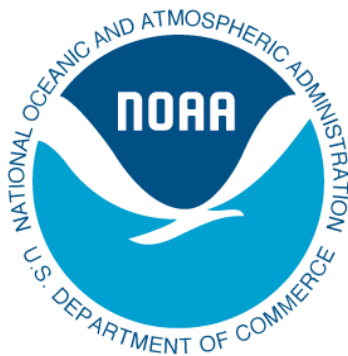


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Moving Adaptation Forward in the Village of Key Biscayne

Key Biscayne Community Foundation

Final Project Report



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July 2017

Final Project Report

Moving Adaptation Forward in the Village of Key Biscayne

Executive Summary

Project Goals and Objectives

The Village of Key Biscayne is situated inside the southernmost barrier island of the Atlantic coast in Miami-Dade County, Florida. The low-lying island (average of 3.4 feet above the Mean Sea Level) sits between the Atlantic Ocean and the Biscayne Bay, which exposes it to major stressors from the Atlantic Ocean. The combination of Key Biscayne's unique position and very low elevation makes the island especially vulnerable to sea level rise and associated increase in storm surges. Furthermore, Key Biscayne can only be accessed through the Rickenbacker Causeway and its three bridges: the West Bridge, the William Powell Bridge, and the Bear Cut Bridge. Also, even though recent renovations to Bear Cut Bridge were completed in 2014, an increase in the exposure to the corrosive effects of saltwater is anticipated with rising sea levels, thus, leaving the two residual bridges, along with the renovated bridge, nevertheless vulnerable.

Key Biscayne faces other major challenges such as the lack of natural beach nourishment normally observed from littoral drift processes that transports sand from north to south along the Florida coastline. Deep artificial inlets, such as Government Cut, have impaired sand nourishment in Key Biscayne. This, when coupled with a lack of mangroves (that serve as barriers to sea level rise) in three quarters of island's beaches and a mass of other structures along the coast, has increased the cost and complexity of re-nourishment or replacement of local ocean-side beaches. Key Biscayne can experience tidal variations of up to 2 feet throughout the year in response to the effect of lunar orbital cycles, thermal expansion of water as it reaches peak warmth (during late summer and early fall), and seasonal changes in onshore wind and atmospheric pressure. The highest of all annual tides, called "king tides," occur during the fall when these stressors act together along with the alignment of the solar and lunar gravitational pull to enhance tidal levels and often causes flooding, even in areas that do not normally flood throughout other periods of the year.

The Village of Key Biscayne, like much of South Florida, sits above bedrock primarily made of highly porous limestone and therefore has an exceptional ability to store and conduct water. The extremely permeable nature of limestone carries two concerns: increasing saltwater intrusion (the movement of ocean saltwater inland) and a rise in the inland groundwater table. Saltwater intrusion and rising groundwater table levels pose threats of freshwater aquifer (drinking water resource) contamination and a reduction in the ground's capability to absorb and store water, respectively. Fortunately, no drinking wells are located on the island, but the ground's lacking ability to absorb and store water during heavy rainfall events increases the risk of rainfall-induced flooding. These stresses are anticipated to worsen as sea level rise increases, at which point more water will seep up from the limestone bedrock and render external barriers less effective for low-lying areas.

The city of Miami Beach has already experienced many of the effects anticipated to impact Key Biscayne due to sea level rise and, due to the similar geology of the two barrier islands, Miami Beach's mitigation efforts can be referenced for establishing a path of adaptation and resilience in Key Biscayne. Miami Beach has invested over \$300 million dollars in its mitigation efforts; however, its current impacts are quite severe and only expected to impact Key Biscayne at this level in 20-30 years. Therefore, using Miami Beach as a case study can help create more cost effective mitigation processes by highlighting successful approaches that will be smaller in scale if implemented before the effects of sea level rise in Key Biscayne increase in magnitude. This will shift Key Biscayne's adaptation plan towards a more proactive approach.

With this grant from National Oceanic and Atmospheric Administration (NOAA) through Florida Sea Grant, the Key Biscayne Community Foundation (KBCF), through its Citizen Science Project (CSP), is working with the Village of Key Biscayne to lay a foundation of structural and natural resilience in Key Biscayne. The goals of this project are to mitigate and adapt to the stresses Key Biscayne faces now and in the future, to develop a resilient island, and to unify and educate its residents in order to engage the community in a manner promoting reaction and participation in the Village's efforts. This project has three main deliverables: Completing a sea level rise risk assessment, prepare and adaptation plan, and design a townhall or Charrette to encourage public participation.

Methodology

Sea Level Rise Vulnerability Report

The Sea level Rise (SLR) risk assessment for the Village was performed to have a baseline on which an adaptation plan could be built. KBCF retained Coastal Risk Consulting (CRC) to perform an assessment and create a plan to address sea level rise on Key Biscayne. After a preliminary public townhall to discuss the SLR risk assessment process, CRC began assessing the island to identify areas most prone to flooding and produce flood predictions maps under different tide scenarios. Three types of flood risks were examined:

1. Tidal or non-storm flooding, or "sunny day flooding" (occurs under clear skies when no rain is present), "fair-weather flooding," and "nuisance flooding" (occurs when sea water rises above existing land elevations)
2. Storm surge flooding (occurs from hurricanes or tropical cyclones making landfall on or near the Village)
3. Heavy rainfall flooding (occurs when rainfall exceeds the drainage and ground storage capacity)

The methods employed by CRC to assess Key Biscayne's risk to flooding include:

- Advanced geospatial modeling capabilities designed to analyze and predict current and future climate impacts (flooding, tidal changes, storm surge, sea-level rise, groundwater conditions, etc.) at the parcel-level for coastal communities throughout the United States
- Framework forecasting the probability of both tidal flooding and storm surge inundation on individual property parcels over the next 30-years.

- The model uses publicly-available databases and best practices from NOAA and the United States Army Corps of Engineers (USACE), which are integrated with CRC's geospatial analysis tools to forecast current flood risk and future change flooding due to sea level rise.
- High-resolution LiDAR measurements of surface topography. The LiDAR measurements provide elevation information with unprecedented resolution, areal coverage, and accuracy for the entire Village. This information is integrated with local tidal records, simulations of hurricane storm surge using the NOAA Sea Lake Overland Surge from Hurricanes (SLOSH), and community-based, scientific projections of future sea level rise to predict future current and future changes in flood risk.
- Proprietary application of the SLOSH model developed by the NOAA (2017), which is widely used to quantify storm surge risk.

Adaptation Plan

Using the SLR risk assessment data and information of previous and future planned work of the Village, a tentative 25-year plan was drafted including baseline risk conditions with respective planned mitigation actions. While considering future sea level projections, various tide scenarios were considered at different projected sea levels. Suggestions from CRC' risk assessment report and flood risk management workshops facilitated by AECOM were then included in the adaptation plan. The plan consists of the following improvements:

1. Drainage Improvements
 - Back flow preventers in all outfalls with service areas less than 3.7 ft elevation
 - Pump stations required for areas drained by gravity wells with elevations less than 3.7ft
 - Backflow preventers in gravity wells
 - Swales and green spaces to be restored as streets are elevated
2. Structure and Road Elevations Rise
 - Street elevations increased above 4.0 ft to a minimum of 6-inches every 15 years in low areas as required
 - Sidewalk elevation above flooding elevation as determined
 - Seawall elevation to be increased to minimum of 5.0 ft
 - House floor elevation certification minimum 10 ft + 2 ft
 - Garage floor elevation certification to minimum 7 ft
 - Utilities elevation as required
3. Monitoring Program
 - Online level measurements including tide
 - Rain Gauge
 - Manual level and salinity monitoring program

All improvements presented here are idealized and hypothetical, and designed to provide intuition into the benefits of various adaptation processes relative to a "no adaptation" scenario. The Village currently experiences tidal and rainfall flooding in many areas, particularly low-lying areas (average of 3.2 ft above sea level) west of Crandon Blvd. Even at current sea levels, the entire island is vulnerable to storm surge flooding. CRC concluded that the threat of storm

surge will increase over the next 30 years and depth of storm surge inundation will increase proportionally to rate of local sea level rise. Therefore, any structural improvements (roads, seawalls, drainage systems, etc.) will only help to reduce flooding under future projections.

CRC compared the extent of tidal flooding projected to occur in 2045 under a no adaptation scenario (Figure 1a) and with backflow valves and sea walls constructed to a minimum of 5 feet (Figure 1b). This demonstrates the benefit of raising sea walls and installing backflow valves. While installation of backflow valves and increased elevation of sea walls is predicted to reduce the severity of tidal flooding throughout the Village, it is not eliminated.

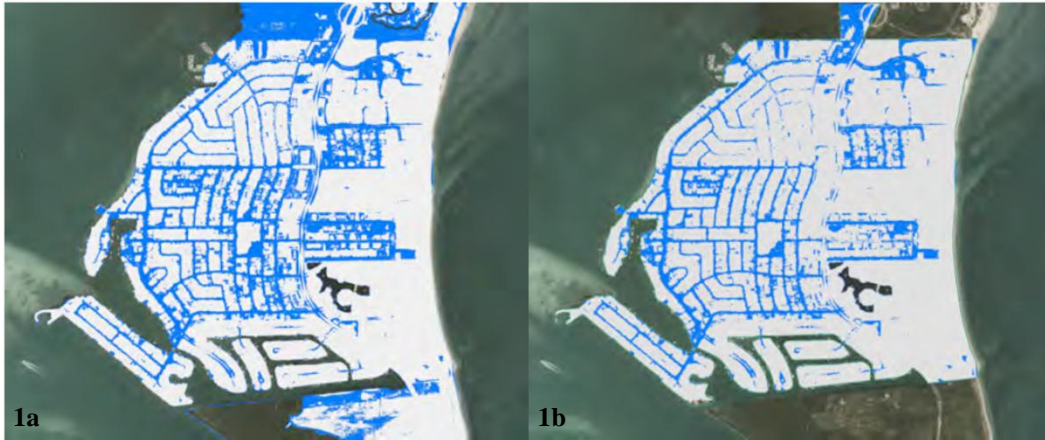


Figure 1a & 1b: The extent of tidal flooding (blue) in the Village of Key Biscayne projected to occur by 2045 under: No adaptation (left) and with backflow valves and elevated to a minimum 5 feet (right).

The most effective adaptation plan is one that combines multiple strategies and accounts for a holistic view of the issues at hand. To demonstrate the benefits of combining multiple strategies in order to mitigate all types of flooding in Key Biscayne, CRC produced a map projection for the extent of flooding by 2045 under a no adaptation scenario (Figure 2a) and a combined adaptation scenario which accounts for the installation of backflow valves, elevation of sea walls, and increasing the elevation of all roads by 1 foot (Figure 2b).

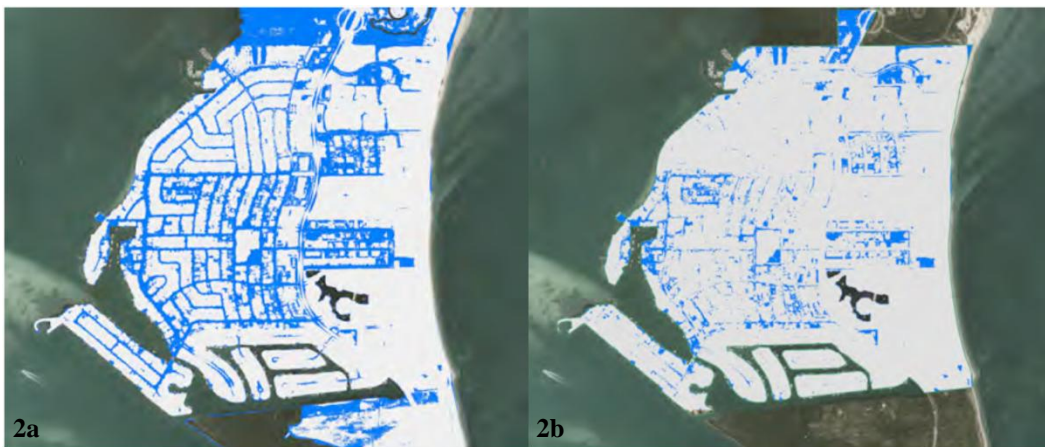


Figure 2a & 2b: The extent of tidal flooding (blue) in the Village of Key Biscayne projected to occur by 2045 under: No adaptation (left) and with backflow valves, elevated sea walls, and 1 foot roadway elevation (right).

This is predicted to eliminate most roadway flooding and partially reduces property flooding throughout the Village. However, despite showing significant improvements, there still are many areas of the Village that remain vulnerable to tidal flooding.

In addition to structural improvements, the Village of Key Biscayne has recently adopted a new floodplain ordinance based on a model ordinance, developed by the Florida Division of Emergency Management. The floodplain ordinance is in coordination with the Florida Building Code (FBC) and meets all requirements established by the National Flood Insurance Program (NFIP). According to the Workshop Summary report from AECOM, “as of early 2017, more than 380 of Florida’s 468 NFIP communities have adopted or are in the process of adopting this model ordinance, and the rest are expected to do so in the coming year.” The Village has decided to amend the model ordinance incorporating a few higher standards: a cumulative Substantial Improvement provision and additional elevation (freeboard). The amendments proposed by the Village are as follows:

1. Cumulative Substantial Improvement: The cumulative cost of improvements (over a one-year period) that equals or exceeds 50 percent of the market value of the building before the improvement/repair is started will trigger the requirement for the whole building to be brought into compliance with the current floodplain regulations.
2. Addition Elevation (Freeboard): One and two family dwellings shall be developed in accordance with the minimum elevation requirements of the (FBC), plus one foot (equivalent to 2 feet above Base Flood Elevations (BFE)). Also, developments other than one and two family dwellings shall be developed in accordance with the minimum elevation requirements of the FBC, plus 2 feet (equivalent to 3 feet above BFE). Lastly, all critical facilities shall be elevated or protected to or above the 500-year flood elevation plus 1 foot (equivalent to 2 feet above 500-year storm).

The benefits of adopting Cumulative Substantial Improvement include a reduction in the likelihood of deliberately phasing improvements to avoid the “50% rule,” earning Community Rating System (CRS) credits, quickly bringing all flood prone structures into NFIP compliance, and reducing future flood damage. In the Workshop Summary report, AECOM gave recommendations on how the proposed ordinances should be implemented, which included:

- A Cumulative Substantial Improvement period of at least five years should be considered to speed up the process of elevating existing buildings.
- Adoption of the proposed ordinance sample language, with edits to adopt a minimum of 3 feet of freeboard for all buildings (This is based on data that once flood levels exceed the lowest floor of a building, the extent of damage increases dramatically, especially in areas subject to coastal waves). This would change the language for One- and Two-Family Dwellings to meet the FBC minimum, plus *two* feet. The language for Developments Other Than One- and Two-Family Dwellings and Critical Facilities would remain the same because they already meet this standard.

Community Outreach

The purpose of the townhalls and public workshops was to engage the community in the plan to address sea level rise, and to gauge their response, ideas, and reaction to the issues at hand. At these public forums CRC, AECOM, and the Village of Key Biscayne have all presented the recommendations they developed for methods of addressing the effects of sea level rise. Gathering the public together to both explain the effects of sea level rise and flooding, and then to explore the suggestions put forward by the different the organizations involved in the process and data collection allowed the creation of a more in-depth and encompassing Adaptation Plan.

- Venue: The venues for the townhall were booked several weeks in advance. After the first townhall had such a huge reception (ending up with standing room only), the second townhall was booked in a larger venue. The Flood Management Workshop facilitated by AECOM was predicted to have a lower attendance as it was the third public forum, therefore the original venue was used.
- Advertising:
 - Flyers were created professionally through a design consultant
 - Flyers were distributed locally by hand and as inserts in the local paper, *The Islander*
 - A full page advertisement was sent out in the *Miami Herald*
 - Email blasts were sent out to the CSP's list (~600 people), the Village of Key Biscayne Constant Contacts list (~4,000 people) and the INFO listserv at Rosenstiel School (University of Miami), which reaches the entire marine campus on neighboring Virginia Key
 - Events were posted on all social media outlets and on the CSP's website
- Information: Agendas and additional informational handouts were available at each of the public forums. These contained relevant and useful facts and particulars about SLR and the participating organizations, and were provided by the KBCF, CRC, AECOM, and Miami-Dade County. Any power points or other informational materials from the presentations were later provided for review and download online at the CSP website.
- Speakers: Experts from CRC, AECOM, and Miami-Dade County were present at one or more of the townhalls or the workshop. Employees of KBCF and the Village of Key Biscayne (including Mayor Mayra Lindsay) who worked or collaborated on the related projects for the Village were present at all events.
- Other: Catered food was ordered for guests, both to encourage attendance and to acknowledge that evening meetings might interfere with the public's regular dinner.

Outcome/Impact

Relevance & Response

Addressing the affects of SLR on Key Biscayne in an appropriately timely manner is imperative to the preservation of the community and infrastructure. Due to similar geology, the effects currently being felt on Miami Beach are expected to occur in the near future on Key Biscayne. Using their strategies as an example, the Village should be able to make significant headway in protecting the island.

Currently, Key Biscayne has a significant lack of natural barriers to SLR. These barriers include dunes and mangroves in three quarters of the island's beaches. Although the beaches and dunes are artificially renourished every few years (natural renourishment has been mostly interrupted), this must be done carefully so that natural systems are not disrupted, such as turtle nesting season. The tidal variations, especially the king tides, can cause and have caused flooding in recent years, and continue to worsen annually. Areas that did not historically flood during normal tidal fluctuations have more recently been flooding with some regularity, and this trend is expected to continue to deteriorate with SLR.

The geology of Key Biscayne is also a factor in the consistent flooding that it experiences. Like Miami Beach and much of South Florida, it sits atop bedrock of porous limestone, and so often the flooding is not just from tidal fluctuations or storm surge, but also from percolation through ground filtered through the limestone. Key Biscayne also has a very high water table, leaving very little room for water to be re-absorbed into the ground during and after flood events. This

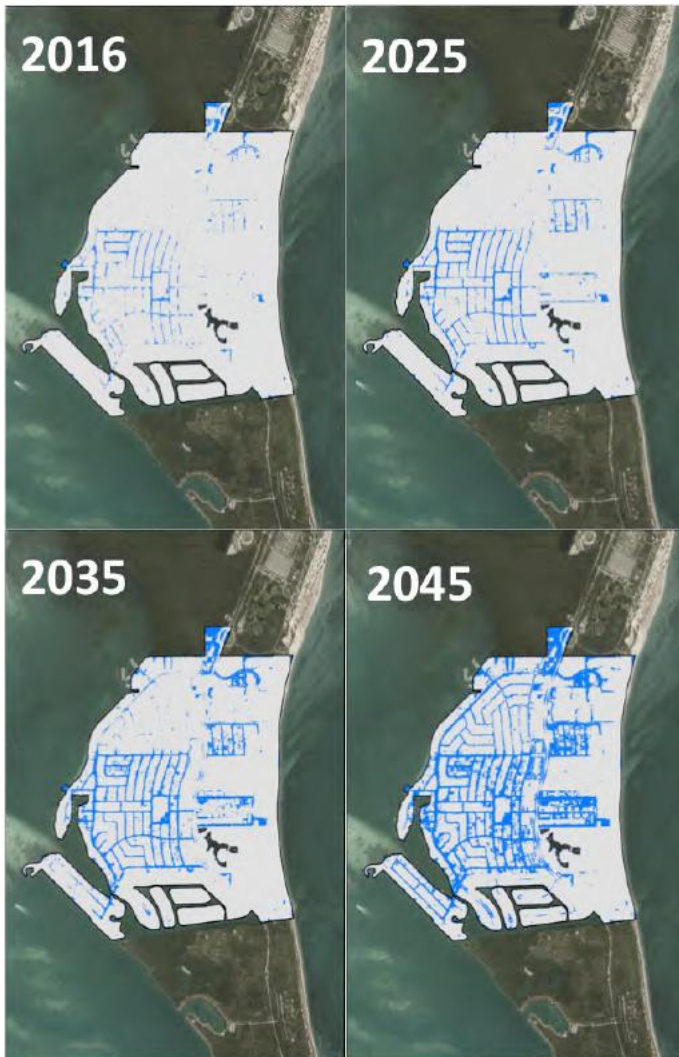


Figure 3. Projected Tidal Flooding for 2016-2045: The blue regions depict areas that will be susceptible to tidal flooding with no adaptation efforts for 2016, 2025, 2035, and 2045.

movement of water into the bedrock also causes salt water intrusion in the freshwater wells. Currently there are 190 total gravity wells on the island, of which only 37 are public and are maintained by the Village (annually inspected). There are 4 wells which are not gravity wells and have water levels sustained with two pump stations. These are also privately owned and maintained.

Over the next three decades, the tidal flooding is projected to affect ever-increasing areas and by 2045, with no adaptation, virtually every road within the Village will experience tidal flooding, as well as a significant number of individual properties. After conducting the SLR risk assessment on Key Biscayne, CRC stated:

“The Village currently experiences tidal flooding and rainfall flooding over limited areas, particularly along low lying roads west of Crandon Blvd. The regions vulnerable to tidal flooding will increase substantially over the next 30 years as sea levels continue to rise. If no adaptation steps are taken by 2045, most roads within the Village will experience tidal

flooding during king tides, as will many low-lying residential and commercial properties.” (Figure 3).

As stated earlier, even at current sea levels the entire island is vulnerable to storm surge flooding. For this reason, the Village is in the Florida Department of Emergency Management’s evacuation Zone A, meaning evacuation is mandatory for a Category 1 or higher storm. Over the next 30 years, the threat of storm surge will increase; with the depth of storm surge inundation increasing roughly in proportion to the rate of local sea level rise. CRC presented maps showing the maximum surge that would result from a Category 3 hurricane under both current and future sea level conditions, to exemplify the general vulnerability of Key Biscayne to storm surges and how this risk will vary with rising sea levels.

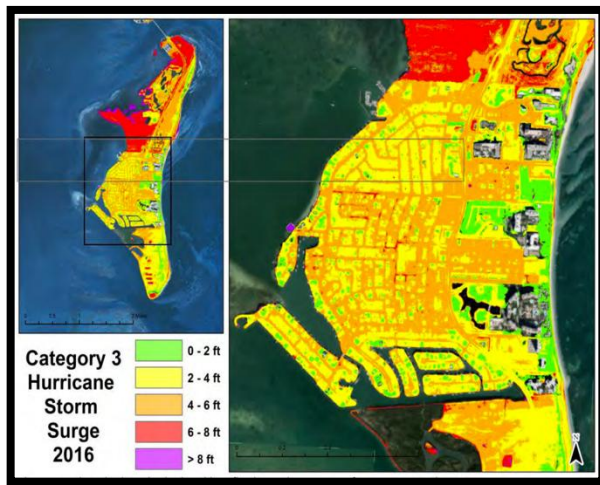


Figure 4: *Current Storm Surge Flooding*: This map shows the maximum height of a storm surge (above the ground elevation) from a Category 3 hurricane at current sea level based on the NOAA SLOSH model simulations and LiDAR topography measurements.

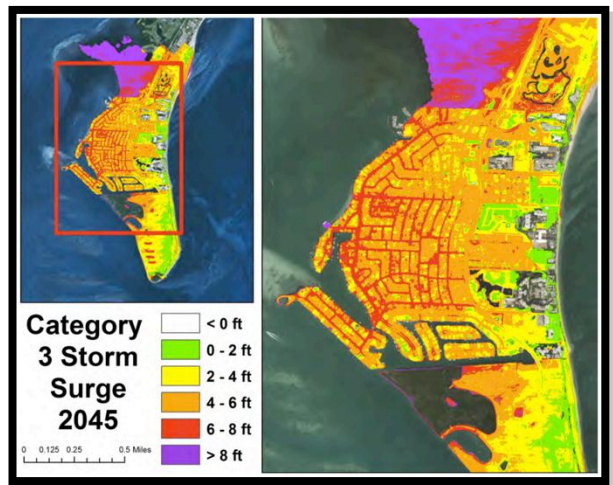


Figure 5: *Projected Storm Surge Flooding for 2045*: This map shows the maximum height of a storm surge (above the ground elevation) from a Category 3 hurricane based on the NOAA SLOSH model simulations using projected sea levels for 2045.

Category 3 hurricanes or higher strike at a rate of approximately once every 8 years for Miami-Dade County, based on historical records from the National Hurricane Center. Note that even for current sea levels, nearly the entire Village will be inundated by the surge, with some areas facing flooding of up to 8 feet (Figure 4). As sea levels rise, storm surging increases proportionately, and, by 2045, the storm surge exceeds 8 feet in certain parts of the Village, with largest water depths occurring primarily over the lowest lying roadways (Figure 5).

Increasing sea levels will also increase the likelihood of rainfall-induced flooding as the water table rises thereby reducing the water holding capacity of the ground (Figure 6). As the difference between mean sea level and elevation of the land decreases, the ability for the land to gravitationally drain into the ocean will also decrease. The water table under Key Biscayne is approximately 0-4 feet below the ground surface,

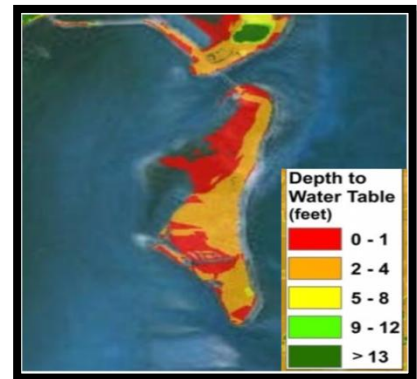


Figure 6: *Depth to water table for the Village of Key Biscayne*. (Source: University of Miami)

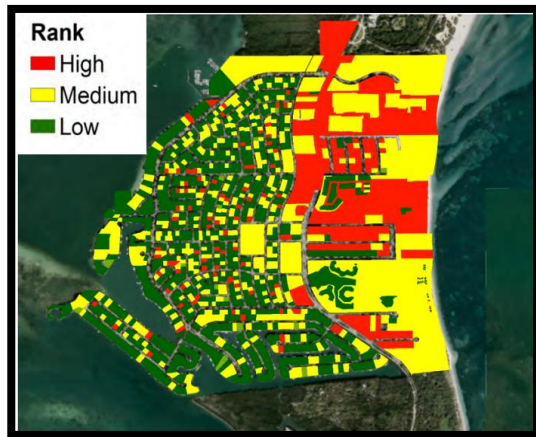


Figure 7: Heavy rainfall flooding risk from low risk (green) to high (red).

meaning there is already not much storage available in the ground to accommodate rainfall.

The vulnerability to rainfall-induced flooding varies substantially throughout the Village of Key Biscayne (Figure 7). A majority of the Village is susceptible to low and or medium risk of heavy rainfall accumulation and groundwater flooding, while areas east of Crandon Blvd generally have a medium to high risk. The large differences from parcel to parcel reflect spatial variations in elevation, water table height, and drainage capacity.

In response to results from the SLR risk assessment and adaptation developments recommended by CRC, AECOM, and NOAA, the Village of Key Biscayne and KBCF began to developing and executing an adaptation plan. The general plan summary is as follows:

Plan Schedule: SLR Adaptation Plan to 2030

- Prepare a SLR Adaptation Master Plan
- Installation of Back Flow Preventers (BFP) → August 2017
- First SLR Public Townhall Forum → November 10, 2016
- Second SLR Public Townhall Forum → February 16, 2017
- Drainage improvements and Flood Management Workshop → May 25, 2017
- Complete installation of level monitoring devices → May 2017
- Evaluate low drainage areas that may require pump stations Plan → completed May 2017
- Backflow preventers in gravity wells → 2025 (first test in September 2017)
- Set up improvement priorities based on remaining finance capabilities → 2018
 - Existing Pump Station (PS) Improvements
 - Deepening shallow gravity wells to 100 ft (contract is currently in place to begin drainage)
 - Lining all metal pipes (priority as problems are identified)
 - Install new PS to wells in K-8 Area
- Pursue additional funding for structure elevations of roads and sidewalks → 2016-2018 (options are being explored as of Fall 2016)
- Pursue additional funding for drainage improvements
- Prepare VKB SLR Adaptation Master Plan for Council Approval → 2017
- Beach Erosion Control Plan implementation (completed)

Results

Drainage Improvements

On November 10, 2016, the KBCF facilitated a townhall forum with CRC and the Village aimed towards educating and informing residents on potential impacts of SLR and courses of action to

be taken by the Village. By the fall of 2016, the Village of Key Biscayne began installing backflow preventers on all municipally owned outflow pipes and has planned to raise existing seawalls protecting the island. In February 2017, the installation of backflow preventers was completed in over 90% of all outfalls with service areas less than 3.7 ft in elevation. The Village completed evaluation of remaining low drainage areas that may require pump stations and backflow preventers by May 2017. Two more pumps stations were installed in low-lying areas (less than 3.7 ft in elevation) which had previously been drained by gravity wells. A suitable location was identified for a third pump station (K-8 center area) and installation of backflow preventers began in the remaining evaluated gravity wells. The Village anticipates to complete the installation of remaining backflow preventers in those gravity wells (in low drainage areas) by 2025, after planned testing of current backflow preventers indicate good functionality. This planned testing should be completed by September 2017. To optimize its mitigation efforts, the Village set up improvement priorities based on remaining finance capabilities. The improvement priorities included: improvements on existing pump stations, deepening shallow gravity wells, lining all metal pipes, and installing new pump station at the K-8 center area.

Monitoring Program

In May 2017, the Village of Key Biscayne completed the installation of sea level monitoring devices that will provide online level measurements including tide. The Village included a rain gauge, which was placed in the south region of the island to provide precipitation instant measurements online as well. To manage the monitoring devices, the Village developed a manual level and salinity monitoring program. This program places responsibility on the Village for both receiving measurements regularly from all devices and also to provide those measurements online.

Beach Erosion Control

The Village of Key Biscayne has implemented a beach erosion control plan, which includes bringing new sand from an offshore site and developing a new dune system along the east coast of the island.

Future recommendations

On top of the improvements already completed, KBCF and the Village have proposed future recommendations of actions. The Village plans on lining all the metal pipes (to account for corrosion) in the island, but will proceed to do so on a “do as we identify” priority basis. There is also a plan to deepen shallow gravity wells in the island to 100 ft, and a contract is already in place to deepen 2 gravity wells (gravity wells 3a and 3b). The Village recommends that in order to move forward with the proposed improvements, additional funding must be pursued for structure elevations of roads, sidewalks, and drainage improvements (stormwater management).

Roadway elevations will be increased to above 4.0 feet. To minimize disruptions, this will be done gradually, by a minimum of 6 inches every 15 years in low-lying areas as required. The street elevation will also be limited by the adjacent houses’ current floor elevation. Sidewalk

elevation will be introduced above flooding elevation as determined by evaluation as needed. Seawall elevation should be increased to a minimum of 5.0 feet.

One of the most important recommendations has to do with new construction. New houses should be raised at least 10 feet minimum (already required) plus another 2.0 feet for safety. Garage floor elevation is recommended to be increased by a minimum of 7.0 feet. Utilities elevation should be performed as required along with new home construction. Also, because Flood Insurance Rate Maps (FIRMs) reflect conditions at the time of the Flood Insurance Study, owners, building designers, and communities should consider future conditions (such as SLR, subsidence, shoreline erosion, and increased storm frequency/intensity) when deciding how high to elevate a building. New structures should be built with 3 feet of freeboard above the BFE, and the appropriate foundation should be selected. Homes in Coastal A Zones are subject to moderate wave action (MoWA) where wave heights are between 1.5 and 3.0 feet and should be constructed to Zone V standards (where wave height is greater than 3 feet).

Recommendations by AECOM, as mentioned earlier, include the following: When it comes to existing buildings, a cumulative Substantial Improvement period of at least five years should be considered to expedite the process of elevation. Once flood levels exceed the lowest floor of a building, the extent of damage increases dramatically, especially in areas subject to coastal waves. We recommend that the proposed ordinance sample language be adopted but edited to adopt a minimum of 3 feet of freeboard for all buildings. This would change the proposed ordinance language for One- and Two-Family Dwellings to be the minimum elevation requirements of the Florida Building Code, plus *two* feet. The language in the proposed ordinance for Developments Other Than One- and Two-Family Dwellings and Critical Facilities would remain the same because they already meet this standard.

The existing zoning code should be updated to tie building height restrictions to the first floor elevation of the structure. This would allow the Village to limit building heights while also allowing for elevation to mitigate future flood damage. Existing homes that cannot be elevated should be mitigated with other techniques such as:

- Abandoning the lowest floor, installing flood openings, using only flood-damage resistant materials below the BFE, and using the below-BFE space solely for storage, parking, and ingress/egress
- Adding additional stories installing flood openings, using only flood-damage resistant materials below the BFE, and using the below-BFE space solely for storage, parking, and ingress/egress
- For homes with high ceilings, raising the elevation of each floor
- Elevating building utilities on platforms and raising electrical outlets and venting above the BFE so that there are no electrical or mechanical systems below the BFE
- Building floodwalls around houses or dry floodproofing