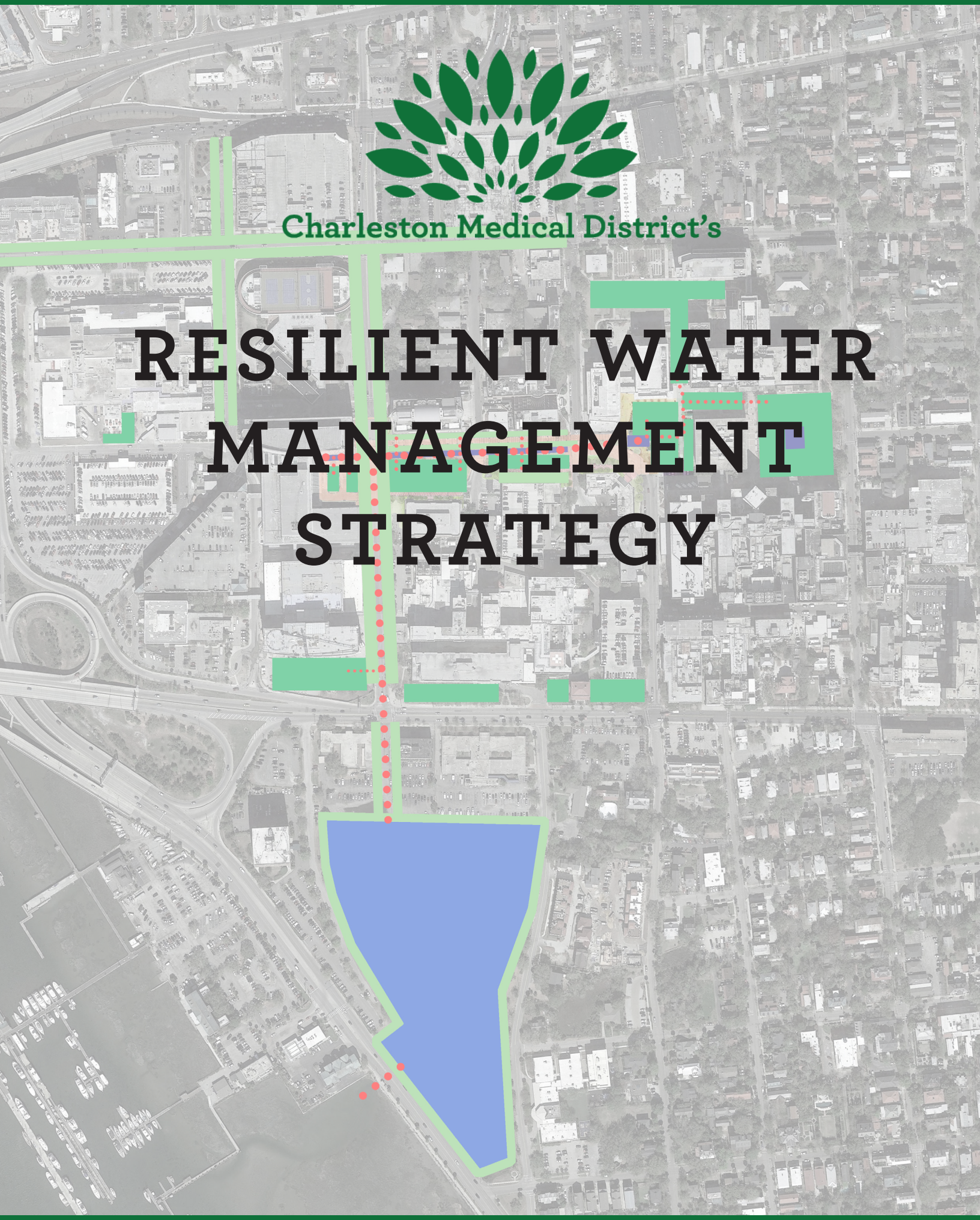


Charleston Medical District's

RESILIENT WATER MANAGEMENT STRATEGY

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The Charleston Medical District (CMD) provides care to the city, county and to South Carolina, the Southeast US, and beyond. Comprised of the Medical University of South Carolina, Ralph Johnson VA Medical Center, Roper Saint Francis Medical Center, and the City of Charleston, the CMD works collectively to provide the best healthcare possible by managing opportunities and challenges that are common to the CMD members.

Climate adaptation is critical as we seek to mitigate and plan new strategies to deal with sea level rise and increased flooding. Storm and flood frequencies are increasing and threaten life and safety of the patients, employees, visitors, and residents in the CMD. Major storm events have hit Charleston and its region yearly for the past five years, affecting access to essential medical care. The delivery of healthcare itself is at risk. These risks are further worsened with exposures to extreme heat, one of the key vulnerabilities identified by the City of Charleston's Vulnerability Analysis. To address these risks, the CMD embraced green infrastructure planning to address water and to cool the CMD environs. Learning to live with water while improving the stability of healthcare delivery and while cooling the district is a key premise.

Rather than fighting water in traditional ways, the CMD has been working on multiple strategies to embrace the idea of living with water. These strategies also introduce greater cooling to the district and so serve multiple purposes. Five short term opportunities are moving forward in 2020. They are:

1. Install and improve the pump stations and connections in the VA parking lot and in the Calhoun/ Lockwood cloverleaf. These pumps stations will reduce VA site flooding and Calhoun Street flooding and improve access.
2. Continued effort to add the Ehrhardt Tunnel Project to the Spring Fishburne Tunnel Project. This connection will reduce President and Bee Street flooding to improve access to the hospitals.
3. Study and design a water collection and storage project along the Doughty Street Greenway between President and Courtenay to mitigate flooding in the center of the CMD. This project will reduce district flooding, increase cooling and improve the overall district experience for faculty, staff and patients.
4. Study and design a water management system connecting to the Doughty St. Greenway, along Courtenay to Long Lake, and adding increased storage capacity to Long Lake with managed in/out flows to the Ashley River. This system will expand on-site retention capacity to reduce flooding and manage the timing of water distribution in concert with tidal cycles.
5. Plan and design an elevated multi-level connector between the MUSC BioEngineering Bldg. and Ashley River Tower, with connection spines to Roper Saint Francis Medical Center and the VA Medical Center. These connections will provide near-term dry-feet access through the campus during times of flooding.

The CMD is actively working to move these short-term projects ahead, while preparing for a 2020 charrette to begin planning on mid and long-range projects for the next 3 years. The planning will include shared goals: flood reduction for improved access to and within the CMD, improved parking and valet services, and improved public space and amenities. This effort works in concert with the City's update to its Comprehensive Plan, the USACE's 3x3 Storm Surge Planning, nearby master planning for West Edge, the Citadel, Low Country Rapid Transit and the Department of Transportation's Ashley River Pedestrian Bike Bridge.

We welcome your suggestions and comments as we learn to live with water while continuing to improve the Charleston Medical District in the years to come.

THE MEDICAL DISTRICT

MUSC
MEDICAL UNIVERSITY of SOUTH CAROLINA

ROPER ST. FRANCIS

VA Ralph H. Johnson VA Medical Center

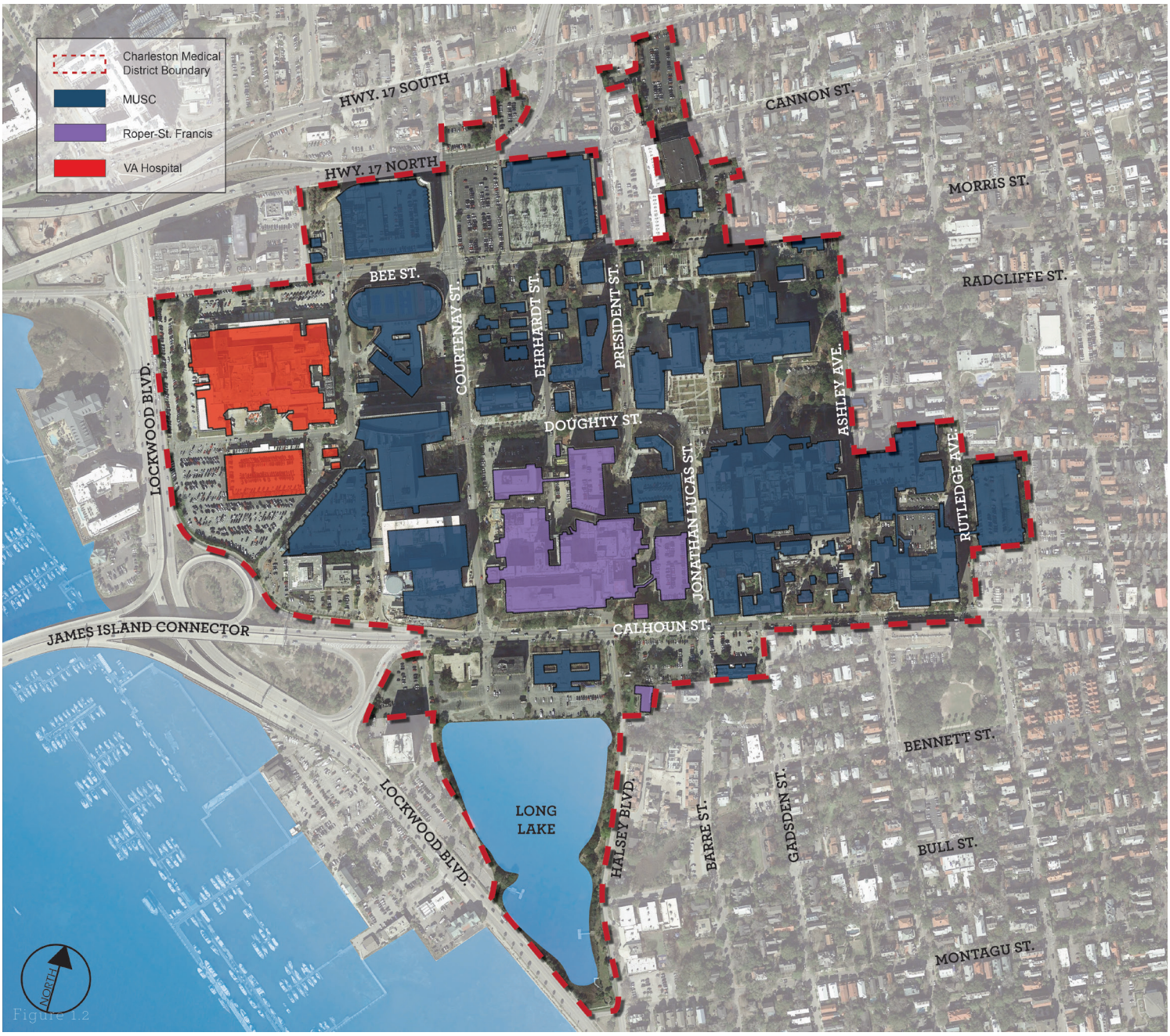


Figure 1.2

Map of the Charleston Medical District showing the three major institutions.

Figure 1.1

Medical District leadership with Mayor John Tecklenburg of Charleston at the grand opening of the Medical District Greenway.

THE MEDICAL DISTRICT

The Charleston Medical District is home to three major medical centers, the premier medical university of the region, and the region's only Children's Hospital.

VA Ralph H. Johnson VA Medical Center

25,000 EMPLOYEES

The CMD is a city within a city. Both MUSC and Roper St. Francis are in the top ten largest employers in the Charleston region. And together, the three hospital systems employ over 25,000 people.

ROPER ST. FRANCIS

+$4 BILLION IMPACT

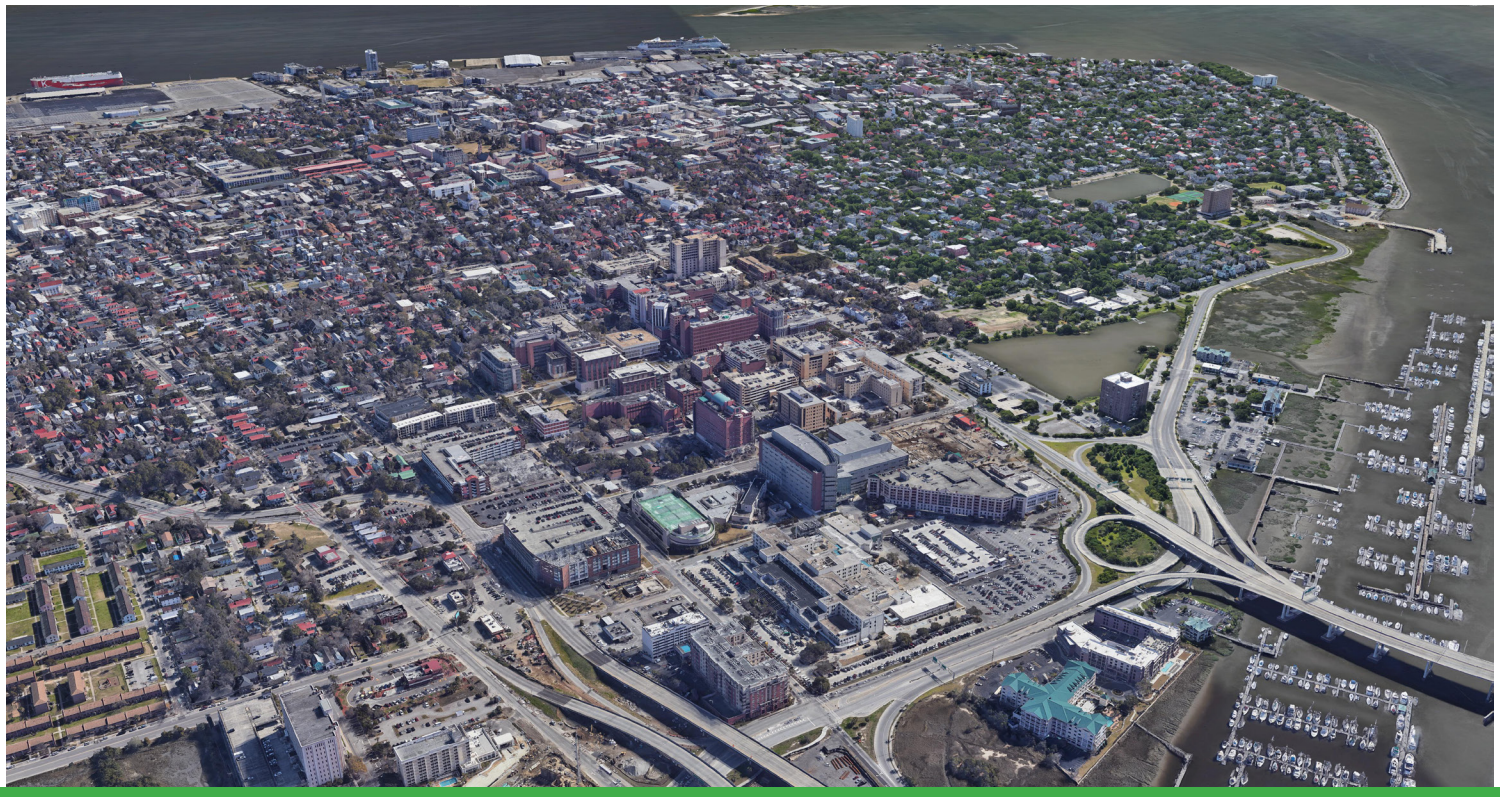
MUSC alone contributes to $3.8 billion in economic impacts to the region, not counting all of the secondary industries that support the CMD.

MUSC MEDICAL UNIVERSITY of SOUTH CAROLINA

+1 MILLION PATIENTS

The CMD sees over 1 million patients on an annual basis.

musc Shawn Jenkins Children's Hospital
Medical University of South Carolina



The Charleston Medical District occupies a precarious position on the peninsula of Charleston.

BUILT ON FILL

The maps on the right show how the land that is now the CMD was filled in over time to create land from what once was the Ashley River and marsh.

BELOW 8' ELEVATION

90% of the land in the medical district is at an elevation of 8' or below. This makes it increasingly vulnerable to flooding, storm surge, and sea level rise. (For more information on elevations, see p. 29.)

CRITICAL INFRASTRUCTURE

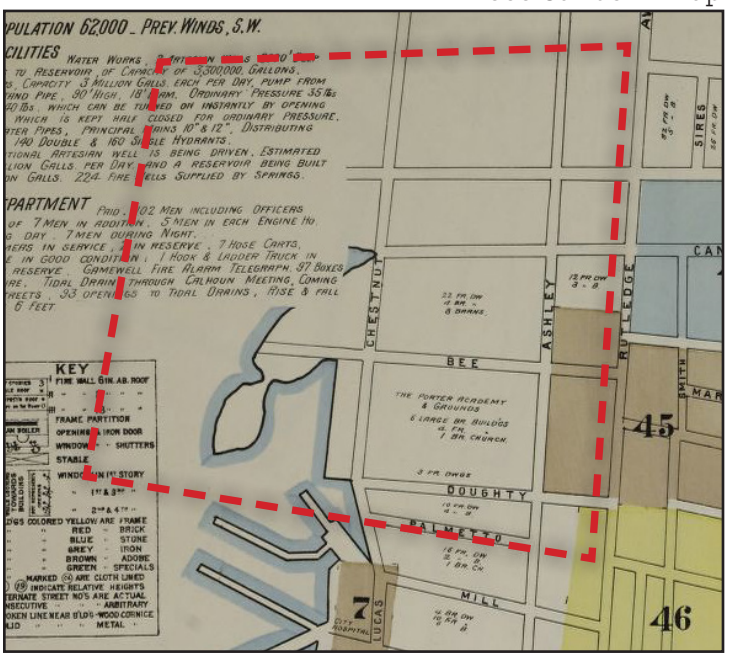
In spite of it's vulnerable position, the CMD houses some of the Charleston's most critical infrastructure, which must be protected and accessible at all times.

PROTECTIVE INFRASTRUCTURE

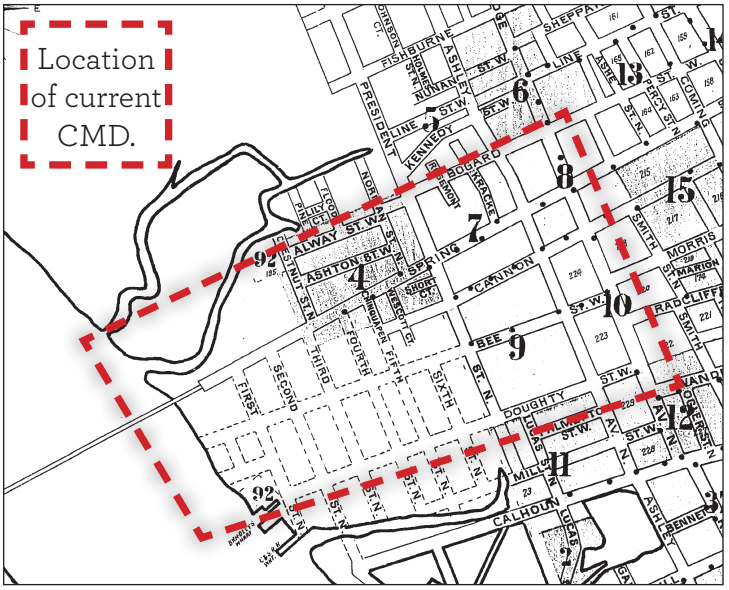
The recently released 3x3 study by the Army Corps of Engineers proposes a sea wall around the Charleston peninsula. This would help protect the CMD from storm surge, but would not help with stormwater flooding.

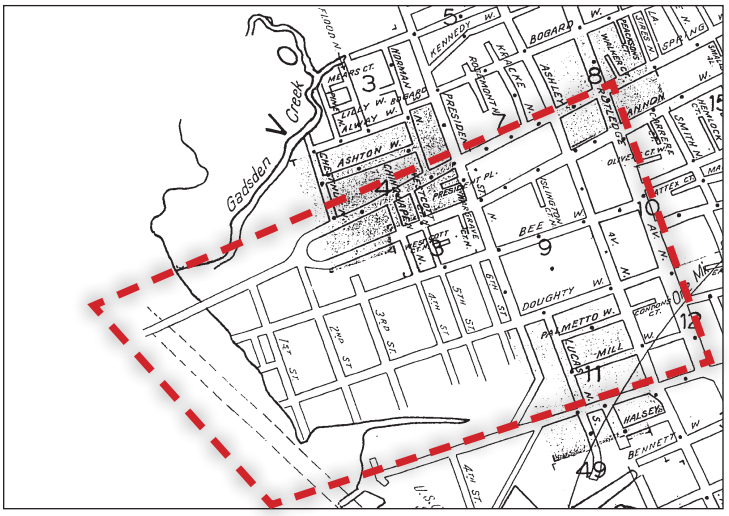
This pamphlet provides solutions and funding opportunities to protect the CMD from dangerous stormwater flooding that it experiences on a regular basis today.

1888 Sanborn Map



1902 Sanborn Map





FLOOD FREQUENCY

- Sea level has risen 1.07 feet in the last 100 years, and continues to rise. It is projected to rise another 2-3 feet over the next 50 years.[1]
- Storm events are more frequent
- Flood events are becoming more severe and more frequent.

"The Charleston Harbor tide gauge reached or exceeded 7.0 feet 89 times. Minor tidal flooding begins at about 7 feet."

-Bo Petersen and Mikaela Porter

Charleston and the South Carolina coast flooded record 89 times in 2019

BY BO PETERSEN AND MIKAELA PORTER BOPETE@POSTANDCOURIER.COM MPORTER@POSTANDCOURIER.COM
JAN 3, 2020

2 of 2

A car drives through floodwaters from a high tide near The Battery on Feb. 20, 2019. File/Lauren Petracca/Staff

BY LAUREN PETRACCA LPETRACCA@POSTANDCOURIER.COM

BUY NOW

Figure 2.1

"The National Weather Service reported...a record number of coastal flood events - 89, on at least 76 individual days - occurred along the Southeast and South Carolina coast last year by an alarmingly wide margin.

The previous record was 58 times, in 2015."

-Bo Petersen and Mikaela Porter

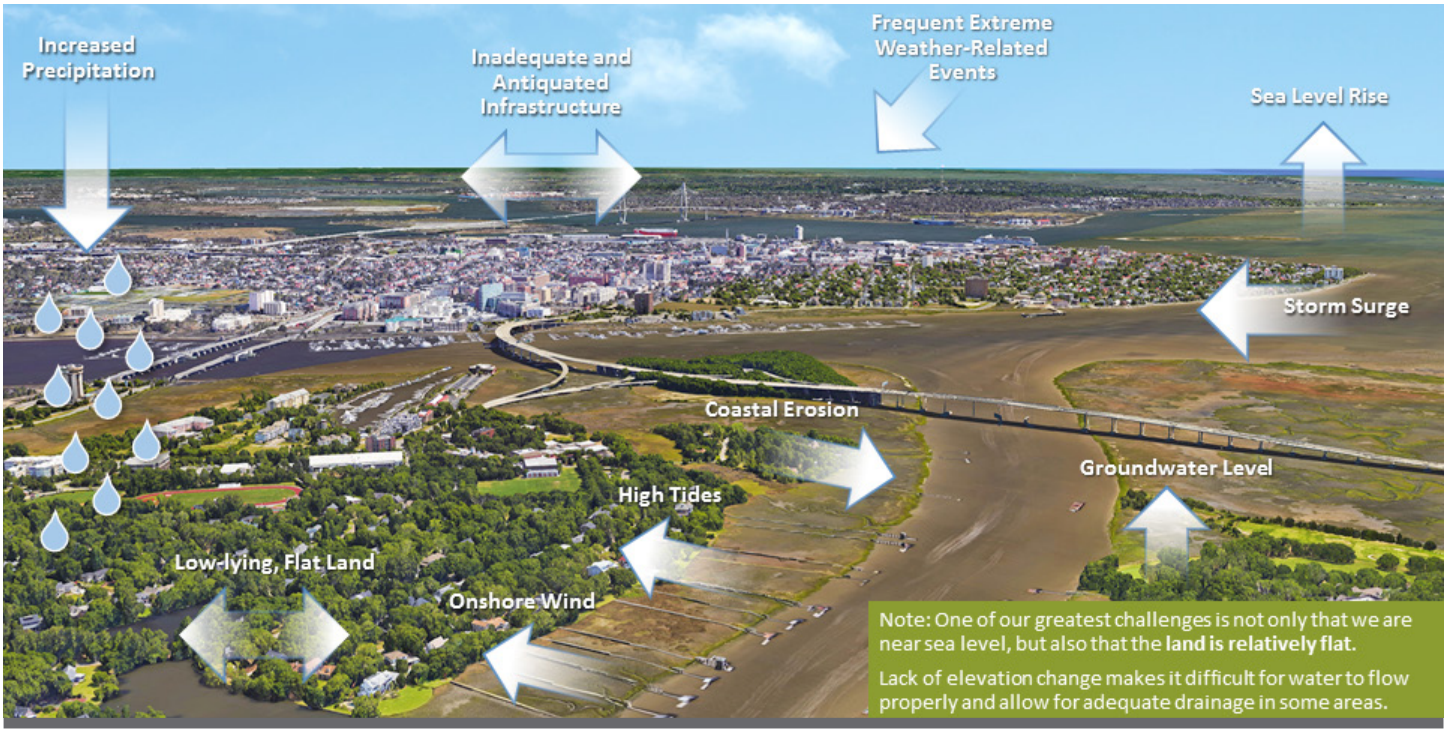
[1] See Appendix, p. 27-19

WHAT CAUSES FLOODING?

Flooding can be caused by many factors working independently or in tandem to create flood events. These can be broken down into two broad categories:

1. Precipitation Events (Stormwater)

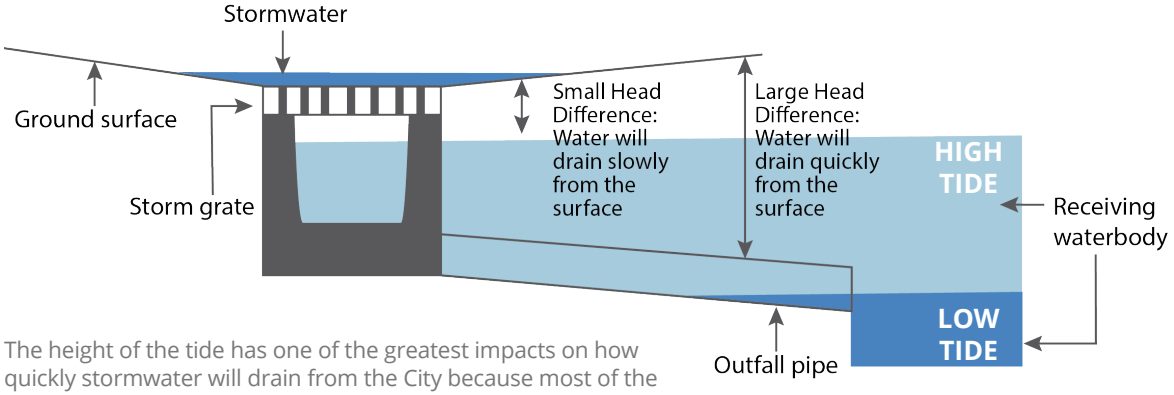
2. High Tides or Storm Events (Sea Level)



Above: Flooding is caused by many factors, which often combine simultaneously to form a complex, multi-faceted challenge.

Figure 2.2

HOW DOES THE TIDE LEVEL AFFECT OUR STORMWATER SYSTEM?



The height of the tide has one of the greatest impacts on how quickly stormwater will drain from the City because most of the outfalls of the City drain to water bodies that are tidally influenced.

Figure 2.3

NUISANCE FLOODING

The Charleston Medical District is main medical center for the Charleston region. When operations are interrupted it has a dramatic impact on the life-safety for the region. It also has impacts on the bottom line for the three institutions within the Medical District.

Impacts of impeded operations due to nuisance flooding include:

- Staff delays in arriving to work
- Patients missing appointments
- Limited access between buildings, and between medical centers
- Standard operations disrupted
- Interrupted delivery of food and medical supplies
- Interruption of critical utility services

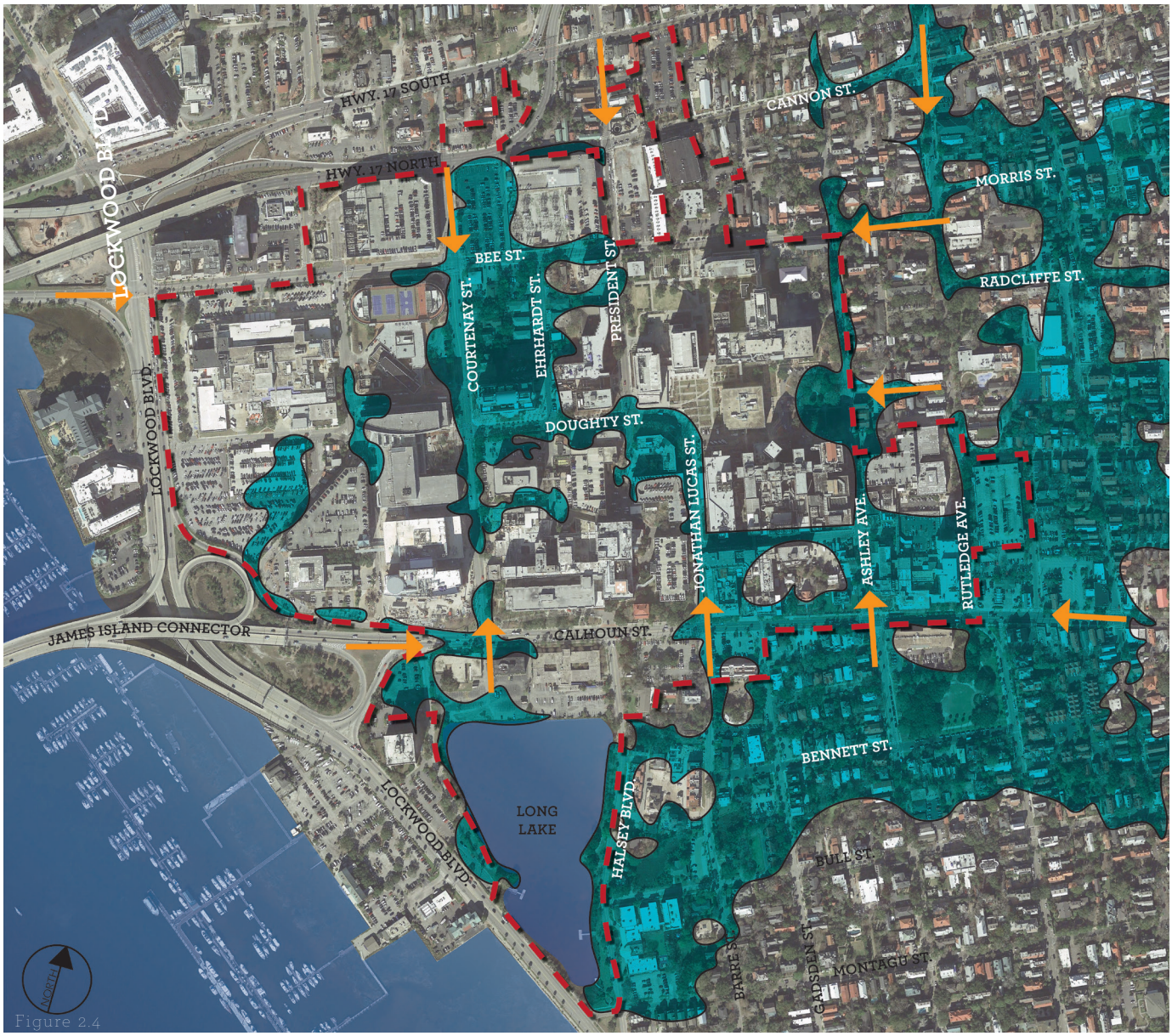


Figure 2.4

This map shows the approximate extent of nuisance flooding in the Medical District. The arrows indicate emergency vehicle access routes, which are impeded in each scenario.

$15 MILLION / YEAR

The CMD estimates the cost of flooding at $15 million/year at a **minimum**. This number was generated from nuisance flooding in years prior to 2019. These costs continue to rise each year.

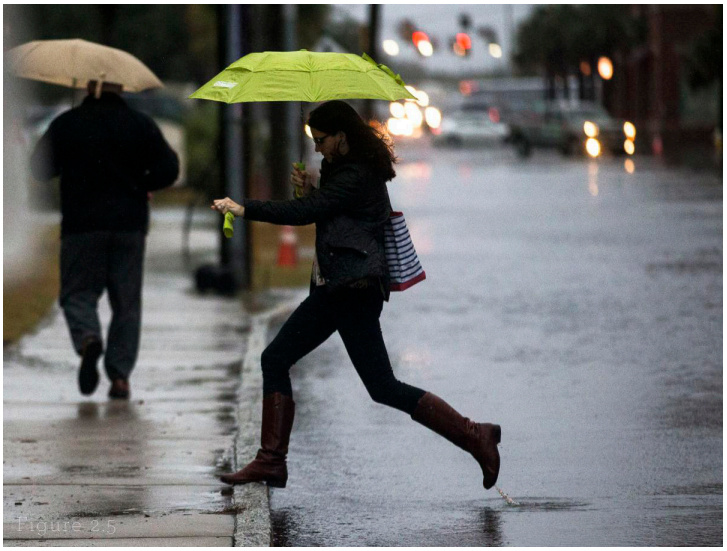


Figure 2.5

89 FLOODS = 154% INCREASE = $23 MILLION IN 2019

The previous record for flooding was set in 2015, at 58 times per year. If the costs remain the same per flood, this means cost of flooding in 2019 was approximately $23 million.

MAJOR STORMS NOT ACCOUNTED FOR

These costs do not account for closures due to hurricanes and tropical storms.

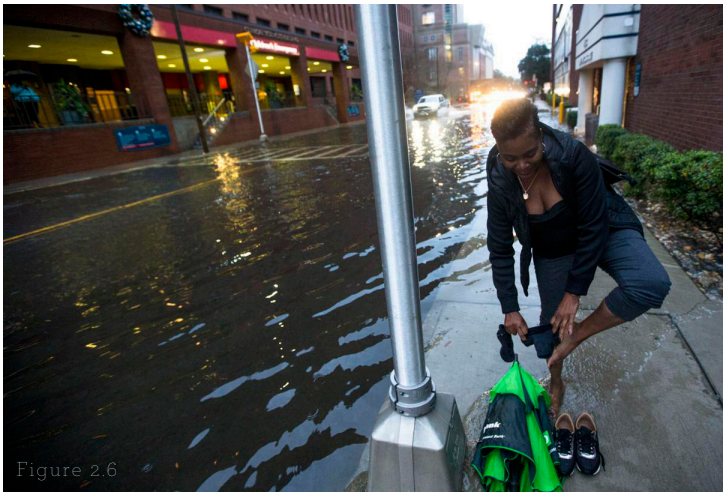


Figure 2.6

$45+ MILLION IN FIVE YEARS

Since the inception of work on the CMD Greenway in 2016, the cost of flooding has been at least $45 million.


Figure 2.7

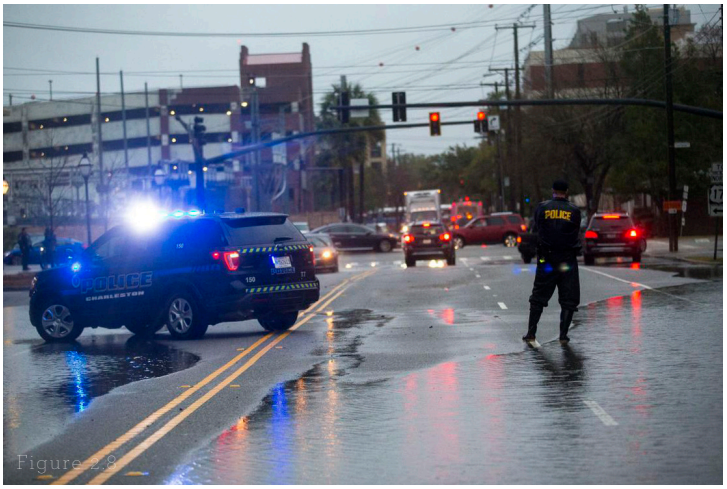


Figure 2.8

These images show flooding in the Medical District resulting from nuisance flooding, or flooding that is result of rainstorms rather than major named storms.

HURRICANES AND MAJOR STORMS

Figure 2.9

LEGEND

Medical District Boundary

Water

Floods with 10' Storm Surge

Emergency Vehicle Access

This map shows the approximate extent of storm surge flooding, if a 10' surge hit at low tide. The CMD is almost entirely consumed by a flood this size, and emergency access is blocked.

The images at right show flooding in the medical district from storms over the past five years.

Figure 2.12

Figure 2.13


Figure 2.11


Figure 2.10

5 STORMS IN 5 YEARS

The Charleston region has experienced five major storms in the last five years, rendering the Medical District non-functional.

- **2015: The Thousand Year Flood** (a result of rain from what was left of Hurricane Joaquin)
- **2016: Hurricane Matthew**
- **2017: Hurricane Irma**
- **2018: Hurricane Florence** (though there was little damage from the storm, the Governor issued a mandatory evacuation order for the region, closing schools and businesses)
- **2019: Hurricane Dorian**

THREATS TO LIFE SAFETY

Major storm events can cause threats to life-safety including:

- Inability to access the premier hospitals in the region.
- Patients being diverted to other hospitals
- Power outages

$40 BILLION/YEAR IN US

Between 2015-2017, hurricanes cost the United States $40 billion/year on average.

2020 TO HAVE MORE STORMS

Scientists at Colorado State University have predicted 2020 to have “above average” hurricane activity. They predict there is a 69% chance of at least one major hurricane (Category 3-5) to hit the Mainland US.

LEARNING TO LIVE WITH WATER

The Medical District has already taken the following steps to learn to live with water:

- Joined the City of Charleston in planning efforts
- Participated in a trip to the Netherlands to learn how they live with water
- Participated in the Dutch Dialogues Charleston Process
- Held a flooding focused work session with the Steering and Advisory Committee

Charleston mayor heading to Netherlands to study flood controls

BY ROBERT BEHRE RBEHRE@POSTANDCOURIER.COM
SEP 26, 2018

In this 2017 photo, a self-raising dike is seen in the Dutch fishing village of Spakenburg. The 300-meter long dike is raised by the very flood waters it is designed to hold back and is an example of Dutch ingenuity in flood prevention that is becoming a major export earner for this low-lying nation. File/Mike Corder/AP

MIKE CORDER

Figure 2.15

Figure 2.17

Figure 2.18

Top image: Dutch Dialogues participants visit Long Lake during the April 30-May 1, 2019 Colloquium. Above left: Dutch Dialogues participants in a charrette session. Above right: The Charleston Medical District Advisory Team's first Adaptation Roadmap meeting in December 2019.

STRATEGIES FOR LIVING WITH WATER

In Charleston, the tidal rivers that surround the region affect our drainage systems. Stormwater that falls on the city during high tide has nowhere to go, which overloads the system, causing flooding. This water needs to be stored on-site until it can be released into the rivers at low-tide.

The Medical District straddles four different drainage basins within the City: the Spring Street basin, the Calhoun Street West basin, The VA Hospital basin, and the Marina basin.

A design storm is a hypothetical storm which includes a frequency and duration, and results in a specific amount of rainfall depending on your area. A 10-year storm is one that has a 10% chance of happening each year. Over a 24-hour period in Charleston, that means that 6.41 inches of rain will fall.

This information can then be used to design stormwater infrastructure to accommodate the runoff generated by the design storm.

The runoff amounts are calculated in acre-feet.

1 acre-foot =
1-foot deep cover a single acre of land =
43,560 cubic feet

Runoff from the 10-year, 24-hour storm, by basin:

Spring Street: **136 Ac-ft**
Calhoun West: **100 Ac-ft**
VA Hospital: **19 Ac-ft**
Marina: **12 Ac-ft**

Medical District Boundary

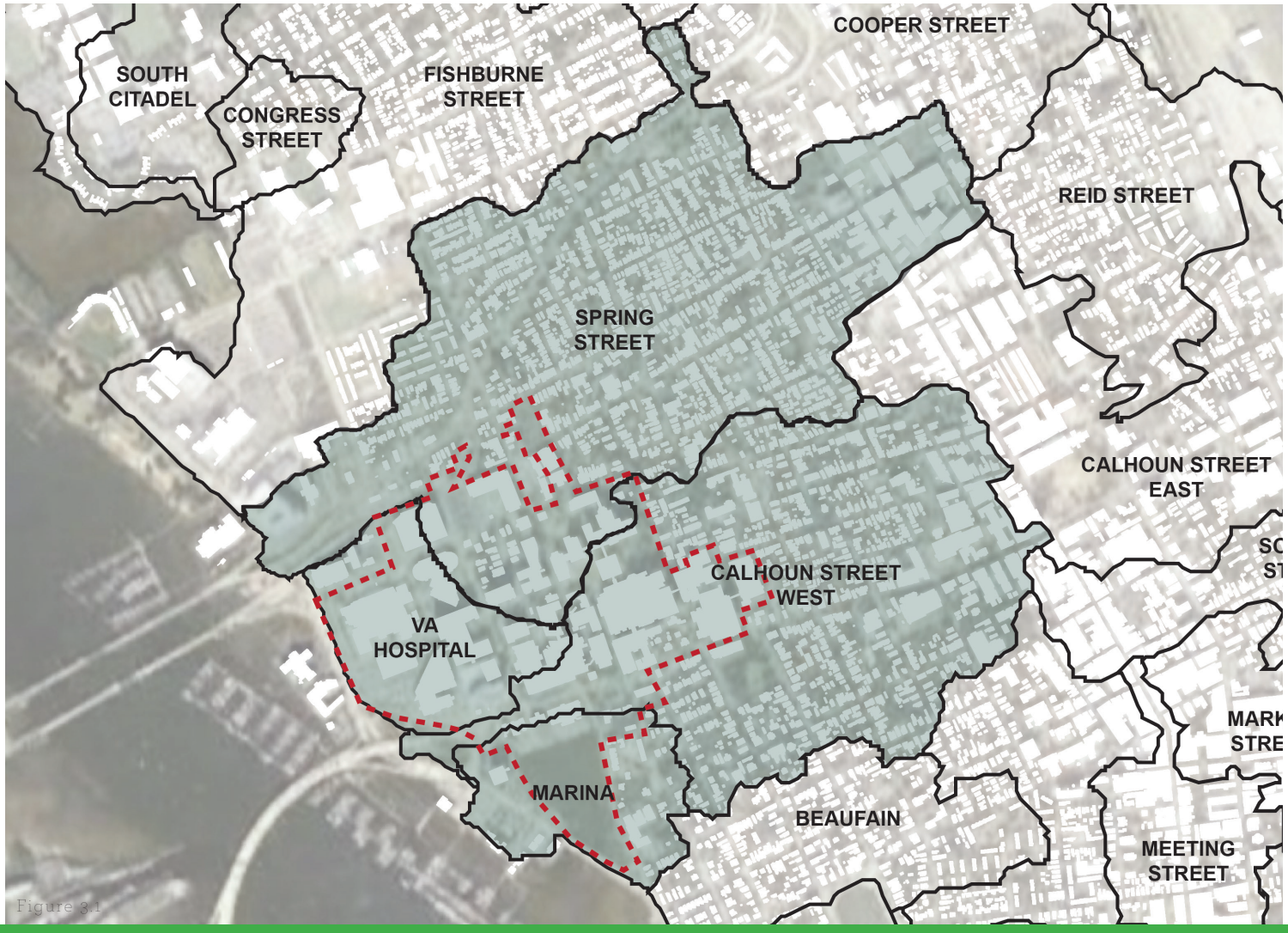


Figure 3.1

CHANGES TO THE BUILT ENVIRONMENT

Adapt the existing built environment to meet the new conditions:

- Elevate roads
- Create elevated access between buildings
- Move essential services to higher floors of buildings

EXISTING CONDITIONS

ADAPTATIONS

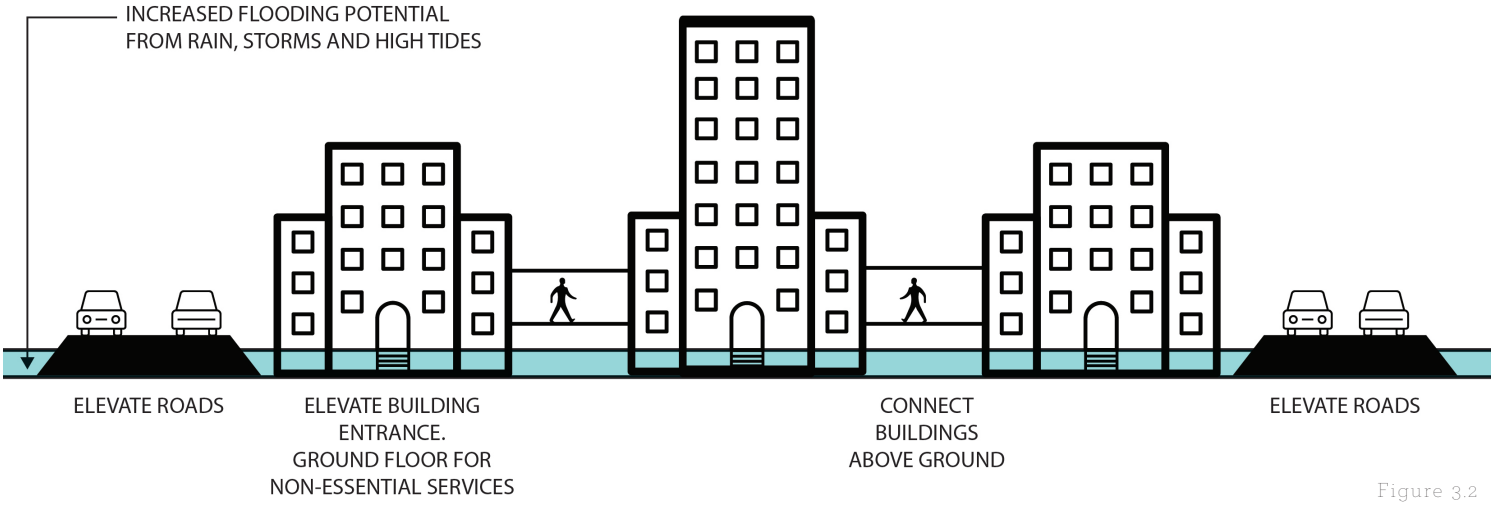
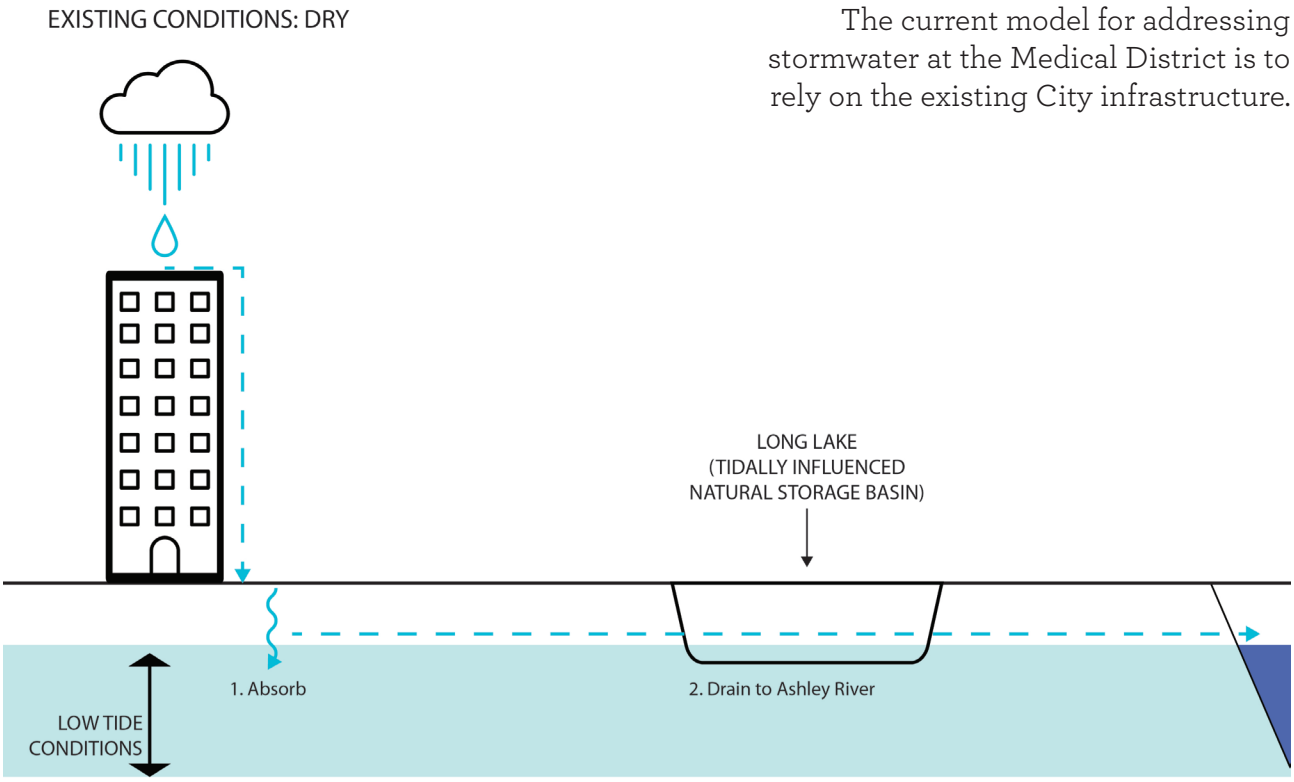


Figure 3.2

ADDING STORAGE CAPACITY TO STORMWATER SYSTEMS

The current model for addressing stormwater at the Medical District is to rely on the existing City infrastructure.



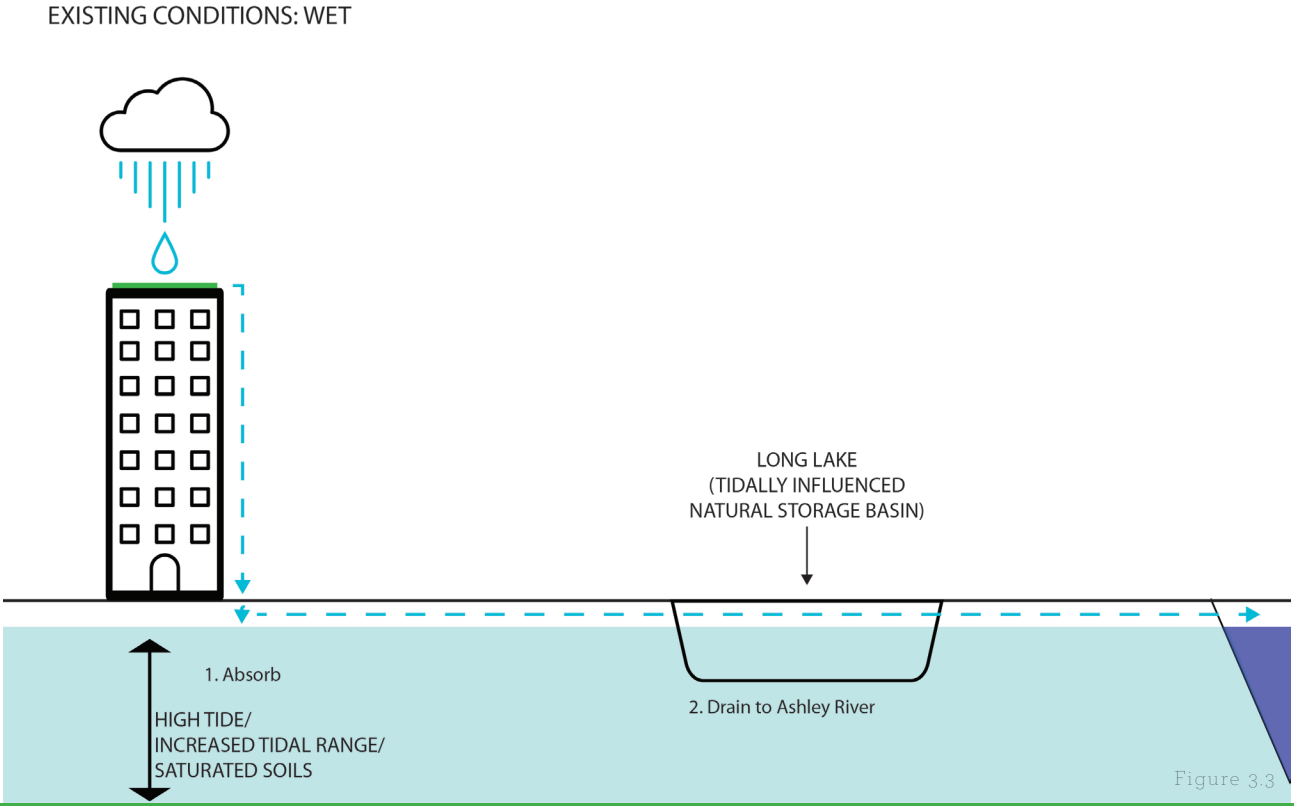
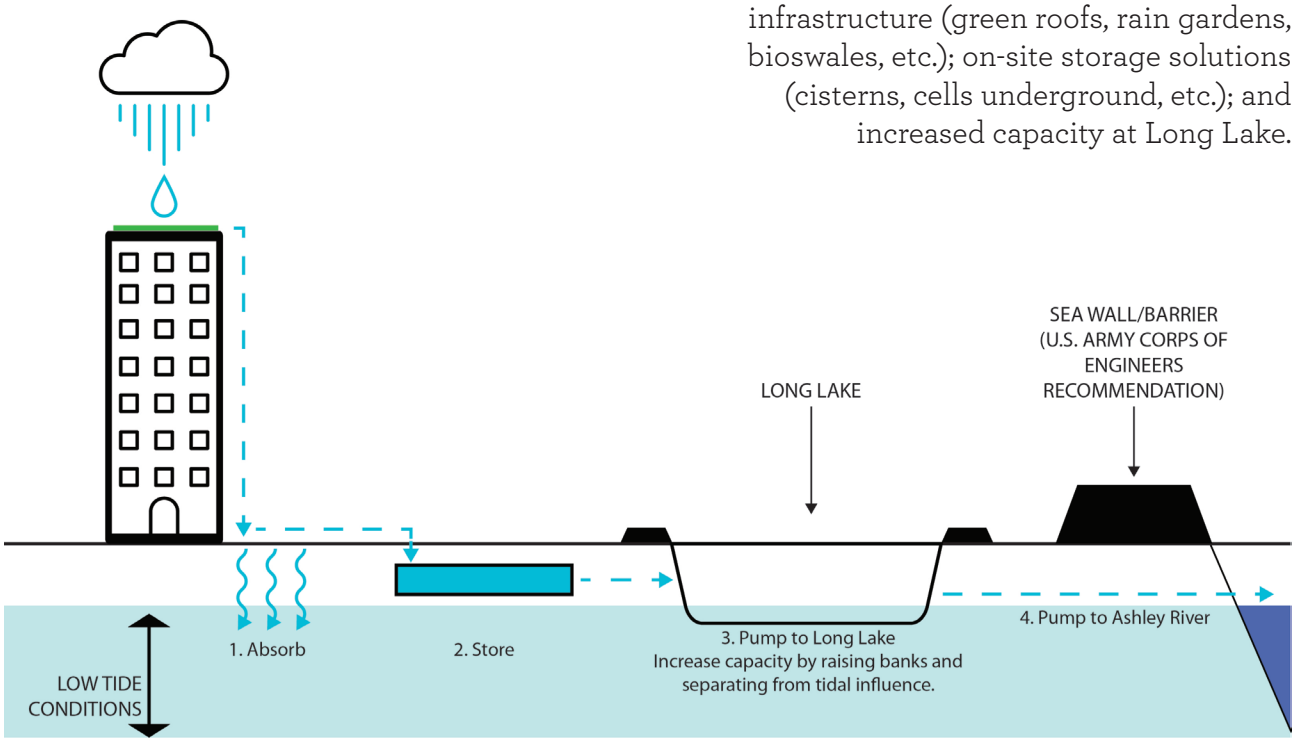


Figure 3.3

Additional capacity can come from green infrastructure (green roofs, rain gardens, bioswales, etc.); on-site storage solutions (cisterns, cells underground, etc.); and increased capacity at Long Lake.



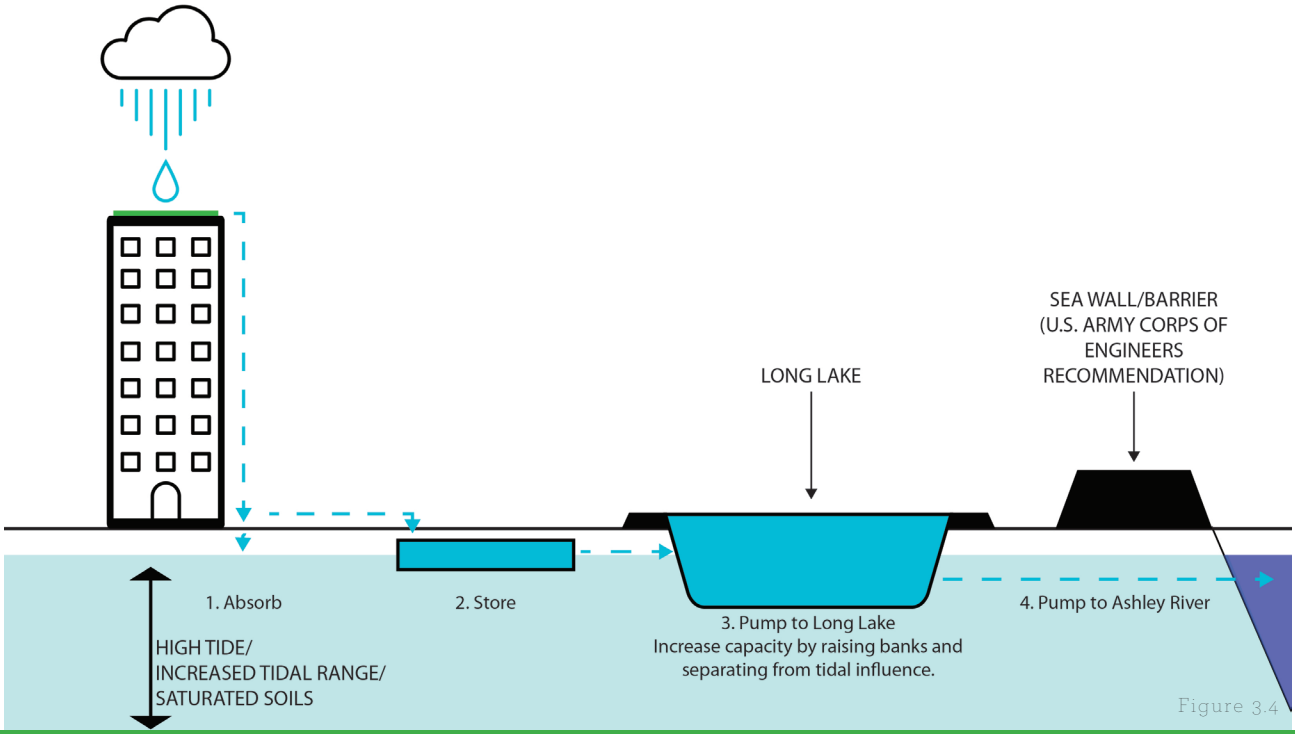


Figure 3.4

FLOOD MANAGEMENT AND GREENWAY

The forthcoming Greenway creates many opportunities for flood management. See image at right for a detailed diagram of the functioning water management strategies. In addition to the many water management strategies proposed here, these images also show how the strategies illustrated on page 15 could work for the Medical District. An elevated porch connects buildings above ground, and creating safe passage between buildings no matter the flood stage.

The Greenway provides a unique opportunity to leverage an investment in stormwater infrastructure, to also enhance the lives of the patients, visitors, and medical staff of the CMD.

Figure 3.5

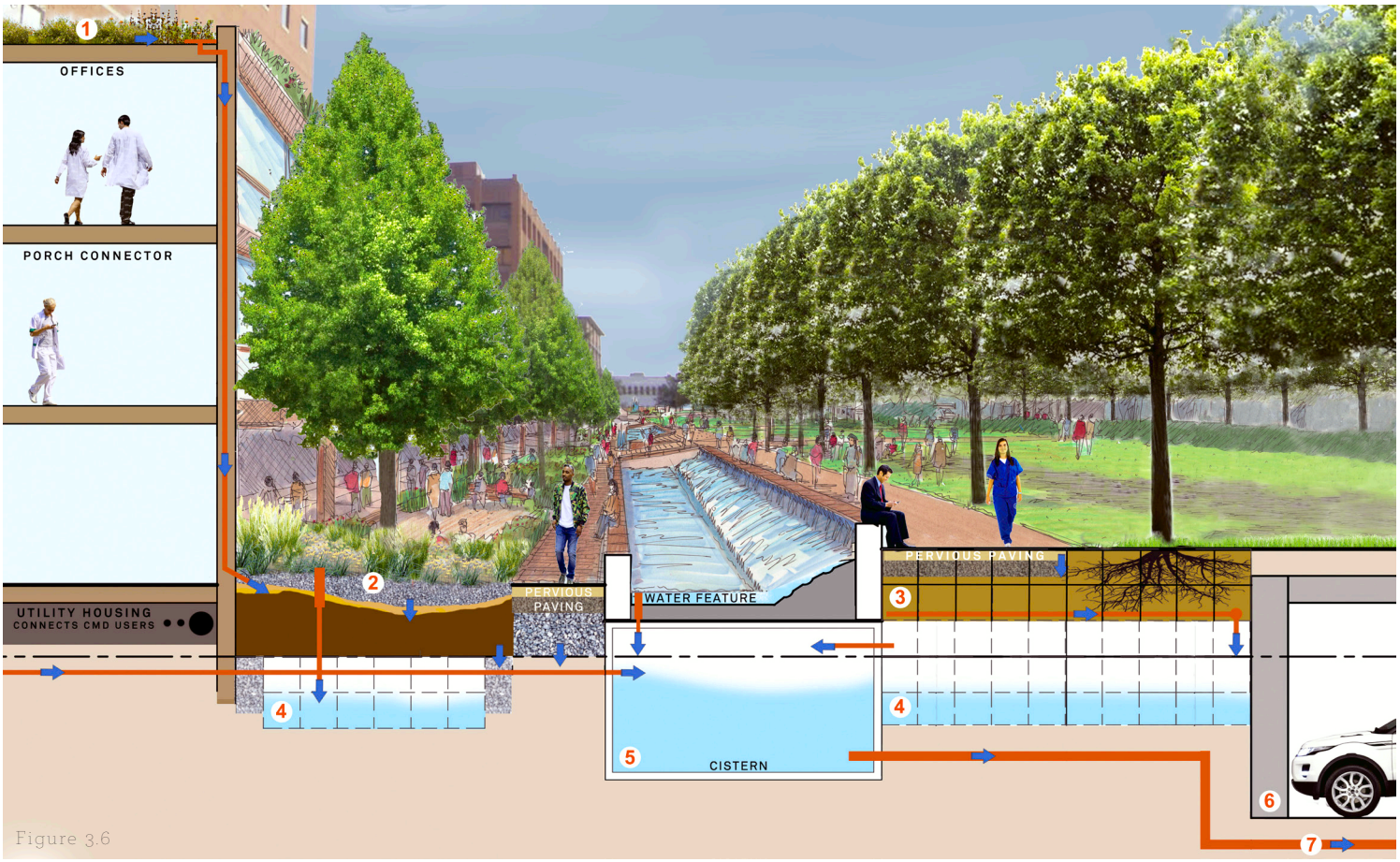


Figure 3.6

1 - GREEN ROOFS

2 - RAIN GARDENS / BIO-SWALES

3 - PERVIOUS PAVERS / STRUCTURAL CELLS

4 - TEMPORARY WATER STORAGE CELL

5 - WATER FEATURE / CISTERN

6 - UNDERGROUND GARAGE

7 - TO LONG LAKE

TUNNEL PROJECTS

Tunnel projects have been completed for three drainage basins on the Charleston Peninsula.

The Spring/Fishburne project currently underway will help alleviate some flooding from the Medical District.

There is an opportunity to build an additional shaft in the Medical District at Ehrhardt Street that would dramatically improve flood conditions in the Medical District. The Ehrhardt Shaft will tie into the Spring/ Fishburne infrastructure already under construction.

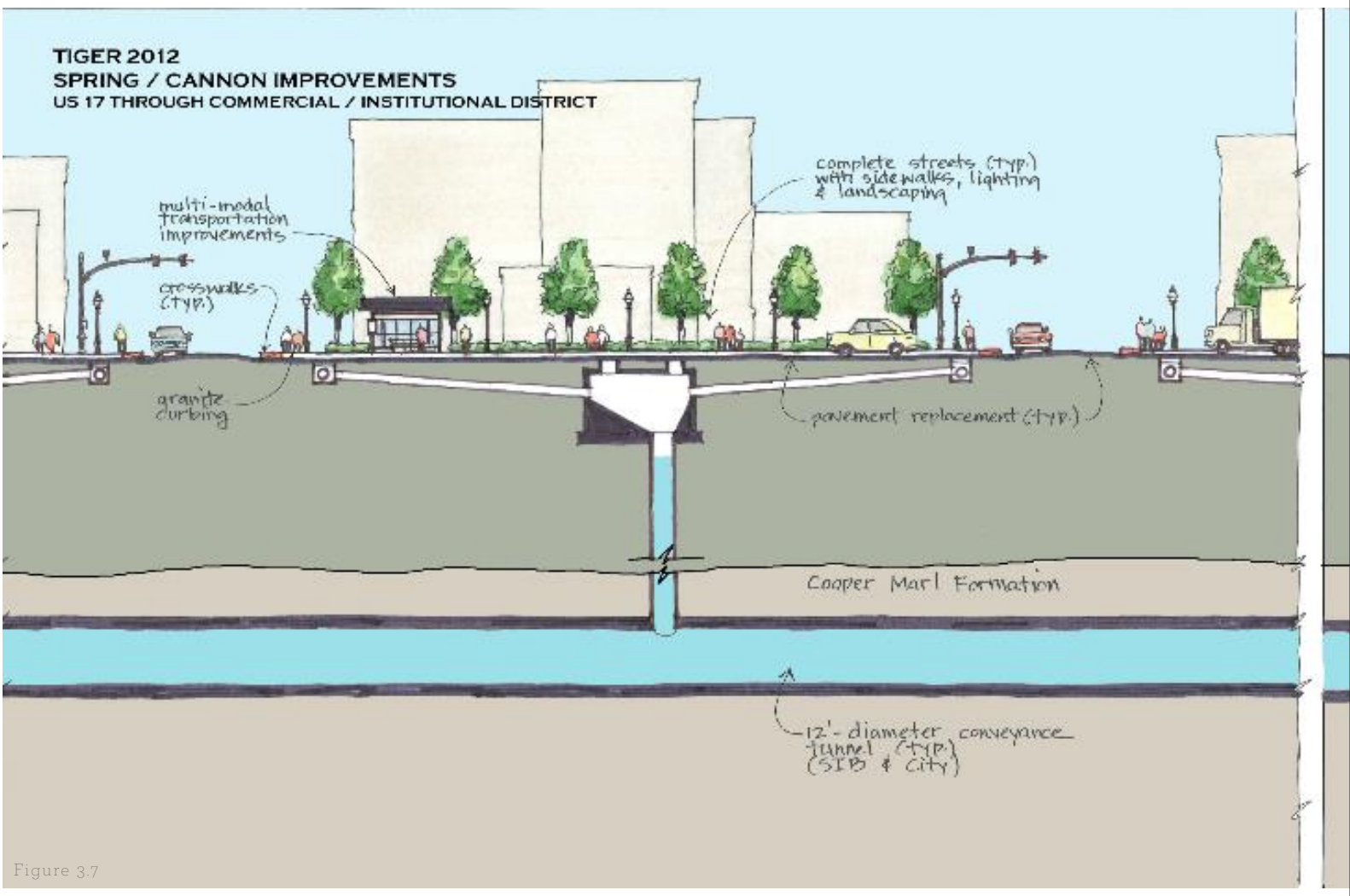
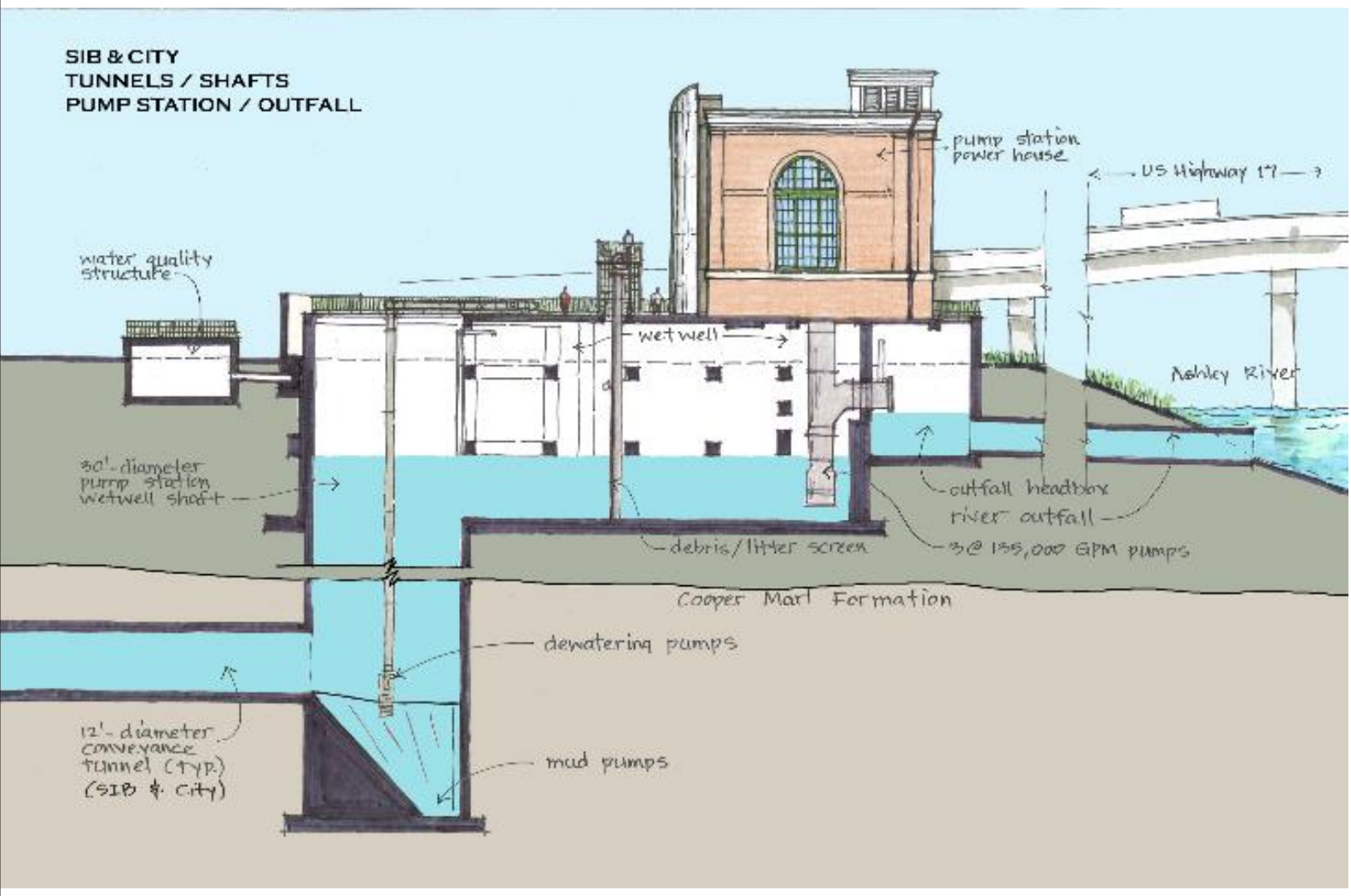


Figure 3.7


SIB & CITY
TUNNELS / SHAFTS
PUMP STATION / OUTFALL
pump station power house
US Highway 17
water quality structure
wetwell
Nehley River
30'-diameter pump station wetwell shaft
outfall headbox
river outfall
debris/litter screen
3@ 155,000 GPM pumps
Cooper Marl Formation
dewatering pumps
12'-diameter conveyance tunnel (typ.) (SIB & City)
mud pumps

INCREASED STORMWATER STORAGE AT LONG LAKE

Long Lake is currently an underutilized tidal pond that ties into the Ashley River. Redesigning Long Lake provides the opportunity to store water from the Medical District and create an amenity for both the CMD and the surrounding neighborhoods. The idea of combining infrastructure and public amenity is one championed by the Dutch.

Removing tidal influence at Long Lake and redesigning the pond provides the opportunity for significant additional stormwater storage. The costs may be less than a tunnel project, and the result would be an additional amenity for the public.

The diagram below shows the connection from Long Lake to the Greenway.

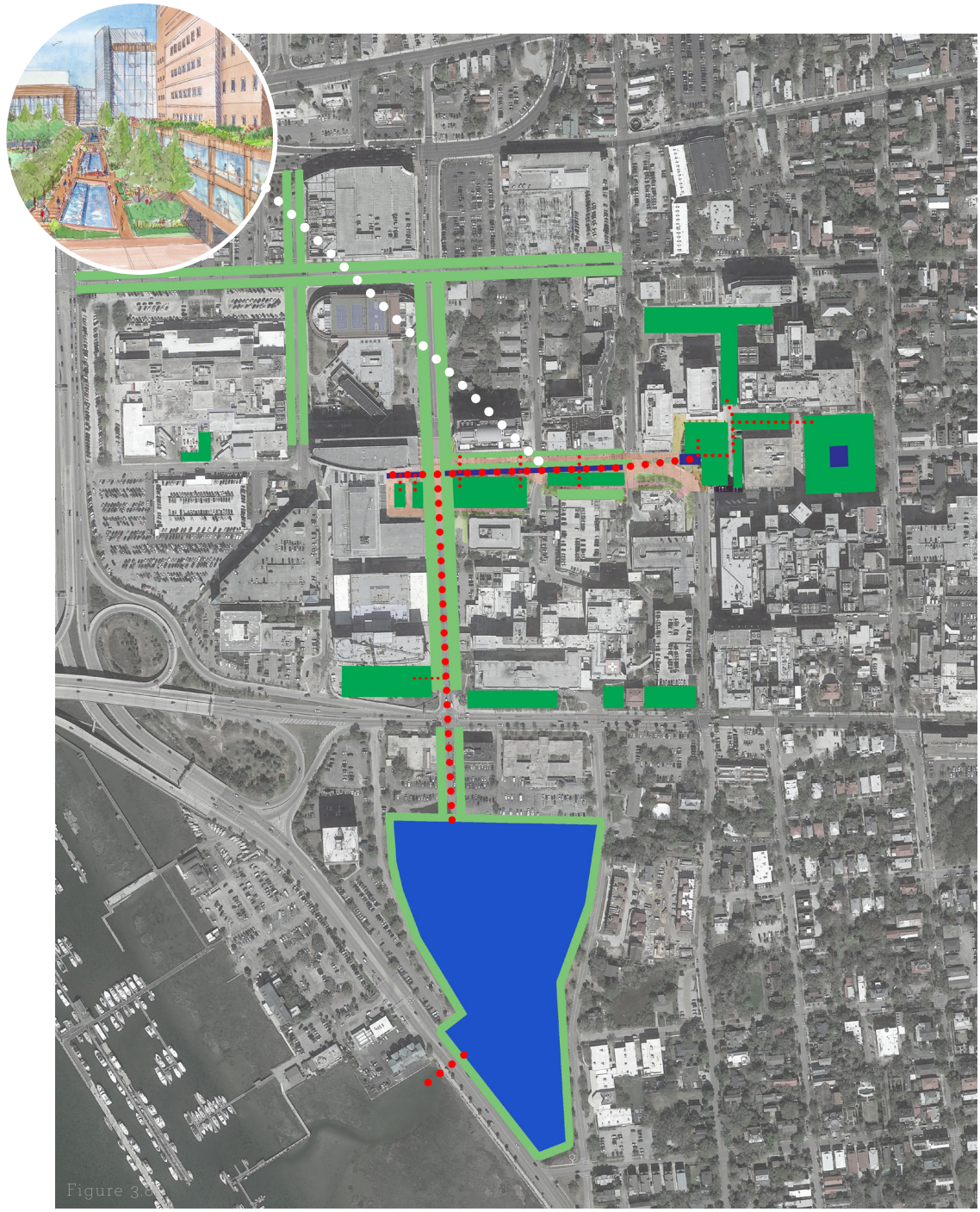


Figure 3.

Long Lake is currently a tidal lake. If it were removed from tidal influence, stormwater could be pumped there to provide more capacity for storage.

The diagram below shows the potential increased capacity of Long Lake by building a levee around the shore.

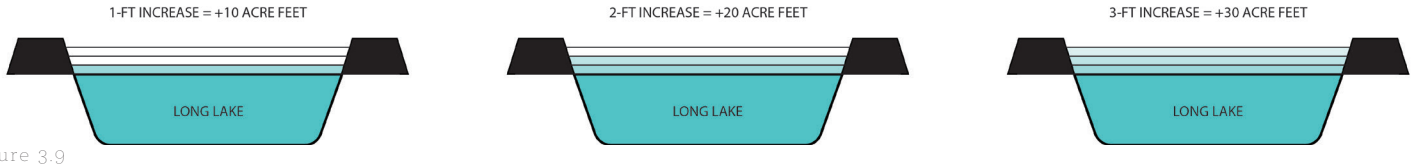


Figure 3.9

10-YEAR, 24-HOUR STORM DATA	
DRAINAGE BASIN:	RUNOFF (ACRE-FEET)
SPRING STREET	136
CALHOUN WEST	100
VA HOSPITAL	19
MARINA	13

1 Acre-foot = 43,560 cubic feet = 325,851 gallons

Additional capacity could be added by dredging the bottom of the lake.

OPPORTUNITIES NEEDING IMMEDIATE FUNDING

There are several different strategies that can be used to handle stormwater and flooding:

1. **SLOW** (green roofs, bioswales, rain gardens, etc.)
2. **STORE** (underground storage cells, cisterns, detention ponds, etc.)
3. **DRAIN** (pumps, tunnel projects, etc.)

The map below shows several of the projects currently in need of funding for the Medical District. These projects use the following strategies:

- The Medical District Greenway: **Slow** and **Store**
- Long Lake: **Store**
- Ehrhardt Tunnel: **Drain**
- Pump at VA Lot: **Drain**
- Pump at Cloverleaf: **Drain**

Medical District Boundary

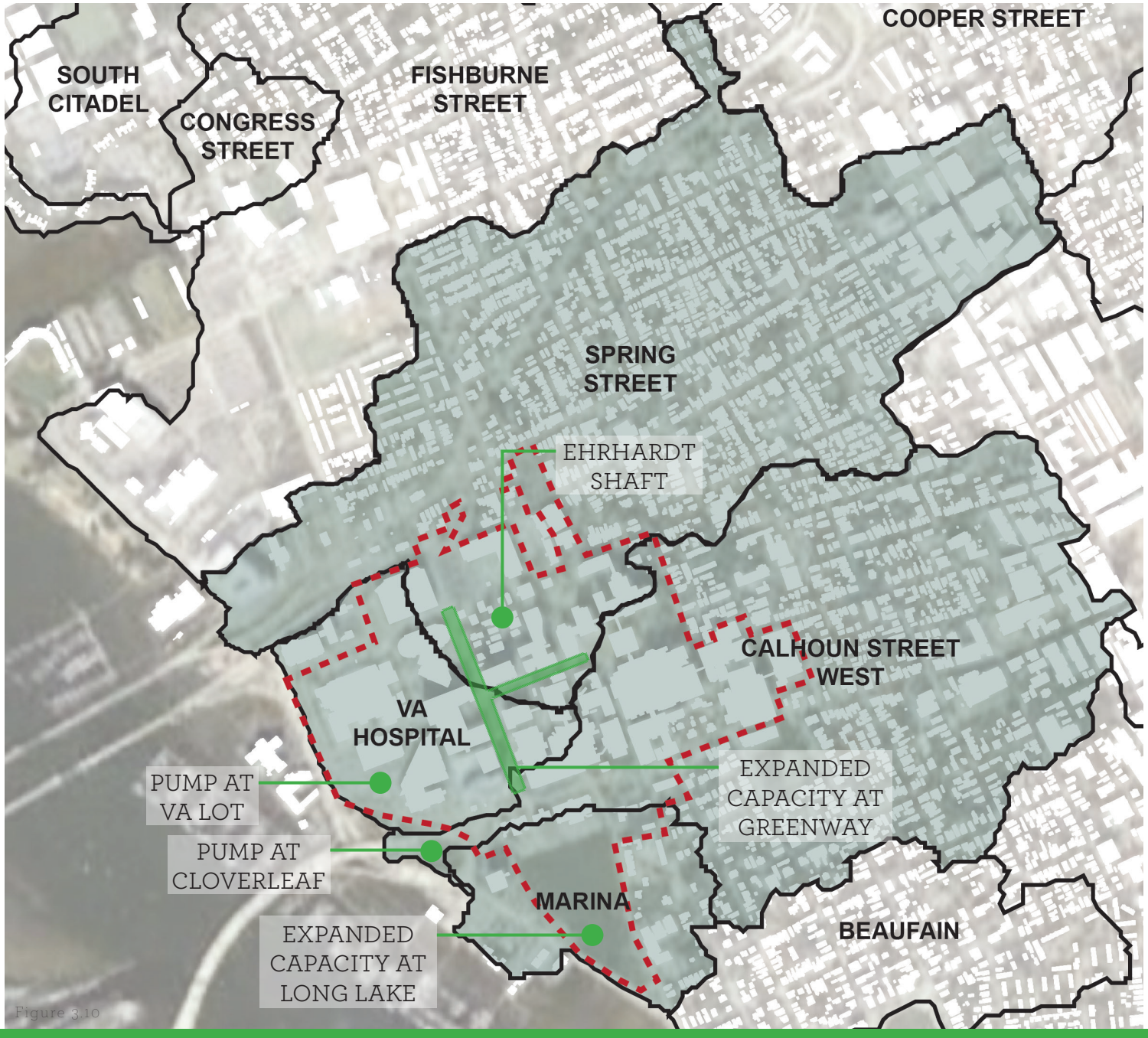


Figure 3.10

OPPORTUNITIES NEEDING IMMEDIATE FUNDING


Figure 3.11

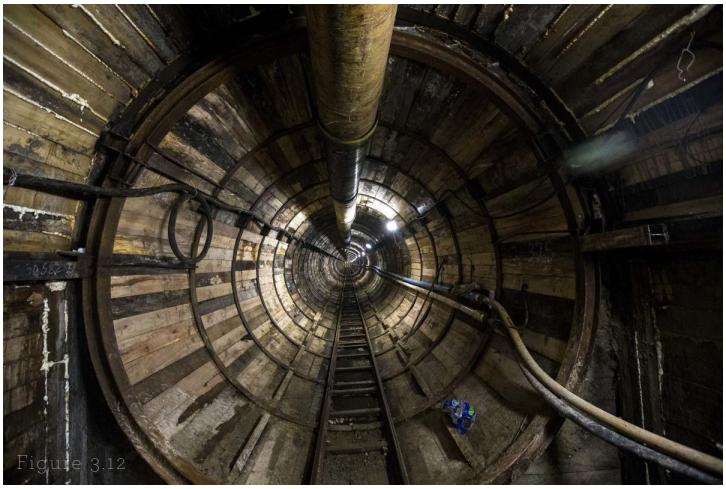


Figure 3.12

Top image: The Doughty Street greenway and elevated bridge. Above: A drop-shaft into the Spring/ Fishburne tunnel. Below: Long Lake redesigned to as stormwater infrastructure and a public amenity.

TIMELINE:

12 MONTHS:

- Begin construction of Ehrhardt shaft (August 2020)
- Install a pump in VA parking lot
- Install a pump at Calhoun/James Island Connector/Lockwood interchange cloverleaf
- Design Long Lake with additional bank height to increase total capacity
- Design Greenway for added storage capacity

1-3 YEARS:

- Add control structure and pump to Long Lake for increased capacity
- Complete installation of additional storage capacity along the Greenway
- Design and build elevated bridge connector between MUSC, VA, and Roper
- Ehrhardt shaft completed and connected to the Spring/Fishburne tunnel (2022)
- Begin enhancements at Long Lake to increase stormwater capacity and create a public promenade and park.


Figure 3.12

APPENDIX

DIFFERING DATA EXPLAINED:

NAVD88: North American Vertical Datum of 1988

"A vertical datum is a surface of zero elevation to which heights of various points are referenced."

-National Oceanic and Atmospheric Administration

Current elevation maps use NAVD88.

Mean Lower Low Water (MLLW)

"The average of the lower low water height of each tidal day observed over the National Tidal Datum Epoch."

-National Oceanic and Atmospheric Administration

For Charleston, the MLLW is currently equal to -3.14 in the NAVD88 datum.

Mean Higher High Water (MHHW)

"The average of all the higher high water height of each tidal day observed over the National Tidal Datum Epoch."

-National Oceanic and Atmospheric Administration

For Charleston, the MHHW is currently equal to 2.26 in the NAVD88 datum.

RISING SEAS

The sea level in the Charleston Harbor has risen by 1.07 feet since recording first began in 1921.

8 of the top 15 highest tides ever recorded in Charleston have occurred in the last five years.

FIGURE 1: OBSERVED SEA LEVEL RISE IN CHARLESTON HARBOR[1]

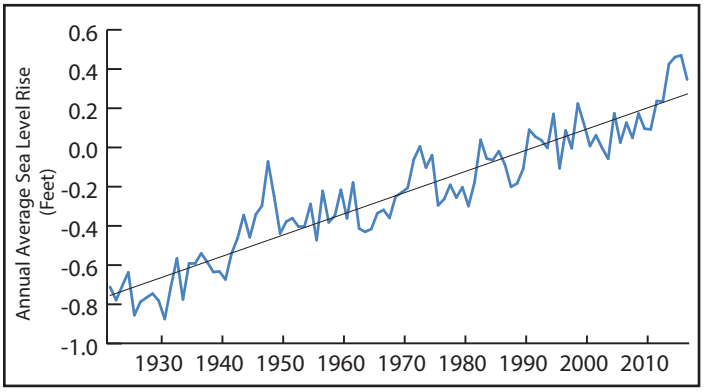


FIGURE 2: SEA LEVEL RISE PROJECTIONS FOR CHARLESTON[2]

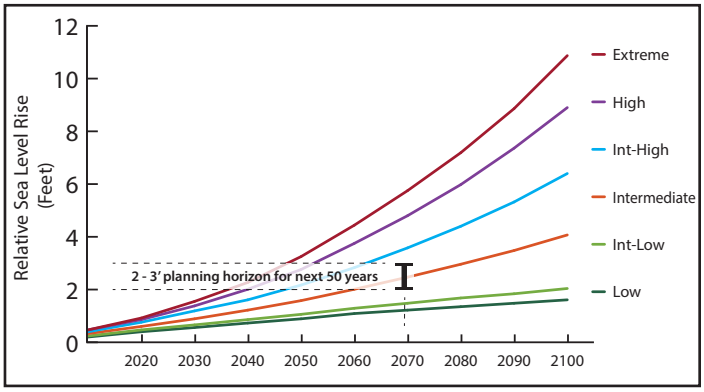
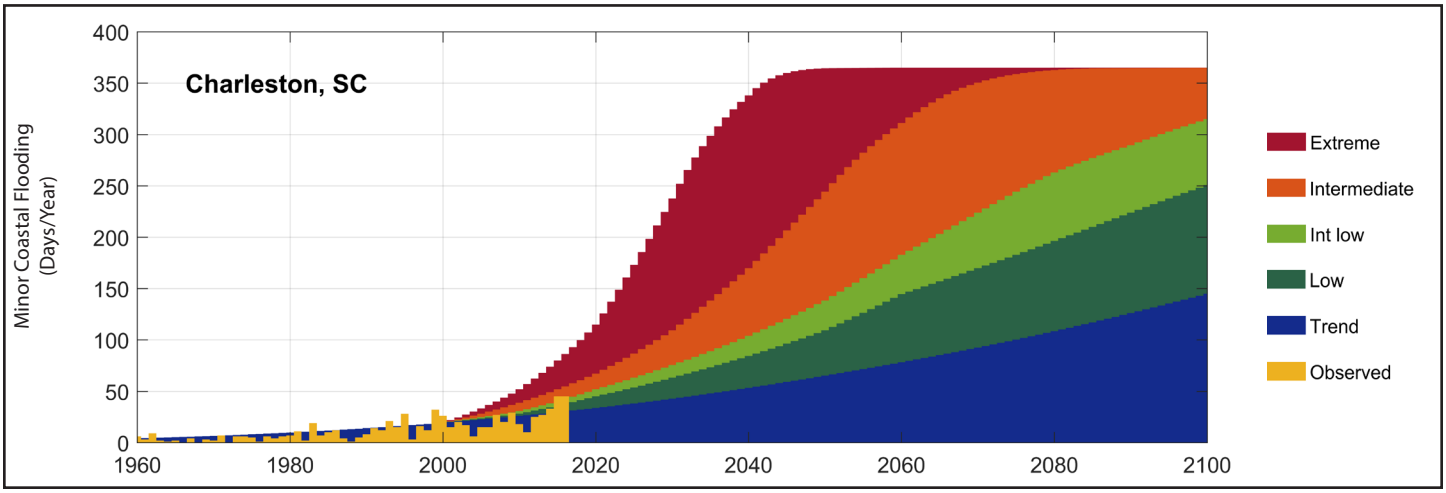


FIGURE 3: OBSERVED AND PREDICTED "MINOR COASTAL FLOODING" IN CHARLESTON[3]



INTERPRETING FLOOD DATA CAN BE CONFUSING!

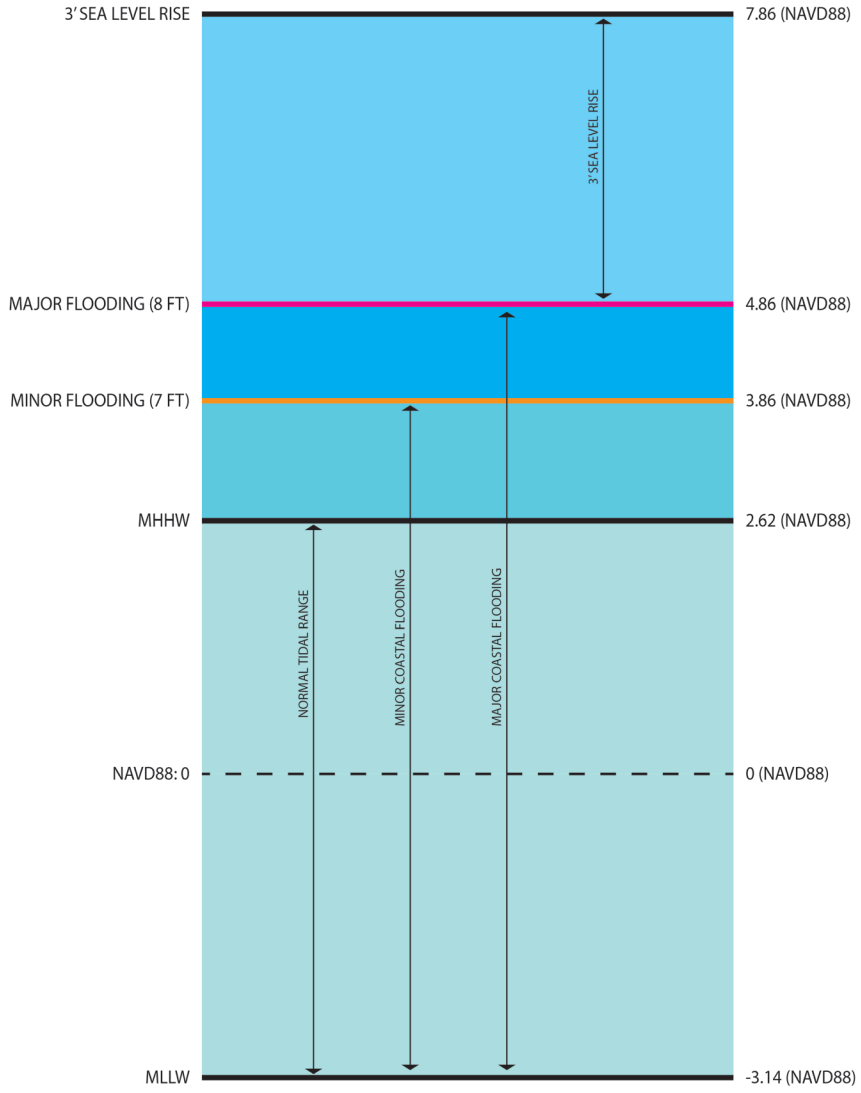


Figure 4.4

The "elevation" used to describe the depth of a high tide is not measured in the same datum used to give "elevations" for a building, street, or mountain.

Minor coastal flooding events occur at 7.0' MLLW on the harbor tidal gauge. This means that any land below 3.86 feet will be susceptible to flooding.

Major coastal flooding events occur at 8.0' MLLW on the harbor tidal gauge. This means that any land below 4.86 feet will be susceptible to flooding.

FLOOD CATEGORIES (IN FEET)

AT 8.0'	MLLW, MAJOR COASTAL FLOODING OCCURS
AT 8.0'	MLLW, MODERATE COASTAL FLOODING OCCURS
AT 7.0'	MLLW, MINOR COASTAL FLOODING TYPICALLY BEGINS
AT 6.5'	MLLW, ACTION BEGINS (CITY OF CHARLESTON)

Figure 4.4

The image at left was taken at the intersection of Courtenay Street and Charleston Center Drive in the Medical District during Hurricane Matthew (2016).

The road here is at approximately 3.75' (NAVD88).

The NOAA maps provided below show flood events (7.0' MLLW or higher)in the Charleston Harbor from 1980 to 2019. Each map shows the same information, but sorted in different ways to see the different implications of the changes.

Figure 4.6

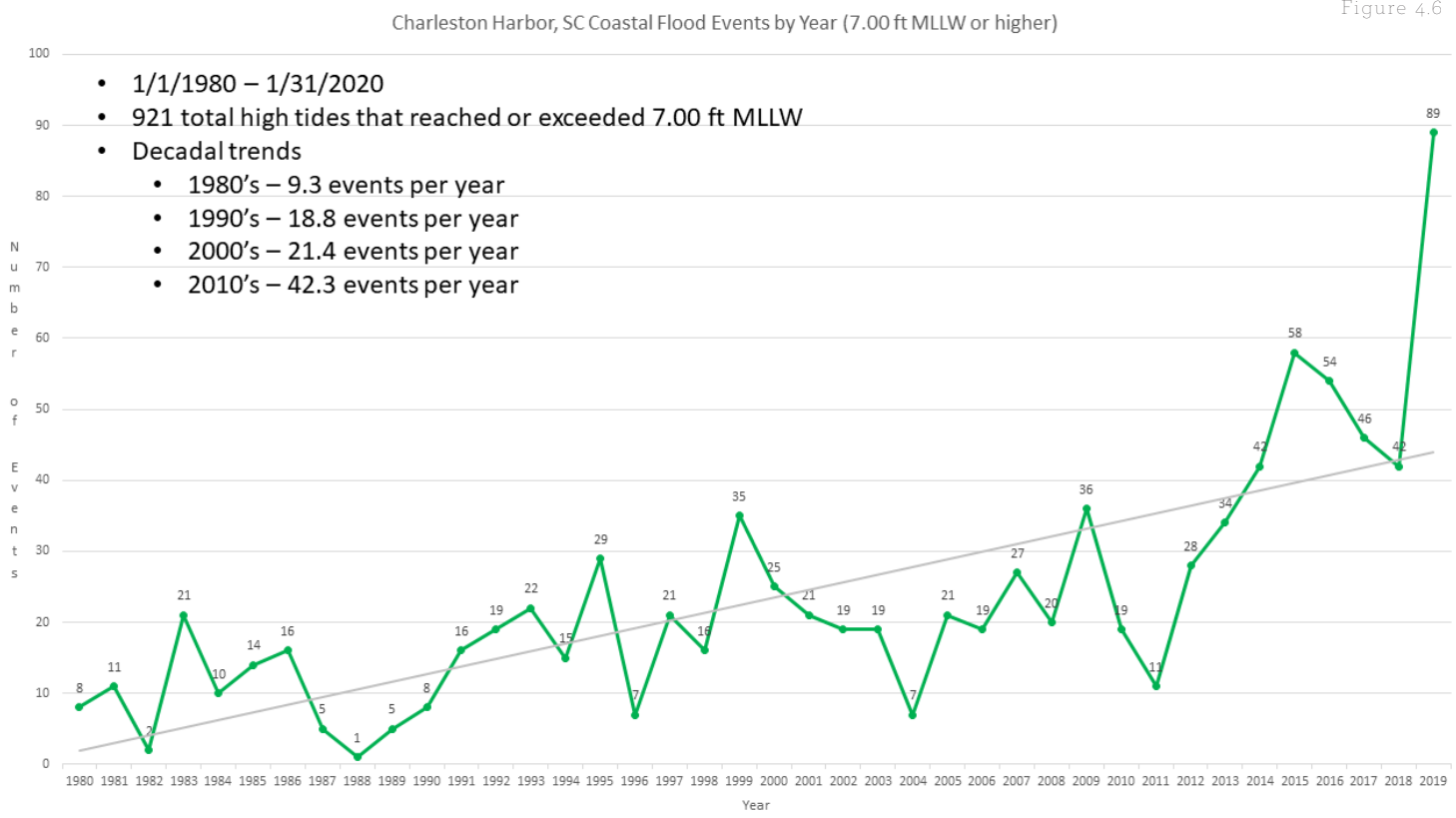


Figure 4.7

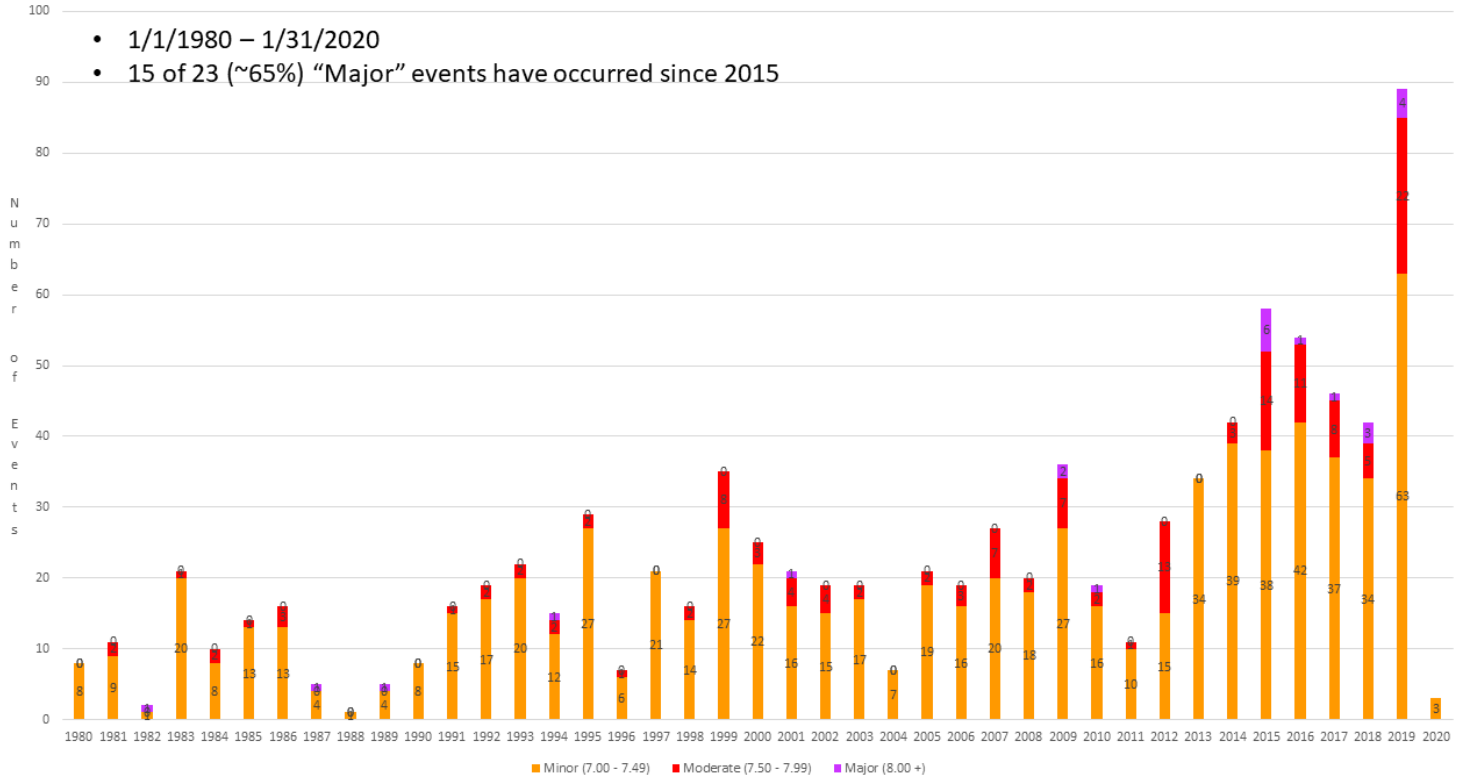


Figure 4.8

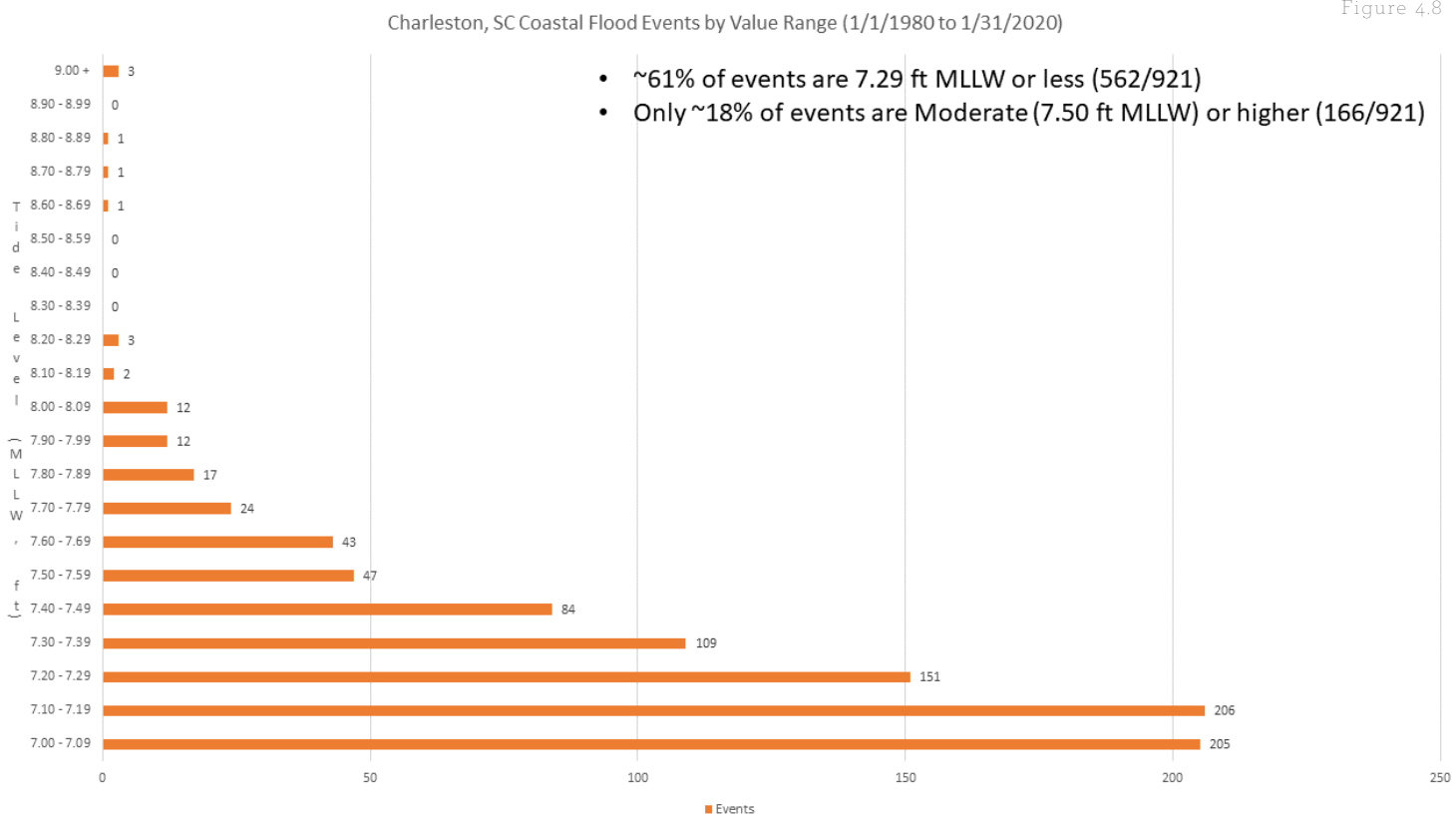
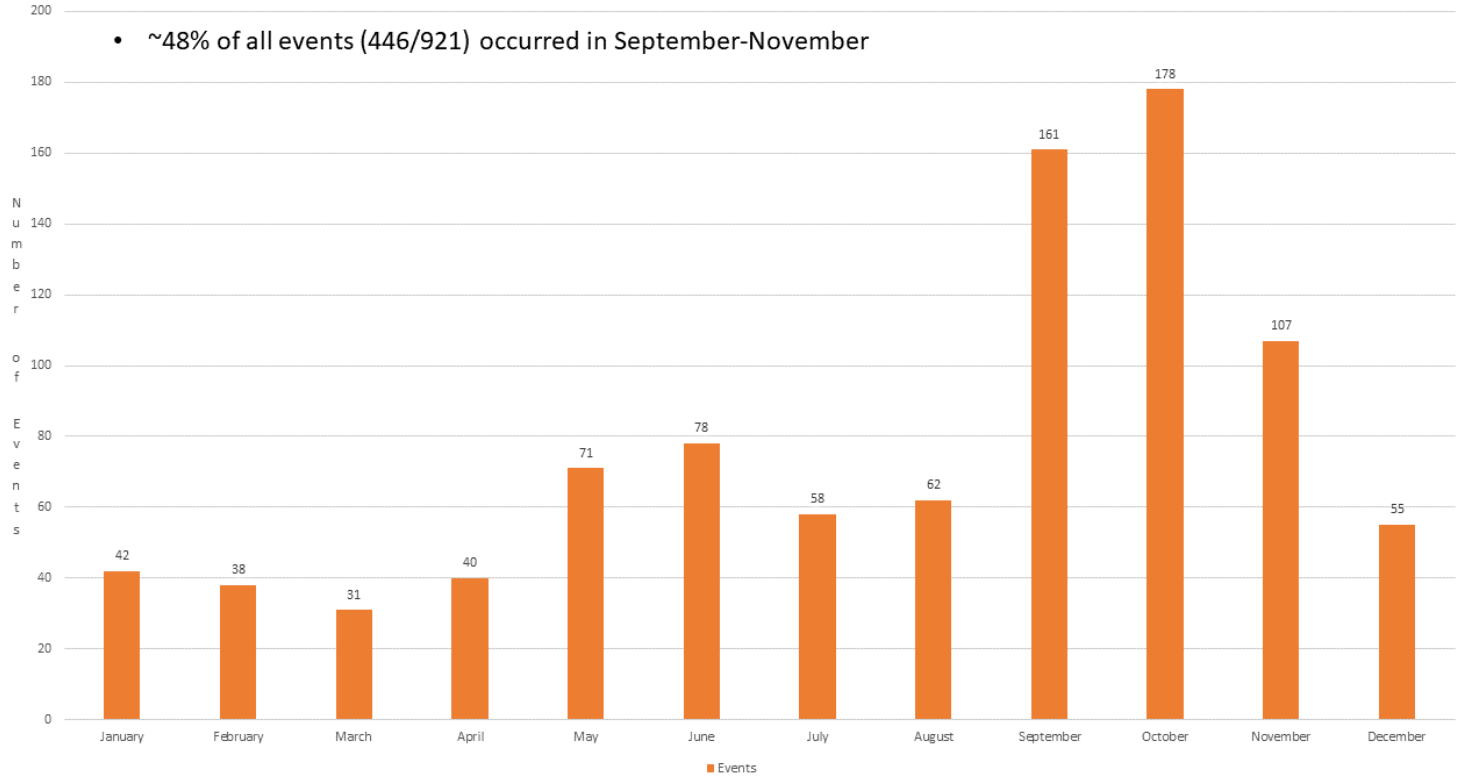


Figure 4.9



CITATIONS

LIST OF FIGURES

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