A Research of Design in arid zones to prevent flood problems.

DESIGN PROPOSAL FOR A FLOODABLE PARK IN CHAÑARAL, CHILE

MASTER THESIS

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Abstract

The mining town of Chañaral has not built a border for its partially dry river regime. This has always become a cause of tragedy for citizens in the rainy season, there is a history of flooding in the city, and however governments have not carried out a specific project for the river El Salado. On March 25, 2015 there was a major flood caused by climate change, which caused the flooding of the city's only river, leaving a major disaster with the destruction of homes and people killed. Experts warn that heavy rains will be more frequent in the future due to global warming.

In 2017 there was another alluvium, the same river overflowed leaving a great collapse in Chañaral, however to date, the government does not have an answer and people demand a project to prevent another disaster. The river nowadays an element that divides the city, becoming a residual and abandoned space that offers nothing to residents.

What is the best landscape option to prevent future flooding in this arid climate with a history of mining pollution?

The thesis proposal is a floodable park suitable for future flooding suitable for an arid climate. A solution that works in both rainy and dry seasons.

The thesis points to a design that takes advantage of rainy seasons through various strategies, the most important are: a) retention pools to retain water, generate more biodiversity through phytoremediation. b) Store rainwater in specific areas to then use them in the irrigation of the future park that will have vegetation that will require little maintenance, but will help generate an oasis that is suitable for the difficult future conditions that lie ahead.

In urban terms, the aim is to change the perception of the river and its edge, from a residual element to the city to a recreational space and articulator of the city that allows generating different activities and local festivities of great magnitude with an appropriate and sustainable infrastructure, improving the quality of life of the inhabitants rescuing elements of the local culture in its design.

Keywords: Flooding, retention, arid.

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I want to thank my father Jorge Ibarra Suitt and my mother Cecilia Sepúlveda Benavides for their unconditional love. My brothers Javier and Catalina, who supported me from Chile. My girlfriend and life companion Ivette Hevia Noa who was always by my side giving me encouragement and love. My grandmothers and my friends.

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Especially to all the people who suffered from the terrible alluvium that occurred on March 25 in Chañaral, Chile. For a better future for them.

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Chapter I: Brief introduction to the specific objectives of this thesis, hypothesis and study methodology.

1.1. Introduction

Chile is the longest coastal country in the world and therefore has many climates and its geography is prone to suffer several natural disasters such as earthquakes, volcanic eruptions, tsunamis and floods.

In times when climate change is very present, problems such as flooding in unusual places are becoming more and more common, this is how we find one of the most terrible episodes occurred in Chañaral, a small city located in northern Chile.

In Chañaral, a city located in the north of Chile, on 25th of March in the year 2015, 23 people died, and more than 22.000 loses their houses, and every summer they suffered because of the increase of the level of the river "El Salado" because of a heavy raining season and the proximity of the houses to the river. From that day this disaster was known as **25M**.

There was no contingency plan to prevent the increase of water of the river El Salado, the existing master plan was not appropriate to manage this issue, either because of the issue of containment elements in the river, or because of the issue of management of settlements located near the river, outside the official master plan. It is not the first time in this place of these kind of disasters related to the rain and the river, in this area the "Bolivian winter" produces normal rainfall, but this time an unusual climatic phenomenon caused an increase in rainfall that caused a collapse in the river, and apparently, according to the research that will address this thesis, due to climate change, this phenomenon will become more frequent in the future. However, not all the blame for this tragedy lies in the climatic effects; problems related to illegal settlements near the river were present at the time of the alluvium, leading to the results already mentioned. Settlements that were outside the official regulatory plan and in turn a master plan that did not consider a good safety zone to protect people.

The image of the river El Salado is not the typical urban fluvial image of the big cities, it is an abandoned river, ignored, and the thesis will deepen more in this subject. This image of river not friendly and without spaces for the stay and recreation and without a clear destiny on the part of the authorities, provoked illegal settlements had appropriated its borders, producing a disorder in the municipal regulating plan.

The green areas in this so arid zone and so exposed to the sun are not of good quality, they lack good infrastructure and nevertheless there is a great potential to discover, using the local vegetation with good solutions one could come to have a public space that receives the necessities of the inhabitants of Chañaral.

The people need solutions, proposals, something for the future, based on these necessities can a proposal of design of landscape architecture prevent a future disaster like 25M? This master thesis postulates that it is possible based on the idea of floodable parks, taking as reference different cases of study of projects in Germany and Italy which works successfully nowadays.

This master thesis is going to take this topics as main themes:

- **The causes of the disaster**: For this thesis, it was considerate the information from thesis of geologist who did studies in Chañaral explaining the reasons behind the 25M related to the geology and some studies from the government which were done in the city asking the residents their necessities and the problems after the 25M.
- **Planting design for arid zones**: One of the challenges for this thesis is the hardest weather of the place, and it is big opportunity to develop the green areas in Chañaral because of the weather there is no good designs of public spaces.
- **Floodable parks**: Which means floodable parks, historical background and how it works in different countries.

1.1.1. Fundaments.

The tragedy of the 25M it was a day that Chile will not forget but until now the lack of proposals from landscape architects and the government after this disaster is a sad reason to pay attention on this city. It is not the first time

that this kind of tragedies appears in Chañaral, in fact there are many registers of flood similar, but there is no responses.

If we look into the landscape of the city, there is no much public open spaces, in fact it is a good opportunity to develop the potentials of a new kind of green areas in this zones with a hard weather.

1.1.2. Aim

The main aim is to develop a sustainable proposal of landscape architecture related to floodable parks to mitigate the problems in Chañaral related to potential increase of volume of the river El Salado in the future and propose an urban river that brings the community closer, reducing the current polarization generated by the El Salado river, respecting the culture and weather of the zone and improving the quality of life of residents and enhancing the development of the city.

1.1.3. Specific Aims

Urban:

- Change the perception of the river from a natural element to an urban element that articulates the city and mitigates the current polarization.
- To study about the culture of the zone, to know all the factors for a good proposal according to the residents.

Arid landscape

- To make a research about plants resistant to the hard weather of Chañaral.

Mitigation:

- To research about all the factors of the disaster of the 25M in Chañaral.
- To make a research about possible solutions to mitigate a future disaster like 25M like for example floodable parks.
- To design a proposal according to the analysis of geologists from Chile which determinate the main reasons behind the disaster.
- Propose safe areas close to the river that in turn contribute to the leisure and recreation of residents.

1.2. Hypothesis

There are many factors which are responsible of the 25M, strong rainfalls located in one zone, the condition of the soil, and maybe the most important cause of all the destruction and the deaths of people is how is designed the city near to the river El Salado, how is the relation of the city to the river.

The hypothesis of this thesis is that the area near the river should be used as a floodable park to mitigate the impacts of a new alluvium and also the area can be used as an articulator of the city and reduce polarization and promote tourism in the area with green areas with good infrastructure appropriate to the climate and culture of the city.

1.3. Methodology

1.3.1. Study of geology

Study the work of a Chilean geologist and the department of geology of the Universidad Católica de Chile who did a research about possible factors of the disaster related to the geology.

1.3.2. Cases of study method

Make a research about cases of study related to floodable parks, these cases must be from Chile and from another countries like Germany, Italy, etc. Understand the information and the context of the proposals and see the possible answers in a scenario such as Chañaral.

Make a research about theory and the background that exists in floodable parks and the raison behind of each parks depending on the geographical situation. Analyze strategies to mitigate floods and the dual function of green areas: containers for recreational equipment and also as alluvial mitigators.

Conduct research through journal articles, books, websites on successful historical and contemporary landscape projects such as squares and parks in arid landscapes that can serve as support for an appropriate design proposal.

1.3.3. Theoretical and literature method

Conduct a study on the image of the urban river, urban water landscape, how the river relates to the city and how the fabric of a city can change and also consult master thesis, magazines, internet articles and books on how the perception of the river influences people and the landscape response that is achieved depending on the relationship of the city with the river.

To carry out a study on arid landscapes, and of the importance and potential that they can have in the city and of how other places in the world have reacted with adverse conditions such as lack of water. In the same field research on sustainability in this type of landscape and how these two concepts go hand in hand.

1.3.4. Design Method

Take geographical, climatological and sun orientation data to establish a framework of environmental parameters to be considered at the time of the design.

Establish the potential of the area to connect the proposal with a possible tourist circuit and also articulating the pedestrian routes with the aim of reducing the perception of polarization that currently exists.

According to the results of the theory of floodable parks, designs of landscape designs in arid zones and the research about the disaster of 25M, to make a review of the design of floodable parks in the world, check the programs and activities and design strategies used to take stock and criticize it for the future design of the new park for of Chañaral.

To compare models of floodable parks and parks in arid zones in order to rescue the most favorable points that can contribute to a better design of the landscape proposal.

Chapter II: Presentation of Chañaral city and its river. Basis for understanding the underlying problem.

2.1. Chile.

Chile is a country located in South America. More than 18 millions of people live in Chile, the capital is Santiago and it has 209 years of independence from the monarchy of Spain. After some politic problems with Pinochet (1973-1989), the dictator, Chile is a free country with democracy. Nowadays Chile is in a good political situation, better than Brazil and Argentina.

In economic terms Chile is better than Argentina and Brazil, Chile is the leader in Latin America of The ranking of global economic freedom[1].

The religion in Chile is the Christianity (68%) and most of the places and festivities are related to the Christianity[2].

In 2018 Chile was on the top of global ranking of renewable energies[3], better than India, China and Brazil. This analysis said that Chile is better in terms of politics related to renewable energies and the dedication coal abandonment.

But at the same time, Chile is on the number 11 in Latin America in the ranking of Environmental Performance Index (EPI)[4], and in global terms, Chile is the number 84. Another relevant information is that Chile has the worst numbers in air pollution. According to Jorge Canals (former Undersecretary for the Environment) said that this information does not show the reality of Chile[5].

According to the WHO (World Health Organization) in 2018, Coyhaique, a city of Chile was on the top of cities more polluted in latin america and in the world ranking Chile is in number 140[6].

2.1.1. The geography.

Chile is a large country (4.300 km from north to south) and for the administration is divided in 16 regions, 56 provinces and 346 communes.

Chile is located between two plates (Nazca and Antartic), which means that Chile suffered several seismic activities, is the second country in the world with more earthquakes (after Japan). Chile has more than 2.000 Vulcans, is the second in the world with more Vulcans after Indonesia.

In the Big north ("Norte Grande" in Chile) there is one of the driest desert on the planet, called Atacama Desert, located in the regions Atacama and Arica.

In the small north ("Norte Chico") is located the most widely land in Chile, and because of the rivers it has many valleys.

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[1] The institute Fraser did this study in 2018. I global terms, Hong Kong is the number one. Source: infobae.org

[2] According to CADEM study in 2018.

[3] According to Climatoscope 2018, the analysis was about 103 countries in the world. Source: cooperativa.cl/noticias/pais/medioambiente/chile-lidera-por-primera-vez-ranking-mundial-de-energias-renovables/2018-11-29/115945.html

[4] Global ranking EPI, the universities Yale and Columbia did this ranking. On the top of the ranking is Switzerland, then France and then Denmark. Source: epi.envirocenter.yale.edu

[5] Source: chilesustentable.net/ranking-ambiental-situa-a-chile-en-el-puesto-84-entre-180-paises/

[6] Source: www.latercera.com/tendencias/noticia/seis-ciudades-chilenas-las-20-mas-contaminadas-america/151630/

In the central zone is located Santiago, the capital, and the concentration of more than 60% of the population in Chile.

In the south we can find many lakes and more vegetation and Vulcans.

In the Patagonia or "Austral zone", the mountains are decreasing in terms of heights until disappear in the extreme south.

Figure 1: Location of Chile. Source: Own elaboration.

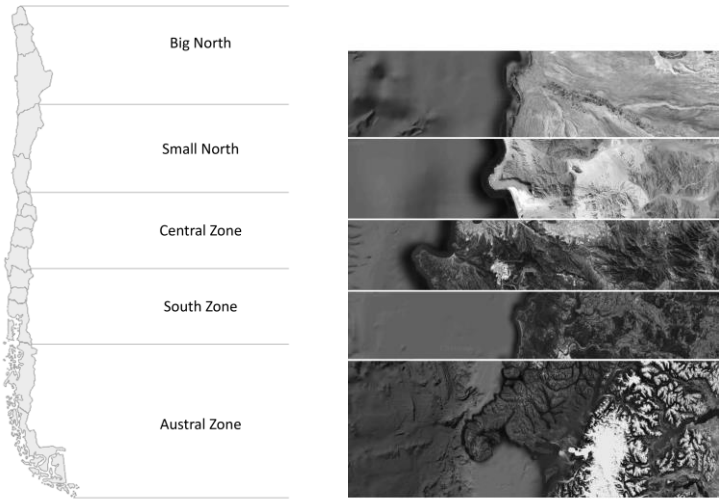

Figure 2:The chilean zones and zooms of each zones. Source: Own elaboration.

2.1.2. The Climate.

In Chile, there are different types of climates and landscapes, and it is because by the geographical position of Chile with respect to areas of high pressure, by the presence of the polar front and the influence of the sea. For the latitude, altitude and relief factors of the country:

1. Desert but on the coast the same temperature: I, II and XV Regions. 2. Desert with a big difference of temperatures between day and night: III Region. 3. Semi-arid: IV Region 4. Mediterranean Climate on the coast and on the interior: V Region 5. Mediterranean Climate: Metropolitan Region. 6. Temperate Mediterranean climate: VI and VII Regions.	7. Temperate climate: VIII Region. 8. Mediterranean climate of warm summer: IX Region 9. Rainy temperate: X Region. 10. Cold climate: XI Region 11. Temperate cold rainy climate without dry season in the insular sector: XII Region 12. Ice of heights and polar climate: Antartic

2.2. Brief description of the Atacama Region.

The Atacama Region is the numbrer III in Chile from North to South. The region of Atacama is divided in 3 provinces: Copiapó, Chañaral and Huasco, the most important city is Copiapó, because it has more than 60% of the population of the region, and the province with lowest population is the province of Chañaral, with 10% of population[7].

[7] Source: INE, región de Atacama.

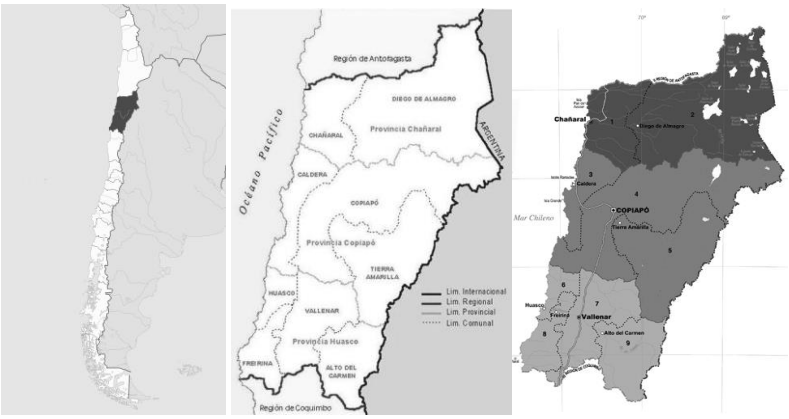

Figure 3: (Left) Region of Atacama location in Chile. (Center) The political division. (Right) Provinces division. Source: educarchile.cl

The most attractive points in this region is the "Flowered Desert", located near to Copiapó city, in the middle of the region. This is a national nature attraction, and the location is in one of the most arid desert in the world. And this phenomenal event is produced by the "El Niño" effect, so it just happens when the raining season started.

Figure 4: Flowered desert before and after. Source: voyhoy.com

Figure 5:Valle El Huasco. Source:Atacamaviva.cl (left) and Ojos del Salado (right). Source: visitchile.cl

The region of Atacama is the fourth least populated of Chile, the capital of the region is Copiapó. From the first inhabitants the relation with the extraction of minerals was very narrow, after the Spanish invasion, the mining was accentuated until what it is nowadays, that continues being the predominant economic activity of the region.

2.3. The study area: Chañaral city.

Chañaral is located in the region of Atacama, the name "Chañaral" means "allee of chañares(Geoffroea decorticans)". Every year the numbers of habitants are decreasing by many reasons which will be explained in the next chapters.

The province of Chañaral is made up of 6 main localities:

- Chañaral
- El Salado
- Diego de Almagro
- El Salvador
- Potrillos
- Llanta

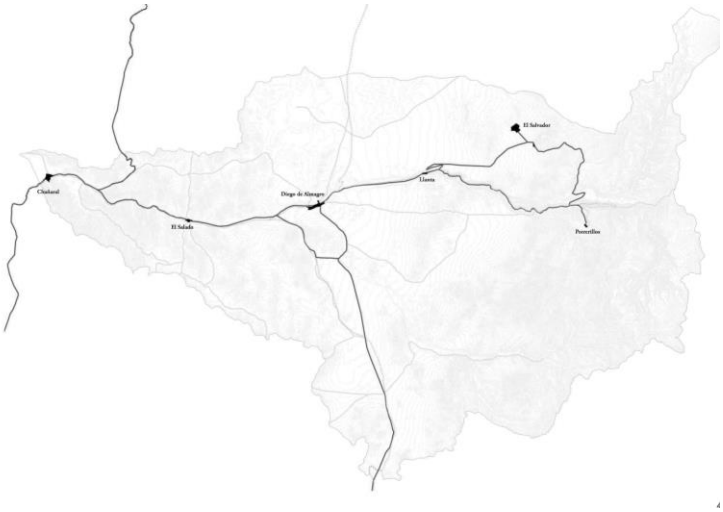

Figure 6: Chañaral and their connections with the other towns. Source: Angel Quiroz

The specific location is 26°20' S and 70°36' W, and it has the river called "El Salado". Nowadays it has 11.893[8] habitants in 5772, 4 km2, with a density of 2,12 hab/km2. For many years there has been a problem with mining industries due to serious environmental disasters, caused by tailings from the town of Potrerillos, who occupied the river "El Salado" to dump waste to the shores of Chañaral. For decades this situation was maintained until the mine stopped producing, however later more mines appeared as in the locality of "El Salvador", occupying the same devastating solution of throwing waste into the sea, until the municipality denounced the situation and after several altercations decided to change the system, this happened after 52 years of throwing toxic waste into the sea. Until today it is possible to see the discoloration in the sand of the beaches of Chañaral as a result of toxic waste as we can see in the picture below.

Figure 7: Artificial opening of El Salado river. Source:El desastre ambiental de la bahía de Chañaral.

Figure 8:Chañaral Map with the location of national parks. ieb-chile.cl

Figure 9: A view of Chañaral from the national park "Pan de Azúcar". Source: Thisischile.cl

Figure 10: Birdview of Chañaral city.Source: conociendochile.com

The map of the province of Chañaral, here we can see the location of the national park Pan de Azúcar and the other places under protection like Norte de Flamenco, Los Juanitos and Quebrada Peralillo.

2.3.1. Social aspects.

2.3.1.1. History of Chañaral. The mining city.

The city has always been related to mining activity, but its first inhabitants, according to archaeological discoveries, were indigenous hunting groups and marine collectors between 12,000 and 8,000 BC. Later came the group of Indians called "Chinchorros", who practiced mummification many years before the Egyptians, in fact you can still see these mummies in museums in northern Chile. Later sedentary groups appeared that were hunters, fishermen and

[8] Source: es.datachile.io/geo/atacama-3/chanaral-39

practiced agriculture, planted corn, beans, pumpkin and quinoa[9]. These Indians are known as the El Molle Culture, which was established in ravines and valleys. They also practiced pottery and carving.

In the year 500 B.C., there is evidence that the indigenous peoples were already engaged in mining, exploiting the "turquoise", a semi-precious stone, with which they made necklaces and also exchanged these products with other peoples.

Later came the culture of "Las Ánimas" exploiting "turquoise" and copper, making necklaces and zoomorphic figures between 700 and 1000 BC.

After "Las Ánimas" came the "Copiapó" culture, an agricultural pottery culture between the years 1000 and 1400 AD. They built towns and fortified sites on low hills, had cemeteries and collected water from a well located miles north of what is now the commune "El Salvador", used camelids as llamas to transport products.

Years later, the conquest of the Inkas would appear[10], those who respected the existing culture but under the submission of the local governors, used as route "the way of the Inca" that arrived until what today is the Cuzco, Peru. To this day you can see part of this road in Chañaral.

With the arrival of the Inkas, the mining-metallurgical process deepened and special spaces called "Wayras" were created, which were large furnaces for melting metals.

Figure 11: Camino del Inca. Source:Chañaral, minería y sociedad.

Figure 12: Wayras. Copiapó Valley. Source: Chañaral minería y sociedad.

Figure 13: Chañaral. 1922. Source: museodeatacama.gob.cl

Figure 14: Las Ánimas mining. Circa. 1880

Later came the Spanish invasion, when the coast inhabited the Changos who were mainly engaged in fishing that at that time the coast of Chañaral was rich in marine species.

The motive of the Spaniards was none other than to find precious metals, so when they invaded the first thing they did was to put the Indians to work in mining as slaves.

In 1744 the first population was founded in which today is Chañaral, at that time was called "San Francisco de la Selva", the population at that time was almost extinct.

Chañaral It was founded in 1833, but it started in 1827 as a zone to extract copper, one of the most important minerals in Chile, on the mining called “Las Animas” 27km from the city of Chañaral, in fact, it was here that Chile's first copper export took place. In 1836, the port was opened. The economic boom began in 1860, and then began with the railway connection, in this period the mine "Las Ánimas" was already out of operation, but in the sector of Potrerillos the mine "Anaconda Cooper Minery" was developed, the connections of railroad circulated by the Basin of the Salado river until arriving at the port of Chañaral for the commercialization of the minerals. Due to the constant contamination produced by the mining companies, the coast began to change drastically, its contamination caused the city to move more than one kilometer away from the coast. Chañaral created Puerto Barquito, for the exclusive mining use of the area. After some good and bad periods, the other boom appeared in 1915 with the construction of El Barquito Port. They later inaugurated the El Salvador mine, which was very important for the mining industry, but also produced many problems for the environment, as they threw tons of waste into the sea through a canal, which

[9] Source: Chañaral minería y sociedad.

[10] Inkas: It was the largest empire in Pre-Columbian America, encompassing southern Colombia, Ecuador, Peru, western Bolivia, northern half of Chile and western Argentina.

was a worldwide scandal and forced the mine to close the canal in 1988. In 1990, the mine inaugurated a tailings dam to prevent contamination of the city's beaches. Nowadays the main company of mining in Chañaral is called ENAMI.

2.3.1.1.1. Human settlement

In the lower map you can see how the city of Chañaral was developed, the first settlements are distributed by what is currently still the main street, which is known as the historic center of the city (1898), where we can find the main square and the main churches. This historic centre connects from the south of the city to the river El Salado. The historical part of Chañaral, is developed in the south sector of the city, later the urban fabric adjacent to the urban helmet is developed, growing towards the east, connecting with the old station of trains, today an abandoned place. The exception to this urban development is the airport located on the north side of the city. The city continues to develop towards the north and south from 1968 to the present, the last settlements are close to the airport and the areas far from the historic center of the city, which are currently blocks of social housing, areas that are expected to densify in the future.

Because the city of Chañaral is exposed to the tsunami, the areas close to the coast are very sparsely populated and also the issue of pollution due to the mining sector adds to the fact that these are not as attractive as recreational spaces. Those of a recreational nature are defined, however, the infrastructure offered is not adequate and becomes an abandoned site and unattractive to citizens.

Currently there are not enough road connections for the whole city and the river becomes an element that divides and does not unify the city.

Figure 15: Map of Distribution. Source: 123cua arquitectos.

2.3.1.2. Economy of Chañaral.

The economy of Chañaral can be grouped into three areas: Mining, fishing and services.

- Services: In terms of exportations, Chañaral's main exports are Grapes to USA, which represent 99% of Chamaral's total exports, followed by Tableware and domestic articles, made of plastic, which represents 2% of responses[11].
- Fishing: There is a lot of artisanal fishing on the coast, but due to the 25M problem, hundreds of fishermen suffered millions of losses[12] tailings product [13].
- Mining: Overall, Chile produces approximately 5.7 tons of copper, representing a direct income of 15% of the country's domestic product. The mining are located in the north of Chile. The main economic activity of the

[11] Source: es.datachile.io/geo/atacama-3/chanaral-39#economy

[12] Source: www.aqua.cl/2017/05/18/pescadores-chanaral-denuncian-abandono/#

[13] Relaves: Desechos tóxicos de procesos mineros.

city is mining, since its foundation has been characterized by being an industrial city with a mining focus, this of course has generated several ecological drawbacks, because for each ton of ore are obtained 80 tons of tailings, toxic waste that in this case are going to give to the sea. The first mines were "of the souls", later "Potrerillos" and "El Salvador" are some of them, and today the mining company that leads in Chañaral and therefore produces the largest amount of tailings is ENAMI, which is still active. Many of these mines remained abandoned. The consequences of these problems will be explained later in the chapter 3 on the consequences of the disaster.

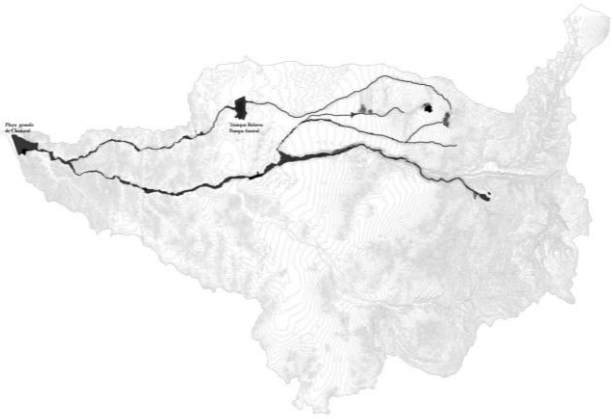

Figure 16: Location of the mining areas and the route of contamination. Source: Angel Quiroz.

Figure 17: Location of ENAMI, the biggest mining company in Chañaral. Source: Google Maps.

2.3.1.3. Transportation in Chañaral.

Chañaral is a very small city with few inhabitants if compared to large cities in Chile, such as Iquique in the north, Santiago in the center or Concepción in the south, so Chañaral does not have a transport system as interurban buses, only buses that connect with other large cities. The system of transport that we can find in the city is that of "colectivos". The “colectivos” is the same system of a taxi but with more passengers.

Another transport system is the use of bicycles, however there is no good infrastructure for bicycles, currently share a track with cars but without delimiting the space for bicycles.

2.3.1.4. Tourism and activities in Chañaral.

Famous places.

1. **Nuestra Señora del Carmen church**: It is the parish church and is located in front of the Plaza de Armas and Casa Molina. This National Monument dates from 1864 and its structure is made of wood, Guayaquil reeds and stucco of mud, sand and lime.
2. **Faro del Milenio (millennium lighthouse)** : The lighthouse was inaugurated on 1 September 2000 and is located on a rocky outcrop in the vicinity of the Lourdes grotto. From the top you can enjoy a beautiful view of the city and the natural landscape that surrounds it. It was built over a high-voltage tower and on the first level there is a circular room that can be used for exhibitions.
3. **Chañaral’s Port and Bay**: It is located at the southern entrance of the city and has a dock for small boats. There are restaurants, sale of fish and seafood. In the cove there is also a library with reference and reading rooms.
   Chañaral Bay is a good place to practice adventure sports, given the qualities of the beach. Fifty years ago the beach was characterized by its abundant flora and fauna, most of which no longer inhabits the place due to man-made pollution. Currently, it is in the process of repopulating species. In recent years it has been the focus of controversy because of the large amount of toxic waste caused by the mining companies.
4. **National Park “Pan de Azúcar”** : Pan de Azúcar National Park is a protected coastal area, located 30 km northwest of Chañaral. It covers a total area of 43,769 hectares, located between the gorges of Peralillo and La Cachina and Sugar Loaf Island.
   The flora of the Park is characterized by being adapted to the lack of water, highlighting the cacti and, in the area of Caleta de Pan de Azúcar, a unique vegetation and semi-desert, fed by the camanchaca. In the Sierra de Vicuña Mackenna there is great diversity, with plants such as coralillo, hualputilla, jarilla, coronilla de

fraile and añañucas. In this sector, the well-known phenomenon of the Flowering Desert is also produced, when the rains increase and the general climatic conditions allow it.

5. **Beaches**: There are 10 beaches in Chañaral, the most famous is Playa El Caleuche: It is located 7 km south of Chañaral and is accessed directly from Route 5 North. It has approximately 100 mts. of front and 5 mts. of depth, with gray and white sands, isolated stones and an impressive view towards the west and to the north that even allows to see the island of Pan de Azúcar. Today it has sites equipped for camping and is suitable for bathing, fishing, water sports, among others.

Figure 18: The most famous church of the city. Source: Geovirtual2.cl

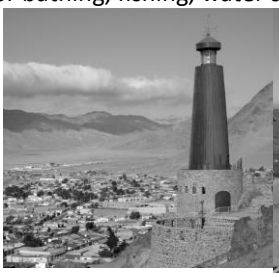

Figure 19: Faro del Milenio. Source: elquintopoder.cl

Figure 20: Chañaral port. Source: Tripadvisor.com

Figure 21: Chañaral Bay. Source: Tripadvisor.com

Activities.

There are three main activities in the zone:

- Cycling
- Sport fishing
- Kayak

2.3.1.5. Culture of Chañaral.

In February, the Millennium Lighthouse Festival is celebrated, an activity attended by people from all over the region and featuring artists from all over Chile.

San Pedro de Chañaral Festival. It is a catholic ceremony celebrated on June 29 in honor of the patron saint of fishermen, San Pedro of the port of Chañaral. This day is characterized by a great march from the Chapel to the port, after which the image of the Saint is taken to its traditional walk by the bay.[14].

Another festivity is for the "Virgen del Carmen"(Virgin of Carmen) or "La Tirana Chica de Diego de Almagro" which starts in Chañaral and continues to the town Diego de Almagro. This is on 16th July.

In October, the Atacama cultural fair and the Motocross event are held on the side of the Pan-American Highway.

Festivity in which the community of Chañaral gathers on December 8, the day of the Immaculate Conception. It is a local celebration and less massive than the feast of St. Peter.

[14] Source: iiiatacama.blogspot.com/2016/07/san-pedro-de-chanaral.html

Figure 22:Festivity for San Pedro in Chañaral. Source: Soychile.cl

Figure 23: La Tirana Chica. Source: regiondeatacama-chile.blogspot.com/2016/02/la-tirana-chica-de-diego-de-almagro.html

Figure 24: Faro del Milenio Festival 2019

2.3.2. Physical aspects.

2.3.2.1. Geography and topography.

In general terms, the region where Chañaral is located, the Atacama region, the number of closed basins at the ocean outlet, creates a danger in the face of imminent heavy rains. The basins in the region of disembarkation in the sea longitudinally, to be more precise, in several points in a focal way, that means: in a single point, in the case of Chañaral, and in the watershed of the Salado River is an exorheic watershed its focal estuary and its arrival to the sea is through the city of Chañaral.

On the other hand, the "Coastal range" is discontinued, due to the presence of transverse cords and, to a lesser extent, to marine erosion, making room for broad "coastal plains" in the Chañaral area. The intermediate depression is interrupted by transverse valleys enclosing river valleys such as Copiapó and Huasco.[15]

The scarce existing vegetation influences by not generating a natural barrier to retain water in the event of rain and the clayey soils generate little permeability in the soil.

Different natural phenomena over time have shaped a unique topography, resulting in dunes, salt flats, beaches, and so on. However, they have a great tourist attraction that boosts the economy of the area.

Therefore we could say that by the geography of Chañaral, its inhabitants are exposed to possible tsunamis in the coast and to possible alluvions as the 25M occurred, due to the channels and streams.

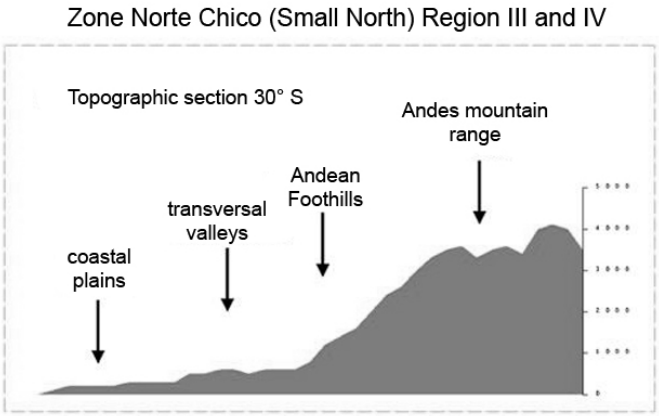

Figure 25:A general topographic section for the Region III (Atacama) and the IV Region of Chile. Source: portaleducatvo.net

[15] Source: bcn.cl/siit/nuestropais/region3/relieve.htm

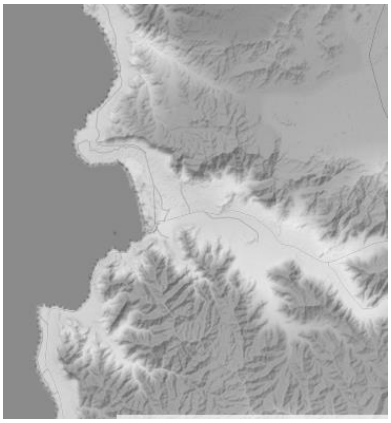

Figure 26:Topographic Map of Chañaral. Source: es-cl.topographic-map.com

Figure 27:Topographic Map of Chañaral. Zoom. Source: es-cl.topographic-map.com

In the Figure above, we can see that all the urban area is located at 21 m above the level of the sea and it is surrounded by hills of more than 270 m. At the beginning of the province in the east, start with a height of 22 m but when the river change the direction is at 10 m above the level of sea.

Due to its topography it can be observed that the city is prone to tsunamis and alluvium. In case of tsunamis, the city has a contingency plan decreed by ONEMI. On the other hand, for alluvions, there are no contingency plans, and as we can see in the images above, the city is surrounded by ravines that can be ravaged by a great storm as the volume of the river flow increases.

2.3.2.2. The river.

The Salado River has a dry and very sporadic regime according to studies by the geologist Victor Grijalba. It originates in Las Vegas de Vicuña, near the border with Bolivia, about 194 kms from the center of Chañaral. It receives several tributaries, such as the Asientos Creek, about 126 kilometers from the center of Chañaral. Another important creek is Chañaral Alto.

This river is one of the first important channels of the north of Chile, the basin has an extension of more than 7.400 km2. The origin of the river is in a place called Las Vegas de Vicuña, located in the hill "Doña Inés", following its course until arriving at the coast of Chañaral. The Salado River is dry or very sporadic, the basin has an area of more than 7,400 km2. It is one of the first most important watercourses in the “big north” of Chile.

As already explained in the chapter 2.3.1.1. (history of Chañaral) the river was contaminated for more than 50 years by mining companies, in addition to the river being a historically dry regime, became an unattractive element for the population and after the flood became a negative element.

In Chañaral, the authorities have not worked on the river in terms of infrastructure either, so the edges of the river are natural land and the banks are not well defined for events such as floods. The streets that cross the river are of low quality and worsened the 25M disaster, since the space between walls is very small and if we add the extra material that the alluvium carried, it caused a collapse.

In the alluvium of 2017, the tailings content decreased due to measures adopted after 25M, but unfortunately the river flow was so large that it caused enormous disasters.

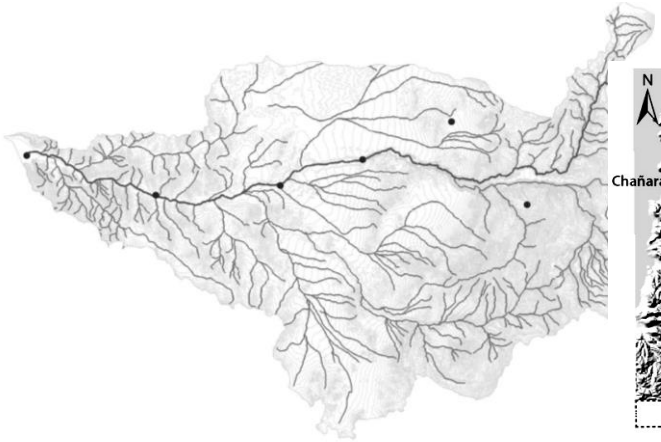

Figure 28: Chañaral rivers. Source: Angel Quiroz.

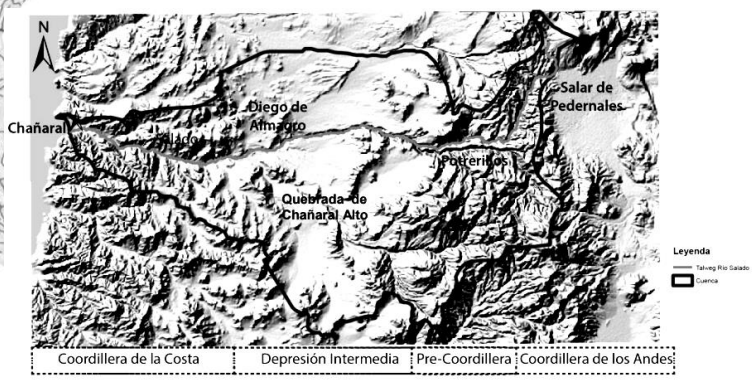

Figure 29:El Salado river(blue) and the basin(purple).Source:Fabiola González: "Estudio y modelación 2D...."

2.3.2.3. The Climate

Chañaral is located to the north of the third region of Atacama, an arid hyper zone and a semi-arid Mediterranean zone. These areas are known for the coastal fog called "camanchaca" that produces native vegetation on hills and in the southern limit of the altiplano. To the south are the transverse valleys where it is common to see agricultural areas.

This area produces the cold Humboldt Current, which has an effect of aridity and produces coastal fog and absence of rain. It is bordering the high mountain range.

In Chañaral we can recognize 3 climatic zones, zone of coastal fog, zone with influence of the Amazonian system of summer rains in the high mountain range and the arid zone in the rest of the territory.

2.3.2.3.1. The Wind.

The wind of Chañaral in seasons like autumn and winter, its predominant direction is from the west, and its speed is an average of 7 kilometers per hour.

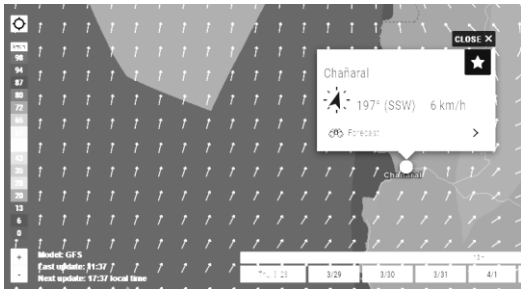

Figure 30: Direction and speed of wind of Chañaral 3/28/2019. Source: Windfinder.com

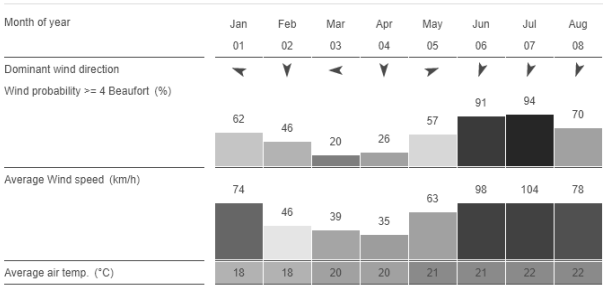

Figure 31: annual analysis of wind speed and direction in Chañaral. Windfinder.com

2.3.2.3.2. The Rain.

Rainfall is scarce in the winter months, not exceeding 1.7 mm a year, so it is an arid zone. Rainfall in the arid zone is due to the movement of the South Pacific Subtropical Anticyclone (ASPS). The ASPS produces a blockage of the system associated with the rains. Normally when this anticyclone moves from its normal zone, it produces important rains, if it is stronger it produces less rains.

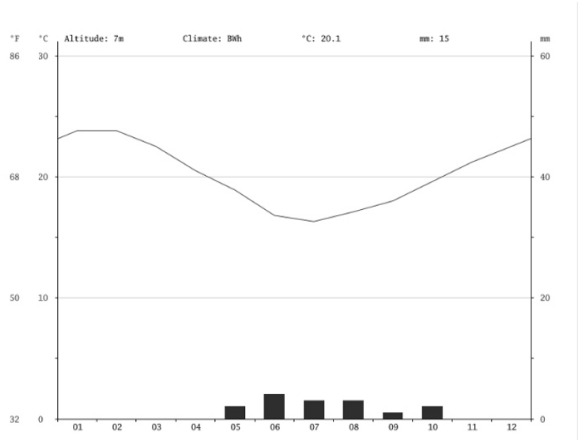

Figure 32:Graphic that shows the rainy seasons. The average is 4mm and June is the rainiest month. Souce: es.climate-data.org/america-del-sur/chile/iii-region-de-atacama/chanaral-21686/

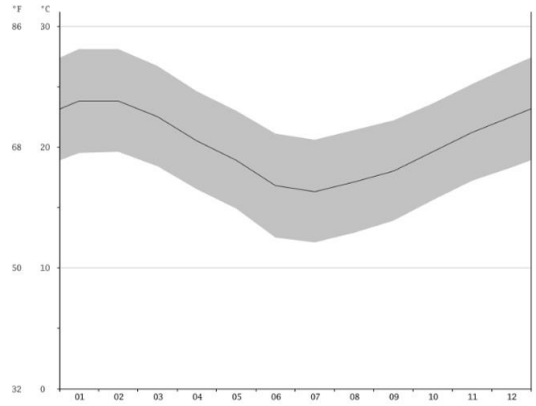

Figure 33:The warmest month is January with 28°C and the coldest month is July with 16,3°C. Souce: es.climate-data.org/america-del-sur/chile/iii-region-de-atacama/chanaral-21686/

2.3.2.3.3. Climate types of Chañaral

There are four types of Climate in Chañaral:

a) Coastal desert with abundant cloud cover: Located on the coast, the bay of Chañaral. Humidity of 74%, the rainfalls are not regulars, it can be 12 mm, temperatures between 10°C and 20°C.
b) Transitional desert climate: It is located in the east of Diego de Almagro. Arid climate. Humidity and rainfall are lower. Temperature of 15°.
c) Cold mountain desert climate: Located from 1500 meters above sea level. The climate is related to the altitudes. Temperatures do not exceed 11°C. The minimum temperatures are below zero.
d) Rainfall in Chañaral: There are two types of rainfall systems in this place.
e) South frontal system: Located in middle latitudes, up to Antofagasta.
f) Altiplano summer rainfall: It is known as the "Bolivian winter", it transports humidity from the east and causes rainfall in the north of Chile. As a result of this, in the summer great floods occur in the north of Chile, which is abnormal in these latitudes taking into account the hyper-aridity of the north. The precipitations produce a circulation of humidity due to the winds of the east, from the mountain range of the andes towards the Altiplano. It is known the devastating effect of the Bolivian winter in the north of Chile, isolating people, interrupting roads, etc.

2.3.3. Biodiversity.

Biodiversity is a concept that was born in 1985 by entomologist E. Wilson, and biodiversity is the diversity of life and includes different species of plants, animals, fungi and microorganisms living in a particular space. The biodiversity in an arid climate like Chañaral is very dense, the Region of Atacama is inside into the 34 hotspots of biodiversity at world-wide level[16]. Unique ecosystems are produced, adapted to the climatic and geographical characteristics of the region. There are different types of environmental conditions and therefore different types of life forms:

- The coast: Living beings that depend on the sea like the chungungo.
- Inner desert: The qualities are very hard for the living beings in this zone, the vegetations resort to the layers of underground water to subsist. We can count the chañares and the algarrobo. Reptiles adapt easily to these spaces.
- Pre-Andean areas: Occasional rains. Condors are birds that adapt easily to these conditions.The native flora has 980 species and 119 introduced and naturalized species and in total is equivalent to 19% of the species present in Chile.

The following diagram is about all the endemic species in the Region of Atacama.

In the region of Atacama there are 100-200 species and near to the east there are 25-50 species.

[16] According to the chapter 7 of the book: “Libro Rojo de la flora nativa y de los Sitios Prioritarios para su conservación: Región de Atacama” Ediciones Universidad de La Serena, La Serena Chile 2008.

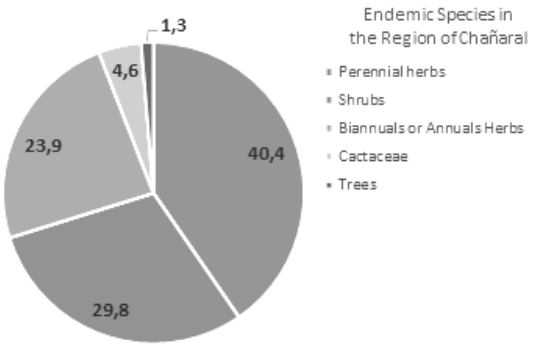

Figure 34: Own elaboration based on the information of the book: Libro Rojo de la Flora Nativa y de los Sitios Prioritarios para su Conservación: Región de Atacama. Chapter 7 Diversidad Vegetal de la Región de Atacama, Chile

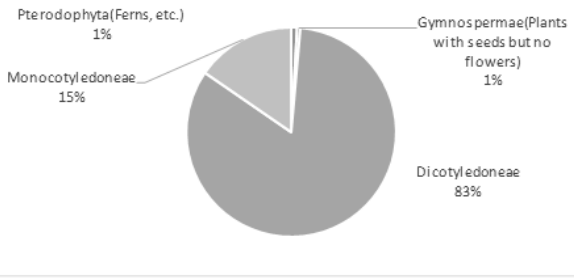

Figure 35:All endemic species. Own elaboration. based on the information of the book: Libro Rojo de la Flora Nativa y de los Sitios Prioritarios para su Conservación: Región de Atacama. Chapter 7 Diversidad Vegetal de la Región de Atacama, Chile.

2.3.3.1. Wild Animals

There are many wild animals in this zone, but we can divide them in the following groups:

Birds • Cóndor(Vultur gryphus): National bird, can reach 3.2 mts, inhabits the whole country. • Chincol (Zonotrichia capensis) • Gorrión (Passer domesticus) • Dormilona(Muscisaxicola masculirostris) • Tenca(Mimus thenca) • Chercán (Troglodytes aedon) • Zorzal (Turdus falckandii)	• Yal (Phrygilus fruticeti) • Pingüino de Humboldt (Spheniscus humboldti): There is a national reserve for this kind of pinguins in Chile since 1990 made up of 3 islands. • Gaviota dominicana (Larus dominicanus) **Insects, reptiles and amphibians** • Lagartija de Atacama (Liolaemus atacamensis) • Mariposas (Lepidópteros)
Mammals • Chungungo (Lontra feline): Better known as Lontra Felina. It lives on the coasts of Peru and Chile. • Whales: A humpback whale, blue whale, minke whale, and so on. • Guanaco (Lama guanicoea): A type of llama that lives in the high mountains, there are many species already domesticated, its wool is very desirable. • Zorro Culpeo (Lycalopex culpaeus): Today they are threatened by the reduction of their habitat, illegal hunting, according to an article published by Romina Alvarado [17].	

[17] Revista La Chiricoca, artículo "Apuntes sobre los Zorros Culpeo y Chilla en Chile" de Romina Alvarado. Diciembre 2011. Chile.

Figure 36:Guanaco. Source:soychile.cl

Figure 37:Zorro culpeo. Source: Deskgram.cl

Figure 38:Condor. Source: T13.cl

Figure 39: Dormilona(Muscisaxicola masculirostris) Soure: Avesdechile.cl

Figure 40:Tenca (Mimus thenca). Source: Avesdechile.cl

Figure 41: Yal (Phyrgilus fruticeti)

Figure 42:Chincol. Source: Avesdechile.cl

Figure 43: Chercán. Source: Avesdechile.cl

Figure 44:Zorzal. Source: Avesdechile.cl

Figure 45:Chungungo. Source:Laderasur.cl

Figure 46:Pingüino de Humboldt. Source:Chañaralaceituno.cl

Figure 47:Whale. Source: profetafm.cl

2.3.3.2. Vegetation

Figure 48:Map of Chañaral province and the six places of different vegetation. Source: Memoria de titulo. Angel Quiroz. 2015

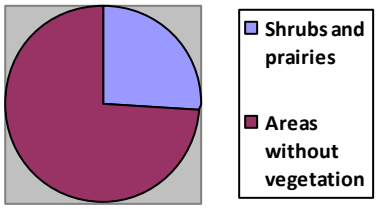

Figure 49: Vegetation in Chañaral. Own elaboration based on data of sit.conaf.cl

There are six different types of vegetation in the province of Chañaral (Gajardo 1994): High Andean Desert, Andean Salt Flats Desert, Domeyco Mountainous Desert, Interior Steppe Desert, Domeco Mountainous Desert, Interior Steppe Desert, Taltal Interior Desert, Coastal Sierras Desert and Taltal Coastal Desert.

According to the information of CONAF (Corporación Nacional Forestal), a public organism of the government related to register and protect the biodiversity in Chile, in Chañaral we can find just 424.215,9 hectares of areas without vegetation and the total area of Chañaral is 576.698,8 hectares. Now from the areas of vegetation, we can find areas with different types of shrubs with 141.697,7 hectares. And Suculent Shrubs with 2.426,9 hectares.

We can classify the sample of plant species in three main types: Trees, shrubs and cactus.

2.3.3.2.1. Trees

- **Algarrobo** (Prosopis chilensis (Molina) Stuntz): It is a tree whose height reaches between 3 to 14 meters high, its trunk can reach 1 meter in diameter, with a crown that reaches 8 meters, is a very common tree in the northern landscape of Chile, although it can also be found in countries such as Peru, Bolivia and Argentina. It flowers from October to December. **It is not in danger of conservation.**

Figure 50: Algarrobo, the tree and the fruits. Source: Gochile.cl(left) and lamanoverde.cl(right)

- **Maitén** (Maytenus boaria): Thick trunk, leafy crown, pendulum branches. Perennial leaves, alternate, variable shape mostly ovado lanceoladas, serrated margin. Monoic or dioic polygamist. Small flowers, axillary. Sepals 5, petals obovate concave, greenish. 5 stamens overlapped with petals, large yellow anthers, ovary oviated with very short style and notorious stigma. Fruit an ovoid coriaceous capsule with 1 to 2 seeds covered with a red aril.

Figure 51: Maitén. Source: M. Teresa Eyzaguirre.

- **Espino** (Acacia caven): A small tree found from the third region to the eighth region. Its height can reach 6 meters high. It flowers in spring. It grows in dry and drought-resistant soils, once planted prevents soil erosion. It is an abundant tree. It is slow growing.

Figure 52: Espino. The tree and the fruits. Source: Gochile.cl(left) and nublenaturaleza.cl (right)

- **Pimiento** (Schinus molle L.): An evergreen crown tree, it can reach heights of 25 meters, and its trunk reaches 1.5 meters in diameter. It grows in different environments, resistant to droughts and saline soils, ranging from sea level to 3,500 meters of altitude[18]. It does not present conservation problems.

Figure 53: Pimiento. The tree and the leaves. Source: Geovirtual2.cl

- **Palma chilena** (Jubaea chilensis): It can reach heights up to 30 m and also It can tolerate frost down to -18°C, and up to over 40°C. Te Jubaea chilensis can withstand strong droughts.

[18] Source: Árboles nativos de Chile.

Figure 54: Jubaea chilensis. Source:http://especieschilenas.blogspot.com/2011/01/palma-chilena-jubaea-chilensis.html

2.3.3.2.2. Shrubs

- Alcaparra (Senna cumingii) It grows in both coastal and arid interior areas, on sandy soils and rocky slopes.

Figure 55: Senna cumingil. Source: http://www.sci.sdsu.edu/plants/chile/plants/Fabac/Senna_cumingii.html

- Cuerno de Cabra (Skytanthus acutus Meyen)

Figure 56: Skytanthus acutus Meyen. Source: Chilebosque.cl

- Reboluta (Nolana divaricata)

Figure 57: Nolana divaricata. Source: http://fundacionphilippi.cl/catalogo/nolana-divaricata

- Nolana stenophylla

Figure 58: Nolana stenophylla. Source: fundacionphilippi.cl

- Schinus polygama var. polygama

Figure 59: Schinus polygama var.polygama. Source: http://fundacionphilippi.cl/catalogo/schinus-polygama-var-polygama

- Chañarcillo (Lycium leiostemum)

Figure 60: Chañarcillo. Source: Geovirtual2.cl

- Dain: Its height varies from 1,5 to 2,5 mts.

Figure 61: Dain. Source: https://www.geovirtual2.cl/Museovirtual/Plantas/Dain1esp.htm

- Algarobilla (Caesalpinia brevifolia).

Figure 62: Caesalpina brevifolia. Source: fundacionphilippi.cl

- Chiropetalum cremnophilum

Figure 63: Chiropetalum cremnophilum. Source: http://fundacionphilippi.cl/catalogo/chiropetalum-cremnophilum

- Colletia hystrix Clos: This shrub is an evergreen shrub that can easily reach 4 m in height.

Figure 64: Colletia hystrix Clos. Source: Guia de flora. Fray Jorge.

- Huingán. (Schinus polygamus(Cav.) Cabrera). The Huingán can reach 3 m in height. In popular medicine, the fruit of the Huingán is used in the preparation of chicha and aguardiente for its favorable antimicrobial properties.

Figure 65: Cordia decandra Hook. & Arn. (Cav.) Cabrera. Source: Guia de flora. Fray Jorge.

2.3.3.2.3. Flowers and herbs

- Brea (Pluchea absinthioides): It can reach a height of 1.4 mt. Pitch resin is still used today as a lubricant. It is found near rivers.

Figure 66: Brea. A general view and the detail. Source: geovirtual2.cl

- Baccharis juncea

Figure 67:Baccharis juncea General view and detail. Source: Franz Xaver.

- Cortaderia atacamensis.

Figure 68: Cortaderia atacamensis. Source: Flickr.com

- Juncus balticus or Juncus andicola.

Figure 69: Carbonillo. Source: Daderot and botanicayjardines.com

- Schizanthus laetus

Figure 70:Schizanthus laetus. Source:http://fundacionphilippi.cl

- Nolana aplocaryoides

Figure 71:Nolana aplocaryoides. Source:http://fundacionphilippi.cl

- Alstroemeria violacea

Figure 72: Alstromeria violacea. Source:http://fundacionphilippi.cl

- Tropaeolum azureum

Figure 73:Tropaeolum azureum. Source:http://fundacionphilippi.cl/catalogo/tropaeolum-azureum

- Caesalpinia angulata

Figure 74:Caesalpina angulata. http://fundacionphilippi.cl/catalogo/tropaeolum-azureum

- Calceolaria collina ssp subincisa: It grows in sandy or stony soils, preferably near the sea or in places influenced by humid air.

Figure 75: source:http://fundacionphilippi.cl/catalogo/calceolaria-collina-ssp-subincisa

2.3.3.2.4. Cactus

- Gatito (Cumulopuntia sphaerica)

Figure 76:Cumulopuntia sphaerica. Source: Frank Vincentz and Pato Novoa

- Copiapoa (Copiapoa dealbata)

Figure 77: Copiapoa cinerascens. Source: Geovirtual2.cl

- Sandillón (Eriosyce rodentiophila): According to llifle.com: "It is a solitary barrel shaped cactus, with stem apex covered by white wool. Spines thick, curved upwards, dull ivory to horn coloured, becoming grey. Distribution: north of Taltal south to below Chanaral".

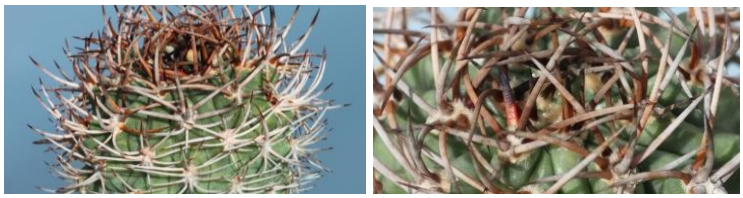

Figure 78: Eriosyce rodentiophila. Source: llifle.com

Chapter III: The flood in Chañaral and the analysis of the failures of the city and the non-handling of the morphological factors of its geography.

3.1. Flood in Chañaral.

3.1.1. 25M, the disaster of Chañaral 2015.

Between the 24th and 25th of march in 2015 in the regions Antofagasta, Atacama and Coquimbo, a big storm with "convective rains" attacked these zones increasing the River "El Salado" destroying most of the zones of the towns Diego de Almagro, El Salado and Chañaral. And another zones like Tierra Amarilla, Copiapó and Alto del Carmen. Because of this disaster 31 people died according to the "servicio medico legal" (legal medical service) and the police of Chile, 16 people disappeared, and more than 16.500 people loses their houses, 2.071 houses destroyed and 40% of the population of the city suffered because of this disaster.

Nowadays this disaster is known in Chile as **25M**.

Some weeks before this disaster, the entire region was under dryness. When the rain started the people was very happy. In the early morning of 25th of March, the alarm for the people increased, and in the morning of 26th of March the government decreed "disaster situation", which means that the government needs all the available resources from Chile to fight the disaster.

On Monday, March 23, the superintendencia de servicios sanitarios or superintendency of health services (SISS) officials began to observe the first images distributed by ONEMI and the Meteorology Department, of the rains that were beginning to appear at a slow rate. On Tuesday 24 everything was normal, despite the rains in the early morning of the same day, everything was still "normal", with about 7 mm of water falling in Copiapó and as already said, people began to celebrate the event, without knowing the tragedy it would cause.

The rain continued on the night of Monday, March 23, until the early morning of the following day, so this set off the alarms of the authorities who were already talking about how to avoid overflowing the river. The cold nucleus in height generated intense precipitations that were maintained until the dawn of March 25, which provoked that the disaster began in Paipote's ravine.

According to Guillermo Donoso, PhD in Natural Resources Economics, the Atacama Region received two days of rain, which normally accumulates in 16 months.

The alluvium destroyed houses in many localities like Paipote, Tierra Amarilla and of course Chañaral. The alluvium caused such damage that it left the city of Chañaral without signal, aggravating the situation for the immediate help it needed.

At first it left several inhabitants without basic services such as water and electricity. Hundreds of kilometers of pipes were damaged, sewage networks and sewage plants collapsed, and the priority was to replenish drinking water and demanded not only the help of all state resources but also the help of private.

The first challenge was to produce drinking water in the driest area of Chile and the world, since an important Copiapó river that served as a supplier was in collapse as a result of another crisis, and at that time it was overexploited. Therefore, Aguas Chañar S.A. had to deal with the construction of new sources. In spite of the strong panorama, the company managed to arrive with a good source of supply located in the sector of Piedra Colgada, 20Km to the west and was able to re-supply the community of basic services.

On March 26, the inhabitants who were on the roofs of the houses were able to cross the road full of mud, for many this was worse than an earthquake, as everything was lost due to the mud. The city was divided in two.

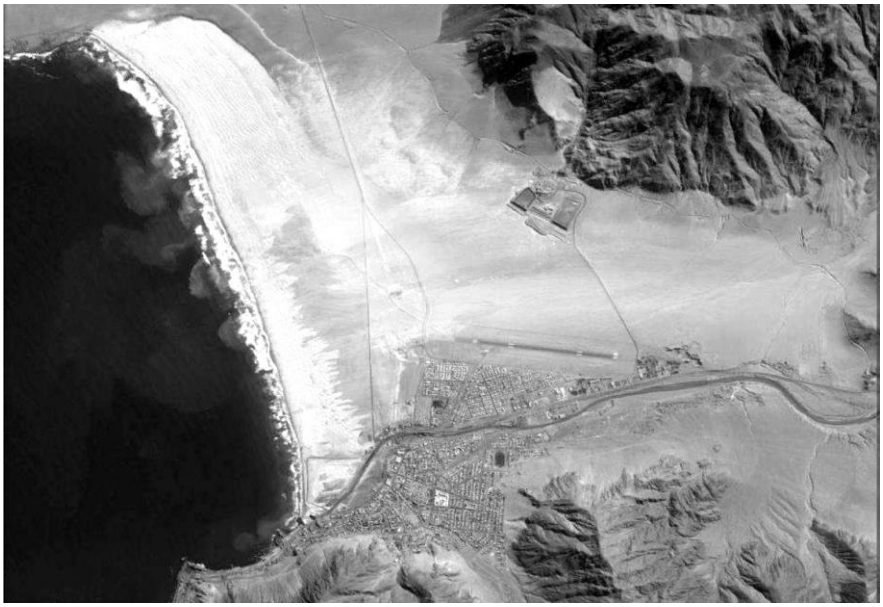

Figure 79: Satelital Picture Chañaral July 2013 .Source: Google Eath.

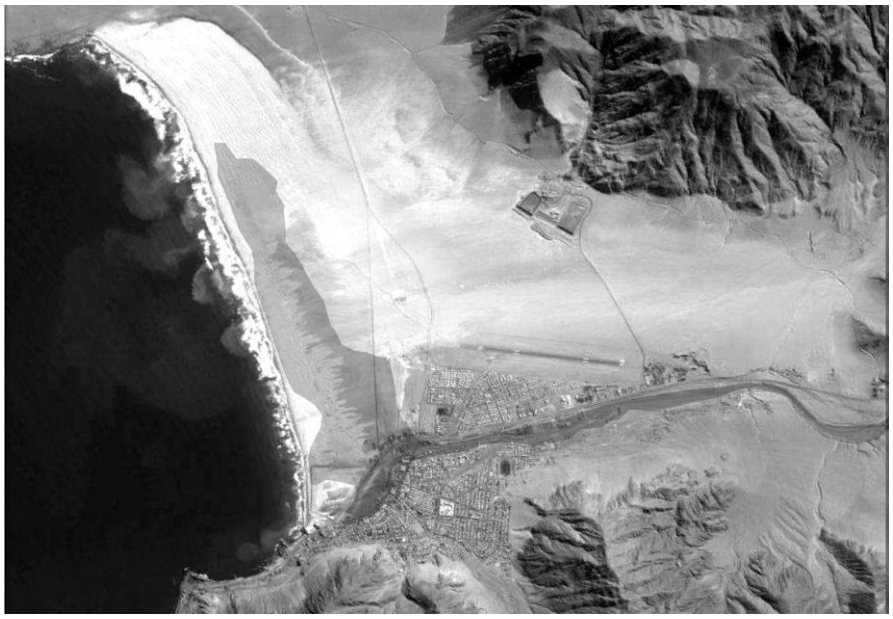

Figure 80: Satelital Picture with the flood. Own elaboration.

Figure 81: Satelital Picture Chañaral. April 215. Source: Google Earth

Figure 82: One of the pictures of the tragedy 25M. We can see the strength of the water. Source: biobiochile.cl

Figure 83: Picture of the 25M. Source: TheClinic.cl

Figure 84: One of the pictures of the tragedy 25M. The day after. Source: biobiochile.cl

Figure 85: The tragedy. 25M. Source: https://issuu.com/siss_chile/docs/25m.aec

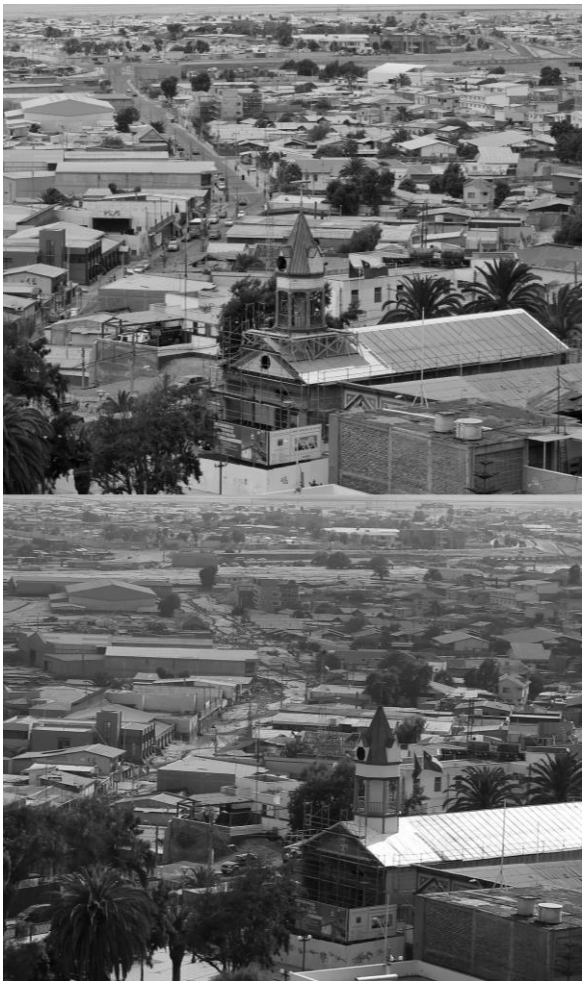

Figure 86:Before and After 25M. Source:Theclinic.cl

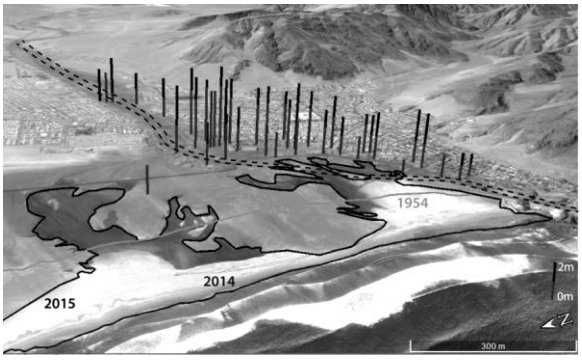

Figure 87: The lines show the height of the flood, the highest lines show the 4.2 meters high and the minimum of 2 meters height. The purple line shows the line of the coast before the 25M. Source: Fabiola González.

Figure 88: Map of the disaster of Chañaral. Source: Victor Grijalba's thesis.

In extension it reached a length (east-west) of 3,3 km dividing the city in two arriving at the sea where it would reach about 4 km bordering the coast. In some cases it reached 3.7 meters in height.

The quantity and strength of the water was able to sweep away different types of vehicles and houses.

3.1.2. The day after the tragedy

President Michelle Bachelet reached the epicenter of the problem on March 25. The mission was to restore all basic services. In Chañaral the northern sector had run out of drinking water as a result of the flood and the sewage system had been destroyed, but it was quickly repaired by means of pit-cleaning trucks. The days were complicated when the mud solidified, since the cleaning of the sector required more complex machinery and a greater work force.

The SISS was in aid in the most complex places, in total they were 422 days without rest cleaning the zones, it was a task that of course required the military aid and of the municipality.

The first actions were to clean the collectors, the armed forces were initially in charge of the sector of El Salado, especially the sector close to the bay, which was the commercial zone.

On April 1st of the same year, Minister Alberto Undurraga summoned all the agencies in charge of cleaning, who together with Aguas Chañar and SISS drew up a plan for quick and efficient cleaning.

Three days after, the largest sanitary cleaning plan that Chile has ever had begun, cleaning main, secondary and household collectors. Trucks were used to clean pits in coordination with the SISS and later with the help of the government's Directorate of Hydraulic Works.

Finally on May 15th, clean-up work was completed throughout the country. Leaving all inhabitants with basic services[19].

Figure 89: The day after the tragedy. Source: https://issuu.com/siss_chile/docs/25m.aec

Figure 90: Level of mud (red line) and level of flood (blue line). Source: Fabiola González.

3.2. History of Floods in the región.

It is not the first time that misfortunes such as floods occur, the following dates are all events related to floods in the region of Atacama [20]:

1655: Temporal Nantoco(212 km from Chañaral city) 1746: Storm and alluvium Paipote and Nantoco. 1878: Flood in Chañaral. 1879: Flood in Chañaral. 1883: Flood in Chañaral. 1888: Great flood Copiapó and yellow earth. 1900: Flood in Chañaral. 1905: Flood in Chañaral. 1906: Flood and alluvium Vallenar and Huasco. 1922: Tsunami. 1922: Big storm in Copiapó, Paipote and Tierra Amarilla. 1940: Alluvium in Chañaral. It affected two cities of Chañaral, cutting roads and communications.	1953: Rainstorm and nine in Copiapó and Vallenar. 1972: Winter Altiplánico El Salado. There was rain and even snow in the area. Flood problems. 1,8 meters height of the River level. 1983: Alluvion. July 1st. It affected 6 cities, including Chañaral. 85 victims in Chañaral. 1991: Flood. June 19th. Overflow of the Salado River,Chañaral. 147 people affected. 2 meters height of the River level. 1997: Temporary higher rainfall in Copiapó and Chañaral. 2015: Flooding in Chañaral, Tierra Amarilla, Paipote, Copiapó and Diego de Almagro. Average of flood heights was 2,7 meters, and 4,2 meters height was the maximum of the river level. 2017: Flood in Chañaral. 150 houses destroyed by the flood. 2 people died.

What differentiates the 25M alluvium from the rest of the alluvium is the way the river flows, all the tributaries are concentrated in a mouth that caused the disaster.

[19] According to the book: 25M. Atacama Estado de Catástrofe. 2015. SISS.

[20] These dates are according to the research “Estudio Más allá del Barro” and “Aluviones y Resilencia en Atacama”.

Figure 91: Chañaral 1972. Flood. Source: Nelson Olave.

3.3. Public Opinion

"*I never thought the magnitude of this event*"[21] said the mayor of Chañaral, Victor Volta in 2015. In the same interview he also said that "*Always when there is a catastrophe in Santiago there are good and fast solutions but here we are waiting for months and nothing happens, we are not going to anywhere, why should we leave this place if the government did nothing*?"

The ex-director of ONEMI, the public organism of the government related to national emergencies, he said that "*they (Chañaral) did not do preventive actions of mitigation to prevent this chaos, and it will be good to think in politics from the government and not do small solutions*…".[22]

Neighbors indicated that they were concerned about contaminants found in the river as a result of the alluvium and that later reached the beach by the same river[23]. Some neighbors claim that the cases of health problems caused by 25M have increased, where many people with respiratory and skin allergies can be counted, all of this information in the same interview with the workers of the government.

The residents of Chañaral have asked that the degree of contamination of the beach waters be examined, but the Chilean Health Council, which was supposed to analyze the situation, has not carried out any investigation into it. It is known by neighbors that trucks carrying sulfuric acid that were parked were knocked down by the 25M alluvium.

The government has taken action and can be read in chapter 4.4.7.

3.4. Causes of the disaster.

There are many causes of the flood, it is not just a topic related to an unusual storm, and it is related also to the existing master plan of the city and the geography of the place.

After this tragedy the government did some actions of the city which also it will be explain in this point of the master thesis.

3.4.1. Master Plan.

According to a technical report by the government, there are several causes related to the city's Master Plan (Figure 42):

- Indefinite river routes that did not have the requirements to receive strong water flows, which at that time were occupied by railway lines, streets, etc.
- The reduction in the width of the river due to the installation of housing.
- There were no solutions to channel the flow of streams to the terraces.
- Residential areas were close to the river, at a distance prone to damage in the event of a river flood.
- Absence of works to channel the flow of the river.
- Fluvial bridges without the required width and height in the event of an eventual flooding of the river.
- Lack of control over the state of the banks of rivers and streams.

[21] Source: biobiochile.cl/noticias/2015/03/25/rio-el-salado-arrasa-pueblo-cercano-a-chanaral-tras-desborde.shtml

[22] Source: eldefinido.cl/actualidad/pais/8548/Mover-Chanaral-La-polemica-de-su-reubicacion-tras-los-aluviones/

[23] Source: Informe mission copiapó.

- The risk area exceeded the risk area defined by the Communal Regulatory Plan.
- The industrial area is very close to the river, and there was no good protection for them in case of a river flood.
- There are no decanting pools or an element that mitigates a possible alluvium in the design of the city. In Taltal there are decanting pools and it mitigated a flood quite a lot.
- The streets that cross the river north-south are not very wide streets increasing the height of the flood and their orientation was a problem because they acted causing the river, whose direction of the alluvium must have been to the west.

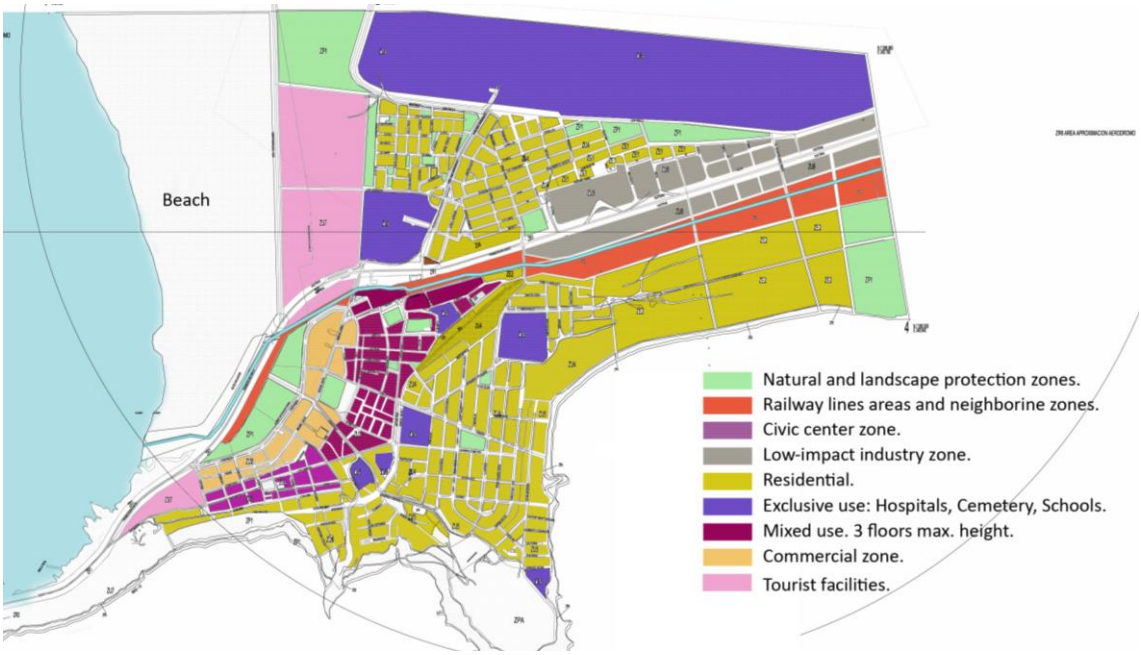

Figure 92:Master plan before 25M. Source:Plan Maestro Chañaral

3.4.2. Unusual rain.

What happened on 25M was a storm from Coquimbo to Antofagasta, with precipitations further south and towards the mountain range causing floods and river overflows, in this case the El Salado River.

The precipitation accumulated in the high mountain range of Chile and also in Peru and Bolivia from the 24th to the 25th of March. The storm of the 24th was key, the amount of precipitation was such that it managed to generate a movement of sediments from the high pre-mountain range. In fact, this fact was a trigger in the disaster, since the location of the storm in this sector (high pre-mountain range) added to the great existing slope was a fatal combination. This movement would move to the east. Precipitation exceeded 25 mm. This storm is the most extensive in northern Chile since 1980, where water vapor levels were extreme. At this time anomalies also occurred in other parts of Chile, the highest surface temperature in Santiago de Chile since 1877, 36.8° on March 20, 2015 and in turn high temperatures in southern Chile.

The explanation of this phenomenon according to the Chilean geologist Victor Grijalba: "This is associated to the extreme temperatures in central Chile with an anomalous high pressure located in the lower troposphere (layer of terrestrial atmosphere that is in contact with the terrestrial surface) and a descending flow from the east".[24]

[24] According to the chapter 2.3.4. of the thesis of the geologist Victor Grijalba: “Geología y análisis histórico-meteorológico del aluvión de marzo 2015 en Chañaral, Atacama”.2015. De acuerdo a las Alturas del lugar, donde se produce una pendiente fuerte es en el acceso a chañaral desde el este, luego la pendiente disminuye y es donde se producen los mayors asentamientos de desperdicio y barro.

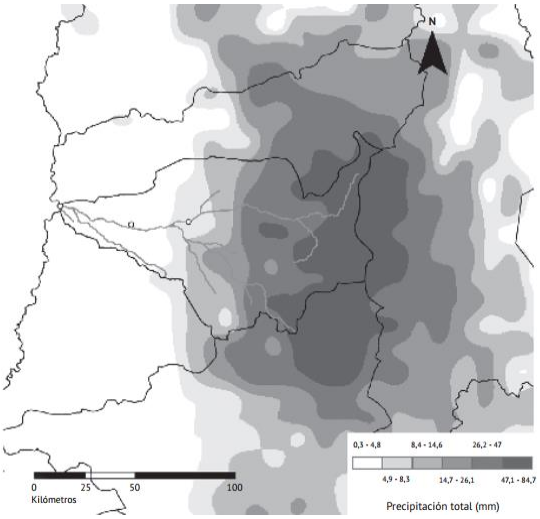

Figure 93: Raining distribution in the region during 25M. Source: Proyecto Chañaral UC.

The precipitations in the region of Atacama and in Chañaral historically have been very scarce, the normal thing is that in the zone rains 1,7 mm in the year, but due to the climatic change together with other factors already described, the precipitations have increased to the point of considering them as "high precipitations", since one considers a high precipitation between the ranks 30,1 to 60mm per hour, what happened the year 2015 surpassed the 50mm, in other words, the year 2015 rained the equivalent to 12 years of "normal" rain of the city.

Below is a sample of the most relevant Chañaral rainfall records.

1890: 21.5 mm

1926: 32.2 mm

1929: 31 mm

1930: 39 mm

1932: 21 mm

1940: 29 mm

1946: 21 mm

1969: 25.1 mm

1983: 11.5 mm

1991: 41.6 mm

2015: 50 mm - 90 mm

2017: 45 mm

3.4.3. Geography.

According to a study conducted by Chilean geologist Victor Grijalba, the flow of destruction reached an area of 2.75 km2, with a north-south extension of 4 kilometers and east-west of 3.3 kilometers. There are differences in levels that caused an increase in the strength of the alluvium.

The different streams converge in a single river, the Salado, accentuating the water levels caused by the alluvium. If the river had a mouth in several points, the problem would have been not so serious. The impact it has is direct on the influence of the extent and deposits of the alluvium.

The soil is not very permeable and the large amount of exposed rocks were vital to aggravate the disaster.

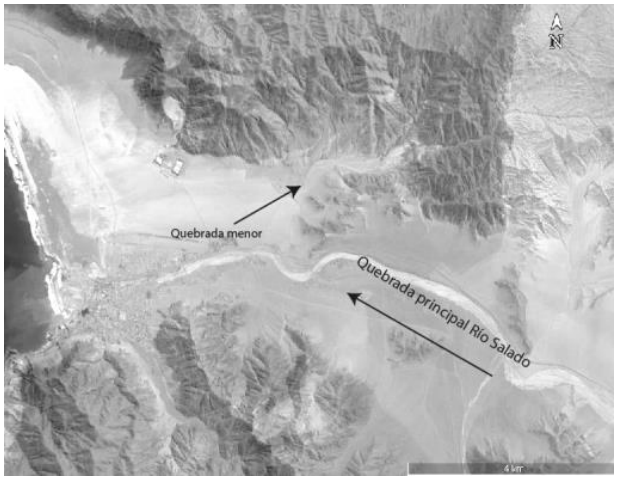

Figure 94: The Gullies in Chañaral next to the river. Source: Grijalba.

3.4.4. The river El Salado.

It has a great slope that has a break from the Pre-Cordillera to the Central Depression, generating a considerable difference in level of 1800 meters in 40 kilometers, causing a great flow of alluvium that flows into the coasts of Chañaral.

Another key factor is the contribution of another source of water from the Domeyko mountain range, located to the north, which in the 25 M increased the flow of the river, which being a single river without divisions to the coast or elements that retain the water, produced the consequences that we already know. It is important to mention that in this sector there is a lot of fine material that contributed to strengthen the alluvium, cutting roads upstream.

3.4.5. The Climate Change.

A study carried out by the Department of Geophysics of the University of Chile (CONAMA 2006) confirms that significant changes have taken place in Chile.

A decrease of precipitations in the subtropical region of Chile an increase in the northeast sector, however, in the decade of 1940 the temperature has been maintained according to the season, this situation was maintained until the decade of 1970, this is associated to a change of phase of the decadal osylation of the Pacific.

With respect to the future, the study assures that the changes in temperature and precipitations will be greater and this is reflected in the different emissions of gases with the known greenhouse effect. So this effect will cause an increase in temperatures. In the region of Atacama it is predicted that in the future, the summer will increase in temperature from 2° to 3°C in all climatic zones and 5° in the Andes mountain range. The increase in temperature leads to greater liquid precipitation, melting of snow and reduction of glaciers and a temporary and seasonal increase in river flows.

As for the effects of these climatic changes, the precipitations will affect the vegetal cover, reason why the landscape as it is known in the Region of Atacama, will change. The mountainous topography would change, so it can cause the extinction of some migratory species, therefore it is suggested to create microclimates in order to conserve biodiversity, it is also suggested (Arroyo in his book "Global Change: Flora and vegetation of Chile. 1993) the change of land use for the preservation of native plants.

The event that took place in Chañaral, 25M, the formation of alluviums in this arid zone was due to the great amount of common precipitations during the phenomenon of "El Niño", that in a month like March for the region of Antofagasta was unusual, generally there are floods of the river with the well-known "Bolivian Winter" and it is in the middle of summer. This is added to a drop in the Anticyclone and if we add it to the aridity of Chañaral this alluvium is understandable. It is not the first time that a flood has occurred as a result of the effect of “El Niño”(the boy) phenomenon, in fact the last floods are associated with the action of "El Niño". In the 1983 alluvium the storm was between June and July, and there was also the influence of "El Niño", however, an important component that changed the intensity was the effect of the SST, since the SST (sea surface temperature) managed that the 1983 precipitations did not occur at great altitude and therefore there was not accumulation of as much fine material as in 2015.

Victor Grijalba assures that there is a connection with **climate change** to express the high numbers of this phenomenon of "El Niño", which in Chile, for that year due to these abnormal characteristics was colloquially called "El Niño Godzilla" (Godzilla Child). The effect of global warming was apparently vital to generate these increases and unfortunately, forecasts expect that these anomalies in the TSM will repeat in the future, so it is appropriate to think of a preventive response.

Figure 95: A graphic about 25M. Source: https://issuu.com/siss_chile/docs/25m.aec

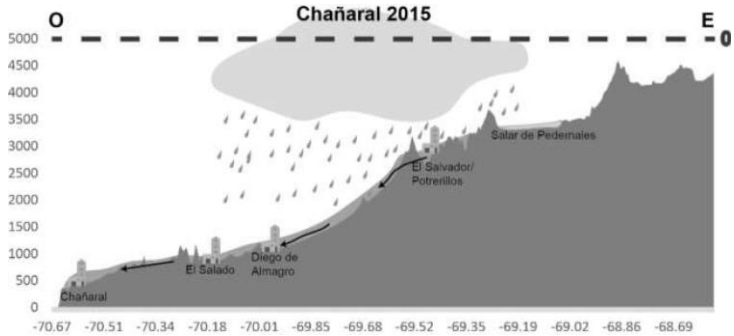

Figure 96: A graphic explaining the location of the rainfall and the transition of the water to the city, Chañaral, in 25M. Source: "Geología y análisis histórico...". Victor Grijalba. 2016. Chile

3.4.6. Pollution and Flow composition.

The alluvium occurred on 25M was not just any alluvion, it did not contain only rainfall water, there were about 600,000 tons of mud that reached the shores of Chañaral. The following analysis will highlight the components of the alluvium and how they portray the problems that exist in the area that aggravated rainfall in the high mountain range.

Alluvial deposits can vary, generally defined as a mixture of water and high density sediments where the mudflows are composed of a fine grain matrix that makes the flow viscous.

According to Victor Grijalba: "Unconsolidated and semi-consolidated deposits are the main source of material transported by the alluvium."

Another factor to consider, according to Grijalba, is the erosion of the slopes near the river, which as a result of the rains served as transport and source of material for the alluvium.

It is very important to consider the strength of the 25M rain, added to the weakness of the slopes are very important because the alluvium when reaching the central depression already carried much sediment according to studies.

Citizens confirmed that the overflow of the El Salado River carried mineral waste accumulated over decades and debris from abandoned silver and gold mines containing toxic substances.

These abandoned mines date from before 1950 and by a Chilean-German company, the Potrillo and El Salvador miners deposited in the bay of Chañaral more than 220 megatonnes of mining waste between 1925 and 1995, causing the UN to declare Chañaral as one of the most worrying cases of marine pollution in the Pacific. Until now, there are still cases of contaminated people, this was measured through urine samples in elderly people.

Among the components that can be declared is the presence of Copper, Zinc and Arsenic, causing pollution in the air, soil and water.

If we consider the aridity of the place, the solid material of the alluvium, when losing humidity dried up and originated fine material that rose like dust due to the wind and this irremediably enters in contact with the people.

Studies carried out by CENMA in 2016, indicate that the metals found exceed the natural levels in the deposited dust that can be in contact with people, causing damage to the health of children and pregnant women.

This problem dates back to 1938, when the U.S.-based Andes Copper Mining Company began dumping copper tailings into the sea via the El Salado River and eventually modified the city's coastline. After some modifications made by the company, such as changing the final destination of the tailings, the commune of Chañaral sued

CODELCO[25]. Only in 1980 for all the ecological disasters they had carried out in the city. As a consequence of this, the company was forced to create tailings dams, but no compensatory measures were defined for the inhabitants for the damage caused by decades.

It is understandable by so many years of waste thrown into the sea, that the quality of the soil and the sea is so deteriorated and also the city to be near wind turbines, receives particulate matter by the air. The sector close to the airport is still one of the most affected, some projects have been proposed vegetation cover near this area[26], in addition to foresting 1200 trees in 2009 with a successful result. Other projects in this area have been mentioned, but they have been postponed until the moment of being forgotten, in order to prioritize smaller coastal projects.

It is understandable to speak of inequality with Chañaral, a city that lives in constant threat due to pollution but receives little support from the government to reduce these rates of imminent danger to the population. Chañaral is still a poor city, and can be seen in the quality of public spaces.

In 2012, studies were conducted that confirmed that the residents of Chañaral suffered from respiratory and cardiovascular diseases caused by the inhalation of metals in the air. One of the brutal consequences demonstrated was the presence of small metals in the residents' urine[27].

Most of the toxic waste thrown into the sea can be seen in what is now the Bay of Chañaral, have emerged projects such as the green beach, an attempt by the mining industry to decontaminate the beach of Chañaral that is still waiting to start.

As an observation, it should be stressed that not only should action be taken in the area of the river, which is the most conflictive area, in order to clean the quality of the soil, it is important to implement natural elements that trap dust particles such as trees and shrubs, to reduce the likelihood of contamination of the population by air.

3.5. Actions of the government

In Chile natural disasters such as tsunamis, earthquakes, volcanic eruptions and floods are common throughout the country's history, and these disasters alter the condition of the territory and therefore modify the regulatory plans in Chile, there is a new need to give order to provide security to the inhabitants after the catastrophe.

As PhD Horacio Torrent points out in his article " Disasters and the forms of legitimization of urbanism in Chile, in the first half of the twentieth century " the tragedies proposed at least three approaches in this field:

- **The gradual construction of the urban information base**. Risk prevention was key and cadastres were carried out that were vital for the prevention of disasters. For example, the Valparaíso catastrophe of 1906, probably one of the worst earthquakes, with a magnitude of 8.2 on the Richter scale, was surveyed. The registers of the Osorno fire in 1936 were vital to establish the methods of short wall fire and the regulatory plan that was subsequently established.

- **The gestation of a legal regulation aimed at prevention**. According to Horacio Torrent, its origins are recorded at the end of the 19th century in Chile, but it was the disasters of the Valparaiso earthquake in 1906 and the Talca earthquake of 1928 that encouraged the need for the existence of norms that would give prevention to the city.

- **The definition of institutional structures of instruments for the reconstruction and control of future urban development**. It was the Talca earthquake of 1928 that triggered the creation of institutions that generated instruments for urban control. It was in the 1936 ordinance when catastrophes, referred mainly to measures against fires, were recently named until after the 1939 Chillán earthquake, the norm was changed, orienting itself more towards building. In the 1960s it changes again to have an objective to respond to catastrophes and to give an impulse to the accomplishment of regulatory plans.

As Torrent says, with each new catastrophe new government agencies continue to be added to prevent disasters, this is how Chile has become a reference when talking about resistant earthquake constructions, and how despite earthquakes of magnitude greater than 7.0 on the Richter scale, after a few weeks the city returns to work, while in

[25] CODELCO: Corporación Nacional del Cobre.

[26] Source: “Chañaral: Un problema insoslayable”.

[27] Source: Proyecto Chañaral UC.

other countries it is total destruction. However the disaster caused by the 25M, took a long time to return to normal and so far there are no reconstruction projects in the area to economically lift the area.

From the 25M there are some actions from the government in different areas:

3.5.1.1. Political actions – Territorials.

After the 25M, the government proposed transitional risk areas called critical zones, which were damaged by the 25M, communes like Chañaral, Diego de Almagro, Copiapó and Alto del Carmen. In these zones, no houses or works can be built except for mitigation works.

A safety level was defined between 7 and 10 meters above the highest tide line. The estimated width necessary to lead the river will be 100 meters to the mouth of the river by the streets Salado and Merino Jarpa as shown in the graph below.

There were no problems in drinking water services in the area.

Figure 97: Map of critical zones in Chañaral. Source: Informe técnico det.zonas críticas localidades afectadas por fenómeno hidrometeorológico 24, 25, 26 y 27 de marzo. Comisión interministerial ciudad, vivienda y territorio. Chile.

Map of critical zones. The red color means the main critical zone in the city of Chañaral.

In terms of housing, the government offers monetary assistance for people who want new housing outside the critical area. People who lost their businesses on Merino Jarpa Street will be considered in a boulevard project located on the same place. The government will not help repair homes and businesses located in the critical area, the idea is to relocate them out of it.

As for a new master plan for the city, Renato Caceres, the region's councilman said in 2016: "there is a Master Plan that the government made and we still do not know. We don't know what it brings. It is one thing that we will see".[28].

In 2016 mayor Volta referred to the delay of the master plan and its cost: "I will not put the signature to something that costs 250 million Chilean pesos and that for now does not satisfy us". As he said they have not seen a particular project during his administration.

In 2017 the mayor of Atacama proposed to relocate the houses destroyed by the disaster and give a bonus of 1 million Chilean pesos for those who lost materials due to the flood.

For the cleaning of Chañaral, the Mayor began a proposal for cleaning in different points such as El Salado, Barquito and the coastal edge, in order to "beautify the city". In the year 2018 the works of cleaning continue in the city, as to continue retiring rubble in some zones.

[28] Source: semanario7dias.cl/index.php/2016/04/14/muchas-criticas-y-cero-propuestas-sepa-que-piensan-las-seis-cartas-que-se-presentaran-a-las-elecciones-municipales-de-octubre/

Figure 98: Before(2015) and after(2016). Source:elquehaydecierto.cl/noticia/sociedad/atacama-se-sigue-parando-luego-del-25m-hotel-de-chanaral-se-sacude-el-barro

As for cleaning the beaches, at the end of 2018, a new mining project called "Green Beach", cleaning the tailings to rebuild the beach, removing the content of copper and arsenic that are currently present according to a report delivered by the same company in 2017.[29].

3.5.1.2. Economical actions

In October 2018, after 3 years of the 25M, the government selected Chañaral as one of the 10 localities in Chile, to invest 1.5 billion of Chilean pesos [30] to improve the city and rebuild it. However, it has not been said which areas will be intervened.

3.5.1.3. Security

The ONEMI[31], an organism of the government for emergencies made zones of protection for eventual tsunamis and floods. The design of this zones is based on the worst disaster of the place, in 1922, a tsunami with an earthquake. They considerate the topography of the place.

Figure 99: The map that shows the safety zones as a green line. The blue dots means meeting points. This map was done by ONEMI in 2001.

Another government security action was to mitigate existing abandoned mining areas, and remedy damage caused by particulate matter, in Chañaral there are 6 abandoned mine hotspots, of which 1 is active.[32] However, in a report

[29] Source:cooperativa.cl/noticias/pais/region-de-atacama/playa-verde-asi-es-el-proyecto-que-divide-a-chanaral/2018-10-31/075207.html

[30] Source: goreatacama.gob.cl/2018/10/28/gobierno-invierte-1500-millones-en-chanaral-para-obras-de-mejoramiento-urbano/

[31] ONEMI: Oficina Nacional de Emergencia del Ministerio del Interior (The National Emergency Office of the Ministry of Interior)

[32] According to the report: INDH – Misión de observación de las comunas Copiapó, Tierra Amarilla y Chañaral, 2015. Chile.

submitted in 2011, it was described that there are 199 mines in the area linked to the extraction of copper, gold and coquina, of which 122 are active. This is so as not to generate more pollution in the air and water as commented in point 4.4.6 of this Master Thesis.

3.6. Commemoration of 25M.

Each year, the 25 May 2015 flood disaster is commemorated. Masses are held on May 24th and 25th at Nuestra Señora del Carmen Church.

Figure 100: There are many activities during these days to remember the 25M. Source: atacamanoticias.cl/2018/03/27/con-profundo-recogimiento-la-comuna-de-chanaral-conmemoro-un-nuevo-aniversario-del-25m/

3.7. Reflections.

- During the years, the areas affected by alluvions are the same, the banks near the river and the area of the historic center of the city of Chañaral, so a solution must be considered in these zoas.
- Due to flooding problems, drinking water and electricity supplies fail, so future proposals must respond to this problem in new ways.
- Lack of coordination between the different agencies and institutions in charge of emergencies such as floods, cause chaos that does not help solve problems such as evacuating the population in time.
- After the tragedies, the government proposes short-term solutions, which solve urgent problems, but do not solve the underlying problems, such as mitigating the amount of water produced by floods.
- They need an appropriate and dignified space to commemorate the people who died as a result of the 25M flood.
- After many years, it is finally possible to advance in territorial order in relation to the master plan, protection areas are established, changing some residential areas that now become protection areas. However, there is no project for such protection areas.

Chapter IV: Analysis of the city of Chañaral from its landscape structure and evaluation of regulatory plans to establish design guidelines.

4.1. Introduction

The structure of the landscape is what conforms the identity of Chañaral, therefore this arid city we could define it by means of 4 important characteristics: The mining city, the river, the coast and the recreation areas, the latter being an indicator of the style and quality of life that the residents of the commune currently lead, but first it is necessary to analyze the organization of the city after the 25M, the current Master Plan.

4.2. Analysis of the current Master Plan and zones next to the river.

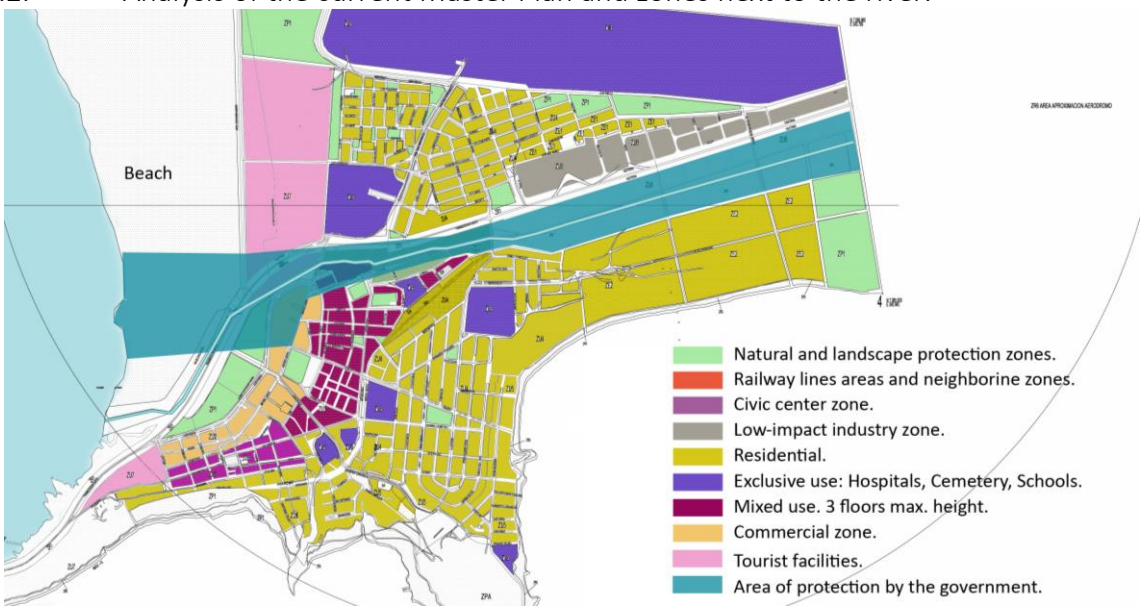

Figure 101: Current Master Plan 2005 with the area of protection. Source: Own elaboration based on data from the municipality.

Figure 102: Areas and zooms to analyze. Own elaboration.

Zoom 1 Zoom 2 Zoom 3 Zoom 4

There are abandoned areas considered as "residential", however they have a historical load, like old train lines that were part of the first miners of Chañaral. This thesis will raise the importance of using these heritage areas and valorize them. In its beginnings it was a meeting point due to the arrival of the trains, this condition could be taken advantage of in the design of the park.

An important aspect is to consider the security strip that exists today decreed by the government and that does not appear in the master plan or as it is called in Chile "Communal Regulatory Plan". The security strip would eliminate low-impact industrial zones near the river, so the government will have to relocate these zones. The east-south zone is striking, with a residential zoning but little mixed use dedicated to commerce, which causes a concentration in the west zone. It is suggested to create more commercial zones if the objective is to carry out an urban renovation in the sector.

As we can see in the image above, after the 25M the uses have not changed and the priority of the government is to work in the area near the coast, as it was the most damaged by the alluvium creating a future boulevard. In 2017 there was another flood that did not cause deaths, however the flood repeated itself.

You can see a great difference of uses in the north and south until today there is no meeting point, currently is the millennium lighthouse located in the south of the city. The city is delimited by its geography and has only one commercial area without a clear route to follow, considering that most people move by bicycle.

4.2.1. Safety and security zones.

So far the government has reported on a study carried out in the area as already discussed in chapter III, in the chapter on "government actions", and established a much larger security zone as can be seen in the figure above. So the industrial zone will be displaced and relocated in the city, so this zone is available for future flood mitigation projects.

It is also intended to regenerate the commercial area with flood mitigation measures related to a possible alluvium or a possible tsunami.

With this space for the protection of the river, a favorable place is established for the meeting of the community that was needed, also shows the close relationship that would have with the residential sector.

Now there is a closer relationship between the river and the coast, a direct visual relationship that would also allow a good tourist circuit and integration of tourists into the mixed use sector that would potentially be oriented to tourism and in turn is an opportunity for residents of the commune to integrate to the coast in an integrated manner.

The vehicular roads are still the same but have the potential to include cycle roads and also pedestrian roads that connect to the edge of the river.

The potentials of the zones are described below according to the needs and problems already explained in chapter III. The analysis will be made by dividing the main overflow zone of the river into four zones that currently do not contemplate plans by the government, they are only being as a protection sector, instead the southern sector of the protection zone is already destined as a large boulevard, as explained in chapter III.

Zoom 1: In the area where the city of Chañaral begins, it is necessary to carry out water containment measures to prevent the effects of a possible alluvium as soon as possible.

We can see that there is a protection zone according to the master plan, but there is no intervention in the terrain, there is no edge that defines the protection zone. Over the years, the northern sector has expanded more rapidly than the southern sector.

Zoom 2: The southern area can be considered as urban renewal, there are already several buildings that demonstrate this, despite being far from the mall the area is still of interest to build low social housing (no more than 4 floors). There are currently no connections to the northern sector from this area, and due to the alluvium, most of the areas considered as low impact, were washed away by the river.

This zone due to the proximity and lack of sports areas in the zone and the location away from the tourist zone is well located for a space with infrastructure for recreation and sport.

Zoom 3: This zone is more urbanized compared to the previous one, however, the edges of the protection zone are quite sad, on the north side there is a fuel station and other shops, on the south side there are houses that managed

to survive the alluvium, however in this zone you can already see vestiges of houses razed by the overflow of the river. This area also connects with what was once a small mining train station. We could say that this area is quite quiet, however being one of the largest areas, is exposed to dust pollution in suspension, having no natural barriers near the river.

Zoom 4: In this sector connected more with the commercial area, with the coast and as an entrance from the coast to the interior, it needs to be attractive for tourism, and therefore must offer good infrastructure for tourism. so this semi privacy could give way to a memorial for the people who died in the 25M and civic square to summon and unite the residents, it is also close to the sector where previously there was a train station, part of the history of Chañaral. Also in this area we can see what were once houses, which disappeared due to the alluvium. You must consider this area with respect and establish a destination according to the history of the place.

4.2.2. Zones exposed to the pollution.

Areas exposed to air pollution. The Chañaral terrain has high rates of metals found in laboratory samples around the river and near the Airport. The city has been exposed to mining waste for more than 50 years and the inhabitants of Chañaral have reflected their displeasure to the authorities. Air pollution is very present, and residents have put things in place to trap the polluting dust, especially near the airport. This problem is aggravated by the lack of sufficient trees and vegetation.

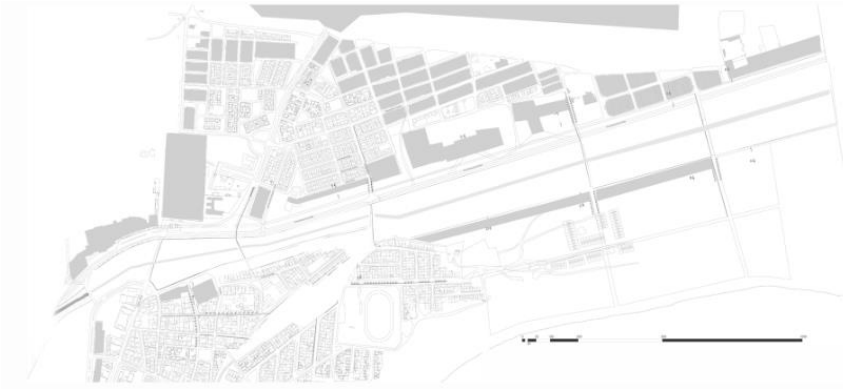

Figure 103:Areas exposed to pollution. Own elaboration.

4.2.3. Buildings and places related to the heritage.

Today there are not many old buildings that can be considered as heritage, however there are Christian and Presbyterian churches of great heritage value, buildings located in the civic center and also vestiges of the old train station, all this located in the south of the city, while in the north there is the nursery and cemetery of the city, of great historical value for the city.

Figure 104: Map with the places related to the heritage. Own elaboration.

4.2.4. Transportation

As already mentioned, there is no public transport, only "colectivos", which is a kind of taxis, their route can be seen in the image below as "local transportation", and they connect mainly with the civic center, bus stations and the airport.

Figure 105:Transportation. Source: Plan Maestro Chañaral + own elaboration

4.2.5. Green Areas.

The green areas are not the typical green areas due to the arid climate, however the few trees are located in houses or private buildings, the squares have very little vegetation and infrastructure. The area with the most trees is the city's main square. The region has a wide range of shrubs, trees and grasses that require little maintenance and are resistant to drought, however there is no such variety in the city. The park "Pan de Azúcar" contains great endemic vegetation, however this vegetation is a product of the coastal fog that occurs at a certain altitude above sea level.

Figure 106: Green areas. Own elaboration.

4.3. Landscape Structure.

4.3.1. The mining city.

The city is based on mining, which is located in the northern sector, where the homes of the first mining workers were located. It is now known as the historic center of the city with a historical and cultural interest.

This sector has the condition of a mining town, which has resulted in high levels of contamination.

The current communal regulatory plan of the city allows urban growth around the river, which explains the number of houses razed 25M, there are no mitigation areas to protect people. The river further divided the northern and southern sectors. These sectors are connected by the river, which would be a nucleus that produces a clear disconnection, the relationship of residents with the river is more to evade a natural element rather than come into contact with the river, and therefore there is no identity in the place. Product of the alluvium the river became even more polluted, as is counted in the chapter on the effects of 25M.

At present it is not easy to distinguish the main roads connecting north and south in the city.

The city from its origin, as already mentioned, was the discovery of the mine "El Salado", which was enhanced with the connection with the coast, so a port (inaugurated in 1836) in response to this new economic opportunity was the detonator to the conformation of the urban fabric of Chañaral.

As can be seen in the image of the city, Chañaral is limited by its geography, which we can see in the topographic image in the Geography chapter of this Master thesis.

Since then, the growth of Chañaral has not had a fixed pattern, growing towards the west and towards the south, as can be seen today in the image of the city. In 1968 the small airport of Chañaral was created, separating the city in two powered by the already existing river "El Salado", which explains again the disaster of the 25M. Until now the airport continues being the northern limit of growth.

As explained in the Economics chapter of this Master Thesis, the city has been strengthened in its condition of economy of services towards the road and began to be more densified on the edge of the river El Salado, that is to say to the center and not on the coast. The coast has been damaged by the various acts of pollution, so tourism remains a good niche to promote.

The architecture of the city in general is characterized by a height of no more than 2 levels in the residential sector, with no front yard forming a straight line. Both north and south have the same morphology and structure.

Figure 107: Houses in the North and the south of Chañaral. Souce: Google Maps.The civic center was built in 1898, the constructions related to commerce are not complex, and however the two churches that are in front of the main square of the city stand out and that in addition are connected visually with the "lighthouse of the millennium", an important milestone in the city of Chañaral. In the civic center is also the municipality, police station, restaurants and banks.

4.3.2. "El Salado" River.

El Salado River currently divides the city in two, the northern sector characterized by the city hospital, the cemetery, the airport and the church San Pedro, while in the south we can see the Luis Alamo Stadium, the bus station, the millennium lighthouse, the main square of the city. Currently there are streets that cross the river and connect the north and south: Jorge Rivera Street and Julio Montt Street. The main street that accompanies the route of the river is Panamericana Norte Street or Route 5, which connects Chañaral with the North of Chile through the interior, since Chañaral Pan de Azúcar Street is born along the coast.

The city is disconnected from the river, has no sense of belonging, leaving this sector as an abandoned site and little maintenance, so it is important to revitalize this area, make it attractive when investors are needed in the future.

Currently, the area of the river resulting from the 25M alluvium is under protection, that is, the government prohibited the reconstruction of damaged homes in that area, as explained in the chapter on "government actions", to prevent another tragedy. As a result of the alluvium, many shopping centers disappeared. The edges of the river are not exactly effective at the time of an emergency like a flood, the lack of a design that manages the possible floods is evident, and there are no green areas to mitigate an eventual impact. Leaving the river untreated could further accentuate the polarization of the city.

4.3.3. The coast.

The coastal condition of Chañaral, presents a danger in the event of a tsunami, and the height above sea level, there is only one evacuation plan present in the chapter "Government Actions". Compared to other coastal cities in northern Chile, Chañaral does not have adequate infrastructure.

Currently there is a good connection between the bays and the commune, however there is not good maintenance by the municipality. The coast is strengthened with activities related to nautical sports and to the south. With respect

to the uses there are different localities that are not linked to recreation and arise as a small port dedicated to fishing.

4.3.4. Recreational areas.

The public recreation areas in the urban area of the city are mainly small squares. In total there are 7.9 m2 of recreation areas per inhabitant in a general analysis of the public recreation areas consolidated within the area, which is well according to WHO standards (10 m2 of green areas per inhabitant).

However, there are no large meeting areas for festivities, announcements, etc., nor is there good access to green and recreational areas. Therefore, although the index of green areas is good, access is not, since the location of these is not very convenient and the type of square that exists is not very conducive to the stay of users considering the arid climate of the area. There is no infrastructure to protect from the sun in the squares and there are no trees so these spaces are not attractive for residents.

There is also little concern for the residents, which could be explained by the design of the squares, which are not friendly in their design and with the heat of the north and without trees or any element that protects children's games from the sun, for example, the residents did not develop a sense of belonging to these squares. The lack of public spaces and the decrease in work in mining companies is generating an increase in migration every year.

The following map shows recreational areas such as squares and also recreational points such as the Millennium Lighthouse, where parties are held, or the small city stadium. Several squares can be seen, however the infrastructure is precarious for a climate as arid as Chañaral. You can also see the great barrier presented by the river, separating the city in two. There are no recreational areas on the edge of the river, the absence of ample places for recreation accentuates the polarization between neighbors, going to the small squares that are nearby, however there is not a recreational sector that is suitable for large religious activities that take place in other cities that do require large square meters. There are green areas in the perimeter but they are too far from the internal urban fabric, and the maintenance and infrastructure is precarious, so it is not attractive for use. Recreational projects on the coast are of good quality but not well consolidated.

Figure 108:Map of Chañaral with recreational areas. Source: Own elaboration.

Figure 109: Plaza de Armas. The main plaza of the city. Source: Google street view.

Figure 110: Cerro Moreno Plaza. Source: Google Street view.

Figure 111. Las palmeras plaza. Source: Google Street view.

Figure 112: Los cóndores plaza. Source: Google Street view.

4.4. SWOT ANALYSIS

4.4.1. Recreational areas

Strengths	Weaknesses	Opportunities	Threats
Natural conditions on the coast to develop nautical sports and surf.	Poor quality public spaces: Most public spaces do not have adequate infrastructure to protect themselves from the sun. Low tourist infrastructure is another factor in public spaces to attract tourists.	The celebrations and festivities continue concentrating great amount of assistants of all the north of Chile like "the celebration of the lighthouse of the millennium".	Decrease in marine fauna. Due to the toxic waste dumped by mines abandoned by fine particulate matter, there are fewer tourist attractions that are attracted by marine fauna.
Landscape value of the environment, which gives a plus to all areas. There is a range of endemic vegetation that makes the places more interesting.	Lack of institutional or cultural spaces for the celebration of religious activities or commemoration of national festivities.	Buildings with heritage value near recreational areas, allows an attractive pedestrian circuit to enhance.	Polarization of cities due to poor pedestrian and vehicular connectivity means that there is no meeting point as a city.
The beaches in the area have good tourist infrastructure, which attract tourists every year, despite the bad reputation of the press.	There is no identity in public spaces, there is no sense of belonging so people neglect these spaces.	Abandoned railway network, is a great potential for public spaces.	Artificial beach contaminated with tailings. Stored for several years on the beaches of Chañaral, despite the fact that several mining companies stopped working, it is still a latent problem due to erosion caused by the sea and wind.

4.4.2. El Salado River

Strengths	Weaknesses	Opportunities	Threats
In an arid zone like Chañaral, the river has the characteristics of regulating the temperature and generating a pleasant space that isolates from the noise of the city.	Image of a non-existent urban river: The river El Salado is only a natural event that divides the city, after 25M, the image of the river is negative, hostile, somewhat threatening, therefore it remains an abandoned area and can later be transformed into a waste area for residents.	There are no concrete projects for the edge of the river El Salado, it is a large deserted area with no function or offer for the inhabitants.	Climate change: According to studies, episodes like the 25M would be more common due to climate change, which implies a new overflow of the river El Salado.
The river is part of the history of Chañaral, related to its industrial context. It connects the mining companies with the port, it is a vestige of the history of the city.	Pollution of the river El Salado: According to the study by geologist Grijalba, there is a great deal of pollution in the river caused by mining waste lying on the ground or by mines abandoned many years ago.	It is a point of connection with important landmarks of the city such as the cemetery, churches, stadium, shopping areas.	Abandoned mines. Due to the 25M alluvium, much abandoned mine material was found.
It connects with the port, which has good infrastructure and continues to function despite the problems caused by the 25M and the contamination of mining waste that gradually lower the level of pollutants due to government control measures.	The river divides the city in two, there is no proposal for integration into the river.	The close connection of the river from the city to the port is a potential tourist route that connects tourists to the city Centre.	Nearby streams: The streams flow into the El Salado River, which increases the chances of overflowing in the event of any unusual increase in rainfall.

4.4.3. Political actions

Strengths	Weaknesses	Opportunities	Threats
Government initiatives to mitigate the effects of particulate pollution in the air. Initiatives such as textile nets in front of the airport have been a success that allows farming to continue.	No proposals have been presented to diminish the polarization that exists in the city between the north and the south, so there are no points of belonging.	Investment of millions of Chilean pesos destined to improve the quality of the city of Chañaral, however there are no projects for the edge of the river.	Airborne contamination continues to be a problem with fine suspended particulate matter containing toxic contaminants. Structures have been installed near the airport to mitigate the impact.
Definition of a security zone by the government. The government has proposed a safety zone in front of the river El Salado where nothing related to housing or commerce can be built.	There is a lack of political will to carry out projects that are on hold; generally no modifications are made that come from previous governments.	Industrial heritage: Chañaral is considered an emblematic mining city, the first copper exports occurred here. Being heritage has big implications for the city's tourism and economy. Reason enough to invest in the city.	Population density has decreased each year, the lack of quality public spaces and the low number of jobs in the mining sector has led to increased migration.
Identification of ground zero. It was established to prohibit housing and commercial constructions.	There are no effective measures to curb airborne contaminants produced by abandoned mining companies.	Residents have had initiatives installing fog traps to capture water from the fog to irrigate their crops.	Latent problem of a new tsunami and an infrastructure not prepared for it.

4.5. Reflections

Chañaral is a small city with great potential to develop, but year after year it does not innovate in attractive and efficient infrastructure for tourism, an activity that will be fundamental with the eminent closure of nearby mines in the future. The El Salado River is an element that has been culturally distanced from the community since it offers nothing for its dry flow and for the nearby infrastructure.

If we add up the political actions taken after the floods, the conclusions we can draw based on this information and which will be vital information for the design process are:

- To change the image of the El Salado river from a potentially threatening natural element to a recreational and friendly place.
- The river should diminish the polarization that currently exists in the area, it should become an area that convokes and unites the community improving the quality of life.
- Infrastructure should be improved for both tourists and residents of the area, especially to protect users from the sun.
- In Chañaral, large festivals are held where people from all over the north attend. However, places such as the lighthouse are far from the center of the city and further polarizes the situation.
- The Salado River should be cleaned up as it has dangerous contaminants for people and has also contributed to the reduction of fauna in the area and the deterioration of the city's coastline.
- The river should be connected to areas of patrimonial value for potential tourism.
- Spaces should be created to retain water from possible alluvium to protect the community. Due to climate change, episodes such as 25M will become more frequent, as was already proven in 2017.
- The government-defined buffer zone should be developed to contain river floods.
- A network of bicycle lanes should be created to link the city, as it is one of the most widely used means of transport by residents.
- Areas that have a patrimonial character such as old disused train lines but that tell the mining history of Chañaral should be promoted.
- The image of a mining city as a tourist attraction should be promoted.
- Areas that are close to the residential area with interest of future real estate, should have an infrastructure that is attractive to investors and also increases the quality of life.
- The use of trees should be encouraged to trap particles in the air that currently cause respiratory problems in residents.
- The connection between the coast and the center of Chañaral should be strengthened in order to integrate the community with the tourist focus of the area and to enhance the space that is destined for protection.

Chapter V: Theoretical framework related to arid zones and the river as an urban element and its importance in the social and cultural fabric. Design references for design guidelines.

5.1. Introduction.

The case of Chañaral is a complex issue that relates arid areas and a river that will gradually have more presence in the city as an element of weight when facing future floods. It is therefore necessary to establish the concept of an arid zone, its possible advantages and how it could become sustainable.

The subject of floodable parks will also be addressed, from the point of view of how the urban water landscape is important and how it is important for the river to take on importance as an urban element in the city.

5.2. Landscape in arid zones.

Chañaral is an arid zone as already explained in the chapter on climate, therefore it requires a landscape proposal that is both adequate and sustainable. To address these issues it is necessary to explain some concepts.

5.2.1. Arid Zones

The concept "arid" may vary in meaning from cultural and historical periods. For example, it may refer to lost areas, but on the other hand it may be culturally and aesthetically rich. In scientific terms, it refers to water scarcity, where plants require special care, as soils may be prone to alkalization problems.

The five main causes and contexts of arid zones are:

- **Subtropical Latitudes:** These are dominated by a high-pressure descending air system that inhibits precipitation by convection. Within the countries with these characteristics we find a: India, Pakistan, Australia, Southern Africa, Southwestern USA and Sahara Desert.
- **Rain Shadow effects**: When air masses meet mountains and these rise they cool, what follows is condensation, and precipitation in the mountains where the wind comes. Then the wind comes down carrying a mass of dry air creating a "rain shadow". Southern India, Hawaii, Some places of Northwestern of USA.
- **Continental Interiors**: Large air masses move along many continents and lose moisture ending up in arid regions. American Great Plains, Central Asia and Western China.
- **Cold Current Costs:** Convection precipitation is reduced. Western coasts of California, Mexico, South America and South Africa.
- **High Altitudes and Polar Latitudes**: Generally perceived as snow-covered landscapes. Polar and mountainous regions, do not have much precipitation and therefore lack liquid water.

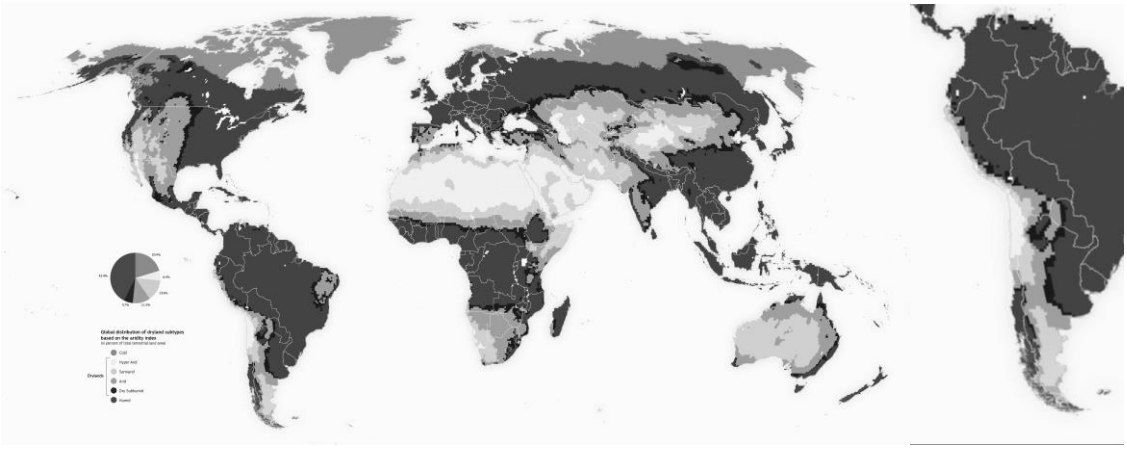

Figure 113: World Aridity Map. Source: wad.jrc.ec.europa.eu/patternsaridity.

In the figure above we can see that Chañaral is classified as a Hyper Arid zone like some places in countries like Egypt, Saudi Arabia, USA, etc. The information about these zones, is that they have an Arid Index of less than 0.005, this index shows the lack of water of the place.

These characteristics may sound like something very difficult, but the truth is that in various sectors people have adapted and applied various techniques of irrigation, grazing, river fields, etc. In cultural terms, arid lands have been the object of admiration and pilgrimage, celebrating when crops are abundant, without droughts, etc. When conditions are more adverse, faith reaches more into the hearts of the faithful.

The difficult conditions of an arid zone motivate people to create, sometimes, complex farming systems that change the cultural, economic, technological and political decisions of a people.

On the other hand, there are places that have been deserted over time, due to climate change or bad state policies, which include deforestation without containment plans, or aggressive monocultures that consume subterranean aquifers and leave no possibility of cultivation for farmers and therefore the area becomes arid.

There are many cultures that have arisen in arid zones and Landscape Architects have played a very important role, their experiments have been successful in the field of landscaping, as an example highlights the Islamic culture guided by al-Kindi (c.795- 870 CE) whose projects have been considered as sustainable, using materials from the area. In medieval times, several experiments are told that were successful in Yemen, Turkey, Ottoman, etc. The garden as an oasis.

In arid areas, a garden is as close to a paradise as some cultures like Iran take it.

In this country, known for its arid climate, water is considered sacred. They have techniques for an optimal use of groundwater, which can be driven without the need to use mechanical equipment, only with the use of gravity, this system is called Qanats. In Shushtar new town, located in Khuzestan, street plants are not a priority, delegating this function to the municipality, so people started to create infrastructure that created shade and then start planting and creating green areas. Their design is usually linear access accessible to all. The idea is for the plants to grow to the street and provide shade. Most of the connections are through passages that allow the wind to circulate in summer, cooling the inhabitants.

In Chañaral, the Molle culture, the first inhabitants of this region of Chile, used mountain streams, but did not use the water of the main river. They planted corn, beans and pumpkins. They didn't link much with the sea.

5.2.2. The industry. A cultural plus in arid zones.

"The identity of a country or region is basically built on the recognition of the landscape as a heritage resource, preserving that which is perceived as socially useful[33]".

An arid zone is usually not the first option when thinking of something attractive, you need something that catch the attention of someone outside the city to go to visit it. A city with an arid climate can still be maintained depending on its economy, but if the city is also considered heritage, this implies high and attractive monetary repercussions for the city and its inhabitants, in the case of Chañaral, it is known as an industrial city.

In the north of Chile, in what is now the third region, it used to be practically virgin due to the harsh climatic conditions, until in 1830 it began to be explored by naturalists and catheters for economic purposes.

In 1827 an important mineral deposit was discovered as the precious copper, this place was baptized as the mine of the Ánimas. This place in the future would be known as Chañaral. In 1870 Chañaral only exploited copper, but did not advance in building a city balanced with agriculture or other activities. Among these years Chile was the number one producer of Copper in the world.[34].

Over the years the most important mine at that time, called "El Salvador" began to lower production until finally closing the year 2009-2010.

In this sense, Chañaral has always had a label of industrial landscape in a context of arid landscape, but UNESCO added the category of Cultural Landscape, so a city with this category could become considered heritage. The cultural landscape can be urban, rural, archeological or industrial. So Chañaral would look for this last category as a contribution to provincial development. The industries are vestiges of what was once an economic power for the world in the area of mineral exports.

The industrial heritage gains strength as an element of reflection on the evolution of the environment and the identity of a community.

However, this can be added to the identity related to the original peoples, in the case of Chañaral, the Molle culture, Atacameña and the Changos.

Heritage can be a resource for the community, but three qualities are needed according to Prats [35]:

1. When the elements are capable of attracting a large number of tourists by themselves, justifying the development of tourism infrastructure.
2. When resources are located near urban areas with a population that would theoretically be willing to invest.
3. When the location of the resources is in an area of a constant large influx of public.

Reflections.

Can Chañaral become heritage? Everything indicates that it has a potential to become heritage, but it is not easy, has resources with heritage characteristics that are recognized and valued by their inhabitants. Being an industrial heritage, it provides a view that understands the territory and its geographical context as a specific object of heritage interest.

Chañaral as a pre-Hispanic and historical mining heritage is something that distinguishes it from other places in Chile, such as Potrerillos, located in the province of Chañaral.

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[33] Alvarez. (2010:22). Proyecciones del legado minero-industrial en la provincia de Chañaral, Región de Atacama, Chile.

[34] Proyecciones del legado minero-industrial en la provincia de Chañaral, Región de Atacama, Chile.

[35] Proyecciones del legado minero-industrial en la provincia de Chañaral, Región de Atacama, Chile

Figure 114:Potrerillos. Chañaral. 1930. Source: Chañaral mineria y sociedad.

Heritage and territory are two concepts that go hand in hand. Chañaral has the potential to become a symbolic reference that highlights the role that mining has played in the area and how it has shaped the current urban fabric.

Heritage converts abandoned sites through sustainable cultural tourism, the development of mining areas that lie in oblivion, and it is that the mining industry is part of Chile's history that deserves to be preserved and shown to future generations as a point of reflection.

5.2.3. Sustainable Landscape in arid zones.

The concept of sustainable development was born in 1987, in the report of the Brutland Commission, and refers to development that responds to the needs of the present without compromising the ability of future generations to meet their own needs(UNESCO2011).

Perhaps the first question to answer is: When is a Project sustainable? A group of Habitat II students in Istanbul indicated that a project is sustainable "when a designed area is totally appropriate to its location, culture, inhabitants and users".[36] On the other hand, the World Commission on Environment and Development states that sustainability "meets the needs of the present without compromising the needs of future generations to meet their own" and is probably the closest definition to sustainability.

Why should the Project be sustainable?

Because as landscape architects we have a duty to create projects that are useful not only for the present but for future generations, is to have a sense of community, is to be aware that any intervention has large and small repercussions in all areas, nature, psychological, etc.

In 1950, UNESCO was one of the actors in being interested in these arid zones and promoted their preservation through research, scientific talks, research centres, published a famous article called "Problems of the desert development" which in turn went hand in hand with research related to erosion, salinity and stabilization of sand dunes, carried out by China on arid areas located in India.

In the 1970s, the Landscape Architect profession gained strength in countries such as Iraq, Turkey, and India, and the professionals of that time were conducting research on plant protection, plant irrigation supplements, and new technologies.

Scientists and activists have promoted reducing irrigation, increasing the number of native species, and reusing graywater for landscape irrigation.

5.2.4. Design guidelines. Cases of Study.

5.2.4.1. Western Asia. Kuwait.

In 2014, architect Ricardo Camacho designed Al Shadeed Park, located in Kuwait. The purpose of the park is to celebrate and commemorate the country's war martyrs. The park contains museums, parking lots, a lake and an aviary.

[36] A Glimpse of the Future from Istanbul. Landscape Design 253(1996):52

The proposal preserves the original structure, with underground services and existing trees. Its proposal is aimed at mitigating the effects of noise, wind and sun. In addition to respecting the direction to Mecca. They use local plants for their landscape design.

Figure 115:Park in Kuwait. Source: Google Maps.

Figure 116: Park in Kuwait. Source: Google street Map.

Figure 117: Park in Kuwait. Source: Plataformaarquitectura.cl

5.2.4.2. Las Vegas. USA.

This Project designed by !melk built in 2016, is located in one of the most touristic sectors of the USA, Las Vegas. The interesting thing about this project is the designs of the structures to mitigate solar radiation, with organic forms, resembling trees and a color to emphasize that it is part of the urban furniture. Desert vegetation and water sources were used.

The other interesting thing is what is behind this project: Financing. The owners of Las Vegas Boulevard realized the great value of public space rather than traditional buildings, as Las Vegas is considered an oasis in the desert.

Figure 118: Source: Landezine.com. Hanns Joosten

Figure 119: Source: Landezine.com. Hanns Joosten

5.3. Floodable Park.

As a way of mitigating the floods of the river El Salado, a floodable park is proposed, but to continue with the proposal, it is necessary to explain general concepts regarding the revitalization of spaces in front of the water. Later, modern case studies will be explained both in Chile and abroad. Changing the concept of river that the Salado River currently has and giving it value as an urban water landscape requires the explanation of certain concepts.

5.3.1. Urban water landscape

We are talking about changing the landscape that Chañaral currently has around its river, so we are talking about a new urban water landscape, which needs to be explained from the theory.

5.3.1.1. General Concepts.

"Let us accept the proposition that the natural (nature) is a process that interacts, that responds to laws and that represents values and opportunities for human use with certain limitations and even prohibitions. (Mc Harg, 1969).

In Chile, the river is an element that seems dangerous, that generally evades and is not integrated into the city. In theory there are 4 paradigms that reflect the evolution and development of water sources[37]:

1. Dependence of ancient civilizations on water, both as supply (through wells), transport (as in Egyptian culture), irrigation and street cleaning through drainage.
2. When cities grow and water is not enough for the population, therefore engineering takes hold and water collection and sewerage strategies appear.
3. It was characterized by issues related to sewage and urban water treatment. It arose in the 20th century, at the height of waterborne diseases.
4. Establish control over diffuse, non-point sources of urban water pollution.
5. Seeks the water and ecological sustainability of cities. Sustainability of urban water basins, overuse of urban waters, hardening of the urban landscape and the resilience of the system to emergencies such as floods, storms or excessive pollution.

The fifth paradigm addresses sustainability and climate change, in other words ecological urbanism.

As MC Harg said in the first quotation of this chapter, the urban must be modelled respecting the natural context and there must be a fluid dialogue between the built and the natural. Everything related to nature must be considered in order to obtain a good answer: Climate, Geology, Hydrology, Vegetation, etc.

Cities and nature should be cohesive in such a way that the symbiosis is fluid and does not seem forced, Anne Whiston Spirn argues that cities are part of the natural world and stated that you can design a city according to natural processes.[38].

5.3.1.2. Ecological urban planning

In most of the cities of Chile, the belief that Nature and city do not go hand in hand is very high, is more many believe that nature is a separate point, for the same reason the environmental problems that Chile has are very big, as the atmospheric pollution and also radicalizes the aesthetics of the cities as gray cities. Cities must respect the natural context and their design must respond efficiently to the factors in which it is set, the city must be part of nature.

According to Anne Whiston Spirn:

- The city must be part of the natural world.
- Cities are habitat
- Cities are ecosystems
- Urban ecosystems are dynamic and interconnected
- Urban design is a tool for human adaptation

Each intervention in the city must respect the environment, and in Chile, each intervention in the city is usually associated with actions of governments, and governments that are associated with different values and principles, are transitory, not so the natural environment where the city is. The resulting landscape between these cultural, political and social interventions are those we see on the surface and reflect the identity of each city.

Underneath the surface there is a structure that is durable, which in the background is what supports the landscape of the surface, this structure expresses climatic, geomorphological and biotic processes of a place. It is also very important for the design of the surface, it defines its future. An example of this structure is the hydric landscape, for example the river.

The Chañaral River is avoided and marginalized from the daily urban activity, denying its urban definition related to the foundational, with the direct connection with the coast of Chañaral, of potential recreational place and temperature regulator in a place as arid as this one.

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[37] Source: Dossier n°80, n°2, Paisajes Urbanos. Universidad Diego Portales, Chile.

[38] According to the book “The Granite Garden: Urban Nature and Human Design” of Anne Whiston (Landscape architect from USA).1984.

The urban development of Chañaral has been dispersed, occupying the river as a divider, boundary and polarization defines, instead of an articulator and source of an enriching recreational urban scenario.

It is enough to see in the satellite images the border treatment that the river possesses, it is neither attractive nor friendly for the users, it does not even possess adequate infrastructure neither to enjoy it nor to mitigate eventual disasters, which leads the users to lose the sense of belonging to the river, leaving it in the oblivion and now after the alluvium, as a dangerous natural element.

5.3.1.3. The water. The leading character.

If we think of places where water is the protagonist, where this resource is managed in a sustainable way and forms part of the urban scene, we immediately think of Holland, and it is not by chance, in Europe in the decade of the 20th century the concept is coined that water is the protagonist, the "first among equals", since 1995 the city has changed around water, creating new water management policies, although Holland has more than 900 years of experience with authorities dedicated to water maintenance.

The government is forced to give more space and new laws for water (rivers) in different spheres:

- Water management
- Urban planning
- Environmental policies

In the year 2000 the Dutch government made a change in water management and put water as a fundamental factor in the spatial planning of the city. Therefore, any intervention in the city must be thought about relating the water systems of the area.

For the Waterplan 2010-2015[39], The Netherlands was already pointing out the consequences of climate change and of considering these changes in the new public policies of urban planning. Some of the problems they point out:

- Average temperature increase
- Increased rainfall in winter
- Extensive heat waves
- Dehydration
- Scarcity of fresh water
- Salinization

The Netherlands therefore declares that it will take into consideration water supply safety in the following cases:

- Drinking water
- Water for cooling
- Maritime transport
- Bathing water
- Urban water
- Water against fire
- Industry
- Nature
- Recreation

Some municipal Waterplan planning strategies are:

1. The space allocated for water should not be changed. This space can only be occupied if it is to reinforce a levee in emergency situations.
2. Contain, store and drain. When rainfall can no longer be contained, the water is temporarily stored in areas created for this purpose and the excess is drained.
3. Water quality. All in order not to contaminate the water, the spatial design must be considering this first factor.
4. Any intervention on the water system must be compensated with the objective of preventing or reducing problems with groundwater and surface water.

[39] Waterplan 2010-2015 Provincie Noord-Holland Beschermen, Benutten, Beleven en Beheren. Source: https://www.kansenvoorwest2.nl/files/waterplan-2010-2015.pdf

5.3.1.4. Philosophy of life around water

His philosophy of life is very simple: Let the water in and not fight against it.

It is because of this philosophy that most public interventions are designed to provide a good service to the community, the same space can be an urban square and at the same time a theater and also respond well in times of emergency, such as collecting rainwater. In the Netherlands they have learned that instead of investing millions in sewers, it is best to create good quality public spaces that absorb water. For example, they have square projects that absorb up to 10,000 cubic metres of rainwater. In fact, the government is encouraging the change of the pavement for greener spaces in some areas, of course everything depends on the support given by citizens.

Letting water in also means being able to live on it, which is why several buildings in the Netherlands are floating with innovative designs.

Henk Ovnik, water ambassador in the Netherlands states: "The reason why Rotterdam is such a climate-resistant city is because it has put all these (mentioned above) measures into practice"[40].

Ovnik believes he can help with his experience in Latin America and in fact has already started working with countries such as Mexico, Argentina, Colombia and Chile.

Figure 120: Square that absorb water from rainfall evading flood problems. Rotterdam. Holland. Source: https://www.bbc.com/mundo/noticias-40328271

5.3.1.5. Denying the river as an urban element.

The negation of the river as an urban element in Chañaral and in many Latin American cities is a proposal totally opposed to what has been explained above.

Latin American cities are new in comparison to European cities, so the urban designs that gave rise to cities in Latin America we could say that they were experiments, in the beginning were established near rivers because they were generators of drinking water. Later, as explained in point 5.1.1.1, the river was no longer the only source of drinking water, so the inhabitants tended to move away from the river, so that the river became an element gradually forgotten and the urban fabric often began to take strategies that seem improvised or poorly designed. What follows is that the city continues to grow and no longer matters the river, so it is neglected and deteriorates, the river edges are precarious and do not integrate into the city and turn their backs on the river and marginal populations begin to occupy the sites near the river, generally changing urban regulatory plans causing the problems that we already know if the river grows as in Chañaral.

When the river is denied it is generally because urban infrastructure and unplanned urban development lead to evasion of the natural landscape like the river.

According to Briceño's thesis, there are three patterns of identification of the city-river relationship:

[40] https://www.bbc.com/mundo/noticias-40328271

1. **Parallel Spaces**: These spaces turn their backs on the river, generally private buildings that enclose the landscape of the river, depriving it of its potential. It can also happen in public properties, when you don't want people to be near the river.
2. **Transversal Spaces:** They intersect the river transversely, they are usually bridges, they are usually a source of pollution and people do not want to live in these areas.
3. **Street auctions:** When urban plots approach the river but do not penetrate it. Physical and visual access generally does not exist. However, there is great potential for access to the river.

Chañaral would be within number two, transverse spaces. Its edge is not configured as a recreational urban edge or transitory articulator between north and south. Its articulation with the river defines the urban border.

The urban border can be appreciated in a set of full and empty that show the interaction with the river, these can be classified according to the degree of intervention they have with the river:

1. **Free Margins**: There is no built intervention that confines the river.
2. **Partially confined margins**: In some points there are interventions and in other points it is pen.
3. **Confined margins**: There are margins but no interaction with the contact area.
4. **Built margins**; No margins, everything is built except the river.
5. **Channeled channel:** The urban area is above the river, the river disappears as an urban element.

Figure 121: Free Margin. Calle Calle river. Source: Flickr.com

Figure 122: Partially confined margins: Amster River Walk. Amsterdam. Source:http://leafywalks.com/amsterdam/walks/amstel-river-walk.html

Figure 123: Confined margins : Hamburg. Source: Google maps.

Figure 124: Built margins: Hamburg. Source: silversea.com/es/cruceros/hamburg.html

When the patterns of articulation between the city and the river finally remove the river from the fabric of the city, they become an annex to the city and not an integral part of the city, resulting in a denial of the landscape as an element of identity. In many cities the river is wasted as an urban element that gives identity to the city, for example the Mapocho river in Santiago de Chile is another example of a river that has all the potential to give identity but the urban fabric does not empower it.

The river seen as an urban landscape can be presented in three characteristics [41]:

- **Fragmented landscape**: The perception of the river is fragmented, the configuration of the city and the relationship of the urban border with the river avoid a total perception of the river.

[41] According to the urbanist Moore.

- **Deteriorated landscape:** There is visual contact with the river but these spaces where the river is seen are not of good quality due to their urban sections.
- **Non-visible landscape:** The River is not directly perceived, its spaces to appreciate it are confined, and the river is transformed into an element that is perceived as something hidden that does not deserve to be seen.

In Chañaral you can see the river in its entirety, but what the river environment offers absolutely nothing, there are no places for recreation or rest, not even a shaded space near the river.

Figure 125: Image of the river in Chañaral. Jorge Rivera street. Source: Google street view 2012.

The Figure above shows the relationship between the river and the urban edge, there is no approximation or attempt to interact with the river, there is no offer by this public space exposed to all the sun and high temperatures of northern Chile, so it becomes an element that generates a cultural rejection, added to the image that the river now has after the 25M alluvium. Perhaps for the majority of the people of Chañaral the term urban river is a term that only remains in the imaginary and is not in the collective unconscious as a daily experience, this is something extremely worrying given the tremendous potential that the river has and the bad infrastructure that the public spaces have in the city.

5.3.2. Floodable Park as a response for the river.

As a response to the problem already raised, the objective is to change the perception of the river El Salado changing its urban image and making it a safe space for the people of Chañaral, making it an urban river that connects north and south in an integral way and give identity to the city through a park that connects and provides quality spaces.

The main objectives of the proposal are:

- To recover areas located on the river's edge.
- Mitigate the effects of an early alluvium in the future by retaining, absorbing and directing the water course.
- To offer spaces that respond to the needs of the place: recreation, institutional, sports, etc.
- Respect the local climate with a sustainable proposal, using native species.

5.3.3. Construction of a Floodable park.

Then there will be a review on general measures of how to treat the edges of a river, how to contain it. This can be through terraces or containment with rocks.

River edges are generally protected due to erosion caused by flow or water runoff.

The river bank should be of a durable, solid material and the type of containment depends on the type of soil, the type of river velocity, the quality of permeability in the soil, etc.

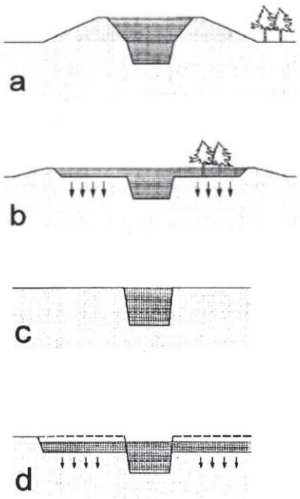

Figure 126:Flood containment. Source: El Río y la Forma. 2009.

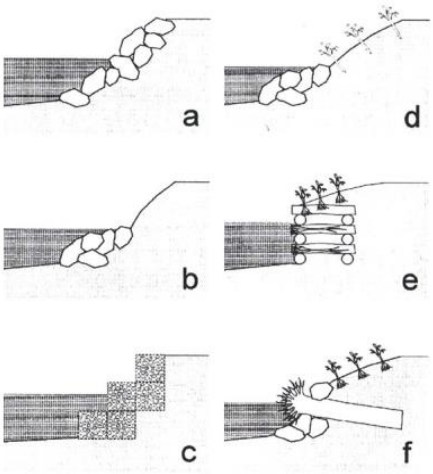

Figure 127: Protection for riverbanks in high-energy environments. Source: El Río y la Forma. 2009.

Flood containment: a) Immediate to the channel. b) Removal of the channel c) Entrenching channel d) excavation around the entrenching channel to make a new floodplain.

Protection for riverbanks: a) Big rocks. b) Rock floor or kerb. c) Gabions. d) Solera and empty stakes e) trunk framework filled with living soil and branches. f) rocks, trunks with roots and living plants.

As for the construction, it must be impermeable, that is why a geotextile layer is added as the first layer and then the material that will face the river directly. Then a layer of 10 centimeters where the rocks are supported. The rocks must be grouped so as to have the minimum percentage of infiltration.

As for the design of channels, must be suitable for water conduction, the important factors to consider are:

a) Roughness of the channel walls. The rougher the walls, the more friction it produces and reduces the speed of the river.
b) The shape of the channel path. If the river is diverted, the speed of the river is reduced.
c) The slope of the river. The steeper the slope without interruption, the faster the flow of the river.
d) The shape of the carcase. They are generally semi-circular, but impractical, so their best shape is a trapezoidal shape
e) If water transports suspended materials, sedimentation is likely to occur and a special area should be dedicated to this purpose.
f) If it is necessary to cross the channel, it is recommended to reduce the width of the channel.
g) The dimensions of the channel shall be sufficient to deal with the normal channel and floods.

Another point to emphasize is the cleaning process that can be carried out for a floodable park, a clear and very effective method is when different pools or retention ponds are occupied that filter the water little by little, and that in turn water the vegetation present in the retention ponds.

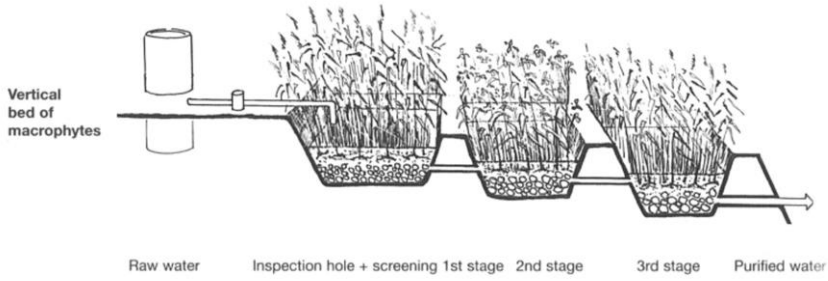

Figure 128: System of retention and purification of the water. Source: Waterscapes, El tratamiento de aguas residuales mediante sistemas vegetales.

5.3.3.1. Gabions.

In order to reduce the speed of the river and channel it, gabions are normally used as borders. The gabion is a box with a rectangular prismatic shape with a metallic trellis of hexagonal mesh of triple torsion, the gabions are filled with stone of quarry or any similar material that is populated to obtain of the surroundings near to the work. The gabions are quick to assemble and do not require specialised labour, they are economical, very durable, adapt to the terrain and work by gravity.

For its design there are different styles, but its basic formula is given by the image below, which illustrates the different designs of gabions most used. In the formula B=Base, H=Total height of the wall.

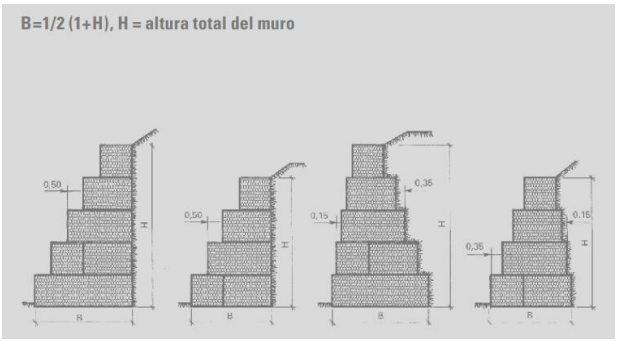

Figure 129: Gabions. Source: Gaviones. Bianchini Ingeniero.

Figure 130: Gabions. Source: Gaviones. Bianchini Ingeniero.

5.3.4. Sustainability in drainage systems.

In order for a flood protection system to be sustainable, it is not enough to protect the city against floods, it is necessary to preserve the resource (water) for future generations, floods have a very broad radar of collateral effects, from biodiversity to problems in the urban fabric.

Sustainability has four pillars: Economy, Culture and Environment, and they are qualities that cannot be separated; it is a balance that must exist in any sustainable project.

As already mentioned, the problem of climate change is present and this must be dealt with as a present factor. We have already seen it as a trigger for climate change in Chañaral, and therefore the flooding of the El Salado River. In Chañaral we have the problem of a river that has little flow and that has the latent problem of a possible new alluvium, so the city must be prepared for it.

In Chile, awareness about water care is not very strong, in 2019 a campaign was carried out to save the amount of water occupied in the showers, called "shower in 3 minutes", there are also several problems of river pollution, as explained above.

There is a global movement called Low Impact Development or also known as Water Sensitive Urban Design, which refers to sustainable drainage systems and good environmental policies. The main idea is to reproduce as faithfully as possible the natural hydrological cycle prior to urbanization and mitigate quantity problems. However, sustainable urban drainage is not intended to replace the traditional system, but to manage water as naturally as possible, without converting it into wastewater.

5.3.4.1. Sustainable Drainage Systems

Sustainable urban drainage systems can be achieved through these actions (U.S. EPA, 1999):

- Manage and reduce the volumes and velocities of erosion produced by a stream of surface water, reducing the impact of urbanization, as urbanization tends to increase the risk of eroding watercourses.
- Contribute to natural groundwater recharge
- Reduce concentrations of pollutants in rainwater, which will protect the quality of water catchment areas.
- Reduce the volume of surface water discharge into underground collector systems.
- Act as a buffer against accidental spills by preventing a direct discharge of high concentrations of contaminants into water catchment areas.
- Contribute to the amenity and aesthetic value of the urbanized areas.
- Provide habitats for wildlife in urban areas and opportunities to enhance biodiversity and citizens' contact with nature.

5.3.4.2. Preventive measures.

There are measures to prevent problems associated with surface runoff, and they have to do with measures that are not related to the design, but which also generate a great deal of help.

A. Legislation regarding respect for the law, informing citizens about sanctions, this can be implemented by the local municipality. Citizens should have free access to information such as environmental ordinances, urban approaches and sanctions and fines associated with non-compliance with measures of the law.
B. Encourage street cleaning to prevent pollution from urban runoff. Educate citizens about municipal regulations, compliance and penalties. This can be carried out by means of advertising campaigns.
C. Economic investment of the authorities that allows to have an annual budget to comply with the rules, to generate publicity already mentioned in the previous point related to solve drainage problems.

5.3.4.3. Infiltration systems.

Systems can be made to filter water from the source, i.e. to intercept the formation of surface runoff from the source, to compensate for the infiltration capacity that cities had before the urbanization of natural soils. There are simple techniques to achieve this such as green zones, permeable pavements, infiltration tanks and infiltration wells.

5.3.4.4. Collection systems.

They're about capturing surface runoff to treatment points. These systems are designed to generate natural processes such as water evaporation, storage, etc. In order to improve water quality.

These systems have alternative uses, so they do not interfere with the functioning of the city, they can be superficial or underground.

5.3.4.5. Treatment and storage systems.

These systems are classified according to the presence of surface water, if the water disappears from the surface it is a detention tank, if it is kept on the surface it is considered a retention pond or artificial wetland. They make it possible to manage large urban basins and also generate a safety measure for roads and surrounding areas.

5.3.5. Design guidelines: Cases of study

The following case studies are selected by the design strategies used by the designers to cope with flooding. Projects from northern and central Chile are shown as well as European projects from Spain and Denmark.

5.3.5.1. South America.

- Parque Kaukari. Atacama. **Chile**.

The Copiapó River was used for many years as an unofficial dump and as a deposit for mining works, so between 1996 and 1999 the municipality formalized its demands for the river, the purpose was to return the river to the residents and value the river. In 2007, after several studies, the communal regulatory plan was changed to give way to this new park located on the Copiapó River.

This project is located in Copiapó, Atacama, the same region of Chañaral and designed by landscape architect Teodoro Fernández[42], has an area of 60,000 m2, about 3.8 kilometers in length, 6,000 m2 of garden, cycle way and a water source for residents. Inaugurated in 2014, its main purpose is to channel the Copiapó River and change the image of the river as a natural element to an urban element. This project proposes to change the amount of green m2 that Copiapó had, which before this project had 1.09 m2 of green m2 per person. With this project the figure will rise to 4.85 m2 green per person[43].

With regard to water, a design is proposed to control possible flooding in the future.

It proposes a green area open to the public with different uses: Sport, recreational, cultural and institutional. Towards the center of the city are located the most urban and civic uses, towards the avenue are located the uses more related to sport and recreation. It includes endemic plants and respects the culture of the place, linked to the railway and mining. 300 new trees were planted which among their characteristics is that they require little water, among the species are: jacarandás, palmas and pimientos (Schinus molle).

Figure 131: The Copiapó river before the project. Source: Plataformaurbana.cl

Figure 132: The stages of the project Kaukari Park. Source: Plataformaurbana.cl

Figure 133: Minerals as decoration.

- Renato Poblete Fluvial Park. Santiago, **Chile**.

Designed by the office BOZA architects and inaugurated in 2015, is a project with a total of 20 hectares divided into two zones, the first of 13 hectares that are located in the diversion of the river that in a controlled way will allow the use of certain boats for navigation.[44] In the design you can see islands that cross the river and increase the pedestrian circuit, generating more viewpoints and points of attraction.

The great success of this project is to return the river to the citizens, to approach it in a different way, from the shore and to demonstrate that in Chile modern parks can also be designed.

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[42] Teodoro Fernández, national prize for Chilean architecture in 2014.

[43] Source: www.plataformaurbana.cl/archive/2014/09/26/parque-kaukari-este-ano-se-abrira-la-1%C2%AA-etapa-del-parque-que-recupera-el-rio-copiapo/

[44] Source: https://www.miparque.cl/se-inauguro-el-parque-fluvial-renato-poblete/

Figure 134: Birdview of the park (left) and a pedestrian view (right). Source: Plataformaarquitectura.cl

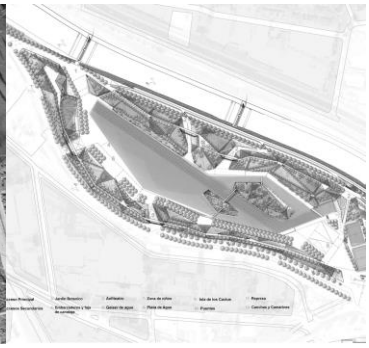

Figure 135: Site plan Renato Poblete Park. Source: plataformaarquitectura.cl

5.3.5.2. Europe.

- Balcón del Guadalquivir. **Spain**.

This project is located in Cordoba, in the Guadalquivir basin and was designed by Juan Navarro Baldeweg. This work is a park on the edge of the river and rehabilitates the mill Martos, which is maintained with a good restoration, recovering the spaces that occupied the machinery. The mill is connected to a new viewpoint offered by the project.

As for strategies for possible rises in river level, the idea is basically three ponds connected to each other to reach the river, between each pond there are inclined planes to facilitate the natural flow of water.

Figure 136: Balcon del guadalquivir. General view. Source: ARQ.72.Chile.

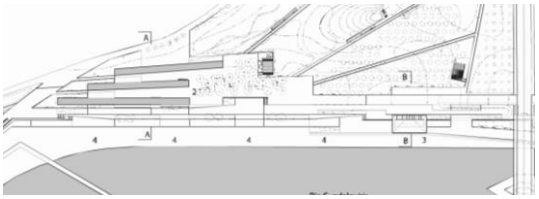

Figure 137: Balcón del Guadalquivir. Siteplan. Souce: ARQ.72. Chile.

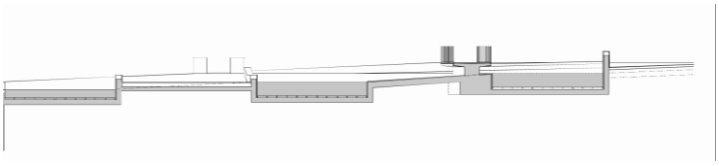

Figure 138: Balcón del Guadalquivir. Section. Source: ARQ.72. Chile.

- Sonderboulevard. Denmark.

The year 2013 presents this project designed by Ramboll Studio Dreiseitl, where the challenge was to manage water quality, and create a large boulevard space with different activities for users. Previously the site suffered floods of more than 1 meter in height in 2011, accumulating more than 150 mm in 2 hours of constant rain.

The main strategy is to establish two zones, a safety zone that in the event of a storm continues to function without problems and an area to accumulate water, these zones are recreation zones in flood situations, such as squares or pedestrian paths with permeable pavement and rainwater collectors that direct the water to the sea.

Figure 139: Flood in Denmark. 2011. Source: landezine.com

Figure 140: The proposal in Denmark. Source: landezine.com

Figure 141: Section.Normal. Denmark project. Source: Landezine.com.

Figure 142: Section.Raining season. Denmark project. Source: Landezine.com.

Chapter VI: The design of a floodable park as a response to mitigation measures to future floods and the valorization of the river as an urban element articulator of the city.

6.1. Main aims of the proposal

Create a green area to mitigate the impacts of new floods of the river El Salado in the future, through a landscape proposal consisting of a floodable park that in turn is a meeting point and an articulating element for the city of Chañaral.

6.2. Specific aims

- **To create the image of an urban river in the city of Chañaral, changing its stigma and abandonment**.
  The project aims to generate spaces with good infrastructure that allow people to get closer to the river and enjoy the environment. The river covers a large part of the city and has the potential to generate different activities around it.
- **Change the current polarization of Chañaral.**
  Due to the urban fabric that has developed over the years, Chañaral has not had a precise order as explained above. The project wants to generate a space that connects the north and the south by means of an integrating landscape proposal.
- **Mitigate the ascents of the river El Salado**
  Due to the 25M, the government has already proposed a buffer strip, however there are no proposals for the edge of the river or for situations related to another overflow, which according to studies, may continue to occur due to climate change.
- **Promote the range of endemic vegetation in public spaces.**
  Chañaral and Atacama in general, have a unique endemic vegetation and should be shown appreciated by both residents and tourists. It would generate more biodiversity and reduce air pollution.

6.3. Legal framework.

The project is based on the Chañaral Master Plan and takes measures adopted by the government as a result of the 25M disaster. These measures were developed by professionals such as geologists, geographers and urban planners. The government has already defined areas in which it is strictly forbidden to build houses or commercial buildings. These areas are considered protected areas, and this is where the project will be established, respecting the conditions established by Chilean regulations.

The project will not address some areas that are destined for a future commercial boulevard.

6.4. Definition of the place.

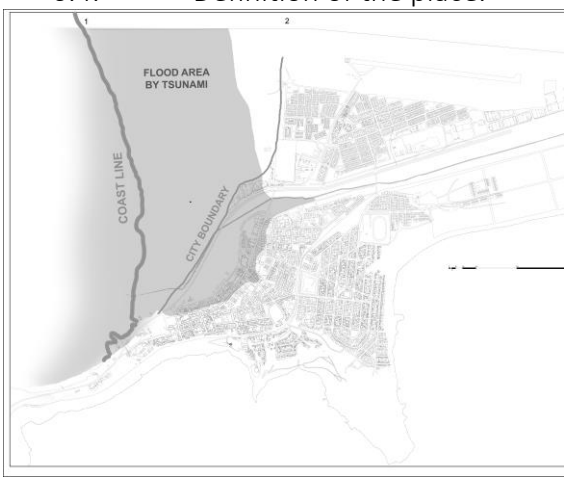

Figure 143: Chañaral city. Flood area and coast line. Own elaboration.

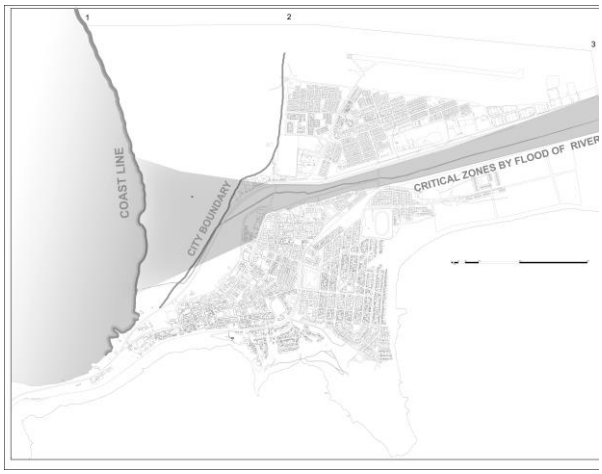

Figure 144: Critical zones by flood. Own elaboration.

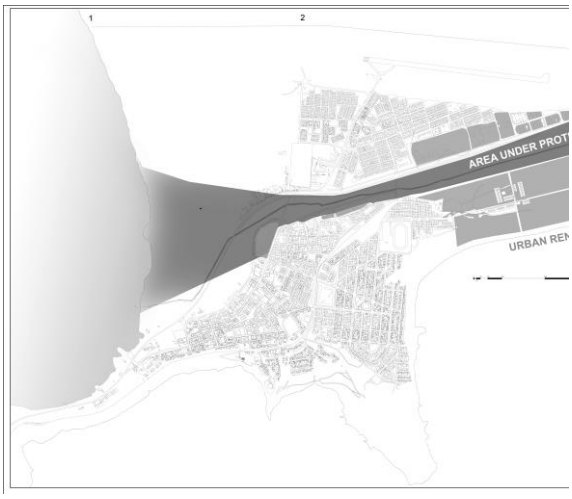

Figure 145: Area under protection and urban renewal. Own elaboration

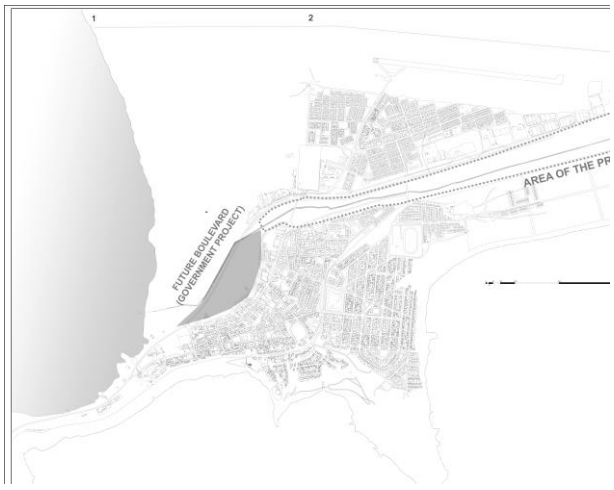

Figure 146: Area of the project + government project. Own elaboration

6.5. Financing

The problem presented in this thesis, that is, floodable parks in the northern sector of Chile, is a solution that could be applied in several areas of the north, so it is proposed as a first instance to coordinate human resources and specialized labor in the area, establish a nonprofit foundation dedicated to promote the implementation of these projects in order to create green lungs with adequate infrastructure for recreation, improving the quality of life of citizens.

The main entities that would form part of this foundation would be the government of Chile, the Atacama region where the project is located, universities located in the north, Chilean tourism organizations and private companies related to the contamination of the Salado River and Chañaral Bay.

- Government: Ministry of Public Works of Chile (MOP), Ministry of Housing of Chile (MINVU), Ministry of Environment of Chile (MMA), National Environment Commission (CONAMA) and National Forestry Corporation (CONAF).
- Region of Atacama: Municipality of Chañaral and Government of Atacama.
- Universities and professional institutes of Northern Chile: University of Atacama, DUOC, INACAP Atacama.
- National Institute of Tourism: SERNATUR, SUBTURISMO, National Institute of Tourism.

- Private companies: CODELCO Chile, Copper Limited Mining Company.

As already mentioned, the government allocated billions of Chilean pesos to the north of the country, however there are no projects for the management of the Salado River in case of floods, so this project could apply for these funds.

There are also Chilean programs aimed at financing public spaces, such as the "National Program of Public Spaces" which allocates up to 30,000 UF (826,680,000 Chilean pesos), equivalent to 1,065,396 Euros.

As for the trees needed for the park, the project can benefit from the tree-planting program that began on Chile's 200th anniversary of independence, called "one tree, one Chilean".

For the maintenance of the project, the design has an arborization that does not require maintenance, are native plants that withstand long droughts and adapt well to local temperatures.

Photovoltaic lighting for pedestrian routes and sports fields is considered for the illumination of the site.

It is also proposed a program of awareness to the community on

The future park would increase the added value of urban regeneration areas, so as in other projects in Chile such as social housing and there is a possibility of negotiations with EGIS (Social Real Estate Management Entities).

6.6. Proposal

The main aims of the proposal are related to the relation city-river.

- **Protect the city against flood and storage water:** As we know after the information about the weather and the climate change of the city, it is important to prevent new alluviums because they are going to be more often, so the most important goal is to protect t city against flood and use the water of these flood to create more storage of water in this arid zone to make the park more sustainable.
- **Clean the river:** The pollution in the city is very dangerous and cleaning the river is one of the first actions to generate more biodiversity and in the future to recover the nature that was lost because of mining.
- **Make closer the river to the people:** The river has a bad reputation because of the flood, and it has many potential to be a friendly zone with accurate design and in the future the riverside can be a good meeting point improving the quality of life.
- **Uniting the city:** The city is divided by the river and there are just few connections between the north and south. One of the main aims is to unify the city by a park that can be change the city in a better way.

With respect to general design lines, straight lines will be related to the purely human such as sculpture, which is why straight lines will be present in the sculpture park and permanence zones, while curved lines will be related to flow (walking) and to nature.

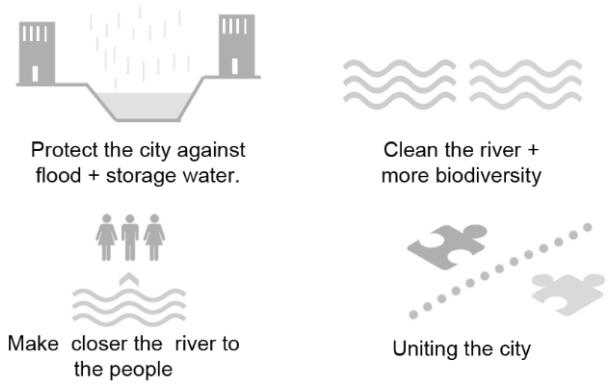

Figure 147: Main aims of the project. Own elaboration.

Figure 148: First design guidelines. Own elaboration.

The project aims have three types of relationships with the river:

Observe:

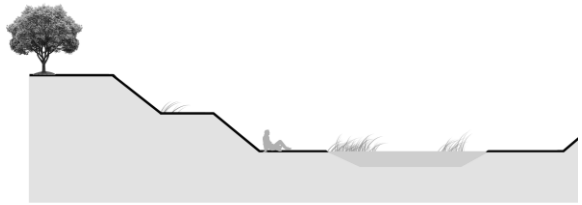

Figure 149: Observe. On the river. Own elaboration.

Lean out:

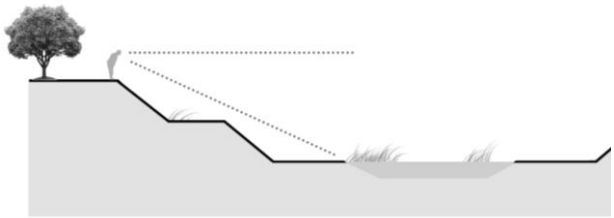

Figure 150: Lean out on the river. Own elaboration.

Into the river:

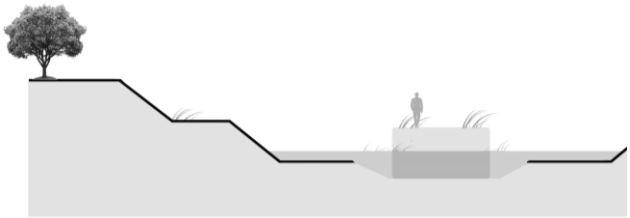

Figure 151: Into the river. Own elaboration.

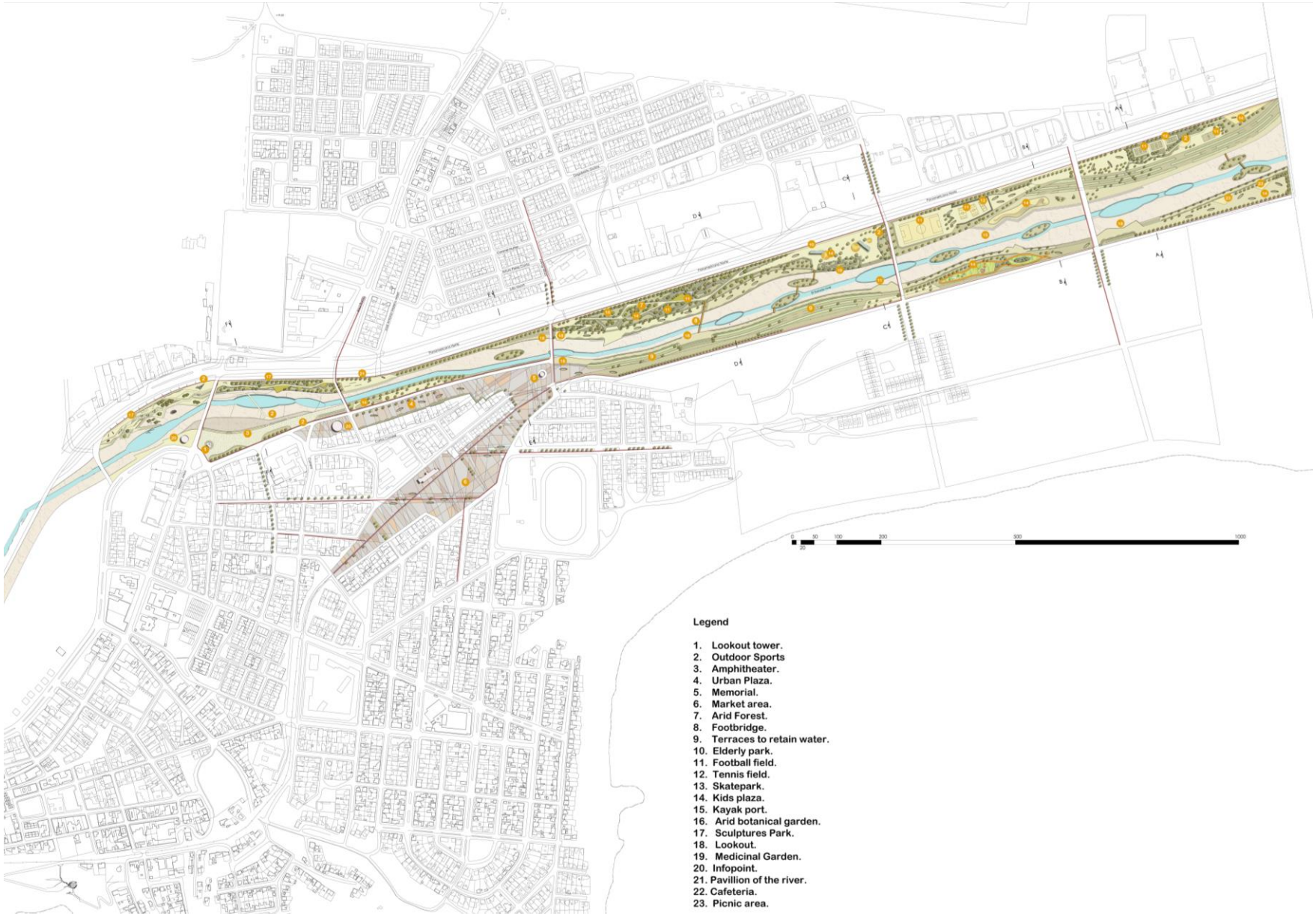

Figure 152: Master plan. Own elaboration.

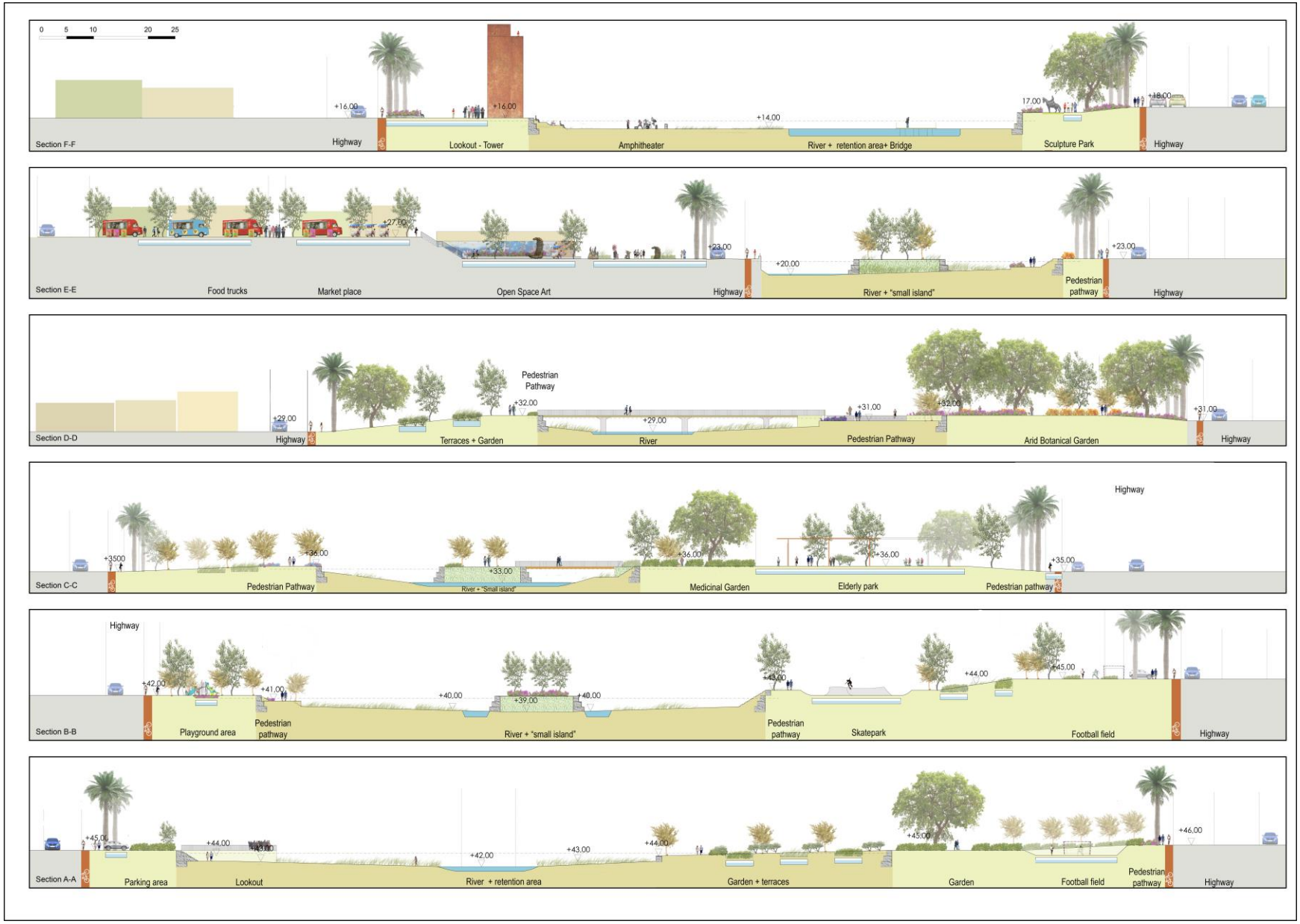

Figure 153: Sections. Own elaboration.

6.6.1. Feautures.

The uses of the park are diverse and zoned, near the coast are more related to tourism, such as Landart Spaces, Sculpture Park and a lookout tower. In the area near the center, there is a square that is suitable for religious events. The memorial area is in the area where the alluvium swept away houses. Close to the urban renewal areas we can see sports areas that are more attractive to real estate investors and attract more people.

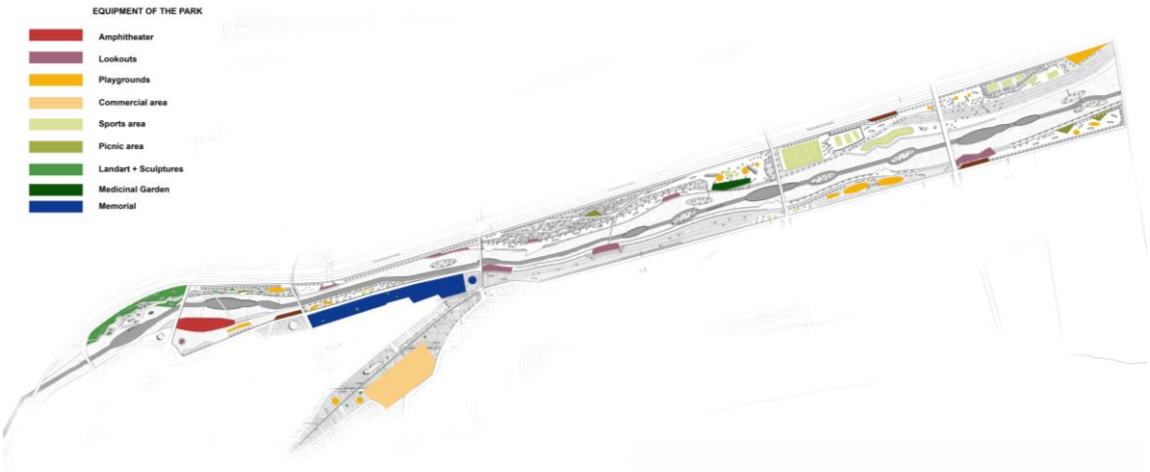

Figure 154: Uses. Own elaboration.

Figure 155: Users. Own elaboration.

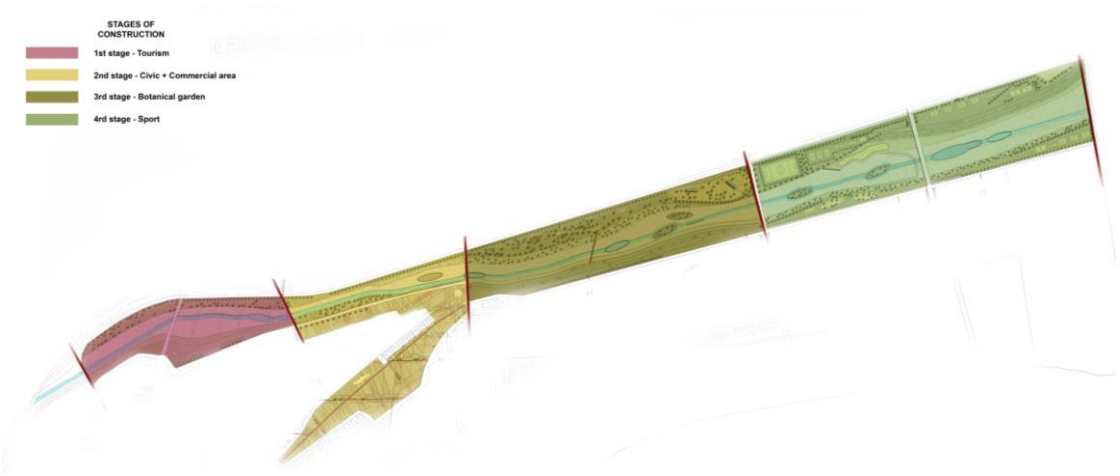

Figure 156: Stages of construction. Own elaboration.

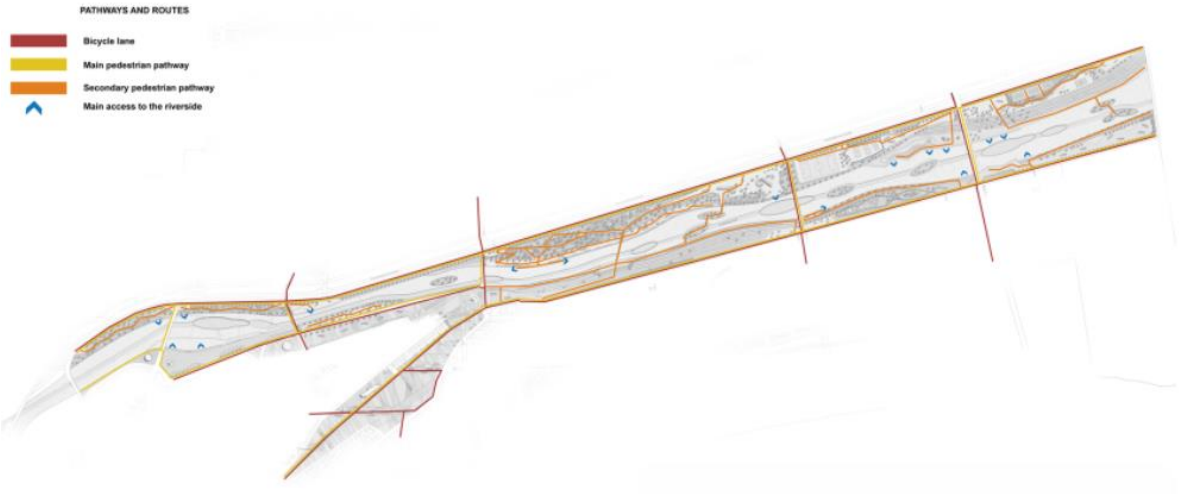

Figure 157: Pathways and routes. Own elaboration.

The first object of construction of the park will be the edges of the river, and the retention pools outside the park to protect people. Subsequently, the construction stages are divided into zones according to a criterion of calling more investors to finance the project. For example, the first zone to be fitted out would be the sculpture park, which would attract more tourists and artists from all over the world to present their works.

The project proposes a new bicycle lane that connects the entire park and the city. In addition, the project will have pedestrian circuits and bridges that connect the entire city, unifying it.

Figure 158: Type of users. Own elaboration.

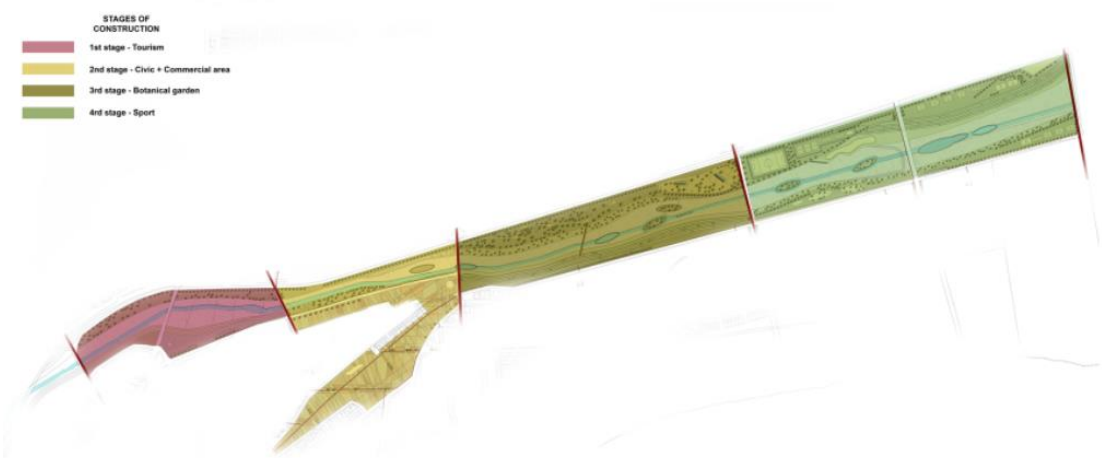

Figure 159: Stages of construction. Own elaboration.

6.6.2. Inspiration

The main inspiration for the design of the park is the typical mask of the religious festival called "La Tirana" that is celebrated every year, on July 16 in northern Chile, in honor of the Virgen del Carmen. It is the largest religious festival in the north. One of the characters that stands out the most is "la Diablada", because of its colorful masks, "la diablada" represents the struggle between good and evil, and how it can be successful in the end. This is a metaphor for the Parque-Rio relationship: the river is a potential danger to the city due to future floods, and on the other hand the city, which must deal with this force of nature but which in the end must succeed. This dance is performed with many dancers and in different parts of Chile, where the most characteristic is the color mask.

For the sculpture park, the inspiration was based on the ancient geoglyph “The big man”, located in the Region of Atacama. The sculpture park must be different to the other zones of the park, because the sculpture park represents something made by the human and not by the nature. That is why the inspiration was based in something with straight lines like the symbol of the region.

The originals Geoglyphs were made by native people from the north 3.000 years ago. There are only few of them in the world. The largest is 15 meters called “the man”, which was the main inspiration for the sculpture park.

The idea is to experience this particular geometry with different heights, because the original geoglyph was made on a slope, the design is to experience every point of the sculpture in different heights, like the original on the slope. Furthermore, this part of the park has places to receive new temporary sculptures.

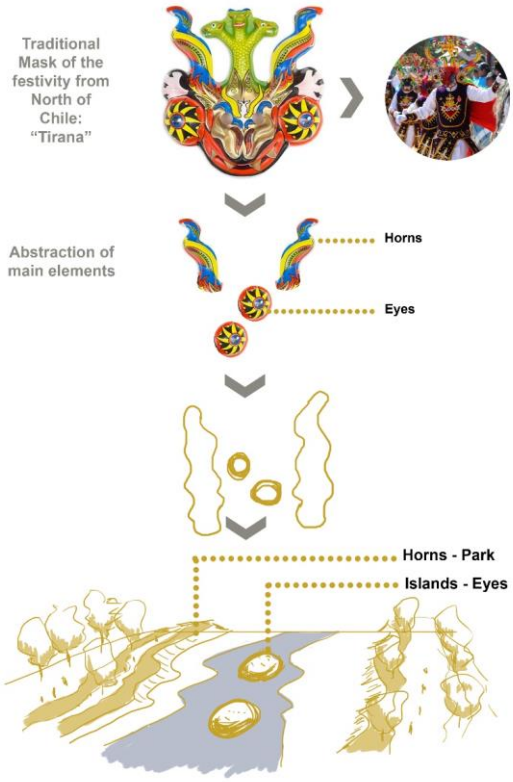

Figure 160: Diagrams of "La Tirana" and the project. Own sketch.

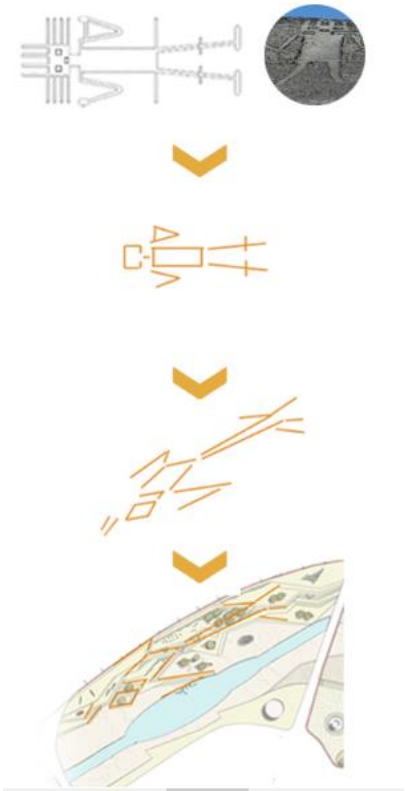

Figure 161: Geoglyph and the design. Own elaboration.

Planting design concept: The inspiration is based on colors of the typical masks of the national dance from the north of Chile. The shape is more organic and the representation is an abstraction of the symbols of the mask.

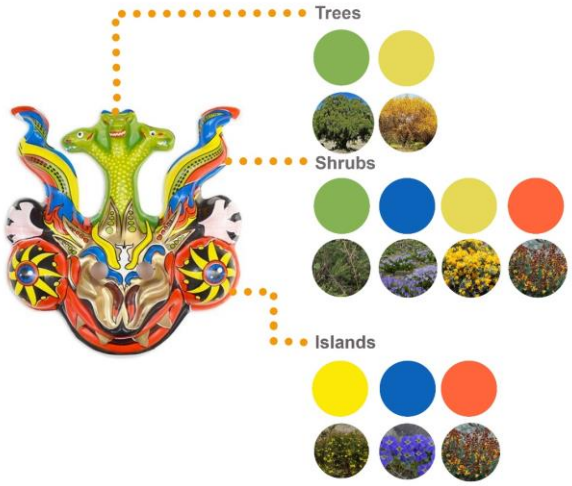

Figure 162: Typical mask from the North of Chile and the colors for plants. Own elaboration.

6.6.3. Flood strategies.

In order to face future floods, exterior strategies are established, which are located outside the range of the park, and interior strategies, which are located in the park itself.

The exterior strategies focus on the main streams that feed the El Salado River during rainy seasons and that also increased the amount of water detonated in the 25M disaster. Here, water retention zones are established to lower the level of water that feeds the Salado River.

Inner strategies are classified in:

Retention areas: Water is retained and purified with different plants, the form of the pools have different forms to generate a visual spectacle for the users, these pools when passing their retention height, and the water is directed to the sea.

Groundwater collector. Water is collected from hard squares, the water that is collected is purified and directed towards the sea.

Terraces to collect + reuse. The water is collected and stored in terraces with plants that can purify it and then redirected to areas of the park as irrigation.

Obstacles to reduce the speed. Artificial islands with gabion edges are created to reduce the speed of the river so that its effect is not so strong and dangerous.

Edges to reduce the speed. The edge of the park has breaks that reduce the speed of the river, this way the friction is greater, the speed decreases and gives more time for evacuation and storage of water in the retention pools.

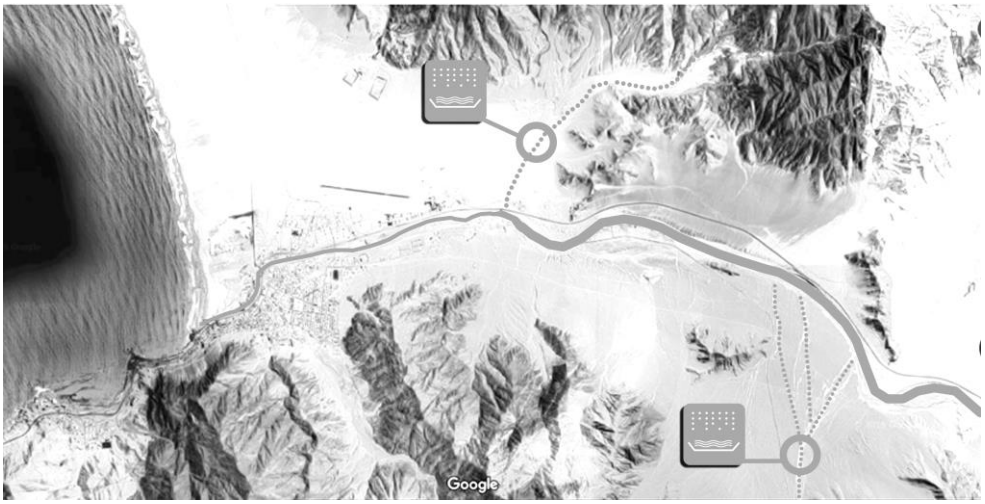

Figure 163:Retention zones. Own elaboration.

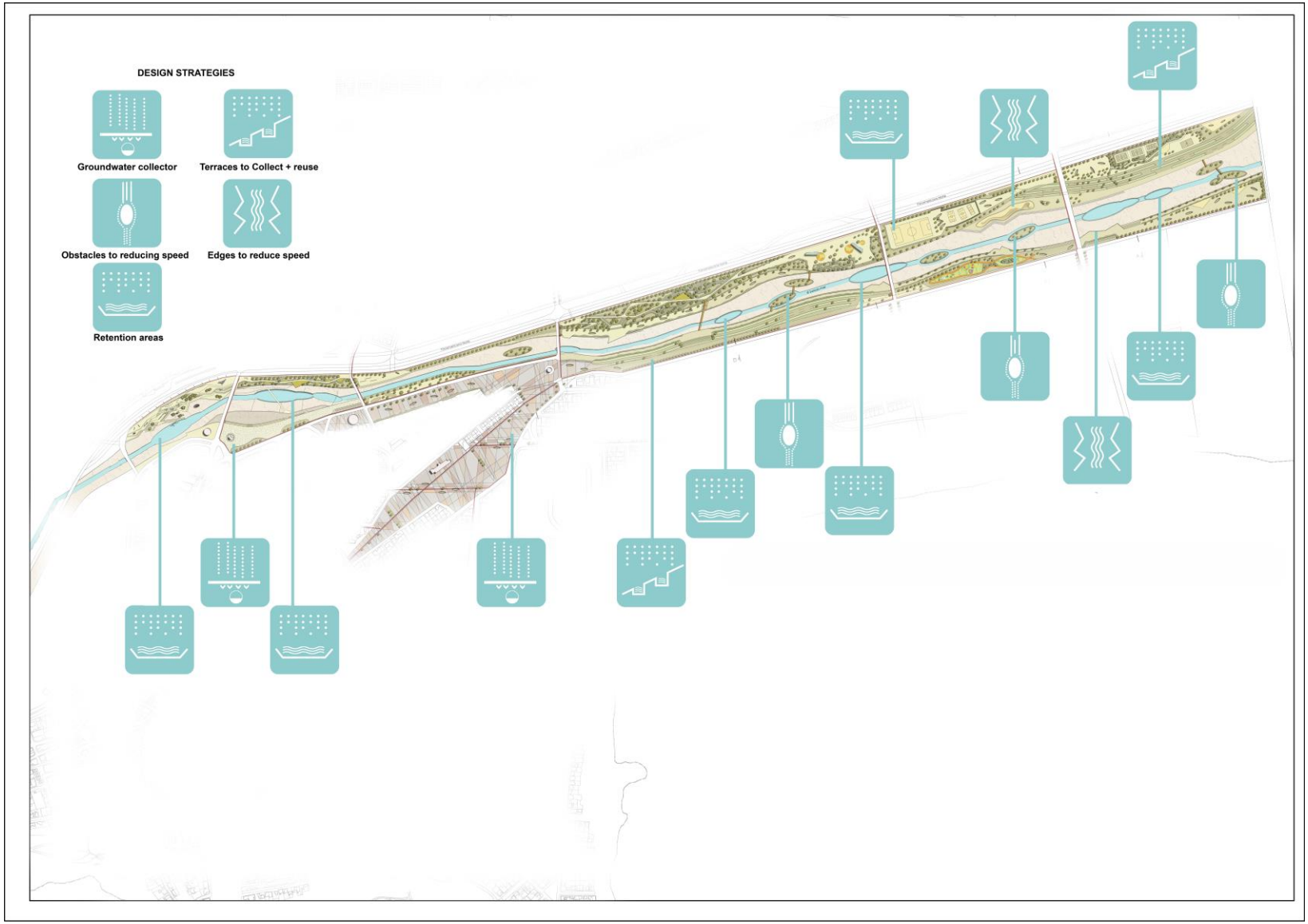

Figure 164: Design strategies for flood. Own elaboration.

6.6.4. Cleaning the river

The project has retention pools, where the objective in addition to retaining river water during floods, is to clean the quality of the soil, which in the case of Chañaral is highly contaminated with metals such as copper and zinc due to mining waste. The cleaning of the soil would be done through phytoremediation. The phytoremediation is a set of technologies that reduce in the same place the concentration of pollutants such as metals from biochemical processes carried out by specific plants and microorganisms associated with them. This alternative is a sustainable option for the project, low cost and effective.

There are two types of phytoremediation: Phytostabilization (immobilizes contaminants in the soil by means of absorption and accumulation in the roots of the plants) and Phytoextraction (Absorption of contaminating metals by means of the roots of the plants and accumulation of metals in their stems and leaves). The project will use phyto-stabilization because the surface contamination that has occurred for decades is devastating, low cost and has an aesthetic bonus. For Phytostabilization the project use the following species: Galega oficinalis, Mulinum spinosum and Heliotropium stenophyllum.

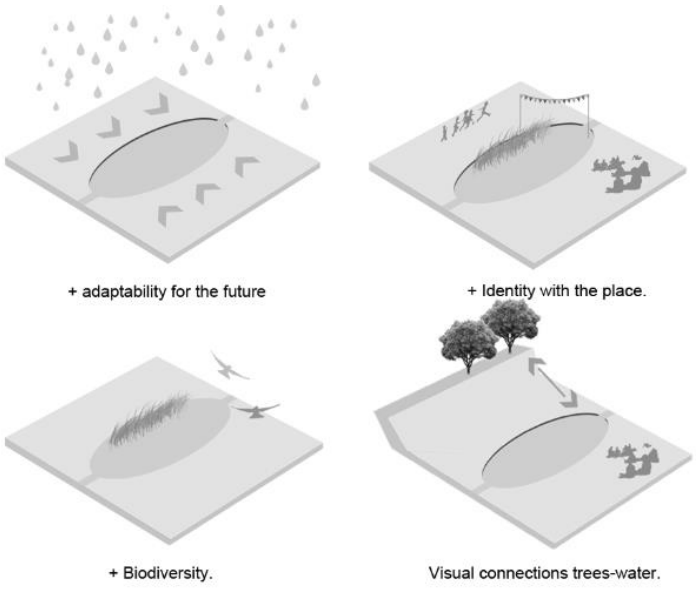

Figure 165: Benefits of retention zones.

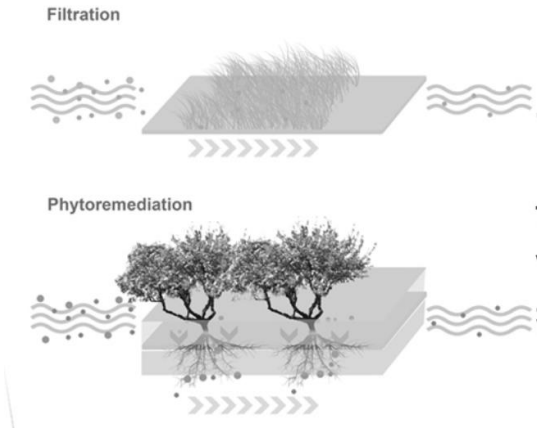

Figure 166: Diagrams of Phytoremediaton. Own elaboration.

6.6.5. Storage strategies.

The project is located in an arid zone, so the storage of rainwater is vital for the maintenance of the park, which is why there are different retention techniques applied in the project that ensure the maintenance of local plants used.

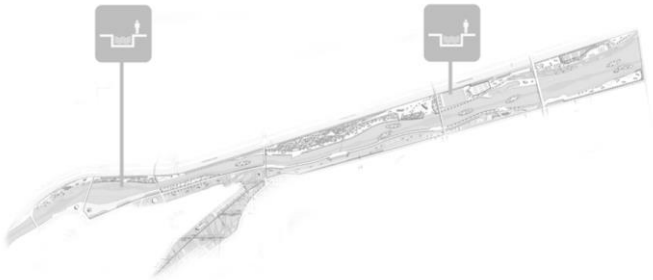

Figure 167: Retention zones. Own elaboration.

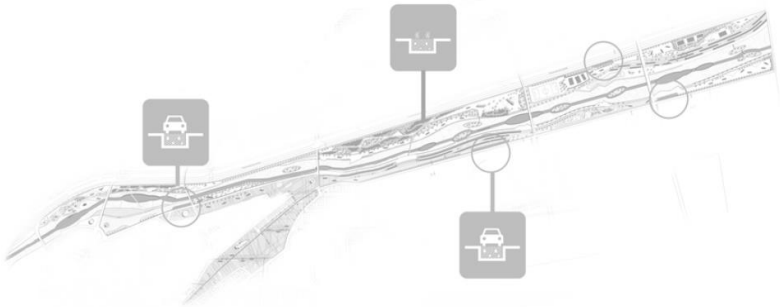

Figure 168: Green retention zones. Own elaboraton

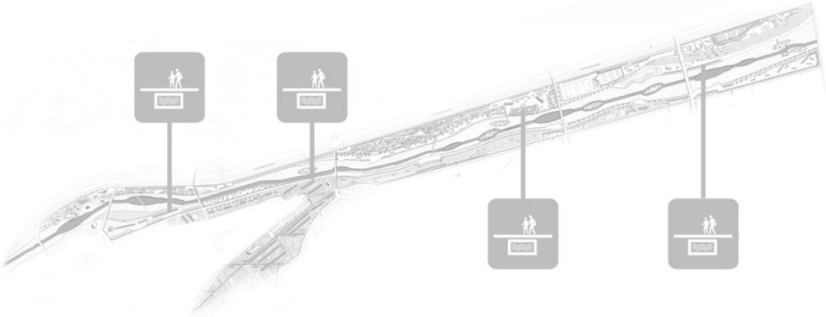

Figure 169: Underground retention zones. Own elaboration.

Figure 170: Diagrams showing the benefits of retention zones. Own elaboration.

Bioretention: Located in green areas.

Bioretention parking: Located in parking lots

Storage basin: Located in the main football field, skatepark, and into the river.

Underground storage: Located in main squares

6.6.6. Renders

Figure 171: The main Square. Own elaboration.

Figure 172: Sculpture park. The big man part. Own elaboration.

Figure 173: Sculpture park. Exhibitions part. Own elaboration.

Figure 174: Arid garden. Own elaboration.

Figure 175: The islands. Normal situation. Own elaboration.

Figure 176: The Island. Raining season. Own elaboration.

Figure 177: Medicinal garden. Riverside. Own elaboration.

Figure 178: Medicinal garden + birds house. Own elaboration.

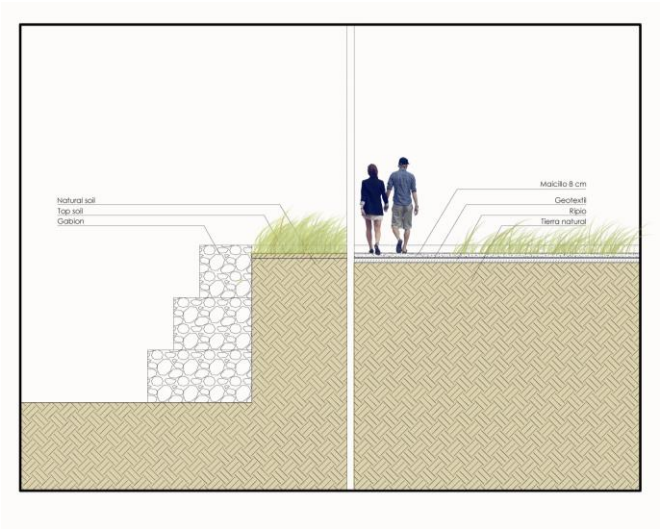

Figure 179: The island. Detail. Own elaboration.

6.6.7. Planting design.

Zones of the planting design. The zones have an order related to the condition of the species. All the selected species for the park are from the north of Chile, and all of them does not need too much water, but because of the special arid weather, there are special strategies to keep the water and using it in summer and spring.

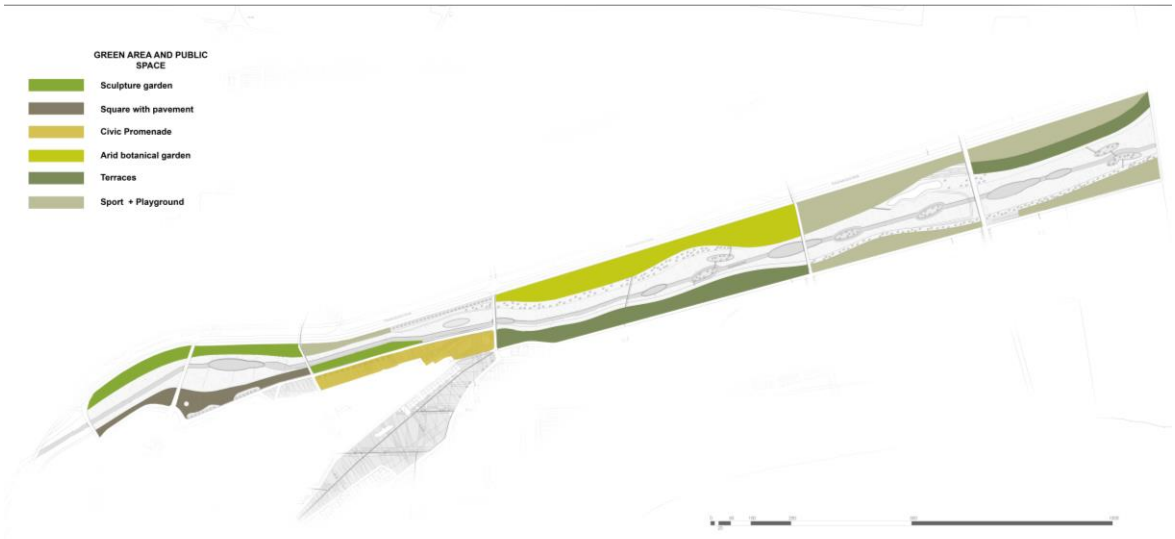

Figure 180: Green area and public space. Own elaboration.

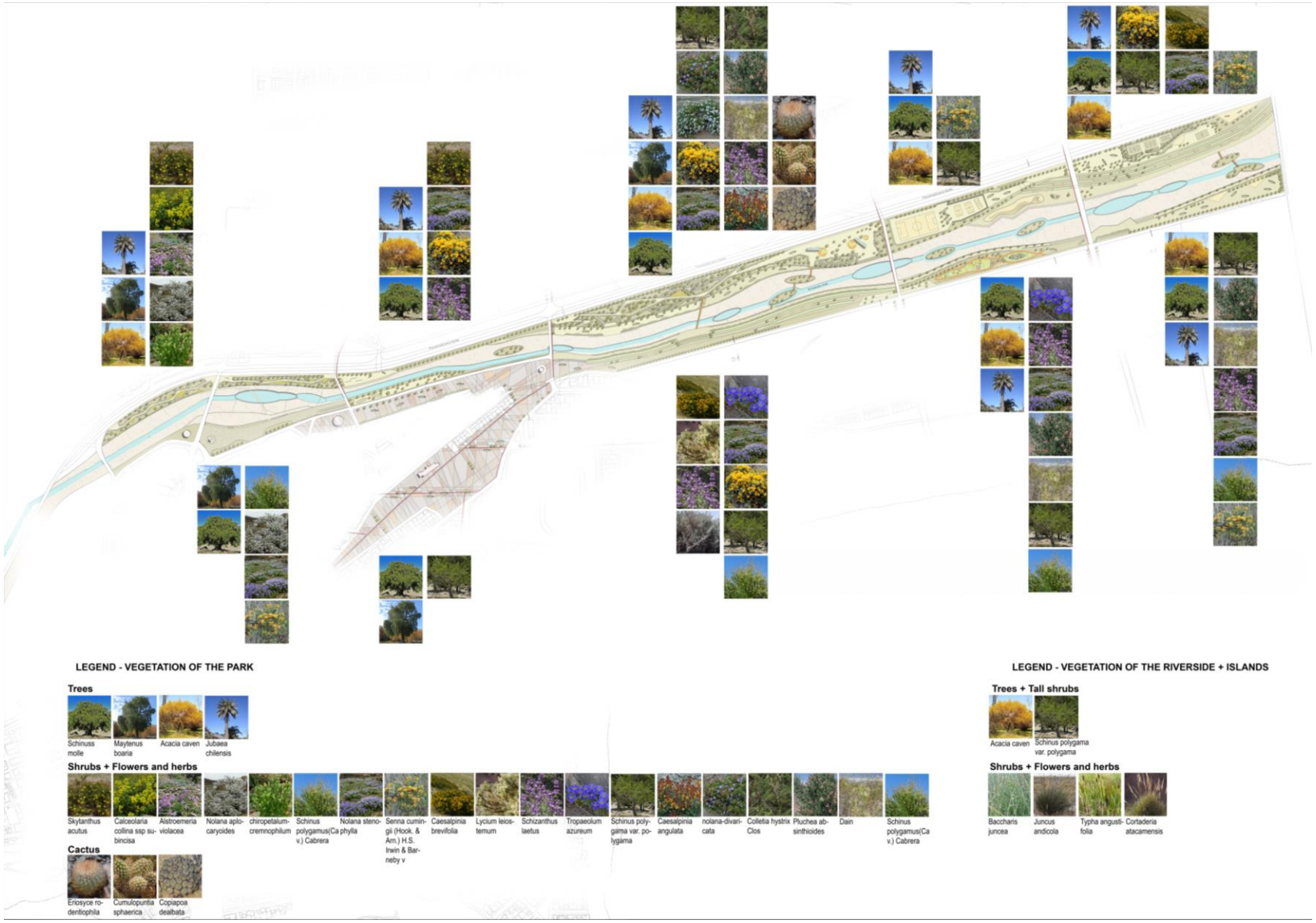

Figure 181: Planting design. Own elaboration.

6.6.8. Materials

The materials used for the proposal are mostly recycled and sustainable. A new technology will be used for places that require shade, with photovoltaic cells that can provide light. Minerals such as copper will be used in the main squares to reflect the site's mining activity, like Landart.

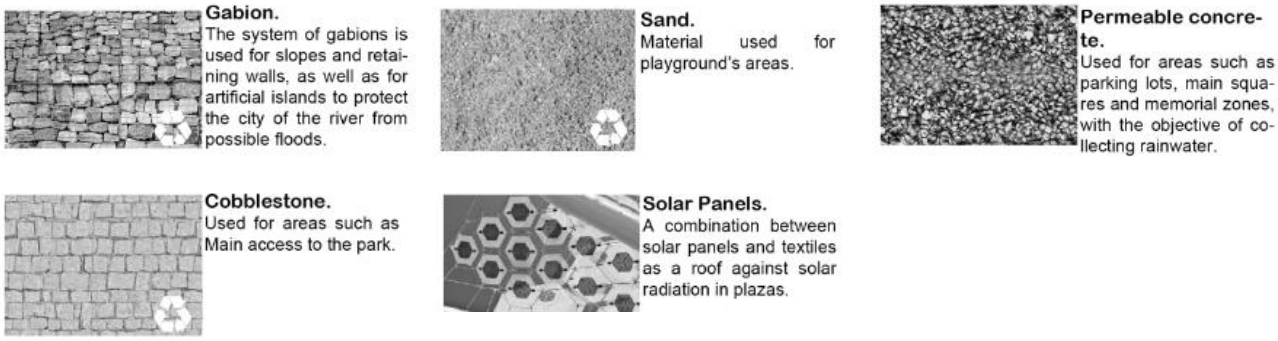

Figure 182: Materials. Source: Textures.com

6.6.9. Sustainability.

Sustainability must be present in a project of this magnitude and taking into consideration the problems of global warming, it is urgent to consider strategies that allow a good connection with the environment in a good way.

Within the sustainability strategies used in the project, we can divide them into two lines of action:

The River: The history of the El Salado River is related to mining, unfortunately it has suffered contamination from several mining companies as explained above, so the project seeks to remedy the soil and water quality that will circulate.

The Park: In this area will be located future landscapes with native forests whose function will be to increase biodiversity, generate a green lung for the city.

6.6.9.1. Strategies into the River.

The main sustainable strategies for the river are dedicated to cleaning up the contaminated river and soil. This project is pointing to the future, so due to the climate with more rainfall, should seize the opportunity to clean the place and increase local biodiversity.

A. Phytostabilization: As previously explained in chapter 6.9.3 , the project proposes retention pools, in these pools, plants will be used to create the phytostabilization effect.
   Phyto-stabilization is a process that consists of using native species preferably or introduced with the specific characteristic that they can resist and survive in contaminated soils or with high levels of metals, with the objective of removing these inorganic contaminants such as metal and organic contaminants such as oils.
B. Filtration: Vegetation that can filter contaminants that reach through other channels. The process uses local plants that can be in humid soils and withstand high temperatures.

6.6.9.2. Strategies into the Park.

The strategies in the park basically refer to luminaires based on solar panels, taking advantage of the great solar radiation that occurs in the area.

Local drought-resistant plants and local trees are also used to trap potentially harmful air particles.

6.6.9.3. Irrigation Strategies.

Taking into consideration the methods explained in chapter 6.6, the project will have rainwater retention areas for the subsequent irrigation of plants in the park.
Water will also be collected through hard squares and then reused to irrigate plants.

Chapter VII: Conclusions.

7.1. Conclusions

Climate change is already present and has been demonstrated in several events across the planet that nothing will ever be the same again.

Chañaral is a city that is experiencing this sudden change with terrible consequences such as the death of people due to the overflow of the river due to a flood, and such a situation will be more frequent in the future and the city is not prepared for this.

Other floodable park projects in Chile only cause the river, but the project is in a highly polluted arid zone, so using strategies to store water for periods of drought and using phytoremediation techniques to heal the soil is at least an alternative to consider.

The landscape found in this city is one with scars from the mining past that deserves to be rescued as a vestige of what should not be repeated, a teaching to future generations about caring for natural resources. Other cities in northern Chile also rescue their mining past with much success in tourism, so Chañaral could opt for the same, given its history of being one of the pioneering cities in dedicating itself to the country's main economic activity.

The project proposes to use species that require little maintenance, in Chañaral can be found more than 200 species, however a very small range can be found in the city and is an aspect to rescue and value in the landscape proposal.

The solution given in the thesis is to look to the future, where climate change is present and must be lived with and take advantage of this change to generate more biodiversity in the area, if the project manages to change the quality of soil, will improve the quality of life of residents through a landscape proposal that aims to unify a city divided by a river that is currently stigmatized by floods.

This project not only controls the river, but also offers an articulating space for an arid city that seeks meeting spaces.

Chapter VIII: Bibliography and references.

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8.2. List of figures and tables