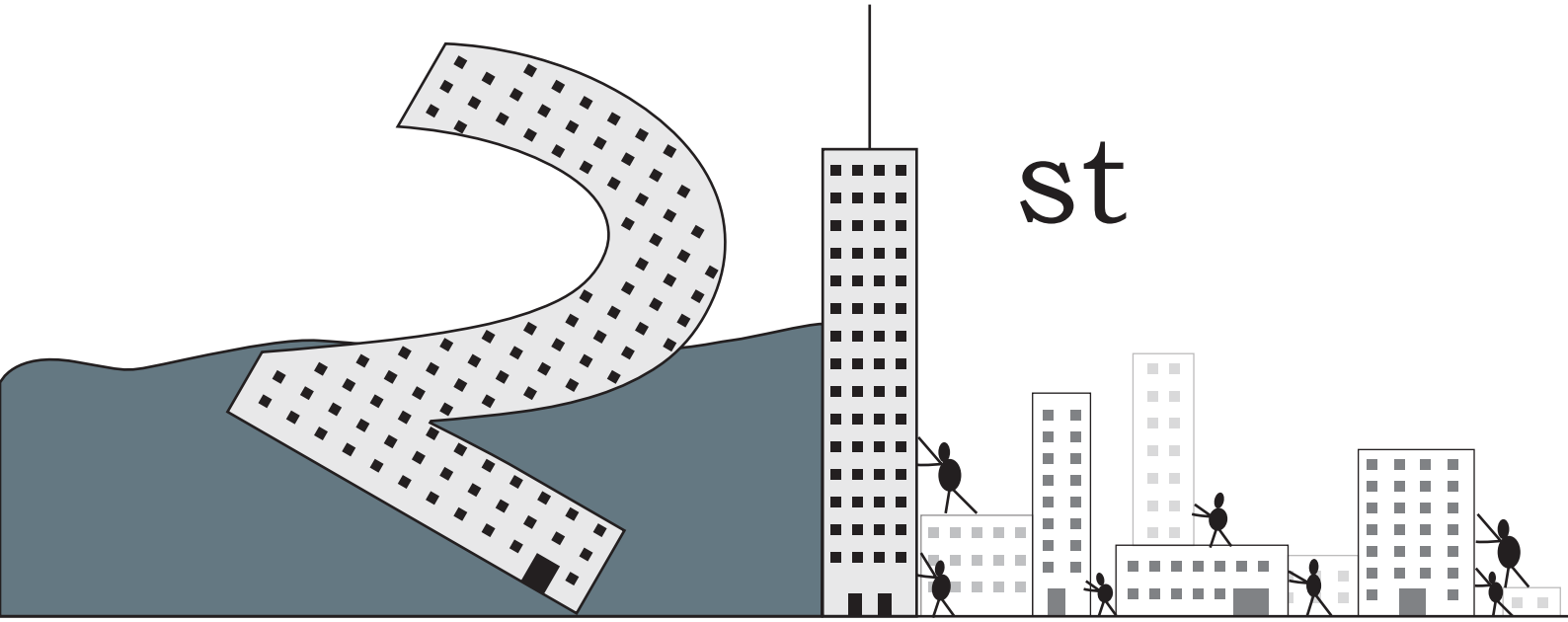
Surges of the 21st Century



Final report Donald Böing

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TU Delft
Delft University of Technology

Surges of the 21st Century

Addressing flood risk, public- and ecological value through urban regeneration,
to reduce socio-economic pressure and flood risk in coastal areas

Final Report

TU Delft

Faculty of Architecture and the Built Environment,
department of Urbanism

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DIMI Delft Infrastructures & Mobility Initiative

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Acknowledgements

You are about to read my graduation thesis for the master track of Urbanism. This MSc study is part of the faculty of Architecture and the Built Environment at the Technical University Delft. The thesis involves work from the last year of the Urbanism track, and allows students to develop their project according to own interests. Ofcourse developing my project would not have been possible without the feedback of my mentors and input from local experts. Therefore I would like to take this opportunity to thank my first mentor Fransje Hooimeijer for all the constructive consultations, even if they had to take place during her holiday. Secondly, the expertise on Red Hook of my second mentor, Peter van Veelen, was of invaluable importance to get a grip on the dynamics of the area.

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Lastly, I´d like to thank Leo van den Burg. On very short notice he agreed to be my replacing second mentor for the P4 and P5 presentations. Working on my thesis has been a great experience, and I wish all readers of this booklet as much enjoyment as I had producing it.

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- Rebuild by Design
- Interviews
- Theory Paper

Introduction



Figure 1.1: Global patterns of urbanization, 1995

Source: Based on United Nations, 2014b.

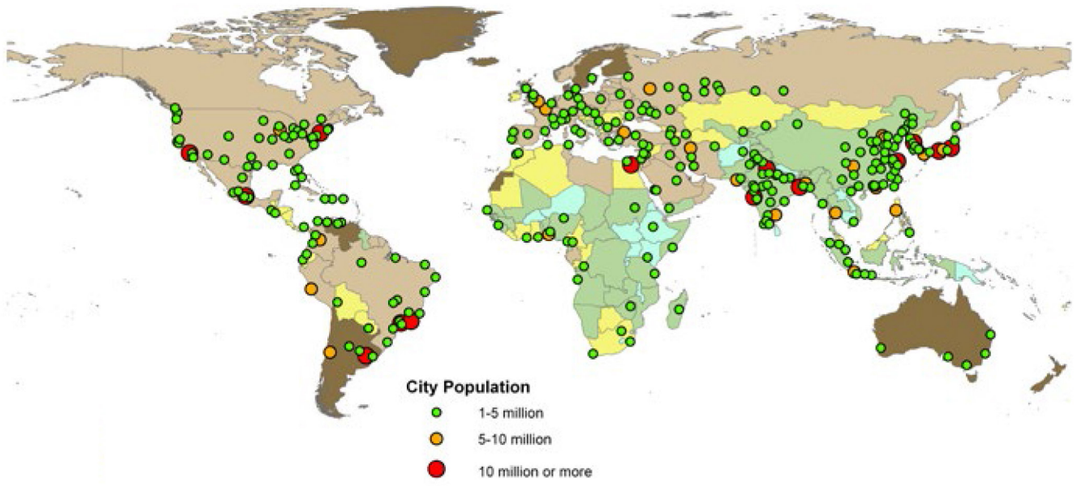
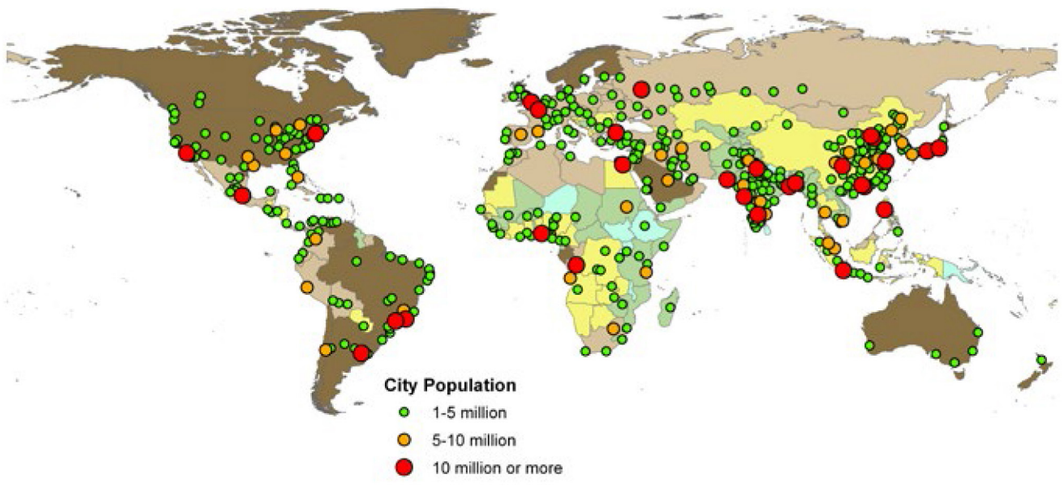


Figure 1.2: Global patterns of urbanization, 2015

Source: Based on United Nations, 2014b.



Figures 1,1 and 1,2. *Global Patterns of Urbanization.* (UN-Habitat, 2016)

The two surges

Low-lying coastal areas are amongst the most vulnerable locations to the effects of climate related events. Despite the fact that only 2% of the world's surface is considered to be low-lying coastal area, they accomodate roughly 13% of the world's population (UN-Habitat, 2016). Global patterns of urbanization have been studied by the United Nations. By mapping growth of urbanized areas from 1995 to 2015 (see figures 1,1 and 1,2), it stands out that most of the megacities of over 10 million inhabitants, are located near coastlines. Additionally, it appears that in urbanized coastal areas cities with the highest densities can be found. With an average of 80 persons per square kilometer, coastal cities accomodate a density which is twice the average amount found in the rest of the world. To conclude illustrating the presence of coastal cities, currently 14 of the worlds 17 largest cities are situated in direct vicinity of coasts (Population Reference Bureau 2017).

What are the consequences of this strong correlation between large urbanized areas and their location in coastal regions? Many of the low-lying urbanized coastal areas are susceptible to flooding. These flooding events can occur through a number of different causes, often working in combination with each other. Astronomical high tides, storm surges, increased discharge of rivers, and stormwater runoff are amongst the most significant causes for flooding events (van Veelen, 2016).

Not only an increase of natural triggered events because of climate change, such as storms and excessive rainfall have an impact on floodrisk. As shown, coastal areas have become incredibly urbanized. These so-called 'human induced stresses' on the environment play a substantial role in the sensitive position of coastal cities. Several studies have indicated that the consequences of human actions, like socio-economic dynamics and extreme (unplanned) urbanisation contribute more to the increase in flood risk than climate change itself (Nicholls et al., 1995, Mc Granahan et al., 2007, Hallegatte et al., 2013, Winsemius et al., 2015, in van Veelen, 2016).

As can be concluded, urbanized coastal areas deal with two kinds of 'surges'. The first being the pressure of climate change and an increased chance of flooding events. Secondly, the rapid increase of extreme urbanization in coastal areas. Not only have these regions become more sensitive to flooding events, they are hosting more inhabitants than ever before and continue to see an increase in urbanization. Complex problems arise that challenge us to plan our cities in a way which can accomodate **The Surges of the 21st Century.**

Rank	Country	Urban Agglomeration	Exposed Assets Current ($Billion)	Exposed Assets 2070 ($Billion)
1	USA	Miami	416.29	3,513.04
2	USA	New York-Newark	320.20	2,147.35
3	USA	New Orleans	233.69	1,013.45
4	JAPAN	Osaka-Kobe	215.62	968.96
5	JAPAN	Tokyo	174.29	1,207.07
6	NETHERLANDS	Amsterdam	128.33	843.70
7	NETHERLANDS	Rotterdam	114.89	825.68
8	JAPAN	Nagoya	109.22	623.42
9	USA	Virginia Beach	84.64	581.69
10	CHINA	Guangzhou	84.17	3,357.72
11	CHINA	Shanghai	72.86	1,771.17
12	INDIA	Mumbai	46.20	1,598.05
13	THAILAND	Bangkok	38.72	1,117.54
14	CHINA,	Hong Kong	35.94	1,163.89
15	INDIA	Kolkata (Calcutta)	31.99	1,961.44
16	CHINA	Tianjin	29.62	1,231.48
17	EGYPT	Alexandria	28.46	563.28
18	VIETNAM	Ho Chi Minh City	26.86	652.82
19	CHINA	Ningbo	9.26	1,073.93
20	CHINA	Qingdao	2.72	601.59

Figure 1,3. *Top 20 cities in terms of assets exposed to coastal flooding.* (Hanson et al., 2011)

Problem field

As introduced, the theme of this thesis will involve urbanized coastal areas that deal with the Surges of the 21st Century. Because there are many cities around the world dealing with similar problems, the research is relevant for a variety of urbanized coastal areas. To be able to go in depth and deliver a sufficiently developed end product, the decision has been made to develop an approach that can be implemented on numerous urbanized coastal areas, but will be tested and developed while focusing on a specific one.

The table on the left page (Hanson et al., 2011) displays the most vulnerable cities to coastal flooding. They are ranked in terms of assets exposed to coastal flooding. Also a projection for exposed assets in 2070 has been made. Both climate change and socio economic pressure have been taken into account for these calculations. When looking at the cities that currently have the most exposed assets however, it stands out that these concern three highly developed, North-American cities. Miami, New York - Newark and New Orleans top off the list when it comes to exposed assets to coastal flooding.

When comparing the three North American cities, it was found that New York is one of the largest American cities with a strong economic influence worldwide. On top of this, the city has a very high building density and deals with the highest amount of socio-economic pressure (NYC Gov, 2014; Citylab, 2017). For these reasons, the decision has been made to further research the conditions in New York to understand whether they are constructive for the thesis.

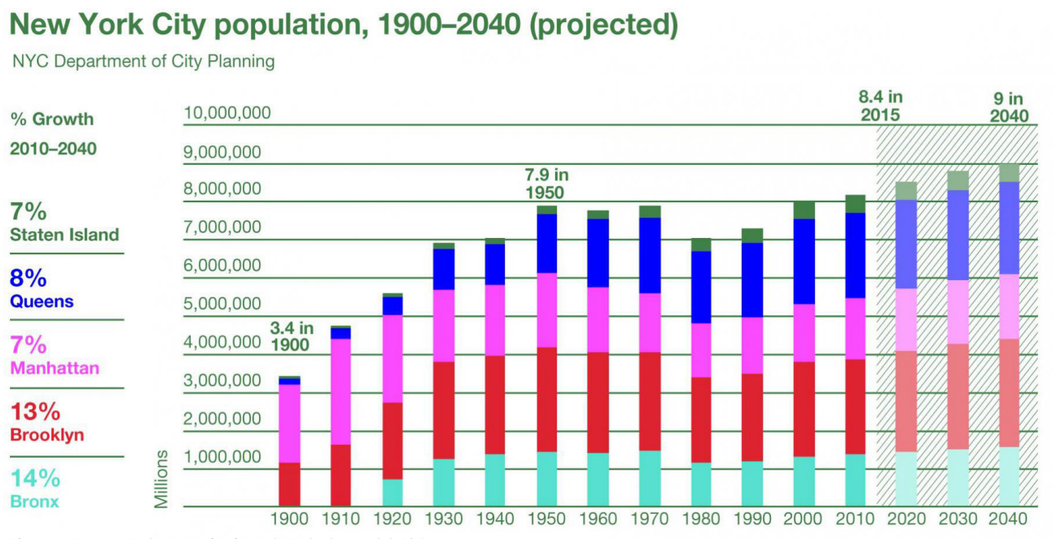


Figure 1,4. *NYC population.* (NYC Gov, 2017)

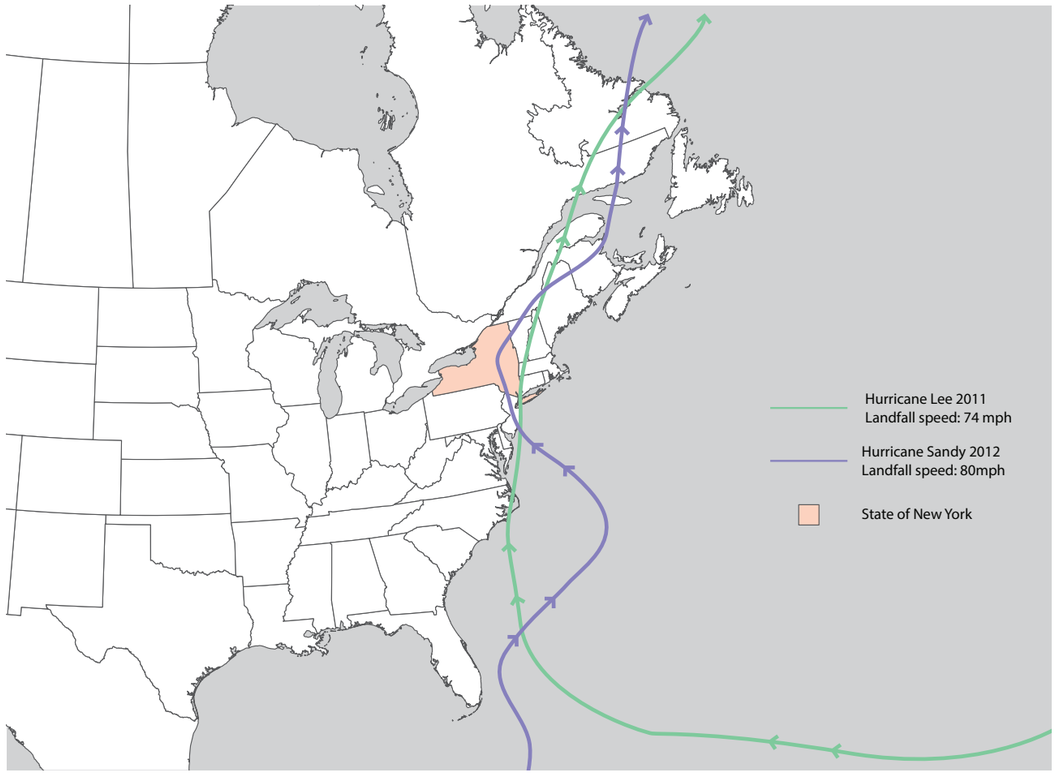


Figure 1,5. *Hurricane Lee and Sandy paths.* (By author, based on National Hurricane Center, 2017)

New York City (NYC) is widely considered to be the most important financial center in the world (Citylab, 2017). Other than having a huge economical influence, NYC is one of the most densely populated coastal areas, with over 8,5 million inhabitants in July 2016 (NYC gov, 2017). With population projected to grow, the social pressure will increase over the coming years (see figure 1,4). This means the city will demand more in physical terms from the available terrain to house additional inhabitants. According to figure 1,4, the boroughs Brooklyn and The Bronx will contribute most to the increase of inhabitants. As van Veelen (2016) pointed out, in some situations it is possible that extreme urbanisation contributes more to the increase in flood risk than climate change related weather events. It is imaginable that this is the case in New York city as well.

While the social pressure in New York will create complex challenges for the city, the environmental situation should not be underestimated either. Being a coastal delta city on the Atlantic ocean, New York city is largely built on low-lying land, which will be shown in detail later. Because of this, NYC is vulnerable to flooding. But what conditions cause the waterlevel to rise? To understand the dynamic conditions NYC is dealing with, maps and illustrations will clarify the situation.

The east coast of the United states has to cope with hurricanes or other strong storms from time to time. Figure 1,5 shows the path hurricanes Lee (2011) and Sandy (2012) took (National Hurricane Center, 2012). Of the two hurricanes, especially Sandy made landfall in New York from the direction of the Atlantic ocean. As a result, water is being pushed into the upper New York bay. The geology of the ocean contributes to the extreme waterlevel rise as well. The hurricane driven storm surge comes from the Atlantic ocean, which is more than 4000 meters deep on most places (Elastic Terrain, 2017). When the water reaches the continental shelf, the depth of the ocean rapidly decreases to a mere 20-60 meters. This causes the water to be pushed up the shelf, resulting in an extreme rise of sea level (National Hurricane Center, 2010). This process is illustrated in figure 1,6.

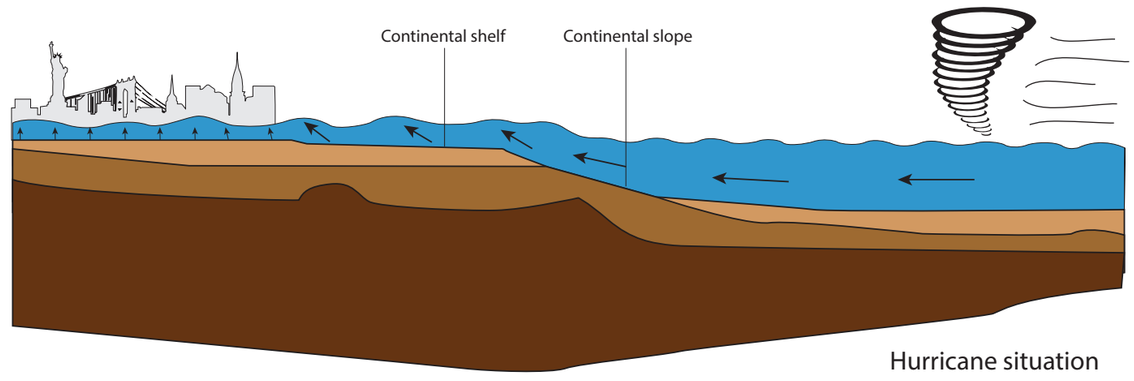


Figure 1,6. *Storm surge water level.* (By author, based on National Hurricane Center, 2010)

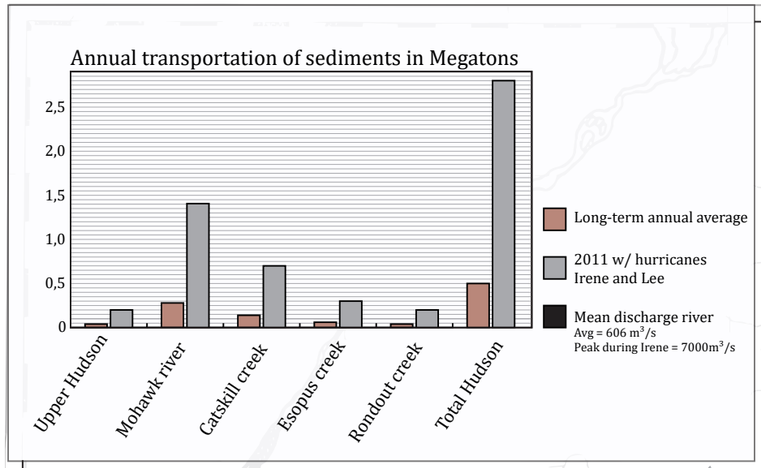




Figure 1,7. *Hudson sediment transportation and discharge.* (By author, based on Ralston et al., 2015)

Figure 1,7 shows the annual average amount of sediment transported by the Hudson river in brown. In 2011 the amounts of sediment transported (in grey) were more than five times as high, due to hurricanes Irene and Lee. Combined with these increased sediment flows, the discharge of the Hudson river went from the average 606 m^3/s to 7000 m^3/s during peak rainfall of the Irene hurricane (Ralston, Geyer, Warner and Wall, 2015).

When heavy rainfall in the catchment area of the Hudson river is combined with storm surge from the Atlantic ocean, a situation illustrated in figure 1,8 occurs. Additional water is being discharged through the Hudson, which meets the water that is being pushed into the bay. This results in an extreme rise of water level (National Hurricane Center, 2010; Van Veelen, 2016). The dark red indicates areas with the highest flood risk. This will be shown in more detail on the next page.

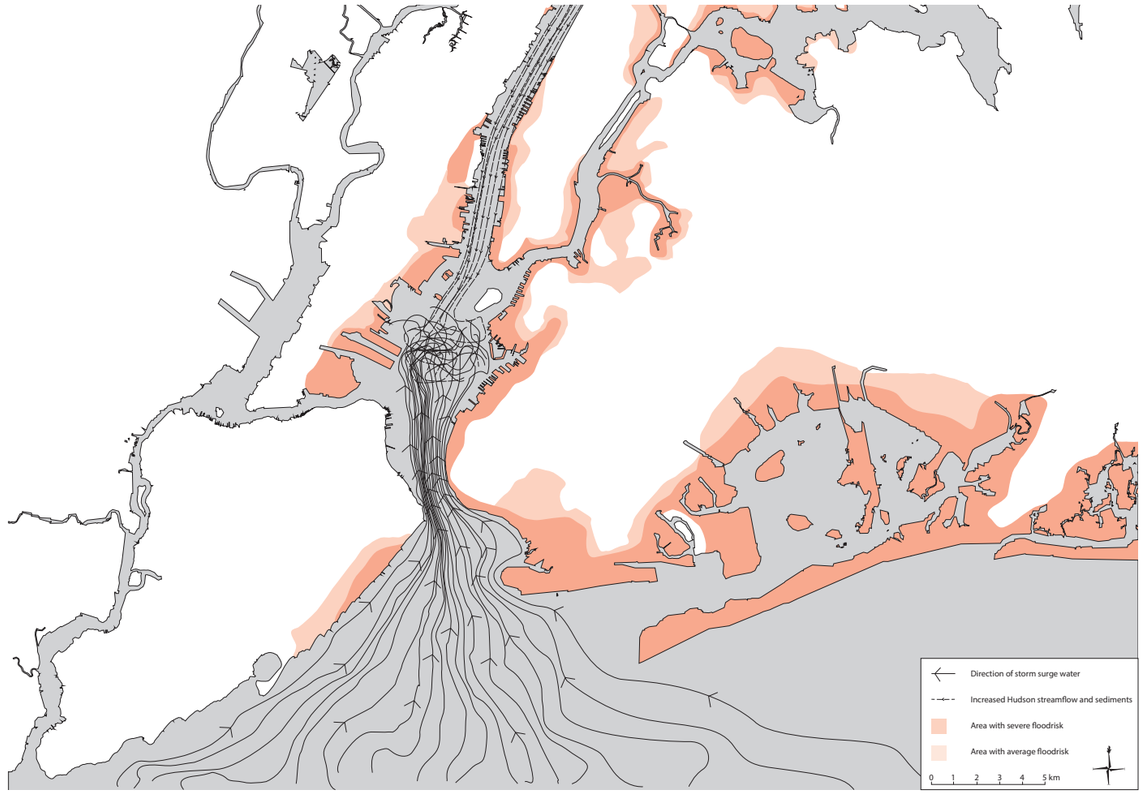


Figure 1,8. *Conflict of forces in the upper New York bay.* (By author, based on figures 1,5 1,7 and 1,9)

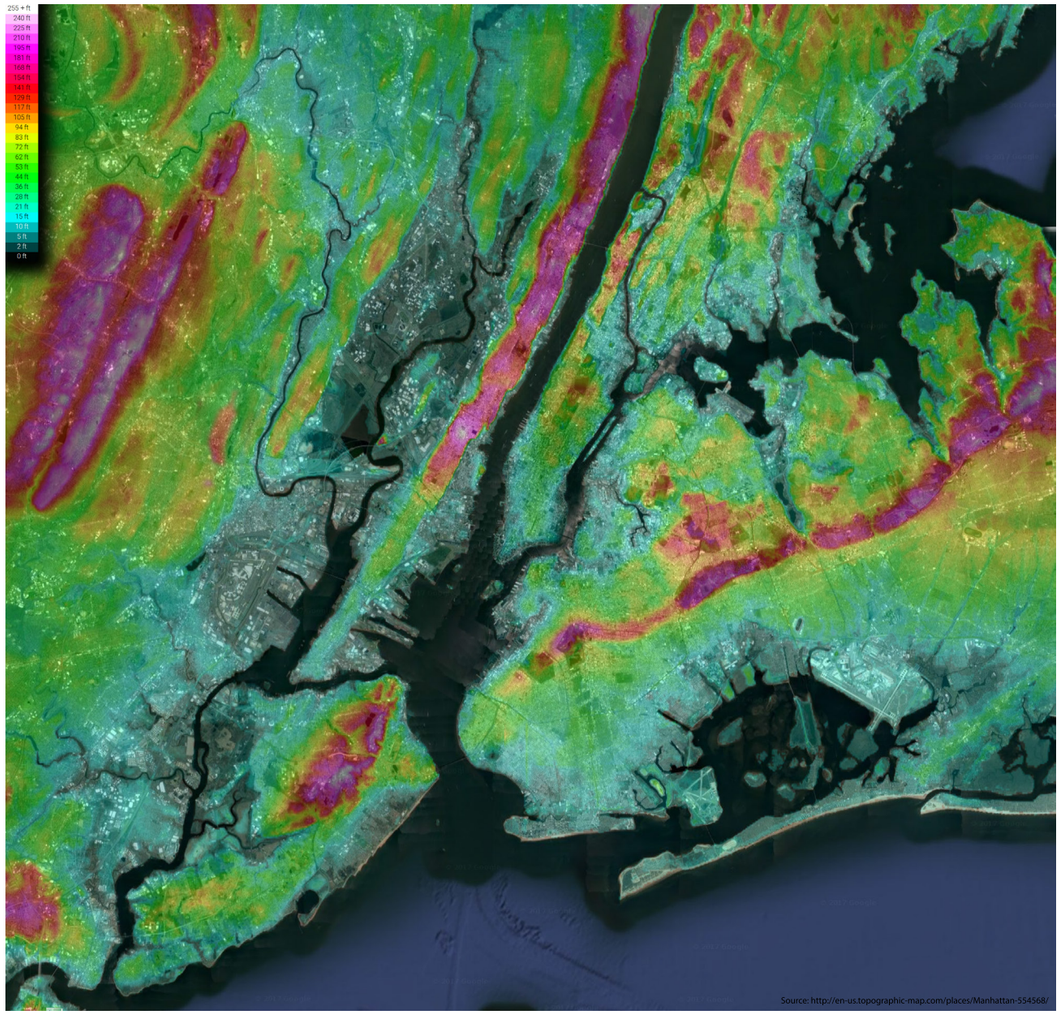


Figure 1,9. *NYC elevations map.* (Topographic map, 2017)

Figure 1,9 shows the natural elevation of New York City. The pink and red colours represent highlands, while the light blue and transparant colours show the low lying areas. Focusing on the upper New York bay, it shows how much land around it is elevated just above sea level. Large parts of Manhattan and Brooklyn are only elevated between 1 and 3 meters above mean sea level. One of the areas that got severely flooded during hurricane Sandy in 2012, is the low-lying neighbourhood of Red Hook, Brooklyn (NYC Department of City Planning, NYC Mayor's Office, 2014; Van Veelen, 2016). This area has been enhanced in the center of figure 1,10 and will be introduced on the next page.

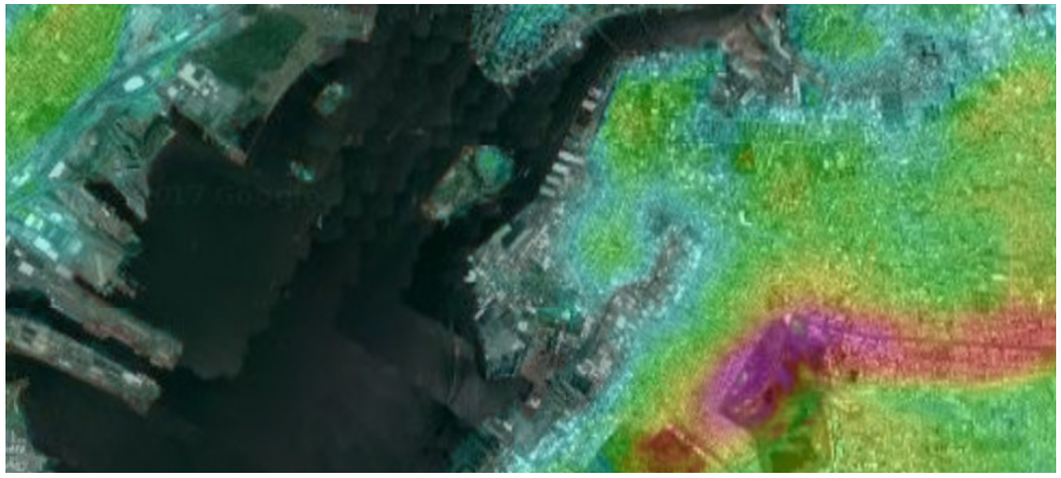


Figure 1,10. *Red Hook zoom in.* (Topographic map, 2017)

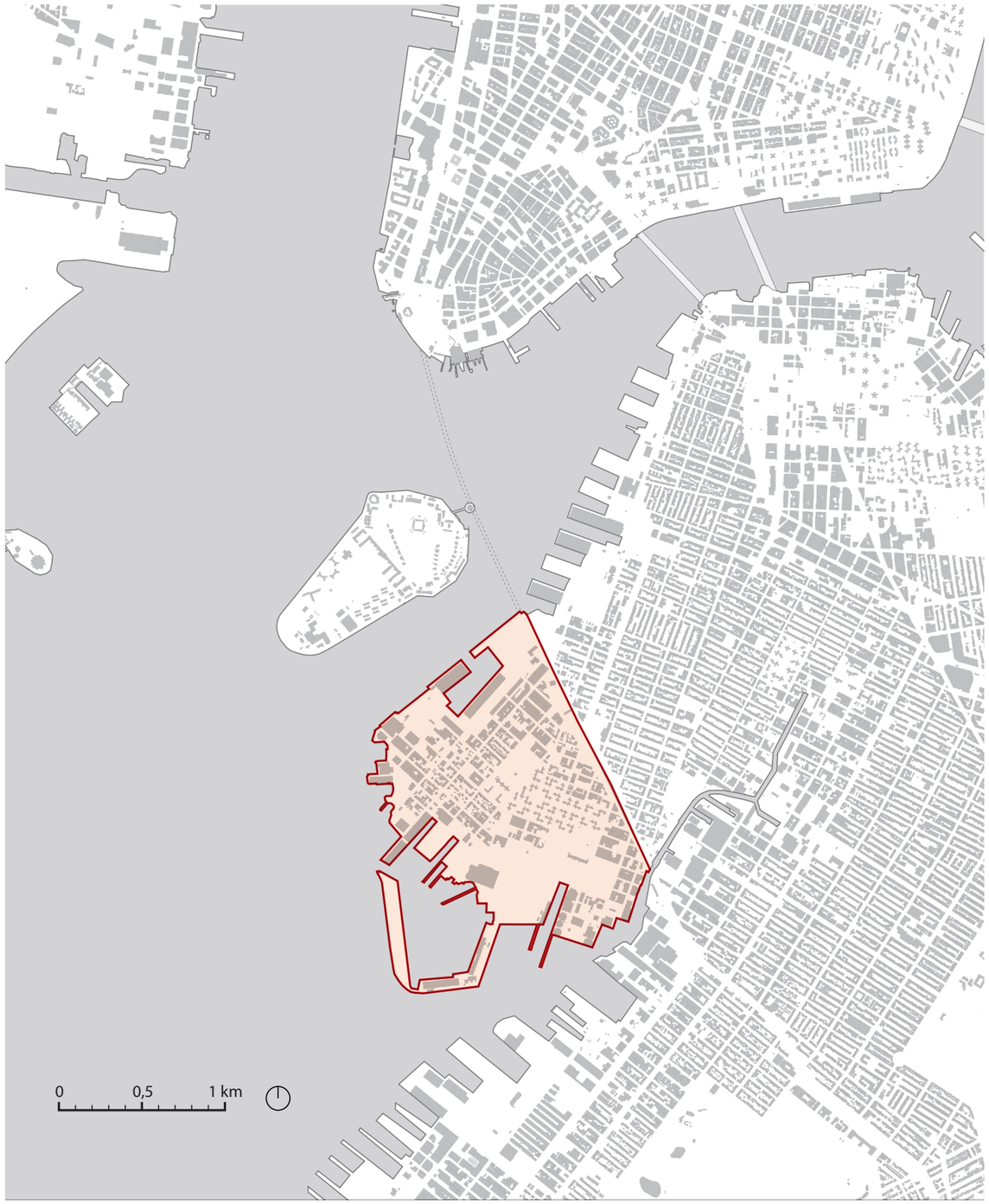


Figure 1,11. *Red Hook Study Area.* (By author)

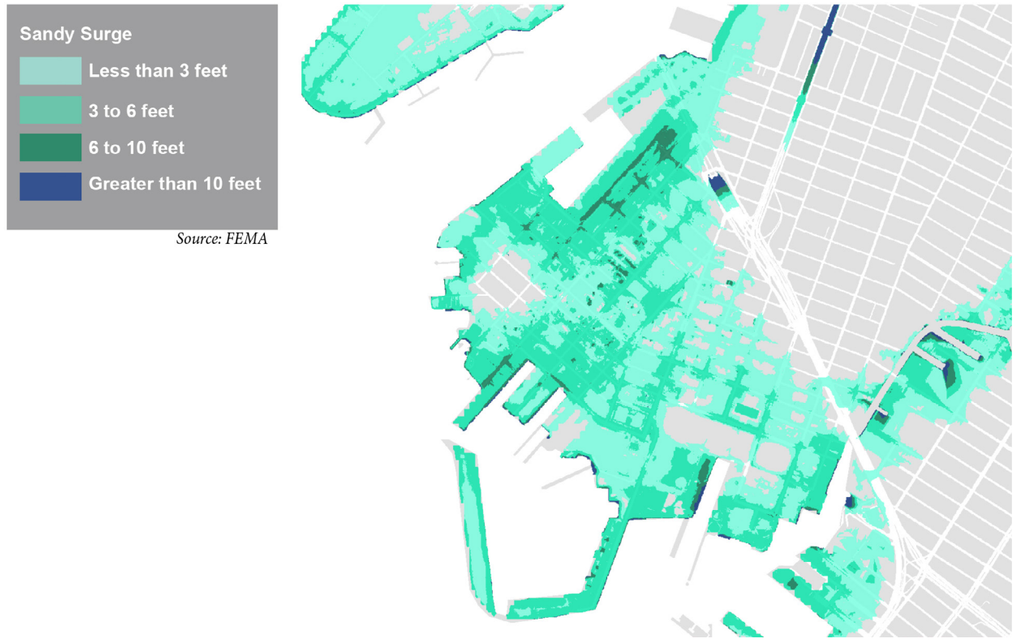
The problem field illustrated both the environmental vulnerability of NYC as well as the socio-economic pressure. A neighbourhood where both these aspects play a significant role is Red Hook, Brooklyn (Van Veelen, 2016).

Red Hook was founded in 1636 by the Dutch, as a small village called 'Roode Hoek'. The name is related to the red clay soil and characteristic shape of the land. As can be seen on the map, Red Hook is located on peninsula shaped land, isolated from the rest of Brooklyn by the Gowanus Expressway, which marks the north-eastern limit of the neighbourhood. On the waterfront of Red Hook, the area developed three basins: the Brooklyn, Atlantic and Erie basin. These basins allowed for a closed off waterbody unaffected by tides, where large ships could unload goods and undergo maintenance. Around the year 1840 the area had grown into one of the largest ports of the US. Because of its success, the city of Brooklyn constructed a street grid around the basins, connecting the harbour to South Brooklyn in 1847. Many of the harbour employees lived in the nearby built 'Red Hook Houses'. After the Second World War, the area fell in decline. Mostly due to the fact the port was unable to transform to new infrastructure standards that came with the invention of the container(ships). Functions started to leave the area and a period of decay began (NYC Department of City Planning, NYC Mayor's Office, 2014).

After multiple initiatives and restructuring plans, the area is currently recovering and experiencing more activity. Different developments of land use including the Fairway Market, the Brooklyn Cruise Terminal and IKEA have put Red Hook on the map again. Despite this fact, there are still multiple brownfield sites and undeveloped plots to be found throughout the neighbourhood (NYC Department of City Planning, NYC Mayor's Office, 2014).

As briefly stated earlier, in October 2012 nearly the entire neighbourhood of Red Hook was flooded by the storm surge caused by hurricane Sandy (NYC Department of City Planning, NYC Mayor's Office, 2014). This resulted in power outage and left many businesses non-functional. Several smaller companies went bankrupt as a result. The recovery from this disaster took many years and is still in progress in some cases. Particularly the events caused by hurricane Sandy show that Red Hook needs to be protected from severe flooding in the future.

Research framework



Source: FEMA

Figure 2,1. *Hurricane Sandy, Storm Surge Extent.* (NYC Mayor's Office, 2014)

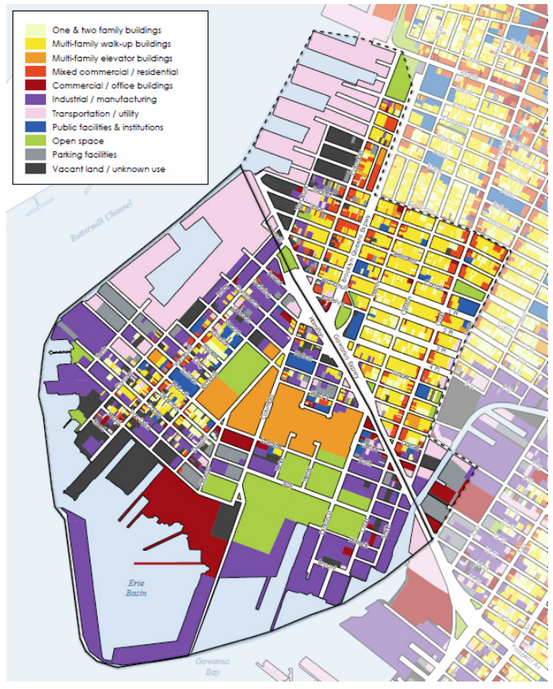


Figure 2,2. *Land Use in Red Hook.* (NYC Department of City Planning, 2014)

Strategic approach

With the ongoing changing climate conditions, Red Hook's vulnerable position will become worse by an increase in flood risk in the future (van Veelen, 2016). This occurs in combination with a higher and intensified socio-economic land use of the waterfront. Because of these trends, the urbanized coastal areas are dealing with pressures from both sides: inland urbanization densifying towards the water, as well as the water pushing up against the land.

However, these pressures also provide opportunities for redevelopment and thinking about strategical approaches. The fact that the amount of inhabitants of NYC and Brooklyn is projected to rise (NYC gov, 2017), calls for densification and/ or restructuring (One NYC, 2015). The shift from industrial waterfront towards residential use and the development of brownfield areas in Red Hook (NYC Department of City Planning, NYC Mayor's Office, 2014) can provide a starting point for a strategic approach regarding flood risk reduction. The strategical framework this thesis has developed aims to integrate three key concepts: reducing flood risk, adding public value and increasing ecological value.

Reducing Flood Risk

First and foremost, the neighbourhood of Red Hook needs to be better protected against coastal flooding. Certain areas have a 10% annual risk of being flooded, which is amongst the highest in NYC (NYC Mayor's Office of Recovery and Resiliency, 2017). Figure 2,1 shows the level of storm surge flood water in the streets of Red Hook during hurricane Sandy, based on information by the Federal Emergency Management Agency (FEMA). In some occassions, the water reached a depth of more than 3 meters. To understand what types of flooding Red Hook deals with and how flood risk works, part of the research will be dedicated to these questions.

Adding Public Value

As can be seen in figure 2,2, the current land use of Red Hook's waterfront is dominated by industrial functions (purple), with the exception of some transportation and commercial use. The map shows that there is very limited to no available qualitative public waterfront space. Especially when restructuring takes place, creating additional housing stock to accomodate the growth of the city, realizing public (waterfront) space is essential. Research revealed what kind of public space is needed and where this can be implemented.

Increasing Ecological Value

One of the phenomena that can occur in urbanized coastal environments is 'coastal squeeze' (Eastern Solent Coastal Partnership, 2017). In a marshland environment, natural ecosystems and habitats can move landwards as sea level rises. However, in an environment with man made structures and quays, as is the case in Red Hook (NYC Department of City Planning, NYC Mayor's Office, 2014), the habitat is prevented from moving towards the land and is being 'squeezed' up to the coastal defences (Eastern Solent Coastal Partnership, 2017). In this case, the habitat has no space to adapt, and will disappear. An ecological marshland type of waterfront provides the room for ecosystems to adapt to changing conditions (Eastern Solent Coastal Partnership, 2017). By integrating an ecological approach in the restructuring of the waterfront, both the social, economical and ecological value of the design can increase (Laidley, 2007).This approach has been implemented on the Toronto waterfront. As Laidley (2007) states: 'The 'ecosystem approach', as it was called, promised to bring together in one development model ' the long-term promise of a healthy environment, economic recovery and sustainability, and maintaining a livable community' (2007, p. 259).

The green infrastructure developed on the Toronto waterfront not only connects public spaces and restored natural habitats, but also successfully tackled contamination issues of the soil and provides defence for flood risk posed by the Don river (Laidley, 2007). The conditions and ongoing plans in Red Hook needed to be further researched to optimize the strategy and design a tailor-made approach. However, the ecosystem approach could prove to be very useful for Red Hook. The future restructuring plans provide opportunities for this strategic approach, which will reduce flood risk by creating and connecting new qualitative public space, while also catering to the restoration and creation of natural habitats.

Research questions

How can **flood risk**, **public**- and **ecological value** be addressed coherently through urban regeneration, in which socio-economic pressure and flood risk are both successfully reduced?

Flood Risk

How can the effects of coastal, tidal, fluvial and pluvial flooding both individually and in combination, be assessed in reciprocity to public- and ecological value?

Public Value

How can spatial interventions regarding flood risk reduction be integrated in existing restructuring plans to increase public value?

Ecological Value

In which conditions does ecological value de- or increase?

What conditions can be created to increase ecological value in urbanized waterfronts?

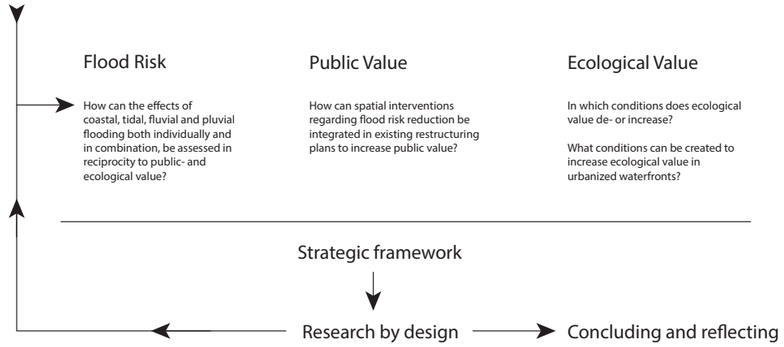


Figure 2,3. *Methodology.* (By author)

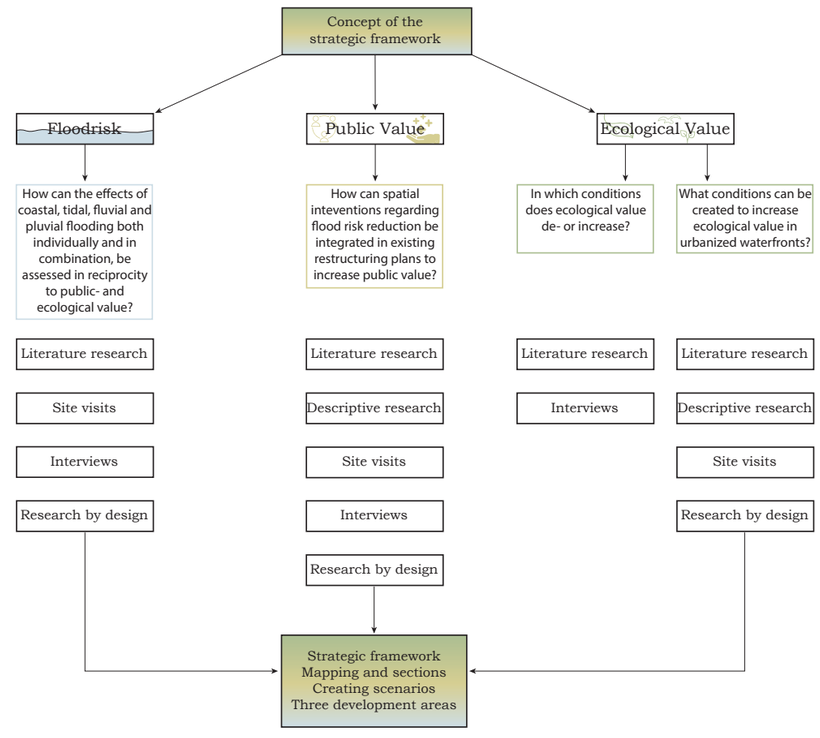


Figure 2,4. Sub-questions and methods. (By author)

Methods

The strategic framework for improving urbanized coastal areas consists of three main components. These components cater to flood risk, public value and ecological value. Each component or 'pillar' of this approach has a specific sub-question. To be able to successfully conduct research it has been decided to take the neighbourhood of Red Hook as a case study for this thesis. The strategic framework should be applicable to a variety of urbanized coastal waterfronts, but has been developed as a pilot project for the neighbourhood of Red Hook.

Beginning with the Flood Risk, the sub-question 'How can the effects of coastal, tidal, fluvial and pluvial flooding both individually and in combination, be assessed in reciprocity to public- and ecological value?' is answered by studying relevant literature. This literature research serves as the starting point for understanding the different kinds of flooding urbanized coastal areas may have to deal with. Because each respective type of flooding creates different situations and has specific consequences, these had to be understood in order to link them to public and ecological value. Van Veelen elaborates on these kinds of flooding in his work Adaptive planning for resilient coastal waterfronts (2016), which was one of the main sources for this literature research. Next, a critical review of existing flood risk assessment took place. This has shed light on the methods for calculating and estimating flood risk in specific areas. To understand how the calculated risk can then be linked to public and ecological value, the next subresearch questions are of essential importance.

The second component, Public Value, was researched through a combination of literature and descriptive research as well as qualitative fieldwork research. Descriptive research does generally not concern 'how' or 'why' questions, but rather with 'what' questions (Breen, 2002). It can be used to describe a future, current or historic situation. In this case, the sub-question 'How can spatial interventions regarding flood risk reduction be integrated in existing restructuring plans to increase public value?' is answered by a descriptive research method studying source material such as maps. Existing conditions as well as future restructuring plans were studied. To get the complete picture of the situation, Red Hook has been visited in the fieldwork period. The question concerns both physical and complex social factors. This means literature reseach provided insight about public value first, followed by descriptive research to map the demographic conditions of Red Hook. After this had taken place, local people and experts were interviewed about their opinion on flood risk and public value in Red Hook, as well as ongoing projects and initiatives.

The final component, ecological value, was addressed through a combination of literature and descriptive research. The question 'In which conditions does ecological value de- or increase?' has been researched by studying literature and theory. Various sources on ecological urban design and natural habitats were consulted, such as Ecological design for urban waterfronts by Dyson and Yocom (2014) and Living Breakwaters by SCAPE architecture (2014) as part of the Rebuild by Design competition. Descriptive research provided insight in 'What conditions can be created to increase ecological value in urbanized waterfronts?' by analyzing potential locations that cater to the found prerequisites from the first sub-question regarding ecological value.

The three components and their respective sub-questions serve as the framework for the strategic approach. Within this approach, the project is developed. Figure 2,5 describes the workflow of the project in slightly more detail. The workflow shows an outline of the most important sources and how evaluations are made based on this literature and theory. Eventually, during the design phase, an integrated design has been made based on the three components. This design is evidence based, as it will be developed within the established theoretical framework for each component of the strategic approach. The design aim is to have specific interventions which create synergy between two or more components at the same time. For example a qualitative public space that provides an ecological habitat and helps to reduce flood risk caters to all three components of the approach.

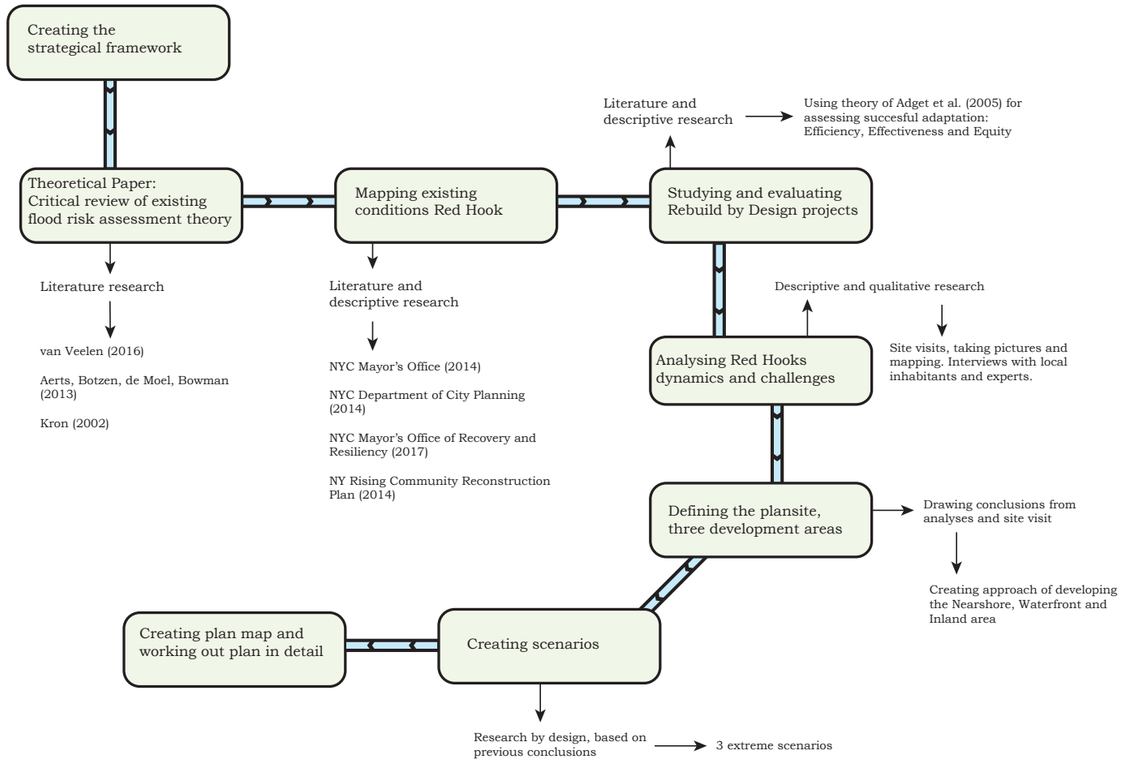


Figure 2,5. *Project workflow.* (By author)

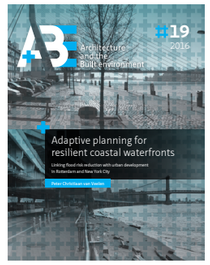
The research by design phase has tried to re-answer sub-questions such as 'How can spatial interventions regarding flood risk reduction be integrated in existing restructuring plans to increase public value?' and 'What conditions can be created to increase ecological value in urbanized waterfronts?' while reducing the flood risk of the area. The interventions were continuously tested and evaluated according to the established framework throughout the design process.
This way, the research questions were addressed by literature-, descriptive-, qualitative-, fieldwork- and design research.

After the research by design phase a conclusion has been drawn, followed by a reflection of the implemented interventions and framework. At this point the project has been assessed by looking at to which extent it was possible to answer the posed questions and how well the strategic framework functioned for improving the Red Hook waterfront. Ethical dillemas and findings as a result of the drawn conclusions were recommended for further research.

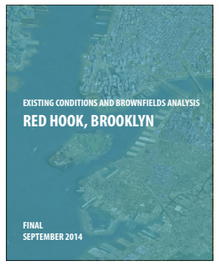
Floodrisk

Public Value

Ecological Value



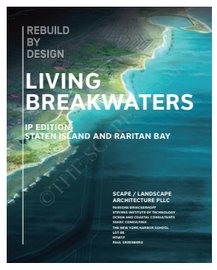




Twelve Quality Criteria

Gehl Institute





New Meadowlands



Figure 2,6. *Strategic approach components with relevant literature.* (Covers by respective owners)

Theory

As illustrated by the methodology approach, a considerable amount of research has been conducted through literature. The most important works have been linked to the three components of the strategic approach (figure 2,6). Besides having consulted a variety of literature to conduct research on floodrisk, public- and ecological value, theory of Adger, Arnell & Tompkins (2005) and Gehl & Koch (2011) were used for assessment purposes. The two works *Successful adaptation to climate change across scales* (2005) and *Life between buildings: Using public space* (2011) form the theoretical framework of this thesis, and have allowed for rational evaluations throughout the process.

Assessing successful adaptation

In their work *Successful adaptation to climate change across scales* (2005) Adger, Arnell & Tompkins describe methods to evaluate the successfulness of projects. To assess implementation of interventions, Adger et al. (2005) use the principles of *efficiency, effectiveness* and *equity.*

Efficiency concerns the balance between costs and benefits (Van Veelen, 2016). The time frame in which adaptations show their positive effects will also be grouped under efficiency. The sooner an intervention will see a positive influence (or successful effectiveness) on it's area, the higher the efficiency of implementing the adaptation can be deemed. **Effectiveness** can be described as '*the capacity of an adaptation action to achieve its expressed objectives*' (Adger et al, 2005, p. 81). In other words, the extent in which the adaptation fulfils the goals for which it was designed. In the context of flood risk, this can be evaluated by determining how much the flood risk decreased as a result of the adapted strategy or interventions. Thirdly, the **equity** factor describes to what extent all involved stakeholders benefit from the adaptation in an equal way (Van Veelen, 2016).

The theory of Adger et al. (2005) is used to evaluate ten Rebuild by Design projects. By taking this theory as a starting point, a rational evaluation method is created (see Rebuild by Design chapter). Through the addition of context specific evaluation criteria, the projects were assessed. The results show which projects are most successfull, and which were most relevant for the development of the thesis.

Twelve Urban Quality Criteria

To assess the quality of public space, theory of Gehl & Koch (2011) is used. In the book *Life between buildings: Using public space* Gehl & Koch describe 12 criteria to evaluate the quality of an urban public space. These criteria are displayed in figure 2,7. They are grouped in three categories: Protection, Comfort and Enjoyment. Any public space can be evaluated through this theoretical framework. Assessment takes place by rating each criterium following the answers to the questions. With a 3 for yes, a 2 for in between, and finally a 1 for no, a space obtains an overall score. Although not specifically explained in the theory by Gehl & Koch (2011), the rating will be established that any score over 24 (An average 2 for the sum of all 12 criteria) will be deemed a successful public space.

Existing conditions on Red Hook's waterfront are evaluated through the Twelve Urban Quality Criteria, as established by Gehl & Koch (2011). Using this framework to assess the current conditions of the public space, it allowed for accurate conclusions regarding what areas are already successful, and which ones needed to get extra attention in the design process.

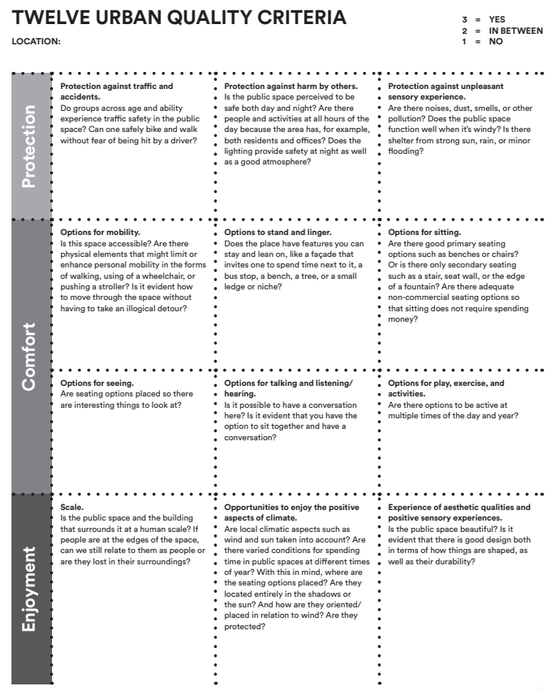


Figure 2,7. *Twelve urban quality criteria.* (Gehl & Koch, 2011)



Figure 2,8. *Basemap Red Hook.* (By author)

Design goal and intended end product

The methods section of this thesis outlined the working method and intended end product.
The design goal of this thesis is to develop and implement a strategic framework to reduce flood risk, while improving public- and ecological value. This strategic framework is tested on Red Hook, but offers general guidelines applicable on other places. To be able to develop a focused, in-depth and thorough end product, a fairly narrow approach has been used in which the scope has been limited to Red Hook only.

Social relevance



Figure 2,9. *Red Hook Houses.* (NYC Department of City Planning, 2014)

Currently almost 7.000 people live in the Red Hook Houses, an area located in evacuation zone A (NYC Department of City Planning, 2014). This means the area is prone to be flooded by any hurricane (of any strength) that makes landfall close to NYC (NYC Department of City Planning, NYC Mayor's Office, 2014). The safety of Red Hook should be improved, in both a technical and societal sense. In a technical way, the reduced flood risk will make the area physically safer by decreasing the likelyhood Red Hook will be flooded. The inhabitants will also benefit from societal safety. Improved public space aims to strengthen the social conditions and therefore increase the safety. The added value in public space also contributes to the social relevance because people have more opportunities for leisure and enjoying qualitative public space. Short-term visits to urban green environments have proven to help with stress relief (Tyrväinen et al. 2013) and thus improve health conditions as well.

The ecological element of the approach also adds natural and social value. By restoring and re-introducing ecological habitats a larger biodiversity is created. This creates opportunities for field trips and educational initiatives. For example, the Harbour School on Governors Island takes part in the Billion Oyster Project (BOP), and teaches middle school students how to take care of the estuary by growing oysters as well as providing scuba diving lessons to study marine life (Billion Oyster Project, 2017).

This research also contributes to benefit the society by providing additional housing. The data in figure 1,4 shows a projection of the number of NYC inhabitants. Since the number of people living in New York is projected to grow in the future, additional housing stock will be necessary. By rezoning and restructuring the waterfront area of Red Hook, additional residential units have been created. This will help to reduce the pressure on the housing market and help people to find housing in the city.



Figure 2,10. *Red Hook around 1875.* (Library of Congress, 2017)

Scientific relevance

A prominent question of the 21st century is how to prepare our coastal cities for climate change related extreme weather events (Future Cities project, 2013). This thesis addresses this question by means of the three components of the strategic framework.

The reduction of flood risk is essential for a successful approach. The way flood risk reduction is combined with adding public and ecological value is where this thesis aims to deliver its scientific relevance. By using an ecological approach to reduce floodrisk rather than the more conventional ways of combatting the threat of flooding, this thesis uses a perspective which contributes to the scientific relevance. Instead of the conventional seawalls, dikes and concrete protection structures, this thesis developed a design in which flood protection is realised through ecological breakwaters, marshland habitats and newly developed floodproof buildings.



Figure 2,11. *Red Hook residents in line for supplies after hurricane Sandy.* (Brooklyn Daily Eagle, 2017)

Ethical paragraph

There are several ethical considerations to be made when it comes to large scale interventions such as restructuring a waterfront area. Research found that property values in flood prone areas are lower than comparable real estate prices in safer areas (Bin & Polasky, 2004). For Red Hook this could mean that property value will increase when the flood risk is successfully reduced. Also the added public- and ecological value could affect the housing prices. This could result in gentrification that drives out current inhabitants. Providing additional housing and densification could facilitate affordable housing and is a potential solution for this problem. This would however, result in increased exposure of buildings in low-lying areas, increasing the flood risk again. This example shows how the interrelation between interventions work and the complexity of the situation at hand. For this reason it is important to critically evaluate all the ethical consequences an implementation of a specific design will have on the natural and societal surroundings.

Analyses existing conditions



Red Hook as a testcase

Red Hook, Brooklyn, is the pilot test site for developing the strategic framework. As briefly introduced before, Red Hook is a neighbourhood coping with both of the surges of 21st century: Flood risk, and socio- economic pressure.

To understand the local conditions that play a tremendous role in decision making, descriptive research has taken place. Several documents and papers are consulted to retrieve information about the neighbourhood. This is mapped to create a clear image of the current conditions. Although in some cases it was be possible to recommend improvements or interventions, the next maps and texts only talk about historic and present situations, and do not recommend future possibilities.

Year of construction

Red Hook's buildings are coloured according to their year of construction in the map on the left page. As illustrated, most buildings were built between 1800 and 1945, in the time the harbour was thriving. It is also in this period that the Red Hook houses project was realized. After the second world war, construction in Red Hook stagnated, as a result of the decline in port activity. Because most buildings are built before the war, a number of them are in poor shape and in need of maintenance (HR&A Advisors with Cooper, Robertson & Partners, 2014). Finally, there are modern additions, such as the Ikea building next to Erie basin.

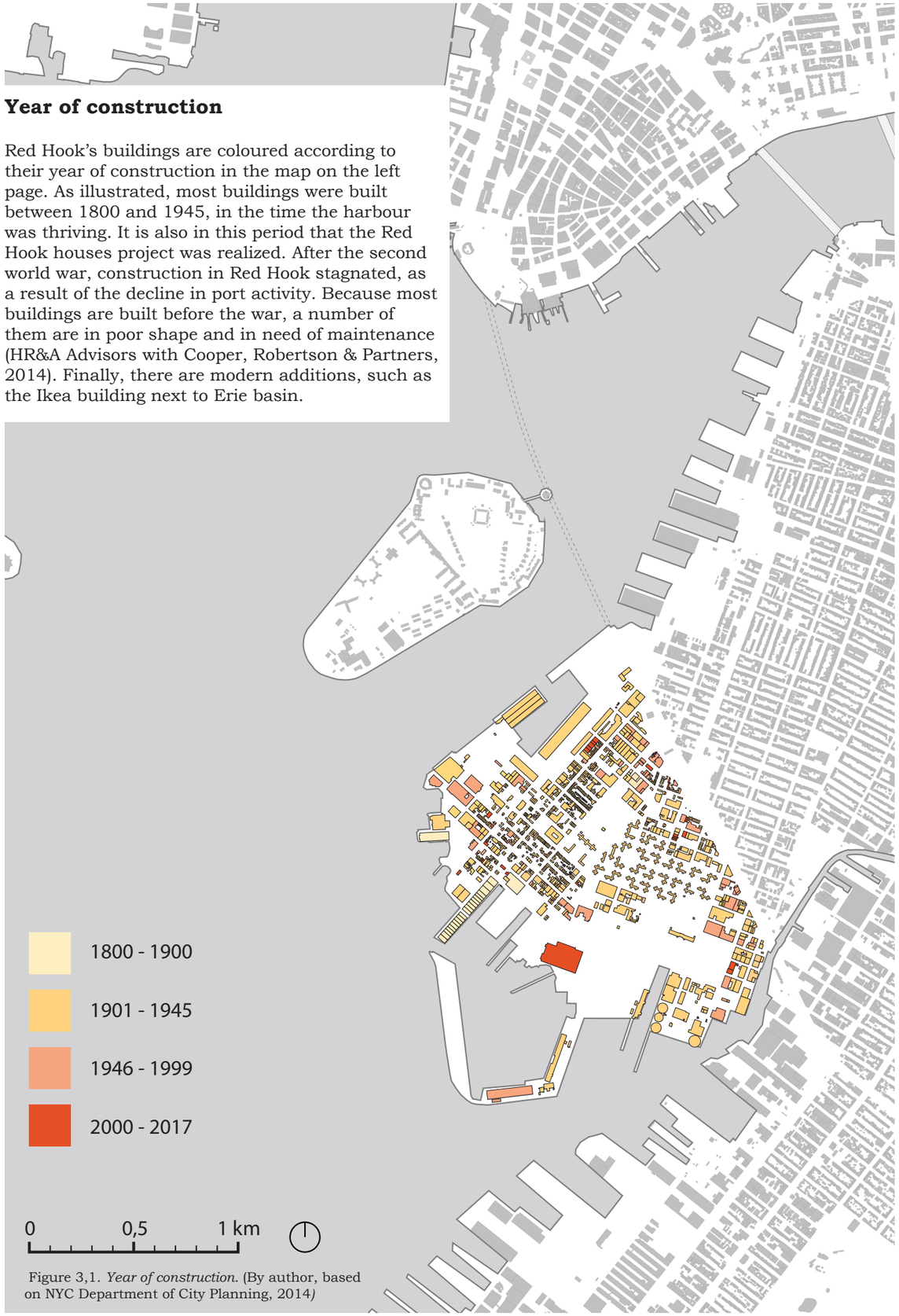


Figure 3,1. *Year of construction.* (By author, based on NYC Department of City Planning, 2014)

Land use

Most of Red Hook's waterfront is dominated by industrial land use (purple). As a result of these manufacturing oriented functions, the waterfront is almost completely inaccessible. With the exception of some small parks such as the Louis Velentino pier, there is hardly any public space along the waterfront. Since Red Hook has a strong historic link with the water, this can be considered a missed opportunity for public value and historic identity of the neighbourhood. There is however, public space (green) to be found south and north-west of the Red Hook houses (orange). This public space mostly consists of fields for sports like football and basketball. The Atlantic basin on the north side of the neighbourhood functions as the cruise ship terminal of New York City. This transportation function is indicated in pink. Lastly, the map shows that most of the residential areas are found north of the Gowanus expressway, the highway that connects south-Brooklyn to Manhattan. These mostly consist of Multi-family walk-up buildings.

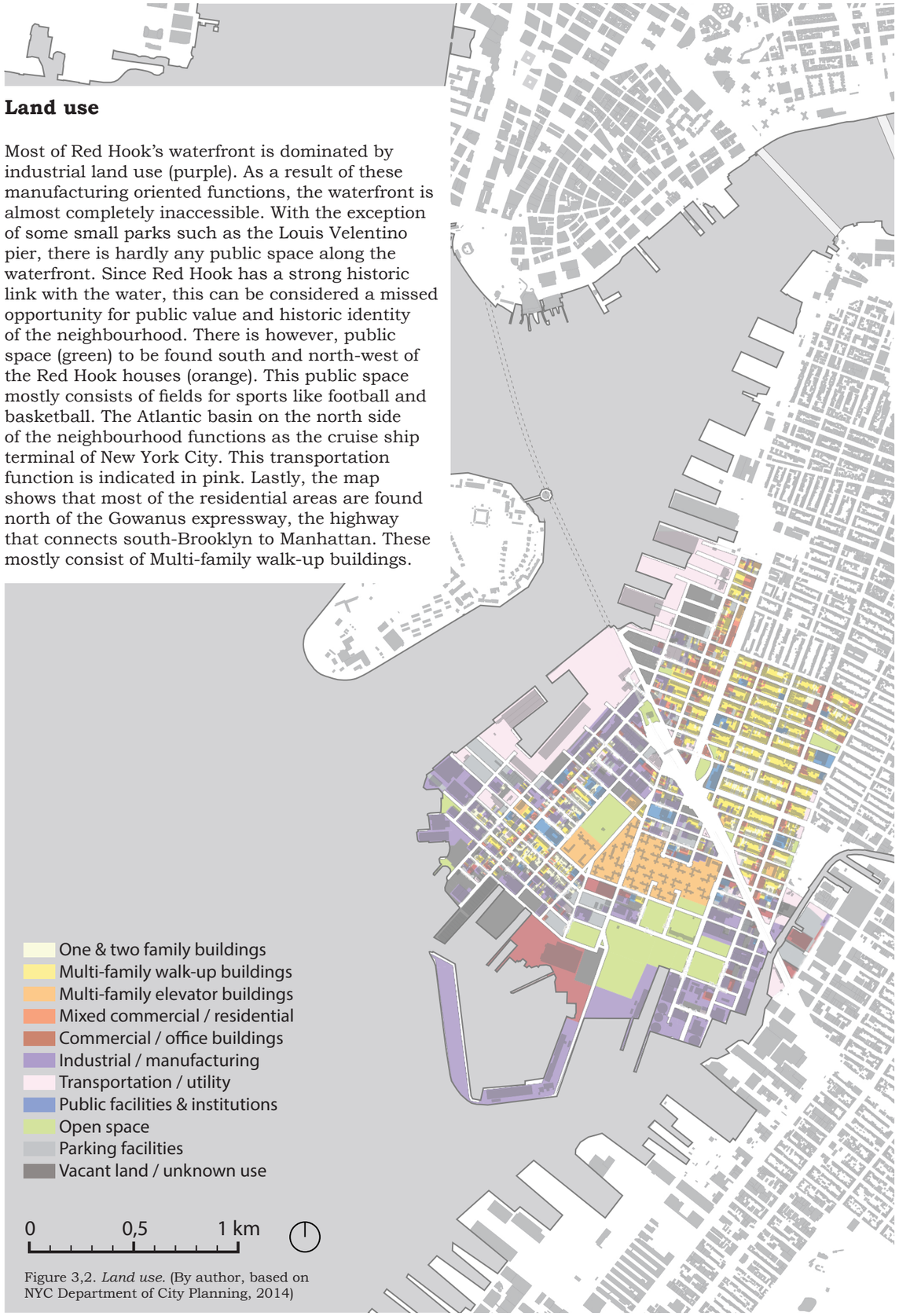


Figure 3,2. *Land use.* (By author, based on NYC Department of City Planning, 2014)

Natural elevation

The map displays the natural elevation of Red Hook and why the area is so sensitive to flooding. Most of the waterfront area is elevated a mere 2/3 meters. These parts of the neighbourhood are directly exposed to influences of the Atlantic ocean. Indicated in shades of green, there are several natural high points in the neighbourhood. As shown later, these are the natural islands that were present since the founding of Red Hook.

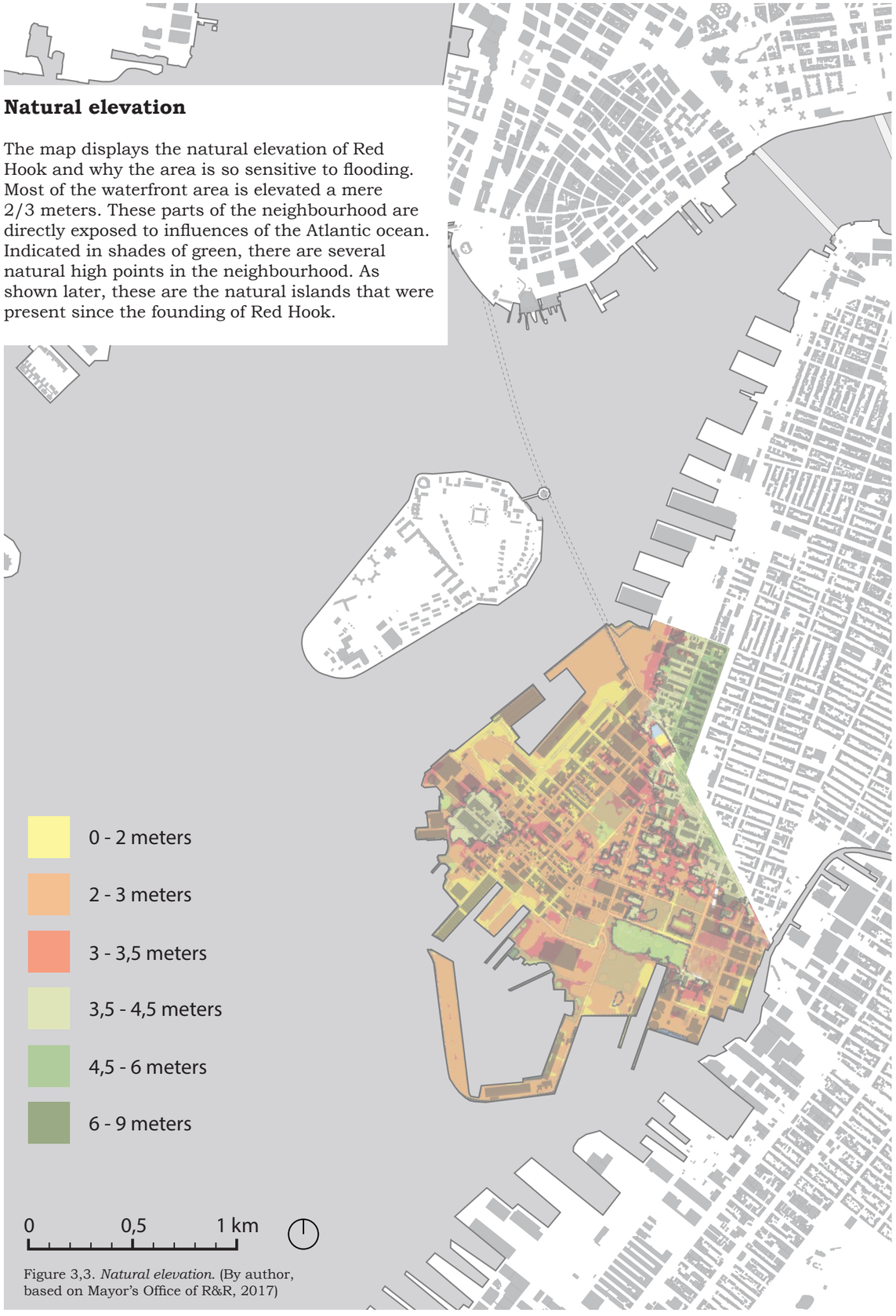


Figure 3,3. *Natural elevation.* (By author, based on Mayor's Office of R&R, 2017)

Flood zones

Three different flood zones are indicated in this map. In light blue the A;AE, and AO zone. This zone corresponds with the FEMA 1/100 years flood plain. The majority of Red Hook is situated in this zone. Even more dangerous are the Coastal A zones. These areas not only deal with the same numbers when it comes to flooding, but can experience strong wave energy when being flooded. Finally, indicated in pink, the 0,2% change annual flood zones. In other words, zones that will flood on average once in 500 years. This corresponds with the high points as indicated in the natural elevations map.

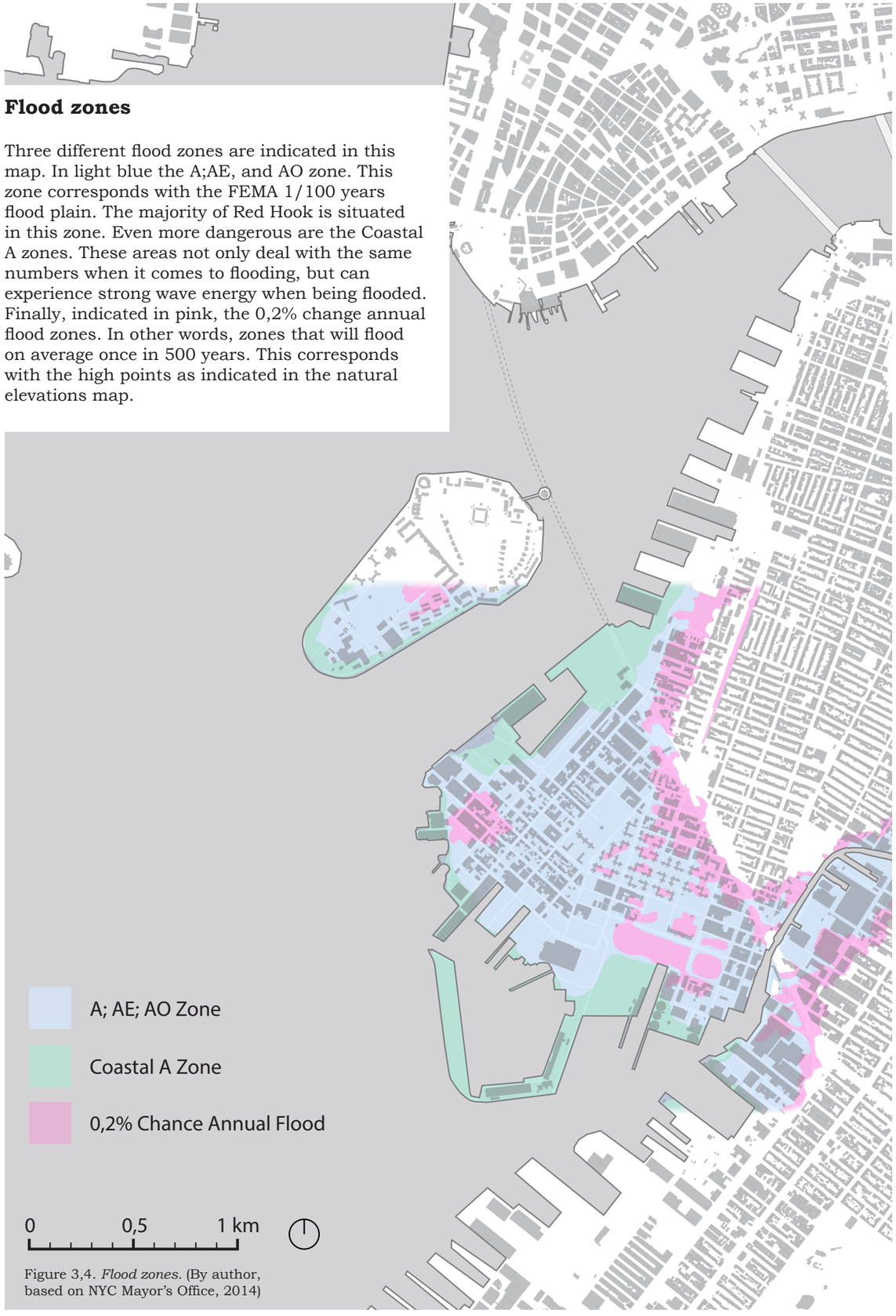


Figure 3,4. *Flood zones.* (By author, based on NYC Mayor's Office, 2014)

Evacuation zones

As with the flood zones, a distinction of three different evacuation zones are made. These are categorized as zone A, B and C. Strikingly, almost the entire neighbourhood of Red Hook is located in evacuation zone A. This means that any hurrice of any strength that makes landfall close to NYC will demand an evacuation of the entire neighbourhood. Only parts of the Red Hook houses are located in zone B.

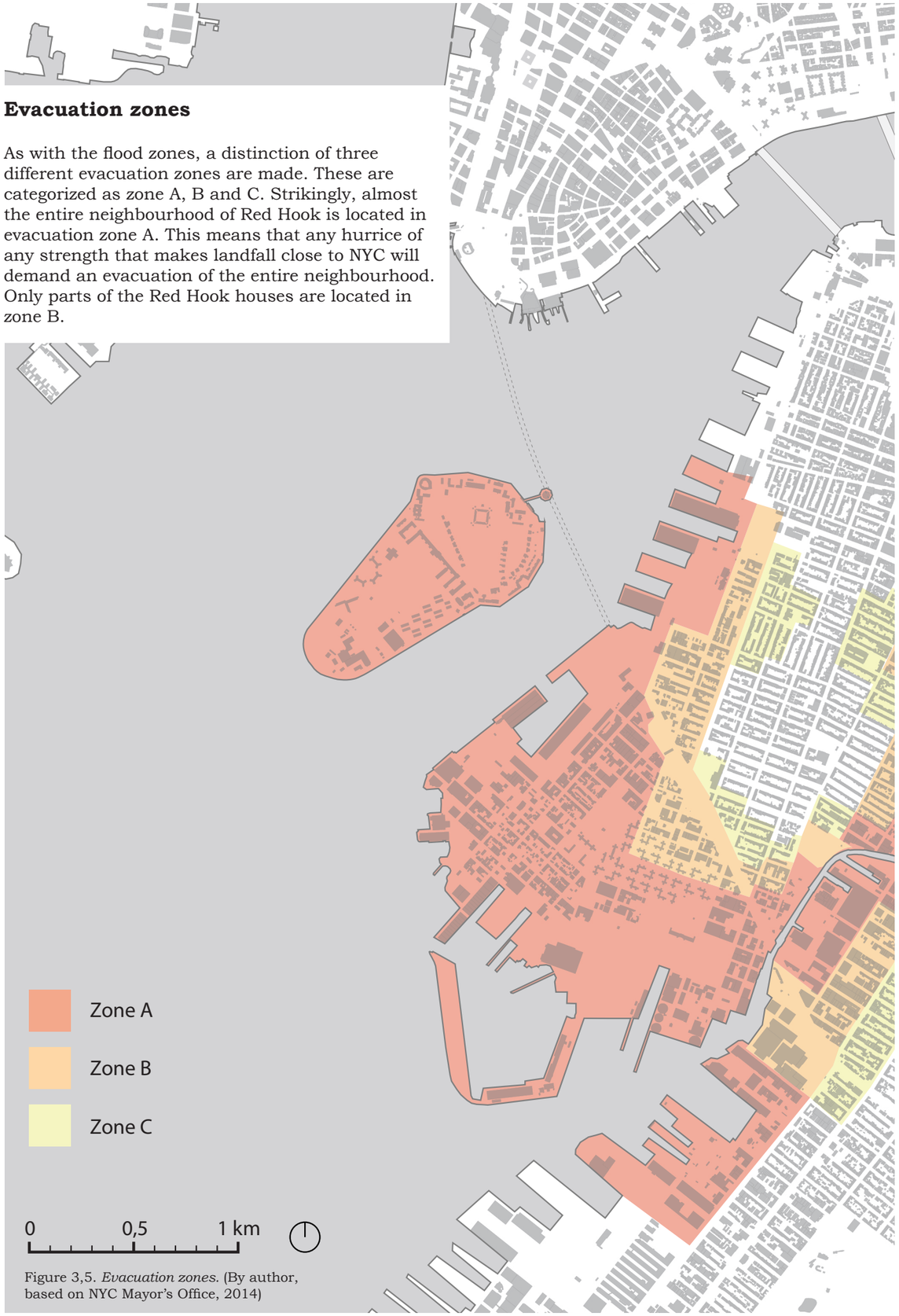


Figure 3,5. *Evacuation zones.* (By author, based on NYC Mayor's Office, 2014)

Sandy surge extent

Another map that shows a strong correlation with the natural elevations of the area, is the one indicating the extend to which Red Hook was flooded during hurricane Sandy. Although the higher points of Red Hook were saved from being flooded, other parts experienced an inundation of up to 3 meters. The entrance of the Hugh L Carey tunnel was completely flooded by storm water. Figure 3,7 displays a flooded Van Brunt street.



Figure 3,7. *Hurricane Sandy.* (Daniel Krieger)

Figure 3,6. *Sandy surge extent.* (By author, based on NYC Mayor's Office, 2014)

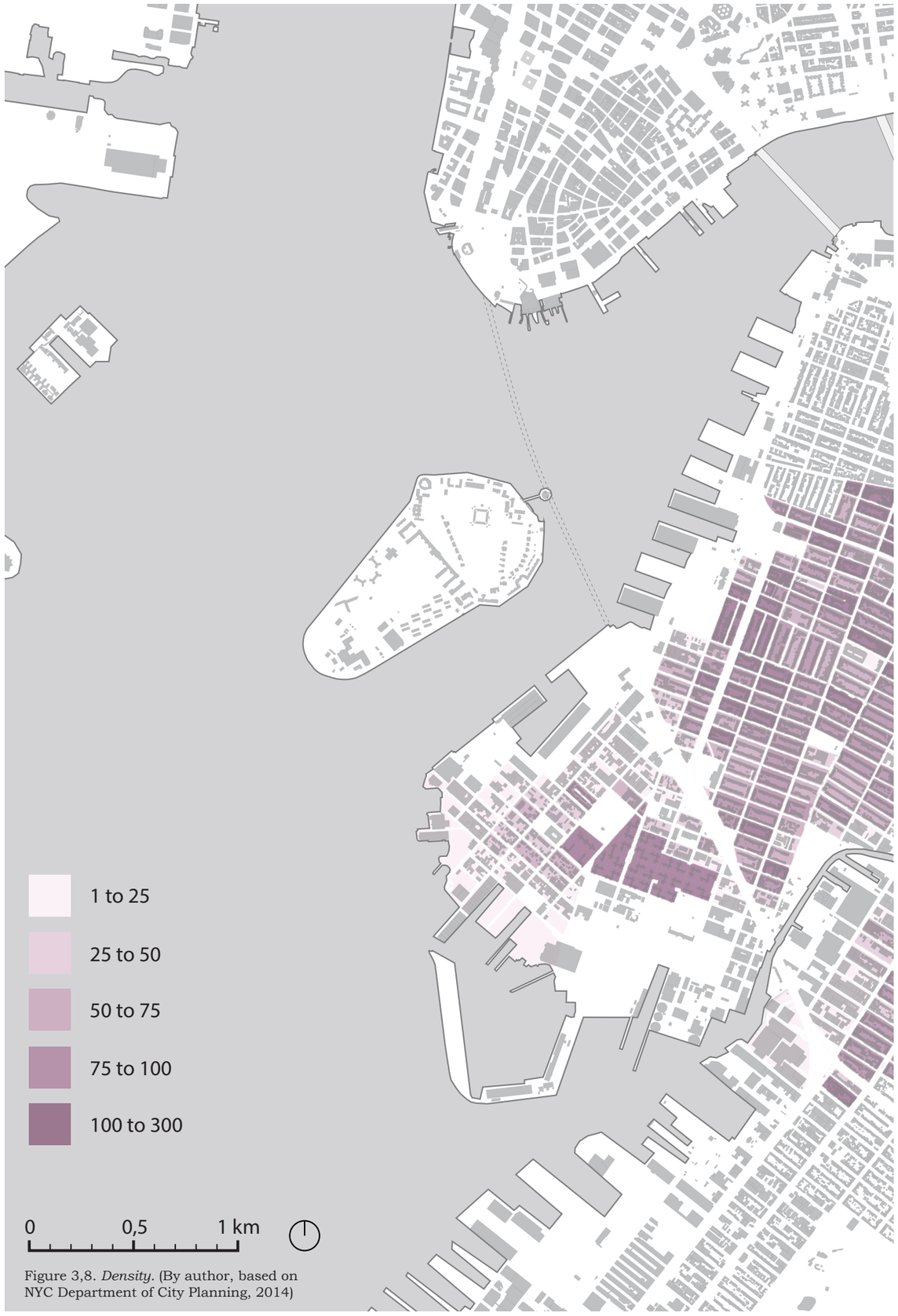


Figure 3,8. *Density*. (By author, based on NYC Department of City Planning, 2014)

Density

The density map shows the amount of inhabitants per acre. Because Red Hook consists mostly of industrial land use, the density of inhabitants is relatively low. Especially along the waterfront, where most of the industrial functions are located, not many residential units are found. The exception is the Red Hook social housing project, with a density of between 100 and 300 inhabitants per acre. Furthermore, there is a distinct difference between the density in Red Hook and Carroll Gardens, north of the Gowanus Expressway. Here the area is clearly more residential with a higher density.



Figure 3,9. *Red Hook Houses*. (NYC Department of City Planning, 2014)

Ethnicity

In Brooklyn, the inhabitants are represented by four main ethnicities. These are Caucasian, Afro Americans, Hispanic people and Asians. Throughout the neighbourhood of Red Hook, these ethnicities are mixed rather well, with the exception of the Red Hook Houses, where mostly Afro Americans and Hispanic people are living. In Carroll Gardens, north of Red Hook, white people make up most of the ethnicity.



Figure 3,10. *Ethnicity.* (By author, based on NYC Department of City Planning, 2014)

Annual income

Where the average annual income in Red Hook is 50k - 75k USD, the Red Hook Houses are left out with a 0 - 25k annual average. Especially compared to the residential area north of the Gowanus expressway, an enormous contrast is visible, where some annual incomes lie even between 100k - 200k. It should be noted however, that most of Red Hook's inhabitants live in the Red Hook Houses project. With a total of 10.227 inhabitants in 2010, around 7.000 of those live in the Red Hook houses (NYC Department of City Planning, 2014). The Red Hook Houses inhabitants should be seen as the majority of Red Hook's population, rather than the exception.

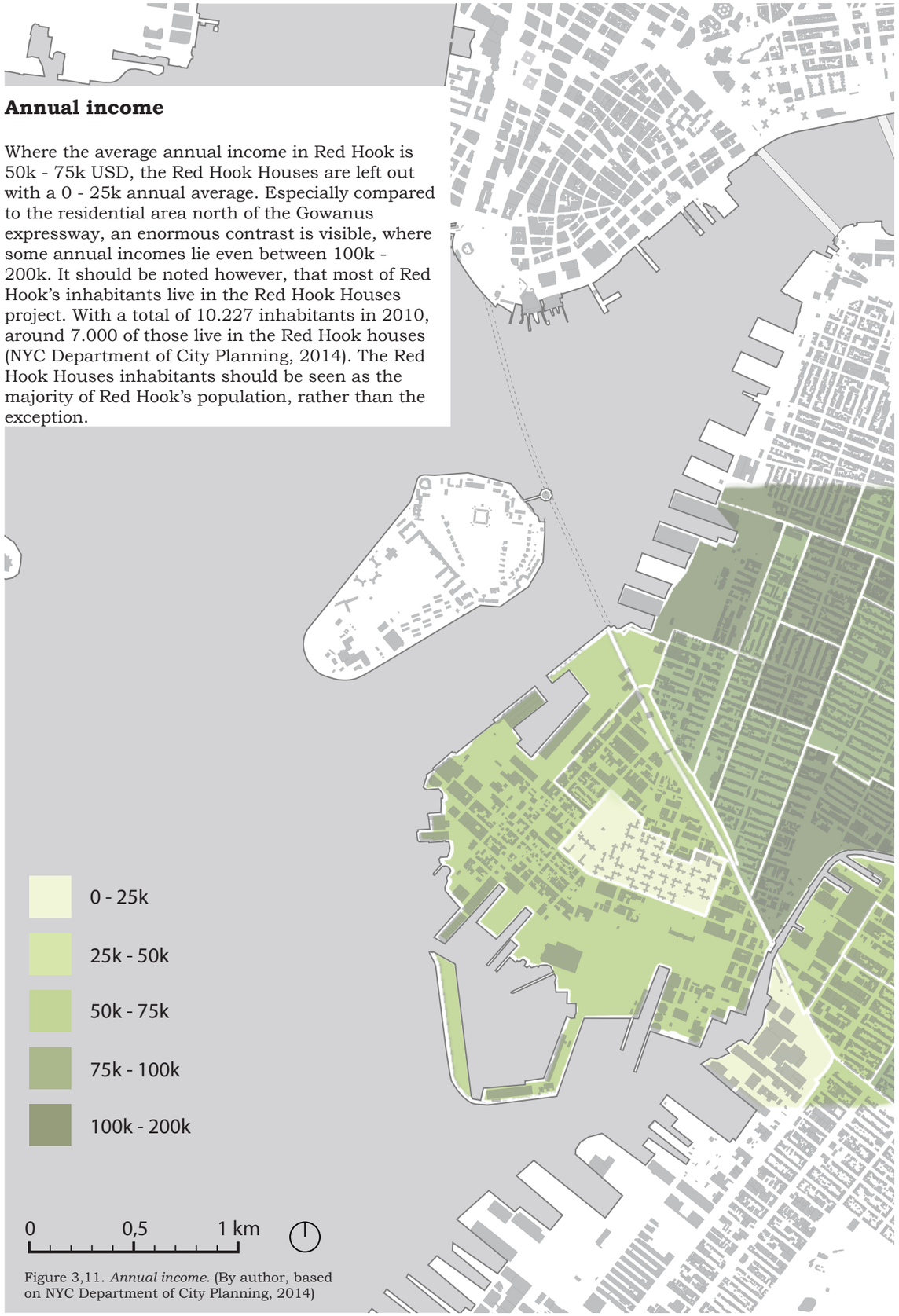


Figure 3,11. *Annual income.* (By author, based on NYC Department of City Planning, 2014)



Figure 3,12. *Public transport.* (By author, based on Google Maps, 2017)

Public transport

New York Cities metrolines are visualized in figure 3,12, and shows how Brooklyn is connected to Manhattan. It also shows how poorly connected Red Hook actually is. Not only is it physically isolated from the rest of Brooklyn by the Gowanus Expressway, it also lacks rapid public transport facilities.

Bicycle lanes

Although bicycle lanes are present in Red Hook, they are sporadic and inconsistent. Whereas there are streets with protected, separated bicycle paths, these often end abruptly. A continuous (protected) route is non-existing, making it hard for bicyclists to get around the neighbourhood safely. Because of the industrial functions, cyclists often find themselves sharing the road with large trucks (NYC Department of City Planning, 2014).



Figure 3,13. *Bicycle lanes.* (By author, based on NYC Department of City Planning, 2014)



Figure 3,14. *Soil pollution.* (By author, based on NYC Mayor's Office of R&R, 2017)

Soil pollution

As a result of the heavy industries being functional for decades along the waterfront, Red Hook now deals with a variety of polluted soil sites. The red dots represent measurements of soil that exceed the allowed values for pollution. Therefore, these sites need to be remediated before extensive development can take place. As indicated, this entails most of the waterfront of Red Hook.

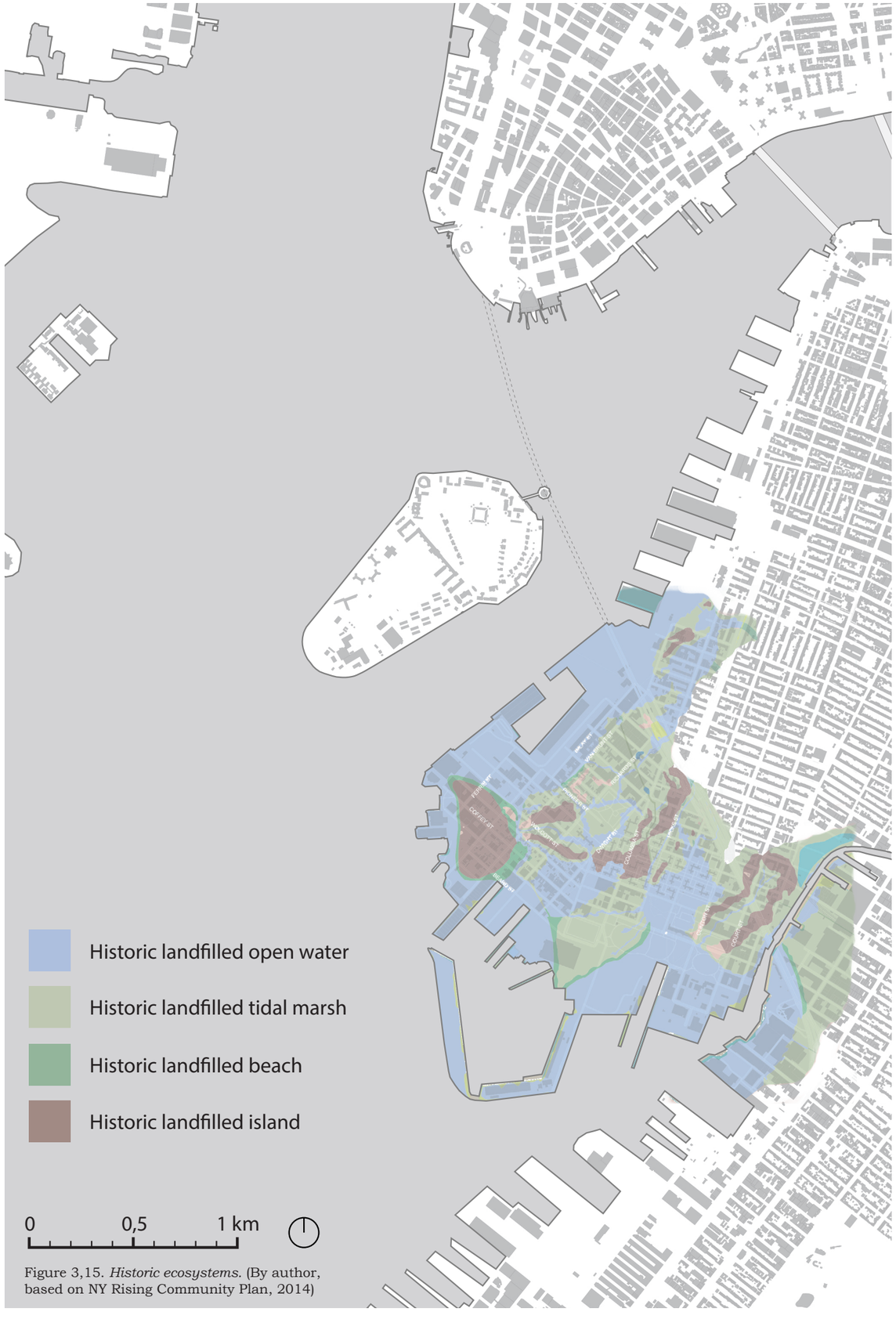


Figure 3,15. *Historic ecosystems.* (By author, based on NY Rising Community Plan, 2014)

Historic ecosystems

When Red Hook was first discovered, it's shape was completely different from what it looks like today. The map displays the historic conditions including the ecosystems present before the industrialisation phase of the neighbourhood. The blue parts used to be open water, while the green lands represent the tidal marshes. These would inundate during hightide, while forming land during the low tide. Only the brown areas are original land, or islands. This variation in dry and wet lands offered excellent opportunities for a variety of ecosystems, thriving in this natural habitat.

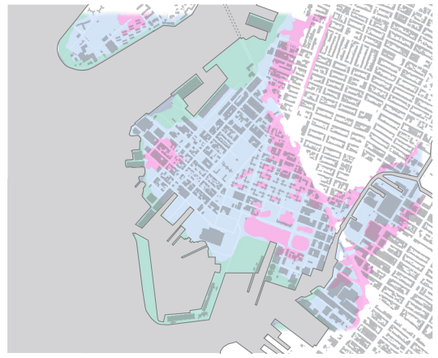
It was around the 19th century, that the upper bay of New York hosted about half of the total oyster population in the world (99% Invisible, 2017; Billion Oyster Project, 2017). These oysters composed 220.000 acres of oyster reefs, which slowed down stormwater and reduced wave energy (Scape / Landscape Architecture PLLC, 2014; 99% Invisible, 2017). In a way, they were NYC's natural protection barrier for strong storms. Due to overconsumption of oysters, and the toxic conditions created by the heavy industry, New Yorkers completely depleted the natural oyster reserve in the bay, leaving the city unprotected. Because almost the entire neighbourhood of Red Hook has been landfilled, as shown on the map, the ecological potential has been significantly decreased. The hard quays that have been created cannot support life forms like tidal marshlands and other natural systems do (Dyson and Yocom, 2014).

> "Two centuries ago, reefs composed of 3 trillion oysters were a "natural seawall" that served as a first line of defense for Manhattan against storms fiercer than 2012's Hurricane Sandy,"
>
> Paul Greenberg

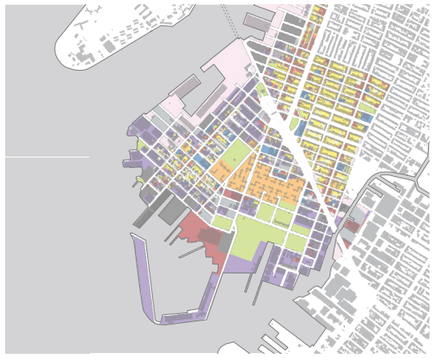


Figure 3,16. *Oyster stalls.* (99 percent invisible, 2014)





Floodrisk





Social dynamics





Ecological situation

Figure 3,17. *Conslusion existing situation.*
(Maps by author, image by 6sqft)

Conclusion

The maps on all relevant topics of the current situation can be grouped in three themes.

The first maps consider the natural elevation level of Red Hook, and the flood- and evacuation zones as a result. It clearly shows why Red Hook is one of the most flood prone areas of NYC and how it was completely inundated during hurricane Sandy in 2012. These maps can all be grouped in the category **Floodrisk**.

The maps of population density, ethnicity and average annual income show how Red Hook has a mixed population, with most of the Afro Americans and Hispanic people concentrated in the Red Hook Houses. This social housing project is also the place with the highest density, combined with the lowest average annual income. These social dynamics in combination with the current land use and public transportation show a need for improving **public value**.

Finally, both current soil conditions as well as historical ecosystems were mapped. It shows how many sites deal with heavy pollution and that natural habitats have been lost as a result of the industrialisation of the waterfront. Not only to restore this natural balance and clean up contaminated sites, but also to combat floodrisk, Red Hook could benefit tremendously from adding **ecological value.**

Flood Risk + Public Value + Ecological Value

Strategic framework

Analyses on city scale

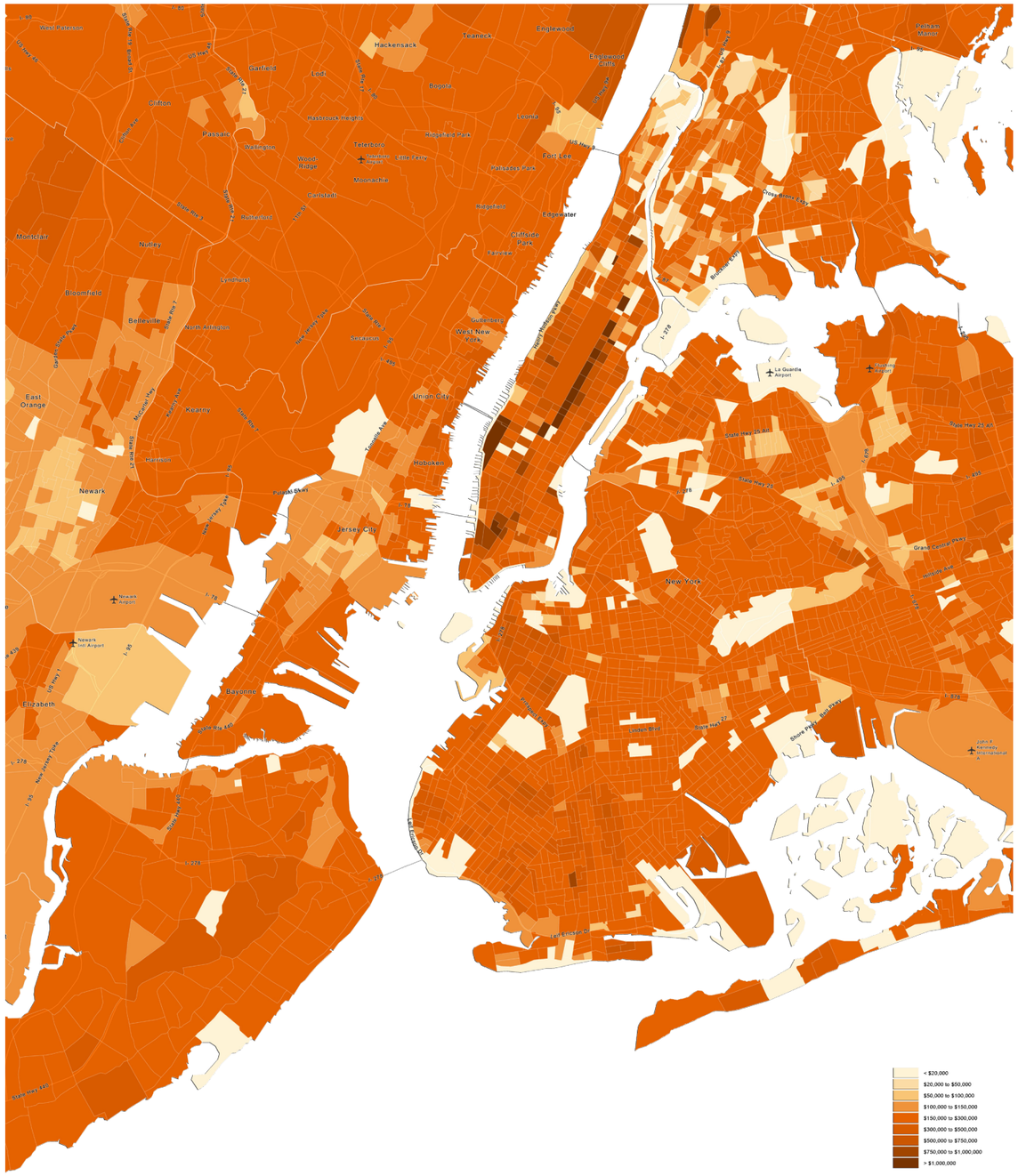


Figure 4,1. *Median house price.*
(By author, based on Social explorer, 2018)

A lack of gentrification

To understand the relation between Red Hook and the of New York City, comparisons and analyses on city scale are done. Although the situation in Red Hook has improved over the last years, the area has not experienced the same kind of gentrification like other parts of Brooklyn (van Veelen, 2016., Westerhof, 2018). This statement is confirmed by the maps in figure 4,1 and 4,2. Based on data from the United State Census, the left map displays the median house price in specific areas, while the map below displays the percentage of people living in poverty. In both cases Red Hook stands out for its low housing prices and high amount of people living in poverty (Social Explorer, 2018).
As showed in the analyses of Red Hook, the area is relatively isolated from the rest of Brooklyn (see figure 3,12). Van Veelen points out that this isolation, and a lack of connection to subway lines is one of the reasons for Red Hook's lack of gentrification (2016). To highlight this isolation further, the study on the next pages investigates the public transit action radius.

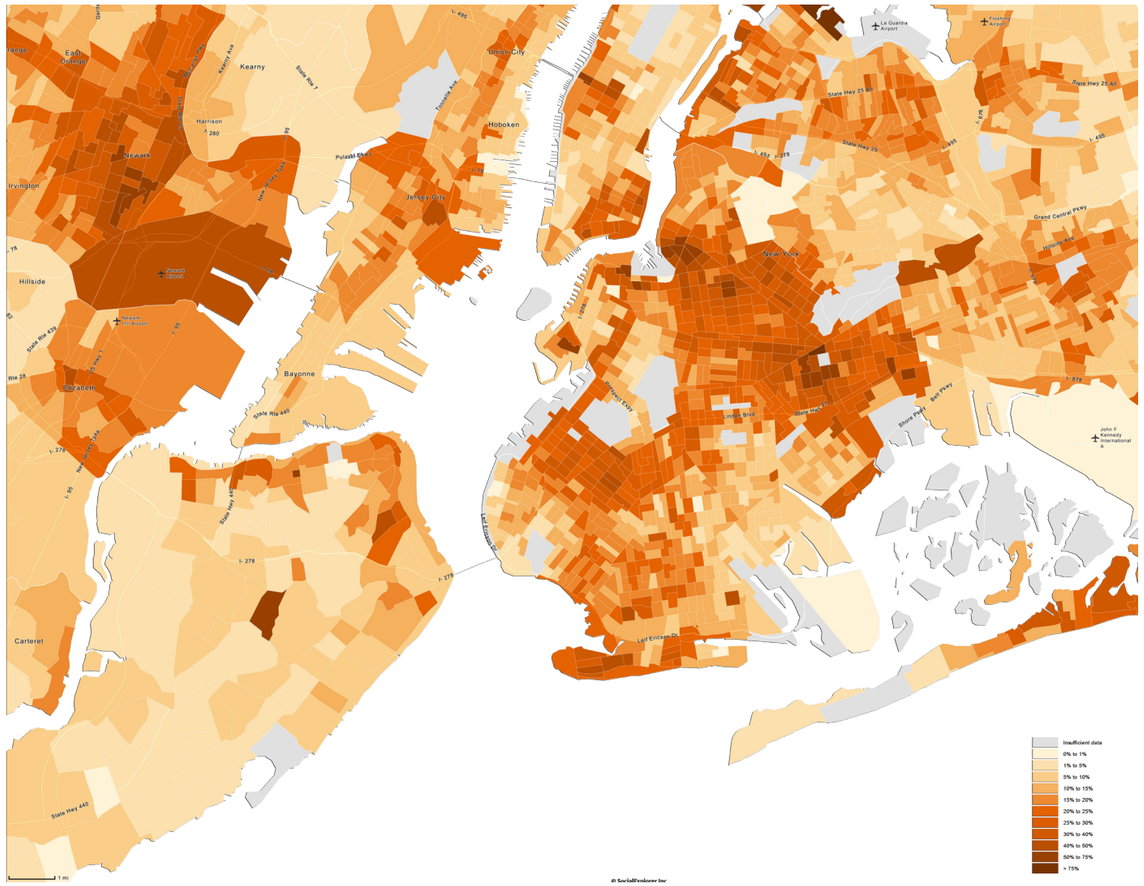


Figure 4,2. *People in poverty.*
(By author, based on Social explorer, 2018)

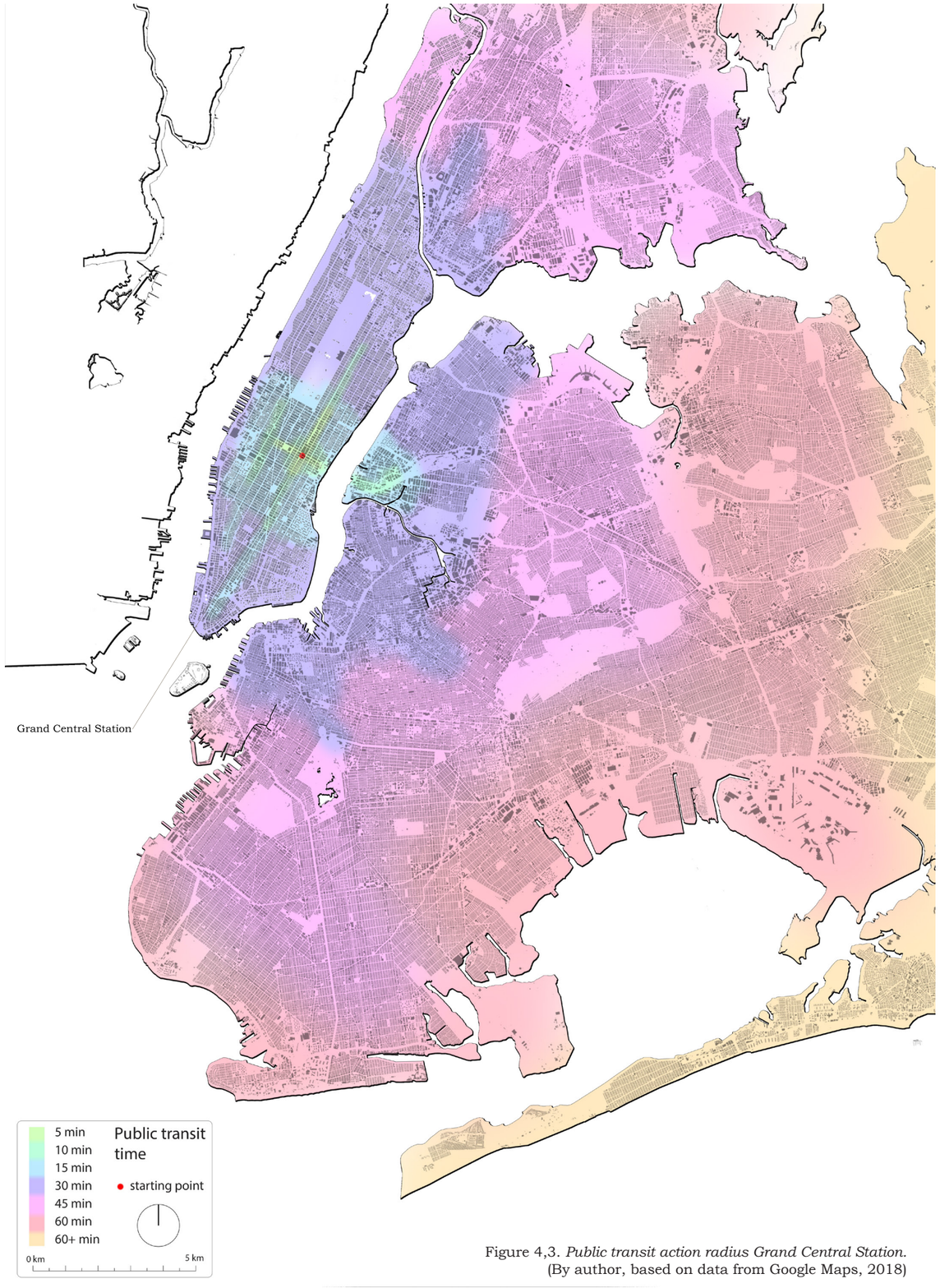


Figure 4,3. *Public transit action radius Grand Central Station.* (By author, based on data from Google Maps, 2018)

Public Transit action radius

To study the action radius of the public transit times in New York City, travel times are mapped. Three respective starting points are used. From these points the areas that can be reached within a specific amount of minutes have been coloured according to the legend.

The first map displays Grand Central station on Manhattan as the starting point. It clearly shows that metrolines follow the grid structure, as these straight lines extent the longest in the 5 and 10 minute area (see figure 4,3). Within 30 minutes, large parts of Brooklyn and almost entire Manhattan can be reached. Within an hour almost every part of New York City can be reached, with the exception of the further parts of Long Island to the east.

The second case takes the Brooklyn Academy of Music as starting point (figure 4,4). Similar to Grand Central Station, the route of metrolines can be distinguised when looking at the 5 to 10 minute radius. In half an hour it is just possible to reach the south side of Central Park, and almost the entire Brooklyn area. However, the west side of Red Hook is an exception to this, as it would take almost 45 minutes to reach this point. A similar distance can be covered in 60 minutes as with Grand Central as starting point, leaving only parts of The Bronx, north of Manhattan in the 60+ minutes range.

Finally the Fairway market in Red Hook is taken as the starting point to measure the public transit action radius (figure 4,5). This map shows a completely different situation from the two previous starting points. The first thing that stands out is the large yellow area which takes more than 60 minutes to reach. While being only seperated a mere 3,5 kilometers from the Brooklyn Academy of Music, the two starting points produce a completely different map. It takes about 15 minutes already to leave Red Hook, and only a very limited part of Brooklyn can be reached within half an hour. Especially when comparing the two maps with Brooklyn and Red Hook as starting point, it becomes clear how severe Red Hook is isolated in terms of public transport. As both van Veelen (2016) and Westerhof (2018) pointed out, this is one of the most important reasons Red Hook has not seen the same amount of gentrification that the rest of Brooklyn has.

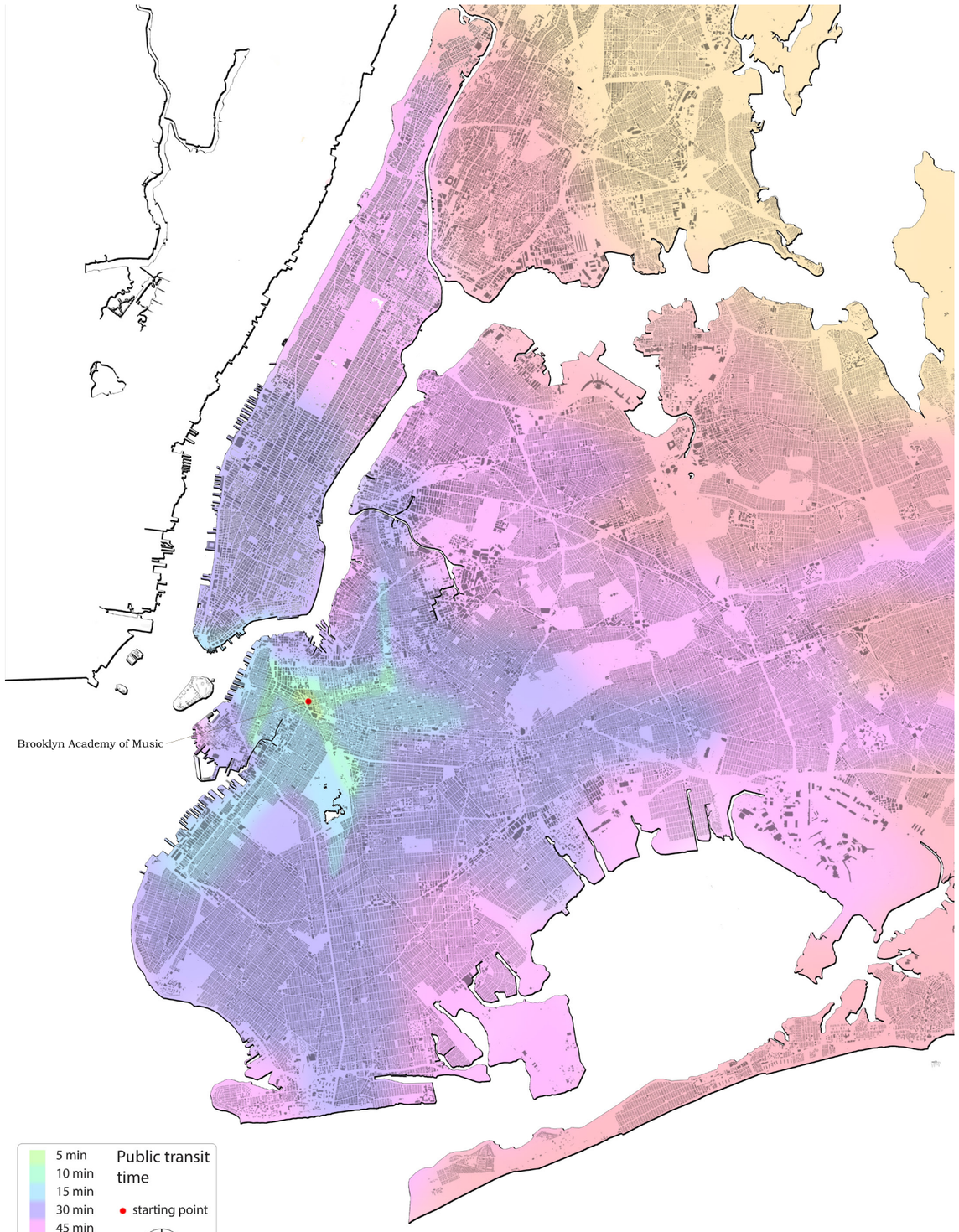


Figure 4,4. *Public transit action radius Brooklyn academy of Music.*
(By author, based on data from Google Maps, 2018)

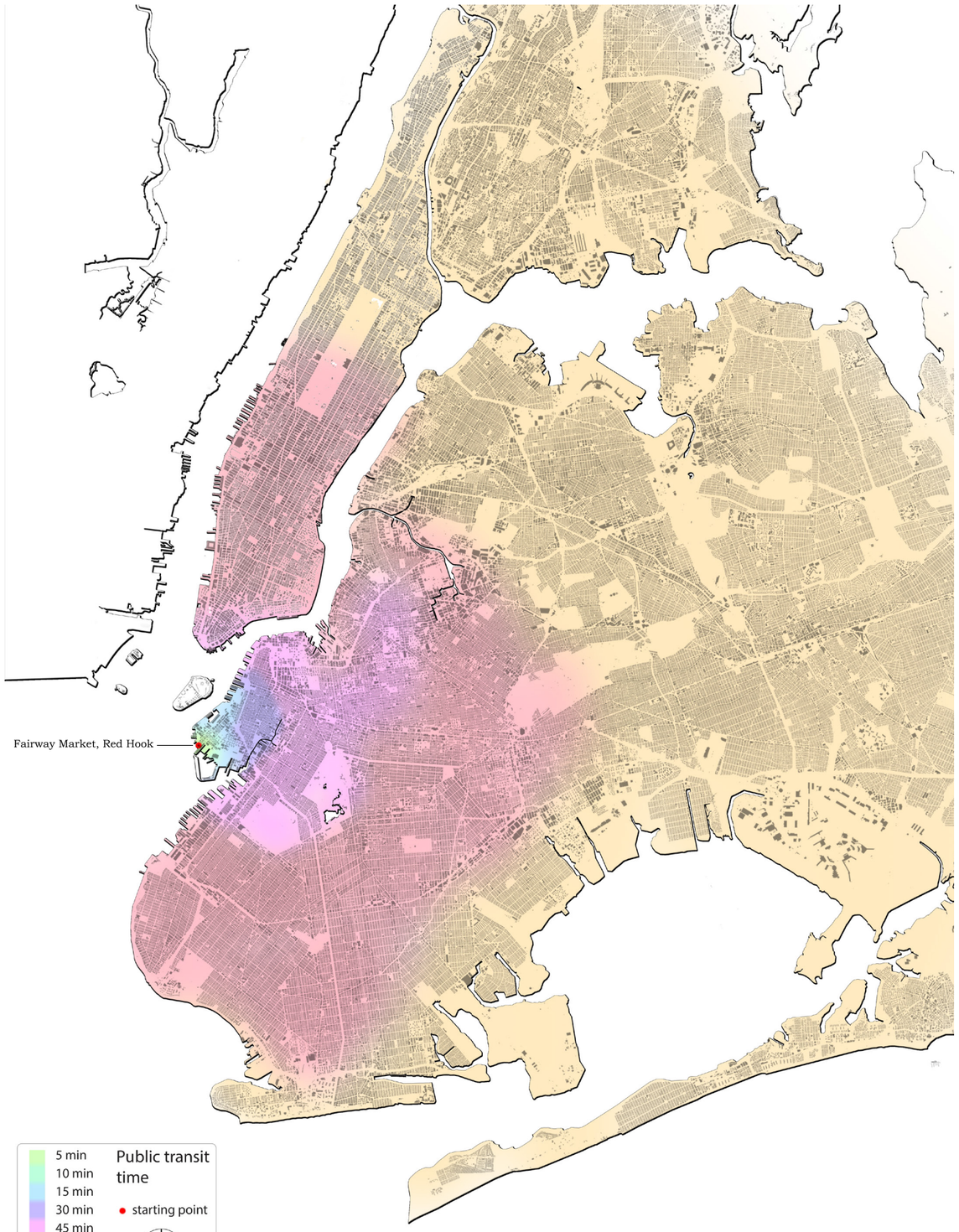


Figure 4,5. *Public transit action radius Fairway market, Red Hook.*
(By author, based on data from Google Maps, 2018)

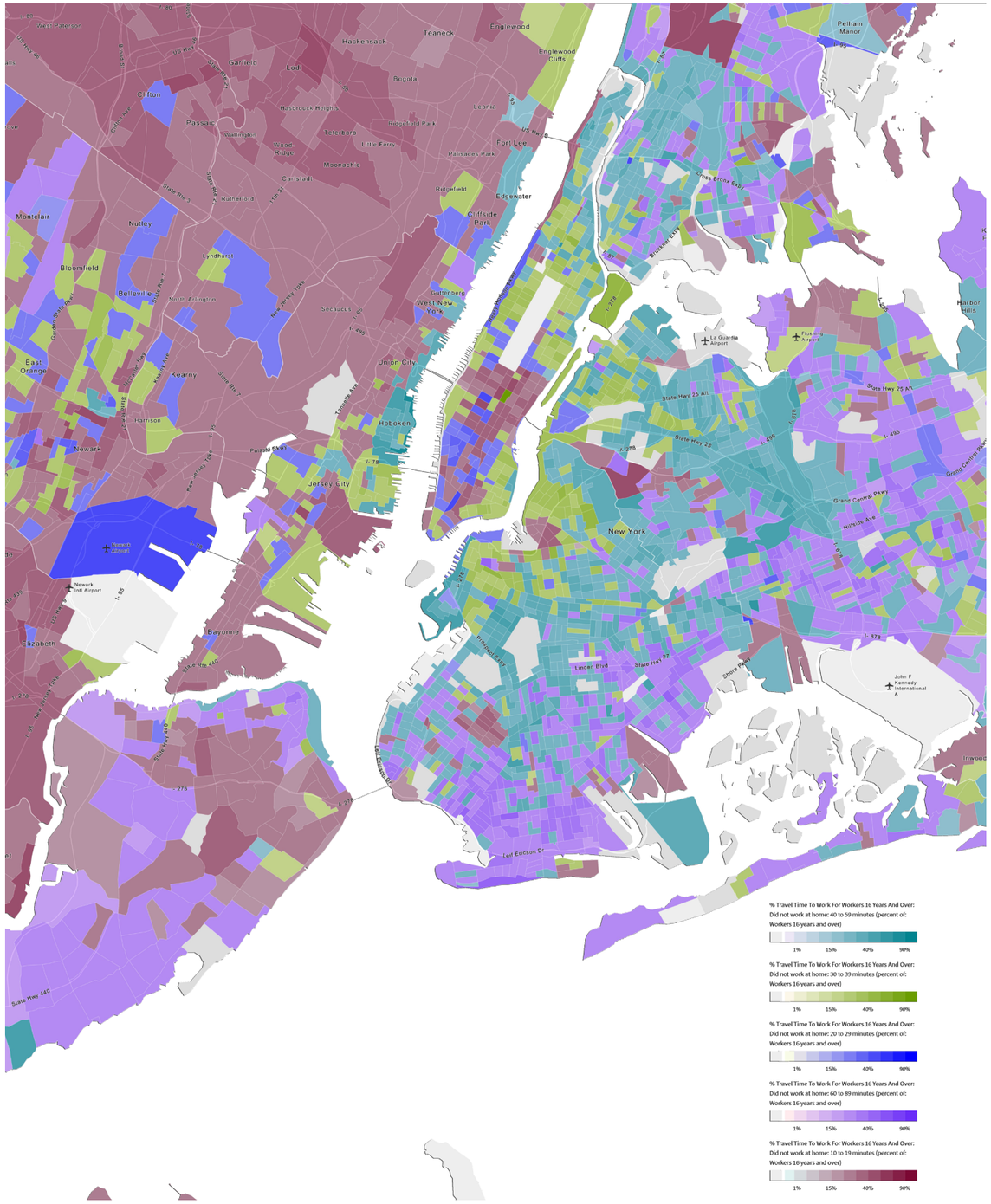


Figure 4,6. *Travel time to work.*
(By author, based on Social explorer, 2018)

Connecting with the findings from the previous maps, the average commute time to work is displayed in figure 4,6. Per census tract (US Census, 2018) the largest demographic group is displayed for a specific area. For example, if 40% of the people in one area travel to their work in 20 to 29 minutes, and the remaining 60% take 30 to 39 minutes, the entire area will display a 60% green (30 to 39 minutes) shade.

Red Hook has a dark shade of turquoise, indicating that as many as 80% of the people have to travel between 40 and 59 minutes to reach their work. This corresponds with the public transit action radius study, as many parts of Brooklyn take up to an hour to reach from Red Hook. This information about the current lack of gentrification as well as the isolation of Red Hook were important aspects to base decisions on in the project.

With the maps in this chapter, basic social dynamics can be understood and put in citywide context. Average housing prices, the amount of people living in poverty as well as connectivity through public transit are presented. With this context in mind, a further zoom out is made to the scale of the bay. On this level a study regarding Rebuild by Design projects is conducted, to analyse what initiatives and research has taken place already.

Rebuild by Design

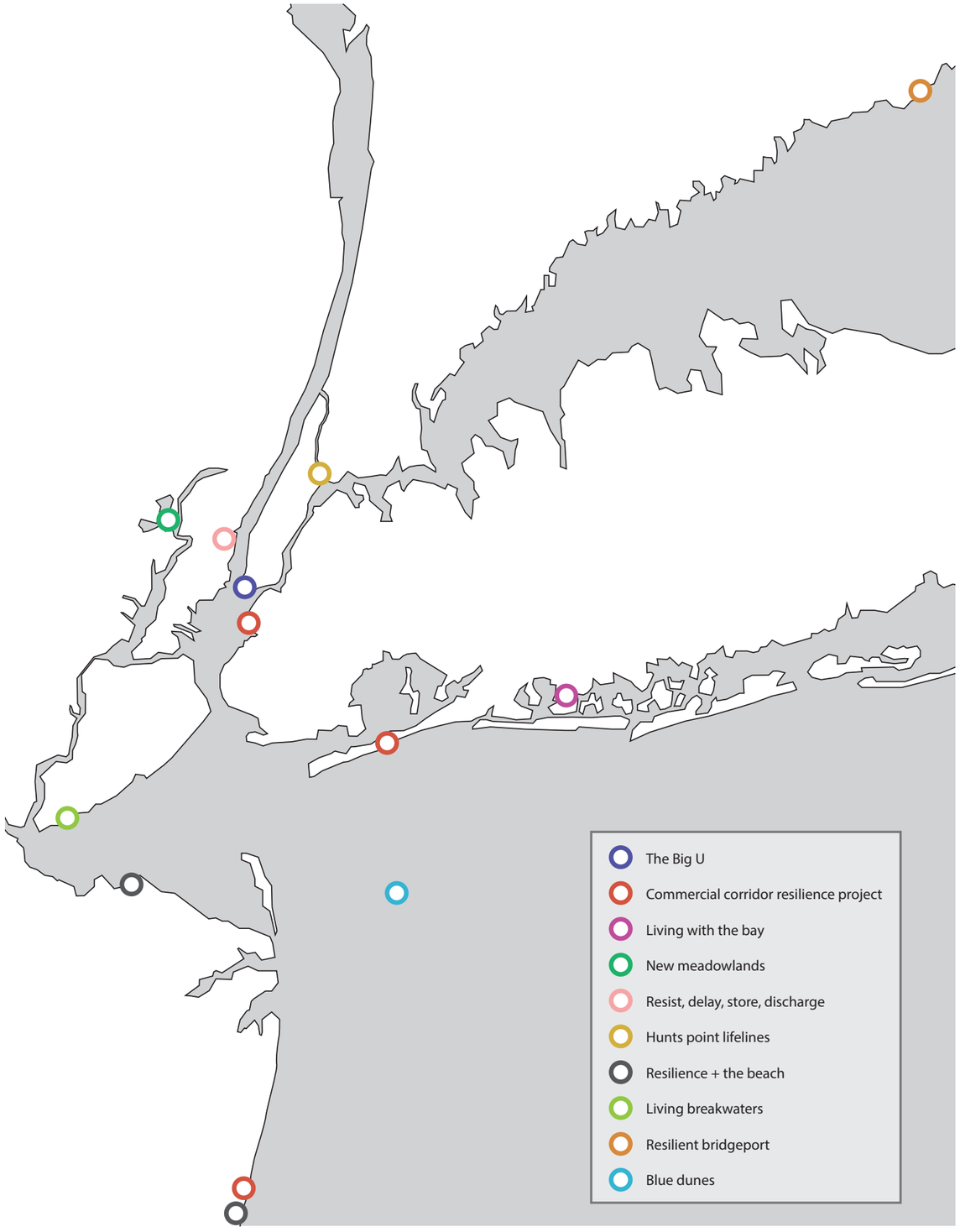


Figure 5,1. *Rebuild by Design projects.* (By author, based on information from Rebuild by Design, 2017)

A response to disaster

The Rebuild by Design competition was initiated as a response to hurricane Sandy in 2012. Initiated by President Obamas Hurricane Sandy Rebuilding Task Force and the U.S. Department of Housing and Urban Development, it focuses on understanding and designing for Sandy-affected regions (Interboro team, 2014). Working together with local communities and countless organizations, Rebuild by Design aims to create innovative solutions to live with the dynamic situations found throughout the region. Of all 41 initial projects, 10 are selected to be further researched (Rebuild by Design, 2017). The project locations are indicated on the map (figure 5,1). Before diving further into the project location of Red Hook, a lot can be learned from studying these Rebuild by Design projects. The projects are reviewed to evaluate how they score on different criteria and if adaptation is successful.

To evaluate the Rebuild by Design projects, theory from Adget et al. (2005) is used, as explained in the theoretical framework. To rate the projects on the components for successful adaptation, nine criteria were chosen. These criteria are based on targets for the Red Hook case and are grouped under the three principles of efficiency, effectiveness and equity (Adger et al., 2005).

Efficiency
- Restructuring existing public space
- Restructuring existing buildings
- Cost / Benefit
- Implementation time

Effectiveness
- Decreasing flood risk
- Increasing public value
- Increasing ecological value

Equity
- Adding housing stock
- Affordable housing

The criteria are visualized in the nonagon diagrams: the higher the peak, the better the project scores on that particular topic. A score from 1 to 10 can be obtained per criterium. An important note regarding the evaluation, is that it is partly based on objective facts, but also on the critical opinion of the author. The criteria that score well in the diagram are investigated in further detail to learn if similar implementation is possible in the personal research.

Additionally, a 'traffic light system' is used to rate the effciency, effectiveness and equity (Adger et al., 2005) of the project. Projects can achieve a red, orange and green light on these three principles of successful adaptation. When rating the effectiveness for example, the sum of the three criteria (in this case decreasing flood risk, increasing public value and increasing ecological value) is divided by 3. This average mark will determine if the effectiveness for this particular project receives a red, orange or green light according to the ranking scale.

Red: average mark of 1 - 4
Orange: average mark of 5 - 7
Green: average mark of 8 - 10

The analyses and concise description of each respective Rebuild by Design project can be found in the appendix of this booklet.



Figure 5,2. *Adaptation ranking all RBD projects.* (By author)

Conclusion Rebuild by Design

To draw conclusions from the Rebuild by Design projects, the traffic lights evaluating the Efficiency, Effectiveness and Equity are displayed for all respective projects. For each component, the highest scoring proposal will be selected to study in detail.

Efficiency
The efficiency component has been constructed by the following four criteria:

- Restructuring existing public space
- Restructuring existing buildings
- Implementation time
- Cost / Benefit

Three projects scored a green traffic light on the efficiency component, being: Commercial corridor project, Hunts point lifelines and Resilient Bridgeport. The Commercial corridor project scored highest out of the three with an average 8,5 for the four criteria. Especially regarding the restructuring of existing buildings to make them less sensitive to flooding, a lot can be learned from this particular project. These smaller interventions have a short implementation time and facilitate a favorable cost/ benefit ratio.

Effectiveness
Three criteria contribute to the effectiveness component:

- Decreasing flood risk
- Increasing public value
- Increasing ecological value

Regarding the effectiveness component, as many as seven projects scored a green light. The two highest scoring proposals are New Meadowlands and Living Breakwaters, both scoring an average 9 for decreasing flood risk and increasing public- and ecological value. Both New Meadowlands and Living Breakwaters use an approach where natural habitats provide flood protection, as well as a surplus in public value. The proposals connect well with existing conditions, while focusing strongly on the three criteria for effectiveness.

Equity
For the equity component, only two criteria have been established:

- Affordable housing
- Adding housing stock

While many of the Rebuild by Design projects are very successful in decreasing flood risk and increasing public value, this leaves a complex ethical situation. In successfully achieving these criteria, land and housing prices will almost inevitably rise (Smith, 1979). Almost none of the projects discuss the possibility of gentrification, and the consequences for current inhabitants. This can be seen when looking at the traffic lights for the equity component. With the exception for the New Meadowlands proposal, all projects score a red light for equity. Although some talk very briefly about adding new houses, or about affordable housing, the two are almost never combined. With the restructuring and rezoning of industrial areas along the 'Meadowband', the New Meadowlands project creates opportunities for the adding of affordable housing stock and scores a 7,5 for the equity component.

Dynamics of the New York Bay



Figure 6,1. *Coastal situation.* (By author, based on NYC Department of City Planning, 2011)

Habitats, tides and currents

As can be concluded from the various locations where the Rebuild by Design projects are situated, the New York Bay area is large and diverse. Waterlevels, tides, currents, wildlife habitats and coastal erosion are all dynamics that have an impact on projects located in this area (Rebuild by Design 2017; NOAA, 2018). To get a better understanding of the dynamics that play a part here, analyses on the scale of the bay are made. The findings will be outlined for the entire area first, after which conclusions will be drawn for Red Hook, and how this area can contribute to improving the dynamics in the New York Bay.

Figure 6,1 displays where natural waterfronts are present in the current situation. On top of this, it shows the location and size of significant coastal wildlife habitats. A correlation exists between the two. Evidently, natural waterfronts provide more opportunities for fish and other coastal wildlife to thrive (Dyson & Yocom, 2014; Scyphers, Powers & Heck, 2015). The fact that wildlife habitats are found in their current locations is also related to the common waterways boats take (NYC Department of City Planning, 2011). Finally, the coasts directly exposed to the Atlantic ocean, seem to struggle with coastal erosion hazards. These are comprised of the south sides of Staten Island, Coney Island and Far Rockaway (left to right).

The next two pages (figure 6,3) display the system of tides and currents in the New York Bay. The National Oceanic and Atmospheric Administration (NOAA) provides accurate oceanic related data for countless measuring points across the United States (NOAA, 2018). 10 measuring points have been selected to show the dynamics between low and high tide. The left section displays the waterlevel on the first of march, 2018 during low tide at the Battery. While the Battery deals with a waterlevel of -30 cm below mean sea level, simultaneously the water is 1,8 meters higher at Whitestone (see figure 6,3). This difference in waterlevel causes a strong current on the East river. The arrows indicate both the speed and direction of the current.

When it is high tide at the Battery 6 hours later, the water is almost 2 meters elevated to 1,6 meters above mean sea level. This causes the current to reverse, as the north part of the East river now has a lower water level. Because there is roughly six hours between low and high tide, the current changes four times a day (NOAA, 2018). The change in current and waterlevel show how the ecosystem of the New York Bay is constantly in motion and has a very dynamic character. This should be taken into account, especially when thinking about ecological interventions.

When looking at the wildlife habitats in the area, it shows a lack of shelter in the Upper New York Bay. Connections between the respective habitats are almost all made via Red Hook. Therefore, this area could serve as the perfect stepping stone to connect existing wildlife habitats, as shown (in green) in the sketch below. When thinking about developing marshlands and other ecology supporting features, information about the currents and difference in waterlevel is of invaluable importance.



Figure 6,2. *New habitat stepping stones.* (By author)

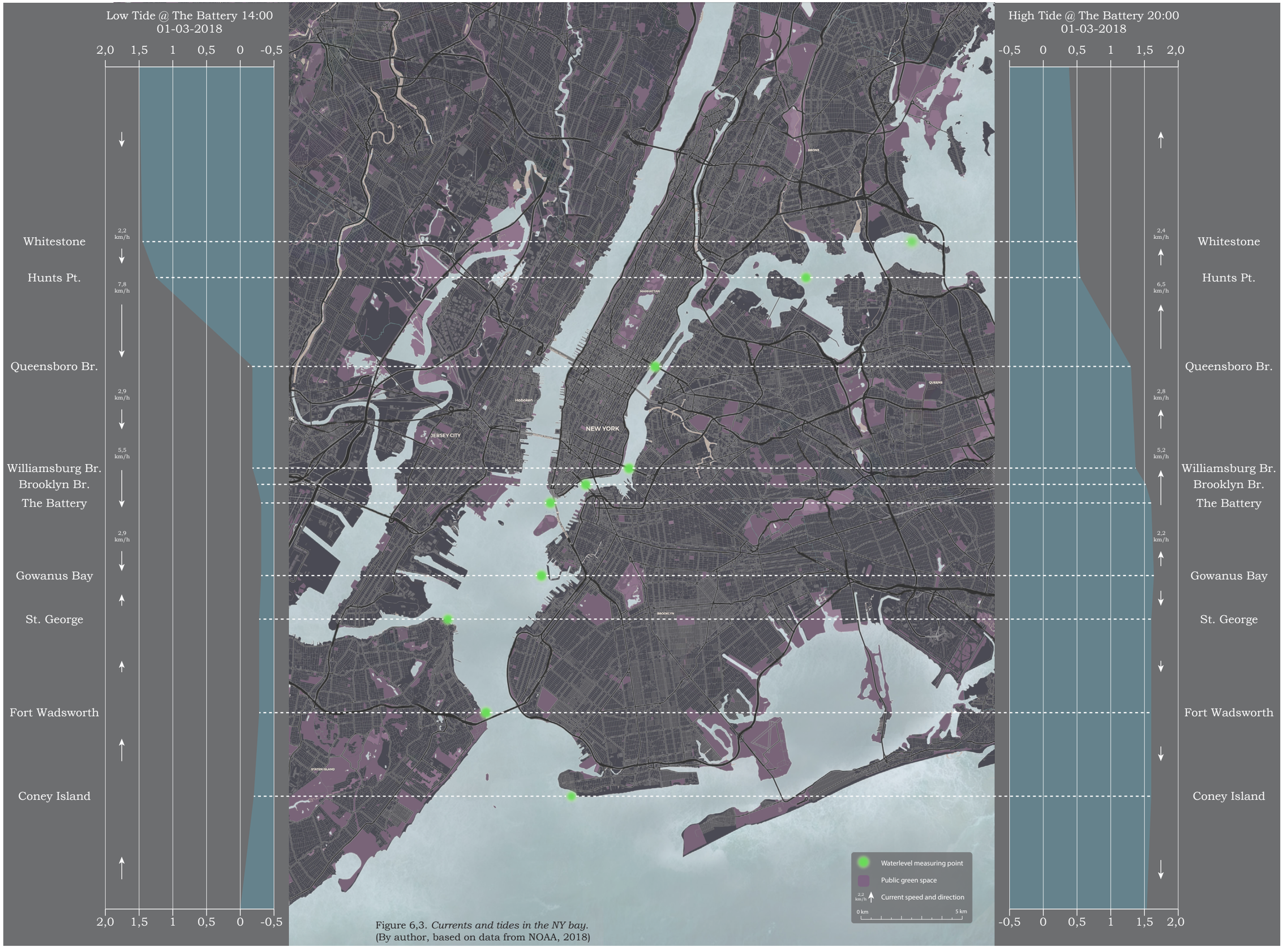


Figure 6,3. *Currents and tides in the NY bay.*
(By author, based on data from NOAA, 2018)

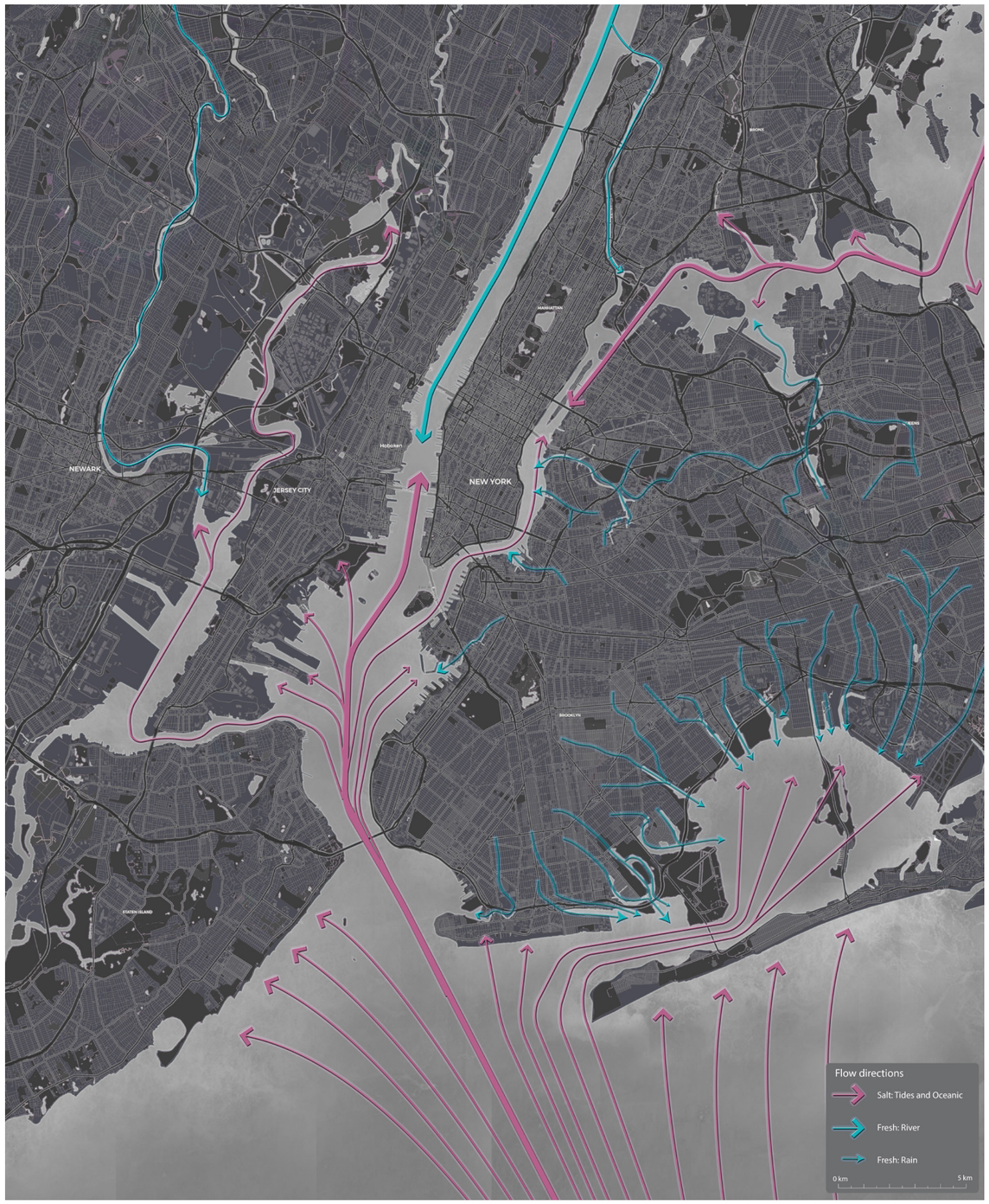


Figure 6,4. *Flow directions and salinity.*
(By author, based on MIT CAU + ZUS + De Urbanisten, 2014)

Flow directions and salinity

The tides and currents map (figure 6,3) shows the flows going back and forth through the New York Bay. These flows cause a constant clashing of fresh and salt water. MIT CAU + ZUS + De Urbanisten have mapped these waterflows in their Rebuild by Design project New Meadowlands (2014). Based on this data the map in figure 6,4 is constructed. Visible in purple arrows are all the salt waterflows, while fresh water flows are represented in blue. Although the clashing points between fresh and salt water are shifting as the tides change, it shows how Red Hook is mostly dealing with a salt water environment. The fresh water input from the Gowanus Canal could provide some local brackish water conditions on the southeast side of the Erie basin pier.

Knowing the salinity of the water is essential to propose certain kinds of habitat. Most flora and fauna need specific conditions regarding the salinity to thrive (Scyphers, Powers, & Heck, 2015). In combination with the knowledge about difference in waterlevel and the current, accurate propositions can be made to encourage habitat development around Red Hook.

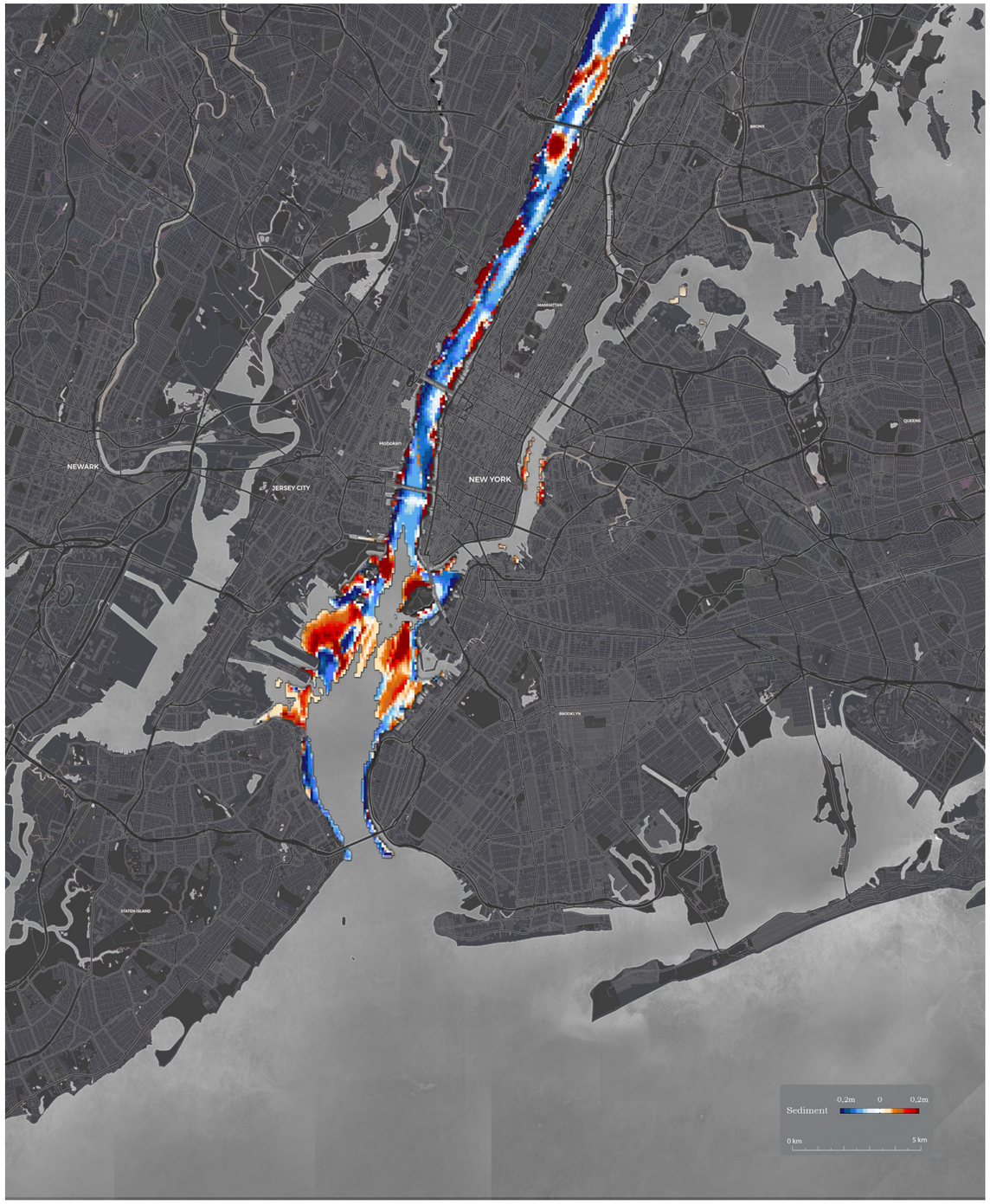


Figure 6,5. *Sedimentation erosion and deposition.*
(By author, data from Ralston, Geyer, Warner, Wall, 2015)

Sediment transportation

Ralston, Geyer, Warner and Wall have mapped the transportation of sediment for their study Linking Sediment Transport in the Hudson from the Tidal River to the Estuary (2015). In this particular map constructed with their data, the erosion and deposition of sediment in the month after hurricane Lee (2011) has been visualized. Because there was excessive rainfall during this period and the process of erosion and deposition was speeded up during this time, an accurate measurement of the dynamics of sediment transportation could be made (Ralston, Geyer, Warner, Wall, 2015). The blue colours represent the erosion of sediment, while the red ones indicate deposition. Large amounts of sediments are being deposited north of Governors Island and west of Red Hook.

The fact that land is formed by the influence of forces of nature, provides incredible possibilities for creating the discussed habitat stepping stone in front of Red Hook. This habitat could at the same time serve as a self-strengthening breakwater, protecting Red Hook's waterfront.



Figure 6,6. *Bathymetry of the New York Bay.*
(By author, data from NOAA Bathymetry, 2018)

The base has been established

When studying bathymetric data from the National Oceanic and Atmospheric Administration, an interesting phenomenon comes up. Because of the ongoing sediment deposition and specific waterway dredging, the base of Red Hook's breakwater and habitat has already been forming under the waterlevel (NOAA Bathymetry, 2018). While the waterways around the underwater island have an average depth of 15 meters, the island has its highest points as shallow as 2 meters under the water surface (NOAA Bathymetry, 2018). With sediments depositing around the island, the underwater base will continue to grow and solidify its position.

On top of the natural growing process, the island can benefit from human influences and vice-versa. Since the completion of interventions in 2016, the Panama Canal allows passage of even larger vessels from China to America's eastcoast (Canal de Panamá, 2018). The New York Port authority and U.S. Army Corps of Engineers anticipated this expansion of the Panama Canal by dredging the New York harbour even deeper (WorkBoat, 2018). To ensure that these enormous vessels can continue to safely dock in New York and New Jersey's harbour, maintenance of the Main Navigation Channel has to take place. Traditionally, the dumping site of dredging material used to be offshore (WorkBoat, 2018). If this dredged material is used to further construct the island in front of Red Hook, this would actually save money, compared to navigating to an offshore dumping site.



Figure 6,7. *Flood risk related projects.*
(By author, based on Mayors Office of Recovery & Resiliency, 2018)

It’s Red Hook’s turn

Concluding the chapter on the dynamics of the New York Bay, this map provides an overview of Flood risk related projects. Although there are more projects initiated in the New York Bay area, only the ones near Red Hook have been shown in figure 6,7. A distinction has been made between four types and stages of projects. In pink, the recovery and reconstruction projects have been indicated. Purple represents the feasibility studies, green projects are in the construction phase, and finally blue projects have been completed. Looking at the waterfront from the tip of Manhattan, passing Red Hook towards the south, there are several projects in the construction phase or have already been completed. However, Red Hook has not come further than the feasibility study phase (Mayors Office of Recovery & Resiliency, 2018). There are recovery projects underway, for example in the Red Hook Houses. These projects however, mostly still reconstruct damage that has been done way back in 2012 by hurricane Sandy (Mayors Office of Recovery & Resiliency, 2018). Red Hook’s waterfront and nearshore area are due for development as well, much like the ongoing and completed projects which have improved other waterfront areas in the vicinity. The favorable dynamics of the New York Bay for developing this area, combined with the need for flood protection, added public- and ecological value, make Red Hook the next area for restructuring.

Fieldwork



Main conclusions fieldwork period

Between 16-01-18 and 06-02-18 New York City was visited. During this fieldwork period local experts and practitioners were interviewed to get a better understanding of Red Hook and its dynamics. Local shop owners have also been approached to discuss their experiences regarding hurricane Sandy in 2012. These interviews are written out in full and can be found in the appendix (page 190-205).
Next to the verbal input on Red Hook, walking through the neighbourhood helped identifying and understanding its character and special features. The following pages summarize the most important conclusions that are drawn from the interviews and visiting the area, which are supported by images to illustrate the drawn conclusion.

The waterfront space is mostly occupied by private companies in large warehouses:



Figure 7,1. *View on the waterfront from Beard st.* (By Author)



Figure 7,2. *Storm surge cannisters placed directly against existing wall (on the right), but skips gate opening to waterfront. Activity directly on the waterfront should also be protected to flooding.* (By Author)

People appreciate and value the historic harbour identity of the warehouses:



Figure 7,3. *Historic tram and warehouse the Fairway market is situated in.* (By Author)

Several companies in the warehouses have initiated building-scale wet floodproofing measures:



Figure 7,4. *Critical equipment on elevated flood in waterfront warehouse.* (By Author)

Infrastructure such as sewer is dilapidated and over capacity:

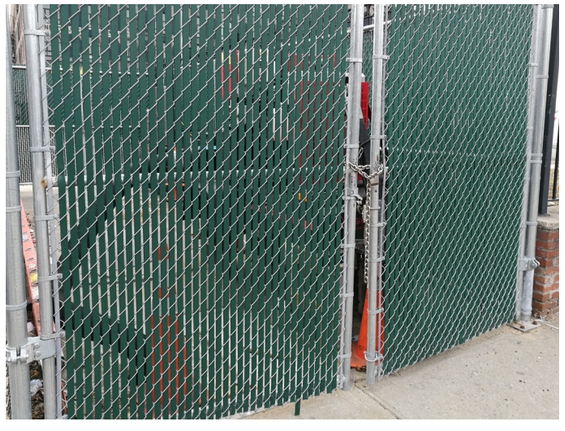


Figure 7,5. *Pump on Van Brunt st turns on in cases of heavy rainfall and when sewer is over capacity.* (By Author)

Many of the warehouses are directly exposed on the waterfront and very poorly protected:



Figure 7,6. *Warehouses directly on water remain unprotected in current flood reduction measurements.* (By Author)

Cycle lanes in the neighbourhood are sporadic and inconsistent:



Figure 7,7. *Inconsistent bicycle paths are fround throughout the neighbourhood.* (By Author)

Clear view on the water is key:



Figure 7,8. *Overlooking the Upper New York bay from behind the fairway market.* (By Author)

Many plots close to the waterfront are undeveloped and consist of large parking spaces:



Figure 7,9. *One of the inland plots used for parking of school busses .* (By Author)

The IKEA parking lot takes up a lot of space directly on the waterfront and consists of unpermeable surface:



Figure 7,10. *The IKEA parking lot occupying substantial waterfront space.* (By Author)

The plansite

Three areas of development

To protect Red Hook against flooding, three areas with different characteristics are developed. The areas are categorized as Nearshore, Waterfront and Inland area and form the plansite for the design (figure 8,1). The developments in the respective locations work as a coherent system to provide the best possible flood protection, while adding public- and ecological value as well (figure 8,2). In this chapter, the existing conditions of the three locations are analysed, to discuss the possibilities and restrictions for development.



Figure 8,1. *Three focus areas of development.* (By author)

Nearshore

In the nearshore area, westbound of the Erie basin pier the underwater island is situated. This island has been introduced in figure 6,6. Developing this island has a variety of benefits. Not only does it serve as a breakwater to reduce wave energy and protect Red Hook, it provides ample space for wildlife habitat as well. The island is developed to be publicly accessible, in order to add public value as well. More arguments for constructing the breakwater island in both environmental and economical sense can be found in the chapter 'Dynamics of the New York Bay', starting at page 78.

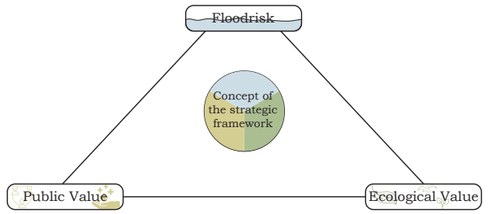


Figure 8,2. *Three components of the strategic framework.* (By Author)

Waterfront

As the spatial and contextual analyses show, a majority of the most challenging issues revolve around the waterfront area of Red Hook. Because of the fact that many warehouses on the waterfront are privately owned, public restructuring attempts so far seem to have ignored protecting this waterfront area (interview R. Hall, 25-01-18). The owners of these warehouses can only protect themselves with flood proofing measures, such as replacing their doors and building temporal walls with sandbags. Inhabitants indicate they appreciate the historic character and identity of the waterfront warehouses (interviews Russell and Thomas, 24-01-18; R. Hall, 25-01-18). A sustainable long-term solution is far from being realised (interview R. Hall, 25-01-18). As depicted in figure 3,4, these areas are coastal A zones and are currently exposed to high energy wave impacts (NYC Mayor's Office, 2014).

Next to the historic warehouses, there are 3 other types of private ownership in the waterfront area: the IKEA terrain and New York police department auto impound claim substantial waterfront space. Finally, there is the undeveloped brownfield area. Reducing the flood risk is a challenging problem, as there is limited space for interventions between the waterfront buildings and water. On top of that, remaining a clear view to the water is absolutely essential (interview R. Hall, 25-01-18). Currently, a lot of waterfront space is not publicly accessible, as can be derived from figure 3,2 (NYC Department of City Planning, 2014). By relocating space-consuming functions such as parking lots, qualitative public space is created near the water.

Inland

The plots inland behind the waterfront form the last focus area of the plansite. These five plots connect two of Red Hook's natural higher points. These natural high points are between 4,5 and 6 meters above mean sea level and did not get flooded during hurricane Sandy as is displayed in figures 3,3 and 3,6 (NYC Department of City Planning; NYC Mayor's Office, 2014; NYC Mayor's Office of Recovery and Resiliency, 2017). The plots are transformed to use them as a flood defence, connecting the elevated areas of Red Hook.

Assessing the current conditions

The current conditions of the waterfront and inland areas are analysed, which is displayed on the next pages. The four owner typologies found on the waterfront are evaluated on multiple aspects. To assess the public space, theory of Gehl & Koch (2011) is used, as introduced in the theoretical framework on page 33. Because some of the owner typologies found in Red Hook's waterfront are very diverse in nature, the criteria have to be assesed on multiple locations. For example the parking lot of the IKEA does not score too well on the 12 criteria, whereas the adjacent park is rated as a pleasant public space. After evaluation of the the waterfront area, an isometric drawing was made to provide an overview of the quality of public space (figure 8,25). Red areas represent public space which scored below 24 points (an average 2 for all 12 criteria) while the green ones depict successful public space with 24 points or higher. This drawing provided an overview of which areas should get extra attention during the development the waterfront area.

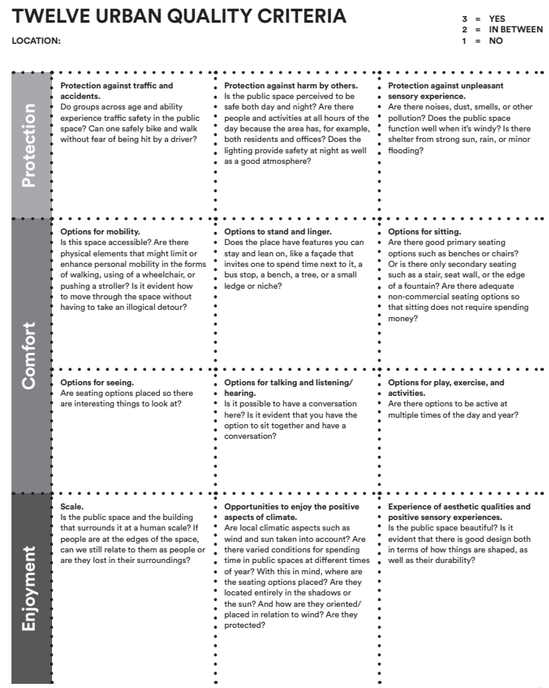


Figure 8,3. *Twelve urban quality criteria.* (Gehl & Koch, 2011)



Figure 8,4. *Waterfront area.* (By author)

Waterfront

1. Historic warehouses

The warehouses on the waterfront are rented out to multiple companies. While some occupy a complete building, like the Fairway market, other buildings are divided into smaller office units. Although the space around most of the warehouses is currently privately owned, there are two public parks in this area.





Figure 8,5. *Historic warehouses.* (Google maps)

2. Brownfield area

Right next to the warehouses on Van Brunt street, a large undeveloped plot is situated. This brownfield area can be developed to contribute to the three components of the approach and respond to the character and identity of the warehouses.



Figure 8,6. *Brownfield area.* (Google maps)

3. IKEA terrain

Since 2008, IKEA resides in Red Hook. Although this development has brought a lot of employment and prosperity to the neighbourhood (Hall, 2018), it has also made a severe impact on the public space. A large car park takes up a lot of space almost directly on the water. The plot is owned by IKEA only, in contrast to the collection of owners in the case of the warehouses.



Figure 8,7. *IKEA terrain.* (Google maps)

4. NYPD auto impound

Finally, the last owner typology found on the waterfront is federally owned. The auto impound of the New York Police Department is situated around Erie basin, formed by the pier. Most of the pier is used for parking cars and is not publicly accessible.

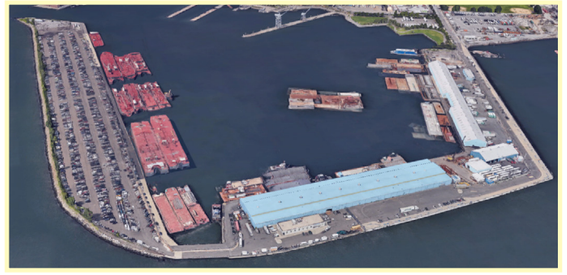


Figure 8,8. *NYPD auto impound.* (Google maps)

Typology 1: Historic warehouses

The warehouses on the waterfront show the original identity of Red Hook's thriving harbour times. For analyzing this area the distinction is made between the absolute waterfront and the streets and parking lots behind it, as indicated in figure 8,9

In the perspective section, (Persection) in figure 8,10, the end point of Van Brunt street is visualized (section line in figure 8,9). Here the waterfront is reached, where most of the historic warehouses are located. Hosting several functions from supermarket to creative office space, the warehouses are fully operational (Interview Hall, 25-01-18). Between the warehouses, there is a lot of public waterfront, as analysed by making the Nolli map (figure 8,12). It is not always clear what is public space and what belongs to the companies in the warehouses. Despite this, most of the waterfront has a qualitative appearance with sufficient seating possibilities. The evaluation describing the 12 quality criteria by Gehl & Koch (2011) scores 30 points, making it the highest scoring area of the 4 typologies.

The remaining area of this typology is mostly filled with parking lots, streets and paved surface (indicated in the lighter colour purple in figure 8,9). Needless to say, these do not provide similar qualities as the waterfront with its small parks and seating options. This area has been evaluated by means of the same criteria by Gehl & Koch (2011). Visualized in the right table of figure 8,11, it scores a total of 19 points, showing options for improvement.



Figure 8,9. *Historic warehouses.* (By author)

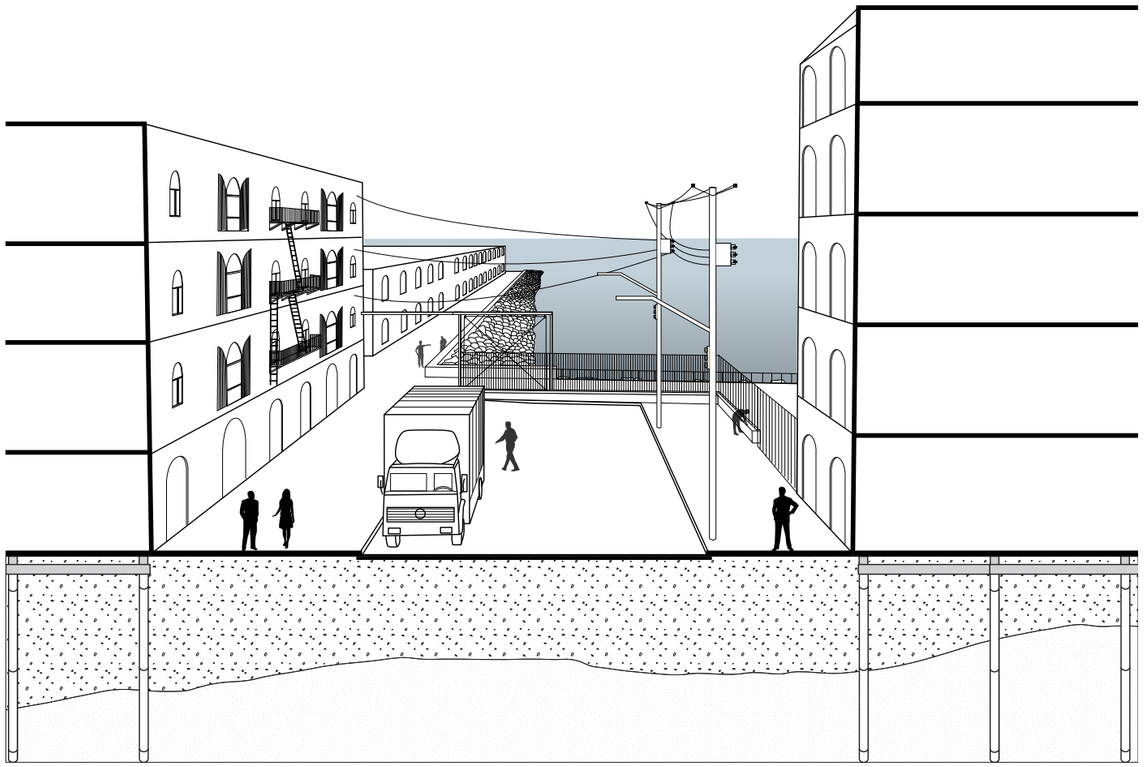


Figure 8,10. *Perspective section historic warehouses.* (By author)

TWELVE URBAN QUALITY CRITERIA — Total score: 30
LOCATION: Historic warehouses, waterfront

Protection	Protection against traffic and accidents. 3	Protection against harm by others. 2	Protection against unpleasant sensory experience. 1
Comfort	Options for mobility. 3	Options to stand and linger. 2	Options for sitting. 3
	Options for seeing. 3	Options for talking and listening/ hearing. 3	Options for play, exercise, and activities. 2
Enjoyment	Scale. 3	Opportunities to enjoy the positive aspects of climate. 2	Experience of aesthetic qualities and positive sensory experiences. 3

TWELVE URBAN QUALITY CRITERIA — Total score: 19
LOCATION: Historic warehouses, streets

Protection	Protection against traffic and accidents. 1	Protection against harm by others. 2	Protection against unpleasant sensory experience. 2
Comfort	Options for mobility. 3	Options to stand and linger. 1	Options for sitting. 1
	Options for seeing. 2	Options for talking and listening/ hearing. 1	Options for play, exercise, and activities. 2
Enjoyment	Scale. 2	Opportunities to enjoy the positive aspects of climate. 1	Experience of aesthetic qualities and positive sensory experiences. 1

Figure 8,11. *Assessment through criteria by Gehl & Koch.* (By author)

Figure 8,12. *Nolli map.* (By author)

Typology 2: Brownfield area

The second typology is an undeveloped brownfield area. It is situated just southeast of the warehouses, and therefore offers great potential to be developed in a way that compliments the identity of these characteristic buildings. This possibility is one of the only positive traits of the area, as it scores only 13 points on Gehls criteria. Ofcourse, since the plot is not publicly accessible, the evaluation is expected to score low. However, with a size of 140 by 213 meters and view on the Upper New York bay, there are plenty of possibilities for development. Moreover, the single ownership of the plot (Interview Hall, 25-01-18) helps with speeding up the development process.

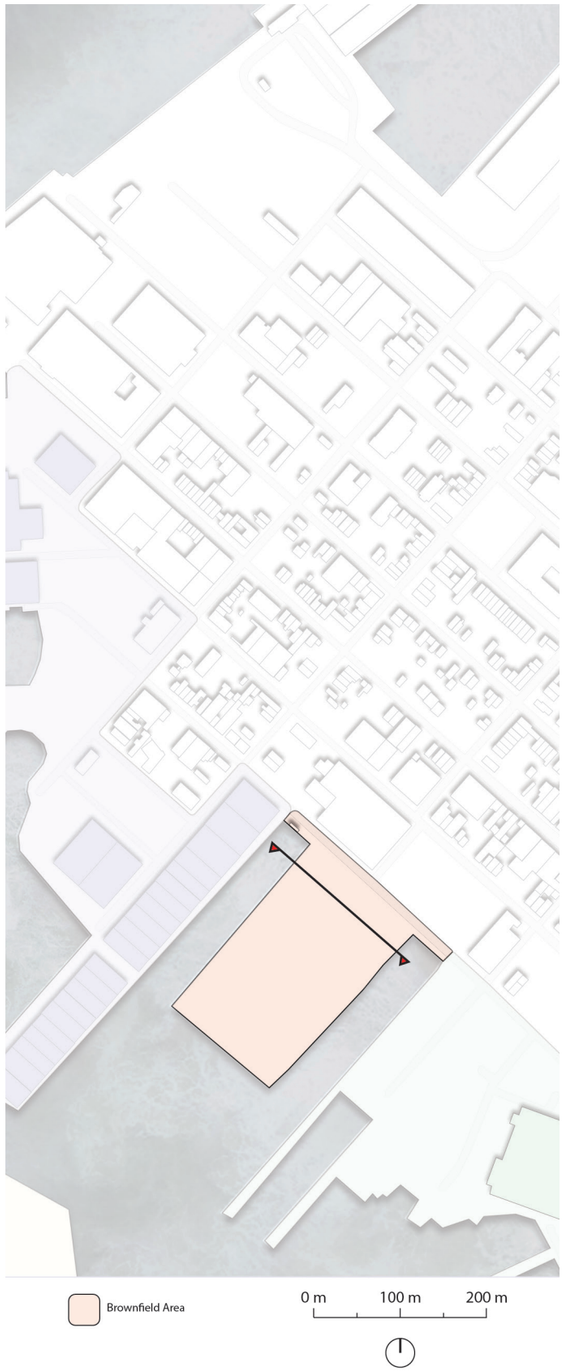


Figure 8,13. *Brownfield area.* (By author)

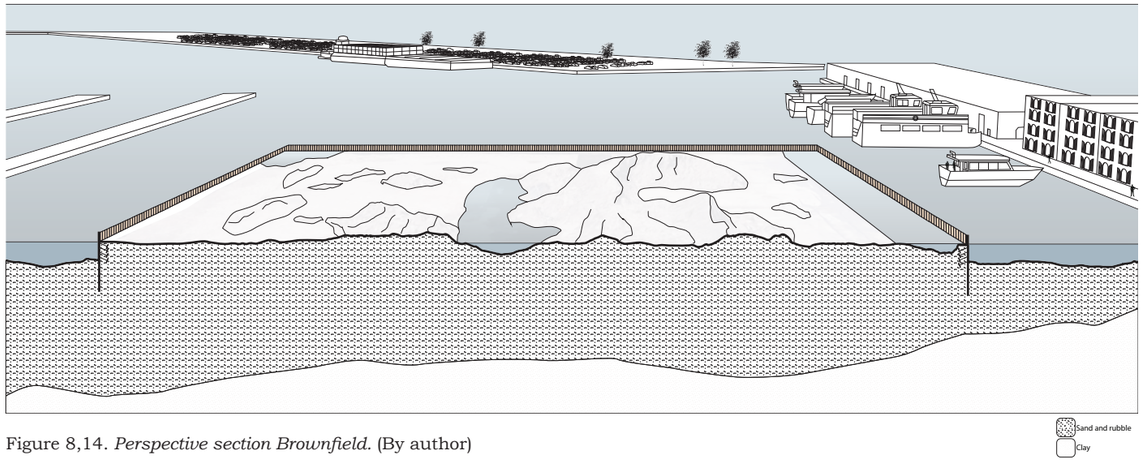


Figure 8,14. *Perspective section Brownfield.* (By author)

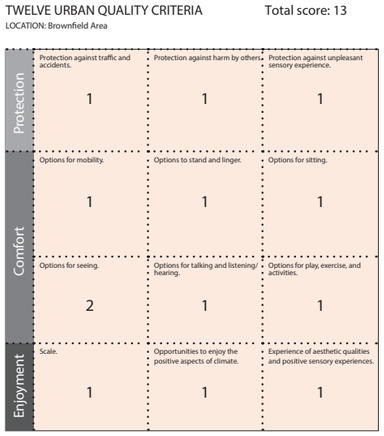


Figure 8,15. *Assessment through criteria by Gehl & Koch.* (By author)

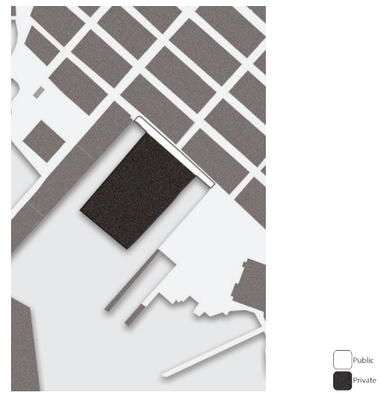


Figure 8,16. *Nolli map.* (By author)

Typology 3: IKEA terrain

The IKEA terrain is split in two different evaluation areas, as a result of their different characters (figure 8,17). The absolute waterfront is comparable to the space between the warehouses. The Persection in figure 8,18 shows that this public space consists of green areas, possibilities for sitting and historic characteristics such as the large harbour cranes. The rows of trees work well to block the view to the adjacent parking lot. Moving further south, there is another small waterfront park with perpendicular edges. This public space scores similar to the one around the warehouses, with 29 points.



Figure 8,17. *IKEA terrain.* (By author)

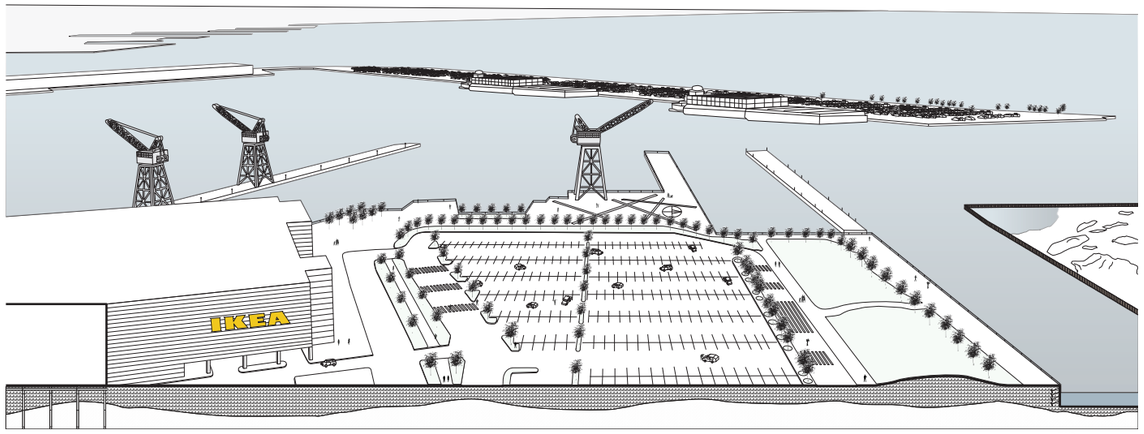
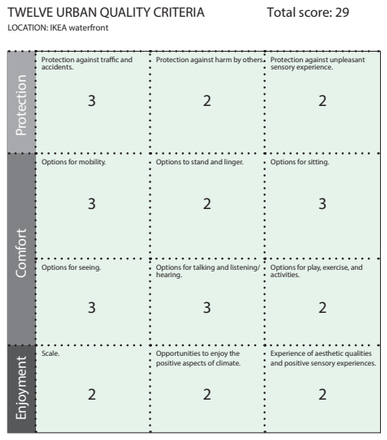


Figure 8,18. *Perspective section IKEA terrain.* (By author)



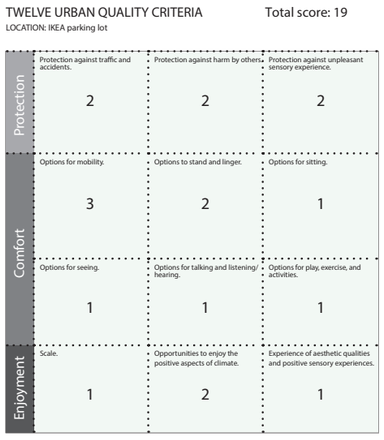


Figure 8,19. *Assessment through criteria by Gehl & Koch.* (By author)



Figure 8,20. *Nolli map.* (By author)

Typology 4: NYPD Auto Impound

The last typology on Red Hook's waterfront is federally owned by the New York Police Department (NYPD). The pier that forms Erie Basin is largely filled with impounded cars, making it an enormous parking lot. As can be seen on the Nolli map, it is not publicly accessible. Much like the undeveloped brownfield area however, it is possible to see the potential of this site. With nearly unobstructed views to the skyline of Manhattan and the Statue of Liberty, the options for seeing (Gehl & Koch, 2011) are great. By moving the impound lot and police office from the pier, a substantial amount of land can be made available with great development potential.



Figure 8,21. *NYPD auto impound.* (By author)

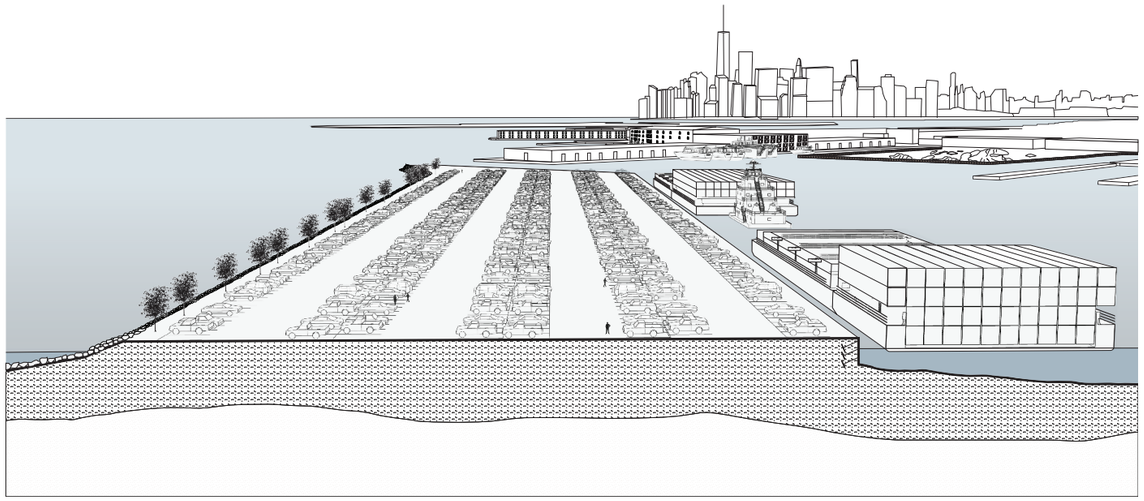


Figure 8,22. *Perspective section NYPD auto impound.* (By author)

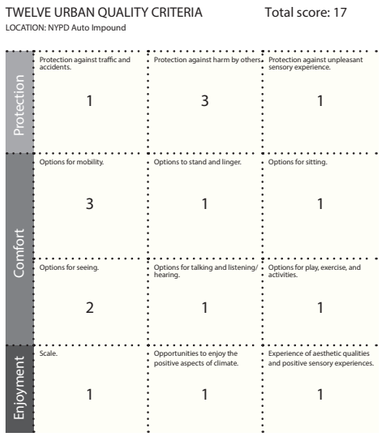


Figure 8,23. *Assessment through criteria by Gehl & Koch.* (By author)

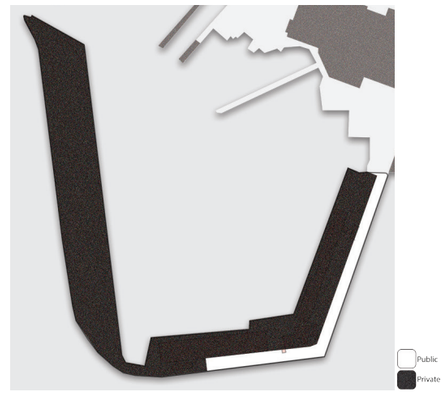


Figure 8,24. *Nolli map.* (By author)

Figure 8,25. *Evaluation existing qualities (green) and deficits (red).* (By author)

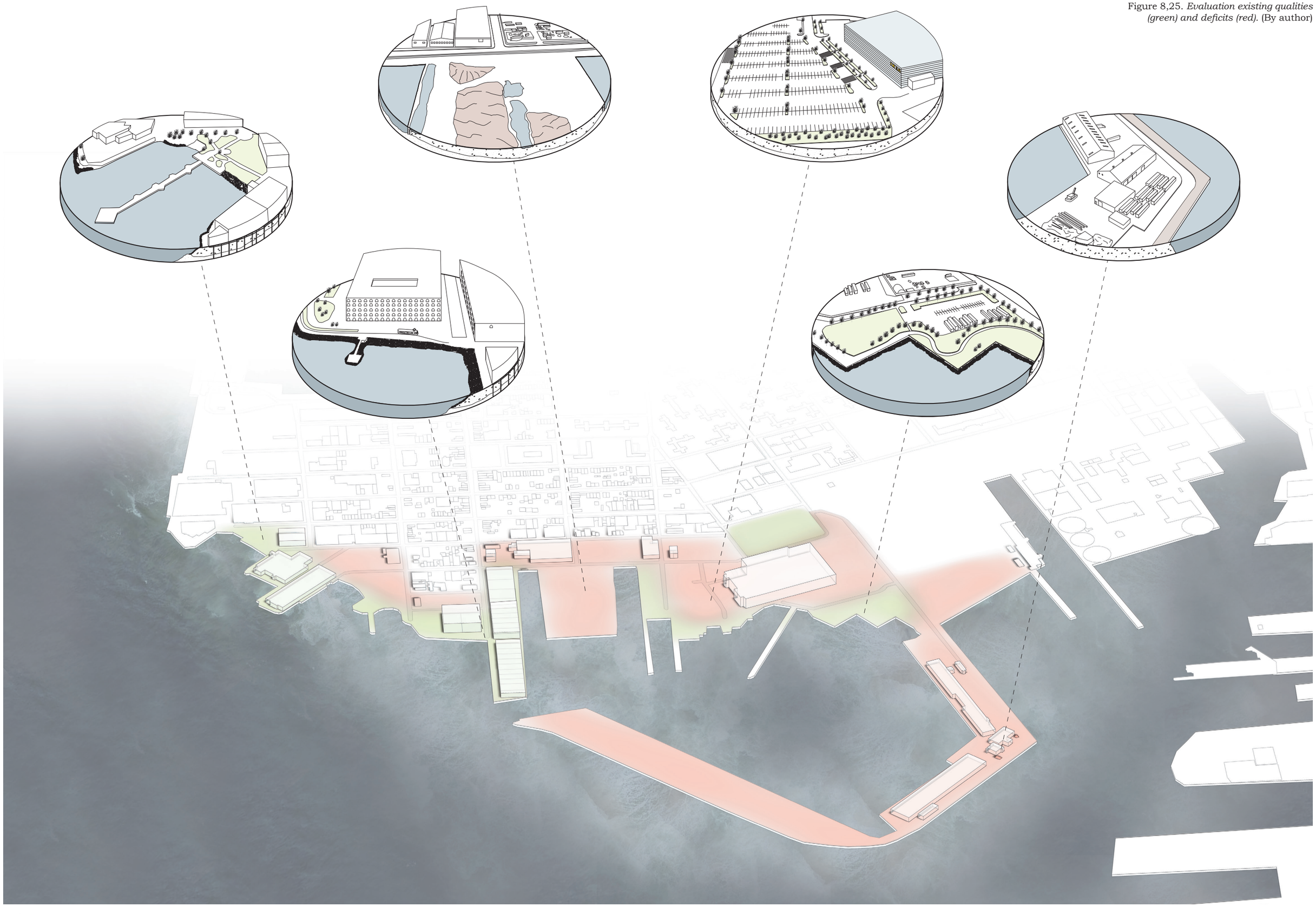




Figure 8,26. *Inland area.* (By author)

Inland

1. Residential plot

The first plot from the west side consists of 2 to 4 layer residential units and garage boxes. Some parts are undeveloped, possibly because of speculation with regard to future rezoning (van Veelen, 2016).



Figure 8,27. *Residential plot.* (Google Maps)

2. Industrial plot

The second plot is mostly occupied with a two-layer warehouse. Several manufacturing companies operate here.



Figure 8,29. *Industrial plot.* (Google Maps)

3. Parking space

The next two plots are completely occupied with parking space. Industrial vehicles, coaches and schoolbusses fill up two sizeable parking lots almost directly on the waterfront. Figure 8,30 not only shows the minimal difference between the main elevation level of the parking space and the water, but also the possibilities these undeveloped plots offer with regard to restructuring and flood protection.



Figure 8,28. *Parking space.* (Google Maps)

4. Community farm

The fifth and final plot connecting the two high points facilitates Red Hook's community farm. This is currently the only plot with a substantial amount of trees and other greenery. Next to growing vegetables, there are photovoltaic cells installed as well.



Figure 8,30. *Community farm.* (Google Maps)

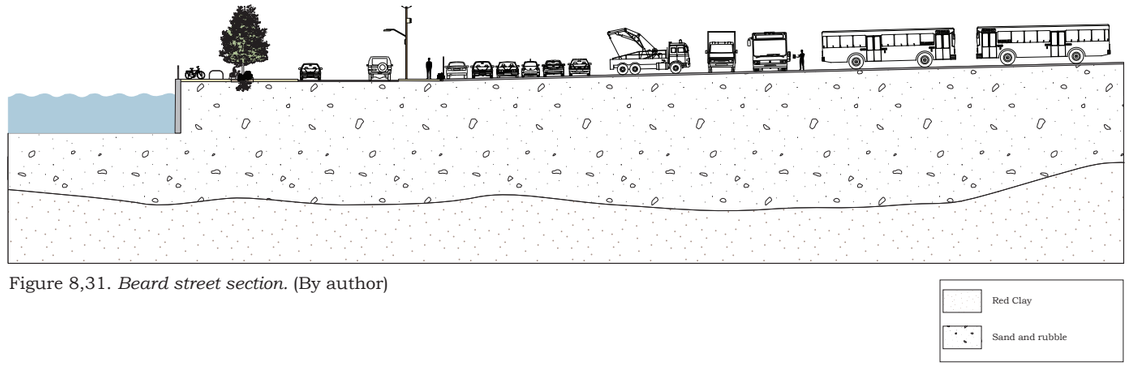


Figure 8,31. *Beard street section.* (By author)

The design



Scenarios

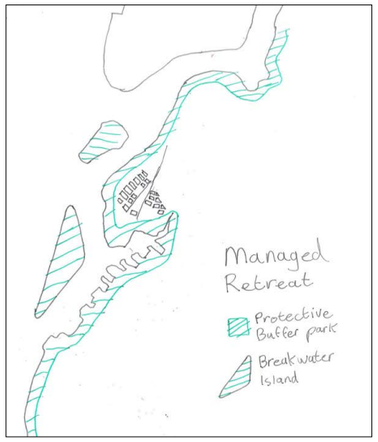
Based on the analyses of both the local and citywide scale, as well as the dynamics of the New York Bay, five scenarios are constructed. The development of scenarios should help to explore the design possibilities in the specific context. The starting point for creating these scenarios is the strategic approach, where flood risk, public value and ecological value are addressed. Therefore, the first three scenarios are extreme versions that cater to only one of these aspects in an excessive way.

Scenario 1 is Managed Retreat, and focuses only on reducing flood risk. To do this in the most safe and extreme way, a giant buffer park has been placed alongside Brooklyn´s entire waterfront. This means that existing buildings on the waterfront would have to be demolished or moved. On top of the large dike body, the floodprotection plan also involves the breakwater in front of Red Hook's coast. This will ensure the most extreme wave energy will be mitigated before reaching the waterfront.

The second scenario is comitted to creating as much public value as possible. This involves the development of new buildings on both the island as well as the Erie basin pier. The large amounts of housing development will also ensure social housing projects are integrated, catering to the economically weaker groups of the society. Ballfields, parks and public greenery will be remediated and developed, to provide ample possibilities for outdoor activities. Also monumental buildings such as the historic waterfront warehouses will be restored and maintained to consolidate Red Hook's harbour identity.

Lastly, the third scenario aims at creating a large scale Wildlife Habitat. By creating the habitat island where marshland conditions are found, a great variety of birds, fish and other marine life will thrive. Governors island will aid in this purpose by becoming completely off-limits for people, providing quiet space for wildlife. On the leeward side of the new island, oyster reefs will get the chance to form again. Also the Gowanus canal and Erie basin pier will be turned into a marshland with natural waterfronts to provide more variety in surface as compared to the hard quays.

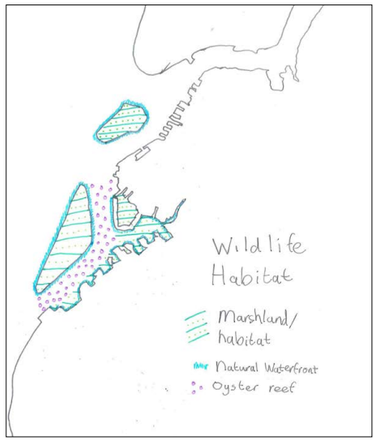
Two scenarios combine elements from the three extreme ones and are realistic, and evidence based. The first scenario, Breakwater reef, proposes a more modest version of the island. Instead of a fully accessible breakwater island, only a reef will be created. The reef, serving as a breakwater and wildlife habitat, will not be consisting of solid land, and will therefore not be available for public development. Since the research showed very favorable circumstances for the development of the Breakwater island, this scenario is created as well. The breakwater island caters to new public development, as well as creating a marshland habitat on the waveward side. The island is connected to Brooklyn by a bridge, as well as by new ferry lines. The Erie basin is also restructured to provide space for development and habitat creation. The next pages show the planmap, where the chosen scenario and its functioning is explained in more detail.



Scenario 1: Managed Retreat



Scenario 2: Public Development

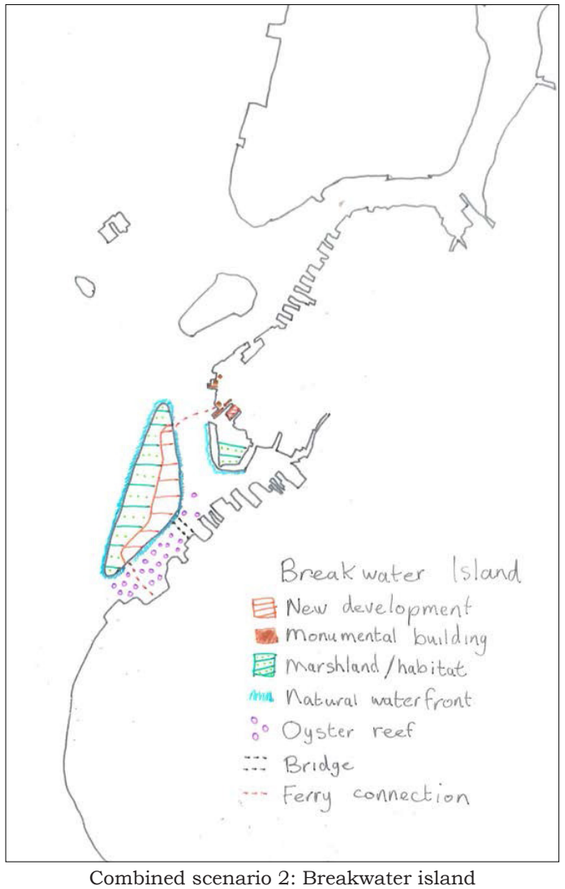


Scenario 3: Wildlife Habitat

Figure 9,1. *The extreme scenarios.* (By author)



Combined scenario 1: Breakwater reef



Combined scenario 2: Breakwater island

Figure 9,2. *The combined scenarios.* (By author)



Figure 9,3. *The planmap.* (By author)

The planmap

As introduced in the plansite chapter, the final design focuses on developing three areas. The nearshore, waterfront and inland area, work coherently to reduce the floodrisk and increase public- and ecological value. The specific function of each area will be visualized and explained in detail in this chapter. For now, the functioning of the three development areas regarding the three respective components will be explained in a general sense.

In the first area, the nearshore location of the plansite, the breakwater island will be realized. As the diagram shows, this island should function as a large breakwater to reduce wave energy (Roland and Douglass, 2005; Scyphers, Powers & Heck, 2015). As explained by the Scape/Landscape team in their project Living Breakwaters: `Breakwaters do not keep the water out, however, they have the ability to calm water, reduce wave heights, and prevent shoreline erosion' (2014, p. 22). In this case, potential flooding would still reach Red Hook's waterfront, but will carry significantly less energy. Therefore, the buildings are protected from high energy wave impacts, but will still experience flooding if the waterlevel rises drastically.

To protect the buildings on the waterfront, there is the option to chose between dry floodproofing and wet floodproofing. Van Veelen explains the two as follows: 'Dry proofing aims to reduce flood vulnerability by keeping water out of a building and wet proofing aims to reduce damages by applying water resilient interiors and materials' (2016, p. 100). Since almost all buildings on Red Hook's waterfront are owned by private companies (interviews Westerhof, 18-01-18; Hall, 25-01-18) initiating large restructuring projects to dry floodproof the entire area is not a feasible strategy (interview Westerhof, 18-01-18; van Veelen, 2018). On top of this, the area with its warehouses directly exposed to the water carries a distinct Red Hook identity which should remain unchanged as much as possible (interviews Russell and Thomas, 24-01-18; Hall, 25-01-18). For these reasons, the decision has been made to wet floodproof buildings on the waterfront. Because of the combination of wave energy reduction by the breakwater and series of smaller interventions on building level, the appearance and identity of the historic buildings can remain unchanged.

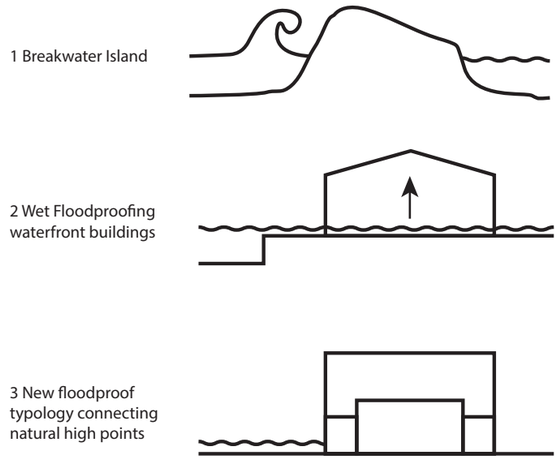


Figure 9,4. *Three layers of flood protection.* (By author)

Despite the measurements of the breakwater and floodproofing of the waterfront, Red Hook can still be flooded. This is where the inland area of the design plays its part. As indicated on the planmap and concluded from earlier analyses (see figure 3,3 and 3,6), Red Hook has two natural high points that did not get flooded during hurricane Sandy (NYC Department of City Planning; NYC Mayor's Office, 2014., NYC Mayor's Office of Recovery and Resiliency, 2017). By restructuring the plots between these elevated points and developing a new floodproof typology, the entire neighbourhood of Red Hook can be protected from flooding.
To connect the new typology with the elevated points, self-closing flood barriers will be used (Aggeres Flood Solutions, 2013). By developing the Brooklyn Waterfront greenway, as projected by the Regional Plan Association and Brooklyn Greenway Initiative (2005), this continuous cycle lane can be strategically elevated to protect further inland areas.

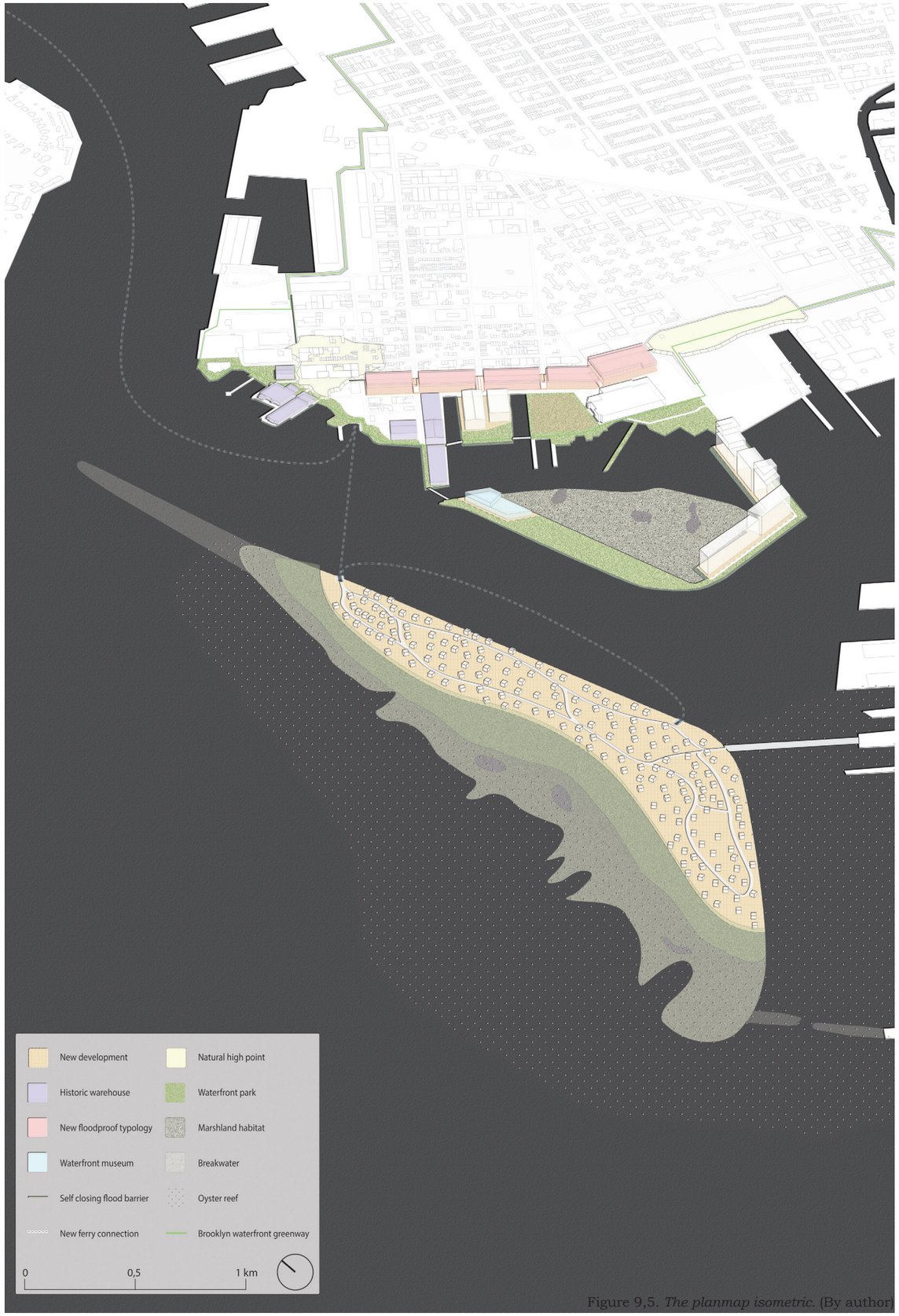


Figure 9,5. *The planmap isometric.* (By author)

Public value is addressed throughout the three areas of the plansite as well. Starting with the nearshore area, the breakwater island will be connected to Brooklyn and Manhattan by means of a new bridge and a frequently departing high speed ferry connection. This ferry will also stop at the Fairway market in Red Hook, before reaching Whitehall street on Manhattan, where several metro lines can be accessed. On the island itself, the plots come with specific parcel passports to steer private development in harmony with the flood defence and ecological value.

In the waterfront area, waterfront parks and the waterfront museum on the current NYPD pier increase public value. This museum will show Red Hook's history with the waterfront, as well as hurricane Sandy's impact on the neighbourhood. The new floodproof typology in the inland area of the plansite also caters to public value. Affordable housing is realized in this building typology to accomodate Red Hook's inhabitants.

The creation of ecological value in the nearshore area is achieved by adding a large surface for new wildlife habitat in the shape of marshlands, breakwaters, oyster reefs and parks. Marshland and natural waterfronts in Red Hook provide more non-hard, varying surfaces for various kinds of wildlife (Laidley, 2007; Dyson and Yocom, 2014).

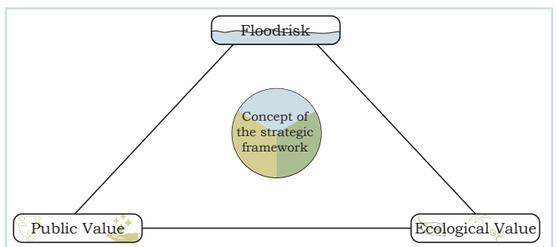


Figure 9,6. *Concept of the strategic framework.* (By author)

The previous pages provided a short introduction on the design and mentioned the most important interventions. Simply put, the design for Red Hook consists of three areas. As described, the strategy uses three development areas to reduce floodrisk and increase public- and ecological value by developing the nearshore, waterfront and inland area (figures 9,6 and 9,7). Because these three aspects are addressed across three areas, there are two ways of explaining the design in detail. The first is to show one area, and discuss all the interventions adressing floodrisk, public- and ecological value. On the other hand, there is the possibility to show only the interventions addressing floodrisk throughout all three areas first, followed by all the interventions that cater to increasing public- and ecological value respectively.

Because both ways of explaining the design could result in an interesting narrative, the reader makes the decision on what to discover first. The next pages elaborate on the design in detail and are split in three parts. There is the possibility to flip all three parts of a page at once, to read about floodrisk (top), public-(middle) and ecological (bottom) value for one of the three areas. The other option is to flip only one third of the page, revealing only interventions that adress one specific topic, throughout the entire plansite.

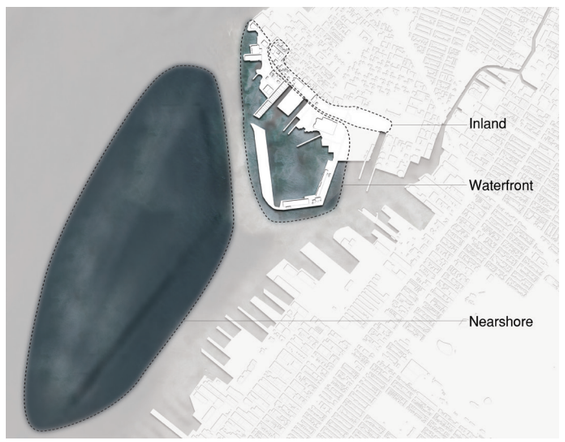


Figure 9,7. *Three focus areas of the layered approach.* (By author)

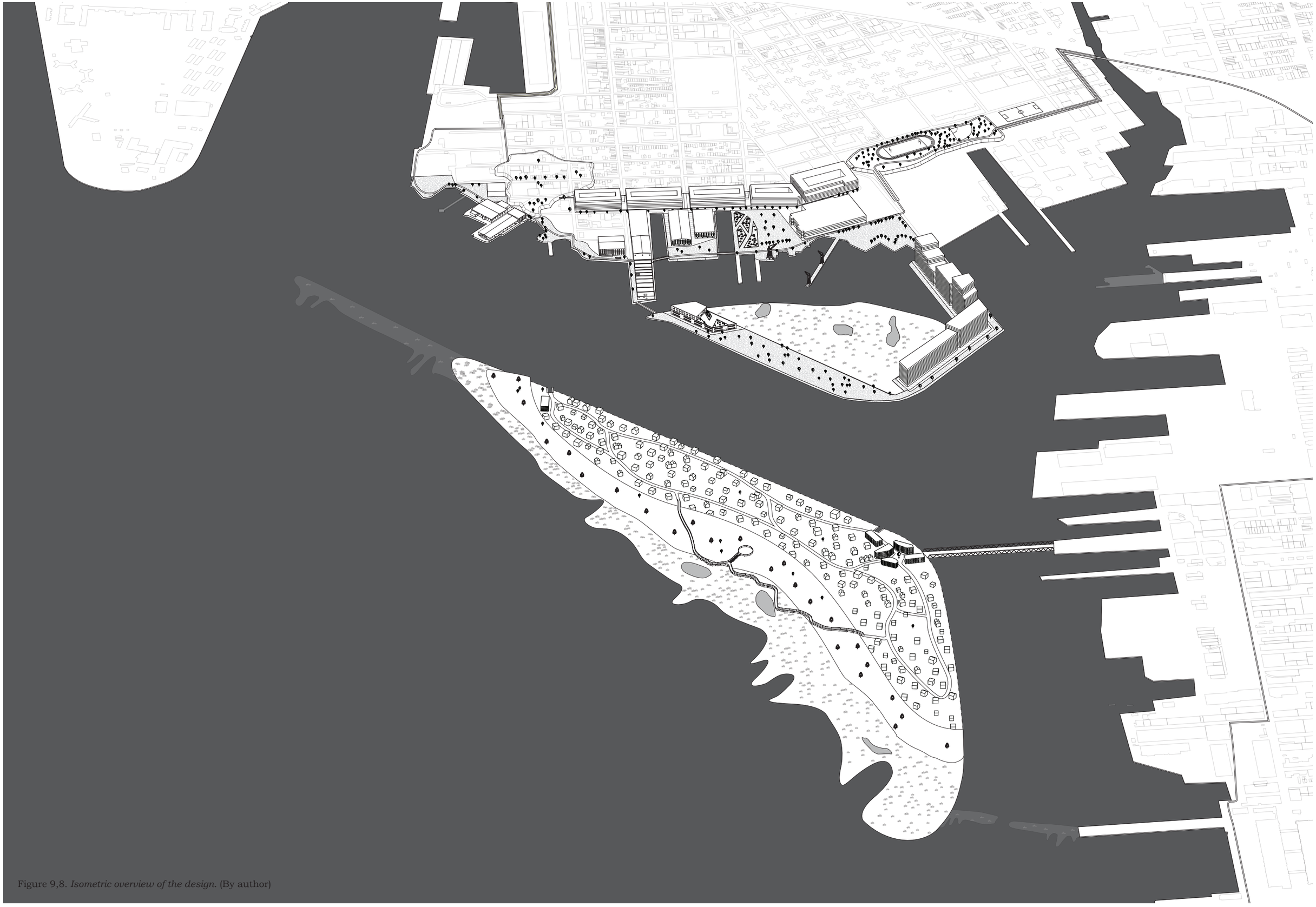


Figure 9,8. *Isometric overview of the design.* (By author)

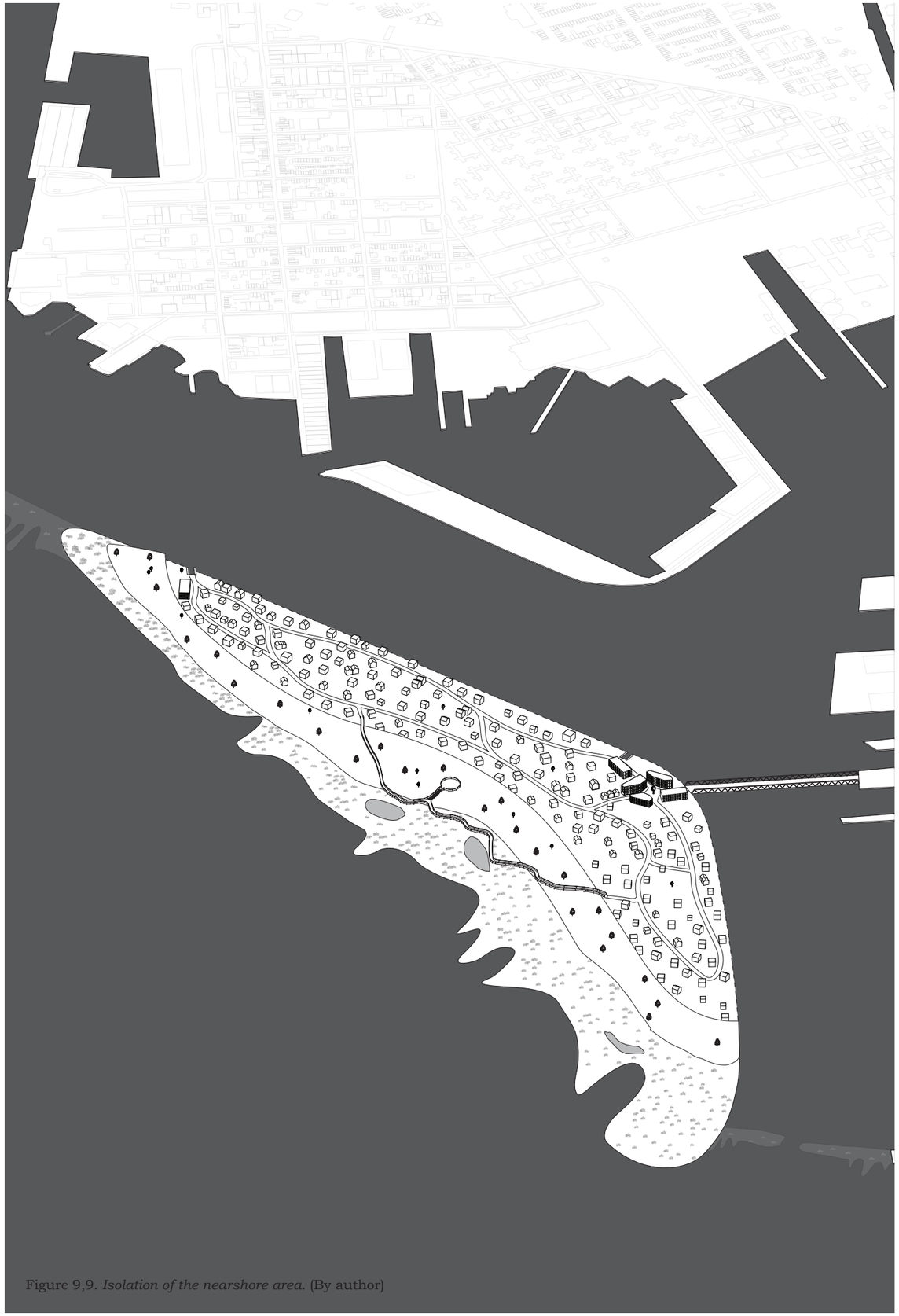


Figure 9,9. *Isolation of the nearshore area.* (By author)

Nearshore

Floodrisk

127

Nearshore

Public value

127

Nearshore

Ecological value

127

Breakwaters



Although wave size and intensity is largely influenced by the strenght of a storm, waves break when their height reaches 75% of the waterdepth (WXY/West 8, 2014). In calm conditions this means that large waves break far away from the coast. In surge conditions when the waterlevel has risen substantially however, waves can become much larger because of deeper waters, therefore coming closer to the shoreline (WXY/West 8, 2014). The most dangerous situation occurs when a wave breaks directly on a solid structure. When a breaking wave impacts, it has 4 to 5 times the amount of energy of a non-breaking wave (WXY/West 8, 2014). To protect Red Hook's waterfront and reduce floodrisk, breakwaters are realized on the far ends of the island. By decreasing the water depth drastically, waves will break before reaching the shoreline, resulting in much calmer water. This eliminates the coastal A zones (high wave impact zones) as illustrated in figure 3,4.

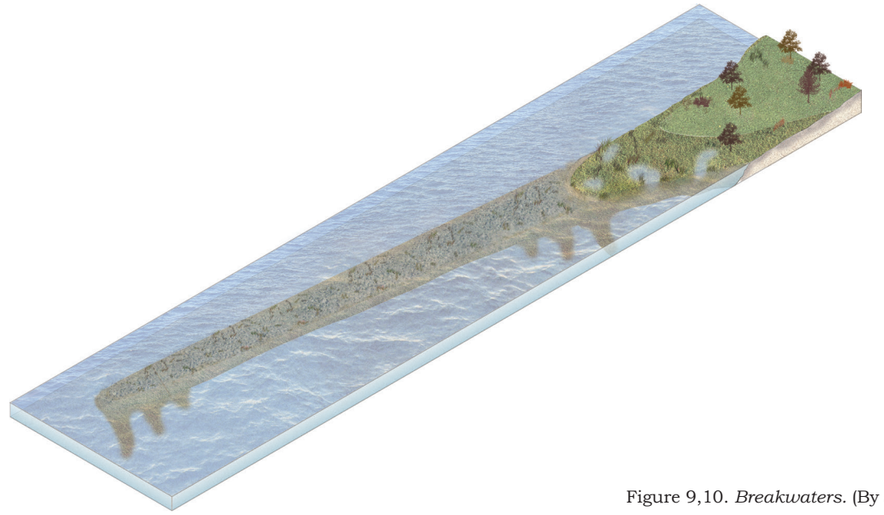


Figure 9,10. *Breakwaters.* (By author)

Free development plots



In the years of development of NYC, it was not unusual for people to buy waterfront plots (van Veelen, 2018). This meant that half of the plot consisted of land, the other of water. Owners of the plots could decide to landfill the water and expand their land surface. The waterfront plots on the breakwater island resemble this history and will grow over time, due to sediment deposition on the leeside of the island (Scape / Landscape Architecture PLLC, 2014; Ralston, Geyer, Warner, Wall, 2015; figure 6,5). To manage this natural process and guide people with the development of their plots, parcel passports are provided for private development. Each plot has a natural, unique shape, resulting in a great variety in public space. Much like the round gardens in Nærum, Denmark (Rovers, 2018), the nature between the parcels provide different views and experiences, as well as opportunities for various habitats.



Figure 9,11. *Free development plots.* (By author)

Marshland



Based on results of the study on the New York Bay scale, the ecological diversity in the new marshland is maximized. Figure 6,3 shows there is a difference in waterlevel of roughly 2 meters between high and low tide in the Gowanus Bay area (NOAA, 2018). This is indicated in figure 9,12 with the high and low tide waterlevel respectively. To maximize the variety in habitat surface, the marshland has slopes ranging between this low tide and high tide, until it reaches the landward side near the protective berm. As concluded in figure 6,4, there are very little fresh water influences in the nearshore area, creating a high salinity (MIT CAU et al., 2014). Based on this information, a range of flora and fauna is identified to thrive on the conditions of this specific context, which is visualized in figure 9,12 (MIT CAU et al., 2014).

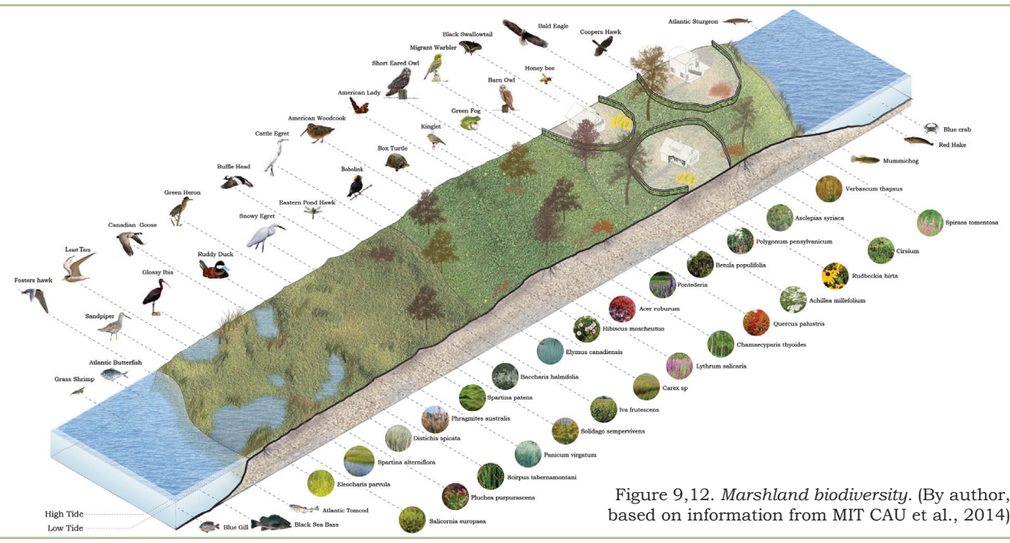
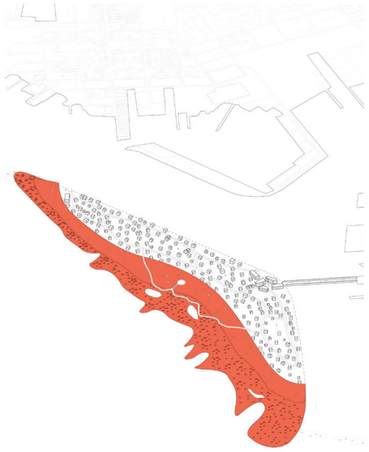


Figure 9,12. *Marshland biodiversity.* (By author, based on information from MIT CAU et al., 2014)

Marshland and berm



To protect the waterfront of Red Hook and houses on the breakwater island itself, the marshland and berm work together. Instead of reflecting the wave energy like man-made seawalls do, the marshland on the waveward side slows down and absorbs wave energy (WXY et al., 2014). Next, the island is protected by a natural berm park. This berm stands 7,5 meters above high tide, and provides ample protection in stormy conditions (NYC Mayor's Office, 2014). If, in extreme conditions, the waterlevel would rise more than 3,5 meters above high tide, the houses on the island could be flooded. However, there would be no hazard from high energy wave impacts, as these are absorbed by the marshland and berm. All houses developed on the island have a wet floodproofed ground floor, as recorded in the parcel passports. This adds another 3 meters of margin, making the development safe until 6,5 meters of waterlevel rise.

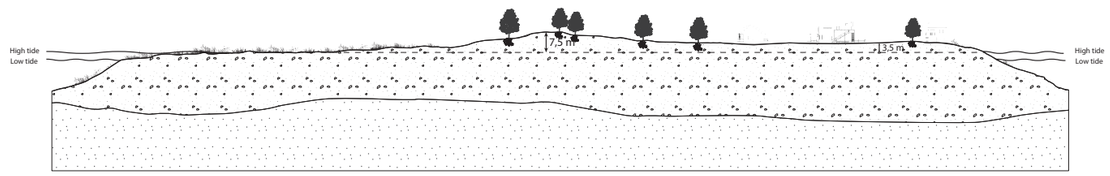


Figure 9,13. *Marshland and berm protection.* (By author)

Walking promenade



Combining flood protection with ecological- and public value, the marshland can be explored by visiting the walking promenade. This wooden pathway is constructed a meter above high tide waterlevel and allows people to visit the marshland habitat without disturbing it. Depending on the successfulness of the promenade, the wooden walkway can be extended to cover more length of the marsh. Also the berm can be used for recreational purposes as long as the weather conditions allow it. There are stimulations for natural use of the area. For example, sufficient bins are placed on the walkway and throughout the area, to encourage visitors keeping the habitat clean.

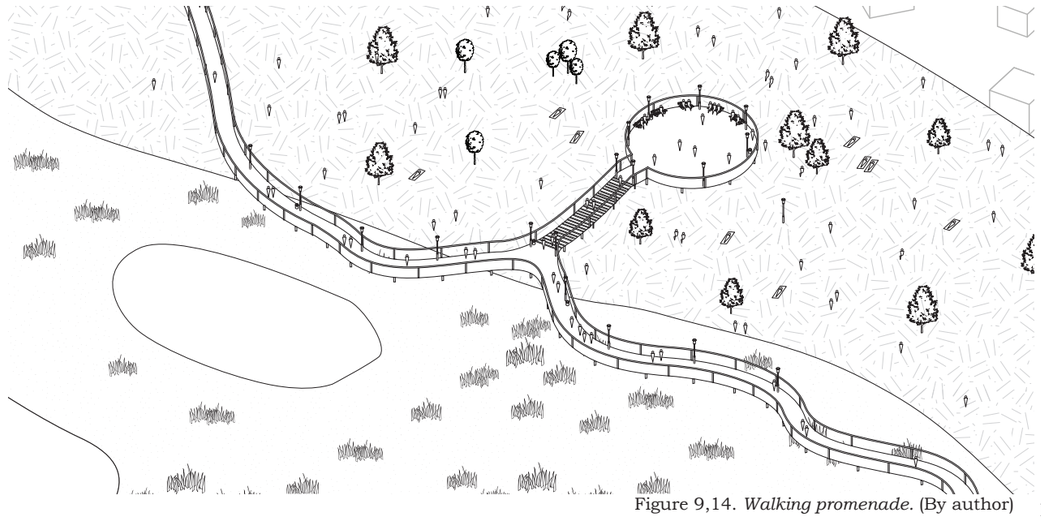


Figure 9,14. *Walking promenade.* (By author)

Breakwaters



On top of having a distinctive wave breaking function, breakwaters are able to provide conditions which support ecological diversity. The principles to maximize this ecological value are visualized in figure 9,15. Instead of creating a straight shape with little variation, pockets are created with more complexity (Scape / Landscape Architecture PLLC, 2014). These created streets offer protection to juvenile fish and shellfish. By supporting these 'reefstreets' with different size rocks and oyster reefs, juvenile fish can find protection against predators. Finally, it is important to place the complexity pockets with reef streets to the waveward side, as the sediment of breaking waves deposits behind the breakwater. If pockets are placed on the leeward side, they would fill up with sediments and lose their complexity, thus lowering their ecological value (Scape / Landscape Architecture PLLC, 2014).

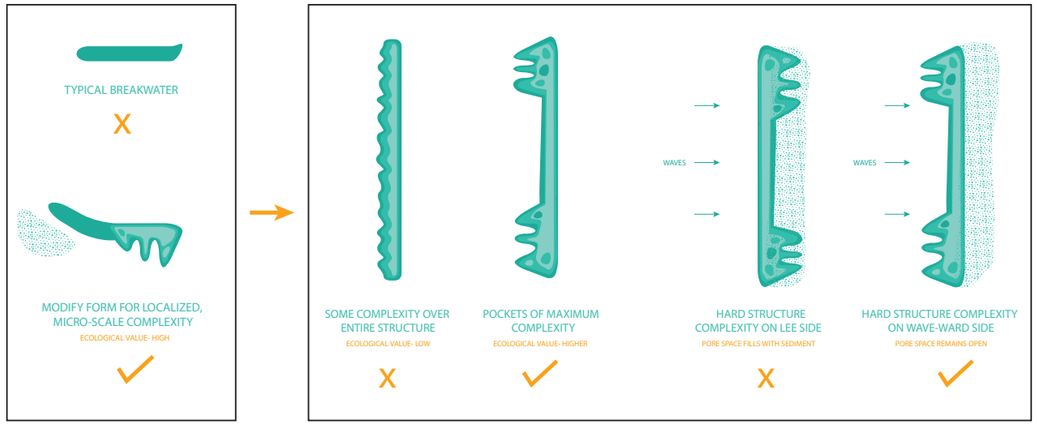


Figure 9,15. *Principles of breakwater design.* (Scape / Landscape Architecture PLLC, 2014)

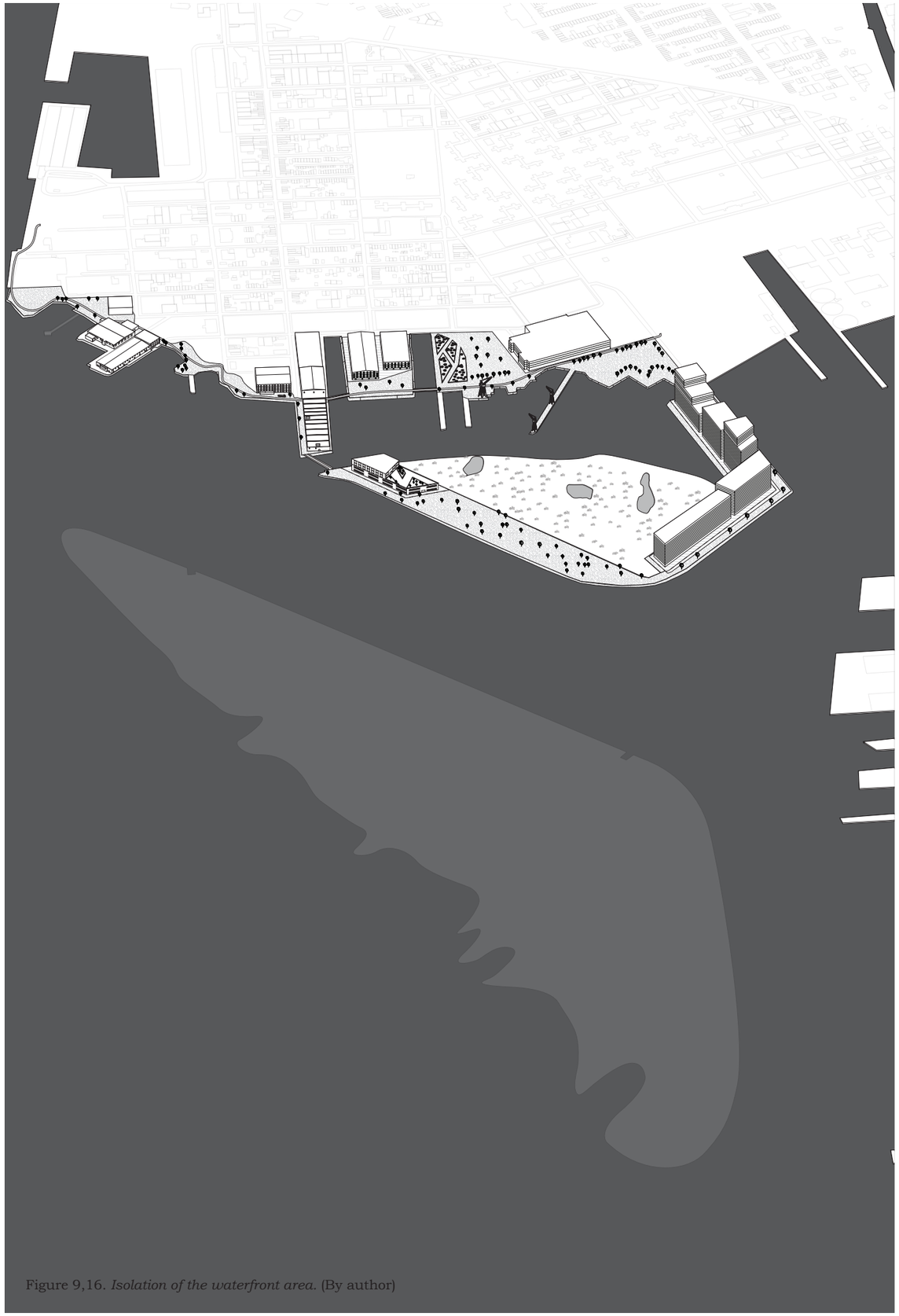


Figure 9,16. *Isolation of the waterfront area.* (By author)

Waterfront

Floodrisk

133

Waterfront

Public value

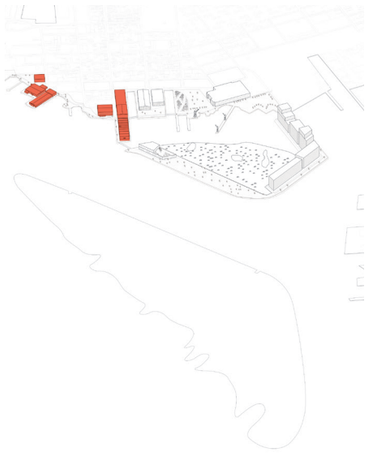
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Waterfront

Ecological value

133

Floodproofing warehouses



The waterfront warehouses date back from the end of the 19th century and have a dominant position in Red Hook's history (Hall, 2018). Many of the warehouses, including the ones built on Van Brunt street, are subleased to various smaller companies (Hall, 2018). On top of that, they are situated directly on the waterfront, providing limited options for interventions in the public space. For these reasons, it is hard to initiate large scaled public interventions to keep the water from reaching the warehouses all together. Instead, smaller interventions on building and even sublease level to wet floodproof the buildings have a higher cost-benefit ratio (HR&A Advisors, Cooper, Robertson & Partners, 2014; Van Veelen, 2018). To execute this wet floodproofing successfully, typical weaknesses of the waterfront warehouses are identified and visualized in figure 9,17 (HR&A Advisors, Cooper, Robertson & Partners, 2014).

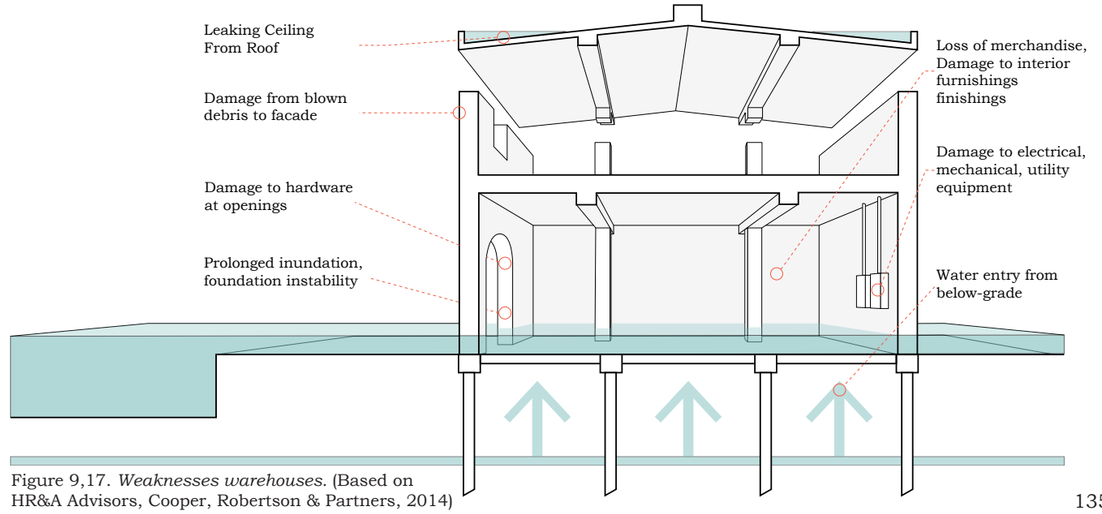
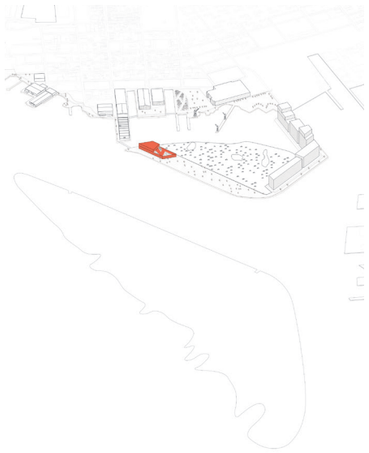


Figure 9,17. *Weaknesses warehouses.* (Based on HR&A Advisors, Cooper, Robertson & Partners, 2014)

Waterfront museum



The waterfront museum is the public center of Red Hook. Due to its unique location on the Erie Basin pier, it hosts a wide variety of functions. It shows Red Hook's founding and history, as well as a permanent exhibition on hurricane Sandy's impact on the area and its community. The Billion Oyster Project (BOP) strives to realize 1 billion live oysters in the New York Bay area by 2035 (Billion Oyster Project, 2017). As the area will see a lot of added ecological value, it contributes substantially to the BOP project. The waterfront museum becomes the educational hub related to all ecological matters. Neighbourhood events, lectures and seminars will be held, as well as workshops on how to grow oyster reefs. Guided tours on the marshlands for people of all ages raise awareness of the importance of the ecology for the city. Finally, a restaurant-café with rooftop terrace overlooks the marshland and Gowanus bay area.

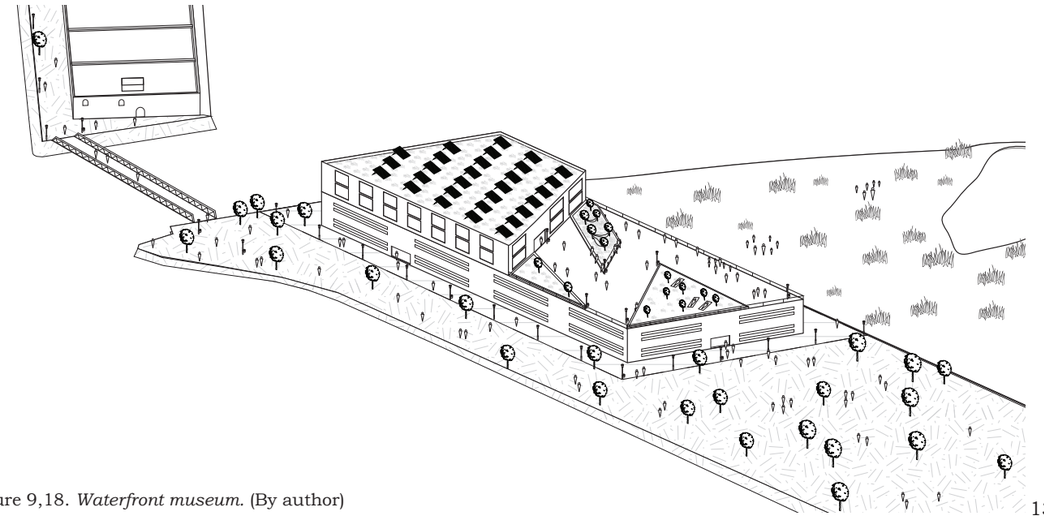
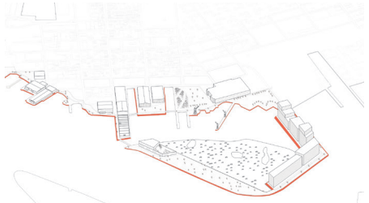


Figure 9,18. *Waterfront museum.* (By author)

Ecological waterfronts



Due to Red Hook's piers and dock inlets, a large amount of waterfront surface is found. Neglecting these waterfront surfaces in relation to ecological value would be a critical error, as they offer a lot of potential for habitat creation (Dyson & Yocom, 2014). As Red Hook originally has had a harbour function, many of the surfaces on the waterfront are hard man-made docks and seawalls (NYC Mayor's Office, 2014). Figure 9,19 shows the difference between a natural waterfront and a vertical seawall. The natural, ecological waterfront provides a large variety of surface orientation and offers wildlife the option to move land- or waterbound as the tides change. The vertical seawall does not provide any of these advantages. Where possible, Red Hook's waterfront is developed with these slopes, to maximize ecological value. The Econcrete units displayed in figure 9,20 are added to reinforce shorelines and add additional habitat (Scape / Landscape Architecture PLLC, 2014).

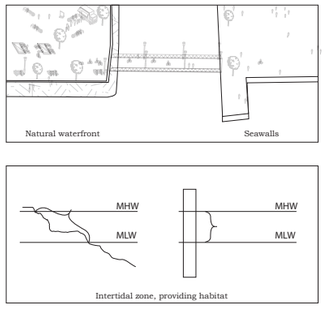
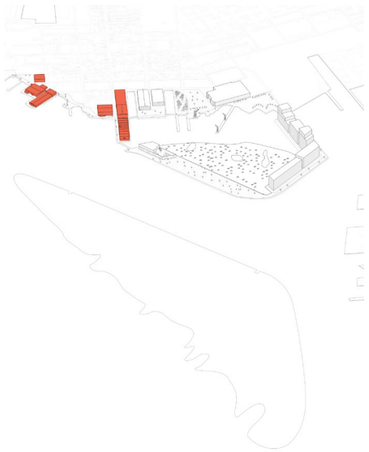


Figure 9,19. *Comparison natural waterfront and seawall.* (By author, based on Dyson & Yocom, 2014)



Figure 9,20. *Econcrete units.* (Scape / Landscape Architecture PLLC, 2014)

Floodproofing warehouses

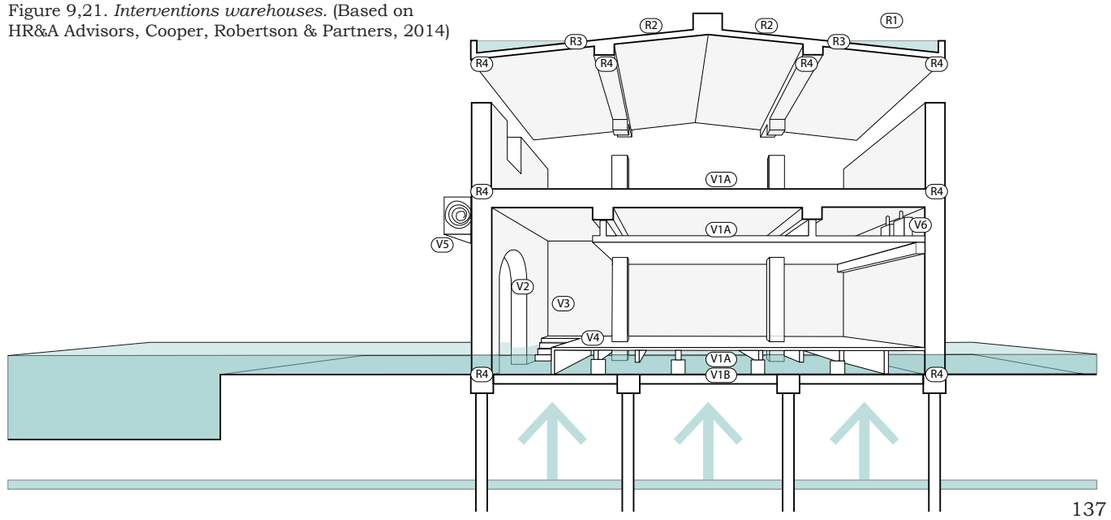


To wet floodproof the existing warehouses, a series of interventions are selected. Owners and subleasers can decide what interventions they deem necessary and relevant for their particular situation. By investing in more interventions, the flood insurance premium will be lower (FEMA, 2018). With the exception of the roll down door, the facades of the warehouses remain unchanged, preserving the historical identity. The following list of interventions corresponds with the numbers in figure 9,21, as established by HR&A Advisors et al. (2014).

R1: Anchor roof-mounted gear
R2: Seal roof deck
R3: Retrofit with ring shank nails
R4: Hurricane straps (Simpson ties)

V1A: Mezzanine/attic/2nd floor
V1B: Pulley & Backflow valve
V2: Caulking and sealants
V3: Water resistant int. finishes
V4: Elevate 1st floor
V5: Roll down door
V6: Raise electrical outlet/boxes

Figure 9,21. *Interventions warehouses.* (Based on HR&A Advisors, Cooper, Robertson & Partners, 2014)



Waterfront parks



The waterfront parks are developed to provide both public and ecological value. Figure 9,22 displays the former brownfield area, after development has taken place. New buildings that refer to the style of the historic warehouses are positioned between ample leisure space. The calm conditions of the water, because of the Erie basin pier, marshland and breakwaters provide opportunities for recreation along the waterfront. The newly designed waterfront park is evaluated through Gehls 12 criteria for urban quality (Gehl & Koch, 2011), and now scores 34 out of 36 points.

TWELVE URBAN QUALITY CRITERIA — Total score: 34
LOCATION: Waterfront park (Former brownfield)

Protection	Protection against traffic and accidents. 3	Protection against harm by others. 3	Protection against unpleasant sensory experience. 2
Comfort	Options for mobility. 2	Options to stand and linger. 3	Options for sitting. 3
	Options for seeing. 3	Options for talking and listening/ hearing. 3	Options for play, exercise, and activities. 3
Enjoyment	Scale. 3	Opportunities to enjoy the positive aspects of climate. 3	Experience of aesthetic qualities and positive sensory experiences. 3

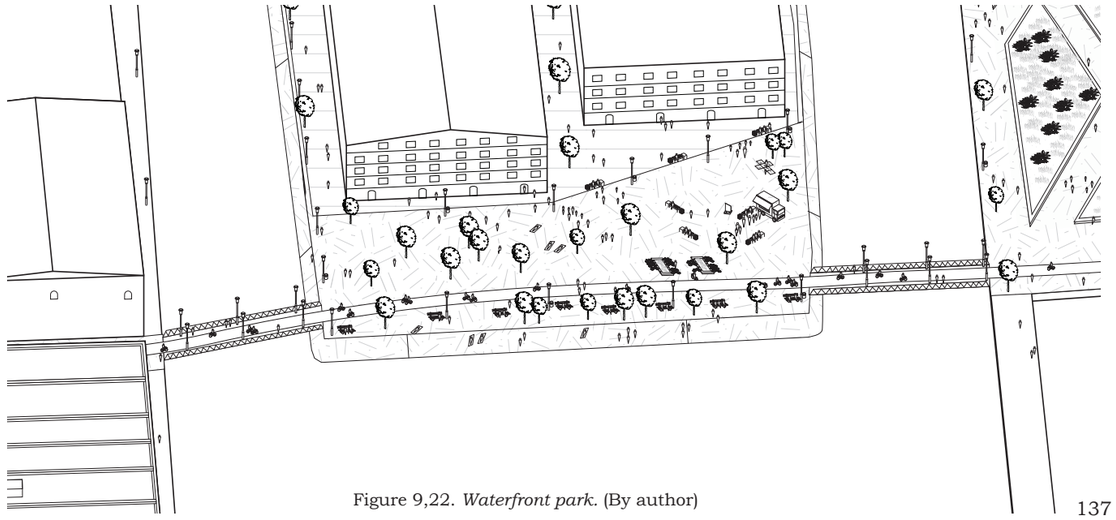


Figure 9,22. *Waterfront park.* (By author)

Ecological waterfronts



Since Red Hook's waterfront features dock and pier structures which do not support the development of natural waterfronts, alternative solutions have been studied. Smaller flexible options are available to provide more complexity in the shoreline and are visualized in figure 9,23, as studied by Dyson & Yocom (2014). Seawall stairs reintroduce intertidal habitat through shallow water tidepools, and have been successfully tested in Vancouver (Slogan, 2011; EBA, 2011). A second option for increasing ecological value is seawall texturing.

By attaching plates to the vertical wall, diverse surface orientations and tidepools can be created. This solution has been successfully applied on the Seattle Seawall (Goff, 2008; 2010). Finally there is the option to construct habitat benches in front of the seawall. On top of creating habitat potential, it protects the structural integrity of the seawall from erosion as well (Toft et al, 2012; 2013).

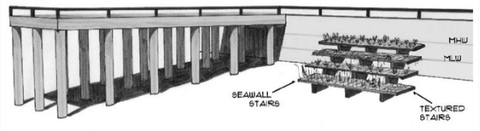
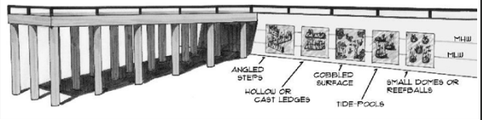
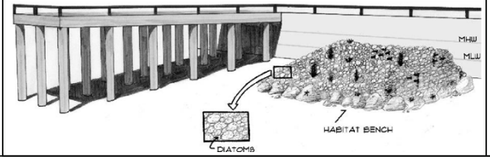
	Impression	Key benefits	Succesful examples	References
Seawall stairs		- Reintroduce microhabitats through tidepools - Increase intertidal habitat - Reintroduce shallow water habitat to benefit fish, vegetation, etc.	Vancouver Convention Center	Slogan, 2011 EBA, 2011
Seawall texturing		- Reintroduce microhabitats through tidepools - Create diverse surface orientations (horizontal, diagonal, vertical).	Seattle Seawall	Goff, 2008 Goff, 2010
Habitat benches		- Increase intertidal habitat - Reintroduce shallow water habitat to benefit fish, vegetation, etc - Protect seawall structural integrity from erosion	Olympic Sculpture Park Seattle	Toft et al., 2012 Toft et al., 2013

Figure 9,23. *Ecological waterfront options.* (Dyson & Yocom, 2014)



Figure 9,24. *Isolation of the inland area.* (By author)

Inland

Floodrisk

139

Inland

Public value

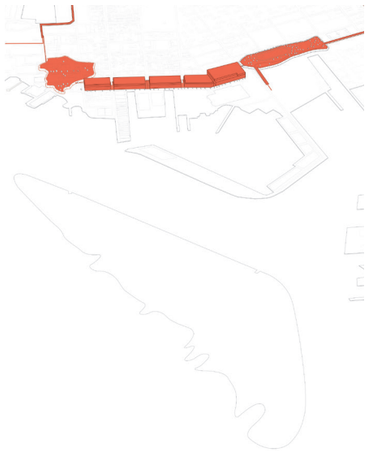
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Inland

Ecological value

139

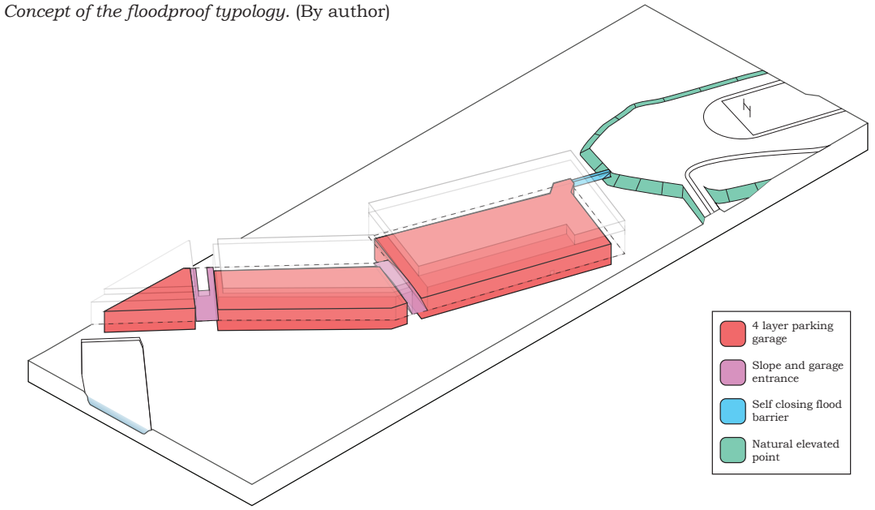
Floodproof typology



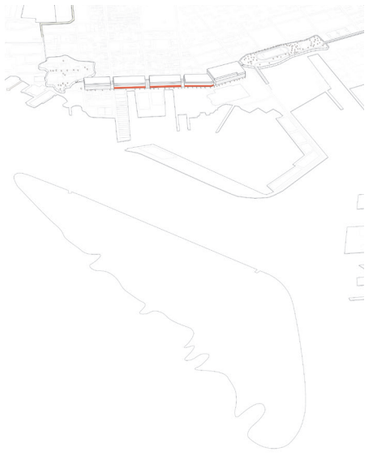
By connecting the two natural high points through restructuring the intermediate plots, Red Hook is protected from up to 5 meters of waterlevel rise. As visualized in figure 9,25, the concept is based on four elements. The size of the 4-layer parking garage (indicated in red) is dimensioned to replace the lost parking space onsite, the IKEA terrain and the NYPD impound lot. The parking garage runs under all the 5 plots, to accomodate this demand of parking space, and functions as flood defence at the same time (Royal HaskoningDHV, 2015).

In purple, the slopes between te buildings are represented. These crossable slopes are open on the landward side, to facilitate the entrances to the parking garage while maintaining their flood defence integrity. Finally, the buildings are connected to the natural high points (green) by means of self-closing flood barriers (Aggeres Flood Solutions, 2013), indicated in blue. The concept of the self-closing flood barrier is shown in figure 9,28.

Figure 9,25. *Concept of the floodproof typology.* (By author)

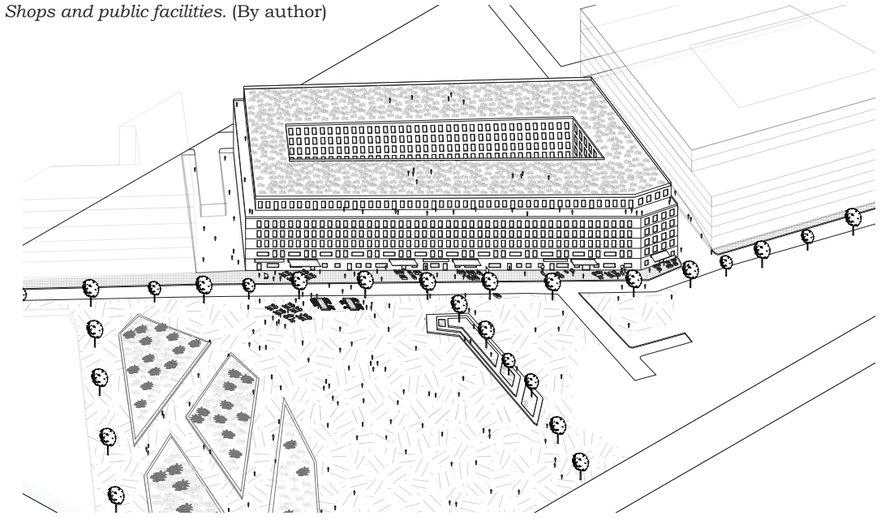


Shops and public facilities

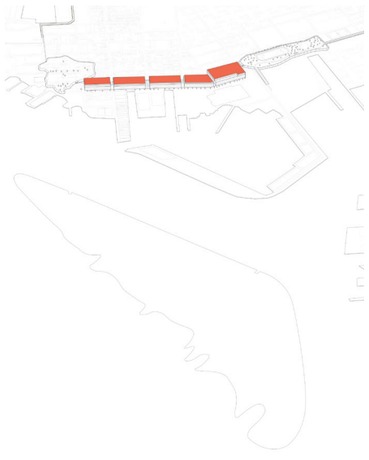


To contribute to an active street around the floodproof typology, public facilities are located on the ground floor. Shops, restaurants and cafes can use both sides of the sidewalk to present their products and place their terrace. As the New York Police department has been moved from the Erie basin pier, the new police station also finds its place in the new building. To be able to maximize sustainable development, taking full advantage of the benefits of the sub-soil is essential (Hooimeijer, Lafleur & Trinh, 2017). Figure 3,15 shows this area of Red Hook has been landfilled. As a result, the rather porous structure of the sub-surface (NY Rising Community Plan, 2014; Van Veelen, 2018), and large scale new development allow for investing in a decentralized energy system. Solutions such as a heat-cold pump provides the shops, public facilities and apartments with a sustainable heating and cooling system.

Figure 9,26. *Shops and public facilities.* (By author)



Rooftop farms



The new typology also contributes to increasing ecological value. The largest of the 5 to be restructured plots currently is home to the Red Hook community farms (see figure 8,30). Because the community farms provide both public and ecological value, these are replaced in the new development. According to demand, the regular green roofs of the blocks will be replaced by rooftop farms. The two southern blocks are developed with a garden from the start. The other three can be transformed over time per request of the community. Photovoltaic cells are installed on the green roofs as well. Studies show efficiency rises when PV cells are placed on green roofs because of lower environmental temperature compared to traditional black bituminous roofs (Scherba, Sailor, Rosenstiel & Wamser, 2011; Building green, 2018).

Figure 9,27. *Rooftop farms.* (By author)



Floodproof typology

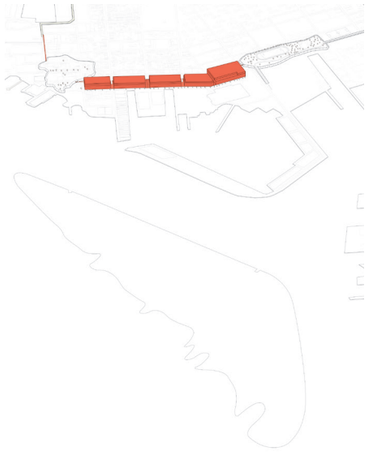


Figure 9,29 displays how the parking garage is integrated in the flooddefence. The garage's floors are not situated on the same height as the buildings floor levels but with half the height difference. Because of this, the entrance ramp can be shorter compared to a regular underground garage. The resulting split level typology allows inhabitants and shop owners to place their critical equipment on the upper floor, while keeping an active plint on the street side. The ground floor and split level layer of the buildings are developed according to dry floodproof standards. To connect the buildings to the high points and keep roads available in regular conditions, self closing flood barriers (SCFB) are chosen. This solution is completely below surface and automatically rises when the water in the activation basin reaches a critical level (Aggeres, 2013).

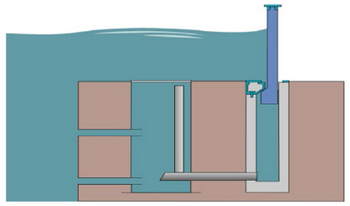
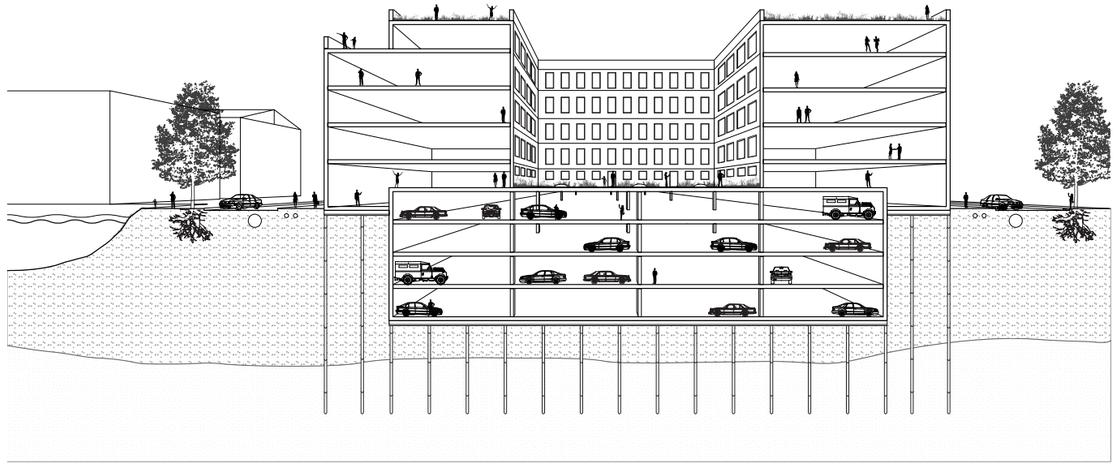
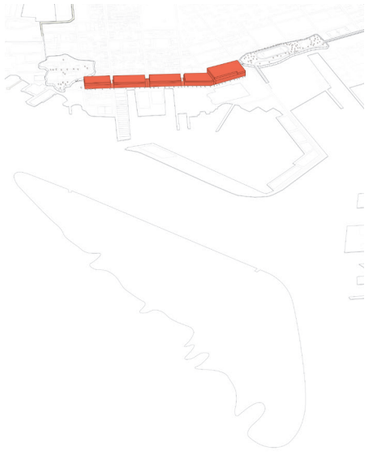


Figure 9,28. *Working of SCFB.* (Aggeres, 2013)

Figure 9,29. *Section floodproof typology.* (By author)

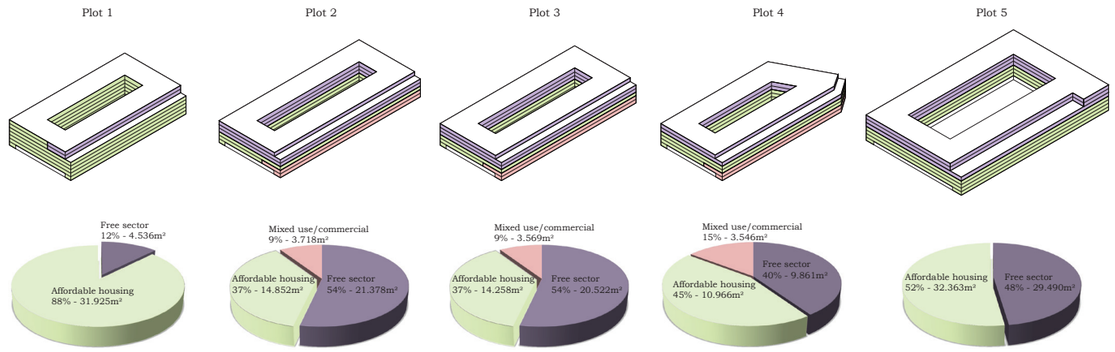


Affordable housing



The demographic analyses showed that many of Red Hook's inhabitants are earning a below-average income (figure 3,11, NYC Department of City Planning, 2014), or even live in poverty (figure 4,2, Social explorer, 2018). To provide opportunities and housing for Red Hook's inhabitants, many of the apartments in the new typologies are classified as affordable housing. Combined in the 5 blocks, over 100.000 m^2 will be available, translating to well over 1.000 affordable housing units (figure 9,30). Combined with free sector apartments and mixed use and commercial functions in the plints. On top of the new public functions, maintenance of new public space such as the waterfront parks will provide jobs for people from the local community. More information about the typology of the apartments and the feasibility of the affordable housing units, is provided on page 164.

Figure 9,30. *Affordable housing, free sector and mixed use ratio.* (By author)



Rooftop farms

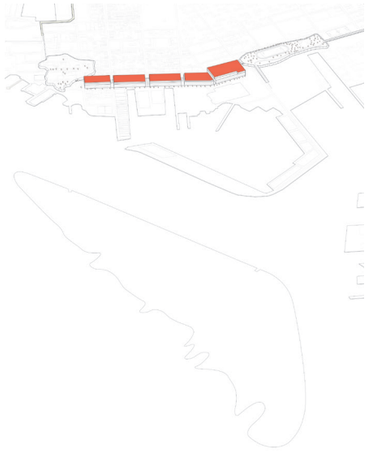


Figure 9,32 displays the proposed design for the rooftop farm on block 4. A variety of vegetables has been selected, according to growing season and root depth (Le & Vischer, 2014). All vegetables have a maximum root depth of 30 centimeters. To ensure the optimal conditions for the vegetables to grow, the roofgarden will be categorized as full soil farming. This layered construction is visualized in figure 9,31 and consists of 30 cm soil, filter membrane, a drainage layer, rootbarrier, waterproofing and finally insulation. This construction weighs around 120 kg/m^2 and is therefore integrated in strenght calculations in the buildings construction phase (Le & Vischer, 2014).

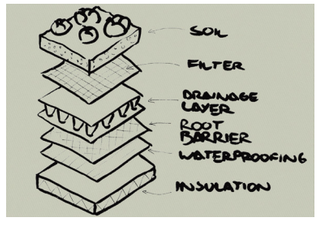
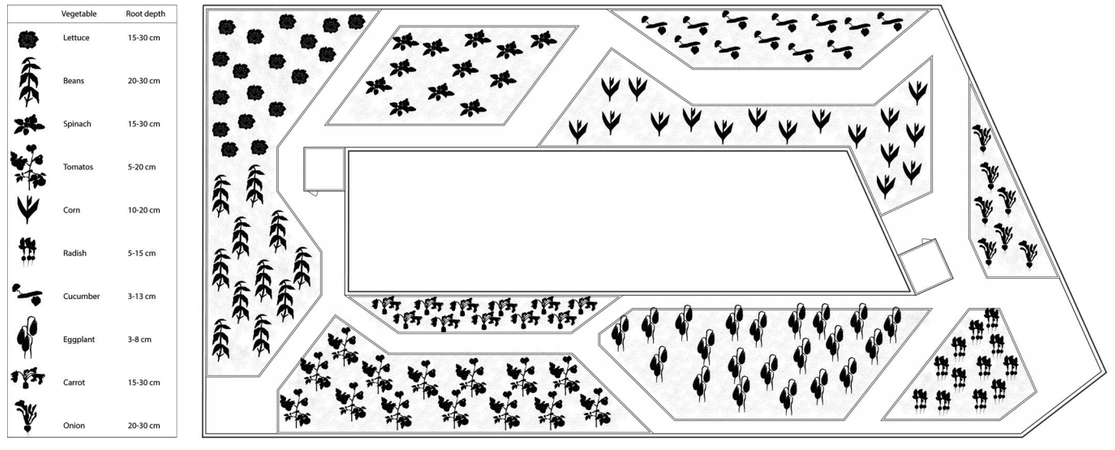


Figure 9,31. *Rooftop farming layers.* (Le & Vischer, 2014)

Figure 9,32. *Rooftop farm.* (By author)



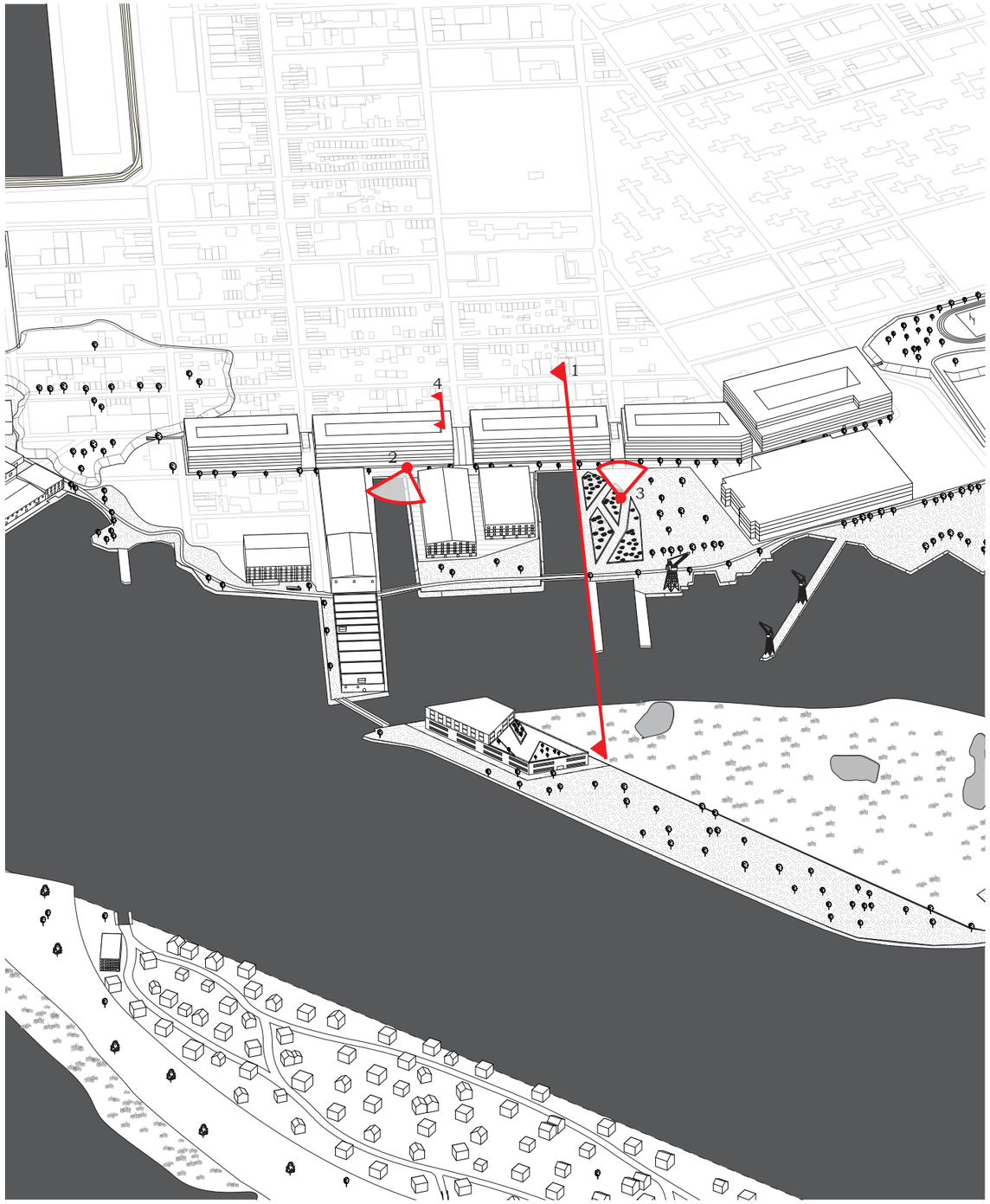


Figure 9,33. *Section and impression indicators.* (By author)

Before and after situation

To visualize the impact the proposed design has on Red Hook, before and after impressions are made. Figure 9,33 shows which locations these drawings display. Each of the four locations are visualized in their current state, as well as the situation when the proposed design is implemented. The section line marked with number 1 in figure 9,33 indicates the location of the birds eye impressions of Red Hook's waterfront and inland area. These are visualized in figures 9,34 till 9,37 and are looking towards the Northwest. The street level impressions are indicated by numbers 2 and 3 respectively. These are visualized in figures 9,38 till 9,41. Finally, the location of the Van Dyke street sections in figure 9,42 and 9,43 are indicated with number 4.

Current situation

Figure 9,34 displays Red Hook´s current situation in good weather conditions. The undeveloped brownfield area is visible in the foreground, as well as the tip of the Erie basin pier on the left side of the frame. The image emphasizes how Red Hook´s waterfront mostly consists of paved surface, and how it lacks trees and parks. Grey and brown are the dominant colours shown in this image of the current situation.



Figure 9,34. *Current situation.* (By author, based on Google Maps)

Situation with interventions

The birds eye section in figure 9,35 shows what Red Hook looks like after the proposed design has been implemented. Despite the fact that the birds eye does not show the complete design, the functioning of the interventions can be explained with the chosen section. Numerous changes, such as the breakwater island, waterfront museum, brownfield development and the new floodproof typology are shown. Trees are planted throughout the waterfront area, to match the green streets found in the inland parts of Red Hook. Leisure space and recreational functions such as the waterfront museum and waterfront parks are connected by the added pedestrian and cyclist bridges.



Figure 9,35. *Situation with interventions.*
(By author, based on Google Maps)

Current situation with extreme weather

Figure 9,36 displays the situation if Red Hook would be facing a 1 in 500 year storm with its current conditions. Waves rolling in from the Atlantic Ocean are not slown down by any form of breakwaters or reefs, and hit the waterfront area with its historic warehouses. Because of the high energy wave impacts, many of the waterfront buildings are threatened with structural failure (WXY et al., 2014; Van Veelen, 2016). Because of these waves, the water penetrates further into Red Hook's neighbourhood, and can reach the inland areas unobstructed.

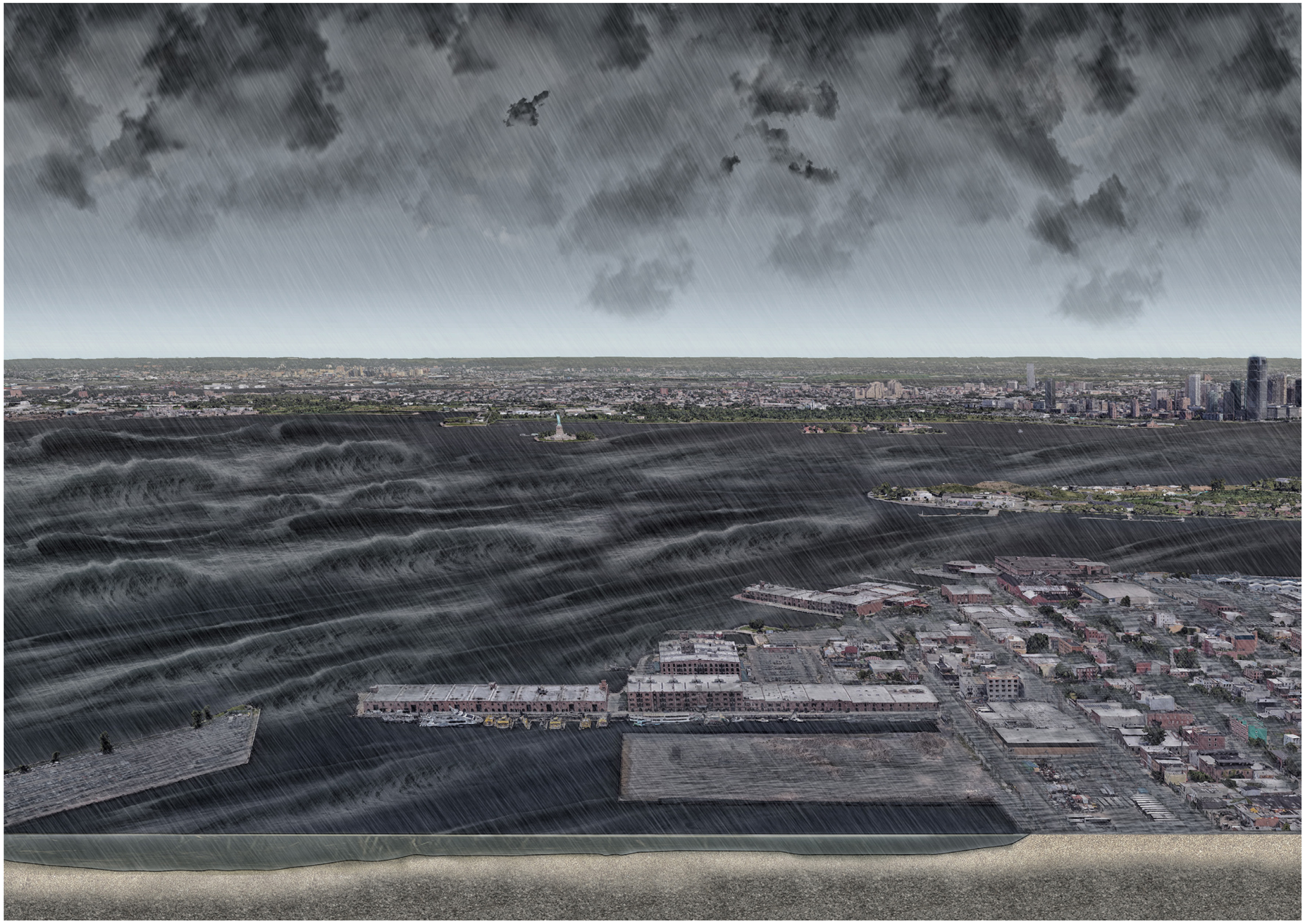


Figure 9,36. *Current situation with extreme weather.* (By author, based on Google Maps)

Interventions with extreme weather

After the proposed interventions are implemented, Red Hook will be protected from extreme storms, as displayed in figure 9,37. The nearshore island with its marshlands and breakwater slows down wave energy to protect Red Hook's waterfront. Water that reaches the waterfront area will not cause significant damage, as all buildings have a wet floodproofed ground floor. The section also shows how the floodproof typology with its underground parking garage stops the water from reaching the inland area of Red Hook.

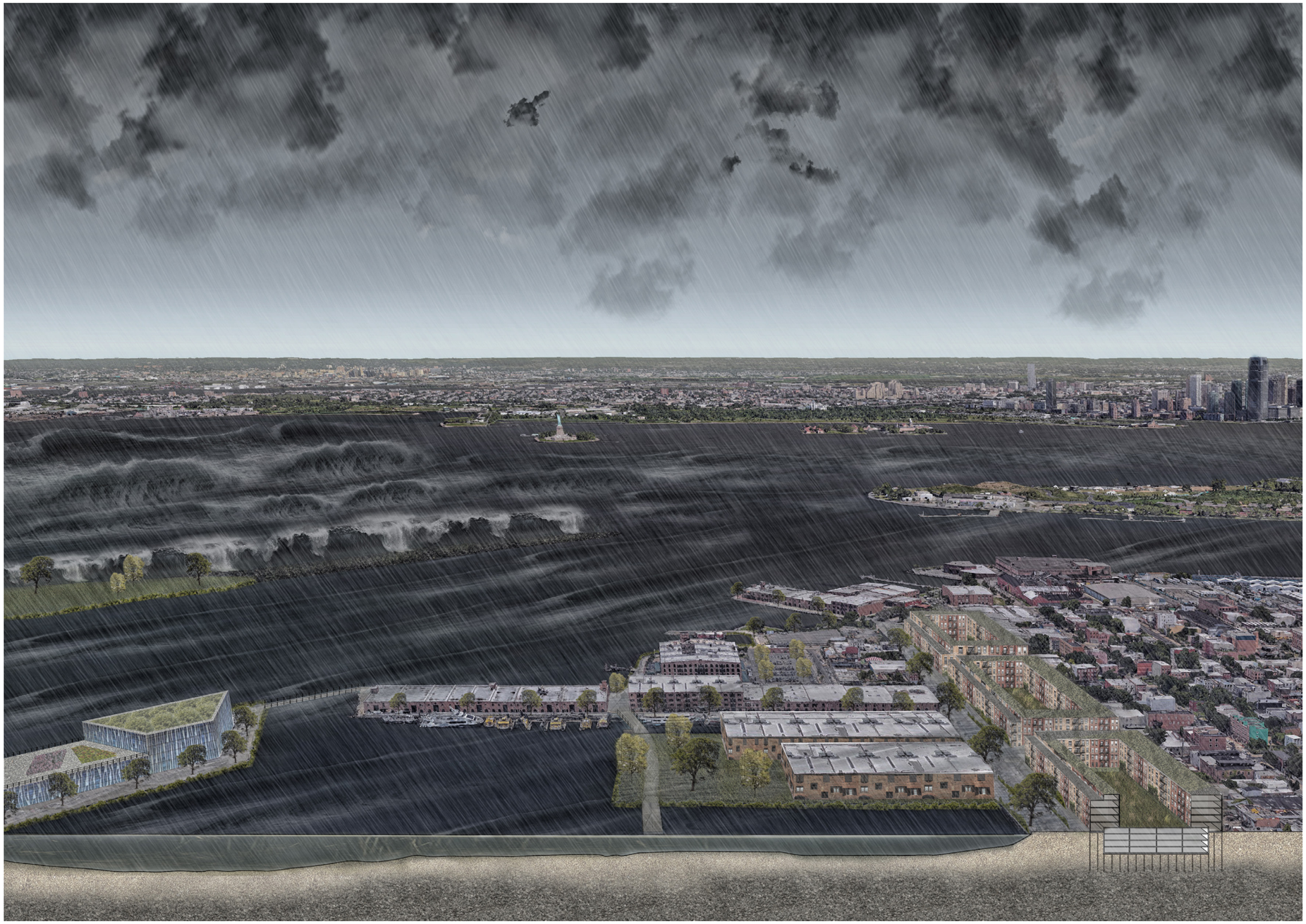


Figure 9,37. *Interventions with extreme weather.*
(By author, based on Google Maps)

Current situation brownfield area

Figure 9,38 displays a picture taken during the fieldwork period. It shows the undeveloped brownfield area next to the historic warehouses on Van Brunt street. Because the brownfield area is located next to one of the docks, the area is permanently semi flooded.



Figure 9,38. *Current situation brownfield area.* (By author)

New situation brownfield area

In the new situation, advantage is taken of the potential qualities of the brownfield area. The walking promenade along the dock leads towards the waterfront park overlooking Erie basin. The new development aesthetically corresponds with the historic warehouses, while offering space for creative industries and apartments. On the landward side, a small scale city beach is realized with options for sports and leisure. The interventions do not intervene with current use of the dock, and allows boats to continue docking on the Van Brunt street side.



Figure 9,39. *New situation brownfield area.* (By author)

Current situation Beard street

Figure 9,40 shows the current situation of the crossing between Beard and Dwight street. The historic crane from Red Hook's thriving harbour time has been preserved. Next to the small tree and electricity poles, the street furniture is rather sober. Behind the crane, the roofs of parked school busses are just visible. The plots on both sides of Dwight street are used almost completely as parking space.



Figure 9,40. *Current situation Beard street.* (By author)

New situation Beard street

After interventions take place, Beard street looks completely different. The historic crane is used as a beacon in the neighbourhood. It is the meeting place for activities, festivals take place, and foodcourts are organized. Over time, the crane can be made accessible to host a variety of functions, such as a small scale restaurant or even hotel rooms. The plots have been transformed from parking space to apartment buildings, creating Red Hook's final layer of flood defence. Further details about characteristics of the buildings are provided on the next pages.



Figure 9,41. *New situation Beard street.* (By author)

Van Dyke street sections

As indicated in figure 9,33, Van Dyke street runs directly behind the five waterfront plots. In the current situation, there is very limited interaction between the buildings and the street. The left side of Van Dyke street consists mostly of a three-story tall blind facade, as is drawn in figure 9,42. This wall has been decorated with graffiti and wildgrowing plants over time. Further down the road on the same side, the windows are bricked up.

Figure 9,43 displays the new situation of Van Dyke street. The industrial buildings on the left side are demolished and replaced with the floodproof typology. The public functions and large windows, as well as small setbacks in the facade, allow for interaction between the building and the street. This difference in the building line is seen in other parts of brooklyn as well, where small stairs are used to reach the front door (figure 9,47). On top of connecting with the Brooklyn architecture, Red Hook's harbour identity is celebrated as well. Steel elements such as fire escape stairs and balconies link to the rough harbour setting of the neighbourhood. A reference project is shown in figures 9,46 and 9,48, to get a more complete impression of the architectural style of the new buildings.

On top of restructuring the plot, the street changes too. Because of the large capacity parking garage under the blocks, the streetprofile can be narrowed. This allows for wider sidewalks with added functions. The small fences are removed and replaced by large strips with different plants and trees. Additionally, these strips serve as parking places for bicycles. Restructuring the streetprofile allows for improving both the sewer infrastructure and the lighting conditions as well.

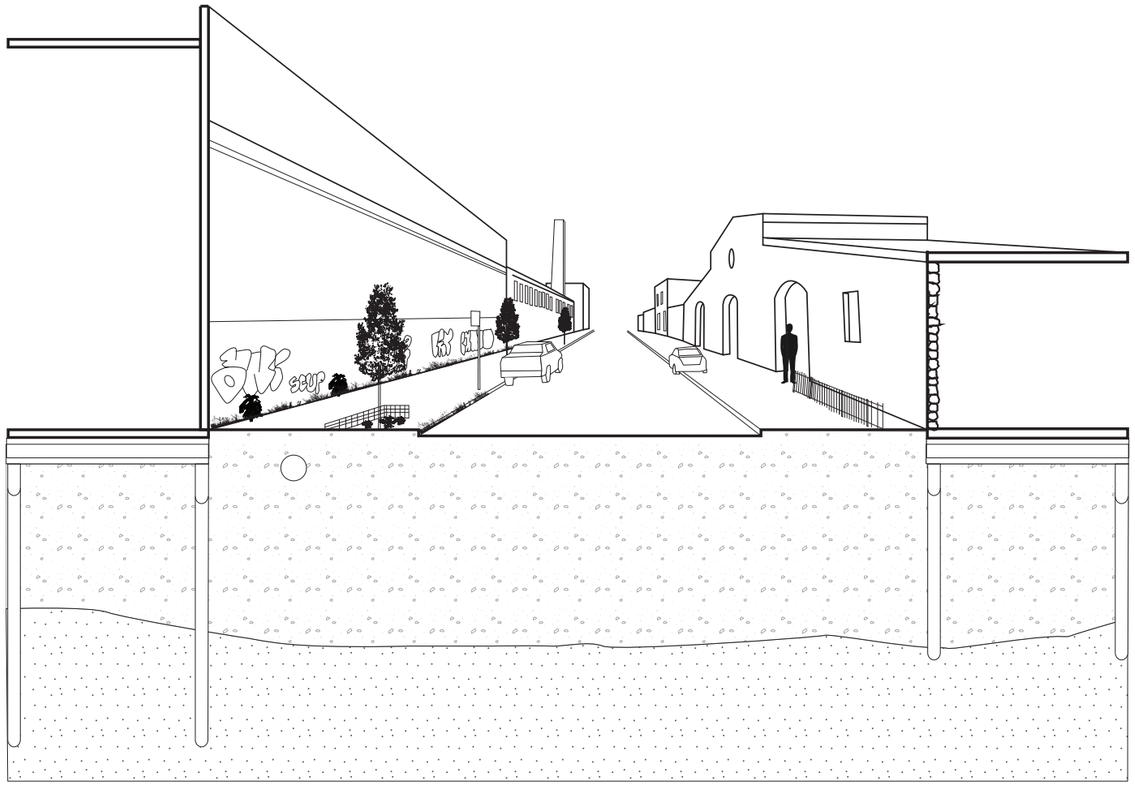


Figure 9,42. *Current situation Van Dyke street.* (By author)

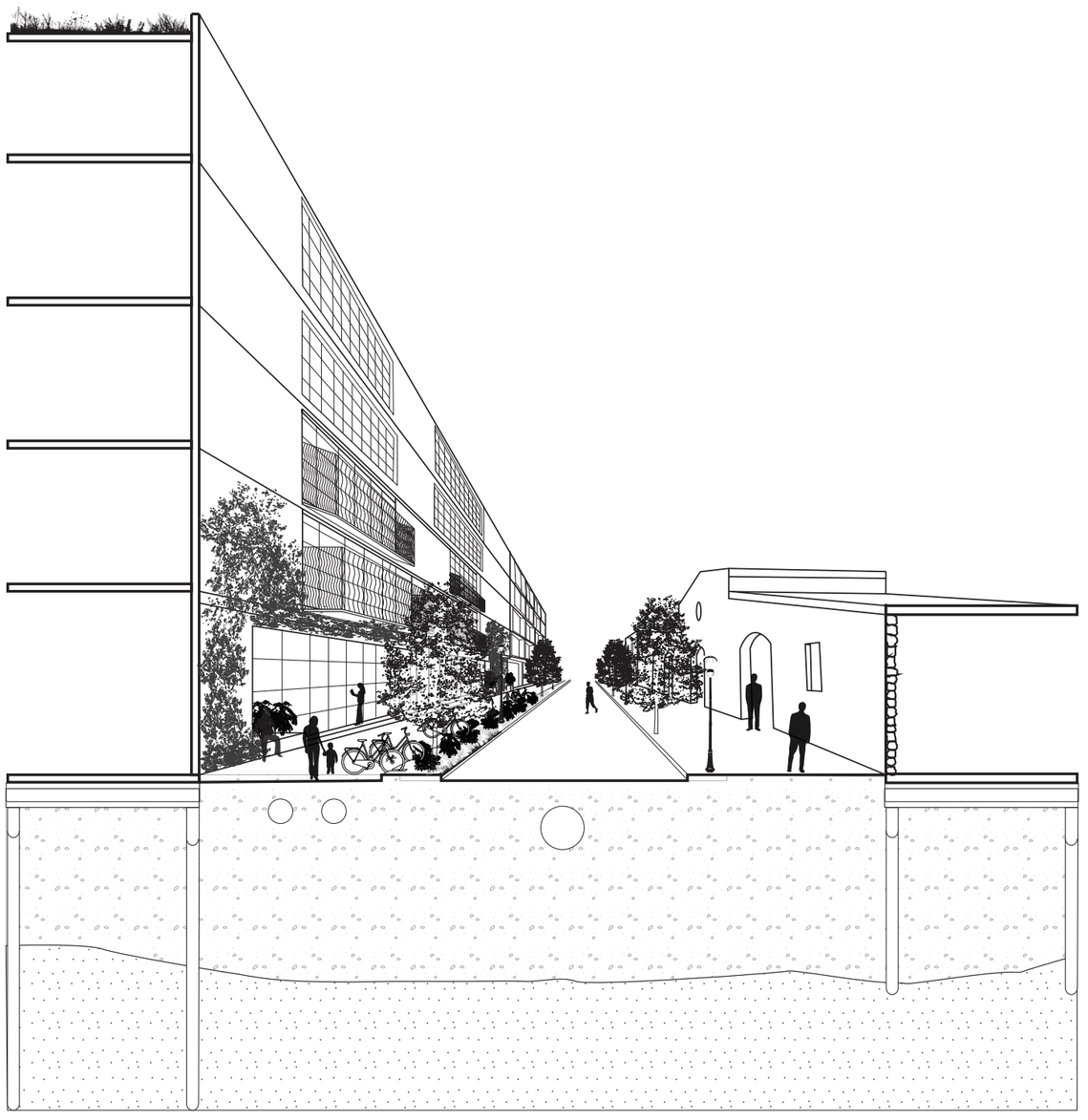


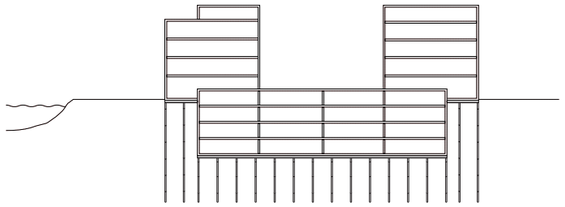
Figure 9,43. *New situation Van Dyke street.* (By author)

The Floodproof typology

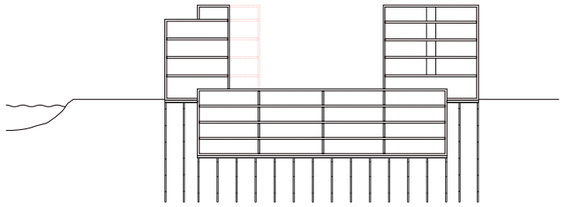
The newly developed floodproof typology plays a substantial role in the design for Red Hook. Since it contributes to reducing both flood risk, as well as socio-economic pressure in the neighbourhood, more visualizations and information is presented to support the proposal.

Since all the building blocks of the floodproof typology host affordable housing, less profit can be made compared to when only free sector apartments are sold. To make up for this financial deficit, two main sources are addressed. As discussed on page 89, the construction of the breakwater island will save money, because of the more convenient dumping site of dredged material. This means the free development plots on the island can be sold with a large margin of profit. This can be used to invest in affordable housing within the floodproof typology. One of the disadvantages of this strategy however, is that both the breakwater island and floodproof typology have to be developed by one developer. Alternatively, a consortium can be formed to divide the costs of this joint development. The second source for funding the affordable housing is the Federal Emergency Management Agency (FEMA). Since the buildings will count as flood defence structures, the development is eligible for federal funding (FEMA, 2003; 2010).

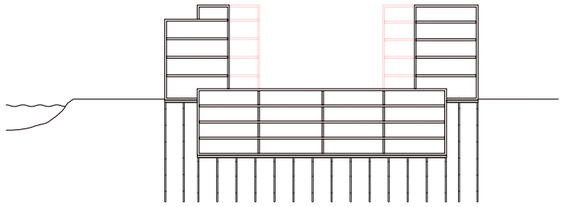
Within the original concept of the floodproof typology, there is a lot of flexibility for the developer. Because the original concept presents floors with substantial width and height, problems can be encountered when trying to realize enough housing density and daylight in the apartments. Because affordable housing consists of smaller apartments, options are presented to meet these demands. All options can be implemented within the original concept, and do not damage the integrity of the building as a flood defence structure. Options to increase density involve lowering the floor height for extra floors, as well as doubling the amount of apartments per floor by connecting them with a corridor. Setbacks in the building facade and creating steps can improve daylight accession and create smaller apartment sizes. These options as variations on the original concept are visualized in figure 9,44.



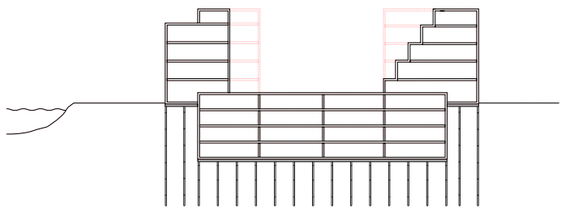
1. Original concept



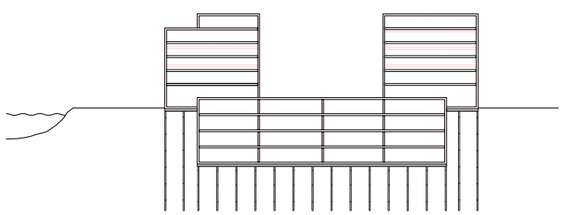
2. Setback and corridor split



3. Setback on both sides



4. Setback and steps



5. Extra floor, lower floor height

Figure 9,44. *Building development options.* (By author)

References

The design for the floodproof typology is supported by references for both the architectural appearance and the technical feasibility. As discussed on page 162, the ground floors will see a variety in the building line, comparable to the Brooklyn houses with their stairs and steel fire escapes. Also the Little Coolhaven project from CULD architects (2018) is used as an aesthetic reference. The link to harbour identity used in this project, connects with the one in Red Hook as well. After reviewing Little Coolhaven, the use of steel elements, such as railings and balconies, combined with dark red, brown and yellow brickwork are chosen as the architectural conditions for design in Red Hook. Finally, the parking garage in Katwijk developed by Royal HaskoningDHV (2015) is used as a technical reference. The 500 meter long concrete structure is integrated in the dunes and serves both as a coastal defence, as well as a parking garage for 663 cars (RoyalHaskoningDHV, 2015; 2018).



Figure 9,45. *Parking garage + flood defence.* (RoyalHaskoningDHV)

Figure 9,46. *Little Coolhaven, Rotterdam.* (CULD)



Figure 9,47. *Brooklyn houses with stairs.* (By Stefan Jeremiah)



Figure 9,48. *Little Coolhaven, ground floor and balconies.* (CULD)

Phasing and functioning

Finally, the construction and technical functioning of the floodproof typology is visualized in figure 9,49. After clearing the five plots between Beard street and Van Dyke street, the excavation for the parking garage begins. When the foundation is in place, three layers of continuous parking garage are constructed. The concrete structure of the garage serves as the foundation for the building and core of the flood defence system.

Next, the seperate parts of the parking garage are constructed. These parts will eventually be located below the building blocks, and are situated half a floor height below the ground level. To connect the seperate parts of the parking garage to each other, but also to facilitate the entrances and exits to the ground level, slopes are constructed. The entrance ramp in the slope takes the road from ground level to -2 meters, resulting in a 10% incline. The entrances and exits are only open on the inland side, as the slopes are part of the flood defence structure. The top of the slopes rise 4 meters above ground level. As Beard street is situated 1,5 meters above sea level, the floodproof typology is watertight until 5,5 meters of waterlevel rise above high tide. After the slopes are installed, the construction of the building blocks begins with the courtyards.

The construction of the blocks continues with the ground floor. This split level building layer connects the slopes and is half constructed over the parking garage. As shown in figure 9,44, different options are possible regarding the construction of the building block. In this visualization, the structure is realized with a small setback, to keep enough roof surface. This allows for the development of a large roof garden. In the last image the floodproof typology is completely finished and protects the neighbourhood of Red Hook.

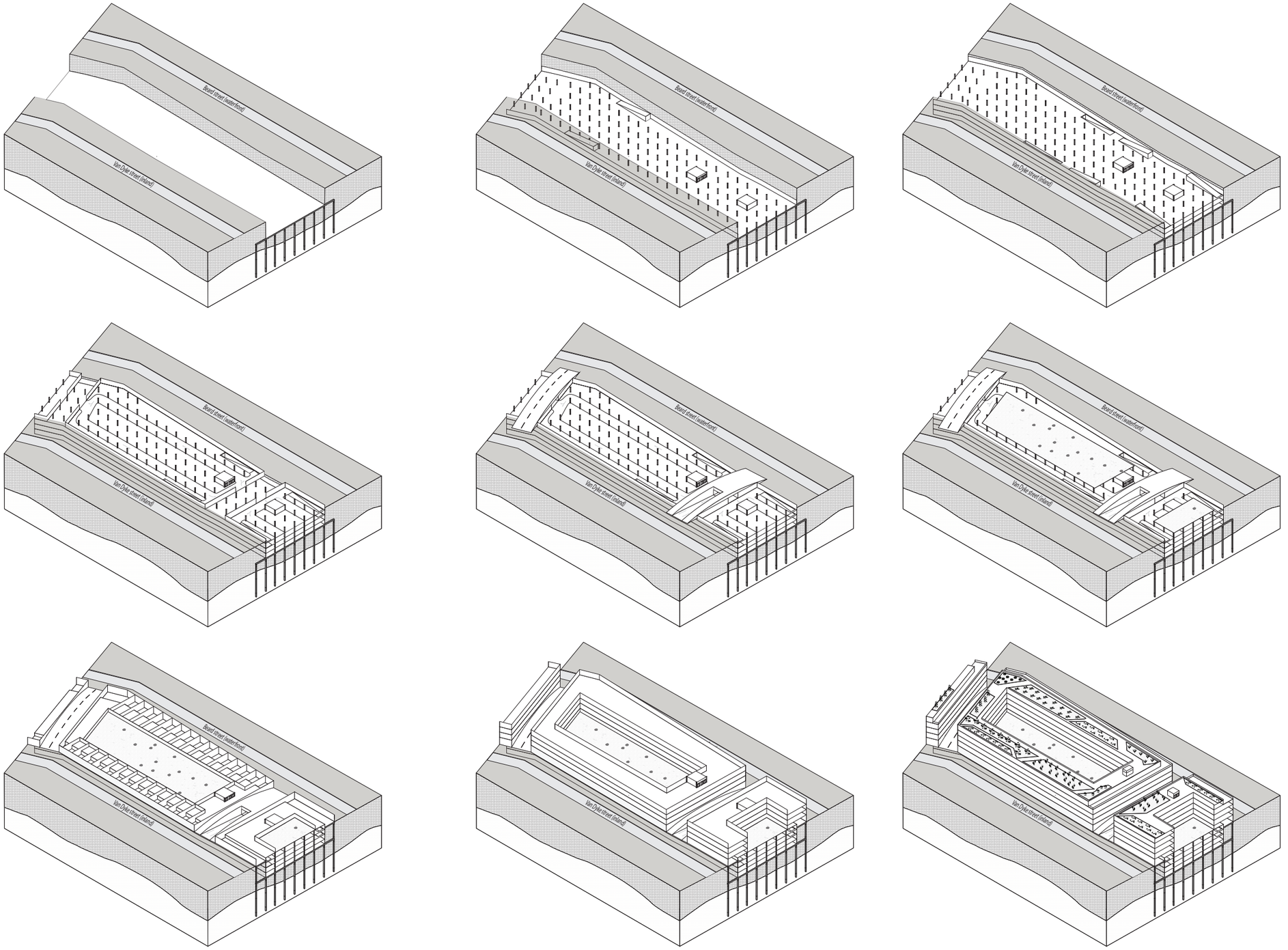


Figure 9,49. *Construction phases of floodproof typology.* (By author)

Conclusion

Research conclusions

This thesis set the goal of developing a strategical framework to guide interventions in urbanized coastal areas. In order to answer the main research question *'How can flood risk, public- and ecological value be addressed coherently through urban regeneration, in which socio-economic pressure and flood risk are both successfully reduced?'*, a design has been made for Red Hook. The design serves as a pilot project, and should provide insight in the functionality and completeness of the strategic framework.

Early on in the process of developing the strategical framework, it was hypothesized that focusing on flood risk, public value and ecological value would give the most complete approach, within a narrowed scope. These three components have been the guiding focus throughout the entire process, and supported guiding numerous decisions. After analysing the pilot neighbourhood of Red Hook within the context of the three components, its complexity became apparant. When analysing through the scales, it became clear that the strategic approach needed to be split further for effective application. At this moment, three focus sites were selected within Red Hook's study area. The nearshore, waterfront and inland area all have their distinctive characteristics, and present different opportunities and limitations. To successfully reduce flood risk and increase public- and ecological value, scales and interventions of different nature work together to combine their individual strenghts. Figure 10,1 shows an evaluation of how each area contributes to the three respective components.

In the proposed design, the nearshore area provides an exceptional amount of wildlife habitat with its marshland, breakwaters and berm. Both on the land and in the water a significant increase in ecological value (indicated in green) can be achieved. It also contributes substantially to reducing flood risk, by protecting Red Hook's waterfront through breakwaters. Although the least significant of the three components, the berm and marshland, as well as the free development plots offer public value as well.

In the waterfront area, Public value (indicated in yellow) is now by far the highest scoring component. Whereas most of Red Hook's waterfront was not publicly accessible before, waterfront parks, shops, public facilities and a museum are developed, while maintaining the integrity of Red Hook's original identity in the historic warehouses. Also the ecological value has been upgraded significantly, by creating natural waterfronts and parks, the marshland in Erie basin, and implementing ecological solutions on the vertical seawalls. The waterfront buildings have been wet floodproofed by interventions on building level. Although these interventions presented the most favorable cost-benefit ratios for the waterfront buildings, it does not slow the water down from reaching the rest of Red Hook. For this reason, when looking at the neighbourhood as a whole, reducing flood risk scores the lowest in the waterfront area.

Finally, the inland area stands out for its flood risk reduction. By restructuring 5 waterfront plots, the natural high points of Red Hook are connected with a new floodproof typology. Combined with the Brooklyn Waterfront Greenway cyclelane, the entire

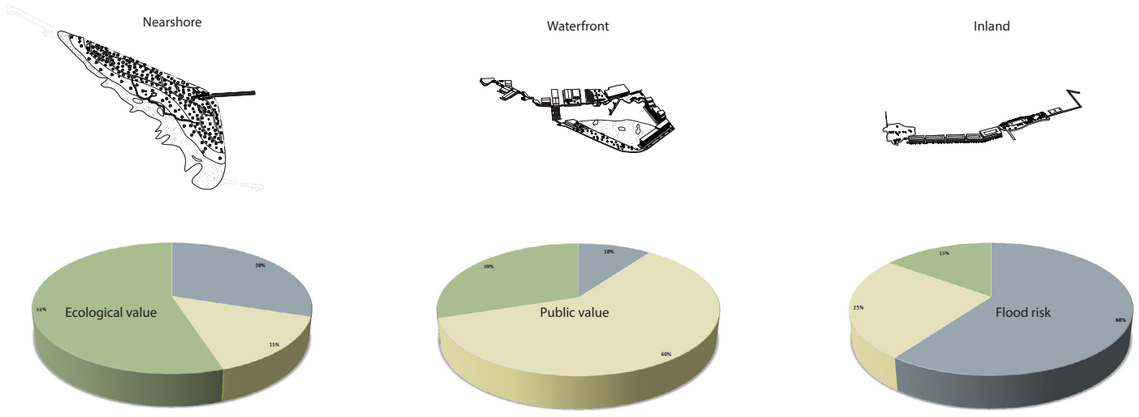


Figure 10,1. *Evaluation of contribution to Flood risk, Public value and Ecological value per area.* (By author)

neighbourhood of Red Hook will be protected from flooding. As not only the floodrisk, but also socio-economic pressure is addressed, the floodproof typology also caters to this challenge. By providing over 1.000 affordable housing units in the 5 blocks, public value scores second highest. Closing the evaluation with ecological value in third place, green roofs and rooftop farms will contribute to increasing biodiversity in the area.

Research questions

The first sub research question *'How can the effects of coastal, tidal, fluvial and pluvial flooding both individually and in combination, be assessed in reciprocity to public- and ecological value?'* has been answered in two parts. In the appendix, the paper discusses the 4 respective types of flooding and their characteristics. Secondly, the design for Red Hook shows how to take the opportunity of reducing flood risk to create public and ecological value. The sub research question *'How can spatial interventions regarding flood risk reduction be integrated in existing restructuring plans to increase public value?'*, has been answered by the design as well, particularly when looking at the restructuring of the waterfront plots to develop the new floodproof typology. The last two sub research questions *'In which conditions does ecological value de- or increase?'* and *'What conditions can be created to increase ecological value in urbanized waterfronts?'* have been answered by the design for marshlands, breakwaters and ecological waterfronts in the nearshore and waterfront areas based on scientific literature.

In finding the answer to the main research question *'How can flood risk, public- and ecological value be addressed coherently through urban regeneration, in which socio-economic pressure and flood risk are both successfully reduced?'* the thesis has shown, that urbanized coastal areas possess far too much complexity and dynamics to address in a single project. However, the project shows how a set of interventions contribute to the components of flood risk, public- and ecological value. The strategical framework proved to be very useful to guide the design for Red Hook and to help answering the research questions. Not only did it provide structure for developing the project, the framework itself developed over time as well, when it was found necessary to be split further down to the three focus areas. As Red Hook is the pilot testcase for this strategical framework, further research has to show if successful adaptation in other urbanized coastal areas is possible as well.

Recommendations for further research

The first step in further research entails the selection of new urbanized coastal areas that deal with severe flood risk and socio-economic pressure. To research to what extent the strategic framework can be successfully applied in other areas, a design has to be made with multiple focus areas, and include the components of reducing flood risk and increasing public- and ecological value. In this design process, the strategic approach once again serves as a framework and starting point, but may develop over time. Once the design process has been completed, a similar evaluation can be made to the one displayed in figure 10,1.

By evaluating the contribution of each area to flood risk reduction and increasing of public- and ecological value, conclusions can be drawn. In the case of Red Hook, it stands out that ecological value is increased most in the nearshore area, followed by the waterfront and the inland area respectively. In other words, the more landward the area is located, the less ecological value has been achieved. The fact that most public value is achieved in the waterfront area may be linked to the positive impact water has on the perception of urban public space. Another conclusion, is that most of the flood risk reduction actually takes place in the inland area, in Red Hook's case. One might expect the waterfront area, where land and water meet would be the number one place to develop interventions to reduce flood risk.

For now, these drawn conclusions are specific to Red Hook's context. By using the framework to analyse and develop a design for multiple urbanized coastal areas, these evaluations can be compared to other locations. It may be possible to detect trends in the functioning of each respective area. Discovering which areas consistently excel in addressing flood risk, public- and ecological value respectively, can provide very useful insights in how to develop specific areas in future urban regeneration plans.

Reflection

Reflection

The final chapter of this thesis involves reflecting on the past year and the project that has been developed. As the Delta Interventions studio had the theme North Sea this year, locations of the projects where pre-determined. Because of my personal interest and motivation to work on a project involving New York City, I wanted to be able to select my own study area. Since the theme of the Delta Interventions studio had my absolute preference, I still decided to graduate in this research group. Thankfully, the flexibility was offered to select your own location if accompanied by a strong personal motivation. This allowed me to work on detaic challenges in the city of my choosing.

Since the research group Delta Interventions focuses on detaic challenges, developing a project in New York City fits perfectly within this studio. Situated in the Hudson river delta and directly next to the Atlantic ocean, New York deals with various water related challenges. The city has always had a close relation with the water, but will have to adapt to be prepared for the challenges in the coming century. In the master track of Urbanism, projects usually deal with complex problems. Rarely it is the case that solid interventions are proposed without understanding the dynamics of the specific context. After carefully analysing the conditions on different scale levels, proposals are made. This proces of getting to know the area and studying all relevant dynamics is something I personally really enjoy, and is essential to develop a successful project. This project has taught me a lot about Red Hook, and made me focus not only on the deltaic challenges of New York city, but also the demographic ones. This complexity makes that I have felt challenged throughout the year to propose the best possible solutions, and is something I relate closely to the field of Urbanism.

Throughout the development of this project there has been a close relation between research and design. The majority of design decisions, have been based on research. For example the design of breakwater to maximize ecological value has been studied in Rebuild by Design projects. By analysing these projects and applying the concepts in my thesis, there is a close link between the research and design. Also the marshland has been developed according to the research done on salinity and waterlevel difference between the tides. Finally, interviews with experts and local inhabitants have provided insight in the design for the waterfront, keeping in mind what the local community needs and values most.

Early on in the project, the strategical framework was established. Although it slightly developed over time, the three components of flood risk, public- and ecological value have remained the same throughout the process. This approach gave solid guidelines for the direction of the project. Another methodology that provided support for design decisions has been descriptive research. Luckily, there was ample data available on the conditions found in and around Red Hook. This enabled me to not only map the current conditions, but also make evidence based decisions on information from trustworthy sources such as municipal documents.

As this thesis addresses highly relevant challenges of the coming decades, it makes a useful contribution to the academic field of urbanism. By developing an ecological approach, rather than solving flood risk with traditional hard man made infrastructure, the thesis tries to explore the benefits of more unconventional ways of urban development. As our understanding of the importance of ecological value in urbanized areas increases, this approach could become more common in the near future.

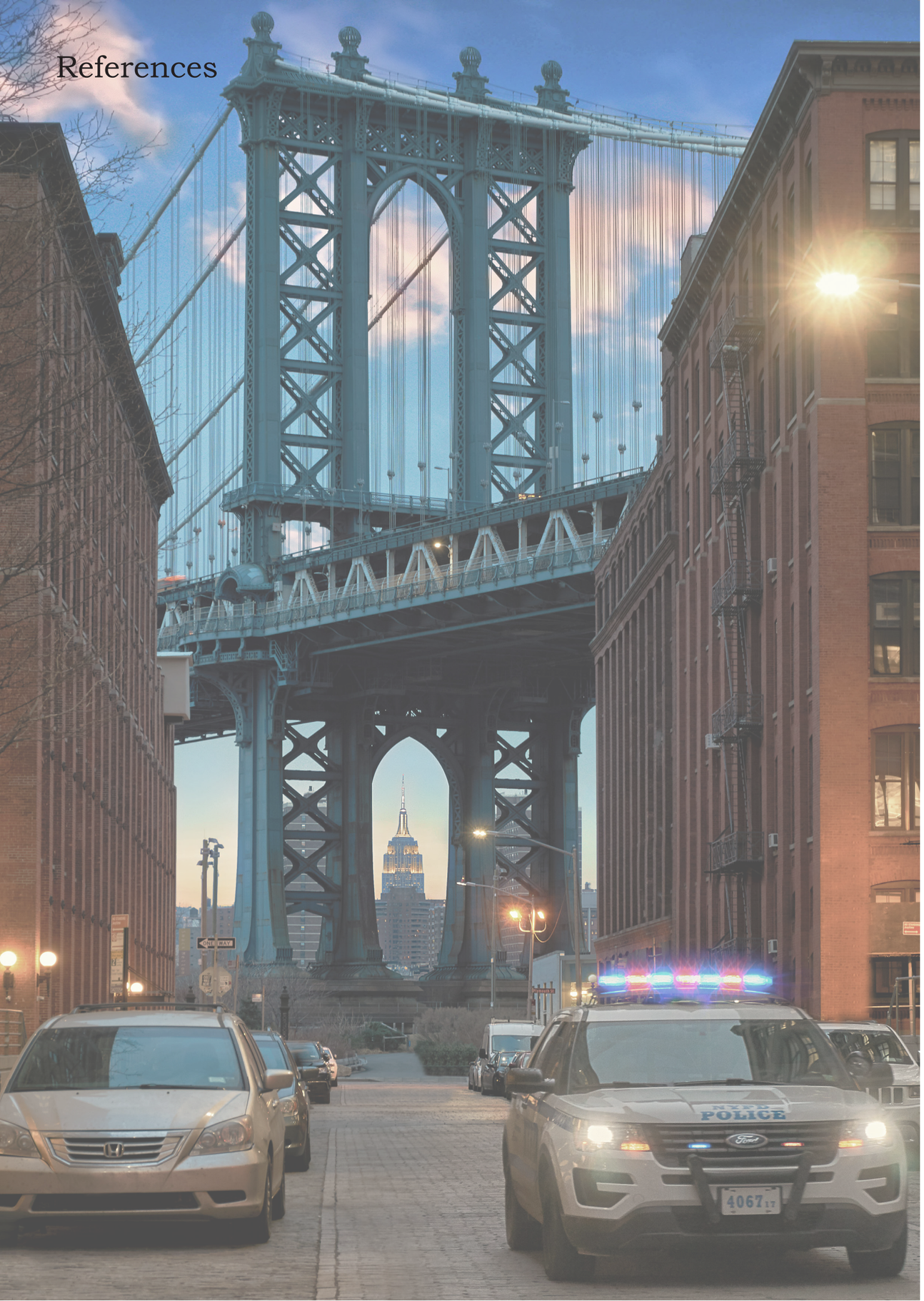
One of the most challenging factors concerning the situation in Red Hook are the societal and ethical aspects. As the analyses have shown, the neighbourhood deals with several demographic challenges, such as a high unemployment rate and low incomes. While housing prices have been rising out of control in most parts of New York City, Red Hook has seen surprisingly low rates of gentrification in the last years. Considering it is located close to Manhattan, it is one of the last neighbourhoods which hasn’t seen the extreme rise in housing prices. The analyses showed several reasons that possibly contribute to this fact. The high flood risk and isolation in terms of public transit of the area are likely to be the biggest contributing factors. These factors are both being addressed in this thesis. With that being said, it is not unthinkable that housing prices will start to rise and the area will see an increase in gentrification, if the proposed design is being implemented. When reducing the flood risk in Red Hook and improving both public- and ecological value successfully, this scenario is very likely.

Although new affordable housing units will be realized to accomodate the low income community, it could still mean that current inhabitants of the Red Hook houses project can no longer afford to pay the rising rent. By providing additional job opportunities the local community also benefits in an economical way of the urban regeneration in Red Hook. Whether these economical benefits will be enough to steer the gentrification of Red Hook in a controlled way remains to be seen. This is an ethical dilemma which proved to be hard to solve.

As the project aimed to address both Surges of the 21st century, it should combat floodrisk and socio-economic pressure in an equal way. Although both aspects are addressed through interventions in the proposed design, flood risk seems to have played a more dominant role in the development of this thesis. Reflecting on the amount of attention both the aspects have received, the social part of the project could have been stronger.

The transferability of the projects results plays a large part in this thesis. After all, the strategical framework to guide development in urbanized coastal areas has to be applicable in various locations. Although the three components of the framework can be researched and developed in all urbanized coastal areas, every situation will be unique. The three development areas with the nearshore, waterfront and inland area might not be feasible in other delta cities for a variety of reasons. In general, the strategic framework proved to be successful for developing the neighbourhood of Red Hook. For this reason, addressing the three components of flood risk, public- and ecological value will most likely be an effective framework for guiding development in urbanized coastal cities elsewhere in the world too.

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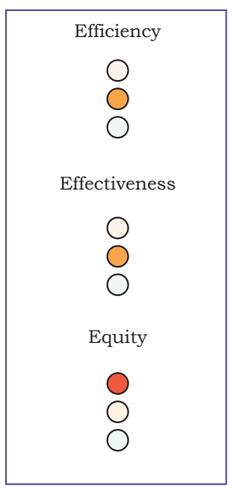


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The Big U

The Big U is a project by BIG architecture for lower Manhattan. The proposal focuses on resiliency infrastructure and the community. The BIG Team describes this combination as a methaphor of teamwork between Robert Moses and Jane Jacobs (2014, p. 3). The proposed interventions will protect 10 continuous miles of Manhattan's waterfront. Although it covers a long stretch of land, each compartment of the design works independently and can be easily phased and implemented. Three compartments of the design have been elaborated in further detail. These components stretch from the Battery Park along the lower east side towards the East River Park. In these parts of the design, most of the focus is aimed at restructuring the public space. Different interventions such as deployable walls that hang underneath the FDR drive, as well as pavillions and restructuring of the public waterfront space should severely reduce flood risk. The three components that have been discussed in the project report cover 4,3 miles of the total 10 miles of waterfront included in the project.

The costs for the interventions proposed in the 3 components alone are estimated at $1,1 billion (BIG Team, 2014).

The main focus of the Big U project is aimed at improving public space. It scores particularly well at increasing public value and decreasing flood risk by the restructuring of existing public space. These are the strongest points of the project, illustrated by the creation of additional housing stock and the restructuring of existing buildings. The initiatives for affordable housing are overshadowed by the attention for the public waterfront. Despite the fact that the project looks to realise ample green public space, it does not address the possibility for increasing ecological value at the same time. Having an estimated cost of over $1 billion for only 4/10 of the total plan, it is one of the most expensive projects.

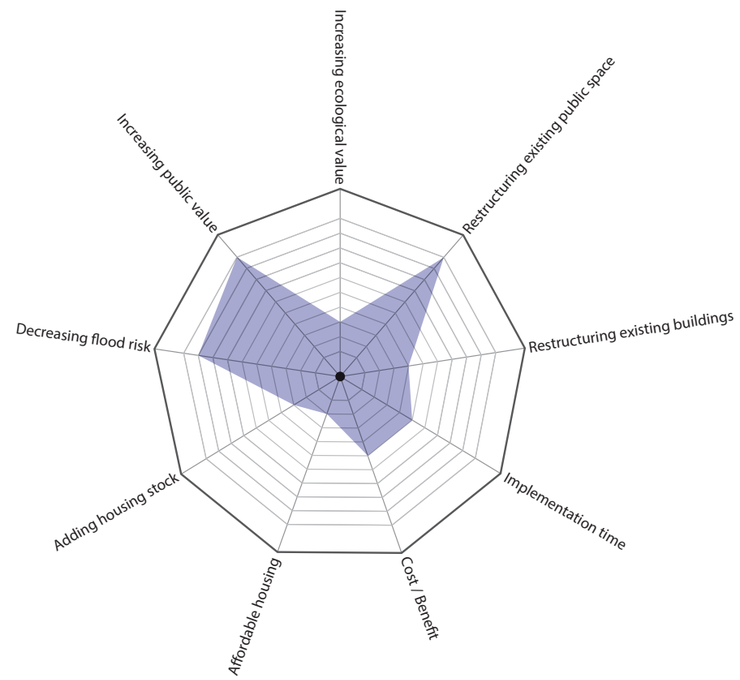


Figure 13,4. *Nonagon diagram The Big U.* (By author)

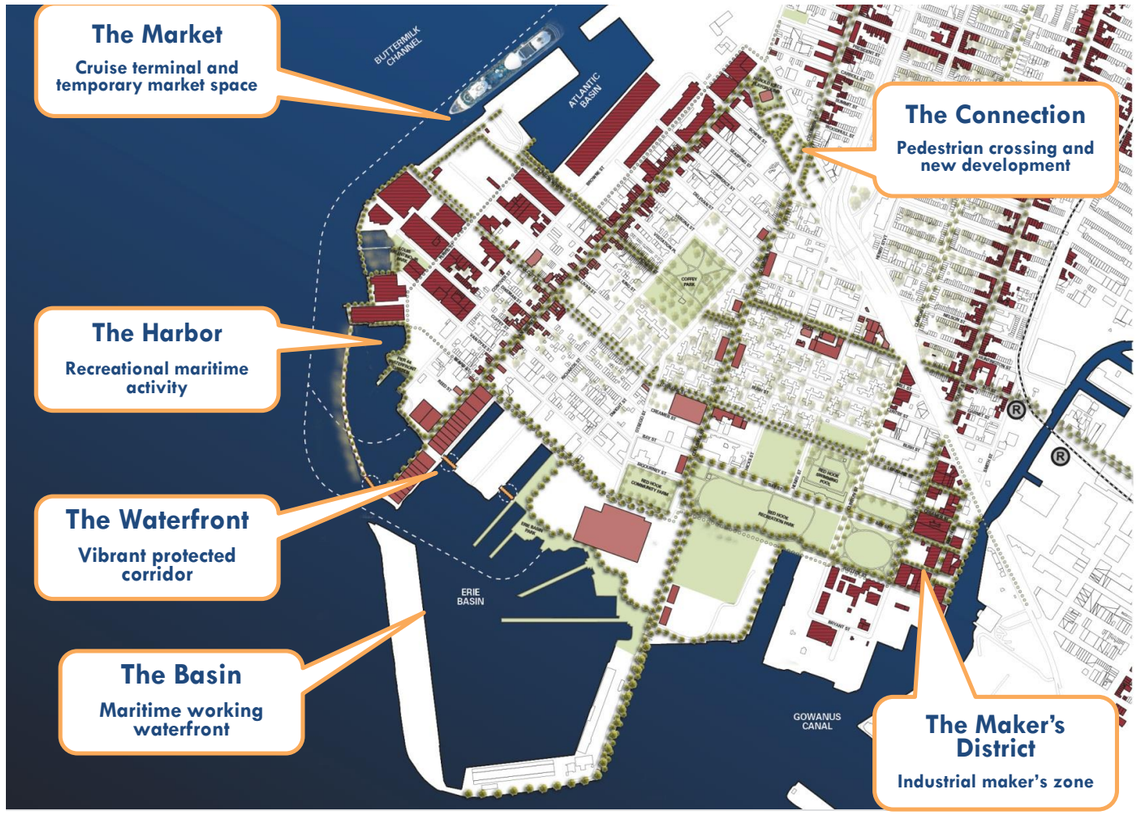


Figure 13,5. *Commercial corridor resilience project.* (HR&A Advisors with Cooper, Robertson & Partners, 2014)



Figure 13,6. *Location CCRP.* (By author)

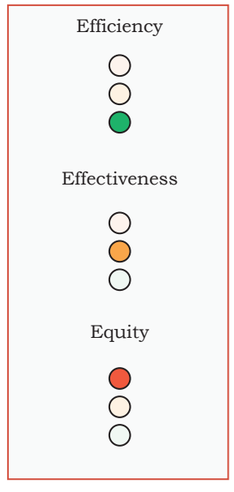


Figure 13,7. *Adaptation ranking.* (By author)

Commercial corridor resilience project

The Commercial corridor resilience project focuses on 3 Sandy-affected coastal areas. Red Hook, Beach 116th street and Asbury park are all flood sensitive areas in need of a better protection system. The map on the lower part of the left page indicates these locations from top to bottom. This short review will focus on the location of Red Hook only. The project is budgeted at $285M and is dedicated to reducing flood risk while improving the local economic situation of the respective locations.

For the neighbourhood of Red Hook the primary focus lies on developing an integrated flood protection system that stimulates commercial or mixed use preservation and expansion. Key interventions within this program are revitalization of the Red Hook Houses, upgrading the connectivity of Columbia street and an elevated Brooklyn Greenway. Interventions on building level as well as public space on neighbourhood scale are proposed. The project focuses on supporting small to medium businesses in the area that have a hard time recovering from the damage caused by hurricane Sandy (HR&A Advisors with Cooper, Robertson & Partners, 2014).

Although the project claims to be beneficial for the local community, and describes an increase in property value because of the proposed interventions, it does not address the possibility of gentrification. This could have a negative impact on the local community as it would drive up housing prices and force local inhabitants to move to affordable housing elsewhere. A last point of criticism is the lack of attention for increasing ecological value through the redesign of the waterfront area. Although the flood risk will be successfully reduced by restructuring existing public space and existing buildings, this can be considered a missed opportunity. As shown in figure 13,8, the project scores well on addressing flood risk through the restructuring of both public space and existing buildings.

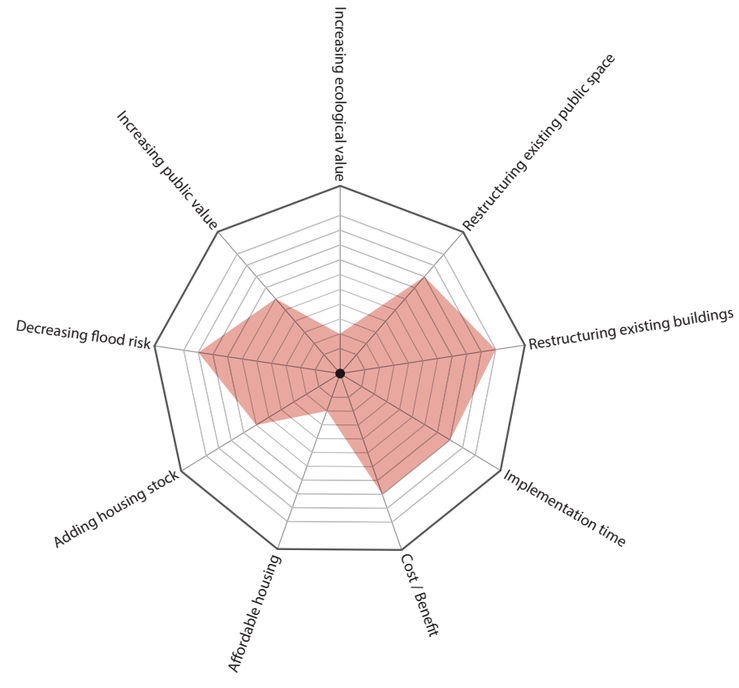


Figure 13,8. *Nonagon diagram CCRP.* (By author)

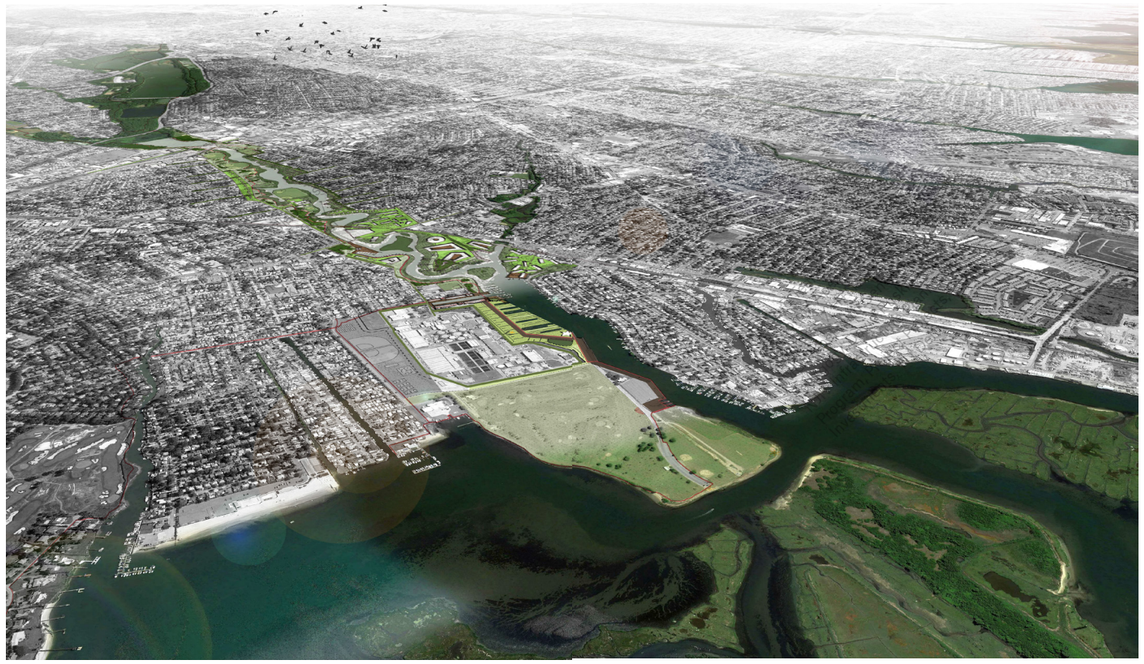


Figure 13,9. *Living with the bay.* (Interboro, 2014)



Figure 13,10. *Location Living with the bay.* (By author)

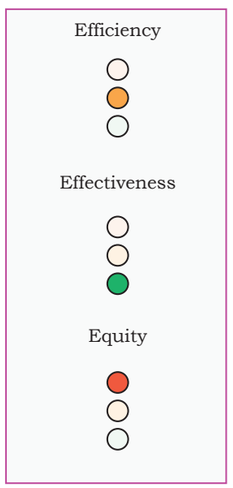


Figure 13,11. *Adaptation ranking.* (By author)

Living with the bay

The main purpose of the Living with the Bay project is to 'make the communities around the South Shore's bays more resilient in the face of future extreme weather events and sea level rise and also to strenghten what makes living near the bays great in the first place' (Interboro, 2014, p. 16). The bays in the island of Nassau County offer great qualities but are also a threat when it comes to extreme weather conditions. The Interboro team researched four possible options to develop the bays (Interboro, 2014, p. 16).

1. a bay that is completely open to the ocean
2. a bay that is buffered from the ocean
3. a bay that can be closed off to the ocean by means of operable surge barriers
4. a bay that is closed off permanently from the ocean by fixed surge barriers

Their preferred approach involves the bay that is buffered from the ocean. Interventions and proposals take place in almost entirely nature-related environments, creating space for the water and additional water storage in urbanized areas.

Through these interventions the flood risk is being severely reduced, while increasing both public and ecological value (Interboro, 2014).
Although public space is being restructured to achieve this more resilient water environment, little has been said about restructuring existing buildings and adding (affordable) housing stock. The project mostly focuses on the natural environment to create a place where living with the bay is safer. Because it involves large scale interventions that all need to be realised before the project can display its full effect, the implementation time is of substantial duration. Because of the many added values on top of flood risk reduction, the cost benefit of the Living with the Bay project can be deemed rather efficient.

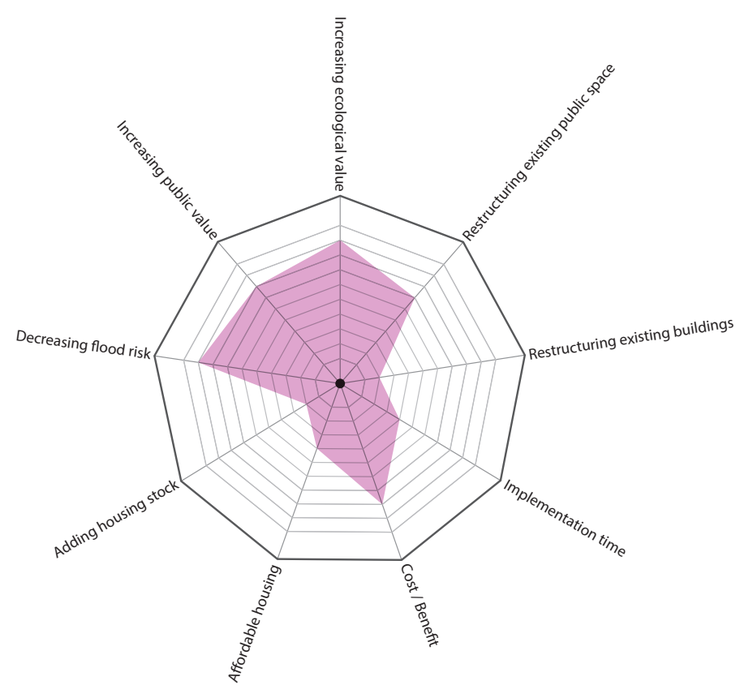


Figure 13,12. *Nonagon diagram Living with the Bay.* (By author)



Figure 13,13. *New Meadowlands.* (MIT CAU + ZUS + De Urbanisten, 2014)



Figure 13,14. *Location New Meadowlands.* (By author)

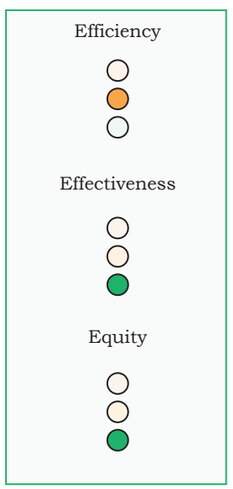


Figure 13,15. *Adaptation ranking.* (By author)

New Meadowlands

The design for the New Meadowlands project aims to create a regional attractor for the New Jersey and New York metropolitan area which offers protection against flooding. While the Meadowpark will be developed as natural marshland, serving as flood protection system as well as regional wildlife refuge, the Meadowband will be the link between ecology and development (MIT CAU et al., 2014). This Meadowband will be developed with a bus rapid transit system, providing access points to the wildlife reserve and a variety of public spaces. Along this band, rezoning and restructuring will take place to increase density by adding (affordable) housing stock (MIT CAU et al., 2014).

As the project focuses on the creation of a wildlife refuge within the meadowland, increasing ecological value scores the highest in the evaluation graph. However, most of the set criteria are met exceptionally well, with the exclusion of implementation time. Because the project entails mostly large scale ecological and infrastructural interventions, full effect of the flood protection system will only be enjoyed after the complete finalization of the project.

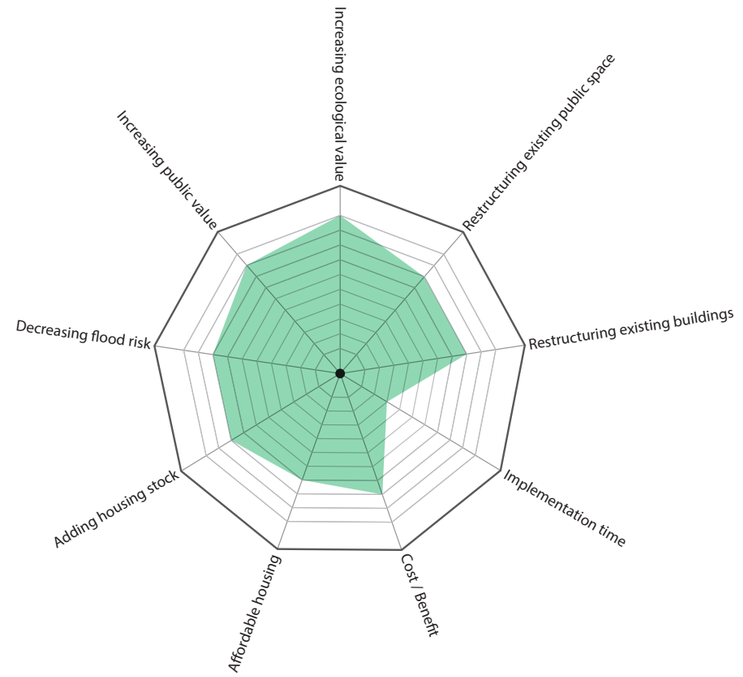


Figure 13,16. *Nonagon diagram New Meadowlands.* (By author)

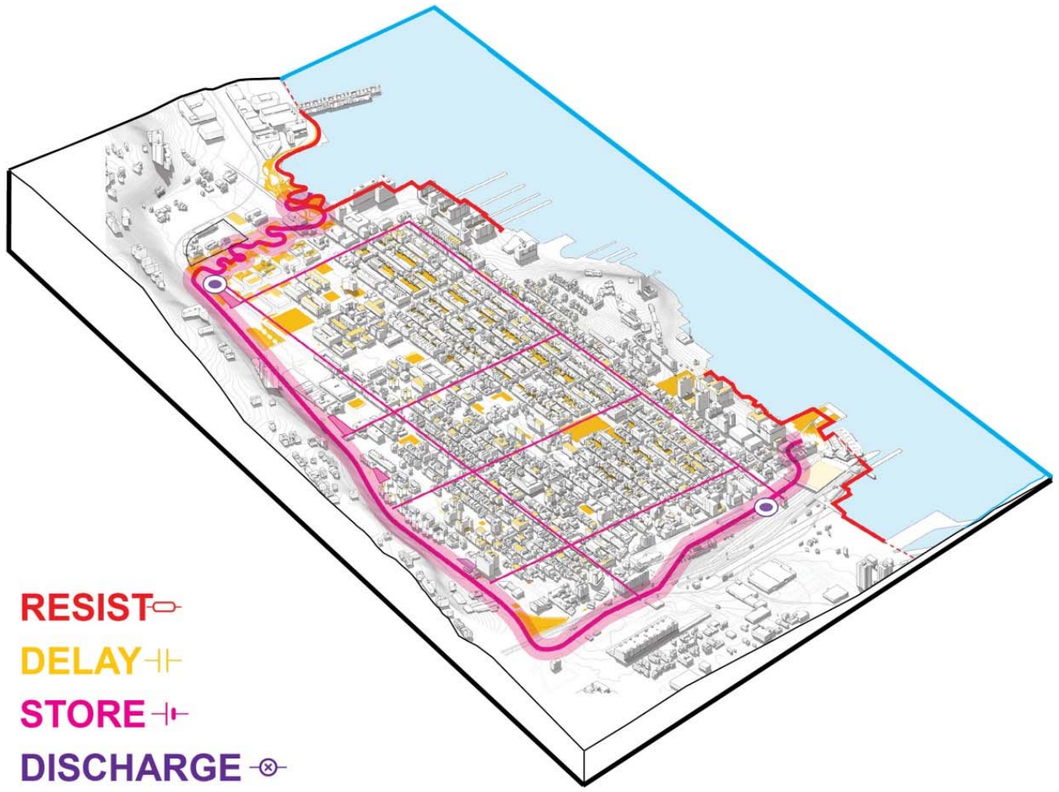


Figure 13,17. *Resist, Delay, Store, Discharge.* (OMA, 2014)



Figure 13,18. *Resist, Delay, Store, Discharge.* (By author)

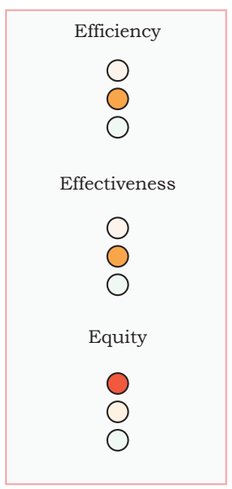


Figure 13,19. *Adaptation ranking.* (By author)

Resist, delay, store, discharge

As the title of this project by team OMA already suggests, it consists of four main components. The approach is tailor-made for the location of Hoboken, which is for 2/3 of its surface located in the FEMA floodzone (OMA, 2014). The resist part focuses on both hard infrastructure and soft landscape that serve as coastal defence against storm surges. Delay involves the possibilities to slow down rainwater runoff, while the store component aims at developing interconnected green infrastructure to store this water. Finally, the discharge factor concerns water pumps and other alternatives to drain the water (OMA, 2014).

As the project uses four layers, most interventions can be split up in smaller ones. Some interventions need the support of ones in different layers, but others, such as bioswales, bioretention basins and constructed wetlands start having a positive effect on their surrounding as soon as they are realised. This makes that the implementation time concerning (parts of) the project are more favorable than when it would concern one large scale intervention. That being said, the proposed interventions mostly focus on restructuring public space to combat flood risk, with the addition of adding green roofs on existing buildings. Little information is to be found about creating additional (affordable) housing. As the plan location is already densely urbanized, one could argue it to be a challenge to add additional housing stock. However, as they state, 7 acres of Hoboken land is planned for reclamation (OMA, 2014, p. 76). Within this reclaimed land the attention mostly goes towards decreasing flood risk by use of public space.

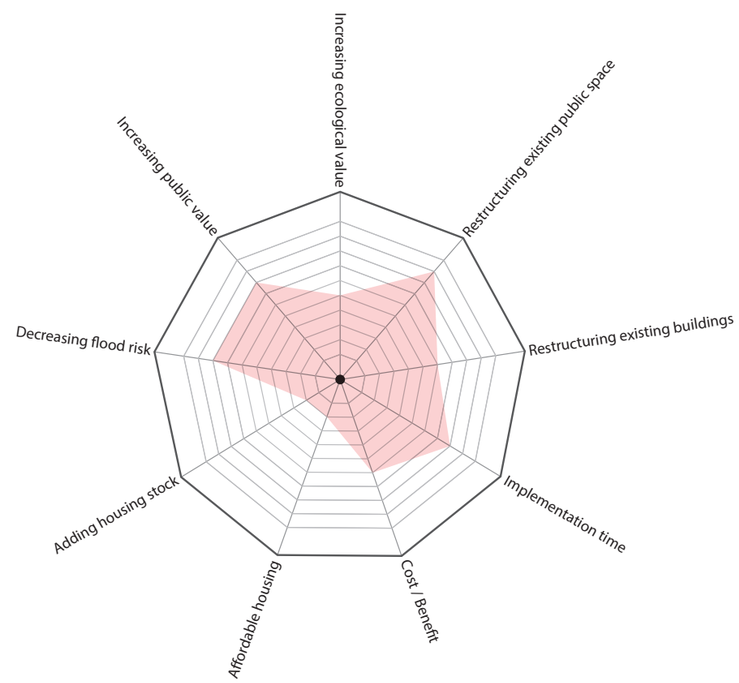


Figure 13,20. *Nonagon diagram Resist, Delay, Store, Discharge.* (By author)



Figure 13,21. *Hunts point lifelines.* (PennDesign/OLIN, 2014)



Figure 13,22. *Location Hunts point lifelines.* (By author)

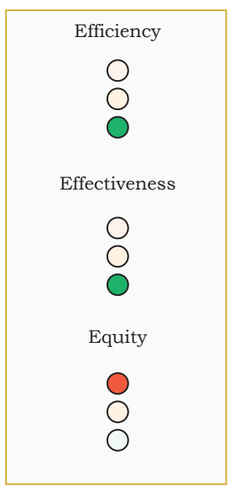


Figure 13,23. *Adaptation ranking.* (By author)

Hunts point lifelines

The Hunts point lifelines focuses on the south peninsula of the Bronx, an area of crucial importance for the whole region. Within the location, food distribution centers provide food for 22 million people living in the metropolitan area. The city of New York strongly recommended to grant Hunts point a high priority for flood risk protection (PennDesign/OLIN, 2014). The project proposes four lifelines. The first lifeline is an integrated flood protection system, designated to keep the regions food supply online during a disaster event. The second lifeline aims to increase the livelihoods by involving local communities to participate in climate adaptation and understanding it's risks and dynamics. Followed by the third lifeline: Cleanways. Cleanways is all about improving connectivity, sociability, air quality and safe passage for pedestrians (PennDesign/OLIN, 2014, p. 10). The final and fourth lifeline talks about Maritime Supply Chain. The project's research discovered that after major disaster events, maritime acces is usually operational the quickest, before road and subway access (PennDesign/OLIN, 2014). Its location allows for Hunts point to become a major distribution node to provide aid to surrounding regions.

As PennDesign and OLIN claim, the estimated time for completion of the interventions can be as early as 2020 (2014, p. 150). If these estimations are correct, the implementation time is one of the quickest of all reviewed projects so far. With a cost/ benefit ratio of 1,6 the efficiency scores rather well (PennDesign/OLIN, 2014). Also in the department of adding public- and ecological value, as well as decreasing flood risk, the interventions promise to do a solid job. However, since the Hunts point involves an industry dominated location, adding (affordable) housing stock hasn't been discussed. A case can be made that this project should not be evaluated on these criteria, simply because the possibility is unavailable. Local enterprises and the community are being strongly involved in the adaptation of the project, so in that sense the equity part has been well taken care of.

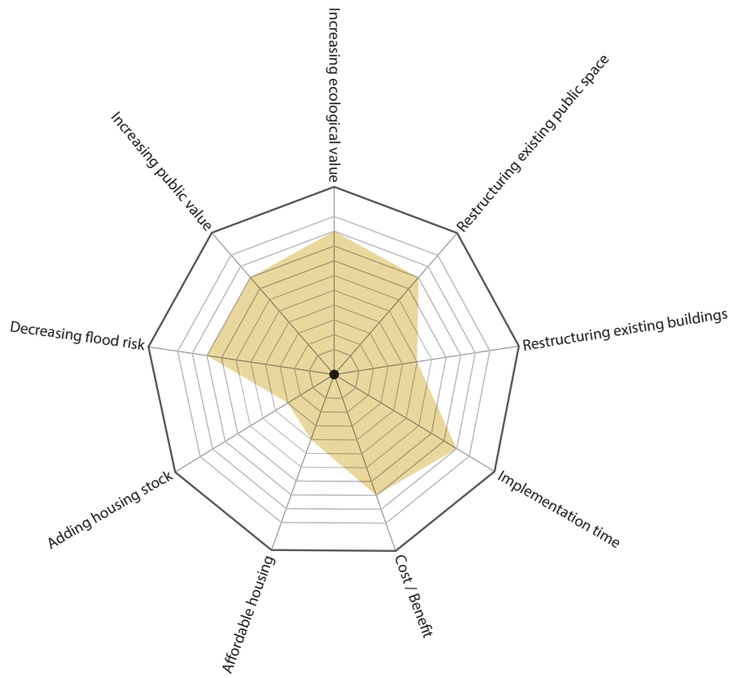


Figure 13,24. *Nonagon diagram Hunts point lifelines.* (By author)



Figure 13,25. *Resilience + the beach.* (Sasaki, Rutgers, ARUP, 2014)



Figure 13,26. *Location Resilience + the beach.* (By author)

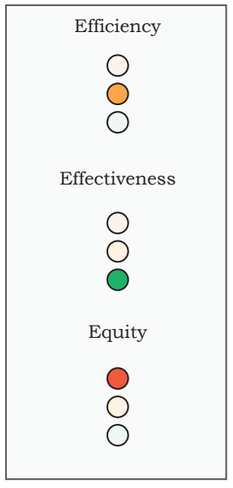


Figure 13,27. *Adaptation ranking.* (By author)

Resilience + the beach

The Resilience + the beach project focuses on 'understanding the characteristics and vulnerabilities of the coast, considering specifically the links between economy, ecology and culture along the beach' (Sasaki, Rutgers, ARUP, 2014, p. 8). The Jersey shore is the location of implementation of this project, which hosts a variety of coastline typologies. Different pilot projects are developed, focusing on the barrier islands, headlands and the inland bay.

All three of the pilot projects focus almost entirely on decreasing flood risk through ecological means. Although the public value benefits from this in a way, the real value is being added to the ecological situation. Adding and restructuring of existing buildings seems to be subordinate to the ecological targets, making the feel of the Resilience + the beach project rather one sided.

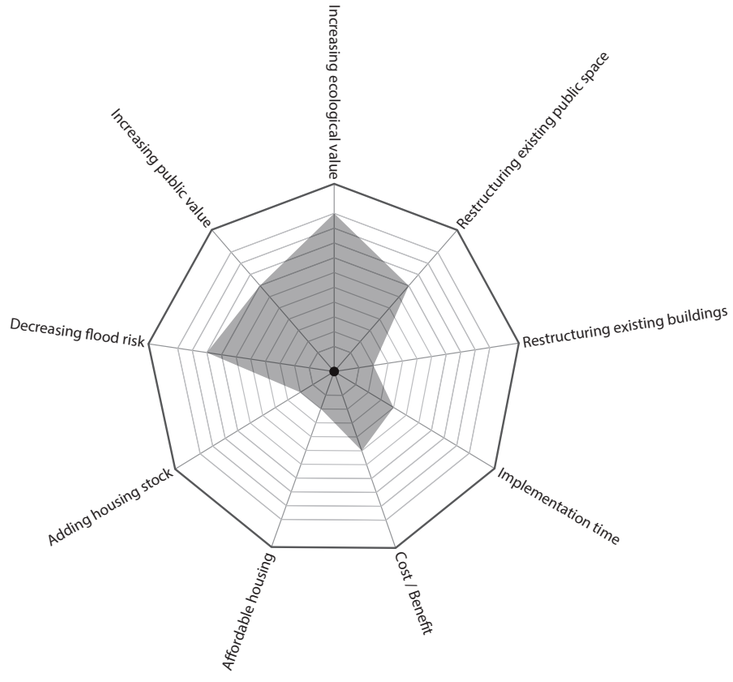


Figure 13,28. *Nonagon diagram Resilience + the beach.* (By author)

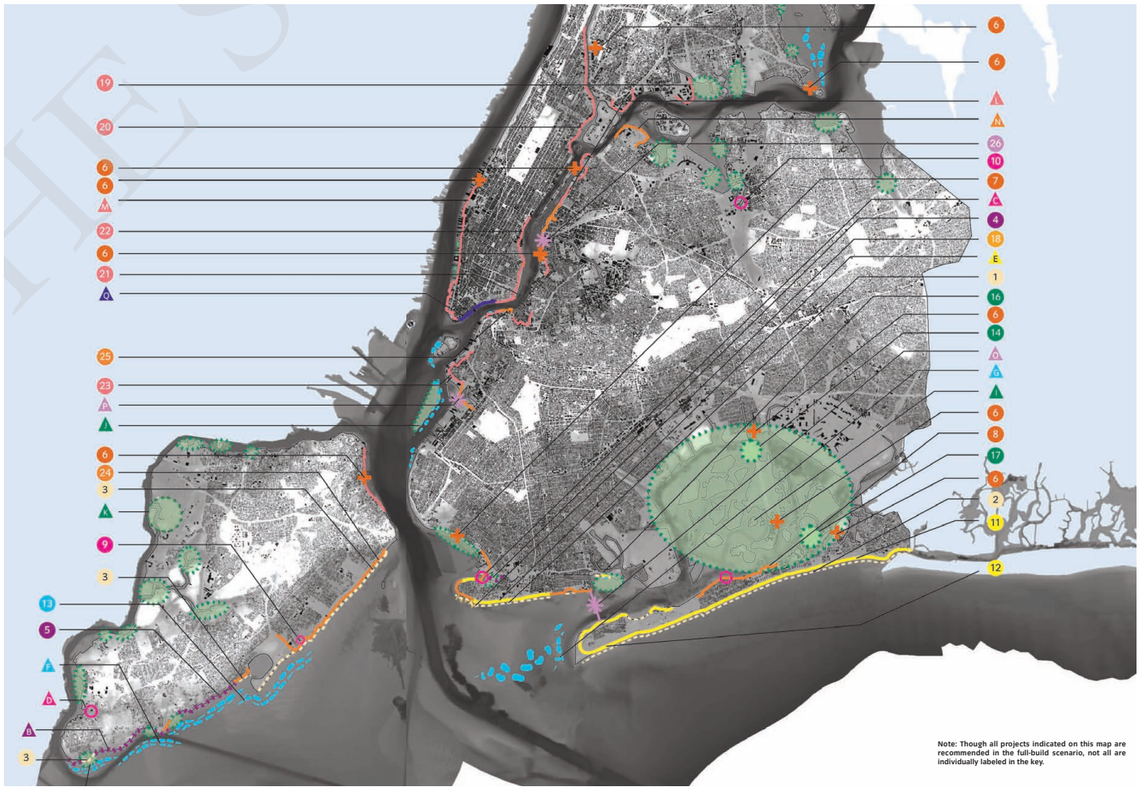


Figure 13,29. Living breakwaters. (Scape / Landscape Architecture PLLC, 2014)



Figure 13,30. *Location Living breakwaters.* (By author)

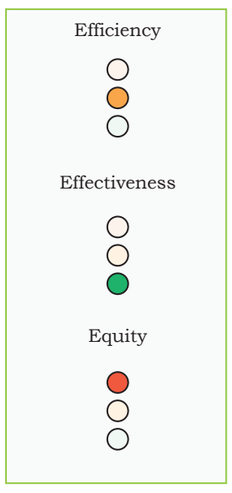


Figure 13,31. *Adaptation ranking.* (By author)

Living breakwaters

The Living Breakwaters project is committed to reducing flood risk, growing ecological resiliency and building social resiliency. It aims at achieving these goals for Staten Island and Raritan bay by using a combination of layered eco-infrastructural systems with social and educational networks. One of their approaches that makes for a unique project is the concept of creating breakwaters with natural habitats. More specifically, oyster reefs have proven to significantly reduce wave heights, calm water and prevent shoreline erosion. This approach is combined with several educational (floating) hubs, to teach people about the importance of the marine system and its protective role (Scape / Landscape Architecture PLLC, 2014).

The Living Breakwaters project does well in identifying the biggest threat for Staten Island regarding flood events, after which it effectively combats this threat with ecological systems. By involving the local community through educational hubs, it adds social value and improves the public space reasonably. The real win is to be found in the improvement of ecological value, where natural habitats are not only being restored, but new ones are created. The growing of oyster reefs can be started on short notice. However, before the effects of these reefs are noticable, the reefs have to be moderately grown. Therefore the implementation time is quicker than some other projects, but not the fastest. A favorable cost/benefit ratio can be achieved, because these natural defence systems for the coast need little to no maintenance. Oyster reefs are self expanding and grow along with the changing climate. When it comes to adding of (affordable) housing and restructuring existing buildings, little has been said. On this criteria the project scores significantly lower.

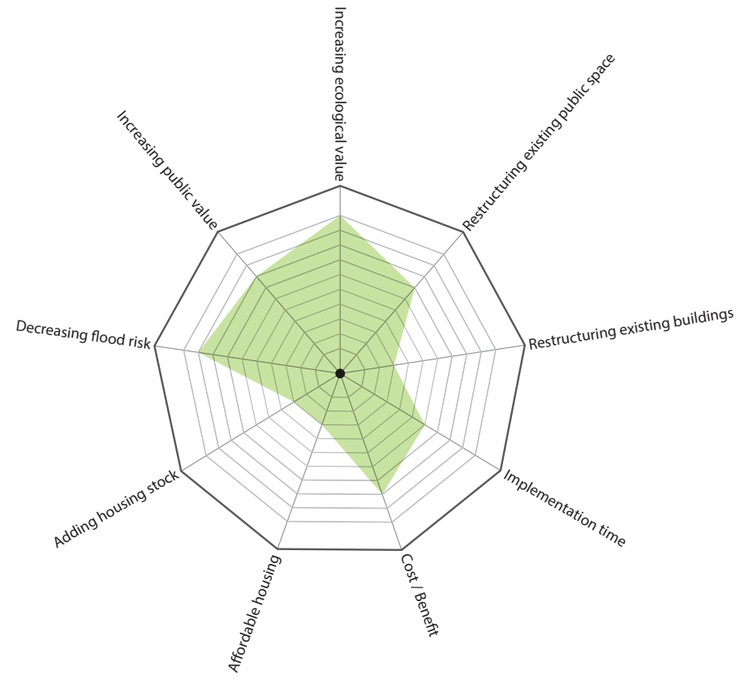


Figure 13,32. *Nonagon diagram Living breakwaters.* (By author)



Figure 13,33. *Resilient Bridgeport.* (WB unabridged, Yale ARCADIS, 2014)



Figure 13,34. *Location Resilient Bridgeport.* (By author)

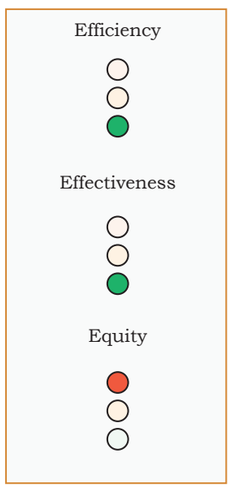


Figure 13,35. *Adaptation ranking.* (By author)

Resilient Bridgeport

The Resilient Bridgeport project by WB Unabridged and Yale ARCADIS consists of three basic principles. These principles are applicable to all interventions in the proposal.

The first principle of integration caters to multiple lines of defense that complement each other. 'Berms, floodwalls and surge gates provide critical surge protection and are complemented by offshore breakwater reef and wetland systems' (WB unabridged, Yale ARCADIS, 2014, p. 6). Also on building level interventions such as elevation of homes is being proposed.

Exchange is the second principle of the proposals. It describes the importance of unobstructed flows of materials and people along the coast region. Large scale walls and floodgates would hinder these exchanges. Therefore, a variegated edge will serve to provide the necessary protection while at the same time allowing, and even stimulating flows between land and water.

The final principle focuses on the identity of Bridgeport. By connecting the city to the water, it will restore aquatic conditions as a centrality in the identity of Bridgeport. Ecology and economic development will also be stimulated through these means.

The project scores rather well on a variety of the set criteria. Both public space and existing buildings will be restructured to see a great decrease in flood risk. Meanwhile, public and especially ecological value will be improved greatly. Also making use of soft, natural systems for creating breakwaters, contributes to a favorable cost/benefit ratio. The project however, does not pay attention to adding (affordable) housing, making this the weaker part on the evaluation scale.

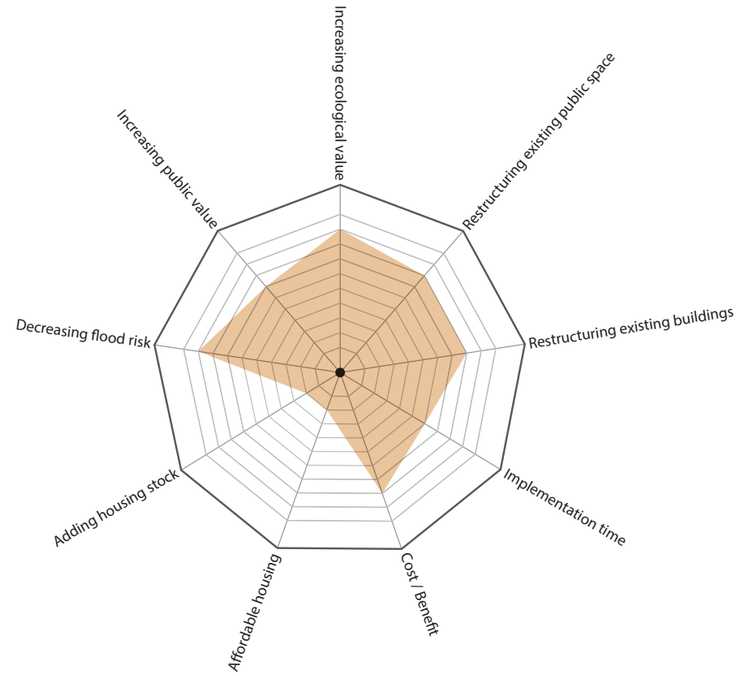


Figure 13,36. *Nonagon diagram Resilient Bridgeport.* (By author)



Figure 13,37. *The Blue Dunes.* (WXY/West 8, 2014)



Figure 13,38. *Location The Blue Dunes.* (By author)

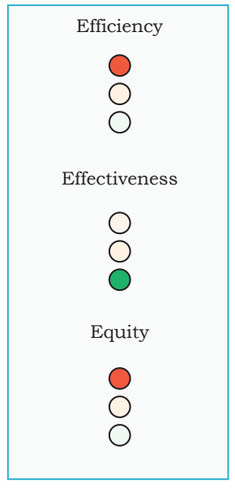


Figure 13,39. *Adaptation ranking.* (By author)

The Blue Dunes

The Blue Dunes project by Team WXY / West 8 is the largest scale project of all Rebuild By Design proposals. As can presented on the image on the left page, the intervention consists of creating offshore islands that will function as barrier islands, creating breakwaters. By means of this natural protection system, large lengths of coastline will be defended, that would otherwise need interventions stretched over more length to cover the whole bay. Although feasibility research is still ongoing, the potential for offshore protection measures seems promising (WXY/West 8, 2014).

The evaluation graph for The Blue Dunes project is one of the most characteristic ones. To start off with the negative points, the project does not discuss any interventions regarding housing or existing structures at all. This can be neglected regarding the fact it entails constructing islands 10 miles off the urbanized coast. For this reason, increased public value will not be experienced directly by inhabitants, although it is argued that The Blue Dunes allow for more modest flood defences on the waterfronts of urbanized areas. This could mean that dikes and other defensive infrastructure can remain lower and have less of a negative impact on the public space. Since creating the offshore islands is a huge intervention, implementation time will be quite long. A favorable cost/benefit ratio can still be achieved however, if one considers how much of urbanized coastline is actually benefitting from this large scale intervention. Therefore the project scores very well on reducing flood risk, while also strongly promoting the development of ecological habitats.

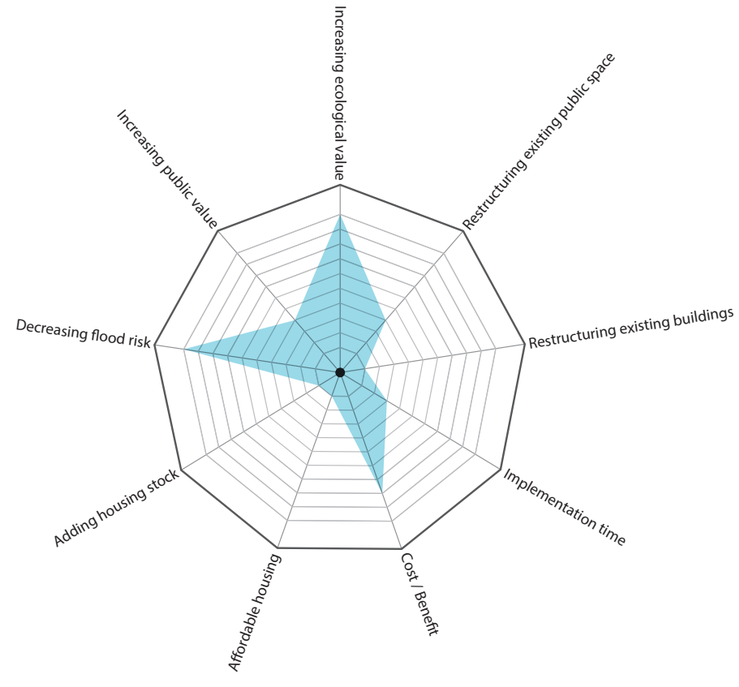


Figure 13,40. *Nonagon diagram The Blue Dunes.* (By author)

Interviews

Interview Edgar Westerhof

Disclaimer: the below interview is a summarized transcript taken from a conversation with Edgar Westerhof on January 18, 2018

As a Dutch person leading the Arcadis US Flood Risk & Resilence Program, what would you say are the biggest differences between the Dutch and American resilence planning practice?

'You can say that the Dutch planning practice is focused on prevention rather than recovery and response approach you find in the US. The Dutch have adopted a really well organized 'Pre-disaster planning system'. This means all measurements are being taken to prevent disasters from happening such as large scale flooding, through storm surge or extreme precipitation. On the other hand, the American approach to response and recovery has features of a military structure n terms of efficiency.

When it comes to flood risk prevention, organization and governance is key. Would you say the Americans could benefit from a nationwide structure like Rijkswaterstaat?

'Perhaps. The organization that is currently operating on nationwide level is the Army Corps of Engineers. But they have a more conventional approach to climate change challenges . I am referring to Henk Ovink's words to this: : 'You can't solve new problems with old solutions'.. I remember presenting the 'Blue Dunes' Rebuild by Design project at their offices explaining our far-reaching concept, and when the presentation was over, they just looked at us and asking: 'And now? Just let us know if you need something from us. .

Looking at the Rebuild by Design process , what happened in the transition period between the proposal planning and what has been accomplished so far?

'The key to success during Rebuild by Design process was the 'participatory planning' approach. All decision makers were invited at the table from day 1 and contributed to the plan that was being developed. This helped propel the acceptance and eased up the permitting process. As the national lead for Flood Risk and Resiliency here at Arcadis, helping to make sure internal and external processes are aligned which drives the outcome of our projects in a positive way. Thanks to our intense planning process with the local community the Big U project is happening and we plan to break ground as early as 2018. Some other projects, ones in Red Hook included, just haven't been able to find the answers for the complex local conditions.

Can the RBD projects be developed as ambitious as the initiators proposed, or do they have to settle for more modest solutions?

In some cases, definitely! The Big U again is one of these examples. Other awarded proposals like Resilient Bridgeport, initiated by David Waggonner is also moving to implementation

What was the role of visualization in Rebuild by Design has the planning process and project outcome changed?

Before Rebuild by Design, landscape architects wanted to sell you on their design. During Rebuild by Design, design was used to develop a level playing field, a baseline to which stakeholder and participants could reflect and add. Design was used to overcome various mindsets and perspectives on what an end-situation should look like. Design also helped bridge the gap between the planning process and actual design phases. Through various iterations of designs, and oversight provided by planners and engineers, pros and cons were taken into account, contributing to the quality and feasibility of the proposals. Studies that emerged through more conventional approaches were clearly lacking this shared commitment. Rebuild by Design has changed the way many involved in resilience planning and design develop and frame their projects, including city leadership.

Are more cities in the US following New York leading role in thinking urban and landscape development as an integrated strategy?

Indeed, many cities look at each other and look at New York. In the Bay Area a similar project to Rebuild by Design, called Resilient by Design is now running. And throughout the entire USA there was the National Disaster Resilience Competition, which is inspired by Rebuild by Design as well. 100 Resilient Cities, pioneered by the Rockefeller Foundation has gained global momentum, working with 100 cities world-wide to increase community resilience. In large these successes originate in an early adoption of a collaborative process.

Where will resilience in the US go from here?

Well, a lot of the infrastructure in the US is around 60/80 years old and has reached the end of its economic lifespan. Robert Moses in New York was a big name in the mid 20th century and while his approach would not be feasible these days, he got a lot done and New York, along with other cities, need to think about their aging assets. Rapid urbanization trends along with rising sea levels will put tremendous pressure on our exstng waterfront landscapes and the fast majority of our current waterfronts are past due repair. It is time for action!



Figure 13,41. *Edgar Westerhof.* Image from nareim.org



Figure 13,42. *Ray Hall indicating waterheight during hurricane Sandy.* (By Author)

Interview Ray Hall (54), 25-01-18

As this large warehouse is owned by private companies, what position do the owners take towards the increased flooding hazard?

Well I mean, there's really not that much you can do as private owner, perse. Let's say you put up a wall. The tenants, they love it down here, we love it down here, it's all about the view you know? You start putting up walls, you take the view away and people probably won't be here. But there are some other areas where they put up these gates, and they look ugly. Hurricane Sandy, that was crazy, we had like 6 and a half foot of water throughout the entire neighbourhood, that shit was crazy.



Figure 13,43. *Waterfront warehouses.* (By Author)

Do they take measurements to combat this increased risks, and what are their responsibilities?

So, the only thing we do as owners when we know it's coming, we hand out sandbags. Give people sandbags. Build walls about 4 feet high, in front of all the doors, we shut the elevators off. In this building right here, we have 14 transformers, which convert 480 power down to 277, and these all got destroyed because they were on the ground. What we did, we raised them all up by 10 feet off the ground. Just in case it happens again, we won't loose power for months again. We raised the concrete up here another 8 inches or whatever it is. A couple of weeks ago we had a full moon here, and the water was over the rocks! You know you got a little wake coming in, you got some water on the street.

Warn the tenants, so people can put their stuff up you know. There are people on the 3rd floors, talking to neighbours on the 2nd and ground floors, yo listen, is it okay if we bring your stuff up here? People are really coorperative in these situations. We also put in different doors, used to have wooden doors, now we have aluminium doors, and now the doors open outwards, instead of pushing in, preventing the water from coming in. The community is really strong, the help from everybody was overwhelming. People who had never spoken to eachother, but in times of crisis everybody came out to help eachother.

Fairway market put up these special gates now, and column that come up about 7 feet high when it's needed to. They also got whiped out, food refridgerators, everything got destroyed then. IKEA lost a few elevators, their parking lot got flooded, but nothing much. They put up their floors and were better prepared.

For how long have you been living in Red Hook?

I moved out from Red Hook 20 years ago, but I've been here all my life. My job is here, I run a non profit here, my whole life I've been in Red Hook man, I just go somewhere else to sleep. Right now I live in crown heights, but my mom lives right here in the projects, the Red Hook houses. So I took her home with me for two weeks during Sandy. I kept working in Red Hook though, also during Sandy. That was something, complete darkness because there was no power, and then a snowstorm man, there was snow everywhere. Unbarable conditions, dark, snow, slush everywhere. The people that stayed here just had nowhere to go. And the people that had some other place to stay left.

What is your experience of hurricane Sandy?

*The water came in so fast, and in a matter of 7 or 8 hours, it was gone again. The water was gone. Yeah cause it came in that monday, and by that evening it was gone. But there was dirt and feces everywhere. The water threatment facility lost power, and opened up the dam, so all that shit got on the street. They said it's designed to do that, who the **** designs it*

to do that?! That was everywhere. Thats why this place is also still heavily contaminated. Not just because of heavy industry, but also that shit.

It was crazy man, i got videos from before the camera systems went down. The stairwells, water is like over the steps. I sent so much photo's to the daily news. I took the DVR's out before they got destroyed, backed them up, because I knew I was gonna make money with that man. I can send some to you. I got unique images that no one else has. It looked like a third world country here man, people outside everywhere. When the sun came out and the snow started melting you saw people everywhere man. But they didn't have haircuts, didn't wash, that was going on down here. It wasn't a good sight, even for someone like me, to see people like that.

Did you experience severe damage or losses during this event?

The salt water was the worst you know. It would probably still been bad if it was just fresh water, but not as bad as with salt water. Because that's the thing, when salt water hits something you have to immediately put fresh water on it. Just like these boats when they come in, you have to hose it down with fresh water. The salt will eat away at anything. If I open the hood of my car, all the nuts and bolts are rusted up. It's beautiful here, but dangerous. It's a price for beauty. And I don't know what more they can do.

That sunday when the wind started kicking up, that's when I took my mom home with me. It was too much man, in that evening it was crazy. The watertaxi here got new owners now, but they lost almost everything. They lost a lot of boats cause they were hanging on the ropes you know. Water came in, lifted them up.

Do you know about ongoing projects/initiatives that help to reduce the flood risk in Red Hook?

In Red Hook, on Columbia street. They had this ugly ass design to go straight down the street with these big dirt mountains and grass hills and shit, it was the ugliest shit i've ever seen. And that was just to stop the water from going beyond Columbia street, but what about back here? What are you gonna do? There are a few other projects I believe, but it's like right now, everybody is so back to their everyday regular routine. 'That was one in a million, that's not gonna happen again, bla bla bla'. But, there's a few groups out there, Red Hook recovery, they are the ones that got a lot of money to help people recover their houses. Some people got money, but a lot of people didn't. A lot of businesses got screwed, people were really hurting. My boss was cool, he gave people like 3/4 months no rent to pay, because it took us like 6 months to get power. Cause everybody needed the same electrical equipment. Who got the most money and contacts, got the transformers sooner than later. That was something.

Like i said, we gotta do something man. The projects right now, they have these portable boilers on the outside, because all the original ones got detroyed by Sandy. You see they got these little storm surge cannisters out there? So I said okay, I'm trying to figure out the logic of em. You got them this way, but you skip this gate opening right here, and you skip IKEA openings, so I don't understand what their purpose is. Waters just gonna come through the gates! Are they gonna come and move em over when the waters gonna come up? I don't know, cause what good are they doing up against the wall over here? I'm hoping that when they get a warning, they come with forklifts, and place them in openings. I'm thinking that's what they probably supposed to do. I have called the community board and the police department, and asked them. So they said yeah they are for the storm surge, if we get like a 3 feet surge, these things are like 4 feet, so okay we got a foot to play with. What's gonna happen if we get a 6/7 feet surge? These things are there for nothing! It's gonna come right over that wall, like with Sandy.

How is the community being involved in these projects?

You gotta assess the damage you know. The census will tell you we got like 20 thousand, 25 thousand people living here? It's more like 50 thousand, a 100 thousand people in these projects. Bruh listen, it's bad. Census is only gonna count for what the lease states. If you are the only one of the lease, they only count you for one. They don't know about your brother who got nowhere to go, or your sister who got kids and got nowhere to live. Thats why funding during that time was really bad, and underestimated. There were 4 times the amount of people the census had on it, so help was not enough.



Figure 13,44. *The questionable storm surge cannisters.* (By Author)



Figure 13,45. *Pump on Van Brunt street.* (By Author)

If Red Hook would be restructured to make it more safe regarding flood risk, what changes would you like to see?

Well, everybody on Van Brunt street got affected. They probably would like to share their story with you, and also tell you what changes they would like to see. I know a lot of people talked about getting solar power up for the projects. At least to get them back on their feet faster than the last time this happened. Try to get response quicker. A lot of people thought about resiliency and other things. But is there a real long term plan now? Real evacuation plans, like where they say, okay this is happening, boom. Is there something on standby, bottles of water, non-perishable foods, something to keep in the closet. Is anybody replacing these things? That would help a lot.

I just hope it won't happen again, because I think some would not survive it. You know it took a lot out of people, I mean, mentally, spiritually. Some people I know would probably just walk away if it happens again. Like I said, i've been in Red Hook all my life, so I came down to the waterfront as a toddler, and I see these waterlevels is rising. The sea level is rising, I see it. I've been working on this pier for 25 years, and I've been on these piers for more than 40 years, and seeing these waters.....it's serious man, it's serious. Couple of weeks ago, we had like the lowest, low tide ever. You could see 30 feet, 20 feet down. That was crazy, a guy showed me a picture, I couldn't believe it. You could see, there's a couple of cars down there, right there, a suburban right there, another van over there. But these moon influences happen on the regular. A large moon with high tide can cause a foot of water down Van Brunt street. Is there even a plan to stop that? If you can't even stop a foot of water, how are you gonna stop 6 feet of water?

And the sewer lines down here, are so old and dilapidated there aren't designed to have all this new construction. All these new buildings built up on Van Brunt streets, like 25, 30 buildings, all tied up into that same sewer line. That alone, if everybody flushing their toilet, cooking dinner or washing at the same time, will have that shit over capacity. So this sewer, the Gowanus one, and one more all come here to the corner, before going to the threatment plant. Right here were the cage is placed with the pump. We had to put a pump there because without it, that whole corner would be flooded.

The water just sits there. Peoples cars were destroyed in that man. Water gets right in the tailpipe, sits there, that's it. Lot's of people lost their car there, im telling you.

We need something that keeps this water out plus preserving what people love about this place. That means none of these big walls or ugly dirt mountains to stop the water halfway back there you know? Water needs to be kept out from this area all together, where people on the very edge are protected.



Figure 13,47. *View from one of the waterfront warehouses.* (By Author)



Figure 13,46. *Sandy waterheight indicated in bark of the tree, and placed storm surge walls.* (By Author)



Figure 13,48. *Oil spills in surge water leaving its mark on the wall.* (By Author)

Russell (72), 24-01-18

For how long have you been living in Red Hook?

Ah, must've been a while man. Came here beginning of the '70's.

Have you experienced flooding events since you live here?

Oh yeah, more than I wish to remember. Whenever we have strong rain and the pump fails or can't keep up we have water in the streets. In last years Irene and Sandy storms gave us the most shit.

Did you experience severe damage or losses during this event?

Here in the Red Hook houses was about as far as the water came you know. I live on the ground floor now so there was some water coming inside but didn't destroy much in my house. We did lose power for weeks though, it was always dark here in that time. Took em so long to get that back up running man.

Do you know about ongoing projects/initiatives that help to reduce the flood risk in Red Hook?

No I haven't heard anything about that in a long time. Right after Sandy there were some things going on left and right, but after that....nothing man.

How is the community being involved in these projects?

I see those farms you know? The ones where people can grow some healthy stuff. Oh for the water problem I don't know.

If Red Hook would be restructured to make it more safe regarding flood risk, what changes would you like to see?

It takes some time for me to get my ass across to the supermarket you know. But the walks here are nice. When I get groceries at Fairway I sit on the benches at the water if weather's nice. See the statue and look at some boats, I like that. There are nice warehouses over there and that old tram.

Are you satisfied with the amount of qualitative public space in Red Hook?

There are nice parks. Sometimes sidewalk is pretty dangerous and I gotta watch my step. Reason I have this thing *points at Rollator**. *I have been living here for years and like the water most here. Sometimes that's far but worth a little trip. Also the old warehouses are really beautiful and show the roots of this place.*

(If no) How and where could this be improved?

I don't know man, I guess you could make something nice for kids to play ball again. There are big fields but are all out of order for some cleanup shit, don't know.

What do you think about nature reintroduction in American cities?

Yeah I like that. Sitting and walking there is nice you know. The city has to much cars and rush going on. It's always quick here, quick there. When you have my age you learn to relax man, it's all good.



Figure 13,49. *Russell walking through his neighbourhood feeding squirrels.* (By Author)

Ting (51), 24-01-18

For how long have you been living in Red Hook?

20 years

Have you experienced flooding events since you live here?

Oh yes, hurricane Sandy was the worst

Did you experience severe damage or losses during this event?

No, fortunately not. Because I live near the tunnel entrance of the Hugh L Carey tunnel, most of the water went in there. That's how my house was saved.

Do you know about ongoing projects/initiatives that help to reduce the flood risk in Red Hook?

You know, I've been hearing about stuff, but I don't think anything is really going on.The flooding is bad here you know? I see it a lot. Every time it rains, there streets get flooded, it's just really bad.

How is the community being involved in these projects?

You know what, i'm not sure. I'm sure there are meetings going on but not that I know of. You know I see stuff on the papers.....but you know they are still building stuff on the water, so someone is in denial about whats going on. Listen, for me, I think this area, within 10 years it's gonna be flooded over here.

If Red Hook would be restructured to make it more safe regarding flood risk, what changes would you like to see?

I mean, i don't know enough about such things. I can imagine though, this is such a low lying area and there's no stability under it...it's all porous and stuff. I mean I know they talk about walls, but we have seen that water just comes over it.

Are you satisfied with the amount of qualitative public space in Red Hook?

The park is great for walking the dogs, it's really nice. I like the waterfront behind IKEA and Fairway too, they have some benches there with a good view.

(If no) How and where could this be improved?

You know, Red Hook is weird because it's a mix. You got the projects right? And then all the new housing which has gone up. They just built on Van Brunt street, they built some new townhouses, and one of them is just on the level again, it's just....people are in denial....
After a couple of years they forget about it.

What do you think about nature reintroduction in American cities?

Like trees and stuff? I mean I think that's great but like I said, I don't believe they're doing it because I only see them keep building on the waterfront. I don't know whats going on over here exactly, but IKEA was the only one smart enough to built 1 floor up, elevate their building.



Figure 13,50. *Ting working in one of the garages in Red Hook.* (By Author)

Thomas (29), 24-01-18

For how long have you been living in Red Hook?

I don't live here, but have been working in Red Hook for 5 years.

Have you experienced flooding events since you live here?

I started just after 2012's hurricane Sandy, so I wasn't here to experience it

Did you experience severe damage or losses during this event?

Personally no, but I work in that building over there (waterfront warehouse), and during the storm the whole first floor was flooded and messed up the power.

Do you know about ongoing projects/initiatives that help to reduce the flood risk in Red Hook?

I only see these impromptu walls they put down here. But I don't really understand what this thing is. Like I said I work in this warehouse, so I'm not sure having these things here would help. Our property is just between this wall and the water.

If Red Hook would be restructured to make it more safe regarding flood risk, what changes would you like to see?

Well like I said, my workplace got hit pretty hard last time. It would be great if something be developed that protects everything on the waterfront.

Are you satisfied with the amount of qualitative public space in Red Hook?

I just came from Valentino park where the dogs can walk around without the leash. That's a very nice place. And the park on the other side of IKEA is alright, right here there isn't much, but i'm not sure what they could do about that.



Figure 13,51. *Thomas walking his dogs during lunchbreak from working in the waterfront warehouse.* (By Author)



Figure 13,52. *Louis Valentino Jr. Park.* (By Author)

Stop 1 supermarket, 01-02-18

Did you experience any damages in your store as a result of hurricane Sandy?

Yes, the whole basement was flooded. We lost all transformers and refridgerators

What position do you take towards the increased flooding hazards, and what actions have you taken to combat this increased risk?

I got a better flood insurance now. Also we raised some compressors from the ground. But the water was like this high (points at 1,5 meters). So if that happens again we would still lose our equipment.

Are there any public-private partnerships to stimulate the development of flood sensitive areas, or are you being involved in larger restructuring plans?

No, not anything going on.



Figure 13,53. *Stop 1 supermarket.* (By Author)

Nates Pharmacy, 01-02-18

Did you experience any damages in your store as a result of hurricane Sandy?

Yes, absolutely! Basically the entire basement was flooded. Lots of critical equipment in there you know, boilers and things like that.

What position do you take towards the increased flooding hazards, and what actions have you taken to combat this increased risk?

Well there's only so much you can prepare for, you can't stop the water from coming in. In a technical sense, we now have some off-site file storage where our files are backed up.

Are there any public-private partnerships to stimulate the development of flood sensitive areas, or are you being involved in larger restructuring plans?

I don't know honestly, I don't know if they've done anything to the neighbourhood or the area.



Figure 13,54. *Nates pharmacy.* (By Author)

Kempton & Co, 01-02-18

Did you experience any damages in your store as a result of hurricane Sandy?

Not too many, luckily we don't house as much expensive electrical equipment. And we are a bit higher up, as you can see on the sidewalk.

What position do you take towards the increased flooding hazards, and what actions have you taken to combat this increased risk? ?

We put all of our bag stock in plastic, so in case it gets flooded the bags aren't ruined.

Are there any public-private partnerships to stimulate the development of flood sensitive areas, or are you being involved in larger restructuring plans?

Oh hmm no wouldn't be able to recall any.

Foxy & Winston, 01-02-18

Did you experience any damages in your store as a result of hurricane Sandy?

We were quite okay, since we are higher compared to other companies on this street. There was water in the basement, but nothing too serious. There was nothing too important in there anyways.

What position do you take towards the increased flooding hazards, and what actions have you taken to combat this increased risk?

Honestly we haven't changed much. Since we didn't experience that much damage we didn't feel the need to invest in flood proofing measurements.

Are there any public-private partnerships to stimulate the development of flood sensitive areas, or are you being involved in larger restructuring plans?

It's still kind of a quiet area. If you compare it to DUMBO for example, that's really busy. They had a lot of restructuring. Here I haven't heard of any projects.





Figure 13,55. *Kempton & Co + Business card.* (By Author)





Figure 13,56. *Foxy & Winston + Business card.* (By Author)

Dry Dock wine + spirits, 01-02-18

Did you experience any damages in your store as a result of hurricane Sandy?

Not extensively. The bottles don't mind to get wet and since most of our wines and spirits are sold at room temperature we don't have much electrical equipment. We did lose power for a long time, like the rest of the street. Also the salt water in the basement affected some wooden chests.

What position do you take towards the increased flooding hazards, and what actions have you taken to combat this increased risk?

After Sandy we elevated our porch and placed an aluminium door. Before the door used to open in, now it opens out. Other than that I make sure the papers for my insurance are always in order.

Are there any public-private partnerships to stimulate the development of flood sensitive areas, or are you being involved in larger restructuring plans?

I don't believe there are any, at least not that we know of.

Hometown Bar B Que, 01-02-18

Did you experience any damages in your store as a result of hurricane Sandy?

We were actually still building the restaurant when Sandy struck.We opened after Sandy, but during the construction there was water all over the site. I'd like to know what these deployed walls are for though, I don't understand them. My only thought is, that if there is a flood they'll bring more, to close off to the wall. They are filled with sand so they should soak up and stop water.

What position do you take towards the increased flooding hazards, and what actions have you taken to combat this increased risk?

We have placed nothing of importance in the basement, everything is up.

Are there any public-private partnerships to stimulate the development of flood sensitive areas, or are you being involved in larger restructuring plans?

Not public private, but there is a guy who has plans to landfill an existing elevation in the water, just behind fairway. Creating a breakwater island of some sort. Other than that there's this pump which kicks in when we get to a critical level. This corner here is about the lowest elevated point in the area.



Figure 13,57. *Dry Dock wine + spirits.* (By Author)





Figure 13,58. *Hometown Bar B Que + Business card.* (By Author)

How to assess flood risk in urbanized coastal areas?

A critical review on existing flood risk assessment theory

AR3U022 Theory of Urbanism
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Abstract - Recent severe weather events have emphasized the vulnerable locations of a multitude of delta and coastal cities around the world. Ongoing trends regarding climate change and increased urbanization only put more pressure on these regions. This paper reviews theory regarding the two sub-questions: 'What are the consequences of different types of flooding in urbanized coastal areas?' and 'What theories exist for assessing flood risk in urbanized coastal areas?' It was found that coastal cities can experience four types or flooding, which can potentially occur at the same time. These are: tidal-, coastal-, fluvial- and pluvial flooding. Each type of flooding has its own characteristics and impact on the urbanized area. Whereas tidal- and fluvial flooding can usually be accurately predicted, coastal flooding involves multiple variables and is therefore more unpredictable. The theories for assessing flood risk mostly agree on the notion that flood risk is a product of hazard * exposure * vulnerability. More specific theories add the concept of response in this equation. Still, despite the fact of being able to determine the adding factors to flood risk, no rational comparison can be made using the existing theories. The lack of specific numbers keeps the assessment rather indefinite. Further research has to point out if flood risk assessment would benefit from linking evaluation scales to all components involved, as to come up with rational numbers for assessing flood risk.

Key words: Flood risk, urbanized coastal areas, risk assessment, flood characteristics, hazard, exposure, vulnerability, response, evaluation

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Introduction

Low-lying coastal areas are amongst the most vulnerable locations to climate related events. Despite the fact that only 2% of the worlds surface can be counted as low-lying coastal area, they accomodate roughly 13% of the entire worlds population (UN-Habitat, 2016). Global patterns of urbanization have been studied by the United Nations. Growth of urbanized areas from 1995 (left) to 2015 (right) has been mapped (see figure 1,1). It stands out that most of the red dots, representing megacities of over 10 million inhabitants, are located near coastlines. In line with this information, it appears that in urbanized coastal areas cities with the highest densities can be found. With an average of 80 persons per square kilometer, coastal cities accomodate a density which is twice the average amount found in the rest of the world (Population Reference Bureau 2017). To conclude illustrating the presence of coastal cities, currently 14 of the worlds 17 largest cities are situated in direct vicinity of coasts (Population Reference Bureau 2017).

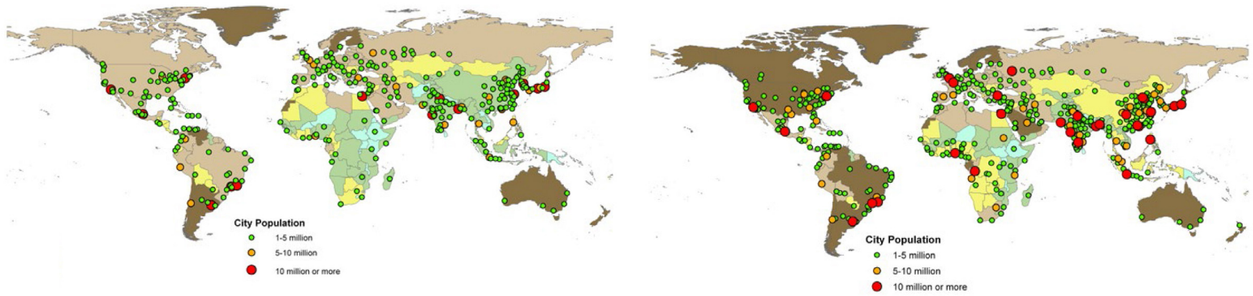


Figure 1,1. *Global patterns of Urbanization.* (UN-Habitat, 2016)

The broad definition of resilience

Facing climate change and an increased frequency of severe weather events, coastal cities understand the need to adapt and protect themselves from such events. Several studies have been conducted on how to make coastal cities more 'flood resilient' (Aerts, Botzen, de Moel, Bowman, 2013., van Veelen, 2016). Resiliency however, is a very broad term that can be interpreted in a multitude of ways. As van Veelen explains resiliency in his work *Adaptive planning for resilient coastal waterfronts* (2016, p. 43): 'The resilience domain is closely related to the concept of vulnerability and is based on (1) the capacity to cope with small disturbances within the systems natural variation and (2) the capacity to recover from extreme situations and return to equilibrium after a certain period of time'. De Bruijn (2004) agrees with van Veelen by saying resiliency indicates the amount of change a system can undergo, while still remaining its critical functions. In my eyes, both theories explain resiliency as a capacity within which a system can bounce back to its original state, or 'equilibrium'. There are however, conflicting theories to this notion of resilience. Wardekker, de Jong, Knoop and van der Sluis (2010) define resilience as the degree to which a system is able to evolve and reorganize itself, in order to absorb external influences. This would mean that the system itself is adaptive, and can continuously change its form or appearance to accomodate changing circumstances.

CONCEPT	CONTEXT	CAPACITY	MEASURE
Engineered resilience	Return to equilibrium (single equilibrium)	Buffering capacity	Resistance/robustness rate
Ecological resilience	Stability within a particular domain	Recovery capacity	Recovery rate
Socio-ecological resilience	Cross-scale dynamic interactions	Adaptive and Transformative capacity	Self-organize and learn and development of desirable trajectories

Figure 1,2. *Concepts of Resilience.* (van Veelen, 2016)

Van Veelen (2016, p. 43) confirms these different notions of resilience by distinguishing three main types of perspective on resilience: The engineered perspective, the ecological perspective and the socio-ecological perspective. These are visualized in figure 1,2 (van Veelen, 2016, p. 49). Each perspective on resiliency has their own distinctive characteristics and measures. The different notions of resilience discussed in the paragraph above combined with smaller subgroups of perspectives makes the term resilience very broad. For this reason, when talking about 'flood resiliency' it is hard to create a clear definition how the word 'resiliency' should be interpreted in the specific context. Therefore, in this paper the concious decision has been made not to address 'flood resiliency', but rather 'flood risk'.

To answer the main research question 'How to assess flood risk in urbanized coastal areas?', a critical review of existing theory will be made. Two sub-questions will be answered: 'What are the consequences of different types of flooding in urbanized coastal areas?' will provide insight in the different kinds of flooding that pose a threat for coastal cities and their characteristics, while the second sub-question 'What theories exist for assessing flood risk in urbanized coastal areas?' will shed light on different notions for calculating and assessing flood risk in specific areas.

Types of flood risk in urbanized coastal areas

Cities located in delta areas are particularly sensitive to flooding. They deal with different types of flooding threats, which can occur at the same time (van Veelen, 2016). To start understanding the risks of flooding that coastal cities face, the four respective types of flooding and their characteristics will be discussed, as well as what approaches are used to study them.

Tidal flooding

Flooding that occurs because of temporal astronomical sea level rise is called tidal flooding (Marfai et al., 2007., van Veelen, 2016). This type of flooding is a recurrent event that coincides with the high tide. Because of this, the duration of the flood event is usually relatively short. Water will flow back to the river or sea when the high tide is over. Since tidal flooding is a recurrent event that is relatively easy to predict, high-resolution impact assessments can be made (Gallien, Schubert, & Sanders, 2011). Aerial laser technology is currently capable of making a digital elevation model (DEM) with a vertical accuracy of 10-15 cm (Sanders, 2007., Gallegos et al., 2009., Gesch, 2009., Colby & Dobson, 2010. in Gallien, Schubert, & Sanders, 2011). Through these models, the social and economic impact of tidal flooding can be mapped. The actual assessment of floodrisk will be discussed later in greater detail.

Coastal flooding

Not as frequent and less predictable is coastal flooding. This kind of flooding takes place when water is being driven up the land by stormwinds (van Veelen, 2016). Often this takes place in combination with astronomical high tides, increasing the rise in water level. Other variables that contribute to water level rise with this type of flooding are strong winds and high-energy waves (Bowman et al., 2005). The duration of the flooding is mostly dependant on the duration of the storm event, but also on the geological situation of the land. When storm surge driven water hits a concave (bended inward) coastline, the funneling effect is stronger than when it hits a convex (bended outward) coast (National Hurricane Center, 2010). As a result, coastlines with concave conditions or narrow bays will see a more dramatic local water level rise. Because coastal flooding happens infrequently and is a product of numerous variables, the consequences can not be mapped as accurately as with tidal flooding (Gallien, Schubert, & Sanders, 2011). Instead, areas sensitive to coastal flooding are often categorized as a specific flood zone (Aerts et al., 2013., van Veelen, 2016). These zones indicate the probability of a flooding event by naming the average occurance period. Common values for categorizing floodzones as done by the Federal Emergency Management Agency (FEMA), are 1/100 or 1/500 years (Aerts et al., 2013., van Veelen, 2016). The unpredictability of coastal flooding can be illustrated by looking at

an example from 2012's hurricane Sandy. Although initially heading back towards the Atlantic ocean, the storm made a hard 90-degree turn towards the continent, giving limited preparation time (National Hurricane Center, 2017., NY Daily News, 2017). The path sandy took has been visualized in figure 1,3.

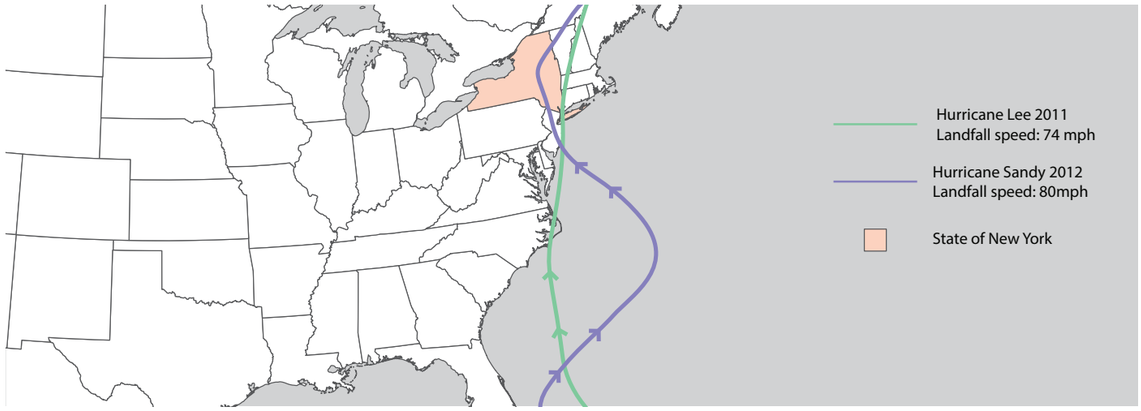


Figure 1,3. *Hurricane Lee and Sandy paths.* (By author, based on NHC, 2017)

Fluvial flooding

Only relevant for cities located near a riversystem, is fluvial flooding. Extreme rainfall in the catchment area of the river results in increased water discharge. When this discharge exceeds the maximum capacity the river channel can handle, fluvial flooding takes place (Cluckie & Han, 2000., van Veelen, 2016). Because this concerns large armounts of water being transported with high velocity, these types of flooding see a deep and rapidly rising water level. The force of these floodings often result in damage to structures or even casualties (van Veelen, 2016). Despite the fact this type of flooding can be regarded as the most aggressive, it is also the one that can be forecasted in advance. Rainfall in the upstream area of the river can be monitored and discharge of the river can be measured before the water reaches the critical weakest points of the river (Cluckie & Han, 2000). Particularly problematic, is the situation when fluvial flooding occurs in combination with coastal and tidal flooding (van Veelen, 2016). In this case, excessive water from the riversystem meets the raised water level in the debouchment area of the river. This combination of events could cause failure in flood defence systems. Flooding that occurs because of fluvial, coastal and tidal flooding combined characterizes itself by a strong water force, a deep level of inundation and a short time for preparation (van Veelen, 2016).

Pluvial flooding

The final type of flooding urbanized coastal areas can experience is pluvial flooding. Pluvial flooding is the result of excessive stormwater accumulating in low areas (Falconer et al., 2009., Maksimović et al., 2009., van Veelen, 2016). Water can accumulate in areas that are relatively low-lying compared to their surrounding geology, meaning flooding can occur in areas which are elevated well above mean sea level (van Veelen, 2016). Since hurricanes often occur in combination with heavy rainfall storms, this poses an additional threat for low-lying coastal areas (Bowman et al., 2005). Areas that rely on gravity to discharge storm water to riversystems or the ocean, can find themselves in a situation where discharge is being blocked by increased water levels because of tidal, coastal and fluvial influences. This type of flooding will cause additional damage to buildings, but also to infrastructure that is insufficiently protected (van Veelen, 2016). Entrances to subway systems outside of coastal flood zones are an example of infrastructure which can be insufficiently protected, because flooding in these areas hasn't been taken into account. Especially in urbanized areas with a lot of unpermeable surface local storm water runoff can cause severe problems. By using an aforementioned Digital Elevation Model (DEM) areas that are most sensitive for pluvial flooding can be accurately identified (Maksimović et al., 2009).

As the paragraphs above illustrate, low-lying urbanized coastal areas are vulnerable to four types of flooding. Some are more severe than others in terms of impact and consequences for the city. They also separate themselves by the degree to which a flooding event can be accurately predicted. Especially tidal and fluvial flooding can be successfully forecasted, and sensitive areas can be accurately identified (Cluckie & Han, 2000., Marfai et al., 2007., Gallien, Schubert, & Sanders, 2011., van Veelen, 2016). Although the same elevation models can be used to identify areas sensitive to coastal flooding, the many variables involved make the predictability of such events to be less accurate (Bowman et al., 2005., Gallien, Schubert, & Sanders, 2011). The real danger however, is that the four types of flooding (Tidal, Coastal, Fluvial, Pluvial) often occur at the very same time as a result of extreme weather. When this happens, the consequences are more severe than the sum of the individual events combined (Aerts et al., 2013). Now that the different types of flooding have been discussed, it is essential to understand how flood risk works to be able to assess the consequences and risk a specific area is exposed to.

Theories on assessing flood risk in urbanized coastal areas

As can be understood from describing the different types of flooding urbanized coastal areas can experience, assessing flood risk involves multiple complicated variables. Despite the many factors involved, flood risk is often described with a simplified formula: Flood risk = Hazard * Exposure * Vulnerability (Kron, 2002., UNISDR, 2011., IPCC, 2012., Aerts et al., 2013). In this description of flood risk, hazard represents the frequency and characteristics of the flood event. Exposure accounts for the amount of people and exposed assets in flood prone areas. The third variable, vulnerability describes the susceptibility for serious damages, for example due to unsafe structures (Aerts et al., 2013).

Kron describes a general increase in flood risk world wide through these three variables in his work *Flood Risk = Hazard x Exposure x Vulnerability* (2002). He states that flood related disasters have become more frequent and severe, despite the fact protective measurements have been improving (Kron, 2002). This statement can be illustrated with examples for each of the three factors contributing to flood risk.

First of all, there has been an increase in (flooding) hazard the last decades (Kron, 2002., Aerts et al., 2013). For different types of flooding, specific reasons can be identified. For example an increased hazard for fluvial flooding can be linked to increased precipitation patterns, but also the channeling of river systems to make land available for urbanization (Kron, 2002). This way, the discharge capacity of the river has been limited while peak water flows are severely larger, causing rivers to overflow and cause fluvial flooding. An increase in hazard for coastal flooding can be linked to the rise of sea level, increase in frequency and severity of storms and coastal erosion (van Veelen, 2016).

Secondly, the exposure has been increasing as well. The rapidly expanding world population is one of the most prominent reasons why losses from flooding disasters have been so severe in the last decades, according to Kron (2002). The increase in severe consequences is a direct function of the amount of people who choose, or are forced, to live in flood prone areas (Kron, 2002). Van Veelen (2016) agrees with this by stating: 'There is growing evidence that in many world cities the increase in flood risk due to the effects of human induced environmental changes, unplanned urbanisation and socio-economic change is expected to surpass climate change as the most important factor in increasing flood risk' (p. 23). In other words, it seems evident that in densely urbanized areas, the increase in exposure contributes more to flood risk than the increased hazard. Indeed, several studies have indicated that the effects of climate change on the increase of flood risk in coastal megacities are being nullified by the influence of socio-economic growth and increased urbanization. (Nicholls et al., 1995., Hallegatte et al., 2013., Winsemius et al., 2015).

The third factor contributing to a rise in flood risk according to Kron (2002) is vulnerability. One of the reasons this has been increasing over the last decades is that former property was hardly susceptible to water damage. Modern (electronic) content often gets completely destroyed when getting in contact with water (Kron, 2002). Another big change is the transition from heating houses by stove to a central heating system, where the central heaters are often located in the basement of buildings (Kron, 2002). These changes result in an increased vulnerability of buildings, where even minor flooding events can cause high amounts of damage (HR&A Advisors, Cooper, Robertson & Partners, 2014). In a more severe sense, unsafe structures leading to collapses and other failures can be life threatening, and contributes highly to the vulnerability of a flood prone area (Aerts et al., 2013).

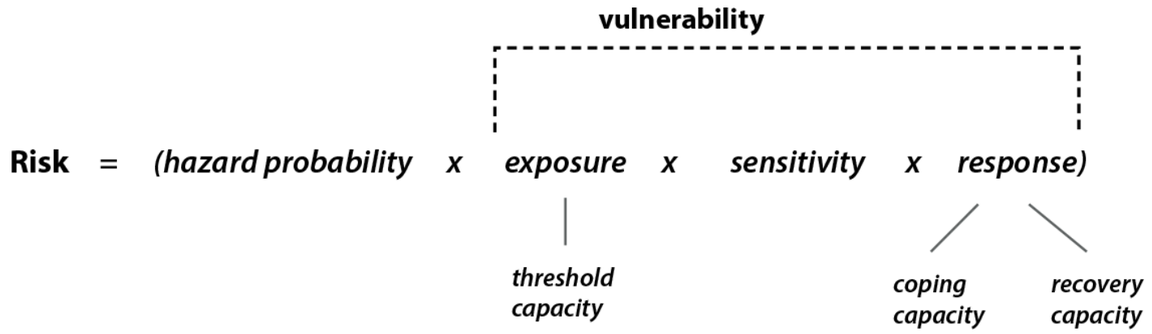


Figure 1,4. *Components of flood risk.* (van Veelen, 2016)

Van Veelen also talks about flood risk in his work *Adaptive planning for resilient coastal waterfronts* (2016). However, instead of describing flood risk as a product of Hazard, Exposure and Vulnerability, a further step has been taken to make it more specific. Van Veelen (2016) agrees with the notion that vulnerability can be described as a systems sensitivity to hazardous events. Adding to this understanding, the theory of Smit & Wandel (2006) is being adhered. Their understanding of vulnerability adds the definition of coping and recovering when they state: 'The vulnerability of any system (at any scale) is a function of the exposure and sensitivity of that system to hazardous conditions and the ability of the system to cope or recover from the effects of those conditions' (Smit & Wandel, 2006, p. 286). To summarize this, the vulnerability of a system is a product of exposure, sensitivity, coping and recovering according to Smit & Wandel (2006). Van Veelen (2016) groups coping and recovering as 'the response' of a system. He therefore describes flood risk as hazard probability * exposure * sensitivity * response, which is visualized in figure 1,4.

The added 'response' component acts to indicate the point where a system is unable to recover to its previous state before the disturbance (van Veelen, 2016). When this happens, the so called 'tipping point' is being reached. This tipping point is based on the coping and recovery capacity of the system. In this specific context, the coping capacity is based on the systems ability to avoid or minimize loss in case of a flood event (van Veelen, 2016). According to van Veelen (2016), this can be achieved through 'emergency planning, early warning systems and the adoption of flood resilience measures to reduce the damage to the buildings and its contents' (p. 73). The recovery capacity refers to 'the capacity of a society to recover to the same or to an equivalent state as before the disaster' (de Graaf, 2009, p. 23). Recovery involves the repairing of buildings and infrastructure, as well as cleaning operations (van Veelen, 2016). The capacity of being able to recover depends largely on the ability of financing reconstructions, socially managing the reconstruction, geographical- and urban conditions (Smit & Wandel, 2006., de Graaf, 2009., Mens et al., 2011. in van Veelen, 2016). Although both coping and recovery seem to have a lot in common, the main difference can be understood as coping refering to damage control at the time of the emergency, whereas recovery talks specifically about the aftermath of an event.

In the previous paragraphs, two main notions of flood risk have been identified and discussed. The concept of flood risk being constructed out of hazard, exposure and vulnerability (Kron, 2002., UNISDR, 2011., IPCC, 2012., Aerts et al., 2013), can be used to assess flood risk in a rather general sense. The added response component (Smit & Wandel, 2006., van Veelen, 2016) adds essential evaluation criteria. The importance of the response factor can be stressed by looking at an example of the 2004 Sumatra earthquake. During this time, the Pacific Tsunami Warning Center (PTWC) had no ocean-based sensor system and was entirely dependant on seismological data to assess the situation. Because of this, the initial prediction issued no threat for a tsunami (Blewitt et al., 2006). Recent development of tsunami warning systems has seen a tremendous increase in accuracy and speed, resulting in a greater coping capacity because of timely evacuations (Blewitt et al., 2006., PTWC, 2017). In this case, even if the hazard, exposure and vulnerability of the assets in the tsunami zone stayed the same, the flood risk still decreased because of an improved response. This example illustrates how the theory of Smit & Wandel (2006) and van Veelen (2016) offers a more complete assessment of the situation.

Although the reviewed theories for assessing flood risk help to identify the biggest contributing factors to the risk at hand, it remains vague to what each component exactly entails. Furthermore, it is hard to relate values from different components to each other. The theories state flood risk is a product of hazard, exposure, vulnerability (and response), but don't explain how each component is being calculated and translated to a rational, comparable number. Van Veelen (2016) confirms this lack of accuracy for calculating the recovery capacity within the response component when he states: 'The question can be raised if such a recovery threshold can be found with any given certainty or be assessed empirically *ex ante*' (p. 73). This also has to do with the fact that recovery capacity can only be properly assessed after the actual flood event. To illustrate the indistinct nature of the existing assessment criteria further, a hypothetical situation has been sketched.

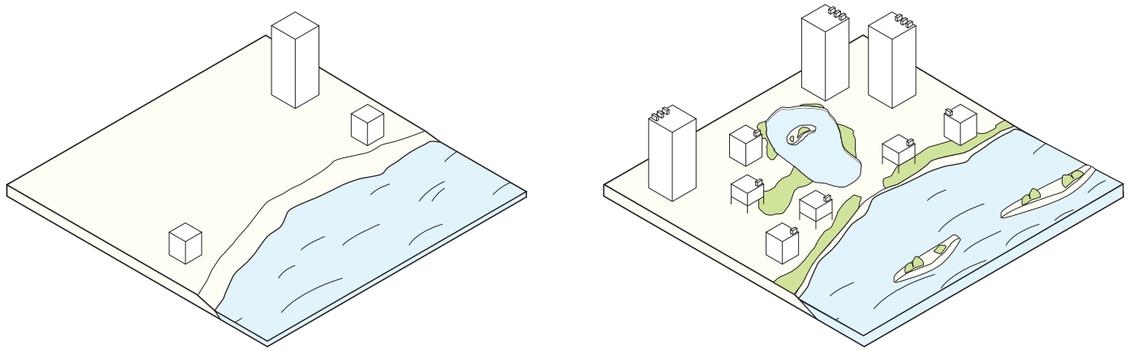


Figure 1,5. *Hypothetical flood risk assessment scenario.* (By author)

The notion that flood risk = hazard * exposure * vulnerability (Kron, 2002., UNISDR, 2011., IPCC, 2012., Aerts et al., 2013) will be used to assess the hypothetical sketched scenario to determine whether the flood risk successfully decreased in the new (right) situation. To start with the hazard, the natural conditions have seen an increase in flood hazard, as the water level has risen and both the intensity and frequency of storms and precipitation have increased. On the other hand, the hazard has been mitigated by the development of islands in front of the coast creating breakwaters, plus additional water retention areas within the urbanized area. The exposure of assets located in the flood zone has greatly increased, contributing severely to an increased flood risk. However, the exposed buildings have seen a great improvement when it comes to their vulnerability, as critical installations have been moved to higher places such as the roofs, and some buildings are even completely elevated above the base flood elevation level. In this case, the coping and recovery capacity (Smit & Wandel, 2006., van Veelen, 2016) will not be discussed, to keep a more simple example. To sum up the illustrated scenario, in the new situation the hazard has remained somewhat similar, the exposure increased tremendously and the vulnerabilty decreased considerably. Despite this step by step assessment, it is almost impossible to determine whether the flood risk eventually increased or decreased. The absence of data in the shape of factual numbers representing the exposed assets, vulnerability, and the current hazard lacks to finalize the assessment.

Ofcourse it is impossible for the theory to provide these factual numbers, as every situation is different and has multiple variables affecting the assessment. However, it could be stressed that a general framework including information about how each of the components should be weighted into the equation is necessary to successfully compare flood risk between different situations. Zhai & Ikeda developed a comparable approach to research flood risk acceptability in their work *Empirical analysis of Japanese flood risk acceptability within multi-risk context* (2008). To be able to rationally compare findings they constructed a framework showing the relationship between different components and the significance of each. This framework, which is visualized in the diagram below, has not been included to understand their approach or study, but merely to show a possible way of constructing a framework that allows for rational comparison of flood risk between different situations. Comparable numbers could be developed for the respective components contributing to flood risk.

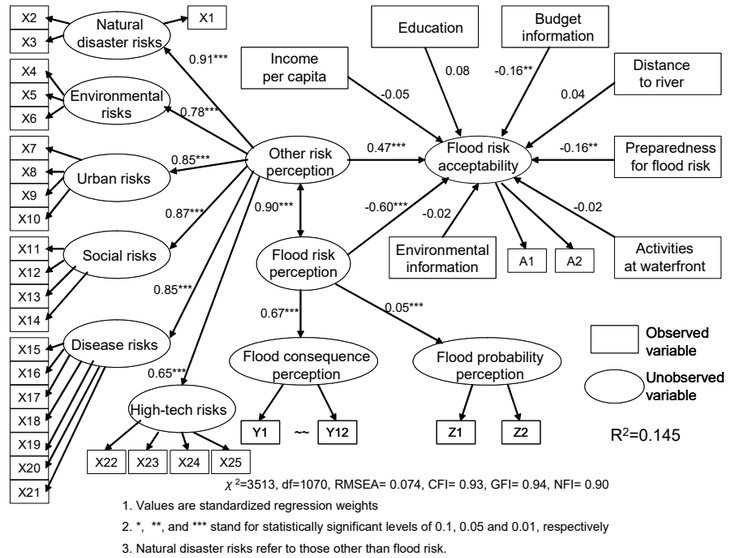


Figure 1,6. *Rational evaluation framework.* (Zhai & Ikeda, 2008)

Conclusion

As this theory paper tried to answer the main question 'How to assess flood risk in urbanized coastal areas?' various works were reviewed to come to the most complete conclusion. The notion that flood risk = hazard * exposure * vulnerability has been widely accepted (Kron, 2002., UNISDR, 2011., IPCC, 2012., Aerts et al., 2013). However, this paper argues that this equation is not complete without the addition of the 'response' component, as proposed by Smit & Wandel (2006) and van Veelen (2016). Regardless, the existing theories for assessing flood risk only provide a general guiding scheme of involved components, but remain rather indefinite when it comes to the actual calculation of risk. Because of the lack of rational numbers and significance of respective components it is hard to draw conclusions on the increase or decrease of flood risk in specific situations. Further research has to show whether a framework can be developed in which the described components that contribute to flood risk can be weighted against each other in a similar way Zhai & Ikeda (2008) propose. As urbanized coastal areas can deal with four types of flooding, each with their own probability and consequences, this framework should be able to provide a calculation method for each of the respective types of flooding.

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