Vulnerability assessment to the impacts of sea level rise in the transportation infrastructure of Cedar Key, FL

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Introduction: Sea Level Rise and the City of Cedar Key, FL.

The State of Florida is already experiencing and is forecasted to see even more noticeable changes to sea levels. With low elevations and exposed to ocean waters, the coastline faces increased risks posed by tropical storms and hurricane force winds, flash flooding, storm surge, coastal erosion, saltwater intrusion, and other related events associated with climate change.

The Cedar Keys are a series of clustered islands offering about 420 acres of dry land and extending about three miles into the Gulf of Mexico. Cedar Key (CK) present a particular challenge when addressing sea level rise (SLR) vulnerability and adaptation strategies. It is a historic and small community with a permanent population of under 1000 inhabitant. The city relies on the coastal location for its existence, culturally and economically.

Research goals and objectives

One of the major treaths to the resilience of cities that face flooding and SLR is their transportation infrastructure. The lost of road connectivity might isolate communities from basic services and utilities. Therefore, this research aims to identify the vulnerabilities to SLR of CK's transportation infrastructure, exploring a methodology that combines 2D and 3D GIS analysis.

Objectives

- Evaluate the total length of roads affected (inundated) with each SLR scenarios;
- Identify the Exposure and Sensitivity of transportation system to SLR;
- Create a 3D elevation model with SLR scenario animations;
- Provide recommendation of adaptation strategies.

Methodology and data

The chart below summarize the data and processes applied during each step of this research. We developed three inundation scenarios (2050, 2070, 2090), based on the United States Army Corps of Engineers (USACE) "high" sea level change projection curves, and NOAA's tide gauge data for the "mean higher high water" (MHHW) (University of Florida GeoPlan Center, 2014).

2D map analysis:

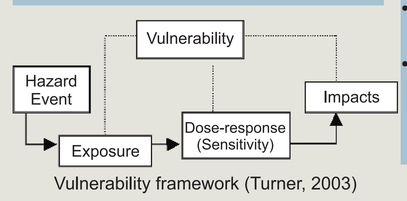
Using ArcGIS with data below:
- City_limit; CK_Roads
- Parcel_2015
- D2W_2050_H_MHHW
- D2W_2070_H_MHHW
- D2W_2090_H_MHHW
- Waterbodies
- Terrain elavation

Calculate:
- Exposure: Measure the length of road inundated under three SLR scenarios;
- Sensitivity: Road conditions;
- Network connectivity interruption, total travel time, and total population affected.

3D model and animations:
- Using ArcScene to transform the LIDAR data to TIN, thus get the 3D model of the city with roads, buildings, city limit, and SLR scenarios;
- Make animations of the sea level rise scenarios for the entire city;
- Make animations for the picked vulnerable and critical areas.

Find out the most vulnerable and critical parts of the road system in Cedar Key.

Recommendations:
- Identify adaptive responses strategies for CK;
- Provide a recommendation following socio, cultural, and economical analysis.



Vulnerability framework (Turner, 2003)

In order to assess the vulnerability of road infrastructure, we analyzed the road exposure and sensitivity. For exposure, we overlapped the flooding scenarios (SLR plus tidal variation) with road layer, and measured the length of inundated roads under each simulation. Then, we identified the residential units exposed to flooding risk by overlapping the parcel data and flooding surfaces, assessing the criticality. The total travel time (TTT) method or Transportation Network Model (TNM) to assess criticality was not adopted in this research. Considering the lack of connectivity of Cedar Key's road network, the TTT on several points would skew to infinite after innundation. Therefore, the critical areas here are identified according to the importance in accessing, connecting and keeping the integrity of the road system, considering the amount of people affected by completely losing connection to the transportation network. As for the sensitivity, we built an inventory of road's condition with in situ assessment.

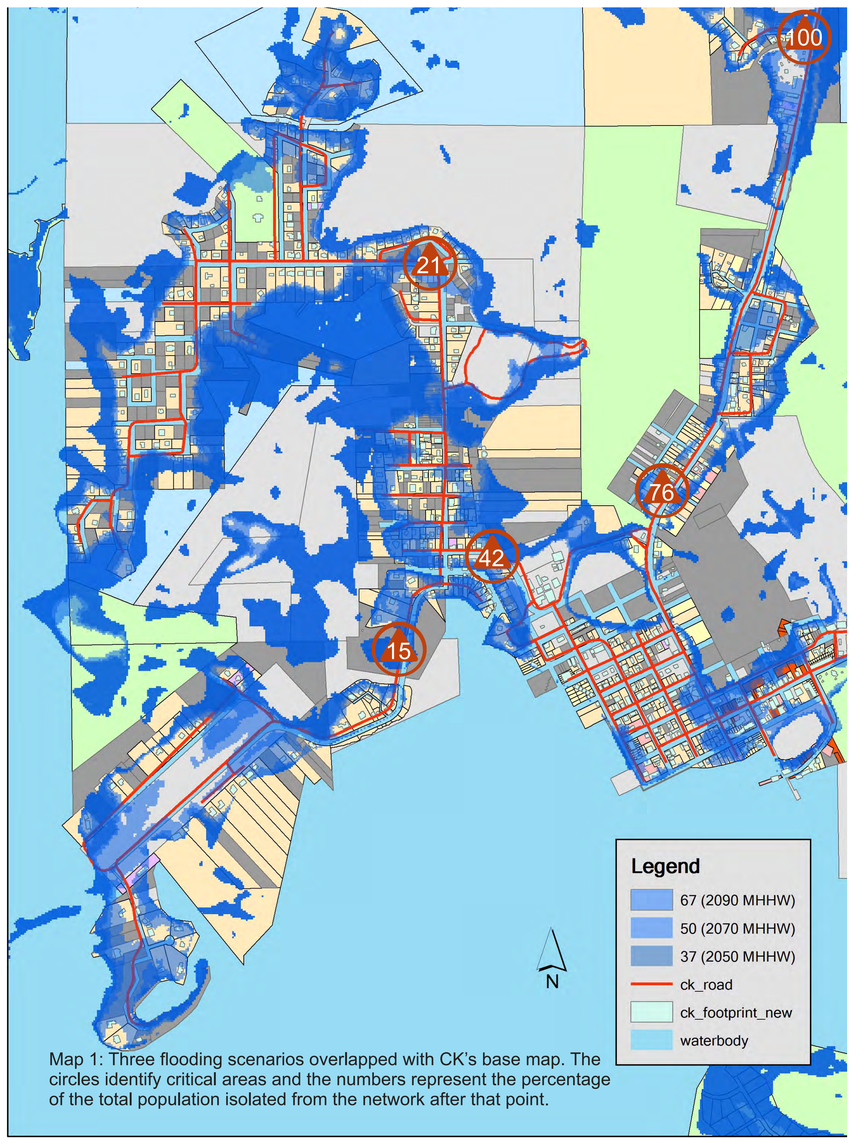

Figure 1: Aerial view of Cedar Key. Credit: "See Cedar Key" initiative, at www.seecedarkey.com".

Results and discussion

The transportation infrastructure of Cedar Key is highly exposed to SLR according to our flooding scenarios. The table below summarizes to total lengh and the percentage of roads innundated in each simulation.

Flooding scenarios (USACE MHHW)	Roads innundated (meters)	Roads innundated (%)
2050	1613	6.03
2070	3930	14.70
2090	8566	32.04

Despite the fact the most residential parcels in CK would not be innundated, even a 14.70% of roads afected under the 2070 scenario could completely isolate the island's transportation network.



Map 1: Three flooding scenarios overlapped with CK's base map. The circles identify critical areas and the numbers represent the percentage of the total population isolated from the network after that point.

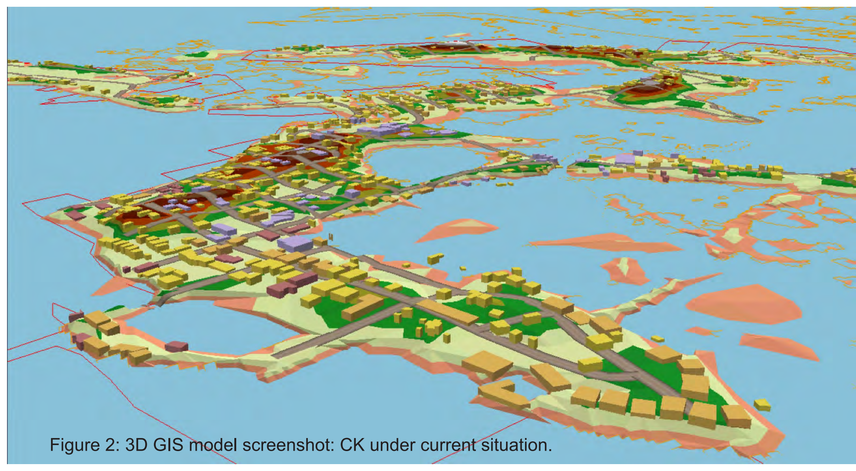


Figure 2: 3D GIS model screenshot: CK under current situation.

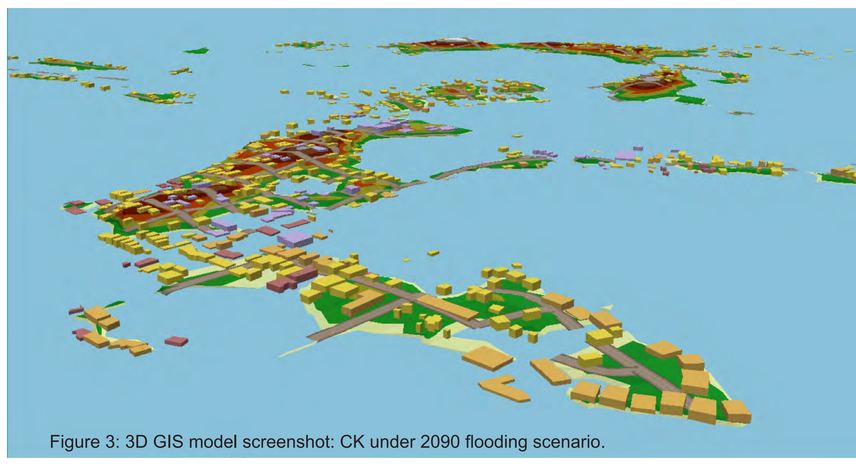


Figure 3: 3D GIS model screenshot: CK under 2090 flooding scenario.

Map 1 overlaps the three innundation scenarios and highlights 5 critical points in the road network. Figures 2 and 3 are screenshots of our 3D GIS model, with the first been the current situation and the former under the 2090 flooding scenario.

Recommendations

Considering the scenarios applied in this research, CK will face significant loss in network connectivity already in 2070. We have developed three response strategies: retreat, elevate the roads, and integrate wet and dry transportation network. After a social, cultural and economical analysis, our recommendation for adaptation strategy is the creation of an integrated water based shuttle system, creating terminals at the identified critical areas.

Finally, the methodology provided a good understandind of flooding scenarios. 3D GIS animations can be a powerful communication tool when addressing SLR. Bridging the gap between climate science and the community is the challenge we have to face to raise awareness and literacy.

References

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