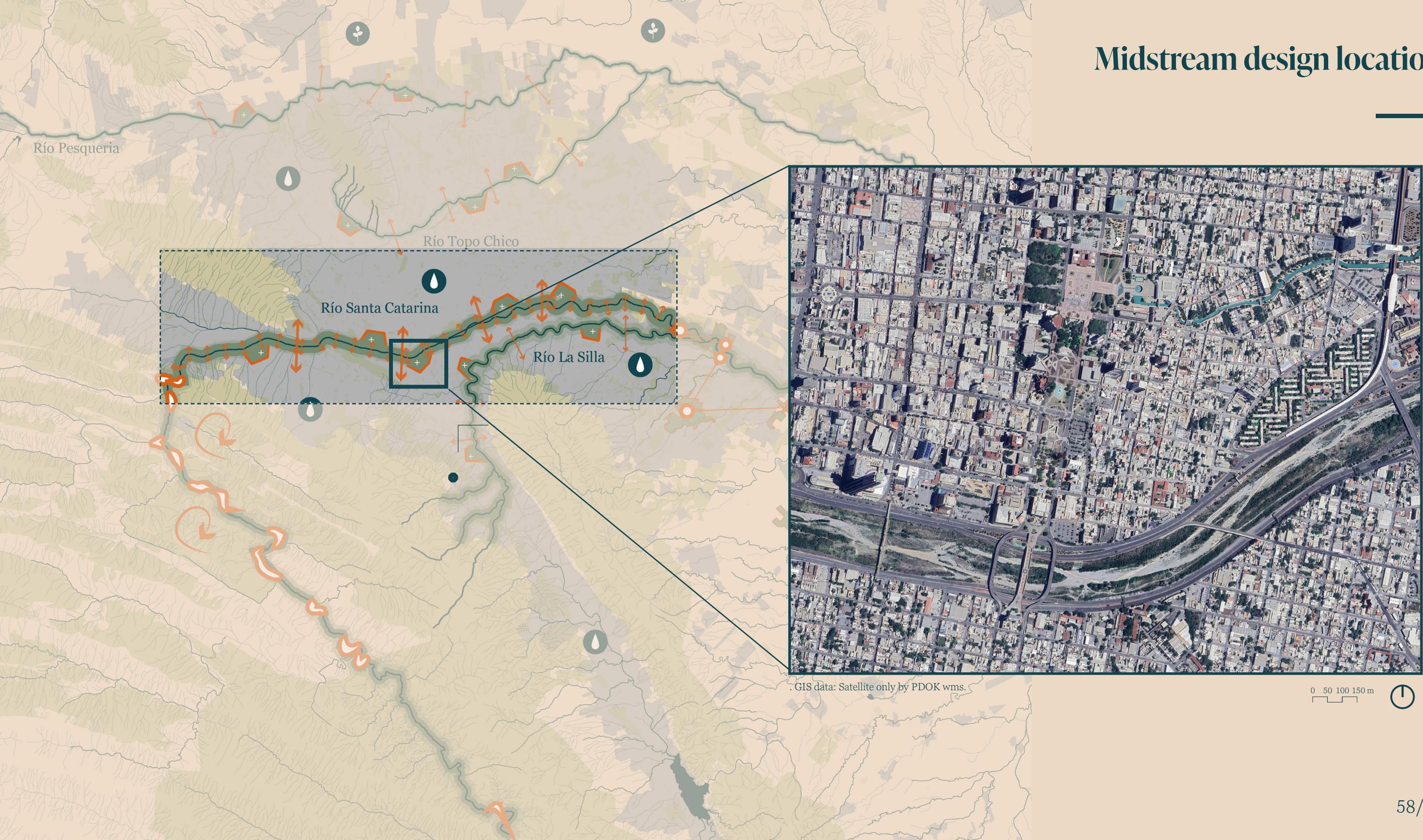
River ecology education



Adding accessibility and recreational functions to the river



Midstream design location



GIS data: Satellite only by PDOK wms.



Midstream current situation



Midstream design location

Midstream design location : current situation



GIS data: Satellite only by PDOK wms.

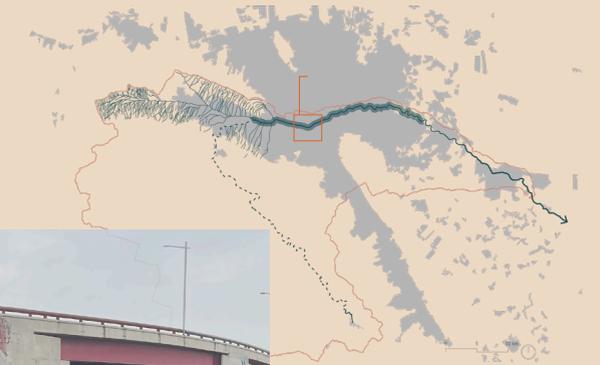
Vegetation



Midstream vegetation analysis map. Based on Google maps.

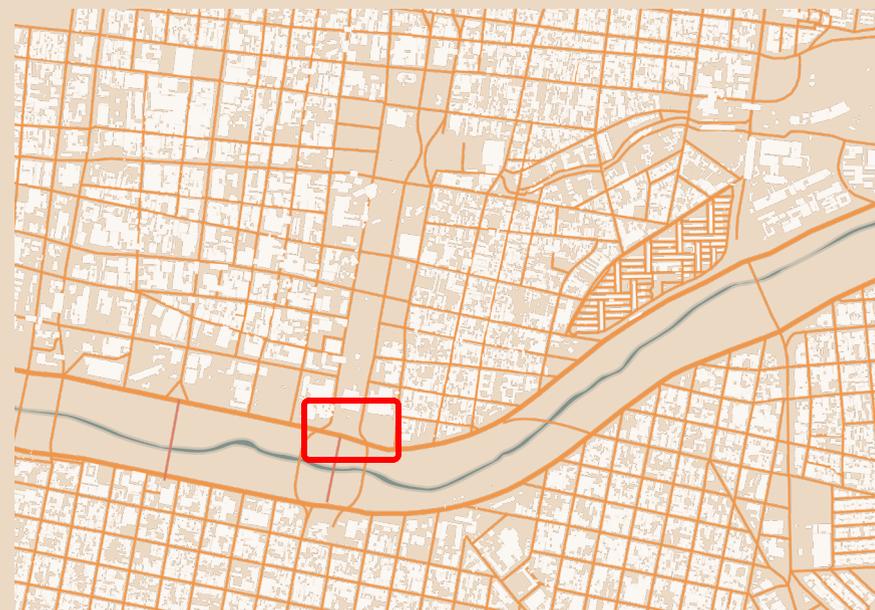


Handelé, K. Site visit in the Santa Catarina river [Photo].



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

Human activity



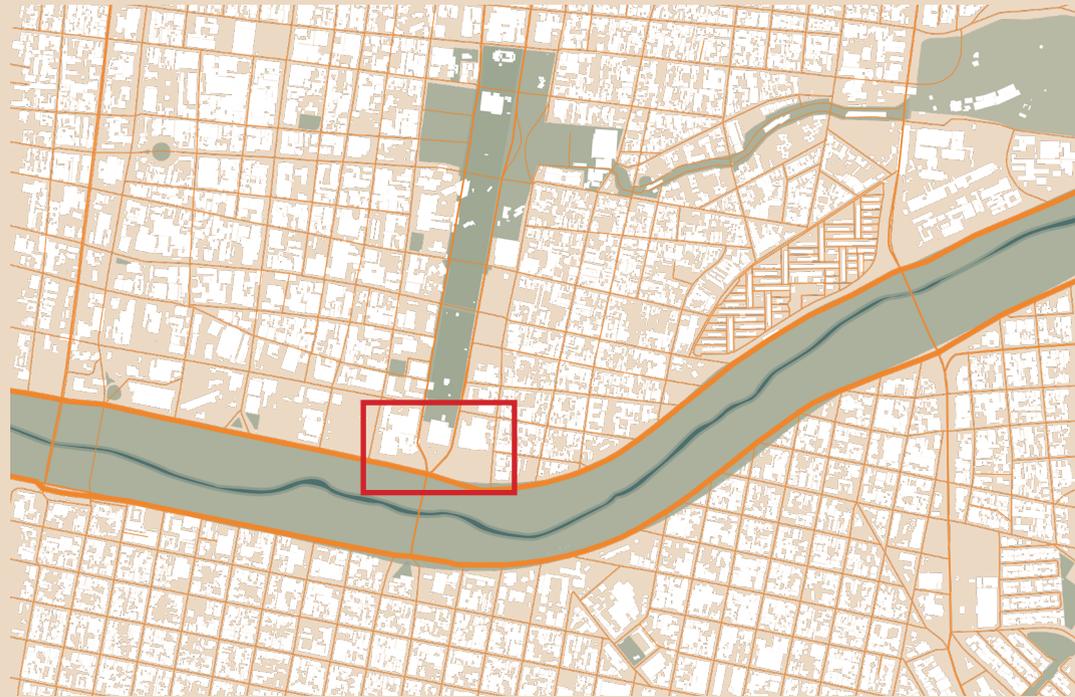
midstream human activity analysis map. Based on Google maps.



Screenshot from Google Earth.

Midstream current situation

current situation



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

design proposal

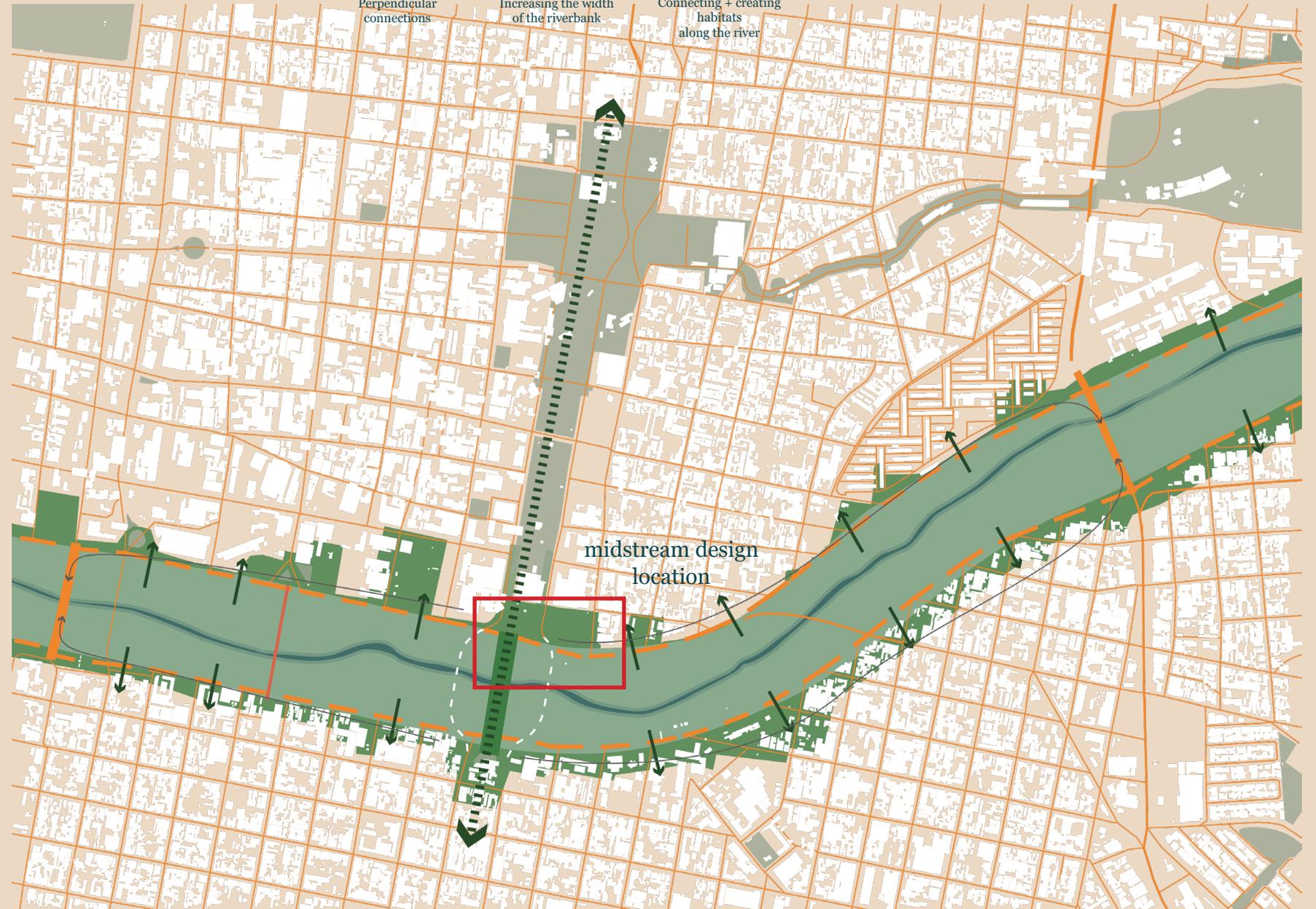
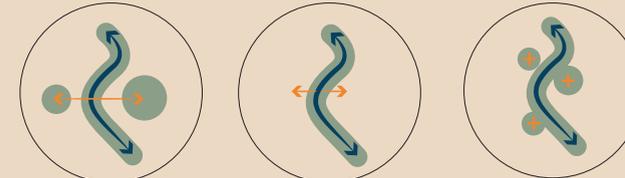




Image Landsat / Copernicus

Google Earth

Redevelopment of the pedestrian/ cyclist bridge

Plaza de Santa Catarina

Accessibility to the river

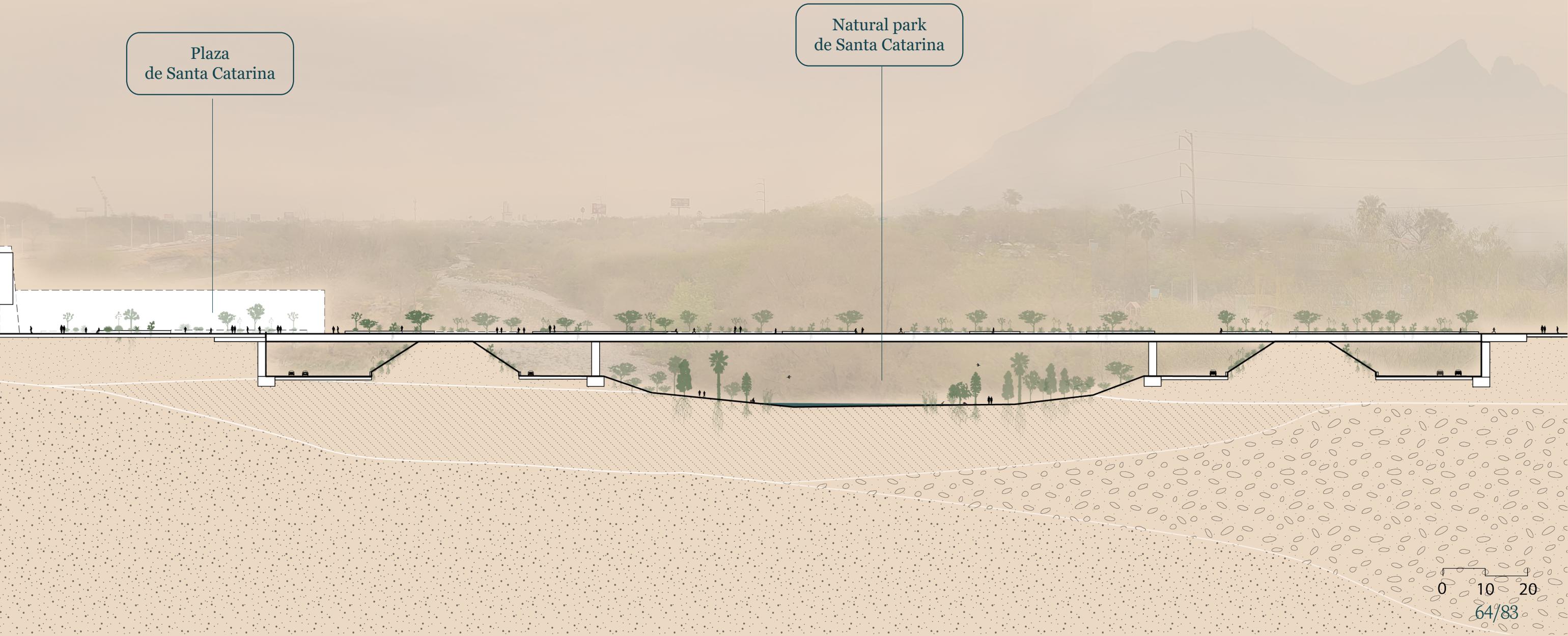
River ecology education

Removal of the concrete slabs

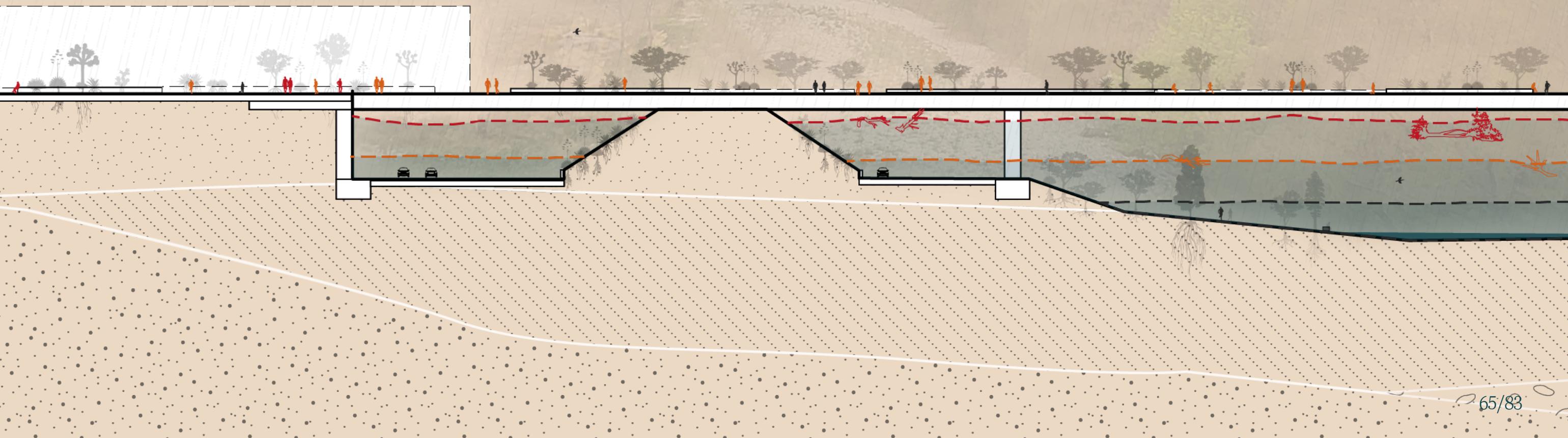
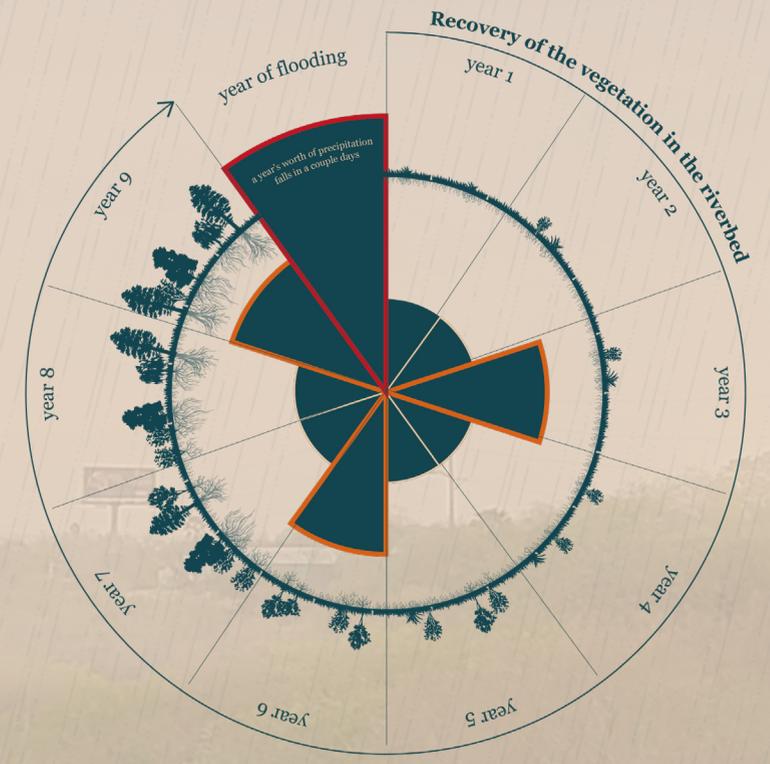
Rain + grey water purification



Midstream Park de Santa Catarina



Midstream design through time: *the different hydrological circumstances*



Plaza de Santa Catarina

Giving room back to the river



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



Reference of mexican garden.



Reference of stairs towards the river.



Santa Catarina bridge



Santa Catarina bridge

Selection of species based on the ecoregion

Tamaulipan matorral

+ Native trees



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



Lacey Oak
Quercus laceyi
© 2019 Leander Area Wholesale Nursery supply



Smooth mesquite
Prosopis laevigata
by Aguascalientes, M.



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



Spanish dagger
Yucca gloriosa
By Holtes, E.O



Desert willow
Chilopsis
By Lukes, L



Texas prickly pear
Opuntia engelmannii
By Urieta, M.



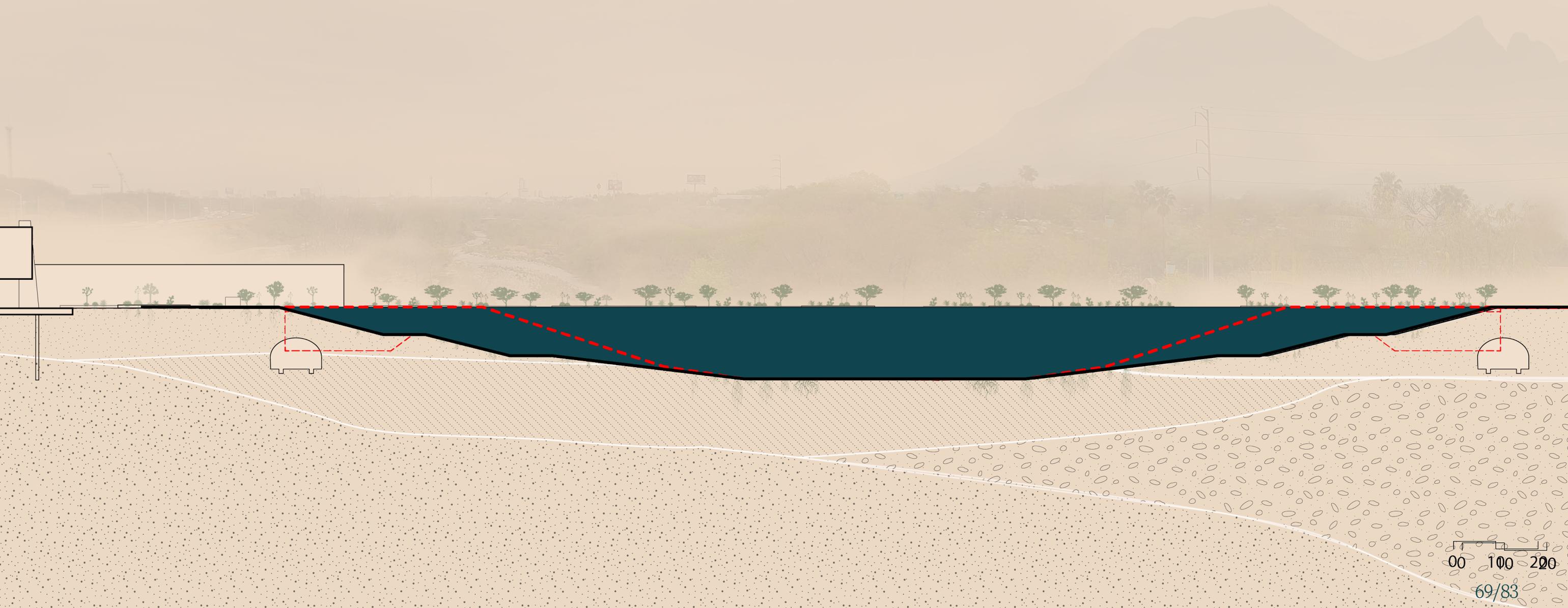
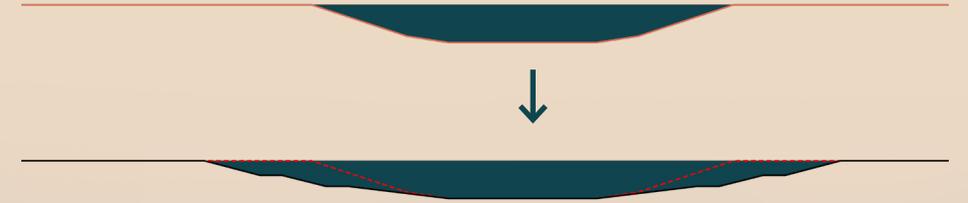
Sandpaper tree
Ehretia anacua
© 2012 Arizona Board of Regents

Midstream Park de Santa Catarina

Giving room back to the river

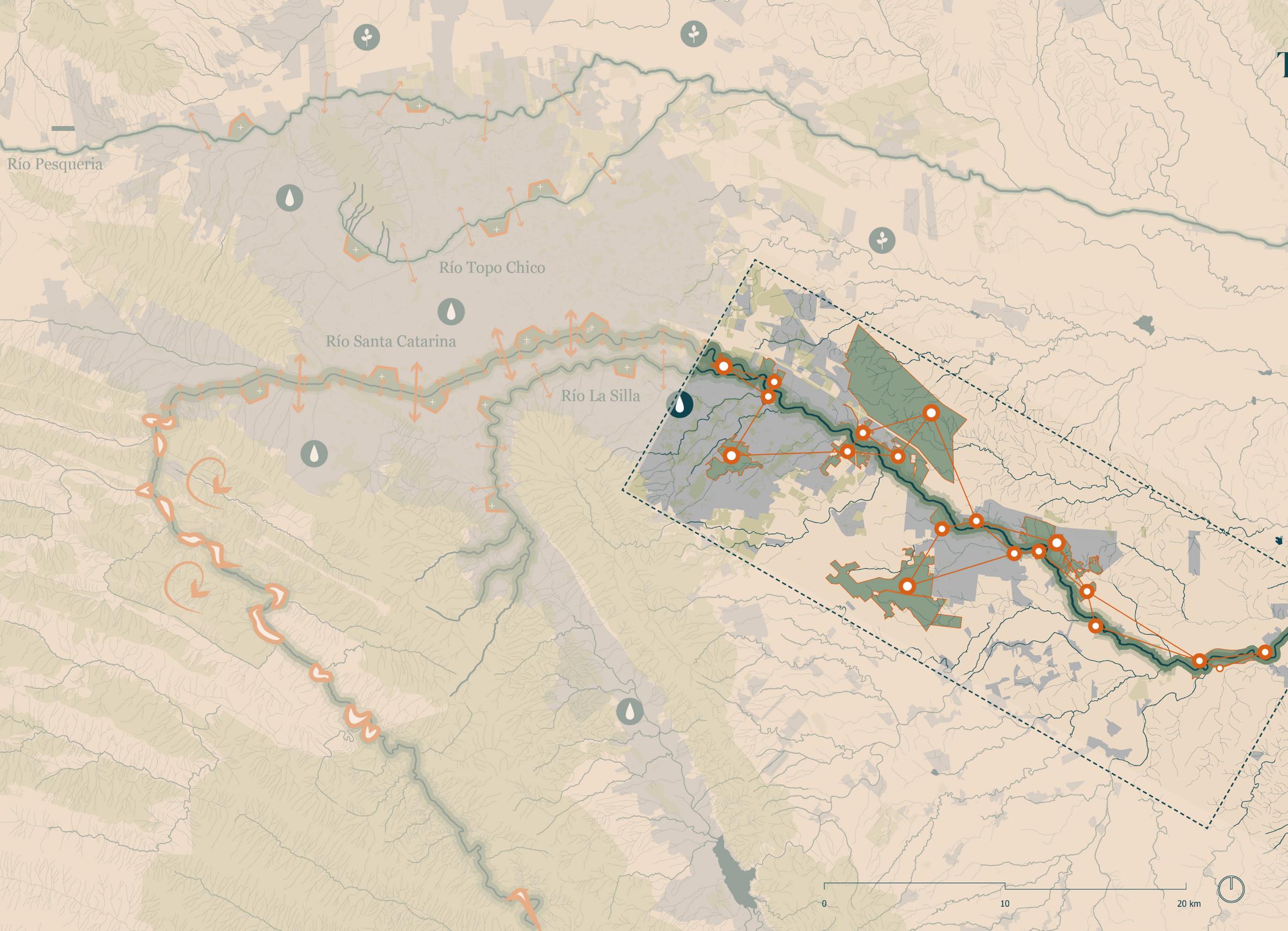
By creating more room for the river, the rivers waterbody flow will increase. And therefore will have a better water carrying capacity in case of heavy rains and the occasional hurricanes.

Improved water carrying capacity



The downstream zone

Allowing the flow



-  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

Vision for the rivers in MMA.

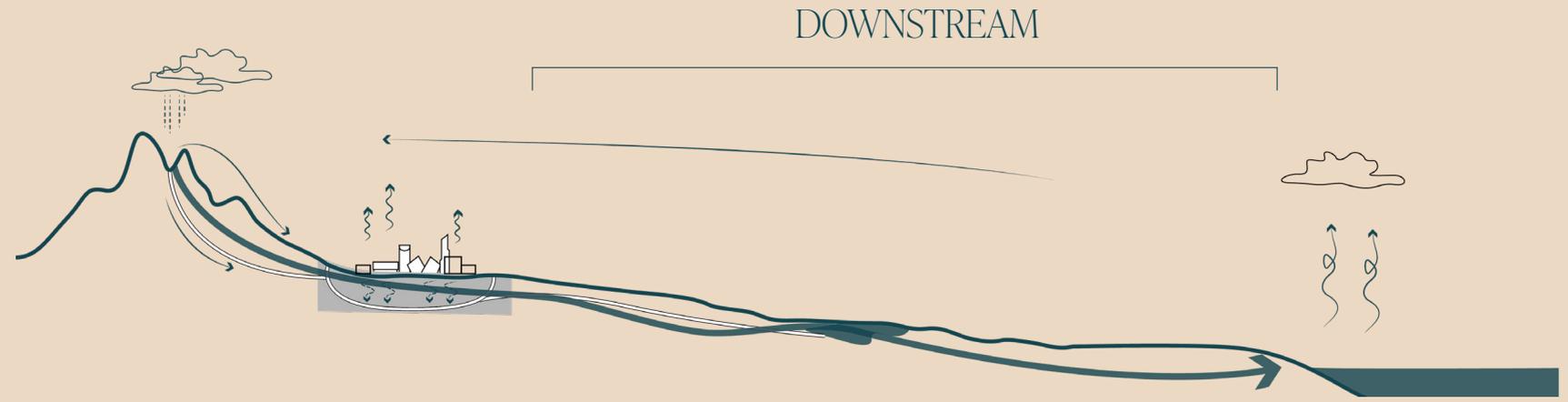
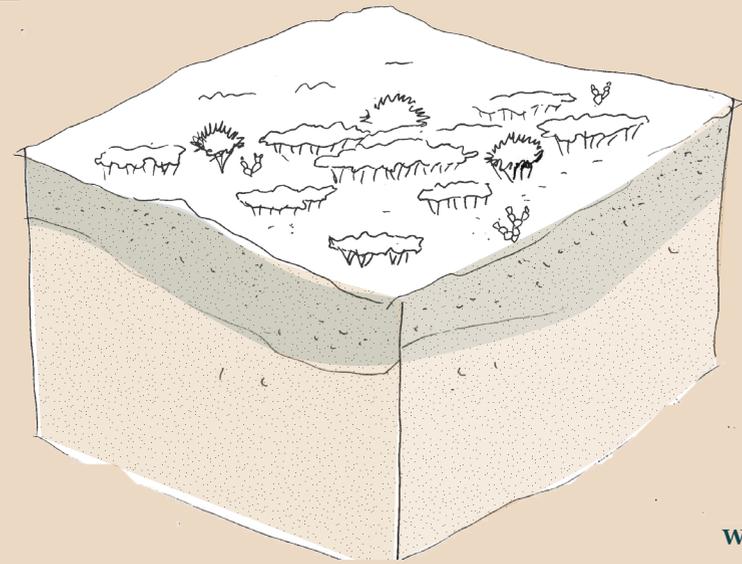


The downstream zone

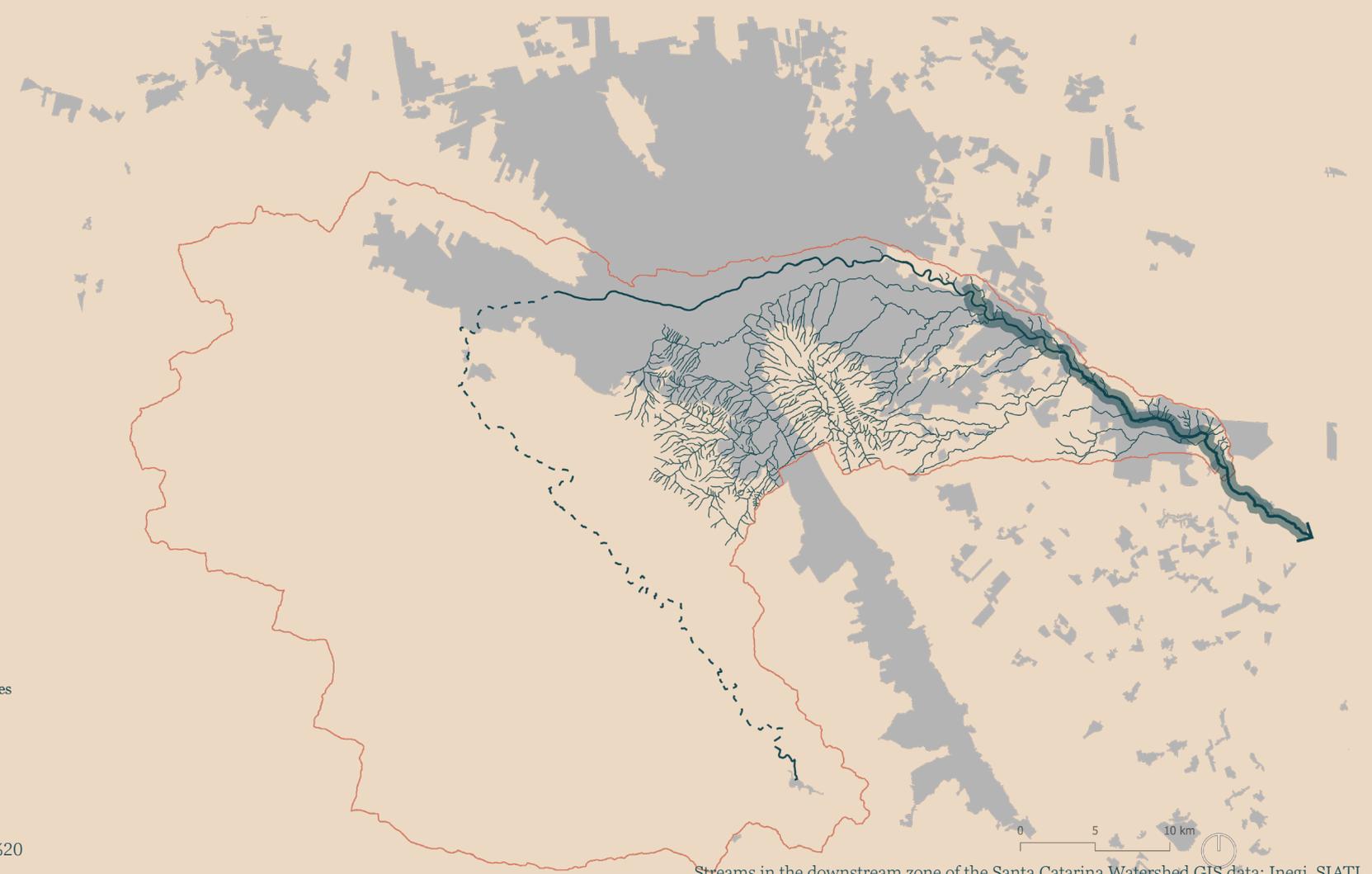
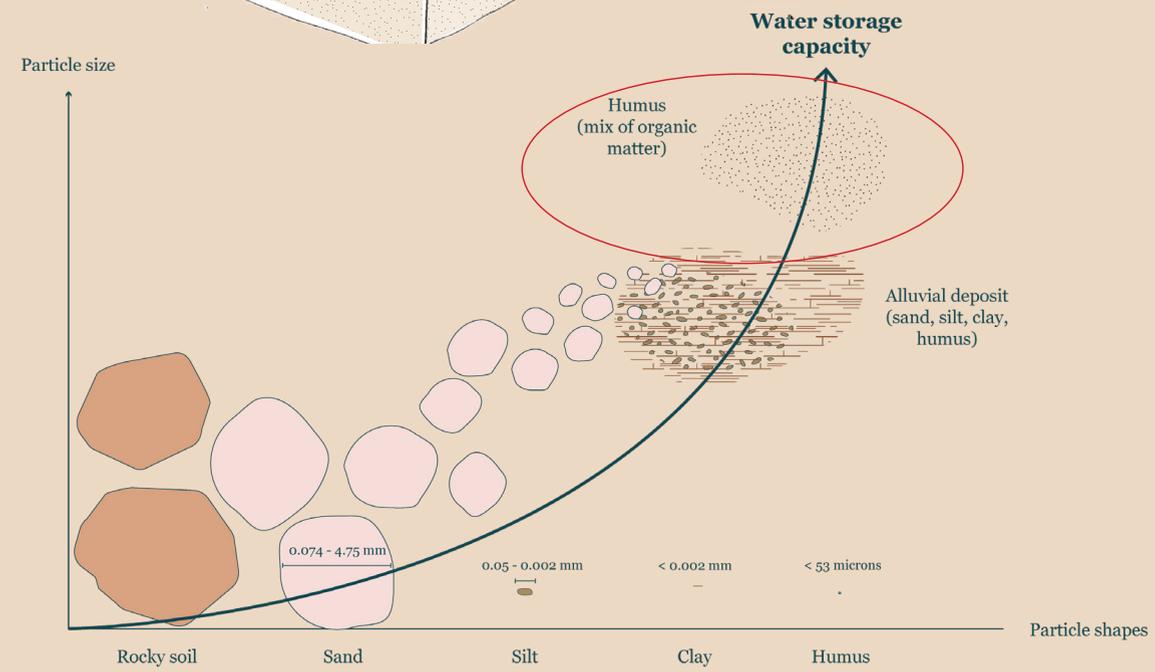


Holtes, E.O. View on the riverbed of the Santa Catarina River in Monterrey.

Downstream conditions



DOWNSTREAM

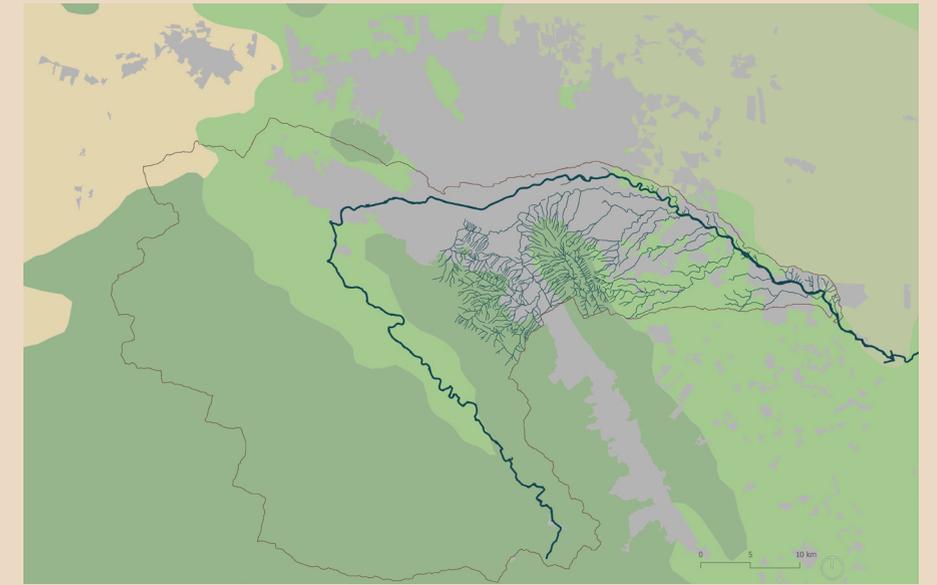


Soil water capacity per soil type. Based on: <https://nrcca.cals.cornell.edu/soil/CA2/CA0212.4.php#:~:text=The%20total%20soil%20water%20storage,70%20to%2085%25%20by%20volume> and <https://www.sciencelearn.org.nz/resources/957-soil-properties>

Streams in the downstream zone of the Santa Catarina Watershed GIS data: Inegi, SIATL.

Downstream conditions

The ecoregion of the Tamaulipan mezquital & river ecology



The ecoregions of the MMA and the watershed of the Santa Catarina. GIS data: Inegi, SIATL



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



E, Castela. *Chaparro* [Photo].



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



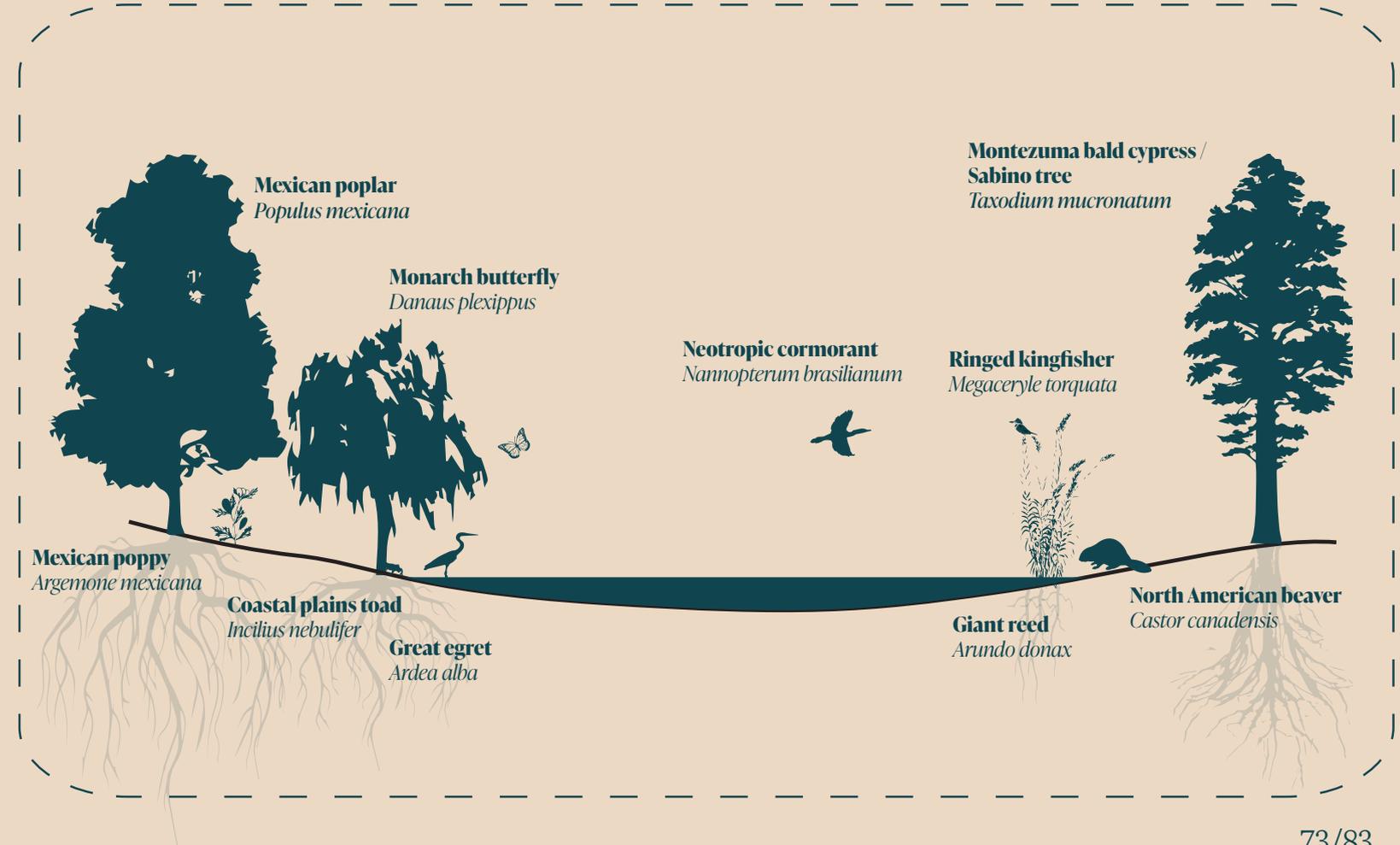
Pfeiffer, M. *hook-billed kite* [Photo].



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



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

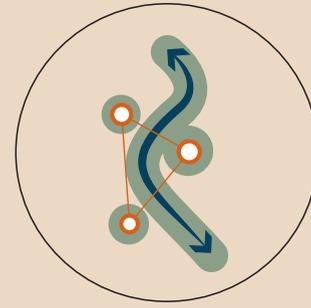


Design interventions downstream

Allowing the flow



Protection of river forests



Connecting the habitats



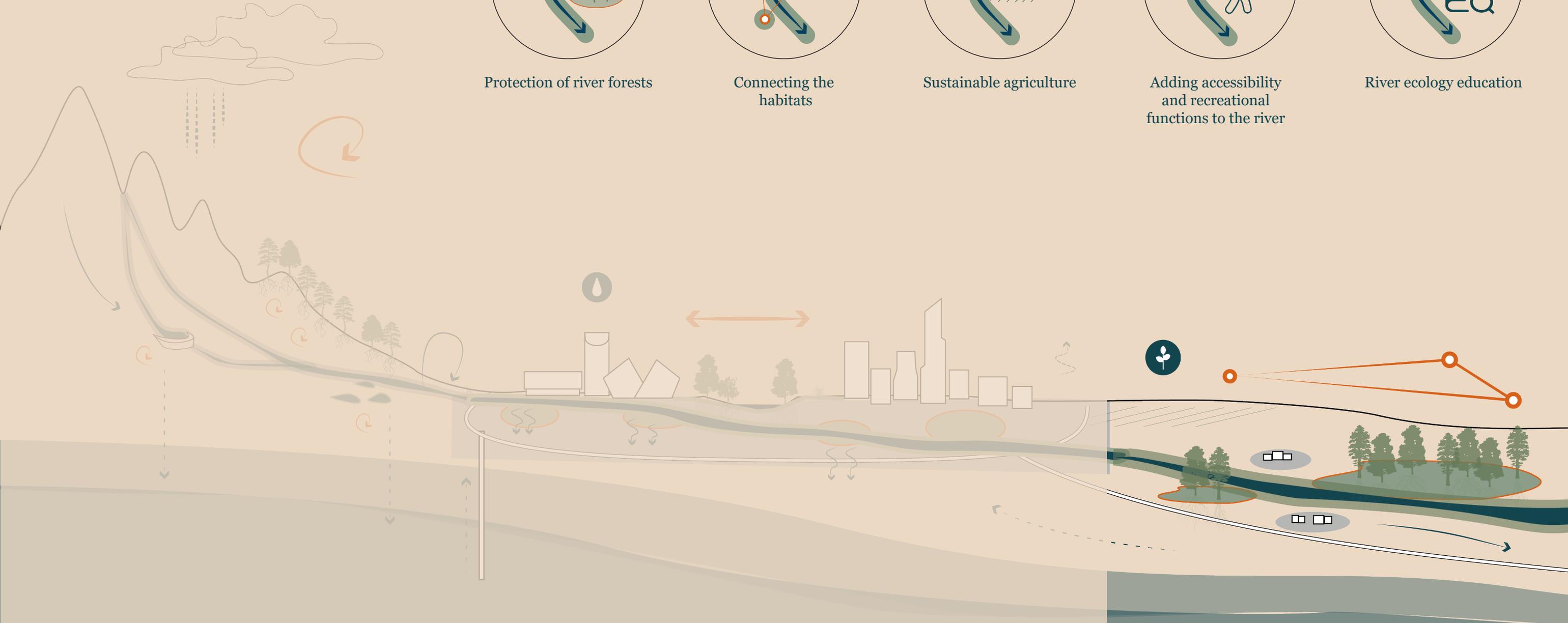
Sustainable agriculture



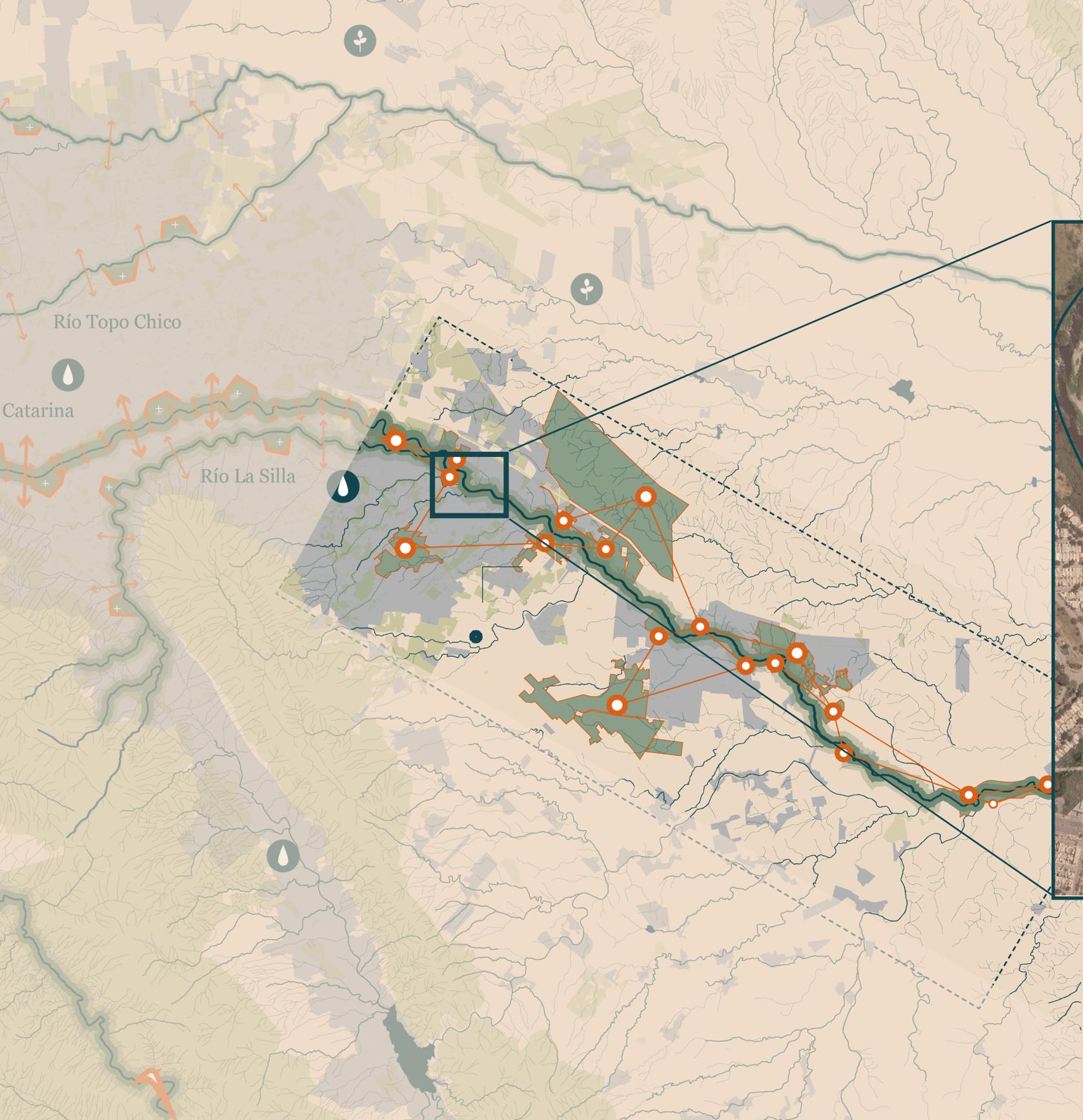
Adding accessibility and recreational functions to the river



River ecology education



Downstream design location



GIS data: Satellite only by PDOK wms.



Downstream current situation



— riverbed GIS data: Satellite only by PDOK wms.

Vegetation



Vegetation analysis of the downstream design location [Map]. Based on Google maps.

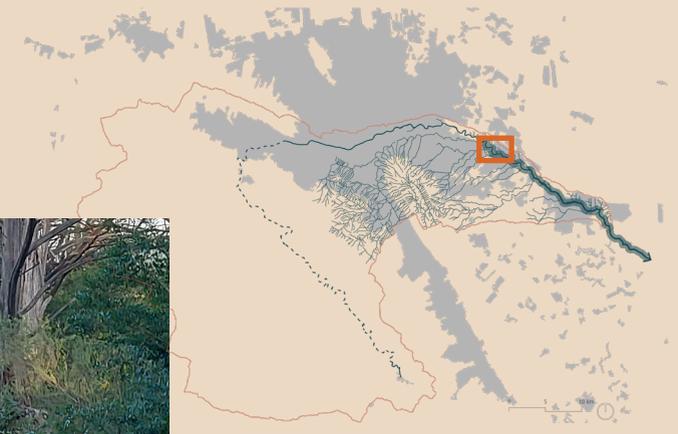
Human activity



Human activity analysis [Map]. Based on Google maps.



Holtes, E.O. River ecology of the downstream zone [Photo].



- forest
- shrub vegetation
- riparian vegetation
- river



The surrounding neighbourhoods downstream [Image]. Screenshot from Google maps streetview.

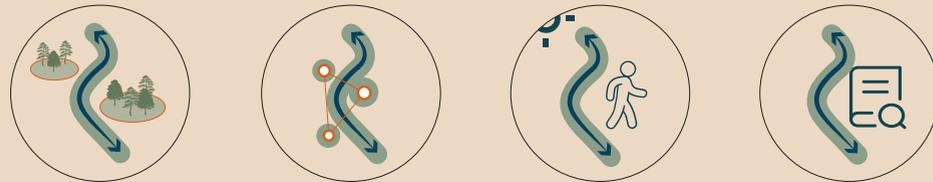
- working-class housing
- river
- sport facilities
- road

Downstream river forest

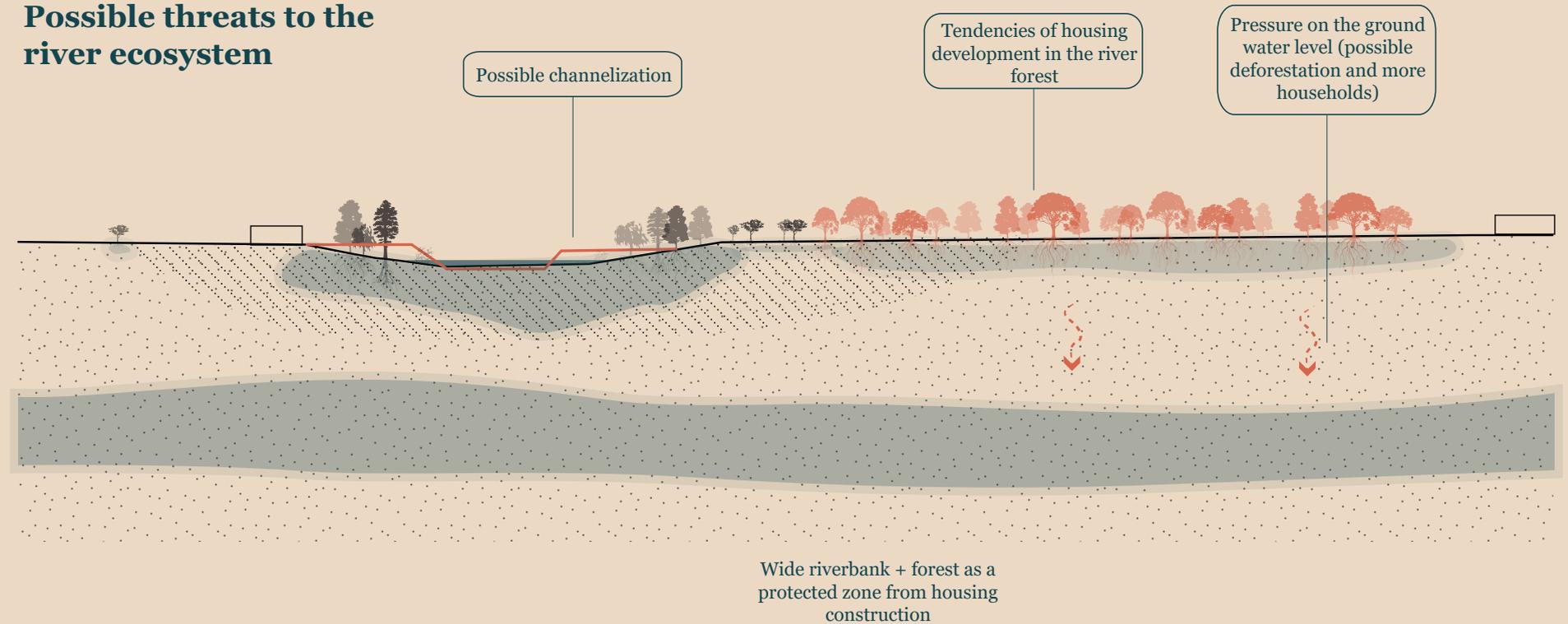
Allowing the flow



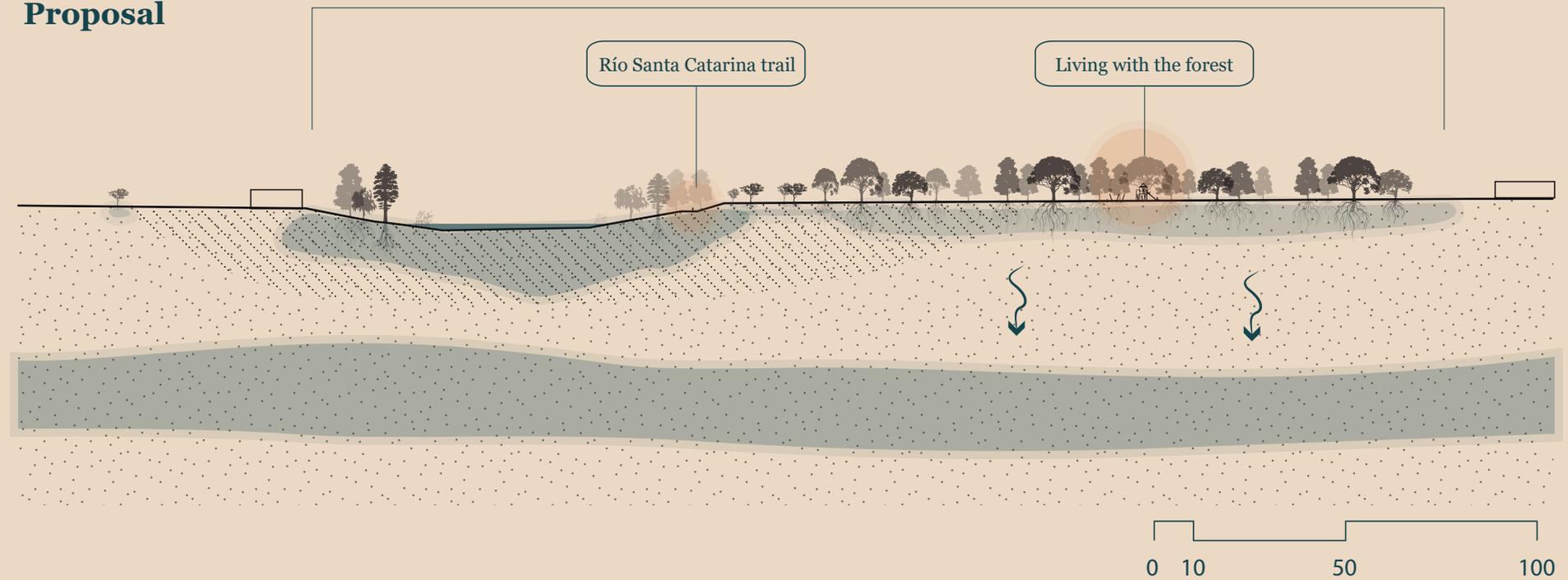
GIS data: Satellite image Google maps.



Possible threats to the river ecosystem



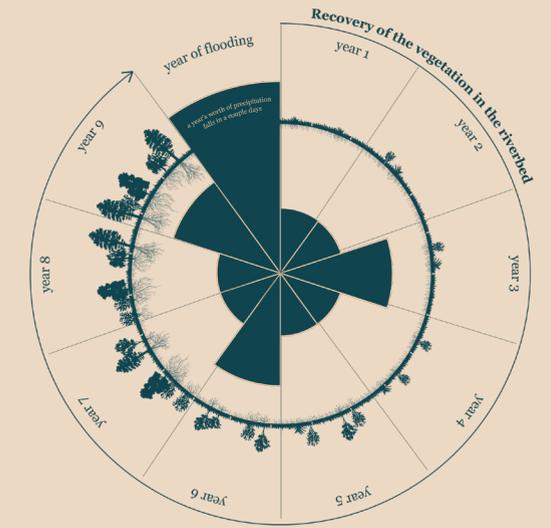
Proposal



0 10 50 100

Downstream design through time

The different hydrological circumstances



Regular conditions

Heavy rains

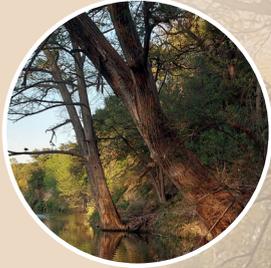
Hurricane



Downstream river forest

Species of the ecoregion

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](https://commons.wikimedia.org/)



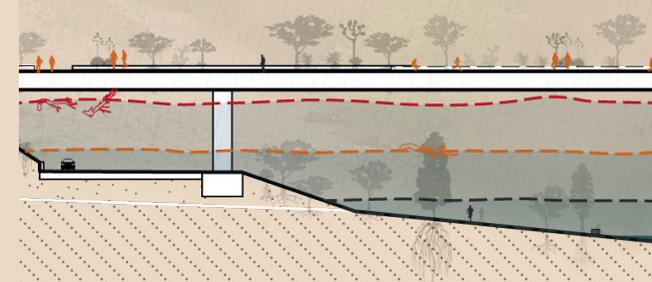
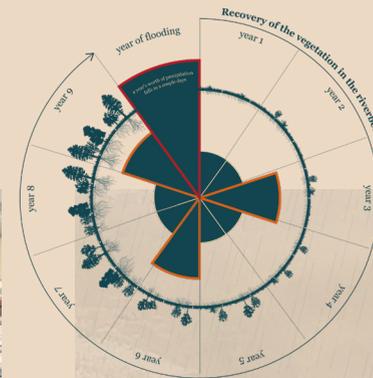
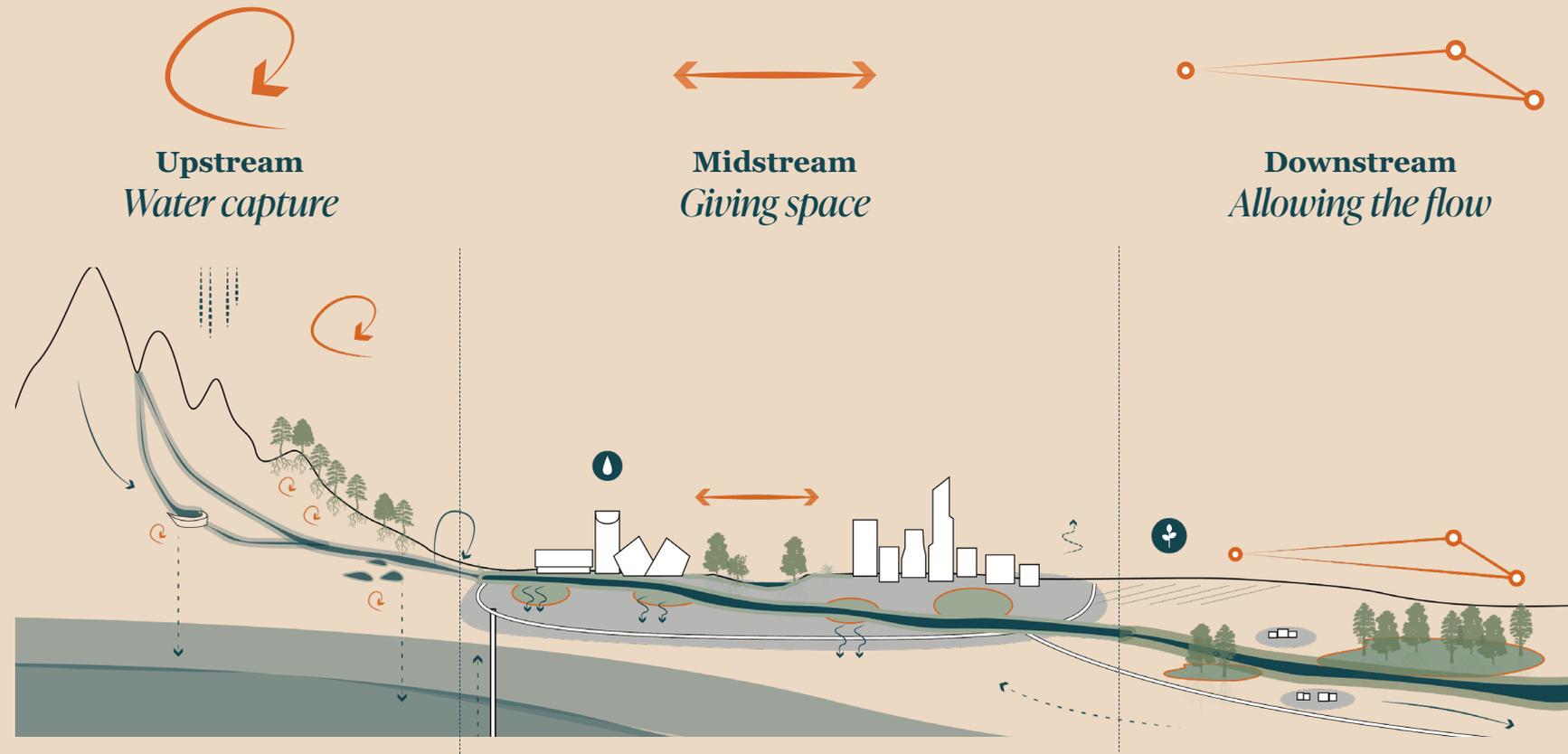
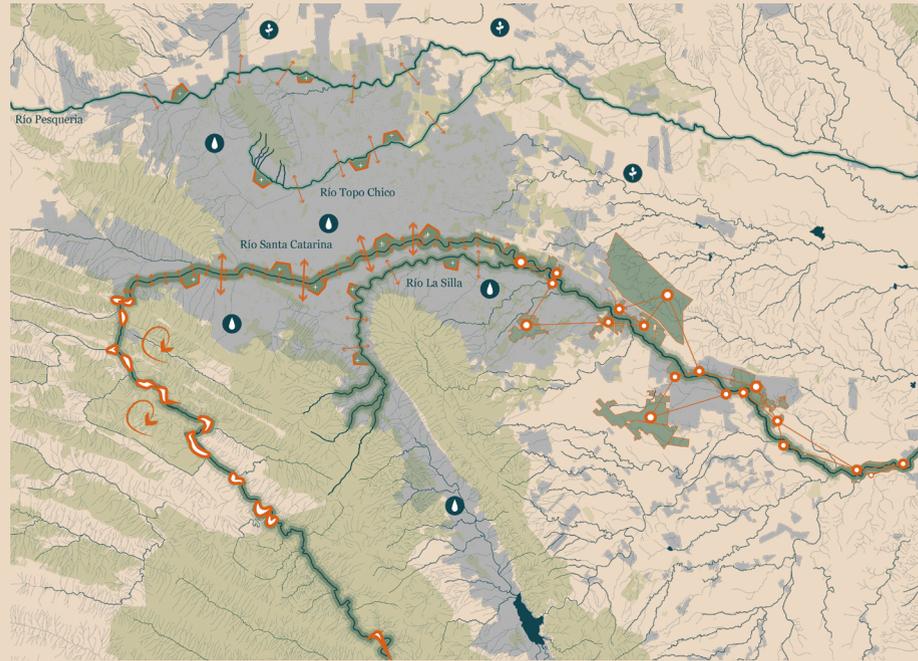
4

Conclusion



We can restore the river
ecosystem of Monterrey!

Conclusion



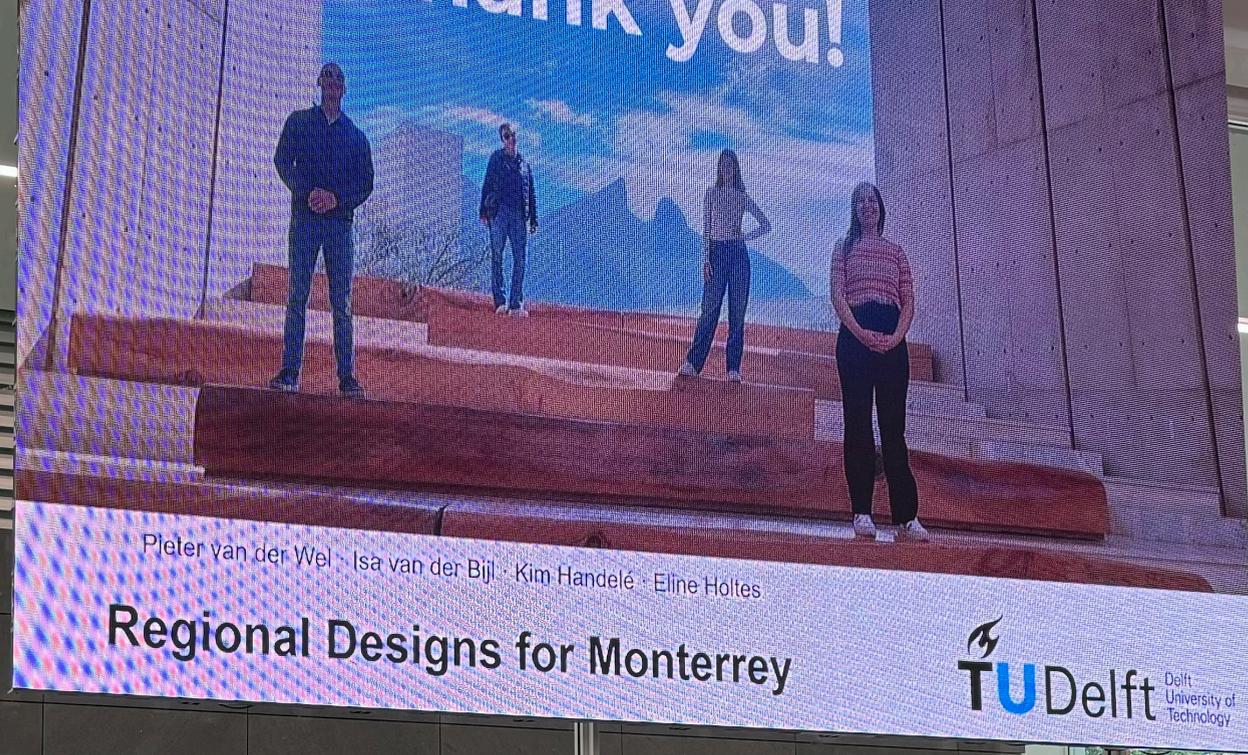


Photo by Steffen Nijhuis, 2024. Monterrey, Mexico

