URBAN WATERBODIES

Stimulating an ecosystem resilient city by integrating climate sensitivity in human-oriented urban design in Houston



Nadine van den Berg

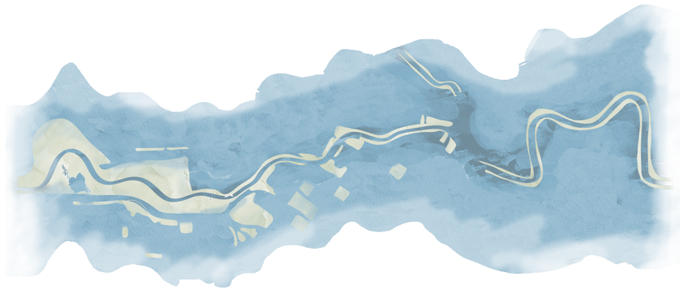
COLOPHON

URBAN WATERBODIES

Stimulating an ecosystem resilient city by integrating climate sensitivity in human-oriented urban design in Houston

Master Thesis Report

MSc. Architecture, Urbanism and Building Sciences
Specialization: Urbanism



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ABSTRACT

Societal problems related to climate change include increasing climate extremes, flood risk and environmental degradation of cities. It is important to address these problems in order to improve urban resilience, reduce flood damage, and promote quality of life. This thesis addresses these problems by focusing on increasing the ecosystem resilience in the urban environment. It seeks to address current shortcomings in cities' approaches towards urban development; the potential of nature-based solutions as an alternative to grey solutions; and the integration of climate sensitive urban design in the built environment. The main research question is "How can an ecosystem resilient approach guide the built environment in order to integrate climate sensitivity in human-oriented urban design?"

The development of a detailed urban design follows from a literature study on ecological urbanism, climate resilience, and nature based solutions, which is supplemented with an in-depth site analysis that focuses on spatial and technical aspects of the built environment in relation to heavy floods, spatial quality, and urbanized landscapes. The study draws on theories of persuasive visual storytelling and research by design.

The interdisciplinary approach taken in this project culminates in an urban design proposal for the Buffalo Bayou Downtown corridor in Houston, Texas. The design proposal introduces new nature-based and water-based features into the urban environment. By reintroducing elements of the lost ecoregions of the East Texan coast (including wetlands and prairies) the design proposal not only contributes to improvements in quality of life, but also to greater urban resilience to pluvial floods.

Keywords – ecosystem resilience, flood resilience, persuasive visual storytelling, human-oriented urban design, reconnecting to nature, Houston

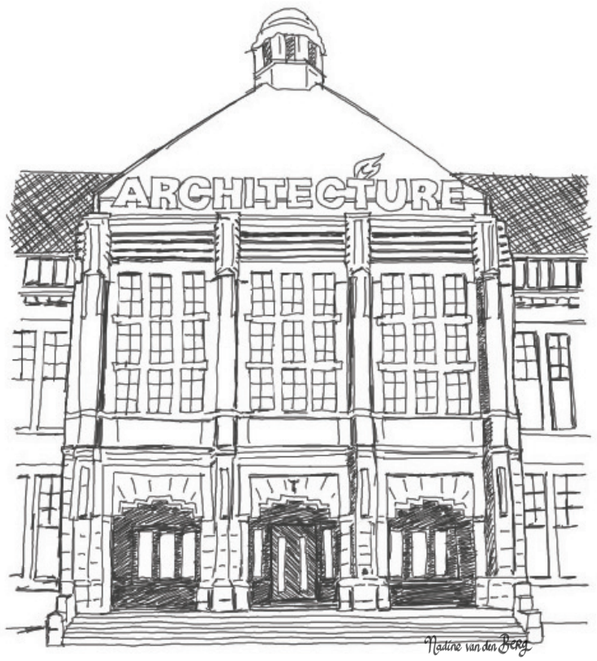
PREFACE

After starting my MSc Urbanism in February 2019, Fransje was my tutor for the Infrastructure and Environment Design course (Q4 - 2019) where she continuously challenged me to make qualitative innovations, which resulted into an interdisciplinary design project in Midtown Houston. This left me with an interest for investigating water related urban and engineering designs in delta metropoles, and a desire to dive deeper into Houston.

A jump forward in time brings us to the Q2 - 2019 project in Rijswijk with my tutor Luisa Calabrese, where I created a vision for the future of Rijswijk, starting from knowledge that is not usually there: microclimate performance and the themes of water, subsoil, energy and ecology. Here I learned how to translate engineering solutions into my own urban design, while contextualizing this by using the classical urbanism aspects. Throughout this project Luisa also guided me to understand my own work and develop a frame of theories around the theme of reconnecting people with nature. I was inspired in particular by The Cultivated Wilderness by Paul Shepheard, where he talks about how the wilderness is not just something you look at; but also something you are part of. You live inside a body made of wilderness material. And the intimacy of this arrangement is the origin of beauty: the wilderness is beautiful because you are part of it. But at the same time, cultivation has a certain beauty as well, since it is the human reordering of the wilderness material–and if it is successful, the beauty of it lies in the warmth of your empathy for another human's effort.

All of this has laid the foundation for this thesis and fueled my interest to go back to Houston to take up the challenge embedded in planning and design to unite natural and human conditions of the built environment. Houston has a long flooding history, and the former solutions are not adequate anymore; especially when taking into account more intense weather events caused by climate extremes. This fascinates me because of its complexity, interdisciplinarity and urgency; and this is where I want to gain more knowledge in.

With this, and my strong interest in understanding the interplay between socio-spatial and environmental processes in city making, I hope my thesis can contribute to more ecosystem resilient cities in the future.



< Bouwkunde faculteit TU Delft / Faculty of Architecture University of Technology Delft (Van den Berg, 2021).

ACKNOWLEDGEMENTS

I would like to thank my mentors, Fransje Hooimeijer and Dominic Stead.

Fransje was my tutor for the second project in my Urbanism studies about Midtown Houston. When we explored Houston during our field trip, I became extremely curious in this peculiar Texan city that seemed to have forgotten that it is a coastal ecology. Fransje noticed this, and provided the oxygen that turned a small spark of interest into a raging fire of creativity that accumulated into this thesis. Throughout this thesis she guided and supported me with unconditional readiness and compassion. Finally, she has been more than a mentor, as she has been advising me not just on academic matters, but also on strategies for career and for life.

Dominic has been the other pillar of my thesis. As a planner, he is extraordinarily open-minded to discuss with me all topics that are not directly related to planning. As a mentor, he did not only point directions and make requirements, but also guided me based on understanding me. My mentors never ceased to inspire me with their words and insights; together, their wise questioning and input has critically shaped this work.

I am grateful for the TU Delft Urbanism staff, especially Claudiu Forgaci, Diego Sepulveda, Luisa Calabrese, and Krik van Ees for giving their helpful advice, useful suggestions, and unlimited enthusiasm.

My gratitude also goes to Baukje Kothuis, whose inspiring conversations and unwavering excitement provided valuable input that further shaped my project.

I am indebted to all the wonderful people from Houston, especially Chula Ross Sanchez, Yoonjeong Lee, and Charles Penland for giving their time, expertise, and materials freely to support my project.

Beside my academic support, I would like to thank my friends Kseniya Otmakhova and Ruiying Liu for the guidance and advice they provided over the years. It was both their MSc Urbanism theses that convinced me to take the plunge and pursue an MSc degree in Urbanism myself. I would also like to thank my dear friend Rosanne Echtermeijer, for her ever-present support throughout my entire university journey.

And finally, I thank my greatest supporters, my family, who earnestly support and encourage me in all my efforts. Especially my sister Natalie, who dared to read this thesis from cover to cover.

Executive Summary

This project makes an effort to contribute to the discourse on ecosystem resilience by showing that a paradigm shift in city development and relationship to nature not only creates a more ecosystem resilient city, but also holds merit in terms of flood resiliency and living quality.

Problem Field

Societal problems related to climate change include increasing climate extremes, flood risk and environmental degradation of cities. It is important to address these problems in order to improve urban resilience, reduce flood damage, and promote quality of life. This thesis addresses these problems by focusing on increasing the ecosystem resilience in the urban environment. Houston, Texas, is used as a case study. The disregard for the natural bayou water systems, extensive expansions of low density suburbs, lack of effective zoning system, and divergence from nature, increased Houston's vulnerability to climate extremes (such as increased peak rain events and extreme hurricanes). Houston's current approach towards these climate extremes is recovering instead of preventing. To make Houston's built environment more resilient to floods, a paradigm shift is needed to change old habits and create new mindsets. In addition, Houston faces social and cultural challenges, such as loss of connection with nature and social unacceptance for nature-based solutions and sustainable planning.

Research Aim

This thesis seeks to address current shortcomings in cities' approaches towards urban development; the potential of nature-based solutions as an alternative to grey solutions; and the integration of climate sensitive urban design in the built environment. The main research question is "How can an ecosystem resilient approach guide the built environment in order to integrate climate sensitivity in human-oriented urban design?"

Methodology

The development of a detailed urban design follows from a literature study on ecological urbanism, climate resilience, and nature based solutions, which is supplemented with an in-depth site analysis that focuses on spatial and technical aspects of the built environment in relation to heavy floods, spatial quality, and urbanized landscapes. The study draws on theories of persuasive visual storytelling and research by design.

Persuasive Visual Storytelling

By using visual storytelling as a part of design research, it becomes possible to project new futures. From a design perspective, the fundamental potentials and limitations of the design location are discovered, and the boundaries of reality are challenged to create out of the box ideas. From a planner perspective, the narrative systems of urban planning and design could be used as powerful tools of communication, persuasion, and education. Visual storytelling has the ability to provide thoughtful content and beautiful visuals that will help in making content or messages an engaging piece that catches and holds the attention of the audience. The old saying 'a picture is worth a thousand words' is true: vision trumps all other senses. Being fluent in the language of images strengthens the ideas and plans, and in combination with storytelling will increase empathy and compassion, which are crucial in a successful planning process.

Findings

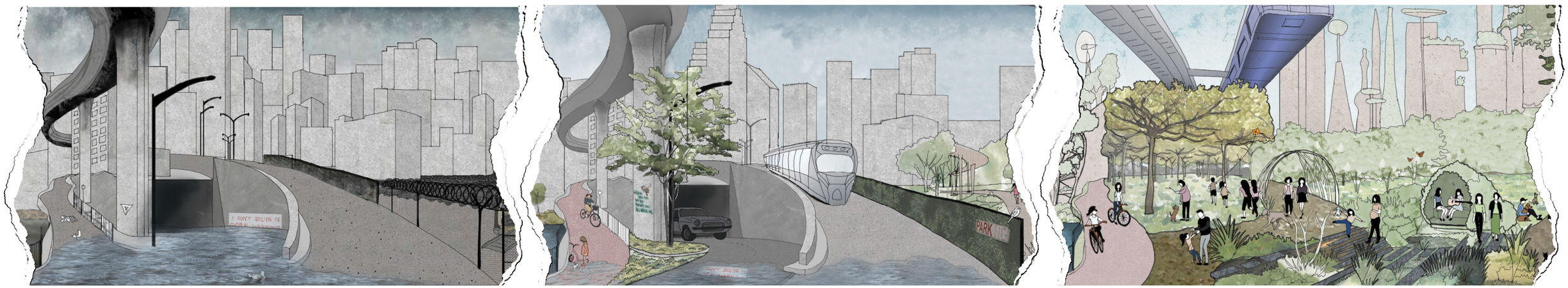
The spatial and technical analysis of the Buffalo Bayou watershed and Buffalo Bayou Downtown corridor on the capacities of the built environment to handle excess rainwater; characteristics and conditions of the existing green spaces; and spatial quality of the Buffalo Bayou adjacent corridors provided valuable conclusions on the challenges that ecosystem and flood resilience faces in Houston. Availability of public space is unevenly distributed in the Buffalo Bayou corridor as it tends to be situated on the west side of Downtown, leaving other parts with almost complete impermeable surfaces and no access to quality green public space. The current practice of implementing mega parks in the city is insufficient since the threshold capacity of residents engaging with those parks is too high, and the benefits of these parks become too centralized in one neighborhood. Concerning the Buffalo Bayou riverbanks, the inconsistent quality of them causes fragmentation of the riparian zone as well as discontinued public spaces. However, the clay and loam based soil add impermeable conditions because it does not allow rainwater to drain well, and influences the choice of vegetation due to high and fluctuating water tables, meaning that proactive measures need to be taken in order to improve flood resilience. Moreover, Houston has lost its sense of place. The city has forgotten that it is a coastal ecology as there are no traces of the landscape that was originally there, and bayous are simply seen as highway obstacles. Urban sprawl has strangled the bayou system and increased the car dependency, because developers have an almost unrestricted liberty of action and decision since the drainage policy and system is quite loose and low-regulated.

Urban design outcome

The interdisciplinary approach taken in this project culminates in an urban design proposal for the Buffalo Bayou Downtown corridor in Houston, Texas. The design proposal introduces new nature-based and water-based features into the urban environment. By reintroducing elements of the lost ecoregions of the East Texan coast (including wetlands and prairies) the design proposal not only contributes to improvements in quality of life, but also to greater urban resilience to pluvial floods.

Recommendations

The proposed design for Buffalo Bayou corridor deploys a reimagined natural system not only as a way to increase ecosystem, climate and flood resilience, but also act as an accelerator for spatial development that includes nature based solutions. To include these, a heavy presence of open soil and water is needed in the built environment of Houston. With a system of wetlands, retention ponds, and green infrastructure projects, the design aims to provide a space in the city where water storage, nature, and education come together. On a larger scale, the design connects both existing and planned improvements to the area's riverbank connectivity and green public space quality. As a way to create added value and merge of interest, the proposed design develops a new form of educational park in Downtown Houston, one that is much more centered around water and nature. Moving away from the typical concrete zones and underutilized parks without native vegetation, the proposed design introduces a new approach to reconnect the relationship between people and nature in the city that offers high quality, human-oriented, climate-sensitive public spaces. The proposed plan aims to successfully fuse the new nature-oriented urban environment with water retention measures. Recommendations for further research are to expand this thesis with studies on financial feasibility, stakeholder involvement, and cultural integration.



Scenario drawings, using persuasive visual storytelling techniques (Van den Berg, 2021).

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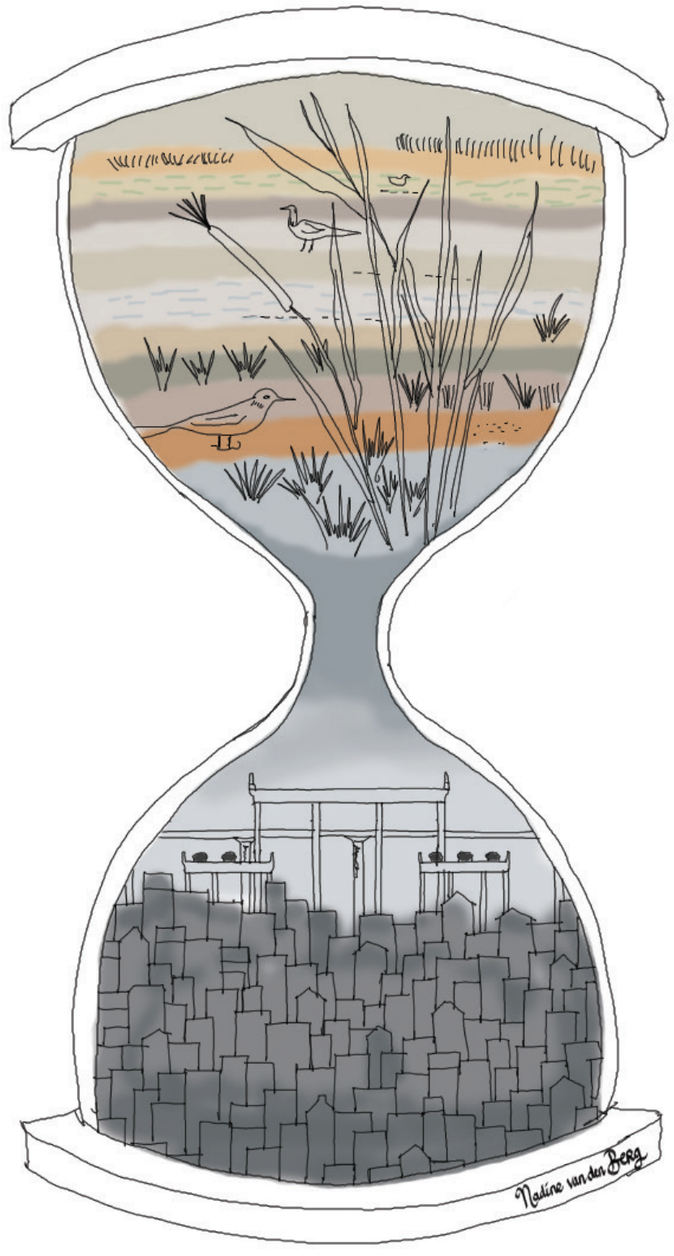
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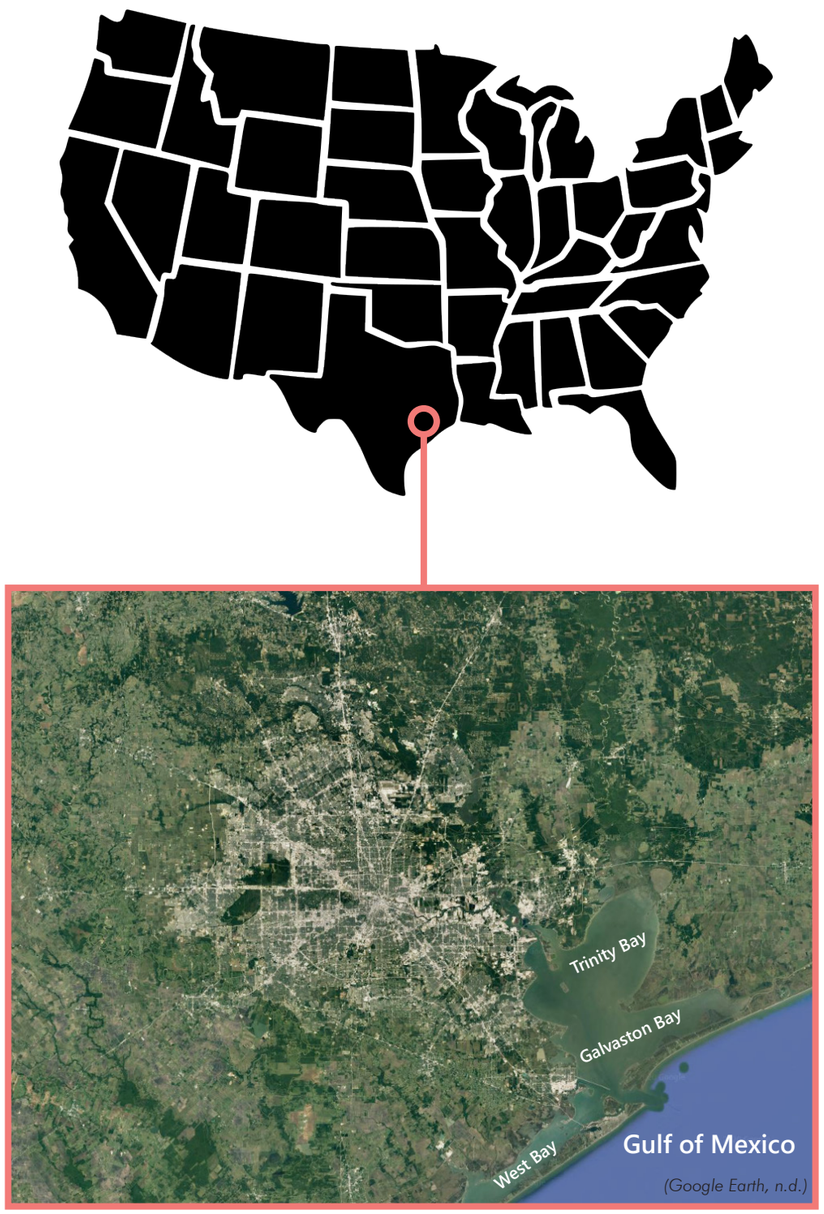
A | Theory Paper

Manifesto



1 INTRODUCTION

1.1 Context
1.2 Problem Field
1.3 Location



HOUSTON, TEXAS, UNITED STATES OF AMERICA

Addicks Reservoir

Barker Reservoir

Buffalo Bayou

Lake Houston

Trinity Bay

Galveston Bay

Gulf of Mexico

1

2

3

Water bodies
Buffalo Bayou
Highway loops
Highway
Primary roads

1 Downtown
2 Inner Loop
3 Outer Loop

0 1 2 10 km
0 1 2 5 mi

N

Fig. 1 | General location of Houston with highway and bayou structures. Map by Google Maps (n.d.) edited by Van den Berg (2021).

1.1 Context

The city of Houston is located around 80 km (50 miles) inland from the Gulf of Mexico in Southeast Texas. With approximately 2,3 million inhabitants in 2019 (World Population Review, 2019), it is one of the largest and fastest growing cities in the U.S. Running through the heart of Houston, is the Buffalo Bayou, to which Houston owes her rich history, and economic and cultural relevance. It was between the two slow moving, tidal rivers (Buffalo Bayou and White Oak Bayou) that Houston was founded in 1836. Ever since its settlement there, Houston grew towards a railway distribution hub for local resources in the late 19th century (TCLF, n.d.). Yet the coastal town of Galveston was still the economic driver in this region due to its location at the coast of the Gulf of Mexico and its port (McComb, n.d.). However, this changed in the early 20th century when Galveston was completely destroyed by two catastrophic hurricanes. After those events, people began to look for a less exposed location for the port. And so financial resources, businesses and residents moved towards Houston. Together with the finalization of the Houston Shipping Channel in 1914 and the discovery of oil, Houston's path towards the massive city of today began (Greater Houston Partnership, n.d.).

So the Houston-Galveston area has a long and intense flooding history. This, together with its unusual approach towards city making (e.g. no zoning regulations) and unsustainable city development (e.g. endless urban sprawl), makes it an interesting and challenging research location. This widespread urban sprawl goes hand in hand with heavy car dependency. The large majority of people in Houston drive a car to work, with only 2% using public transit, and another 2% reaching their work by foot or bike (U.S. Census Bureau, 2017). Additionally, this urbanization has significant effects on local weather and climate (Landsberg, 1981). The most recent disaster in the minds of Houstonians is Hurricane Harvey in 2017, which caused almost 70 deaths, as well as severe damage to the built and natural environment. The costs of this physical damage reached a total of €104 billion ($125 billion) in damages. Generally, Houston deals with three types of floods:

1. Pluvial floods: occurs when intense rainfall creates a flood. It is not necessary to be close to any water bodies for this to happen.
2. Flash floods: occurs within minutes to hours after an extreme rain event or via a sudden release of water from a levee or dam.
3. Fluvial floods: occurs when the water level in a river rises because of rain fall and overflows onto the surrounding lands.

However, there were also some occurrences of storm surges in Houston, for example during Hurricane Ike in 2008.

Since the early 20th century, water and land use experts have advised the City of Houston to better use its extensive bayou system (Hersey, 2014). The bayou corridors serve a vital role in providing water amenities and natural spaces, and improving the quality of life. However, these warnings have been ignored for a century; only recently the hydrological value of the bayou system and its ecological significance has emerged as an important urban planning tool (Hersey, 2014). The greater Houston area contains prairie uplands, piney woods, coastal wetlands and bays, and waterways that all host a rich mix of flora and fauna (White & Hupp, 2014). And the bayous' riparian corridors are the ones that provide connections between all these unique habitats, maintain the water quality, buffer flood risk potential, provide nurseries for fish, control erosion and support recreational pursuits (White & Hupp, 2014). Therefore it is important for the owners and managers of property alongside the bayous to realize that cooperation is crucial in order to preserve and restore nature, as well as our connection to it. Everything we are, have, and see has its roots in nature. The water that runs through the bayous and through our bodies, is all a part of the same nature, which connects us in ways both seen and unseen.



Fig. 2 | Buffalo Bayou with I-45 highway crossing (Kyoung Lee, 2014).

1.2 Problem Field

The problem field introduces the relevant fundamental boundary conditions, relating to socio-spatial, environmental, and ecosystem issues.

1. Increasing climate extremes

Human-induced climate change has increased the number and strength of extreme weather events all over the globe, resulting in heatwaves, drought, heavy downpours, floods, hurricanes to occur more frequently and with higher intensity.

2. Urban floods

Over the years, more and more surfaces in cities were built over with impermeable surfaces, with little open soil that could be used for water storage. The lack of appropriate drainage in combination with increasing high-intensity precipitation causes urban flooding. In order to mitigate these severe effects of climate change, urban environments are forced to adapt.

3. Rapid urbanization

The increasing need for city expansion causes unsustainable urban development. Especially American cities are prone to experience excessive, low density, urban sprawl, which results in a large amount of impermeable, paved-over surfaces (e.g. concrete, asphalt) which disallows the infiltration of rainwater.

4. Loss of connection with nature

Fewer people in the western world have daily contact with nature, and the social consequences of this loss of interaction with nature include a deterioration of public health and well-being, a reduced emotional affinity toward nature, and a decline in pro-environmental attitudes, causing a cycle of disaffection toward nature. Yet there is the possibility of integrating native ecology with critical stormwater management and mitigation measures.

5. Social unacceptance

The concerted effort to discredit the scientific consensus over man-made global warming has been continuing for two decades in the U.S., and shows no sign of weakening (Collomb, 2014). According to Collomb (2014), three factors have been strongly blocking climate action in the U.S.: First, fossil fuel industries short-term economic interests hinder governmental regulations on their activities. Second, climate denial stems from the strong ideological opposition to regulation. Third, there is a high level of commitment to the American way of life, defined by high consumption and ever-expanding material prosperity.

6. Poor accessibility; dependency on cars

Many American cities are mainly reliant on cars for transportation, making access to a car practically a prerequisite to securing employment. This results in sprawling cities designed for car-users.

In Houston, these problems appear in the following ways:

1. Increasing high-intensity precipitation

Over the past decades the precipitation in Houston has increased significantly (see fig. 4). The daily as well as five-day rainfall intensities have increased; this is a key factor of urban flooding in Houston, and in the next decades this is expected to increase even more (Carter et al., 2014).

2. Urban floods

An outdated drainage system, in combination with a location that is prone to extreme storms and hurricanes makes Houston vulnerable to urban floodings. Creating synergies between urban and ecological systems is up to now lacking in urban planning strategies in Houston.

3. Rapid urbanization

Houston, as a city with aggressive urban sprawl, consists mostly of low density suburbs. The built environment of Houston is quite homogeneous and contains high amounts of impermeable surfaces, which makes it difficult to successfully deal with flooding.

4. Loss of connection with nature:

In Houston, this problem is quite extreme, as nature is often seen as an obstacle for modern development.

5. Social unacceptance

Houston, being a Texan oil town that strongly values freedom and material prosperity, includes all three factors Collomb (2014) listed as being largely responsible for blocking climate action. This social unacceptance of global warming, in combination with a loss of connection with nature, makes Houston a difficult city to convince to embrace high environmental standards.

6. Poor accessibility; dependency on cars

Like many American cities, Houston is mainly reliant on cars for transportation. Three main Houston job centers are Downtown, the Texas Medical Center (TMC) and Uptown (business district). Houston's job centers are in need of a better connection to the regional transportation network. Currently, the frequency of this service is quite low in most parts of the system, which, together with the fact that Houston is rather spread out geographically and therefore of relatively low density and designed for car-users, is not ideal

Additionally, Houston is affected by these problems:

7. Unsustainable planning approach

The approach towards planning in Houston is part of the reason why it is so hard to stimulate an ecosystem resilient approach in the city. Without a paradigm shift, it is going to be difficult to create effective multi-scale changes that have a positive impact on the natural systems of the city. Flood adaptation solutions need to be approached from the bigger system, with different actors involved, to have a positive result. Processes of urbanization and climate change require Houston to consider the sustainability of urban land use in their planning approaches.

8. Negligence of the Buffalo Bayou

The urban river corridor of the Buffalo Bayou has become a largely neglected, forgotten part of the city. The river is home to a web of Interstate Highway overpasses and long forgotten railroad bridges. It also stores waste products of industry in its proximity in the eastern part (close to the Houston Ship Channel).

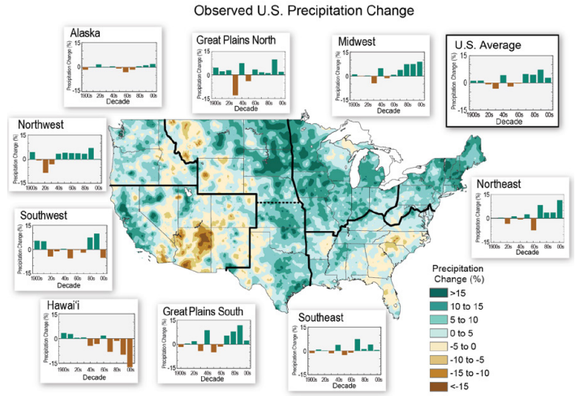


Fig. 3 | Observed precipitation changes in the United States (Melillo, Richmond, and Yohe, 2014).

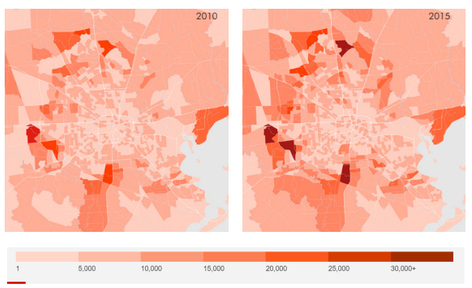


Fig. 4 | Houston's downtown population remains stable, but its suburbs continue to grow (US census, 2015).



Fig. 5 | Disconnection with nature: a neighborhood located inside the Buffalo Bayou riparian zone (Google Maps, 2015).



Fig. 6 | Inaccesible parts of the Buffalo Bayou. Spatial quality in the adjecent neighborhoods is low as well (Google Earth, n.d.).

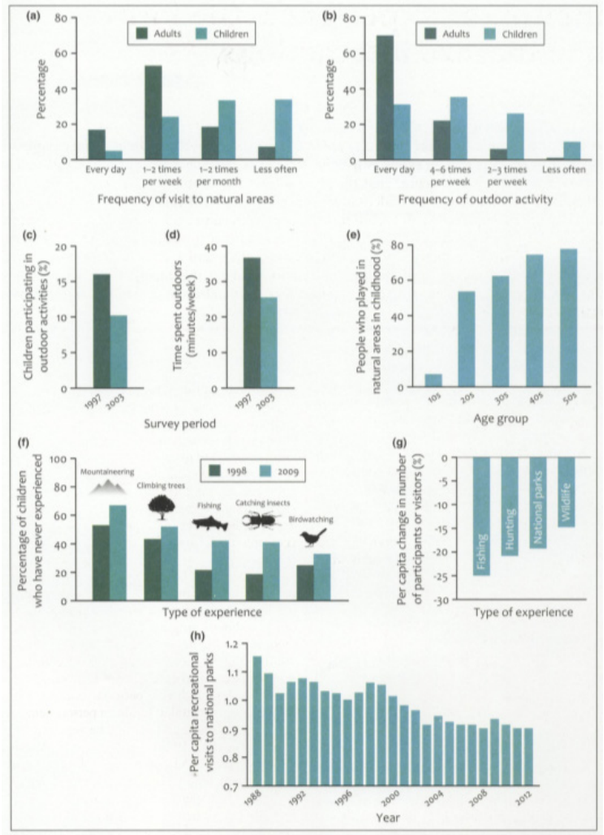


Fig. 7 | Childeren spend less time engaged with nature (Soga & Gaston, 2016).

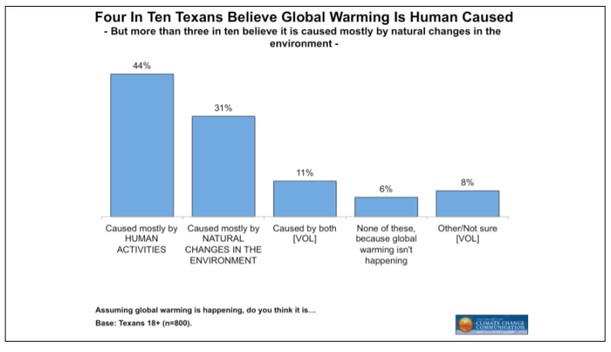


Fig. 8 | Climate Change in the Texan Mind (Yale, 2013).

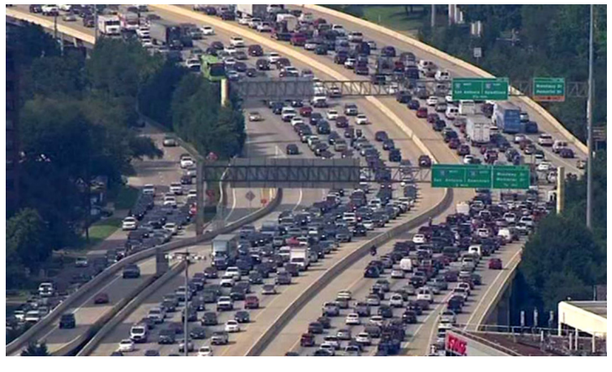
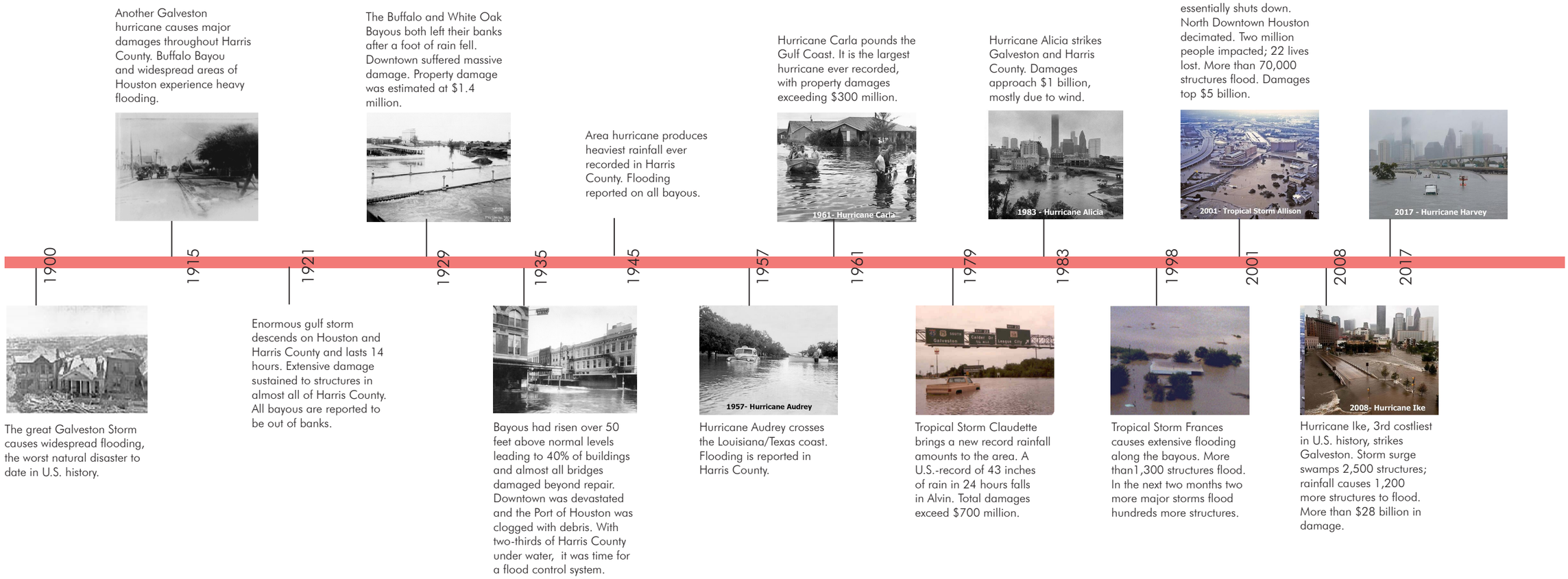


Fig. 9 | Congested highway in Houston (ABC13, 2018).



A History of Floods

Since Houston's settlement in the 1800s, it has faced many floods. People started draining the swamp land which increased the effects of floods (DTN, 2017). Additionally, Houston is prone to hurricanes and damaging storms, as is shown in fig. 11. This chronology is important for Houston's residents, because more hurricanes are predicted to strike Houston (and Texas) in the upcoming years and learning from what happened in past storms can help to prepare for the future. If the past is ignored, mistakes made in previous storms are likely to occur again.

In 2017 an unprecedented storm event hit Houston in the form of Hurricane Harvey. It lasted for 4 days in Houston (HCFCD, 2018). There were three main factors for Harveys destructive power:

- the immense amount of rainfall
- simultaneous rainfall within all watersheds
- the duration Harvey spent over Houston

Which resulted into:

- Over 80 deaths
- Around 37,000 people in need of rescue
- Over 155.000 flooded structures in Harris County

During Hurricane Harvey, the Addicks and Barker reservoirs failed and the surrounding houses located behind the reservoirs started to flood. To prevent even bigger damage, the US Army Corps decided to release water from the dams into Buffalo Bayou, which normally should be supported by the reservoirs. As a result of the unusually large amount of stormwater, many downstream areas, including Downtown Houston, flooded (Brusse, van der Doef, Jansen & Oostrum, 2017).

Fig. 10 | A Timeline of Floods in Houston.
Source images: (Reini, 2003) and (Roth, 2010).
Source information: HCFCD
Timeline: (Van den Berg, 2021).

Houston Underwater: A Tale As Old As Time, 1935

Texas Ave in Downtown



Fig. 12 | (Gonzales, 1935).

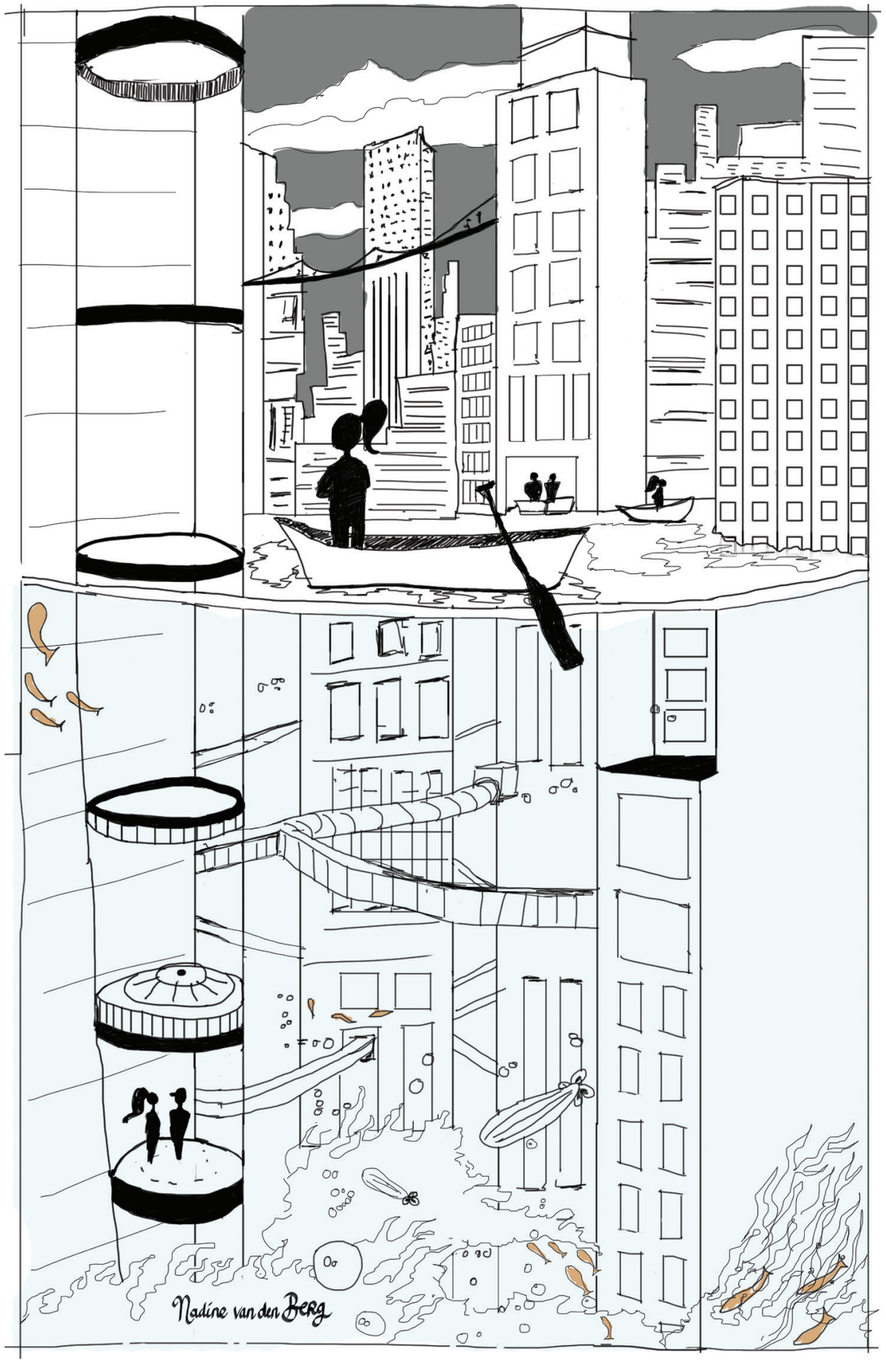
Houston Underwater: A Tale As Old As Time, 2015

Buffalo Bayou in Downtown

Fig. 12 | Travis and Milam St. in Downtown Houston 2015.

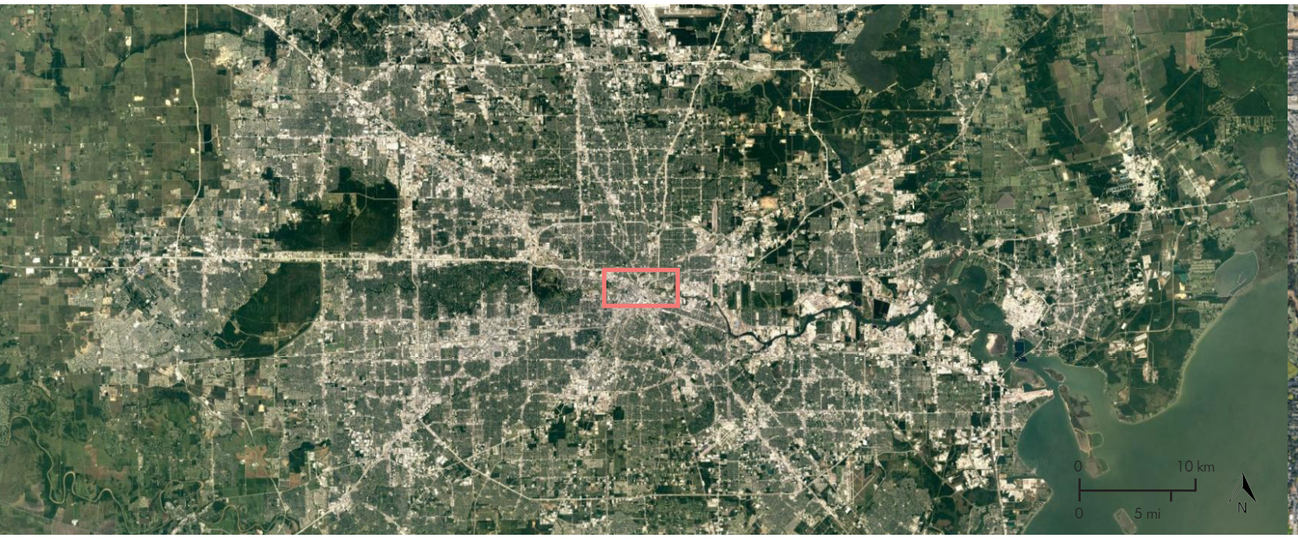
Houston Underwater: A Tale As Old As Time, 2120?

New Atlantis in Downtown



1.3 Location

Based on the previously mentioned problematizations, the Buffalo Bayou corridor in Downtown Houston is chosen as the project area 1.0 x 4.0 km (0.6 x 2.5 miles). A river is not a line, but an area shaped by river dynamics, and therefore it must also be defined from a spatial point of view (Forgaci, 2018). A river's natural corridor is a fundamental spatial condition and should be embedded in the development of the urban fabric. The outer boundary of an urban river corridor is the area accessible within a walking distance of approx. 500 m (0.3 miles), calculated from both edges of the river (Forgaci, 2018). The riparian zones are the interface between aquatic and terrestrial environments (Hansen et al., 2010). A minimum width of 100 m (328 ft) is required for riparian zones to protect flowing waters and to conserve biodiversity (Forgaci, 2018). Furthermore, these riparian zones need to be reconnected to ensure they are fully ecologically and physically functional (Hansen et al., 2010).



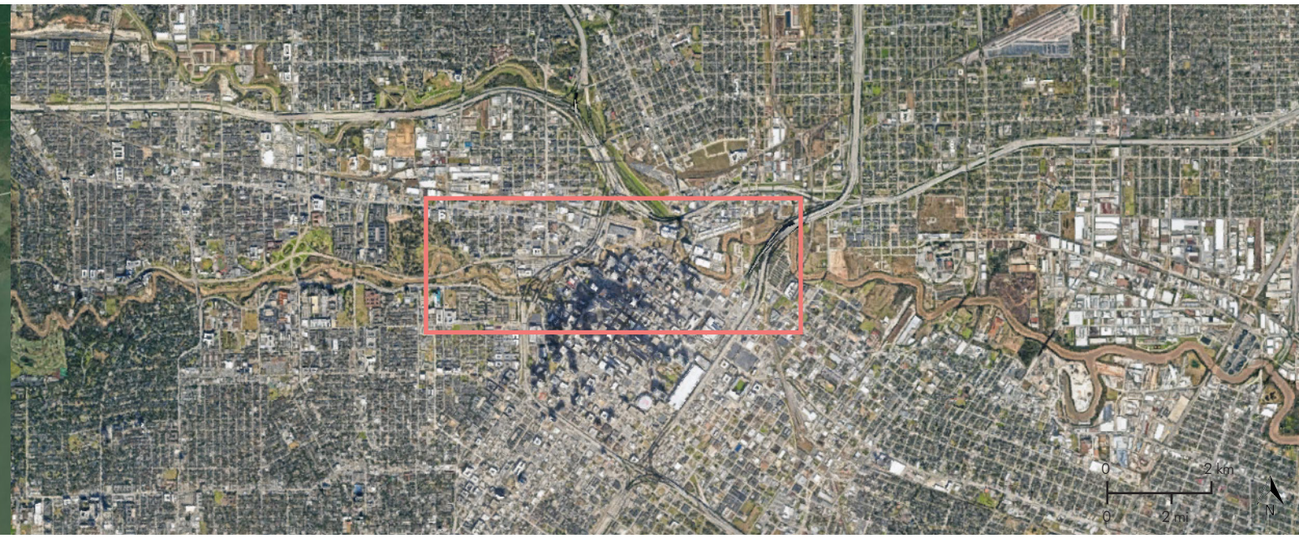


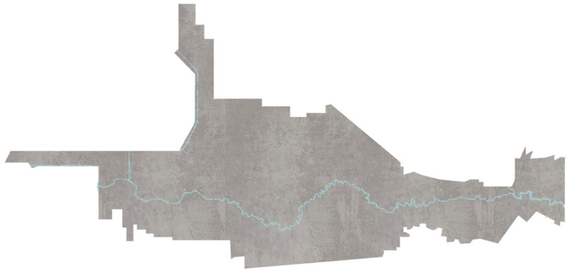


Fig. 14 | Project location on three scales (Google Earth, n.d.), edited by Van den Berg (2021).

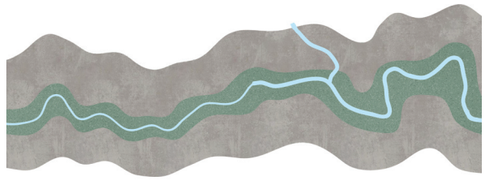
SCALES AND LAYERS



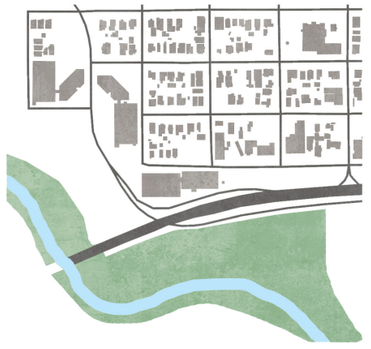
1| City of Houston



2| Buffalo Bayou watershed



3| Buffalo Bayou Downtown corridor



4| Neighborhood



5| Block

Applied Scales and Layers in Analysis
The top of this page displays the applied scales in the analysis of this chapter, from city scale to block scale.

Buildings (objects of architectural design) are the objects with which people can have direct sensory experiences. A building is different from a neighbourhood also in the sense that it can be seen (almost) as a whole from the outside. Neighborhoods, cities, and regions are of a larger scale where direction experience as whole is impossible, so their mental representation of these objects requires special efforts and skills to construct (Stolk, 2015).

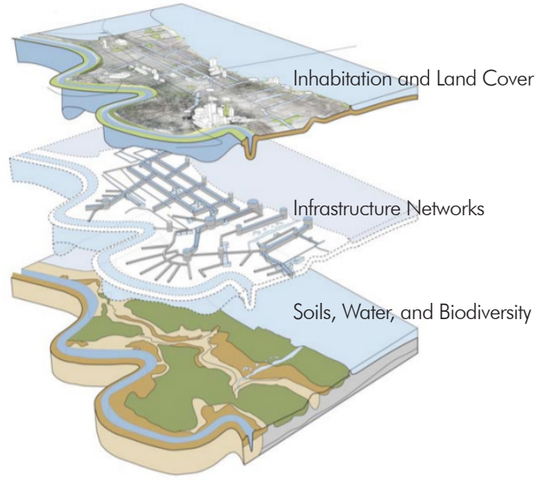


Fig. 15 | Planning layers (Waggoner & Ball Architects, 2013).

Managing the resources of the built environment, Fig. 15 outlines principles for urban design, regional planning and water management. This process considers 1.The area's soils, water, and biodiversity, 2.Existing infrastructure networks, and 3.The urban fabric.

1.4 NARRATIVE

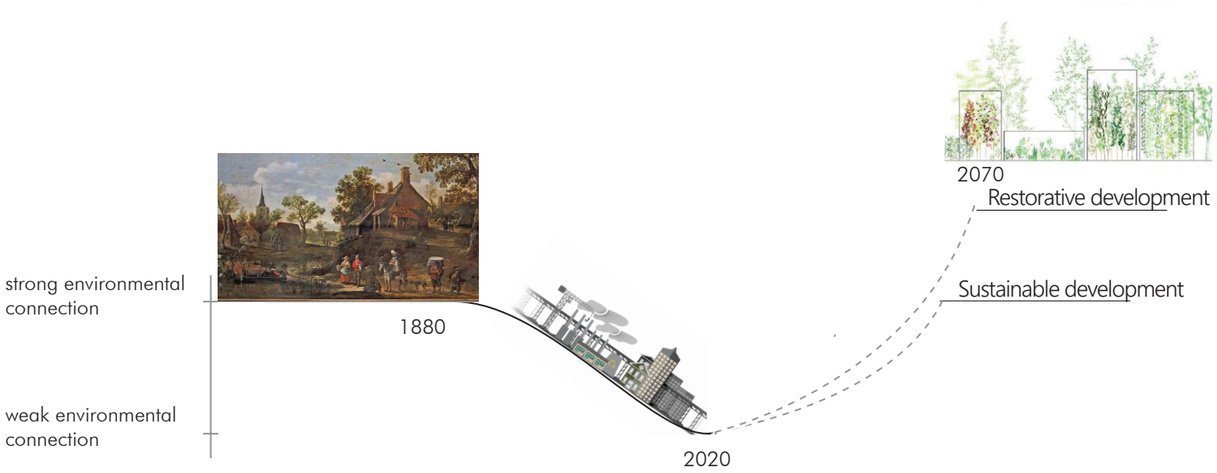


Fig. 16 | People's environmental connection through time (Van den Berg, 2021).

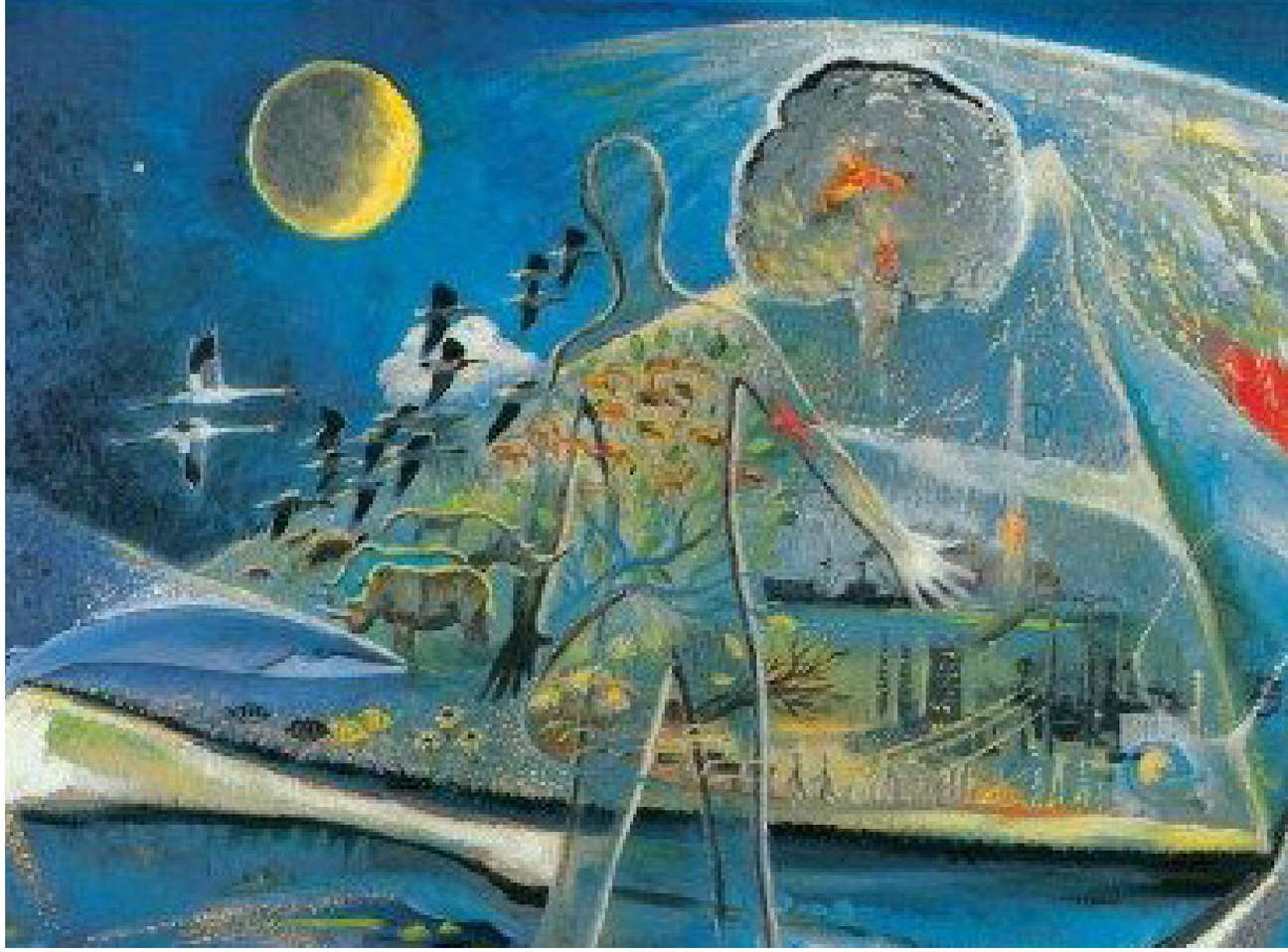


Fig. 17 | The Natural World of Man (Scott, 1961).

Our Natural World

In his painting 'The Natural World of Man' (Fig.17) Peter Scott comments on the dilemma faced by us humans in contemplating the advances of technology (on the right) and the consequent losses to ecosystems (on the left). The central person stands apart from the scene. This represents philosophies that regard the natural world as something to be controlled by humans in their own interests, but is also transparent and melds into the natural world. After all, humans are as dependent on the biosphere as all other creatures. The central person also holds their arms in a gesture of uncertainty, not quite knowing what to do about the problems that are being caused by unrestricted human activities.

One of the most renowned writers on regional planning using natural systems is the Scottisch landscape architect Ian McHarg. His 1969 book "Design with Nature" pioneered the concept of ecological planning. In this book, he set forth the basic concepts that were to develop later in Geographic Information Systems; it continues to be one of the most widely celebrated books on landscape architecture and land-use planning. McHarg relies on the functional narrative of urban ecology. McHarg and the urban designers that he has influenced seek to restore nature in urban space as a response to degradation of the original ecosystem upon which the city was built. Using the ecological inventory, this indigenous ecosystem is remembered and restored as functional green space amidst urban space. In this design with nature version, the restoration privileges native flora and fauna as the authentic nature to restore in the city. In doing so, a new narrative of urban nature emerged, focused on restoring ecological function to the damaged urban ecosystem by including nature in urban design.

A 'Design with Nature' approach also includes developing compact, complete communities; increasing transportation options; reducing the loads on water, waste and energy systems; protecting and restoring urban green space; striving for a lighter hydrologic footprint; and achieving higher levels of stream, wetland and lake protection. After formalizing a design practice that prioritized incorporating nature throughout the urban landscape and promoting landscape architecture as an instrument of environmentalism, McHarg insists that urban design should try to find rules in nature. Those rules emerged from scientific study of nature where ecologists provide commands, in addition to explanations. 1. It is based on scientific, mechanistic manipulation of nature for our own ends to produce green space. 2. Nature as a process. 3. Humans as the great disrupters.

Sustainable development is defined as "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs." in Our Common Future Report from the United Nations World Commission on Environment and Development in 1987. "From space, we see a small and fragile ball dominated not by human activity and edifice, but by a pattern of clouds, oceans, greenery, and soils. Humanity's inability to fit its activities into that pattern is changing planetary systems, fundamentally. Many such changes are accompanied by life-threatening hazards. This new reality, from which there is no escape, must be recognized and managed." Throughout time, people's connection with their environment changed significantly. Fig.16 shows this change in a timeline. While in Europe the industrial revolution started in 1760, this process started in Houston around 1880 (since the city was founded in 1836). By aiming for restorative development instead of sustainable development, the situation will be improved instead of being brought back to its previous state, which is not enough anymore. Sustainability has lost its meaning/purpose over the years. Instead, we should look at a situation and think about how we could make it better than when we found it through restorative development, which builds on the concepts of sustainable development, but goes further to incorporate a new paradigm of technology, science, and ethics.

2 Methodology

2.1 Project Outline
2.2 Methodological Framework
2.3 Theoretical Framework
2.4 Research Approach
2.5 Research Outcomes



Fig. 18 | Flood impacts on Houston (Max-o-matic, n.d.)

2.1 Project Outline

Problem Focus
Based on the issues relating to the problem field, the research field is narrowed down further with the knowledge gap, problem statement and research aim. The problem focus of this thesis is on increasing climate extremes, urban floodings, rapid urbanization, loss of connection with nature, and social unacceptance to improve the environment.

Knowledge gap
General Knowledge Gap
There are certain knowledge gaps between relevant disciplines that are capable of dealing with the aforementioned problems (think of urban planning and design, landscape architecture, architecture, water management etc.) that this thesis addresses through a multidisciplinary approach in order to strengthen the positive impact of each individual discipline. Furthermore, the mindset that dominates large parts of the Western world is that natural resources should be controlled by engineering resources. This is a result of human divergence from the natural world, caused by technological advances in the past centuries. This thesis addresses the error of the past attempts to try and dominate nature, and explores how our modern ways of living could benefit from a stronger reconnection to nature.

Houston's Knowledge Gap
This thesis addresses the limitations of the currently used interventions in the built environment of Houston in regards to the effects of heavy rains and destructive storms that hit the city. Houston's current approach of dealing with these floods caused by extreme weather is to repair damage afterwards, while not enough is being done to prevent these floods in the first place. By integrating spatial strategies and urban design with ecological engineering elements and so, Houston could benefit considerably in terms of adapting and recovering from recurring storm events.

Problem Statement
The disregard for the natural bayou water systems, extensive expansions of low density suburbs, lack of effective zoning system, and divergence from nature, increased Houston's vulnerability to climate extremes (such as increased peak rain events and extreme hurricanes). Houston's current approach towards these climate extremes is recovering instead of preventing. To make Houston's built environment more resilient to floods a paradigm shift is needed to change old habits and create new mindsets.

Research Aim
The ultimate aim of this thesis is to research how Houston could use an ecosystem resilient approach by integrating climate-sensitivity in human-oriented urban design, in order to improve flood resilience in Houston, specifically in the Buffalo Bayou corridor. The second aim is to redefine Houston's built environment and propose a set of planning and design interventions for the city of Houston that will (1) encourage an ecosystem resilient approach, (2) embed nature based flood solutions in respect to the local context, (3) restore people's relationship with nature.

Research Questions

MAIN RESEARCH QUESTION:
How can an ecosystem resilient approach guide the built environment in order to integrate climate-sensitivity in human-oriented urban design?

DOMAINS:
A= ecosystem resilient approach
B= climate sensitivity in built environment
C= human oriented urban design

A+B	*Sub1: What are the effects of nature based solutions on urban flood resilience in flood prone areas?*
A+C	*Sub2: How can the strengthening of people's relationship with nature through urban design function as an accelerator to improve the global environmental crisis?*
B+C *design perspective*	*Sub3: How can flood adaptation measures be consistently integrated within the built environment on multi-scale levels?*
B+C *planning perspective*	*Sub4: What are the effects of urban sprawl and permeability level on the performance of stormwater drainage systems in flood-prone areas specific to the U.S. context?*
Design Question	*Sub5: How could the redesign of the urban river corridor of the Buffalo Bayou function as a catalyst to decrease pluvial floods and increase the urban quality?*

2.2 Methodological Framework

2.2.1 Methodological Flowchart

In this methodological flowchart, the fundamental structure of this thesis is explained, as well as the main themes, research questions and sequence of research.

How Plans Work
In his book 'Urban Developments: The Logic of Making Plans' Hopkins (2001) discusses the different ways of how plans work through agenda, policy, vision, design, and strategy. An agenda lists actions and works by reminding and showing commitment; policies are if-then rules for actions and works by automating repeat decisions and fair circumstances; visions visualize what could be the outcome and works by motivating people to take actions they believe will give the imagined result; design describes fully worked out outcomes and works by showing fully worked out results of interdependent actions; strategies show contingent actions and work by determining which actions to take when and where.

Plans for urban development in this project include vision, design, and strategy aspects in order to figure out the substantive logic of a plan, and address the interdependence among actions; therefore they precede policies, which are means of framing the actions implied by the plan. This project takes shape as a sequence of design projects linked together by strategies about related decisions. Strategies fit in this situation where there are many interdependent actions under the authority of many different actors and occurring over a long time in relation to an uncertain environment. The crucial difference between design and strategy is the degree to which all decisions should or can be taken at once or only sequentially.

What are the effects of urban sprawl and permeability level on the performance of stormwater drainage systems in flood-prone areas specific to the U.S. context?

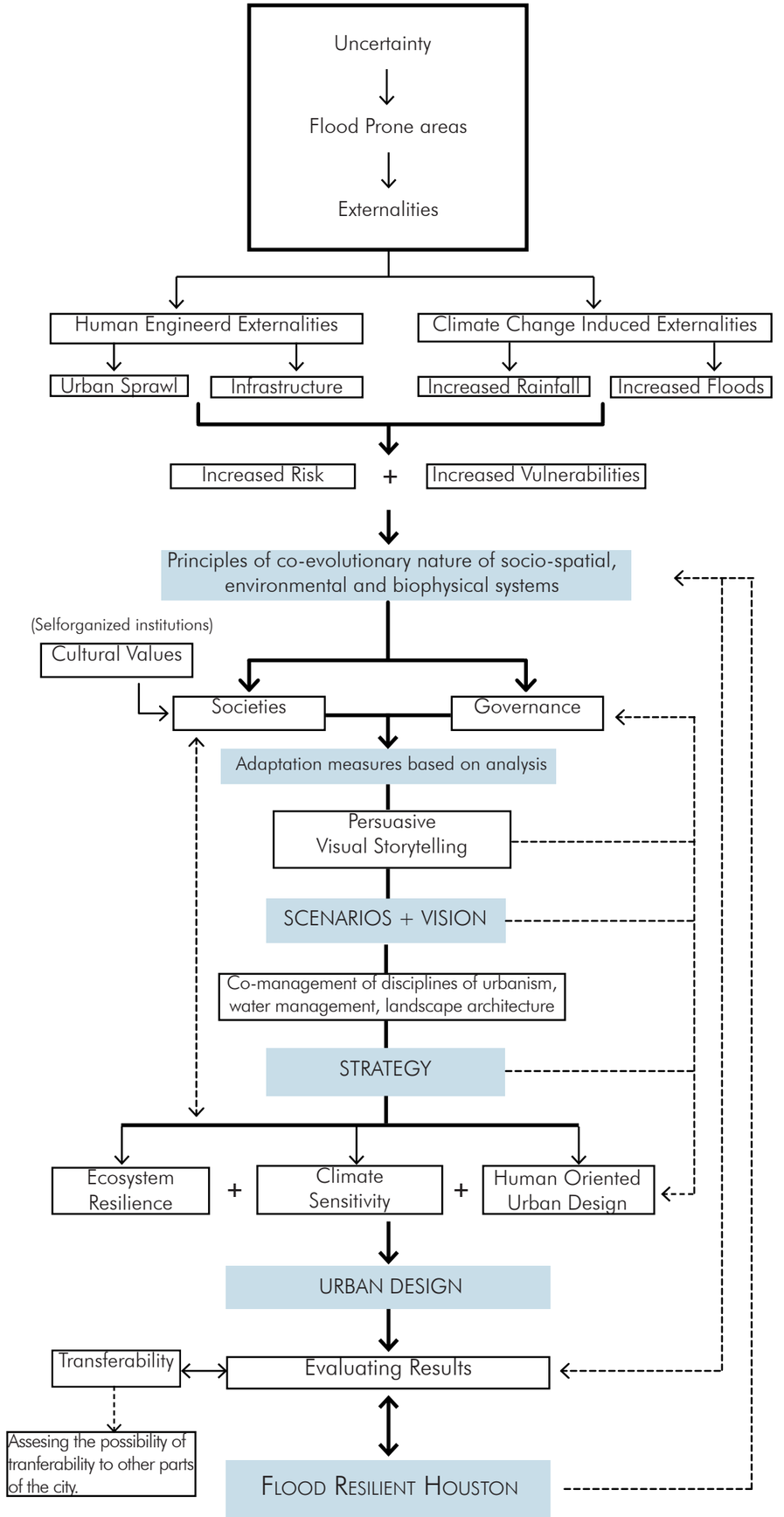
How can flood adaptation measures be consistently integrated within the built environment on multi-scale levels?

What are the effects of nature based solutions on urban flood resilience in flood prone areas?

How can the strengthening of people's relationship with nature through urban design function as an accelerator to improve the global environmental crisis?

How could the redesign of the urban river corridor of the Buffalo Bayou function as a catalyst to decrease pluvial floods and increase the urban quality?

Main research question:
How can an **ecosystem resilient approach** *guide the built environment in order to integrate* **climate-sensitivity** *in* **human-oriented urban design?**



2.2.2 Conceptual Framework

The conceptual framework explains the interrelations between the problem field, the research aim and the relevant theories involving climate resilience, ecological urbanism, and nature based solutions. It includes three different fields of the project: urban design, engineering and planning.

The three primary themes are climate sensitive urban design, ecosystem resilience, and governance. Climate sensitive urban design includes climate resilience, socio-spatial processes, as well as people's relationship to nature. Ecosystem resilience includes research on ecological urbanism, the local conditions of Houston's ecosystems, and flood adaptation measures. Governance refers to planning guidelines that could have beneficial effects of ecosystem en flood resilience in Houston, also in combination with implementing nature based solutions.

Synergies between these themes will be created through assessment, strategies and policies. These themes relate to the current shortcoming in Houston's approach and mindset towards their approach towards the natural environment as well as flooding, and combine into the aim of enabling a flood resilient Houston.

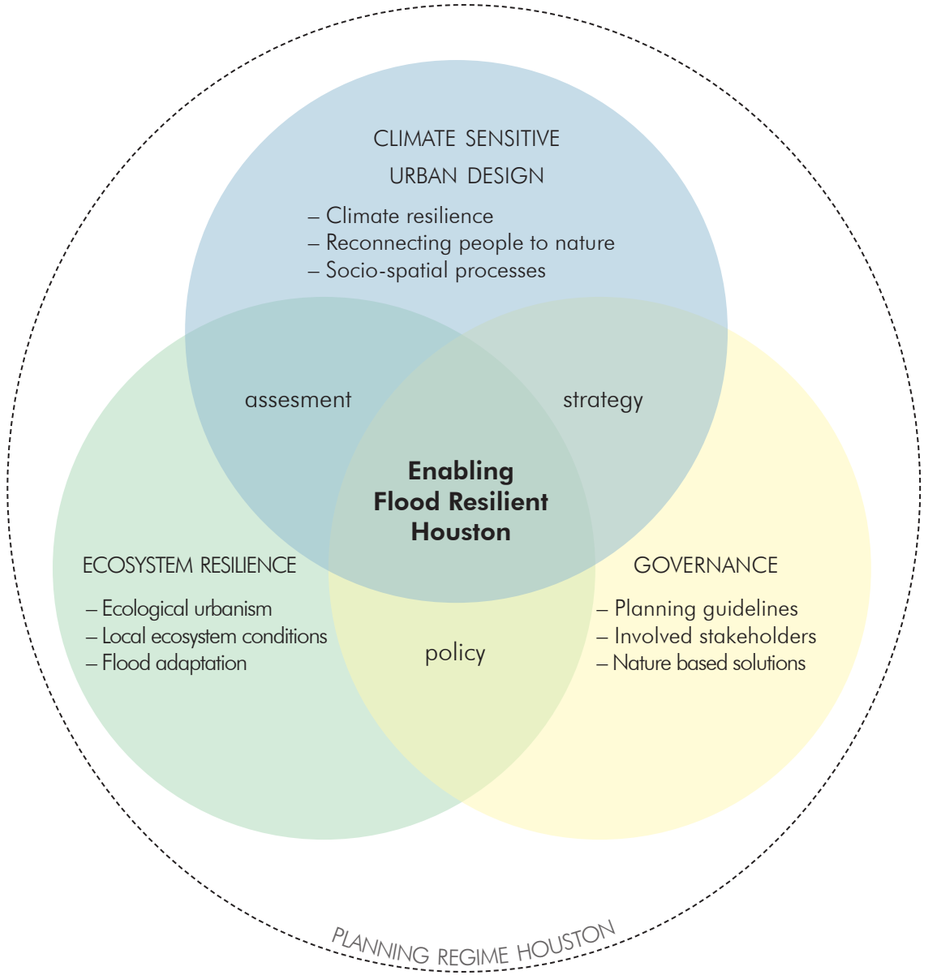




Fig. 19 | A sign outside a post office warns of high water to come (Ciaglo, 2016).

2.3 Theoretical Framework

The main research themes are interconnected with the theoretical framework. This paragraph will explain these themes, together with their relevant authors. For the supporting theoretical paper "Reconnecting with Nature: using urban river corridors to provide better flood resilience in Houston", see Appendix A.

Nature Based Solutions

This theme refers to research about the integration and performance of nature based solutions in urban environments. The book 'Green-blue grids' by Pötz (2016) explains the principles in the field of sustainable urban development and possible measures. These principles and measures relate to the water challenge, limiting urban heat, biodiversity, urban agriculture, sustainable energy production, air quality and quality of life. Many ecosystem services can be realized through these green-blue networks, for example water storage and biodiversity. It argues that we could allow nature to fulfill tasks that we traditionally leave to grey engineering and technology (think of water storage). By working together with nature, it becomes possible to truly improve the living environment.

Work by Nillesen (2018) discusses the urgency to develop integrated strategies and designs in which technical and spatial aspects are combined. By using research-by-design as a method, it is possible to explore the potential spatial impact and spatial economic opportunities that are associated with the necessary flood risk measures. Together with a multidisciplinary team, a designer's spatial implementation can become a selection criteria, leading to improved results compared to an approach where disciplines operate separately.

For adaptation measures relating to urban rivers, literature by Forgaci (2018) will be assessed. Forgaci (2018) defines urban river corridors as spaces where the interaction between the urban systems and the river system is the most intense. With an integrated spatial understanding, planning and design of rivers and the urban fabric surrounding them, cities could become more resilient to floods and other chronic stresses as well. This is relevant to Houston, because of the strong potential to combine social-ecological integration with human-oriented urban design in the urban environment.

Ecological Urbanism

In the book 'Ecological Urbanism' by Mostafavi & Doherty (2010) a range of disciplines are brought together (design practitioners and theorists, engineers, artists, environmental scientists etc.) in order to create an understanding of ecological urbanism. An ecological approach towards cities is urgently needed, and Mostafavi & Doherty (2010) argue that design could provide the synthetic key to connect ecology with an urban environment that is in harmony with the natural environment.

Additionally, in the book 'Design with Nature' (1963) McHarg presents us with a vision of a better world, established by ecology and ecological design, by addressing the importance of ecological principles in regional planning in order to establish a healthier relationship between the built environment and nature. He also discusses people's place in nature, and nature's place in people's lifes, including both physical sciences and humanities in the process. McHarg's emphasis on the integration of nature and the built environment is still valid. However, new challenges for ecological planning have arisen in the past decades, such as population growth, infrastructure needs, climate change, and social equity and environmental justice.

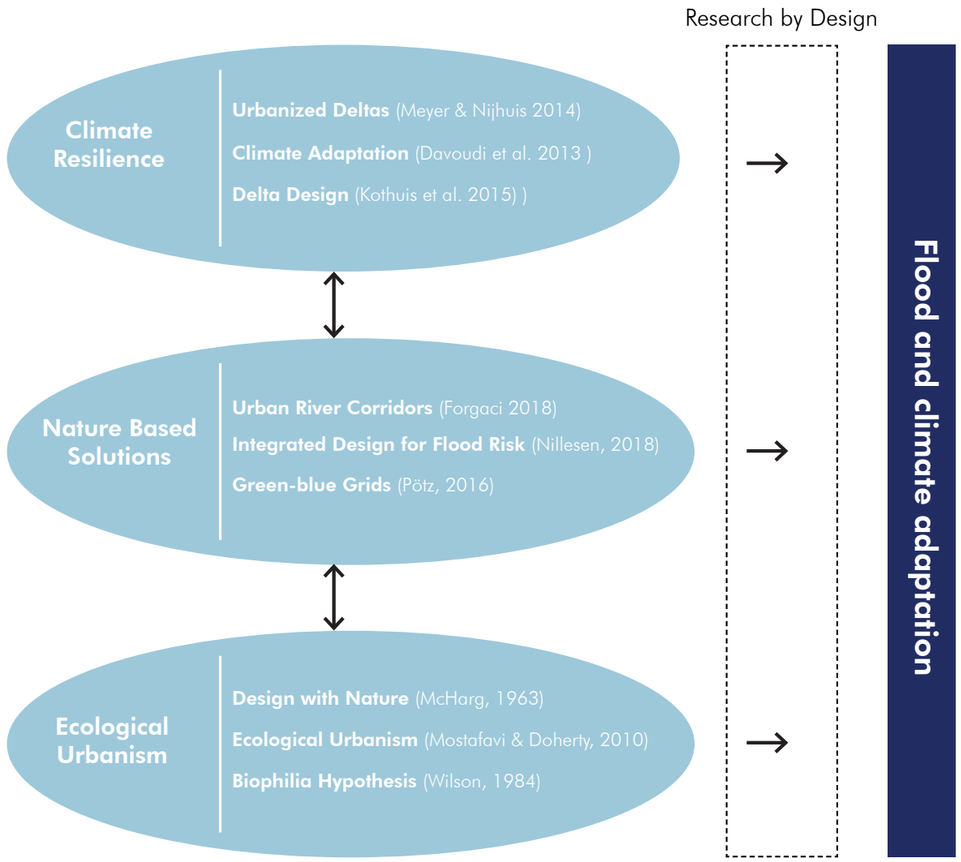
Moreover, Wilson (1984) in his book 'Biophilia Hypothesis' argues that a decline in biophilic behavior removes meaning from nature, and results in a loss of human respect for the natural world. Being exposed to natural features and environments increases our psychological well-being, and this reconnection to nature has the ability to cure a lot of social, governance and health ills. This is especially relevant for a city like Houston, where nature is mostly seen as an obstacle to cross.

Climate Resilience

Climate resilience refers to the ability to anticipate, prepare for, and respond to destructive events and trends relating to the climate. Improving climate resilience involves evaluation of new climate-related risks will occur in the future, as a result of climate change. Davoudi et al. (2013) discusses how persistence is viewed as the marker of resilience and more generally as the sign of a well-managed organization or network. This is in contrast with evolutionary resilience and its pursuit of building capacity for envisaging and embracing transformation through creativity and imagination at institutional, community and individual levels and through cultivating flexibility, resourcefulness and cooperative networks at various scales. Additionally, Davoudi et al. (2013) urge planners to consider when translating resilience from ecology to society what the politics of place are in order to shape the challenges we face. A consequence of a full engineering approach is its limited attention to social process, which diminishes resilience. The importance of people's memories, stories, networks, and cooperative relationships in building resilience can enhance it.

Moreover, works by Meyer & Nijhuis (2014) discuss how it would be possible to combine the attractiveness of an accessible urban waterfront for urban and economic development with a maximum of safety from the dangers of the same delta. Meyer & Nijhuis (2014) compare eight international deltas, including the Houston-Galveston area. In order to relate large-scale interventions with small-scale opportunities, communication and integration are necessary.

In the publication by Kothuis et al. (2015), researchers and students from TU Delft, Texas A&M, and Rice University investigate regional strategies for flood risk reduction and reflect on the research, design, and insight that was created from this collaboration, for example integrating natural functions, recreational elements. The different approach between the U.S. and the Netherlands in the journey towards climate resilience is discussed, and it touches upon the hurdles in changing U.S. flood policies, a consequence of the U.S. embracing a recovery-based approach to flood mitigation events; by contrast, a protection-based approach to flood mitigation like the one in the Netherlands. The combination of protecting communities from flooding while simultaneously enhancing natural coastal ecosystems.



2.4 Research Approach

Different methods are used at different points in the thesis. The table on the right explains which methods are used for what purpose. In the text below this is explained more in depth.

1. Literature Study: For gaining more knowledge about the domains of ecosystem resilience, climate sensitivity, and human-oriented urban design, as well as the socio-spatial and planning characteristics of Houston. Part of this is a theoretical paper on using urban river corridors to provide better flood resilience in Houston on page 42.

2. Interviews: Online interviews are conducted to understand the specifics of environmental, socio-spatial, and water management issues in Houston's context.

3. Mapping: In order to understand the spatial relation on relevant aspects of Houston's urban fabric, mapping is used. This way intervention opportunities are identified.

4. Scenario Making: Scenarios are used as a method to help us understand longer-term futures. In order to bridge the gap between research and design, visual storytelling techniques are used to apply scenarios on the site in order to come to a design.

5. Persuasive Visual Storytelling: This thesis explores the possibilities of using persuasive visual storytelling in the design process and develops techniques for effective use of it from the perspective of an urban designer. A more in depth explanation is given on p.50.

6. Research by Design: Design research is both the study of design and the process of knowledge production (see fig.18) that occurs through the act of design (Roggema, 2016). It also allows an expressive component in research, which in turn allows for the possibility of expressing qualitative aspects, experiments and proposals.

Analytical Framework

The analytical framework on page 48 explains the relations between the research questions and the proposed methods for this thesis.

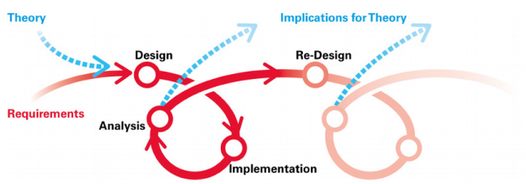


Fig. 20 | Research by design process (Fraefel, 2014).

	Method 1	Method 2	Method 3	Method 4	Method 5	Method 6
	Literature Study	Interviews	Mapping	Scenario Making	Persuasive Visual Storytelling	Research by Design
Main research question: How can an **ecosystem resilient approach** *guide the built environment in order to integrate* **climate-sensitivity** *in* **human-oriented urban design?**						
Sub1: How can flood adaptation measures be consistently integrated within the built environment on multi-scale levels?	●	●	●	●	●	●
Sub2: What are the effects of nature based solutions on urban flood resilience in flood prone areas?	●	●	●		●	●
Sub3: How can the strengthening of people's relationship with nature through urban design function as an accelerator to improve the global environmental crisis?	●			●	●	●
Sub4: What are the effects of urban sprawl and permeability level on the performance of stormwater drainage systems in flood-prone areas specific to the U.S. context?	●	●	●		●	
Sub5: How could the redesign of the urban river corridor of the Buffalo Bayou function as a catalyst to decrease pluvial floods and increase the urban quality?	●		●	●	●	●

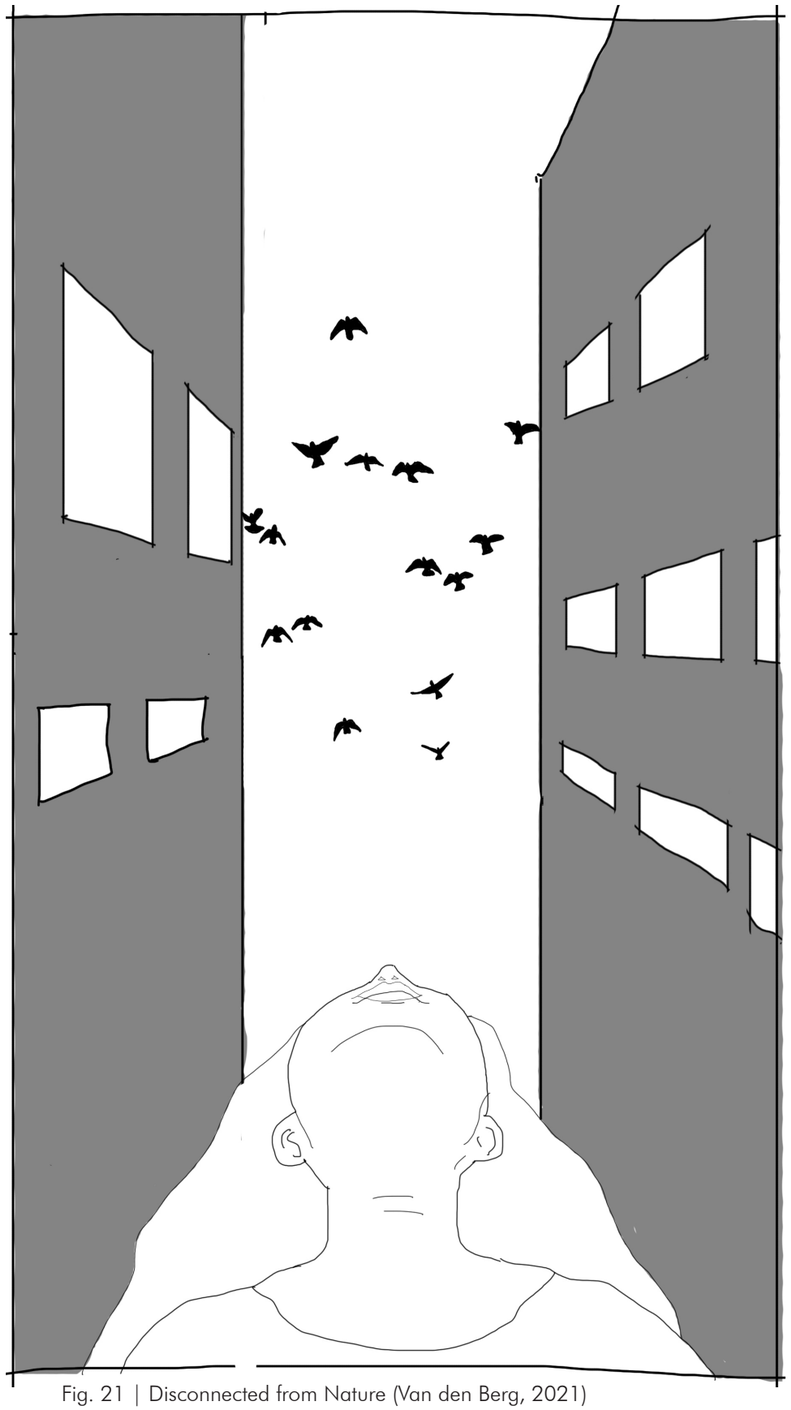


Fig. 21 | Disconnected from Nature (Van den Berg, 2021)

WHY STORIES MATTER

Storytelling is a key aspect of human nature and part of our social life. It is in our nature to need stories, because their logic is how we naturally think: nature shaped us to be ultra-social, and as a result of that humans tend to be sharply attentive to character and plot (Bhalla, 2013). The overarching similarities in many stories help us to process information, shape identity, and make connections; the strength of storytelling is that the narrative itself has a stronger logic and is likely to remain in people's memories much longer than any essential detail (Bruner, 1991). Even though storytelling is mostly implicit in urban planning and design proposals, (visual) stories can be used explicitly as research and design methodology.

VISUAL STORYTELLING

Additionally, visual storytelling in particular has the ability to produce thoughtful content and compelling visuals that will support your work and create a message that engages your audience. Vision is the most powerful of our senses; the old saying of 'a picture is worth a thousand words' is true. Being fluent in the language of images strengthens the ideas and plans; and by combining it with storytelling it is possible to motivate voluntary cooperation, increase empathy (Zak, 2014), both important for a successful planning process.

Visual storytelling has existed since humans have been living in caves and created drawings on walls (Parkes, 2020). From the Ice Age to the era of Instagram, the medium has changed, but the need to visually capture stories has not. Visual storytelling has the ability to display a history of the past, an identity for the present, and a story for the future to compare and appreciate (Wallace, 2007). Essentially, the built environment could be perceived as an ever-present, ever-changing form of visual storytelling: capturing history and telling a story through space.

IMPORTANCE FOR THE URBANISM COMMUNITY

This thesis uses the method of persuasive visual storytelling as a part of design research in which new futures are projected and ideas are provoked (see images on p.52-53). From a design perspective, the fundamental potentials and limitations of the design location are discovered. Additionally, the boundaries of reality are challenged by creating out of the box ideas. From a planner perspective, visual narrative systems could be applied to urban planning and design as powerful tools of communication, persuasion, and education to improve policymaking processes and to improve the communication of innovative policies and programmes to the public (Throgmorton, 1996). By adding a strong visual element to textual storytelling, it is possible to enhance urban planning engagement, because it takes away planning jargon, making effective communication possible between residents, planners, and other stakeholders.

In order to bridge the gap between research and design, this thesis uses visual storytelling as a research method, applying three specific scenarios on the project location in order to come to a design (see chapter 4). Using scenarios to determine the potential of a place allows us to think outside of the box, and by creating stories in this fictional space it becomes possible to explore various choices that lead to different effects. I studied these effects before deciding which elements I would like to apply in my own design. In addition to using visual storytelling for scenario purposes and a discovery tool, visual storytelling is also applied as method to capture the past, present, and future; to present the vision (see p.50).

To summarize, visual stories are universal, conveying meaning and purpose that help us understand ourselves better and find commonality with others. Urban planners and designers, as future-oriented storytellers, can use the valuable skill of visual storytelling as part of their design thinking, research by design, and creation of persuasive plans. By persuasive visual storytelling as part of design research, urban planners and designers are able to project new futures. On the one hand, to discover the potentials and limitations that are fundamental to the location, and on the other to envision how the boundaries of reality can be stretched, challenged and provoked.

THE POETICS OF SPACE

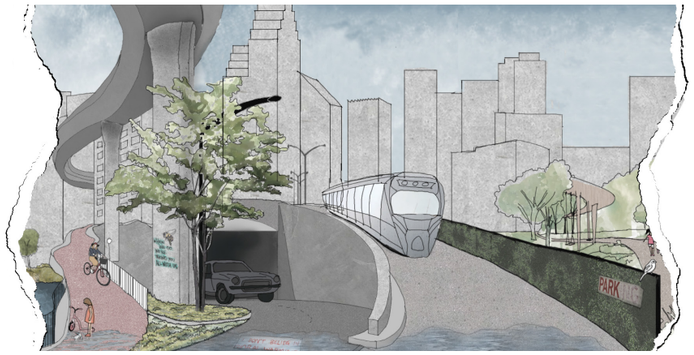
Drawing is a frame of the imagination, encouraging the gaze to move beyond the frame of the visible to the invisible, the probable to the improbable, an important part of the process of thinking about the urban fabric, the mental construction of the architecture as it evolves and develops. Drawing is a way to convey an impression of buildings and cities as they might be, from a hypothetical perspective, suggesting an exciting new world of people and activities, like a film set, to a set of details visualizing how the buildings or spaces within cities might be built (Farrelly, 2011). These interpretations can be quite fantastical and may suggest either surreal environments or a photo-realistic sense of place. Visual storytelling is largely about the art of suggestion (see fig. 24); drawings allow a child to imagine a place to play, a contractor to understand how to build, an engineer to develop their structural idea (Farrelly, 2011). Drawings will not explore every scale or aspect of the idea, but they will provide enough information to allow a glimpse into the possibilities for a scheme (Farrelly, 2011). In order to be a successful urban designer and planner, effective communication is crucial.

The poetics of space lies in the experience of it; the views, the movements, the ever changing surroundings. Reading lines by tracing, conversing with space in lines, and feeling a world created by lines form a line of inquiry that leads to the centre of design (Palmboom, 2017). The visual mode of working is defining the profession of urban designers and planners. Lines are designers' agents to represent, to give forms and to create narratives (see fig. 21).

THE USE OF VISUAL STORYTELLING IN THE DESIGN PROCESS

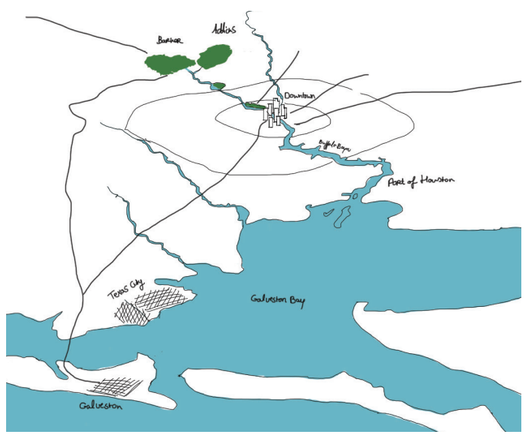
All images on spread by Van den Berg (2021).







INVESTIGATING SCENARIOS



SPATIAL ANALYSIS



EXPLAINING CONCEPTS



REFLECTING ON DESIGN IMPACTS



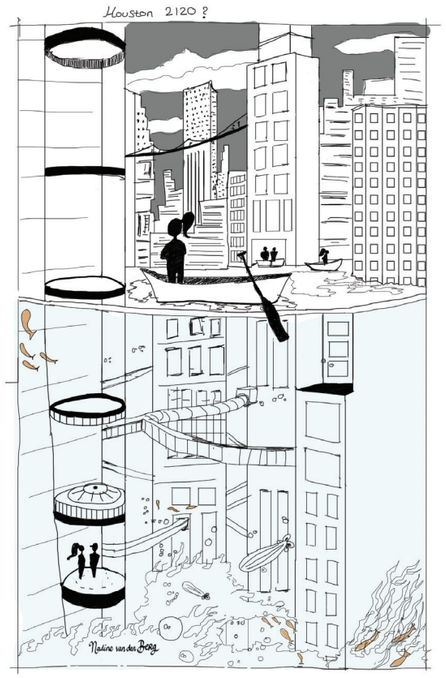
COMMUNICATING STEPS IN THE PROCESS



CAPTURING THE PAST,



....THE PRESENT,



... AND THE FUTURE

2.5 Research Outcomes

Product 1
An academic paper about using urban river corridors to provide better flood resilience in Houston.

Product 2
A journal article in Bnieuws, where I explain the use of scenarios and persuasive visual storytelling techniques in my thesis. Please see Bnieuws 54.03, p.19-21 on
www.issuu.com/bnieuws/docs/digital_space

Product 3
Spatial and technical analysis for the Buffalo Bayou corridor, with the main focus being the part of Buffalo Bayou that runs through Downtown Houston.

Product 4
Three scenarios for the Buffalo Bayou corridor in Downtown, that are developed by using possible future trends and exploring them through a sequence of drawings, and using persuasive visual storytelling to communicate to communicate the effects of these scenarios.

Product 5
Three scenario projections on different locations within the site to discover the potentials and limitations that are fundamental to the location, as well as to envision how the boundaries of reality can be stretched and challenged.

Product 6
A vision for the Buffalo Bayou corridor that includes socio-spatial, environmental, and technical elements on multiple scales.

Product 7
A set of planning guidelines for developing the proposed vision.

Product 8
A detailed urban design for the former post office site; this is a vulnerable part in the Buffalo Bayou corridor and is prone to flooding.

Product 9
A reflection on the relevance of the project, the used methodology, and possibilities of transferability.

Product 10
A series of drawings that explore how visual storytelling can be used as powerful tools of communication, persuasion, and education.



Fig. 22 | Biking alongside the Buffalo Bayou, underneath interstate highway (SWA Group, 2010).

3 ANALYSIS SYNTHESIS

3.1 Development
3.2 Infrastructure
3.3 Climate Conditions
3.4 Urbanized Landscape
3.5 Flood Susceptibility
3.6 Spatial Quality
3.7 Analysis Conclusions

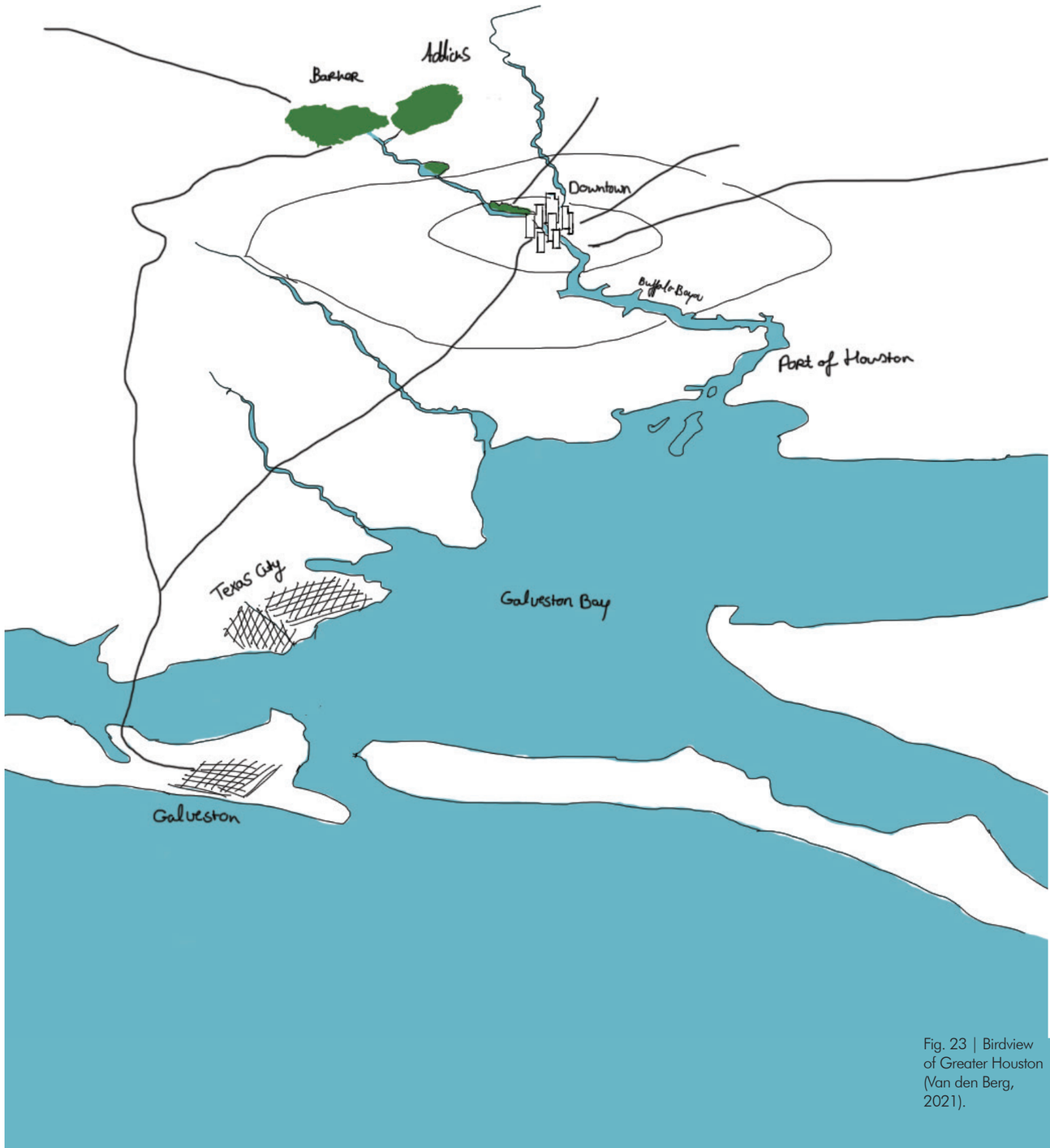
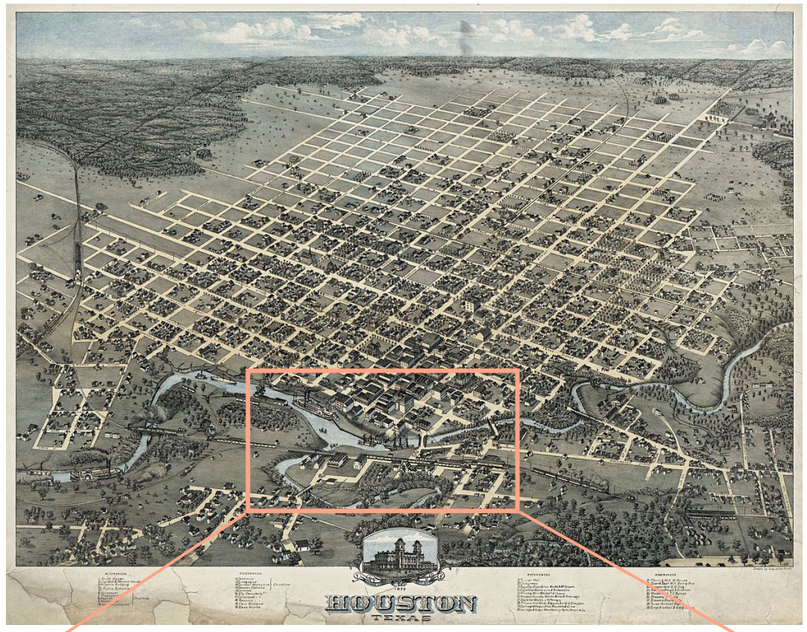


Fig. 23 | Birdview of Greater Houston (Van den Berg, 2021).

3.1 HOUSTON DEVELOPMENT



Fig. 24| Houston 1920s (University of Houston Digital Library, n.d.).



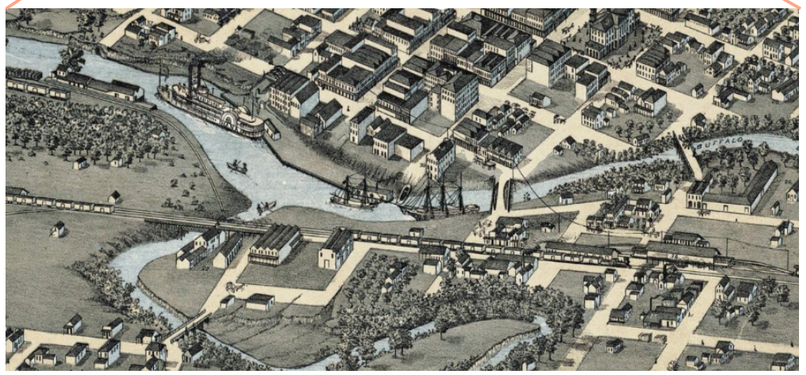


Fig. 25 | Houston in 1873, bird's eye view (Stoner, 1873).

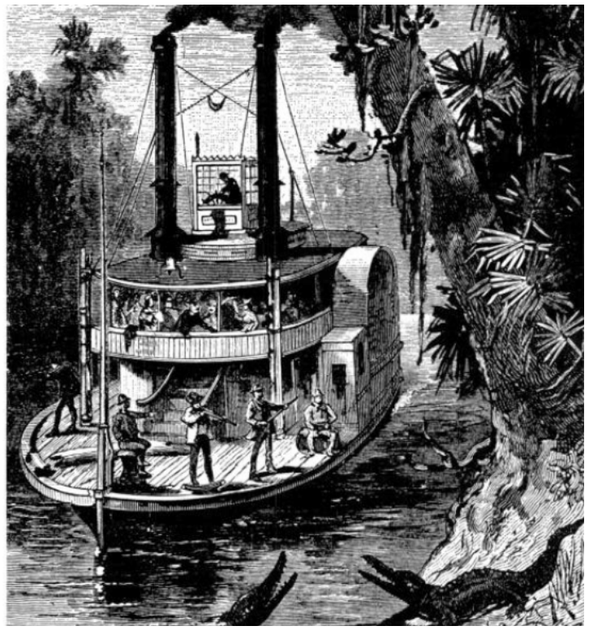


Fig. 26 | Buffalo Bayou in the early days (Farrar, 1926).



Fig. 27 | Allen's Landing as a commercial hub (Photograph, 1910).



Fig. 28 | Buffalo Bayou's unique and undisturbed riparian vegetation (Raphael Tuck & Sons, 1908).

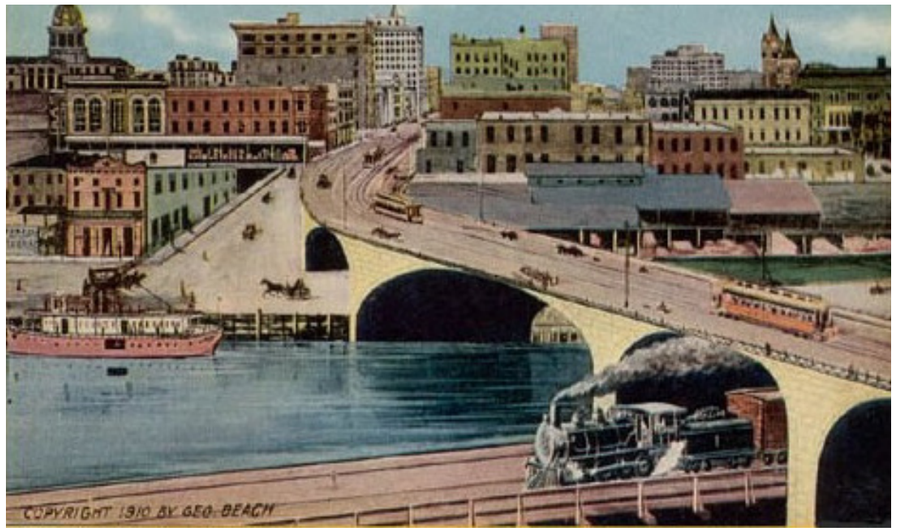
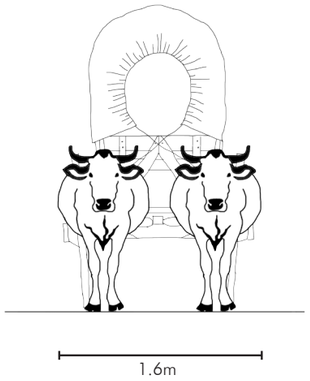


Fig. 29 | Main Street Viaduct and Ship Canal (Postcard, 1910).

The Story of Houston

The brothers Augustus and John Allen arrived in Galveston from New York in late 1831 when they were in their 20s. Soon they realized the commercial potential of the area surrounding the Buffalo Bayou. After they discovered that the Buffalo Bayou was navigable to a point further upstream, they decided that the confluence of the White Oak and Buffalo Bayou would make a good spot for a settlement. In August 1836 they purchased 6,000 acres of land on the southern bank of the murky, tree-lined Buffalo Bayou and announced the opening of their townsite, offering land sale at one dollar per acre. Praising Houston as the future "great interior commercial emporium of Texas", they advertised its merits, both real and anticipated, and often exaggerated in their descriptions. They named the town Houston in honor of Sam Houston: the man who had become the hero of the new republic by leading the Texian Army to victory at the Battle of San Jacinto, the decisive battle in Texas's war for independence against Mexico. The Republic of Texas became a sovereign state, and Sam Houston became Houston's first president.

In November 1836, the brothers Gail and Thomas Borden surveyed and mapped the original site, from Buffalo Bayou on the north to what is now Texas Avenue on the south. In order to accommodate cattle drivers, the Bordens plotted Texas Avenue (back then the southern border) to be 100 feet (30m) wide to fit 14 steers, and most other first streets to be 80 feet (24m) wide to fit 11 steers. These streets were quite overdimensioned for the size and population of the time, yet became very useful for the rapidly increasing trade in the future, and the introduction of the car. However, the city started to pave its street only in the 1890s.



The Allen brothers offered their new town as the capital of Texas, which was accepted. Faced with the enormous task of building a capital city from scratch, the Allen brothers began three major buildings projects: the capitol, the county courthouse and a long row of buildings divided into stores and stalls. The block designated by the Allens for the county courthouse is today, as in the past, occupied by that institution. When the new republic's congress arrived in Houston in April 1837, the capital was still incomplete, and only a few buildings had been erected, even though Houston was incorporated as a city with some 1.200 residents. However, it rapidly developed as a trade center for agricultural products, cotton, lumber and hides from the surrounding areas. Still, for some time to come, Buffalo Bayou constantly needed dredging, and railroads did not reach the town until the 1850s. In 1839 congress decided to move Texas' capital from Houston to Austin, citing heat, humidity, mosquitoes, and other discomforts that plagued the city as reasons to move. The Allen brothers never completed the planned government structures, and therefore the Congress Square remained unbuilt, becoming a convenient spot for farmers to sell their goods, calling it the Market Square, which still exists today.

Well into the 1840s, Houston looked like a frontier town, featuring characteristics of both the slower paced South and the wild West. In 1841, a city ordinance officially created the Port of Houston, at a time of economic crisis, hoping to improve the business atmosphere. In 1845, Texas became the 28th state of the United States. Soon after, the Mexican-American War broke out, and the increased traffic through the Port of Houston further contributed to the city's growth. Farther downstream, at the Gulf of Mexico, Galveston ranked as the largest and wealthiest city in Texas, as well as the largest port. Competition and rivalry between Galveston and Houston began in the 1840s, which characterized their relationship for the remainder of the 19th century. From the 1850s on, Houston emerged as the regional center of rail transportation and the cotton trade. Because Houston is prone to heavy rains that could wipe out carriage roads, dependable rail transportation was a key factor in its economy's development, boosting exports in wheat, cattle, rice and sugar. The slave trade, active in Houston until the 1860s, contributed significantly to the initial growth.

However, Houston's growth was not without its setbacks. Sporadic epidemics of cholera and yellow fever plagued Houston; the Buffalo Bayou overflowed its banks and caused the first major flood in the city in 1853; fires ravaged the central part of the city. But with a resiliency that became characteristic, Houston recovered again. By 1882 there were ten railway lines serving the city, and so Houston became one of the railway hubs in the South. The electric streetcar was introduced in 1891 and the automobile in 1897, bearing with them the spawning of industry and much of the growth of 20th century Houston. In 1900 Houston was a progressive, small city of 45,000 people. It was in this year that the Great Storm devastated Galveston; the violent hurricane destroyed most of what lay in its path. Over 5,000 people had died and many of the storm's survivors fled to Houston, which escaped the brunt of the storm, mainly suffering from property damage caused by the strong winds. Galveston's misfortune provided new growth in the Bayou City.

Soon after in 1901, the first great gusher of oil in Texas erupted, further ensuring Houston's role in replacing Galveston as the major Texas port. And so the beginning of the petrochemical age started that would change the course of Houston's history. By 1906, around 30 oil companies and 7 banks had opened offices in Houston, and the construction of the city's first "skyscrapers'' (8 stories high), began in Downtown. By the year 1929, the city's population exceeded 292,00, and at the same time around 100,000 motor vehicles were registered. World War II increased the



Fig. 30 | (upper right) Original Plan of Houston (1869). A reproduction of a map created by Gail Borden, who was commissioned by the city founders, the Allen brothers. The map shows how the city is 'hugging' the Buffalo Bayou (Library of Houston, 1869)

Fig. 31 | (left) Cart driven by cattle. Based on its dimension the first streets of Houston were designed (Van den Berg, 2021)

Fig. 32 | (lower right) Main Street between Congress and Preston in 1856, still showing many characteristic of a frontier town. (University of Houston Digital Library, 1856).

demand for petroleum; the petrochemical industry became a large scale development in Houston. The years after the war were characterized by enormous urban growth and prosperity in Houston. City engineers laid plans for the construction of radical arterials and the "loop" system of freeways. However, the planners underestimated the volume of traffic that the freeways were later expected to handle. Urban sprawl and transportation was already a problem in the 1950s. In order to alleviate them, the city dedicated the Gulf Freeway (I-45). However, Houstonians gave little support to the idea of improving the city's mass public transportation system, preferring instead the appropriation of funds for freeways, causing bus riderships to decline. In order to give pedestrians easy access to facilities, Houston created a system of privately constructed underground tunnels beneath Downtown. The main tunnel system is around 2.8 miles (4.5 km) in length and connects about 50 building and parking facilities.

In 1962, Houston became the center of the manned space exploration of NASA, receiving the nickname "Space City", causing an influx of both scientists and related industries from throughout the world to the city. International trade started to increase in the 1960s, and by the late 1970s tall skyscrapers began defining Houston's skyline, dramatically rising above the green, flat, expansive terrain. Builders and developers were among the busiest groups in Houston. In the following decades, commuters increasingly dominated Downtown. Houston's love affair with their cars resulted in the commercial strips and shopping centers alongside the loops, arteries and radials of the increasingly complex network of freeways.

Today, Houston is once again ready to reinvent itself as a great 21st century city. One of Houston's greatest traditions and competitive advantages is the willingness of citizens to pull together to overcome virtually any obstacle to create great results for their city. Houstonians are attracted to their city for many of the same reasons that influenced its founding fathers to settle in the area; opportunity, hope and freedom from restrictions are chief among them.

This text is based on information from the book "Houston: The City of Destiny" by Unibook (1980).



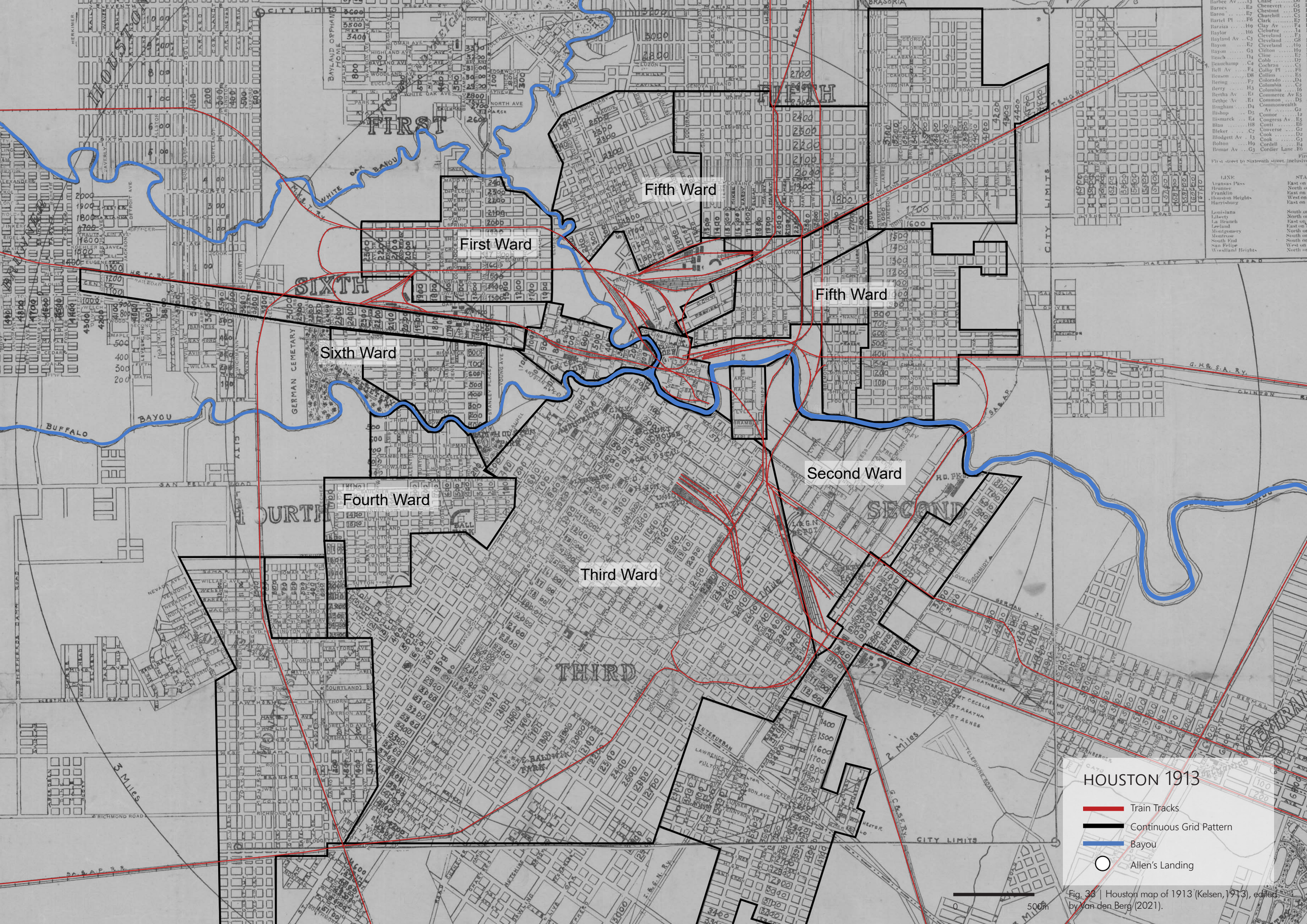


Fig. 33 | Houston map of 1913 (Kelsen,1913), edited by Van den Berg (2021).

The use of street grids emerged in multiple cultural contexts across the world throughout the course of history, long before it was implemented in the U.S. as a means of territorial organization, where the grid served as a means of disciplining mobility by structuring spatial interaction according to the logic of the perpendicular (Reps, 1965).

THOMAS JEFFERSON AND THE CHECKERBOARD PLAN

The vast majority of America's cities have a grid pattern that was first proposed by Thomas Jefferson shortly after the American Revolutionary War, when the federal government came into possession of large areas of land. This newly acquired land needed to be surveyed before it could be distributed and sold. Before this, people used to define property boundaries by local geography and topography. However, relying on natural topography to define properties has its flaws. Trees might disappear and rivers might shift course. Additionally, this was not an efficient approach for large regions. Therefore, Thomas Jefferson proposed the grid system, which was easier and logical to implement, and it allowed the government to plot and sell land to investors without them actually visiting the site. Jeffeson's plan was adopted in the Land Ordinance of 1785, and Jefferson became the third U.S. president two decades later.

Fast forward some 230 years and the gridiron plan stamped an identical brand of uniformity on American cities. From coast to coast: the rectilinear street system predominated. Cities with other types of plans always constituted a distinct minority. However, over time more and more people began to view these gridiron plans with distaste, because of their functional shortcomings, their lack of beauty, and their overwhelming monotony. Although new patterns have emerged in suburbs, the great grids of the central cities remain virtually unaltered, even under the impact of our growing modern redevelopment projects. Where at first the grid was seen as the most effective and certainly the quickest system for laying out towns, now the disadvantage of having no other features that serve to relieve its monotony with points of interest and beauty becomes clear.

URBAN PATTERNS

The urban grid in Houston played a formative role in urban development as an ultimate form in which the grids themselves act as structural units. The numbers of grids are running in different directions. Especially in suburbs after 1900 around water systems there is a softer, rounded pattern. The Jeffersonian Grid can be found in the early development of Downtown and its immediate surroundings.

Furthermore, the coming of the railroad opened a new era of city development and city planning in the U.S. Railroads affected the speed of city building, opened vast new areas for population growth, and resulted in hundreds of new towns laid out to take advantage of this more efficient means of transportation. The patterns of existing cities changed to accommodate the new stations, rail lines, yards, and shops required for railroad operation. Railroads, too, made the development of suburban communities for the well-to-do possible and thus began the phenomenon of urban sprawl which continues unabated to the present day (yet now stimulated by cars). The railroads and their sponsors influenced the laying out towns and promoting town development. The tracks will follow some of the patterns, but the development and road patterns follow the pattern of the top mode of transportation at the time. It is possible to tell the age of an area by whether the roads or development are parallel or perpendicular to a railroad or an interstate.

EARLY U.S. CITY PLANNING

Although initially supported by private sponsors, city planning rather quickly became a function of the local government. While many of the early plan commissions had little funds and still less power or authority and were created without any clear definition of their place in the hierarchy of local government, at least there was recognition that planning was an official duty of the city officials. With this development came efforts to control urban growth, including privately owned land. Zoning was first introduced in 1916 in New York. In response to the rise in interest in city planning and the growing demand for technical assistance in plan preparation, a new profession came into being. Specialized training in planning began at Harvard University, and there was growing recognition that city planning was an art or science which, although related to other disciplines, constituted a separate and increasingly complex field of endeavor (Reps, 1965).

(LACK OF) ZONING OF HOUSTON

In 1929 Hare & Hare planning consultants published a report on behalf of the Houston Planning Commission and the Houston Parks Commission with recommendations for appropriate city planning in Houston. The plan included the first proposed zoning ordinance for Houston. However, the zoning ordinance failed after heated opposition from the Houston Property Owners League and the Planning Commission was disbanded shortly afterward (City of Houston, 2010). In 1937 the Planning Commission was reconstituted again to investigate a zoning ordinance, but intense political opposition caused the City Council to withdraw the Commission's funding and so the second effort to enact zoning was abandoned. In 1940 the Department of City Planning was created by city ordinance and the Planning Commission was re-formed, but zoning implementation kept failing at citywide straw poll. Houston had mandatory development rules for the first time in 1982. Zoning failed for the fifth time at the citywide referendum in 1993. Throughout the following years many ordinances passed, for regulating things such as hazardous enterprises, hotels, and trees (City of Houston, 2010).

THE HOUSTONIAN GRID

Grid systems possess significant potentials for high density cities to meet future demands (Busquets, 2013). The examination of the history of the grid system offers valuable insights. The grid is a matrix for innovation within urban development, allowing the creation of sustainable compact cities and performative urban infrastructures, forming new networks and innovative city systems (Busquets, 2013). Houston is an example of an accumulative city, where different grids are developed in patches over time, causing different grids being juxtaposed over time. This type of grid layout has been applied frequently on cities throughout the U.S. Having separate and distinct sectors in which the grids have been added together to form a coherent, well organized whole (Busquets, 2013). The city of Houston in 1839 started to organize the city into four wards. By 1900 which extended 70-80 square miles along the Buffalo Bayou (Qian, 2008). From the patterns in the grid system it is easy to discern the different grid systems, which reflects back on the previous historical events in urbanisation. Apart from the linear grid, over time the outskirts of Houston started using a curvilinear loop pattern with cul-de-sacs, as well as conventional culs-de-sac pattern.

Fig. 36 depicts a polar histogram that shows how a city's streets are oriented. Each bar's direction represents the compass bearings of the streets and its length represents the relative frequency of the streets with those bearings. We can clearly see Houston's primarily orthogonal street grid, the small tilted rose in the middle depicts Houston's original North-East grid orientation of the 1830s grid. In contrast with Houston, Amsterdam's streets are more evenly distributed in every direction.

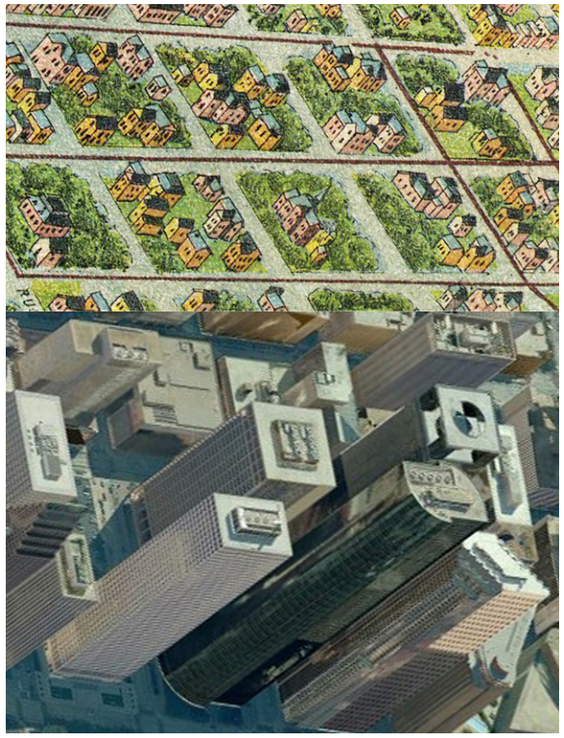


Fig. 34 | Houston usage of the grid in the 19th century (Library of Congress, 1891) and the 21st century (Google Earth, n.d.)

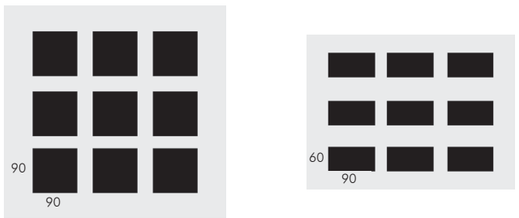


Fig. 35 | Dominant grids in project site; left is the Downtown grid, right the old sixth ward. Dimensions in meters (Van den Berg, 2021).

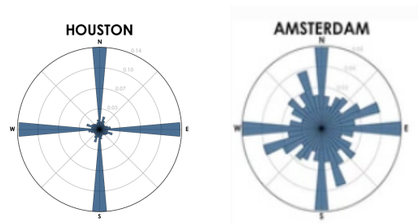


Fig. 36 | Polar histogram of Houston and Amsterdam, showing the city's street orientation (Boeing, 2019).

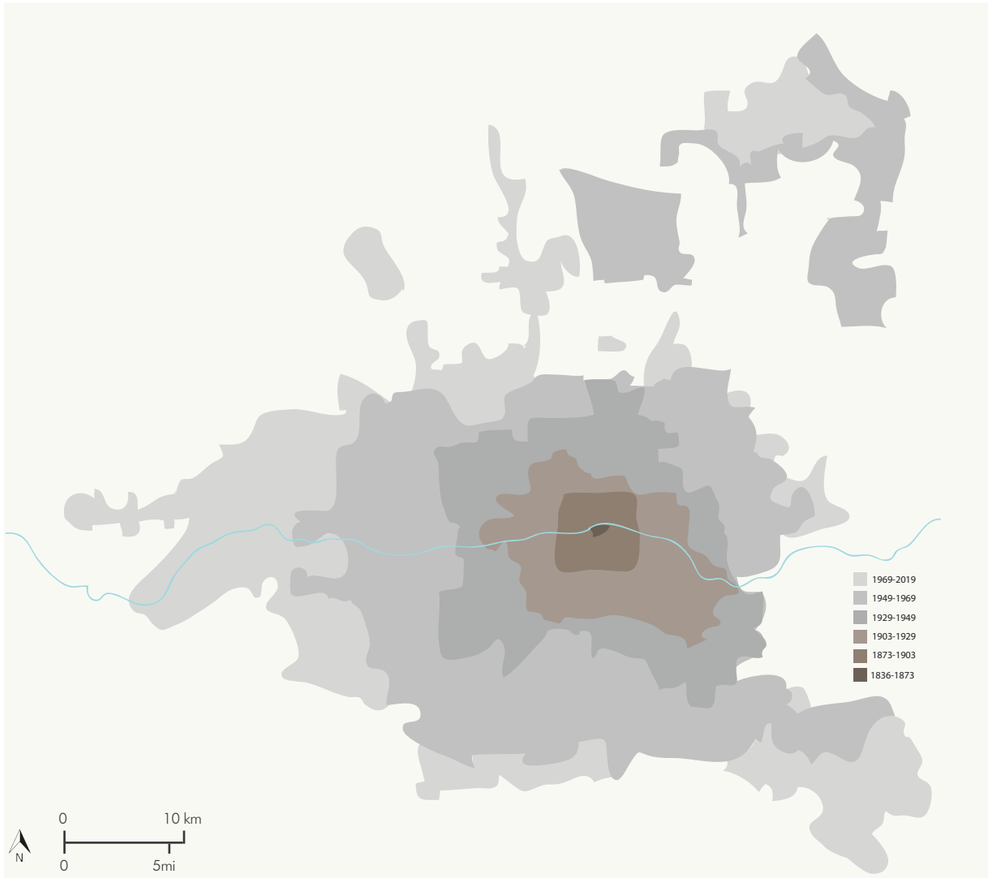


Fig. 37 | Houston through the years (Van den Berg, 2020).

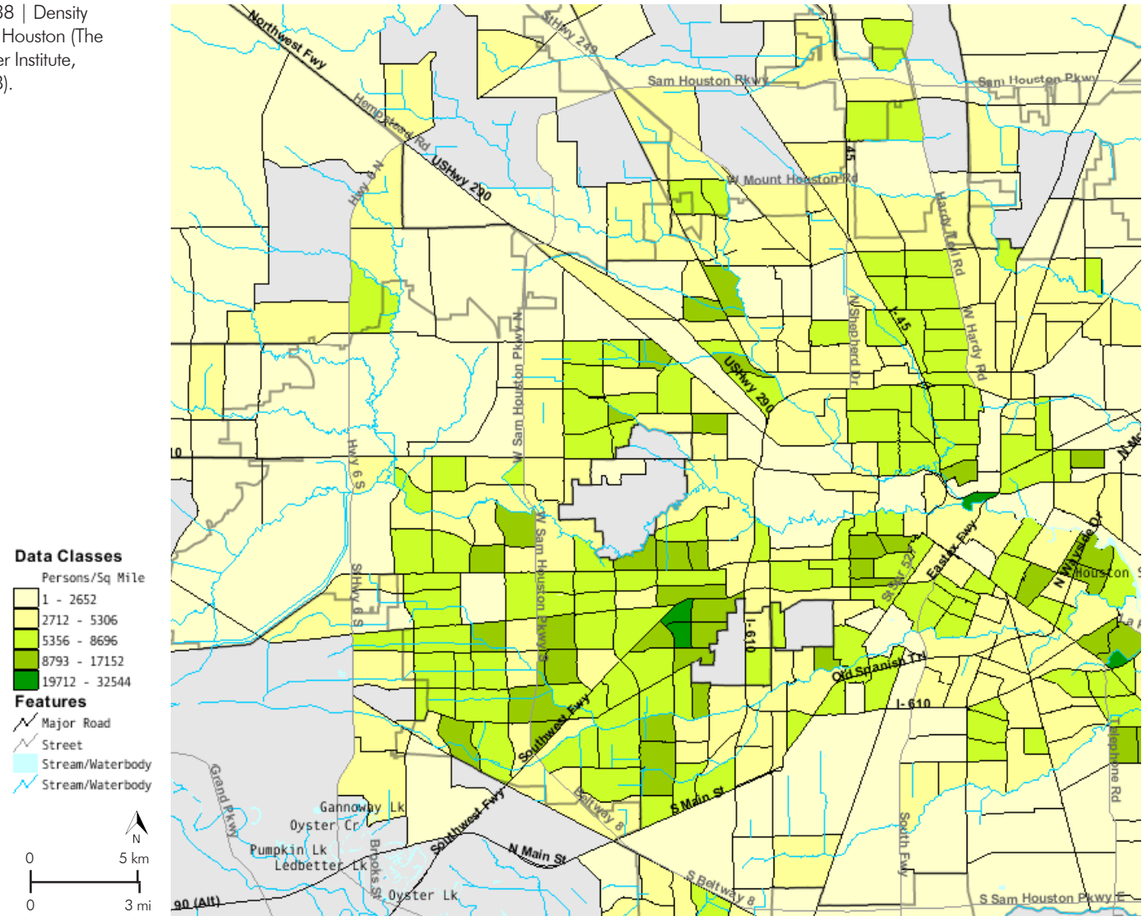


Fig. 38 | Density Map Houston (The Kinder Institute, 2018).

Houston's original 1836 city covered only 147 acres. In the next 170 years this expanded to a size of 620 square miles, partially through annexation of settlements outside city limits. The rapid development, together with the lack of proper zoning resulted in Houston being the only major city in the U.S. promoting fast urban dynamics, which are only regulated by municipal policies. This urban development depicts a traditional market philosophy where zoning would violate the value of the private property and personal freedom. The absence of zoning laws encouraged the enormous footprint of Houston as well as the phenomena of urbanism and sprawl (Qian, 2009). In turn this leads to unsuitable development in vulnerable areas; think of densification and the increase of impervious surface within floodplains and watersheds, which brings its own negative effects with it in relation to floods (Brody et al. 2008). The consequences of unregulated densification within the theme of draining water will be discussed in a later chapter.

Houstonians cling to many of their old outlooks and habits. The conservative majority displays a deep antipathy to a more activist government or higher taxes; they mostly want to be left alone by the government (Calvert, De Léon & Cantrell, 2014). Their libertarian attitude towards natural resources and the environment, that goes together with a persistent need to own their own land or own property (Fehrenbach, 1986), and are still present in Houston (Calvert, De Léon & Cantrell, 2014). This attitude also strongly influences their urban planning approach; Houston does not have any zoning laws for land use, and in most cases there are also no restrictions for density or height, which sometimes result in disruptive buildings being built next to homes or parks (Kinder Institute, 2020). Instead of governing land use, the city uses a complex system of codes that result in a more market-based approach to development (Kinder Institute, 2020).

While oil made Houston boom, a more complicated set of factors made it sprawl. Houston absorbed its surrounding areas through state annexation; it is cheaper for developers to build horizontally instead of vertically; and Houston faces few physical impediments such as rivers, lakes or mountains that are able to physically stop them. In short, land availability and cost (Governing, 2013). This urban sprawl is central to the wasteful use of water, energy, land, and time spent in traffic. Sprawl has been linked to increased air and water pollution; greenhouse gas emissions; loss of open space and natural habitat; floods; exponential increase in new infrastructure costs; social problems related to the lack of diversity; and health problems such as obesity because sprawl enforces auto-dependence. Historically, Houston has been viewed as "the most sprawling, least dense, most automobile-dependent major city in America." However, an annual survey in 2014 from the Kinder Institute for Urban Research showed that half the residents of Harris County would prefer to live in an area with mixed development, including homes, shops and restaurants as opposed to a single-family residential area (Kinder Institute Research, 2017).

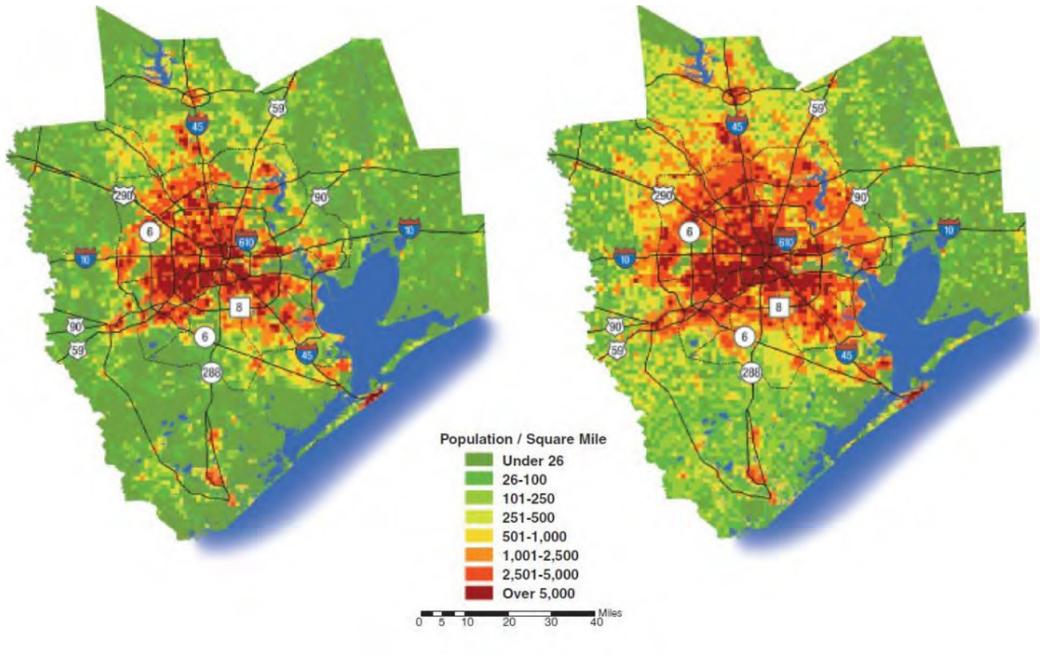


Fig. 39 | Population Growth Forecast 2005-2035 in Houston-Gaveston Area (Houston-Galveston Area Council, n.d.).

Means of Transportation to Work
City of Houston by Council Districts

PLANNING & DEVELOPMENT DEPARTMENT

Source: U.S. Census Bureau, 2013 American Community Survey
Date: October 2015

Council Districts	Total	Car, truck, or van:	Drove alone	Carpooled	In 2-person carpool	In 3-person carpool	In 4-or-more-person carpool	Public transportation (excluding taxicab)	Walked	Bicycle	Taxi Cab Motor Cycle or Other Means	Worked at home
A	109,010	97,999	82,408	15,591	11,110	2,753	1,818	3,144	2,769	471	1,652	2,975
B	79,026	68,628	58,250	10,378	7,749	1,780	940	5,020	711	100	3,210	1,358
C	114,263	97,329	89,294	8,035	6,656	926	544	3,973	3,340	1,886	1,447	6,287
D	84,838	73,527	65,227	8,300	6,615	1,129	647	5,004	2,039	684	1,316	2,269
E	125,978	116,199	102,804	13,394	10,900	1,602	983	2,074	1,669	347	1,644	4,045
F	92,420	83,280	71,254	12,026	8,858	2,459	800	4,244	1,113	177	551	3,055
G	98,668	88,321	82,653	5,668	4,812	755	192	2,434	1,837	97	441	5,538
H	65,405	55,580	46,212	9,368	6,404	1,800	1,255	3,823	2,011	375	2,156	1,459
I	71,723	63,011	50,611	12,400	8,926	1,648	1,918	2,810	2,237	353	1,964	1,348
J	70,506	57,420	40,907	16,514	8,637	4,825	3,143	5,818	2,440	277	2,402	2,149
K	87,516	78,136	66,890	11,246	7,275	2,310	1,752	4,628	821	231	1,205	2,495
City of Houston	999,353	879,431	756,510	122,920	87,943	21,986	13,991	42,972	20,986	4,997	17,988	32,979

Fig. 40 | Means of Transportation to Work (U.S. Census Bureau, 2013).

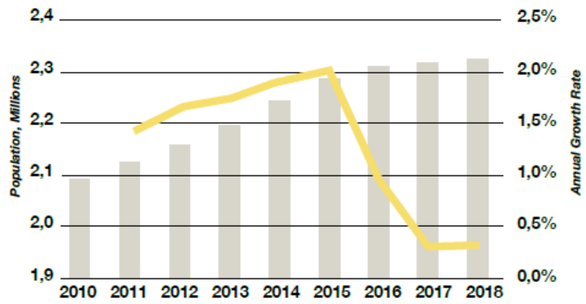


Fig. 41 | Houston's Population Development from 2010 to 2018 (Valliani, 2019).

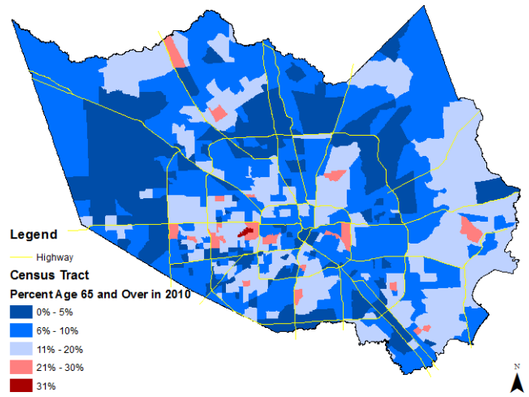


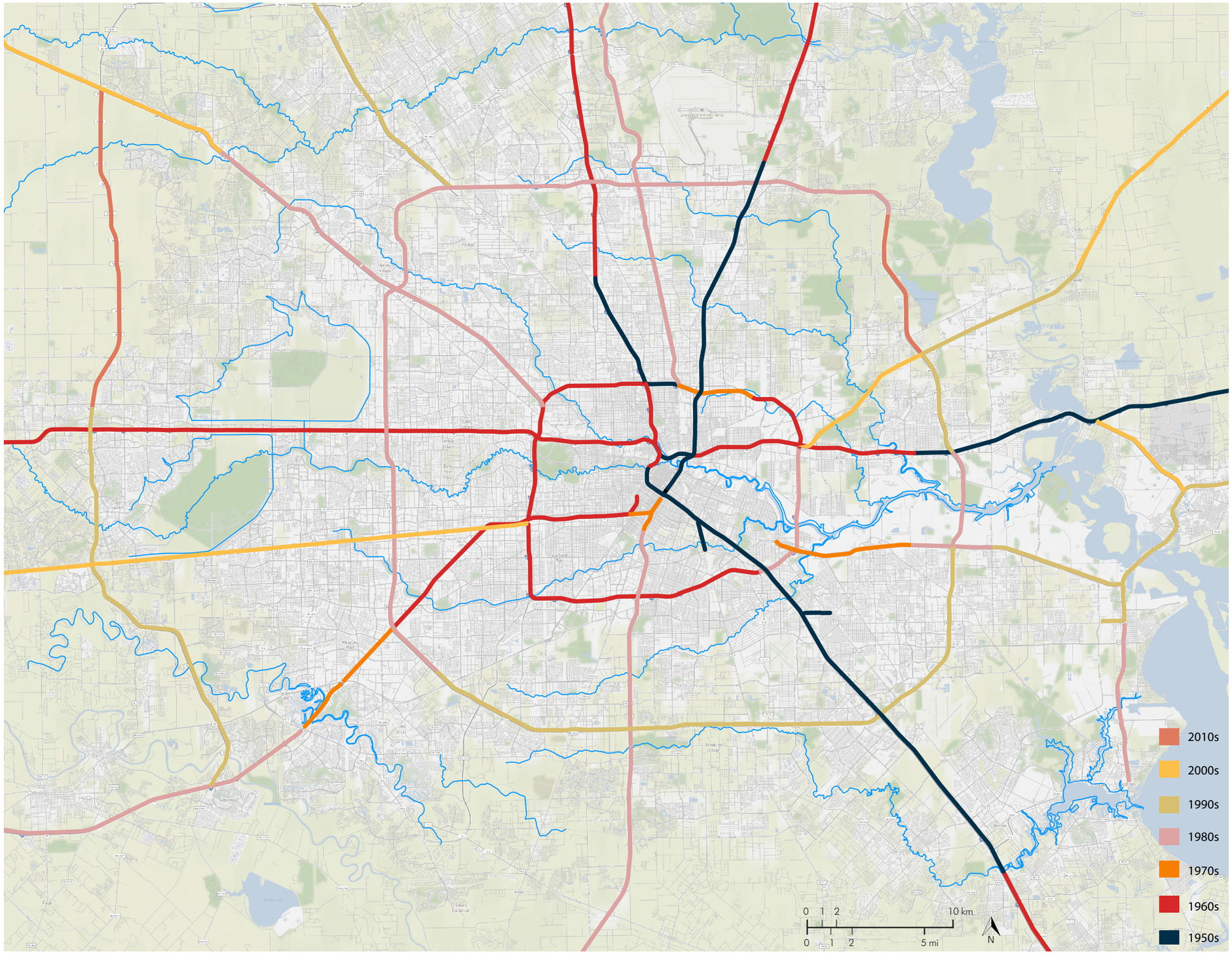
Fig. 42 | Age, Percentage 65 Years & Older in 2010 (Harris County, 2012).

According to Steve Murdock, Rice University Professor and former State Demographer, four key demographic elements are changing the U.S., Texas, and Houston: 1.The rate of population growth 2.The aging of the population 3.The growth in racial/ethnic minority populations 4.Changes in household composition. Murdock notes that the Texas of today is the U. S. of tomorrow, because the state has more than doubled its population within the span of a single lifetime (Harris County, 2012).

3.2 Infrastructure



Fig. 43 | Traffic creeps along Interstate 45 near Downtown Houston (Lee , 2017).



In the minds of many, Houston is a city defined by its highway map. Houston relies on this extensive network of highways to connect suburbs to employment centres (Houston Parks Boards, 2018). Houston is caught in an endless cycle of expanding roads, which encourages more people to drive, which produces more congestion, which is then again addressed by expanding roads. The main issue here is the way communities are designed: sprawling suburbs. The core purpose of transportation infrastructure is to provide access to to work, education, healthcare, recreation, etc. The map on the left shows this constant extension of the highway network in the past decades. This situation could be improved by focusing on connecting people to the necessary services. For example, focusing on making short trips safe to walk; including safe bike paths in the street profile; rewarding infill development to densify neighborhoods and offer community services nearby (Olin, 2020).

Much of this highway and suburb development has occurred with impunity to the natural systems underlying the Houston region (Houston Parks Boards, 2018). This network of highways has strangled the bayou system, and the native prairie grasslands suffered greatly from urban growth and have been almost completely destroyed; yet Houston's climate, soil, and topography remain conductive to this native prairie ecology. In addition to the environmental abilities like building soil, absorbing rainwater, capturing carbon, and trapping sediment, prairies are part of Houston's history and therefore have a cultural value as well: Houstonians deserve to know their own landscape.

Fig. 43 | Highway Development through the years. Map by Van den Berg (2021), based on data from Wittenberg, Chang & Kinder Institute for Urban Research (2018).

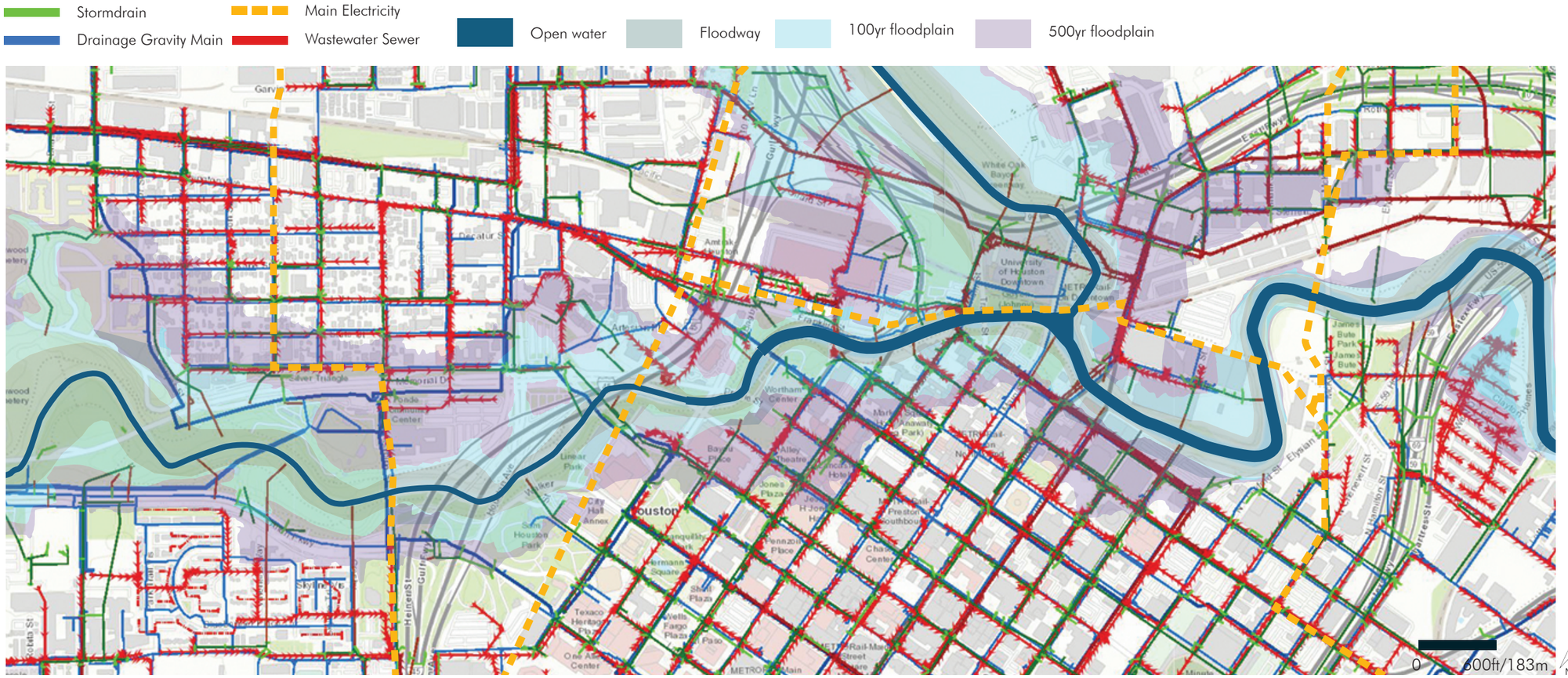


Fig. 44 | Technical Profile, Map: Van den Berg (2021), based on data from GIMS Houston (2020).

Because much of Houston's new development has occurred with impunity to the natural systems underlying the Houston region. Homes and businesses were built within floodplains and floodways. The poorly drained soils were paved over, so that they were not able to drain at all and instead ran straight into the bayous. More and more floods were the result of these unsustainable development patterns. In response, the city attempted to develop engineering solutions to accommodate this development by reconstructing the natural systems–yet they always lag behind the forces of nature (Houston Parks Boards, 2018). By modifying bayou, their biological diversity was nearly eliminated; anly a few natural bayous remain (including Buffalo Bayou). Being stripped of their ecological value in interest of flood control, they are now lined with concrete and turf grass. While people are able to approach the water of the bayous, they do not connect with its full range of bayou ecology.

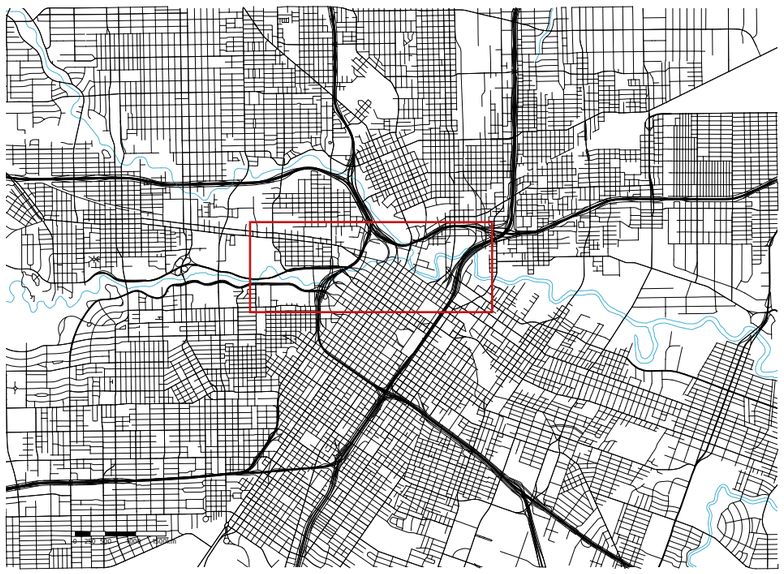


Fig. 45 | Infrastructure (GIMS Houston, 2019).

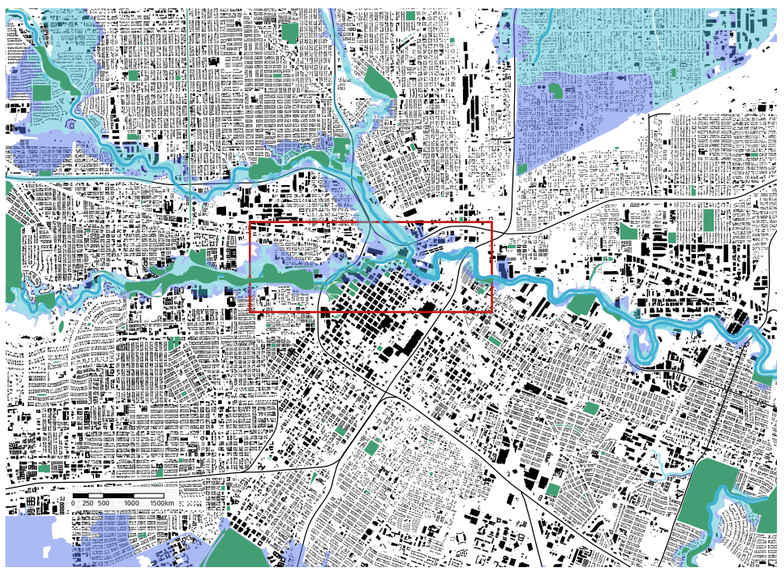


Fig. 45 | Green/Blue Network (GIMS Houston, 2019).

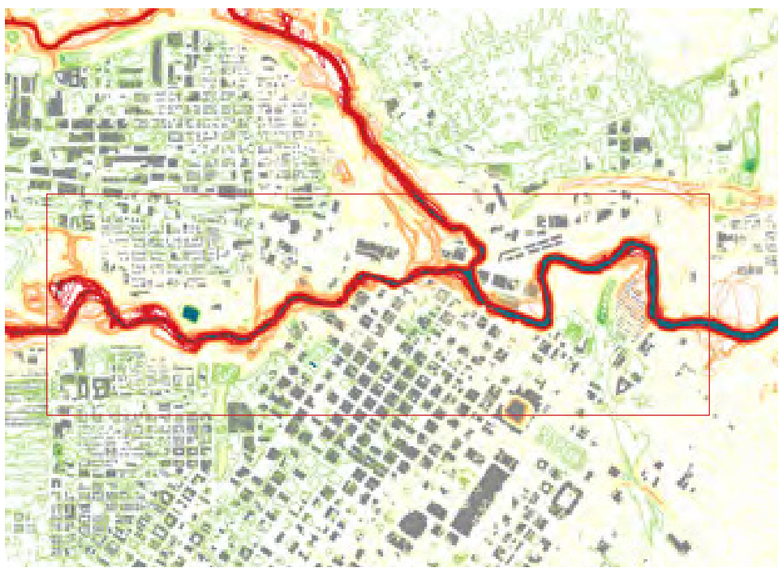


Fig. 46 | Two Feet Evelvation (GIMS Houston, 2019).

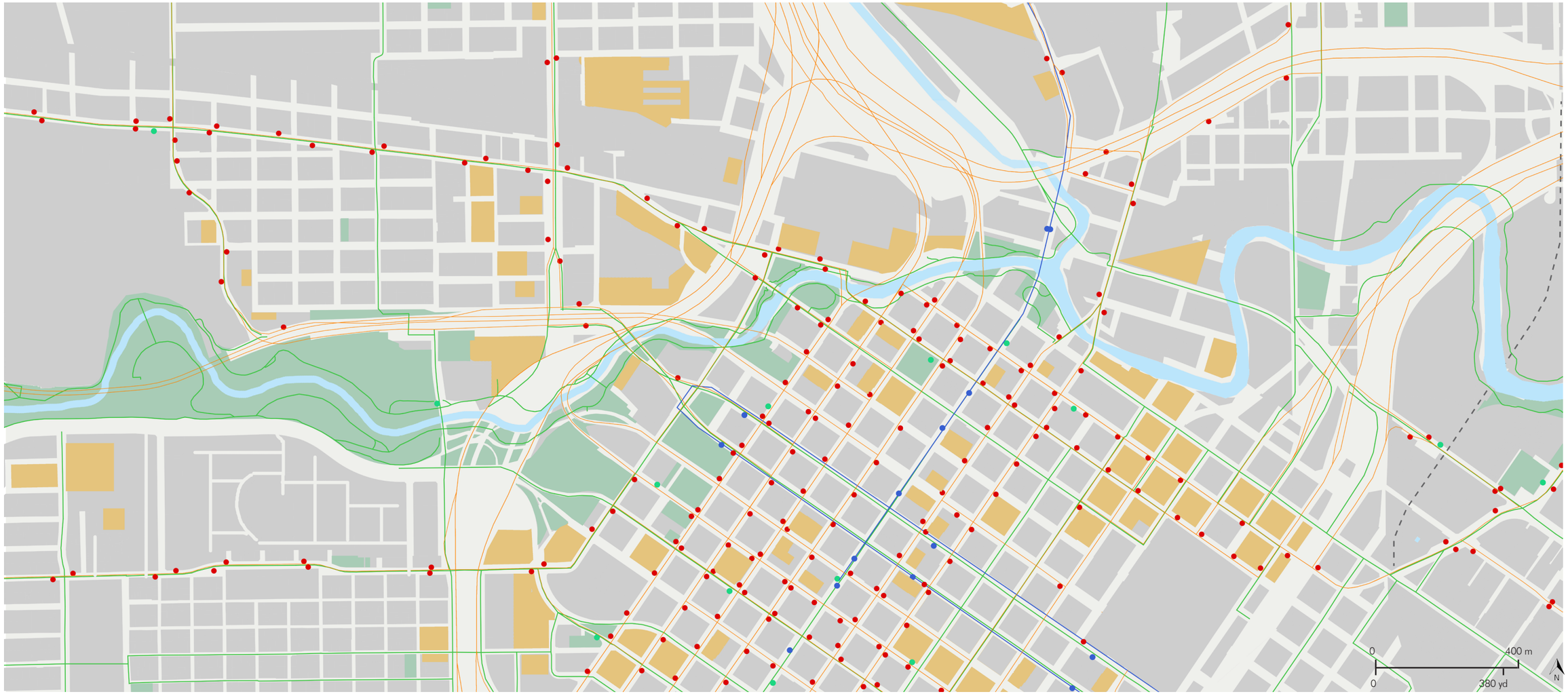


Fig. 47 | Transportation network inside project site (Van den Berg, 2021). public parking bus bike tram



Fig. 48 | Houston's BCycle bike stop (photograph, 2013).



Fig. 49 | Tram in Downtown (Eschipul, 2006).



Fig. 50 | Bus stop in Downtown Houston (photograph, 2013).



Fig. 51 | Parking Lot in Downtown Houston (Google Earth, 2021).

This extensive road network that facilitates car travels create physical barriers to alternative forms of transportation. In long stretches between highway overpasses, pedestrian and bike crossing is impossible. And where there is the ability to cross, it is made difficult and unsafe by high-speed frontage roads. This asks for a large amount of parking lots and parking garages, which creates a lot of inactive spaces and impermeable surfaces.

In recent years there have been positive improvements in Houston like a tram network, shared biking stops and an expanding bus network. The map above shows its extent in Downtown. However, outside of the city centre, the availability and frequency of public transit severely lessens.

3.3 CLIMATE CONDITIONS



Fig. 52 | Severe weather breakout on the I-10 in Houston (Timmer, 2018)

Houston is situated in a humid subtropical climate, which results in the occurrence of extreme precipitation. South-east continental US has a high annual precipitation (Fig. 52), with a large seasonal variability in precipitation intensity (Fig. 53). The Buffalo Bayou watershed, where the project location is situated, is crucial for dealing with this rain. It is a relatively small watershed, being only 60 miles (100km) long, but critical for Houston's drainage. The extent of this watershed is displayed in Fig. 54.

Seasons

Houston's proximity to large water bodies that connect Houston to the Gulf of Mexico, bring in warm air during a large part of the year. This causes long, hot and humid summers. Humidity is high throughout the year but peaks during summer because of clashes between air masses that travel from the Gulf of Mexico and the desert lands. The winters are short and mild; usually without snow. Inbetween, spring and autumn are known for their wet and warm weather conditions. However, several extremes have been recorded throughout history, such as the highest temperature of 109°F (43°C) in September 2000, and the lowest temperature of 5°F (-15°C) in January 1930 (FlowArchive, 2019).

Weather Hazards

Since 1851 there have been on average 5.5 Atlantic Hurricanes per year. The frequency is rising from 4.4 Hurricanes per year in 1851 to 6.3 per year in 2019. Even though Houston lies a bit south of the U.S. 'Tornado Alley', it still faces occasional tornadoes and thunderstorms that come with destructive winds and heavy rainfall. These weather hazards mostly occur during late spring and summer, and often result in floods.

Hurricane Harvey

In August 2017 Hurricane Harvey made landfall in Texas. Within four days, many areas received over a 1,000 mm (40 inches) of rain, causing severe floods. Hurricane Harvey was the wettest tropical cyclone on record in the U.S. (Roth, 2018), with peak rainfall of 1,539 mm (60.58 inches) just outside of Houston (in Nederland, TX). This caused near-record water levels at every bridge crossing along Buffalo Bayou and 1 out of every 10 building.

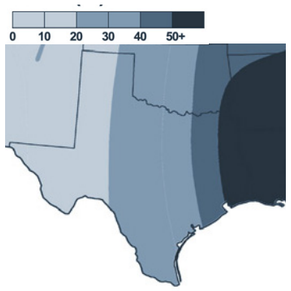


Fig. 52 | Annual Average Precipitation in Texas, in inches (Waggonner & Ball Architects, 2013).

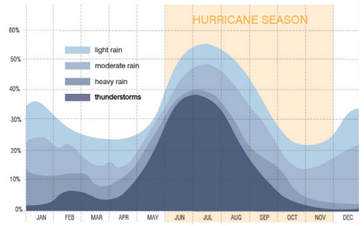


Fig. 53 | Annual Average Precipitation, in inches (Waggonner & Ball Architects, 2013).

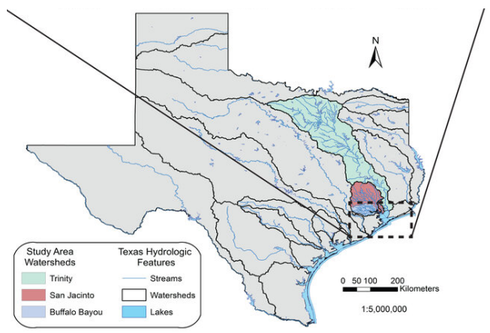


Fig. 54 | The Buffalo Bayou watershed in the Houston area (Flow Archive, 2019).

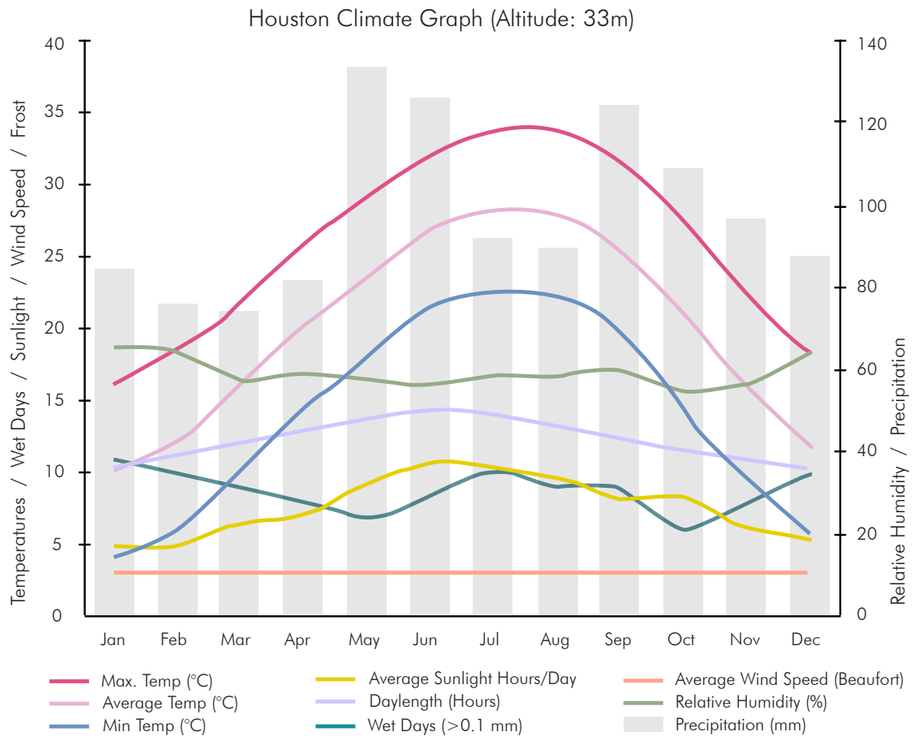


Fig. 55 | Climate graph of Houston. Graph by Van den Berg (2021); based on data from www.hereinhouston.org/climate-change.

3.4 Urbanized Landscape



Fig. 56 | Buffalo Bayou park (SWA, n.d.)

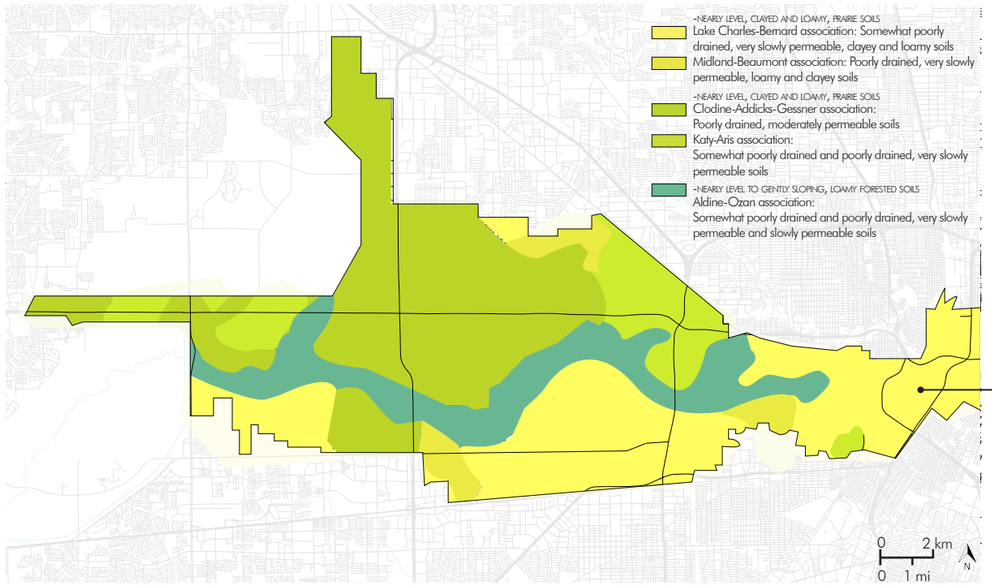


Fig. 57 | Soil types in Buffalo watershed. Map by Van den Berg (2021), based on data from U.S. Departement of Agriculture Soil Conservation Service (1976).

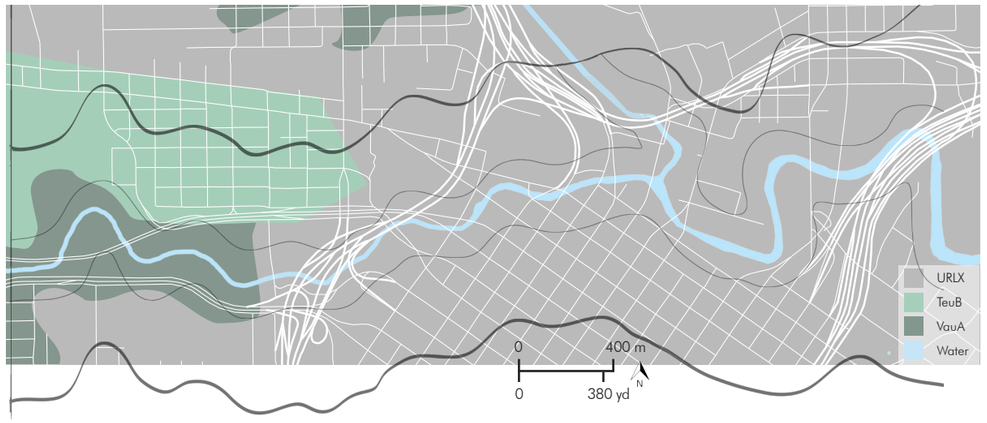
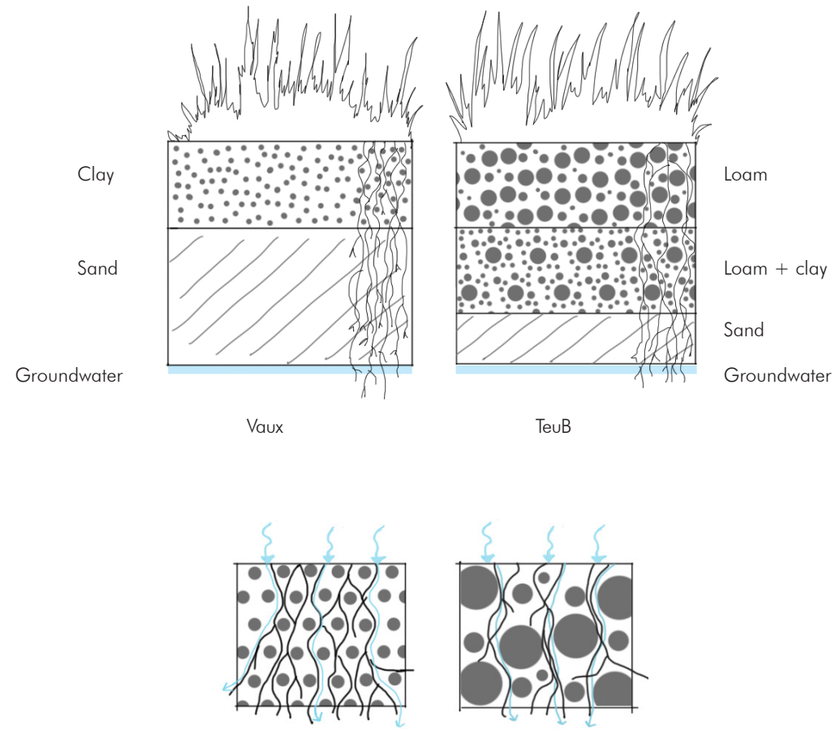


Fig. 58 | Map by Van den Berg (2021), based on data from the Custom Soil Resource Report for Harris County (United States Department of Agriculture, 2019).

Table 1 | Description of soil types. Table by Van den Berg (2021), based on data from the Custom Soil Resource Report for Harris County (United States Department of Agriculture, 2019).

PROPERTIES AND QUALITIES	DESCRIPTION VAMONT-URBAN (VAUA)	DESCRIPTION TEXLA-URBAN LAND COMPLEX (TEUB)	DESCRIPTION URBAN LAND (URLX)
Landform:	Flats	Flats	Flats
Landform position:	Talf	Rise	Talf
Down-slope shape:	Linear	Linear	Linear
Across-slope shape:	Linear	Convex	Linear
Parent material:	Clayey fluviomarine deposits derived from igneous, meta morphic	Loamy fluviomarine deposits derived from igneous, meta morphic and sedimentary rock	Clayey fluviomarine deposits derived from igneous, meta morphic
Typical profile:	A-0 to 4 inches: silty clay Bss-4 to 20 inches: clay Bssg1-20 to 60 inches: clay Bssg2-60 to 80 inches: clay	A-0 to 4 inches: silt loam E-4 to 14 inches: silt loam Bt/E-14 to 24 inches: silt loam Bt-24 to 65 inches: silty clay loam Btg-65 to 80 inches: silty clay loam	M - 0 to 40 inches: variable
Slope:	0 to 1%	0 to 2%	0 to 3%
Depth to restrictive feature:	More than 80 inches	More than 80 inches	0 inches to manufactured layer
Natural drainage class:	Somewhat poorly drained	Somewhat poorly drained	Somewhat poorly drained
Runoff class:	High	High	Very high
Depth to water table:	About 14 to 37 inches	About 6 to 18 inches	About 14 to 37 inches
Available water storage in profile:	Moderate (about 7.0 inches)	Very low to moderate (0 to 0.06 inches/hr)	Very low (0 inches/hr)

Fig. 59 | Soil profiles with native prairie grasses; their roots allow rainwater to be easier absorped in the soil. Drawing by Van den Berg (2021), based on data from Brakel (2015).



There are three soil types in the chosen project area, which are mostly clay and loam based, adding impermeable conditions. These soil types are characterized in Table 1. The choice of vegetation is also influenced by the clay soil, because it does not allow rainwater to drain will. Additionally, Houston has a relatively high and fluctuating water table, causing trees to develop weak and shallow roots; this is because the roots of most trees only reach as deep as the unsaturated zone in the soil. And the problem with root-boxes is that water logging causes roots to rot. The roots from native vegetation, such as prairie grasses create more space between soil particles and therefore rainwater can be easier absorbed into the soil, see Fig.59.

Houston used to be the home of a large prairie ecosystem, before urbanization started. The prairie is wide and flat, with trees scattered around. However, the fast expansion of the city caused the prairies to be nearly extinct. There is little to no native vegetation to absorb rainwater anymore, causing bigger rainfall problems for the built environment. Around the bayous, the landscape has a denser character, with lots of trees. In between the prairies and the bayou wilderness, there is usually a transition zone where many shrubs can be found.

NATIVE PRAIRIE LANDSCAPE



This is the prairie landscape that is native to the east texan coast. You can see Tall grasses rising up,there are groups of trees scattered around, and there are more than 70 different flower species, like the bluebonnets in the right corner. However, the prairies did not survive the growth of the city and agriculture, and today less than 1% of this original coastal ecosystem remains.

Fig. 60 | Collage of native prairie landscape characterisitcs in Harris County (Van den Berg, 2021).

LANDSCAPE TYPOLOGIES: UPSTREAM BUFFALO BAYOU

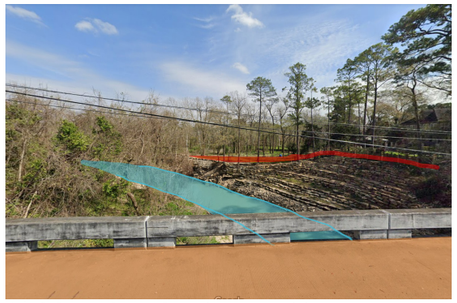
The landscape surrounding the Buffalo Bayou upstream area is barely accessible and at some places looks like it has never been touched by humans. Most riverbanks are characterized by their riparian forest, and are only seen from the bridges that cross the bayou. Part of the land adjacent to the bayou is privately owned (suburban villa's dominate here) and sometimes that results in a privately accessible Buffalo Bayou; the other parts are parks that are publicly accessible, although the riverbanks may not be due to the preservation of riparian forest.



1| Terry Hershey Park Hike & Bike Trail. Accessible in public park, visible.



2| Gessner Road. Inaccessible. Visible only from bridge.



3| S Piney Point Road. Accessible on private property. Visible from bridge and private property.



4| Briar Bend Park. Inaccesible. Slightly visible from parallel running roads.



5| San Felipe Street. Inaccesible. Visible only from bridge.

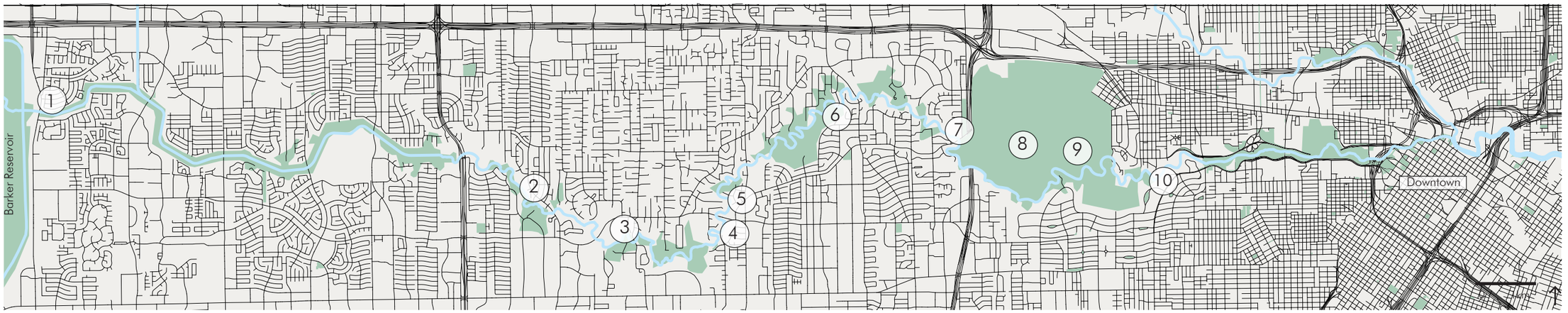
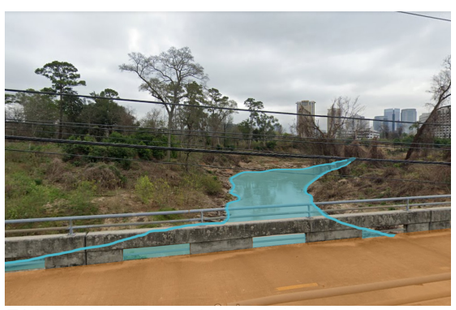


Fig. 61 | Upstream Buffalo Bayou (Van den Berg, 2021)



6| Farther Point. Inaccessible. Visible only from bridge.



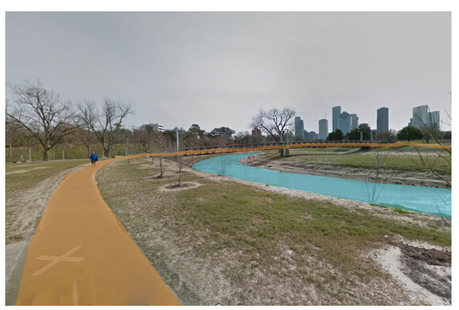
7| Woodway Drive. Inaccessible. Visible only from bridge.



8| Memorial Park 1. Inaccessible. Not visible.



9| Memorial Park 2. Inaccessible. Partly visible from walking trail.



10| Buffalo Bayou park. Accessible from walking and biking trails. Very visible.

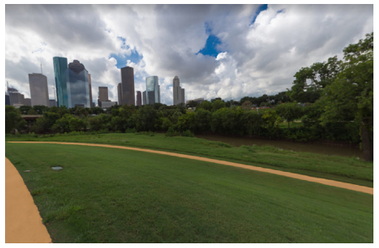
Picture 1-10 by Google Maps (n.d.), edited by Van den Berg (2021).



Fig. 62 | A different perspective from the Buffalo Bayou (Van den Berg, 2021)

A different perspective from the Buffalo Bayou, looking towards Downtown. Next to riverbanks and bridges, traffic also occurs on the water. Currently there are several spots along the bayou that offer canoe services. However, apart from canoes and a couple of small tourist tour boats, traffic in this part of the bayou is scarce.

LANDSCAPE TYPOLOGIES: INSIDE PROJECT AREA



1| Buffalo Bayou Park East



2| Sam Houston Park



3| Ideson Library Garden



4| Hermann Square



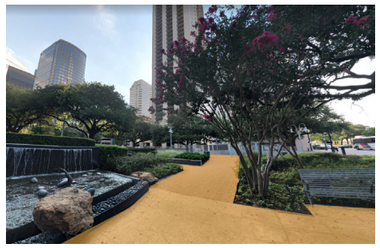
5| Tranquillity Park https://tclf.org/landscapes/tranquillity-park



6| Wortham Centre



7| Buffalo Bayou Greenway



8| Market Square Park



9| Johnny Goyen Park



10| Allen's Landing Park



11| Congress Street at Caroline Street



12| James Bute Park

Picture 1-9, 11-12 by Google Maps (n.d.), picture 10 by The Cultural Landscape Foundation; edited by Van den Berg (2021)

Fig. 63 | Parks inside project area (Van den Berg, 2021)

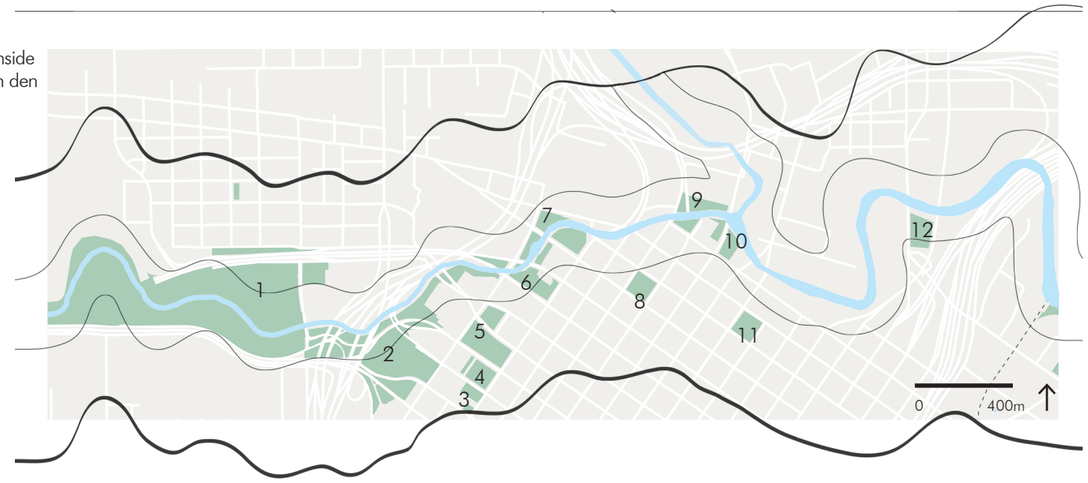


Fig. 64 | Different park typologies inside project area (Van den Berg, 2021)



1.Natural Park

no. 1, 2, 7

2.Paved Park

no. 3–6, 8, 10, 11

3.Neglected Park

no. 9, 12

Inside the project area there are three park typologies to be found:

1.Natural Parks. These parks contain a lot of permeable surface and have a significant amount of vegetation. They provide meeting places and thinking spaces; a moment of quiet to satisfy our need to escape the hustle and bustle of our busy lives for a moment and allow ourselves to clear our heads.

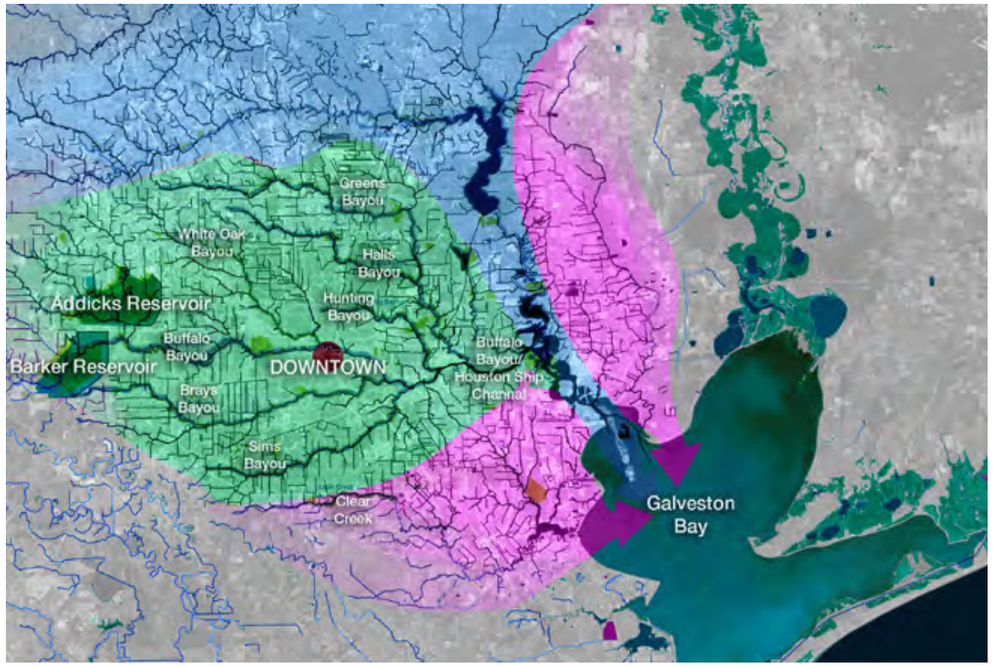
2.Paved Parks. These parks, while having a decent amount of green space, are dominantly paved. They provide meeting places and recreational spaces; a moment of activity to build up our energy for the rest of the day.

3.Neglected Parks. These parks are barren, underutilized spaces, primarily used to reach other points. However, they have potential to become active civic and recreational spaces, or become a more inviting quiet space.

3.5 FLOOD SUSCEPTIBILITY



Fig. 65 | Homes outside official flood zones flood during Hurricane Harvey (McNamee, 2017).



Drains to Galveston Bay through San Jacinto River

Drains to Galveston Bay through Buffalo Bayou

Drains to Galveston Bay to Galveston Bay

Addicks and Barker Reservoir

Fig. 66 | Natural drainage system, Flow direction of the Bayous into Galveston Bay (HCFCD, n.d.).

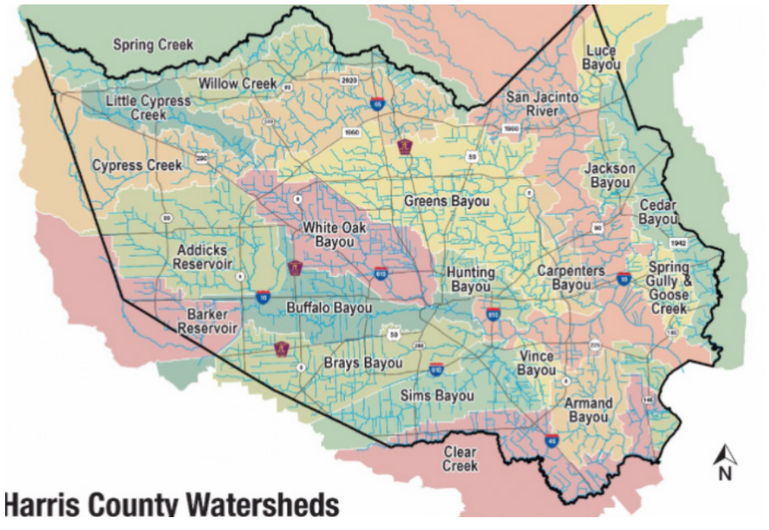


Fig. 67 | Harris County 22 Watersheds (HCFCD, n.d.)

Fig. 68 | Addicks and Baker Reservoir (HCFCD, n.d.)

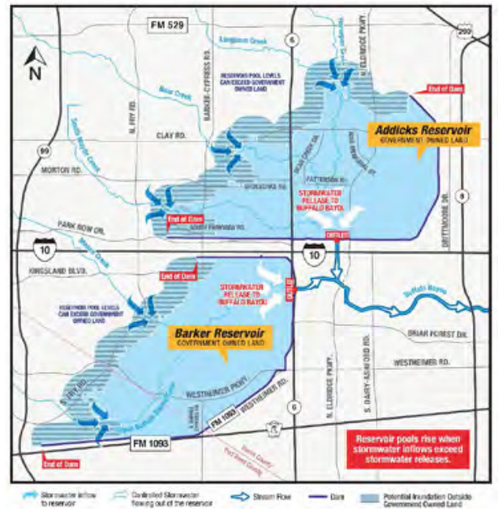


Fig. 69 | Barker Dam and Reservoir in Houston on 19 September 2017 (Stravato, 2017).



Harris County covers around 4400 square km with almost 1500 channels and ditches of water with a total length of 4000 kilometer within 22 watersheds defined by the 22 bayous. Only 1300 km of those streams and drainage systems are natural. Most of them are either human-made and improved for more efficient stormwater management (HCFCD, n.d.).

A watershed is an area that drains rainfall runoff and stormwater from the surface towards a common body of water. They are mostly divided in big, major main-watersheds as well as sub-watersheds formed by smallest branches bayous, creeks and gullies, which then can have their own sub-watersheds again. The 22 watersheds are defined as natural drainage areas that lead the water into one of the 22 bayous. They are shaped by topography which brings each area an individual and unique flooding issue (HCFCD, n.d.).

The Addicks and Barker reservoirs are the only two, large scale stormwater storages in Harris County. Made in the 1940s, those basins have been constructed to collect precipitation and run-off from upstream locations, in order to reduce the pressure on the Buffalo Bayou as well as to prevent Downtown Houston and other downstream areas from flooding (HCFCD, n.d.). During Hurricane Harvey, the two emergency reservoirs started to fail, due to densification and intense residential development within the Addicks and Barker watersheds. Many of the houses located behind the reservoirs started to flood. To prevent even bigger damage, the US Army Corps decided to release water from the dams into Buffalo Bayou, which originally should be supported by the reservoirs. The large amount of stormwater created floods of many downstream areas (Brussee et. al, 2017).

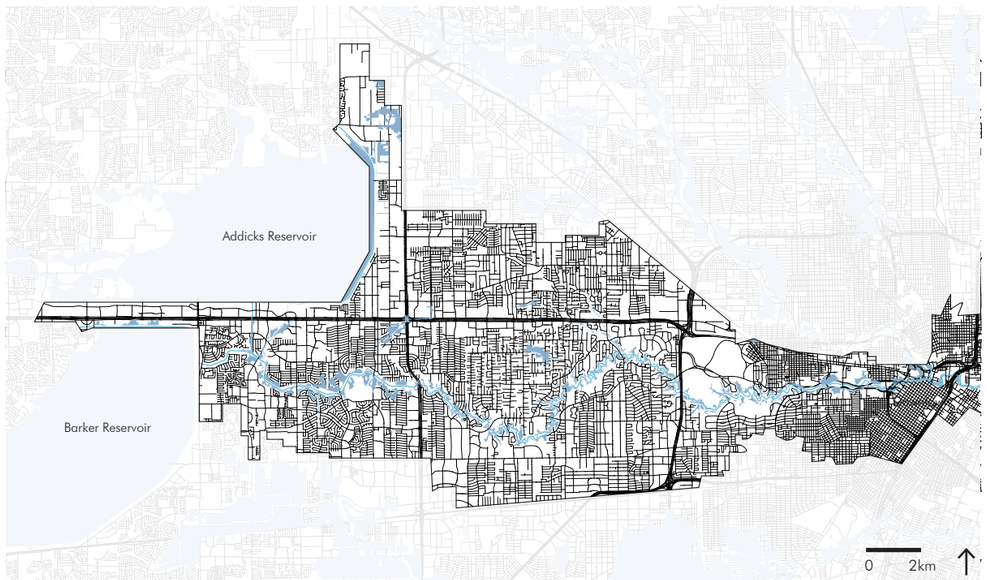


Fig. 70 | Floodplains in Buffalo Bayou watershed (Van den Berg, 2021).

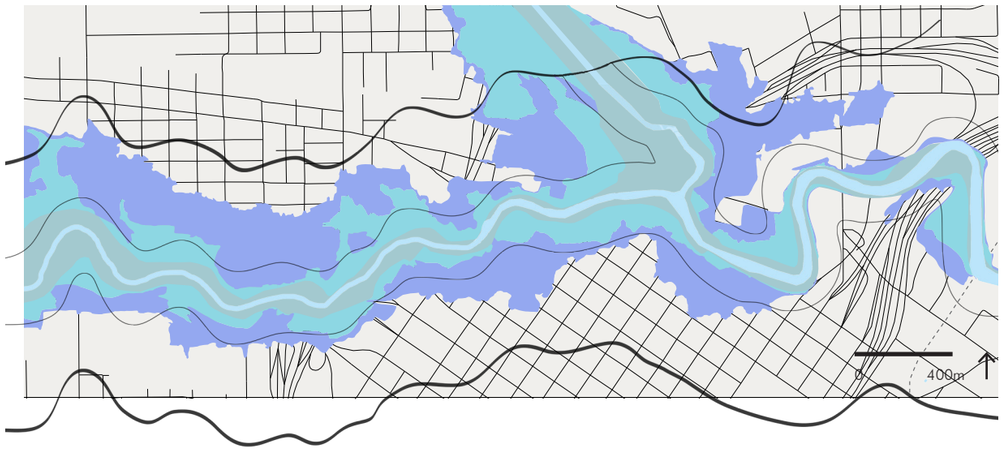


Fig. 71 | Floodplains at site location (Van den Berg, 2021).

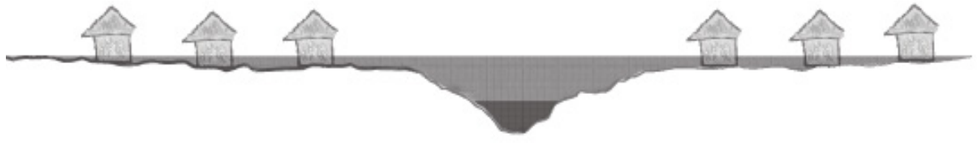


Fig. 72 | Shallow floodplain illustation (HCFCD, n.d.)

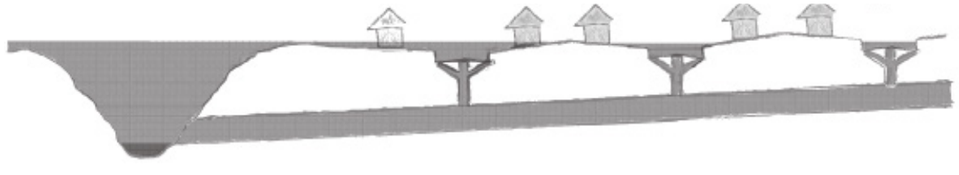


Fig. 73 | Ponding floodplain illustation (HCFCD, n.d.)

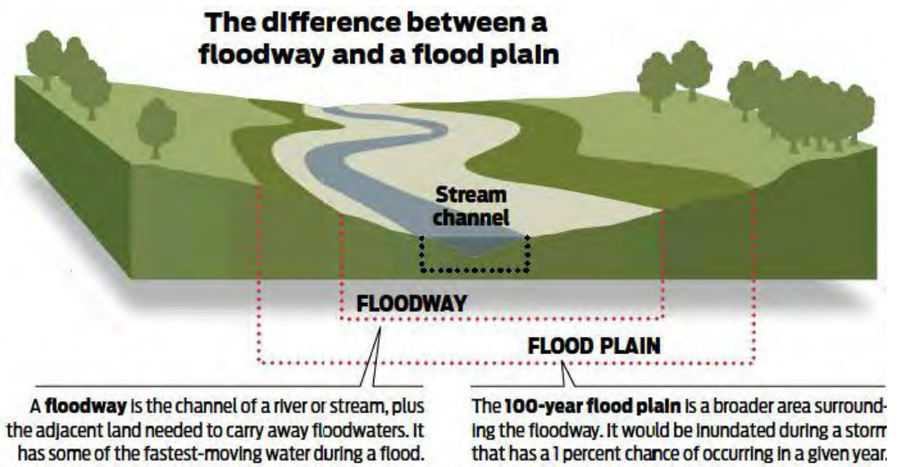


Fig. 74 | The difference between a floodway and a flood plain (Association of State Floodplain Managers, n.d.).

Urban development within floodplains causes wetland loss and increased impervious surface, and eventually caused many homes outside of the marked floodplains to flood during Hurricane Harvey´s rampage. Houston's development is characterized by the lack of a regulating zoning law, missing restrictions and guidelines. This caused many areas within floodplains and watersheds being developed towards residential and commercial use. This has drastic consequences for the intensity of flooding especially when they occur in upper stream areas (Sebastian et al., 2017). An increasing amount of impervious surface such as buildings, parking lots, streets, as well as deforestation and the displacement of natural vegetation and wetlands caused an increase in speed and amount of runoff into the often already overloaded and sometimes badly maintained stormwater drainage systems.

Areas in major floodplains have been heavily densified over the last decades. This caused the flooding of many of those houses and areas and also created flooding in areas where those events never happened before. Sam Brody, Professor of Marine Sciences at Texas A&M University states: "Other flood-prone areas around the world like the Netherlands are planning for 10,000-year storms. In Houston, officials are still allowing new construction in the path of a 100-year storm."

The two types of floodplains in the project area are 1. Shallow floodplains; It exists throughout a significant part of the city and it affects thousands of residences and businesses. When the channel capacity is exceeded, flooding begins. 2.Ponding floodplains; This type of flooding occurs when intense local rainfall exceeds the storm sewer or roadside ditch capacity. The water then ponds in the streets deep enough to flood buildings that are not close to a bayou or creek.

LEVEL OF PAVEMENT

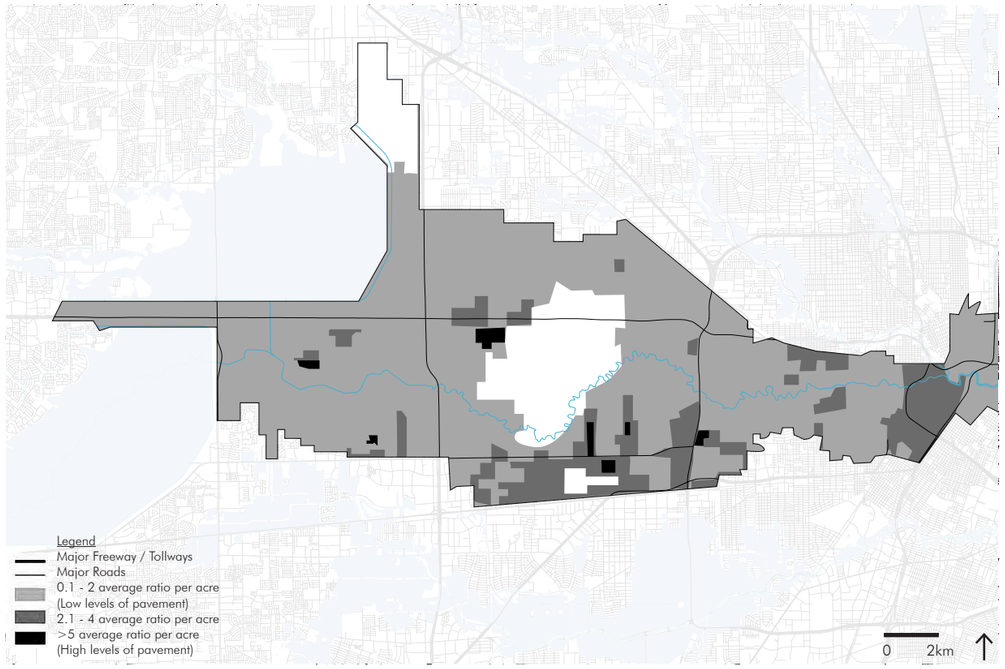


Fig. 75 | Level of Pavement in Houston. Data from Galveston Area Council Planning & Development Department (2017), map by Van den Berg (2021).

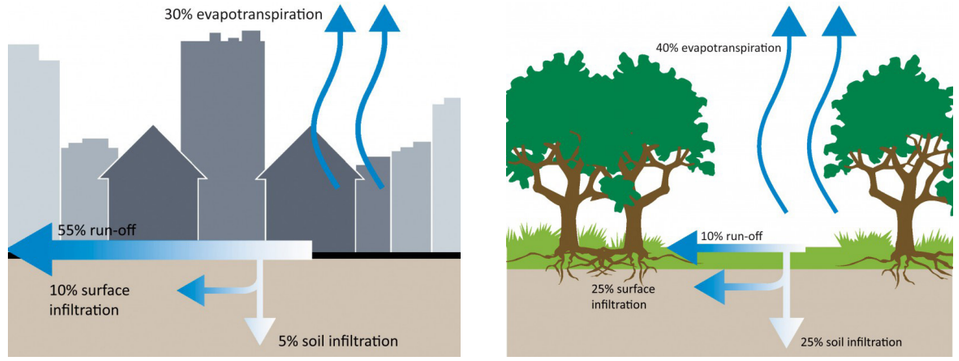


Fig. 76| City waterbalance (left) and natural water balance (right) (EPA, 2008).

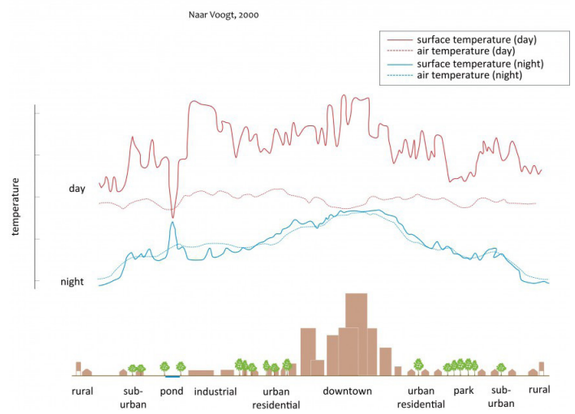


Fig. 77 | Air and surface temperature during the day and night (EPA, 2008).

The high amounts of pavement increases the likelihood of flooding during rain events because there is no grass, soil or vegetation to capture stormwater runoff moving over streets, parking lots, sidewalks, etc. Low impact development (LID) techniques such as permeable paving, rainwater cisterns, bioswales and rain gardens can help to offset this flooding. Studies have also correlated impervious/pervious cover ratio with urban heat island effect. Paved surfaces and concrete absorb rays from the sun and produce heat. Chemicals emitted by cars, built structures and even trees can trap sun in urban areas and produce more heat. Heated air rises, and then collides with moist air from nearby bodies of water, which usually releases precipitation somewhere downwind from the heat island. This warm air and precipitation can affect winds and weather patterns for hundreds of miles surrounding an urban heat island (United States Environmental Protection Agency, 2013).

Most of Houston's pavement is concentrated within Loop 610, as this is where the impervious/pervious cover ratio begins to get closer to 1 (which indicates high levels of pavement and concrete). Sidewalks, roads and plazas are part of an urban environment, but there are ways to offset the impacts of paving on stormwater through LID techniques.

Furthermore, urban heating also affects the quality of water. Rainwater running off from hot roofs and roads on hot summer days can heat up. The surface water into which it drains also heats up, and the temperature of the water impacts every process in the water (EPA, 2008). Similar to other American cities, Houston uses asphalt and cement concrete as the most common paving materials. In the 1970s, the City of Houston adopted the practice of using cement concrete for major street construction. For street maintenance and resurfacing, asphalt concrete and coatings are generally used (HARC, n.d.).

Porous pavement allows water to drain through it or between segments, thus slowing the movement of water into storm drain facilities and waterways. This helps to prevent flooding by more evenly distributing runoff over time. By slowing and reducing runoff, porous paving reduces or even eliminates peak stormwater discharges from paved areas. This same phenomena increases the amount of water that is available for groundwater recharge. In the Houston region, the presence of clay soils in much of the area decreases this benefit. Water quality is improved with porous paving by the filtering action that occurs when water is drained through soil and rocks rather than directly into drainage facilities or waterways. Soil erosion that can occur from rapid stormwater runoff is also reduced. Water runoff from hot paved surfaces into a waterway can affect the quality of the habitat in the waterway and organisms living in that habitat. Porous paving not only retains water, but the water that is released is cooler than other paving surfaces. This reduces thermal pollution.

HURRICANE HARVEY: FLOODPLAIN DAMAGE

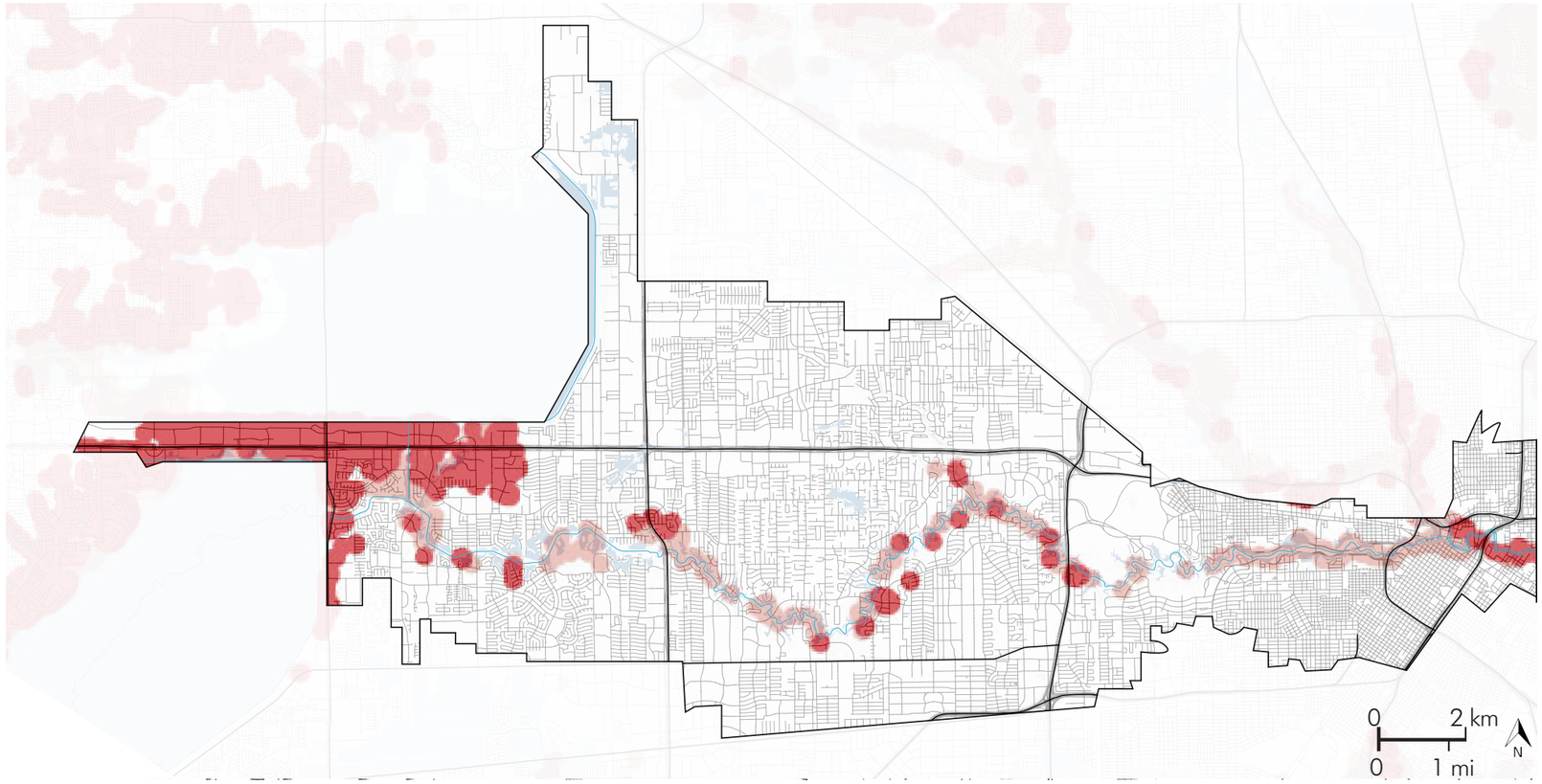


Fig. 78 |Damage inside and outside floodplain during Hurricane Harvey (Van den Berg, 2021) based on data from FEMA.

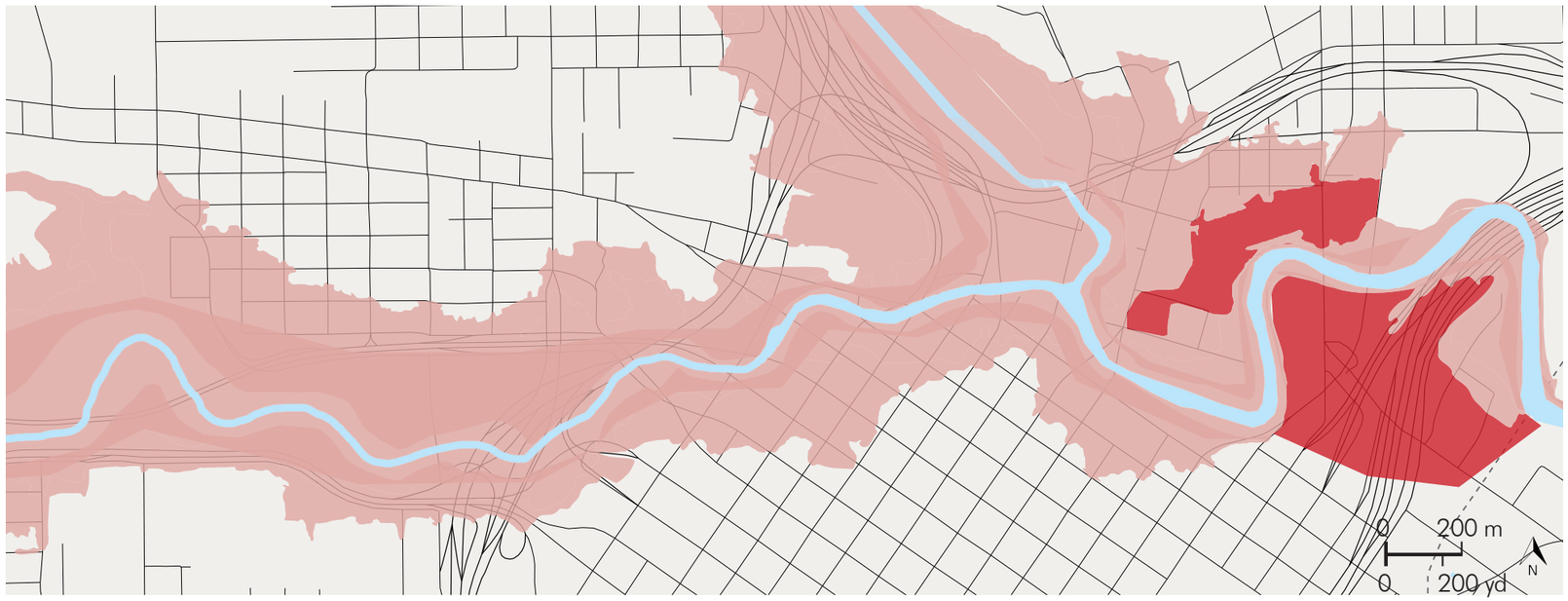


Fig. 79 |Damage inside and outside floodplain during Hurricane Harvey (Van den Berg, 2021) based on data from FEMA.

It is important to note that heavy flood damage also occurs outside of the official floodplains, suggesting that available maps are not entirely accurate. All along upstream Buffalo Bayou certain places were more heavily affected than others, and in the project site it is mainly the eastern part of Downtown that was affected outside of official boundaries.

3.6 SPATIAL QUALITY



Fig. 80 | Travis Street in Houston's Historic District (Photograph, 2013).

BAYOU RELATED DISTRICTS

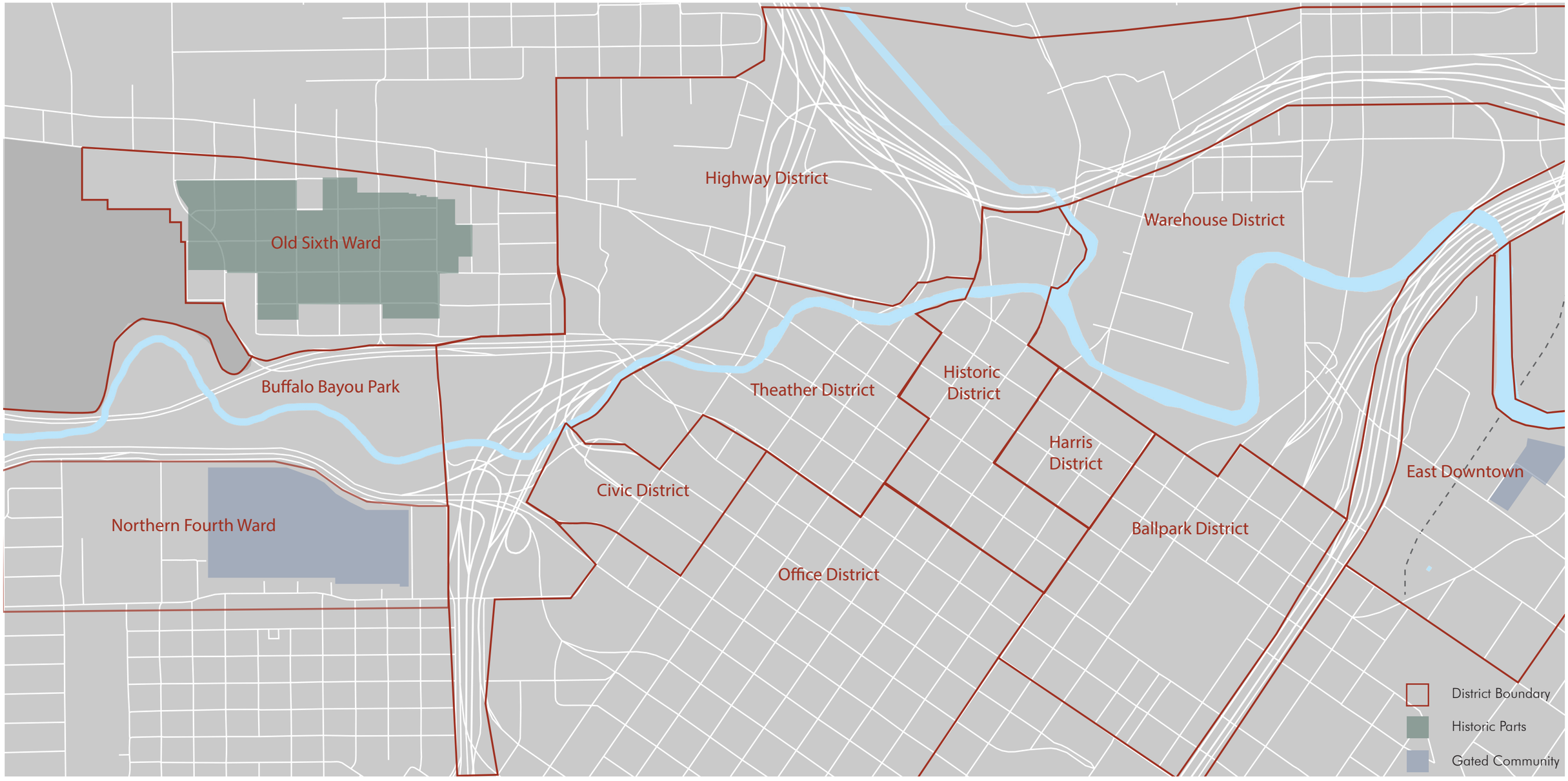


Fig. 81 | Bayou related districts (Van den Berg, 2021).

Based on their typology, function, and location, there are ten different districts situated within the urban river corridor boundaries in the project site. These divisions will be used to analyze their characteristics and relationship with the Buffalo Bayou.

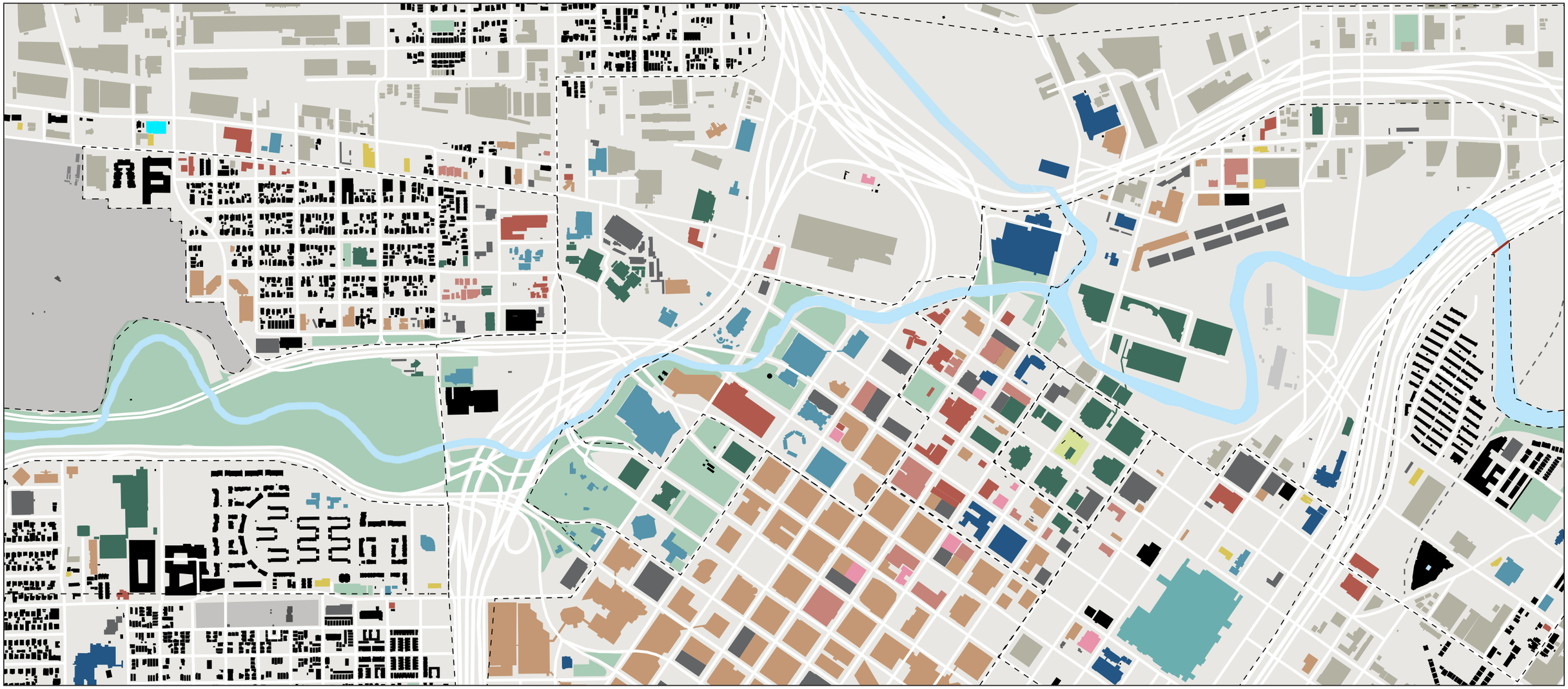


Fig. 82 | Functional diversity analysis (Van den Berg, 2021).

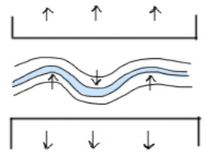
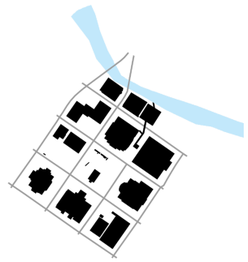
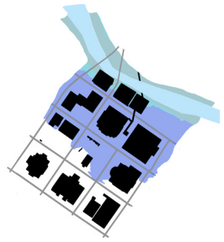
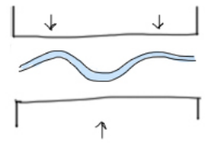
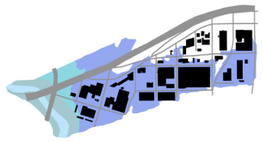
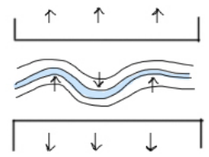
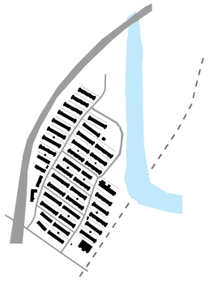
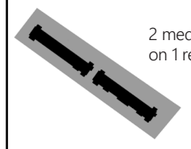
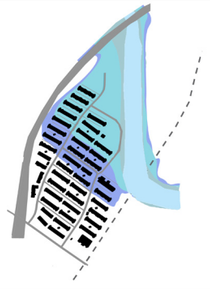
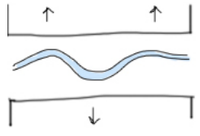
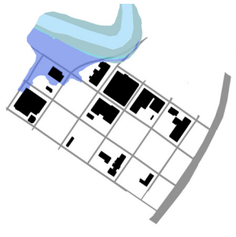
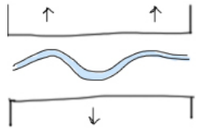
Functional homogeneity and a lack of diversity is often associated with a low resilience to disturbances (Tyler & Moench, 2012), and analysis of the spatial diversity of functions provides insight in the adaptive capacity of the urban environment. Fig.82 shows the distribution of functions in the project area and its immediate surroundings. It highlights a certain amount of segregation of function, with soft borders in between them. Commercial activities are scattered around, and can be divided into being either car-oriented or pedestrian-oriented (e.g. large retail vs corner store). Availability of open space is unevenly distributed across the project area; parks are more concentrated on the west side of downtown, while massive open parking spaces are located on the eastside of Downtown. Inside residential areas there is a small amount of quality public space.

BAYOU RELATED DISTRICTS

Table 2 | Bayou related districts (Van den Berg, 2021).

500yr 100yr floodway bayou

permeable impermeable

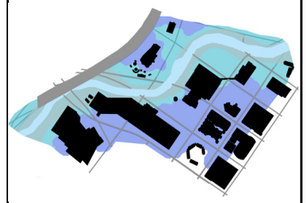
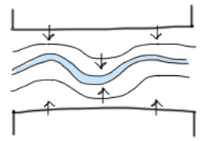
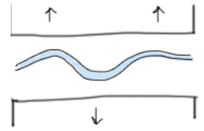
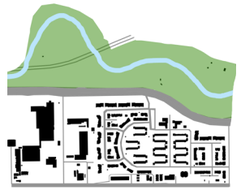
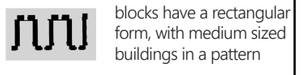
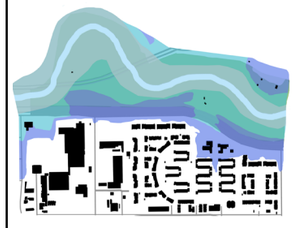
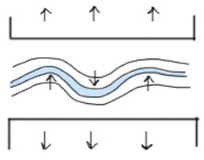
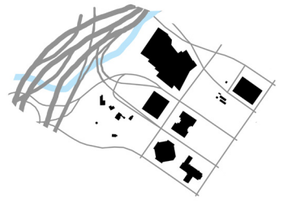
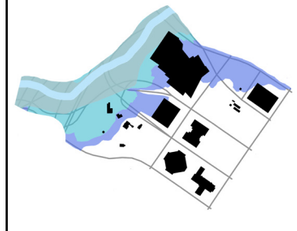
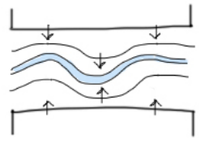
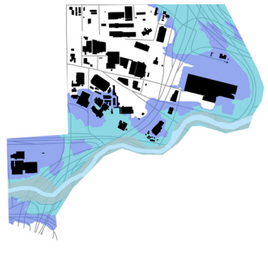
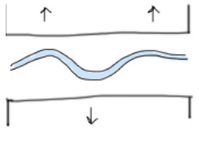
AREA	GRID RELATING TO BAYOU	BLOCK	FUNCTION	FLOODPLAIN	RELATION TO BAYOU	SOIL TYPE TOP LAYER	PERMEABILITY %
OLD SIXTH WARD		 multiple buildings on 1 rectangular block  1 or few large building on 1 rectangular block	family homes apartments small businesses retail		not visible, accesible 	clay and silt loam	
HARRIS DISTRICT		 building takes up most of the square block  1 or few building take up half of the square block	courthouses jail		partly visible, not accesible 	clay	
WAREHOUSE DISTRICT		 irregular rectangular blocks, where the building takes up half or less of the block  irregular rectangular blocks, where the building takes up most of the block	warehouses small businesses apartments offices		not visible, partly accesible 	clay	
EAST DOWNTOWN		 2 medium buildings on 1 rectangle block  1 medium building on 1 rectangle block	apartments family homes small businesses		not visible, not accesible 	clay	
BALLPARK DISTRICT		 several buildings take up half or less of the square block entire square block is open parking lot	sports stadium apartments small businesses		not visible, not accesible 	clay	

BAYOU RELATED DISTRICTS

Table 3 | Bayou related districts (Van den Berg, 2021).

500yr 100yr floodway bayou

permeable impermeable

AREA	GRID RELATING TO BAYOU	BLOCK	FUNCTION	FLOODPLAIN	RELATION TO BAYOU	SOIL TYPE TOP LAYER	PERMEABILITY %
THEATER DISTRICT		 1 building on 2 blocks via skyway  1 building on quarter of the square block  1 or few buildings take up entire square block	theaters offices apartments		visible, accesible 	clay	
HISTORIC DOWNTOWN		 1 or few buildings take up entire square block  several building scattered around the square block	commercial/retail apartments offices institutional		not visible, not accesible 	clay	
NORTH 4TH WARD		 blocks have a rectangular form, with medium sized buildings in a pattern  blocks have a rounded form, with medium sized buildings in a pattern  several building scattered around irregular sized blocks	townhouses apartments small business		not visible, accesible 	silty clay and clay	
CIVIC DISTRICT		 rectangular block with 1 or several buildings, not taking up the whole block  irregular shaped block, adjusting itself to the bayou	city hall library office		partly visible, accesible 	clay	
HIGHWAY DISTRICT		 irregular shaped blocks, with small and large buildings scattered around.	warehouses office instituational		not visible, not accesible 	clay	

A | WAREHOUSE DISTRICT

1. Mid Rise Early 20th Century Warehouse, Renovated



2. Low Rise Late 19th Century Warehouse, Abandoned



3. Mid Rise Early 2000's, Public Building



4. Low Rise Late 20th Century Warehouse



Fig. 83 | Dakota Lofts 1910) at Sterrett Street (Google Maps, n.d.)

Fig. 84 | Sterrett Street (Google Maps, n.d.)

Fig. 85 | Harris County Sherrif's Office (2003) at Baker Street (Google Maps, n.d.)

Fig. 86 | Wood Street (Google Maps, n.d.)

Fig. 87 | East Drive (Google Maps, n.d.)

Fig. 88 | Runnels Street (Google Maps, n.d.)

Fig. 88 | Ann Street, located inside a gated community (Altis-ource, n.d.)

B | EAST DOWNTOWN

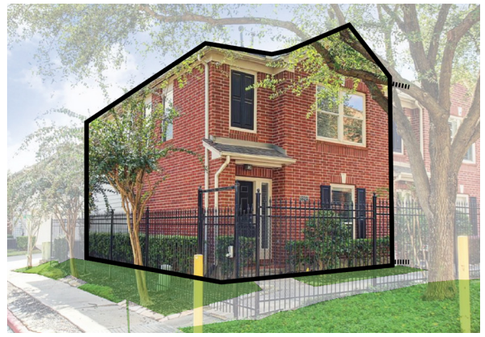
1. Low Rise Late 20th Century, Terraced House



2. Mid Rise Late 19th Century Warehouse, Renovated



3. Low Rise 21st Century Attached House



Once this district hosted purely industrial buildings, but in recent years the old, oftentimes neglected warehouses slowly started to be converted into lofts, offices and art studios. However, the majority of this district is still dominated by (abandoned) warehouses and businesses. These buildings date from the late 19th century till the late 20th century and are mostly low to mid rise in height. The south side of this district is home to many of Harris County justice related buildings, some of them which are connected with each other across the Buffalo Bayou with skyways.

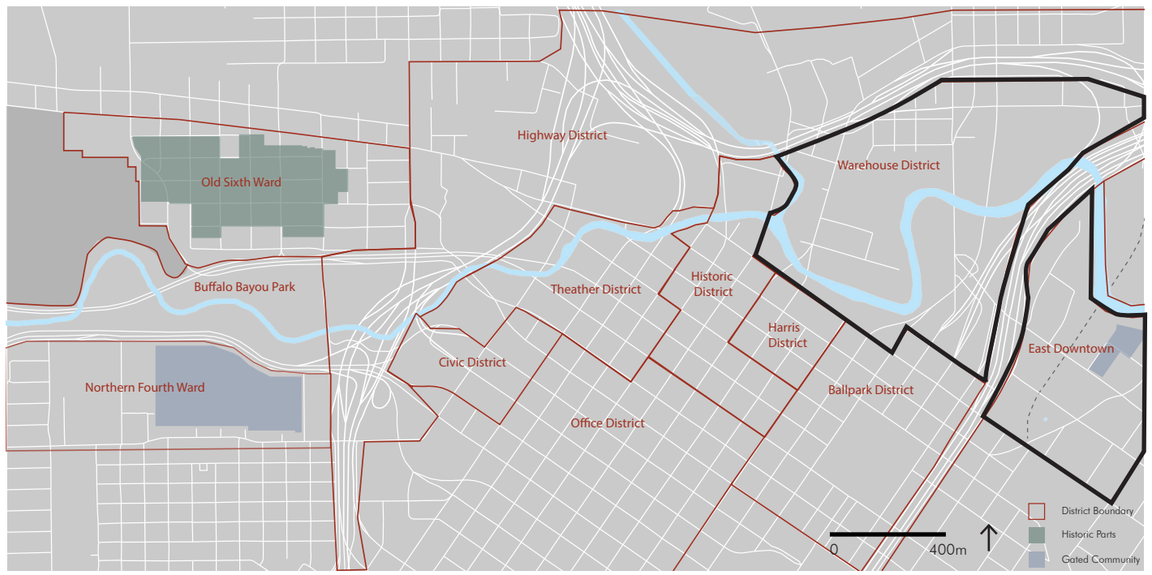


Fig. 89 | Bayou related districts (Van den Berg, 2021).

This neighborhood is separated from Downtown by the I-69. It is a mixture of renovated 19th century warehouses, and late 20th century development that consists mostly of row houses and townhouses. However, there are also quite some neglected buildings and empty lots. Residents report a lot of crime in the area, mostly break-ins; there is also a gated community with around sixty attached or semi-attached houses.

C | OLD 6TH WARD

1. Late 19th/Early 20th Century Cottage



2. Mid Rise Apartment Complex



3. Mid Rise Late 20th/Early 21st Century Offices



4. Low Rise 21st Century Free Standing Homes



Fig. 90 | Central Hall Cottage (City of Houston, 2007)

Fig. 91 | N Memorial Way (Google Maps, n.d.)

Fig. 92 | State Street (Google Maps, n.d.)

Fig. 93 | N Memorial Way (Google Maps, n.d.)

Fig. 94 | Main Street (Google Maps, n.d.)

Fig. 95 | The Magnolia Brewing Building (1912) at Franklin Street (The Heritage Society., n.d.).

Fig. 96 | Aris Market Square Apartments (2017) at Travis Street (Aris Market Square., 2017).

Fig. 97 | Hotel Icon at Congress Street (Google Maps, n.d.).

The historic character of the old sixth ward derives from a building tradition that was based on wood framing and carpentry; brick construction in buildings before WWII is uncommon. The typical wood-framed examples are characterized by: 1.Raised pier and beam foundations 2.Front porches, which often run along the entire front of the building 3.Pitched roofs, usually with end gables. Landscaping within the front yard is intended to enhance the visual experience for the pedestrian and to provide a sense of continuity of design. Fig. 90 displays many of the defining characteristics of the historic houses in the old sixth ward. This is one of Houston's best hidden neighborhoods, as it is tucked behind a mishmash of busy thoroughfares on the western edge of Downtown, which allowed it to become the oldest continuously existing neighborhood in Houston.

These historic buildings (mainly residential) are most common in this area. Over the years other typologies showed up here as well, such as offices, apartment complexes and free standing homes.

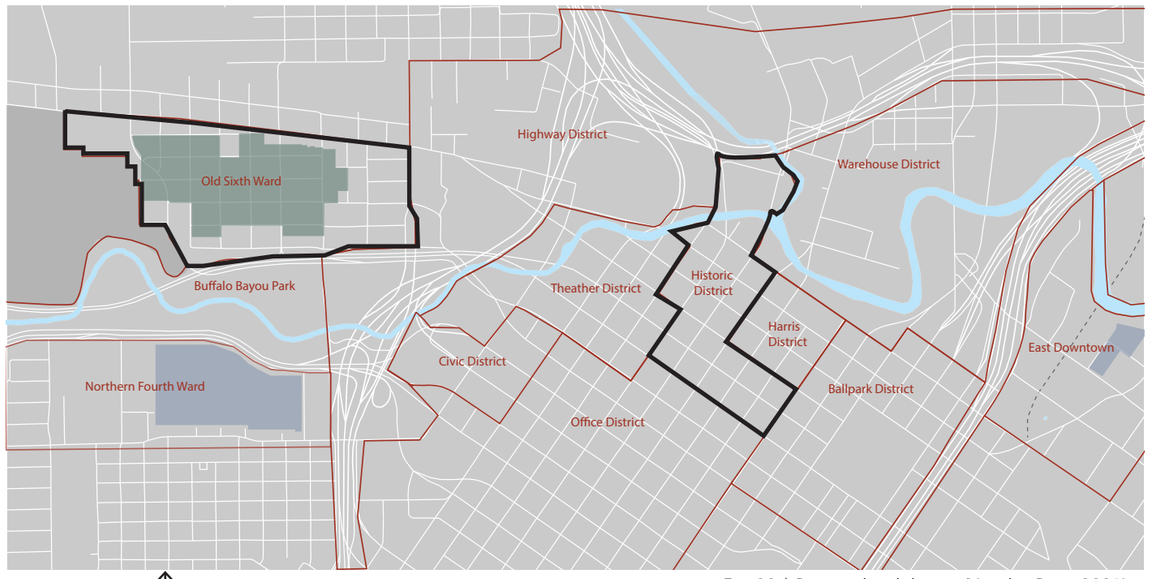
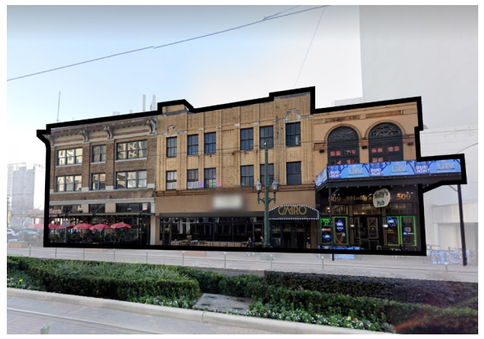


Fig. 98 | Bayou related districts (Van den Berg, 2021).

D | HISTORIC DISTRICT DOWNTOWN

1. Low to Mid Rise, Late 19th Century, Attached



2. Low Rise Early 20th Century, Freestanding



3. High Rise, 21st Century



4. Mid Rise, Early 20th Century, Tower



This part of Houston is characterized by historic buildings, in a mixture of styles. There are quite some residential buildings in this part of Downtown. The historic facades make it feel like a neighborhood, despite just a few blocks away. Closer to the bayou there are remnants of the area's industrial history. Nevertheless, new development also found its way here, mostly as high rise apartment towers and parking garages.

E | THEATHER DISTRICT DOWNTOWN

1. Theaters, Unique Buildings, Mid Rise



2. Mid Rise Early 20th Century Tower



3. High Rise 21st Century Tower



Fig. 99 | Jones Hall for the Performing Arts (1966) at Luisiana Street (Theater District Houston., n.d.).

Fig. 100 | The Lancaster Hotel (1926) at Texas Ave (The Lancaster Hotel, 2015).

Fig. 101 | Market Square Tower (2017) at Preston Street (Market Square Tower, n.d.)

The theater district contains entertainment complexes, restaurants, movies, plazas, and parks. More than two million people visit this district annually; resulting into many parking garages as well. Houston is recognized as an important city for contemporary visual arts. In addition to this, residential towers recently found their way into these districts.

F | CIVIC DISTRICT DOWNTOWN

1. High Rise Monumental



2. Mid Rise 20th Century Tower



3. Low Rise Early 20th Century



Fig. 102 | City Hall (1939) at Bagby Street (Houstonia, 2019).

Fig. 103 | U.S. Postal Office at Smith Street (Google Maps, n.d.)

Fig. 104 | Julia Ideson Library (1926) at McKinney Street (Houston Public Library, n.d.).

The core of Houston's government is located in Downtown Civic Center. It is home to many events and festivals, as well as Houston Public Library's Central Library. The many parks in this district are used by residents for many activities.

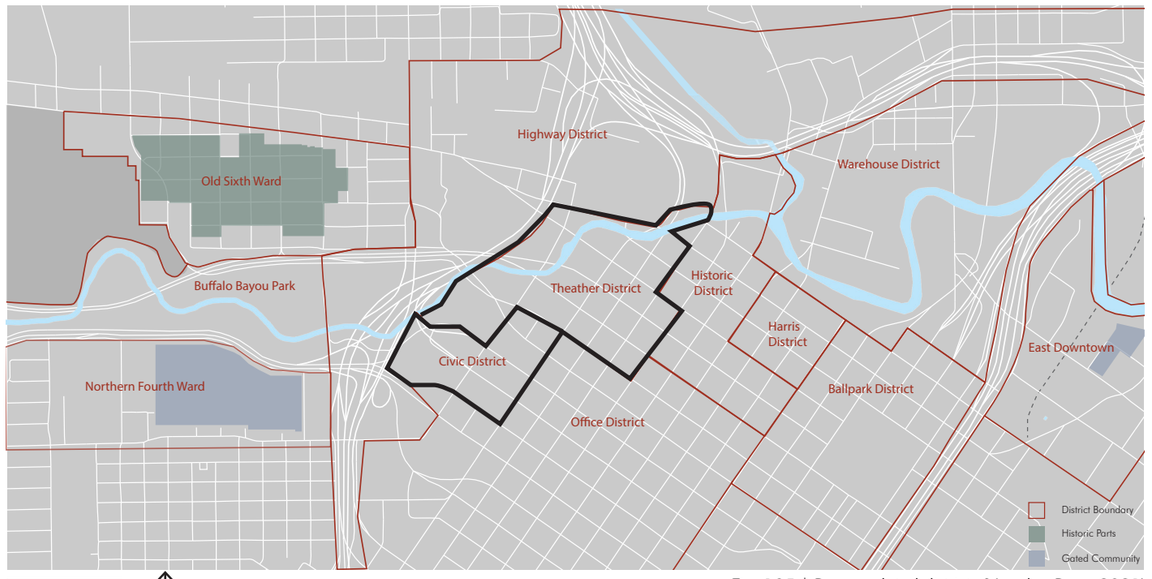


Fig. 105 | Bayou related districts (Van den Berg, 2021).

G | HARRIS DISTRICT DOWNTOWN

1. Mid Rise Neo-Classical



2. Mid Rise Mid 20th Century



3. High Rise Neo-Classical



Fig. 106 | Harris County Courthouse (1910) at Fannin Street, neo-classical design (courthouselover, 2016).

Fig. 107 | Harris County Juvenile Detention Center (1951) at Congress Street (Satterfield & Pontikes Construction, n.d.)

Fig. 108 | Harris County Civil Courthouse (2008) at Caroline Street (PGAL, 2008).

Fig. 109 | National Biscuit Company Building (1910) at Chenevert Street, now renovated into apartments (Google Maps, n.d.)

Fig. 110 | Sanction Centre at Commerce Street (Google Maps, n.d.)

Fig. 111 | Minute Maid Park (2000) at Crawford Street (StadiumPage, n.d.)

Fig. 112 | Jackson St . The Majority of the blocks in this district are open parking lots (Google Maps, n.d.)

H | BALLPARK DISTRICT DOWNTOWN

1. Mid Rise Early 20th Century



2. Low Rise Mid 20th Century



3. Baseball Stadium



4. Open Parking Lots



Harris County, home to over 4 million residents, is the most populous county in Texas. Its county seat is Houston and the core of the Harris County government resides in the Harris County District in Downtown. Thousands of Houstonians come to the Downtown campus daily for jury duty or other legal reasons; for these reasons there are many parking garages, but also causes functional homogeneity.

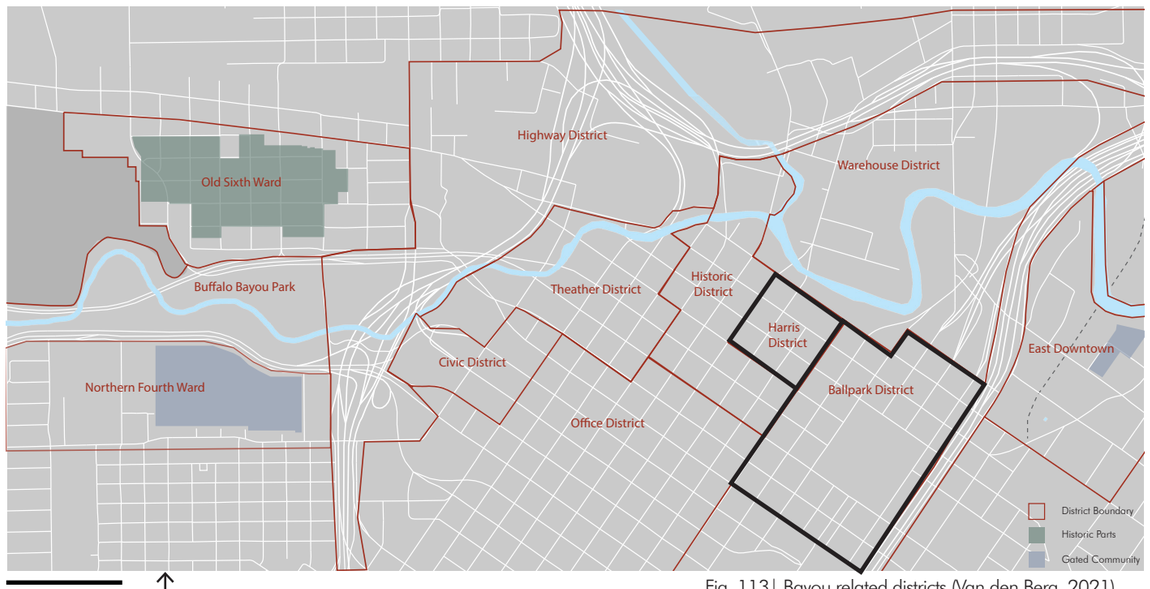


Fig. 113| Bayou related districts (Van den Berg, 2021).

The heart of the ballpark district is the Minute Maid Park, a baseball stadium located in the old Union Station with vintage features. Surrounding the ballpark is an array of restaurants and old warehouse buildings that have been converted to lofts and office space, as well as new residential properties. Because of the baseball stadium the majority of this district is dedicated to parking, making it a low density area.

I | NORTHERN FOURTH WARD

1. Low Rise Mid 20th Century Terraced Houses



2. Mid Rise 21st Century Apartment Blocks



3. Low Rise 21st Century Town House



Fig. 114 | Bayou Oak Vista Dr inside the Historic Oaks gated community (Houston Housing Authority, n.d.).

Fig. 115 | Gillette Street (Google Maps, n.d.)

Fig. 116 | Dallas Street; these homes are located within the gated community (Google Maps, n.d.)

Fig. 117 | Marquis Lofts (2001) on Sabine Street (Google Maps, n.d.)

Fig. 118 | Former Downtown Post Office (1962) at Franklin Street (CBRE, n.d.).

Fig. 119 | The city's Green Resource Center (1920), renovated from a former rice warehouse to offices (Google Maps, n.d.)

J | HIGHWAY DISTRICT

1. Mid Rise 21st Century Apartment Block



2. Mid Rise 20th Century Offices



3. Mid Rise Early 20th Century Warehouse



This part of the fourth ward is home to a large gated community: Historic Oaks of Allen Parkway Village. Built between 1940-2015, it contains a mixture of apartment blocks and townhouses. Revitalization efforts resulted in a 500-unit complex. Surrounding this gated community is a mixture between 21st century apartment blocks and small scale amenities.

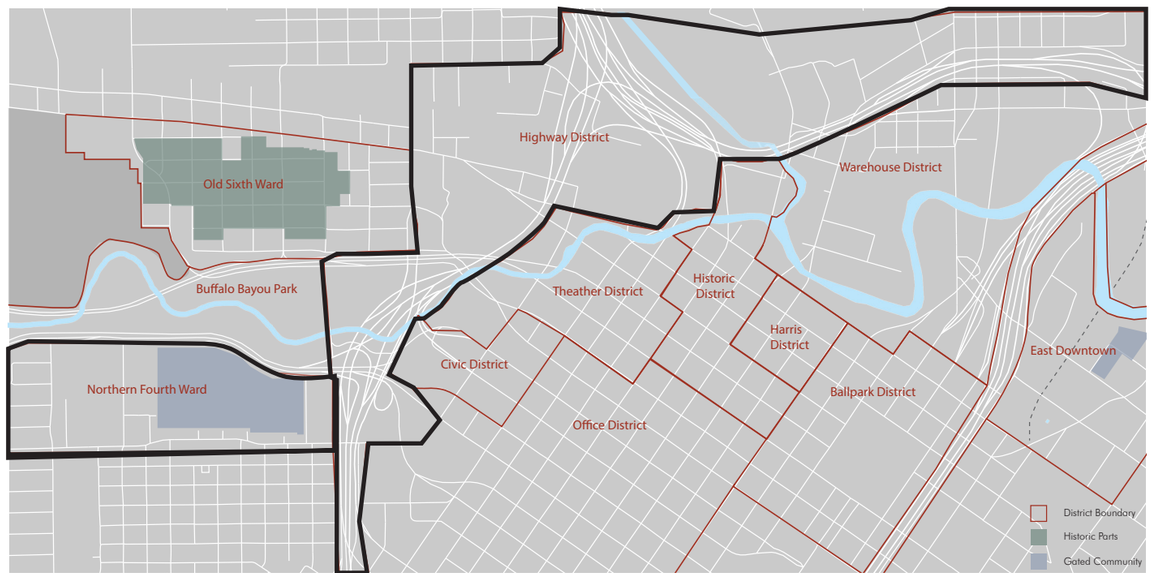


Fig. 120 | Bayou related districts (Van den Berg, 2021).

The defining characteristic of this area is the I-45 and the I-10. While individual buildings can be of good quality, the overall quality of public space is quite low and it is not a place to stay. This district is home to warehouses, industry and offices, and you won't cross its path unless you need to use its services. In more recent years, renovation of old warehouses resulted in apartment buildings next to the highway.



Fig. 121 | Riverbanks Buffalo Bayou (Van den Berg, 2021).

Landscape architect Arthur Coleman Comey, called the Buffalo Bayou as the focal point for Houston's development and livability:
"...the backbone of a park system for Houston will naturally be its bayou or creek valleys, which readily lend themselves to 'parking', and cannot so advantageously be used for any other purpose. These valleys intersect the city in such a way as to furnish opportunity for parks of unusual value within a comparatively short distance of most residential areas..."
Arthur Coleman Comey, Landscape Architect, quote from Planning Report of 1913 for the Houston Park Commission.

When looking at the current riverbanks, they are fragmented, with no continuous public space or riparian area from one side of Downtown to the other. On page 128 these riverbanks are further analyzed.



Fig. 122 | Natural riverbanks of the Buffalo Bayou in 1908 (Raphael Tuck & Sons, 1908).



Fig. 123 | Paved over riverbanks of the Buffalo Bayou in 2019 (Clemens, 2019).

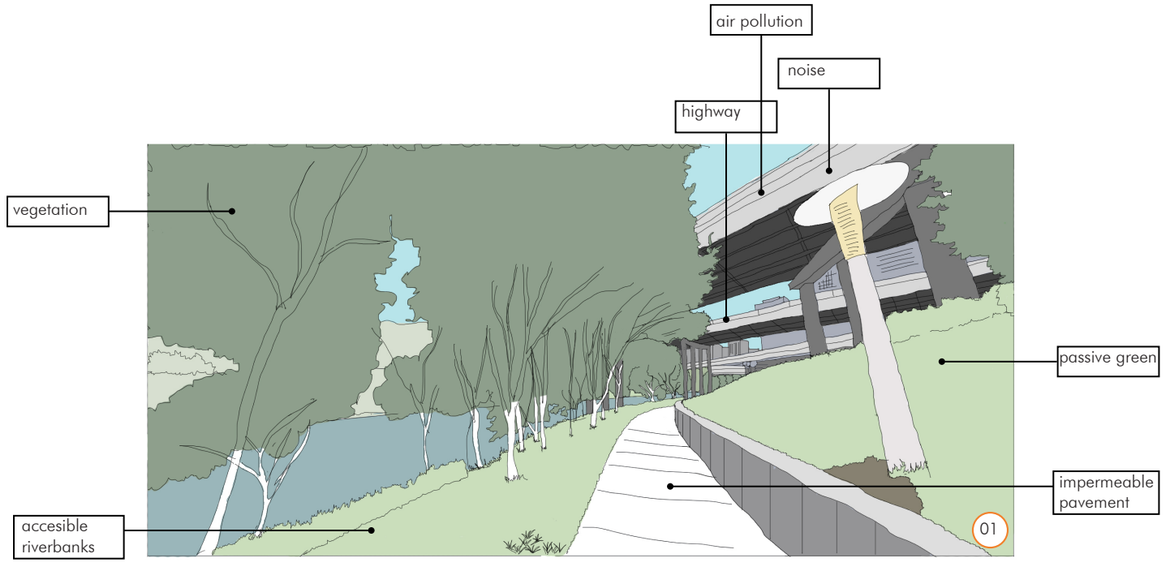


Fig. 124 | Urban green riverbanks (Van den Berg, 2021).

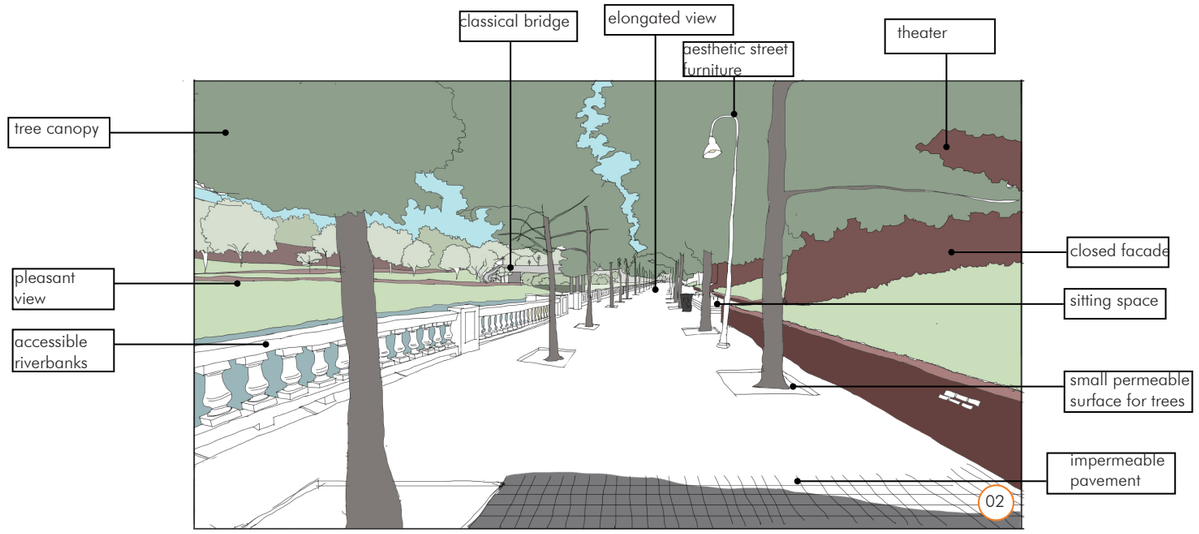


Fig. 126 | Urban riverbanks (Van den Berg, 2021).

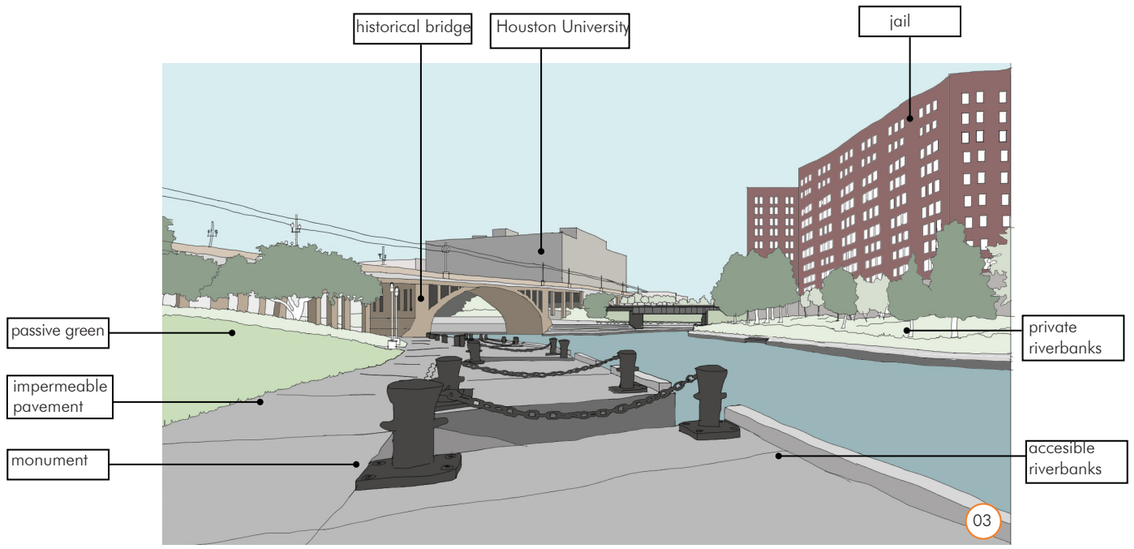


Fig. 125 | Historic riverbanks (Van den Berg, 2021).

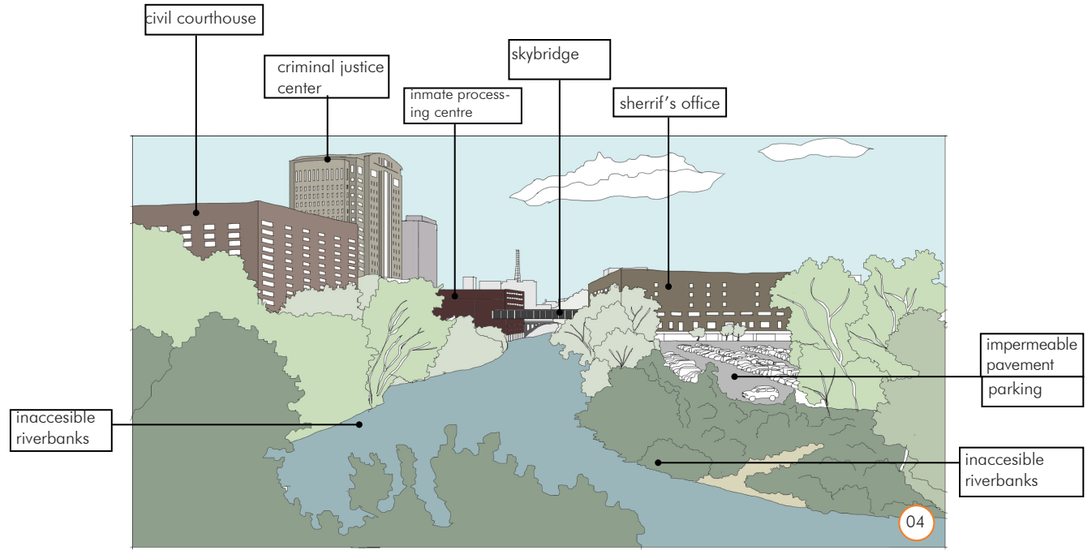


Fig. 127| Inaccessible green riverbanks (Van den Berg, 2021).

BUFFALO BAYOU BRIDGES

Until 1842 there was no bridge across the Buffalo Bayou. There was no need for one, because north of Downtown in those days contained only scant settlement. But after some years the first street at the foot of Preston Street was built, which also allowed farmers to travel faster with their produce. Nowadays Downtown Houston has 16 highway bridges, 17 car focused bridges, and only 2 pedestrian/bicycle only bridges. The oldest bridge still in use dates back to 1914, while the newest addition to Downtown's bridges will be finished in 2020.

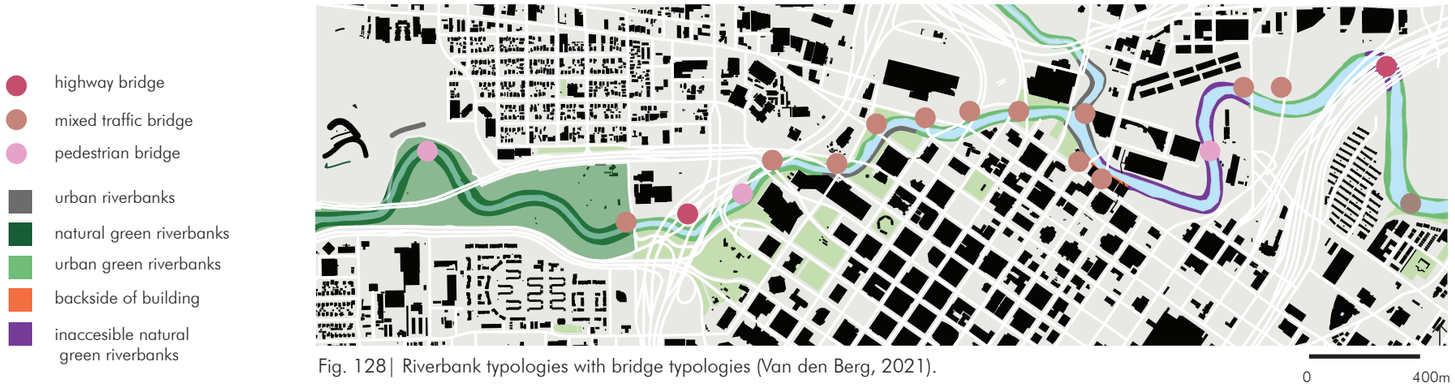


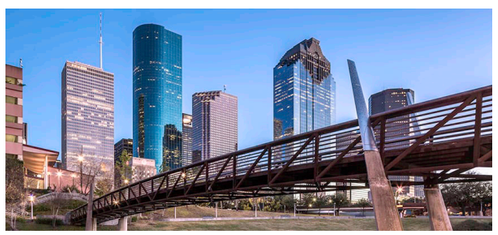
Fig. 128| Riverbank typologies with bridge typologies (Van den Berg, 2021).



1| Sabine Street Bridge (1924). The bridge is still in service today and handles approximately 1,100 in average daily traffic.



2 | Highway junction west of Downtown. Eight bridges cross the Buffalo Bayou, including the I-45.



3| Hobby Centre Pedestrian Bridge (2011). The pedestrian infrastructure of inner Houston is starting to improve in recent years. It allows pedestrian to acces Buffalo Bayou Park from Downtown, without having to cross any busy streets.



4| Capitol Street Bridge and Rusk Street Bridge. These bridges pass underneath the highway junction, and over the Buffalo Bayou Hike and Bike trail. They are quite similar to the bridges on Memorial Drive and Prairie Street.



5| Preston Street Bridge, similar in style to Congress Street Bridge.



6| Smith Street Bridge (1925), similar in style to N Milam Street and Travis Street.



7| Main Street Bridge (1914). Concrete arch bridge over Buffalo Bayou on Main Street in Houston, also containing a tramline.



8 | Fannin Street Bridge.



9| San Jacinto Street Bridge (1914), a concrete arch bridge. The bridge is still in service today and handles approximately 6,600 in average daily traffic.



10| Heights Bike Trail - Buffalo Bayou Bridge. One of the few pedestrian only bridge in Downtown Houston. Originally part of theold Galveston, Houston and Henderson Railroad line, it was converted into a hike and bike trail.



11| McKee Street Bridge (1932). This unique bridge design was a direct result of the challenge to create a bridge that could not only accommodate small watercraft navigating the bayou, but also adapt to the sharp angle of the Buffalo Bayou.



12 | Elysian Street (2020). The newest addition to Downtown's bridges.



13 | Highway junction East of Downtown. Eight bridges cross the Buffalo Bayou, including the I-69.



14 | Train Bridge.

3.7 ANALYSIS CONCLUSIONS

Inhabitation and Land Cover

Grid structure	The grid streets were very overdimensioned for the time they were built and were based on the size of cattle transporting produce; yet these dimensions became very useful for the rapidly growing poplation and the introduction of the car.
Urban sprawl	The rapid development, together with the lack of proper zoning resultes in Houston promoting fast urban dynamics (only regulated by municipal policies), which will probably continue in the near future due to an expected population increase.
Functional diversity	There are parts with functional homogeneity, which has negative effects on resiliency to disturbances such as floods.
Typologies	Diverse, but unbalanced. New development and abandoned buildings sometimes reside on the same street corner.
Public space	Availability of public space is unevenly distributed across the project area. It tends to be situated on the west side of Downtown, leaving other parts with almost complete impermeable surfaces.
Riverbank quality	Inconsistent quality of the Buffalo Bayou corridor causes fragmentation of the riparian zone, as well as a discontinued public space.

Infrastructure Networks

Car infrastructure	The fact that Houston is a car dependent city is visible on all aspects of the urban fabric.
Walk & Bike infrastructure	Still severely underdeveloped in comparison with the car; yet positive initiatives are being made, such as the construction of pedestrian only bridges and hike&bike trails in the city centre.
Public Transit	Heavily concentrated in Downtown, with bus and tram. Further away from the centre availability of those rapidly decreases.
Green infrastructure	Fragmentation of parks, with no connections between them, decreasing biodiversity. There is potential for revitalizing neglected parks.

Soils, Water, and Biodiversity

Soils	Mainly clay and loam based, adding impermeable conditions because it does not allow rainwater to drain well, and influences the choice of vegetation due to high and fluctuating water table
Climate change	The frequency Hurricanes per year has been rising for the last century; this will cause increased precipitation, resulting in more and heavier floods.
Flood vulnerability	A significant part of the project site is part of the 100yr and 500yr floodplain; however, recent storms have pointed out that available floodplain maps are not always completely accurate, as floods (with heavy flood damage) also occur outside those floodplains.
Loss of biodiversity	Disappearing prairies made room for a concrete jungle, and many invasive species endanger the remainder of the native flora and fauna of the prairielands and bayou wilderness.
U.S. Watermanagement	The city of Houston could take a much stronger role in development regulation and floodplain policy. It is important to start discussion about the existing policy issues and the changes that are necessary an desirable, with both public and private parties involved.

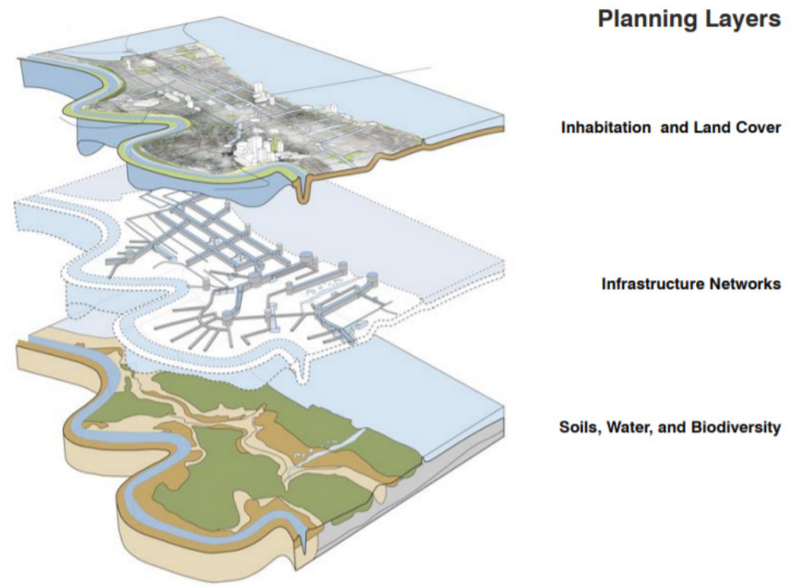


Fig. 129| Proposed planning layers (Waggoner & Ball Architects, (2013).

4 SCENARIOS

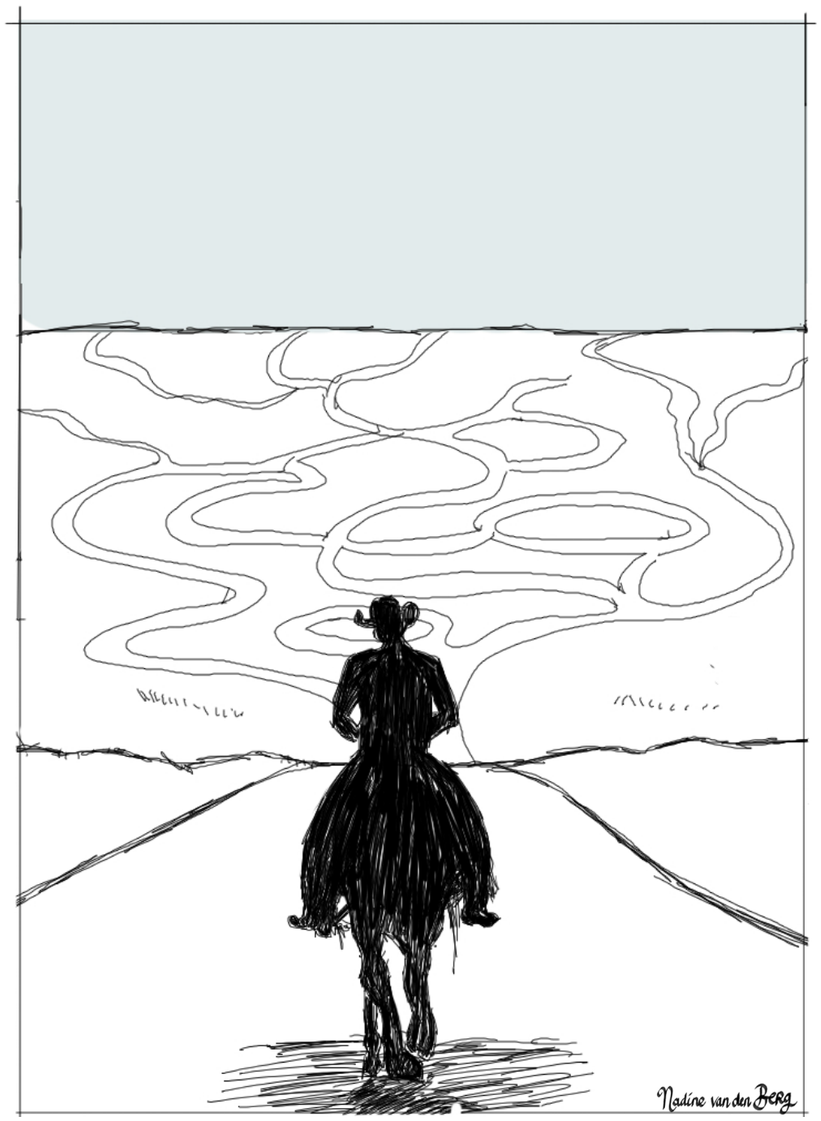


Fig. 130 | What could be the way forward? (Van den Berg, 2021).

THINKING THE UNTHINKABLE

The idea of scenarios was first used by American futurologist Herman Kahn in the 1950s. By using several different scenarios, he broadens thoughts about the future and provides the means to arrive at robust conclusions. By thinking the unthinkable, an urban designer can include creative but dire scenarios in their design process. Additionally, scenarios offer a means of dealing with critical issues of innovation, reflexivity and framing in analysing change in socio-economic systems; data relationships are not enough to foresee the future, because drivers of change in social systems are both multiple and unstable (Berkhout and Hertin, 2002).

Thinking about longer term possibilities and directions can help anticipate the unexpected. An uncertain future asks for support to derive potential futures, including issues of possibility, plausibility, and desirability (Banister & Hickman, 2012). This thesis develops three examples of potential scenarios, and then contextualizes them with local elements specific to the site. The three scenario examples used in this thesis are called dystopian, restorative, and utopian, and their key factors are further described in the matrix on p.140. These potential futures illustrate the effects on the city if the current trends remain unchanged, are adapted, or are completly redefined. Together, they show the strong need for action and adaptation in order to create a livable city in the future.

There are different types of scenario approaches that use different elements to customise the process for a particular situation (Banister & Hickman, 2012). This thesis uses a combination of the exploratory approach and the backcasting approach.

The main aim of the explanatory approach is to be challenging and to trigger new thinking (Banister & Hickman, 2012). It tends to be trend breaking and shape varied futures. The effects of the central variables are exaggerated so that there is more space for creative design within each scenario, and each presented future develops its own narrative structure.

The main aim of the backcasting approach is to show how desirable futures can be attained, instead of futures that are likely to happen (Robinson, 1982). It involves working backwards from a particular desirable end-point to the present in order to determine the physical suiteability of that future and what measures are necessary to achieve it (Robinson, 1990).

This thesis combines an explanatory approach and a backcasting approach, by challenging new thinking and examining the means by which possible futures can be achieved by visualizing from where we might want to be, back to the present. By doing so, the perspective of the scope of human choice, strategic decisions, and desirable futures define interesting futures.

DRAWING THE UNTHINKABLE

This thesis combines the use of scenarios with persuasive visual storytelling. By doing so, a series of images of the future are constructed for desirable, feasible, and undesirable alternatives.

Providing powerful images of the future allows for space to think about alternative courses of action and keep options open to respond to the changing external environment. Scenario development provides a rich background against which it is possible to project the city's futures and how it can actively respond to pressing issues that could influence such a future. Scenarios can help to shape the future, but they do not control or predict it (Eriksson & Weber, 2006).

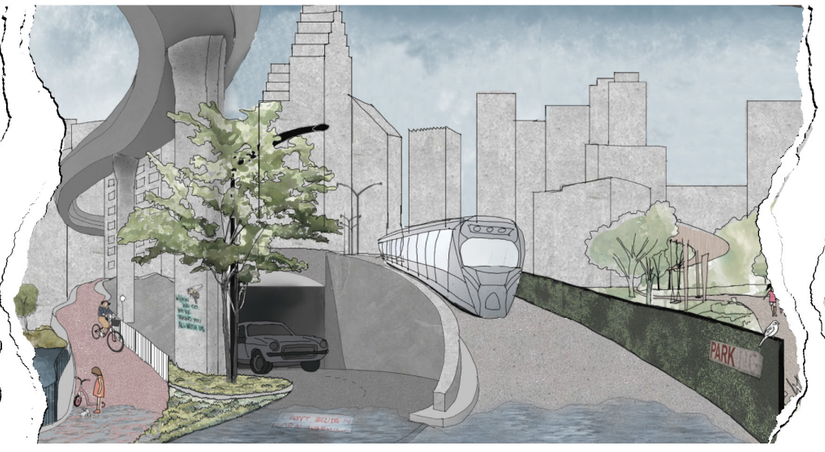
By combining scenario development with persuasive visual storytelling, it gives the opportunity to create memorable and inspirational images linked to reality, to break out of normative thinking, and to aid communication about a city's pressing issues. The images presented below are the combination of three scenarios used in this thesis and drawings based on visual storytelling. While these visualizations are unlikely to result in blueprints for a particular future, they do have the mind-stretching ability to help shape the future. This thesis addresses the intense effects of climate change, which makes it necessary to look at longer-term futures, because improving our planet takes time to be effective (Banister & Hickman, 2012).

Essentially, this combination of scenario building and persuasive visual storytelling becomes part of design research. It allows urban designers to discover the potentials and limitations that are fundamental to the site, as well as envision how the boundaries of reality can be stretched, challenged an provoked.

Fig. 131 | Developed scenarios using persuasive storytelling techniques (Van den Berg, 2021).



DYSTOPIAN



RESTORATIVE



UTOPIAN

FUTURE SCENARIO'S	1. Dystopian	2. Restorative	3. Utopian
Approach	>Coping & recovery approach	>Threshold approach	>Adaptive approach
Scenario effect	Business as usual; following conservative values	Respect the built environment, but allow for bold interventions	Nature first
Impact on resilience	In time this approach will result in major disaster, destroying the city completely.	Enables to bounce back.	Enables to bounce forward.
Societal behavior	An abandonist view; abandoning city for drier ground.	This standpoint acknowledges that it is impossible to either completely rebuild the city, or to abandon it at all.	Complete preservation of the city's footprint and proactive attitude towards building neighborhoods in innovative ways.
Effect on native landscape	Destructive/polluting effect, but also uncontrolled growth in some places.	Native landscapes are allowed to recover in designated places.	Native landscapes are allowed to fully flourish and are protected. Native landscapes are allowed to recover and become the centerpiece of cities/ neighborhoods.
Influence on flood resilience	Disaster floods.	Improved over time. Instead of repeatedly repairing hurricane damage, the city invests in adequate and far-reaching protection.	New ways of living with water that allows more room for water and thus creating a symbiotic relationship between humans and nature.
Effect on built environment/ way of living/typologies	Introducing no new typologies.	Introducing new typologies, meeting points.	Introducing innovative typologies that create new ways of living, a biophilic city. Even though the outcomes might be fictional, the design shows how a creative and imaginative research by design approach has the ability and power to communicate the needs and possibilities for a new cooperation between nature and city.
Effect on the grid structure	Continues to be a traditional grid.	Introduces new typologies, while respecting the existing buildings and grid.	Introduces new typologies, disregarding existing buildings and grid.
Result	The city as corporation.	The city as collage.	The city as organic process.
Stakeholders	National governments, corporate bodies, activists.	Public sector, national governments, legislators, urban development authorities, corporate bodies, tourism sector (hotels/tours), research/universities, IT, civil society.	Public sector, national governments, legislators, urban development authorities, corporate bodies, tourism sector (hotels/tours), research/universities, IT, civil society, the Buffalo Bayou.
Mobility	Increase in cars and fossil fuels.	Introduces sustainable transportation options, such as electric cars, extensive public transport, bike and pedestrian lanes.	Introduces new types of transportation, which may use the air (not ground) as main medium for movement.



Fig. 132 | Dystopian scenario (Chanthara, 2018)

1. Dystopian



Fig. 133 | Restorative scenario (Chuchupalova, 2020)

2. Restorative



Fig. 134 | Utopian scenario (Callebout, 2019)

3. Utopian

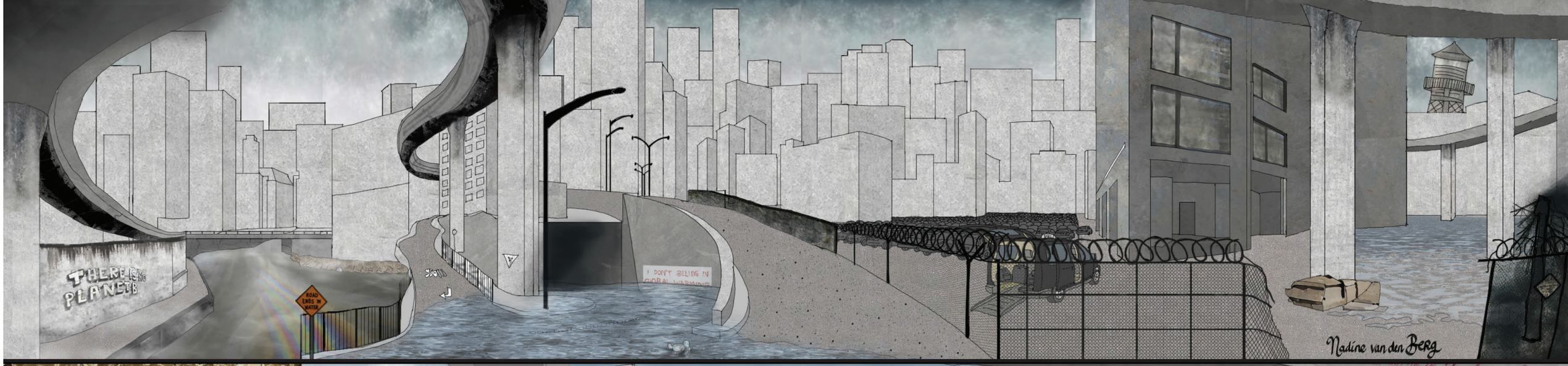
SCENARIOS VISUALIZATIONS (ON THE FOLLOWING PAGES)

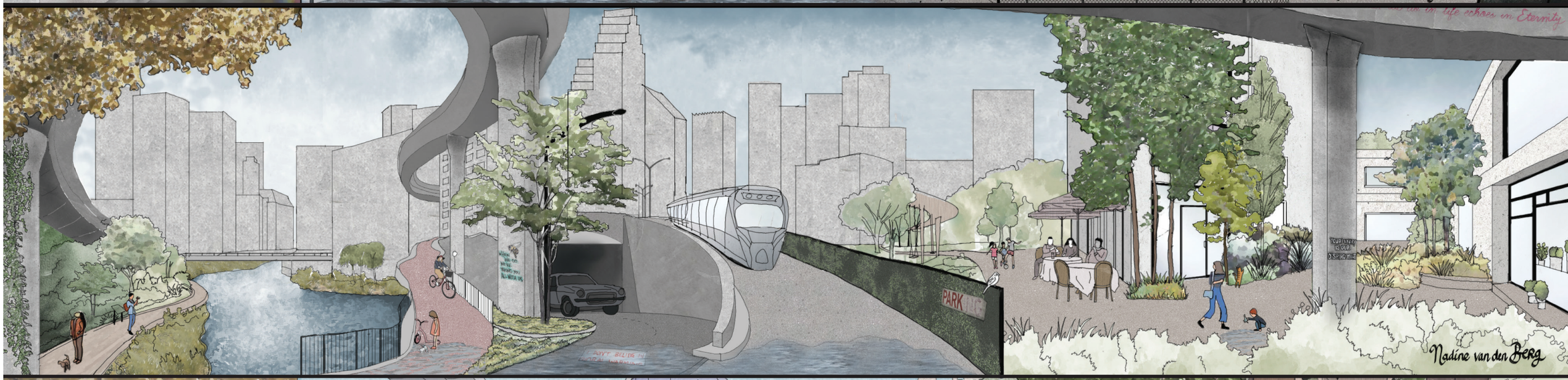
On the following pages the three scenarios are combined with persuasive visual storytelling. This approach makes it possible to stretch, challenge and provoke reality and so discover the potentials and limitations that are fundamental to the location. In addition to the visual narrative, there is a short supporting textual narrative as well. Visual stories are universal, conveying meaning and purpose that help us find commonality with others. By using visual storytelling as part of research by design it is possible to project new futures. On the one hand, to discover the potentials and limitations that are fundamental to the location, and on the other to envision how the boundaries of reality can be stretched, challenged and provoked.

DYSTOPIAN

RESTORATIVE

UTOPIAN

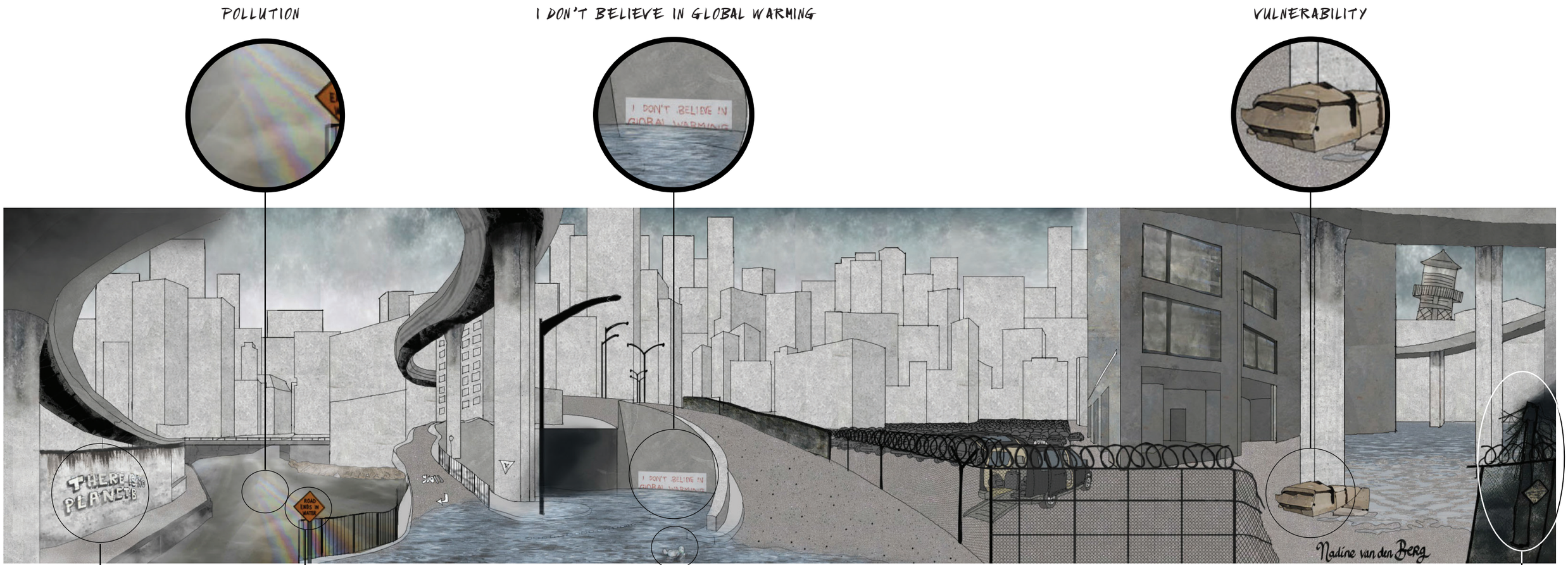






1) DYSTOPIA

"When parents dare to take their children out onto the street, you will occasionally hear a child ask with sympathetic curiosity what happened to the river. 'There is no planet B' activists write on the wall, still fighting for a healthier earth. Yet water already flows into the tunnel, flooding the words 'I don't believe in global warming'. The road is blocked so frequently, that traffic signs have to warn drivers that the road ends in water. Completely drenched in this water, lies a child's teddy bear, representing the trauma that such a future brings…"



144 Fig. 135 | Dystopian scenario (Van den Berg, 2021).

2) RESTORATIVE

"Nature in the city is encouraged, but only in confined places, trapped. Despite improvements, nature is not accessible to all. Still, the future is not all bleak. Some highways came down. Of course there was some disquiet: 'Typical government, pushing into the lives of regular people.' In order to change old habits, you need to change mindsets first. Made up from different patches, the city becomes a collage where humans have created carefully constructed parks along the river, presenting themselves to nature, but also their power over it…"

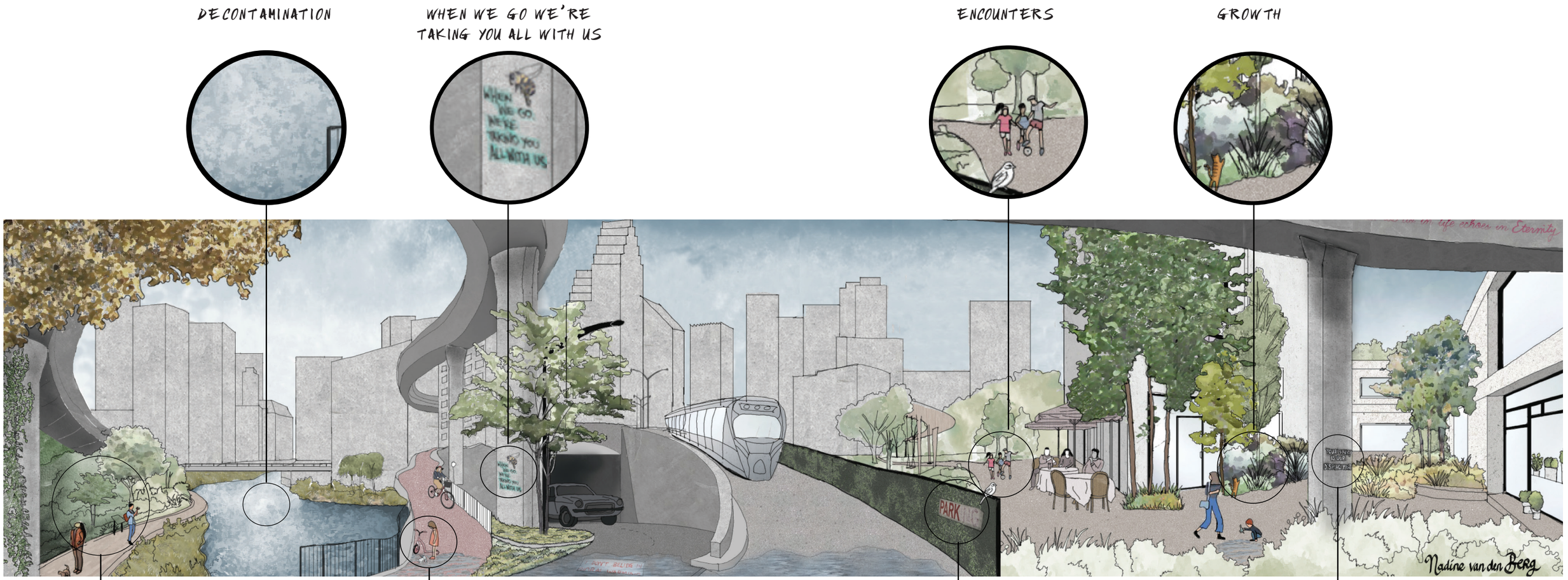


Fig. 136 | Restorative scenario (Van den Berg, 2021).

3) UTOPIA

"The wetland grasses gently flow in the rhythm of the stream. The river is wide and muddy, so people stroll on wooden structures along the water. The surrounding trees whisper their age-old tune. A great egret with its long legs firmly planted in the stream is hunting for its prey. Monarch butterflies with their familiar orange and black veins attract cheerful smiles. The city has created something crucial; and this allows a stronger than ever connectedness between humans and nature…"

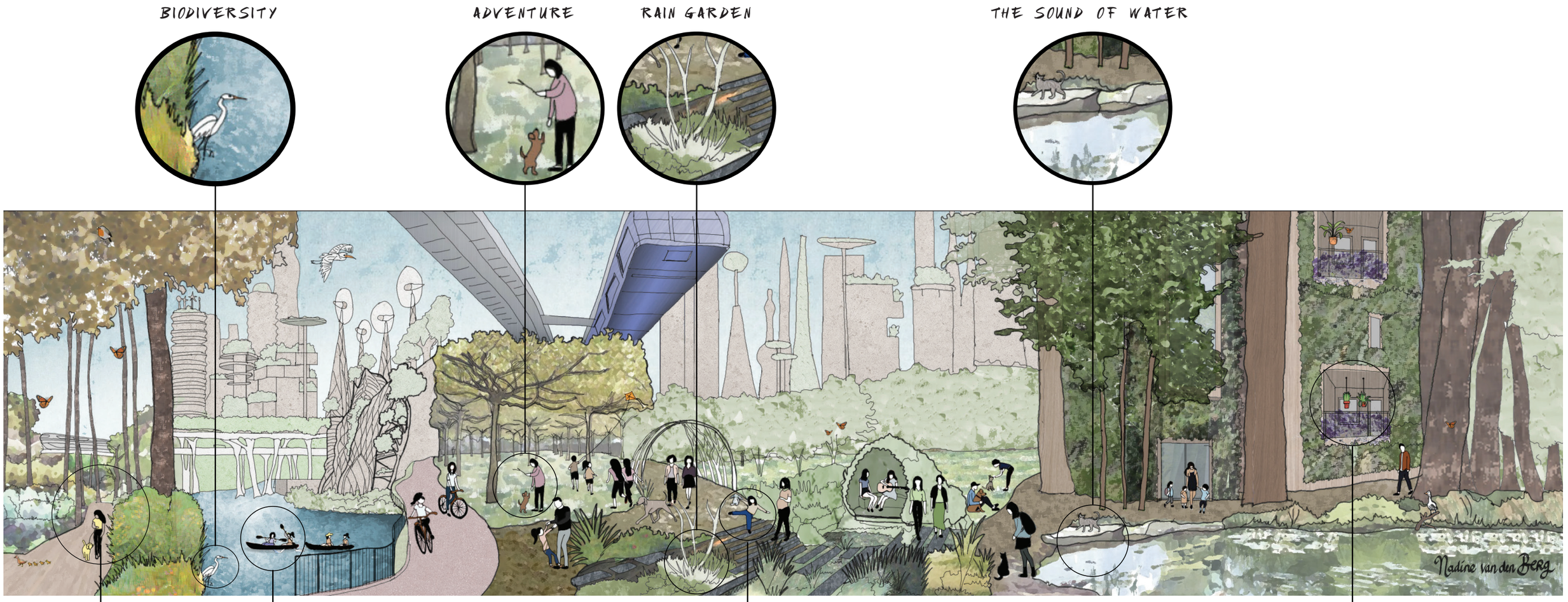


Fig. 137 | Utopian scenario (Van den Berg, 2021).

5 VISION

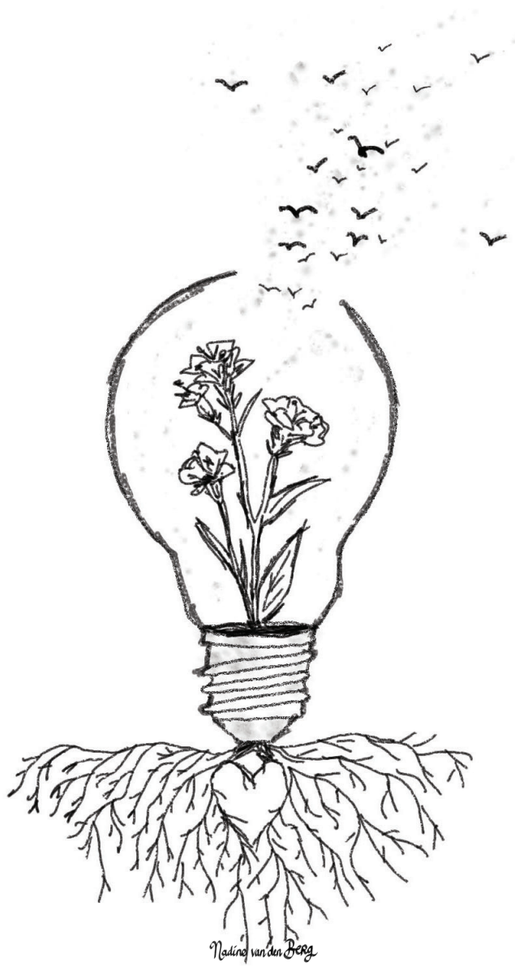


Fig. 138 | Planting Ideas (Van den Berg, 2021).



Fig. 139 | City scale vision map (Van den Berg, 2021).



Fig. 140 | Buffalo Bayou corridor scale map showing the scattered and unconnected nature that is left inside the Buffalo Bayou Downtown corridor (Van den Berg, 2021).

The vision for the Buffalo Bayou corridor is called 'From Islands to Archipelago'. The idea is to connect previously unconnected parts of the urban river corridor and make it one system.

On city scale, the Downtown Buffalo Bayou corridor is the missing link between an existing park (Buffalo Bayou Park) and a planned park (East End Buffalo Bayou). By including this part in this larger scale, a continuous riparian zone, as well as recreational zone could be realized.

On Buffalo Bayou corridor scale, the nature that is left in it is scattered, unconnected, and often does not include native vegetation. Therefore the Buffalo Bayou is used as the blue thread that links everything together. By stitching together the urban landscape, like healing a wound, there is also the opportunity to bring people closer to nature, and nature to where they are.

This vision includes the following elements:

–Utilize the bayou as a connector on city scale. Use the Buffalo Bayou corridor to activate a continuous urban river corridor by connecting the downtown part to Buffalo Bayou Park in the west and the planned East End Buffalo Bayou Park in the east. It is the blue thread that is the connector, and will turn the scattered green islands into a connected archipelago.

–Reconnect people to nature by creating accessible nature within walking distance. In addition to this, an educational nature center will stimulate people to gain more knowledge about the native flora and fauna, and different ecoregions in Harris County. The power of naming lies in the fact that when you know the names of plants and animals, you get to google them; there is amazing knowledge that you can unlock with a name.

–Stimulate an informed, flood-literate, and engaged community in order to improve flood-related problems on a smaller scale; these small scale water retention implementations will become (partially) the community's responsibility (think of maintaining bioswales).

–Create room for the Buffalo Bayou. Houston has built too close to most of their bayous inside the floodplains. It is crucial to have a healthy riparian corridor around waterways in order to preserve the natural river dynamics so the aquatic and terrestrial environment can thrive.

–Stimulate community scale within urban design by focusing on well balanced environments, as well as creating community activities (such as collective food gardens).

–Recycle unused/underused urban elements, such as parking lots, vacant lots and underused public spaces, in order to improve spatial quality and permeability.

–Create continuous connections between the old and new green spaces inside the Buffalo Bayou corridor, in order to optimize the ecological advantages.

–Realize the full potential of the Buffalo Bayou corridor in order to create an ecological, functional and scenic spine of the city, that reflects the optimistic, creative, and energetic culture of Houston.

–Include the TxDot plan to relocate part of the I-45 freeway that leaves Pierce Elevated unused, in order to improve the fragmentation of the riparian zones, as well as air and sound quality.

–Include the North Canal plan that cuts a new channel in Downtown to allow water to be rerouted in order to lessen the impact of stormwater build-up. As a result of this intervention, there will be a reduction of the water level of 0.60-1.52 m (2-5 foot) during 100 and 500 year storms. Spatially, an island is created in Downtown.

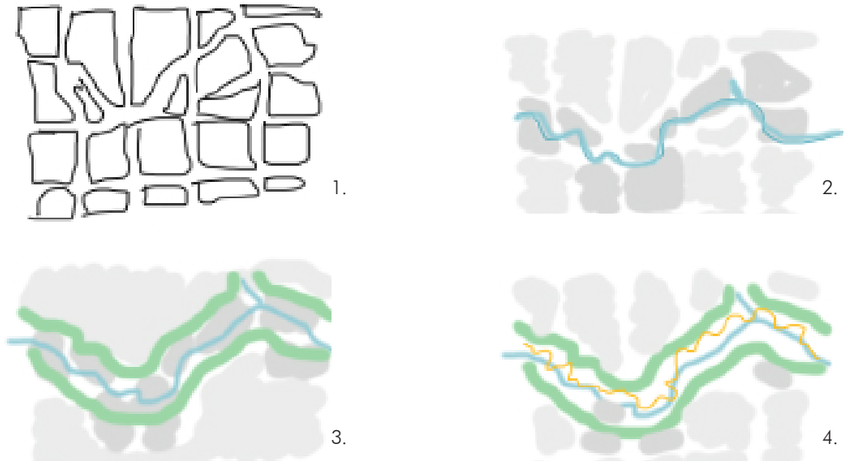


Fig. 139 | Steps in activating the Buffalo Bayou corridor (Van den Berg, 2021).
1. Unconnected islands in the urban fabric, caused by infrastructure systems.
2. The Buffalo Bayou is crossing these 'islands'.
3. Adding a green urban river corridor will connect previously unconnected neighborhoods.
4. Within the urban river corridor slow traffic infrastructure is added, including walk and bike paths.

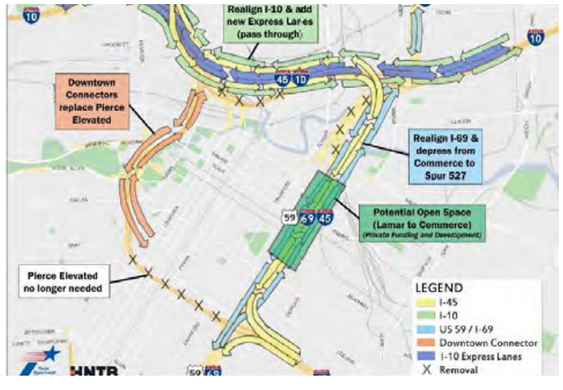


Fig. 140 | Official Plans of the improvements of the Interstate 45 along Houston Downtown (Texas Department of Traffic, 2018).

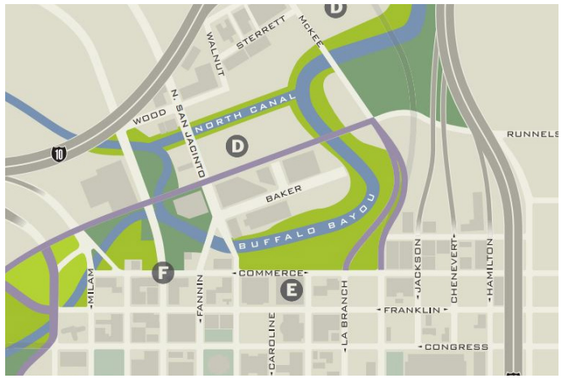
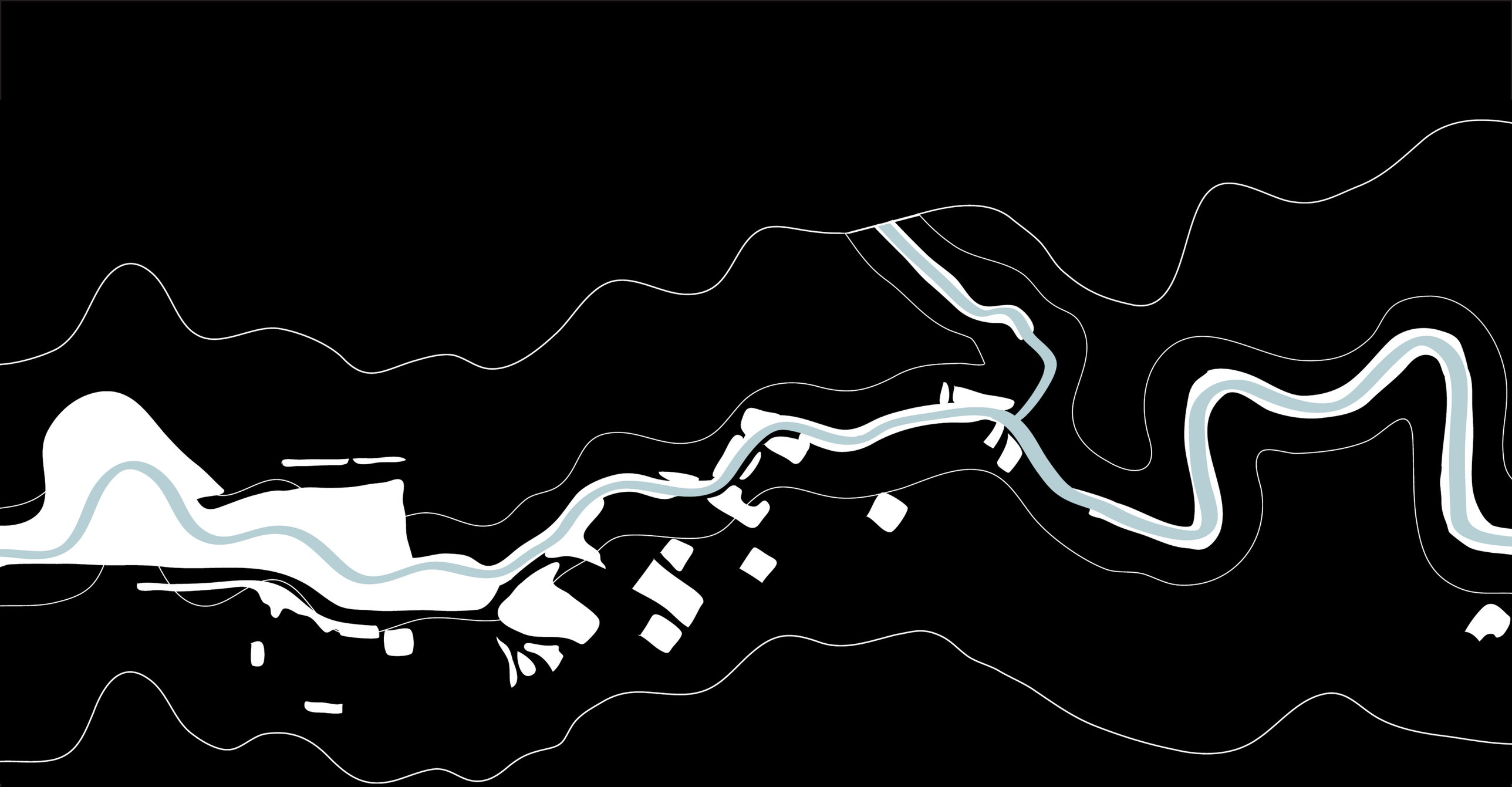


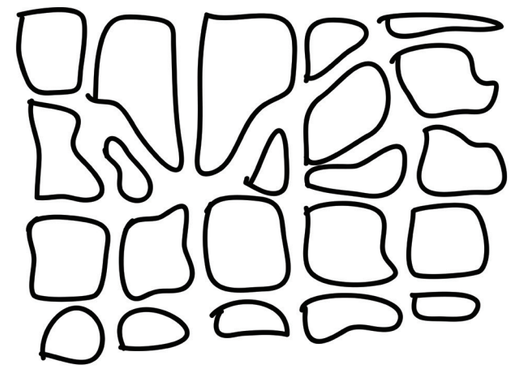
Fig. 141 | Proposed North Canal (Plan Downtown, n.d.).

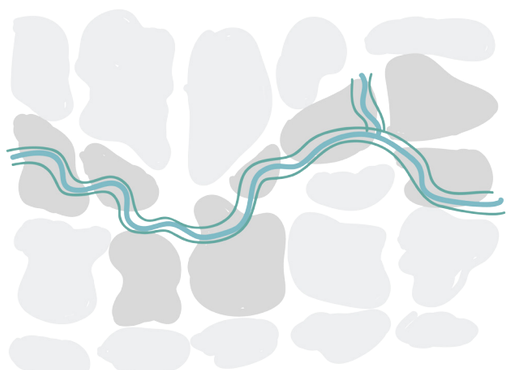


FROM ISLANDS TO ARCHIPELAGO

THE BLUE THREAD








URBAN DESIGNER
GREEN CONNECTION
Nadine van den Berg
URBAN FABRIC

VISION MAP

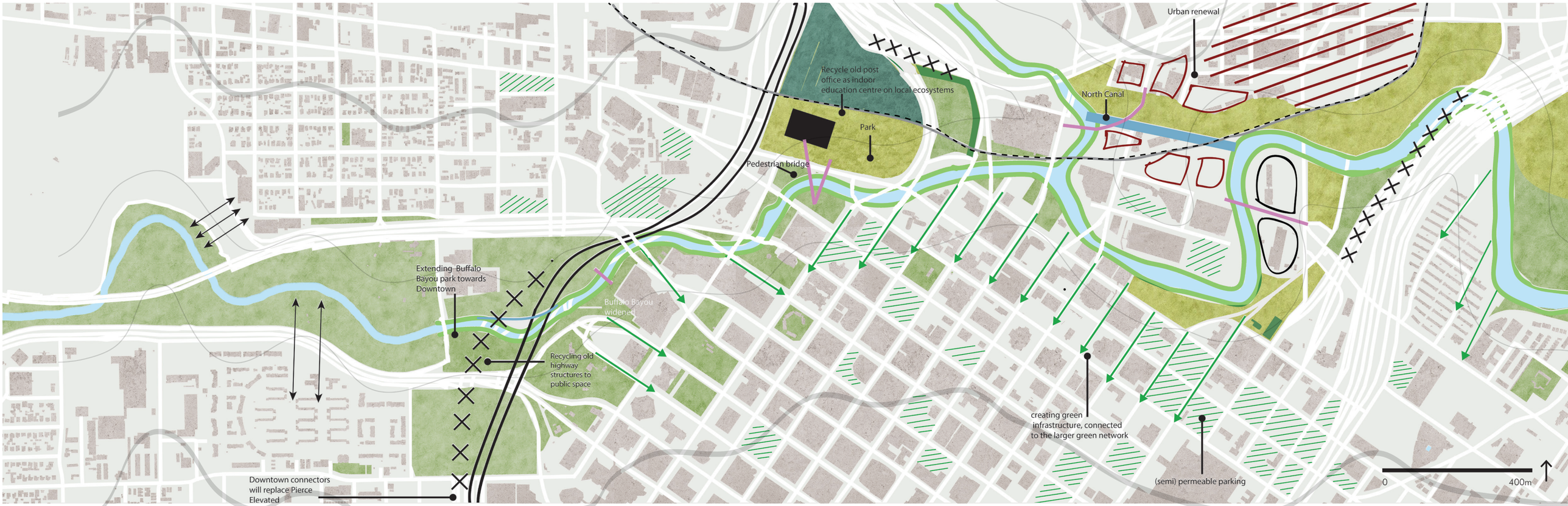


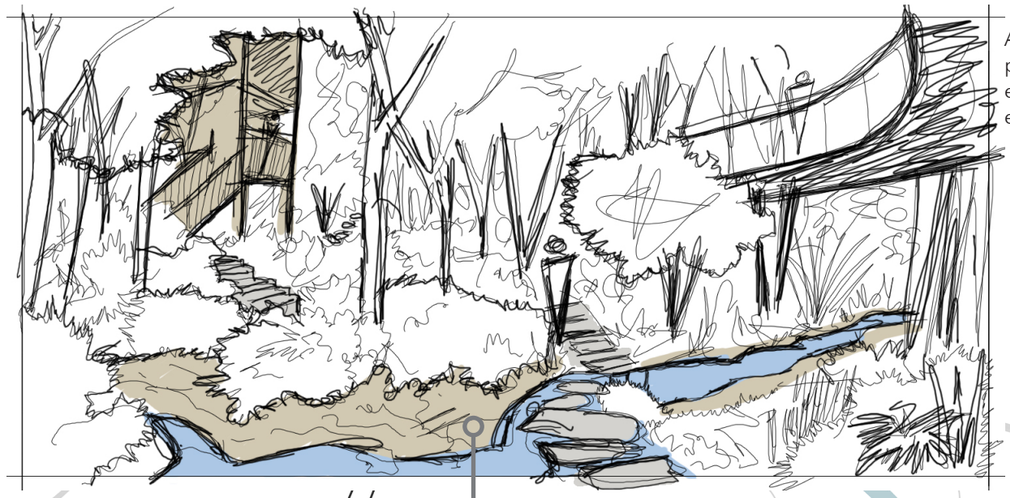
Fig. 142 | Vision map (Van den Berg, 2021).

This vision map supports the vision explained on p.152 by illustrating proposed interventions and connections in the Buffalo Bayou Downtown corridor in order to implement the 'From Islands to Archipelago' approach. The main idea is to connect previously unconnected parts of the urban river corridor and make it one system.

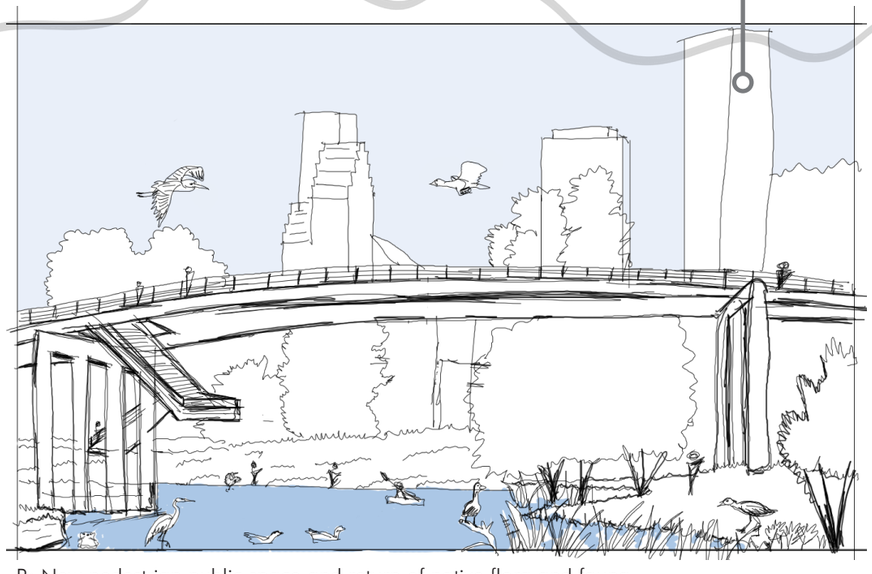
VISUALIZATIONS ALONG THE BUFFALO BAYOU

In order to clarify some of the key points of the vision (explained in the vision map on p.160) the following locations are visualized. Image A visualizes the possibility of including elements of the native ecoregion typologies of the Houston region (the woodlands, prairies, wetlands) in the form of a public park. Image B + C visualize the opportunities that the restructuring of the I-45 highway could bring for the ecosystems of the Buffalo Bayou corridor and living quality of Houston. Image D visualizes new types of building typologies to Houston like mid rise buildings with collective courtyards.

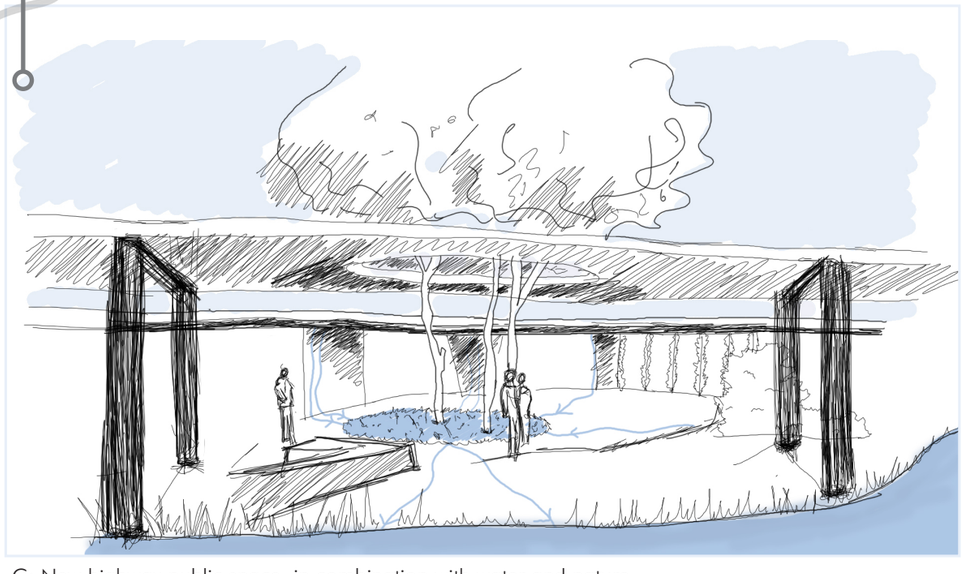
All images on spread by Van den Berg (2021).



A: The realization of a public park that includes elements of the native ecoregio of the woodlands.



B: New pedestrian public space and return of native flora and fauna.



C: New highway public space, in combination with water and nature.



D: New living typology: midrise with collective courtyards.

6 STRATEGY

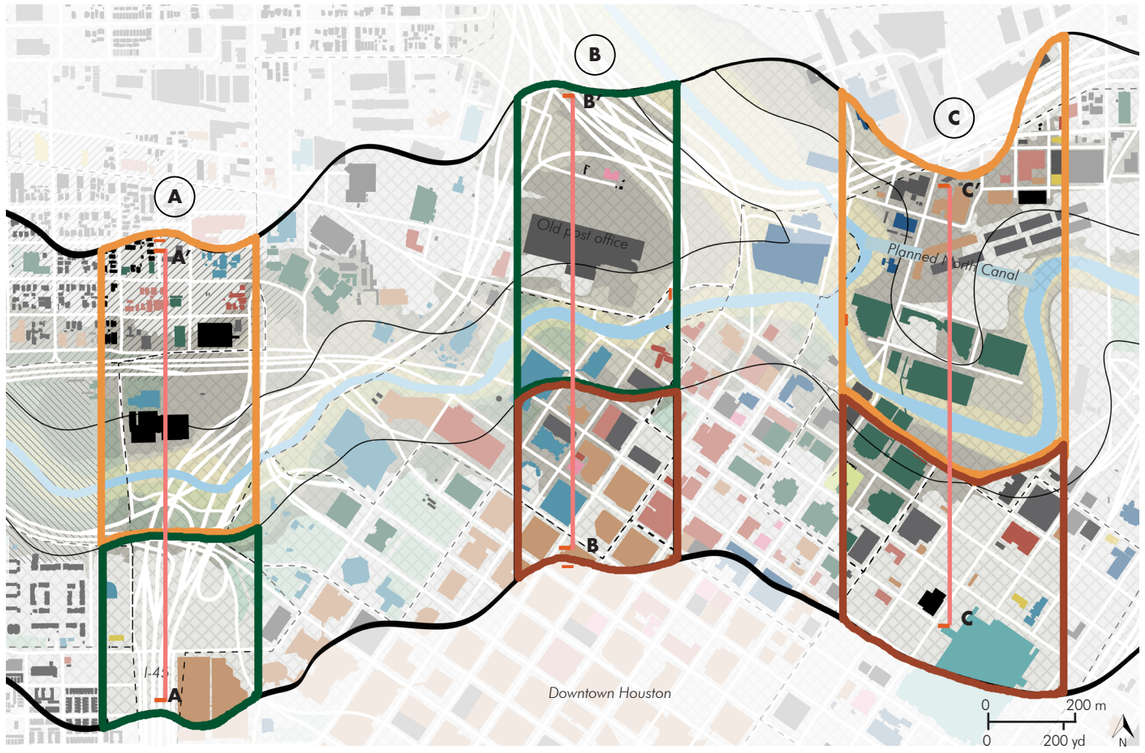


Fig. 143 | Buffalo Bayou in Downtown Houston at night (jld3 Photography/ Getty Images, 2018).

PLANNING GUIDELINES

This project takes shape as a sequence of design projects linked together by strategies about related decisions. For the Buffalo Bayou Downtown corridor, many interdependent actions need to be carried out under the authority of many different actors, and occuring over a long period of time in relation to an uncertain environment that is vulnerable to flooding.

In order to improve the current urban environment in terms of spatial quality and flood risk inside the Buffalo Bayou's river corridor, planning guidelines are created for future urban development. Three different characters are discerned within this corridor: natural, semi-urban, and urban. They differ in terms of density, permeability level, vertical level, and speed. Three representative slices are chosen for which planning guidelines are formulated. Location A: I-45 highway junction, B: Vacant post office site, C: Future North Canal Island. These planning guidelines use three different levels: stamp, block, and plot. Houston does not have any zoning laws, therefore sustainable urban development needs to be guided. These guidelines state what should be included on each level, and as a result allows freedom to be interpreted in different ways, as long as the main objective is reached. These guidelines are meant for the municipality to contribute to, and for developers to take into account.



For the sections A-A', B-B', and C-C', see p. 172-173

Fig. 144 | The three slices that contain natural, semi-urban, and urban characters (Van den Berg, 2021).

In Texas, property taxes are much higher than personal income taxes. This means that the property tax is the primary source of local government revenue in Texas, with the vast majority of public funds coming from property taxes. Taking this into account, it is important to include real estate developers in the execution of these planning guidelines; this can be done by convincing their interest, not only in environmental terms, but also improved quality of life and desirability that would interest potential buyers.

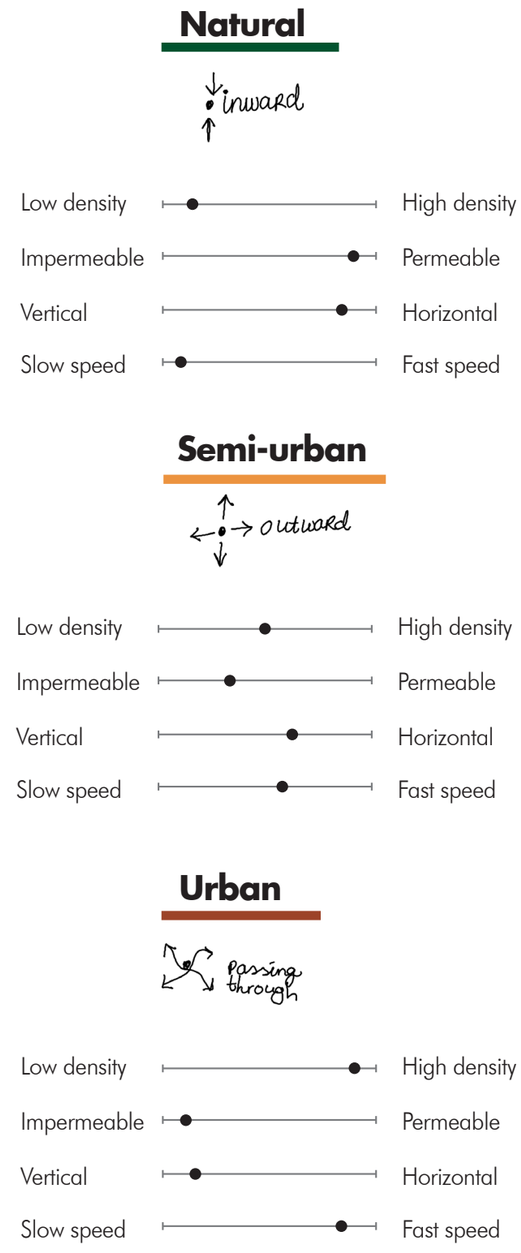


Fig. 145 | The three different characters within the urban river corridor explained (Van den Berg, 2021).

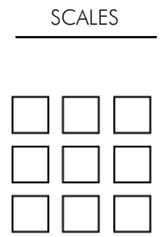


Fig. 146 | Three different scales for the guidelines (Van den Berg, 2021).

Icons on spread by Van den Berg (2021)

STAMP SCALE

NATURAL

+/- 300 x 300m area



90% of area is green space



Connect green areas



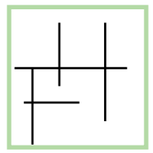
3 shared biking points



Increased native vegetation in open areas



Boardwalk paths follow rectangular grid

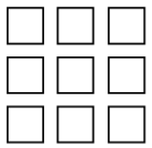


Paths adjecent to the bayou, follow the shape of it

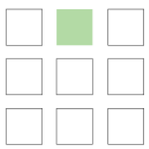


SEMI URBAN

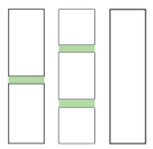
Includes 9 blocks of 3x3 grid



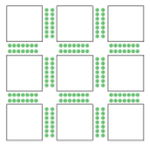
1/9 blocks is a green park



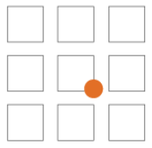
Green corridors



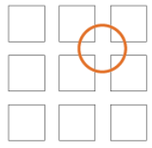
Increased tree growth in streets



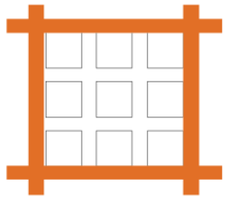
1 shared biking point



1 intersection has cut off corners for visibility



Busy main streets contour each stamp

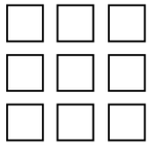


Inside streets are calmer

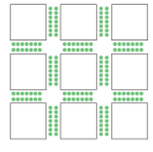


URBAN

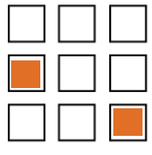
Includes 9 blocks of 3x3 grid



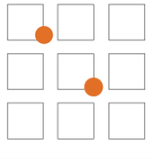
Increased tree growth in streets



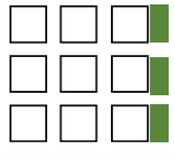
Increase of residential buildings



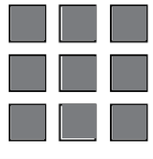
2 shared biking points



Green buffer against highway pollution



No hierarchy of the streets



Icons on spread by Van den Berg (2021)

BLOCK SCALE

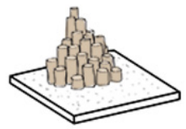
PLOT SCALE

NATURAL

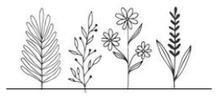
Animal sightseeing spots



Natural playgrounds



Diverse flora



Community maintenance



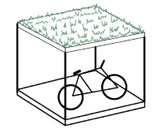
Increased meet up spaces



High porosity



Green roofs (bike shed)



Shadow by tensile structures



Shadow by trees



Open water



Seasonal design



Community food garden

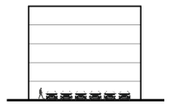


SEMI URBAN

33% open green space



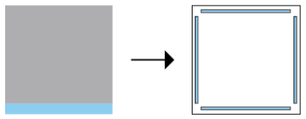
Ground floor parking



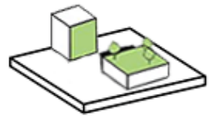
Community maintenance



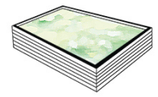
10% ditches



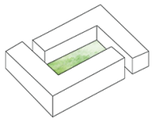
Green roofs and walls (residential)



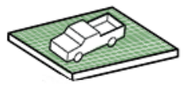
Green roofs (parking garage)



New urban typology



Create semi-permeable parking lots



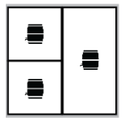
Increased meet up spaces



Shadow by trees



1 rain barrel per plot



Community food garden



Create semi-permeable parking lots



URBAN

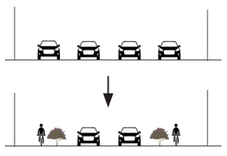
Create semi-permeable parking lots



Shadow by trees



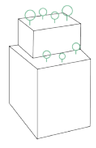
Include cyclists in street profile



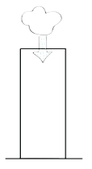
Green public transit stop



Green roof decks



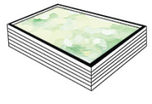
Rainwater harvest



Increased meet up spaces

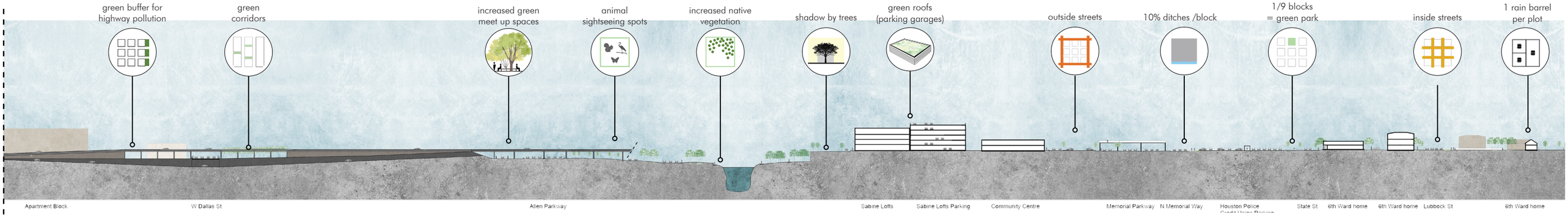


Green roofs (parking garages)

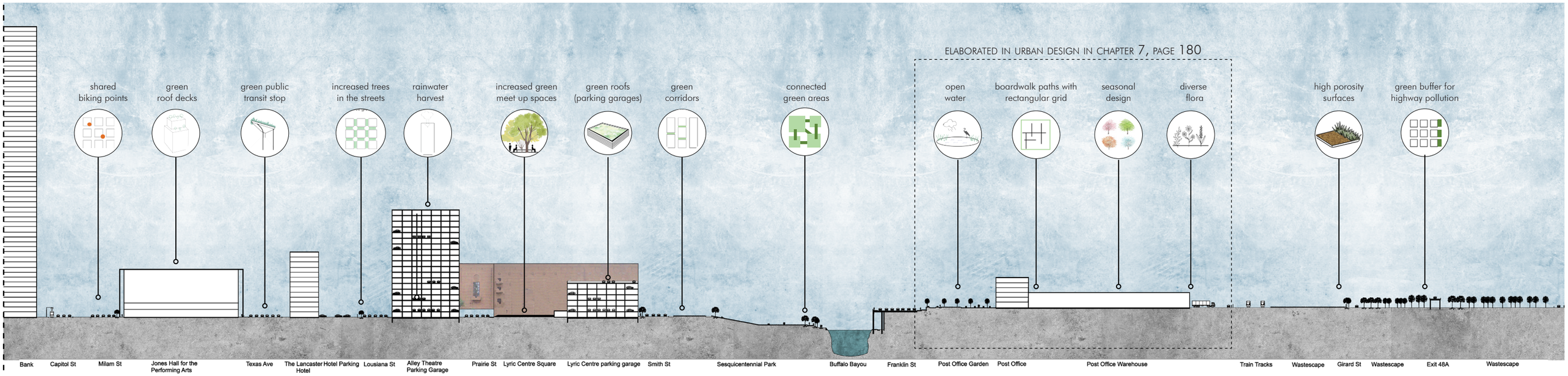


PLANNING GUIDELINES IN SPATIAL SEQUENCE SITE A, B & C

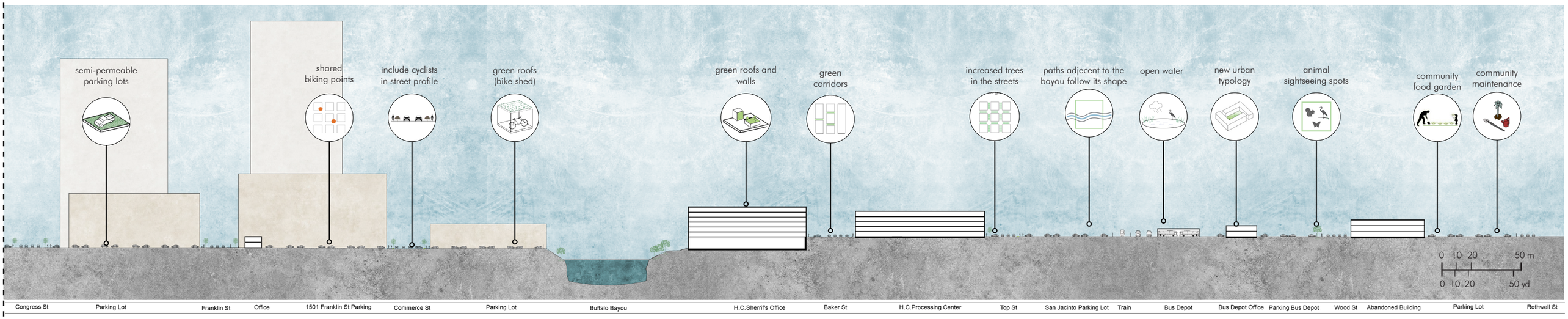
For the section map, see p.166



Section A-A'



Section B-B'



Section C-C'

THE STAKEHOLDERS INVOLVED

The local, state, and federal governmental systems are all involved in flooding to various degrees. The Harris County government has been most involved in flooding issues, with the Harris County Flood Control District (HCFCD) having primary responsibility for our flood management policies and concepts. The HCFCD is also the local sponsor that is often required for federal or state-funded projects. The Harris County Commissioners Court governs Harris County and oversees HCFCD. The Commissioners Court is administered by the county judge. There are also four commissioners, each with their own precincts (see Fig.126); they are quite powerful in their districts and have substantial budgets for road and drainage work.

The City of Houston has not exercised as much of a role in flooding matters as it could, choosing instead to often defer to the county on policy matters. The city does administer a floodplain regulatory system, as does the county outside of city boundaries. The City of Houston is responsible for storm sewer construction and street drainage. Harris County has these roles in the unincorporated area outside the boundary of any city. The city could take a much stronger role in development regulation and floodplain policy if it chooses to do so.

The federal government is very involved in flooding issues in Houston and Harris County. The Addicks and Barker reservoirs are operated by the U.S. Army Corps of Engineers. The corps is also the federal sponsor for many other flood control projects in the county. FEMA is responsible for emergency relief and the federal flood insurance program, and the Department of Housing and Urban Development helps provide disaster-related funding, including block grants that can be used for buyouts, among other things.

State government has not taken a large role in Harris County and Houston flooding issues in the recent past, and there is no doubt that the Texas Legislature could address many flood related issues such as a stronger role for state agencies in flooding oversight as well as state funding to assist in recovery and future buyouts. The Texas state government is presided over by the governor, who appoints many administrative agency boards and is the policy leader for the state. The lieutenant governor presides over the Texas Senate where he has a powerful oversight role. Additionally, Texas' numerous state senators and representatives could affect flood policy in the future.

Furthermore, there is a major role for the private sector, in addition to the public sector, in improving the flood related problems that all levels of government and the development community, as well as their engineers and lawyers, have created together. If Houston does not develop an appropriate response to its flooding crisis, a severe economic decline might follow over time. Therefore discussion is needed about the existing policy issues and the changes that are necessary and desirable.

This text is based on the essays 'Living with Houston Flooding' by Blackburn (2017) and 'Houston a Year After Harvey: Where we are and where we need to be' by Blackburn & Bedient (2018).

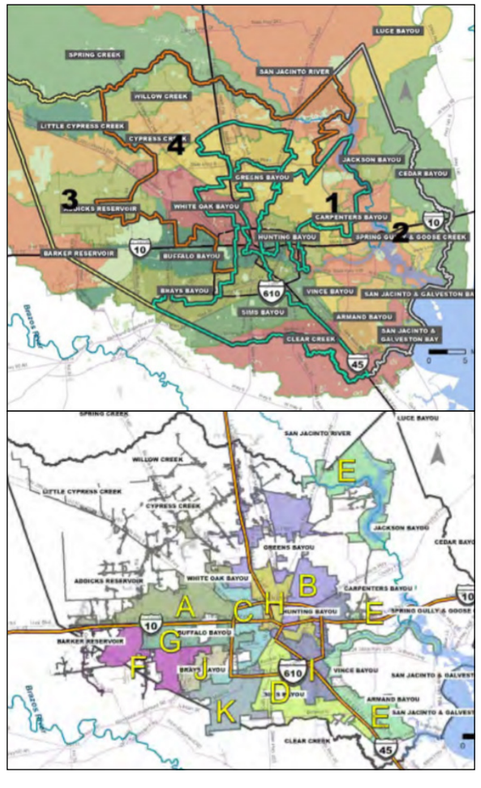


Fig. 147 | County commissioner precints and watersheds in Harris County (upper) and Houston City Council Districts and Watersheds (lower) (Walsh, 2017).

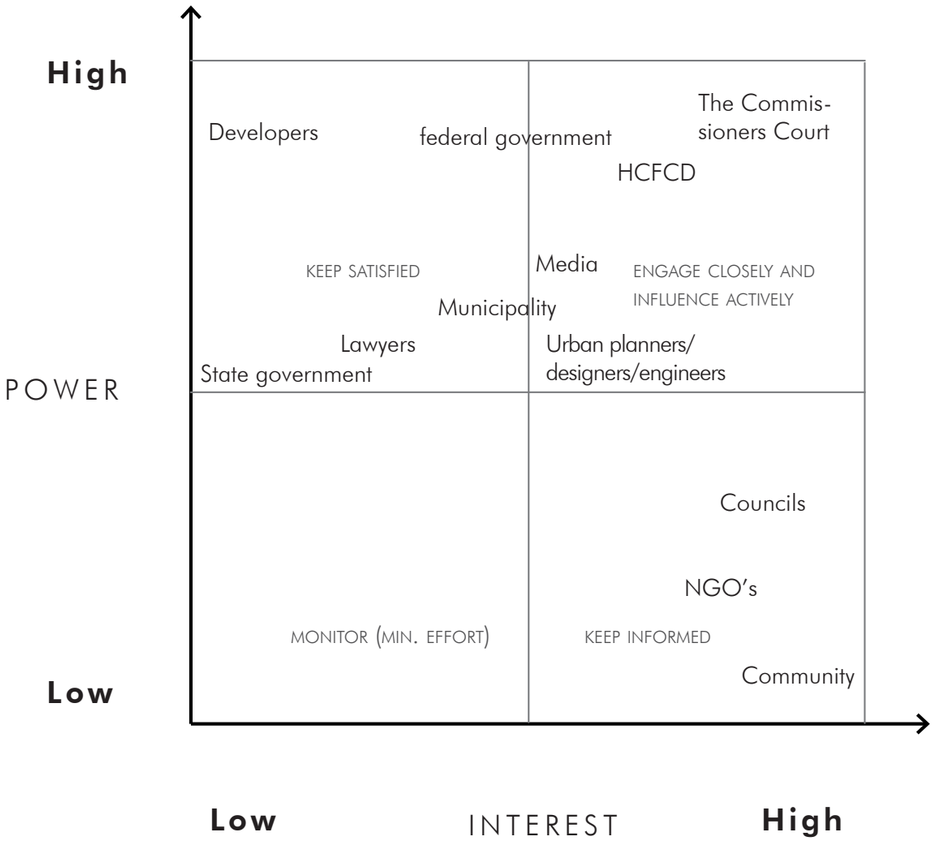


Fig. 148 | Stakeholder analysis for the project. Based on stakeholder analysis framework from Hovland (2005). Graph by Van den Berg (2021).

A stakeholder analysis is most useful when it is focused on a specific policy or topic (Schmeer, 1999). The basic ideas about this policy or the topics to be addressed will need to be specified and made concise in order to be explained to stakeholders during the process (Poolman & Mostert, 2007). Attention to stakeholders is needed throughout the process to assess and enhance political feasibility (Bryson, 2004). The matrix above identifies who the key stakeholders are in Houston, in relation to creating a flood resilient city.

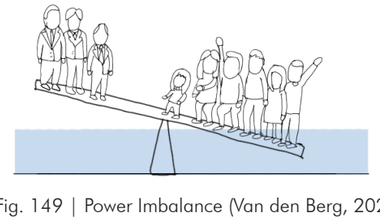


Fig. 149 | Power Imbalance (Van den Berg, 2021).

7 URBAN DESIGN

7.1 Scenario Projections
7.2 Detailed Urban Design



Fig. 150 | The Changing of Seasons
(Van den Berg, 2021).

7.1 SCENARIO PROJECTIONS

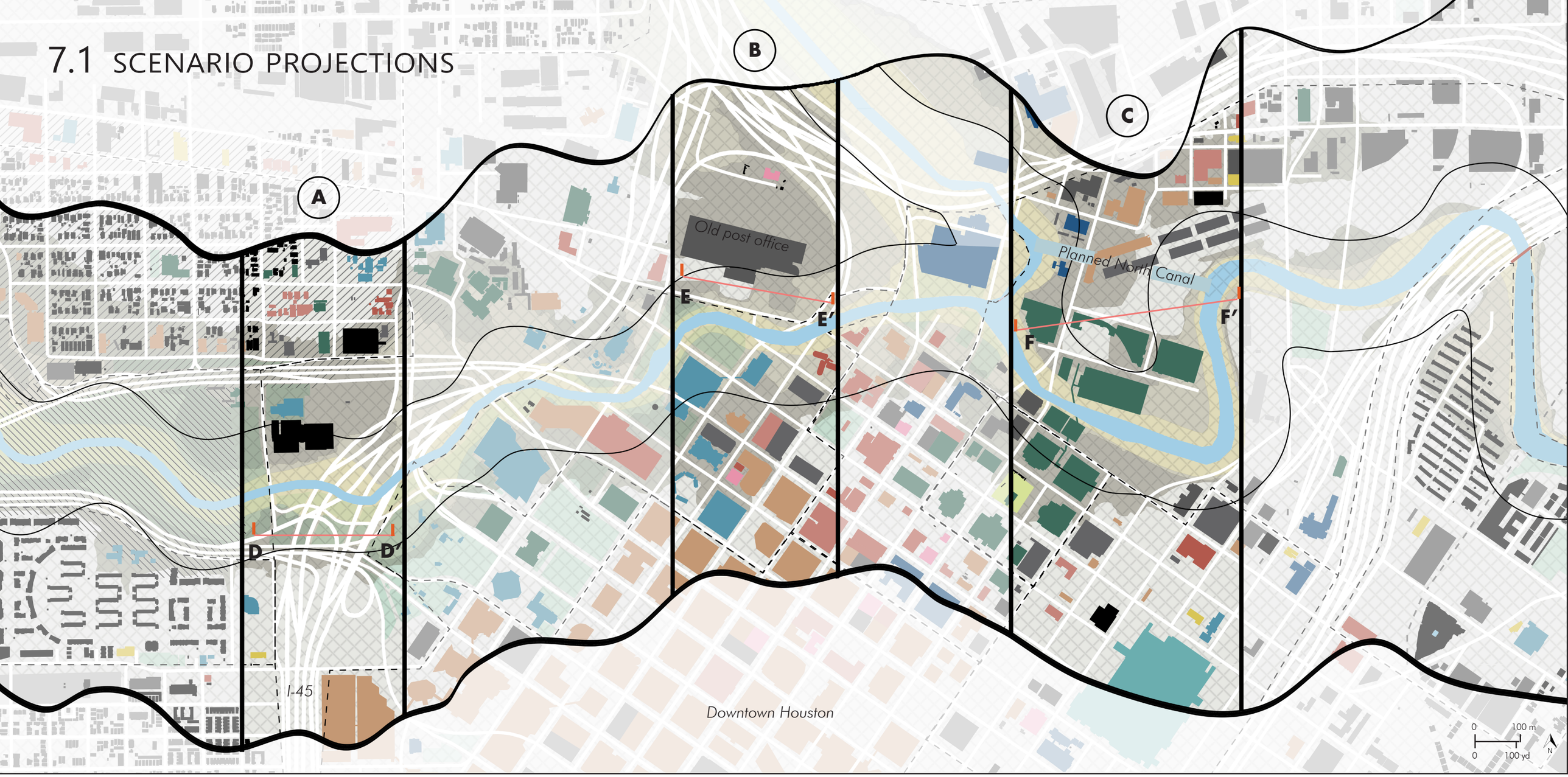


Fig. 151 | Functional Buffalo Bayou corridor map with chosen locations (Van den Berg, 2021).

In order to test the possibilities and limitations of the three scenarios (dystopian, restorative, utopian) on location, three different sites within the Buffalo Bayou corridor (that were previously used for the development of planning guidelines):
A. I-45 Highway Junction
B. Vacant Post Office
C. North Canal Island
The section locations are chosen because of their unique character, difference in functionality, and typologies connected to it. For the sections D-D', E-E', and F-F' see p. 180-185.

CURRENT SITUATION

DYSTOPIAN SITUATION

RESTORATIVE SITUATION

UTOPIAN SITUATION

0 10 m

0 10 yd

N

SECTION D–D′: I-45 HIGHWAY

Fig. 152 | Projection drawings location A (Van den Berg, 2021).

CURRENT SITUATION

DYSTOPIAN SITUATION

RESTORATIVE SITUATION

UTOPIAN SITUATION

0 10 m
0 10 yd

SECTION E–E′ : VACANT POST OFFICE

Fig. 153 | Projection drawings location B (Van den Berg, 2021).

CURRENT SITUATION

DYSTOPIAN SITUATION

RESTORATIVE SITUATION

0 10 m
0 10 yd

UTOPIAN SITUATION

SECTION F–F′ : NORTH CANAL

Fig. 154 | Projection drawings location C (Van den Berg, 2021).

7.2 DETAILED URBAN DESIGN

Design Location

Based on the scenario projections, the potentials and limitations of the site became clear, and now the next step is zooming in even further, in order to create a detailed urban design that promotes micro-climate performance and allows people to reconnect with nature inside the city. For this urban design, location B (the vacant post office) is chosen, because of the large plot (400x180m), its lack of strong connection with the Buffalo Bayou, its proximity to Downtown (which has an urban character), and the fact that it is surrounded by grey infrastructures like highways.

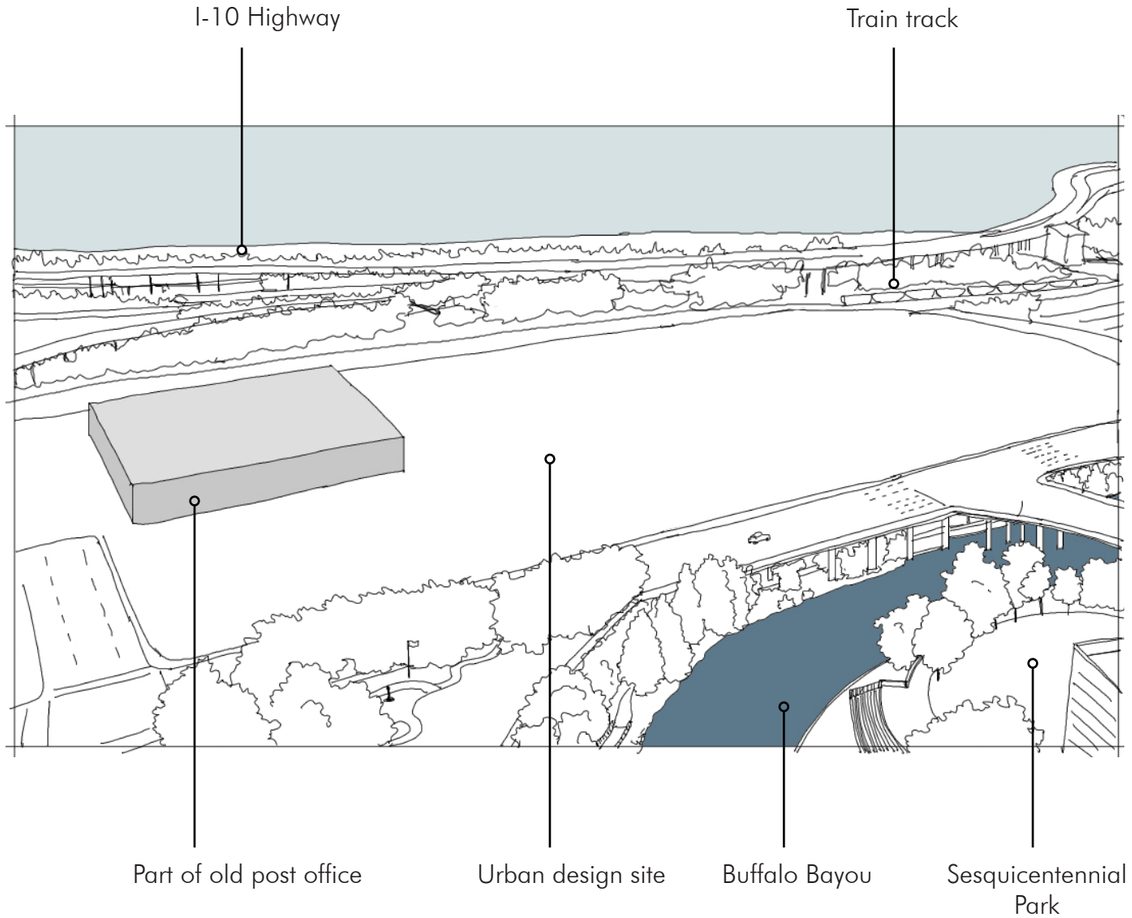


Fig. 155| Urban design site: former post office (Van den Berg, 2021).

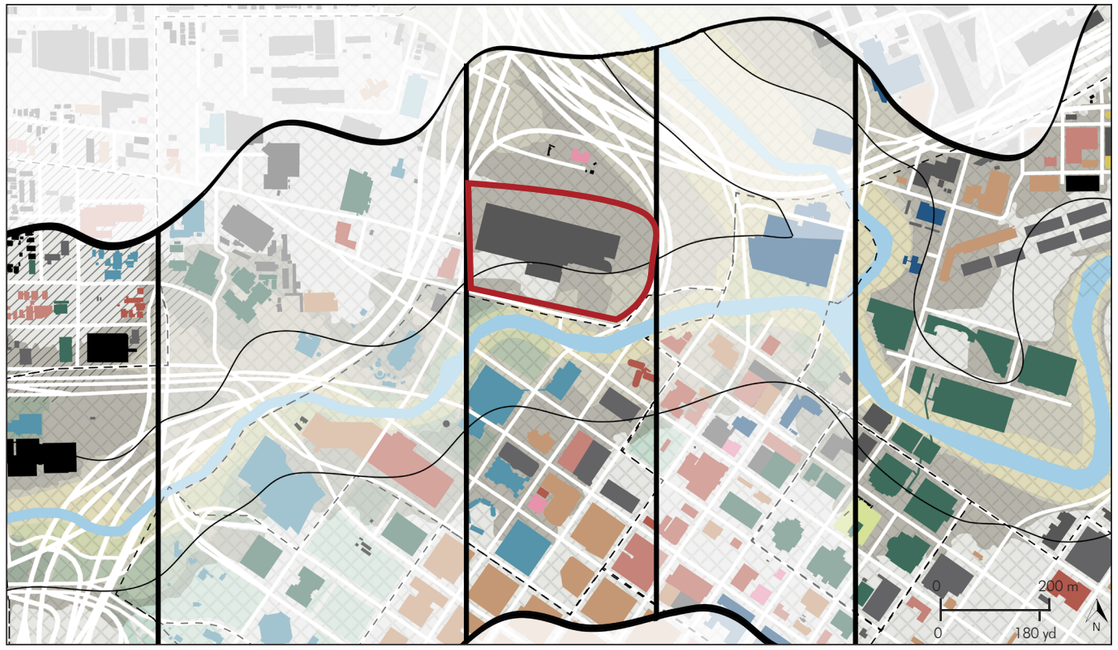


Fig. 156 | Urban design site in the Buffalo Bayou corridor (Van den Berg, 2021).



Fig. 157 | Urban design site: former post office on map (Google Maps, 2021).

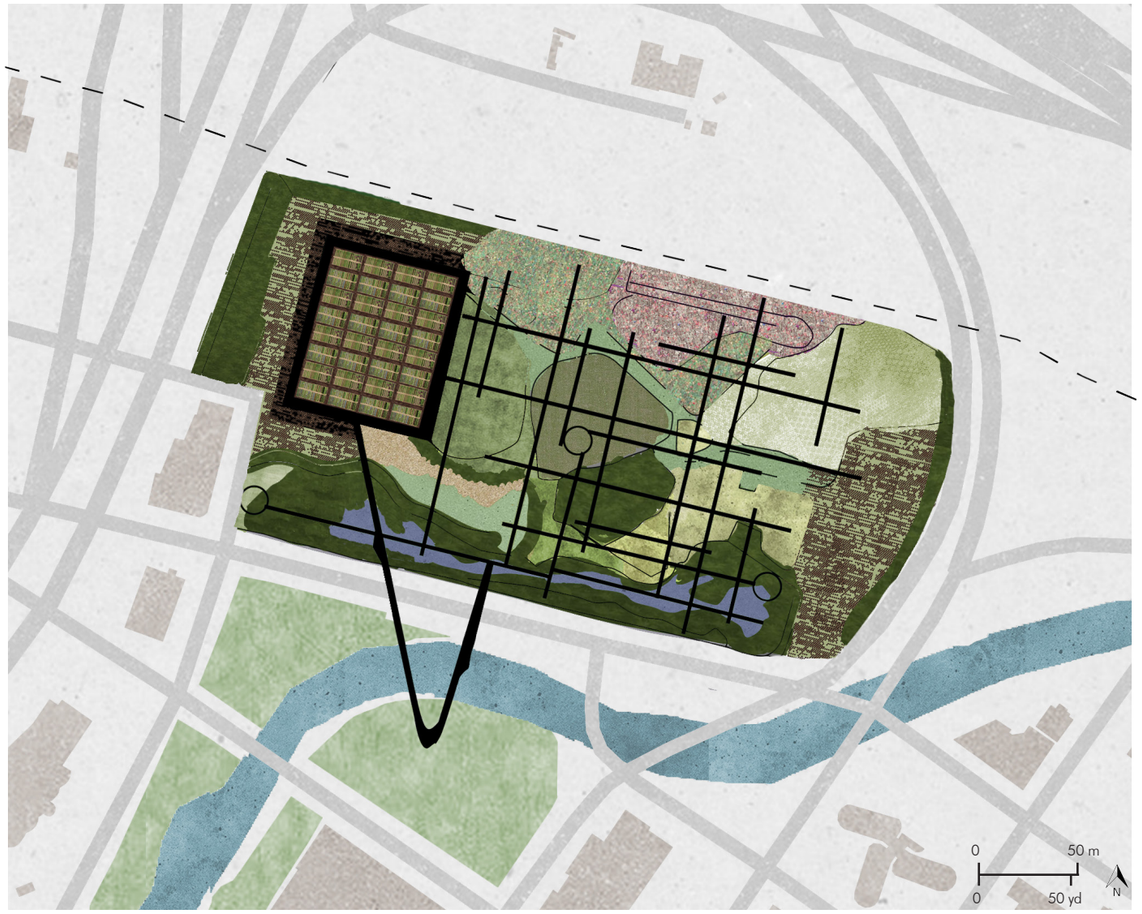
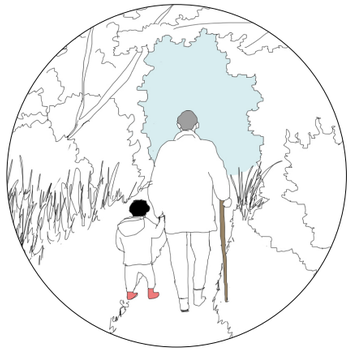


Fig. 158 | Urban design proposal (Van den Berg, 2021).

Form
In order to create maximum permeability, wooden structures are used to navigate the park. They create an non-organic pattern, in contrast with the organic pattern of the flora underneath. Nature plays a large role here, but this grid structure of paths allows for a stronger orientation of the plan.

Function
The old post office is partially demolished; the remaining part will be transformed into an educational nature center with a florarium containing plants from all over Texas. This center invites people of all ages to join workshops, courses, and excursions devoted to Houston's and Texas' native flora and fauna. On the roof, a community food garden is created to offer residents of the nearby neighborhoods a chance to get actively involved in the site, as well as to create stronger bonds with each other.

The pedestrian bridge that connects two parks on either side of the bayou offers panoramic views of the bayou and the Houston skyline. And in the park itself, between the plants and trees, people have the opportunity to take a break from the high-paced city life. The park itself offers visitors the chance to experience the atmosphere of different ecoregions in and surrounding Harris County: prairies (floral & grass), wetlands, and woodlands. Within this park there are characterstic places for four types of activities: to congregate, explore, play, and create (see following page).



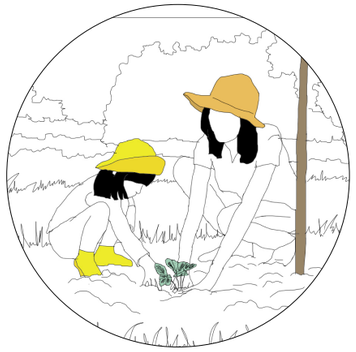
CONGREGATE | meet & slow down
Walking trails, meeting spots, places for contemplation



EXPLORE | learn & discover
Walking trails, education centre, ecoregion gardens



PLAY | enjoy & learn
Wilderness playgrounds, swinging seats, active meeting spots



CREATE | create & share
Workshops, urban farming, exibition spaces

Fig. 159 | Activity types (Van den Berg, 2021).

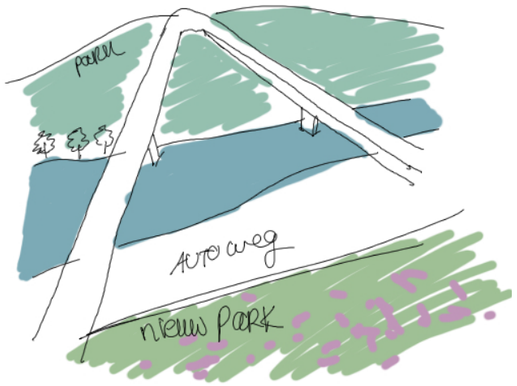


Fig. 160 | Pedestrian bridge: crossing the Buffalo Bayou and Franklin Street to connect the new park to the existing Sesquicentennial Park (Van den Berg, 2021).

This may seem like an ambitious program for a relatively small site. However, its intelligent selection of significant flora, combination of ecoregions, and digital enrichments work well in sketching the most important aspects of getting to know the native nature that once reigned the East Texas plaines. The focus of the curatorial choices is on the visitor with no specialist knowledge; while the specialist can find a more in depth treatment of the topics in a complimentary catalogue. This way the park with its exhibition will make a rewarding experience for all types of visitors. The exhibition inside the renovated post office presents various characteristics of the different ecoregions located in South-East Texas. Moving from the practical aspects of the vegetable gardens to the ideological dimensions of the ecoregion representative gardens.

This urban design presents urban parks in a way that allows the visitor to follow their emergence and developments, as well as their ideological and technical aspects. Minor shortcomings do not subtract from the general merit of the exhibition installed in the former post office, which, along with its catalogue, presents a useful and inspiring overview of significant aspects of native ecosystem (resilience) studies that have been developed in the previous decades.

To strengthen our bonds with the natural world we ought to reintroduce nature into our daily lives. Interacting with nature on a regular basis can be stimulated by lowering the threshold for reaching it. 500m distance to the river might already be too high of a barrier for certain groups (think of small children, elderly, disabled). Spending time with nature should not be a grand adventure which needs preparation; it could be, but then we are talking about a different type of space (which is also necessary, but in combination with low threshold nature). High threshold vs low threshold nature should be combined for the best experience of residents. Available, accessible and high quality natural public space for all (it already has a quite utopian sound to it), will channel people's inborn excitement and enthusiasm and turn it towards the local nature. The educational nature center proposed in my urban design will support this effort. Lowering the interaction threshold with nature will also increase the support for realization of urban designs that include ecosystem resilience elements.

The urban design needs to be a bit utopian, in order to excite people into making an effort themselves. The location of the urban design (B) is quite unfortunate, laying in between all kinds of grey infrastructure. Yet what better place to start with an inspirational park. That contrast will only highlight its message of how important coexistence and collaboration with nature is and that an ecosystem resilient approach is a justifiable one.



Fig. 161 | Learning About Nature (Van den Berg, 2021).

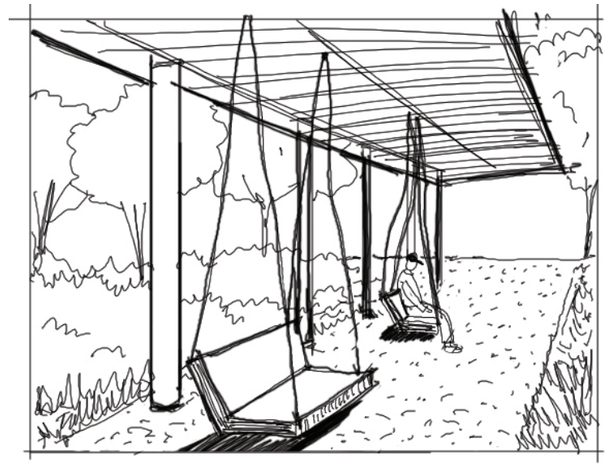
FUNCTIONAL PROGRAM



Fig. 162 | Program map (Van den Berg, 2021).

A

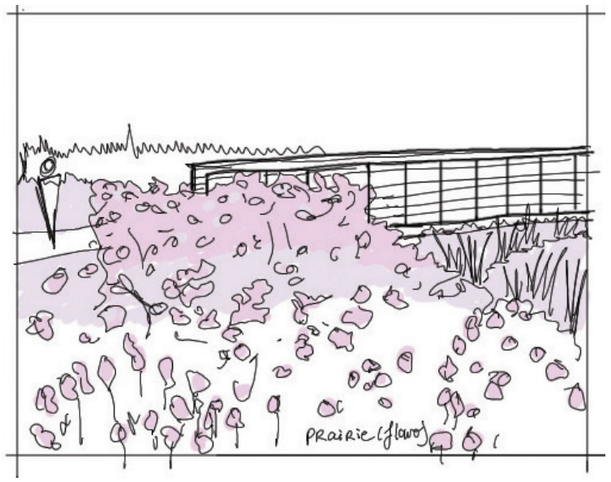
B



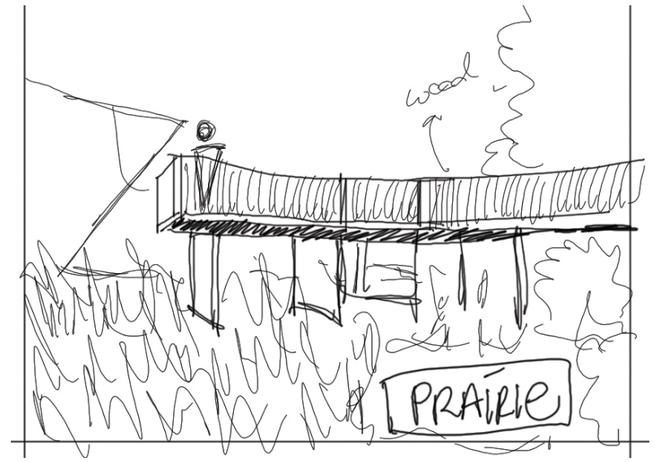
C



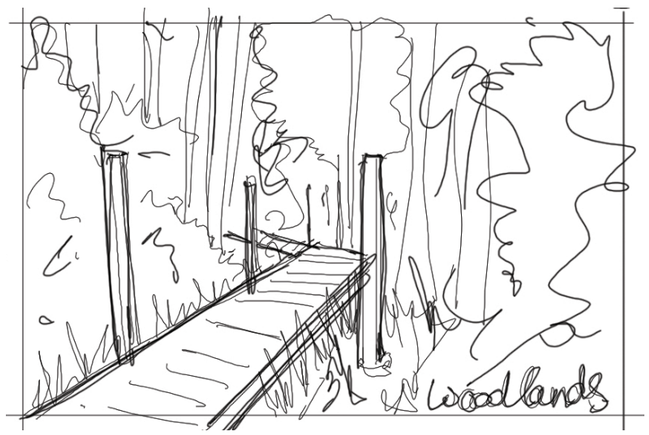
D



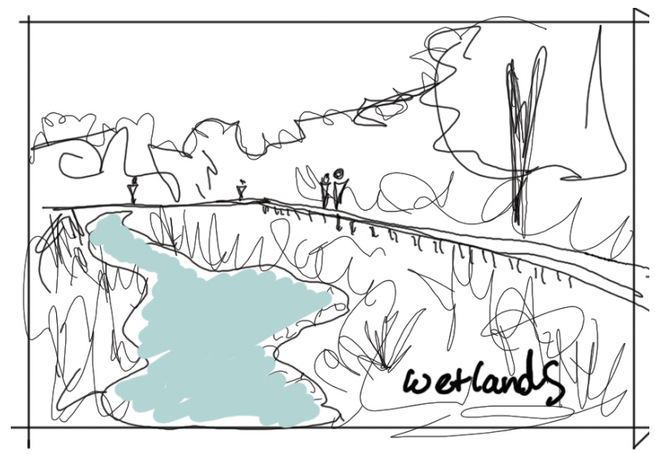
E



F



G



H

Fig. 163 | Program sketches (Van den Berg, 2021).

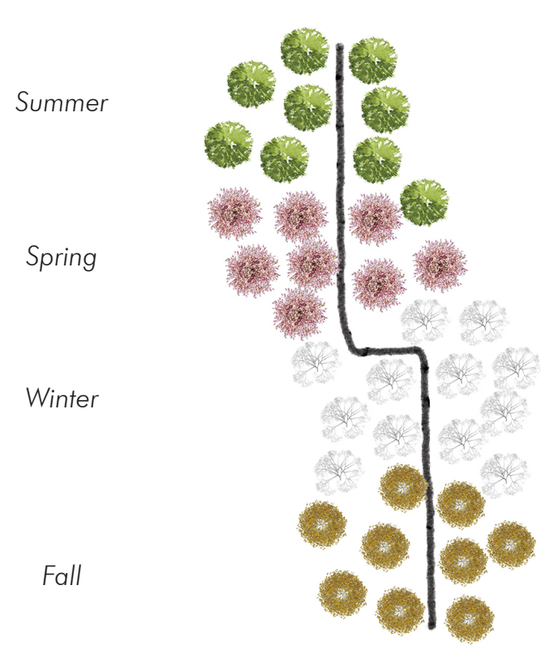
PLANTING STRATEGY

Flora and fauna both have their own best time during the year. People use topography in different ways from season to season, and this aspect is included when creating this seasonal public space design. Regarding the planting strategy: for trees, each season creates another visual route; for flowers, each season highlights another part of the route.

The leaves changing colors is a natural element showing us the progression of time. Trees are changing every day, just as people are. The unique qualities of every season makes it a anchor point in time. The element of time is displayed through flowers in a different way. Depending on the blooming period of flowers, a different part of the route is highlighted. This means that throughout the year, you never walk the same route.

EACH SEASON HIGHLIGHTS ANOTHER PART OF THE ROUTE

flowers



EACH SEASON CREATES ANOTHER VISUAL ROUTE

trees

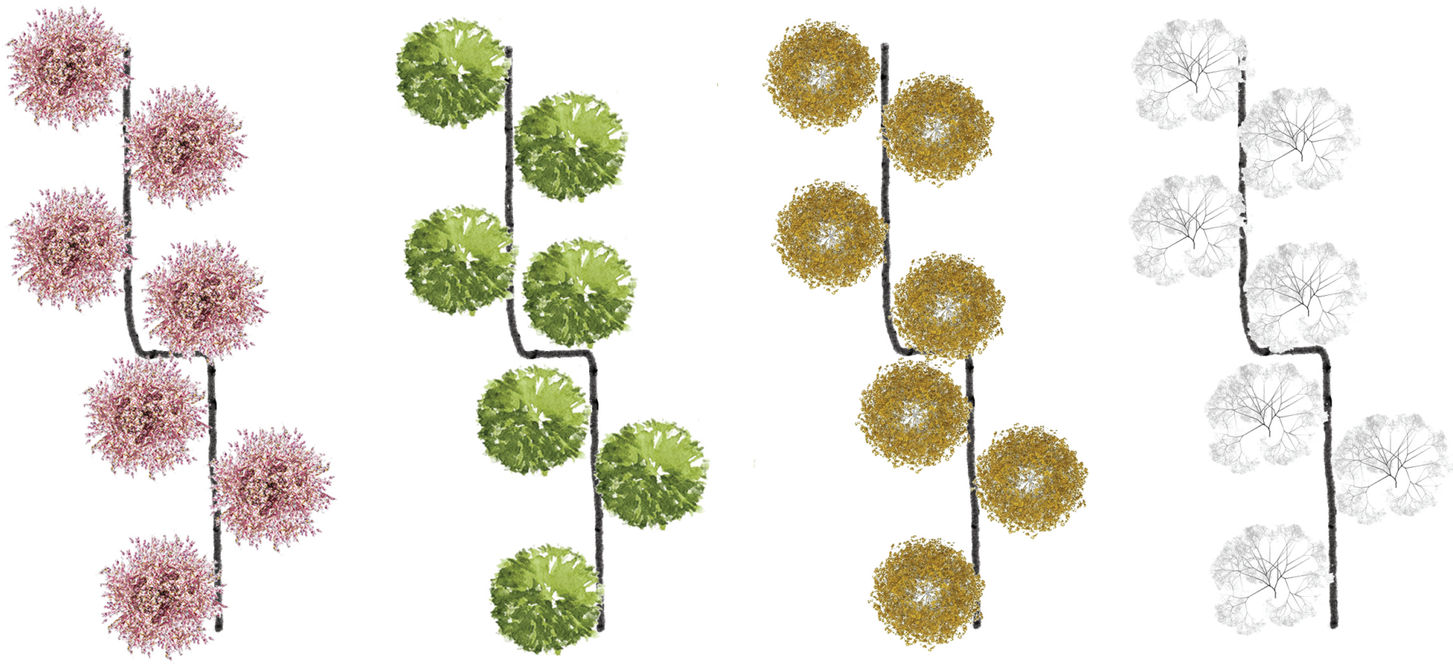
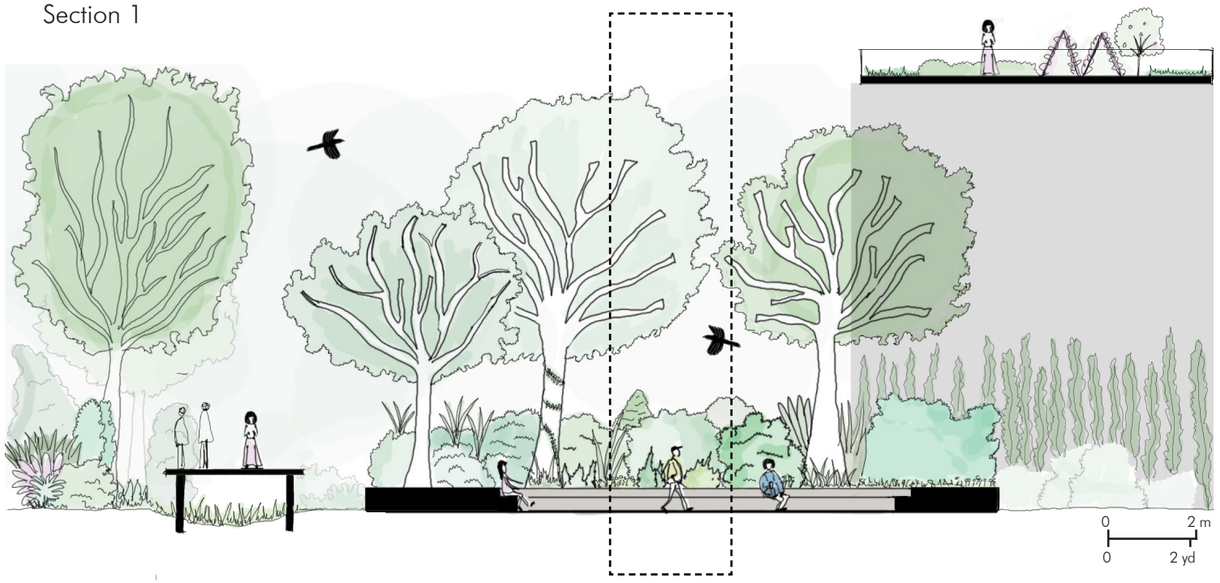
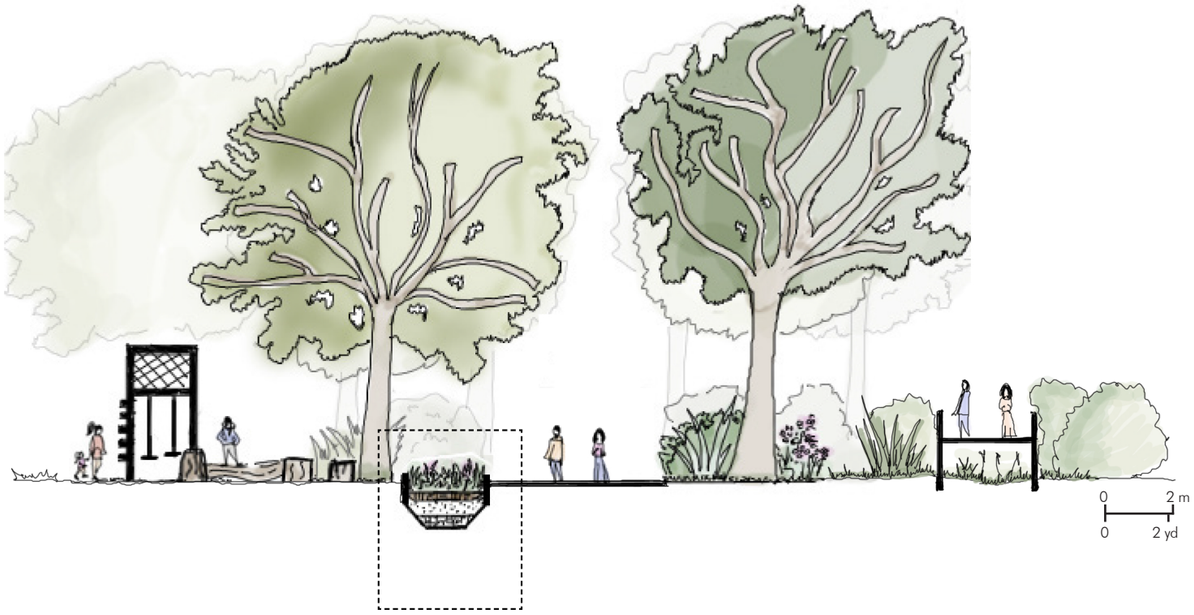


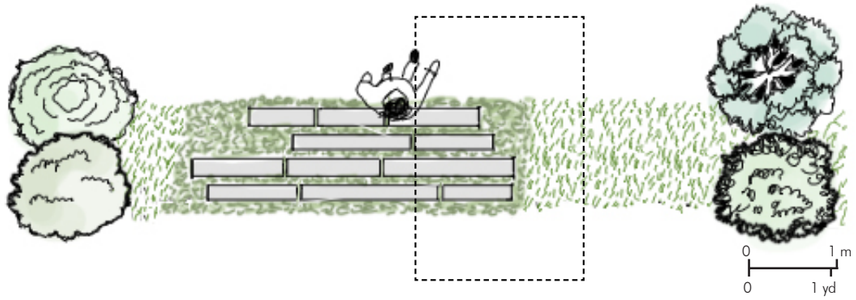
Fig. 164 | Seasonal Design (Van den Berg, 2021).

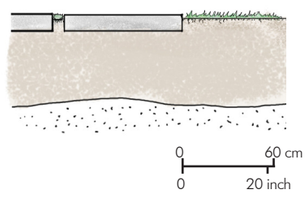
Section 1



Section 2







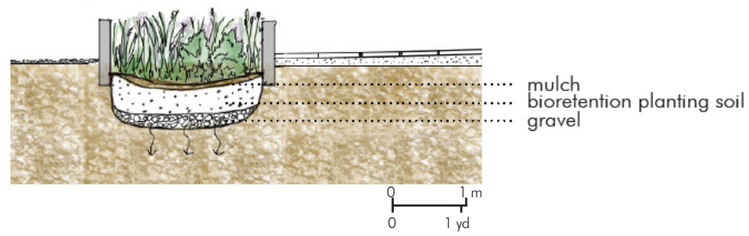




Fig. 165 | Proposed urban design sections (Van den Berg, 2021).

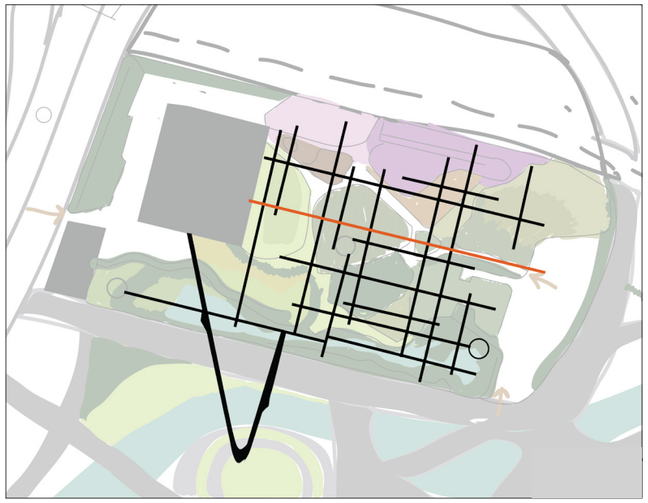
POSSIBLE ROUTES

There are different ways to walk around the park. The wooden structures create a series of unscripted pathways where visitors are encouraged to explore freely.

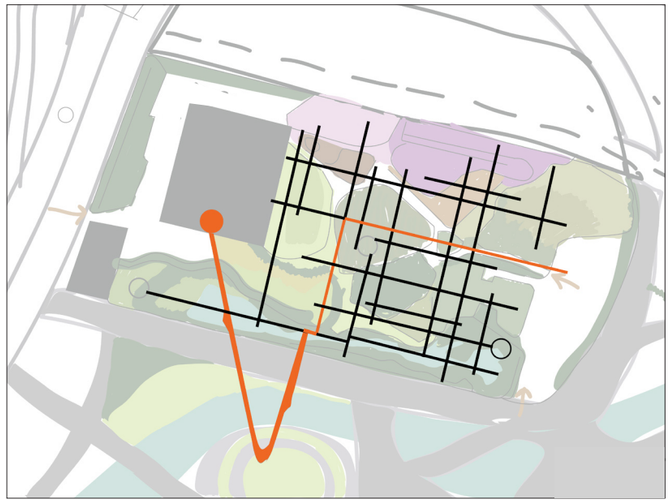
1. You can walk with a destination. For example, straight towards the educational Nature Center.

2. You can walk with a panoramic view. For example, by using the pedestrian bridge to explore the other side of the bayou, and afterwards reach the roof food gardens.

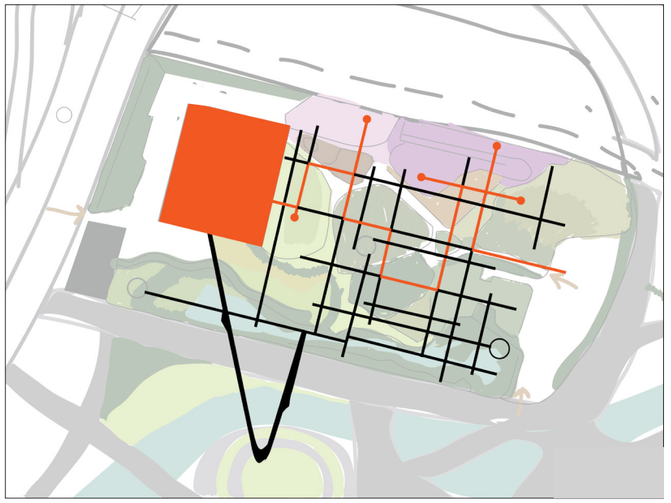
3. You can explore the park spontauously. For example, by walking through the prairies and woodlands in a zigzag pattern.



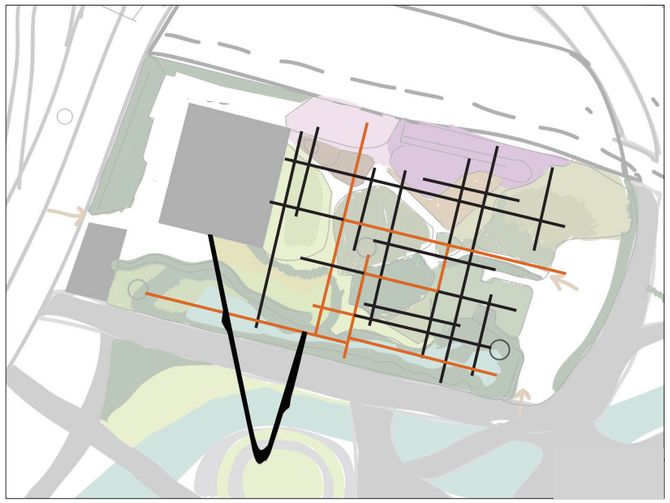
1. Straight towards the education Nature Center.



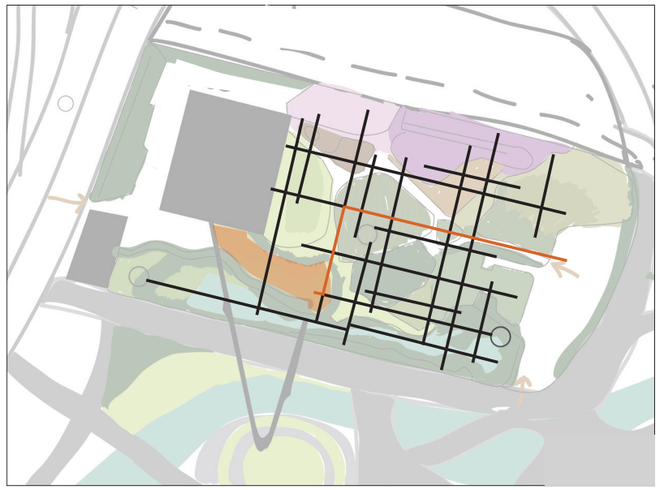
2. Using the pedestrian bridge to explore the other side of the bayou, and afterwards reach the roofgardens.



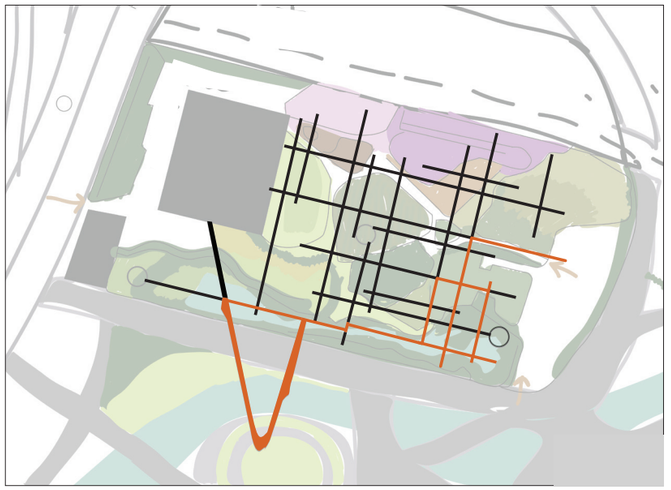
3. Exploring the prairies and woodlands, before entering the education center.



4. Exploring the prairie, woodlands, and wetlands typologies.



5. Destination: playground.



6. Focusing on the woodlands and wetlands, enjoying the view on the bayou and city from the pedestrian bridge.

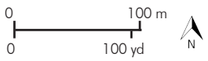
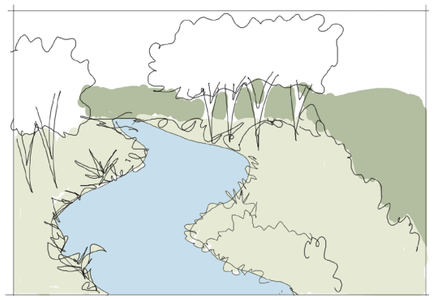


Fig. 166 | Possible routes in the design (Van den Berg, 2021).

WATER RETENTION

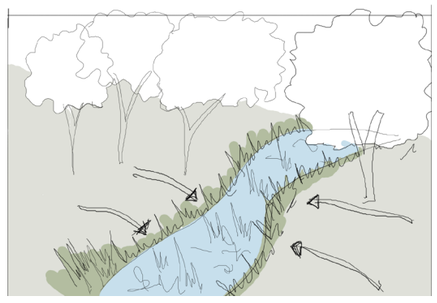
Three possibilities to lessen the impact of heavy rains inside the project site:

1. Enhancing the receiving environment: This can be achieved by widening the riparian zone of the bayou; this means removing built structures and impermeable materials, and increasing native vegetation.



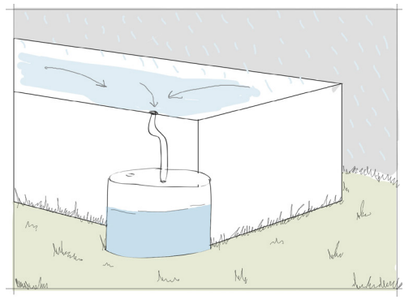
ENHANCING RECEIVING ENVIRONMENT:
Widening riparian corridor

2. Conveyance: This can be achieved by including small scale blue/green infrastructure, in the form of swales, wetlands, etc. This allows water to drain into the soil instead of building up on the (impermeable) pavement.



CONVEYANCE:
Introducing swales and wetlands

3. At Home: On the smallest scale, capturing and reusing rainwater can relieve the amount of water that needs to be drained.



AT HOME:
Capture and re-use of rainwater

Fig. 167 | Water retention options (Van den Berg, 2021).

WOODEN WALKWAYS

To increase the amount of open soil in the plan, wooden walkways are included inside the park for pedestrian movement. This allows water to drain into the soil instead of building up on the (impermeable) pavement. By removing paved materials from the site, and instead include wooden structures to walk on, it is possible to include wetlands with native vegetation.



Wetlands: low water situation



Wetlands: high water situation (after heavy rainfall)

Fig. 168 | Wetlands high and low water situation (Van den Berg, 2021).

8 CONCLUSIONS, RECOMMENDATIONS & REFLECTIONS

8.1 Conclusions

This section returns to the main research question and its sub-questions. First, the elaborate answer to the main research question is given, supported by brief answers to the subquestions.

MAIN RESEARCH QUESTION

How can an ecosystem resilient approach guide the built environment in order to integrate climate-sensitivity in human-oriented urban design?

Societal problems related to climate change include increasing climate extremes, flood risk and environmental degradation of cities. It is important to address these problems in order to improve urban resilience, reduce flood damage, and promote quality of life. This thesis also discusses the error of past attempts to try and dominate nature, and discusses how modern ways of living could benefit from a stronger reconnection to nature.

This thesis addresses these problems and the limitations of the currently used interventions in the case study of Houston, in regards to dealing with heavy rainfall. Houston's current approach of dealing with floods is to repair damage afterwards, while not enough is being done to prevent or lessen the impact of these floods.

The ultimate aim of this thesis is to research how an ecosystem resilient approach could integrate climate-sensitivity in human-oriented urban design, in order to improve flood resilience in Houston, specifically in the Buffalo Bayou corridor. The second aim is to redefine Houston's built environment and propose a set of planning and design interventions for the city of Houston that will (1) encourage an ecosystem resilient approach, (2) embed nature based flood solutions in respect to the local context, (3) restore people's relationship with nature.

A thorough spatial and technical analysis of the Buffalo Bayou watershed and Buffalo Bayou Downtown corridor on the capacities of the built environment to handle excess rainwater; characteristics and conditions of the existing green spaces; and spatial quality of the Buffalo Bayou adjacent corridors provided valuable conclusions on the challenges that ecosystem and flood resilience faces in Houston. Availability of public space is unevenly distributed in the Buffalo Bayou corridor as it tends to be situated on the west side of Downtown, leaving other parts with almost complete impermeable surfaces and no access to quality green public space. The current practice of implementing mega parks in the city is insufficient since the threshold capacity of residents engaging with those parks is too high, and the benefits of these parks become too centralized in one neighborhood. Concerning the Buffalo Bayou riverbanks, the inconsistent quality of them causes fragmentation of the riparian zone as well as discontinued public spaces. However, the clay and loam based soil add impermeable conditions because it does not allow rainwater to drain well, and influences the choice of vegetation due to high and fluctuating water tables, meaning that more is needed to improve flood resilience than simply open soil.

Moreover, Houston has lost its sense of place. The city has forgotten that it is a coastal ecology as there are no traces of the landscape that was originally there, and bayous are simply seen as highway obstacles. Urban sprawl has strangled the bayou system and increased the car dependency, because developers have an almost unrestricted liberty of action and decision since the drainage policy and system is quite loose and low-regulated. This thesis also uses the method of persuasive visual storytelling as a way to discover the potentials and limitations that are fundamental to the site, and to think outside of the box during the design process. Furthermore, persuasive visual storytelling enhances people's memories, stories, networks, and cooperative relationships in building urban resilience.

The proposed design for the urban river corridor deploys a reimagined park system not only as a way to include climate-sensitivity and increase flood resilience, but also act as accelerator for reinvigorating people's bond with nature, because design transforms awareness. Designs that work in partnership with nature articulate an implicit hope that we might do the same. This results in a heavy presence of vegetation and open water in the design site of the former post office. With the inclusion of elements of the ecoregions in and around Houston (prairies, wetlands, woodlands), the design aims to provide residents with a closer proximity to nature, and open the dialogue with nature. As a way to create added value and address the current disinterest in the environment, the design engages people through educational programs. By allowing people to experience the unique elements of native flora and fauna, public support for the natural environment can be fostered, and existing myths can be dispelled.

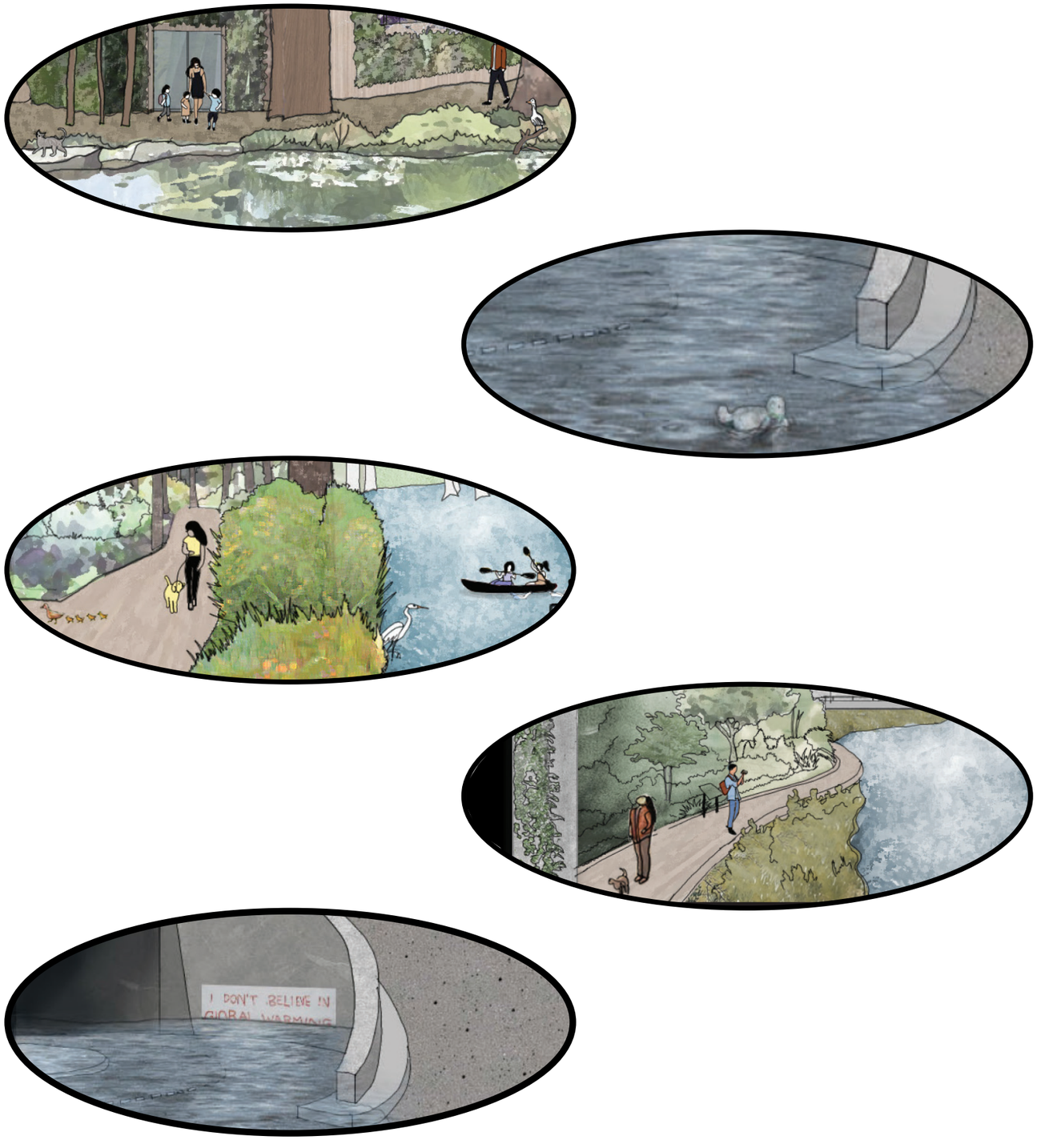
The proposed design conveys a new form of ecosystem resilience, one that is much more centered around reconnecting people to nature and allows for a shift in people's physical relationship to the environment. Dialogue with nature is crucial and contrary to the often used Western approach ruled by dualism by building in opposition to nature. This way, the proposed design introduces a natural environment that offers high quality public space. The proposed plan aims to illustrate with this key project and persuasive visual storytelling what stronger collaboration between people and nature could look like, and to built excitement and belief in an ecosystem resilient approach for the city, while taking into account that change does not come easy to a culture that has been invested for so long in exponential economic growth at all costs.

In summary, this project makes an effort to contribute to the discourse on ecosystem resilience by showing that a paradigm shift in city development and relationship to nature not only creates a more ecosystem resilient city, but also holds merit in terms of flood resiliency and living quality. The method of persuasive visual storytelling could play a role in discussion of proposed options for interventions in cities with strong environmental degradation between professional, community, academic and political stakeholders.

What are the effects of nature based solutions on urban flood resilience in flood prone areas?
Nature-based solutions can be seen as a new approach to strengthen the human-ecological connection, and holds a strong potential to improve urban flood resilience through an integration towards a water sensitive design in combination with natural processes and ecosystems. Additionally, they have the power to stimulate inspiration by nature in people, and give people the ability to reconnect with nature in their own city. This in turn could transform their ecological awareness and create a larger platform in support of nature based solutions to improve urban flood resilience.

How can the strengthening of people's relationship with nature through urban design function as an accelerator to improve the global environmental crisis?
The relationship between people and nature could be revitalized through climate-sensitive urban design, because it brings nature to where the people are, educates people on the error of trying to dominate nature (as has been done in the past) and the fragility of the native ecologies in and surrounding their city caused by environmental crisis. Reconnecting to nature cures a lot of social, governance, and health ills. We need more daily access to nature, but many people do not have any access at all; it is not uncommon for city dwellers not to know what kind of ecoregion their city is built on or nearby. If we want to improve the global environmental crisis, the key lies in promoting conservation and appreciation of nature on the smaller scales as to affect people on a personal level. Changing mindsets is crucial to preventing environmental disaster. Essentially, all substantial improvements start with home, on the domestic scale.

How can flood adaptation measures be consistently integrated within the built environment on multi-scale levels?
Consistent integration of flood adaptation measures will be most successful when a strong plan is combined with a strong coalition of relevant stakeholders. This will always be a political topic as well, and by persuading public, private, NGO, and community stakeholders a strong plan has the potential to grow quite powerful. This thesis found that by utilizing persuasive visual storytelling, innovative policies and programmes could be more convincingly communicated towards the public to illustrate how residents' living environment could positively change; and towards powerful stakeholders to gain their support and investment in these measures.



What are the effects of urban sprawl and permeability level on the performance of stormwater drainage systems in flood-prone areas specific to the U.S. context?
Currently integrated drainage systems in the U.S. context often consist of grey infrastructure. This grey approach does not address the causes of flooding, and from recent heavy floods in major cities (e.g. Houston, New Orleans) it became clear that they are not sufficient anymore to deal with the increased precipitation and increases the vulnerability of the urban environment. Additionally, the low permeability level caused by urban sprawl is of course an obstacle in water drainage since concrete does not drain and green spaces are too sparse to sufficiently absorb it. This urban sprawl is a result of cities being run by developers; they are often the biggest campaign donors of local politicians, and as a result of that have free rein to unrestricted liberty of action and decision. For Houston specifically, this caused the city to have the loosest, least-regulated drainage policy and system in the U.S.

How could the redesign of an urban river corridor function as a catalyst to decrease pluvial floods and increase the urban quality?
Redesigning an urban river corridor would mean to reconnect the natural riverbanks to each other in order to create one elongated riparian zone. This thesis found that by linking improvements in ecology, connectivity and spatial quality to the urban river corridor, a stronger link between flood resilience and ecosystem resilience can be achieved. By introducing sustainable projects built in harmony with nature and attuned to water, and spread it all over the city, they become even stronger. It also allows residents to see it, interact with it, and discover what is possible when you think about things in a different way. To start such a movement, one site in particular could be used to show what the effects of the proposed implementations would be. Thereafter, multiplying certain elements of it to other designated places in the city. These other locations then become points of ignition, with the help of the formulated planning guidelines, that will show the direction the city could go to. Because if there are only one or two places in the city that will include ecosystem resilience in their urban designs, then the city essentially stays in a dystopian mindset. However, when it is intelligently repeated, then the city has the potential and means to go towards a more restorative or even utopian direction; even a restorative approach has the potential to turn utopian if it is repeated enough times. So in order to achieve the highest positive impact with this design, expanding its key elements is the way forward.

Fig. 169 | Images by Van den Berg (2021); parts of the scenario development drawings. For the complete drawings, see chapter 4.

8.2 Recommendations

The first section discusses the future practice potential, and elaborates on the applicability of the proposed design for other similar places that are also affected by climate, based on the lessons learned from this thesis. The second section discusses future research possibilities, and indicates areas for further research that are beyond the scope of this thesis.

FUTURE PRACTICE

The methodology of persuasive visual storytelling and analytical research are well transferable to other cities, which increases the societal and academic relevance of this thesis. There are other cities in the world that face similar issues like Houston, like the environmental vulnerability and unacceptance of ecosystem resilient approach by the residents. First Street Foundation's national flood risk assessment report 2020 identifies properties at risk of more than 1 cm flooding in the next 30 years, concluding that 23.5 million properties are at risk of flooding in the U.S. (Lisa, 2020). Houston is the number one most flood prone U.S. city with the highest amount of properties (over 186,000) at risk; ten other cities that are prone to severe precipitation and are vulnerable to floods are identified in the figure below; these ten cities are selected based on their large amount of properties (and thus people) at risk and therefore have a higher urgency to be addressed.

There are several factors that make the proposed approach to ecosystem and flood resilience inherently transferable to other flood prone U.S. cities. First of all, the widespread grid system in U.S. cities allows for the development of strong typological planning guidelines. Then there is the common problem of urban sprawl/suburbia, low quality public space and lack of connection to the natural environment that are similar to those in Houston. Most U.S. cities are also used to rely on grey drainage infrastructure to handle excess stormwater. However, Houston's flat geography and lack of zoning system and its resulting challenges does ask for a slightly different approach in those cities.

The analytical part of this thesis that explores ecosystem resilience considering city development, climate conditions, geography, urbanized landscape, flood susceptibility, infrastructure and spatial quality, is well transferable to analyze other cities with similar ecological and climate problems as Houston in order to adapt the built environment.



Fig. 170 | U.S. Map. Map by Zntrip@Wikipedia (2006), edited by Van den Berg (2021).

Using the relationship between people and nature as an accelerator for sustainable urban development with the intent of creating human-oriented urban design is one of the primary outcomes of this thesis. And while the design decisions that are made specifically for Houston's context might not be transferable, it is the approach that holds the large potential to create an ecosystem resilience project rather than the results.

Making drastic changes, however desirable and positive, does have far reaching implications for the living environment of people in their city. The U.S. is large, and every state could be seen as a country on its own. In order to appropriately handle the issues and create a successful urban design, it requires adaptation and sensitivity to the local context and culture. This thesis could function as an example or guide to be considered in following similar circumstances and endeavors for how ecosystem resilient interventions on urban river corridor scale could be translated into human-oriented urban design for residents of the city.

FUTURE RESEARCH

Increasing environmental connection will increase the quality of life. In terms of health, in terms of wellbeing, in terms of the condition of the planet. However, such a topic can be approached from many different levels, resulting in significant possibilities for further research and design. For instance, it would be beneficial to continue research in combination with multidisciplinary collaboration in order to optimize knowledge and viewpoints from other disciplines. This new collaboration would create new questions, new viewpoints, and new solutions, which will increase the performance of ecosystem resilience in ways that would also benefit the spatial and social quality in the urban design.
Additional research is necessary for social and financial feasibility in order to create successful cooperation between the relevant stakeholders. In order for a successful ecosystem resilient approach to integrate climate sensitivity in human-oriented urban design, a combination of a strong plan plus a strong coalition is needed. In order for Houston to survive on the Texas Gulf Coast in the next century, the city and its surrounding region need to make careful planning decisions to guide growth. Additional research is needed to create a more in depth understanding of how it will be possible to create better coordination between federal, state and local governments in terms of power and funds, as well as handling the opportunistic pursuit of power and profit of developers, and the issue of property rights. This thesis contributes to this by creating a plan to illustrate how an ecosystem resilient approach could benefit Houston and so create support of the residents. The next step would be to create a phasing strategy in order to attain some of the far-reaching interventions proposed in this thesis.

Finally, this thesis addresses ecosystem resilience within the urban context of Houston. However, in order for this to truly prosper, further understanding of what is occurring outside the city in the surrounding landscape is necessary, therefore a better coordination between ecosystem resilience projects on different scales and levels could be created.

8.3 Reflections

Methodology

In my methodological chapter I explain the main methods that I have used to address the knowledge gap and to arrive at my design proposal. The main methods are: literature review, mapping, interviews, creating scenarios, persuasive visual storytelling, and research by design. Initially I planned to include field work as well, but this became impossible due to the pandemic.

PERSUASIVE VISUAL STORYTELLING

This thesis uses visual storytelling as a part of design research in which new futures are projected. From a design perspective, the fundamental potentials and limitations of the design location are discovered, and the boundaries of reality are challenged to create out of the box ideas. From a planner perspective, the narrative systems of urban planning and design could be used as powerful tools of communication, persuasion, and education. Using textual and visual storytelling as a tool to enhance urban planning engagement takes away planning jargon, making effective communication possible between residents, planners, and other stakeholders. Additionally, visual storytelling in particular has the ability to provide thoughtful content and beautiful visuals that will help in making your content or message an engaging piece that catches and holds the attention of your audience. The old saying 'a picture is worth a thousand words' is true: vision trumps all other senses. Being fluent in the language of images strengthens the ideas and plans, and in combination with storytelling will increase empathy and compassion, which are crucial in a successful planning process.

OTHER METHODS

The literature research provided a solid base for this project. Through this I was allowed to indulge in the pursuit of knowledge and gain insight in the main themes of climate resilience, nature-based solutions, and ecological urbanism. Even though Texas in general has a proper provision of data sets, government reports, etc., there are sometimes restrictions or lack of data available for the public. However, by talking to my contacts in Houston I managed to collect the necessary data. The largest problem that I had to overcome was the impossibility of doing site research. I have tried as much as possible to use previous research, GoogleEarth and online articles to compensate for this, but there is only so far it can take you. By mapping the different aspects of the built environment in Houston, it gave me the necessary instruments to overlay spatial, social and engineering aspects that were relevant in order to envision the potentials of the place and the synergies that could be created in order to reach those.

Due to the pandemic, I was unable to travel to Houston for my project as I had initially planned. This limited my interactions with the local community, as mentioned before, and the ability to do site research. In order to compensate for this unexpected turn of events, I spent extra time doing online research for this, diving as deep as I possibly could in cyberspace. For my interviews, I spoke mostly to people who were active in the water management/design field from a Houstonian perspective. Although I made an effort to reach local actors who are living inside the site location, I was limited by my own capacities for travel due to the pandemic, but also the lack of available interview partners (due to all interviews being held through Zoom, it limits spontaneous unplanned conversations and lessens the human connection). However, to some extent, it is possible to imagine from my external viewpoint how residents live there and see the city through second-hand accounts and news articles. The results of the online interviews are not ideal, because they only provide you with a general understanding of the community environments. On the other hand, I discovered that, now people are more used to using Zoom, it was more acceptable to ask for such a meeting than I think would have been the case before online learning/working became popular.

The creation of different scenarios took a larger role than I had originally planned. Using scenarios to determine the potential of a place allowed me to think outside of the box. By telling stories in a fictional space it is possible to explore various choices that lead to different effects. I studied these effects before deciding which elements I would like to apply to my own design. Therefore this method became a part of design research in which I was able to project these new futures to discover the potentials and limitations that are fundamental to the location, and also envision how the boundaries of reality can be stretched, challenged and provoked. The combination of scenarios and storytelling was a very fruitful method that helped me develop the base of my design.

Design research is both the study of design and the process of knowledge production (see figure below) that occurs through the act of design (Roggema, 2016). An expressive component in research allows the possibility of expressing qualitative aspects and adding something new to the existing research through experiments and proposals (Hauberg, 2011). My approach can be described as quite intuitive and people-oriented, as I started to create drawings from an early stage in the process. Because design is a conversation held via paper and pencil, a quick sketch becomes an instance of creativity, personal research and commitment, and it is through this circular process that novelty can be generated (Roggema, 2016).

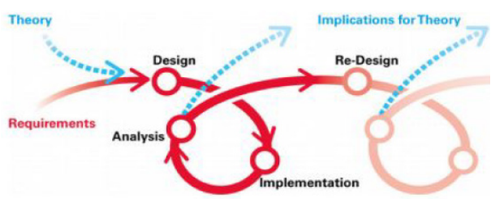


Fig. 171 | Research by design (Fraefel, 2014)

In my project's problem field, issues are often well researched on their own, but do not come together in a design. During the process of designing sections, information I gathered through research is added. As a result, a constant exchange happened between analysis, literature and design, creating a strong dialogue between them.

Furthermore, this thesis uses Forgaci's (2018) Urban River Corridor definition, where he outlines the use of 500m for the area that has potential for a closer active relationship with the river. Outside of this 500m zone the main goal is to get towards the river. This distance can be challenged, for physical barriers like alleviation, highway constructions and waterways significantly influence people's ability to reach a river. Therefore a more accurate way to create an estimation of how wide an urban river corridor could be, is by measuring in time instead of distance. By using time as a measurement, connecting people to the river on a flat terrain (like Houston) would take around 6 minutes (for 500m). Additionally, for cyclists, it would take even less time. By including this type of transportation, the urban river corridor could be extended in width and the bicycle is successfully integrated in the city. The main use of the urban river corridor in this project was as a way to frame the research area and use this boundary in order to narrow down the possible urban design site.

Stakeholder engagement and tax system

Improving the relationship between nature and people (and thus the condition of the natural environment) is a challenge, since many stakeholders want to maintain their control, and only give their spin on things when they have a certain way to profit from the solution. One way of approaching this, is by creating persuasive narratives through visual storytelling in order to interest the less interested (often the most powerful stakeholders). The possibility of increased stakeholders interest in a closer relationship with nature presents exciting opportunities for a concrete city like Houston, that up until the early 2000's has been starved of green space.

Houston should start thinking about who wants to live in this city when fossil fuels run out during this century. One of the benefits of nature-based solutions is also attracting new kinds of intellectual capital that sustain cities. By illustrating with key projects how cohabitation between people and nature could look like (gradual improvements in stages), trust and belief can be built, and money can be raised. Yet change does not come easy to a culture that has been invested in exponential economic growth at all costs.

However, it seems that Houston's current political system is designed for the gain of wealth and power. Every U.S. state differs in terms of legislature, and the way the tax system works in Texas is the following: there is a quite high property tax, and no state income tax. Texans pay roughly a third more in property taxes than the national average, and the amount in proportion to income is rising (Direct Tax Loan, n.d.). The main reason for why Texas property taxes are that high, is this absence of state income tax, and therefore local governments rely heavily on property tax income, because this makes up the majority of their tax revenue that is used to fund schools, road maintenance, parks and recreations, libraries, emergency services, etc. This tax system with high property taxes unfortunately becomes a contra-incentive for nature-based solutions, since it is more profitable for the city to have endless expansion. Therefore the task of stimulating ecosystem resilience becomes more complicated.

NGO participation

In order for a successful ecosystem approach to integrate climate sensitivity in human-oriented urban design, a combination of a strong plan + a strong coalition is needed. At the moment there is a political stalemate in Houston, where politicians only do what gets them elected. If you really want to do or change something, you need the NGO's: they are the ones that really drive change. These nonprofit organizations depend heavily on the generous donations of wealthy residents. Charity events can be used to persuade the wealthy residents and powerful stakeholders to fund projects that will support a future ecosystem resilient Houston that is able to successfully deal with floods and live in closer relation to nature. Persuasive storytelling is a key factor to get these projects off the ground– when the donators understand and care for the cause more, they will find participating in it worth it. Stronger NGO participation could create a strong coalition in favor of these suggestions. As an example of how powerful persuasion could be, one should look to ancient Athens. In ancient Athens only the 300 wealthiest citizens had to pay taxes; this was considered a high honor (Jones, 2017). The key is that they provided the required community services themselves, instead of giving their taxes to the state; and the wealthy competed with each other to provide the greatest public goods. They started boasting of funding public services and what they did to the community; they rejoiced in performing these public services and in turn gained gratitude and respect among their own people. Of course ancient Athens and contemporary Houston are worlds apart; and this idea might sound quite utopian in this day and age. However, it would be helpful to turn more attention to providing 'the wealthy 300' of Houston with attractive incentives in order to get them involved.

Houston's relationship with nature

On the one hand, this thesis aims at illustrating the importance of a paradigm shift towards a closer connection, collaboration, and cohabitation with nature. On the other hand, it also seeks to illuminate the various types and functions of ecosystem resilience practices in the built environment of Houston. Houston's current relationship with the natural environment is an unsustainable one, where nature is treated callously as a source for profit, city growth, and 'freedom'. This treatment of the natural environment has resulted in a level of detachment from nature that negatively influences future endeavors to introduce ecosystem resiliency in city development. In order to not completely destroy the natural environment that is left, the city should reevaluate its relationship with nature, and strive to create a more symbiotic relationship where a mutually beneficial relationship between people and nature is stimulated. Nature Based Solutions hold a strong potential in improving Houston's ecosystem resilience, although an integration towards a water sensitive design in combination with natural processes and ecosystems is essential. Scales, levels and perspectives are all dots to be connected, so that we can uncover the true face of the terrain on which urbanism operates, and individual design cycles flourish.

Cultural challenges

Bringing nature into the city is one thing; bringing nature into Houston's culture and daily lives is another. The uncoordinated, unaffordable, unscientific, and unsustainable form of city development that has resulted into the classic Houston freeway landscape, has also resulted into a point of pride that the city's unsightliness was a direct result of its success, since it was growing too fast to care about its looks (Swartz, 2015). Educational programs (like the one proposed in this thesis' urban design) have the power to dispel myths and foster public support for the natural environment. They could utilize the strong pride Houstonians have for their city, identity, and heritage as a starting point for a closer relationship with nature. Houston (and Texas) is about independence, honor, land, and making your own way in life. Approaching ecosystem resiliency from this fierce devotion, instead of contempt and fear, will be a much more effective motivator to help influence the current unsustainable way of living. By allowing people to experience the unique elements of plants and animals native to their land through education and examples, it is possible to promote and convince how beneficial living in harmony with nature is. Focusing too much on how people's current materialistic lifestyle is harmful to the environment will fall on deaf ears due to the fact that on a daily basis people are too occupied with their own lives; people have an overwhelming feeling of powerlessness; or people's salaries are utterly dependent on not caring. This will only result in more indifference to their own environment. Instead, may Houston be what it always intended to be: a place for independent, free-spirited people to come, work, and prosper; even though it is high time to redefine its meaning. Ultimately a paradigm shift is needed for transforming how people relate to and interact with the environment. It is not feasible anymore for the planet and humanity alike to live in a world where the future is something we deal with only if we have time. It will be quite a journey to accomplish all of this, and this thesis might only be one droplet in the ocean of knowledge that is necessary in order to achieve this; yet that does not diminish the efforts and results generated.

Reflection on academic, societal and ethical relevance

The relation between my graduation topic and the Transitional Territories studio is the focus on the perception of territory as a constructed project across scales, disciplines and media; the design in territories at risk between water and land (like the riverine landscapes in Houston); and the relation between humans and nature. From a social relevance perspective, urban flood resilience continues to be an urgent matter in cities around the world. For Houston, it is essential to make a reinterpretation of the built environment in flood resilience in order to create a strong city that has the ability to deal with future uncertainties generated by increasing climate extremes. By considering the built environment and water system as one joined system, synergistic relations can be created in interdisciplinary collaboration, strategies, and policies. In this way, the overall positive impact is increased. By researching these opportunities to improve Houston's ability to adapt to changing environmental conditions, the city's vulnerability can be further reduced by continuing adaptation efforts to reduce environmental, physical and economic damage (instead of rebuilding things back to the pre-disaster state after destructive events).

The scientific relevance of my project lies within the power of combining urban planning & design with other relevant disciplines (like architecture, landscape architecture, and engineering). This way I am able to create synergies through assessment, strategy and policy. By doing so, the current shortcomings in Houston's approach towards flooding are addressed and the potential by adding to a growing body of research is enhanced, which is necessary in order to create a flood resilient Houston. Furthermore, the unprecedented speed with which urbanization is currently happening in the world (McKinsey Global Institute, 2012) often causes urban designers/ planners to produce short term and quick solutions so they can keep up with the demand. This reduces the city's ability to handle floods effectively when extreme downpours happen (among other climate change related effects) as well as the quality of the built environment. Moreover, in recent decades people's connection with nature increasingly deteriorated. In 'The Biophilia Hypothesis' (Wilson, 1984) several writers state that it is crucial to mend that connection. Reconnecting to nature cures a lot of social, governance and health ills, and yet the mindset that dominates the U.S. is that natural resources need to be controlled by engineering resources which eventually resulted in a human divergence from the natural world. This thesis addresses the potential of reconnecting people in urban environments to nature by using the possibilities of reviving previously neglected urban river corridors, and the role urban designers have in this process. It seeks to evaluate the potential benefits, both environmental and social, of re-introducing accessible nature inside the city.

The research by design approach as used in this thesis as well as the research findings are well transferable to other (U.S.) delta cities. However, it is important to keep in mind that the suggested approach and the developed design also depend on the culture of the place and therefore would probably work better in the Netherlands than in Texas. Trust in the government, amount of taxes and public awareness of water in their city/land plays a role in this. Texas continues to persist a libertarian attitude towards natural resources and the environment, that goes together with a persistent need to own their own land or own property (Fehrenbach, 1986), aspects that are still present in twenty-first century Texas (and Houston) (Calvert, De Léon & Cantrell, 2014). So the proposed interventions might take much longer to be accepted in Houston than elsewhere, and this paradigm shift could take decades before significant action will be taken, all while the city continues to be vulnerable to floods.

Reflection on ethical issues and dilemmas

The process of creating designs to improve climate resilience includes making decisions that affect a lot of people's lives, and is therefore heavily influenced by politicized decisions. This results in a large responsibility from urban designers and planners to the local community. What often happens in practice is that a privileged group of experts design and carry out developments that have a very high impact on residents' daily lives. So it is important to always question which way the ethical way is to undertake such plans. During my research I have encountered many personal stories of Houstonians whose homes flooded on a perpetual basis. And it is often the poorer neighborhoods that have to deal with this, while the richer neighborhoods are conveniently located on the parts of the city that are less susceptible to flooding. People have to bounce between motels and hotels for weeks (or even months) in order for their home to be repaired, on an almost annual basis. This causes a very unstable and uncertain living environment, especially for children growing up in such circumstances. A city should focus on providing its people with physical security first, before other issues can effectively be addressed. As an outsider, I found the complexity and dynamics of political and social interrelations in Houston a delicate and complicated matter, but at the same time it provided me with a challenge to learn something new and break away from the usual way of approaching a project in the (for me well-known) Dutch context.

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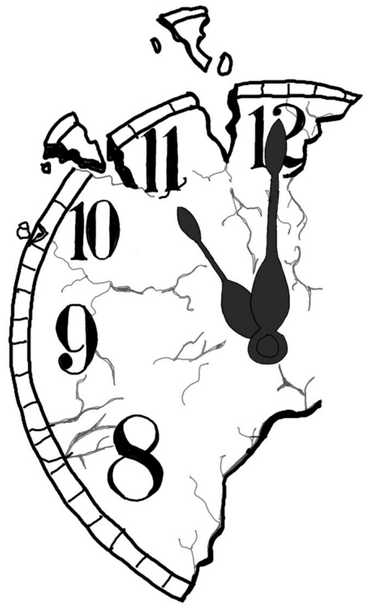
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APPENDIX

time...



a luxury we do not have

Fig. 172 | Time, a luxury we do not have (Van den Berg, 2021).

Reconnecting with Nature: using urban river corridors to provide better flood resilience in Houston

Abstract | This paper addresses the potential of reconnecting people in urban environments to nature by using the possibilities of reviving previously neglected urban river corridors, and the role urban designers have in this process. It seeks to evaluate the potential benefits, both environmental and social, of re-introducing accessible nature inside the city. Furthermore it identifies what trends have contributed to people seeing nature as something removed from them. Arguably, the root driver of the loss of human–nature interactions is the decline in opportunities to experience nature directly. Over the years, an increasing number of people rapidly concentrated themselves in urban areas, where a high proportion of space is segregated from natural systems and processes. Literature research shows that a green approach holds potential in multiple capacities, underlining the argument of this paper in favor of Nature Based Solutions instead of traditional grey infrastructures. Nature Based Solutions principles hold a strong potential of improving urban flood resilience, although an integration towards a water sensitive urban design in combination with natural processes and ecosystems is essential. Furthermore, the design principles used to reconnect people with nature also contribute to improve environmental and social aspects; this contributes to achieving healthy societies and overcoming a wide range of environmental issues such as flooding. As a case study, the Buffalo Bayou in Houston, a flood prone city, is used to appraise to what extent reintroducing nature to the urban river corridors can contribute to increasing urban flood resilience.

Key Words | Reconnecting to nature, urban river corridors, flood resilience, climate vulnerability, Houston

1 | Introduction to Houston's Context

In this paper the potential of reconnecting people in urban environments to nature by using the possibilities of reviving previously neglected urban river corridors will be addresses, together with an evaluation of potential benefits, both environmental and social, of re-introducing accessible nature inside the city. As a case study, the Buffalo bayou in Houston is used to identify multiple aspects how urban nature can improve the performance of these environmental and social processes. Therefore this paper starts with an introduction to this location, in order to understand how the Buffalo Bayou fits in its context.

Houston is a city in Texas, the United States of America, around 50 miles (or 80 km) away from the Gulf of Mexico. It has a population of approximately 2.3 million people and at the moment this city is one of the fastest growing cities in the US (World Population Review, 2019). The Buffalo Bayou runs straight through the heart of Houston; subsequently it is also the point where the city was founded and the reason for the city's rich historic and economic relevance. However, the Bayou City of Houston has a long flooding history, which makes it an interesting yet challenging location to reintroduce a stronger connection with nature. Ever since Houston was founded, it has frequently dealt with extreme weather situations, such as tropical storms and hurricanes, with Hurricane Harvey in August of 2017 being the most notable one because of the unprecedented damages it caused (worth $125 billion) (National Hurricane Center, 2018). Houston's flooding issues are due to high precipitation and flash floods in combination with a large amount of impermeable paving which makes storm water infiltration difficult (Suripin et al., 2018), and leads to pluvial flooding all around the city. Additionally, it is well documented that urbanization can have significant effects on local weather and climate (Landsberg 1981). Ever since Houston's settlement in 1837 between two slow moving tidal rivers, namely the Buffalo Bayou and White Oak Bayou, Houston's ambition was to become a railway distribution hub for local resources; but it was only after the regional economic driver Galveston was destroyed by catastrophic hurricanes (McComb, n.d.) in the early 1900s that Houston became the regional centre for resources, business and residents. Together with the finalization of the Houston Ship Channel in 1914 and the discovery of oil, Houston's started its journey towards the massive city it is today. And once relegated to the dirty work of storing industry's waste products, urban rivers such as the Buffalo Bayou are being converted from old industrial districts to the renewed flowing heart of the city (Schulman, n.d.). Thus the design principles used to reconnect people with nature hold a strong potential in improving environmental and social aspects of Houston which contribute greatly both to achieving healthy societies and overcoming a wide range of environmental issues such as floodings.

However, Texans (including Houstonians) cling to many of their old outlooks and habits. The conservative majority displays a deep antipathy to a more activist government or higher taxes; they mostly want to be left alone by the government (Calvert, De Léon & Cantrell, 2014). Texas continues to persist a libertarian attitude towards natural resources and the environment, that goes together with a persistent need to own their own land or own property (Fehrenbach, 1986), aspects that are still present in twenty-first century Texas (and Houston) (Calvert, De Léon & Cantrell, 2014). This attitude also strongly influences their urban planning approach; Houston does not have any zoning laws for land use, and in most cases there are also no restrictions for density or height, which sometimes result in disruptive buildings being built next to homes or parks (Kinder Institute, 2020). Instead of governing land use, the city uses a complex system of codes that result in a more market-based approach to development (Kinder Institute, 2020).

2 | Exploring the Relationship Between City and Nature

The relationship between the city and nature has been researched since ancient times, but has gained renewed interest by the negative environmental consequences (think of air and water pollution, deforestation, and landscape fragmentation) of the Industrial Revolution (Sijmons, 2020). There are three main types of ideals in urbanism that establish a relationship with landscape and nature, and also address the dichotomy between city and nature (Sijmons, 2020). The oldest one is the ideal of the Garden City, where the city was considered being an unhealthy place to live; which it was in the early 1900s. The solution to this was to create satellites

around the city where people could live in a healthier way, closer to nature (Howard, 1902). Slightly later in the 20th century the ideal of the Lobe City started to win ground by bringing nature into the city. This ideal shares the diagnosis of the Garden City movement, but cure it in the opposite way (Sijmons, 2020; Eberstadt et al., 1910). Then there is the ideal of the Broadacre City of Wright (1932) which was a planning model and a socio-political scheme in one where a one-acre plot of land should be given to each U.S. family to make their home and produce their own food (Wright, 1932). All these ideals appeared around the world in some form: the Garden Cities mostly as 'Garden Quarters', but also as satellites and new towns; the Lobe City model guided green planning and city extensions in places like Amsterdam and Copenhagen; and the Broadacre City has been stripped from its early intention of self-sufficiency and used as a legitimation for suburban sprawl (Sijmons, 2020). These three archetypical urban concepts stand for contrast, contact, and contract between the city and nature (Sijmons, 2020).

Societal developments have also influenced the relationship between people and nature, which has always been changing. A vital turning point here is the Industrial Revolution, which started in 1760. From there on, the environmental connection people have, has deteriorated more and more; it can even be said that in 2020 we are at a point in time with a shallow connection between people and their natural environment. The decline of meaningful interactions between children and nature is a continuous trend, see Fig. 1 (Soga & Gaston, 2016). Ives et al. (2018) explain that by reconnecting people with nature, many of today's ecological and sustainability challenges can be addressed. In order to do so, specific changes should be directed with tangible action in all aspects of daily life, such as health, well-being, and education. To achieve this, it is beneficial to specify particular types of connections with nature as a first step; these connections can be classified in five categories: material, experiential, cognitive, emotional, and philosophical (Ives et al., 2018). As a second step, framing them with literature of demonstrated causes and consequences of connections with nature and plausible theories of change is suggested; which is necessary in order to dispose of vagueness surrounding this topic and create evidence based support, see Fig. 2 and 3 (Ives et al., 2018).

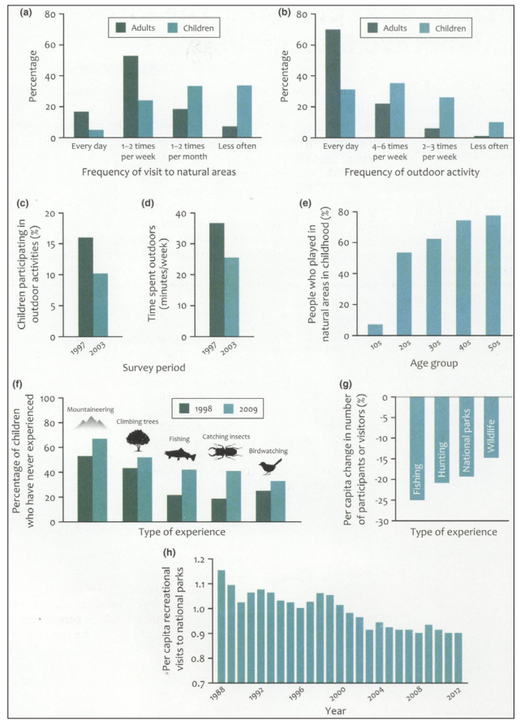


Fig. 1 | Source: Soga & Gaston (2016). The graphs above shows the empirical evidence that in previous decades children spend less and less time engaged in outdoor nature experiences.

However, most of the time the nature-based connections are most likely to be only superficial, shallow contact with nature, which in turn leads to more shallow solutions for conservation as well. Additionally, when looking at inclusivity of reaching nature in the city, the radius is much smaller for those who are poor, disabled, old or very young (Pyle, 2003). It is common that a neighborhood's ability to fascinate and excite their people, turns into dullness and apathy as the wealth of those neighborhoods diminishes; this leads to greater detachment, because those who know and recognize less, in turn care and act less about nature (Pyle, 2003). Ecologist Aldo Leopold states in his essay "Land Ethic" (1949) that a call for moral responsibility to the natural world is necessary; and to practice a land ethic that is quite simple: caring more about people, about land and about strengthening the relationship between them. "A thing is right when it tends to preserve the integrity, stability, and beauty

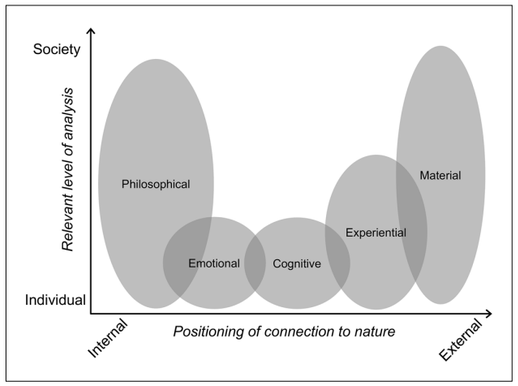


Fig. 2 | Source: Ives et al. (2018). This graph shows the conceptualization of different types of human-nature connections. The x-axis shows a spectrum of people's inner to outer worlds, and the y-axis shows their relevance at different scales of social aggregation. It is important to note that in reality there is overlap of different types of human-nature connections.

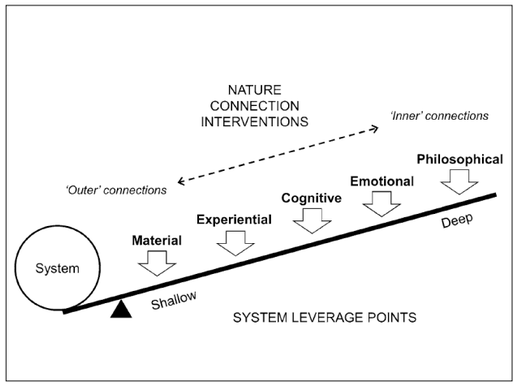


Fig. 3 | Source: Ives et al. (2018). This scheme shows an abstraction of how interventions for reconnecting people with nature can lead to system change. The more externally-defined connections are more likely to influence a system's parameters and the more internally-defined ones are more likely to influence the underlying goals and values that are embodied in a system.

of the biotic community. It is wrong when it tends otherwise" (Leopold, 1949).

Other factors that influence the relationship between nature and people are modern trends such as urban sprawl, increased mobility by car use, and population growth, and the moving of more people to cities. These trends affect the permeability of the urban landscape, because it decreases the opportunity for all organisms to find suitable space to courage, occupy and cross (Sijmons, 2020). Most of the time, the level of permeability in a city is depended on the size and configuration of green/blue networks. They work like an archipelago, and the amount of interconnectedness between the urban landscape determines whether the urban environment is a fruitful place for the distribution and settlement of different species, in combination with how permeable the artificial layers in the city are (Sijmons, 2020). Usually, the park systems in cities create this green archipelago in the urban fabric; because of this they offer an important refuge for species. Furthermore, the majority of parks are cultural as well, focusing on leisure and play in a carefully crafted replica of nature, and in this way improve citizens' well-being in a metropolitan surrounding (Sijmons, 2020). This is important, because the loss of daily contact with nature which result in social consequences, including a deteriorating public health and well-being, a reduced emotional affinity towards nature, and a decline in pro-environmental attitudes, which causes a cycle of disaffection towards nature (Soga & Gaston, 2016). And with growing recognition of environmental crises over the past decades, society's increasing disconnection from nature has been proposed as an underlying cause of unsustainability (Ives et al., 2017).

3 | The Environmental Benefits of Reconnecting the City to Nature

River cities require a management approach to prevent floods based on resilience instead of resistance, because decreasing floods through man-made structures fails to address future extreme weather events influenced by climate change. Therefore not a reliable approach to long-term flood safety (Liao, 2012). Urban resilience to floods is defined as a city's capacity to tolerate flooding, but also to reorganize when physical damage and socioeconomic disruption happens; living with periodic floods could be used by the city as a learning opportunity (Liao, 2012). In order to replace flood control as the approach to mitigate flood hazards, flood adaptation could enable natural floodplain functions to build a city's urban resilience to flood (Liao, 2012).

According to social-ecological systems scientist Sara Meerow (personal communication, 04 May 2020) 'resilience' remains a fuzzy concept that is hard to measure up to this day. However, discussing resilience unites different disciplines to collaborate and recognize the differences in the understanding of resilience. Meerow also states that seeing resilience as 'bouncing back' is problematic; we should always aim to bounce forward in order to improve progress, and resilience can be a driver in this. Cities could operationalize resilience in an transformative way and by organizing effort (Sara Meerow, personal communication, 04 May 2020). We cannot predict all novel disruptions, yet the core of resilience is flexibility: the ability do deal with everything. Furthermore, this essay acknowledges that up to now resilience has failed to deal adequately with equity, however this falls outside the scope of this essay.

By reviving the relationship between cities and nature, environmental, economic, and social resilience could be increased through solutions supported by nature; these solutions are labeled as Nature Based Solutions (NBS) (World Bank, 2017). They make use of natural processes and ecosystem services in order to effectively mitigate urban flooding caused by extreme precipitation, while also providing additional economical, ecological, and social benefits (World Bank, 2017). Currently the majority of flood risk management is conducted through grey infrastructure such as embankments, dams, levees and channels to control flooding; but recently NBS has emerged as a good alternative for grey flood risk management (World Bank, 2017). Right now there is an increasing momentum for the use of NBS. They are becoming part of resilience-building strategies and sustainable adaptations (World Bank, 2017). Furthermore, there is a growing awareness of NBS from communities, policy- and decision-makers and investors (World Bank, 2017) which in turn will increase the role of NBS in order to reach sustainable development goals in multiple countries (Huang et al., 2020). The benefits of NBS in relation to flood mitigation is threefold: firstly it improves water supply security through reforestation, wetland restoration and rainwater harvesting (Van et al., 2017). Secondly it increases water availability, water quality and stormwater runoff reduction by urban green infrastructures such as permeable pavements, green walls, and roof gardens (World Bank, 2017). Thirdly NBS are usually cost-efficient and require little energy, making it an inviting option (Palmer et al., 2015). These NBS can be applied to river basins (such as reforestation and green embankments), coastal zones (such as mangroves and wetlands), and cities (such as urban parks) (World Bank, 2017) and bring more diverse natural features and processes into cities (European Commission, 2015). Additionally, NBS can help mitigate drought, erosion and landslide; decrease vulnerability to climate change; and create benefits to both the environment and local communities (World Bank, 2017).

However, the effectiveness of applying NBS requires a comprehensive assessment and implementation process (just as conventional engineering solutions), and in addition to this NBS are quite often implemented on an irregular basis (World Bank, 2017). While significant advances in design and testing protocols for ecosystems and their role in risk mitigation have been made, they have not yet been fully evaluated and standardized (World Bank, 2017). Yet the reason NBS have a positive effect on urban flood resilience is because they address the source of the flooding problem by reducing stormwater runoff mainly through water infiltration, whereas grey solutions such as upgrading or redesigning existing drainage systems do not (Suripin, 2018).

4 | The Role of Urban Designers in Reconnecting People with Nature

Reinvigorating our bond with nature is a challenge; and the discipline of urban design is in a position to adequately address this challenge. Urban designers have the ability to change the cities' current approach towards nature, and design cities where people have the ability connect to nature. In order to achieve a change of our proximity to nature and shift our physical relationship more towards to the environment, an interdisciplinary approach is necessary; researchers and policy makers also need to focus more of their attention and effort on the possibilities of reducing the extinction of experience and reconnect people with nature (Hopkins, 2017). Urban designers can transform awareness by developing designs that highlight the environment in the urban context, because designs that work in partnership with nature articulate an implicit hope that we, as people, might do the same some day (Van der Ryn & Cowan, 2007). The key to reviving awareness of the natural systems, is to make it visible by designing places grounded by their unique environment by recovering local knowledge (Van der Ryn & Cowan, 2007). Dialogue with nature is crucial in order to move forward to a sustainable future. However, it is quite contrary to the often used Western approach ruled by dualism by building in opposition to nature. Yet it should be noted that the approach of the Western world towards nature is an ever-changing *modus operandi*. Before the Western world became to view nature as something separate and inferior, the West considered nature as something sublime (influenced by Romanticism), and before that as something orderly and useful (influenced by the Enlightenment), and before that nature was considered as something chaotic and dangerous (influenced by Puritanism) (University of Wisconsin, n.d.). Therefore, we should not simply accept that building in opposition to nature is the only acceptable approach. We can learn from the past that a change of ways is always just around the corner.

In order to open new possibilities to restructure ecosystem understanding and city design and planning, we should look towards developments in urban ecology and landscape urbanism (Steiner, 2011). Since the mid-1990s, two ideas emerged with implications for how urban designers design and plan cities in the twenty-first century. On the one hand there is landscape urbanism that combines both design and ecology, stating that the landscape should be the fundamental aspect of designing a city; this is in contrast with more traditional urbanism where some kind of structure (walls, roads, buildings) lead developments, and nature is relegated to the remaining spaces that are unsuitable for buildings, or is used as a decorative item (Steiner, 2011). To use natural processes in order to help the urban designer to organize urban form, landscape urbanism provides an opportunity to create the same space for both people and nature. Furthermore, it can help to construct new urban ecologies that consider the dynamics between sociality, culture, and environment (Steiner, 2011). On the other hand, there is the idea of urban ecology, which is an evolving discipline with a focus on landscapes and urban regions (Steiner, 2011). Forman and Godron defined a significant part of this field and addressed its potential for planning as well (Forman & Gordon, 1981; Forman & Gordon, 1986). Now the emerging field of urban ecology is drawing attention to an interdisciplinary approach to understand what the drivers, patterns, processes and outcomes associated with urban landscapes are. Based on this, Mostafavi & Doherty (2010) promote the concept of ecological urbanism in order to create more understanding of the inherent conflicting conditions between the disciplines of ecology and urbanism; they draw strongly on landscape urbanism for this. Because urbanization posses social and environmental challenges, it is necessary to create new ideas about urban design and planning. A goal of urban ecology is to design cities with nature to increase ecosystem services, so the quality of the city rises for everyone: people, plants, and animals (Mostafavi & Doherty, 2010).

All of this suggests that new areas of research in the fields of landscape and urban planning and design are emerging, making it an exciting opportunity to propose new approaches. The previously mentioned approaches suggest that humanities-based design theory can be a powerful force in how places are created, and that while ecological research has moved into cities, it is crucial to include the citizen's role in urban ecosystems; additionally, there is potential for advancing human ecology with concepts like sustainability, regeneration, resilience, and ecosystem services (Steiner, 2011).

5 | Rethinking City-River Relations Through Nature-Based Thinking

The spatial relationship between city and river is researched by fields that are landscape-related (landscape ecology, landscape architecture, landscape urbanism), design-related (landscape architecture, urban design, architecture), and engineering-related (river ecology, hydrology, hydraulic engineering) (Forgaci, 2018). A river should not be seen by itself; it is important to always take into account an entire river corridor to understand its entire influence. The Vermont

Agency of Natural Resources (2004) defines a river corridor as the following: "The area that the stream or river needs to maintain physical/geomorphic equilibrium" and "the land area adjacent to a river that is required to accommodate the dimensions, slope, planform, and buffer of the naturally stable channel […]". Forgaci (2018) states about urban river corridors (URC's) that "URC's are at the same time artificial and natural, large- and small-scale, functional and experiential, ecological and social, to name just the extremes of a wide range of in between variations of their multivalence." (Forgaci, 2018, pp. 67).

In recent years, cities around the world have slowly moved towards a more river-centred perspective by rethinking the city-river relations (Knoll, Lubken & Schott, 2017) and there has been an increase in river restoration and river rehabilitation since the 1990s (Forgaci, 2018). In urban environments, river restoration is mostly partial, therefore a proper understanding of past river dynamics is crucial as well (Forgaci, 2018). For the case of Houston, the Buffalo Bayou has been the birthplace of the city, and an important transportation artery. However, with the introduction of the car this urban river started to be neglected more and more; losing its visibility by being buried under a web of interstate-highways. This development caused the Buffalo Bayou's disappearance from the daily lives of Houstonians. It has been acknowledged that urbanization has negative effects on stream- and river ecosystems (Gregory, 2006; Bernhardt & Palmer, 2007). However, if a river can disappear, it can reappear as well (Knoll, Lubken & Schott, 2017). And there are cities who have successfully re-established their relationship with their local urban river and accessed their fluvial assets as well; think for example of Seoul, where they removed a 4 mile (or 6 km) highway that covered their central river (Knoll, Lubken & Schott, 2017). Actualized projects could provide helpful lessons about what works and what does not through actual experience. Case studies have the ability to built on reflective practice by incorporating ecological research and design theory (Burns, 2017). In the process, new ways to design and plan city-regions with nature and culture could result.

Furthermore, by broadening the scope of the concept of NBS, which is an effort to address our dependence on nature and develop resilient urban areas together with human life, the concept of Nature-Based Thinking is introduced as way to refocus our thoughts and speech in order to stimulate a broader nature-based, but also social-ecological inclusive approach for greener cities (Randrup et al., 2020). Nature-based Thinking can contribute to adequately name and frame planned goals (which is relevant for our quest for solutions), we can move a step forward from only being inspired by nature towards developing the outset for the transition of more sustainable cities (Randrup et al., 2020; Lakoff & Johnson, 2003). However, NBS remains important in order to move beyond the stage of being inspired by nature; therefore acknowledging that human-nature-technology relationships could offer alternative, integrated pathways towards urban sustainability is essential (Randrup et al., 2020). They could play a key role in approaching five of the most important challenges that river restoration practices face today: resistance and a lack of integration with other development goals: excess stormwater runoff, insufficient riparian space, altered sediment regimes, legacy impacts, and social and institutional challenges (Vietz et al., 2016). Nature-Based Thinking shows us how the interconnectedness of humans, nature and technology is a useful starting point to be inspired by natural elements and processes in different aspects of urban development in order to reach a holistic approach to sustainable cities.

6 | Conclusion: What This All Means for the Future of the Buffalo Bayou in Houston

This paper aimed to appraise to what extent reintroducing nature to the urban river corridor of the Buffalo Bayou can contribute to an increased flood resilience in Houston. Literature research showed that a green approach holds potential on multiple capacities, underlining the argument of this paper in favor of Nature Based Solutions instead of traditional grey infrastructures. Nature Based Solutions principles hold a strong potential in improving Houston's urban flood resilience, although an integration towards a water sensitive design in combination with natural processes and ecosystems is essential. Throughout the years there has been a decline of meaningful interactions between people and nature, which lead to shallow solutions for conservation of nature and social consequences such as a deteriorating public health and well-being, a reduced emotional affinity towards nature, and a decline in pro-environmental attitudes, which caused a cycle of disaffection towards nature and is seen as an underlying cause of unsustainability. Furthermore, it is important to note that at this point in time there is an increasing momentum for the use of Nature Based Solutions in resilience-building strategies and sustainable adaptations. Nature Based Thinking can contribute in helping to refocus people's thoughts and speech in order to stimulate a broader nature-based approach for cities and move forward to transitioning towards a more sustainable city. This is especially important in Houston, where a libertarian attitude towards natural resources and the environment still persists. The core principles of reconnecting people with nature hold merits in several disciplines, but especially urban designers are in a position to adequately address the challenge of invigorating our bond with nature by changing cities' current approach towards nature, and design cities where people are given the ability to connect to nature and transform awareness by developing designs that highlight the environment in the urban context.

Therefore, the first steps Houston should take in order to reintroduce nature to urban river corridors in order to increase flood resilience is to start with river restorations on the Buffalo Bayou, so the river can be restored back to its natural state and functioning of the river system in support of biodiversity, recreation, flood management and landscape development. This transformation could reintroduce accessible nature inside the city and become a catalyst in the process of reconnecting people to nature and improving flood resilience in Houston. Additionally, it increases the environmental, social, historic, aesthetic and economic value of the city. Dialogue with nature inspires hope that we, as people, might do the same someday and is crucial in order to move forward to a sustainable future.

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