Program Summary:
Layered analysis of the physical environment of one of America's most historic cities, present and future, to guide its Comprehensive Plan update.

Program Statement:
Building off the previous water planning processes and embedded within Charleston's Comprehensive Plan, this urban planning study served as the analytic preface to a long term strategy for the City's land use and flood mitigation planning.

The process began from the ground up with a study of fundamental aspects of land and water. The team mapped multiple types of water-based risk, from tide to rain to storm surge, and met with local communities and stakeholders to get an on-the-ground sense of flooding throughout the city. Watershed boundaries, not political boundaries, guided the analytical approach, sometimes requiring a view beyond City jurisdiction. The outcome of the analysis is four broad planning categories for the City and its citizens to weigh as it reimagines its future: grow, defend, adapt, and reserve.

With multiple flood risk mitigation projects on the horizon and an imperative to adapt vast swaths of Charleston's built environment to ever changing flood risk, the need for an analytic framework to guide those tasks is crucial. The goal of this study is to create a way to see flood risk and opportunities to increase resiliency in Charleston that inform the next decade of change and beyond.

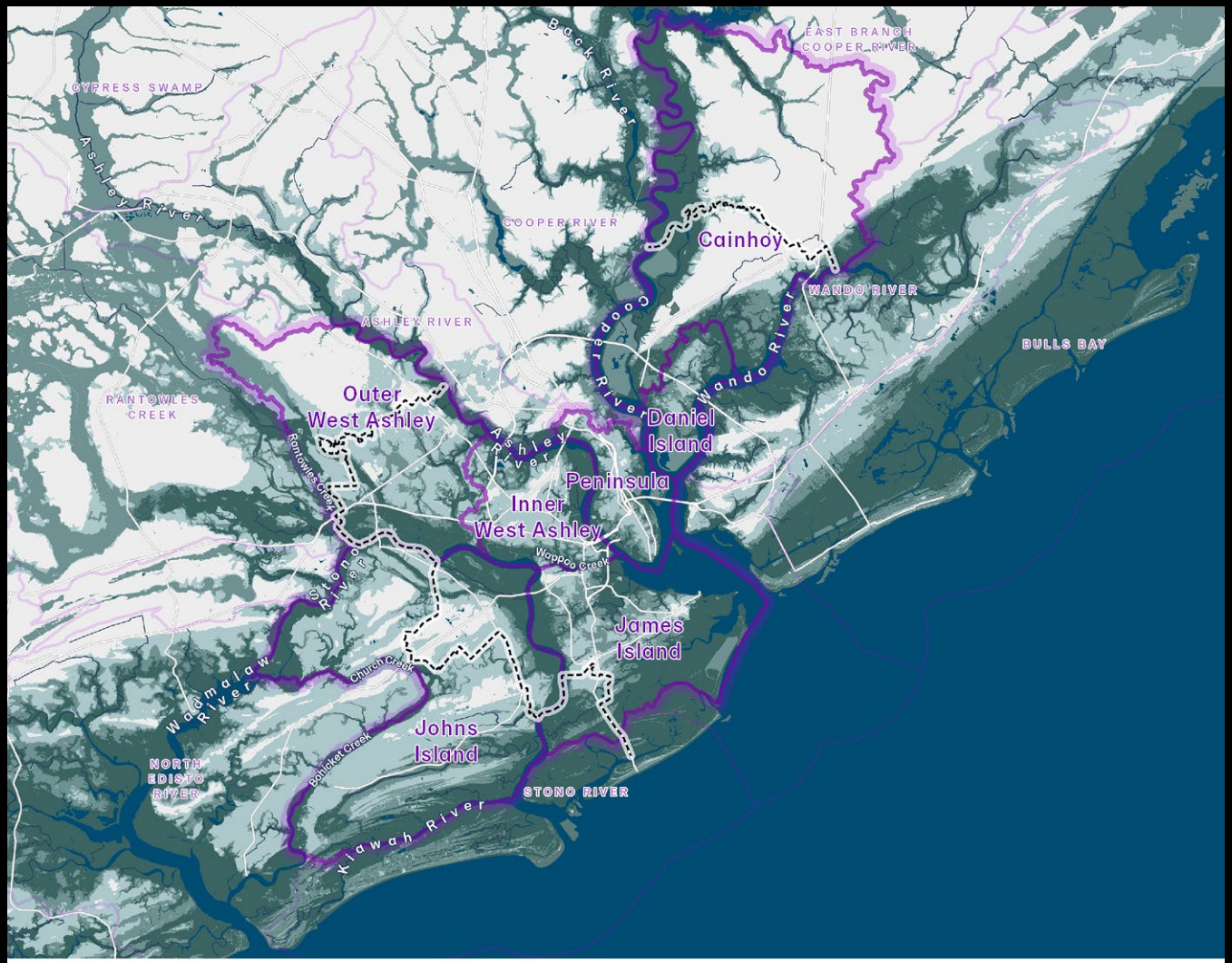
MP-345.01

Building Area: (sf)
N/A

Cost per Square Foot:
N/A

Construction Cost
N/A

Date of Completion:
2021



Watersheds Neighborhood

Urban Growth Boundary

Water

2/3 of Charleston

Inside the urban growth boundary is in the FEMA 100 Year Floodplain

10.2 inches of Rain

Over 24 hours in 100 year storm

17 feet storm surge

NOAA Maximum possible category 3 storm

3 ft of Sea Level Rise

By 2080

7 Watershed Areas

Peninsula, Inner West Ashley, Outer West Ashley, James Island, Johns Island, Daniel Island, and Cainhoy

MP-345.02

Charleston is facing widespread growth and flooding challenges. The interaction between the forces of growth and climate make flood risk a moving target, creating new areas of risk and exacerbating old ones. A long-term strategy is necessary to address this relationship between development and flooding. This study aims to direct the development of Charleston over the next ten years with an awareness of these long-term trends. Embedded within the City's Comprehensive Plan, this analysis serves as the preface to that strategy, the underlying data to inform City planning decisions.

Land & Water Context

Land	Water
Elevation	Rain
Land Cover	Tides
Development	Floodplain
Ecology	Storm Surge
Soils	Sea Level Rise

1 **Elevation Zones** ↕

What is your risk?

+

2 **Watershed Sensitivity** ↔

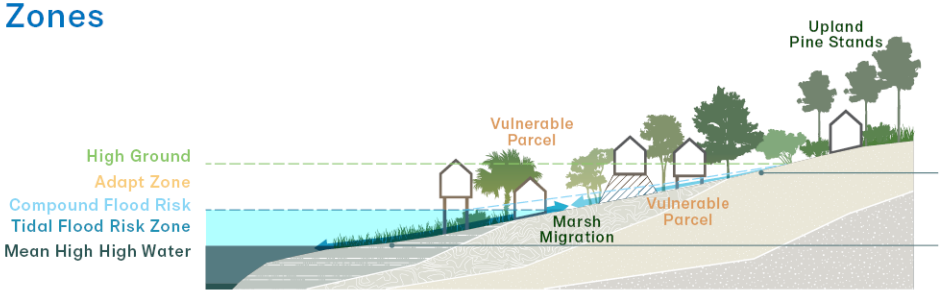
How do you impact your surroundings?

+

3 **Environmental Sensitivity** ⋮⋮⋮⋮⋮

What other ecological considerations need to be taken into account?

1. Elevation Zones



2. Watershed Sensitivity

Vulnerability
Number of vulnerable parcels
Locally and Downstream

Watershed Size
Potential for Runoff Accumulation

Tidal Extent
Potential for Drainage Backup

3. Environmental Sensitivity

Ecology
Marsh Migration, Existing Canopy, Large Intact Ecosystems

Soils
Ability to Infiltrate, Groundwater Levels

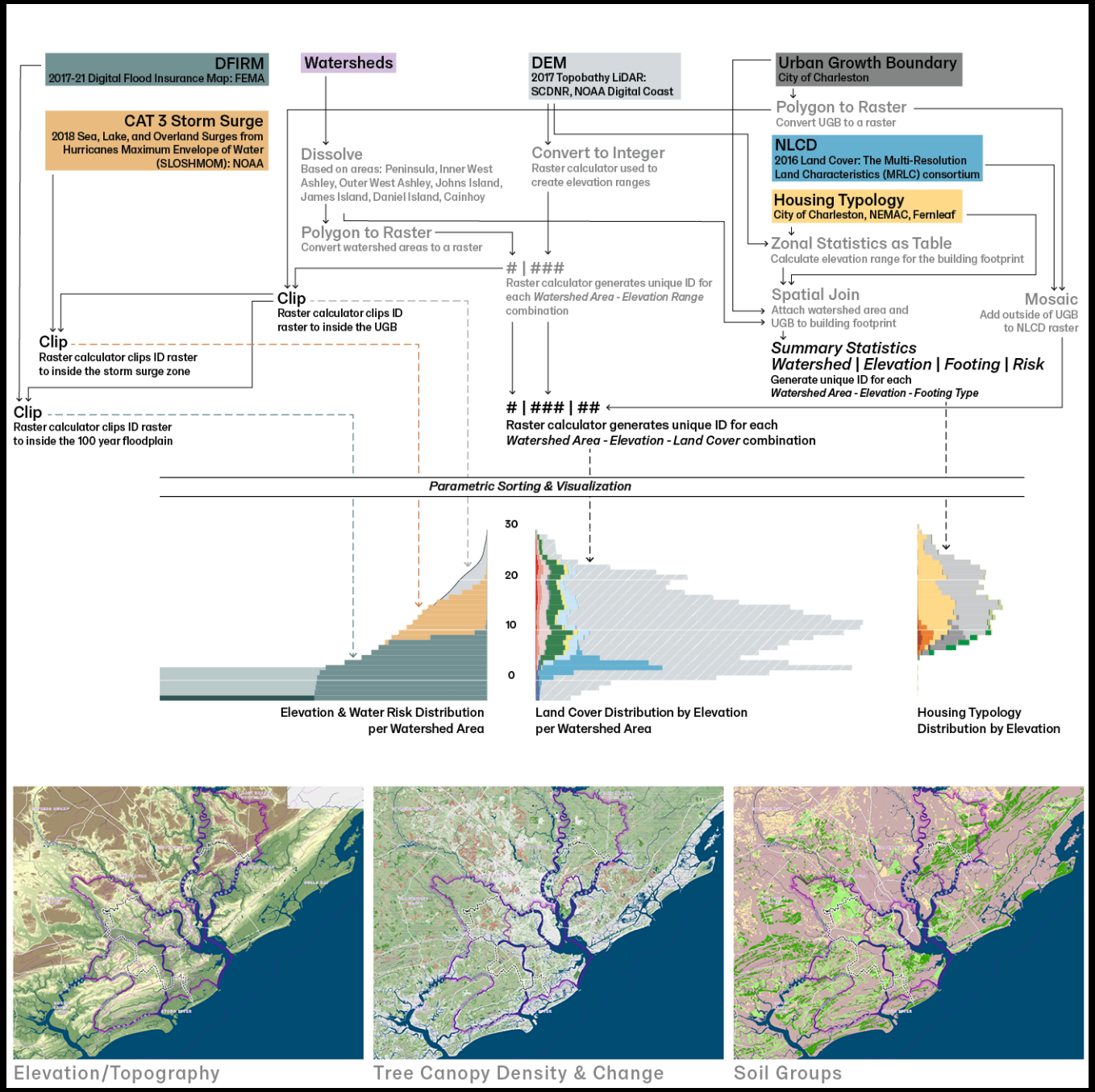
MP-345.03

Analytical Approach

The analysis began with elevation: What is the land's relative risk?

It mapped watershed sensitivity: How does land affect its surroundings?

And it overlayed environmental sensitivity: Where are critical habitats and ecological resources located and how are they changing?



Elevation/Topography

Tree Canopy Density & Change

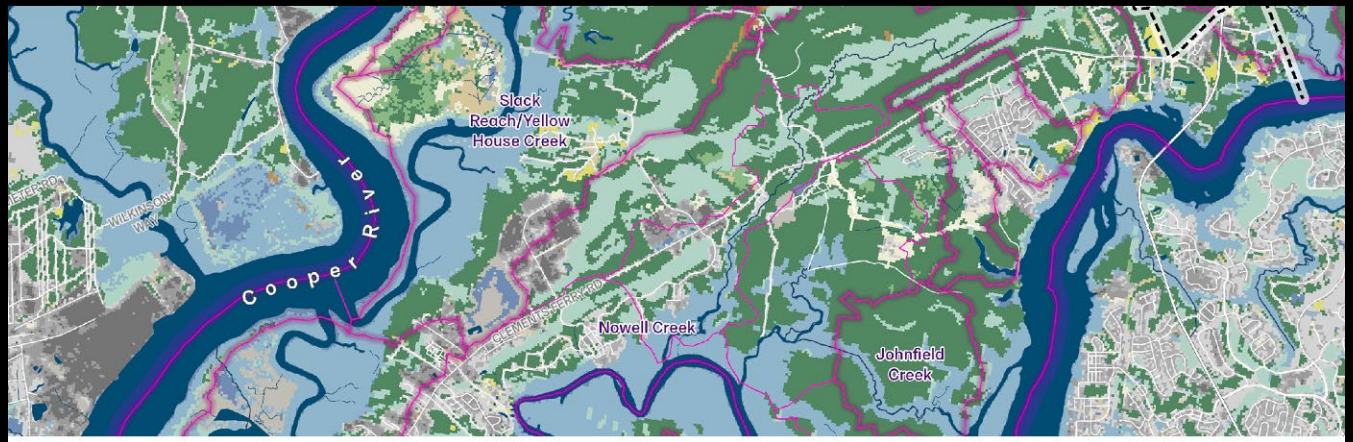
Soil Groups

MP-345.04

Mapping and Workflow

The mapping and graphic visualization process was done through a combination of ArcGIS and Grasshopper. This process was recursive with data analysis informing visualization and visualization informing analysis. The graphic on the left shows how multiple data sets form a single graphic, revealing the relationships between elevation, flood risk, building typology, and land cover. Through this visualization we can communicate how flood mitigation in Charleston is a complex balance of elevation, watershed sensitivity, and ecology.

Layers mapped include: Elevation Zones
Watershed Sensitivity
Marsh Migration with 3 Feet of Sea Level Rise
Tree Canopy Density & Change
Soil Hydrologic Groups



CAINHOY

SURFACE ELEVATION

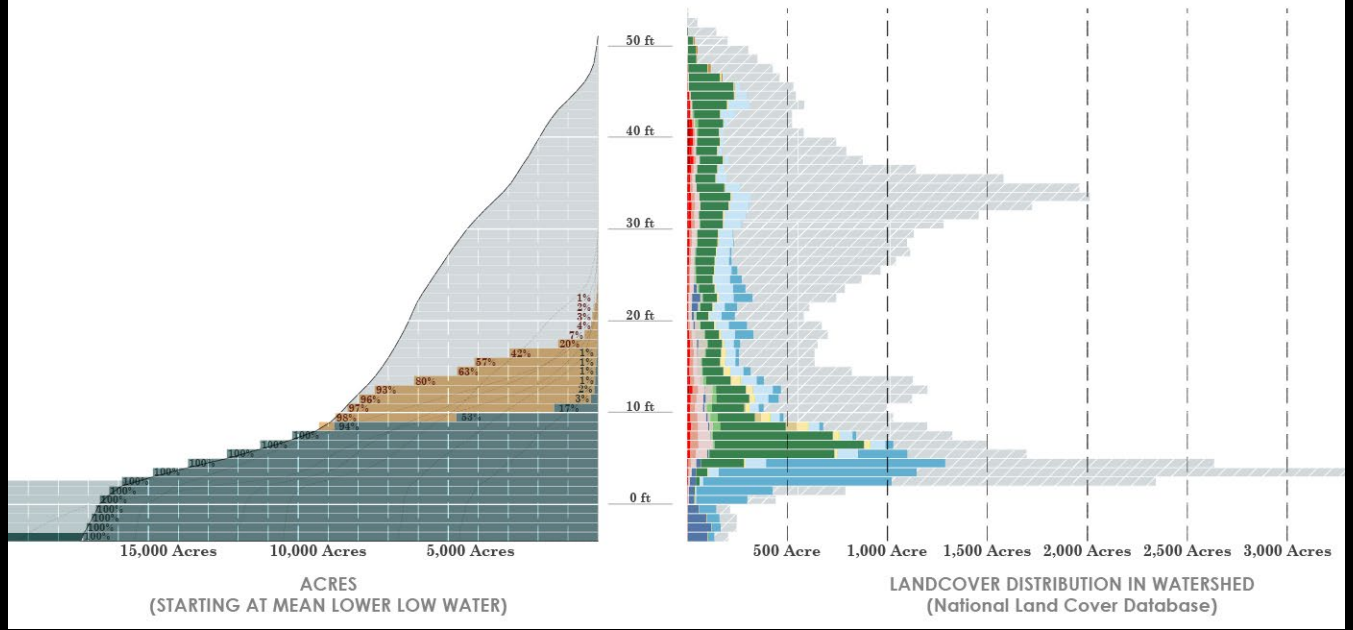
Surface Elevation (NOAA, LiDAR)

% Of Elevation Range in the 100 Year Floodplain (FEMA, Flood Insurance Rate Map)

% Of Elevation Range in the Category 3 Max Storm Surge (NOAA, SLOSH Model)

LAND COVER

- Developed High Intensity
- Developed Medium Intensity
- Developed Low Intensity
- Developed Open Space
- Open Water
- Barren Land
- Deciduous Forest
- Evergreen Forest
- Shrub/Scrub
- Grassland
- Pasture
- Crops
- Woody Wetland
- Emergent Herbaceous Wetland
- Outside Urban Growth Boundary



ACRES
(STARTING AT MEAN LOWER LOW WATER)

LANDCOVER DISTRIBUTION IN WATERSHED
(National Land Cover Database)

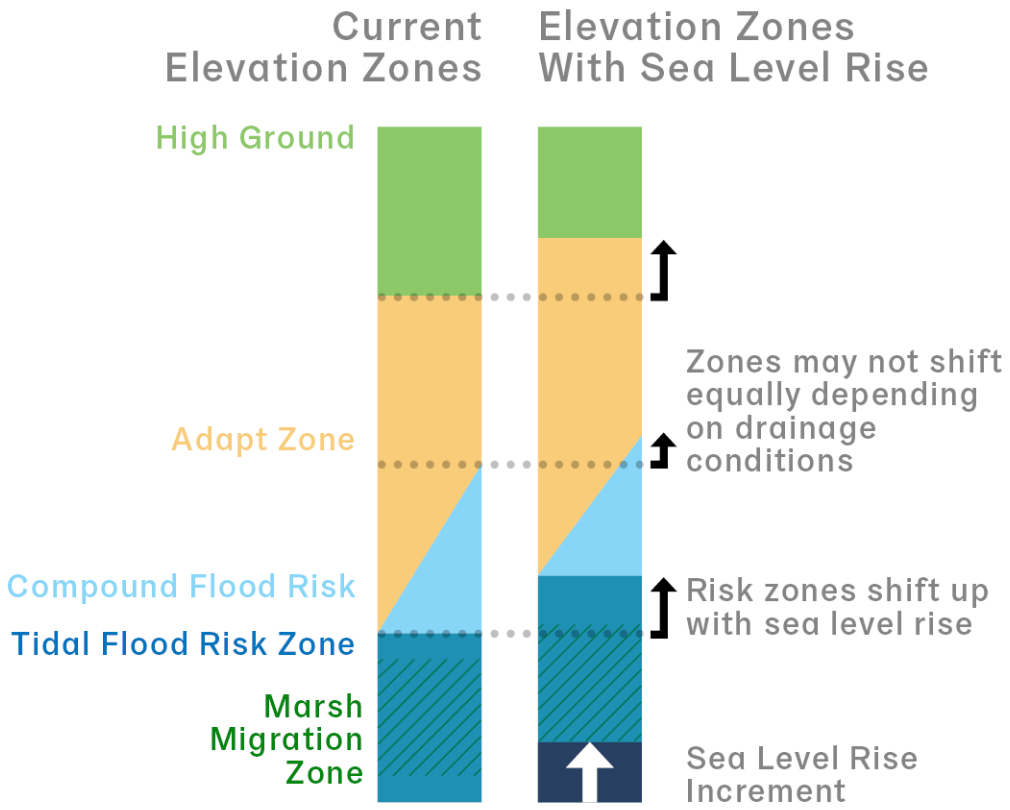
MP-345.05

Elevation & Land Cover Distribution

Using parametric modeling in Grasshopper, multiple data sets were sorted and visualized simultaneously to highlight connections between elevation, flood risk, land use, and ecology.

Land cover indicates the area and density of development, with a range of conditions for undeveloped land, such as wetlands and forests. Together, these graphs show how land is used and how high it is, and reveal opportunities for a long term strategy for resilience.

For example, the map and graphs for the Cainhoy study area show a relatively large amount of high ground that is still undeveloped, indicating an opportunity to concentrate future development in this part of Charleston.



High Ground

High ground is defined as land outside of the FEMA 100 year floodplain and above the NOAA max category 3 storm surge. High ground has the lowest flood risk and stormwater detention here has the greatest watershed benefit.

Adapt Zone

The adapt zone consists of land outside of the FEMA 100 year floodplain that is still within the NOAA maximum storm surge of a category 3 hurricane. Rain and storm surge flooding in this zone is infrequent but not impossible.

Compound Flood Risk

This zone encompasses areas within the floodplain above the tidal flood risk zone where flood risk comes from a mixture of rainfall, runoff and tidal conditions.

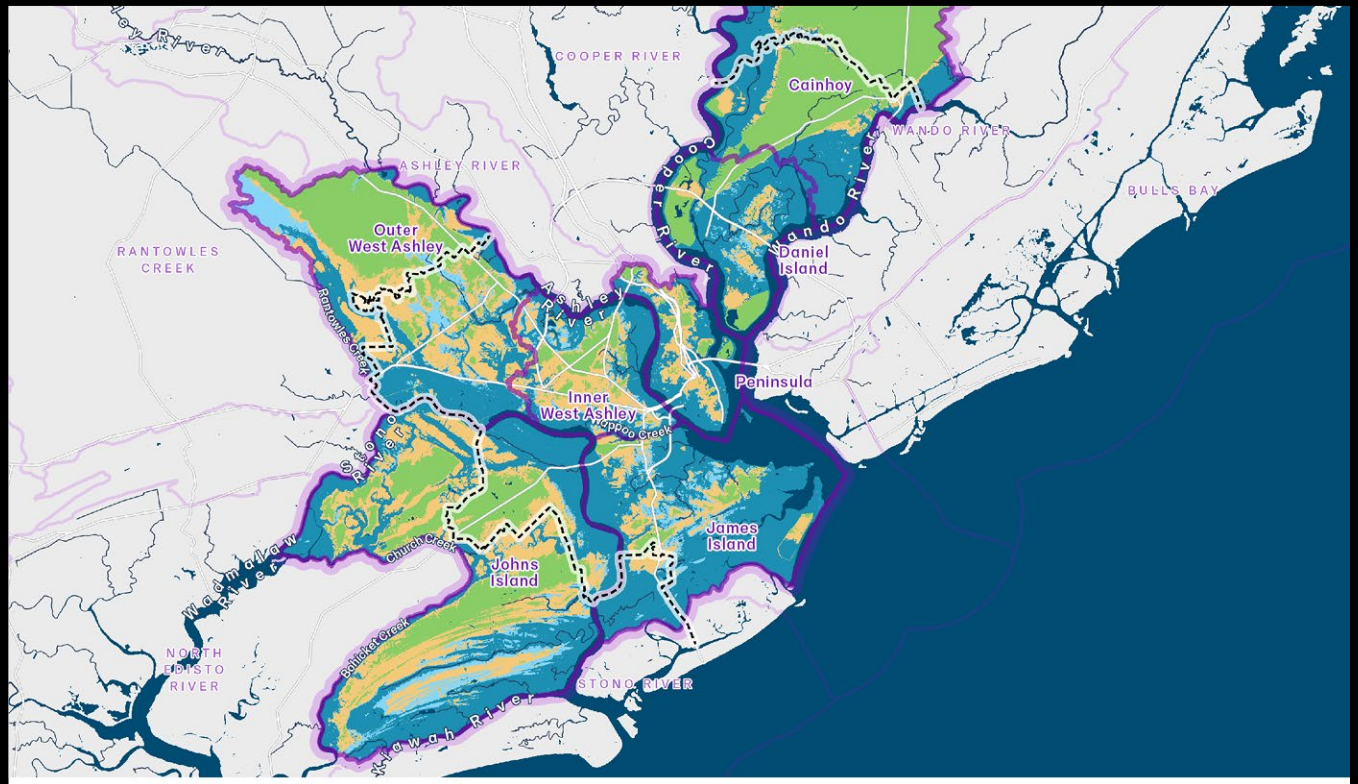
Tidal Flood Risk Zone

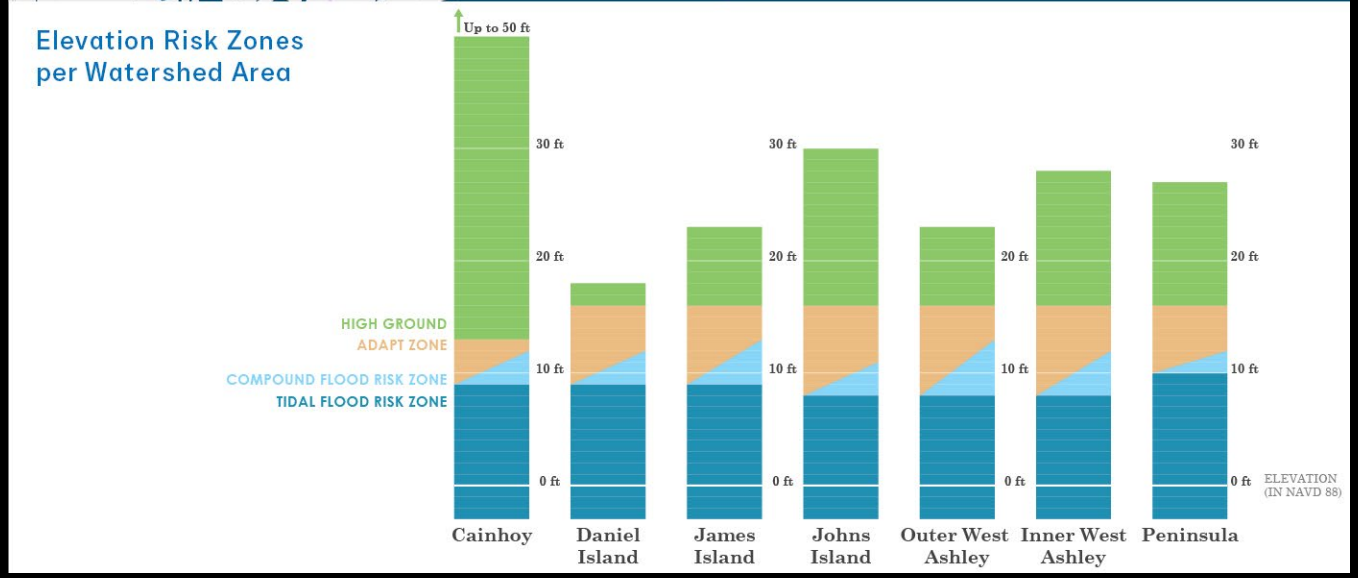
This zone encompasses the lowest land in Charleston, with nearly all of this zone in the 100 year floodplain. Flooding is frequent and can come solely from tidal events independent of precipitation. Sea level rise driven marsh migration occurs in this dynamic zone.

MP-345.06

Elevation Zones

The study analyzed four elevation zones to describe flood risk and adaptation opportunities. Furthermore, these zones shift upwards with sea level rise, complicating any simplistic boundaries drawn between them. But by defining risk in terms of elevation, risk mitigation strategies can be adapted to account for future sea level rise.





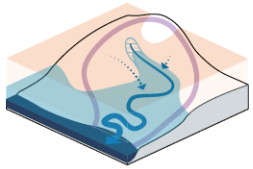
MP-345.07

Elevation and Risk Zone Distributions

Elevation zones vary across watershed areas in Charleston based on local conditions such as topography, existing development, and drainage systems. Little land within the urban growth boundary is above both the floodplain and the storm surge zone, and making use of this limited land is critical for future sustainable development.

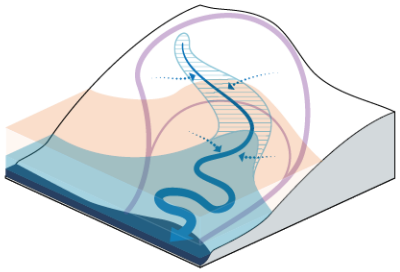
Small Watersheds

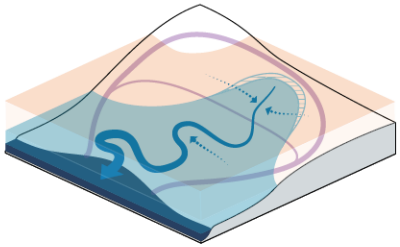
- Small waterways or sheet flow
- Lower potential runoff accumulation
- Lower potential drainage backup



Large Watersheds

- Large, well-defined waterways
- Watersheds are large enough to be broken down into Upstream & downstream subwatersheds





Runoff
Drainage Path
Watersheds
Subwatersheds
Tidal Flooding
Compound Flooding
Maximum Storm surge

Large Inland

- Upstream portions significantly above the tidal range
- Higher potential Runoff Accumulation
- Moderate Potential Drainage Backup

Large Tidal

- Majority is tidal or tidally influenced
- Higher potential Runoff Accumulation
- Higher Potential Drainage Backup

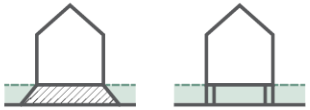
Structure Type & Vulnerability

"Vulnerable" Definition used for watershed analysis

High Combined Vulnerability & Risk

In the 100 year floodplain

Built before BFE requirements
(1971 for Charleston, 1983 for Berkeley)



Medium Combined Vulnerability & Risk

In the 100 year floodplain

Built after BFE requirements
(1971 for Charleston, 1983 for Berkeley)

Low Combined Vulnerability & Risk

Outside the 100 year floodplain

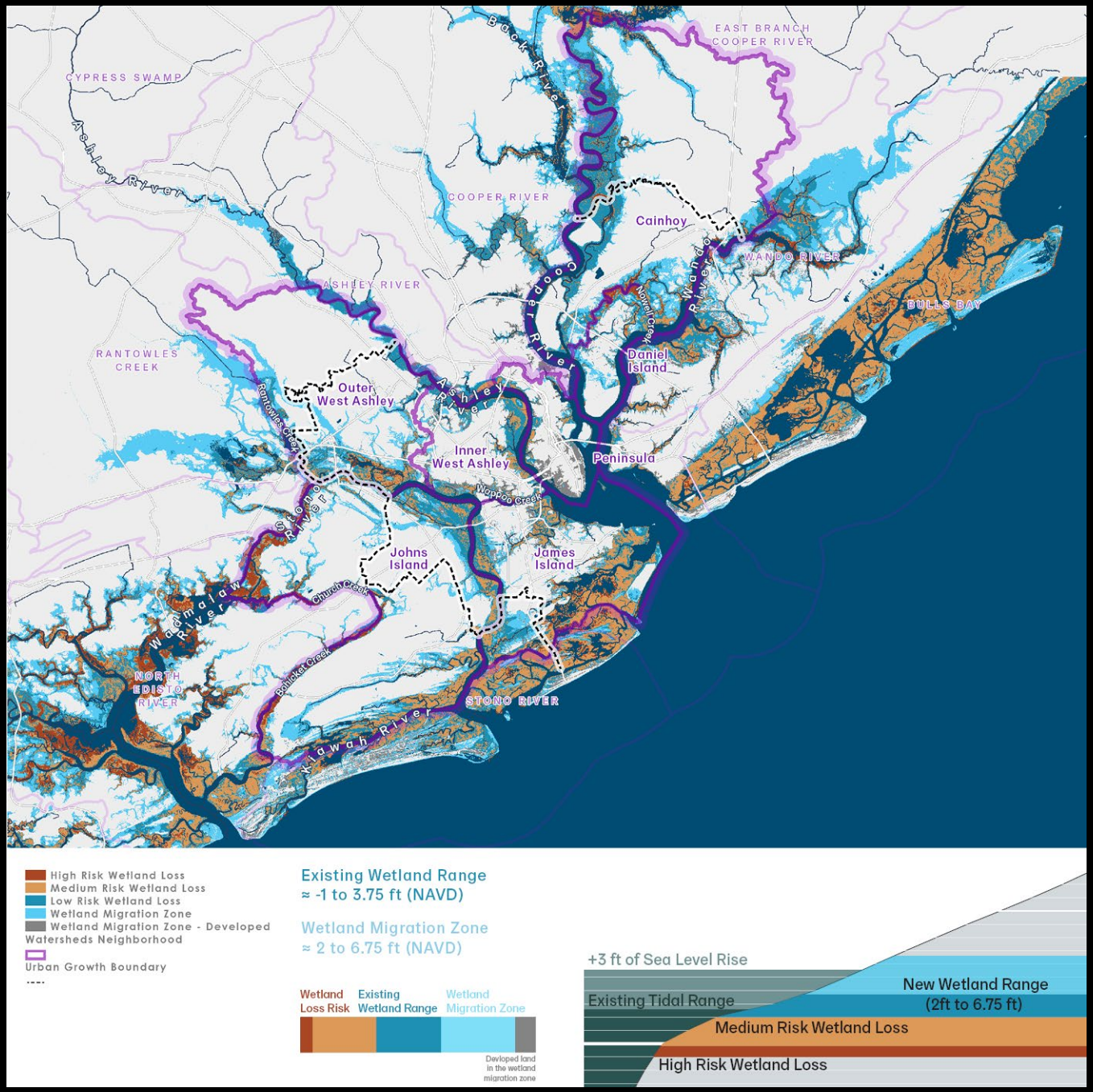
Built after BFE+1 requirements
(2015 for Charleston, 2018 for Berkeley)

MP-345.08

Analyzing Watershed Sensitivity

Watershed typology influences potential flood risk. Each watershed type has different characteristics that can affect existing building types and their vulnerability for flooding.

Combined Vulnerability & Risk Definitions come from the NEMAC+Fernleaf Vulnerability and Risk Assessment (2020).



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Incorporating Environmental Sensitivity

As sea levels rise, wetlands stand to erode or migrate inland depending on their exposure to wave action and ability to migrate onto undeveloped land. Risk of wetland loss is highest along the coast, while most of the space for marsh migration is in inland watershed areas like inner West Ashley and Cainhoy.

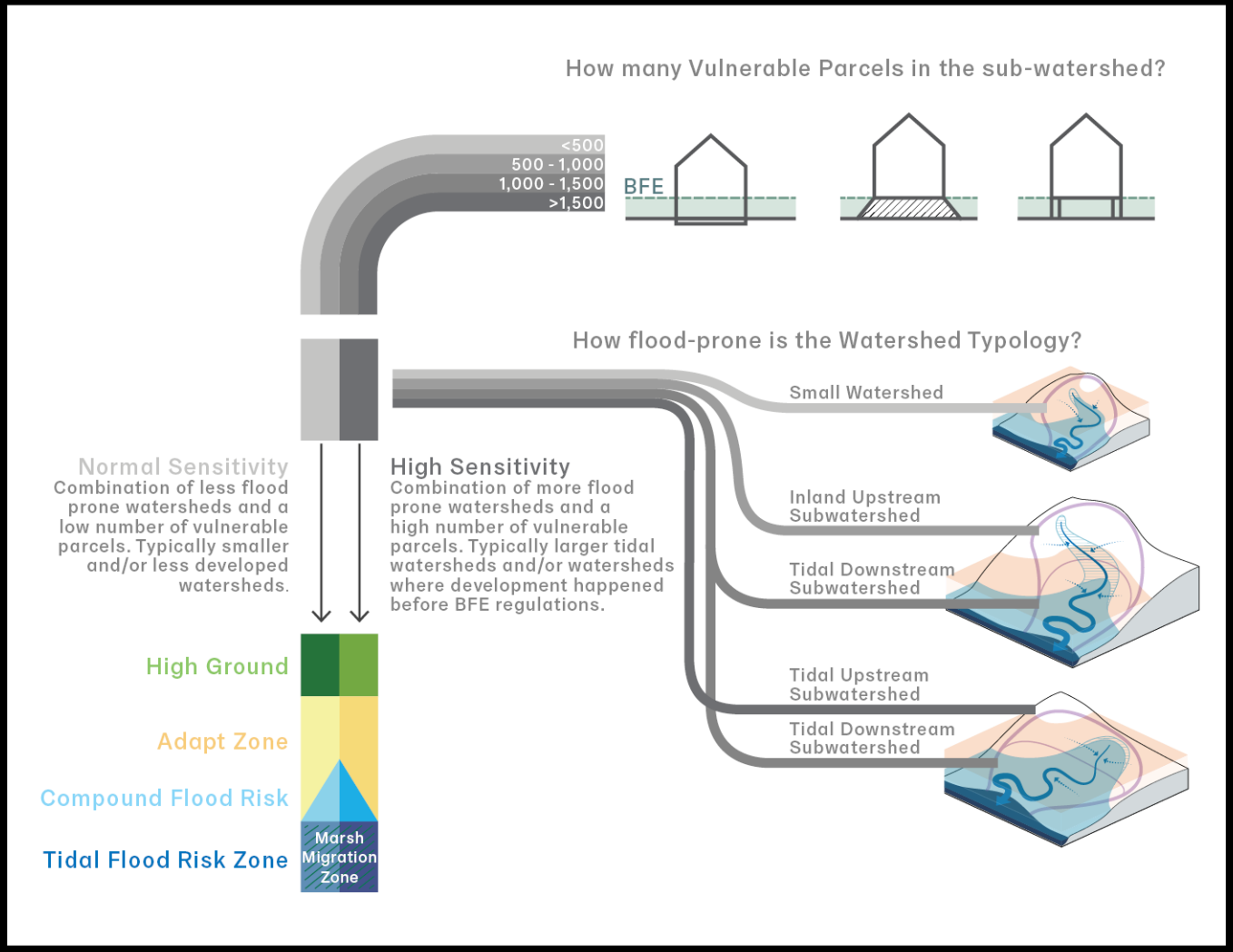
Data sources: USGS, MRLC

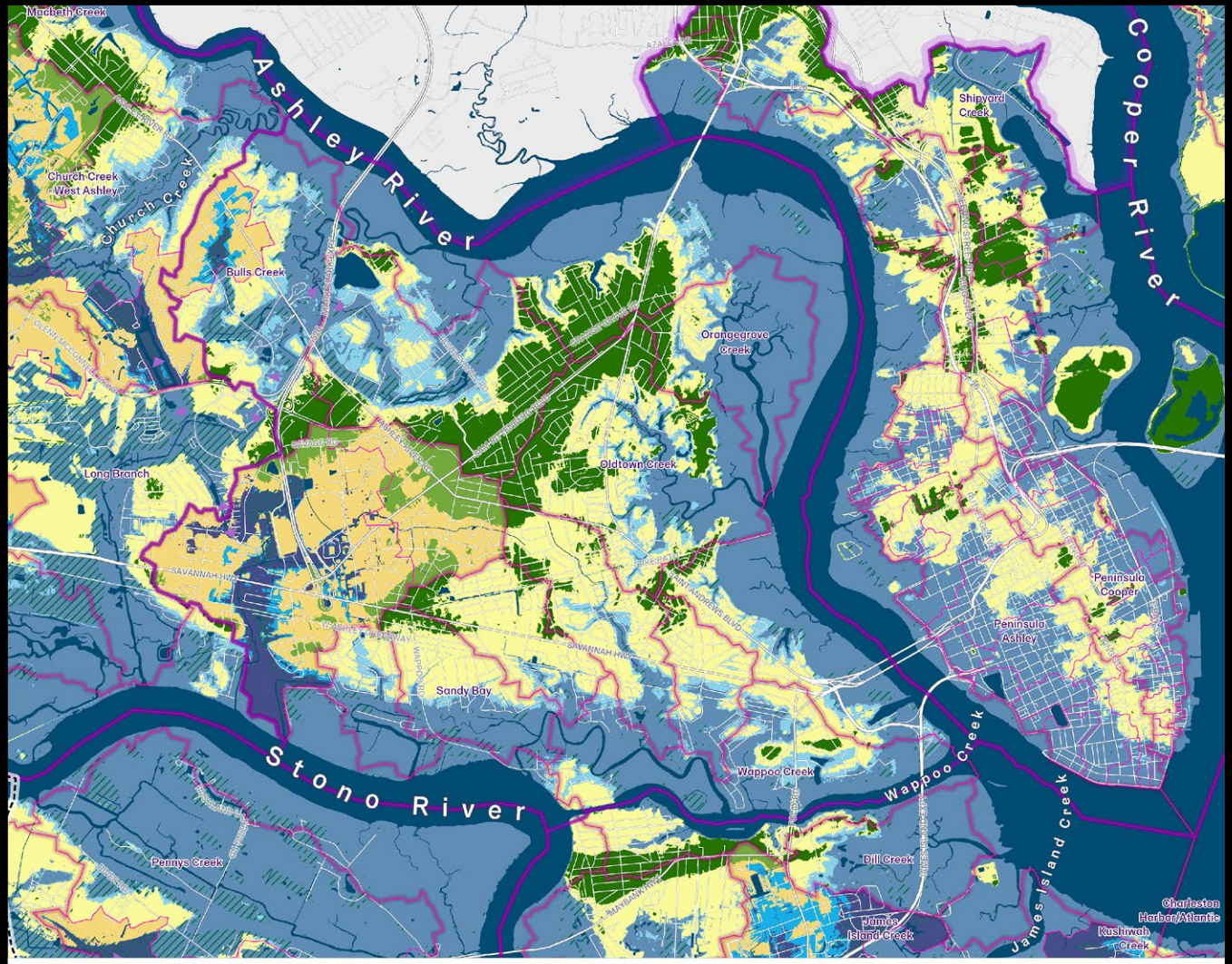
MP-345.10

Watershed Sensitivity: Vulnerable Parcels and Watershed Typology

Watershed sensitivity refers to a parcel's effect on its surroundings and properties downstream. Watershed sensitivity combines the number of vulnerable parcels in a watershed with the typological flood risk of the watershed.

Depending on the combination of those two factors, watershed and zone are classified as high or normal sensitivity. Number of vulnerable parcels are weighted higher than watershed typology to preference potential real impacts to structures.





Legend

Risk & Watershed Impact

- Tidal Flood Risk, High Impact
- Tidal Flood Risk, Low Impact
- Compound Flood Risk, High Impact
- Compound Flood Risk, Low Impact
- Adapt Zone, High Impact
- Adapt Zone, Medium Low Impact
- High Ground, High Impact
- High Ground, Low Impact
- Marsh Migration Zone

MP-345.11

Composite Risk Mapping: Elevation Zones and Watershed Sensitivity

The combined elevation zone and watershed sensitivity maps show the relative risk of an area and how that area impacts the flood risk of its surroundings. A zoomed in view shows finer grained detail of how elevation and water are considered together as the foundation for a future planning strategy.

Upland Ridges

Lowland Floodplain

Coastal Edge Community

Urban/Suburban Reforestation

MP-345.12

Landscape Typologies

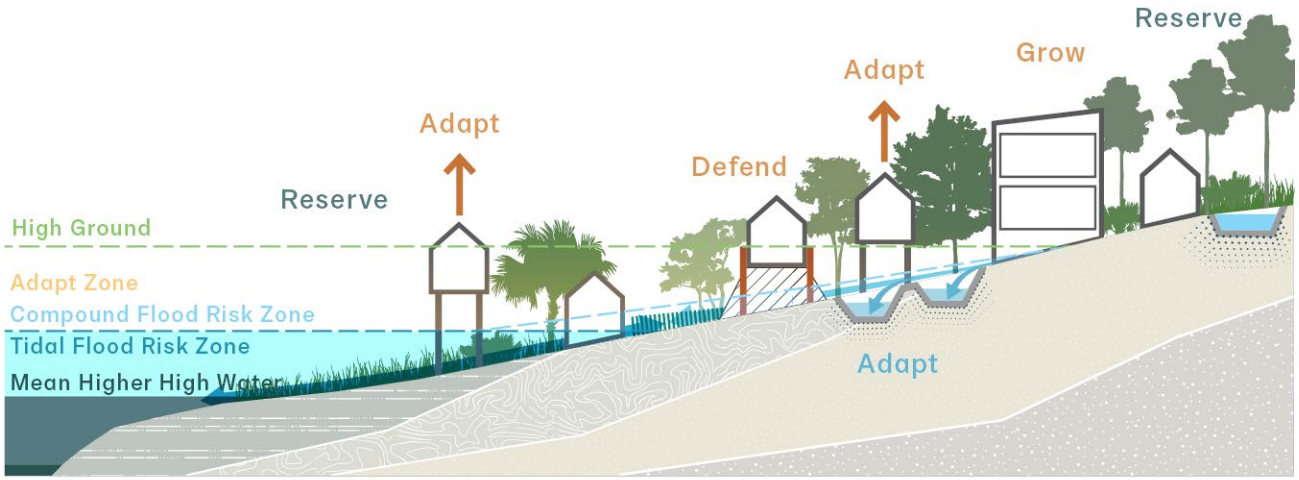
Landscapes at different elevations inform water management goals:

The goal in the High Ground Zone is to maintain or increase existing permeable surface cover and limit net volume of stormwater runoff.

The goal in the Adapt Zone is to manage both the runoff generated within the watershed and the runoff shed from the High Ground Zone, and to protect against storm surge events.

The goal in the Compound Flood Risk Zone is to limit growth, maintain or reduce net volume of stormwater runoff, and adapt vulnerable infrastructure.

The goal in the Tidal Zone is to limit growth, restore marsh and wetland function, and allow for marsh migration where appropriate.



	Tidal Flood Risk Zone		Compound Flood Risk		Adapt Zone		High Ground	
	High Sensitivity	Normal Sensitivity	High Sensitivity	Normal Sensitivity	High Sensitivity	Normal Sensitivity	High Sensitivity	Normal Sensitivity
GROW					◒	◒	◒	●
DEFEND	◒	●		◒				
ADAPT	◒	◒	◒	◒	◒	◒		
RESERVE	●	●	●	◒	●	◒	◒	◒

MP-345.13

Planning Strategies

The study's recommendations lay the groundwork for Charleston's effort to develop elevation-based zoning. Grow: Responsibly increase development and population density in areas with low sensitivity and low risk, with water management. Defend: Protect buildings and infrastructure with engineered measures in areas with the highest risk and lowest sensitivity. Adapt: retrofit vulnerable existing infrastructure to be resilient to water risks, as limited by building typology. Reserve: restore and preserve natural ecosystems, considering future change.

Part of the City's resilience strategy is a toolkit of measures to better manage water based on elevation. The toolkit includes a description of each water management measure, in which elevation risk zone it would be appropriate, and the additional benefits it would provide as an amenity or habitat.

Project Name:
Charleston City Plan: Land & Water Analysis

Project Location:
Charleston, SC

Owner/Client:
City of Charleston

Architect(s) of Record:
(names and addresses)
Waggonner & Ball
Architecture / Environment
2200 Prytania Street
New Orleans, LA 70130

Project Team:
Waggonner & Ball
Robinson Design Engineers
Surculus

Landscape Architect:
Surculus

Consultants:
Robinson Design Engineers
Surculus

General Contractor:
N/A

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