# Acknowledgments

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To Lars, my partner, my friend, I thank you for your enormous support and constant motivation. Thanks for all!

Dedicated to my mom, today, and always…

# Abstract

In San José city, the rapid urbanization and changes on the ground cover (impervious surfaces) lead to a reduction of surfaces capable of absorbing rainfall, increasing the water runoff. In some instances, insufficient maintenance of the storm sewer in combination with waste dumping causes the overwhelm of the rivers and stormwater drainage systems infrastructure during the rainy season or in the presence of extreme weather events.

Some areas of the city suffer from the damages and distress of the floods every year, creating a 'damage recovery damage' cycle that reduces their resilience and signifies a burden for the community.

Resilience building depends strongly on community participation. Making use of social learning and build knowledge from the flood-affected people can facilitate the creation of tailored risk reduction and adaptation strategies.

Part of the findings of this research shows that the communities developed significant knowledge throughout their experience with the floods. They increased their understanding of the context and the problematic; they created tools, keep documentation, and want to make use of these resources to improve the situation.

So far, a lack of teamwork between the local government and the community on risk prevention-reduction and the actions limited to the emergency attention and response leads to mistrust from the residents' side.

Despite the restricted resources and capacities, the local government may have, it is crucial to advance towards a participatory approach to address the problems.

# Chapter 1. Introduction

## 1.1 Problematic definition

In San José city, the rapid urbanization and changes on the ground cover to impervious materials, lead to a reduction of surfaces capable of absorbing rainfall, increasing the water runoff. In some instances, insufficient maintenance of the storm sewer in combination with waste dumping causes the overflow of the infrastructure during the rainy season or in the presence of extreme weather events (Figure1).

Figure1. Flood events in the study area during May 2019. Source: Communal Early Warning Group.

Some areas of the city suffer from floods every year during the rainy season, creating a 'damage -recovery - damage' cycle that requires prompt actions.

In addition to the already mentioned problematics, are the challenges that Climate change poses for Costa Rica at the country level, like sea-level rise, variation of the average temperatures, variation of the average rainfall, extreme weather events (drought

Figure2. Constructions right alongside the Ocloro river. Source: P. Bermúdez-Meneses (2019)

and heavy rain), negative impacts on local ecosystems and adverse effects on fauna and flora.

Costa Rica is a country highly exposed to hazards, where building resilience, reducing risk, and raising awareness are urgent.

Settling down in the flood plain has been a common practice, observed in many urban areas of the country. The neighborhoods along the Ocloro river, have been developed in the natural flood plain of the river (see Figure 2).

Actions like the modification of the natural course of the river and piped river sections aggravate the problematics.

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Actions like the modification of the natural course of the river and piped river sections aggravate the problematics.

An essential aspect for this research is to understand the flood situation of the affected communities, get to know what they have learned, collect their knowledge and try to enhance their resilience with the addition of technical measures to cope better with the hazard and reduce the risk.

The accomplished social learning of these communities throughout the years living with the floods can also bring tools, and examples to other communities

in the country are facing similar hazards.

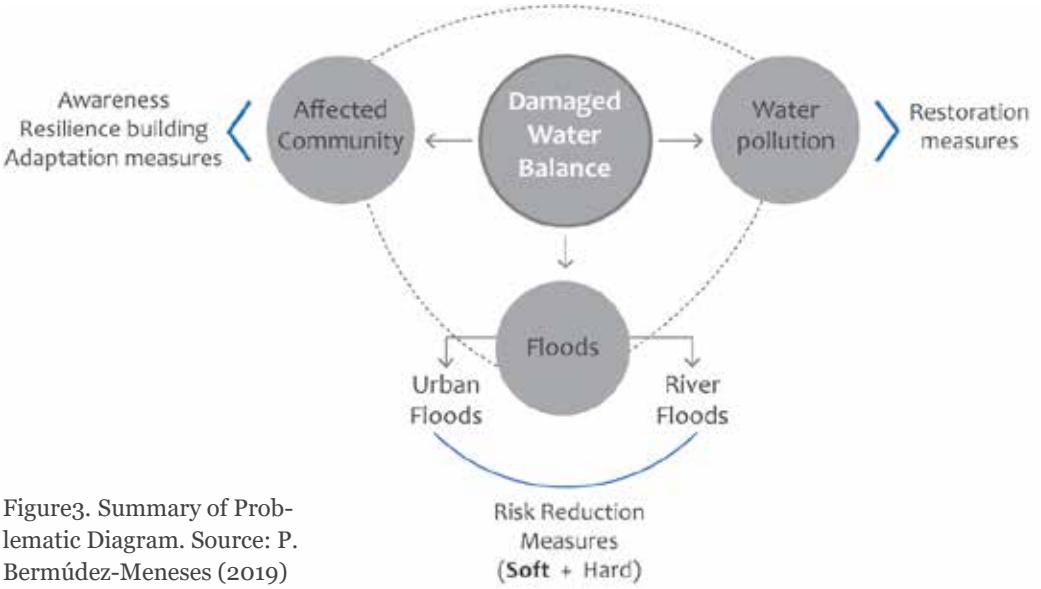



Figure3. Summary of Problematic Diagram. Source: P. Bermúdez-Meneses (2019)

### 1.2 Climate of the Central Region of Costa Rica and Climate Change

Situated on the south part of Central America, between Nicaragua to the north and Panama to the southeast. With the Caribbean Sea to the northeast and the Pacific Ocean to the southwest. Costa Rica occupies a surface of 51,100km².

*"The topography is varied and includes coastal plains separated by rugged mountains, including over 100 volcanic cones. Even though Costa Rica constitutes only 0.034% of the total Earth surface, its habitats represent around 5% of the planet's biodiversity."* (Climate Change Knowledge Portal, 2019)

Costa Rica belongs to the Neotropical zone. As a tropical country, it is in general terms, characterized by warm temperatures and rainfall a large part of the year. "Costa Rica's climate display generally well-defined annual patterns (Figure 4), which are periodically affected by fluctuations in the temperature of the surrounding oceans, the interaction of the atmospheric circulation with the volcanic mountain range that runs northeast to southeast, and the El Niño/La Niña cycles and Pacific Decadal Oscillation." (GFDRR 2011)

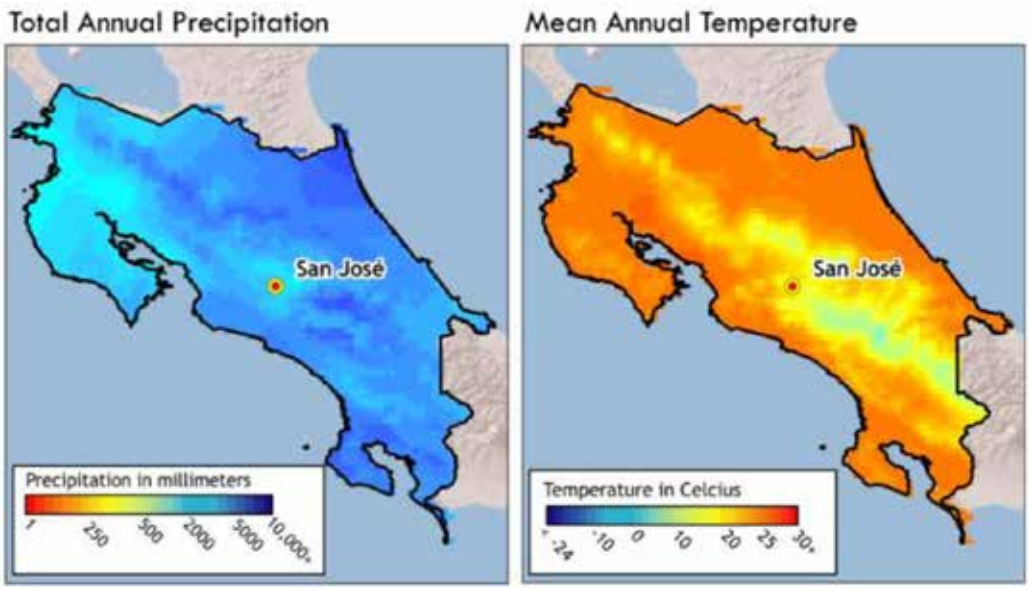



Figure4. Total Annual Precipitation and Mean Annual Temperature (respectively) for Costa Rica. Source: WorldClim 1960-1990 averages, http://www.worldclim.org/current

## Climate of the Central Region

San José city belongs to the called Central Region (center of the country). Tecto-volcanic region surrounded by hills and mountain ranges. The limit to the north is the central volcanic mountain range, to the south are the Escazú hills, Tablazo, Cedral and Fila Candelaria, to the west the Aguacate mountains and to the east the foothills of the Talamanca mountain range.

The Central Region is formed by two valleys, Western and Eastern, separated by the Candelaria and Ochomogo hills; San José city is located in the Western Valley. According to Solano and Villalobos (2001), the lower parts of the western valley are characterized by a dry climate owing to the Pacific Ocean influence. The Western valley has three well defined climatic conditions according to the altitude. The mid-height areas including San José, have a temperate climate and the higher areas are colder and rainier, a characteristic mountain climate.

As shown in Figure5, the average rainfall in the Western Valley (2300mm) is higher than in the Eastern Valley (1700mm). Though, in the Eastern Valley the rainfall is distributed along a larger period, having more rainfall during December, January and February. The longer distribution of rainfall is attributed to the influence of the Caribbean Sea.

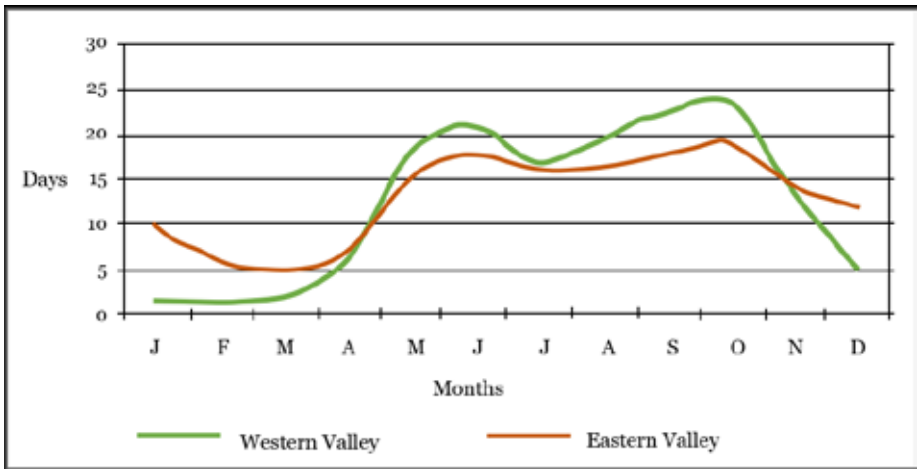



Figure5. Average days of rain per month in the Western and Eastern valleys in Costa Rica (1961-1990). Source: National Meteorological Institute (IMN) https://www.imn.ac.cr/documents - adapted and translated by the author.

The altitude has direct effect on the temperature of an area. The Western Valley has an average height of 1100 mamsl while the Eastern Valley has an average height of 1300 mamsl. The altitude difference added to the influence of the coasts from the respective sides, the trade winds and the southwest winds; regulate the climate of each valley. The Western Valley is lower, warmer and has more rainfall while the Eastern Valley is higher, colder and has less rainfall.

The Figure6 displays the maximum and minimum temperatures for both valleys in the throughout the reference period of 1961-1990. The Western Valley has a higher temperature, in fact, its average temperature, approximately corresponds to the maximum temperature of the Eastern Valley. The maximum temperatures in the Western Valley occur during March and April and for the Eastern Valley they occur during April and May. The Western Valley experience the larger interannual variation of the temperatures.

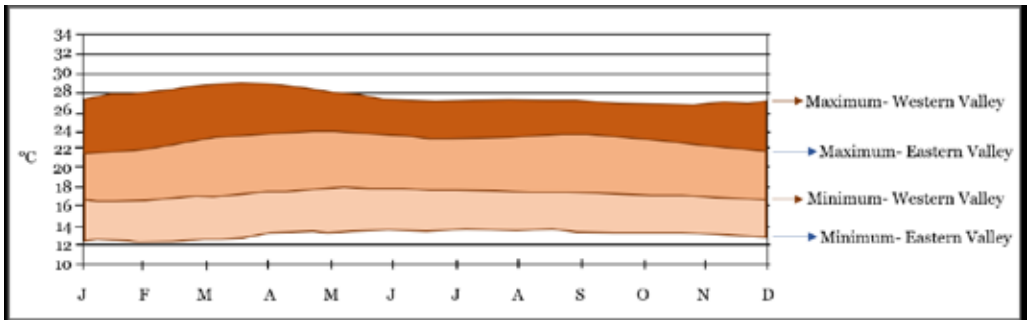



Figure6. Maximum and minimum temperature in the Western and Eastern Valleys of the Central Region in Costa Rica (1961-1990). Source: National Meteorological Institute (IMN) https://www.imn.ac.cr/documents - adapted and translated by the author

## Climate Change Scenarios for Costa Rica

"As a result of climate change, the impact of hydrological events continues to increase. Considering only direct loss, these extreme climate events have created economic losses estimated around 1.13 Billion US Dollars of 2011, representing damages for 2005-2011. Regarding impact to sectors, road infrastructure has experienced the biggest impact, followed by power distribution networks, agriculture and housing; four vital activities for country development." (MINAE, 2015, p.15)

The most vulnerable sectors to climate change are related to water supply and agriculture, therefore, research and knowledge building on those topics have increased to find possible solutions and tools to impulse their adaptation capacity.

According to the IPCC (2007) the climatic scenarios are consistent and coherent descriptions of how the global climatic system may manifest in the future.

The scenarios provide an ensemble of possible future climates under specific conditions, that can be used to perform integral evaluations and posterior identification of sectors potentially vulnerable to Climate Change (Figure7). This approach can set a base for decision making and outline of mitigation and adaptation strategies.

Giorgi (2006) and Baettig et al. (2007) claimed that Central America is the most prominent tropical Hot-Spot or most responsive regions to climate change. The fourth evaluation report of the IPCC (2007) considers probable a decrease of the average annual precipitation in most of Central America during the XXI century.

"In the past decades we have observed important changes in rainfall and increase of average temperature in Costa Rica, which adds to changes on land use and soil degradation processes. If the climate variability conditions continue to dominate the annual weather, there are multiple phenomena that may increase or lower their frequency or intensity. As a result, Costa Rica's weather will be subject to simultaneous extreme drought and extreme rain." (Costa Rica Central Government-MINAE, 2015, p.15)

According to the GFDRR (2011, p.4), the recent climate trends observed for Costa Rica since 1960 are:

Temperatures have increased between 0.2 and 0.3°C per decade with a prolonged and hotter dry season.

| Sector | | | | | | |
|---|---|---|---|---|---|---|
| Climate variables | Water resources | Agriculture | Health and other human aspects | Biodiversity | Forest resources | Coastal zones |
| Costa Rica | | | | | | |
| • Reduction of precipitation by 46 to 63%<br>• Temperature rise of 3.2–3.5 °C | • Problems of erosion and sedimentation, with repercussions for use of the resource and hydroelectric energy generation<br>• Variations (positive and negative, depending on the scenario) in runoff | • Reductions in production of rice, beans and potatoes<br>• Coffee increases production with a 2 °C. temperature rise, with a good water supply | | • Reduction of montane, premontane, wet and rainforest life zones<br>• Wet tropical and dry tropical life zones would be the most affected<br>• Plant and animal species at the lowest or tropical belt would be the most vulnerable | • Migration of species, loss of civersity | • Breeches of the coastline and expansion of areas prone to tidal flooding<br>• With a 0.3 m sea level rise, 60% of Puntarenas would be flooded (90% with a 1m rise) |

Figure7. Effects of Climate Change on different sectors of Costa Rica. Source: Cifuentes, M. (2010)

The number of warm days increased by 2.5 percent and nights by 1.7 percent, while the number of cold nights and cold days decreased by -2.2 and -2.4 percent per decade.

Temperature extremes increased by between 0.2 and 0.3°C per decade;

While most climate data show positive trends (increased precipitation), overall average annual precipitation in the region and the number of consecutive wet days do not show significant changes although there has been a slight increase in its intensity; and

Extreme precipitation has increased significantly and is strongly correlated with the temperature of the tropical Atlantic Ocean. The latter indicates that prolonged rainy seasons are related to the warm waters in that oceanic basin.

The trend over the last 40 years suggests a strengthening of the hydrological cycle, with more intense rain occurring during shorter periods of time that produce greater average precipitation per episode. This trend is expected to continue in the future due to climate change, possibly resulting in a greater frequency or intensity of extreme events such as floods and droughts. This poses obvious impacts on agricultural production, soil and forest conservation and water availability, all of which are already showing signs of stress and vulnerability.

The number of dry days is expected to increase, along with the frequency of more intense precipitations and extreme events such as storms and floods toward 2080.

## Climate change impacts on hazard vulnerability

As Cifuentes (2010) explains, Central America is a highly disaster-prone region. The disasters in the area have increased to an annual rate of 5% over the last 30 years. Climate change effects in combination with aspects as location of the population in risk zones like river banks and wetlands, environmental degradation and weak capacity of the government for management and risk reduction.

“Since the effects of these disasters are cumulative and the resilience of systems is reduced following repeated events, the occurrence of more than one natural disaster per year could impact the countries even more severely.” (Cifuentes 2010, p.62)

CCAD-SICA (2010) states that in Costa Rica, between 2001 and 2008, the flood and storm events had the highest human and economic impact. During that period, 8 flood events affected 106,000 people and the caused damages reached US$ 106 million.

“Despite its high exposure to adverse natural events, Costa Rica has built an efficient disaster response system and has managed to limit vulnerabilities through the effective enforcement of building codes, environmental standards, and land use planning. Costa Rica has also made substantial progress in strengthening its institutional and legal framework and mainstreaming disaster risk management in its national development program.” GFDRR (2011, p.8)

## Costa Rica’s Adaptation Action for 2016-2030

The national government of Costa Rica emitted as part of the National Climate Change Strategy, the Adaptation Action for 2016-2030 were the country assumes the following commitments in terms of adaptation:

Development of a National Adaptation Plan: completion of the plan including plans for sectors and territories identified as priorities Biodiversity, Agriculture, Water, Coastline, Fishery, Health, Infrastructure, Energy, Tourism, Cities.

Disaster Risk Reduction: finalize the National Disaster Risk Management Policy 2016-2030 with Risk Reduction, Disaster Response and Readiness, and Disaster Recovery as pillars. Climate change adaptation is the cross-cutting issue for this policy.

Community Based Adaptation: the purpose is to empower the population to face climate change impacts by increasing their resilience. Promotion of Green

and Inclusive Development (DVI). Over 30 community-based adaption projects have been financed and assisted by the Adaptation Fund since 2014.

Ecosystem Based Adaptation: to convey an ecosystem-based adaptation focus. One objective is to increase forest coverage to 60% (by 2013 it was 54.4%), this also favors reduction of emissions through the afforestation. Environmental Services Payment Program and the Forest Certification Program to promote sustainable development and protection of water sources. National Biological Corridor System and the National Protected Areas System (SINAC).

Local Planning and Management of Territory Adaptation: aims to develop a land use plan for each city which integrates and works on regards of the vulnerabilities to climate change and impulse the adaptation and mitigation actions.

Public Infrastructure Adaptation: existing documentation on damages due to extreme weather events, show that public infrastructure is the most affected sector. The purpose is to design and implement a national vulnerability monitoring program for infrastructure during drought, flood, landslides and sea level rising.

Environmental Health as an Adaptation Measure: “With the understanding that environmental health in all of its components (Basic Sanitation, Integrated Waste Management, Water Quality for human consumption, sewers, storm drains and dangerous substance controls) is a condition needed to reduce future vulnerabilities of human population and wildlife, Costa Rica commits to, by 2030, increase the sewer and storm drain coverage, maintenance and sustainability up to a 90%; and set an environmental health surveillance program, by 2018, to follow up on pathologies associated with climate change.” MINAE (2015)

Capacity Building, Technology Transfer and financing Adaptation: The identification of vulnerabilities, setting priorities and conducting studies to address-reduce these vulnerabilities. It is necessary to strengthen the coordination and cooperation among institutions as well as between the government and the civil society. Greater transparency and open data are part of the commitment of the government on this topic. Consolidation of information systems (SNIT and CENIGA), follow-up of the extreme weather events by the National Meteorological Institute and strengthen the early warning systems cooperating with the National Emergency Commission.

## 1.3 Research objective and aim

Perform analysis to understand the flood-affected context, the behavior of the floods. Work with the residents to get to know their experiences, collect their knowledge, and try to enhance their resilience with the addition of technical measures to cope better with the hazard and reduce the risk.

### Research aim

1. Analyzing the study area context and the floods affecting it.

2. Study the build-knowledge and local responses from the affected-communities to face the floods.

3. Outlining a set of complementary technical measures to enhance resilience in the study area and to impulse the restoration of the water balance.

Research Questions

What are the influences that trigger the floods in the affected areas?

How are the affected communities coping with the hazard?

How to impulse from the communities, resilience, and restoration of the water balance? (bottom-up approach)

### Hypothesis

The analysis of flood-affected areas with an emphasis on the experience-knowledge of the residents and strategies they used to cope with the hazard can provide a set of local responses for adaptation to potentiate by adding technical measures and impulse their resilience.

## 1.4 Research methodology

This research has been developed following a methodology of 4 phases.

*Phase 1. Desk research and framework preparation* – this phase includes

Literature review, study of related cases, remote data collection, research on flooding events in San José-Costa Rica (identify affected areas - weakened links in the water cycle), choice of study area, definition of research aim and objective.

Mapping of physical conditions and main features of the urban ecosystem of San José.

*Phase 2. Fieldwork* – this phase includes

Data collection (typology of the buildings, location, infrastructure, land use), analyze the context and contact with the inhabitants.

Interviews (unstructured - structured), sketch mapping, site observation, expert interviews, institutions data collection, river walks, photographic register.

*Phase 3. Analysis* – this phase includes

Processing collected data, overlapping (physical conditions, ecosystem elements and affected areas).

Analyzing data and study of measures developed and applied by the affected communities.

Application of the Source-Pathway-Receptor-Consequence Model and construction of a Risk-Mistake-Solution Matrix.

During the analysis of data, is necessary to make a revision of the research aim, objectives and hypothesis and possibly adjusts several aspects according to the gained knowledge and findings.

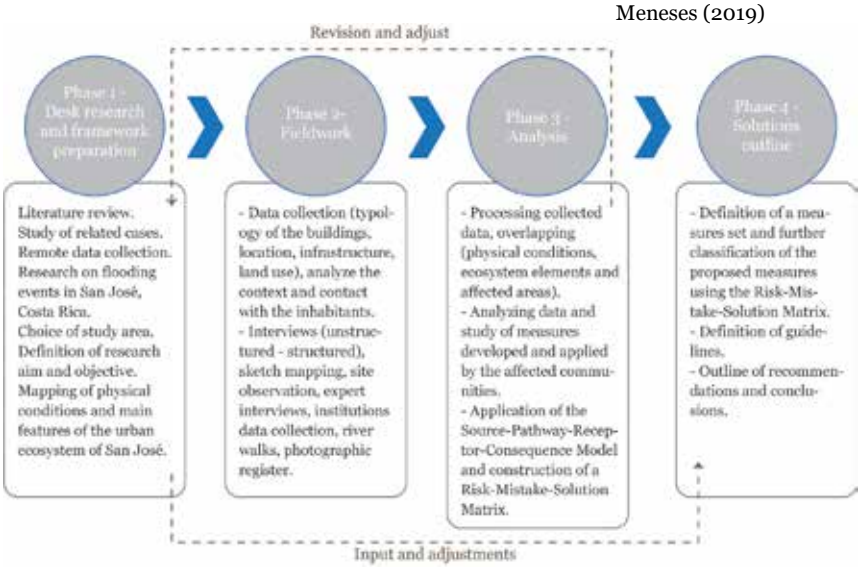
*Phase 4. Outlining solutions* – This phase includes

Definition of a measures set and further classification of the proposed measures using the Risk-Mistake-Solution Matrix.

Definition of guidelines.

Outline of recommendations and conclusions.

Figure8. Methodology Conceptual Diagram. Source: P. Bermúdez-Meneses (2019)



The practical approach towards the Water Balance restoration in the study area focuses on three main axes Livability and wellness, Environmental conditions, and Stormwater management. The axes correspond to the problematics identified in the study area.

The approach is for the three-axis and its proposed measures to cooperate and benefit from each other. In this way, a multi-benefit approach (symbiosis). The three-axis and their measures, additionally work correspondently to the defined study levels, Watershed-Ocloro river level and Neighborhood-household level. (Figure9)

> *"Defending against future floods will therefore require more robust approaches to flood management that can cope with larger uncertainty or be adaptive to a wider range of futures" (A. Jha, R. Bloch and J. Lamond, 2012).*

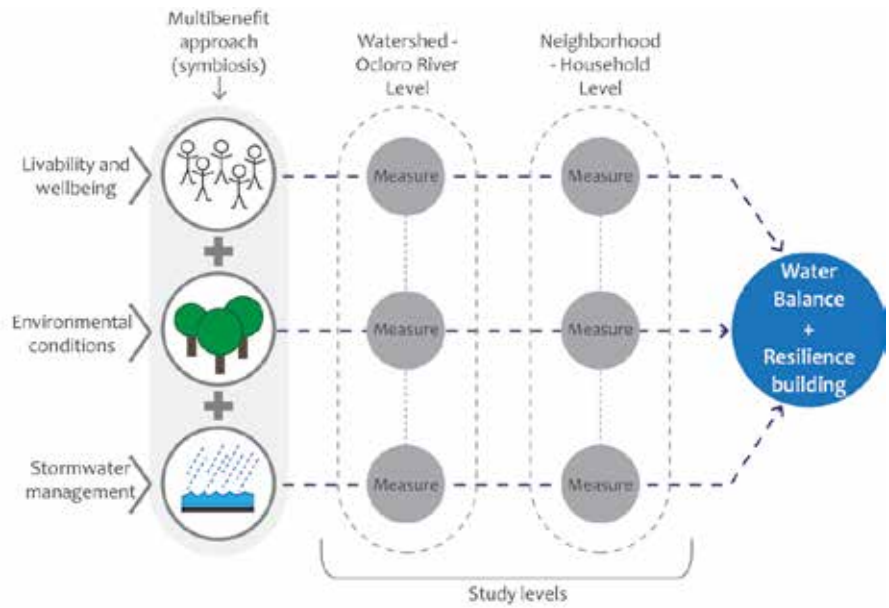



Figure9. Research Story Line Diagram. Source: P. Bermúdez-Meneses (2019)

# Chapter 2. Theoretical Framework

## 2.1 Water cycle and Water balance

The natural water cycle also referred to as the hydrologic cycle, consists of 4 main phases:

Evaporation – is the process where heated water transforms into gas, called water vapor. This process can be trigger by sun radiation as well as the transpiration of plants (known as evapotranspiration).

Condensation – is the process where the air cools down the water vapor, which reaches its saturation point, turning in to a liquid and forming clouds.

Precipitation – the process occurs when clouds meet low air temperature areas, then the water they contained, returns to the ground as rain, snow or sleet.

Water movement – this process includes movement of water on the ground surface called runoff, the process of infiltration of the water in the ground and the

process of percolation, when the water moves through the soil layers, getting filtered, recharging the underground water bodies and eventually reaching the sea.

Extensive construction and impermeabilization reduce the infiltration capacity of the soil and increase the amount and speed of rainwater runoff.

This condition often one of the primary triggers of urban floods. The process of percolation and last recharge of the underground water is also affected by the reduction of water infiltrated in the ground layers.

The relevance of the hydrologic cycle in the process of resilience building is supported by Watson and Adams (2011) when they state that design for resilience recognizes the natural processes of the hydrological cycle and the role of soil, plants, and reservoirs in holding and using water.

The previous statement is a defining concept behind the enhancement of the landscape as we find it, design it, and remediate it to limit and mitigate flooding.

Stormwater should be managed more sustainably, working in coherence with the hydrologic cycle, ensuring the groundwater recharge and healthy conditions of water flows and aquatic ecosystems.

*"As stormwater runoff is generated across distributed areas, distributed green infrastructure presents the best opportunity for delivering multiple benefit outcomes while managing stormwater impacts" (Cooperative Research Centre for Water Sensitive Cities, 2013).*


Figure10. The hydrologic cycle. Source: https://australianmuseum.net.au

## 2.2 Resilience and Adaptive capacity

Resilience

López and Tschakert (2011) define the concept of Resilience as the capacity of a system to absorb hazard disturbances, learn from mistakes in past responses, reorganize after disturbance events, and prepare for possible future shocks and anticipated impacts.

Proag, V (2014), makes emphasis on the two forms of Resilience, described by Moench (2009):

(a) Hard Resilience: enhancement of the Resilience of a structure employing strenthening built measures for damage prevention.

(b) Soft Resilience: capacity to adapt or be flexible to adsorb and recover from the impact of shocks.

Due to the principles of flexibility and adaptability of soft Resilience, it is an excellent strategy to start the strengthening work on this form of Resilience. The adaptability may have a material impact on the reduction of vulnerability.

While both forms of Resilience must take action, hard resilience-building tends to require longer time and higher investment while soft Resilience can produce some positive effects in a shorter-term with lower investment.

Besides the forms of Resilience, it is essential to evaluate and consider two related concepts within the realm of Resilience. Bounce back and Bounce forward, they both refer to the way how a particular element overcomes the stress.

The most significant difference between these two concepts is the process and outcome of the recovery. While the bounce back implies to overcome the stress inflected by reestablishing form or condition as before the shock-disaster occurrence. The bounce forward takes a step further, employing learning from experience, reinventing itself, and preparing better to endure future stresses.

López and Tschakert (2011) advocate for the social learning approach, by enhancing common knowledge, awareness, and skills, engagement of multiple participants (more on the soft resilience side). They warn about a single focus on technical measures because this undermines the self-organization (a vital component of the Resilience) due to the little involvement of the community.

The IPCC (2014) defines adaptive capacity as the skill to adjust to climate change effects, mitigate potential damages, make use of potential opportunities,

and deal with the consequences.

### 2.3 Risk= Hazard + Vulnerability

Proag, V (2014) presents in his work the following definitions for the concepts Vulnerability, Hazard, and Risk:

Vulnerability is the intensity to which a system may react adversely during a hazard. It relates to the social, physical and economic aspects and the impacts according to the coping capacity of the system.

Hazard and Risk: A naturally occurring or human-induced process or event with the potential to create loss is a hazard, i.e., an endless source of danger. The actual exposure of something of human value to a hazard is a risk, and it is often the combination of probability and loss. „Thus, a hazard is a potential threat to humans and their welfare, and risk (or consequence) is the probability of occurrence of a specific hazard“ (Sahni et al. 2001).

Handmer et Dovers (2009) describe the possible reactions of a system that is aware of possible future disturbances. They established three types of responses:

1- Resistance and maintenance, is a system that avoids change and probably denies the existence of a problem.

2- Change at the margins, is a system that acknowledges the problem, discusses the implications, and ideally, understands the system needs to change.

3- Openness and adaptability, is the system that reduces its vulnerability by being flexible, working on preparedness, and adopting new operation settings and structures.

### 2.4 River flood and urban flood

Urban flood

An urban flood occurs when heavy rainfall collapses the stormwater drainage leading to a flood in the built environment and especially densely populated areas with large impervious surfaces.

River flood

A river flood occurs when the river bursts its banks, and the water spills onto the flood plain. Among the factors that boost a river flood are, highly steep-sided banks, lack of vegetation or woodland on the surroundings of the river,

a basin formed mostly by an impervious rock or a basin in an urban area with mostly impervious surfaces.

## 2.5 Nature based solutions

"Effective management of natural systems and 'green infrastructure' can make major contributions to the sustainability and livability of our cities" (Cooperative Research Centre for Water Sensitive Cities, 2013).

*Green infrastructure*

According to Selman (2012), the concept of green infrastructure encompasses ideas about ecological and hydrological connectivity and a general reduction in reliance on grey infrastructure… if sustainably managed and physically reconnected, it can contribute in a multifaceted way to the amelioration of living conditions…

The Landscape Institute in the UK (2009) argues that the multifunctional nature of the green infrastructure, underpinned by ecosystem services, and enhanced through connectivity, can yield a diverse range of mutually reinforcing benefits.

Throughout the revision of the studies related to green infrastructure, it appears more evident the need for reconnecting natural landscape elements with our cities. In other to do so, we first need to recognize the ecosystem, its components, and understand the broken relations to work on the process of regeneration.

Green infrastructure can function as Low impact development (LID) measures to control the runoff, in terms of speed and amount; a side benefit from the implementation of green infrastructure as LID control measures is the reduction of pollutants (see Figure 8). Examples of green infrastructure application are:

*Rain gardens*. Depressed area planted with different types of grass and other plants, that capture rainwater from roofs, sidewalks, driveways and allows the infiltration in the ground.

*Bio retention cells*. They are in the configuration, similar to the rain garden, but it contains a designed soil mixture placed above a layer of gravel (drainage). This combination allows the storage, infiltration, and evaporation of the rainwater.

*Vegetative swales*. Channels covered with grass and vegetation, to collect and

slow down the runoff.

*Infiltration trenches*. Ditches filled with gravel to intercept the runoff, storage a particular volume, and allow infiltration.

*Green roof (extensive and intensive)*. It is a variation of a retention cell, and it consists of a base of drainage mat material with soil above it and vegetation that enables rainwater infiltration and posterior evapotranspiration.

*Rooftop (downspout) disconnection*. Discharge of the roof rainfall into pervious areas and lawns instead of the storm sewer.

*Rain barrels-rainwater harvesting*. Collection of roof rainfall in barrels or cisterns (bigger capacity) for later release or re-use during dry periods.

*Continuous permeable pavement systems*. Excavated areas that allow the transit of rainwater through the pavement into a gravel storage layer, for later infiltration.

*Landscape planning and urban ecology*

In terms of physical connections in landscapes, Selman (2012) highlights how urban development and intensive agriculture broadly take place on the flood plains, and the need to protect that investment has led to disconnect the river from its flood plain by engineering works.

The previous statement goes along with what the experience in San José city, the intervention of rivers by tubing, construction right next to the rivers and sealing of surfaces have been part of the development actions of the city for decades.

In terms of water storage, Watson and Adams (2011) claim that watershed planning and floodplain management considers water flow as an integrated system. Flood control begins with the protection and management of wetlands and the vegetated landscape of riparian buffers along streams, rivers, and water bodies.

Watson and Adams (2011) sustain that the Water Cycle and the carbon Cycle are linked processes balanced and sustained by functioning watersheds. They propose the enhancement of landscapes, afforestation, and carbon sequestration. One can conclude that an integrated work approach focused on different elements of the urban ecosystem boosting the delivery of ecosystem services.

Urban ecology studies the interactions of organisms, built structures, and the physical environment, where people are concentrated. This discipline focuses

its attention on the place where we live. The urban ecology itself studies the ways the organisms interact with their environment. For this understanding, we can analyze the ways the present organisms, including humans, interact and relate to an urban environment, the positive and negative effects in the different possible directions.

From the urban ecology, it is possible to visualize organisms, components, and actors present in the urban ecosystem to understand the role, interactions, and effects. It is also possible to highlight potential conflicts or broken links that are necessary to reconnect to improve the conditions for both actors and the environment.

Most experts, classify ecosystem services on four categories:

1. Provisioning services - raw materials, resources, water, food.

2. Regulating services - purification of water and air, the stability of the soil, crop pollination.

3. Supporting services - seed and nutrient dispersal.

4. Cultural services - beauty, recreation, inspiration, scientific discovery.

In terms of diversity and interconnection between the different features of an ecosystem, Watson and Adams (2011) claim that the more complex an ecosystem or community is, the more likely it goes on throughout time and the less vulnerable it is to damage.

Figure11. Examples of green infrastructure use as LID. Source: https://www.epa.gov

# Chapter 3. Context of study

## 3.1 Geographical location, administrative division and population data

The selected study area is situated in the southeast part of San José city. The macro-level for the analysis consists of the minimum unit of the tributary of the Ocloro River (see Figure12); this area has an approximate extension of 612 hectares.

The Ocloro River is a tributary of the María Aguilar River, together, both rivers form a micro-basin within the watershed of the Tárcoles River. This watershed is one of the main four basins of the country.

In its complete trajectory, the Ocloro River flows through part of the territory of three different cantones, costarican administrative units governed by a municipality (local government). The three cantones, in this case, are San José, Montes de Oca and Curidabat. In terms of extension, a large section of the river

corresponds to the territory of San José, followed by Montes de Oca and basically, only the origin of the river belongs to Curridabat.

It is an urban context, broadly consolidated with a percentage of surface impermeabilization.

The population data provided by the Municipality of San José corresponds to 2013 and states the following distribution of population per neighborhood.

Barrio Luján: 2,871 inhabitants

Cerrito: 777 inhabitants

Calderón Muñoz: 1,369 inhabitants

Francisco Peralta: 450 inhabitants

Barrio La Cruz: 1,421 inhabitants

Naciones Unidas: 660 inhabitants

Los Yoses Sur: 826 inhabitants

Zapote: 564 inhabitants

The open data from the Municipality of Montes de Oca (East of San José) corresponds to 2018 and states that the population of San Pedro district, where a section of the Ocloro river flows, is equivalent to 29,126 inhabitants.

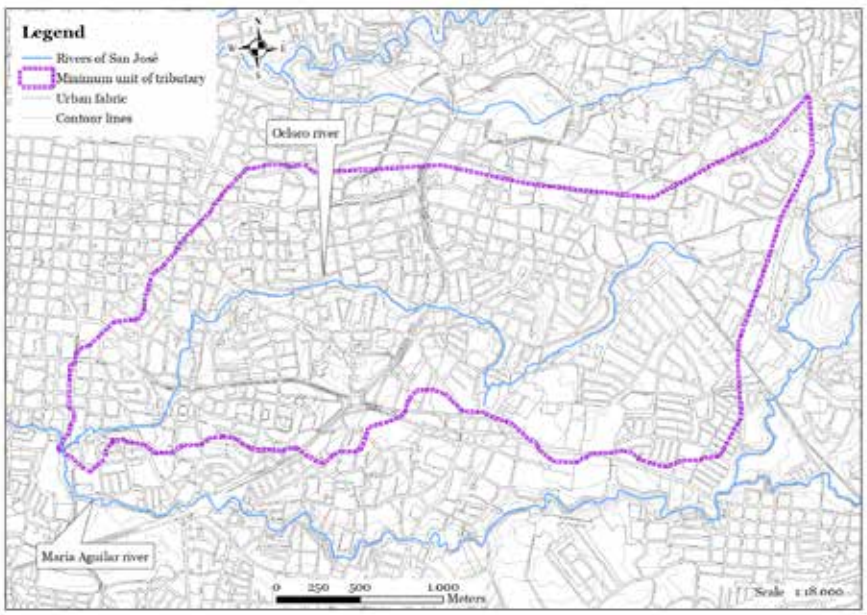



Figure12. Location and extension of the Study Area. Source: P. Bermúdez-Meneses (2019)

### 3.2 Climatic conditions

According to the Aranjuez automatic weather station of the National Meteorological Institute, the summary of the monthly averages of climate date correspondent to the study area for the period between 1996 and 2019 is:

| Element | Period | | Average | Total | Unit |
|---|---|---|---|---|---|
| Rainfall | 1996 | 2018 | 144.7 | **1736.4** | mm |
| Max. Temp. | 1996 | 2018 | 24.9 | | °C |
| Min. Temp. | 1996 | 2018 | 17.4 | | °C |
| Mean Temp. | 1996 | 2018 | 21.1 | | °C |
| Humidity | 1996 | 2018 | 76.8 | | % |
| Wind speed | 1996 | 2018 | 10.2 | | km/h |
| Radiation | 1996 | 2018 | 13.0 | | $MJ/m^2$ |
| Pressure | 1998 | 2019 | 882.4 | | hPa |

## 3.3 Topographic conditions

The topography in the study area is diverse, developed close around the river, in the flood plain and slopes. Besides, the presence of hills makes for a complex terrain condition.

The following map and topographic profiles (Figure13 and Figure14) show more in detail the situation of the terrain and facilitate the understanding of the water cycle and rainwater behavior in this specific context.

## 3.4 Urban development in the watershed of the Ocloro river

The urban growth-consolidation of the neighborhoods along the rivers has posed high pressure on the urban rivers, typical panorama in Costa Rica. The Ocloro River is a clear example of an urban river affected by this trend.

On February 16th, 1996 Costa Rica emitted the Forestry law #7575, among other things, this law established as mandatory the creation of protective buffers for all rivers and defined the regulations for the dimensions of the buffers according to the topographic conditions of the river banks.

The protective buffer has as targets, the creation of natural green corridor along the river, provision of habitat for local fauna, space for the river in case of increase of water volume and consequently, the protection of the infrastructure and

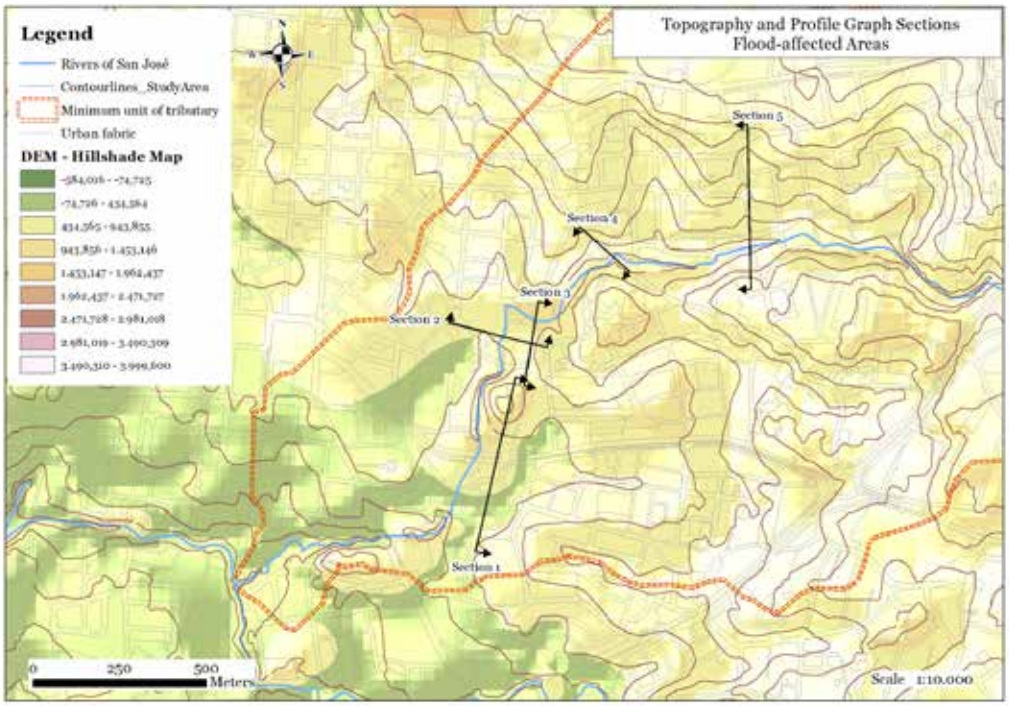



Figure13. Map of Topography and Profile Graph (sections) of the flood-affected areas. Source: P. Bermúdez-Meneses (2019), Base data: MSJ, ProDUS-UCR, SENARA

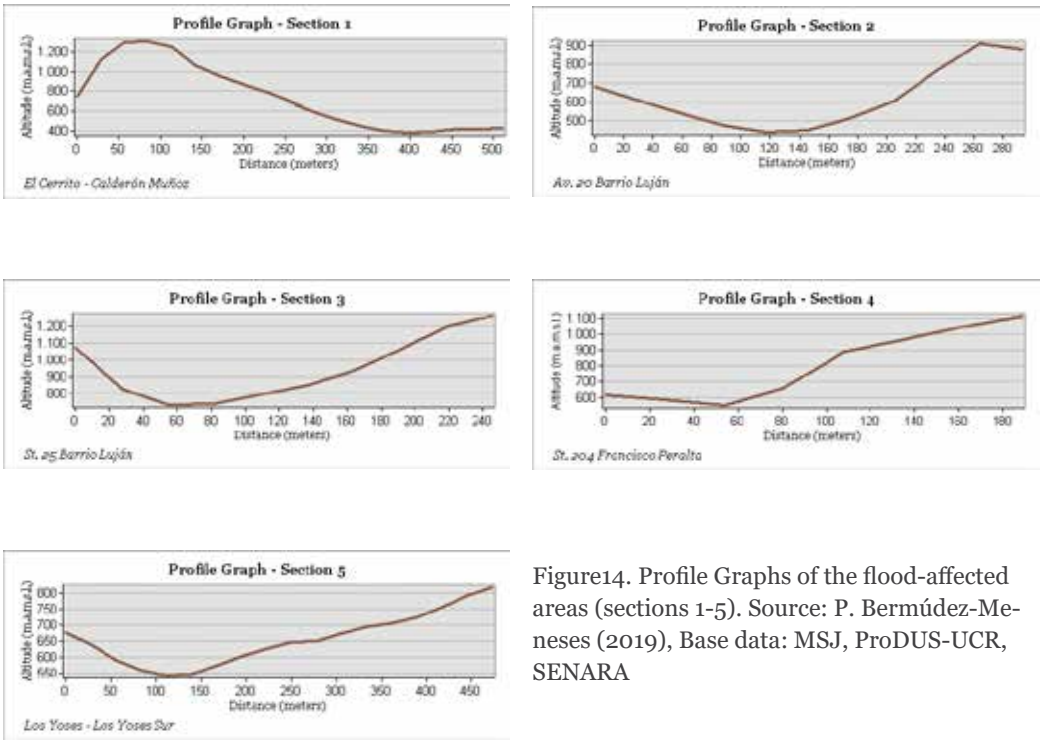



Figure14. Profile Graphs of the flood-affected areas (sections 1-5). Source: P. Bermúdez-Meneses (2019), Base data: MSJ, ProDUS-UCR, SENARA

people living in the proximities of the river.

Due to the antiquity of most neighborhoods of San José, before 1996, and the limitation of the law to be applied retroactively, many sections of the river do not possess a protective buffer. The situation described can be observed in several points along the Ocloro River.

Some problematics are complete lack of protective buffer, piped river to give space for more construction space in Los Yoses, modification of the natural course of the river, creating straight lines where there used to meander, construction on the flood plain.

Also, illegal discharges of sewer water and other residues into the river have a significant adverse effect on the environment and livability around the river.

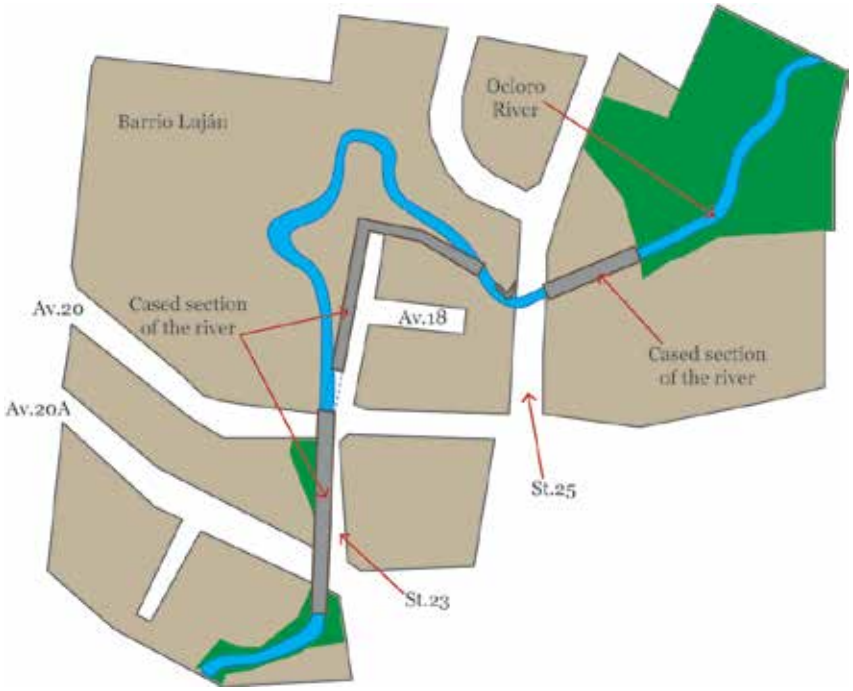
It is possible to picture the situation as the urban growth choking the river to the point the river becomes a problem in itself when it cannot hold the pressure any longer (Figure15).

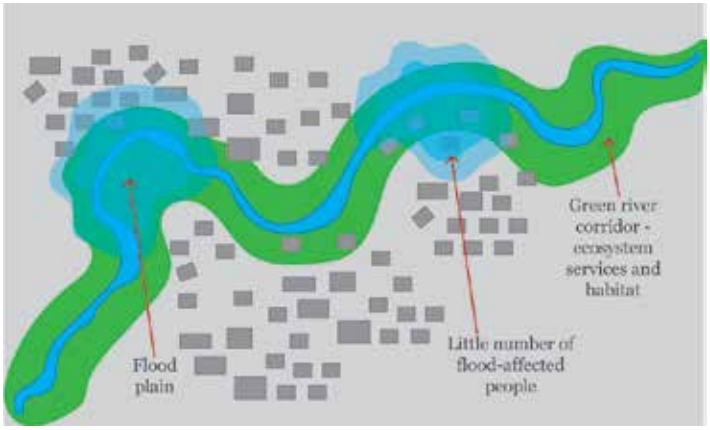
### 3.5 Risk Management in Costa Rica

In 2006, the government of Costa Rica emitted the Law 8488 - National Emergency and Risk Prevention Law. As the document itself expresses, the purpose of the law is to establish an effective and agile legal framework to reduce the causes of risk and facilitate the coordination during emergencies. This law includes the participation of the society in risk prevention and poses on the state, the responsibility of risk prevention. It defines an emergency plan and the management of funds during emergencies.

The National Emergency Commission creates regional, municipal and community emergency committees to set a coordination structure among public entities, private entities, NGOs and civil society. The Law 8488 also promotes the creation of risk prevention plans.

The Municipal Emergency Committee is integrated by public Institutions of first and second response. The members are: National Children‘s Board, Costa Rican Social Security, Ministry of Health, National Police Force, Municipal Police Force, Firefighters Department, Costa Rica’s Red Cross, Costa Rican Institute of Electricity (ICE), Chamber of Commerce, Costa Rican Institute of Aqueducts and Sewers (AyA), National Light Company (CNFL) and the Mixed Institute of Social Assistance (IMAS).



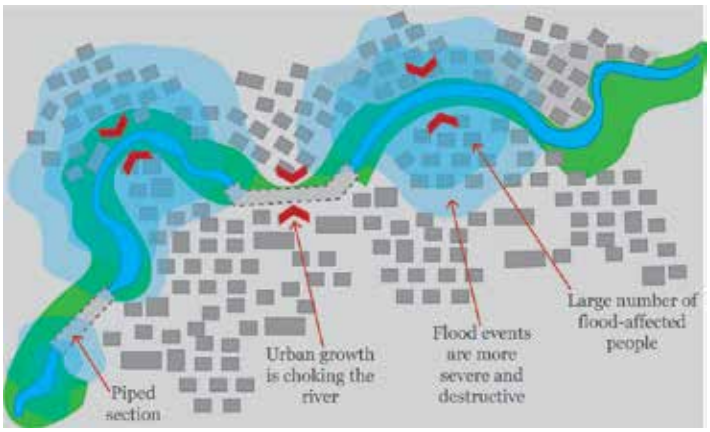
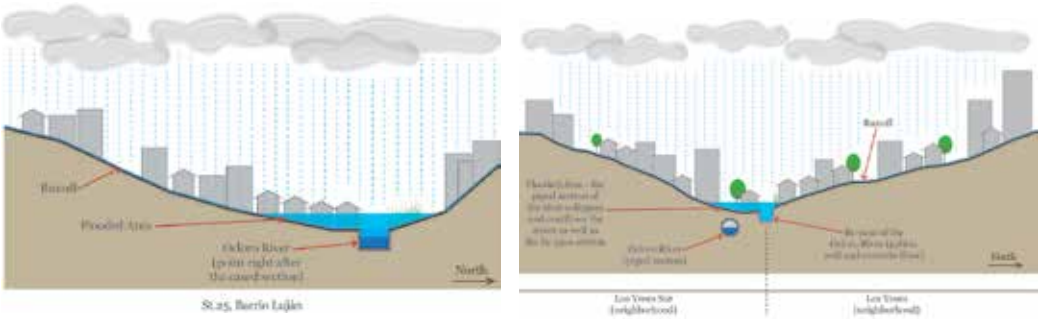




Figure15. Effects of unplanned urban growth on the river, change of the natural river course and flood behavior sections. Source: P. Bermúdez-Meneses (2019)




The Municipality of San José made a 'reactivation' and restructure of the Community Emergency Committee in 2013. Municipal Committee for Emergencies offered a training on 'incidents command' USAID international strategy-protocol for emergencies. Focused on usage of certain terminology, facilitating work and communication in international emergency response teams, and response measures during an emergency. After the training, the Community Emergency Committee took the responsibility of managing the emergencies as first response group.

Actions of the Community Emergency Committee of Barrio Luján (CEC)

The CEC, had a cooperation with Anthropology students from the University of Costa Rica. The residents made a training on the usage and potentials of technological tools as Facebook, smartphones, email management over smartphone. They created a Facebook page for the Communal Emergency Committee to use it as an informative-research tool.

After the major flood event occurred in 2014, the CEC made improvements on the field form used to document the flood events. The field form was provided by the Municipal Emergency Committee. The members of the CEC consider the format not adequate (from their experience in the community) and performed some editions like adding photos and other details.

The CEC and the community observed the problems of flood due to collapsed inlets. They organized and ran a monitoring work of inlets and street gutters to send complaint-reports to the Department of Water from the Municipality of San José and request the cleaning of the infrastructure.

The devastating flood event occurred on October 2015, had severe effects on the infrastructure of the area and affected approximately 69 families only in the

neighborhoods of Barrio Luján and Calderón Muñoz. After this event, the CEC performed an independent research on how to prepare for the floods.

Throughout the experience, and inspired by the software with data of the area, infrastructure, rivers created and used by the Municipal Emergency Committee Curridabat; the CEC of Barrio Luján has developed an 'Emergency Census' of the flood-affected houses and buildings during 2016 and 2017.

The information gathered in the census includes vulnerable points or flood access points (front side or back side), house number for the census, names and age of the residents, medicaments or special treatments of the residents, pets and a picture of the house. The census was linked to a software-data base developed by a programmer, member of the CEC and for security reasons, only the coordinator of the CEC and the programmer have access to the data. This year, they also started the creation of a new census on fire risk (area of old wooden houses).

The affected families (47) of Barrio Luján on 2015, received an economic help from the IMAS, the sum between USD 524 - 1400 (300,000.00 - 800,000.00 CRC). The families gathered in the community center and the financial help was distributed there. All the affected families managed to buy stove, fridge, furniture and bed.

The CEC used the field form they modified, to collect the personal data of the affected families. The IMAS used the new format data, that simplified the distribution of assistance and funds.

The CEC distributed informative material to the community on what to do before, during and after the flood: storage important documents in a safe place, raise the furniture, storage the food in a high place. The flood event of June 2016, left 15 families affected, there is a reduction of damages and they consider as a contributing factor that people were better prepared.

Recently, the CEC has worked house to house with the neighbors on studying their houses and making sketches for evacuation routes.  The purpose of this work is to reinforce preparedness and to know how to proceed when the emergency occurs.

# Chapter 4. Case study

## 4.1 Methods and Tools

This section offers a description of the tools used to collect data during the fieldwork and explains how they were applied.

Fieldwork Form – Observation

The observations worked with a predesigned field form in addition to the photographic register. The filed is a tool for rapid and systematic collection of data through observation of physical aspects of the study area (see Figure16).

The sites previously identified by members of the community as flood-affected areas were the main objects of observation and some new places according to their particularities or apparent potential.

The observation exercises also facilitate the understanding of the study area and the familiarity with

certain aspects mentioned during the interviews. It helps to follow up on the descriptions and anecdotes the residents shared during the structured and unstructured interviews.

The information to collect with the field form consists of the morphology of the area, topography, land uses, buildings height, pervious areas, infrastructure, and relation with water bodies.

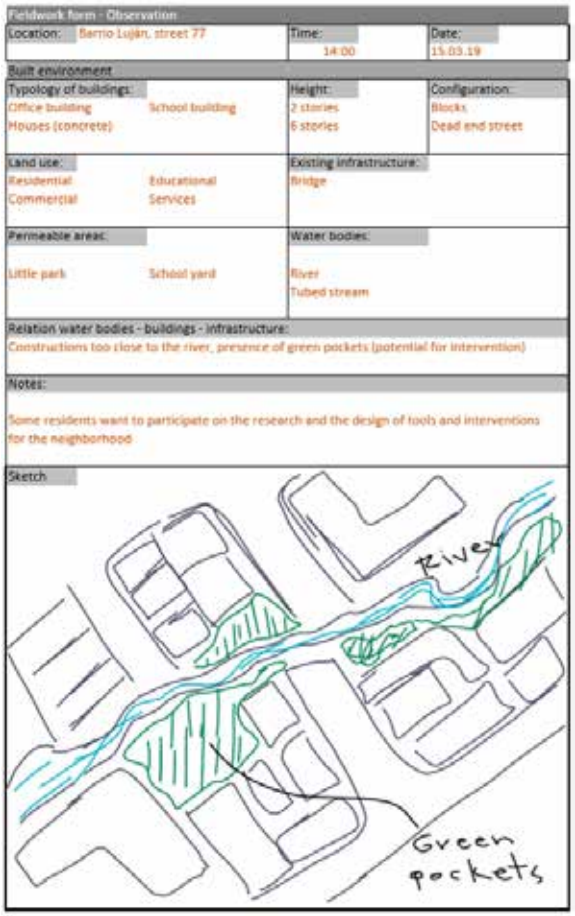



Figure16. Example of structure of the Fieldwork form for observation. Source: P. Bermúdez-Meneses (2019)

Unstructured interviews

In some cases, residents did not participate in structured interviews, but they shared part of their time and engaged in conversations to express their thoughts about the problematics affecting the community, what they consider are the causes and even brainstorming on potential solutions.

These conversations occurred mostly during the walks and observations while meeting neighbors in the streets of the study area.

From the unstructured interviews, it was possible to obtained data and got references for key informants to consult.

Structured Interview Questionnaire

The structured interviews followed a predesigned questionnaire of 14 questions. The 14 questions try to systematize the extraction of information on relevant aspects, hopefully, without taking much time from the interviewees.

The questionnaire aims to extract information about the behavior of the floods, causes, incidence, magnitude, sense of the awareness level of the residents and how they live with the hazard. Always open and positive to receive more personal stories-anecdotes, perceptions, and insides.

Despite the efforts to optimize the time use during the interviews and keep a script, the interviews went on in a very organic way. People spared much time for the conversation, showed photographs, guided walks around to explain better their point.

The aspects related to the primary analysis axes were mentioned and discussed during the interviews with the participants searching for validation of the axes and input on them.

These are the 14 questions applied during the interviews.

*1- How long have you lived in this neighborhood?*

*2- Since when have you experience the flood events? Or have knowledge of this events in here?*

*3- How often occur the floods? Source of the water…*

*4- Was your house directly affected by the flood?*

*5- How long did it take for you to clean and restore the house? How much would you estimate was the cost of the restoration process?*

*6- Can you draw or indicate the affected area on this map? Level…*

*7- What do you think are the causes of the flood in this neighborhood?*

*8- Do you make any preparation before the rainy season (flood events) in your house?*

*9- Do you cooperate among the residents to prepare for the rainy season (flood events)?*

*10- Is there any form of cooperation with the local government for flood-prevention?*

*11- Has the local government performed interventions for flood-prevention in the community?*

*12-Do you have knowledge of flood-prevention plans from the local government to be developed in the neighborhood?*

*13- Do you have ideas on how to prevent the floods or to reduce the impacts of these events in your community?*

*14- Would you like to work and cooperate with your neighbors on the development of tools and local interventions to reduce the risk?*

Sketch mapping

The sketch mapping sessions were part of the structured interviews, with those interviewees that felt comfortable with the use of such a tool. The intention to execute this exercise was mixing the story-telling aspect of the interview with an easy sketching process; to reduce the pressure and collect valuable data as the extension and location of the flooded areas.

To facilitate the execution of the exercise, modest maps from Google Maps (a familiar format that includes many popular references) on different scales and focus areas, were prepared in an A3 format.

A set of markers were there for the addition of different types of data, and the interviewees were encouraged to sketch and map all the things they wanted to use as reference or as a media to express their experiences (see Figure17).

Expert interviews

The target group for expert interviews was members and officials of state institutions related to the topics of urban planning, emergency response, hydrologic resources, climatic conditions. The goal of these interviews was to request related data for the analysis of the study area and to learn about the existing and future policies, strategies and plans to work on risk reduction, disaster management, and hydrologic resources.

Due to their responsibilities and a tight agenda, it was not possible to reach officials from all the intended institutions.

The performed interviews were with officials from the Municipal Observatory

from the Municipality of San José, Risk Management Department from the Municipality of San José, Firefighters Department of Barrio Luján, and the National Underground Water, Irrigation and Drainage Service (SENARA).

Figure17. Examples of sketch mapping exercises. Source: P. Bermúdez-Meneses (2019)

Guided river walks

These are walks following the trajectory of the river to get to know the context, get a sense of scale, observe the configuration of the urban fabric, interventions, and problematics along the river. The river walks were part of the listed tasks for the fieldwork, though, after the interview, two of the residents offered to arrange the walks and serve as guides to show their findings and discuss the situation.

The tools for data collection during the visits were photographic register, use of a tracking app to record the route, and written notes of the explanations and details highlighted by the residents.

### 4.2 Fieldwork process

Before the fieldwork research, the necessary material and tools for data collection were prepared and set. Additionally, the request for information and communication to state institutions related to the study subject started.

The fieldwork phase covered 7 weeks, from mid-March till the beginning of May. The starting point for the fieldwork research phase was the meeting (structured interview) with one key stakeholder, Ruth Ávila. She is a member of the community and the coordinator of the Communal Emergencies Committee of Barrio Luján. This first interview served to generate a fuller vision of the context and some historical background.

During this research phase, it was possible to participate in two meetings held by the local government with the community, to present and discuss a project

of measures for Flood risk mitigation in Barrio Luján. Barrio Luján is one of the several neighborhoods affected by the floods in the Ocloro river watershed.

The participation in the government-community meetings facilitates the introduction and contact-making with several members of the affected communities (Figure18). Initially, the target group corresponded to the residents of Barrio Luján. Nevertheless, during the meetings and the first interviews, people suggested other contacts and potential interviewees. The process changed into a snowball sampling that, as a result, covers residents from 4 different neighborhoods situated along the Ocloro river (Figure19).

The tasks and activities developed during the fieldwork include 3 unstructured

Figure18. Government-community meetings. Source: P. Bermúdez-Meneses (2019)

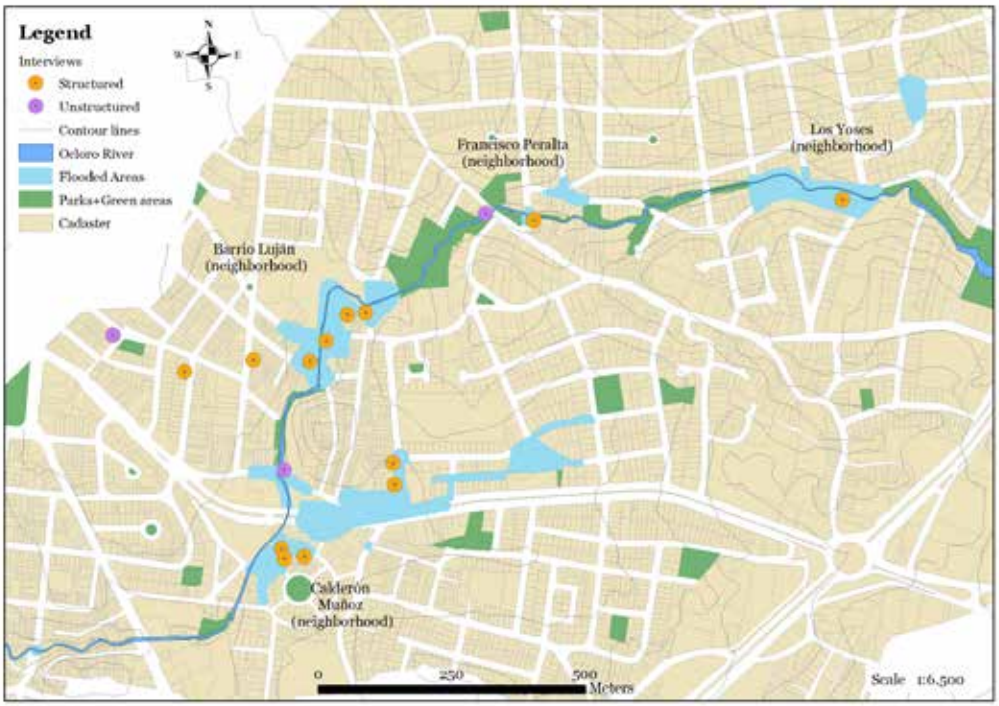



Figure19. Map of location and type of interviews performed. Source: P. Bermúdez-Meneses (2019)

interviews and 13 structured interviews (Figure19), 12 sketch mapping exercises, 3 expert interviews, 7 field observation forms, 2 guided walks along the Ocloro river with members of the community, participation in two meetings local government-community and visits to state institutions to request data and make questions about the topic of study.

### 4.3 Source – Pathway – Receptor – Consequence Model

The model helps to visualize the relationship between risk and hazard in a determined context or event. It can be applied to predict outcomes (potential damages) during specific events and to understand-identify where to intervene to minimize negatives effects.

Another aspect of this model is that it facilitates the envision of the appropriate locations to set controls to minimize the adverse effects of a hazard. Understanding the components of the model and identifying their location in the study site leads to a systematic outline of measures to apply in each component. The Flood Site Net describes the components of the model (see Figure 14) as it follows,

Source: consists of the origin of the hazard.

Pathway: the route taken by the hazard to reach the receptors.

Receptor: corresponds to the entity or element that may be affected (property, person, habitat, others).

Consequence: corresponds to the impact generated by the hazard (social, economic, environmental). The classification of consequence can be quantitative, by category or descriptively.

### 4.4 Risk – Mistake – Solution Matrix

Afterwards, the study of the general problematics and the application of the Source – Pathway - Receptor – Consequence Model to understand the dynamics of the hazard in the different points of the study area; the Risk – Mistake – Solution Matrix is constructed to visualize the triggers of the problematics and the potential solutions to address them.

The tasks are to determine additional potential solutions, compare and evaluate the incidence the different solutions may have, and elaborate further classifications in terms of complexity, scale, individual or collective approach, timeframe, others.

# Chapter 5. Research Results and Outcomes

### 5.1 Flood stories - Summary of Interviews and Sketch mapping

Interview with - Ruth Ávila

She moved to Barrio Luján in 1989.

She is the current coordinator of the Community Emergency Committee.

Since the moment she arrived, she heard of flood issues in the neighborhood. There were two main events when the river entered the house.

The residents could not document the events that occurred in the ’80s of the lack of resources and tools to keep a record (no smartphones, no Internet, no Google Maps, and analog cameras were expensive).

In 1992, the river entered her house more than 1 meter high. Firefighters arrived to extract the people from the house; Ruth was eight months pregnant.

Rats, mice, scorpions, snakes, and toads were swimming inside the house. There were 14 people inside the house during the event. People were standing on the table and couches to avoid the animals. The water removed the asphalt of the street. That was a critical event.

During the overflow of the river, in front of her house use to pass bathtubs, mattresses, plastic containers, shoes, couches (lots of solid residues). Once, the river dragged a house and left it in front of her house.

Her family used to gather with neighbors during the floods and earthquakes, to support each other; turning the disaster into a social gathering for the community.

They used to leave the house in the afternoon during the rainy season. Ruth and daughters used to watch the sky to be prepared and anticipate the flood events, when it looked like a storm was coming, Ruth got them prepared to leave the house on a “trip” as she called it (to prevent the kids from the fear of the flood).

The river manifests the damage inflicted on it during the years.

In 2013 the floods were less intense, due to the DRENACA project, the river diversion to connect the Ocloro river to the María Aguilar in Zapote, barrio La Gloria.

2015 flood event in Barrio Luján and the surroundings, was the same year the municipality of Montes de Oca started the water collector of Los Yoses project, the collector discharges right before the administrative border of Montes de Oca, into the Ocloro river.

October 2015, heavy rainfall, suddenly the water was coming out from the garage of the neighbor’s house, the water destroyed and dragged the gates and walls of several houses. The amount of water was enormous and unusual.

Environmentalist Association of Barrio Luján established by a group of residents (neighbors closer to the river, flood-affected - Olga Barquero) work on restoration and cleaning of the river, the goals are research and educational projects in the communities along the river. Presentation of denounces to the MINAE line 1192, about pollution points in the river. They are interested in recover green-public spaces and consider essential to recover the forest of the factory.

24 October 2016 till March 2017 (when they suddenly stop), demolition of the

factory facilities, from that moment, the river bursts its banks and floods the plot of the old factory, and it does not affect the areas downstream as it used to do before the demolition work. Neighbors say the plot was “house of the river” with the modification of the natural course of the river, the floods got worse, reduction of space.

March 2016, is presented to the community the Plan of Measures for Flood Mitigation in Barrio Luján, in November of the previous year they had a meeting. They gave a schedule for the interventions to execute during that year. First phase 2019 (bridge, tubing, pipes for drainage system Calderón Muñoz) and second phase 2019-2022. The community had no participation in the development of the plan.

The community has done research and documentation work on the historical evolution of the river and the flood events. The methodology of the Communal Emergency Committee is Observation - Formulation of Conclusions - Taking actions.

Interview – Lorena Muñoz

She has been living in Calderón Muñoz for approximately 18 years.

She perceives a change in the rainfall patterns. Years ago, the rainfall used to be distributed along the day, currently, the same amount of rainwater falls in few hours (intense rain).

Floods have affected the neighborhood since she arrived and even before. During rainfall of moderate to high intensity, the street gutters in front of her house get flooded. The previous residents of her house made some flood protection-oriented interventions in the house, like the drainage system from the garden to the street underneath the house.

Rainwater sewer was too old and had poor capacity, she made a demand to require actions from the Municipality. After realizing the flood problem was not particular to Calderón Muñoz neighborhood, but also the upstream neighborhood, Barrio Luján, was affected, she decided to approach some of the residents of that community. That is how the cooperation between them started.

27 Oct. 2015 and November, despite a recent capacity-enhancement work done in the rainwater sewer of the neighborhood, the house was flooded, 1,2m high inside the house, all the things inside the house below that height were affected and lost. Serious damages occurred in some walls and the wooden doors. One of

her dogs died drowned out.

Water has entered the clinic Carlos Durán when the river overflows, water runoff on the street 215 and enters Calderón Muñoz.

The water pollution makes it impossible, in most of the cases to rescue the things once they are submerged in the water. In conclusion, they lost everything. After the extreme flood event of 2015, owing to the pollution and various damages, there was a Hepatitis outbreak in the neighborhood (Calderón Muñoz).

Fixing and restoring the house takes a long time, some furniture was given to her for free (friends and family), fixing walls and painting work when she has the money. There are still things to fix from the flood of last year. Plugs are located higher than they were before, to prevent newer damage.

The constant fear of going out and far from the house and wonder if a new flood will occur while you are gone, when rain comes, been scared and asking who is closer to the neighborhood to check and inform about the situation - that‘s no life, it is unfair - The fight is for safety, life quality and mental peace.

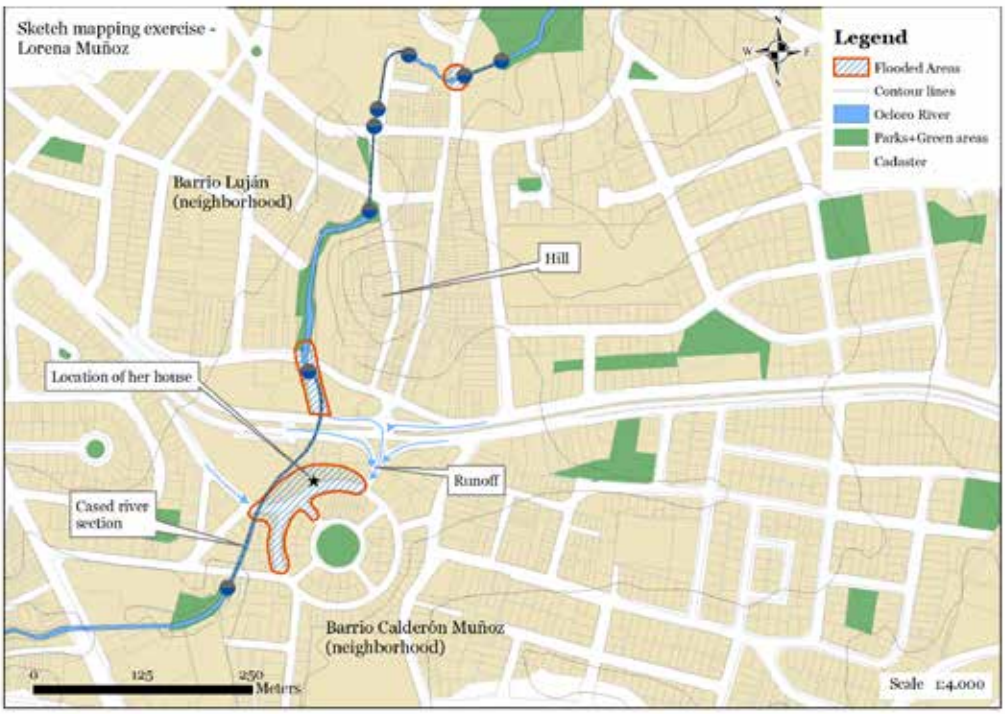



Figure20. Sketch mapping exercise - Lorena Muñoz. Digitalization: P. Bermúdez-Meneses (2019)

Conversation – Carlos Delgado

He has lived all his life in Barrio Luján (around 80 years). In his childhood, the river was clean, full of fish and there were snakes in the riverbanks. They used to swim in the river and build ponds with his father, using stones and tree trunks.

In those years, some people used to discharge the sewer water in the river. He estimates, the small number of residents at the time had a small impact in the water quality of the river.

He complains, nowadays, most of our houses are connected to sewage system and there is infrastructure for an adequate collection and conveyance. Nevertheless, some neighbors discharge the sewer water into the river.

He worries about the disregard of some people, lack of education and respect for nature among some of the residents. People who dump trash into the river and the streets, they do not care about the damage they cause.

Interview – Sol Fernández

She lives in the Francisco Peralta neighborhood since 1987.

The first flood event that affected her house occurred in 1990. The house stands a bit below the street level; then, when it rains very strong, the water goes into the pipes of the sewer system, causing a backflow through the toilette and the shower and severe pollution.

Central Avenue is on a much higher point than her house. During rainfall, the significant slope increases the runoff speed the street that connects her house to Central Avenue.

Before 1970, there were houses across the street, right next to the river. One flood event destroyed the houses, the National Commission for Emergencies (CNE) declared the area uninhabitable and then, created a park instead.

Between the 1960 and 1970 the area east from the av. 14 in Los Yoses was developing with more residential buildings, plus weather changes, the river receives a much bigger volume of water with a stronger current. There was no year without severe floods and damages in this avenue.

She says the river does not know about administrative limits. The river has to be worked from downstream to upstream on improving the capacity.

She refers to another flood-affected area nearby, in Los Yoses neighborhood. The affected area is on av. 14 and street 39-41 and she comments that during one flood event cars were floating. The piped section of the river goes for two blocks in the av. 14 and the bypass goes behind the houses. People get trapped inside the house when it rains heavily because the water blocks the way.

Also, in Los Yoses, Av. 12 - street 31 has been affected several times by urban flood, the rainwater exceeds the capacity of the drainage system, and runs on the street north to south until the avenue and enters the houses (rainwater).

Much rain in a short time leads to significant flood events.

She placed a lightweight hinged lid, made out of metal on the sewer pipes of her house (non-return valve). The hinged lid moves in one direction to allow the discharge of the sewer water out of the house, and it closes after the discharge preventing the access of water during flooding.

She places a board-panel acrylic type of material, of the exact width of the door frame and approx. 60cm high to block the doors before she leaves the house during the rainy season to try to hold the water.

She planted bushes and plants to impulse the infiltration of rainwater into the soil and to hold-reinforce the terrain. Experiments she working on to protect her house and try to help the river.

'El Piedrómetro' (meter-stone) is a rock in the river, next to her house. They realized that, from the moment when the rock gets cover by the water, 2 to 5 minutes later, the river overflows its banks in Barrio Luján. Now they use the 'Piedrómetro' as a reference to emit the alarm over the Early warning group on Whatsapp.

She has a digital pluviograph at home, and during the rainfalls, she uses it to give regular reports over the Early warning group and keep a register of the rainfall and flood events.

The flood event of 25th October affected her house. This event was the result of the overflow of the riverbanks.

Workshop-training – given by CNE about risk but almost no one participated.

Association of Los Yoses is more organized than Francisco Peralta; they have almost 20 years working together. Francisco Peralta is less prepared-organized, but they are working on a neighbor's group in Whatsapp, for people of the area

to help each other with the security topics and the river issues.

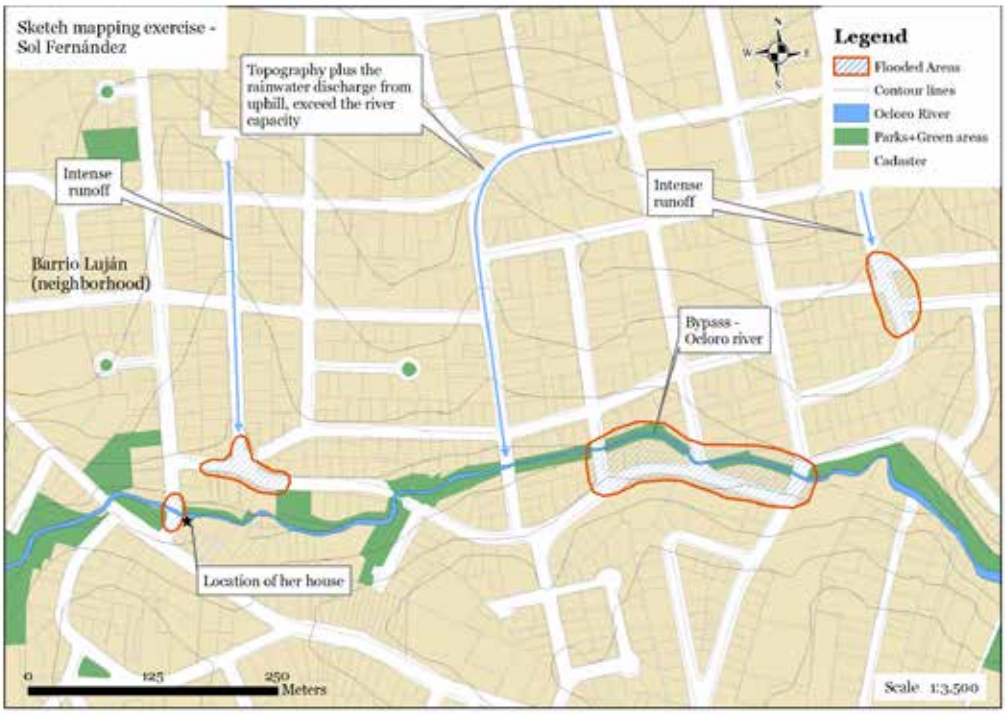



Figure21. Sketch mapping exercise - Sol Fernández. Digitalization: P. Bermúdez-Meneses (2019)

Interview – Katya Louzau

She has lived in Barrio Luján for 53 years.

She has experienced floods in the neighborhood all her life. The river has always flooded the area, but the modifications of the river intensified the severity of flood events.

As a kid, she used to play and run inside the pipes of the river (cased sections). Children used to swim in the river and after the floods, collect fish from the puddles.

In 1934, her great grandmother bought the plot – wooden houses elevated on (5 steps) stilts, vertical boards were covering the stilts, with gaps in between to allow the water flow under the house without affecting the structure.

Later, she and her husband rebuilt the house in concrete, keeping the elevation aspect (a bit less than before). They kept the garden area with grass, they have fruit trees, and a little wooden deck area elevated to allow rainwater to infiltrate in the ground.

During the flood event of 2015, the water accessed her house and reached 10 cm high. She was terrified. Her shoes were floating; some furniture got ruined, damages in the walls, damaged books, her tailoring workshop (all the fabrics ruined). All the clothes of his son got damaged. Family memories, albums, photographs, and personal items were damaged, desk computer damaged. Their house stands at the lowest point of the street, another problem in terms of water runoff and floods.

They needed around a week to clean and organize the house. She was alone at home during the flood, so it was a traumatic event.

The floods usually last 1,5 hours, the whole event. The water retreats very fast. When the houses were standing on stilts, the water could flow under them; the water level was lower cause it had more room to expand, but after the rebuilt of the houses on concrete (barrier) the water level during the floods increased (less room).

Gretel Vargas' house goes along the block (plot with two fronts), 'the river' water used to flow through the house, dragging furniture and everything on its way to the street. Another neighbor had the same situation. In both plots, they build contention walls that stopped the access of the water through the properties.

The houses and apartments across the street are the most affected. People from those houses had to be rescued by the firefighters through the roof during the most severe events. In some cases, the water reached approximately 1 m high from the sidewalk level.

In 2015, inside the forest of the Dos Pinos, some tree branches fell in the river. The trash in the river got stuck in the branches and formed sort of a dike. Some neighbors warned earlier about that risk, without results.

The pollution of the river is a major-evident problem. For decades they have lived with it, until the point that to see trash drifting, abnormal colored water by the discharges of houses-businesses upstream and perceiving bad smells became the usual dynamic around the river.

People in the neighborhood got used to the floods; they see them as part of their lives.

Before DRENACA (river water diverting project), the floods were stronger, even to rip off the pavement of the street.

The modification of the natural river course intensified the floods. There was a lagoon in the current parking lot of the factory. The lagoon was the energy reduction point; the river used to slow down there, expand and continue with a softer flow. She considers the destruction of the lagoon as the biggest mistake (no room for the river).

The making of the river case occurred in the 50s, during the construction of the factory. After that, the intensity of the floods increased. The collapse of the street gutters due to trash dumping. Some restaurants discharge the grease and oil into the street gutters. All the inlets collapse due to trash and topography in addition to the overflow of the river. The two sources of water have different colors, and it is visible the mixing point.

The trash collection point is problematic. The corner Av. 20A and street 23 has become a dumping site. They had the initiative to rescue the corner spot, and they made a garden.

After the extreme event of 2015, the floods had continued, as usual, no extreme events. The floods are regular not so severe, but the main problem is that people get trapped in their houses or cannot access them.

The first days and months after the extreme events, she remains scared and nervous, so she and her family applied some techniques in those days. When the river begins to overflow its banks, she blocks the gaps under the doors with newspapers, they place all the food on higher points, shoe trauma – all the shoes are in sealed plastic boxes, clothes in the laundry room are always in baskets on top of high benches (out of water reach), she moves the food to the top shelf when it starts the rainy season. The dog's bed is close to the gate (first thing to move), the couches are water-resistant, she uses the Early warning group as reference and especially the Piedrómetro (2-5 minutes after the water covers the rock, the river overflows in her street), she warns the front neighbor to remove things from danger.

The Early warning group (Whatsapp) has brought peace for her because she knows in real-time what is happening, they can react on time and helps with the emotional aspects like leaving the house alone during the rainy season and the fear of the possibility of been displaced by the hazard.

After the factory in the area left, the water quality improved a bit, but from 2-3 years ago water pollution has increased again – other sources of pollution

upstream. For a specific time, the pollution of some paint. They have now a parallel-group related to pollution and environmental aspects related to the river.

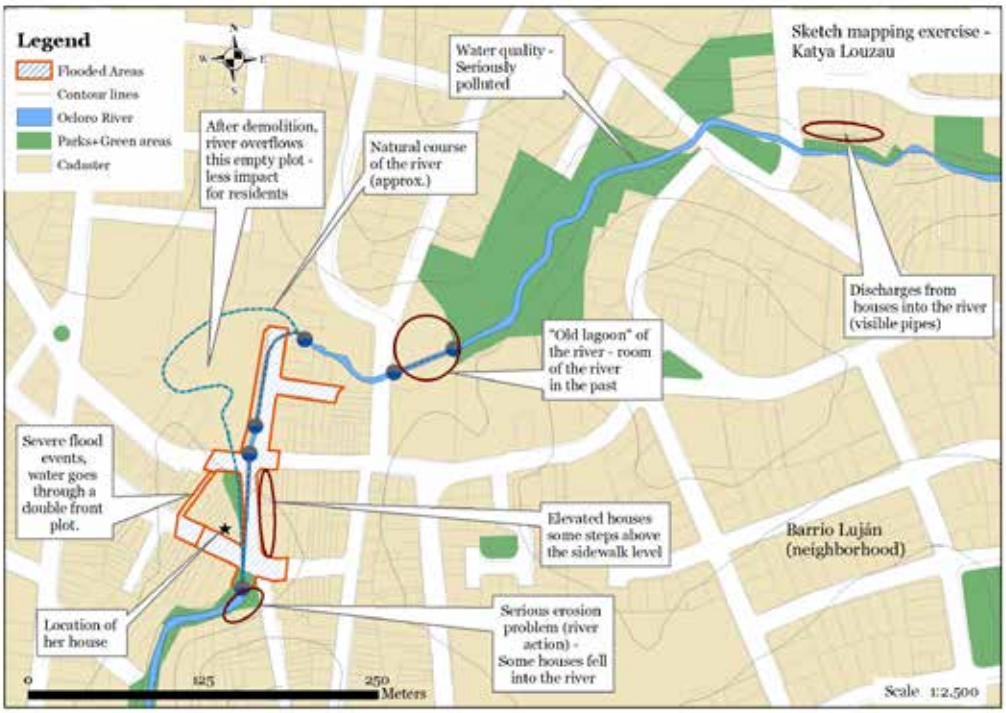



Figure22. Sketch mapping exercise - Katya Louzau. Digitalization: P. Bermúdez-Meneses (2019)

Interview – Olga Barquero Sandoval

She was born in Barrio Luján, and four generations of her family have lived in the neighborhood.

Floods have occurred all her life. However, in the past, the river had more space. Every day, more constructions with more concrete and more water discharged into the Ocloro river.

She had to leave the area 40 years ago, displaced by the flood after one event destroyed her house and she lost all her things. Later she managed to get a loan to rebuild the house. Her idea was to build a raised house with a protection wall. The municipality refused to give them the construction permits due to the risk. Then, she moved out.

Olga and her brother made some improvements in the house and rented it. After the damages inflected in the house during the flood of 2015, they only use the house as a storage place.

Rainfall patterns and behavior from the past were very different from what we have in the present.

She used to lift the bed and place things on the upper shelves before living the house during the rainy season.

She remains in contact with the community, is interested in cooperating with the neighbors, and she is already active in the community work.

She states that her story is there, all her family history is there, she wanted to stay and continue her life in Barrio Luján, tragically, the floods displaced her from her home.

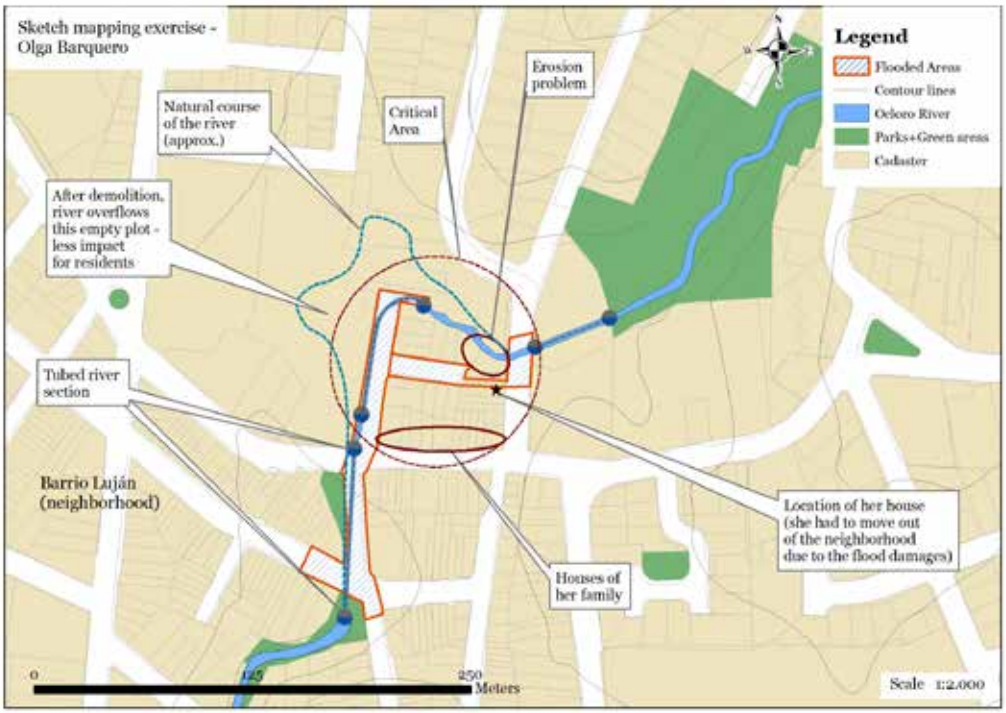



Figure23. Sketch mapping exercise - Olga Barquero. Digitalization: P. Bermúdez-Meneses (2019)

Interview – Flory Jackson

She has lived all her life in Barrio Luján. The neighborhood always has experienced floods. Floods happen every time it rains in the neighborhood.

She was the Coordinator of the Communal Emergency Committee between 2013-2016.

The floods often affect her restaurant, located in street 23. It takes approximately two hours to extract the water out of the restaurant. During the flood events,

the water rises at high-speed. The water infiltrates through the walls of the restaurant, back-flow in the toilette, and the access steps are damaged.

She claims that Ruth Ávila (from Barrio Luján), Lorena Muñoz (from Calderón Muñoz), and Sol Fernández (from Francisco Peralta) are the most active and informed people-representatives of the community side.

In 2017 the municipality presented to the community a project of placing new pipes in the street 23. Flory criticizes how the municipality does not include the community in the development of strategies to reduce the flood risk and river intervention plans.

The factory arrived in Barrio Luján during the1950's. Partial demolition of the facilities occurred in 2016. Now, there is insecurity due to the recklessness of the property (presence of rubble and one building still standing).

Some neighbors raised their houses to prevent water access. Her sister makes a barrier against the doors with concrete blocks. The floor level inside a neighbor's house is below the sidewalk level, but they raised the door and built up a step outside in the sidewalk to access the house and block the water. The frequent floods force people to change the way they live.

There is a lack of interest and participation of the not directly affected part of the community.

2013 the Municipality of San José and the NEC held a workshop on 'Risk and Prevention' oriented to work with residents of the four central districts of San José. The purpose was collecting data on the risks and problematics directly from the members of the communities. She is not aware of any follow-up process after the workshop.

She perceives that some institutions are satisfied with giving financial help and food as a response after emergencies instead of working more on prevention and solving the situations causing the emergencies.

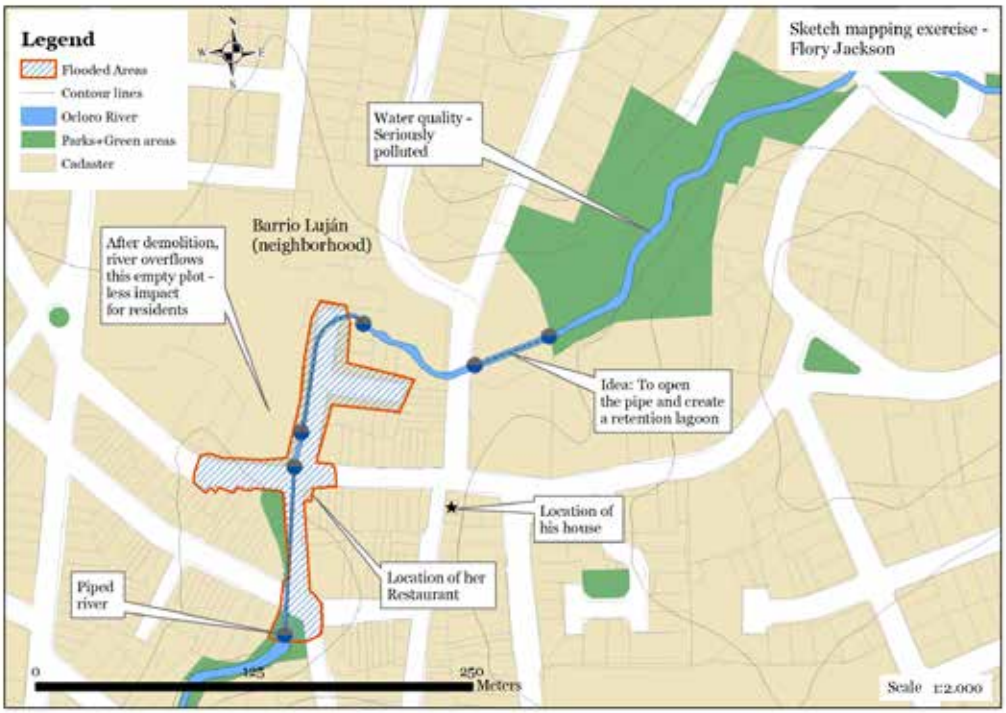



Figure24. Sketch mapping exercise - Flory Jackson. Digitalization: P. Bermúdez-Meneses (2019)

Interview – Francisco Zamora

He has lived in Barrio Luján for 12 years.

He is aware the flood-problems occur already for many years but he remembers particularly, the severe events from 2015-2016.

He claims that Curridabat and San Pedro districts are the primary sources of water. In the sector of Barrio Luján where he used to live before, inlets and street gutters collapse due to small capacity and the inadequate management of solids residues (trash dumping in the streets).

In 2015 and 2016, flood events affected the street 25A, between Av. 24 and 215, where he used to live. The plot of his house is higher than the sidewalk level, the water did not access to the houses, and that prevented further damages.

The flood in 2007 caused damages in the external wall, and the water weakened the foundation of the wall. It took two days to clean and reestablish the house. The water that flooded the area was only rainwater.

Among his neighbors, there was no previous preparation for the rainy season.

Municipality – organized a collection of 'no-traditional' solid residues. Coope-

ration of the Clinic. – Few prevention cleaning campaigns of the river, most cleaning work is done after the floods.

Ministry of Health organized a walk and evaluation of the river state for Dengue prevention and observation of empty plots. From street 23 till the av. 26 next to the river, the limit of jurisdiction of the local health center.

He noticed that after the demolition of the factory facilities, the intensity of the flood has reduced because the river overflows on the empty plot and loses speed and strength.

The radio station around the corner made a work to deepen the street gutters and divert part of the water to the closest inlet.

One of the local committees had an initiative for street and street gutters cleaning, he thinks it is essential to reinforce this type of action and education of the community on solid residues management.

He plans to start a rainwater harvesting system at home and is making more greens areas for water infiltration in his new house (in Barrio Luján).

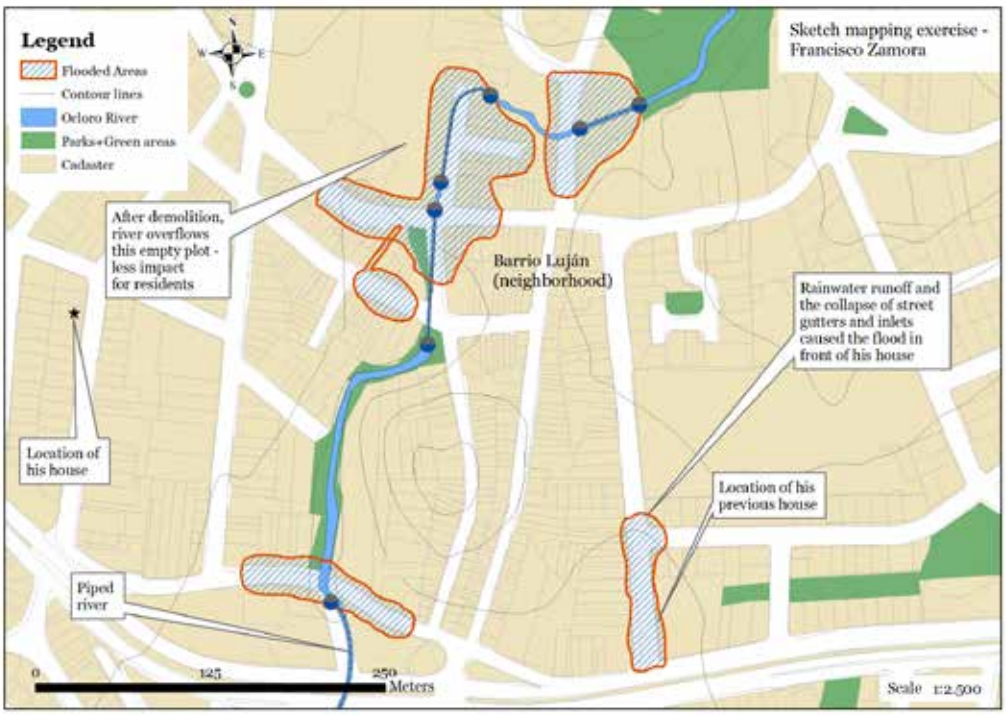



Figure25. Sketch mapping exercise - Francisco Zamora. Digitalization: P. Bermúdez-Meneses (2019)

Interview – Leda Méndez

She lives in Barrio Luján for already four years.

She heard the neighborhood suffers from floods for 40-45 years.

The flood dynamic has changed due to the weather changes, the demolition of the factory facilities. Another significant problem is the trash dumping in the river.

She considers the municipality has part of the responsibility for the floods.

Modification of the natural course of the river intensified the problematic.

She says it is necessary to work at the watershed level to solve the flood problems.

She is considering to build drainage in the backyard to enhance the capacity of infiltration.

It is necessary to give space to the river and stop the illegal discharge of sewer water into the river.

She thinks to implement rainwater harvesting systems is necessary to provide training and workshops for the community to learn the techniques.

Her house has not been directly affected, and she considers unlikely to get affected in future events due to the topography where her house stands.

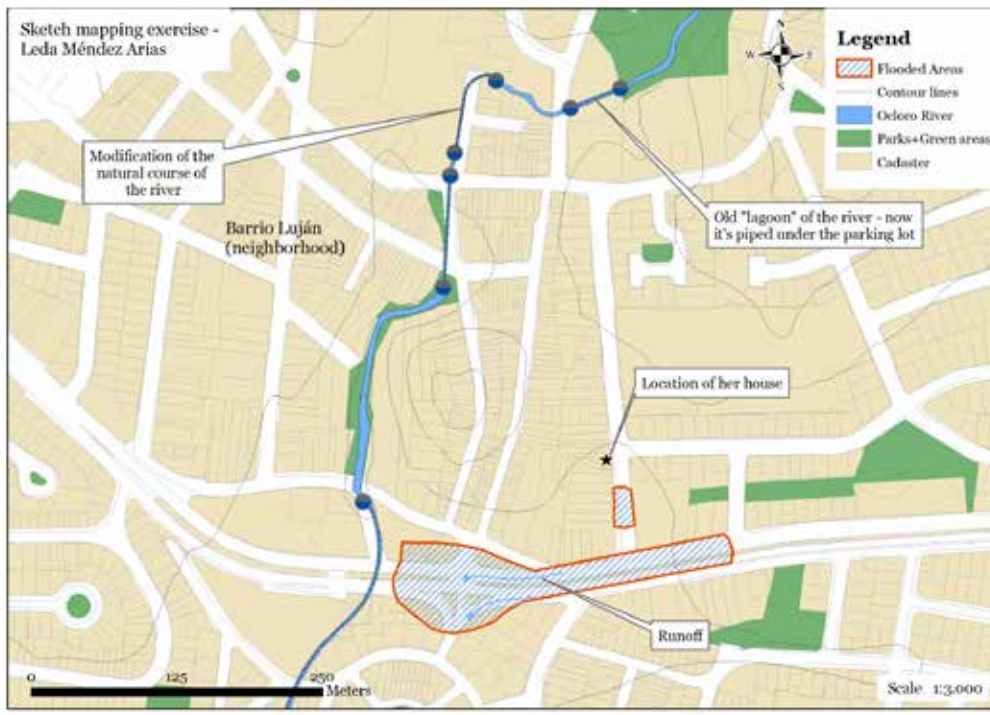



Figure26. Sketch mapping exercise - Leda Mendez. Digitalization: P. Bermúdez-Meneses (2019)

Interview – Alfredo Vicente

He moved to Barrio Luján 15 years ago. Since he arrived, he has experienced flood events. During the most severe flood event, the water reached 1,20m high. The water flooded his car, loss of the products from his store. They had to work a week in the cleaning of the house and business.

Recently, in Barrio Córdoba, the capacity of the drainage system was increased, which benefited the situation in his street.

The nearby radio station hired a company to redesign their street gutters; they made them more in-depth and connected them to an inlet across the street. This intervention reduced the amount of rainwater that flows (runoff) towards the street 25A (less extreme flood events)

He requests the municipality to make cleaning of the drainage system and inlets before the rainy season (the municipality does the work). Besides, he makes reports to the Hydrology department and residues department of the municipality, about observed problems and risks in the area.

When the rain starts, he moves the products from the business to a higher spot.

He is considering to build flood gates for his house.

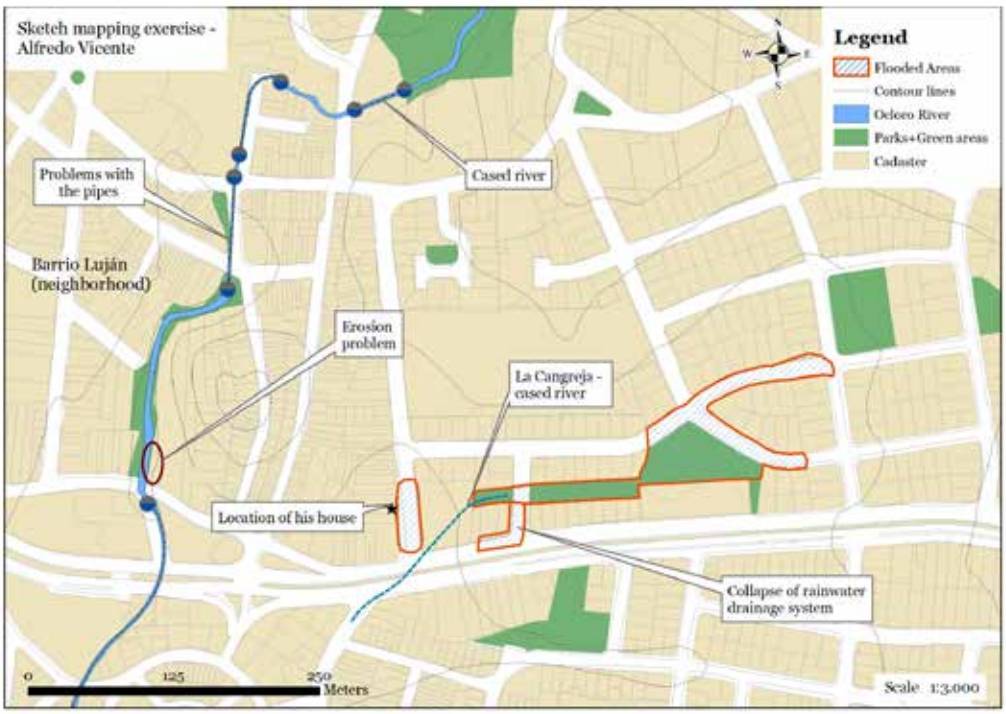



Figure27. Sketch mapping exercise - Alfredo Vicente. Digitalization: P. Bermúdez-Meneses (2019)

Interview – Omar Solís

He moved to Calderón Muñoz with his parents when he was seven years old. He has lived in the neighborhood for 80 years.

When his family arrived in the neighborhood, the area was very different; there were many empty plots. The area of the Carlos Durán Clinic and the houses in front of his house did not exist.

He used to swim with friends (he was 10-12 years) in the bridge of Av. 26, when the river was clean and had fish. When the factory arrived, it polluted the river and killed all the fauna, no more fish.

Before the construction of Av. 215, the river used to cross open that area, abundant until the end of today's clinic, and then the river used to fall into a square tunnel (section 4x4m). He says, in that time there were no floods in Calderón Muñoz, cause the river had more space and less trash. At the time, Barrio Luján already had flooding issues at the intersection Av. 20 and street 23.

There is a little creek flowing from the Colegio Rosario area, crosses the Av. 215, flows in front of the Palí supermarket, crosses the little circular park of Calderón Muñoz and then falls into the tunnel of the Ocloro river. This creek already cased long ago.

There have been flooding events in several points of San José center, since his childhood, mostly linked to cased rivers inside the city.

His house has not been directly affected, it is a higher point of the street, and the house is three steps above the sidewalk level.

There are lots of cased creeks in the area, and he thinks it is one cause of so many floods. That is possibly the reason to rise his house three steps, to prevent the flood events.

The urbanization process had made the situation of the floods more severe before the floods started in Calderón Muñoz; the areas to the north were mostly ‚potreros' pastures for cattle.

Memo and Lorena Muñoz, are the most committed members of the community with the flood issues.

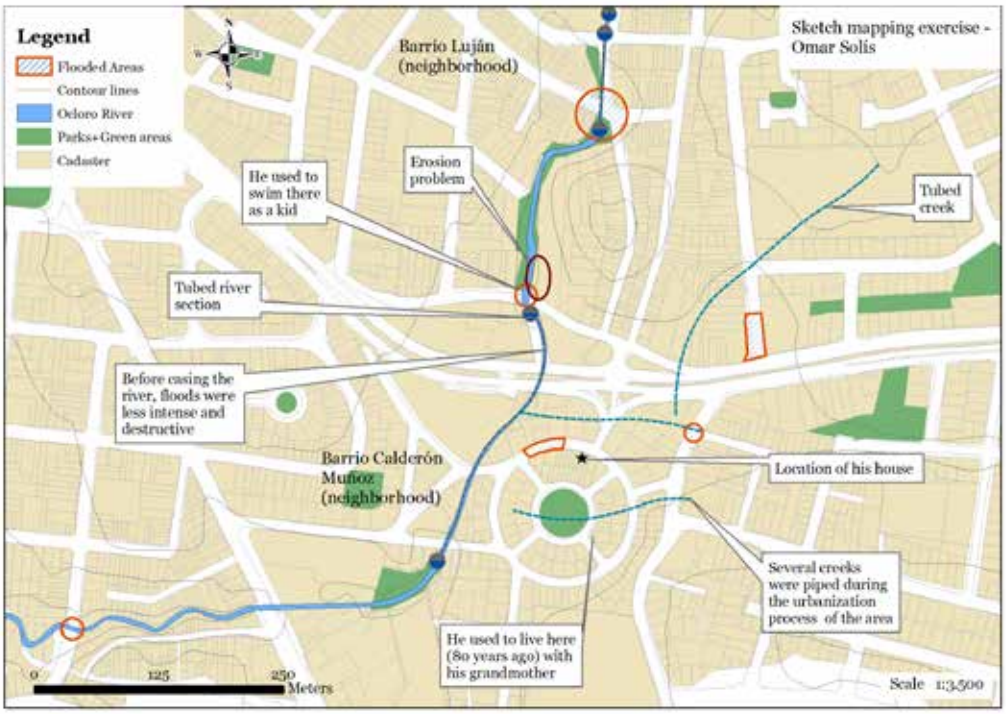



Figure28. Sketch mapping exercise - Omar Solís. Digitalization: P. Bermúdez-Meneses (2019)

Interview - Patricia Morúa Navarro

She has 63 years living in Calderón Muñoz.

In her childhood, there were no floods in Calderón Muñoz, because Barrio Córdoba and Los Yoses (to the east) did not exist; those areas were coffee fields.

Around 50 years ago, it was the first event when the water flooded her house, it was heavy rainfall, and Barrio Córdoba was already under construction.

As a kid, she used to play and fish in the river. The river was clean, and they used to play in the section where now is located the Av. 215 (today is a piped section). There were a pond and fruit trees.

The following years with heavy rainfall the street got flooded, and the water usually reached the sidewalk, the step to enter her house or till the house door because her house stands in the lowest point of the street.

Passing cars during the flood, make waves and push water inside the houses.

Frequent flood till the sidewalk level. With more construction throughout the years and more rain, the stormwater sewer cannot withstand the amount of water.

There are much water flows in the area, several piped creeks since long ago.

With the urbanization process of the area to the east from Calderón Muñoz, they piped many creeks and start discharges of sewage water into the river.

During the flood events the water comes out from the inlets as a fountain, there is no way to stop it, the river has such a large volume of water that at some point the water comes out through any space it finds.

In 2015 occurred a severe flood event, this time the water reached neighbors that were never affected in the past. The car sales business on the av. 215 got flooded (like a lagoon) the water destroyed the backyard wall, accessed to her aunt‘s house and locked the door (door opens to the inside), trapping her inside (she lost everything). A neighbor woman died of a heart attack due to the shock and fear during the flood.

The river bursts the riverbanks, too much water, trash.

The storm sewer also has capacity problems

The water comes from San Pedro.

Another area profoundly affected is Barrio Luján, and she thinks it is even more severe the damage in Barrio Luján than in Calderón Muñoz. The water accesses the houses more often there.

The flood event 2015 reached 50-60cm height inside her house, damaged furniture, a television, electrical outlets, kitchenware, washing machine cover on mud damaged, fridge damaged, several appliances damaged and they had to revise the electrical system of the house. The fixing and cleaning work never ends, she says (more than a week to reestablish).

The house has steps to access the house.

The CNE arrived after the flood event to collect data and provide help.

Cleaning of gutters, cleaning of the street gutters, move appliances and essential documents to higher spots. Calderón Muñoz has a WhatsApp chat for emergencies, Lorena communicates the info from the Early warning group.

In the event of 2014, the water reached approx. 40 cm.

Between 2016-2017, the municipality made a capacity enhancement work of the storm sewer in Calderón Muñoz.

There is not much organization among the neighbors in her neighborhood.

There is no cooperation of the municipality with the neighborhood and no communication.

She thinks it is necessary to analyze the situation along the river, deepen the river in San Pedro (Los Yoses).

She considers that the municipalities have responsibility for the flood issues.

She wants to participate and cooperate with the neighbors.

Rainwater harvesting – she has buckets in the backyard and collects some water, she uses the water to wash the car – she thinks it is a great tool to save water, water the plants and reduce water consumption. A challenge can be the space availability to set a tank.

There is no regular municipal recycling material collection in the neighborhood. – It is essential to structure and improve management.

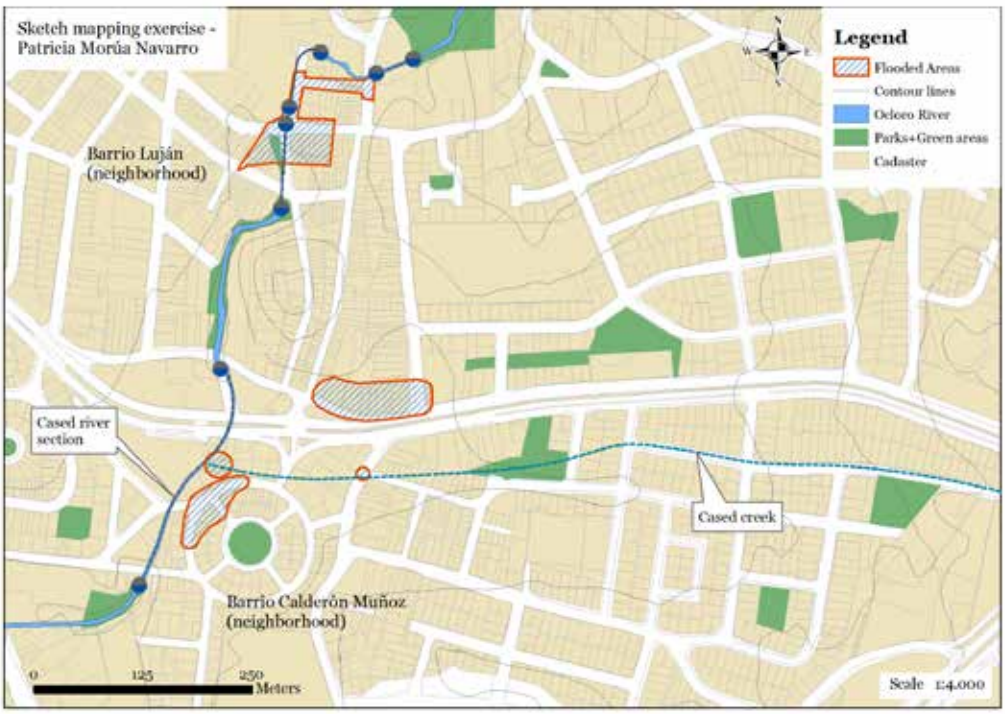



Figure29. Sketch mapping exercise - Patricia Morúa Navarro. Digitalization: P. Bermúdez-Meneses (2019)

Interview - Luis Alvarado

He has lived in Los Yoses for 53 years.

All his life floods have affected the neighborhood.

The development of Los Yoses did not respect the river. When his mother bought the plot, the av. 14 and the streets 39- 41 did not exist, and the only existing road was the avenue on the Zapote district side (to the south).

The Ocloro river used to flow open, in front of his house, where today are the neighbor houses and the avenue 14. The river channel was broader than today's avenue 14 in that point, and they had a distance between his house and the river (protection buffer); more than 55 years ago. The river was wide and not much deep.

To build more houses, the MOPT and the municipality piped the river and to create more plots. After that work, the developer made the rest of the houses to the south.

One developing company (a family, original owners of the land) developed the neighborhood. During the urbanization of the area, they found several water springs, and they piped them to continue the construction (today, the houses are standing above those pipes).

To solve the flood issues in the Central Avenue, the municipality of Montes de Oca build a rainwater collector from the Central Avenue to the south (Los Yoses) going along the street 45, connecting pipes from the different blocks and discharging into the Ocloro River.

The river has the same capacity for years and the places around it, have been developing and adding discharges of a larger volume. In many places, people also discharge sewage water that damages, even more, the river.

In the '70s during a flood, a car fell into a flooded well, two people drowned. Now, one point of the street sank, they have denounced the risk, but so far the municipality has not attended the issue.

The municipality of San José made the by-pass (behind his house) because the flood events were extremely severe, due to insufficient capacity of the river pipes under the street.

During 2018, they had 2 to 3 flood events in the neighborhood. Usually, the floods occur twice per month during the rainy season.

Before they made fixing and adaptation work in the house, the water used to access, and all their belongings were floating. They made a garden wall around the house, and they set flood gates outside the garden wall.

Back-flow from the toilettes of the house occurred in the past. The municipality of San José made changes on the sewage system connections to prevent the back-flow, and they solved that problem.

When the river was flowing open, they had no flood issues, after the MOPT and the municipality piped the river, the neighborhood suffers from extreme floods all the time. Once, the firefighters rescued his family during a flood event.

The municipality has not enough resources to work on prevention, then, they work mostly on emergency response and fixing things when the damage occurs.

People in his neighborhood are not organized to cooperate during the flood events.

Both municipalities, clean the grid in the river in the point where the by-pass starts. Erosion of the riverbanks in the natural sections (without maintenance) and the river drags trees and branches that later block the grid; creating more problems.

He considers, a crucial problem is that the municipalities use little capacity pipes in the interventions; and they soon collapse due to overwhelmed capacity and the lack of maintenance.

He claims the main mistakes are, usage of small capacity pipes, no maintenance, no demand for hydraulic studies or rainwater management strategies before giving construction permits. No previous studies to prevent floods and to develop adequately.

Municipality of San José demanded a rainwater retention tank to a new building to get the construction permit, and the developer made a tank of insufficient capacity – lack of monitoring.

There is no prevention work from both municipalities, no communication or coordination between the government and the community.

No Communal Emergency Committee in Los Yoses.

It is necessary to do the fixing works in the whole extension of the river.

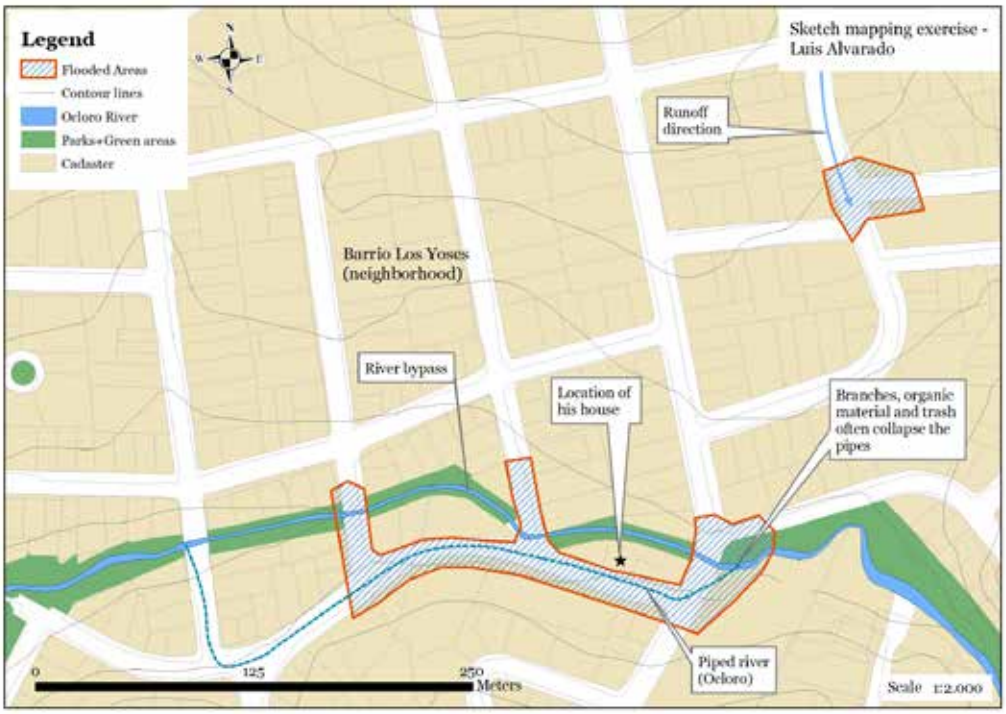



Figure30. Sketch mapping exercise - Luis Alvarado. Digitalization: P. Bermúdez-Meneses (2019)

## 5.2 Guided River Walks

Part of the fieldwork task was the execution of observation walks around the river area.

After the first conversations with two residents Ruth Ávila and Lorena Muñoz (critical stakeholders), they proposed, to guide the river walks to get to know better the context (ecosystem), the extension of the river, and visualize the modifications suffered by the river

The river walks help to understand better the 'anatomy' and situation of the river. The residents have done these walks several times to monitor the changes in the river in terms of interventions, discharges, visualize the piped sections, the infrastructure along the river, problematics and critical points as well as the potentials.

During the walks, the residents, who are also active members of the association for the defense of the Ocloro river (environmental group), take the chance to establish contact with residents of other neighborhoods along the river. They share information, concerns, and advocate for the protection of the river.

The river walks also facilitate the understanding of the urbanization process, and the evolution of the problematics.

The members of the community who have made this type of observation have a broader perception of the river situation and tend to search and demand integrated working approaches on the river level (watershed).

The location of critical points of pollution, environmental, and problematic aspects observed during the walks help to recognize points in need of actions to improve the environmental conditions (one of the three analysis axes).

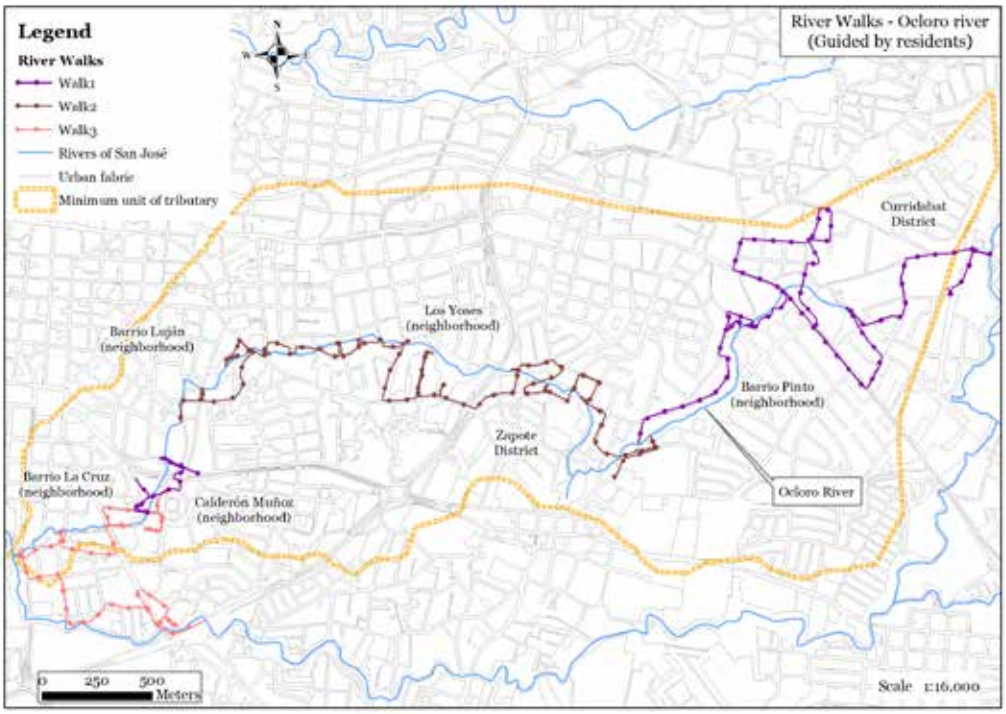



Figure31. Map - Routes of the Guided River Walks. Source: P. Bermúdez-Meneses (2019)

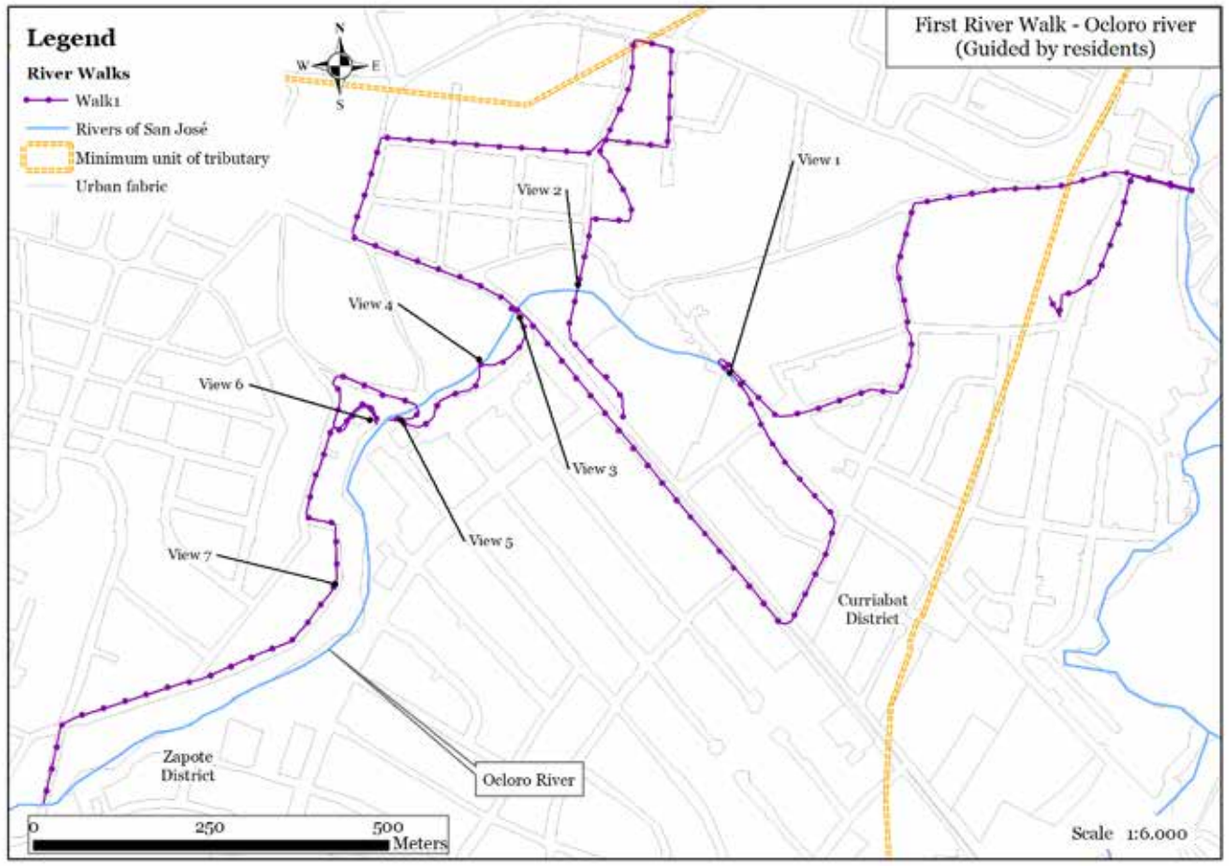



Figure32. Map - Route of the River Walk 1 - Views of the areas. Source: P. Bermúdez-Meneses (2019)

It is possible to observe pollution problems from the origin point of the river. Piped sections and constructions above them.

Many residents along these areas do not know the Ocloro River or its trajectory.

Densely populated area and large percentage of impervious surfaces.

**View 1**

**View 2**

**View 3**

**View 4**

**View 5**

**View 6**

**View 7**

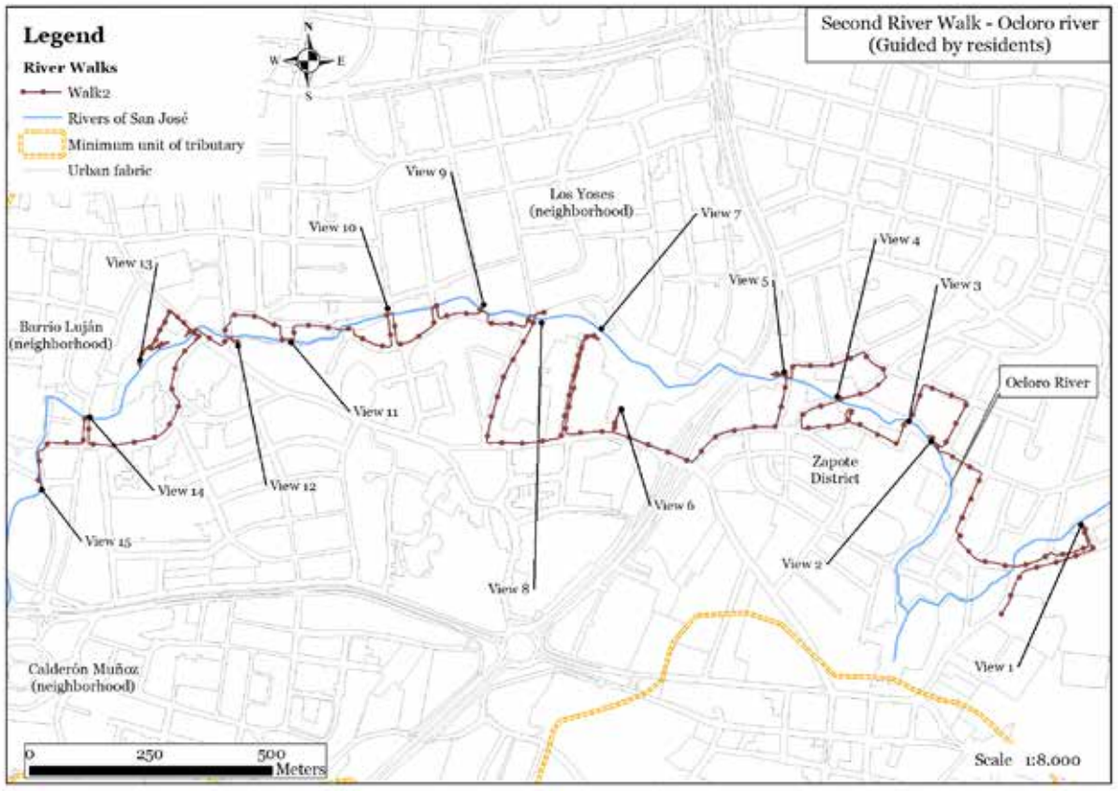



Figure33. Map - Route of the River Walk 2 - Views of the areas. Source: P. Bermúdez-Meneses (2019)

View 7

View 8

View 9

View 10

View 11

View 12

View 13

View 13

View 14

View 15

View 1

View 2

View 3

View 4

View 5

View 6

View 1

View 2

View 3

View 4

View 5

View 6

View 7

View 8

View 9

View 10

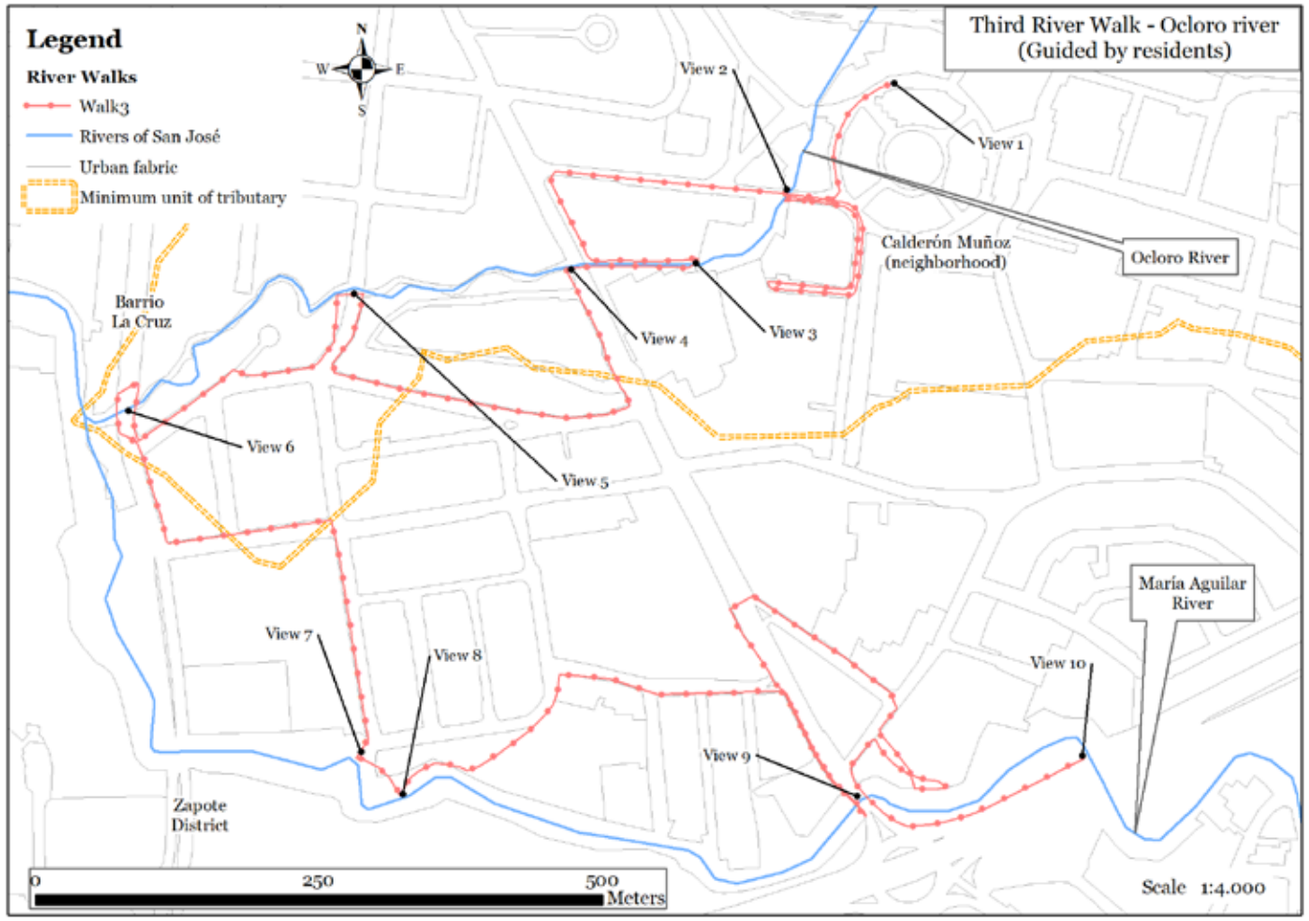



Figure34. Map - Route of the River Walk 3 - Views of the areas. Source: P. Bermúdez-Meneses (2019)

## 5.3 Source – Pathway – Receptor – Consequence Model

SPRC Model – Ocloro river critical section

In this setting of the model, the analysis works along the critical section of the Ocloro river (Figure35). The river originates in Curridabat, from there it flows between Zapote and San Pedro. These three districts currently experience a major construction wave, mostly new apartment buildings.

The increase in the construction and urban development in the districts, filling up the plot, leads to a reduction of the pervious surfaces and an increase of the runoff. A high percentage of the stormwater drainage discharges in the Ocloro river.

The Curridabat, Zapote and San Pedro districts conform the Source of the hazard as the origin of the river is located in Curridabat and a big amount of rainwater diverted to the Ocloro river. The river itself is the Pathway or route taken by a significant amount of stormwater. The Receptor consists of Barrio Luján and Barrio Calderón Muñoz, where the flood events are severe and frequent during the rainy season.

The model allows the visualization of the origin of the hazard, the pathway that follows and the vulnerable groups (Receptor). In this setting, the model shows as Consequence a river flood.

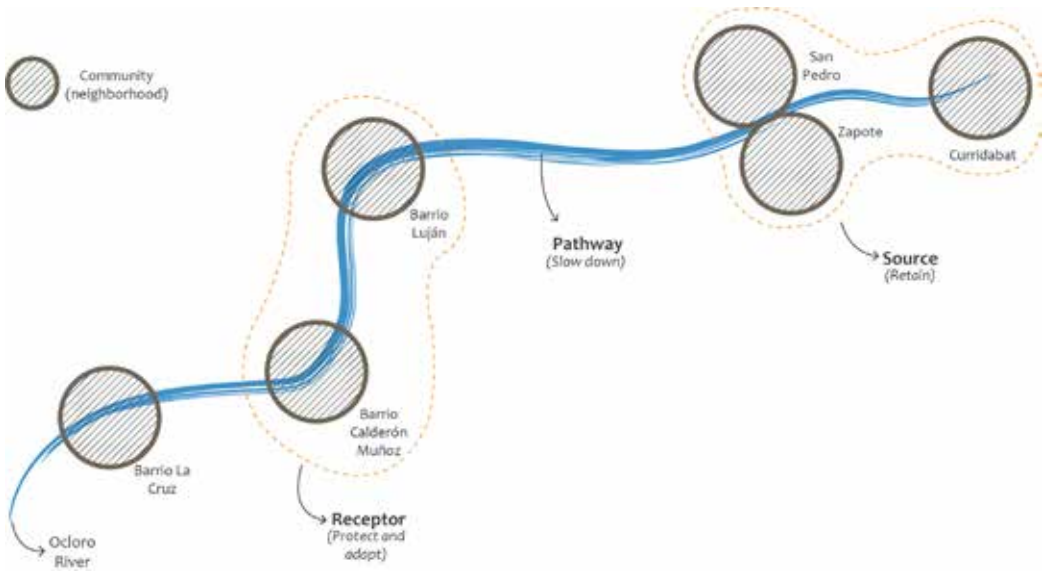



Figure35. SPRC Model – Analysis of critical section of the Ocloro river. Source: P.Bermúdez-Meneses (2019)

SPRC Model – Neighborhood Calderón Muñoz

When the Ocloro river overflows the capacity of the pipe of its cased section, the water flows over the street, direction west-east towards a lowest point. The runoff on the street also flows towards the lowest point, direction east-west. The lowest point of this intersection is the street to access to Barrio Calderón Muñoz (see Figure36).

The catchment area of the water that flows towards the access of the neighborhood corresponds to the Source, the streets in that intersection conform the Pathway and the Receptor includes the northeast blocks of the neighborhood (see Figure37).

In this setting, the model shows as Consequence an urban flood.

Figure36. Access street to Calderón Muñoz – lowest point of intersection. Source: P.Bermúdez-Meneses (2019)

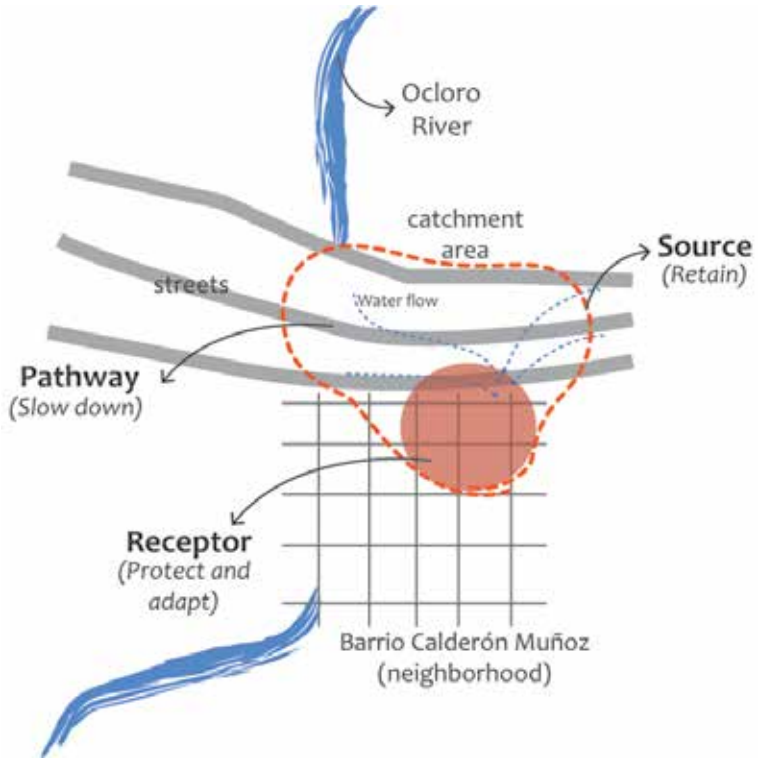



Figure37. SPRC Model – Analysis of the flood in Calderón Muñoz. Source: P.Bermúdez-Meneses (2019)

Figure38. SPRC Model – Lowest point of the street 25A (Receptor). Source: P.Bermúdez-Meneses (2019)

SPRC Model – Barrio (Neighborhood) Luján (street 25A)

During heavy rain events in Barrio Luján, the rainwater exceeds the capacity of the stormwater drainage in the area between Av. 24 – 26 and streets 25A – 27. The stormwater overflow runs over the streets towards the lowest point of the street 25A (see Figure38), flooding that area. The most severe events have also caused the stormwater accessing the sewer leading to an overflow of the sewer and a serious pollution problem.

The catchment area of the rainwater flowing on the streets corresponds to the Source, the streets are the Pathway used by the runoff and the lowest area in the street 25A is the Receptor (see Figure39).

In this setting, the model shows as Consequence an urban flood.

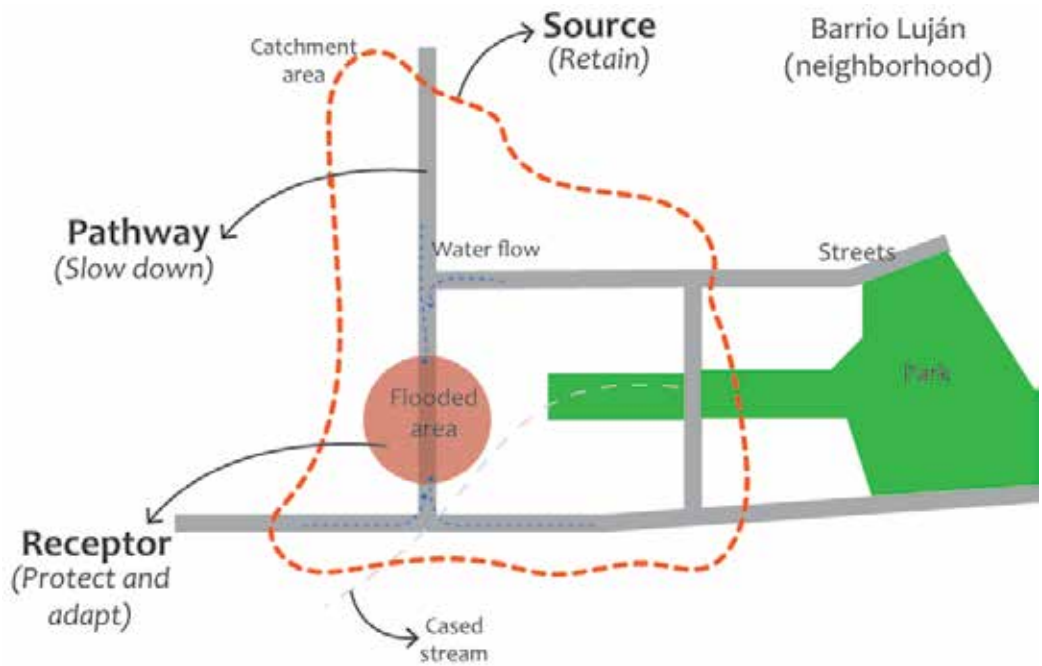



Figure39. SPRC Model – Analysis of the east part of Barrio Luján. Source: P.Bermúdez-Meneses (2019)

## 5.3 Impacts of the flood

Problematics

- Wellbeing affectation - When Olga Barquero states that her story is Barrio Luján, all her family history is there, she wanted to stay and continue her life in there, tragically, the floods displaced her from her home.
- Wellbeing affectation - Lorena Muñoz highlights the lack of peace-life quality; as residents are always concerned when they live their houses, fearing the possibility of flood and damage while they are gone. Every rainfall rises anxiety and dreadful thoughts.
- Wellbeing affectation - People are forced to change the way they live.
- Wellbeing affectation and environmental damage The back-flow into the sewer system causes serious pollution problems due to the mixture between residual water and rainwater.
- Wellbeing affectation due to economic loss - The damage and loss of products in a local supermarket due to the flood.
- Wellbeing affectation - When Katya lost all her shoes during the flooding of her house.
- Wellbeing affectation due to health risk and environmental damage - Problem with bad smells and mosquitos nearby the river.
- Wellbeing affectation due to public health and environmental damage - Hepatitis outbreak in Calderón Muñoz after one of the most severe flood events as a result of the water pollution levels.
- Wellbeing affectation - One of the house dogs (pet) died drowned during the flooding of the house.
- Wellbeing affectation - Damaged house appliances, furniture, clothing, food, personal documents.
- Wellbeing affectation and environmental damage - - The water pollution makes it impossible, in most of the cases to rescue the things once the water touches them. In conclusion, they lose everything that has contact with the water.
- Wellbeing affectation - After every damage inflicted by the flooding, starts a new recovery process, that people cover mostly by own means. It is a

vicious-unsustainable cycle that many cannot embrace for long.

- Wellbeing affectation - Some flood-affected residents state that in her neighborhood the tendency is, 'people that do not get wet do not care' about the river and the flood issues.
- Environmental damage - Several residents state with concern that a large percentage of the watershed consists of impervious surfaces due to unplanned urban growth.
- Wellbeing affectation and environmental damage -- Placing the trash bags in the street gutters, during the rainy season the rain drags away the bags and they cause the collapse of the drainage system. The solid waste is a factor that makes more severe the floods by blocking the water flow in the street gutters and the river flow.
- Wellbeing affectation and environmental damage - Lack of awareness of the part of the population – illegal discharges into the river, trash dumping, lack of a proper recycling system in the area.

### 5.4 Local responses – Community actions and ideas

After analyzing physical and technical aspects of the context where the hazard occurs; it is relevant for the research to learn about the experiences of the residents and to rescue the knowledge they built while dealing with the floods. That is a crucial input to work on strategies for enhancing the resilience of these communities.

The extraction of local responses or measures to face the flood comes from the information given by the residents in the structured interviews. For a better understanding and further analysis, the 'local measures' fall into four categories following their performance, Barriers, Drainage, Adaptation, and Prevention.

Local Measures Type 1 – Barriers (see Figure40)

1. Installment of flood gates in the doors of houses and buildings.
2. Place a lightweight metal hinged lid on the sewer pipes of her house (non-return valve). The hinged lid moves in one direction to allow the discharge of the sewer water out of the house and prevents the access of water during the floods.

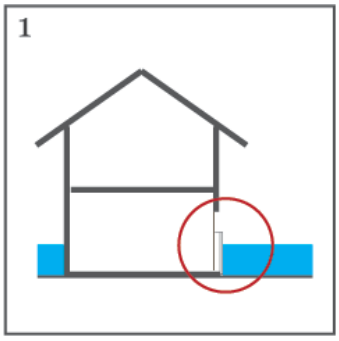
3. Walls and a tight gate around the garden to hold the water.
4. Build a barrier against the doors (inside) with concrete blocks.
5. Raise the door and built up a step outside in the sidewalk to access the house and block the water (one example has the floor level inside the house is below the sidewalk level).
6. Set a panel of a water-resistant material, of the exact width of the door frame and approx. 60cm high to block the doors before he leaving the house during the rainy season.

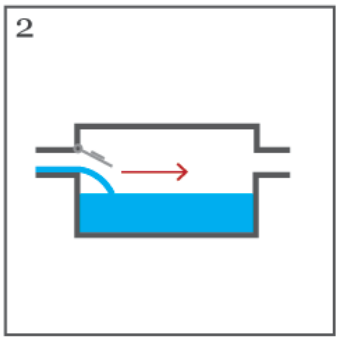
Local Measures Type 2 - Drainage (see Figure41)

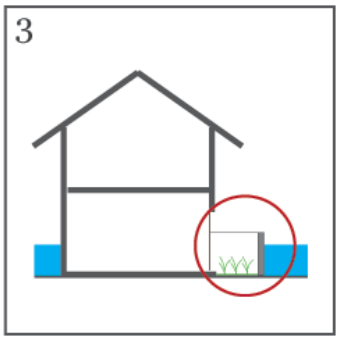
1. Pipes under the flooring from the backyard to the street to drain water out of the house.
2. Deepen the street gutters and connected them to the closest inlet.
3. Use of electric pump to extract water from the house.

Local Measures Type 3 - Adaptation (see Figure42)

1. Storage shoes in a sealed plastic box.
2. Place important papers and personal documents in sealed plastic bags.
3. Create a house evacuation plan.
4. Ladder prepared in the backyard and rain ponchos to get cover, climb to the roof and wait for help.
5. Using water proof materials inside the house to reduce future damage (floors, walls).
6. Place the stock-products (stores) and delicate items (houses) in a higher area at the beginning of the rainy season.
7. “El Piedrómetro” (meter-stone) rock inside the river in Francisco Peralta. The rock has a mark, used as indicator of coming flood for Barrio Luján and downstream. The water level in relation to the rock is communicated in real time, over the Early warning group (Whatsapp).
8. Early warning group on WhatsApp, integrated by residents from neighborhoods along the river.
9. Relocation of electric plugs to a higher position.



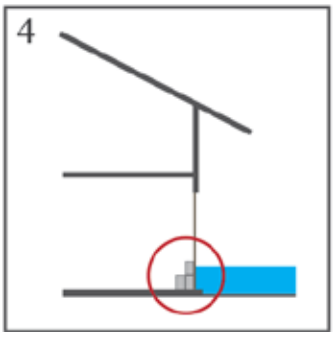



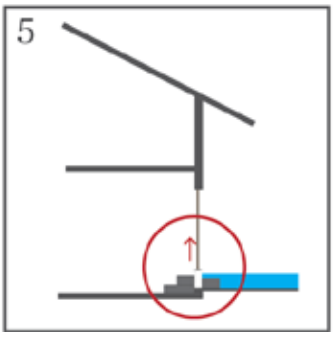




10. Relocation of appliances to the second floor of the house or on a high shelf.
11. Construction of houses above the sidewalk level.
12. Census for emergencies made by the CCE. It contains number of people in the house, number of pets, clothes size of the people, shoes size, usage of medicaments. A card-sheet with the data is storage in a safe point inside the house (a copy is saved by the CCE), facilitates the response procedure when the emergency occurs.

Local Measures Type 4 – Prevention (see Figure43)

1. Afforestation of riverbanks with plants that stabilize the terrain.
2. Keeping the garden area with grass and fruit trees to allow rainwater to infiltrate in the ground.
3. Request the municipality to make a cleaning of the drainage system and inlets before the rainy season.
4. Providing reports to the municipality (Hydrology department and residues department) of problems and risks in the area.



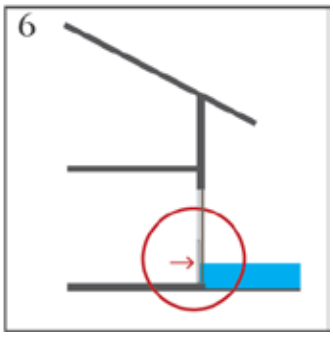




Figure40. Local Measures Barriers - Measures 1-6. Source: P.Bermúdez-Meneses (2019)

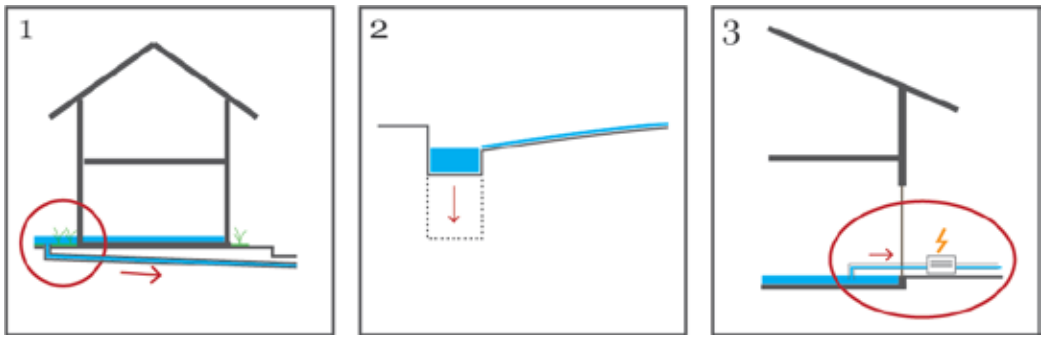



Figure41. Local Measures Drainage - Measures 1-3. Source: P.Bermúdez-Meneses (2019)

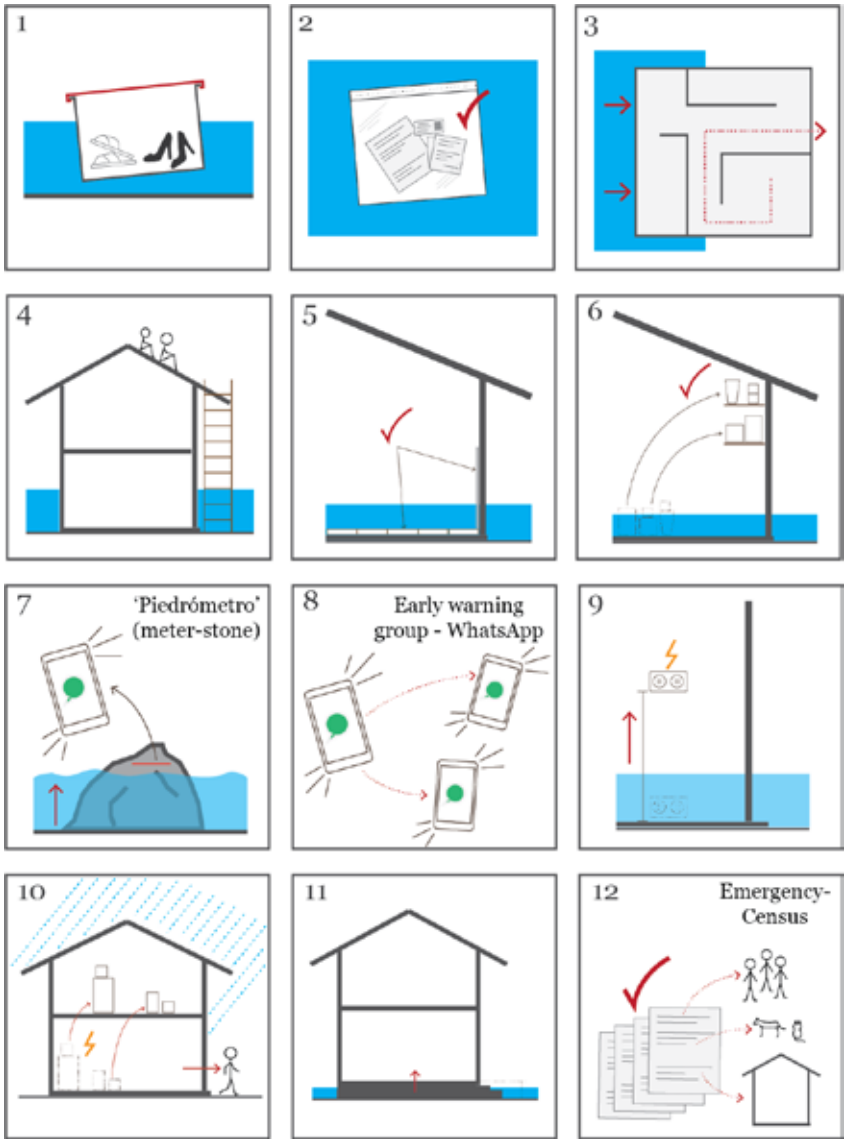



Figure42. Local Measures Adaptation - Measures 1-12. Source: P.Bermúdez-Meneses (2019)

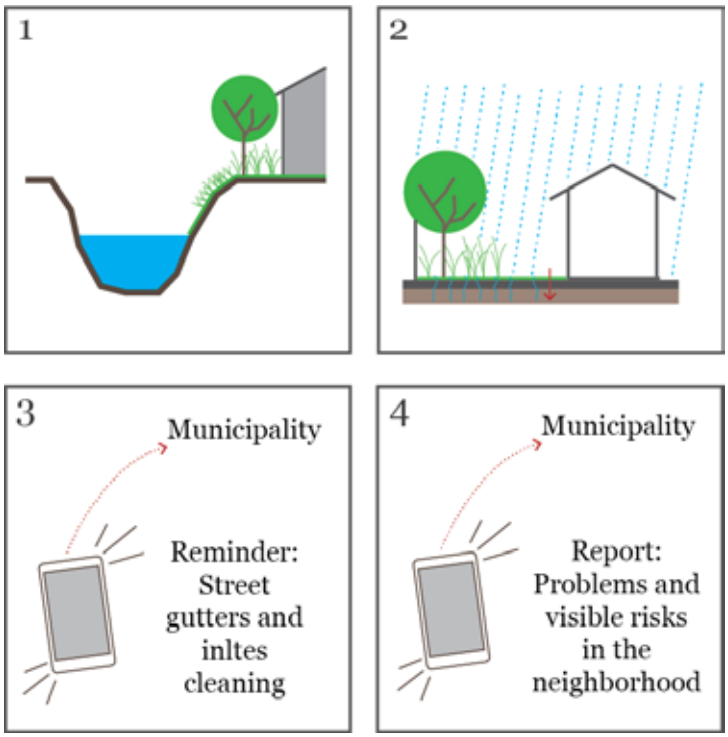



Figure43. Local Measures Prevention - Measures 1-4. Source: P.Bermúdez-Meneses (2019)

*Brainstorming with the community – Possible solutions to address the problematics*

- It is necessary to finish the construction of the bridge on Av. 26 and improve the arrangement of the river pipes at that point.
- Creation of an extensive campaign for sustainable management of solid residues (recycling and upcycling) + culture to reduce the flood problem and improve the environmental conditions.
- Rainwater harvesting could be an excellent tool to implement in the area, and especially for San Pedro district in the new apartment building projects.
- It is necessary to work at the watershed level to solve the flood problems. Teamwork approach among municipalities and communities along the river.
- Construction of a new drainage system in the backyard to enhance the capacity of infiltration.
- Provision of room for the river.
- Stop illegal discharges of sewer water into the river.

- Training and workshops for the community to learn about the techniques and proper implementation of rainwater harvesting systems.
- Enhancement of capacity of the storm sewer system, improve and organize the management of the solid residues.
- Increase and reinforce the local communal initiative of street and street gutters cleaning.
- Start a rainwater harvesting system at the home level.
- Try to keep and increase the greens areas for water infiltration.
- Opening of the pipe under the parking lot and create a retention lagoon in there (room for the river) to slow down the water.
- Raise the new constructions and build protection walls.
- Give regular maintenance to the forest and opening of the fence inside the parking lot of the factory.
- Monitoring and inspection of the discharges and trash dumping upstream.

### 5.6 Summary of findings

- The analysis of the area's physical characteristics and the description of the flood events by the residents indicate that the events correspond to urban floods and river floods.
- According to the research on documentation and the experience-knowledge of the residents, the river floods have a long history impacting the area (around 70 years of occurrence).
- The Ocloro river presents broad interventions (change of the natural course, cased, by-pass, reduction of channel width, deviation of the river). All these modifications have had a direct impact on flood patterns and intensity.
- A significant portion of the community is well informed about the problematic and situation because they have done research, reach out for experts, and have gained significant knowledge.
- The existing tools and mechanisms from the local government work mostly for the response to the emergencies, but they are not yet sufficient when it comes to prevention and risk reduction.

- From the conversation-interview with officials from the Risk Management Department of the municipality. The department has not yet a detailed database of the hazards and threats on GIS (Geographical Information System), that makes difficult the evaluation of the risk in the territory as well as the land regulation in terms of hazardous areas. They are beginning the creation of such a base using the existing hazards record.
- Easy access to technology (smartphones, internet, e-mails, WhatsApp, Facebook) has enormous relevance in terms of documentation, diffusion of information, learning, preparedness, and adaptation. This is the case of the community of this research.
- People in the study area are aware of technology's advantages; and they want to enhance their capacities in the use of these tools.
- The communities set along the Ocloro River, specially Barrio Luján and Calderón Muñoz, have learned a lot from the experience of decades dealing with the floods. They have studied the topic, their context, the river, they built up cooperation among each other and created their tools to document, understand, and prepare better to face the hazard.
- This set of communities can serve as an example for other flood-affected communities in Costa Rica on how to manage their human resources and put in action their social learning to enhance resilience.
- Little application of risk prevention actions from the side of the local government and few opportunities for involvement of the community-participation on risk reduction and disaster management creates more despair and mistrust from the community side.
- The experience and knowledge of the communities are not yet serving as tools and input to understand better the risk and address adequately the problematic.

# Chapter 6. Towards the Water Balance

## 6.1 Outline of Guidelines and Technical Measures

This section presents the set of guidelines and the proposed measures.

After the study of the area and a revision of the local responses or community measures and the findings, comes the selection of suitable technical measures to suggest as a complement to the current efforts performed.

A revision of related case studies and already produced material in terms of guidelines and tool kits for flood adaptation and risk reduction was the main base for the selection of the technical measures and principals to recommend for the study area.

The references consulted for the study and selection of adequate measures are the Climate App Organiza-

tion, Climate-ADAPT, Urban Green-Blue Grids for sustainable-resilient cities, Climate-KIC from the Imperial College London, Ramboll, Environment Agency of the UK Government, the European Natural Water Retention Measures Platform, and some specific case studies of strategy design for flood adaptation.

The selection of technical measures follows the three axes defined for the analysis, Stormwater management, Livability-wellbeing, and Environmental conditions.

## *Guidelines*

- The green spaces are essential spaces to develop more sustainable stormwater management strategies, like infiltration, retention, and purification of rainwater.

- Trees and vegetation have positive effects on air quality, rainwater absorption, flood mitigation, soil stabilization, among others.

- Nature-based solutions have a high impact on stormwater management and flood risk reduction, and on top of that, they trigger many additional benefits to the site of implementation and the life quality of its residents.

- Water is a vital resource to protect and exploit consciously. Especially nowadays, it is necessary to make sustainable use of it; rainwater harvesting, filtering, and recycling for specific uses are formidable-relatively easy techniques to impulse water balance.

- Rapid discharge of rainwater out of each building leads to significant amounts of runoff and sooner overflow of the stormwater sewer. Therefore, harvesting, temporarily retention, and infiltration are vital tools to prevent floods.

- Reduction of impervious surfaces contributes to rainwater infiltration and flood risk reduction.

- For the use of pervious materials, it is essential to consider if the area possesses high exposure to pollutants if it is the case is necessary to treat-purify the water before infiltration.

## *Measures for Stormwater management*

*Reduction of paved surfaces:* use permeable materials in for walkways and dri-

veways, pervious parking lots, increase of green areas, creation of green stripes on sidewalks.

*Green roofs:* (extensive – lighter weight) – for the single-family houses and small buildings Green roofs (intensive – heavier weight) – for the new apartment buildings and existing large buildings. (Effectiveness: both types of green roofs are highly effective in case of urban flood and little effective in case of river flood).

*Rainwater ponds for buffering and holding water:* buffer ponds capture rainfall temporarily and drain it off slowly to create room for the next rainfall. They contribute to the city landscape value.

*Rainwater harvesting:* also known as rainwater tank. The system consists of a tank to collect and store rainwater runoff from rooftops conveyed by gutters and downspouts to the tank. The collected water can be used for watering gardens, washing clothes, washing cars, flushing toilets, others. Some benefits of the system are a reduction of water use (water service) helping the environment and the economy, reduction of the runoff during rainfall events and self-sufficiency during dry periods.

*Temporary flood protection:* consists of flood barriers built out of removable components. It can be installed after a flood warning and disassembled when the flood has retreated. The usage of this type of protection is convenient in urban areas, as it requires less space than permanent protection structures. Training is necessary to implement this system.

*Usage of pervious paving materials:* consists of the substitution of impervious pavements for materials through which water can pass. Porous and partially open materials are suitable for this purpose. Some examples of materials are woodchips, gravel, grass-concrete pavers, porous clinkers, open-joint clinkers. Also, ordinary clinkers or similar can be laid in semi-open patterns to set grass in the openings and facilitate the pass of water. Places like heavy traffic roads and car parks are not suitable for the use of permeable paving materials due to the risk of pollution.

*Flood gates:* gates and elements that work sealing doors and entrances of buildings to keep the water out of the building. Some examples are bulkheads and shutters. There are flood gates of different formats and sizes to adapt to diverse types of openings.Despite the use of these elements, water may access the inf-

rastructure at some point; therefore, it is crucial to combine this measure with water-resistant materials to reduce potential damages.

*Non-return valve:* consists of a hinged lid that allows discharge in one direction and blocks any access. It is suitable for pipes vulnerable to backflows like toilette pipes and sewage systems.

*Inlet protection basket:* these are usually manufactured elements to set inside the inlets. Their purpose is to catch sediments, silt and solid residues that rainwater drags right before they access the storm sewer to prevent malfunction and blockage of the system. They include baskets, bags, racks, and others.Inlet protection devices are a practical, small scale, and cost-efficient measure though it requires regular cleaning and maintenance. (Reference: https://stormwater.pca.state.mn.us)

*Retention ponds:* are permanent ponds designed keeping additional storage capacity to receive runoff during rainfall. They can serve for both purposes, retaining stormwater and treating the water. The pond captures the runoff, holds it, treats the water, and later releases it slowly, once the flood risk passes. An additional benefit of the retention ponds is the usage of the water in neighboring buildings.

*Infiltration trenches:* Ditches filled with gravel to intercept the runoff, storage a particular volume, and allow infiltration.

*Vegetative swales - Bioswales:* correspond to channels covered with vegetation and a permeable bottom. These channels collect- intercept the rainwater running off from roofs and roads, preventing it from going into the storm sewer, in that way, slowing down the runoff and infiltrating the rainwater into the ground.

The structure consists of a top layer of enhanced soil with plants, below it has a layer of gravel, scoria or baked clay pellets packed in geotextile. In case the rainfall exceeds the capacity of the bioswale, the overflow runs into a drainpipe.

They are highly effective for runoff control, contribute to the biodiversity, the construction costs are medium, and they require a medium level of maintenance. (Reference- https://www.urbangreenbluegrids.com)

*Bioretention cells:* these units consist of a ground depression filled with several layers; the surface is mulch, enhanced soil, pervious geotextile, gravel, and at the bottom, there is a perforated pipe. In case the water can not infiltrate, it

exits the cell via the drain pipe.

They collect the runoff, capture the pollutants using beneficial microorganisms, and percolate the water. Bioretention cells are very efficient in soils without inadequate percolation capacity. For the vegetation, it is common the use of native plants, because they tend to develop a deep root system. (Reference - http://www.fourmilecreekwatershed.org)

*Measures for Environmental conditions*

*Constructed wetlands:* for cleaning of polluted water. These units work as retention, wastewater treatment, traps for sediments, and harmful microorganisms. It is possible to implement them with or without additions to improve treatment capacity.

Some of the co-benefits of the constructed wetlands are a reduction of the downstream flood, water availability during dry periods, an increase of the landscape value and according to the design, they can improve the livability of the area.

*Biogardens for water treatment:* consists of a garden constructed in a pit filled with stones, gravel, and plants. The system works for sedimentation, and the roots of the plants inside the pit absorb the nutrients. The result is a clean water effluent.

*Rainwater ponds for Buffering and purifying extremely polluted water:* used to pre-purify the rainwater runoff from busy streets. It is essential to seal the system from the ground employing a film. After the pre-purification of the water, the overflow can connect to a surface water body or an infiltration system. Only when there is no surface water nearby, and infiltration is no possible, the overflow should connect to the storm sewer.

*Green riparian zones and wet biotopes:* this nature-friendly approach instead of the reinforced riverbanks, forms a gradual green transition from the land to the water. These structures have a positive impact on water quality by absorbing nutrients and floating particles (especially plants like reeds and rushes) increasing clarity and quality of the water. Additionally, they provide habitat to many species of plants, birds, insects, amphibians, fish, and mammals. It is vital to mix reeds and rushes with other plants to keep the biodiversity and prevent reeds and rushes from taking over the entire area.

This approach is highly effective in terms of water management, is cost-effici-

ent, and requires little maintenance.

*Afforestation of public spaces and sidewalks:* Floodplain woodlands can contribute to ameliorate downstream floods. Afforestation of floodplains or flood-affected areas can function as a soft-resilience strategy for flood control. Among the benefits of afforestation is an increase in biodiversity, nature conservation, improvement of water quality, recreation, landscape value, and livability.

Before developing an afforestation project in a flood-affected is crucial to perform an analysis of the area, using hydraulic models, streamflow, and topography to assess the effect of the woodland on the flood patterns and identify suitable sites for planting. (Reference - https://www.forestresearch.gov.uk)

*Set trash bins (classified residues) on the streets:* the setting of recycling containers modules on the streets, in the flood-affected neighborhoods, in addition to awareness campaigns as part of the efforts to reduce the number of solid residues that end up in the storm sewer and the river.

Measures for Livability and well-being

It is relevant to emphasize that the livability and well-being of the flood-affected communities will benefit directly from the better management of the stormwater and the improvement of the environmental conditions linked to the quality of the river water and ecosystem features of the area.

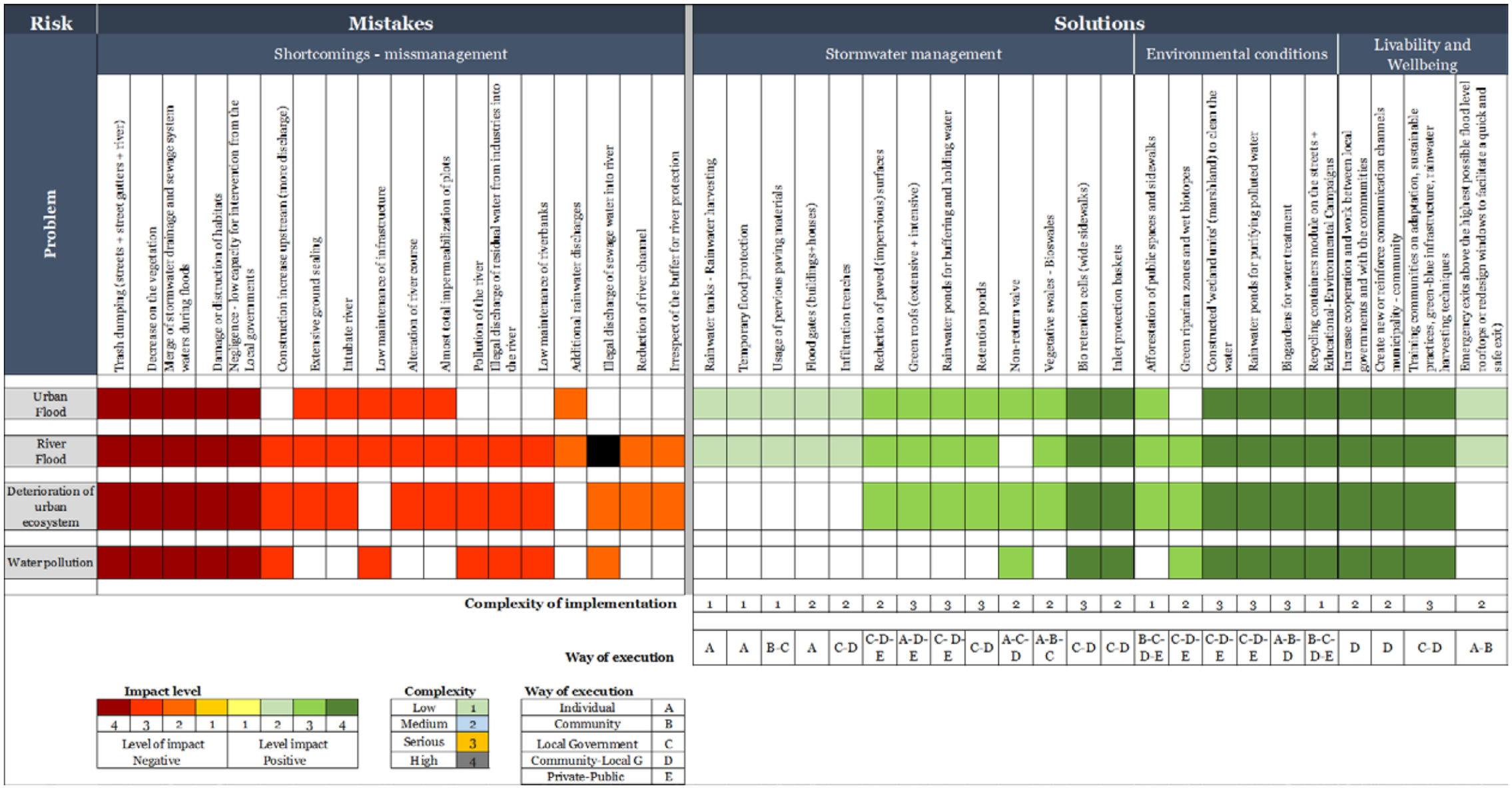
- Increase cooperation and work between local governments and with the communities.

- Create new or reinforce existing mechanisms and channels of communication from the local government towards the community.

- Offer training for the communities on topics like adaptation, sustainable practices, usage of green-blue infrastructure, rainwater harvesting techniques, and other related.

- Creation of emergency exits above the highest flood level: it consists of placing an exit door-gate above the highest possible flood level, this could be in rooftops or redesign windows to facilitate a quick and safe exit.

*Risk - Mistake - Solution Matrix*



## 6.2 Further steps

Due to the time limitations for this research, it is necessary to make a selection of tasks and products to develop as further steps. This selection corresponds to the products this research attempts to deliver to the communities and local governments as practical outcomes or tools.

- The local measures, in addition to the selection of technical measures, will give form to a catalog or tool-box for resilience building, flood-adaptation, and risk reduction strategies.

- Translation of the tool-box content and suggested guidelines to Spanish.

- Compilation of the material in the Spanish version in a format easy to distribute.

- Translation of the research maps to Spanish.

- Preparation of a package with flood-affected areas data (GIS) to deliver to the local government to contribute to their project of consolidation of GIS hazard database for the canton of San José.

- Delivery of the Resilience building tool-box to the affected communities and the local governments as a practical outcome.

Ideally, other flood-affected communities can make use of the tool-box as a reference and instrument for their resilience building process.

# Chapter 7. Discussion, Conclusions and Recommendations

## 7.1 Discussion

In Costa Rica, as a context challenged by the limited financial resources, it is vital to reach out first, for the use of cost-efficient, nature-based solutions to build resilience and reduce risk flood.

Non-planned urban growth has a significant effect on hazard incidence. Part of the results of inadequate urban growth is environmental deterioration, which enhances vulnerability. The context of the study is a victim of this cycle of environmental damage, vulnerability, urban problems, and hazard incidence.

This research shows the social learning of the community fully; it is clear, people have gained much comprehension; some have even reached out for other sources of knowledge and done research. The findings present how the residents have learned to

live with the hazard, reinvent themselves, restore their houses, restore their lives. Reduce the damages.

The analyzed communities are a clear example of adaptation from the community side.

The current work approach is more focused on hard resilience measures, building protection walls, river by-passes, river diversion works. Many of these government interventions had no prior coordination with other municipalities or analysis at the watershed level. These interventions usually have negative impacts on communities downstream.

To reduce risk flood and enhance the resilience of the flood-affected communities is necessary to apply an integrated approach, working among municipalities and with the residents.
The local governments are not yet taking advantage of the valuable knowledge and human capital existent in the flood-affected communities, to boost flood risk reduction, resilience building, and climate change adaptation.

The research depicts how isolated interventions for flood risk reduction can intensify the problematics in other locations of the watershed.

The findings also state how relying only on hard resilience measures tends to failure, due to the high investment, not solve the whole problem, and externalities in other areas of the basin.

They prove how flood risk reduction requires an integrated approach.
Shows how a community can work together, develop their adaptation tools, and organize to improve the situation.

Despite specific working efforts, at the moment, the municipalities lack relevant data on hazards. There is a change to overcome the issue by making use of the built-knowledge and information from the communities.

The practical approach on the municipality level (axes of work) is not yet coherent with the National Climate Change Strategy, which contains thematics as community-based adaptation, ecosystem-based strategies – these factors are

not yet transferred to the municipalities work – local vs. national level. These are challenges and gaps to bridge.

The findings allow to see the panorama of the risk reduction and climate adaptation efforts at a relatively small scale and detect the flaws-shortcomings in the approaches as well they allow spotting opportunities and resources that were maybe not yet visible.

The study of the local government action side is more focused on the Municipality of San José because a substantial extension of the river belongs to its territory, the highest incidence of the hazard occurred in its territory and the time limitations for the analysis. Therefore, the findings do not present a full panorama of the actions and strategies of the three municipalities; nevertheless, the interviews provide information on these aspects from the community perspective.

It is still necessary to elaborate a closer study to determine the implementation points and to outline the detail specifications and for the technical measures. That level of specification will require additional and probably several parallel

## 7.2 Recommendations

The local governments along the Ocloro River need to make efforts to consolidate teamwork management of the river conditions in terms of stormwater management, riverbank maintenance, monitoring of discharges into the river, and adequate solid residues management.

Coordination between the municipalities along the watershed - Work on the development of a GIS-based flood risk mapping for the watershed area. This tool can be applied for the creation of prevention measures and the establishment of construction and use regulation in the vulnerable areas.

It is essential to make investment and potentiate the existing human capital within the communities. These efforts enhance the working capacities and impulse the processes of detection, evaluation, and solution of problematics.

It would be highly beneficial to create an inter-municipal commission that also includes representatives of the communities to work and coordinate actions related to the Ocloro River.

To teach volunteer community members on the usage of technological tools

(smartphones, GPS track app, Google Earth, Google Maps) for documentation and data collection of hazards. This work can provide the respective Risk Management Departments of the municipalities with valuable information to build-up faster a database of the hazards and facilitate the adaptation strategies — capacity building and overcoming the lack of resources.

Organize regular call-outs for guided river walks along the Ocloro River to raise awareness, network building, monitoring and brainstorming on solutions and desire scenarios for the river.

Organize community round table meetings including the communities upstream (neighbor and non-neighbor of the river) to share the experiences of the flood-affected communities to raise awareness on the linkages between communities (cause and effect) and the understanding of the neighborhoods inside one watershed as a unit.

It is vital from both the local governments and the communities, to rescue and potentiate the existing green spaces and to impulse the increase of green infrastructure within the city. These actions lead to flood mitigation, environmental recovery, life quality improvement, among others.

A suggestion for the case of Barrio Luján is for the community to team up with the municipality as a mediator and the proprietary of the empty plot-old factory plot to develop a temporary project (in the meantime the plot remains empty). The purpose would be to apply a model of temporary designation of unused plots for nature and ecosystem services. The project could mean the usage of moveable elements to implement minimum-impact activities like the creation of a communal garden, recreational space for the residents, open gathering spaces, intentional flood area, and others.

# Acronyms

CNE: National Emergency Commission

MINAE: Ministry of Environment and Energy

IMN: National Meteorological Institute

MOPT: Ministry of Public Infrastructure and Transportation

MSJ: Municipality of San José

MMO: Municipality of Montes de Oca

MC: Municipality of Curridabat

PANI: National Children‘s Board

CCSS: Costa Rican Social Security

MS: Ministry of Health

ICE: Costa Rican Institute of Electricity

AyA: Costa Rican Institute of Aqueducts and Sewers

CNFL: National Light Company

IMAS: Mixed Institute of Social Assistance

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