COVA ADAPTATION & RESILIENCE

Old Dominion University

Institute for Coastal Adaptation & Resilience

EDF Environmental Defense Fund — Finding the ways that work

Hampton University 1868

Carol Considine, Director of Applied Projects, CCRFR,
Institute for Coastal Adaptation and Resilience/ODU.

September 15, 2022

This project was funded in part by GO VIRGINIA, a state-funded initiative administered by the Virginia Department of Housing and Community Development (DHCD) that strengthens and diversifies Virginia's economy and fosters the creation of higher wage jobs in strategic industries.

Launching a Coastal Resilience and Adaptation Economy in Coastal VA Project

MIDDLE PENINSULA PLANNING DISTRICT COMMISSION

Sea Grant Virginia

RISE Resilience Innovations

VIMS | WILLIAM & MARY
VIRGINIA INSTITUTE OF MARINE SCIENCE
SCHOOL OF MARINE SCIENCE

OLD DOMINION UNIVERSITY

GO VIRGINIA
VIRGINIA INITIATIVE FOR GROWTH & OPPORTUNITY IN EACH REGION

GO Virginia Coastal Resilience & Adaptation Economy

Lead Organization: Virginia Sea Grant (VASG)

Resilience Entrepreneurship Capacity-Building Businesses Accelerator Services

RISE, VASG, MP Public Access Authority

- Apply Region 5 RISE's proven business plan competition model and business accelerator services to coastal rural Region 6
- Launch new business-university partnerships for product performance validation
- Leverage Region 6 network of field stations for resilience R&D

Region 5-6 Consortium

ODU

- Broaden industry education, training, and engagement in coastal resilience and adaptation.
- Enable urban-rural business resilience strategy development
- Advance local best practices and infrastructure investment opportunities
- Resource and capabilities web-portal

- Promote business success stories
- Small business—large business collaboration for resilience execution
- Rural—urban capacity-building and knowledge transfer
- Advance Virginia's global identity as leader in the coastal resilience & adaptation economy

COVA ADAPTATION & RESILIENCE

- Mission:

To grow and diversify the coastal adaptation and resilience sector by preparing business communities for changing environments and rising water levels.

- Tag Line

Rising to the challenge of a changing environment.

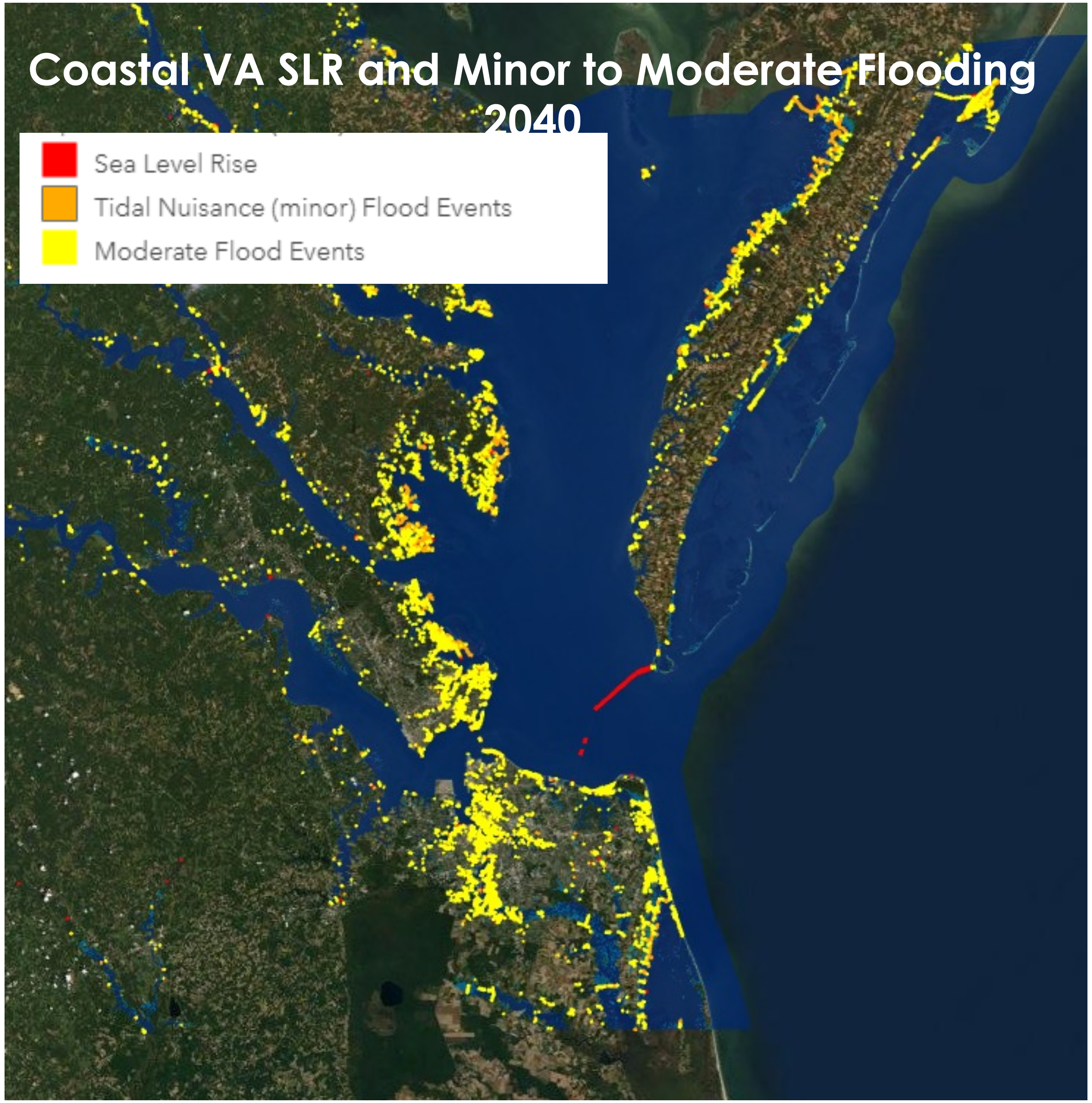
COVA ADAPTATION & RESILIENCE

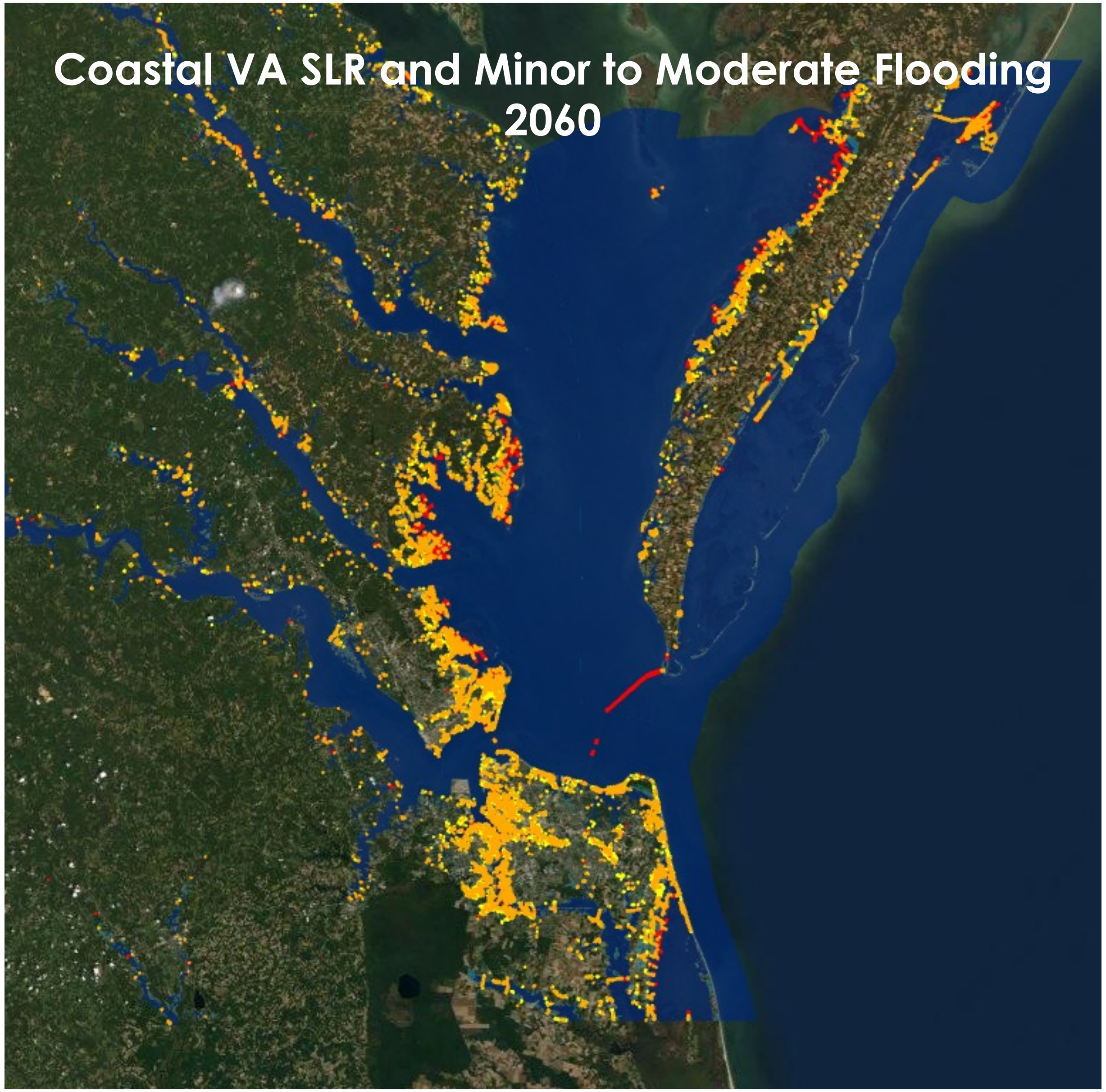
Coastal Virginia Adaptation and Resilience Consortium

- Engage the broader business communities in the resilience and adaptation sector to advance collaboration
- Provide opportunities for growth and diversification of the coastal resilience and adaptation sector
- Prepare businesses for a future with water thru education and best practices
- Catalyze growth in new and existing firms.

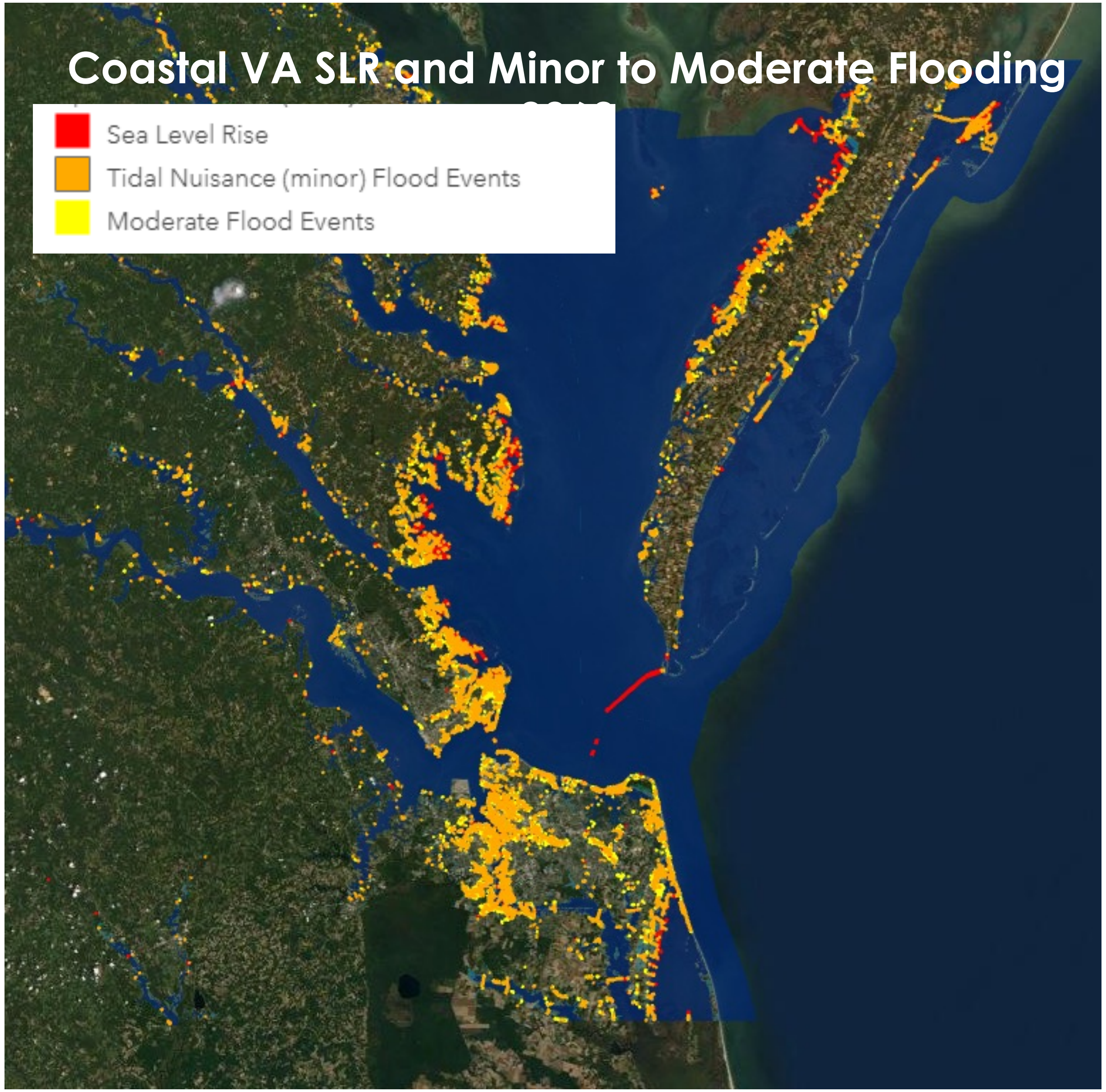
COVA
ADAPTATION & RESILIENCE

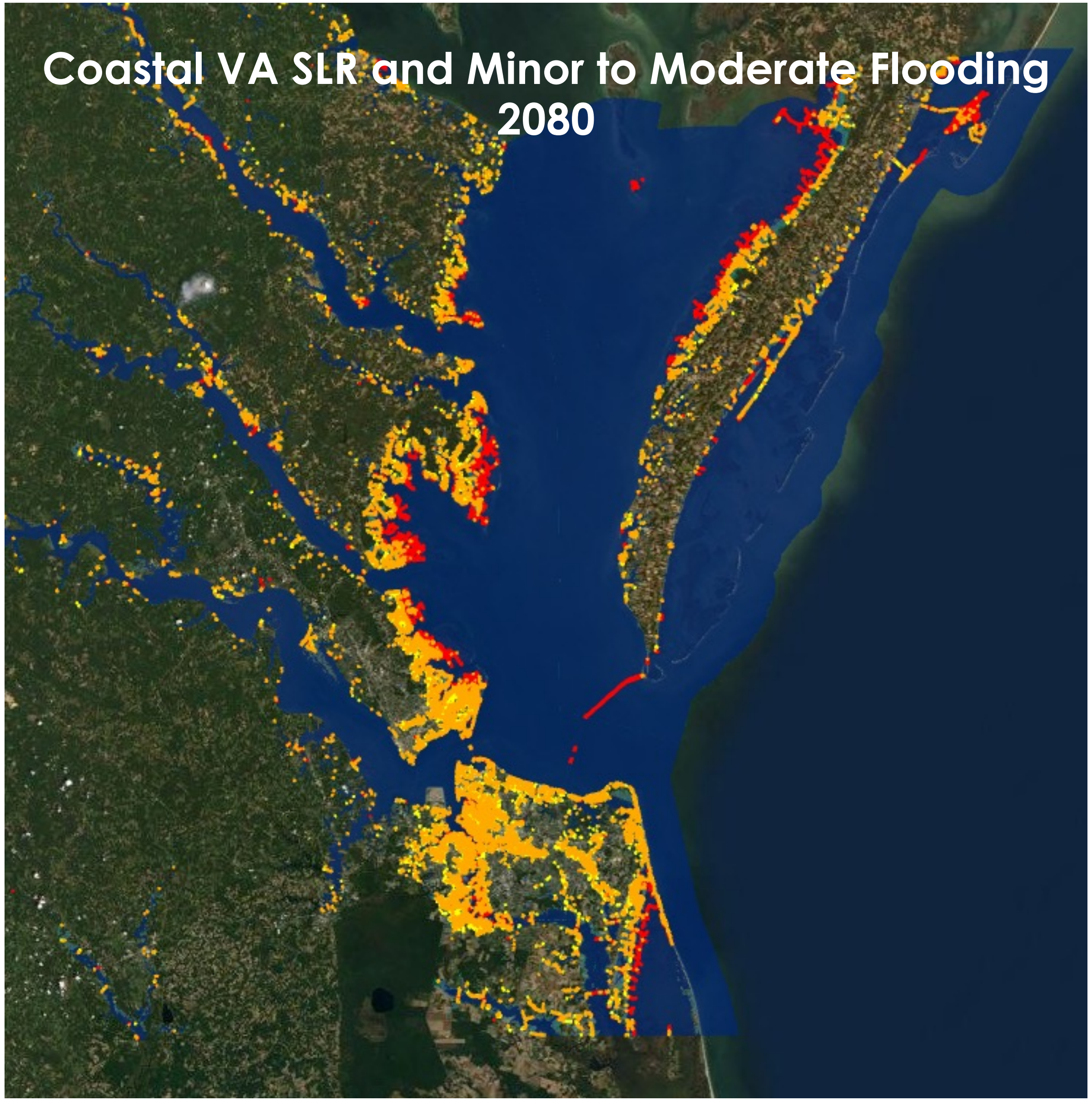
2021-2022	2022-2023	2023-2024
Project Launch April Steering committee and working groups formed. Consortium economic impacts breakfast (hurricane). Industry outreach to 4 industry sectors.	Consortium economic impacts breakfast (SLR/Flooding). Consortium website development & launch. Build collaboration across industry sectors. Talent gaps working group launch. Resilience industry strategies developed.	Consortium economic impacts breakfast. Encourage adoption of resilience strategies. Continuity strategy implemented. **Consortium Continuity**



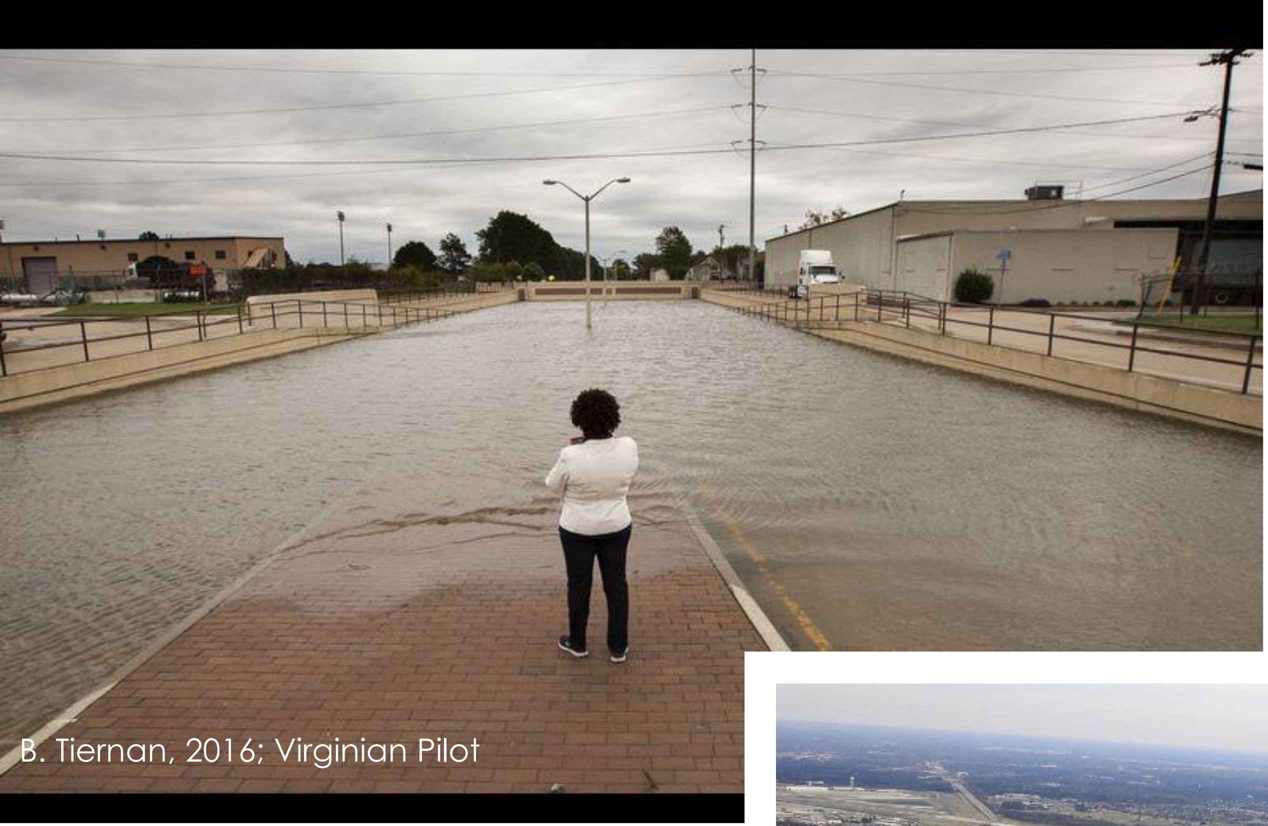


Source: Future-Sea-Level-and-Recurrent-Flooding-Risk-for-Coastal-Virginia-Final-Version.pdf (floodingresiliency.org)





Source: [Future-Sea-Level-and-Recurrent-Flooding-Risk-for-Coastal-Virginia-Final-Version.pdf (floodingresiliency.org)]



B. Tiernan, 2016; Virginian Pilot

J. Westcott, 2018;Washington Post

B. Tiernan, 2017; Virginian Pilot

Scott, 2012; Wikipedia.org

Port of Virginia; portofvirginia.com

Government is providing opportunities!

2022 Inflation Reduction Act: $369 billion

- Consumer energy costs ($10B)
- American energy security and domestic manufacturing ($64.5 B)
- Decarbonizing the economy ($72 B)
- Investment in communities and environmental justice ($10 B)
- Farmers, forestland owners and resilient rural communities ($47.6 B)

2021 Infrastructure Investment and Jobs Act (IIJA): $550 billion

- Roads, bridges, major projects, rail ($176 B)
- Safety and public transit ($50.2 B)
- Broadband ($65 B)
- Ports waterways and airports ($42.3 B)
- Water infrastructure ($55 B)
- Power and grid (73 B)
- Resiliency ($46 B)
- Low-carbon, zero-emission and EV busses and ferries ($15 B)

Why take action? Benefits outweigh costs

Studies:	Benefit-Cost Ratio:
Economic Impact of Recurrent Flooding in Virginia Beach from 2021-2069 (McNab et al. 2021)	19:1 to 20:1 (economic output)
Natural Hazard Mitigation Saves Interim Report (FEMA 2018)	4:1 to 6:1 (overall hazard)
ADAPT NOW: A Global Call For Leadership On Climate Resilience (The Commission on Adaptation 2019)	2:1 to 10:1

Consortium Website https://oduadaptationandresilience.org/consortium/

Working Groups

Benefits of Joining a Working Group

- Education opportunities including business continuity training, economic impacts of hurricanes and recurrent flooding, and local best practices related to adaptation and resilience.
- Understanding adaptation and resilience project needs and exploring opportunities to drive progress through funding strategy development (PPP opportunities).
- Developing Coastal VA resources and capabilities for the adaptation and resilience sector, to include defining the problem, describing the sector, highlighting opportunities, innovation, and success stories, and promoting urban and rural expertise in the sector.

Local Best Practices

Identification of local best practices for adoption in urban and rural settings for individual, commercial, and community properties.

Team Leads:
Mujde Erten-Unal (Old Dominion

Infrastructure Investment Opportunities

Cataloging of infrastructure projects identified in previous studies (JLUS, RAFT, etc.) and development of implementation strategies to include Public-Private Partnerships and other

Resources and Capabilities

Assessment of resources and capabilities within Regions 5 and 6 building upon work of VASG Planning Grant that: defines the problem (scale & impact); describes the Water Technology sector and pathways for

Talent Gaps

Based on results from working group outputs in Year 1, identify talent gaps, and education and training needs to create jobs and support coastal resilience and adaptation sector growth. (Year 2)

Next Steps...

Questions?

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OLD DOMINION UNIVERSITY

Projecting the Cost of Recurrent Flooding in Virginia

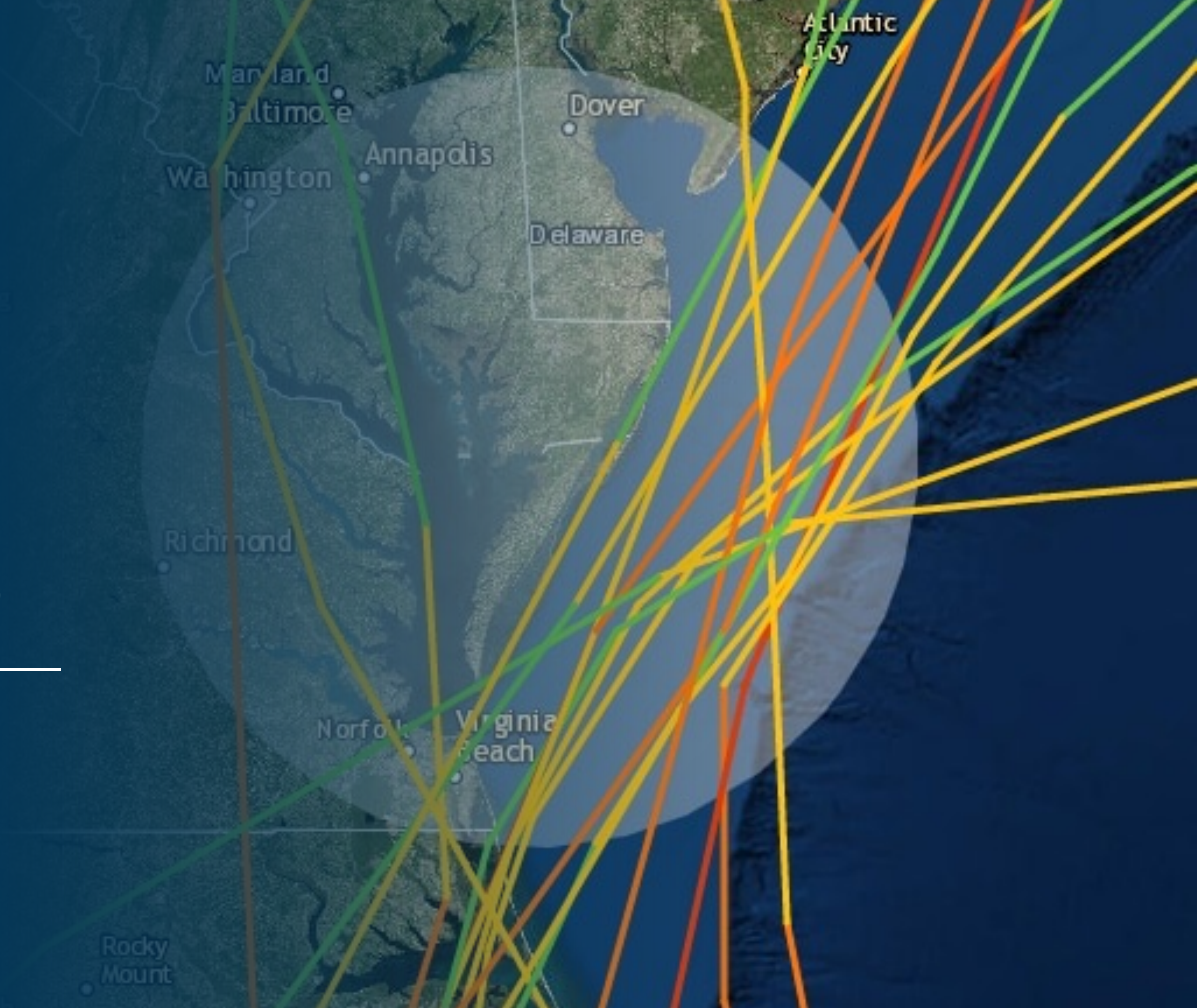
Robert M. McNab
Dragas Center for Economic Analysis and Policy
Strome College of Business
Old Dominion University

September 15, 2022

Bottom Line Up Front

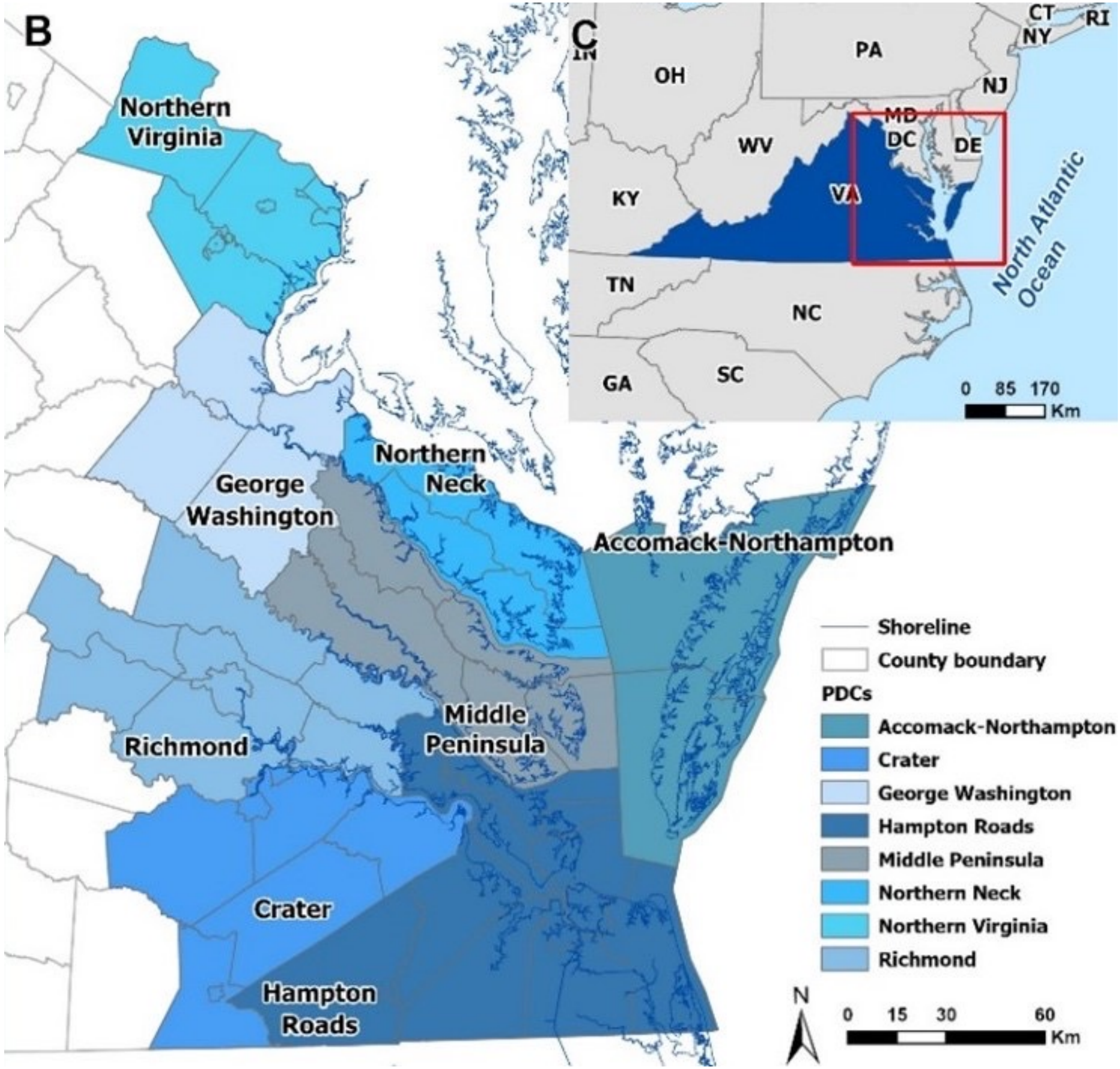
- **How will sea level rise and recurrent flooding impact Virginia this century?**
- **We estimate the average annualized losses due to sea level rise, recurrent flooding, and major storms using projections from HAZUS.**
- **We focus on eight planning districts that comprise "Coastal Virginia" and that are most at risk from sea level rise.**
- **We discount the financial and economic losses into 2021 dollars to provide insight into the impact of future flooding.**
- **Unmitigated flooding from 2020 to 2099 will result in $56.1 billion in financial damages in 2021 dollars, resulting in a $79.1 billion decline in economic output in 2021 dollars.**
- **The discounted future losses of unmitigated flooding are at least equal to 13.5% of Virginia's 2021 Gross Domestic Product.**

Study Areas

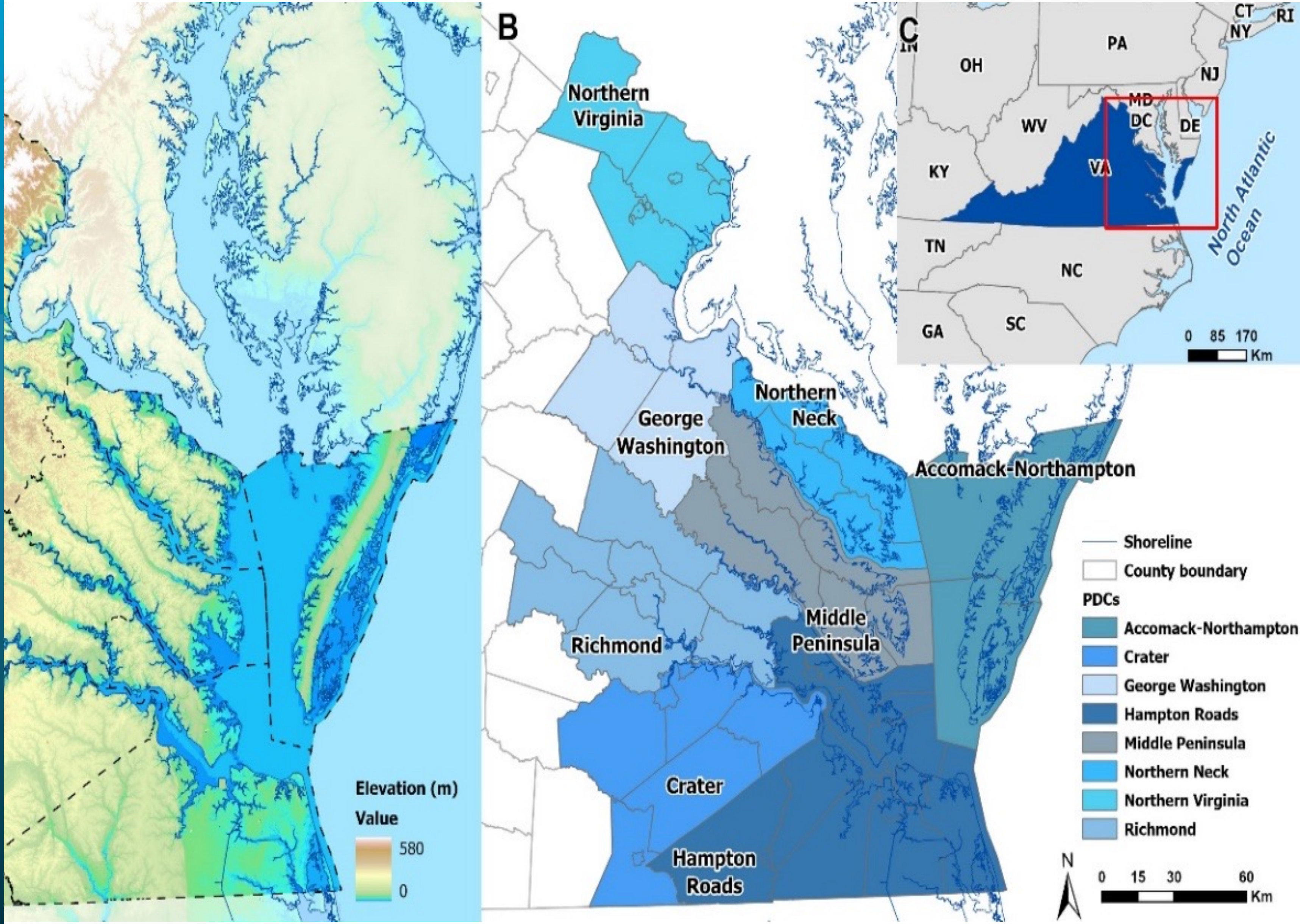


- Coastal Virginia is divided into eight Planning District Commissions (PDCs) by the Virginia General Assembly.

- The eight PDCs are:
  - Accomack-Northampton
  - Crater
  - George Washington
  - Hampton Roads
  - Middle Peninsula
  - Northern Neck
  - Northern Virginia
  - Richmond



PDCs and Elevation



Economic Characteristics

- The eight PDCs comprised approximately 60% of Virginia's 2019 population.
- The eight PDCs accounted for approximately 70% of Virginia's Gross Domestic Product (GDP) in 2019.
- Within the eight PDCs, economic activity and population are primarily concentrated in:
  - Hampton Roads
  - Northern Virginia
  - Richmond
- The spatial concentration of population and economic activity drives financial losses and economic impacts.

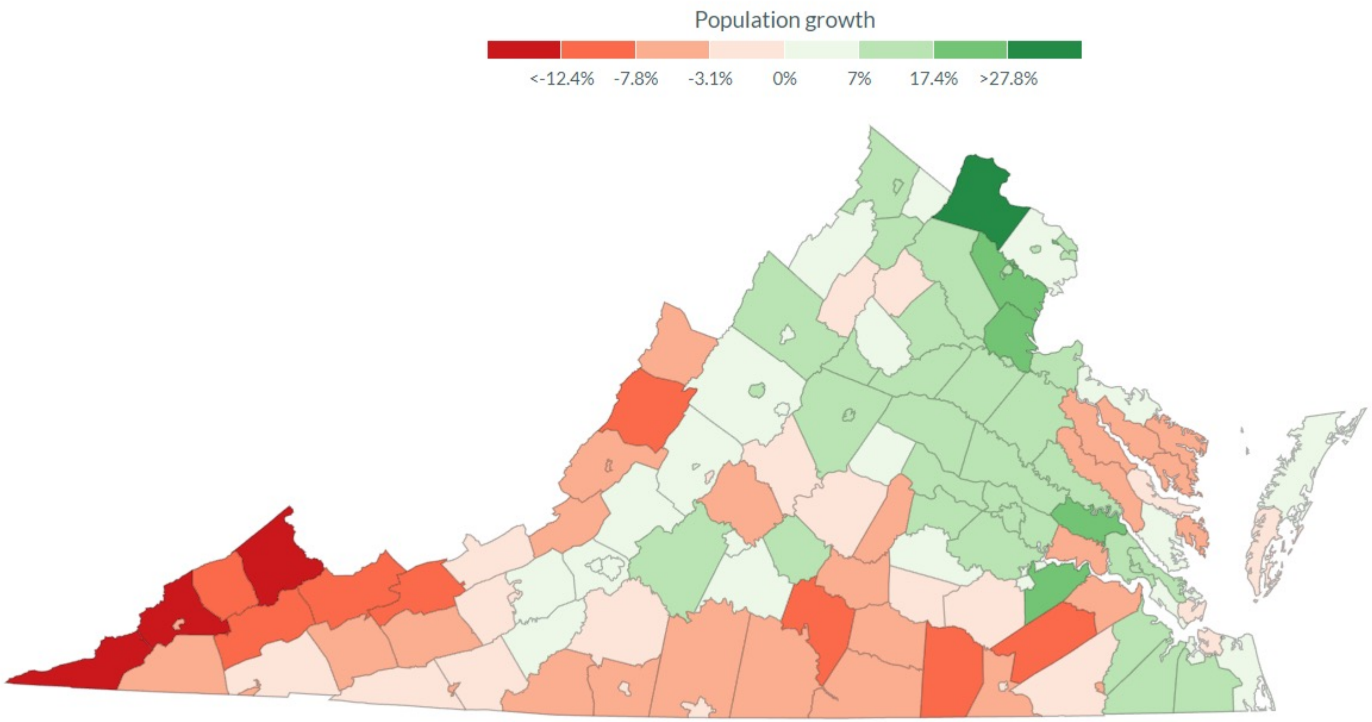
Population Change in Virginia, 2010-2019

Over 70% of the Virginia population resides in the "urban crescent" formed by Northern Virginia, Richmond, and Hampton Roads.

Southwestern Virginia has lost population over the last decade.

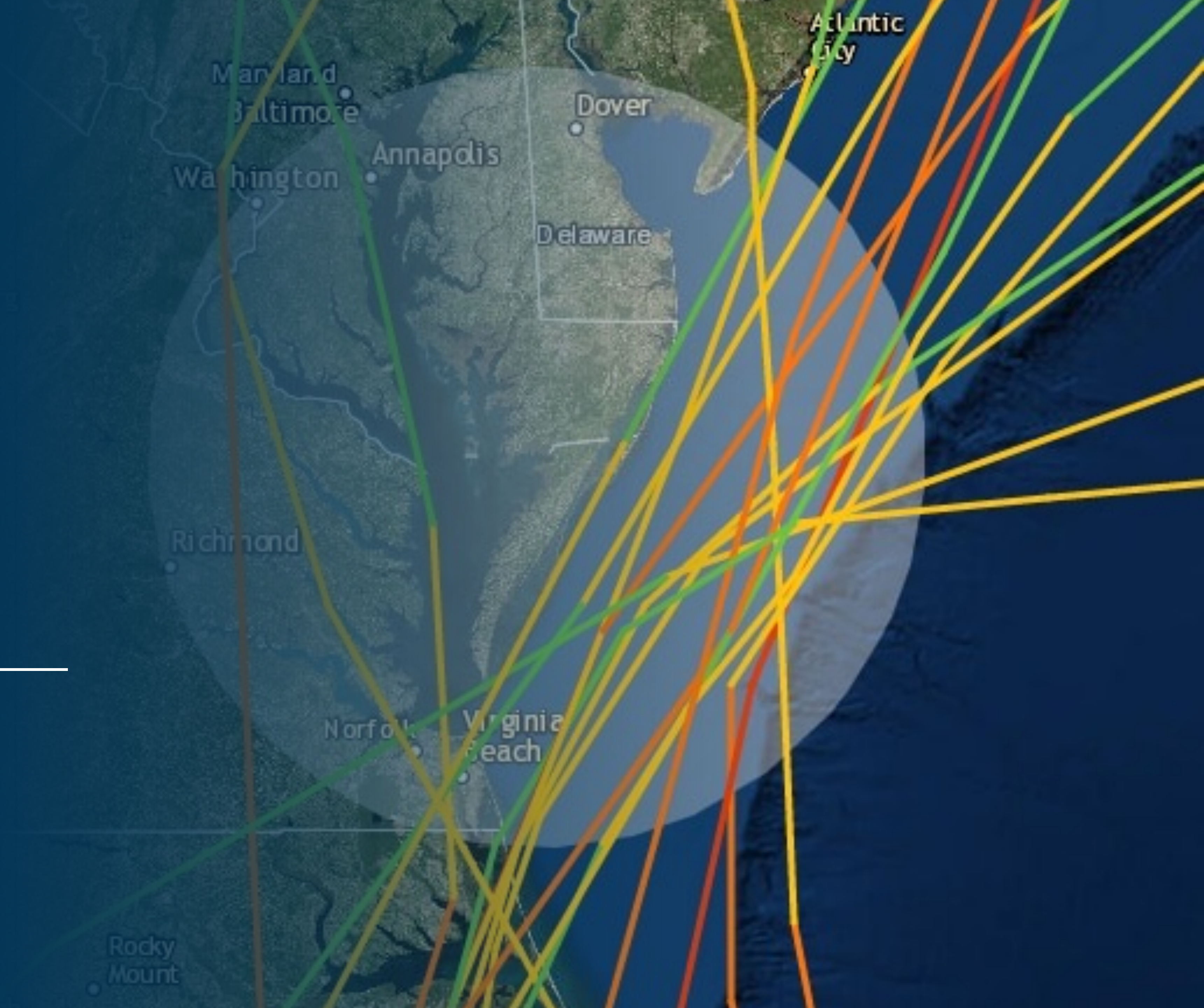
More people are living in areas prone to sea level rise and recurrent flooding.

Virginia's population grew by 7.9 percent in the last decade. The bulk of the growth was focused in the northern part of the state, while 62 of 133 localities -- largely in Southwest and Southside Virginia -- lost residents.



Source: https://www.vpap.org/visuals/visual/population-change/

Approach



Study Timeframe and Periods

- We estimate the economic impact of sea level rise and recurrent flooding from 2020 to 2099 using four distinct study periods.

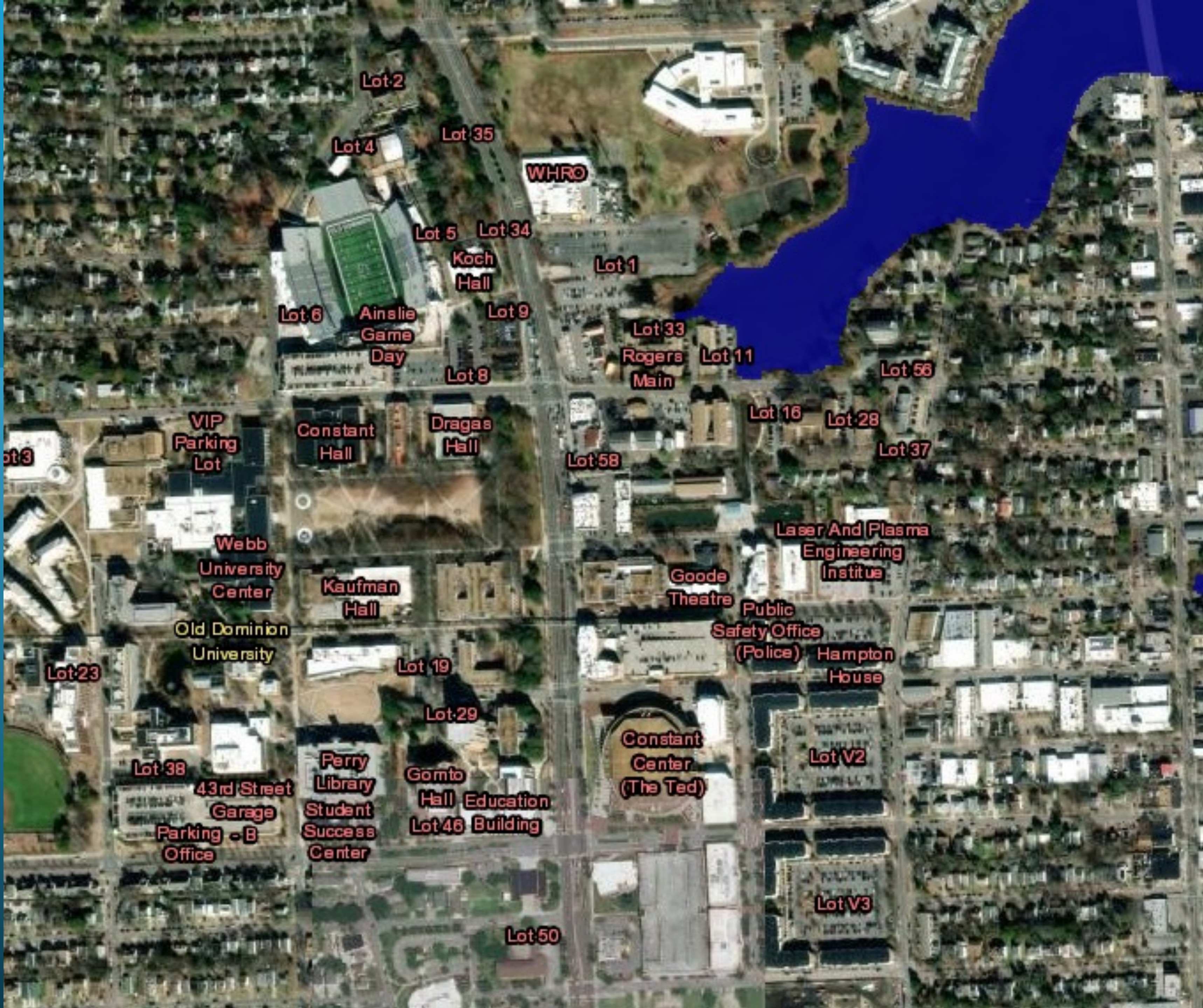
- The study periods correspond to NOAA's 2022 projections of average sea level rise in Virginia.
  - 2052 – 1.74 feet
  - 2073 – 3.05 feet
  - 2094 – 4.76 feet

- The study periods are:
  - 2020 – 2039 (Baseline)
  - 2040 – 2059 (2052 NOAA SLR projection)
  - 2060 – 2079 (2073 NOAA SLR projection)
  - 2080 – 2099 (2094 NOAA SLR projection)

Sea Level Rise – The Impact on ODU

- We can use NOAA's Sea Level Rise Viewer to examine how sea level rise changes the landscape.
- As sea level rises progresses from 2 to 4 to 6 feet, low lying areas are increasingly vulnerable to recurrent flooding.
- Remember, NOAA's projection is an average rise of 4.74 feet near the end of the century.
- While most of the campus may be "dry," sea level rise will increasingly impact transportation networks.
- An increase in the "base" sea level of 4.74 feet increases the likelihood of damage from a storm event.
- **With unmitigated sea level rise, is there a long-term future for ODU's main campus?**

ODU – Current Sea Level



ODU – 2 Feet SLR Scenario

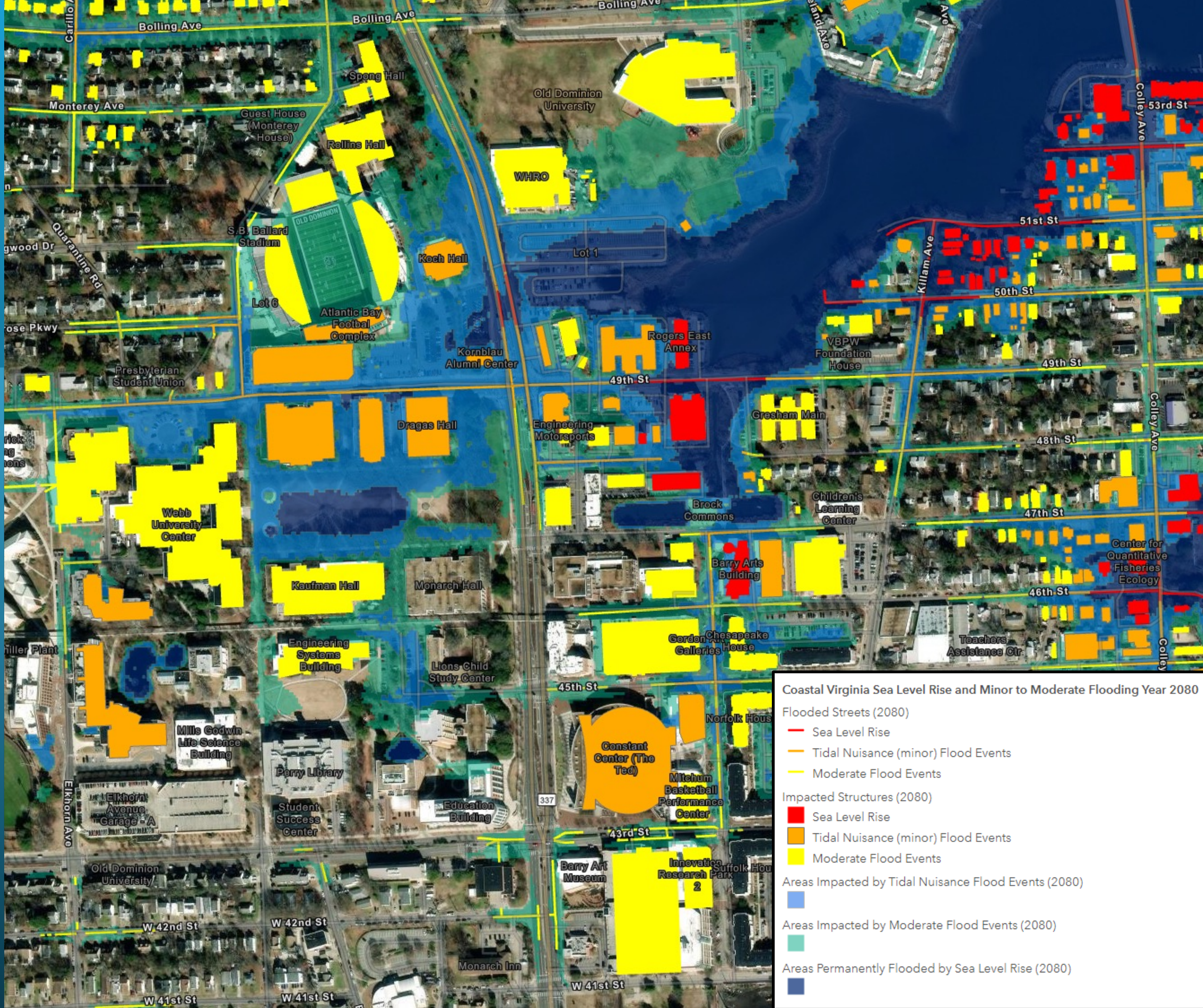
ODU – 4 Feet SLR Scenario

ODU – 6 Feet SLR Scenario

ODU – 8 Feet SLR Scenario

ODU – 10 Feet SLR Scenario

ODU – Year 2080 SLR with tidal and storm flooding



Storm Events

- For each study period, we estimate the financial damages associated with storm events.
- The odds of each storm event are:
  - 1 in 10
  - 1 in 25
  - 1 in 50
  - 1 in 100
  - 1 in 500
- As the odds of a storm event decline, the damages from the storm event increase.
- **The losses from a lower probability storm (1 in 100-year) will be higher than the losses from a higher probability storm (1 in 10-year).**

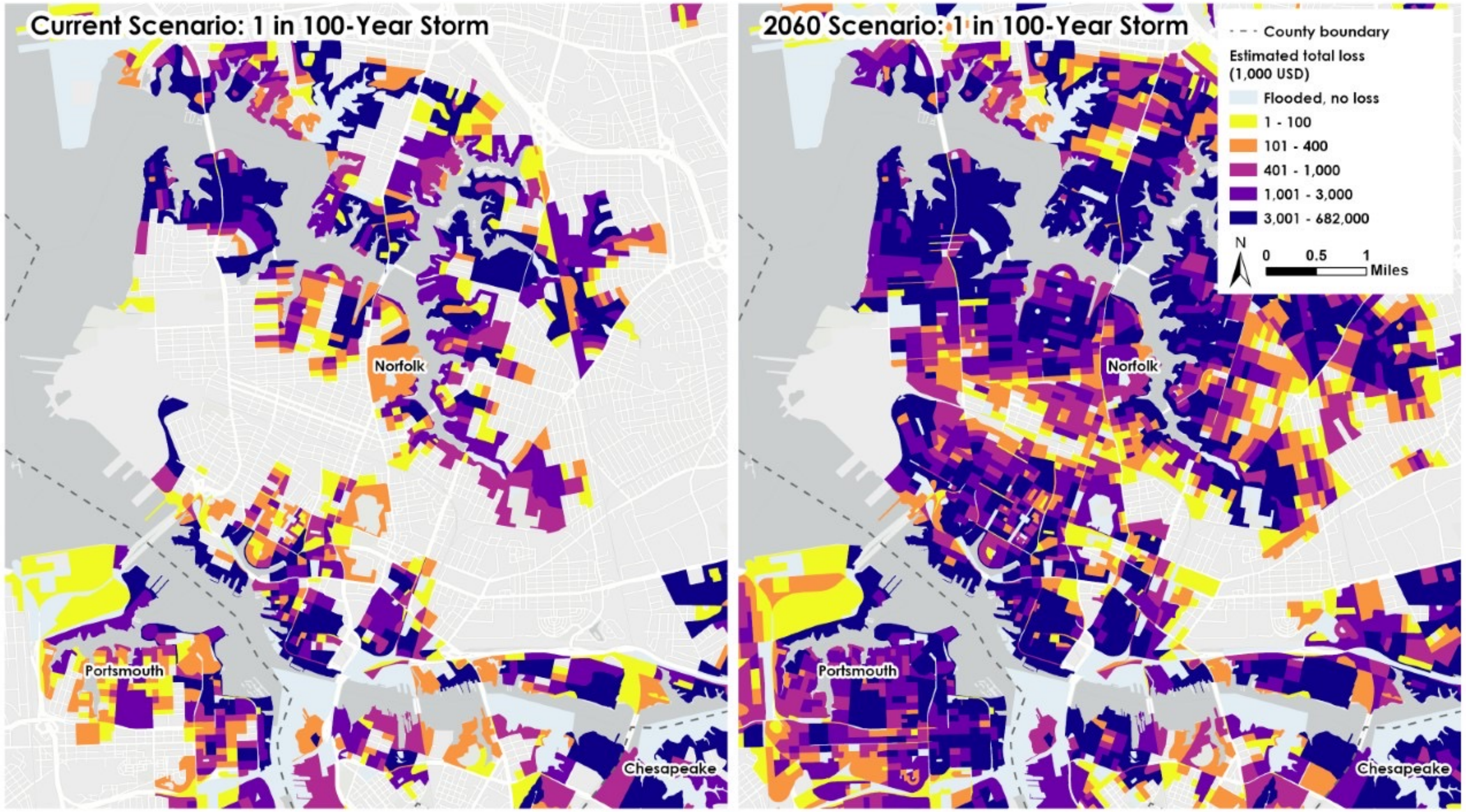
Storm Event Probability

- A "1 in 100-year" storm event is often thought of as occurring only once in 100 years.
- However, the probability of a "1 in 100-year" storm event is 0.01 in any given year.
- What is the probability of at least one "1 in 100-year" storm occurring over a 50-year period?
- The probability is equal to 1 – P(no storm)^(periods)
- **Over a 50-year period, there is a 39.5% likelihood of being impacted by at least one "1 in 100-year" storm.**

Storm Event Damages

- As sea level rise occurs, the damages for a given storm increase.
- In other words, a 1 in 10-year storm produces higher damages in 2040 than in 2020 and higher damages in 2060 than 2040.
- Another perspective is to focus on damages and ask what happens to the probability of a storm event.
- As sea level rise occurs, the probability of experiencing the same damages as a 1 in 10-year storm in 2020 increase.
- **Virginia Beach requires storm design events to be 20% longer and intense than what is recommended by NOAA.**

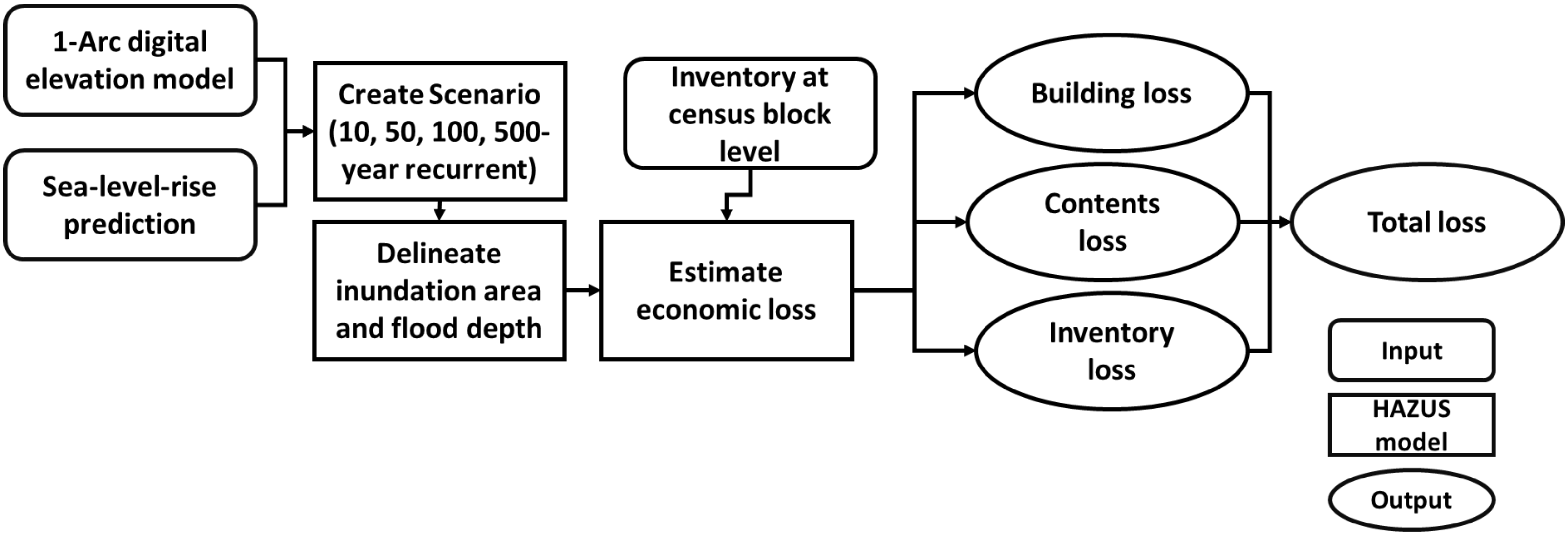
Storm Event Damages



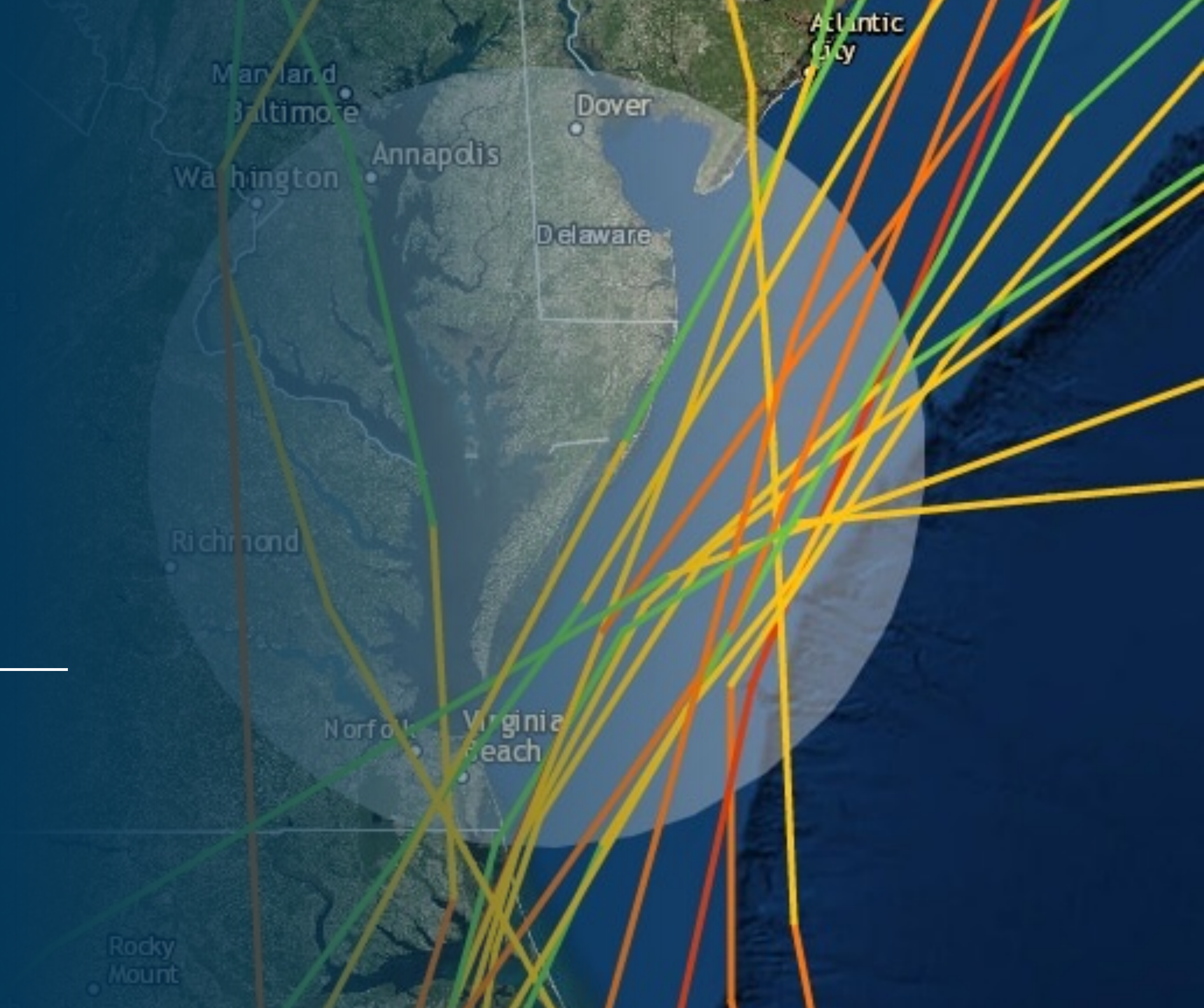
HAZUS

- We applied HAZUS Flood Model to compute unrefined baseline losses for the study regions.
- Sea level rise values were added to the current stillwater elevation to simulate the raised water surface "platform" upon which future storms will ingress.
- For example, if the current stillwater elevation is 3.75 feet and predicted sea level rise in 2080 is 4.72 feet, then the raised water surface platform is approximately 8.48 feet.
- Using predicted values of sea level rise (NOAA intermediate-high scenario, 2017), flood models were executed for each study region to compute flood boundary and depth for storm recurrence periods.
- Model outcomes from HAZUS including building, contents, and inventory losses were categorized according to seven general occupancies.

Workflow in HAZUS



Economic Approach



Estimation Overview

- We estimate damages for four study periods using projections of sea level rise.
  - 2020
  - 2040
  - 2060
  - 2080

- Within each study period, four study events are run
  - 1 in 10-year storm
  - 1 in 50-year storm
  - 1 in 100-year storm
  - 1 in 500-year storm

- We interpolate the damages for a 1 in 25-year storm in each study period.

- These losses are estimated by type of occupancy (industry)
  - Agriculture
  - Commercial
  - Educational
  - Government
  - Industrial
  - Religion
  - Residential

- **This process yields 1,120 estimates of damage across the eight PDCs, four study periods, seven industries, and five study events.**

Damage Estimates Example

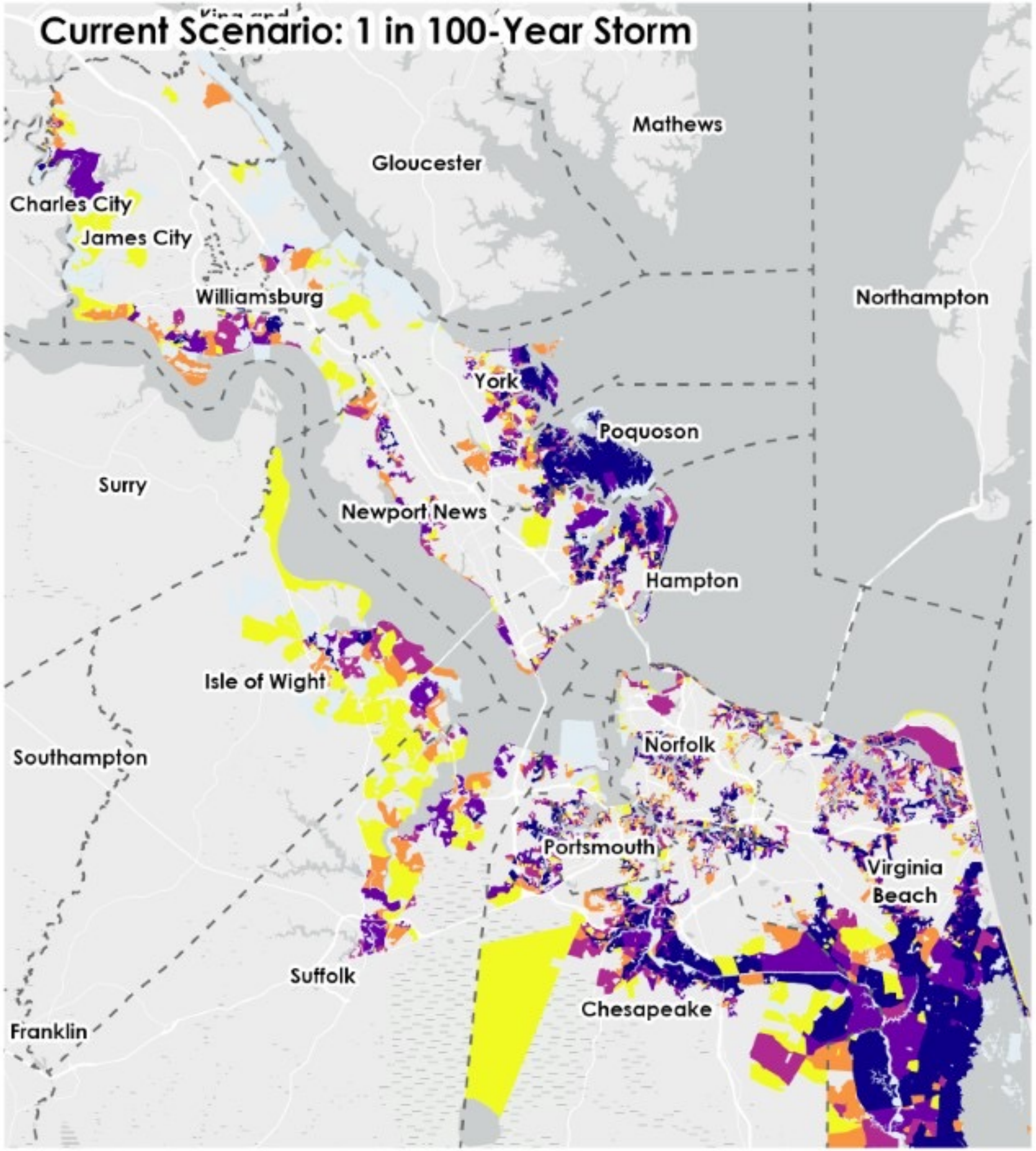
Hampton Roads

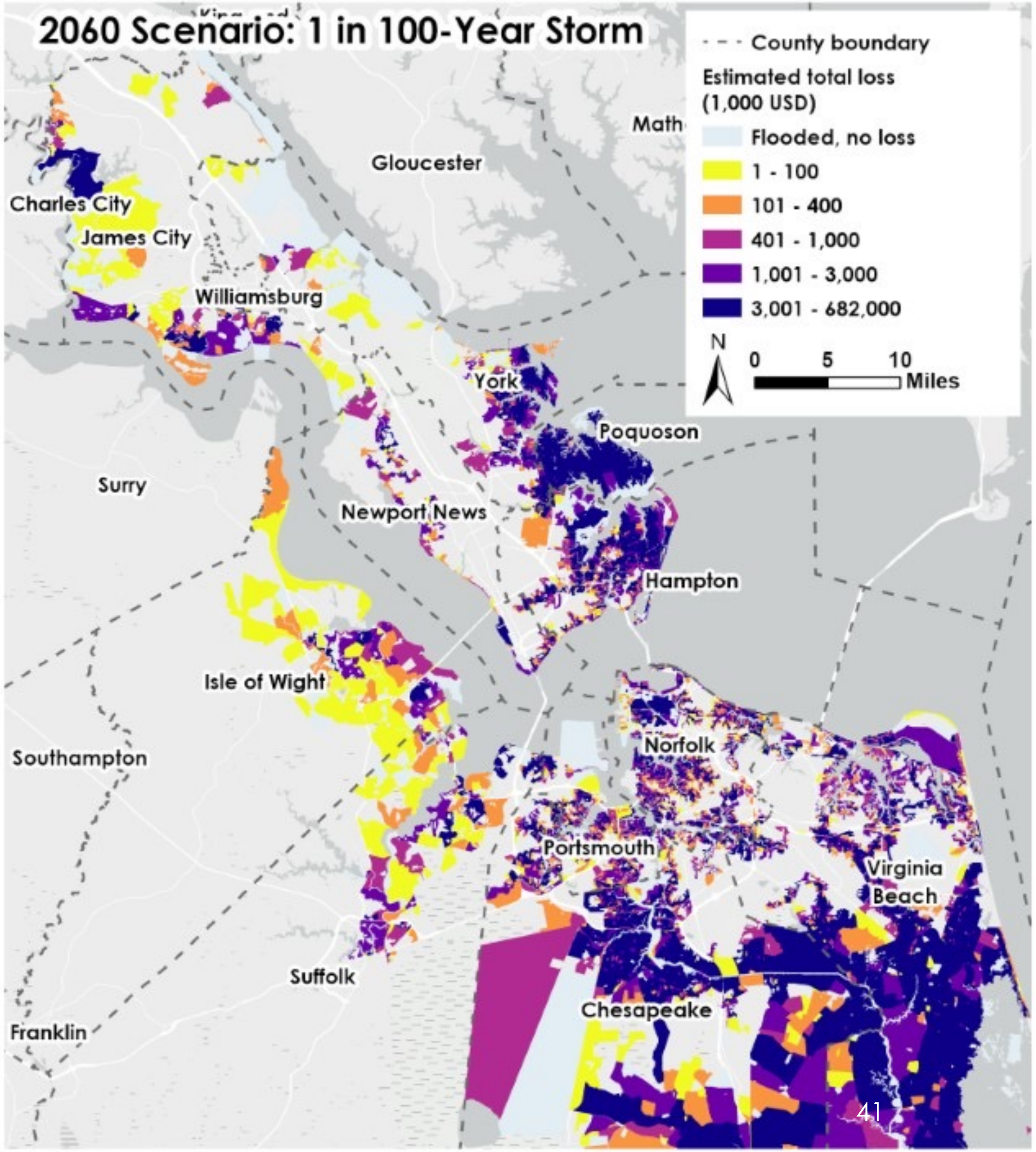
- Study period: 2020
  - SLR projection: Current
  - Study event: 1 in 100-year storm
  - Industry: Commercial
  - Total damage estimate: $870,043,000

- Study period: 2040
  - SLR projection: 1.61 feet
  - Study event: 1 in 100-year storm
  - Industry: Commercial
  - Total damage estimate: $1,718,698,000

- Study period: 2060
  - SLR projection: 2.95 feet
  - Study event: 1 in 100-year storm
  - Industry: Commercial
  - Total damage estimate: $2,604,908,000

- Study period: 2080
  - SLR projection: 4.66 feet
  - Study event: 1 in 100-year storm
  - Industry: Commercial
  - Total damage estimate: $4,331,748,000


Current Scenario: 1 in 100-Year Storm
Mathews
Gloucester
Charles City
James City
Williamsburg
Northampton
York
Poquoson
Surry
Newport News
Hampton
Isle of Wight
Southampton
Norfolk
Portsmouth
Virginia Beach
Suffolk
Chesapeake
Franklin


2060 Scenario: 1 in 100-Year Storm
County boundary
Estimated total loss (1,000 USD)
Flooded, no loss
1 - 100
101 - 400
401 - 1,000
1,001 - 3,000
3,001 - 682,000
N
0 5 10 Miles
Gloucester
Charles City
James City
Williamsburg
York
Poquoson
Surry
Newport News
Hampton
Isle of Wight
Southampton
Norfolk
Portsmouth
Virginia Beach
Suffolk
Chesapeake
Franklin

Average Annualized Loss

- Average Annualized Losses (AALs) represent the expected coast flood losses for any given year in a study period.
- The AAL for a given study period uses the discrete probabilities and damages to approximate the continuous damage function of that study period.
- We assume that a storm that has a probability > 0.1 creates no additional damage.
- We assume that a storm that has a probability < 0.02 has the same damages as a storm with a probability of 0.02.
- AAL = [f(10)*L(10)] +

  + 0.5*[(f(10)-f(25))*(L(10)+L(25))]

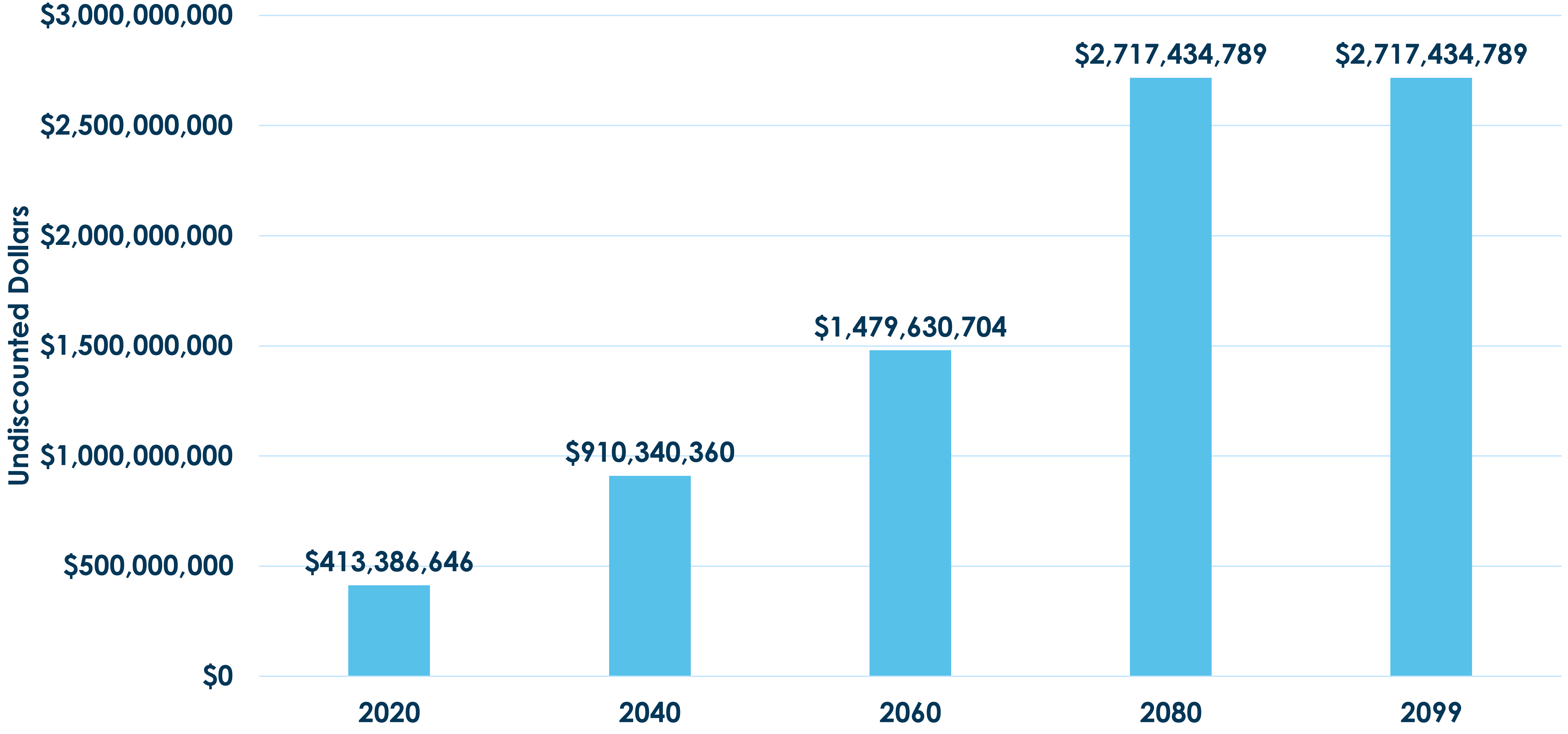
  + 0.5*[(f(25)-f(50))*(L(25)+L(50))]

  + 0.5*[(f(50)-f(100))*(L(50)+L(100))]

  + 0.5*[(f(100)-f(500))*(L(100)+L(500))]

  +[f(500)*L(500)]

Estimated Average Annualized Losses
Hampton Roads, 2020 - 2099



Source: Dragas Center for Economic Analysis and Policy Estimates

Economic Impact

Present Value of Damages

- We now have annual estimates of **direct economic losses** by industry and PDC.
- **However, we also know that losses in the future have less value than losses in the present.**
- We linearly interpolate losses between the study periods to arrive at annual losses by PDC by industry.
- We then apply a discount rate of 2.5% to estimate the present value of damages in 2021 dollars.
- We also use an alternative discount rate of 5% to test the sensitivity of our results.

Economic Impacts

- Direct effects are the set of expenditures (or losses) in an industry.
- **We need to consider the indirect and induced effects.**
- Indirect economic effects are business-to-business purchases in the supply chain resulting from the initial direct spending (or loss).
- Induced economic effects are the spending of employees within the affected supply chain.
- Economic impact is the result of direct, indirect, and induced effects.

Economic Impacts

- We obtain economic impact multipliers from the Bureau of Economic Analysis.
- **We apply the multipliers to the discounted annual damages by industry and PDC to obtain estimates of the total economic impact.**
- The total economic impact by PDC measures the loss in economic output across the study period due to sea level rise and recurrent flooding.
- What would be an equivalent impact on today's economic activity?
- These estimates allow us to think about the costs associated with unmitigated sea level rise in Virginia.

	Estimated Undiscounted Direct Losses 2020 - 2099	Estimated Discounted Direct Losses 2020 - 2099
Crater	$209,768,491	$91,054,999
Accomack-Northampton	$8,566,196,631	$3,261,993,947
George Washington	$379,064,531	$147,446,202
Hampton Roads	$132,304,307,339	$47,697,826,444
Middle Peninsula	$4,497,720,014	$1,906,213,269
Northern Neck	$1,928,891,087	$784,212,240
Northern Virginia	$4,959,661,875	$1,931,280,060
Richmond	$584,193,253	$232,554,900
Total	**$153,429,803,219**	**$56,052,582,062**

	Estimated Discounted Direct Losses 2020 - 2099	Estimated Loss in Economic Output 2020 – 2099
Crater	$91,054,999	$128,161,297
Accomack-Northampton	$3,261,993,947	$4,587,418,551
George Washington	$147,446,202	$207,080,751
Hampton Roads	$47,697,826,444	$67,336,907,119
Middle Peninsula	$1,906,213,269	$2,682,522,922
Northern Neck	$784,212,240	$1,100,199,963
Northern Virginia	$1,931,280,060	$2,766,360,134
Richmond	$232,554,900	$326,434,695
Total	**$56,052,582,062**	**$79,135,085,432**

Economic Impacts

- We estimate the economic impacts for unmitigated sea level rise and recurrent flooding from 2020 to 2099.
- **We find that the direct damages are equal to $56.1 billion in 2021 dollars.**
- **We find that the total economic impacts are equal to at least $79.1 billion in 2021 dollars.**
- We project that the cost of unmitigated flooding this century is at least equal to 13.5% of all economic activity in Virginia in 2021.
- **Hampton Roads accounts for 85.1% of estimated future losses due to sea level rise and recurrent flooding.**

Network Effects

- Our analysis does not capture potential network effects associated with sea level rise and recurrent flooding.

- As the financial and economic damages from flooding rise, disincentives rise.

- An increased likelihood of flooding will increase insurance premiums, lower covered insurance ratios, and, in the limit, result in ‘no insurance’ zones in Coastal Virginia.

- Insurance deserts will increase the living and business costs, leading to outmigration and declining economic activity.

- **Our estimates should be viewed as a lower-bound on the potential economic losses associated with sea level rise and recurrent flooding.**

One Last Thing

- A natural disaster will likely lead to a significant injection of private insurance funds, public flood program funds, and federal and state disaster aid.

- Sea level rise and recurrent flooding may result in the “death by a thousand small cuts” instead of a large natural disaster shock like Hurricane Katrina.

- However, incentives are not aligned.
  - Mitigation costs must be paid now.
  - Mitigation benefits are in the future.
  - The costs of future damages need to be internalized to change behavior.

- Remember, our estimates are a lower bound
  - Storm probabilities will increase as climate change accelerates.
  - Storm damages may increase more rapidly than we expect.
  - Network effects may lead to higher economic impacts than projected.

Questions?