land | waterscape as projective infrastructure

To condition landscape as an infrastructure addressing hydrological uncertainties within deltaic territories

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On a personal note, I would like to thank my parents and friends for constant support and encouragement.

Summary

In past quarter century, the frequency and intensity of natural disasters occurring, coupled with infrastructure failures has demonstrated vulnerability induced within the urbanised regions. Majority of these incidents are in relation to flooding of rivers or storm surges and are situated in deltaic conditions which have very high economic values, large concentrated population and intense urbanisation. This questions the urbanisation process and its ramification into a dichotomous position with the environment. Having said that, the broad aim of this research project is to explore this dichotomy between process of urbanisation and environmental degradation in the light of climate change.

The emergence of ecological ideology in planning and management within last two decades, has challenged the traditional economic model of stability, certainty and order. The urbanisation process which is very much driven by this economic model needs a shift of paradigm by embracing this ecological approach to address the uncertainties concerned with frequent flooding and storm surges. Hence, this research project aligns itself with the principles of persistence, change and unpredictability; and perceives the issue through the lens of ecological resilience. Within this context, the challenge for an urbanised delta lies in how to develop resiliency towards urban water issues, storm surges and sea level rise simultaneously. This leads to the research question;

How to systematically develop landscape as an operative ground for infrastructure through multiple scales in an urbanized delta addressing uncertainties involved within hydrologically induced vulnerability?

The research question is addressed building upon two hypotheses; 1. tackling complex systems demands for an approach spanning across scale and time, as local and large-scale knowledge combined with time factor is necessary to understand the system behaviour in its normal and disruptive state. 2. addressing uncertainties requires an open-ended dimension where, the design or the strategy has inbuilt flexibility to adapt with changing conditions while maintaining the operation of the system. The hypotheses highlight two important aspects of understanding system behaviour and developing adaptive character for the same due to uncertain circumstances (natural and urban). This demands for a strategy which operates at varying degrees of performance in relation to uncertainty.

This enquiry is projected upon San Francisco bay area, a region with very interesting economic, social and ecological setup. The region represents spatial transformation dominated by dynamic economy and infrastructural development. Urbanisation along the bay is highly driven by economic decisions and infrastructural networking, and this is visible spatially supported by historic mappings. Bay area faces a major challenge due to climate change, as most of its critical infrastructure and economic assets are rooted within the reclaimed lands of bay which are under the threat of inundation due to sea level rise. Moreover, the ecosystem along the bay which consisted of marsh lands and mudflats has been degraded and the land use intensity has altered the hydrological system along the transect from upstream to downstream at the bay. This sets the context to perceive the broad aim of exploring the relation between the urban processes and environmental degradation.

To answer the research question and delve into the hypotheses, three elements shape the methodology of the research project - scale, performance and temporal dimension. Scale - based on the first hypothesis related to tackling complex systems demands for an approach spanning across scale and time; four spatial scales – macro, meso, micro and nano are delineated based on common geographic conditions, challenges and hydrological setup of watershed, river basins, sub-basins and micro-basins. These scales range from watershed of California as the largest to an individual land parcel within city of Oakland as the smallest. The complex layers involved work differently at different scales. Hence, scaling up or down cannot be a simple linear addition or subtraction. Not only do the large and slow variables of larger system control smaller and faster variables of a smaller one, but the latter also occasionally revolts to affect the former. Performance - having mentioned variables within the systems, the second hypothesis addressing uncertainty through open-ended dimension highlights the operative nature and varying degree of performance of the strategy. Here, it is the micro and nano scale where these strategies are spatially implemented to explore suitability of the system. Temporal dimension - the third element is very crucial for the sustainable development of both, the territory and the system. Within this element, idea is to explore the multiple possibilities or the aspect of uncertainty present due climate issues as well as economic advances. The process explores the adaptive nature or in-built flexibility of system designed over time.

The objective is to condition the landscape as an operational ground for an infrastructure addressing the hydrological issues. It refers to the system which is achieved by creating a network of hydrological elements interwoven within the urban fabric to manage urban storm water, storm surge and sea level rise challenges. This network is derived following the design thinking process of analysis-synthesis-projection; where, the stage of analysis is to dissect the complex layers and information, synthesis is to re-assemble and understand through relational thinking and projection is to speculate the future behaviour of these layers or systems involved.

The specificity of this research project lies in the context being in a deltaic condition. Managing urban storm water which needs to be conveyed, stored and discharged but also the brackish or saline bay water which inundates the downstream temporarily during storm surges or permanently in the process of sea level rise, lies at the core of this research. The challenge lies in how the system can accommodate the bidirectional flow of fresh and saline water while improving the built environment for the territory. Along with designing a strategy and a system, a careful exploration is carried out in understanding building typologies, ownership, economic trends, vegetation which needs to be incorporated to achieve the desired performance.

The conclusion of this exploration leads to the understanding that, urban process is proactive and opportunistic whereas the natural processes are reactive in their behaviour. It is difficult to manage such complex systems of nature, so to achieve a desired reaction from the natural process, as humans we need to manage our activities within these systems. Moreover, the research highlights confrontation of pluvial, fluvial and coastal flooding, where managing fresh and saline water is vital. Embracing an ecological approach asks for establishing parameters and creating conditions from understanding natural processes and using them as a framework, which will further guide the economic and social realm for a sustainable development.

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Figure 1.1: Sacramento - San Joaquin River Delta, California (Edward Burtynsky) - Pixdaus. Source : http://pixdaus.com/sacramento-san-joaquin-river-delta-california-edward-burtyns/items/view/244245/

Introduction

Increased frequency and severity of flooding in past decades has demonstrated the vulnerability of urban regions, especially in the deltaic zones (Meyer and Nijhuis, 2014). Moreover, these incidents also prove the changes occurring in the climatic conditions globally. However, this phenomenon of climate change is not recognised or rather not appreciated by the current global economic model (Brown, 2014). History is evidence of the opportunistic nature of urbanising patterns, where most of the major settlements developed along the coasts or rivers, which either served as a highly fertile region for production or strategically located setup for trade. However, there were times when human lived respecting the nature. Today, majority of the cities with high economic values, concentrated population and intense urbanisation fall under these deltas which are highly vulnerable to sea level rise and increasing frequency of flooding and storm surges (Meyer and Nijhuis, 2014).

These deltas form a unique condition, where rivers discharge into the sea or ocean thereby forming new lands due to sediment transport and tidal currents. It is a very dynamic setup of territorial formation and land – water transition. However, the land use pattern and its intensity disrupts these fragile processes thereby inducing threat to both, the ecosystem and the urban settlement (Reed and Lister, 2014). The urbanised deltas not only have hydrological threat from the high precipitation and rivers which discharge water downstream from their overheads but also from the tidal currents, storm surges and sea level rise. These hydrological threats have short term effects of immediate property damage and human loss, moreover it also has long term effects generated by disrupted critical systems, like transportation, communication and energy. Over long run it affects the local and the national economic growth. The 2015 World Economic Forum (WEF) Risks Report has put the impact of Water Crises as the number one global risk. The hard-engineered solutions to tackle these issues have proven their failure in the in 2005 New Orleans floods. The aspect of uncertainty and unpredictability challenges the engineered approach for these dynamic threats, thereby demanding an attention which is well informed from engineering, design and planning perspective (Reed and Lister, 2014). Understanding the natural processes involved, integrating planning and management policies along with the economic models and supported by strategic design and engineering solutions is crucial.

This leads to the broad aim of this research project, which is, to explore and understand this dichotomous relation between the process of urbanisation and environmental degradation, in the light of climate change.

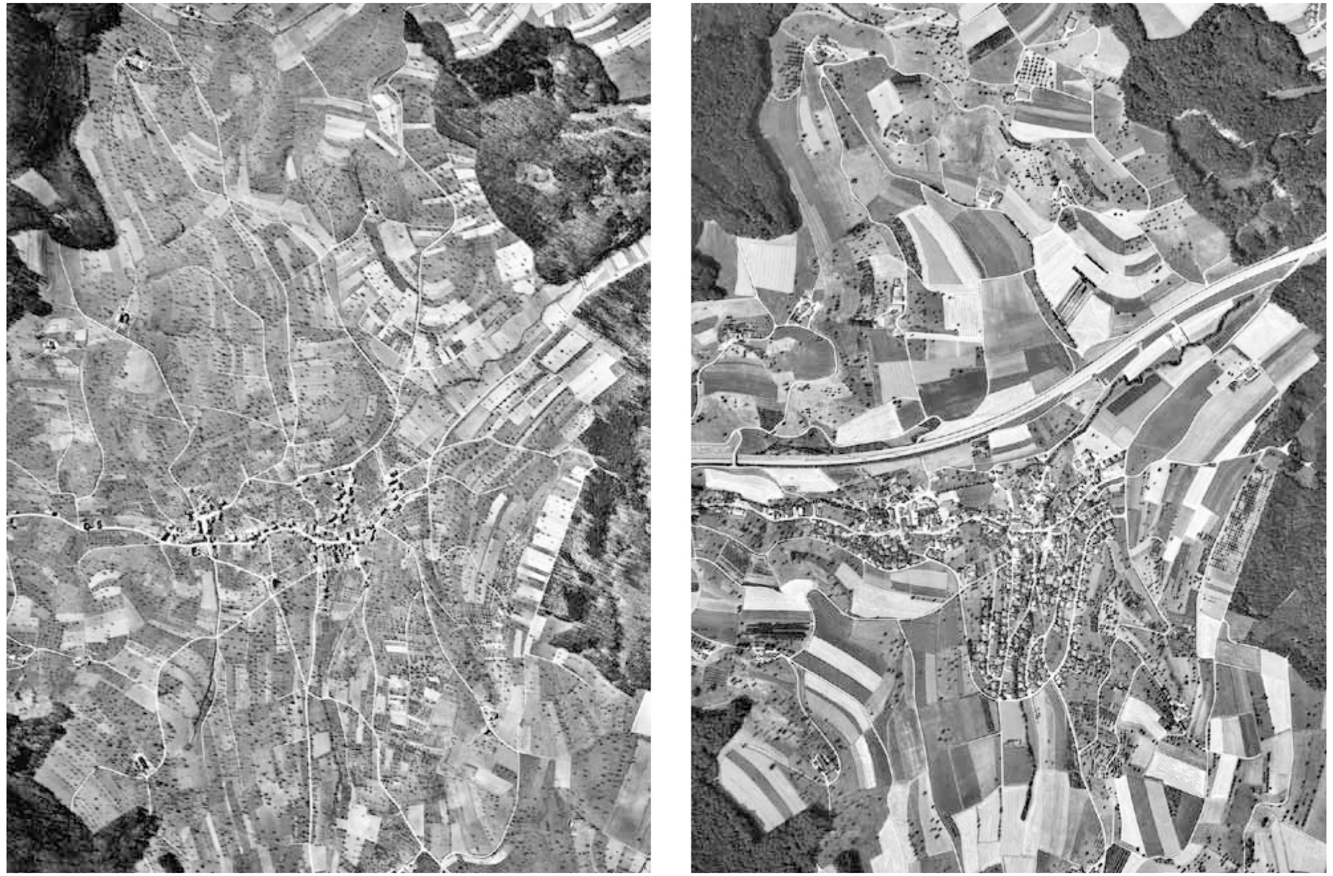


Figure 2.1: Fragmented Landscapes. Source : Tanner 1999, © Federal Office of Topography swisstopo, reproduced by permission of swisstopo BA110233.

Project Field

This chapter is intended to introduce the domain of research. It introduces the discussion about relation between urban processes and environmental shifts in deltaic conditions. Further, it highlights the specificity of delta territories with respect to urban processes, environmental changes and its effects on hydrological issues within the region. Later, the study dives into the context of San Francisco bay area, thereby by exploring the evolution of the region with respect to urban patterns, economic advances and environmental changes. As a conclusion, the section summarizes certain issues in hand which boils down to the problem statement of the research project.

Urban Deltas

Delta is a territory of confluence of a river, creek or a stream with a larger waterscape of bay, estuary, sea or ocean(Meyer and Nijhuis, 2014). It is a territory with a complex interactive processes of river discharge, tidal currents, oceanic waves, sediment transports and land formations (Bradshaw and Weaver, 1995). Its fertile conditions for production and strategic location for trade led to formation of major urban settlements in such setup. Urban deltas are regions of dynamic natural processes, of high economic values, concentrated population conditions and intense urbanisation (Meyer and Nijhuis, 2014). This has resulted in degradation of natural deltaic conditions, land-water transition, formative power of deltas thereby reducing the regions adaptive capacity towards flood risk and inducing vulnerability (Overeem and Brakenridge, 2009). Moreover, the increasing frequency of floods and rising sea level has added into the threat. However, urbanising deltas are not only victims of climate change but also contribute to it as important centres and transportation hubs of fossil fuels (Meyer and Nijhuis, 2014). The new greenfield developments previously outside urban areas are now encroachments in these flood prone or low land zones. Cities are increasingly losing their capacity to deal with fast changes in climate and ability to anticipate and adapt to slow changes and trends (Zevenbergen et al., 2008). Major flood disasters have created the need to shift from flood protection to a more integrated approach. In last decade, however, climate change has become a potential trend breaker in the way that hydrological variables and existing statistical distribution of flood probabilities are affected (Kabat et al., 2005). The present challenge seems to recognize the future as being inherently uncertain and that science will not necessarily reduce that uncertainty (Zevenbergen et al., 2008).

Risk and Vulnerability

The risk of an event is determined by the product of its probability for its occurrence with the impact it would make over a system; where risk is a very hazard specific term. Hence, within flood risk management, risk is a product of flood probability and its impact or consequence (Brooks, 2003). In this equation probability determines the frequency of occurrence of the event whereas, consequence or impact relates to the intensity, duration and vulnerability. The term vulnerability, represents social and biophysical aspect of the territory; where biophysical associates with the physical damage caused to people, property, ecosystem, habitat, infrastructure, etc.; while social vulnerability relates to the inherent qualities of the territory such as poverty, lack of public services or disaster response services, insurance policies, etc. irrespective of hazard, which will add into the physical damage caused to the region (Brooks, 2003). A system, in this case the region, requires certain amount of time to react, respond or recover from the impact of a hazard. This time represents the adaptive capacity of that system and higher the adaptive capacity of a system, lesser is the time taken by it to recover from the impact, corresponding to lower vulnerability level (Brooks, 2003).

From Prevention to Management

In last two decades, the frequency and intensity of floods and storm surges has increased, which demands for a shift in approach from flood risk prevention or reduction to flood risk management, where former focuses on the aspect of probability reduction by building dike systems and later aims to combine the probability reduction along with minimizing impact or consequence (Hall and Solomatine, 2008). Flood risk management approach focuses on a multi-layered system of prevention, reduction and evacuation operating through various disciplines of engineering, planning and management, which also demands for addressing uncertainty of consequences while dealing with threat (Sutton-Grier et al., 2015). The research project inclines towards the flood risk management approach which considers the unpredictability in the frequency and intensity of flooding due to climate change.

Dichotomous Relation

The way we as humans occupy land is very much driven by the opportunistic nature striving for economic well-being. Even though, it demands for stability, certainty and efficiency, the processes of occupying and thriving itself is dynamic and exploitive in nature, and in this process of urbanising, the environment has suffered and degraded (Bélanger, 2013). A comprehensive study done by Swiss Federal Office for the Environment and European Environment Agency called Landscape Fragmentation, displays the effects of urbanisation as environmental degradation by structurally and functionally fragmenting the landscape. These effects cause numerous alterations especially within the hydrological systems. As mentioned before, most of the urbanised regions situated along the coast, tend to become vulnerable due to altered hydrological cycles and climatic changes like sea level rise and increased precipitation add to these vulnerability aspects (Jaeger et al., 2011).
Major urban densification and valuable economic assets are situated at the midstream or downstream of a transect along the coast where the runoff is discharged into the larger waterscape. Pierre Belanger states in one of his lectures, "….as much as we are concerned about decentralization today and about urban sprawl; we should be paying attention to the larger processes that are happening around the planet, which is not the phenomena of urban sprawl, but the phenomena of coastal crawl; we are creeping along the coast line at an unprecedented rate" (University of British Columbia, 2015). This itself demonstrates the degradation of environmental buffer along the coast in the process of occupying it, there-by inducing threat not only from the upstream runoff which can accumulate downstream due to lack of absorbing agents, but also from downstream during storm surges or sea level rise. The land use patterns resulting into soil sealing reduces the capacity of the region to infiltrate and increases the peak discharge during heavy rains (Jaeger et al., 2011). Moreover, the modification of land-water transitions from soft to hard degrade the existing marshes or mudflats which absorb the wave impacts. This degradation of the natural buffer induces vulnerability within these regions putting large number of people and high valued assets at risk (Overeem and Brakenridge, 2009).

Richard Forman, one of the prominent figures in the field of landscape ecology or urban ecology has classified this degradation of environment into five morphologies in his book Landscape Ecology (1984);

1. Fragmentation – breaking up a larger/intact habitat into smaller dispersed patches.

2. Dissection – splitting an intact habitat into two patches separated by a corridor.

3. Perforation – creating holes within an intact habitat.
4. Shrinkage – decrease in size of one or more habitats.

5. Attrition – disappearance of one or more habitat patches.

These five morphologies suggest a relation with the urban patterns, which will either fragment, dissect, perforate, shrink or attrite the environment. This point is well established not only by Forman but also in Landscape Fragmentation report (Jaeger et al., 2011) by Swiss Federal Office for Environment and European Environment Agency. Moreover, Belanger mentions civil engineering and urban planning in city building process of 19th and 20th century were derived from notions of standardization, efficiency, monofunctional, parcellation and permeance; which oppose the nature of ecological systems which are interwoven, dynamic and constantly under a state of shift (Bélanger, 2013). This creates an opposing or a dichotomous relation between the urban occupational process and ecological systems. This is further explored with the context of Bay area in the study.

3x3x3 Analysis

This section co-relates the situation of landscape fragmentation (Dramstad et al., 1996) in an urbanised delta to the San Francisco bay area. With the help of text, illustrations, literature study, mapping; the evolutionary process of bay is understood to identify major shifts and the driving forces behind those shifts. The urbanised deltas are formed of several sub-systems and processes which influence each other through scales and time (Holling, 2001) (McHarg and Mumford, 1969). These sub-systems can be summarized in three layers (Meyer and Nijhuis, 2016); natural system of territory and water (substratum), the layer of network of infrastructure and the layer of occupation (urban patterns, agriculture). Each layer is characterised by its own dynamic and speed. A method of 3x3x3 analysis (Meyer and Nijhuis, 2016) is used; where each layer is analysed in three

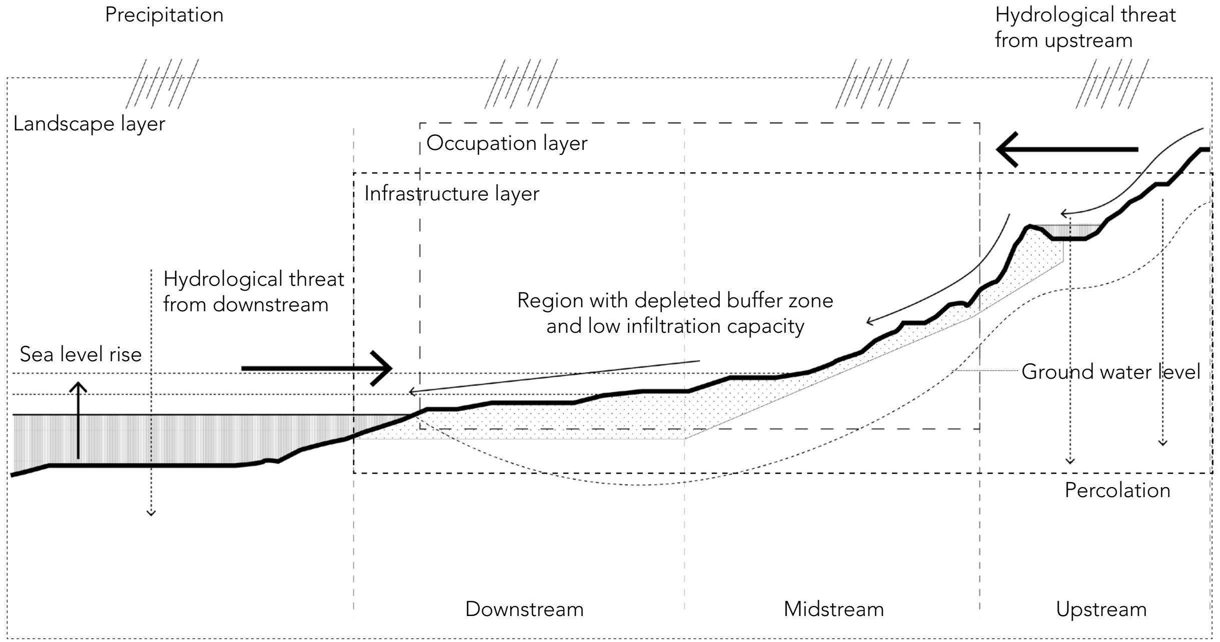


Figure 2.2: Transect of urbanized delta. Illustration : Author

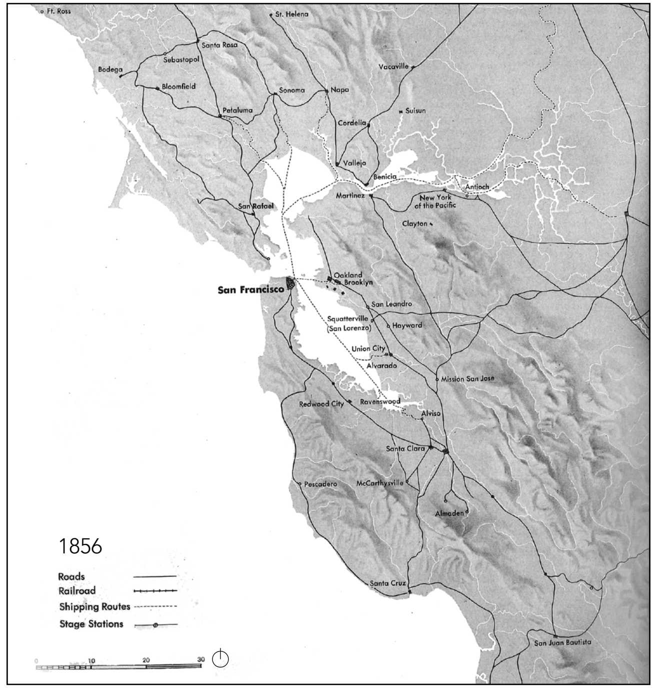


Figure 2.3: 1856 Map of San Francisco bay area. Source : SCOTT, M. 1985. The San Francisco Bay area: A metropolis in perspective, Univ of California Press.

different scales and three different time periods. This leads to a basic understanding of driving forces and the speed of change of each layer, thereby identifying contradictions, opportunities, challenges within the territory. In addition to these three layers of landscape, infrastructure and occupation, a fourth layer of economy is used to relate the events through history within the Bay area.

Gold Rush

Californian Gold Rush began in January 1848, which led to massive migration to the Bay Area. San Francisco grew from a small settlement of about 200 residents in 1846 to about 36,000 by 1852. Gold was retrieved from streams and riverbeds by process of panning. Later, technological advances reached a point where significant financing was required, increasing the proportion of gold companies to individual miners. This affected the environment, especially the sedimentation pattern of the river system in the Bay area. The migration of people and mining activity resulted in railway network along the Bay. The ecological resource of river system and its sedimentation which was feeding into the Bay was disrupted due to this activity (Scott, 1985).

Economy – Excess mining activity

Infrastructure – Waterways and Railway

Occupational pattern – Grew exponentially and along the infrastructure lines.

Ecology – The resource of river system and sedimentation was disrupted.

Shift to agriculture

During Gold Rush, the population within Bay area increased tremendously. To support this population agriculture increased around the Bay. San Francisco started developing as a major port to trade gold and food produce as well. By 1855, Gold Rush lost its pace and agriculture became the new economic power house. The big investors who were attracted to the Bay area during Gold Rush realised the potentials of the estuary and the presence of brackish water, which led them to invest in salt ponds. The marshes along the edge of Bay started being converted into salt ponds for financial gains, as it was easiest way to gain profit.

The occupational pattern kept on growing even though there was a shift in the economic profile. The railway network grew to cater to the growing population and transport the produce to hinterlands (Scott, 1985).

Economy – Agriculture and salt production

Infrastructure – Waterways and increased railway network

Occupational pattern – San Francisco city grew followed by Oakland. Third major city in development was San Jose to south.

Ecology – The buffer zone between land-water transition of marsh lands were converted to agricultural lands or salt producing ponds.

The first automobile industry

In 1907, first automobile industry was established in the Bay area in Oakland, which gave a new dimension to the urbanization pattern. Oakland was developed as a port to facilitate the industrial functions, San Francisco port was upgraded, ship building was massive industrial activity taking place along these ports as well. To the north of Bay, oil refineries were established. Sand was dredged from the bay to reclaim more land along the edge of Bay. The edge conditions or the land-water transitions were altered. Due to introduction of automobile industry, a new line of infrastructure; highways and

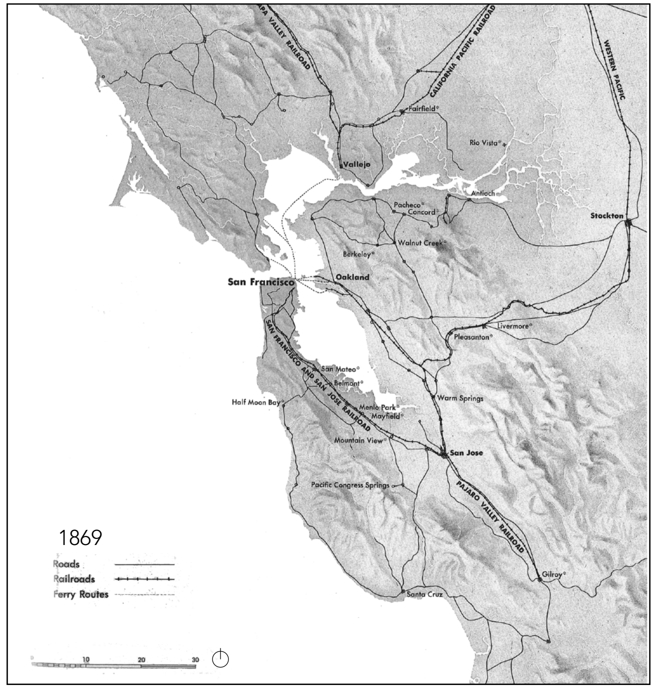


Figure 2.4: 1869 Map of San Francisco bay area. Source : SCOTT, M. 1985. The San Francisco Bay area: A metropolis in perspective, Univ of California Press.

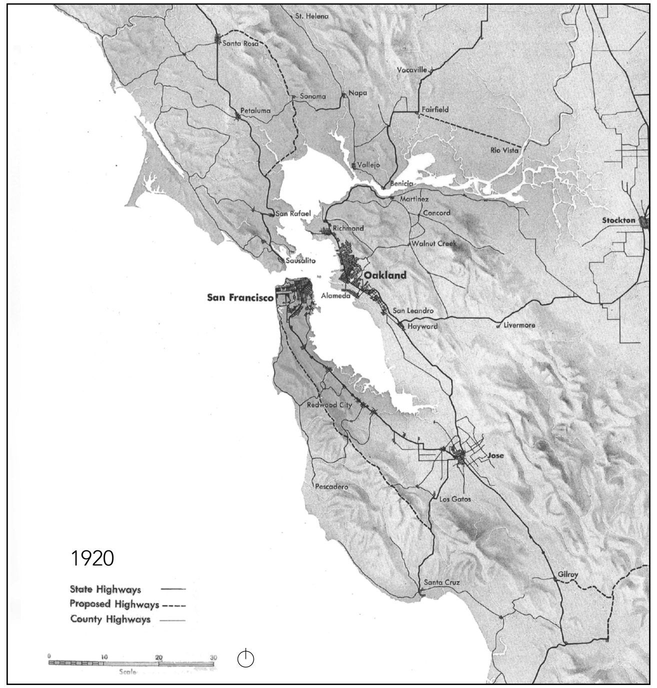


Figure 2.5: 1920 Map of San Francisco bay area. Source : SCOTT, M. 1985. The San Francisco Bay area: A metropolis in perspective, Univ of California Press.

roadways grew tremendously. The divide between ecology and the urbanization started to be increasingly prominent. The edge of bay was getting urbanised along these infrastructural lines (Scott, 1985).

Economy – Industrialization.

Infrastructure – San Francisco and Oakland ports, railway network and massive roadway network along the edges of Bay.

Occupational pattern – south Bay under massive urbanisation along the edges and infrastructure lines.

Ecology – Due to industrial activities, land was contaminated, land-water transition altered, dredging of Bay affected the hydrological conditions, marshes exploited through continued agriculture and salt production.

The rise of Silicon Valley

Post World War, the manufacturing sector within Bay area grew tremendously, from industries to oil refineries, from agricultural to salt production, from highway networks to port upgradation. Later, during 1970's, in phase of Cold War, a lot of investment was made in the information technology sector. New lands were reclaimed in the south of Bay for this new development; commercial companies, service sector and ICT oriented. This gave rise to Silicon Valley. A new age Gold Rush occurred, as it attracted numerous companies to establish their offices along with them attracting the population with new job opportunities. A complete belt of urbanisation encircled the Bay and disconnected its ecology with the hinterland (Scott, 1985).

Economy – Information and Technology industry, commercial offices.

Infrastructure – Port upgradation, massive road networks, metros and subways, electricity power and water treatment plants.

Occupational pattern – South Bay with a massive population habituated with an uninterrupted ring of urbanisation along the entire Bay.

Ecology – Massive shrinkage of Bay itself due to land reclamation, loss of marsh lands, covering up of streams feeding in the bay from upstream.

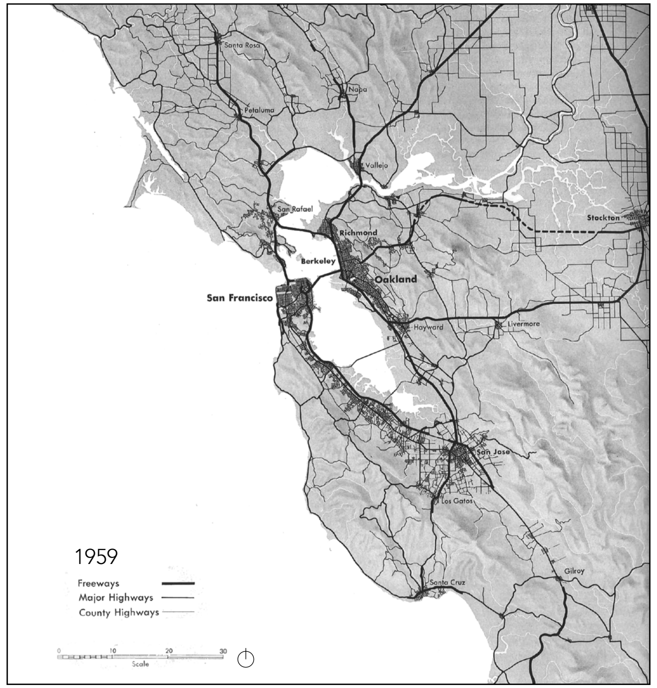


Figure 2.6: 1959 Map of San Francisco bay area. Source : SCOTT, M. 1985. The San Francisco Bay area: A metropolis in perspective, Univ of California Press.

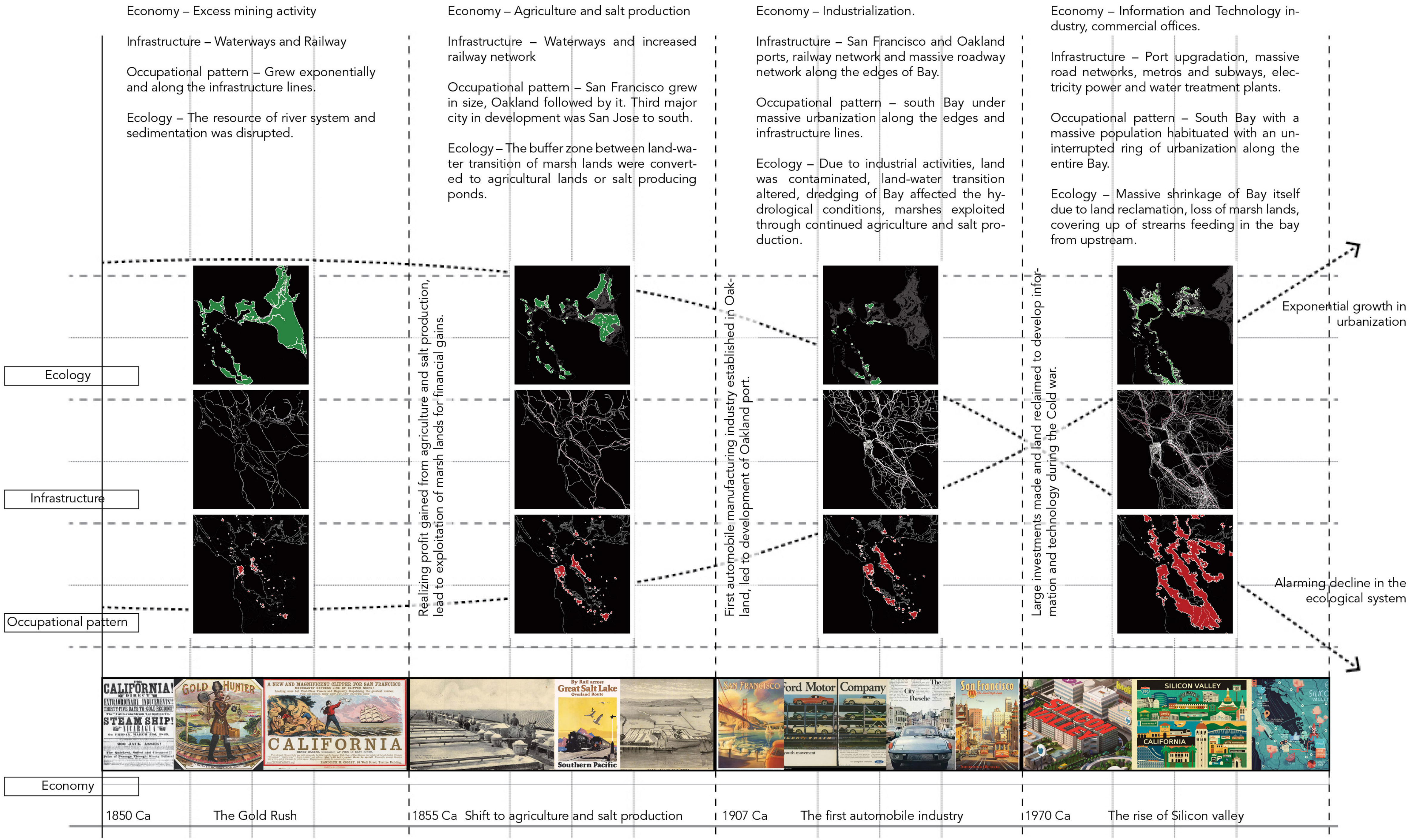


Figure 2.7: Evolutionary mapping of Bay area. Illustration : Author

Bay Area – Present

From the previous section, it is clear that economy and infrastructure can be considered the guiding factors in the urbanisation process of San Francisco Bay area. As a result, there has been a divide between the bay ecology and the hinterland, thereby altering the land-water transition throughout the bay. The geographic conditions have led the urbanisation sprawl along the edge and the process dissected the ecological system. This is evident in the map below.

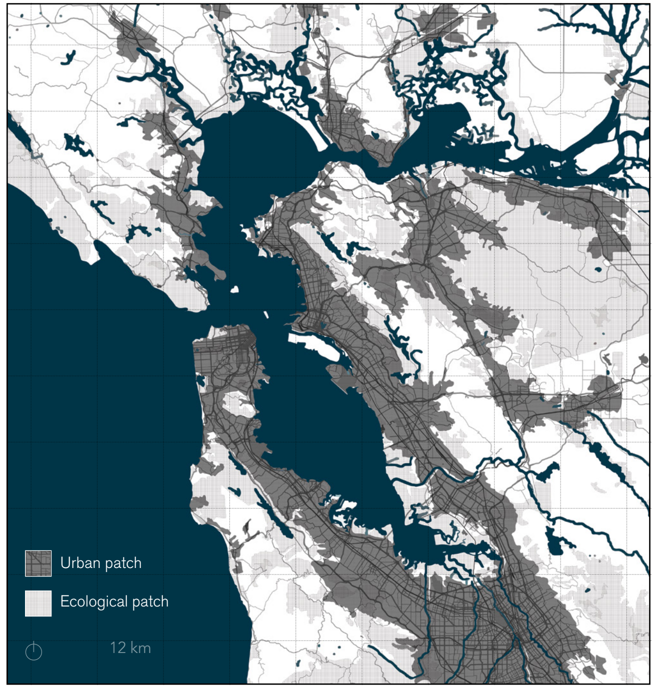


Figure 3.1: Dissected landscapes of Bay area. Illustration : Author

Administrative boundaries

The Bay area consists of nine counties around it and a total of 101 municipalities which are distributed within these counties; San Francisco being the county and municipality both. Administratively, Bay area is very dispersed in nature, as every municipality has its own agenda and vision which is not in line with other municipalities around it, neither it is with any county (Plan Bay Area 2040 report, 2017). The infrastructural lines cross these administrative boundaries are managed by the private sector. The municipalities encourage development within their city by leasing land to industries like automobile manufacturing or showrooms which provide greater revenue to them, resulting in an unprecedented exploitation of land and soil disrupting the landscape around it. The challenges of sea level rise and storm surges definitely do not coincide with these administrative boundaries. The higher government organisations have guide-lines but implementation is done by local authorities. Hence, managing hydrological risks within the region requires a shift of perspective regarding the regulatory, planning and design systems; one that enables the delineation of areas based on common challenges and potentials (Bélanger, 2013).

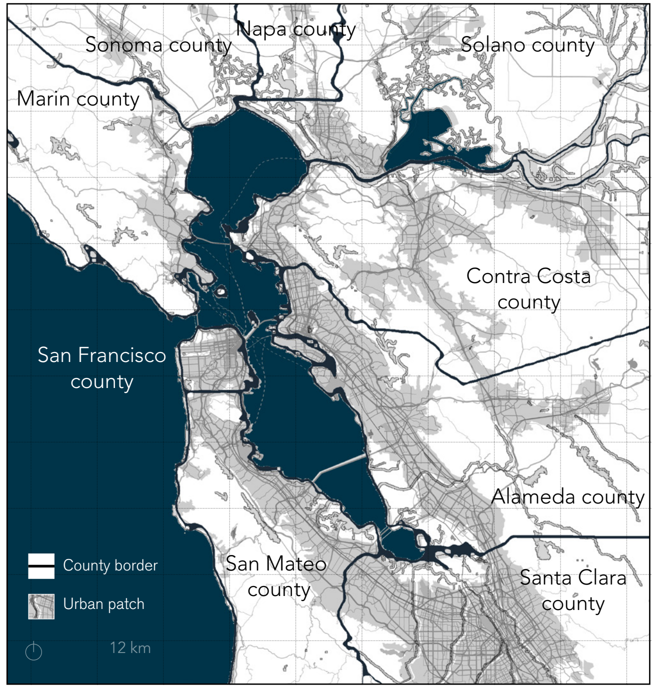


Figure 3.2: Administrative boundaries of Bay area. Illustration : Author

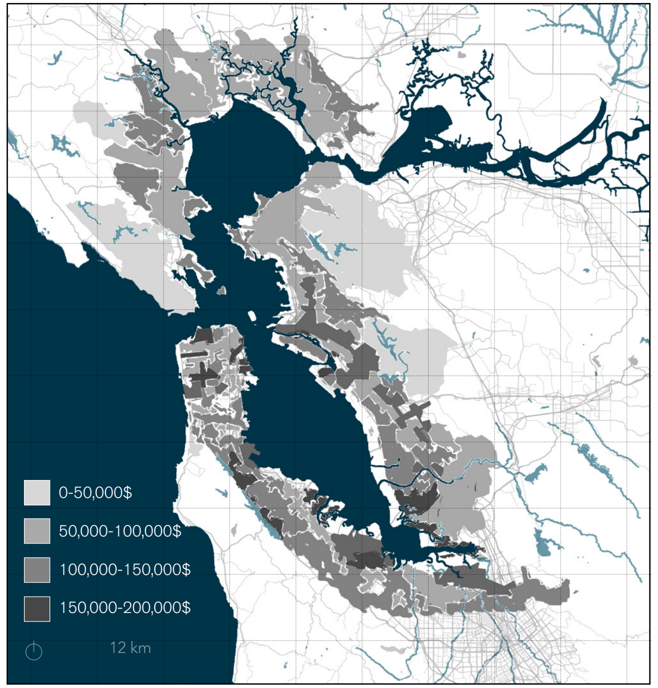


Figure 3.3: Household income of Bay area. Illustration : Author

Social structure

Socially, the Bay Area is quite segregated in terms of neighbourhoods or districts which are dominated by high income class of people or places with disadvantage communities inhabiting them. Criteria used to identify disadvantaged communities in California have not been consistent. As an example, disadvantaged communities are defined in the Safe Drinking Water Act as the entire area of a water system or community where the median household income is less than 80 percent of the state-wide average. Several state programs also use a median household income threshold to identify disadvantaged communities (Climate change hits home, SPUR report, 2011). Similarly, the Housing-related Parks Program administered by the California Department of Housing and Community Development implements a statutory definition for disadvantaged communities as census tracts designated by the United States Department of

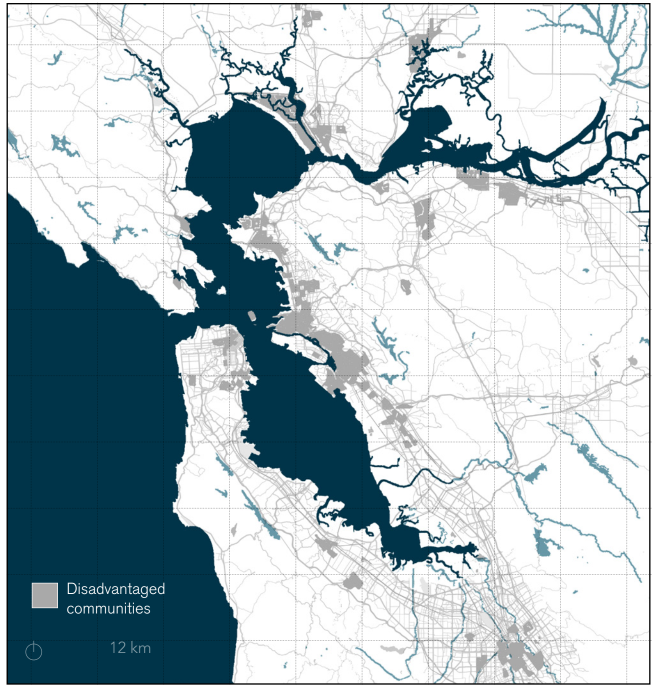


Figure 3.4: Disadvantaged communities of Bay area. Illustration : Author

Housing and Urban Development with at least 51 percent of its residents at low- or moderate-income levels. This again points to the ill communicated administrative efforts.

Bay-lands

It is evident from the historical evolution that cities around bay have reclaimed tremendous area of land for its development from the bay waters. In this process, the region has been altered in relation to land-water transition throughout the periphery of the bay. The urbanisation pattern and infrastructure lines act as a wall between the bay ecology downstream and ecology in the hinterland. In this process, the earlier surface which belonged to either the bay waters or the marshes, but is now reclaimed for development is termed as Bay-lands. As mentioned by Belanger, it is not the urban sprawl but coastal crawl. This crawl is evident in the Bay area due to its changing land-water transition (Baylands ecosystem habitat goals, science update report, 2015).

Rising sea level

California coast has observed a sea level rise of 8 inches in past century (Heberger, 2012). The coastline has become prone to multiple types of flood risk; storm surges, sea level rise, tsunami inundation and riverine floods. Major transportation corridors and other critical infrastructures are under threat due to sea level rise, including energy facilities, major ports, harbours and wastewater treatment plants. The Pacific Institute of Climate Change model developed from medium to high greenhouse gas emission scenario predicted that if sea level rises by 1 meter at a risk of a 100-year flood event, it will affect 220000 people in the bay area. And if same level rises to 1.4 meters, it will affect 270000 people. In these numbers, large population affected belongs to low income group. Corresponding to this, monetary damage to the bay area will be 49 billion dollars (for the year 2000) for 1 meter sea level rise and 62 billion dollars (for the year 2000) for 1.4 meter sea level rise (Heberger, 2012). Continued development in these vulnerable areas would put the additional areas at risk and raise the protection and damage costs (Nguyen et al., 2011).

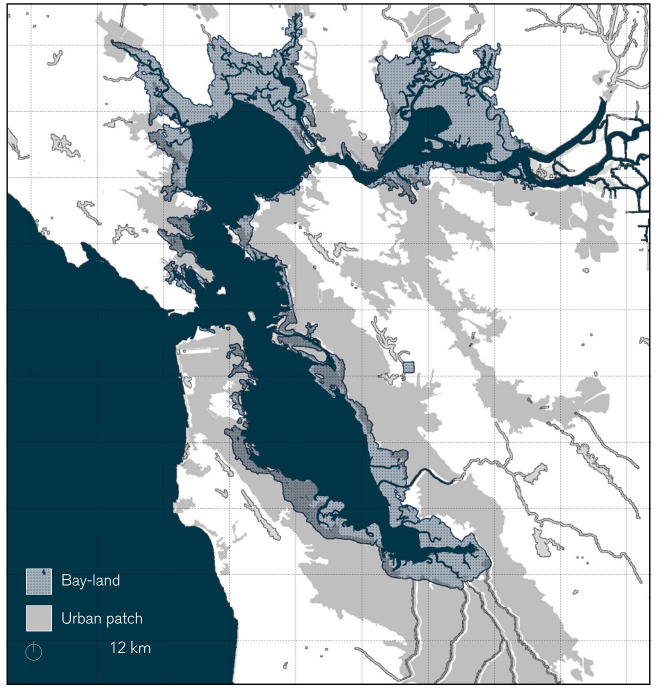


Figure 3.5: Historic Bay-lands. Illustration : Author

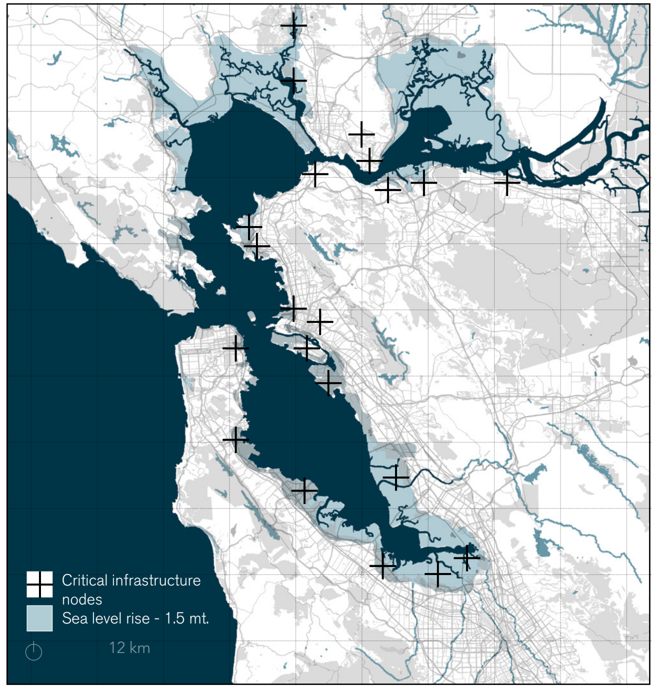


Figure 3.6: Critical infrastructure vulnerability map. Illustration : Author

Problem Analysis

In the earlier chapter, the 3x3x3 analysis made the urbanisation process along the bay evident. It was steered by the economic investments and infrastructure which developed supporting those investment. The geographic conditions posed limitations to the sprawl thereby resulting the present pattern of urbanisation. The map of sea level rise of 1.5 meters and bay-lands which are the reclaimed lands from bay coincide thereby posing threat to major infrastructures and dense urban regions. The historic marshlands and mudflats which would have acted as a buffer against the storm surges are depleting in size and degrading in conditions, the creeks which fed the bay with fresh water and sediments to replenish the marshlands and mudflats have been channelized or buried under the surface (Baylands ecosystem habitat goals, science update report, 2015), the current urban development of the region suggests that this urbanisation might just get intensified further (Plan Bay Area 2040 report, 2017).

In this situation, the challenge lies in how will San Francisco bay area deal with the stress of rising sea level and frequent shocks of riverine flooding and storm surges, while synergizing with the current urban development trends.

Problem Statement

San Francisco Bay area represents the spatial transformation dominated by dynamic economy and infrastructure development starting from Gold Rush. The region has contributed tremendously in this process of development to the national economy as well (3rd in USA GDP, US Department of Commerce, 2014).

However, this process of urbanisation and economic shifts exploited and degraded the ecological conditions. Infrastructure and occupational patterns dissected the landscape and degraded the connection between land-water transition and hinterlands. The transect of upstream and downstream is fragmented in terms of hydrological systems making the urban region more vulnerable to threats from riverine flooding, storm surges and sea level rise.

Figure 3.7: Google earth image representing bay land-water transition. Source : google maps

Figure 3.8: Annie Kohut Frankel of the California Coastal Commission educates the public at Pier 14 during a king tide in November 2015. Source : Paul Chinn, The Chronicle.

"Landscape fragmentation is the result of transforming large habitat patches into smaller, more isolated fragments of habitat. This process is most evident in urbanised or otherwise intensively used regions, where fragmentation is the product of the linkage of built-up areas via linear infrastructure, such as roads and railroads"

- Saunders et al., 1991; Forman 1995

Hypothesis

The problem statement in the earlier section is based on the analysis and two hypotheses are developed to suggest a method to deal with the systems involved in these changing climatic conditions.

1. tackling complex systems demands for an approach spanning across space and time, reason being, local and large-scale knowledge combined with time factor is necessary to understand the system behaviour in its normal and disruptive state.

2. addressing uncertainties requires an open-ended dimension, where, the design or the strategy has to have inbuilt flexibility to adapt with changing conditions and multiple possibilities while maintaining the performance of the system.

These two hypotheses act as preliminary suggestive assumptions for the methods to be adopted. These assumptions are tested in the processes of this research project.

Objectives

The objectives of this research project are,

1. To re-align the relation between urban and natural processes with respect to hydrological vulnerability induced within the territory.

2. To translate this relation into a system of infrastructure which conditions the territory for future urban growth.

3. To develop this infrastructure in a systemic manner which operates across spatial and temporal scales to address the uncertainty aspect of research.

4. To induce in-built flexibility within the designed system to embrace the uncertainty involved in the process.

Research Question

How to systematically develop **landscape as an operative ground** for infrastructure through **multiple scales in an urbanized delta** to address **uncertainties** involved within **hydrologically induced vulnerability**?

The research question intends to address the problem statement and objectives, building upon two hypotheses formulated.

Sub-research Questions

The research question is broken down into several sub-research questions to tackle the complexity involved within it. The sub-questions have been classified as scientific i.e. questions which can be answered by following a process or a method (how questions); and operational i.e. questions which can be answered by analysing and identifying (what questions).

Scientific;

1. How can landscape be understood and conditioned as an operative ground for infrastructure system to address frequent flooding, storm surges and sea level rise?

2. How will a trans-scalar approach help in addressing uncertainty within hydrological challenges of urbanised deltas?

3. How will an open-ended design approach guide in addressing the uncertain contingents of the research project?

4. How to determine criteria to delineate spatial and temporal scales in a trans-scalar approach?

Operational;

1. What is the specificity of an urbanised delta in terms of hydrological system?

2. How does uncertain variables of economic shifts and climate change increase the vulnerability of an urbanised delta?

3. What is an open-ended design process?

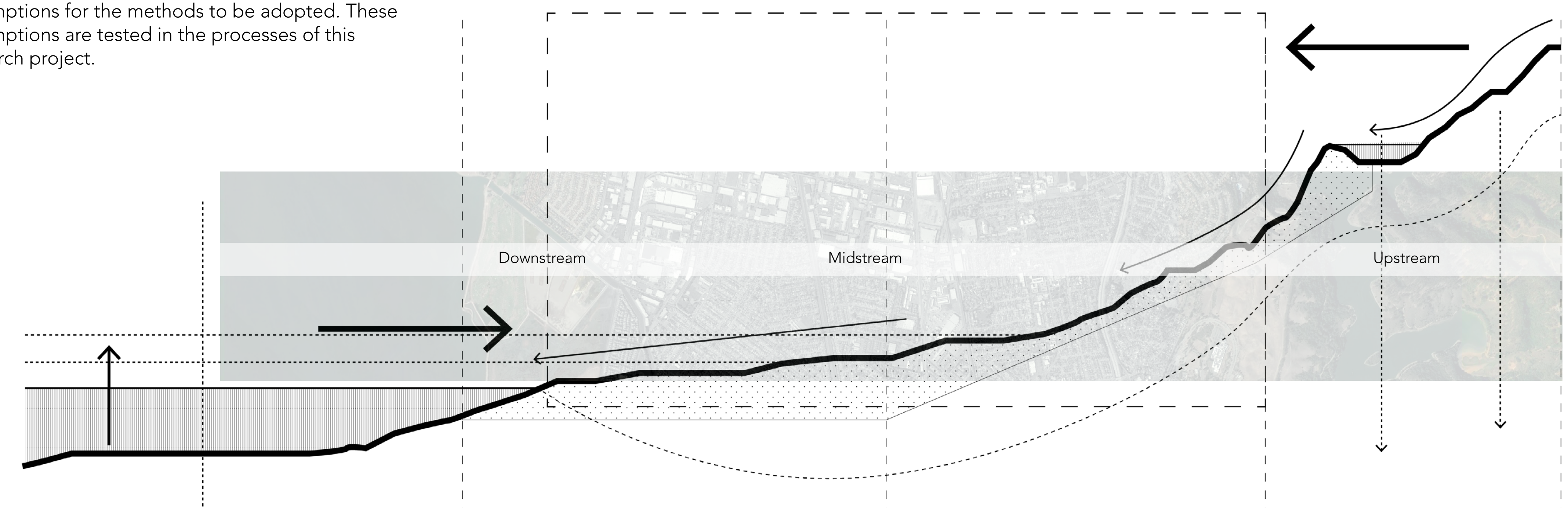


Figure 3.9: Transect along urbanized delta. Illustration : Author

Figure 4.1: Skyline of San Francisco. Image : Author

Societal Relevance

Climate change has moved to the forefront of global agenda in recent years. Most of the issues related to climate change are related to water; flooding and sea level rise to be specific (Jha et al., 2012). In the past twenty years, the number of reported flood events has been significantly increasing. Number of people affected by floods and financial, economic and insured damages has increased too. In 2010 alone, 178 million people were affected by floods (Jha et al., 2012). The total losses in exceptional years such as 1998 and 2010 exceeds $ 40 billion. San Francisco bay area is one of the highly vulnerable deltas prone to flooding due to sea level rise. 140000 people live in areas within San Francisco bay, that are currently at risk of being inundated in 100-year flood event (Heberger, 2012). (Jha et al., 2012). All the major infrastructure, from ports, harbours, railway lines, highways to schools, hospitals, waste water and drinking water supply plants, electricity grids; lie in this inundated land. The damage to people's lives and damage caused economically and ecologically is very high which makes it highly relevant in today's context.

Recently, ecology has been emerging into focus as a strategy and system of design for urban environment and economies. It has generated a sense of urgency to redesign urban infrastructure and rethink about the performance of urban economies. This is due to the inertia in urban planning and overexertion of civil engineering (Bélanger, 2013). Predominant challenges facing urban regions today such as changing climates, resource flows, and population mobility amplify this transition.

Economy, infrastructure, and ecology are important agents that facilitate the processes that shape the built environment and landscape. The worldwide shift from industrialization to urbanization in past century has led to ecological degradation. Contemporary urbanization demands for convergence of landscape and infrastructure to reimagine beyond its strictly utilitarian definition, while allowing spatial design to gain operative force in territorial transformation processes (Nijhuis and Jauslin, 2015). Moreover, climate change has affected frequency and consequence of flood and has amplified its characteristic of uncertainty. For past few years the scientific studies have been in the direction to examine and evaluate these patterns to understand its potential risk and harm. This thesis project contributes to the integration between planning, engineering, design and ecological studies to explore the conceptual frameworks developed so far for system based flood risk management approaches.

Scientific Relevance

The project aims to explore the concept of landscape as an infrastructure; a strategic design and dynamic system that operates as urban infrastructure to shape and direct the future of urban economies and occupational pattern into the 21st century. The broad aim of the project is to understand the relation between the urban dynamics and ecological conditions in deltaic territory. Using the layers of landscape, infrastructure and occupation the research aims on deriving a system at regional scale and set of rules and parameters at local scale to accommodate the hydrological threats. The specificity of the research lies in addressing the bidirectional flow and interception of fresh and saline water at the downstream conditions of delta. Operating through the geomorphology over and under the surface, the research derives a thick strategic approach.

Moreover, inspired from 4 Domain Approach (Digman et al., 2014, Kuzniecow Bacchin, 2015) the research develops an understanding of incremental nature of hydrological threats from the stand point of pluvial and fluvial floods form upstream and coastal flooding from downstream. Using this new modification the design is tested with respect to its performance to accommodate water. The research advocates working through scales and while doing so has developed a methodology which is a combination of analysis, synthesis and projection performed in plan and through sections (transects). The research focuses on developing these methodologies and further reflects on transferability of interventions within bay at different locations.

Theoretical Framework

The research objectives and the approach sets this project in a certain domain of theories and concepts. This chapter briefly introduces those theories, concepts and notions and further derives a framework which structures the project.

Complexity Theory

The initial 3x3x3 analysis (Meyer and Nijhuis, 2016) of Bay area made it evident that this research project involves various systems which are operating at different scales and at different speeds. This finding resonates with C.S. Holllings complexity theory (Holling, 2001). While operating through a systemic approach, especially the ecological and urban processes, it operates hierarchically across scale and time, which is the concept of Panarchy (Holling, 2001), where, interlinked systems of transformation range in scale from a leaf to biosphere over period of a day to geological epoch (Holling, 2001). “That means, each level is allowed to operate at its own pace, protected from above by slower, larger levels but invigorated from below by faster, smaller cycles of innovation” (Holling, 2001). It combines the concepts of space and time hierarchies with the concept of adaptive cycles. This theoretical domain helps to support and explore the first hypothesis of the research; which relates to working through systems and multiple scales of space and time.

Concept of Resilience

The urban deltas are complex systems with dynamic territorial transformations; either natural or anthropogenic. The uncertainties involved within the territory are high which needs to be considered. The approach for this project focuses on a resilient system development which can inherit the capacity to absorb or accommodate these uncertainties; in this case economic shifts or climatic changes. Resilience determines the persistence of relationships within a

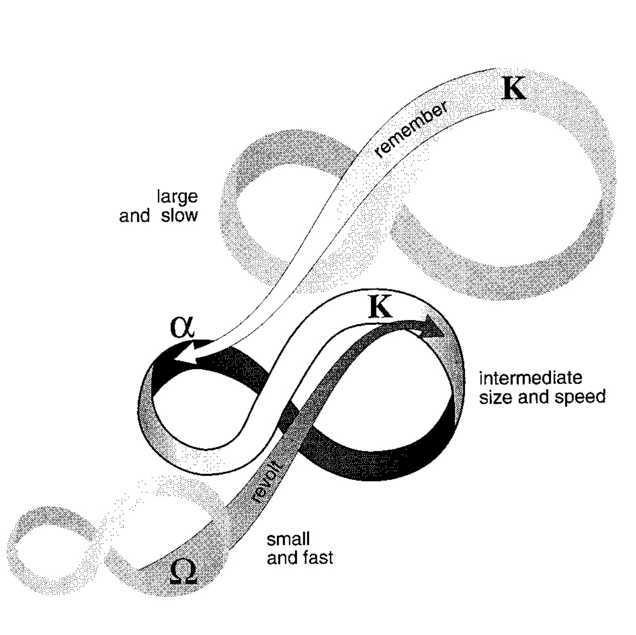


Figure 5.1: Panarchy diagram. Source : (Holling, 2001)

system and is a measure of the ability of these systems to absorb changes from state variables, driving variables and parameters, and still be able to persist (Holling, 1973). The important aspect of this definition lies within “the ability of a system to absorb changes”, which is crucial as a response to flood events, storm surges and sea level rise; where, the flood events and storm surges act as shocks which are onetime events that occur occasionally, whereas sea level rise is stress which is a process that keeps on increasing. If this idea of shock and stress is applied to the concept of adaptation and resilience it can be derived that shock requires resilience which can absorb the impact of change whereas stress demands for adaptation which will evolve with the processes of increasing intensity. The hydrological challenges in hand with respect to Bay area demand for both, addressing shocks of pluvial and fluvial flooding along with occasional storm surge events and stress situation of sea level rise due to changing climatic conditions. The approach for this project requires a short and mid-term resilient strategies for the addressing shocks whereas long-term adaptive strategies for addressing stress situations.

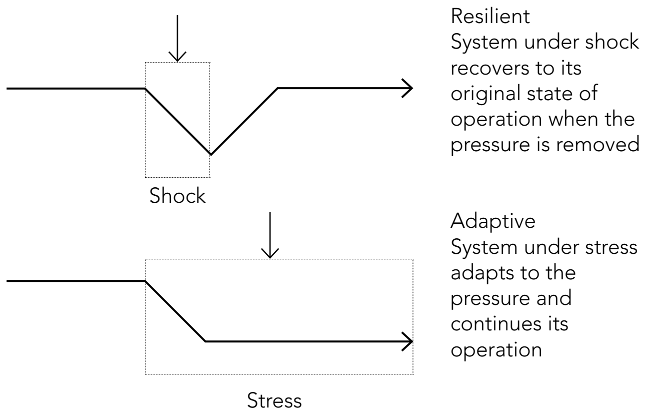


Figure 5.2: Diagram of Hydrological Shock and Stress. Illustration : Author

Ecological Resilience

C. S. Holling, in his paper ‘Engineering Resilience versus Ecological Resilience’ (Holling, 1996) identifies the fundamental differences between two perspectives towards resilience. According to him, engineering resiliency is about maintaining stability and equilibrium state, whereas ecological resiliency is about instability which can flip the system into another regime of behaviour which is another stability domain. The engineering resiliency thrives for efficiency, constancy and predictability and is measured by system’s resistance to disturbance and its speed of return to equilibrium. Whereas, ecological resiliency thrives for persistence, change and unpredictability and is measured in terms of magnitude of disturbance the system can absorb (Holling, 1996). Based on the objectives and hypotheses of the research, the project aligns itself with the principles of persistence, change and unpredictability; and perceives the issue through the lens of ecological resilience to tackle the uncertainty within hydrological challenges of urban deltas.

The Ecological Approach

The context of this research project in terms of operational variables involved is complex (systems) and uncertain in terms of challenges at hand. Building upon the complexity theory and idea of Panarchy (Holling, 2001) along with Holling’s definition of resilience through ecological perspective, the project aligns itself with the ecological principles of persistence, change and unpredictability. In last quarter century, ecology has been emerging as a strategy and system in design of urban infrastructure and economics (Bélanger, 2013). Nina Marie Lister in an interview during the launch of book Ecological Urbanism states, “…there has been a paradigm shift in ecology towards organic model of open-ended-ness, flexibility, resilience and adaptation, and away from mechanistic model of stability and control” (2011). The shift demands a perspective change from managing ecosystems from principally economic focus to managing human actions within it (Mostafavi and Doherty, 2010). The current challenges and ecological complexities demand a collaborative and compound formulation of landscape infrastructure as a contemporary field of practice that addresses flows of urban economies and dynamics of global ecologies; where, urban landscape infrastructure is a concept of conditioning landscape itself and not about specific technical constructions in landscape (Bélanger, 2013). It is about creating conditions for future development as an operative ground (Nijhuis and Jauslin, 2015).

Such an ecological approach requires questioning the existing administrative boundaries, as these systems operate beyond the political boundaries and have their own territorial demarcations. It is important to understand the territory and important changes that shape its spatial, economic and social structure, to focus on time, lifecycle, impermanence and biotic and social relations (Viganò, 2014). This very well relates to the theory of Landscape Ecology described by Richard Forman in his book Land Mosaics (Forman, 2014) and Landscape Ecology (Dramstad et al., 1996). The idea of using landscape to develop a framework requires better understanding of ecological systems which is done through the concept of patches, corridors and matrix, and working through different scales guided by watershed, river basins, sub-basins, micro-basins or transects to upstream-midstream-downstream (Forman, 2014). In pairing landscape with urbanism, it seeks to reintroduce critical connections with natural and hidden systems and proposes the use of such systems as a flexible approach to the current concerns and problems of the urban condition (Grey, 2011). Moreover, the issue in hand is about hydrological challenges which draws attention to the theories related to the working of Green infrastructure (Ahern, 2007) and water management networked systems such as Water sensitive urban design (WSUD, Australia), Low impact development (LID, U.S.A.) and Sustainable urban drainage system (SUDS, U.K.). The legacy of green blue infrastructures advocate for a more systemic, multifunctional and multi-scalar design of infrastructural networks and is regarded as one of the way in which cities can achieve resilience (Ahern et al., 2014). This approach is evident in the PhD thesis work of Taneha K. Bacchin; Performative nature – Urban landscape infrastructure design in water sensitive cities (Kuzniecow Bacchin, 2015).

Conclusion

To summarize, the research project is setup in a context of complex natural and urban systems within deltaic territory. The intention is to address uncertain hydrological challenges the region will face and develop an adaptive strategy which can persist in multiple possible futures under changing economic shifts and climatic changes. Holling's complexity theory sets a basis to structure the systemic approach, whereas the landscape urbanism (Waldheim, 2012) theories establish the principles which guide this approach. It is through the concept of Panarchy (Holling, 2001) which helps to read through the complex systems of ecology and urbanisation. This reading is crucial to speculate the impacts of interventions to be made within the territory over time. The ecological resilience approach by Holling (Holling, 1996) draws important findings of resiliency for shock situations (pluvial, fluvial and storm surge events) and adaptive strategies for stress situations (sea level rise).

The domain of urban ecology helps to understand the anthropogenic impacts on environment, specifically to the hydrological structure within the territories (Viganò, 2014). The concepts of landscape ecology stated by Forman in Landscape Ecology (Dramstad et al., 1996) and Land Mosaics (Forman, 2014) help understand the spatial configuration of natural processes. The geometry and network of patches and corridors help to understand the notions of landscape infrastructure (Bélanger, 2013). These theories of complexity, urban ecologies and landscape infrastructure establish crucial links between the land use patterns, hydrological structures and potentials to create a synergy among these systems. Building upon these findings, the project unfolds itself towards developing an adaptive and resilient strategy for bay area towards its hydrological challenges.

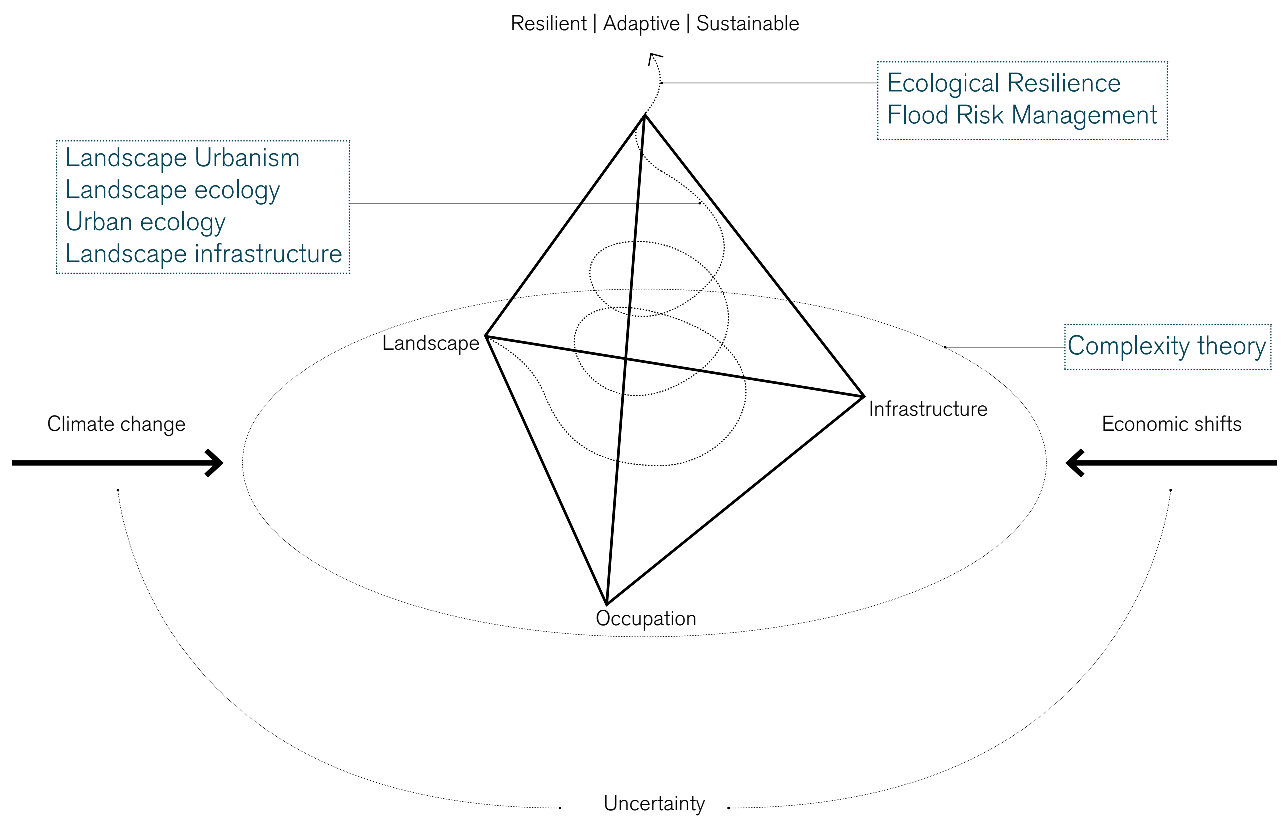


Figure 5.3: Theoretical Framework. Illustration : Author

Methodology

The former chapter structures the theoretical basis for this research whereas this chapter intends to structure the methods used to analyse and speculate the future with respect to the challenges in hand. It highlights the tools and instruments which shape the research in process of establishing strategies and exploring its implementation in varying conditions. The two hypotheses highlight three important aspects of this research project; first is about developing a systemic approach which operates through different scales of space and time, second is to speculate the changing degree of performance of this system in changing hydrological conditions and third is to explore multiple possibilities of future. These three aspects shape the methodology as Scale, Performance and Temporal dimension.

Analysis – Synthesis - Projection

Process of mapping has agency because of the double-sided characteristics of all maps; first, their surfaces are directly analogous to actual ground c onditions as horizontal planes, they record the surface of the earth as direct impressions, by contrast, the other side of this analogous characteristic is the inevitable abstractness of maps, the result of selection, omission, isolation, distance and codification (Corner, 1999). As a creative practice, mapping precipitates its most productive effects through a finding that is also a founding; its agency lies in neither reproduction nor imposition but rather in uncovering realities previously unseen or imagined, even across seemingly exhausted grounds (Corner, 1999). Thus, mapping unfolds potential; it remakes territory over and over again, each time with new and diverse consequence. Throughout the project, at various scales, the complex systems of ecology and urbanization have been dissected into different layers, framed, coded and then again reframed and recoded through mapping by conceptualizing the information for a projective analysis. Even Belanger highlights, when working with complex systems of landscape ecology and urbanization, it is important to index elements associated with both systems and requires a relational thinking process which looks beyond plan through sections because these processes perform at different levels not only in scales but also in cross section (Bélanger, 2013). Such relational thinking and integrative design process of plans and sections, unfolds the project through a series of analysis, synthesis and projections, which codify and recodify the layers by decontextualizing and re-contextualizing them throughout the process.

Analysis - De-codification, Disassembling, Selection, Separation, Classification

Synthesis - Relational thinking, Interplays, Interlinks, Simplification, Reduction methods

Projection - Re-operationalization, Re-codification, Re-assembling, Re-materializing

Scale

While operating through a systemic approach, especially the ecological and urban processes, it operates hierarchically across scale and time (Holling, 2001), hence it is very important to set parameters to delineate every scale within the analytical and projective process. The extent of risks that are emerging as a result of the inevitable effects of urbanisation do not coincide with administrative borders. Topographic scales along with consideration of common challenges could provide a strategic argument to plan across jurisdictions (Bélanger, 2013). Having said that, the scales are set by geomorphological boundaries of watershed, river basins and their sub and micro basin, as all these units share common hydrological conditions which lies at the core of this research. The higher scales define the objectives and inform the lower scale with design agendas, whereas the lower scales evaluate the objectives defined at higher scales. The 3x3x3 analysis method (Meyer and Nijhuis, 2016) helps to identify the critical elements within the territory which can be used to develop the infrastructure to restructure the ecological conditions and address the dissected hydrological system.

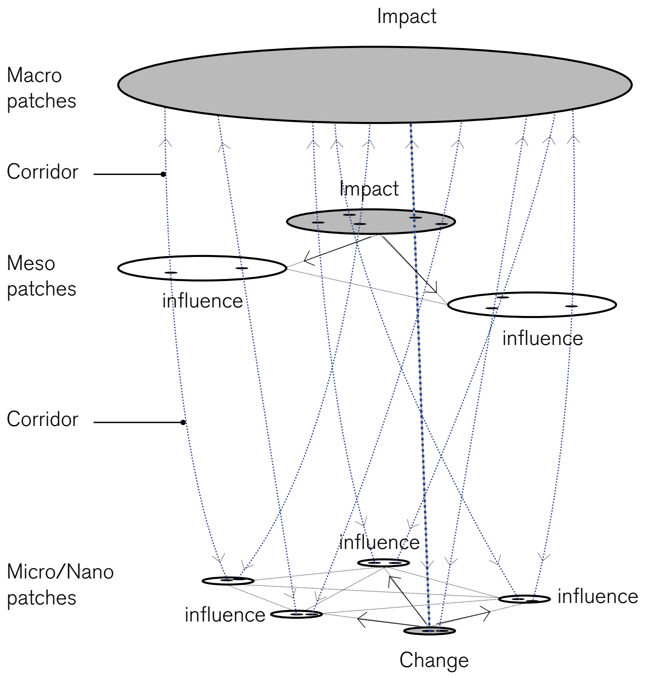


Figure 6.1: Interdependency of scales. Illustration : Author

The Syntax and Matrix

Through the process of analysis-synthesis-projection the research project identifies a need to develop a network of infrastructure defined by the principles of Landscape Ecology (Forman, 2014) to address the hydrological challenges of pluvial and fluvial flooding, storm surges and sea level rise. The concepts of patches and corridors defined by Forman (Forman, 2014) is used to develop this network. At macro scale (bay area) the patches are defined by open spaces, regional parks, important nature reserves. At meso scale (city) these patches are defined by local greens, community parks, playgrounds. The corridors; identified as existing creeks and mobility network, provide a strategic link between different scales by connecting these patches belonging either to macro scale or meso scale. The objective of this network is to infiltrate, delay, convey and discharge fresh water during high precipitation whereas accommodate saline water during storm surges. The patches and corridors identified at macro scale (bay area) define these objectives, whereas the patches and corridors at meso scale (city) represent the spatial manifestation of these objectives within the given context.

The PhD thesis by Taneha K. Bacchin, Performative nature – Urban landscape infrastructure design in water sensitive cities, defines these networks as Urban Landscape syntax at macro scale and Urban Landscape matrix at meso scale (Kuzniecow Bacchin, 2015). The syntax and matrix embed the patches and corridors in the system as armatures for urban landscape development, facilitating interaction between human and natural systems (Nijhuis and Jauslin, 2015). The urban landscape syntax (Kuzniecow Bacchin, 2015) establishes a vision and objectives at macro scale (bay area) whereas the urban landscape matrix (Kuzniecow Bacchin, 2015) realizes these objectives in form of strategies. The micro and nano scales play an important role in manifestation of these strategies at a neighbourhood scale or street level or even a block level. These two scales; micro and nano; also help in determining the potential of change and how it might affect the performance of the system. These scales will evaluate the higher scales, thereby creating a feedback loop from nano and micro back to meso and further upgrading to macro, eventually reflecting on the objectives set in the beginning.

Transect

Working with complex systems of landscape ecology and urbanization requires a relational thinking process which looks beyond plan through sections because these processes perform at different levels not only in scales but also in cross section (Bélanger, 2013). While developing network of patches and corridors across the scales, it is important to understand the topography, soil composition, gradient of slope and the land-water transition edge along the bay. The transect study is the method used to analyse these aspects. The bay edge is categorized into different schemes of diagrams at macro scale (bay area) based on the three layers of landscape, infrastructure and occupation from 3x3x3 analysis (Meyer and Nijhuis, 2016). Further, at meso scale (city) to contextualize the diagrammatic schemes, economic, social and urban fabric layers are superimposed. The relation of different building typologies to the economic function, to its social profile and to the ecological system around it with respect to the hydrological threats is analysed and synthesised to project the potential infrastructure within the territory. The transect study plays a vital role as the research deals with land-water transition along the bay.

Performance

The hypotheses highlight two important aspects of understanding system behaviour and developing adaptive character for the same due to uncertain circumstances (natural and urban). This demands for a strategy which operates at varying degrees of performance in relation to this uncertainty. The aspect of scale aids in developing the network of infrastructure, but the aspect of performance helps to understand the different degrees of operation of this network with the increment in hydrological challenges.

It is important to do a quantitative study to understand the required capacity of the system designed to absorb the excess runoff. This is achieved by the rational method (Thompson, 2006), which is based on a simple formula that relates runoff-producing potential of the watershed, the average intensity of rainfall for a particular length of time (the time of concentration), and the watershed drainage area. This formula derives the excess water within the selected watershed which needs to be stored or infiltrated to reduce the peak discharge. These calculations are performed at the meso scale (city) which help define the network in a spatial and quantitative nature.

$$Q = C_f \times C \times i \times A$$

Where, Q – peak flow

Cf - runoff coefficient adjustment factor to account for the reduction of infiltration and other losses during high intensity storms

C – runoff coefficient to reflect the ratio of rainfall to surface runoff

i – rainfall intensity

A – drainage area

The 4 Domain Approach

Once the quantitative study is performed and systemic strategy is in place, the 4 domain approach (Digman et al., 2014) adopted from Digmen and Performative Nature: urban landscape infrastructure design in water sensitive cities (Kuzniecow Bacchin, 2015) is used to explore the degree of performance with incrementation in hydrological threats. The method is established to understand spatially the four degrees of storm water management. Within this research project, risk of coastal flooding has been projected upon this method to address storm surge events. The performance of the network is incremental in a sense; in domain 1 (regular rainfall), the existing storm water drains operate to convey water to desired spots. In domain 2 (heavy rainfall), the open spaces and bio-swales along the streets hold the runoff to reduce peak discharge. In domain 3 (exceedance rainfall), public spaces which are designed for flooding

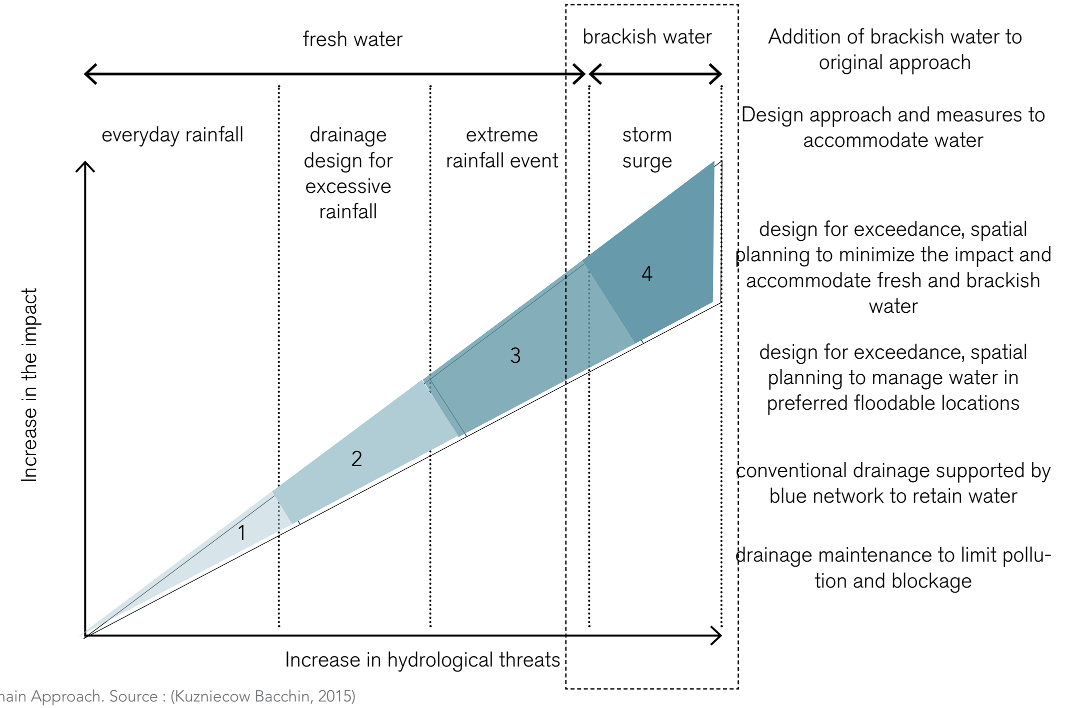


Figure 6.2: 4 Domain Approach. Source : (Kuzniecow Bacchin, 2015)

accommodate excessive runoff, moreover parking areas store water below their surfaces. In domain 4 (storm surge event), the incoming saline water from bay is redirected towards floodable areas which can store this brackish water temporarily.

Temporal Dimension

Designing for time is one of the important aspects for this research project as second hypothesis focuses on open-ended dimension for the uncertain future. The idea of design being open-ended is explored; where design principles are defined rather than design solutions; the difference being, these principles establish set of actions to be performed and goals to be achieved which can be done in multiple possible ways. The exploration is achieved inspired from methods developed by Delta Programmes scenarios for Adaptive Delta Management (Deltafact: Delta scenarios and adaptive Delta management, 2012) and drawing facts and figures for future projections of Bay area from government documents of Plan Bay Area 2040 (2017). Based on these documents three scenarios are developed which are speculated as possible futures derived from socio-economic shifts within the Bay area. The systems performance is tested by following similar 4 Domain Approach within these scenarios. The project intends to showcase multiple possibilities in which the infrastructure can be conditioned rather than defining one static possibility.

Research by Design

Working through scales and through relational thinking of analysis-synthesis-projection method is a non-linear process. It is a process of moving to and fro which in this research project starts off with assumption of two hypotheses. The process derives certain projections which may or may not be true to the hypotheses. It can be considered as a way of research in itself, which is creative and experimental while building upon scientific knowledge of established theories and concepts.

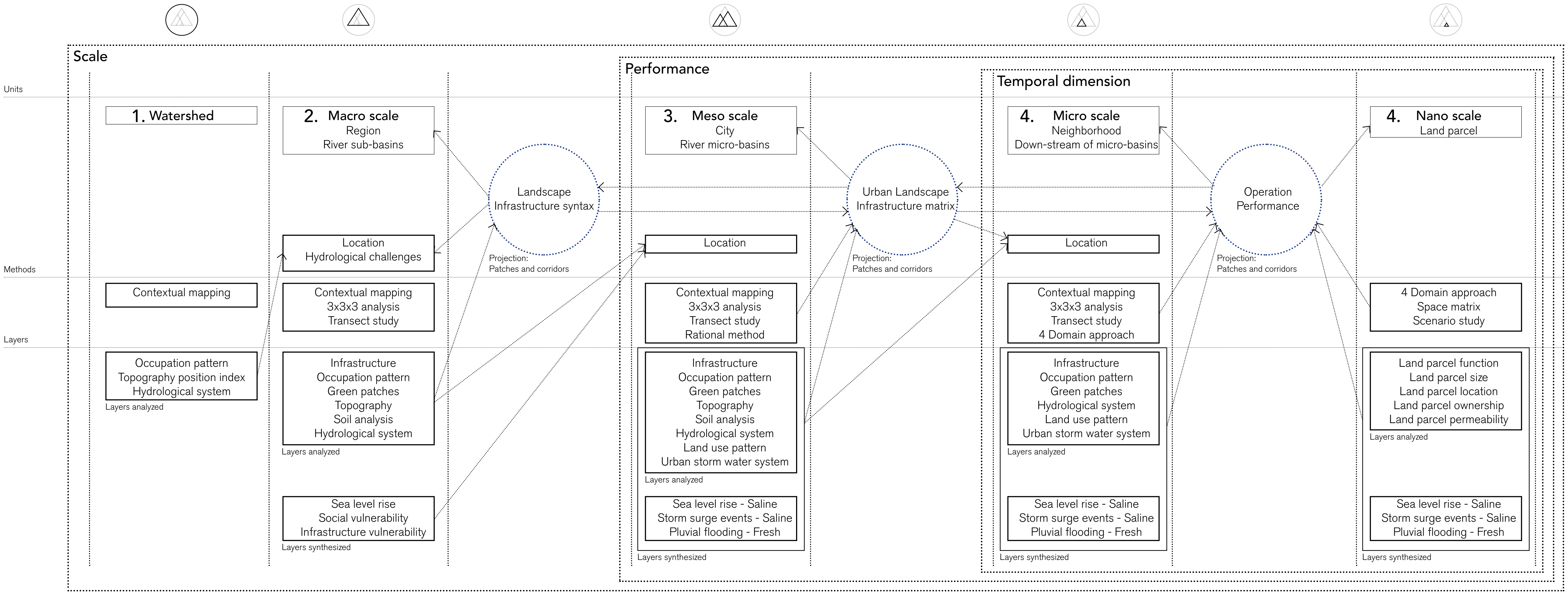


Figure 6.3: Methodology chart. Illustration : Author

Figure 7.1: Salt evaporation ponds, San Francisco bay. Source : https://propelsteps.wordpress.com/2013/06/29/eco-preservation-salt-evaporation-ponds/

Scale

The extent of risks that are emerging as a result of the inevitable effects of urbanisation do not coincide with administrative borders. This demands for a systemic and trans-scalar design strategy, where, local and large-scale knowledge is combined with time factor to understand its behaviour in normal and disruptive situation. This study will help to identify the elements which help the system to recover or adapt. The scales are set by geomorphological boundaries of watershed, river basins and their sub and micro basin as all these units share common hydrological conditions which lies at the core of this research. These parameters of delineating the scale boundary and analysis performed within, is explained in the following chapters.

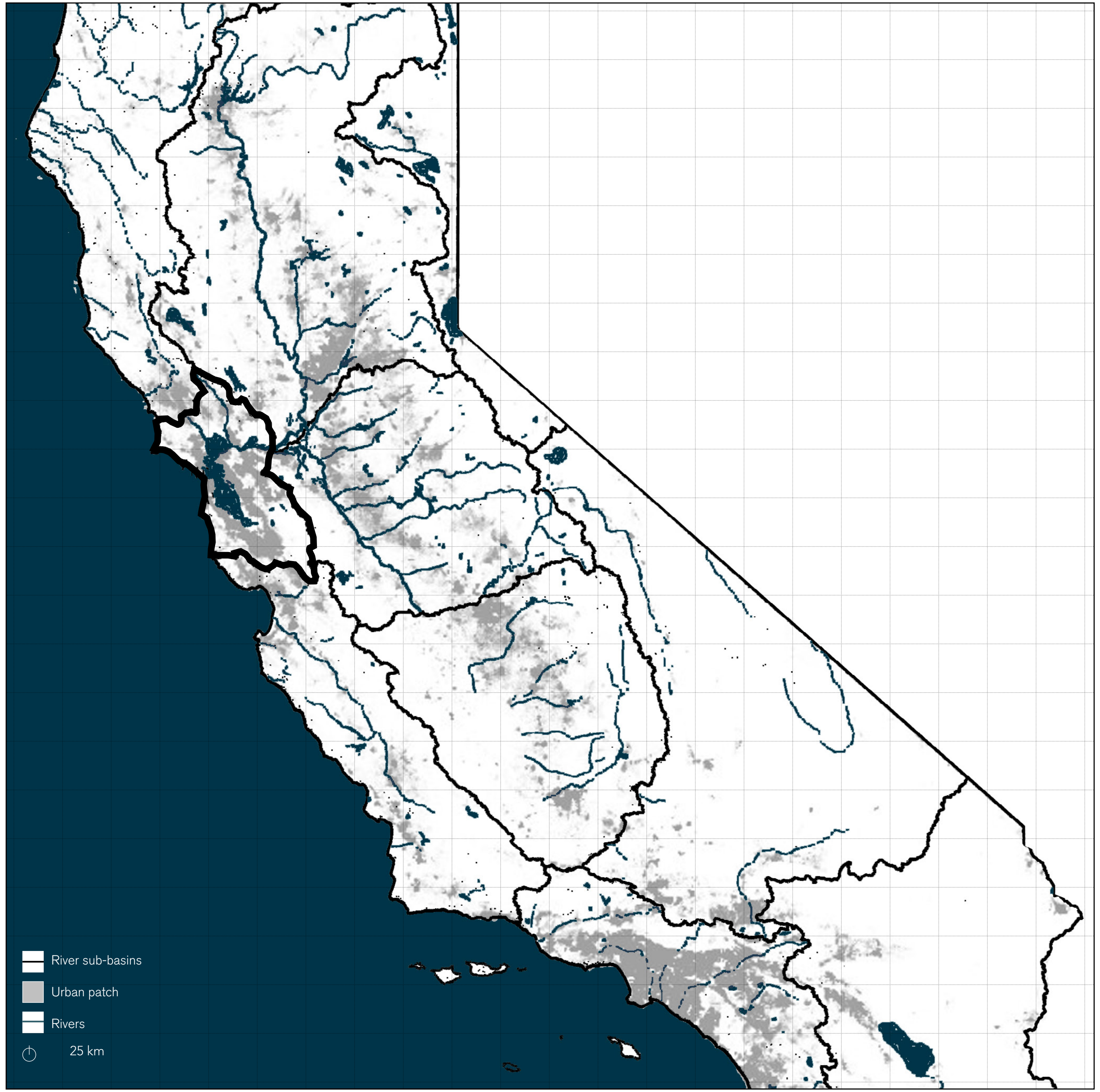
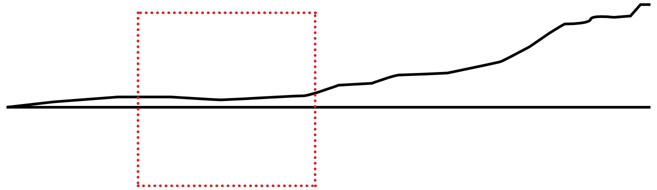


Figure 7.2: Urbanization v/s Hydrological structure, California watershed. Illustration : Author

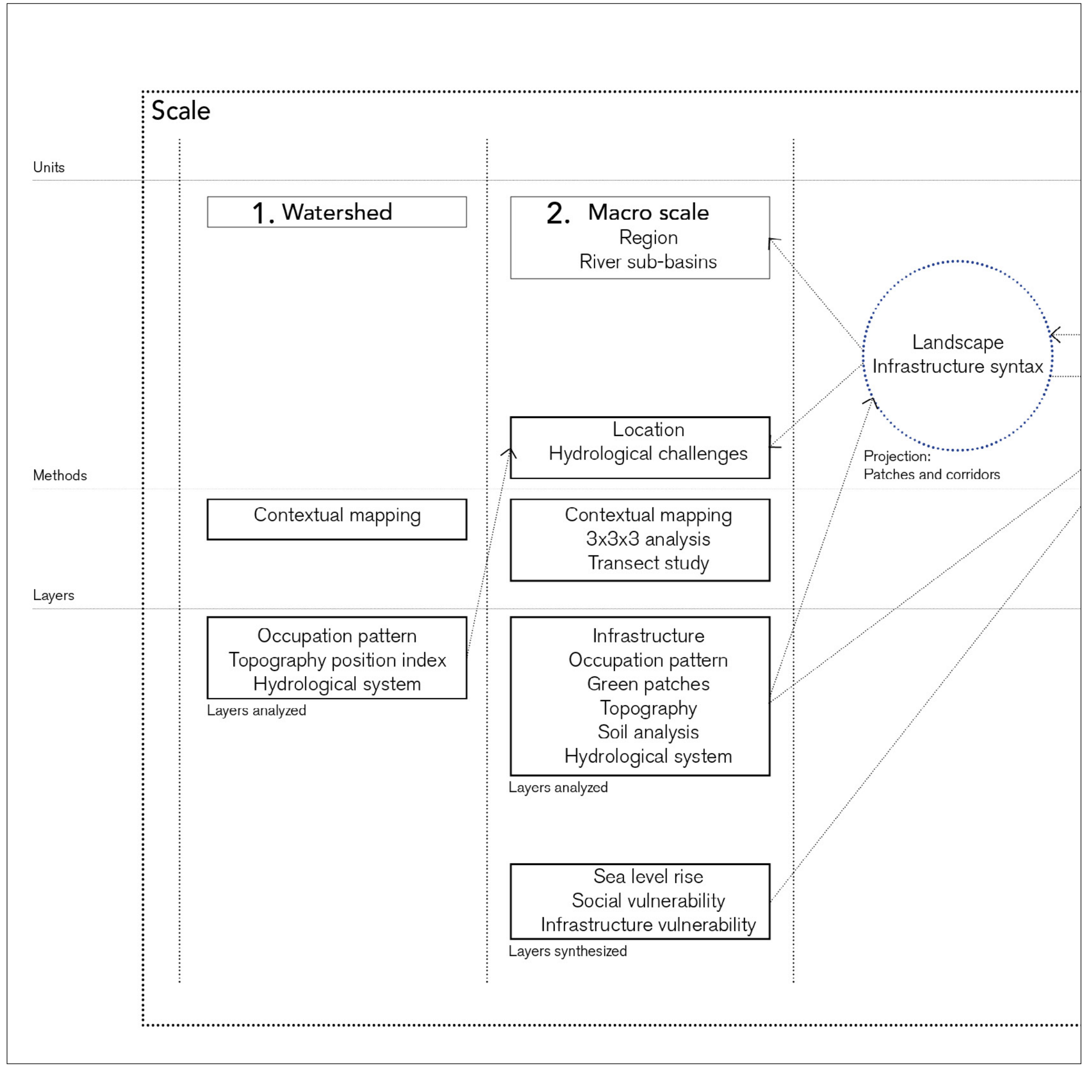
Watershed

The watershed of California, as the name suggests, is delineated by the state of California. It is one of the very few states within United States of America where the administrative boundary coincides with a hydrological unit of watershed. It comprises of multiple rivers which originate from the Serra Nevada and run into the Pacific Ocean. It is structured by the hydrological basins of these rivers, where Sacremento and San Joaquin are two major rivers which drain water into the bay. The mapping performed at this scale is to understand the broader water system within California and the role of San Francisco bay within this system. The layers analysed within this scale are the topological flow of rivers, the topographic positioning of San Francisco bay within the watershed and the occupational pattern within California.

From the layer analysis, it is observed that the California watershed faces three hydrological issues; first is drought, which is along the foothills of Serra Nevada due to excessive use of water from reservoirs for agriculture and also due to the dams constructed along these rivers (Brechin, 2006). Second is major fluvial flooding at the delta just before the bay where two major rivers of California meet, Sacramento and San Joaquin. And the third is at the Bay, one due to increasing frequency of storm surges and risking threat of sea level (Heberger et al., 2009). The analysis also suggests the vulnerability, as major urban patches are situated at the delta area or downstream of the entire watershed, which is either Los Angeles or San Francisco bay (Heberger et al., 2009). If the watershed is summarized into upstream-midstream-downstream, it can be observed that, upstream faces drought issues due to dams which are constructed, while midstream has threat of excess of water flowing from upstream due to tampering of the hydrological system, and downstream is under the risk of excessive water from up and midstream at the same time from sea front. All these factors are results of constructing multiple number of dams upstream and intense urban development downstream.


Topographic Position Index

Macro scale


Scale
Units
Methods
Layers
1. Watershed
2. Macro scale
Region
River sub-basins
Landscape
Infrastructure syntax
Projection:
Patches and corridors
Location
Hydrological challenges
Contextual mapping
Contextual mapping
3x3x3 analysis
Transect study
Occupation pattern
Topography position index
Hydrological system
Layers analyzed
Infrastructure
Occupation pattern
Green patches
Topography
Soil analysis
Hydrological system
Layers analyzed
Sea level rise
Social vulnerability
Infrastructure vulnerability
Layers synthesized

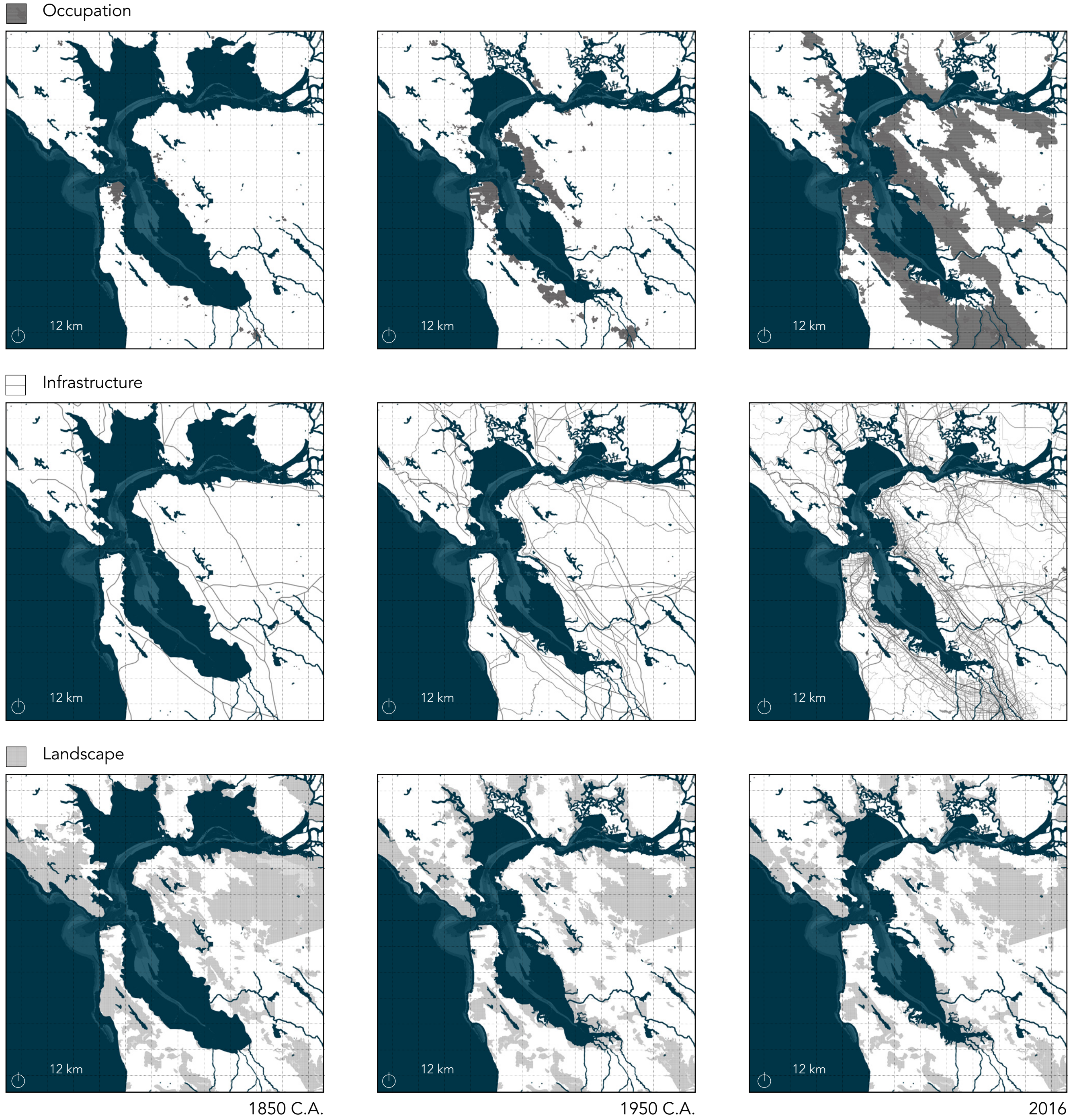


Figure 7.3: 3x3x3 Analysis, San Francisco bay area. Illustration : Author

Macro scale: Bay area region

The watershed of California established the understanding of territory on a larger scale, which helped to understand the geomorphological units which can be used to delineate the macro scale. As described in the watershed paragraph, there are three major challenges within California; drought, delta flooding and combination of sea level rise and storm surges. Moreover, the bay area also faces the issues due to occasional high precipitation resulting in pluvial flooding (Extreme storms: San Francisco bay past to present, AECOM report, 2016). The study at watershed scale suggests the downstream to be the most vulnerable due to the hydrological risks of excessive water flowing from upstream and storm surge threat supported by long term challenge of sea level rise from bay. Moreover, the downstream is highly urbanised as well. Based on these challenges and geomorphological units of river basins, the macro scale is delineated by sub-watershed along the bay – San Francisco bay sub-watershed or basin, which is composed of four sub-basins. The bay is fed by the two major rivers, Sacramento and San Joaquin. Moreover, it is surrounded by smaller creeks which drain into the bay.

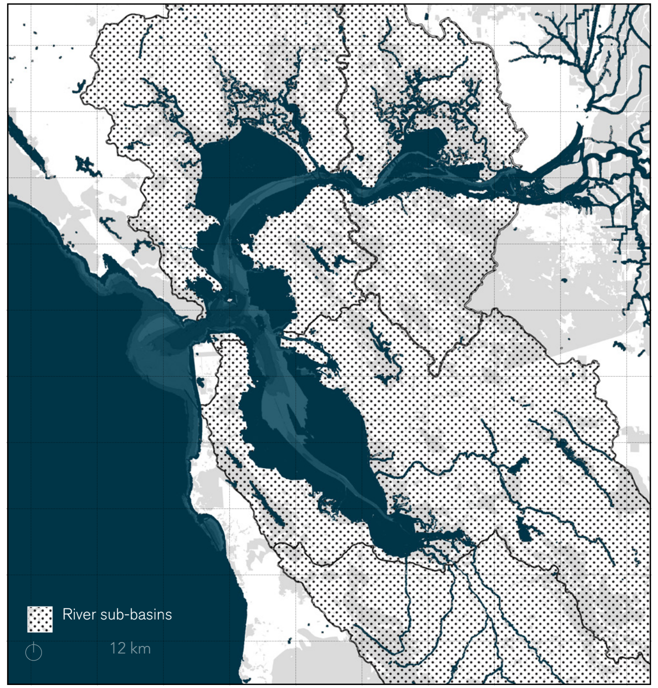


Figure 7.4: River basins, San Francisco bay area. Illustration : Author

The intention at macro scale is to identify the potentials of the territory and critical landscape elements which can be conditioned to develop the infrastructure. This is achieved by developing the syntax structured by the geometry of patches and corridors which address the hydrological threats of territory. To do so, initially a 3x3x3 analysis (Meyer and Nijhuis, 2016) is performed where infrastructure, occupation pattern and landscape is studied over three time intervals which highlight the changing patterns within the territory. This leads to a basic understanding of driving forces and the speed of change of each layer, thereby identifying contradictions, opportunities, challenges within the territory.

The analysis through time and three layers of infrastructure, occupation and landscape led to understanding that Bay area's urbanisation sprawl is restricted due to its geographic conditions. Due to bay being in the centre surrounded by hills, the urban pattern has evolved between these two geographic conditions resulting in a ring development around the bay. In this process, the connection between the bay edge and the hills has been dissected in terms of ecological and hydrological structure. Most of the creeks which feed the bay originating from these hills have been channelized or buried underground. This is visible in the map representing the dissected landscapes of Bay area.

The geological study of bay area suggests that most of the urban development has been over surficial sediments of alluvial soil deposited by creeks and over the reclaimed lands which were built by dredging mud from the bay and using debris of collapsed buildings during 1906 earthquake (Brechin, 2006).

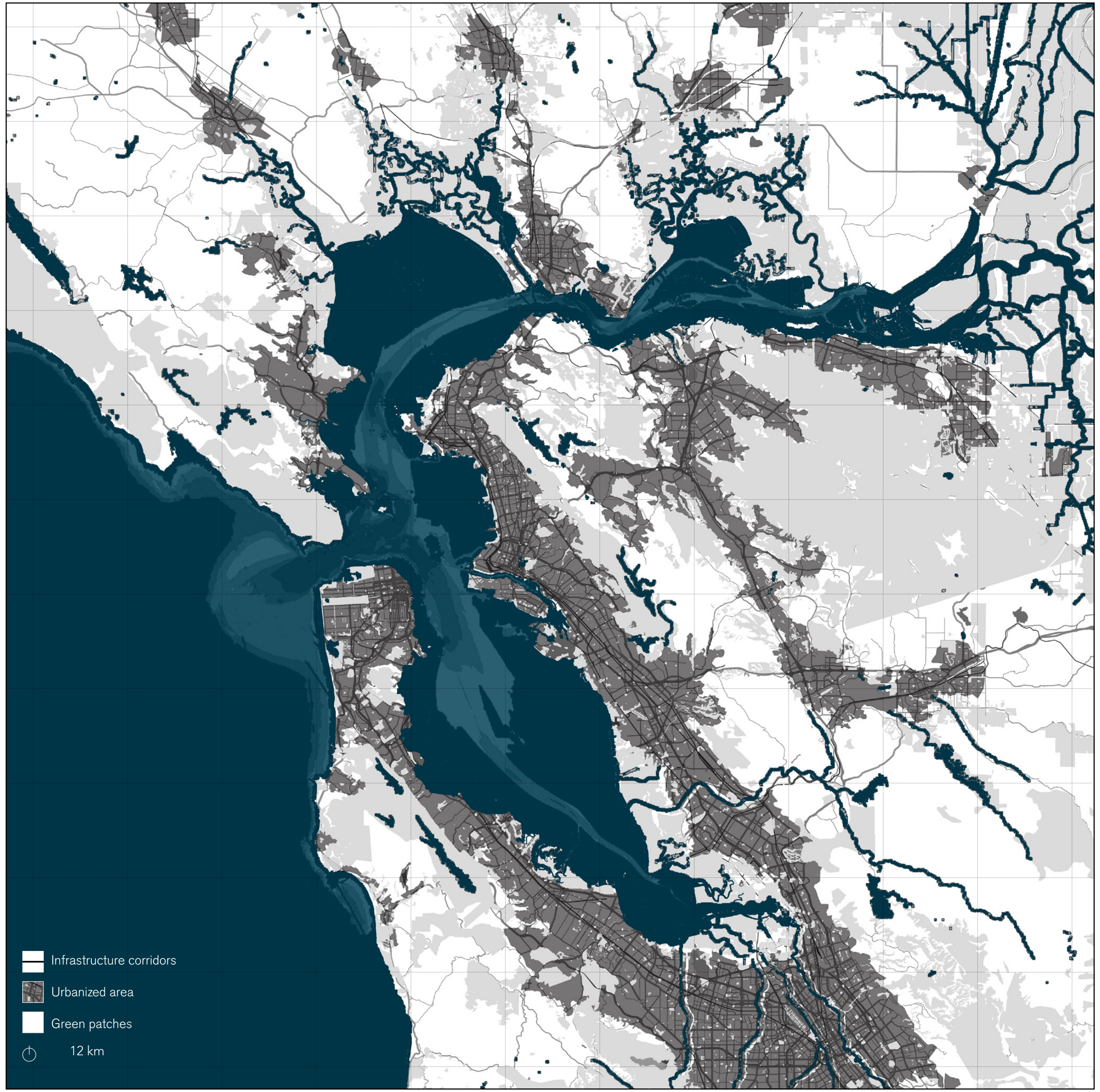


Figure 7.5: Dissected landscapes, San Francisco bay area. Illustration : Author

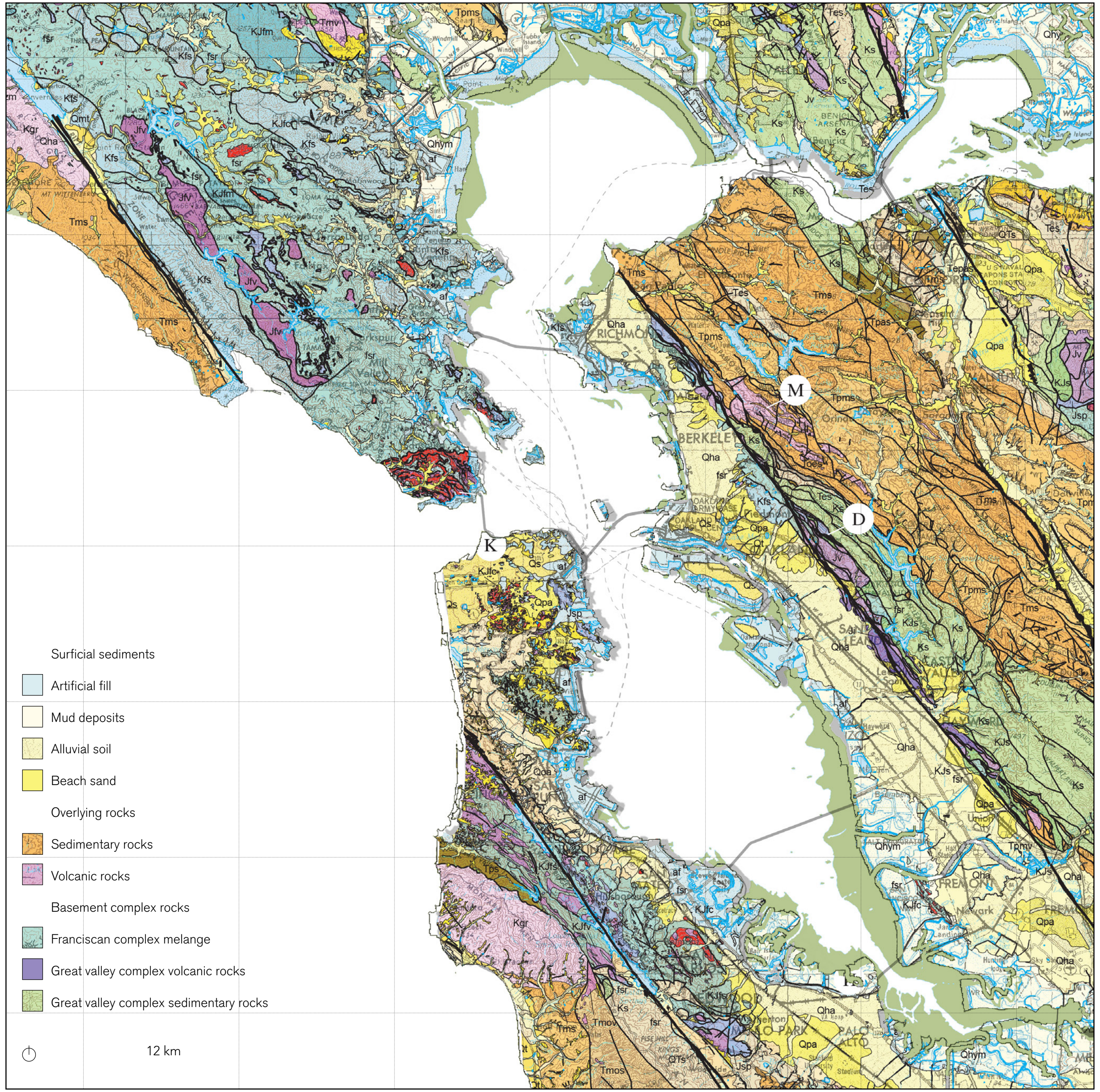


Figure 7.6: Geology study of bay area. Source : U.S. Department of Interior, U.S. Geology Survey.

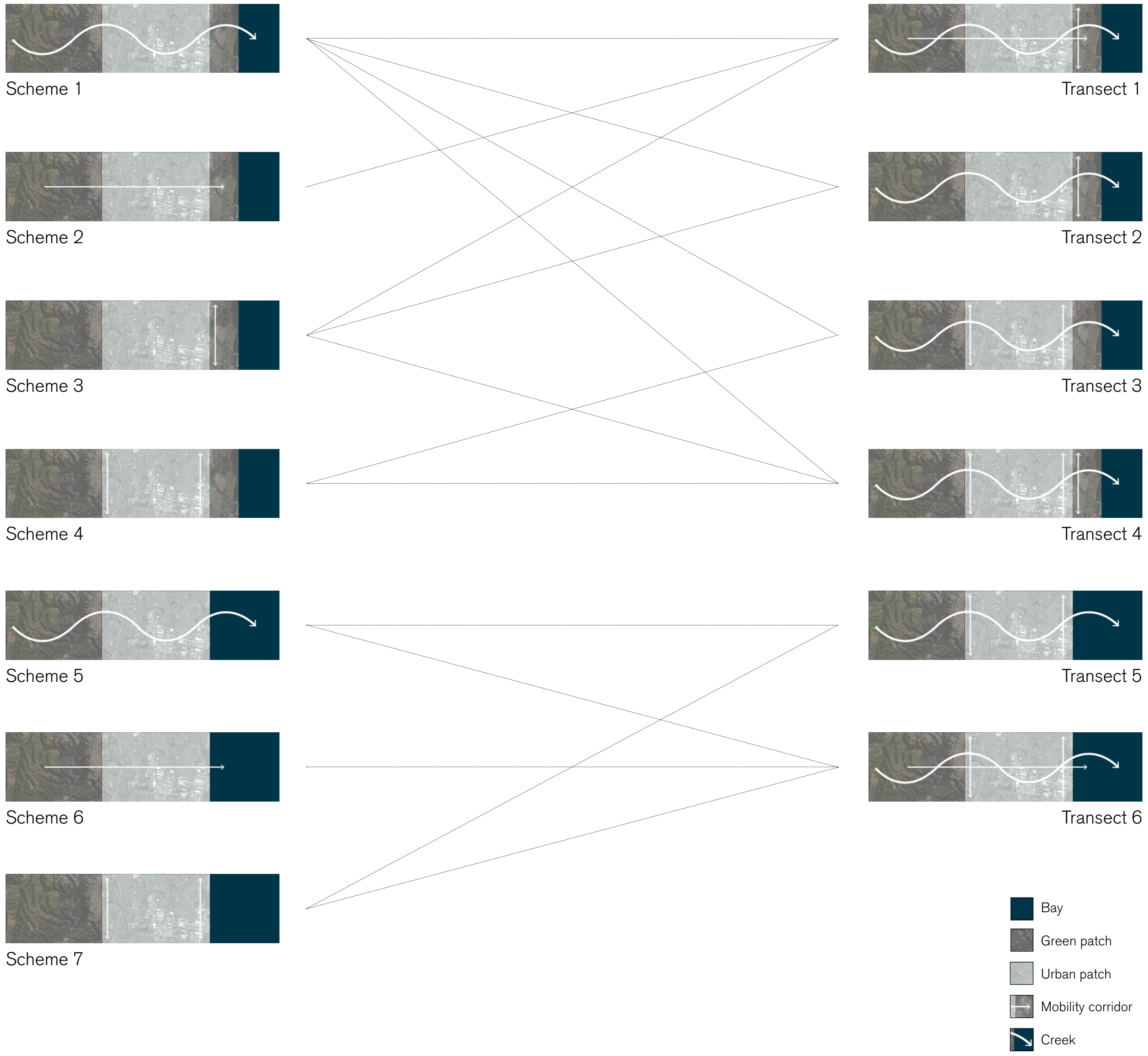


Figure 7.7: Transect study at Bay Area. Illustration : Author

Transects

While developing network of patches and corridors across the scales, it is important to understand the topography, soil composition, gradient of slope and the land-water transition edge along the bay. The transect study is the method used to analyse these aspects. The bay edge is categorized into different schemes of diagrams at macro scale (bay area) based on the three layers of landscape, infrastructure and occupation from 3x3x3 analysis (Meyer and Nijhuis, 2016).

The map of dissected landscapes along bay area highlights the degradation of ecology. The geographic conditions have restricted the territory from sprawling and has pushed along the edge of bay thereby reclaiming land in the process. Most of the land-water transitional edge has been transformed from soft to hard. The transect study helps to understand this situation better. After analysing the territory, seven possible diagrammatic sections of land-water transition are identified which represent the topography, bay edge condition, the green patches, mobility corridors, creeks and urban areas. Combination of these sections derive six transect schemes that exist along the bay at ten different spots. These transects give an schematic overview of spatial configuration in terms of urban patches, mobility corridors, green patches and their relation to sea level rise of 1.4 meters in a topographic positioning.

The topographic position index establishes the gradient of each transect and the location of urban occupation along the slope. Combining transect study with geological study makes it clear how is the territory's runoff and permeability. The urban occupation has majority of land either occupied by buildings or covered with pavement. This reduces the capacity to infiltrate the runoff. Majority of urban occupation is built upon artificial landfills, mud deposits or alluvial soil. The inference of this study being, longer the urban occupation along the transect, likelier is the risk of flooding at downstream due the high volume of storm water runoff. Moreover, this study identifies creeks as major corridors which can structure the landscape infrastructure syntax along bay area. These creeks will connect the downstream of bay to the hinterland upstream which can convey the pluvial and fluvial floods and urban runoffs. The green patches along these corridors can help delay the discharge thereby reducing the hydrological threats from upstream.

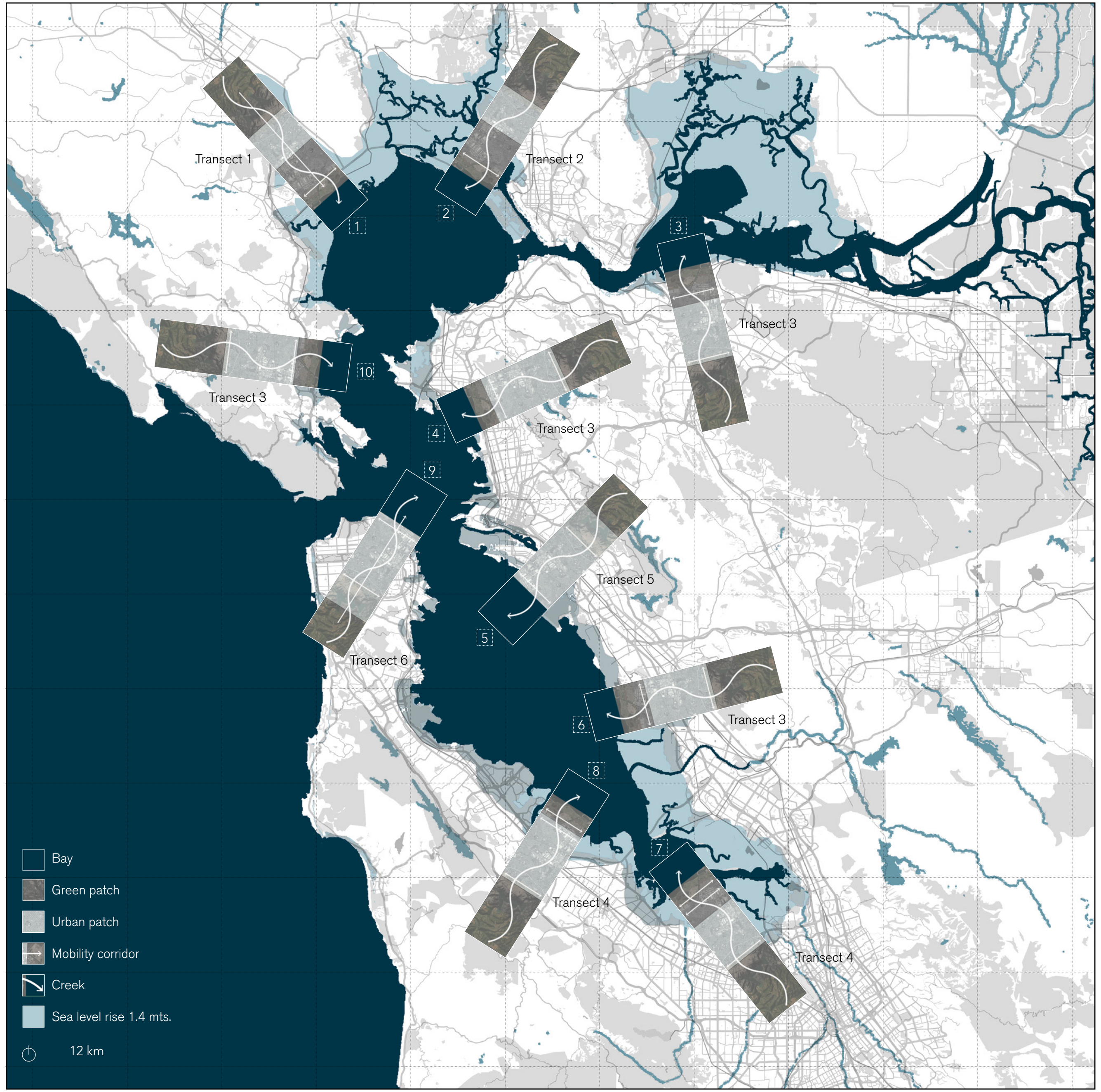


Figure 7.8: Transect study projected on Bay Area. Illustration : Author

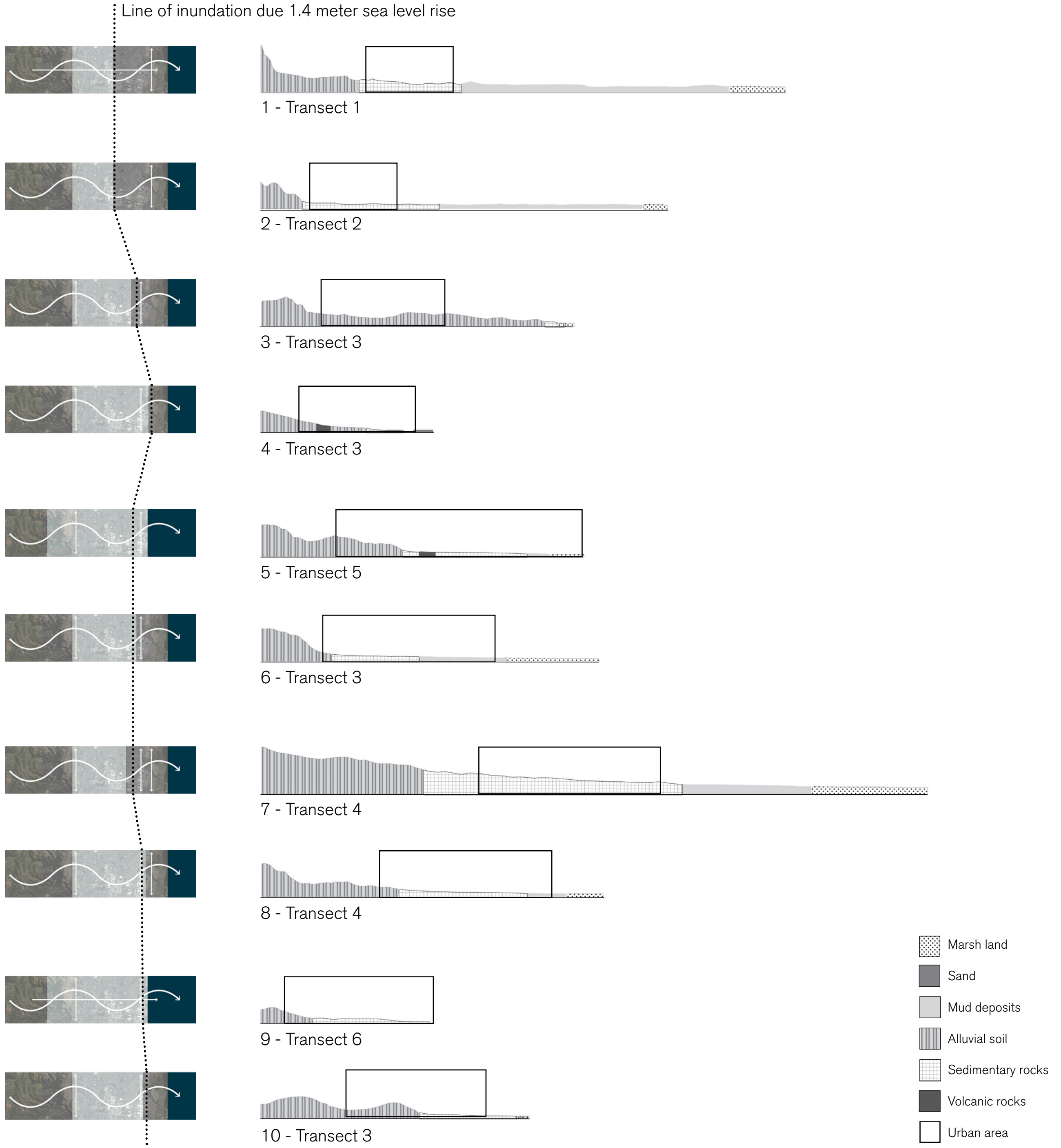


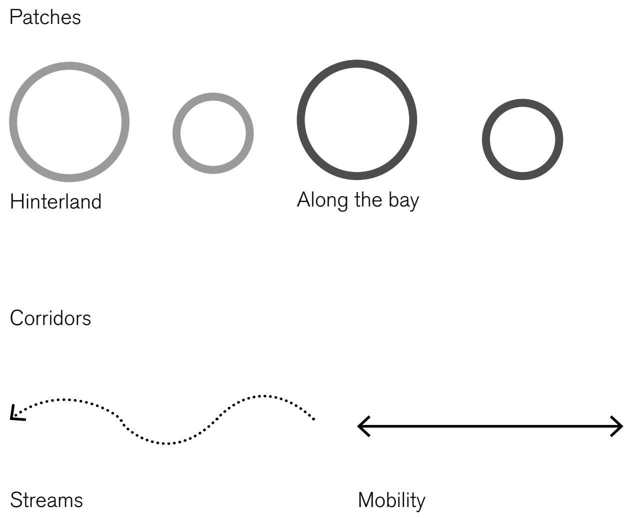
Figure 7.9: Transect study synthesized with geology and topography study. Illustration : Author

“Landscape becomes the operative platform of human existence; where landscape exists, so does infrastructure. By understanding landscape as the operative ground for infrastructure, and any landscape intervention as inherently infrastructural, our ability to radically redefine infrastructure is expanded and solidified.”

- Dane Carlson, The Humanity Of Infrastructure: Landscape As Operative Ground , Scenario Journal, 2013

Patches and Corridors for the syntax

The concepts of patches and corridors defined by Forman (Forman, 2014) are used to develop the landscape infrastructure syntax for the region. The transect study helped to identify creeks along the bay as the critical elements which will structure this syntax to address the hydrological challenges of pluvial and fluvial flooding. Drawing from the analysis and synthesis performed, a network of potential green patches and green/blue corridors of creeks and mobility networks are identified which can be conditioned into an infrastructure that can accommodate the water. To restructure the hydrological system and reconnect the upstream to the downstream of bay three types of green/blue corridor development have been mentioned below.



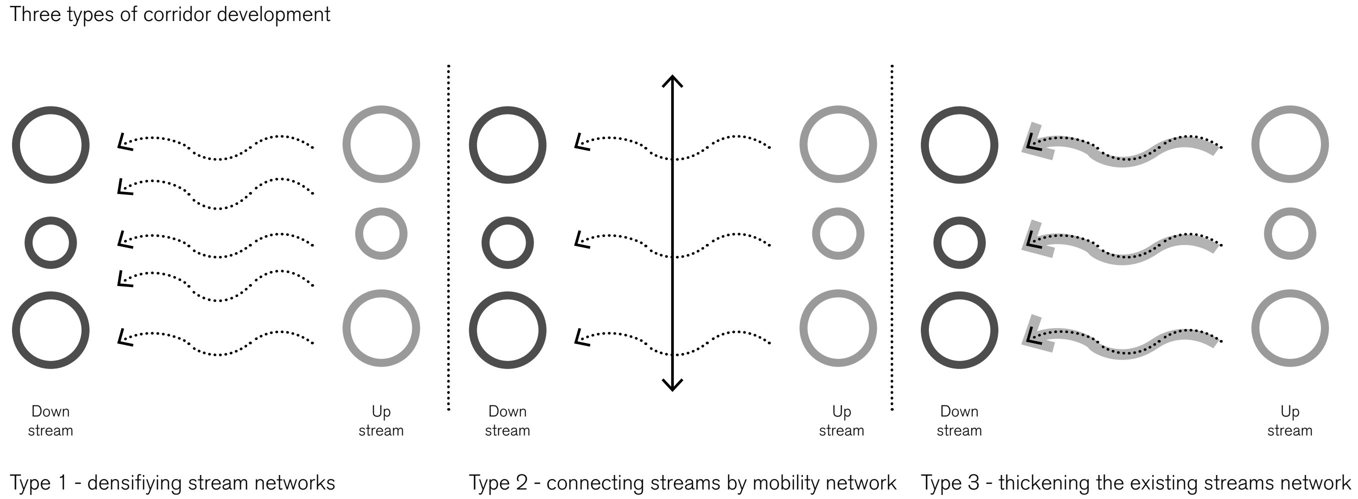


Figure 7.10: Concept of patches and corridors. Illustration : Author

Connecting patches

The circles highlight patches within hinterland upstream and along the bay edge downstream. The map indicates the intended connecting directions from hinterland to the bay, thereby facilitating conveyance of water on a regular day and reduce peak discharge by delaying the runoff during pluvial and fluvial floods. Theses patches will be crucial downstream to accommodate saline water during occasional storm surges and increasing threat of sea level rise.

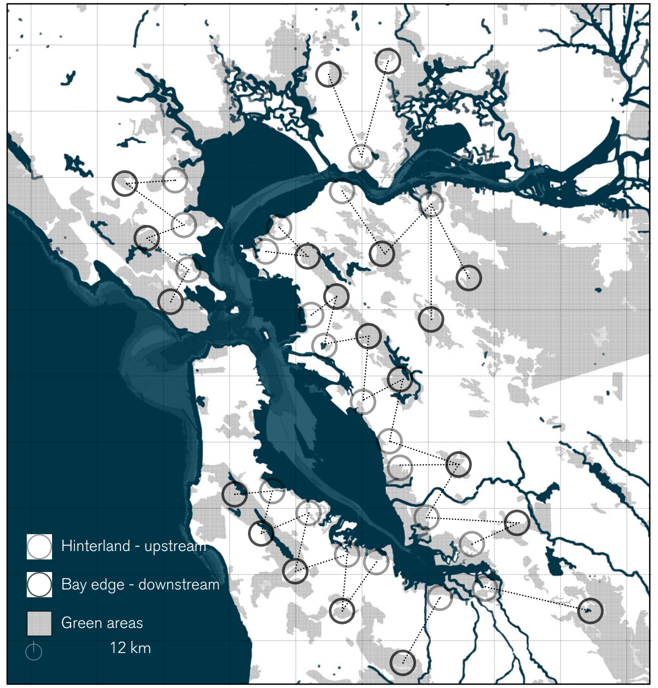


Figure 7.11: Connecting patches. Illustration : Author

Topography study

The topography map indicates the uphill and downhill spots which indicate ridges and valleys along the bay. This map is crucial for establishing the direction of flow of water conveyance. Moreover, this layer is necessary to identify the sequencing of patches within the syntax. Topography study along with the transect study indicates positioning of ten transects around bay edge with respect to the gradient and land-water transition.

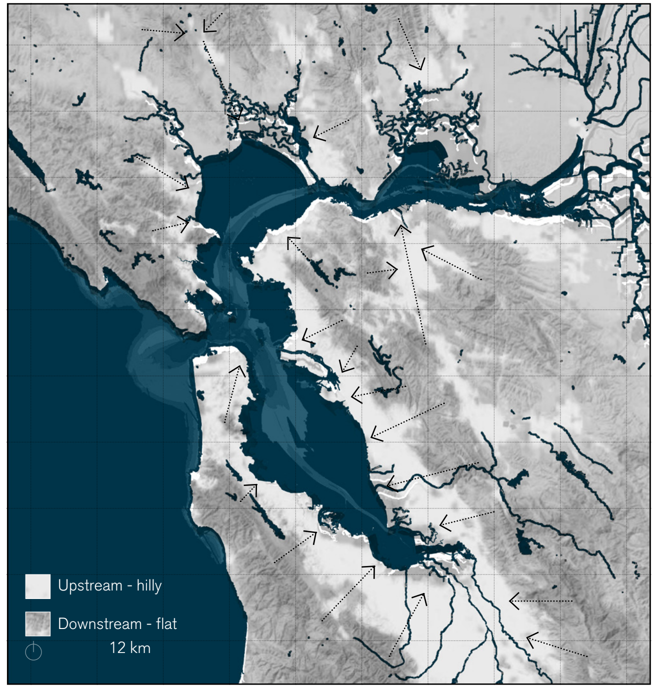


Figure 7.12: Topography study. Illustration : Author

Geological study

The soil analysis map indicates the conditions which need to be considered while developing this syntax. The upstream region has sedimentary or metamorphic rocks, the midstream have combinations of sedimentary rocks and alluvial soil while the downstream has a mix of alluvial soil, sand, mud deposits and marshes. But if observed in the map, this is not the case throughout the edge of bay, which sets guidelines while developing the urban landscape syntax. While relating this information to topography study, every patch's capacity to infiltrate water is understood.

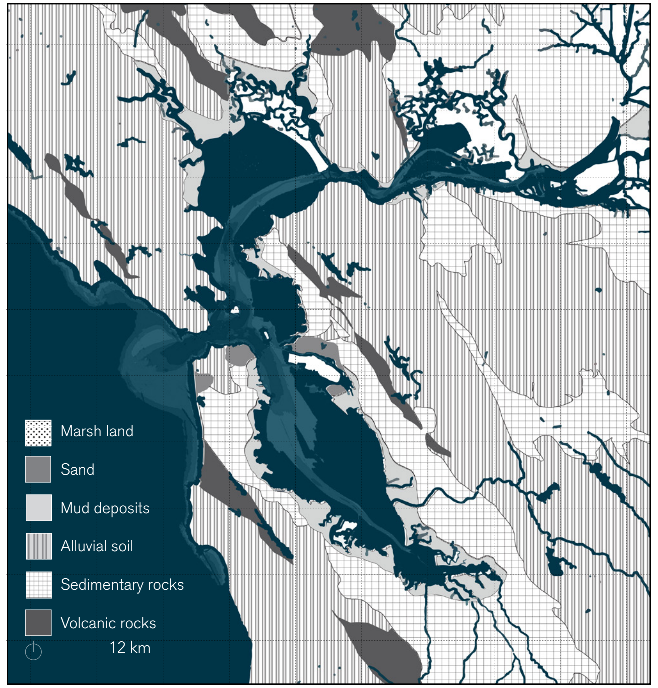


Figure 7.13: Geological study. Illustration : Author

Identifying corridors

The transect study indicated importance of creeks within the territory as corridors to develop landscape infrastructure syntax. These creeks run across the transect from upstream to downstream which can convey water and reconnect the hydrological structure and ecological system. Based on local conditions, these creeks can be developed either by densifying, connecting by mobility networks or thickening the existing ones. While doing so, these corridors will connect the identified patches which will develop the syntax together.

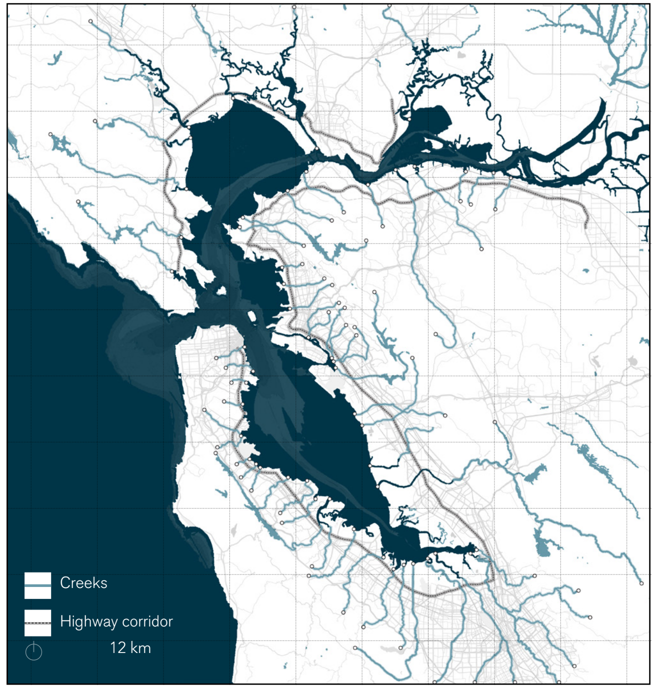


Figure 7.14: Identifying corridors. Illustration : Author

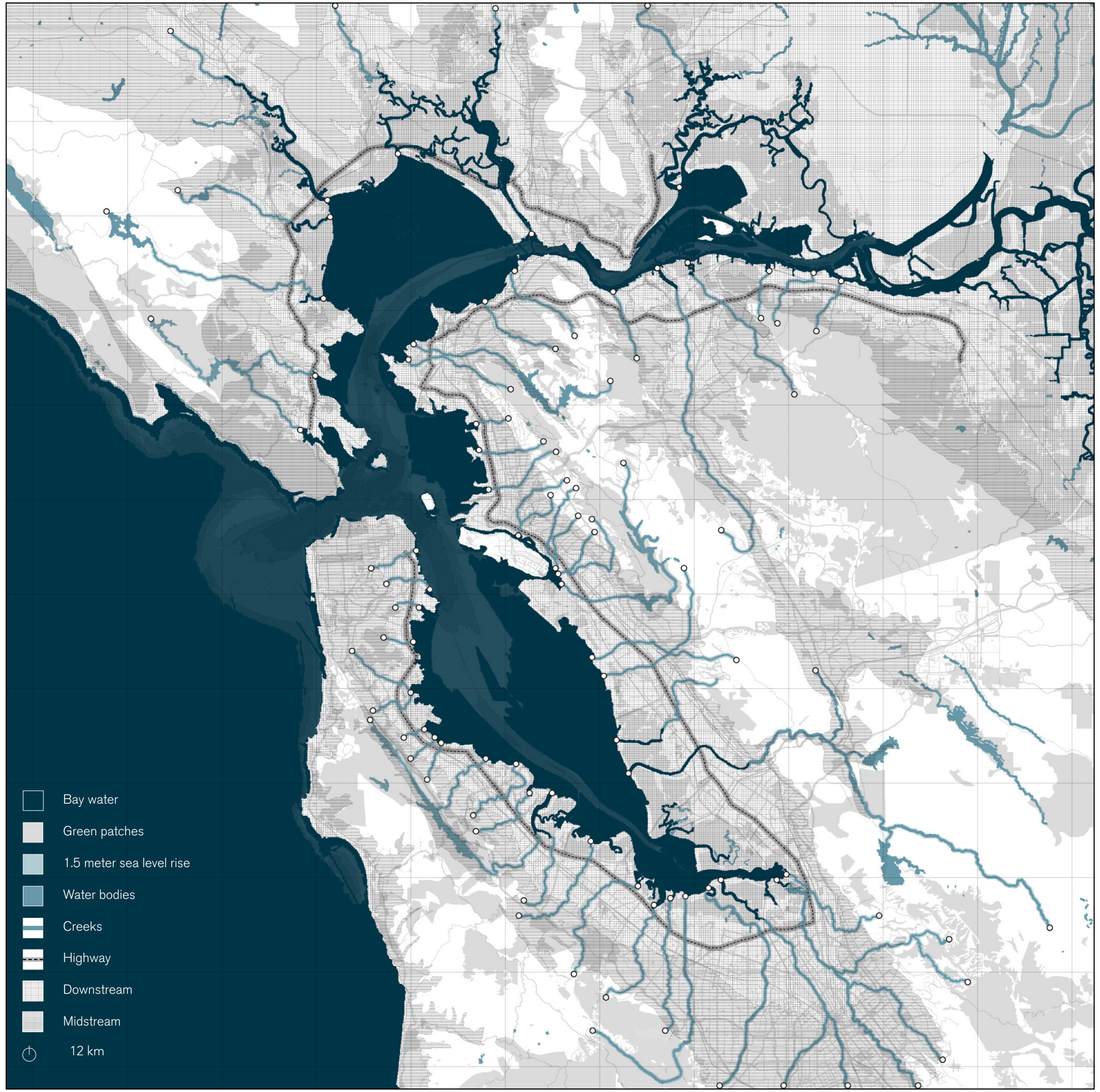
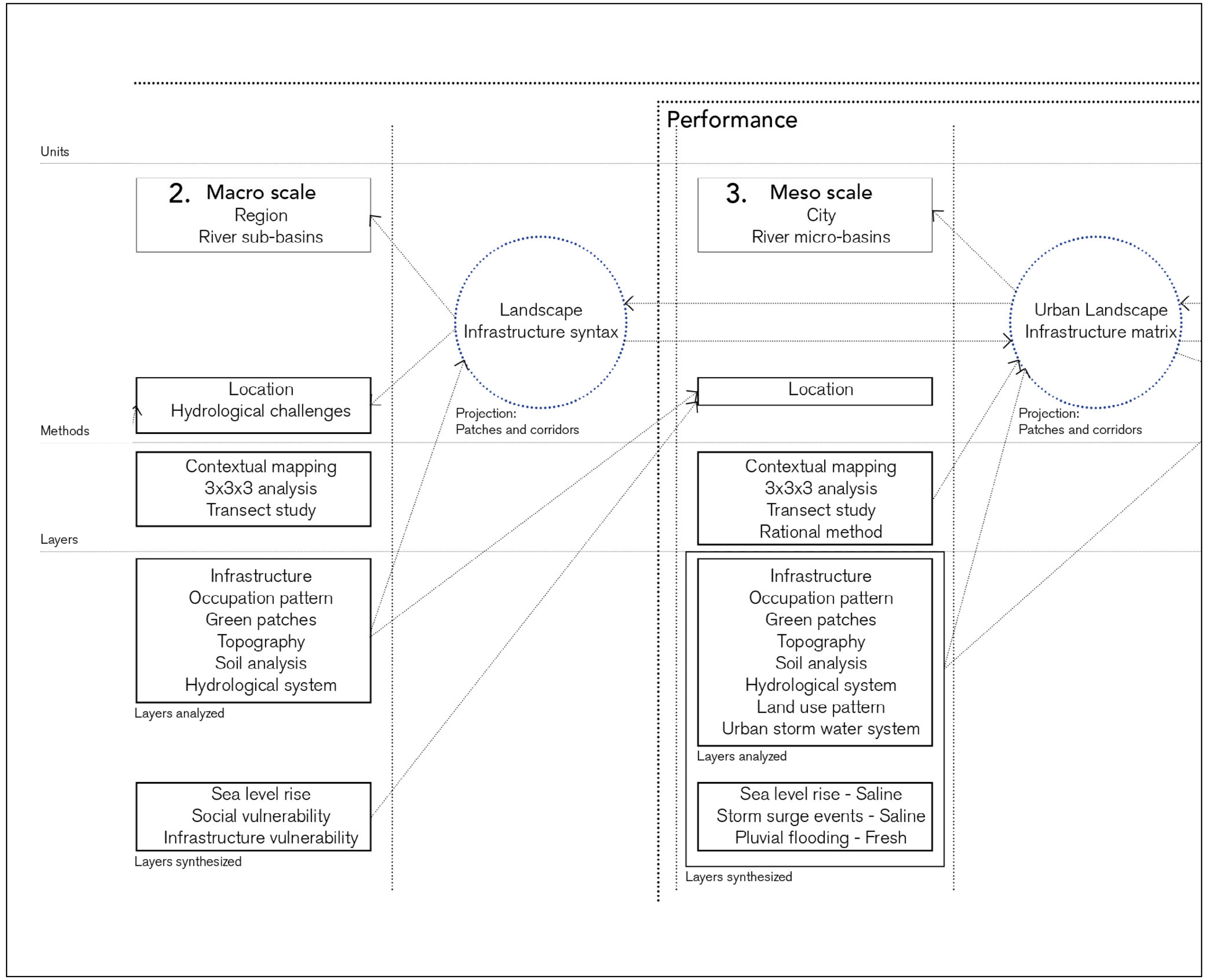


Figure 7.15: Landscape Infrastructure syntax. Illustration : Author

Landscape Infrastructure Syntax - regional

The method of conceptualizing complex information, diverging in the processes of analysis and converging in the processes of synthesis, through the layers of landscape structure, landscape processes, topography, geology, mobility networks and occupation patterns has led to the development of Urban Landscape Syntax. It is a projection or a suggestive scheme to understand the geomorphological units and elements which can be used to restructure the ecology and hydrological system from upstream to downstream. This projection shall inform the strategic development to achieve the conditioning required for landscape to act as an infrastructure. The Landscape infrastructure syntax sets certain rules and parameters for the project to unfold further.

Meso scale


Performance
Units
Methods
Layers
2. Macro scale
Region
River sub-basins
Location
Hydrological challenges
Contextual mapping
3x3x3 analysis
Transect study
Infrastructure
Occupation pattern
Green patches
Topography
Soil analysis
Hydrological system
Layers analyzed
Sea level rise
Social vulnerability
Infrastructure vulnerability
Layers synthesized
Landscape
Infrastructure syntax
Projection:
Patches and corridors
3. Meso scale
City
River micro-basins
Location
Contextual mapping
3x3x3 analysis
Transect study
Rational method
Infrastructure
Occupation pattern
Green patches
Topography
Soil analysis
Hydrological system
Land use pattern
Urban storm water system
Layers analyzed
Sea level rise - Saline
Storm surge events - Saline
Pluvial flooding - Fresh
Layers synthesized
Urban Landscape
Infrastructure matrix
Projection:
Patches and corridors

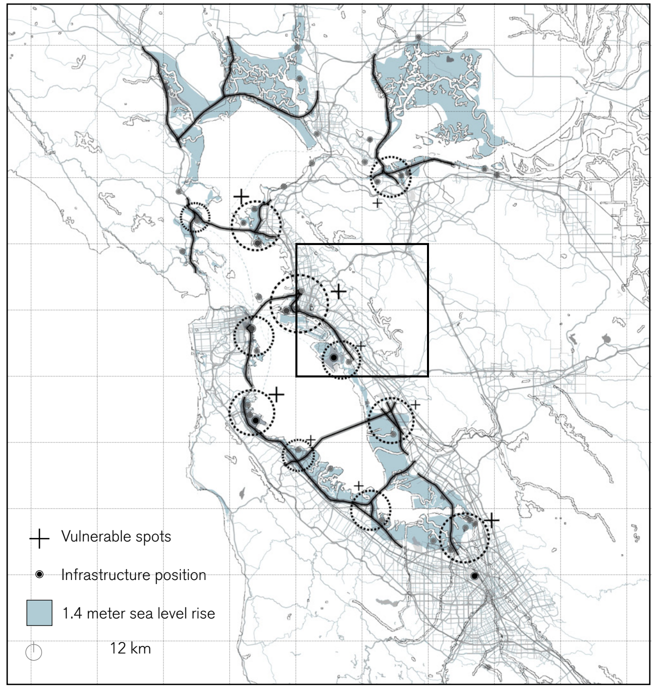


Figure 7.16: Infrastructure vulnerability map. Illustration : Author

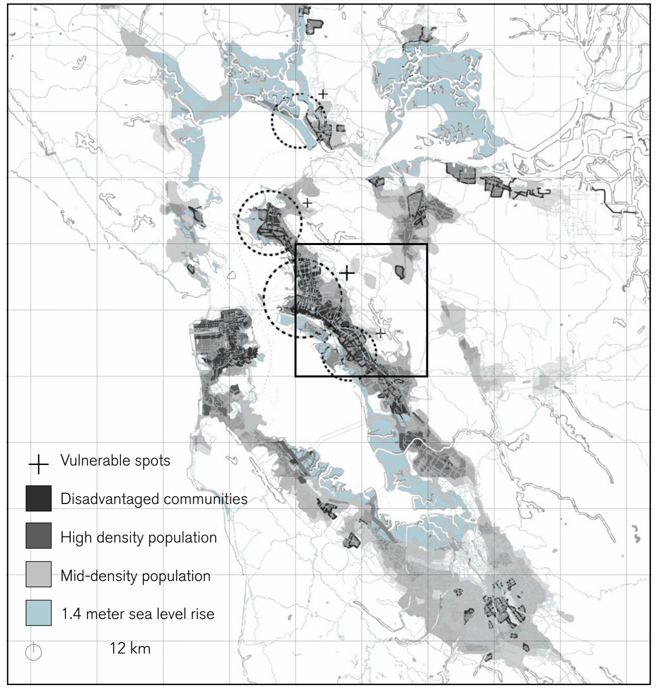


Figure 7.17: Social vulnerability map. Illustration : Author

Meso scale: City of Oakland

Taking forward the findings of macro scale (bay area) and building upon the Landscape Infrastructure syntax, objectives for meso scale (city) are defined. The important link between macro and meso scale is both focus on conveying water from upstream to downstream by connecting through green patches and using creek as a primary conveyor. Macro scale identifies potential elements which can structure the system, whereas meso scale uses these elements to strategies the system in a spatial context.

Using the transect study, bay is classified into ten different transects, which also represent the local issues like a smooth land-water transition from bay towards upstream which can absorb the tidal currents during storm event or sea level rise, but the urbanised area has a threat from upstream due to run-off during heavy rainfall, whereas, a hard land-water transition which is highly degraded in terms of ecological buffering of marshes or mudflats, which makes it vulnerable during high tides and sea level rise. This study, it is evident that transects which are represent the conditions of Oakland and San Francisco are highly vulnerable in terms of lack of ecological buffering during tidal situations and sea level rise due to intense urbanisation.

Moreover, the other two aspects which play a vital role in delineating the Meso scale are, the infrastructural vulnerability and social vulnerability. The map of infrastructure vulnerability indicates the critical systems of transportation like highways, railways, sea ports, airports; waste water treatment plants; electricity plant; if are inundates due to sea level rise will lead to short term and long-term disruption within the territory. The second is map of social vulnerability, which indicates population concentrations along the bay and area with socially and economically weak background. When these aspects are superimposed with the sea level rise, the maps will highlight the zones which will have maximum damage in terms of economy, population and areas which might not be able to recover due to lack of services. The two maps have high indications which suggest to narrow focus further to the east bay near the city of Oakland.

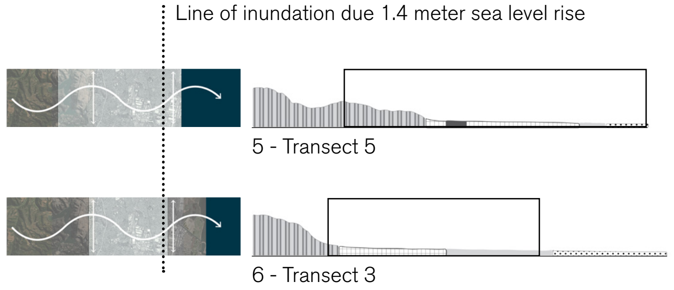


Figure 7.18: Transect study, Meso scale identification. Illustration : Author

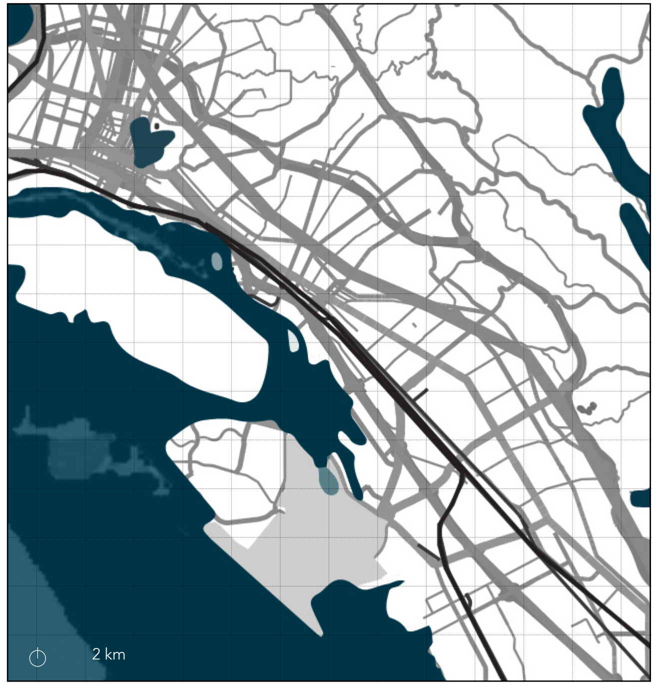


Figure 7.19: Meso scale delineation. Illustration : Author

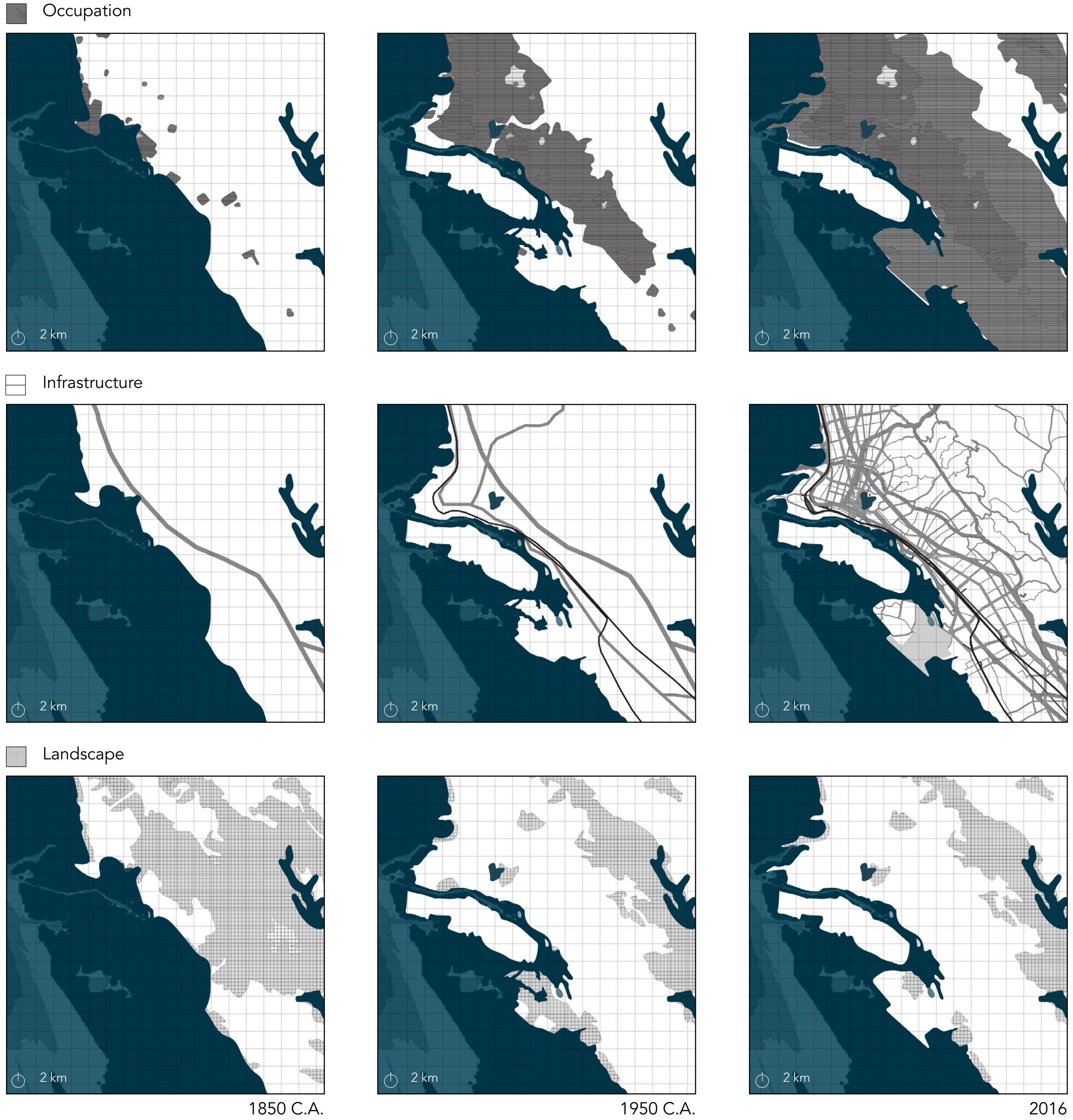


Figure 7.20: 3x3x3 analysis, City of Oakland. Illustration : Author

The 3x3x3 analysis of the selected stretch near city of Oakland confirms the problem statement established at bay area level, which is dissection of landscape and hydrological structure over time due to occupation patterns and infrastructural development. Further, the Landscape Infrastructure syntax established in the earlier chapter informs the objectives for this scale, which is to connect the landscape patches along upstream-midstream-downstream to develop a network of infrastructure for hydrological risk accommodation.

The Macro scale identifies creeks and streams as the corridors to convey water. The geomorphological units of micro-basins are used to delineate the Meso scale, but the question is which micro basins to select; or rather what are the criteria which helps to delineate the micro basins? To do so, an analysis of ridge and valley to derive the natural flow of runoff is carried out within these micro basins. This analysis is further super imposed on the layer of riverine flooding to confirm the floodable zones. This study concludes that four micro basins drain out the creek water through an engineered channel at one point which makes the system fail during peak discharge. This is the final parameter to delineate the Meso scale, which is defined by these four micro basins.

The intention at Meso scale is to strategize the objectives which are established at Marco scale. These creeks will act as corridors whereas the open spaces, public parks and various other plots will act as patches to develop a network of infrastructure. This infrastructure will condition the territory to accommodate the hydrological risk of pluvial and fluvial flooding (shock), storm surge events (shock) and sea level rise (stress).

The map indicates four micro basins which topographically should have four different points of outlet or discharge for the creeks within it. But due to channelization of creeks they drain out the run-off from two points into San Leandro bay. This concludes that these creeks need to be naturalized with respect to topography and cannot have a single outlet.

As mseo scale (city) is delineated by the four micro basins near the city of Oakland, it is important to understand the urban fabric within these micro basins. To do so, first land use pattern is mapped. Analysing the land use pattern indicates that the upstream of all four micro basins is composed of nature reserves or big urban parks. Moreover, relating land use to the geology study highlights upstream area's a good capacity to hold and infiltrate water during heavy rainfall event due to presence of large unpaved areas and sedimentary rocks underneath. The midstream section of the transect is dominated by residential usage with few strips of commercial streets. Geologically it is composed of sedimentary and alluvial soil which has good infiltration capacity. The houses within this region are either single family

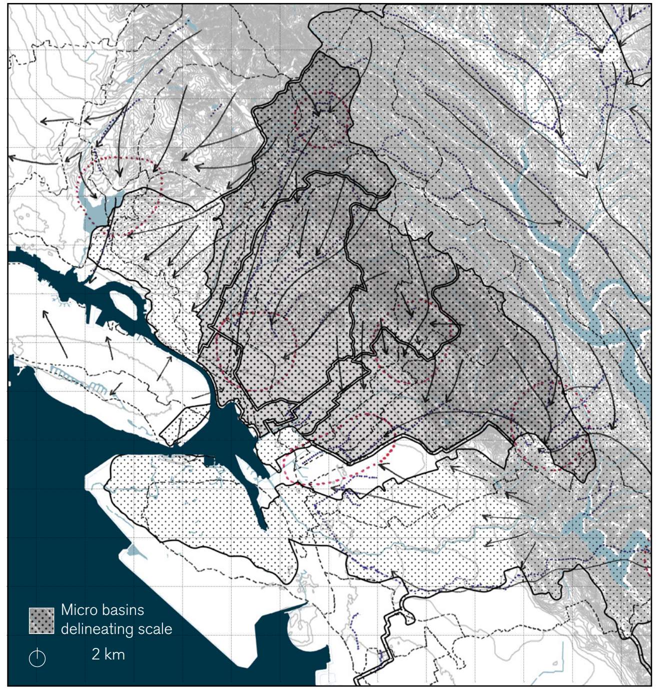


Figure 7.21: Topographic hydrological flow of creeks. Illustration : Author

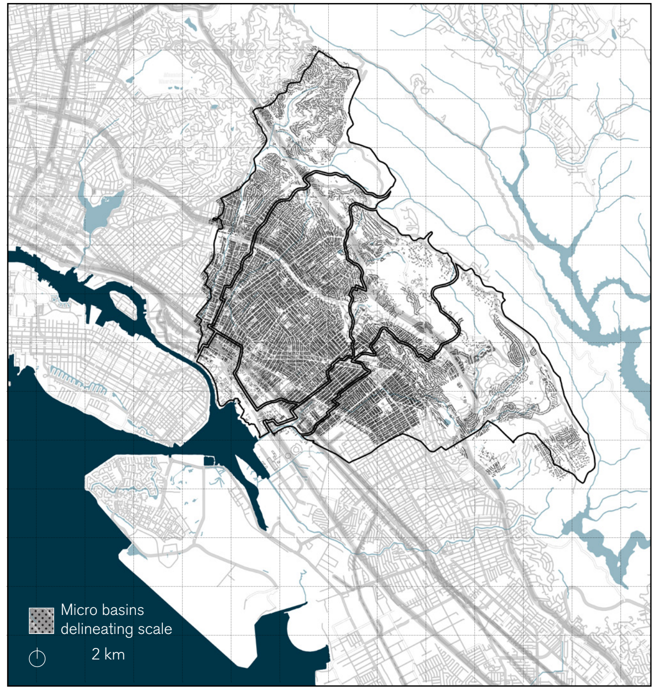


Figure 7.22: Buildings footprint. Illustration : Author

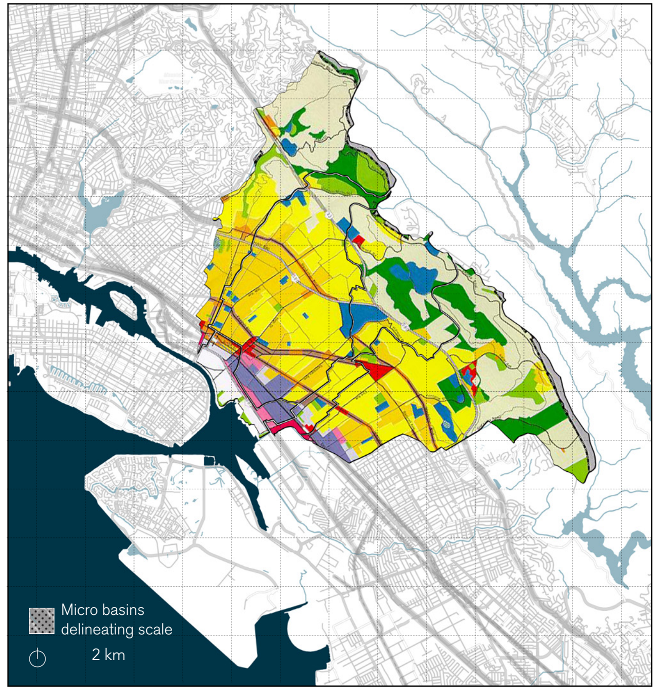


Figure 7.23: Land use plan, City of Oakland. Illustration : Author

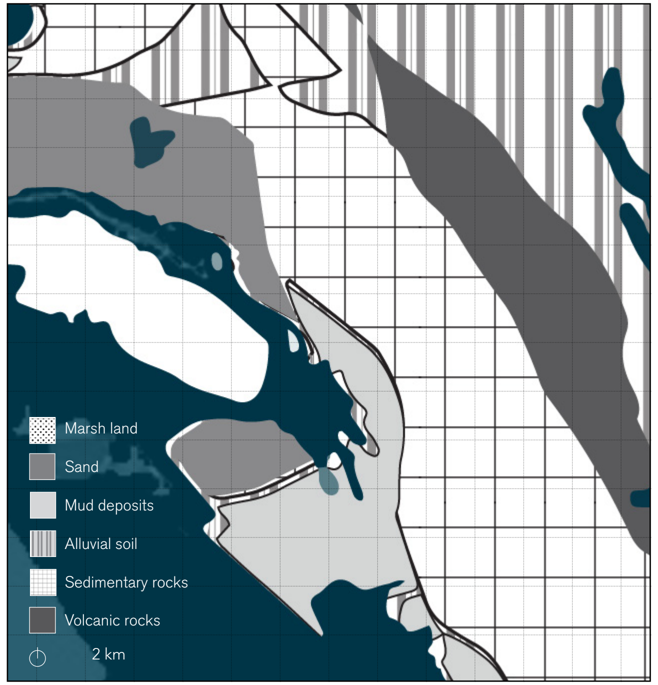


Figure 7.24: Geological study at City scale. Illustration : Author

detached units or mixed commercial and residential blocks (Plan Bay Area 2040 report, 2017). The plot sizes are small which makes the urban grain very dense. The buildings occupy almost 70 to 80 percent of plot size thereby reducing area for open soil. However, this section of transect has majority of local community parks, gardens and playgrounds which have a potential if networked into the intended infrastructure. The downstream is composed of major industrial units and commercial blocks. The land parcels are large in size where it is occupied by building or majorly paved for parking and storage. Geological study indicates downstream composed of sand, mud and artificial fill. This artificial fill is composed of quary rocks during early reclamations, building debris post 1906 earthquake and dredged mud from bay (Baylands ecosystem habitat goals, science update report, 2015). The mobility network is dense downstream due to the freeways, highways, railway and metro corridors. It can be observed that the commercial and industrial belt is developed along these mobility corridors.

To achieve the objectives of Macro scale, the open spaces need to be connected hydrologically to convey water into the creek during heavy rainfall event. The streets will play a major role in doing so. Meanwhile, urban parks, community gardens, institutional blocks will act as parcels which will retain and infiltrate water to reduce the peak discharge. The creeks, at some locations are buried underground, these need to be re-surfaced. Whereas, the places with concretised creeks need to be re-naturalised. This will increase the capacity of the creek to hold water. Moreover, at downstream, these creeks need to be branched out to increase the number of outlets in the bay, instead of draining them from one single point. This will reduce the pressure at outlet point. Multiple outlets will also increase the possibility of sediment deposition downstream which will feed the formation of mudflats and marshes. This will over time soften the edges along the bay thereby increasing the buffer area for storm surge events. The principle strategy at meso scale is to infiltrate, retain, convey and discharge the runoff.

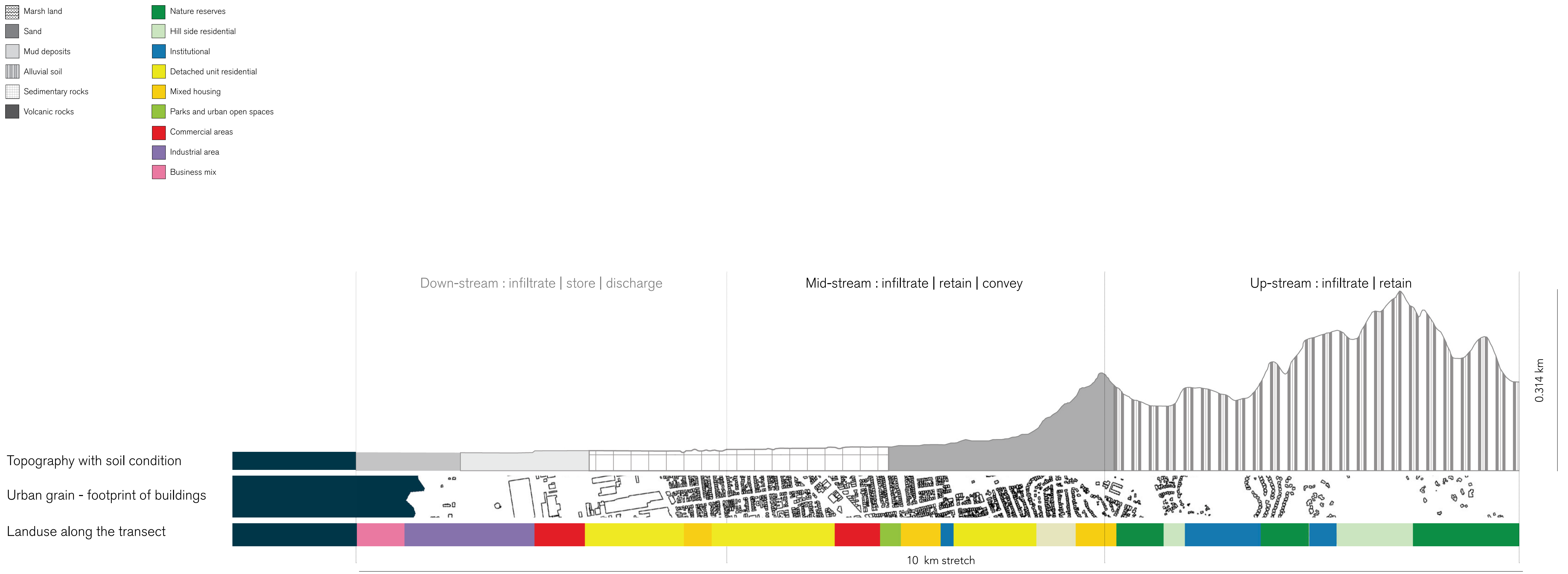


Figure 7.25: Transect study - topography, land use, building footprint, geology. Illustration : Author

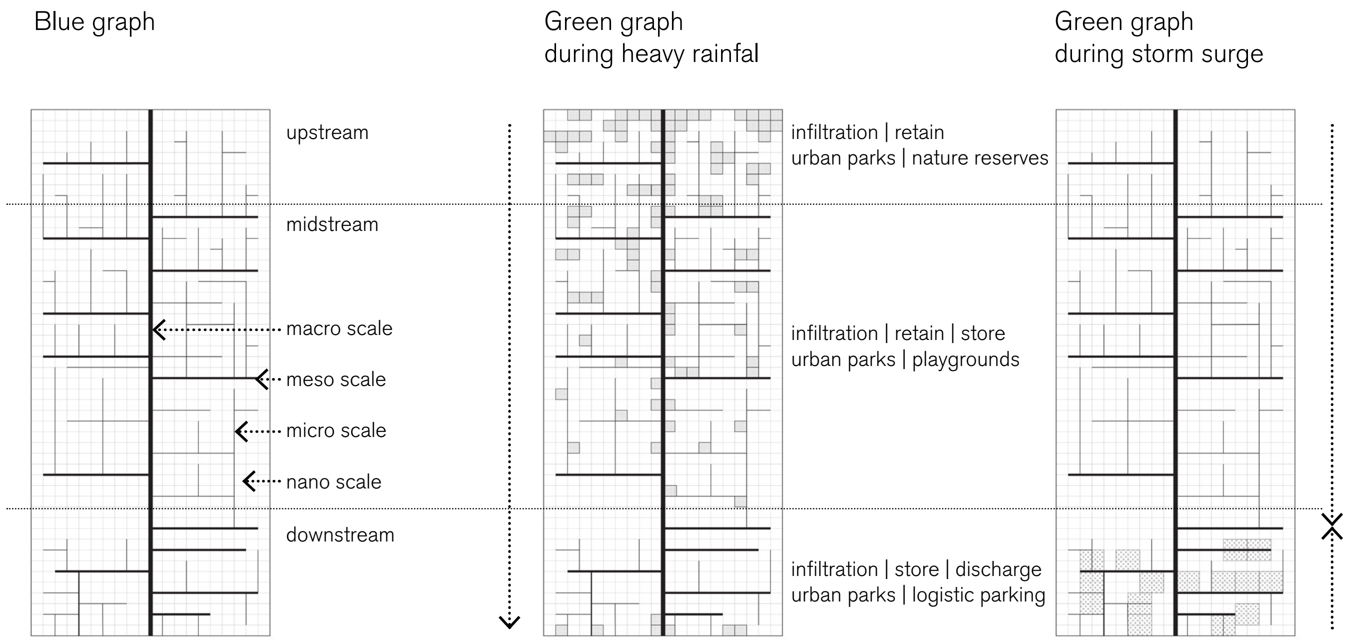


Figure 7.26: Green-Blue Graph diagram. Illustration : Author

The "blue and green graph"

The term "blue and green graph" is referred to from Performative nature: urban landscape infrastructure design in water sensitive cities (Kuzniecow Bacchin, 2015).The principle strategy of the system is to convey the runoff and reduce the peak discharge during heavy rainfall events, whereas during storm surge events accommodate the water rising from the bay. To achieve this strategy a system is designed which is composed of blue elements - creeks and street networks; which will convey the water on surface or through subsurface to desired spots of green elements - open spaces, parking lots, urban parks, institutional blocks; which will retain, infiltrate and store water.

The blue graph is composed of creeks as a primary conveyor of runoff and the streets as secondary or tertiary. This network is the backbone of the system. While addressing uncertainty related to hydrological systems it is necessary to keep the approach adaptive and incremental with respect to increasing threats over time. The strategy is built upon elements of landscape, infrastructure and urban fabric which change over time but with different pace and this needs to be under consideration. Hence, identifying critical elements structuring this system and sequencing them is very crucial. The term "blue and green graph" represents this sequencing and prioritizing element within system.

The blue graph consists of elements which need to be maintained for successful operation of the strategy. It also relates to the trans-scalar approach of the project, where the creek belongs to the Macro scale (bay) of connecting the upstream and downstream at the same time, it also plays an important role in Meso scale (city) to convey water and accommodate discharge from the street network which is part of Micro (neighbourhood) and Nano (land parcel) scale. The green graph is composed of

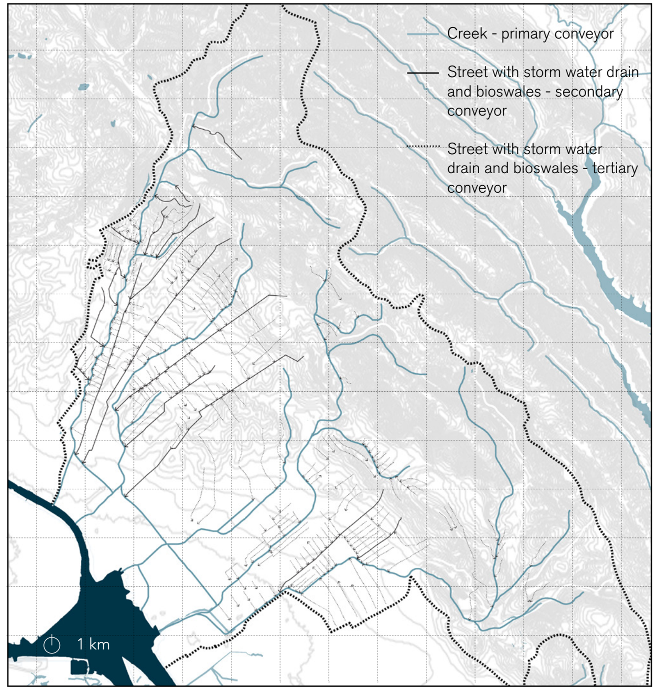


Figure 7.27: Blue network - matrix development. Illustration : Author

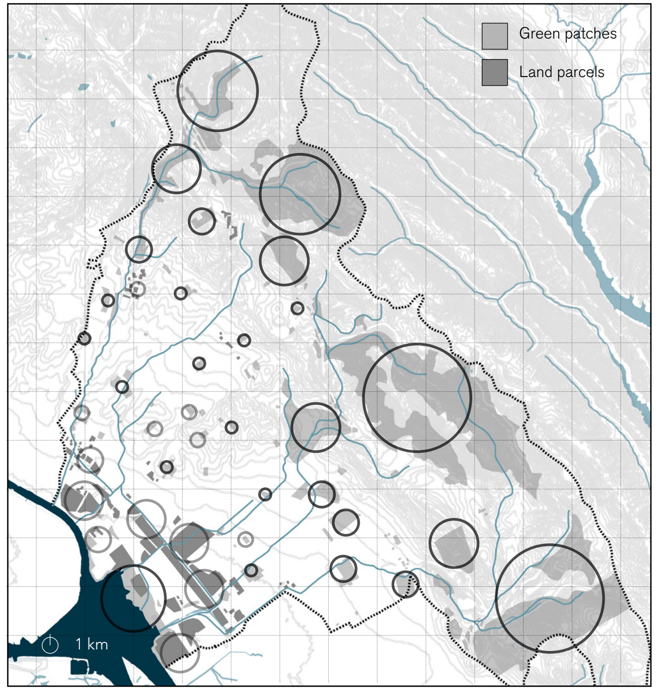


Figure 7.28: Green elements - matrix development. Illustration : Author

land parcels which determine the potential of the performance of strategy. These land parcels are hierarchal in nature which perform incrementally in case of rainfall events. The hierarchy is defined based on its topographic position index along transect, its proximity to the creek, function of land parcel and permeability based on its paved and unpaved area. Green graph is composed of element starting from open spaces and urban parks as primary parcels to institutional blocks or parking islands as secondary, followed by logistic or commercial blocks as tertiary. But this hierarchy is true for pluvial and fluvial flooding as a runoff from upstream. In case of storm surge events the hierarchy starts from open spaces and urban parks located downstream as primary parcels, followed by parking facilities and logistic centres and secondary and institutional blocks as tertiary.

To identify land parcels for developing the "green graph" and structuring the network connecting them as the "blue graph" rational method (Thompson, 2006) is used which derives the excess water within the selected basin which needs to be stored or infiltrated to reduce the peak discharge. Based on criteria mentioned for the hierarchy of green graph land parcels are identified which will infiltrate or store fresh water. Further, parcels which need to store brackish water downstream are highlighted which are analysed in detail at micro scale (neighbourhood). The network of blue and green graph is individually determined for every micro basin by calculating the infiltration capacity and deriving the exceedance of overflow of runoff. The calculations can be found in the Appendix. The combination of blue and green graph together is a performance graph for individual micro basin.

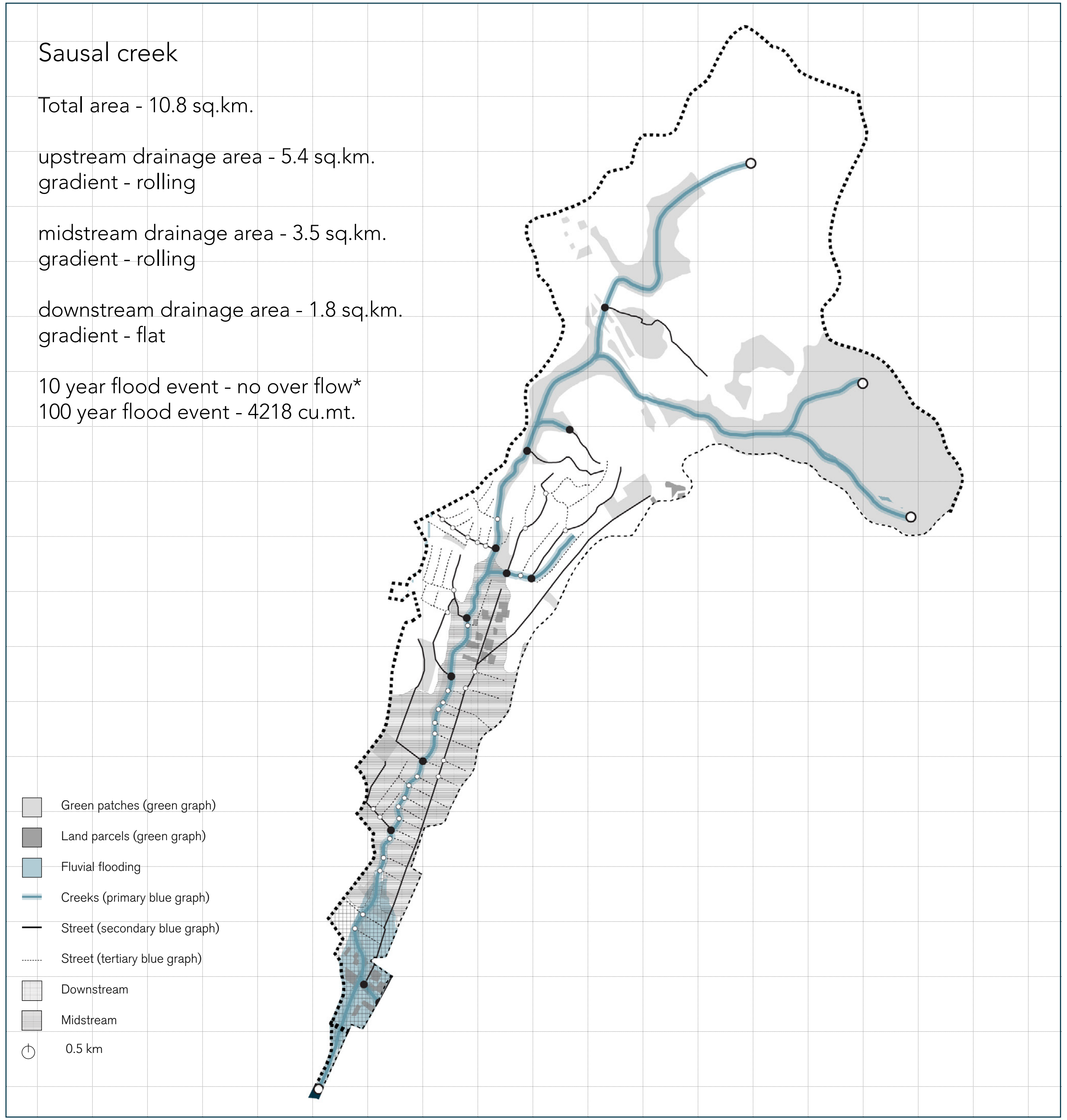


Figure 7.29: Runoff co-efficient calculations, Sausal creek. Illustration : Author

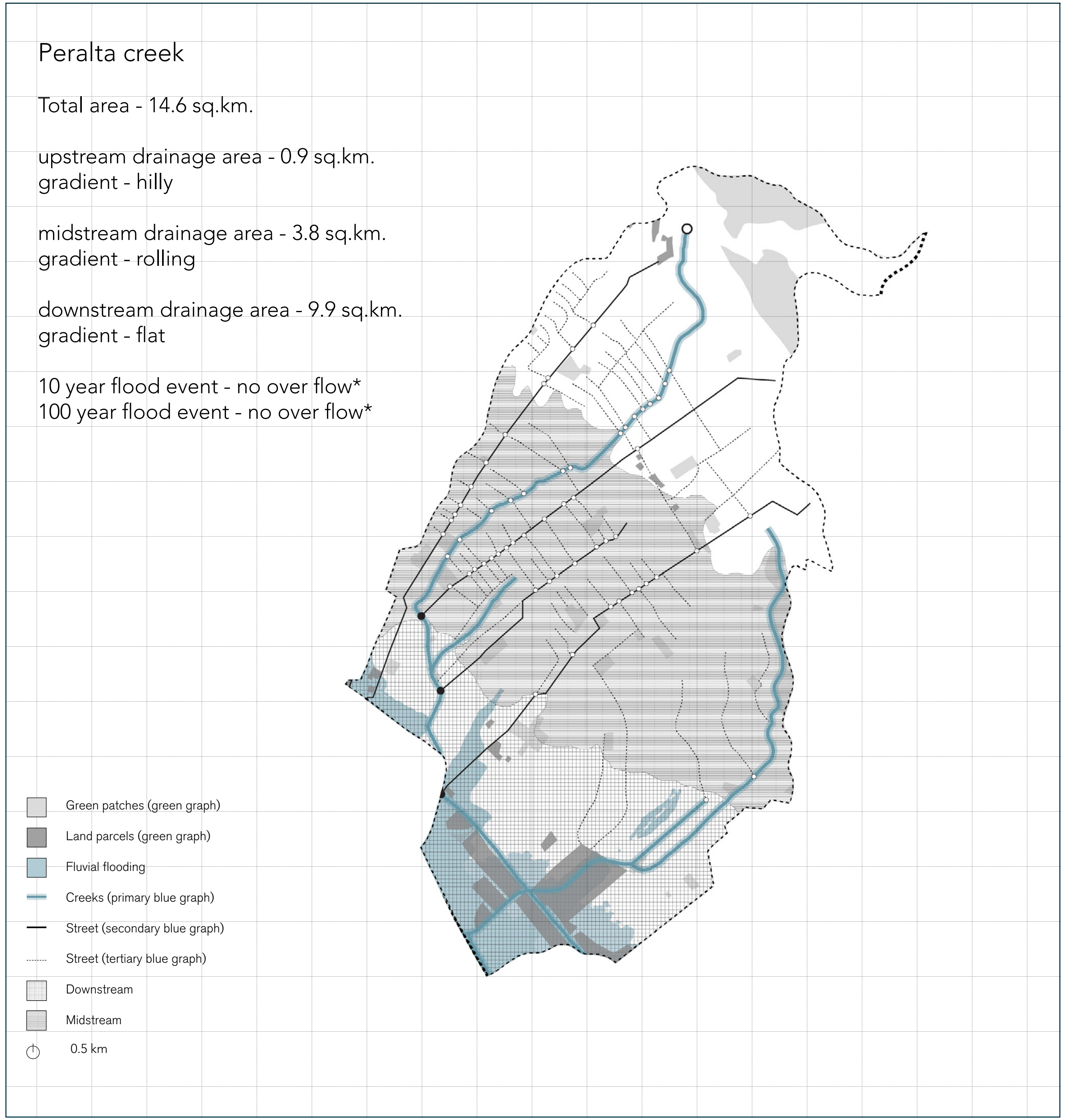


Figure 7.29: Runoff co-efficient calculations, Peralta creek. Illustration : Author

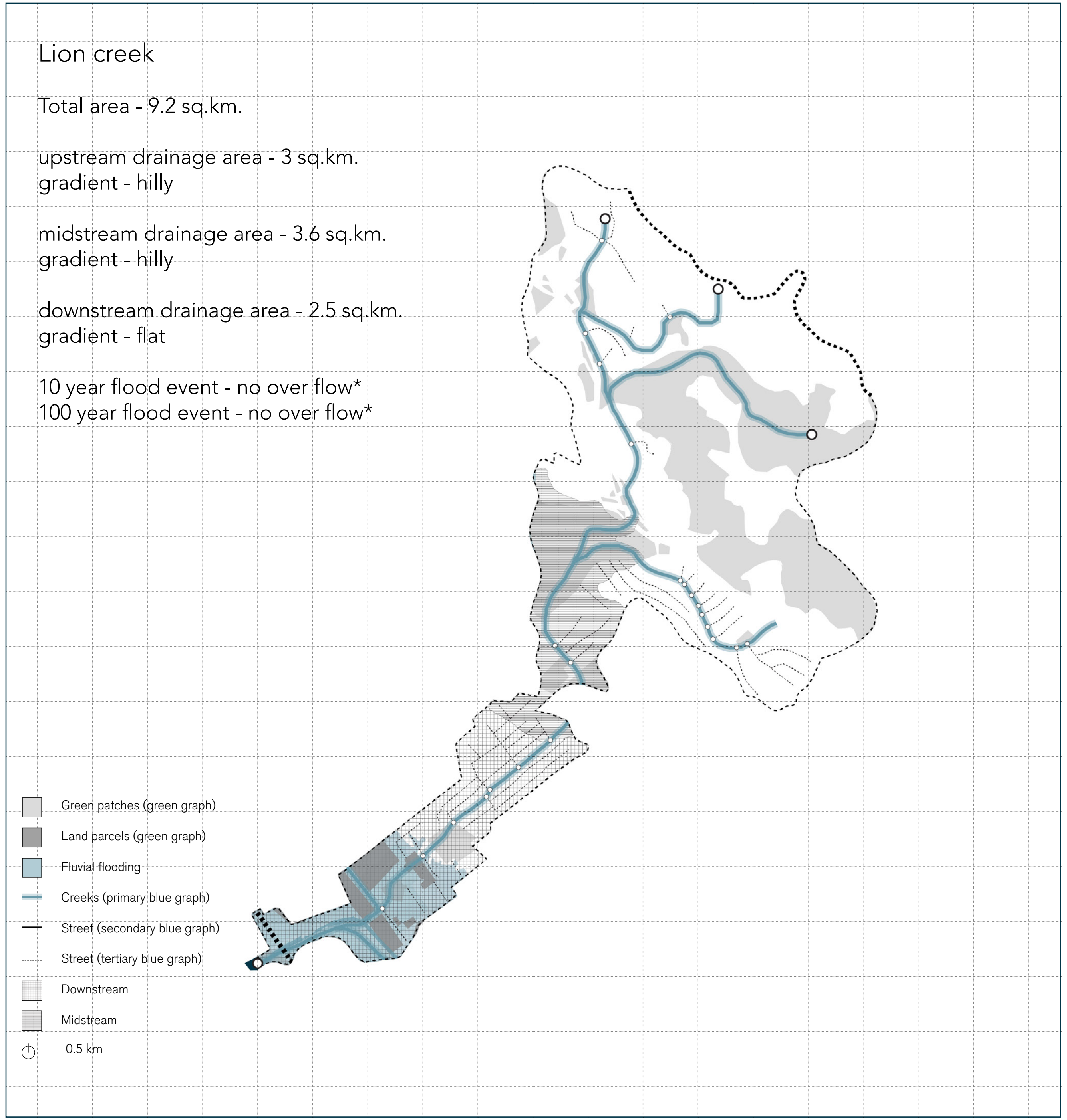


Figure 7.30: Runoff co-efficient calculations, Lion creek. Illustration : Author

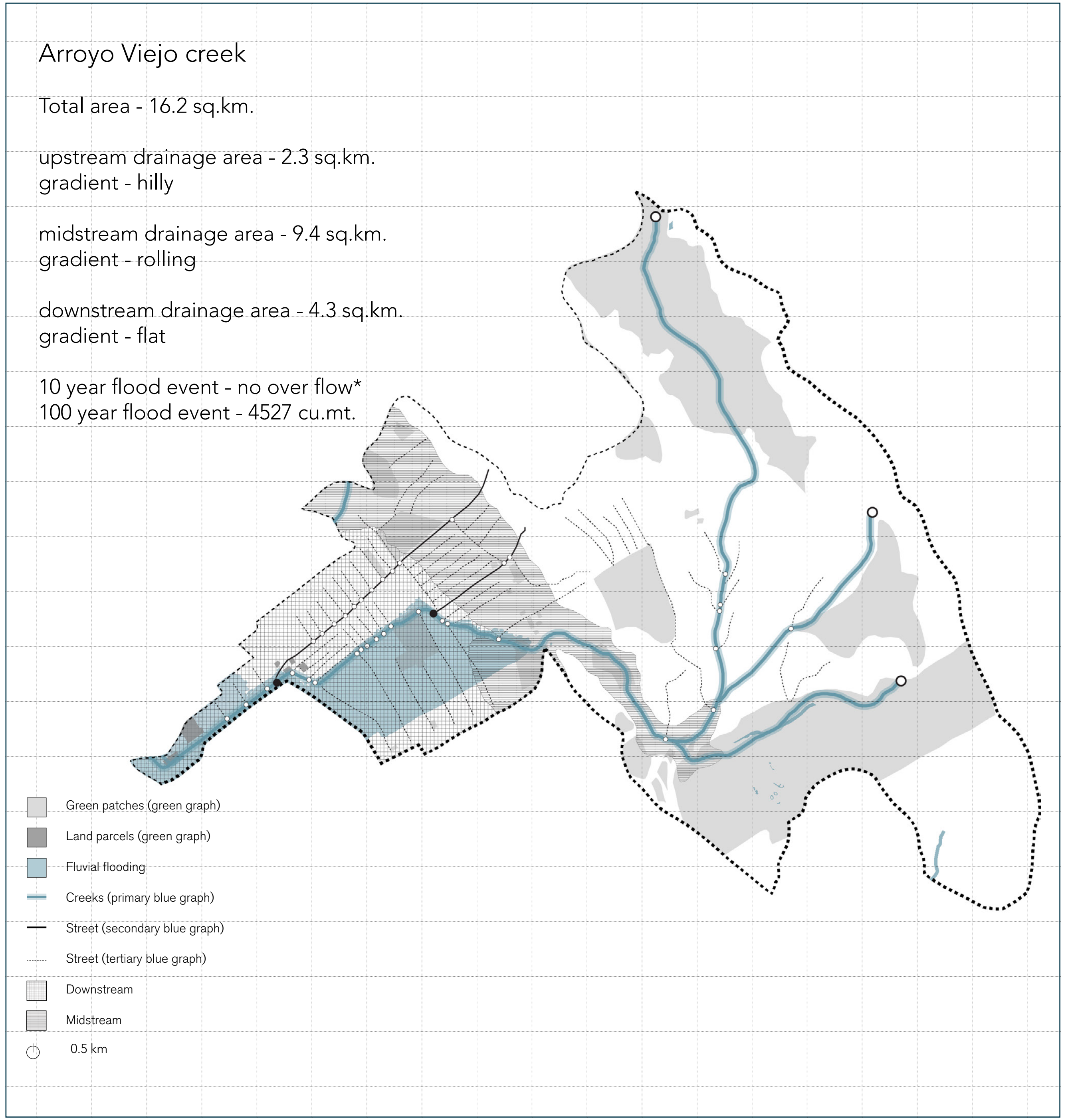


Figure 7.31: Runoff co-efficient calculations, Arroyo Viejo creek. Illustration : Author

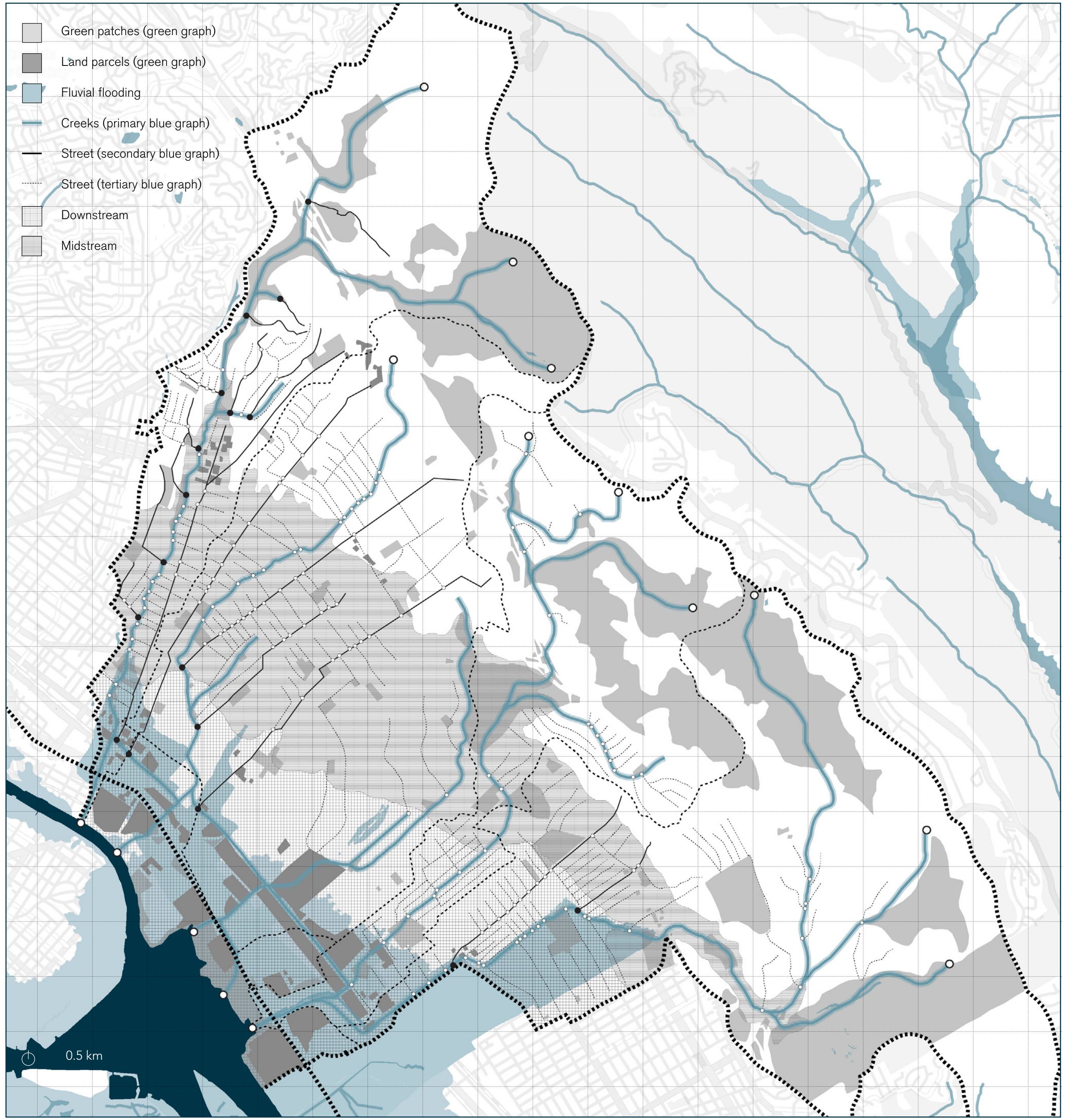


Figure 7.32: Urban Landscape Infrastructure matrix. Illustration : Author

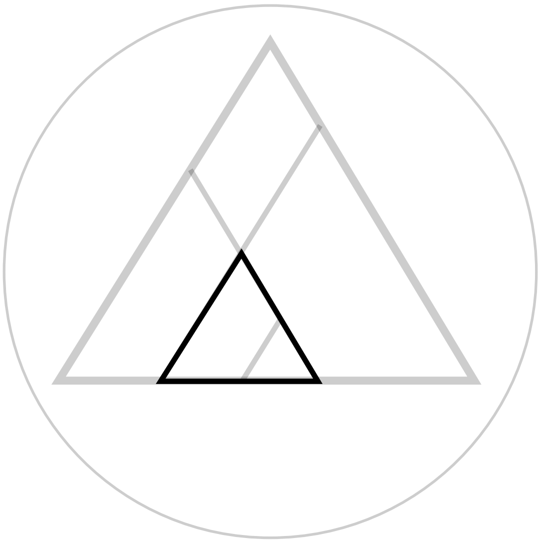
Urban Landscape Infrastructure Matrix – city

In alignment with the objective established at Bay area scale by Landscape Infrastructure Syntax, the matrix in the plan is actualization of these objectives at city of Oakland. The matrix is developed by identifying the "blue and green graph" elements which operate incrementally with respect to increase in hydrological threats over time. This incrementation of elements is established based on water calculations by rational method (Thompson, 2006) within four micro basins. These four micro basins have common hydrological threats of pluvial and fluvial flooding and sea level rise. The network with creeks as primary conveyors and streets with bio-swales and storm drains as secondary and tertiary conveyors act as an infrastructure managing surface run-off due extreme rainfall event. These are the elements of "blue graph" which connect elements of "green graph". The urban green patches and selective land parcels act as add-ons to the performance of system in terms of high stress due to exceedance of water. These add-ons are elements composing "green graph" for the system. Moreover, downstream these land parcels accommodate brackish water in case of storm surge event or sea level rise. Together these elements operate as an infrastructure which conveys, infiltrates, retains and stores fresh and brackish water in shock (pluvial, fluvial flooding and storm surge events) and stress (sea level rise) events.

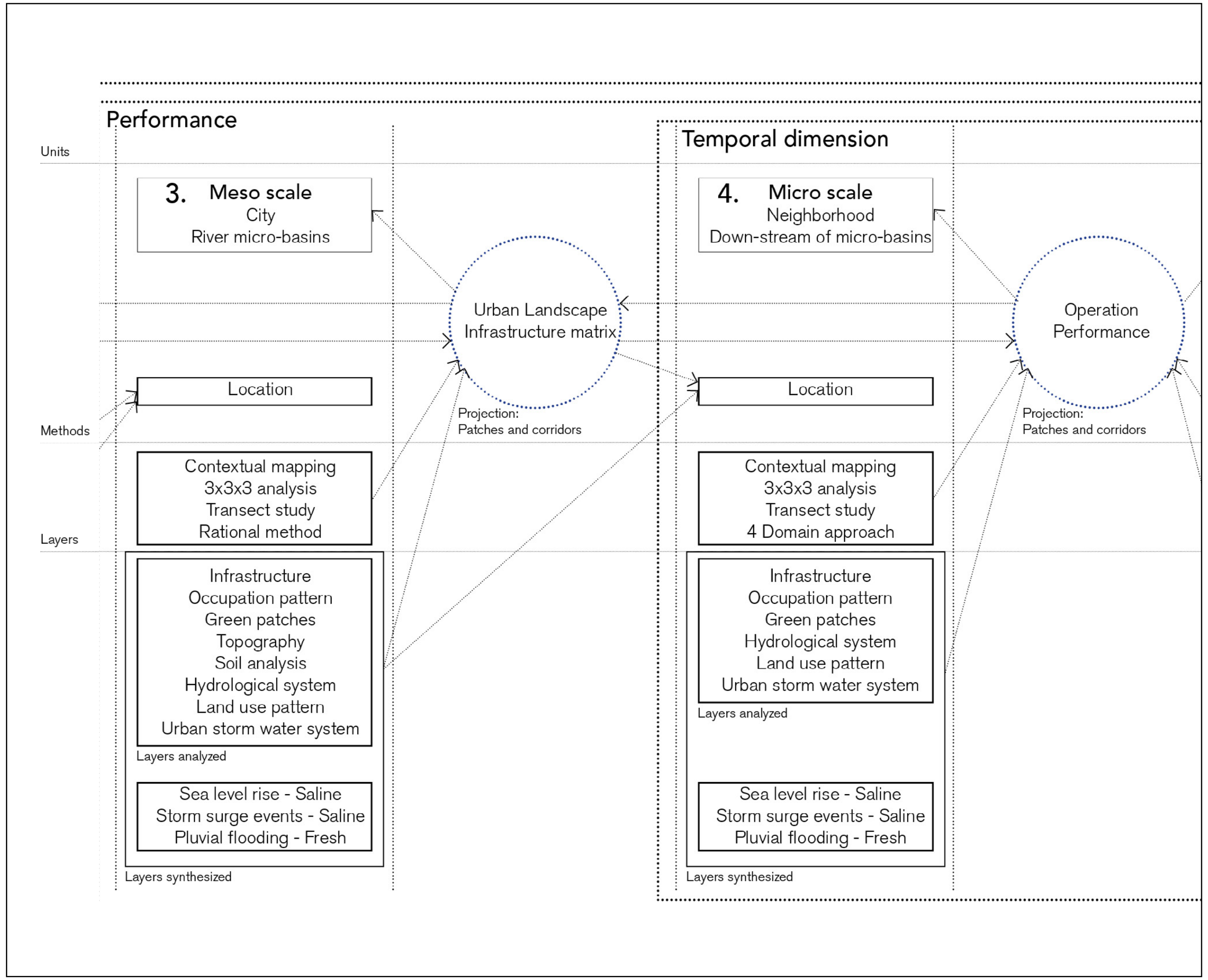
Figure 8.1: Salt evaporation ponds, San Francisco Bay area. Source : Doc Searls, flickr - https://www.flickr.com/photos/docsearls/4096329287

Performance

The hypotheses highlight two important aspects of understanding system behaviour and developing adaptive character for the same due to uncertain circumstances (natural and urban). The aspect of scale aids in developing the network of infrastructure, but the aspect of performance helps to understand the different degrees of operation at which this network can address hydrological challenges. Micro and Nano scales are where the performance is explored and determined. The study of exploring these potentials help to identify the critical and dynamic elements within design. What is the minimum requirement or maximum extent the system can operate at, is derived from the potentials of this performance. The aspect of manifestation and implementation of design strategy and its degree of performance in multiple future possibilities is explored further.



Micro scale


Performance
Temporal dimension
Units
Methods
Layers
3. Meso scale
City
River micro-basins
Urban Landscape
Infrastructure matrix
Projection:
Patches and corridors
Location
Contextual mapping
3x3x3 analysis
Transect study
Rational method
Infrastructure
Occupation pattern
Green patches
Topography
Soil analysis
Hydrological system
Land use pattern
Urban storm water system
Layers analyzed
Sea level rise - Saline
Storm surge events - Saline
Pluvial flooding - Fresh
Layers synthesized
4. Micro scale
Neighborhood
Down-stream of micro-basins
Operation
Performance
Projection:
Patches and corridors
Location
Contextual mapping
3x3x3 analysis
Transect study
4 Domain approach
Infrastructure
Occupation pattern
Green patches
Hydrological system
Land use pattern
Urban storm water system
Layers analyzed
Sea level rise - Saline
Storm surge events - Saline
Pluvial flooding - Fresh
Layers synthesized

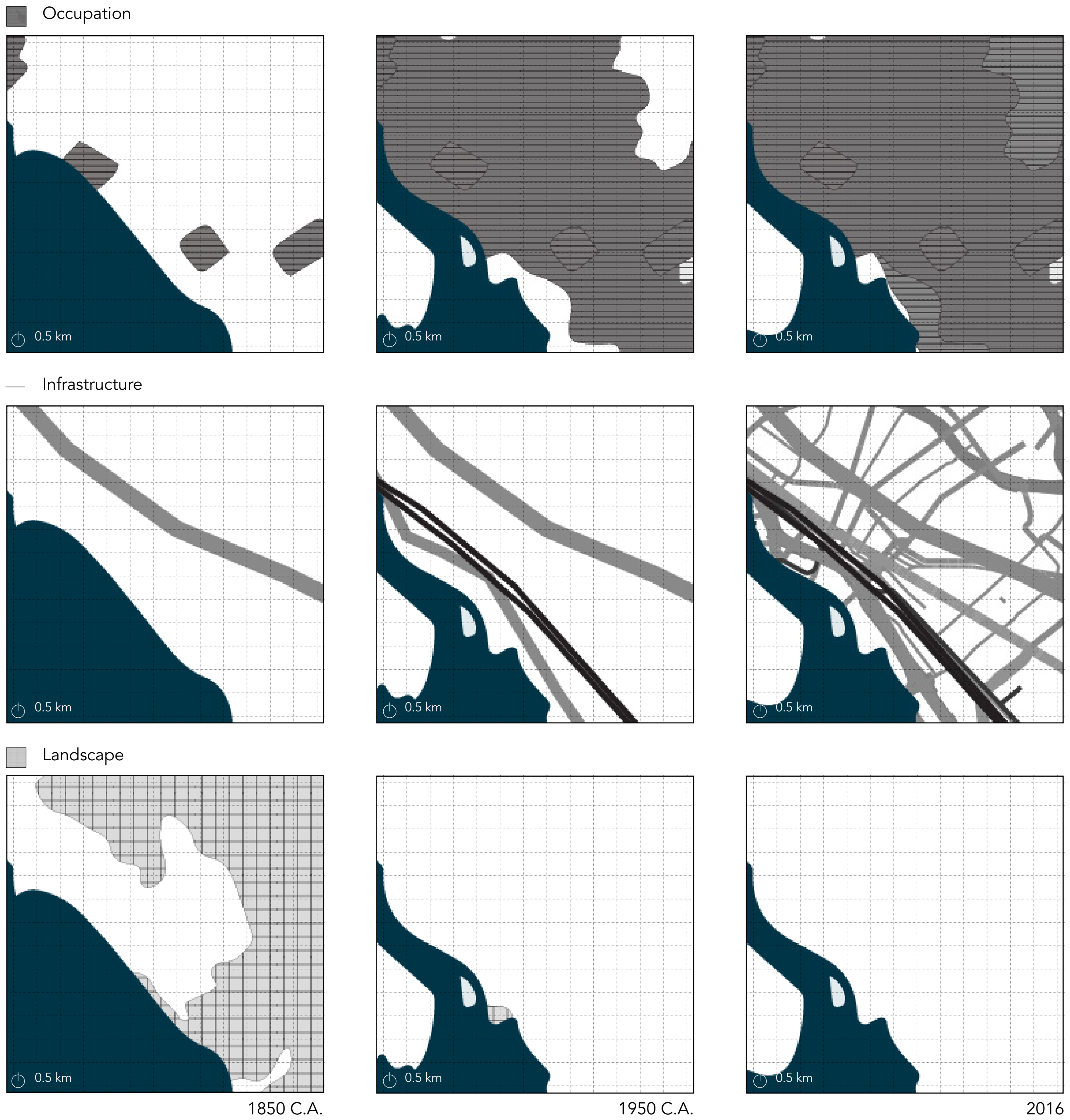


Figure 8.2: 3x3x3 analysis, District scale. Illustration : Author

Micro scale: Urban District

Right from watershed to meso scale, it has been observed that the downstream of a transect is most vulnerable if it is urbanised. It has the threat of runoff from upstream during heavy rainfall event and from downstream due to tidal currents, storm surges or sea level rise. The 3x3x3 analysis (Meyer and Nijhuis, 2016) at micro scale highlights changing land-water edge, sprawling urban occupation pattern and dense infrastructure corridor development. The Urban Landscape Infrastructure matrix identified creeks as major conveyors of water from upstream and the "blue graph" showcased the hierarchy of street networks which feed into these creeks. Moreover, the land parcels operate as "green elements" to infiltrate or store water, either fresh running from upstream or saline rising from bay. At micro scale, the task in hand is to actualize this network of corridors and patches. It is downstream, where two types of hydrological conditions, fresh and saline, coincide. This plays an important aspect in defining the micro scale. While developing the matrix at meso scale it was observed that all four micro basins faced the challenge of intense pluvial and fluvial flooding downstream.

Further, superimposing these layers of analysis of flooding over urban fabric defined by footprint of buildings and mobility corridors defines the boundaries to be considered for micro scale. The intention at this scale is to explore the changing degrees of performance of the system designed at meso scale. The function, shape and size of land parcels which will be operating as "green elements" is studied. Moreover, sequencing of these elements is established using 4 domain approach (Digman et al., 2014). This sequencing will showcase the incremental nature of infrastructure with respect to the hydrological threats in time. Working at micro (urban district) and nano (land parcel) scale simultaneously is crucial because evaluating performance requires understanding operation of the smallest component.

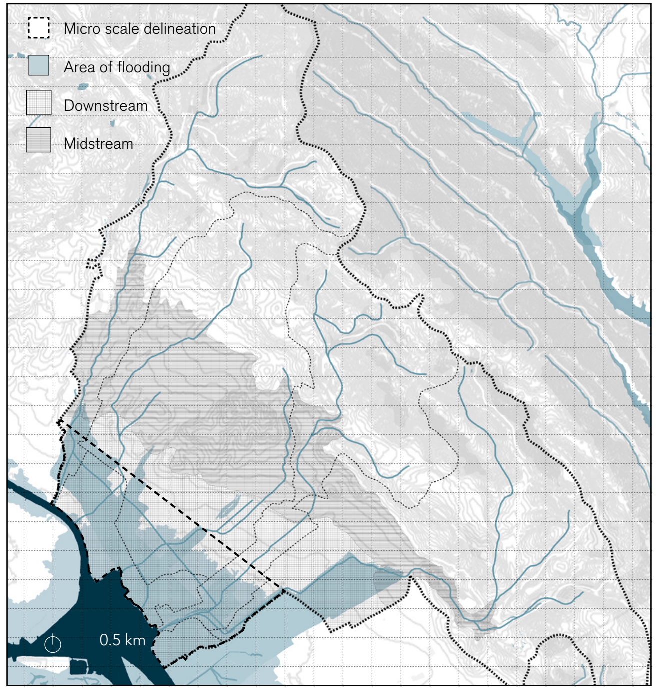


Figure 8.3: Hydrological risk of flooding. Illustration : Author

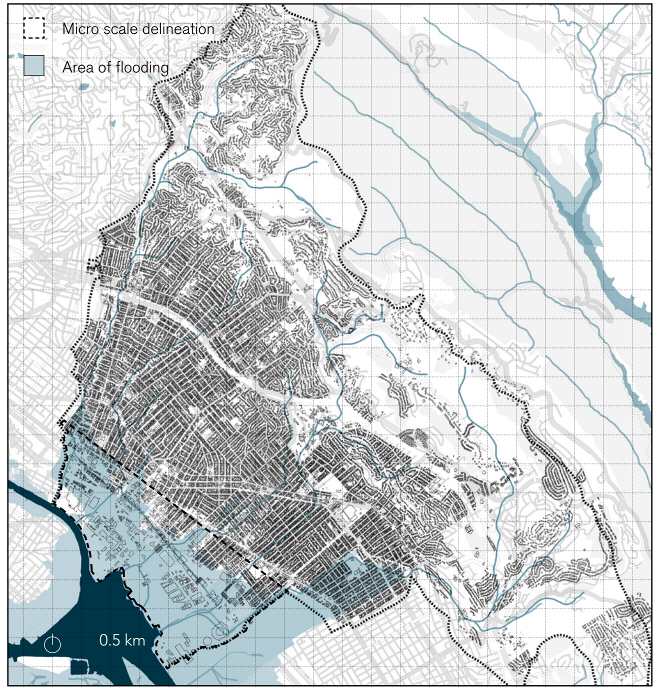
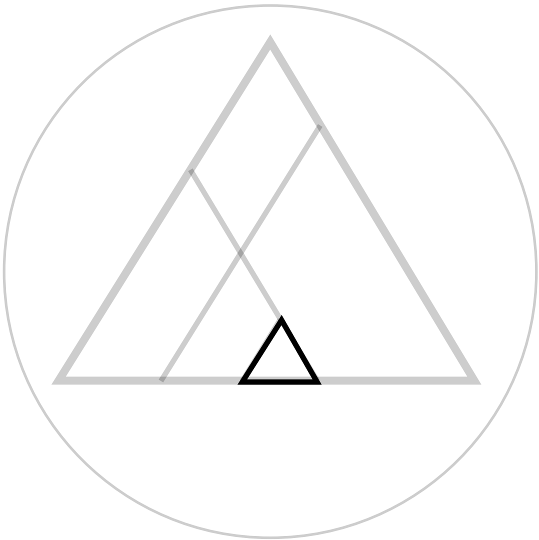


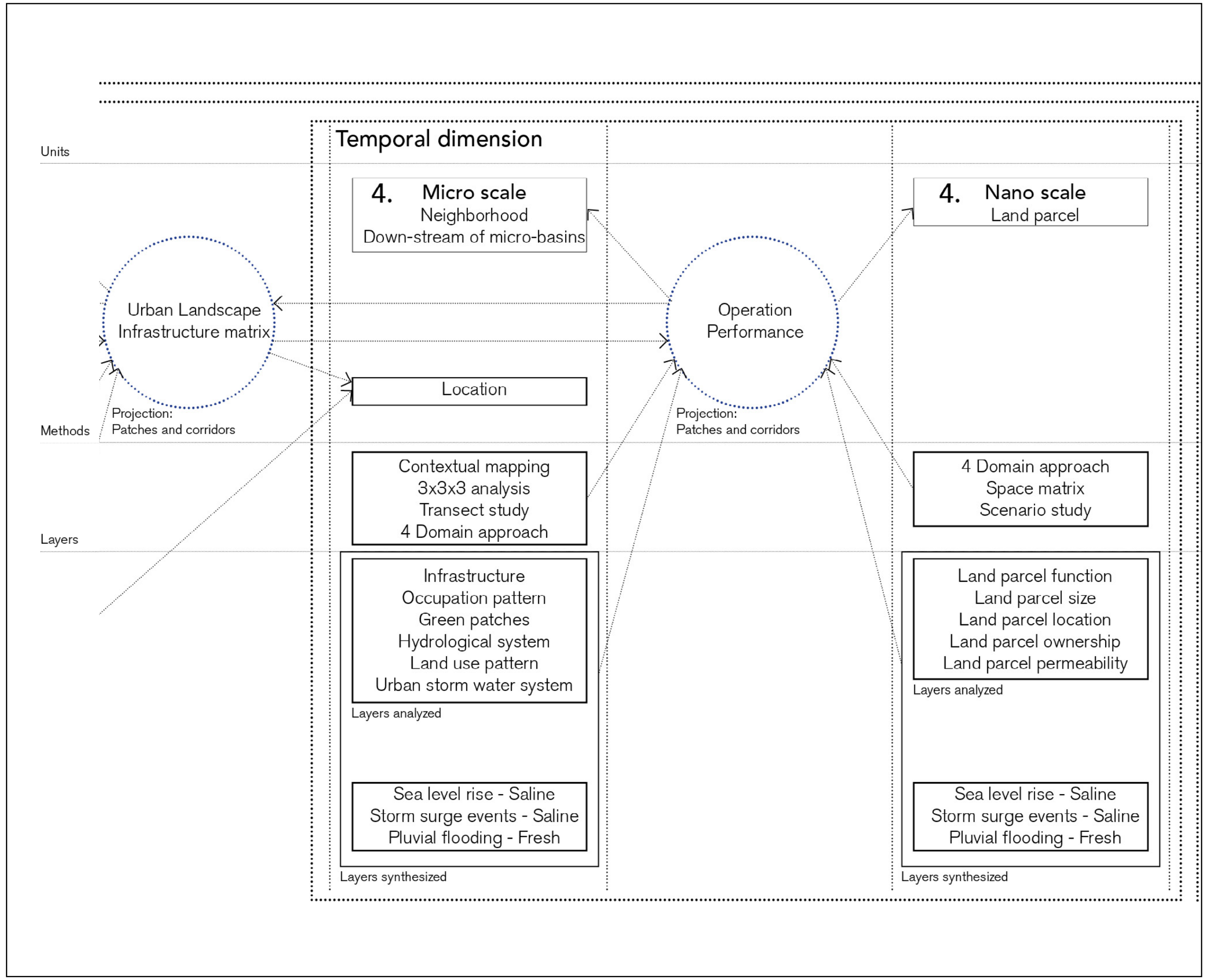
Figure 8.4: Buildings footprint. Illustration : Author

Figure 8.5: Street view industrial district Oakland. Source : google street view

Figure 8.6: Street view industrial district Oakland. Source : google street view



Nano scale



Temporal dimension
Units
Methods
Layers
4. Micro scale
Neighborhood
Down-stream of micro-basins
4. Nano scale
Land parcel
Urban Landscape
Infrastructure matrix
Operation
Performance
Projection:
Patches and corridors
Projection:
Patches and corridors
Location
Contextual mapping
3x3x3 analysis
Transect study
4 Domain approach
4 Domain approach
Space matrix
Scenario study
Infrastructure
Occupation pattern
Green patches
Hydrological system
Land use pattern
Urban storm water system
Layers analyzed
Land parcel function
Land parcel size
Land parcel location
Land parcel ownership
Land parcel permeability
Layers analyzed
Sea level rise - Saline
Storm surge events - Saline
Pluvial flooding - Fresh
Layers synthesized
Sea level rise - Saline
Storm surge events - Saline
Pluvial flooding - Fresh
Layers synthesized

Figure 8.7: Identification of land parcels. Illustration : Author

Nano scale: Land Parcel | Street level

Based on the calculations performed (appendix) at meso scale using rational method (Thompson, 2006) within the micro basins, the land parcels are identified due to their better infiltration capacity as compared to others. These are, the parks or open spaces, vacant parcels, interstitial spaces created due to mobility corridors, institutional blocks, playgrounds, commercial blocks with large parking areas and logistic centres with big storage and parking facility.

The criteria for their selection being function/land use, size of land parcel, proximity to creek and topographic position index and land cover. These land parcels are identified at micro scale to derive the strategic potentials. The performance of the system will be determined by these parcel's function in the 4 domains of hydrological events derived from 4 domain approach (Digman et al., 2014).

The green graph being the determinant of the performance of strategy, it is important to establish criteria and parameters to analyse and classify the elements. This classification is crucial to allocate function within the operation of infrastructure. The land parcels identified are classified based on function/land use, size, topographic position index, location with respect to creek, ownership, land cover and ground space index.

All the parameters of classification for land parcels determine the suitability (McHarg and Mumford, 1969) to operate within system of infrastructure, performance to function at various degrees of hydrological threat and quality which relates to the built environment within each land parcel based on its function and change.

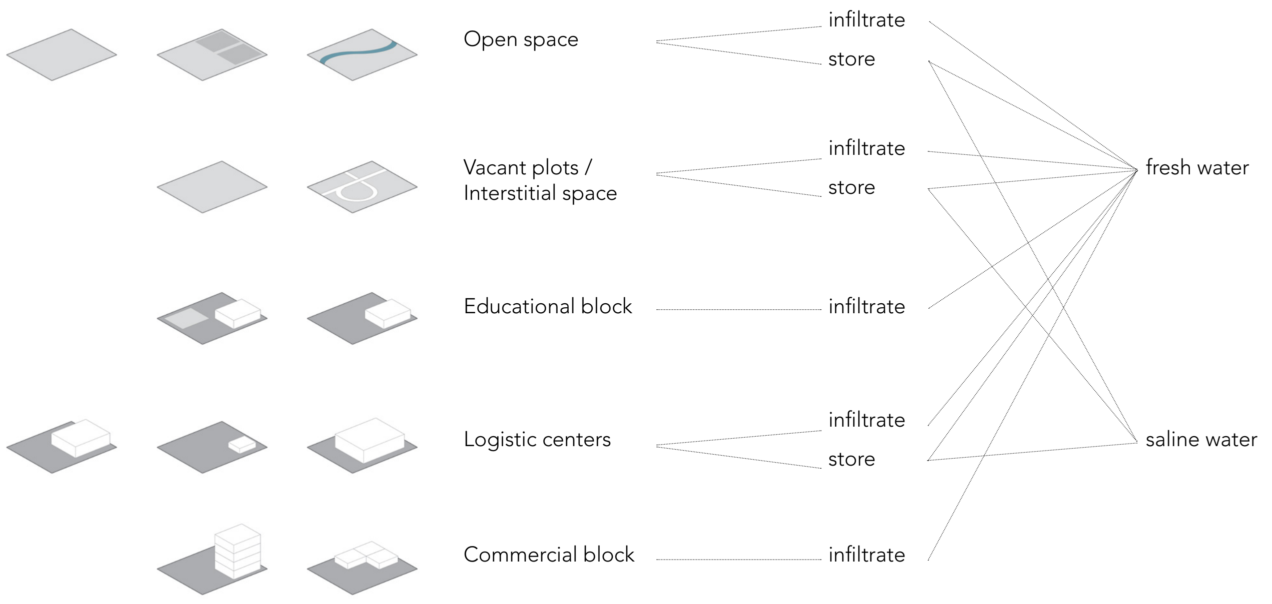


Figure 8.8: Operation of land parcels with respect to land use and water qulaity . Illustration : Author

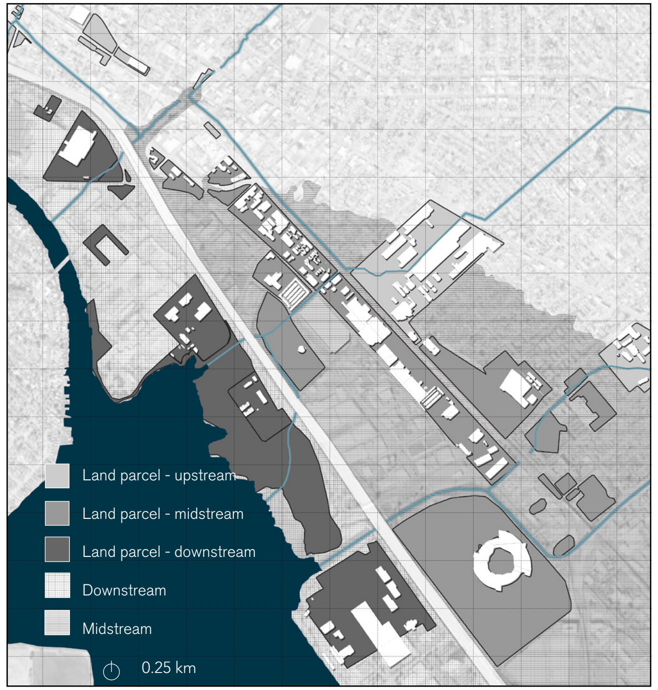


Figure 8.9: Topographic positions of land parcels. Illustration : Author

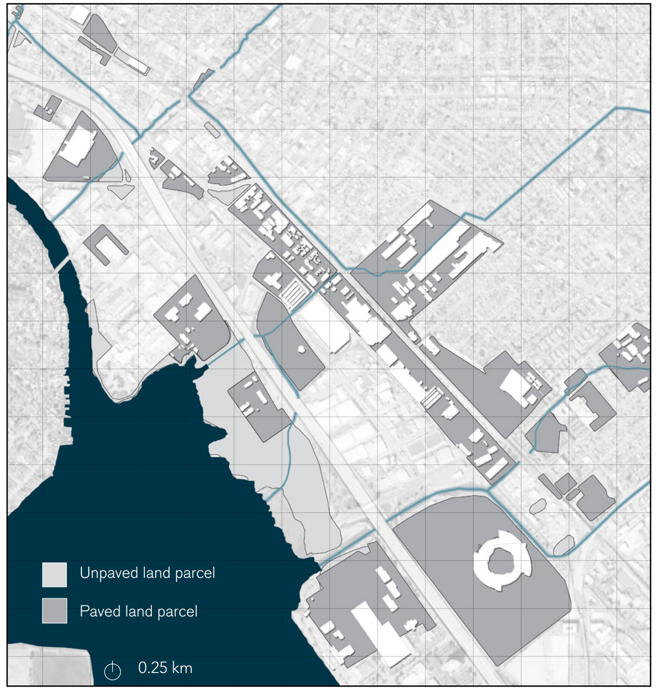


Figure 8.10: Classification of land parcels by land cover. Illustration : Author

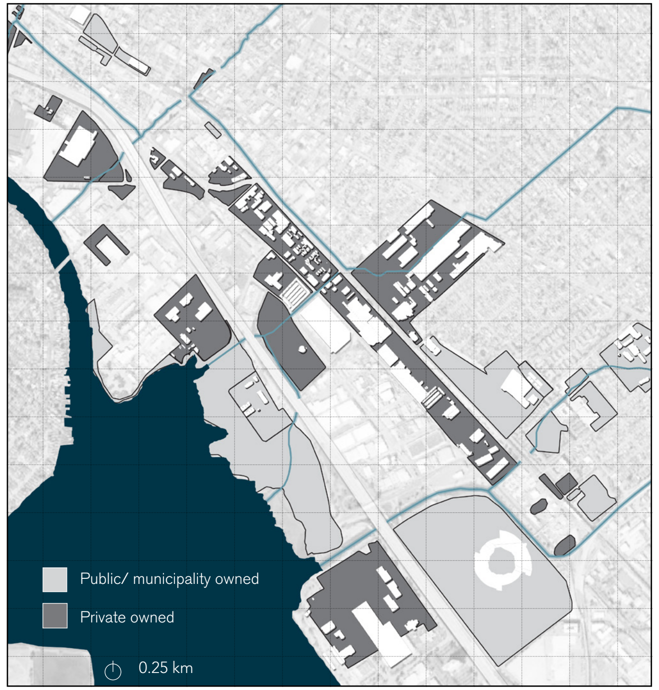


Figure 8.11: Classification of land parcels by ownership. Illustration : Author

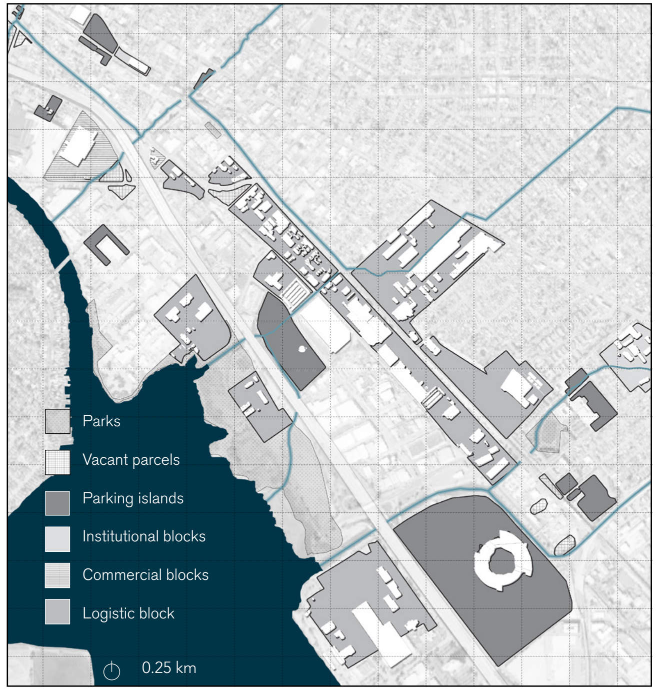


Figure 8.12: Classification of land parcels by land use. Illustration : Author

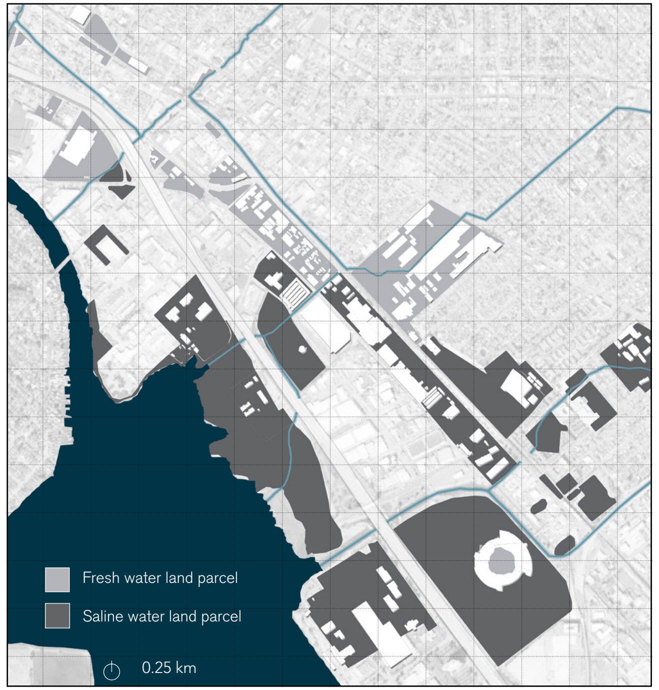


Figure 8.13: Classification of land parcels by quality of water to be stored. Illustration : Author

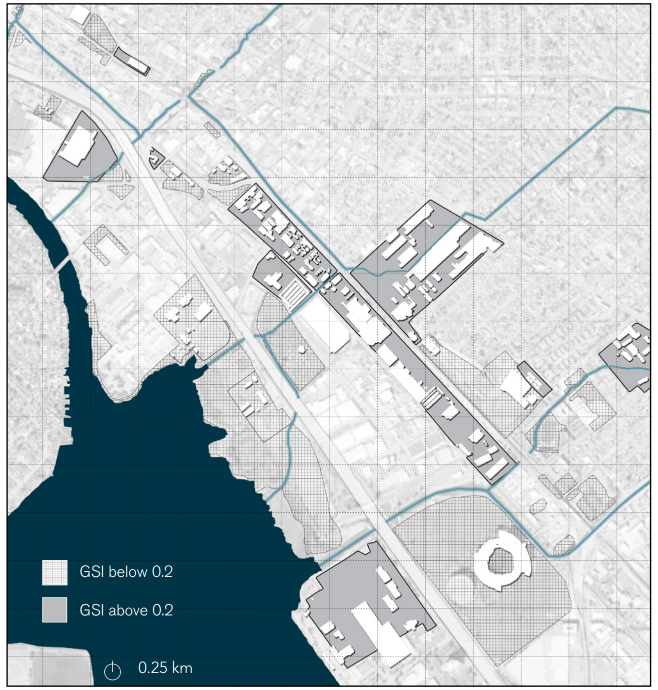


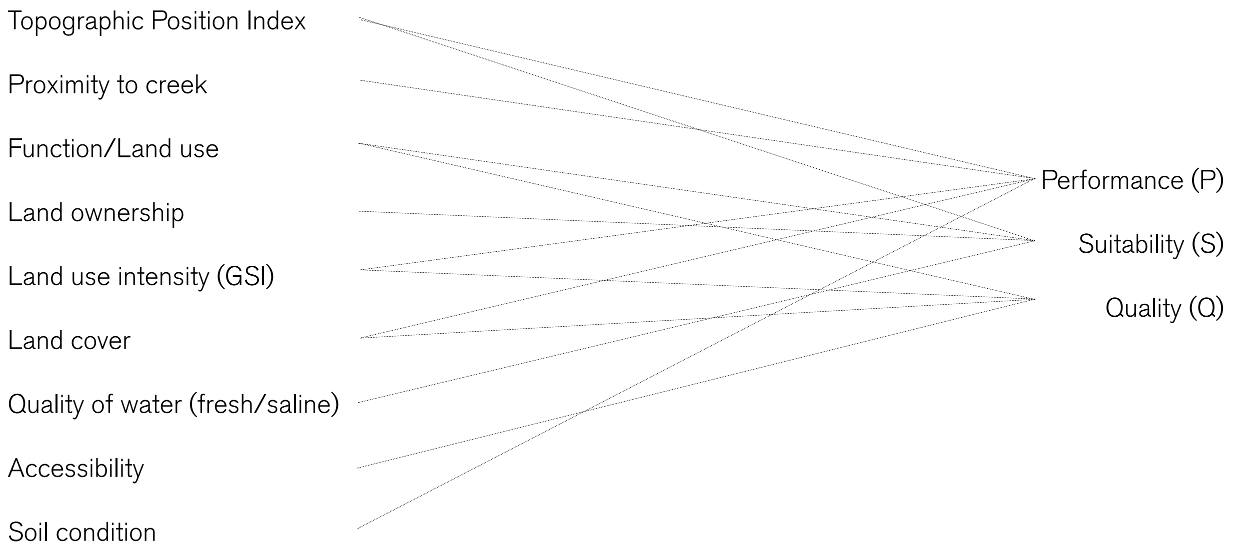
Figure 8.14: Classification of land parcels by ground space index values. Illustration : Author

Performance | Suitability | Quality

Performance – The factor of performance is determined for a land parcel to understand its variation in operation within the system. It is the capacity or ability of parcel to retain or hold water during peak discharge or storm events. Performance is assessed primarily on the topographic position index and soil condition of parcel which determines in which domain of flood event the parcel will operate. Further, the aspect of land cover is used to understand how much area is paved and how much is open soil. This determines the infiltration capacity of the parcel. The method of space matrix helps establish ground space index (GSI) to understand the relation between open and built area which is crucial for infiltration as third criteria.

Suitability (McHarg and Mumford, 1969) – It is crucial to understand the suitability of land parcel which will determine the function within the system's operation. The factor of suitability appropriates function to the land parcel with respect to accommodation of water, either fresh or saline. This is explored through topographic positioning of parcel which indicates whether the parcel will operate in the first, second, third or fourth domain of 4 domain approach. Second criteria for suitability is land use followed by ownership. These criteria help understand how much can the land parcel achieve within the system of infrastructure.

Quality – The factor of quality is very subjective in nature. Hence to ease and make the assessment scientific three criteria are considered to determine quality of built environment. First is land cover, which is related to whether parcel has vegetation, pavement or hard concrete as ground cover. This relates to habitat diversity in terms of ecosystem services the land parcel can provide. The second is land use itself where the quality of built environment can be compared between a harsh industrial area and open recreational park. The third criteria is ground space index which relates to the proportions of building to open space.



Performance | Suitability | Quality - configuration for land parcels

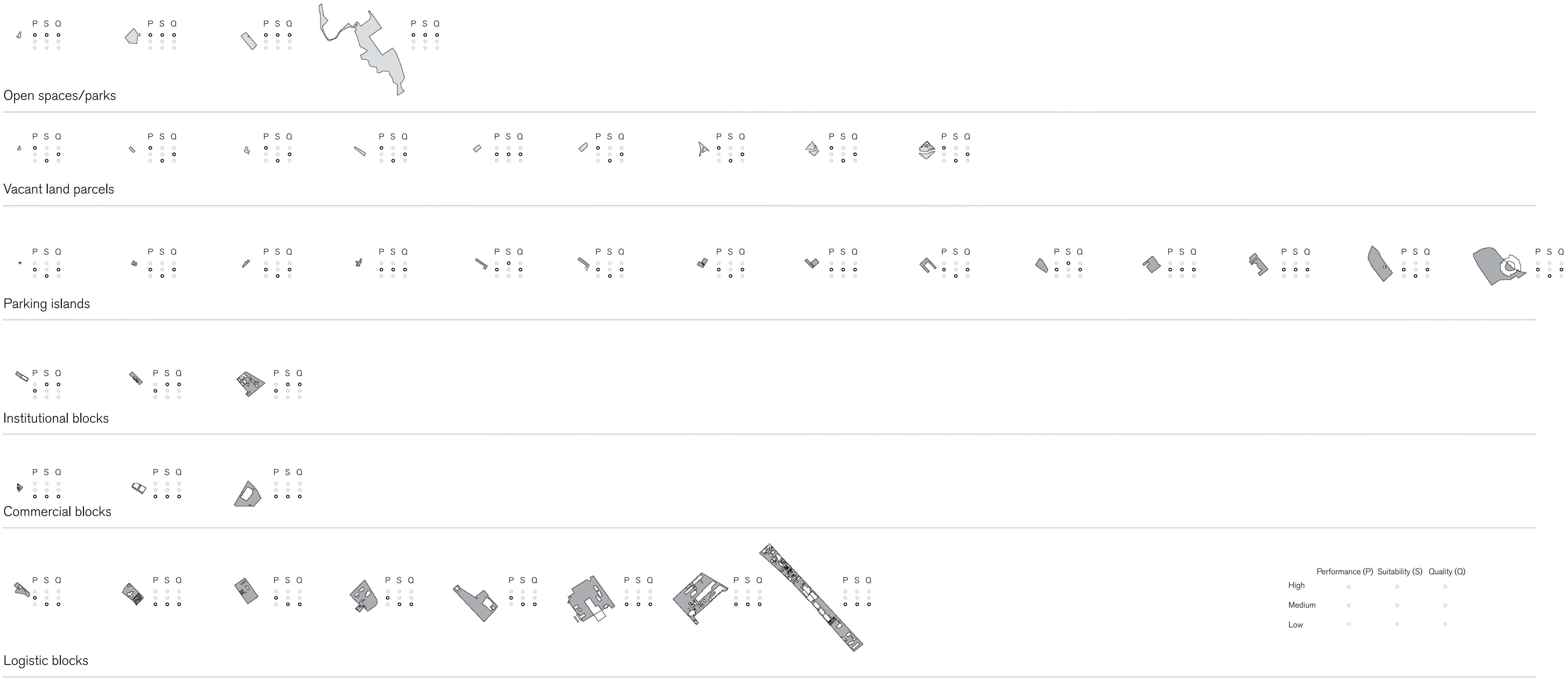


Figure 8.15: Land parcel configuration base on performance, suitability and quality. Illustration : Author

Figure 8.16: Street view industrial district Oakland. Source : google street view

Figure 8.17: Street view industrial district Oakland. Source : google street view

GRO	Definition
Phytoextraction	The removal of metal(loid)s or organics from soils by accumulating them in the harvestable biomass of plants. When aided by use of soil amendments, this is termed aided phytoextraction.
Phytodegradation / phytotransformation	The use of plants (and associated microorganisms such as rhizosphere and endophytic bacteria) to uptake, store and degrade organic pollutants.
Rhizodegradation	The use of plant roots and rhizosphere microorganisms to degrade organic pollutants.
Rhizofiltration	The removal of pollutants from aqueous sources by plant roots and associated microorganisms.
Phytostabilisation	Reduction in the bioavailability of pollutants by immobilisation in root systems and / or living or dead biomass in the rhizosphere soil – creating a milieu which enables the growth of a vegetation cover. When aided by use of soil amendments, this is termed aided phytostabilisation.
Phytovolatilisation	Use of plants to remove pollutants from the growth matrix, transform them and disperse them (or their degradation products) into the atmosphere.
In situ immobilisation / phytoexclusion	Reduction in the bioavailability of pollutants by immobilizing or binding them to the soil matrix through the incorporation into the soil of organic or inorganic compounds, singly or in combination, to prevent the excessive uptake of essential elements and non-essential contaminants into the food chain. Phytoexclusion, the implementation of a stable vegetation cover using excluder plants which do not accumulate contaminants in the harvestable plant biomass can be combined with *in situ* immobilisation.

Figure 8.18: General remediation options definitions. Source : (Cundy et al., 2015)

Contaminated Land Parcels

When the factor of quality is introduced, the district has numerous industries which makes these land parcels and soil underneath contaminated. Moreover, the land parcels which will be storing brackish water will infiltrate salts into the soil. This will make the soil condition saline. To reduce the degree of contamination and saline conditions certain plant species are used to remediate soil and filter water.

Process of phytoremediation

Two broad concepts have emerged in contaminated land management or salinity management over the past 30 years: the use of risk assessment to determine the seriousness of problems, and the use of risk management to mitigate problems found by risk assessment to be significant. Requirements for land and groundwater remediation strictly depend on risk management needs, whether the intended use of the remediated land is for a "hard" end use such as a built development or a "soft" end use, where the soil remains unsealed, such as community parkland (Cundy et al., 2015). Conventional approaches to contaminated land risk management have focussed on containment, cover and removal to landfill (or "dig and dump"). However, since the late 1990s there has been a move towards treatment-based remediation strategies using in situ and ex situ treatment technologies (e.g. soil washing) (Cundy et al., 2015). More recently the concept of Gentle Remediation Options (GRO) has emerged. These are risk management strategies/techniques that result in a net gain (or at least no gross reduction) in soil functionality as well as risk management. Hence, they have particular usefulness for either maintaining or restoring biologically productive soils (Cundy et al., 2015). GROs encompass several technologies which include the use of plant (phyto-), fungal (myco-) or bacterial-based methods, with or without chemical additives, for reducing exposure of local receptors to contaminants by in situ stabilisation (using biological and / or chemical processes), or extraction, transformation or degradation of contaminants. GRO includes techniques such as in situ immobilisation/ phytoexclusion, phytovolatilisation, phytostabilisation, rhizofiltration, rhizodegradation, phytodegradation/ phytotransformation and phytoextraction (Cundy et al., 2015). The further mentioned set of plant species are all phytoremediation species native to city of Oakland, classified into ones which are habitable in fresh water and ones which are habitable in brackish (Storm water Technical guidance report, Alameda county, 2016).

Phytoremediation plant species native to Oakland - brackish water


Carex obnupta


Distichlis spicata


Hordeum brachyantherum


Limonium californicum


Scirpus americanus


Spartina foliosa


Juncus lesueurii


Typha angustifolia


Typha latifolia

Phytoremediation plant species native to Oakland - fresh water


Achillea millefolium


Deschampsia cespitosa


Eleocharis palustris


Mimulus cardinalis


Salix laevigata


Salix lucida lasiandra


Platanus racemosa


Populus fremontii


Morus alba

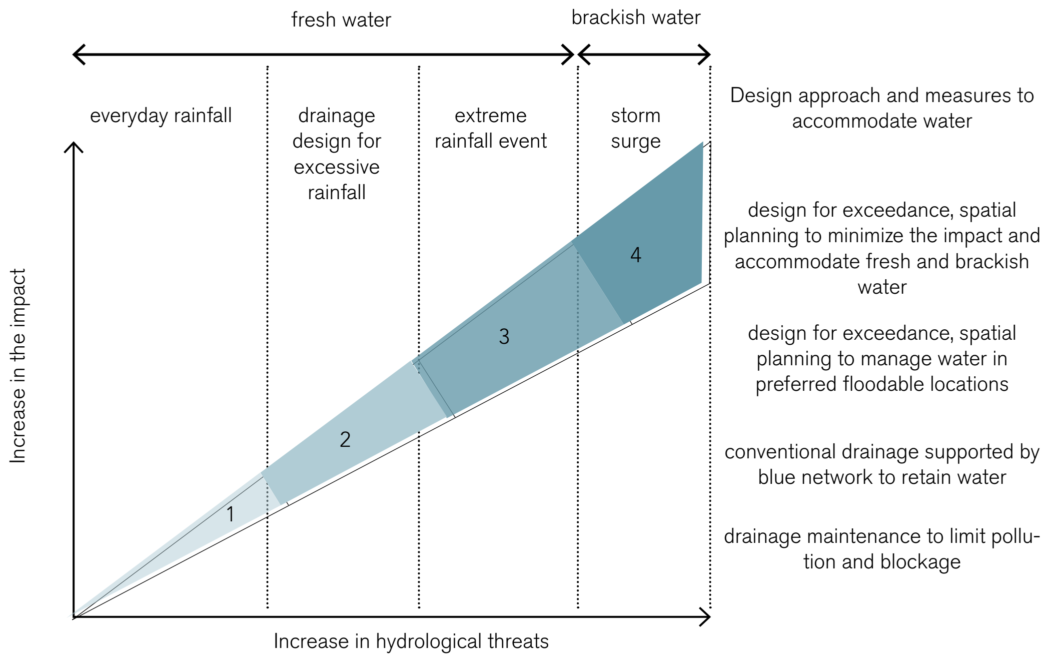


Figure 8.19: 4 Domain Approach. Source : (Kuzniecow Bacchin, 2015)

The 4 Domain Approach

The green graph within the system is hierarchal and incremental in nature. There is a certain sequencing necessary for these land parcel to be added into the performance. This sequencing is established using modified 4 Domain approach (Digman et al., 2014) (Kuzniecow Bacchin, 2015). It defines the spatial strategy in an incremental method, higher the volume of rainfall more is the surface area necessary to accommodate water, correspondingly the land parcels operating within the system increase.

Domain 1

No water on surface other than in ponds or wetlands, and in creeks. It is important to maintain the existing manmade drains and natural streams and creeks to reduce pollution and blockages causing flooding. In this domain, the built environment is largely untouched, mostly maintenance of existing structures is necessary.

Domain 2

Controlled exceedance of surface water. The operation is the retrofitting of existing drainage network with soft measures to limit flooding. In this domain, the objective is to delay drainage via infiltration method; raingardens, sports fields, community parks, pervious pavements, trenches; or through buffer storage of detention and retention basins and wetlands. The land parcels in the close proximity of blue network are active in this domain.

Domain 3

Manage exceedance pathways along with overall improved spatial quality of the streetscape. This domain requires design for exceedance to manage water in preferred locations or land parcels. Runoff exceedance is safely conveyed via diversion structures – new streams or bypass; or via conveyance structures – swales, ditches, gutters and stored in multifunctional spaces of green areas, floodable public spaces, sports fields, playgrounds, parking islands or interstitial spaces. This domain is very critical in terms of retrofitting the urban fabric to accommodate the exceedance of runoff.

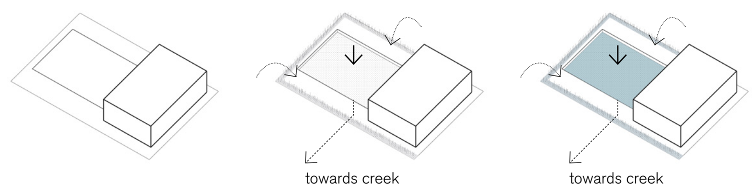
Domain 4

The 4th domain is crucial for this research project as it deals with storm surge or sea level rise event. This is the situation when there is hydrological threat from upstream due to exceedance of runoff and flooding from bay due to storm surge. The urban fabric needs to be retrofitted to accommodate this flooding by allowing certain land parcels to temporarily store water to reduce damage in other spots. This is the idea of floodable parcels. Moreover, theses parcels not only store polluted runoff water but also have possibility to store brackish water from bay. This needs to considered in terms of ecological conditions and built environment. Over here, along with using soft merges to retain and store water by retrofitting urban fabric, it also demands for certain character of vegetation to accommodate brackish water quality. So, the research opens up to not only considering the multiple usage of urban fabric to manage hydrological threats but also to explore the vegetation species for a better habitat development.

The performance, suitability and dynamicity of each land parcel develops a configuration. These configurations are related to 4 Domain approach (Digman et al., 2014) to derive design interventions for each land parcel addressing hydrological issues.

Configuration 1 (open spaces | parks | institutional blocks)

C 1.1 a (Institutional block - fresh water)



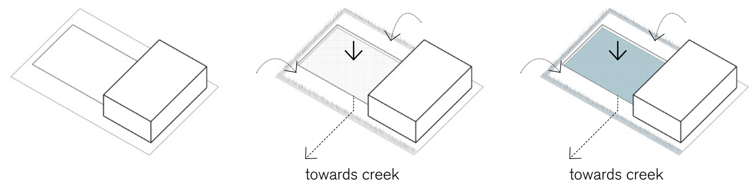
TPI - upstream

Domain - 3 (D3)

Operation - Infiltrate/store

Actions
- Grading to lower the sports field for storage
- De-paving to increase the infiltration capacity
- Edge of the parcel phytoremediation plants to filter surface pollutants (biotopes)

C 1.1 b (Institutional block - brackish/fresh water)



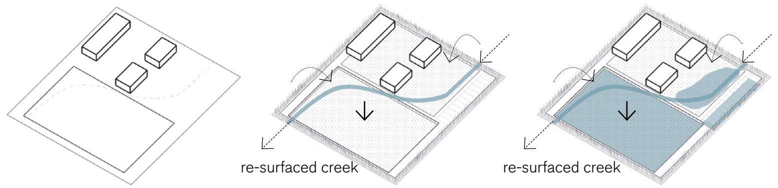
TPI - midstream

Domain - 3 (D3) / 4 (D4)

Operation - Infiltrate/store

Actions
- Grading to lower the sports field for storage
- De-paving to increase the infiltration capacity
- Edge of the parcel phytoremediation plants to filter surface pollutants and treat brackish water (biotopes)

C 1.2 (Institutional block - fresh water)



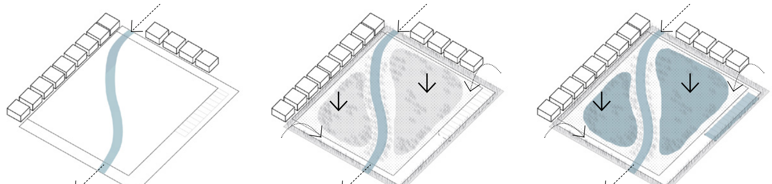
TPI - upstream

Domain - 3 (D3)

Operation - Infiltrate/store

Actions
- Grading to lower the sports field for storage
- De-paving to increase the infiltration capacity
- Edge of the parcel phytoremediation plants to filter surface pollutants (biotopes)
- Biotopes near parking
- Storage below parking blocks

C 1.3 (Community park - brackish/fresh water)



TPI - midstream

Domain - 2 (D2) / 4 (D4)

Operation - Infiltrate/store

Actions
- Grading to lower the park for retention
- Vegetation within land parcel as phytoremediation process to treat sur face runoff pollutants and brackish water
- Biotopes near parking blocks
- Storage below parking blocks

Configuration 1 is composed of open spaces, urban parks, institutional blocks with sports field and community parks. The common thread connecting all these land parcel types is that they have unpaved surface or open soil. This increases the potential of land parcel to perform better in the operation of system designed. Majority of configuration 1 land parcels are either upstream which can infiltrate water and delay the discharge downstream. Moreover, the operate within domain 2 and 3 which relates to heavy and extreme rainfall events. The interventions which need to be done within these land parcels is to regrade the land for temporary storage of water and use plant species native to Oakland which can perform for phytoremediation.

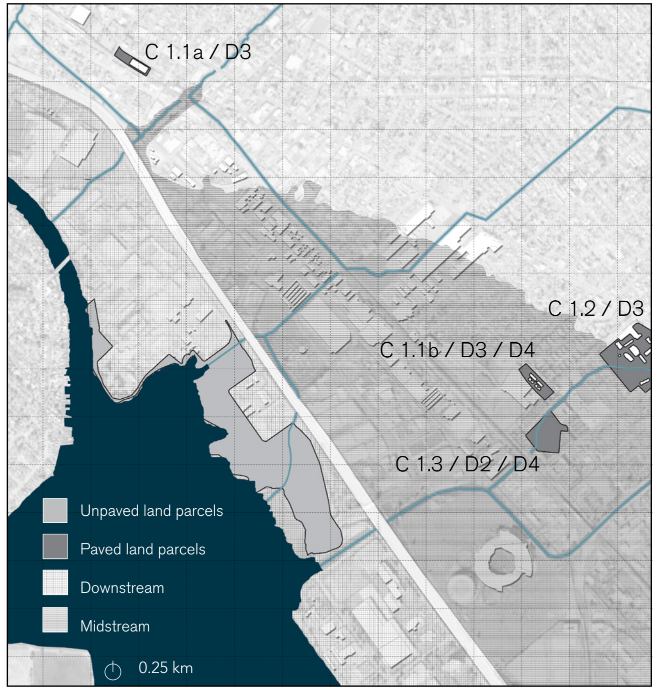
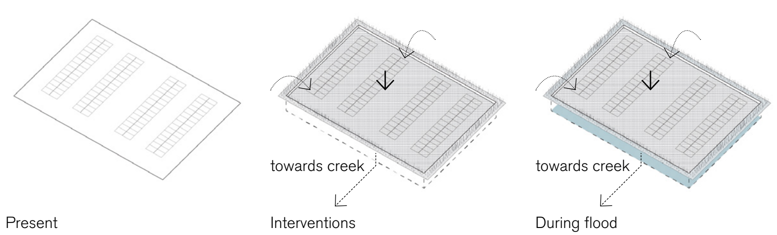


Figure 8.20: Location of configuration 1 land parcels. Illustration : Author

Configuration 2 (public parking islands | urban parking blocks | community parking)

C 2.1 a (Public parking island - fresh water)

P S Q



TPI - upstream

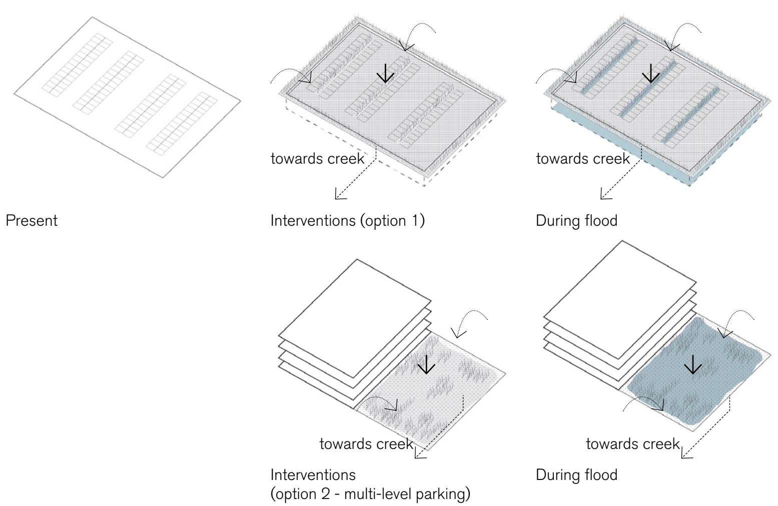
Domain - 3 (D3)

Operation - Infiltrate/store

Actions
- Grading to lower the parcel for retention
- Edge of the parcel phytoremediation plants to filter surface pollutants (biotopes)
- Storage below parking blocks
- Semi-permeable paving

C 2.1 b (Public parking island - brackish/fresh water)

P S Q



TPI - midstream / downstream

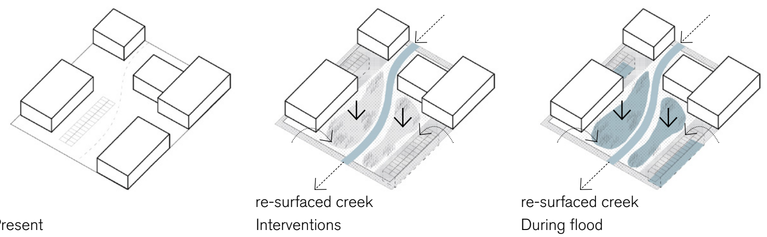
Domain - 3 (D3) / 4 (D4)

Operation - Infiltrate/store

Actions
- Grading to lower the parcel for retention
- Edge of the parcel phytoremediation plants to filter surface pollutants (biotopes)
- Biotopes near parking slots
- Semi-permeable paving
- Reduced number of parking
- Multi-level parking
- Swamp condition to retain water

C 1.3 (Community park - brackish/fresh water)

P S Q



TPI - midstream

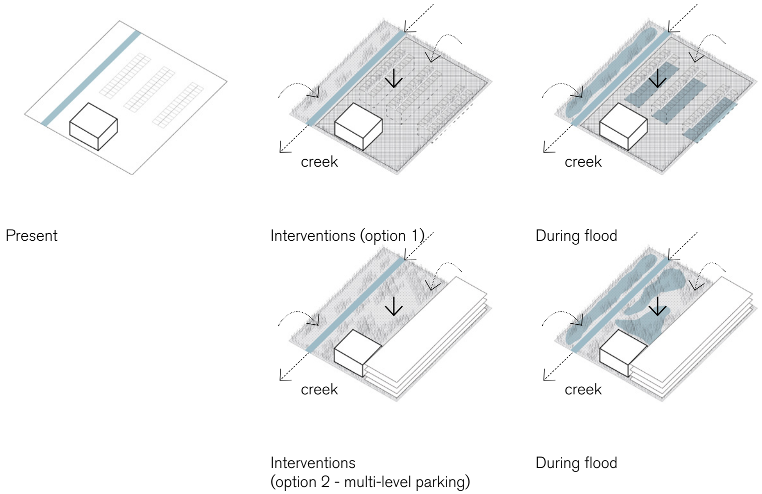
Domain - 3 (D3)

Operation - Infiltrate/store

Actions
- Grading to lower the parcel for retention
- Edge of the parcel phytoremediation plants to filter surface pollutants (biotopes)
- Biotopes near parking slots
- Semi-permeable paving
- Reduced land use intensity

C 2.1 b (Public parking island - brackish/fresh water)

P S Q



TPI - midstream / downstream

Domain - 3 (D3) / 4 (D4)

Operation - Infiltrate/store

Actions
- Grading to lower the parcel for retention
- Edge of the parcel phytoremediation plants to filter surface pollutants and treat brackish water (biotopes)
- Biotopes near parking slots
- Semi-permeable paving
- Storage below parking slots
- Multi-level parking
- Swamp conditions to retain water

Configuration 2 is structured by the parking islands, whether large scale public parking facilities near metro transit stops, small scale urban block parking islands or community parking areas. The common factor between these land parcels is that all are paved surfaces which have potential to store water and perform as multi-utility spaces in different situations. These land parcels can hold water especially during extreme rainfall events and convert into water squares instead of parking facility. The primary interventions within these land parcels is regrading to hold water, geo-cellular tanks below the facility to store, semi-permeable paving to increase infiltration capacity and using phytoremediation plant species native to Oakland along the edge to filter surface pollutants.

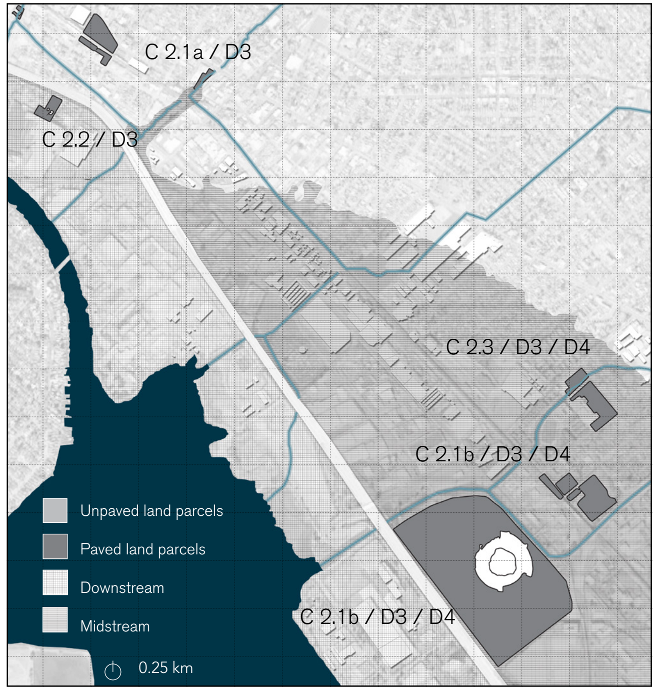
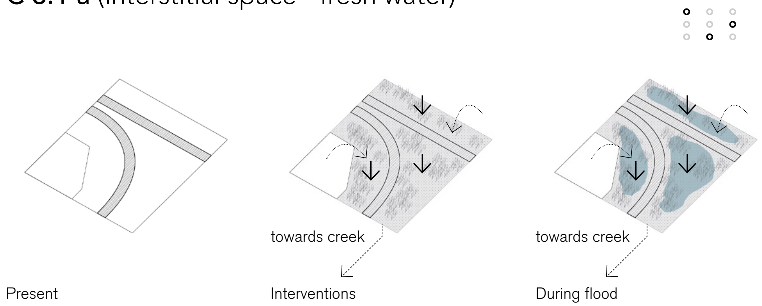


Figure 8.21: Location of configuration 2 land parcels. Illustration : Author

Configuration 3 (vacant land parcels | interstitial spaces)

C 3.1 a (Interstitial space - fresh water)



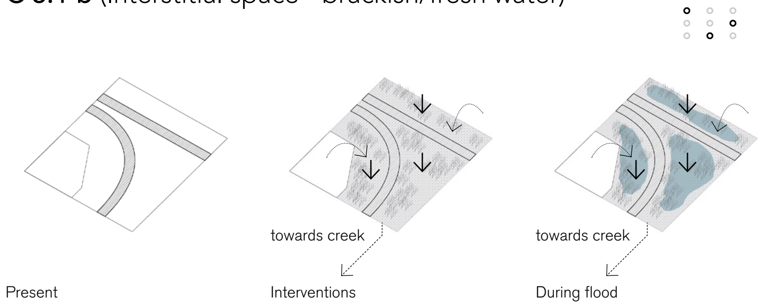
TPI - upstream / midstream

Domain - 2 (D2)

Operation - Infiltrate/store

Actions
- Grading to lower the land for retention
- Vegetation as phytoremediation plants to filter surface pollutants (biotopes)
- De-paving to increase infiltration capacity

C 3.1 b (Interstitial space - brackish/fresh water)



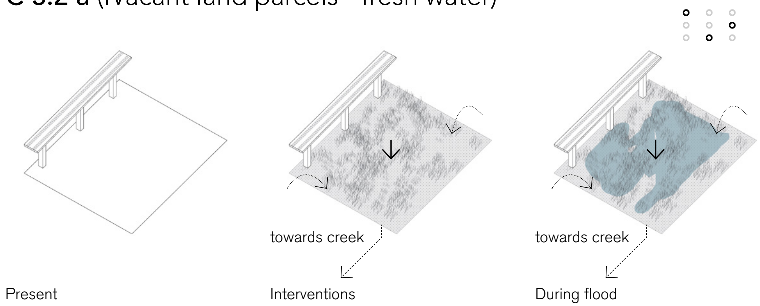
TPI - midstream

Domain - 2 (D2) / 4 (D4)

Operation - Infiltrate/store

Actions
- Grading to lower the land for retention
- Vegetation as phytoremediation plants to filter surface pollutants (biotopes)
- De-paving to increase infiltration capacity
- Swamp condition

C 3.2 a (IVacant land parcels - fresh water)



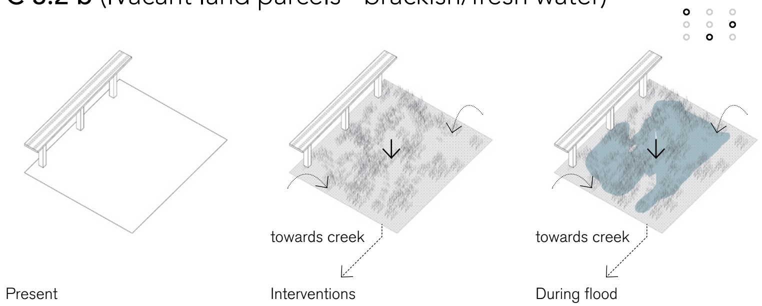
TPI - upstream

Domain - 2 (D2)

Operation - Infiltrate/store

Actions
- Grading to lower the land for retention
- Vegetation as phytoremediation plants to filter surface pollutants (biotopes)
- De-paving to increase infiltration capacity

C 3.2 b (IVacant land parcels - brackish/fresh water)



TPI - midstream / downstream

Domain - 2 (D2) / 4 (D4)

Operation - Infiltrate/store

Actions
- Grading to lower the land for retention
- Vegetation as phytoremediation plants to filter surface pollutants (biotopes)
- De-paving to increase infiltration capacity
- Swamp condition

Configuration 3 consists of vacant land parcels and interstitial spaces which have high potential to operate within system due to the unpaved surfaces. These land parcels are contaminated due to abandoned nature and under utility. The land parcels have potential to perform through three domains from heavy rainfall to extreme and during storm surge events. These parcels are positioned mid and down-stream of topography. The major interventions required within these land parcels is to de-pave to increase infiltration capacity and use phytoremediation plant species to treat the polluted soil.

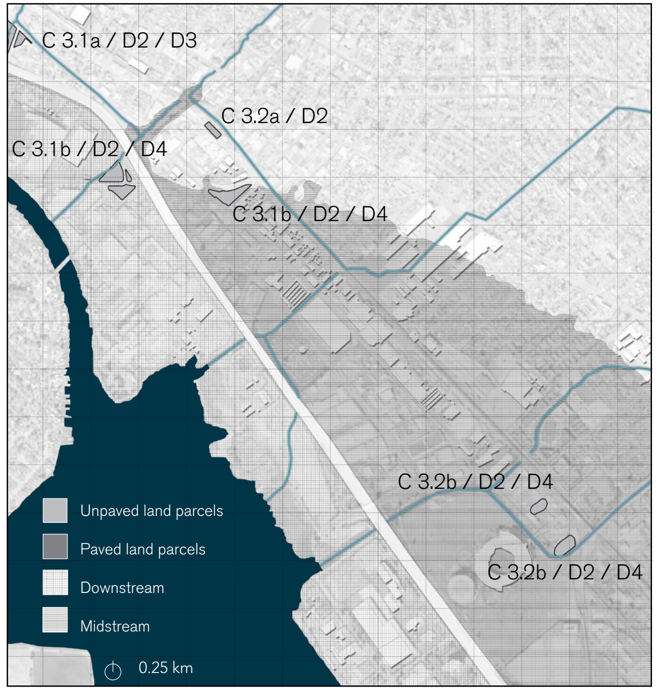
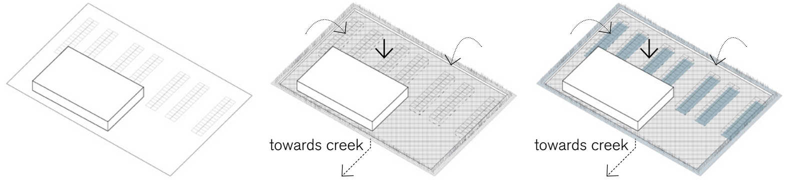


Figure 8.22: Location of configuration 3 land parcels. Illustration : Author

Configuration 4 (logistic | commercial blocks)

C 4.1 a (Logistic and super market - fresh water)

P S Q



Present | Interventions | During flood

TPI - upstream

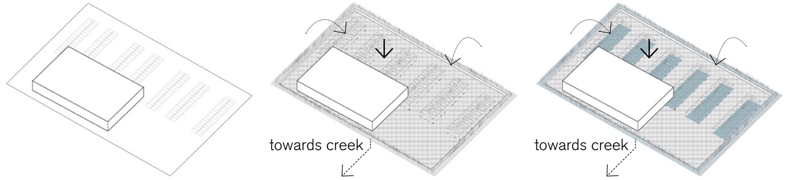
Domain - 3 (D3)

Operation - Infiltrate/store

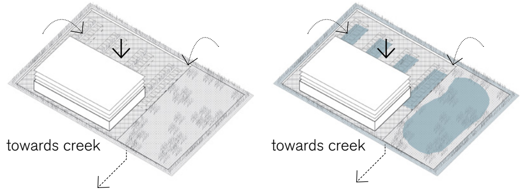
Actions
- Grading to lower the parcel for retention
- Edge of the parcel phytoremediation plants to filter surface pollutants (biotopes)
- Biotopes near parking slots
- Semi-permeable paving
- Storage below parking slots

C 4.1 b (Logistic and super market - brackish/fresh water)

P S Q



Present | Interventions (option 1) | During flood



Interventions (option 2 - multi-level parking) | During flood

TPI - midstream / downstream

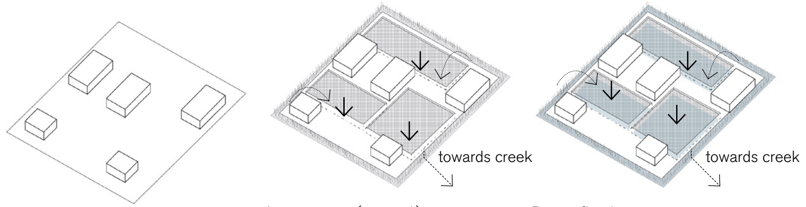
Domain - 3 (D3) / 4 (D4)

Operation - Infiltrate/store

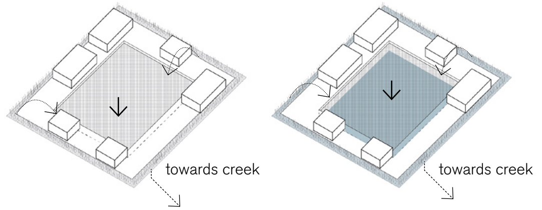
Actions
- Grading to lower the parcel for retention
- Edge of the parcel phytoremediation plants to filter surface pollutants and treat brackish water (biotopes)
- Biotopes near parking slots
- Semi-permeable paving
- Reduced number of parking
- Storage below parking slots
- Multi-level parking
- Swamp condition to retain water

C 4.2 (Logistic facility - brackish/fresh water)

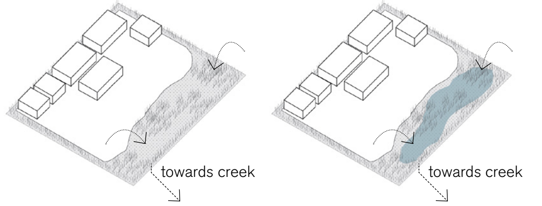
P S Q



Present | Interventions (option 1) | During flood



Interventions (option 2 - reconfiguration of land parcel to periphery) | During flood



Interventions (option 3 - reconfiguration of land parcel for swamp conditions) | During flood

TPI - midstream / downstream

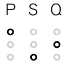
Domain - 3 (D3) / 4 (D4)

Operation - Infiltrate/store

Actions
- Grading to lower parts of parcel for retention
- Edge of the parcel phytoremediation plants to filter surface pollutants and treat brackish water (biotopes)
- Biotopes near parking slots
- Semi-permeable paving
- Reduced number of parking and capacity of function
- Storage below parking slots
- Reconfiguration of land parcel at periphery to maximize storage and infiltration capacity of water in center
- Reconfiguration of land parcel to create swamp condition to retain water

Configuration 4 (logistic | commercial blocks)

C 4.3 a (Commercial block - fresh water)

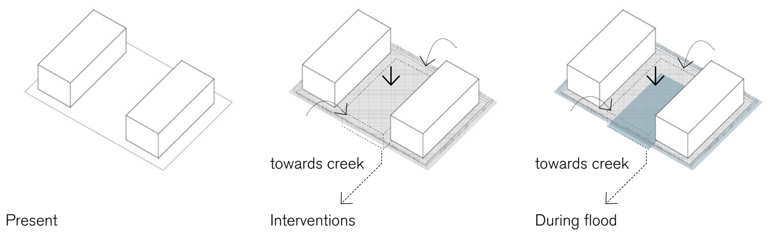


TPI - upstream

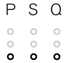
Domain - 3 (D3)

Operation - Infiltrate/store

Actions
- Grading to lower the parcel for retention
- Edge of the parcel phytoremediation plants to filter surface pollutants (biotopes)
- Semi-permeable paving
- Storage below plaza



C 4.3 b (Commercial block - brackish/fresh water)

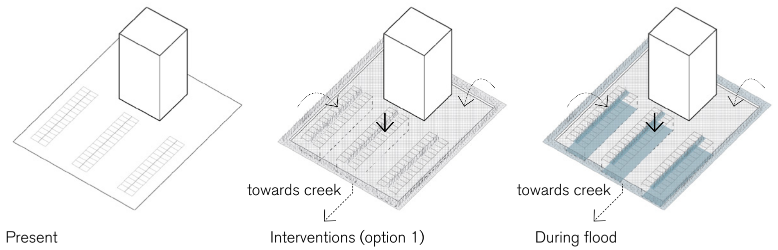


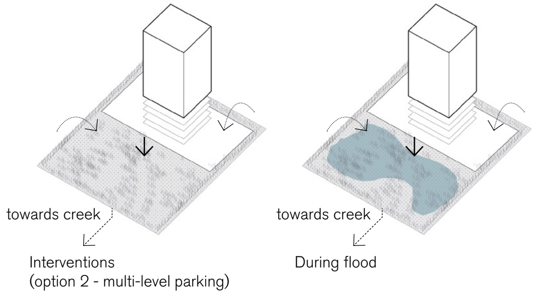
TPI - downstream

Domain - 4 (D4)

Operation - Infiltrate/store

Actions
- Grading to lower the parcel for retention
- Edge of the parcel phytoremediation plants to filter surface pollutants and treat brackish water (biotopes)
- Biotopes near parking slots
- Semi-permeable paving
- Reduced number of parking
- Storage below parking slots
- Multi-level parking
- Swamp condition to retain water





Configuration 4 consists of logistic centres and commercial blocks which are prominently found within the industrial district of Oakland. All the land parcels have hard paved or asphalt surfaces in common due to large surface areas dedicated for parking and storage. Majority of these land parcels are located mid-stream or down-stream of topography and they operate within domain 3 and 4. Theses parcels need to accommodate fresh and saline water. The primary interventions within the parcels are to re-grade the surface to create compartments to store water. This will reduce the capacity of parking and storage. Use of phytoremediation plant species is necessary to treat polluted surface runoff within industrial setting and to filter saline water. The other major interventions which can be achieved are changing the parcel layout by concentrating all build areas to periphery to increase the infiltration areas or provide multi-level parking facility thereby by freeing space on ground to introduce swamp conditions.

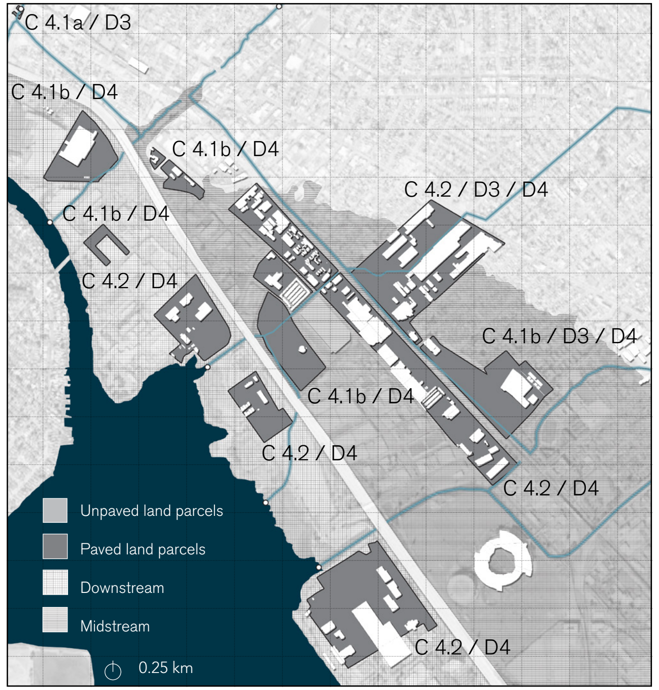


Figure 8.23: Location of configuration 4 land parcels. Illustration : Author

Figure 8.24: Urban Landscape Infrastructure matrix at district scale. Illustration : Author

Conditioning Landscape towards Infrastructure Matrix

The analysis and synthesis at micro scale (district) has identified land parcels which will act as "green elements" within the system and has further projected potential interventions to enhance their performance. But for the system to function these "green elements" need to be networked. This is achieved by strengthening and reprofiling creeks and appropriating and intercepting street networks with urban storm water drains.

The existing creeks are reprofiled either by widening or by increasing the freeboard. This will increase the capacity of creek to accommodate water. The edge of creeks is re-naturalized from a hard concrete to a soft gradient which will act as a buffer and provide a diverse habitat of flora and fauna. This will add to the quality of built environment. The streets are retrofitted with bio-swales and trenches which infiltrate and convey water during heavy and extreme rainfall events. The storm water drains are intercepted with these streets which will help reduce the peak discharge. The identified land parcels intersect this blue network of creeks and streets which hold water during extreme rainfall events. The water is redirected into these land parcels and like a cascade effect the land parcels overflow into other from upstream to downstream.

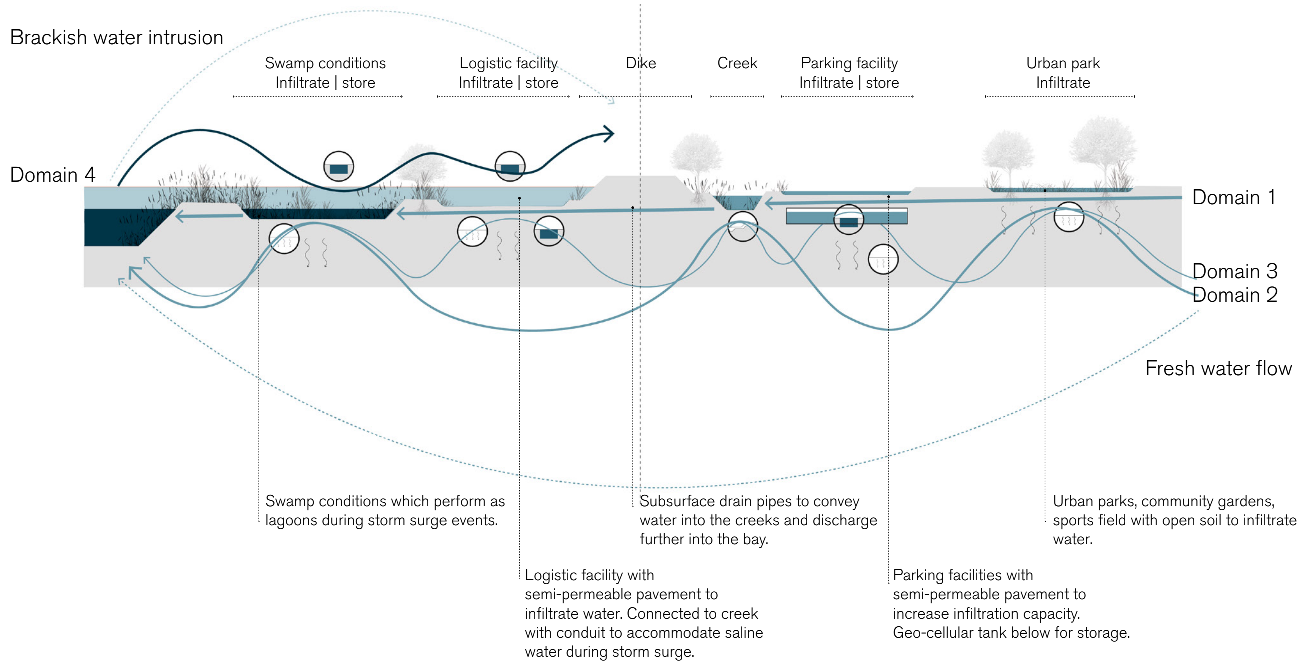


Figure 8.25: Principle section of thick strategy. Illustration : Author

Thick Strategy

Developing strategy through section in the subsurface is equally important as developing a network on surface, especially while dealing with hydrological issues consisting of fresh and saline water conditions. The principle section represents operation of system designed to address these hydrological challenges from up-stream and down-stream. The combination of land parcels, creeks, streets with bio-swales and subsurface storm drain pipes make the system function. The 4 Domain Approach (Digman et al., 2014) derives the sequencing of operations for all these elements.

Domain 1 – the subsurface drain pipes convey water into creeks on a regular day. For efficient functioning of these elements regular maintenance is necessary to avoid blockages.

Domain 2 – during heavy rainfall event the bio-swales reduce the peak flow of water into subsurface pipes. Moreover, they retain and infiltrate water in the process. The land parcels with functions of urban parks, community parks and sports field hold water temporarily.

Domain 3 – at the event of extreme rainfall, storm water drain pipes and streets with bio-swales redirect excess water to parking facilities. These land parcels with their semi-permeable pavement infiltrate water. The geo-cellular tanks store water for temporary interval thereby reducing peak discharge.

Domain 4 – during storm surge events the saline water is redirected to the floodable land parcels. These land parcels comprise of phytoremediation plant species which treat the saline water to certain extent before infiltration. Moreover, these plants also treat the saline soil conditions. The brackish water is redirected into the floodable areas through subsurface conduits which are present below storm drain pipes. These conduits avoid interaction of saline storm surge water with the storm drain system operating for fresh water.

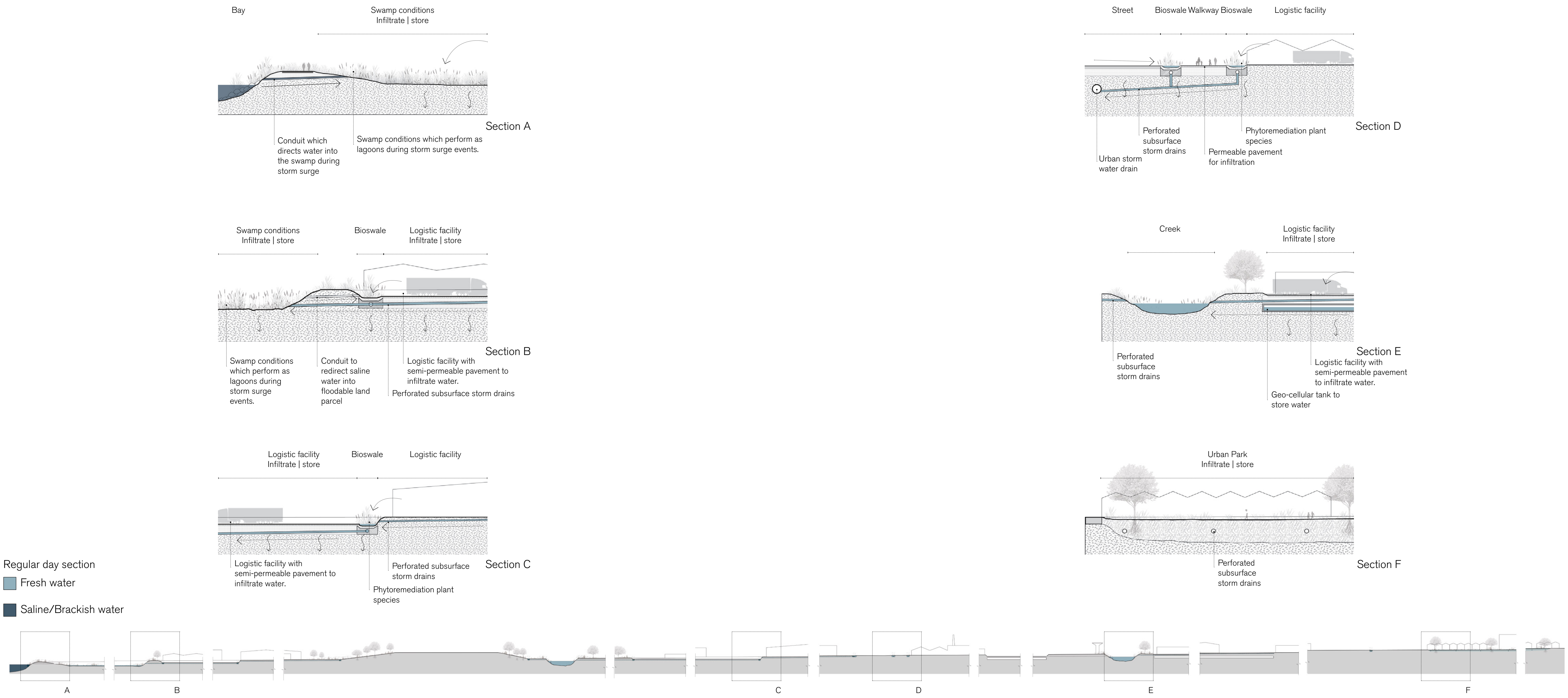


Figure 8.26: Section upstream to downstream, Technical details. Illustration : Author

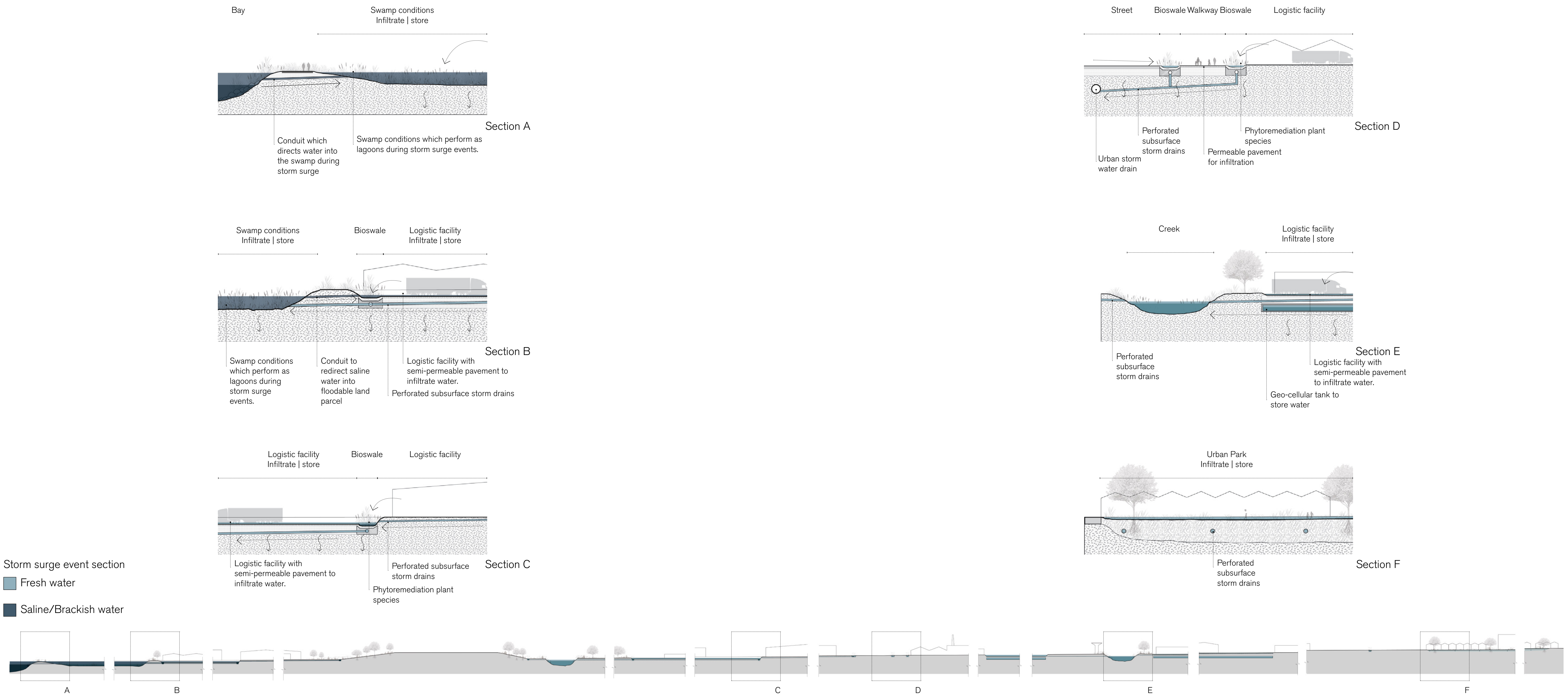


Figure 8.27: Section upstream to downstream, Technical details. Illustration : Author

Domain 1

No water on surface other than in ponds or wetlands, and in creeks. It is important to maintain the existing manmade drains and natural streams and creeks to reduce pollution and blockages causing flooding. In this domain, the built environment is largely untouched, mostly maintenance of existing structures is necessary.

Domain 2

Controlled exceedance of surface water. The operation is the retrofitting of existing drainage network with soft measures to limit flooding. In this domain, the objective is to delay drainage via infiltration method; raingardens, sports fields, community parks, pervious pavements, trenches; or through buffer storage of detention and retention basins and wetlands. The land parcels in the close proximity of blue network are active in this domain.

Domain 3

Manage exceedance pathways along with overall improved spatial quality of the streetscape. This domain requires design for exceedance to manage water in preferred locations or land parcels. Runoff exceedance is safely conveyed via diversion structures – new streams or bypass; or via conveyance structures – swales, ditches, gutters and stored in multifunctional spaces of green areas, floodable public spaces, sports fields, playgrounds, parking islands or interstitial spaces. This domain is very critical in terms of retrofitting the urban fabric to accommodate the exceedance of runoff.

Domain 4

The 4th domain is the situation when there is hydrological threat from upstream due to exceedance of runoff and flooding from bay due to storm surge. The urban fabric needs to be retrofitted to accommodate this flooding by allowing certain land parcels to temporarily store water to reduce damage in other spots. This is the idea of floodable parcels. Moreover, theses parcels not only store polluted runoff water but also have possibility to store brackish water from bay.

Figure 8.28: Spatial impact domain 1. Illustration : Author

Figure 8.29: Spatial impact domain 2. Illustration : Author

Figure 8.30: Spatial impact domain 3. Illustration : Author

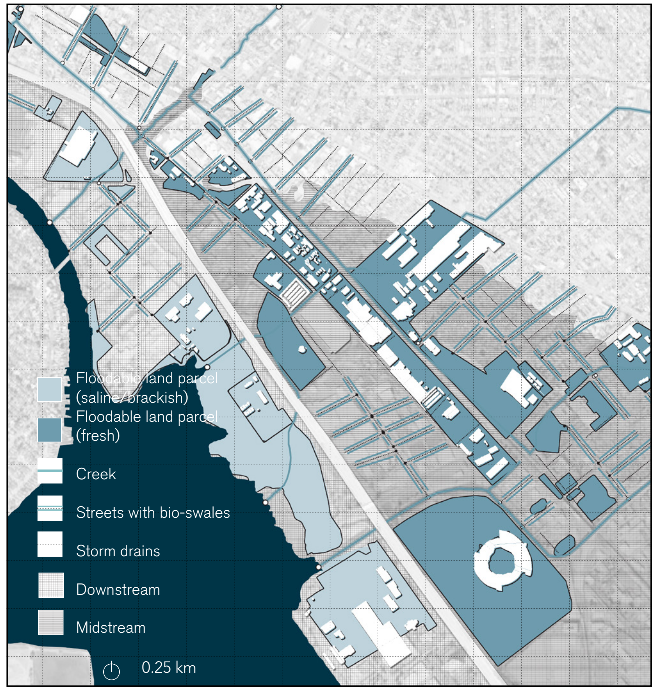


Figure 8.31: Spatial impact domain 4. Illustration : Author

Figure 8.32: Impression at bay edge - dry condition. Illustration : Author

Figure 8.33: Impression at bay edge - wet condition. Illustration : Author

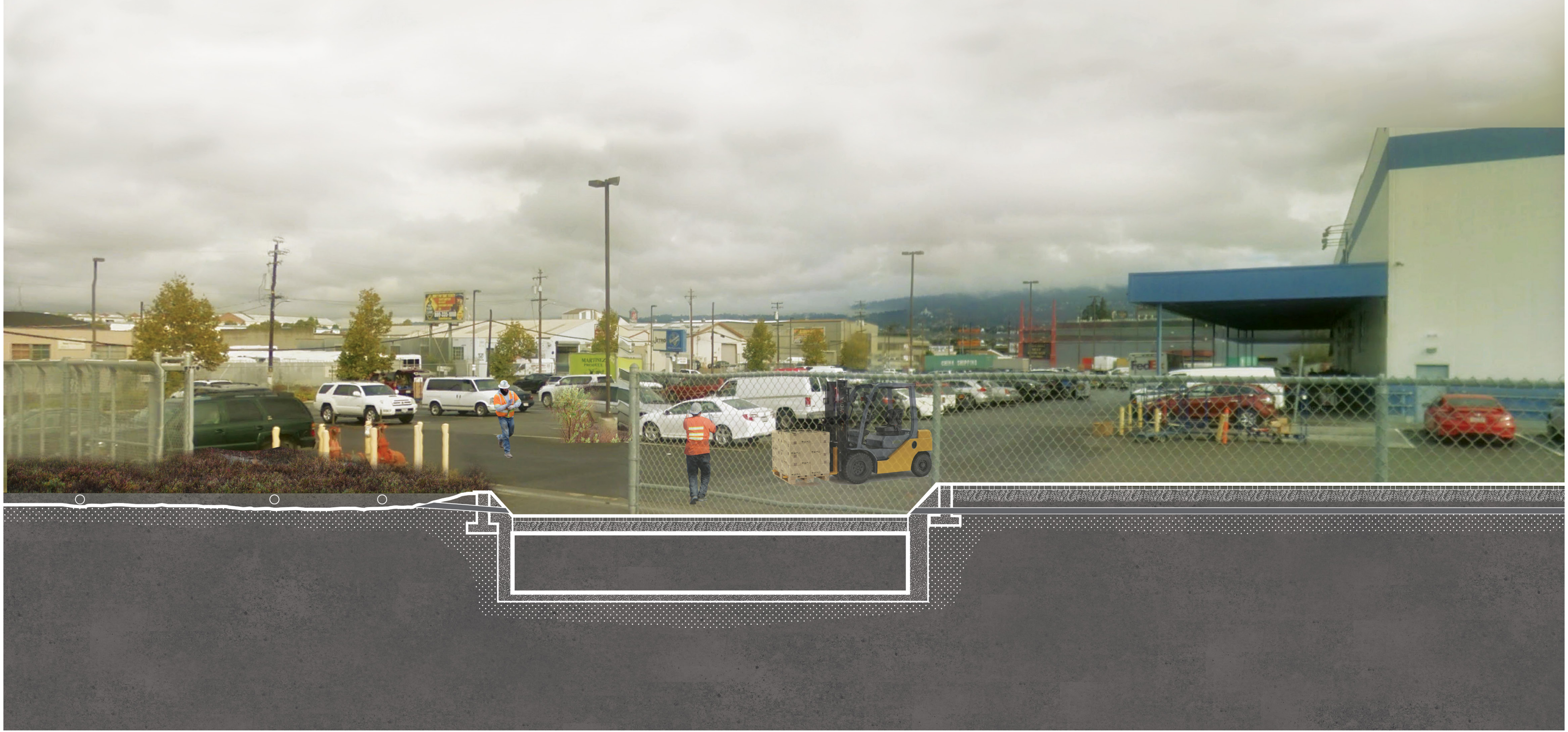


Figure 8.34: Logistic facility - dry condition. Illustration : Author

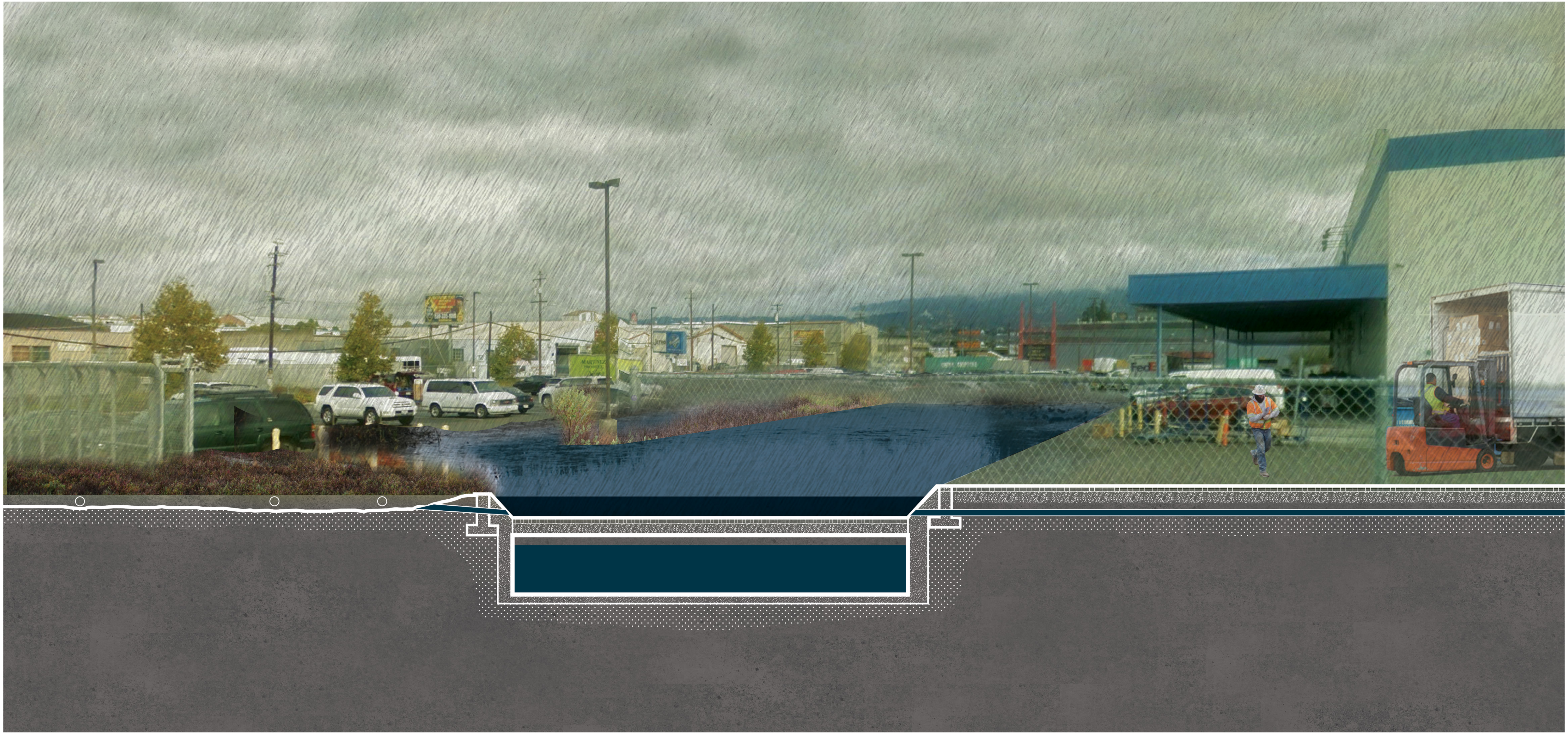


Figure 8.35: Logistic facility - wet condition. Illustration : Author

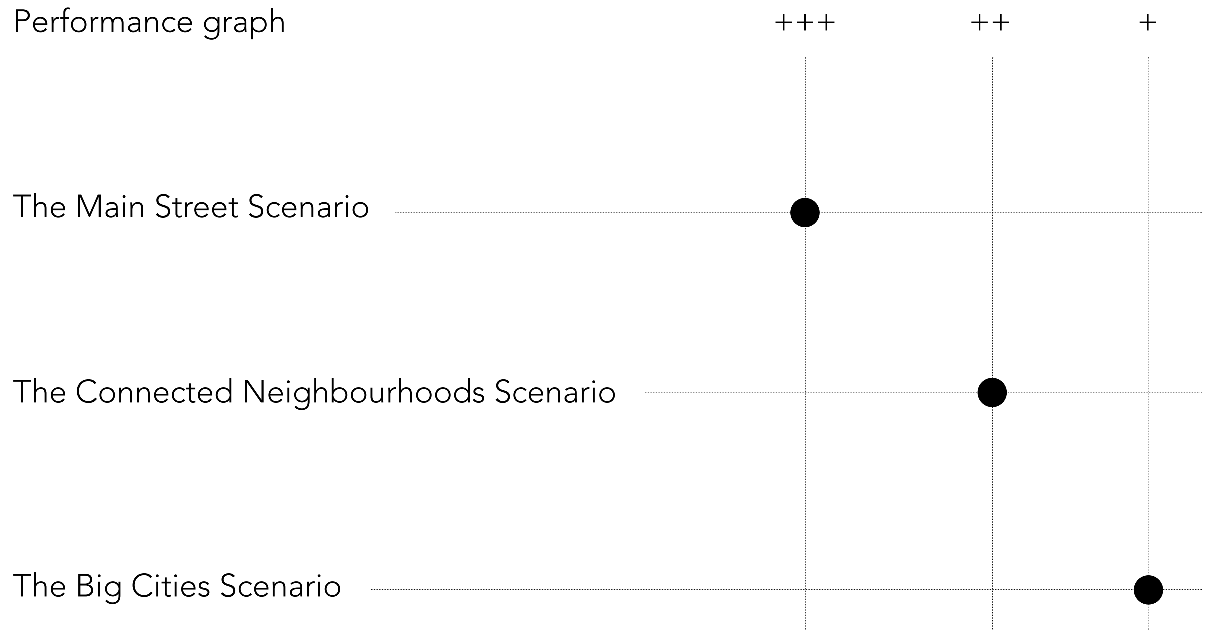
Figure 8.36: Parking facility - dry condition. Illustration : Author

Figure 8.37: Parking facility - wet condition. Illustration : Author

Figure 9.1: Salt ponds San Francisco. Source : http://www.dailyoverview.com/contact/

Temporal dimension

Designing for time is one of the important aspects for an ecological resilience approach (Holling, 1996). As the three fundaments of this approach are persistence, change and unpredictability; working through time helps to identify the critical elements as mentioned before. The other aspect of working through time is to prepare for contingencies. For this, the idea of design being open-ended is explored. The design principles defined in earlier chapter establish set of actions to be performed and goals to be achieved. Temporal dimension explores multiple possible ways to achieve it in different scenarios. The intention is to develop a system which can achieve its objectives to address the hydrological challenges in various possible ways and the temporal dimension helps to explore these multiple possibilities.



Scenario study

The scenario study is useful to explore possible futures, more or less likely to happen. Although the research project clearly advocates for a specific vision, the uncertainties due to climate change and economic trends makes it important to explore these possibilities.

In this study the idea of design being open-ended is explored; where design principles are defined rather than design solutions; the difference being, these principles establish set of actions to be performed and goals to be achieved which can be done in multiple possible ways. The exploration is achieved inspired from methods developed by Delta Programmes scenarios for Adaptive Delta Management (Deltafact: Delta scenarios and adaptive Delta management, 2012) and drawing facts and figures for future projections of Bay area from government documents of Plan Bay Area 2040 (2017). Based on these documents three scenarios are developed which are speculated as possible futures derived from socio-economic shifts within the Bay area. The systems performance is tested by following similar 4 Domain Approach within these scenarios. The project intends to showcase multiple possibilities in which the infrastructure can be conditioned rather than defining one static possibility.

Plan Bay Area 2040 report, 2017 has projected three scenarios of the region.

Main Streets Scenario places future population and employment growth in the downtowns in all Bay Area cities. This scenario would expand high-occupancy toll lanes and increase highway widenings. It would also assume some development on land that is currently undeveloped.

Connected Neighbourhoods Scenario places future population and employment growth in medium-sized cities and provides increased access to the region's major rail services, such as BART and Caltrain. It would place most of the growth in areas that cities determine as having room for growth, with some additional growth in the biggest cities. There would be no development on open spaces outside the urban footprint.

Big Cities Scenario concentrates future population and employment growth within the Bay Area's three largest cities: San Jose, San Francisco and Oakland. Transportation investments would go to the transit and freeways serving these cities. There would be no development on open spaces outside the urban footprint.

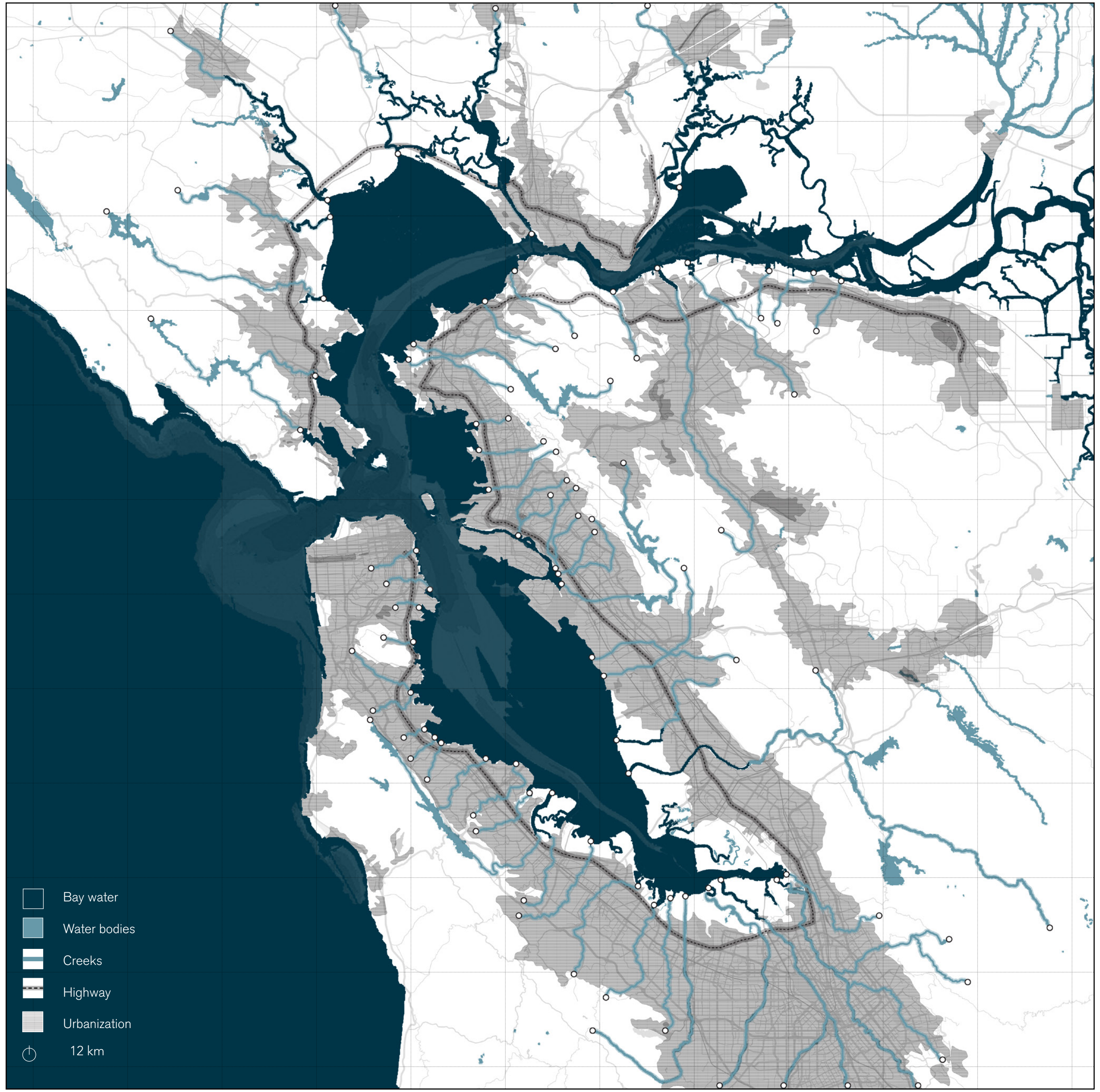


Figure 9.2: The Main streets scenario. Illustration : Author

The Main Street Scenario

The Main Streets Scenario targets future population and employment growth in the downtowns of every Bay Area city to foster a region of moderately sized, integrated town centres. This scenario offers the most dispersed growth pattern, meaning cities outside of the region's largest — Oakland, San Jose and San Francisco — are likely to see higher levels of growth. In this scenario, more growth will occur in currently undeveloped areas outside of Priority Development Areas (PDAs) than the other two scenarios (Plan Bay Area 2040 report, 2017).

General considerations:

- Represents traditional suburban development is regions outside core cities; San Francisco, Oakland and San Jose.

- Improved and efficient mobility network to facilitate dispersed region.

- Using technological advances like self-driven cars and buses to improve efficiency of roadway capacity.

- Parking policies will be reformed.

- Encourages urban sprawl.

- Significant increase in travel time to work.

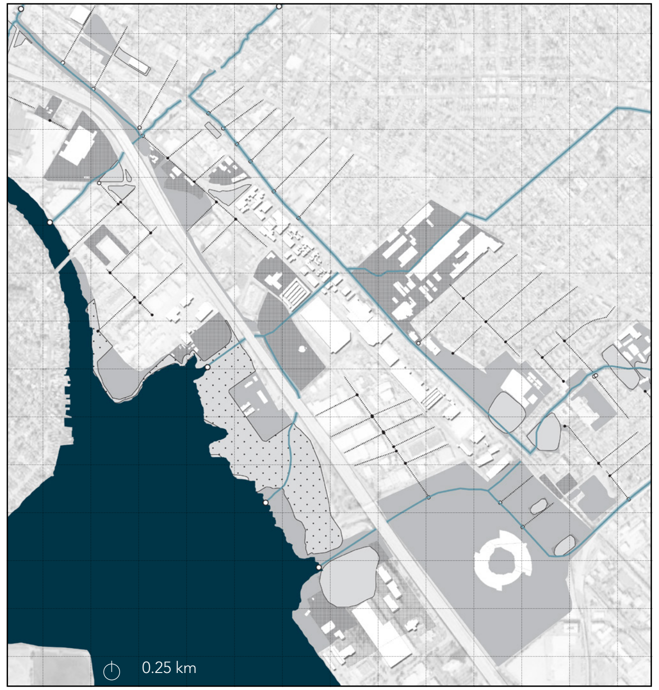
- Smart operations and deliverables for logistic centres.

- Heavy investments in technology advancements for clean vehicles and incentives to meet climate goals.

Landscape Infrastructure performance:

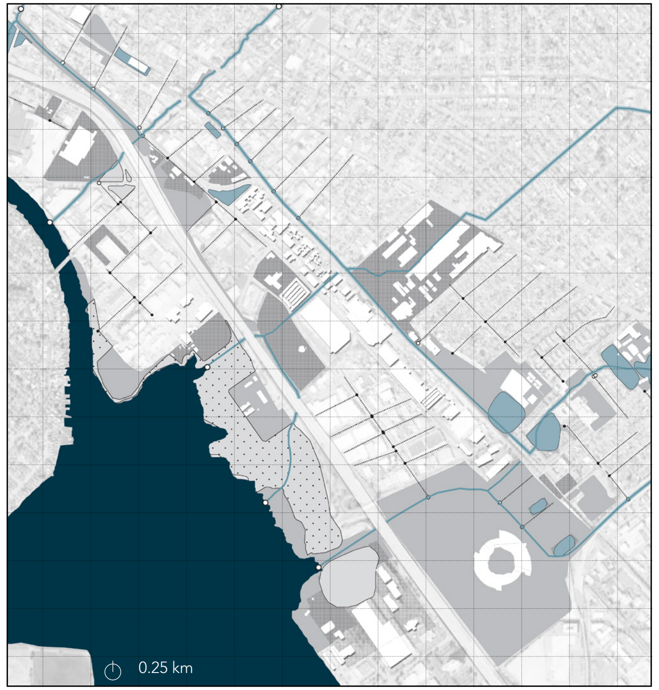
Re-naturalizing creeks, streets retrofitted with bio-swales and subsurface storm drains, parking facilities reduced in number due to automated vehicles and improved mobility network, retrofitting parking facilities to urban parks and retention areas, logistic centres operations optimized thereby reducing paved surface area, use of new open soil from logistic centres for green patches in system, providing subsidies for initiatives taken for climate change, environmental compensation.

Domain 1



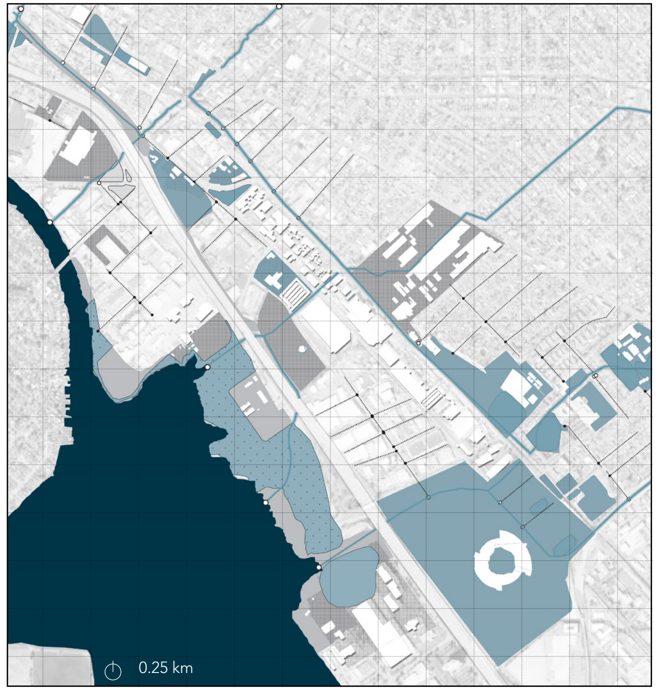
- Creek
- Streets with bio-swales
- Storm drains
- Regional Green patch
- Private owned land parcel
- Green patch - Municipality
- Public owned land parcel

Domain 2



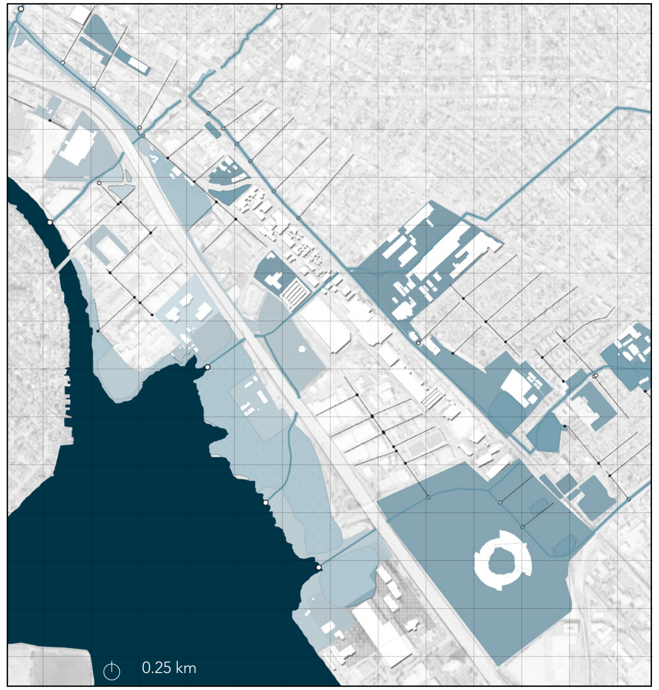
- Creek
- Streets with bio-swales
- Storm drains
- Regional Green patch
- Private owned land parcel
- Green patch - Municipality
- Public owned land parcel
- Floodable land parcel (fresh)

Domain 3



- Creek
- Streets with bio-swales
- Storm drains
- Regional Green patch
- Private owned land parcel
- Green patch - Municipality
- Public owned land parcel
- Floodable land parcel (fresh)

Domain 4



- Creek
- Streets with bio-swales
- Storm drains
- Regional Green patch
- Private owned land parcel
- Green patch - Municipality
- Public owned land parcel
- Floodable land parcel (fresh)
- Floodable land parcel (saline/brackish)

Figure 9.3: 4 Domain approach exploration in Main Street Scenario. Illustration : Author

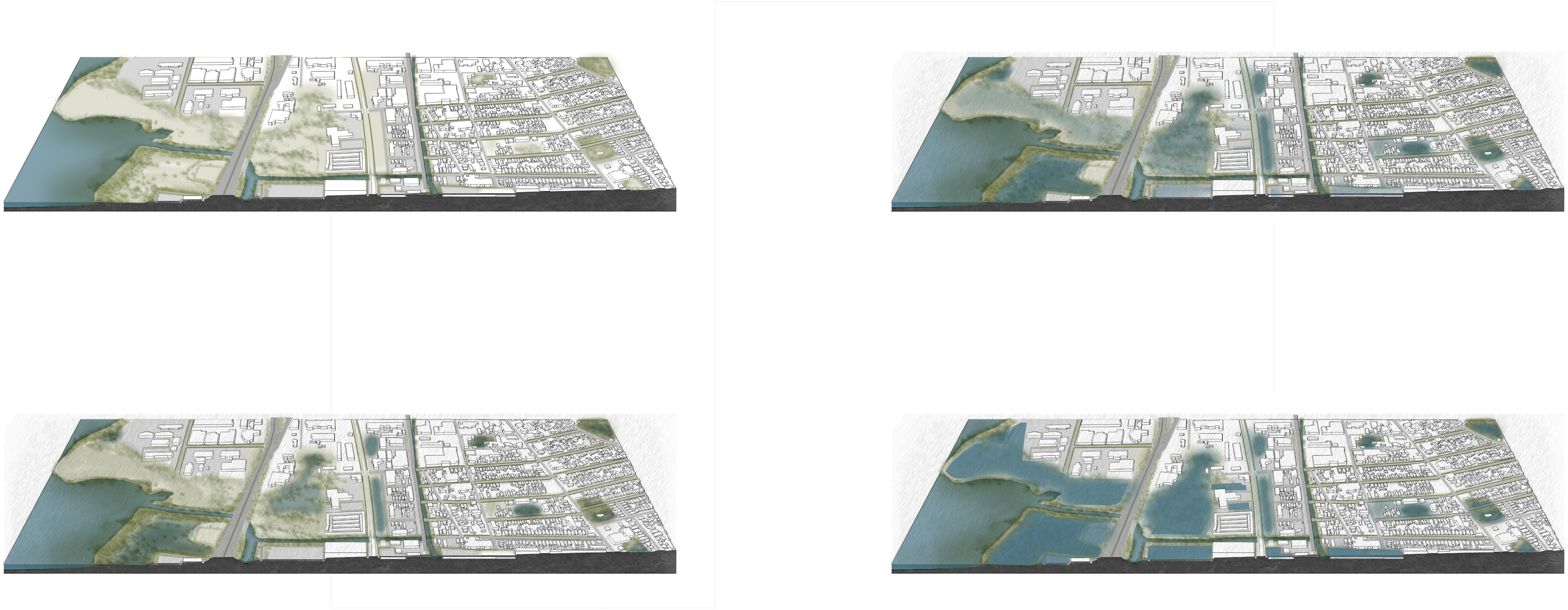


Figure 9.4: 4 Domain approach exploration in Main Street Scenario. Illustration : Author

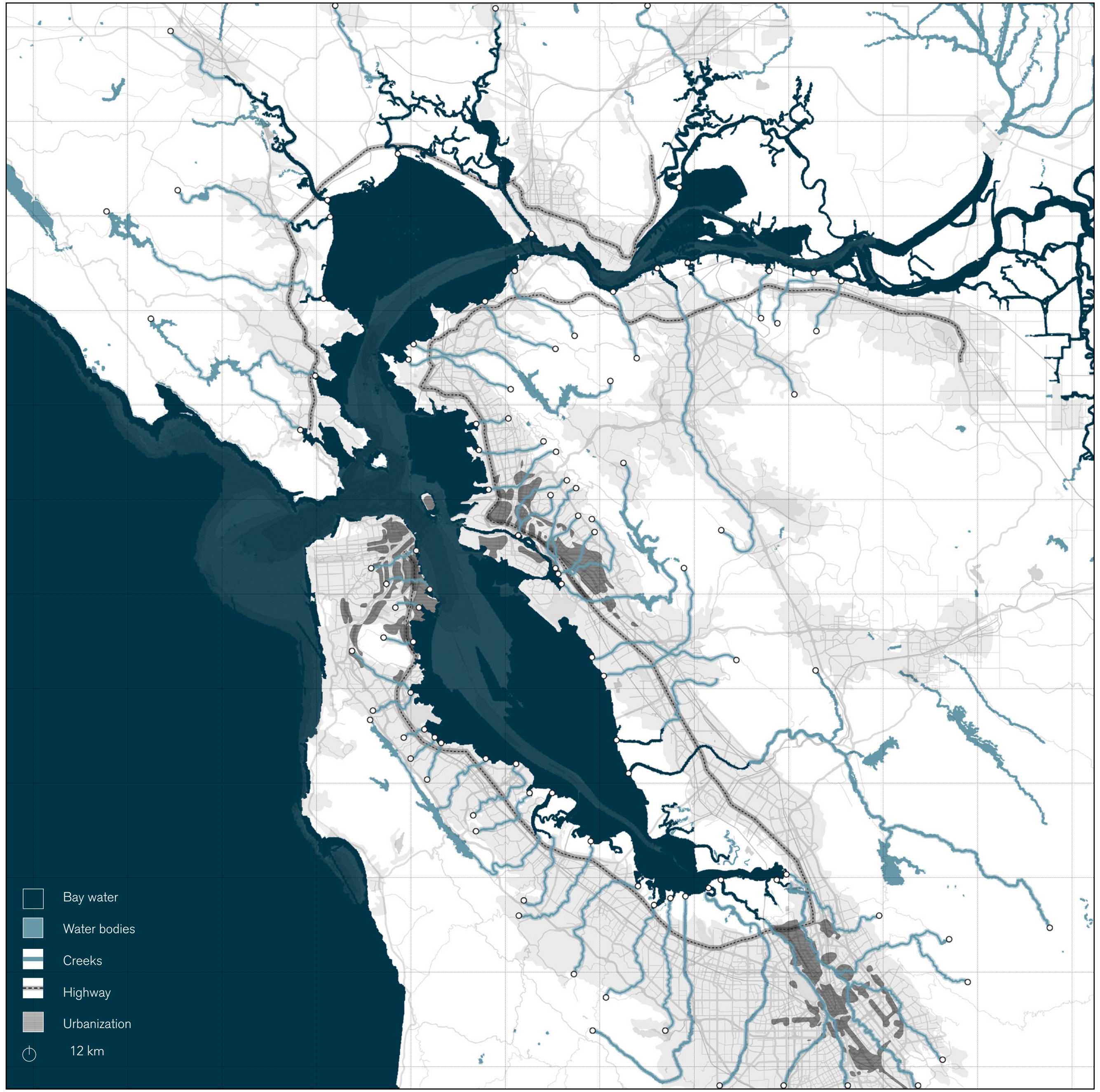


Figure 9.5: Connected Neighborhoods Scenario. Illustration : Author

The Connected Neighbourhoods Scenario

The Connected Neighbourhoods Scenario targets future population and employment growth in locally adopted Priority Development Areas (PDAs) throughout the region. This scenario emphasizes growth in medium-sized cities with access to the region's major rail services. Outside of PDAs, this scenario will see modest infill development and no growth outside the urban footprint on currently undeveloped land. This scenario builds on the adopted Plan Bay Area 2013 (Plan Bay Area 2040 report, 2017).

General considerations:

- Represents the current state of development within identified Priority Development Areas.

- Transit oriented development with investments in maintenance of existing infrastructure.

- Walkable and bike friendly city centres.

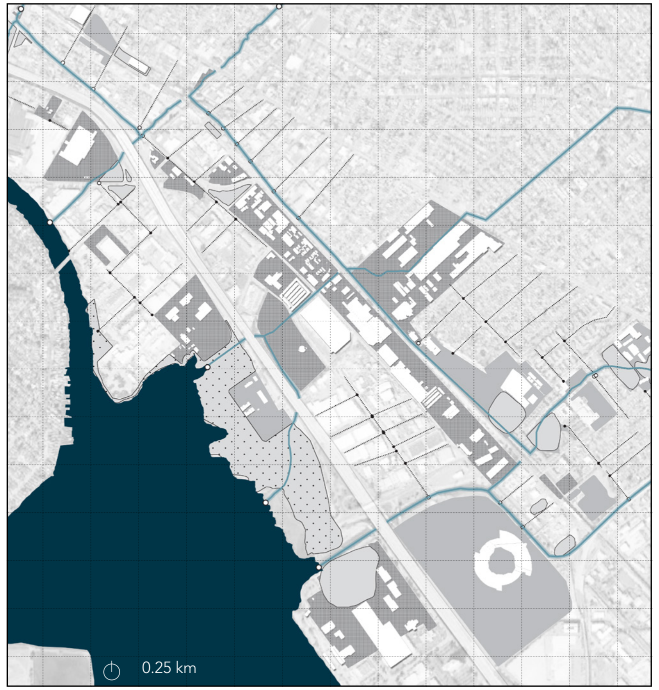
- Intends to attract international commerce and protect community jobs.

- Supports investments in environmentally sustainable initiatives.

Landscape Infrastructure performance:

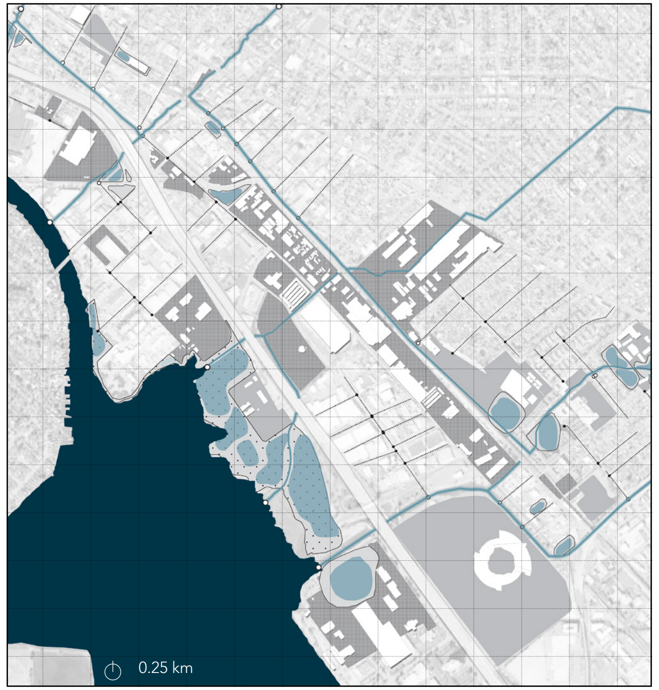
Re-naturalizing creeks, streets retrofitted with bio-swales and subsurface storm drains, subsidise to be provided for private investments in developing water retention within land parcels, public-private initiatives for the infrastructure development, promoting low-tech solutions through community development.

Domain 1



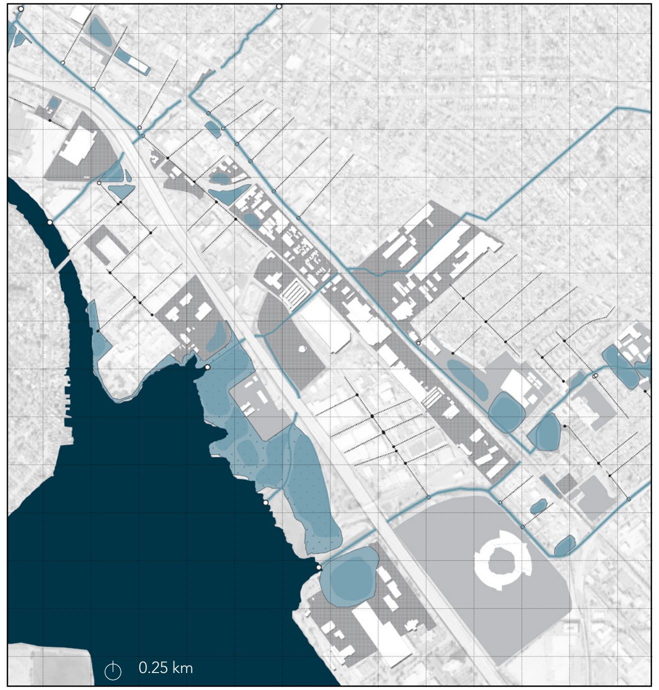
- Creek
- Streets with bio-swales
- Storm drains
- Regional Green patch
- Private owned land parcel
- Green patch - Municipality
- Public owned land parcel

Domain 2



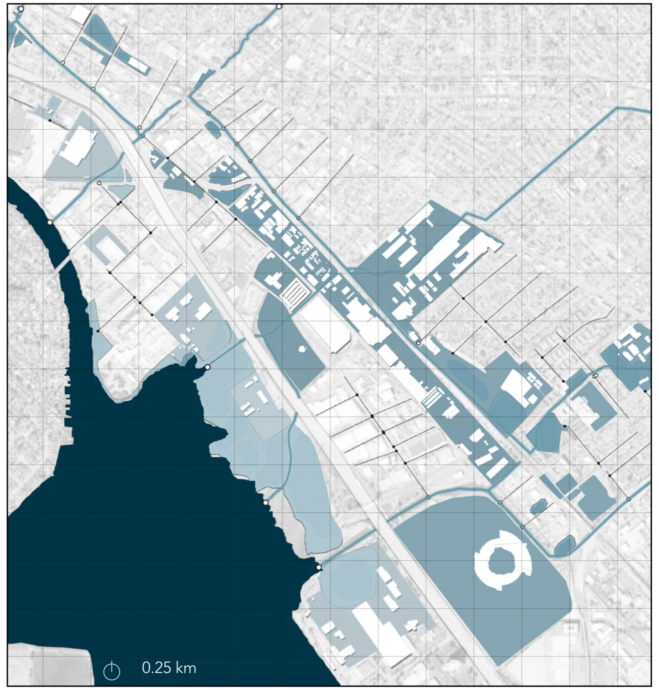
- Creek
- Streets with bio-swales
- Storm drains
- Regional Green patch
- Private owned land parcel
- Green patch - Municipality
- Public owned land parcel
- Floodable land parcel (fresh)

Domain 3



- Creek
- Streets with bio-swales
- Storm drains
- Regional Green patch
- Private owned land parcel
- Green patch - Municipality
- Public owned land parcel
- Floodable land parcel (fresh)

Domain 4



- Creek
- Streets with bio-swales
- Storm drains
- Regional Green patch
- Private owned land parcel
- Green patch - Municipality
- Public owned land parcel
- Floodable land parcel (fresh)
- Floodable land parcel (saline/brackish)

Figure 9.6: 4 Domain Approach exploration in Connected Neighborhoods Scenario. Illustration : Author

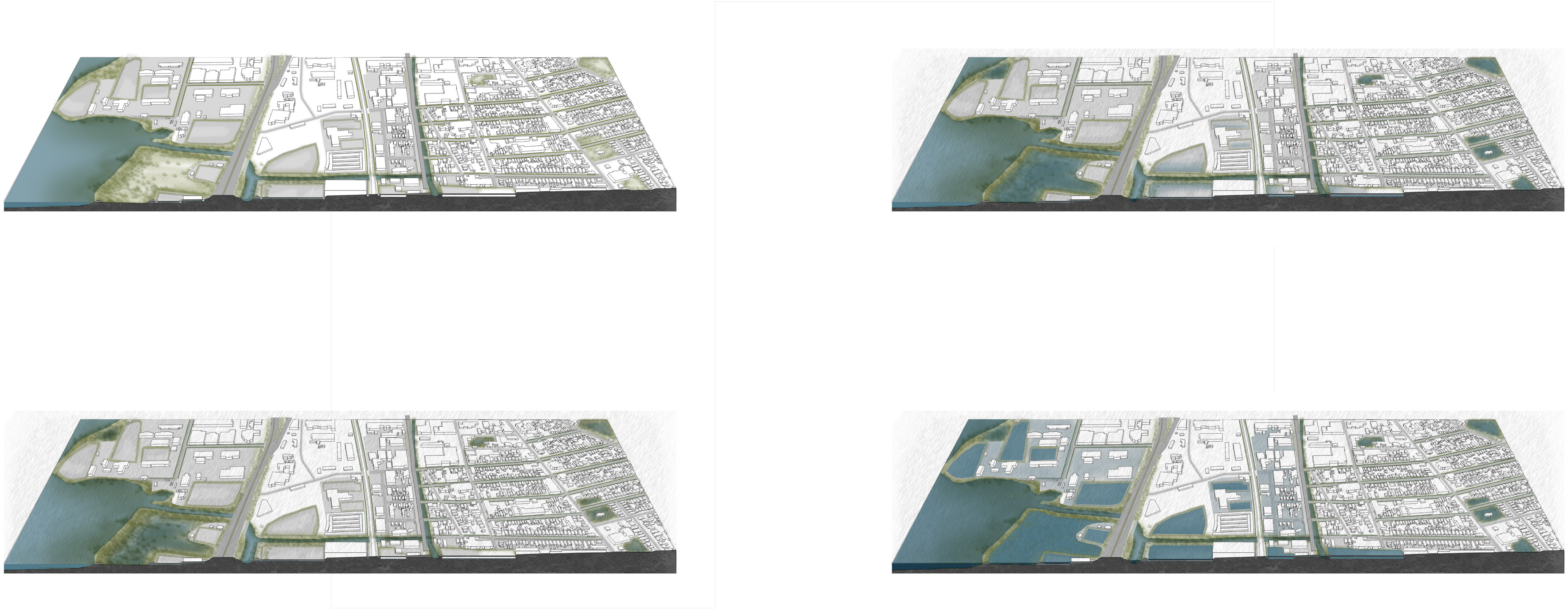


Figure 9.7: 4 Domain Approach exploration in Connected Neighborhoods Scenario. Illustration : Author

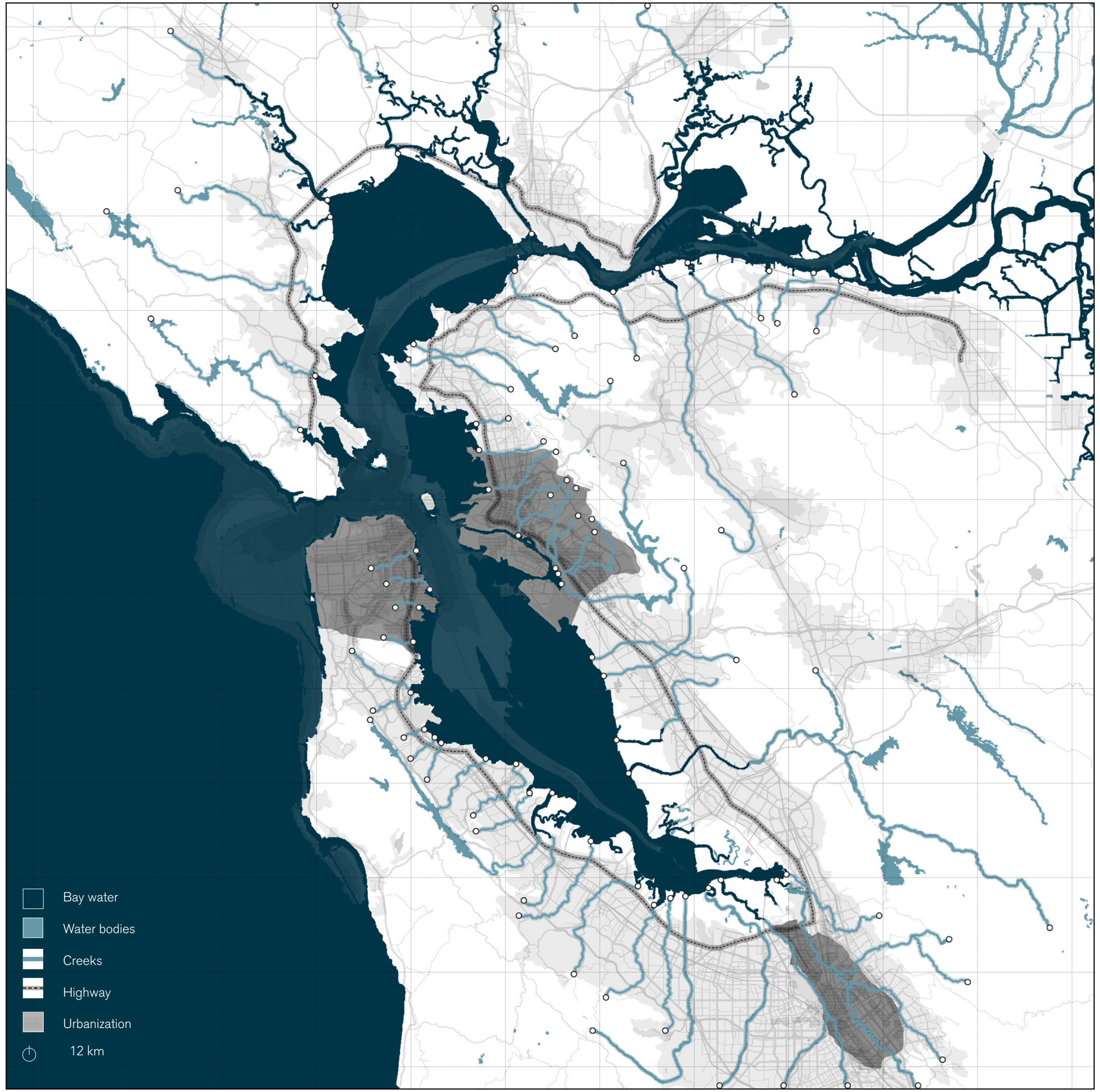


Figure 9.7: Big Cities Scenario. Illustration : Author

The Big Cities Scenario

The Big Cities Scenario targets future population and employment growth in locally adopted Priority Development Areas (PDAs) within San Jose, San Francisco and Oakland. Neighbouring cities already well-connected to the region's three largest cities would also see growth, particularly in their locally adopted PDAs. Growth outside of these three cities would be small, with limited infill development in PDAs and no development on currently undeveloped land (Plan Bay Area 2040 report, 2017).

General considerations:

- Represents high density rapid urbanization in three major cities of San Francisco, Oakland and San Jose.

- Growth in suburbs is limited and minimal.

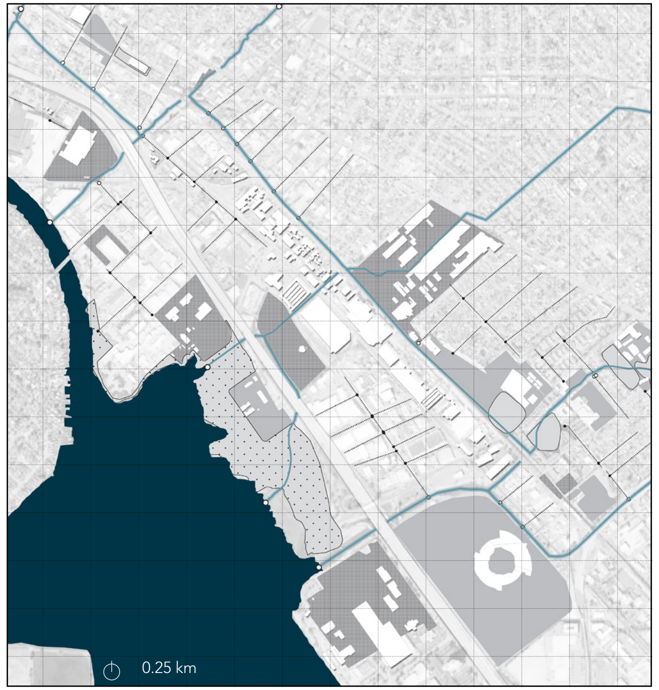
- Mobility corridors expanded for better connectivity of cities.

- Port of Oakland expanded to meet regional economic needs.

Landscape Infrastructure performance:

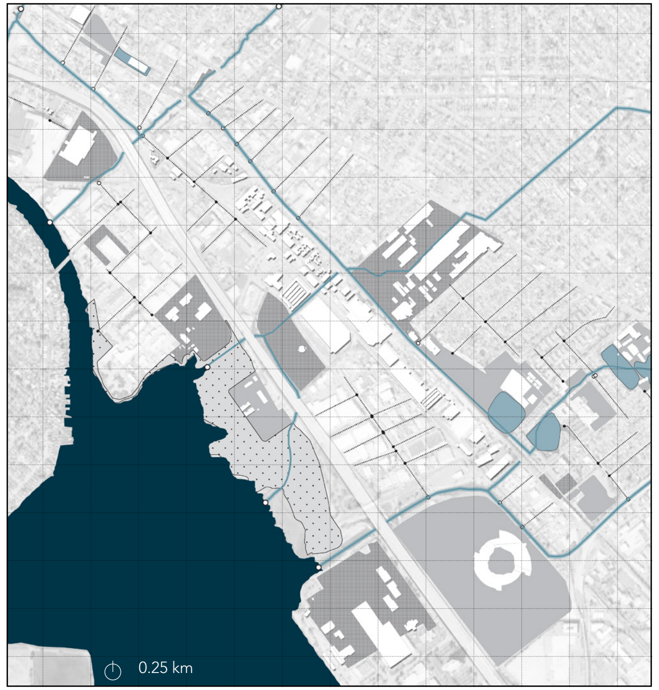
Streets retrofitted with bio-swales and subsurface storm drains, subsidise to be provided for private investments in developing water retention within land parcels, public-private initiatives for the infrastructure development.

Domain 1



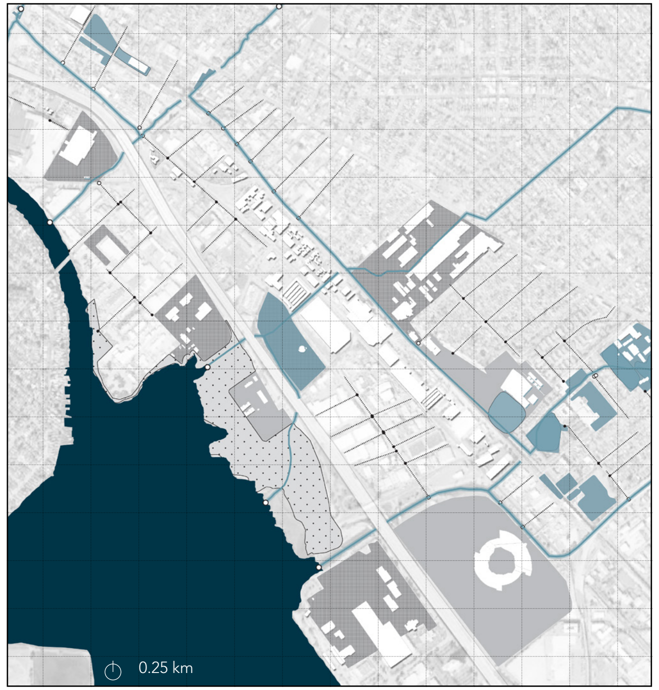
- Creek
- Streets with bio-swales
- Storm drains
- Regional Green patch
- Private owned land parcel
- Green patch - Municipality
- Public owned land parcel

Domain 2



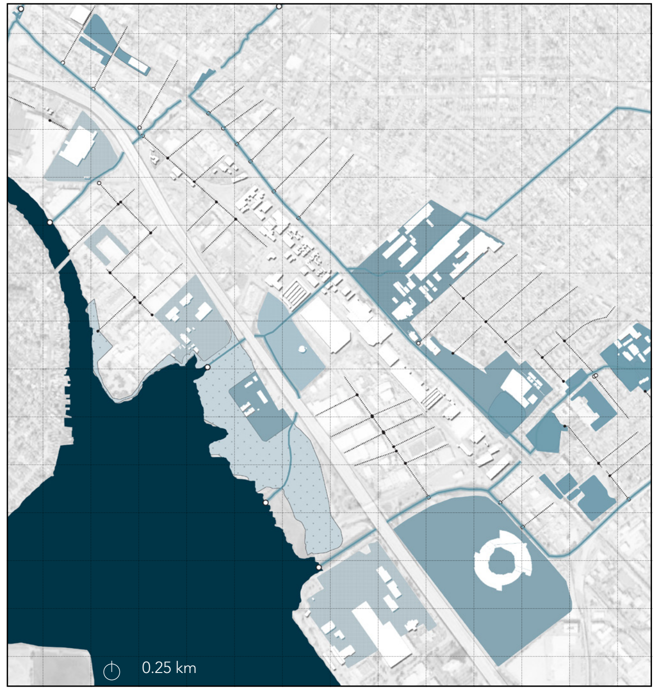
- Creek
- Streets with bio-swales
- Storm drains
- Regional Green patch
- Private owned land parcel
- Green patch - Municipality
- Public owned land parcel
- Floodable land parcel (fresh)

Domain 3



- Creek
- Streets with bio-swales
- Storm drains
- Regional Green patch
- Private owned land parcel
- Green patch - Municipality
- Public owned land parcel
- Floodable land parcel (fresh)

Domain 4



- Creek
- Streets with bio-swales
- Storm drains
- Regional Green patch
- Private owned land parcel
- Green patch - Municipality
- Public owned land parcel
- Floodable land parcel (fresh)
- Floodable land parcel (saline/brackish)

Figure 9.8: 4 Domain Approach exploration in Big Cities Scenario. Illustration : Author

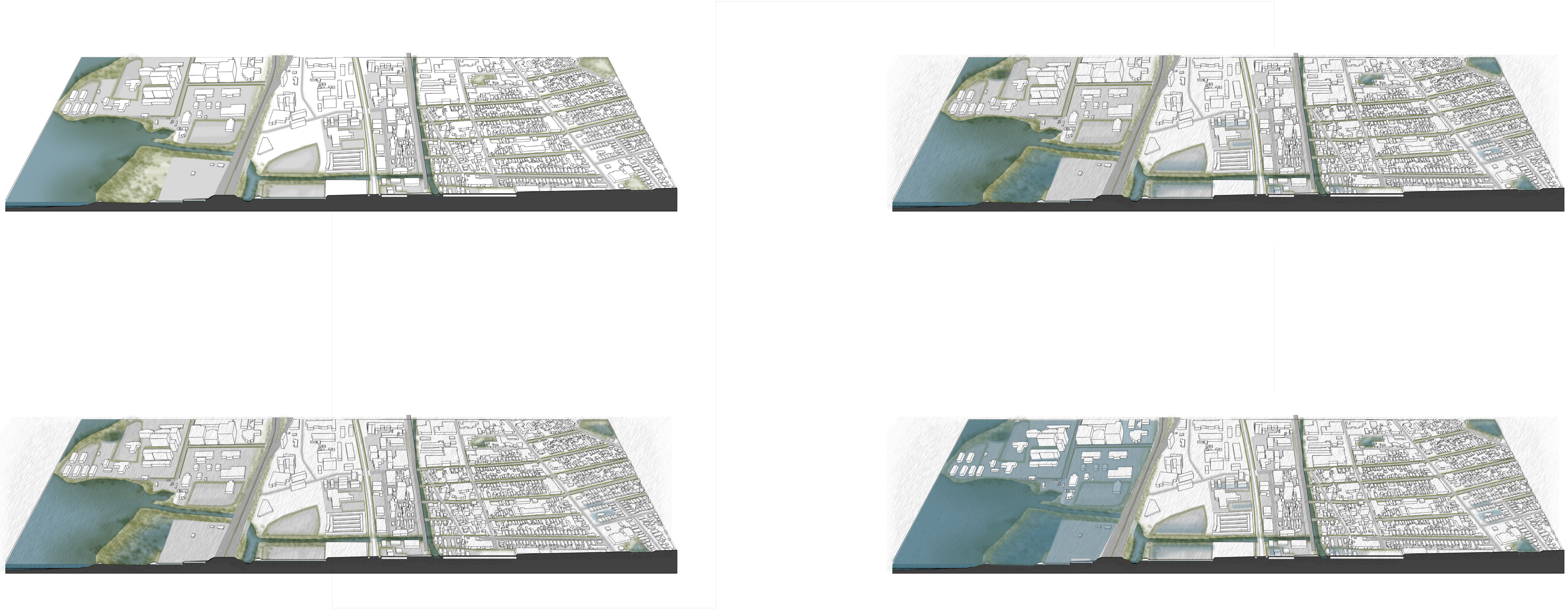


Figure 9.9: 4 Domain Approach exploration in Big Cities Scenario. Illustration : Author

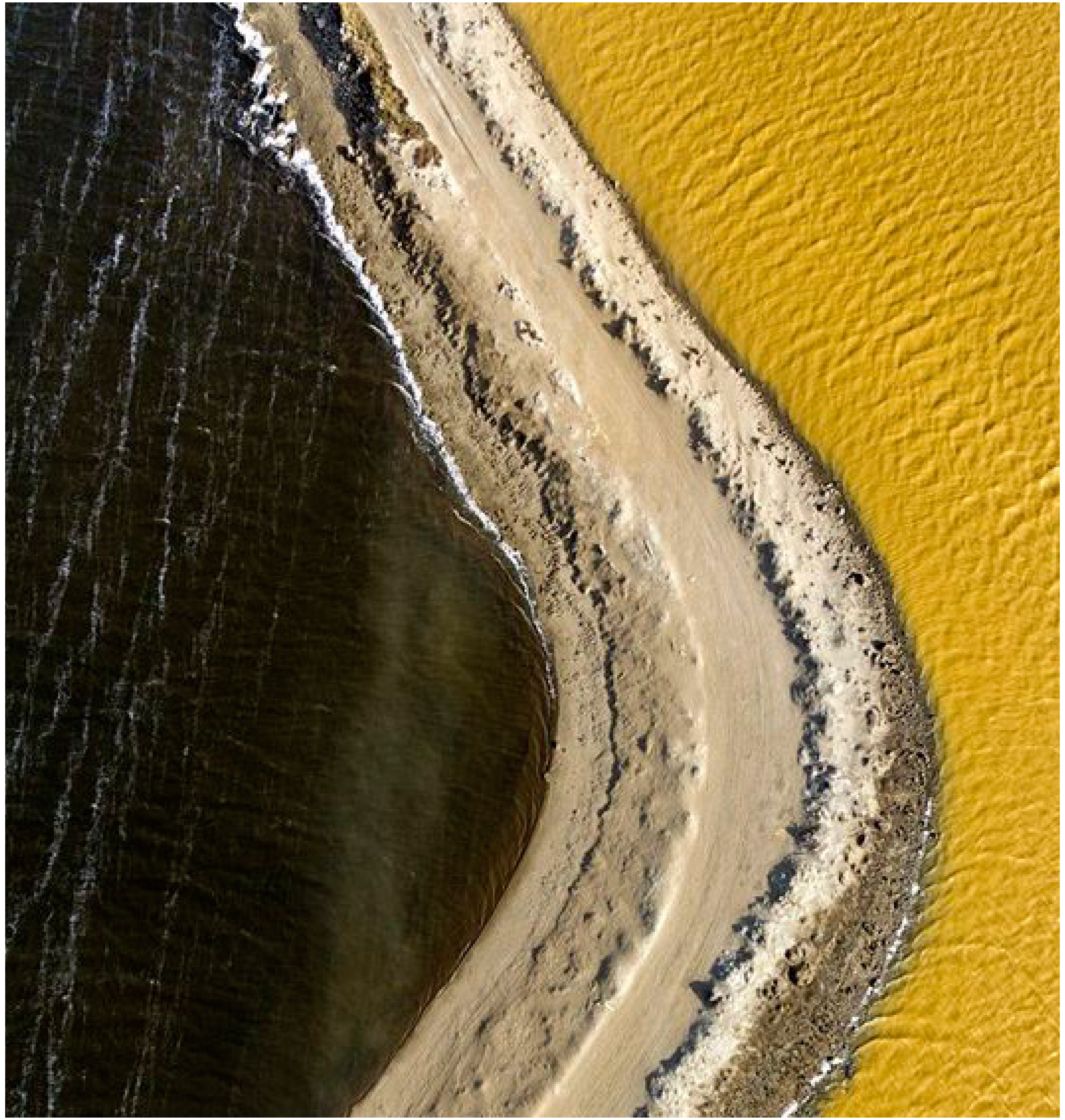


Figure 10.1: Aerial Saltscapes. Source : https://in.pinterest.com/pin/510384570249924805/

Conclusions

The premise of this research project was to understand the relation between urbanization pattern and environmental processes within a delta territory in the light of climate change. In the process of unfolding the project, it was observed that the aspect of vulnerability corresponds to the intensity and density of urbanization, as it alters the ecological and hydrological structure which operates as an absorbent towards these threats. The case of San Francisco bay area very well represented this dichotomy. The spatial distribution of flood risk is an outcome of this relationship between urban and natural processes. Namely, land use intensity, land cover patterns alter water processes and likelihood of hydrological threat. Scale of urbanization delineates the impact of these threats and to what degree are they mitigated by buffering capacity of natural or semi-natural areas in the territory.

The transect study at bay scale identifies this distribution and relation. It was very crucial method to understand the topography in relation to landscape, infrastructure and occupation, with respect to land-water transition and hydrological challenges in hand. The interventions derived at district level to correspond to the strategy at city scale. Land-water transition is one of the important factors while considering the transferability of these interventions. The relation of topography, urbanization and landscape structure within Oakland is similar to that of San Francisco. the transect scheme have similar components and conditions. The measures to address these hydrological threats will be very different from Petaluma to the north bay or Alviso to the south, which have a different transect scheme. In case of Oakland and San Francisco the urbanization is very dense and at the edge of bay. Retrofitting the landscape infrastructure within the land parcels and built form is the challenge. Whereas, the urban occupation for Petaluma and Alviso is in the interior with a buffer of marshes from the bay. The challenge here is to develop landscape infrastructure for new land formation as buffer and steer the urban development respecting the hydrological threats. However, the common link between all these transect conditions along the bay edge is the creeks which need to be conditioned as a framework to develop the adaptive capacity within Bay for changing climatic conditions.

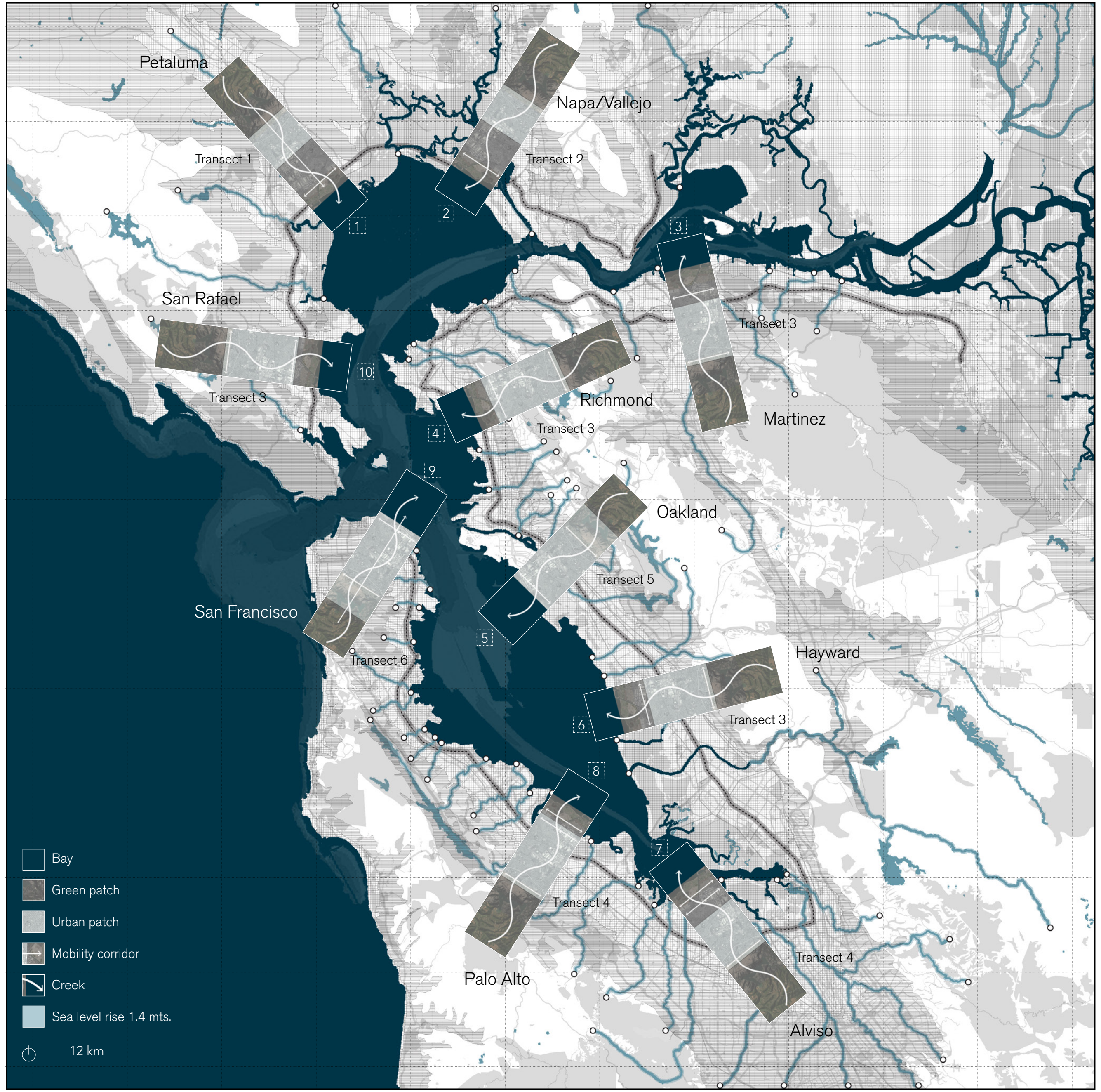


Figure 10.2: Transect study related to Landscape Infrastructure syntax. Conclusion map. Illustration : Author

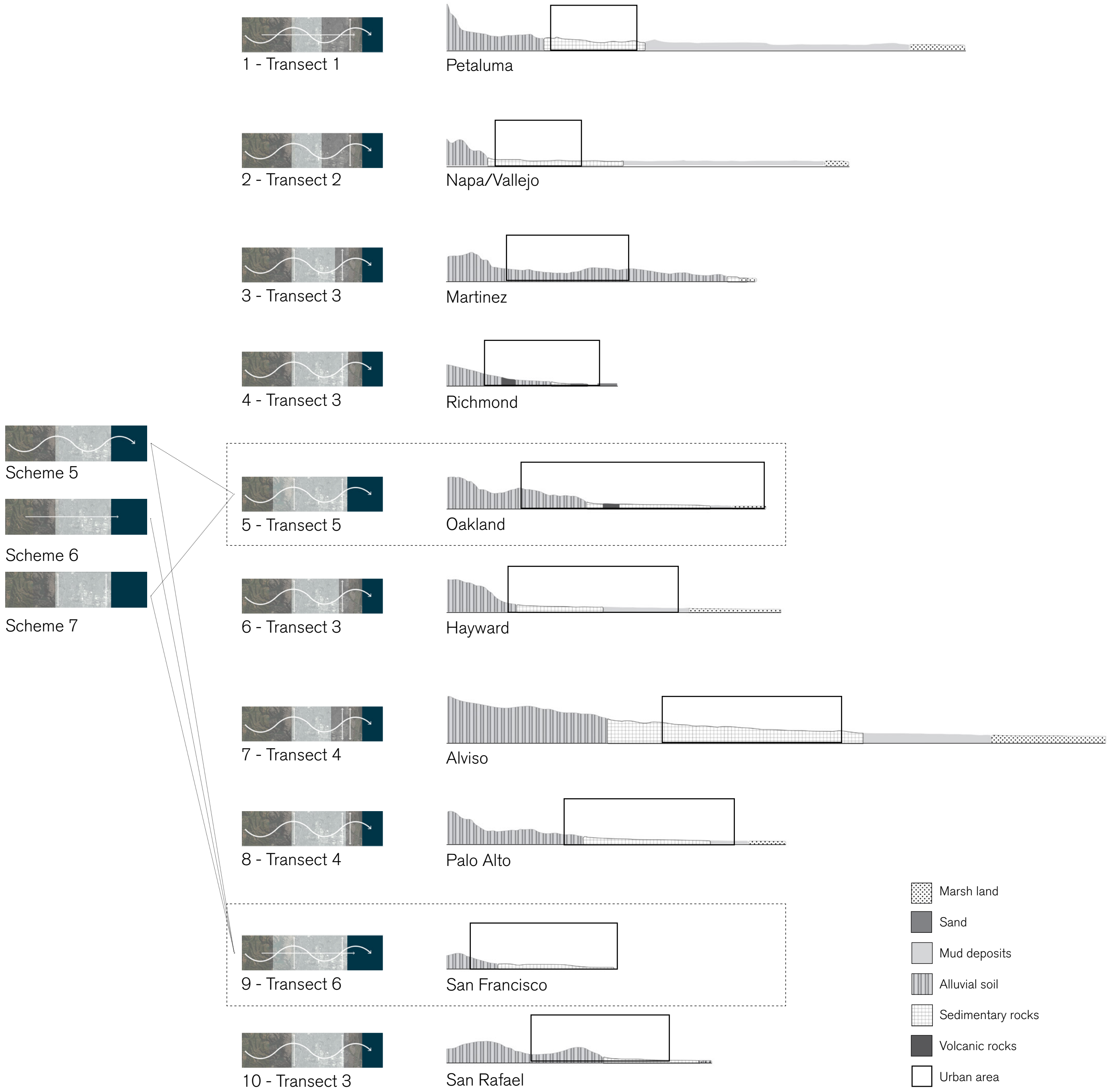


Figure 10.3: Transect study related to location of urban centers. Conclusion diagram. Illustration : Author

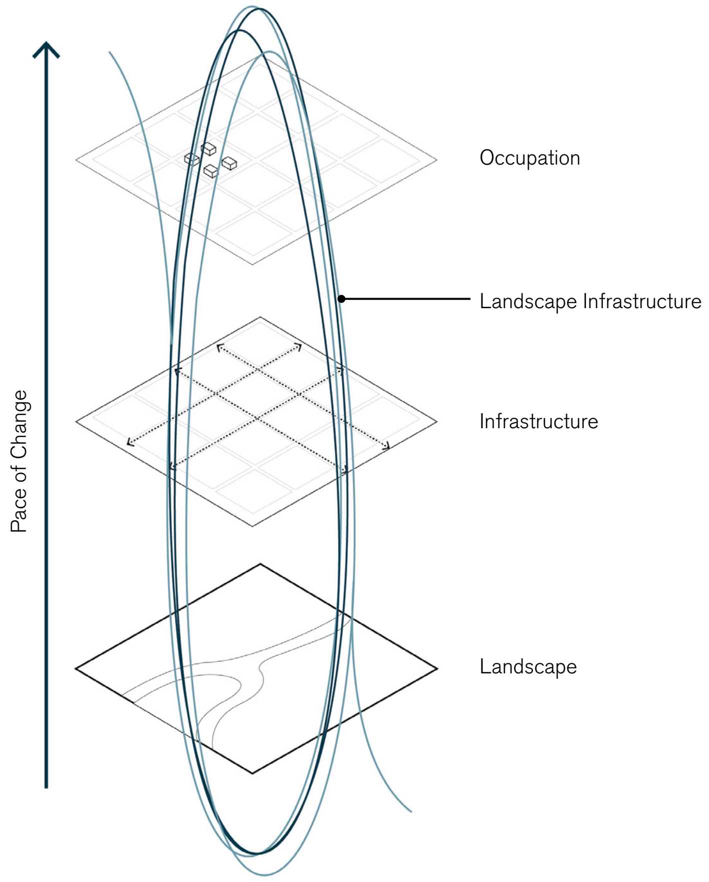


Figure 10.4: Conclusion drawing for research. Illustration : Author

Research conclusions

The three layers of landscape, infrastructure and occupation have been crucial in exploration of this research. The process of developing infrastructure to accommodate hydrological threats needs input from both layers; landscape and urban/occupation. This is observed while unfolding the project. The primary conclusion of the research is, while dealing with hydrological threats the separation of three layers of landscape, occupation and infrastructure gets blurred as one operates through the scales. the separation is vital in the state of analysis but the layers converge while synthesizing which further projects intended infrastructure development.

Reflecting on Objectives

To re-align the relation between urban and natural processes with respect to hydrological vulnerability induced within the territory.

The analysis and synthesis of occupation patterns, infrastructure network and landscape layers through 3x3x3 analysis (Meyer and Nijhuis, 2016) demanded for synergy between urban and natural processes to address the hydrological threats within bay. These threats were addresses through an Ecological approach (Holling, 1996) which embraced the dynamics of both systems and uncertainties involved while operating through their layers. The project commenced by understanding the natural processes as a system and identified critical elements as creeks and open spaces to structure a framework. Further, zooming down to micro scale, it was through the layers of occupation pattern, the land parcels and street networks which were configured with set of rules and parameters derived from this framework. These rules and parameters were designed to meet required performance for functioning of the system. The objective of re-aligning urban and natural processes lead to development of an infrastructure which is derived from landscape and urban elements to accommodate hydrological threats.

To translate this relation into a system of infrastructure which conditions the territory for future urban growth.

The rules and parameters configured at micro scale showcase design principles rather than design solutions. These principles can be achieved in multiple possible ways for the system as a whole to function. The strategy facilitates the future development by embracing challenges due to sea level rise and pluvial and fluvial floods. It creates conditions for future urban growth in the light of climate change. However, project showcases that sea level rise threat is global and regional whereas the design strategies and interventions projected are local.

To develop infrastructure with a systemic approach which operates across spatial and temporal scales to address the uncertainty.

Urbanized delta being a very complex condition involves urban and natural processes which operate at different scales and speed. Hence working through scales and a systemic approach is important for this project. Local and large-scale knowledge combined with temporal dimension is necessary to understand system behavior in normal and disruptive state. This understanding helped identify critical elements of green and blue network which will recover the system from disruption due to pluvial and fluvial flooding or adapt to changing conditions of sea level rise. The systemic method of analysis and synthesis of layers lead to the projection of infrastructure which operates from a regional scale down to land parcel level.

To induce in-built flexibility within the designed system to embrace uncertainty involved in the process.

The uncertainty involved within the project is twofold; first it relates to the hydrological threats which is explored through the performance study of the system and second is related to regional socio-economic changes which can have multiple future possibilities. Due to these crucial variables, the design strategy cannot be static and operating at single situation but needs to explored with its possibilities. This induces resilience towards occasional shock situations (pluvial and fluvial floods, storm surge events) and adaptive capacity towards increasing stress (sea level rise).

Reflecting and Verifying Hypotheses

The hypotheses of working through scales (space and time) for complex systems has been tested in this project. The 3x3x3 analysis (Meyer and Nijhuis, 2016) helped to understand the evolution of Bay area and identify challenges, contradictions and opportunities within these complex layers. The methodology advocates the approach of working through scales where objectives were set at macro level (Bay area) which were strategized within the context of meso scale (city of Oakland) and further spatially implemented at micro and nano scale (district, land parcels and street).

The primary objective being to restructure the dissected hydrological system is achieved by operating through scales from Bay to the smallest of street network and land parcel. It was observed that working through scales requires establishing parameters for classification of information which can be translated into knowledge that derives decisions for next scale. Further, the process of implementing these decisions helps to evaluate the knowledge and understand transferability within other areas. Delineation and definition of scales is crucial for this approach. Criteria related to common hydrological challenges and geomorphic conditions were used to do so. The idea of patches and corridors were used to develop a system of infrastructure to address hydrological challenges. The function and shape of these patches and corridors changed at every scale, but critical elements like creeks or green patches like urban parks were identified which intersect the scales by operating through them. These elements were the binding factors for all scales.

As described previously, the uncertainty involved within this project is twofold; one related to hydrological threats of frequent flooding (fluvial and pluvial) and sea level rise and second related to uncertain future of the socio-economic conditions of Bay. The project addresses these aspects by exploring the performance of the system designed in terms of hydrological threats and affordance of the system designed in terms of flexibility. These two elements showcase the open-ended nature of project which is a process oriented and performance driven.

Relation of Sub-Research Questions to Methodology

How can landscape be understood and conditioned as an operative ground for infrastructure to address frequent flooding, storm surges and sea level rise?

Methods – Analysis | Synthesis | Projection
Study – Mapping | Transect | Rational method | 4 Domain Approach | Scenario
Projection – Landscape Infrastructure Syntax | Urban Landscape Infrastructure Matrix

The method of 3x3x3 analysis (Meyer and Nijhuis, 2016) and the concepts of corridors and patches explained in Landscape Ecology (Dramstad et al., 1996) played a vital role in reading the territory. It was realized through the project that, to develop landscape as an infrastructure it is crucial to read and identify critical elements which structure the ecology of territory. Managing complex systems of natural processes is very difficult, hence the project focuses on developing a framework based on these critical landscape structures which will condition and facilitate future urban growth by embracing the hydrological threats of territory. By working through scales in space, time and through section the territory is developed as an infrastructure ground to accommodate water. The process of reading landscape and urban forms within it is done through analysis and synthesis of their layers. This analysis and synthesis speculates a projection of potential infrastructure.

How will trans-scalar approach help in addressing uncertainty within hydrological challenges of urbanized deltas?

Methods – Analysis | Synthesis | Projection
Study – Mapping | Transect | 4 Domain Approach | Scenario
Projection – Landscape Infrastructure Syntax | Urban Landscape Infrastructure Matrix | Land parcel configurations
Urbanized delta being a very complex condition involves urban and natural processes which operate at different scales and speed. Hence working through scales and a systemic approach is important for this project. Local and large-scale knowledge combined with temporal dimension is necessary to understand system behavior in normal and disruptive state. This understanding helped identify critical elements of green and blue network which will recover the system from disruption due to pluvial and fluvial flooding or adapt to changing conditions of sea level rise. The systemic method of analysis and synthesis of layers lead to the projection of infrastructure which operates from a regional scale down to land parcel level.

How will an open-ended design approach guide in addressing the uncertain contingents of the research project?

Methods – Analysis | Synthesis | Projection
Study – 4 Domain Approach | Scenario
Projection – Urban Landscape Infrastructure Matrix | Land parcel configurations | Affordance exploration
The uncertainty involved within the project is twofold; first it relates to the hydrological threats which is explored through the performance study of the system and second is related to regional socio-economic changes which can have multiple future possibilities. Due to these crucial variables, the design strategy cannot be static and operating at single situation but needs to explored with its possibilities. This induces resilience towards occasional shock situations (pluvial and fluvial floods, storm surge events) and adaptive capacity towards increasing stress (sea level rise).

How to determine criteria to delineate scales in a trans-scalar approach?

Methods – Analysis | Synthesis
Study – Mapping | Transect
Projection – Landscape Infrastructure Syntax | Urban Landscape Infrastructure Matrix
It is very important to set parameters to delineate every scale within the analytical and projective process. The extent of risks that are emerging as a result of the inevitable effects of urbanisation do not coincide with administrative borders. The scales are set by geomorphological boundaries of watershed, river basins and their sub and micro basin, as all these units share common hydrological conditions which lies at the core of this research.

Figure 11.1: Aerial photo of Golden Gate Bridge. Source : Getty images

Reflection

Relation between the research and design

The overall aim of the research project was to understand the relation between the urbanization pattern and environmental processes within the context of delta regions in the light of climate change, specifically sea level rise and increased frequency of floods. The projection of this enquiry upon the case of San Francisco bay area led to the inference that; the dichotomy between urbanization pattern and environmental degradation led to increase in hydrologically induced vulnerability.

The region requires a resilient and an adaptive approach to tackle these challenges. The reason being both the processes (urbanization and ecology) are dynamic in nature with multiple potential futures which are uncertain. Due to these uncertainties and dynamic behaviour an Ecological resilience (Holling, 1996) approach was perceived in the project. The principles defining this approach are persistence, change and unpredictability (Holling, 1996). These aspects framed the research question;

How to systematically develop landscape as an operative ground for infrastructure through multiple scales in an urbanized delta to address uncertainties involved within hydrologically induced vulnerability?

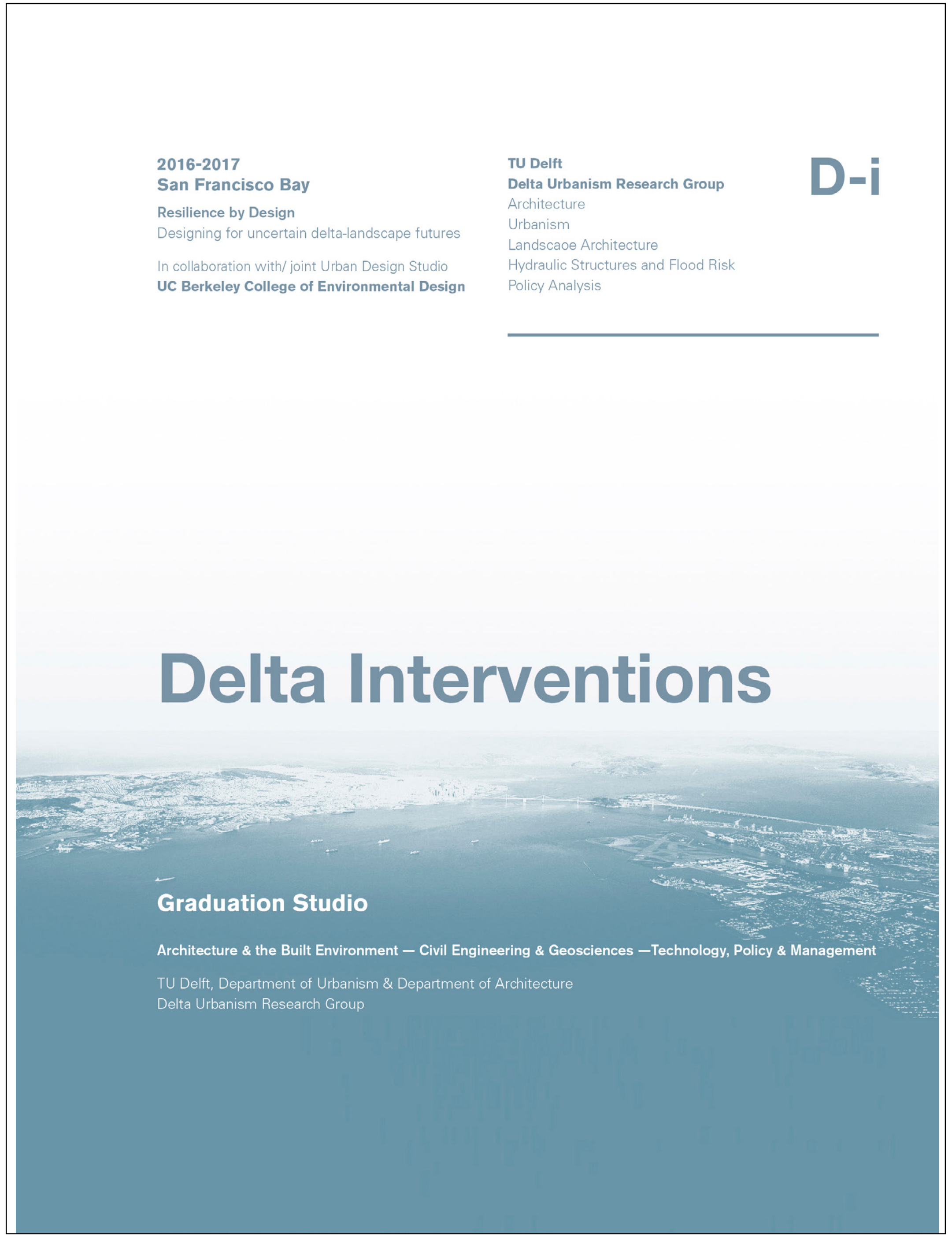
The research had three major aspects to deal with;

1. Developing landscape as an operative ground for infrastructure.
2. Working through different scales.
3. Working in a temporal dimension.

Aspect one - from the research it was realised that urbanization process most of the time is proactive and opportunistic whereas the ecological process or landscape is reactive. When a project perceives a landscape based approach, more than managing the ecological systems, managing the human activities is crucial, to which over time landscape will react. It is very important to understand system behaviour in its normal state and its disaster response to identify critical elements which bring change and which help the system to return to a desirable state after disturbance. These elements structure the framework which is informed through the layers of landscape, infrastructure and occupational patterns or urbanization. In this project, the creeks along the bay were critical elements identified which were used to establish the framework for the operation of infrastructure.

Aspect two - In the process of understanding the relation between these two systems of urbanization and ecology there are several sub-systems which make these processes function. These sub-systems work at different scales; for instance, from a leaf to regional ecosystem or from a tap to regional network of water supply infrastructure. To identify critical structure or elements of change or persistence it is very important for a local and large-scale knowledge to be combined with time factor. Having said that, within the research project four scales were identified based on common challenges, objectives and implementation ideas. Each scale influenced or informed the adjacent scale to address these hydrological challenges. Within this trans-scalar approach, method of analysis-synthesis-projection was used while moving from one scale to another. The projections on a particular scale acted as a hypothesis for the next scale which was either proved true or false post understanding the latter scale. This method made it evident that a trans-scalar approach is a part of research by design methodology which also demands for a non-linear method of working. Moreover, this methodology was realised to be more about the process and assessment rather than single solution.

Aspect three - designing for time is one of the important aspects for an ecological resilience


2016-2017
San Francisco Bay
Resilience by Design
Designing for uncertain delta-landscape futures
In collaboration with/ joint Urban Design Studio
UC Berkeley College of Environmental Design

TU Delft
Delta Urbanism Research Group
Architecture
Urbanism
Landscaoe Architecture
Hydraulic Structures and Flood Risk
Policy Analysis

D-i

Delta Interventions

Graduation Studio

Architecture & the Built Environment — Civil Engineering & Geosciences —Technology, Policy & Management

TU Delft, Department of Urbanism & Department of Architecture
Delta Urbanism Research Group

approach. As the three fundaments of this approach are persistence, change and unpredictability; working through time helps to identify the critical elements as mentioned before. The other aspect of working through time is to prepare for contingencies. For this, the idea of design being open-ended was explored; where design principles are defined rather than design solutions; the difference being, these principles establish set of actions to be performed and goals to be achieved which can be done in multiple possible ways. These design principles are developed based on the analysis-synthesis-projection method. The intention is to develop a system which can achieve its objectives to address the hydrological challenges in various possible ways and the temporal dimension helps to explore these multiple possibilities.

In the process of perceiving the aim of research, a methodological framework was developed with three major dimensions of scale, time and performance. The design was informed by these dimensions to approach the project and derive certain set of actions. The research itself demanded for a process driven, evolutionary design rather than a static end product outcome. Moreover, the design decisions were continuously assessing the objectives of research at every scale. This process led to strong belief that the research followed a method of Research by Design. The three layers of landscape, infrastructure and occupation were crucial in exploration of this research. The process of developing infrastructure to accommodate hydrological threats needs input from both layers; landscape and urban/occupation. This is observed while unfolding the project. The primary conclusion of the research is, while dealing with hydrological threats the separation of three layers of landscape, occupation and infrastructure gets blurred as one operates through the scales.

The separation is vital in the state of analysis but the layers converge while synthesizing which further projects intended infrastructure development.

The research perceives challenges in hand through the lens of landscape. However, this needs three more perspectives; social, economic and political, which would create a holistic study which can be opened for discussion.

Relation between the research group and subject of the project

Delta urbanism is a research group which focuses on integrated approach between design, engineering, planning and policy management within deltaic context; one of the highly urbanized, economically rich and hydrologically vulnerable regions. The climate disruption adds into this vulnerability which is what the research group also focuses on, thereby building on new relations between the natural processes and societal practices for a sustainable and resilient future.

The graduation project shares the similar interest as a premise for the research being; to understand the relation between the urbanization pattern and environmental processes within the context of delta regions in the light of climate change; specifically, sea level rise and increased frequency of floods. Moreover, the goal of the research is to develop a performative, multifunctional design or an adaptive strategy for a dynamic and uncertain future. One of the three major aspects of the research project lie in developing a strategy with an open-ended design dimension to address uncertainties.

The research group aims to approach the goal through different scales working across different disciplines. The second aspect of the research project is to work through scales. The systems involved demand for a trans-scalar analysis due to their complexity. This analysis helped to identify the critical elements and structures which determined the core performance of the new infrastructure to address the hydrological challenges.

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Risk and Hazard maps by temblor
link - http://temblor.net/earthquake-insights/us-flood-maps-flood-zone-1146/

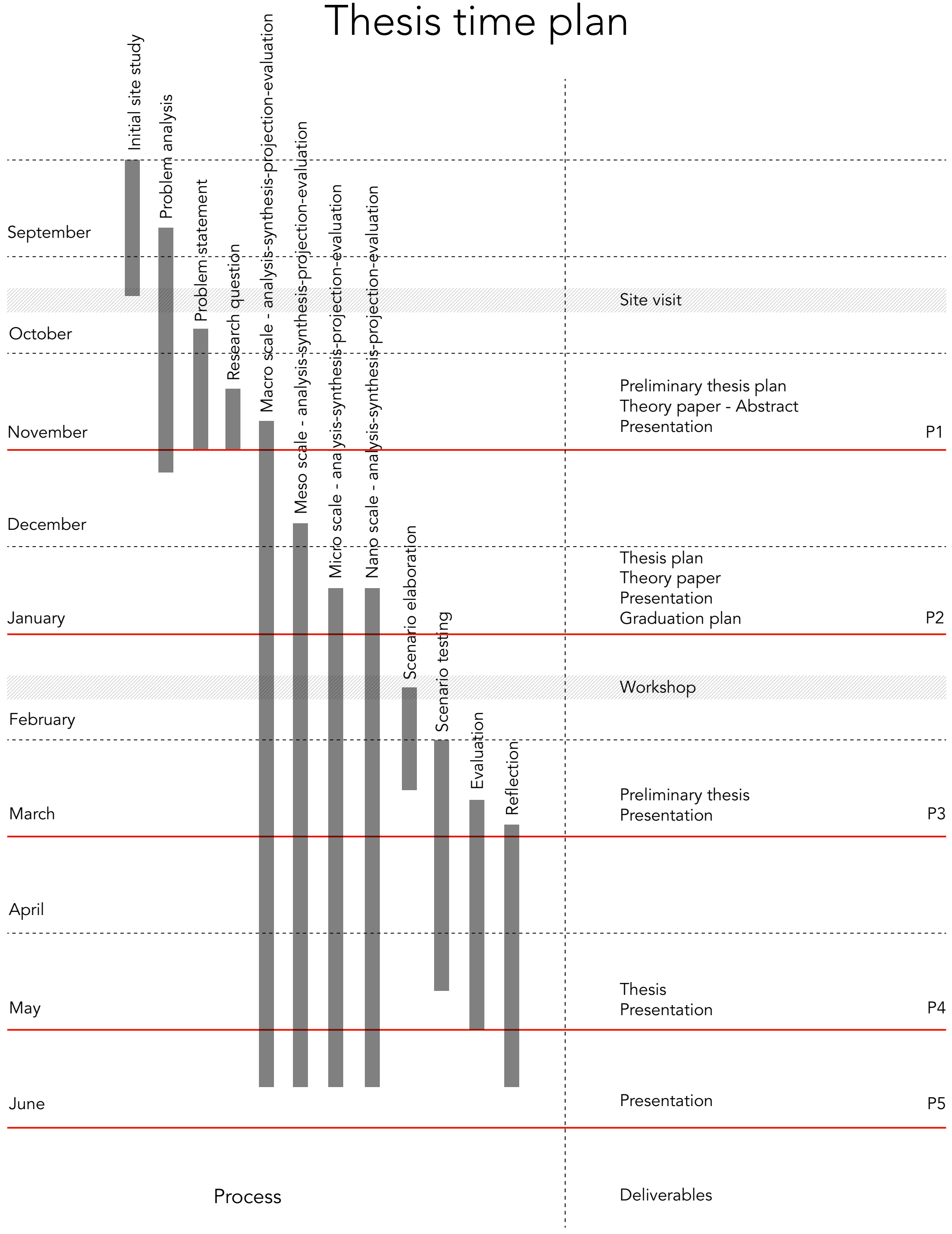
Surging Seas Risk Finder
link - http://riskfinder.climatecentral.org/place/san-francisco.ca.us?comparisonType=place&forecastType=NRC_Medium&level=3&unit=ft

Flood control and water conservation district, Alameda county
link - http://www.acfloodcontrol.org/resources/explore-watersheds/

Appendix

Figure 12.1: Source : http://68.media.tumblr.com/09e24ff84b6e88bc4775135a26122f27/tumblr_oc2zrhDScC1tkxublo1_1280.jpg

Thesis time plan



Rational Method Calculations

Table 1 Runoff Coefficients for the Rational Method

	FLAT	ROLLING	HILLY
Pavement & Roofs	**0.90**	**0.90**	**0.90**
Earth Shoulders	0.50	0.50	0.50
Drives & Walks	0.75	0.80	**0.85**
Gravel Pavement	**0.85**	**0.85**	**0.85**
City Business Areas	0.80	**0.85**	**0.85**
Apartment Dwelling Areas	0.50	0.60	0.70
Light Residential: 1 to 3 units/acre	0.35	0.40	0.45
Normal Residential: 3 to 6 units/acre	0.50	0.55	0.60
Dense Residential: 6 to 15 units/acre	0.70	0.75	0.80
Lawns	0.17	0.22	0.35
Grass Shoulders	0.25	0.25	0.25
Side Slopes, Earth	0.60	0.60	0.60
Side Slopes, Turf	0.30	0.30	0.30
Median Areas, Turf	0.25	0.30	0.30
Cultivated Land, Clay & Loam	0.50	0.55	0.60
Cultivated Land, Sand & Gravel	0.25	0.30	0.35
Industrial Areas, Light	0.50	0.70	0.80
Industrial Areas, Heavy	0.60	0.80	**0.90**
Parks & Cemeteries	0.10	0.15	0.25
Playgrounds	0.20	0.25	0.30
Woodland & Forests	0.10	0.15	0.20
Meadows & Pasture Land	0.25	0.30	0.35
Unimproved Areas	0.10	0.20	0.30

Note:

- ***Impervious surfaces in bold***
- *Rolling = ground slope between 2 percent to 10 percent*
- *Hilly = ground slope greater than 10 percent*

Sausal creek

	flat	rolling	hilly			
Total area of micro basin			10855244.14	sq.mt		
sub-division 1 - sq.km			5452367.08	sq.mt		
roof		469914	422922.6		8.618532	%
road		450106.88	405096.192		8.255256	%
woodlands and forest		2128838.91	319325.8365		39.04431	%
unknown		2403507.29	480701.458		44.08191	% balance area
composite value of C			1628046.087	sq.mt		
			100 yr	10 yr		
Cf			1.25	1		
i			0.03	mt/hr		
p			147.57	91.94 mm/day		
Q=Cf*C*i*A			61051.72824	48841.38 cu.mt/hr		
Q=p*A*0.001			240250.761	149682.6 cu.mt		
			4.406357046	2.745277		% area reqiured with 1 mt depth
new green			148451.54		2.722699	%
sub-division 2 - sq.km			3579618.94	sq.mt		
roof		484269.57	435842.613		13.52852	%
road		595538.16	535984.344		16.63691	%
schools and university		151280.04	128588.034		4.226149	%
business/commercial		13341.37	11340.1645		0.372704	%
parks		293752.45	44062.8675		8.206249	%
playgrounds		29451.24	7362.81		0.822748	%
heathlands		27042.91	22986.4735		0.755469	%
unknown		1984943.2	396988.64		55.45124	% balance area
composite value of C			1583155.947	sq.mt		
			100 yr	10 yr		
Cf			1.25	1		
i			0.03	mt/hr		
p			147.57	91.94 mm/day		
Q=Cf*C*i*A			59368.34799	47494.68 cu.mt/hr		
Q=p*A*0.001			233626.323	145555.4 cu.mt		
			6.526569642	4.066225		% area reqiured with 1 mt depth
new green			197455.88		5.516115	%
sub-division 3 - sq.km			1823213.99	sq.mt		
roof	463616.23		417254.607		25.42851	%
road	319420.69		287478.621		17.51965	%
school/university (in)	49006.35		41655.3975		2.68791	%
commercial (in)	7995.89		6396.712		0.43856	%
brownfield (in)	10629.09		1062.909		0.582986	%
parks	24607.46		2460.746		1.349675	%
heathlands (in)	55721.25		47363.0625		3.05621	%
unknown	892217.03		89221.703		48.9365	% balance area
composite value of C			892893.758	sq.mt		
			100 yr	10 yr		
Cf			1.25	1		
i			0.03	mt/hr		
p			147.57	91.94 mm/day		
Q=Cf*C*i*A			33483.51593	26786.81 cu.mt/hr		
Q=p*A*0.001			131764.3319	82092.65 cu.mt		
			7.227036025	4.502634		% area reqiured with 1 mt depth
new green			103672.25		5.686236	%
sea level rise by 2100 area in micro basin			13883.1	sq.mt.		
approx. till the contour of 6.09 mts. Hence total vol.			84548.079	cu.mt	4.63731	%

Lion creek

	flat	rolling	hilly			
Total area of micro basin			9226174.93	sq.mt		
sub-division 1 - sq.km			3059903.93	sq.mt		
roof		238771.8	214894.62		7.803245	%
road		669277.05	602349.345		21.87249	%
forest		802170.98	160434.196		26.21556	%
parks		221888.2	55472.05		7.251476	%
sports field		44628.79	13388.637		1.458503	%
heathlands		66026.58	56122.593		2.157799	%
school university		305272.42	259481.557		9.976536	%
unknown		711868.11	213560.433		23.26439	% balance area
composite value of C			1575703.431	sq.mt		
		100 yr		10 yr		
Cf			1.25	1		
i			0.03	mt/hr		
p			147.57	91.94 mm/day		
Q=Cf*C*i*A			59088.87866	47271.1 cu.mt/hr		
Q=p*A*0.001			232526.5553	144870.2 cu.mt		
			7.599145615	4.734468		% area reqiured with 1 mt depth
new green						%
sub-division 2 - sq.km			3638590.41	sq.mt		
roof		429078.43	386170.587		11.79244	%
road		478715.15	430843.635		13.15661	%
forest		706627.28	141325.456		19.42036	%
parks		290458.3	72614.575		7.982715	%
sports		10784.02	3235.206		0.296379	%
logistics		8765.4	7012.32		0.240901	%
commercial		25464	21644.4		0.699831	%
heathlands		23084.21	19621.5785		0.634427	%
schools university		131875.02	112093.767		3.624344	%
unknown		1533738.6	460121.58		42.152	% balance area
composite value of C			1654683.105	sq.mt		
		100 yr		10 yr		
Cf			1.25	1		
i			0.03	mt/hr		
p			147.57	91.94 mm/day		
Q=Cf*C*i*A			62050.61642	49640.49 cu.mt/hr		
Q=p*A*0.001			244181.5857	152131.6 cu.mt		
			6.710884112	4.181058		% area reqiured with 1 mt depth
new green						%
sub-division 3 - sq.km			2527270.51	sq.mt		
roof	502962.61		452666.349		19.90142	%
road	404749.92		364274.928		16.0153	%
parks	76852.19		7685.219		3.040917	%
sports field	34852.8		6970.56		1.379069	%
logistics	153467.5		76733.75		6.07246	%
brownfield	4848.35		484.835		0.191841	%
heathland	80710.78		68604.163		3.193595	%
school/university	507069.89		431009.4065		20.06393	%
unknown	761756.47		76175.647		30.14147	% balance area
composite value of C			1484604.858	sq.mt		
		100 yr		10 yr		
Cf			1.25	1		
i			0.03	mt/hr		
p			147.57	91.94 mm/day		
Q=Cf*C*i*A			55672.68216	44538.15 cu.mt/hr		
Q=p*A*0.001			219083.1388	136494.6 cu.mt		
			8.668764897	5.400869		% area reqiured with 1 mt depth
new green						%

Peralta creek

	flat	rolling	hilly					
Total area of micro basin				14639406.92	sq.mt			
sub-division 1 - sq.km				907727.92	sq.mt			
roof			95906.11	86315.499			10.56551	%
road			70975.42	63877.878			7.819019	%
parks			387007.38	96751.845			42.63473	%
sports field			2578.56	773.568			0.284067	%
meadows			28148.37	9851.9295			3.10097	%
heathlands			8383.68	7126.128			0.92359	%
unknown			314728.4	94418.52			34.67211	% balance area
composite value of C				359115.3675	sq.mt			
				100 yr	10 yr			
Cf				1.25	1			
i				0.03		mt/hr		
p				147.57	91.94	mm/day		
Q=Cf*C*i*A				13466.82628	10773.46	cu.mt/hr		
Q=p*A*0.001				52994.65478	33017.07	cu.mt		
				5.838165117	3.637331			% area reqiured with 1 mt depth
new green								%
sub-division 2 - sq.km				3805048.3	sq.mt			
roof		905135.94		814622.346			23.78776	%
road		518729.28		466856.352			13.63266	%
schools and university		175656.34		149307.889			4.616402	%
parks		5193.45		779.0175			0.136488	%
heathlands		29660		25211			0.779491	%
unknown		2170673.29		434134.658			57.04719	% balance area
composite value of C				1890911.263	sq.mt			
				100 yr	10 yr			
Cf				1.25	1			
i				0.03		mt/hr		
p				147.57	91.94	mm/day		
Q=Cf*C*i*A				70909.17234	56727.34	cu.mt/hr		
Q=p*A*0.001				279041.775	173850.4	cu.mt		
				7.333462101	4.56894			% area reqiured with 1 mt depth
new green								%
sub-division 3 - sq.km				9928106.43	sq.mt			
roof	2864216.6			2577794.94			28.84958	%
road	1369466.7			1232520.03			13.79384	%
parks	105253.62			10525.362			1.060158	%
sports field	28214.05			5642.81			0.284184	%
heathland	72548.96			61666.616			0.730743	%
school/university	220886.54			187753.559			2.224861	%
logistics	420697.86			210348.93			4.237443	%
brownfield	18285.76			1828.576			0.184182	%
unknown	4828536.34			482853.634			48.63502	% balance area
composite value of C				4770934.457	sq.mt			
				100 yr	10 yr			
Cf				1.25	1			
i				0.03		mt/hr		
p				147.57	91.94	mm/day		
Q=Cf*C*i*A				85974.91281	68779.93	cu.mt/hr		
Q=p*A*0.001				704046.7978	438639.7	cu.mt		
				7.091450951	4.418161			% area reqiured with 1 mt depth
new green								%
downstream area out of both basins - sq.km				1412464.24	sq.mt			
roof	326906.28			294215.652			23.14439	%
road	200951.89			180856.701			14.22704	%
park	41967.82			4196.782			2.971248	%
sports	1149.24			229.848			0.081364	%
heathlands	83881.53			71299.3005			5.938666	%
schools/university	10130.79			8611.1715			0.717242	%
logistics	295747.93			147873.965			20.93844	%
brown field	14172.64			1417.264			1.003398	%
commercial	91670.51			73336.408			6.490112	%
unknown	345885.61			34588.561			24.4881	% balance area
composite value of C				816625.653	sq.mt			
				100 yr	10 yr			
Cf				1.25	1			
i				0.03		mt/hr		
p				147.57	91.94	mm/day		
Q=Cf*C*i*A				30623.46199	24498.77	cu.mt/hr		
Q=p*A*0.001				120509.4476	75080.56	cu.mt		
				8.531858308	5.315573			% area reqiured with 1 mt depth
new green								%

Arryo creek

	flat	rolling	hilly					
Total area of micro basin				16203922.27	sq.mt			
sub-division 1 - sq.km				2384811.42	sq.mt			
roof			177686.77	159918.093			7.450768	%
road			122580.42	110322.378			5.140047	%
forest			869933.45	173986.69			36.47808	%
unknown			1214610.8	364383.234			50.9311	% balance area
composite value of C				808610.395	sq.mt			
				100 yr	10 yr			
Cf				1.25	1			
i				0.03		mt/hr		
p				147.57	91.94	mm/day		
Q=Cf*C*i*A				30322.88981	24258.31	cu.mt/hr		
Q=p*A*0.001				119326.636	74343.64	cu.mt		
				5.00360888	3.11738			% area reqiured with 1 mt depth
new green								%
sub-division 2 - sq.km				9419080.85	sq.mt			
roof		811580.99		730422.891			8.61635	%
road		827829.19		745046.271			8.788853	%
forest		1833212.33		274981.8495			19.46275	%
parks		227330.09		34099.5135			2.413506	%
sports		13340.24		3335.06			0.14163	%
golf		701079.7		175269.925			7.443186	%
heathlands		46973.26		39927.271			0.498703	%
schools university		162770.61		138355.0185			1.728094	%
unknown		4794964.44		958992.888			50.90693	% balance area
composite value of C				3100430.688	sq.mt			
				100 yr	10 yr			
Cf				1.25	1			
i				0.03		mt/hr		
p				147.57	91.94	mm/day		
Q=Cf*C*i*A				116266.1508	93012.92	cu.mt/hr		
Q=p*A*0.001				457530.5566	285053.6	cu.mt		
				4.857486244	3.026342			% area reqiured with 1 mt depth
new green								%
sub-division 3 - sq.km				4398472.52	sq.mt			
roof	1234495.77			1111046.193			28.06647	%
road	612018.84			550816.956			13.91435	%
parks	176815.8			17681.58			4.019936	%
sports field	33397.74			6679.548			0.759303	%
commercial	112001			89600.8			2.546361	%
brownfield	22631.02			2263.102			0.51452	%
heathland	81717.27			69459.6795			1.857856	%
school/university	207353.86			176250.781			4.714224	%
unknown	1918041.22			191804.122			43.60698	% balance area
composite value of C				2215602.762	sq.mt			
				100 yr	10 yr			
Cf				1.25	1			
i				0.03		mt/hr		
p				147.57	91.94	mm/day		
Q=Cf*C*i*A				83085.10356	66468.08	cu.mt/hr		
Q=p*A*0.001				326956.4995	203702.5	cu.mt		
				7.433410077	4.63121			% area reqiured with 1 mt depth
new green								%

Table B-1 Plant List for Stormwater Measures

		Bioretention Area - including linear treatment measure	Flow-Through Planters	Tree Well Filters[2]	Vegetated Buffer Strip	Infiltration Trench	Extended Detention Basin - biotreatment soil	Extended Detention Basin - non-biotreatment soil	Turf Block Pavers	Green Roof - extensive	Green Roof - intensive	California Native	Drought Tolerant^
Emergent Species													
Artemisia douglasiana	mugwort						✓	✓				✓	
Carex barbarae	Santa Barbara sedge				✓		✓	✓		✓	✓	✓	✓
Carex densa	dense sedge						✓	✓				✓	
Carex obnupta	slough sedge						✓	✓				✓	
Eleocharis macrostachya	creeping spikerush					✓	✓	✓				✓	
Hydrocotyle ranunculoides	marsh pennywort		✓					✓				✓	
Juncus balitcus [1]	baltic rush						✓	✓				✓	
Juncus bufonius	toad rush						✓	✓				✓	
Juncus effusus [1]	Pacific rush						✓	✓				✓	
Juncus leseurii	common rush						✓	✓				✓	
Juncus mexicanus	Mexican rush						✓	✓				✓	
Juncus patens	blue rush	✓	✓		✓	✓	✓	✓			✓	✓	✓
Juncus xiphioides	iris-leaved rush						✓	✓				✓	
Limonium californicum	Marsh rosemary						✓	✓				✓	✓
Phragmites spp.	common reeds						✓	✓					
Scirpus actutus	tule						✓	✓				✓	
Scirpus americanus [1]	three square	✓					✓	✓				✓	
Scirpus californicus [1]	california bulrush						✓	✓				✓	
Spartina foliosa	California cordgrass						✓	✓				✓	
Typha angustifolia	narrowleaf cattail						✓	✓				✓	
Typha latifolia	cattail						✓	✓				✓	
Grass Species													
Agrostis exarata	spike bentgrass						✓	✓	✓			✓	
Alopecurus aequalis	shortawn foxtail						✓	✓				✓	
Alopecurus saccatus	Pacific foxtail						✓	✓				✓	
Aristida purpurea	Purple three-awn	✓	✓		✓						✓	✓	✓
Carex pansa	California meadow sedge			✓	✓		✓	✓	✓	✓	✓	✓	✓
Carex praegracilus	clustered field sedge						✓	✓				✓	
Carex divulsa (tumulicola)	Berkeley sedge							✓				✓	
Chondropetalum tectorum	cape rush	✓	✓		✓	✓	✓	✓			✓		✓
Danthonia californica	California oatgrass						✓	✓				✓	
Deschampsia cespitosa [1]	tufted hairgrass	✓			✓	✓	✓	✓			✓	✓	✓
Deschampsia cespitosa ssp. holciformis	Pacific hairgrass	✓			✓	✓	✓	✓			✓	✓	✓
Deschampsia danthonioides	annual hairgrass						✓	✓			✓	✓	
Distichlis spicata	salt grass						✓	✓				✓	
Eleocharis palustris	creeping spikerush						✓	✓				✓	
Elymus glaucus	blue wild rye	✓			✓			✓		✓	✓	✓	✓
Festuca californica	California fescue	✓	✓	✓	✓						✓	✓	✓
Festuca idahoensis	Idaho fescue		✓	✓	✓				✓		✓	✓	
Festuca rubra[1]	red fescue		✓	✓	✓				✓		✓	✓	✓
Festuca rubra 'molate'	Molate fescue		✓	✓	✓				✓		✓	✓	✓
Hordeum brachyantherum [1]	meadow barley	✓			✓		✓	✓				✓	✓
Leymus triticoides	creeping wildrye	✓			✓	✓		✓			✓	✓	✓
Linum usitatissimum [1]	flax	✓	✓										✓
Lolium perenne [1]	ryegrass	✓	✓			✓							
Melica californica	California melic				✓							✓	✓
Grass Species cont'd													
Melica imperfecta	coast range melic	✓	✓		✓							✓	✓
Muhlenbergia rigens	deergrass	✓	✓		✓	✓	✓	✓			✓	✓	✓

** Denotes riparian species with limited drought tolerance*
[1] Denotes species with phytoremediation capabilities
[2] Non-tree species to be used only with adequate planting surface and when infiltration rates are 5-10 inches/hour

Table B-1 Plant List for Stormwater Measures

		Bioretention Area - including linear treatment measure	Flow-Through Planters	Tree Well Filters[2]	Vegetated Buffer Strip	Infiltration Trench	Extended Detention Basin - biotreatment soil	Extended Detention Basin - non-biotreatment soil	Turf Block Pavers	Green Roof - extensive	Green Roof - intensive	California Native	Drought Tolerant^
Nasella pulchra	purple needlegrass	✓		✓	✓	✓					✓	✓	✓
Nassella lepida	Foothill needlegrass			✓	✓	✓					✓	✓	✓
Panicum coloratum [1]	kleingrass	✓	✓		✓	✓							
Panicum virgatum [1]	switchgrass	✓	✓		✓	✓							
Phalaris californica	California canarygrass	✓			✓	✓						✓	
Pleuropogon californicus	semaphore grass				✓	✓						✓	
Sisyrinchium bellum	blue-eyed grass		✓		✓	✓				✓		✓	✓
Sisyrinchium douglasii	purple-eyed grass					✓				✓		✓	
Herbaceous Species													
Achillea millefolium [1]	common yarrow		✓	✓	✓					✓	✓	✓	✓
Allium spp.	wild onion	✓	✓		✓					✓	✓		
Anthemis nobilis (Chamaemelum nobile)	chamomile			✓					✓				✓
Armeria maritima	sea pink		✓	✓	✓					✓	✓	✓	✓
Clarkia spp.	Clarkia	✓			✓					✓	✓	✓	✓
Epilobium densiflorum	dense spike-primrose	✓	✓		✓	✓						✓	✓
Eriogonum latifolium	coast buckwheat			✓	✓							✓	✓
Eriogonum fasciculatum	flattop buckwheat			✓	✓							✓	✓
Eschscholzia californica	California poppy	✓	✓		✓				✓	✓	✓	✓	✓
Layia platyglossa	tidy tips				✓					✓	✓	✓	✓
Limonium californicum	marsh rosemary	✓	✓		✓	✓	✓	✓				✓	✓
Linanthus spp.	Linanthus	✓			✓					✓	✓	✓	✓
Lotus scoparius	deerweed	✓			✓					✓	✓	✓	✓
Mimulus aurantiacus	common monkeyflower	✓	✓		✓						✓	✓	✓
Mimulus cardinalis	scarlet monkeyflower	✓	✓	✓	✓		✓	✓			✓	✓	
Monardella spp.	coyote mint	✓			✓							✓	✓
Nepeta spp.	catmint	✓		✓	✓						✓		✓
Penstemon spp.	bearded tongue	✓		✓	✓						✓	✓	✓
Sedum spp.	stonecrop				✓					✓	✓		✓
Sempervivum spp.	hen and chicks				✓					✓	✓		✓
Solidago spp. [1]	goldenrod		✓		✓					✓	✓		
Thymus pseudolanuginosus	woolly thyme	✓	✓	✓	✓				✓	✓	✓		
Vigna unguiculata [1]	cowpea		✓		✓						✓		
Shrub Species													
Adenostoma fasciculatum	chamise				✓						✓	✓	✓
Arctostaphylos densiflora 'McMinn'	manzanita 'McMinn'	✓	✓		✓						✓	✓	✓
Arctostaphylos manzanita	common manzanita		✓		✓						✓	✓	✓
Arctostaphylos uva-ursi 'Emerald Carpet'	manzanita 'Emerald Carpet'	✓	✓	✓	✓						✓	✓	✓
Baccharis pilularis 'Twin Peaks'	coyote brush prostrate	✓	✓	✓	✓						✓	✓	✓
Baccharis salicifolia	mulefat				✓		✓	✓				✓	
Buddleia spp.	butterfly bush	✓			✓								✓
Calycanthus occidentalis	Spicebush	✓	✓		✓	✓						✓	✓
Carpenteria californica	bush anemone	✓	✓		✓							✓	✓
Shrub Species cont'd													
Ceanothus hearstiorum	ceanothus	✓			✓						✓	✓	✓
Ceanothus spp.	ceanothus	✓			✓						✓	✓	✓
Cercocarpus betuloides	mountain mahogany				✓							✓	✓
Cistus spp.	rockrose				✓								✓
Cornus sericea (same as C. stolonifera)	western dogwood	✓	✓		✓	✓	✓	✓				✓	
Garrya elliptica	coast silk tassle		✓		✓						✓	✓	✓
Echium candicans	pride-of-madeira		✓		✓						✓		✓
Heteromeles arbutifolia	toyon	✓	✓		✓						✓	✓	✓
Holodiscus sp.	oceanspray	✓			✓							✓	✓
Lavandula spp.	lavender		✓	✓	✓						✓		✓
Lavatera spp.	tree mallow				✓								✓

** Denotes riparian species with limited drought tolerance*
[1] Denotes species with phytoremediation capabilities
[2] Non-tree species to be used only with adequate planting surface and when infiltration rates are 5-10 inches/hour

Table B-1 Plant List for Stormwater Measures

		Bioretention Area - including linear treatment measure	Flow-Through Planters	Tree Well Filters[2]	Vegetated Buffer Strip	Infiltration Trench	Extended Detention Basin - biotreatment soil	Extended Detention Basin - non-biotreatment soil	Turf Block Pavers	Green Roof - extensive	Green Roof - intensive	California Native	Drought Tolerant*
Lepechina calycina	pitcher sage				✓							✓	✓
Lupinus albifrons	bush lupine				✓							✓	✓
Mahonia aquifolium	Oregon grape	✓	✓		✓						✓	✓	✓
Mahonia repens	creeping Oregon grape	✓	✓	✓	✓						✓	✓	✓
Myrica californica	Pacific wax myrtle				✓						✓	✓	✓
Physocarpus capitatus	Pacific ninebark	✓		✓	✓		✓	✓			✓	✓	
Pittosporum tobira	mock orange		✓		✓								✓
Prunus ilicifolia	holleyleaf cherry				✓	✓						✓	✓
Rhamnus Californica	coffeeberry	✓	✓		✓						✓	✓	✓
Rhus integrifolia	lemonade berry				✓							✓	✓
Ribes aureum	golden currant	✓	✓		✓	✓						✓	✓
Ribes malvaceum	chaparral currant				✓							✓	✓
Ribes sanguineum	red-flowering currant				✓							✓	✓
Rosa californica	California wild rose	✓	✓		✓	✓						✓	✓
Rubus parviflorus	thimbleberry	✓	✓		✓	✓						✓	
Rubus spectabilis	salmonberry	✓	✓		✓	✓						✓	
Rubus ursinus	California blackberry	✓			✓							✓	✓
Salvia brandegii	black sage				✓							✓	✓
Salvia clevelandii	Cleveland sage	✓			✓							✓	✓
Salvia leucophylla	purple sage	✓			✓							✓	✓
Salvia melifera	black sage				✓							✓	✓
Salvia sonomensis	creeping sage	✓	✓	✓	✓							✓	✓
Sambucus mexicana	elderberry	✓	✓		✓							✓	✓
Santolina spp.	santolina	✓	✓		✓							✓	✓
Symphoricarpos albus	snowberry		✓		✓							✓	✓
Stachys spp.	lambs ear	✓		✓	✓					✓	✓		✓
Styrax officinalis redivivus	California snowdrop	✓			✓							✓	✓
Trichostema spp.	wooly blue curls	✓			✓						✓	✓	✓
Vaccinium ovatum	evergreen huckleberry	✓	✓		✓							✓	
Zauschneria californica (Epilobium c.)	California fuchsia			✓	✓						✓	✓	✓
Tree Species													
Acer circinatum	Vine Maple	✓		✓	✓	✓					✓	✓	
*Acer macrophyllum**	big leaf maple	✓			✓							✓	
Acer negundo v. Californicum*	box elder	✓		✓	✓	✓	✓	✓				✓	
Aesculus californica	buckeye				✓							✓	✓
*Alnus rhombifolia **	white alder	✓		✓	✓		✓	✓				✓	
*Alnus rubra**	red alder	✓		✓	✓	✓	✓	✓				✓	
Arbutus menziesii	Madrone				✓							✓	✓
Arbutus unedo	strawberry tree				✓						✓		✓
Betula nigra	river birch	✓		✓	✓	✓							
Calocedrus decurrens	incense cedar				✓							✓	
Celtis occidentalis	common hackberry				✓								✓
Cercidium floridum	Blue palo verde				✓							✓	✓
Cercis occidentalis	redbud				✓						✓	✓	✓
Chionanthus retusus	Chinese fringe tree				✓								

** Denotes riparian species with limited drought tolerance*
[1] Denotes species with phytoremediation capabilities
[2] Non-tree species to be used only with adequate planting surface and when infiltration rates are 5-10 inches/hour

CLEAN WATER PROGRAM ALAMEDA COUNTY

Table B-1 Plant List for Stormwater Measures

		Bioretention Area - including linear treatment measure	Flow-Through Planters	Tree Well Filters[2]	Vegetated Buffer Strip	Infiltration Trench	Extended Detention Basin - biotreatment soil	Extended Detention Basin - non-biotreatment soil	Turf Block Pavers	Green Roof - extensive	Green Roof - intensive	California Native	Drought Tolerant*
Corylus cornuta v. Californica	California hazelnut	✓		✓	✓							✓	✓
Crataegus	Hawthorn			✓							✓		✓
Fraxinus latifolia	Oregon ash	✓		✓	✓	✓	✓	✓				✓	
Geijera parviflora	Australian willow				✓								
Lagerstroemia spp.	crepe myrtle				✓						✓		✓
Lyanothamnus floribundus asplendifolius	Catalina Ironwood				✓							✓	✓
Morus alba (fruitless var.)[1]	white mulberry				✓								
Platanus acerifolia	london plane tree				✓								✓
*Platanus racemosa**	sycamore	✓			✓		✓	✓				✓	
*Populus fremontii** [1]	Fremont's cottonwood	✓		✓	✓	✓						✓	
Prunus, spp.	plum				✓								✓
Quercus agrifolia	California live oak				✓							✓	✓
Quercus kellogii	California black oak				✓							✓	✓
Quercus lobata	valley oak	✓			✓							✓	✓
Quercus palustris	pin oak				✓								
Quercus virginiana	Southern live oak			✓									
Salix laevigata[1]	red willow	✓			✓	✓	✓	✓				✓	
Salix lasiolepis[1]	arroyo willow	✓			✓	✓	✓	✓				✓	
Salix lucida ssp. lasiandra [1]	shining willow	✓			✓	✓	✓	✓				✓	
Sequoia sempervirens	coast redwood				✓		✓	✓				✓	
Umbellularia californica	California bay				✓							✓	

** Denotes riparian species with limited drought tolerance*
[1] Denotes species with phytoremediation capabilities
[2] Non-tree species to be used only with adequate planting surface and when infiltration rates are 5-10 inches/hour

Re-coupling: Landscape as infrastructure or landscape for infrastructure

Abstract

Since 1970's ecology has been emerging into focus as a strategy and system of design for urban environment and economies. The environmental crisis has generated a sense of urgency to redesign urban infrastructure and rethink about the performance of urban economies. This is due to the inertia in urban planning and overexertion of civil engineering (Bélanger, 2013). Predominant challenges facing urban regions today such as changing climates, resource flows, and population mobility amplify this transition.

Economy, infrastructure, and ecology are important agents that facilitate the processes that shape the built environment and landscape. The worldwide shift from industrial oriented urbanization to globally oriented one in past century has led to ecological degradation. Contemporary urbanization demands for convergence of landscape and infrastructure to reimagine beyond its strictly utilitarian definition, while allowing spatial design to gain operative force in territorial transformation processes (Nijhuis and Jauslin, 2015).

This paper aims to explore the concept of landscape as an infrastructure; a strategic design and dynamic system that operates as urban infrastructure to shape and direct the future of urban economies and occupational pattern into the 21st century.

Introduction

Landscape urbanism, ecological urbanism, landscape infrastructure; these are some of the concepts already in discussion since 1970's environmental crisis emerging recently. The core idea is of integrating landscape or ecology into the planning and design aspect of contemporary city building, addressing in particular to the environmental issues and sustainability. Moreover, challenges like changing climate, resource flows and population mobility have made these concepts more relevant. In this era of Anthropocene, human dominated geological epoch (Crutzen, 2002), the urban landscape has evolved into a complex system extending into deep hinterlands and into the environmental sphere with direct and indirect human influences.

From the nineteenth century onwards, complete river systems became controlled by man in favour of economic growth (e.g. Cioc, 2002; Disco, 2008). Rail, road and energy infrastructures were constructed to integrate and control nations (e.g. Badenoch & Fickers, 2010; Guldi, 2012). Natural landscapes have been transformed into urban, logistic, industrial and waste landscapes (e.g. Meyer & Nijhuis, 2014; Waldheim & Berger, 2008; Prossek et al., 2009; Berger, 2006). Though often successful in geopolitical and economic terms, the engineered infrastructure disrupted the natural setting and defaced the cultural values. Such irreversible harms created by these single purpose design interventions have generated an awareness to strive for more harmonious urban landscape infrastructure.

Infrastructural design; especially the mobility network, plays an important role in steering the urbanization. However, the mono-functional attribute of its design and execution limits its potentials. The unravelling of the dialectic between landscape and infrastructure, and the relationship between processes and formal aspects, is at the core of contemporary criticism and debate among the disciplines of landscape architecture, urban design, civil engineering and architecture (Nijhuis and Jauslin, 2015). So the question lies in, is it about integrating the landscape and ecology in city building and infrastructural design? Or perusing landscape not as a discipline but as a method or a perspective to look at new forms of urbanization? This paper aims at exploring the concept of landscape as an infrastructure in context of strategic designing and process driven attributes among the disciplines of civil engineering, urban design and planning and landscape architecture.

Utility and efficiency

As mentioned earlier, concept of integrating ecology with urbanization process as a strategy and system in design is emerging into focus due to awareness generated by irreversible harms caused during ecological crisis in the due course of Anthropocene era. This transition is also largely visible by the attributes of three major shifts; the rise of environmental concerns since 1970's, the crisis of public works planning in the 1980's, and the erosion of post war structures from 1990's onwards which need an urgent reinvestment (Bélanger, 2013). Predominant challenges facing urban regions today such as changing climates, resource flows, and population mobility amplify this transition. The scale and frequency of infrastructural disasters and technological accidents have increased tremendously. The upward sloping timeline of these disasters in past 3 decades is a blatant indicator; sudden power outages in northeast, rolling blackouts in the southwest, bridge collapses in Midwest, as well as oil spills, hurricanes and levee breaks along gulf coast of North American continent (Petroski, 1985).

These disasters are heightened by the outmoded patterns of land development, supported by standardized engineering solutions, Euclidian land use planning and uncoordinated reactionary planning. Did the practices of engineering and planning really operate well in 20th century under tenets of efficiency and control through centralization or it was just the onset of 21st century and the irreversible harms it caused made us realise the ill practices? This raises the argument whether Fordist modes of production and Taylorist principles of efficiency have oversimplified ecology of urban economies and environment thereby underplaying the social role of urban infrastructure by way of marginalizing and suppressing the living biophysical systems?

The twin disciplines

Central to the argument of reconsideration of role of urban infrastructure in 21st century, civil engineering and urban planning have played a major role in the 19th and 20th century in the city building process. As twin disciplines, they have exercised tremendous influence in building the contemporary urban environment. According to Belanger, the baseline principles of these two disciplines are instructive;

1. Standardization- singular nature of infrastructure as a linear and closed system which is designed for efficiency and economy. It is purely on the bases on eliminating the unknown variables and only considering the known factors which makes it a closed system.

2. Mono-functionality- singularity of land use patterns leads to economic, social and ecological segregation. The dynamic systems become parcelled and closed.

3. Permanence- standardized infrastructure and mono-functional land uses are inflexible to change and fragile to uncertainty.

Through illusion of safety and certainty created by specialization, excluding unknown variables and standardization often exposes larger concentration of urban population to greater risks. This can be observed from the earlier mentioned engineering and planning disasters and technological failures.

Belanger argues that, dominance of efficiency and standardization has led civil engineering central to the design of urban environment. As compared to other

fields of design such as architecture, urban design, social sciences, regional planning, which are over theorized civil engineering has made leaps and bounds by literally operating without theory. Quantitative logic and numerical precision have become foundations for accuracy, efficiency and safety. But the debate lies in, aren't these logics and precisions derived from certain set of thumb rules derived from certain set of theories? There is no doubt that these logics and precisions are for maximum efficiency and utilitarian objectives. But the interesting fact lies in the idea of closed systems which are considered in these calculations. Its foundation relies on isolation of variables and exclusion of less quantifiable and more complex information (Bélanger, 2013).

This points back to the baseline instructive principles of 19th and 20th century engineering and planning of standardization, mono-functionality and permanence, where these disciplines tend to decontextualize the environment by excluding unknown and complex information to make the system efficient. Does this relate to the infrastructural disasters and technological accidents occurring in recent times?

Notions of planning, predictability, centralization and control which were core ideas in the factories and production processes or even military strategies during the rise of mechanization and mass production influenced city building (Bélanger, 2013). Belanger has view that principles of city building such as density and compactness, growth and permanence, stability have deep roots in traditions of military engineering and war time planning. But the current urban infrastructure demands for a collaborative approach which includes the social and ecological aspect of the environment along with accepting and taking into consideration the complexities involved.

This shift in paradigm is a critique on the industrial, Fordist or Taylorist ideologies of efficiency and control as well as a catalyst for decentralised ecological strategies that move beyond engineering and planning.

The divide

The historic lack of engagement of infrastructure in territory of design stems from its dystopic and banal nature (Bélanger, 2013). But this is not true. This lack is not constant throughout the history but has been created during the industrialization process, when the focus was on gaining the maximum from the resources, which still continues. Post industrialization, followed the population explosion and migration or so called urban sprawl. This was majorly due to the low quality of living and pollution within the city centres. Around 60% population in Europe and 80% population in USA started living in along the periphery of the urban areas (Bélanger, 2013). This increased the demand of urban services of transportation and mobility. The sprawl over leaped the city boundaries which were once demarcated during war time or made due to political decisions. And the uncontrollable growth become the new urban problem, which demonstrated the inflexibility of planning.

The idea of decentralization and separating services and functions with land use classification was introduced. In this process planning principles became entrenched in legislation and land use economics, consequently creating a divide between geography and ecology.

"Static boundaries of political jurisdiction stand in sharp contrast to fluid, dynamic patterns of urban growth, whereby flows of water, waste, energy and food transcend geopolitical borders" (Bélanger, 2013).

Rethinking engineering, design and planning

Looking back at these arguments and statements, it

Figure 12.2: Source : Introduced hydrology: The Central Arizona Aqueduct is a 336 mile canal that diverts water from the Colorado River in order to irrigate a million acres of farmland in central Arizona and to provide municipal water in Pheonix and Tucson. Image by USBR on Flickr.

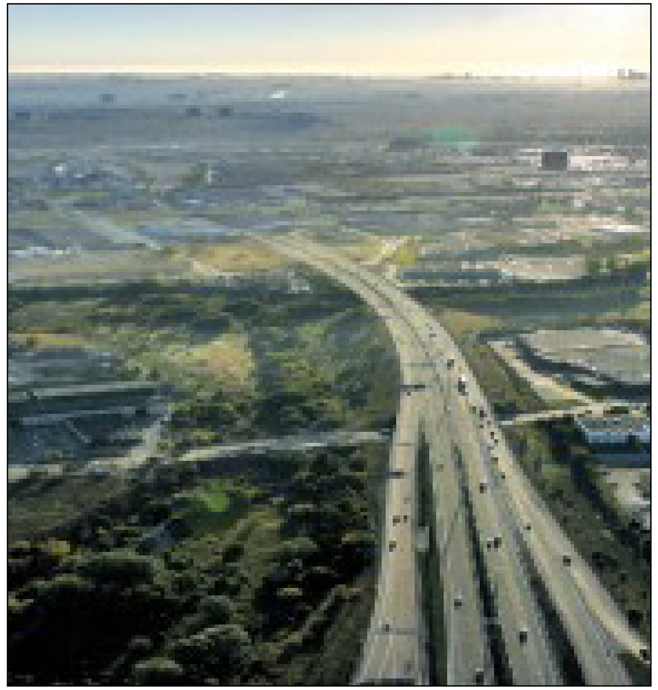


Figure 12.3: Source : http://www.vdaconstruction.com/

makes one re-think about the dominant principles from past 2 centuries which gradually created this divide between disciplines and systems. This thought urges for; or gives rise to a field of multi-disciplinary and cross-scalar convergence of ecology and economy, social and political, organic and technological complexities in and around the urban conditions. This idea might not be a profession or a field but a way of practice which has various terms for it as off; landscape urbanism, landscape infrastructure, ecological urbanism, urban landscape infrastructure.

"In pairing landscape with urbanism, landscape urbanism seeks to reintroduce critical connections with natural and hidden systems and proposes the use of such systems as a flexible approach to the current concerns and problems of the urban condition." (Grey, 2011)

This concept of landscape infrastructure offers a renewed understanding of landscape as infrastructure or an operative ground for infrastructure which can be explored for opportunities and possibilities at regional strategic designs or local interventions. This concept converges civil, agricultural, natural, environmental techniques as operative instruments involving disciplines line civil engineering, hydraulic engineering, landscape architecture, planning. There are at least three potential fields for urban landscape infrastructure design, which emerge from practices which employ the principles as described above: (Nijhuis and Jauslin, 2015)

1. Transport landscape infrastructure – in this field of landscape infrastructure, it is about the urban utility services for mobility and transport, energy production and supply, water supply, waste treatment. This is the field where the integration of technical, aesthetic and social aspect needs to blend. Even ports and dock design involve in this field.

2. Green landscape infrastructure – green landscape field relates to the existing green spaces within and around the urban setup and how these can be connected through network of patches and corridors. This is in line with Richard Forman's Land Mosaics. This adds to the ecological, social and even economic value of the environment.

3. Water landscape infrastructure – water landscape infrastructure field is an important field where landscape plays a vital role of infrastructure for water management and flood risk control. Designing for sea wall, levees, or planning in riparian areas is associated with this field.

All these three fields suggests that, urban landscape infrastructure requires collaboration through scales as well as through disciplines of engineering expertise to design to management.

Reflection

Dane Carlson from graduate School of Design, Harvard; questions Belanger's argument of integrating landscape and infrastructure to guide 21st century city building. According to him landscape is inherently infrastructure, which gives an interesting new take to the debate all together.

"Landscape is defined by human intervention, created through the interactions of humans and a given environment. If we understand landscape to be the result of modification or utilization, and facilitation of program is the intent of modification, landscape becomes infrastructural whenever it is created" (Carlisle and Pevzner).

The above extract from the article mentions that human inhabits landscape to live, produce and commute. And when changes are made to do so, indirectly landscape acts as an infrastructure to aid the functionality of following operations. In short, landscape performs as an operational ground for the infrastructural activity.

Through this understanding, Belanger's proposal of integrating landscape ecology with infrastructure means, appropriating current infrastructural typologies to develop a new system which utilizes landscape as an operational ground.

Infrastructure, by definition, sustains and defines all human settlement and activity. For example, in Nicaragua, harvesting of fruits from the tamarind tree results in the emergence of an ephemeral landscape infrastructure as the ground underneath each tree is cleared before harvesting, resulting in network of circular clearings below the dense tree canopy; Transhumance practices, such as the veranadas of South America, also create a landscape infrastructural network defined by seasonal and climatic flux through the movement of livestock to different seasonal pastures; use of a river by a fishing boat transforms it into an infrastructural entity through the introduction of a system of production derived from the landscape, and this system of production was part of a much larger network of food provision.

The recent shift or an urge of integrating or coupling of engineered infrastructure with the biophysical systems of ecology can be more accurately described as re-integrating or re-coupling. By calling so the diverse and complex history of human work is recognized. As highlighted by Belanger, the industrial era created a divide between ecology and economy, this phenomenon was not constant in the history. There are instances where, the economic functions were in balance with ecological environments long before industrial age. For example, the chinampa agricultural system of the Aztec capital Tenochtitlan was formed by a series of canals which provided continuous subsurface irrigation to island agricultural plots fertilized by nutrient-rich muck from the bottom of Lake Texcoco. By utilizing the existing network of biophysical systems and creating an infrastructural landscape specifically designed for this production system, the chinampas were able to produce an astounding amount of crop yields (up to seven crops of corn per year). Not only was the provision of food an infrastructural system in itself, but the series of canals joining the chinampas allowed goods to be directly taken to market via waterway in addition to providing fertilization and irrigation (Aguilar-Moreno, 2007).

By understanding landscape as the operative ground for infrastructure, and any landscape intervention as inherently infrastructural, our ability to radically redefine infrastructure is expanded and solidified. Recognition of the combined cultural and biophysical parentage of infrastructure also brings historical case study (beyond the industrial age) to a point of particular relevance. Integration of infrastructure with biophysical systems is not a phenomenon limited to a potential future, but has been achieved on a significant scale for thousands of years; rather than discovering this anew, we have the opportunity to rediscover biophysical infrastructure as an integral component of landscape.

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Figure 12.4: Screen shots of movie developed for workshop. Source : Author

Graduation Orientation / workshop

As a part of this research, three day workshop was conducted; Lets Talk About Water - Landscape Narratives: Mainstreaming of Water Sensitive Design; under the guidance of Dr. ir. Taneha Bacchin. The intention of the workshop was to focus on communication of water related complex issues.

The main question raised as a premise for this workshop was; how to best communicate about the needed transformation of paradigm in delivery of the urban water project?   .

The instruments and processes followed in this workshop were construction of narratives/story telling – use of different media and its effects (from text, drawings, diagrams towards video, installations, etc.). The workshop took place in the second week of February, starting on the 6th, final presentation of results on the 10th of February. It was a three day workshop in parallel to the film festival in Delft and Amsterdam. The audience targeted were mainly students from Delta Urbanism and Flowscapes research groups.

This workshop was very much in line with the intention of the research project, that is to develop an infrastructure through landscape as an operative ground for addressing river floods and sea level rise. Volunteering and participating in this workshop provided more perspectives and insights for this topic.

About "Let's Talk About Water"

Let´s Talk About Water aims to start a dialogue between scientists, students and the general public by bringing film and water science together. This year's theme is Water and Power. The title is derived from an experimental film from a California filmmaker, Pat O'Neill, but it is also the name of the utility company in California and the name of the book, Water and Power: the conflict over Los Angeles water supply in the Owen Valley by William Kahrl, upon which Chinatown, the film, is based. The events organised during the programme will take place at De Balie (Amsterdam), Filmhuis Lumen (Delft) and UNESCO-IHE.

Figure 12.5: Embarcadero, San Francisco. Source : Author