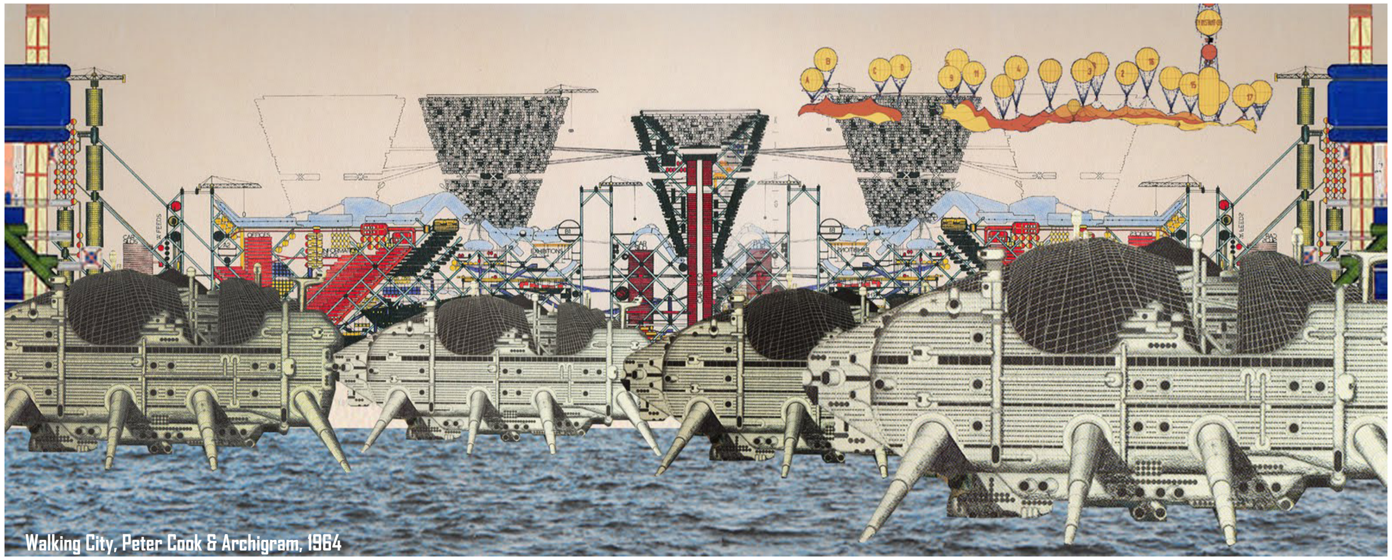
CITY IN/ABOVE WATER



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A thesis submitted in partial fulfillment of the requirements for the Master of Landscape Architecture Degree in the Department of Landscape Architecture of the Rhode Island School of Design, Providence, Rhode Island.

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CONTENTS

Overview 6

Site 7

Phase 1: Investigation 9
Abstract
Introduction
Methods
Infrastructure status and issue
*Vulnerability Analysis 21
Conclusion & Assesment

Phase 2: Schematic Design 25
Abstract
Introduction
Methods
Failure of sea wall
Precedents
*Scheme: Regional Infrastructure Transition Unit 35
*Logic of Regional Water Treatment Plant 37

Phase 3: On Site Application 45
*Units Assembly 46
*Units Distribution 48
*Construction Schedule 52

Overall Assessment 53
Final Conclusion
*Final Assessment 54

Bibliography 55

Overview

Sea level rise is a serious situation facing coastal cities in the world. In the United States, Miami is one of the most vulnerable cities as far as sea level rise is concerned. Floods in Miami not only come from high seawater but also from inland rivers and frequent storm surges. With Miami as a target city, this paper was prepared after taking care of its current political, economic, and cultural status, aiming to explore the way in which Miami responds to rising sea levels and proposes future urban visions. The new solution may also be applied partially or completely in other coastal cities.

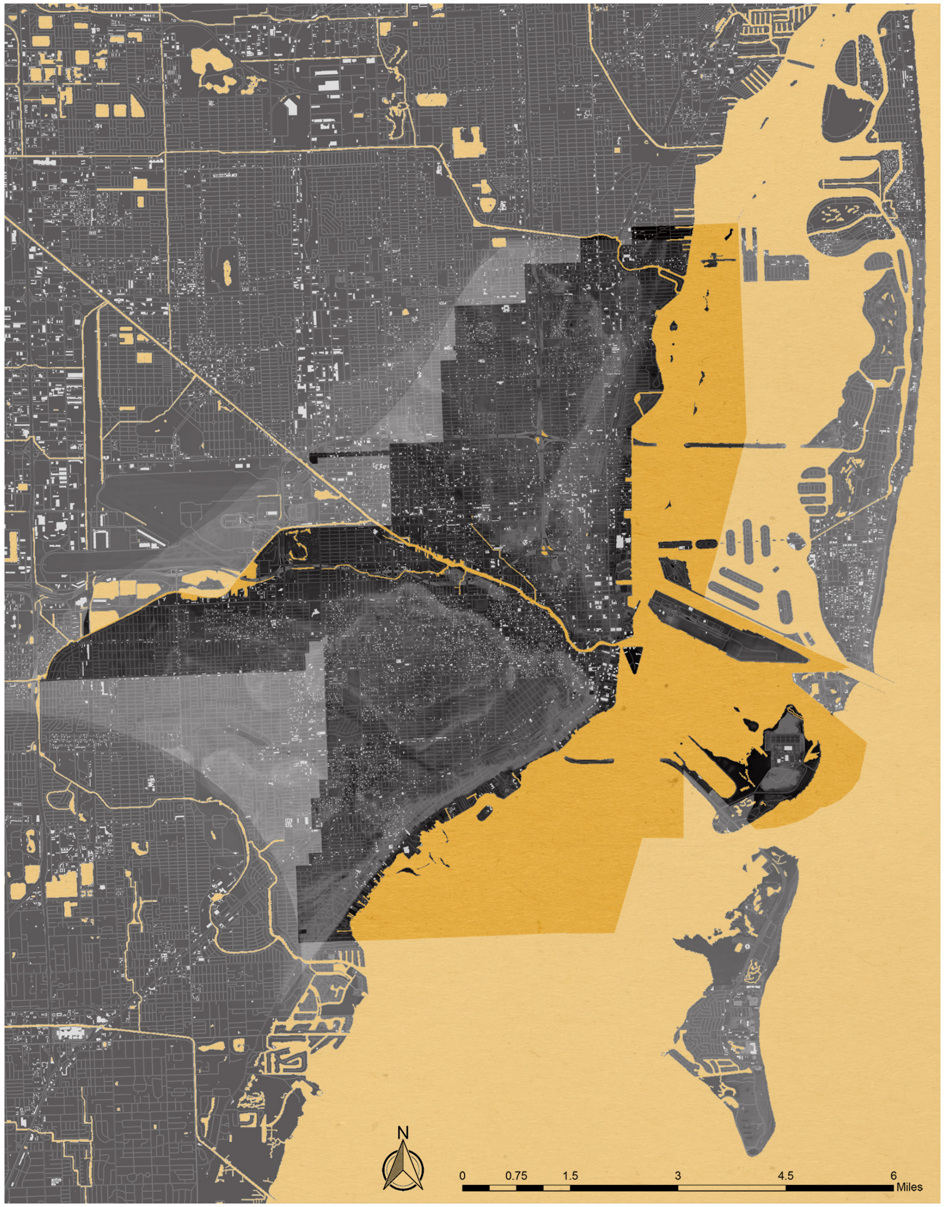
This work is divided into three phases. The first phase is an in-depth study that involves four aspects of Miami. They are the Water Environment (the origin and causes of the floods in Miami and existing large-scale solutions), Ecological Environment (main existing plant and animal species in Miami, species differences in coastal and inland areas, and ecological migration caused by seawater intrusion), Humanistic Environment (Miami's demographic composition and cultural composition, as well as the history of migration) and Urban Infrastructure (Miami's infrastructure, existing public transportation, water supply and drainage systems, green infrastructure with proper measures and defects in response to floods and deficiencies) .

The second phase proposes the concept of future assumptions for urban infrastructure. The concept is mainly based on the study in the first phase, as well as the famous case about the future of the city in history, which may be applied to Miami's unique geographical and cultural background. Due to the high permeability of the foundations in the city, the ordinary sea-crossing dams cannot effectively block seawater. That means the low-lying areas are difficult to retain in the next 50 years. The future vision proposed in this paper is to establish a series of infrastructure conversion centers, including the underground regional water treatment center and the elevated traffic conversion center. The lowland city will become the city of water in the future, and the "infrastructure center" will provide the transfer and berthing of waterborne vehicles, amphibious vehicles and land vehicles, all being connected via elevated viaducts and light rails.

The third phase is the in-depth study and design of the concept. First of all, it is determined that the newly-built infrastructure conversion center is located at the site of the urban backbone road network in order to connect existing urban fabrics and roads. Then the population of each block and the frequency of flood disasters are analyzed. According to different needs, the conversion centers with different functions and sizes are designed, each placed in the existing city map. The final part of the design is the plan for the construction, that is, the construction progress that the government can control at different times.

Site

Miami, "Magic City" and also "Capital of Latin Americas", is famous for its cultural diversity caused by immigrants from Cuba, Haiti and Nicaragua. Formed from wet terrain, Miami is threatened by floods because of precipitation in flood season; Miami canal flood flow, tidal and underground water rise caused by permanent sea level rise. Within the easy-flooded circumstance, not only the cultural diversity is threatened, but also the ecosystem is interfered. Even though some adaptations have been made, city major infrastructure including canal system, sewage system and transportation system still present failure in protecting and evacuating people from flooding.



Miami topology map with
large buildings and streets

Phase 1 Investigation

Evacuation Problems of Transportation System
and Consequential Vulnerable Neighborhoods

Abstract

The main questions for the "Infrastructure Team" are how infrastructure act during flooding and what are the successful adaptation in city of Miami and where is the most vulnerable area in Miami and the ability that people could be evacuated and protected during disasters. The systematic mapping of GIS data, section drawing and data analysis reveals that besides the impact of flooding in Miami, the failure in infrastructure has made people and ecosystem not be protected well. Especially the transportation system, people cannot evacuate from flood efficiently, has caused huge loss to Miami people.

Failures happened along city roadways, canal, bioretention system and sewage system, according to the news report and official statistics.

Introduction

The study of infrastructure in Miami started from mapping of different infrastructure system in the city scale and understanding the function of each infrastructure system as the city is flooded. Then analyze each system's effectiveness of water drainage and victim evacuation when the city is flooded. Canal system in city of Miami is both a source and drainage of flooding. The capacity for sewage system to drain water plays a significant role as well. While transportation system is critical to evacuate people from disaster areas during flooding period.

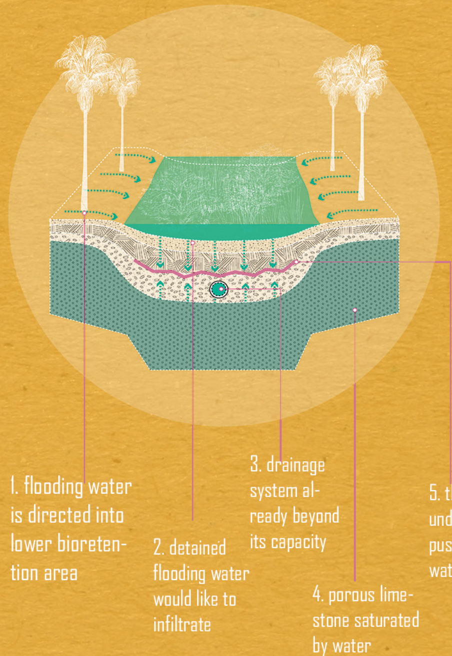
Methods

1. Literature review: knowledge about city infrastructure and its function.
2. Modeling: systematic mapping and section of infrastructure in Miami, inorder to understand the relationship among each system and their function.
3. Analysis: analyze the effectiveness of each system answering to floods.

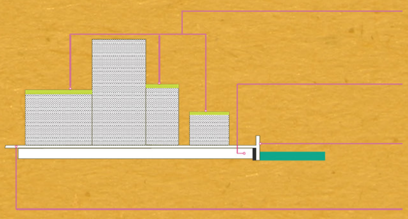
FLOOD CONTROL INFRASTRUCTURE SYSTEM AND FAILURE

Current Infrastructure Confliction during Storm

1. storm surge caused by hurricane go upstream throught canal system
2. gates closed to prevent surge continue go upstream
3. high water level because of upstream heavy precipitation
4. drainage system continue drain stormwater from the city
5. water level in canal raises up without an outlet, causing water overflow on to the urban street



Brickell Adaptation



Green Infrastructure System:
status quo and issues

In flood control, infrastructure systems face two major problems. The first is during the storm surge, sea waves from the direction of the sea and rivers from the inland hedged over the canal. In addition, when floods come, the main roads work with the green infrastructure to play a key role in guiding and absorbing floodwaters. Due to the insufficiency of the bio-retention system along major roads, the poor absorption capacity is far from satisfaction. At present, there are insufficient green spaces along the road network of major cities. Floods affect the biological retention system in two ways. One is the intrusion of saltwater caused by flooding and sea level rise, and the other is the flushing of fresh water caused by heavy precipitation. The complexity of the water source indicates that the city's bio-protection system should be capable of managing salt water and fresh water. What's more, the soil beneath the bio-retention system is always saturated and it is difficult to absorb more water. Bio-retention systems may fail when the drainage system below the bio-retention area fails. So the green infrastructure does not work in the lowlands of Miami.

The existing flood prevention measures in Miami are mainly flood control valves arranged along the river. When the flood rushes from the inland to the city, each flood control valve closes, preventing the flood from rushing down to densely populated areas in the city.

The number of urban green spaces along the Miami Canal is limited. Floods from Lake Okeechobee's precipitation increase the level of water in the main canals of Miami City, which may overwhelm the canals and cause devastating consequences for the surrounding communities. Especially when the flood control valve is closed, large amounts of water could be forced into the residential area. Low-lying residential areas are densely populated with low per capita income. Although the flood control valve may protect the downtown commercial area, it cannot avoid greater economic losses to people in low-lying areas.

FAILURE AND ADAPTATION OF SEWAGE SYSTEM IN MIAMI DADE COUNTY

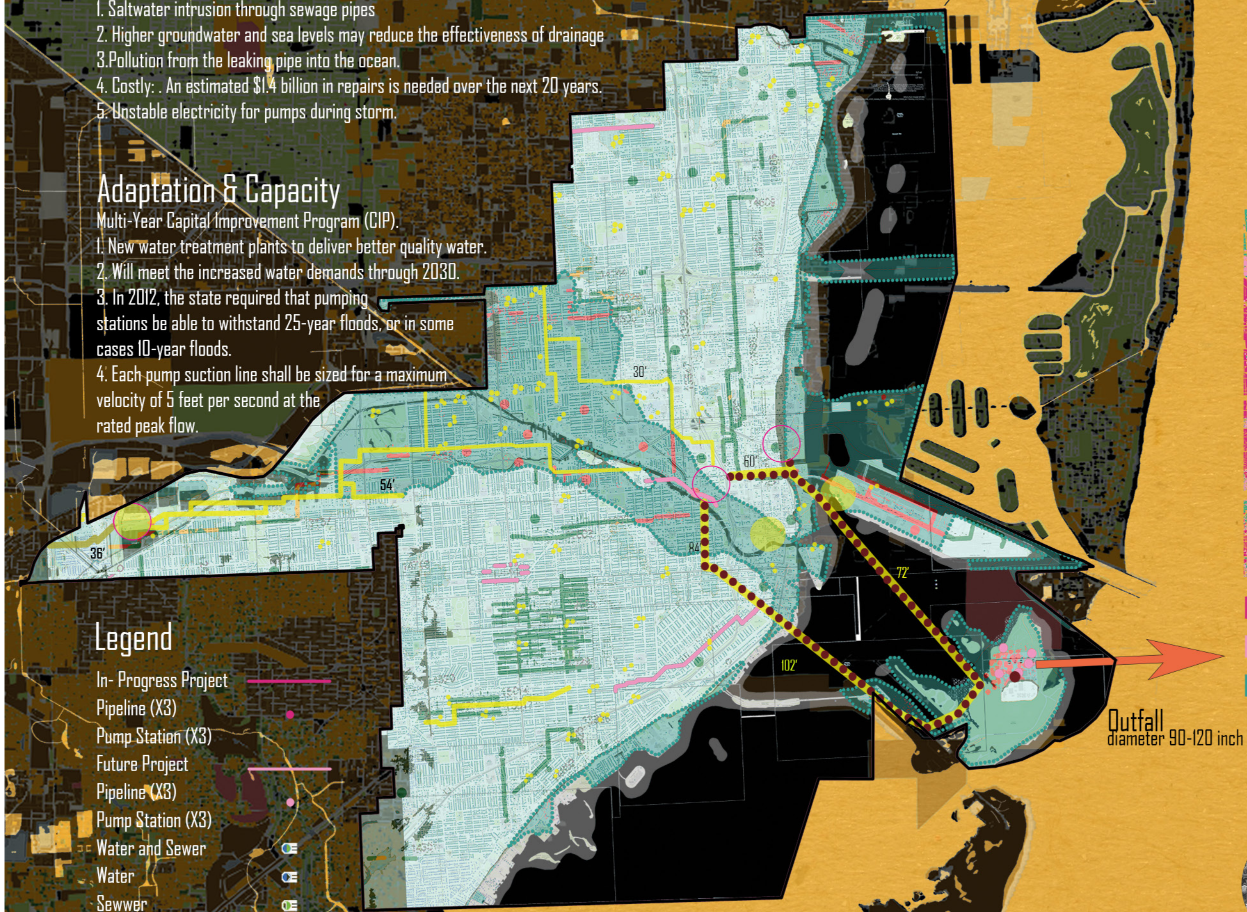
Problem

1. Saltwater intrusion through sewage pipes
2. Higher groundwater and sea levels may reduce the effectiveness of drainage
3.Pollution from the leaking pipe into the ocean.
4. Costly: . An estimated $1.4 billion in repairs is needed over the next 20 years.
5. Unstable electricity for pumps during storm.

Adaptation & Capacity

Multi-Year Capital Improvement Program (CIP).

1. New water treatment plants to deliver better quality water.
2. Will meet the increased water demands through 2030.
3. In 2012, the state required that pumping stations be able to withstand 25-year floods, or in some cases 10-year floods.
4. Each pump suction line shall be sized for a maximum velocity of 5 feet per second at the rated peak flow.



Legend

- In- Progress Project
- Pipeline (X3)
- Pump Station (X3)
- Future Project
- Pipeline (X3)
- Pump Station (X3)
- Water and Sewer
- Water
- Sewwer
- Existing Force Mains
- Existing Pump station
- Regional Pump

SEWAGE SYSTEM IN MIAMI DADE COUNTY

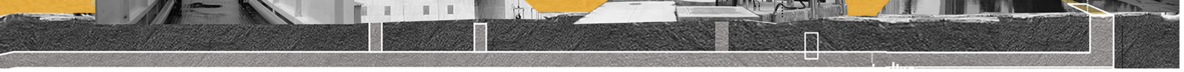
- Waste Water
  - Sanitary Sewer
- Other (Rainfall Runoff, Stormwater)
  - Alternative systems, such as onsite retention systems
  - Positive drainage (without pretreatment)

- Known sewer
- Likely sewer
- Septic

- Underground (seepage) disposal through exfiltration
- Drainage well
- Trenches (French drains)
- Retention ponds
- Surface infiltration

Plants

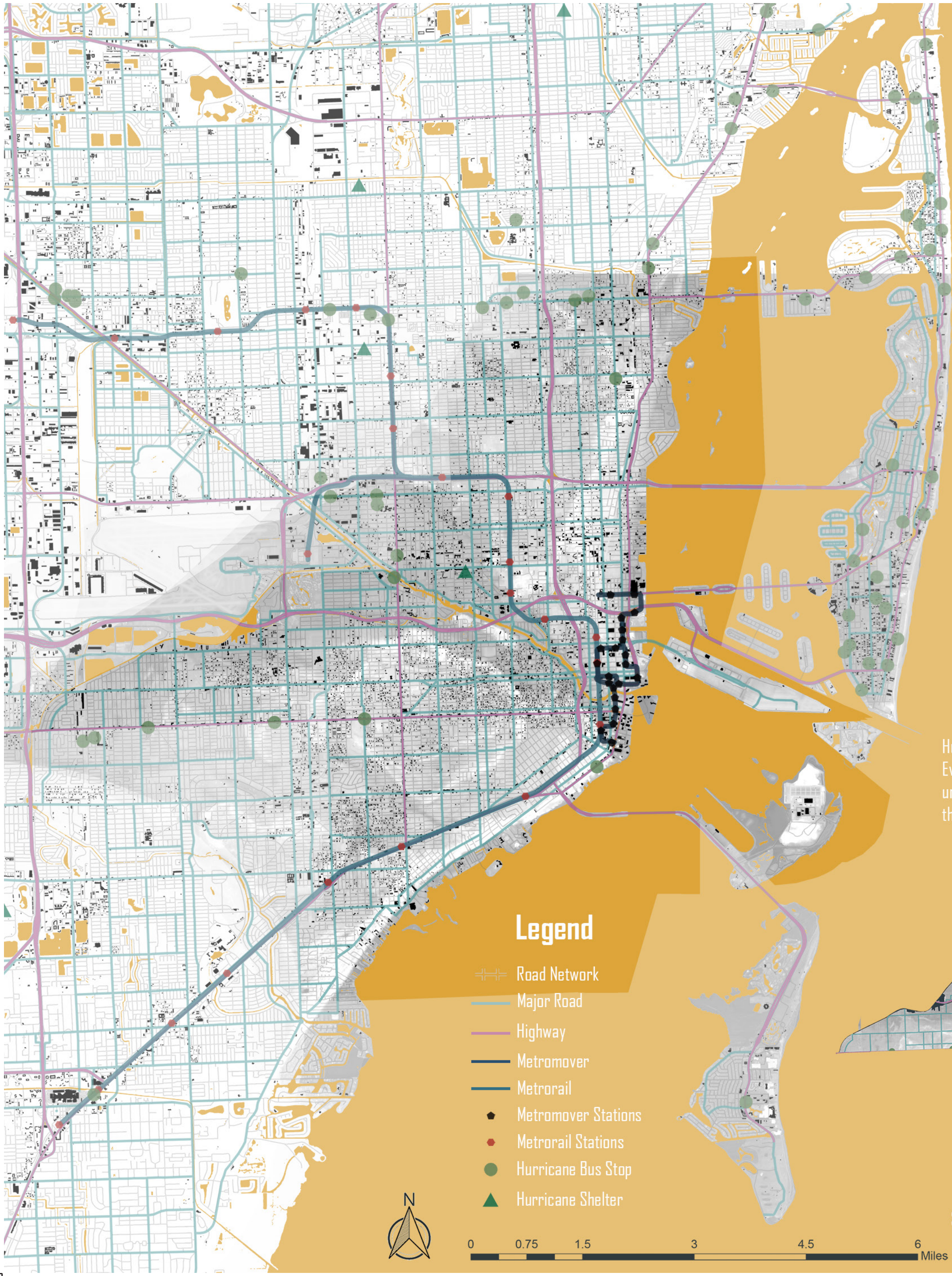
Pump Station To send sewage from households to a sewage treatment plant by gravity, it would be necessary to dig deep into the earth



Sewage System:
status quo and issues

Currently, Miami has proposed two wastewater treatment systems based on two different sources of water: waste water and rainwater. One is to collect the house effluent that then enters the no-processing center for unified treatment. After the treated effluent is directly discharged into the ocean, a deep drainage system is being developed, that is, the deep underground pipeline discharges the effluent into the deep aquifer. The other is designed to carry rainfall runoff. The sewerage system carrying rainfall includes two drainage systems: one is a positive drainage system (without pretreatment), such as a canal, and the other is an alternative system such as an on-site reservation system. The on-site retention system includes squat ground storage, underground (leakage) disposal, and surface infiltration through outlets, ditches (French drainage ditch), reserved pools and drainage wells.

(1) Now that sea level is often higher than the outlet of the drainage pipeline, making it possible for salt water to flow into the street through the system.
(2) During the rainy season. Higher groundwater levels and sea levels may reduce the effectiveness of the drainage infrastructure. For example, when the water level of the canal is higher than land, the canal loses its draining function and becomes a source of flood water.
(3) Pipeline leakage pollutes the ocean.
(4) Expensive Expenses: In the next 20 years, an estimated 1.4 billion U.S. dollars will be required for maintenance.
(5) The pump station needs electric power. The fact is that during the hurricane Elam, there was a shortage of electricity supply.
Due to the unreasonable design, the water supply and drainage system in Miami has even become a booster for floods intangibly.



TRANSPORTATION SYSTEM IN MIAMI & ADAPTATION TO FLOODING

Metrobus: ground level bus route, daily and basic public transportation.

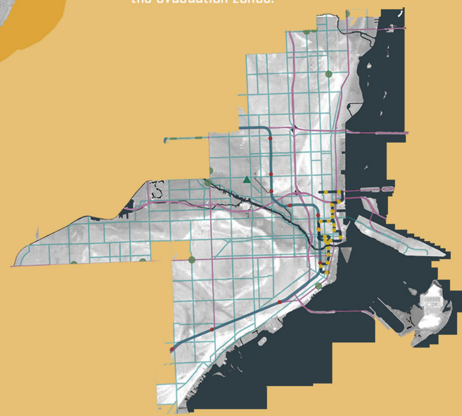
Metromover: 4.4-mile electrically-powered, elevated, fully automated people mover system.

Metrorail: 25-mile dual track, elevated rapid transit system.

Adaptation

Hurricane Bus Stop: Miami-Dade Transit will activate specific Emergency Evacuation Bus Pick-Up Sites by "Storm Surge Planning Zone" as directed by the Miami-Dade County Office of Emergency Management.

Hurricane Shelters: OEM partners with Miami-Dade County Public Schools and the American Red Cross (ARC) to operate Evacuation Centers (EC). These ECs provide refuges of last resort for those individuals who need to evacuate and are unable to make their own evacuation and sheltering arrangements, such as with friends, family, or in hotels outside of the evacuation zones.



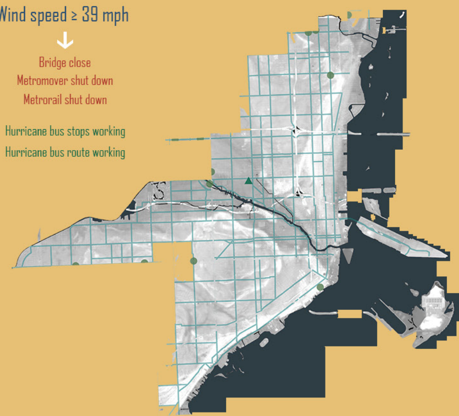
Survival Transportation in Tidal Flood

Wind speed ≥ 39 mph

↓

Bridge close
Metromover shut down
Metrorail shut down

Hurricane bus stops working
Hurricane bus route working



Survival Transportation in Hurricane

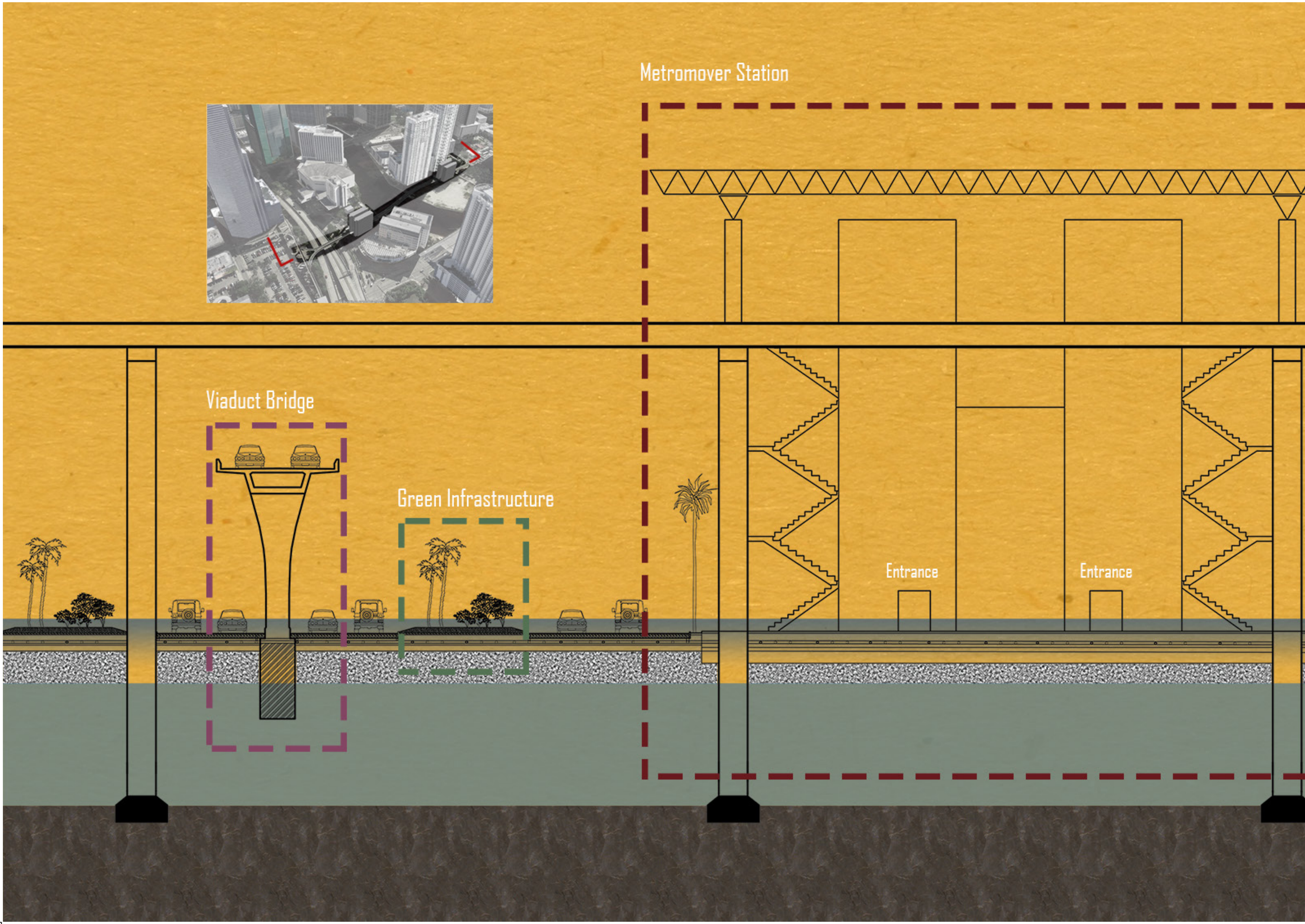
Transportation System:
status quo and issues

Transportation system in Miami has 3 layers, ground level roads, viaduct bridges, and elevated railway for light railway. There are three different public transportation routes, Metrobus as daily and ground bus route; Metromover as a 4.4-mile electrically-powered, elevated, fully automated people mover system; and Metrorail as a 25-mile dual track, elevated rapid transit system.

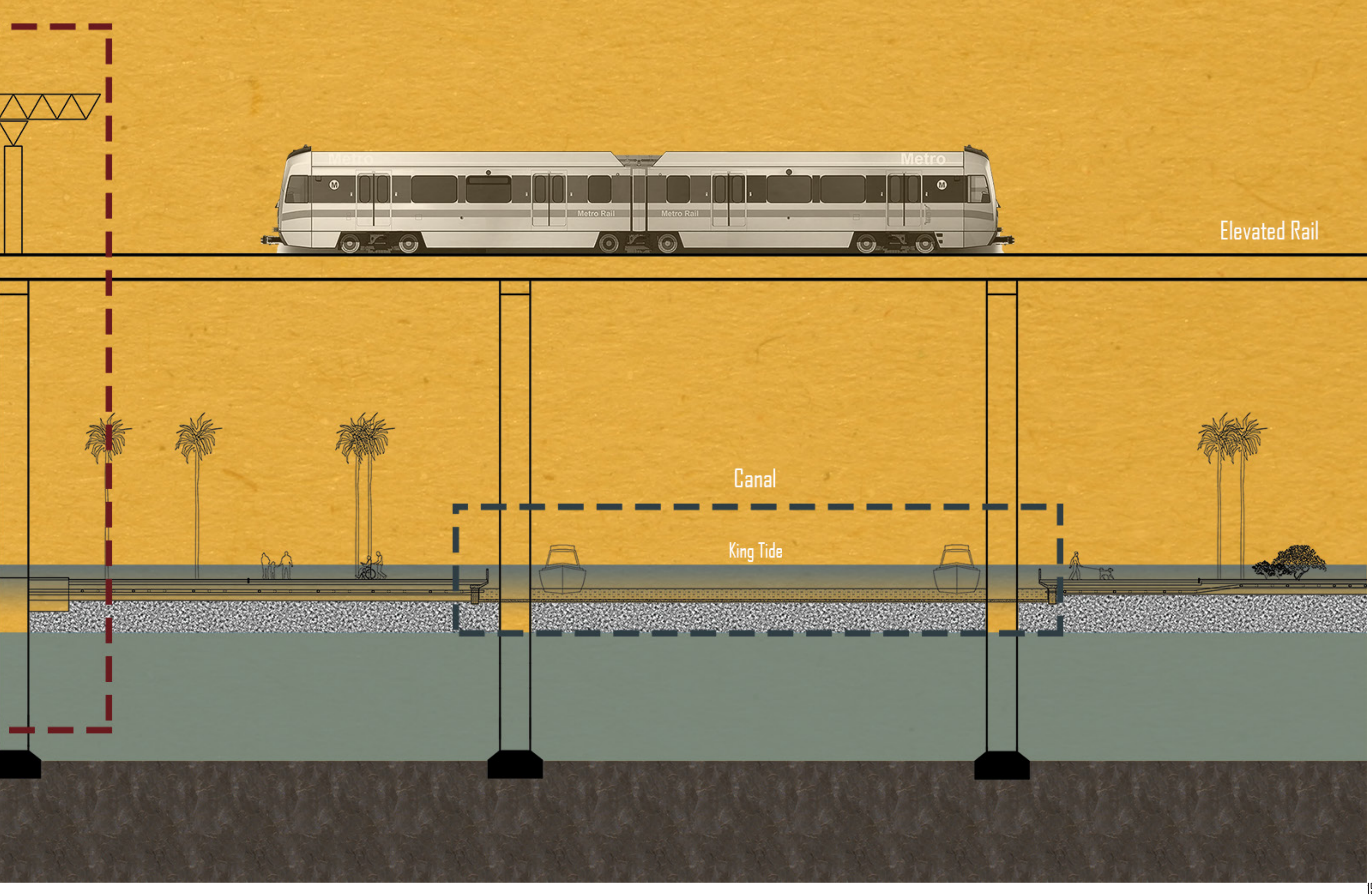
Hurricane Bus Stops are stops of hurricane bus route that only working during flood times to evacuate people from flooded area to hurricane shelters. Hurricane Shelters are places set as public shelter during flooding time.

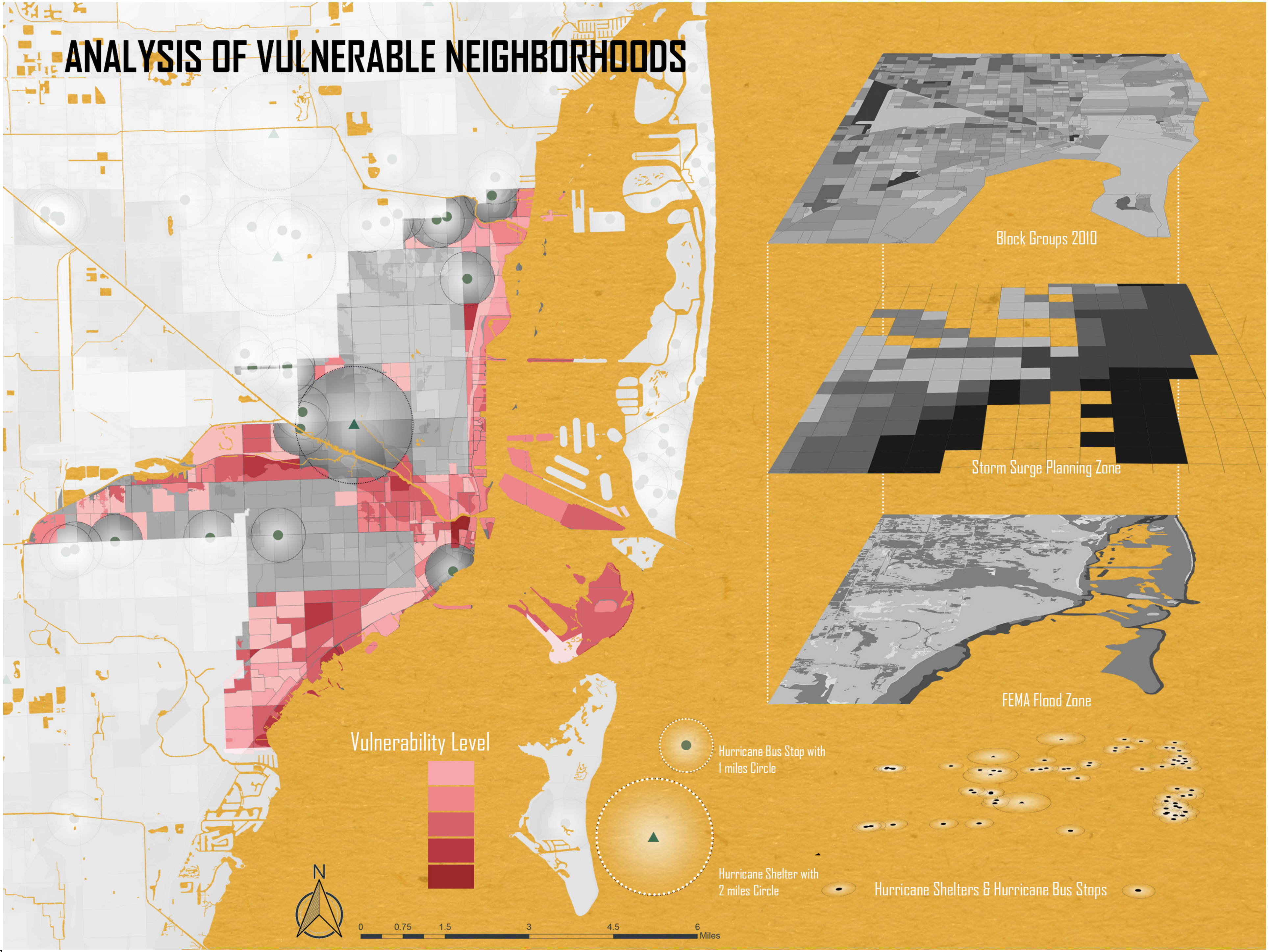
In addition to the daily public transportation system, there are emergency bus services to and from the various emergency bus stations are scattered throughout the city when the disaster strikes. The passengers can then be sent to the nearest evacuation centers. The Public Refuge Center is a series of large space facilities arranged by the government, such as school gymnasiums and public stadiums, to provide people with temporary shelter services.

Flooding in Miami has two situations. The tidal flood, which is mainly caused by high tide, is a more friendly type of flood with only a higher water level. Although low-lying areas are prone to flooding, major public transport including Metromover and Metrorail are still operational. The design of the Metromover station provides access for people, facilitating them to go upstairs to avoid floods. Nevertheless, the situation of hurricanes or storms can be quite bad more than imagined. Due to the precipitation and the flow of the canals, not only the city could be submerged, but buildings and people could also be threatened by winds. When the wind speed exceeds 39 miles, the viaduct would be closed and both Metromover and Metrorail would cease to operate. In this case, the only vehicle available is the Hurricane Emergency Bus Line, and it is still very dangerous for people to enter the street under strong winds.


Metromover Station
Viaduct Bridge
Green Infrastructure
Entrance
Entrance

SECTION DRAWING OF EXISTING INFRASTRUCTURE SYSTEM




ANALYSIS OF VULNERABLE NEIGHBORHOODS
Block Groups 2010
Storm Surge Planning Zone
FEMA Flood Zone
Vulnerability Level
Hurricane Bus Stop with
1 miles Circle
Hurricane Shelter with
2 miles Circle
Hurricane Shelters & Hurricane Bus Stops
N
0
0.75
1.5
3
4.5
6
Miles

Regulation of Analysis

By checking the three indicators, i.e. the population density of the community, the frequency of flooding of the community and the service scope of the existing transport system, the conclusion of the distribution of the disadvantaged communities can be drawn. Because the higher the population density is, the greater the evacuation pressure is when disasters occur, and people are less likely to obtain effective evacuation. The flood frequency chart directly shows the frequency of flooding that have occurred in the area. The existing disaster-service-oriented transportation systems in Miami are mainly temporary evacuation points, emergency bus routes, and centralized evacuation centers at Metromover stations. The location of these service points also directly affects the efficiency with which people are evacuated during the disaster. The overlay of these three layers of data can provide a preliminary picture of the relatively more vulnerable areas in Miami's urban areas. The final data shows that the low-lying residential areas on both sides of the river channel are not only densely populated but also have a high probability of flooding, and the existing metromover stations are all concentrated in the lower city commercial area. These areas became the most vulnerable area in the city.

General Conclusions

Based on the survey in the first phase, the research team discovered the relationship between the formation of Miami City and the history of water, the way of how Miami's ecosystem and people are affected by floods and efforts to solve these problems.

Specifically, the results of the "Water Team" study indicated that water came to Miami from four directions: precipitation in the flood season; flooding in the Miami Canal; rising tides and groundwater levels; long-term sea level rise. All of these reasons together lead to frequent floods in Miami.

As shown in the "ecological team" study, long-term sea level rise may create new distributions of saltwater and freshwater. In addition, the entire ecosystem may be affected, particularly in the Miami County area, and the Everglades, known as the area's freshwater resources, would also disappear.

According to the "Crowd Team" analysis, Miami's cultural diversity is also threatened because flooding may affect the most vulnerable areas where immigrants are concentrated to celebrate their original culture, such as Little Havana and Little Haiti.

The analysis provided by the "infrastructure team" also shows that in addition to the impact of the Miami flood, people and ecosystems are not well protected due to the failure of infrastructure. In particular, the transportation system failed to efficiently evacuate from flood areas and caused huge losses to Miami people.

Research Assessment

The research work on the transport system was divided into three steps. The first step was a literature review to give an overall impression of Miami's existing transportation system. After searching the Internet, the definition and classification of different transportation systems in Miami are clear enough. The second step is modeling. In this step, the mapping of GIS data and profile drawings help to understand the overall traffic situation. GIS data provides accurate traffic stations and the location of each transportation route. Combined with the topographic maps, some correlation in-between can be revealed. Given that the mapping of GIS data is still too flat to show more complex relationships between different systems, the profile is made to compensate for this problem. Note that the profile is limited to all combinations of infrastructure systems. Although the display shows the correlation between all systems, it cannot represent the relationships between communities and systems in other city nodes. The combination of different locations of the facet nodes and surrounding communities may reveal more detailed relationships and conclusions. Drawings were made with precise dimensions, which reflected more reality. Especially in the case of high tides throughout the year, the threat of sea level rise is clearly visible for all to see.

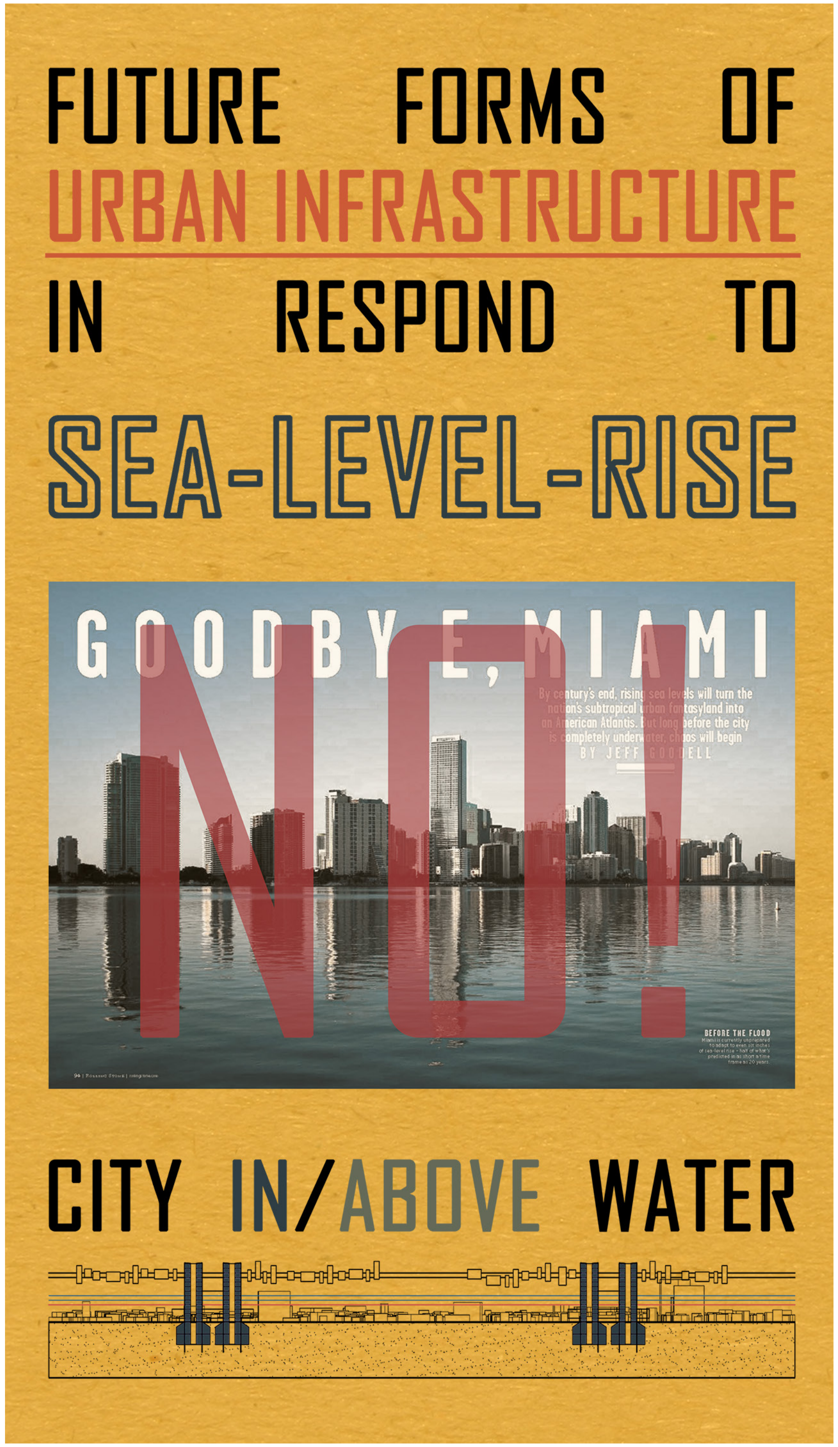
The third step is mapping analysis. In this step, four layers of information are stacked in order to draw the conclusions of the vulnerable community. The "FEMA Area" map shows the level of risk of being submerged. The "Storm Tide Planning Area" map is the priority for the government to organize an evacuation during the flooding occurrence. The "Block Groups 2010" map shows the population density of each demographic unit. Every hurricane emergency parking lot and shelters are surrounded by gradients, meaning residents can enter evacuation points. The four maps are monochrome and translucent. They share the same rules. The darker the color is, the higher the vulnerability. When stacked together, darker areas may exhibit higher levels of vulnerability. The data sources for this assessment are reasonable, but the importance of each data is that the scale factor is not yet known. By adding a percentage for each data, the results may change. In order to create more accurate results, more information needs to be calculated. Now, four map stacks with the same translucency are only used for rough estimation of relatively weak areas.

Phase 2 Schematic Design

Future Forms of Urban Infrastructure
In Response to Sea-level-rise

Abstract

Due to the special surface material of Miami, the normal sea-isolating mode failed, and the low-lying areas became particularly vulnerable. Therefore, measures aiming at this part of the region should focus on considering the mitigation of flood disasters. When the sea level rises to a certain height in the future, it will selectively abandon single-storey houses that are difficult to transform. When this area is flooded in the future, although it is uninhabited, distinctive buildings can still be preserved and become underwater museums. The original arterial road junctions would be replaced by regional infrastructure conversion centers, which could assume horizontal and vertical transportation as well as daily life services.



Introduction

In order to assess the effectivness of existing infrastructure system and its predictable future form in the aspect of protecting neighborhoods and keeping the city oprating well, phase 2 will build on Phase 1 by looking at the structure, organization of infrastructure system in Miami and its relationship to neighborhood blocks. Based on the existing political situation and social structure, under the thread of sea level rise and flooding in Miami, how infrastructure system can be evolved to adapt to more severe situation in future? What are possible alternative infrastructure system and city structure? How will the cityscape be look like with new infrastructure system?

Methods

1. Case study: Through the study of historically famous future city ideas, the role of infrastructure in cities was understood to explore the forms of cities that may be applicable to Miami.
2. Model Design: Through the production of models, the urban infrastructure of the new type of infrastructure was studied.
3. Classification: After determining the basic concepts, city blocks are classified and rated. According to the rating, different functional infrastructure units are placed in different neighborhoods.

PEOPLE & HISTORY & STREET FACADE

1566 — Pedro Menendez de Aviles

1900 — Population 1,700. Railway reached Miami in 1903

1910 — Population 5471

1920 — LAND BOOM. Population 29,517

1930 — Population 110,637

1940 — Population 172,172

1950 — PEACEFUL AREA. Population 249,276. W : B = 7 : 3

1960 — SEGREGATION. Population 291,688. W : H : B = 8 : 0.5 : 1.5

1970 — CHANGING PERIOD. Population 334,859. W : H : B = 6 : 2 : 2

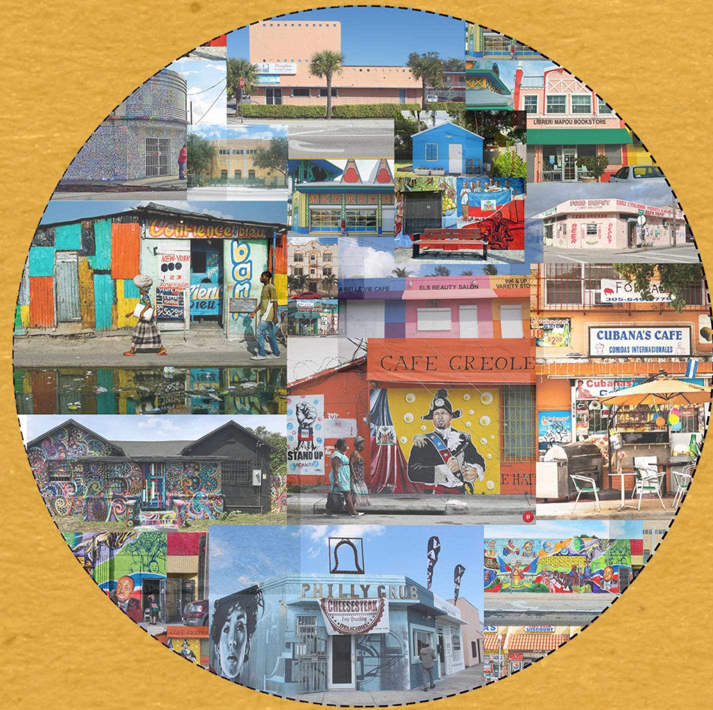
1980 — REFUGEE/ DRUG. Population 346,681. W : H : B = 5 : 3 : 2

1990 — CENTRIFICATION. Population 358,548. W : H : B = 3 : 5 : 2

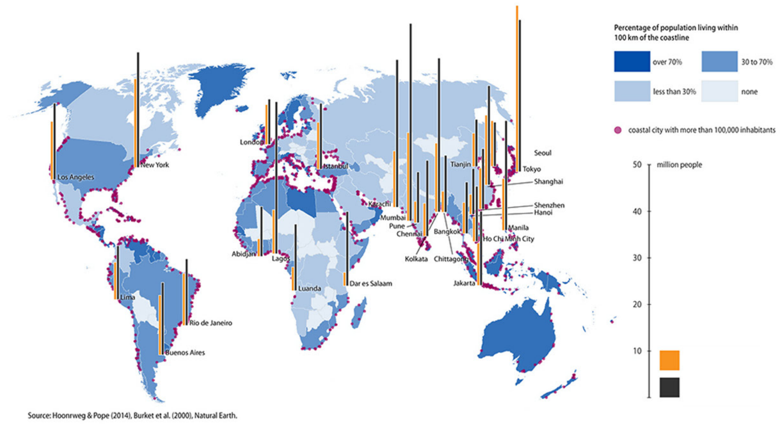
2000 — CHANGING COMMUNITIES. Population 362,470. W : H : B = 2 : 6 : 2

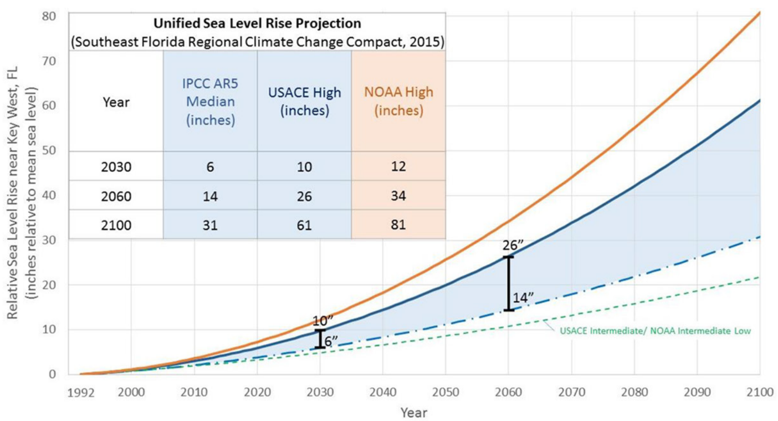
2010 — ART/ CULTURE. Population 399,457. W : H : B = 1 : 7 : 2

Now

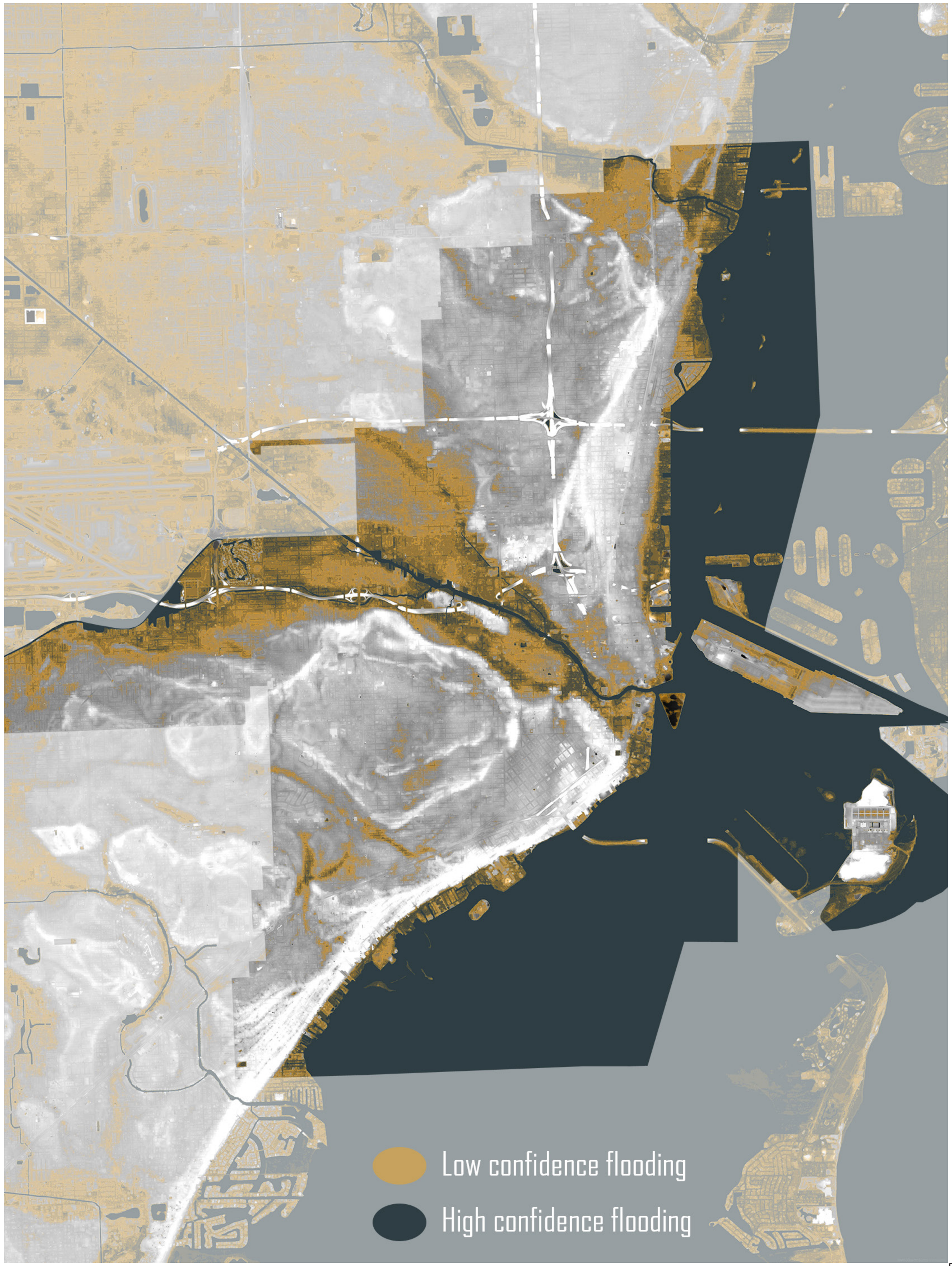


The lowland area of Miami is dominated by "Little Havana" and "Little Haiti". The buildings are diverse in form and quite colorful, recording the immigration history of Miami's rich Latin American ethnicity.

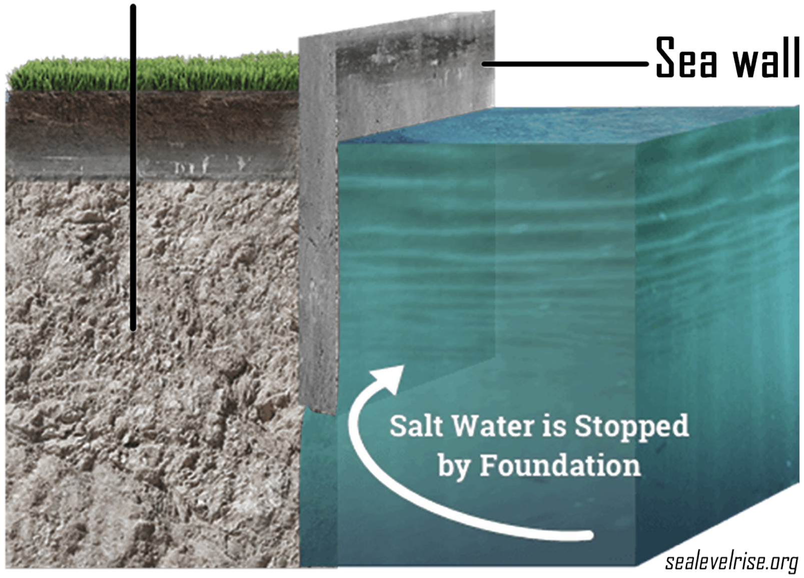




Miami's sea level rises much faster than the global average level. By 2100, sea level would rise by 6 Ft. In extreme weather such as storm surge, sea level could reach 10 Ft. Most of the lower areas in the city will be covered by water.

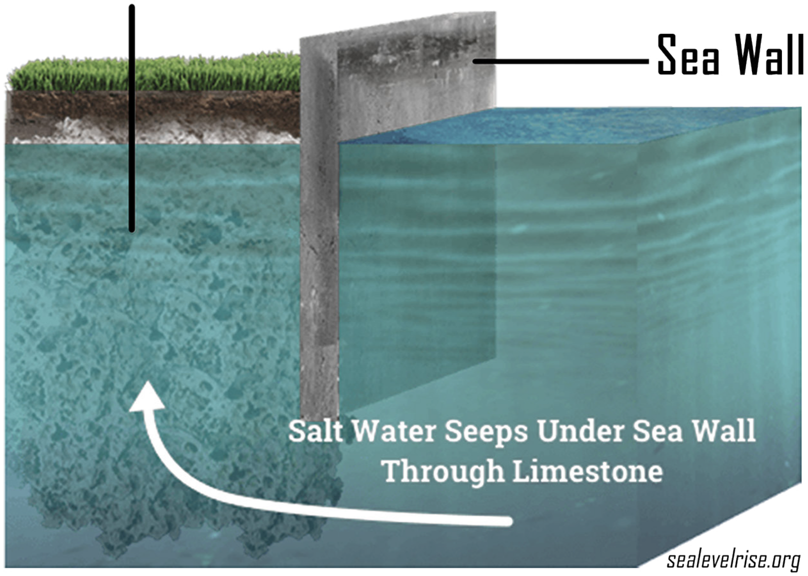


Typical coastal city foundation



Miami

Florida's limestone foundation



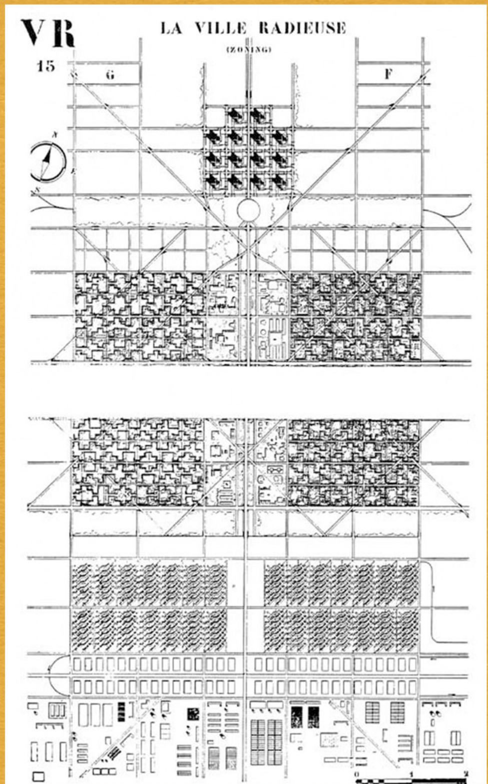
Failure of Sea Wall

Usually sea water can be blocked by “sea wall” when constructed concrete walls are connected with confining ground surface layer. However, the foundation of Miami is different. The composition of Miami faoundation is mainly limestone, which is highly permeable. Even the surface sea water can be blocked by sea wall, the body of salt water can still infultrate into city area through the permeable limestone.

Sea wall cannot be a long term solution to sea level rise.

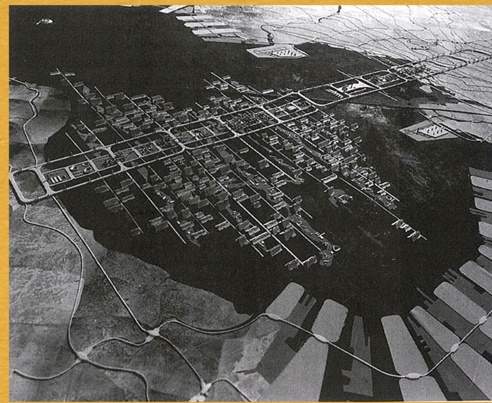
PRECEDENTS

1. The Radiant City by Le Corbusier (1924)

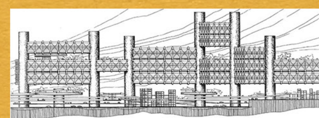


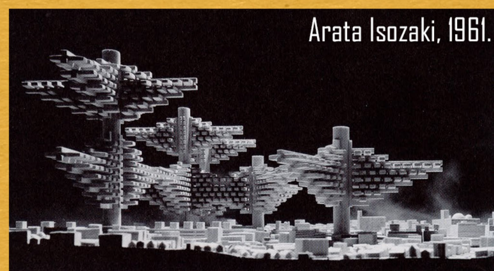
The new city would contain prefabricated and identical high-density skyscrapers, spread across a vast green area and arranged in a Cartesian grid, allowing the city to function as a "living machine." Le Corbusier explains: "The city of today is a dying thing because its planning is not in the proportion of geometrical one fourth. The result of a true geometrical lay-out is repetition, The result of repetition is a standard. The perfect form."

3. Era of Metabolism (1960s)



Plan for Tokyo, 1960. Photomontage and model. Kenzo Tange. The huge monumental axis built across the Tokyo Bay was designed for cars, keeping pedestrians away in separate areas through a hierarchy of expressways. The proposal differed from the ideas of CIAM, which was in favor of "urban centers" and proposed "civic areas" instead.

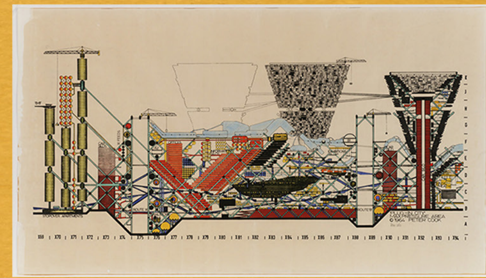




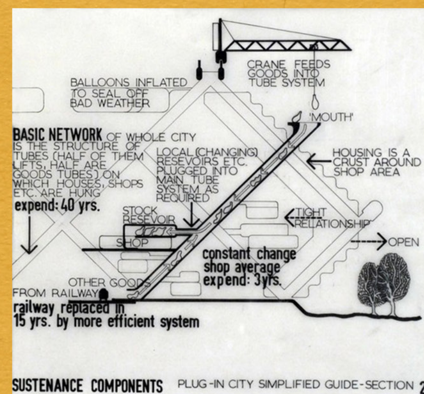
Arata Isozaki, 1961.

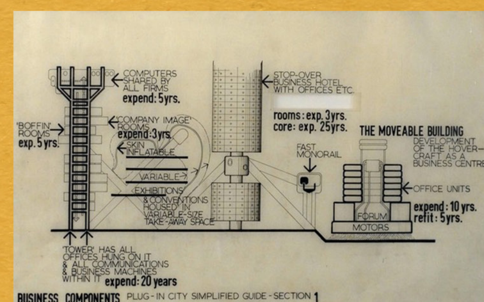
Joint Core System. Arata Isozaki, 1960. The plan assembled large horizontal arms around vertical elements, forming groups of offices. It was integrated into the Plan for Tokyo by Tange, his master.

4. Plug-in City by Peter Cook (Archigram)



This provocative project suggests a hypothetical fantasy city, containing modular residential units that "plug in" to a central infrastructural mega machine. The Plug-in City is in fact not a city, but a constantly evolving megastructure that incorporates residences, transportation and other essential services--all movable by giant cranes.

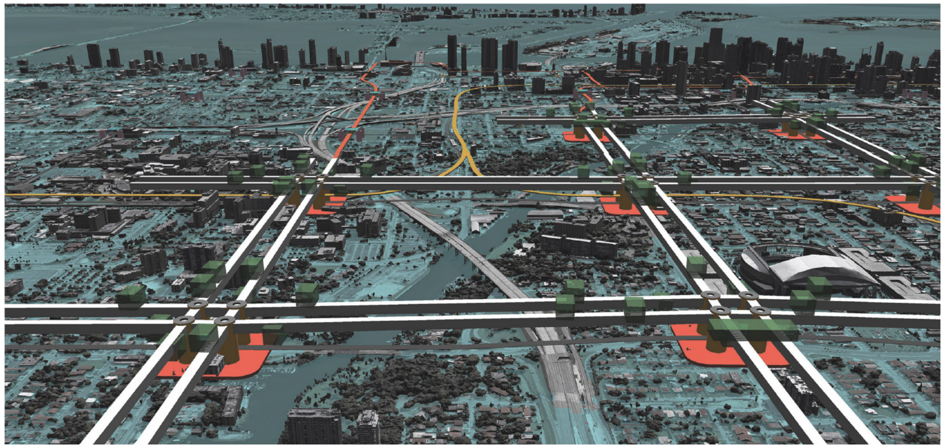




Inspired by Precedents

The vision of the future city is often idealistic, expressing the author's expectations or dissatisfaction with social relations and institutions. Nonetheless, these ideas have brought some inspiration to Miami, which is about to face rising sea levels. In addition to the one proposed by Wright, the other three proposals all agreed to have the city elevated. The purpose of the Corbusier's elevation is for the liberation of the human's ground living space, as well as the idea of human self-respect. Metabolism and Archigram are looking for a living space upward to cope with expanding cities. For Miami, unavoidable seawater intrusion and land inundation, the elevation becomes more reasonable, giving people the opportunity to live above the water.

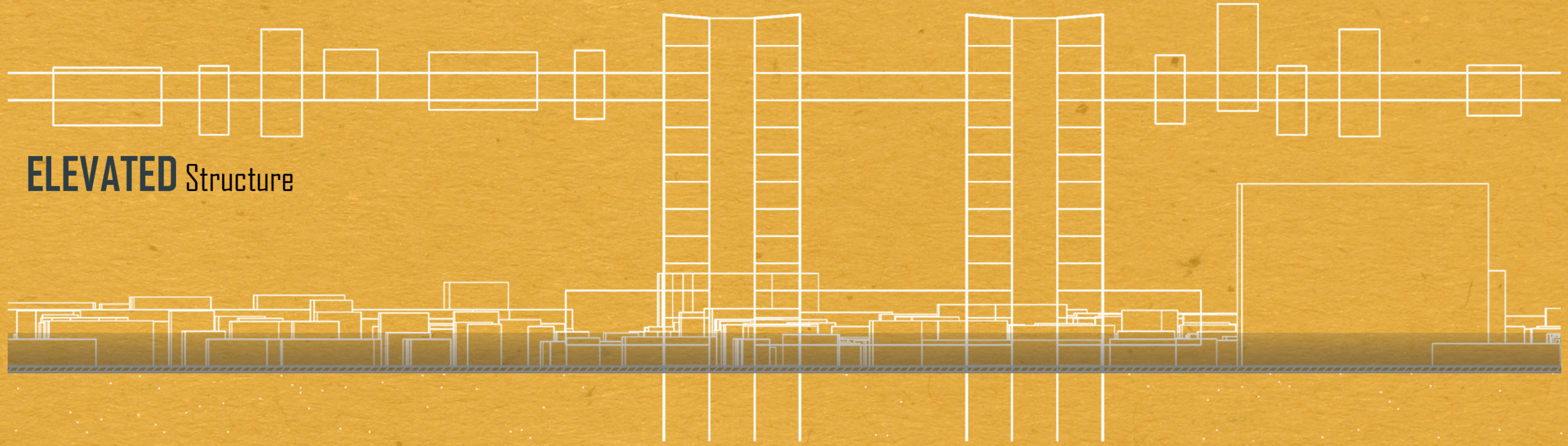
Following to the current sea level rising trend, in the next 100 to 200 years, Miami's lowland areas will be completely submerged with the water depth up to 3 to 6 feet. The submerged low-lying areas are mostly one or two-story houses and are extremely worn out, making it difficult to cope with sea level rise. Should we relocate the residents of the lowland areas out of the city and give up them? If global coastal cities adopt the idea of migration and selective abandonment, we will lose more architectural heritage and even regional culture. The lowland area of Miami is dominated by "Little Havana" and "Little Haiti". The buildings are diverse in form and quite colorful, recording the immigration history of Miami's rich Latin American ethnicity. Therefore, even if some houses cannot continue to be used normally due to flooding, they can still be protected. People do not need to relocate far away from the cities and regions that bear the weight of their own memories, but live on the original remains. The future Miami lowland area will be an underwater buildings exposition center, where elevated water structures coexist with flooded remains. People ride water or amphibious vehicles in submerged houses and use the regional infrastructure centers to switch other modes of transportation to travel more extensively. People in an elevated structure can always overlook the city's past memories, and those beautiful buildings still shine in the water.

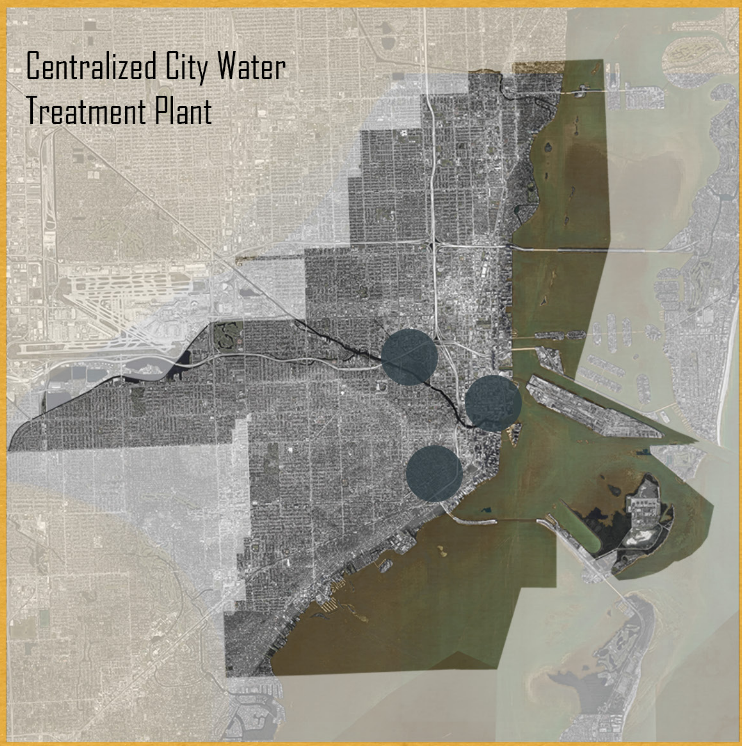


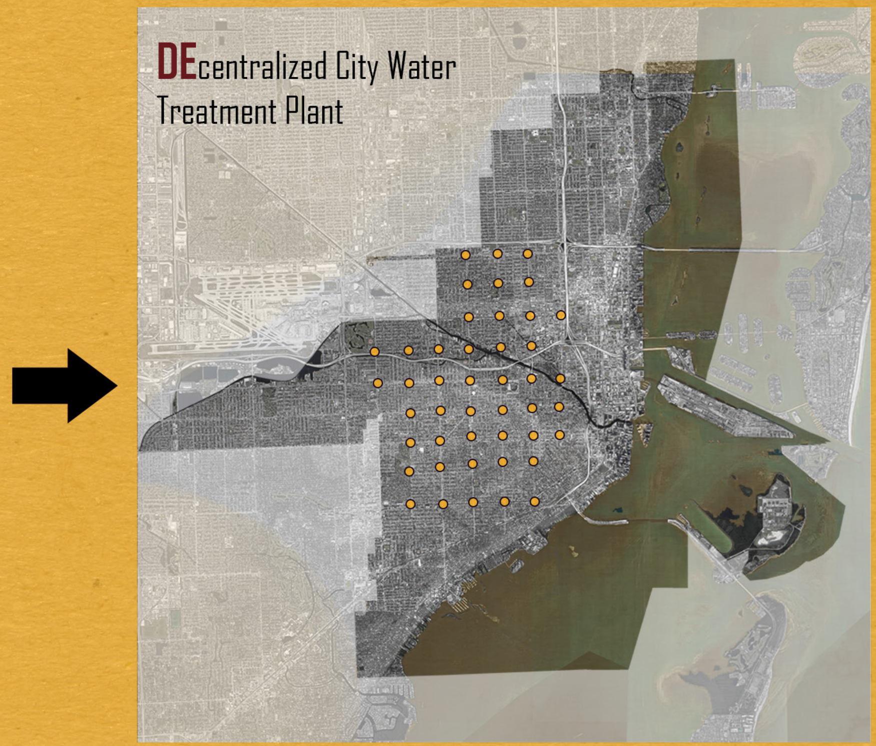
Imagination of Living Above the Inundated City

Miami's urban tourism industry is extremely developed as the preferred destination for the north residents of the northern coast of the United States. Once the city's iconic, sunny beach was a major attraction for tourists. Nowadays, people come to Miami and will not only enjoy the comfortable temperature, but also can overlook the entire "Little Havana" at any time, and even sail through the streets in the middle of the past.

The value of this idea lies in the attitude towards rising sea levels, not to fear nature, but to adapt to nature and use it for good. When residents of coastal cities are forced to co-exist with water, there should be a new infrastructure system to serve people's normal lives.


ELEVATED Structure

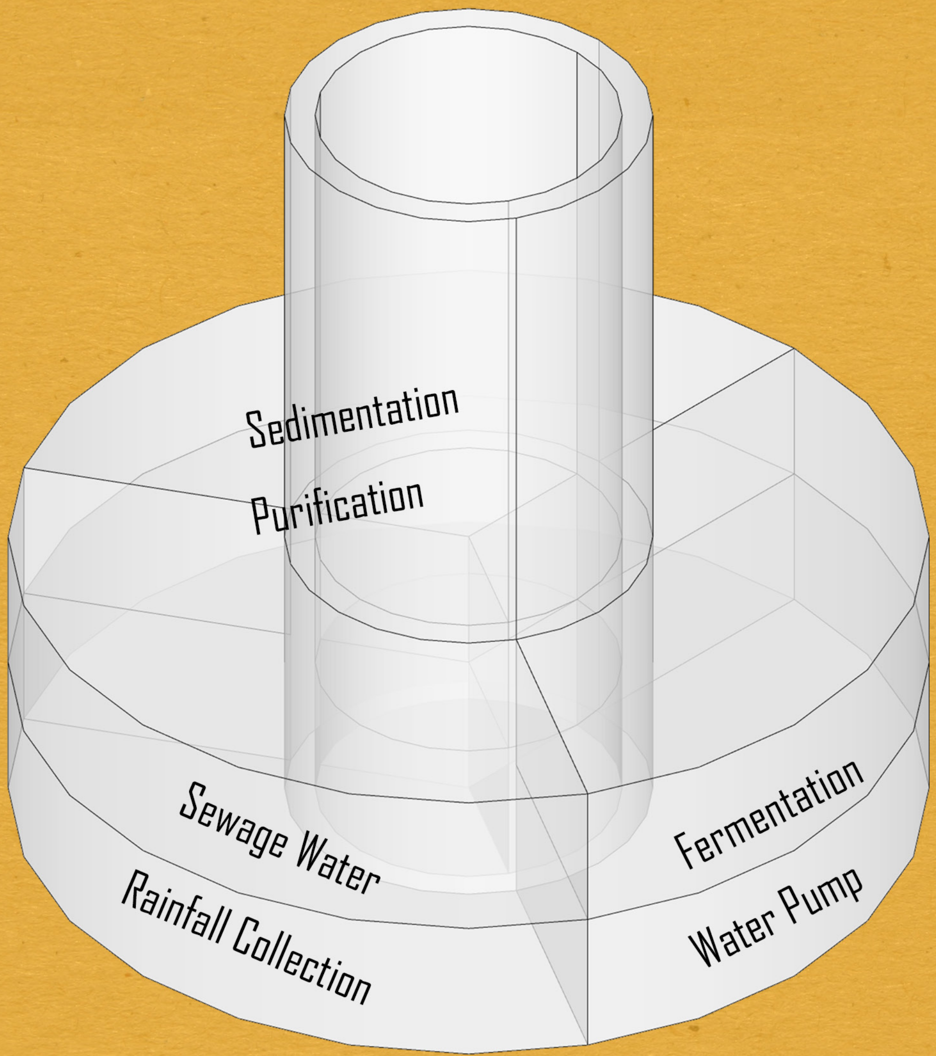

Centralized City Water
Treatment Plant


DEcentralized City Water
Treatment Plant

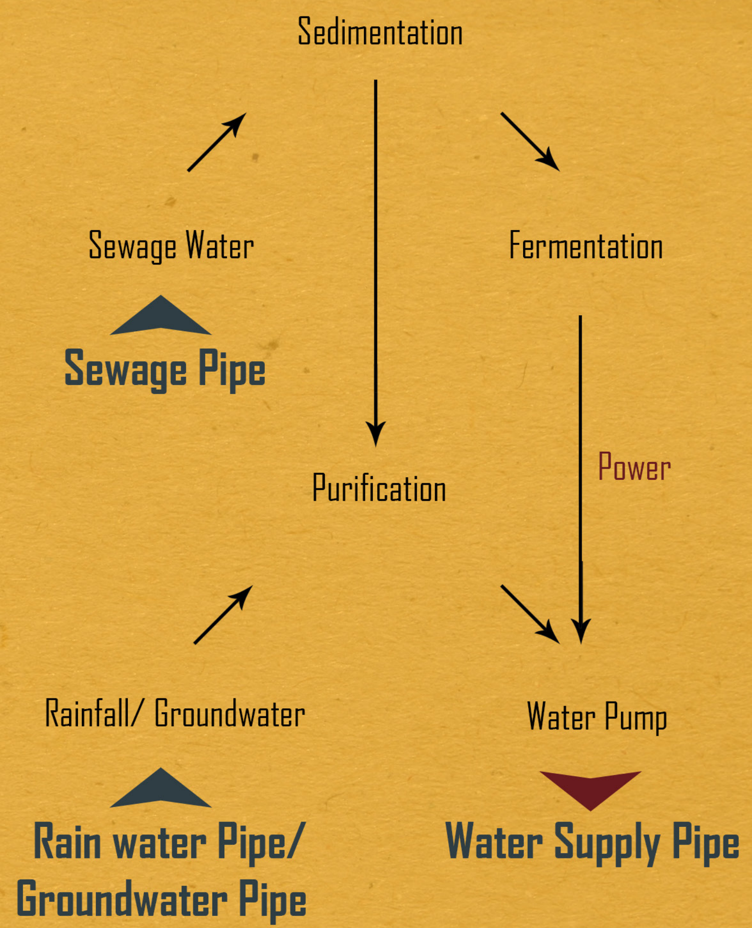
Strategy of
REGIONAL INFRASTRUCTURE TRANSITION CENTRE

The main purpose of the "regional infrastructure transition center" is to solve two problems in the lowland area. The first is the transport connection, that is, how to meet people's travel in flooded state and how to connect existing transport infrastructure. Therefore, the ground section is designed as a column structure to support the elevated bridges and rail traffic. Although the original road surface will be difficult to use, in the next 30 to 50 years, the area will still maintain its basic security during the sea level rise. So these cylinders are arranged at the intersection of each main road, so that the new elevated road network will cover the original road surface and keep the original texture of the city intact. Before the advent of floods, columnar structures will transport people to the elevated transportation network as vertical traffic and meet the basic needs of people at transfer stations. When the city is submerged, the regional infrastructure center will also undertake a transfer across vehicles to meet the needs of people mooring boats and cars.

The second is the circulation of water. The underground city of Miami has a very precious aquifer that provides freshwater resources for current urban residents. In spite of that, with the rise of sea level, salt water intrusion becomes an unavoidable trend and Miami's drinking water is greatly threatened. Therefore, exploring new freshwater resources is particularly important for regional sustainable development. If water is not used inland, the largest source of freshwater resources available in Miami is water, followed by desalinated water. Due to the high cost of desalinating seawater, and the inability to anticipate the future state of science and technology, and the very high rainfall in Miami, it seems that collecting rainwater is more economical in the short term. Clean water can greatly reduce the cost of purification, so every house should be equipped with more perfect rainwater collection pipes on the roof, and the rainwater from the roof should be sent directly to the rainwater collection tank in the center of the regional infrastructure.



Sedimentation
Purification
Sewage Water
Rainfall Collection
Fermentation
Water Pump

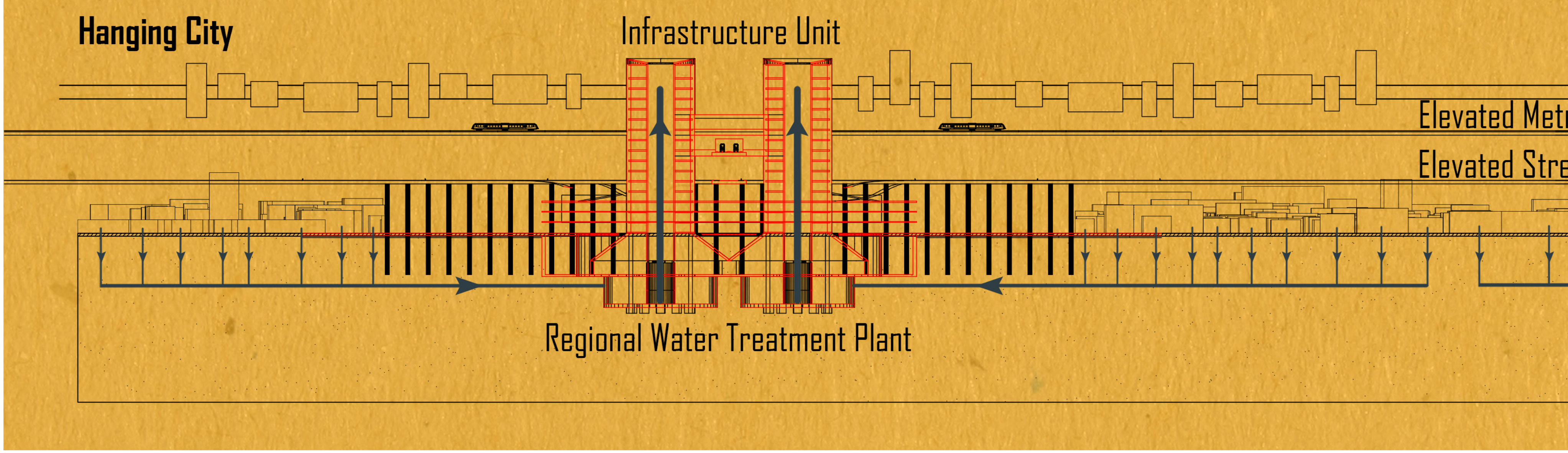


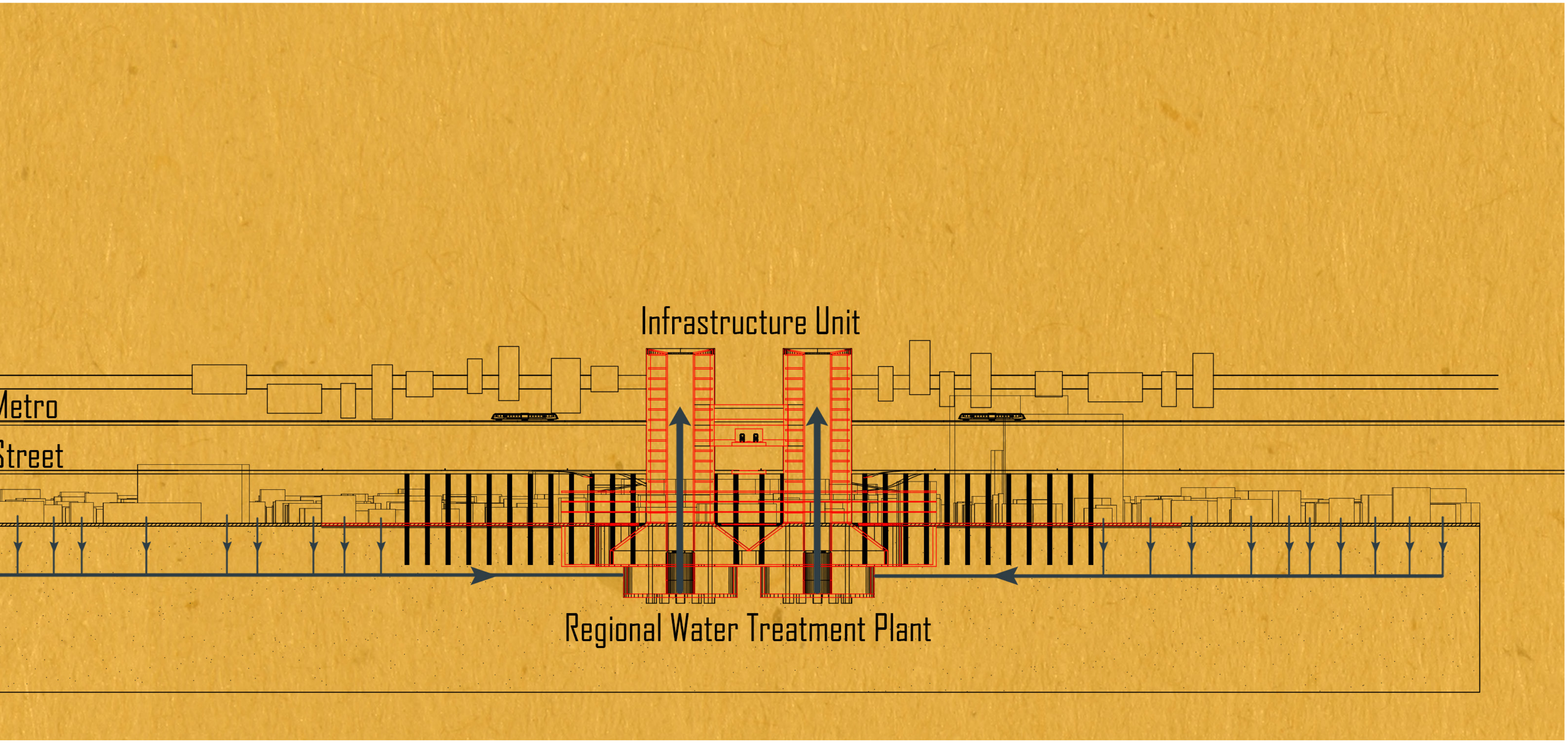
Sedimentation
Sewage Water
Fermentation
Sewage Pipe
Purification
Power
Rainfall/ Groundwater
Water Pump
Rain water Pipe/
Groundwater Pipe
Water Supply Pipe

Logic of
REGIONAL WATER TREATMENT PLANT

In this way, there are four types of existing water sources in Miami. Rainwater and groundwater can be directly purified and utilized. Surface runoff floods can be used after sedimentation and domestic wastewater can be treated as medium water for reuse. Such four sources of water will greatly ease the freshwater crisis in the city. The center of the cylinder is the core of the water system on which people rely, including water supply pipes, drainage pipes, and water collection pipes. These pipes lead to the underground part of the cylinder - a small area water station. Underground space is divided into rainwater recovery pools, groundwater collection areas, flood buffer pools, water treatment facilities, clean water reservoirs, and water pumps. This small-scale regional water station will meet the daily water and sewage treatment in the surrounding neighborhoods. The volume of the flood buffer pool is calculated based on the amount of storm precipitation. It will attract surface runoff during the storm to ease the drainage pressure within the area.

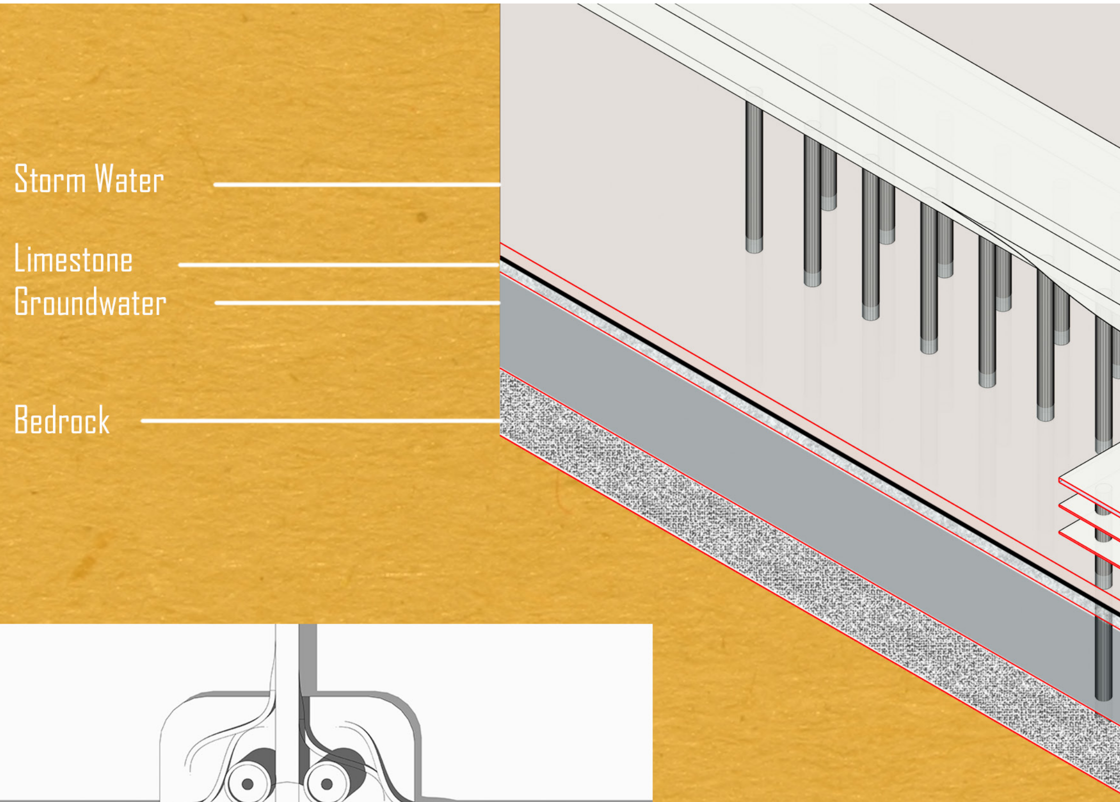
SECTION DRAWING: RAIN WATER RECYCLE

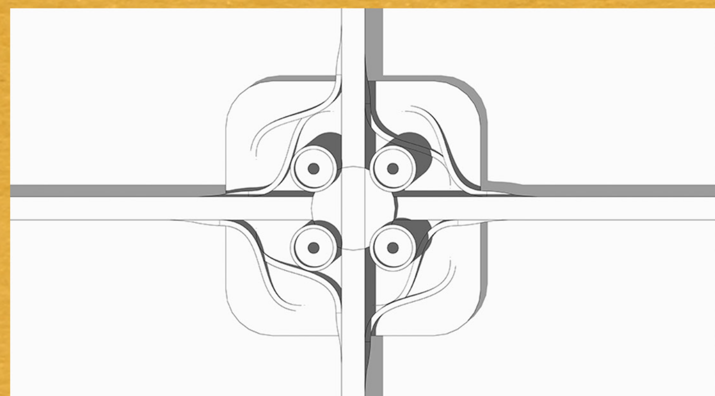


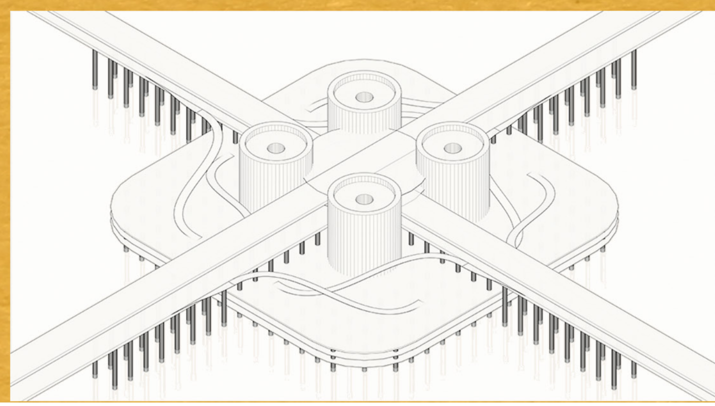

Infrastructure Unit
Metro
Street
Regional Water Treatment Plant

In this way, there are four types of existing water sources in Miami. Rainwater and groundwater can be directly purified and utilized. Surface runoff floods can be used after sedimentation and domestic wastewater can be treated as medium water for reuse. Such four sources of water will greatly ease the freshwater crisis in the city. The center of the cylinder is the core of the water system on which people rely, including water supply pipes, drainage pipes, and water collection pipes. These pipes lead to the underground part of the cylinder - a small area water station. Underground space is divided into rainwater recovery pools, groundwater collection areas, flood buffer pools, water treatment facilities, clean water reservoirs, and water pumps. This small-scale regional water station will meet the daily water and sewage treatment in the surrounding neighborhoods. The volume of the flood buffer pool is calculated based on the amount of storm precipitation. It will attract surface runoff during the storm to ease the drainage pressure within the area.

The unit's volume of stormwater collection pond and flood buffer pool can be extrapolated from the roof area within the street block. For example, near "Little Havana", all roof areas are 22% of the whole area. Because of the poor absorption capacity of Miami soil, it can be assumed that all rainwater will eventually flow into the water station in the center of the regional infrastructure during the storm. The amount of rainwater collected is the sum of all rooftop precipitation, while the flood buffer pool should meet the drainage requirements for other volumes of water.

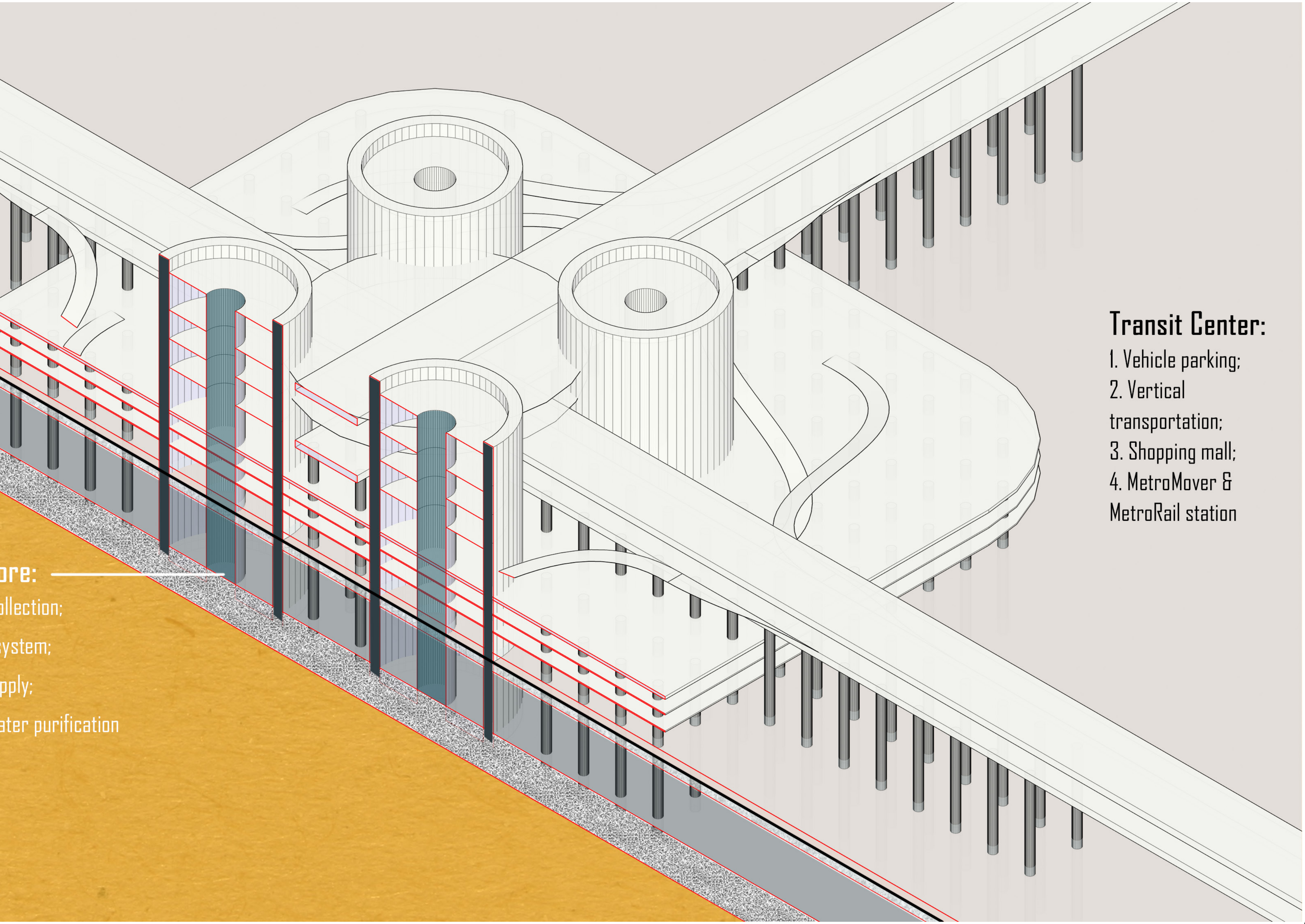






Water Core

1. Rainfall collec
2. Sewage syste
3. Water supply
4. Groundwater


Transit Center:
1. Vehicle parking;
2. Vertical transportation;
3. Shopping mall;
4. MetroMover & MetroRail station
ore:
llection;
ystem;
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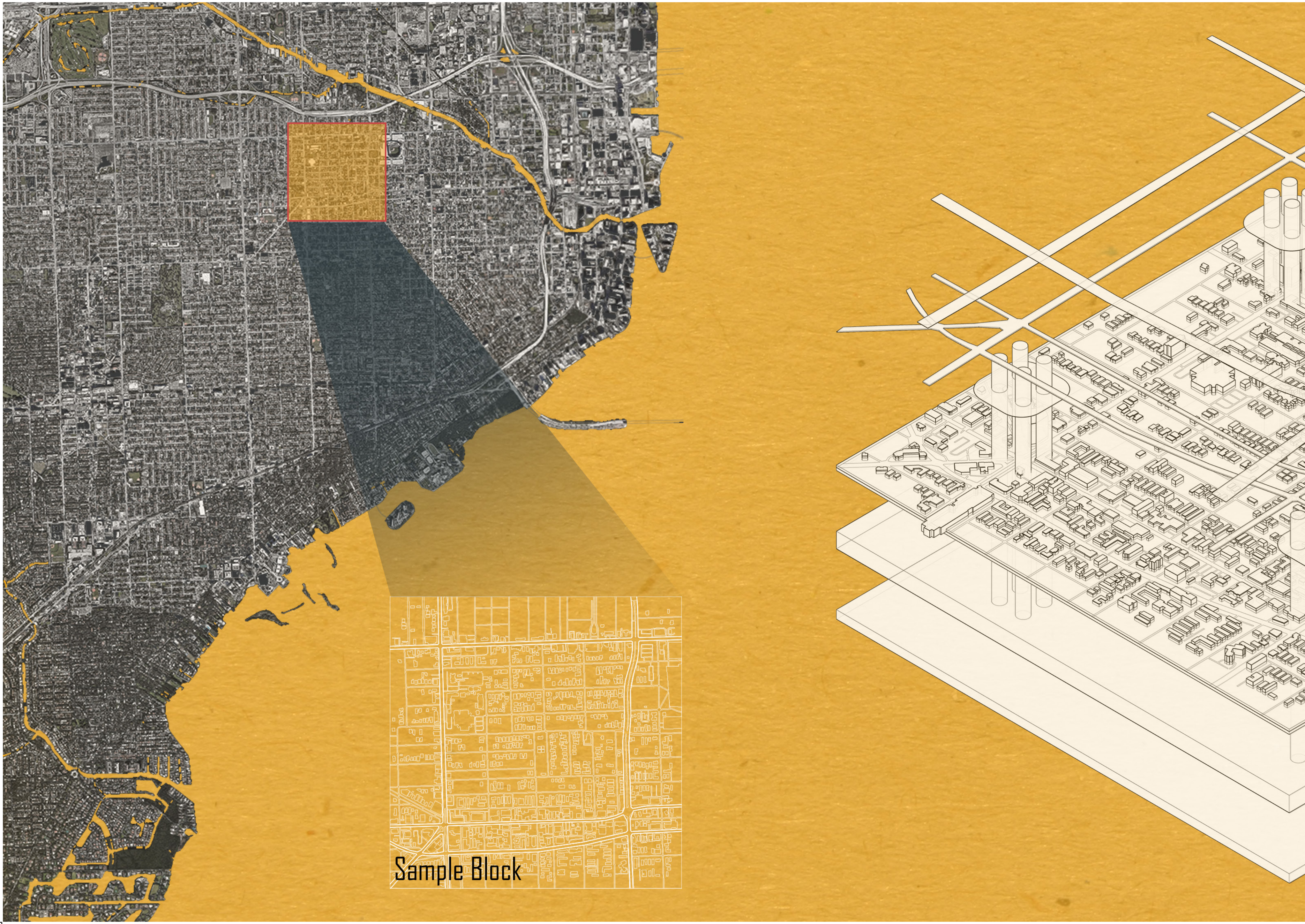
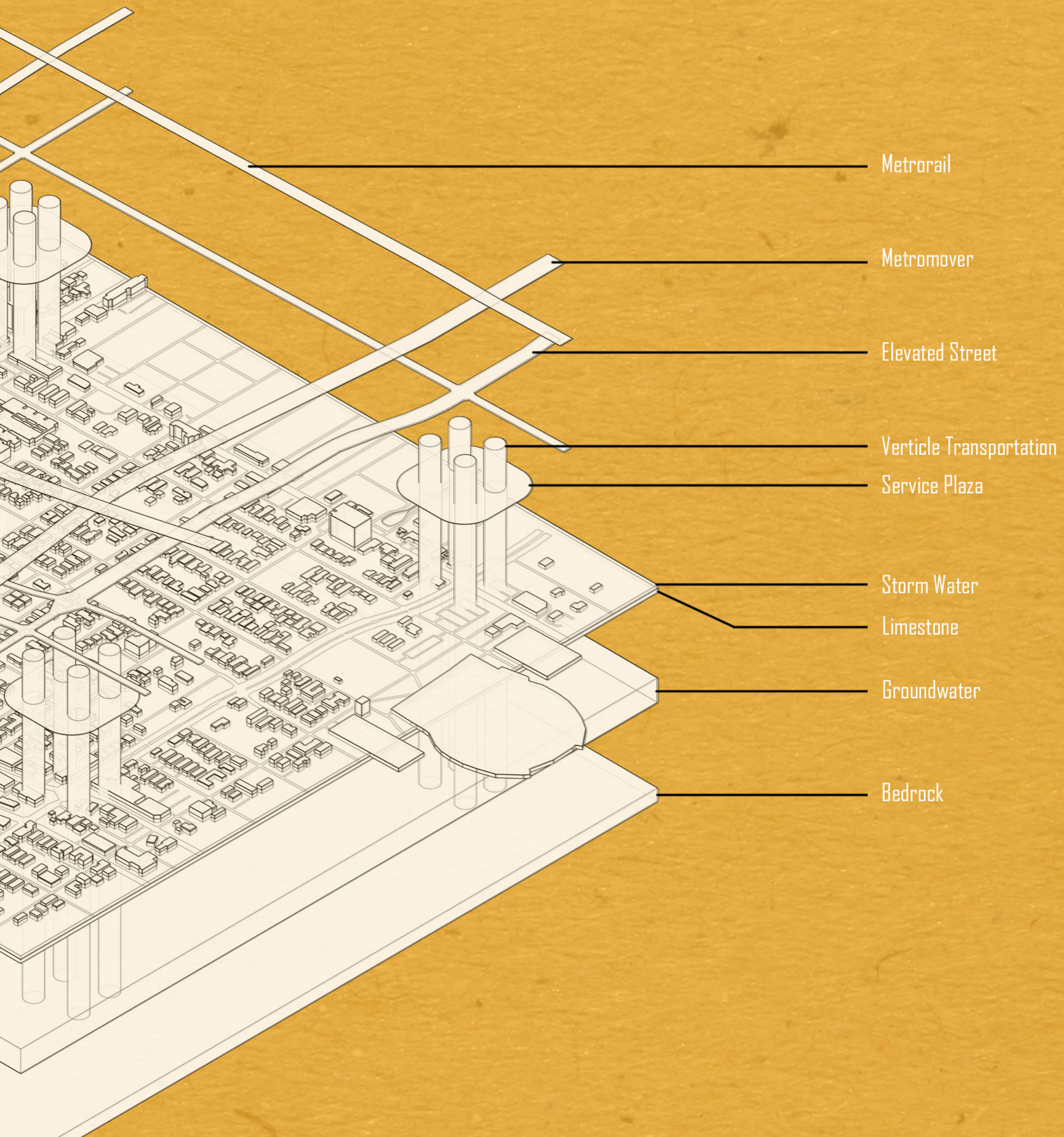
ater purification


Sample Block



City Grafting

Sample Precipitation Calculation

Area of block: 7127,485 Ft2

Area of roof: 1576,865 Ft2

Percentage of collectable stormwater: 22%

Volumn of one-time Precipitation: 533,000,000 Gal

↓

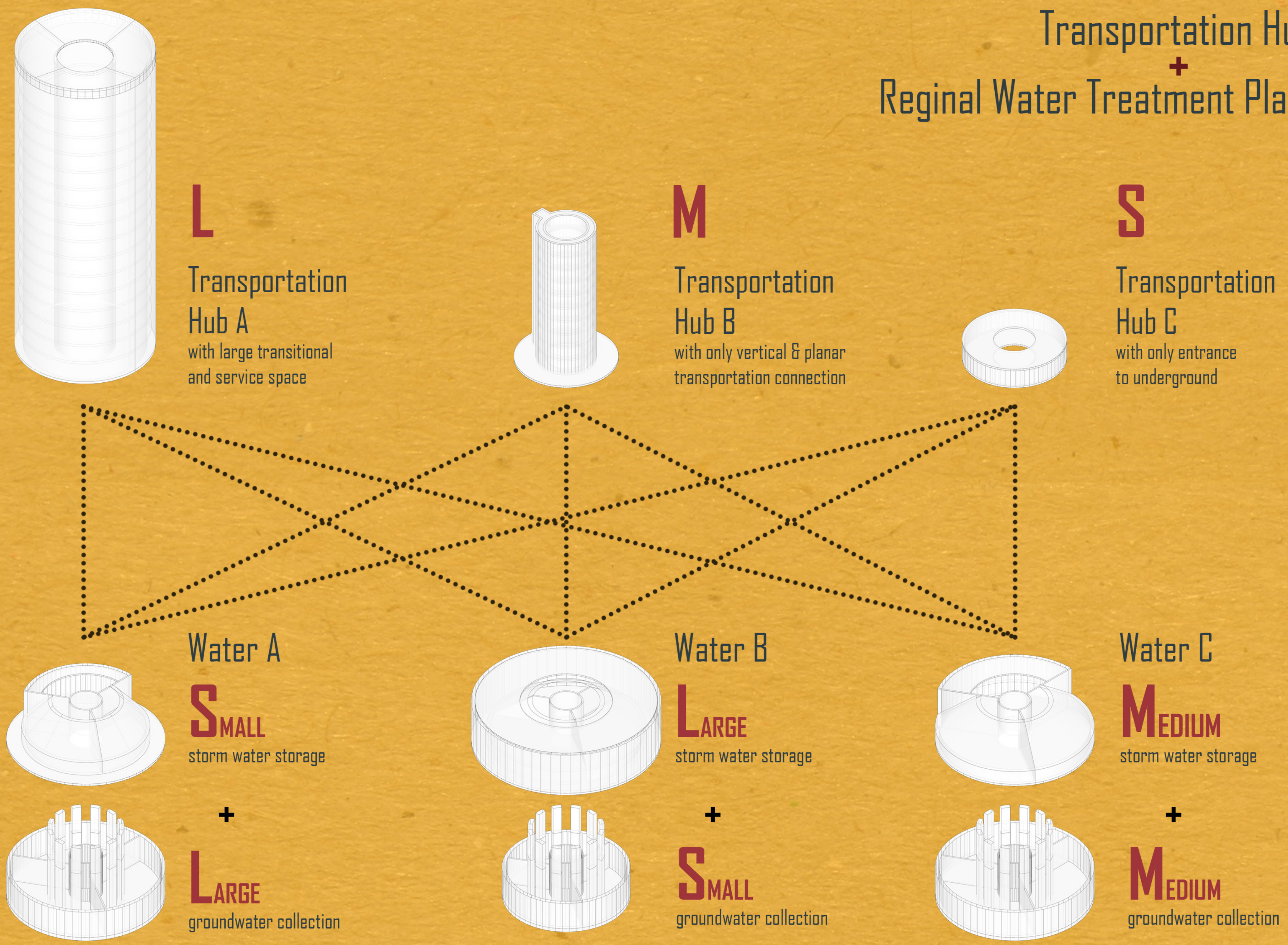
Volumn of Flooding Buffer Tank: 415,740,000 Gal

Volumn of Stormwater storage Tank: 117,260,000 Gal

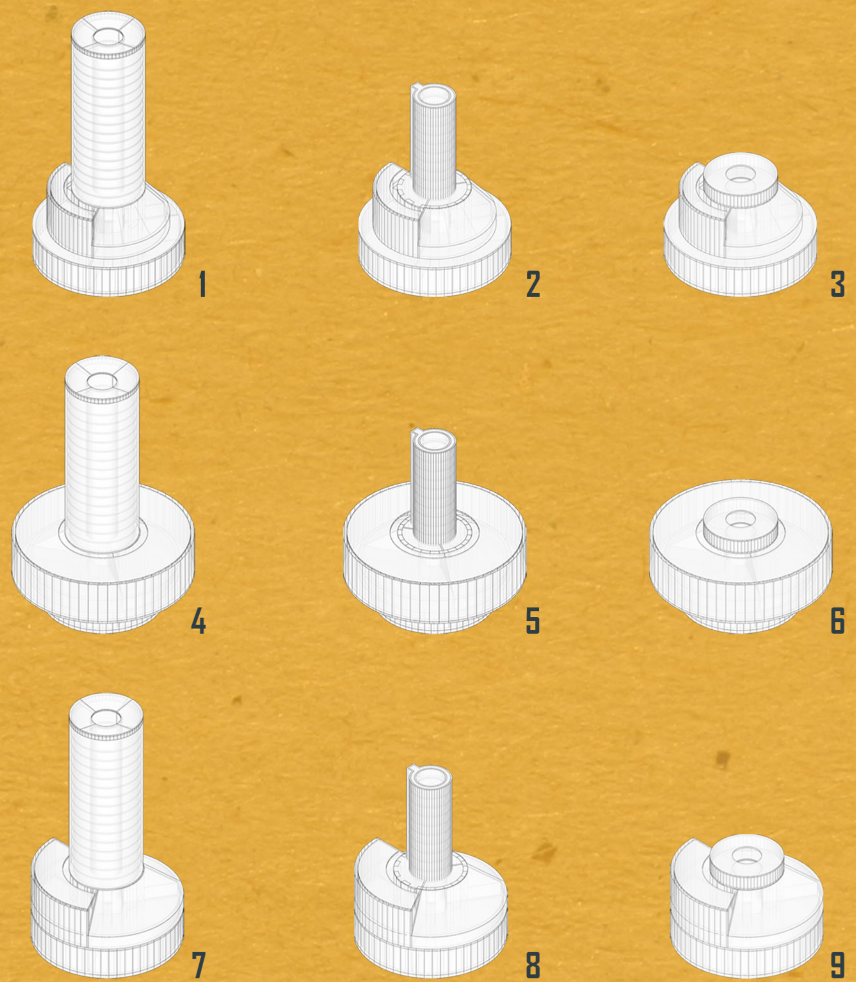
Phase 3 On-site Application

Units Distribution & Construction Schedule

Transportation Hub
+
Reginal Water Treatment Plant



Units Assembly



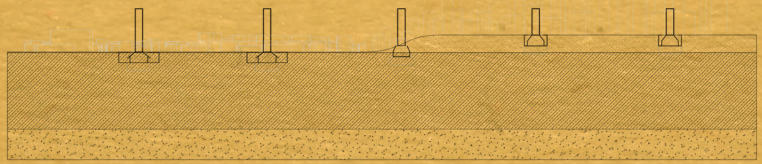
Each regional infrastructure center is an individual unit that serves its own neighborhood. They will be contacted by the new elevated road network and rail transit to serve all nearby residents. Remarkably, in the urban area of Miami, the terrain changes, and the population density may also vary. Therefore, the traffic load and water capacity of each conversion center unit are different from each other.

To handle this issue, the unit is designed to match the ground structure with the underground structure. The ground structure is divided into three different schemes in line with the number of people and the needs of the block. The first is the densely populated areas, and there is no elevated traffic, and the largest surface transportation transfer system is needed. The second is followed by areas where the population density is moderate, and where there is no elevated traffic and a smaller area of traffic transfer system is needed. In the end, there is an area with elevated traffic, namely, the commercial center of downtown. There is no need for a new ground transfer system in this area. The transfer system in other areas can be connected to the existing elevated system.

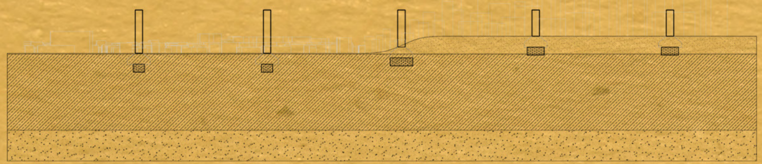
Underground structures are also divided into three different scenarios. The first is the low-lying area, which is the most vulnerable to floods, requires the largest volume of flood buffer space. As groundwater is more vulnerable to saltwater intrusion, only minimal groundwater absorption systems are required. Secondly, in the highland areas, the groundwater resources are relatively safe and the surface runoff is slow. Therefore, large flood buffer space capacity is needed, and there is also a large groundwater collection center. Finally, in urban slopes, surface runoff flows to low ground, so a minimum flood buffer space is needed. Groundwater depth is shallow and relatively safe, so there is a lower cost to establish a larger groundwater collection center.

Therefore, the combination of the ground structure and the underground structure may form nine different units according to various conditions.

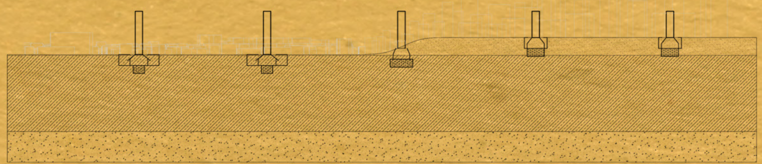
UNITS DISTRIBUTION



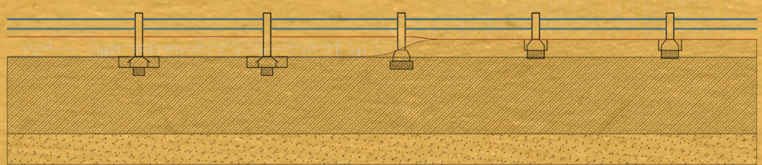
Storm Water Storage Capacity



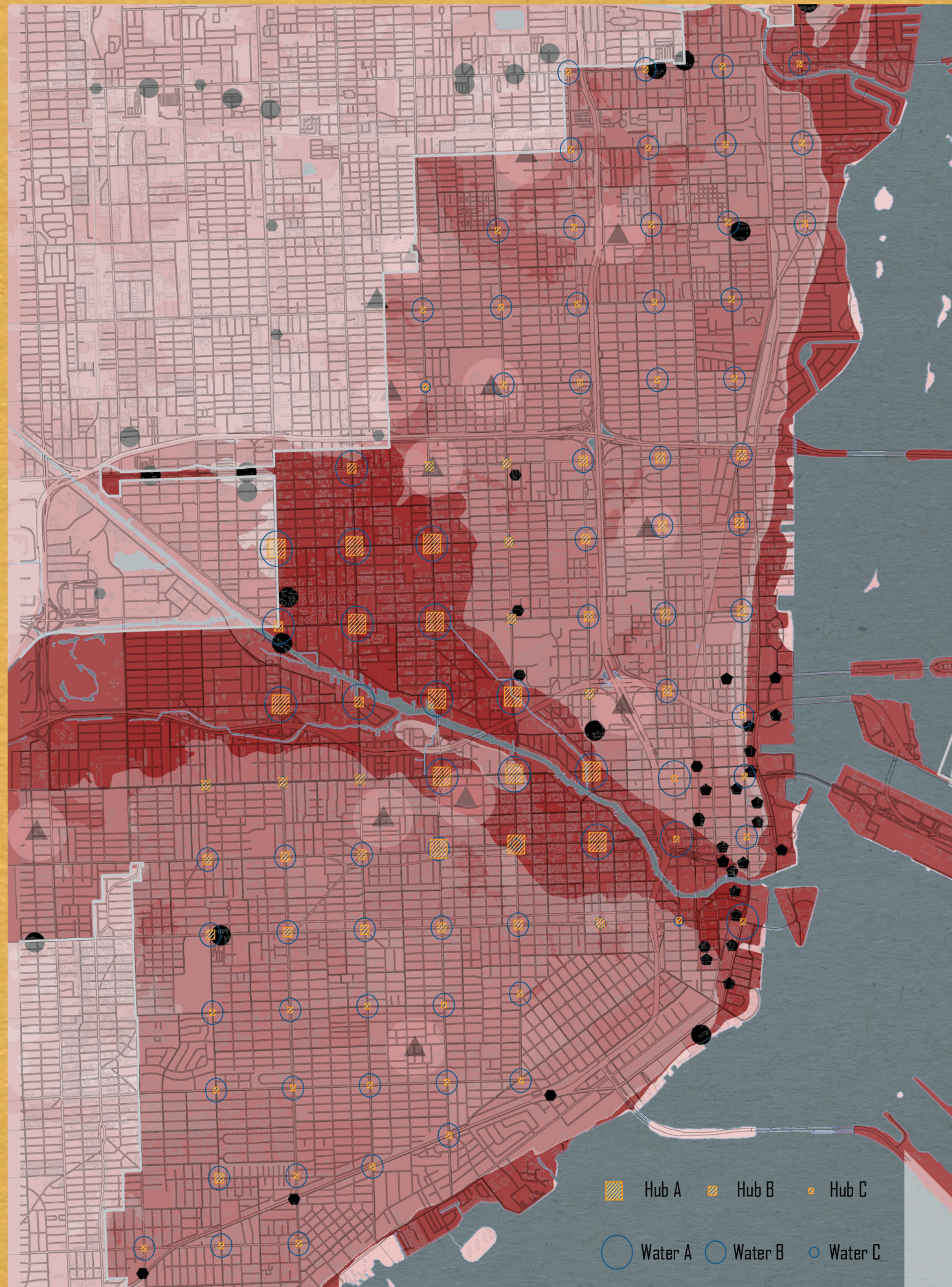
Ground Water Exploitation Amount

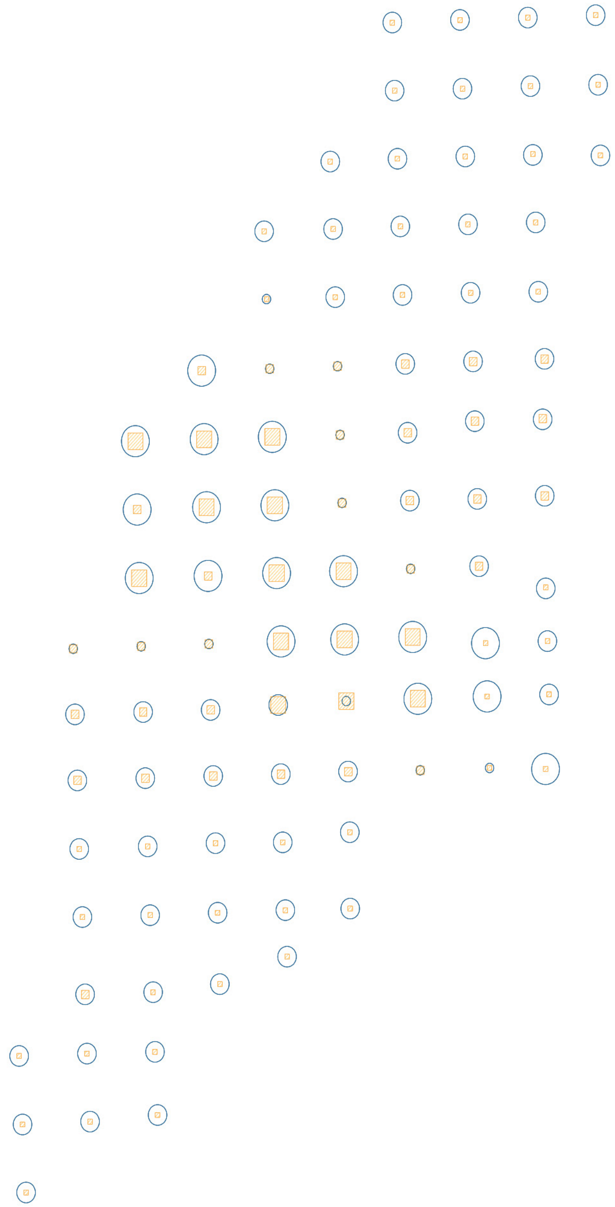


Water Treratment Plant Units



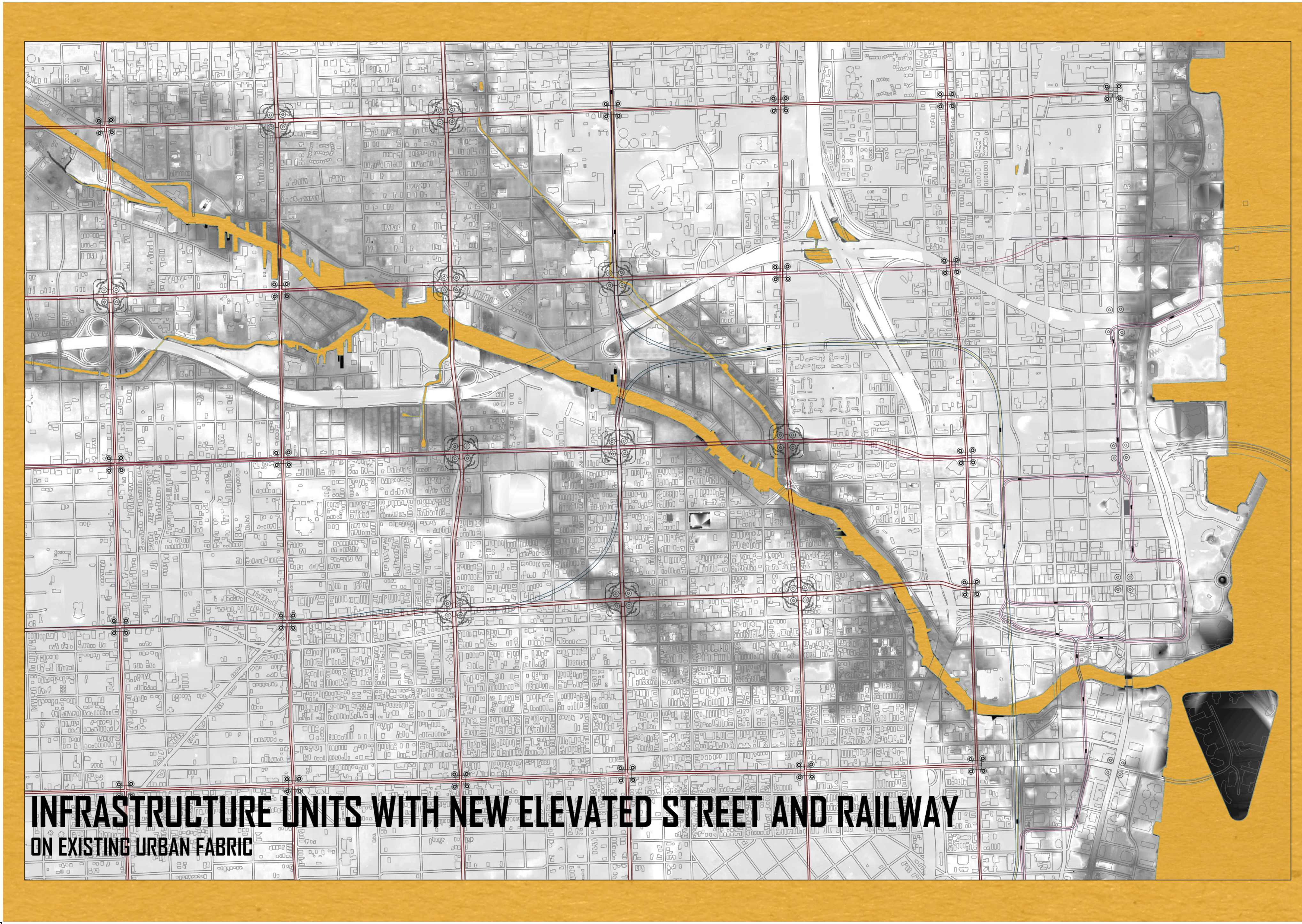
Transportation Connection



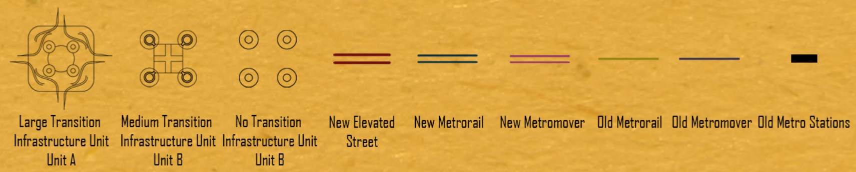


Regulation of Units Distribution

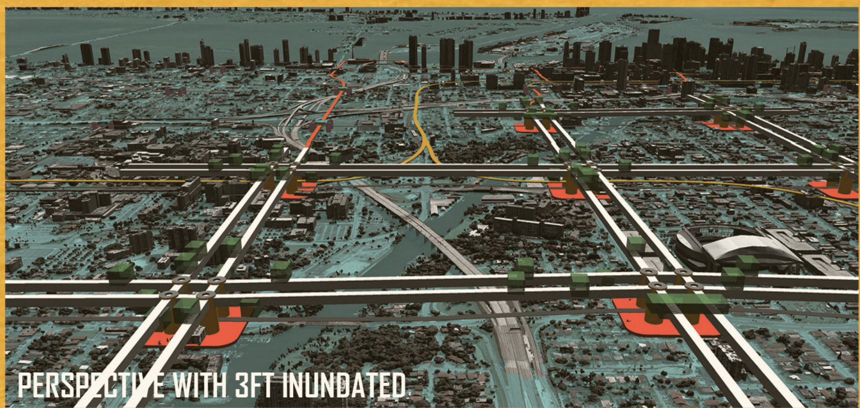
The nine different can be distributed to each road node via the city's main road network. The final city plane allocation is determined by a hierarchical map of different impact factors. The first is a population census map representing population density. A total of five levels of color from dark to light represent population density from high to low. Followed by the flood frequency map of the USGS, the same five deep-to-light colors represent the frequency of flood disasters in the area. This data basically coincides with the contour line, so the contour line is no longer set. The last is the city's existing elevated transit and refuge. Since elevated transit stations also provide refuge in extreme weather, these nodes can reduce the risk index in the surrounding areas. The lightest colors on these maps of the stations and shelters indicate that the risk index is at the lowest level. Since flood frequency maps have the most direct impact on the region, the map has an impact factor of 70%, a population density of 20%, and stations and shelters of 10%. The last three groups of information are superimposed, and the deepest color represents the most vulnerable block. The degree of vulnerability of the blocks resulting from the superposition of information could determine both the volume of the water system and the area of the traffic system. In the comprehensive consideration of the previous topographical basis and whether or not an elevated station has been completed has resulted in a final distribution map of different infrastructure units across the city.

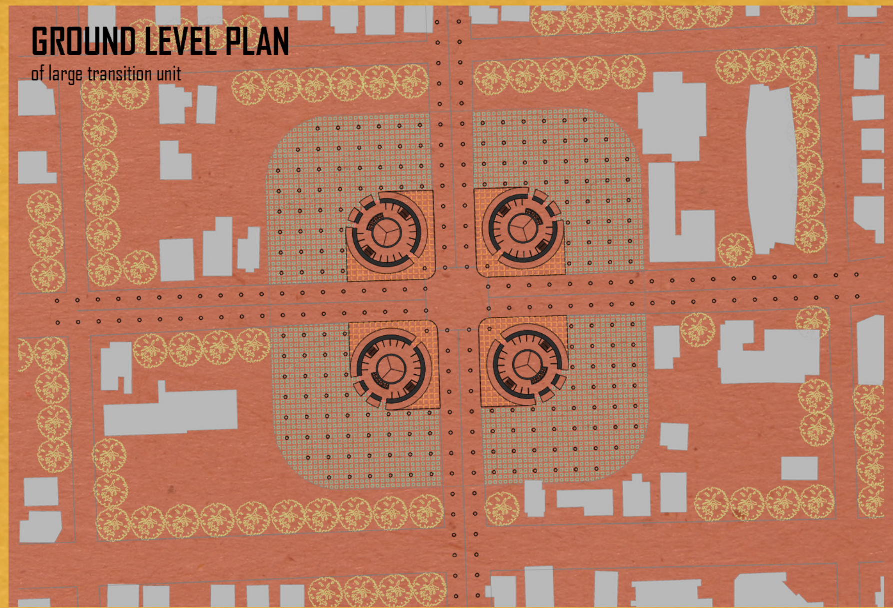

INFRASTRUCTURE UNITS WITH NEW ELEVATED STREET AND RAILWAY
ON EXISTING URBAN FABRIC

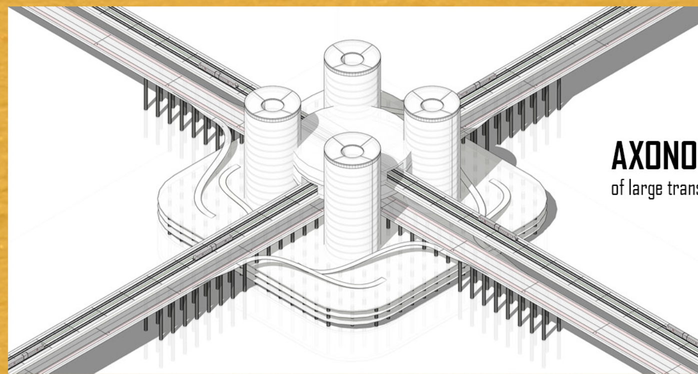
Legend




PERSPECTIVE IN DRY ERA


PERSPECTIVE WITH 3FT INUNDATED


GROUND LEVEL PLAN
of large transition unit



AXONOMETRIC DRAWING
of large transition unit

Construction Schedule

Based on the rate of sea-level rise and taking into account the altitude of the Miami lowland area, time nodes can be divided into 30 years, 100 years and 200 years. In the first 30 years, the lowland areas will still not be submerged by seawater. As a preparation stage, the government should focus on the construction of infrastructure units and the installation and connection of roof rainwater collection pipes for each house. Because even if the sea level rises for hundreds of years, most houses still have the ability to collect clean rain on the roof, which is Miami's most economical renewable freshwater resource in the future.

After 100 years, Miami's lowland neighborhoods will be completely submerged, but the water depth is only one meter below. During the 30- to 100-year period of the sea-level rise, people need to gradually adapt to the environment in which they live in water. During this period, elevated traffic should be relatively complete, and amphibious transport is becoming the most practical means of transportation. The groundwater treatment center's flood buffer area is closed as a seawater purification space or other water treatment space.

Between 100 and 200 years, the water depth will be close to two meters, satisfying the displacement of most private vessels. The low-lying areas of this period will become completely water cities, and the elevated structure will have the opportunity to extend and build more futuristic cities, overlooking the city's remains in the water. The elevated transit center on the ground is equipped with more perfect parking spaces for people. People can leave their transfer stations to take their own boats or rent boats to come back to their homes.

Overall Assessment

Final Conclusions

This paper focuses on the existing infrastructure in Miami and concludes that there are problems and adaptive advantages in the infrastructure. Then, the new infrastructure system could be optimally used to make up for the deficiencies of the original system. The existing effective design was continued, such as the urban elevated system and the traffic transition center with temporary evacuation functions.

At the same time, aiming at the current status of human geography in Miami, the vision and plan for the future city are proposed. The program's rational use of sea level rise not only enables the city to exist in a new form, but also provides Miami with new urban labels and memory points. The development of the plan respects the existing infrastructure of the city and connects the elevated structures that have been built. While dealing with the longer-term future, it also alleviates the short-term flood drainage pressure through the regional flood buffer design.

Final Assessment

1. The centralized water treatment centers still in use in all cities today have deeper reasons. The concept of decentralized regional water treatment centers requires more theoretical support and cost estimation.

2. The calculation of volumn of water tank can only be used as astimation.

3. The biggest question is connection of new infrastructure system with existing community. Even the size of units is determined by community situations, still they may be failed to serve the audience. Each community is formed historically, and following human's land life. Future water life is hard to be predicted. Plus the different life modes may cause a dramatic change of each community's connection, structure and size.

4. An interesting question about community structure change. The existing communities are relatively independent blocks surrounding with streets. Streets both connect and seperate two blocks. People within one block have more connections with each other. While the new infrastructure system provide a super structure to be a new center serving adjacent blocks. The new centre ties four blocks up and no longer to seperated them. This change of public space can be an update for better community establishment.

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12. Rendering of project in **page 51** with **goolge earth**