Bryan Bay

LIVING BELOW SEA LEVEL

Independent Study on New Orleans, Rotterdam, and Venice

Preface

The intent behind this independent study was to study three cities: Rotterdam, Venice, New Orleans. At the start of this study, these cities were looked at as the *Good, Okay,* and the *Bad* in terms of how well each city has responded to the sea level challenges confronting them. As the study progressed, it became less about comparison and more about each unique mindset.

Living Below Sea Level serves as background research into the issues surrounding my architectural thesis, *Adapting to a Rising Chesapeake,* which hopes to define a path forward for the built and natural environments of the Chesapeake Bay region in the face of sea level rise — a result of human-caused Climate Change. The project will be the culmination of my architectural education, where I have strived to work beyond the boundaries of the Bachelor of Architecture to create an education wide-reaching enough to facilitate real change in the way we design, politicize, and understand our interactions with water.

My family is no stranger to losing our history to the Chesapeake, ours is richly intwined with the islands of it. My great great-grandfather was Shark Fin Shoal Lighthouse's keeper, with the rest of the family names (Hall, Holland, Parks, Price) scattered throughout most of the islands. Pictured right is Holland House, an icon of sea level rise and erosion on the Bay. Recognize the name? The house is believed to be ours, once a part of a 360 persons watermen town, the last remaining structure and land of Holland Island — until it washed away in October 2010. What is left of my family history, on Deals Island and

the Dames Quarter, will wash away by 2050 after just two feet of sea level rise.

This independent study took longer than anticipated, firstly because of Covid-19 but also a result of its entanglement with my thesis. It still is, in some ways, incomplete. The research has been completed, yet as I continue to develop the thesis, I find myself referring back to parts of my research here that I did not find crucial during the process of the independent study.

New Orleans

New Orleans is no stranger to living below sea level and the dangers of it. For many, it is considered one of the doomed cities of America. Originally, the city developed on the natural levees formed by sediment drops of the Mississippi River; although as the city grew, it began to drain marshes and swamps to become the below sea level city we know today. The Louisiana Delta lost 40 square miles per year at its peak, now only losing around 30 square miles per year. At the same time, the barrier islands that have protected New Orleans are eroding quickly with each powerful hurricane without ever recovering. These islands, marshes, and swamps have been maintained by the flow of sediment delivered by the Mississippi River over the years, however in the last 70 years this sediment has failed to develop due to the city's system of levees and dams.

The city is famous for this flood protection system, which have defended the city successfully from flooding with the notable exception of Hurricane Katrina. This system was developed mostly during the growth of the 1950s and is responsible for much of the city's natural barriers' erosion. It is a catch twenty-two; the system protects the city from flooding and allowed growth, yet at the same time by preventing the water's flow to the marshes south of the city, blocked the flow of sediment that had maintained the natural defenses.

A Drained Swamp

New Orleans is the center of population in the LA SAFE initiative, which is a comprehensive planning document by the state of Louisiana to mitigate the effects on the most at-risk parishes of southern Louisiana.

The city, except for a few locations, has always been at or under sea level. The architecture of New Orleans has always responded to this. The historic Shotgun House typology was raised, originally above the normal flood of the river, made of resilient and hard material below the first floor. They were designed to flood underneath and keep the home dry. The oldest surviving example of this architecture is Madame John's house. The building is was built by an American for a Spanish owner while adapting French and Caribbean architecture to the New Orleans climate. The only floor of living space is raised eight feet from the road, high enough to survive floods. The street level was built of solid brick covered in stucco, the early New Orleans' method of building resilient foundations that could flood multiple times without damage. The building also employs other strategies to passively respond to the climate. While the city's early architecture responded to the intrinsic risk of living in New Orleans, as its inhabitants developed confidence in its system of levees, the architecture stopped responding to the possibility of a flood.

The system of levees has failed the city three time. In 1927, the Great Mississippi Flood was routed to reach New Orleans and looked to be strong enough to breach its levees for the first time. As a response, a group of city businessmen used dynamite to blow up the levees protecting nearby parishes to reroute the flood waters. In the end, neither New Orleans or the nearby parishes would have flooded, and it displaced the low-income communities in a way that would never be forgotten. In 1965, during Hurricane

Betsy caused widespread flooding and destruction which lead to the modern system of levees built by the US Army Corps of Engineers that successfully defended the city until Hurricane Katrina redefined the high water mark possible in the city. When the levees failed during Katrina in 2005, it left a path of destruction not seen before in New Orleans. During the storm, many inhabitants thought the storm had passed as it was not until the evening after the storm's eye passed that the levees system built in the 1960s failed. While the devastation was a result of a natural event, it was an engineering disaster — not a natural disaster. The engineering of New Orleans failed in two ways. First, the levee system failed as the main drainage canal was breached by the storm. This occurred due to the original design process, where not only did they use outdated storm estimates that did not account for winds higher than 100 mph, but they also designed the levee system based around the wrong datum elevation. It was constructed using the National Geodetic Vertical Datum of 1929 as a substitute for the local mean sea level, leaving a 1-2-foot difference between what was intended and actually designed. Making things worse, they did not include the rate of land subsidence of 4-5 feet a century. Had the levees been designed for the local mean sea level and considered land subsidence, the city would not have seen the widespread damage (Heerden & Kemp, 2006).

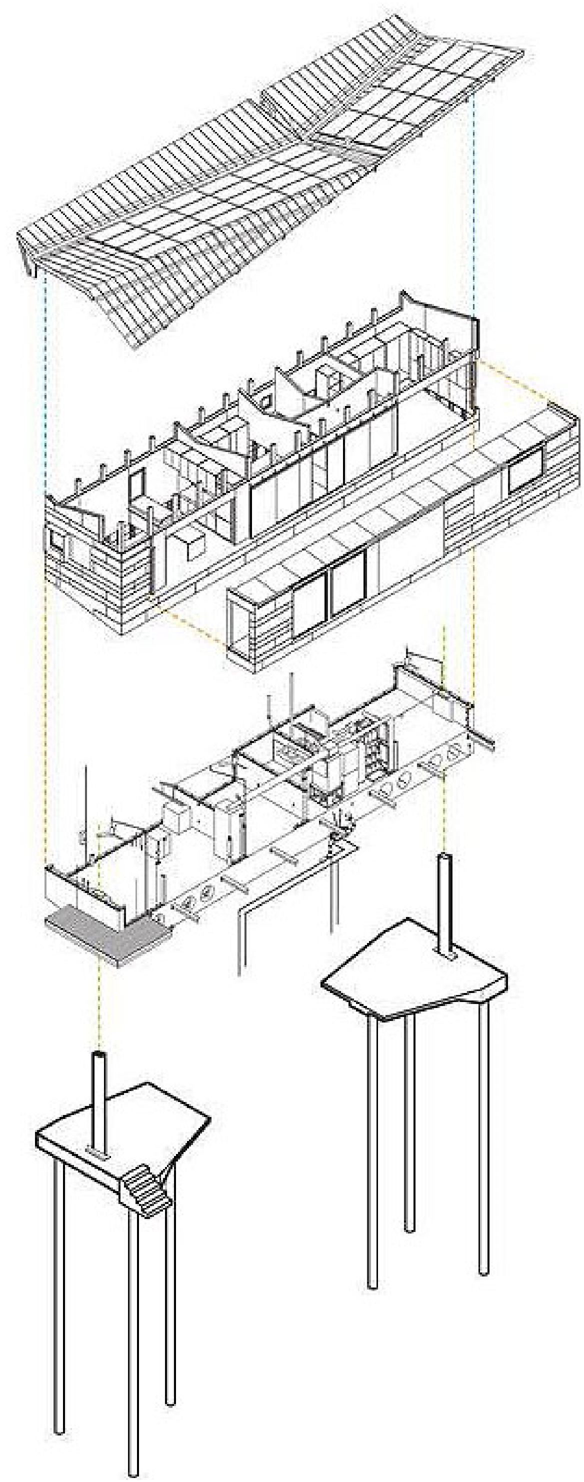
Post-Katrina Renewal

When Katrina's eye passed over the city in 2005, many thought they had avoided the worst of the storm. It was not until the night after, that with one loud noise, the levees failed. Katrina's storm surge reached levels that were never expected. The old shotgun houses that were raised like Madame John were not high enough to avoid the flooding; parts of the city that never expected to flood did. All of this resulted in widespread damage of all the housing stock in the city. In the aftermath of Katrina, there have been multiple efforts to rethink the way people lived in New Orleans.

The Make It Right Foundation was the first of these efforts that tried to rethink how people lived. The foundation brought in top architects, such as Shigeru Ban, David Adjaye, and Morphosis, to design new safe and sustainable housing stock for the city. The majority of the houses that resulted were designed for sustainability, many of them not responding to the question of another Katrina (like Frank Gehry's pink

house). Some like Graft's house, responded by offering multiple levels to escape. Graft did not want to ostracize the street, yet he did not want to repeat the same error of lacking higher ground, resulting in the multileveled approach picture. The most visionary approach to the problem is the house designed by Morphosis.

The Float House was Morphosis and Thom Mayne's interpretation of a Katrina-proof shotgun house. They first started by creating a structure that could survive the flooding seen in Katrina. The result was a floating chassis, rather than foundation, that was inspired by auto manufacturer's flexible chassis that can grow and shrink to work for multiple models. This chassis is flexible, allowing it to serve varying size structures, while being mass-producible to lower the costs of the project. The chassis is formed using glass reinforced cement, similar to ferro cement boat construction, to provide buoyancy around its two fixed pilings that allows the structure to rise with flood waters up to 12 feet above its resting point. In this move, the architect took the historic typology of the Shotgun's raised resilient foundation and adapted the concept to the modern day challenges, allowing its residents to flee future storms without fearing of their home being destroyed by flooding. The architects also recognized that in most cases, it is the flooding from stormwater [rain] that presents the greatest danger — rather than the levees overflowing. In response, the structure is designed to store most of the rainwater through its unique roof design. The water is then stored in the chassis, lowering the structure's center of gravity which lessens the effects of flood conditions on the house when it is floating (Alarcon, 2012).

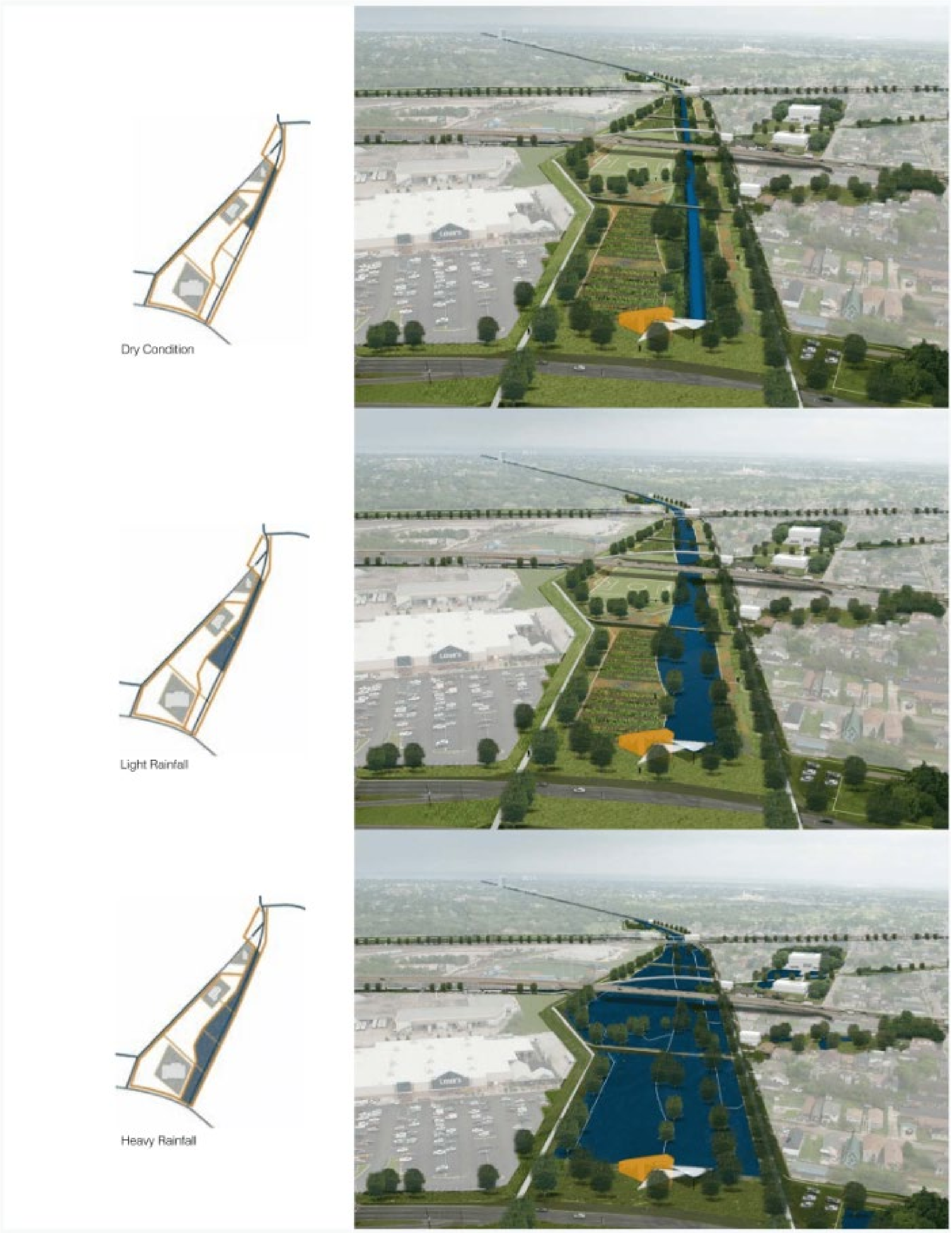


Resilient New Orleans

On the tenth anniversary of Katrina, the City of New Orleans and the surrounding counties entered a new stage of planning through a new guideline document, *A Resilient New Orleans, Strategic Actions to Shape our Future City*. This was building off a 2013 guidance document, *Greater New Orleans Urban Water Plan*. The Urban Water Plan is a three-part report, split into vision, urban design, and implementation. Throughout the reports, there is an emphasis on designing good architecture and urban spaces for a range of stormwater conditions (. At the core of this good design are direct interactions with the water, something that has not been a part of New Orleans' identity for a long time. In the same vein, every proposed project like the Monticello Canal Park has multiple modes of transportation and activities. Bike paths become a crucial link between all the projects. Resilient community gardens and recreational facilities become loci of the parishes, building stronger communities (Architects, 2013).

How the city reinvigorates its natural conditions have also been a key focus. Many recent studies have placed the blame for New Orleans' flooding to the hard drainage systems installed in the twentieth century. At the time, these systems were considered progress in part to how quickly they removed the water from the city. This resulted in a rapid increase in land subsidence in the developed areas, due to the water being removed so quickly that the vast majority of it was unable to seep into the water table. The dire consequences of removing the water rapidly from the city was only realized recently. In these two sets of reports, the city makes a much needed ideological shift from draining the water out to keep as much as possible in when under stormwater stresses.

New Orleans has a resilient future head of itself thanks to this shift in ideology. The city government expects most of the projects laid out in these planning guidelines by the year 2050. They believe their walls are already tall enough post-Katrina to hold back the rising seas for another century and that their biggest challenge is how to open the city back up to the water (Orleans).


Dry Condition
Light Rainfall
Heavy Rainfall

Venice

Defined by its relationship with its lagoon, Venice is a city defined by its water. The city has always flooded and its citizens have always adapted. Yet the rate of inundation is increasing exponentially as the years go by. There are three factors involved, the same three factors that the Chesapeake Bay region faces: subsidence of its land, over drafting fresh water aquifers, and global sea level rise due to climate change (Pierluigi Viaroli, 2004).

ADAPATING THE ARCHITECTURE

While Venetian architecture does not directly adapt to the rise in sea levels the city has witnessed over its history, a comparison of paintings and recent photographs can demonstrate the increase in water level that the city has already incurred. Doorways have been raised, entry steps that once were a few steps above water are now rarely seen. In this way, Venetian architecture has been slowly adapting to rising waters. Some projects within the city have been designed differently and have chosen to interact with the tides rather than keep them out. Carlos Scarpa's Pinacoteca Querini Stampalia is designed to showcase the rise and falls of the tides and how they increase over the years. Scarpa took a building in desperate need of repair after a history of flooding and selectively restored it, saving what could be saved while intervening in new ways. He took the main floor that had become unusable and created a bridge that connected rooms that acted as islands. He removed the doorways to the canal and let the tides inhabit the building. Within the original entry, Scarpa created a series of steps that allowed inhabitants to measure and interact directly with the tides. While projects like Scarpa's are rare in Venice, it highlights a playful mode of adaptation — one that melds a new space out of what would otherwise become unusable in the face of rising seas (Filippenko, 2017).

KEEPING VENICE ABOVE WATER

Venice has a whole has a lot of cultural differences in terms of how it has chosen to live with the water, yet these have not percolated into the architecture and its urban plan in a meaningful way when looked at in the eyes of sea level rise. The city has theorized a couple different solutions over the last few decades, yet long term projects are infamously difficult to achieve in Italy. In recent months, the city has finally begun using its first flood protection system, the MOSE system, which was first theorized

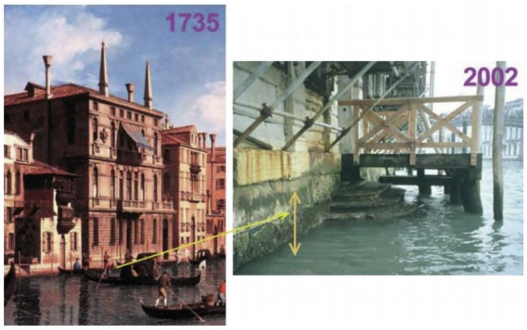


Figure 3.9 A view of Palace Giustinian-Lolin painted by Bellotto in 1735 (left) and a detail of the main entrance today (right). The algae shift is 66±10cm. The main staircase is now submersed and a new wooden wharf was necessary to enter.
Source: Taken from Camuffo and Sturaro (2003).

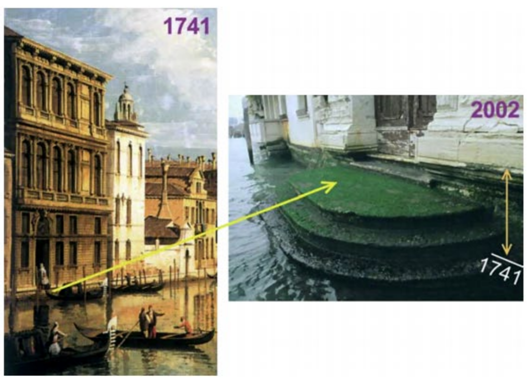


Figure 3.10 A view of Palace Flangini painted by Bellotto in 1741 (left) and a detail of the main entrance today (right). The algae shift is 71±12cm. The main staircase is now submersed and covered by algae.
Source: Taken from Camuffo and Sturaro (2003).

back in the 1980s. This system took fifteen years to build and even longer to design. Around the same time many engineering projects were considered by the Ministry of Public Works.

Their first idea was to simply raise Venice up. There were two ideas, first to raise just the outer rims of the Venetian islands. This though was deemed extremely unlikely due to the network of drains that to this day remain largely unmapped and too complex. The other method was to reinflate the entirety of the Venetian islands. There were two methods to achieve this, injecting vast amounts of water into the aquifers and injecting a special grout layers beneath the city. The latter was actually tested in 1972, the test was successful in raising the whole of Poveglia Island (the now abandoned mental asylum, hospital, mass fire burial, and plague quarantine island).

Raising the historic architecture of Venice remains the only option that has been truly considered in the race to adapt to rising sea levels that is directly architecture related. The rest of the decisions that Venice has theorized are completely urban design solutions. At one point dividing the lagoon into two sections using a dyke was proposed as a solution that could preserve Venice while still maintaining an open harbor for commercial areas. In this proposal, the Lido Pass entrance to the lagoon would become a lock gate and the dyke would be built south of it. This would effectively create two lagoons.

A second environmental urban intervention was theorized at this time as well, a system of mobile gates that are located within the entries to the lagoon. These gates are interlocking barriers that are filled with air, allowing their upper edges to float above the lagoon entrances. Once they have floated upwards, they form a barrier separating the tidal conditions of the lagoon and Mediterranean. This system was originally created by the Consiglio Nazionaie delle Ricerche (National Research Council) of Venice in the late 1970s. Nearly fifty years later this system has finally entered service as the MoSE system after fifteen years of construction and further years spend on development. (Pirazzoli, 1987)

THE MODERN ERA AND ITS FUTURE

This past fall, Venice prevented itself from flooding for the first time in its history. The MoSE system worked and remains operational, protecting the city.

The system is not the end all solution for Venice, it has many flaws that still cause disputes to this day.

Environmentalists like the World Wildlife Fund have remained ardently against the project, suing it since its inception and still attempting to block its continued usage. The concerns are the same of any dyke or flood defense system, it blocks aquatic life from executing their typical movements. Beyond the environmental concerns, MoSE does not act as a solution in the face of global sea level rise. Some projects have stated that the number of days that are 110cm above datum water level, triggering MoSE into action, will increase from "the present 4-5 times per year to 21-250 times per year. (Venice Shall Rise Again,)" Such an occurrence would essentially make the activated MoSE a permanent installation, preventing maritime traffic and aquatic life from entering the lagoon which would have drastic economic and environmental damages respectively to Venice. Another issue with the MoSE system are the modifications to the natural formation of the inlets. The system's depth and widths were designed solely for the navigational needs of the port, redesigning the inlets to be both deeper and narrower. This has had the result of a bottle neck current, creating navigational challenges for boats while creating hydrodynamic imbalances. These imbalances have caused a quickening in Venice's land subsidence, as the land is washing away even quicker than before MoSE. This has been further compounded by Venice's short-lived decision to allow gross-tonnage cruise ships to enter the lagoon, whose propellers and size dredged out the navigational channels only to have land subsidence fill them in once more (Teatini).

So while Venice recently celebrating MoSE saving the city, the celebration is likely to be short-lived in the face of ever increasing global sea level. The city, like much of the world, as not yet defined a clear path forward to secure itself a resilient future in the face of rising seas.

Rotterdam

Rotterdam is Europe's largest port city. Roughly ninety percent of the city is below sea level and it is at the core of the Netherland's Delta Works project. Three of Europe's largest rivers flow through Rotterdam, the Rhine, Meuse, and Scheldt. The city, along with the rest of the Netherlands, is no stranger to living below sea level and flooding. It deploys a trifecta of strategies, soft and hard, to live below the sea.

The Delta Works

The Delta Works project was the national response to the North Sea Flood of 1953, a mix of spring tide and a Force Ten northwesterly storm, that killed 1,836 people, wiped out countless villages, and killed off tens of thousands of livestock. Prior to the flood, the Dutch dykes were a patchwork of local systems — a system that when put under max strain failed in over 150 places. What national funding there was for flood protection at the time, was minimal as the country was more focused on rebuilding the port and city of Rotterdam that had been brought to ashes by the Third Reich. After 1953, the government directed the Rijkswaterstatt (Ministry of Infrastructure and Water Management) to begin the Detla Works. The project had extended, rebuilt, and raised dykes across the country, while adding five storm surge barriers, three locks, and six dams. Three of these, the Oosterschelde, the Afsluitdikj Fish River, and the Maeslantkering are important to this project (Rijkswaterstaat, 2020).

THE MAESLANTKERING

The Maeslantkering is the world's largest storm surge barrier. Located at the entrance of Rotterdam's port and main waterway, the Nieuwe Waterweg, it is the last defense of Rotterdam. It encloses the 360 meter wide waterway, to restrict the North Sea from flooding Rotterdam, with its two 210 meter log barriers that swing on the world's largest ball joint on two 237 meter long steel trusses. When a storm surge of three meters is predicted, the gates close by being floated out into the waterway and being filled with water when in position. In the case tha they remain closed for a long period of time, the gates can be slightly floated to allow the waterway to drain. While the technology is remarkable, it is the Dutch's planning exceeds it as it was designed to withstand a one is ten-thousand year storm.

THE OOSTERSCHELDKERING

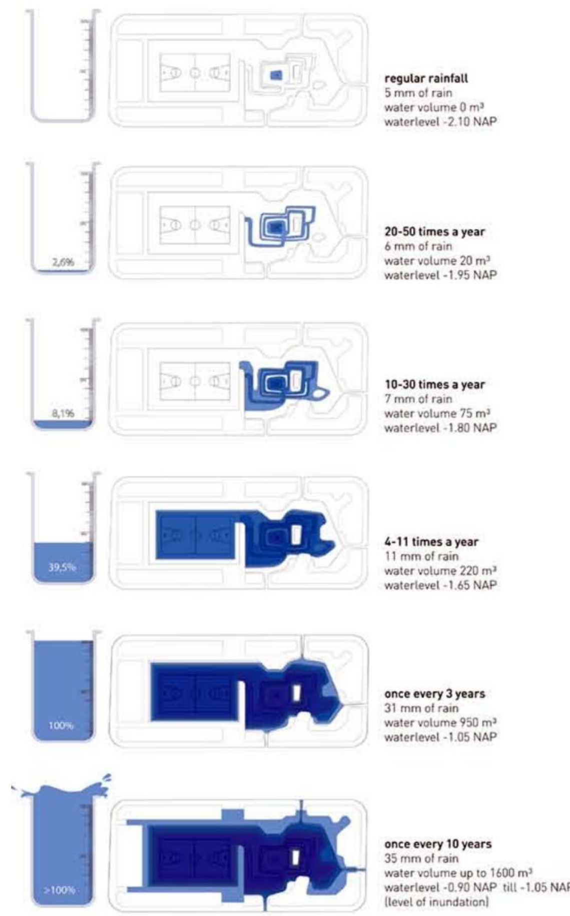
The Oosterscheldkering was the first storm barrier to allow the mixture of salt and fresh waters. Its design was revolutionary at its time and was the result of well over a decade of design process by the Dutch government. The process is well-documented through the 238 page "Design Plan, Oosterschelde Storm-surge Barrier. Overall Design and Design Philosophy." the Chesapeake Project's structure comes to life. This structure's well-documented process highlights the good and bad ideas in building water barriers (Netherlands M. v., 1994).

THE AFSLUIDIKJ FISH RIVER

The Afsluitdikj Fish River is the first mechanism that allows free movement of fish through a dyke. This project and its technical features were studied in order to create the two different dykes the Chesapeake Project theorizes. Through its nearly two kilometer long stream of water, the Fish River allows fish to switch waters without assistance. The design is a breakthrough, figuring out the attraction currents and allowing such a break in the dyke to exist without enacting the laws of displacement. While the project is revolutionary, it has one major flaw — it will not work with sea level rise (Netherlands, 2020).

Stormwater Storage

The latest initiative in Rotterdam has been to make room for the river and its own stormwater, preparing for the days when the Maeslantkering is closed for high seas occur simultaneously with heavy storms in mainland Europe. The city of Rotterdam has established water storage capacities that each part of the city must meet in order to survive these days through the "Waterplan 2," in place since 2007. Through the planning board, the city highlights upcoming projects that have a large potential for affordably incorporating water storage, like the Museumplein Parking Garage that covers twelve percent of the capacity for the city center. This project utilizes the volume below unusable areas like the driving ramps to store copious amounts of water. A more common approach being taken by the Dutch governments is the creation of water parks. Any new park designed in the Netherlands is looked at as a water storage facility. They have come in many forms, but the Watersquare park was the template project. The park converts the typology of the square commonly found in the Netherlands and converts it into water storage in an interactive manner as it floods, revealing various forms influenced by the water levels. By their estimates, the park will remain dry ninety percent of the time while providing crucial stormwater storage the other ten percent. (Boer, 2010)



In Closing

For an issue so prevalent across the world, there is such a small body of work that applies itself to the issues of sea level rise. The vast majority of it comes from within the Netherlands, yet an even larger majority of it is purely water management and engineering. There has not been much attention paid towards how architecture could respond to this beyond to float. The knowledge is out there in terms of how to keep the water back, but the ability to keep the water out yet let wildlife in is lacking. The Netherlands are starting to tackle this issue but do not have it figured out. So far though most solutions remain within the urban planning world. Architecture, while clearly not having a role in designing for rising seas, has the ability to start working towards a multi-disciplined approach to the issue. Few professions are as well positioned as architecture to act as a unifying force between the science and culture required to come to a solution.

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