

ABSTRACT

Title of Thesis: URBAN OSMOSIS: NEIGHBORHOOD-
SCALE WATER INFRASTRUCTURE FOR
RESILIENCE IN MIAMI'S LITTLE HAITI

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Water is political and infrastructure is the arbiter of access. Human settlement has always relied on access to water and the ability to manipulate its distribution plays a significant role in shaping the social, political and spatial economies of cities. Today, rapid urbanization, increased consumption and anthropogenic climate change are causing drastic shifts in water cycles and flows. Coastal cities now face the paradox of potable water scarcity and increased flood risk. Large-scale desalination is heralded as the solution. However, just as it transforms the properties of water, large desalination facilities transform urban landscapes and shift relational norms of water; potentially exacerbating existing spatial and social inequalities through climate gentrification. A rethinking of scale, and a move from municipal to neighborhood scale facilities presents a unique opportunity to leverage the power and opportunity of desalination in a more ecologically and socially responsive approach.

URBAN OSMOSIS: NEIGHBORHOOD-SCALE WATER INFRASTRUCTURE
FOR RESILIENCE IN MIAMI'S LITTLE HAITI

by

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Chapter 1: Water and Human Settlement

Waters' Intrinsic Ties with Humanity

“A truly ecological landscape architecture might be less about the construction of finished and complete works, and more about the design of ‘processes,’ ‘strategies,’ ‘agencies,’ and ‘scaffoldings’ – catalytic frameworks that might enable a diversity of relationships to create, emerge, network, interconnect, and differentiate.”

- James Corner

The relationship between water and life is inextricable, and for humans the profundity of this tie extends far deeper than water’s biological imperative for our survival. Dating to the earliest evidence of humanity across the world, there are indications that access to and use of water has played a universally seminal role in the development of human civilizations. The development of water conveyance and storage infrastructure systems facilitated the establishment of sedentary, agrarian societies nearly 10,000 years ago. Early concentrated urban settlements developed from 8000 BCE in Jericho, Egypt and later the arid regions of the Mediterranean where rainfall was scarce. Water infrastructure systems played a vital role in these civilizations and the first century writings of Vitruvius document the importance of considering water conditions when choosing a site for a city.¹

Water’s natural and socially constructed power also brings about destruction and disruption to our social order. Across cultures and throughout time, water has

¹ “A Brief History of Water and Health from Ancient Civilizations to Modern Times IWA Publishing,” n.d., 2

carried both symbolic and material value, and thus the control of it is given even greater weight. The first textually documented war, fought between the Mesopotamian city-states of Lagash and Umma, centered on control of a canal and the associated irrigated fields.² In present day it remains true that the most significant urbanization is occurring in coastal regions and, thus the role of water remains a prominent component of the political, social and economic landscapes of urban built environments. This phenomenon of hydro-social relationship- “the socio-natural process by which water and society make and re-make each other”- is dynamic and powerful.³

Water runs through the many challenges and questions faced acutely today – climate change, natural resource scarcity, pollution, habitat destruction, social and economic inequality and more. Adapting the governance and infrastructure that manages our water access will be vital to meeting the imperatives of these multi-faceted challenges.

Water Resources

Earth’s vast but finite water resources occur primarily in forms not readily accessible for human consumption. Approximately 97% of the Earth’s water is saline ocean and seawater, with a scant 2.5% available as freshwater. Of that 2.5%, just 1.3% of it is surface water, 30% is groundwater, and the remaining 67% remains sequestered in glaciers and ice caps (Fig. 1).

² Johann Tempelhoff et al., “Where Has the Water Come from?: Editorial ‘Water History,’” *Water History* 1, no. 1 (July 2009): 2, <https://doi.org/10.1007/s12685-009-0003-6>.

³ Melissa Haeffner, Kathleen Galvin, and Alba Eritrea Gámez Vázquez, “Urban Water Development in La Paz, Mexico 1960-Present: A Hydrosocial Perspective,” *Water History* 9, no. 2 (June 2017): 169–87, <https://doi.org/10.1007/s12685-016-0180-z>.

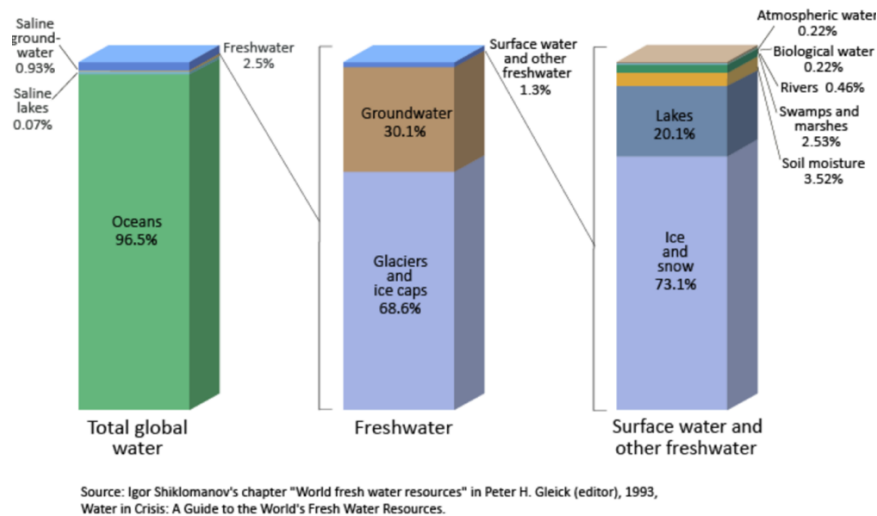


Figure 1. Global water distribution

Unsurprisingly, easily tapped groundwater, surface water (in areas where it is available), and rainwater have traditionally been people's primary water sources for domestic and industrial use. As a result of population growth, significantly increased water consumption habits, and climate change factors, the global supply of water no longer meets the needs of the population in an increasing number of areas around the world. A recent study of groundwater use found that the global groundwater footprint is "3.5 times the actual area of the aquifers and that 1.7 billion people live in areas where groundwater resources and/or groundwater- dependent ecosystems are under threat." (Fig 3)⁴ This agrees with the United Nation's assessments, to which they add that a further 1.6 billion people face economic shortages of water, meaning they reside in places lacking the necessary infrastructure to take waters from rivers and aquifers.

⁴ Tom Gleeson et al., "Water Balance of Global Aquifers Revealed by Groundwater Footprint," *Nature* 488 (August 8, 2012): 197.

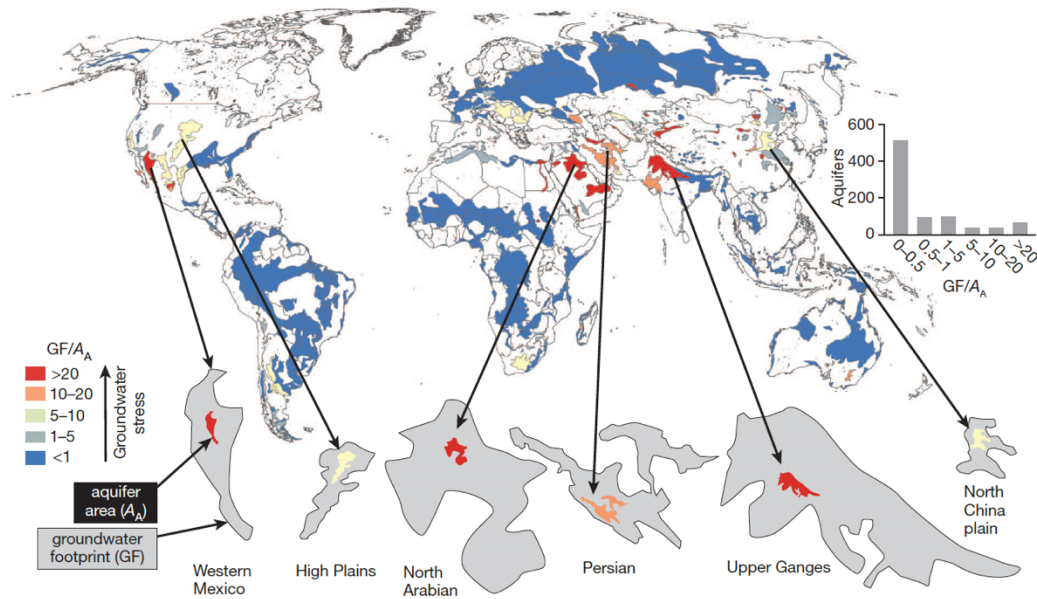


Fig. 3: Global aquifers compared to the “global water demand footprint” of the population reliant on that aquifer. Areas in red have water demand that significantly outstrips the size of the groundwater aquifer available to them. Two of these regions- the Middle East and the Western United States are increasingly looking to desalination as a potential means of meeting their water demands.⁵

The 1948 Universal Declaration of Human Rights defined the right to water as a human right. A 2002 UN comment went further, defining water as a social and cultural good- not just an economic commodity- and establishing the state as legally responsible for fulfilling their citizens’ right to water. While these statements were useful for establishing a theoretical and legal framework of water resource management, the realities of competing demands and access to water across populations is not so neatly defined.

Water Scarcity

The taxing of the finite available water resources and the fundamental nature of water access to the well-being of ecosystems and all those within it makes water

⁵ Gleeson et al.

scarcity among our most pressing challenges. Scarcity is a function of natural, social, and political factors and a more nuanced probe of this is necessary in envisioning effective responses. First-order scarcity is a physical lack of water and often requires technical as well as governance interventions. Second-order scarcity is a socio-economic function that renders a population unable to access water due to material constraints. This is characterized by inadequate water infrastructure or poor management mechanisms. Third-order scarcity refers to a populations' limited capacity to adapt to the physical scarcity because of social, political or economic barriers. And finally, fourth-order scarcity is a product of socio-political processes and resource governance issues that favor one entity over another. This may not stem from a physical lack of water at all, but could be due to preferential or uneven distribution of water resources amongst groups.⁶ Water scarcity is a relative problem that is often not experienced evenly by all strata of a population or community. Understanding the nature of the water scarcity problem faced is essential to mounting an effective response. When faced with first-order scarcity, what are the technical options for increasing supply? This is where desalination may have a role to play.

⁶ Lyla Mehta, "Water and Human Development," *World Development* 59 (July 2014): 60, <https://doi.org/10.1016/j.worlddev.2013.12.018>.

Chapter 2: Salt of the Earth

Salt and Human Settlement

The investigation of water's conditioning of the built environment necessarily requires exploration of another life sustaining element- salt. Like water, the human relationship to salt is inextricable and the presence of salt has conditioned how and where we have lived from early stages of human life on Earth. Settlements dating from 4,500 BCE in present day Bulgaria appear to have been built up around a salt production facility and references to ritual use of salt appears in ancient Egyptian and Biblical passages. Shipping trade routes, wars, and social hierarchies and organizations developed in their relation to who controlled the salt. This elevated status of salt perhaps points to some level of early understanding of salt's essential role in the healthy regulation of the body of most living things. Cells are primarily made up of salts, or ions that help regulate the amount of water inside and outside the cells. Salts are a vital conduit for the circulation of information throughout the body and play a prominent role in moving water through the Earth's ecosystems. Ancient civilizations sought to separate water from salt to access their prized commodity, and thousands of years later we are beginning to revisit this concept as a means to access the commodity increasingly prized to us today- water. As global population has ballooned and industry and largescale agriculture has expanded in kind, demand for water drives deeper and more involved means of harvesting the water necessary to support the modern levels of consumption. The UN estimates that 700 million people

and counting suffer from water scarcity, and they predict largescale migration of over 24 million people in the coming decades in search of accessible water sources.⁷

Desalination- the process of removing salt from water- turns saltwater into a consumable freshwater and the process increasingly factors into the conversation of how to address water scarcity issues.

Groundwater levels are directly tied with precipitation levels. When groundwater sources are drawn out more quickly than the cycle of precipitation replenishes them, one of the results is an increase in the salinity levels of the soil. Saltwater moves increasingly toward the fresh groundwater and as the water is drawn out, the salt is left behind. This process, called salt-water intrusion, can have detrimental effects on the overall health of soil and it's viable use as arable land. Higher soil salinity levels lead to lower rates of oxygen in the soil and suppresses plant growth and therefore decreases crop outputs. Recent data indicates that 20% of arable land is impacted by soil salinity and this number is on the rise.⁸ Largescale salinization can lead to crop collapse and force the abandonment of land for cultivation. These results are usually irreversible.

⁷ Madison Powers, "Water Scarcity Issues- We're Running Out of Water," *Few Resources* (blog), n.d., <https://www.fewresources.org/water-scarcity-issues-were-running-out-of-water.html>.

⁸ Pooja Shrivastava and Rajesh Kumar, "Soil Salinity: A Serious Environmental Issue and Plant Growth Promoting Bacteria as One of the Tools for Its Alleviation," *Saudi Journal of Biological Sciences* 22, no. 2 (March 2015): 123–31, <https://doi.org/10.1016/j.sjbs.2014.12.001>.

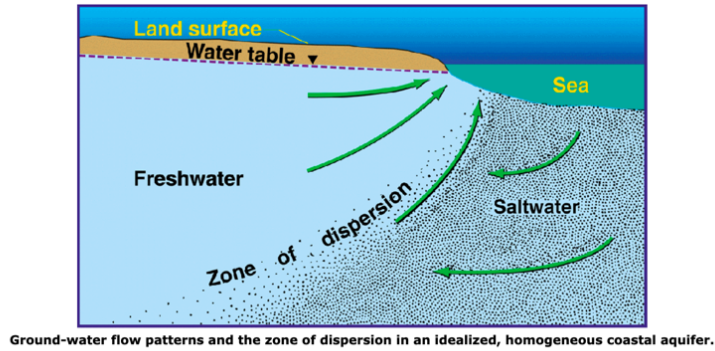


Fig. 3: “Freshwater and saltwater mix in the zone of dispersion in the process of diffusion and mechanical dispersion. A circulation of saltwater from the sea to the zone of dispersion and then back to the sea is induced by mixing within this zone. Groundwater pumping can reduce freshwater flow toward coastal discharge areas and cause saltwater to be drawn toward the freshwater zones of the aquifer. Saltwater intrusion decreases freshwater storage in the aquifers, and, in extreme cases, can result in the abandonment of supply wells.”⁹

Desalinization

While largescale salinization of soil is a newer issue experienced in the last couple decades, the industrialized pursuit of removing salt from water for potable consumption began in earnest in the World War II era when naval missions sought to capitalize on the seawater all around them. The effort yielded the reverse osmosis (RO) process that remains the prevailing approach to desalination today. Modern desalination methods have experienced marginal technological advancement in recent years, but overwhelmingly the methods used today are the same processes developed in the post-World War II era. Reverse osmosis functions not unlike the osmotic regulation of salt within the cells of our bodies. Saline water is pumped from a source location and pushed through semi-permeable polyamide membranes with microscopic holes that catch the soluble particles, including salt, and produces freshwater on the other side (Fig 4). Higher salinity water is denser and therefore

⁹ “Freshwater-Saltwater Interactions along the Atlantic Coast,” *U.S. Groundwater Services*, n.d., <https://water.usgs.gov/ogw/gwrp/saltwater/salt.html>.

requires more force to push it through the membranes. As a result, seawater requires greater energy to desalinate than lower salinity brackish water. Source water conditions also determine the degree to which the water must be pre-treated before going through the RO process.

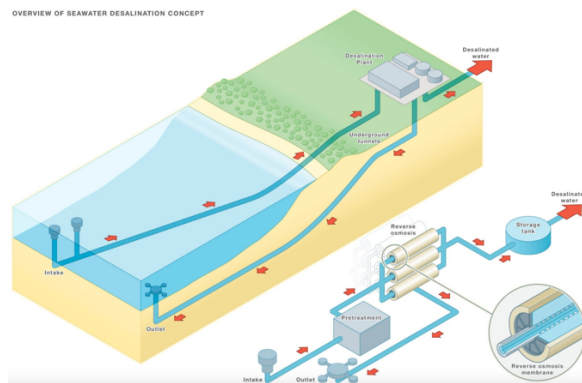


Fig. 4: Depiction of the reverse osmosis desalination process. This graphic downplays the scale of the brine produced, which would be greater than the volume of freshwater produced. This would likely travel through the “Outlet” pipe for discharge back into the ocean. Image source: <http://victoriasdesalinationplant-present.blogspot.com/>

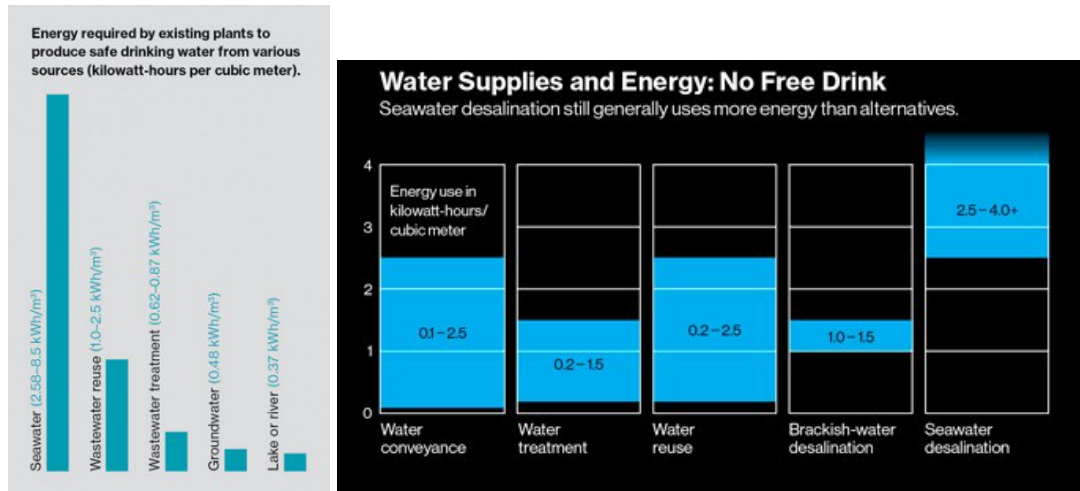
The primary direct environmental concern associated with the desalination process is the safe disposal of the high salinity brine byproduct. For every liter of drinking water produced, desalination produces 1.5 liters of brine. The degree of salinity in this brine varies widely based on the conditions of the source water, but regardless, the disposal of this highly concentrated saline solution, which also contains other chemicals that are part of the priming process, presents a significant challenge each plant must confront. Disposal of the brine in locations and manners where it can easily seep into the groundwater supply could promote undesirable land salinization and salt water intrusion into the soil. Given that over 80% of desalination facilities are within 10km of a coastline, brine is most commonly dumped back into the sea. A recent UN University study on the issue states that, "Brine underflows

deplete dissolved oxygen in the receiving waters. High salinity and reduced dissolved oxygen levels can have profound impacts on benthic organisms, which can translate into ecological effects observable throughout the food chain."¹⁰ Taking cues from the ancient valuation of salt, the study goes on to state with greater technological exploration the brine could provide valuable opportunity to harvest other minerals and or aid in cultivation of high salt tolerant aquaculture.

Desalination is currently the most economically and energy intensive methods of water (Fig. 5) treatment, and nearly 40% of the operating budget of a desalination facility is generally related to energy cost. Though some outliers use renewable energy sources as a power source for their facilities, most conventional plants burn fossil fuels and thus the CO₂ emissions associated with desalination mounts as more plants come online. Much of the technological research around desalination has thus centered on ways to make the process less energy intensive, particularly by using alternate materials to the conventional polyamide filtration membrane. Preliminary research indicates that an alternative graphene membrane that has less drag could help reduce the necessary energy consumption to push the water through by 15 to 46%, depending on source water salinity.¹¹

¹⁰ United Nations University, "UN Warns of Rising Levels of Toxic Brine as Desalination Plants Meet Growing Water Needs," *Phys.Org* (blog), January 14, 2019, <https://phys.org/news/2019-01-toxic-brine-desalination.html>.

¹¹ David Talbot, "Desalination out of Desperation," *MIT Technology Review* (blog), December 16, 2014, <https://www.technologyreview.com/s/533446/desalination-out-of-desperation/>.



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Fig 5. Energy consumption by type of water treatment approach and salinity level. The wide range in estimates is attributable to variations in plant configurations and age, both of which can have impacts on the efficiencies of the process.¹³

There are currently 19,744 desalination plants in 150 countries worldwide, with 300 million people relying on desalinated water for some or all of their daily needs. Both the number of facilities and the scale of the water capacity they process has increased significantly in recent years, with the latter having grown 26% in 2016-2017 alone and tripled since 2000.¹⁴ The growth in the industry and nearly half of global desalination plants are located along the coastal areas of the Middle East, but with few regions untouched by increasing water scarcity, desalination proliferation is widespread throughout the world. (Fig. 6). Most desalination plants around the world process primarily seawater, with the U.S. the only country that produces a majority of brackish water within their plants (Fig 7.). The following seawater desalination projects in Australia, California and Israel provide case studies

¹² Talbot.

¹³ David Talbot, "Megascall Desalination," Review, *MIT Technology Review* (blog), March 2015, <https://www.technologyreview.com/s/534996/megascall-desalination/#comments>.

¹⁴ "Dynamic Growth for Desalination and Water Reuse in 2019," *World Water*, February 2019, <https://idadesal.org/dynamic-growth-for-desalination-and-water-reuse-in-2019/>.

representative of many of the ways desalination plants come about and the challenges they pose to the environments and municipalities that host them.

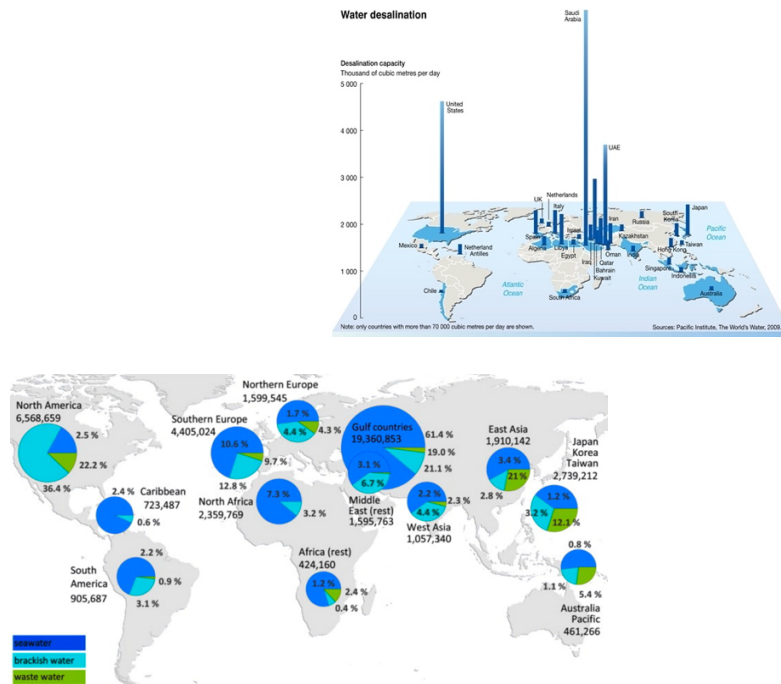


Fig 7: Global desalination distribution by type of water source processed. Relative size of the graph and numbers next to regional names represent the number of cubic meters of water processed annually through desalination facilities in that region.¹⁵

¹⁵ "Desalination Market Outlook," *Yates Environmental Services* (blog), February 26, 2013, <https://yatesenvironmentalservices.wordpress.com/2013/02/26/desalination-market-outlook/>.

Precedent: Victorian Desalination Plant (Australia)

Site: Wontaggi, Australia- Victoria- 130km from Melbourne

Developer/Architect: ARM Architecture

The architectural award-winning Victorian Desalination Plant is a massive complex of 29 buildings covering 93 acres on the coastal area of the Bass Strait roughly 130 kms from Melbourne. The complex sits within a larger 650-acre site designated for a long-term ecological restoration into a coastal park and thus the approach to the project design included consideration for the plants' existence within a larger interactive space beyond it's purely functional water desalination role. Developed through a public private partnership at a total cost of \$9.5 billion AUD, at the time of it's development in 2009 the Victorian Desalination Plant was the largest public sector investment in water infrastructure in Australia's history. The project was designed to supply up to 60% of Melbourne's annual water supply, with projected processing of 150 billion liters annually. It was built with the potential to scale up operations by 30% should demand require and the primary pipeline feeding the plant has the capacity to pump up to 200 billion liters annually. The main processing facilities within the complex are topped with a green roof which dampens the significant noise of the pumping equipment, provides thermal insulation, and, in response to significant public opposition to the project, obscures the facility from the view of the main road.¹⁶ After completion in 2012 the plant sat idle for 5 years and delivered its' first water to residents in mid 2017. It has been called into operation only intermittently since that time.

¹⁶ ARM Architecture, "Victorian Desalination Plant," n.d., <http://armarchitecture.com.au/projects/victorian-desalination-plant/>.



The green roof and low elevation from the landscape obscures the view of the facility from the road and the coastline. The desalination facility is situated within a larger ecological park that Wonthaggi residents traverse on dedicated trails and pathways. According to the architect, the overall design is intended to evoke the hills that historically existed on this site before agricultural development flattened the land.



Images of the interior of the main processing facility and operational offices lobby.
 Images sources: <http://armarchitecture.com.au/projects/victorian-desalination-plant/>

The intention of the project was to provide Melbourne with a consistent, rainfall independent source of water. The Victorian Desalination project was conceived in 2007 along with 6 other desalination facilities as part of a broader water intervention strategy to deal with water scarcity issues throughout Australia and especially pronounced in Victoria State. An ongoing drought starting in 1996 reduced water reservoir reserves to less than 25% of their capacity. Referred to as the

Millennium Draught, the 16 year dry-spell represented the worst in Australian history and brought on significant decreases in agricultural output and prompted government mandated implementation of severe restrictions on domestic water usage.

Despite the prolonged and severe impacts of the drought and the carefully considered architectural design, the Victorian Desalination Plant project faced substantial public resistance and backlash. Cost estimates for the construction of the project were continuously revised up over time and the share of the ongoing operating costs that would be passed along to consumers also continued to rise as the scope of the project became more defined. Environmental groups voiced opposition after a 2008 study by the Water Association of Australia found that when modeled alongside other water sourcing alternatives desalination was the most energy-intensive option, and if desalinated water became the primary daily source it would increase per person energy consumption rates by 400% over their levels at the time. In response to the pushback, the government scrapped plans for additional desalination facilities and implemented a benchmark that operation of the Victorian plant would be triggered only when existing reservoir reserves dropped below 60% of their capacity. Upon completion of the project in December 2012, local water reserves sat at 81% after increased rainfall, and remained above the threshold until mid 2017. Under the defined operating agreement with the private partner, AquaSure, Victoria taxpayers remain obligated to pay \$1.8 million AUD per day (\$600 million annually) for the desalination plant, regardless of whether or not it produces anything. Meanwhile, as the Millennium Drought and its impacts fade from memory, Melbourne and other cities throughout Australia have seen domestic water usage creeping back up,

increasing the likelihood that the Victorian plant will be called into action more regularly and triggering talks that capacity may even need to be increased to its full 200 billion liter maximum.¹⁷

Precedent: Carlsbad Seawater Desalination Plant (California, USA)

Site: Carlsbad, California

Developer: IDE Technologies (Development entity of Israel Desalination Enterprises)



Aerial view of the Carlsbad Seawater Desalination Plant

Image source: <https://www.ide-tech.com/en/>

Inaugurated in 2015 after 14 years of planning, the Carlsbad Seawater Desalination Plant is a RO facility situated on a 6-acre coastal plot in San Diego County. The 100 million gallons of water processing capacity produces up to 54 million gallons of freshwater per day, making Carlsbad the largest seawater

¹⁷ Adam Carey, "Melbourne's Dwindling Water Shortages Could Trigger Maximum Order from Desal Plant," Newspaper, July 19, 2017, <https://www.theage.com.au/national/victoria/melbournes-dwindling-water-storages-could-trigger-maximum-order-from-desal-plant-20170718-gxdois.html>.

desalination plant in the Western Hemisphere. This staggering amount constitutes just 10% of San Diego County's water demand. The Carlsbad plant draws water from the Pacific Ocean where it first passes through the adjacent Encina Power Plant as a coolant. The water then flows to the desalination plant where it is forced through the RO membranes, channeling freshwater out to a reservoir and discharging the brine (after a slight dilution) back into the Pacific (Fig. 8).¹⁸ The Encina natural gas power plant was decommissioned in 2018 and until the replacement facility is built on the same site the desalination plant continues to operate without this step.

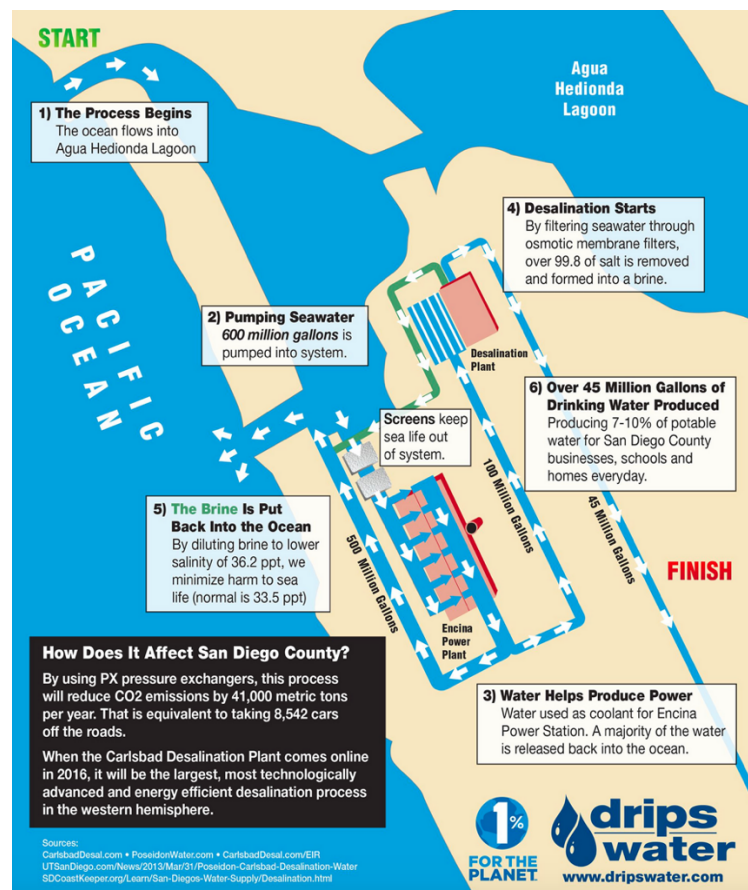


Fig 8. Diagram of the Carlsbad Seawater Desalination Plant process

¹⁸ Talbot, "Desalination out of Desperation."

Unlike some facilities used only for back-up water supply, the Carlsbad plant was conceived to work continuously as a daily provider of water and contains multiple layers of membranes and back up pumps for redundancy. As a result, it has an energy consumption rate towards the higher end of desalination facility averages (approximately 28 kWh/ cubic meter of water pumped). This translates into 35 megawatts of energy consumption annually, or the annual amount necessary to power 30,000 California households. On top of the \$1 billion for the plant's construction, it incurs an annual energy bill of \$30 million. All these factors together mean that San Diego County pays 80% more for the Carlsbad desalinated water as compared to the treated water brought in from sources outside the county.¹⁹

But, San Diego County and the state of California more broadly face smaller and smaller water reserves on which to draw and desalination increasingly features in conversations about how to address the state's water scarcity issues. Agricultural activity within the state comprises roughly 80% of the total statewide water consumption and inefficient irrigation practices mean California farms rely almost entirely on groundwater reserves when rainfall is low. Nearly 80% of the aquifers serving California are classified as "stressed" and contain too little water to keep up with demand (as shown above in Fig 2). Coupled with successive years of drought level rainfall dating back to 2010, California has implemented water use restrictions and increased attention and dialog around expanding desalination facilities. This is neither a quick nor uncontested intervention. Opponents in the state cite amongst their objections the high up front and ongoing cost of desalination facilities as well as

¹⁹ Talbot.

the disruptive effects on marine ecosystems created by the pipelines. Some California municipalities who built desalination facilities years ago with less efficient configurations than what is technologically available today have since abandoned the plants as energy costs rose and updating to viable efficiency levels was deemed too cost prohibitive.

Precedent: Sorek Desalination Plant (Israel)

Site: Sorek, Israel- 10 miles south of Tel Aviv

Developer: Israel Desalination Enterprises (IDE)

The Sorek Desalination plant became operational in 2015 and is the largest desalination facility in the world. The plant is one key element within Israel's broader governmental response to a regional water crisis brought into acute visibility in 2008 by the effects of a decade long drought. At that time, Israel's largest source of freshwater, the Sea of Galilee (a freshwater lake), had dropped to within an inch of the level at which it would have caused irreversible salt infiltration to the surrounding agricultural land, significantly compounding the damage of the prolonged drought. In 2004, Israel relied entirely on groundwater and rainwater for its domestic supply, and since making a commitment to desalination in 2005 the amount of desalinated water the country produces and the share of water that comes from desalination has steadily increased (Fig. 9). Sorek is one of five desalination plants in Israel, with two more contracted for construction. With Sorek's addition, Israel now gets 70% of its total water supply, and 55% of its domestic water from their desalination facilities.²⁰

²⁰ Rowan Jacobsen, "Israel Proves the Desalination Era Is Here," *Scientific American*, July 29, 2016, <https://www.scientificamerican.com/article/israel-proves-the-desalination-era-is-here/>.

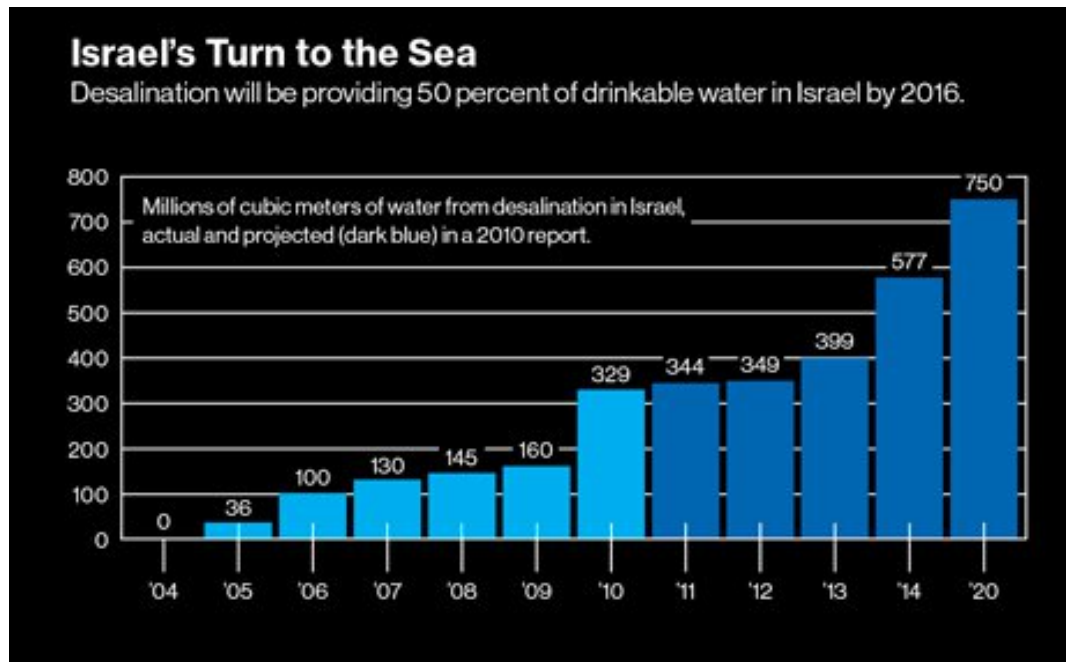


Fig 9. Since 2004 Israel has embraced desalination as a key element in their attempts to address the water scarcity issues plaguing them and their neighbors in the region.²¹

Sorek is a reverse osmosis (RO) facility that engages a number of techniques and technologies to mitigate the downsides and challenges of the conventional RO desalination process. First, to address the issue of high ongoing operational costs due to significant energy use, Sorek uses pressure tubes double the diameter of the conventional 8-inch tubes. In conjunction with the high efficiency pumps and recovery devices, this means that more water can pass through the membrane with less energy expenditure.²² Secondly, Sorek implemented a locally sourced intervention to deal with “biofouling”. Usually over time the polymer membranes accumulate a buildup of microorganisms from the seawater, which inhibits the passage of water through the membrane. This decreases the efficiency of the process and adds cost as the membranes need to be regularly replaced. Instead, Sorek uses a

²¹ Talbot, “Megascale Desalination.”

²² Talbot.

chemical free process of placing porous lava stone in front of the membrane, trapping the microorganisms before they reach it, thereby prolonging the life of the costly membrane and maintaining the efficiency of the water passing through. Finally, Sorek has developed a system for dealing with the problematic high salinity brine generated as a waste product of the desalination process. The brine is piped 100 miles north, through Jordan and deposited into the Dead Sea. Since the 1960's when Israel and Jordan diverted the only river that fed the sea, the water levels have been dropping a meter per year. The replenishment with the Sorek brine aims to bring these levels back up. Though the highly concentrated salty brine can be problematic for many marine ecosystems, the naturally high salinity of the Dead Sea means that the marine ecosystem already adapted to very high salinity levels and is less disrupted by the addition of the brine.²³

Construction of the Sorek Desalination facility cost \$500 million USD, but because of the noted interventions, it generates the cheapest water from seawater desalination produced in the world and is able to profitably sell water to the Israeli water authority at a cost of approximately \$0.58/cubic meter-the approximate amount the average Israeli consumes in a week.²⁴

Israel's handling of their water crisis, and wholesale embrace and commitment to desalination has the potential to transform the region, as Israeli neighbors naturally grapple with the same water scarcity challenges. Iran, Iraq, Syria and Jordan suffer under the same water scarcity conditions as Israel but lack the

²³ Jacobsen, "Israel Proves the Desalination Era Is Here."

²⁴ Talbot, "Megascall Desalination."

political will and stability necessary to implement effective interventions to address it. Israel's current desalination project pipeline has them on track to generate a surplus of water through their desalination efforts that could serve to assist neighboring countries.

Takeaways from these precedents

All three of these desalination projects came about in response to prolonged drought and declarations of suffering from water scarcity, but this latter aspect is a relative term. Water scarcity is a function of whether a place has access to adequate water to meet their demand, and not necessarily their innate need. California, Victoria State, Australia and Israel have drastically different water consumption rates owing to different lifestyles. Both Australia and Israel implemented drastic government mandated water restriction and monitoring policies for domestic use and as a result decreased household consumption by 37% and 40% respectively. This indicates that within the context of most developed countries, water demand presumably contains a cushion related to habitual use rather than true need. Given the significant economic and environmental costs presented by these three cases, desalination as practiced today should reasonably be considered an intervention of last result and not the panacea. Technological advancement may address the key challenges of energy consumption and brine disposal that challenge desalination today.



Fig. 10: Profiled desalinization plants superimposed on site. (Left) Victoria, Australia desalination facility (78 acres ; (Middle) Sorek, Israel desalination plant (55 acres), (Right) Carlsbad, California desalination plant (9 acres). Images by author.

Chapter 3: Florida's Land Formation

Defining South Florida

From its inception as a part of this experiment known as the United States, Florida has been a frontier of speculation and voracious pursuit of wealth accumulation. The Southern part of the state in particular drew settlers with the promise of coastal land ripe for exploitation. The rapid development of the southern part of the state and seemingly miraculous wealth amassed by a notable few earned Miami the moniker of Magic City that has stuck with the city to this day.

Indigenous tribes such as the Seminole and Miccosukees inhabited the territory now defined as Florida for at least 12,000 years before the 1510 invasion of the territory by European settlers. Wars fought over control of the land in the subsequent 300 years forced the native population from the ecologically rich and economically lucrative coastal areas to the interior of the Southern Everglades, and dwindled the native population from 200,000 to a mere 1,500 inhabitants in the state today. The Spanish ceded the territory- and the ongoing conflict within it- to the United States in 1819. The U.S. Navy established military outposts and continued their attacks through the Second and Third Seminole Wars, with the native populations putting up a dogged fight. Florida joined the Union as a slave state in 1845, and nearly half the population of the time were African-Americans but development remained slow as potential residents were kept away by the ongoing fighting. However, the passage of the 1862 Homestead Act and the land ownership

opportunities it promised drew Northern white transplants in droves that vastly accelerated the growth of what would become Miami.

Carbon-dating of human made artifacts found in Southern Florida date human presence in the territory to the Paleolithic era 14,500 years ago. Land and ice formations at that time would have required these hunter-gatherers to arrive in the territory by a lengthy boat journey, indicating that these settlers possessed well-developed understanding of ocean currents, navigating coastlines, and perhaps most essentially for survival- the creation and storage of potable water.²⁵ This hydrological understanding was essential, as the timeline of the settlers' arrival coincides with the start of the melt of the last ice age and the begin of a 350 year period of dramatic, and swift sea level rise. For the low-lying, flat terrain of Southern coastal Florida, this meant the settlers watched as the seas crept inland at an estimated 500-600 feet per year, consuming a mile of coastline each decade.²⁶ While indications are that many settlers abandoned or were wiped out as a result of the inundation, groups such as the Calusa remained for centuries and, in tandem with the water, shaped the land formations we confront today in the region today.

Middens- or the domestic waste sites associated with these early human settlements- compacted over time to form the oolitic limestone that is the land of Southern Florida, and Miami in particular. The four unmistakably man-made landforms floating in Biscayne Bay just off the Western shore of Miami Beach are the luxury enclaves of Sunset Islands. They were created in 1952 using the same

²⁵ Jeff Goodell, *The Water Will Come : Rising Seas, Sinking Cities, and the Remaking of the Civilized World*, First edition. (New York ; Little, Brown and Company, 2017), 19.

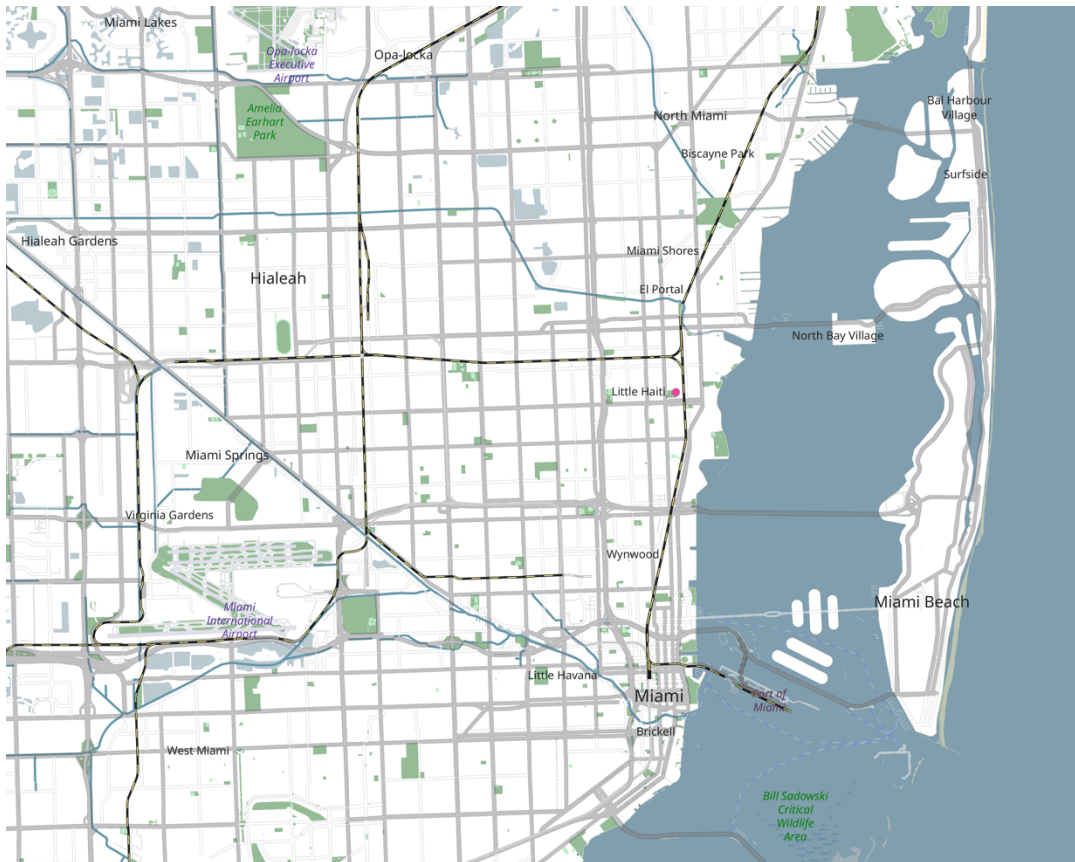
²⁶ Goodell, 19.

technique the Calusa used centuries before- dredging up salty mud, piling it high, creating a wall around the perimeter to keep the tides from washing it away as the sun dried it out.

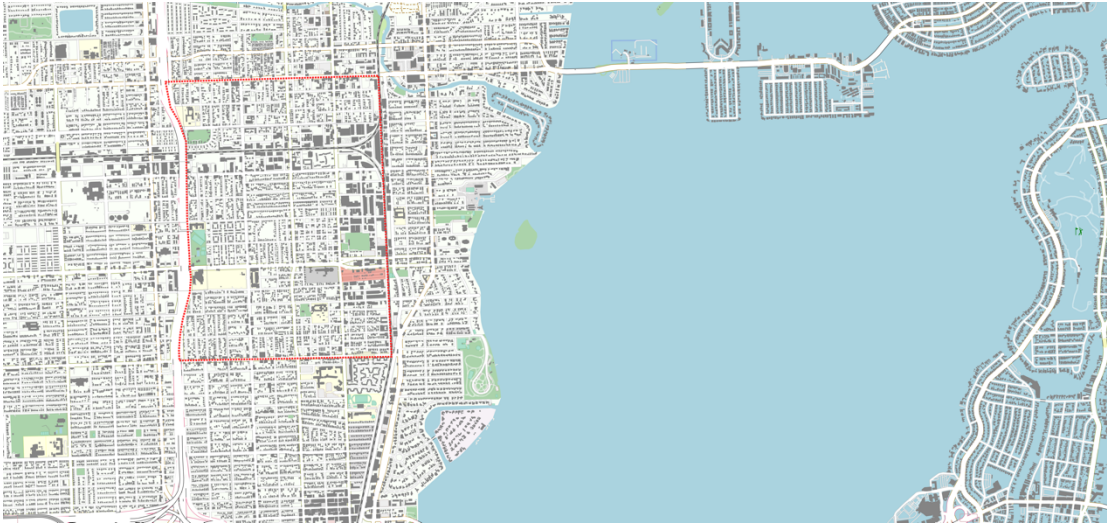
Chapter 5: Site Analysis

Location and Physical Site Conditions

The focal site is a rectangular 17 acre plot of land at the eastern edge of Little Haiti, bounded by NE 62nd street on the north, NE 60th street on the south, NE 2nd avenue on the west, and the train tracks parallel to NE 4th court on the east. The eastern edge of the site sits just 0.46 miles (2,408 feet) from the current waters' edge of Key Biscayne, at an elevation of +11 feet above current sea level.



Map of Miami with site location identified. Image created by author.



Site Location: Boundary of Little Haiti outlined in red with the focal site highlighted in pink. Image created by author.



Aerial view of site. Underlying image courtesy of GoogleEarth.

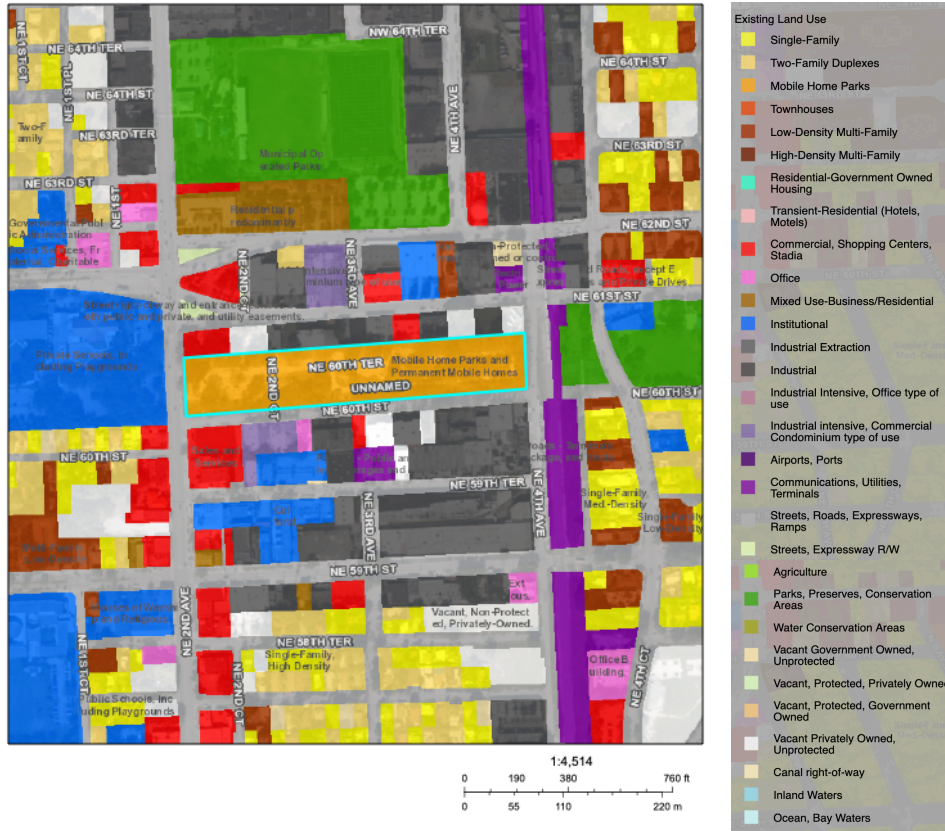
The topography of the site is generally flat with many old-growth trees of various palm, ficus and pine species, as well as live oaks and Black Ironwood trees. Except for the small single-story commercial/light-industrial buildings fronting NE 61st Street, the site is currently unbuilt and features patchy grass that reveals sandy soil and large, crumbly grains of the characteristic Miami oolitic limestone. Despite adjacency to the relatively busy throughfare of NE2ndnd Avenue and the train tracks, the site is notably quiet, with the trees providing a buffer that makes the site feel set apart from the surrounding urban fabric.



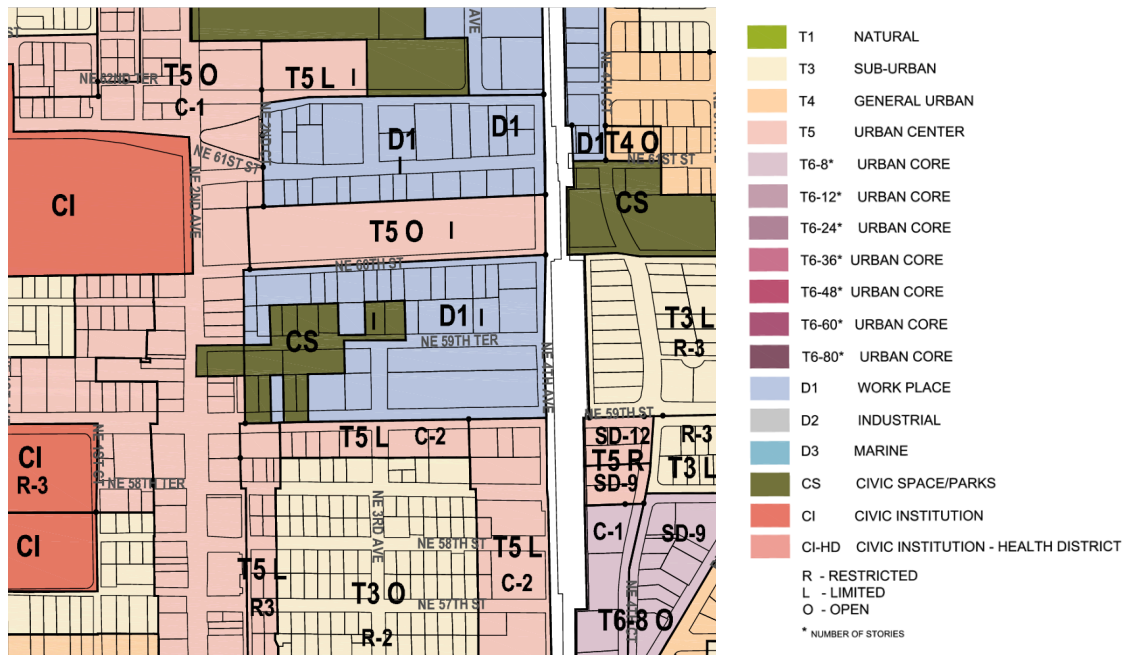


Site images taken by author.

The site is currently surrounded by an eclectic mix of building scale and uses.



Current Land Use on and around site: The site area currently features an eclectic mix of building scales and uses.



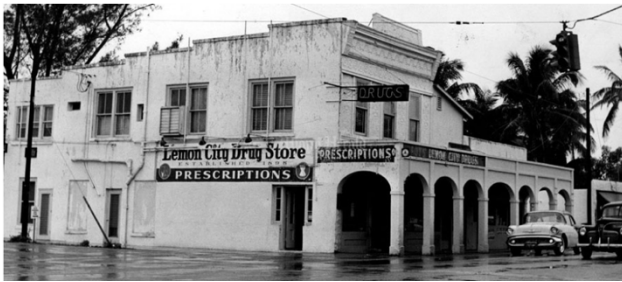
Zoning on and around site: The Miami21 zoning code put in place in 2012 shifted from a Euclidean to a form-based code that allows for greater density as the site area is re-developed.

Socio-Cultural Site History

The site holds historic significance dating to the founding days of the city of Miami, and tracing the history of the area provides a snapshot of the social, cultural and economic development of Miami at large. The area now known as Little Haiti was originally dubbed Lemon City, and with it's roots dating to the 1850's, is the oldest continuously settled area in Miami-Dade County. While rampant speculation made land cost-prohibitive in the quickly growing city of Miami, blue-collar workers could acquire land just north of the city for free through a Homestead Act application. Though the area was wild and challenging to develop, the Little River provided a water source that made it attractive to exploit the land for agricultural use. Black Bahamian settlers accustomed to farming on the rocky limestone soil helped white land owners cultivate crops, with the native Florida coontie roots to make arrowroot

starch chief among the exports. The close proximity to the port at Key Biscayne allowed for easy access to shipping of agricultural products grown in the area. By 1870, the settlement had taken shape as a working-class enclave of mixed races and boasted a population of over 1,000 people. Henry Flagler's extension of the East Coast Railroad into Miami and the 1896 construction of the Lemon City Train Station between NE 59th and 60th streets increased Lemon City's connection to Miami and further afield. The rail depot that sat adjacent to the focus site became the locus of community development and activity and catalyzed many of the defining structures of the district.

The vacant structure currently standing on the sites NE 61st Street and NE 2nd Avenue corner was built in 1898 by prominent community member and doctor Dr. John Gordon DuPuis. The structure functioned until 1955 as the community drug store, medical practice and community anchor. Notably, it was the first concrete building constructed north of downtown Miami.



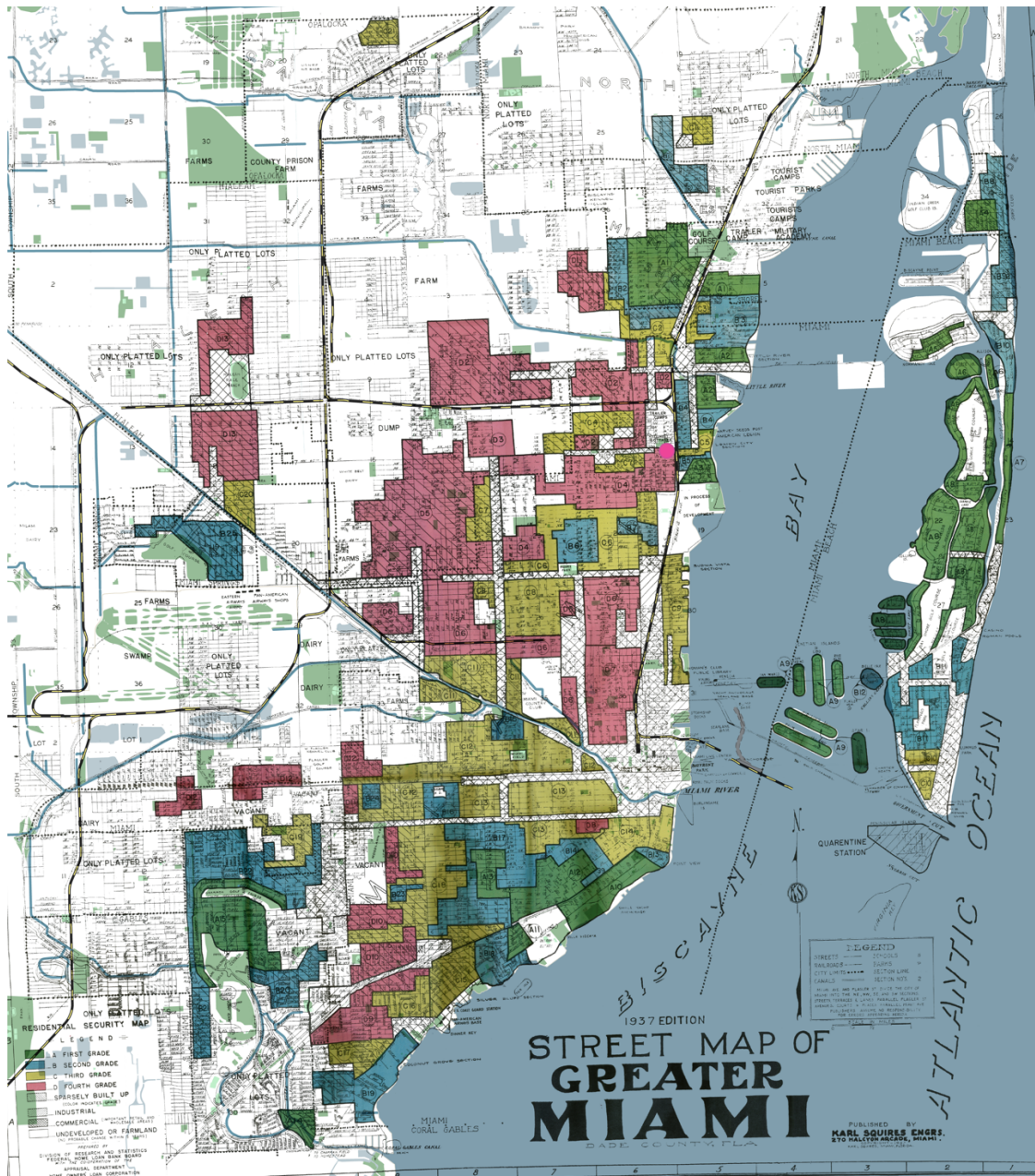
The former Lemon City Pharmacy at the corner of NE 61st. Street and 2nd Avenue, circa 1940 and present day. Historic Image courtesy of [http://flashbackmiami.com/2014/07/16/lemon-city/#lightbox\[group-3061\]/30/](http://flashbackmiami.com/2014/07/16/lemon-city/#lightbox[group-3061]/30/) Present day image by author.

As the community grew through the 1890's, local schoolteachers and prominent community members (Dr. DuPuis among them) established what is now Miami-Dade's oldest library just adjacent to the train depot. The original wood-frame building was inaugurated in 1905 and was replaced by a modern concrete structure that houses the library today.

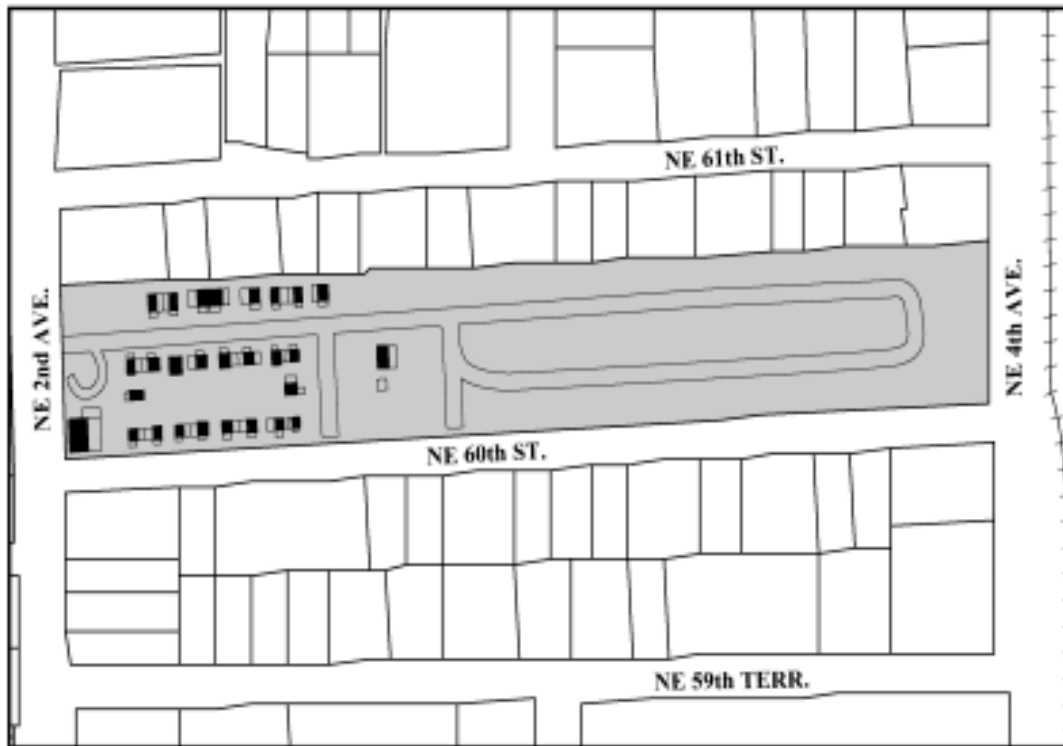
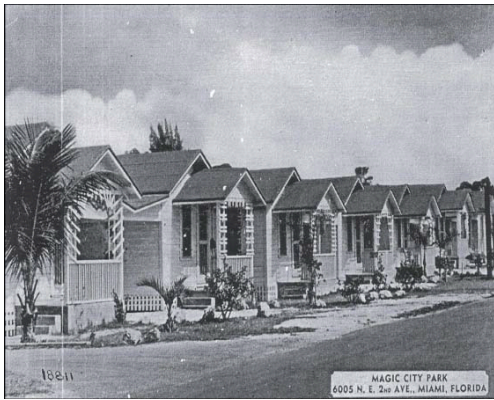


Original Lemon City Library in 1962, with the newly constructed (and current) library building visible in the rear.

Lemon City thrived through the 1920's with the arrival of industrial facilities for agricultural processing serving as the economic backbone of the community. Many of these factories relied on the inexpensive Black labor, and as the Black community in the area grew, white members began to depart, particularly in the post- WWI era. By the 1940's Lemon City was a majority Black community and alongside redlining the community declined.



1938 redlining map superimposed on current map with site identified. By Author.



Magic City Park. The vernacular wood structures of the "tourist court" that inhabited the western portion of the site (as shown on map). These were popular accommodations for visitors in the 1920's and 1930's, and the shared the site with the transient mobile homes that set up camp along the eastern portion of the site. Petition was made in the early 2000's for historic designation and protection of the vernacular structures (then still intact), but they were later demolished, leaving the site in it's current unbuilt state. Images circa 1945 (left) and 2002 (right).²⁷

²⁷ Aileen de la Torre, Sarah E. Eaton, "MAGIC CITY PARK 6001–6005 NE 2ND AVENUE Designation Report" (City of Miami Historic and Environmental Preservation Board, n.d.), <http://historicpreservationmiami.com/pdfs/magic%20city.pdf>.

The first waves of the Haitian migration to Miami occurred in the late 1960's after a political coup ushered in a dictatorial regime. By 1973, the community had begun to settle in the former Lemon City due to the affordable rents and available housing stock. The 1980's and early 1990's saw even larger waves of Haitian migrants arrive and by 2000 the largest Haitian diaspora in the United States had taken root in Miami. The concentration of the community formed around the Notre Dame d'Haiti Catholic Church (adjacent to the site) and Lemon City had become known colloquially as "Little Haiti". Despite the political violence and instability faced at home, the vast majority of arriving Haitian migrants were classification as "economic migrants" and thus not eligible for asylum or other statuses that might confer pathways to citizenship and/or permanent residency statuses. Perhaps because of the persistent threat of needing to return, the ties to Haiti as "home" remained strong and social and cultural cohesion in Little Haiti was robust.

As more severe storms and awareness of the threats of sea level in Miami have become increasingly unable to be ignored, the relative high elevation of Little Haiti has made brought it onto the radar of developers looking for prime real estate at a lower risk. Since 2016 Little Haiti as seen rents and property values grow exponentially. A 2018 Harvard study identified the neighborhood as undergoing "climate gentrification", which was identified as an increase in property rates driven by an areas' relatively favorable conditions for climate change adaptation or

resilience.²⁸ As deeper-pocketed developers have arrived with lucrative offers for landlords in Little Haiti, many residents and business owners have been unable to keep up or benefit from the rising rents and have been forced to relocate.

Ecological and Environmental Site Character

The site's relatively high elevation (+11 feet), given its close proximity to the Key Biscayne waters' edge (0.46 miles), is of important note in understanding the ecological and economic value it holds. A site visit conducted during the rainy season (July) within hours of a heavy rainfall showed minimal standing water on the site itself, while surrounding streets still contained water high enough to inhibit passage of pedestrians and low vehicles.

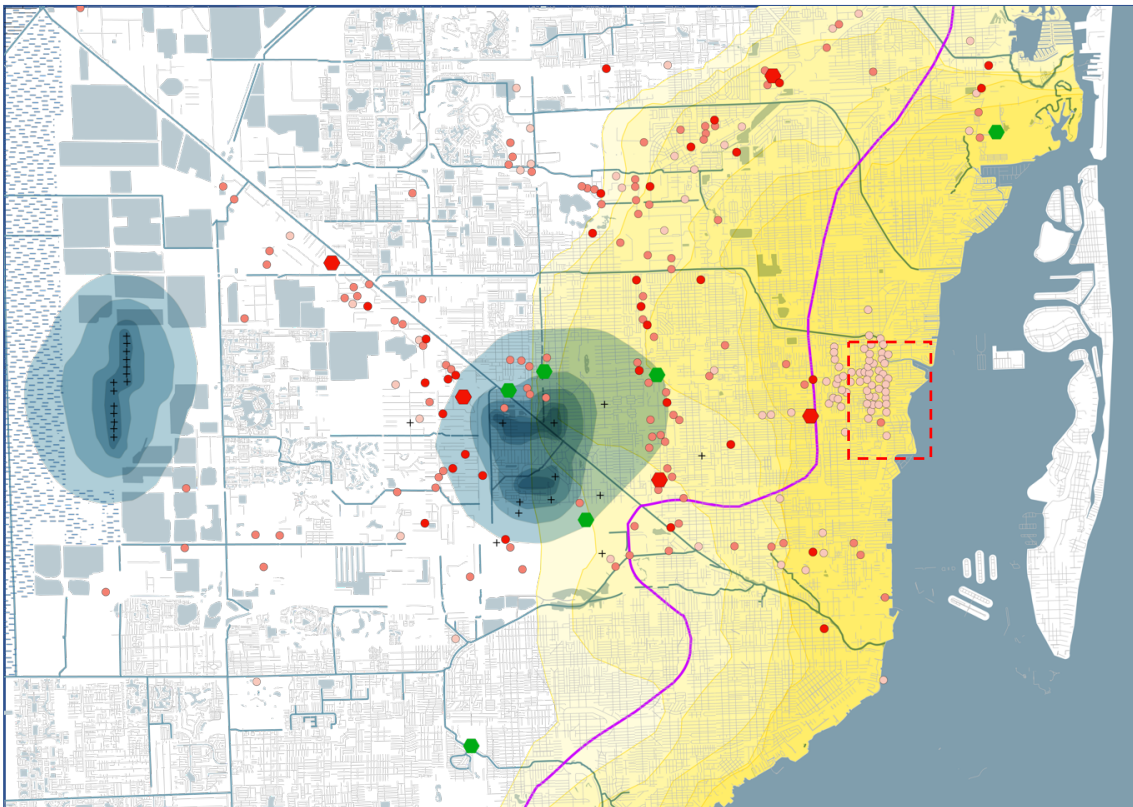


Curb height standing water along the streets near the site. Images by author.

²⁸ Jesse M. Keenan, Thomas Hill, and Anurag Gumber, "Climate Gentrification: From Theory to Empiricism in Miami-Dade County, Florida," *Environmental Research Letters* 13, no. 5 (April 2018): 054001, <https://doi.org/10.1088/1748-9326/aabb32>.



Based on modeling of projected buildings at risk with 3ft of sea level rise, the site remains safe from catastrophic flooding (Site location in blue)



Dating to the areas industrial past, Little Haiti (dashed red line) sits on a dense cluster of unmitigated superfund sites (pink dots), as well as within the saltwater intrusion zone (yellow). The combination leads to a high risk of contamination of the local ground water.

Chapter 7: Design Proposal

Site Strategy and Design Drivers

The approach to site development drew inspiration from the Haitian concept of the Lakou. In Haiti, the Lakou is a communal unit of extended family member living and working collectively to function as a self-sufficient unit. The concept grew out of the Haitian post-colonial period when formerly-enslaved peoples sought to establish their lives without reliance on the state and organized themselves around family resource sharing. The Lakou is considered a symbiotic intersection between the land, family, and spirituality. In rural and traditional settings the community would have a spatial arrangement of housing and gathering structures centered around a Mapou tree as the totem of this spiritual connection. To present day and in settings from rural to urban, the concept of Lakou remains powerful as indicative of working communally and collaboratively for mutual benefit, and in reverence of the land and ancestors. In creating a work of water infrastructure in symbiosis with the landscape and for the benefit of the local community, the concept of the Lakou is translated to a unique expression.

The building massing drew influence from the recognizable form of the repetitious arches of ancient aqueducts. The site structure and visibility from all sides necessitated consideration of the views of the building from the car and as an 360 degree object building. The building forms is made dynamic with an undulating roof

that gradually steps down as the arches repeat in the long direction. This references the form and gravity-fed nature of traditional aqueducts in a distinctly modern form. The concrete structure creates a pavilion like structure for the public space while a translucent curtain wall volume inscribed inside houses the essential functions of the desalinization operations.

The reverse-osmosis desalinization facility creates a shaded public thoroughfare and sits within a site plan that also hosts a constructed wetland, plaza with splash pool, evaporative salt production pools, a water tower and pump house, and shaded elevated pathway for fluid movement through the site. The site plan arrangement prioritized sustaining the old growth trees on the southern portion of the site, minimizing additional site disruptions by utilizing the foundations and footprints of the current buildings on site, and creating a building massing that activated the site for public use while housing and revealing the inner workings of the desalinization functions. The water inlet point for the desalinization plant was placed at the shore of the Key Biscayne at the location of the historic Lemon City Port and piped underground to the site. The water is revealed on site in a constructed wetland that utilized the existing building footprints and is populated with salt-tolerant and salt-sequestering plants that aid in the pre-filtration process for the reverse-osmosis process. As the water filters into the building, users can proceed through the covered colonnade that serves as the front-porch of the structures, providing a sheltered pathway and public gathering place. There are views into the interior workings of the plant through the translucent curtain wall, which also helps the building function as a lantern after dark. The open plaza on the northwest portion of the site features a

shallow splash pool paved in oolitic limestone, making visible the material commonly covered up by the structures on top. A 150' tall water tower marks the western edge and entrance to the site, and the historic DuPuis pharmacy is repurposed as a pump house serving the water tower. Arms extending out from the base of the water tower make reference to the dramatic and figural roots of the Mapou tree around which the Lakou traditionally takes shape. Pedestrians can proceed through the southern portion of the site along an elevated ground plane, that meanders between the old-growth trees sustained on the site. The wood decking of the pathway refers to the wooden vernacular structures that historically sat on this portion of the site in it's previous use as a tourist park. From this vantage point, users gain views of the buildings' southern elevation/colonnade with the shallow constructed pools of salt water in the foreground. Although the site is officially outside of a floodplain, observed pooling on the site indicates that periodic and significant flooding does occur. The generally unbuilt nature of the site makes it an essential resource for storm water management and rain-water catchment. The creation of an elevated walkway, rather than hardscaping at ground level preserves the undisturbed ground for absorption of runoff while allowing uninterrupted pedestrian access through the site. The highly concentrated salty brine that is a byproduct of the reverse osmosis process is revealed and celebrated on the site as it undergoes a productive process. As the water flows through the salt pools, it undergoes a passive solar evaporative process, leaving behind a salt product able to be used in many industrial functions. The overflow water gathers in a pool toward the eastern edge of the site where it

enters an underground pipe that conveys it out 61st street for release into Key Biscayne.

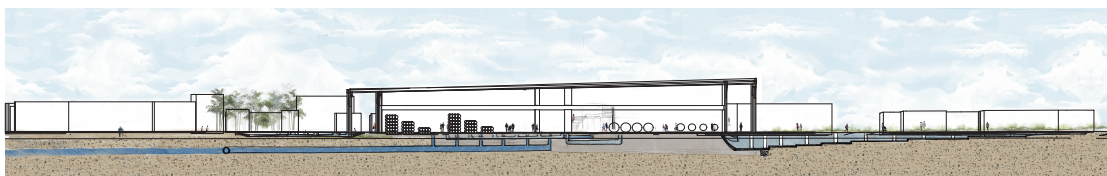
Design Representation



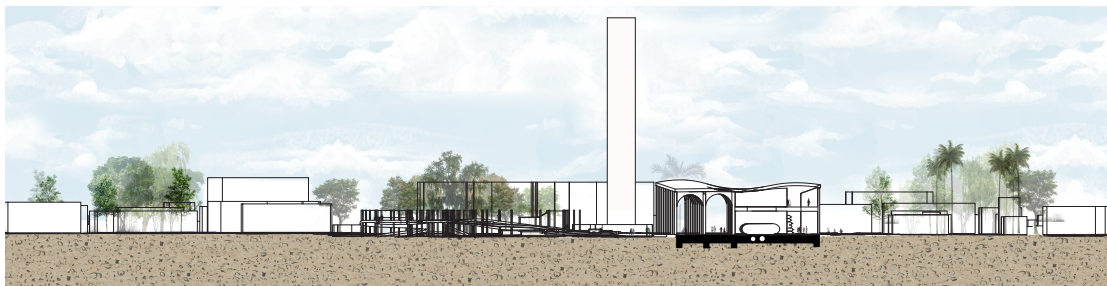
Site plan



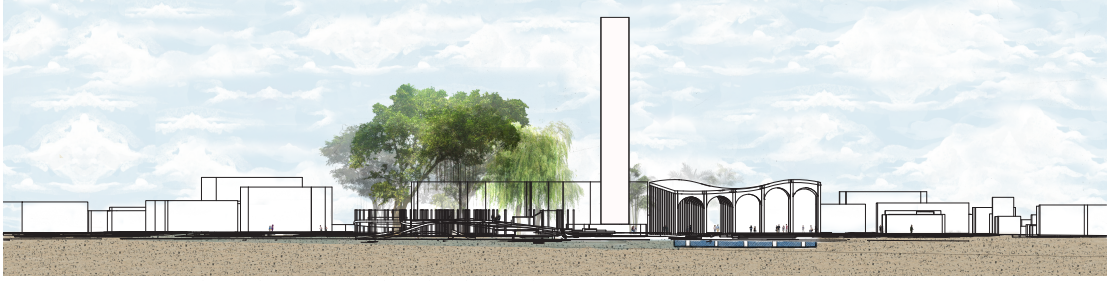
Longitudinal Section through walk way and South Elevation



Longitudinal section through building looking north



Transverse section through building looking west towards water tower.



Transverse section through constructed wetland east elevation.



Site approach from east with view of users proceeding through the constructed wetland and the salt garden visible on the left.



Site approach from west with view of the Mapou water tower and historic DuPuis Pharmacy repurposed as a pump house for the water tower.



Approaching the building colonnade from the west plaza.



View of the south elevation of the building and salt pools viewed from the elevated ground plane meandering through the sustained old-growth trees.

This design proposal creates a monumental work of infrastructure embedded within Little Haiti that simultaneously activates and establishes a community amenity and much needed public space. The integration of the building with the landscape and the preservation and reverence for the existing natural infrastructure on site (old-growth trees) models a more symbiotic relationship of built and ecological functions in an urban setting. The inspiration of the Haitian Lakou in creating this productive, self-sufficient landscape imprints the cultural significance of the community on this site as an enduring marker, and a hopeful anchor of community resilience through our most essential of elements- water.

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