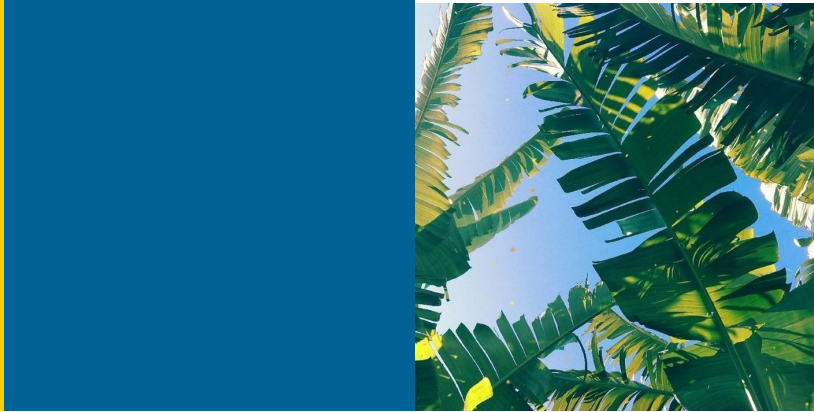




# City of Clearwater Vulnerability Assessment Summary

Completed March 2025  
FDEP Grant #22PLN91





# I. Executive Summary

The city of Clearwater worked with a consultant to conduct a comprehensive Vulnerability Assessment (VA) to evaluate future risks from climate-related hazards. Funded through Florida Department of Environmental Protection's (FDEP) Resilient Florida Program (grant #22PLN91), this study satisfies statutory requirements and enables the city to pursue additional adaptation funding (p. 2). The consultant worked closely alongside a project action team (PAT) consisting of internal city staff and a multi-disciplinary technical advisory committee (TAC) that involved regional partners for stakeholder engagement and feedback integration.

The assessment utilized the consultant's geospatial resilience modeling tool, Simulator, which was used to create a digital twin of the city that included buildings, parcels and transportation infrastructure. The tool was used to model the city from 2020 to 2100, simulating both its growth and activity and relevant climate hazards. The study focused on tidal flooding, riverine flooding (when inland rivers overtop their banks), pluvial flooding (from heavy local rainfall) and storm surge. While sea-level rise (SLR) was the core concern under the grant's scope, Clearwater also elected to include heat stress impacts as a proactive step toward comprehensive resilience planning (p. 56).

Major findings show significant increases in storm intensity, flood depth and temperature through 2100. Critical assets, especially in low-lying coastal communities, face growing exposure. Fifteen mitigation and adaptation scenarios were modeled for a cost-benefit analysis. These scenarios illustrate potential future resilience investments and offer data-driven project examples for grant funding opportunities (p. 116).

# II. Methodology

The study relied on scientifically grounded projections and high-resolution modeling using the Simulator. Key steps in the methodology included:

## 1. Climate Drivers and Projections

- **Rainfall:** Monthly rainfall projections from General Circulation Models (GCM), which are global computer-based climate simulators, were blended with historical and local daily rainfall in a process called downscaling to produce daily rainfall projections that reflect the micro-climates of the area. The GCM data were compiled in the coupled model intercomparison project (CMIP5) and extracted from the USGS THREDDS server. The historical data was extracted from the global hydroclimatic data network (GHCN) served through NOAA's National Center for Environmental Information (NCEI). The GHCN Tarpon Springs gauge (08-8824), which is north of the city, was chosen over the Clearwater gauge (08-1632) for historical observations and future predictions, due to it having a longer period of record with no gaps (p. 13-19). Rainfall statistics for the city were extracted from NOAA's Atlas 14, which is a comprehensive source of precipitation frequency estimates across the United States.
- **Temperature:** Heat projections used Localized Constructed Analogs (LOCA) datasets from Scripps Institute at the University of California, San Diego (UCSD) which is commonly used in vulnerability assessments (p. 21).



- **Future Sea Level:** Following the FDEP Resilient Florida grant requirements, sea level projections were based on the NOAA 2017 Intermediate-Low and Intermediate-High projections (p. 23). The consultant was also able to add the newer 2022 projections for additional analysis.

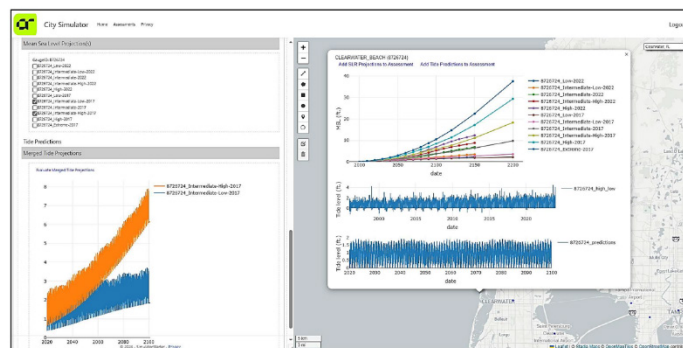


Figure 2-11 - Redesigned City Simulator to allow the user to select any of the 2017 or 2022 projections to be used in the climate simulations.

Page 25: Figure 2-11 – Redesigned City Simulator interface

o **Tidal Predictions:** The mean sea level projections were summed with NOAA’s prediction of tide level to capture the impact of changing mean sea level on daily tidal fluctuations; specifically, the Clearwater Beach station tide gauge (ID: 8726724) was used to simulate when, where and how frequently tidal inundations will occur to the city’s roads and buildings (p. 25).

o **Surge Predictions:** The study blended NOAA projections of mean sea level with U.S. Army Corps of Engineers’ (USACE) South Atlantic Coastal Study (SACS) models to estimate depth and frequency (p. 28).

## 2. Exposure Analysis (p. 31)

- Focused on quantifying the depth and location of flooding and heat that will potentially impact the community in future.
- Used GIS-based analysis of ~52,000 parcels and thousands of critical infrastructure points.
- Evaluated exposure under three planning horizons (2040, 2070, 2100).
- Assessed “days flooded,” flood depth and heat intensity per structure.

## 3. Scenario Development and Cost-Benefit Analysis

In addition to identifying exposure and sensitivity to climate hazards, the city also used the project to test adaptation and mitigation actions aimed at reducing the potential consequences of increased flooding and heat. Ten adaptation scenarios were analyzed for risk reduction and return on investment (ROI) using the Simulator, five of which were further refined. Examples include seawall elevation, structural elevation, acquisitions and tree planting (p. 116).



### III. Outcomes

The study outlined the following impacts to flooding and heat exposure.

#### 1. Flooding Impacts

Clearwater will experience various flooding scenarios, including tidal, rainfall and storm surge. These floods will impact various infrastructure, including buildings (residential and commercial), roads and stormwater systems. The study analyzed stormwater and transportation assets and projected increased disruptions for residents and businesses as they try to navigate the city's transportation network (p. 55).

#### Tidal Flooding:

- By 2100, using the intermediate-high SLR projection, 3,000+ parcels may flood 300+ days/year. This represents close to 10% of parcels in the city (p. 34).
- Coastal areas are especially vulnerable, including barrier islands and downtown (p. 35-40).

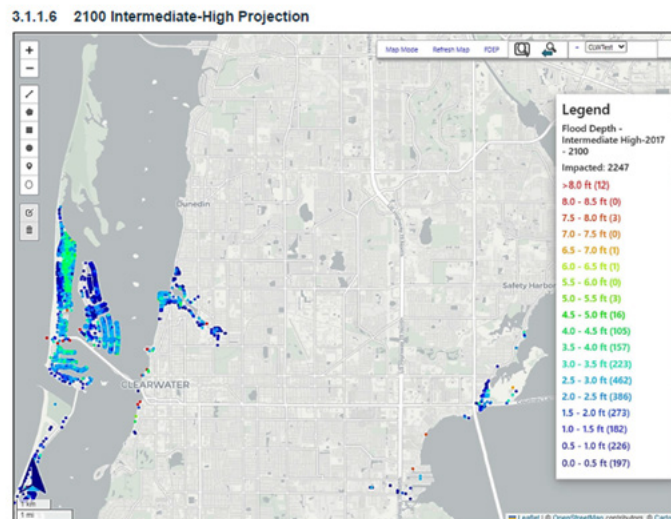


Figure 3-8 - 2100 Intermediate-High Projection (2017) - Representative Depths and Extents of Tidal Only



### **Flooding – Large Rainfall Events:**

- The maximum expected flood depth above ground for a 100-year (1% probability) rainfall event increases from 13.73 ft (2040) to 14.34 ft (2100) (p. 41).
- The maximum expected flood depth above ground for a 500-year (0.2% probability) rainfall event increases from 15.32 ft (2040) to 20.38 ft (2100) (p. 41).



A 100-year rainfall event refers to a rainstorm that has a 1% chance of occurring in any given year. Similarly, a 500-year event has a 0.2% chance of occurring in any given year. These terms describe statistical probabilities, not guaranteed schedules. A 100-year storm can happen more than once in a century, and in some cases, even multiple times in a few years. These events are used by engineers and planners to design infrastructure (like stormwater systems and flood protection) that can withstand extreme weather.



**100-YEAR  
RAINFALL EVENT**

**1% CHANCE IN A GIVEN YEAR**



**500-YEAR  
RAINFALL EVENT**

**0.2% CHANCE IN A GIVEN YEAR**



3.1.2.3 2100 Planning Horizon – Pluvial Flooding; 100-Yr-Event

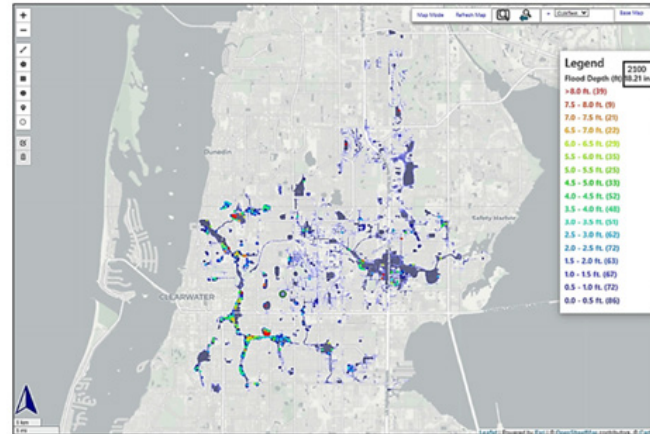


Figure 3-11 - Existing 100-year flood depth grid with locations (circles) representing flood depths and extents of the modeled 2100 rainfall event (19.21 inches in 24-hour period)

**Flooding - Storm Surge Events:**

- Maximum projected surge depth increases from 17.1 ft (2040 Planning Horizon) to 22.7 ft (2100 Planning Horizon) according to the Intermediate-High (2017) projections (p. 48).
- Heavily affects coastal and low-lying neighborhoods (p.54).

3.1.3.6 2100 Intermediate-High Projection (2017) - Storm Surge

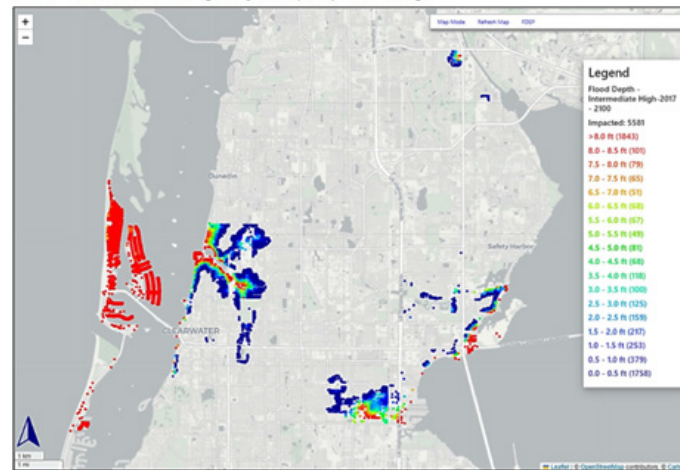
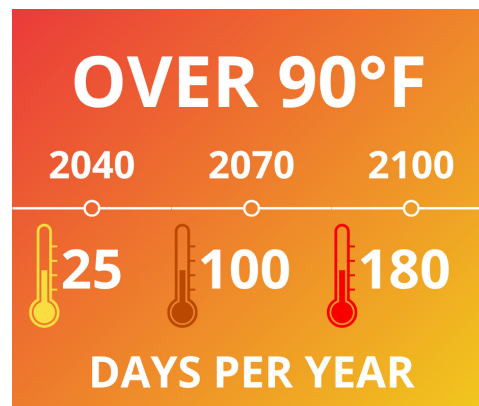


Figure 3-20 - 2100 Intermediate-High (2017) - Storm Surge Extent and Depths



## 2. Heat Exposure

- Both the number of days per year with high temperatures as well as the number of locations will increase (p. 57).
- Days above 90°F increase from 1-25 days (2040 Planning Horizon) to 176-200 days (2100 Planning Horizon) in many areas (p. 56-57).



- Areas with limited tree coverage see higher heat intensity (p. 56).
- By 2100, 17,446 study locations face heightened heat exposure. See maps below for locations spread over time.

Year 2040 Locations with Days Greater than 90 Degrees (2017 Projections)

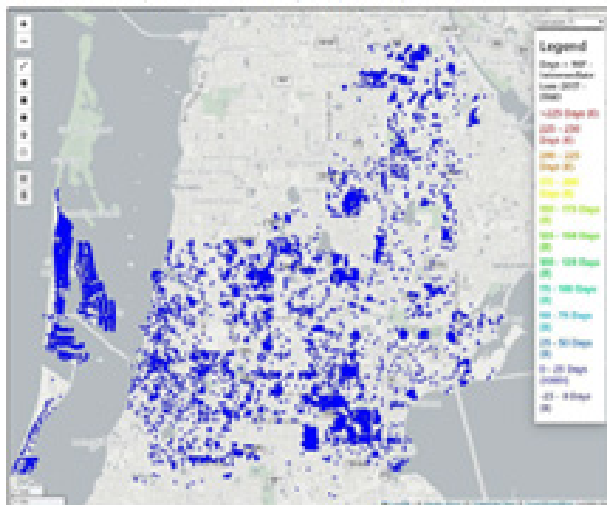


Figure 3-23 - Heat impacts at building locations using the 2017 projections (Year 2040).

Year 2100 Locations with Days Greater than 90 Degrees (2017 Projections)

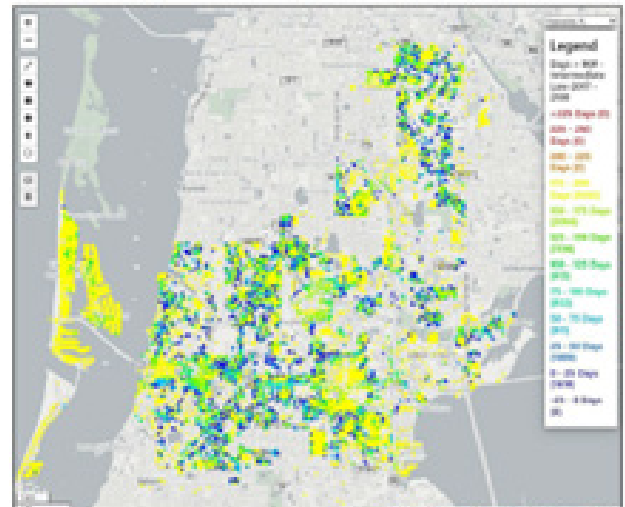


Figure 3-25 - Heat impacts at building locations using the 2017 projections (Year 2100).





#### **Scenario 5: Elevate Structures on Barrier Islands**

- Assessed elevating residential structures on the beach barrier islands. High benefit in terms of avoided flood damage, especially with phased or budget-limited approaches. The ROI was maximized when ~\$88 million is spent on 602 projects, which is estimated to avoid ~\$240 million in damages.
- ROI ratio =  $\$240\text{M} / \$88\text{M} = 2.73$

#### **Scenario 6: Acquisition of Structures Citywide**

- Modeled a citywide buyout program based on ROI of individual properties. Found this to be one of the most effective long-term strategies for reducing overall flood exposure. The ROI was maximized when ~\$1.5 billion is spent on 1,282 projects, which is estimated to avoid ~\$2.45 billion in damages.
- ROI ratio =  $\$2.45\text{B} / \$1.5\text{B} = 1.63$

#### **Scenario 7: Hercules and US 19 Corridors**

- Focused on acquiring structures in economic development corridors prone to flooding. The scenario showed strong ROI from targeted acquisitions on a cost to benefit curve, maximized when ~\$26.35 million is spent on 8 acquisition projects, which is estimated to avoid ~\$43.17 million in damages.
- ROI ratio =  $\$43.17\text{M} / \$26.35\text{M} = 1.64$

#### **Scenario 8: Coastal Zone 1, Downtown and North Greenwood**

- The scenario evaluated the North Greenwood Community Redevelopment Area (CRA), the Downtown District and Coastal Zone 1, as a combined geography where reinvestment is ongoing and social vulnerabilities have been identified. It evaluated the estimated costs and benefits if flood-exposed structures were acquired, and additional trees were planted to reduce heat exposure. Showed that mixed-use adaptation (acquisitions and tree planting) had high potential return, especially in vulnerable census tracts.

#### **Scenario 9: SR 60, Drew St. and S Missouri (Alt 19)**

- This scenario was intended to evaluate stormwater improvements, density changes and tree coverage of future investment corridors. The model was not able to accurately evaluate the mix of soft and hard mitigation strategies; however, flooding exposure and tree planting benefit analyses were demonstrated.

#### **Scenario 10: Elevate Structures Citywide**

- A broad scenario assessing the benefits of elevating all vulnerable buildings. Results showed this approach is costly but impactful, with the best ROI in the high-exposure zones of Clearwater Beach, Stevenson Creek and near the Old Tampa Bay coast. The ROI is maximized when ~\$141.1 million is spent on 837 elevation projects, which is estimated to avoid ~\$389.3 million in damages.
- ROI ratio =  $\$389.3\text{M} / \$141.1\text{M} = 2.76$



### Five Refined Scenarios (Pages 166–180)

After modeling the original ten, five refined scenarios incorporated more localized interventions (e.g., bridge upgrades, targeted acquisitions, tree planting) and homed in on more specific locations for improved outcomes over the original versions.

#### Refined Scenario 1: Stevenson Creek with Bridges

- Updated Scenario 1 to assess bridge vulnerability to inundation. The scenario identified three bridges that would be good candidates for upgrades, with further analysis (planning, design and cost information) and coordination with county, state and federal agencies needed.

#### Refined Scenario 8a: North Greenwood

- Targeted acquisitions and tree planting in this socially vulnerable neighborhood. There is a high ROI due to building exposure, community vulnerability and limited shade coverage. The ROI is maximized when ~\$76 million is spent on 1,184 projects (1,141 tree plantings and 43 building acquisitions), which is estimated to avoid ~\$98 million in damages.
- ROI ratio =  $\$98\text{M} / \$76\text{M} = 1.29$

**\*Note:** Recommended tree planting locations would need to be further evaluated before implementation, as some sites may be unsuitable due to physical constraints or professional guidance.

#### Refined Scenario 8b: Downtown

- Focused on tree planting and a few critical acquisitions. Found to improve walkability and reduce urban heat while offering modest flood mitigation benefits. The ROI is maximized when ~\$9 million is spent on 1,572 projects (1,568 tree plantings and 4 building acquisitions), which is estimated to avoid ~\$17.8 million in damages. The study also included a map of 25% budget scenario that highlights tree planting (919) and building acquisition (33) that returns the highest ROI.
- ROI ratio =  $\$17.8\text{M} / \$9\text{M} = 1.98$

**\*Note:** Recommended tree planting locations would need to be further evaluated before implementation, as some sites may be unsuitable due to physical constraints or professional guidance.

#### Refined Scenario 8c: Coastal Zone 1 (mainland west coast)

- Focused on tree planting and a few critical acquisitions. Provided strong benefits for long-term risk reduction and resilience. The ROI is maximized when ~\$65 million is spent on 2,111 projects (2,058 tree plantings and 53 building acquisitions), which is estimated to avoid ~\$120.36 million in damages.
- ROI ratio =  $\$120.36\text{M} / \$65\text{M} = 1.85$

#### Scenario 11: Identify Tree Deserts

- Further refined Scenario 2 and developed the tree planting benefit index, based on the city's parcel fabric and demographics to estimate relative benefits to tree planting locations. Identified priority areas for tree planting with the highest cooling potential.



#### **V. Final TAC Committee Recommendations (p. 181)**

During the final TAC meeting, members made several recommendations for future research and projects, including:

- Use the St. Petersburg station, as recommended by the Tampa Bay Estuary Program's (TBEP) Climate Science Advisory Panel (CSAP). This will ensure the region is using one consistent station.
- Evaluate surface water models for water quality and include groundwater modeling.
- Emphasize public opportunities like rain gardens and individual property protection actions as well as regional solutions.
- Consider including land acquisition costs to evaluate opportunities for new or additional stormwater retention and treatment needs.
- Pursue grant funding to expand upon visualization and educational outreach opportunities that communicate vulnerabilities.



# Impact and Next Steps

The city of Clearwater's Vulnerability Assessment project successfully met its primary goals of assessing the city's vulnerabilities and evaluating potential climate adaptation strategies. By creating a digital twin of the city and utilizing the Simulator, the project provided detailed simulations of future climate scenarios, including tidal, riverine, pluvial and surge flooding and rising temperatures. These simulations gave the city valuable insights into the expected impacts of climate change on critical infrastructure and communities, enabling the city to make informed decisions regarding adaptation planning.

Based on the findings from the Vulnerability Assessment, the city will consider the following strategies to increase the city's resilience to climate hazards and ensure long-term sustainability:

**1. Implement Priority Adaptation Projects and Prioritize Flood Mitigation in Vulnerable Areas:**

The VA laid the foundation for high impact adaptation measures, such as elevating seawalls and structures, acquiring at-risk properties and upgrading infrastructure to protect the most vulnerable populations and city assets in areas most affected by frequent flooding, such as Stevenson Creek and coastal zones.

**2. Increase Green Space and Tree Coverage:**

Expanding urban forestry efforts, particularly in vulnerable areas such as North Greenwood and downtown, would be greatly beneficial. This will not only help mitigate heat but also provide additional environmental and social benefits, including improved air and water quality and increased community well-being.

**3. Expand Data Collection for Future Modeling:**

To improve the accuracy of future resilience planning efforts, the city should continue to enhance its data collection efforts. Gathering more granular data on economic vulnerability, the impacts on specific neighborhoods and additional climate variables will allow for improved forecasting.

**4. Ongoing Community Engagement in Planning:**

Ongoing community involvement is essential to ensure that resilience solutions are equitable and meet the needs of all residents. Continued engagement with community members, particularly those in vulnerable areas, will help prioritize actions and ensure that the benefits of adaptation measures are broadly shared across the city.

**5. Pursue Grant Funding:**

The city will actively pursue grant funding options like FDEP Resilient Florida and various federal funding options to support resilience planning and project implementation.

**6. Coordinate with Regional and State Partners:**

The city shall continue and strengthen collaboration efforts with Pinellas County, neighboring municipalities, Tampa Bay Regional Planning Council (TBRPC), state agencies (FDEP, FDOT, etc.), Tampa Bay Estuary Program (TBEP) and community organizations for consistent and regional resilience planning.

**7. Integrate Findings into City Planning Documents:**

Integrate VA results and resilience adaptation and mitigation strategies into future updates to city documents, including, but not limited to the Comprehensive Plan, Strategic Plan, Capital Improvements Plan, Sustainability Action Plan (Greenprint), etc.



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