SOUTHEAST FLORIDA REGIONAL COMPACT CLIMATE CHANGE

RCAP

Implementation Guidance Series

Regional Impacts of Climate Change and Issues for Stormwater Management

Implementation support to the Compact is provided by: Institute for Sustainable Communities

With funding support from: The Kresge Foundation

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For more on the Southeast Florida Regional Climate Change Compact:
www.southeastfloridaclimatecompact.org

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Background and Acknowledgments

As part of the continuing implementation workshop series, the Southeast Florida Regional Climate Change Compact held the Regional Impacts of Climate Change and Issues for Stormwater Management Workshop. This workshop brought together local experts with varying applicable experience to solve local challenges.

The Regional Impacts of Climate Change and Issues for Stormwater Management compact guidance document is one in a series of publications designed to assist county and municipal policymakers, administrators and program staff with implementation of the 110 recommendations contained within the Southeast Florida Regional Climate Change Compact's 2012 Regional Climate Action Plan. This publication series is produced by the Institute for Sustainable Communities in partnership with the Southeast Florida Regional Climate Change Compact and funding from the Kresge Foundation.

Regional Impacts of Climate Change and Issues for Stormwater Management was developed by workshop session speakers, with assistance from the Florida Stormwater Association and Broward County's Environmental Protection & Growth Management Department staff who provided their experience, expertise and insights. The Institute for Sustainable Communities and Compact partners gratefully acknowledge their participation. Particular thanks to the following document contributors: Jason Bregman, Associate, Michael Singer Studio and Owner – Jason Bregman Environmental Planning and Designs; Henry O. Briceño, Southeast Environmental Research Center & Department of Earth and Environment, Florida International University; Brett Cunningham, Vice President Jones Edmunds & Associates; Nancy J. Gassman, Ph.D. Assistant Public Works Director Sustainability Division, City of Fort Lauderdale; Jeff Kivett, Director, Division of Operations, Engineering & Construction, South Florida Water Management District; Bruce Mowery, City Engineer, City of Miami Beach; Elizabeth M. Perez, PE, D.WRE, President, Collective Water Resources; Penni Redford, Sustainability Director, City of West Palm Beach; Emilie Smith, Budget Manager, City of Ft. Lauderdale; Tommy Strowd, Director of Operations & Maintenance, Lake Worth Water Management District; Betsy Wheaton, Assistant Building Director – Environment & Sustainability Division at City of Miami Beach.

Know the Flow – Our Regional Water System in Southeast Florida Moving Toward the Future

Tommy B. Strowd, P.E., Lake Worth Drainage District
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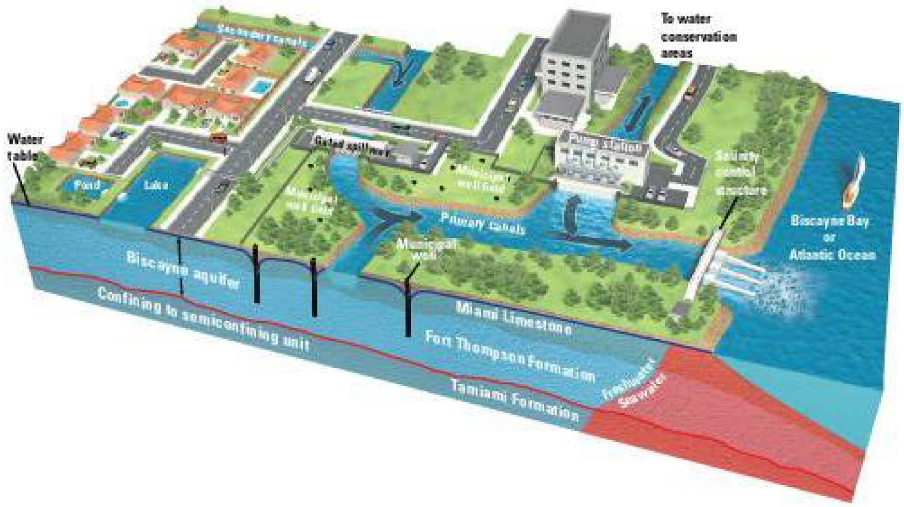
Water Management is a Daily Balancing Act



The regional water management system in south Florida was developed to meet multiple water resource objectives. During wet periods, the system discharges high volumes of rainfall runoff through the canal network to minimize potential flood impacts to both developed and natural areas.

Conversely the system holds back water during dry periods to make it available for developed and natural system supplemental water needs. Water levels in the regional system of canals and the Water Conservation Areas are maintained to recharge the underground freshwater aquifers. This serves to push back against the inland migration of sea water that could threaten the quality of drinking water supplied by the coastal well fields. These intricate water control operations occur 365 days per year across the entire South Florida Water Management District (SFWMD).

The Central and Southern Florida Project for Flood Control and Other Purposes

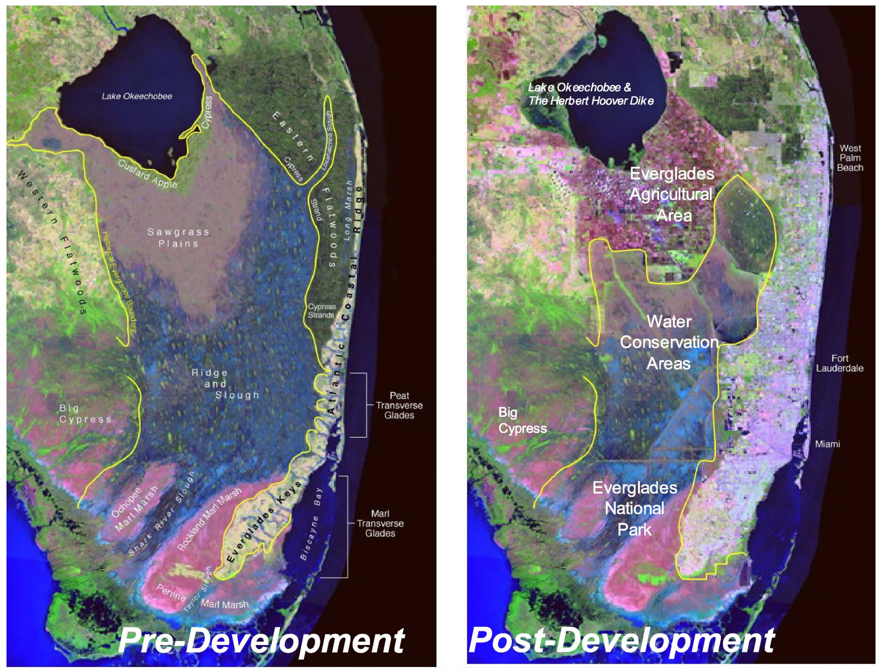
The Central and Southern Florida Project for Flood Control and Other Purposes (C&SF Project), was authorized by Congress in 1948 at the request of the State of Florida, after a series of devastating hurricanes struck south Florida in 1947. It was designed and constructed to meet multiple objectives. Primary among those are:

- Flood Control
- Water Supply
- Prevention of Saltwater Intrusion
- Environmental Preservation

The project consists a broad range of physical facilities, such as canals, levees, gated spillways, pumping stations and surface water impoundments, which were constructed by the U.S. Army Corps of Engineers between 1950 and 1970. It is currently operated by SFWMD, which serves as the local sponsor for the federal project.

Historical Changes in the South Florida Landscape

Pre-Development



Over 150 years ago, the south Florida landscape was almost completely dominated by natural features. Rainfall runoff from hardwood hammocks and pine flatwoods surrounding the Kissimmee Chain of Lakes flowed naturally into the lake system that cascaded from one lake to another and eventually into the headwaters of the Kissimmee River.

The Kissimmee River naturally meandered through a broad, flat wetland flood plain and discharged into Lake Okeechobee; one of the largest natural lakes in North America. The lake's only outlet was along its southern shoreline where it frequently spilled-over into the upper reaches of the Everglades.

The Everglades landscape was a massive flat plain that was covered with a shallow, slowly flowing sheet of freshwater. The northern reaches of the Everglades, south of Lake Okeechobee, was dominated by a thick sawgrass plain that served to severely slow the flow of water south of the Lake and resulted in relatively high lake levels compared to today's conditions. Water from the sawgrass plain flowed into a similarly large, flat system of wetland ridges and sloughs that were populated with numerous tree islands throughout. Sheet flows from the ridge and slough landscape were ultimately concentrated into Shark River Slough that streamed between higher marl marshes into the shallow mangrove areas of Florida Bay protected from high energy ocean influences by the Florida Keys.

Along the lower east coast of the peninsula, a nearly continuous high coastal sand ridge existed that generally separated the Everglades from the coastal environment. However, the coastal ridge was breached by numerous small rivers that connected the Everglades to the coastal estuarine system in isolated areas. In the lower portions of what is now south Miami-Dade County, the predominant source of freshwater flow into coastal areas like Biscayne Bay was via groundwater upwelling.

Post-Development

The construction of the regional drainage system resulted in significant changes to the south Florida landscape. The Kissimmee Upper Chain of Lakes were interconnected by canals and gated spillways. The Kissimmee River was 'straightened' by the construction of the C-41 canal.

The Herbert Hoover Dike was constructed encircling Lake Okeechobee, changing it forever from a lake into a surface water reservoir, with highly managed inflows and outflows. The historic hydrologic connection with the Everglades was severed. To avoid dangerously high stages in the Lake, massive spillways were constructed to push high volumes of excess water from Lake Okeechobee to the St. Lucie and Caloosahatchee estuaries.

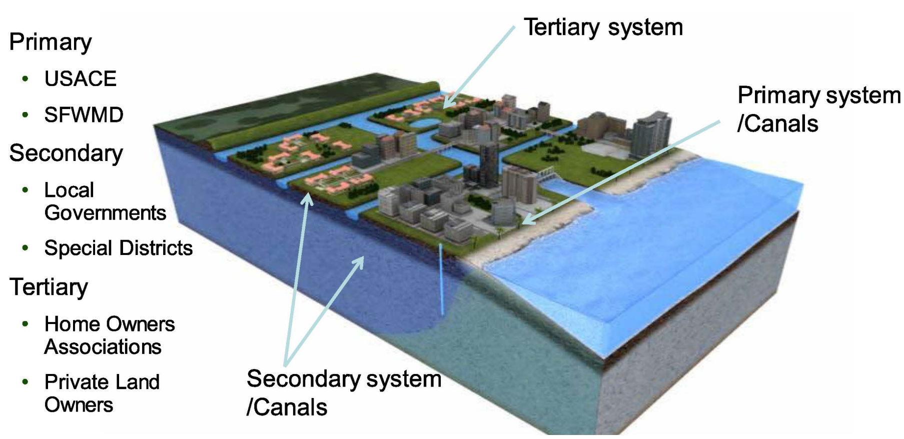
The broad sawgrass plain south of the lake was cordoned-off with levees and canals and drained for the purpose of supporting seasonal agriculture and sugarcane production. The remaining Everglades was encircled by levees and water control structures to create a series of Water Conservation Areas, which support urban water supply as well as the protection of fish and wildlife. A levee system was constructed through the eastern part of the Everglades and a drainage system was built to drain the lower east coast of Florida to support both urban and agricultural land uses.

All of this work resulted in a flood protection system that is unrivaled almost anywhere in the world. Furthermore, it was designed to also maintain adequate groundwater elevations in agricultural and urban areas for the water supply needs of a growing population and hold back the potential intrusion of saltwater into the inland freshwater aquifers.

In total however, these changes had tremendous negative effects on the natural Everglades ecosystems, as well as coastal estuaries across south Florida. The wetland extent of the Everglades was reduced by half, and the wading bird populations were reduced by 90% through a combination of hunting and an altered hydrology. Southern estuaries like Biscayne Bay and Florida Bay are persistently starved for freshwater, while northern estuaries like the Indian River Lagoon and Caloosahatchee Estuary are frequently pummeled by excess runoff.

Three-Tiered System

The current water management system in south Florida is managed in a three-tiered fashion, very similar to the urban transportation system of streets, roads and highways.



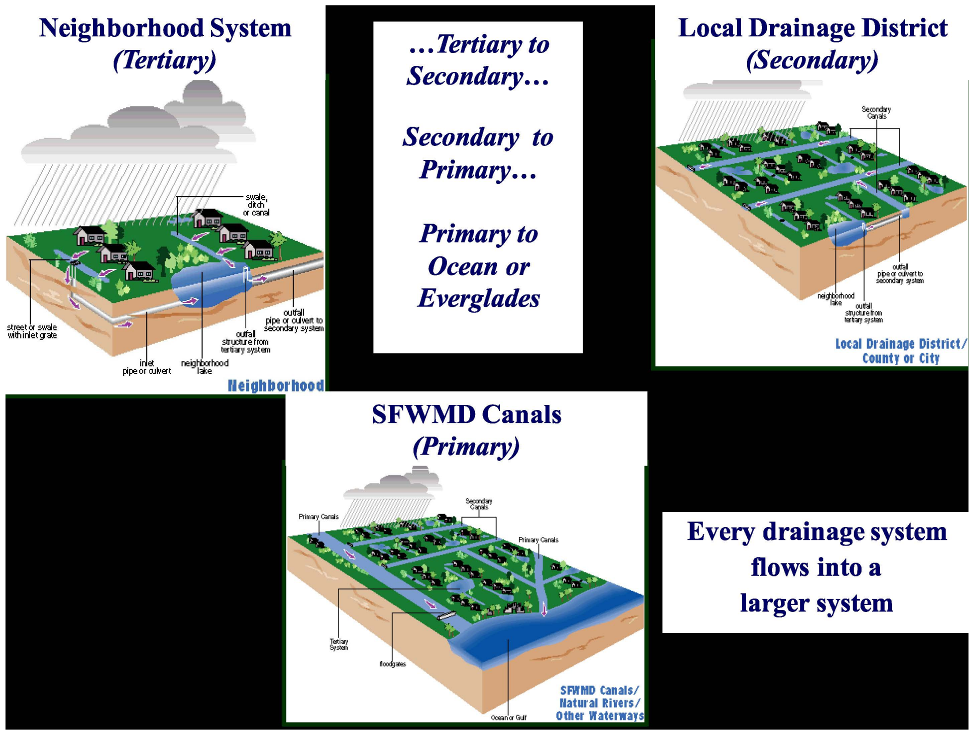
Primary Canal System

Similar to the Interstate Highway System, south Florida's primary canal system manages water resources from a regional perspective. It is managed on a day-to-day basis by the State of Florida through the

South Florida Water Management District, while federal interest in the system is managed by the U.S. Army Corps of Engineers. Just as the highway system provides a regional transportation corridor for local traffic to move across city and county jurisdictions; the primary canal system manages regional water flows and levels, as well as discharge flood waters from numerous communities, cities and counties within the 16-County jurisdiction of the South Florida Water Management District.

Secondary Canal System

Local governments, such as cities, counties or special taxing districts, manage smaller, sub-regional watersheds. These governmental entities accept runoff from individual residential communities or commercial / agricultural areas and convey that water through their network of sub-regional canals / ditches to the primary canal system.



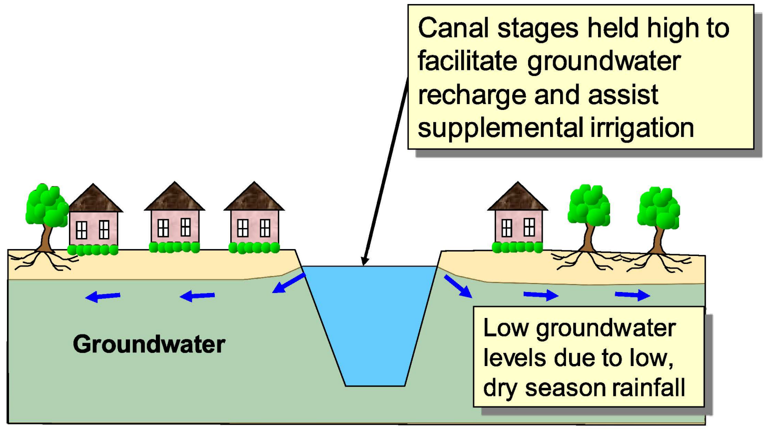
Tertiary Drainage System

The smallest subdivision of water management in south Florida is the system of drainage ditches, swales, storm sewers and water detention ponds that are owned and maintained by private land owners, home owner associations, etc. These systems are the first line of defense in the water resource system. A significant percentage of the overall water storage capability in south Florida is contained within the lakes and ponds of every residential and commercial development built since the mid-1970's. These community-based systems not only retain water to avoid serious flooding, but they also provide a source of groundwater recharge and support supplemental irrigation during dry periods.

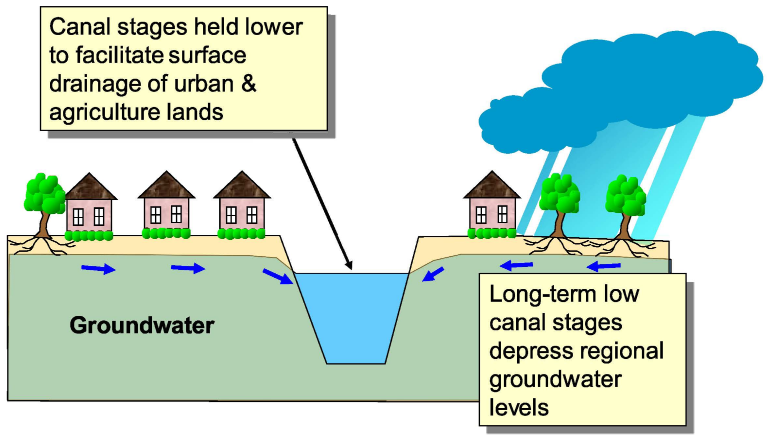
Canal / Groundwater Interaction – The Dual Role of the Primary Canals

So how do canal systems function to serve the water resource needs of a region? Canals in south Florida have a dual role in managing water resources:

1. They serve as a conveyance mechanism to quickly remove excess rainfall runoff from urban and agricultural areas to minimize impacts from flooding. Just as a highway provides a path for traffic that reduces traffic jams in highly populated areas, a canal provides a corridor for excess runoff from populated areas to reduce flooding in streets and neighborhoods. As major storms approach, water levels in the canals can be proactively lowered, which serves to provide additional discharge capacity for adjacent neighborhood drainage facilities in advance of expected heavy rainfall.

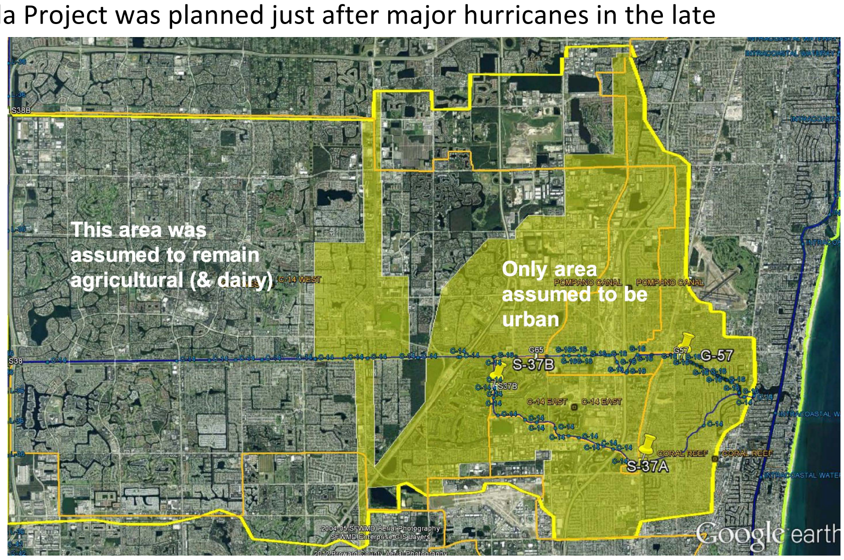


2. They also assist in the management of regional groundwater recharge. Water levels in canals are raised in dry times, when there is low risk of heavy rains. This allows water from canal to more effectively drain slowly into the underlying sands and recharge the underground freshwater aquifers that both urban and agricultural uses rely upon for water supply.



The Central & Southern Florida Flood Control System – 1950's Planning Assumptions

Most of the Central and Southern Florida Project was planned just after major hurricanes in the late 1940's and during the 1950's, after World War II. Prior to this, the economy of Florida was dominated by agriculture, primarily due to the uniquely warm seasonal climate – but it was also heavily affected by the Great Depression. The planners of the C&SF Project understood that a post-war economy would foster new tourism and development in south Florida. In fact, the concept that improved flood control and the ultimate 'reclamation' of vast areas of

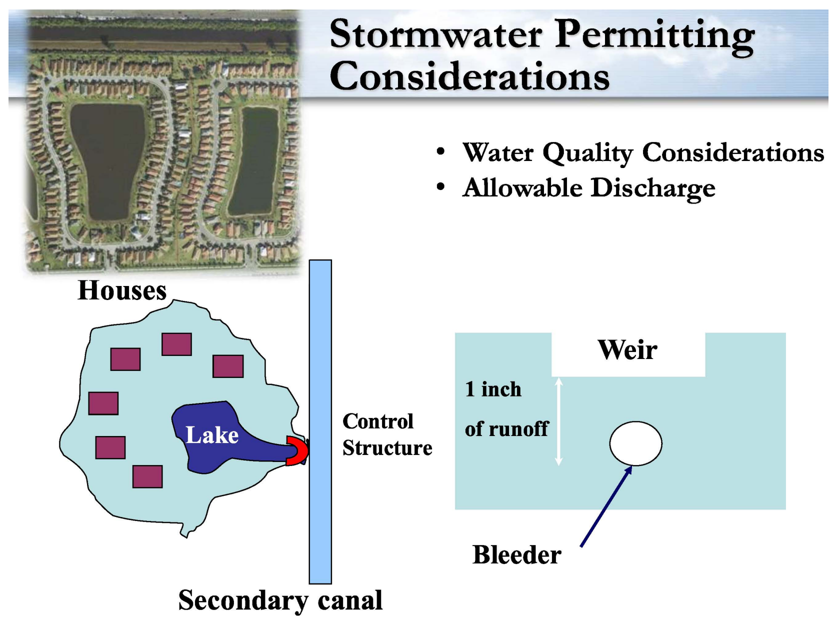


submerged lands was a major focus of the plan and key to the benefits attributed to south Florida. It is clear that the planners of the project could not have anticipated the post war/post depression development boom that has continued since the 1950's.

In south Florida, urban development was not anticipated to extend much farther west than the coastal ridge, which is approximately where Interstate 95 is located today. Between this ridge and the East Coast Protective Levee, agriculture was expected to dominate in the form of summer vegetables, dairies, sugar cane, etc. However, recent economic prosperity has resulted in an extended period of urban growth along the lower east coast of Florida – particularly Miami, Broward and Palm Beach counties. In Broward County, for instance, urban development has completely displaced the pre-existing farms, which has ultimately resulted in a solid swath of residential neighborhoods and commercial facilities from the coastline west to the eastern margin of the remnant Everglades.

Surface Water Regulation

In 1972, the Florida Legislature created the five regional water management districts, which were delegated the authority to regulate stormwater management systems for new development. These systems were intended to deal with increased rainfall runoff caused by impervious surfaces in new developments (e.g. roads, parking lots, roof tops). These surfaces prevent rainfall from soaking into the ground and so water must be drained away to avoid flooding. The key mechanism in achieving this goal is the requirement for new developments to construct stormwater storage ponds to attenuate flood flows.



This additional water storage offsets the increase in runoff from the new impervious surfaces—thereby ensuring that new developments do not increase the amount of runoff into the receiving canals, further pushing them beyond their design flow capacity. This approach has virtually eliminated the need to periodically enlarge the regional canal network in response to increased development pressure.

The control of discharge water quality, known as an allowable discharge, is accomplished by calculations that determine the size of lakes and ponds needed for a water control structure that meters the water flow volume to a determined particulate range of water levels in the water management system. This detention of stormwater over time significantly improves the water quality of the runoff discharged from the developments.

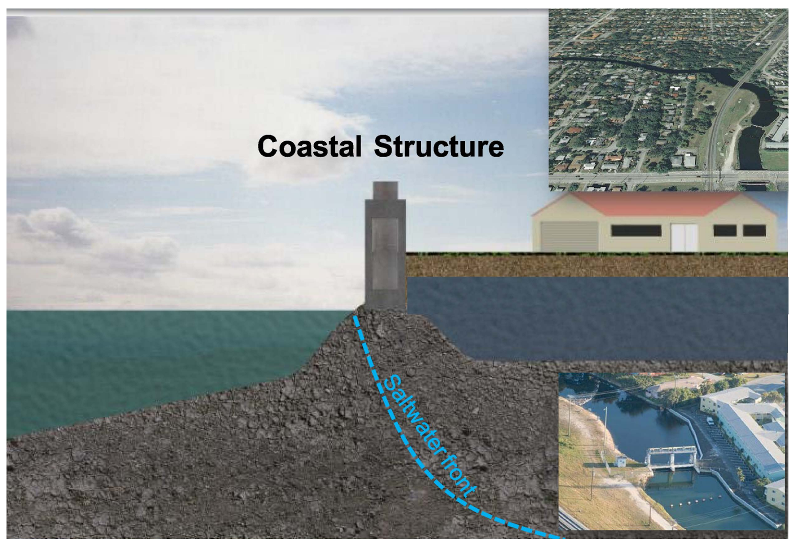
Potential Impacts of Sea Level Rise on Water Management

As the sea level continues to rise in response to the changing global climate, south Florida will become more and more susceptible to a wide variety of negative effects, primarily due to its very low topographic elevation. While the effects of sea level rise on coastal communities in south Florida are being reported worldwide, the more subtle impacts to the regional water resource management system, have recently come to light. The impacts fall into three general areas:

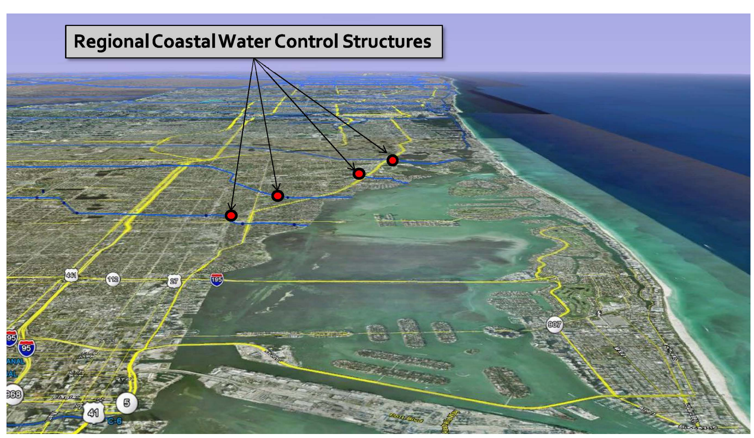
1. Flood protection and drainage systems
2. Quality of existing underground water supply sources
3. Natural systems already impacted by human activity

Flood Protection

The first, and most obvious impact is to the overall drainage system—which in virtually every case ultimately releases excess stormwater into the ocean through the coastal estuaries. These systems are almost exclusively gravity driven. This means that water flows from higher elevations on the landscape to lower elevations simply by allowing gravity to pull the water from one drainage feature (swale, ditch, canal, pond, etc.) down to another until it finally flows into the ocean at the lowest level. When the ocean elevation rises, the elevation difference between upland areas and the ocean is lessened, which in turn lessens the gravitational pressure to move large volumes of rainfall runoff out to sea. This effect ultimately reduces the flow of water through the structure—slowing it down and increasing the frequency and duration of flooding resulting from heavy rains.

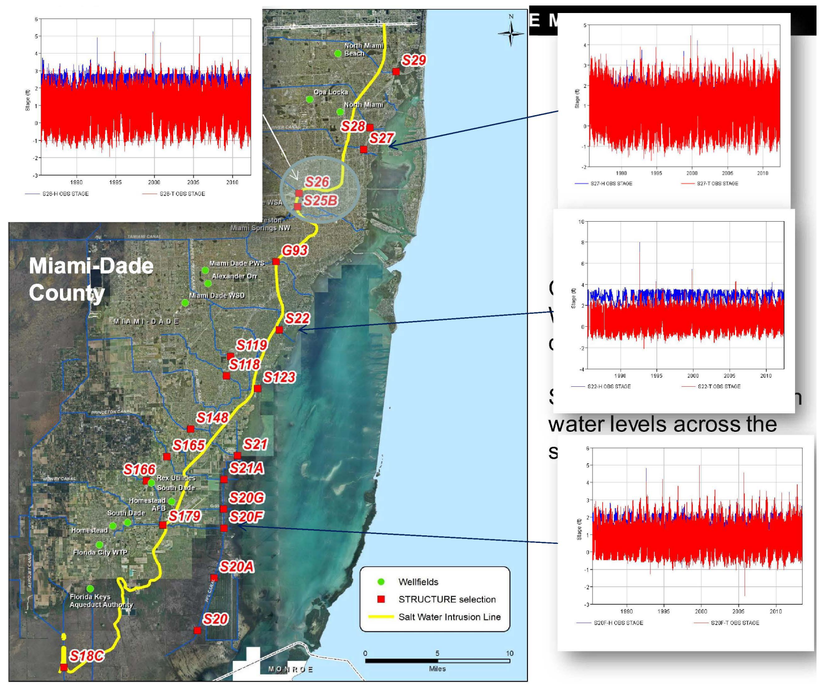


The path that stormwater takes from its beginning as runoff from heavy rains, to its release into the ocean, is managed by a series of numerous physical structures made up of pipes, gates and sluices. These structures are operated (opened or closed) in conjunction with one another to release water from developed areas to avoid flooding or hold it back to enhance water storage and groundwater recharge.



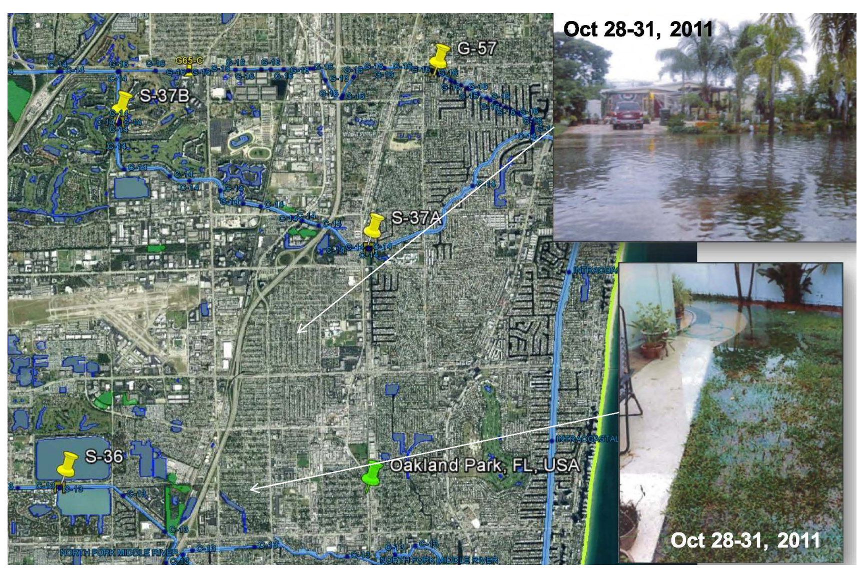
As sea level rises, coastal water control structures are the first line of defense for the regional flood control system.

Slow drainage problems are amplified when coastal structures are hit with a heavy rainfall event—which is typical during land-falling tropical storms and hurricanes. In these cases the elevation of the storm surge downstream of a structure (ocean side) can be pushed above the water level in canals upstream (land side). In these situations, the system operational personnel have no choice but to close the water control structure to avoid the inland rush of the coastal storm surge into the canal network, thereby further worsening flooding impacts.



Regional coastal structures maintain groundwater levels, which hold back saltwater intrusion into underground freshwater aquifers; they are also critical to minimizing flooding impacts. But numerous communities downstream of these facilities do not directly benefit from their operation, yet face the same threat to their drainage infrastructure. The cities of Miami, Miami Beach and Fort Lauderdale are key examples of this situation.

Sea level has risen about eight inches over the past 100 years, and there are clear indications from recent tidal data that the rate of rise is accelerating. This forces immediate attention on the regions, like coastal south Miami-Dade County, where the current water control elevations are already very close to the current range of tidal fluctuations.

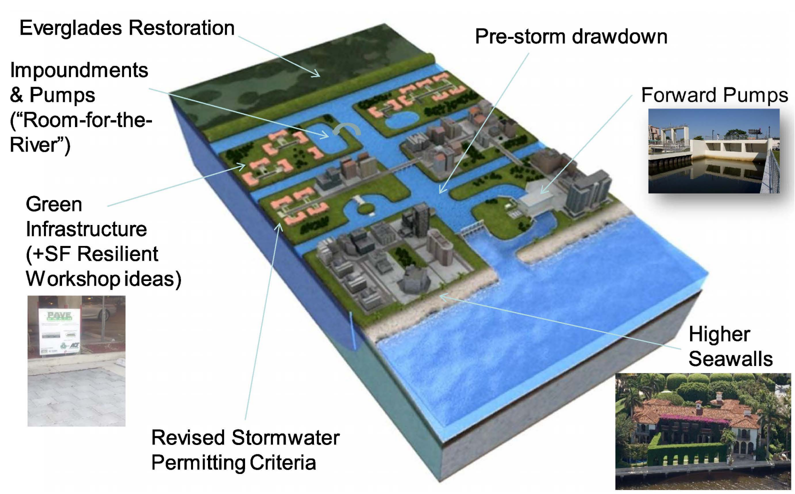


Most of the major water control structures along the coastline in Miami-Dade County already maintain canal elevations very close to the upper end of the normal tidal elevation range. In some cases, spring tides already exceed the normal canal elevation, which forces gate closures at least twice a day during those periods.

Similar situations exist in Broward County, where numerous communities and their local drainage systems are situated downstream of the regional water control system. These communities find themselves in the position of facing a double-threat associated with flooding. They are threatened by both direct impacts of rising seas on their local drainage systems, and storm discharges from the western regional systems flowing through the canal systems in their communities. A simple solution would be to stop or reduce the releases from the western communities. However, this action would most certainly worsen flooding in those towns and cities. Adaption strategies can be complicated and expensive but must be considered.

Adaptation Strategies - Basin Scale

Adaptation strategies to address the threats associated with sea level rise are necessary to extend the continued functionality of existing neighborhoods given the range of probable sea level rise predictions. The conceptual adaptation strategies presented here are multi-faceted, and focuses on a response to the changing hydrology driven by the changing climate. These strategies involve the following elements:



1. ***Everglades Restoration*** – This multibillion-dollar federal/state program is focused on restoring a more natural regional hydrologic flow regime from the Kissimmee River through Lake Okeechobee into the remaining Everglades and ultimately Florida Bay.

2. ***Regional Water Control Modification*** – The current water control system is fairly robust, even though most of it was designed in the 1950's and 60's by engineers with slide rules and graph paper. Elements of the system that warrant further consideration include:
    a. Modification of canal water control elevations – particularly with regard to pre-storm drawdowns
    b. Installation of 'Forward-Pump' systems to push stormwater out against high tides
    c. Revised stormwater permitting criteria to enhance regional water storage

3. ***Local Adaptation Concepts*** – There are numerous ideas at a small scale that focus on reducing rainfall runoff and enhancing water conservation that in aggregate could assist in the community adaptation to rising sea level:
    a. Additional stormwater impoundments, or the relocation (horizontal and/or vertical) of existing land uses to enhance water storage. A pertinent example would be the Dutch

effort to reduce regional flooding by restoring natural flood plain storage, known as the Room for the River Project.

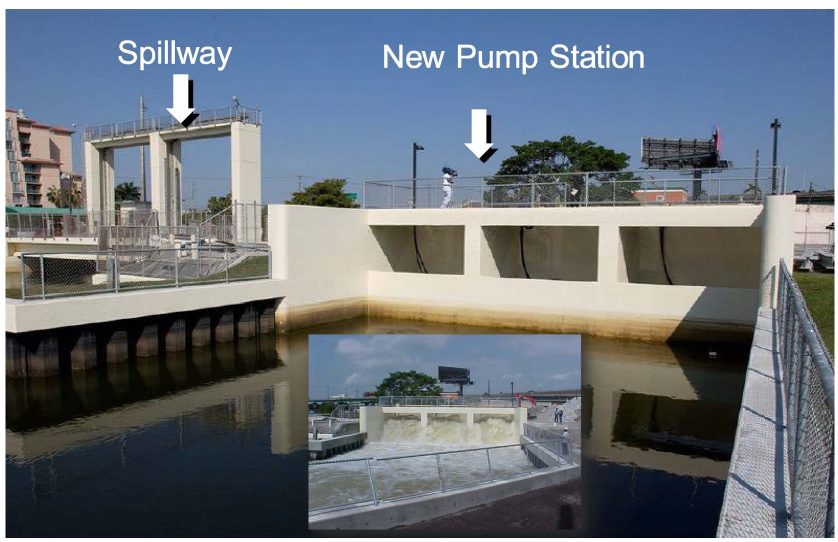
b. Green Infrastructure Components implemented at a neighborhood level.

Adaptation Example: Everglades Restoration

"Climate change should be a reason to accelerate Everglades restoration, not a reason for delays." - National Academy of Sciences 2008 report.

Restored Everglades flow is critical to the preservation of the natural Everglades ecosystem (tidal estuaries, mangrove forests, Everglades' ridge and slough habitat features, tree islands, etc.). Without this increased flow regime, increased salt water intrusion into the slough features of the Everglades will quickly move far inland in response to increasing tide levels. The increased flow associated with the restoration effort will allow nature to respond to this transition in a more gradual fashion. Increased flows into the southern estuaries will reinstate widespread organic soil formation and maintain the freshwater head in order to mitigate the effects of sea level rise and saltwater intrusion. It's important to recognize however, that the restoration of the Everglades does not insure that the key habitat components will remain in their current geographic location—but rather that these key components of the natural habitat will remain healthy (supported by ample quantities of clean freshwater) as the transition of their location occurs in response to rising seas.

Adaptation Example: Forward Pumping and Impoundment (not so 'Green'!)



On October 27th 1999, Hurricane Irene moved from Cuba into southeast Miami-Dade County overnight. Heavy rains fell in the region all night and into the next day causing widespread flooding in low-lying inland areas of the county. At the peak of the storm, a wind-driven storm surge pushed inland against the flood flows and raised downstream water levels well above the inland canal levels at the S-26 structure — forcing closure of the gates during the peak of the flooding impact. A similar flood occurred almost exactly one year later from a no-name storm originating in the Gulf of Mexico. This prompted a review of the flood control system in that area by both the SFWMD and a Flooding Task Force created by the Miami-Dade County Commission. Each of these efforts supported a series of drainage improvements. Foremost among these was the proposal to install forward pumps at the S-26 and S-25B coastal water control structures. Installed in 20xx, these pumps force floodwaters out against storm surges.

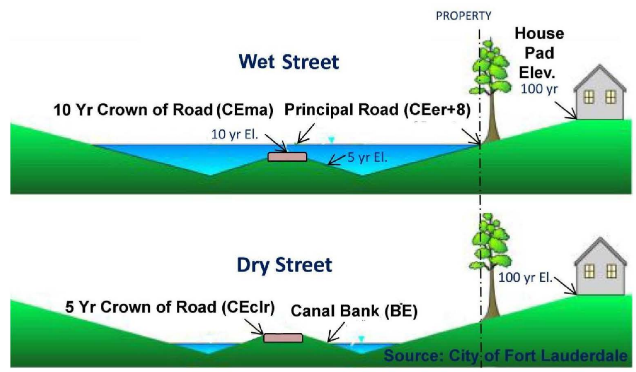
Another proposed drainage improvement was the construction of an Emergency Flood Detention Basin in the western portion of the C-4 basin. This facility was designed to work in conjunction with the forward pumps, by removing stormwater from the western portion of the C-4 Basin and detaining it until the peak of the basin flood flows pass.

At the time, no one considered these facilities as prototypes for adaptation to address the threat of sea level rise. But in today's context these approaches are considered one concept to mitigate flooding in the face of rising seas. A downside to this approach is that the system relies on large pumping facilities in order to function—which in turn use large quantities of electrical power. In order to develop a sustainable adaptation strategy, this issue needs to be considered and addressed.

Stormwater Adaptation Developments and Tools

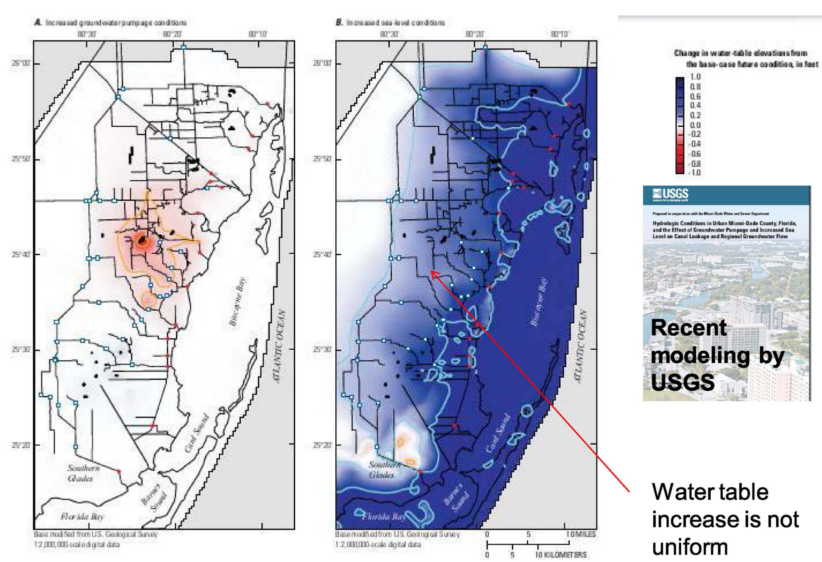
Level Of Service (LOS) Program Elements

The South Florida Water Management District is currently in the process of evaluating the flood control LOS in a pilot study at the basin level. The flood protection LOS is generally defined as a criteria used to measure protection of people and property. This evaluation of current LOS will consider the future implications of sea level rise and the potential changing rainfall patterns associated with climate change predictions and will include sub-regional hydrologic simulation modeling and updating the Basin Atlas' for all regions of the District.



Changes in Water Table: Pumping (decrease) & Sea Level Rise (increase)

Recent groundwater studies by the U.S. Geological Survey (USGS) have revealed some interesting results specific to the response of the surficial aquifer in Miami-Dade County associated with sea level rise. Initial indications are that because of the existence and operation of the regional canal network, the increase in groundwater levels associated with rising sea level will be greater along the coastal fringe that it will in inland areas. Furthermore, the higher groundwater levels will ultimately result in less well field



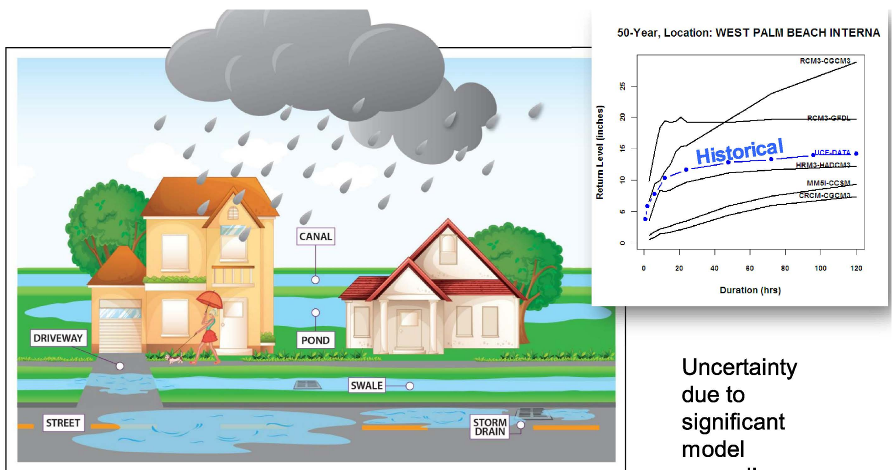
pumping for urban uses.

Tropical Storms & Climate Change

Current science anticipates an increase in tropical cyclone intensity as a result of the changing climate. While it appears that frequency of the more intense cyclones may increase, it currently remains unsettled if the frequency of the overall occurrence of tropical cyclones will increase or decrease. There are also projections that the rainfall generated by tropical activity will increase by approximately 20% within 100 km of the center of the storm systems.

Potential Changes in Rainfall Extremes: Update Depth-Area-Duration Curves

One key design tool used by the designers of stormwater systems is the estimate of rainfall depth-area-duration, which is used as the basis of design performance for a stormwater system. These estimates are made by looking-back at the historical rainfall record statistics. Obviously, this approach misses the implications of future climate conditions. The underlying premise of this approach is that what occurred in the past is what will occur in the future. This was a valid assumption when the design of a stormwater facility had an expected life span of about 50 to 100 years and its performance was based on a rainfall event whose magnitude was expected to occur once every 100 years (or statistically speaking; has an annual chance of recurrence of approximately 1%). But, if the changing climate significantly increases statistical rainfall depths and durations, systems designed by the current standard may see a greater frequency of flooding than anticipated in the design.

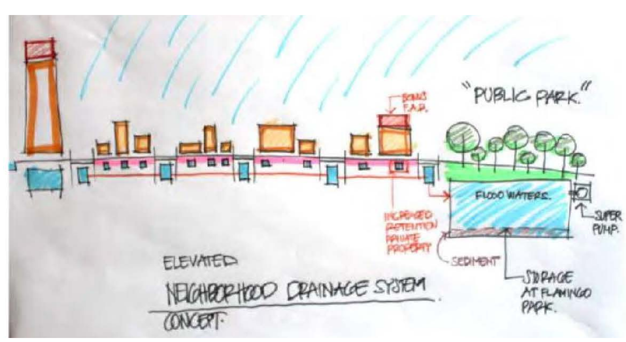


Uncertainty due to significant model spread!

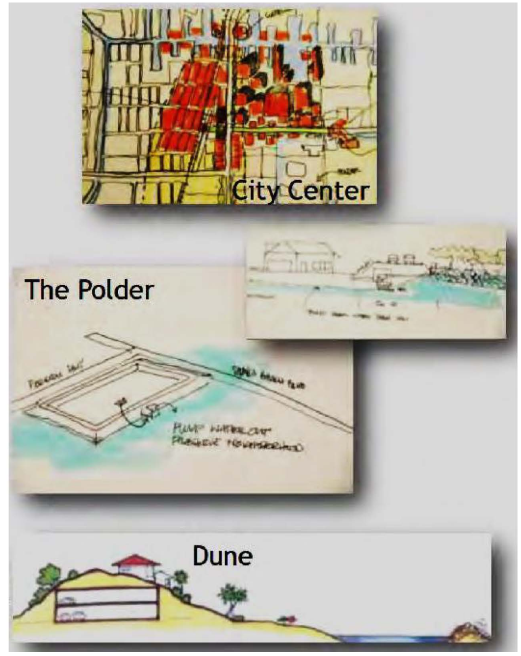
Resilient Design Workshop (August 2014)

In August 2014, the South Florida Regional Climate Change Compact sponsored a Resilient Design Workshop with the support of The Miami Center for Architectural Design, the Miami Chapter of the American Institute of Architects, and the Kingdom of the Netherlands. This workshop was attended by representatives of various governmental entities at all levels — federal, state and local. The goal of the workshop was to develop resilient design scenarios for three test cases in south Florida.

- Design Concepts: Urban – Alton Road
  This concept focused on resilient design concepts for the Alton Road area of Miami Beach. The outcome of this session was the recommendation of a central promenade drainage system, raised streets and



associated infrastructure, which included underground storage vaults. The concept also included a garden city master plan and urban densification.



- Design Concepts: Urban – East Dania Beach Blvd
  This concept also looked at a dense urban environment in the East Dania Beach Blvd area of Broward County just south of Fort Lauderdale International Airport. This concept focused on a city center located on the coastal ridge, incorporating a dune barrier with a collocated underground parking garage. The main hydrologic feature was the construction of a 'polder' for flood control — an impounded area below sea level with pumps to remove excess seepage and rainfall runoff.

- Design Concepts: Suburban – Unincorporated Miami-Dade County
  This concept focused on the portions of unincorporated western Miami-Dade County, near the communities of Sweetwater, West Miami, etc. Several design components were integrated into this approach that considered more energy-intensive solutions. However, this concept focused changes in land use patterns as the most sustainable approach to addressing the threat of sea level rise. A unique suggestion was incorporated to coordinate a voluntary land readjustment program that would result in existing landowners reconfigure their neighborhoods such that more water storage could be incorporated into the community. Another concept included a floating trailer park that would be incorporated into the overall stormwater system.

First Steps: Vulnerability Analysis Mapping

By: Nancy Gassman

Understanding your community's vulnerabilities is one of the first steps in addressing how the evolving impacts of climate change will affect your stormwater systems. The Intergovernmental Panel on Climate Change (IPCC), in its Second Assessment Report, defines vulnerability as "the extent to which climate change may damage or harm a system." It adds that vulnerability "depends not only on a system's sensitivity, but also on its ability to adapt to new climatic conditions."[1]

Mapping of these vulnerabilities helps determine which areas are most susceptible to flooding, providing visuals for stakeholder engagement and assessing next steps to reduce current and future risk. Several mapping tools are available to local governments in Southeast Florida.

Geographic Information System (GIS) practitioners from Compact Counties worked in collaboration with the National Oceanic and Atmospheric Administration (NOAA) and SFWMD to develop a consistent methodology used to generate a set of inundation maps which formed the basis for a regional vulnerability analysis (http://www.southeastfloridaclimatecompact.org/wp-content/uploads/2014/09/vulnerability-assessment.pdf). These tools were used to assess regional infrastructures' vulnerability to one, two and three-foot sea level rise scenarios. Physical features such as ports, airports, hospitals and evacuations routes as well as property values were tested under the three scenarios. These maps and GIS databases are available from each of the Compact Counties.

In addition, Broward County performed a more local vulnerability assessment on county-owned infrastructure. Using a grant from the Florida Coastal Management Program, Broward also assessed vulnerability of its 13 coastal cities' municipal assets (http://www.broward.org/NaturalResources/ClimateChange/Documents/ResilientCoastalComm/vulnerability-assessment.pdf).

In addition to the Compact vulnerability maps, interested parties can also access online tools to visualize vulnerability to sea level rise in their communities. One of these online mapping systems is Climate Central's Surging Seas (http://sealevel.climatecentral.org/). This tool allows the user to look at impacts of up to 10 feet of sea level rise. It is connected to databases, which analyze financial, infrastructure and sociopolitical impacts.

Another visualization tool is NOAA's Digital Coast Sea Level Rise Viewer (http://coast.noaa.gov/digitalcoast/tools/slr). This tool allows the user to test up to six feet of sea level rise and also contains an interface to understand social vulnerability.

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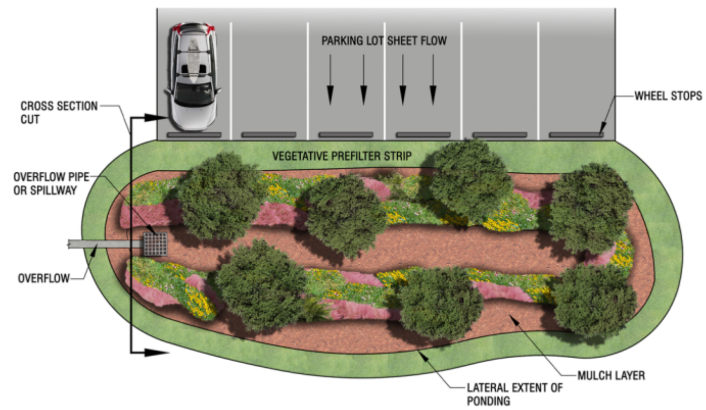
[1] (Watson et al. 1996: 23)

Municipalities and interested parties in the Southeast Florida area are able to use or access many of these tools to better understand local vulnerability to future sea level rise scenarios. Using the tools, the City of Fort Lauderdale has been able to advance is understanding of its adaptation challenges and improve its strategic planning for sea level rise.

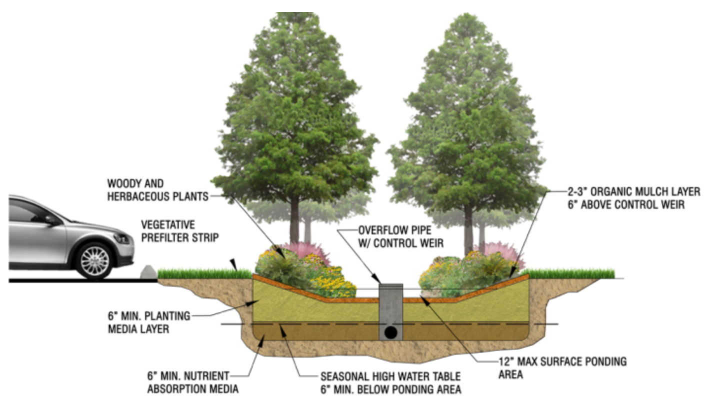
How Green Infrastructure (GI) and Low Impact Development (LID) can Lessen the Impacts of Climate Change

By Brett Cunningham

By some definitions, Green Infrastructure (GI) can be thought of as a component of Low-Impact Development (LID), with LID covering non-green elements that GI does not. For the purposes of this section they are used interchangeably/together.



PLAN VIEW OF SHALLOW BIORETENTION SYSTEM



CROSS SECTION OF SHALLOW BIORETENTION SYSTEM

Low impact development is, in many respects, the polar opposite of stormwater management approaches in most land development. The current development method typically involves removing existing vegetation down to bare earth, importing fill, compacting the soil, adding significant imperviousness (often directly connected to the drainage system), and then treating and attenuating stormwater at a central or downstream location. Conversely, the LID/GI approach to land development:

- Maintains as much existing vegetation as possible (especially in areas of higher habitat value)
- Minimizes fill, compaction, and imperviousness
- Incorporates vegetation and soils as part of the treatment process
- Promotes infiltration wherever possible
- Distributes treatment closer to the loading sources

In addition to structural practices such as bioretention, greenroof treatment systems, permeable pavement and stormwater harvesting, LID approaches include site design elements such as preserving conservation areas, disconnecting impervious areas and using narrower streets when possible. Advantages of LID are lower energy costs and carbon footprint, improved aesthetics, improved habitat, increased groundwater recharge and a more natural water budget.

The two biggest drivers for constructing stormwater Best Management Practices (BMPs) are requirements in the Environmental Resource Permitting (ERP) process and implementation of Basin Management Action Plans (BMAPs). Although Florida has been at the forefront of many advances in stormwater management, widespread use of LID/GI practices in Florida have been met with some challenges in ERPs and BMAPs. Many of those challenges fall under the reasonable assurance category that is a foundational element of the ERP process.

For instance, should local-scale BMPs be observed if they are not in a drainage easement? How does an enforcement agency know if a LID/GI practice is not functioning as designed? Additionally, local design criteria for many LID/GI practices have not been developed like they have for conventional BMPs. One solution that can help with many of the items identified above is development of LID/GI design manuals similar to what Sarasota County and Duval County have done and what Pinellas County is currently doing. In each of these instances, the respective Water Management District and the Florida Department of Environmental Protection have been a part of the LID/GI Design Manual development process so that it will have acceptance by their respective regulatory branches.

An area of particular importance for LID/GI practices in the watersheds of impaired water bodies. In these watersheds new development is held to net improvement standards, meaning that the post-development condition must deliver the same load or less for the pollutant(s) of concern than existing conditions. It is not possible to achieve this standard for some pollutants with conventional BMPs alone – they must be supplemented with LID/GI practices.

An excellent recent example of a LID/GI implementation is the Sunset Boulevard bioretention project in the Town of Melbourne Beach. The town has a nutrient reduction goal as part of the Indian River Lagoon TMDL/BMAP. Creating space for conventional BMPs within the town would require purchasing properties and demolishing their existing structures – an expensive and unpopular option. Sunset Boulevard had a raised median with a storm sewer outfall serving approximately 24 acres of urban area running under the median to the Indian River Lagoon. The pavement on Sunset Boulevard was also getting towards the end of its useful life. So, the retrofit project converted the raised median to a depressed median in the form a 1,000-ft long bioretention facility with Florida-friendly vegetation. Portions of the pavement were also converted to brick pavers to promote infiltration and improve aesthetics. Shortly after construction, the area received an eight-inch rain event. The bioretention facility captured the entire event and recovered quickly, suggesting an annual capture percentage of nearly 100 percent. Additionally, the eight-inch event required virtually no post-storm maintenance, suggesting that the facility will be relatively low-maintenance from storm events. Residents interviewed in the area have been very pleased with the project and feel that it has increased their property values.

Examples of Green Infrastructure Design & Place-Making

The following information was selected from the RCAP workshop presentation of South Florida-based Michael Singer Studio Associate Jason Bregman.

Examples are from West Palm Beach, Coconut Creek and Lake Worth, Florida, as well as relevant examples from the Netherlands and New York City.

Alterra Atria Water Cleansing Gardens – The Netherlands

BENEFIT: Process stormwater for use on site
CO-BENEFITS: Filter and cleanse interior air, climate control, reduce energy
http://www.michaelsinger.com/project/alterra-atria-gardens-2/

Alterra is the Dutch research institute for the environment and an integral part of the Partnership for European Environmental Research. The institute focuses on interdisciplinary collaboration for sustainable development in balance with ecological systems. Michael Singer was selected as a part of a winning architectural team to provide sculptural interactions with the building's core environmental systems where they developed a series of sculptural spaces within the two core atriums of the building complex.

The Alterra Atria Gardens function as the lungs and kidneys of the building complex, cleaning air and gray water as well as providing comfortable climate control. The process begins with stormwater, filtered through an exterior retention pond and constructed wetlands, which is then conveyed into the atria spaces. In the first atrium, the water moves through a series of pools and weirs with a range of aquatic and emergent vegetation and fish that continue the filtration process. Below the water's surface these pools have a variety of sculpted layers and forms that provide shelter for fish and support vegetation requiring different depths of water. Water then flows into another smaller clarifying pool only slightly recessed below grade and composed of concrete elements connected to an adjacent sculpted garden shelter. From the first atrium the water is then conveyed into the second atrium for final cleansing. The sculpted pool in the second atrium has a large shallow-patterned concrete plate with water plants growing on its surface. The water slowly overtops the pool and drips into a deep cistern for storage and recycling in the building's irrigation system and toilets. Singer's design also provides research and experimentation sites within the garden for environmental scientists working for the institute.

The two atria spaces form the enclosed courtyards of the E-shaped building and are the principal basis of the building's innovative energy strategy. The atria allow for natural light to infuse the entire complex and for most offices to have garden access and views. The atria help to moderate temperatures between the interior and exterior of the building. They are utilized for solar heat gain in the winter, reducing heating requirements within adjacent offices and rooms. In combination with sensor activated shading devices, increased ventilation and dense interior vegetation (for shade and evaporative cooling) the atria allow for the building to function comfortably in the summer with no air-conditioning except in the library and kitchen. The sculptural water pools were carefully integrated to combine with this innovative energy strategy, assisting with humidity levels.

Queens Plaza

BENEFITS: Stormwater collection, filtration and infiltration system
CO-BENEFITS: Public space, regrowth of vegetation
http://www.michaelsinger.com/project/queens-plaza/http://www.michaelsinger.com/project/queens-plaza/

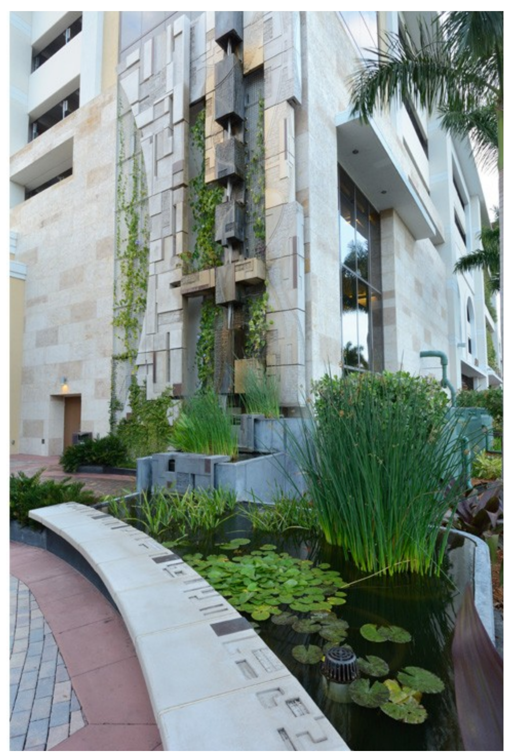
The New York City Department of City Planning and the NYC Economic Development Corporation hired Michael Singer Studio as a part of a design team lead by Margie Ruddick Landscape to provide planning, streetscape and landscape design for the public spaces in Queens Plaza near the Queensboro Bridge in

Long Island City, New York. At the heart of the Queens Plaza design is a stormwater collection, filtration and infiltration system that supports a massive re-growth of vegetation from within the tangled urban core of over 14 lanes of traffic, two elevated subway lines, two bridges and a multitude of subways and utilities.

Michael Singer Studio ultimately created over 3,000 individual sculptural paver, runnel and bench cap elements for the project, which are dispersed throughout the core of the project site. The installation was completed in 2011. These elements create a sculptural tapestry and unite the project through pattern, texture, form and repetition. Some elements, such as the runnels and planted permeable paver groups, are an integral part of the stormwater cleansing system for the site

Seminole Sculptural Biofiltration Wall – Coconut Creek, Florida

BENEFIT: Stormwater reuse and Improve water quality
CO-BENEFIT: Educational, public art and enhance habitat viability
http://www.michaelsinger.com/project/seminole-sculptural-biofiltration-wall/

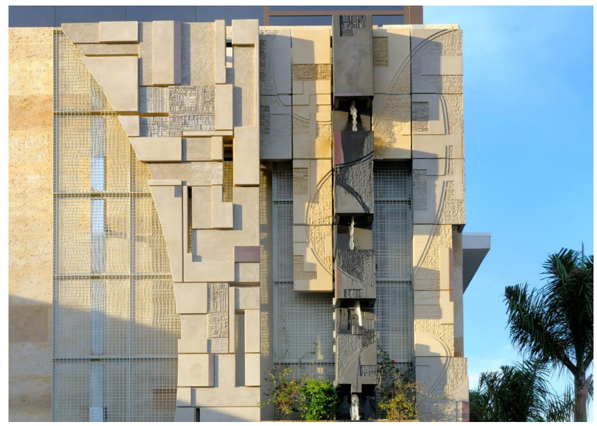


The Sculptural Biofiltration Wall was created as an integral part of the 2012 expansion of the Seminole Coconut Creek Casino. The project is comprised of a 40-foot tall sculptural wall and a multi-level aquatic garden located in a courtyard adjacent to a new seven-story parking structure. The Sculptural Biofiltration Wall was conceived as a living system designed to regenerate the surrounding environment by improving water quality, enhancing habitat viability, as well as informing and inspiring the public about ecological systems. The project filters approximately 150,000 gallons of water a day through mechanical and biological systems, improving the water quality of the adjacent retention ponds.

Retention pond water is used for irrigating all of the vegetation on site including the parking structure green walls, and may be used for future plaza water elements, reducing the use of potable water. Harvested rainwater supplements the water system with 10,000 gallons of water storage capacity. The rainwater is filtered and stored within four tanks along the east wall of the parking structure and is planned for use in a future valet car wash.

The Sculptural Biofiltration Wall fosters biological systems including plants, fish, and beneficial bacteria that naturally cleanse water. Improving water quality in the retention ponds also assists to improve habitat viability and biodiversity of the ponds. The sculptural wall itself supports a range of vegetation to attract avian wildlife, especially hummingbirds and of course butterflies, as Coconut Creek is the "Butterfly Capital of the World".

In addition, the 23kW solar photovoltaic canopy arrays on the parking roof deck provide enough power to supply three to four average Florida homes. This renewable energy source provides many times the energy needed to power the pumps, filters and lighting for the Sculptural Biofiltration Wall; the remaining electricity helps to power lighting and elevators within the parking structure. The solar canopies are also the source of the harvested rainwater. All of the project lighting is energy efficient LED lighting.



The Sculptural Biofiltration Wall was a part of both the fulfillment of the public art ordinance requirements for the City of Coconut Creek, an element of the parking structure aesthetic enhancements, and an aspect of the City's request for a 'conspicuous display of green technology' as a part of approvals for the overall project. A large display adjacent to the wall explains how this ecoart project merges art, science and engineering to regenerate damaged ecosystems.

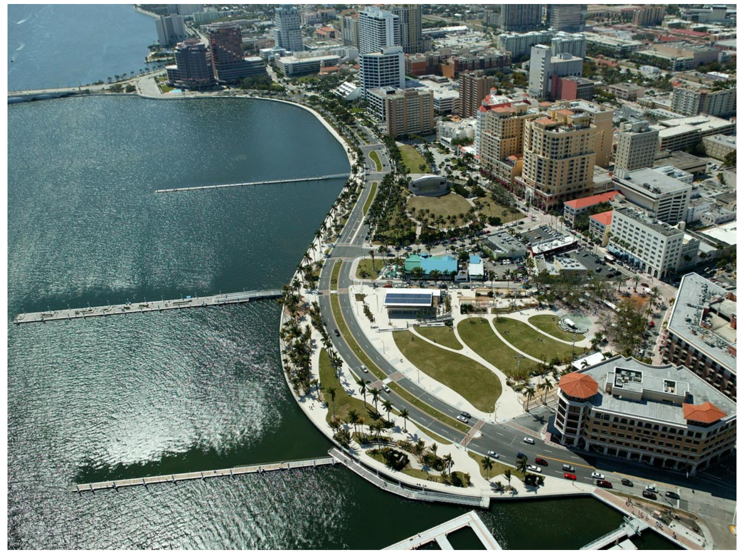
http://www.michaelsinger.com/project/infrastructure-and-community/

Waterfront Living Dock and South Cove - West Palm Beach, Florida

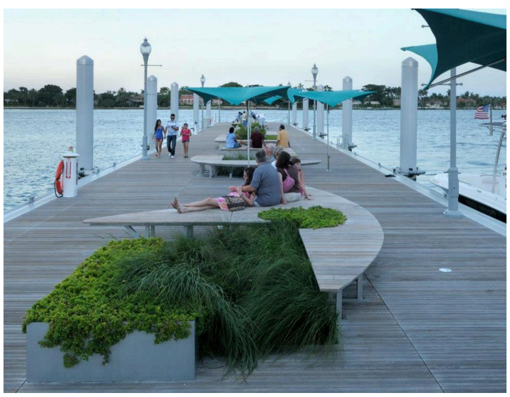
BENEFIT: Ecological Regeneration
CO-BENEFIT: Waterfront public space, education
http://www.michaelsinger.com/project/west-palm-beach-waterfront/

The West Palm Beach waterfront is over a 1/2 mile long and encompasses over 12.5 acres along the Intracoastal Waterway. The new civic space revitalizes the city's historic downtown and restores the natural beauty of West Palm Beach's waterfront. The studio designed the main commons and event spaces, three new floating docks, shaded gardens, two community buildings, a continuous waterfront esplanade, shade trellises, custom benches, seven water elements and an estuarine ecological regeneration area known as the South Cove. The $30 million park (with $9 million of that coming from federal, state and local grants) opened in early 2010, with an estimated 80,000 people attending the grand opening celebration.

Shaded garden pathways along both North and South Clematis Streets have several unique sculptural water gardens. The main central space of the commons was designed to accommodate major downtown events such as the Palm Beach Boat Show, Sunfest and the Fourth on Flagler. The landing and beach areas result from repositioning Flagler Drive west to gain more public access to the water's edge.



The beach area consists of recycled concrete fines paving, mature coconut palms and pockets of seating nestled into swathes of native vegetation. The esplanade consists of several discreet spaces including intimate seating areas and small 'rooms' along a continuous bike and pedestrian path. Existing trees were saved and some were transplanted to create a more varied and mature shade canopy along the Beach and Esplanade.



Living Docks: The central dock is designed with in-water planters that have native mangroves, spartina and a visible oyster reef set into the dock. Perhaps the first of its kind in the nation, the boat dock and promenade actually functions as a living system- filtering water and providing small pockets of habitat within an estuarine man-made structure.

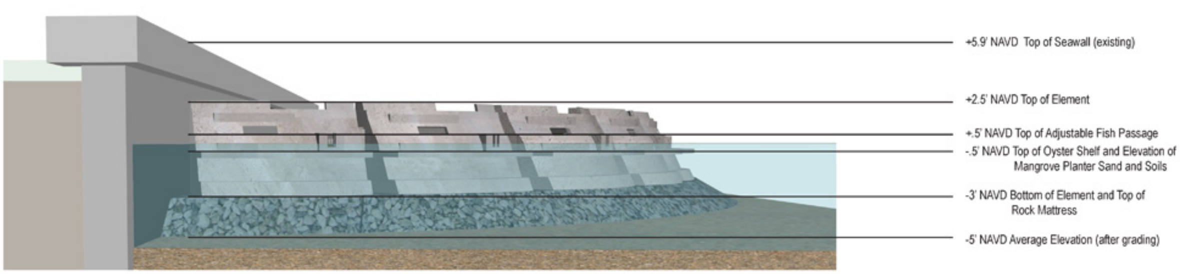
http://www.michaelsinger.com/project-category/landscapes/

Living Shorelines Regeneration Project – Lake Worth, Florida

BENEFITS: Habitat for fish and oyster habitat.
CO-BENEFITS: Water quality improvement, sea wall protection, public space improvements.
http://www.michaelsinger.com/philosophy/living-shorelines-initiative/

The Living Shoreline is comprised of 11 Sculptural Elements that are designed to retain soils to support the growth of mangroves and emergent grasses, create shelter and passage for fish, and establish oyster reef habitat within the Lake Worth Lagoon. The Living Shoreline will ultimately assist in improving water quality, it will protect the adjacent bulkhead seawall, public park, and infrastructure (including from early sea level rise impacts), and it will support the restoration of habitat. In fabrication has been funded in part by the National Endowment for the Arts Living Shorelines Regeneration Project.

The Living Shoreline Perspectival Elevations



Living Shoreline in-situ perspective elevation looking north. Conceptual drawing shown without plants. Approximate scale 1/4"=1'.

Living Shoreline in-situ elevation looking west. Conceptual drawing shown without plants. Approximate scale 1/8"=1'.

For More Information on Green Infrastructure Design & Place-Making

Infrastructure and Community, a white paper created through a collaboration between the Studio and the Environmental Defense Fund's Living Cities Program. The purpose of Infrastructure and Community is to put forward concepts and ideas that can integrate infrastructure with its surrounding community. The paper uses three infrastructure case studies (a power plant and two waste transfer /recycling facilities) and examines each project in terms of five main topics: site context (including ecological design), energy, public access, water, and architectural design. This infrastructure white paper was distributed as a planning tool for policy makers, community groups, planners, and infrastructure developers across the United States and to select groups internationally to encourage creative thinking, spark ideas that are outside of typical considerations, and result in new approaches in siting and design of infrastructure facilities.

One current sustainable infrastructure project is the new SWA Waste-to-Energy Facility in Palm Beach County, Florida. This project was developed in collaboration with SWA and Arcadis, and will be the newest and most environmentally advanced waste-to-energy facility in the United States (see project details here).

The **Green Infrastructure and the Sustainable Communities Initiative Report**, published by U.S. Department of Housing and Urban Development's (HUD) Office of Economic Resilience, shares the green infrastructure best practices and outputs of grantees under HUD's Sustainable Communities Initiative (SCI). As part of HUD's commitment under the Green Infrastructure Collaborative, the report features 30 HUD SCI grantees, which have incorporated green infrastructure strategies and projects within their Community Challenge and Regional Planning grants.

The grantee profiles featured in this report present a brief background of the larger planning projects funded by HUD and how green infrastructure investments advanced communities' goals for more vibrant economies, healthier environments, and more effective public infrastructure. Project overviews detail the specific goals related to green infrastructure and the green infrastructure outputs or outcomes that are likely to result. Each profile includes links to other resources with more detailed information.

See the report here:
http://portal.hud.gov/hudportal/documents/huddoc?id=greeninfrastructsci.pdfhttp://portal.hud.gov/hudportal/documents/huddoc?id=greeninfrastructsci.pdf

More information on HUD's Office of Economic Resiliency can be found here:
www.hud.gov/resiliencehttp://www.hud.gov/resilience

Financing Strategies Toward Sustainable Stormwater Systems

Brett Cunningham

Communities have many needs related to stormwater management. Flood protection is perhaps the most obvious need because of its relationship to safety and damage prevention, and communities have flood protection responsibilities related to the National Flood Insurance Program and emergency response during large storm events. Communities are also required to manage the quality of their stormwater runoff through their National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) Permit and the EPA and DEP Total Maximum Daily Load Programs. Most communities also have some of regulatory controls over stormwater related to development/redevelopment, and all provide some level of operation and maintenance. To meet all of these various stormwater obligations, communities must have a properly-funded stormwater management program.

Comparison of Stormwater Funding Options

The table below provides a general comparison of typical options for funding stormwater programs. The ideal funding source will satisfy all five criteria listed in the table below. As shown in the table below, a stormwater utility is one of the few funding options that satisfies all five criteria. It should be noted that a stormwater utility could be thought of as an enterprise fund, which is in turn usually funded by fee or assessment.

Funding Option	Sufficient	Dedicated	Not Limited	Fair / Equitable	Recurring
Ad Valorem Taxes	✓		✓		✓
Gas Tax		✓			✓
Sales Tax		✓			✓
MSTU	✓	✓	✓		✓
MSBU	✓	✓	✓	✓	✓
Stormwater Assessment Fee	✓	✓	✓	✓	✓
Stormwater Utility	✓	✓	✓	✓	✓

General Obligation Bond	✓	✓	✓		✓
Grants and Appropriations		✓			
Loans		✓			
Impact Fees		✓			

Stormwater Utilities in Florida

Implementation of a stormwater utility is authorized under 403.0893 of the Florida Statutes. Some of the finance benefits of a stormwater utility are:

- They are more fair than other revenue streams because users pay based on use of the system
- The funding source is dedicated and not subject to shortfalls in other funds
- They provide increased opportunities for grant funding and bonding
- They can help to improve the Community Rating System score.

Although there is not an exact count of stormwater utilities in Florida, the estimated number is approximately 175. The Florida Stormwater Association (FSA) advocates for stormwater utilities, and maintains a manual for developing a stormwater utility and has expanded its scope over time to include education, training, litigation, regulatory and legislative issues.

Stormwater Grants

Although grants cannot be relied on as a steady funding source, most communities spend significant effort securing grant funding since it is a funding source outside of the community that supplements internal funding sources. There are a large number of grants that are available to fund different elements of a stormwater program, with most coming from federal, state, or water management district funds. Communities seeking grants related to flood protection often apply for one of several grants from the Federal Emergency Management Agency (FEMA). Although FEMA grants are highly competitive, the amount of annual funding is significant.

The SFWMD recently initiated its Cooperative Funding Program for stormwater (water quality), alternative water supply, and water conservation. They established the program with a two-part application process so that projects that are not favorably rated will not have the burden of going through a more extensive application process. Similar to many grants, cooperative funding grants usually require a local match of 50-60%. An element that is less common with cooperative funding grants is that they can cover design and study phases of projects.

At the state level, 319 and TMDL grants are ones that are more readily obtainable. The application process and requirements are similar for both types of grants, with the biggest difference being the source of funding. They are generally limited to construction of restoration projects in impaired water bodies and require at least a 50% match.

Stormwater Financing at-a-Glance: City of Fort Lauderdale

Emilie Smith, Budget Manager, City of Ft. Lauderdale

The City of Ft. Lauderdale has taken a multifaceted approach to funding solutions for climate resiliency and long-term sustainable solutions. The City's immediate challenges include renewal and replacement of aged or inadequate infrastructure, new infrastructure where absent, risk mitigation and ensuring a fair and equitable rate structure for all Fort Lauderdale residents.

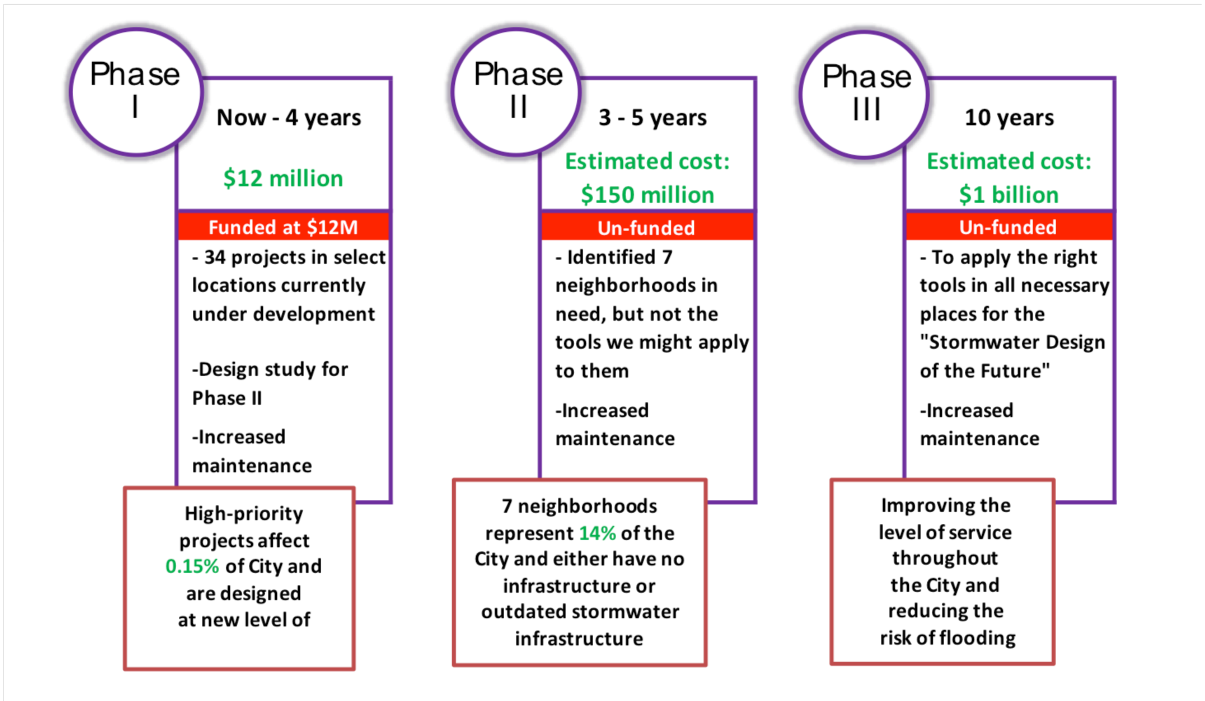
A comprehensive approach must be taken to determine the right balance of needs, funding, and risk mitigation. The city will begin by identifying the comprehensive needs, define the high-risk areas and various property classes, update the Stormwater Rate Study, and evaluate alternatives to increasing rates.

1. **City of Fort Lauderdale – Pay as you go funding**
    a. Approximately $12 million allocated for projects
    b. Includes additional operating funds and personnel

2. **City of Fort Lauderdale – Stormwater Rate Study**
    a. Risk Based Assessment
    b. Bifurcated Rate or Trifurcated Rate
    c. Flat rate per property class (Fort Lauderdale currently has a flat rate)
    d. Risk Criteria to Consider in new rate structure
        i. Property Type
        ii. Property Size
        iii. Hydrologic Areas
        iv. Low Elevation
        v. Proximity to Tidal Water
        vi. Repetitive Loss Properties/Areas
        vii. Lack of Infrastructure/Insufficient Infrastructure
    e. Interactive model to test sensitivity
        i. Ensure Fair and Equitable Rates across the City
    f. Cities have the ability to Increase Rates under Home Rule.
        i. Rates across the state are varied
        ii. Not uncommon to have monthly rates of more than $10
        iii. Fort Lauderdale current rate is $4.09

3. City of Fort Lauderdale – Bond Funding

a. Most Likely a Stormwater Revenue Bond
b. Could also be a General Obligation Bond
c. Approximately $150 million in Bond Funding in 2018
d. Approximately $1 billion over the next 10 to 20 years



Regional Innovation in Stormwater Management Master Planning

Case Study: Miami Beach

Development of a Comprehensive Stormwater Management Plan

On June 9, 2010, the City of Miami Beach authorized CDM Smith Inc. to develop a citywide comprehensive Stormwater Management Master Plan (SWMMP) in order to evaluate and update its stormwater management practices, infrastructure, funding and regulatory policies.

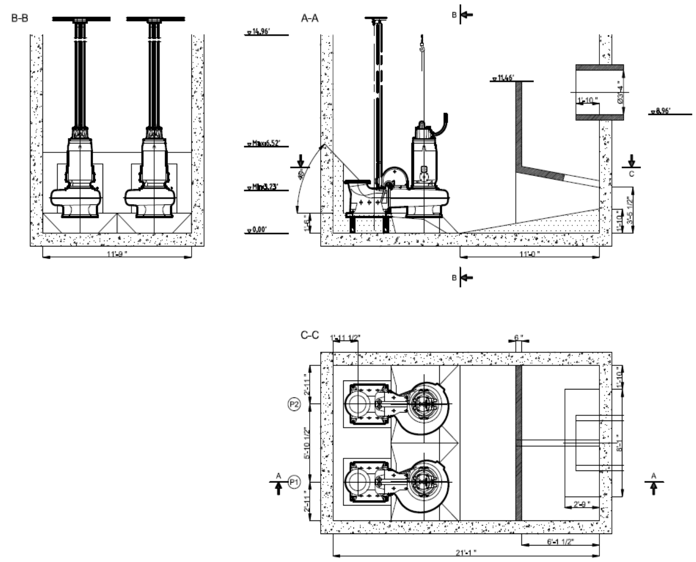
The previous plan was based on anecdotal data but the new plan is based on substantial data collection, including citywide modeling like LIDAR data pictured right. Ongoing data collection includes rain data (three rain gauges in South Beach, Middle Beach and North Beach) and tidal data from gauges in pre-existing monitoring wells. There is continued challenge of obtaining reliable data, but in the interim the City is working with the best available data.

The SWMMP is a long-term planning document that provides guidance for the upgrades to the City's stormwater infrastructure performance improvements for the next 50 years. The plan takes into consideration sea level rise as well as how infrastructure is designed to handle water from storms and tidal waters that enter the system when the tides are higher than the outfalls. The document also proposes improvements based on the design life of the infrastructure (20 years for pumps and 50 years for seawalls).

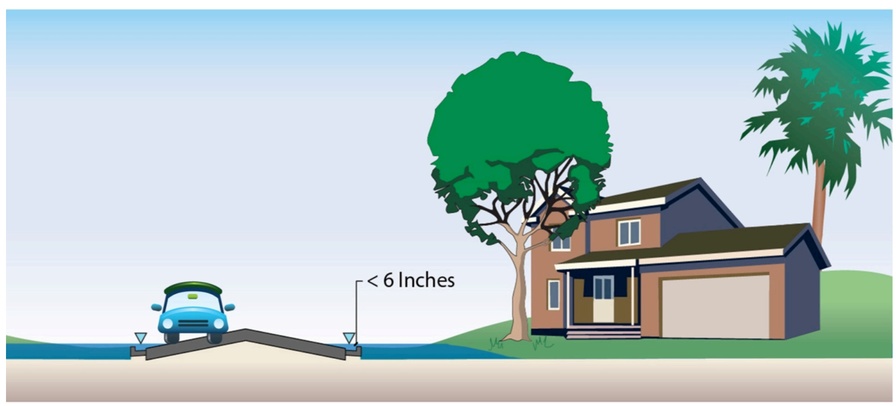
The $400 million stormwater upgrades handle stormwater/tidal waters throughout the year and are also designed to keep city streets dry during the highest tides of the year, including the spring tides or king tides that occur in the late spring and fall. The updated plan includes installing approximately 60 pumps as well as back flow preventers. The SWMMP provides a preliminary schedule of prioritized capital improvements necessary for the City to modernize its existing stormwater systems to meet the increasing performance and regulatory demands, while maintaining the high LOS expected in a modern urban environment.

In addition, the SWMMP helps address potential impacts of sea level rise such as higher groundwater, higher tides, increased flooding and decreased effectiveness of the existing stormwater system. The purpose of the SWMMP project is to create a comprehensive model that will look at cost-effective stormwater infrastructure improvements to meet City demand for level of service, remediate excessive flooding, prioritize stormwater capital projects, and ensure continued compliance with the City's National Pollutant Discharge Elimination System (NPDES) permit.

In developing the new plan, city took advantage of robust modeling not available during the development of old plan to account for sea level rise and full design life to minimize need for future retrofitting and ensure improvements provide level of service for intended time period. Since predicted SLR rates will continue to change as scientific research progresses, the plan is flexible.



FUNDING: $430 million in capital improvements are proposed for the City's recommended primary stormwater management system. The first $100 million is from a stormwater assessment fee. The remainder of the balance is still being discussed.



The primary purposes of LOS criteria are to protect public safety and property. Program goals are to maintain passable roads for emergency and evacuation traffic during 7.5 inches of rainfall in 24 hours and to keep flood stages below the first floors of homes and buildings. The LOS criteria were first used to identify and define potential problem areas using the stormwater model. The LOS criteria were then used to evaluate the effectiveness of contemplated improvements. LOS achievement decisions directly affected the size and cost of proposed improvement alternatives.

Miami Beach is one of 16 municipalities that entered into an Interlocal Agreement (ILA) with Miami-Dade County in 1993 (subsequently 17 additional municipalities have also entered an ILA with Miami-Dade County), authorizing Miami-Dade County to be the lead permittee in submitting a NPDES Stormwater Permit Application, which was required by federal law. One condition of the ILA requires the City of Miami Beach to develop a SWMMP that is consistent with Miami-Dade County's Master Plan. This report is the update and expansion of the SWMMP.

System Maintenance

The City of Miami Beach drainage system consists of approximately 92 miles of stormwater mains that utilize 348 storm sewer outfalls and 132 drainage wells. The City's Stormwater Operations Division is responsible for maintaining the system.

The drainage system is routinely scheduled for maintenance and inspection. The City schedules all structures within the storm sewer system for maintenance in accordance with the standards established under City's NPDES Permit. Any repair requirements, system inventory conflicts or evidence of illicit discharges are immediately referred to the appropriate division supervisors or to the City's Code Compliance Department for further enforcement action. The City of Miami Beach also maintains a 24-hour citizen complaint hotline (305.604.CITY). Complaints received are routed to the appropriate division supervisors for response. Public Works Department personnel are available around the clock in case of emergency.

The storm sewer system is cleaned on a continuous basis. Any sediment, debris or other obstructions are removed, immediately following the inspection of each structure. A Vac-Con vacuum truck is utilized to clean the stormwater mains and structures. Also, the City hires a contractor to supplement service.

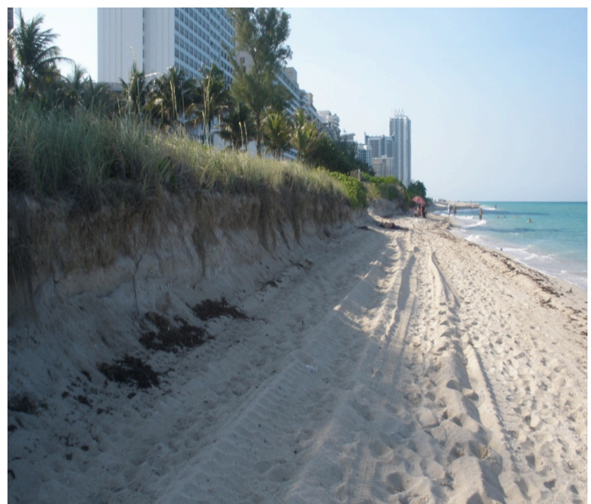
Stormwater Maintenance Best Management Practice:

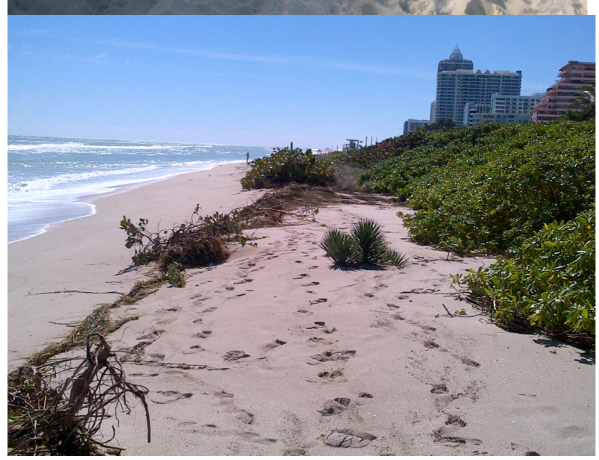
- Daily street sweeping and sidewalk trash pickup.
- City waterways are cleaned twice weekly.
- Each year before hurricane season and historical high tide events, the City inspects the drainage system in areas known to be prone to flooding.
- Inspections are conducted after each storm that adversely impacts the drainage system.
- The City maintains a 24-hour citizen complaint hotline, and responds immediately to drainage or flooding complaints.
- Inspections and removal of debris from drainage infrastructure is conducted on a continual basis throughout the entire drainage system.
- Collection and removal of road debris.
- Education and outreach to encourage litter and debris control management.
- Disposal of accumulated sediment collected from urban runoff management and pollution control devices, and proper disposal of waste generated during maintenance operations.
- Timely repair of potholes.
- Regular sweeping/vacuuming of streets and parking lots.
- Implementation of an anti-litter and stormwater education program, including a stormwater curb-marker program.
- Maintenance and addition of trash and recycling receptacles throughout the City, and replacement of vandalize receptacles when necessary.

Structural Control	Frequency of Inspection	Frequency of Maintenance
Exfiltration Trench / French Drains	• New systems: annually for first two years of operation • Existing systems: 1x / 3 years • Existing systems with chronic problems: annually until chronic problems are corrected	As needed based on inspection to assure proper operation.
Pollution Control Boxes (e.g., baffle boxes, CDS units, hydrodynamic separators, catch basin inserts, etc.)	Quarterly, unless historic cleaning records show a more or less frequent schedule is appropriate	As needed based on inspection to assure proper operation.

Preserving a Healthy Dune System

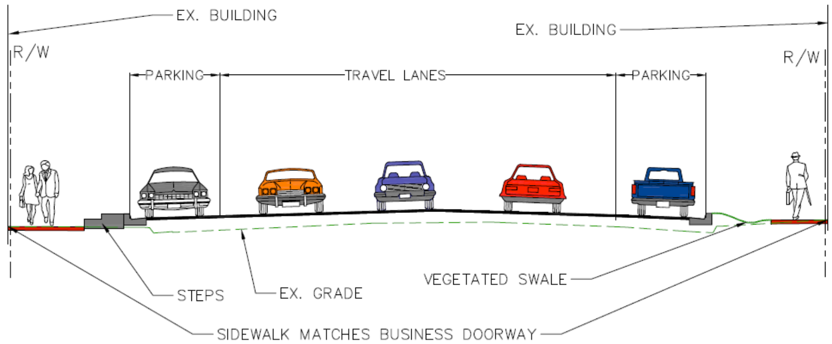
A healthy dune system is an invaluable asset to coastal communities like Miami Beach not only because they are the area of highest elevation, but also because they provide habitat for wildlife and support a high biodiversity of flora and fauna. They also keep beaches healthy by accreting sand and minimizing beach erosion rates. And, they protect coastal infrastructure and upland properties from storm damage by blocking storm surges and absorbing wave energy.



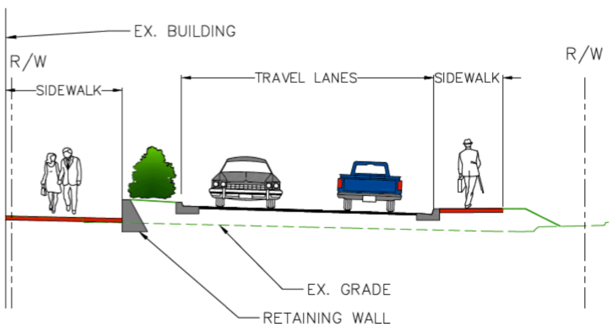


The photos show the rates of erosion observed at 55 Street, one of the city's erosional hot spots, after Tropical Storm Sandy. Sandy did not directly hit the City of Miami Beach but the beach lost a substantial volume of sand all the way to the dune line. The deep-rooted system prevented further erosion westward. Other communities without a dune saw much larger impacts from the storm. For example, portions of A1A were compromised in Broward County as a result of the storm.

On February 12, 2014 the City Commission approved the recommendation of the Flooding Mitigation Committee to amend the Stormwater Management Master Plan's tailwater elevation design criteria from 0.5 FT-NAVD to 2.7 FT-NAVD, which dictates a higher crown of road elevation than what exists in some areas in the City.

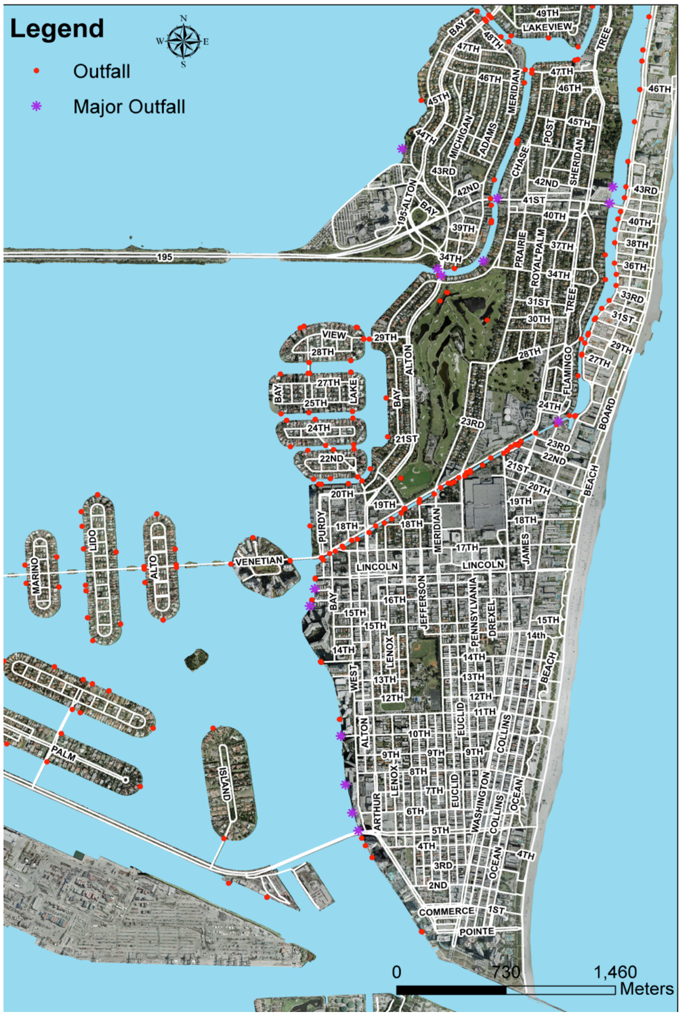


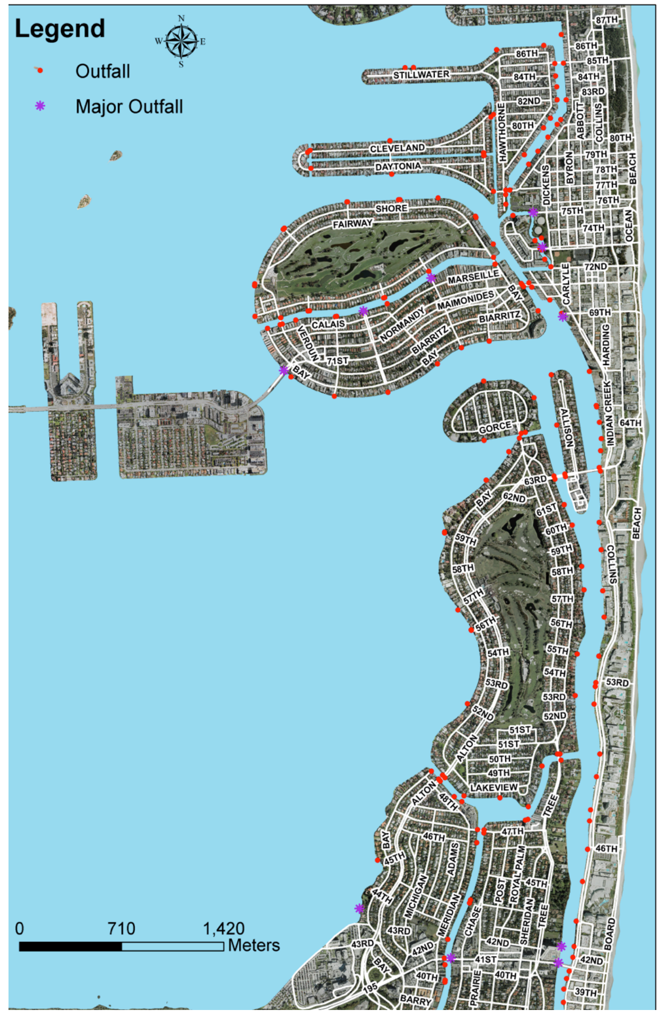
1657 WEST AVE
(LINCOLN INSURANCE
AND LINCOLN WEST TOWERS)



520 WEST AVENUE
(ANTHONY'S PIZZA)

In July 2014, CMB Commission approved 5.7 feet NAVD for sea walls based on accrued value of work not to exceed $300 per linear foot in a five-year period. This is an increase from the old criteria of 3.2 feet NAVD.





Map depicting the locations of the major outfalls (larger than 36") and smaller outfalls in the city. (left) south beach to middle beach - (right) midd le beach to north beach

Miami Beach recognizes that these are small initial steps and that the City is going to need to expand its existing efforts to become more resilient. Going forward the City will continue to:

- Plan for future changes in technology and scientific research
- Continue to monitor data to ensure we are using the best available data
- Work to communicate with our community and to manage public perception
- Continue collaborating with new and existing partners to make use of the available expertise in the region in challenges such as identifying and developing long-term financing mechanisms
- Maintain an open forum between the City and the public via the Blue Ribbon Panel and the Sustainability and Resiliency Committee

Conclusion

Water management is one of the greatest adaptation challenges Southeast Florida faces as sea level rises. As seas rise, water management decisions have tremendous impact on flooding, drinking water and the rare, fragile and essential ecology of the area. How Southeast Florida meets the challenge of water management will be a model for the nation and the world–these decisions will determine if the area becomes an exemplar or a cautionary tale.

While the most obvious choices for addressing mounting drainage issues are a combination of storage, pumping and increasing elevation of infrastructure, there is no one-size-fits-all solution to a growing problem, which is already challenging the existing regional water management system–one of the most complex systems in the world. Florida's solutions must address seemingly conflicting purposes of flood control, water supply and environmental protection. Aside from status quo and unsustainable systems like pumps and ponds, new low impact development techniques are not only effective sustainable water management approaches, but can also serve as community amenities and art.

When it comes to deploying these approaches, Southeast Florida's communities need to document results and then come together through the Compact to share what is working and what is not. This sharing mechanism will streamline and accelerate the iterative process so critical to successful resiliency and innovation in all communities.

First and foremost, the area must continue to use and develop modeling systems in a consistent manner across the region. These systems allow officials, planners, engineers and the general public to assess current and future risk of adaptation approaches, infrastructure and developments. They will continue to be an essential tool for evaluation of alternative sea level rise scenarios and engineering interventions.

At the Institute for Sustainable Communities, we define resilience as bouncing forward, not bouncing back. The difference lies in the fact that a resilient community does not continue to build sensitive infrastructure in the same vulnerable places after an extreme weather event, natural disaster or flooding, but instead reevaluates what and where they are building. It is important, using historic data and high-tech modeling tools, to consider new standards and benchmarks (such as storm return frequencies, base flood elevations, and standardization of the sea level datum) to be applied as development and redevelopment happen so that progress is made towards a more resilient built environment as new investment occurs.

It will take the region and its communities working cooperatively to address the complex challenges presented by this rapidly changing water management future. Communities can lead by trying promising approaches, documenting results and sharing with other communities via the Compact. The Southeast Florida water management system as a whole is deeply interconnected. It will take leadership in every community to make that system stronger.

For more information visit:

www.southeastfloridaclimatecompact.org

Regional Impacts of Climate Change and Issues for Stormwater Management

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