Workshop Summary:
Adaptation to Sea Level Rise
Best Practices
Village of Key Biscayne

Presented by:
AECOM
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Figures

CHAPTER 1 INTRODUCTION

On May 26, 2017, AECOM held two workshops for the Village of Key Biscayne to discuss best practices for adaptation to seal level rise. The morning workshop was held with invited stakeholders, including engineers, architects, scientists, and council members. The evening workshop was held for the public. The objective of this report is to summarize the information that was presented and to address the commentary that arose during the workshops.

CHAPTER 2 FLOOD HAZARDS

Flooding is a hazard throughout Florida, especially South Florida. The Village of Key Biscayne is vulnerable to "king tides[1]", flash flooding, short but very intense rain events, storms coupled with high tides, and hurricanes.

2.1 FEMA Flood Mapping

FEMA Flood Insurance Rate Maps (FIRMs) are official maps that show the community's flood hazard areas, including high-hazard areas (Special Flood Hazard Areas [SFHAs]) and modeled Base Flood Elevations[2] (BFEs). Different flood insurance rates and building requirements apply to these flood hazard areas.

FIRMs are only as accurate as the technical information and analyses performed to create them. FIRMs are a snapshot in time and may become outdated as physical conditions, climate, and engineering methods change.

> The Miami-Dade County Flood Insurance Study and the Village of Key Biscayne FIRMs based on the study were last revised September 11, 2009. FEMA FIRM updates are expected to be released for public comment in 2018 and are likely to be adopted in 2019. The updated FIRMs will likely reflect higher flood risks than the previous versions.

In terms of protecting structures, although elevating to the BFE has previously been recommended, it does not provide sufficient protection against flooding. Storms more severe than the BFE frequently occur, and floods often exceed the BFE and extend beyond the SFHA. In some recent storms (Hurricanes Katrina, Ike, and Sandy), flood levels exceeded the BFE by several feet in some areas and extended far beyond the SFHA shown on the FIRM. Some buildings constructed in compliance with today's BFEs and flood hazard zones may be subject to significantly higher flood insurance premiums in the future if revised FIRMs show higher BFEs and increased flood risk.

Recommendation

Because FIRMs reflect conditions at the time of the Flood Insurance Study, owners, building designers, and communities should consider future conditions (such as sea level rise, subsidence, shoreline erosion, and increased storm frequency/intensity) when deciding how high to elevate a building.

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[1] A King Tide is a non-scientific term people often use to describe exceptionally high tides. Tides are long-period waves that roll around the planet as the ocean is "pulled" back and forth by the gravitational pull of the moon and the sun as these bodies interact with the Earth in their monthly and yearly orbits. Higher than normal tides typically occur during a new or full moon and when the Earth is at its perigee, or during specific seasons around the country. (Source: http://oceanservice.noaa.gov/facts/kingtide.html)

[2] The BFE (also known as the1-percent annual chance flood) is based on model studies of both historical and hypothetical storms. The 1-percent annual chance flood means that, statistically, there's a 1% chance every year that there will be a flood that looks like the one on the FEMA maps. The BFE is a baseline pulled together from historic weather data, local topography, and the best science available at the time. It's a reasonable standard to insure against, but it is not a guarantee that it will flood only 1 time every 100 years and the flood will look exactly like it does on the maps.

2.2 Southeast Florida Regional Climate Change Compact

In January 2010, the Southeast Florida Regional Climate Change Compact was executed by Broward, Miami-Dade, Monroe, and Palm Beach Counties to coordinate mitigation and adaptation activities across county lines. The counties recognized the vulnerability of Southeast Florida to the impacts of climate change and resolved to work collaboratively on mitigation and adaptation strategies such as establishing joint policies to influence climate and energy legislation and funding at State and Federal levels, developing a Regional Climate Change Action Plan, and hosting annual summits to review progress and discuss strategies.

In October 2015, the Southeast Florida Regional Climate Change Compact issued a Unified Sea Level Rise Projection report for Southeast Florida. Based on a review of several models and other scientific literature, the report projected sea level rise to be between 14 and 26 inches by the year 2060 (Figure 1). For more information, the report can be accessed at: http://www.southeastfloridaclimatecompact.org/wp-content/uploads/2015/10/2015-Compact-Unified-Sea-Level-Rise-Projection.pdf.

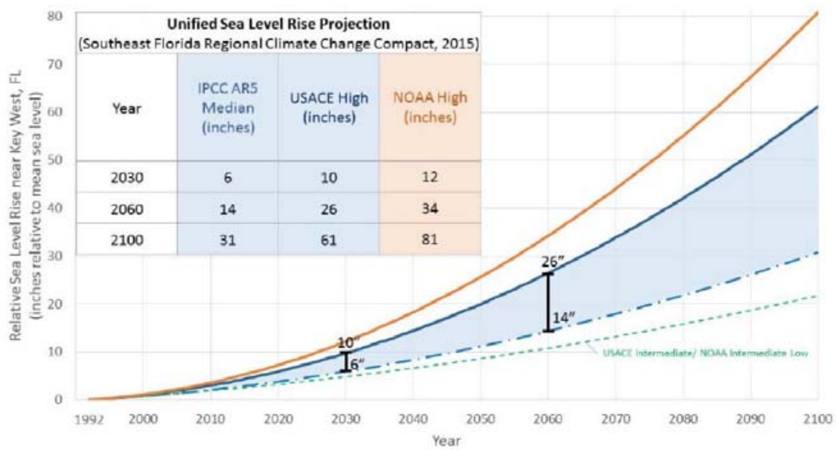

Figure 1: Unified Sea Level Rise Projection. These projections are referenced to mean sea level at the Key West tide gauge. The projection includes three global curves adapted for regional application: the median of the IPCC AR5 RCP8.5 scenario as the lowest boundary (blue dashed curve), the USACE High curve as the upper boundary for the short term for use until 2060 (solid blue line), and the NOAA High curve as the uppermost boundary for medium and long term use (orange solid curve). The incorporated table lists the projection values at years 2030, 2060 and 2100. The USACE Intermediate or NOAA Intermediate Low curve is displayed on the figure for reference (green dashed curve). This scenario would require significant reductions in greenhouse gas emissions in order to be plausible and does not reflect current emissions trends.

Figure 1: Southeast Florida Regional Climate Change Compact, projected sea level rise

2.3 April 2017 Flood Vulnerability Assessment (by Coastal Risk Consulting)

In April 2017, Coastal Risk Consulting issued a Flood Vulnerability Assessment for the Village of Key Biscayne. This vulnerability assessment focused the effects of sea level rise on projected:

- Tidal flooding (including king tides)
- Storm surge flooding
- Flooding due to rain

The study used a proprietary model based on publicly available databases and best practices from the National Oceanic and Atmospheric Administration (NOAA) and United States Army Corps of Engineers.

The report can be accessed at: http://www.keyscience.org/wp-content/uploads/2017/02/CRC-VillageOfKeyBiscayne-FinaltVulnAssess-SM.pdf.

2.3.1 Tidal Flooding

The Coastal Risk Consulting study concluded that, due to sea level rise, virtually every road, as well as a significant number of individual properties within the Village, will experience tidal flooding by the year 2045. The portions of the Village that will be most significantly affected are the area west of Crandon Blvd. between Heather and Mashta Drives, the area east of Crandon Blvd. between Heather and Sonesta Drives, and Galen and Enid Drives (Figure 2).

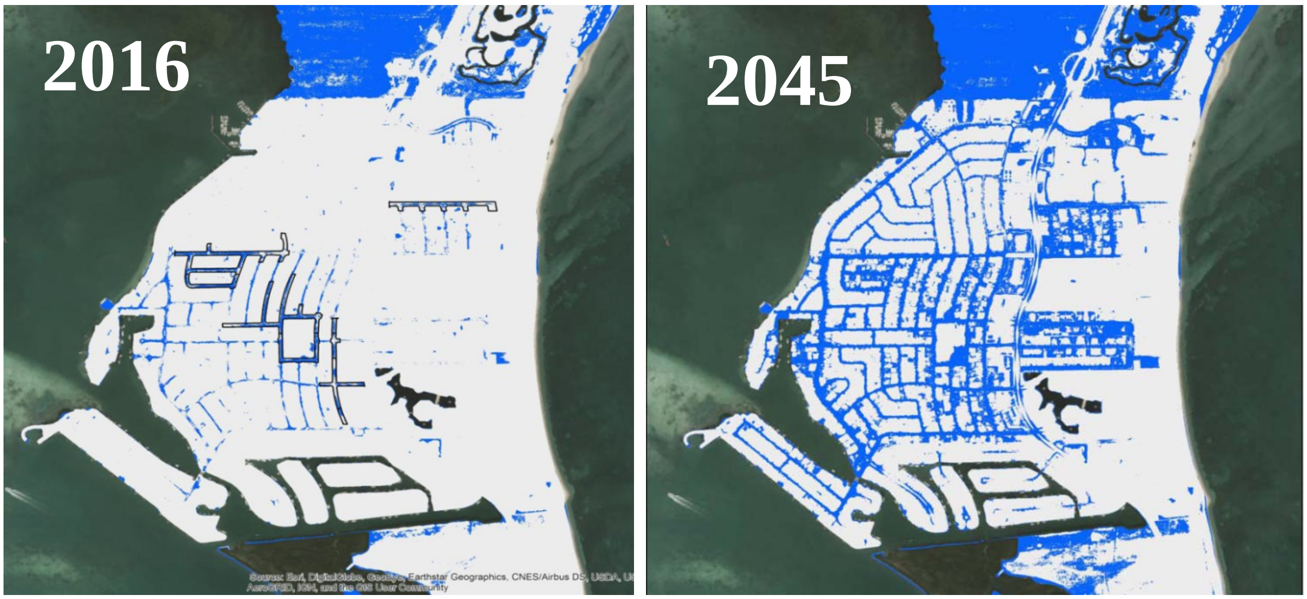

Figure 2: Side-by-side comparison of expected king tide flooding for the years 2016 and 2045

2.3.2 Storm Surge Flooding

The Coastal Risk Consulting study concluded that roads would be inundated by approximately 6 to 8 feet of water, and most private properties would be inundated by 4 to 6 feet of water during a modeled Category 3 hurricane in the year 2045 (Figure 3).

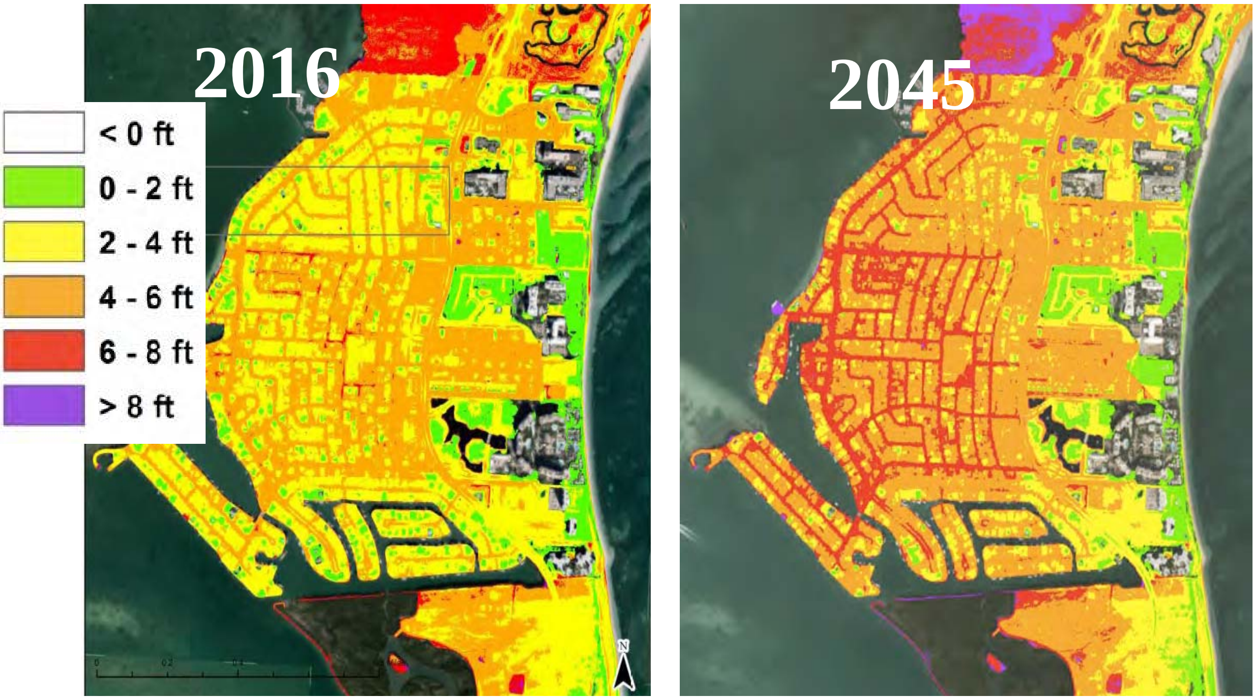

Figure 3: Maximum height of a storm surge (above the ground elevation) from a Category 3 hurricane based on the NOAA Sea, Lake and Overland Surges from Hurricanes (SLOSH) model simulations and LiDAR topography measurements. The models show the difference between predicted storm surge based on 2016 and 2045 sea levels.

2.3.3 Flooding Due to Rainfall

The Coastal Risk Consulting study also concluded that as the mean sea level rises, flooding caused by heavy rainfall will become more and more frequent as the average water table height rises in the limestone bedrock underneath, and the ground becomes less absorbent in heavy rain events.

The water table under Key Biscayne is only approximately 0 to 4 feet below the ground surface, so there is not much storage available in the ground to accommodate rainfall (Figure 4).

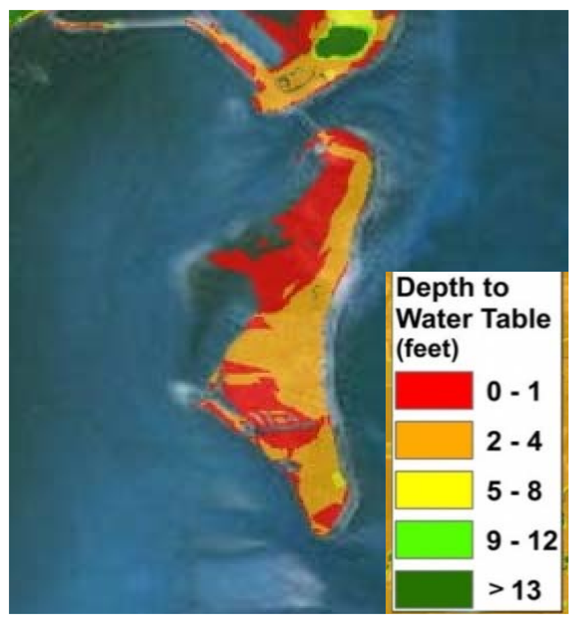

Figure 4: Depth to water table for the Village of Key Biscayne. (Source: University of Miami)

CHAPTER 3 PROPOSED FLOODPLAIN ORDINANCE

The Village of Key Biscayne is currently in the process of adopting a new floodplain ordinance based on a model ordinance (developed by the Florida Division of Emergency Management). It is coordinated with the Florida Building Code (FBC) and satisfies the requirements of the National Flood Insurance Program (NFIP).

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 of Key Biscayne chose to amend the model ordinance with a few higher standards:

- Cumulative Substantial Improvement
- Additional elevation (freeboard)

3.1 Cumulative Substantial Improvement

The proposed ordinance includes a cumulative Substantial Improvement provision, meaning that 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.

> See FEMA P-758, *Substantial Improvement/Substantial Damage Desk Reference*, for a complete explanation of the Substantial Improvement/Substantial Damage determination. Section 5.7.2 of the Desk Reference has a description of cumulative substantial Improvement.

Some requirements may include:

- Elevation above the BFE
- Use of flood-damage-resistant materials below the BFE
- Open foundations in Zone V (piles or columns)
- Flood openings in Zone A
- Elevation of utilities

The benefits of adopting cumulative Substantial Improvement include:

- Reduces the likelihood of deliberately phasing improvements to avoid the "50% rule"
- Earns Community Rating System (CRS) credits
- Speeds up bringing all floodprone structures into NFIP compliance
- Reduces future flood damage

Some possible disadvantages of cumulative Substantial Improvement include:

- Higher initial cost to bring the entire structure into compliance
- Requires extra recordkeeping and administrative procedures

There are also pros and cons for selecting longer cumulative periods (such as 10 years or the life of the structure) and for selecting shorter periods (such as one year or five years). The period of time will also determine the number of CRS points. Please see FEMA P-758 for more information on how market value over time will be handled. Communities that adopt this provision should have written administrative procedures in place.

Recommendation

A cumulative Substantial Improvement period of at least five years should be considered to expedite the process of elevating existing buildings.

3.2 Additional Elevation (Freeboard)

The proposed ordinance does include freeboard, but not the maximum amount.

The proposed ordinance states:

- One- and Two-Family Dwellings. One- and two-family dwellings, shall be developed in accordance with the minimum elevation requirements of the Florida Building Code, plus one foot. (equivalent to 2 feet above BFE[3])
- Developments Other Than One- and Two-Family Dwellings. All developments other than one- and two- family dwellings shall be developed in accordance with the minimum elevation requirements of the Florida Building Code, plus two feet. (equivalent to 3 feet above BFE[3])
- Critical Facilities. All Critical Facilities shall be elevated or protected to or above the 500-year flood elevation plus one foot. (equivalent to 2 feet above 500-year strom[3])

> The Florida Building Code (FBC) applies to all buildings other than dwellings and refers to American Society of Civil Engineers (ASCE) 24, *Flood Resistant Design and Construction*, for specific requirements. Virtually all buildings within the scope of the FBC are required to be higher than the minimum BFE. See the "Highlights of ASCE 24" on the Florida Division of Emergency Management's code resources webpage: http://www.floridadisaster.org/Mitigation/SFMP/lobc_resources.htm.

Recommendation

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.

[3] The 2015 I-Codes, on which the next (6th) edition of the FBC will be based, require minimum freeboard of BFE + 1 foot in all flood zones for all buildings, including dwellings, so the proposed ordinance will require an additional foot beyond that.

CHAPTER 4 CONSTRUCTION BEST PRACTICES FOR ADAPTATION TO SEA LEVEL RISE

Given the Village's vulnerability to hurricanes and storm surge in addition to sea level rise, flood damage prevention for buildings and infrastructure is vital. The workshop facilitators presented many different best practices for mitigating flood vulnerability including:

- Elevation of New Structures
- Flood Damage Mitigation for Existing Structures that Cannot be Elevated
- Street and sidewalk elevation
- Seawall elevation
- Utility improvements

The 2012 NFIP reauthorization legislation (called the Biggert-Waters Flood Insurance Reform Act of 2012) eliminates flood insurance premium subsidies and "grandfathering" for many existing buildings that are—or may be in the future—below the BFE. This means that homes that are not elevated to or above the BFE may be subject to substantial increases in flood insurance premiums. For more information, see https://www.fema.gov/media-library/assets/documents/83905.

4.1 Elevation of New Structures

Elevating structures above the projected flood levels is one of the best ways to mitigate future damage to the structure due to flooding. There are many advantages to structure elevation:

- Less burden on government and nonprofit organizations for assistance
- More money spent locally to help tax revenues recover
- Property owners use less savings and borrow less for repairs
- Small businesses are more likely to stay open
- Flood insurance premiums drop significantly as freeboard increases

Coastal A Zones will be identified in the new FIRMs expected to be released in 2018 for public comment, and structures in these areas will be required to be built to Zone V standards by the next edition of the FBC.

Elevating new buildings can add initial construction costs to a project, but studies have found that the initial costs are recuperated over the life of the structure due to flood damage avoided and flood insurance premium savings. An independent report prepared for FEMA, *Evaluation of the National Flood Insurance Program's Building Standards* (Christopher Jones and Associates, October 2006), provides clear evidence of the benefits of adding freeboard. It documents the added costs (as a percent of the cost of building to the BFE) and the benefits of adding freeboard. Approximately 1,500 combinations of house size, foundation type, flood zone, flood elevation, freeboard added, and discount rate were evaluated. The benefits considered were two-fold: flood damages avoided and flood insurance premium savings. The report concluded that, based only on flood damages avoided, it is worth spending an additional percentage of the at-BFE building cost to incorporate freeboard, where the percentage of benefits generally ranged from less than 1 percent to 5 percent for 1 foot of freeboard, depending on the flood hazard zone. By comparison, the cost of adding 1 foot of freeboard ranged from 0.25 percent to 3 percent of the at-BFE building cost, depending on the type of foundation and the flood hazard zone. For more information, the report can be accessed at: https://www.fema.gov/media-library-data/20130726-1602-20490-5110/nfip_eval_building_standards.pdf.

Recommendation

New structures should be built with 3 feet of freeboard above the BFE, and the appropriate foundation should be selected (Figures 5 and 6). 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 (Figure 7).

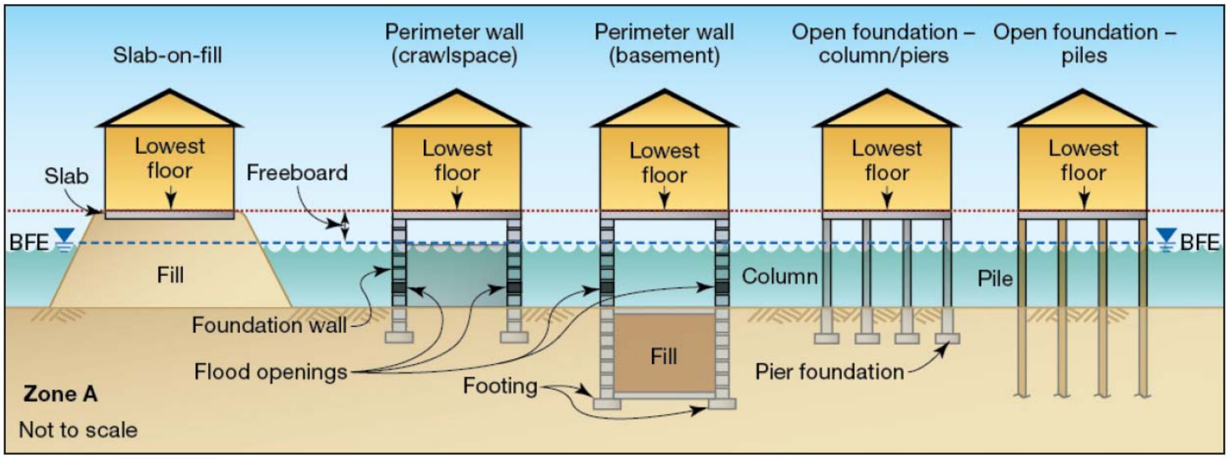

Figure 5: Recommended foundation types for Zone A. (Source: FEMA Hurricane Sandy Fact Sheet 2)

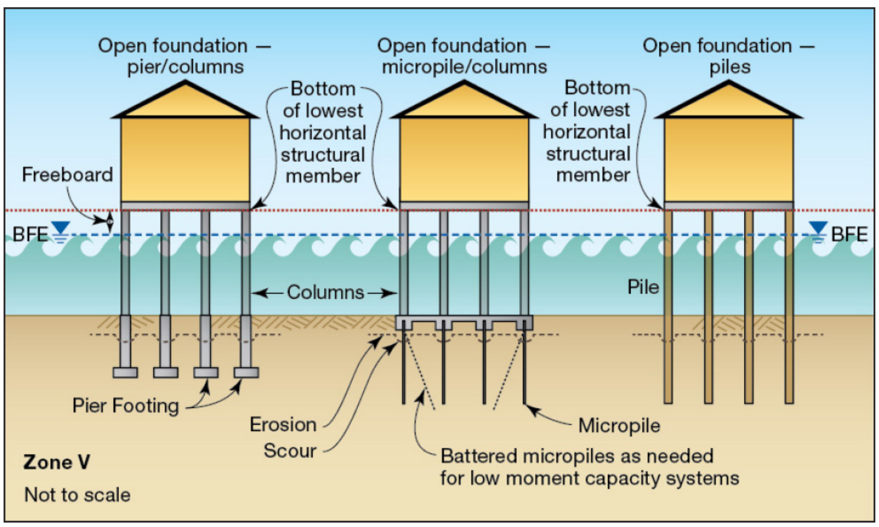

Figure 6: Recommended foundations types for Zone V and Coastal A Zones. (Source: FEMA Hurricane Sandy Fact Sheet 2)

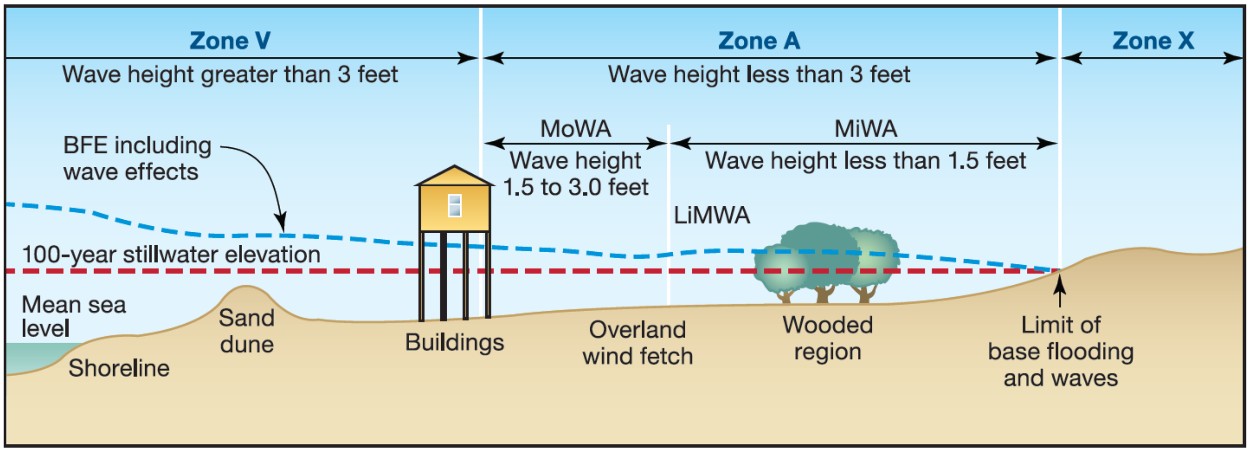

Figure 7: Schematic of FEMA flood zones. The coastal A Zone is the "MoWA" area where wave heights are between 1.5 and 3.0 feet. (Source: FEMA Independent Study)

4.2 Flood Damage Mitigation for Existing Structures that Cannot be Elevated

There are some challenges to elevating existing structures in the Village of Key Biscayne. The existing building stock is typically made with masonry walls that cannot be elevated, and elevating could also conflict with building height restrictions in the zoning code.

Recommendations

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 (Figure 8)
- 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 (Figure 9)
- 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 (Figure 10)
- Building floodwalls around houses (Figure 11) or dry floodproofing (Figure 12)

FEMA P-1037, Reducing Flood Risk to Residential Buildings That Cannot Be Elevated provides mitigation options that can be used to protect properties from flooding, save money over time, and potentially reduce flood insurance premiums for homes where elevation is not an option. FEMA P-1037 can be accessed at: https://www.fema.gov/media-library/assets/documents/109669.

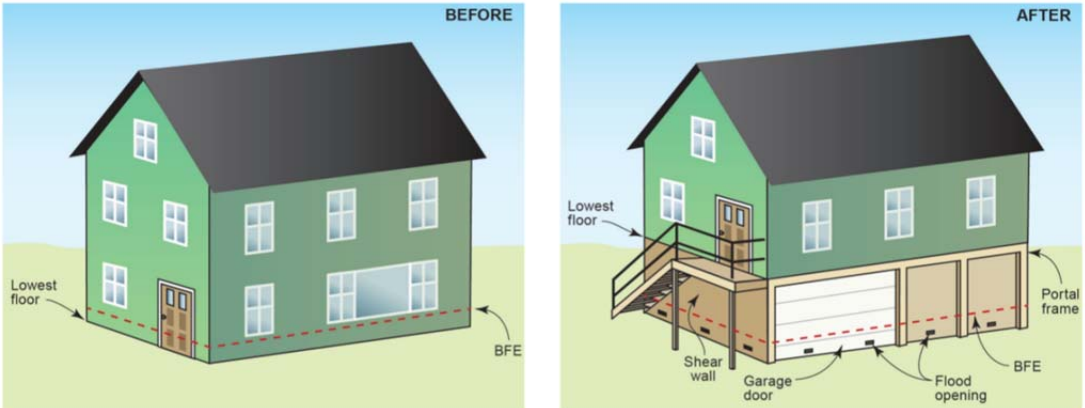

Figure 8: Abandoning the lowest floor and using the below-BFE space solely for storage, parking, and ingress/egress (Source: FEMA P-1037)

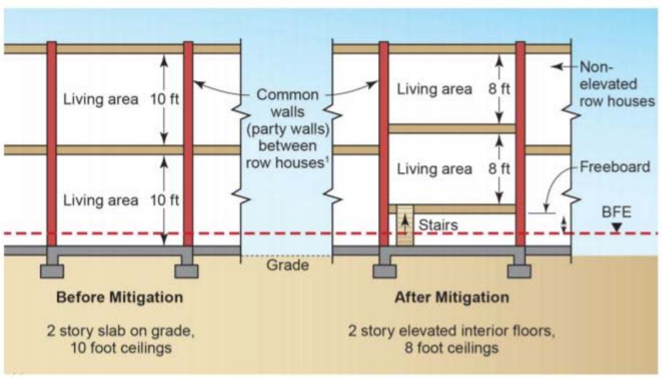

Figure 9: Raising the elevation of each floor for homes with high ceilings. The below-BFE space would be used solely for storage, parking, and ingress/egress. (Source: FEMA P-1037)

Figure 10: Elevation of building utilities (mechanical and electrical equipment) on platforms. (Source: FEMA P-1037)

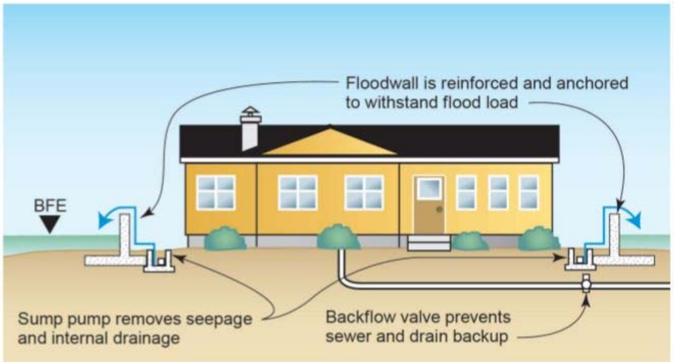

Figure 11: Building floodwalls around houses, and installing backflow valves and sump pump drainage. (Source: FEMA P-1037)

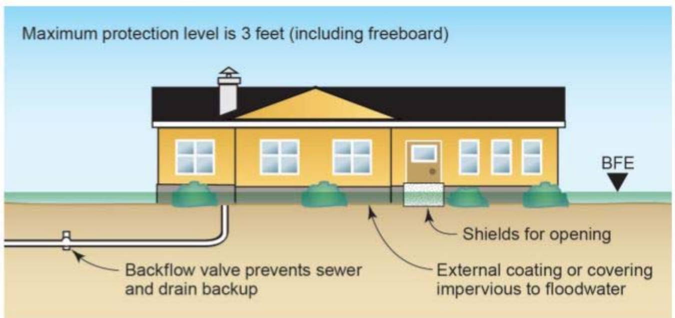

Figure 12: Dry floodproofing by reinforcing foundation walls, using flood shields over openings, and installing backflow valves. (Source: FEMA P-1037)

Additionally, there are many resources for homes that can be elevated. For more information, see the following resources:

- The FEMA NFIP Technical Bulletins, https://www.fema.gov/media-library/collections/4, contain relevant information about the NFIP.
- FEMA P-259, *Engineering Principles and Practices of Retrofitting Floodprone Residential Structures* (2012), http://www.fema.gov/media-library/assets/documents/3001, FEMA P-259 provides engineering design and economic guidance on what constitutes feasible and cost-effective retrofitting measures for floodprone residential structures.
- FEMA P-312, *Homeowner's Guide to Retrofitting*, 3rd Edition (2014), http://www.fema.gov/media-library/assets/documents/480, provides information about available options for retrofitting existing residential buildings.

4.3 Street and Sidewalk Elevation

Miami Beach is in the process of elevating streets (Figure 13). Water from the elevated streets and residential properties is collected, filtered, and discharged into Biscayne Bay. This requires cooperation from adjacent property owners. Water that would be trapped by the elevated streets and sidewalks is drained into the underground storm drains.

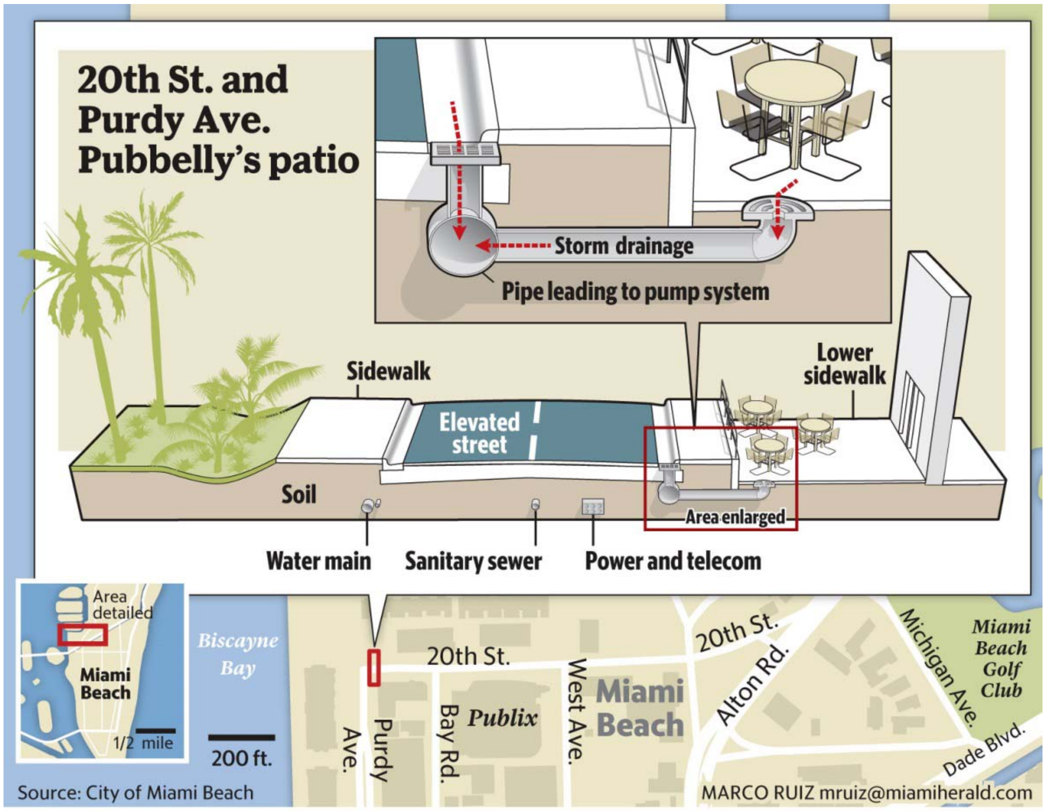

Figure 13: Elevated roadway at 20th Street and Purdy Avenue. The patio (private property) is 2 feet lower than the street. Floor drains in the patio convey water into the roadway drainage system, which routes water to the pump station.
(Source: http://www.miamiherald.com/news/local/community/miami-dade/miami-beach/article41141856.html)

Recommendation

Streets and sidewalks can be elevated; however, care needs to be taken to reduce negative impacts on neighboring properties, and minimize other unintended consequences. Streets and sidewalks should be elevated above projected sea level rise elevations. Pump systems may be needed to convey trapped floodwater away from impacted properties. If the streets and sidewalks are elevated in phases, the drainage/pumping system should be designed and sized to accommodate all of the anticipated water that would be trapped or diverted once the streets and sidewalks are raised to the final elevation.

4.4 Seawall Elevation

The Village of Key Biscayne has an extensive system of seawalls along the west side and a few sea walls on the east side, facing the Atlantic Ocean. The majority of the seawalls are privately owned. The seawalls offer protection from waves and some protection from elevated bay floodwater. However, the porous nature of the foundation soil allows water to infiltrate the foundation and rise within areas protected by the seawall.

Ft. Lauderdale is also considering changing their floodplain ordinance to increase the required height of seawalls. This would be triggered when:

- The owner installs a new seawall

- The owner applies for a repair permit and it is determined that the damage to the seawall triggers substantial repair threshold (at least 50 percent of the value or the structure must be repaired or replaced)
- The owner is cited for having a seawall in disrepair and it is determined that the damage to the seawall triggers a substantial repair threshold
- The owner is cited for allowing tidal waters entering his/her property to impact adjacent properties or a public right-of-way and the owner elects to install a new seawall or to raise his/her seawall to come into compliance

In April 2016, Miami Beach commissioners approved a plan to increase the minimum seawall height to 5 feet 6 inches above mean sea level for private seawalls, and 7 feet 3 inches for public seawalls. They did not dictate a maximum height.

Recommendations

Before elevating seawalls, the following parameters should be considered over the design life of the structure:

- Potential wave height
- Extreme high tides
- Storm surge
- Sea level rise

Floodplain ordinance changes similar to the ones being adopted in Ft. Lauderdale and Miami Beach could be adopted by the Village of Key Biscayne to motivate residents to elevate their private seawalls. Note that FEMA FIRM updates are expected in 2018/2019. It might be prudent to wait for the updated maps before setting a new minimum height.

4.5 Utility Improvements

Florida Power and Light's website states that more than 37 percent of its current system is already underground, and more than two-thirds of new distribution lines have been placed underground. The buried power lines are resilient because when one line becomes damaged, redundant lines switch on to supply power in the event of a disruption. The redundant systems are advantageous because they are more reliable in both normal and adverse weather conditions, especially during wind and lightning events, there are fewer power interruptions, and there are no poles or overhead wires that would be subject to wind and storm damage.

Recommendations

The Village of Key Biscayne should work with Florida Power and Light to ensure that redundant underground electrical systems are installed and maintained.

Backflow preventers should be installed on all outlet pipes with inverts below the projected flood levels. Backflow preventer valves should also be installed for all homes that have sewer pipes below the projected flood level (Figures 10 and 11).

Facility owners should install fuel pumps for large storage tanks that are designed to operate during flood conditions. Residential and commercial electric power systems and cooling systems should be elevated 1 foot above the ASCE 24-recommended elevation[4].

Owners of critical facilities, schools, high-rise residential buildings, etc. should provide emergency back-up power systems in their buildings and protect them from flood damage. Redundant systems that automatically turn on when the main power system shuts off are critical to building performance and recovery after flood events. FEMA P-348, *Protecting Building Utility Systems from Flood Damage* (2017), https://www.fema.gov/media-library/assets/documents/3729, provides guidance on the design and construction of flood-resistant building utility systems.

[4] *American Society of Civil Engineers Flood Resistant Design and Construction* (ASCE-24) is a referenced standard in the International Building Code® (IBC) and the International Residential Code® (IRC). Building and structures within the scope of the IRC/IBC proposed to be constructed in flood hazard areas must be designed in accordance with ASCE 24.

CHAPTER 5 CONCLUSION

Overall, the workshops were well received by attendees. Despite the challenges the Village of Key Biscayne faces due to sea level rise, there are many mitigation options that can be applied to reduce flood risks now and into the future. As the Village moves forward, there are several topics under consideration:

1. Changes in the Village's built environment and visual appearance as buildings are elevated due to higher freeboard.
2. Relationship of commercial and retail spaces to the sidewalk and street levels, as building elevation is considered. The use of other floodproofing methods may be more appealing but the ease and effectiveness are challenging.
3. Utility of pervious pavement in appropriate areas, especially with regard to the amount of storage space below ground for water runoff.
4. The balance between investment in mitigation options and the return realized in flood protection and insurance premiums.

The Village is very proactive in addressing these issues, and this will benefit the residents and commercial interests as future conditions change.