Aquatecture: Architectural adaptation to rising sea levels

Erica Williams
University of South Florida

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Aquitectture: Architectural Adaptation to Rising Sea Levels

by

Erica Williams

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Architecture
School of Architecture and Community Design
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DEDICATION

I want to thank those that
Inspire me,
Motivate me,
Believe in me.
This one is for you.
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Our world is drastically changing. Temperatures are rising, skies over cities are blanketed with smoke, and melting glaciers are raising sea levels at alarming rates. Although the destruction we face is already threatening the quality of life for billions around the world, it could just be the beginning. What is projected to come in the future could be catastrophic.

It is crucial to realize that climate change is already happening. One of the main concerns relating to climate change is that as the polar ice caps continue to melt, rising water will invade our coastal cities around the world. In accordance with sea level projection maps, sea levels will rise 20 feet\(^1\), and major cities like Miami, Shanghai, Calcutta, and Manhattan will be completely submerged.\(^2\) We must ask ourselves: How can we avoid a mass migration as water levels invade our homes and cities?

Instead of retreating inland, adaptation strategies should be devised. This proposal will explore how homes and cities should respond to sea level increase through the implementation of a new architectural typology—Aquatecture.

Aquatecture is defined as an architectural adaptation typology used to mitigate and manage flooding (long and short term). With this typology, water and architectural design can unite to produce dynamic and reliable mitigation solutions. The main course of action involves redefining three main living systems: a home, a neighborhood, and a residential tower to resist destruction of rising water levels and to continue city-town-home inhabitation.

In addition to adaptable building design, supporting systems will be integrated throughout affected areas. Systems such as alternative energy production, alternative farming, mixed-used industry, alternative transportation, and water filtration zones will be incorporated.

With the help of Aquatecture, alternatives to abandoning our coastal cities are provided. Due to the flexibility of site location that Aquatecture allows, this intervention can serve as a long-term solution and standard of living within current and projected flood prone areas around the world.

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\(^2\) Ibid.
CHAPTER 1: THE PROBLEM
Climate Change: A Global Crisis

Our world is drastically changing. Within the recent years, climate change has become a growing concern worldwide. The various modes of destruction imposed on our environment are targeted to be the catalyst to these changes. A substantial increase in hurricane activity, noticeable fluctuations in temperature, and an influx in CO2 emissions have all been noted concerns for many.

One of the primary fears stemming from global warming is that not only will weather patterns become more severe and unpredictable, but our oceans will rise and destroy our coastlines, buildings, homes, and communities world-wide. According to climate scientists, sea level rise is "One of the most important impacts of global climate change."\textsuperscript{3} Sea level has been consistently rising over the past 100 years, and global warming is expected to increase the annual rate by two to five times.\textsuperscript{4}


\textsuperscript{4} Ibid.
Main Contributions to Sea Level Rise

The vast expanse of ice that has characterized the Arctic Ocean is predicted to "completely melt far faster than anyone has imagined, and will certainly be gone before the century is out." Current projections of sea level rise "should be of major concern for coastal zones and small islands."  

The main contributor to global sea level rise is expected to come from thermal expansion of ocean water, followed by an increased melting of glaciers and ice caps. The majority of these ice caps are located in Antarctica and "comprise about 99 percent of the world’s land ice." If the Antarctic ice sheet were to completely melt, it would be roughly equivalent to a 180-foot increase.  

The ice sheets located on Greenland are another contributor to the increase. According to Intergovernmental Panel on Climate Change (IPCC), if the Greenland Ice Sheet completely melted, sea level would rise 25 feet world-wide.  

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6 The Threat of Sea Level Rise

7 Ibid.

8 Ibid.

9 Ibid.

10 Ibid.

Figure 1.8. Satellite Image of Shrinking Ice Cap Over a Two Decade Span
CURRENT AND PROJECTED IMPACTS

Recent Flooding Triggered by Climate Change

The consequences of climate change are impacting people and communities world-wide. While many people remain unaware of the scope of climate change and sea level rise, threats are constantly being posed.

On a global scale, the numbers of climate-related incidents are rapidly rising. “On average, 250 million people a year are affected by climate-related disasters.”\(^\text{11}\) In Asia, approximately 66 million households suffered from damage or destruction of their homes by floods in 2007.\(^\text{12}\) “In November 2007, Mexico’s Tabasco state was swamped by a flood, having all crops ruined and affecting more than two million people directly.”\(^\text{13}\) In the United States, “Hurricane Katrina killed more than 1,600 people, destroyed 200,000 Gulf Coast homes, and displaced approximately 1 million people.”\(^\text{14}\)

\(^{11}\) “Number of People Affected by Climate Disaster up 54 Percent by 2015.” Oxfam America. http://www.oxfamamerica.org. (accessed


\(^{13}\) Climate Action, “The Case for Action” 2007, p.21

Future Impacts of Climate Change

As the earth continues to warm, it is predicted that average sea levels will rise between 7 and 36 centimeters by the 2050’s, and by 9 and 69 centimeters by the 2080’s. By the year 2100, sea levels are projected to be approximately 22 inches higher than they are today. An increase of this magnitude could inundate coastal areas, erode beaches and increase coastal flooding and storm surge. The destruction around the world could be devastating.

Higher temperatures are expected to raise sea level by:

- Expanding ocean water,
- Melting mountain glaciers and small ice caps,
- Causing portions of the coastal section of the Greenland and Antarctic ice sheets to melt or slide into the ocean.

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16 Ibid.
17 Ibid.
Global Impacts

As noted by the Intergovernmental Panel on Climate Change's Third Assessment Report (WG II), the current and future climate changes induced by global warming will have such impacts:

- Increased coastal erosion, higher storm-surge flooding, inhibition of primary production processes, more extensive coastal inundation, changes in surface water quality and groundwater characteristics, increased loss of property and coastal habitats, increased flood risk and potential loss of life, loss of nonmonetary cultural resources and values, impacts on agriculture through decline in soil and water quality, and loss of tourism, recreation, and transportation functions.\(^\text{18}\)

Projected Impacts on Communities

It is important to acknowledge that the affects of global warming and the increase in sea levels will not only affect coastline environments, but it will greatly affect the communities within them. With more than 70 percent of the world’s population living on coastal plains, the human and socioeconomic effects of rising sea levels will be substantial. A sea-level rise of just 20 centimeters will cause 740,000 people to lose their homes in Nigeria. “A sea-level rise of just 40 cm in the Bay of Bengal, would put 11 percent of the country’s coastal land underwater, creating 7 to 10 million ‘climate refugees’.” Seventeen percent of Bangladesh could disappear with a three-foot rise in sea level, and approximately 140 million people could be impacted in China and Bangladesh.

In the Pacific, there are growing concerns that rising seas could submerge whole island nations. Kiribati, the Marshall Islands, and the Federated States of Micronesia could lose much of their territory and face severe freshwater shortages in the years to come.

Projected Sea Levels and the United States

A significant and increasing proportion of the United States population lives within the coastal zone. “By 2100, sea levels could rise 13 inches in Los Angeles, 20 inches in Miami Beach, 22 inches in Boston, 38 inches in Galveston, and 55 inches in Grand Isle, Louisiana.”

Louisiana and Texas are already experiencing the highest rates of relative sea level rise in the U.S. “Louisiana

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20 Ibid.
23 Ibid.
loses 25 square miles of wetlands per year, due to subsidence.”

Sea level near Galveston is also steadily increasing. Though the city was designed to withstand moderate sea level rise it could not withstand the levels predicted to result from global warming. Along the Chesapeake Bay, where many beaches have already been lost, the sea is rising “more than an inch per decade.”

“In the U.S., a sea level rise consistent with IPCC’s estimates could drown more than 5,000 square miles of dry land—an area the size of Connecticut—by the year 2100.” The highest risk areas are those currently experiencing rapid erosion rates and areas at low levels, such as “parts of the Atlantic and Gulf coasts where sea level is already rising by small amounts each year.”

Climate Change: A Problem that is ‘Slow to Stop’

Tom Agnew, a research meteorologist with the Meteorology Service of Canada, states that “Global warming is linked to the greenhouse-gas emissions that humans are pumping into the atmosphere as they burn fossil fuels.” As much as we need to re-evaluate our consumption and reduce CO2 emissions, the habits formed by nations could be difficult to stop.

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26 Ibid.
29 Mitchell. “Arctic Ice Melting Much Faster Than Thought.”
30 Mitchell. “Arctic Ice Melting Much Faster Than Thought.”
Even if global greenhouse gas emissions are stabilized, nearly all projections show that sea levels will continue to rise beyond the year 2100 due to delay in climate response.  

It is believed that even if we eliminated all greenhouse gas emissions today, “We have already bought decades of climate change impacts.” Over the course of decades the environment has been slowly destroyed. As research meteorologist Tom Agnew states, “This change is already taking effect; the whole system is very slow to start and also very slow to stop.” Due to the current circumstances, we should not only reduce and counteract climate change, but we should prepare for worst-case scenarios.

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31 Ibid.
33 Mitchell. “Arctic Ice Melting Much Faster Than Thought.”

Figure 1.7. Tom Agnew Quote Discussing the Severity of Climate Change
Devising a Plan: Project Goals

We should be at a time of great concern. With catastrophic scenarios posing a threat to billions of people and communities around the world, it is crucial that defense strategies against devastation are prepared.

The main goal and intent of this proposal, is to provide long-term solutions to flooding and rising sea levels for coastal cities. By taking into considerations the risks created by rising water levels on a short term and long term (climate-change) scale, the predominate questions to be answered are: Where will people go when the water rises? How can people continue to live in coastal cities in spite of the threats that inundation poses? What will happen to homes, to cities—to architecture?

Strategies must be implemented to make populated, economic and city infrastructure “climate proof.” Adaptation strategies should be focused within ‘hot spots’, which are areas that are highly vulnerable to the impacts of climate change—areas with high human, social, and economic activity.

If the areas that are currently threatened by rising sea levels start to plan and invest in a variety of reliable mitigation strategies, coastline abandonment could be avoided when water levels become threatening. However, to successfully do so, architecture and city planning must start to redefine its current position.

Figure 2.1. Lifted Conceptual Diagram

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35 Ibid.
Redefining Architecture to Sustain Communities

People have an unexplainable connection and desire to live by the water—they will continue to live by water systems in spite of risk factors and threats they may pose. According to Frits Schoute, a Dutch engineering professor and advocate of living at sea, “People are still migrating to metropolises—most of which lie in coastal regions. Soon there will be these enormous pressures to colonize the sea.”36 The number of people living in world is approximately 6-billion, and it will increase to 9-billion by 2050.37

The Solution: Implementing Aquatecture

The main course of action is to avoid the destruction of communities through adaptation and the implementation of a new architectural typology—Aquatecture. Aquatecture—derived from merging water and architecture—pertains to building types and adaptive re-use strategies that mitigate and manage flood-related threats.

To successfully, counteract potential destruction and migration caused by rising sea levels, the built environment within coastal communities need to be redefined.

Step 1: Redefining a Coastal Home

Homes are a primary component in a coastal community. Without a safe and reliable place to live, people will become threatened and migrate to inland locations. To avoid this migration, it is important to redefine the current housing typology. As a first line of defense, a home that adapts with rising water will be the first step towards providing alternative, reliable, and adaptable living solutions.

Step 2: Redefining a Coastal Community

Following the implementation of a reliable and safe home, a coastal community will be redefined. The proposed water houses will be one of many components that make up the water community.

In this proposal, a micro community comprised of 40 homes will be integrated as an introduction to water community design. As the water rises, and the need increases, growth and adaptation of the community will follow. This small community of 40 homes will serve as an archetype for future communities in ‘endangered areas’ to adopt.

Step 3: Redefining a Coastal City

As the final phase of Aquatecture, city components will be redefined. As time progresses, and water rises, high-rise residential towers, bridges, city infrastructure, etc. will become

36 Ibid.
37 Ibid.
affected or unusable because of flood waters. In this case, pre-existing city infrastructure is no longer suitable for its intended use. As a result of this, adaptive re-use strategies for the building envelopes and existing infrastructure will be integrated within the city core.
CASE STUDY: INDIVIDUAL HOUSING UNIT

Project: Floating Homes, Berlin, Germany, 2002-2005
Architect: Forster Trabitzsch Architects
Location: Berlin, Germany, 2002-2003

Summary
The maritime building project by the Hamburg architect duo Förster + Trabitzsch, “Floating Homes,” affirms living on the water to be a viable option. Its material palette of glass, steel, and wood, create a tone of transparency and reflectivity to connect the living space with the surrounding water.

Critique
The home is floating on a hollow concrete pontoon system. Although this strategy is good to prevent water damage, the home is susceptible to rocking and drifting, producing possible lack of comfort and vulnerability to its users. Also, the orientation and design of the exterior creates no delineation between public and private space. This design represents itself as a home for luxury—vacation style living.
CASE STUDY: ADAPTIVE RE-USE

Project: Hotelier at Sea, Gulf of Mexico
Architect: Morris Architects
Location: Gulf of Mexico

Summary
There are approximately 4,000 oil rigs in the Gulf of Mexico varying in size, depth and mobility that will be decommissioned within the next century. If a deck on one of these rigs is about 20,000 square feet, then there is potentially 80 million square feet of programmable space just off the coast of the United States. The current method for rig removal is explosion, which costs millions of dollars and destroys massive amounts of aquatic life.

Critique
Pro: Efficient adaptive reuse of an Oil Rig that would be otherwise demolished.

Con: The community’s isolated location suggest exclusiveness and luxury living. The adaptive re-use strategy relates to the mitigation of rising sea levels, however, its location makes it hard for transitions to occur for surrounding communities.
CASE STUDY: COMMUNITY ON THE WATER

Project: Silodam
Architect: MVRDV
Location: Amsterdam, Netherlands

Summary
Silodam is equipped with 157 apartments, business units, and public spaces. The apartments are different sizes and are stacked to create internally connected neighborhoods. Residents can walk through the building, passing different facades and roof tops, under the building through the hall to the terrace, or along the marina where boats can be docked.38

Critique
Pro: The incorporation of mixed used industry allows for the development of a community. The Silodam is not only a place to live, but it provides, jobs, and public spaces. Also, the location of Silodam is beneficial to promote transitions from land to aquatic living in the event of a rising sea/river level crisis.

Con: Although the Silodam successfully promotes the idea of mixed-use industry and living, it does not fully promote self-sufficiency. More alternative energy and living methods could be incorporated. Its design is internalized and because of this, it lacks the opportunity for growth on a larger scope.

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Adopting Dutch Strategies

When choosing precedents, Holland serves as a successful example. The Netherlands have been threatened by the water systems that surround them for hundreds of years. The top two-thirds of the country are at or below sea level, and the whole country is vulnerable to river flooding and tidal inundation. In spite of these circumstances, more than 11 million people—two-thirds of all Dutch citizens—live in these areas, and 70 percent of Dutch gross domestic product is produced in these flood prone areas."39

Due to these circumstances, the Dutch have had to conceptualize and develop their communities to avoid flooding. While developing this proposal—Aquatecture—the Netherlands served as a predecessor for innovation.

For years, they have battled the sea instead of constantly fighting it; their country has learned to view water as a site opportunity. Currently in the Netherlands, projects are being designed to accommodate living and the sea.

Hurricane Katrina’s devastation shocked the world. As a response to the unfortunate event, the Dutch have strategized with U.S. public and private sector officials how Dutch expertise and technology might strengthen U.S. flood protection systems. Currently, Policymakers from Florida and the Netherlands are sharing best practices on water system management, climate change, environmental restoration, emergency response, and sound waterfront development.40

Figure 3.7. Waterstudio NL Waterhouse Architecture

39 "Pioneering Water." Royal Netherlands Embassy. 25.

40 Ibid, 27.
CHAPTER 4: PROJECT CONCEPT
Aquatecture Strategies: Mitigate, Adapt, and Sustain

The main concept or theme of this proposal is mitigation, adaptation, and sustainability.

Mitigate

Mitigation is the first line of defense. If successful and reliable defense strategies are incorporated into the construction in homes and communities, migration will not be a necessity.

Adapt

Once water starts to immediately threaten coastal city infrastructure and industry, adaptive re-use strategies will become an option for communities, towns, and cities.

Sustain

Although mitigation and adaptation will be crucial initial steps to lessen the threat of rising sea levels, sustaining communities will be an important strategy for long-term projections. If the inundated environment is providing the necessities to sustain life (food, energy, transportation) then it is more likely that residents of coastal communities will not be inclined to migrate.
SITE SELECTION PROCESS

Site Selection and Risk Management

As water levels rise and start to impact communities worldwide, the areas with the highest population, infrastructure, and economic investment should be benchmarks as to where adaptation should occur. It is important to examine the risks in order to ‘water-proof’ the coastlines threatened by inundation. There are varying degrees of threats dispersed around the world. Targeting areas with the highest risk factors first, will provide rankings of possible impact—most vulnerable sites to least vulnerable site. Three factors used to evaluate site risks are: (1) Vulnerability (2) Exposure (3) Hazard.41

Vulnerability: The lack of ability people may have to adapt to sea level rise.

Exposure: Relating to geographical location, latitude, and the current risk to water. In the case of inundation, developments situated adjacent to a water systems will be the most exposed.

Hazard: The size of the risk and the frequency with which it will be experienced.

This risk analysis model provides a practical strategy for site selection and scenario planning. From this analysis, the site was chosen.

(Possible) Hazard X Vulnerability X Exposure= (Possible) Impact

Figure 5.1 The Crichton Risk Triangle

41 “Adapting Cities for Climate Change” 63-65.

Rising Tides: Florida

Florida is one of the nation’s most vulnerable states for destruction caused by sea level rise. The entire coast of Florida is threatened by rising seas and stronger storm surges.

The future looks bad for apartments and homes that crowd the coasts. Rising sea levels are also driving sea water into the Everglades, inundating mangroves, and directly threatening all low lying islands.

The Effects on Florida

In a June 2009 report, the National Oceanic and Atmospheric Administration (NOAA) outlined what Florida would endure if no significant action is enforced to curb consequences of climate change:

Over time, sea-level rise will put 99.6 percent of Monroe County under water. In Miami-Dade, 70 percent would be awash, while 10-22 percent of land would be flooded in 14 other coastal counties. This would destroy real estate worth more than $130 billion.43 Florida’s tourism industry will lose $9 billion by 2025 and $167 billion from beaches and attractions by the end of the century.44

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44 Ibid.
Sea-level rise will destroy important infrastructure throughout South Florida: Two nuclear power plants, three prisons, 68 hospitals, 74 airports, 334 public schools and nearly 20,000 historic structures.\(^45\)

Gradual warming and rising of the seas will increase hurricane-intensity, inflicting an estimated $25 billion in damages on Floridians by 2050\(^46\).

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**Figure 5.3. South Florida Projected to be the Most Vulnerable Area in Florida**

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\(^45\) Ibid.

\(^46\) Ibid.
Miami, Florida

Miami is ranked number one on the list of top 20 cities ranked in terms of assets exposed to coastal flooding. Miami is the most exposed city to coastal flooding today and “will remain in that ranking in 2070, with exposed assets rising from approximately $400 billion today to over $3.5 trillion.” In terms of assets, “Guangzhou is the second most exposed city, followed by New York, Calcutta, Shanghai, Mumbai, Tianjin, Tokyo, and Hong Kong.”

Risk Management

Miami’s high economic investment + high risk for short- and long-term flooding= high population= high impact.

Miami: An Endangered City

Miami is one of the United States’ most important financial centers. It is a major center of commerce, finances, corporate headquarters, and boasts a strong international business community. According to the ranking of world cities undertaken by the Globalization and World Cities Study Group & Network (GaWC) and based on the level of presence of global corporate service organizations, Miami is considered a “beta world city.”

Sea-level rise in Miami-Dade County and Its Impact On
Urban and Natural Resources

“By 2100, projected sea level in Miami-Dade County will have: (1) Inundated much of the barrier island and coastal wetlands, (2) seriously degraded freshwater availability in coastal counties, and (3) modified the coastal climate.” This rise will

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50 Ibid.

51 Ibid.

also result in unique ecological problems as the region’s natural resources respond to relatively rapid and widespread flooding. In order to better understand the impact of sea-level rise in the Miami-Dade County area, maps of the region’s coastal topography were constructed and then “flooded” at one foot intervals to sea level heights projected by the Intergovernmental Panel on Climate Change. The impact of each flooding scenario on urban and natural resources was then evaluated.

Two sea-level elevations were identified as critical “nick points” that trigger rapid and widespread flooding. “At a nick point of about +6 ft, a very plausible height under even the most conservative sea level-rise models, only the highest mainland elevations on the Atlantic Coastal Ridge will remain above sea level, while the vast majority of urbanized areas and associated ecosystems will be under water.”

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54 Ibid.

55 Ibid.
Miami Residents: Interview

Due to Miami's proximity to water, they are a city constantly threatened by water. Interviews were conducted to discover the inconveniences brought on by short-term flooding. As stated by Miguel Quesada, a 25-year resident of Miami Beach, "Every rainy season, my house floods….Frequently, it floods to the point that I can't even leave my house." He continued to explain how this problem is getting worse and it is not only triggered by hurricane activity—it occurs every time there is a heavy downpour. Unfortunately, heavy downpours are very common during the summertime in Florida.

Figure 5.7. Miguel Quesada, Resident of Miami Beach for 25-Years

Average Rainfall and Impact

In August, the rainfall average is 8.68 inches.56 From the interview with Quesada, it is appropriate to conclude that the crisis of flooding is current problem. However efforts to control or mitigate the causes remain unsatisfactory.

![Average Rainfall in Miami](image)

Figure 5.8. Average Rainfall in Miami

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Is Miami Prepared for Rising Sea Levels?

In spite of the current threat, Miami does not have a sufficient plan to combat the reality of rising sea levels. “Miami’s Current Mitigation Strategies to Short-Term and Long Term Flooding” are as follows:

Prepare for Flooding

- Elevate the furnace, water heater, and electric panel in your home if you live in an area that has a high flood risk.
- Consider installing ”check valves” to prevent flood water from backing up into the drains of your home.
- A flash flood warning means a flash flood is occurring. Seek higher ground immediately; do not wait for instructions.

Plan to Evacuate

- Plan how you will leave and where you will go if you are advised to evacuate.
- If you do not have a car, plan alternate means of evacuating.
- Do not walk through moving water, if possible. Look for areas where the water is not moving. What might see like a small amount of moving water can easily knock you down.
- Do not drive into flooded areas. If your vehicle becomes surrounded by rising water, get out quickly and move to higher ground, if possible.
Stay Informed

- Stay out of flood waters, if possible. The water may be contaminated or electrically charged. However, should you find yourself trapped in your vehicle in rising water get out immediately and seek higher ground.
- Stay away from downed power lines to avoid the risk of electric shock or electrocution.
- Do not return to your home until local authorities say it is safe. Even after flood waters recede, roads may be weakened and could collapse. Buildings may be unstable, and drinking water may be contaminated. Use common sense and exercise caution.  

Aquatecture Opportunities within the Miami-Miami Beach Context

Many areas in Miami will be affected in some way by rising sea levels. Aquatecture will be presented in phases.

- Phase 1: Incorporating housing units that adapt to water level increases
- Phase 2: Aqua-Communities start to form within intercoastal water
- Phase 3: Adaptive Re-use of existing building structures in urban conditions: Barnacle-Living

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As a primary strategy to mitigate flooding, a responsive housing design will be implemented throughout the Miami-Miami Beach area. A home that can infinitely raise or lower with water fluctuations is the primary design solution.

**Mitigation Principles for Living Units**

Design principles for designing this housing prototype were developed to ensure protection and safety from long and short-term inundation. They are as follows:

- **Lifted**: A home that will rise with the water level.

- **Waterproof**: Interior protection from water by way of materiality and building methods.

- **Resistance**: Dwellings will be resistant to those that are floating but are restricted from shifting because of the lifted piling system.

**Necessity of an Adaptable Home In Existing Communities**

The desire and necessity for this housing typology is current. Every year houses are damaged or destroyed with flooding.

![Figure 6.1. H20ME Flood Protection Diagram](image-url)
Lifted: Rising with the Water

Nautical engineering will be adopted to redefine living unit design and construction methods. To create a living situation that is reliable and adaptable in high-risk areas for flooding, floating dock technology will be adopted. Traditionally, a floating dock is comprised of a buoyant subsurface material and topped with a secondary material. Some floating docks are designed with pilings incorporated that act as guides to allow the platform to glide up and down in accordance with the surrounding water levels.

The base of each home will be equipped with a buoyant platform to keep each unit afloat. Additionally, pilings will be used as guides to allow each unit to rise in accordance to the level of water in which it resides. The piling system is designed to promote adaptation to a variety of water levels. Each piling guide is comprised of five-foot galvanized steel sections. As the water continues to rise and the distance of the exposed piling is reduced, another guide can be linked and attached to create more length. This additive and subtractive method provides reassurance that the unit can withstand any height increase in water levels.

Ultimately, this flood protection system can provide a sense of security and reliability for home owners residing in endangered community zones. This adaptable ‘floating dock strategy can also be very useful in locations where dramatic fluctuations in water levels occur frequently.

Figure 6.2. Floating Boat Dock in the Everglades, Florida
Figure 6.3. H2OME: Housing Unit Concept
Figure 6.4. Housing Unit Designs
Figure 6.5. One Bedroom Housing Unit Design

1. MAIN ENTRY
2. GARDEN
3. BEDROOM
4. KITCHEN
5. SERVICES
6. STORAGE
7. LIVING
8. DINING
9. PORCH
10. BOAT DOCKING AREA
11. BATHROOM

Legend:
1. Main Entry
2. Garden
3. Bedroom
4. Kitchen
5. Services
6. Storage
7. Living
8. Dining
9. Porch
10. Boat Docking Area
11. Bathroom
Figure 6.6. Two Bedroom Housing Unit Design
Figure 6.7. Three Bedroom Housing Unit Design
Figure 6.8. Row of Waterhouses in Miami Intercoastal Waters
HOME FEATURES

INFINITELY RISES
WITH WATER LEVEL
CHANGES

INSET WINDOW TO PREVENT FROM
POTENTIAL DEBRIS

PORCH AREA

RUNOFF FILTRATION
SYSTEM

Figure 6.9. Unit Systems
UNIT SYSTEMS

PHOTOVOLTAIC PANELS
ALTERNATIVE POWER GENERATION FOR USE IN INDIVIDUAL UNIT

SIP PANEL SYSTEM
6” x 6” GRID STRUCTURAL INSULATED PANEL (SIP) SYSTEM FOR BUILDING EFFICIENCY AND EASE OF TRANSPORT. EXTERIOR COATED IN AN BIO-ORGANISM RESISTANT MICROFILM TO CONTRIBUTE ALGAE AND BARRACUDA PRODUCTION IN UNIT.

GREEN ROOF
PUBLIC SPACE AND RUN-OFF FILTRATION

WATER STORAGE
STORAGE OF COLLECTED WATER TO BE USED WITHIN A CLOSED-LOOP SYSTEM

DESALINIZATION/REVERSE OSMOSIS WATER FILTRATION
PRODUCTION OF POTABLE WATER FROM A SECONDARY SOURCE BY WAY OF FILTRATION (IE: RAIN WATER, SURROUNDING WATER, GREY WATER)

Figure 6.10. Unit Sustainable Systems
Figure 6.11. Exploded Axonometric of Unit Components
Figure 6.12. Set of Housing Units from Above
Figure 6.13. Exterior Perspective of Two Bedroom Housing Unit
Figure 6.14. Longitudinal Section of Three-Bedroom Unit
Figure 6.15. Cross Section of Three Bedroom Unit
Figure 6.17. Final Model: One Bedroom Unit View #1
Figure 6.18. Final Model: One Bedroom Unit View #2
Figure 6.19. Final Model: Two Bedroom Unit View #1
Figure 6.20. Final Model: Two Bedroom Unit View #2
Figure 6.21. Final Model: One Bedroom Unit View #1
Figure 6.22. Final Model: Two Bedroom Unit View #4
Figure 6.23. Final Model: Showing Linking Capabilities of Housing Units
Figure 6.24. Final Model: Three Bedroom Unit View # 1
Figure 6.25. Final Model: Three Bedroom Unit View #2
Aquatecture Community Development

Following the implementation of a reliable and safe home, each unit will be oriented to promote community development. In this proposal, a micro community of 40 homes will be created. From that, possibilities of growth and adaptation will be explored. This small community of 40 homes serves as an archetype to future communities and will be an example to future Aquatecture communities in threatened areas.

Main Community Goals

Goals are set forth to exemplify the main intent of water community development. They are as follows:

- Alternative Living
- Adaptability
- Self Sustain
- Archetype

Alternative Living:

Over-time, the majority of the water communities will be branching from island and areas affected by rising water levels. Due to the adjacency to the previously inhabited (now destroyed and inundated) environments, a transition will occur. As water continues to be a threat to pre-existing communities, the need for water communities will increase.

Adaptability

Due to the magnitude of people that this crisis will be affecting, it is important to consider the possibilities of growth and configurations that these communities can undergo. The community is built on a 20” by 20” structural module. The housing units are designed for their width to fit on this module. Because of this system, a house can be added or removed from the community module at any time.

On a macro-scale, the community system is designed as a ‘kit of parts’. When the need for expansion and growth arises, the community has linking capabilities—possibly turning a 20-home community into a 100-home community network.
**Self Sustain:**

As water levels rise, it is important to design for self-sustainability and independence from land. Essentials will be provided to the community such as food, potable water, energy, etc. When the community starts to provide living necessities, it will create an independence from land.

**Archetype**

Rising sea levels and flooding continues to destroy homes and communities. If these strategies are implemented within threatened communities Aquatecture can serve as an archetype for future developments.
Figure 7.1. Panoramic View of Proposed Community Location (from Mac Arthur Causeway)

Figure 7.2. Panoramic View of Proposed Community Location (from Star Island Bridge)
Figure 7.3. Panoramic of Proposed Water-Community of Site (year 2009)

Figure 7.4. Site Panoramic of Projected Water level Height (year 2050)
Figure 7.5. Site Location and Context
Figure 7.6. Community Conceptual Model
Incorporating Community Needs to Avoid Migration

In order to promote an independent self-sustaining community on the water, Essential Community Needs (ECNs) are to be integrated:

In addition to the living units, the next step towards growth is the implementation of supporting community functions. Environments will be redefined when implemented into the water communities. The preconceived notions of what a park, a garden, a front yard, and a street will change and be redefined to relate to the water. The circulation of these communities can be conceptually to a street. The main connection all of these units and functions will be through a boardwalk pedestrian path.

These networks of circulations will not only be used as a mode for the users to move throughout the area, but it will also provide recreational spaces, community gathering spaces, and boat docking areas.
Farming Methods for an Inundated Environment

The standard of farming will be drastically changed and be reinvented. Hydroponics, aquaponics, and other forms of aquaculture will be implemented within each specific site context. “Aquaponics is the symbiotic cultivation of plants and aquatic animals in a re-circulating closed loop system”\textsuperscript{58}

With aquaponic systems, fish and plants can grow together in one integrated, soilless system. The fish waste provides a food source for the growing plants and the plants provide a natural filter for the water the fish live in. Aquaponics is a sustainable ecosystem in which both fish and plants can thrive. It produces safe, fresh, organic fish and vegetables.\textsuperscript{59}

When soilless culture (aquaponics or hydroponics) is combined within a controlled environment or a greenhouse, premium quality crops can be grown on a year-round basis, anywhere in the world.


\textsuperscript{59} Ibid.

In addition to alternative farming sectors within the community, Green roofing systems will be a part of the living units design. Not only are they incorporated to serve as a community space, but they are a means to provide filtration methods for grey water collection.
Transportation Services: Alternative Mobility

The community will maintain its independence from land through the implementation of alternative mobility. Boats and other means of aquatic mobility will be the main means of transport within the community. To accommodate for the incorporation of the alternative transportation services on the micro-scale, each living unit and main public space will be equipped with a docking area for boats and/or small water crafts. In addition to the small unit docks, there will be a larger area within the community to accommodate for the storage of boats.

The Effects of Alternative Transportation Services

Due to the elimination of the car and other on-land transportation services, an effort to reduce the level of CO2 emissions will be achieved.
Aquaculture

“Aquaculture is the farming of freshwater and saltwater organisms including fish, mollusks, crustaceans and aquatic plants.” Unlike fishing, aquaculture, also known as aquafarming, implies the cultivation of aquatic populations under controlled conditions. Particular kinds of aquaculture include algaculture (the production of kelp/seaweed and other algae), fish farming, shrimp farming, oyster farming, and the growing of cultured pearls.

Mariculture

Mariculture will also be introduced into the aquaculture communities. Mariculture refers to aquaculture practiced in marine environments. “Mariculture is a specific branch of aquaculture involving the cultivation of marine organisms for food and other products in the open ocean, an enclosed section of the ocean, or in tanks, ponds or raceways which are filled with seawater.”

Alternatives to Controlled Farming

Although this is a controlled and reliable way to provide food for the community ‘wild’ or uncontrolled fishing will still be promoted in the communities as a source for food as well.

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60 American Heritage Definition of Aquaculture

61 Ibid.

Desalination and Water Filtration

Water will be taken from the immediate surrounding source and filtered for use by way of desalination or other filtration methods. From there, it would be distributed to the consumers of the town to be used for their primary necessities.

Grey Water Filtration Methods

Subsequently, the grey water (from sinks, showers, etc) would be disinfected and reused for appropriate purposes—such as irrigation—within its own loop. “Black” water (from toilets) would be cleansed in greenhouse living machines. Microbial cells in the “living machines would harvest naturally occurring energy produced by bacteria during the cleaning process.”63 Once the process has concluded, the water would be returned to the original water source through an artificial wetland filtration process located within the respective aquaculture vicinity.

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Alternative Energy Production

In order to create a self-sustaining community on the water, sources to provide energy need to be introduced. Through the use of wind, water, and solar energy the aqua communities will acquire sustainable energy supply. For main communities on the water, hydroelectric power could be the most efficient option for energy production. Tidal power is also a viable energy producer. Tidal power, sometimes called tidal energy, is a form of "hydropower that converts the energy of tides into electricity or other useful forms of power." Although not widely used yet, tidal power has potential for water communities. In many cases, tides are more predictable than wind energy and solar power.

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65 Ibid.
Figure 7.12. Site Plan of Proposed Water Community, Miami (Year 2025)
Figure 7.13. Community Diagrams
COMMUNITY PHASING DRAWINGS

Figure 7.14. Possible Linking Configurations
Figure 7.15. Phase 1 View of Miami-Dade Inter-coastal Showing Primary Component of Water Community
Figure 7.16. Phase 2 Showing Addition to Existing Community
Figure 7.17. Phase 3 View Showing Growth of Existing Community
Figure 7.18. Phase 4 View Showing Small Water Communities Branching from Vulnerable/ Flooded Areas
Figure Phase 7.19. View Showing Small Water Communities Growing from Vulnerable/Flooded Areas
Figure 7.20: Phase 6 view of Miami-Dade Inter-coastal Water Community Network
Figure 7.21. Phase 7 view of Miami-Dade Inter-coastal Water Community Network
Figure 7.22. Elevation (North-Side) of Community
Figure 7.23. Cross-Section of Community Center Area and Inhabitation Capabilities within Substructure to be used as Shelter and Storage Area
Figure 7.24. Cross-Section Showing Desalination Tanks, Pedestrian Paths, and Housing Units within Community Context
Figure 7.25. Section of Community and Surrounding Context
Figure 7.26. Aerial View of Community
Figure 7.27. Community With Water 'Removed' to Show Piling to Ground Connections
Figure 7.28. Bio-Swales for Water Run-off Management
Figure 7.29. Tide Gardens Between Housing Units
Figure 7.30. Undulating Boardwalk and Waterhouses
Figure 7.31. Micro-Hydroelectric Power Chamber and Desalination Silo
Figure 7.32. Housing Unit Configurations
Figure 7.33. Community Park
Figure 7.34. View of Dock at Night
Figure 7.35. Final Model: Water Community View #1
Figure 7.37. Final Model: Water Community View #3
CHAPTER 8: REDEFINING A COASTAL CITY
Figure 8.1. Concept Statement: Barnacle Colony Biomimicry

IN THE STAGES OF VULNERABILITY, THE NAUPLIUS LARVA SEARCHES FOR A DURABLE SURFACE TO REPTX ITSELF AS A MEANS OF SURVIVAL. BY LATCHING ONTO EXISTING STRUCTURES AND MARINE OBJECTS, THE LARVA SETTLES, Creates A PROTECTIVE SHELL, AND A BARNACLE IS BORN.

AS TIME PROGRESSES, AND PROTECTION IS宋合出 BY MORE LARVAE, A BARNACLE COLONY DEVELOPS.

EQUIPPED WITH PROTECTIVE EXTERIOR SHELL COMPOUNDS, DURABLE ADHESIVE TECHNIQUES, LOCATION SELECTION, AND SELF-SUFFICIENCY, THE BARNACLE COLONY IS ABLE TO WITHSTAND THREATS AND FORCES OF THE OCEAN.
What Happens to Our City Cores?

Water levels will not only impact small homes and towns, but it will affect coastal city urban cores as well. Instead of abandoning the city of Miami, adaptive re-use strategies can be implemented.

Adaptive Re-Use Strategies

Building envelopes, bridges, and other types of infrastructure will present opportunities for adaption. In the event, that the pre-existing buildings, towers, bridges, and other types of infrastructure become no longer suitable for their intended use, the barnacle-living adaptive re-use strategy will be implemented.

For example, housing units, public spaces, farming spaces and energy production zones can start to use the foundation, interior, and exterior spaces that that building envelope provides.

The housing units can start to form community clusters on the exterior of abandoned residential towers and use their interior spaces for pedestrian paths, vertical farming and energy production zones.

Figure 8.2. Housing Units Latch onto Pre-Existing Miami Towers
BARNACLE LIVING: AN ADAPTIVE RE-USE STRATEGY INCORPORATED WHEN WATER LEVELS INVADE INTO CITY CENTERS, URBAN CONDITIONS, HIGH RISE AREAS, ETC.

HOUSING AND OTHER SYSTEMS ARE TO LATCH ON EXISTING STRUCTURES, BRIDGES, ETC. 5-10 FEET ABOVE PROJECTED MAX WATER LINE.

INTERIOR OF TOWERS HOUSE VERTICAL FARMS, BUILDING SERVICES, AND PEDESTRIAN PATHWAYS.

Figure 8.3. Barnacle Living Presentation Board
Figure 8.4. Adaptive Re-use of Downtown Miami Infrastructure
Figure 8.5. Community Cluster Along Bridge
Figure 8.6. Final Model: Barnacle Living-Adaptive Re-use
Figure 8.7. Clusters of Units Latch onto Existing Tower
Figure 8.8. Roof of Existing Towers to be Public Garden Spaces
Conclusion

With the flexibility of site location, this intervention can serve as an archetype that can be implemented throughout coastlines all around the world. The architecture will respond accordingly to the specific site location, climate, and cultural identity of the area and/or its inhabitants. For example, Aquatecture located in a sub-tropical climate will have the materiality and design to promote passive cooling strategies, accommodate for heavy rainfall, and grow plants appropriate for the temperature. Aquatecture located in cooler climates will be constructed with materials that support passive heating strategies, and provide varying degrees of enclosure.

Ultimately, it is crucial to understand that as the world changes, so should architecture. The threats that global warming presents to our coastlines are severe. In addition to what already has happened, thousands of cities will be destroyed and billions of people will lose their homes. If we do not take the precautions to provide mitigating strategies, the effects on coastlines could be detrimental. Strategies, such as the implementation of dikes, dams, and levees have proven to be unsatisfactory solutions. The inadequacy of such conventional systems should provoke a comprehensive reconsideration of coastal planning. It is the time that pro-active efforts are made to improve the quality of life and safety of coastline communities.

With Aquatecture, we can provide the necessary safeguarding of rising sea levels, flooding, and storm surges. Individuals, families, and communities can continue to inhabit coastlines, and cities provided these adaptation strategies are implemented. Through Aquatecture, coastal cities are provided with new options to mitigate against sea level increase, and have the opportunities for non-threatening co-habitation with water.


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