Final Progress Report

Envision Cedar Key: Sea Level Rise Adaptation Planning Tool

(Grant Number: 21.h.sm.100.125)

June 30, 2021

City of Cedar Key & University of Florida Historic Preservation Program

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City of Cedar Key & University of Florida Historic Preservation Program
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Project Overview

Envision Cedar Key: Sea Level Rise Adaptation Planning Tool is the Phase Two project expanding the Phase One *Cedar Key Digital Flood Vulnerability Assessment* (19.h.sm.200.071). The goal of Phase One was to design and examine the methodology and workflow of 3D digital sea-level-rise modeling, visualization, and impact assessment using digital documentation technologies, including terrestrial laser scanning and geographic information system (GIS). Building upon the success of Phase One, the Phase Two project focused on developing an online database where planners, residents, and people outside the town can access the information generated from the two projects, understand short-term flood and longer-term sea-level-rise issues, and make informed decisions for mitigation and adaption for the city and individual properties, including historic structures. Phase Two expanded the documentation of the historic urban environment of Cedar Key, including the northwestern area between 5th Street and 8th Street and the eastern end stretched from A Street.

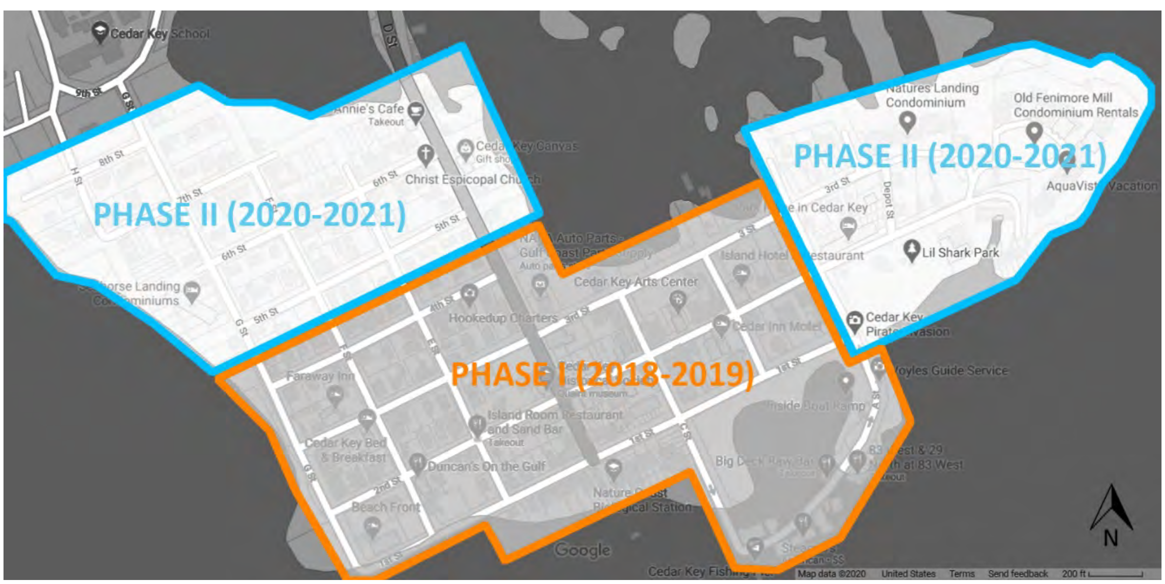


Figure 1. Study Area Map, Cedar Key, Levy County, Florida

Project Deliverables (Phase Two)

- Florida Master Site File (FMSF) forms, photographs, and maps
- Terrestrial-laser-scan data
- 3D sea-level-rise (flood) visualizations
- Vulnerability assessments: First-floor levels of every individual structure in the study areas (both Phase One and Phase Two) measured from the sea level and grade
- Geospatially referenced online database (geographic information system or GIS), housing FMSF and photographic records, first-floor levels, and building type information
- Resiliency and adaptation strategy guideline, including a guide to the GIS database as an adaptation planning tool
- StoryMaps website, combining the virtual tour of Cedar Key's present (360-degree panoramas) and future (sea-level-rise visualizations) conditions and the viewer of the 3D terrestrial-laser-scan data

Florida Master Site File and Digital Documentation

The University of Florida Historic Preservation Program team, in collaboration with the City of Cedar Key, completed 50 FMSF records, including 45 new and 5 update forms. The new surveys selected properties based on their ages of 45 or older (built in or earlier than 1976). The team checked the validity of the existing FMSF surveys (dated 1986-2004 and 2006-2007) in the Phase Two area and updated the forms when alteration or demolition was recognized. The FMSF forms, photographs, and maps were submitted.

The project team completed 3D terrestrial-laser-scan data acquisition using two laser scanners, including FARO Focus S 350 and FARO Focus 3D X 130. Terrestrial laser scanning helped measure the visible surfaces of objects and environments with millimeter accuracy and a great range. It recorded hundreds or thousands of spot coordinates (represented by x, y, and z axes) per second. The resolution was set to 10240 x 4267 points (the maximum number of points each scanning can acquire in an empty box room), which was recommended for a typical outdoor built environment.

The team collected laser-scan data from 252 locations in the Phase Two area. The laser-scan data was then processed into 3D point clouds (digital models), which were a photo-realistic, movable, scalable 3D data set that relays existing conditions. The project team conducted data acquisition only from the streets (right of way). The recorded urbanscape includes building exteriors visible from the streets (e.g., building facades), topography, landscapes, and other street features. Some screenshots of the dataset were attached below.

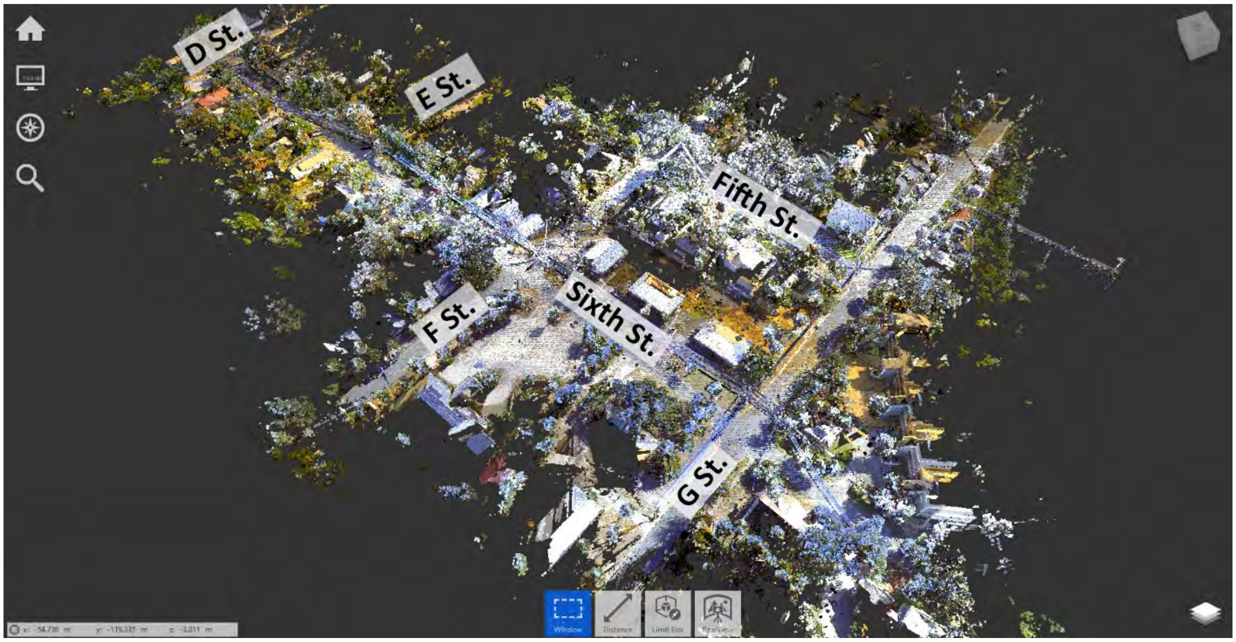


Figure 2. Laser scan point cloud aerial view, looking southeast.

Figure 3. Laser scan point cloud aerial view, looking south.

Figure 4. Laser scan point cloud aerial view, looking southwest.

Figure 5. 2nd Street and Old Mill Drive, looking northeast.

Figure 6. 6th Street intersecting with D Street at the end.

Figure 7. Single-family residence (FMSF #: LV01032) on 8th Street and H Street.

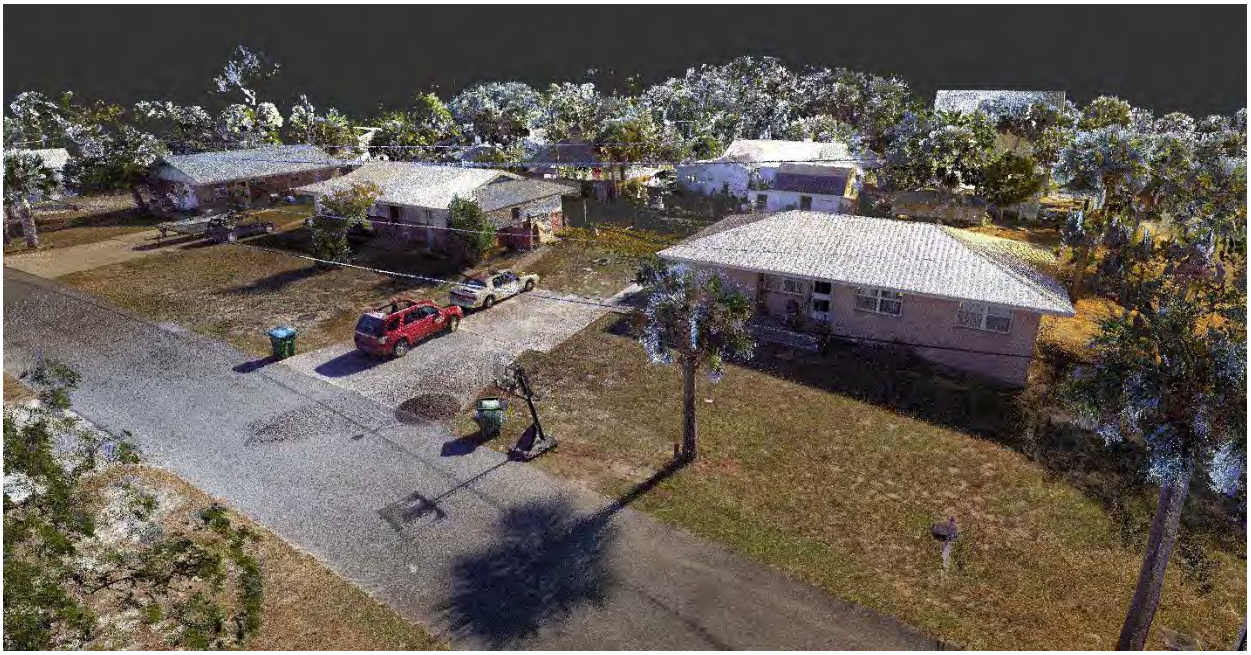


Figure 8. Housing complex (FMSF #: LV01022) on 6th Street near G Street.

Figure 9. Single-family residence (FMSF #: LV00192) on 5th Street near F Street.

Figure 10. Single-family residence (FMSF #: LV00728) on 7th Street and H Street.

Figure 11. Cedar Key Community Center and “Indian Burial Mound” (left)

Figure 12. Fiber Factory Warehouse (FMSF #: LV01050) on Old Mill Drive.

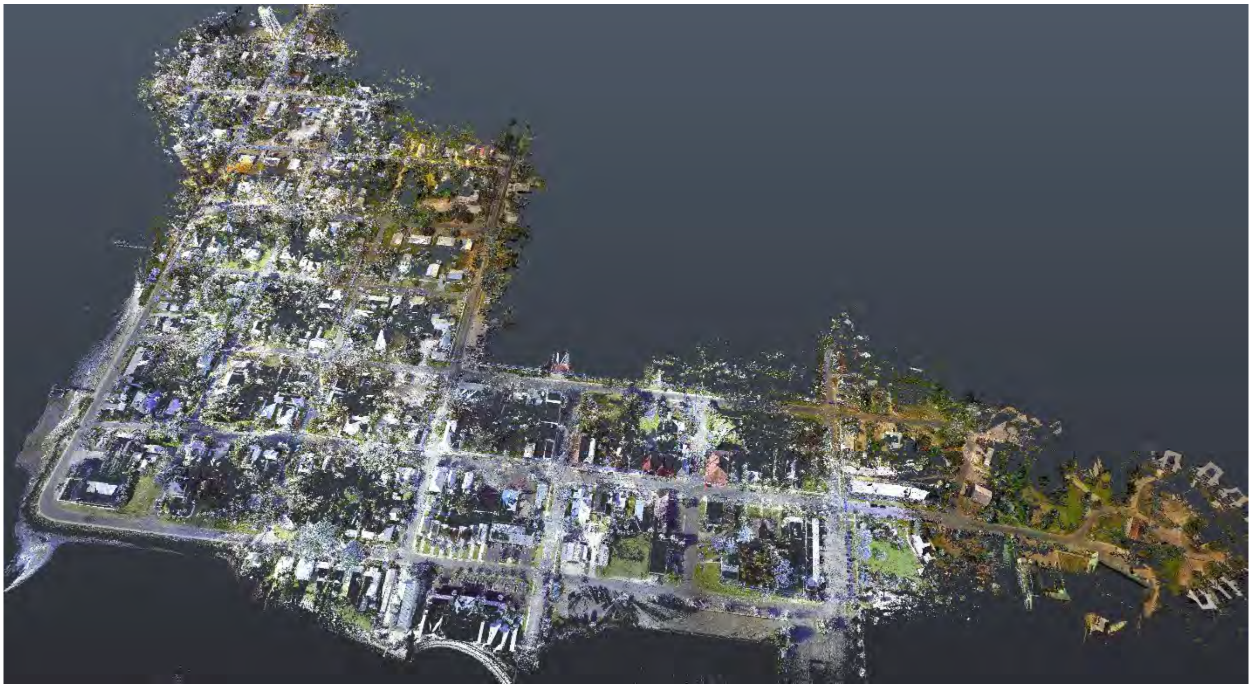


Figure 13. 3D laser-scan point cloud merging the Phase One and Phase Two datasets.

3D Sea-Level-Rise (Flood) Visualizations

The project team created 15 sea-level-rise (flood) visualizations for three vulnerable locations in Cedar Key. These are additions to the Phase One visualizations of three other places. The new simulation locations were selected through a discussion with a Cedar Key Water and Sewer District representative. The results are on the following pages, and the files were submitted.

Process and Data Collection

The team first collected the National Oceanic and Atmospheric Administration (NOAA)'s sea-level-rise scenarios for Cedar Key and primary past floods, like Hurricane Hermine. The project team chose the Intermediate-High scenario, a medium-level intensity, to avoid underestimating or exaggerating future circumstances. The scenario represented future high-tide-level projections with ten-year intervals.

Scenarios from the NOAA website were initially relative to the local mean higher high water (MHHW) (i.e., high tide) tidal datum to represent the increases of high tide levels. The project team referenced the projections to the North American Vertical Datum of 1988 (NAVD88), a national geodetic vertical datum, to align all the collected data to one common datum. The up-to-date difference between the NAVD88 and the current local MHHW is 1.54 ft.

The daily high tide level of the year 2100 is expected to be close to the 2016 Hurricane Hermine flood, which caused severe damage to Cedar Key. Hurricane Hermine's verified peak flood level was 7.45 ft from NAVD88 (5.91 ft, from MHHW).

Datum	2020	2030	2040	2050	2060	2070	2080	2090	2100
High Tide Level Ref. to NAVD88	**2.10**	**2.46**	**2.85**	**3.38**	**4.00**	**4.72**	**5.48**	**6.40**	**7.38**
Sea Level Rise Relative to Yr. 2000 High Tide (MHHW)	0.56	0.92	1.31	1.84	2.46	3.18	3.94	4.86	5.84

Table 1. High tide elevations under the NOAA sea-level-rise Intermediate-High scenario for Cedar Key, Florida (unit: feet).

Data Source: NOAA. Sea Level Rise Viewer. https://coast.noaa.gov/slr/
NOAA Tidal Station ID: 8727520 Cedar Key, Florida
Cedar Key Elevation Datum Chart: https://tidesandcurrents.noaa.gov/datums.html?id=8727520

Secondly, the project team georeferenced the 3D terrestrial-laser-scan data to existing ground elevation data. The University of Florida's GeoPlan Center has recently updated its *Sea Level Scenario Sketch Planning Tool*, developed for the Florida Department of Transportation. It added the most current airborne LiDAR data (state-wide ground elevation data) in the digital elevation model (DEM) format, a 2D rasterized image whose each pixel contains an elevation value. The elevation data for Cedar Key is from 2007, and its vertical datum is NAVD88.

UF GeoPlan Center. Sea Level Scenario Sketch Planning Tool. https://sls.geoplan.ufl.edu/

Lastly, the project team placed water surfaces (current high tide) in the 3D laser-scanned copy of the built environment aligned with the ground elevation data referenced to NAVD88. The team then virtually inundated the examined areas based on the chosen sea-level-rise scenario, NOAA Intermediate-High (I-H). The modeling adopted a so-called "bathtub model," where the project team moved the water surfaces vertically and horizontally without taking wind and wave actions, subsidence, and other variables into account. The visualizations represent daily high tides in the future and the new sea levels' potential impacts on the urban environment of Cedar Key.

Sea-Level-Rise (Flood) Visualization Results

Visualization 1. Year 2020. NOAA I-H 1.54 ft Referenced to NAVD88. 1st Street & D Street.

Visualization 2. Year 2060. NOAA I-H 4.00 ft Referenced to NAVD88. 1st Street & D Street.

Visualization 3. Year 2070. NOAA I-H 4.72 ft Referenced to NAVD88. 1st Street & D Street.

Visualization 4. Year 2080. NOAA I-H 5.48 ft Referenced to NAVD88. 1st Street & D Street.

Visualization 5. Year 2100. NOAA I-H 7.38 ft Referenced to NAVD88. 1st Street & D Street.

Visualization 6. Year 2020. NOAA I-H 1.54 ft Referenced to NAVD88. 4th Street & D Street.

Visualization 7. Year 2060. NOAA I-H 4.00 ft Referenced to NAVD88. 4th Street & D Street.

Visualization 8. Year 2070. NOAA I-H 4.72 ft Referenced to NAVD88. 4th Street & D Street.

Visualization 9. Year 2080. NOAA I-H 5.48 ft Referenced to NAVD88. 4th Street & D Street.

Visualization 10. Year 2100. NOAA I-H 7.38 ft Referenced to NAVD88. 4th Street & D Street.

Visualization 11. Year 2020. NOAA I-H 1.54 ft Referenced to NAVD88. 2nd & Depot Streets.

Visualization 12. Year 2060. NOAA I-H 4.00 ft Referenced to NAVD88. 2nd & Depot Streets.

Visualization 13. Year 2070. NOAA I-H 4.72 ft Referenced to NAVD88. 2nd & Depot Streets.

Visualization 14. Year 2080. NOAA I-H 5.48 ft Referenced to NAVD88. 2nd & Depot Streets.

Visualization 15. Year 2100. NOAA I-H 7.38 ft Referenced to NAVD88. 2nd & Depot Streets.

Vulnerability Assessments: The Measurement of First-Floor Levels

For flood and sea-level rise vulnerability assessment, the project team measured and collected the first-floor levels of nearly every building in both Phase One and Phase Two areas. They are approximately 265 structures, including a few primary outbuildings and building complexes. Each structure's first-floor levels include one measured from NAVD88 (the sea level) and one from the grade. The first-floor levels were included in the GIS database, explained in the next section. To understand the vulnerability of the individual properties, planners and property owners can compare the current first-floor levels to the sea-level-rise scenarios and the Federal Emergency Management Agency (FEMA)'s base flood elevations (BFE), among others.

To measure the first-floor levels, the project team utilized the laser-scan data. In the virtual environment (the 3D digital copy of Cedar Key's urban environment), the project team measured the heights of the entrance thresholds from the benchmarks referenced to the most current elevation survey and the common vertical datum NAVD88, described in the previous section. To make this possible, the team had captured the entrances, specifically thresholds, while laser-scanning the building facades and urban contexts. In most situations, the project team had good visual access to the thresholds. Sometimes, living-space entrances were obscured by visual obstacles, such as enclosed porches and landscapes. Some buildings were much elevated, and the ground-level doors did not represent living floors. In these cases, the project team alternatively measured the floors of the porches or balconies and added 0.25 feet as porch decks were slightly lower than main living floors. The GIS database includes notes on accuracy (visual access).

Geospatially Referenced (GIS) Database

The project team developed a geospatially referenced online database, commonly referred to as a geographic information system (GIS), to manage and share the cultural resource surveys and vulnerability assessments from the Phase One and Phase Two projects.

GIS Database Link:
https://ufl.maps.arcgis.com/apps/webappviewer/index.html?id=898d99e72f434456adce8683dba2e017

Each building's attribute pop-up window includes:

1. Property and building type information, such as an address, parcel ID, current use, construction year, structural type, foundation, and the number of stories
2. Florida Master Site File (FMSF) existence, FMSF site number, and FMSF survey date
3. FMSF form as a downloadable PDF, compiling new/update and older survey forms, a photographic survey cover, new photographs (2019-2021), maps, and additional notes with archival resources, if available (click on "more info" in the pop-up.)

4. Additional photographic surveys for recent constructions that do not have FMSF records
5. First-floor levels from NAVD88 (the sea level) and grade and accuracy notes on visual access to the first-floor entrance threshold

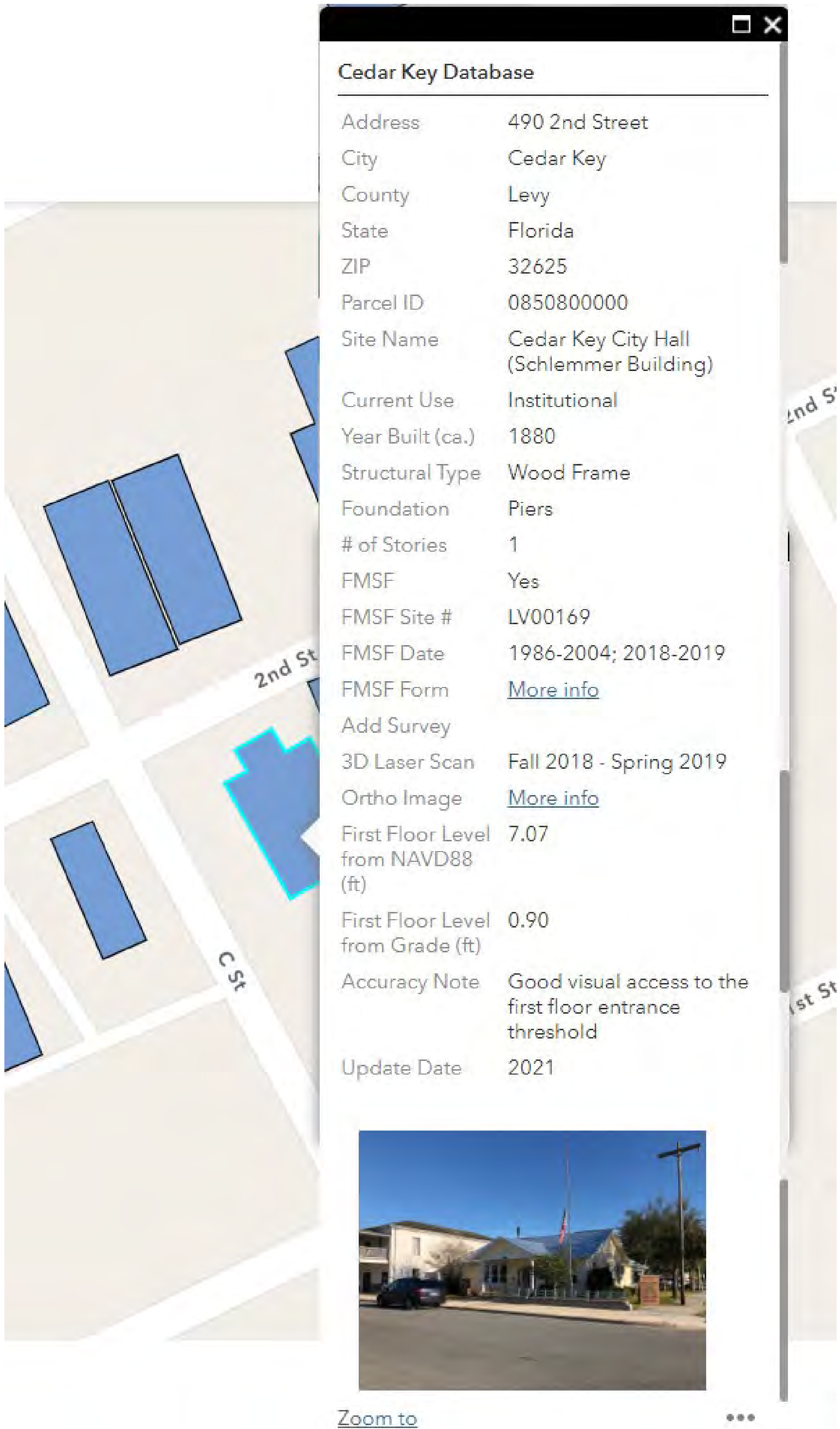


Figure 14. Example of the pop-up attributes in the geospatially referenced (GIS) database.

Cedar Key Resiliency and Adaptation Strategy Guideline

Envision Cedar Key: Sea Level Rise Adaptation Planning Tool includes a geospatially referenced (GIS) local database that can serve as a planning tool in concert with universal adaptation guidelines developed by the Federal Emergency Management Agency (FEMA) and National Park Service (NPS), among others. The GIS database can inform planners and individual property owners to determine the feasibility of the short-term flood and longer-term sea-level-rise mitigation and adaption measures before consulting and hiring an expert.

GIS Database Link:
https://ufl.maps.arcgis.com/apps/webappviewer/index.html?id=898d99e72f434456adce8683dba2e017

Attributes of the GIS database specifically relevant to adaptation and mitigation planning include:

1. **Structural Type**: Wood Frame or Masonry
2. **Current Use**: Residential, Commercial, Institutional, Outbuilding, or Demolished
3. **Number of Stories**: 1, 1.5, 2, or 3
4. **Foundation**: Piers, Continuous, or Slab on Grade
5. **First-Floor Level from NAVD88** (from the sea level)
6. **Orthographic Image** (scalable laser-scan image of the building facade)

The applicability of specific mitigation and adaptation strategies can be determined based on the attributes. This table provides a quick reference.

	Adaptation Strategies	**Conditions**
1	Dry Floodproofing	**Masonry** only
2	Wet Floodproofing	**Non-residential** only; Both masonry and wood frame possible
3	Abandoning the First Story	**Multi-story, masonry** only
4	Elevating the Building	**Any types** possible (different technical approaches required for masonry, slab-on-grade, and large ones); **Lowest floor level** (from the sea level) lifted to or above the Base Flood Elevation (BFE) + 1ft (freeboard)

Flood Mitigation and Adaptation Strategies

Temporary Barrier

Temporary protective measures are the most affordable and widely-used methods for flood mitigation. Tools include sandbags, removable dams, floodgates, and wrapping systems. Any structural type can deploy these options, but they are more suitable for relatively shallow floods of limited duration. Temporary barriers require time and labor to install; thus, they are not recommended where flooding can frequently occur without sufficient warning time. As temporary barriers can fail, pumps and emergency generators can be necessary.

Dry Floodproofing

Dry floodproofing prevents floodwater from entering the building by sealing all openings, exteriors, and interiors below the established flood risk level (e.g., Base Flood Elevation). Tools range from temporary flood barriers to the permanent door and window installation, vent infill, and waterproof coating. Building components below the established flood risk level must withstand strong hydrostatic forces. For this reason, dry floodproofing is only suitable for load-bearing masonry structures. Also, due to floodwater forces and maintenance issues, this method is more appropriate where projected inundation levels are lower than three feet with less frequency of flood. Given the rising sea level, this method is a short-term solution even where it is applicable currently.

Wet Floodproofing

Wet floodproofing allows floodwater to enter the building and drain out. It is of importance that floodwater flows through the building at a consistent rate. Interior door openings and additional vents at lower walls help control water flow. Wet floodproofing is suitable for masonry and wood-frame structures. The structure may need reinforcement and anchoring to withstand hydrostatic forces. This method requires flood-damage-resistant and impervious building materials for the portions that will be inundated. It also needs the protection of utilities by elevating, relocating, or enclosing. After a flood, this approach will require a lengthy, intensive cleaning and drying process during which the building may not be habitable. This method is only suitable for non-residential properties or non-living spaces of a residence.

Abandoning the First Story

This approach moves habitable spaces to floors above the established flood risk level. The abandoned story can be converted into a dry or wet floodproofed space for non-living purposes like storage. This adaptation measure is appropriate for multi-story masonry structures.

Elevating the Building

This adaptation strategy lifts the building, builds a higher foundation, and resets the building on the new base. Any structural and foundation types and building scales can be considered for elevating. This method is best suited for wood-frame buildings on piers or continuous wall foundations; however, the structure must be stable. Masonry, slab-on-grade, and large buildings can require different technical approaches.

According to the Federal Emergency Management Agency (FEMA) guidelines and Florida Building Code, the lowest living floor should be set to or above the Base Flood Elevation (BFE) plus 1 foot (freeboard to put the floor beams above BFE) when being elevated. BFE is the elevation of 1% annual chance floodwater relative to the local mean sea level. Cedar Key's mean sea level is 0.22 feet lower than NAVD88 (national geodetic vertical datum).

Cedar Key elevation datum chart: https://tidesandcurrents.noaa.gov/datums.html?id=8727520

Except for the southern hill area between E Street and F Street and the northern area between F Street and H Street, the study area mainly falls under the AE flood zones (subject to a 1% annual chance of flooding), with BFE 12 to 14 feet. The Dock Street and 1st Street areas are in the VE flood zones (coastal areas with a 1% or greater chance of flooding and an additional hazard), with BFE 15 to 16 feet (see Map 1 & 2). Many of the structures in the AE and VE zones have floors below these BFEs. The GIS database can inform how high the building should be elevated potentially.

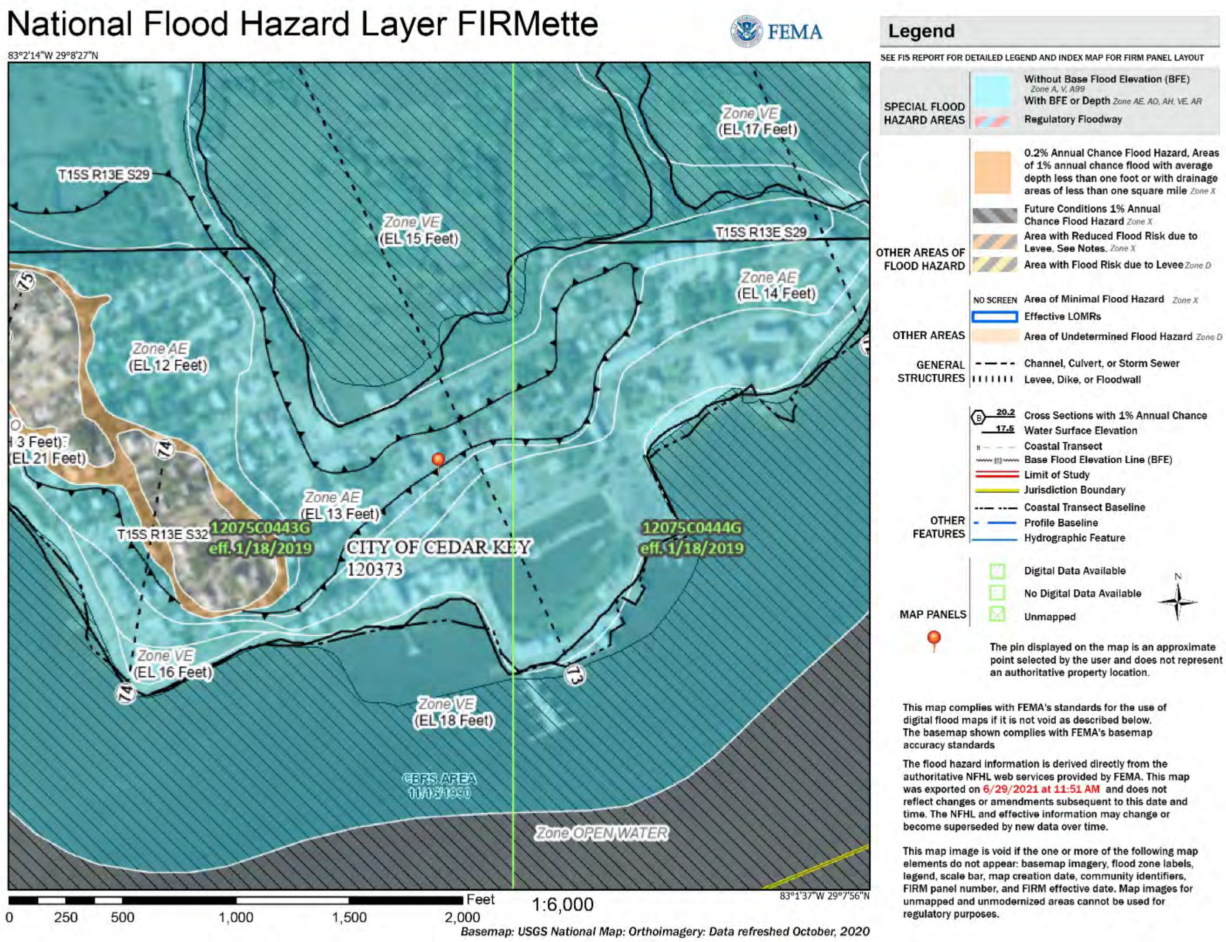
In the National Register Historic District, Cedar Key Historic and Archaeological District (listed in 1989), its contributing structures (which need to be updated) are exempt from the height rule. The City's historic district is bounded by A Street, F Street, 1st Street, and 3rd Street, although the National Register Historic District's boundary is unclear.

The National Park Service's guideline highlights that changes in height should be determined based on the historic characters of the structure and urban context and discourages elevating historic structures too much. At the same time, the guideline explains that where a tradition of elevating buildings exists, there can be more flexibility. In Cedar Key, historic wood-frame buildings have been elevated and relocated, and recent constructions have tall pilotis.

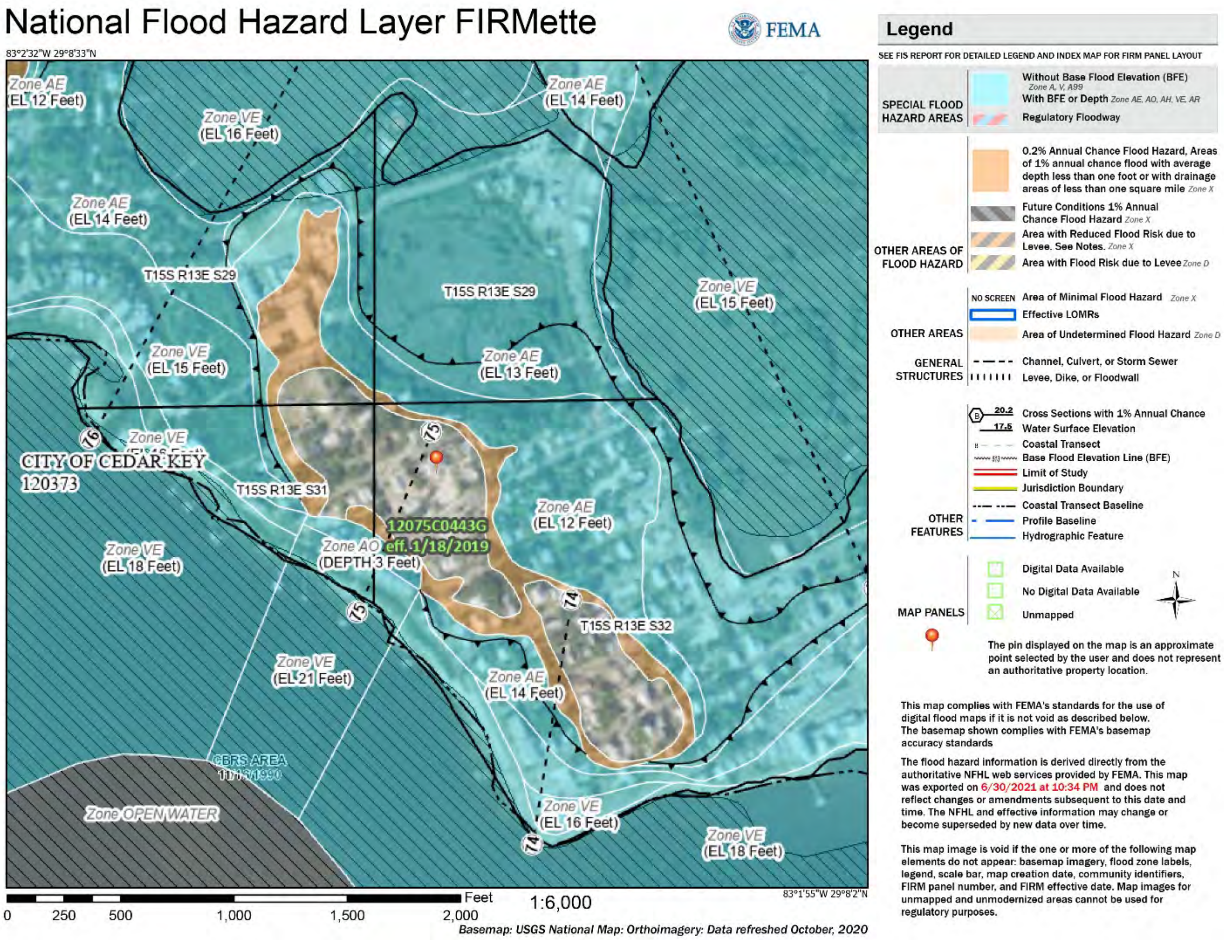
References

FEMA. *Homeowner's Guide to Retrofitting: Six Ways to Protecting Your Home from Flooding*. 3rd Edition, 2014. https://www.fema.gov/sites/default/files/2020-08/FEMA_P-312.pdf

National Park Service. *The Secretary of the Interior's Standards for Rehabilitation & Guidelines on Flood Adaption for Rehabilitating Historic Buildings*. 2021. https://www.nps.gov/orgs/1739/upload/flood-adaptation-guidelines-2021.pdf



Map 1. FEMA Flood Map for Cedar Key, Levy County, Florida (accessed June 29th, 2021 https://msc.fema.gov/portal/home)



Map 2. FEMA Flood Map for Cedar Key, Levy County, Florida (accessed June 29th, 2021 https://msc.fema.gov/portal/home)

StoryMaps

To share the information and products from the Phase One and Two projects with the public, the project team developed a StoryMaps (a platform made by Esri GIS software company) website merging the GIS database, an interactive virtual tour, and a point cloud viewer. The StoryMaps website provided a platform where the GIS database could be combined with those that were not part of the database, such as the sea-level-rise projection images and 3D laser-scan data.

First, the project team created a virtual tour of Cedar Key, integrating the sea-level-rise visualizations as a new, interactive way of informing the public about the potential impacts of rising sea levels on Cedar Key's built environment. The project team took 39 eye-level panoramas (using 360-degree camera Ricoh Theta Z1) and 6 aerial panoramas (using DJI Mini 2 drone) at the six locations of the sea-level-rise modeling from Phase One and Phase Two. These images were then linked through the portal "hotspots" (buttons that allow virtual visitors to move between scenes). The project team also added information buttons to play animated images of the sea-level-rise projections. While visitors explore Cedar Key's current urban environment virtually, they can watch the sea-level-rise visualizations (future simulation) and compare.

Cedar Key Virtual Tour + Sea-Level-Rise Visualizations:
http://images.envisionheritage.com/CedarKey360/index.htm

Second, the project team converted the reduced-resolution version of the laser-scan point cloud into an online publishable format using the Potree, an open-source point cloud viewer. Here is the guide to how to navigate using a computer mouse:

Step 1: Zoom-in by scrolling the mouse wheel

Step 2: Drag the point cloud by pressing the right mouse button

Step 3: Select an area to look closer by double-clicking the left mouse button

Step 4: Turn the point cloud by holding the left mouse button and moving the mouse

Step 5: Zoom out by scrolling the mouse wheel and select another area by double-clicking

Potree Point Cloud Viewer:
http://images.envisionheritage.com/Cedar_Key/PointCloud/CedarKey/CedarKey-PointCloud.html

Lastly, these two new media were put together with the GIS database, the project overview, and other background information on the StoryMaps website.

StoryMaps Link:
https://storymaps.arcgis.com/stories/86a0deaca5aa40e3bbe1bda95c2317c9