Coastal Flood Resilience Planning in Virginia Beach, VA

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Sea Level Wise
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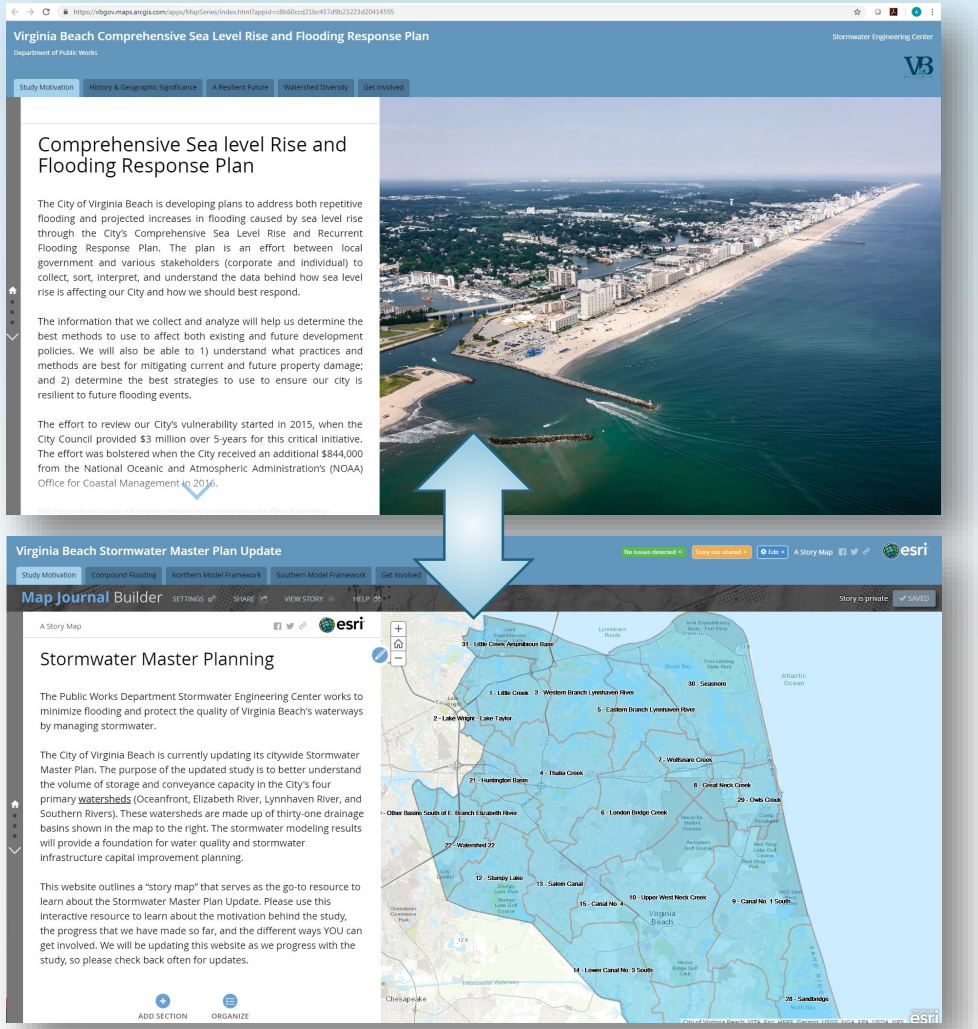
Outline

- Introduction
- Hazards and Risk
- Policy
- Informing Design
- Structural Approaches and Tools
- Takeaways

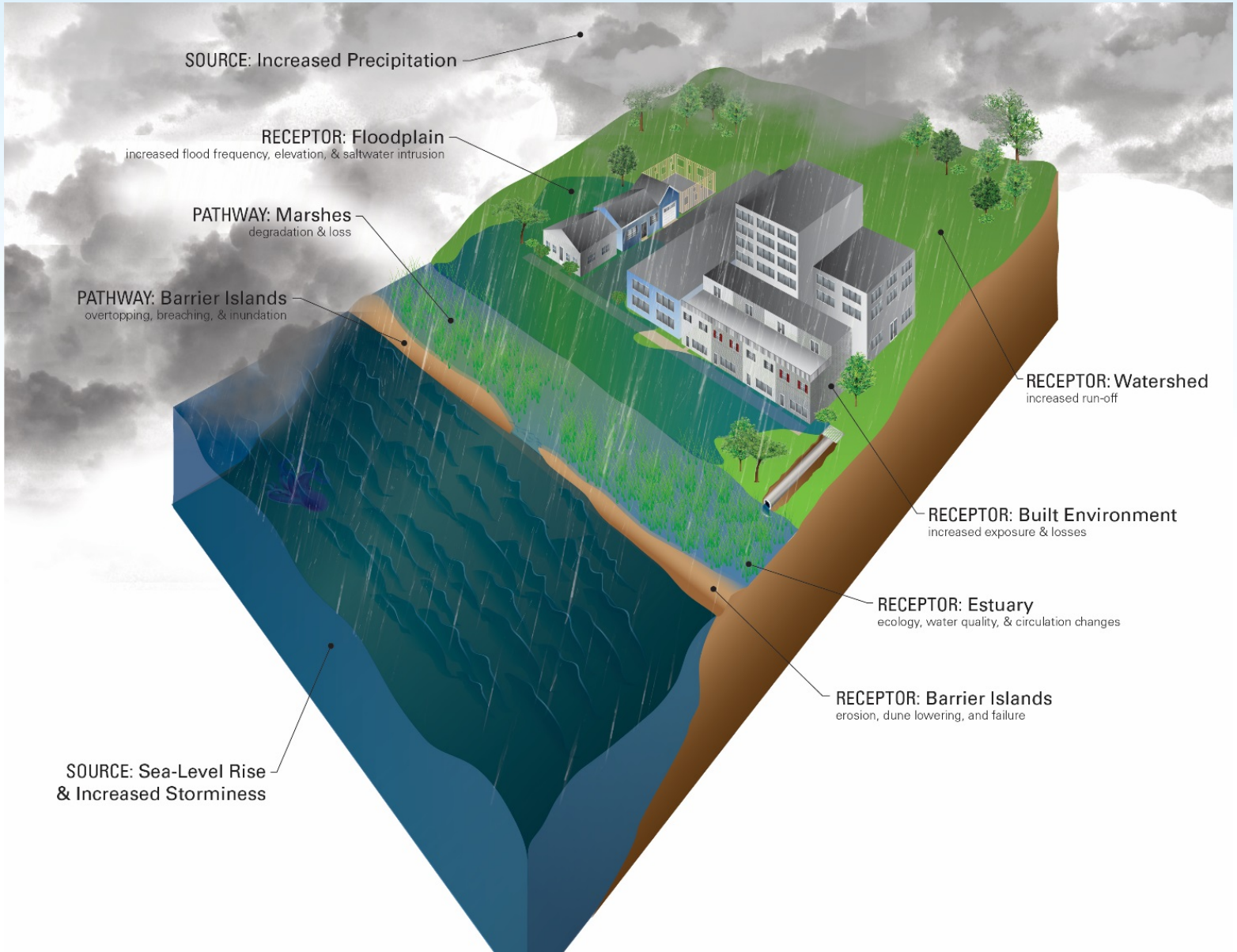
Ongoing Studies

Project Website:
http://www.vbgov.com/pwSLR

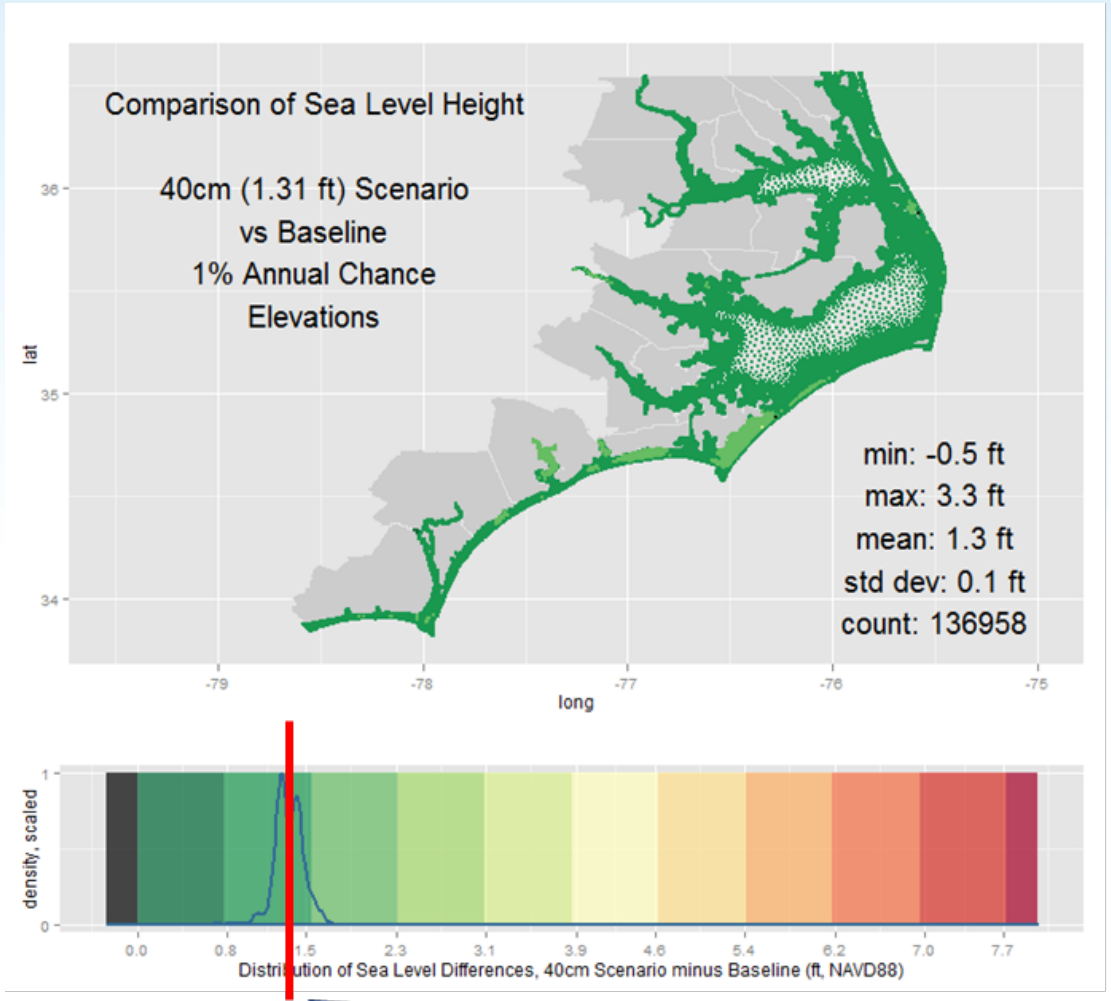
- Comprehensive Sea Level Rise and Recurrent Flooding Study
  - Assessing existing and future flood vulnerabilities across the City's four unique watersheds
  - Identifying strategies to ensure our city is resilient to future flooding events
- Master Drainage Study
  - Detailed inventory of the City's stormwater system
  - Assessing the system's performance
  - Identifying deficiencies or needed improvements

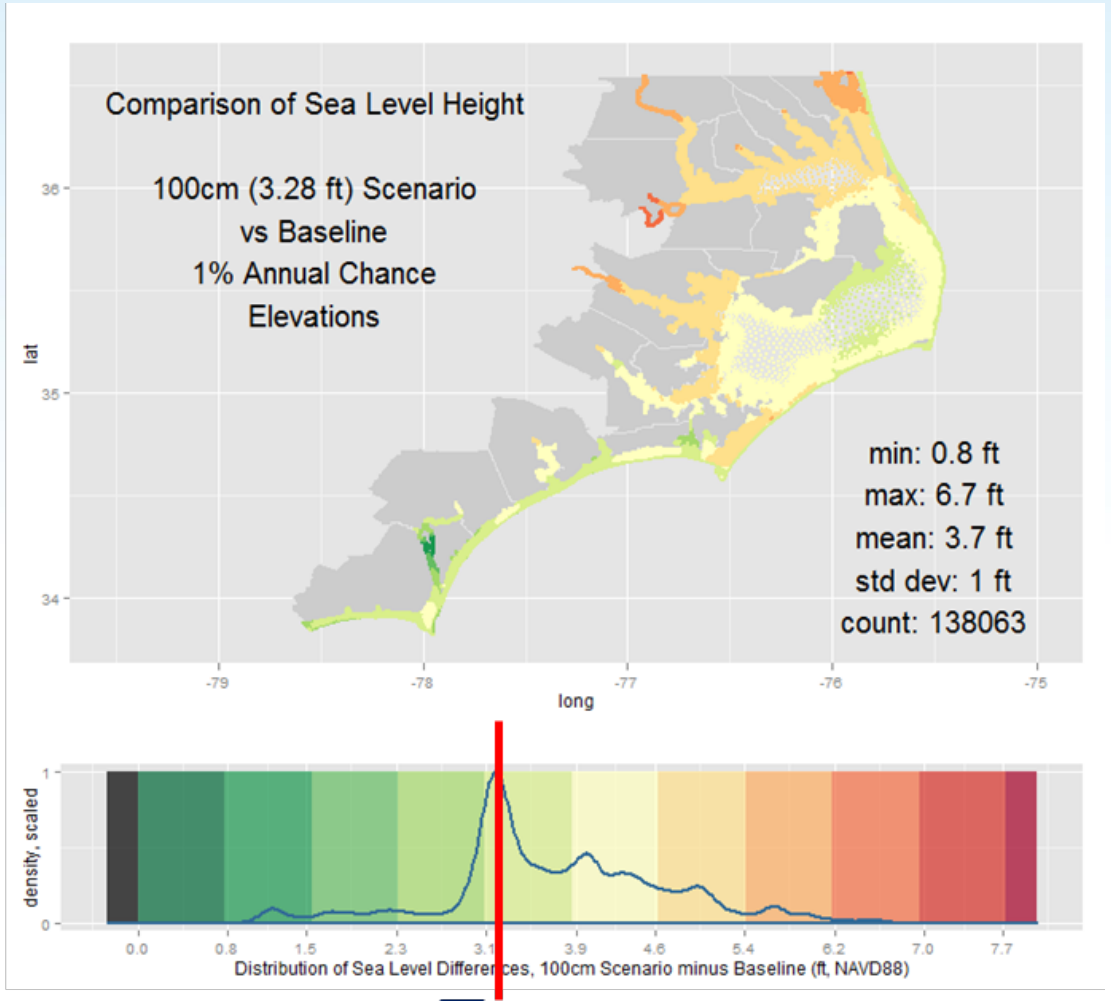


Future Hazards are Complicated!



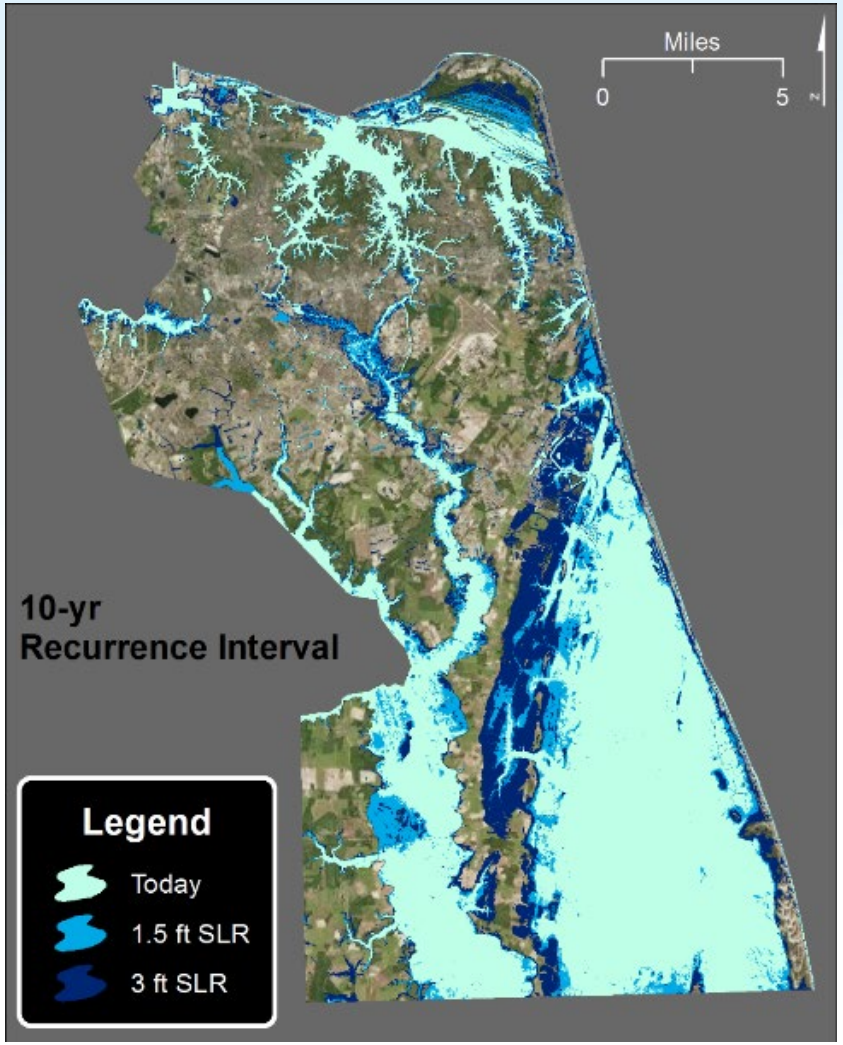
SLR and non-linear responses



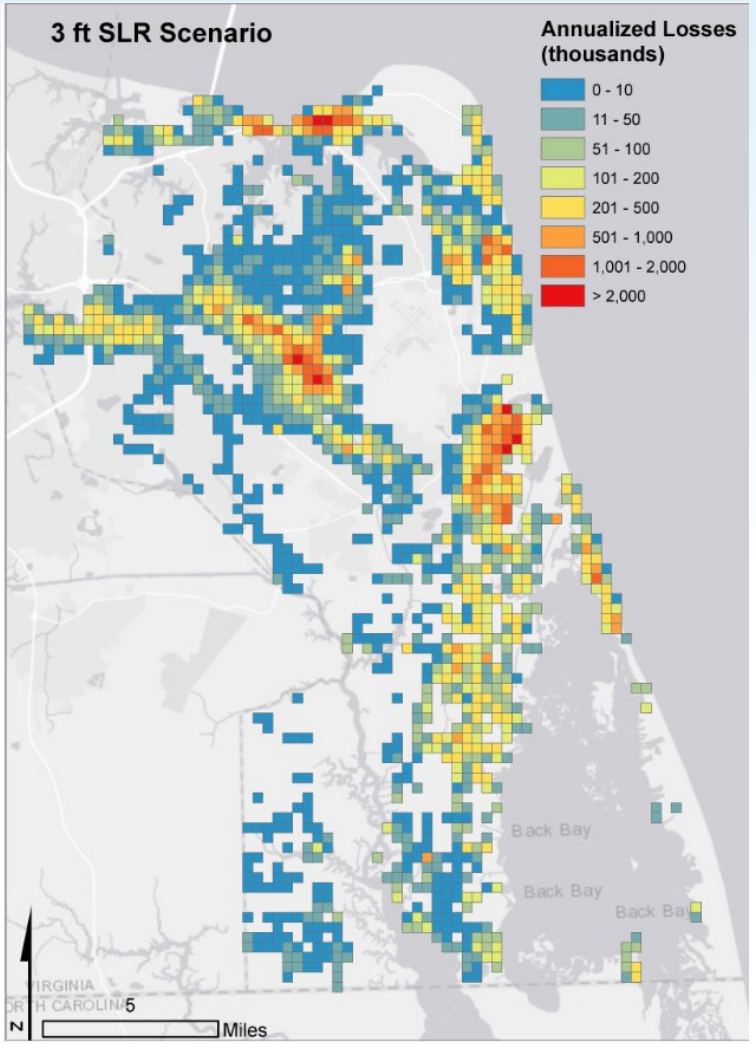


If surge elevations increased linearly with SLR

Hazard and Risk Assessment

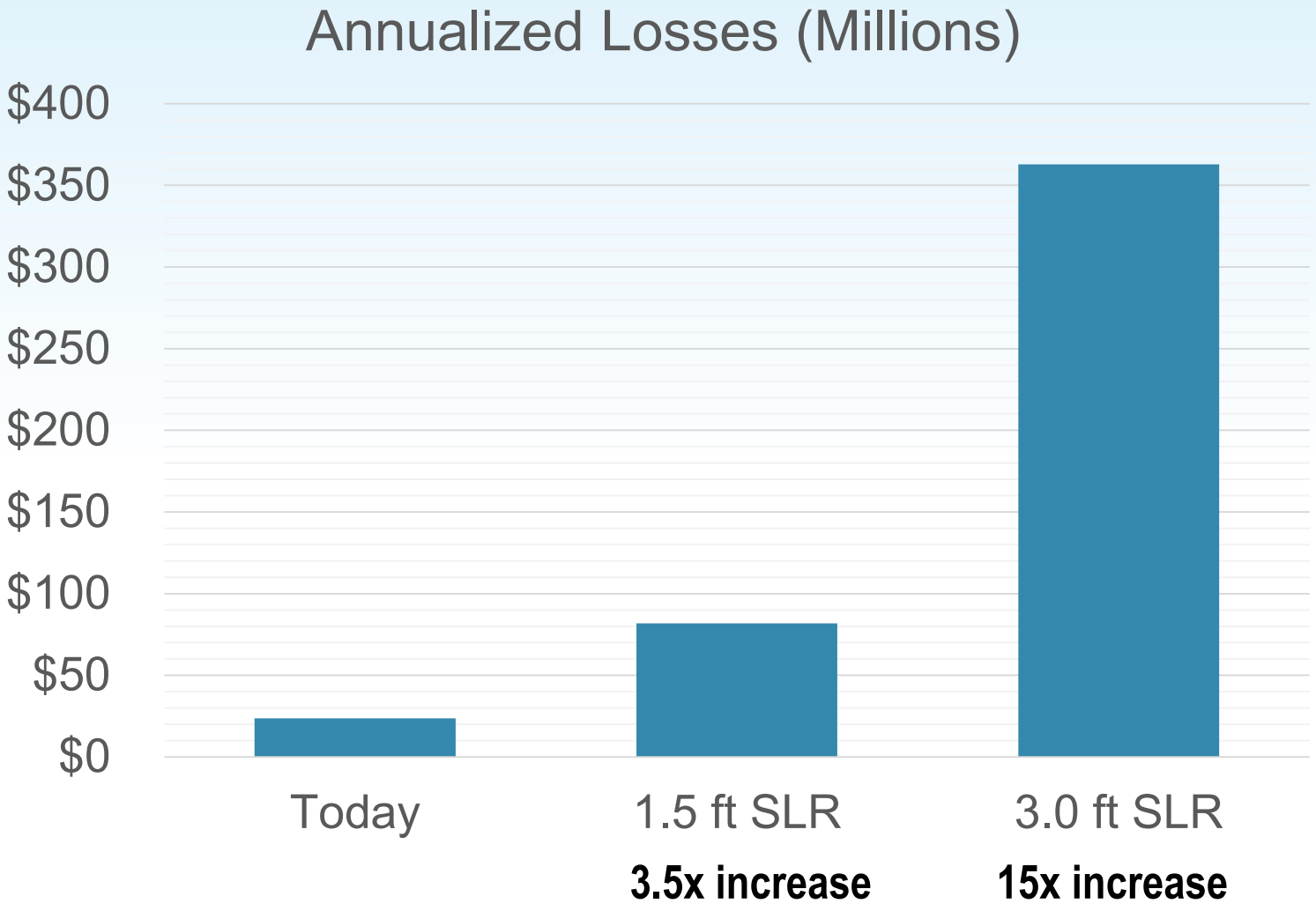


HAZUS MH
EARTHQUAKE • WIND • FLOOD



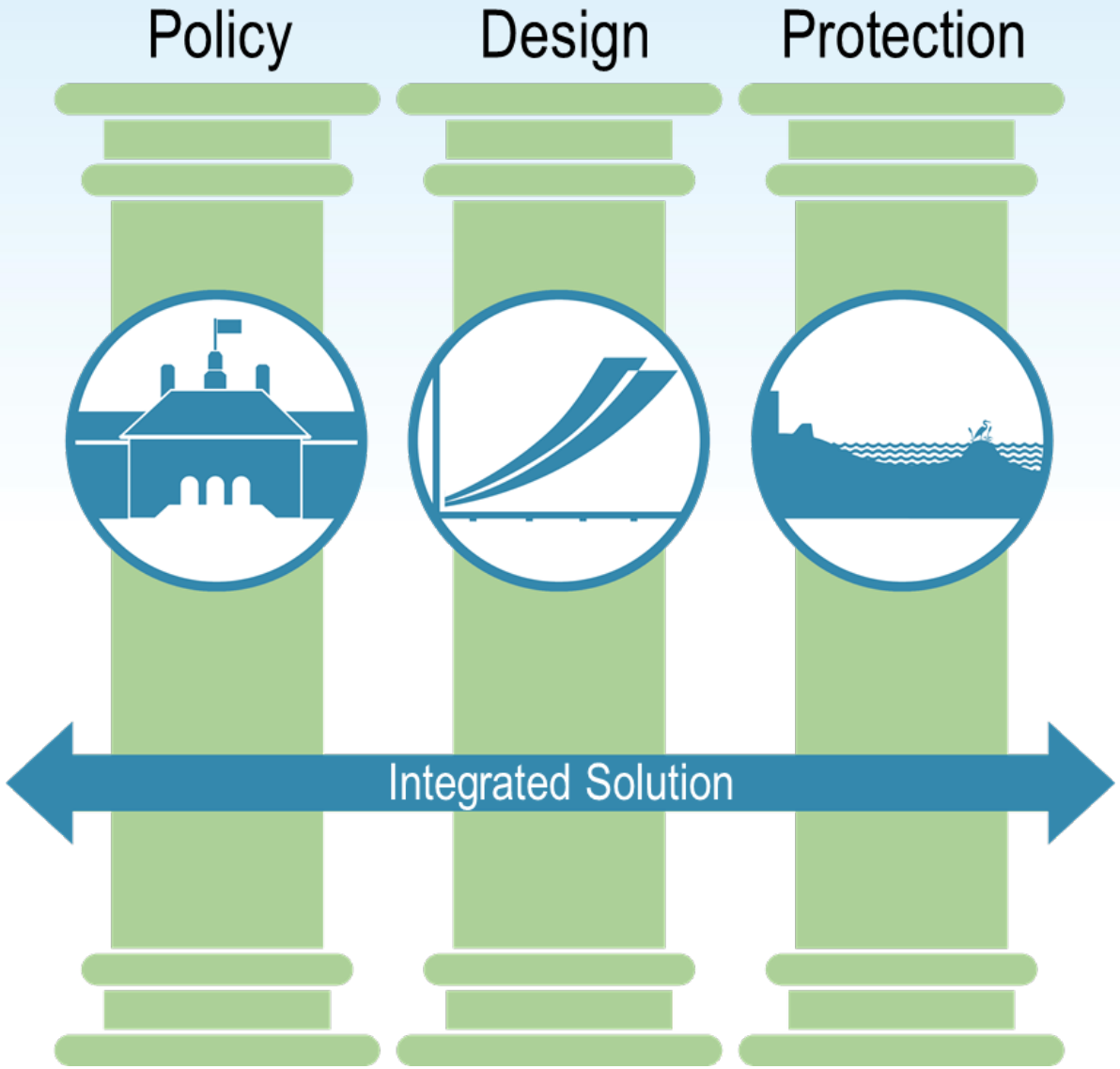
Hazard and Risk-driven Decision-Making

The Cost of Doing Nothing…

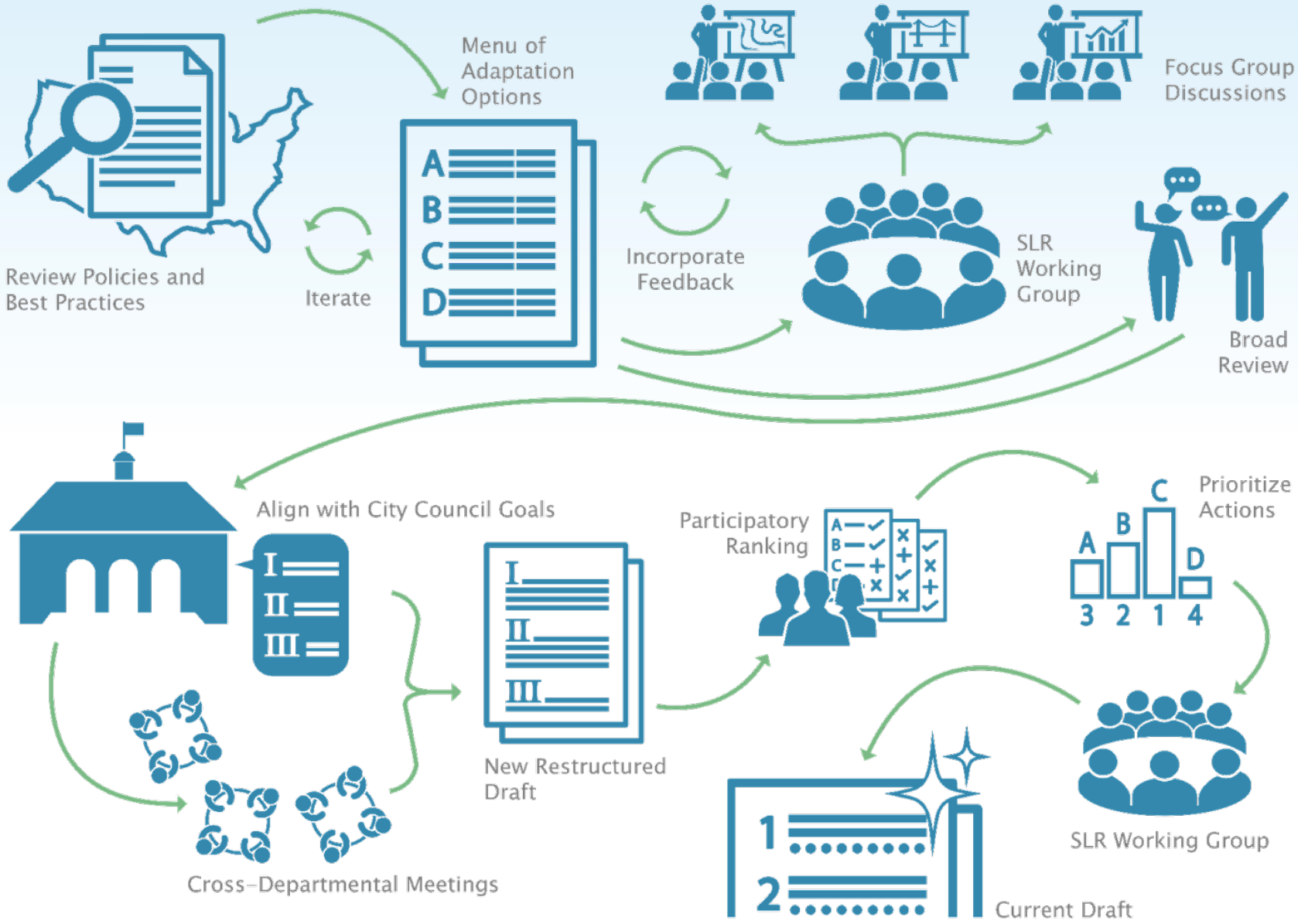


*reflects structure, content, and displacement costs, no indirect cascading broad economic impacts

Adaptation Strategies

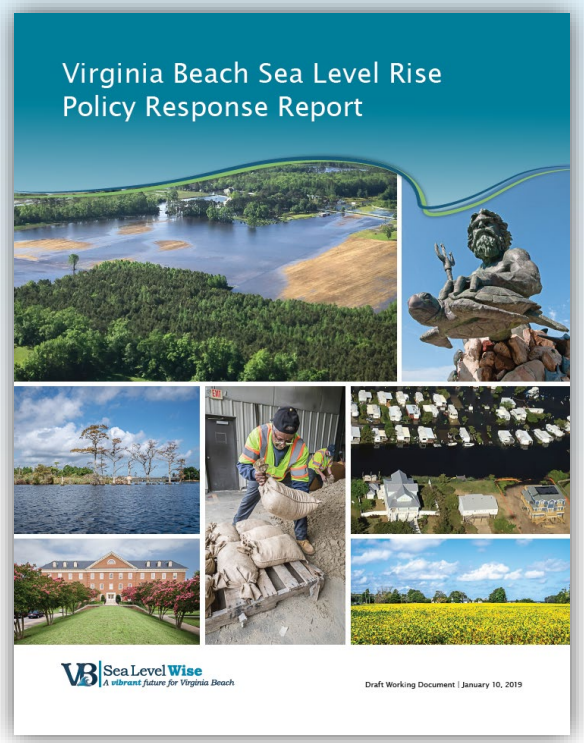


Policy Process



Policy Goals

- Plan for a Future with More Frequent and Intense Flooding
- Enhance the Flood Resilience of Infrastructure Systems
- Enhance the Flood Resilience of Buildings and Neighborhoods
- Protect Businesses and Enhance the Local Economy
- Preserve and Enhance Natural Flood Buffers and Open Space
- Improve City Coordination and Responsiveness
- Advocate for Policy Changes that Support Local Resilience



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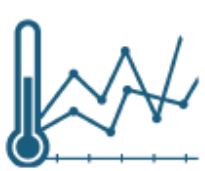
Policy Content

- Content:
  - 7 goals
  - 29 objectives
  - 175 action items
- Structure for Goals:
  - Overview
  - Objectives
    - Actions and Priority
    - Benefits and Considerations
- Implementation Examples



GOAL 1

Plan for a Future with More Frequent and Intense Flooding

In order to plan for a future with more frequent and intense flooding, the City is working to incorporate the most recent data, research, and future projections regarding changing precipitation patterns, sea level rise, and recurrent flooding into local plans, resources, and processes. The institutional use of up-to-date data and forward looking projections will inform decision-makers in the implementation of resilience focused policies, codes, and ordinances.

> **Strategy:** To achieve this goal the City should incorporate the most recent sea level rise, precipitation, and recurrent flooding data, such as the CSLRRF analysis outputs, including future flooding considerations, into all relevant City plans and process documents during their next update, or no later than 2025. The following objectives and accompanying action items will help the City plan for a future with more frequent and intense flooding.

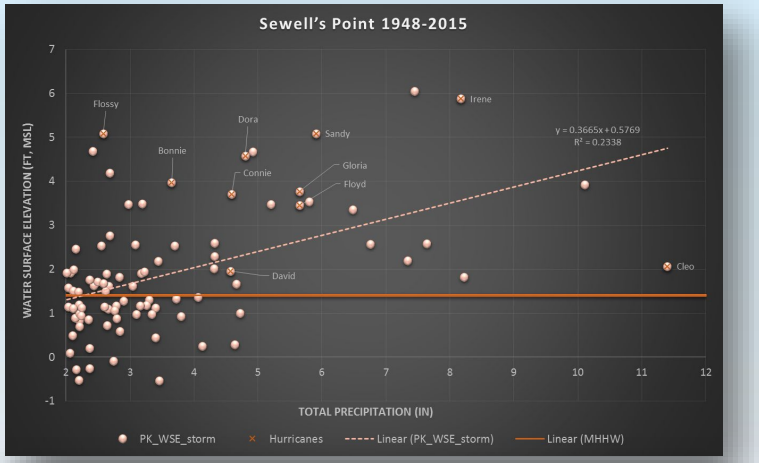
Objective 1.1: Comprehensive Planning

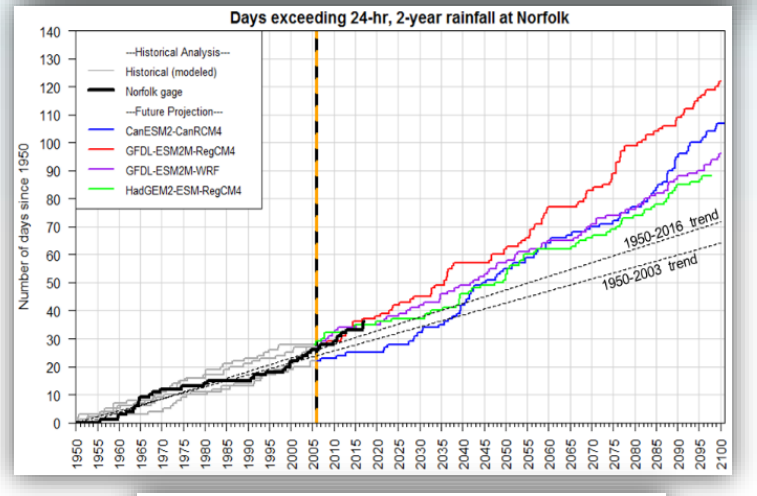
Incorporate the most recent sea level rise, precipitation, and recurrent flooding data into the next update of the City's Comprehensive Plan.

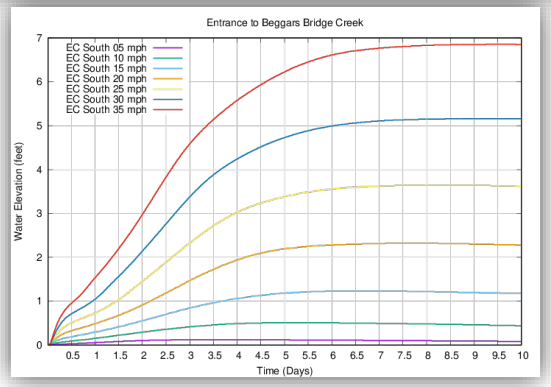
	COMPREHENSIVE PLANNING ACTION ITEMS	PRIORITY
1.	Integrate the scientific and legal justification for short- and long-term recommendations for land use regulations needed to accommodate sea level rise.	HIGH
2.	Overlay areas of expanding floodplains and concentrated flood risk with the land use plan.	HIGH
3.	Adjust existing and future development goals and locations, including SGAs, based on the anticipated flood risks.	MED-HIGH
4.	Extend the planning-time horizon for visioning purposes, especially in the SGAs, to consider the effects of flood scenarios out to 2075 or 2100.	MED-HIGH
5.	Identify and designate "high and dry" areas with minimal flood risk for higher-density development and higher-intensity land uses.	MED-HIGH
6.	Incorporate flood-resilience strategies into sections of Comprehensive Plan related to specific watersheds, zoning districts, and vulnerable neighborhoods.	MED-HIGH

Informing Design

- Rainfall/surge correlation
  - >50% of rainfall events occur during elevated water levels
- Joint-probability of rainfall/storm surge
  - Concurrent rainfall/surge design values
- Regional Precipitation Trends
  - Atlas 14 outdated
  - Heavy rainfall increasing, 20% needed over design life cycle
- Probable maximum event precipitation
  - Design “check storm”
- Wind Tides
  - Water level response to wind tide conditions
  - Minimum design tailwaters

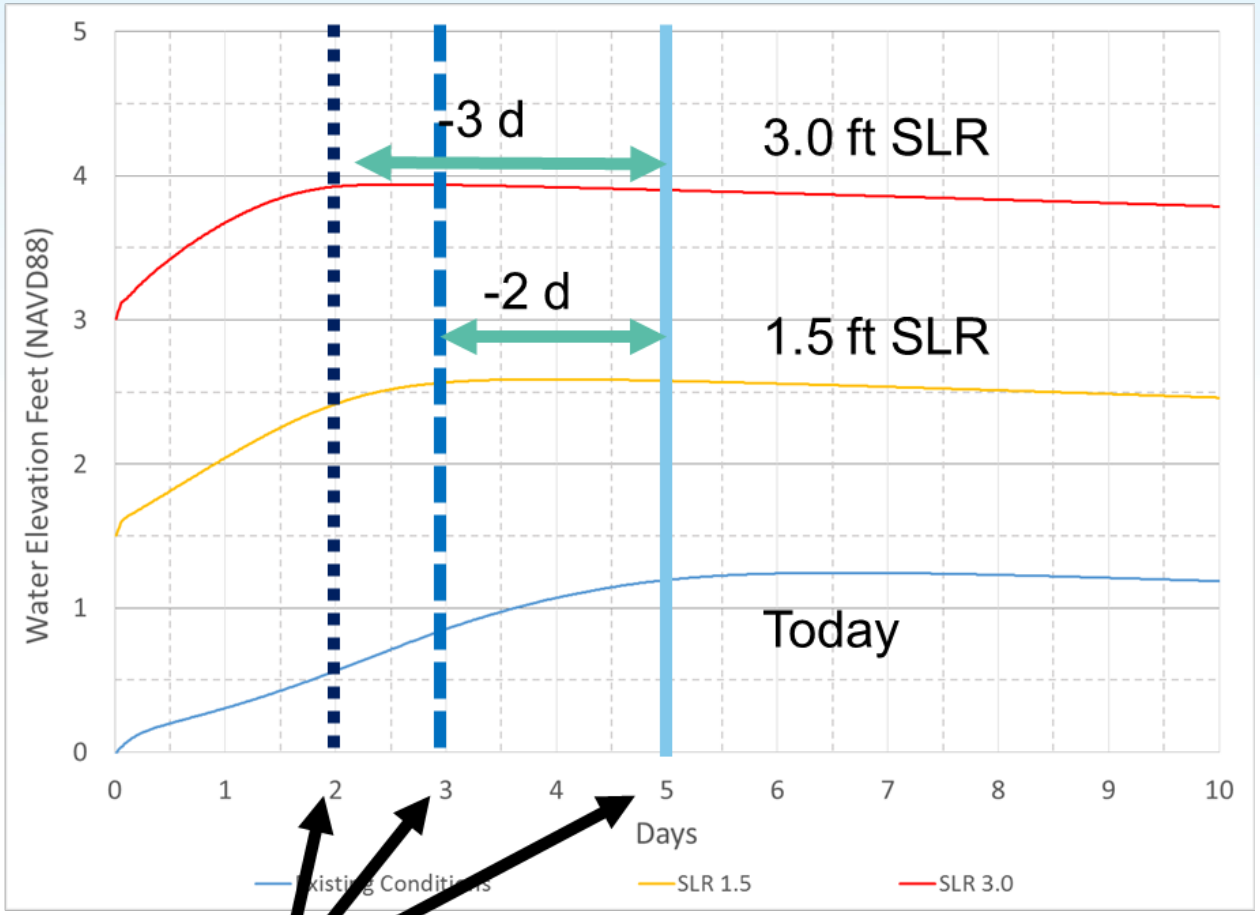






Wind Tide Changes with SLR

Water level response
Sustained 15 mph southerly wind



Time to near maximum water level

Stormwater Design Standard Outputs

GOAL 2

Enhance the Flood Resilience of Critical Infrastructure and Transportation Systems and Invest in Capital Improvements to Reduce Community Flood Risk

	STORMWATER PLAN AND MANAGEMENT ACTION ITEMS	PRIORITY
1.	Formally adopt the most recent findings regarding sea level rise estimates and increased rainfall provisions into the stormwater design requirements and fully integrate these considerations into stormwater management and design practice.	HIGH

Table VIII-0
Design Rainfall Depths for City of Virginia Beach (in.)

Design Frequency	NOAA Atlas 14 Rainfall	Design Rainfall (NOAA Atlas 14 + 20%)
1-YR	3.00	
2-YR	3.65	
10-YR	5.64	
25-YR	6.99	
50-YR	8.16	
100-YR	9.45	

Note: NOAA Atlas 14 precipitation depths
the City (generally < 0.1" difference). The
above represent the area northeast of Naval

Table VIII-1A
Design Storm/Tide Joint Probabili
Determining Controlling Tailwate

10-YR Design		25-YR Design		50-YR Desig	
Tide	Rain	Tide	Rain	Tide	Rain
10-YR	1-YR	25-YR	1-YR	50-YR	1-YR
1-YR	10-YR	2-YR	25-YR	2-YR	50-Y

Note: Refer to ***Table J-12*** *Design Tidal Elevations for* ***Appendix J*** for corresponding tide elevations. Refer to *Depths for City of Virginia Beach* for corresponding rai ***J-13*** *24-Hour Rainfall Distributions for Virginia Beach* corresponding rainfall distribution.

Note: Joint probability pairs represent the highest-frequ lowest-frequency rainfall and the highest-frequency rain frequency tide for each design frequency, as informed by joint probability studies undertaken by the City. Please refer to the City of Virginia Beach study titled "Joint Occurrence and Probabilities of Tides and Rainfall," dated October 2017 (CIP 7-030, PWCN-15-0014, Work Orders 2 and 5A) for additional information.

Table J-12
Design Tidal Elevations for Virginia Beach
All Elevations in feet relative to the North American Vertical Datum (NAVD) of 1988

Location	Design Level	1-YR	2-YR	3-YR	5-YR	10-YR	25-YR	50-YR	100-YR	500-YR
Lynnhaven Bay & River, Eastern Branch	Existing Condition	3.1	3.6	4.0	4.4	5.2	5.8	6.2	6.7	8.5
	1.5 ft SLR	4.6	5.1	5.5	5.9	6.7	7.3	7.7	8.2	10.0
	3.0 ft SLR	6.3	6.9	7.3	7.7	8.5	9.2	9.6	10.1	12.0
Lynnhaven Bay & River, Incl. all areas other than Eastern	Existing Condition	3.2	3.9	4.3	4.8	5.5	6.3	6.9	7.4	9.3
	1.5 ft SLR	4.7	5.4	5.8	6.3	7.0	7.8	8.4	8.9	10.8
	3.0 ft SLR	6.4	7.2	7.6	8.1	8.8	9.7	10.3	10.8	12.8
Chesapeake Bay	Existing Condition	3.2	3.8	4.1	4.5	5.2	5.9	6.5	7.1	8.5
	1.5 ft SLR	4.7	5.3	5.6	6.0	6.7	7.4	8.0	8.6	10.0
	3.0 ft SLR	6.4	7.1	7.4	7.8	8.5	9.3	9.9	10.5	12.0
Atlantic Ocean & Rudee Inlet	Existing Condition	3.6	4.1	4.5	4.9	5.4	6.3	6.8	7.3	8.7
	1.5 ft SLR	5.1	5.6	6.0	6.4	6.9	7.8	8.3	8.8	10.2
	3.0 ft SLR	7.2	7.7	8.2	8.6	9.2	10.1	10.7	11.2	12.8
Back Bay, North of Beggars Bridge Creek	Existing Condition	-	-	-	1.8	2.4	3.4	4.2	4.9	6.4
	1.5 ft SLR	-	-	-	3.3	3.9	4.9	5.7	6.4	7.9
	3.0 ft SLR	-	-	-	6.7	7.6	9.0	10.1	11.1	13.2
Back Bay, South of Beggars Bridge Creek	Existing Condition	-	-	-	1.5	1.9	2.4	2.8	3.3	4.2
	1.5 ft SLR	-	-	-	3.0	3.4	3.9	4.3	4.8	5.7
	3.0 ft SLR	-	-	-	6.3	6.9	7.6	8.1	8.8	10.1
North Landing River	Existing Condition	-	-	-	1.3	1.6	2.8	3.4	3.9	4.9
	1.5 ft SLR	-	-	-	2.8	3.1	4.3	4.9	5.4	6.4
	3.0 ft SLR	-	-	-	4.6	5.0	6.3	6.9	7.5	8.5
Elizabeth River	Existing Condition	2.8	3.6	4.1	4.7	5.8	6.5	7.1	7.9	10.3
	1.5 ft SLR	4.3	5.1	5.6	6.2	7.3	8.0	8.6	9.4	11.8
	3.0 ft SLR	5.9	6.7	7.2	7.8	8.9	9.6	10.2	11.0	13.4

Notes:

1. All elevations sourced from direct sampling and statistical analysis of the distribution of water elevations in each watershed
2. Lynnhaven, Elizabeth River, and Atlantic Ocean elevations were sourced from the 2015 FEMA Flood Insurance Study
3. Back Bay and North Landing River elevations were sourced from CIP 7-030, PWCN-15-0014, WO2A
4. The values do not represent potential wind-driven water levels in the Back Bay and North Landing River
5. The 5-year return period should be used as a minimum elevation for design in Back Bay and North Landing River due to wind tides.
6. Conditions related to a 3-ft rise in sea level include non-linear increases derived from numerical modeling completed by the U.S. Army Corps of Engineers and the North Carolina Floodplain Mapping Program

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Flood Intervention Strategies

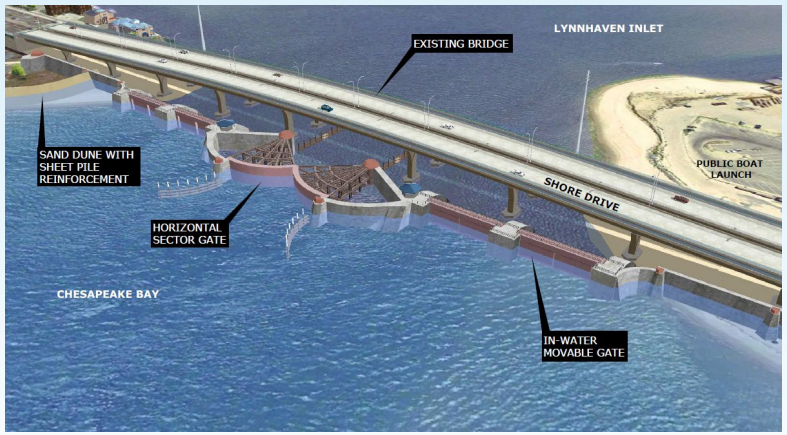
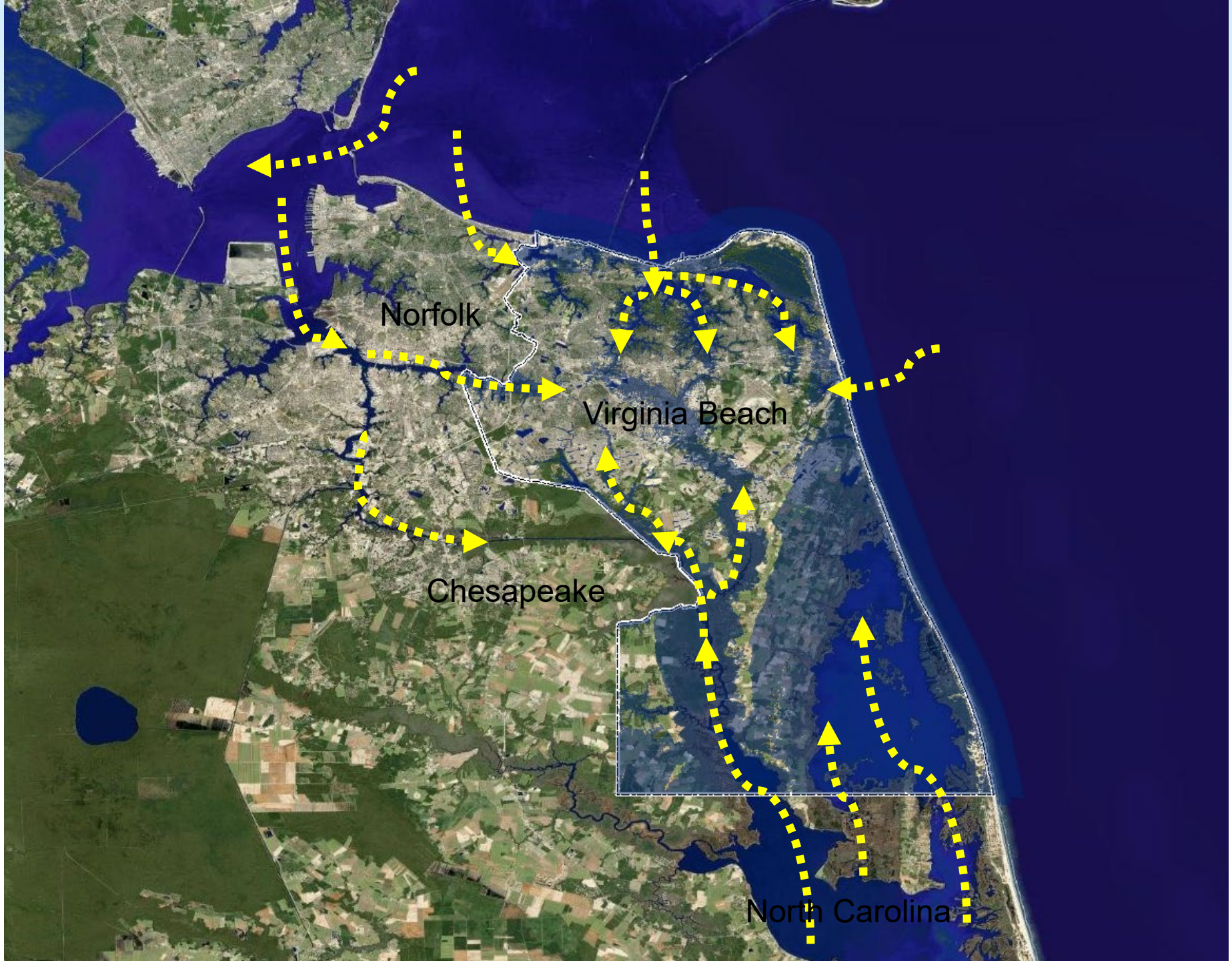


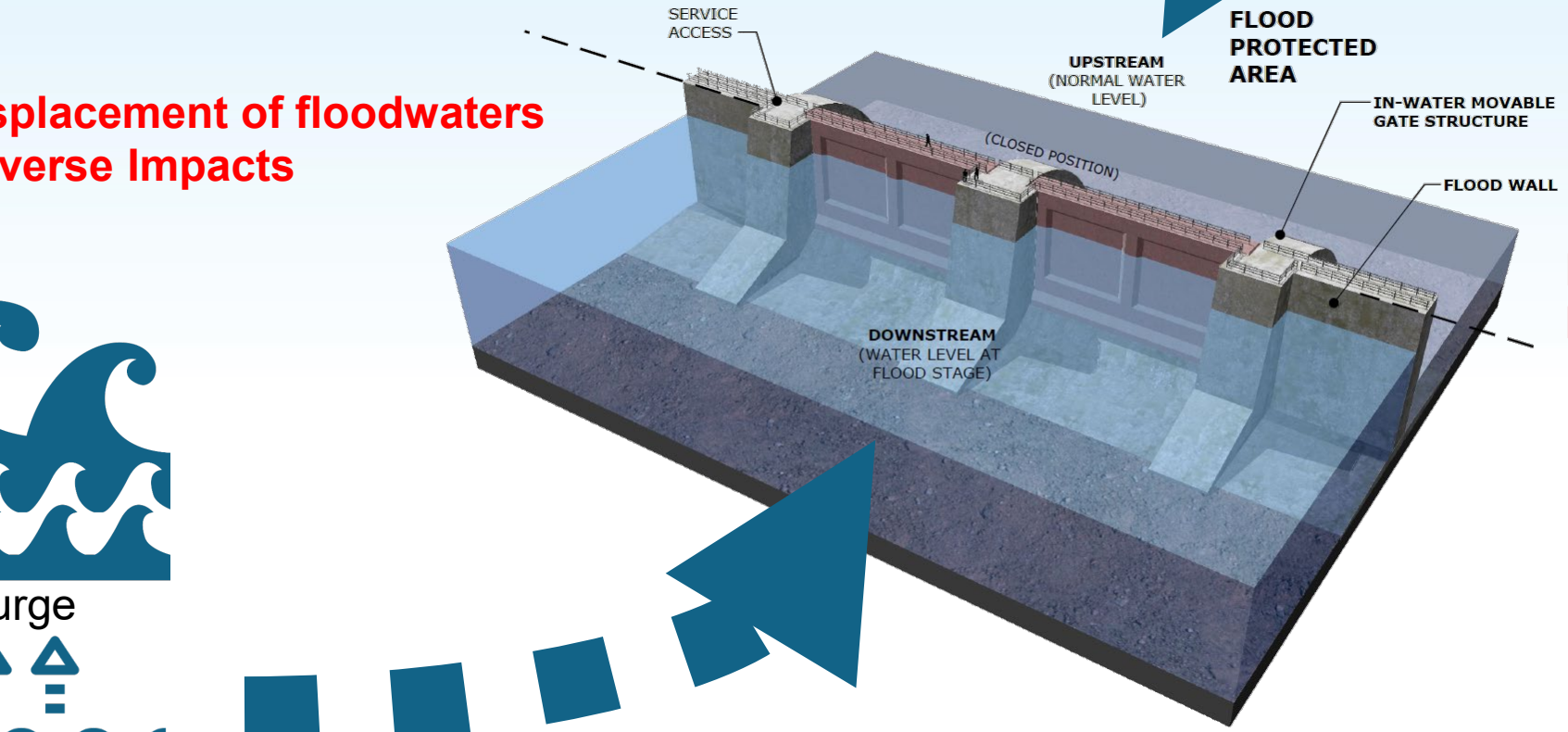
Photo courtesy of ERDC


Norfolk
Virginia Beach
Chesapeake
North Carolina

Compound Flooding

Dewberry

Rainfall



Displacement of floodwaters
Adverse Impacts

Reduced coastal flooding
Blockage of runoff drainage

Surge

Sea-level rise

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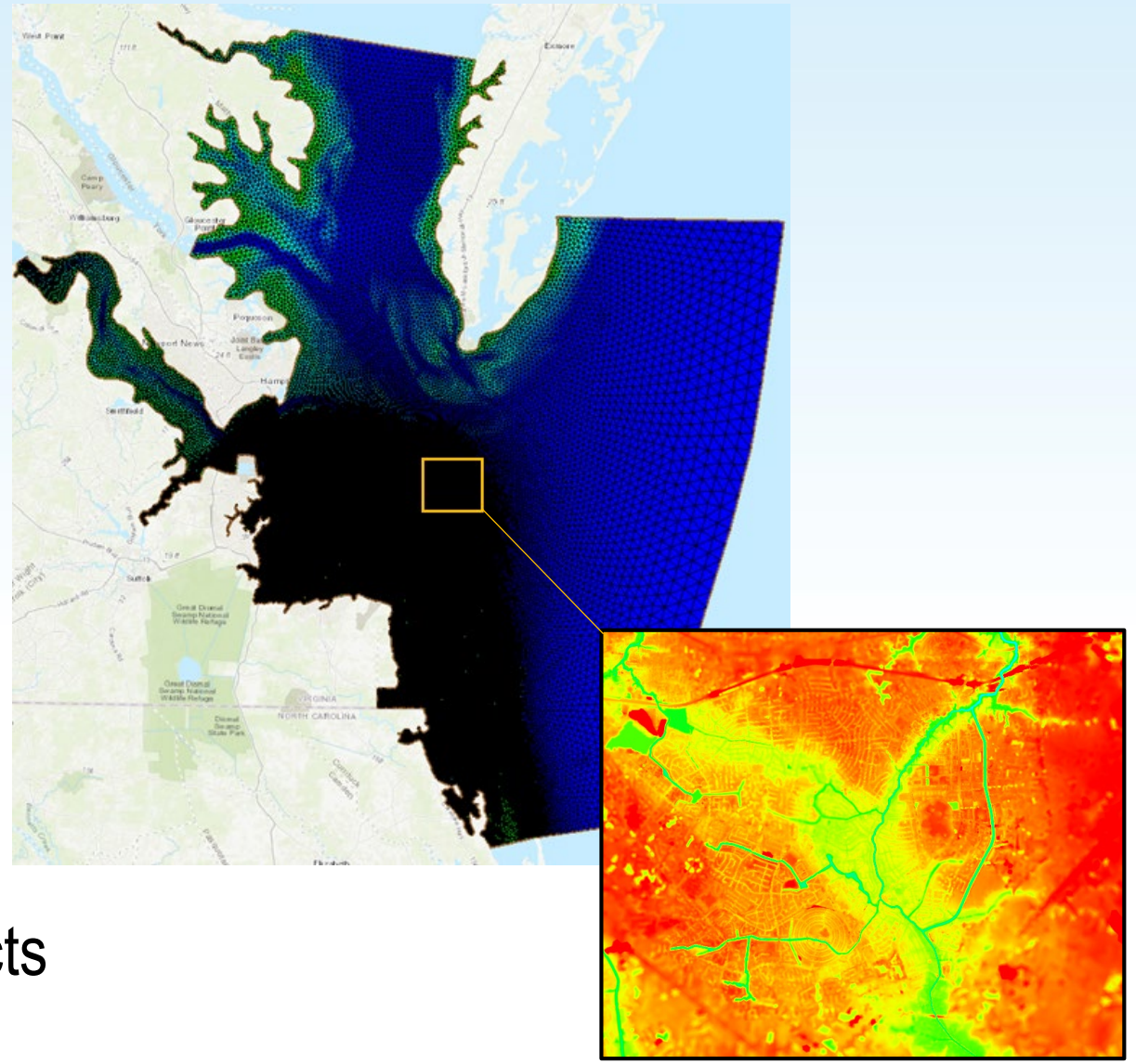
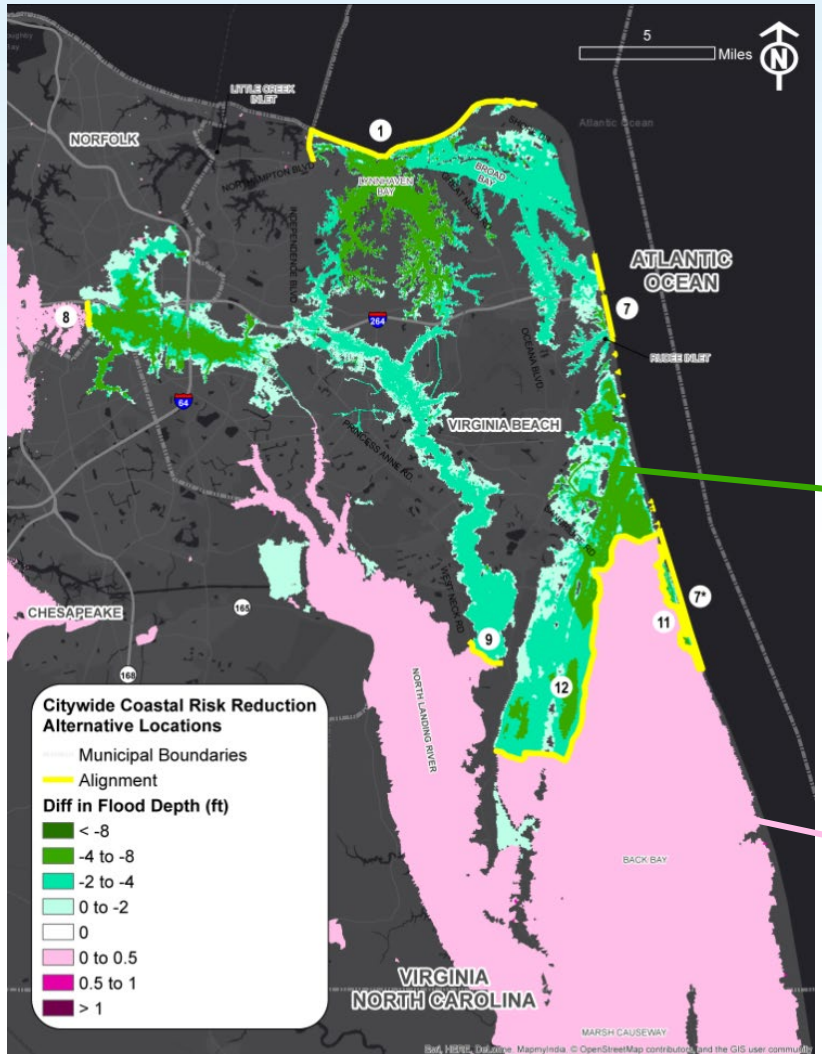
Integrated Modeling

- DHI MIKE21 – coastal surge
- MIKE FLOOD - stormwater
- Tidal calibrated, validated
- 10-/100-yr surge forcing with/without 10-yr runoff
- Structure implementation
- Flood depth benefits and adverse impacts



Model Evaluation Benefits and Impacts

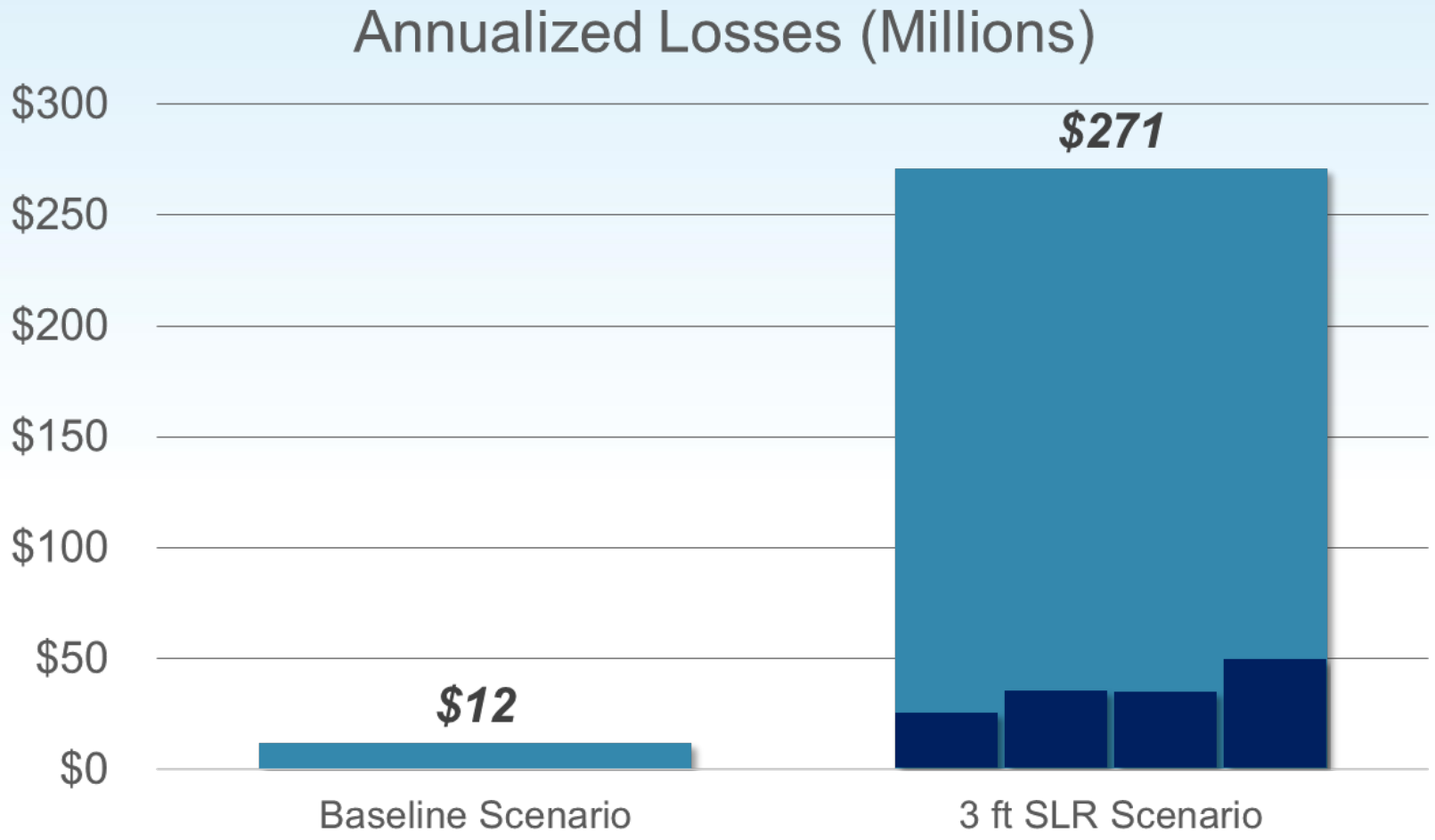
- Insights gained:
  - Areas of benefit, adverse impacts
  - Drainage impacts
  - Pumping requirements
  - Economic benefits (via Hazus and FEMA BCA modeling)



Areas of Benefit (reduced flood depth)

Areas of Adverse Impact (increased flood depth)

Future With/Without Alternatives



FOR INFORMATIONAL PURPOSES
Initial values shown, currently under refinement

Losses without Project

Losses with Project Alternatives

Challenges

- Broader and better consideration of system-wide future conditions
- Integration of surge and rainfall in process
- Regional perspective in adaptation strategies

Questions?

Project Website:
http://www.vbgov.com/pwSLR

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Acknowledgements:
Aspects of this effort were funded by National Oceanic and Atmospheric Administration Office of Coastal Management award number NA16NOS4730011.

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