

**Circular Water Stories, Worldwide 2 edition**  
**Traditional Water Systems Worldwide 2018/2019 and 2019/2020**

Bobbink, I.; Rey Hernández, C.D.P.; Rivero Lamela, G.; Chouairi, A.; Di Nicola, C.; Gupta, T.; Naeema Ali, N.; Ayu Tri Prestasia, Ayu; Kim, B.; Surajaras, R.

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# Circular Water Stories | Worldwide

**2<sup>nd</sup> Edition CWS lab 2019/2020**

Including works from the 1<sup>st</sup> Edition 2018/2019





# Circular Water Stories | Worldwide

**Traditional Water Systems Worldwide  
2018/2019 and 2019/2020**

**Research works of  
international graduation students**

Delft University of Technology, The Netherlands

Faculty of Architecture and the Built Environment  
Master Track Landscape Architecture.



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**BK**Bouwkunde

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Spelling and grammar check  
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# Introduction.

## **CIRCULAR WATER STORIES, WORLDWIDE** **2<sup>nd</sup> Edition - July 2020**

**Keywords:** landscape architecture, traditional water system, water landscape elements, waterworks, water stories, irrigation, drainage, inundation, collecting, retaining, filtering, farming, circularity, comprehensive water design, living landscapes, illustrative method.

### **Text by Dr. ir. Inge Bobbink.**

The research is done within the Circular Water Stories (CWS) lab, one of the labs of the graduate studio Flowscapes in the master track of Landscape Architecture at the Faculty of Architecture and the Built Environment TU Delft, the Netherlands. It is conducted by graduate students using the illustrative method offering insights on divers' managements of traditional (indigenous) water systems throughout the world. By mapping a traditional water system of their own choice, students gather knowledge for their thesis project that ideally is directly (site of intervention) or indirectly (offering insight on designing with water) linked to the landscape architectonic research.

People all over the world transformed natural water flows into ingenious controlled water systems which makes it possible to settle and cultivate all kinds of topographies according to the possibilities of the water sources and the climate conditions. Traditional water systems can be read as comprehensive systems closely connected to the existing landscape and its people, creating new cultivated landscapes. The transformation asked for precise reading of the landscape and the necessity to find a new balance between water and land, permeable and impermeable surfaces. 'The primitive logic of 'cut-and-fill' and differences

in micro-topography was a powerful tool. Levels of inundation determined distinct land uses, and therefore the definition of wet/dry, productive/inhabited, and safe/unsafe component parts of the land mosaic was considered essential.' (K. Shannon, 2019)

Traditional water systems developed over a long period by trial and error and because of this store knowledge, especially on adaptation to an ever-changing context. As a reaction on all kinds of changes - population growth, use, climate etc. measures to retain, to infiltrate, to drain, to flood and to reuse the water was developed by the people living in, and knowing the area. Many of these systems are still, some only partly alive and demonstrate to us an inevitable involvement (care) of people living nearby. Therefore, the work delivers lessons for redesigning today's often-anonymous, technical driven water management systems into more communal, resilient, ecological divers and multi-functional public spaces.

The illustrative method (developed by I. Bobbink and M. Ryu 2017) was used as a starting point to analyze the rationality of the water management, its spatial appearance as part of the landscape and the way people constructed and used the water systems over time. During the research in the first edition of the CWS lab (2018-2019), a fixed content table and drawing legend for all projects were developed. Within the second edition of the CWS lab a glossary categorized by water landscape elements, waterworks and water stories is added. Water landscape elements are components of a water system made with a material like, soil, stones etc. that manipulate the water flow. Waterworks are built structures, like sluices, weirs, pumping stations of different materials



Dr. ir. Inge Bobbink

involving a certain amount of craftsmanship. Water stories are about the involvement of people towards the water. These stories can be about the use: like fishing traps or gathering aqua plants or of spiritual nature: like a water temple or symbols which celebrate the art of guiding the water.

In the sets of drawings of the projects from the second edition, the elements of the glossary are used for the circularity drawing, in which the system, with its tangible and intangible aspects, are illustrated in a holistic way. It is precisely this circularity drawing which makes us understand that the water system is the engine of a specific living water landscapes. To organize the sequence and intensity of the drawings of all projects, in the same way, allows us to compare the traditional water systems once the lab continuous for several years and enough material is gathered.

Anyway, within the framework, there is freedom for the students to develop their hand-writing and change the order of the sequence. All projects are pointed out on the world map.

Each set of drawings consist of:

**Context** - a short introduction and description of the project;

**Catchment area** - the water system on the regional scale combined with the topography map;

**Transformation** - a sequence of the system showing its development over a more extended period;

**Human interaction** - photos of the past and/or today in which actions in relation to water are indicated;

**Climate** - a diagram of climate zone combined with precipitation over the year;

**Water system** - a technical water management drawing;

**Circularity** - section-diagrams in which the interaction between water system, people and ecology is explained (related to time aspect);

**Detail** - to understand more about the making of (design) of the traditional water system;

**Glossary** - water landscape elements, waterworks and water stories, including people as scale reference and to show the

interaction;

**Conclusions** - a list of values and lessons to be learned. The analyses on the values are based on heritage values of the PhD work of G. Rivero-Lamela (2018) and altered by I. Bobbink.

**Landscape values** - natural landscapes are transformed to cultural landscapes, by doing so, the natural landscape is architectonically pronounced and is part of our cultural expression.

**Strategic values** - smart use of the site to achieve maximum profitability with the minimum resources and infrastructures by taking advantage of natural elements, topographic changes, slopes, river bends...

**Functional values** - water systems are constructions with simple formal and practical solutions.

**Material and tangible values** - water elements and waterworks are a source of knowledge of construction techniques, materials from the surrounding area are used that adapt to climate and lithology, expression of rituals.

**Values of sustainability** - Using regional materials (non-polluting materials) to make for examples the waterworks, maintaining and repairing them whenever needed. The water stays as long as possible in the system and is used for different purposes (from clean to dirty) and brought back into the natural circuit, preferably through filters.

**Ethnographic and identity values** - to encompass the knowledge of what was the main activities of the region.

**Lessons to learn** - The graduation lab focuses on the spatial, ecological and interactivity of human-made water systems. The outcome of the research is a source of knowledge and inspiration for future design.

Lately, the focus of the research towards composition and systems includes people's behavior as being the water workers, managers and users of a water system. By involving communities of a specific region in the management of water systems the relation towards the water becomes less anonymous. The relationship can take on a more nurturing form, based on a better understanding of the natural cycles and ongoing adaptations.

The graduation lab CWS is part of the research theme Circular Water Stories (research leader Dr. ir. I. Bobbink) embedded in the research-portfolio "Composition and Systems" of the section Landscape Architecture, TU Delft. The research is already going on for several years and puts water systems as a vivid part of the landscape in the center of attention.

This booklet is a selection of CWS work of the graduation year of 2018/2019 and 2019/2020. The projects are organized geographically. The first project is located on the American continent, from there the order moves to Europe, Asia and Australia. At the end of the booklet different water elements of these Circular Water Stories are presented as part of the Glossary (p. 142).

## References.

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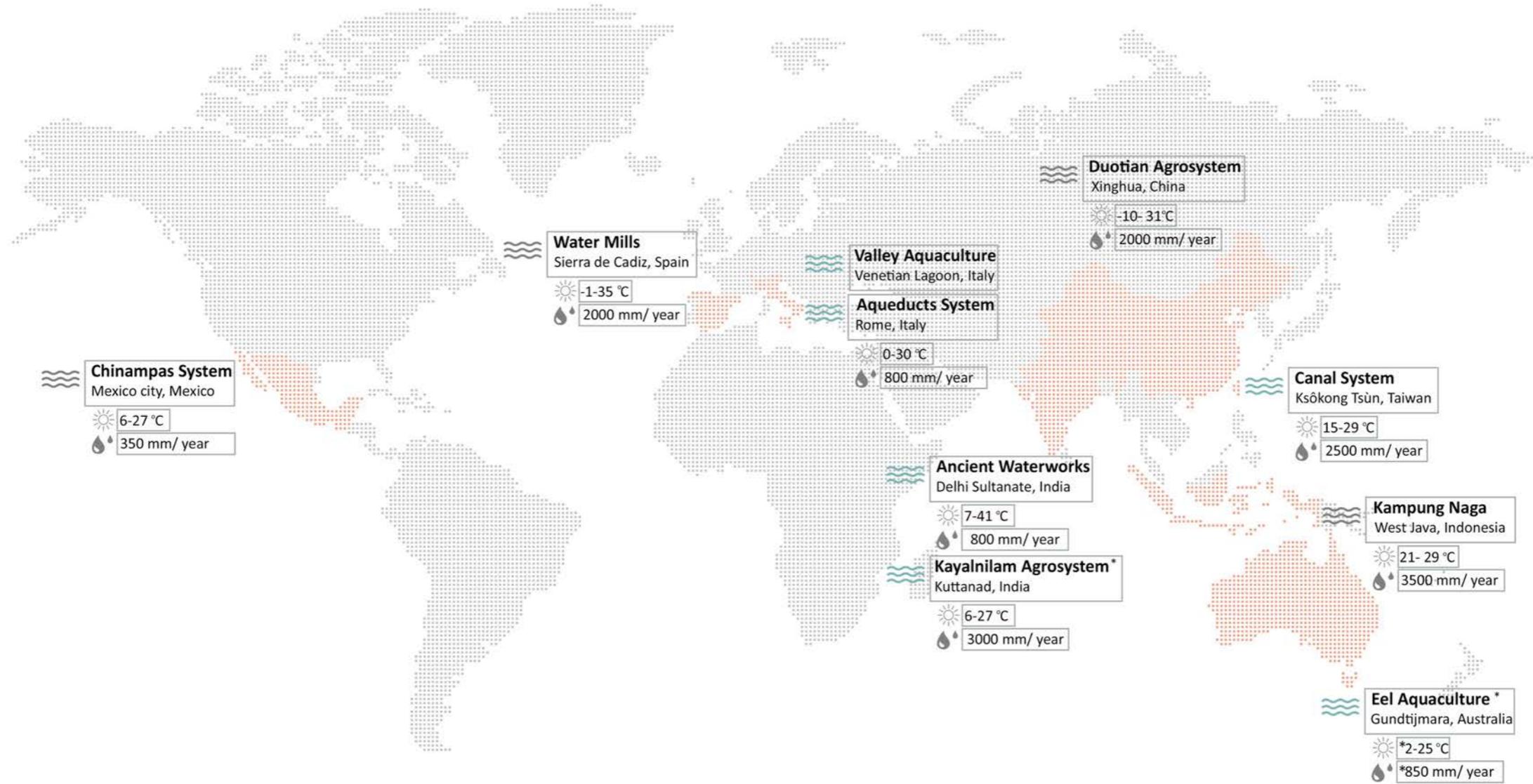
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 **2018-19**  
 **2019-20**  
*Work in progress*  
 \* **Climatic Data**  
*when the traditional water system was documented*



# People.



Catalina Rey Hernández from Concepción, Chile  
Landscape Architect driven by the development of innovative urban-landscape designs related to challenges of urban pressure, climate change and landscape identity.

Chinampas agriculture in Mexico City, Mexico.



Gloria Rivero-Lamela from Cádiz, Spain.  
Researcher fellow in the University of Seville, addressing issues related to heritage landscape and rural architecture.

The water mills of Sierra de Cádiz in Andalucía, Spain.



Amina Chouairi from Milan, Italy.  
Graduated in Landscape Architecture interested in nature-based flood defense solutions and building-with-nature principles.

The fishing valleys for aquaculture in the Venetian Lagoon, Italy.



Camilla Di Nicola from Rome, Italy.  
Graduated in Landscape Architecture with an interest in nature-based solutions for urban water management.

The Roman aqueducts in Rome, Italy.



Tanvi Gupta from Delhi, India  
Graduated in Landscape Architecture interested in nature based solutions for dynamic landscape systems and urban water management.

The Delhi Sultanate Waterworks in Delhi, India.



Naeema Ali born in India and based in United Arab Emirates.  
Graduated in Landscape Architecture, social activist determined to build a symbiotic relationship between humans and nature through flexible and climate resilient landscapes.

The Kuttanad Kayalnilam Agrosystem in Kerala, India.



Ayu Tri Prestasia (left) from Yogyakarta, Indonesia.  
Landscape Architect interested in the integration of water, ecology and anthro-systems in landscape spatial strategies.

Boomi Kim (right) from Daegu, South Korea.  
Landscape Architect into the cultural relationship between people and nature and its influences on waterscapes.

The integrated living system of Kampung Naga in Tasikmalaya, Indonesia.



Paan Rapa Surajaras from Bangkok, Thailand.  
Landscape Architect passionate in water-related issues and human behavior. Currently Landscape Architect at Defacto architecture and urbanism.

The Xinghua Duotian Agrosystem in Xinghua, China.



Sandy Man-Chuan Lin from Kaohsiung, Taiwan.  
Landscape-graduate-to-be with the strong belief that people involvement is the key to an authentic place.

The Ksôkong Tsùn Irrigation System in Kaohsiung, Taiwan.



María José Zúñiga from San José, Costa Rica.  
Graduated in Landscape Architecture with an interest in resilient coastal landscapes.

The aboriginal eel aquaculture system in Gunditjmarra Country, South West Victoria, Australia.

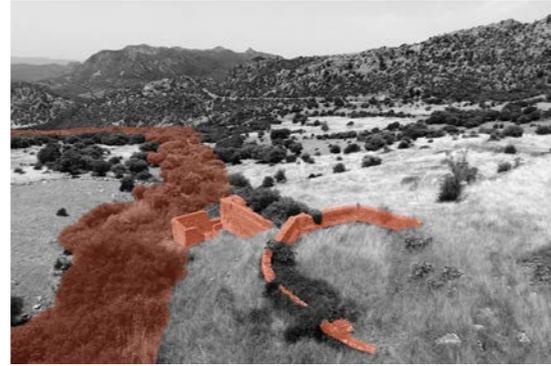
# Projects.



Chinampas Agriculture System (floating gardens)

Land and water management for agriculture and settlement patterns of land reclamation.  
Mexico City, Mexico.

Catalina Rey Hernández.  
Page 11



Water Mills (energy source)

Water as a driving force in the historical production of staple food, bread.  
Sierra de Cádiz, Andalusia, Spain.

Gloria Rivero-Lamela.  
Page 27



Fishing valleys (extensive production)

A traditional extensive aquaculture system of embanked valleys, located along the border of the Venetian Lagoon.  
Venetian Lagoon, Veneto, Italy.

Amina Chouairi.  
Page 39



The Roman Aqueducts (water transportation)

A system of pipes, canals, and supporting structures used to convey water from its source to its distribution point.  
Rome, Lazio, Italy.

Camilla Di Nicola.  
Page 53



Delhi Sultanate Waterworks (water storage)

Ancient network of water harvesting structures.

Delhi, India

Tanvi Gupta.  
Page 65



Kuttanad Kayalnilam Agrosystem (agricultural polders)

A traditional paddy farming system below sea level.

Kerala, India.

Naeema Ali.  
Page 77



Kampung Naga (integrated water system)

Water as a driving source for creating circular water supply and sanitation system.  
West Java, Indonesia.

Ayu Tri Prestasia & Boomi Kim.  
Page 89



Xinghua Duotian Agrosystem (cut and fill farming)

A traditional water-land utilization technique developed by Chinese ancestors.  
Xinghua, China.

Paan Surajaras.  
Page 105



Ksókong Tsùn Irrigation System (production)

A traditional irrigation system that set the foundation of Kaohsiung City.  
Kaohsiung, Taiwan.

Man-Chuan Sandy Lin.  
Page 121



Aboriginal aquaculture (subsistence production)

Eel aquaculture, Gunditjmarra Country. Aboriginal eel aquaculture system.  
Gunditjmarra Country, South West Victoria, Australia.

María José Zúñiga.  
Page 133





# Chinampas Agriculture System

Floating gardens of the Aztec Empire of  
the city of Tenochtitlán.

Catalina Rey Hernández

- 01
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Figure 1: Floating gardens of Xochimilco.

# Context.

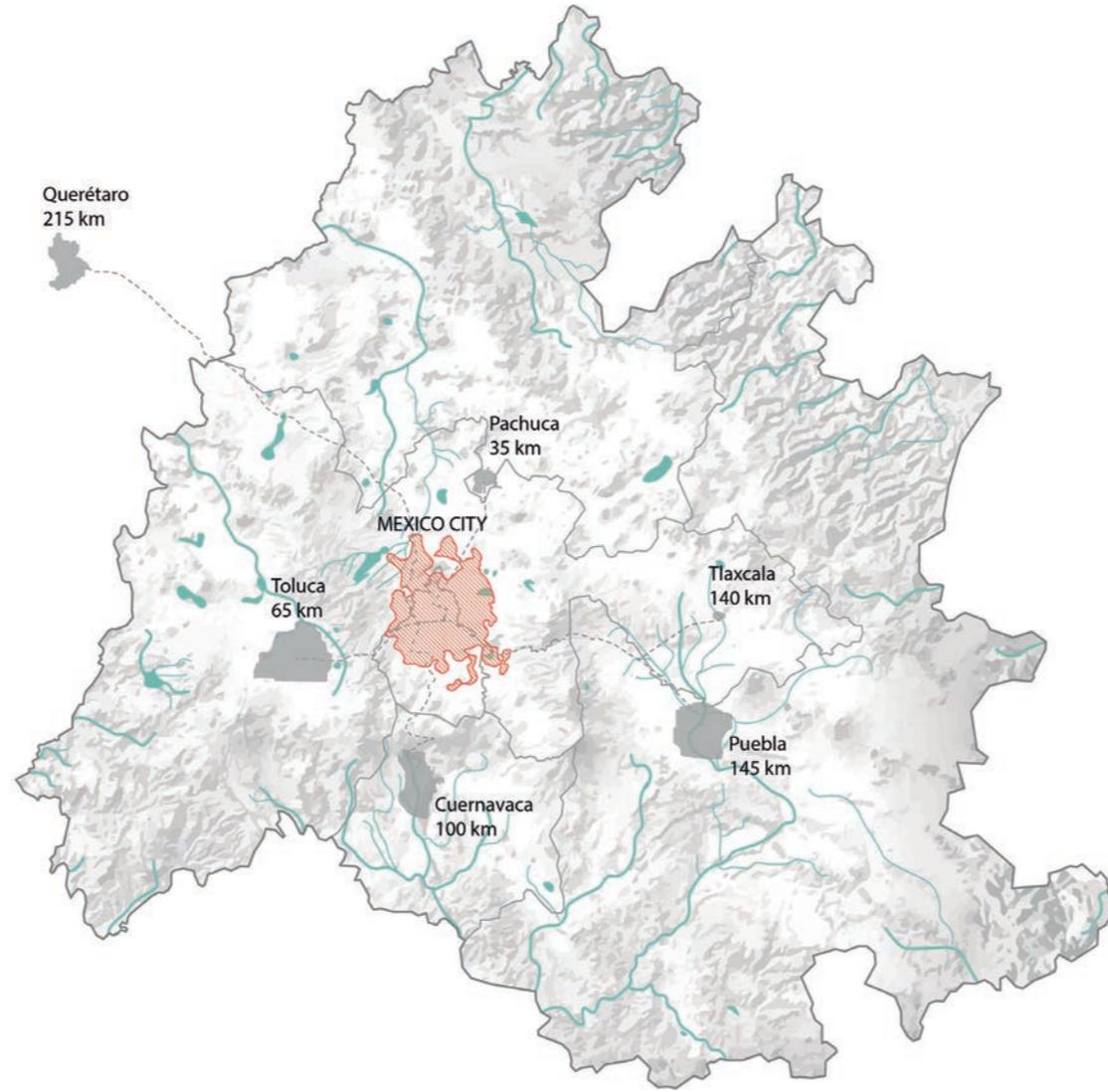
Location: Mexico City, Valley of Mexico.  
Landscape Type: Former lake basin.  
Area: 150.000 ha (originally).  
Function: Agriculture, land reclamation.  
Water Quality: Fresh and Brackish water.  
Dynamic: Seasonal Flooding

The Valley of Mexico is a highlands plateau, located in the Trans-Mexican Volcanic Belt. It contains most of the Mexico City Metropolitan Area. The valley has a minimum elevation of 2.200 meters above sea level and it is surrounded by mountains and volcanoes that reach elevations of over 5.000 meters.

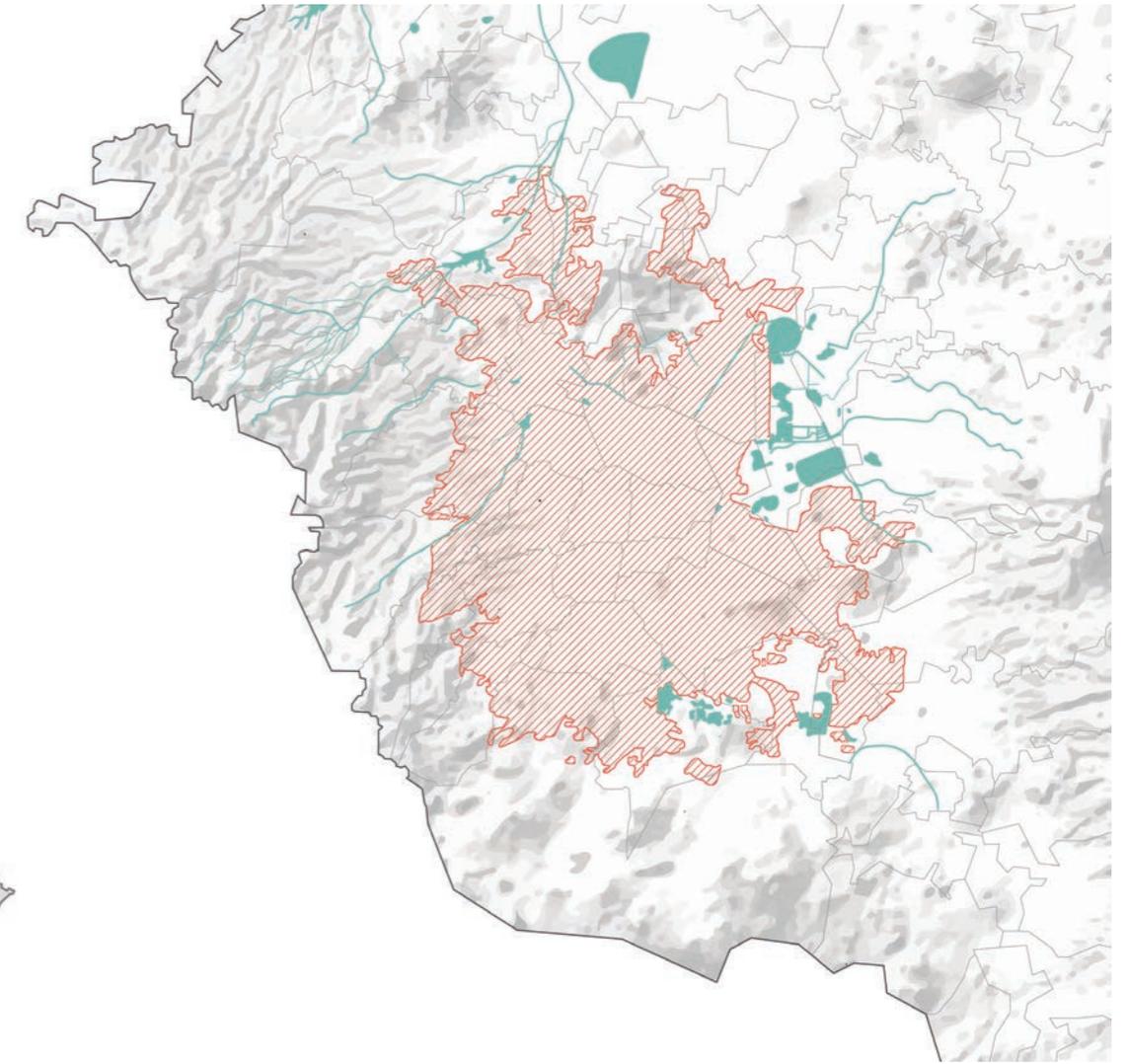
Hydrologically, it is an enclosed valley containing the bed of five lakes which are currently extinct. The lakes did not have a natural outlet for water to flow, leading to several floods in the area. The Spaniards decided to drain the former lake-beds to make the city safer, thus transforming the lacustrine landscape into a valley.



**Figure 2**  
Mexico



**Figure 3**  
Valley of Mexico

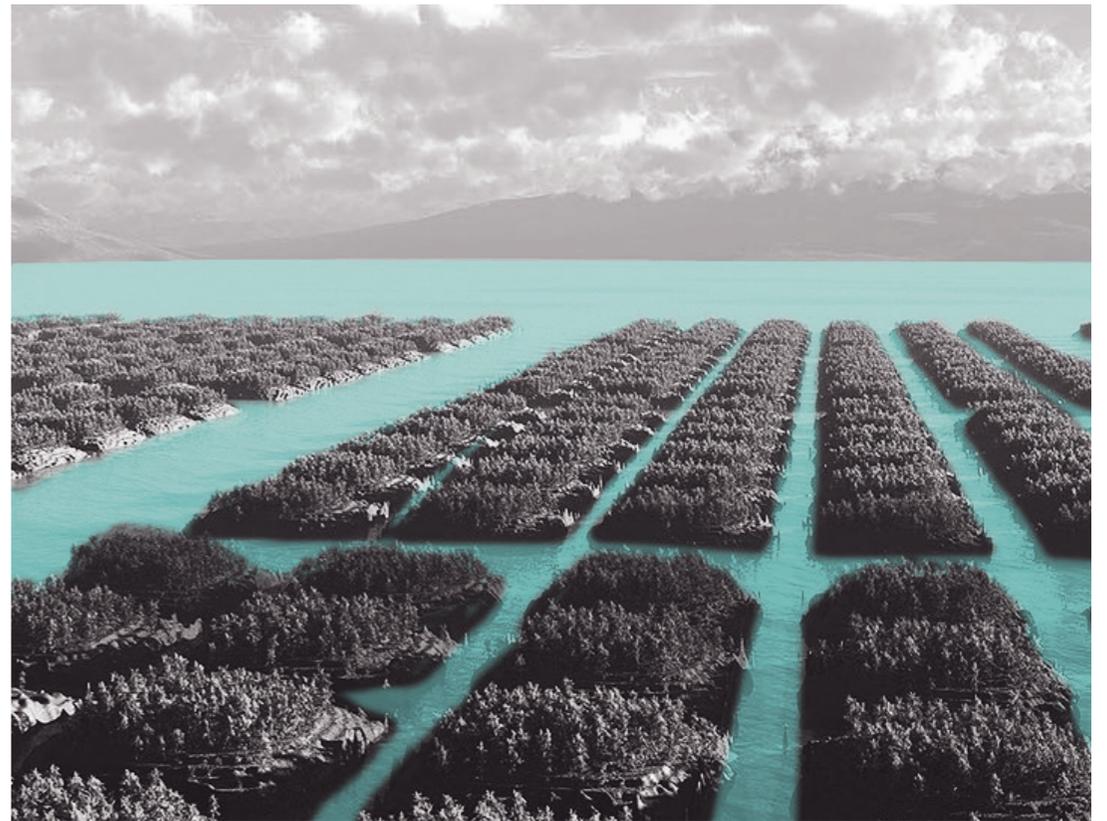
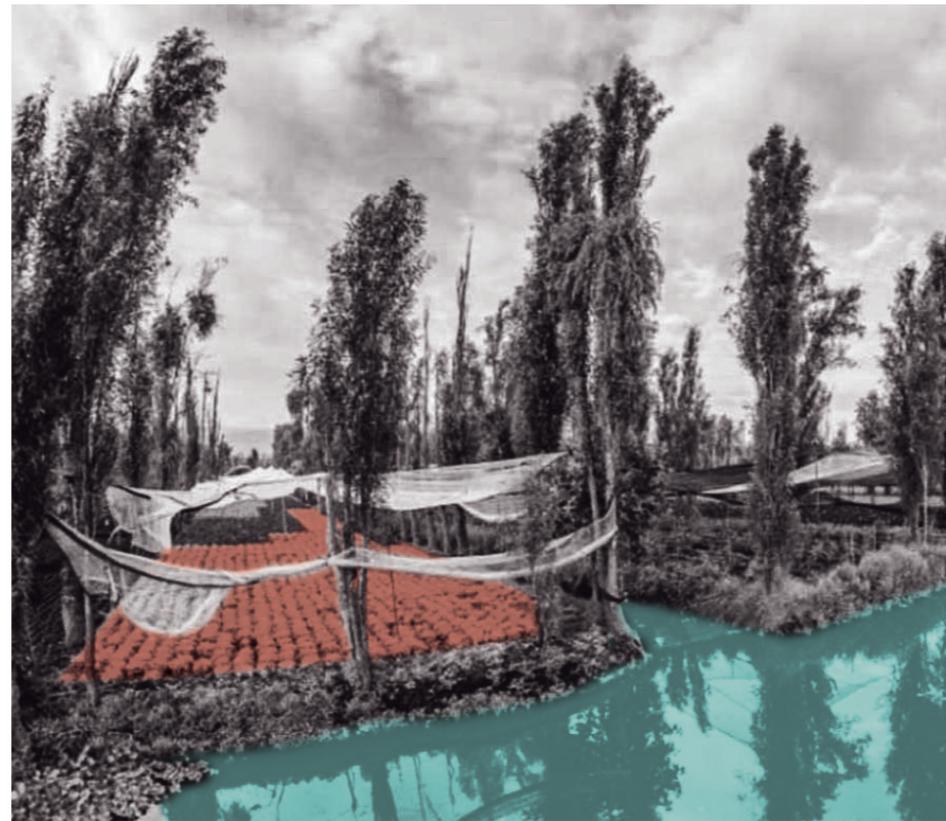


**Figure 4**  
Metropolitan area of Mexico City

# The Floating Gardens.

Chinampas, also known as floating gardens, are an ancient Mesoamerican water system for agriculture and territorial expansion. This was done through a raft covered with soil which was used to cultivate vegetables and flowers as well as to expand the territory on the water surface of lakes and lagoons of the valley of the city of Tenochtitlan, Mexico, converting it into a floating city.

The origin of chinampas started with one of the main problems that the Aztecs faced: lack of land to build their houses. Tenochtitlan island didn't have enough room for all the inhabitants. Therefore, they fixed this situation by extending those parts of the island where the water was shallow by reclaiming land with alternate beds of reeds and mud taken from the bottom of the lagoon. While the inhabited islands could be enlarged, other lands could be created to support wildlife for hunting and gathering, while other Chinampas served as extensive gardens.



**Figure 5** Chinampas agricultural system (top left).

**Figure 6** Aerial view of current situation of land reclamation through Chinampas system (top middle).

**Figure 7** Palisade: Detail of the construction of the fenced boundary of a Chinampa (top right).

**Figure 8** Cultivation nurseries and channel system (bottom left).

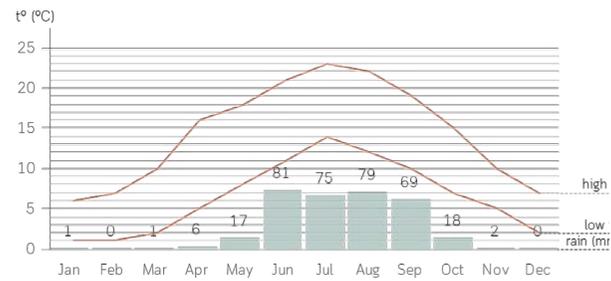
**Figure 9** Actual use and "re invention" of the Chinampas water system (bottom right).

# Climate.

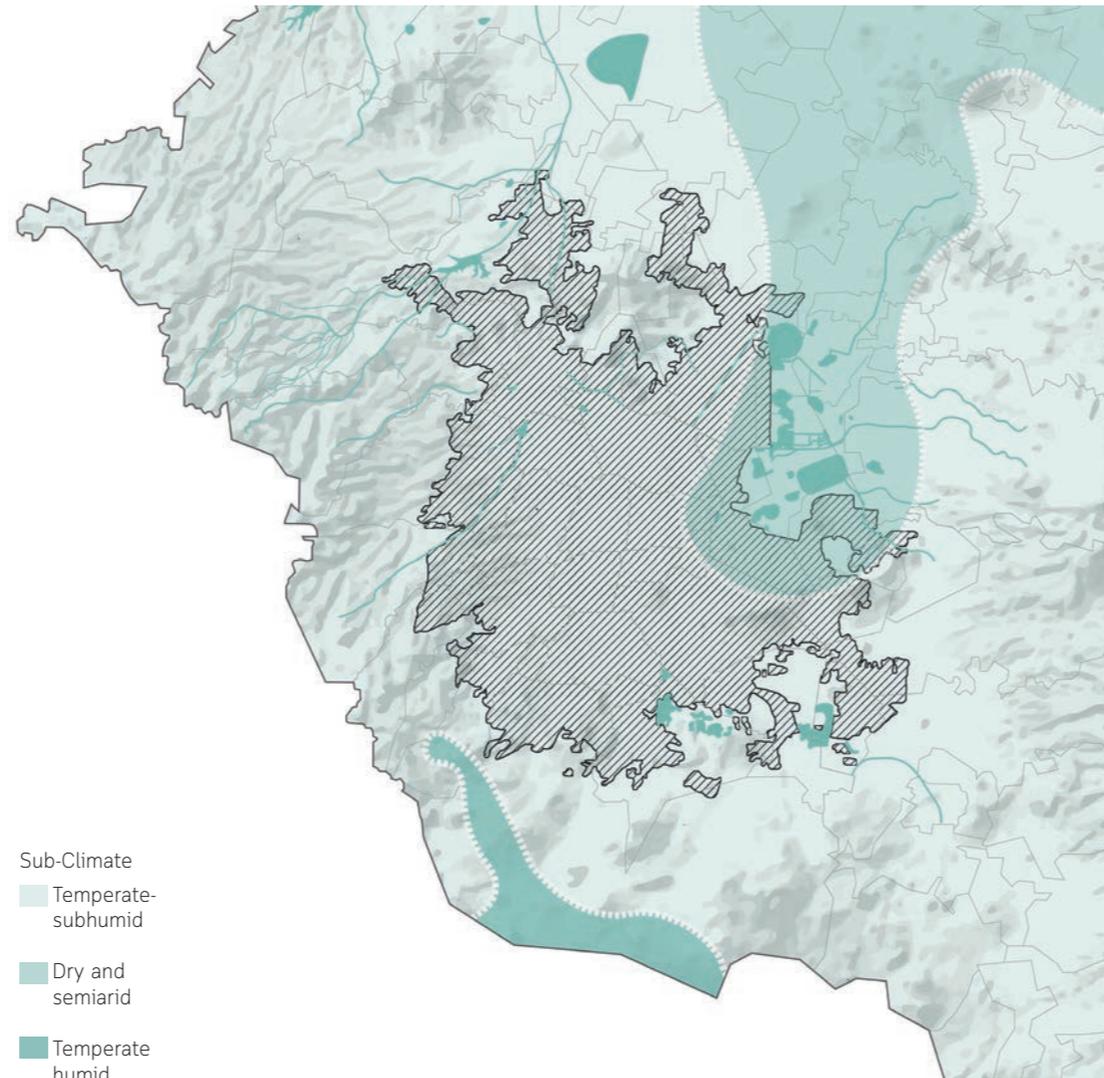
**Climate zone:** Subtropical  
**Sub-climate:** Temperate sub-humid  
 Dry and semi-dry  
 Temperate humid

## Climate & Weather Averages

High t°: 27°C  
 Low t°: 6°C  
 Mean t°: 17°C  
 Precipitation: 29.0 mm  
 Humidity: 54%  
 Dew point: 6°C  
 Wind: 10 km/h  
 Pressure: 1009 mbar  
 Annual Rainfall: 347.8 mm per year

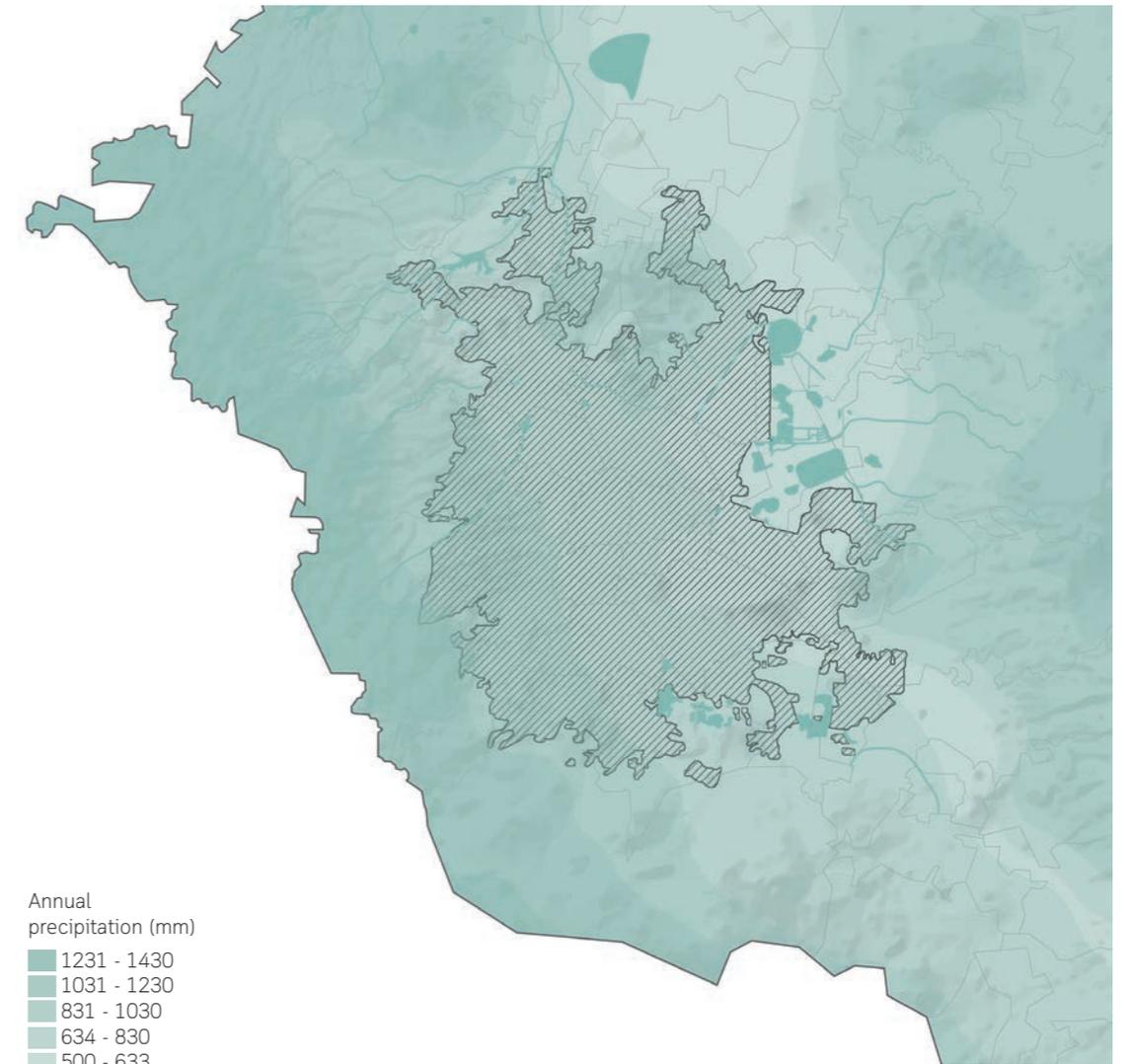


**Figure 10**  
 Temperature and amount of rainfall



Sub-Climate  
 Temperate-subhumid  
 Dry and semiarid  
 Temperate humid

**Figure 11**  
 Sub-climates of the Valley of Mexico



Annual precipitation (mm)  
 1231 - 1430  
 1031 - 1230  
 831 - 1030  
 634 - 830  
 500 - 633

**Figure 12**  
 Annual precipitation of the Valley of Mexico

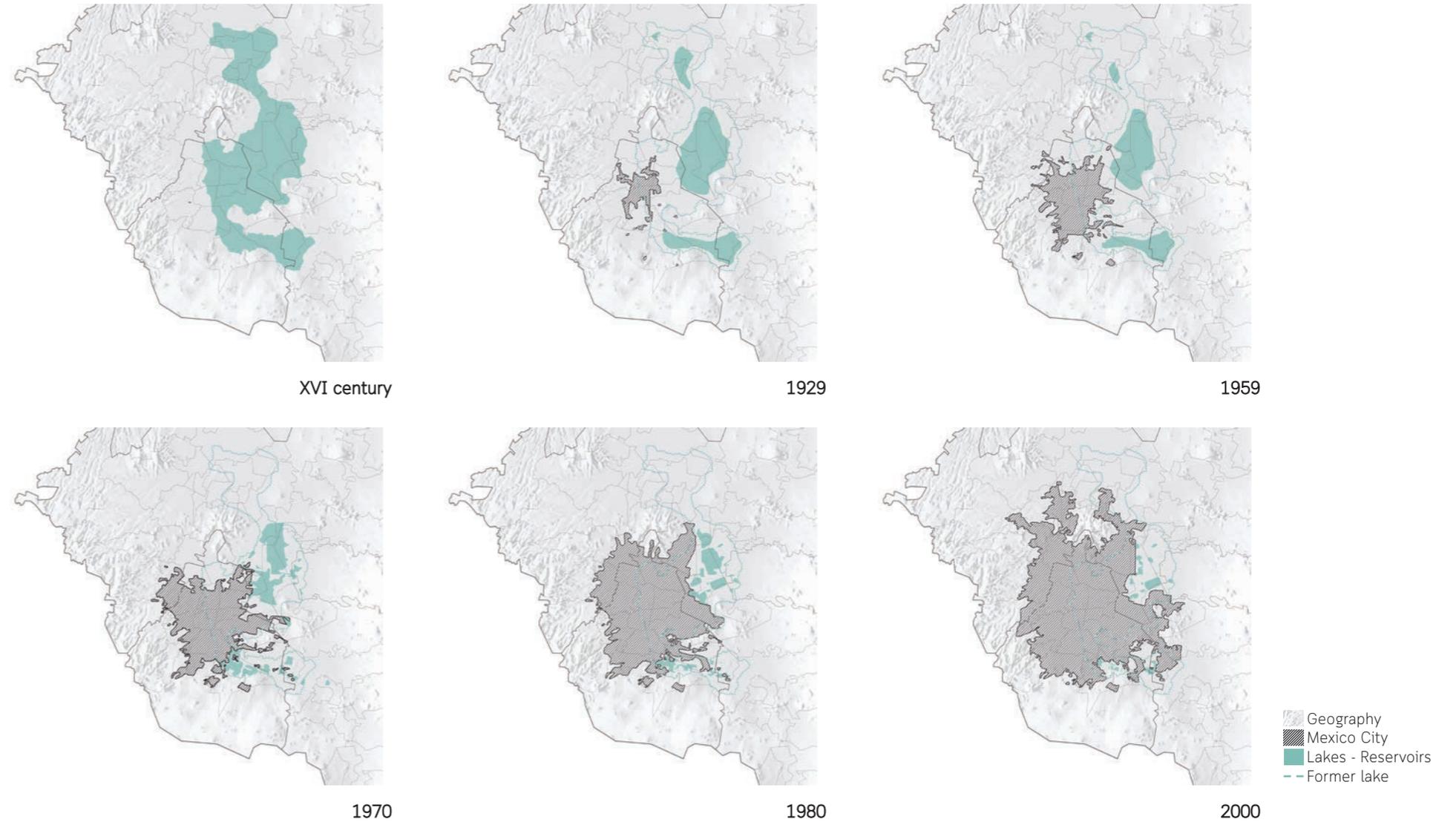
# Landscape transformation.

Transformation of the hydraulic system due to the drainage of the former lakebeds transformed the lacustrine landscape into a valley one.

During the colonial period, Europeans introduced a new economy, new issues of political control and new religious perspectives, that led to 2 major changes:

1 - Draining of the lakes, that lasted nearly 4 hundred years starting at the beginning of the 17th century with the construction of channels to deviate the rivers and prevent flooding: the lacustrine environment became a valley.

2 - Introduction of European plants and flowers, changing the variety of crops that the Aztec managed to grow together in the same Chinampa.



**Figure 13** Development of the city and reduction of the lacustrine system from the XVI century to 2000.

# Catchment area.

## Chinampas distribution in the Valley of Mexico in 1519

Since the beginning of their civilization, Aztecs had mastered hydraulic technology such as dikes and water control systems to maintain the water levels. Because the basin was closed, heavily mineralized sediments accumulated in the lakes, making the waters nitrous and harmful to plants and humans. Furthermore, fluctuations in stream discharge

rates, coupled with periodic droughts, radically altered lake levels, resulting in flooded or dry chinampas plots.

To prevent damage by floods or salt contamination, dikes or causeways spanned across portions of the lakes. Effectively separating the embayment from the greater body of the lake, the dike promoted chinampa cultivation and the development of potable water supplies.



## Chinampas distribution in the Valley of Mexico today

When the Spaniards arrived, the natives could not be controlled and the chinampas zones were not possible to have a registered land and it was impossible to tax mobile lands, therefore, the Spaniards ordered all the floating gardens to be fixed to the bottom of the lagoon with Ahuejotes trees (*Salix bonplandiana*).

The draining process that started after the conquest continues to the present with extracting the water through clandestine wells. This systematic drainage and drying of the lacustrine zone has modified the traditional chinampa techniques, as well as the use of the cultural landscape. It is possible to conclude that the chinampa tradition managed to survive, in spite of the Spaniard draining of the basin of Mexico.

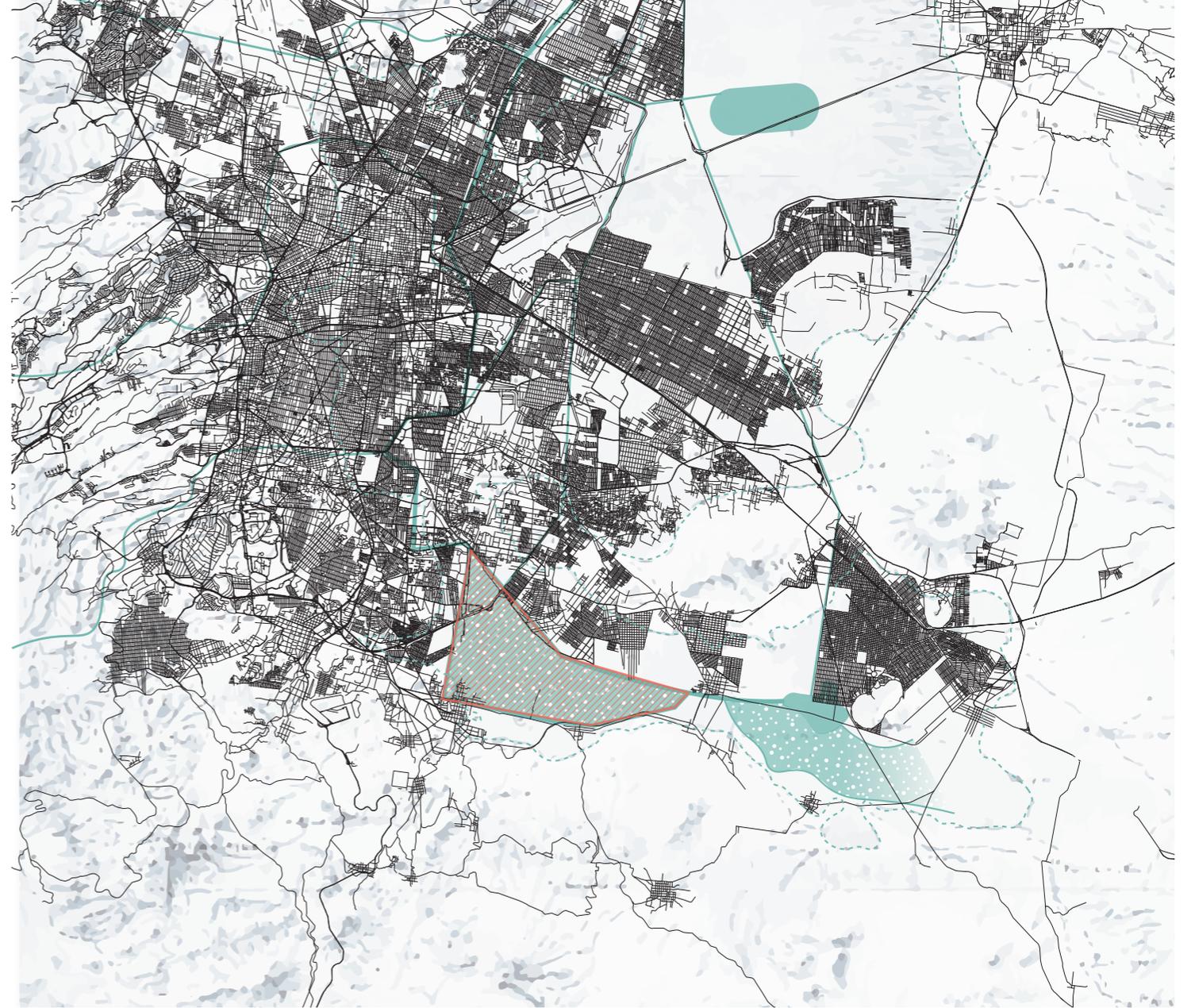




**Figure 14**  
Catchment area of the Valley of Mexico in 1519



- Brackish water
- Fresh water
- River courses
- Marshes
- Chinampas
- Causeways
- - Dam



**Figure 15**  
Actual system of canals, retention basins and Chinampas in the Metropolitan area of Mexico City

- Water retention
- Chinampas
- Channels
- City pattern

# Water system.

In the lacustrine zone of the Xochimilco and Tlahuac delegations are the last agricultural relicts of Chinampas.

At present, these zones and other agricultural systems associated with lacustrine soil, have been overtaken by urbanization becoming an enormous island of traditional urban agriculture in the middle of Mexico City.

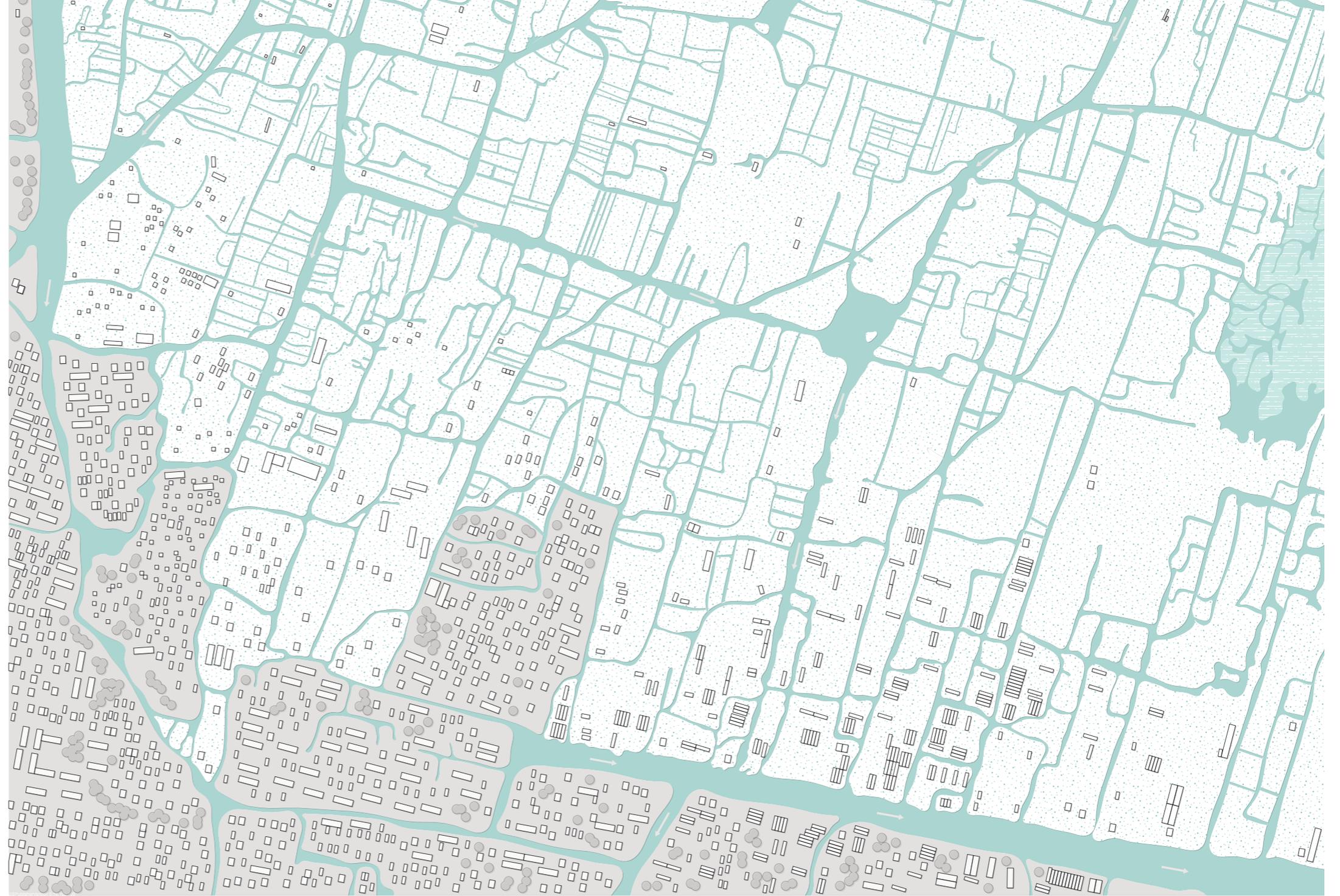
In this area, a variety of vegetables and ornamental plants continue to be cultivated, productive activities have diversified, creating conditions for the development of the local economy as well as the provision of goods and services for the city. Tourism, stabled livestock, backyard crops, greenhouse horticulture and Chinampas horticulture are the main activities associated with the conservation of soil.

The original chinampas plots have been merged together due to the land reclamation as it can be seen in the bottom left part of Figure 17, where those areas are becoming bigger land plots in order to host new zones of urbanization. However, in the center of the water system (Figure 17) it is still possible to identify the characteristic long and narrow plots of the original chinampas.

**Figure 17** Actual Chinampas water system on the Xochimilco area.



**Figure 16**  
Analysed sub-watersystem of the Xochimilco agricultural Chinampas



- Chinampas Watersystem (Crops)
- Land Agriculture
- Water courses - Canals
- Marshes
- Houses



# Chinampa cultivation system.

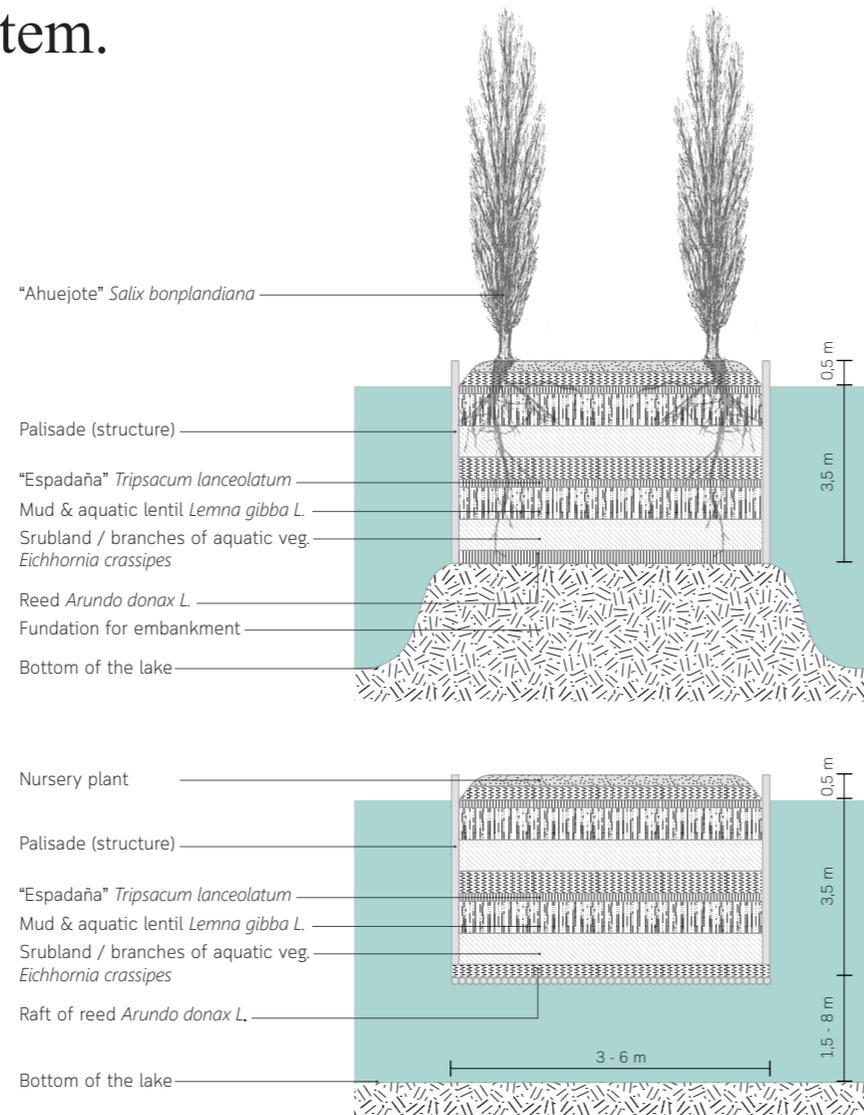
Chinampas were artificial islands from about 15 to 30 m long and 2,5 to 6 m width, created by staking the shallow lake bed and then fencing in the rectangle with wattle.

The fenced area was then layered with mud, lake sediment, and properly selected topsoil with biodegradable materials such as grass, leaves, husks of different fruits and vegetables, etc. that eventually bring it above the level of the lake.

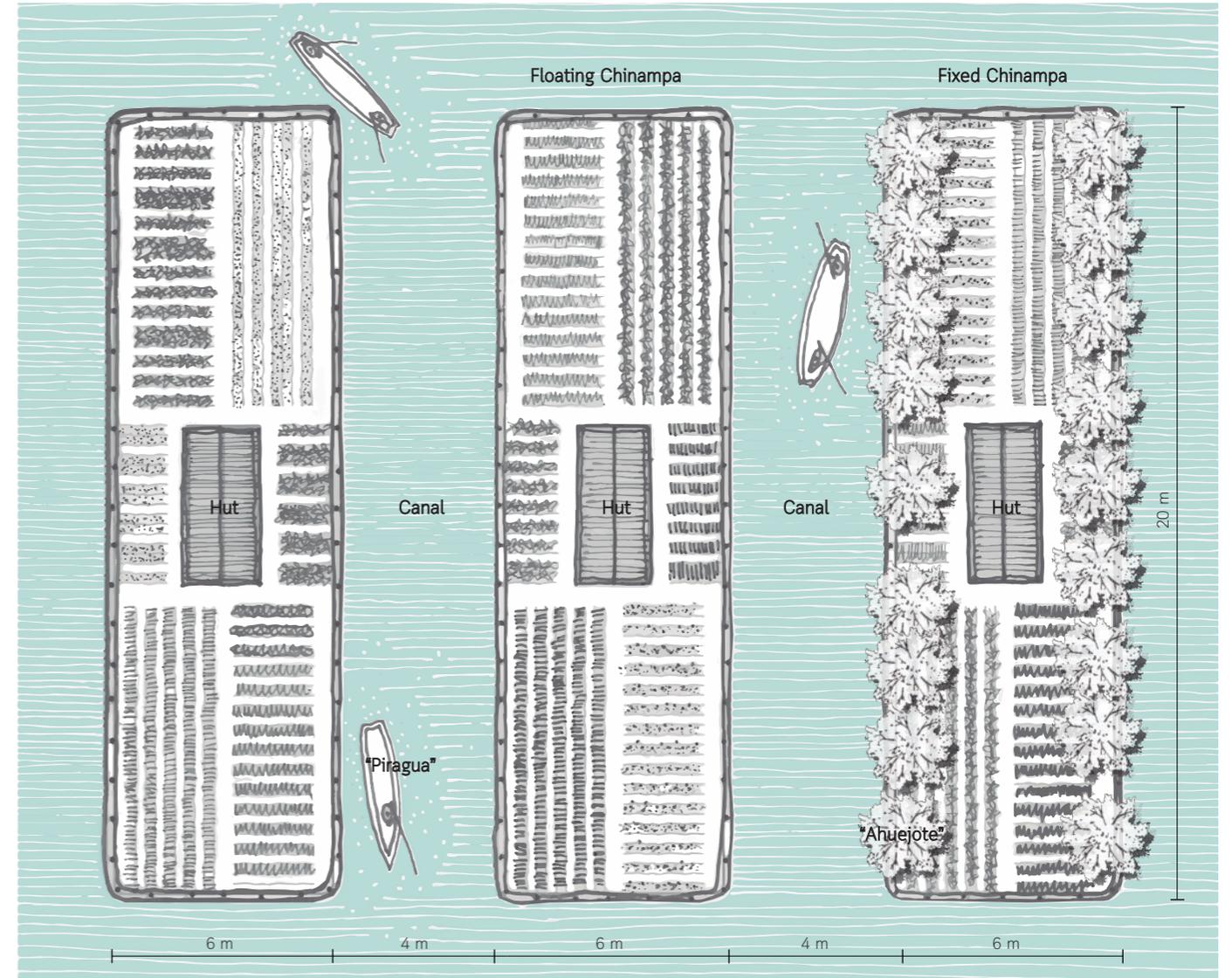
Furthermore, trees such as *Salix bonplandiana* and *Taxodium mucronatum* were planted at the corners to secure the Chinampa. Each Chinampa were separated by channels wide enough for a canoe to pass. These islands had very high crop yields with up to three crops a year.

On the fields of corns in the chinampas, Aztecs used to build a kind of stick turrets, where a man, protected from sun and rain, watched and hunted with a sling the birds that went there to damage the Chinampas.

The floating orchards were where their efforts went further. These plant nurseries were made in movable sections that measured between 6 and 9 m in length and the width that they desired, founded on the water over aquatic grass, rush and reed. Then, they tied them with ropes to take them from one place to another in the lagoon. On these mobile islands, or floating gardens, they made the nursery of their vegetables to be transplanted later to the fixed chinampas.



**Figure 18** Section of a fixed Chinampa (top left).  
**Figure 19** Section of a floating Chinampa (bottom left).  
**Figure 20** Plan of a Chinampa cultivation system (right).



With the development of this system, the farmers were able to grow different kinds of crops all together in one Chinampa, obtaining an abundant production to feed the occupants of the large urban centers.

Originally, Chinampas have been the source of all cereal, fruit, vegetable and flower riches for the Mexicas - Aztecs, and allowed the expansion of their cities around the lakes of the Basin.

Now, Xochimilco stands out for two kinds of cultivation: production of bedding plants for later transplant to the mainland that fulfills a significant economic role, and production of flowers, important both for economic and symbolic reasons.

The most cultivated species (among others):

- |                 |                                       |
|-----------------|---------------------------------------|
| Crops           | Fruits                                |
| - Maize or corn | - Avocado                             |
| - Zucchini      | - Guava                               |
| - Onions        | - Camote                              |
| - Garlic        |                                       |
| - Tomatoes      | Flowers:                              |
| - Beans         | Religious importance.                 |
| - Pumpkins      | - Amaranthus leucocarpus              |
| - Spinach       | - Tagetes erecta (flower of the dead) |
| - Radish        | - Didymaea mexicana                   |
| - Lettuce       | - Talauma mexicana                    |
|                 | - Vanilla fragans                     |
|                 | - Dahlia coccinea.                    |

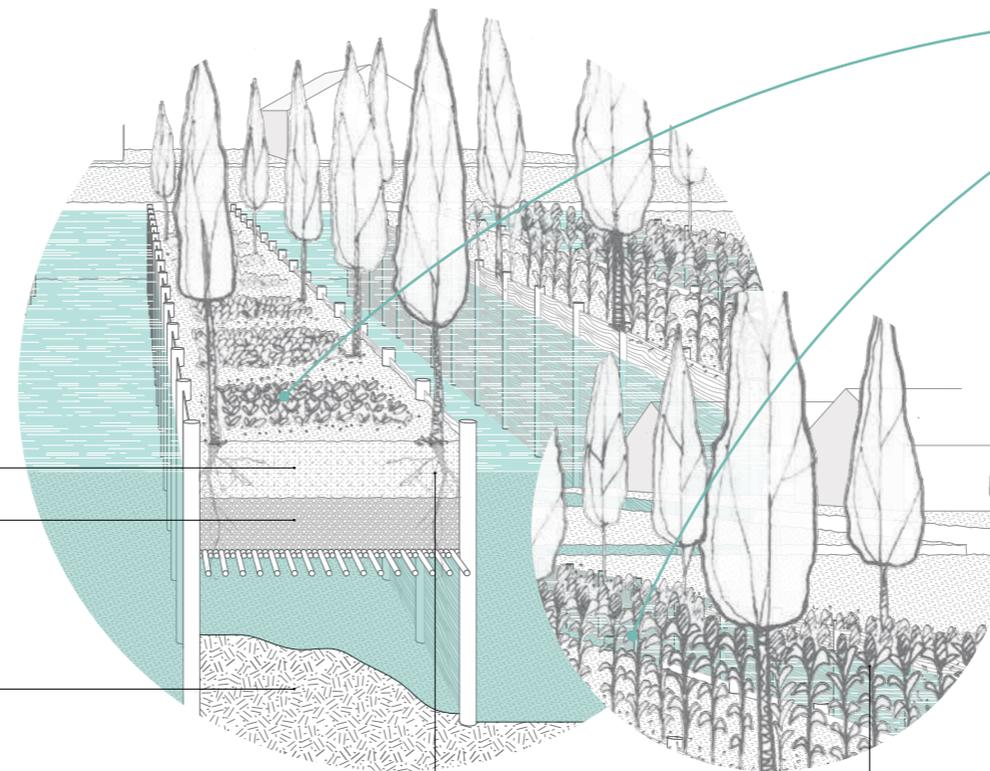
The roots, mud and organic waste of previous harvest allow to use and reuse a 100% of the resources from the Chinampa.

An organic layer of branches of aquatic vegetation allows water to filter and soak the upper soil layers.

The Chinampas help with the retention of water through filtration to the subsoil, avoiding erosion and subsidence.

The "Ahuejotes" roots expand horizontally without much depth, interlacing the layers of mud and reeds to prevent the soil from falling apart.

Due to its composition and materiality, the Chinampa allows a uniform humidity throughout its structure, which benefits the growth and variety of crops.



Variety of Crops in the same Chinampa:

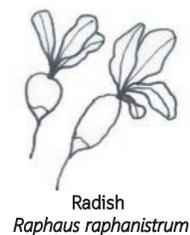
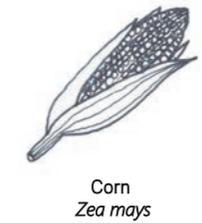


Figure 21 Section of a Chinampa (middle).

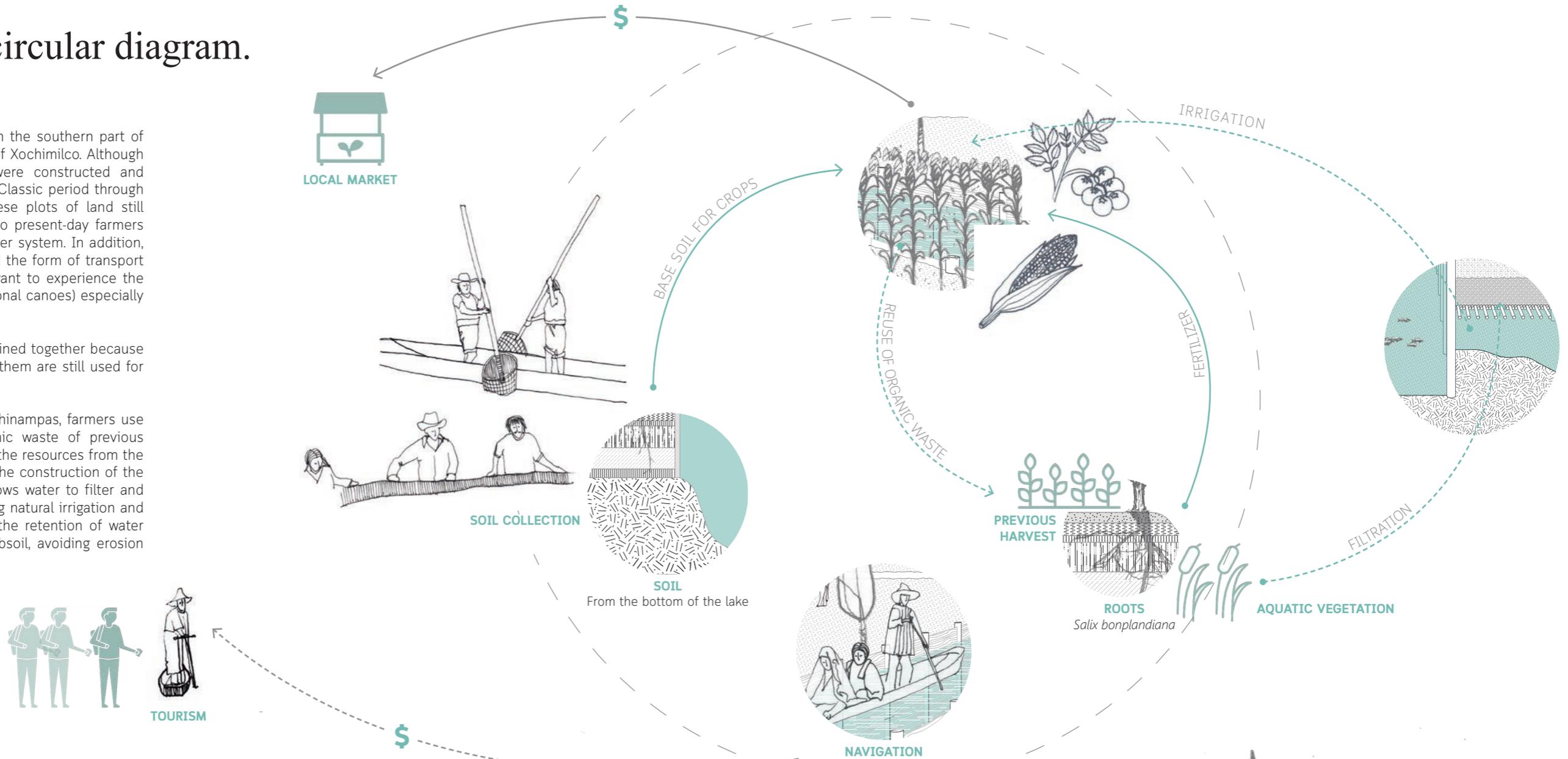
Figure 22 Most cultivated in the Chinampa agricultural system (left).

# Water system circular diagram.

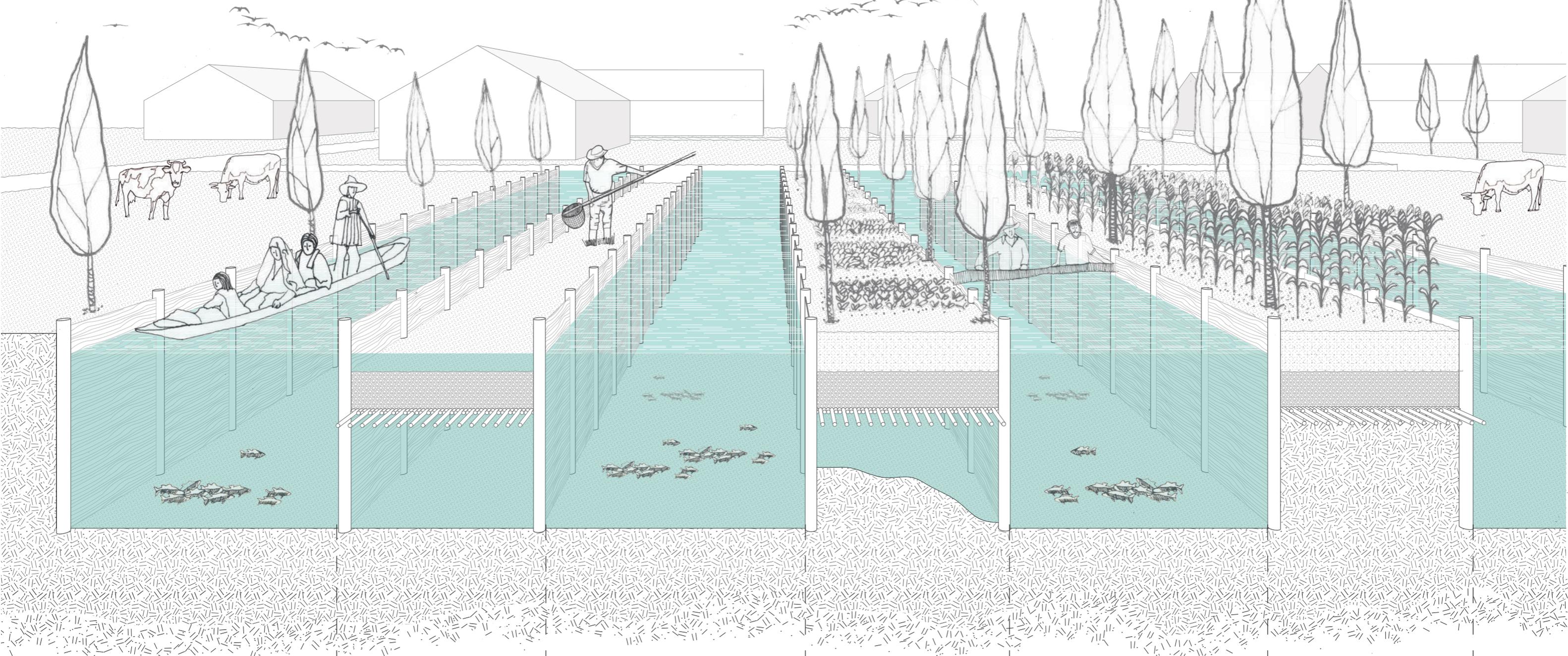
Today, Chinampas are still present in the southern part of the Valley of Mexico, on the canals of Xochimilco. Although many of these floating gardens were constructed and thoroughly tended to from the Post-Classic period through the Spanish conquest, many of these plots of land still exist and are in active use thanks to present-day farmers that have revived this traditional water system. In addition, the traditional way of cultivation and the form of transport have attracted many tourists who want to experience the Chinampas, through piragüas (traditional canoes) especially to see flower nurseries.

Although many fields are naturally joined together because of drying up of the canals, some of them are still used for agriculture in a sustainable way.

In order to maintain and built the Chinampas, farmers use roots, lake bottom mud and organic waste of previous harvest to use and reuse a 100% of the resources from the fields. The use of organic matter in the construction of the layers of the agricultural system allows water to filter and soak the upper soil layers, generating natural irrigation and at the same time the system help the retention of water through its filtration through the subsoil, avoiding erosion and subsidence.



**Figure 23** Circularity of the system - Representation of sustainability.  
**Figure 24** Section perspective of the Chinampas water-system (bottom).



Development of the Chinampa water-system

Basic structure of a Chinampa (1° stage)

Navigation canal

Crops growth & mud collection (2° stage)

Navigation canal

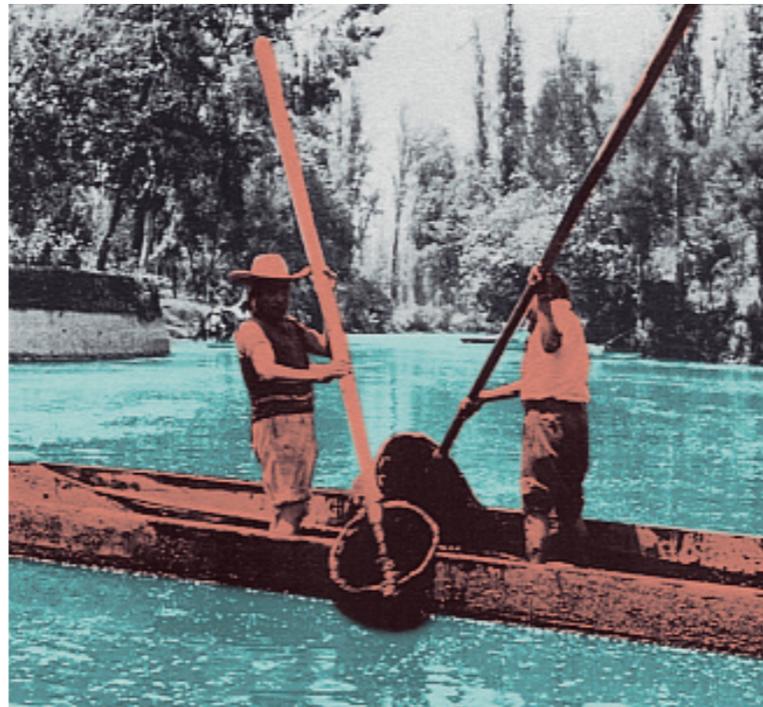
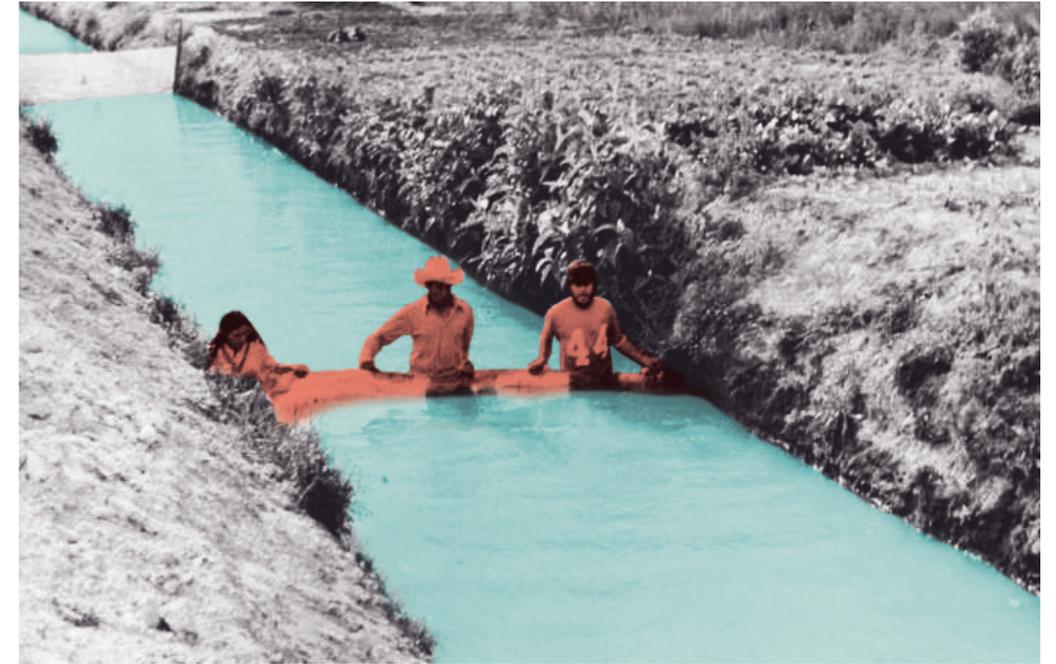
Fixation of the Chinampa (3° stage)

## Traditional methods.

"(...) they make their farming (...) fetching grass in canoes from dry land, throwing them into the water until it is about four to five feet thick, and rises about one and half foot above the water being between eight and twelve feet wide. And the natives make a farm out of a number of them, go in their canoes, growing up herbs and profiting in a way that had not been seen before."

"(they) are built in the water, stacking many alternated layers of reed and mud from the same lagoon, and making them at times very narrow (...) leaving one channel between two chinampas rising two feet or less above the water and carrying ears of corn that grow very big because they get water directly from the lagoon without need of rain falling from the sky and they also make seedbeds of corn in their chinampas producing young plants to be later transplanted according to a very common practice in that land."

Father Alonso Torquemada



**Figure 25** "Chinampero" collecting mud (top left).

**Figure 26** Cleaning of the Chinampas channels (top right).

**Figure 27** Collection of mud from the bottom of the lake for Chinampas soil (bottom left).

**Figure 28** Use of the channels for transportation (bottom right).

# Conclusion.

The Chinampas water system has been used mainly for crops and agriculture, but with the current situation of drainage and dry up of canals, many fields are naturally joined together, giving the possibility of new purposes as cattle feed and land reclamation for the extension of the city.

Nowadays, there is a new awareness of the landscape and economic value of this system, encouraging farmers to continue with the traditional agricultural methods. Thus, it is possible to conclude that the Chinampa tradition managed to survive, in spite of the Spaniard draining of the basin of Mexico. Yet significance changed completely.

**Landscape values** - The lacustrine landscape of the Valley of Mexico has been dramatically changed due to the drainage efforts in order to expand the city and avoid flooding events, creating a transition from a lacustrine to a mountain valley landscape. However, the Chinampas are the remains of the former landscape and the traditional and ancient understanding of it, generating a cultural landscape that rescues the water qualities of the former lakes.

**Strategic values** - Chinampas works as a smart use of the site to achieve maximum profitability with the minimum resources and infrastructures, by taking advantage of the natural wetlands that provide all the resources in order to generate more efficient crops, without using external sources of energy.

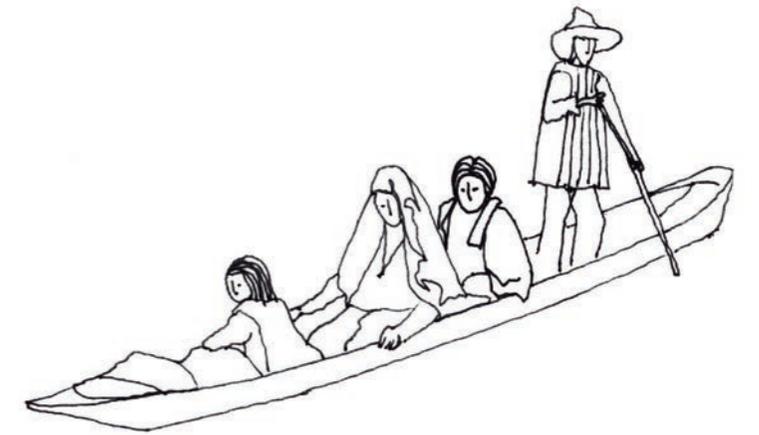
**Material and tangible values** - The structural elements of the system came from the knowledge of traditional construction techniques from the Aztec culture to get the maximum profit of the land. Furthermore, due to its composition and materiality, the Chinampa allows a uniform humidity throughout its structure, which benefits the growth and variety of crops.

**Values of sustainability and circularity** - The materials from the surrounding area provide a sustainable way of resource use, creating cyclic crop harvesting using the natural irrigation and filtration of the water. Thus the system uses the water existing in the site for natural irrigation bringing it back into the natural circuit

**Ethnographic and identity values** - As the system was created by the Aztecs, it is one of the most tangible legacy that the ancient people left to the modern farmers who maintain their identity as inhabitants of the valley of Mexico through the use and revival of the agricultural system of their ancestors.

**Lessons to Learn** - The analysis of Chinampas gives us a -forgotten- insight about a landscape-based method of settlement and urban expansion. Understanding this kind of water systems gives an important value to the circularity in the use of resources, making possible to create cyclic processes of urban and natural growth, where we can create new visions for cities and human settlements as part of the bigger natural and urban system.

By taking this landscape based methodologies as examples for new urban developments we can reformulate the role of landscape as a multi-functional provider, where natural entities such as wetlands and lakes can be seen and understood as potential areas for multi-functional development with cultural, economic and ecological value.



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## Illustration Credits

**Figure 1** Floating gardens of Xochimilco. [Image]. Retrieved from [https://mxcity.mx/wp-content/uploads/2016/06/mxcity.mx\\_chinampa-768x511.jpg](https://mxcity.mx/wp-content/uploads/2016/06/mxcity.mx_chinampa-768x511.jpg)

**Figure 2** Administrative map of Mexico. [Image]. Retrieved from [https://upload.wikimedia.org/wikipedia/commons/8/84/Mapa\\_de\\_Mexico\\_Yucatan.PNG](https://upload.wikimedia.org/wikipedia/commons/8/84/Mapa_de_Mexico_Yucatan.PNG)

**Figure 3** Valley of Mexico, developed from Echeverría, I. (2009). Parque Ecológico, Lago de Texoco. Retrieved from [http://www.parquetexcoco.com/descargas/presentacion\\_en.pdf](http://www.parquetexcoco.com/descargas/presentacion_en.pdf)

**Figure 4** Metropolitan area of Mexico, developed from Echeverría, I. (2009). Parque Ecológico, Lago de Texoco. Retrieved from [http://www.parquetexcoco.com/descargas/presentacion\\_en.pdf](http://www.parquetexcoco.com/descargas/presentacion_en.pdf)

**Figure 5** Climate graphic, developed from <https://www.timeanddate.com/weather/mexico/mexico-city/climate>

**Figure 6** Sub-climate map, developed from <https://www.timeanddate.com/weather/mexico/mexico-city/climate>

**Figure 7** Annual precipitation of the Valley of Mexico, developed from [https://www.researchgate.net/profile/Baldemar\\_Mendez-Antonio/publication/228623685/figure/fig4/AS:301981873786889@1449009497897/Average-annual-rainfall-in-Mexico-City\\_W640.jpg](https://www.researchgate.net/profile/Baldemar_Mendez-Antonio/publication/228623685/figure/fig4/AS:301981873786889@1449009497897/Average-annual-rainfall-in-Mexico-City_W640.jpg)

**Figure 8** Chinampas agricultural system. [Image]. Retrieved from <http://www.2000agro.com.mx/wp-content/uploads/chinampaspatrimonio-1.jpg>

**Figure 9** Aerial view of Chinampas system. [Image]. Retrieved from <https://z6k4e9ngmp-flywheel.netdna-ssl.com/wp-content/uploads/urban-farming-chinampas-modern-xochimilco.jpg>

**Figure 10** Detail of Chinampa's construction. [Image]. Retrieved from <http://neomexicanismos.com/wp-content/uploads/2017/07/chinampas-18.jpg>

**Figure 11** Chinampa's nurseries. [Image]. Retrieved

from <https://periodicocorreio.com.mx/wp-content/uploads/2018/07/chinampa.jpg>

**Figure 12** Chinampa's reinvention. [Image]. Retrieved from [https://embamex.sre.gob.mx/paisesbajos/images/M\\_images/Chinampas.jpg](https://embamex.sre.gob.mx/paisesbajos/images/M_images/Chinampas.jpg)

**Figure 13** Landscape transformation of the Valley of Mexico, developed from Echeverría, I. (2009). Parque Ecológico, Lago de Texoco. Retrieved from [http://www.parquetexcoco.com/descargas/presentacion\\_en.pdf](http://www.parquetexcoco.com/descargas/presentacion_en.pdf)

**Figure 14** Valley of Mexico in 1519, developed from [https://sidewalksprouts.files.wordpress.com/2008/04/lake\\_texcoco\\_c\\_1519.jpg](https://sidewalksprouts.files.wordpress.com/2008/04/lake_texcoco_c_1519.jpg)

**Figure 15** Actual map of Mexico City, developed from [https://upload.wikimedia.org/wikipedia/commons/b/b4/Ciudad\\_de\\_M%C3%A9xico\\_y\\_Lago\\_de\\_Texcoco.png](https://upload.wikimedia.org/wikipedia/commons/b/b4/Ciudad_de_M%C3%A9xico_y_Lago_de_Texcoco.png)

**Figure 16** Agricultural Chinampas of Xochimilco. Drawn by Author.

**Figure 17** Chinampas of Xochimilco. Drawn by Author.

**Figure 18** Section of a fixed Chinampa, developed from S. A. (2007). The Chinampas Before and After the Conquest. In Botanical Progress, Horticultural Innovation and Cultural Change (pp. 159-175). Washington, D.C.: Dumbarton Oaks Research Library and Collection.

**Figure 19** Section of a floating Chinampa, developed from S. A. (2007). The Chinampas Before and After the Conquest. In Botanical Progress, Horticultural Innovation and Cultural Change (pp. 159-175). Washington, D.C.: Dumbarton Oaks Research Library and Collection.

**Figure 20** Plan of a Chinampa's cultivation system, developed from S. A. (2007). The Chinampas Before and After the Conquest. In Botanical Progress, Horticultural Innovation and Cultural Change (pp. 159-175). Washington, D.C.: Dumbarton Oaks Research Library and Collection.

**Figure 21** Section of a Chinampa. Drawn by Author.

**Figure 22** Chinampa's crops. Drawn by Author.

**Figure 23** Circularity diagram. Drawn by Author.

**Figure 24** Chinampa's perspective section. Drawn by Author.





# The water mills of Sierra de Cádiz

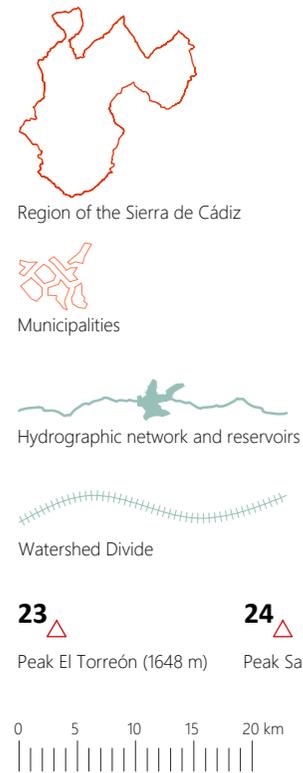
Water as a driving force in the historical production of staple food: bread.

Gloria Rivero-Lamela

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# Context.

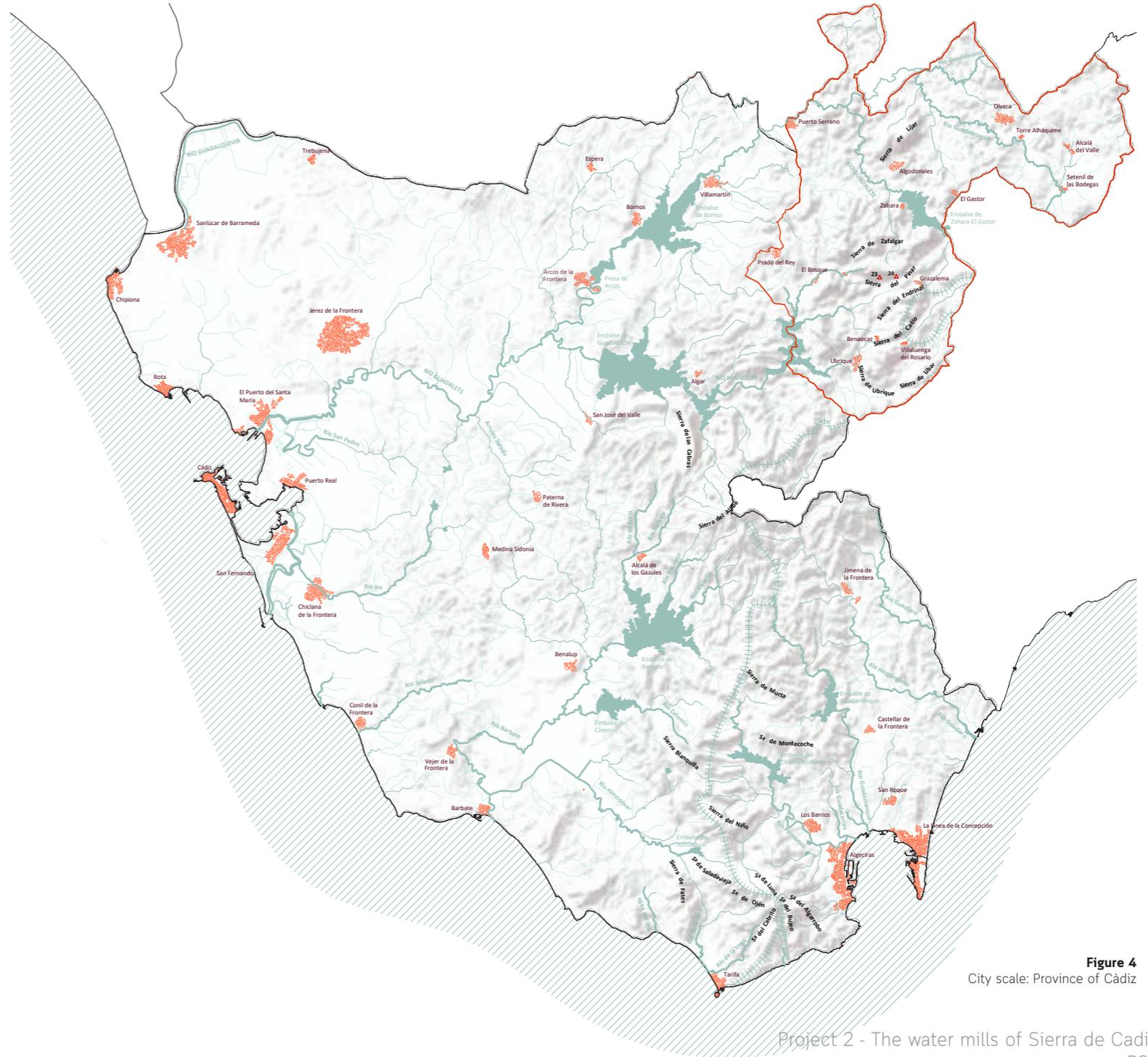
The water flour mills of the Sierra de Cádiz (Andalucía, Spain) make up a network of more than 80 buildings strategically distributed throughout the region. They are architectural interventions linked to the milling of wheat and the production of flour and bread, historically related to agricultural use. They are part of *productive rural architecture*, a group considered heritage because it combines cultural relevance and tradition. However, they are now obsolete and remain inactive or in ruin.



**Figure 2**  
Country scale: Spain



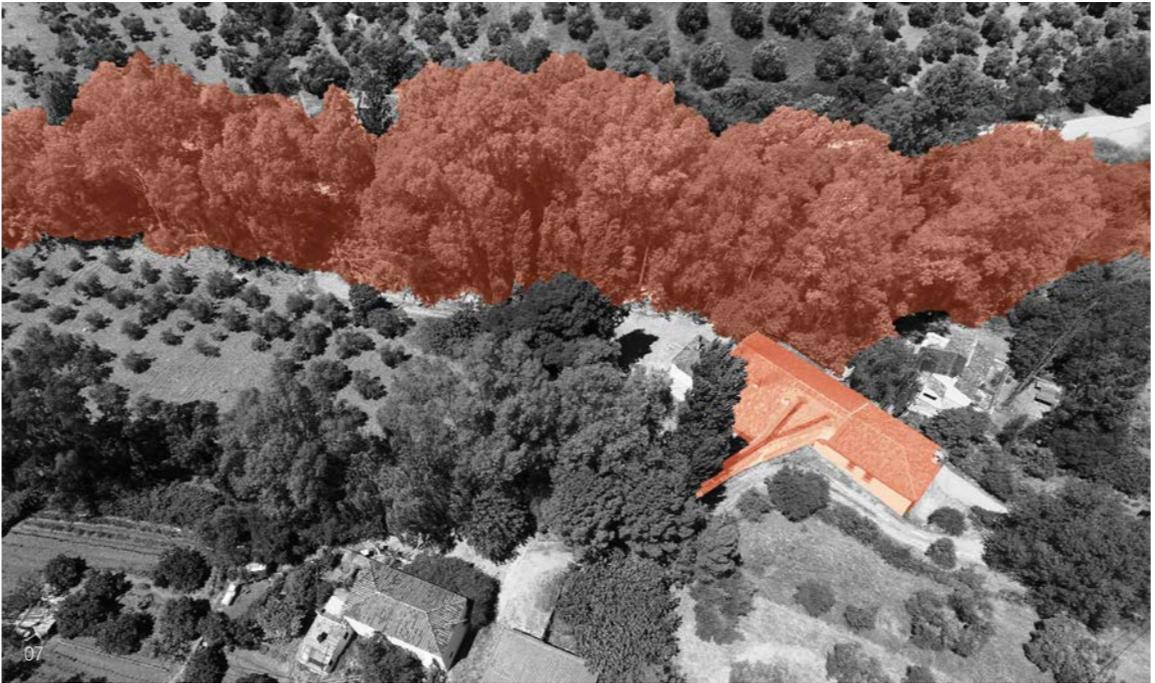
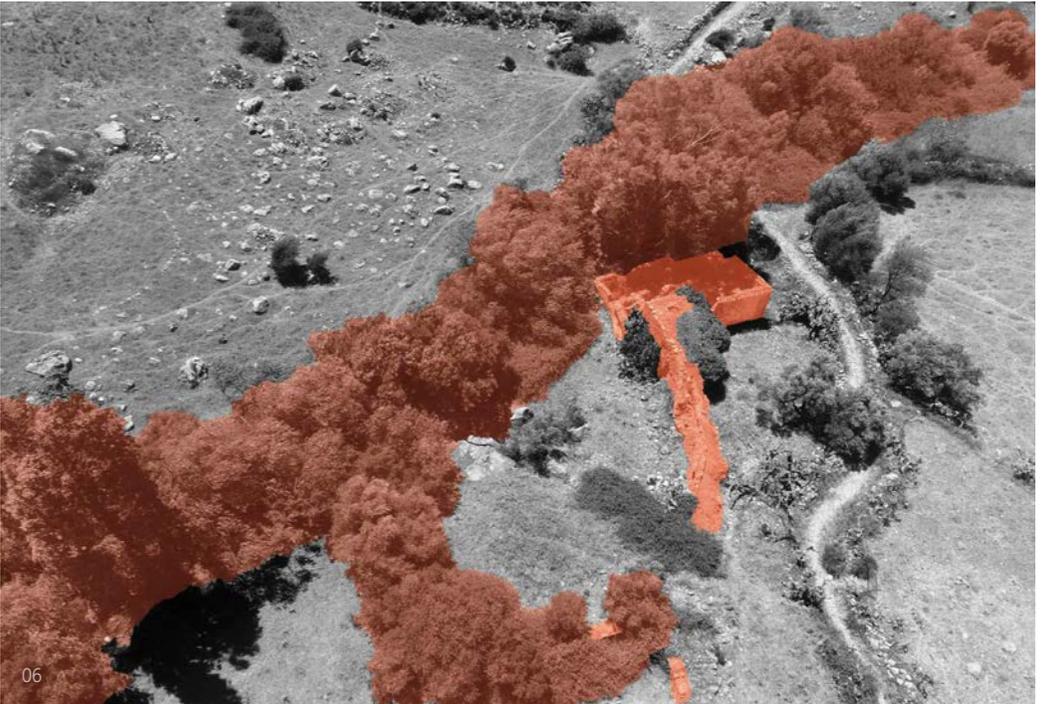
**Figure 3**  
Regional scale: Andalucía



**Figure 4**  
City scale: Province of Cádiz

# Archaeological ruins of mills.

They are, in addition, functional architectural interventions: for its industrial use and for the required productive profitability, water was necessary for its operation. Therefore, these mills were built with the precision and logic of the small hydraulic engineering works that, together with other minor and usual works in these places, such as ditches, canals, ponds, etc., make up a network of constructions aimed at control and management of hydrological resources that the artisanal industries of the Sierra de Cádiz region require.



**Figure 5** - Water mill "Segundo". Riverside of Arroyo Seco, Benaocaz.  
**Figure 6** - Water mill "Primer". Riverside of Arroyo Seco, Benaocaz.  
**Figure 7** - Water mill "Alto". Riverside of Arroyomolinos, Zahara de la Sierra.  
**Figure 8** - Water mill "El Caballo". Riverside of Gaidovar, ZGrazalema.

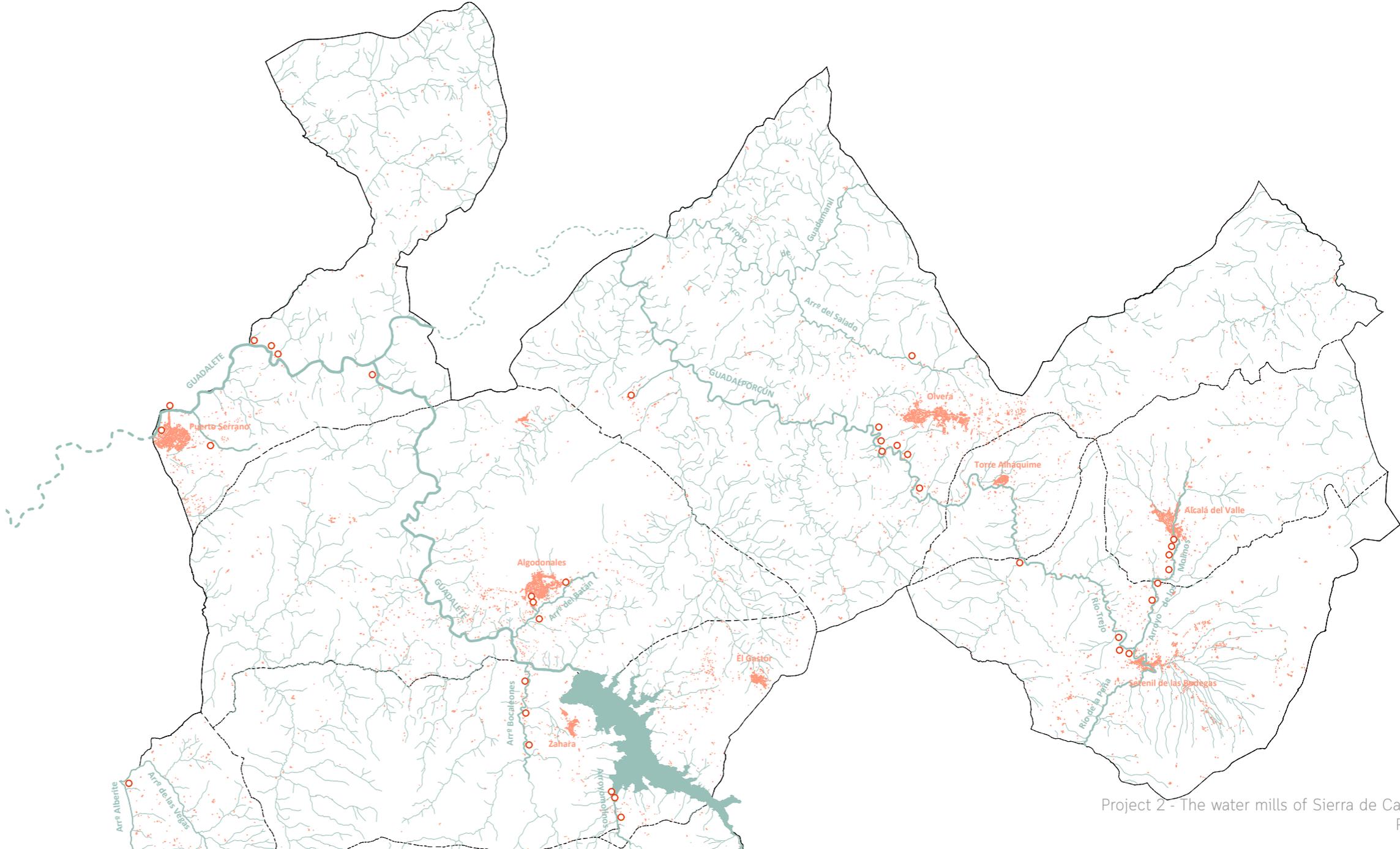
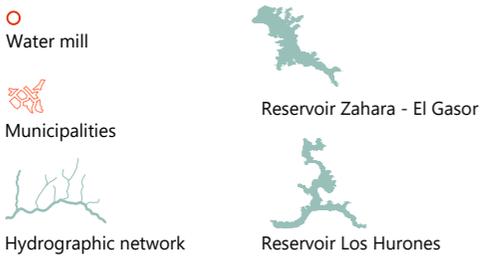
# Catchment area.

The Sierra de Cádiz is located in the north-eastern end of the province of Cádiz; within Andalusia, in Spain. It has an area of 105,435 ha (14.2% of the provincial area) and is administratively composed of 14 municipalities. It comprises a large part of the Sierra de Grazalema Natural Park, declared a Biosphere Reserve in January 1977 and a Natural Park in December 1984.

It presents a rugged orography of steep slopes, resulting in average altitudes that vary between 285 and 1,072 m with slopes that exceed 18%. This causes the Sierra de Cádiz to be the area where the provincial hydrographic network springs. The Majaceite, Guadalete, Guadalporcún and the Zahara and Hurones reservoirs stand out.

In addition to these physical issues, it is a cultural region, since it has been an isolated area (Hispanic-Muslim border during more than two centuries) that has generated among its inhabitants the awareness of sharing a common history and a cultural past.

Figure 9 Catchment area of Sierra de Cadiz





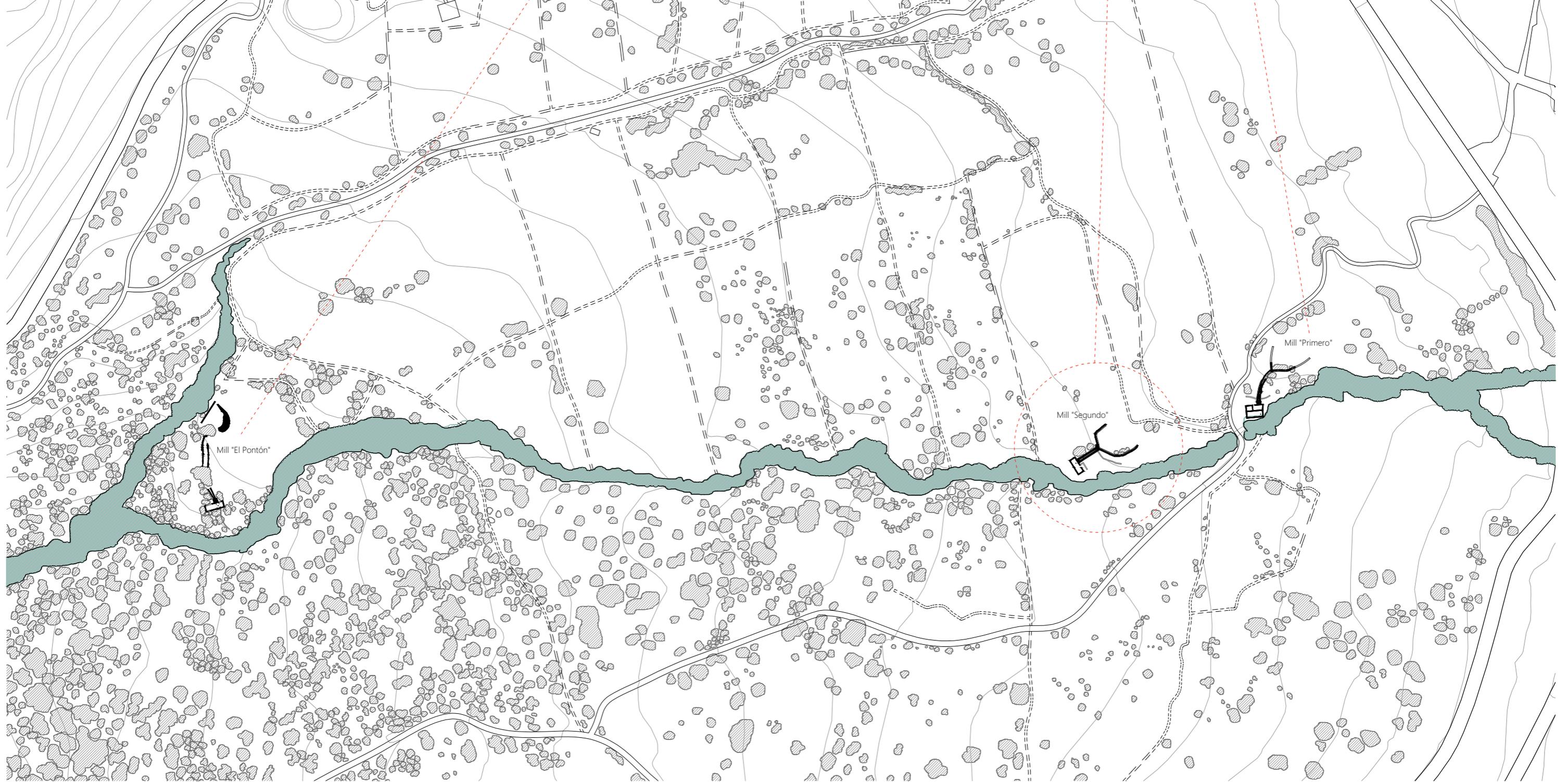
# Water System near Benaocaz village.

The riverside of "Arroyo Seco" (it would be translated as a "dry stream") is drawn on this map as a representative example of the 21 milling banks existing in the Sierra de Cádiz. It is located in the municipality of Benaocaz, and has three hydraulic flour mills. This scale is very important, since mills should not be considered as autonomous buildings, but inseparably connected to the streams that activated their mechanism.

Regarding the factors conditioning mills' location, the first thing is the fundamental dependence of the presence of water courses. Second, there is a tendency to locate the mills as close as possible to the villages, main flour consumption centres, or in more remote areas to supply other rural constructions.

Figure 10 Plan showing water system near Benaocaz village.





# Functional diagram of the mills.

The function of the mills determines its design. On a small scale, the mill is distinguished by its location close to the rivers and by the external infrastructure works that channel the water to its interior: the millrace, the well and the wheelhouse.

All the water mills of the Sierra de Cádiz have a horizontal wheel and a well, one or two at most, and they may or may not have a pond. They were built when the water courses had no speed or sufficient flow.

Almost all the mills had a mixed structure with masonry load-bearing walls of irregular stone, taken with mortar of sand and lime, 60-80 cm thick, plastered with lime and wooden beams. Most of the roofs had one or two water structures, also made with wooden structure, thatched and Arab tile. The main space that articulates the building is the grinding room, located above the wheelhouse.

If it exists, the pond is built where the slope of the land is not excessive to achieve, with minimal construction resources, store as much water as possible. The water is conducted from the pond to the well by the millrace, which bypasses the topography. The well is located in the area of greatest slope so that the waterfall generates enough force to move the horizontal wheel. The position and length of the millrace result from the position of the pond and the well according to the topography. The system is further optimized with the mill's proximity to the river for the immediate return of the water to the natural course.

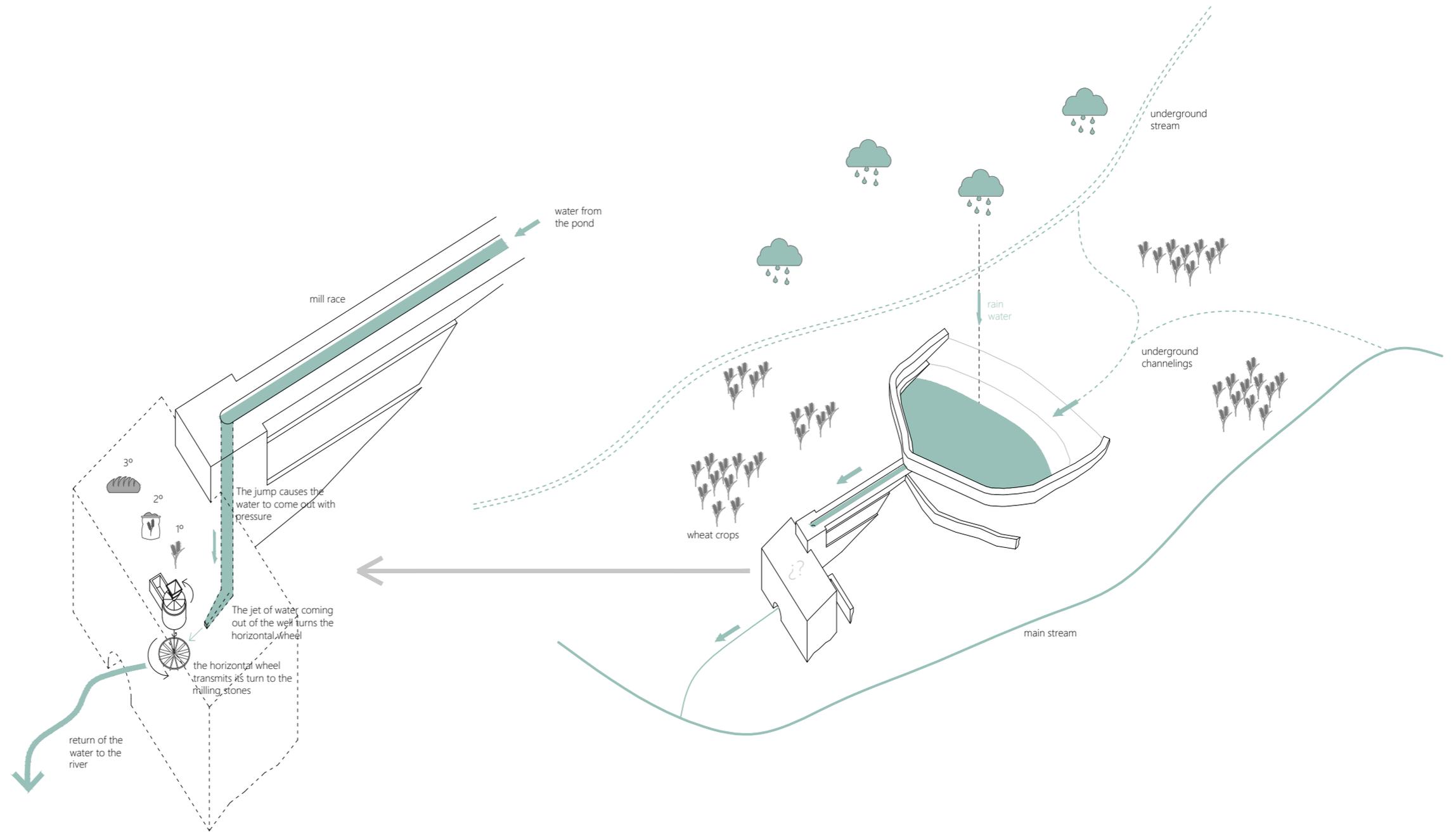
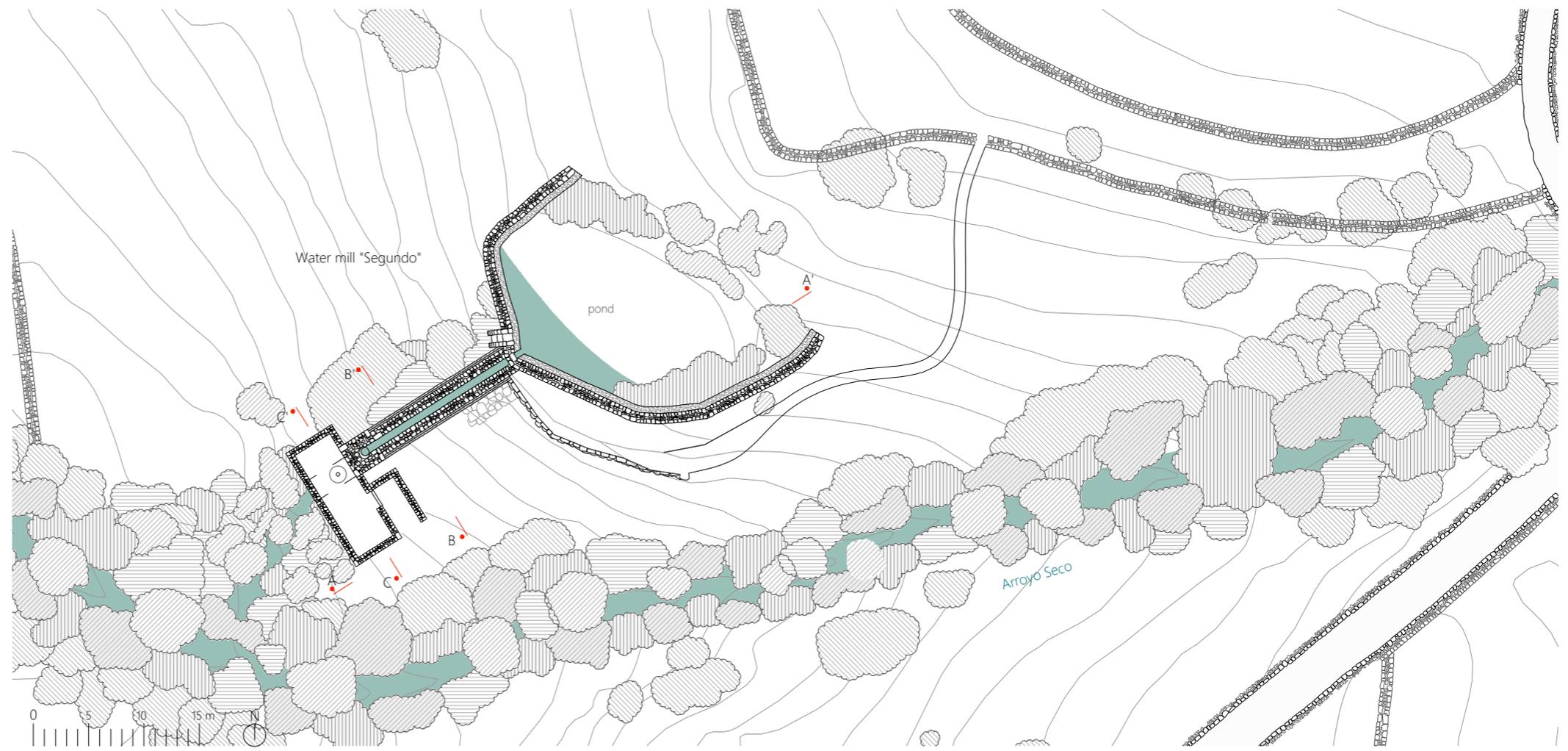
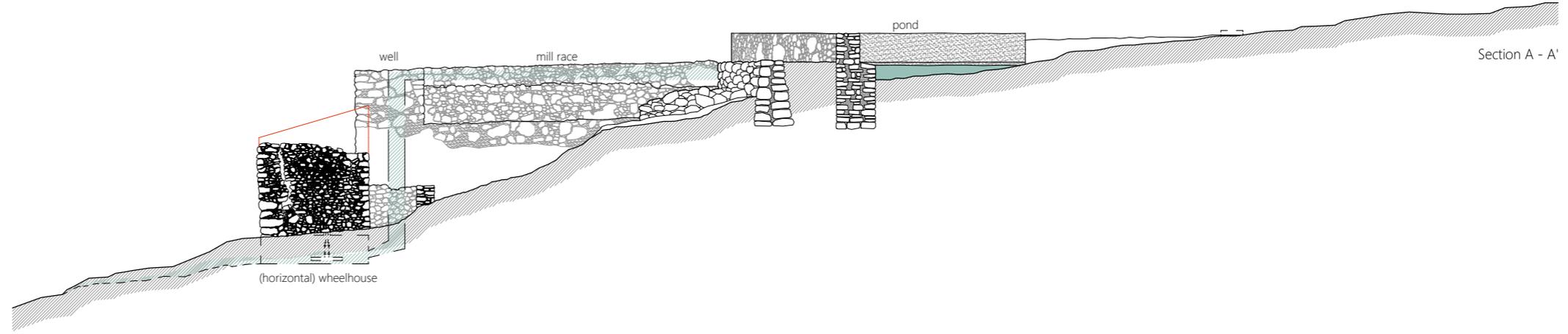
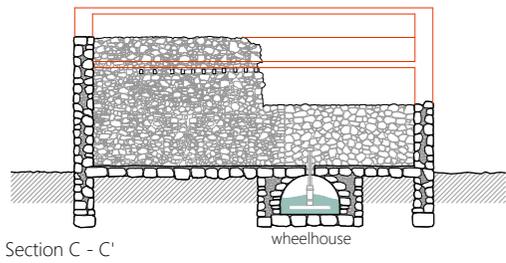
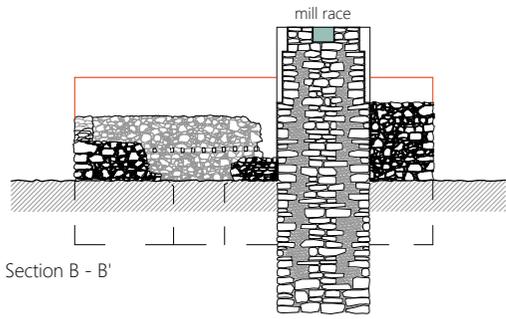


Figure 11 Functional diagram of the mills.

# Water mill "Segundo".

This milling infrastructure works like a hydraulic dam and constitutes the necessary structural support, arranged on the ground, from which the mill is built.

**Figure 12** Section of the Water mill "Segundo" (left & top)  
**Figure 13** Plan of the Water mill "Segundo" (right)



# Conclusion.

Although these anonymous architectural interventions are not exactly dated, it is known that they already existed in the Middle Ages, when the lordships hoarded the production and transformation of crops, so the mills also served for territorial and social control. It is from the eighteenth century when the presence of mills is more pronounced in the Sierra de Cádiz, and they continued to operate in the Sierra de Cádiz until the 70s and 80s of the twentieth century, a singular fact if one takes into account that in the rest of the country, due to technological innovations (Austro-Hungarian milling system), the traditional mills were disappearing at the beginning of the 20th century.

In short, the orographic and hydro-graphic conditions of the region and its mountain character have determined a socioeconomic development supported by livestock, agriculture and grinding. Grinding or milling is a cottage industry based on the use of rivers and the circularity of water. It has a great importance and presence in the region: the architectural impact of this activity is evident in the number of buildings that existed and still exist in the region. Origin of life and culture, the mills have also generated roads and paths, and have coexisted in symbiosis with the nearby villages and with other rural constructions. They are architectural interventions of the past, lethargic, but from which we can learn a lot because they treasure a very different set of values:

**Landscape Values** - The paths that connect the mills form a network of rural roads that go through the entire Sierra de Cádiz and help its route.

**Strategic values** - The mills reveal with its positioning the optimum enclaves to achieve maximum profitability

with the minimum resources and infrastructures, by taking advantage of natural elements, topographic changes, slopes, river bends...

**Functional values** - Since they are architectural interventions with simple formal and constructive solutions, mills are buildings constructed with precision and logic; in them, each space serves a specific function.

**Material and tangible values** - The mills are a source of knowledge about traditional construction techniques and use materials from the surrounding area that adapt to our climate and lithology: masonry based on the limestone of the area, mortar, lime, wood, straw, mud...

**Values of sustainability and circularity** - They use elements of the surroundings and non-polluting materials. In the case of these mills, water is the driving force. It is also used to irrigate surrounding crops and gardens, and is returned to the river once the mill mechanism has been activated. In this way, a pseudo natural circuit perfectly integrated into the environment is created.

**Ethnographic and identity values** - The mills encompass the knowledge of what was one of the main activities of the region, grinding with water.

**Lessons to Learn** - This study shows how in this southern region of the Iberian Peninsula, milling was not only a way of subsistence and flour and bread production, but also of sustainable management of the region's natural resources. The number of mills and their position in the territory show the balance between demand and production that characterized the places that were self-sufficient and that lived off the surrounding lands. Although obsolete, this traditional water system preserves many lessons that can be useful for today's society and for the contemporary landscape project.

It is an example of using renewable and non-polluting energy, since the mills used the driving force of water to grind grain. In addition, they used recycled or recyclable materials from the area surrounding for their construction, as currently required by the Triple Zero® concept: Zero Energy Building, Zero Emission Building; Zero Waste Building. They show how a powerful hydrographic network can be profited, where the rugged topography did not allow other productive uses of the land. At the same time, they teach us to optimize rural infrastructures, since the ditches or ponds that were built to bring water to the mills were also used in agricultural activities, and the roads that led to the mills were also livestock trails. They are architectural interventions that dialogue with their natural support, integrating themselves in a sensitive way in the territory, and that were built in a rational and logical way to solve the needs of the society of a certain period, and that is a lesson we should not forget.

Although the mills are in ruins, their renovation could reactivate them and involve them, from a new perspective, in the development of the region; they could become space containers that would house ethnographic activities related

to milling and landscape projects in the region, whose environmental values have earned them international recognition as a Biosphere Reserve by UNESCO.

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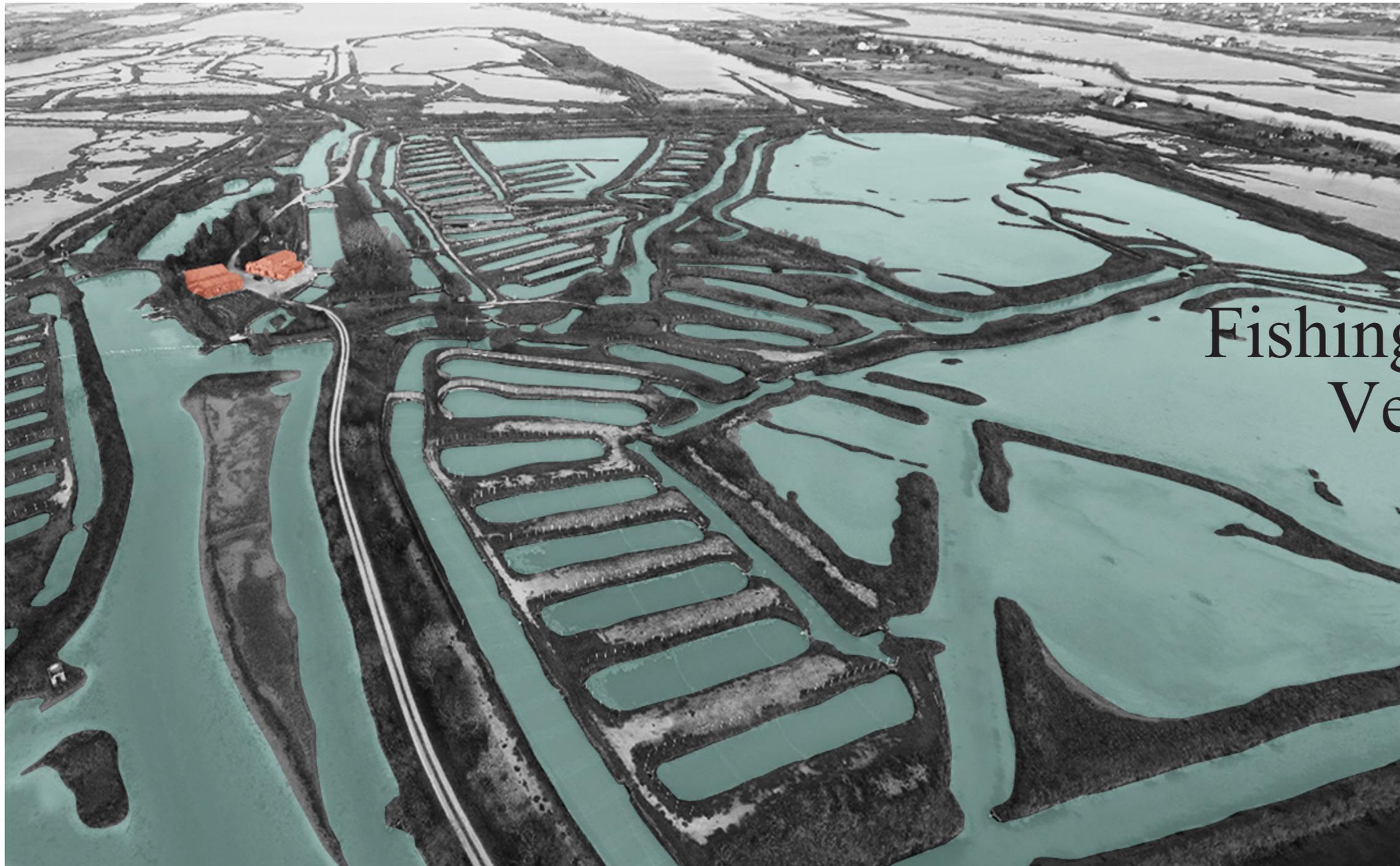
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## **Illustration Credits**

Photos with drone by Gloria Rivero Lamela.







# Fishing valleys in the Venetian Lagoon

A traditional extensive aquaculture system, still functioning and spread along the border of the Venetian Lagoon.

Amina Chouairi

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**Figure 1** Fishing valley in Lio Piccolo, northern Venetian Lagoon.

Project 3 - Fishing valleys of the Venetian Lagoon

# Context.

Location: Venetian Lagoon, Veneto region, Italy.  
Period: 11th Century A.D.  
Function: Aquaculture system.  
Type: Extensive fish cultivation system.  
Area: 8500 ha.  
Components: The main elements are the fishing ponds, the embankments separating the valleys from the lagoon, the mansions, and the waterworks able to calibrate the amount of fresh water and salt water to introduce in the valleys.  
Status: In use.



Figure 2 Continental scale Europe and Italy



Figure 3 Country scale Italy and Veneto region

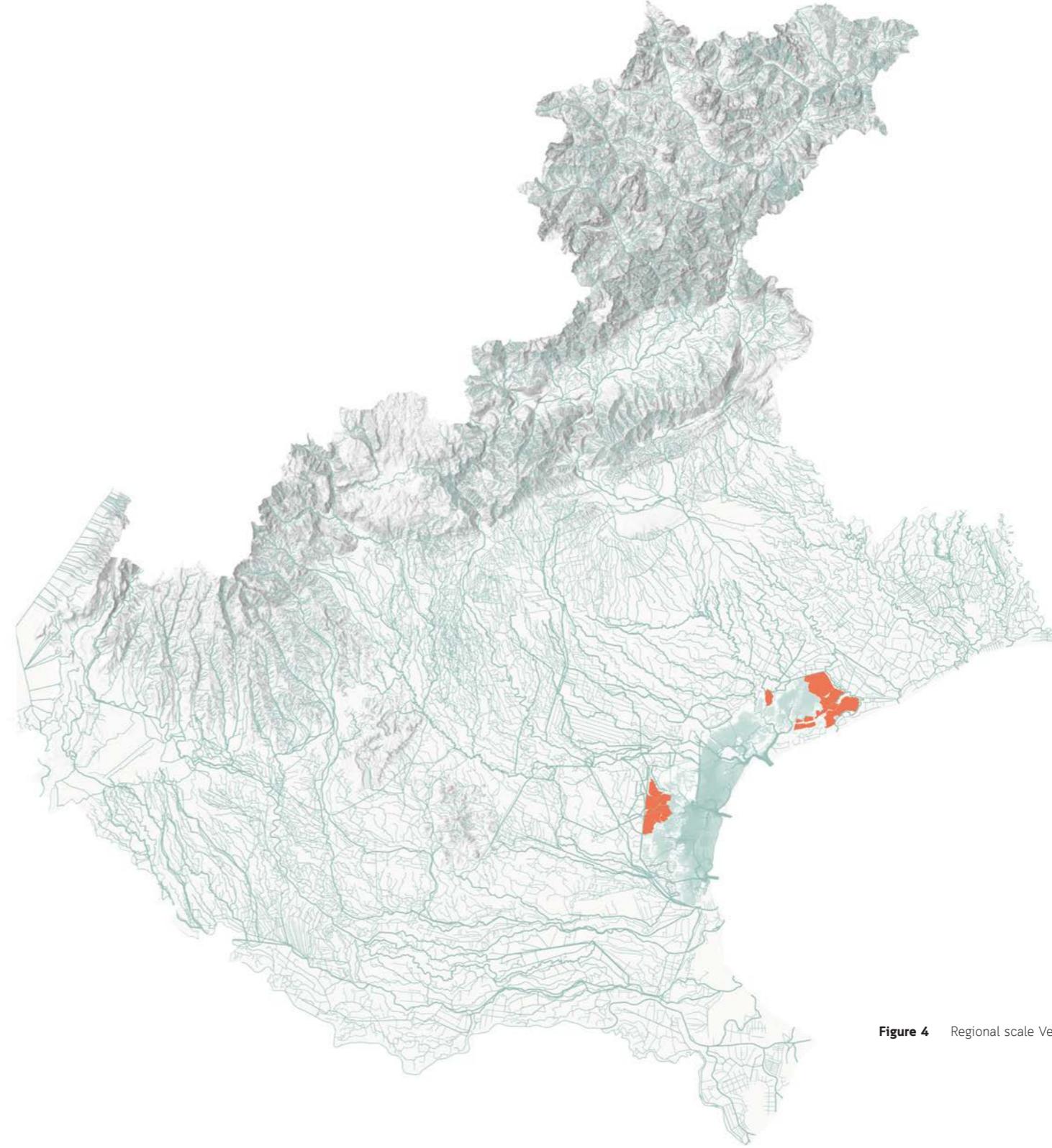


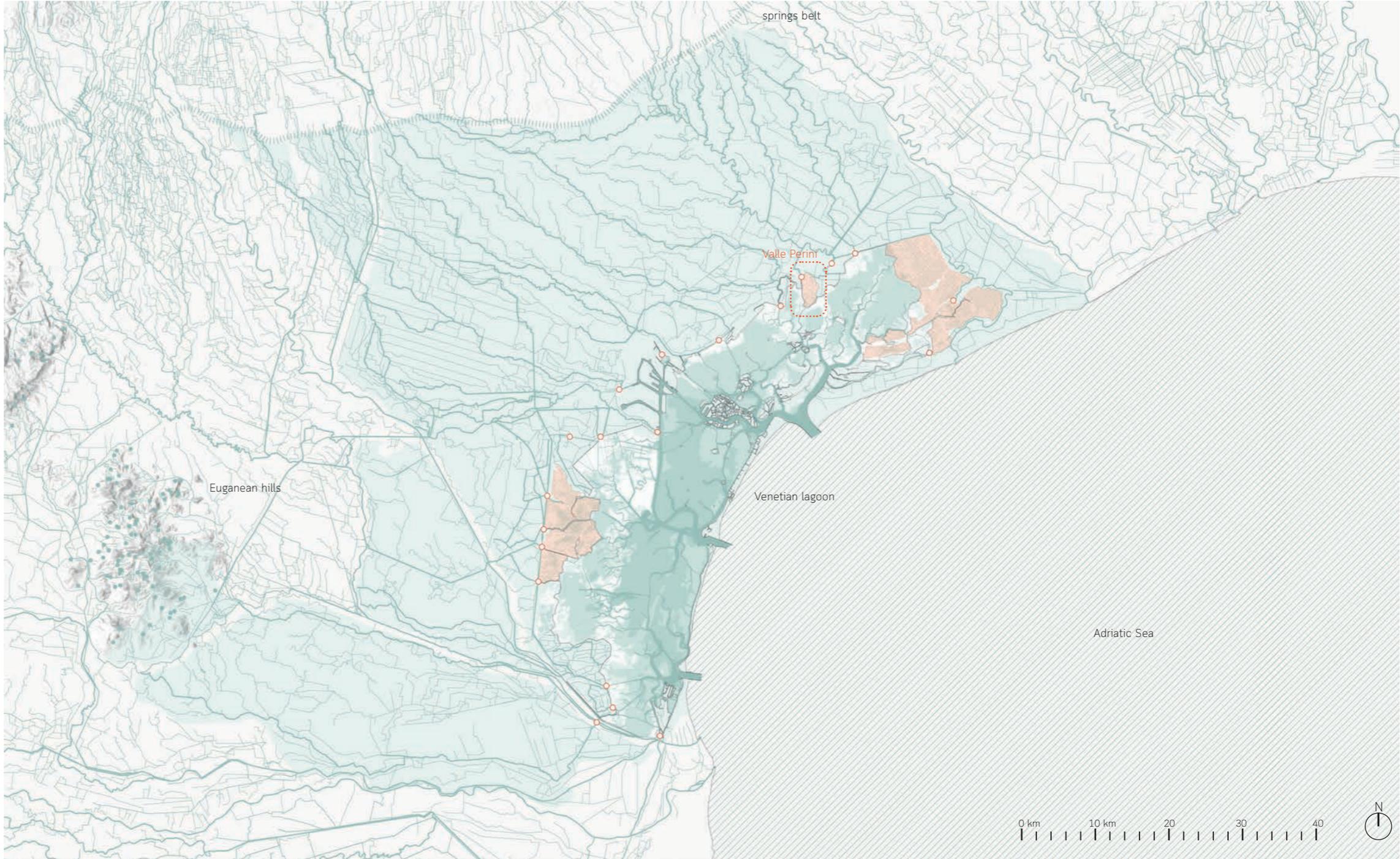
Figure 4 Regional scale Veneto region and Venetian lagoon

# Catchment Area.

The freshwater catchment area discharges directly in the Venetian Lagoon, and therefore it provides with freshwater the fishing valleys. It originates from two different sources: the so-called *springs belt* formed by those waters, which accumulated in the underground aquifers, resurface; and the Euganean Hills, a group of hills of volcanic origin that rise to heights of 300 to 600 m from the Paduan-Venetian Plain a few km south of Padua.

During the past centuries, because of the innumerable interventions conducted by the Republic of Venice to ensure the survival of the city of Venice and to avoid the silting of the whole Venetian Lagoon, many of rivers naturally discharging in it (as Brenta, Bacchiglione, Tagliamento, Sile and Piave) got diverted. This engineering decision had a tremendous negative effect on both the amount of sediments and the amount of freshwater discharged inside the lagoon, reducing them and altering the hydromorphological balance in act.

The orange elements highlighted in the map are the areas occupied nowadays by the fishing valleys, in total 23, completely limited by embankments along the border of the Venetian Lagoon.



**Figure 5** Venetian Lagoon watershed. With an orange dotted line is marked Valle Perini, the fishing valley which will be further analyzed in the research.

# Human Interactions.

The fishing valley master, *capovalle*, the fishing valley workers and the guardian are the three fundamental figures for the fishing valley management in the Venetian Lagoon. The *capovalle* is the chief of the fishing valleys, regulating the water regime and employing of seasonal workers; the workers are in charge of different managing activities; the guardian monitors the valley daily.



## Spring.

From March to May, in the open lagoon, *pescenovellanti* know where to flush the juvenile fishes out. They are there, nearby the inlets where the water is constantly fresh and flowing, all hidden in the shallow waters populated by tall and impenetrable seaweeds. Then, it is time for seasonal workers to sow the larvae in the *seragio per il novellame*, an impervious labyrinth where the fry acclimatize with the valley's conditions.



## Summer.

From June to the end of September, inside the fishing valley, the *capovalle* is the main director of the scene. He is in charge of controlling the whole system, from the water salinity to nutrients and oxygen levels regulation. In the summer humid air, it is time to take care, maintain, manage, adjust, fix and repair, small actions to ensure the valley its smooth procedure.



## Autumn.

From October to the end of December, the *fraima* takes place. This natural migration instinct arises because of the progressive cooling of the waters and bring the shoals of fish populating the valley towards the *lavorièri*. In these traps, the fishes are captured by the workers and selected in relation to the species and the size: specimens suitable for marketing are sent directly to fish markets; small specimens, instead, are placed in *peschiere di sverno* where they will face the difficult winter season.

**Figure 6** Spring. Fishing valley worker sowing juvenile larvae in the valley.

**Figure 7** Summer. Fishing valley workers inspecting the valley lakes.  
**Figure 8** Autumn. Fishing valley workers standing on the *lavorièro* (fish trap) with nets.

**Figure 9** Winter. Fishing valley workers capturing fishes and managing the valley.



## Winter.

From January until the beginning of March, takes place the most delicate phase regarding the fishing valleys management. During winter becomes extremely critical controlling living conditions and protecting the ponds from potential predators, as herons, cormorants, and seagulls.

# Climate.

Climate zone: **Temperate**  
 Sub-climate: **Mediterranean**

## Climate & Weather Averages

High t°: 30°C  
 Low t°: 1.1°C  
 Mean t°: 14.5°C  
 Precipitation: 700.0 mm  
 Humidity: 75.3%  
 Wind: 9.36 km/h  
 Pressure: 1015,5 mbar  
 Hottest Months: July and August (28°C avg)  
 Coldest Month: January (4°C avg)  
 Wettest Months: April and November (78 mm avg)  
 Windiest Months: April and November (10.08 km/h avg)  
 Annual Rainfall: 748.0 mm per year

It is important to notice three tendencies, readable from the three drawings presented here: the first one, from the graph below, is the proportional relation between monthly highest and lowest temperatures; the second one, as well from the graph below, is the constant amount of monthly average precipitation, between 50 and 80 mm; the third one, from the comparison between average temperature and average rainfall, is the mitigating effect of the Adriatic Sea, allowing higher average temperatures and lower rainfall events in the Venetian lagoon.

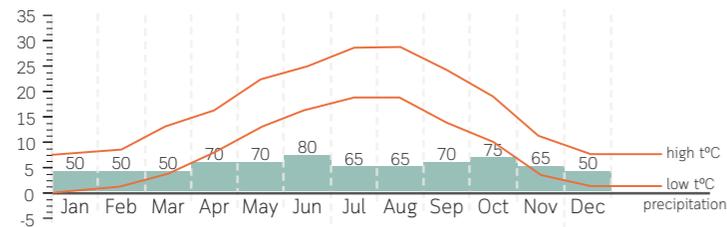


Figure 10 Venetian lagoon annual precipitation and temperature

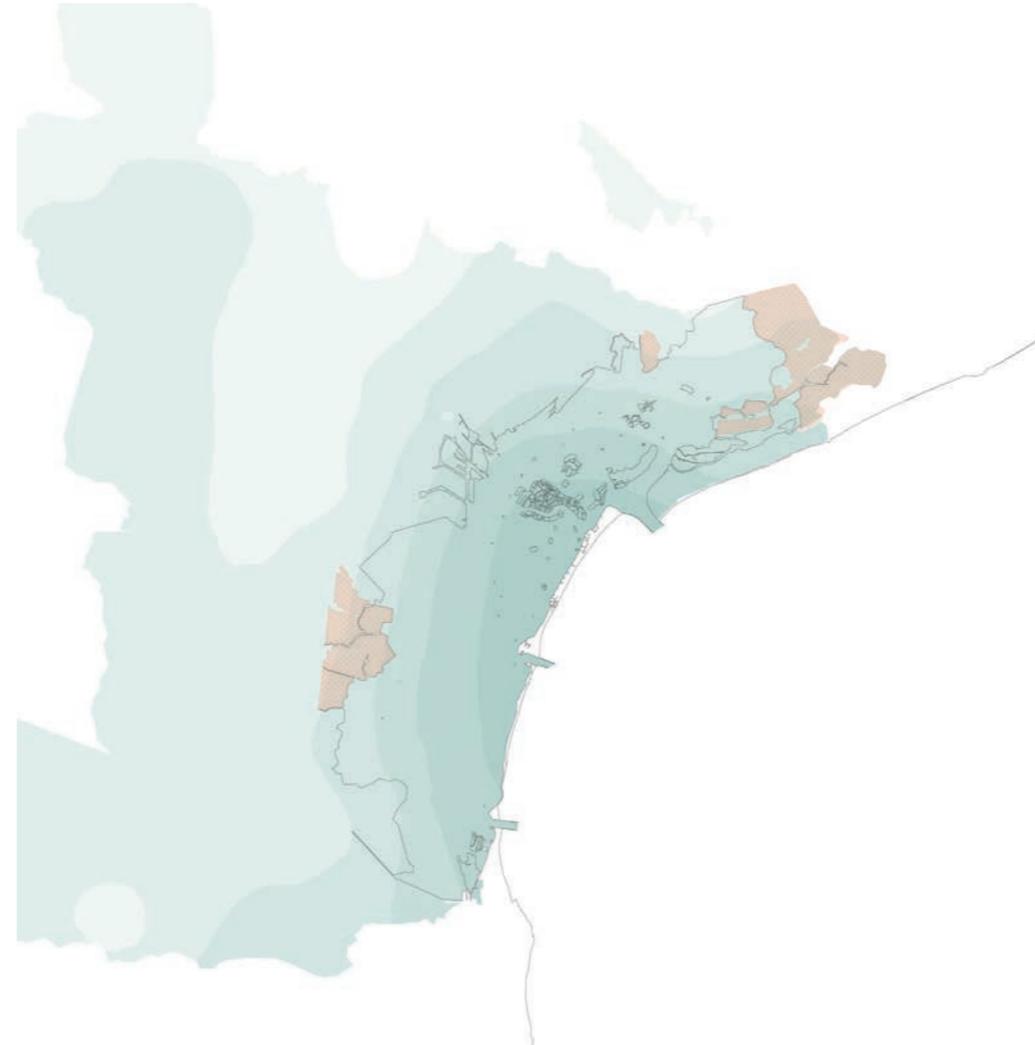


Figure 11 Average temperature (C)

- + 14.5
- 14.2 - 14.5
- 14 - 14.2
- 13.8 - 14
- 13.6 - 13.8
- 13.4 - 13.6

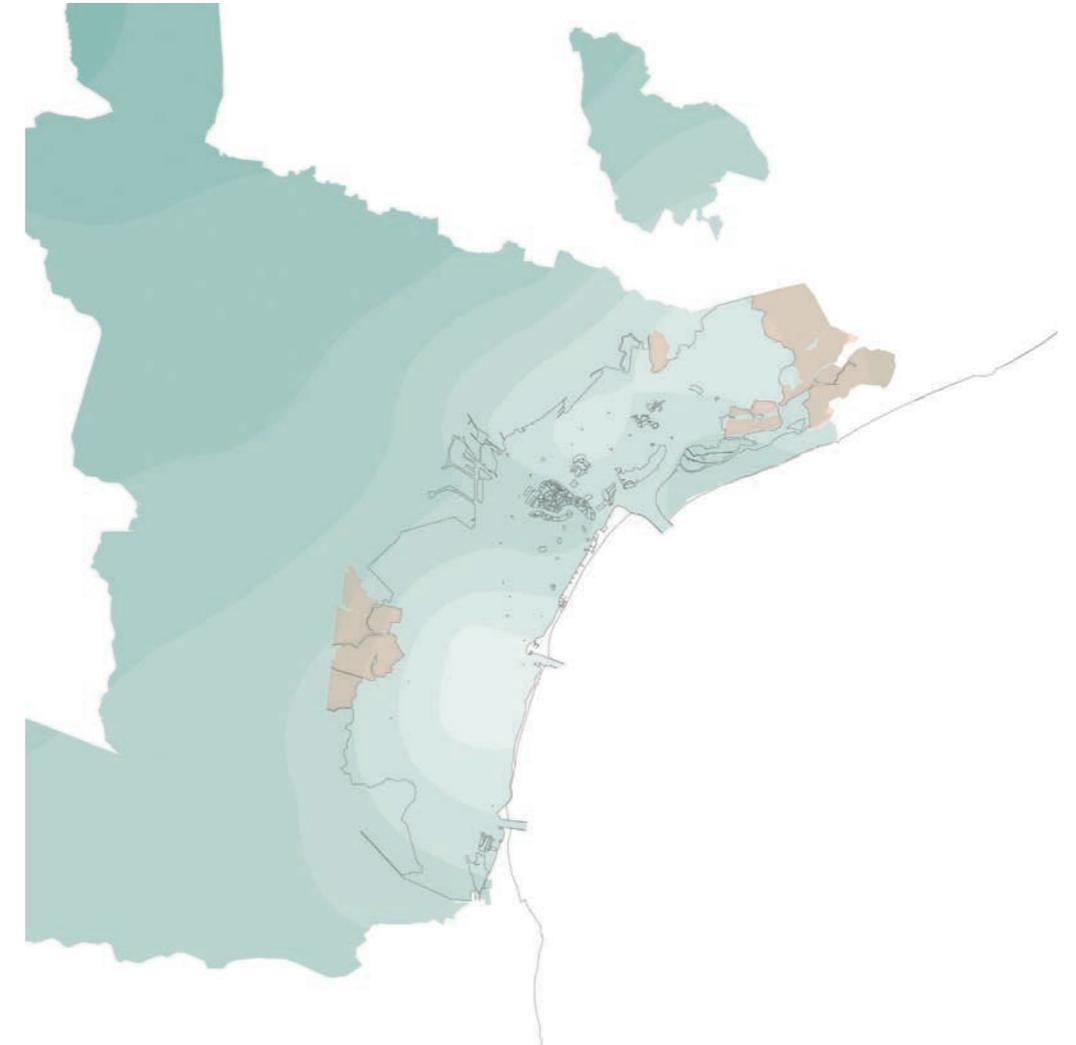


Figure 12 Average rainfall (mm)

- 1200
- 1100
- 1000
- 900
- 800
- 700
- 600
- 500
- 400



# Origins and evolution.

The origins of the fishing valleys are lost in the remote antiquity. A legend narrates that the St. Mark Evangelist, sailing through the waters of the lagoon, forced by a storm docked his boat at the banks of a valley already in good conditions (Fortibuoni, 2009, p. 143).

In ancient times, fishing activities were carried out mainly in the shallow waters of the Venetian Lagoon. From Roman Empire until 15<sup>th</sup> century this system started to be implemented with nets and fixed structures, gaining the name of *enclosed waters* or *piscariae* (from Latin, *of or pertaining to fish or fishing*), evolving afterwards in *valleys* or *fishing valleys* (stage 0). These primitive open valleys were in direct communication with the lagoon, taking advantage of its tidal fluctuations and were located in shallow waters.

Subsequently, to tackle the problems caused by durability and perishability, Venetians anglers started to reinforce their valleys, until that moment nomadic and subject to tidal influence, with hard dikes (stage 1). These semi-embanked valleys, *valli semi-arginate*, had the part windward delimited by earth embankments. From this moment onwards, the fishing valleys were permanently transformed into managed systems, where, during winter, the undersized fishes were kept in winter fishponds, *peschiere di sverno*, instead of being sold anyway. In addition, the valleys no longer depended only on the fish natural migration, but also on fry's sowing, captured in the lagoon by the *pesce novellanti*, fishermen specialized in fishing juvenile larvae.

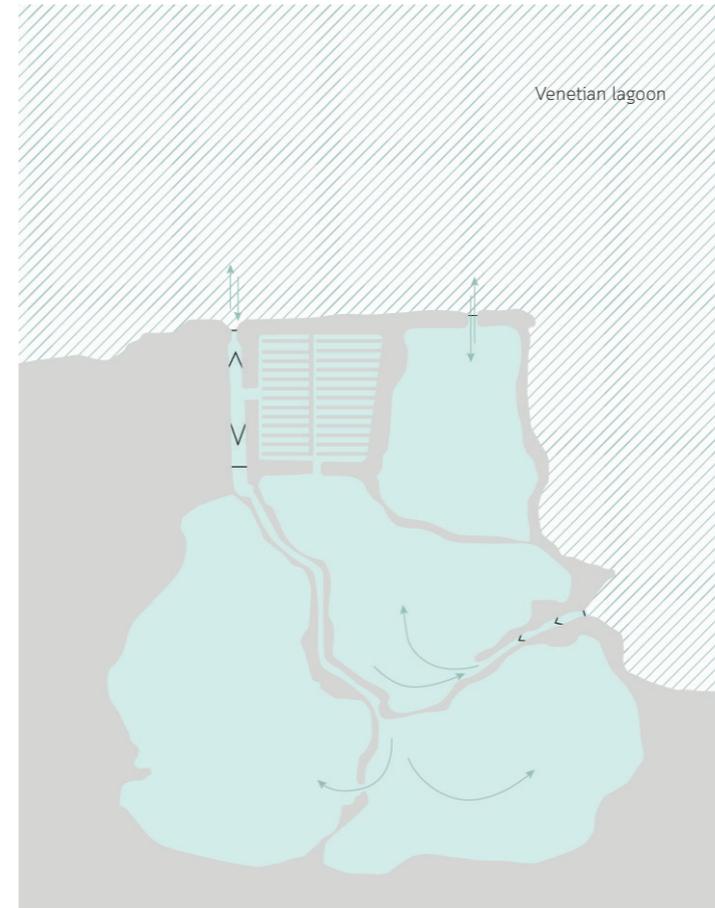
The final stage, still in function today, is represented by the embanked valleys (stage 2), *valli arginate*, completely enclosed by elevated embankments and communicating with surrounding water bodies through sluices. The valleys drew both brackish water from the open Venetian Lagoon and freshwater from streams discharging in their proximity.



- Brackish marshlands
- Brackish water
- Land

- ⋈ Removable and permeable barriers
- ⋈ Water movement

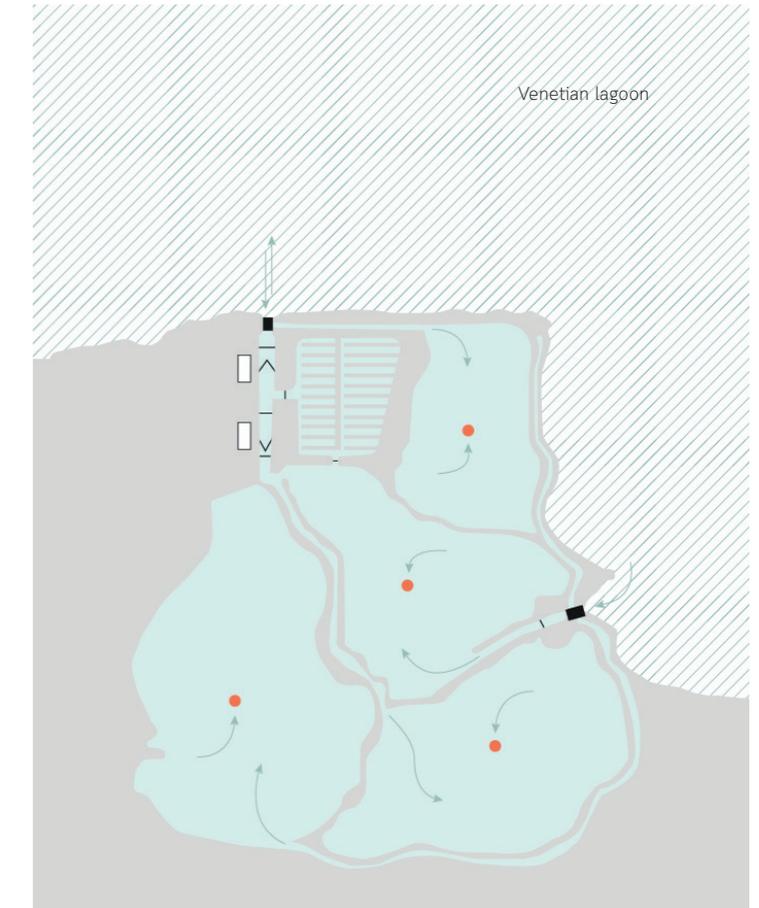
**Figure 13** Stage 1: semi-embanked valley, *valle semi-arginata*, schematic representation of plan. In use from 15<sup>th</sup> to 20<sup>th</sup> century, the fishing valley is still subject to tidal influence, in fact the barriers are made of weaved reeds, in the specific *Phragmites australis*.



- Brackish water
- Embankments
- Winter pond

- ⋈ Fixed trap to capture fishes
- ⋈ Water movement

**Figure 14** Stage 2: embanked valley, *valle arginata*, schematic representation of plan. In use from 15<sup>th</sup> to 20<sup>th</sup> century, the fishing valley is completely enclosed and separated from the Venetian lagoon.



- Water pump
- Brackish water
- Embankments
- Winter pond
- Fishing valley mansion
- Water sluice
- ⋈ Fixed trap to capture fishes
- ⋈ Water movement

**Figure 15** Stage 3, embanked valley with water pumping system, *valle arginata con sistema di pompaggio idrovoro*, schematic representation of plan. From mid 20<sup>th</sup> century to present, the fishing valley has been implemented technically with a water pumping system, to better regulate water flows and amounts.

# Seasonality.

As in every aquaculture system, in the fishing valleys of the Venetian lagoon the most important variable is the seasonal succession, and the whole functioning is calibrated on this repetition.

The water temperature and nutrient composition, the salinity gradient, fluctuating from more salty, to more brackish, to more fresh, the fish natural migrating instinct from the Adriatic sea to the lagoon in spring and vice versa during autumn, and the human actions of capturing, sowing, breeding, and selling are extremely complex and interconnected, depending on seasonal variations.

The natural migrating instinct of fishes and the controlled movement of water are the fluxes which directly shape the fishing valleys functioning.

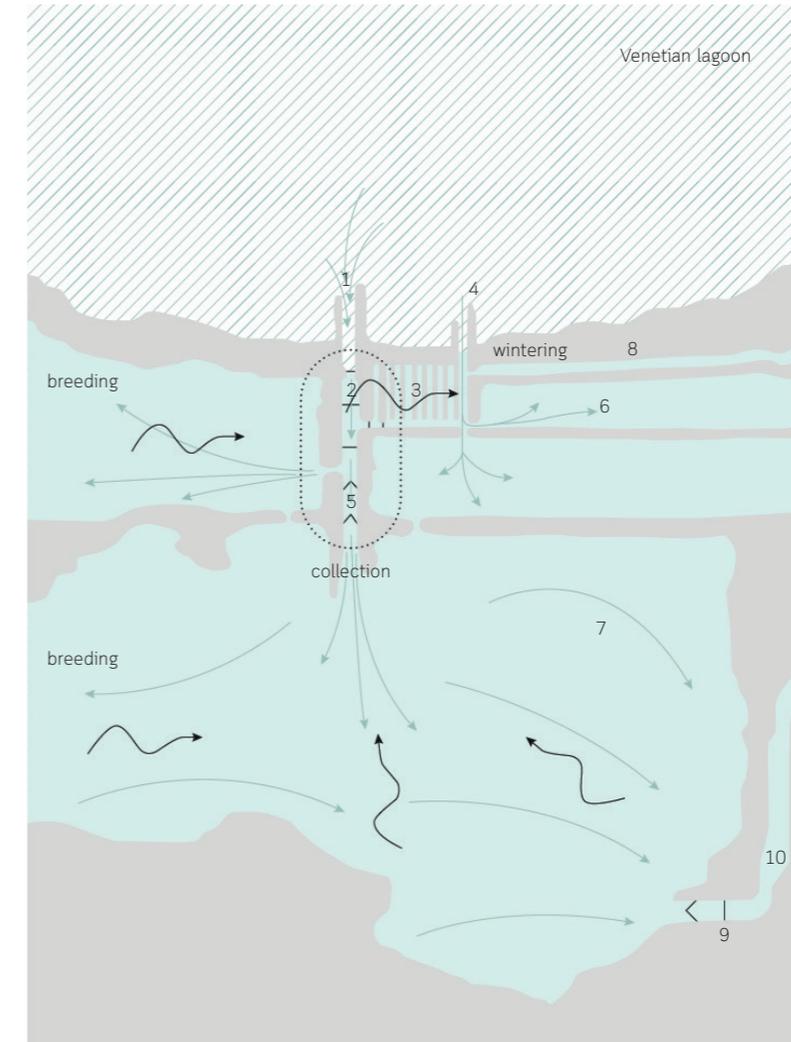
In spring, freshwater is pumped within the pasture basins where fishes are recalled after having wintered in the winter ponds.

In autumn, the temperature of shallow waters in the valley decrease. Cold brackish water from the lagoon is introduced inside the fishing valley, while the warmer water of the pasture basins is sucked by the water pumps. This combined procedure stimulates the fishes' natural impulse to migrate towards the sea. The fishes, following the source of the cold water, remain trapped in the *lavorièro*, where the collection takes place.



- 1 Salt water sluice
  - 2 Collection basin (*colaùro*)
  - 3 Winter ponds (*peschiere di sverno*)
  - 4 Salt water sluice for the winter ponds
  - 5 *Lavorièro*
  - 6 Breeding basin
  - 7 Pasture basin
  - 8 Fresh water canal
  - 9 Dewatering pump
  - 10 Discharging canal
- Lagoon
  - Fishing valley water
  - Embankments
  - Water flow direction
  - Fish flow direction

**Figure 16** Scheme of the water flows of an extensive breeding in the post-winter phase of re-entry of the fish loads in the pasture basins. Spring: grazing and sowing.



**Figure 17** Scheme of water flows (drying and recall) in an extensive breeding in the autumn phase of collection, selection and capture of fish. Fall: fish collection, selection and wintering.

# Water System: Valle Perini.

Valle Perini is located in the northern Venetian Lagoon. In past times, it was part of the Cà de Riva farm estate. It was part of a more complex system of valleys and, already before 19<sup>th</sup> century, was an embanked valley, *valle arginata*, internally subdivided: the subdivision by parallel and longitudinal channels is still recognizable today, and it underlines the original intended use for agricultural cultivation.

It is delimited to the north, east and west by freshwater courses: respectively from Taglietto Canal, Silone Canal and Lovigno Dolce Canal (an ancient lagoon branch of the Sile river) and Siloncello Canal. Along the southern border, facing directly the lagoon and therefore mainly characterized by brackish water, Valle Perini is tightened between Palude di Cona and Palude della Rosa.

Still accessible exclusively by water, the valley has changed very little over the centuries, maintaining a strong continuity with tradition, both in terms of equipment and management methods.

It is one of the less built fishing valleys; there is a unique settlement on the Venetian Lagoon front in front of the Palude di Cona. There, the fishing valley mansion, *casòn di valle*, and a warehouse, *cavana*, both artifacts from the 17<sup>th</sup> century, are built on the upper embankment of the fish collection basin, *colaùro*, which continues in the combs of the winter ponds; there are two other *cavane*, one on the access to the valley, the other in the winter ponds area. The fishing valley mansion-*colaùro*-winter fishponds-embankment is functionally integrated and morphologically continuous.





- Brackish marshland, *barene*
- Winter fishpond, *peschiere di sverno*
- Reinforced embankment
- Lavorièro*
- Water sluice
- Fishing valley mansion, *casòn di valle*
- Storage, *cavana*, of Valle Perini
- Freshwater sluice
- Saltwater sluice
- Reinforced embankment
- Valle Perini building
- Brackish marshland, *barene*
- Lagoon brackish marshland
- Valle Perini reed bed

**Figure 18** Plan of Valle Perini (right).

**Figure 19** Detail of Valle Perini fishing valley mansion, *casòn di valle*, winter ponds, *peschiere di sverno*, and fishing trap, *lavorièro* (top).



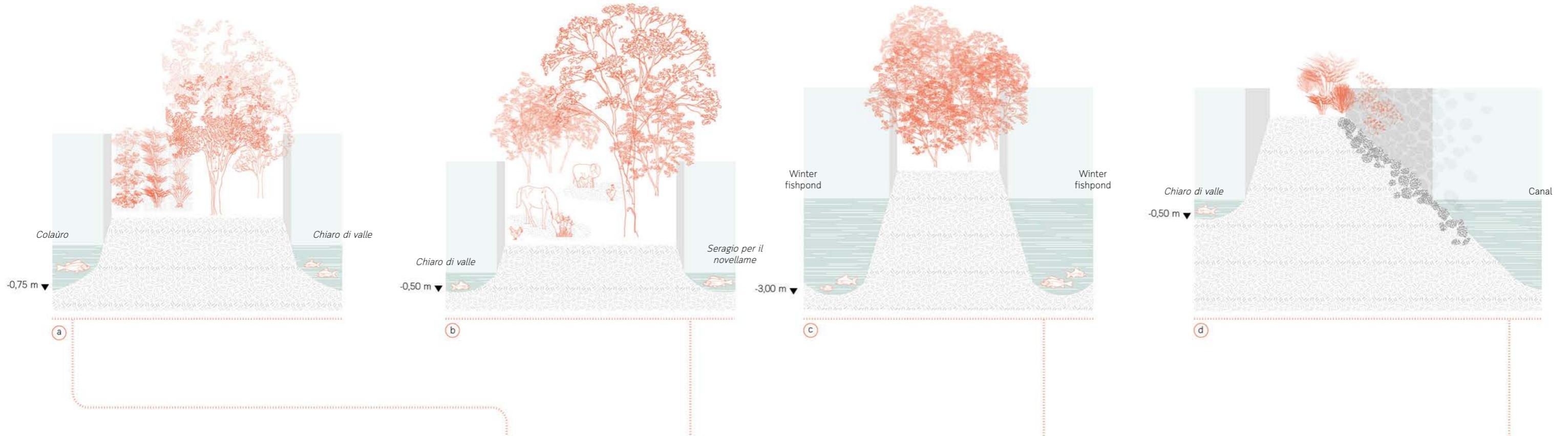
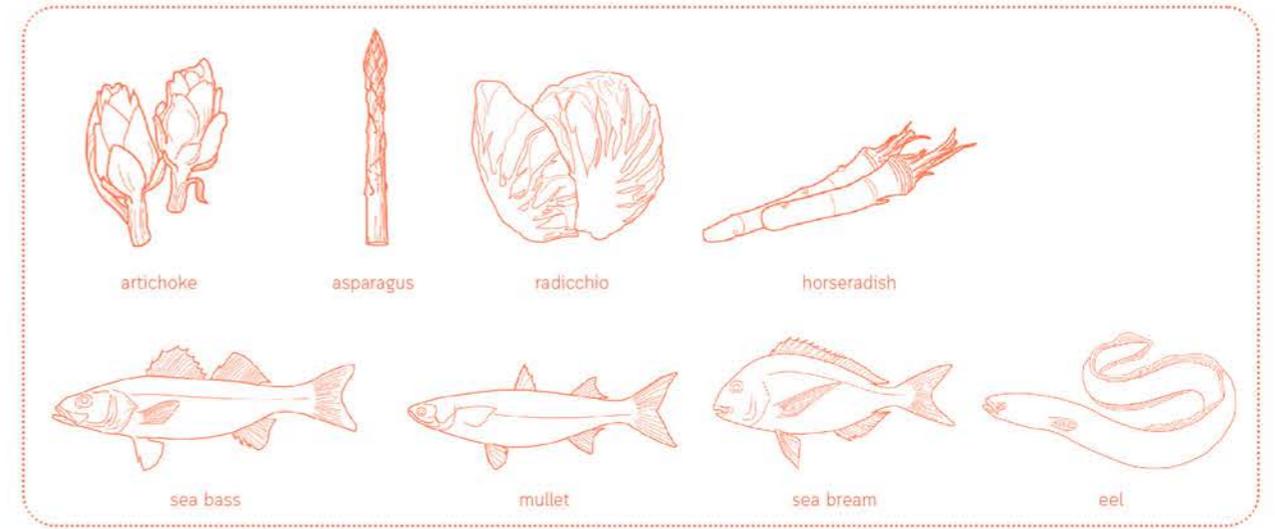
# Water System: Circularity.

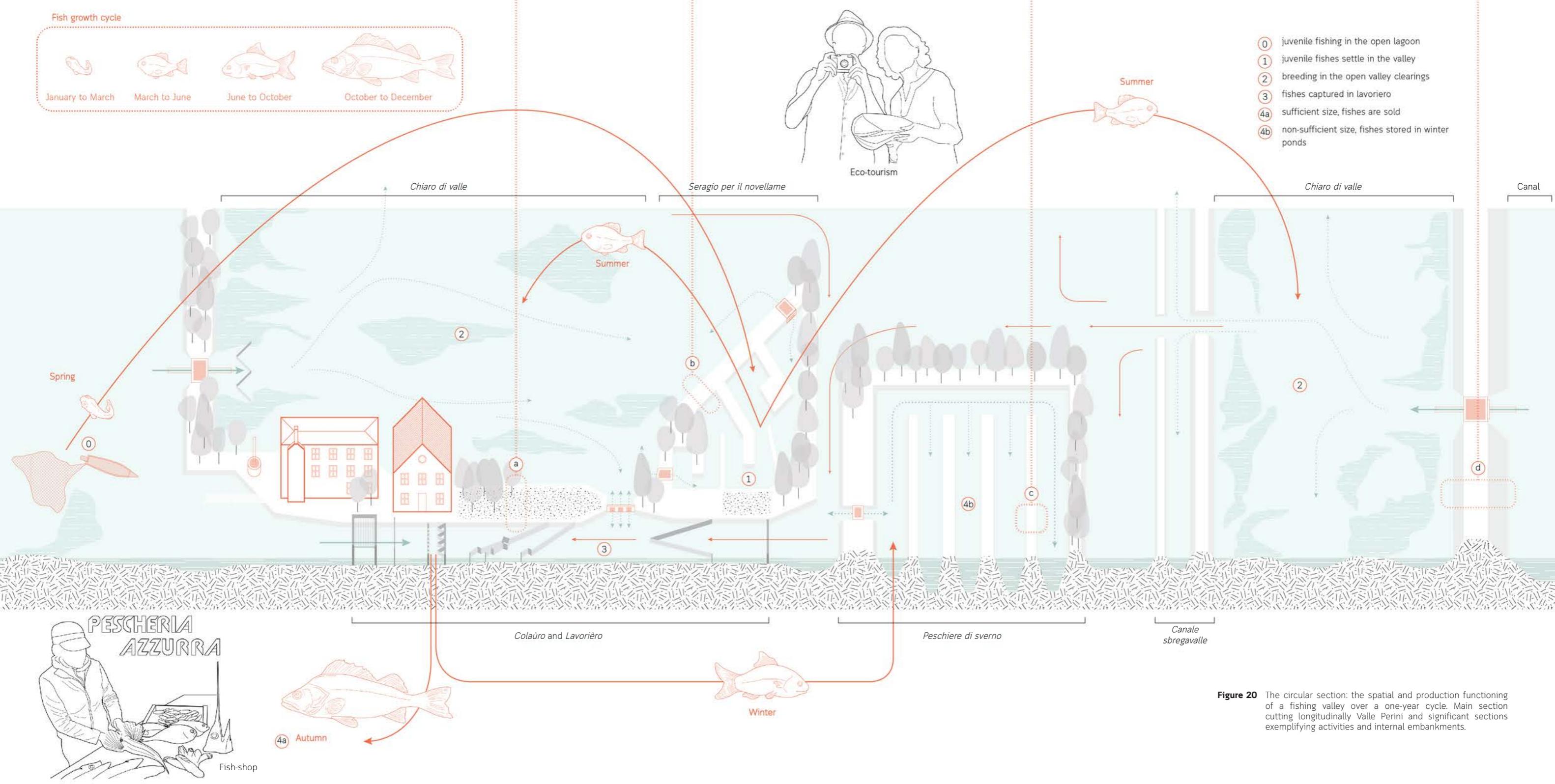
Since the first decades of the 20<sup>th</sup> century, the fishing valleys can be addressed as an extensive polyculture, where the main activity of fish farming has been juxtaposed by farm animals breeding (as horses, sheep, hens, goats, cows, etc.), vegetable gardens and orchards (cultivating horseradish, radicchio, asparagus, artichoke, etc.), reeds, mulch, fertilizer and hay production.

Despite its relatively low rates in terms of production, compared to other intensive aquacultures, this activity is

associated with reasonably low management costs: fishing valleys in the Venetian Lagoon are mainly family farms employing seasonal workers during the busiest seasons (spring and autumn). Recently, many of the fishing valleys have implemented their accommodation activity, providing a slower and lighter touristic alternative to discover the outer lagoon territory, in counter-trend to the mass tourism suffocating the historical center of Venice.

Main species cultivated in fishing valleys





**Figure 20** The circular section: the spatial and production functioning of a fishing valley over a one-year cycle. Main section cutting longitudinally Valle Perini and significant sections exemplifying activities and internal embankments.

# Conclusion.

The complex and almost legendary origin, the highly evolutionary tendency, and the multi-layered functioning and productivity make the fishing valleys the most antique and characteristic aquaculture system of the Venetian Lagoon and of the whole Mediterranean Sea. Its long-standing performance has ensured the *Serenissima* Republic of Venice seafood and fishes until its collapse, but even in that moment of weakness, this structure has not downfallen on its turn. It can be ascribed as a strong identity catalyst for the people involved in its management and, undoubtedly, as the most peculiar element of the productive heritage of the Venetian lagoon.

**Landscape values** - Since the 20<sup>th</sup> century, despite having been embanked for productivity reasons to limit losses, the current fifteen fishing valleys located alongside the Venetian Lagoon contermination (border) have allowed the conservation of peculiar traits and elements of the Venetian Lagoon landscape. The brackish marshlands, *barene*, included within the valleys and at the same time protected by their embankments, have not suffered from erosion as the ones in the open lagoon, and have been able to perform their supportive ecological role within the ecosystem.

**Architectural values** - Fishing valley mansions, *casoni da pesca*, and anglers' storages, *cavane*, represent two of the earliest examples of Venetian Lagoon vernacular architecture. These elements of necessity were built from scratch by Venetian anglers in need for shelter for themselves, their boats and their working tools during the fishing season. Mainly constructed with very resistant wood, like chestnut or larch coming from Venetian Dolomites, the primitive examples were consolidated with clay and silt and their roofs were made with reeds and branches. As the time passed, the mansion became the symbol of power and wealth of the family owning the fishing valley.

**Functionality values** - Many of the elements characterizing the fishing valleys' structure and architecture, and their simple formal and constructive solutions, answer the vocation of pure functionalism. The winter ponds, the canals, the open pasture basins, derive from the organic forms already shaping the lagoon landscape along its extreme boundaries.

**Sustainability values** - The main natural forces determining the functioning and the performance of the Venetian Lagoon fishing valleys are fishes and water. Their seasonal movements are the crucial behaviours considered by the water workers to define their role to intervene and to profit from this interaction. With the passing of centuries, the fishing valleys have become more complex systems, not only made of aquaculture but also agro-production, agro-tourism and eco-environmental conservation (WWF site of Valle Averte, southern Venetian lagoon). In a succeeding manner, they have been implementing their scope of action, tending to perform as more circular systems rather than linear activities.

**Ethnographic and identity values** - Even before the foundation of the city of Venice, since 5<sup>th</sup> century A.D., those populations that occupied the swampy lagoon took advantage of its natural provisioning of raw material: the fishes. Fishing have always constituted the most important source of work and food, and traditionally it was handed down from one generation to another. However, this expertise combined with the natural characteristics of the lagoon landscape (extended surfaces of shallow and brackish waters), has opened the doors for the development of the fishing valleys' extensive aquaculture system as it is known nowadays.

**Strategic values** - The present geographic location of the fishing valleys results to be extremely strategic, even

if not directly chosen. In fact, after many bureaucratic vicissitudes, at the end the valleys have been placed along the Venetian Lagoon contermination (border). This current positioning ensure them the vicinity to freshwater outlets and the distance from the, sometimes extremely powerful, sea water currents entering in the lagoon.

**Lessons to learn** - The key aspects to be taken from the Venetian Lagoon fishing valleys example are the integration of the aquaculture extensive system with multiple parallel activities, as agricultural production and slow tourism enhancement and the respectful and sustainable coexistence with the natural landscape of the Venetian Lagoon, especially the brackish marshlands, which they have been actively preserving.

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**Figure 5** Venetian Lagoon watershed [Figure]. Information retrieved from <https://idt2.regione.veneto.it/>. Drawn by the author.

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**Figure 8** Autumn [Image]. Retrieved from <https://polesineazzurra.blogspot.com/2018/01/pescabellaniil-bilancio-positivo-del.html>. Edited by the author.

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**Figure 10** Annual precipitation and temperature [Figure]. Retrieved from <http://www.isprambiente.gov.it/it/banche-dati>. Drawn by the author.

**Figure 11-12** Temperature and rainfall average [Figures] GIS shapefile and information retrieved from <https://idt2.regione.veneto.it/>. Drawn by the author.

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# The Roman Aqueducts

A system of pipes, canals, and supporting structures used to convey water from its source to its main distribution point.

Camilla Di Nicola

- 01
- 02
- 03
- 04**
- 05
- 06
- 07
- 08
- 09
- 10

**Figure 1** *Aqua Claudia*, Parco degli Acquadotti, Rome.

# Context.

Location: Rome, Italy  
Period: 312 B.C. to A.D. 226  
Function: Bring water from outside sources into cities  
Type: Artificial system  
Area: 201562 ha  
Water Quality: Fresh and drinkable water

*"If we consider the distances traversed by the water before it arrives, the raising of the arches, the tunneling of mountains and the building of level routes across deep valleys, we shall readily admit that there has never been anything more remarkable in the whole world."*

Pliny the Elder, Roman author, I century AD

The Roman aqueduct was a channel used to transport fresh water to highly populated areas. Aqueducts were amazing feats of engineering given the time period. Though earlier civilizations in Egypt and India also built aqueducts, the Romans improved on the structure and built an extensive and complex network across their territories.



Figure 2 Continental scale Europe and Italy.

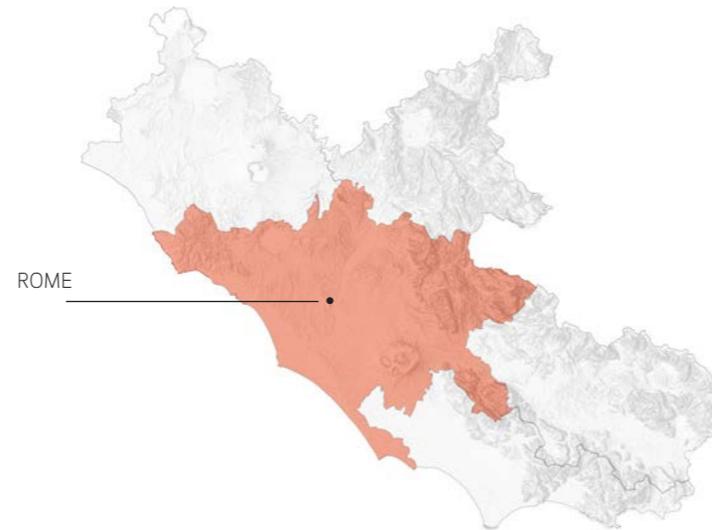


Figure 3 Regional scale and Rome's municipality in red.

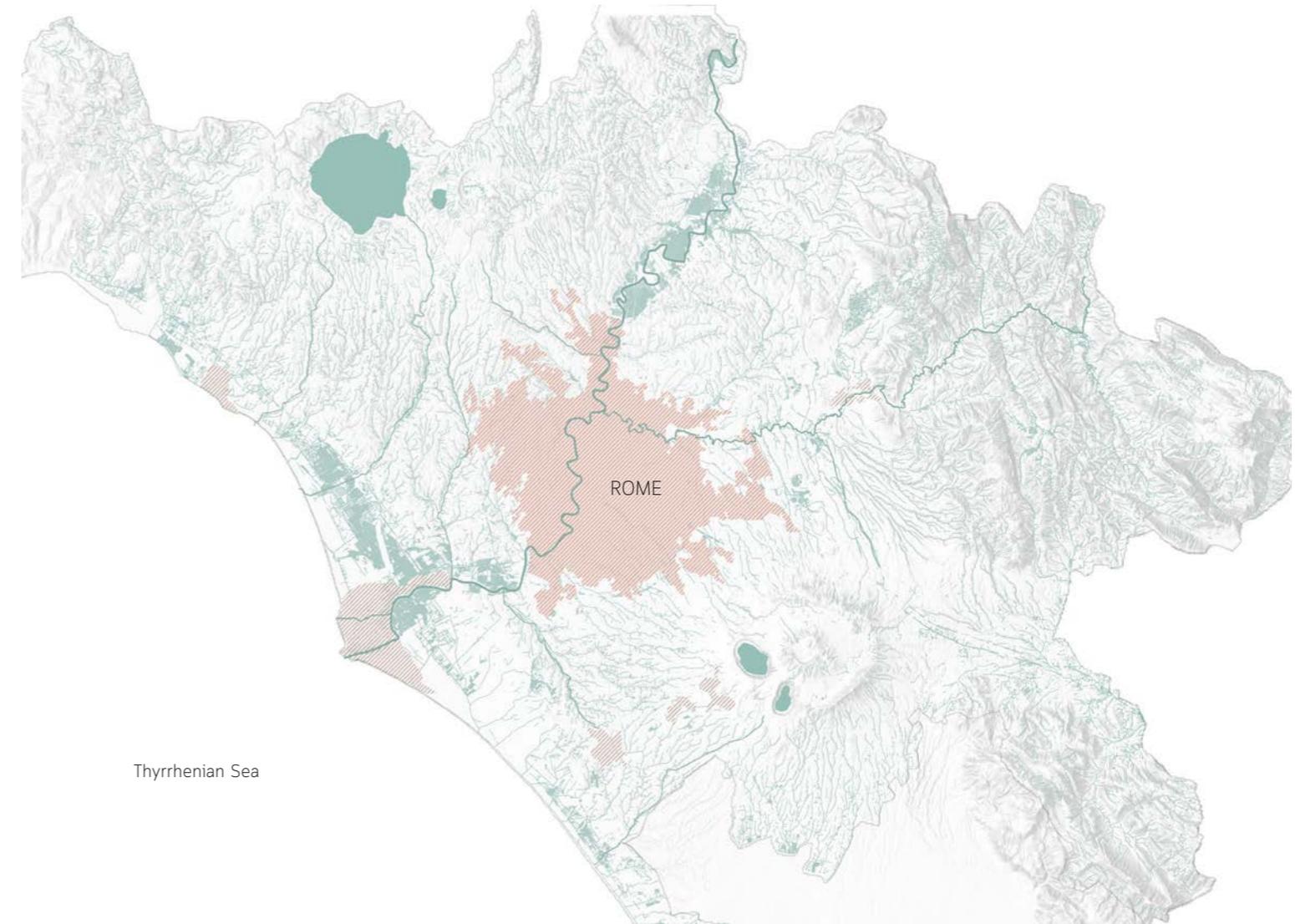


Figure 4 Hydrographic Map.

## Archaeological ruins of the Aqueducts.

The aqueduct system consisted of several elements, of which the remains can still be seen. The *piscina limaria* that were sedimentation tanks that were used to purify the water, the *cisterna*, cistern, that collected rainwater or excess water from the aqueducts for periods of drought. At the end of the aqueducts there was the *castellum aquae* which distributed the water inside the city. The aqueducts were fundamental to provide drinking water to the city but also for other functions such as *thermae*, baths, that helped the well-being and health of citizens.



**Figure 5** *Piscina Limaria*, water settling and sedimentation tanks (top left).  
**Figure 6** Aqueducts and *cisterna*, cistern in order to collect rain water (top right).  
**Figure 7** *Castellum aquae*, water distributor (bottom left).  
**Figure 8** Aqueducts and *cisterna*, cistern in order to collect rain water (top right).

# Climate.

Climate zone: **Temperate**  
 Sub-climate: **Mediterranean**

## Climate & Weather Averages

High t°: 31.2°C  
 Low t°: 1.9°C  
 Mean t°: 18°C  
 Precipitation: 50 mm  
 Humidity: 45%  
 Wind: 13 km/h  
 Hottest Months: July (28°C avg)  
 Coldest Month: January (3°C avg)  
 Wettest Months: November  
 Windiest Months: April  
 Annual Rainfall: 837.3 mm per year

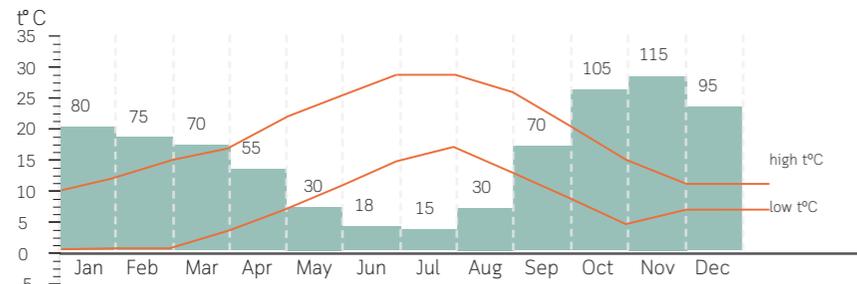


Figure 9 Venetian lagoon annual precipitation and temperature

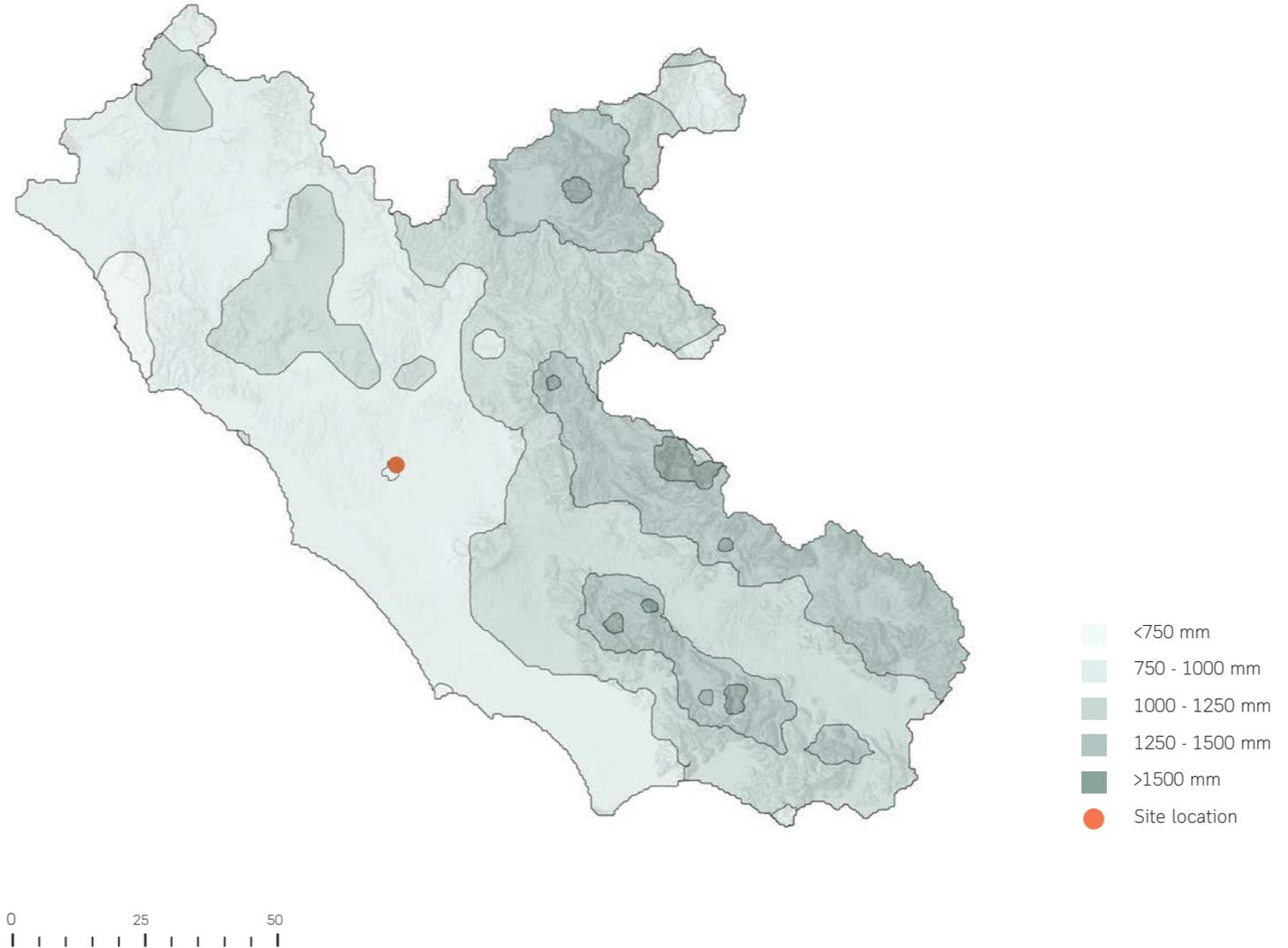


Figure 10 Average rainfall (mm).

# The Aqueducts system.

Roman aqueduct systems were built over a period of about 500 years, from 312 B.C. to A.D. 226. Both public and private funds paid for construction. The city of Rome had around 11 aqueduct systems supplying freshwater from sources as far as 92 km away.

The aqueducts were made from a series of pipes, tunnels, canals, and bridges. Gravity and the natural slope of the land allowed aqueducts to channel water from a freshwater source, such as a lake or underground springs, to a city. As water flowed into the cities, it was used for drinking, irrigation, and to supply hundreds of public fountains and baths.

The principle was relatively simple: pure and abundant sources in the hills around Rome could be tapped, and their waters diverted into artificial channels running gently towards the city on a gradient designed to deliver them at a useful height, to flow around the city and feed street fountains, baths, and (for a fee) private houses.

The cheapest route had to be surveyed very precisely: the gradient had to be steep enough to ensure a good flow (to stop the water dropping sediment which would clog the system), but shallow enough to avoid damaging surges. An array of settling tanks, distribution towers or *castella*, pipes, cisterns and fountains had to be built and, for maximum publicity value, richly decorated.

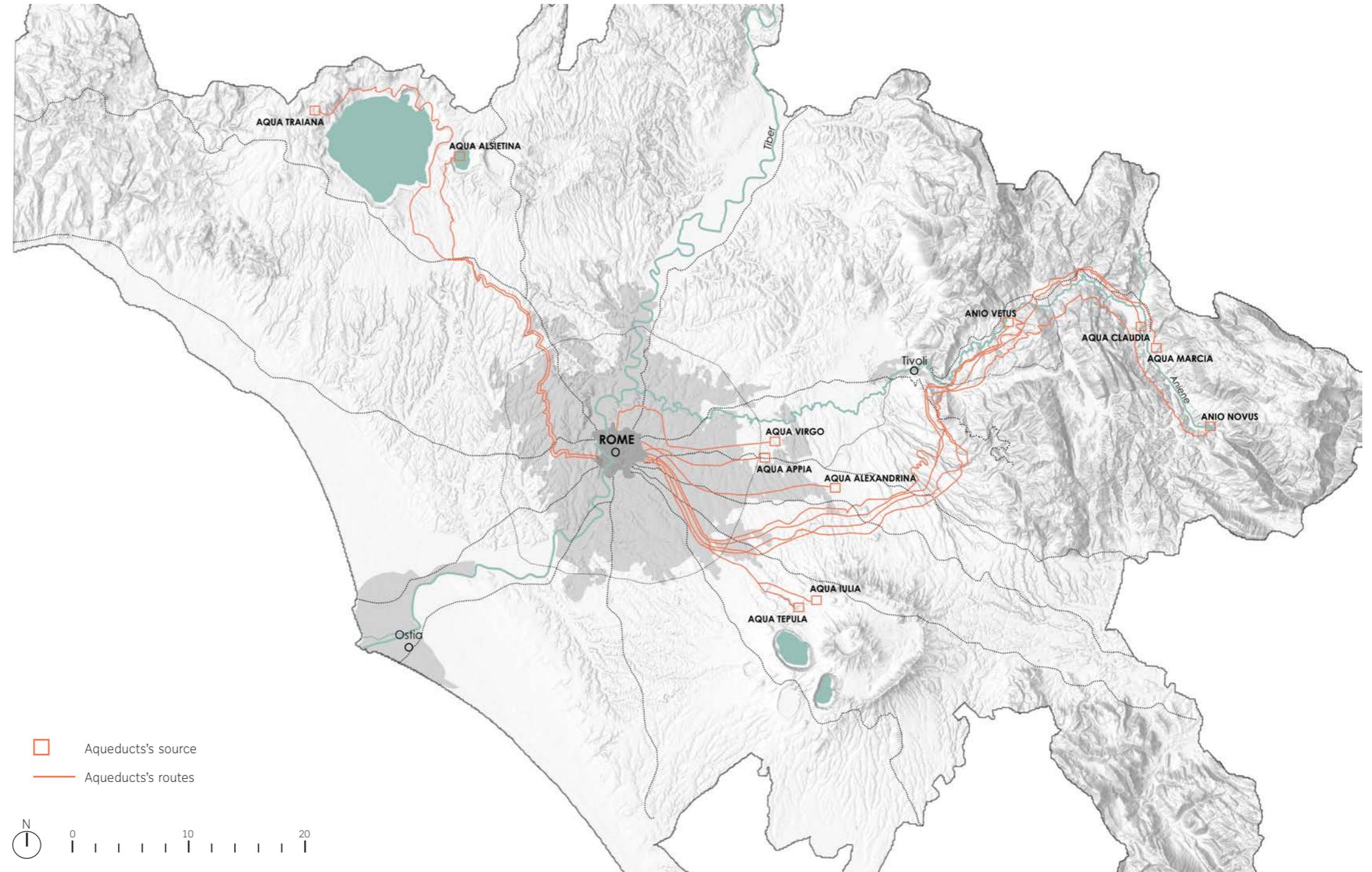


Figure 11 Map of the aqueducts, from the countryside to the city center.

# The Aqueducts over time.

312 BC TO A.D. 226



Rome's first aqueduct, the Aqua Appia, was built in 312 BC. This brought water in from about 16km away, ran almost all its length underground, and could only supply a small and low-lying part of the city. Within 170 years the Marcia aqueduct was built that tapped springs over 90km away, and ran for over 10km on arches; by the 1st century AD the entire city was served by aqueduct water, and by the early third century there were 11 major aqueducts, mostly running in from the Sabine Hills to the southeast, converging at the "Porta Maggiore" gate. They brought to the city an availability of water of about 1,127,000 cubic meters each day, distributed among the private houses, about 1300 public fountains, 15 monumental fountains, and around 11 public baths, as well as basins used for shows such as *naumachie*, water battle, and artificial lakes.

V to XV CENTURY



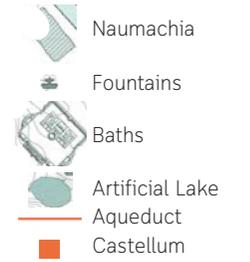
With the fall of the Western Roman Empire, some aqueducts were deliberately cut by enemies, but many more fell into disuse due to the lack of organized maintenance. The scarce presence of aqueducts and therefore of public fountains led to a serious hygienic-sanitary situation within the city, diseases were widespread and the population dropped from its peak of over 1 million inhabitants in the imperial era to 30,000 in the Middle Ages. The inhabitants returned to refer to the river Tiber as the main source of water.

XVI to XVII CENTURY



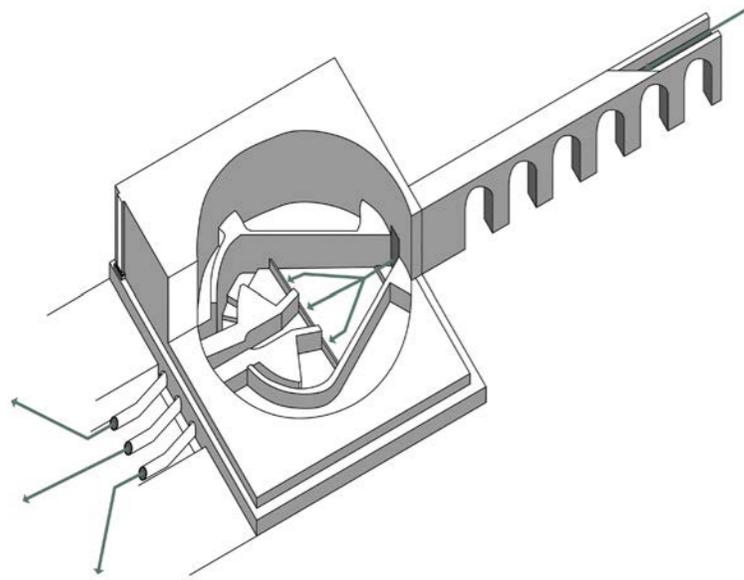
Thanks to the Baroque (XVI-XVII) and the period known as *renovatio romae* that the ancient splendor of the city returns to shine. The popes understood the importance of running water in a city and above all they understood the power it can bring. In fact, the popes wanted to oppose the austerity of the protestantism, which was spreading at the time in the northern Europe, with the elegance, the magnificent, the creativity of the Catholic Church, who amused and improved the life of their faithfuls. Therefore, some of the ancient Roman aqueducts were rebuilt and a lot of money was invested in famous public works such as the fountains, through which the city returned full.

**Figure 12** Rome's city center during Roman Empire. All the water elements are highlighted. In dashed line there is the zoom which is on the following page.  
**Figure 13** Rome's city center during Medieval Era.  
**Figure 14** Rome's city center during Renaissance.

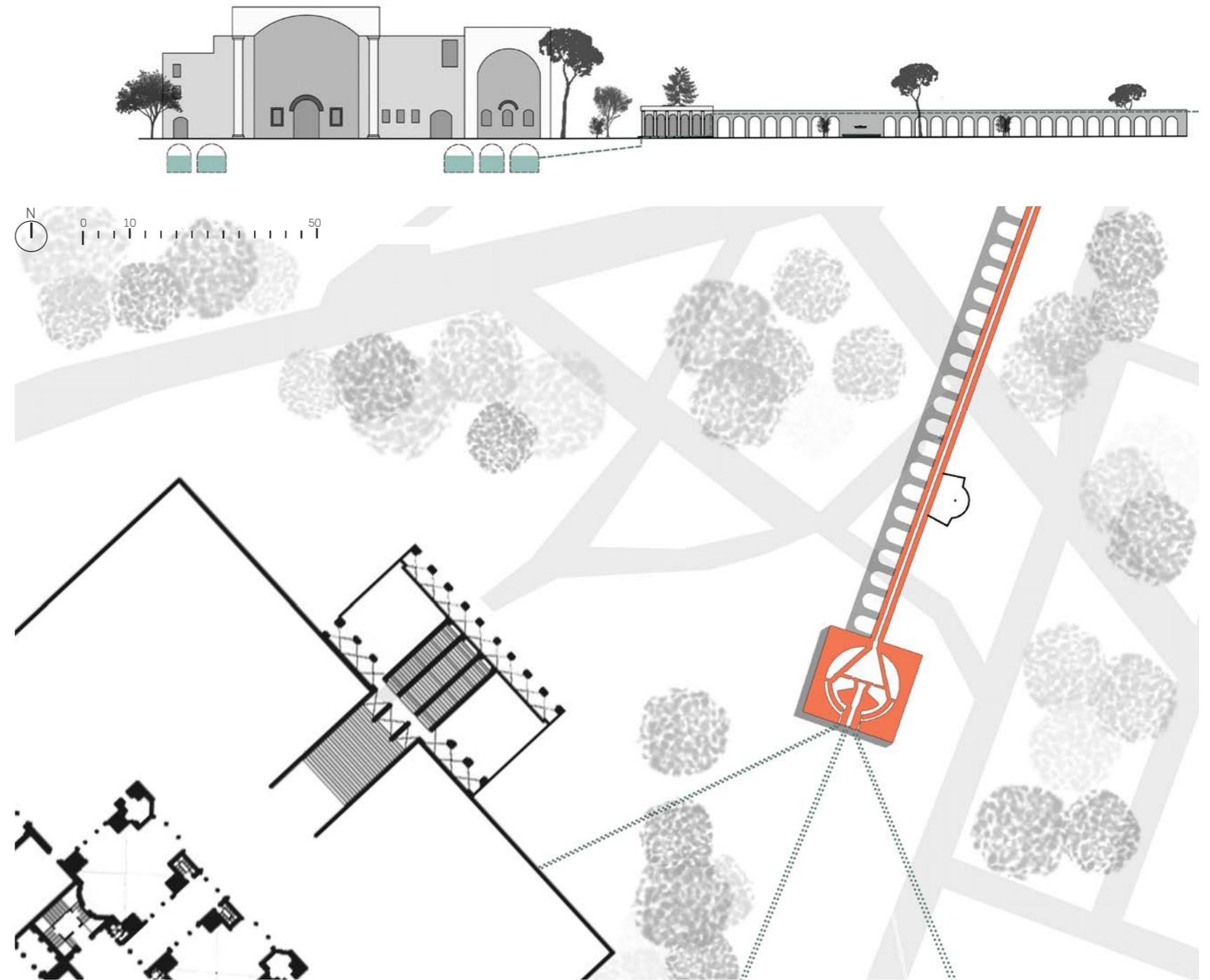


# Water distribution system.

A *castellum* is a Roman structure that was situated at the end of an aqueduct, where the water was delivered to a basin and then dispersed. It is estimated that there were about 247 *castella* in Rome, usually located in the highest point of the city, and they received water from the aqueducts, taking advantage of the fall pressure, and then the water was conveyed into three conduits, so as to reach the whole city; however, a shutter system regulated the flow of water according to availability. *Castellum Aquae* has a circular plan, with a dome vault with a diameter of six meters and externally it has a trapezoidal shape. Inside, the large tank was divided into three compartments, each of which fed a pipeline: one was used for fountains, one for public buildings, such as baths and the other for private houses; in case of lack of water, the only supply was that for public fountains.



**Figure 15** Plan of Trajan's Bath and the detail of the aqueduct system with the *castellum* and the pipes (bottom right).  
**Figure 16** Section of Trajan Bath (top right).  
**Figure 17** Axonometry of the *castellum* (left).

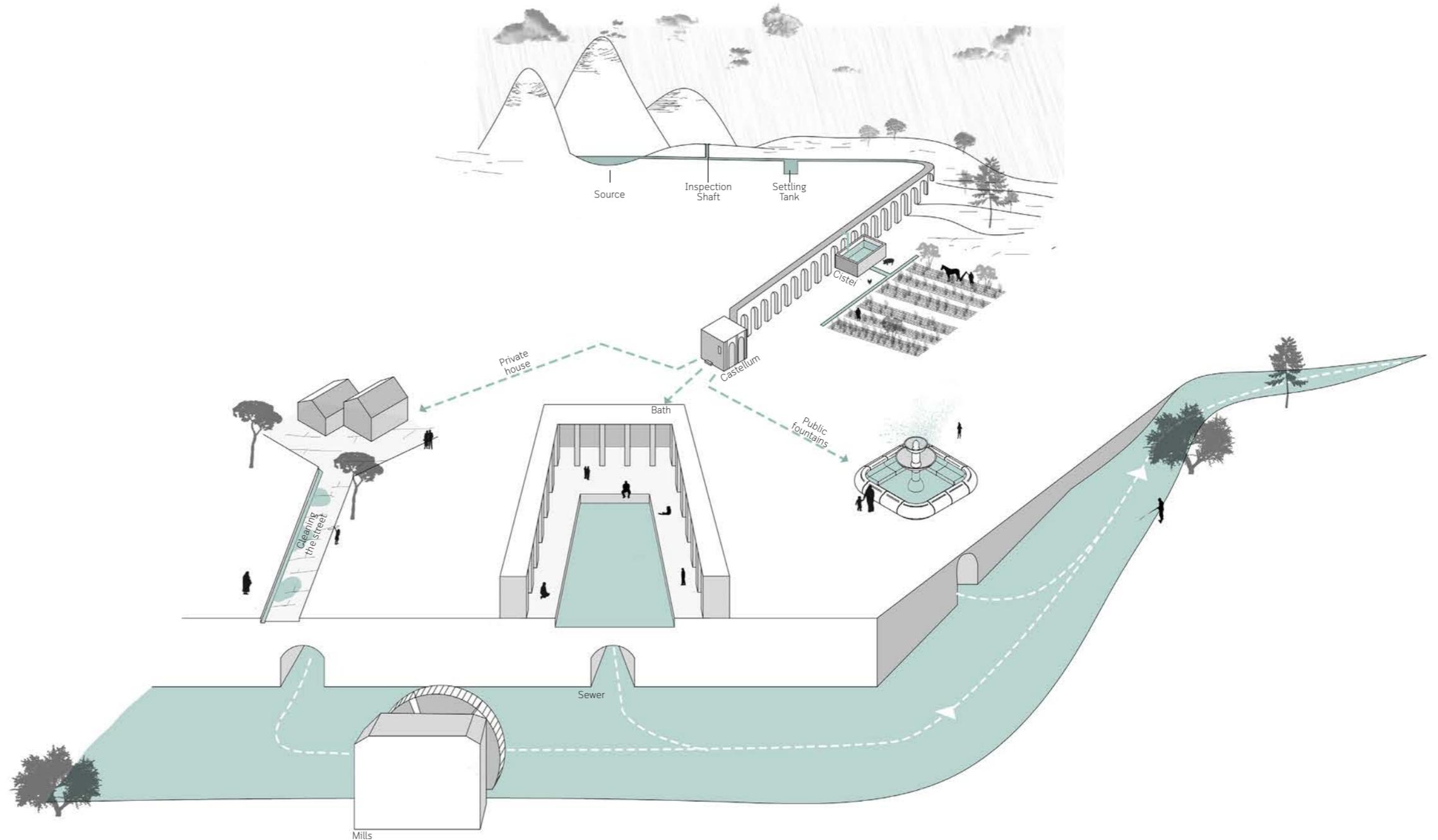


# Circularity.

The first thing to do to start the construction of an aqueduct was to find a source of water that was drinkable and at a certain height that could allow its exploitation through pressure. After the inspection of the water quality they built long underground tunnels in which the water flowed. Through the inspection shafts they could verify that the pipes were working. Moreover, the purification of the water was also guaranteed by the porosity of the soil (mainly tuff) that filtered the rainwater, which was then collected in the tunnel.

Finally, the settling tank (*piscina limaria*) improved the water purification by collecting the debris at the bottom of the tank. The canal, or *specus*, were constructed to maintain a constant slope so as to overcome the differences in height the arches. Excess water from the aqueducts and rainwater was collected in the cisterns. Often in the countryside, they were then used to water the fields.

Once arrived in the city, the water was distributed through the *castellum* in three different directions: for public fountains for baths and for some privileged private houses. The water was also used to clean the streets, improving the sanitary quality of the city. Only then, this water was channeled into the sewer system and then ended up in the river which was organized with a system of grain mills.



**Figure 18** The spatial representation of an aqueduct and the different functions that the water has before its final destination, the river.

## Cultural Significance.

The aqueducts went wherever Rome went, an outward symbol of all that Rome stood for and all that Rome had to offer. The aqueducts gave the city of Rome the opportunity to grow economically and culturally.

Some elements that highlight the importance of the aqueduct system are still visible within the city of Rome, highlighting the incredible engineering effort of the Romans.



*Porta Maggiore*

Located in the point where eight of the original eleven roman aqueducts converged, it could be found in *Porta Maggiore* Square, a fundamental area in the road network of the city, point of convergence of *via Prenestina*, *via Casilina*, the Esquilin area and *San Lorenzo* district. The square derives its name from one of the ancient gates of Rome, *Porta Maggiore* (Larger Gate), so called because of its imposing dimension. This monumental gate was built in 52 A.D. by the emperor Aurelian to celebrate the end of the construction of two large aqueducts, the *Aqua Claudia* and the *Anio Novus*.



*Bocca della Verità* - Mouth of Truth

According to the legend all the people telling a lie keeping the hand into the mouth of the mask would have lost it, eaten by the terrible mouth. In reality, during Roman age, this mysterious mask was a sewer cover connected to the *cloaca maxima*, the main sewage system of the roman forum. In order to celebrate the sewage system that managed to clean the city, it was decorated with these manholes represented water and river divinities, drinking the rain, letting the water flow to the sea.



*Mostra d'acqua* - Water Show

*Mostra* comes from the Latin word *mostrare* that it means to show, to reveal, to exhibit. These beautiful fountains were the terminal of the aqueducts. The fountains become a visible element to show the great engineer's effort of the complex system of the aqueducts.

# Conclusion.

As symbol of civilization and progress, the aqueducts were built throughout the empire. The aqueduct system was an incredible monumental work, a symbol of the cultural and engineering progress of the ancient Romans. Thanks to the aqueducts, the Roman empire had the opportunity to exist and expand throughout Europe.

**Architectural values** - The aqueducts of the Romans may be divided into three general groups, according to the materials with which they are constructed. This classification is more convenient in that it conforms very nearly to their chronological arrangement. The earliest of these monuments that show any architectural character was built around 144 B.C. entirely of cut stone, laid dry in regular courses. During the early Empire, the Romans continued to employ *tufa* and *peperino* cut and laid similarly, though with rather less care and precision. Under the Emperor Augustus, it had become the custom to build the smaller aqueducts, and those in the provinces, of concrete faced with a revetment of a stone laid in courses or the form of *opus reticulatum*.

**Functional values** - The general and fundamental principle on which the construction of the aqueducts are based is the gravity flow. It meant that the engineer had to lay out a line avoiding both too steep a gradient, a fast flow, in fact, would erode or damage the conduit, and one too shallow, to avoid the current stagnating. For this reason, sometimes bridges and viaducts were needed to cross intervening valleys.

**Landscape values** - Although the aqueducts are artificial artifacts, they are extremely connected with the ground. The slope, the heights and the distances were carefully studied to obtain the most effective result.

**Strategic values** - As mentioned above, gravity was the fundamental principle of the aqueduct; this meant that the study of topography was essential. The aqueducts ran most-

ly underground, and the study of the terrain was essential for building shorter routes and with the right endurance. By studying the maps, it is possible to understand how the course of the aqueducts often followed the terrain itself, avoiding sudden changes in altitude unless necessary.

**Values of Sustainability** - Most of the outlets, private and public, were kept running 24 hours a day, the aqueducts were like a river and they carried water from the source to the city continuously. Any attempt to stop the flow would have resulted in structural damage as well as have made the water overflow from the conduits and flood the town. Although this may seem wasteful today, in reality, the Romans didn't waste even a drop of water. If the water from the aqueducts was in excess it was kept in the cisterns and used for irrigation, or, in the city, it was used for washing the streets. The continuous flow, also, had the advantage that the sewers were kept constantly flushed, allowing a high level of hygiene in the city.

**Ethnographic and Identity values** - *"I ask you; just compare the vast monuments of this vital aqueduct network with those useless Pyramids, or the good-for-nothing tourist attraction of the Greeks!"* (Frontinus, De Aquaeductu, I 16). This was the spirit of the Romans when they referred to the aqueducts, in fact, this system is not a simple and useless piece of art but something solid, grand, practical, complex and a symbol of civilization. The aqueducts went wherever Rome went, an outward symbol of all that Rome stood for: civilization, engineering genius, pragmatism. To possess an aqueduct was a clear mark of prestige and prosperity that none could mistake.

**Lessons to learn** - The Roman aqueducts were one of the first great human works which, by combining ingenuity and aesthetics, contributed to the founding of one of the most important ancient cities in the world.

Without the help of any kind of mechanical or electrical instrument the Romans were able to bring fresh and drinkable water miles and miles away to their cities.

Although, of course, we refer to a very different era, in which thousands of slaves were exploited for this type of work and the command and decisions were made by one man, the emperor, it is clear that this work was exceptional.

Their genius was the care and study carried out on their territory: to study its properties, a porous soil that filtered a lot of water into the subsoil must also have contained many aquifers, and its characteristics, so as to be able to adequately exploit the slope in order to transport the water with the right moderation. And then the invention of the materials for the pipes and the accurate and solid construction of the aqueducts, which still today, 2000 years later, mark and characterize the landscape of the Roman countryside, making it unique in the world.

Despite the fact that today the construction of modern aqueducts is easy and quick thanks to the mechanical pumps

that conveniently distribute the water in every house, it is important to remember that great results can be obtained even with the scarcity of tools. The care, patience and careful study of the surrounding area has given the Romans the possibility to have running water and to be able to use it for alimentary, sanitary but also recreational purposes.



**Figure 22** Montage of the aqueduct arriving into the city.

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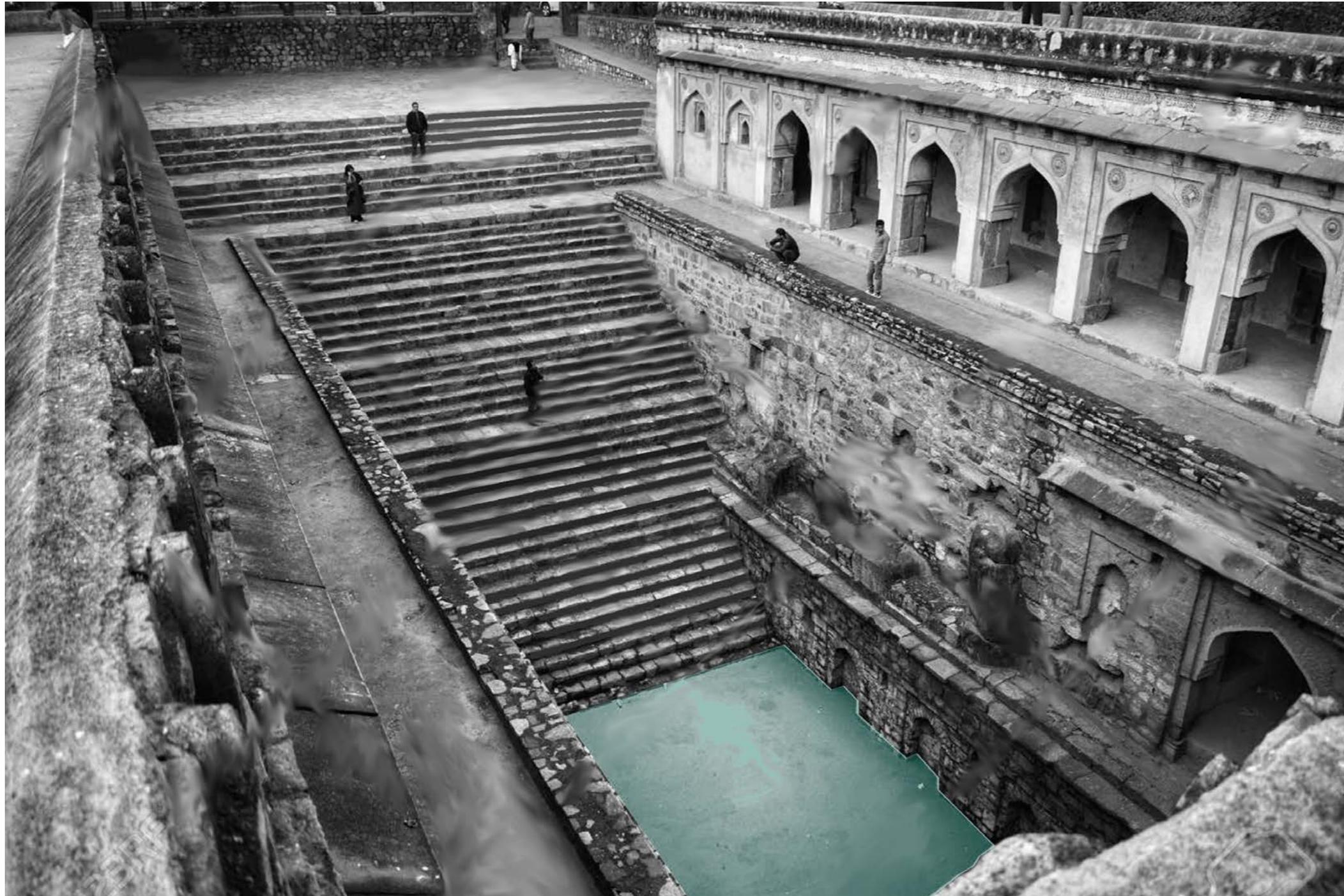
**Figure 20** Bocca della Verità [Figure]. Retrieved from <http://gezinoktasi.blogspot.com/2014/07/bocca-della-verita-mermeri-turkiyeden.html> Edited by the author.

**Figure 21** Mostra dell'Acqua Felice [Image]. Retrieved from [https://en.wikipedia.org/wiki/Acqua\\_Felice](https://en.wikipedia.org/wiki/Acqua_Felice).

**Figure 22** Montage [Figure]. Drawn by the author.







# Delhi Sultanate Waterworks

Ancient network of water harvesting  
structures in Delhi, India.

Tanvi Gupta

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Figure 1 Typical Baoli stepwell atmosphere.

# Context.

Delhi is located in the Northern part of India between 28.7041 N latitudes and 77.1025 E longitude. It occupies an area of 1,484 sq. km. and is continuously inhabited since the 6th century BCE. Through most of its history Delhi has served as capital of various kingdoms, most notably the Delhi Sultanate and Maughal empire.

Two prominent features of the geography of Delhi are the Yamuna floodplains and the Delhi ridge. The ridge is the northern extension of the ancient Aravalli range covering an area of about 35 km and reaching height of 318 m (1,043 ft), it is a dominant feature of the region.



Figure 2 Country scale map

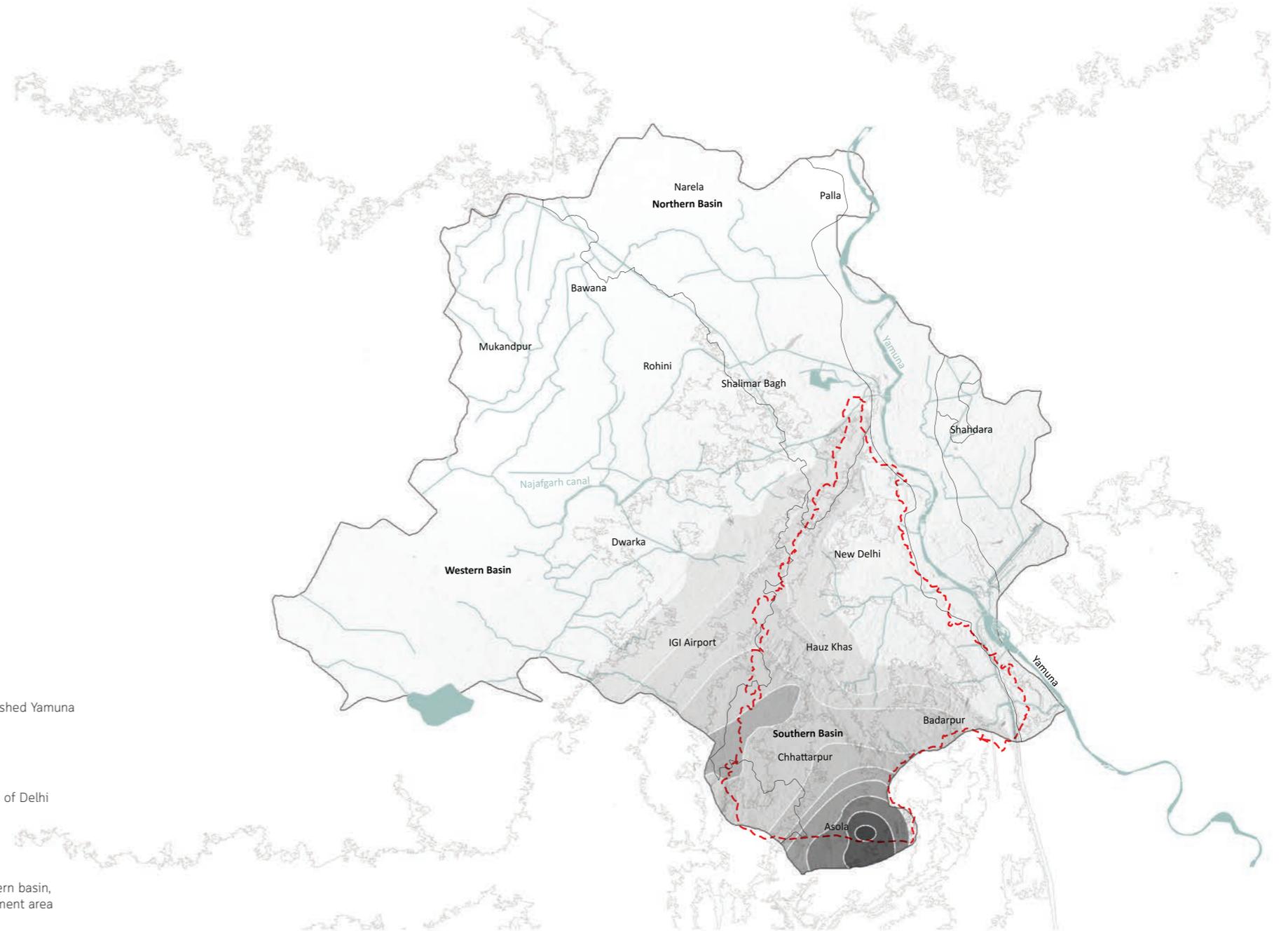
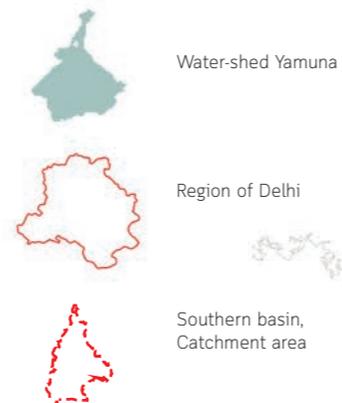


Figure 3 City scale map: the traditional water system of the bund baoli and hauz starting from the Delhi sultanate is chosen for study.

## Sultanate Waterworks.

Delhi's urban waterworks developed in early thirteenth century. They took the following main forms of Hauz (water tank), baoli (stepwell) and bund (embankment). Collectively these small structures served the sultanate capitals of South Western Delhi. As with other ancient and medieval water systems, they were incremental and coordinated.

Urban lakes, tanks and reservoirs were sited in gently sloping areas adjacent to hillside water control structures.



**Figure 4** Historical photo of Satpulla embankment or bund.  
**Figure 5** Historical photo of Baoli at Tughlaqabad.  
**Figure 6** Historical photo of Hauz-i-khas lake (water tank).  
**Figure 7** Historical photo of Sluice gate at Tughlaqabad.

# Climate.

**Climate zone:** Overlap of Humid Sub-tropical & Semi-arid  
**Sub climate:** humid, dry & semi-dry

## Climate and weather averages

High t°: 45°C  
 Low t°: 6°C  
 Mean t°: 29°C  
 Precipitation: 47.5 mm  
 Humidity: 63 %  
 Dew Point: 17°C  
 Wind: 6 km/hr  
 Pressure: 1008 mbar  
 Annual rainfall: 693 mm

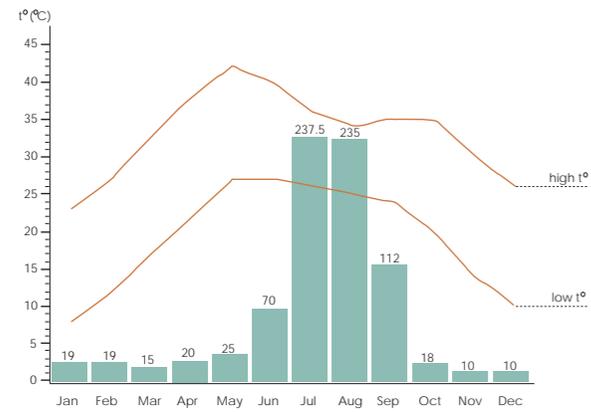


Figure 8 Temperature and precipitation graph.

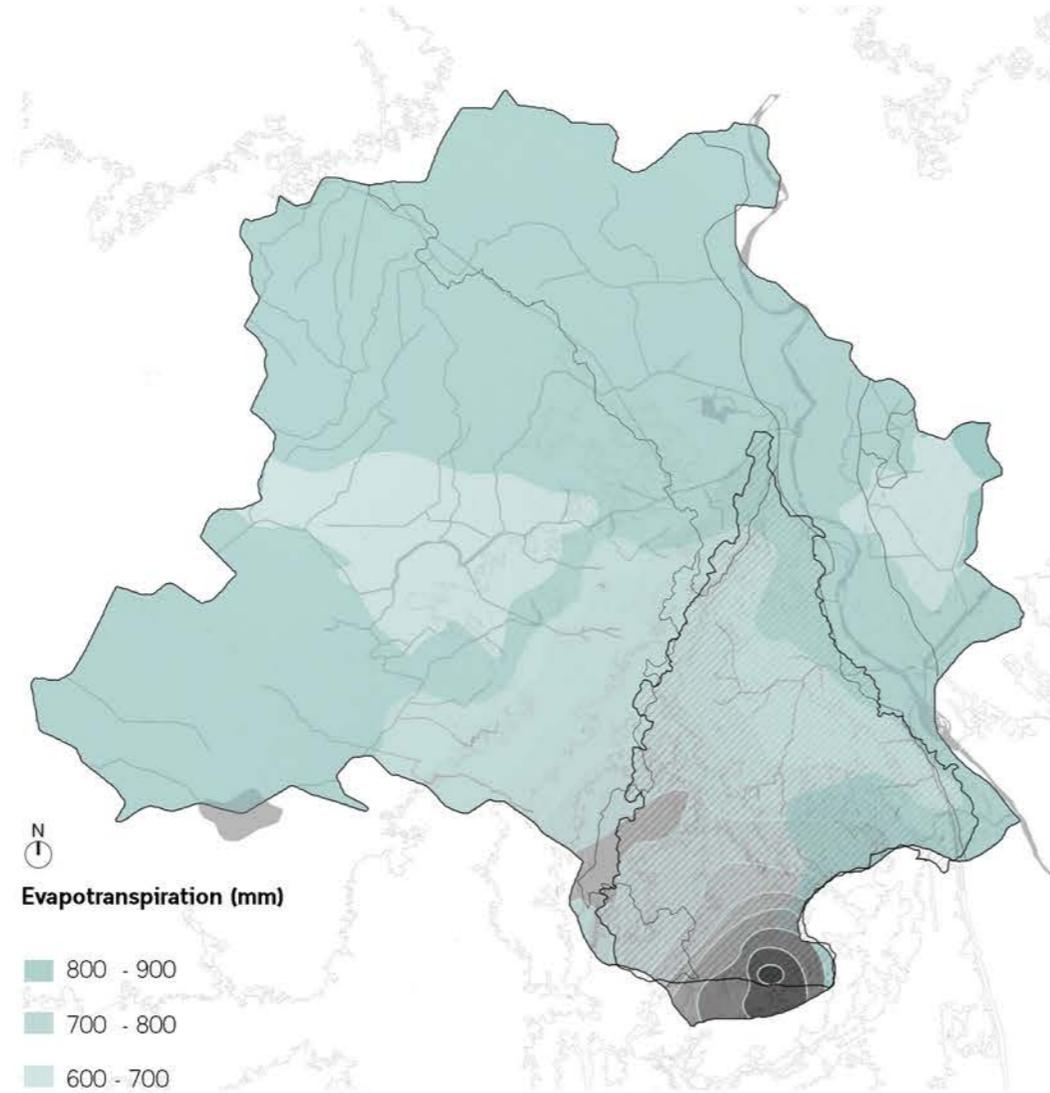


Figure 9 Evapotranspiration map

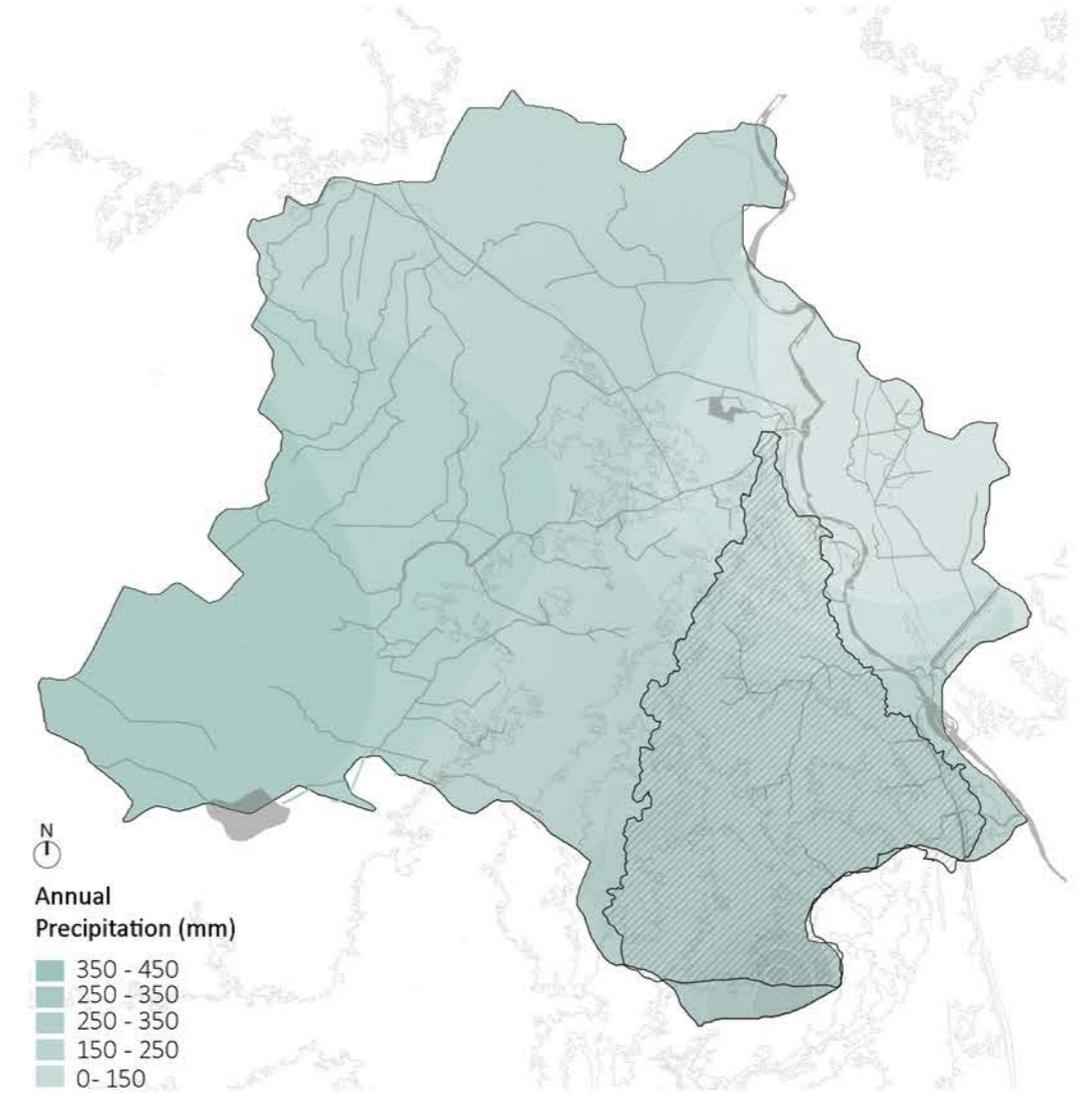


Figure 10 Annual Precipitation map

# Catchment Area.

The contours of the physical landscape of Delhi as we see today, including its flora and fauna are very different from what they were thousands of years ago. The Delhi ridge as shown in the figure constitute the Northernmost extensions of the Aravalli hills, the oldest mountains in India formed hundreds of million years ago. They enter Delhi from the South-West running through the city in a North-east direction. Today the height of the rocky Delhi ridge ranges between 2.5 m to 90 m above floodplain in North and South Delhi, in ancient times it would have been much higher (S. Upinder, 2006).

Most Sultanate cities and waterworks aligned themselves along this ridge to capture its runoff. The junction between the central and the Southern ridge became the preferred location for Sultanate urbanization and water control. Delhi sultanate waterworks developed during the early 13th century. They took three main forms - the bund network (embankment), hauz (water tank), and baoli (stepwell). These reflect the main strategies of the Delhi Sultanate water works - the bund network helps in directing and capturing the runoff from the ridge, the hauz stores the surplus monsoon surface water runoff and recharges ground water while the baolis tap into the shallow ground water along with storing rainwater.

The bunds define a network of 25 water structures along 40 miles of the ridge as shown in the figure. They harnessed rain fed rivulets or sheet drainage along the slopes of Delhi ridge to create perennial reservoirs, for use in the dry winter months.

Thus, the first bund sequence on either side of the ridge entrapped rain runoff and the second sequence controlled and channeled water to city reservoirs, defense moats and irrigation canals. This 40 mile network with over 15 rivulets and 60 miles of running water was in continuous use for over two centuries.

### Delhi's Streams or Nallahs

In the triangle created or the ridge, Delhi's alluvial plain is watered by a number of seasonal or perennial nallahs (canals). These *nallahs* flow down the Aravalli hills (ridge) slope through eroded gullies into the Yamuna river.

East flowing streams were tapped to feed large, lined lakes such as Anangtal, Hauz-i-Shamsi, Hauz-i-rani, and hauz-i-khas which sustained the cities of Anangpur, Mehrauli, Jahanpanah and Siri. Despite the presence of river Yamuna most of Delhi's population depended on underground or stored water until the arrival of piped water supply in the late nineteenth century. Water tables recharged by *nallahs* allowed a number of baolis (large stepwells built with several levels).

The quality of groundwater shows wide variations with depth, at most locations water quality deteriorates with depth. Canals and streams play an important role in sustaining fresh water aquifers in Delhi's upper strata of water-bearing soil.

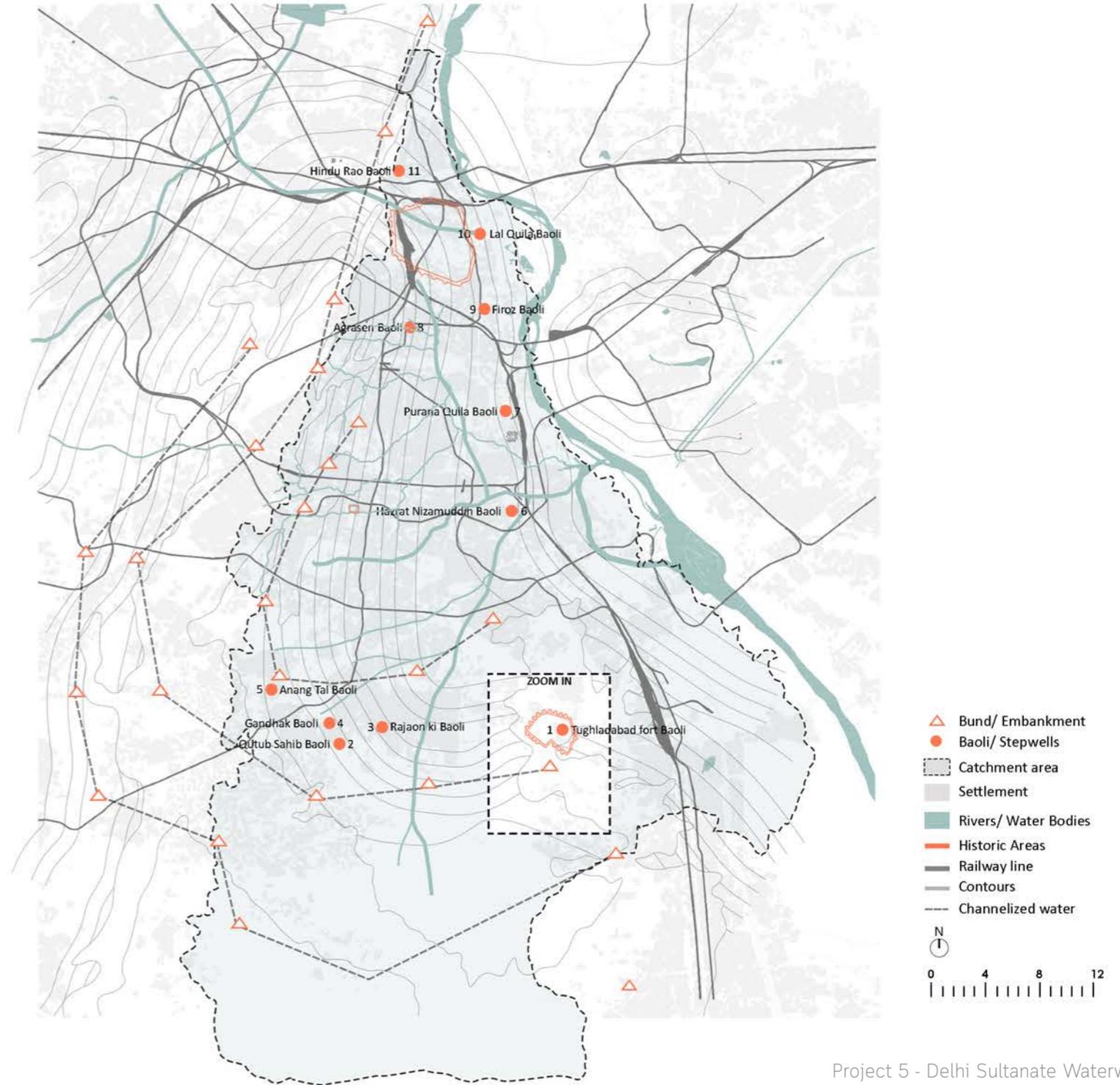


Figure 11 Bund network along Ridge.

# Tughlaqabad Fort Water system.

Stepwells, water channels, embankments and canals.

During the period of Delhi Sultanate, new cities were founded at strategic locations where water was the most important factor in their siting - its collection, storage and distribution predominated the settlement pattern. Tughlaqabad fort was built by Ghiyas-ud-din Tughlaq, located on a hill surrounded by a basin.

The fort was planned based on the contours of the site to form an irregular trapezium. The palace was quarried from the site itself and the quarries were subsequently used as moats and reservoirs. The surroundings of Tughlaqabad was transformed into a large lake with the help of waterworks (bunds) which collected water from the ridge. Tughlaqabad had 3 huge baolis and several wells for water supply as highlighted in the illustration.

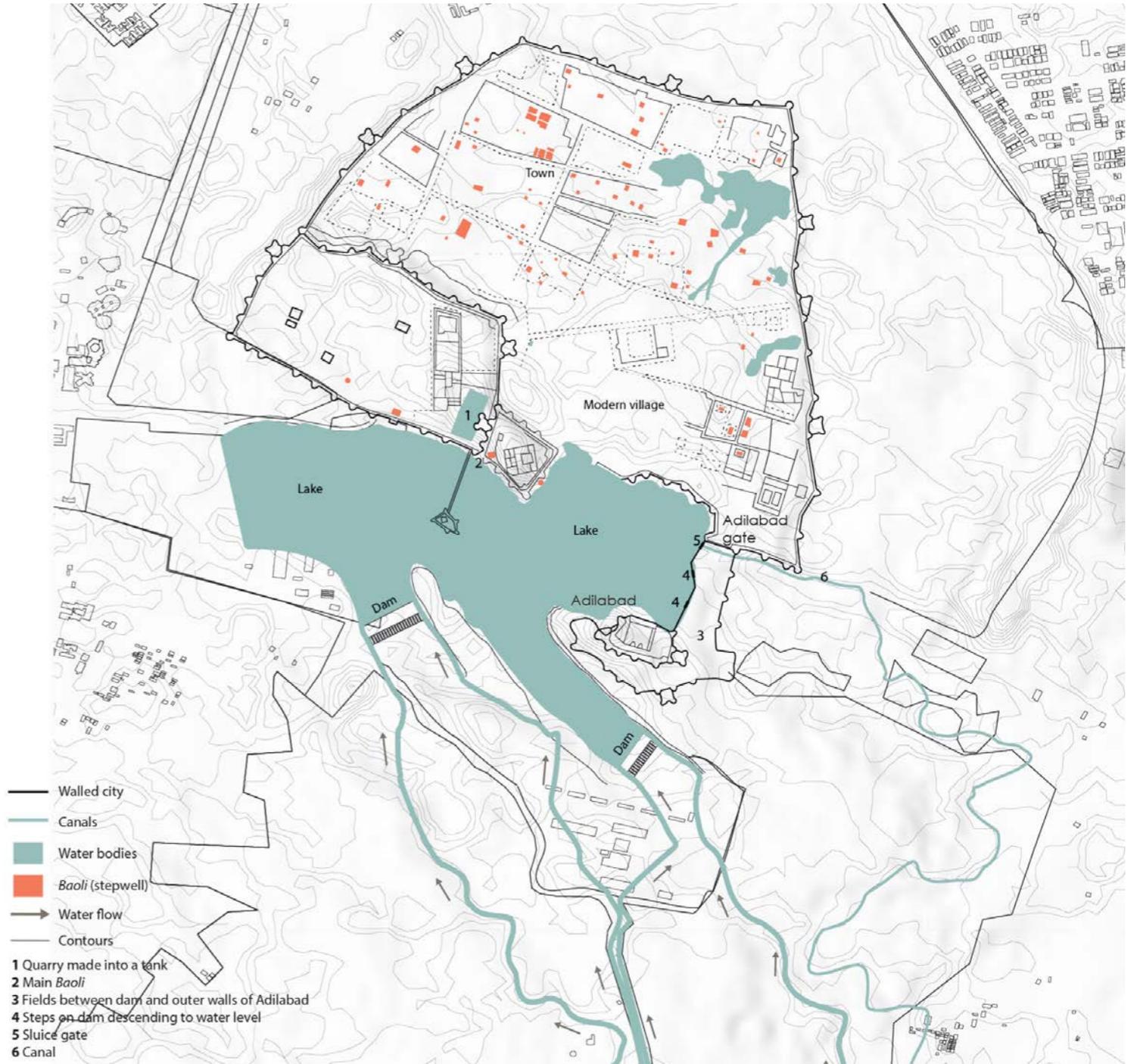
Creating a lake at the South of the Tughlaqabad fort was a challenge since the site was not close to river Yamuna and in order to bring the river water up to the hilltop where the fort was located, water had to be pumped up by means of a canal which was considered impractical. The lake was therefore dependent on local streams and monsoon floodwater which was channeled into a depression at the south of the town where the water was regulated by means of several dams and a sluice gate controlling the outlet which flowed into a canal. The dams are constructed as simple earth embankments lined on the lake side with blocks of stone. This stretch is around 200m long and runs between Adilabad and Tughlaqabad.



**Figure 12** View of Southern end of retaining wall of the dam between Adilabad and Tughlaqabad seen from lakeside showing steps leading to water.

**Figure 13** View of Tughlaqabad lake surrounding tomb of Ghiyas-ud-din Tughlaq.

**Figure 14** Tughlaqabad town water system plan.



# Tughlaqabad Fort Baoli.

Stepwells, water channels and embankments.

A main water feature in the Tughlaqabad fort is a deep stepped reservoir (*baoli*). The baoli is roughly rectangular about 20 x 18 m. Towards the east side we see the remains of the steps which gave access to the water, the baoli is approximately over 16m deep. Towards the North we see the stone brackets for wheel or pulley are preserved, extending over the water. This apparatus was used for withdrawing large quantities of water for irrigation and it is likely that this baoli was a major source of water for farmlands, while drinking water was provided elsewhere.

It was a usual practice during this period to construct forts on rocky hillsides to excavate wells down to the water table to ensure permanent supply of potable water.

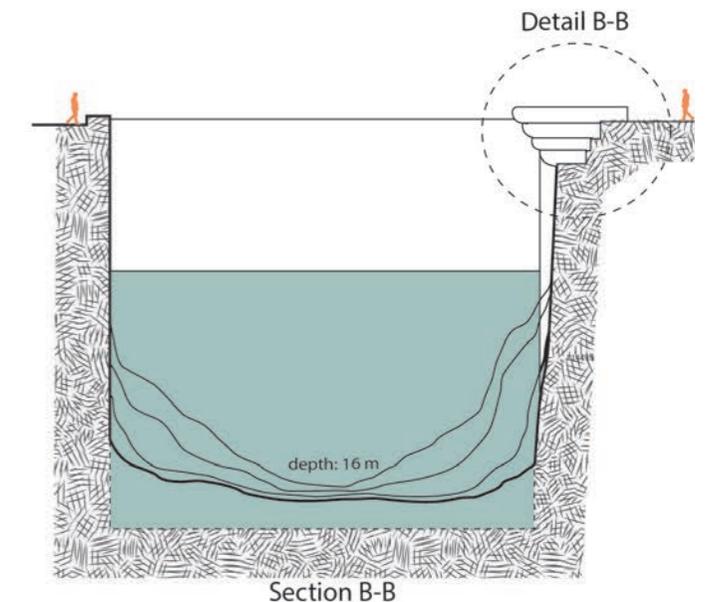
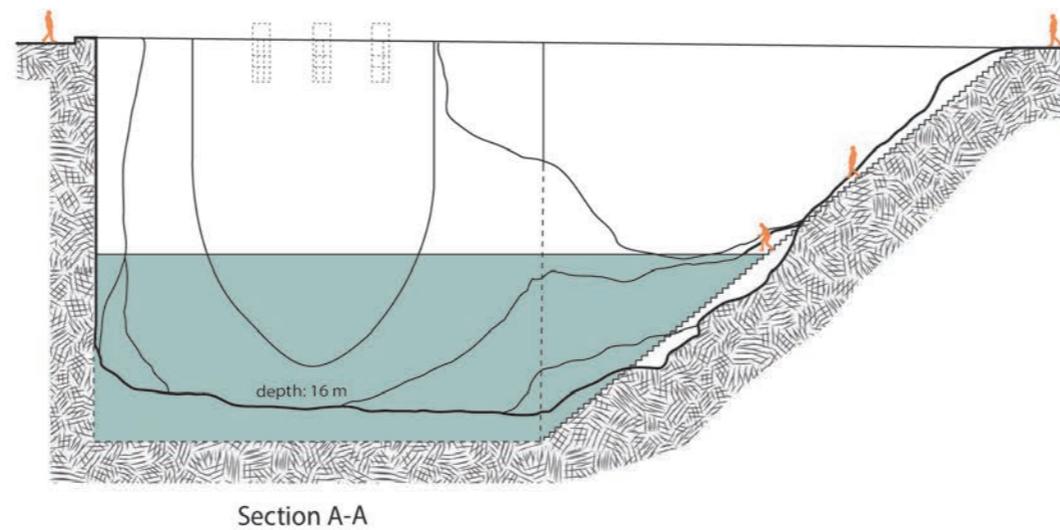
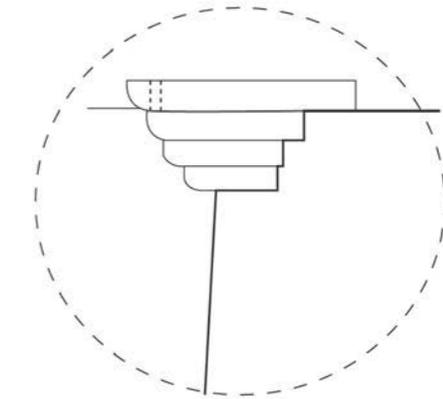
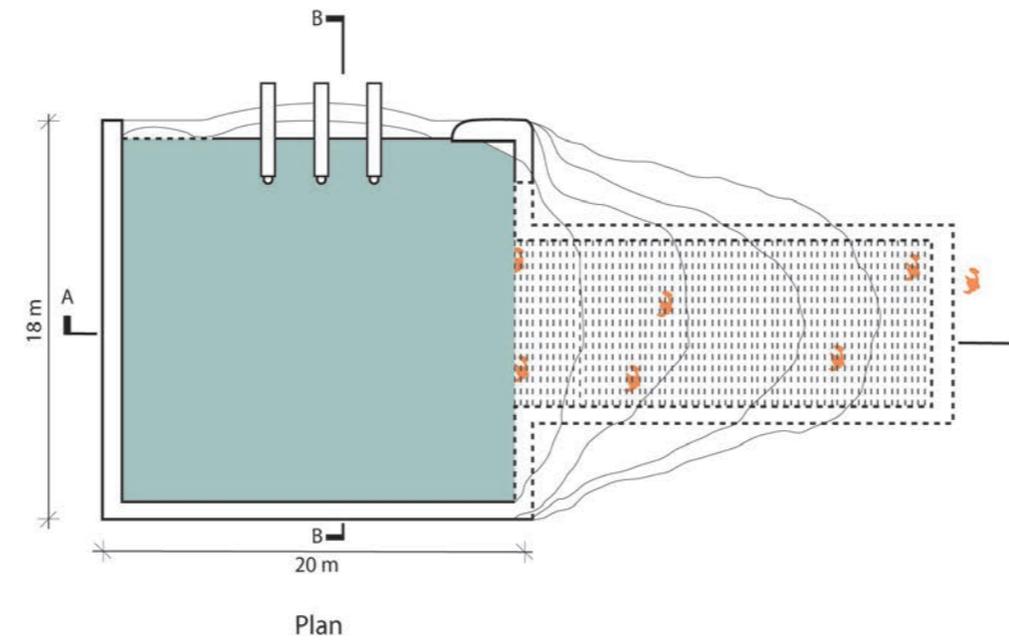


Figure 15 Baoli typology analysis and details. Key plan (above).

# Tughlaqabad Fort bund.

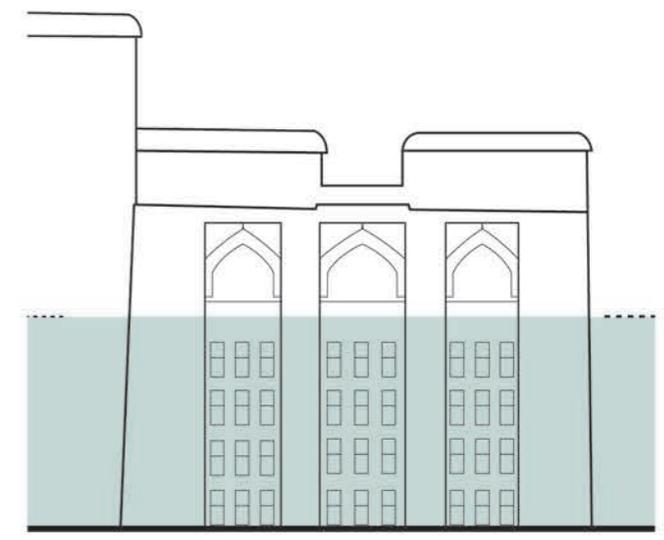
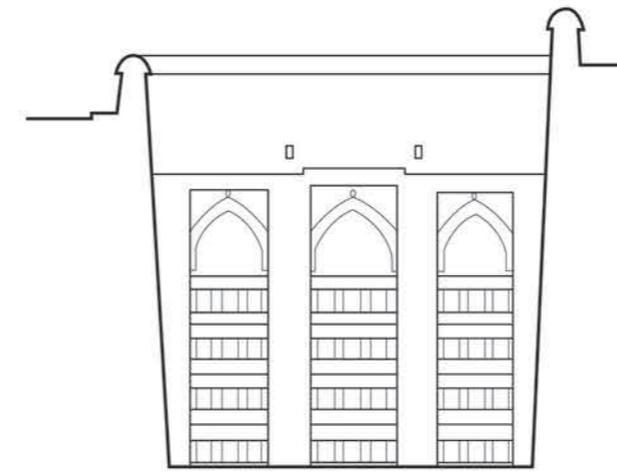
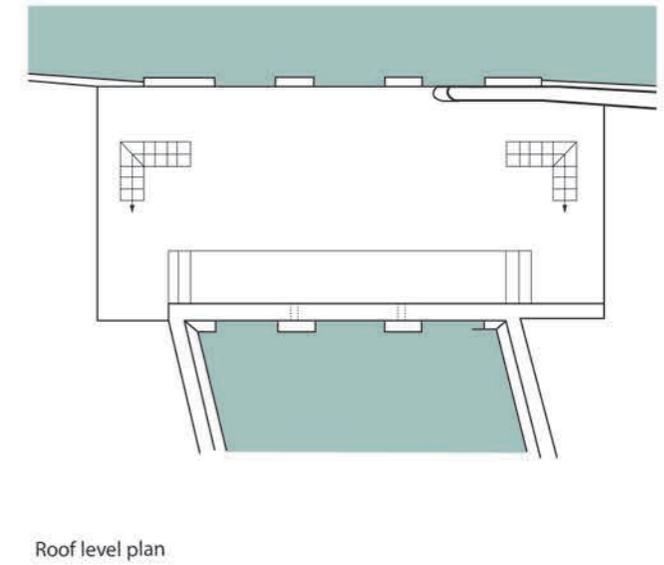
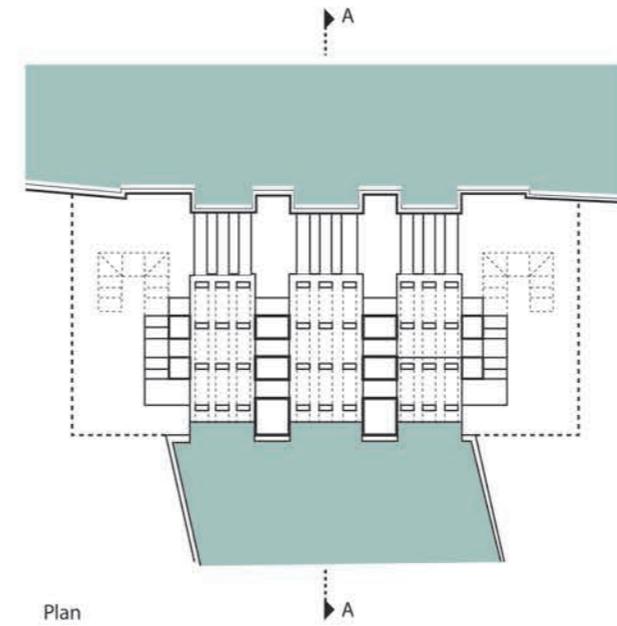
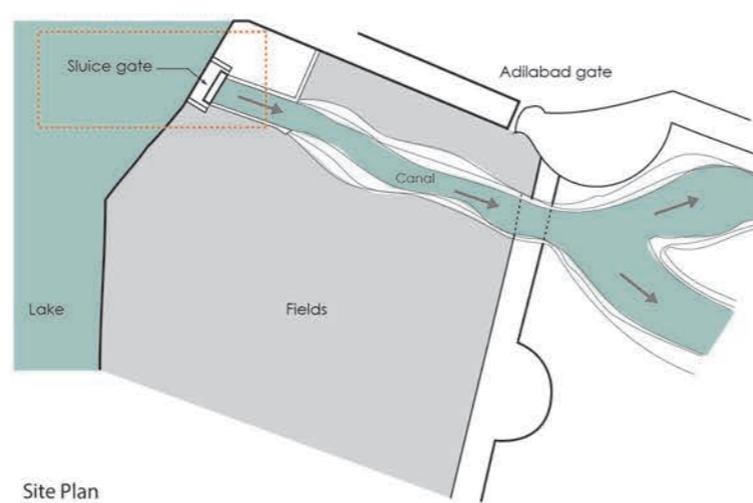
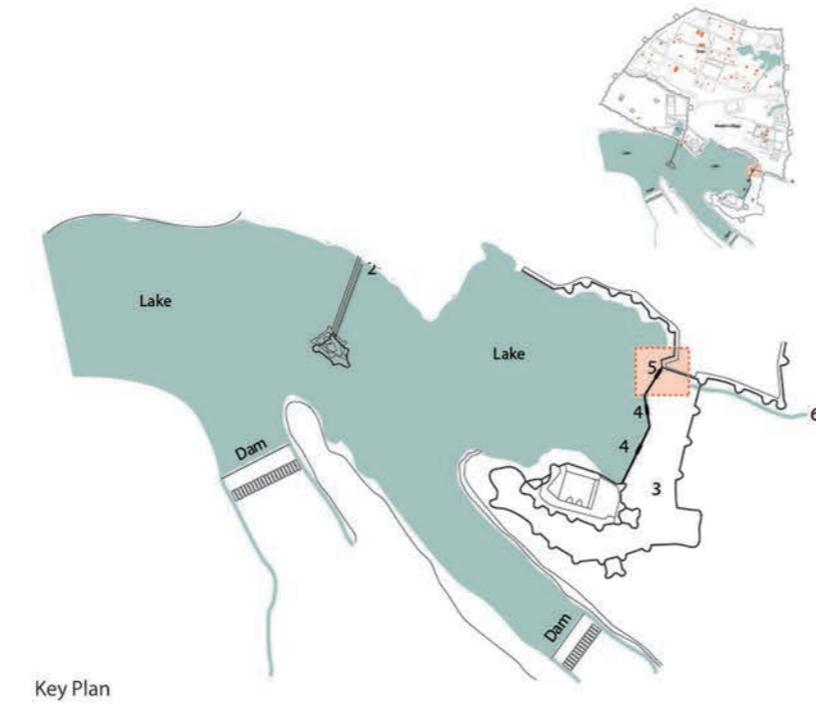
Stepwells, water channels and embankments.

Another example of the ingenious water structure is the sluice gate, controlling the level of water in the lake water south of the town of Tughlaqabad. The water work was a simple device which could be operated by an unskilled person - an uncomplicated structure with a sophisticated design.

The structure opens to a canal with stone lined walls which runs between the dam and the outer fortification walls of Adilabad. The canal was further divided into two branches, one taking the water to the irrigated fields and the other leading to moat around town wall.

The sluice gate itself consists of three arches, each containing twelve small sluices at four levels, three sluices at each level. The western side of the arch facing the lake is walled up with massive stones and the inlet of the sluices are small rectangular canals, which appear as small apertures on lake side. Inside the arches, the four levels of sluices are stacked in a step form with eight steps. The lower step is for standing on and the upper one has the slots. Each slot measured 35x10 cm wide and 75 cm deep to house wooden shutters which controlled the flow of water. Access to these steps is provided via two sets of stairs built into the piers at either end of the structure.

**Figure 16** The sluice gate and Dam south of Tughlaqabad.  
**Figure 17** Sluice gate site plan.  
**Figure 18** Sluice gate plan.  
**Figure 19** Sluice gate plan at roof level.  
**Figure 20** Sluice gate view from lake looking Eastwards.  
**Figure 21** Sluice gate elevation lake side looking eastwards.



### Functioning

The operation of the sluice gate was simple and could be carried out by a single person, who first went down to the lowest level to insert small shutters into slots of the lowest nine canals. The water of the lake would then rise up to the next level and the same process would be repeated at this level. In the case of heavy monsoon, a single person would remove the shutter of the upper level and excess water would gush out as small waterfall through the arches into the canal.

The site of the lake is now used for cultivation. The design concept of this sluice gate, to retain and control the water of a relatively large lake by a very simple method and no use of power was a great achievement of its time.



Figure 22 Sluice gate elevation dam side looking westwards

Figure 23 Sluice gate plan

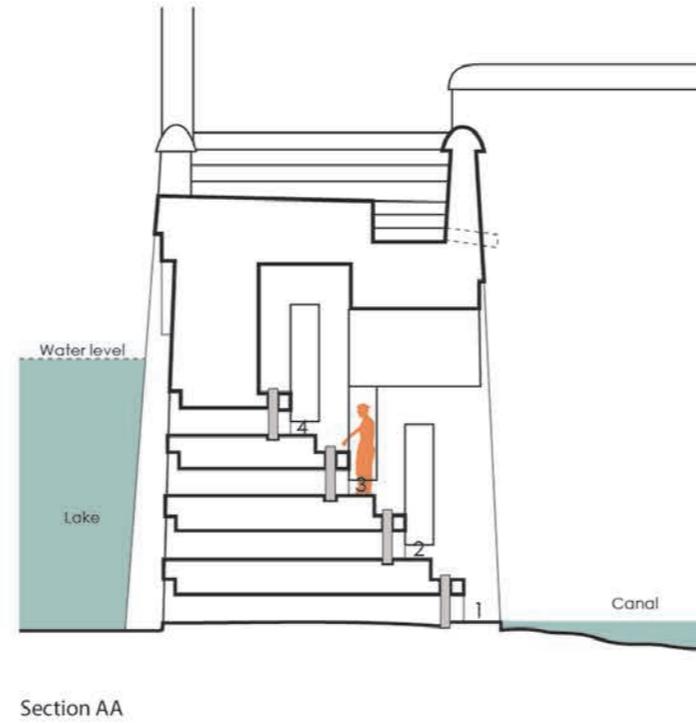
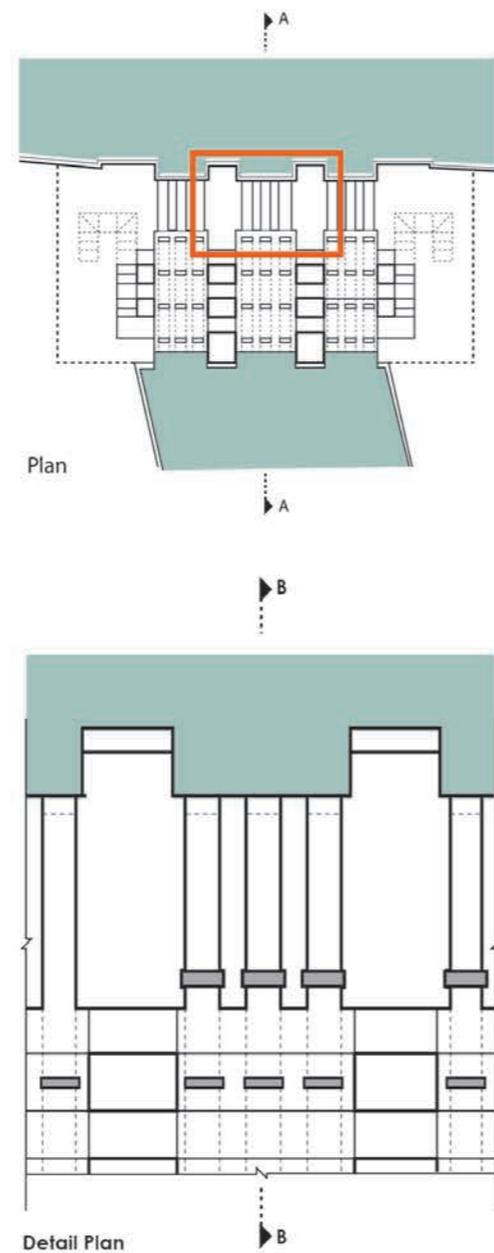
Figure 24 Detail plan of central slots

Figure 25 Section AA through central arch showing four levels of sluices and highest water level

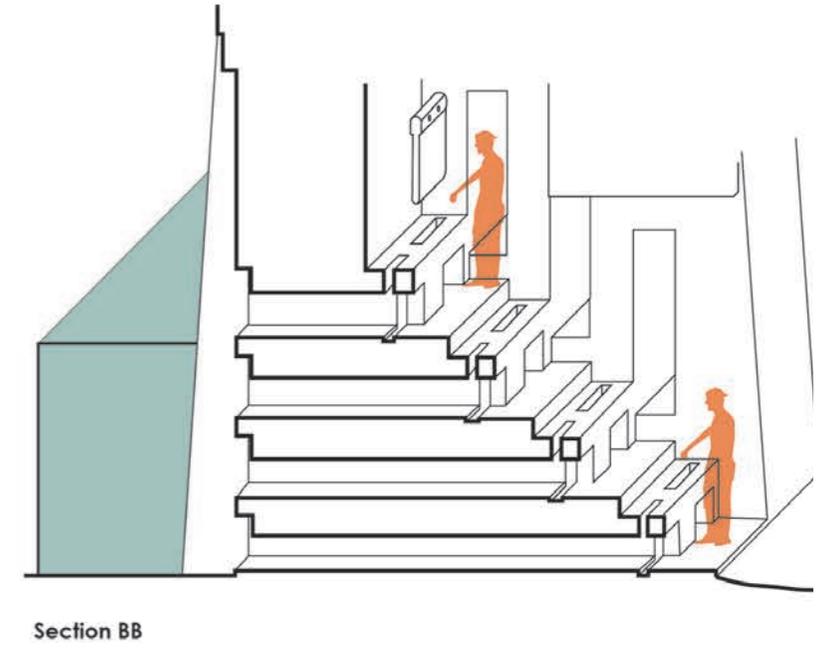
Figure 26 Perspective section showing sluice functioning

Figure 27 Showing function of sluice with help of wooden shutter

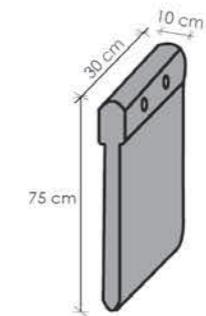
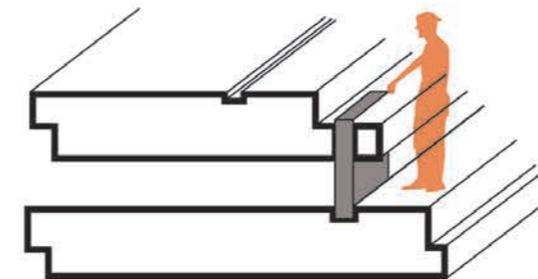
Figure 28 Wooden shutter detail



Section AA



Section BB



# Circularity.

Delhi Sultanate waterworks or harvesting structures were well coordinated with one another, each structure supporting the existence of the other. The bunds helped in controlling the rainwater runoff from the ridge which was further directed to feed large lakes or royal tanks called hauz. The baoli were recharged by the rainwater and helped in tapping the inaccessible ground water with the help of steps. These water storage structures aided water evaporation and condensation into the atmosphere which again would be captured in the ridge landscape during monsoon.

Today, these water structures lie in a dilapidated state with some having been restored for heritage and tourism purposes. Thus, it is important to learn from past methods of harvesting water to overcome the hydrological problems Delhi is facing today, despite having a combination of river and ridge landscape as part of its natural terrain.

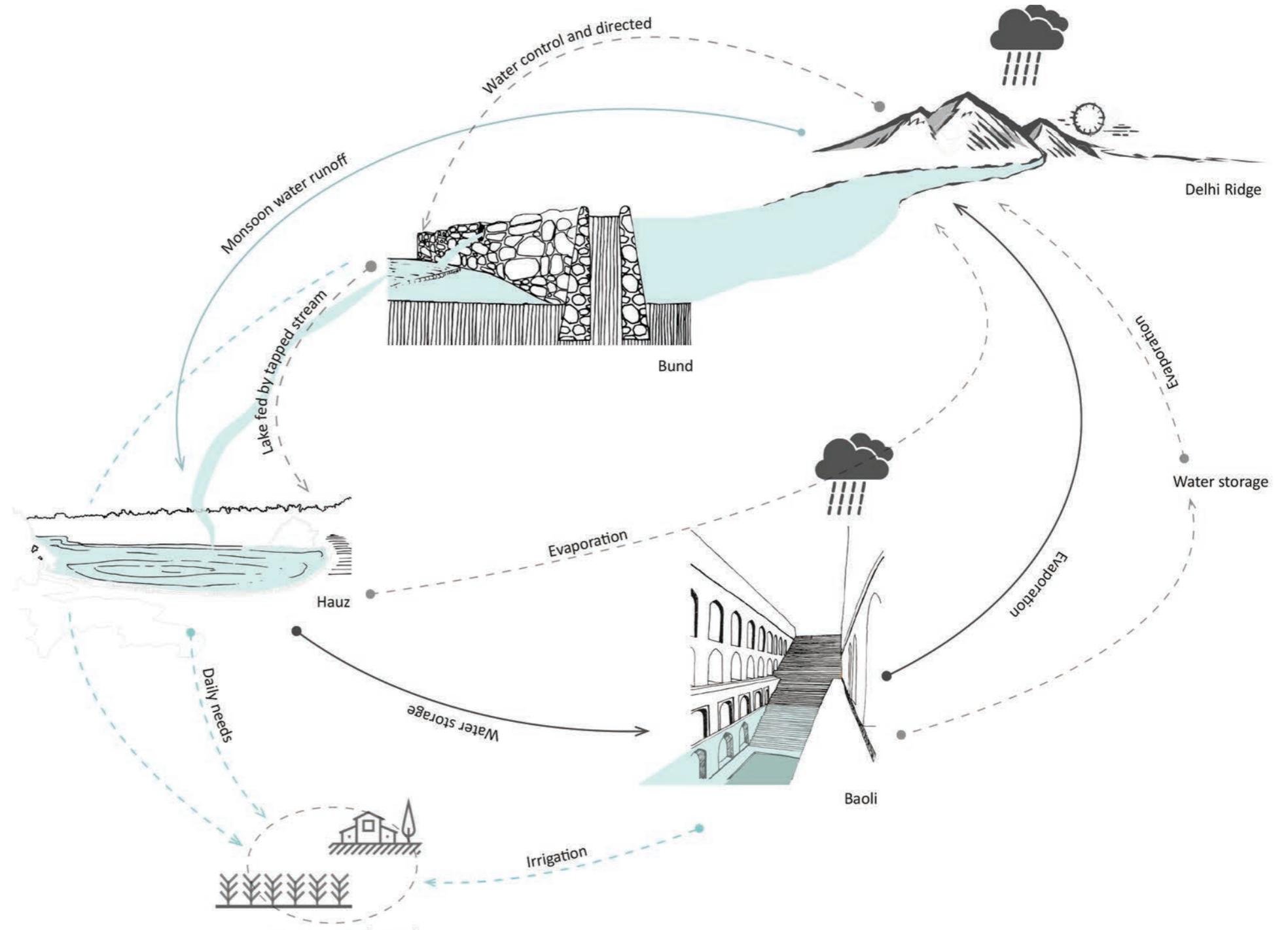


Figure 29 Circularity of the system.

# Conclusion.

The purpose of this research is to study the ancient or medieval water management system during the period of Sultanate Delhi and their understanding of the region's terrain to harvest water through various water work structures. The study focuses on the urban water management of Sultanate Delhi, where most of the cities were located on Delhi's hilly ridge terrain from where rain water was controlled and channelized. Being in a humid sub tropical and semi arid zone, the frequency of water shortages and droughts is high. However 'Ancient civilizations grasped the complex reciprocities of natural systems and created an infrastructure that was modeled on, and worked in tandem with those reciprocities' (Brown and Stigge, 2017).

The Delhi watershed comprised of ridge, river and plains, its constellation of channels, canals, bridges and tanks served all important for conserving the city. Delhi Sultanate waterworks influenced subsequent eras of urban development and conservation.

The historical water works of Sultanate Delhi have urban-scale significance. With efforts to recover the dying wisdom of traditional water harvesting systems which have expanding meaning and utility. Many of these urban historical waterworks are at a risk of further deterioration along with the degraded canals of the city. However, their imposing architecture continue to persist in the city's landscape.

**Architectural values** - The structural elements and materials used in the system came from the knowledge of traditional or vernacular construction techniques which adapt to the climate and lithology of the region. The smaller bunds or embankments were constructed of Earth, however large dams were built of rubble masonry or wood which were easily available local materials.

**Strategic values** - During this period Delhi's terrain was used smartly to gain maximum profit with the minimum resources by taking advantage of Delhi's hilly ridge landscape where most of the waterworks were situated. This landscape provided all resources like maximum rain, groundwater in order to harvest water efficiently without using any source of energy or power.

**Values of Sustainability** - The project shows the sustainability of the water system, the natural and human resources have been carefully used such as taking advantage of the natural flow of water from higher terrain to lower. This water captured was used for both the purpose of meeting the drinking water needs of Delhi and also the irrigation needs for agriculture. These also served the purpose of rainwater storage or rainwater harvesting. Most of the elements performed more than double the function.

**Ethnographic and Identity values** - The Sultanate period is known for its famous tank system (hauz), another very important structure of water management the period is known for its the network of stepwells or baolis. Most of Sultanate waterworks were of secular character whereby anyone could draw water from them and were mainly used for common people's water needs and requirements.

**Landscape values** - Water played an important role in the location of most of Sultanate cities and settlements. This whole system of tank, baolis and wells manages water supply to whole complex of settlements during medieval history period of Delhi. Moreover, the system was planned to function as a decentralized runoff harvesting such that silting of a tank at one location did not affect the others. The homogeneity of the system avoided all post-harvesting social problems of water management that are involved in water management.

**Lessons to learn** - The study shows that Delhi was not always short of water. It was ensured that Delhi had enough water from its wells, baolis, water tanks, canals, ridge and the Yamuna. The ancient rulers of Delhi had an intricately worked out water conservation and distribution system along the Southern ridge, the tail end of the Aravalli hills. They realized the importance of water security and made an elaborate system of bunds across gullies to capture water off this rocky landscape.

In present times, these water structures lie in a dilapidated state, some have been restored to their past glory but only for heritage purposes. Most of these sites have been taken over by the powerful and the rich to make their houses and other urban infrastructure, decimating the cities water resources.

Today, most of the water needs of the citizens of Delhi are met by exploiting its ground water resource by continuous extraction of ground water through private tube-wells. If these dilapidated water structures of Delhi are restored and protected they can still contribute to some of the city's water requirements. Thus, it is important to learn how Delhi's historical rulers made use of its terrain of ridge and river landscape to ensure supply of water to its citizens without exploiting and wasting its resources.



Figure 30 Conserved baoli in Delhi, India

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**Figure 22** Sluice gate elevation dam side looking westwards. [Image] Retrieved from <https://susycogamipybix.hotseattleseahawksjerseys.com/tughluqabad-book-35070zv.php>

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**Figure 29** Circularity of the system [Figure] Drawn by Author

**Figure 30** Conserved baoli in Delhi, India [Image] Retrieved from <https://archnet.org/sites/6400>





# Kuttanad Kayalnilam Agrosystem

A traditional paddy farming system  
below sea level.

Naeema Ali

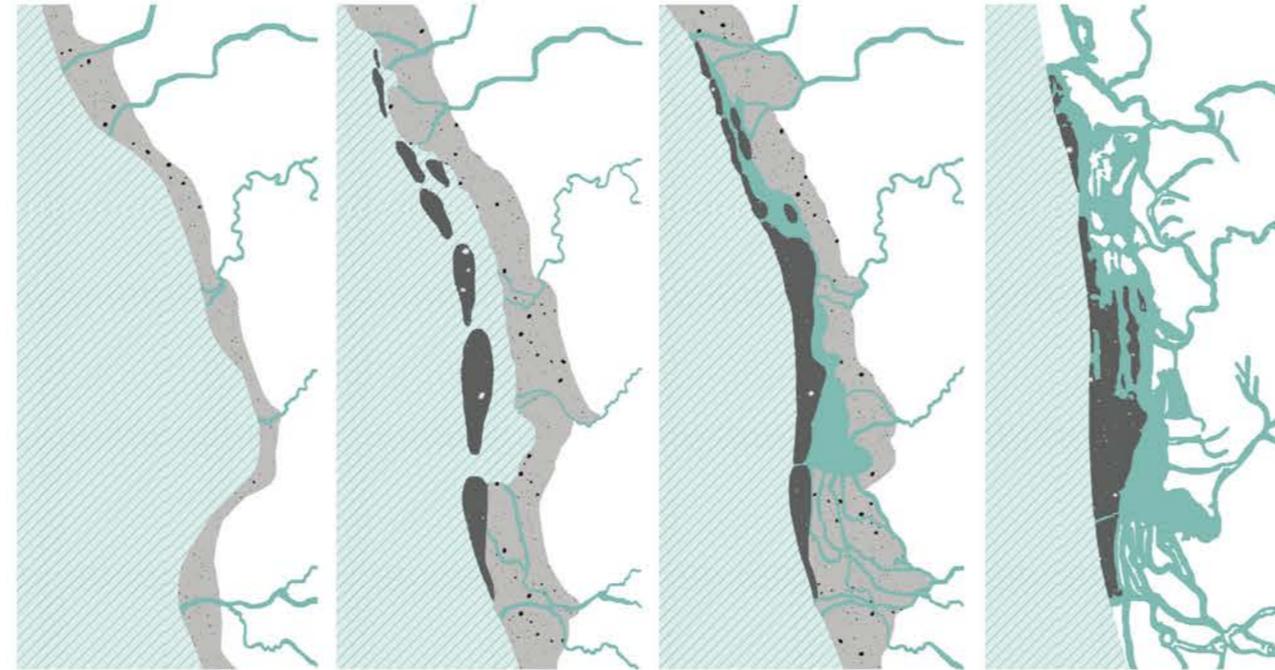
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Figure 1 Aerial view of the agrosystem.

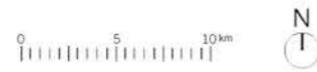
# Context Overview.

Location: Kuttanad, Kerala, India  
 Landscape Type: Low-lying wetland  
 Area: 4400 hectares  
 Function: Land Reclamation, Paddy farming  
 Water Quality: Fresh to slightly brackish water

The Kuttanad Kayalnilam is a traditional water-land utilization system that practiced paddy farming below sea level for more than a century. It is located in the deltaic region of Kuttanad, a low lying-wetland (0.6 to 2.2 m below mean sea level) adjacent to the Vembanad backwater system.



If we trace the genesis of this landscape, in the Pre-Holocene period this was a shallow embayment in the Arabian Sea  
 A sand barrier system was developed which was later breached into barrier islands due to the reduced supply of sand  
 A partly closed lagoon was formed with limited inlet-outlet systems due to the constant supply of sediments  
 Eventually, major part of the lagoon silted up giving rise to a shallow fertile region at the mouth of the Lagoon



The birth of the cultural landscape was marked by the onset of the land reclamation process, locally known as “Kayalkuthu”. When the region encountered acute food shortage in the late 1800s, the virgin landscapes were considered as a gift from the backwaters and were brought to agricultural glory. The singular unit of this landscape is the “Kayalnilam”- an artificially created landform where land was lifted out of water.

Figure 2: Kerala in India (Extreme left)  
 Figure 3: Natural Landscape, Pre-Holocene (Second from left)  
 Figure 4: Natural Landscape, Middle-Holocene (Third from left)  
 Figure 5: Natural Landscape, Late-Holocene (Third from right)  
 Figure 6: Natural Landscape, Early 1800 (Second from right)  
 Figure 7: Cultural Landscape (Extreme right)

# Polder Landscape.

The most modest imagination of the Kuttanad landscape would be that of a polder system laid with an intricate network of canals and water channels. Due to this resemblance with the Traditional Dutch landscape, Kuttanad is often referred to as the "Holland of the East".

Here, water management was quintessentially a unit of the cultural expression of the site-specific challenges faced by people, be it in terms of topography, climate or social hierarchy. In this case, the main challenge was to utilize the useless watery landscape adjacent to the backwaters. The low-lying landscape was subjugated for the benefit of men and women and how they did this narrates the legend behind the existing agricultural landscape of Kuttanad. These radical ingenuities tell us stories of how humans and nature exchanged roles between being makers and takers of the landscape.

**Figure 8:** Reclaimed polder along the backwaters (Top left)

**Figure 9:** Reclaimed polder landscape (Bottom left)

**Figure 10:** Major Canal and Minor Canal (Top right)

**Figure 11:** Inner Canal (Bottom right)



# Rhythm of Kuttanad.

Climatic Zone: Tropical Monsoon  
 Max Temperature: 35 C  
 Min Temperature: 22 C  
 Annual Rainfall: 3000 mm  
 Relative Humidity: Fresh to slightly brackish water  
 Dynamic: Seasonal Flooding and Salinity Intrusion

The rhythm or the recurring patterns in the Kuttanad landscape was largely determined by the circular and cyclical movement of water and salt in the system. As a thumb rule, water flowed from the rivers and canals into the Vembanad backwaters before being discharged into the Arabian sea. But this flow was reversed during summer, between February and May (pre-monsoon) due to the dwindling flow of the rivers and correspondingly increasing temperatures. This marks the entry of salt from the sea into the low-lying areas due to tidal action. With the onset of monsoon in the month of June, the water level in the rivers rises and the water once again flows from the rivers into the sea.

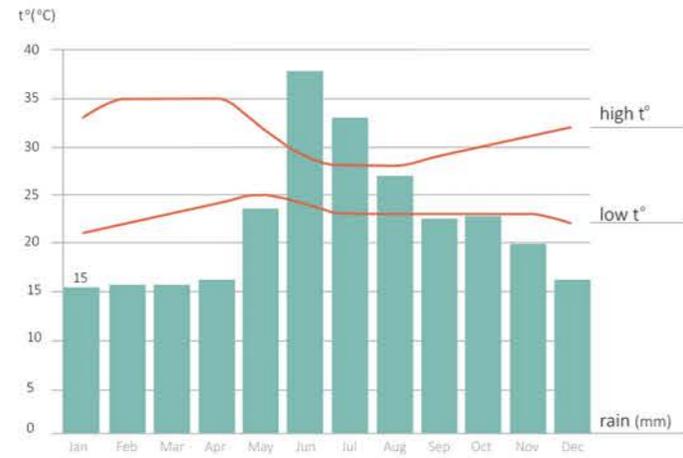
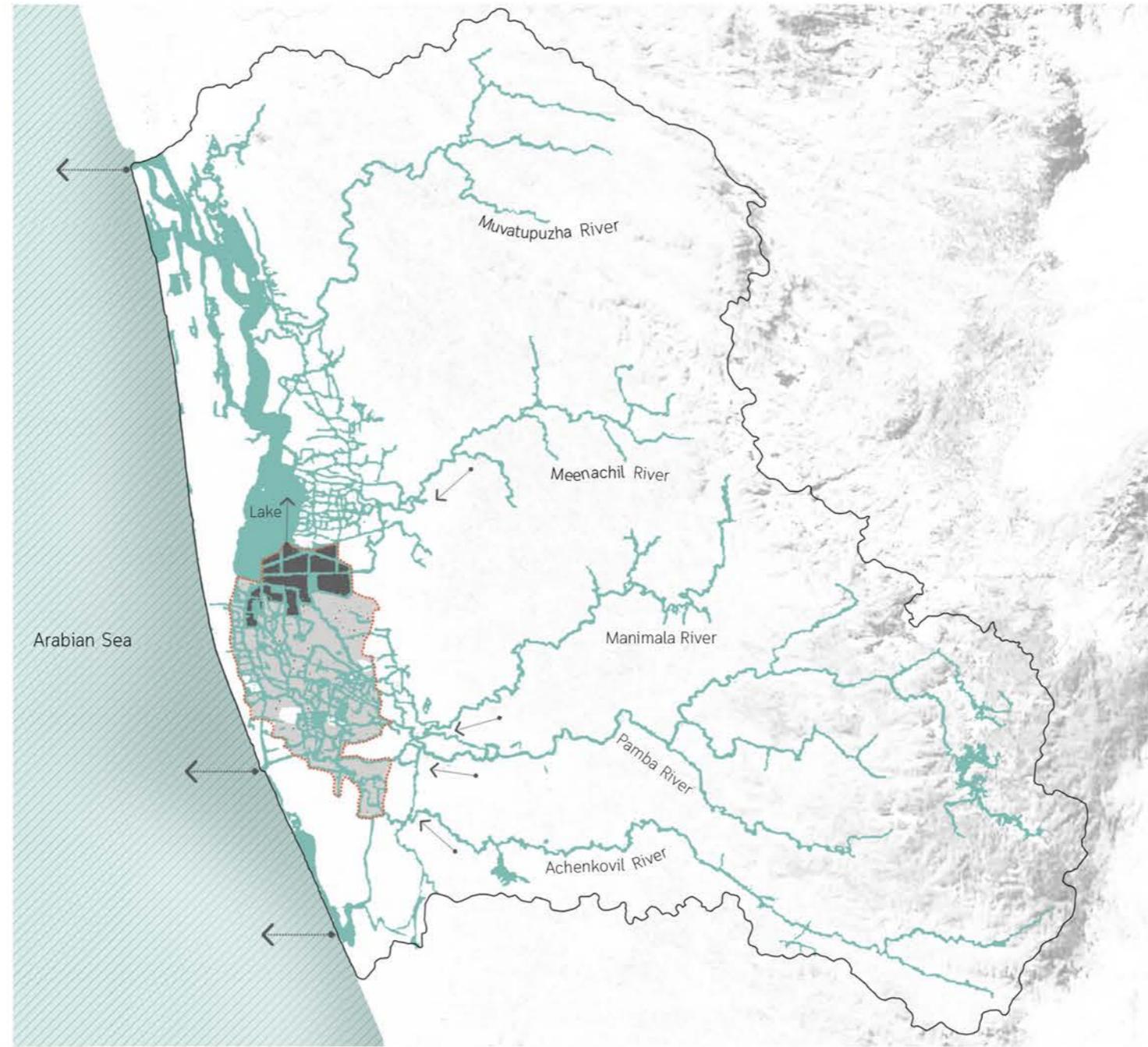


Figure 12: Climate graph (Extreme left)

Figure 13: Watershed (Middle)

Figure 14: Water and Salt Movement ( Extreme right)



Post Monsoon  
 Oct to Jan



Pre- Monsoon  
 Feb to May



Monsoon  
 June to Sep

# Circular and Cyclical Water System .

The salt which came across as a curse sealing the fate of the farmers however was a blessing for the fishermen due to fish migration from the sea. Hence, the circle of life in Kuttanad was explicitly linked to this cycle of blessing and curse intermingling with the cycle of water and salt. Likewise, Kayalnilams also operated to optimize their performance within this spatio-temporal context specific to Kuttanad.

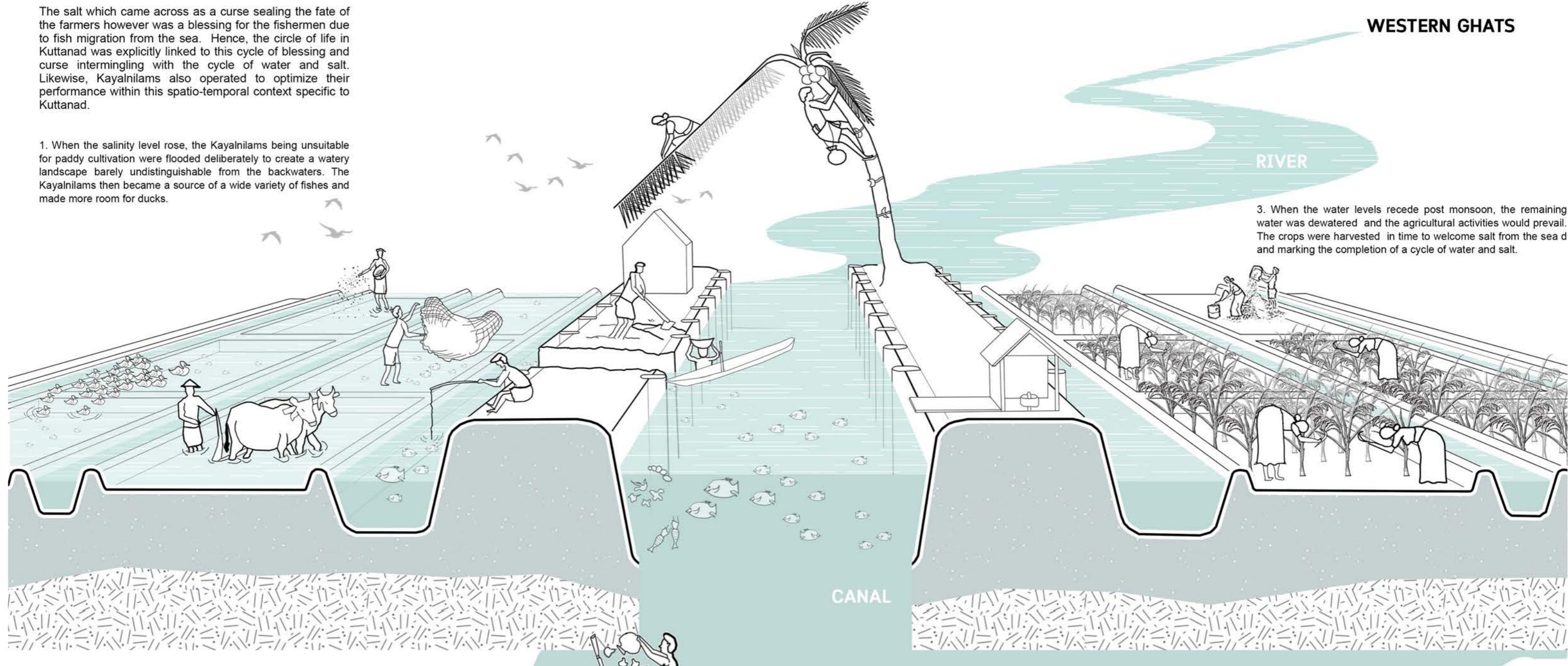
1. When the salinity level rose, the Kayalnilams being unsuitable for paddy cultivation were flooded deliberately to create a watery landscape barely undistinguishable from the backwaters. The Kayalnilams then became a source of a wide variety of fishes and made more room for ducks.

## WESTERN GHATS

RIVER

3. When the water levels recede post monsoon, the remaining water was dewatered and the agricultural activities would prevail. The crops were harvested in time to welcome salt from the sea and marking the completion of a cycle of water and salt.

CANAL



2. With the onset of monsoon, the rivers flowed back into the sea and the wetlands continued to be a freshwater body collecting silt from the rivers. However, the increased levels of water also meant that the Kayalnilams remained drowned. During this period, the farmers would prepare the new ground enriched with silt for paddy cultivation with the help of simple tools and animals.

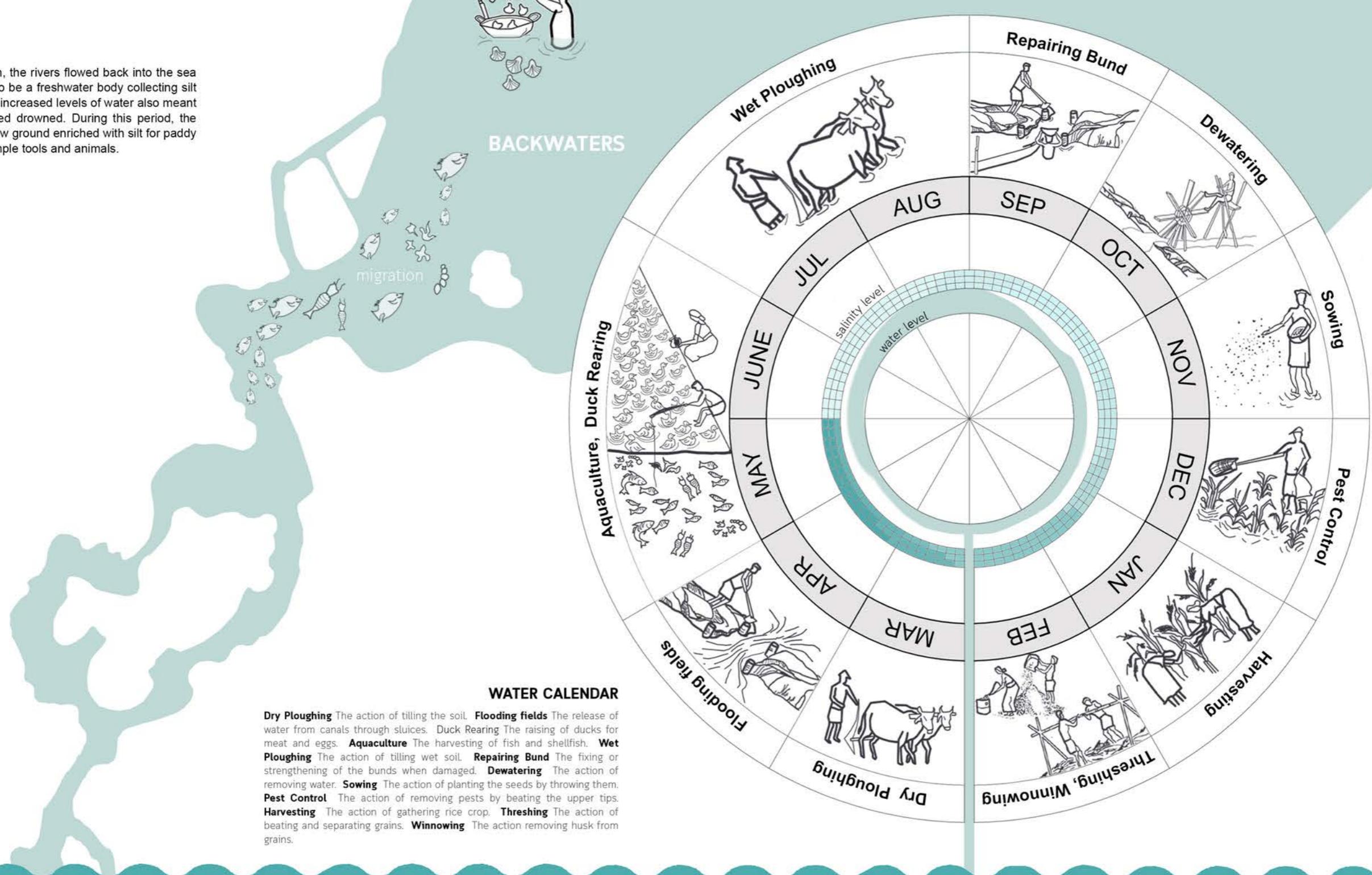


Figure 18: Cyclical Water System diagram

# Water System.

A total of 4400 hectares of land were reclaimed from the backwaters between 1880 and 1945 in three phases. Rani is one such Kayalnilam which is the closest to the Vembanad backwaters. The reclaimed Kayalnilams were separated by canals or rivers. There was a flexible outlet from the Kayalnilam to these canals or rivers with the help of a dewatering wheel or pump. An intricate network of paddy farm lands with a two-tier water system (major canal- ring canal) were formed which were divided by the earthen bunds yet interlinked by the canals or backwaters.

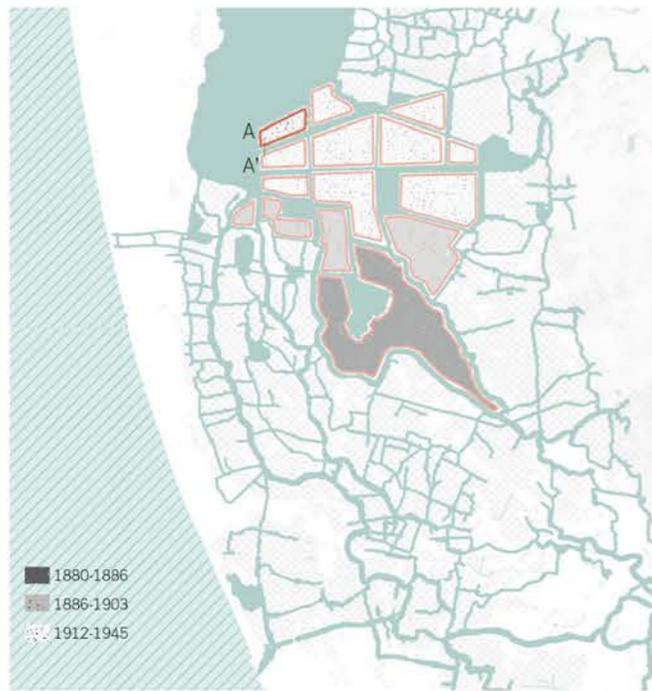
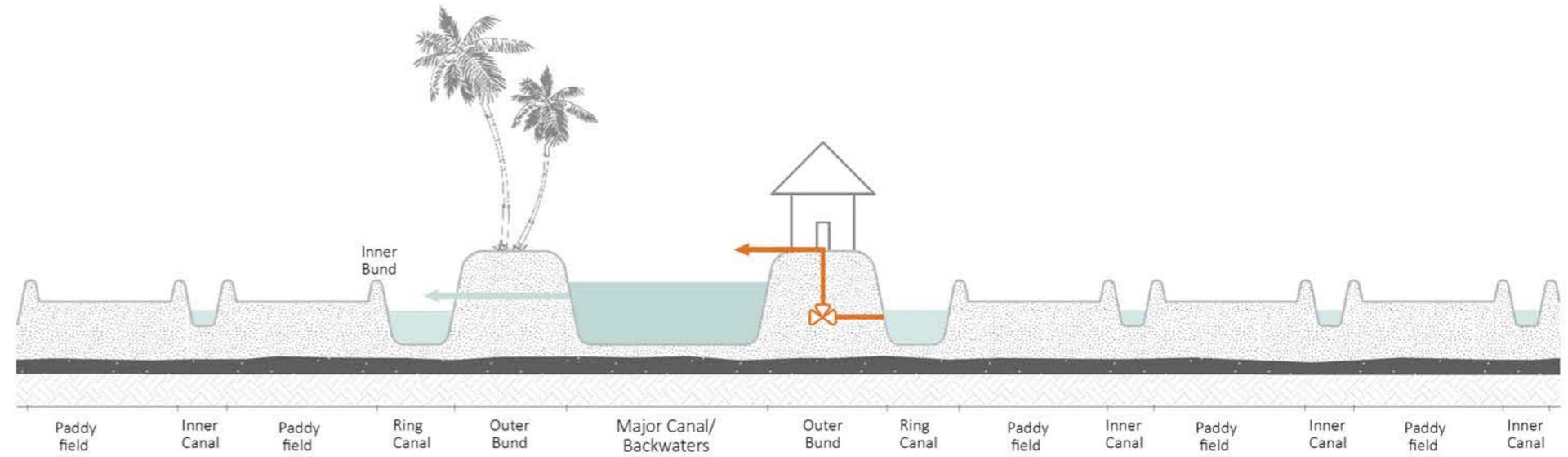
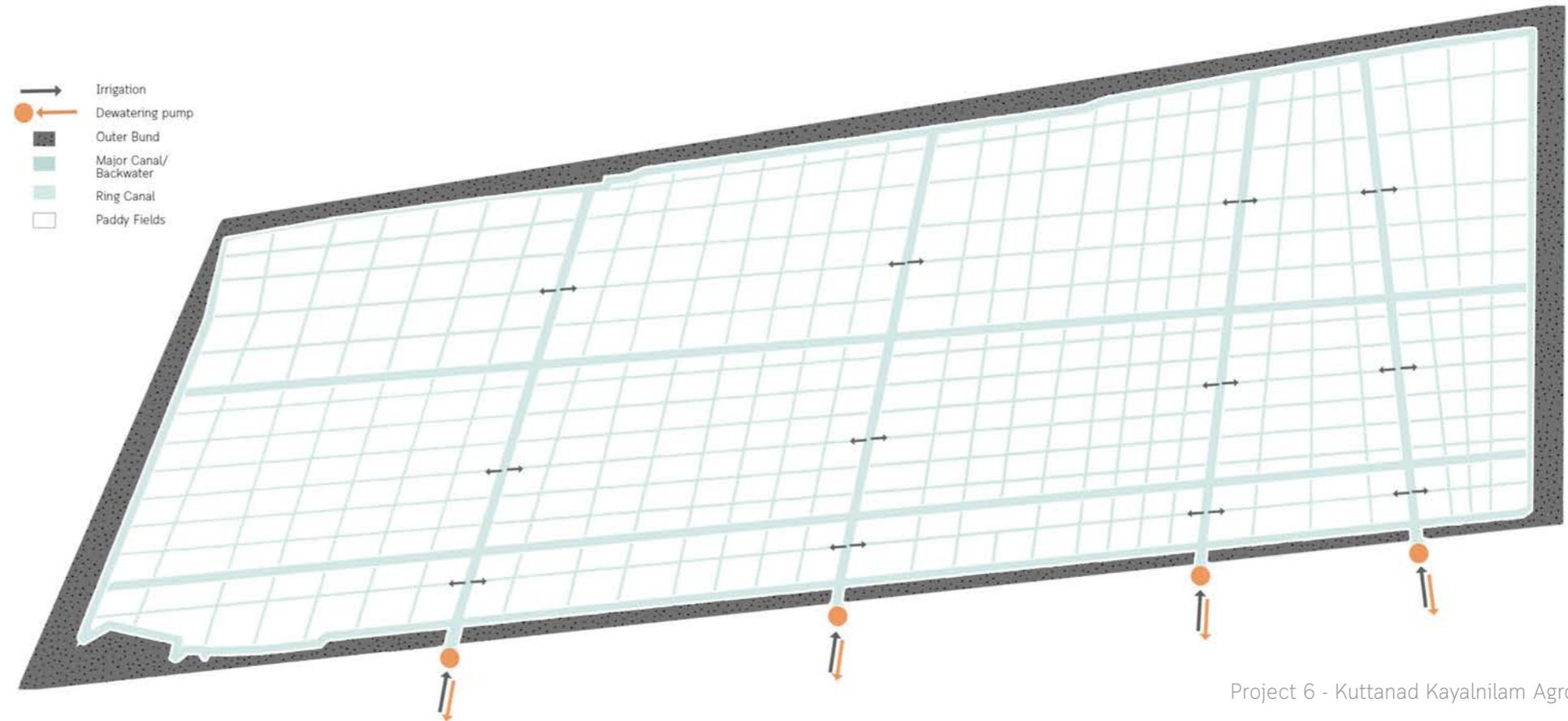


Figure 15: Phases of Reclamation (Bottom left)

Figure 16: Section AA(Top)

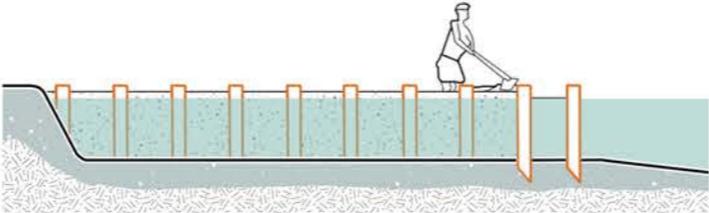
Figure 17: Water Management Plan of Rani (Bottom Right)



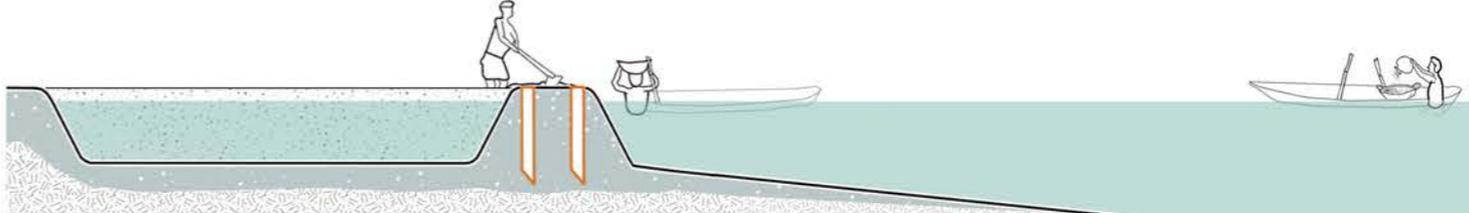
# Kayalnilam Construction.

The construction and functioning of these Kayalnilams demonstrates years of human strength, wisdom and ingenuity while dealing with water management. Nearly 400 to 500 men were engaged in a year to complete the reclamation process of about 2000 ha of land. This labour-intensive process would start with identification of the shallow regions in the Vembanad Backwaters.

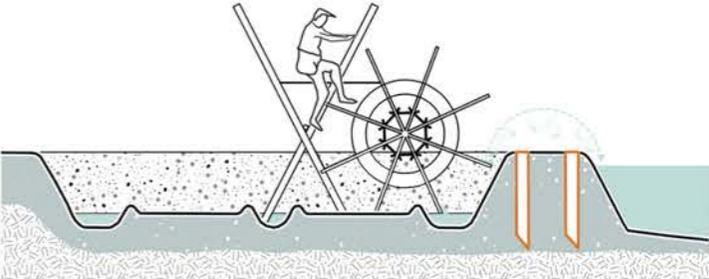
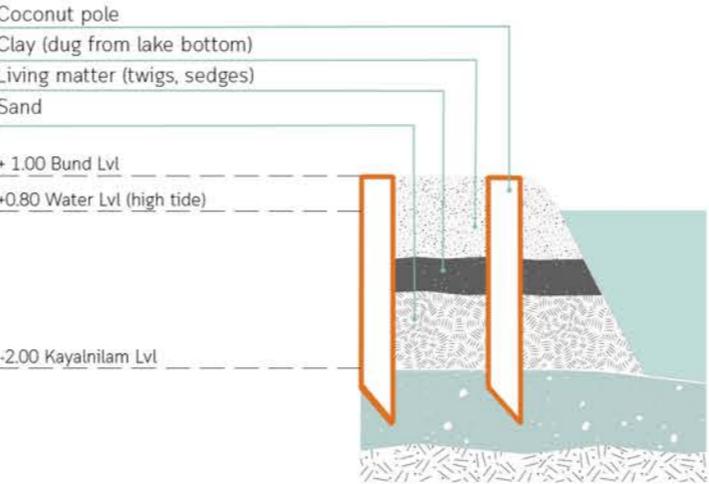
Eventually when the earthen bunds collapse due to heavy rainfall, as the oral history goes by, human sacrifice was seen as a practice to repair this high maintenance structure. A section of these earthen bunds would have dead bodies stacked and buried in an exhilarating depth of mud to stop paddy fields from drowning.



1. Firstly, the boundaries are marked. Then an array of long and stout coconut poles would be hammered deep enough into the lake bed in two rows, normally in 1.5m to 2.5m width, enveloping the entire area. Then they would be fenced with bamboo mats on either side to form a skeleton for the bund



2. Then the channels of the bund would be filled to the desired height, first with sand, followed by twigs, sedges like Typha and Sheoneplectus (Kora Pullu) and dead materials that were brought from distant places and interspersed with high quality clay that was dug from a depth of 20-25m from the lake. Clay digging was called Katta kuth, which involves diving deep in to the lake-bed. In this manner, the earthen bunds are constructed and they are further stabilized or strengthened by planting vegetation cover



3. Dewatering or removing excess water from fields. Traditionally, water wheels of 10-12 feet diameter with blade width of 1-15 feet were used, which were pedalled manually by men. The water wheel ranges from 4-leaved to 18 leaved. Water is pumped out periodically into the surrounding lake or canals

Figure 19: Step 1- Hammering and fencing (Top left)  
 Figure 20: Step 2- Cutting and filling (Top left)  
 Figure 21: Construction Section Detail (Bottom left)  
 Figure 22: Step 3- Dewatering (Bottom right)

## Living with water.

Being water-logged most of the year, these landscapes were geographically isolated and only accessible through a vallam or a local canoe until recently. Alongside paddy cultivation, there was a thriving duck, fishing and clam industry. People were also dependent on allied ecosystem services like coir industry, toddy tapping, fishing net industry etc. Majority of the livelihood strategies were directly linked to the ecosystem services provided by the backwaters and the adjacent low-lying lands. Hence, people also chose to stay here even after facing perpetual flooding issues for the sake of their livelihood.

Not just their livelihoods, but water was the centre of their cultural traditions, social life and daily activities. Because their life was in between land and water, their life can be termed as amphibious in short.

**Figure 23:** Farmer irrigating the field manually using a water wheel (Top left)

**Figure 24:** Female labourers harvesting paddy (Bottom left)

**Figure 25:** Man navigating through waterway in vallam, canoe boat (Top right)

**Figure 26:** Lady washing utensils by the canal (Bottom right)





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# Kampung Naga

Integrated living system of a traditional  
Sundanese hamlet in Indonesia.

Ayu Tri Prestasia & Boomi Kim

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Figure 1 View of Kampung Naga.

# Context.

Kampung Naga is located in between Garut and Tasikmalaya, West Java, Indonesia. The region is rich in water reserves and forest on mountainous topography.

Although it is located close to the main road connecting the two towns, the hamlet with 10,5 hectares area is not within urbanization's reach yet. To reach Kampung Naga, 20 minutes walk down the valley from the parking area for the visitors who wanted to experience one of the preserved traditional Sundanese village where the inhabitants still conform to nature and conserve traditional lifestyle as circular ecology including the water system.



Figure 2 Indonesia Archipelago

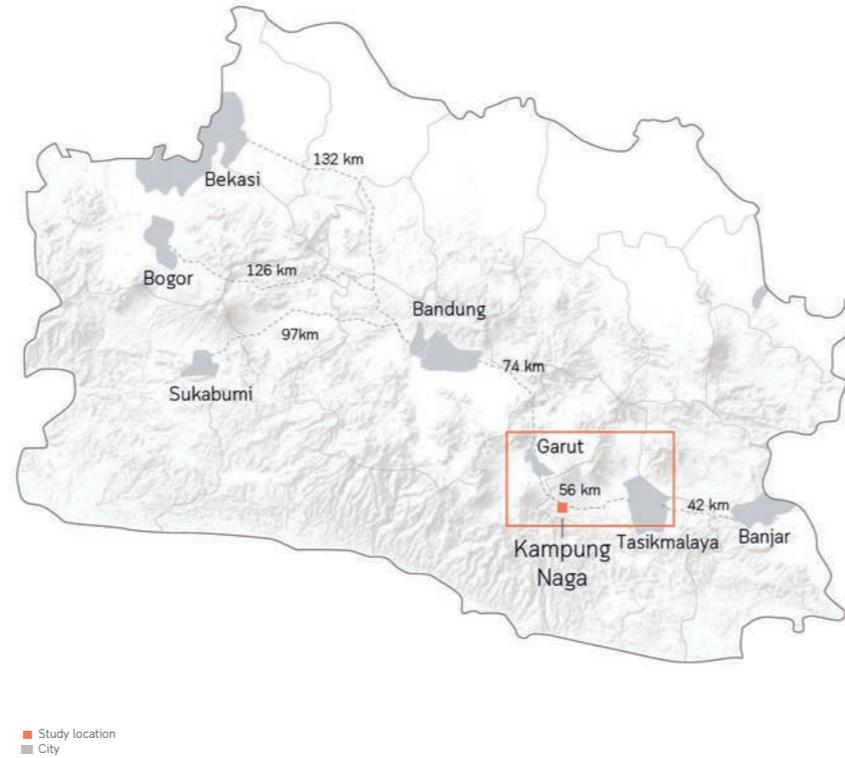


Figure 3 West Java

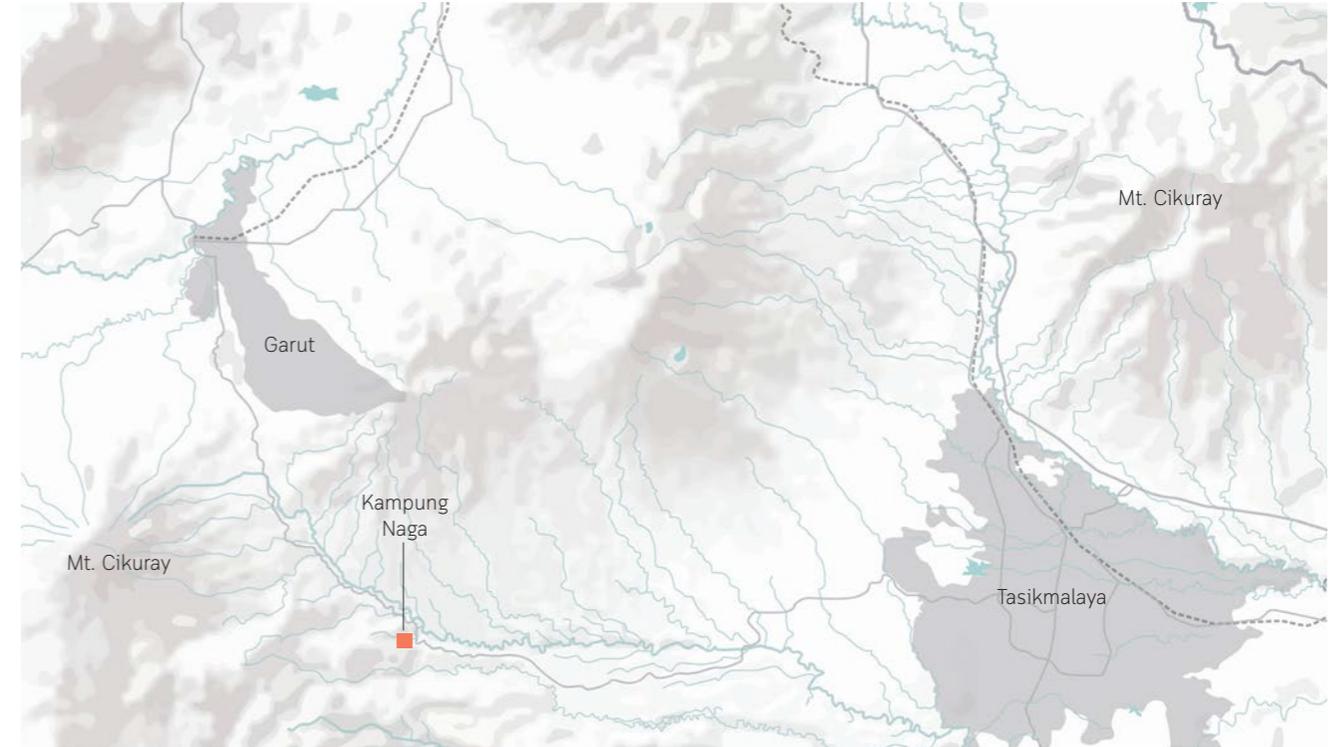


Figure 4 Garut - Tasikmalaya region

# Life in Kampung Naga.

Kampung Naga maintains the traditional living with nature amidst modernity that develop around the area. No new technology such as the use of electricity and related devices is allowed in the hamlet. The boundary of Kampung Naga is strictly preserved to balance the number of people whose lives can be supported by the food supply and the ability to manage the wastewater inside the village. While maintaining the number of people who live inside, the rest of the family members can live outside the village.

Although almost all water-related activities are located on the outer area, water is treated as a major part of their lives. People keep its space to “breathe”, use it wisely, and purify the wastewater before finally being returned to its original place. Centralization of the activities are designed as an integrated system of water and ecological cycle.



**Figure 9** Women use the only water found inside the Inner Area at the Mosque to clean food materials (above left).  
**Figure 10** Rice husking station is located above the fishpond (above center).  
**Figure 11** Rice terraces which are irrigated from the river (above right).  
**Figure 12** Man feeding the fishes (below left).  
**Figure 13** Woman washing dishes at the latrine building above the fishponds (below center).  
**Figure 14** Woman filling container with Nyusu Water (below right).

# Climate.

Climate zone: tropical  
 Sub-climate: Mild Temperate humid

## Climate & Weather Averages

High t°: 29.2°C  
 Low t°: 21.2°C  
 Mean t°: 23.4°C  
 Precipitation: 289 mm  
 Humidity: 76%  
 Dew point: 23°C  
 Wind: 4 km/h  
 Pressure: 1011 mbar  
 Visibility: 8 km  
 Hottest Month: April (25.8°C avg)  
 Coldest Month: August (19.9°C avg)  
 Wettest Month: March (409 mm avg)  
 Windiest Month: September (14 km/h avg)  
 Annual Rainfall: 3478 mm per year

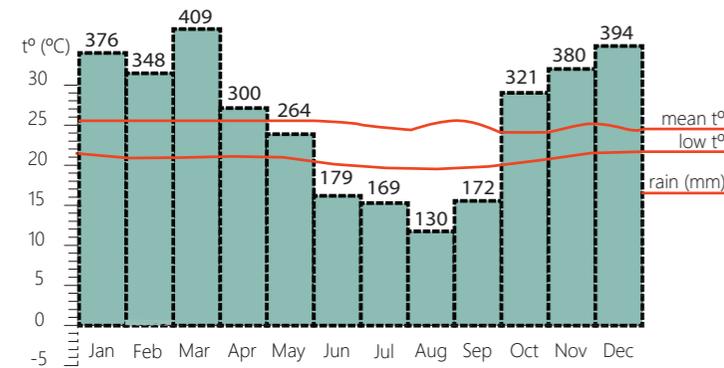


Figure 5 Climate of Kampung Naga

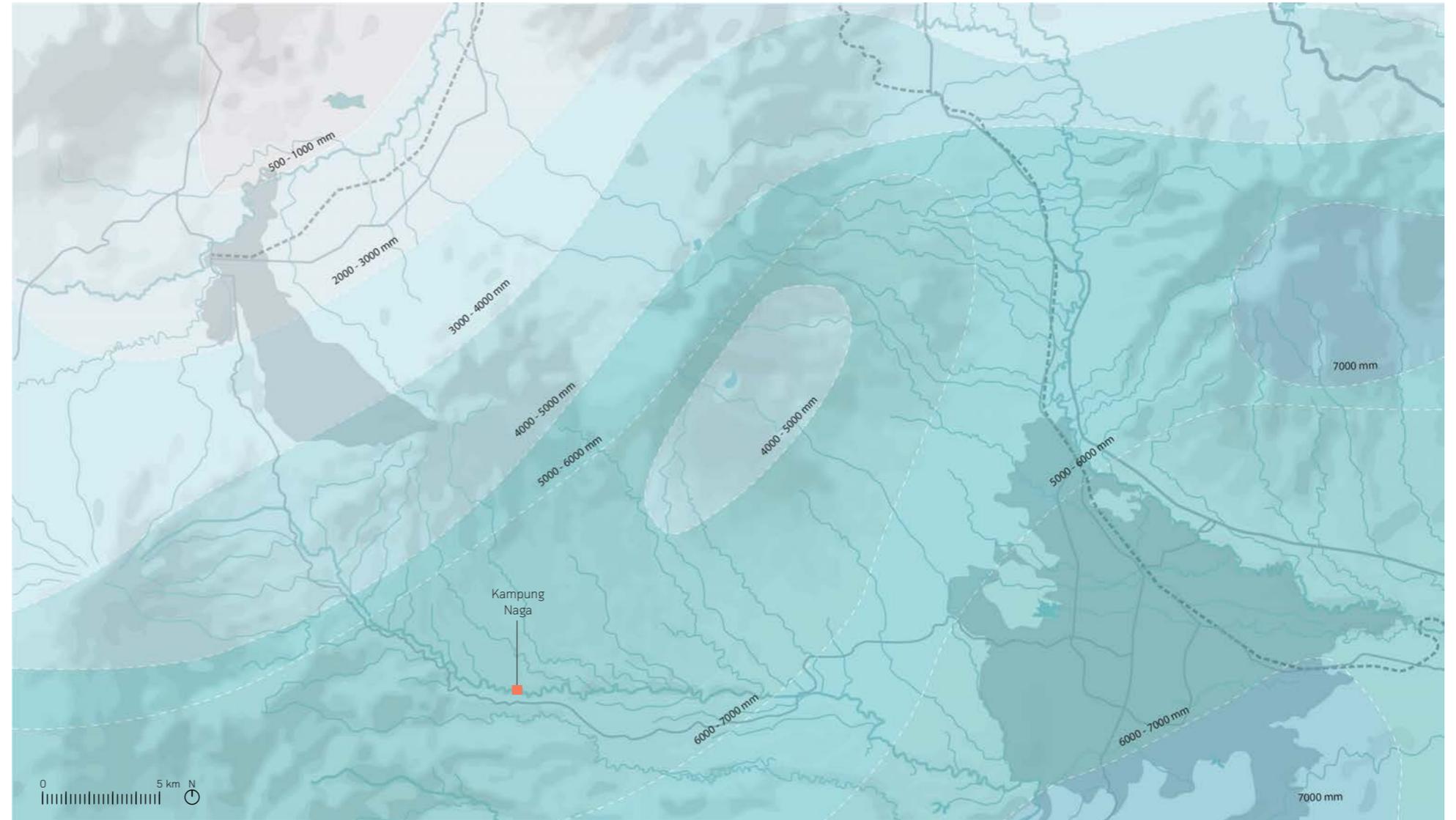
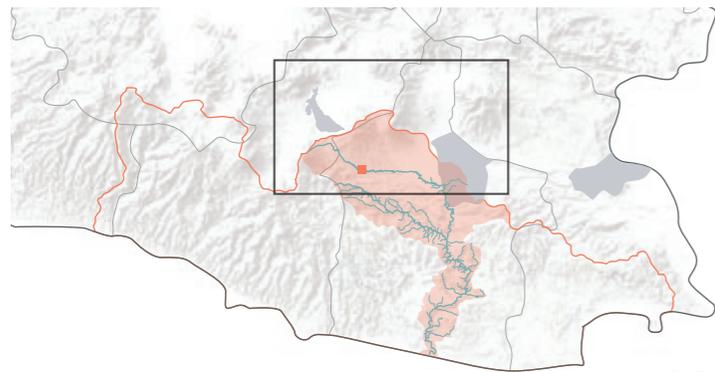


Figure 6 Rainfall map in Kampung Naga

# Catchment area.

Kampung Naga is situated in the area of Ciwulan River Basin. It is the largest catchment area in the Tasikmalaya District with the total area of 59114,25 km<sup>2</sup>. The Ciwulan river starts from Cikuray mountain and flows naturally following topography due to mountainous landscape, and passes Kampung Naga. Thereby, the Ciwulan river become the main water resources of Kampung Naga as it mostly always has sufficient water both in the quality and quantity all year long. The area is dominated with Inceptisols & Entisols soils which are cultivated into terraced agricultural fields.

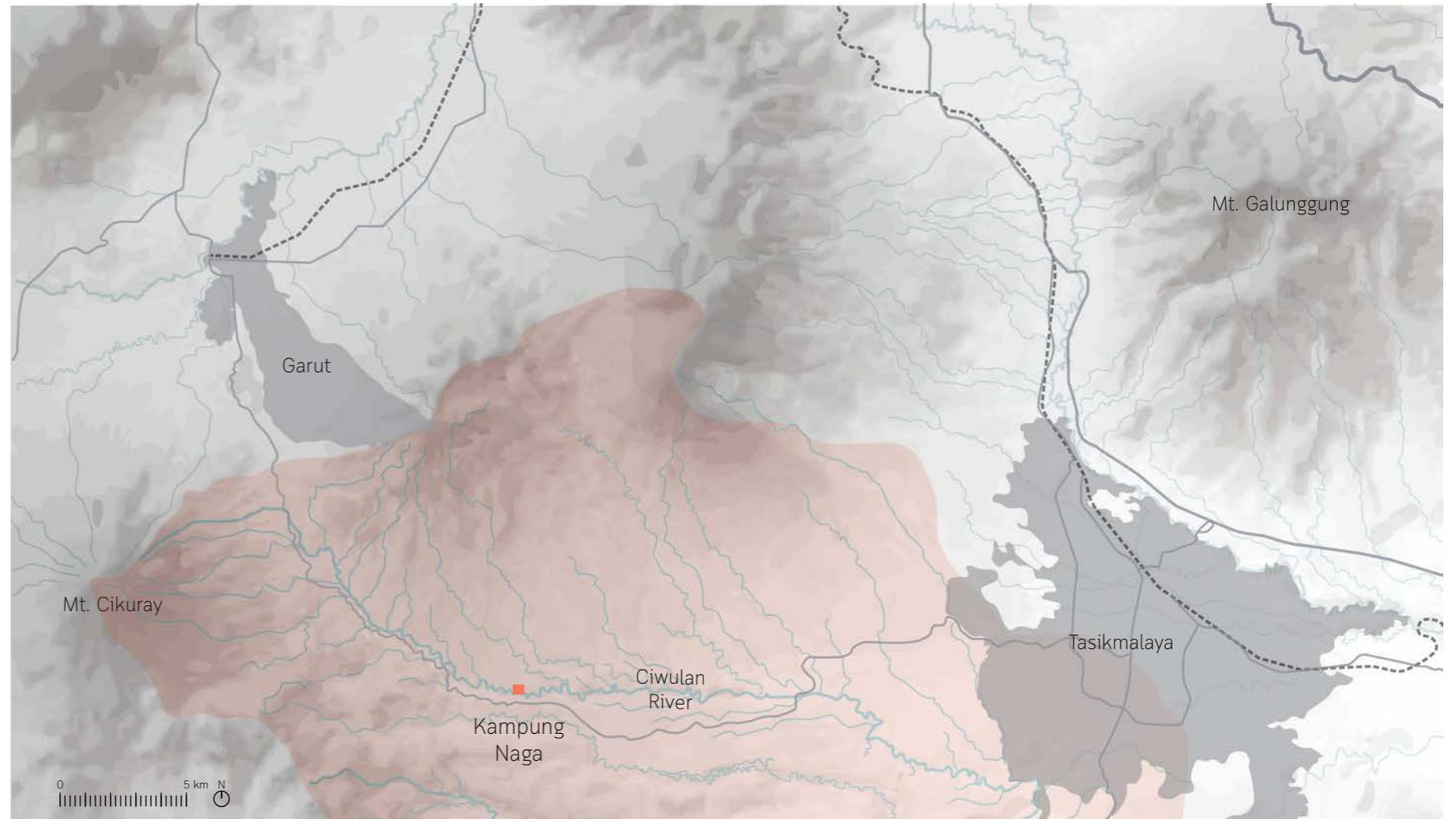


**LEGEND**

- Study location
- Ciwulan River catchment area
- City
- Water
- Ciwulan-Cilaki watershed
- River
- Railway
- Road

**ELEVATION (m)**

- 2700
- 2590
- 2400
- 2225
- 2050
- 1880
- 1715
- 1560
- 1400
- 1250
- 1110
- 975
- 840
- 720
- 610
- 500



**Figure 7** Ciwulan-Cilaki water catchment area (above)  
**Figure 8** Ciwulan water catchment area (right)

# Water System Plan.

The spatial organization of Kampung Naga is influenced by its location on the valley. The topographical characteristics of the site defines the vertical zonation of the hamlet, which is closely related to the utilization of the landscape into the water management system.

Based on its spatial relation to the settlement area, Kampung Naga can be divided into 3 distinctive zones. The 'forbidden' forest, which is called the Sacred Area, is preserved at the top of the composition to infiltrate, filter and store the water through its roots. The accessibility to this area is strictly restricted. The settlement area (the Inner Area) is located in the middle with terraced soils following its natural topography. At the lowest level (the Outer Area), fish pond system become the location where almost all the water-related activities is taken place, while at the same time it is functioned to purify the wastewater before it is discharged back to the river. Bamboo fences are used as the boundary of the settlement area which at the same time clearly separates these three zones.

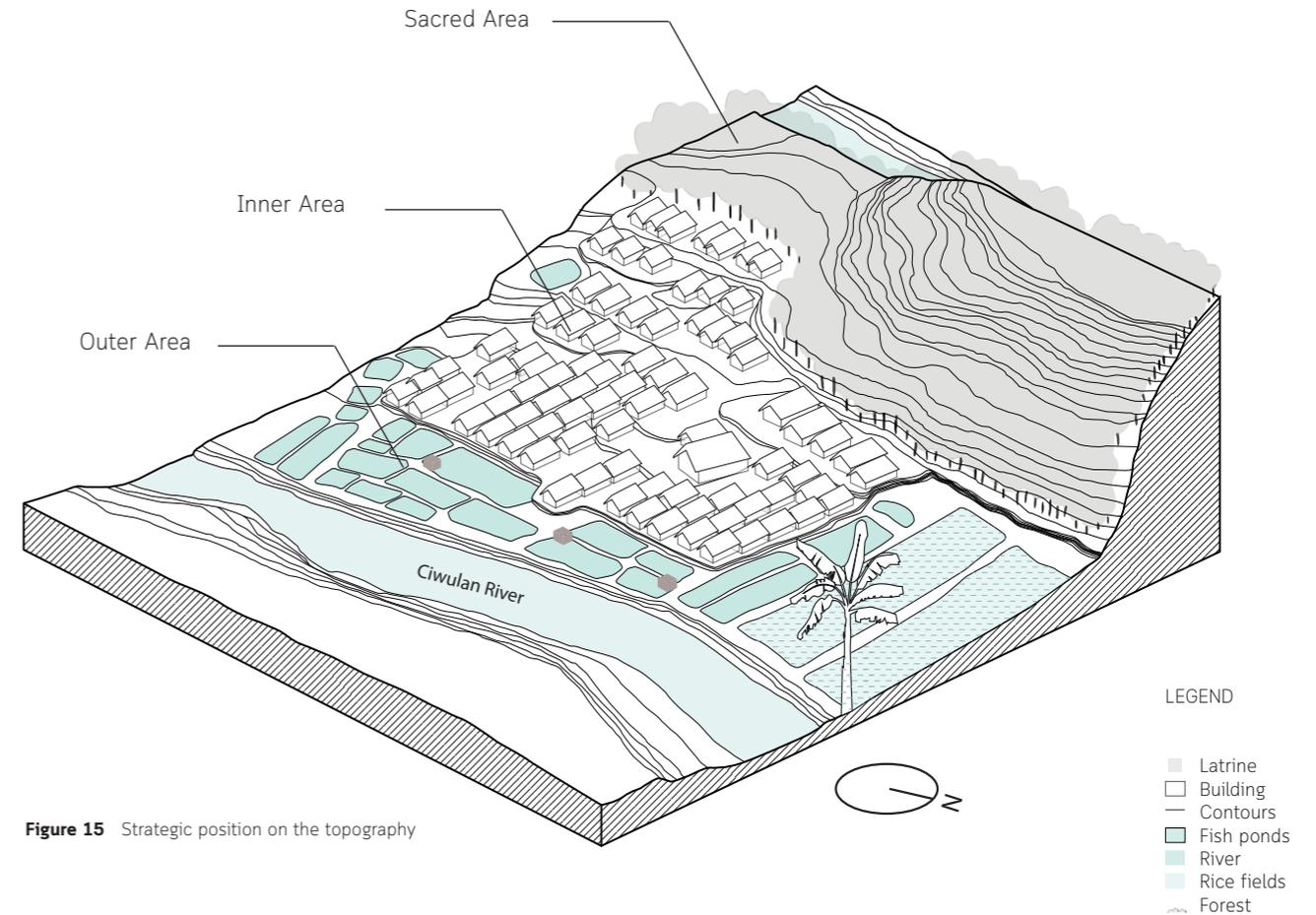
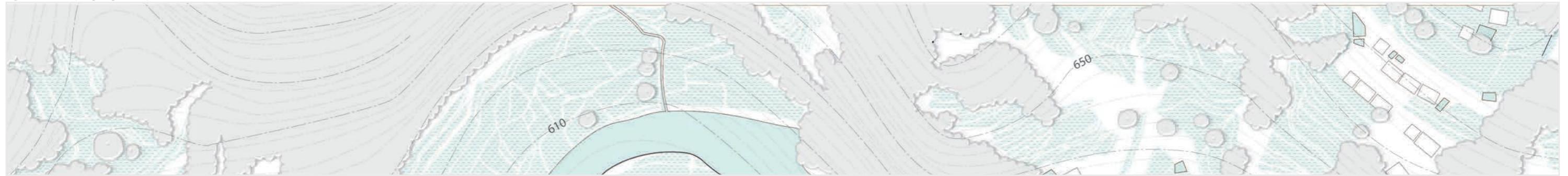
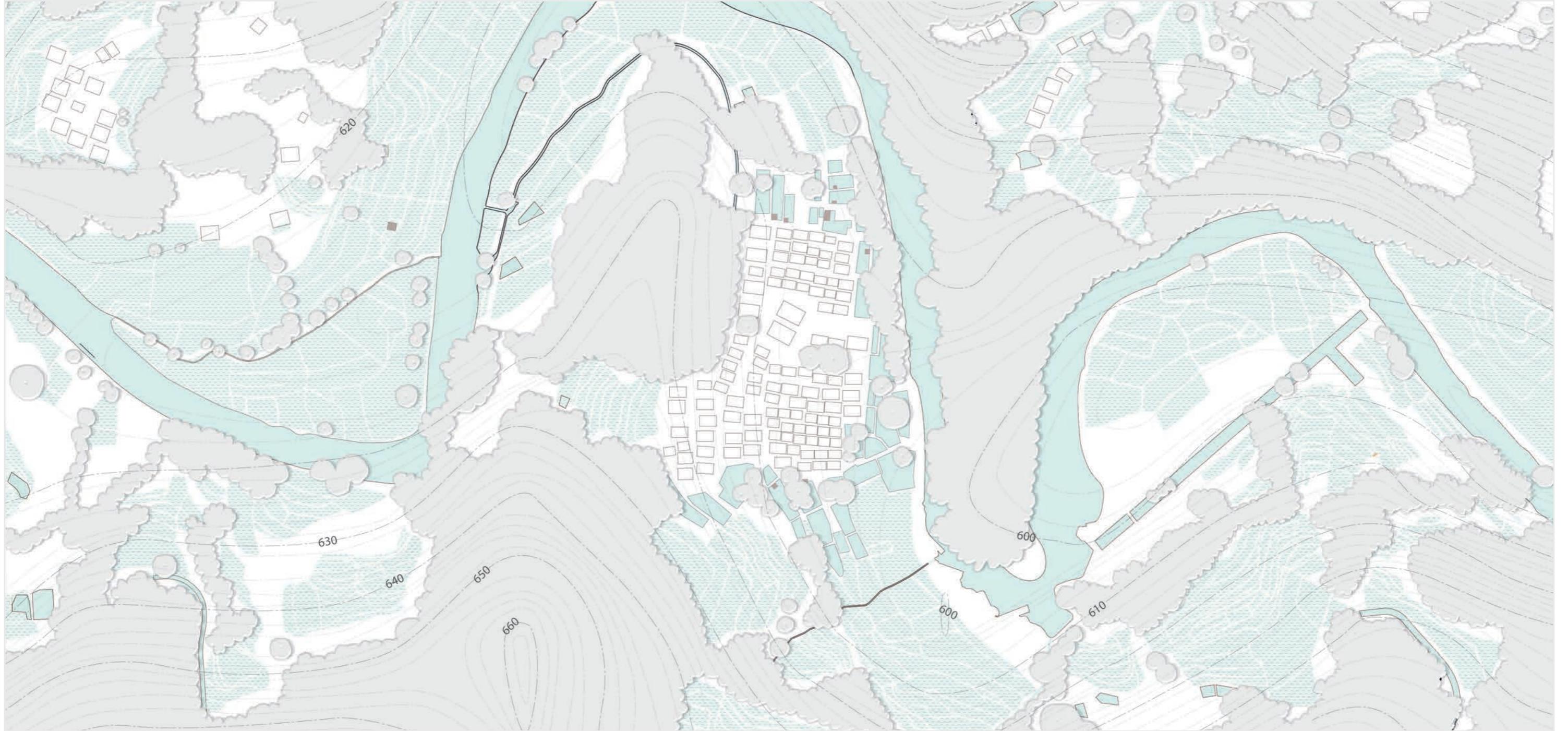


Figure 15 Strategic position on the topography

Figure 16 Kampung Naga floor plan.





# Source of Water.

Kampung Naga has three water sources for daily activities. The sources are from Ciwulan River and two springs on the hills which people diversify one to another (Spring Water and Nyusu Water) based on the consistency of its quantity and quality which influence the use of each water. Ciwulan River flows constantly all year round with two main sluices (Garunggang and Biuk Sluice) located close to Kampung Naga to regulate its stream. Water discharge from the river is regulated with piles of rocks towards two main channels. It is filtered naturally by wild grasses and gravels and distributed towards the agriculture area and water tubes at the latrines.

The spring water is located behind the hill at the back of the village. It is channeled towards two directions. First, it is channeled to the mosque, the only building in the center of the village which has access to water for the cleansing rituals before praying activities. Second, it is channeled towards the latrines in the Outer Area. While the rice fields only use the river water for irrigation, the spring water substitutes the river water for washing and bathing in the rainy season as the river water turns murky by rising muds and ploughing activities. With two kinds of water sources, each latrine has two separated cisterns to maintain the water quality.

Located closer to the hamlet, another spring called Nyusu Water is utilized as the only source of potable water for the inhabitants. Nyusu water is a result of water infiltration through the roots of a pristine forest on the hill bordering the village on the western side. It is constant in both quality and quantity regardless of seasonal change.

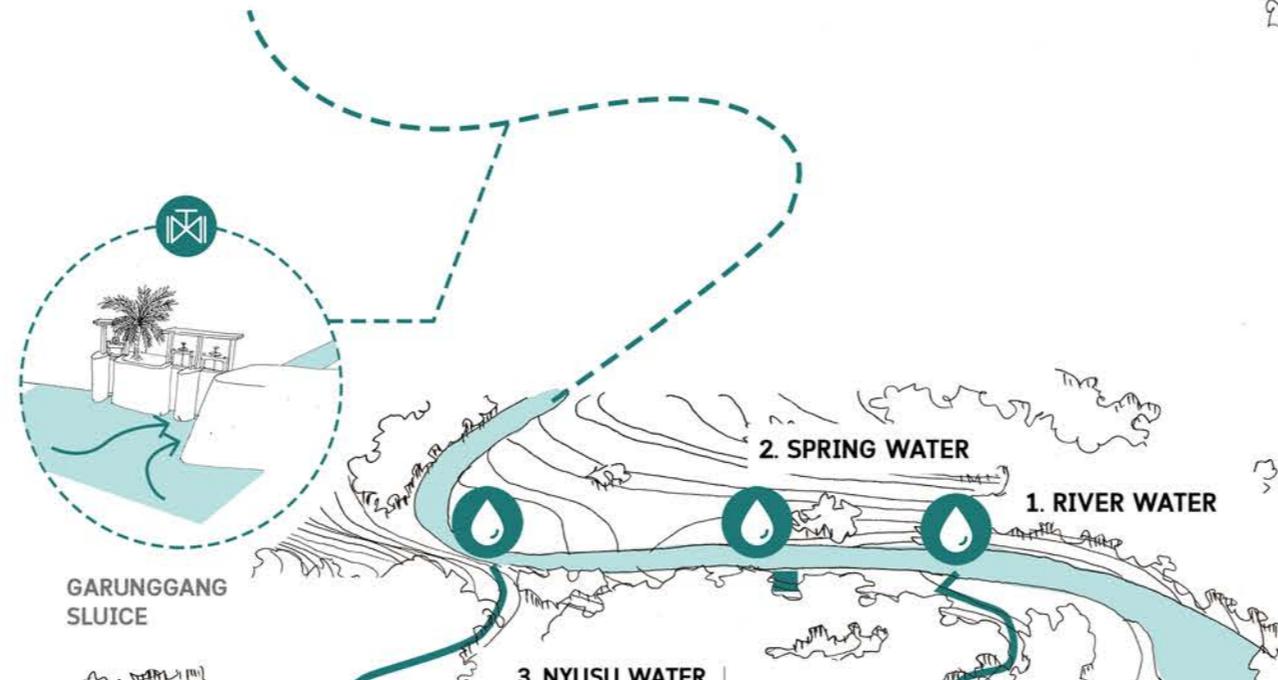
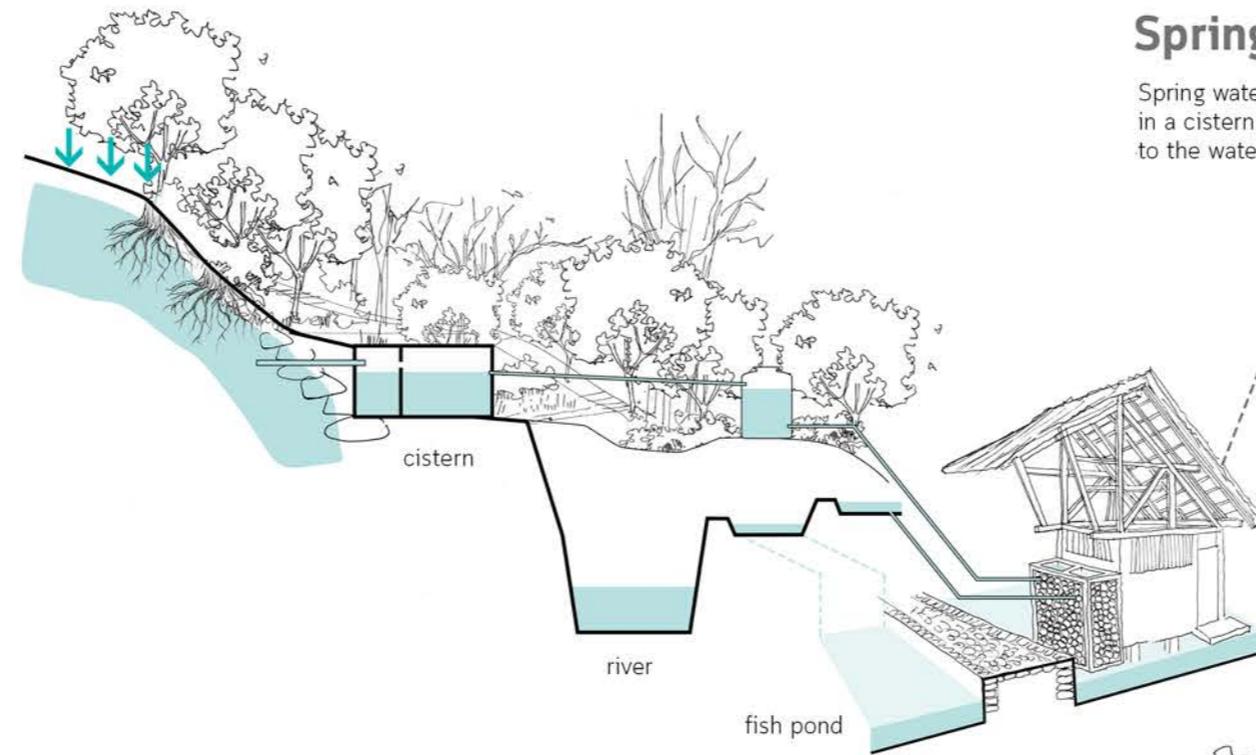


Figure 17 Water source - Spring water

## Spring Water

Spring water is collected in a cistern and distributed with pipes to the water tanks at the latrines.

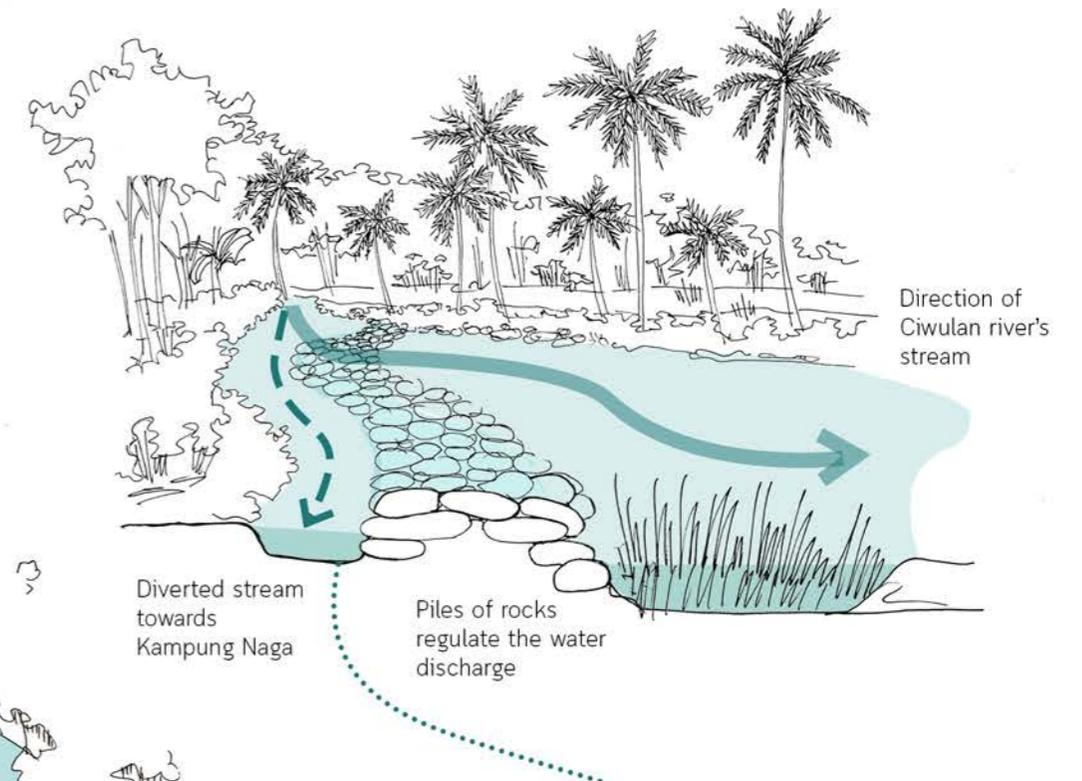


Each latrine has two tubs for water from the river and the spring

## River Water

River stream is diverted by using piles of rock. It flows towards the main channels in Kampung Naga and be used for irrigation and daily activities.

Figure 18 Water source - River water



Direction of Ciwulan river's stream

Diverted stream towards Kampung Naga

Piles of rocks regulate the water discharge

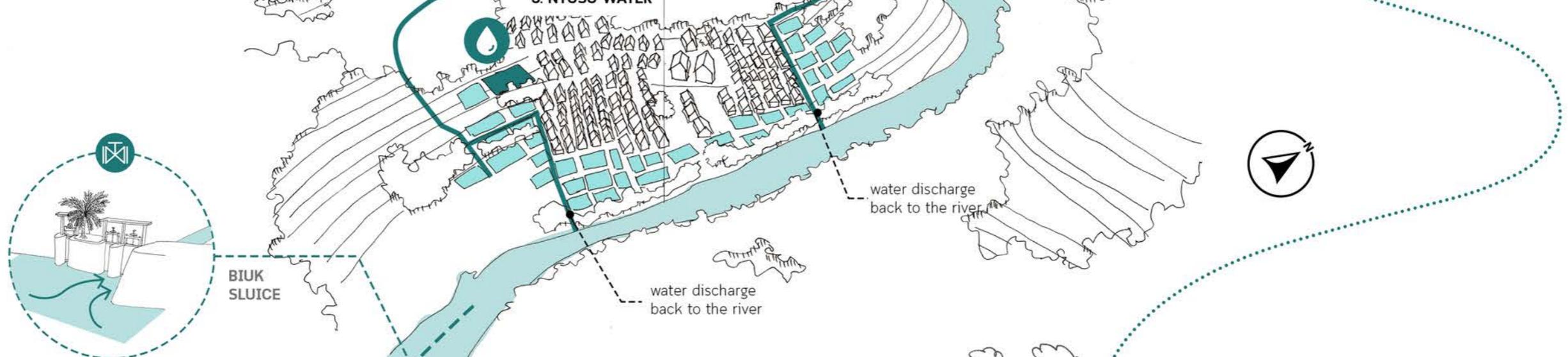


Figure 19 Source of water in Kampung Naga

## Nyusu Water

Nyusu water is a water spring located close to the settlement. It is used as the only drinking water source for the inhabitants.

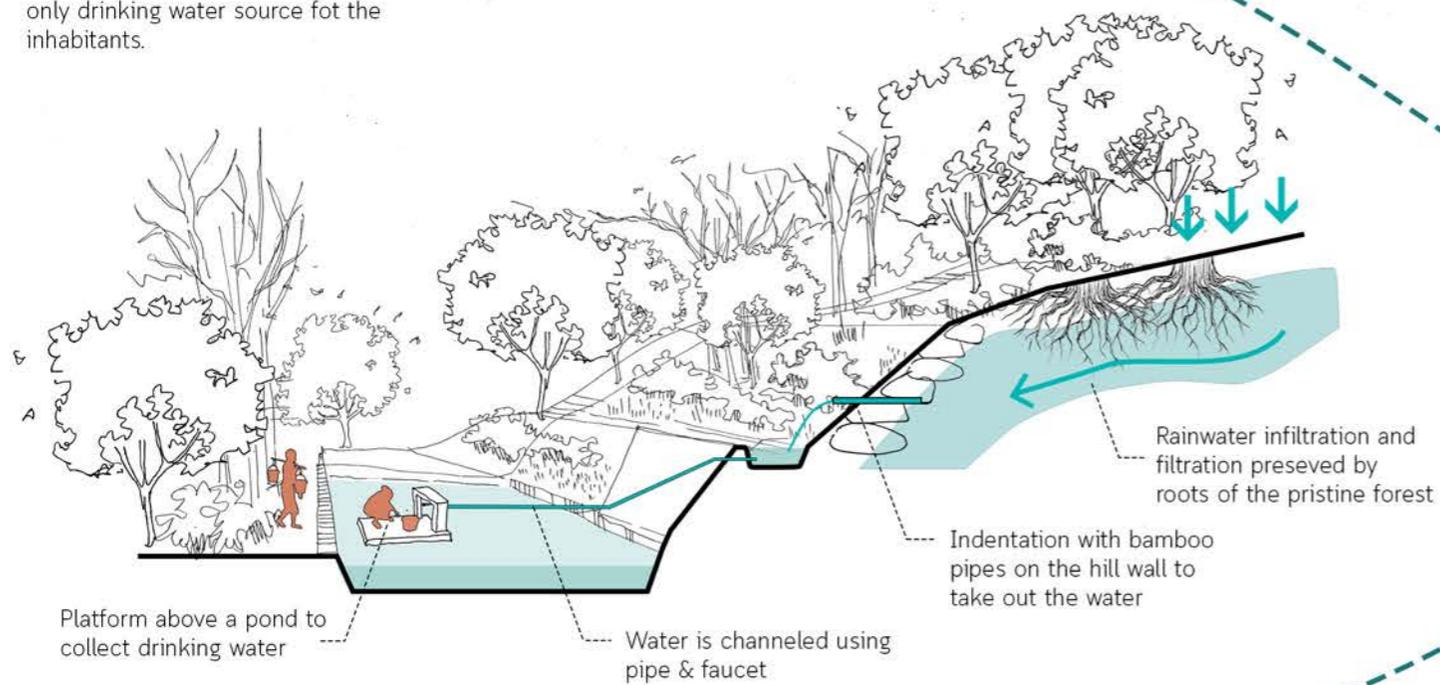


Figure 20 Water source - Nyusu water

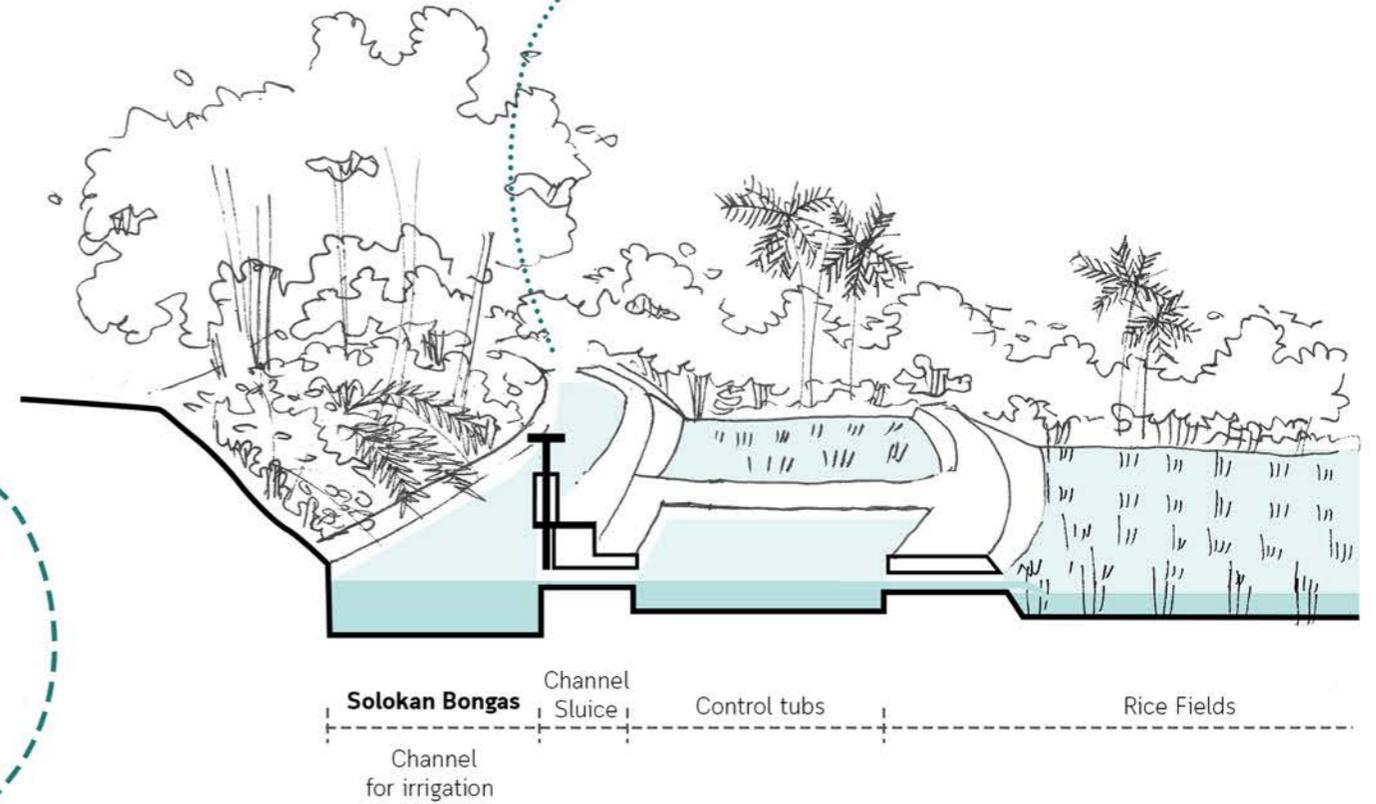


Figure 21 Irrigation channel - Solokan Bongas

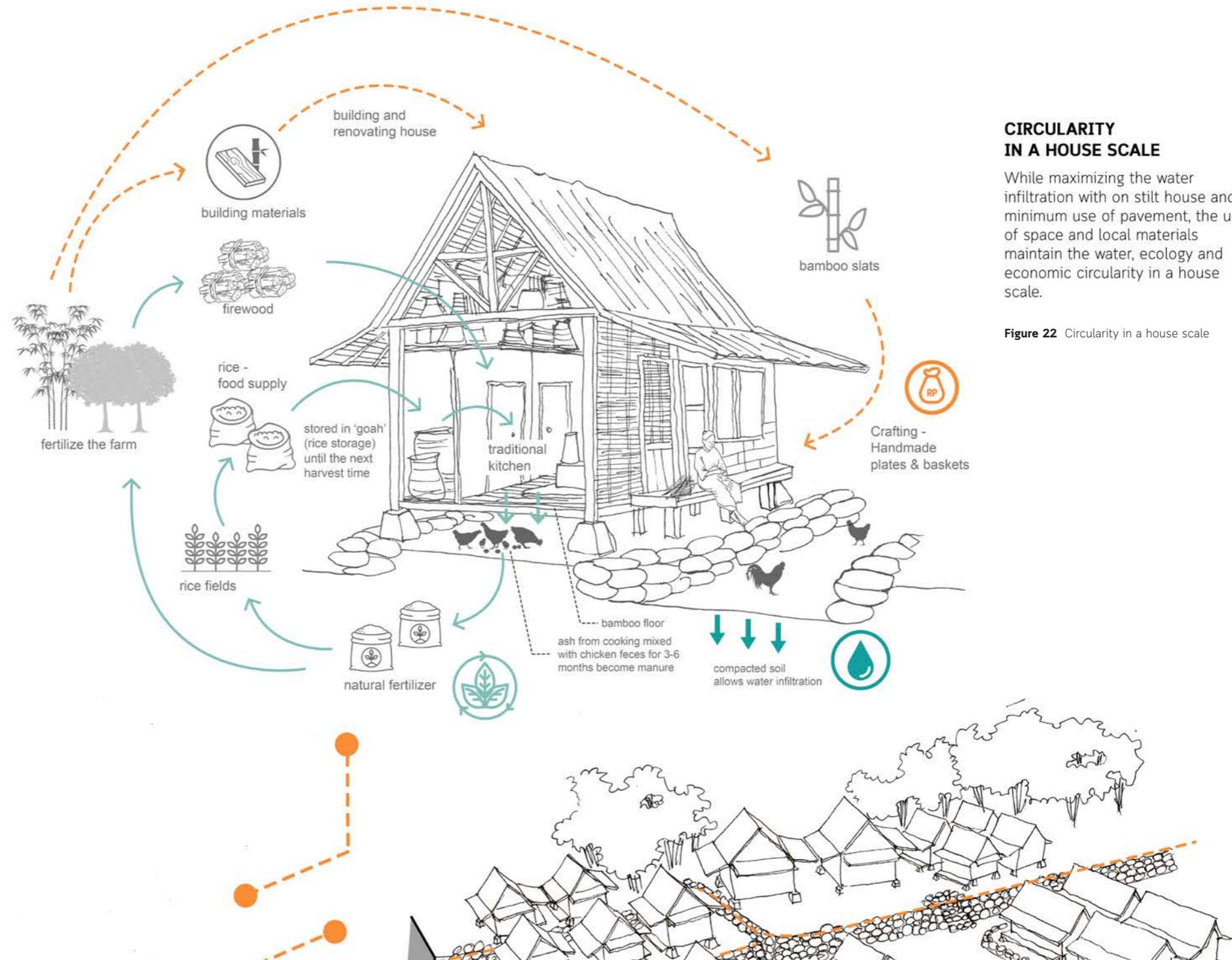


# Circularity

Nature works in circular systems. Living with nature, people in Kampung Naga believe that they need to understand thoroughly and preserve this circularity. Water, as one of the main resources of lives, is used wisely to maintain its circularity. The three water sources which are located on the higher parts of the topography are kept clean free from any activities that could contaminate the water quality. People are forbidden to cut trees in the forest on the hill to maintain its ability to absorb and purify the rainwater to the ground water table. In this case, myth and tradition are used by the community as rules that have to be obeyed. After the water is used for daily activities, it is purified by fishpond systems before finally being returned to the river.

In the Inner Area where the settlement is built, houses are organized in rows to form corridors where the tips of the roofs are meeting on lines. With this arrangement, rainwater is collected on the ordered gravel ditch lanes. Long standing water is anticipated by a continuous gutter following the higher to the lower contours, to the main drainage system that flows to the river. In support of this solution, houses are built above raised ground with stone borders which also function as the border of the gutter. The principle of using natural topography also influences the parallel pattern between houses and contour lines where the house width is determined by the width of the existing plains or the favorable position to build retaining boulder structure. It is built without any adhesive materials which make it possible for the rainwater to seep through. Minimum use of pavements inside the settlement area that maximizes the rainwater infiltration to the soil.

Stilt house design and the gravel gutter that support the storm-water management also maintain ecological circularity in a house scale. The stilt house avoids moisture from the ground to enter the house and avoid termites to destroy the wood structures. The space under the house is used to



## CIRCULARITY IN A HOUSE SCALE

While maximizing the water infiltration with on stilt house and minimum use of pavement, the use of space and local materials maintain the water, ecology and economic circularity in a house scale.

Figure 22 Circularity in a house scale

store firewood and raise chicken which also become natural control for the termites. The kitchen area uses bamboo slats floors which have gaps in its order. Ashes from burning the firewood to cook will fall down through the floor gaps and be mixed with chicken feces naturally by the chicken under the house. Within 3-6 months, this mixture will form natural fertilizer for the community's crop. The wood from the inhabitant fields are used as firewood and building material, while bamboo slats are also used as handmade craft.

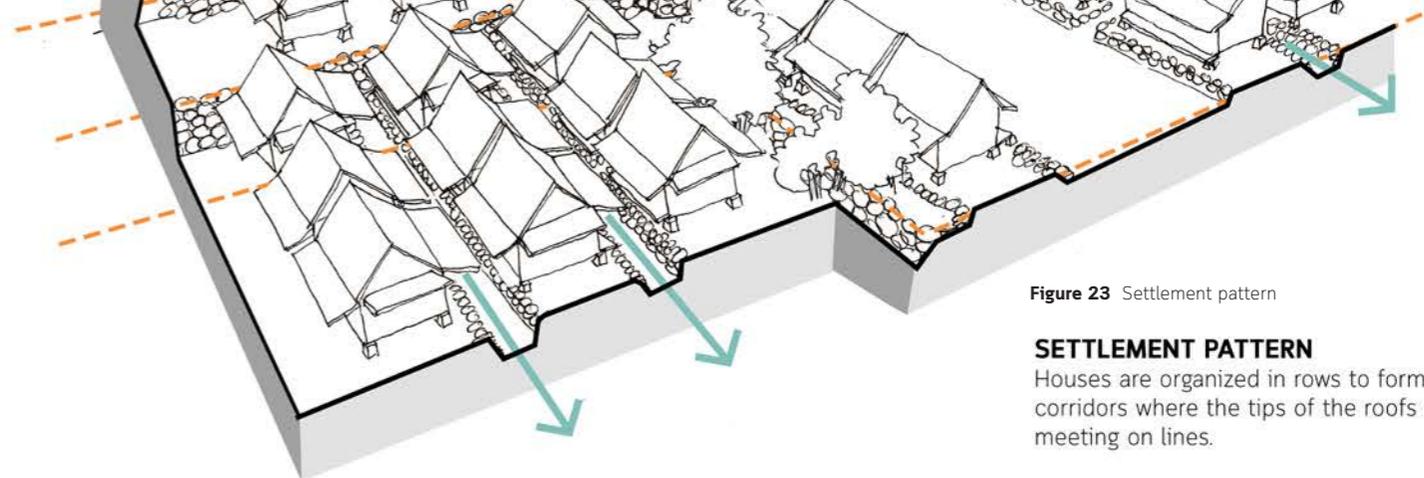


Figure 23 Settlement pattern

**SETTLEMENT PATTERN**  
Houses are organized in rows to form corridors where the tips of the roofs are meeting on lines.

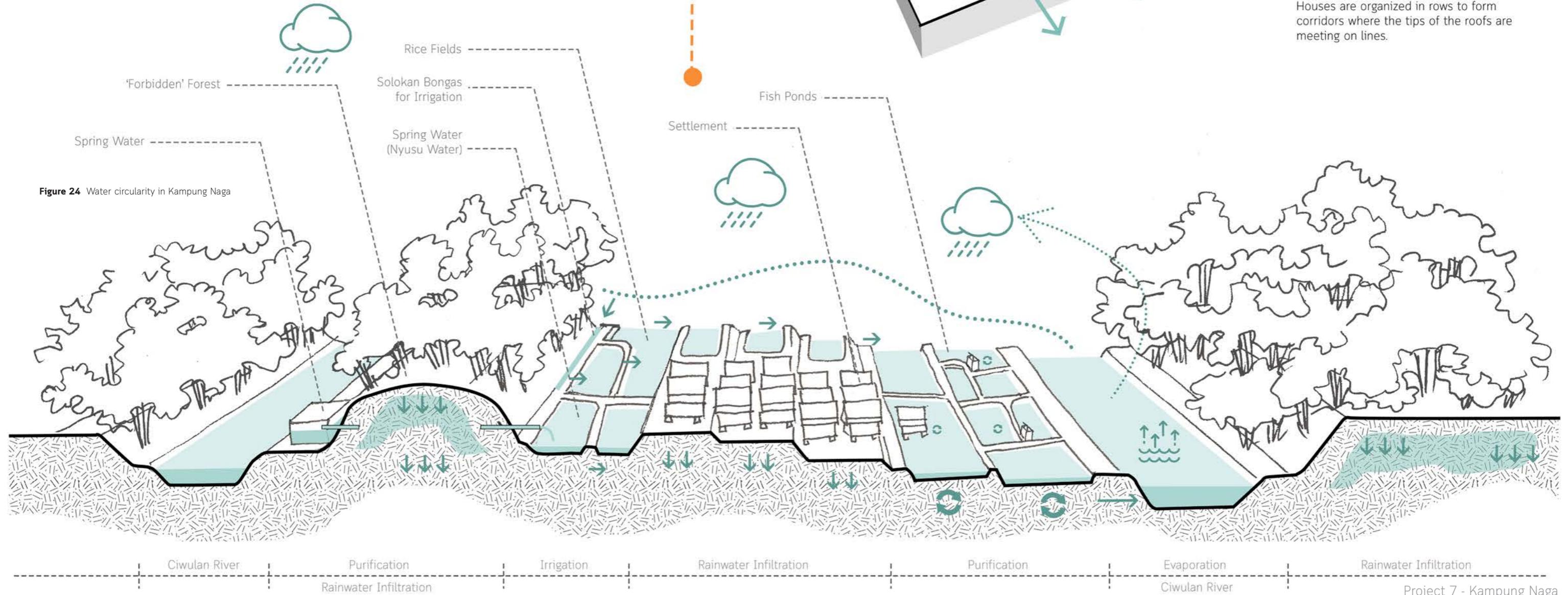
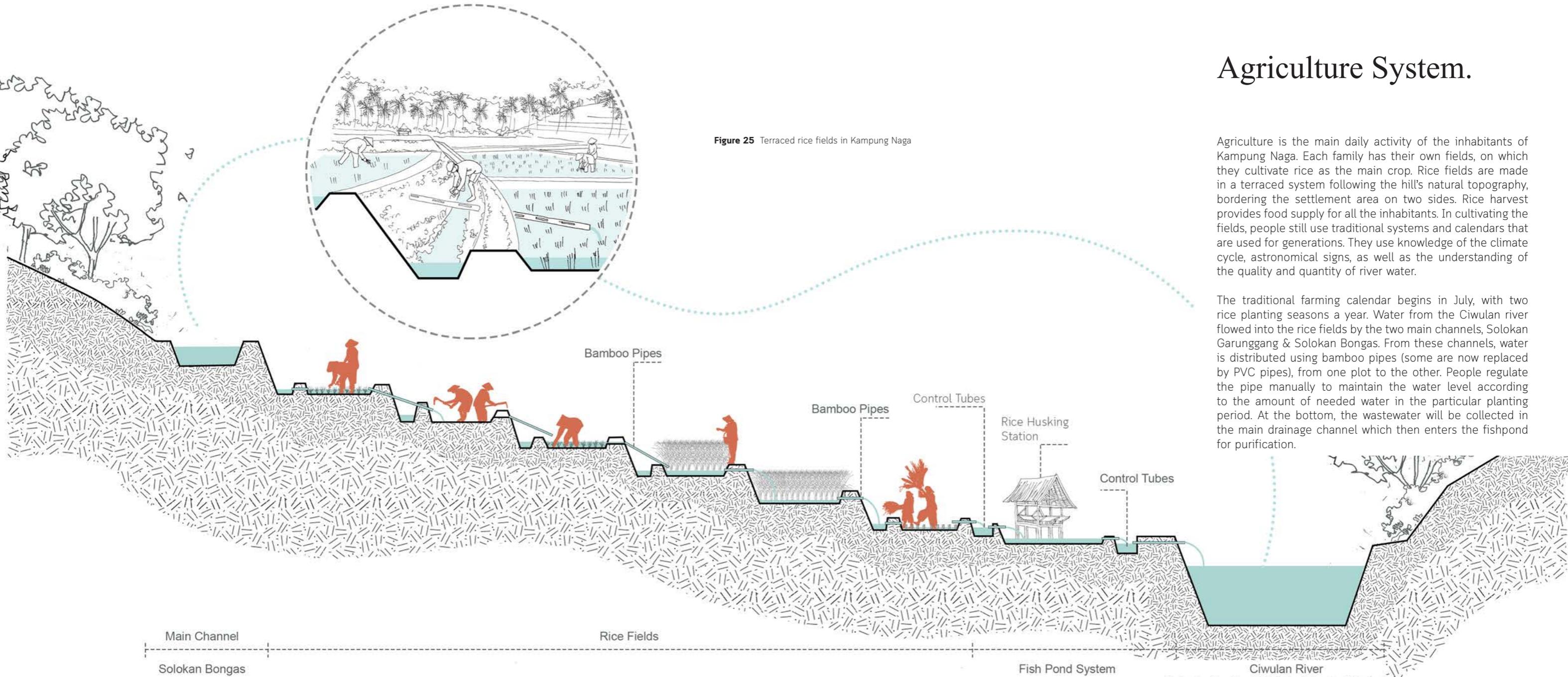


Figure 24 Water circularity in Kampung Naga

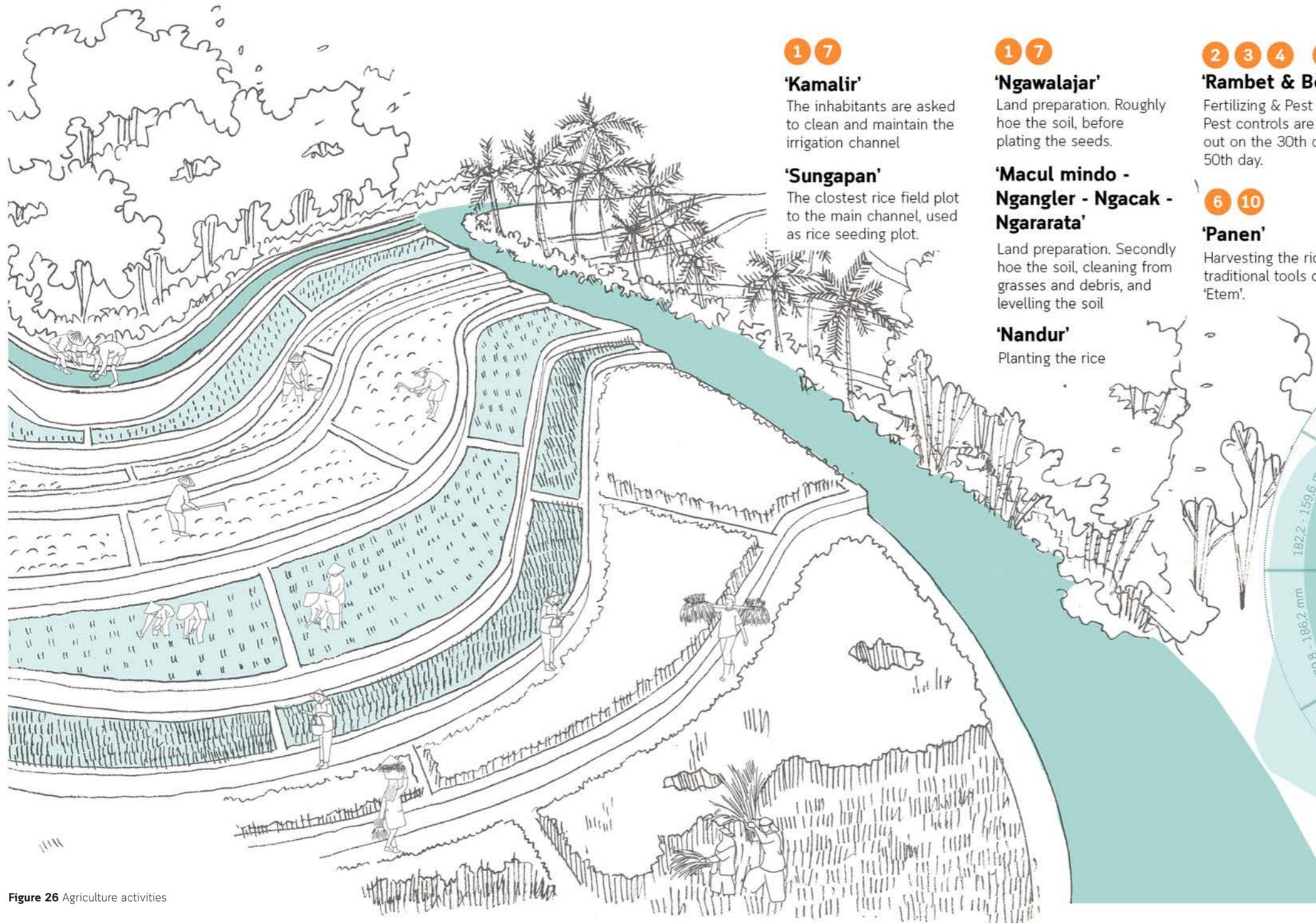
## Agriculture System.

Figure 25 Terraced rice fields in Kampung Naga



Agriculture is the main daily activity of the inhabitants of Kampung Naga. Each family has their own fields, on which they cultivate rice as the main crop. Rice fields are made in a terraced system following the hill's natural topography, bordering the settlement area on two sides. Rice harvest provides food supply for all the inhabitants. In cultivating the fields, people still use traditional systems and calendars that are used for generations. They use knowledge of the climate cycle, astronomical signs, as well as the understanding of the quality and quantity of river water.

The traditional farming calendar begins in July, with two rice planting seasons a year. Water from the Ciwulan river flowed into the rice fields by the two main channels, Solokan Garunggang & Solokan Bongas. From these channels, water is distributed using bamboo pipes (some are now replaced by PVC pipes), from one plot to the other. People regulate the pipe manually to maintain the water level according to the amount of needed water in the particular planting period. At the bottom, the wastewater will be collected in the main drainage channel which then enters the fishpond for purification.



1 7

**'Kamali'**

The inhabitants are asked to clean and maintain the irrigation channel

**'Sungapan'**

The closest rice field plot to the main channel, used as rice seeding plot.

1 7

**'Ngawalajar'**

Land preparation. Roughly hoe the soil, before plating the seeds.

**'Macul mindo - Ngangler - Ngacak - Ngararata'**

Land preparation. Secondly hoe the soil, cleaning from grasses and debris, and levelling the soil

**'Nandur'**

Planting the rice

2 3 4 8 9

**'Rambet & Berak'**

Fertilizing & Pest Control. Pest controls are carried out on the 30th day and 50th day.

6 10

**'Panen'**

Harvesting the rice using traditional tools called 'Etem'.

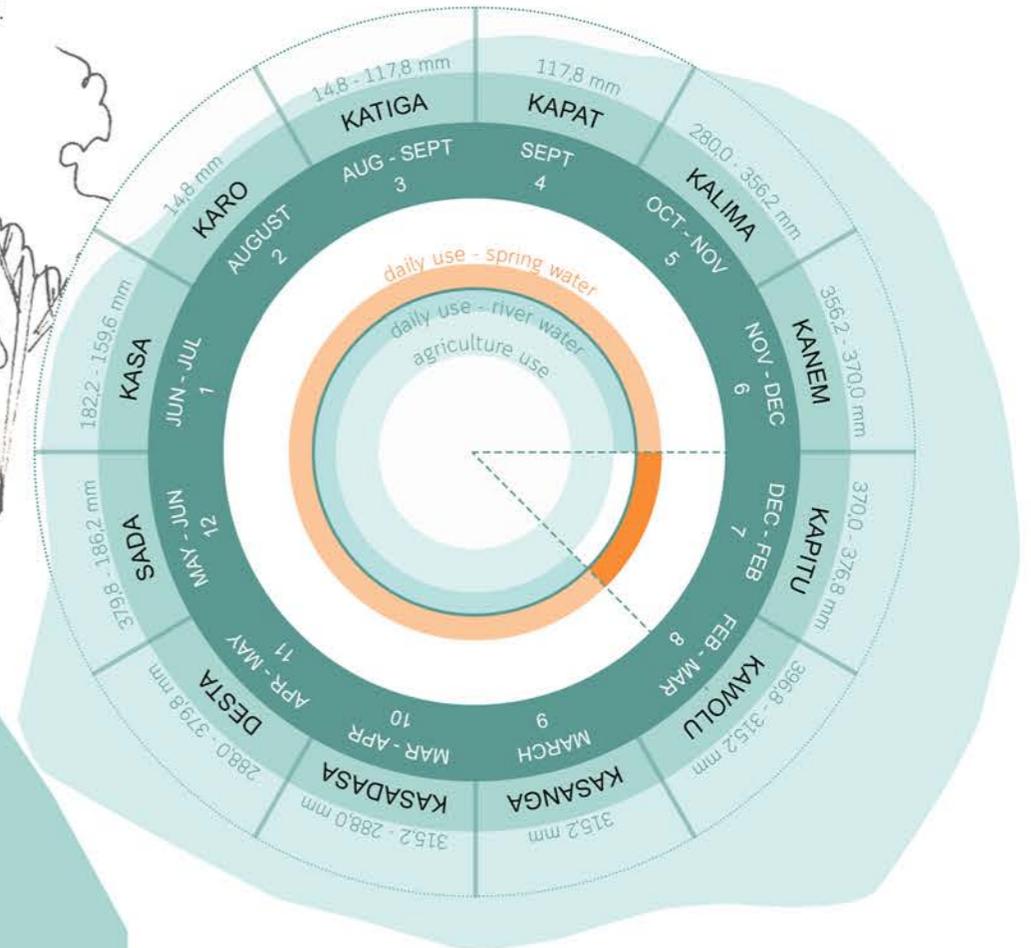


Figure 26 Agriculture activities

Figure 27 Traditional agriculture calendar of Kampung Naga

# Fishpond System.

Fishpond system is the main component in the management of household wastewater in Kampung Naga. It is located at the Outer Area where the public bathrooms, rice husking station, and washing area are also located above it. The area is designed as an integrated system where people use and purify the water and maintain ecological cycles at the same place.

Each latrine has two water tubs outside to collect water both from the river and the spring. Wastewater directly flows from the latrine to the fishponds underneath. In its multi functionality, fishpond is a place to raise fishes. On the other hand, it naturally filters the wastewater from both feces and urine. Through a water distribution system between the ponds and control tubs, purified water flows to the main ditch towards the river.

A rice husking station is built above the fish ponds. In this station, the rice is manually pounded to separate the rice grains from the outer husk. The husks are thrown into the pond to feed the fish. Fishes are harvested to become a source of food for the community. Besides, the stems are collected and burned to be used as natural shampoo, cure some skin diseases and also used as a natural preservative for certain food.

Centralized location for the public interest is also applied in the fish pond system. The largest pond located in the center is owned by the village, raising fishes which can only be harvested for public consumption during special events, while the surrounding fish ponds are owned privately by the inhabitants.

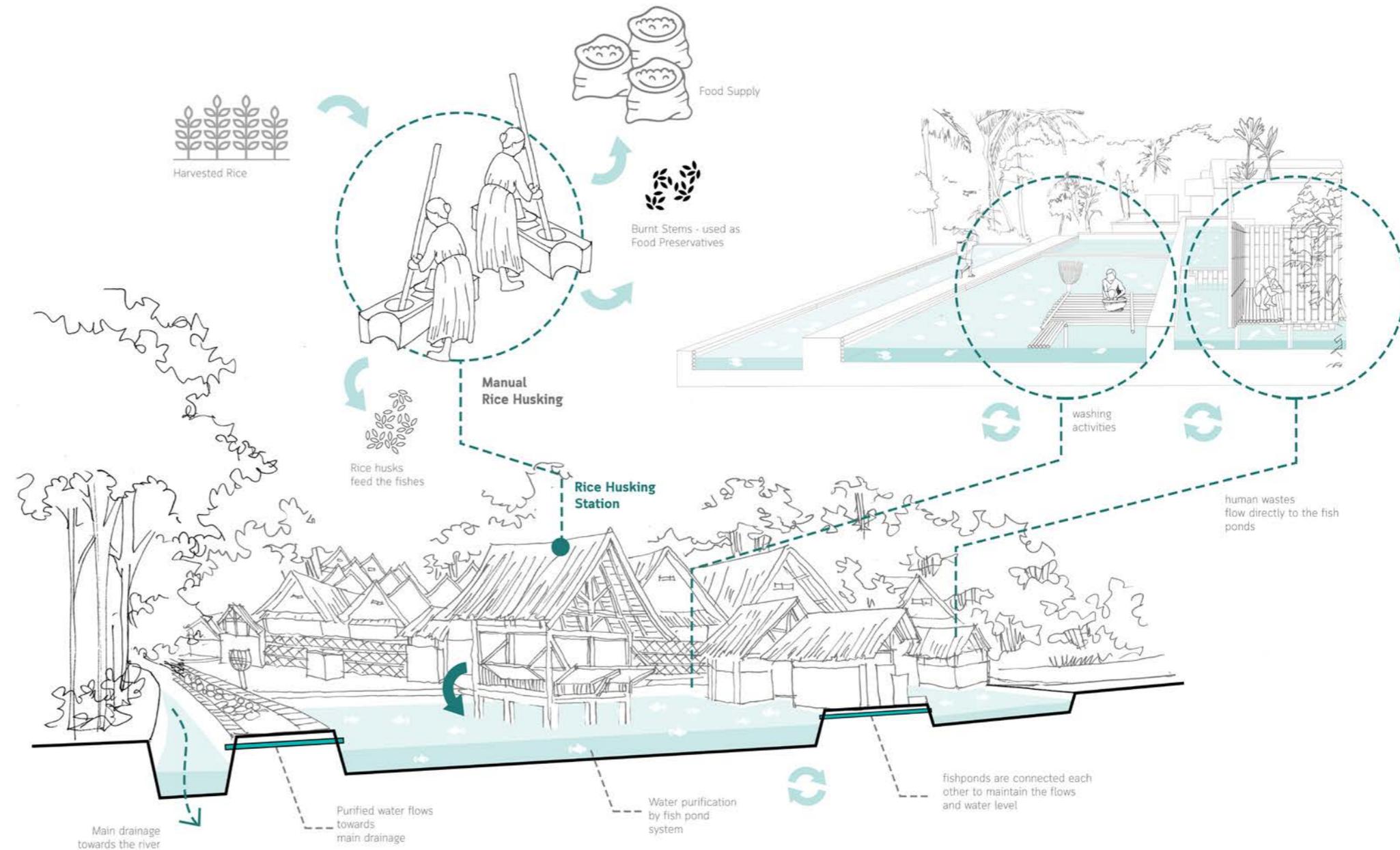


Figure 28 Fishpond system as an integrated water & ecological cycle (right)

# Conclusion.

**Landscape values** - Built on a valley, the slopes are shaped into terraces to create space to build settlement and rice fields. The natural shapes are preserved, creating uneven platform size which determines the width of each house and the area of rice field plots.

**Strategic values** - Kampung Naga is located at the bend of meandering Ciwulan River which makes it covers two sides of the hamlet and makes it easier for the inhabitants to access the water. Topography-based zoning system supports the whole water management system in the village. The valley where the settlement is located is facing east with the forbidden forest on the western side at the back of the village. It protects Kampung Naga from the west sun exposure and the mountain wind that blows harder from the west direction. The forbidden forest on the highest area preserves and filters the rainwater through its roots into the groundwater table which then is extracted as a water source. The houses are built parallel to the contour line and arranged in linear rows perpendicular to the contour line to create drainage lanes inside the village.

Topography-based zoning also assigns the lowest part as the location of the purification system with fish ponds. It becomes the last place to collect and purify the wastewater before discharging back to the river without contaminating the water and the soil on the upper part where the water source and the living place are located.

**Functional values** - Gravel ditches are made linear as a space between the house rows. The ditches are also aligned as terraces following the topography to fasten the flows of the overflowed storm-water and prevent the humidity from entering the house that is made out of wood construction.

Square control tubs are located along the water distribution pipe to ease the identification when a problem occurs on

the lanes. Separated water tubs on the latrines are made to avoid mixing water from two different sources.

**Material and tangible values** - Local materials are widely used in the construction of water elements and waterworks. Fluvial boulders and gravels are used to build retaining walls without any adhesive materials. It holds the soil structure for the houses and forms ditches, as well as allows the rainwater to seep through. Bamboo was originally used to distribute the water in the rice fields, building the fishponds and the latrines, although in current situations, some of the bamboo structures are replaced by concrete and PVC pipes. Knowledge of soil characters found in the immediate environment also helps to shape the embankment of the plot to contain water at the terraced rice fields.

**Values of sustainability** - The water system in Kampung Naga shows that the inhabitants utilize water in a complete cycle. Water is infiltrated, gathered, used, and purified inside the village before it is brought back to the natural system with an equal quality. All the construction of water elements and waterworks use the technique and craftsmanship of the inhabitants. With the material that can be found around the village, all the maintenance of the water system can be done independently. Some features of the water management system are kept not only in the perspective of functionality, but also in the perspective of social tradition. For example, to regulate the water discharge from the river to the irrigation channel, piles of rocks are used. The maintenance activity of this construction is also used as a gathering activity to maintain the social cohesion in the community.

**Ethnographic and identity values** - The inhabitants of Kampung Naga is an agriculture community. As the main daily activity, agriculture also shapes the attitude of the people towards nature and how they form the cultural

landscape. The management of the water system both for the daily and agricultural activities are based on the belief that maintaining the natural cycle will ultimately make it provide all that they need to live with. With the inevitable development outside the village, local wisdom and tradition with rules and restrictions are held to keep the ecological balance and ensure the sustainability of the whole system.

**Lessons to learn** - Kampung Naga has succeeded in cohesive inhabiting with nature in the midst of the urban development around it. It maintains the balance interaction between water, ecology and athropo-systems which influences the spatial layout of the village, forms its cultural landscape, and shapes people's social life.

The case of Kampung Naga clearly shows that the role of users is imperative to maintain the circular water system and supported ecosystem services. Bonded by beliefs and tradition, rules and restrictions, the inhabitants of Kampung Naga maintain the local knowledge & the nature of circularity in the place they live in to become part of its ecosystem, which makes living with nature possible. The inhabitants thoroughly understand the limits and boundary on managing its community to keep certain balance of the needs and supply from the resources they have in the village, including the water circularity. This balance makes Kampung Naga defend themselves as a self-sustained living landscape. The management of the water system for the daily and agricultural activities is based on the belief that maintaining the natural cycle will ultimately make it provide all that they need to live with. With the inevitable development outside the village, local wisdom and tradition with rules and restrictions are held to keep the ecological balance and ensure the sustainability of the whole system.



**Figure 29** Traditional technique to pound rice.

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# Xinghua Duotian Agrosystem

A traditional water-land utilization technique  
developed by Chinese ancestors

Rapa Surajaras

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Figure 1 Atmosphere of the system with boats for tourist

# Context.

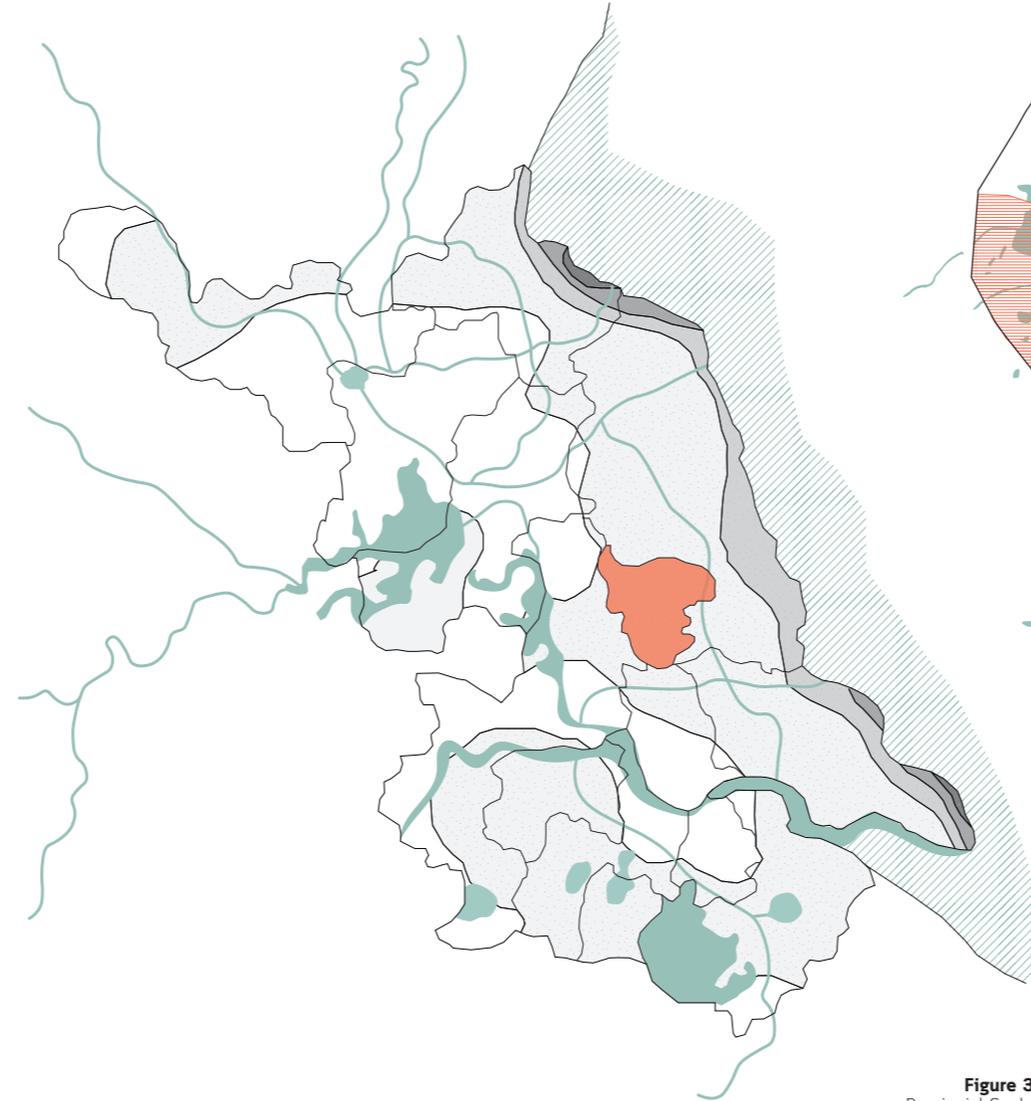
Location: Xinghua city Jiangsu Province, China  
Landscape Type: Low-lying wetland  
Area: 31200 ha  
Function: Irrigation, land reclamation, agriculture  
Water Quality: Fresh Water  
Dynamic: Seasonal Flooding

Xinghua Duotian is a traditional water-land utilization system that has been used for more than three thousand years. It is located in Xinghua city of Jiangsu Province in China. It includes a total area of 312 km<sup>2</sup>, covering five townships (The People's Government of Xinghua City ,2014). The project will primarily discuss the Duotian town since the agrosystem is originated from this area.

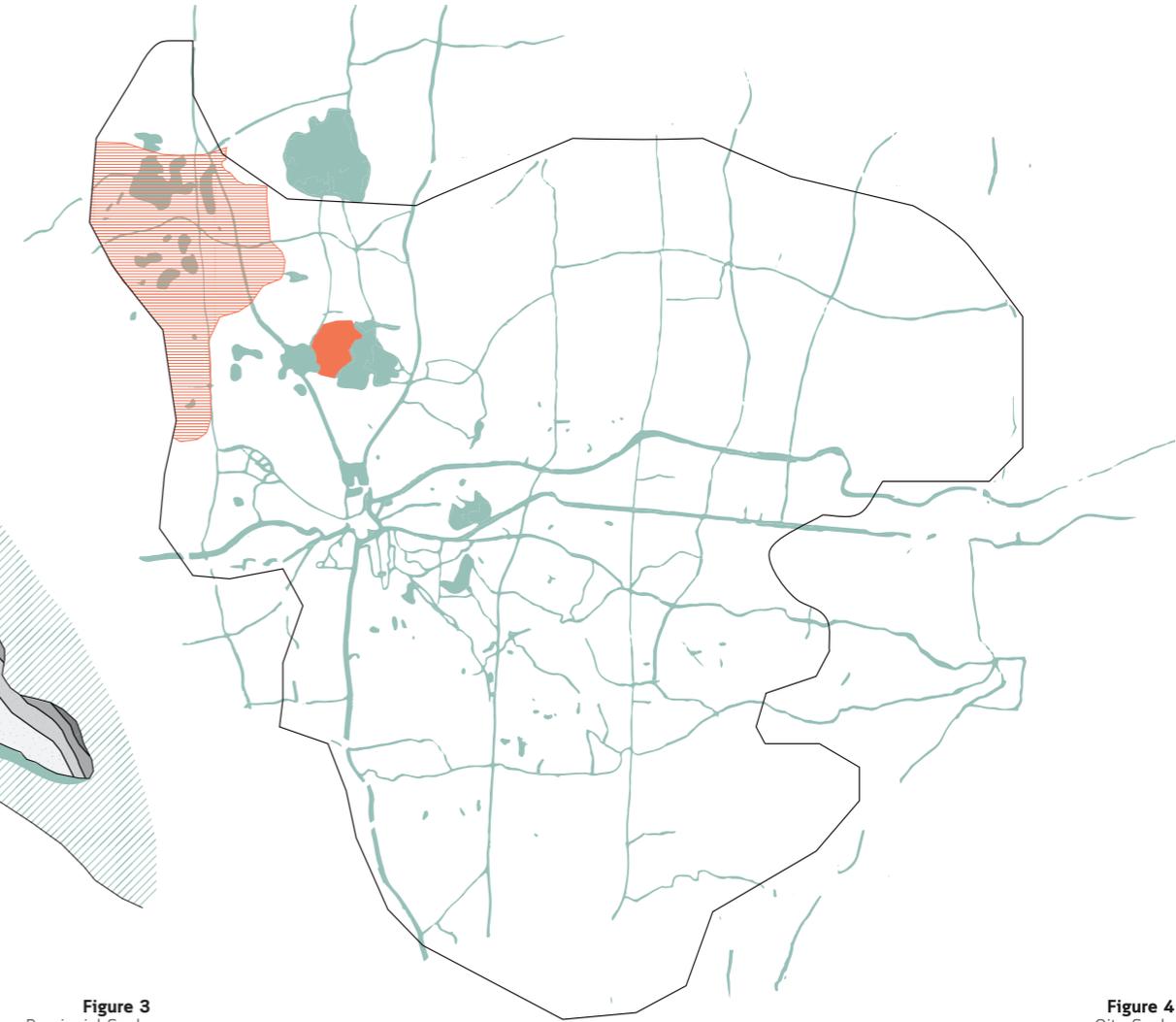
The system transformed floodplain into the cultivable area by creating "Raised filed" that can grow crops in uncertain water level. This technique represented a sustainable way to adapt to the changes in local fluvial conditions, to tackle the threat of floods and to meet the needs of a rapidly expanding population.



**Figure 2**  
Country Scale



**Figure 3**  
Provincial Scale  
Delta area



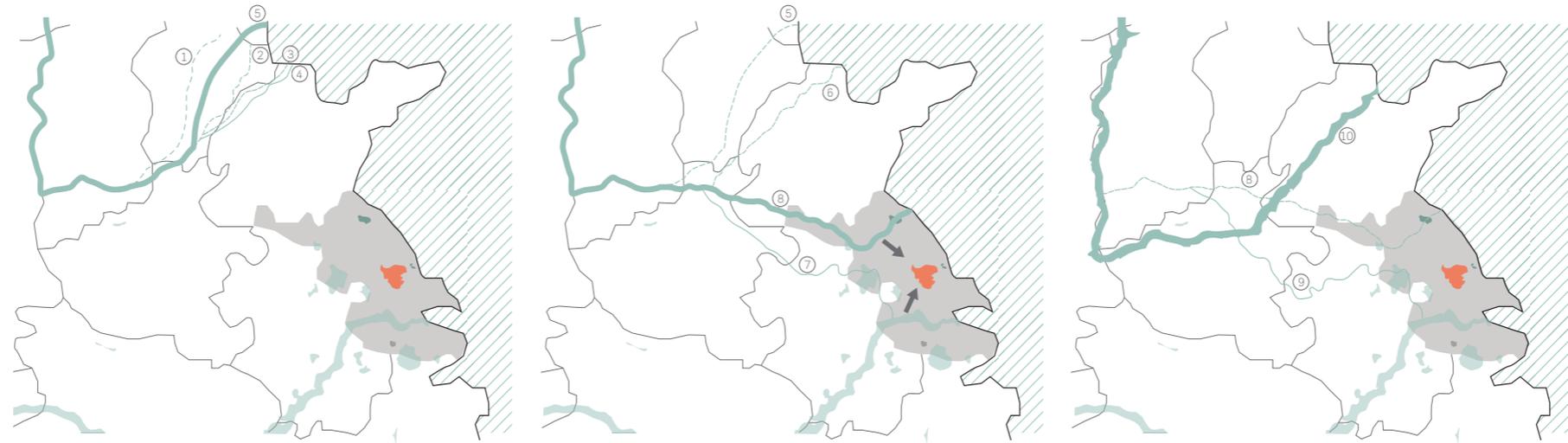
**Figure 4**  
City Scale  
with hundreds of rivers and canals

# The Origin.

The water system has been initiated due to the natural condition of the area that created difficulty for people to live. Xinghua city is a flat plain located in between the Huai River and the two alluvial plains along the Yangtze river.

In the past, this area was originally a lagoon and the corridor for floods (Figure 11). People suffered from frequent floods and the lagoon was mainly used for fishing. As time passed by, freshwater from the tributaries continuously flowed to the lagoon, the quality of a lagoon gradually changed into fresh-water (Yanying, Xueping, Mi & Fuller, 2014) (Figure 12). During this time, the eastward-moving coastal line also caused a fall in the water level of the lake (The People's Government of Xinghua City, 2014). Moreover, a large amount of sediment that is deposited by the Yellow River divided the existing water surface into a wetland with numerous lakes (Yanying et al., 2014).

Due to the high frequency of flooding events, the Fan Gong Dike is constructed and the yellow river is dammed in order to block the seawater from pouring in the east (Figure 13). This construction effectively transformed the wetland into cultivable land (Yanying et al., 2014). Besides, the continuity of sediment deposit from the Yellow River raised swamps in Xinghua above the average water level. During this time, the raised field system has been invented by Xinghua community and began to expand its territory (Figure 14).

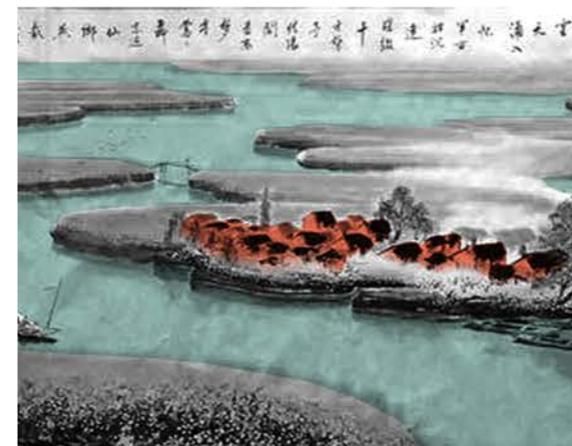


- ① Before 602BC
- ② 602BC - 11AD
- ③ 11-893
- ④ 893-1048
- ⑤ 1048-1194
- ⑥ 1194-1289
- ⑦ 1289-1324
- ⑧ 1324-1853
- ⑨ 1939-1947
- ⑩ 1947-present

**Figure 5** The Development of the Yellow River (top)  
**Figure 6** Historical images of the area (bottom)



Period 1  
Lagoon area



Period 2  
Lake area



Period 3  
Raised field over marshland

Period 1  
High raised field

## Catchment area.

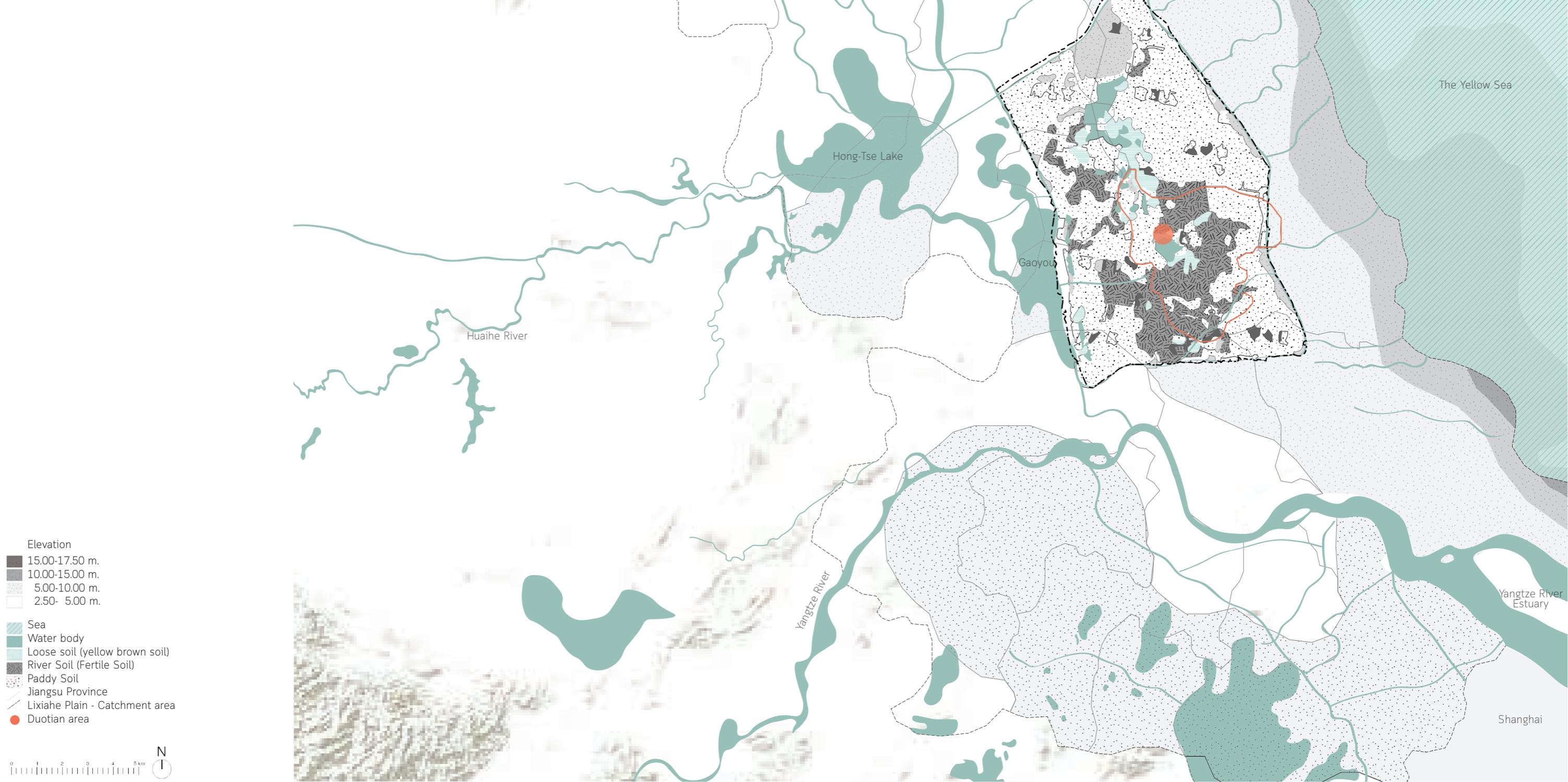
The map illustrates the landscape condition of the area which is located inside the Lixiahe plain. The geographical condition is a low-lying area surrounded by higher land as the borders. Lixiahe plain is highly influenced by the rivers and the Yellow Sea since it is a deltaic area with an average height of 2.5 meters above sea level. The development of the Yellow river brought various types of soil and sedimentation to the area, and this led to the changed of the ecological condition of the wetland.

Landscape condition is not the only factor that triggered the Chinese ancestor to invent the raised field, but the socio-logical condition was also a significant aspect. Xinghua is located in the area surrounded by major rivers which were distinctively an important commercial trade area (Yanying etl., 2014). The population overgrew which led to massive food demand. This essential problem can only be solved by increasing the cultivable area (The People's Government of Xinghua City ,2014).

As a consequence, Xinghua people began to explore the possibility to increase cultivable land. One of the potentials brought by the occurrence of the hygrophytes which began to grow in the area (The People's Government of Xinghua City, 2014), this is the indicator of the fertile soil quality brought by the yellow river. Xinghua people began to dig the soil from the river and mounding the earth platform to create the floating farmland. It is when the raised field has begun to form.

**Figure 7** Catchment map shows different type of soil and sedimentation brought by the Yellow River



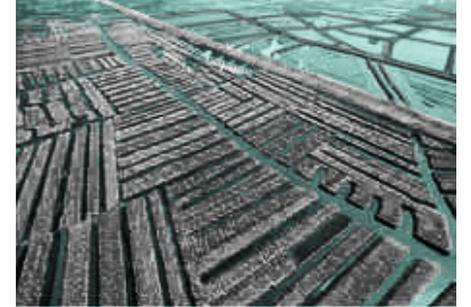
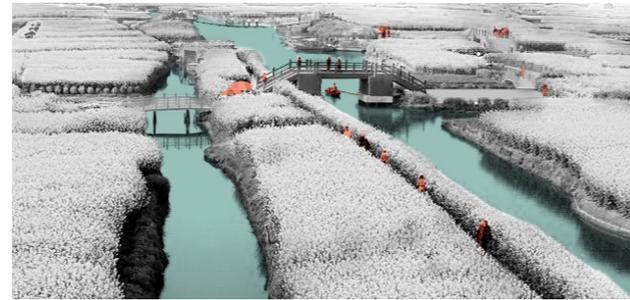
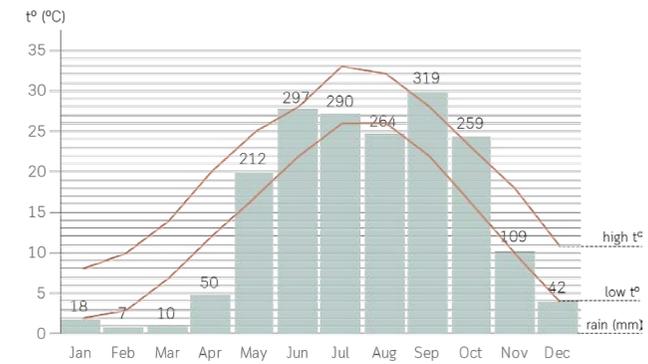


# Active raised field.

More than thousands of raised fields had been constructed to produce agricultural products for the community. It created a unique landscape pattern for the area. Xinghua became the important cultivated land and the Duotian-raised field also contributed to a flood control system of the area.

Although this technique has been applied in various areas all over the world, Xinghua Duotian is one of the few traditional systems which is still functional. Its long history and adaptability to the excessive water condition make Xinghua Duotian different from other raised field systems. It is recognized as an example of sustainability in agriculture (The People's Government of Xinghua City, 2014).

Temperature and precipitation graph



**Figure 8** Tourist routes (top left).  
**Figure 9** Traditional way of watering vegetation (top middle left).  
**Figure 10** Forest Zone at the border of the area (top middle right).  
**Figure 11** The distinct differences between raise field pattern and traditional rice field (top right).  
**Figure 12** Aerial view of the area and nearby settlement (bottom left).  
**Figure 13** Atmosphere of in the area (bottom right).

# Duotian Development.

The raised field principally composed of a layer of a pile of wood as the base, following by the existing wetland soil, fertile soil from the river and lotus roots and the vegetation layer on top (Period 1). This platform floated on the water surface, it rises during the flood and falls when water released. The land has been utilized and free from being submerged during the flood.

They carried on building higher ridges and forming the raised field as high as 2-4 m (Period 2), hundreds of thousands of raised fields is created. Then the base of the raised field has been attached to the ground due to its size, weight and maintaining issue (Period 3). Until 1949, the frequency of floods had been decreased remarkably. The height of the raised field has been lowered to 1 meter. This soil has been used to expand the width of the field to be three times larger than the original size, this is to provide more planting area (Period 4).

+4.00 Raised field height (Before1949)

+1.00 Raised field height (Present)

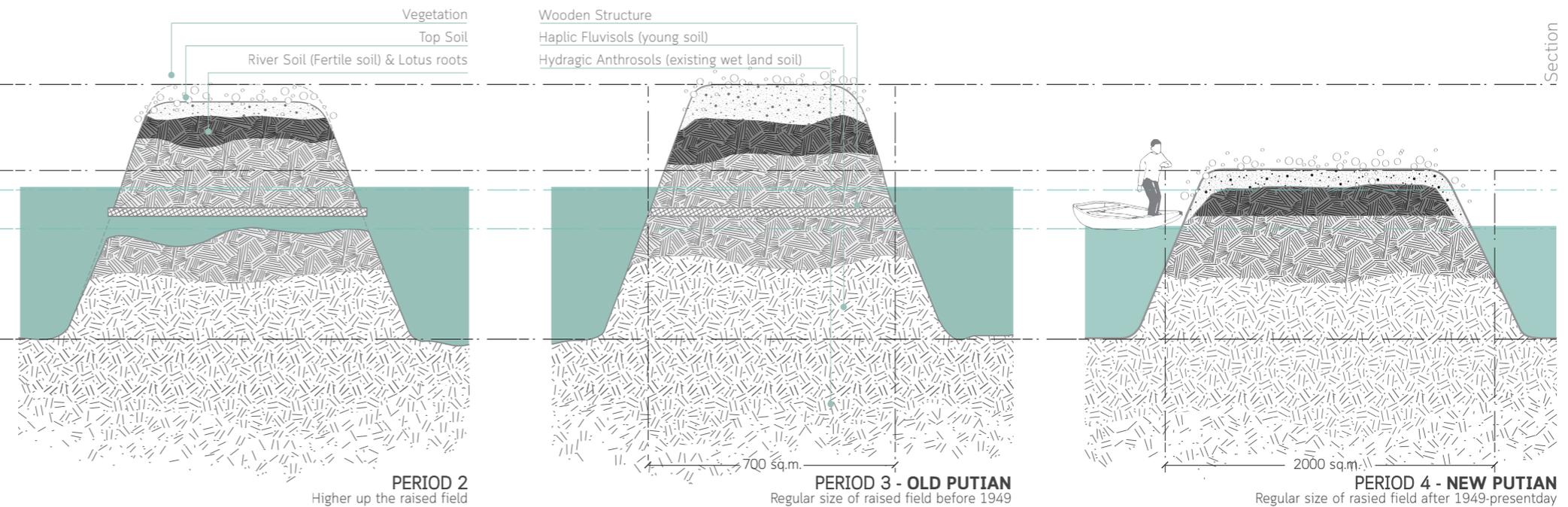
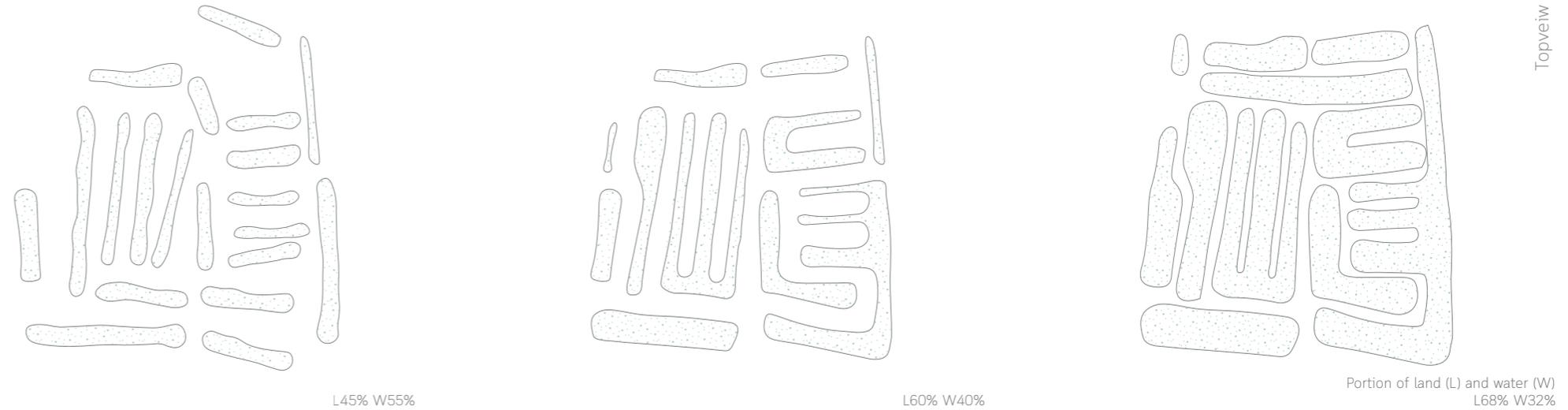
+0.00 Water Level (before1949)

-1.50 Water Level (Present)

-4.50 Ground Level

**Figure 14** Development of raise field - top view (top)

**Figure 15** Development of raise field from section (bottom)



Topview

Section

## Water System Plan.

The water system plan portrays a distinctive landscape pattern of Xinghua Duotian which is different from its surrounding. The overall system consists of a series of earth platforms on which crops are grown, they are surrounded by water which is connected to inlet and outlet ditches. The dike and the road act as a border of the field while the major waterway are visually connected from inside the field to outside, they are controlled by the water gates. These waterways were used as the main circulation for cultivating and transporting the crops as well as tourism routes. Each group of the raised field is accessible only by small boat for maintenance purposes. All year round, the raised field will be covered by different types of crops and flowers due to the practice of local farmers that adopt the idea of inter-cropping and crops rotation in the land.



**Figure 16** Overall plan of Xinghua Duotian Agrosystem.



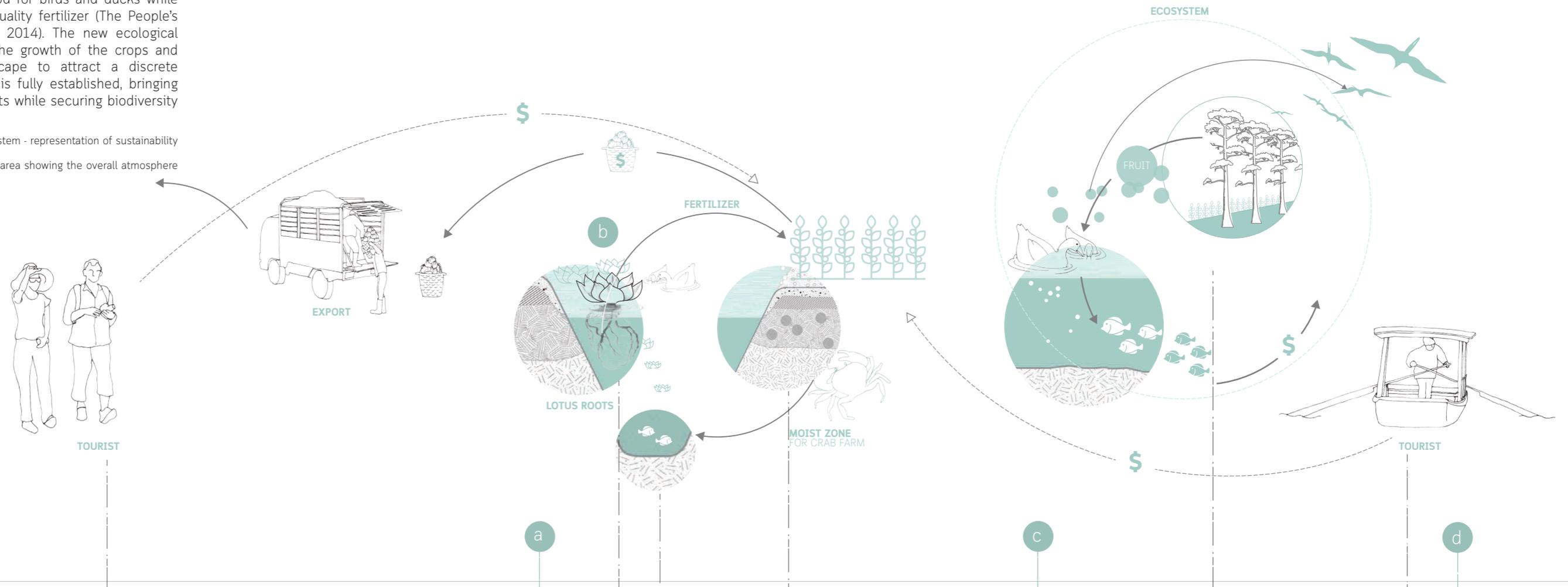
-  Duotian
-  Water body
-  Water Gate
-  Crops
-  Rice field
-  Dike
-  Road
-  Housing

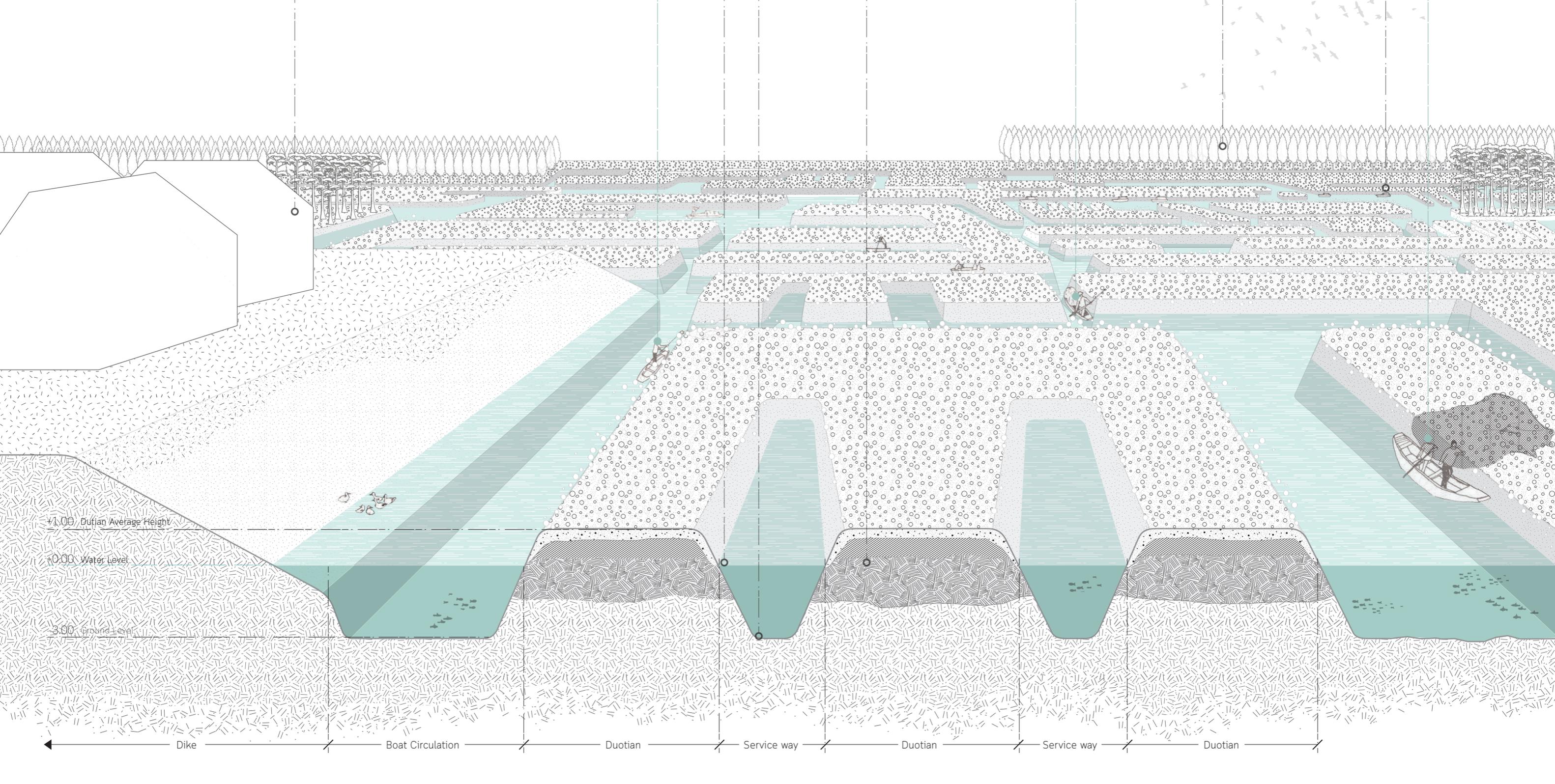


# Water System Section.

The previous flood-prone area has been sustainably utilized by combining forestry, agriculture and aquaculture. The trees planted on the ridges provided fruits and food for the ducks, feeding fishes in the ditches, raising crabs and lobsters inside the soil of the raised field. The natural aqua-planting became a great source of food for birds and ducks while their roots acted as a high quality fertilizer (The People's Government of Xinghua City, 2014). The new ecological network has contributed to the growth of the crops and created a remarkable landscape to attract a discrete number of tourists. The area is fully established, bringing considerable economic benefits while securing biodiversity and ecosystem services.

**Figure 17** Circular economy of the system - representation of sustainability (top).  
**Figure 18** Section perspective of the area showing the overall atmosphere (bottom).





+1.00 / Duotian Average Height

+0.00 / Water Level

-3.00 / Ground Level

← Dike / Boat Circulation / Duotian / Service way / Duotian / Service way / Duotian →

# Traditional Living

One of the distinct characters of the Duotian landscape is the traditional farming methods. Modern farming equipment could not be applied in the Duotian due to its special fragmented topographic features. Therefore, the original landscape has been retained and the wisdom of the town has been passed on from generation to generation.



**Bailing water**

The only way for irrigation is by the boat in which the farmer uses the water scoop to sprinkle water to the plant. With the know-how of the local farmer the water is expected to land on the young and delicate sprouts like small raindrops and created no harm to the vegetation.



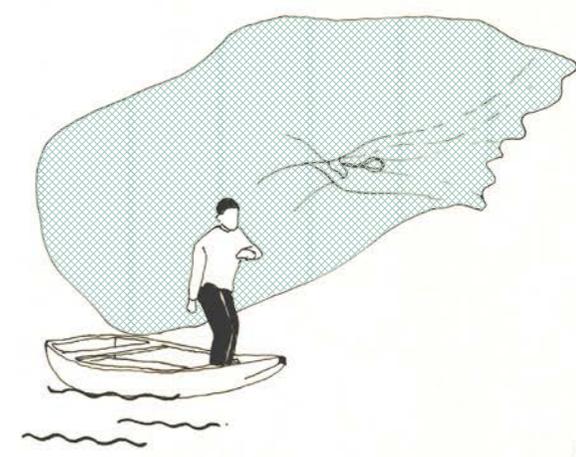
**Gathering aqua plants**

The farmers put “Zhanguan” into the water where the aqua plants abound then uproot the aqua plants and keep them in their cabins. The plants are later laid between the lines of vegetables where they provide shade, keep the soil humid and provide fertilizers.



**Dredging up sludge**

Collecting organic fertilizer using the “Lanzi” and “Lanyi,” local equipment to gather the sludge at the river bottom and pull them up to grow the crops.



**Net - for fishing**

A traditional fishing method requires no toxic and no harm to the environment. The use of the net will rather increase the survival rate of the fish during their post-harvest transportation, and thus improve the economic benefits for farmers.

- Figure 19** Sketch of traditional irrigation (left).
- Figure 20** Sketch of traditional way to gathering lotus roots (middle left).
- Figure 21** Sketch of traditional way to dredging (middle right).
- Figure 22** Sketch of a man using net to catch the fish (right).

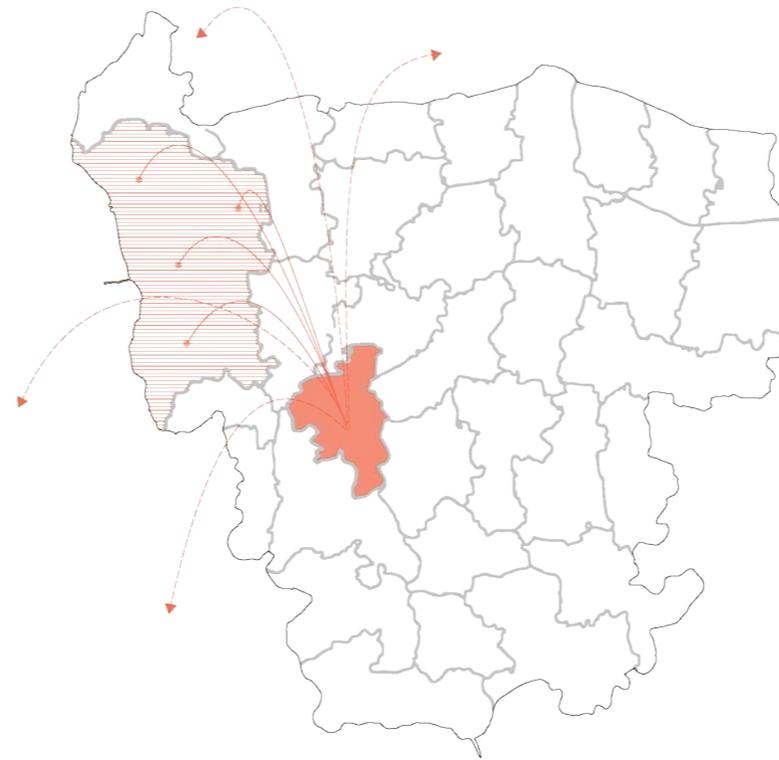
# Conclusion.

Xinghua Duotian Agrosystem is a representation of human beings living harmoniously with the changing landscape. The success of the project has continued for more than three thousand years and it is still functioning until a present day. The territory of Duotian Agrosystem has expanded to four more townships and it is functioned as a major agricultural hub for the province and nearby city. In conclusion, the system portrayed three special values included landscape values, strategic values and sustainable values.

**Strategic Values** - By using the strategy of land utilization, the bowl-shaped area of Xinghua province which used to be the problem area has been transformed into the enormous cultivable area. This technique has taken benefits of the existing condition such as soil from the river, the ability to hold a large amount of water and created a greater advantage to the area.

**Landscape Values** - The transformation of the area has not only changed the natural landscape condition, but it also changed the way of living for Xinghua people. After the raised field is established, Xinghua people began to do traditional Chinese farming. This new way of living represented the cultural interaction between people to people as well as people to the landscape. The raise field agrosystem has entirely reconstructed the image of Xinghua from the flooded city into "the city with thousand islets."

**Value of sustainability and circularity** - The project showed the circularity of the water system. The natural resources and human resources have been carefully used such as the aquatic plants in the area is used as food for the duck and birds as well as the roots are used as fertilizer for crops, water has been used to watering crops, raise the fish as well as sustain the raised field. Most of the elements performed more than double function and this wisdom is sustainably inherited from generation to generation.



**Figure 23** Xinghua map showing the expansion of the raise field.

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Note: Some of the drawing have based on information from Chinese website and news of following sources, then elaborated and interpreted by author.

## Illustration Credits

**Figure 1** Wu, L. Projected image special theme water. [Image]. Retrieved from <http://www.digirap.sg/index.php/winners/projected-image-special-theme-water-colour/>

**Figure 2-4** The People's Government of Xinghua City (2014). Country/location/Site [Figure]. In GIAHS Proposal - Globally Important Agricultural Heritage Systems (GIAHS) Initiative. Jiangsu, China: GIAHS

**Figure 5** Flood-induced course changes on the Yellow River [Image]. Retrieved from <http://factsanddetails.com/china/cat2/4sub7/item2835.html>

**Figure 6** The People's Government of Xinghua City (2014). Xinghua duotian agrosystem historic photos [Image]. In GIAHS Proposal - Globally Important Agricultural Heritage Systems (GIAHS) Initiative. Jiangsu, China: GIAHS

**Figure 7** Lixiahe River Network [Image]. Retrieved from <http://e-wiki.org/ja/images>

**Figure 8** Qingming Holiday, Jiangnan Spring Tour [Image]. Retrieved from <http://www.huodongxing.com/event/6431962314712>

**Figure 9** The People's Government of Xinghua City (2014). Bailing Water [Image]. In GIAHS Proposal - Globally Important Agricultural Heritage Systems (GIAHS) Initiative. Jiangsu, China: GIAHS

**Figure 10** The People's Government of Xinghua City (2014). Forest Zone [Image]. In GIAHS Proposal - Globally Important Agricultural Heritage Systems (GIAHS) Initiative. Jiangsu, China: GIAHS

**Figure 11** River has Wanwan Duobi paddy field without a yellow flower [Image]. Retrieved from <http://www.huodongxing.com>

**Figure 12** The People's Government of Xinghua City (2014). Aerial view of Duotian [Image]. In GIAHS Proposal - Globally Important Agricultural Heritage Systems (GIAHS) Initiative. Jiangsu, China: GIAHS

**Figure 13** Xinghua Puotian Atlas [Image]. Retrieved from <https://baike.baidu.com/item/%E5%85%B4%E5%8C%96%E5%9E%9B%E7%94%B0>

**Figure 14** Development of raised field from top view. Drawn by Author.

**Figure 15** Development of raised field from section. Drawn by Author.

**Figure 16** Overall plan of Xinghua Duotian Agrosystem. Drawn by Author.

**Figure 17** Circular economy of the system. Drawn by Author.

**Figure 18** Section perspective of the area showing the overall atmosphere. Drawn by Author.

**Figure 19-22** Sketches of traditional farming. Drawn by Author.

**Figure 23** The People's Government of Xinghua City (2014). Location of agrosystem in Xinghua [Figure]. In GIAHS Proposal - Globally Important Agricultural Heritage Systems (GIAHS) Initiative. Jiangsu, China: GIAHS.









# Ksôkong Tsùn Irrigation System

A traditional irrigation system that set the  
foundation of Kaohsiung City.

Man-Chuan Sandy Lin

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# Context.

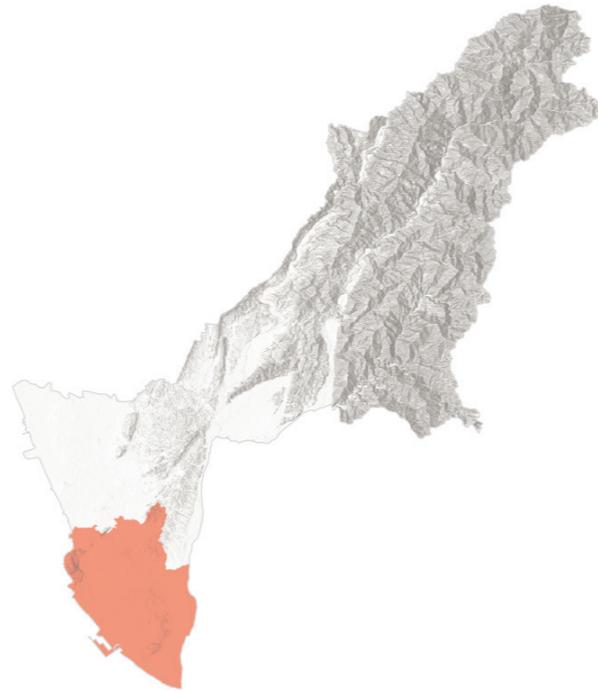
Location: Kaohsiung, Taiwan  
Period: 19 Century A.D.  
Function: Agriculture irrigation, drinking water source  
Area: 16000 ha  
Components: Dam, water inlet, water retention, irrigation ditch  
Status: Kaohsiung municipal heritage site

The growth of Kaohsiung is closely related to its irrigation system. The Ksòkong Tsùn irrigation system is a traditional water management and irrigation system used for the purpose of agriculture.



**Figure 2**  
Country Scale

Taiwan is a country in East Asia. The main island of Taiwan is known historically in English as Formosa, measuring 35,808 square kilometers.



**Figure 3**  
Municipal Scale

Located in southern Taiwan, Kaohsiung is the second largest metropolis of the country.



**Figure 4**  
Regional Scale

The Cao-Gong irrigation system located in the most populated area of Kaohsiung.

# Historical photos.

The Ksòkong Tsùn irrigation system consists mainly four types of elements: dam, inlet, waterway, water retention pond.

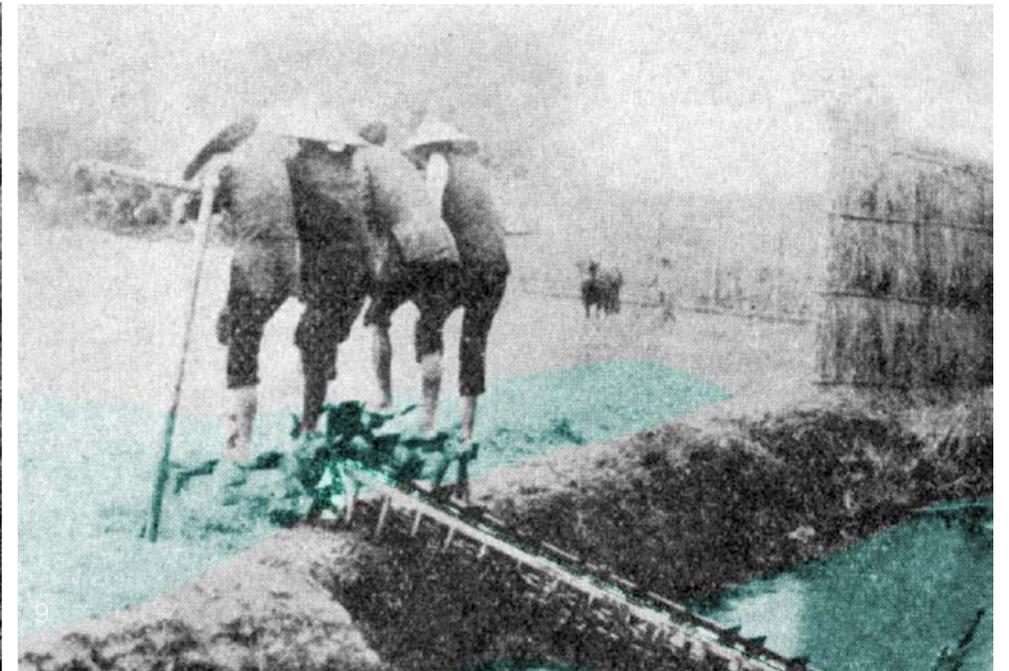
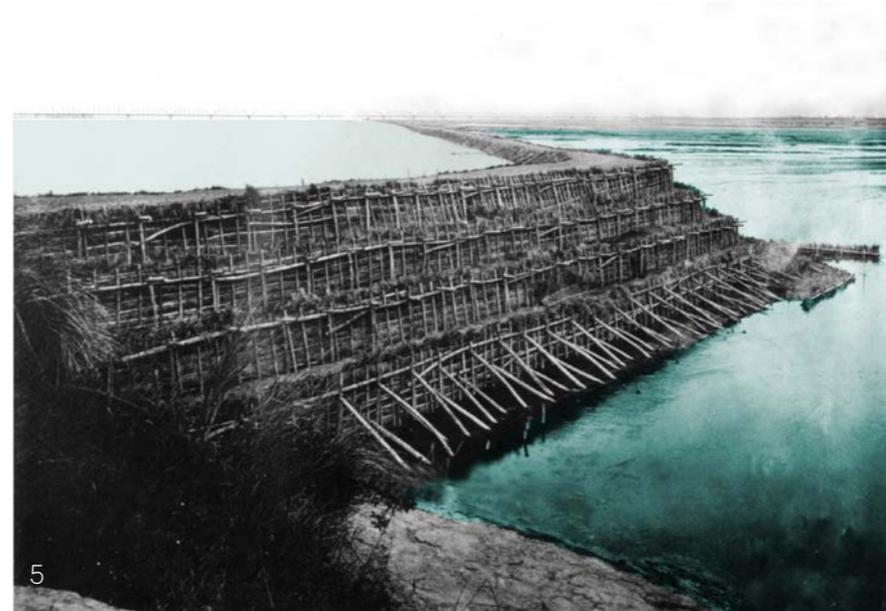
**Figure 5** top left - Thê (dam): A linear obstacle built perpendicular to a river to guild and direct water to the river water inlet for irrigation ditch.

**Figure 6** top right - Pi(water retention): An artificial water retention that is based on the naturally formed pond according to land topography. The retention was used for drinking and irrigation use. Small ones are called "Ti", larger ones are called "Pi".

**Figure 7** bottom left - Tsùn-thâu (river water inlet): A gate element that can control the amount of irrigation water intake. In typhoon season, the gate can be closed to protect crops from flooding.

**Figure 8** bottom middle - Moat: segments of waterway near city wall were use as defense system

**Figure 9** bottom right - farmer use watermill to get water from water way



# Climate and catchment area.

**Climate zone:** Tropical  
**Sub-climate:** Tropical Savanna Climate with dry-winter characteristics

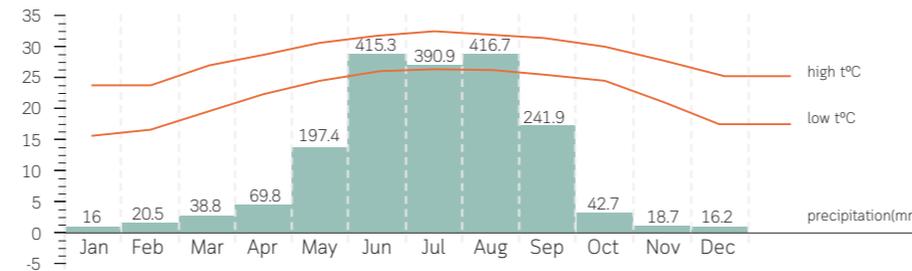
## Climate & Weather Averages

High t°: 32.4°C  
 Low t°: 15.7°C  
 Mean t°: 25.1°C  
 Precipitation: 13.6mm  
 Humidity: 75.9%  
 Dew point: 20°C  
 Wind: 7.56-9.36 km/h  
 Pressure: 1012.0 mbar  
 Visibility: 8 km  
 Hottest Month: July (29.2°C avg)  
 Coldest Month: January (19.3°C avg)  
 Wettest Month: August (416.7 mm avg)  
 Windiest Month: July (12 km/h avg)  
 Annual Rainfall: 1884.9 mm per year

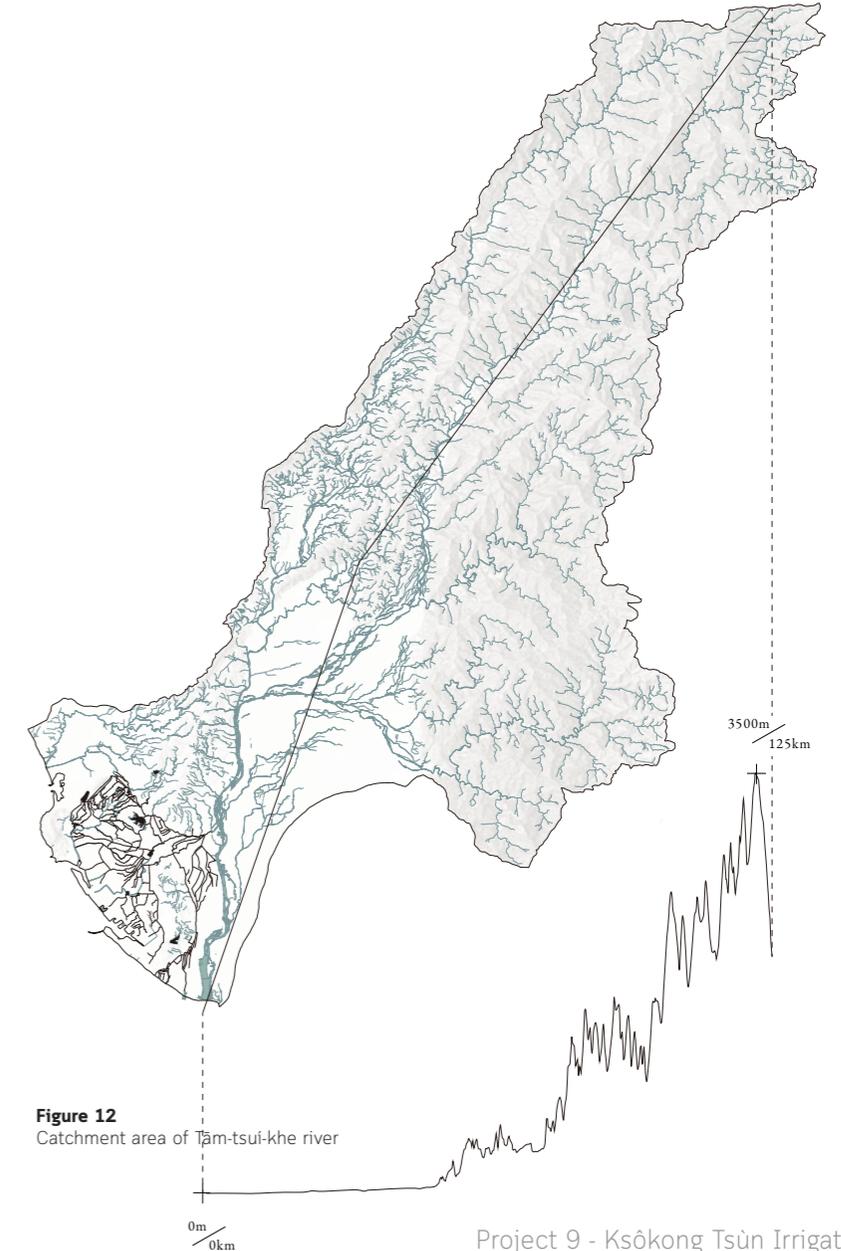
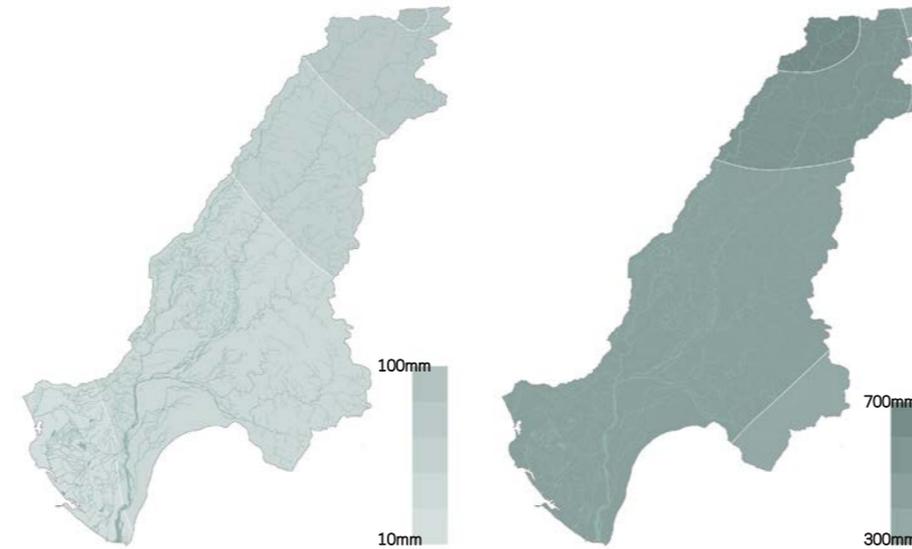
The island of Taiwan is geologically formed on a complex convergent boundary between the Eurasian Plate and the Philippine Plate. Located on the Circum-Pacific belt, which is a major area in the basin of the Pacific Ocean where many earthquakes and volcanic eruptions occur. Therefore, watershed of rivers are vertically steep. The watershed of Tām-tsui-khe river, which CaoGong Tsun obtains water from, also falls into this criteria above.

Southern Taiwan has the climate type of “Tropical savanna climate with dry-winter characteristics”, and falls into the frequent typhoon zone. The rain-dry season is clearly apart. High slope and concentrated rain season bring redundant and rapid rainfall in the summer, and lack of water resources during the winter.

**Figure 10**  
Climate of Kaohsiung



**Figure 11**  
Rain Distribution in driest and wettest month (monthly average rainfall).  
Left: January, Right: August.



**Figure 12**  
Catchment area of Tām-tsui-khe river

# Development.

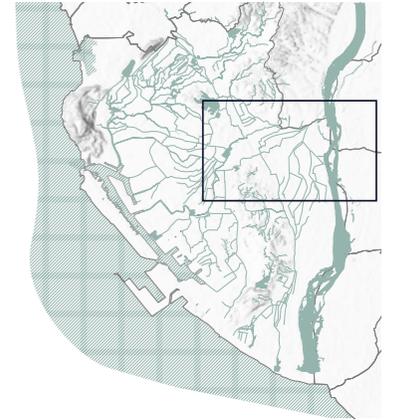
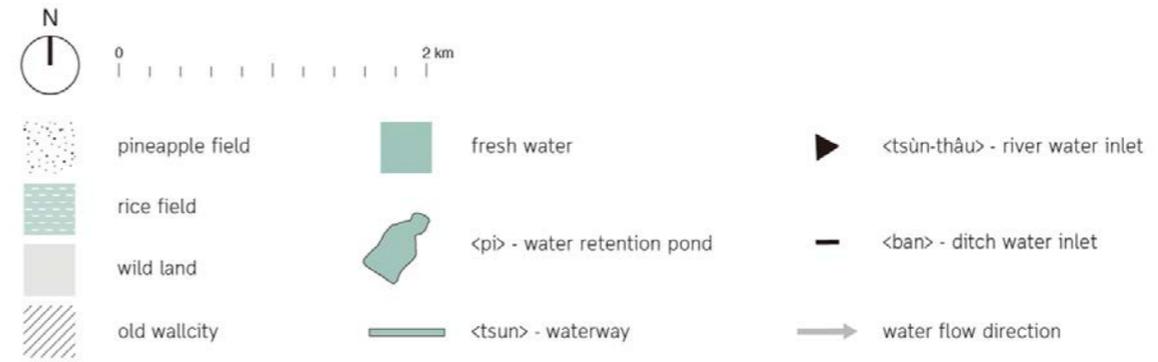
The Ksôkong Tsùn irrigation system was the solution for an uneven distribution of water resources in Kaohsiung. Water retention ponds (Pi) were dug out to reserve water before a systematic intervention. In 1837, the Cao-Gong irrigation system transferred water from an east side river, Tam-Tsui-khe, to start weaving a water web in Kaohsiung and the process continued expanding until the last canal was completed in 1931.

**Figure 13**  
Spatial development order of Ksôkong Tsùn irrigation system.



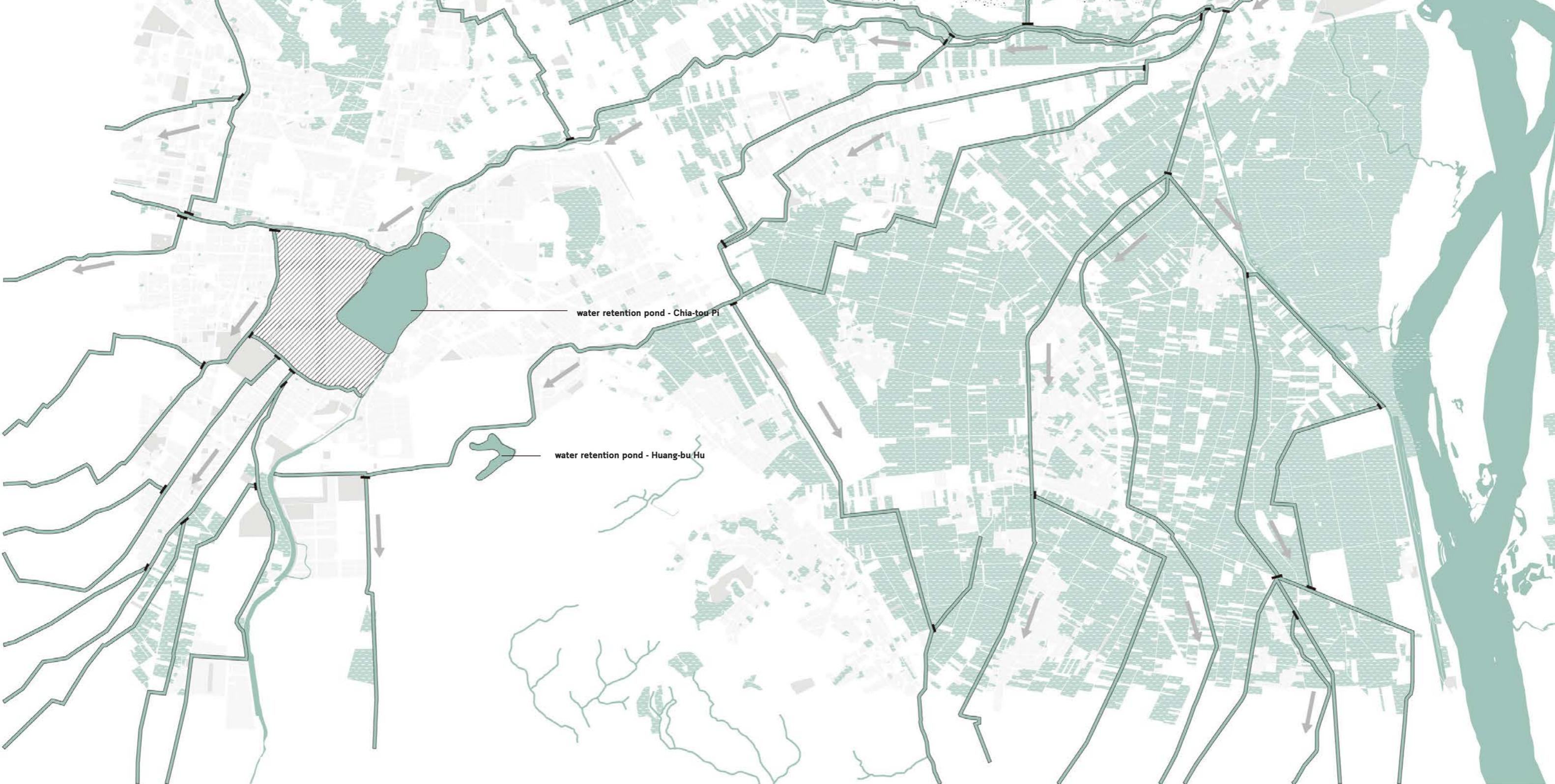
# Water System Plan.

A formation of water networks consisted of canals and ponds contributing to the establishment of agricultural production of 16000 ha. Agriculture in Kaohsiung was transformed from being weather dependent on a stable two-yield-per-year. Therefore, the establishment of steady agriculture consequently set the foundation for economic growth and accelerated industrialization process.



**Figure 14**  
Plan showing zoom in detail of Cao-Gong irrigation system.





water retention pond - Chia-tou Pi

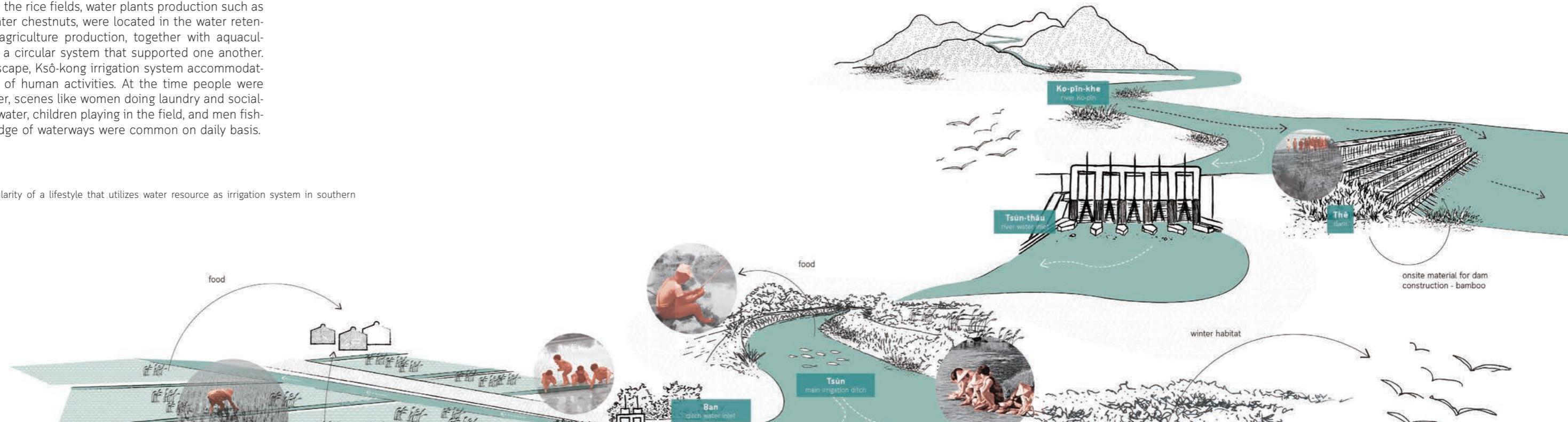
water retention pond - Huang-bu Hu

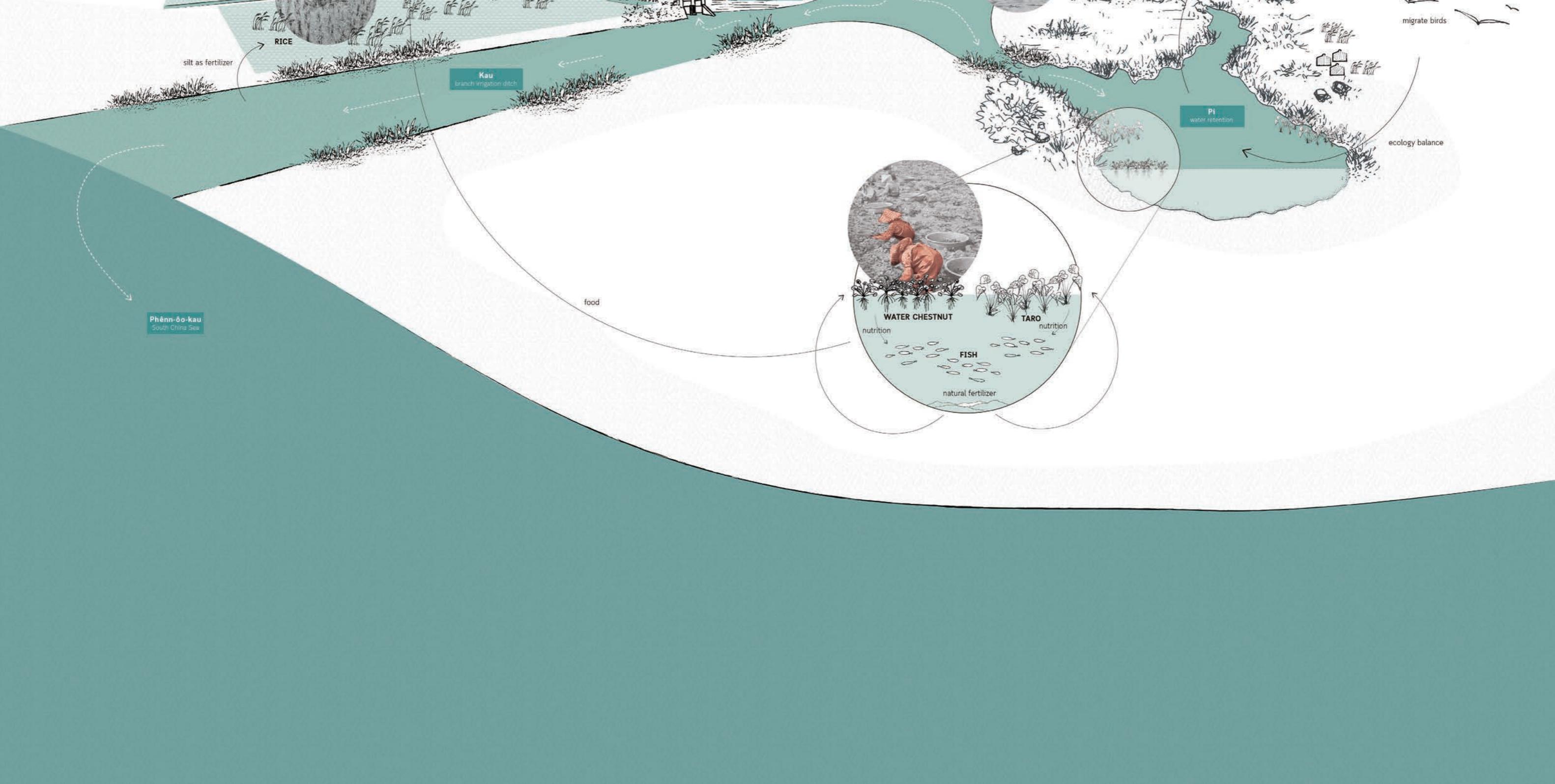
# Details and Circularity.

In Taiwan, the connection between land and people was once profound and unbreakable, especially in the agricultural society before modernization. At the time, people lived closely with the landscape that intertwined by water and fields and constituted a complex living lifestyle consisting of several social and cultural aspects. From food yield, settlement arrangement, daily leisure and religious beliefs, ways of living evolved intensely around the landscape.

Water from river Ko-pin-khe is obtained from a dam, regulated using inlets, directed through ditches, then transported to irrigate rice fields following natural topography on-site and weaved an aquatic landscape to flourish food production. Besides the rice fields, water plants production such as taros and water chestnuts, were located in the water retention. These agriculture production, together with aquaculture, formed a circular system that supported one another. On the landscape, Ksô-kong irrigation system accommodated a variety of human activities. At the time people were close to water, scenes like women doing laundry and socializing by the water, children playing in the field, and men fishing on the edge of waterways were common on daily basis.

**Figure 15**  
A story of circularity of a lifestyle that utilizes water resource as irrigation system in southern Taiwan.





# Conclusion.

Ksôkong Tsùn irrigation system shows how people live closely by/with water and the living way is adaptive to the changing landscape. The system portrayed three special values including functionality value, value of sustainability and landscape value.

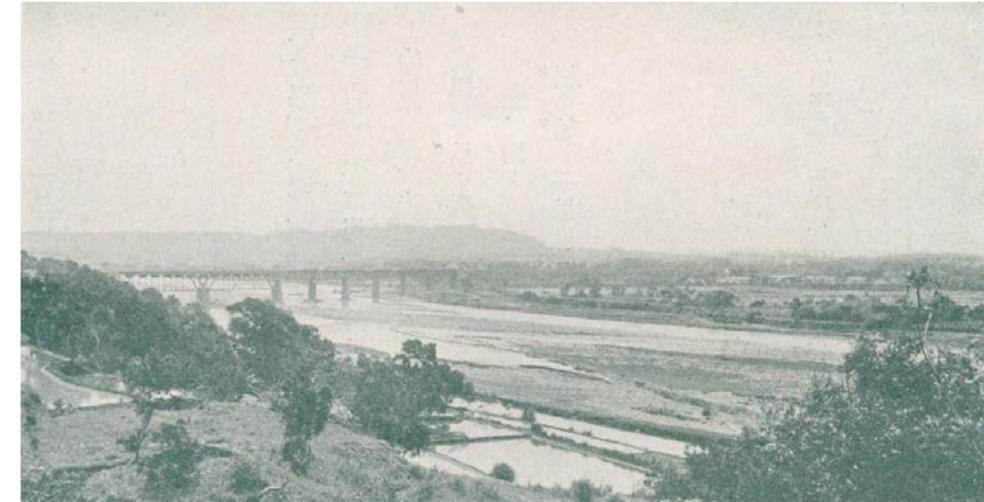
**Functionality value** - The purpose of Ksôkong Tsùn irrigation system was to provide clean water source for the city. By using simple form such as line, surface, and point: water is directed by a network of lines, retained by surface of ponds, and regulated by points of water inlets. Regarding the change of climate and city content, these functional values could possibly help transforming the system into a climate adaptive network in Kaohsiung.

**Value of sustainability** - The project showed the circularity of the water system. The natural resources and human resources are carefully used. Water has been used to water crops, the aquatic plants are used as food for both humans and fish, and the waste of fish as fertilizer for crops. Most of the elements performed more than double function and this wisdom should be sustainably inherited from generation to generation.

**Landscape value** - The river flooding plain was developed based on Ksôkong Tsùn irrigation system which then became a major city in Taiwan.

**Lessons to learn** - Looking towards the future, the acknowledgment of the traditional water system in Kaohsiung could possibly contribute to adding a valuable layer to the city's planning.

The process of modernization in Asia oftentimes resulted in rapid urbanization and brought landscape morphology change in a short period of time. Oftentimes, urban spaces didn't have time to adapt to the ever-changing social-economical transition with a well-planned spatial strategy and led to a featureless cityscape. Since the water was no longer clean, people lost their intimate attachment with it. However, through a brief understanding of the water system, it is evident that the water system provided a place far beyond a source of water, but also culture, economy, art and memory. Perhaps, this study could provide a thread that leads to an action of retrieving a sense of place and builds up a passage from past to future, memory to hope (Harvey, 2009).



**Figure 16**

Ko-pîn-khe River.

From this point on, through Ksôkong Tsùn irrigation system, the river water starts a different journey on the land of Kaohsiung, intertwined with culture, art, economy and memory, narrated a tale of the city.

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**Figure 15** Information from <https://doie.coa.gov.tw/water-slang.php>. Drawn by author.







# Eel aquaculture in Gunditjmara Country

Aboriginal eel aquaculture system in Gunditjmara Country, South West Victoria, Australia.

María José Zúñiga

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Figure 1 Network of shallow races and ponds for eel harvesting.

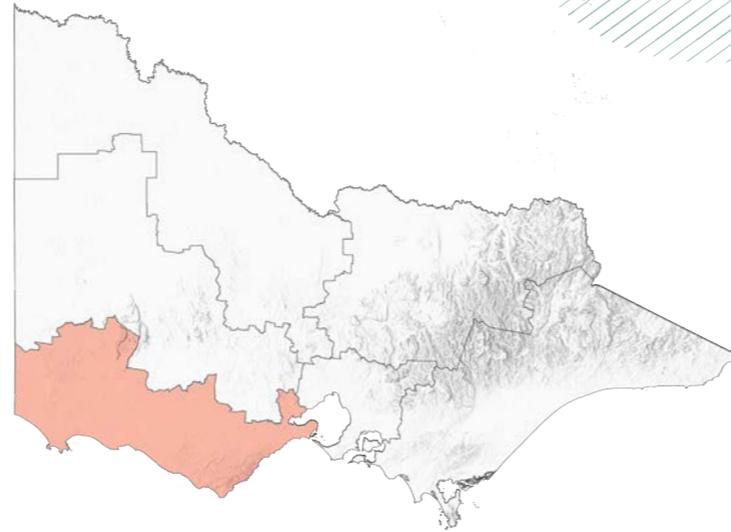
# Context.

Location: Victoria, Australia  
 Period: 4000 B.C  
 Function: Eel aquaculture  
 Landscape type: Volcano stream  
 Area: 9935 ha.  
 Water type: Fresh water  
 Components: Canals, weirs, races and traps following the trace of a volcano stream.  
 Status: Recreational use  
 UNESCO World Heritage Site for cultural landscape.

The Budj Bim Cultural Landscape is located in the Country of the Gunditjmara aboriginal people in Victoria, Australia. Budj Bim (known today as Mount Eccles) is the volcano that thousands of years ago caused an extensive lava flow that transformed the landscape and provided the base for the aquaculture system developed by the Gunditjmara people. The extensive network of canals, traps and weirs was once a highly productive aquaculture system constructed to trap, store and harvest eels. Today, it is recognized as one of the world's most extensive and oldest aquaculture systems.



**Figure 2**  
Country scale  
Australia



**Figure 3**  
Provincial scale  
Victoria



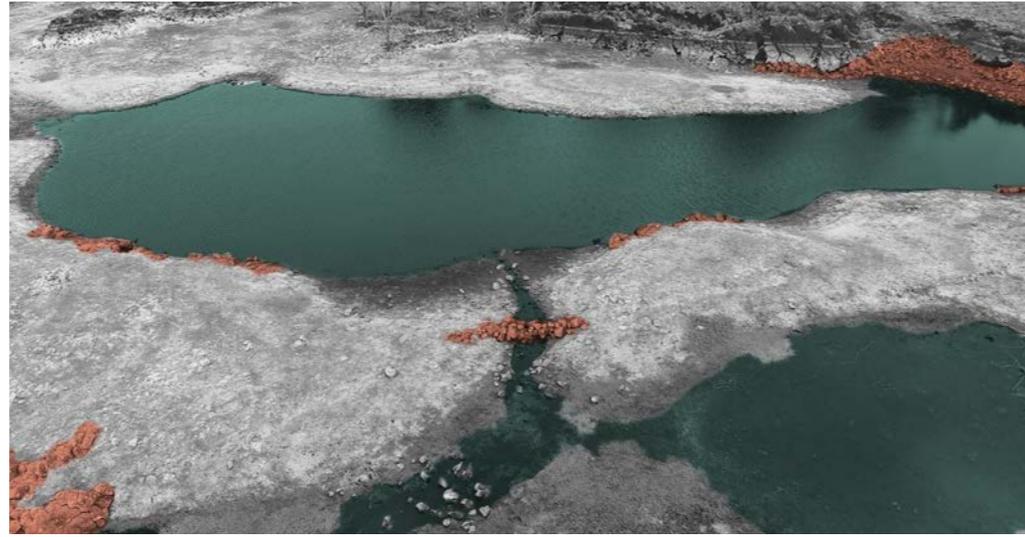
 Watershed  
 Lava flow

**Figure 4**  
Regional scale  
South West Victoria

## Remaining traces in the landscape.

Large parts of the system have now disappeared, not only because of environmental changes through time, but also because of the modifications done to the site during British colonization. Nowadays, it is hard to grasp the entirety of what the system once was. However, several areas have been protected and reconstructed, showing a network of components that blend in with the landscape. The traces that can be seen now, hold the cultural practice of many generations which had a deep understanding of their land and lived a dynamic relationship with water, materials, nature, and climate.

The most recognizable features are the constructions made with the placement of basalt rocks. This material was used for constraining the water in canals, shallow races or sinkholes. The rocks were also piled up across waterways to form weirs and dams. Timber fences were placed across waterways and became traps in which woven baskets were placed to catch the eels.



**Fig 7** Top Left: 3 different components, a larger pond, a weir and a sinkhole.

**Fig 8** Top Centre: Basalt stacked canal.

**Fig 9** Top Right: A Sinkhole.

**Fig 10** Bottom Left: A woven timber trap.

**Fig 11** Bottom Right: A shallow canal / Race.

# Climate.

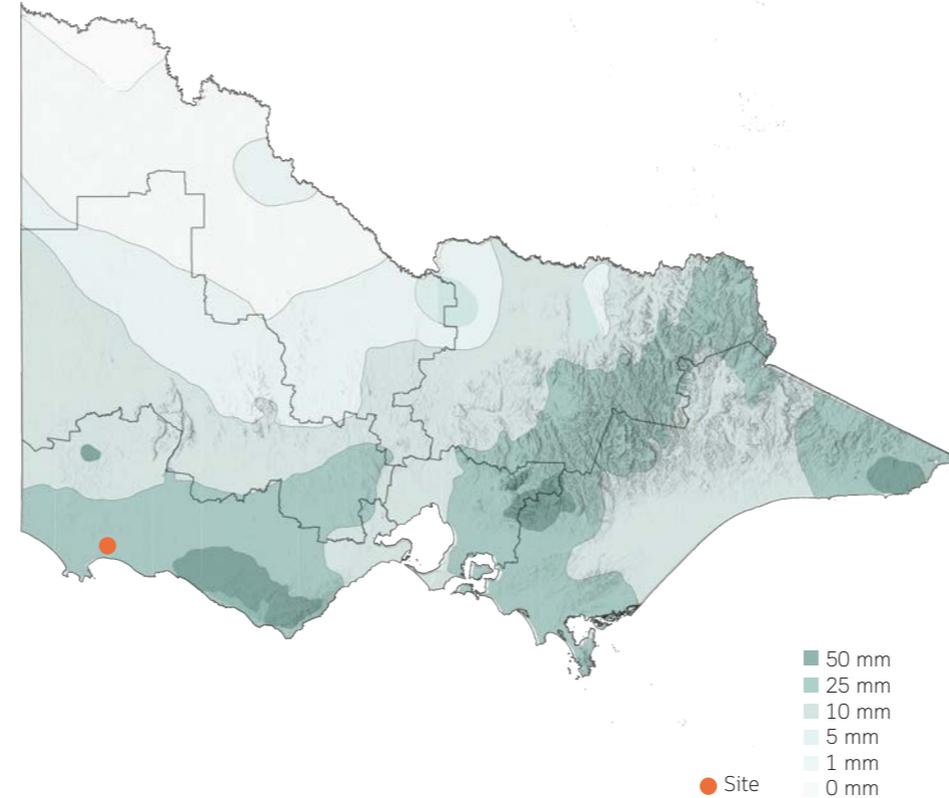
**Climate zone:** Warm-summer Mediterranean

**Climate & Weather Averages**

High t°: 25°C  
 Low t°: 5°C  
 Mean t°: 15°C  
 Precipitation: 63.0 mm  
 Humidity: 77%  
 Dew point: 9°C  
 Wind: 15 km/h  
 Pressure: 1017 mbar  
 Visibility: 10 km  
 Hottest Month: Jan (22°C avg)  
 Coldest Month: June (5°C avg)  
 Wettest Month: July (120.0 mm avg)  
 Windiest Month: Aug (17 km/h avg)  
 Annual Rainfall: 756 mm per year

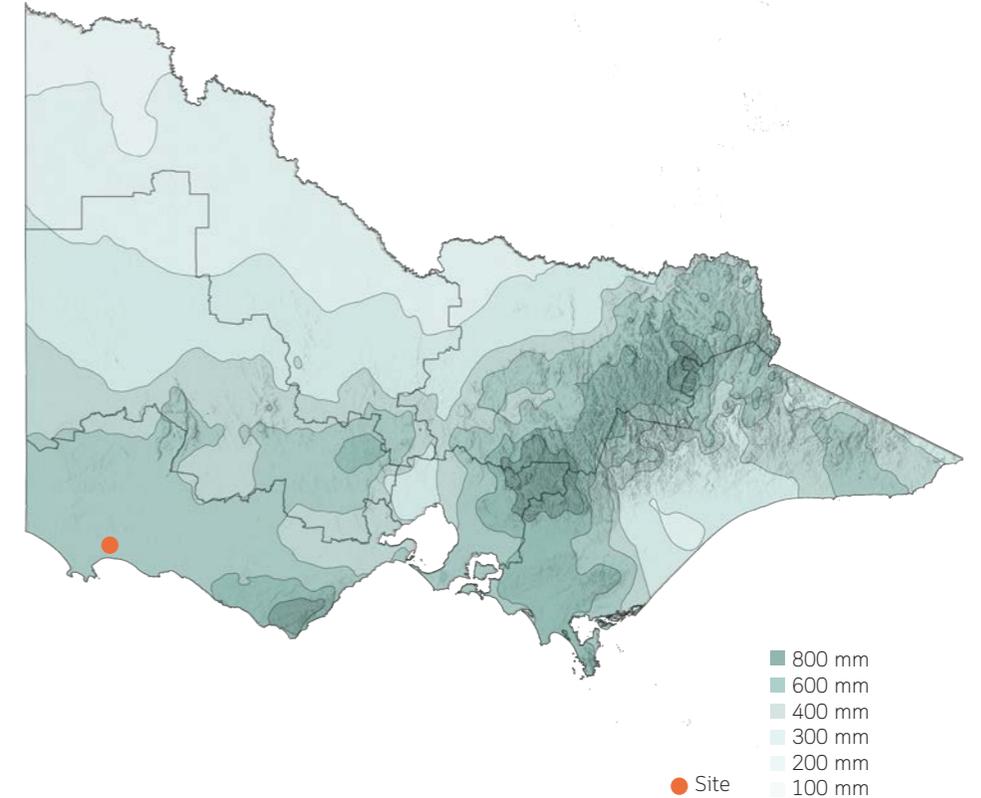
In this region of Victoria the average precipitation levels have very drastic changes depending on the season. The time frame between the months of May and September is considered the wet season.

The graphics below show the differences in climate from the end of the 1800's and most recent numbers. Back when this water system was most productive, the seasonal differences were not as drastic as they are now. There is also a clear raise in the average temperature.



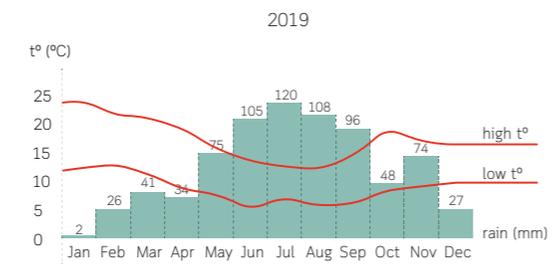
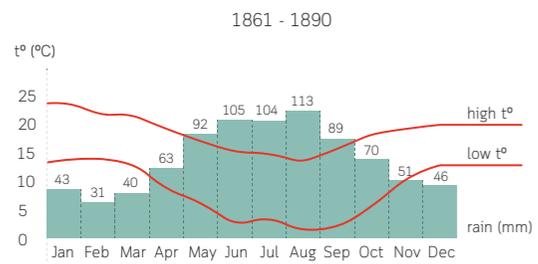
50 mm  
25 mm  
10 mm  
5 mm  
1 mm  
0 mm  
Site

**Figure 5**  
Precipitation  
October - April



800 mm  
600 mm  
400 mm  
300 mm  
200 mm  
100 mm  
Site

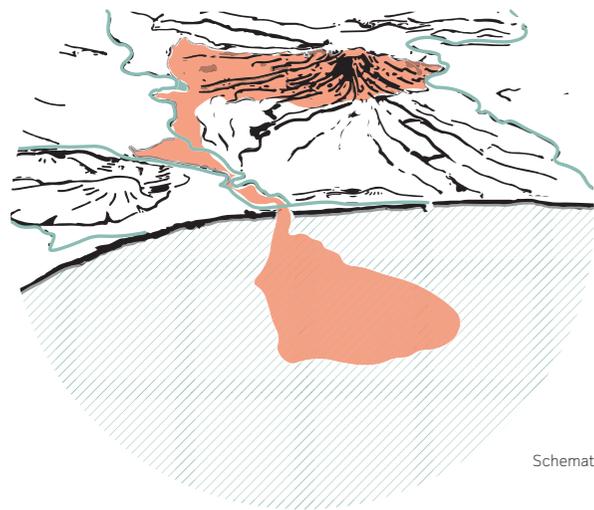
**Figure 6**  
Precipitation  
May - September



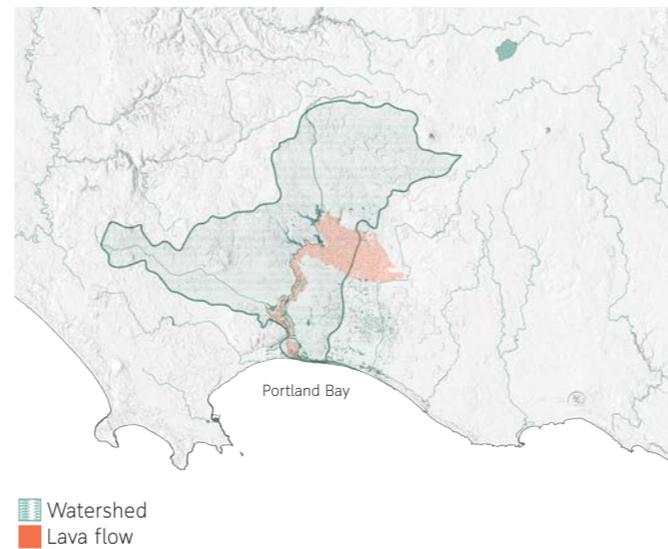
# Catchment area.

The transformation on this landscape began nearly 6000 years ago with the eruption of the Budj Bim mount and the expansion of the lava flow for nearly 50km. Following the lava stream and using the resulting material of the basalt rocks, the Gunditjmara people shaped and manipulated the land to deliberately direct and manage the waterways and wetlands.

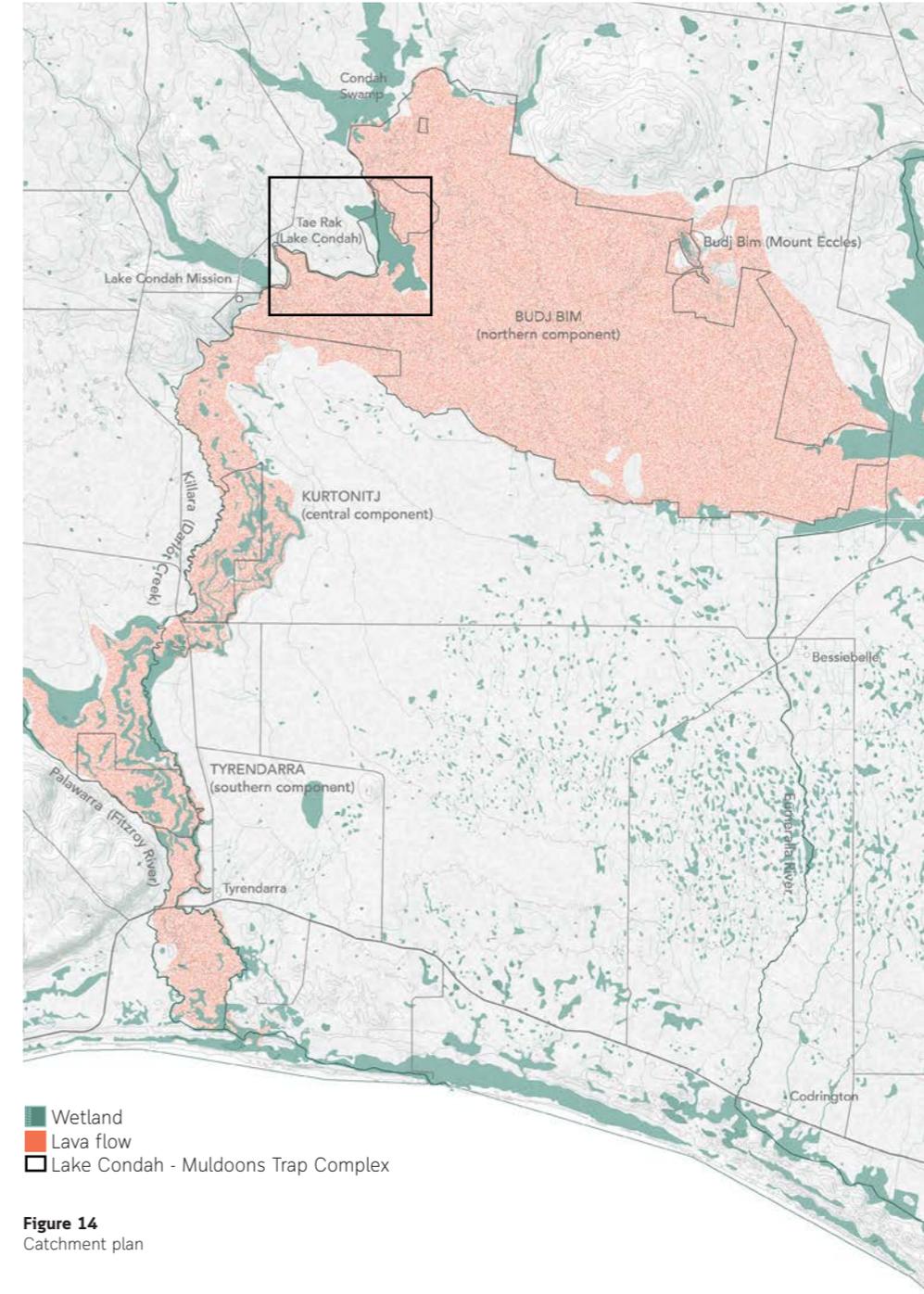
The system is spread in clusters of networks that start in the upstream creeks and lakes and continue all the way down to the ocean at Portland Bay. The sources of the fresh-water that feed into these wetlands are the two rivers that join as they reach the coast. The volcanic stony soil supports woodland and open forest dominated by Eucalyptus and Blackwood trees. The highest terrains in the northern areas are only 60 m.a.s.l.



**Figure 12**  
Schematic diagram  
Lava flow



**Figure 13**  
Watershed area



**Figure 14**  
Catchment plan

# Water System Plan.

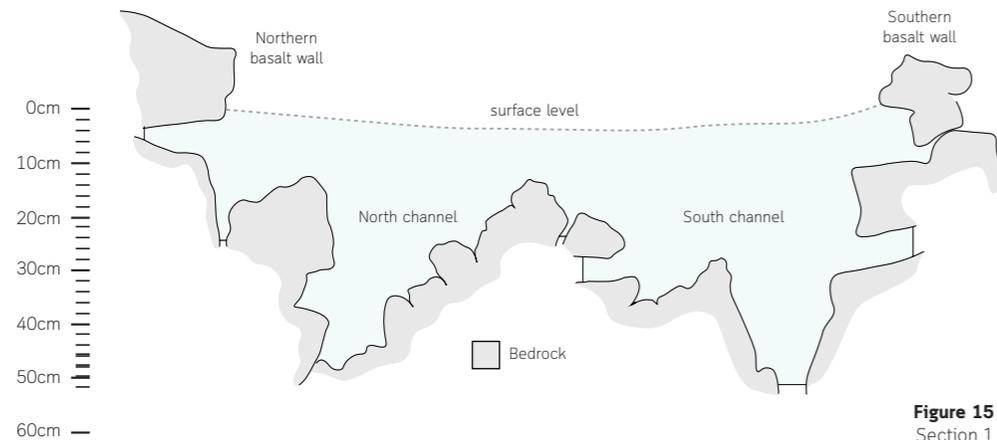
The following representation of the system is a reconstruction of the Muldoons Trap Complex, located west of Lake Condah, which is on the edge of the Mount Eccles lava flow. This trap complex is positioned within a basalt lava flow, surrounded by eucalyptus woodland and grasses. In this section of the system, there are at least 350m of canals, they are located 2-3m above normal levels of the lake, which suggests they operated during strong flooding periods. This complex allowed the eels and other fish to swim seasonally between the lake and the following water bodies.

The canals were dug about 60cm into sediments and lava flow, taking advantage of natural cracks in the terrain (see fig.15). Basalt rocks were displaced and used to build block walls of about 0,4m high. Water flowed from the eastern end of the complex, passing through the canal features and several weirs and dams. Some of these canals would only be used when water levels were too high. The excess water would be emptied into the sinkhole.



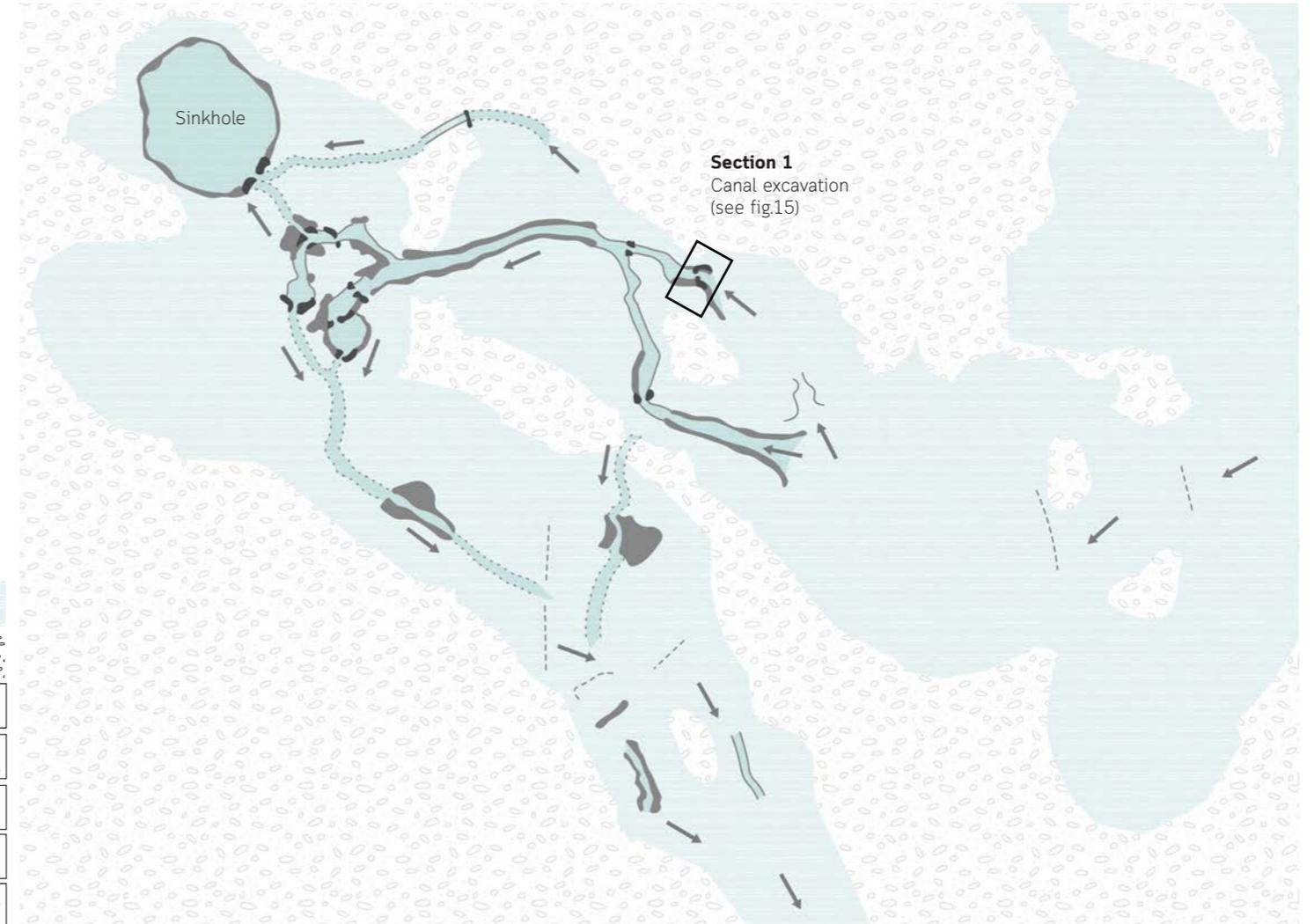
● Muldoons Trap Complex

**Figure 16**  
Lake Condah



**Figure 15**  
Section 1  
Canal excavation

- Wetland
- Stony Rise / Basalt Exposure
- Basalt Stacked Canal
- Excavated Canal
- Shallow Canal / Race
- Low Rock barrier / Weir
- Basalt Stacked Trap
- Water flow direction



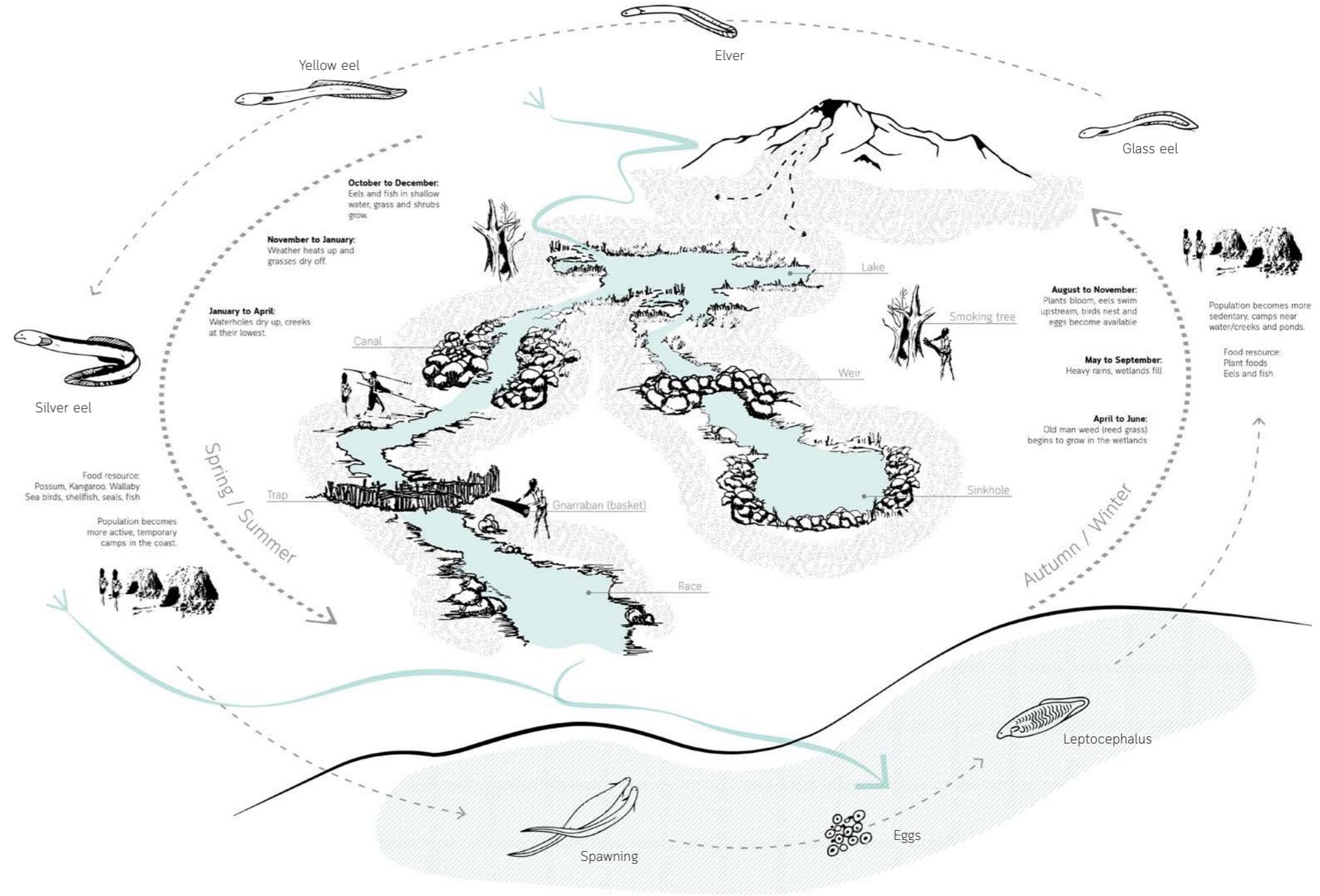
**Figure 17**  
System plan  
Muldoons Trap Complex

# Circularity.

One of the most remarkable aspects of the Gunditjmara people is their extensive knowledge and understanding of their land. This knowledge was passed through generations through oral transmission for thousands of years, and allowed them to obtain an active and profound relationship with nature and the living beings that surround them.

The productivity of the system as well as the settlement of the communities was largely determined by the different seasons. Another factor that was key for the productivity of the system is the understanding of the eel's life cycle and their migratory behavior. The kooyang (short-finned eels), spend the majority of their life cycle in fresh waters but return to their spawning grounds along the Coral Sea. The eels have five stages in their life cycle, as adults they migrate to the sea during summer and autumn for spawning, and return to the fresh water during winter and spring.

Because the eels returned to fresh waters during the winter, this meant the population was more sedentary around this time. They remained close to the water, creeks and ponds, where they had more food resources. One of the main objectives of this system was to extend the time in which eels are available. The construction of canals, races and weirs allowed them to control water and eel flows, an example of this is the adaptation of the sinkholes, where they could keep eels for capturing when needed. During the summer, when eels migrate to the ocean and water levels decrease in the wetland, the communities would be more mobile, having temporary camps along the coast and diversifying their food sources.



**Figure 18**  
Water cycle and eel growth cycle in Gunditjmara Country.

# Conclusion.

**Ethnographic and Identity values** - This system remains an important part of the cultural identity for the Gunditjmara people. It reaffirms their presence in the land from thousands of years ago, and the extensive knowledge of their environment continues to be carried through generations.

**Landscape Value** - The system is born because of the changes and special characteristics within the landscape. The major input for the system is found within the land, the materials, the soil and the water. The human activities and movement are determined by the functioning of the larger system.

**Functional Value** - The system provided the main economic and social base for the Gunditjmara people for thousands of years. The system also allowed them to manage the water during heavy rain winters.

**Sustainability Value** - The system entirely uses materials which are found locally within the same natural resources. The knowledge of the Gunditjmara people in regards to the natural cycles allowed for the understanding of scarcity and abundance of resources, and working with nature instead of against it.

**Strategic Value** - The location of the system is in favour of the natural course of the water, taking advantage of the topography and soil conditions resulting from the volcanic eruption and lava flow. This condition also allows for the use of Basalt rock for most of the structures within the system. Other materials grow naturally on the site.

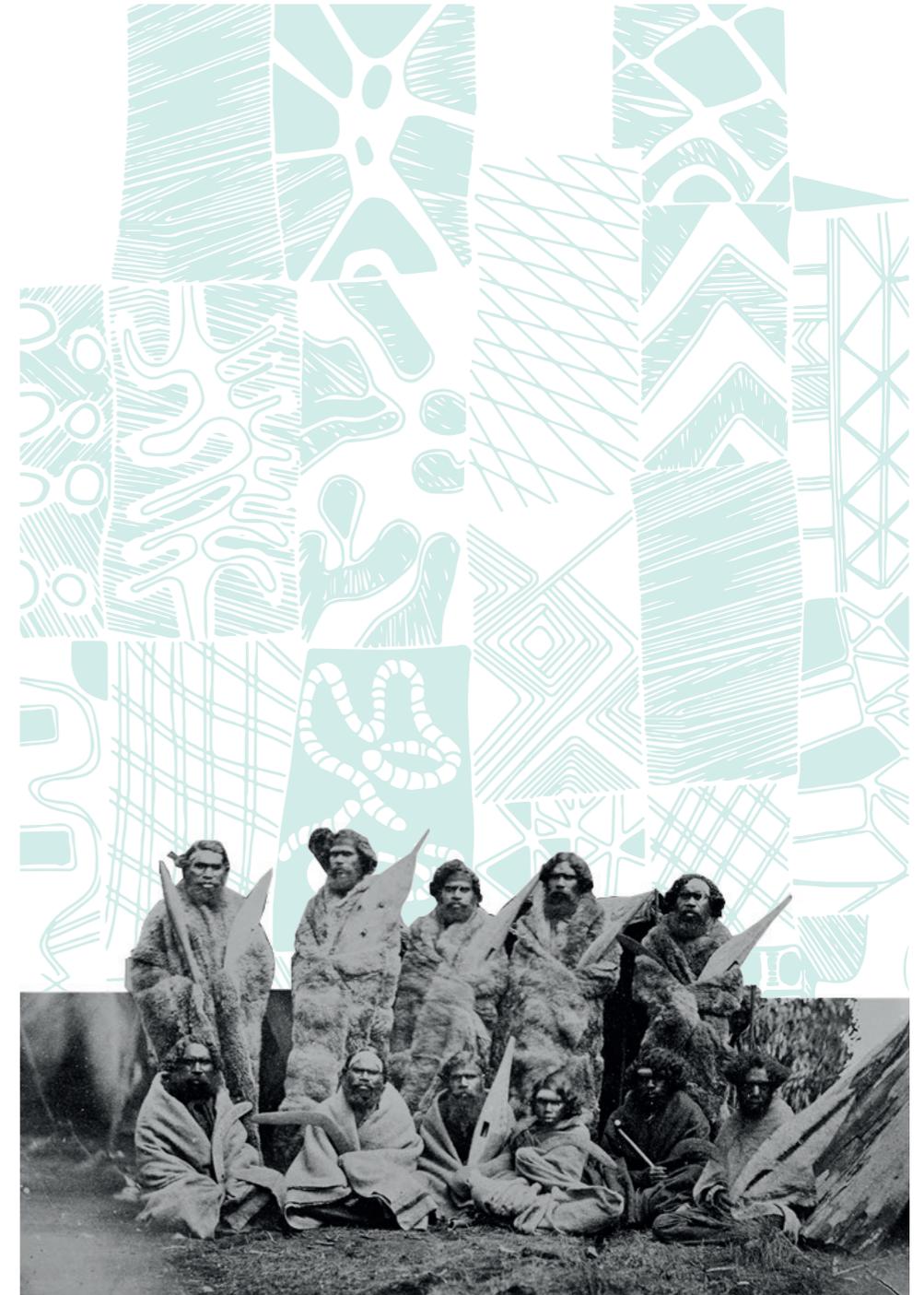
**Architectural Value** - It presents a remarkable knowledge and experience within hydrology and the natural processes surrounding the site, being present and functioning for 6000 years. The construction and materials adapt to the natural landscape and the use.

**Lessons to learn** - This system is a clear example of the overlapping relations between culture and landscape. The land became the primary source of knowledge, the understanding of the land became their most important message to pass down. This knowledge not only meant the economic survival of a community but also the tangible representation of their identity and their life.

From this system we can learn the importance in the knowledge of spatial and seasonal distributions that allow for a sustainable and coherent use of resources and can be matched with active and diverse human conditions. The understanding of biological cycles, in this case the behaviour and migratory patterns of animals, is key to adapt water systems into responding to these behaviours, adjusting in order to allow for increased or decreased productivity, depending on the needs.

Essentially, this system exemplifies a dimension of an eco-cultural landscape, where local ecology is not significantly altered, yet it is strategically enhanced, resulting in a more sustainable and resilient management of the land. It shows that a highly functional system does not need large and strongly invasive alterations in nature and can be built and sustained with only local resources.

Finally, it also exemplifies the value in maintaining and spreading traditional ecological knowledge, where both tangible and intangible factors create a distinctive cultural landscape that should always be present in the future developments of the land.



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## Illustration credits

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**Figures 2-4** Information from: <https://unimelb.libguides.com/GIS/base>. Drawn by the author.

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**Figures 10-11** Information from: [http://www.bom.gov.au/jsp/ncc/climate\\_averages/rainfall/index.jsp?period=jan&area=vc#maps](http://www.bom.gov.au/jsp/ncc/climate_averages/rainfall/index.jsp?period=jan&area=vc#maps). Drawn by the author.

**Figure 12** Illustration by Marion Marks from "The People of Budj Bim". Retrieved from: <https://portal.engineersaustralia.org.au/system/files/engineering-heritage-australia/panel-title/Budj%20Bim%20Lake%20Condah%20Interpretation%20Panel.pdf>. Edited by the author.

**Figure 13** Information from: [http://www.bom.gov.au/jsp/ncc/climate\\_averages/rainfall/index.jsp?period=jan&area=vc#maps](http://www.bom.gov.au/jsp/ncc/climate_averages/rainfall/index.jsp?period=jan&area=vc#maps). Drawn by the author.

**Figure 14** Map retrieved from: Budj Bim Cultural Landscape: World Heritage Nomination. Department of the Environment and Energy. (2017). Edited by author.

**Figures 15-17** Information from: Dating Aboriginal stone-walled fishtraps at Lake Condah, southeast Australia. (2012). Drawn and edited by author.

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and Energy. (2017). Drawn by author.

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# Glossary.

A glossary is a list of concepts, that are defined and described and, in this case, drawn.

The glossary of traditional water systems explains words with a certain complexity that focus on “water” in relation to the landscape, in relation to its form aspects and in relation to people. To understand their function and meaning, and their position in the system and territory it is crucial to take the entire water system as a start to understand the concept of the element, the work or the story. By putting them in a specific order - the goal is to find them easily - the glossary will work as a reference book.

The glossary is divided in three categories: water elements, water works and water stories. Within these category a strict protocol on how to draw and describe the glossary-word helps to get the information designers need. The glossary is made for them.

The protocol asks for: project name, climate, year, water type, landscape type, altitude, soil condition, materials, temporality, form, use or function and meaning.

By describing and drawing water elements, water works and water stories of different systems - situated in different cultures, and constructed during different times - similarities between them are revealed. After a few years of research, it might be possible to arrange them according to a few prototypes.

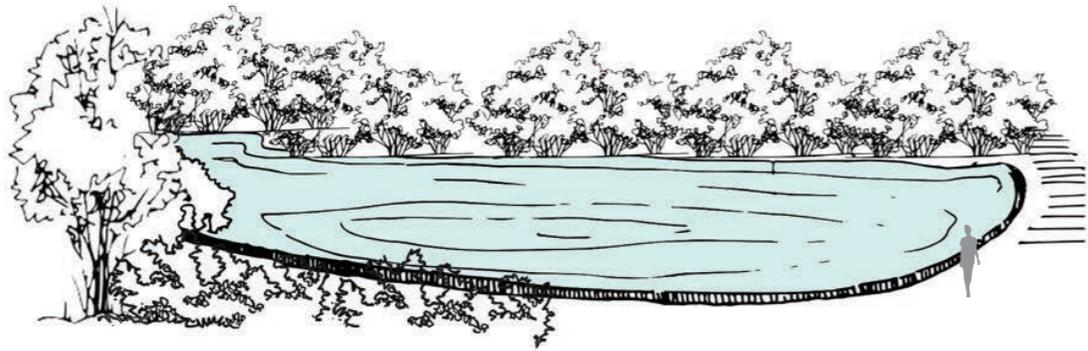
**Water landscape elements** are large scale water elements, which are made by people using mainly natural material that can be found at the territory. A person is added to the drawing to understand the scale.

**Water works** are built structures of natural or artificial materials that guide the waterflow. A person is added to the drawing to understand the scale.

**Water stories** illustrate actions (spiritual, cultivation, or other) of people and/or animals related to the water. A person or animal in action is added to the drawing to highlight the relationship between the element and people’s culture.



## Water landscape elements.



### **Hauz**

*Lake*

Water tanks which harvest rainwater and storm-water during monsoon season. Main function of the hauz was to collect rainwater over a large expanse of land.

Project Name: Delhi Sultanate Waterworks, Ancient network of water harvesting structures, Delhi, India

Climate: Overlap of humid subtropical and semi arid

Year: 1206 A.D. - 1526 A.D.

Water type: Drinkable rainwater

Landscape type: Ridge landscape

Altitude: 220-230 m.a.s.l

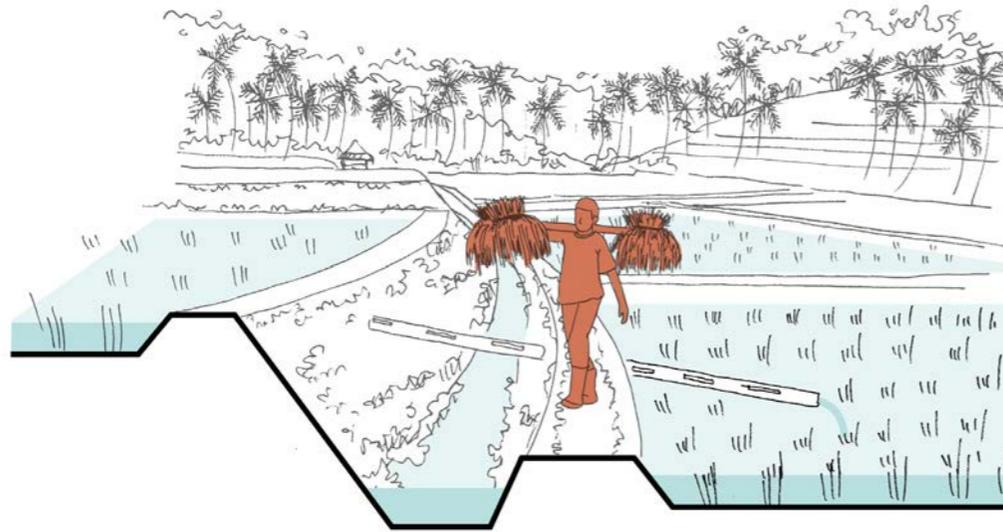
Soil condition: Alluvium, Quartzitic ridge

Material: Excavated soil

Period: Fixed

Form: Surface

Use/ function: Water harvesting

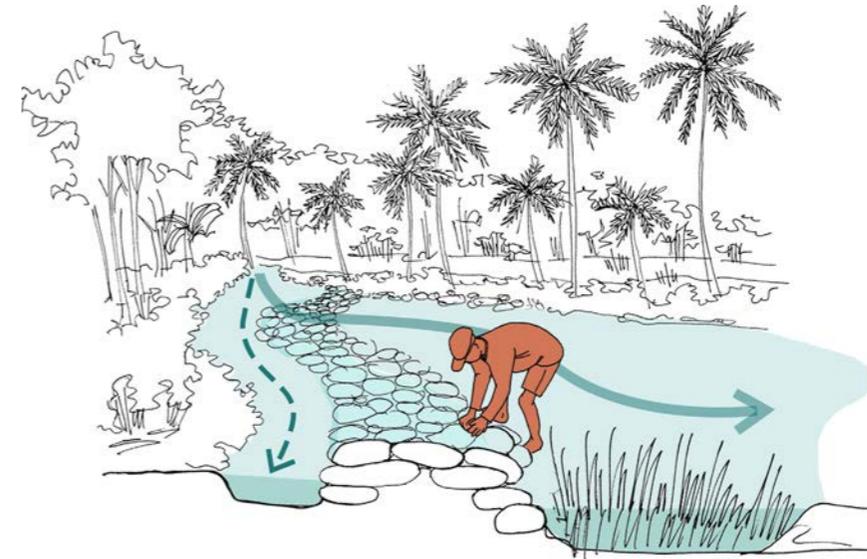


**Sawah**

*Terraced rice fields*

Successively receding platforms, which were a result from cutting a piece of sloped plane to resemble steps, bordered by a small embankment to grow rice crops which need a flooded area to be grown. Bamboo pipes connect the field parcels and distribute the water.

Project: Kampung Naga  
 Climate: Tropical - Mild temperate humid  
 Year: Current  
 Water Type: Fresh water  
 Landscape: Terraced valley  
 Altitude: 584 m.a.s.l  
 Soil Condition: Inceptisols & Entisols  
 Material: paddy soils  
 Period: Fixed  
 Form: Surface  
 Use or Function: Agriculture

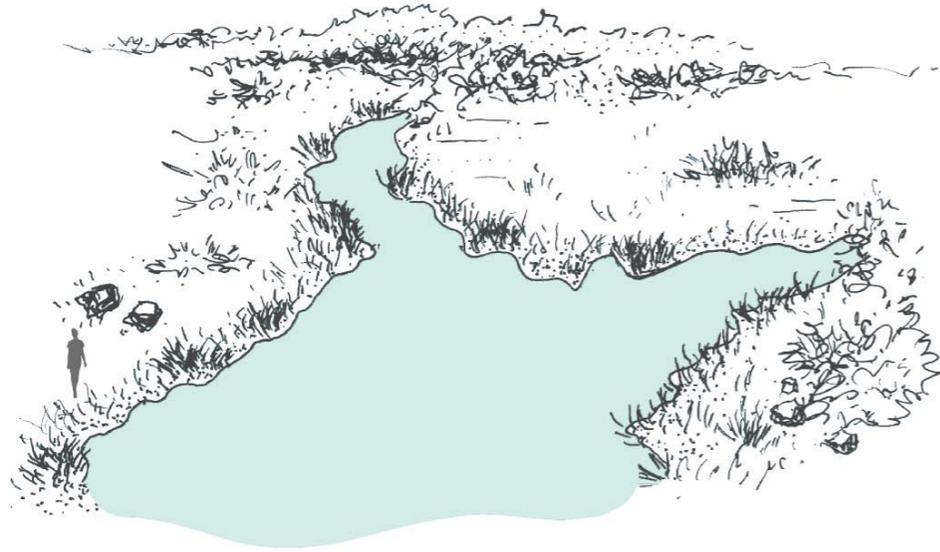


**Ereng**

*Rock dam and channel*

The waterways flow the river water into the main irrigation channel leading to Kampung Naga. It utilizes piles of alluvial rocks that can be adjusted according to the seasonal change of the river water discharge. The people in Kampung Naga maintain this system manually as part of community activities to maintain social bonds.

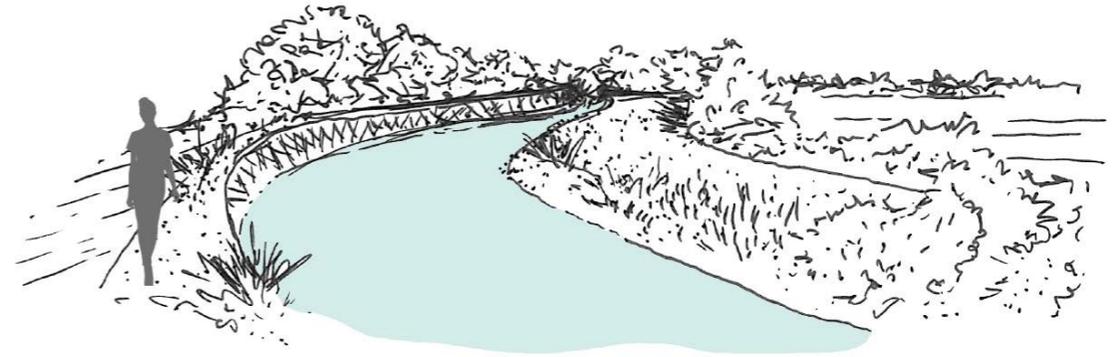
Project: Kampung Naga  
 Climate: Tropical - Mild temperate humid  
 Year: Current  
 Water Type: Fresh water  
 Landscape: River  
 Altitude: 584 m.a.s.l  
 Soil Condition: Alluvial Soil  
 Material: Fluvial rocks & River boulders  
 Period: Regulated based on seasons  
 Form: Line  
 Use or Function: Regulate water discharge from the river



**Pi - 陂**  
*Water retention*

An artificial water retention that based on the naturally formed pond according to land topography. The retention was used for drinking and irrigation use. Small ones are called "Ti", larger ones are called "Pi".

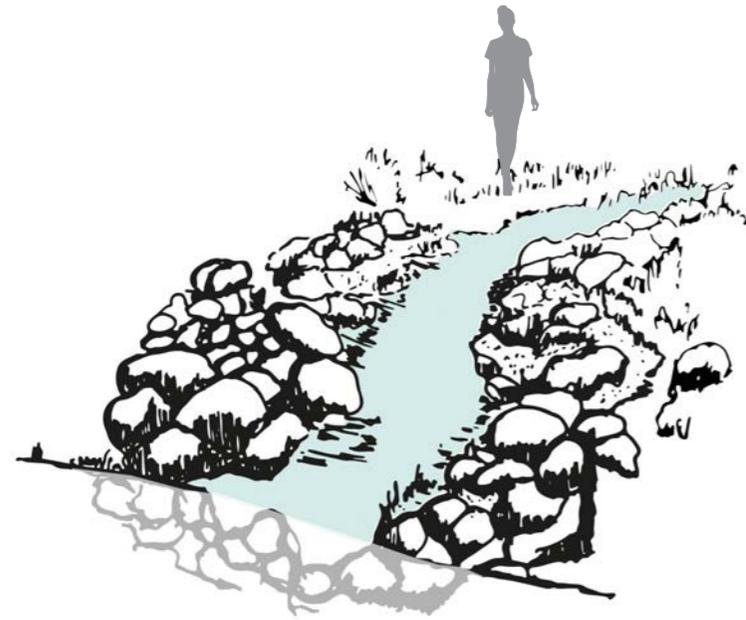
Project: Ksôkong Tsùn Irrigation System, Taiwan  
 Climate: Tropical savanna climate with dry-winter characteristics  
 Year: ca. 1683  
 Water type: Rain water  
 Landscape type: River plain  
 Altitude: 0-20 m.a.s.l.  
 Soil condition: Alluvial soil  
 Materials: Excavated soil and rammed earth  
 Period: Permanent  
 Form: Surface  
 Use or Function: Water supply for agriculture



**Tsùn - 圳**  
*Irrigation ditch*

A open waterway that provides clean fresh water for drinking and irrigation use. Small ones are called "Kau", big ones are called "Tsùn".

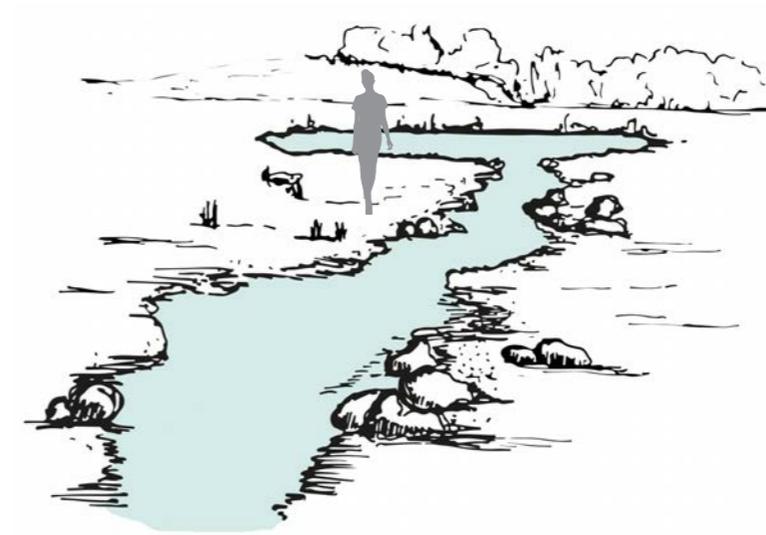
Project: Ksôkong Tsùn Irrigation System, Taiwan  
 Climate: Tropical savanna climate with dry-winter characteristics  
 Year: ca. 1839  
 Water type: River water  
 Landscape type: River plain  
 Altitude: 0-20 m.a.s.l.  
 Soil condition: Alluvial soil  
 Materials: Excavated soil and rammed earth  
 Period: Permanent  
 Form: Network of lines  
 Use or Function: Water supply for agriculture



### Canal

Artificial and excavated features constructed from eroded basalt rocks found on the site. Some are more than 300m long, used mostly during rainy season to channel water flow from wetland to wetland.

Project: Aboriginal eel Aquaculture - Gunditjmarra Country  
Climate: Temperate - Warm summer Mediterranean  
Year: 4000 BC  
Water type: Fresh water  
Landscape: Volcano stream  
Altitude: 20-30 m.a.s.l  
Soil condition: Peat and basalt rocks  
Material: Basalt rocks  
Temporality: Seasonal, dry to wet  
Form: Line  
Use or Function: Aquaculture



### Race

Artificial water line built above the ground and partially delimited with eroded basalt rocks. Some are more than 50m long and 0.75m high, used generally for directing water.

Project: Aboriginal eel Aquaculture - Gunditjmarra Country  
Climate: Temperate - Warm summer Mediterranean  
Year: 4000 BC  
Water type: Fresh water  
Landscape: Volcano stream  
Altitude: 20-30 m.a.s.l  
Soil condition: Peat and basalt rocks  
Material: Basalt rocks  
Temporality: Seasonal, dry to wet  
Form: Line  
Use or Function: Aquaculture

# Water works.



## **Aqueduct**

*Network of water channel*

An artificial channel for conveying water. It was built underground and on embankments, according to the level, but also for great distances on long arcades.

Project Name: Roman Aqueducts, Rome, Italy

Climate: Temperate, Mediterranean Climate

Year: III century B.C - I A.D. century

Water Type: Drinkable, fresh water

Landscape Type: From the mountains to the city

Altitude: 400 - 20 m.a.s.l.

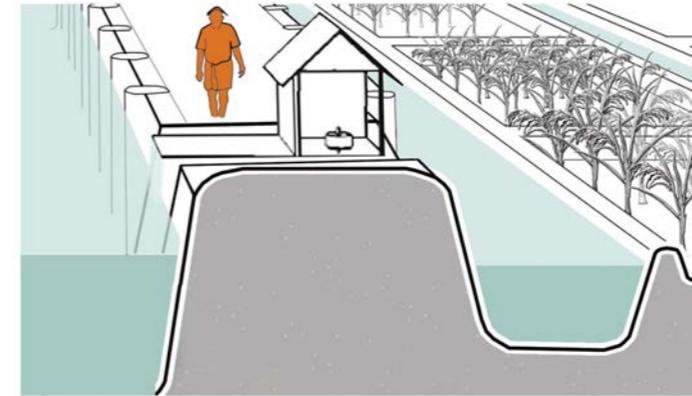
Soil condition: Not relevant

Materials: Bricks and lime

Temporality: Fixed

Form: Network of line

Use or Functions: To bring drinkable water into the city



## **Dewatering motor**

An indigenous technical device placed at the edge of the Kayalnilam for pumping water out from low-lying areas to the major canals or backwaters. It consists of a submerged brass vessel that sucks water out and it is run by an electric motor kept inside the pump house. The sucked water flows out through a rectangular brass box.

Project Name: Kuttanad Kayalnilam Agro-system, Kerala, India

Climate: Tropical monsoon

Year: 1880 - 1974 (a modified version still in use)

Water type: Seasonal mixing of saline and fresh water

Landscape type: Polder landscape in a deltaic basin

Altitude: -3 - + 1.5 m.a.s.l

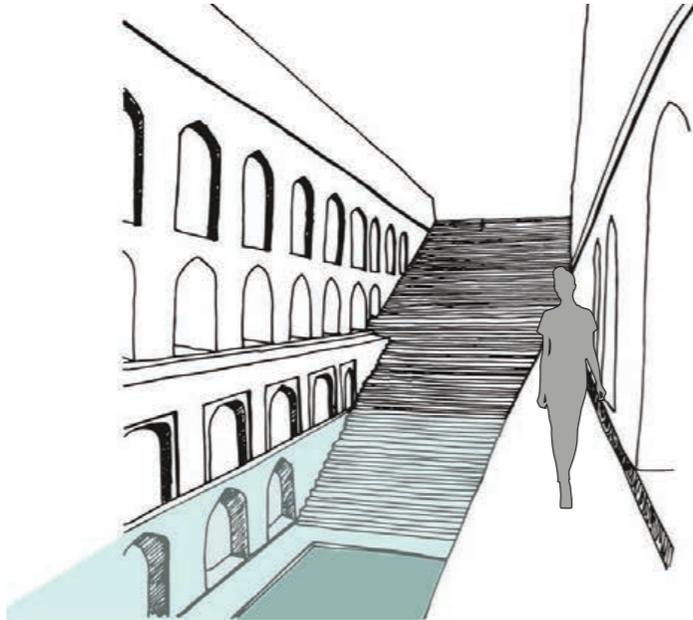
Soil: Sandy loam clay formed from riverine and lacustrine deposits

Material: Wood and brass

Period: Seasonal

Form: Point

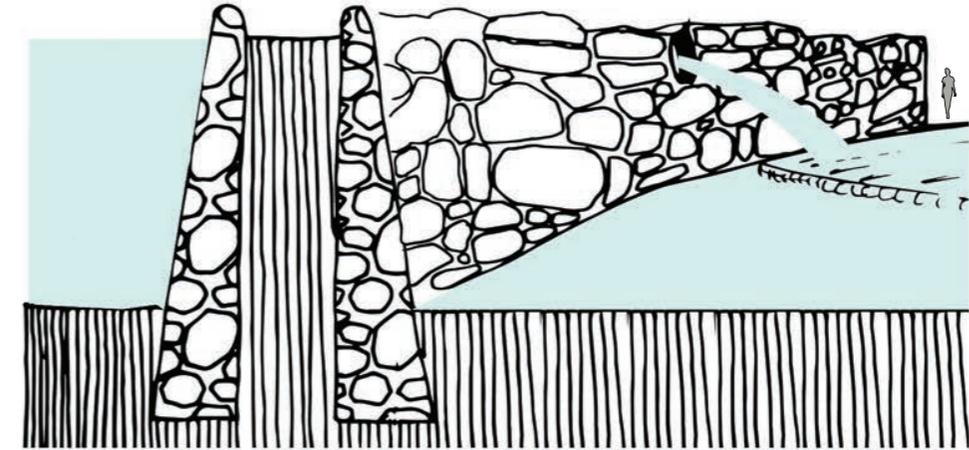
Use or function: Pump water out



**Baoli**  
*Stepwell*

Rainwater and natural storm water channels from Delhi ridge is stored in ground and it is directly accessible to people by a flight of stairs. The narrow staircase is divided into three parts, which runs along inner three walls of rectangular baoli.

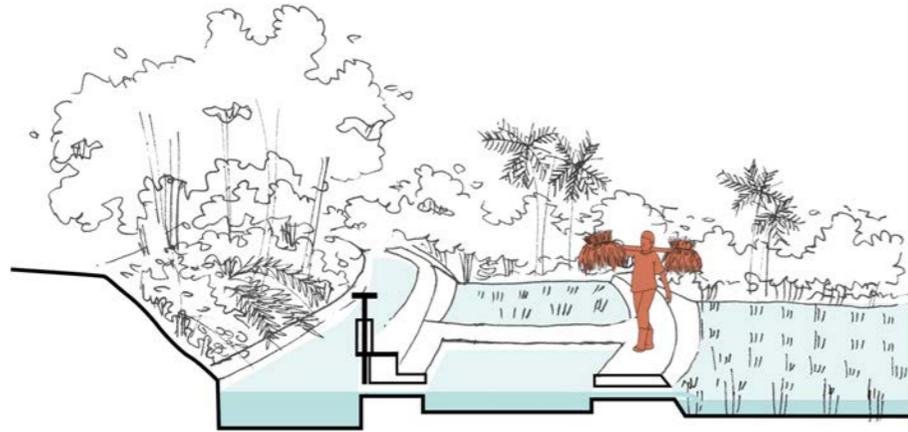
Project Name: Delhi Sultanate Waterworks, Ancient network of water harvesting structures, Delhi, India  
 Climate: Overlap of humid subtropical and semi arid  
 Year: 1206 A.D. - 1526 A.D.  
 Water type: Drinkable rainwater  
 Landscape type: Ridge landscape  
 Altitude: 220-230 m.a.s.l  
 Soil condition: Alluvium, Quartzitic ridge  
 Material: Delhi quartzite stone  
 Period: Fixed  
 Form: Surface  
 Use or function: Water harvesting



**Bund**  
*Embankment*

Water harvesting mud embankment structures, restrains natural streams of stormwater runoff in its upper reaches and directs it for storage in hauz (lake) and baoli (stepwell).

Project Name: Delhi Sultanate Waterworks, Ancient network of water harvesting structures, Delhi, India  
 Climate: Overlap of humid subtropical and semi arid  
 Year: 1206 A.D. - 1526 A.D.  
 Water type: Drinkable rainwater  
 Landscape type: Ridge landscape  
 Altitude: 220-230 m.a.s.l  
 Soil condition: Alluvium, Quartzitic ridge  
 Material: Stone masonry  
 Period: Fixed  
 Form: Point  
 Use or function: Water directing

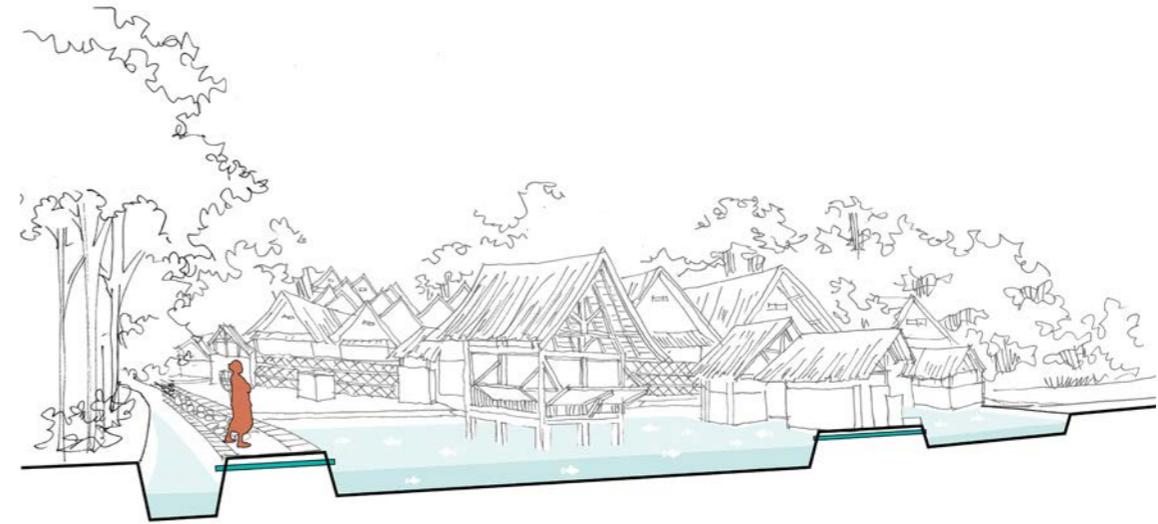


### **Solokan**

*Irrigation canal*

The main irrigation channel that distributes water from the river to the rice fields, fishponds, and latrines. It is equipped with small sluices and control tubs to regulate the amount of water that enters the field parcels.

Project: Kampung Naga  
 Climate: Tropical - Mild temperate humid  
 Year: Current  
 Water Type: Fresh water  
 Landscape: Terraced valley  
 Altitude: 584 m.a.s.l  
 Soil Condition: Inceptisols & Entisols  
 Material: Stones & Concrete  
 Period: Fixed  
 Form: Line  
 Use or Function : Irrigation

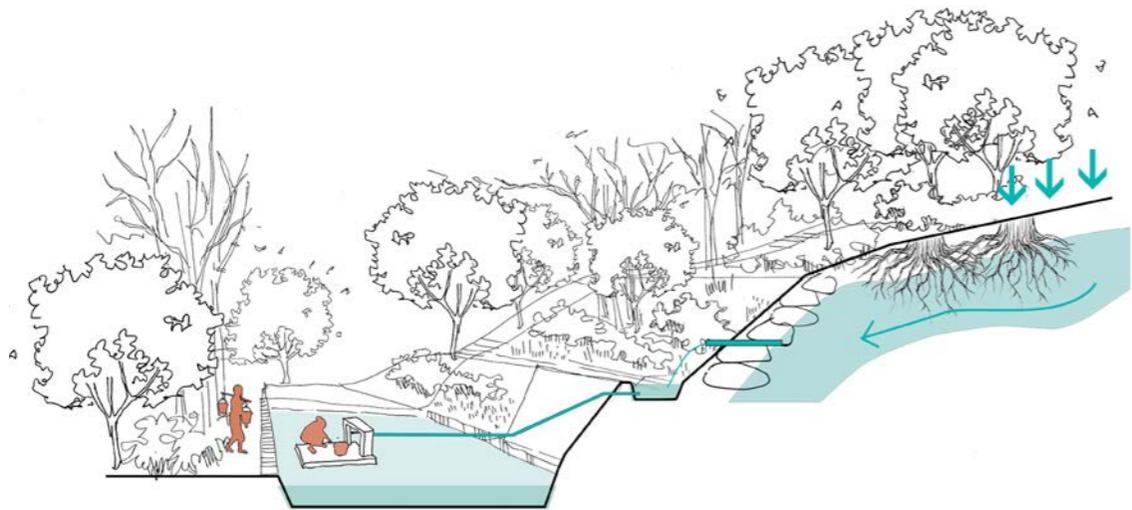


### **Balong**

*Fishpond system*

This system consists of several ponds that are interconnected using pipes and control tubs, with the latrines, washing stations, and rice husking stations built above it. The pond is also used for fish farming. The purified water flows to the main drainage to discharge the water back to the river.

Project: Kampung Naga  
 Climate: Tropical - Mild temperate humid  
 Year: Current  
 Water Type: Fresh water  
 Landscape: Plain  
 Altitude: 584 m.a.s.l  
 Soil Condition: Inceptisols & Entisols  
 Material: Fluvial rocks & Concrete  
 Period: Fixed  
 Form: Surface  
 Use or Function : Fish farming, natural water purification

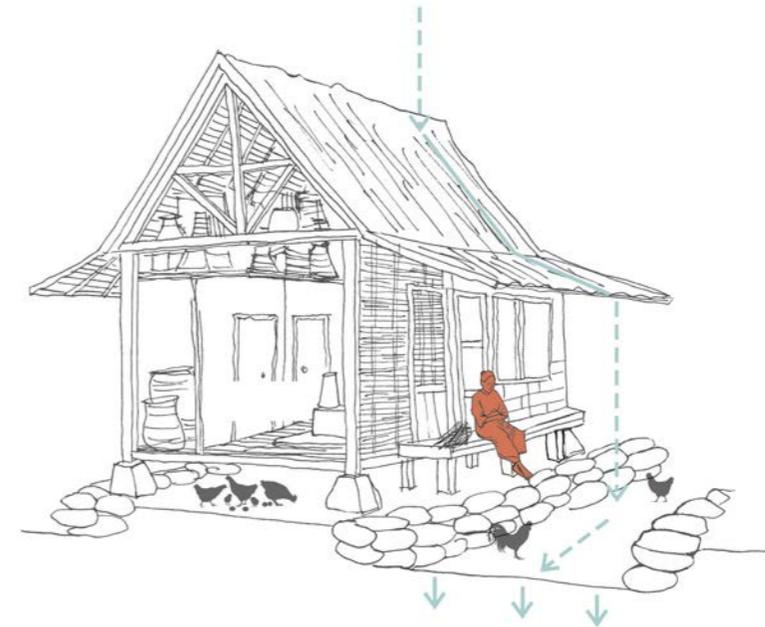


**Air nyusu**

*Spring water*

A system to extract the spring water by creating a hole against the hill wall and channeling the water with pipes to the platform underneath. The spring water is a result of water infiltration through the pristine 'forbidden' forest and filtered by its roots. The people of Kampung Naga use it as a source for drinking water.

- Project: Kampung Naga
- Climate: Tropical - Mild temperate humid
- Year: Current
- Water Type: Fresh water
- Landscape: Valley
- Altitude: 584 m.a.s.l
- Soil Condition: Inceptisols & Entisols
- Material: Stones, Concrete, Pipes
- Period: Fixed
- Form: Point
- Use or Function : Potable water source



**Curugan**

*Gutter*

The houses in Kampung Naga are built on a raised platform in a linear arrangement. This level difference forms a gutter that is bounded by river stones, creating storm-water drainage channels.

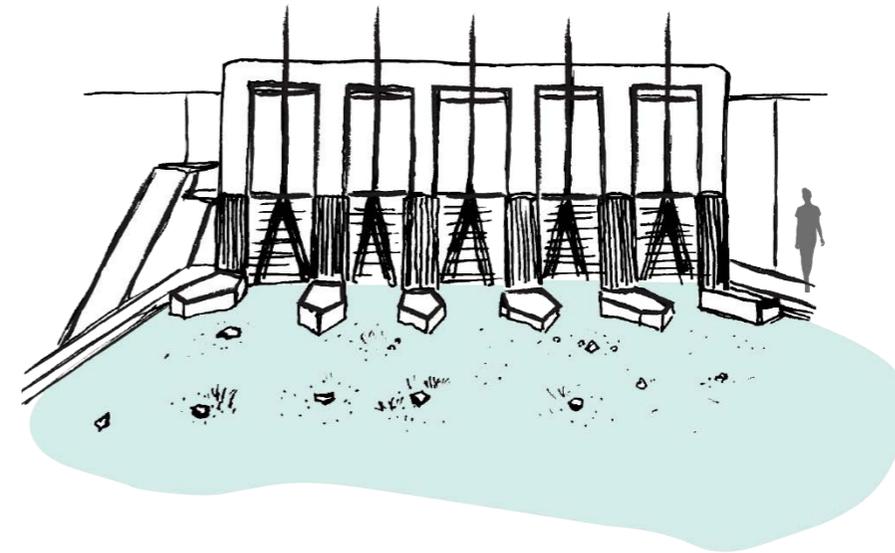
- Project: Kampung Naga
- Climate: Tropical - Mild temperate humid
- Year: Current
- Water Type: Fresh water
- Landscape: Plain
- Altitude: 584 m.a.s.l
- Soil Condition: Inceptisols & Entisols
- Material: Fluvial rocks
- Temporality: Fixed
- Form: Line
- Use or Function : Stormwater drainage



**Thê**  
Dam

A linear obstacle built perpendicular to a river to guild and direct water to the river water inlet for irrigation ditch.

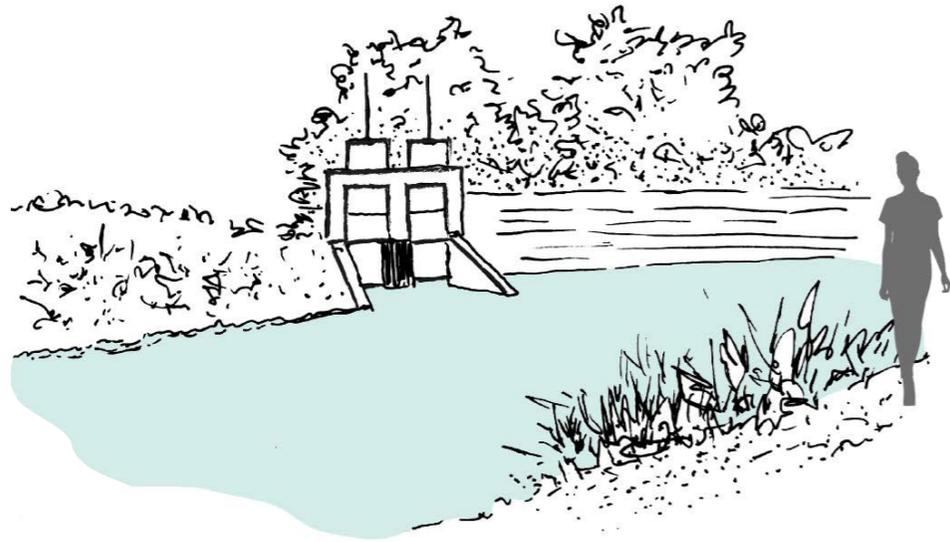
Project: Ksôkong Tsùn Irrigation System, Taiwan  
 Climate: Tropical savanna climate with dry-winter characteristics  
 Year: ca. 1839  
 Water type: River water  
 Landscape type: River plain  
 Altitude: 0-20 m.a.s.l.  
 Soil condition: Alluvial soil  
 Materials: Bamboo, excavated earth  
 Period: From October to July (re-built every October during the dry season and got flooded away during typhoon season)  
 Form: Point  
 Use or Function: Direction



**Tsùn-thâu - 圳頭**  
River water inlet

A gate element that can control the amount of irrigation water intake. In typhoon season, the gate can be closed to protect crops from flooding.

Project: Ksôkong Tsùn Irrigation System, Taiwan  
 Climate: Tropical savanna climate with dry-winter characteristics  
 Year: ca. 1839  
 Water type: River water  
 Landscape type: River plain  
 Altitude: 0-20 m.a.s.l.  
 Soil condition: Alluvial soil  
 Materials: Brick, wood, metal  
 Period: Permanent  
 Form: Point  
 Use or Function: Control



**Pān - 汴**

*Irrigation ditch water inlet*

Water gate that regulate water between irrigation ditch.

Project: Ksôkong Tsùn Irrigation System, Taiwan

Climate: Tropical savanna climate with dry-winter characteristics

Year: 1839

Water type: river water

Landscape type: river plain

Altitude: 0-20 m.a.s.l. (meters above sea level)

Soil condition: alluvial soil

Materials: brick, metal, wood

Period: permanent

Form: Point

Use or Function: control



**Trap**

Artificial and built up structures with gaps or sections for water to flow through and where a Gnarraban (basket) can be placed. These structures were positioned across races and natural drainage lines. The traps could be built as V-shaped basalt block walls, or as a woven timber fence.

Project: Aboriginal eel Aquaculture - Gunditjmarra Country.

Climate: Temperate - Warm-summer Mediterranean

Year: 4000 BC

Water type: Fresh water

Landscape: Volcano stream

Altitude: 20-30 m.a.s.l

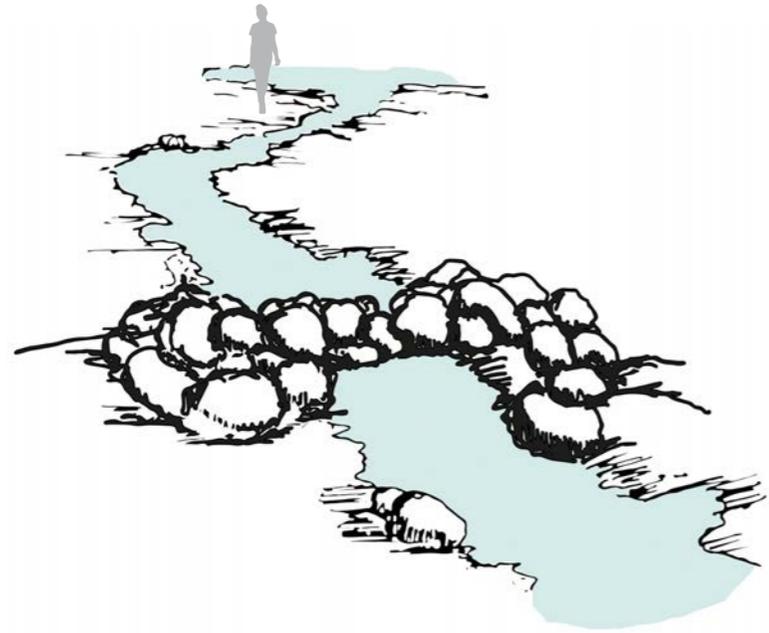
Soil condition: Peat and basalt rocks

Material: Basalt rocks or timber

Temporality: Seasonal, autumn and winter

Form: Point

Use or Function: Aquaculture



### **Weir**

Flexible walls constructed with eroded basalt rock, positioned across waterways and wetland areas. Used to capture large pools of water where eels and fish could be kept fresh, during autumn and winter, for maturing or to catch when required.

Project: Aboriginal eel Aquaculture - Gunditjmara Country.

Climate: Temperate - Warm-summer Mediterranean

Year: 4000 BC

Water type: Fresh water

Landscape: Volcano stream

Altitude: 20-30 m.a.s.l

Soil condition: Peat and basalt rocks

Material: Basalt rocks

Temporality: Seasonal, autumn and winter

Form: Point

Use or Function: Aquaculture

# Water stories.



## Mostra d'acqua

From Latin *mostrare*, to show, to reveal, to exhibit.  
It was the name for large public fountain with monumental functions.  
Usually, they were the terminus of an aqueduct.

Project Name: Roman Aqueducts, Rome, Italy  
Climate: Temperate, Mediterranean Climate  
Year: III B.C - I A.D. century  
Water Type: Drinkable, fresh water  
Landscape Type: Not relevant  
Meaning: Representation, exhibition  
Users: Citizens  
Accessibility: Mainly public  
Soil condition: Not relevant  
Materials: Travertine and Carrara marble  
Temporality: Fixed  
Form: Point  
Use or Functions: To drink, ornamental



## Nasoni

Literally, big nose. It is the typical roman drinking fountain. The city of Rome began installing Nasoni in the 1870s to provide a water supply for citizens; today there are still between 2500 and 2800 Nasoni in Rome.

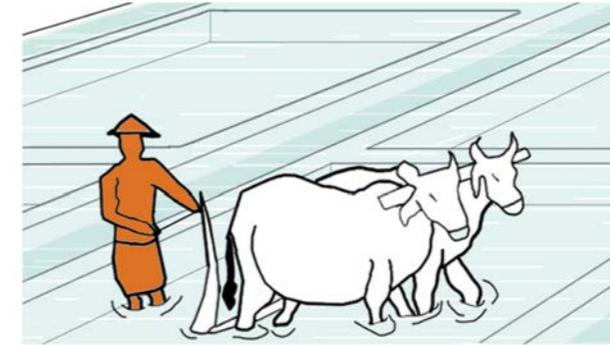
Project Name: Roman Aqueducts - Rome, Italy.  
Climate: Temperate - Mediterranean Climate  
Year: 1874  
Water Type: Drinkable  
Meaning: Fountains of contemporary Rome  
Users: Citizens  
Accessibility: Public  
Materials: Cast iron  
Temporality: Fixed  
Form: Point  
Use or function: Aside from the social-welfare benefits of supplying drinkable water to citizens, Nasoni serve as needed ventilation valves for the Roman water-supply system.



**Baoli**  
*Stepwell*

Rainwater and natural storm water channels from Delhi ridge is stored in ground and it is directly accessible to people by a flight of stairs. The narrow staircase is divided into three parts, which runs along inner three walls of rectangular baoli.

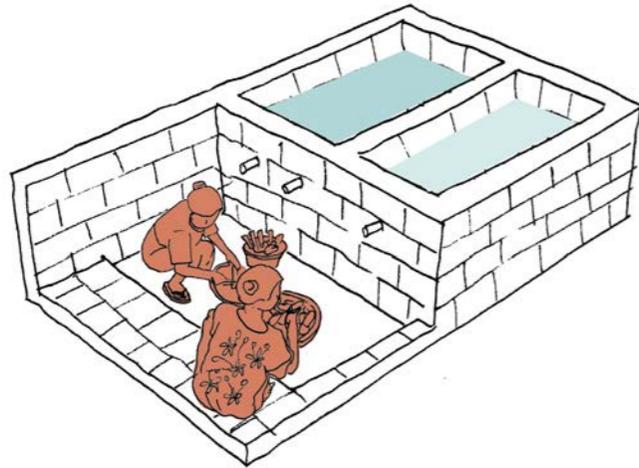
Project Name: Delhi Sultanate Waterworks, Ancient network of water harvesting structures, Delhi, India  
 Climate: Overlap of humid subtropical and semi arid  
 Year: 1206 A.D. - 1526 A.D.  
 Water type: Drinkable rainwater  
 Landscape type: Ridge landscape  
 Altitude: 220-230 m.a.s.l  
 Soil condition: Alluvium, Quartzitic ridge  
 Material: Delhi quartzite stone  
 Period: Fixed  
 Form: Surface  
 Use or function: Water harvesting



**Wet ploughing**

The action of turning up earth when the fields are flooded with a plough that is made of locally available materials, like wood, in order to improve the workability of the soil. In the older days and even nowadays, some of the farmers employ cattle, like cows, to pull the plough manually.

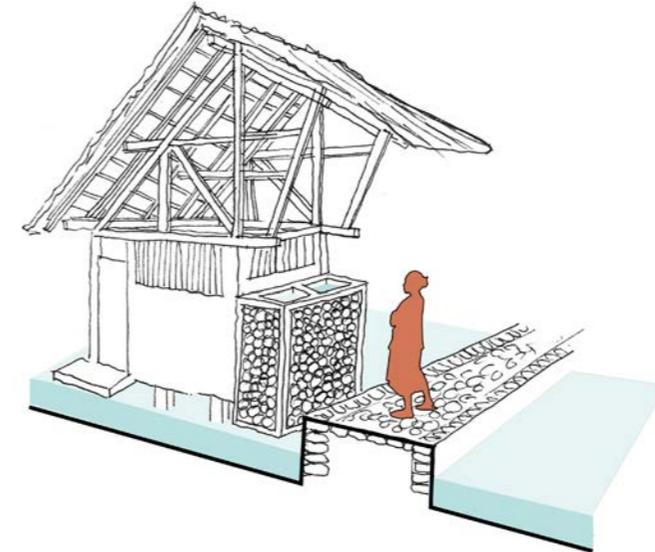
Project Name: Kuttanad Kayalnilam Agro-system, Kerala, India  
 Climate: Tropical monsoon  
 Year: 1880 - 1974 (a modified version still in use)  
 Water type: Seasonal mixing of saline and fresh water  
 Landscape type: Polder landscape in a deltaic basin  
 Meaning: Utilitarian landscape  
 Water Workers and Users: Farmers and fishermen  
 Soil: Sandy loam clay formed from riverine and lacustrine deposits  
 Material: Timber  
 Period: Seasonal  
 Use or function: Tilt wet soil



### Cleaning the mosque

In the settlement area of Kampung Naga, the use of water is only found at the mosque, as part of religious rituals before prayer. Besides, sometimes people also use it to wash food materials. This water tub has 2 tanks which are used to separate water from the river or the spring.

Project: Kampung Naga  
 Climate: Tropical - Mild temperate humid  
 Year: Current  
 Water Type: Fresh water  
 Landscape: Plains  
 Meaning: Utilitarian  
 Water workers & users: Inhabitants  
 Material: Concrete & Stone  
 Period: Fixed construction for daily activities  
 Use or Function: Cleaning rituals before prayer, washing food materials



### Latrine

In Kampung Naga, toilet units were built above the fishponds in a communal area outside the settlement area. Each latrine has 2 water tanks that separate water from the river and the spring.

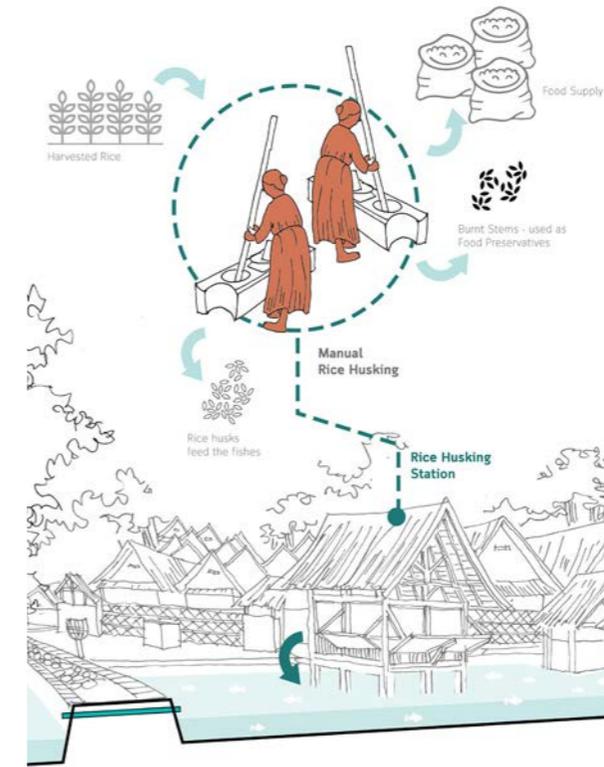
Project: Kampung Naga  
 Climate: Tropical - Mild temperate humid  
 Year: Current  
 Water Type: Fresh water  
 Landscape: Plains  
 Meaning: Utilitarian  
 Water workers & users: Inhabitants  
 Material: Concrete, Stone, Wood & Bamboo  
 Period: Fixed construction for daily activities  
 Use or Function: Toilet & washing station



**Platform at spring water (nyusu air)**

*Nyusu air* - spring water - is the only source of drinking water in Kampung Naga. The inhabitants collect the *Nyusu* water from the faucet at a platform on a fishpond.

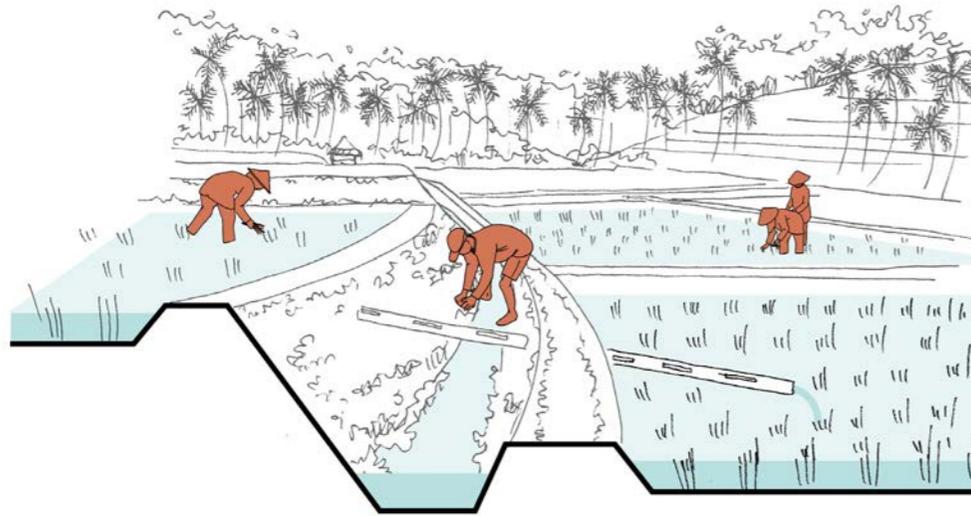
- Project: Kampung Naga
- Climate: Tropical - Mild temperate humid
- Year: Current
- Water Type: Fresh water
- Landscape: Plains
- Meaning: Utilitarian
- Water workers & users: Inhabitants
- Material: Concrete & Bamboo
- Period: Fixed construction for daily activities
- Use or Function: Collect potable water from the spring



**Rice husking station**

In Kampung Naga, rice is pounded manually using traditional tools. This activity is carried out at the rice husking station which is built on a fishpond. Rice husks will be thrown into fishpond to feed the fish.

- Project: Kampung Naga
- Climate: Tropical - Mild temperate humid
- Year: Current
- Water Type: Fresh water
- Landscape: Plains
- Meaning: Utilitarian
- Water workers & users: Inhabitants/Women
- Material: Concrete, Stone, Wood & Bamboo
- Period: Fixed construction for daily activities
- Use or Function: Rice husking station



### **Kamalir & nandur**

*Clearing waterways and planting rice*

*Kamalir* is cleaning waterways from weeds and parasites. It is done by the men in Kampung Naga as part of regular community activities before the planting season. *Nandur* is the activity of plating rice in the fields. This includes regulating the amount of water collected in each parcel to suit the needs of rice seeds to grow properly.

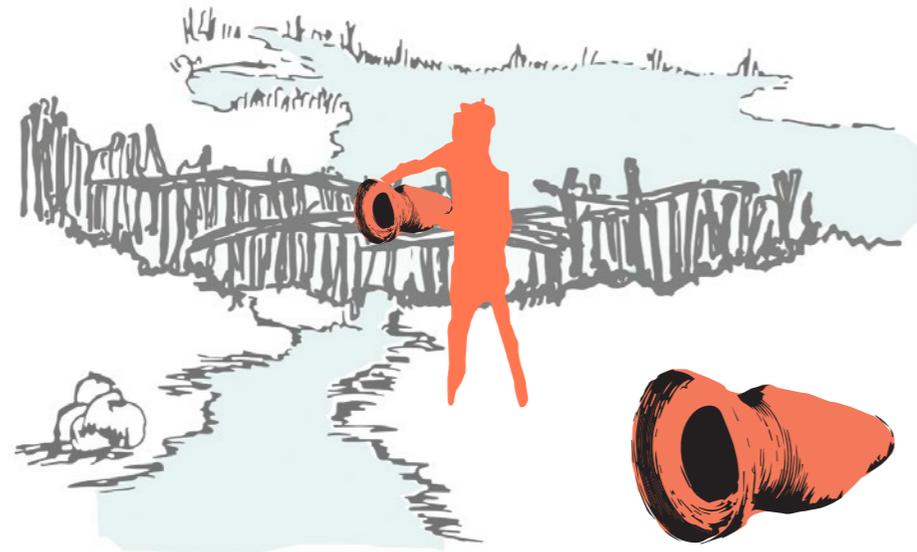
Project: Kampung Naga  
 Climate: Tropical - Mild temperate humid  
 Year: Current  
 Water Type: Fresh water  
 Landscape: Terraced valley  
 Meaning : Utilitarian  
 Water workers & users: Inhabitants/ Farmers  
 Material: Paddy soils  
 Period: Fixed parcels  
 Use or Function : Agriculture



### **Smoking Trees**

Manna Gum and Red Gum trees were used to smoke eels and fish. Existing hollows at the base of a tree were expanded and burnt out forming a chimney. Eels and fish were hung inside the chimney and smoke from the small fire lit inside the base of the tree would start the smoking process. Smoking eels and fish preserved the meat to be stored for when food was scarce, or to be traded to other areas.

Project: Aboriginal eel Aquaculture - Gunditjmara Country.  
 Climate: Temperate - Warm-summer Mediterranean  
 Year: 4000 BC  
 Water type: Fresh water  
 Landscape: Volcano stream  
 Meaning: Utilitarian  
 Water workers and users: Aboriginal fishers  
 Material: Manna Gum (*Eucalyptus viminalis*) and Red Gum (*Eucalyptus camaldulensis*)  
 Temporality: Seasonal, autumn and winter  
 Use or Function: Smoking eel and fish



### **Gnarraban**

*Eel basket*

Eel baskets were placed in gaps of stone and wooden fish traps with an opening to capture mature eels and let immature eels through. The baskets were mostly woven with Common Reed and Spear grass found in the area. Basket making was commonly performed by women.

Project: Aboriginal eel Aquaculture - Gunditjmara Country.

Climate: Temperate - Warm-summer Mediterranean

Year: 4000 BC

Water type: Fresh water

Landscape: Volcano stream

Meaning: Utilitarian

Water workers and users: Aboriginal fishers

Material: Common Reed (*Phragmites australis*) and Spear grass (*Heteropogon contortus*)

Temporality: Seasonal, autumn and winter

Use or Function: Capture eels