Visualizing a Salty Future: The Role of LID and Green Infrastructure in Adapting to Accelerating Sea Level Rise and a Changing Climate

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MRC
Marine Resources Council

SALTY URBANISM

Sea Level Rise Adaptation Framework for Urban Areas

VISUALIZING A SALTY FUTURE: The Role of LID and Green Infrastructure in Adapting to Accelerating Sea Level Rise and Climate Change

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Marine Resources Council
LID Conference, Center for Collaboration, Rockledge Florida

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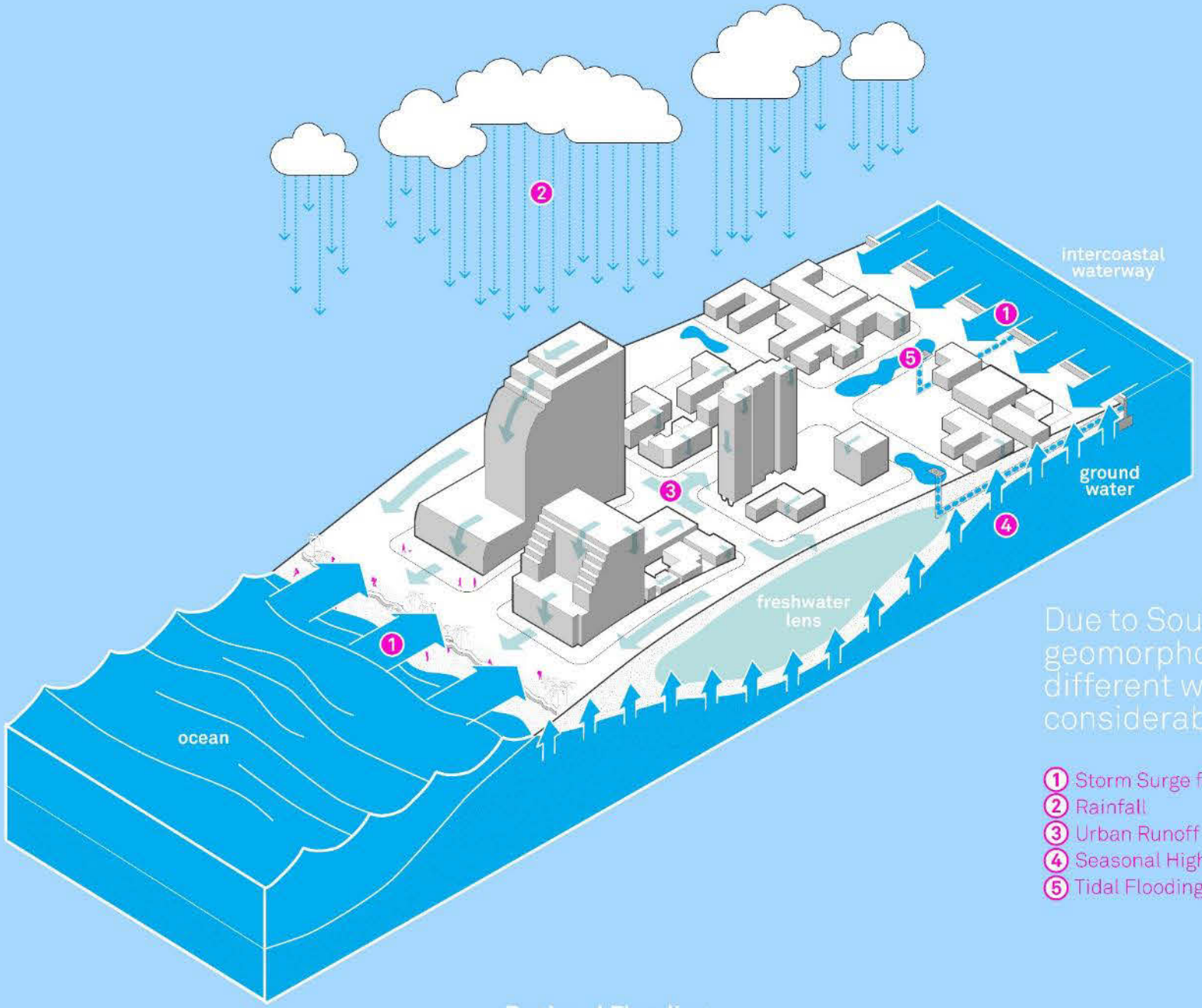


Due to South Florida's unique geomorphology it floods five different ways and poses considerable challenges.

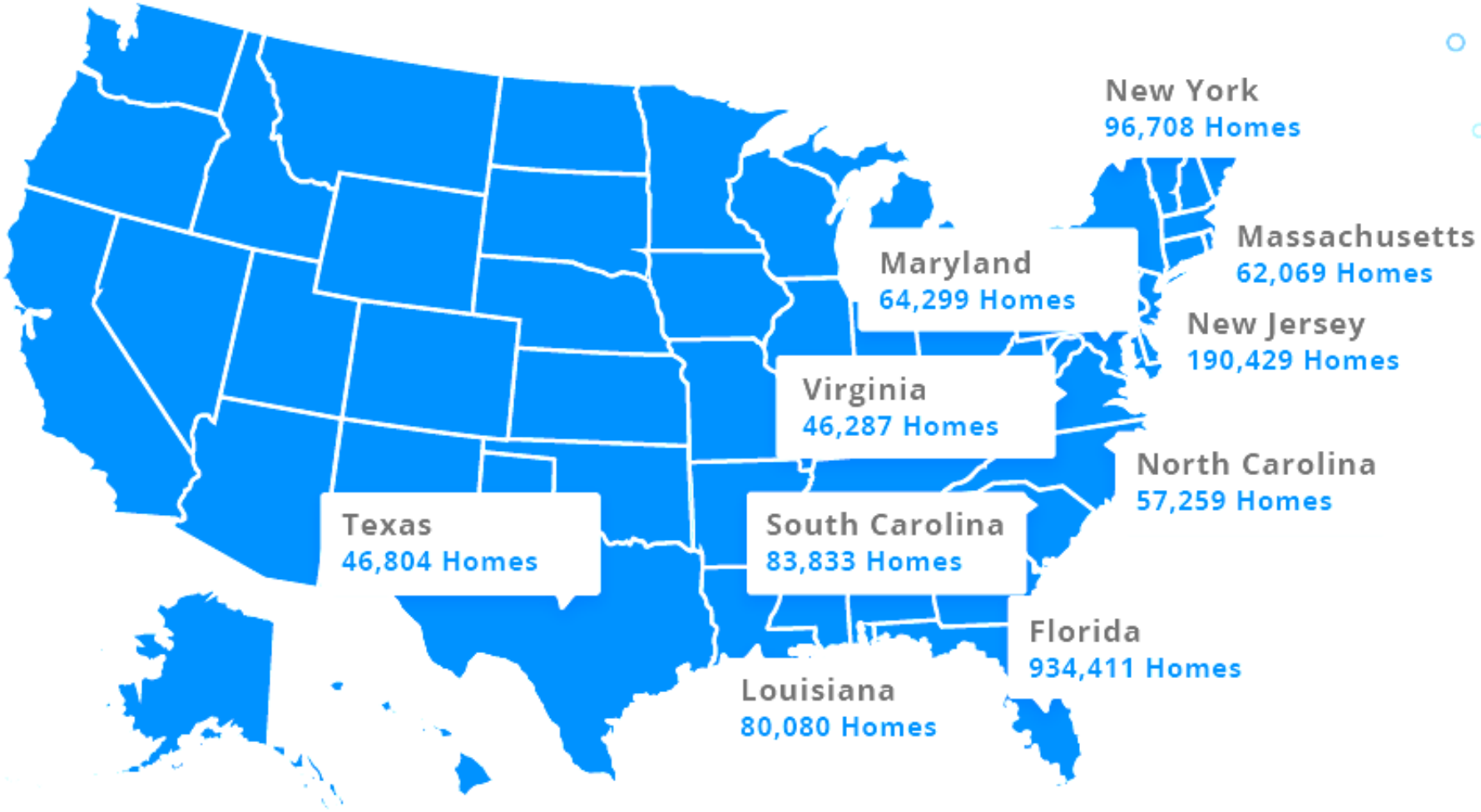
1. Storm Surge from Coastal Storms
2. Rainfall
3. Urban Runoff
4. Seasonal High Ground Water
5. Tidal Flooding/ Future Sea level Rise

Regional Flooding

Seasonal high tide flooding, commonly referred to as “King Tides.”

How many homes would be under water if the oceans **rose 6 feet**?*

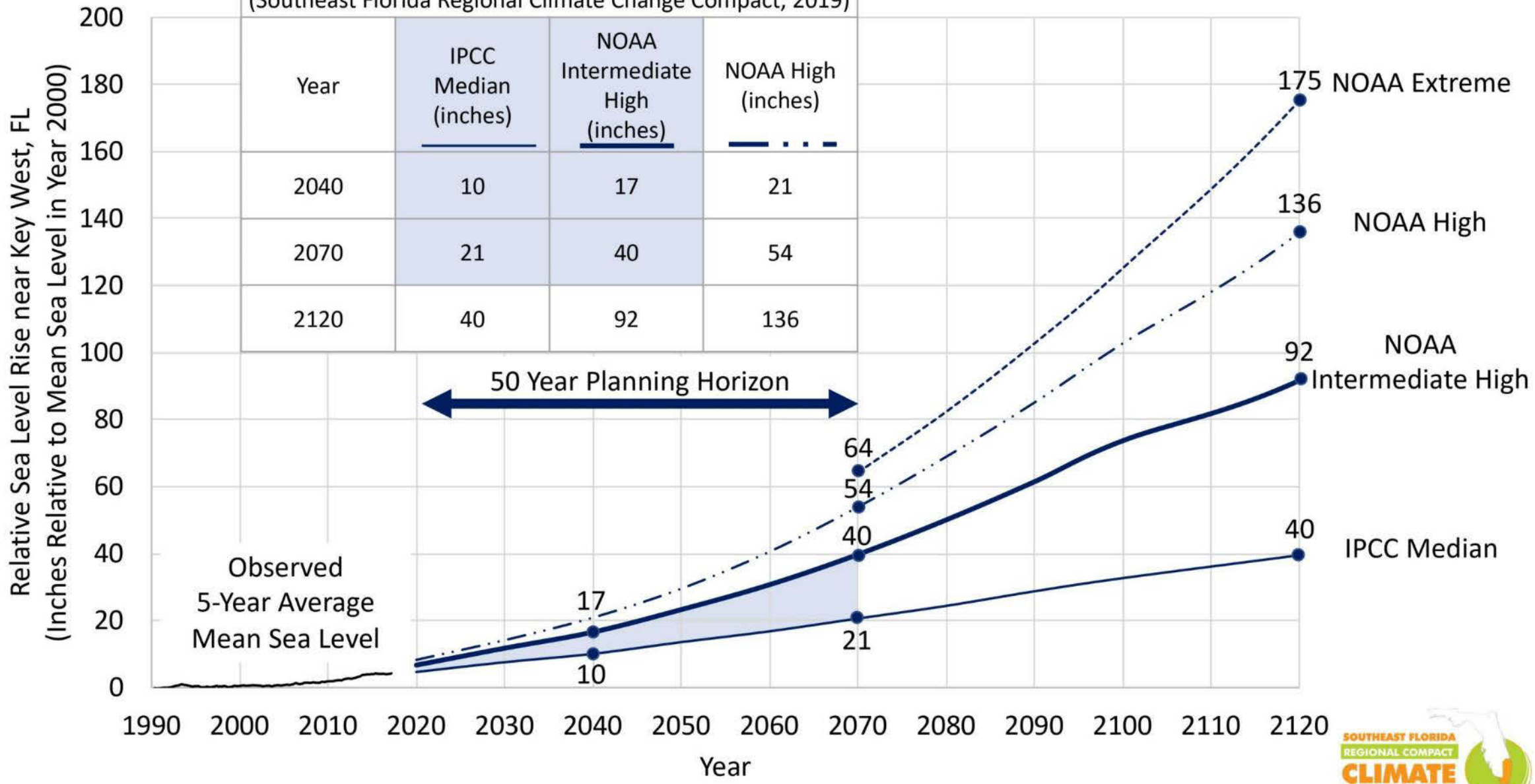
Nationally, 1.9 million homes worth **$882 billion**.



*A new study found oceans could rise 6 feet by 2100.

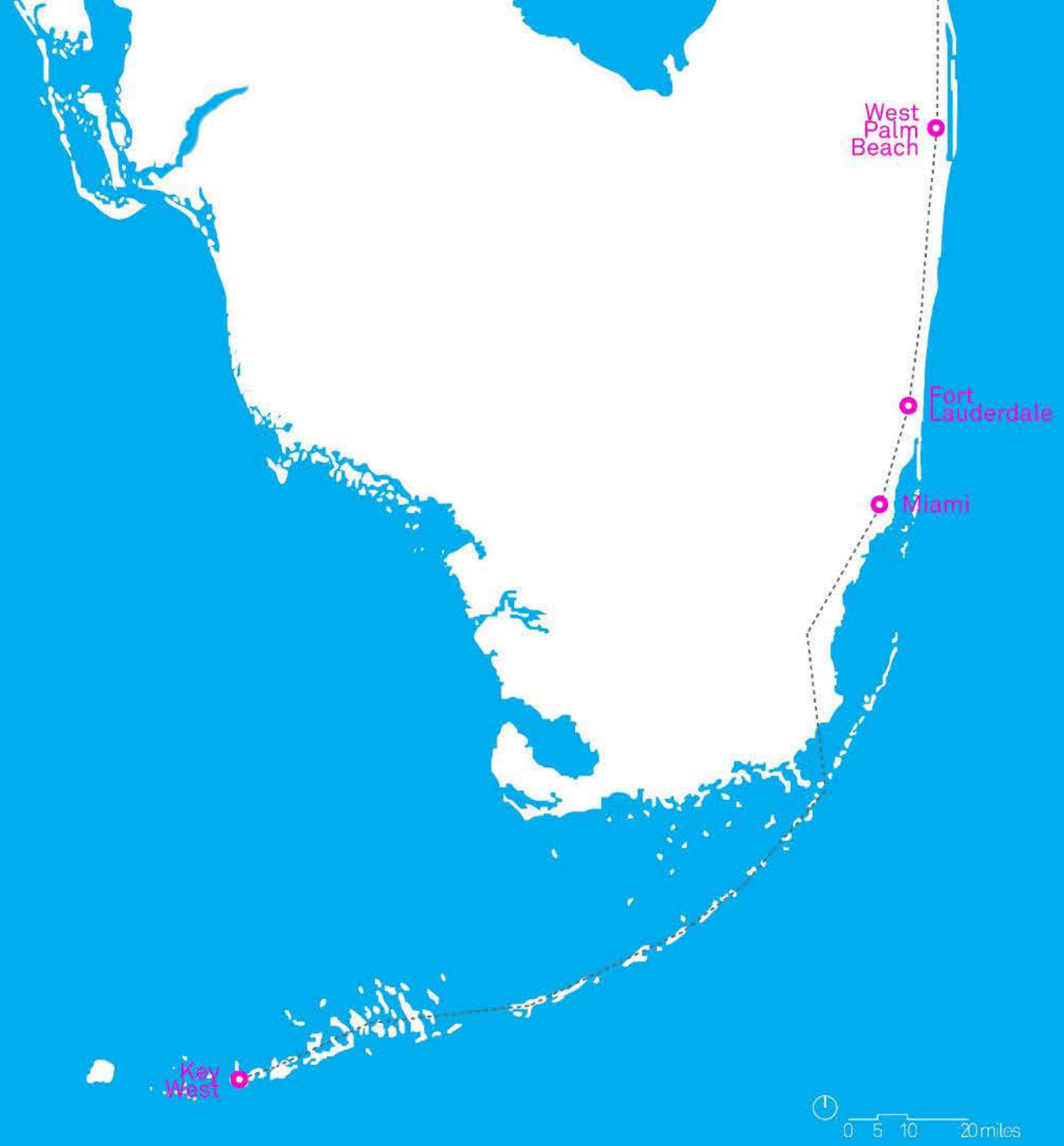
Unified Sea Level Rise Projection
(Southeast Florida Regional Climate Change Compact, 2019)

Year	IPCC Median (inches)	NOAA Intermediate High (inches)	NOAA High (inches)
2040	10	17	21
2070	21	40	54
2120	40	92	136

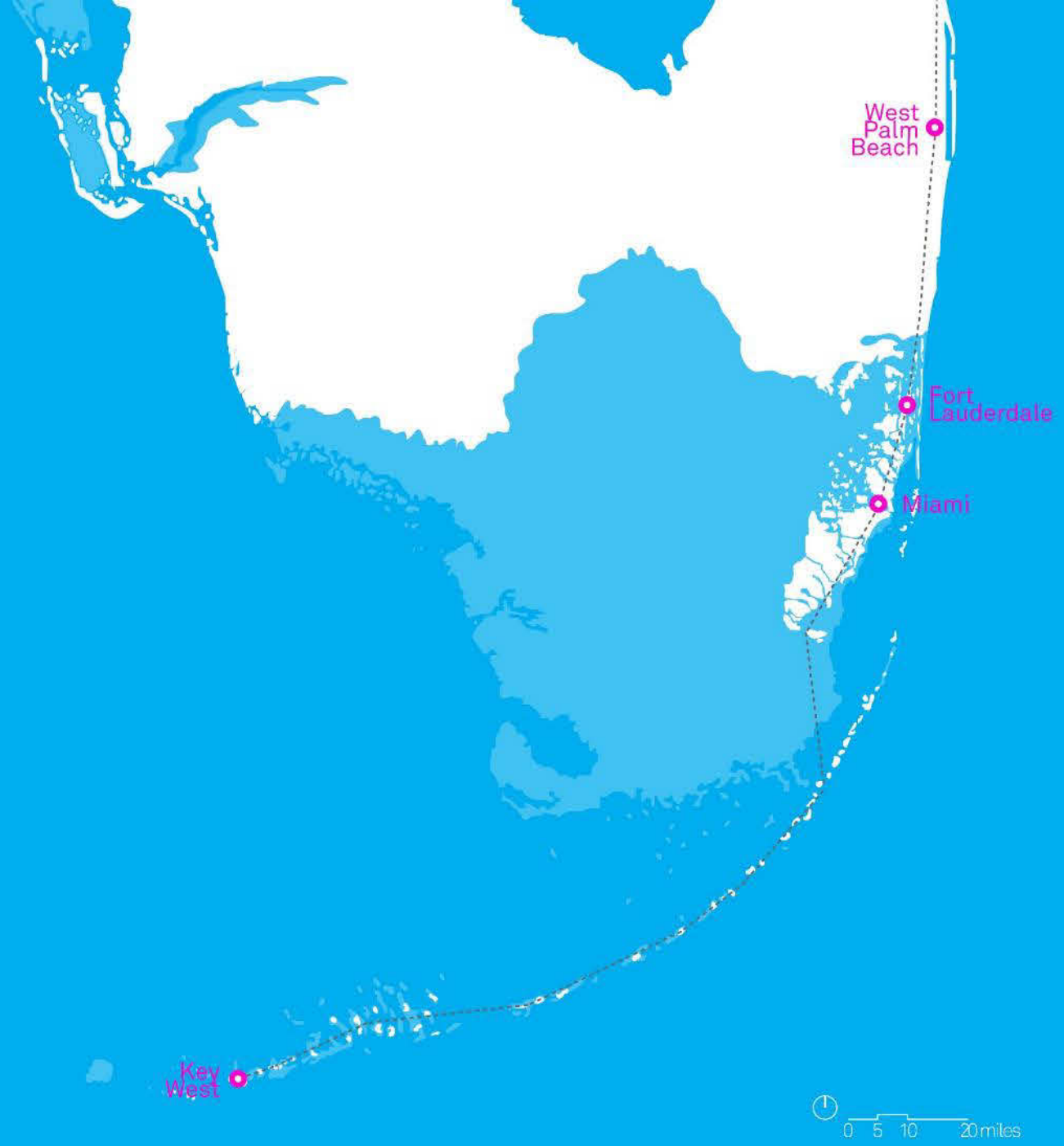


"The most important line on this planet is the coastline, and we mistake it as something static, but understandably so because throughout recorded human history it has relatively remained the same, but it's now shifting and we need to adapt."

-John Englander, Oceanographer-



Just **six feet of sea level rise** will inundate the region, drastically changing the environment. Essentially South Florida will become the Upper Keys.



FAU
SCHOOL OF ARCHITECTURE
Florida Atlantic University

KU SCHOOL OF ARCHITECTURE, DESIGN & PLANNING
The University of Kansas

USC School of Architecture

BROOKS SCARPA

CITY OF FORT LAUDERDALE

FAU
SCHOOL OF URBAN & REGIONAL PLANNING
Florida Atlantic University

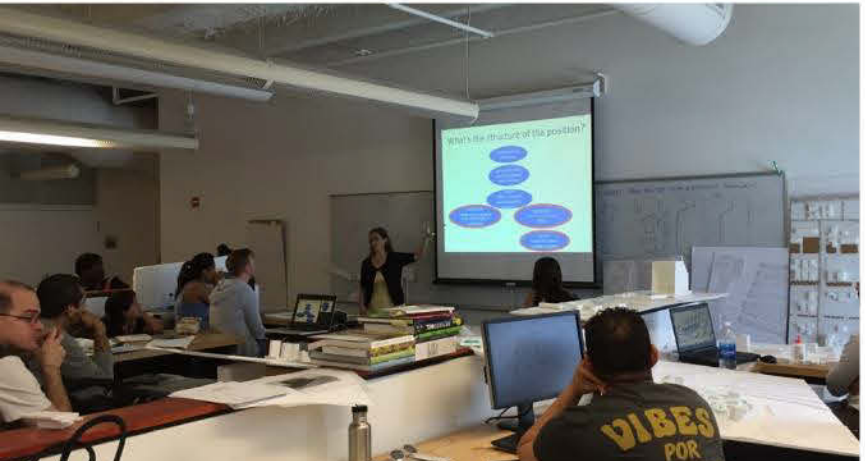
FAU
COLLEGE OF ENGINEERING & COMPUTER SCIENCE
Florida Atlantic University

FAU FLORIDA CENTER FOR ENVIRONMENTAL STUDIES
Charles E. Schmidt College of Science
Florida Atlantic University

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NOAA
U.S. DEPARTMENT OF COMMERCE

Sea Grant
Florida

NATIONAL ENDOWMENT FOR THE ARTS
A great nation deserves great art.

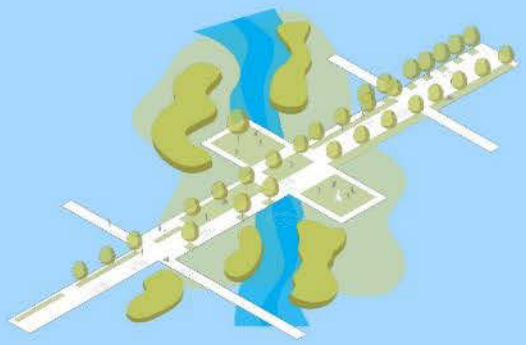

What's the structure of the position?
VIBES
POR

Salty Urbanism provides a methodology and design framework through five toolboxes and scenario visioning.

ADaPT TOOLBOX 1:

ADaPT Waterscape Urbanisms

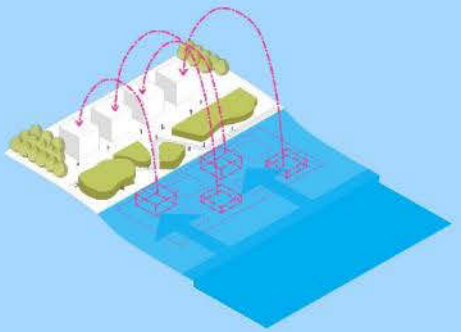
A menu of ten urban adaptation strategies provide *contextual*, *successive* and *incremental* approaches to land/coastline development in South Florida



green streets to blueways

inundation district

dunescape littoral defense

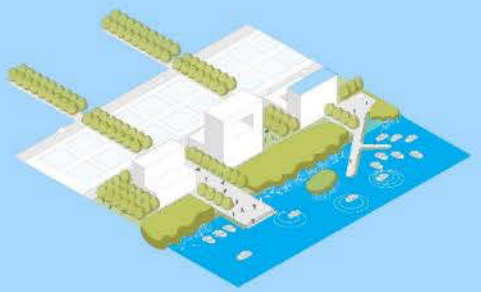


strategic retreat neighborhood

transverse glades canal retrofit

amphibious neighborhoods

ecological retrofit neighborhood



living shoreline district

transit-oriented-development ridge

Example 1:

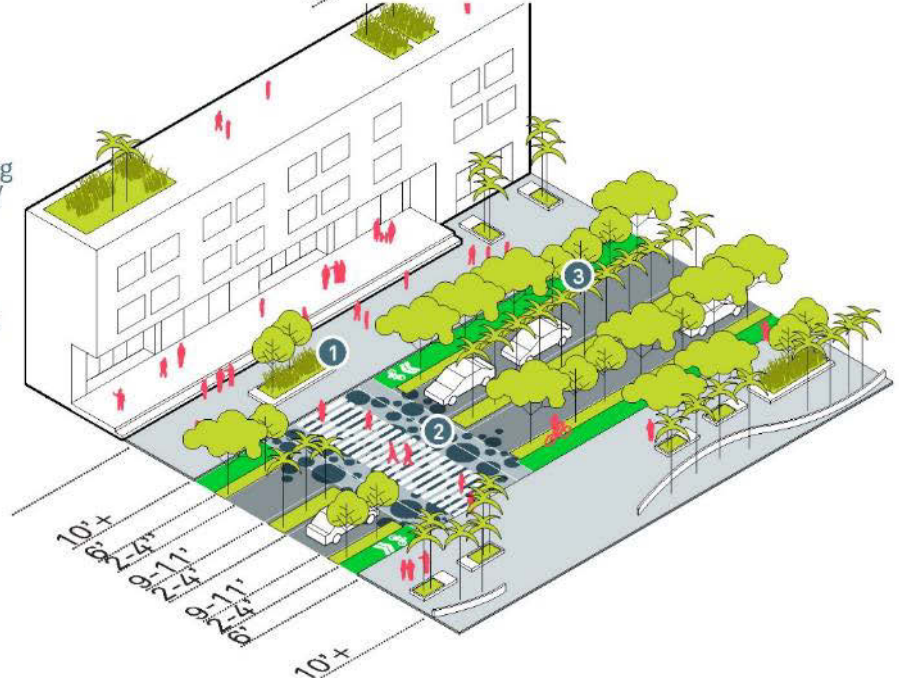
1. Buffered bike lanes provide safety and comfort for cyclists.
2. Offsetting bioswales can allow for wider swales while shifting lanes to help with traffic calming.
3. Increasing shade trees provide better conditions for pedestrians and improves walkability.

10'+	SIDEWALK	
6'	BIKE LANE	
9-10'	CAR LANE	
8-10'	BIOSWALE	PLANTER

Example 2:

1. Raised planters protect landscape from saltwater intrusion and provide seating and social spaces for pedestrians.
2. Mid-block crossings can be highlighted by using painted surfaces and function as wayfinding by identifying locations.
3. Locations or certain areas can be highlighted or distinguished by using certain landscape configurations. Additional trees can also help reduce heat island effects and provide comfort for pedestrians and cyclists.

10'+	SIDEWALK
6'	BIKE LANE
2-4'	LANDSCAPE BUFFER
9-11'	CAR LANE



ADaPT TOOLBOX 2:

Reconciliation Ecologies (learning from what was once there)

What if we learned from nature? A set of analytical drawings that explore and educate about various eco-types across the region were developed and illustrate latent opportunities. This example of the barrier island offers a resilient redesign model to be considered in the scenario visioning where unique geological and ecological characteristics would be considered in design solutions.

Maritime Hammock Guild
gumbo limbo (*Bursera simaruba*)
cocoplum (*Chrysobalanus icaco*)
seagrape (*Coccoloba uvifera*)
silver palm (*Coccothrinax argentata*)
sevenyear apple (*Genipa clusiifolia*)
firebush (*Hamelia patens*)
erect pricklypear (*Opuntia stricta*)
cabbage palm (*Sabal palmetto*)
thatch palm (*Thrinax radiata*)

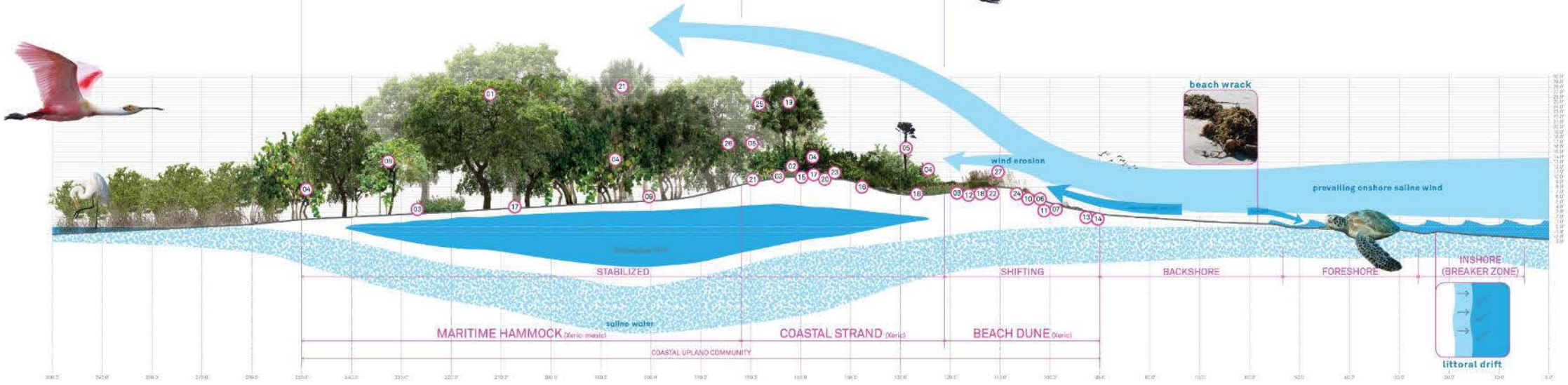
Tropical maritime hammocks serve as crucial resting and foraging areas for songbirds during fall and spring migration to and from the tropics.

Coastal Strand Guild
beach bean (*Canavalia maritima*)
cocoplum (*Chrysobalanus icaco*)
seagrape (*Coccoloba uvifera*)
silver palm (*Coccothrinax argentata*)
sea lavender (*Heliotropium gnaphalodes*)
wild sage (*Lantana involucrata*)
beach peanut (*Okenia hypogaea*)
erect pricklypear (*Opuntia stricta*)
bitter panicgrass (*Panicum amarum*)
cabbage palm (*Sabal palmetto*)
inkberry (*Scaevola plumieri*)
saw palmetto (*Serenoa repens*)
necklace pod (*Sophora tomentosa*)
bay cedar (*Suriana maritima*)
aloe yucca (*Yucca aloifolia*)

Provides critical habitat for gopher tortoises.

Beach Dune Guild
cocoplum (*Chrysobalanus icaco*)
seagrape (*Coccoloba uvifera*)
beach croton (*Croton punctatus*)
blanketflower (*Gaillardia pulchella*)
beach sunflower (*Helianthus debilis subsp. debilis*)
sea lavender (*Heliotropium gnaphalodes*)
spiderlily (*Hymenocallis latifolia*)
railroad vine (*Ipomoea pes-caprae*)
beachaddar (*Ivo imbricata*)
bitter panicgrass (*Panicum amarum*)
shoreline purslane (*Sesuvium portulacastrum*)
saltmeadow cordgrass (*Spartina patens*)
sea oats (*Uniola paniculata*)

Beach and beach dunes are used for foraging and nesting by beach mice, shorebirds, and sea turtles, especially Loggerhead (Caretta caretta).



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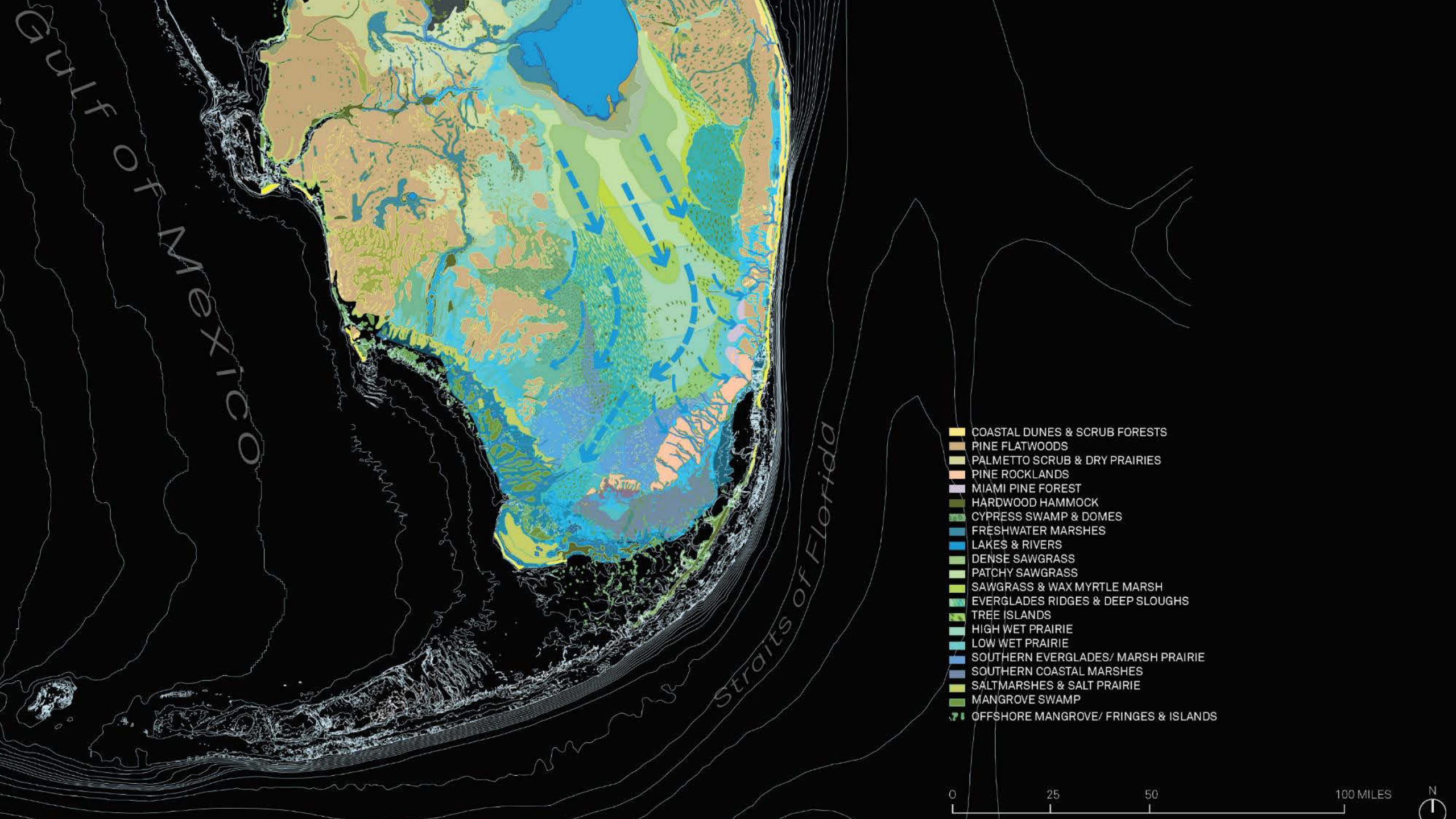
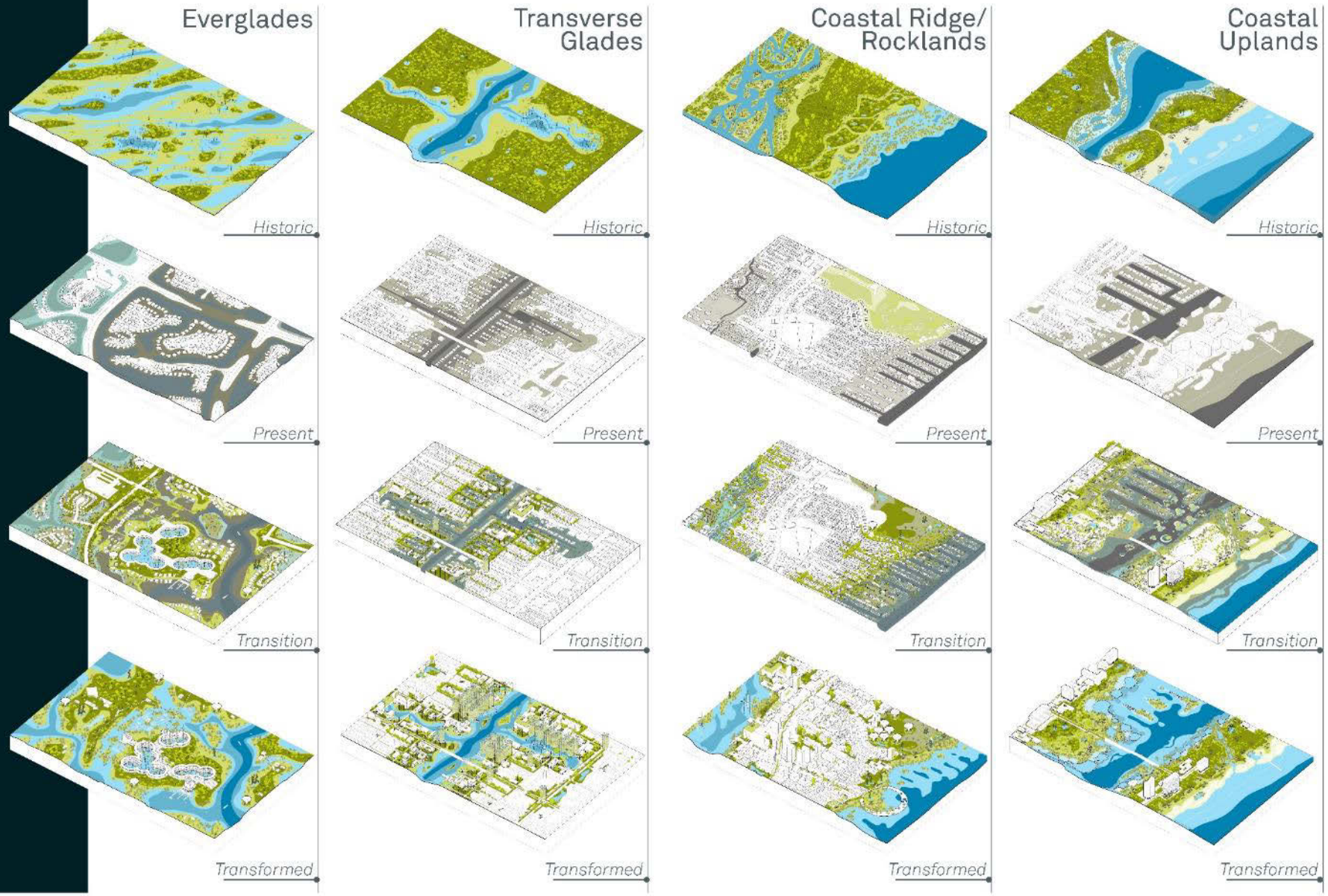

Gulf of Mexico
Straits of Florida
COASTAL DUNES & SCRUB FORESTS
PINE FLATWOODS
PALMETTO SCRUB & DRY PRAIRIES
PINE ROCKLANDS
MIAMI PINE FOREST
HARDWOOD HAMMOCK
CYPRESS SWAMP & DOMES
FRESHWATER MARSHES
LAKES & RIVERS
DENSE SAWGRASS
PATCHY SAWGRASS
SAWGRASS & WAX MYRTLE MARSH
EVERGLADES RIDGES & DEEP SLOUGHS
TREE ISLANDS
HIGH WET PRAIRIE
LOW WET PRAIRIE
SOUTHERN EVERGLADES/ MARSH PRAIRIE
SOUTHERN COASTAL MARSHES
SALTMARSHES & SALT PRAIRIE
MANGROVE SWAMP
OFFSHORE MANGROVE/ FRINGES & ISLANDS
0
25
50
100 MILES
N

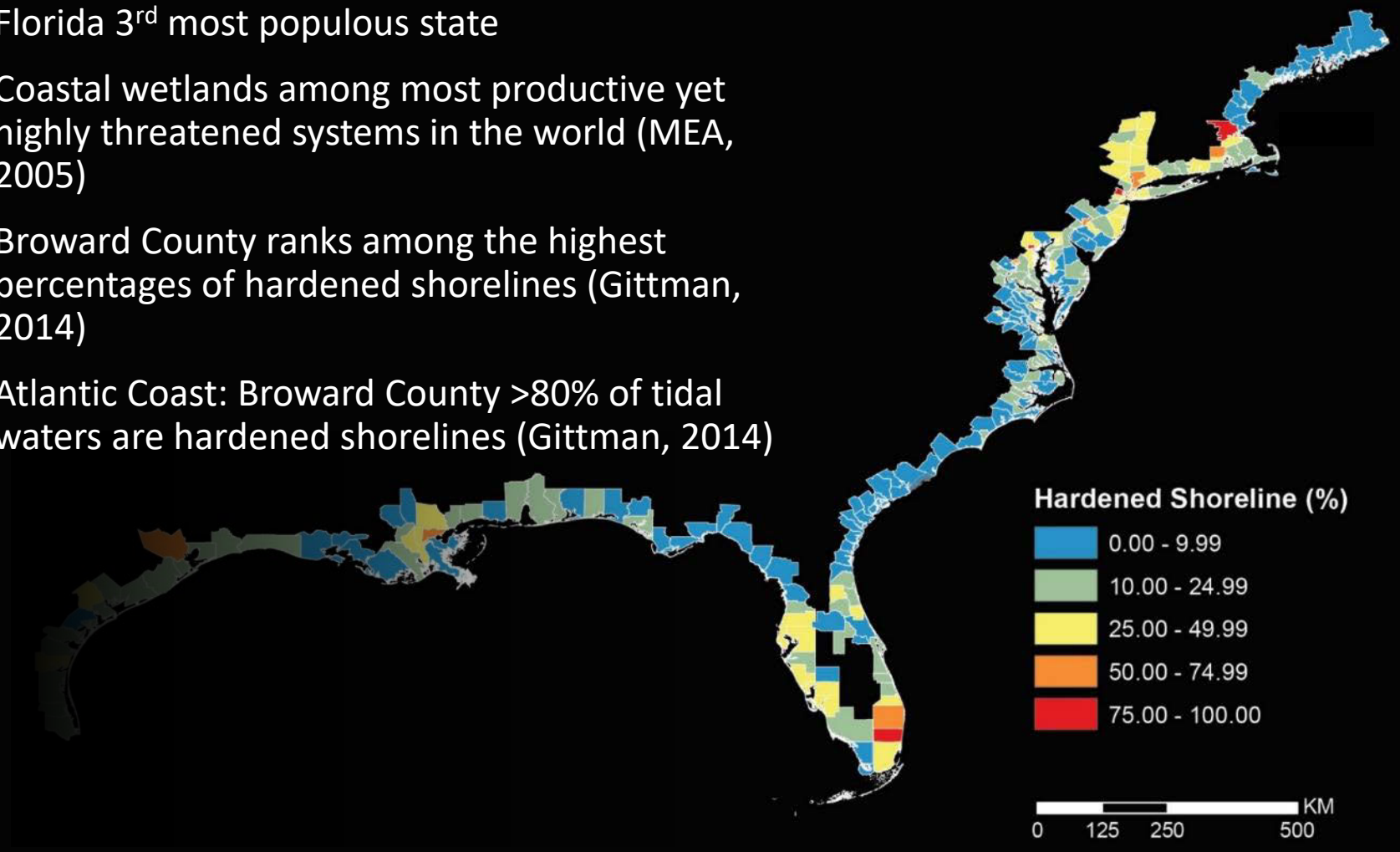
Ecotypic Response Matrix

Basic services and economies organized around a decentralized network tooled for salty and desert-like conditions creates novel approaches to tourism (ruin porn), agriculture, and scientific research. Water would be produced through harvesting and cleaning rainwater, as well as desalination. Waste would be collected and metabolized through phytoremediation networks. Power would be generated with wave, wind, waste, and solar as a distributed and redundant system. Food would be grown within localized networks to service and provide sustenance farming for residents and visitors. Automated and autonomous vehicles would be placed into service to aide in clean up and detoxifying previously developed areas and waters. Abandoned structures become scaffolding for transitional and transformed ecologies.



Loss of Wetlands Correlates to Population Density

- Near half U.S. lives in coastal counties; Florida 3rd most populous state
- Coastal wetlands among most productive yet highly threatened systems in the world (MEA, 2005)
- Broward County ranks among the highest percentages of hardened shorelines (Gittman, 2014)
- Atlantic Coast: Broward County >80% of tidal waters are hardened shorelines (Gittman, 2014)

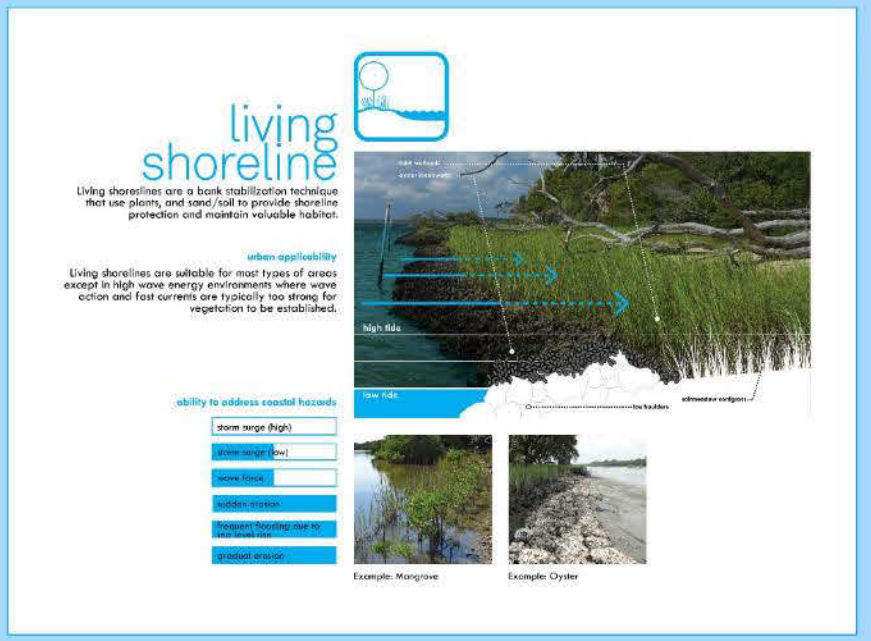


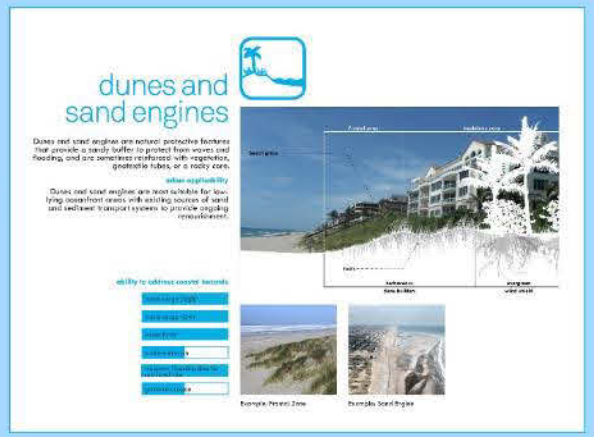
Graphic modified from Gittman, 2014

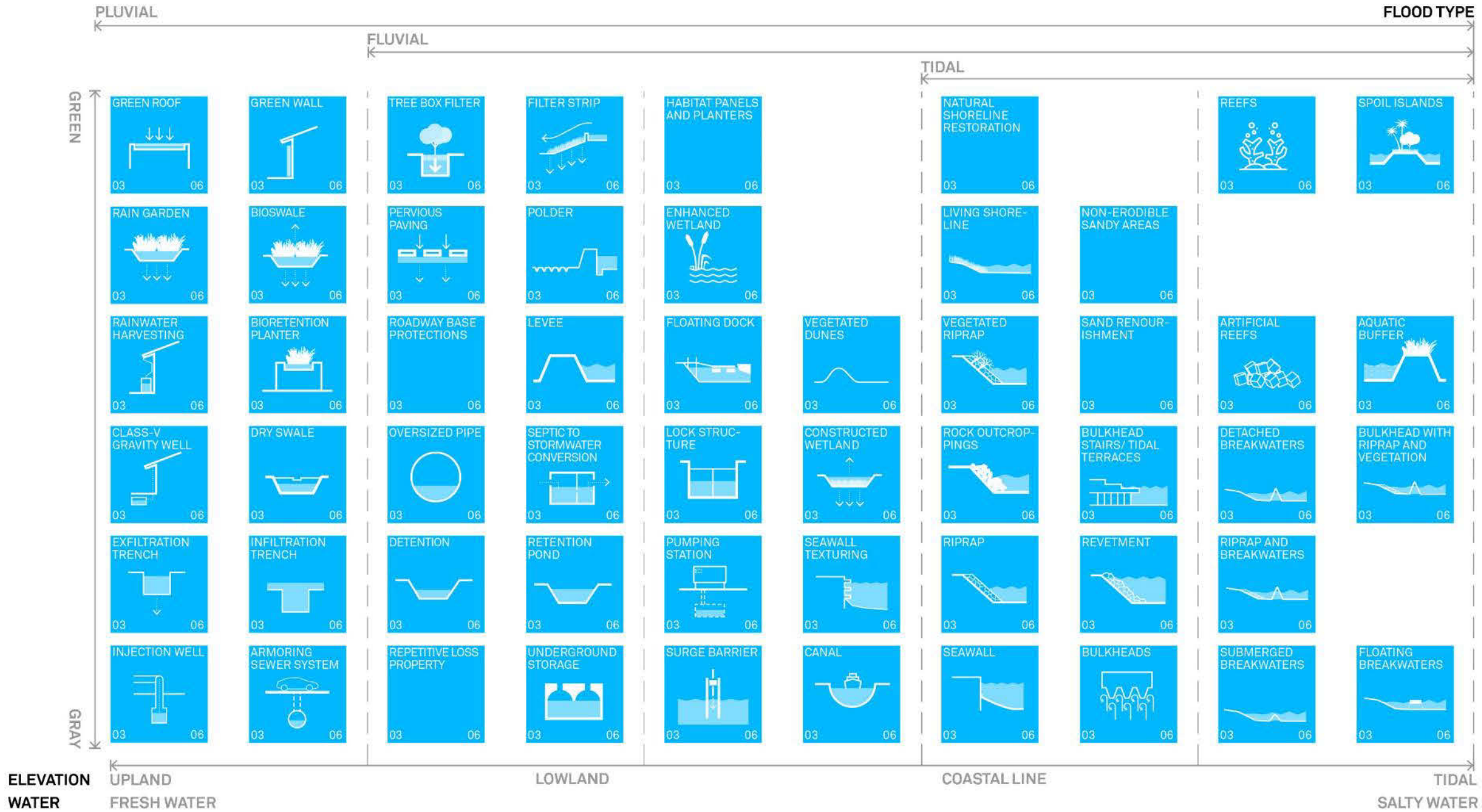
ADaPT TOOLBOX 3:

ADaPT Shoreline Soft Infrastructure Menu

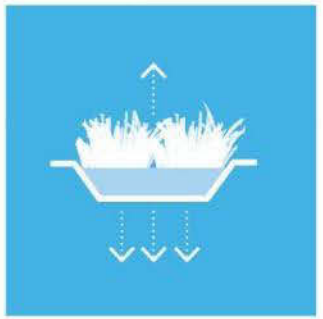
As much a community engagement process as development of an adaptation planning tool for coastal areas, *Salty Urbanism* has developed a catalog of available coastal infrastructure to educate and tool the profession and public of potential technological strategies. This set of techniques is used within workshops to build knowledge of possible place-specific implementation.






FLOOD TYPE
PLUVIAL
FLUVIAL
TIDAL
GREEN
GRAY
GREEN ROOF
GREEN WALL
TREE BOX FILTER
FILTER STRIP
HABITAT PANELS AND PLANTERS
NATURAL SHORELINE RESTORATION
REEFS
SPOIL ISLANDS
RAIN GARDEN
BIOSWALE
PERVIOUS PAVING
POLDER
ENHANCED WETLAND
LIVING SHORE-LINE
NON-ERODIBLE SANDY AREAS
RAINWATER HARVESTING
BIORETENTION PLANTER
ROADWAY BASE PROTECTIONS
LEVEE
FLOATING DOCK
VEGETATED DUNES
VEGETATED RIPRAP
SAND RENOUR-ISHMENT
ARTIFICIAL REEFS
AQUATIC BUFFER
CLASS-V GRAVITY WELL
DRY SWALE
OVERSIZED PIPE
SEPTIC TO STORMWATER CONVERSION
LOCK STRUC-TURE
CONSTRUCTED WETLAND
ROCK OUTCROP-PINGS
BULKHEAD STAIRS/ TIDAL TERRACES
DETACHED BREAKWATERS
BULKHEAD WITH RIPRAP AND VEGETATION
EXFILTRATION TRENCH
INFILTRATION TRENCH
DETENTION
RETENTION POND
PUMPING STATION
SEAWALL TEXTURING
RIPRAP
REVETMENT
RIPRAP AND BREAKWATERS
INJECTION WELL
ARMORING SEWER SYSTEM
REPETITIVE LOSS PROPERTY
UNDERGROUND STORAGE
SURGE BARRIER
CANAL
SEAWALL
BULKHEADS
SUBMERGED BREAKWATERS
FLOATING BREAKWATERS
03
06
ELEVATION
UPLAND
LOWLAND
COASTAL LINE
TIDAL
WATER
FRESH WATER
SALTY WATER

BIOSWALE



DESCRIPTION

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OPPORTUNITIES & CHALLENGES

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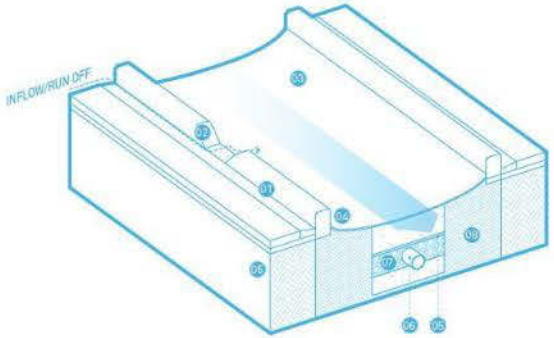
DESIGN SCALE & CONSIDERATIONS

Limited to soils with high permeability, integration with greater drainage system required

BASIC INFORMATION

COST	$ - $$
COMPLEXITY/DIFFICULTY	Low to Moderate
FLOOD HAZARDS ADDRESSED	Stormwater Runoff
ECOTYPES	Uplands, Coastal, Transverse Glades
PLANT PALETTES/ GUILDS	
STAKEHOLDER	Developers
PROJECT TYPES	Public works projects with open spaces, public works projects in ROWs



01 CURB & GUTTER
02 CURB CUT
03 BIOLOGICAL UPTAKE BY GRASS (OR OTHER OPTIONAL VEGETATION)
04 ENGINEERED MEDIA/ PERMEABLE SOILS
05 FILTER FABRIC
06 PERFORATED UNDERDRAIN PIPE
07 GRAVEL FILLED TRENCH
08 UNDERLYING SOIL

TREE BOX FILTER

DESCRIPTION

luptate pore velest voluptat es dolorio. Cabo. Xeruntio volorib erumenis doloribus si ut quatectur aliquissi quia nihilit moloreium sus ea doluptam, cum non et am fugiate volectur seque es prehenis sitassi occus sa eos es imus is rectus.
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OPPORTUNITIES & CHALLENGES

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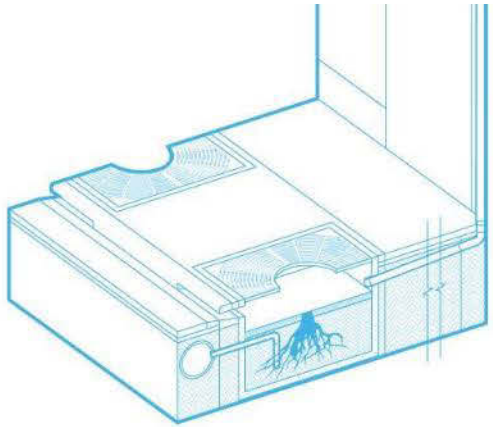
DESIGN SCALE & CONSIDERATIONS

Street-level only, can be integrated with sidewalk and median aesthetics, tree debris should be considered with respect to drain clogging

BASIC INFORMATION

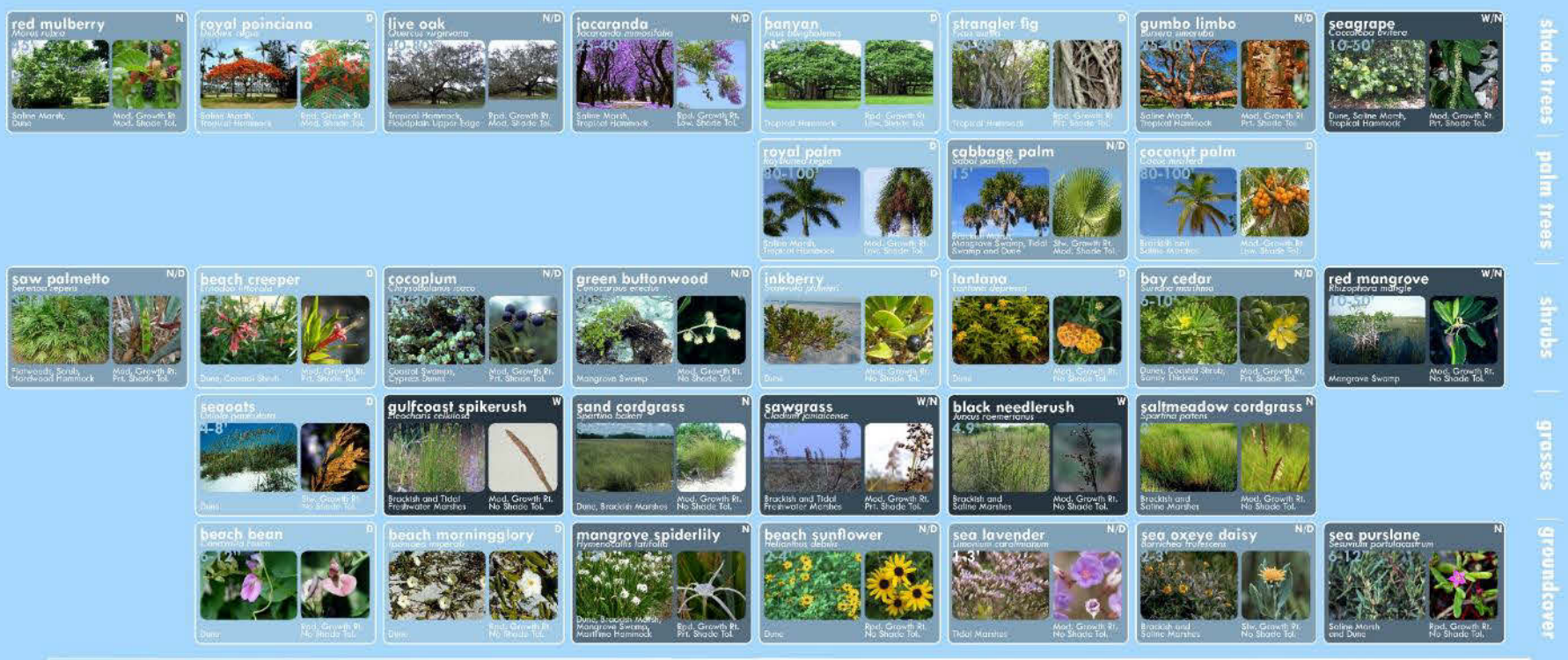
COST	$ - $$
COMPLEXITY/DIFFICULTY	Low
FLOOD HAZARDS ADDRESSED	Some Stormwater Runoff
ECOTYPES	All
PLANT PALETTES/ GUILDS	
STAKEHOLDER	Developers
PROJECT TYPES	Public works projects with open spaces, public works projects in ROWs



ADaPT TOOLBOX 4:

Salt-Tolerant Landscape Palette

As neighborhoods become more salty, a saltwater tolerant plant palette will be essential for the longevity of an landscape installed. The proposed plant palette provides a tool for designers, property owners and the city to strategically begin installing plants that will thrive and provide critical ecosystem services as sea levels rise. Devised as a clear graphic of communication addressing floristics (the character and structure of a plant type, i.e. shade tree vs. groundcover) and salt tolerance.

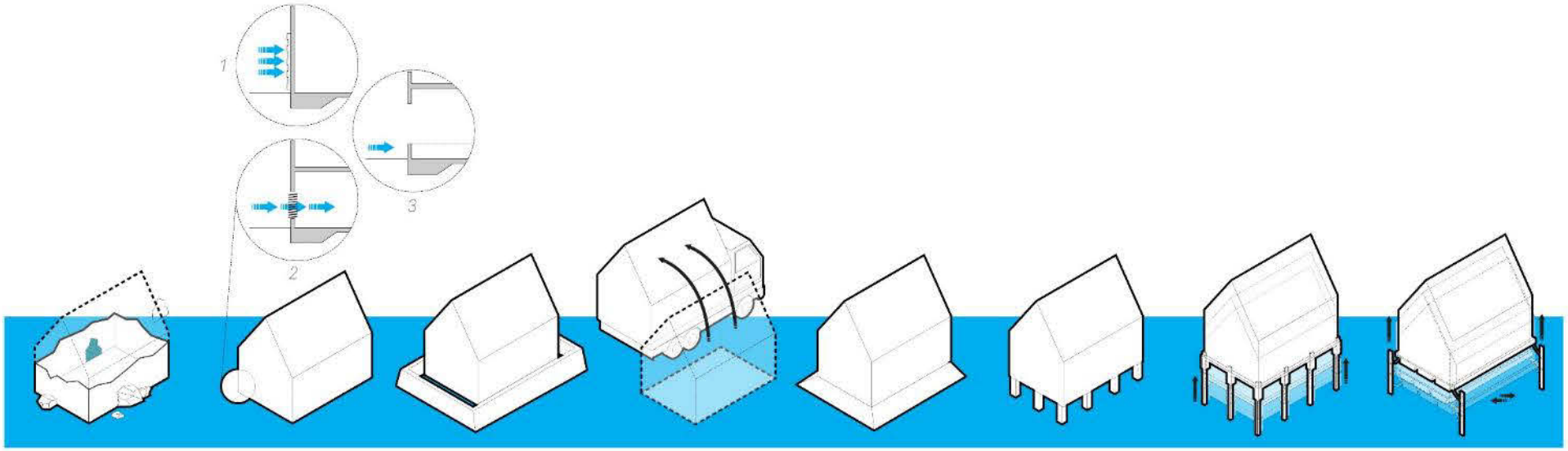


D=Dry N=Neutral W=Wet Rpd./Rapid, Prt./Part, Mod./Moderate, Slw./Slow, Rt./ Rate, Tol./Tolerance

ADaPT TOOLBOX 5:

ADaPT Building Typologies

Flood-adaptive architecture will build a portfolio of flood proofing building standards. Building code modifications that move beyond merely raising buildings on filled land provide developers and the city placed-based techniques that weigh future vulnerabilities when considering a design approach.



ABANDON

Abandoned structures can be reclaimed or re-purposed, for example the building could become an artificial reef or breakwater once materials that can pollute waterways is removed.

FLOOD PROOFING (BUILDING)

1. Dry Flood-proofing: Utilizes water resistant materials and panel systems at openings.

2. Wet Flood-proofing: Utilizes flood vents or breakaway walls to allow surge waters and flooding to pass through.

3. Or simply increase the floor to ceiling dimension at ground level and raise floor over time.

FLOOD PROOFING (SITE)

Utilizes flood walls, berms or levees to hold water back.

RETREAT

Relocation of buildings to higher elevations where flooding is less likely to occur. This could be a few hundred feet or miles.

RAISED MOUND

Building is raised above BFE on earthen mound. Keep in mind that NFIP criteria does not account for future land development, coastal erosion and subsidence, or sea level rise. These would have to be factored in to ensure lifespan considerations.

RAISED STILTS

Building is raised above BFE on stilts. Keep in mind that NFIP criteria does not account for future land development, coastal erosion and subsidence, or sea level rise. These would have to be factored in to ensure lifespan considerations. Considerations of what happens under the building should be addressed.

AMPHIBIOUS STRUCTURE

Structure is built to float on elevated flood waters. The piles anchor the structure in place while the buoyant base floats up and down. The building rests atop the ground during non-flood events.

FLOATING STRUCTURE

Structure is built to float on water and tethered to a mooring or anchoring device while allowing the building to move freely in multiple directions.

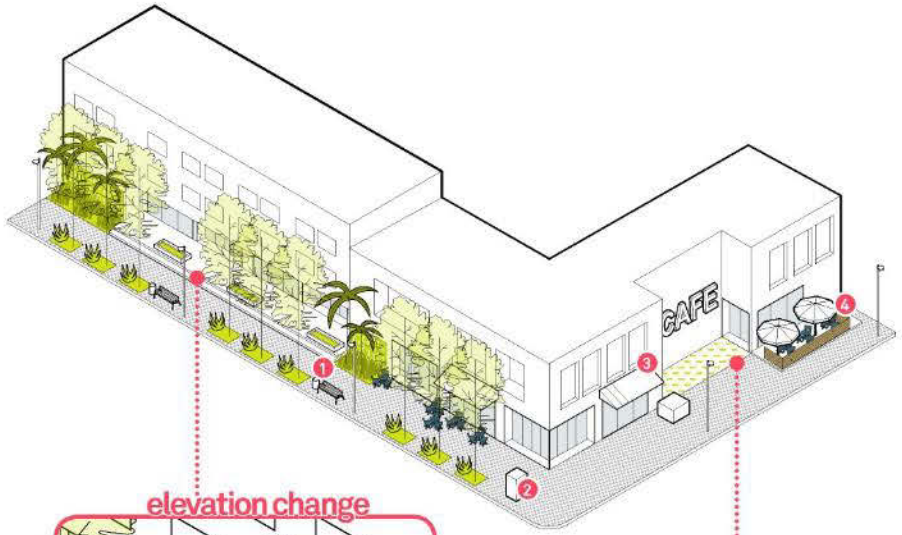
frontage design principles

1. Bio-retention planters, street trees, and other living infrastructure helps manage stormwater and urban run-off. Green walls and other landscaping can improve environmental conditions for pedestrians such as providing shade and cooling qualities.

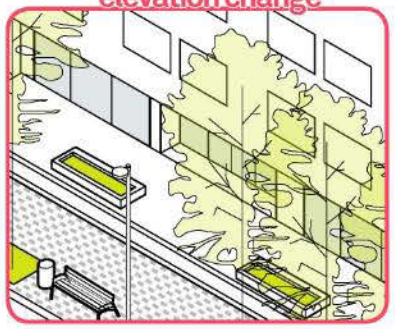
2. Utilities and other infrastructure can be integrated into frontage and buildings through alcoves or setbacks to reduce clutter in the right of way while still allowing for access

3. Overhangs and other shading devices provide protection for pedestrians during sudden downpours and provide shade when trees are not an option as a result of available space or utility infrastructure. Shading devices can also add to the identity of a place.

4. Frontage can incorporate social and resting spaces such as cafes and other seating elements. Additionally, these spaces can be connected to the public realm by using similar aesthetics found in the neighboring public realm.



elevation change



Architecture connects the public realm with the private realm. Access and openings shape this connection and can add to the identity and experience of the pedestrians. Elevational changes as a result of designing for flood events can alter this connection and should be done without loosing the connection.

typologies

Frontage typologies should reflect the **Place and Identity** while being appropriate for the immediate public realm.

flood-adaptive building/public realm interface

To accommodate future sea level rise many new developments are designing with a higher elevation in mind. In some cases, the public realm may be raised, this could include roads and sidewalks, and both existing and new buildings would have to find a way to connect to this new baseline.

ELEVATE

Instead of elevating the ground floor from the exterior, connect to the public realm by using the interior of the building to bring people up to the elevated level as needed over time.

ADAPT

New construction can integrate adaptive building strategies, such as a higher floor to ceiling height on the first floor. Instead of a traditional 15' it should be built to 20'. This allows for the floor to be raised incrementally in the future to match the roads and public realm as they are incrementally raised.

INUNDATE

Some buildings will interact with water and parts of the structures maybe inundated with water. These buildings will look at new connections to the public realm that may require water connections.

RETREAT

In some cases, buildings and structures will have to retreat as a result of sea level rise. These retreated areas will be new areas of opportunity for resilient and sustainable public realm projects that are continuously or regularly flooded.

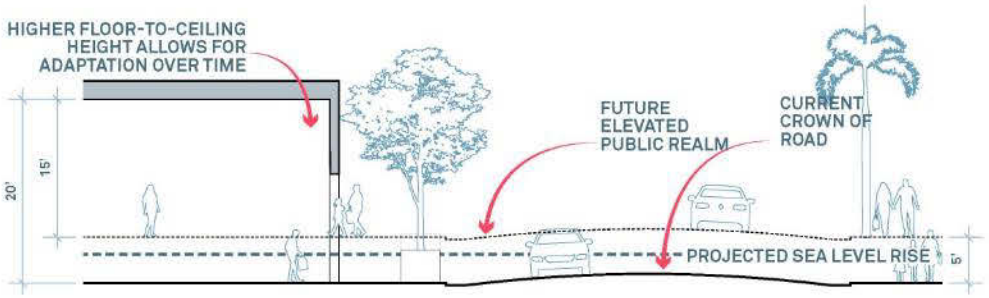
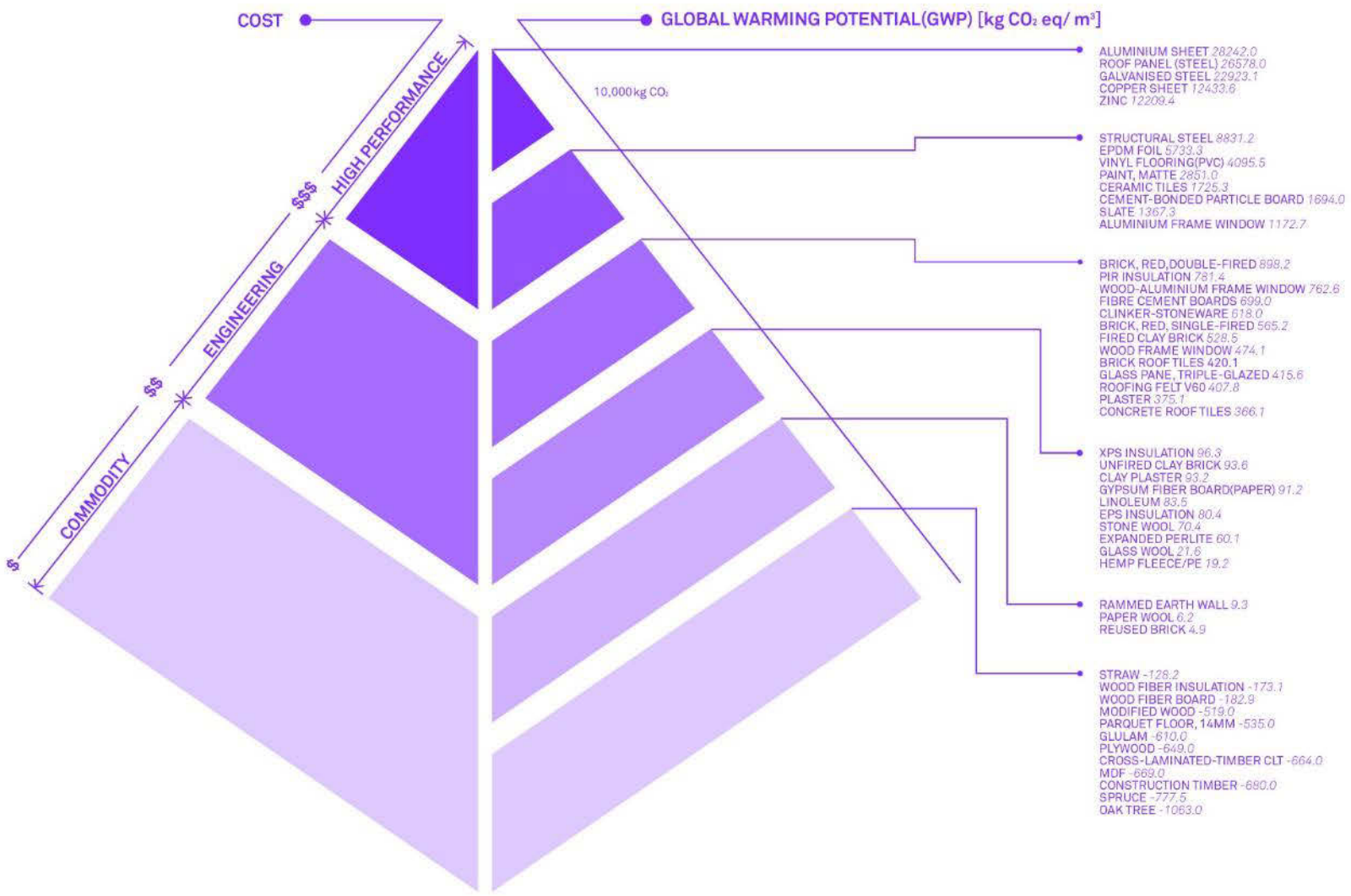


TABLE OF MATERIAL

Lorem ipsum
dolore magna
suscipit lobo
vulputate vel
iusto odio dig



ALUMINIUM SHEET *28242.0*
ROOF PANEL (STEEL) *26578.0*
GALVANISED STEEL *22923.1*
COPPER SHEET *12433.6*
ZINC *12209.4*

STRUCTURAL STEEL *8831.2*
EPDM FOIL *5733.3*
VINYL FLOORING(PVC) *4095.5*
PAINT, MATTE *2851.0*
CERAMIC TILES *1725.3*
CEMENT-BONDED PARTICLE BOARD *1694.0*
SLATE *1367.3*
ALUMINIUM FRAME WINDOW *1172.7*

BRICK, RED,DOUBLE-FIRED *898.2*
PIR INSULATION *781.4*
WOOD-ALUMINIUM FRAME WINDOW *762.6*
FIBRE CEMENT BOARDS *699.0*
CLINKER-STONEWARE *618.0*
BRICK, RED, SINGLE-FIRED *565.2*
FIRED CLAY BRICK *528.5*
WOOD FRAME WINDOW *474.1*
BRICK ROOF TILES 420.1
GLASS PANE, TRIPLE-GLAZED *415.6*
ROOFING FELT V60 *407.8*
PLASTER *375.1*
CONCRETE ROOF TILES *366.1*

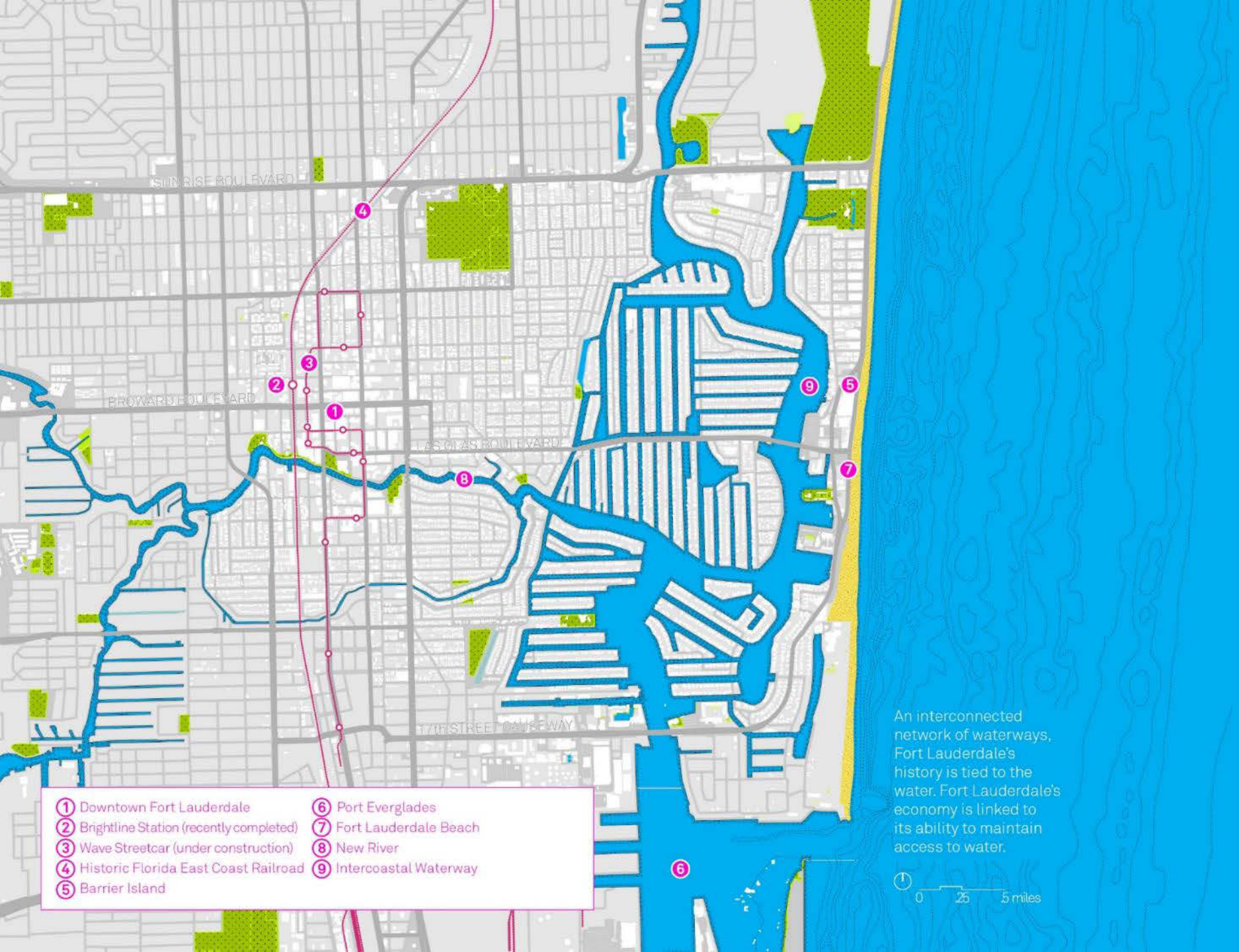
CONCRETE C30/37 *288.0*
PP ROOFING MEMBRANE *271.5*
GLASS PANE, DOUBLE-GLAZED *266.1*
PE FILM(VAPOR BARRIER) *266.3*
LIME SANDSTONE *244.8*
FOAM GLASS *244.2*
CONCRETE C20/25 *229.0*
LIGHTWEIGHT CONCRETE ELEMENTS *202.3*
LIME RENDER *190.6*
AERATED CONCRETE BLOCKS *180.0*
GYPSUM BOARD *169.6*
POROTON BRICKS *138.0*
PUR INSULATION *123.3*

XPS INSULATION *96.3*
UNFIRED CLAY BRICK *93.6*
CLAY PLASTER *93.2*
GYPSUM FIBER BOARD(PAPER) *91.2*
LINOLEUM *83.5*
EPS INSULATION *80.4*
STONE WOOL *70.4*
EXPANDED PERLITE *60.1*
GLASS WOOL *21.6*
HEMP FLEECE/PE *19.2*

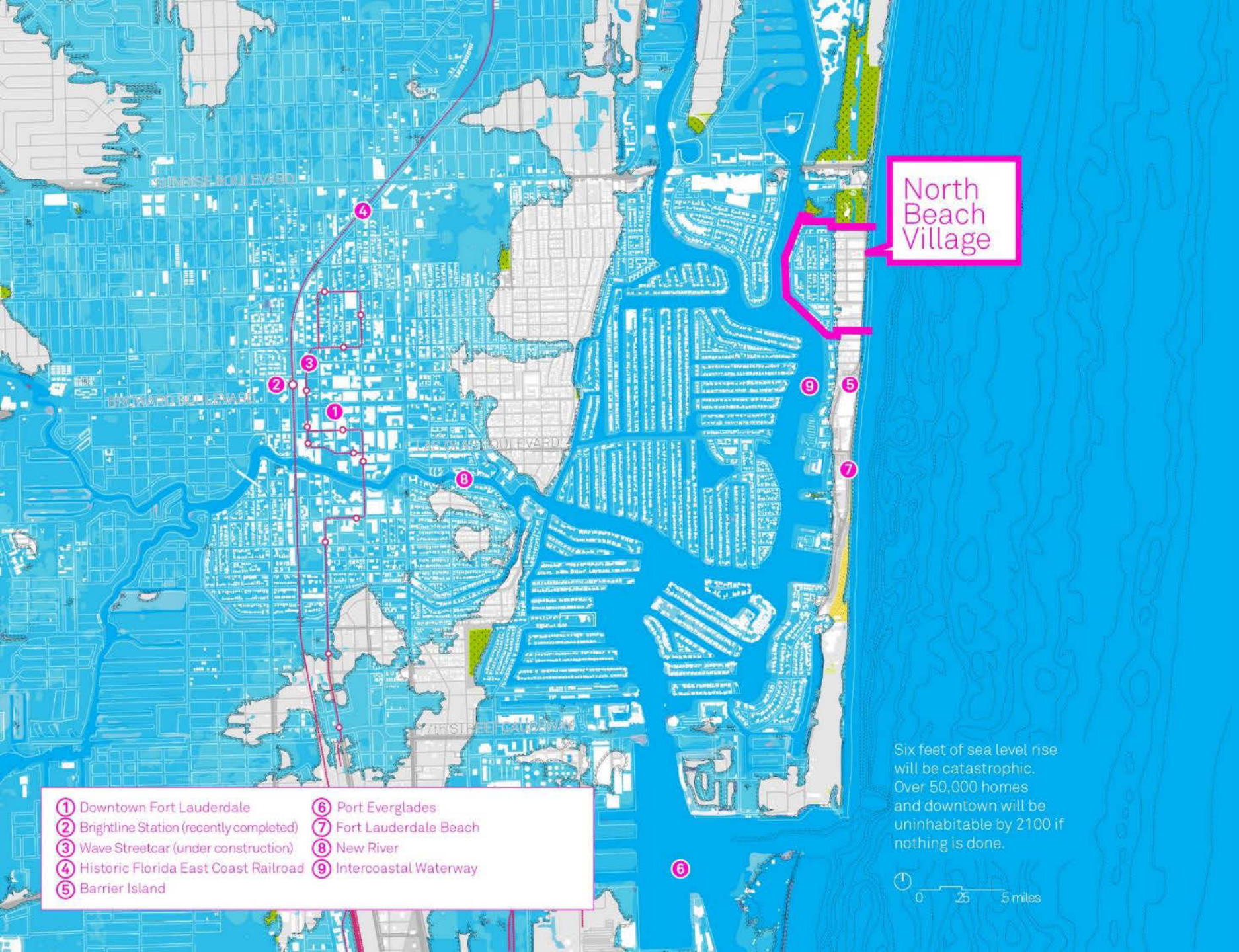
RAMMED EARTH WALL *9.3*
PAPER WOOL *6.2*
REUSED BRICK *4.9*

STRAW *-128.2*
WOOD FIBER INSULATION *-173.1*
WOOD FIBER BOARD *-182.9*
MODIFIED WOOD *-519.0*
PARQUET FLOOR, 14MM *-535.0*
GLULAM *-610.0*
PLYWOOD *-649.0*
CROSS-LAMINATED-TIMBER CLT *-664.0*
MDF *-669.0*
CONSTRUCTION TIMBER *-680.0*
SPRUCE *-777.5*
OAK TREE *-1063.0*

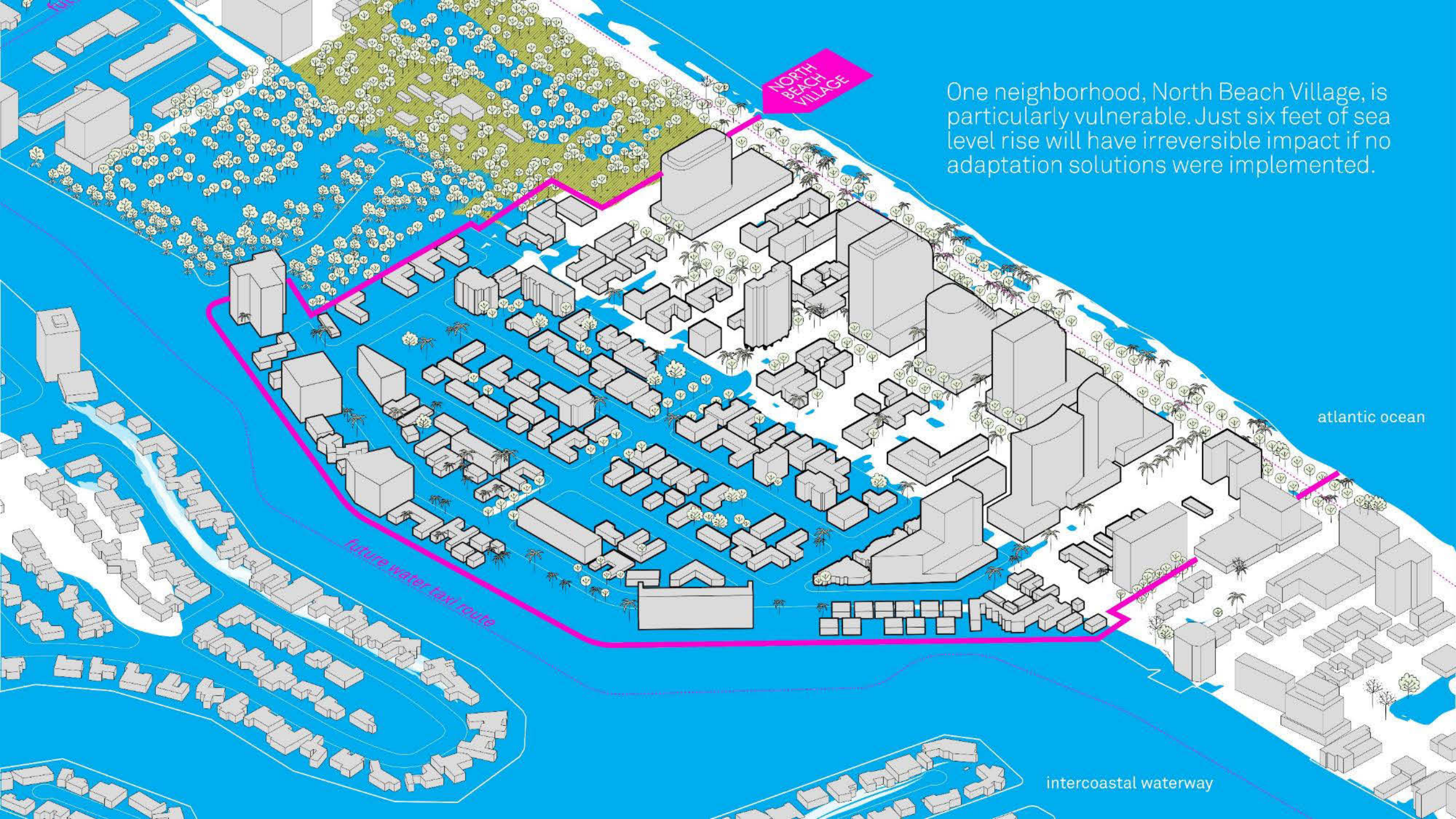
Fort Lauderdale Case Study



An interconnected network of waterways, Fort Lauderdale's history is tied to the water. Fort Lauderdale's economy is linked to its ability to maintain access to water.



Responses will be based on a free-market Darwinism

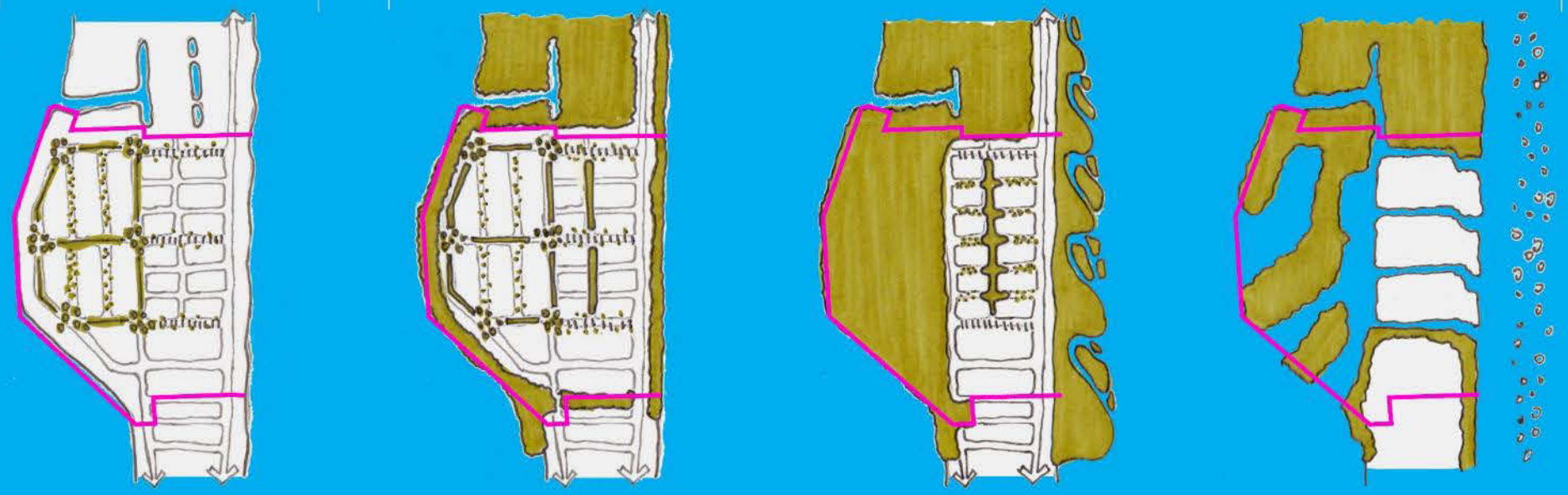


One neighborhood, North Beach Village, is particularly vulnerable. Just six feet of sea level rise will have irreversible impact if no adaptation solutions were implemented.

Utilizing the toolboxes, immediate investments as well as three long-term scenario approaches were developed with neighborhood workshop (*soft defense*, *strategic retreat*, and *land adjust*) and balance stakeholder buy in and political will.

0-10 years

10-60 years



Over the first ten years investments focus on streetscape improvements. These initial investments provide critical "botanizing" infrastructure in an artful way to showcase techniques and provide pilot projects that aim to illustrate plausible ways forward toward a preferred adaptation solution.

Scenario 1: *Soft Defense*

1

Scenario 2: *Strategic Retreat*

2

Scenario 3: *Land Adjust*

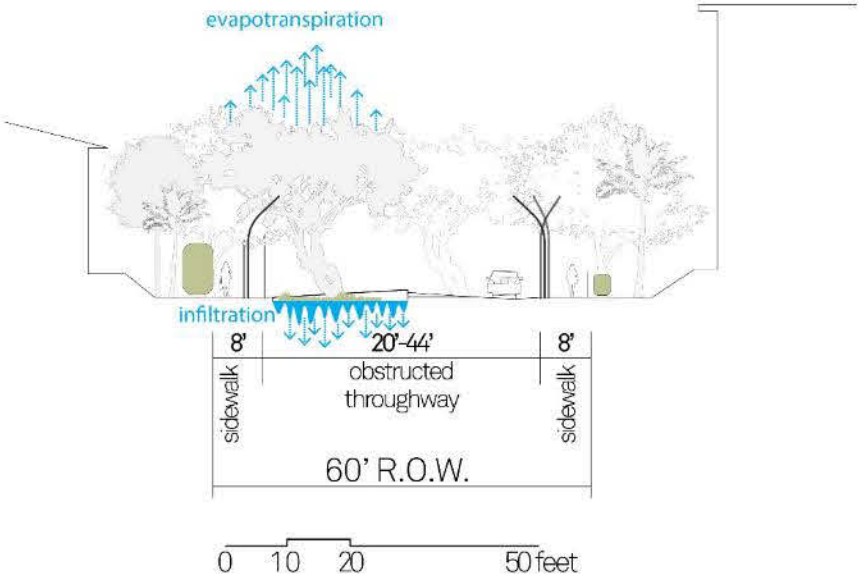
3

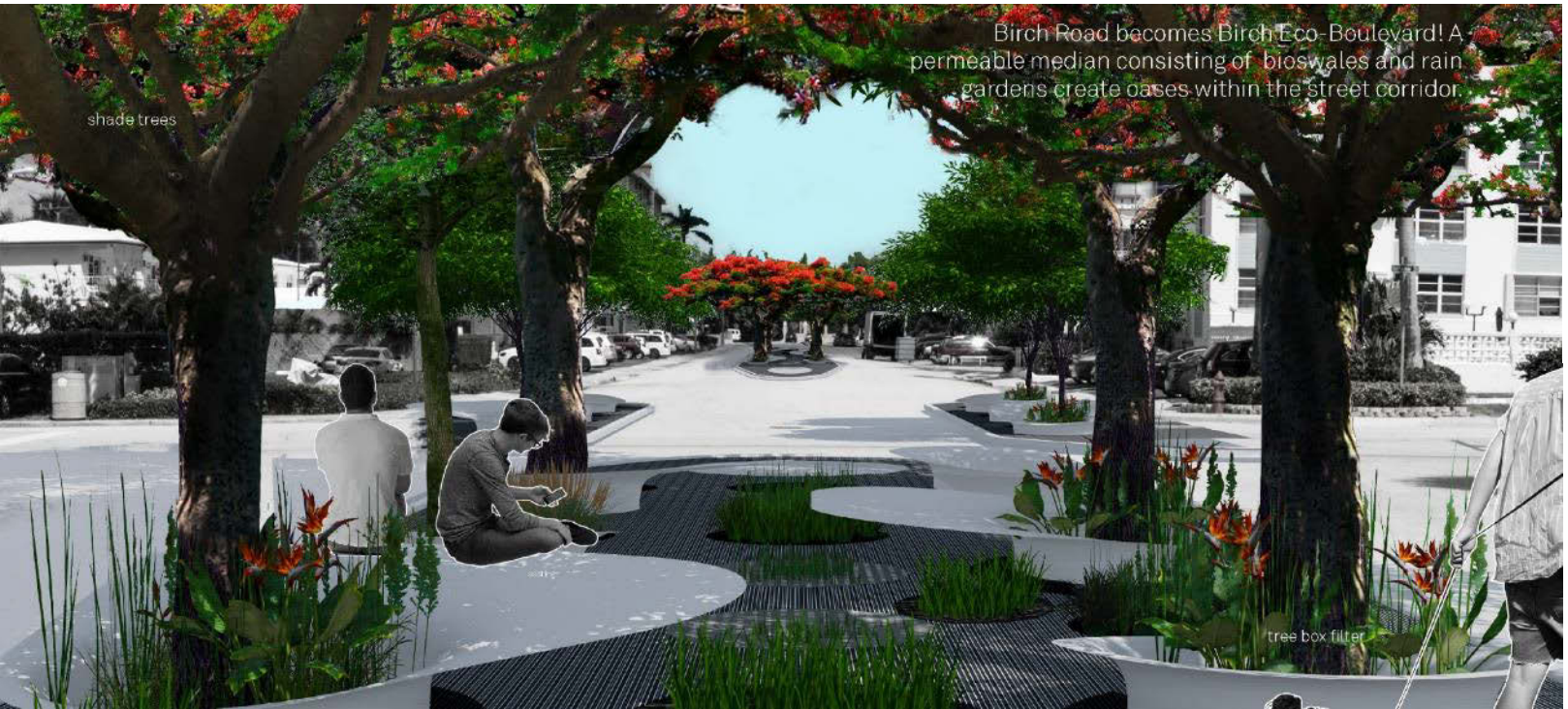
150 feet from building edge to building edge

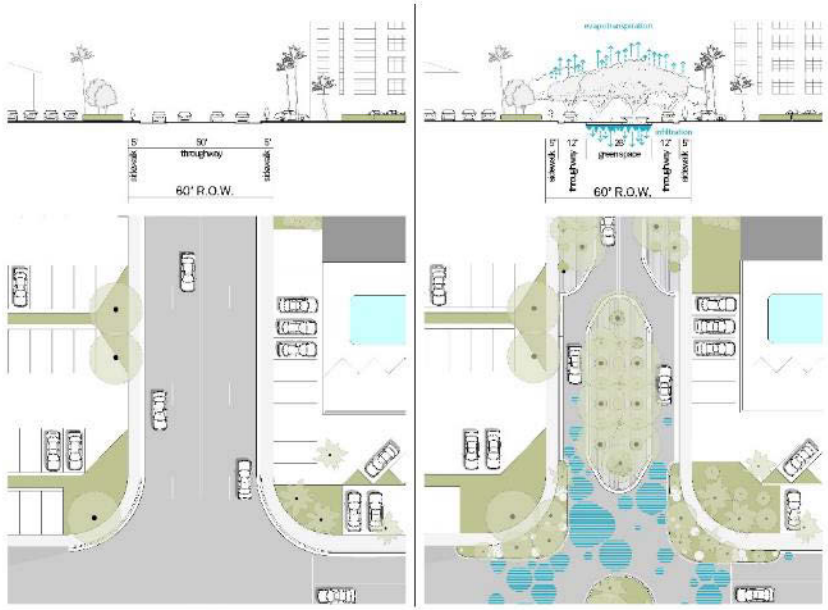
100 feet from building edge to building edge

Modern codes diminish delivery of both urban and ecosystem services


shade trees
Streets become net producers of ecosystem services rather than runoff and pollutant generators. "Slow streets" with interconnected pixelated rain gardens essentially become parks for neighborhood residents.
rain garden
seating


evapotranspiration
infiltration
8'
20'-44'
8'
sidewalk
obstructed throughway
sidewalk
60' R.O.W.
0 10 20 50 feet





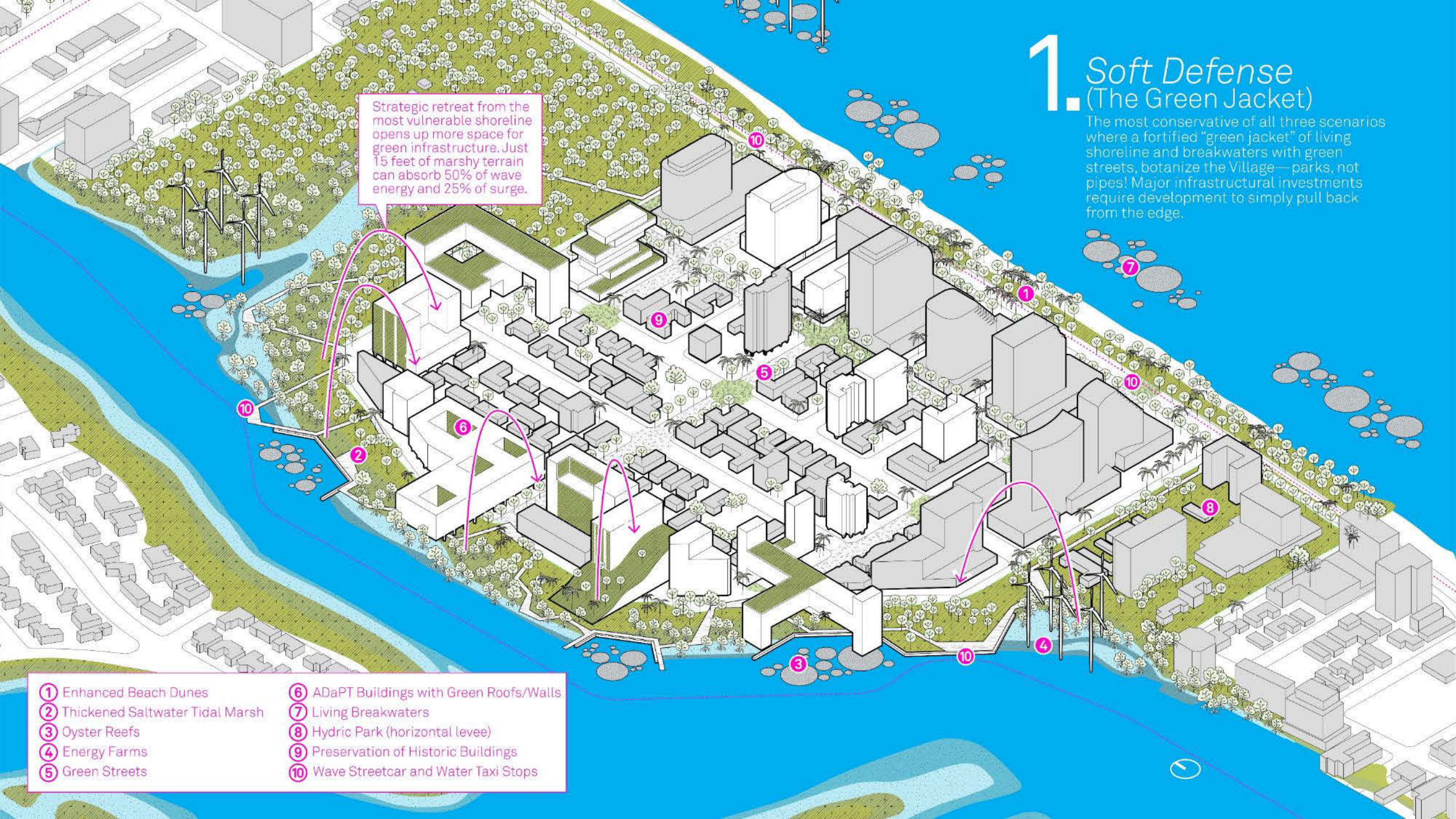
existing

proposed

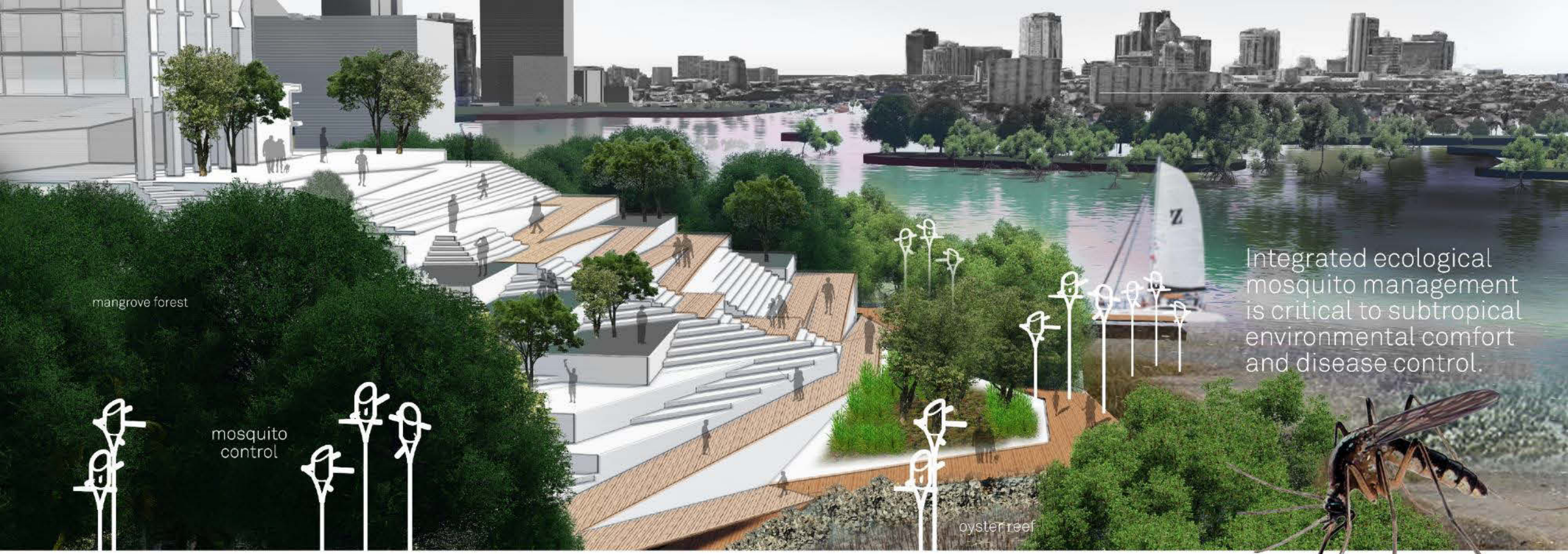
Birch Eco-Boulevard

1. *Soft Defense* (The Green Jacket)

The most conservative of all three scenarios where a fortified "green jacket" of living shoreline and breakwaters with green streets, botanize the Village—parks, not pipes! Major infrastructural investments require development to simply pull back from the edge.




BIGASS FANS
BOAT CHARGING
Restaurant
4
3
5

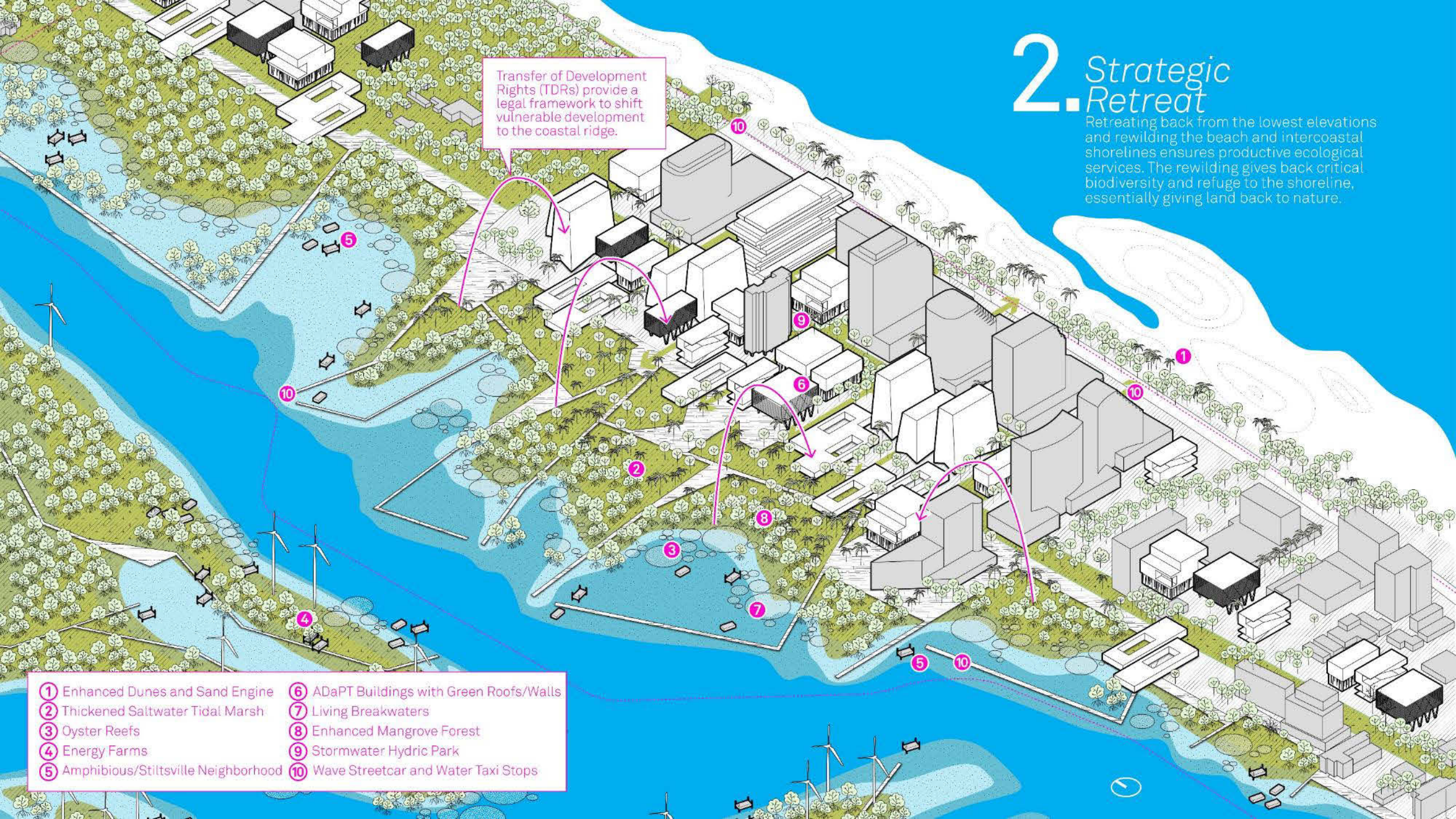


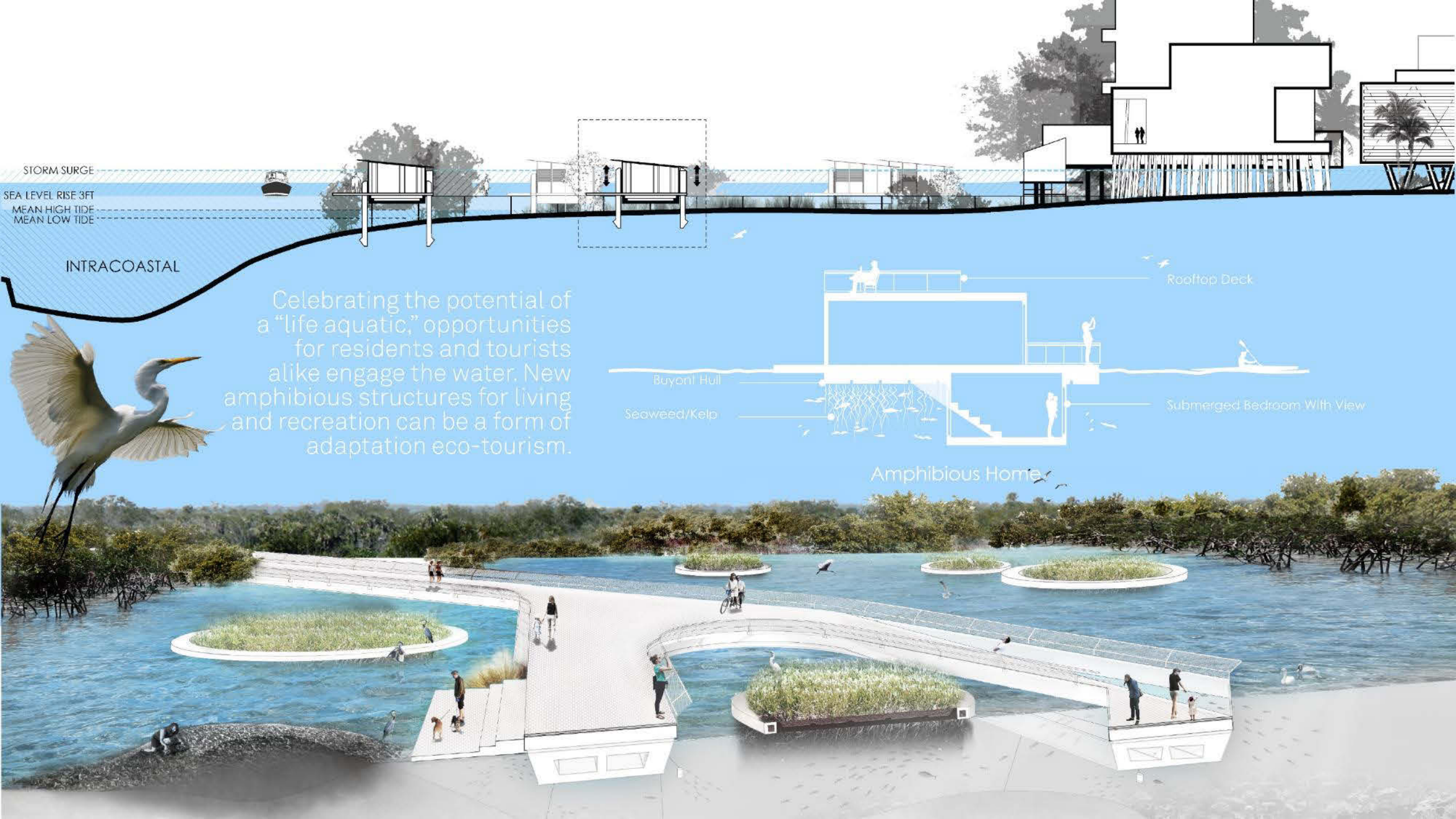
Integrated ecological mosquito management is critical to subtropical environmental comfort and disease control.

The beach is enhanced with "root" dunes and sand engines.

2. *Strategic Retreat*

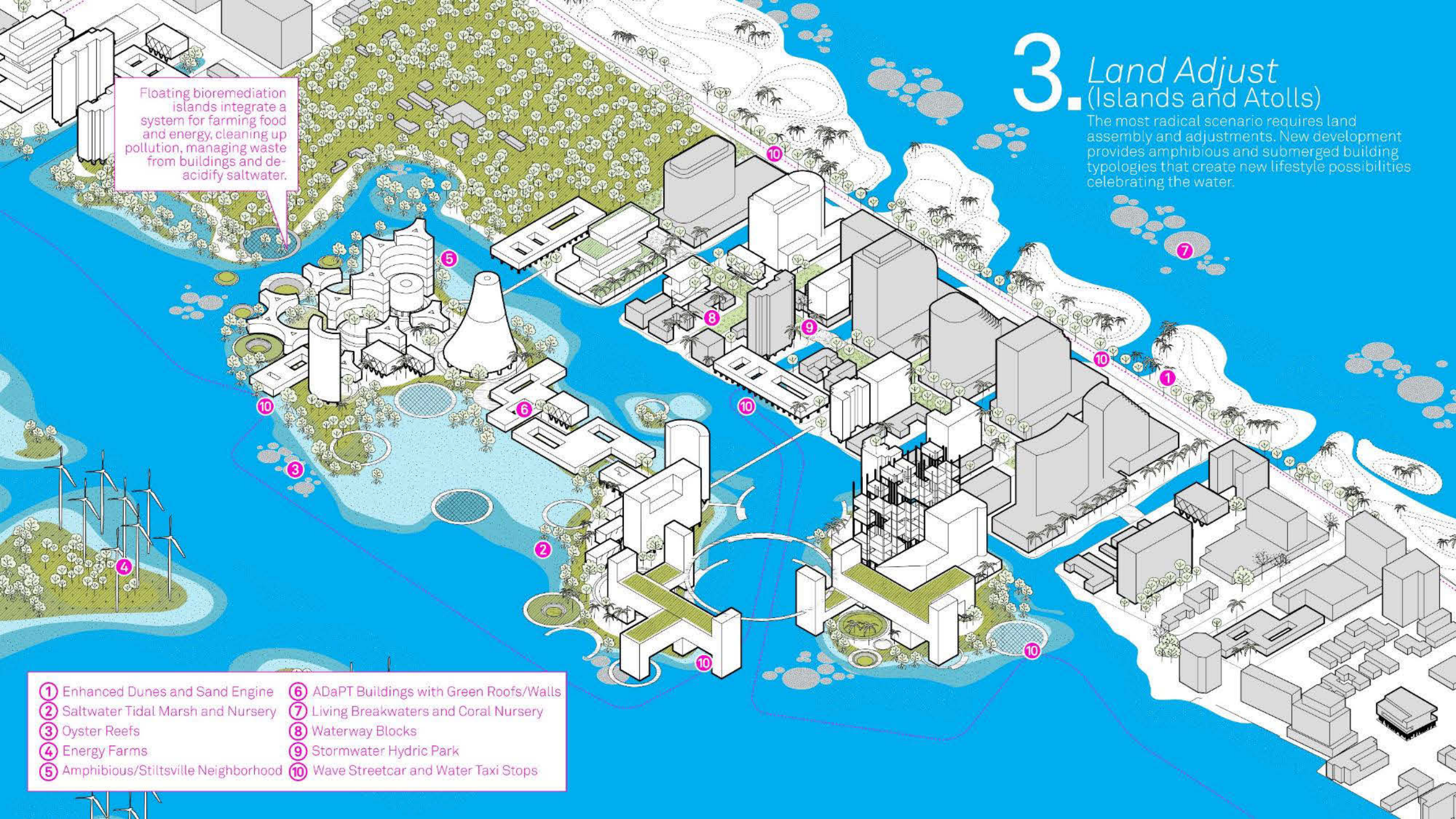
Retreating back from the lowest elevations and rewilding the beach and intercoastal shorelines ensures productive ecological services. The rewilding gives back critical biodiversity and refuge to the shoreline, essentially giving land back to nature.




STORM SURGE
SEA LEVEL RISE 3FT
MEAN HIGH TIDE
MEAN LOW TIDE
INTRACOASTAL
Celebrating the potential of a "life aquatic," opportunities for residents and tourists alike engage the water. New amphibious structures for living and recreation can be a form of adaptation eco-tourism.
Rooftop Deck
Buyont Hull
Seaweed/Kelp
Submerged Bedroom With View
Amphibious Home

3. *Land Adjust* (Islands and Atolls)

The most radical scenario requires land assembly and adjustments. New development provides amphibious and submerged building typologies that create new lifestyle possibilities celebrating the water.




Sea level rise in of itself is not an extinction level event, we can simply move to higher ground. More to the issue is our ability to produce food, water and energy locally and treat pollutants and waste.
amphibious housing
aquaculture
farming
oyster nursery
mangrove nursery

...a salty future will require *Salty Urbanism.*

Only urbanism gives the architectural profession a holistic framework through which complex systems can be engaged, even though urban design is usually the missing piece in discussions on resilience and adaptation.