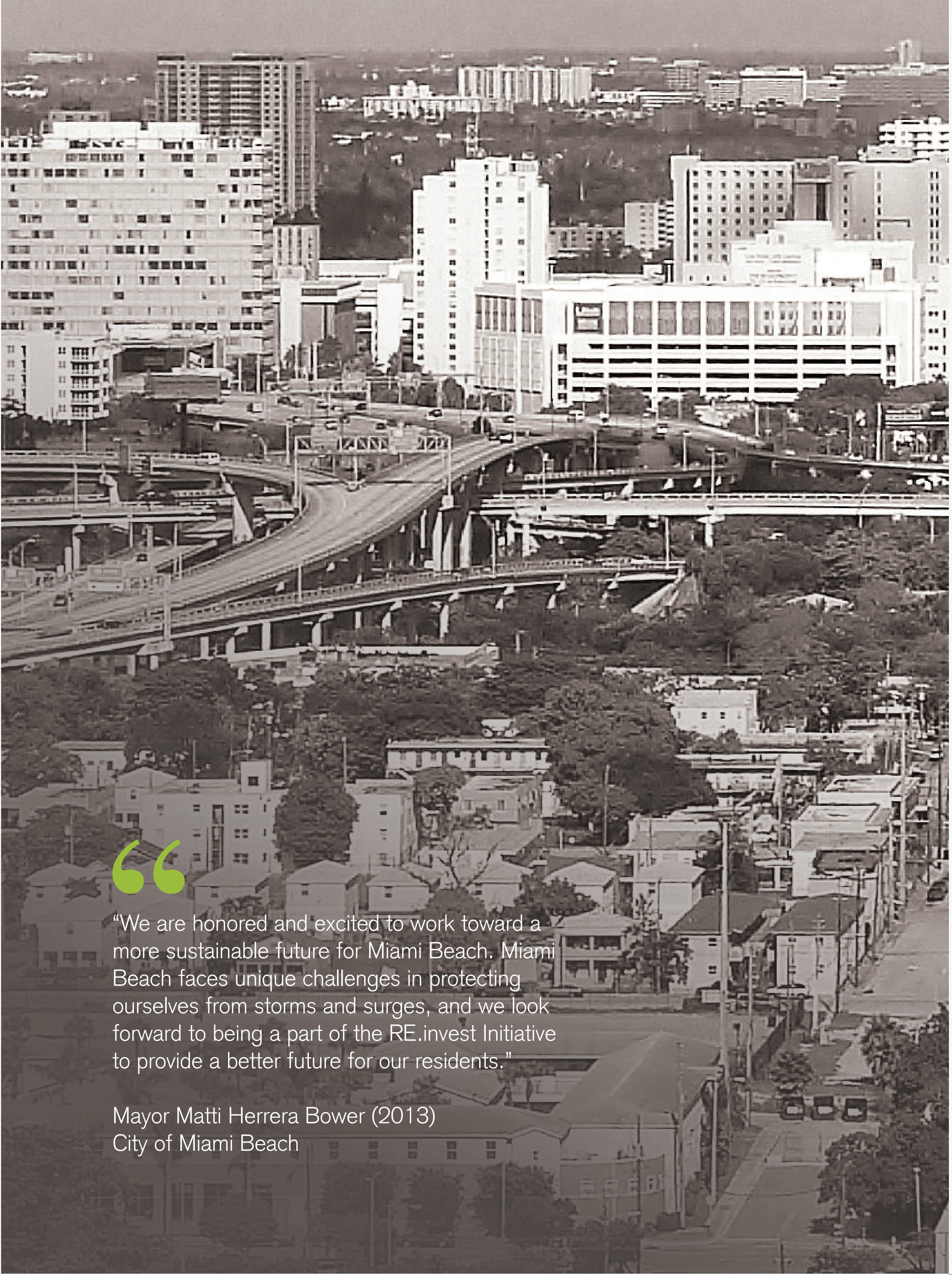
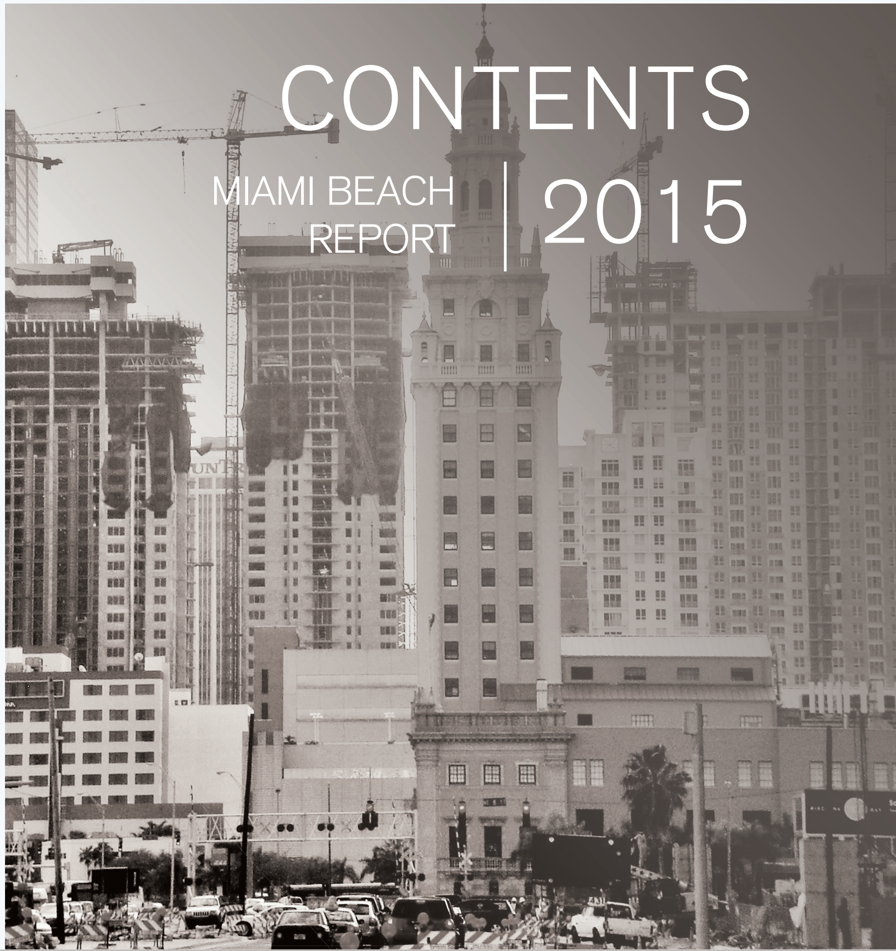
REinvest | CITY REPORT 2015

MIAMI BEACH



“We are honored and excited to work toward a more sustainable future for Miami Beach. Miami Beach faces unique challenges in protecting ourselves from storms and surges, and we look forward to being a part of the RE.invest Initiative to provide a better future for our residents.”

Mayor Matti Herrera Bower (2013)
City of Miami Beach



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RE.invest Introduction

The RE.invest Initiative focused on rethinking city infrastructure systems - including stormwater, energy, and communications among others - to enhance community resilience. By looking beyond individual projects to target city priorities, this initiative is structured to fill the gaps between planning and large-scale project delivery. There has been significant coverage in the national media about chronic underinvestment in urban infrastructure. It is clear that governments alone cannot be expected to meet our future infrastructure needs, especially with increasingly strained public budgets. This is especially true in the face of emerging climate impacts, like more severe storms, that mean our future infrastructure systems need to look and function differently than our current systems.

In the face of these challenges, RE.invest recognized that designing new types of projects – not just building more of the same – is essential. To this end, RE.invest was based on three core ideas. First, resilience is about systems, not just projects. Careful integration, coordination, and sequencing are essential to make sure that when one structure fails it doesn't take down a whole system. In practice that means that green, resilient, and sustainable infrastructure systems are not made up of a few large projects, but many small pieces and parts. Second, finding new ways to align public and private interests to help cities plan large systems of small projects to invest at scale is necessary. Costs and benefits associated with resilient infrastructure systems are often spread across sectors – therefore coordination among sectors during project design is critical – not just for government agencies, but also for investors. Third, when it comes to green and resilient systems, success is often something that doesn't happen. The city didn't flood, the power didn't turn off, even though the storm hit. Capturing those benefits and savings over time requires thoughtful design and advance planning.

To date, the field of sustainable infrastructure investment has focused largely on developing the financial instruments to deliver resources more effectively. This is essential; however, it is only one part of the solution. Cities and communities must also put forward viable, large-scale projects. To that end, the RE.invest team focused on providing the support necessary to translate city needs to financeable projects through a rapid, structured, and replicable project preparation and delivery process for integrated resilient infrastructure systems.

In Miami Beach, RE.invest focused on designing a comprehensive sea-wall upgrade plan and flood management approach to improve coastal protection for the city.

Overview

Cities across the country are seeing seawalls that were designed to protect communities against historical tides, regularly breached by tidal surges - resulting in significant coastal erosion and property damage. Given the already measurable sea-level rise in cities like Miami Beach, and anticipated increases in storm frequency and intensity, existing seawalls need to be upgraded to provide adequate protection in coming years. Specifically, the images in Figure 1 indicate areas of high frequency flooding within Miami Beach.

Despite the widely recognized need for city-wide upgrades, coastal cities, including Miami Beach, face significant challenges in mobilizing resources for such large-scale infrastructure investments. Another key barrier to action is that most seawalls are privately owned and managed by hundreds of individual coastal property owners.

Given that any solution to combat rising seas will take years to develop and install, the RE.invest team has focused on identifying short-, medium- and long-term strategies that the City of Miami Beach could pursue in concert. Those engineering, legal and finance strategies are described in this report.

Figure 1. Tidal Flood Areas (Source: Miami Beach GIS)

Existing Conditions

Miami Beach is a coastal city in Miami-Dade County, Florida located on a series of natural and man-made barrier islands between the Atlantic Ocean and Biscayne Bay, the latter separates the Beach from Miami city proper. As of the 2010 census, the city had a total population of 87,779 with a metropolitan population of about 5,564,635. In 2010, the median income for a household in the city was $27,322, and the median income for a family was $33,440 with about 17.0% of families and 21.8% of the population were below the poverty line, including 25.2% of those under age 18 and 24.5% of those ages sixty-five or over.

While much of the region's commerce is centered in Miami proper, in recent years, Miami Beach has made a concerted effort to grow beyond its traditional tourism based economy to become a multifaceted industrial center and regional leader for the location of Information, Health Care, and Arts & Culture industries. That said, tourism remains the largest sector of the City's economy with over $1.6 billion in direct annual visitor spending on hotel, food, and beverage, and also a large portion of the City's $900 million retail marketplace.

A mayor and six commissioners govern Miami Beach. The mayor serves for a two-year term with a term limit of three terms and commissioners serve for four-year terms and are limited to two terms. An appointed city manager is responsible for administering governmental operations and day-to-day management of the city. The current Mayor of Miami Beach is Philip Levine, and the City Manager Jimmy L. Morales was appointed in 2013.

Geology & Hydrology

The hydrostratigraphic framework of Florida consists of a thick sequence of Cenozoic sediments that comprise three main units (SEGS, 1986):

- The surficial aquifer, containing the Biscayne aquifer and semi-confining Tamiami Formation;
- The intermediate confining unit, referred to as the Hawthorn Group; and
- The Floridan aquifer system.

The Biscayne aquifer underlies Miami Beach to a depth of approximately 200 feet or more (USGS, 2014). The groundwater in the Biscayne aquifer is unconfined and will likely fluctuate in direct response to variations from precipitation and sea level rise.

The "Groundwater Elevation Monitoring and Mapping Report" from E Sciences investigated rainfall and tidal influence on groundwater elevations throughout Miami Beach. The report demonstrated that high tide events can exacerbate flooding when coincident with saturated soil conditions in the rainy season (E Sciences, 2014). The correlation between temporal changes in tidal elevation and groundwater elevation within Miami Beach is not surprising given the high permeability and unconfined nature of the Biscayne aquifer. The E Sciences report concludes that low lying areas with insufficient subsurface storage capacity will be more prone to flooding from global sea level rise.

The E Sciences study shows that reducing the water table level is a method for increasing storage capacity on the island. Drawing down the water table, in tandem with good stormwater and surface water management practices, would provide increased flood protection to property and infrastructure from global sea level rise. This, in effect, is highly dependent on the hydrogeologic makeup of the City of Miami Beach's subsurface aquifer system.

There are regionally identified hydrogeologic units within the Biscayne aquifer that may or may not be present at Miami Beach. Test drilling and aquifer-test data in the Miami-Dade region indicate a complex hydraulic conductivity distribution throughout the aquifer (Fish, 1991). In general, the aquifer contains highly permeable limestone accompanied by less-permeable sandstone & sand; either of which can be lens-like or thick, laterally extensive or localized (USGS, 2014). There are also reports of denser limestone exhibiting lower conductivities (Krupa, 2005) and solution cavities providing preferential flow paths with dramatically higher conductivities (Langevin, 2001).

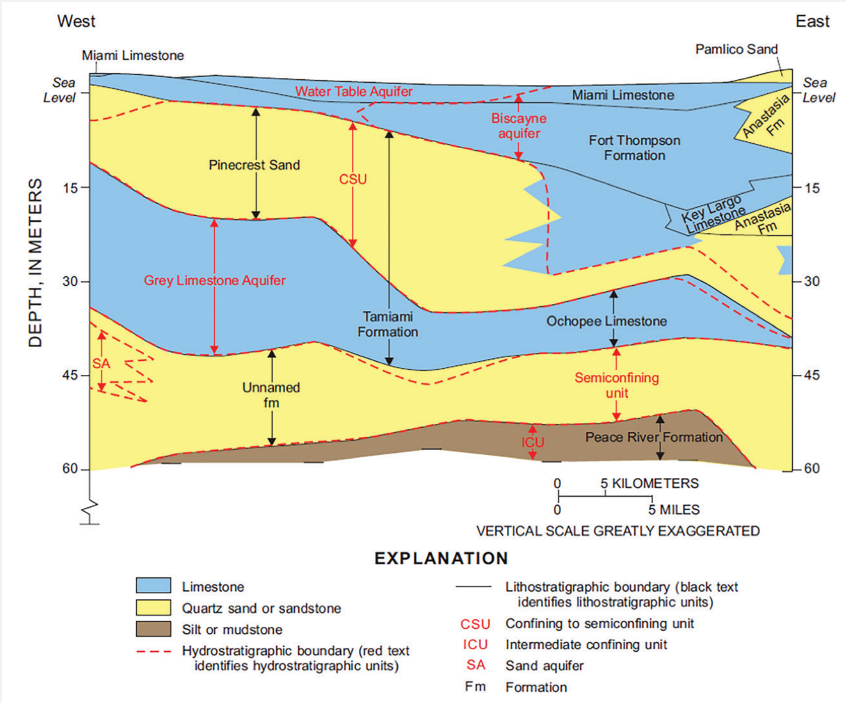

Figure 2. Surficial aquifer system across Miami-Dade County (Reese and Cunningham, 2000)

HYDROGEOLOGIC UNIT	HORIZONTAL HYDRAULIC CONDUCTIVITY, Kh, cm/s		HORIZONTAL HYDRAULIC CONDUCTIVITY, Kh, cm/s	
	min	max	min	max
Marl	3.5×10^{-5}	1.8×10^{-2}	3.5×10^{-4}	1.8×10^{-3}
Miami Limestone	3.5×10^{-5}	11	3.5×10^{-2}	1.1
Key Largo	1.1	35	.11	
Freshwater Limestone	3.5×10^{-5}	3.5×10^{-4}	3.5×10^{-5}	3.0×10^{-3}
Fort Thompson	.18	11	1.8×10^{-2}	1.1
Tamiami Formation	3.5×10^{-5}	.71	3.5×10^{-6}	7.1×10^{-3}

Table 1. Literature Review of hydraulic conductivity values for Biscayne aquifer

Given various hydrogeologic units and various facies within these units, many zones containing a range of hydraulic conductivities are expected beneath Miami Beach. The Biscayne aquifer is one of the most highly yielding aquifers in the world and the anticipated hydraulic conductivity values, based on a review of the published literature, are all high.

The Hawthorn Group is an intermediate confining layer beneath the Biscayne aquifer. A sequence of low-permeability, largely clayey deposits about 1,000 feet thick separates the Biscayne aquifer from the underlying Floridan aquifer system (USGS, 2014).

For reference, the Turkey Point Nuclear Generating Station is located 25 miles south of Miami. A study at the plant included aquifer testing as part of a Combined Operating License Application (COLA). The Tamiami Formation was located approximately 100 to 120 feet below ground level. This formation can contain calcareous sandstone to low-permeability sandy silt, among other lithologies (USGS, 2014). At Turkey Point, the Tamiami Formation was determined to be semi-confining and consisted of local marine limestone & sandstone. The Hawthorn Group was approximately 220 feet below ground level. Turkey Point has recently been approved for construction using the concept of a groundwater cutoff for deep excavation of the power block.

Constraints to remediation are unclear given the lack of site-specific hydrogeologic information for the City of Miami Beach.

Existing Infrastructure

The Public Works Department in Miami Beach is a full service organization providing planning, design, construction, maintenance and repair, and operation of City infrastructure including utility systems, buildings and facilities. The Department manages solid waste collection and disposal, streets and street lighting, engineering, construction management, environmental resources management, water, sanitary sewer and stormwater.

The Storm Water Utility Section is responsible for operating and maintaining a reliable stormwater collection and conveyance system that protects public health and safety while complying with all federal, state and local regulations. This includes 59 miles of drainage pipes, 82 gravity drainage wells, 4 injection wells, 353 stormwater outfalls. 172 drainage basins, 6,000 catch basins and 3,000 manholes. This division is responsible for reducing and eliminating polluted storm water run-off; complying with National Pollutant Discharge Elimination System (NPDES) permit requirements; and relieving flooding conditions.

In 2012, the City of Miami Beach approved a city-wide Comprehensive Stormwater Management Master Plan that includes planning for improving stormwater management practices, infrastructure, funding, and regulatory policies. This effort was coordinated in conjunction with a city sustainability plan and in response to major findings of the Miami-Dade Climate Change Task Force which predicted a three to five foot rise in sea-level over the next century. The Stormwater Management Master Plan includes a comprehensive 20-year capital improvement plan at the estimated cost of about $196 million, but up to over $206 million should sea-level rise be higher than anticipated. In addition, the plan focuses on increased data collection, reducing impervious surfaces through green alleys and green roofs, stormwater harvesting, reuse and aquifer recharge, and long term financing.

Most seawalls within the City of Miami were constructed during the City's inception and are over 50 years old. The existing sea walls are relatively basic, low profile, minimum elevation designs. A recent investigation report prepared by Coastal Systems International Inc. shows that these sea walls are of three types of construction: (1) Limestone gravity walls, (2) Intermittent Concrete piles/filler concrete panels with a concrete cap, (3) Steel sheet piling with a concrete cap. Most of these seawalls appear to have strong visible signs of distress including evidence of cracking, spalls, voids, section loss, extensive concrete deterioration, settlement, rotation, misalignment, erosion behind seawall, sinkhole with significant loss of fill and corrosion.

Figure 3. Eroded Portion of Canal Bulkhead (Source: City of Miami Beach)

Figure 4. Erosion Behind Bulkhead (Source: City of Miami Beach)

As an example, Collins Canal is an approximately 50-ft wide, man-made waterway that runs across the island from Biscayne Bay to Collins Avenue/Lake Pancoast (approximately 6440 ft). It opens into Biscayne Bay south of the City's Sunset Harbour neighborhood/the easternmost entrance to the Venetian Causeway and is influenced by tidal action from Biscayne Bay. As the canal is sheltered from the effects of coastal erosion on the Atlantic side of the peninsula, its geometry has changed little since construction in 1912. The canal bed material is concrete covered with a thick unstable layer of detritus composed of leaves, and sediment estimated to be about 1-2 feet deep. The salinity of the canal is expected to mimic that of the Biscayne Bay which ranges seasonally from about 32 parts per thousand (ppt) to 40 ppt, with higher salinities occurring during the dry winter months when there is a lack of freshwater influx from rains to contribute to dilution. The retaining walls for the canal are mostly on private property. They have been built, maintained, and repaired to varying standards resulting in portions that are in relatively good shape compared to those that are failing. Figures 3 and 4 are photos provided by the City of Miami Beach that show evidence of erosion and bulkhead deterioration within the canal.

Enabling Environment

In January 2014, Mayor Levine formed a Blue Ribbon Panel on Flooding Mitigation to oversee the city's response to flooding and provide a comprehensive and visionary approach to flood management and sea-level rise adaptation.

Guided by panel recommendations and an updated Stormwater Management Master Plan, the City is working to upgrade aging gravity-based stormwater infrastructure with tidal control valves, pump stations, and other structures to improve drainage by preventing seawater from entering the system and by quickly expelling flood waters from urban areas, even during periods of elevated tidal or water table levels. Per the provisions of the Stormwater Management Master Plan, the standards used to design these on-going drainage projects will be updated as new data, including sea-level rise projections and local ground water hydrology, become available.

The city is also reinforcing the engineering and natural buffers surrounding Miami Beach to protect against storm surge. The City has completed design and construction for upgrading the 3 miles of public seawall surrounding the city to meet projected sea level rise and storm surge.

In coastal areas without seawalls, the city is looking at natural infrastructure, such as building a more robust beach and dune system and living shorelines, for storm protection. For example, an on-going dune restoration and enhancement project uses an ecosystem-based approach to restore the health of the dune system so it can continue to provide critical storm surge and erosion protection along the eastern coast.

RE invest Solutions: Short-Term

Perhaps the most important short-term activity the City of Miami Beach, and any coastal community, can pursue is actionable data collection. Improved real-time hydrological data will help the city to understand current and future challenges to better refine solutions, and increased regular-loss data will define the value of any infrastructure upgrades to beneficiaries in a way that is capturable. Given this, the RE.invest team developed a three-pronged strategy—hydrological modeling, infrastructure testing, and avoided loss estimation—to help the City of Miami Beach pursue actionable data collection to support future coastal reinforcement and flood management investments.

Data Collection on Groundwater Flows & Infiltration

In order to develop viable long-term solutions to the problem of groundwater rise caused by sea-level rise, additional data and information are needed. The RE.invest team suggests the City pursue additional hydrogeologic investigation and data collection.

The first step would be to complete a geotechnical and hydrogeological desktop study synthesizing all available data from past geotechnical investigations in support of construction projects on the island and from other studies on subsurface conditions for the island of Miami Beach. This would likely be an internal effort, although could be contracted out if need be – as it would include contacting the city department that grants construction permits to inquire about the availability of geotechnical reports, or other data, that may have been submitted to the City for the permitting of large construction projects (hotels, etc.) on the island.

Based on the review of the data collected in the desktop study, the team suggests the City develop and implement a geotechnical and hydrogeological field investigation providing data on the extent, thickness and properties of different hydrogeologic units under the island, and especially the depth to an aquitard; hydraulic testing to determine the aquifer response; the hydraulic conductivity of different zones; and other parameters for estimating any pumping rates. The geotechnical investigation should be performed in two phases:

- Phase I: an initial phase involving a relatively small number of boreholes (approximately 10), intended to ensure a confining layer exists under the island and that it is technically feasible to move to the next step of field testing the concept of a vertical cutoff wall that would isolate the water table unit on the island from the ocean.

- Phase II: a second phase with a larger number of boreholes (approximately 30) in support of the initiation of an island-wide hydraulic barrier.

Technology Innovation, Demonstration, and Evaluation

Even with better data to define the problem—municipal governments like Miami Beach often lack access to best-available solutions and have limited opportunities to “try before buying” through conventional procurement processes. Often the same opaque contracting, permitting, and regulatory processes that limit public sector innovation also stymie private sector companies.

One of the most important barriers to both public and private innovation is the inability to test technologies in real systems and validate forecasted performance improvements. Even as many city infrastructure networks are crumbling, municipal governments are struggling to identify appropriate technology and system upgrades and companies are struggling to demonstrate their technologies’ performance. The RE.invest envisioned “innovation park” proposal, described in more detail below, is designed to overcome both of these barriers.

Specifically, the City can use the geotechnical and hydrogeological information captured in Phase I of the data collection exercise described above to design and complete a field test to provide proof of concept for any system-wide solution. For example, should the City choose to pursue a dewatering system it would need to enclose a small area with a hydraulic barrier to facilitate pumping to control groundwater levels and monitoring. In this case, the City could invite ground improvement contractors and/or technology providers to demonstrate their solution. Each contractor should be given a test cell, for example one of the boreholes, for three months in which to demonstrate their technology, optimized by their own technical staff.

Guided by the City to focus on Collins Canal, the RE.invest team has worked to scope out a testing zone for bayside grey versus green shoreline techniques to prevent erosion, intrusion and tidal flooding. Structuring a testing zone within Collins Canal near the Convention Center can provide the City a useful platform for engaging residents and tourists alike in resilience learning and planning, however the proposed innovation park structure is scalable and can be located in a single, or set of, locations throughout Miami Beach as space is available.

COLLINS CANAL INFRASTRUCTURE TESTING ZONE (iPark)

Collins Canal is an approximately 50-ft wide, man-made waterway that runs across the island from Biscayne Bay to Collins Avenue/Lake Pancoast (approximately 6440 ft). The canal bed material is concrete covered with a thick unstable layer of detritus composed of leaves, and sediment estimated to be about 1-2 feet deep. The retaining walls are mostly on private property and have been built, maintained, and repaired to varying standards resulting in a patchwork of good condition and failing structures. Its location, indicated in Figure 5, near the new Convention Center development is an ideal spot to both test the value of emerging seawall systems in Miami Beach, while also providing space for showcasing these systems to residents and encouraging the adoption of these approaches when residents repair retaining walls on private property.

The City could also use this space to test upland green infrastructure systems including slope breaks to interrupt erosive overland sheetflow to the canal retaining walls, rain gardens and bioretention areas. Additionally, failing seawalls could be repaired using modern methods instead of the methods employed when originally constructed in the early 1900s. These could include the use of geotextile and coir logs to create a barrier between the canal bank soil and the back of the retaining wall to reduce erosion behind the wall and the migration of soil material into small voids within the retaining wall where they can lead to damage.
Miami Beach could also pursue installing a living shoreline - a method of using wetlands plants, submerged aquatic vegetation, oyster reefs, coir fiber logs, bio-logs, sand fill, and limited use of stone rather than hard structures to stabilize a bank. Figure 6 is a representation of a typical Living shoreline.

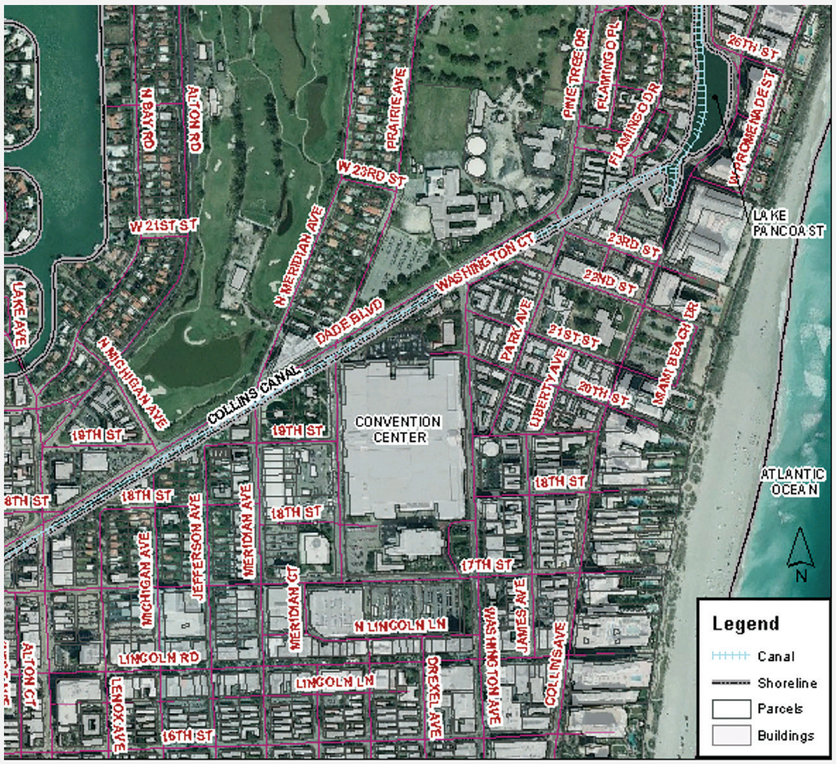

Figure 5. Collins Canal Location Map

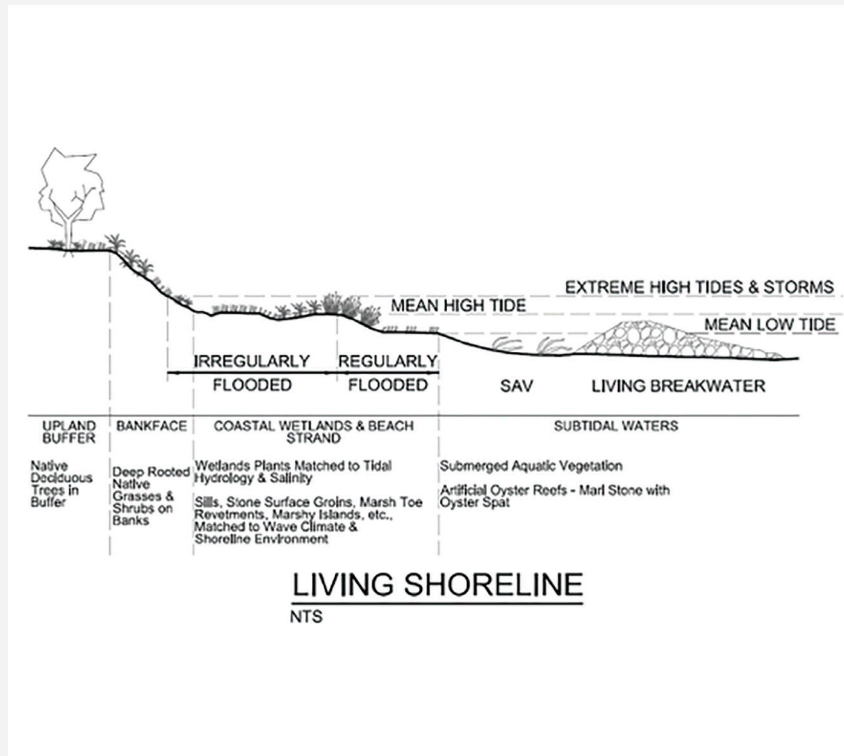

Figure 6. Living Shoreline

Living shorelines mimic natural shorelines by dispersing the energy from waves and currents gradually rather than abruptly stopping a wave as a wall would. There are variations of living shoreline based upon the expected energy from waves and currents. Some low-energy, non-structural applications such as tidal creeks and estuaries can consists solely of vegetated areas. Medium energy, non-structural applications can be met by adding a breakwater of coir logs or geotechnical tubes. Higher energy, non-structural applications can include breakwaters of shell or stone. Structural applications, in any energy environment such as bridge abutments, shipping canals, may require a hybrid system. A hybrid system combines traditional structure such as revetments or bulkheads but includes more natural materials and vegetation to make the combined system more robust. An example of a hybrid system is the Hillsboro Canal Bank Stabilization Project that the South Florida Water Management District (SFWMD) is currently constructing in Broward County. The stabilization includes articulated concrete mats and reinforced turf vegetation.

Framed as a living lab and marketing facility for contractors and technology providers, large and small companies from around the world can enter to test and validate their technologies for eventual sale in Miami Beach and elsewhere. Much like an art installation, the City can require that companies cover the cost of system installation and teardown should it be necessary. The RE.invest team suggests that the City of Miami Beach not only target companies developing living shoreline or constructed seawall strategies but also companies that are looking to utilize tidal flows for energy production, desalination or other purposes.

The living lab framing also makes the space an interesting opportunity for engaging the public and helping residents both learn about current and future challenges and get involved in creating a solution. Leveraging this space for educational and community engagement purposes positions the proposed “innovation park” for philanthropic funding as well.

Understanding Future Impacts & Benefits

In the short term, quantifying Miami Beach hydrogeological challenges and assessing different technical solutions are the most important steps toward determining the best solution to the City’s flooding issues. However, there is a critical third step that is essential for securing financing for whatever technical solutions emerge.

This step involves gathering data on losses—property damage, business disruption, insurance payouts, mold, and myriad costs associated with localized flooding and storms. Currently, it is clear that nearly all properties in Miami Beach are at risk from sea-level rise and hurricane damage. Insurance premiums have risen dramatically in recent years. However, the City lacks access to robust data on current and future (anticipated) losses due to flooding, storm surge, wind, and related damages.

In order to secure private financing for part or all of any coastal protection infrastructure system, the City needs to systematically build an understanding of the benefits or financial value created by a proposed project design.

Sea walls and other coastal infrastructure do not generate any direct revenue. Unlike toll roads, where drivers pay to use the system, the benefits are indirect and diffuse. However, these systems have many important financial benefits that can be more easily compared to investments in energy efficiency, where installing a new system can create savings and risk reductions for individual residents. The benefits of new seawall investments in Miami Beach extend far beyond direct benefits to coastal property owners. There are financial benefits that could extend to the city of Miami with reduced hurricane risk and damage.

In order to monetize and capture this value, the City needs to systematically improve its data collection on the scale of current impacts and future risks for all at-risk commercial or residential properties. Understanding current and predictable future losses is the type of information that third-party investors and insurance companies would need to turn a benefit into a revenue stream, and support comprehensive preventative investments through catastrophe or social impact bonds.

The RE.invest team proposes that the City pursue a partnership with one or more leading insurance firms and philanthropies to create a new resilience-focused “big data” initiative that includes a broad-based survey of home and business owners to assess the total costs of flooding in recent years. Examples of the type of data include: sandbags purchased, mold clean-up, and car and home related damages.

Starting with an effective baseline on current losses can also help create public momentum for new infrastructure investment to mitigate existing problems and ward off future risks that are likely to come with even higher costs to residents.

RE invest Solutions: Mid-Term

In parallel to the three short-term activities described above, the City should also initiate processes that will take longer to implement, including enacting policies that encourage or even mandate each individual property owner to make upgrades to their properties. Here the RE.invest team identifies how the City could go about structuring such a program and creatively support community investment.

The City of Miami Beach can leverage Florida's authorization for municipalities to structure special assessment districts that can levy a series of taxes and/or fees for specific district upgrades not covered by general government services. For example, Punta Gorda established two separate canal maintenance assessment districts responsible for maintenance of all canals, seawalls and navigation channels within a designated geographic area. Flat fees are assessed for single-family lots. Properties not zoned as single family dwellings are assessed a fee based on the calculated square footage of land lying within 120 feet of any waterway. In this case property owners share the cost of system maintenance and have seen property values increase.

The City of Miami Beach could structure a linear coastal special assessment district that encompasses all properties along the waterways, both bayside and oceanside, or create two adjacent districts—one along the bayside and a second linear district to cover inland properties—with the aim of dedicating collected funds for flood-management investments not only along the coast but throughout the City. Collected funds could then be more defensibly earmarked for flood-management investments not only along the waterfront but throughout the City. Fees should be assessed on property value and structured as a percentage based on risk, or more specifically exposure to risk, meaning that larger properties would pay a higher rate, as would properties at a lower relative elevation. In addition,assessments should be proportional to the scale of required upgrade. Additional analysis based on local flood-loss data is recommended in the short-term, current federal flood maps and risk designations, and public engagement would be required to determine the exact assessment allocation formula.

The City's ability to create a special assessment authority or district that can levy taxes and/or fees offers a unique opportunity for financing comprehensive resilience upgrades like the proposed seawall solution. Across the country, local governments have used value capture mechanisms and borrowing against future tax revenues (i.e. tax-increment financing, TIF) to incentivize, if not directly finance, investments in areas with high private investment risk. These value capture mechanisms use special district-level taxes and community improvement fees to capture a portion of the value created for private property owners and developers as a result of public investments.

The same mechanism used to capture value created for private entities by public investment in transport or drainage systems could, in principle, be applied to both public and private investments that reduce disaster or insurance risks to landowners. Tax-increment financing is a form of value capture based on borrowing against future increases in market based land values and associated increases in tax revenues in order to finance investments in higher-risk areas. In Miami Beach, by establishing that climate and/or disaster risks are directly lowering property values - TIF or similar types of value capture mechanisms should be available to finance flood management and erosion solutions that would reduce those risks. Even more, because the proposed solution will add square footage to waterfront properties, the increase in taxable property and property value could also be captured to bolster payback streams. However, should the political need arise, the City could also preserve that additional property value for the individual property owners as an incentive for building support any special taxing district structure.

More generally, other value capture and savings based financial instruments such PACE bonds for energy efficiency retrofits and upgrades have been deployed with great success to support large-scale investments in private property, such as rooftop solar energy systems. In contrast to TIF mechanisms, PACE and similar instruments do not require the designation of any specific geographic area or district for funding eligibility, giving a City more flexibility to administer a broad program of upgrades.

Should the city choose to pursue a coordinated seawall upgrade strategy as described, the RE.invest team has identified a series of structural and legal considerations the City will need to address in the mid-term.

CITY MANDATED AND/OR ORGANIZED SEAWALL UPGRADES

Structural Decisions	• City builds and maintains seawall and assesses property owners for their share of cost
	  ◦ City can establish a special assessment district to pay for improvements and maintenance (similar to Punta Gorda)
	  ◦ City can expand property boundaries and pay for improvements/maintenance with increase in property tax payments

Regulatory Issues	• Consider requirements for establishing special assessment district • Research legal authority to expand property boundaries • Determine whether there are permitting requirements • Cultivate political/property owner support and address opposition

Ownership/ Operational Issues	• Follow procedure for establishing special assessment district
	  ◦ Identify legal/political issues and approach for addressing
	  ◦ Determine whether better approach is to tax added value of expanded land boundary or simply assess for construction and maintenance of seawall (Punta Gorda)
	• For cost efficiency, the City could contract one firm to serve as a special purpose entity that would design, build, finance and maintain the seawall or the City could allow individual properties to pursue separate contracts
	• Consider financing – upgrades could be financed with bonds paid back with revenues from special assessment
	• Consider pay-for-performance contracts

Contractual issues	• Prepare documents necessary to establish Special Assessment District and take required steps to establish district and administer it, including payment stream
	• Contract with speciatl purpose entity or individual contractors to design, operate, maintain and possibly finance the system
	• Draft financing documents
	  ◦ Bond financing by City
	  ◦ Agreement with private entity to finance in exchange for receiving fees collected by District

REinvest Solutions: Long-Term

Infrastructure Solutions

Implementing policies that mandate individual property owners to make upgrades is the traditional option for upgrading privately held infrastructure with public benefits. However, this approach runs the risk of mandating or incentivizing piecemeal construction that creates poor quality “seams” – imagine a patchwork quilt – and reduces the resilience of the overall system, making every property more vulnerable to loss and damage over time. Additionally, this piecemeal approach does not allow property owners or the city to take advantage of economies of scale that could reduce the costs of design and construction.

For this reason, after an iterative conceptual design process with the City of Miami Beach, the RE.invest Initiative engineering team identified several comprehensive technical options and system-wide structural seawall retrofit solutions to serve as one of the ways the City could both protect against tidal surges and erosion, and help mitigate localized flooding due to seawater intrusion and rising groundwater tables.

SEAWALL UPGRADE

While most of the existing seawalls are no longer fully functional as they are past design life and do not meet forecasted tidal elevations, demolishing or repairing the wall would add no value for the City of Miami Beach and result in costly construction and demolition costs. As a result, in most cases along the 63 miles of existing seawall, a new seawall would need to be constructed seaward. The existing seawall and properties behind the new wall would be left undisturbed by this type of construction and once the new seawall is built, the space between the existing and new wall could be filled with dredged sand or a concrete water retention conduit. Alternate seawall replacement strategies are shown on Figures 7, 8, and 9.

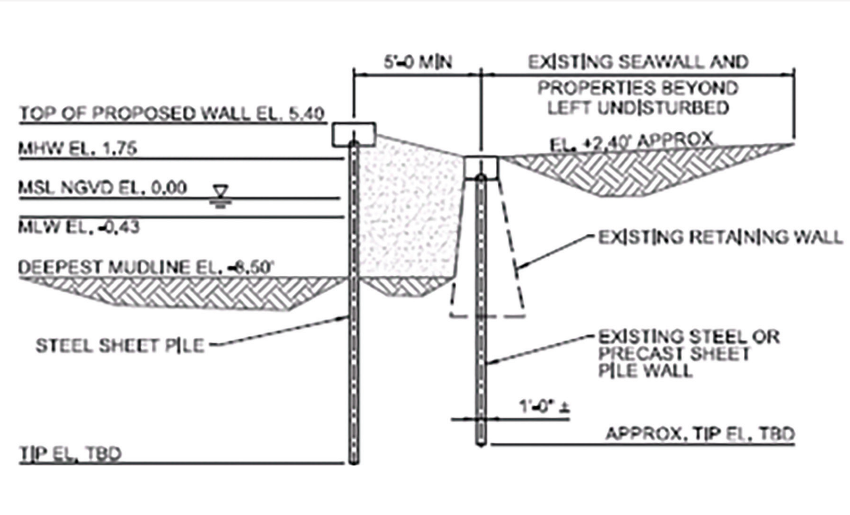

Figure 7. Sheet Pile Wall

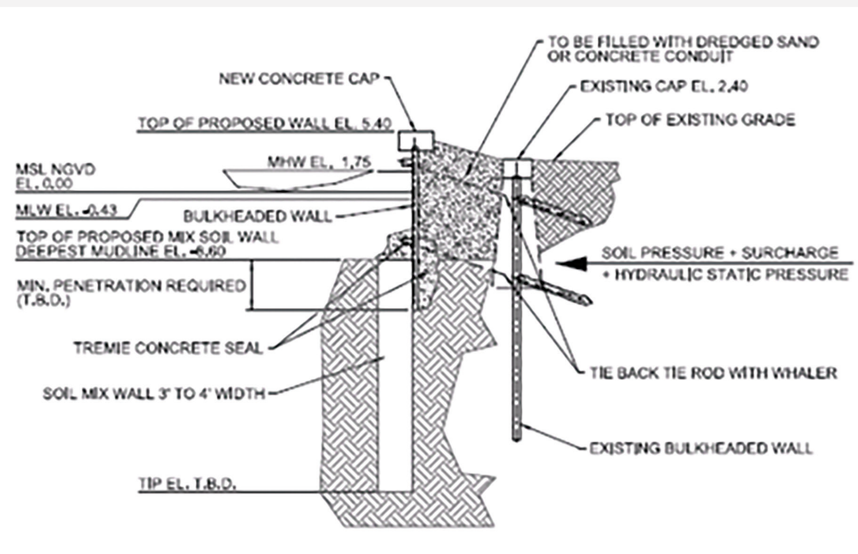

Figure 8. Sheet Pile and Soil Mix Wall

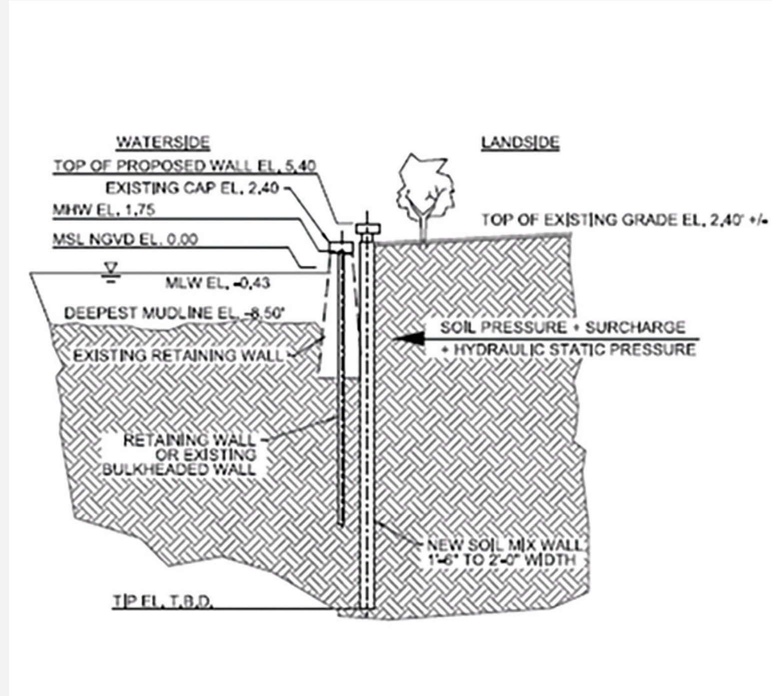

Figure 9. Soil Mix Wall

The designs suggested within this report are preliminary in nature and in no way depict a detailed plan for of all 63 miles of the seawall. As highlighted in the short-term recommendations, further research would need to be conducted to mitigate design clashes and the logistics behind designing and constructing a project of this magnitude in close proximity to residences and businesses.

In addition, the various recommended concepts would need to be implemented along different portions of the 63-mile seawall replacement and solutions may vary depending on site-specific conditions. For example, where a shallow aquitard (less than 40 feet) exists sheet piles can be used, while soil mixing would be applicable at medium depths (up to 80’ depths), and in locations where the aquitards are deepest (greater than 80’ up to 200’ depth) a grout curtain would be the best option. Where limestone or other resistant rock is present in the soil column this might make soil mixing challenging.

INTEGRATED HYDROLOGICAL MANAGEMENT

Designing a dewatering system for the whole island is one approach for keeping the groundwater table under the island below the mean sea level to prevent saltwater infiltration. This solution is an effective option, if an aquitard (i.e., a body of distinctly less permeable materials), exists below the unconfined aquifer at a depth that would allow construction of a vertical cutoff wall to intercept this layer.

Given the high permeabilities in the aquifer beneath Miami Beach, a permanent dewatering system without a hydraulic barrier keyed to a low permeability confining layer (aquitard) would not be technically feasible or cost effective.

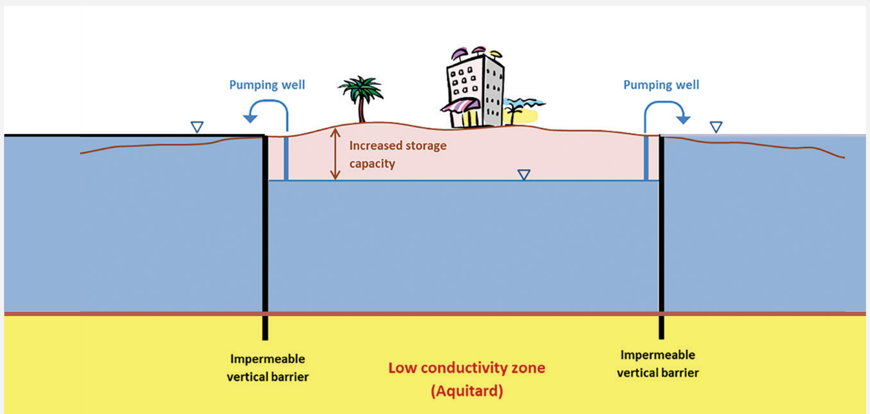

Figure 10. Conceptual sketch of vertical cutoff barrier with pumping wells

Provided a lower aquitard is within range, within 200 ft or less, it would be possible to construct a vertical barrier that contains the island. The system would intercept flow through the permeable aquifer, creating a “bathtub” that reduces groundwater flow from the ocean towards the island beneath the City, and within which the water table level can be controlled through pumping.

Lowering of the water table may require maintenance pumping to remove water that naturally recharges beneath the vertical cutoff. However, by keying the cutoff wall into a lower confining unit, the amount of pumping would be reduced by several orders of magnitude over a permanent dewatering system without a vertical cutoff.

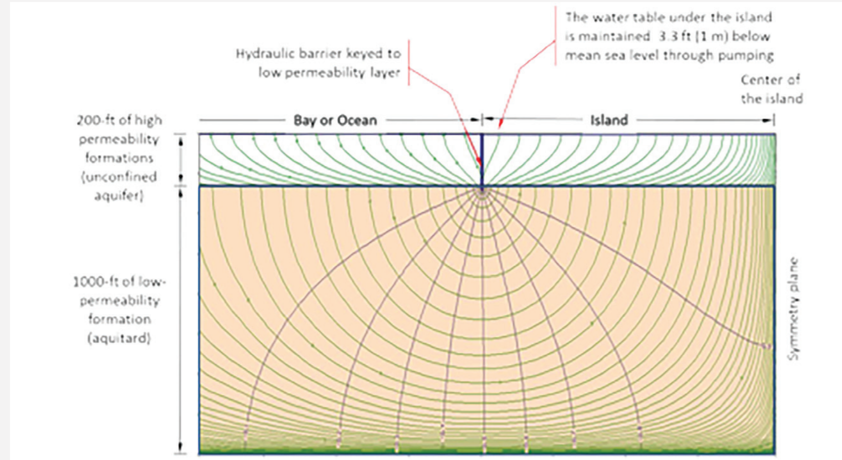

Figure 11. Groundwater flow field on a vertical cross section illustrating the lengthened seepage paths and reduced flow using vertical cutoff (blue: equipotential lines; green: flow lines).

A preliminary groundwater model using the USGS computer code MODFLOW was developed to illustrate the need for a vertical cutoff barrier that would penetrate the entire depth of the aquifer and be keyed in the confining unit. For demonstration purposes it was assumed that sea level rise is 3.3 ft (1 m), and that the depth to an extensive, 1000-ft thick confining unit (the Hawthorn formation) is 200 feet, the vertical hydraulic conductivity of the confining unit is three orders of magnitude lower than that of the unconfined aquifer, and the hydraulic conductivity of the vertical cutoff hydraulic barrier is six orders of magnitude lower than that of the unconfined aquifer. The analysis also assumed that any upward flow from the lower Floridan aquifer system towards the unconfined aquifer through the confining unit (aquitard) is negligible.

Figure 11 shows the simulated flow field under these assumptions. Each of the flow lines (in green) illustrates the path a water particle would have to travel to get from the ocean to the water table under the island. The model shows that under these assumptions the vertical cutoff wall forces the subsurface flow from the ocean towards the island into the much lower conductivity formation (aquitard), which reduces significantly the rate of flow towards the island. To maintain the water table on the island at a given level, lower than the level of the ocean, groundwater would have to be pumped out at a rate equal to the rate of subsurface flow from the ocean to the island.

It is important to note that the success of a viable groundwater control system depends on two factors: (1) the existence of a continuous low-permeability confining layer (aquitard) and (2) the installation of an effective hydraulic barrier keyed in the aquitard. If a low permeability confining layer does not exist below the high permeability formation (unconfined aquifer) then the required pumping rate to maintain the water table in Miami Beach below sea level would be two to three orders of magnitude higher. Similarly, if the hydraulic barrier is not keyed in the confining unit (aquitard) the required pumping rate would be substantially higher. Figure 6 shows the flow field for a simulated case under the same assumptions as in Figure 5, the only difference being that the hydraulic barrier in the simulation shown in Figure 11 is only 100 ft deep, i.e. it extends only half way to the top of the low-permeability confining unit. In this case, as illustrated by the seepage lines shown in Figure 11, substantial flow takes place below the bottom of the barrier through the part of the unconfined aquifer between the bottom of the barrier and the top of the confining unit (aquitard). The estimated flow towards the island in this case is three orders of magnitude higher than that for the case shown in Figure 11. This is because, even though the cutoff wall prevents flow towards the island through the upper part of the high permeability unconfined unit, the lower part of this unit allows very high flow from the ocean towards the island. To maintain a low water table groundwater pumping on the island must be equal to this flow.

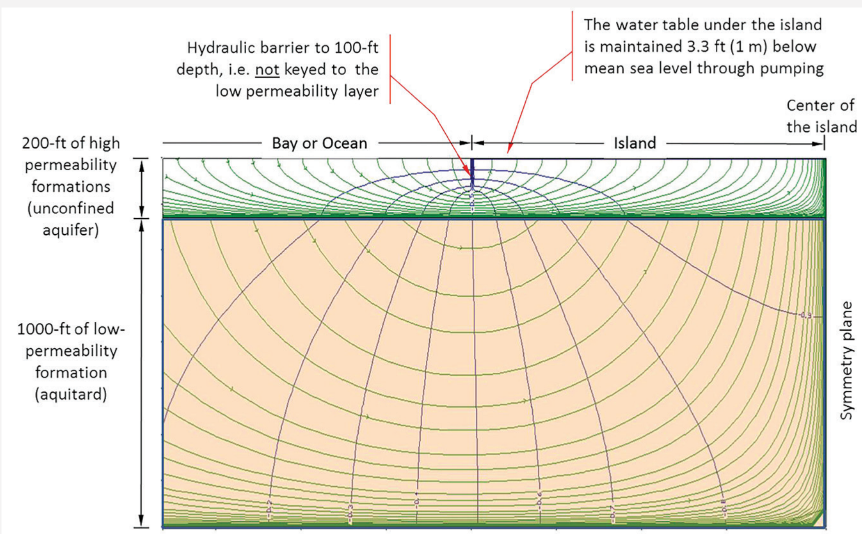

Figure 12. Groundwater flow field illustrating the shorter seepage paths and higher flow in the case that the hydraulic barrier is not keyed in the aquitard (blue: equipotential lines; green: flow lines).

Figure 12 shows how the estimated pumping rate on the island required to keep the water table below mean sea level varies as a function of the vertical hydraulic conductivity (Kv) of the materials below 200 ft depth. The results are shown in the form of the ratio of the required pumping rate over that for the base case described in Figure 11. Estimates are shown for the case that the horizontal hydraulic conductivity (Kh) of the materials below 200 ft is equal to the vertical hydraulic conductivity (Kv), and for the case that it is ten times higher. Also, results are shown for the case that the hydraulic barrier is 200 ft deep and for the case that it is only 100 ft. As can be seen in Figure 13, if the barrier does not extend to the confining layer and is not keyed in it, the assumption regarding the hydraulic conductivity of the confining unit does not affect the estimated flow. The results shown in Figure 13 are all based on simulations for a part of the island 1 km wide and assuming that the same subsurface conditions exist on the Biscayne Bay and the Atlantic Ocean side of the island, making therefore possible due to symmetry to consider only half of the island.

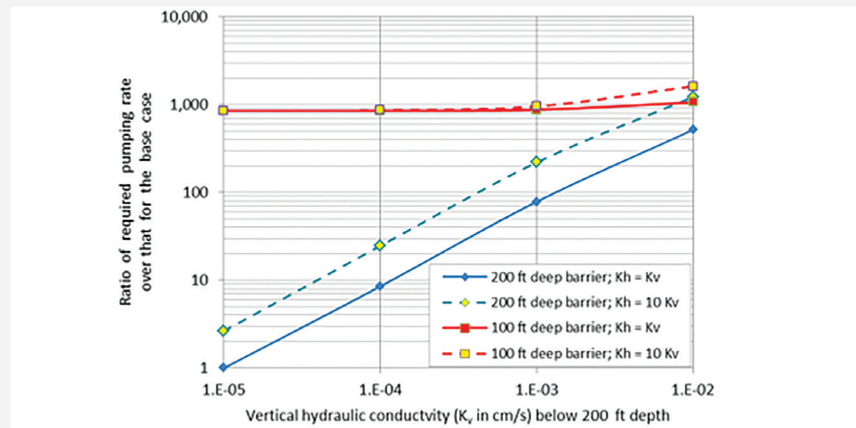

Figure 13. Ratio of the required pumping rate to maintain the water table on the island below mean sea level over that of the base case presented in Figure 4. Results are shown for the case of a hydraulic barrier 200 ft deep keyed into the confining unit, and for a barrier half as deep, and for different values of the hydraulic conductivity of the materials below 200 ft.

A constructed aquitard was also considered and there are a number of methods to install a near surface horizontal barrier that blocks or lessens the impact from rising groundwater. The treatment could be applied to individual properties or done in sections, depending on priority, and therefore would not be delayed by constructing a containment for the entire island. The construction of a horizontal barrier is practical only at a small scale.

Conceptual Mitigation Approaches

Various approaches are presented for vertical and horizontal seepage barriers in Table 2. Viable options are further ranked in Table 3 based on anticipated construction, quality, relative cost, technology risk and schedule considerations based on available regional geologic information was used and it is assumed that the target depth of the vertical cutoff is an aquitard at a depth of 200 ft. The table presents a qualitative appraisal of methods used in the industry to construct barriers. The methods are proven for general ground conditions encountered at most project sites. However, the geology at City of Miami Beach is atypical and therefore would require further refinement of the selected method(s) prior to performing a field test. Design and construction issues could include high mud loss, salt-water interaction with mud chemistry, formation abrasivity, high compressive strength, and the sourcing of economical backfill material with low enough permeability.

Overall, it was concluded that a permanent dewatering system could be installed in the City of Miami Beach to address concerns about rising groundwater levels associated with global sea-level rise.

Different options for a vertical hydraulic barrier were considered. The top three options from a technical viewpoint in terms of their effectiveness in providing hydraulic isolation are:

- A vertical barrier wall, which can be constructed either as a diaphragm wall (continuous cutoff barrier constructed with hydrofraise), or as a secant wall (contiguous drilled shafts forming a barrier wall)

- Deep soil mixing barrier, such as a Trench cutting Re-mixing Deep (TRD) vertical cutoff

- Jet grouted vertical barrier

In order to advance the plan of a permanent dewatering system further, the RE.invest team recommends the City pursue additional hydrogeologic investigation and testing (described in the short-term section above) to provide a basis for more detailed design and analysis on available construction approaches.

METHOD	TECHNOLOGY	TIME DURATION	RELATIVE COST	SEEPAGE REDUCTION	COMMENT
DEWATERING WELLS					
Permanent Dewatering, No Barrier	Pumping wells	3-5 years, depending on number of rigs	Very High	None	Not realistic due to high conductivity of limestone. However, combined with a seepage cutoff barrier and bottom barrier, dewatering is viable.
VERTICAL CUTOFF BARRIER METHODS					
Diaphragm Wall	Construct a Continuous Cutoff Barrier with Hydrofraise (Rock Mill)	2-4 years, depending on the number of machines	High	1 x 10 E-8 cm/sec	Vertical cutoff achieved, but will require a bottom barrier due to high conductivity of LS bedrock.
Vibrated Beam	Vibrated beam cutoff barrier	2-3 years, depending on the number of machines	Medium to High	1 x 10 E-8 cm/sec	Depth is a factor. Feasibility has not been proven beyond 80 ft depth in soil. Viability depends on ability to penetrate rock.
Secant Wall	Contiguous drilled shafts forming a barrier wall	3-5 years, depending on number of machines	High	1 x 10 E-8 cm/sec	Depth is a factor. Limited to less than 100 ft.
Jet Grouted Barrier	Directional jet grouting - vertical panels	2-3 years	Medium	1 x 10 E-6 to E-7 cm/sec	Depends on depth of barrier because vertical alignment is critical.
Grout Injection	Permeation grouting using sleeve-port pipes	2-3 years	Low to Medium	1 x 10 E-5 to E-6 cm/sec	Relatively fast and low cost. Able to reduce permeability by two orders of magnitude but is not a continuous cutoff.
HORIZONTAL AQUITARD METHODS					
Jet Grouting	Multiple intersecting columns	2-4 years	Medium	1 x 10 E-5 to E-6 cm/sec	Depends on depth of barrier. Verticality is critical and therefore is limited to shallow depth.
Blanket Grouting	Permeation grouting on a grid pattern	2-4 years	Low to Medium	1 x 10 E-5 to E-6 cm/sec	Successful in high conductivity host material. Cementitious slurry to blended cement-bentonite grout materials.
Horizontal Cutting and Grouting	Horizontal cutting with a large "chain saw" used in tunneling	3-5 years	Medium to High	1 x 10 E-5 to E-6 cm/sec	Method proven on small scale. Grout or clay slurry circulated as coolant and barrier material. Localized treatment.
Compensation Grouting	Radial holes drilled from shafts	4-5 years	Medium to High	1 x 10 E-6 to E-7 cm/sec	Grouting from multiple shafts to provide a horizontal barrier under structures.
Soil Mixed Wall and Blanket Grouting	Vertical barrier (DSM) and grouting	2-4 years	Medium	1 x 10 E-5 to E-6 cm/sec	Treat beneath individual structures.
Horizontal Drilling and Grouting	Horizontal barrier by grouting holes using directional drilling	2-4 years	Medium	1 x 10 E-5 to E-6 cm/sec	Treat beneath individual structures. Track grout plume by magnetic particle signature.

Table 2. Conceptual mitigation approaches

METHOD	RELATIVE COST	CONSTRUCTION TIME	QUALITY	TECHNOLOGY RISK	CONSTRUCTION	PRELIMINARY RANKING
Diaphragm Wall, Vertical Cutoff	High	2-4 years	4/5	4/5	4/5	#1
Secant Wall, Vertical Cutoff	High	3-5 years	3/5	4/5	3/5	#2
Trench Cutting Re-mixing Deep (TRD), Vertical Cutoff	Medium to High	2-4 years	4/5	3/5	2/5	#3
Jet Grouting, Vertical Cutoff	Medium	2-3 years	2/5	4/5	3/5	#4
Grout Injection, Vertical Cutoff	Low to Medium	2-3 years	2/5	3/5	3/5	#5
Blanket Grouting, Horizontal Aquitard	Medium	2-4 years	2/5	4/5	4/5	#6
Permanent Dewatering, No Barrier	Very High	3-5 years	4/5	5/5	5/5	#7

Table 3. Conceptual sea-level rise mitigation rankings for City of Miami Beach

Note: Rankings on 5-point scale; higher rankings denote better outcome.
Relative Cost: Order of magnitude comparison relative to other options
Construction Time: Estimated construction time
Quality: Construction uncertainty and quality control options
Technology Risk: Proven performance and/or industry acceptance
Construction: Foreseen and unforeseen construction uncertainty

Implementation Strategy

Promoting integrated construction and management in the absence of regulation requires creative solutions that align homeowner incentives with access to capital for a shared community construction program. While the engineering solutions identified by the RE.invest team vary, all of the options include two major engineered components:

1. a new seawall to be constructed outside of the existing seawall segments
2. an integrated barrier system to better manage subsurface hydrological flows

The proposed seawall and barrier have multiple direct and indirect benefits to the City and individual private property owners that translate to potential financing options. First, because all of the proposed solutions include the construction of a new structure to the outside (into the water along the bay and canals) of the current seawall, this guarantees that some amount of additional square footage would be added to each individual property. For example, a new 1-foot wide section of wall directly adjacent to the existing wall on a 100-foot wide waterfront property would add at least 100 sq.ft. to the total taxable size of the property. Second, this structure would limit property loss and land erosion. Third, because the proposed structures are designed to provide surge protection and decrease flood related risks and damages, insurance premiums and damage claims will be reduced not only for waterfront property owners but also for property owners further inland.

Based on these projected benefits, the City and property owners can expect to see both property value increases—from a direct addition to their total amount of property/land and from indirect property upgrades—and insurance related savings. These two types of benefits are already the basis for financing for a variety of infrastructure projects. For example, property tax-increment financing for transit projects is based on capturing a percentage of the projected increases in property values adjacent to new transit stops and stations. Similarly, Property-Assessed Clean Energy or PACE bonds are designed to finance retrofits that create measurable energy savings. A similar approach could be used to retrofit seawalls and capture savings related to avoided damages and insurance costs.

Potential Beneficiaries

In order to structure a financing and management plan for a comprehensive seawall and flood management system, a first step is to define the direct and indirect beneficiaries of the proposed investment and to monetize the value of these benefits. In the case of Miami Beach, the following categories of beneficiaries would need to be involved in the project implementation and financing:

- PRIVATE PROPERTY OWNERS
  Individual landowners along the bay and canals are most immediately impacted by rising sea levels, tidal surges, and unmanaged groundwater up-swelling. Property owners already have and will continue to see rising flood insurance premiums coupled with increasing costs for individual seawall structure and property upgrades. However, because of the high cost of flood insurance premiums and a lack of coordination, most property owners are investing in temporary protection (e.g. sandbags) and regular damage cleanup rather than seawall upgrades. Providing investment incentives based on property value increases and insurance benefits could provide property owners with capital to invest in preventative upgrades and maintenance and realize greater savings.

- CITY GOVERNMENT
  The City of Miami Beach is the primary party responsible for building and maintaining local flood management infrastructure, ranging from pumps to keep water off the streets and out of local businesses, to raising the height of seawalls to protect against rising seas and eroding shorelines. Given the projected costs of these investments, the City does not have the public funding available or sufficient revenue from their tax base to support all of the necessary infrastructure upgrades. However, the City would be a direct beneficiary of coordinated upgrades to private property that reduce risks and prevent flood damages to public property.

- STATE/FEDERAL GOVERNMENTS
  In many cases, State and Federal governments are the primary source of funding following a disaster. For example, since Superstorm Sandy hit the eastern seaboard in October 2012, FEMA has provided nearly $3.9 billion in federal disaster assistance to affected areas. Given the increase in federal disaster declarations and the vulnerability of coastal cities, State and Federal agencies have a direct interest in protecting and increasing the resilience of a barrier island city like Miami Beach to reduce national disaster risk and financial liabilities.

- INSURANCE & RE-INSURANCE FIRMS
  The public flood insurance market in Florida is saturated and seeing annual double-digit increases in premiums. Private insurance companies see this as an opportunity to enter a new market, which they are doing slowly because they cannot at this point offer a better rate that the heavily subsidized existing insurance market. In the absence of infrastructure investments, current flood and storm risks are simply too high for insurers, and therefore the premiums they can offer are too high for most consumers. Many of the largest insurance and re-insurance companies have publicly expressed interest in supporting risk reduction measures that could allow them to actively diversify and manage risks—reduce damage payments—and reach new markets and policy-holders.

Translating these benefits into real sources of revenue requires adequate data to define cost allocations between parties and projected current and future savings, and also structures that make those cash flows more secure. Table 4 provides basic cost estimates for construction of the three types of seawall upgrades relevant to Miami Beach, depending on the specific location of the aquitard.

DESIGN ELEMENT	CONSTRUCTION COST ($M/MILE)	CONSTRUCTION TIME (MONTHS)	TOTAL COST ($M/60-miles)
40 Foot Sheet Pile	13	16	780
40 Foot Sheet Pile & 200 Foot Soil Mix Wall	44	18	2.640
200 Foot Soil Mix Wall	28	16	1.680

Table 4. Estimated Construction Cost for Seawall Upgrade

All three seawall types shown in Table 4 result in the extension of current property lines to include the new seawall, meaning that total lot size would increase by a minimum of 1-linear foot. For a 100-foot wide property, this means the lot size would increase by a total of at least 100 sq.ft. Based on the added land value, the RE.invest team conservatively estimates that revenue generation potential for the City over 35-years at the current tax rate is between $10M to $120M for a range of assessed land values. Calculations were based on a property with 100-feet of frontage gaining from a minimum of 100 sq.ft. to a maximum of 300 sq.ft., and assessed land value ranging from $150/sq.ft. and a maximum of $600/sq.ft. This calculation does not include ancillary benefits of seawall retrofit for non-waterfront properties, or include any insurance benefits and/or flood related property loss benefits, as those data are not readily available.

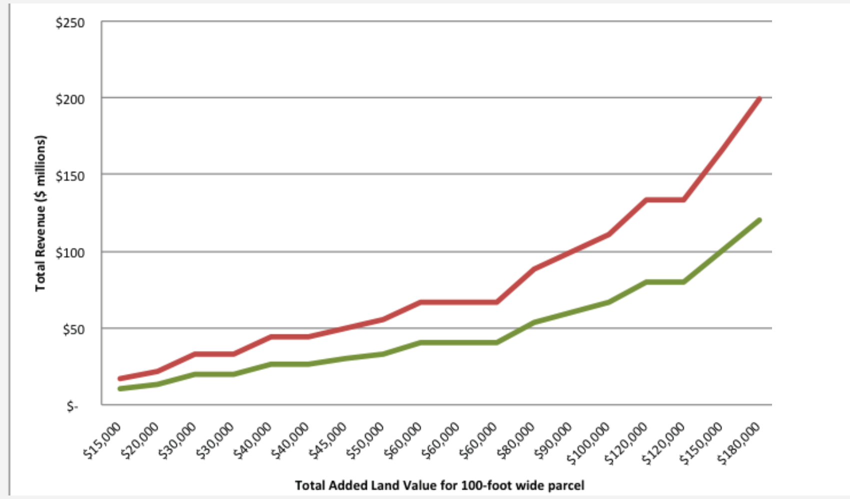

Figure 14. Potential Total Revenue from Additional Taxable Property

Property Tax Rate $6.025 per 1000$ assessed value
Property Tax Rate $10 per 1000$ assessed value

Analysis shows that at the current tax rate of $6.025 per 1000$ of assessed land value, the revenue generation potential over 35-years could cover a portion, but not all of the payback necessary for comprehensive system upgrade. The City of Miami Beach could consider increasing the waterfront property tax rate so it is closer to the maximum property tax (millage) rates of $10/yr tax assessment per 1000$ of assessed value, in which case a larger fraction of the project cost could be covered. Alternatively, without changes to assessed value or tax rates, the potential additional property tax revenue collected by the city would need to be packaged with insurance savings, special assessments or other funds to support comprehensive system upgrade.

Monetizing the total value of these benefits requires additional baseline data and modeling to refine these engineering design options and identify the most effective and cost-efficient solution for the City. However, these major project elements offer a basis for identifying relevant financial and legal models that could be applied to implement any final solution. Described below are a series of legal and financial structures that can be put in place to leverage those projected cash flows help to reduce financial risk.

Value Capture Mechanisms

While capital expenses for the proposed seawall solution are likely to be large (several hundred million dollars), the potential value created through additional square footage to existing private property, reduction of local flooding, and protection against storm damage could conceivably justify the costs. Like many large infrastructure projects, seawall systems generally have greater economies of scale (lower costs) and higher resilience benefits (fewer "seams") when constructed in large segments (multiple miles in length) versus as piecemeal investments by various private owners. Given that currently all but 3 of the 63 miles of seawall in Miami Beach are privately owned and maintained, the most important element to financing the system as a single structure is reshaping current ownership and management responsibilities. Therefore, the RE.invest team has focused on a number of potential strategies for capturing benefits and generating revenues that can support not only capital expenses but also ongoing operation and maintenance costs of new coastal protection systems. Each of these models would need to be adapted to match the City's administrative and financial needs and local resident and property-owner preferences. These more expansive strategies would build on the legal and financial mechanisms that the RE.invest team identified and recommend the City pursue in the mid-term.

SPECIAL DISTRICTS

Florida has authorized municipalities to structure special assessment districts that can levy a series of taxes and/or fees for specific district upgrades not covered by general government services. For example, Punta Gorda established two separate canal maintenance assessment districts responsible for maintenance of all canals, seawalls and navigation channels within the specified geographic area. Flat fees are assessed for single family lots and properties not zoned single family are assessed a fee based on the square footage of land lying within 120 feet of any waterway. In this case property owners share the cost of system maintenance and have seen property values increase, but the City is not in a financial position to make comprehensive upgrades.

As described previously, the City of Miami Beach could structure a significantly larger special assessment district that encompasses all properties along the waterways, both bayside and oceanside, or bayside along with second layer inland properties – with the intention of dedicating collected funds for flood-management investments not only along the coast but throughout the City. Fees should be assessed on property value and structured as a percentage based on risk, or more specifically exposure to risk, meaning that larger properties would pay a higher rate, as would properties at a lower relative elevation. In addition, assessments should be proportional to the scale of required upgrade – for example, a waterway special assessment district would have a significantly higher assessment in relation to any related inland flood-management assessment district. Additional analysis based on local flood-loss data, current federal flood maps and risk designations and public engagement would be required to determine the exact assessment allocation formula. Coupling those assessments with a portion of captured insurance savings would feasibly provide the City of Miami Beach with sufficient revenue to capitalize major infrastructure investments like the proposed seawall solution.

PUBLIC-PRIVATE PARTNERSHIPS

Another option the City of Miami Beach could explore is a public-private partnership (PPP) model structured in the United Kingdom. In the case of UK Coastal Management Partnerships, local governments were authorized to partner with non-profit, philanthropic and private entities to aggregate sufficient funds for investment in coastal protection infrastructure. In East Anglia, the British Marine Aggregates Producers Association (BMAPA), the Crown Estate, and the Centre for the Environment, Fisheries and Aquaculture Science (CEFAS) partnered to test the affects of aggregate dredging. In Pevensey Bay, the British Environment Agency tendered a 25-year design, build, operate and maintain public-private partnership to invest in coastal defense systems that would protect a 50-km2 area of low-lying land behind the coast[1].

While at the outset of structuring this partnership there were legitimate concerns that capital costs of the project would be higher by using a PPP than if the public sector had secured a low-interest loan on its own, the concern proved to be unfounded. Instead, because of the careful focus on operational specifications and pre-negotiated cash flow conditions, the UK Environment Agency realized a better risk allocation than it would have on its own, created cost-saving innovations throughout the process, and improved the financial security of its position with an overall savings on project cost.

Miami Beach could apply similar PPP models to facilitate more cost-effective and comprehensive approach to flood mitigation infrastructure. One of the major benefits of a PPP project is that it enables public entities to undertake projects they might otherwise postpone or ignore due to lack of funds.

The State of Florida has pursued a number of transportation projects utilizing PPP legislation, and in 2013 Florida's House of Representatives and Florida Senate passed the House of Representatives Bill 85 (HB85) which enabled the PPP model for use by counties, cities, school boards, and regional entities to construct government buildings and related social infrastructure.

Included is a PPP model that could be applicable for the City of Miami Beach. In this structure, a Special Purpose Vehicle (SPV) could be formed by the City, private construction partner, and any other relevant parties (for example a development district) to serve as the landowner and would be financially responsible for the operations and maintenance of all surface and subsurface infrastructure. Established as the umbrella structure for a set of partners, the SPV would likely not require significant staffing and would instead pass responsibilities and money along to relevant entities through a pre-defined contractual agreement that defines management responsibilities, sources of funding and payback responsibilities. The structure presented below is a basic model of this type of public-private partnership.

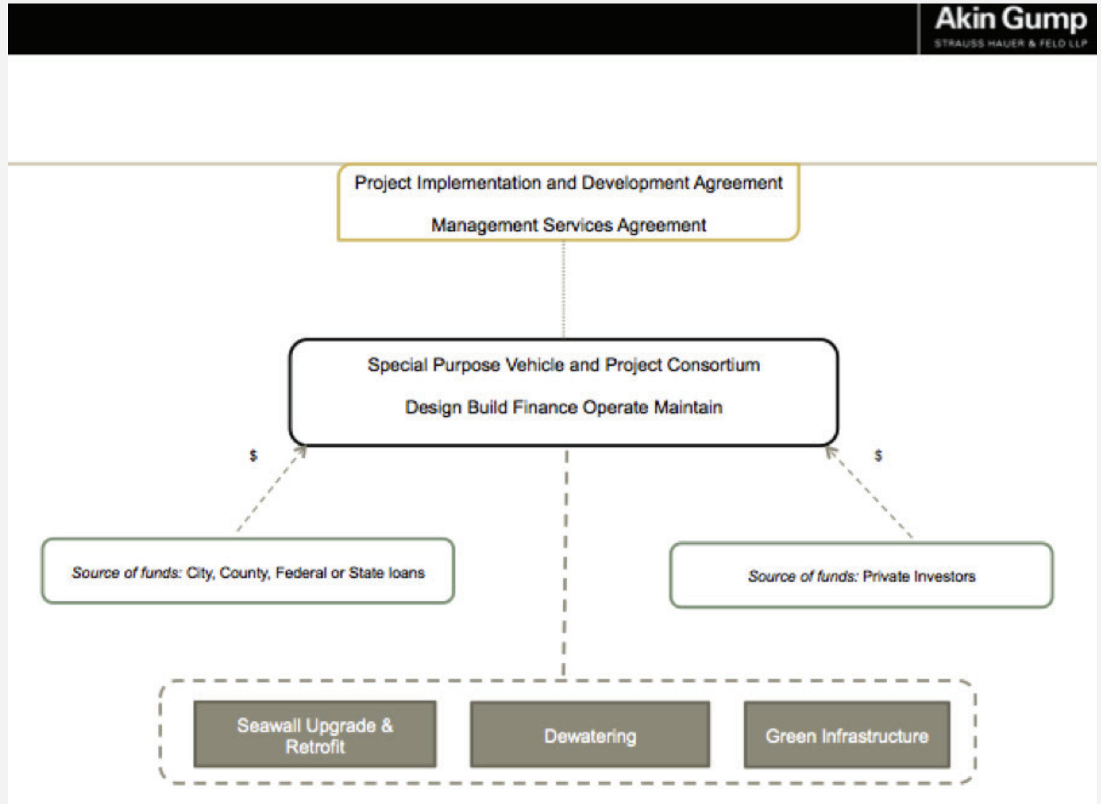

Figure 15. Public-Private Partnerships Model

Data Collection & Public Participation

In order to pursue any of the options above, the RE.invest team has developed the following high-level strategy for the City of Miami Beach. The activities described below offer a roadmap to streamline data collection, engage property owners, and ensure cost-effective design and construction of a comprehensive package of infrastructure designed to protect city residents.

To successfully implement any comprehensive resilient infrastructure projects, the City must systematically engage and get approvals from hundreds of private property owners and managers along Miami Beach's sea walls.

The RE.invest team has explored models of participatory engagement that can support coordinated action but also data collection and investment, and the following steps are offered as a model for Miami Beach to creatively engage its residents in the planning, implementation, and financing of new coastal protection projects.

- *Partner with technology firms and local businesses to build a new platform for local data collection on flood and storm related costs and losses (short-term)*
  Crowdfunding and crowdsourcing platforms have been used for over a decade to successfully engage individuals in projects and causes. Some examples are Wikipedia (collaborative encyclopedia), Kiva (microfinance), Kickstarter (project funding), FoldIt! (games for health and science), and Kaggle (data analysis prizes and competitions). Government agencies including NASA have also used crowdsourcing tools to engage communities in participatory monitoring and citizen science programs to creatively fill budget shortfalls.

  Because there are few property-level sources of data on Miami Beach's current and historical losses from storms and flooding, the RE.invest team recommends that the City explore partnerships with one or more small technology firms, that have been successfully crowdfunding small scale community projects, to crowdsource data on flood related costs and losses. Using technology to engage residents on local priorities, this type of approach can be applied to engage Miami Beach residents to gather data on existing conditions of their seawall and their experiences with flooding. Other options include partnering with local flood protection or clean-up related small businesses to aggregate data and assess patterns of flood risk and loss or even working with large companies and corporate foundations, such as the Mastercard Foundation, to track local expenditures on "indicator" products associated with clean-up or flood related repairs.

- *Set-up a system of prizes and rewards to encourage participation (short-term)*
  In order to maximize local participation in data reporting, the City can also consider working with local businesses to offer incentives to participating residents. For example, residents who share information can register to serve as local "coastal protection champions" or receive updates on public meetings, and in exchange, they could get discounts with participating merchants selling products to improve their resilience (e.g. emergency preparedness supplies, free sandbags, solar chargers, etc.). Rewards can also be tiered based on the level of participation or environmental monitoring that residents provide over time.

- *Launch a competition or a "Race to Resilience" to get public buy-in, accelerate local approvals and construction schedules, and reduce costs (medium-term)*
  After a final design is selected and approved, the City should also consider implementing a competition to get residents to sign-up to be first "block" to upgrade their seawalls. Given the scale of the seawall system, engineering proposals for any upgrade should contain options for phasing the project along the 60 miles of private coastal property. Each phase will likely include segments of adjacent walls—for example, 3-5 mile blocks or 15-25 adjacent properties—that could be built more cost-effectively as one project. These economies of scale and cost reductions have the added benefit of reducing the number of "seams" along the length of the seawall and improving the overall resilience benefits of the structure. A competition organized around these predetermined segments could encourage residents to sign-up with their neighbors to be the first in line for implementation. The blocks with all residents who "approve" the project and agree to start construction first can also be offered rewards or prizes, such as a dock upgrade benefit or other financial incentive. If a design-build or public-private partnership approach is pursued by the City, then this type of competition could be integrated into the public outreach and community engagement components of the project.

- *Involve residents, schools, and local universities in evaluating the system and reporting benefits (long-term)*
  Similar to highway clean-up volunteer organizations, the City can consider how to also engage residents in ensuring the long-term health of the local coastal protection system. Schools could be engaged to "sponsor" sections of the wall to regularly conduct environmental monitoring and visual inspections. For more complex analyses, local universities can provide additional capacity for monitoring hydrological conditions and evaluating risk reductions over time.

  Together the steps above offer a cost-effective implementation roadmap for any final infrastructure solution that requires local property owner participation and approvals.

Innovative Financing

Following the participatory steps recommended will help the City to collect enough relevant information to attract third-party investment to support future financing. Based on the quantified value these flood management projects create for individual property owners, for the City system as a whole, and for the Federal Government as the insurer of last resort - the RE.invest team recommends the city consider two financing strategies (1) working with reinsurance firms to explore options for local catastrophe bonds issuances that can leverage project finance for risk reduction measures, (2) structuring a pooled fund to support flood management investments. Both options can be pursued in parallel.

Redesigning Catastrophe Bonds

Traditionally, insurance instruments do not create new streams of capital for reinvestment in risk reduction measures. However, in recent years a number of insurance models have emerged in the healthcare industry that can be applied to climate and disaster risk management. For instance, in 2006 ICICI Prudential launched a specialized insurance policy for people with Type 2 diabetes and pre-diabetic symptoms. The policy covers not only treatment, but also the cost of a preventative wellness program, and reduces insurance premiums for individuals who demonstrate good control of their condition. Applying this approach to risk management in coastal cities like Miami Beach, offers a model for how insurance policies and premiums can be structured to create special funds for investment in upfront risk reduction measures in addition to covering potential losses.

Based on these models, and the fact that insurance is an instrument for reducing the extent of losses for those holding assets in city systems – its clear that insurance mechanisms can be an important financial instrument to mobilize capital for urban infrastructure. In the case of Miami Beach, the proposed set of flood management infrastructure options are likely to reduce both the rate of insurance premium increases and total damage claims. This combination of benefits provides an opportunity to assess and capture savings to both individual property owners and to local and international insurance firms.

One of the tools that the insurance industry has developed to hedge their financial risks is a catastrophe bond. Currently passive financial instruments, where proceeds are held in managed funds and payouts occur only when eligible catastrophic losses can be claimed. In years where such an event does not occur, the invested funds generate a return that is paid out to private investors willing to assume the risk. These investment interests are very attractive to investors seeking to diversify their portfolios since disaster risks are generally uncorrelated with other market-based investment risks. An actively structured catastrophe bond would function more like a social impact bond, which is designed to generate funds to finance specific projects that reduce a social ills, costs, or risks over the long-term.

Generally catastrophe bonds are issued by re-insurance firms in collaboration with large public entities (i.e. Mexico's national government or the World Bank) to provide diversification of risk across geographies or sectors. However, re-insurance companies are now exploring their ability to issue private catastrophe bonds that would allow them to build a diverse portfolio of specific kinds of catastrophic risk across a large number of cities. In this structure, private re-insurance companies have an incentive to use a portion of the proceeds to finance resilience upgrades and risk mitigation measures in participating cities in a way that establishes predictable reductions of the risks and damages covered by the bond.

Given the current market appetite, the RE.invest team recommends that the City consider options for partnering with the Port and/or State of Florida to explore a catastrophe bond similar to Mexico City's current bond structure or the World Bank's June 2014 issuance covering 16 Caribbean islands for storm and flood risks, with a minor structural change to ensure a small percentage of funds is made available for project finance through a revolving loan fund. An important prerequisite for the City is having baseline data that definitively documents not only predictable losses and damages from rising sea-levels and storm surges, but also shows anticipated future savings based on planned resilience investments, such as the upgraded seawall structure with integrated hydrological management, to project a future revenue stream for capital payback.

Creating Pooled Funds

As noted, the challenge with investing in any structural retrofit is that working within existing properties is complicated. Beyond that, often the financial savings are distributed and can only be accrued over a long period of time. Traditionally public financing has leveraged taxing authority, through TIF and other structures, to capture distributed benefits. And since the 1970s, the private sector has created other mechanisms to capture sector-specific savings effectively – particularly through the energy efficiency and renewable energy sectors via ESCOs and the PACE program. Now that the practice is well understood it is starting to be applied more broadly to support infrastructure investments that generate significant longer-term financial value, and the City of Miami Beach could leverage this market interest to support a series of property retrofit upgrades the produce flood management benefits, including raising properties by retrofitting foundations in the short-term and seawall reconstruction in the long-term.

In California, the City and County of San Francisco has leveraged this expanding market interest to structure a pooled fund to support seismic retrofitting private buildings to implement their Community Action Plan for Seismic Safety – a $1 million study to understand the areas earthquake risk. The CAPSS is similar in many respects to the investments Miami Beach has made in flood management studies, and outlines a series of important steps that must be taken by the City and residents to prepare for the worst impacts.

One of the first steps taken by San Francisco under the Earthquake Safety Implementation Program was to sign into law the Mandatory Soft Story Retrofit Ordinance, which requires evaluation and retrofit for multi-unit soft story buildings. To support both mandatory and voluntary retrofits, the City created a grant fund to support earthquake retrofit upgrades, but learned quickly that funding, even when coupled with an ordinance was not enough to compel action. Because any retrofitting comes with high up-front analysis and transactions costs, the grant funds to support construction were seen as too little too late for many private property owners. Interested in motivating both mandatory and voluntary retrofits, the City and County of San Francisco approached Alliance NRG, an energy service company, and Deutsche Bank to restructure their grant funds into a public financing option.

Launched in the Fall of 2014, the program is has a simple structure – Deutsche Bank provides the upfront capital guarantee to Alliance NRG, who then accepts applications from individual property owners and manages the upgrade process from design through construction. Alliance NRG has a contractual relationship with the City to recoup their investment plus interest via an additional line item on each participating property owners' regular property tax invoice from the city.

In order to pursue this financing model to support integrated seawall upgrades, the City of Miami Beach would need to first define project types, structure a mandate to cover retrofits and coordinate relevant contractors who could provide the retrofit services. In addition, the City must be able to credit flood related savings via property tax assessments. Such a credit system may appear at first glance difficult to accomplish administratively as most flood related costs are covered by insurance or not reported. However, the recommended local crowdsourcing data collection effort presents an opportunity to calculate the quantity or percentage of savings related to flood management investments for each individual property owner on the coast and further inland. In this case, the City would need to quantify the individual property's risk profile, flood related losses and then calculate the scale of savings that the property provides by upgrading flood management systems more broadly via integrated seawall retrofit. Unlike on-bill savings, which accrue to property owners directly in the form of reductions on bills, the savings created in this model accrue to the City system more broadly. While any single property may not make a large impact, the collective impact has the potential to be significant for the City.

The City could follow a similarly simple structure to support the financing of integrated flood management system retrofits. Transferring management to a private bank would help provide the necessary upfront capital guarantee to a private contractor. Like the soft-story pooled fund, the selected contractor would then accept applications from property owners, and manage the upgrade process from design through construction. This contractor would require a series of contractual relationships to recoup their investment plus interest. The first would obligate property owners to pass-through insurance and property related savings, and a second agreement with the City would ensure the contractor receive an annual or semi-annual payment that scales based on system-wide savings accruing to the City. This pooled fund would go beyond providing financing to help streamline the retrofit process and reduce transaction costs in a way that can also increase project uptake.

While none of the proposed strategies will produce wholly private financing options for green and blue infrastructure upgrades in the short term, when combined they can offer a menu of options for the city to support long term resilient infrastructure investment.

REinvest

Innovations

The City of Miami Beach can pursue a series of structural design options and strategies to improve data collection in support of comprehensive seawall upgrade and flood management investments.

- Design a multi-purpose infrastructure system that combines:
    - Seawall reinforcements to reduce erosion and tidal flooding
    - Subsurface hydrological management systems to limit saltwater intrusion and groundwater related flooding

- Consider financing options, such as tax-increment finance (TIF) or special assessment districts, designed to capture real estate value increases, based on the construction of a new wall on the outside of any existing seawalls and the resulting addition of land to associated waterfront properties

- Calculate "avoided losses" and potential financial savings due to both physical and financial risk reductions created by new coastal protection measures

- Partner with technology firms and local businesses to crowd-source data on unreported losses, such as flood damages or mold clean-up, to quantify potential savings and monetize projected benefits to accrue to residents and small businesses

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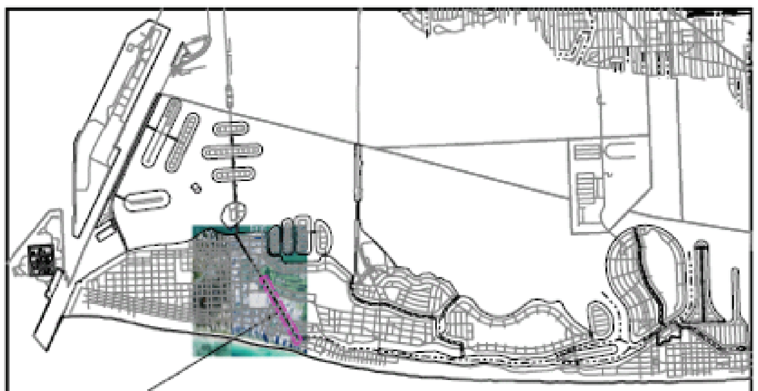
RE.invest INITIATIVE
MIAMI BEACH, FL

DRAWING INDEX

SHEET NO.	DRAWING NO.	DESCRIPTION
GENERAL		
1	G-1	TITLE SHEET, LOCATION MAPS & DRAWING INDEX
2	G-2	ABBREVIATIONS, LEGENDS & NOTES
CIVIL		
3	C-1	COLLINS CANAL - PROPOSED SEAWALL PLAN
4	C-2	COLLINS CANAL - SEAWALL OPTIONS DETAILS



PROJECT SITE

VICINITY MAP
NTS

COLLINS CANAL
NTS

NOT FOR CONSTRUCTION

GENERAL
TITLE SHEET, LOCATION MAPS & DRAWING INDEX

Drawing No. G-1

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2014-06-03

ABBREVIATIONS

CB	CATCH BASIN
CONC	CONCRETE
DIA	DIAMETER
DWG	DRAWING
EL	ELEVATION
EXST	EXISTING
FT	FOOT, FEET
FH	FIRE HYDRANT
G	NATURAL GAS
HDPE	HIGH-DENSITY POLYETHYLENE
IE	INVERT
MAX	MAXIMUM
MH	MANHOLE
MIN	MINIMUM
No.	NUMBER
NTS	NOT TO SCALE
PVC	POLYVINYL CHLORIDE
R/W	RIGHT-OF-WAY
RCP	REINFORCED CONCRETE PIPE
REQD	REQUIRED
R.O.C.	RUN-OF-CRUSHER
SAN	SANITARY
SD	STORM DRAIN
SMP	STORMWATER MANAGEMENT PRACTICE
TC	TOP OF CASTING
TOC	TOP OF CURB
TYP	TYPICAL
UG	UNDERGROUND
VERT	VERTICAL
W	POTABLE WATER

LEGEND

- EXISTING STORM DRAIN
- EXISTING BUILDING
- PROPOSED WORK
- SITE LIMITS
- CITY OWNED PROPERTY
- KEY NOTE
- NORTH ARROW

GENERAL NOTES:

SECTION / VIEW / DETAIL DESIGNATIONS

ON DRAWING WHERE SECTION, VIEW OR DETAIL IS TAKEN:

PROFILE, SECTION (LETTER) OR DETAIL (NUMBER) DESIGNATION

A / C-1

DRAWING NUMBER WHERE PROFILE, SECTION (LETTER) OR DETAIL (NUMBER) IS SHOWN, USE — IF TAKEN AND SHOWN ON SAME SHEET.

ON DRAWING WHERE SECTION OR DETAIL IS SHOWN:

A / C-2 SECTION SCALE

2 / — DETAIL SCALE

2 STD DETAIL SCALE

DRAWING NUMBER(S) WHERE TAKEN

ON DRAWING WHERE ONLY A TITLE IS REQD WITH NO REFERENCE: (e.g. PLANS, ELEVATIONS, PROFILES)

DRAWING TITLE
SCALE

SECTION CALLOUT: (LINE IS BROKEN FOR CUTS LONGER THAN 3")

A / C-1

DRAWING NUMBER DESIGNATIONS

C-1 — DRAWING NUMBER; DRAWING DISCIPLINE

DISCIPLINE LIST

- G - GENERAL
- C - CIVIL
- M - MECHANICAL
- E - ELECTRICAL

RE invest — investing in resilience, investing in communities.

GENERAL

ABBREVIATIONS, NOTES & LEGEND

re:focus

File No. 25683_100FL_GI0002
Drawing No. G-2
Date 04/04/2014
Sheet 2

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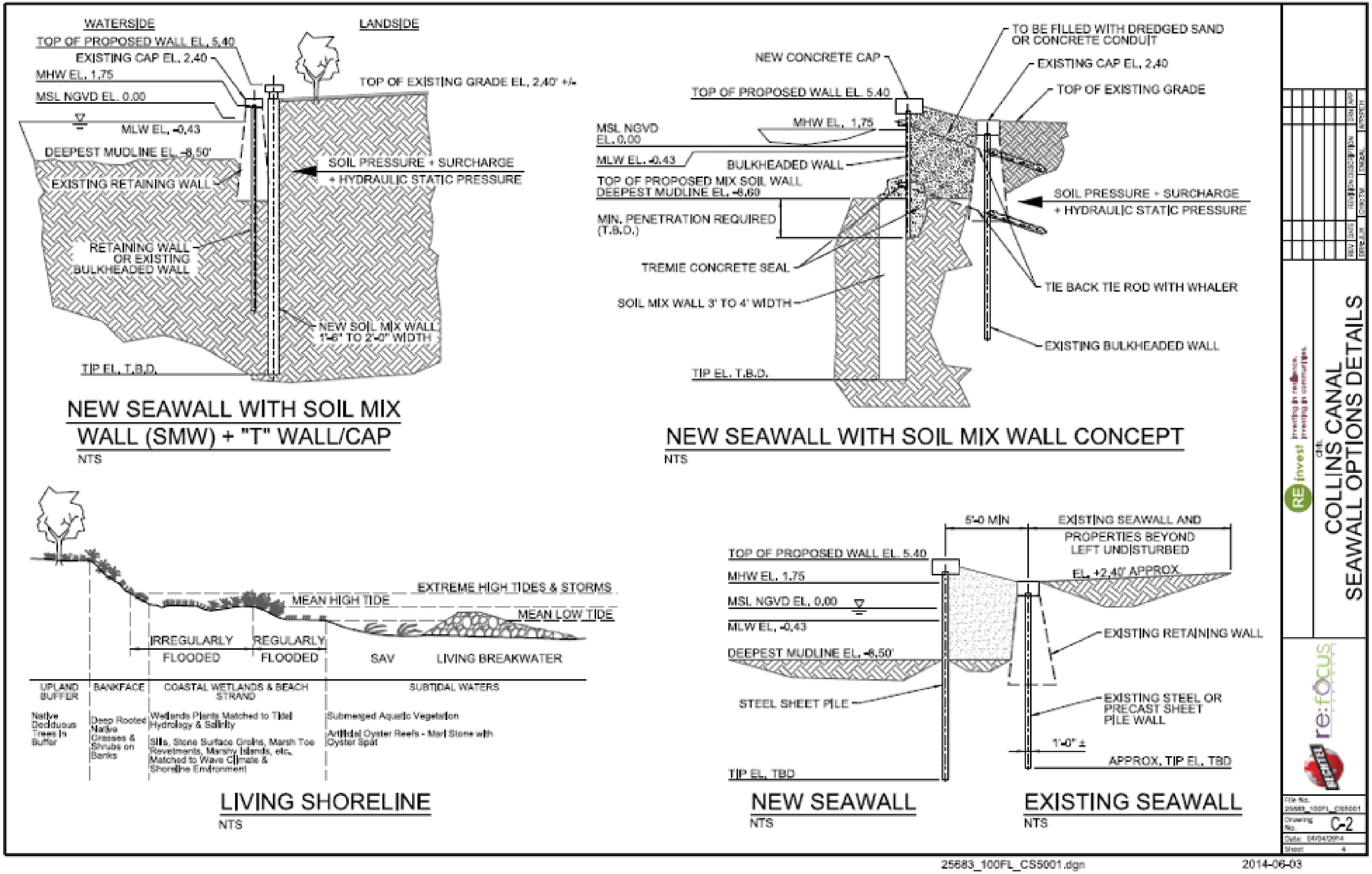
25683_100FL_CS4001.dgn 2014-06-03


WATERSIDE
LANDSIDE
TOP OF PROPOSED WALL EL. 5.40
EXISTING CAP EL. 2.40
MHW EL. 1.75
MSL NGVD EL. 0.00
MLW EL. -0.43
TOP OF EXISTING GRADE EL. 2.40' +/-
DEEPEST MUDLINE EL. -8.50'
SOIL PRESSURE + SURCHARGE
+ HYDRAULIC STATIC PRESSURE
EXISTING RETAINING WALL
RETAINING WALL OR EXISTING BULKHEADED WALL
NEW SOIL MIX WALL 1'-6" TO 2'-0" WIDTH
TIP EL. T.B.D.
NEW SEAWALL WITH SOIL MIX WALL (SMW) + "T" WALL/CAP
NTS
TO BE FILLED WITH DREDGED SAND OR CONCRETE CONDUIT
NEW CONCRETE CAP
EXISTING CAP EL. 2.40
TOP OF PROPOSED WALL EL. 5.40
TOP OF EXISTING GRADE
MSL NGVD EL. 0.00
MHW EL. 1.75
MLW EL. -0.43
BULKHEADED WALL
TOP OF PROPOSED MIX SOIL WALL
DEEPEST MUDLINE EL. -8.60
SOIL PRESSURE + SURCHARGE
+ HYDRAULIC STATIC PRESSURE
MIN. PENETRATION REQUIRED (T.B.D.)
TREMIE CONCRETE SEAL
TIE BACK TIE ROD WITH WHALER
SOIL MIX WALL 3' TO 4' WIDTH
EXISTING BULKHEADED WALL
TIP EL. T.B.D.
NEW SEAWALL WITH SOIL MIX WALL CONCEPT
NTS
EXTREME HIGH TIDES & STORMS
MEAN HIGH TIDE
MEAN LOW TIDE
IRREGULARLY FLOODED
REGULARLY FLOODED
SAV
LIVING BREAKWATER
UPLAND BUFFER
BANKFACE
COASTAL WETLANDS & BEACH STRAND
SUBTIDAL WATERS
Native Deciduous Trees in Buffer
Deep Rooted Native Grasses & Shrubs on Banks
Wetlands Plants Matched to Tidal Hydrology & Salinity
Sills, Stone Surface Groins, Marsh Toe Revetments, Marshy Islands, etc. Matched to Wave Climate & Shoreline Environment
Submerged Aquatic Vegetation
Artificial Oyster Reefs - Marl Stone with Oyster Spat
LIVING SHORELINE
NTS
5'-0 MIN
EXISTING SEAWALL AND PROPERTIES BEYOND LEFT UNDISTURBED
TOP OF PROPOSED WALL EL. 5.40
MHW EL. 1.75
EL. +2.40' APPROX.
MSL NGVD EL. 0.00
MLW EL. -0.43
EXISTING RETAINING WALL
DEEPEST MUDLINE EL. -8.50'
STEEL SHEET PILE
EXISTING STEEL OR PRECAST SHEET PILE WALL
1'-0" ±
APPROX. TIP EL. TBD
TIP EL. TBD
NEW SEAWALL
NTS
EXISTING SEAWALL
NTS
REinvest
COLLINS CANAL
SEAWALL OPTIONS DETAILS
re:focus
C-2
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