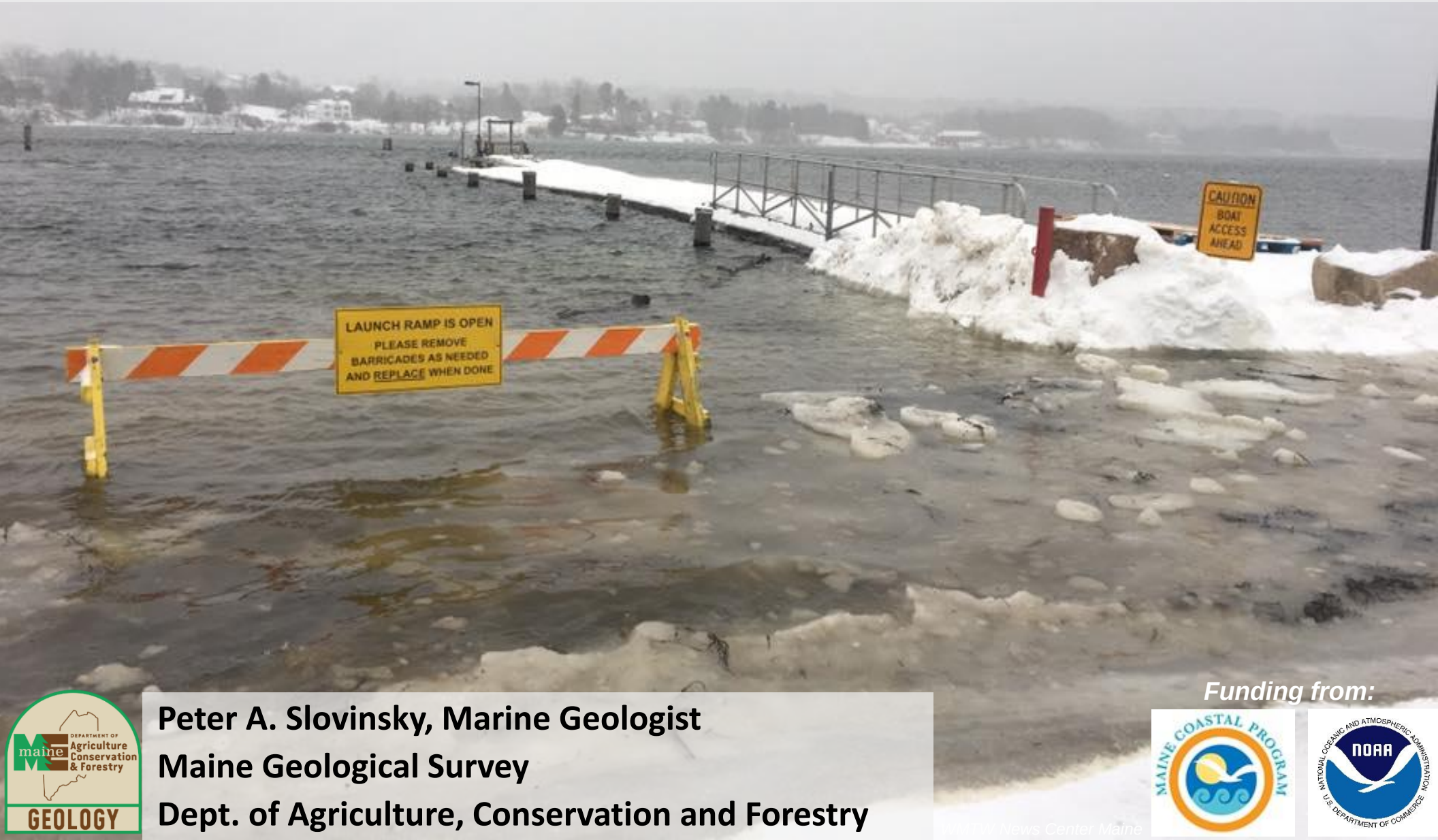
Sea Level Rise, Storms, and Coastal Impacts in Belfast and What to Potentially Do About It

Belfast Shoreline Property Owner's Meeting

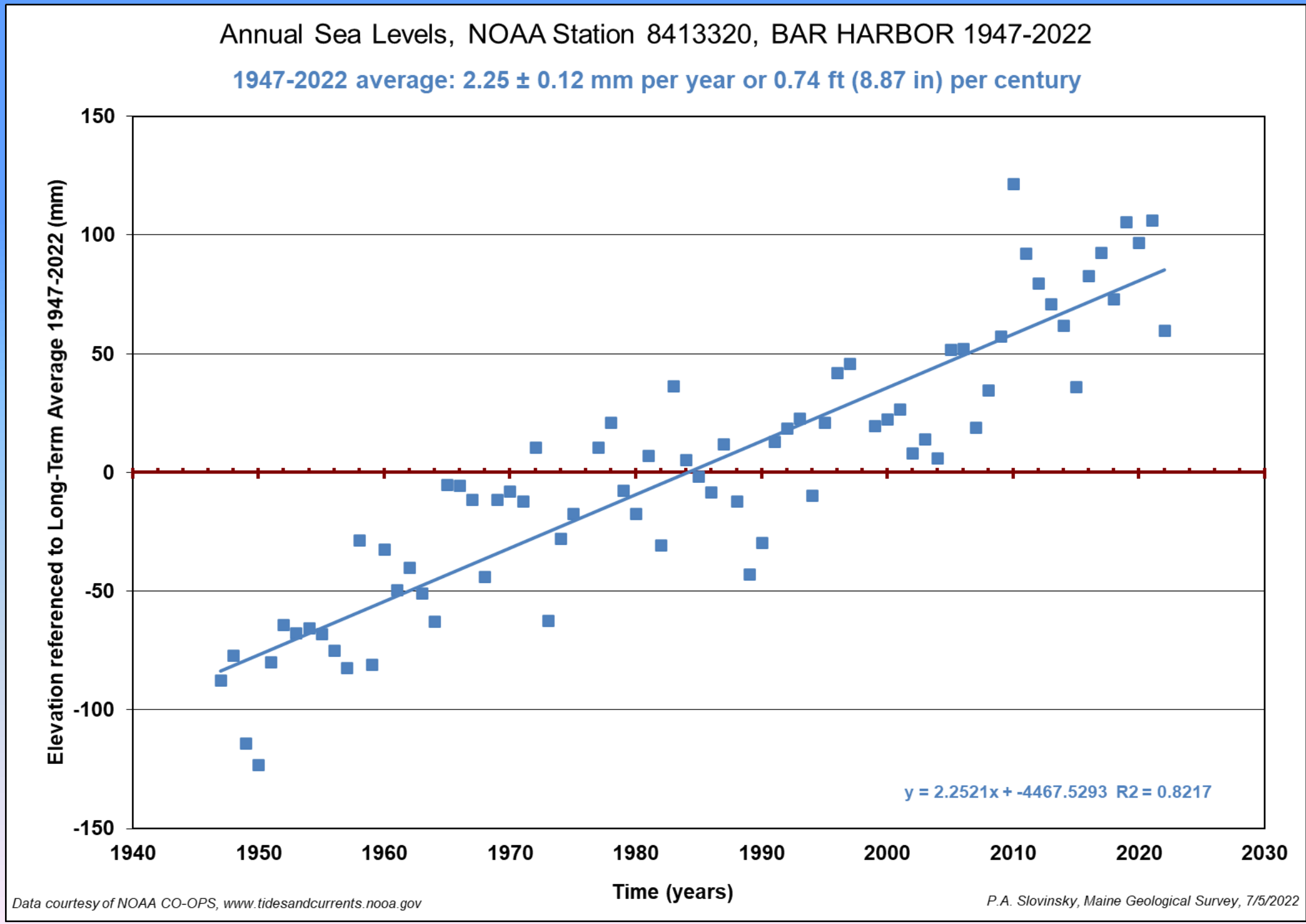
July 6, 2022



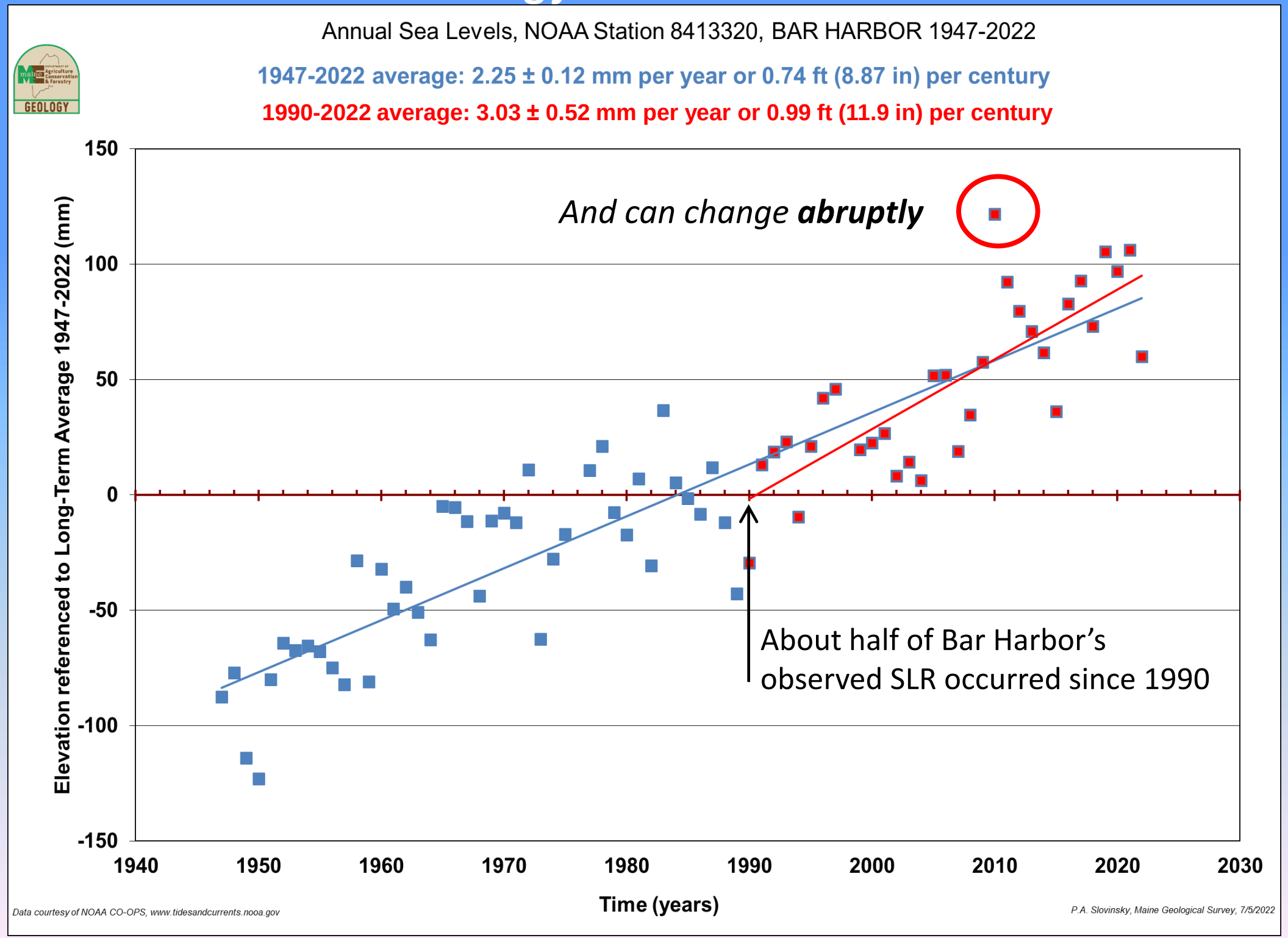
Peter A. Slovinsky, Marine Geologist
Maine Geological Survey
Dept. of Agriculture, Conservation and Forestry

Funding from:

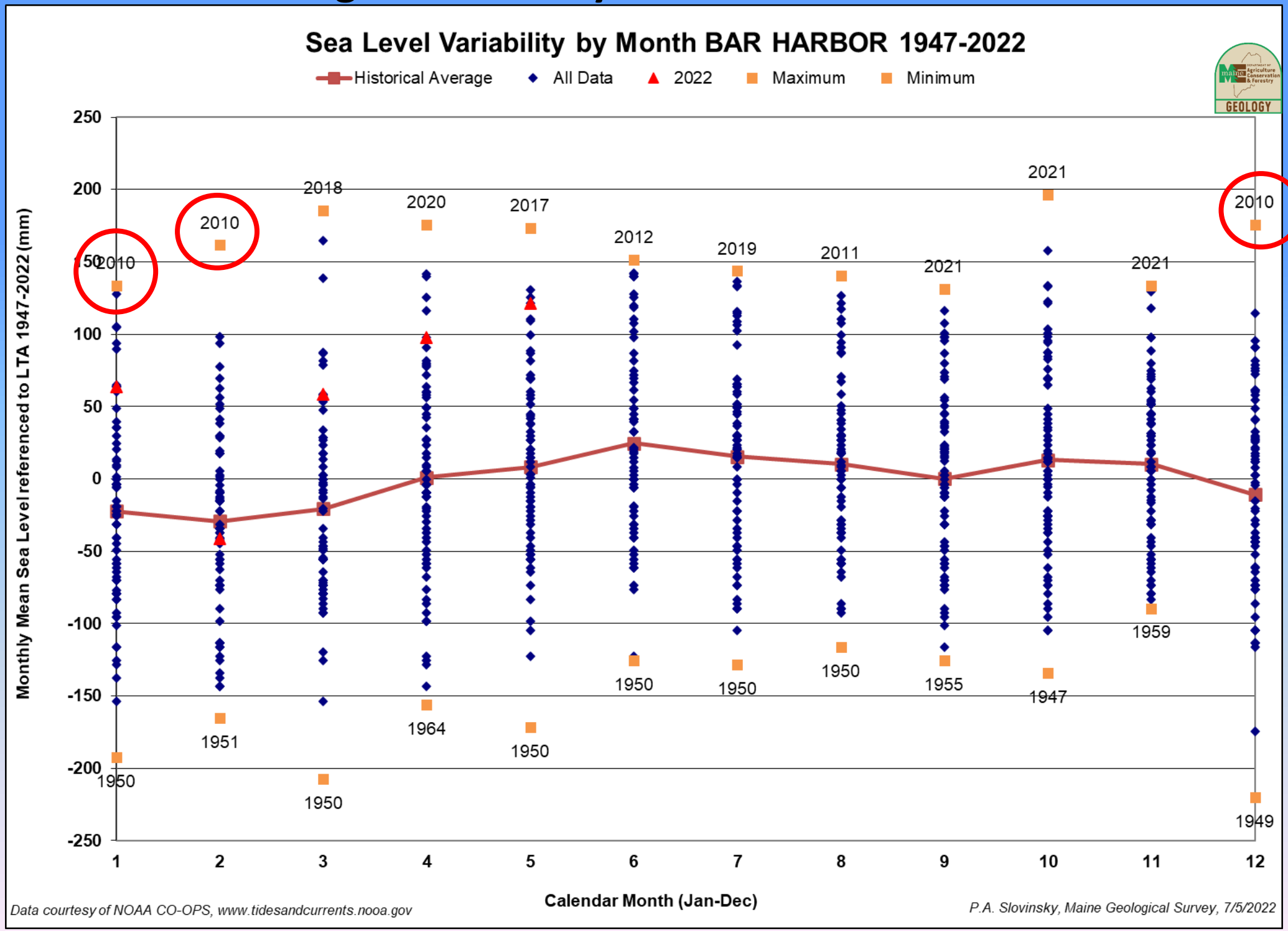
In Maine, sea level is *rising* in the long term…



And is rising *faster* in the short term…



3 of the highest monthly sea levels occurred *in 2010*



In Bar Harbor, 100% of the *highest monthly sea levels* have occurred since 2010, and 58% since 2017.

Month	Highest Average Monthly Sea Levels (through May 2022)					
	Seavey Island	Wells	Portland	Bar Harbor	Cutler	Eastport
	1930-2022*	2005-2022	1912-2022	1947-2022	2011-2022	1929-2022
January	2021	2021	2010	2010	2021	2019
February	1978	2010	2010	2010	2020	2010
March	1958	2018	2010	2018	2018	2018
April	2021	2020	2020	2020	2020	2020
May	2022	2017	2017	2017	2017	2017
June	1998	2012	2012	2012	2018	2011
July	2020	2019	2009	2019	2019	2011
August	2021	2021	2011	2011	2011	2011
September	2021	2021	1996	2021	2021	2010
October	2021	2021	2021	2021	2021	2021
November	2021	2021	1970	2021	2019	2019
December	2020	2012	2010	2010	2019	2010

** Seavey Island, ME tide gauge has data gaps from 1987-1998 and 2001-2019*

Occurred since 2017

Occurred since 2010

STS (2020) Table 1 updated through 5/2022.

Maine Department of Agriculture, Conservation & Forestry GEOLOGY

Four out of five months in 2022 have seen water levels in the top 10 values for each month in Bar Harbor

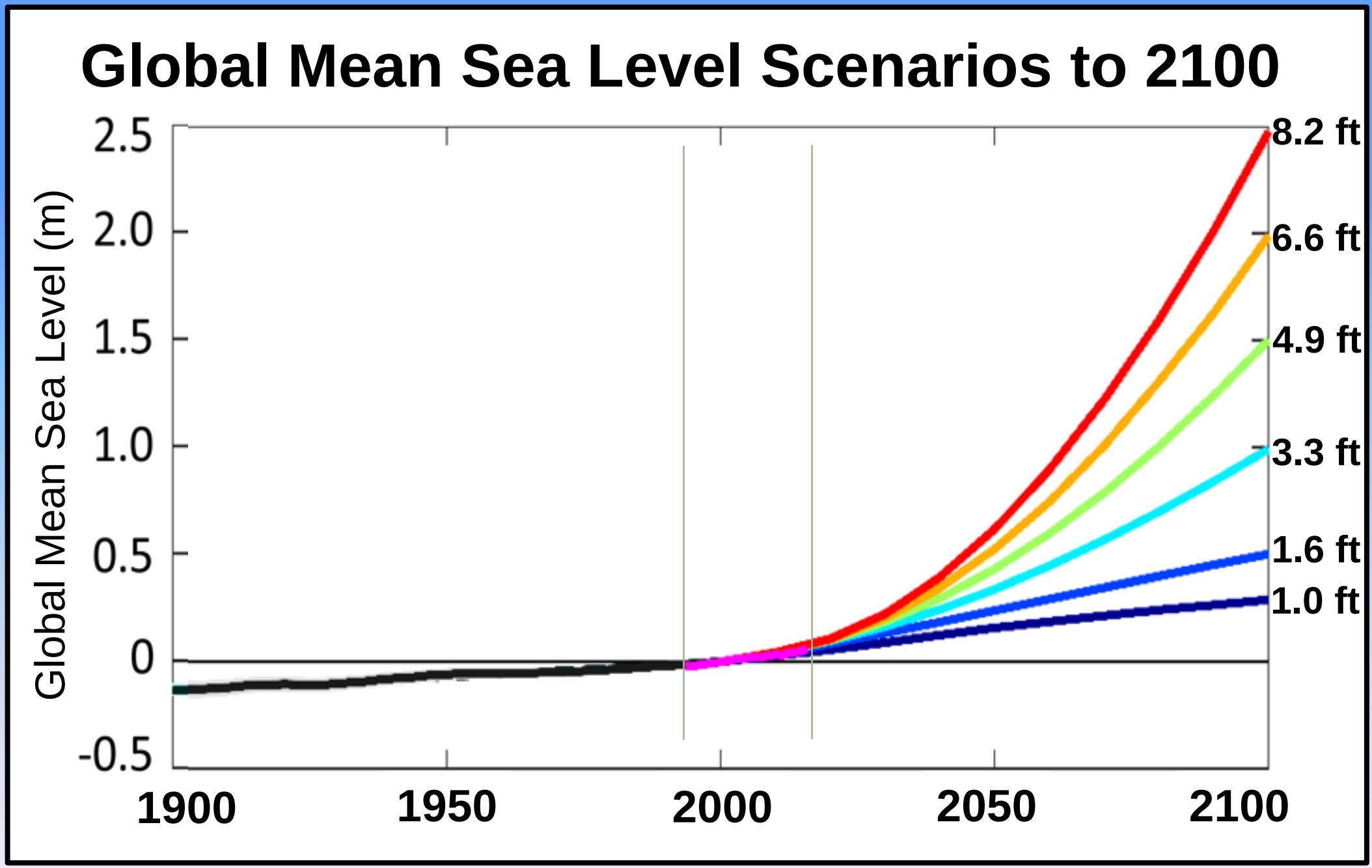
	2022 Tide Gauge Water level Rankings (through May 2022)					
Month	Seavey Island	Wells	Portland	Bar Harbor	Cutler	Eastport
	1930-2022*	2005-2022	1912-2022	1947-2022	2011-2022	1929-2022
January	2nd	5th	10th	10th	5th	4th
February	17th	15th	56th	42nd	10th	35th
March	6th	7th	22nd	8th	4th	6th
April	4th	5th	16th	6th	4th	5th
May	1st	2nd	5th	4th	3rd	4th
June						
July						
August						
September						
October						
November						
December						

** Seavey Island, ME tide gauge has data gaps from 1987-1998 and 2001-2019*

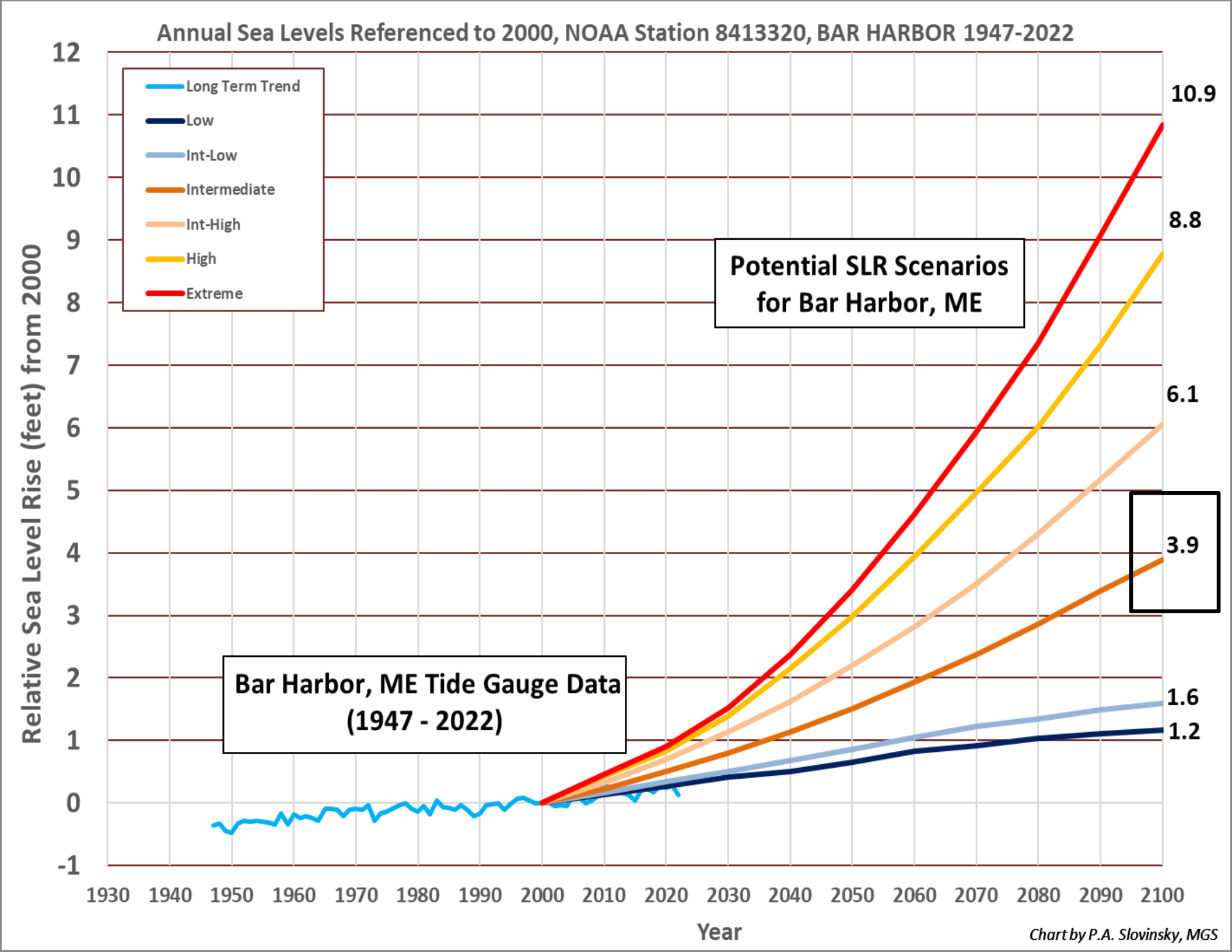
2022 monthly ranking is in the top 5 for that month

2022 monthly ranking is in top 10 for that month

Sea level is expected to *continue to rise...*



Adapted from ***NOAA Technical Report NOS CO-OPS 083, 1/2017***


Annual Sea Levels Referenced to 2000, NOAA Station 8413320, BAR HARBOR 1947-2022
Long Term Trend
Low
Int-Low
Intermediate
Int-High
High
Extreme
Potential SLR Scenarios for Bar Harbor, ME
Bar Harbor, ME Tide Gauge Data (1947 - 2022)
10.9
8.8
6.1
3.9
1.6
1.2
Relative Sea Level Rise (feet) from 2000
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Year
Chart by P.A. Slovinsky, MGS

Recommended Sea Level Rise - Central Estimates for Planning in Maine (averaged for all of Maine's tide gauges)

Planning Scenario	"Commit to Manage"
Year	Intermediate Scenario
2030	0.8
2050	1.5
2070	2.4
2100	3.9

Relative Sea Level Rise (feet) from 2000

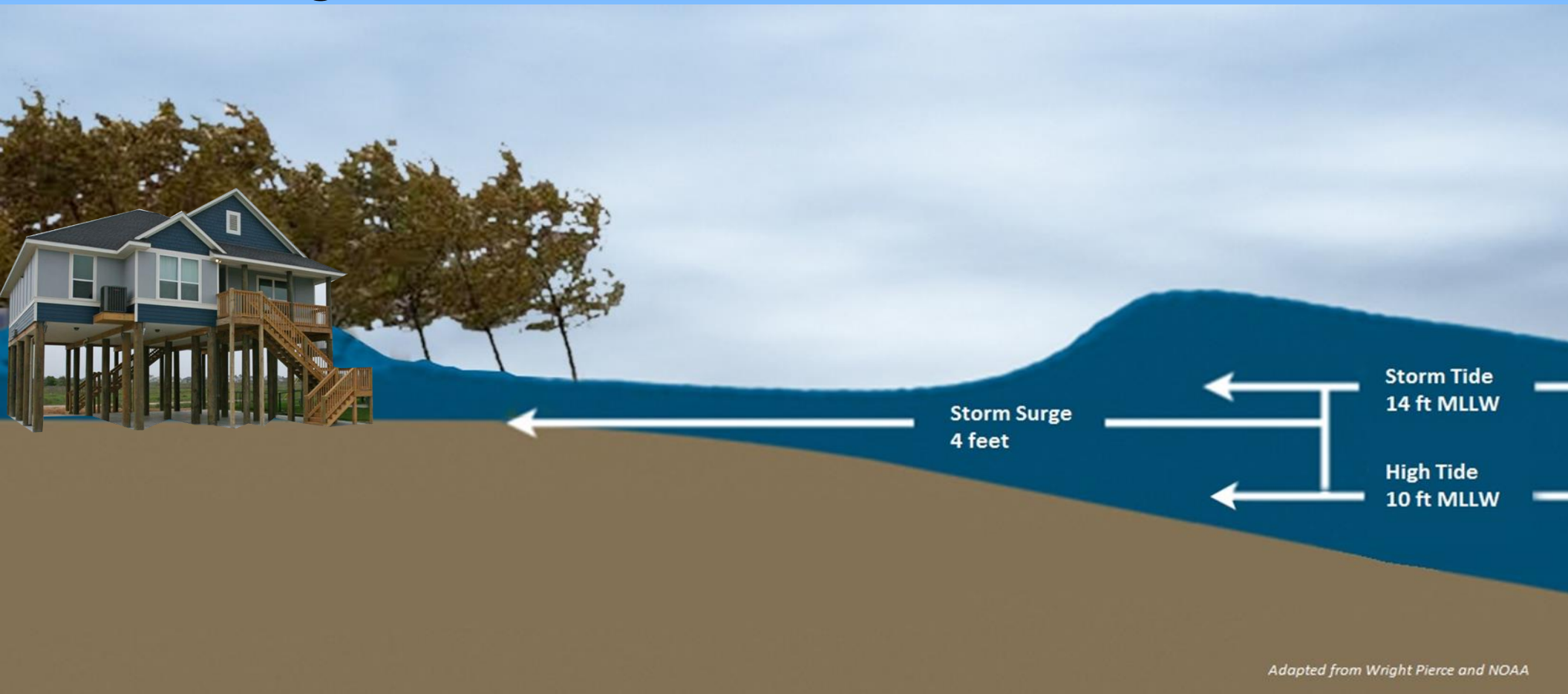
These scenarios were adopted in the State's Maine Won't Wait Report

STS (2020) Table 7b, p. 83.

Sea level rise will exacerbate storm surges and storm tides

Storm surge is an abnormal rise of water generated by a storm, over and above the predicted astronomical tides.

Storm tide is defined as the water level rise due to the **combination of storm surge and the astronomical tide**.

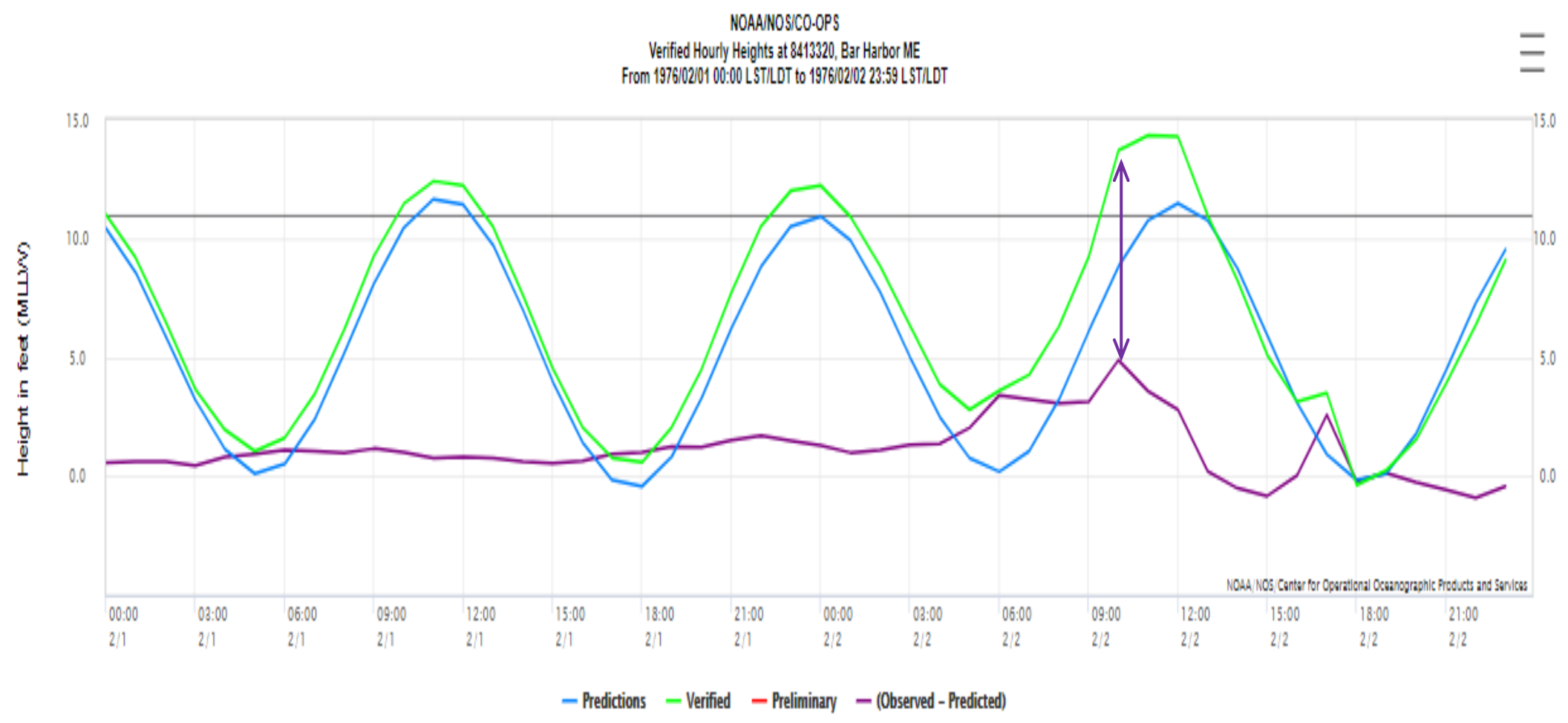


Bar Harbor, ME during 1976 Groundhog Day Storm

Predicted Tide = 8.8 ft MLLW

Storm Tide = 13.7 ft MLLW

Storm Surge = 4.9 ft



Storm Surge Recurrence Intervals* for Maine Tide Gauges

Recurrence Interval	% Annual Chance	Storm Surge (feet)					
		Seavey Isl.	Wells	Portland	Bar Harbor	Cutler	Eastport
		1930-2022	2005-2022	1912-2022	1947-2022	2011-2022	1929-2022
1	100%	1.8	2.1	2.0	1.8	2.1	2.0
5	20%	2.7	3.6	2.9	2.8	2.8	2.9
10	10%	3.1	4.3	3.3	3.2	3.1	3.3
25	4%	3.7	5.2	3.9	3.8	3.5	3.9
50	2%	4.1	5.8	4.3	4.3	3.8	4.2
100	1%	4.5	6.5	4.7	4.7	4.1	4.6

For Maine's coastline, there is a 10% chance we can see about 3 feet of storm surge every year, and a 1% chance of seeing storm surges in excess of 4.5 feet.

MCC STS (2020) Table 8, updated 7/5022

** Determined from best-fit equations to available NOAA CO-OPs data through 7/5/2022*

Storm Tide Recurrence Intervals for Maine Tide Gauges

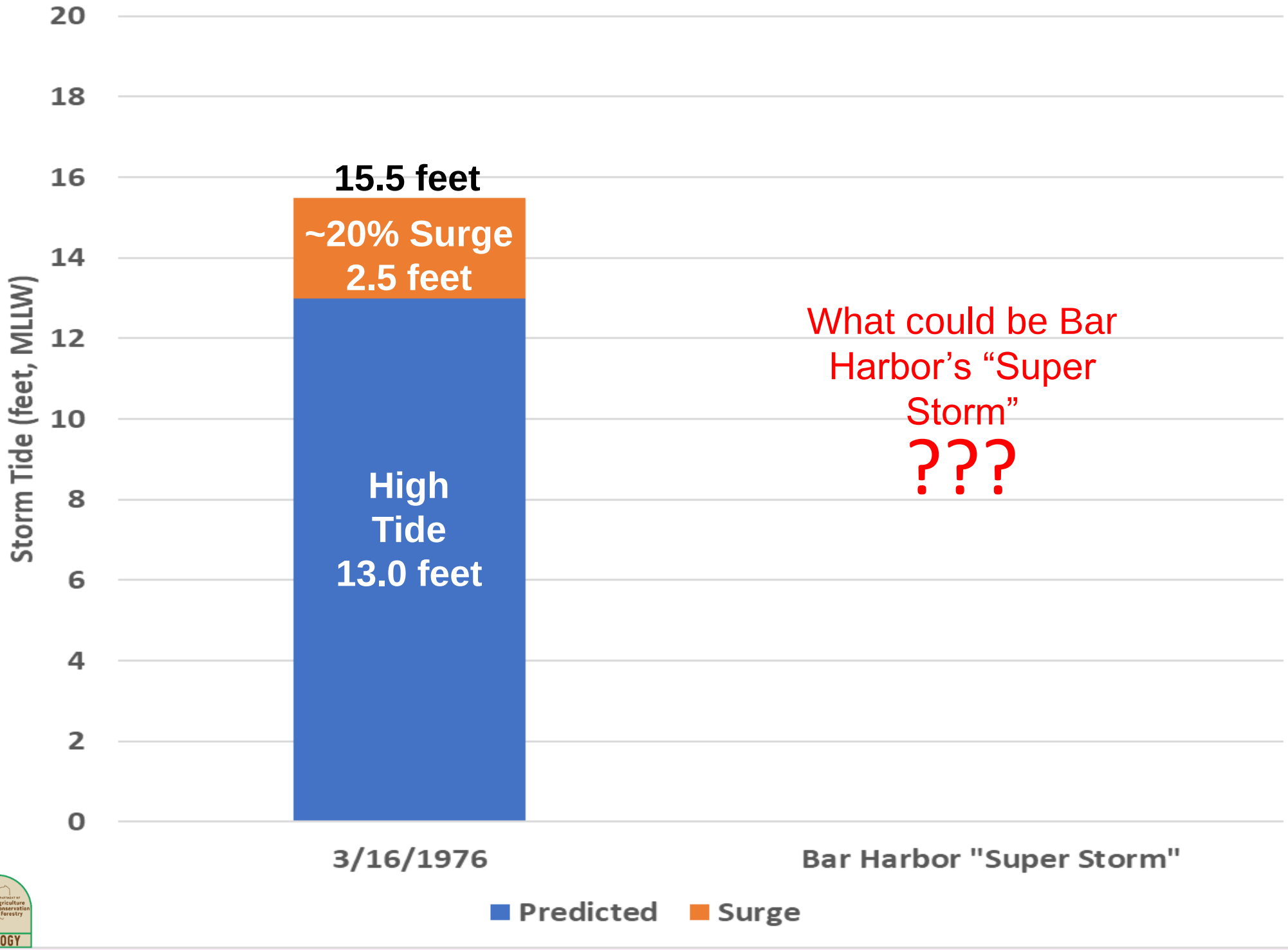
Recurrence Interval	% Annual Chance	Storm Tide (feet, MLLW)					
		Seavey Isl.	Wells	Portland	Bar Harbor	Cutler	Eastport
		1930-2022	2005-2021	1912-2021	1947-2021	2011-2021	1929-2021
1	100%	10.5	11.6	11.7	13.4	17.5	22.1
5	20%	11.4	12.6	12.6	14.2	18.3	23.0
10	10%	11.8	13.1	12.9	14.6	18.6	23.4
25	4%	12.3	13.7	13.4	15.1	19.1	23.9
50	2%	12.7	14.1	13.7	15.4	19.5	24.3
100	1%	13.1	14.6	14.1	15.8	19.8	24.7

For Maine's coastline, there is *only about a 1 – 1.5 foot difference between our 10 and 100-year storm tides*

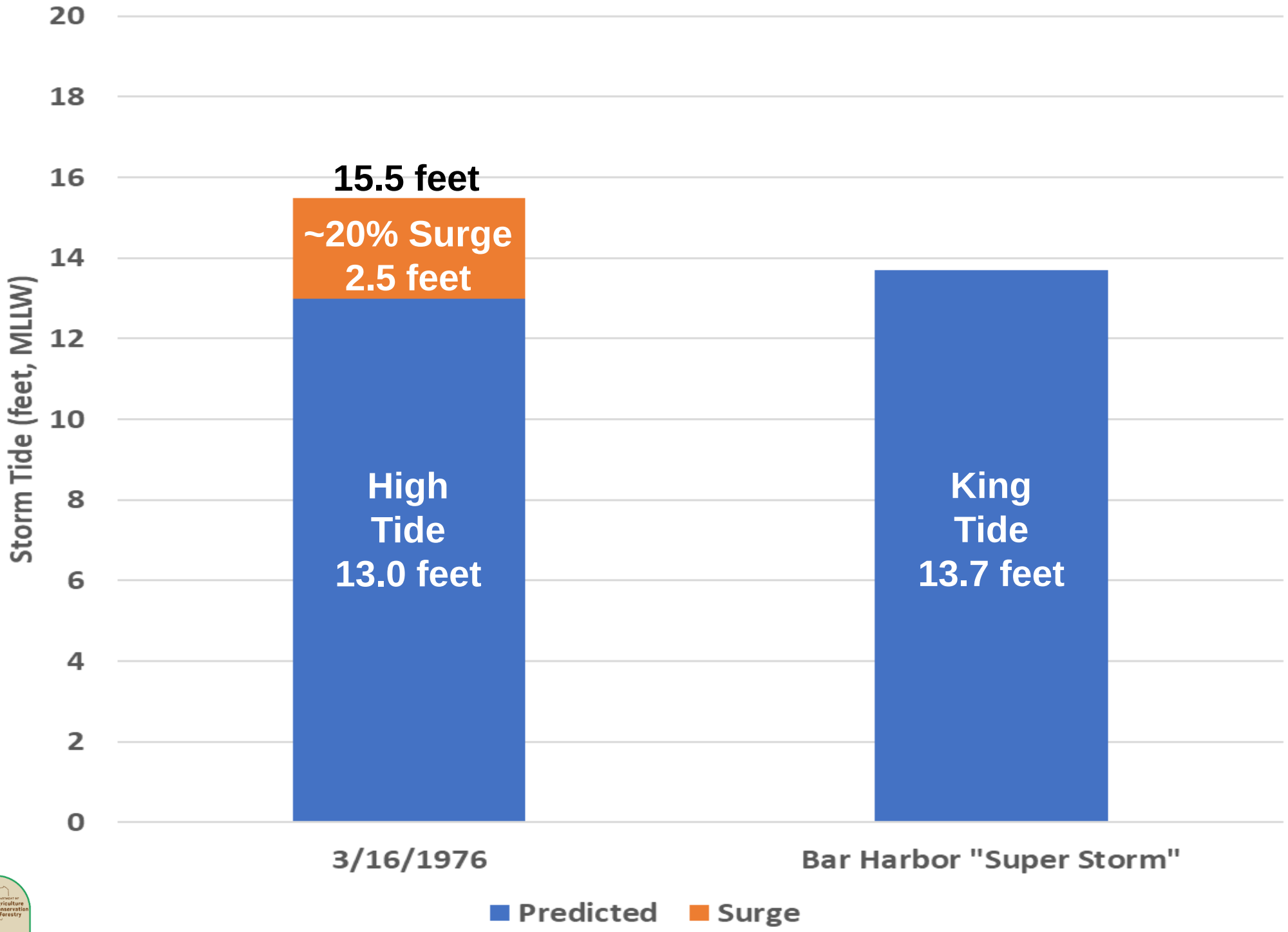
STS (2020) Table 9, updated 7/5/2022

** Determined **from best-fit equations** to available NOAA CO-OPs data through 7//52022*

Bar Harbor's Highest Water Level – March 16, 1976



Bar Harbor's Super Storm?



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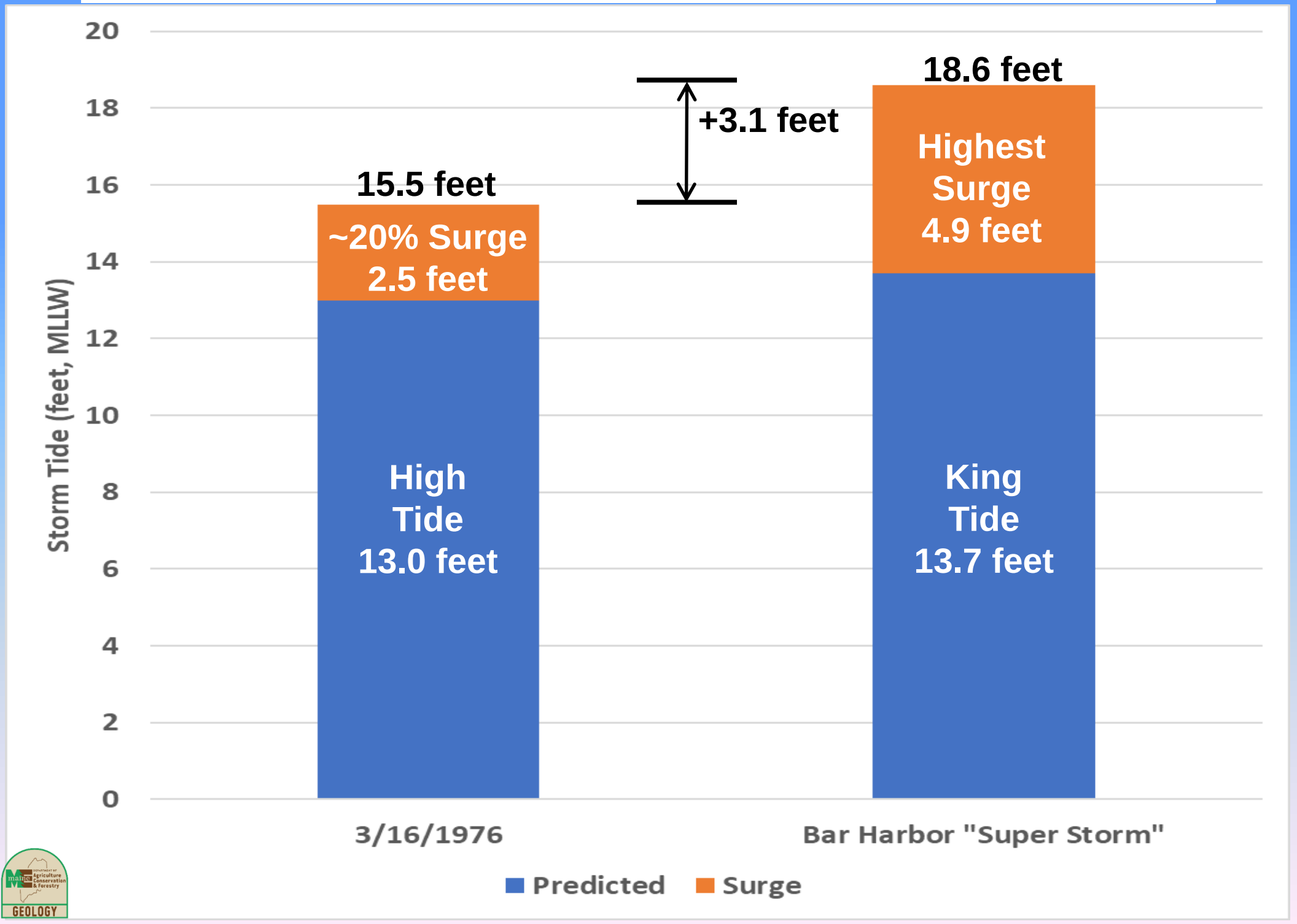
Bar Harbor's Super Storm?



"Nuisance" flooding along Maine's coast **is increasing**. Sea level rise is significantly increasing the ***frequency and duration*** of nuisance flooding.

Portland, ME Nuisance Flooding Historical Averages

1912-2022 = 3.8 hours/year

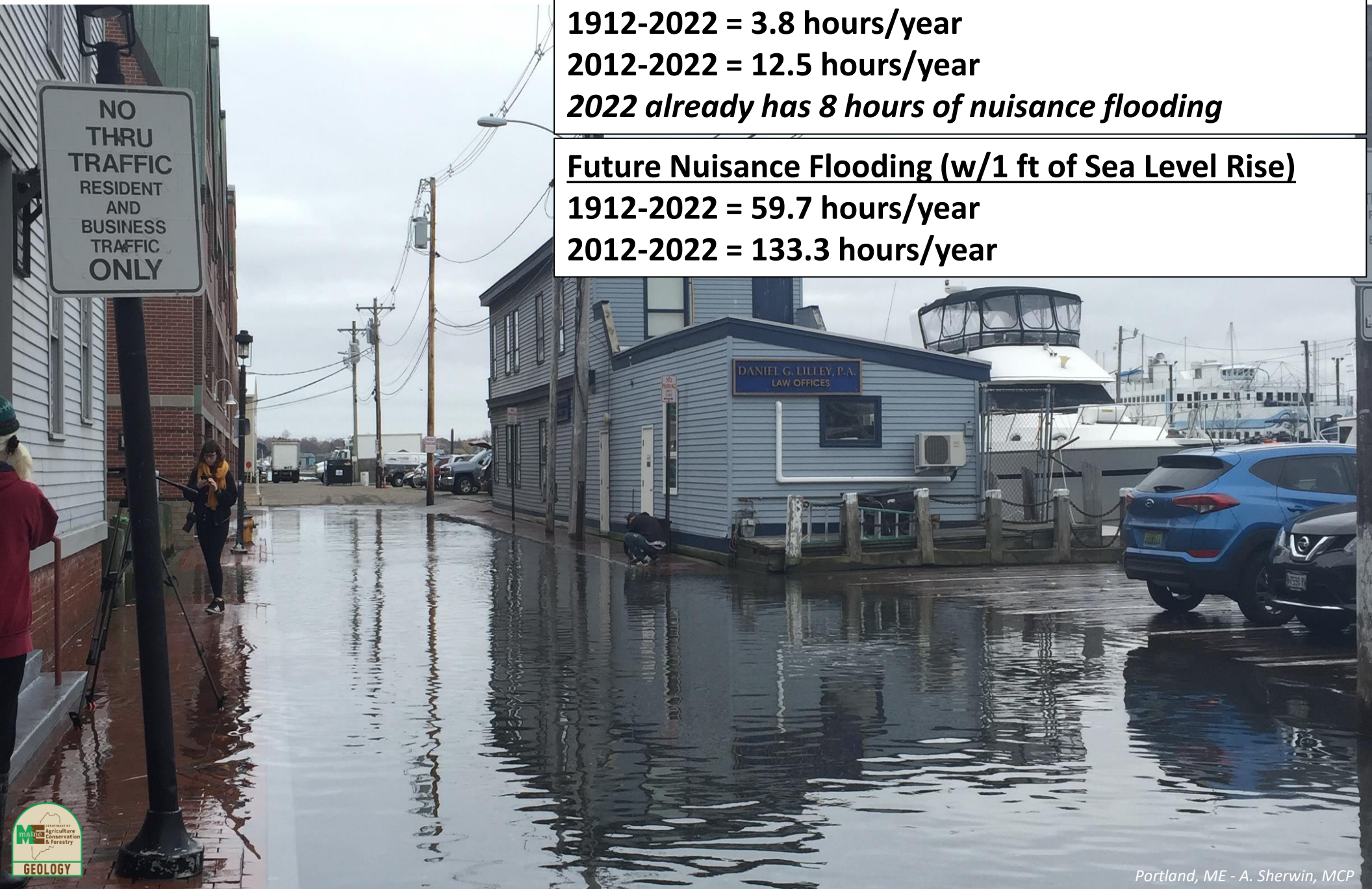
2012-2022 = 12.5 hours/year

2022 already has 8 hours of nuisance flooding

Future Nuisance Flooding (w/1 ft of Sea Level Rise)

1912-2022 = 59.7 hours/year

2012-2022 = 133.3 hours/year



Portland, ME - A. Sherwin, MCP

Currently, there are ***less than 20 miles*** of private and public roads at-risk to monthly tidal flooding

Deer Isle Causeway, Jack Sullivan, Island Institute

With 3.9 feet of SLR, over ***115 miles of roads**** could be at-risk during higher tides, especially impacting peninsular and island communities

**ERG (2020), p. 40*

In coastal Maine municipalities, ***there are 10 WWTPs mapped in the current*** 1% FEMA SFHA.

With 1.6 feet of SLR on top of the 1% floodplain, 6 of these might be **permanently inundated** by 2050 costing between **$31-$91M to replace***. Belfast's WWTP *is just on the edge.*

*Maine Won't Wait (2020)

Compounding normal **coastal flooding** are **greater intensity precipitation events**, which can lead to more common *flood events of greater magnitude.*

Route 1/Waldo Avenue, Belfast
6 inches of rain in 5 hours (a 500-year event)
on October 31, 2021

Eric Sanders/PenBayPilot

Sea level rise is causing **more frequent marsh inundation**, **loss of marsh** (conversion to open water), **conversion of dominant marsh types**, and **increased stress** to threatened species. Shoreline armoring also inhibits landward migration of marshes.

RCWF Marsh, Saco - P. Slovinsky, MGS

48% of the Maine coast is made up of erodible coastal bluffs and 1/3 are eroding and are being **armored at high rates**. *These features supply most of the sediment to nearby mudflats and fringe wetlands.*

Bunganuc Bluff, Brunswick, ME, Walsh Engineering

Sea Level Rise and Storm Summaries

- About **half of the last century's observed sea level rise occurred since the early 1990s.**

- **Abrupt short-term sea level** changes do occur **and can significantly influence beach and bluff erosion.**

- **A 1-foot rise in sea level** will lead to a **10 to 15-fold increase in nuisance flooding** along low-lying areas in Maine.

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Sea Level Rise and Storm Summaries

- A **1-foot rise in sea level** will lead to a 10-year storm having the impact of a 100-year event, or a 100-year event having a 10-year recurrence interval.

- The state has decided to ***commit to manage*** for a **higher probability, lower risk scenario:**
  - **Intermediate scenario = 1.5 feet (2050) and 4 feet (2100).**

- **Sea level will *continue to rise beyond 2100.***

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Coastal Hazards and Adaptation

The general process of coastal hazard adaptation:

- Understand the types of coastal hazard(s) that may impact your property and their extent;
- Understand the level of risk for your property to said hazard(s);
- Determine a level of risk acceptable to you and given your expectations of the property;
- Select appropriate adaptation strategies.

Maine Coastal Property Owner's Guide to Erosion, Flooding, and Other Hazards, 2nd edition

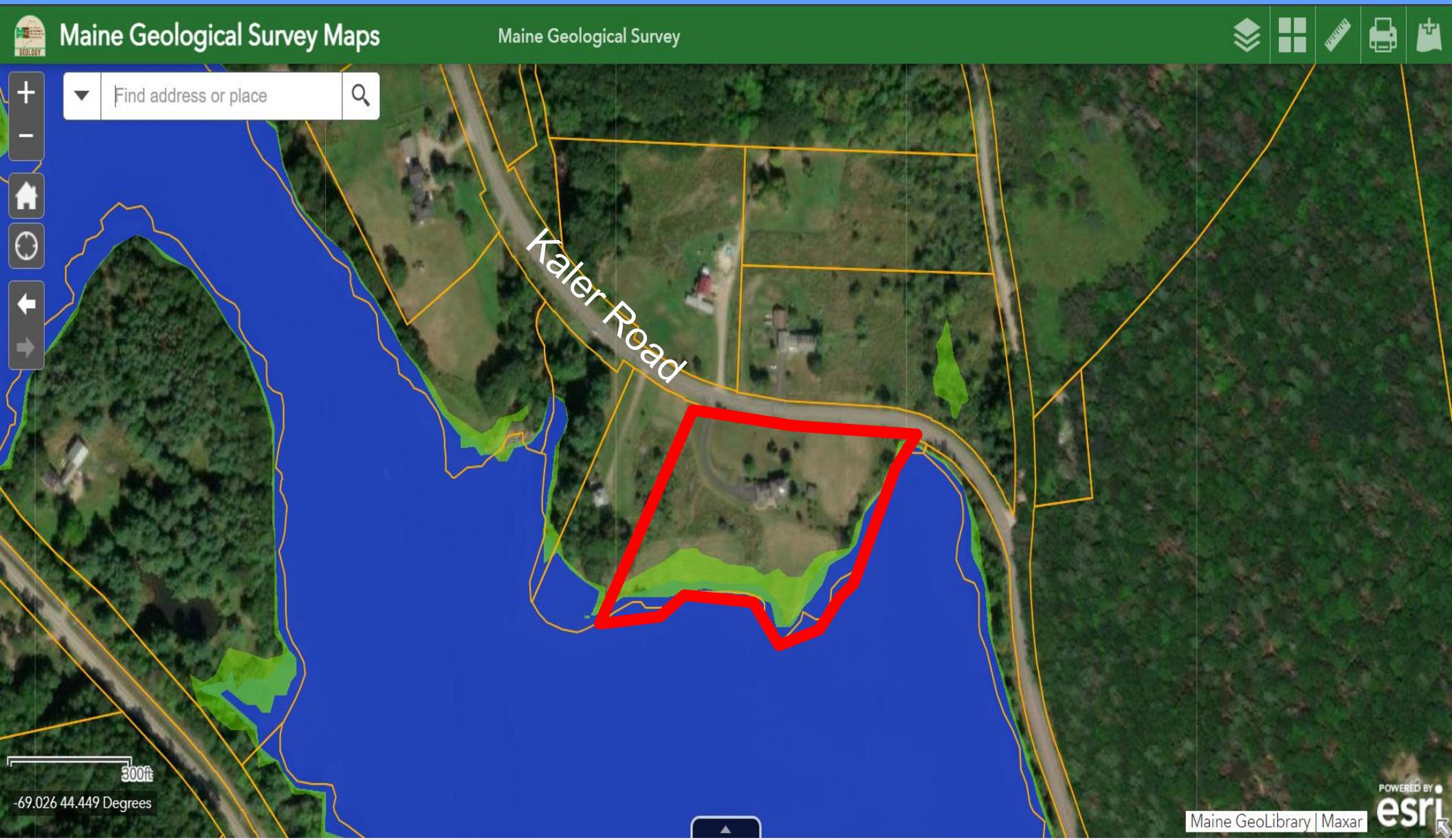
Responding to Storms and Sea Level Rise

There are <u>really only 5 options</u>:

1) Do Nothing
2) Avoid
3) Accommodate/Adapt
4) Protect
5) Relocate

Saco, ME, P. Slovinsky, MGS

Do Nothing – given the extent of the hazard, land use type, your level of risk and expected use of the property, the do-nothing option may make the most sense.



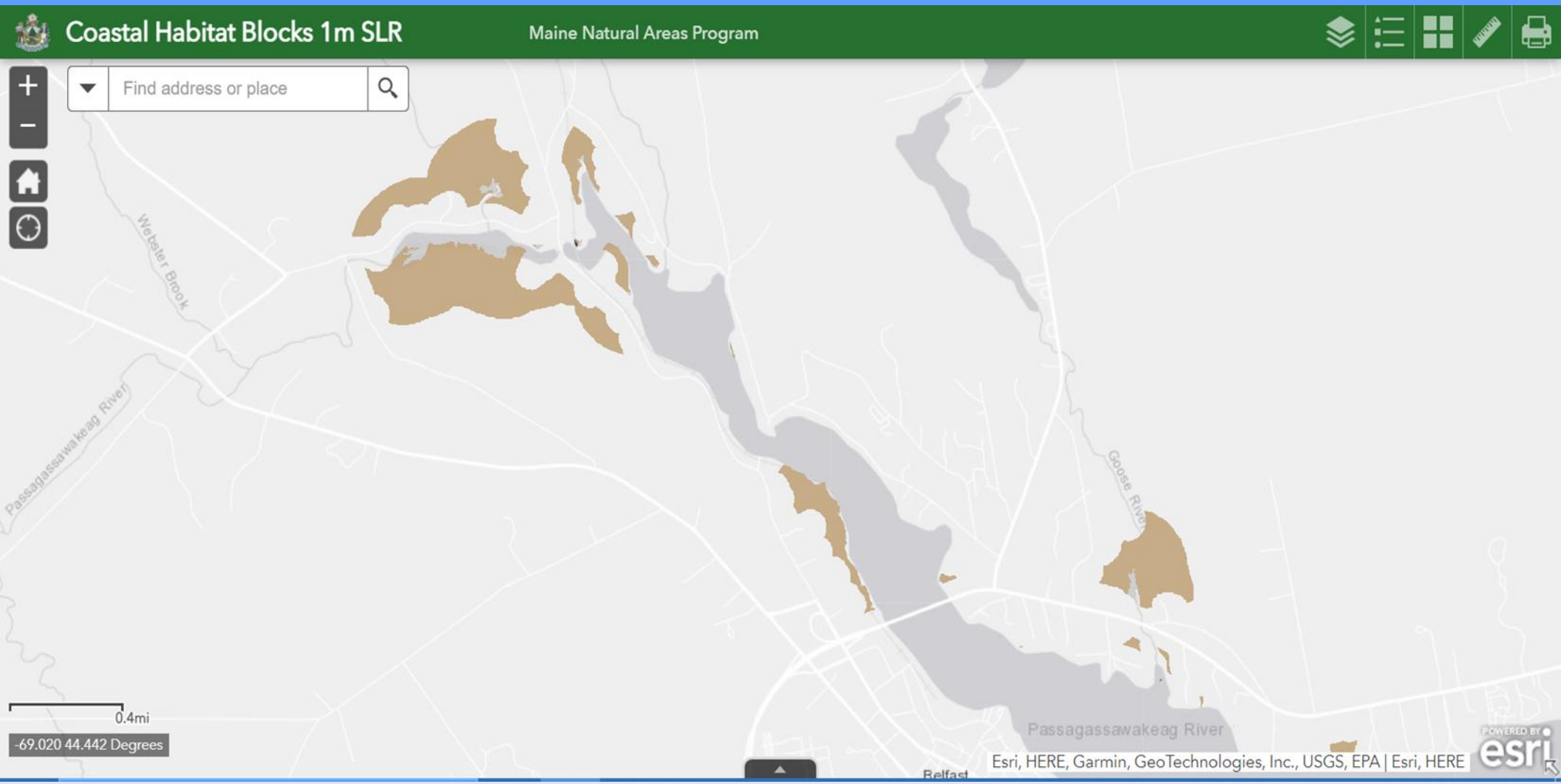
https://maine.maps.arcgis.com/apps/webappviewer/index.html?id=f52e6fa4f79b46a48203ad07cd55a9d7

Avoid - Use hazard data and regulatory and land conservation mechanisms (existing and new) *to avoid new development or limit redevelopment in high-hazard coastal areas*

National Flood Hazard Layer (NFHL)

https://maine.maps.arcgis.com/apps/webappviewer/index.html?id=f52e6fa4f79b46a48203ad07cd55a9d7

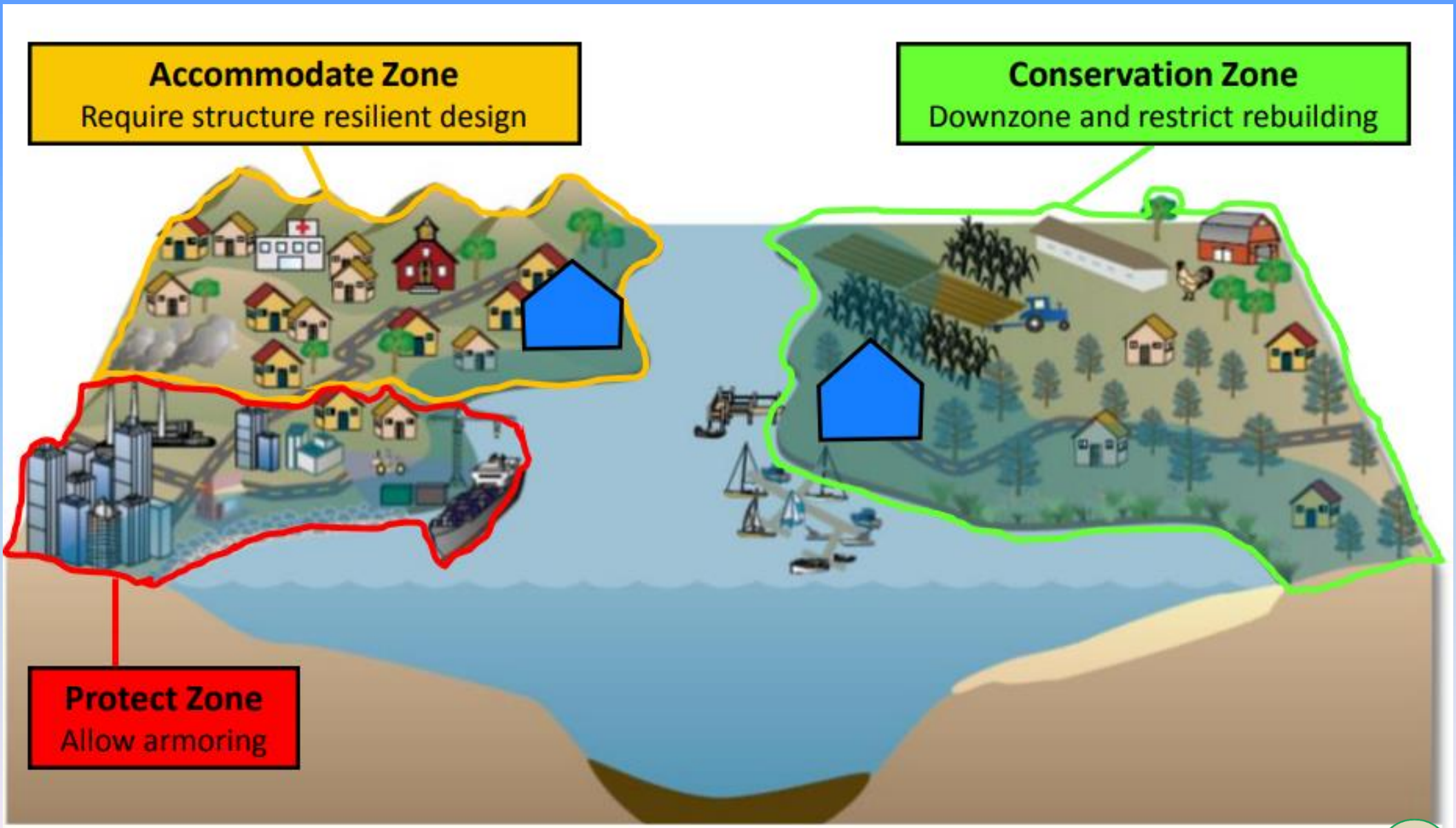
Avoid - Use hazard data and regulatory and land conservation mechanisms (existing and new) *to avoid new development or limit redevelopment in high-hazard coastal areas*



Coastal Undeveloped Blocks

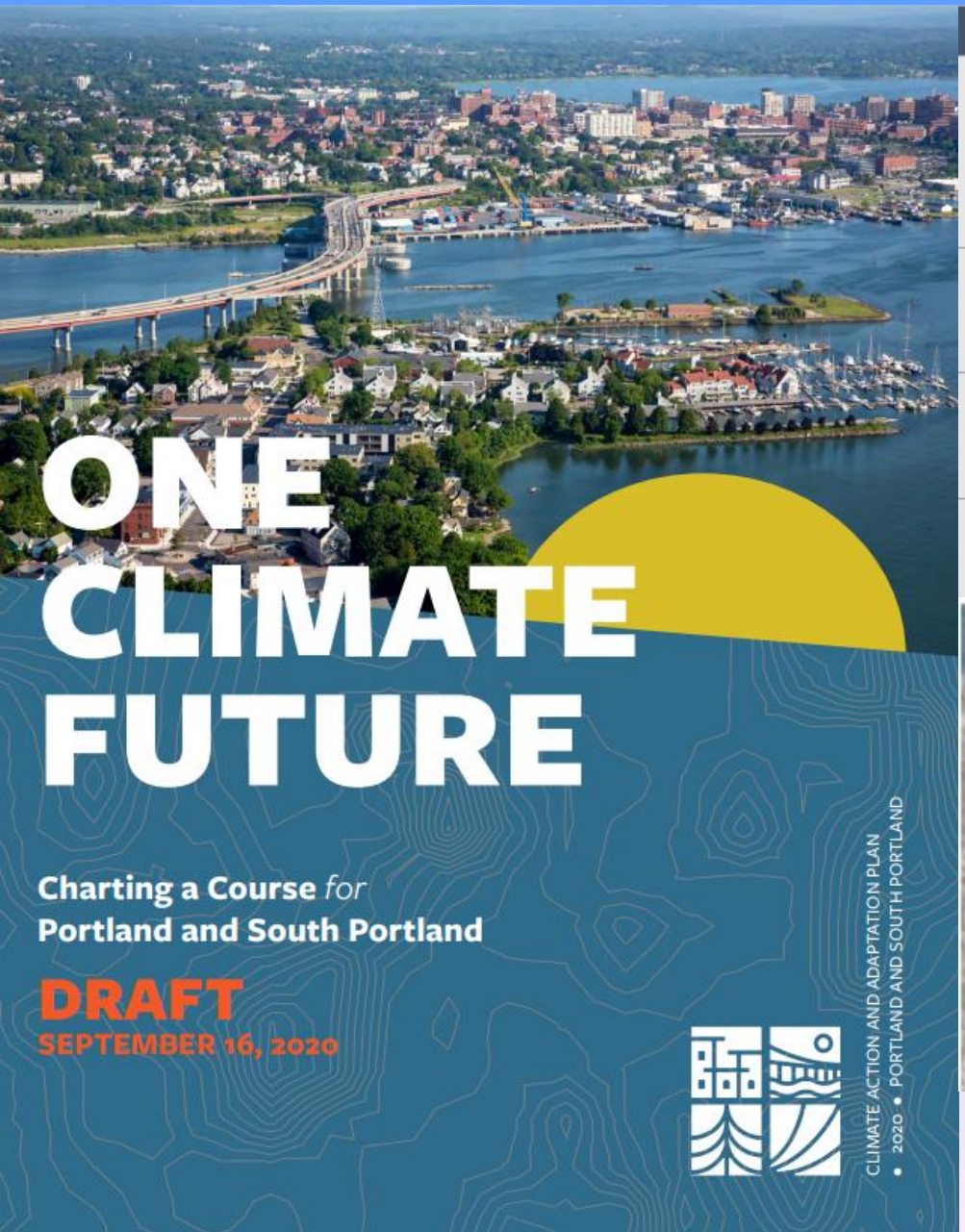
https://www.maine.gov/dacf/mnap/assistance/coastal_blocks_1m_slr.htm

Adapt - Consider the use of Coastal Hazard Overlay Zones to conserve land and *adapt development coastal areas*



Graphic courtesy of the Integration and Application Network, University of Maryland Center for Environmental Science (ian.umces.edu/symbols/).

Adapt – Consider the use of Coastal Hazard Overlay Zones to conserve land and *adapt development coastal areas*



Resilience Overlay	Basis of Boundary	Zoning Parameters
Tier 1: Highest Flood Risk	Future high tide (no storm) conditions in 2100 under the Intermediate sea level rise scenario	• Land use decisions prioritize the preservation and creation of natural spaces (based on hierarchy of land use) • Restrictions on the development of incompatible, vulnerable, or hazardous uses • All development (compatible uses) shall meet resilient building requirements
Tier 2: High Flood Risk	Future 1% annual chance storm in 2100 with the Intermediate sea level rise scenario	• All development (or all development requiring development review) shall meet resilient building requirements
Tier 3: Moderate Flood Risk	Future 0.2% annual chance storm in 2100 with the Intermediate sea level rise scenario	• Development is encouraged to consider resilient building parameters as part of a broader suite of resilience considerations in the whole-city overlay
Tier 4: Whole-City Overlay	Entire city	• Development is either required or incentivized to meet specific point requirements for stormwater retention and cooling capacity

https://www.oneclimatefuture.org/wp-content/uploads/2021/02/Appendix-C.pdf

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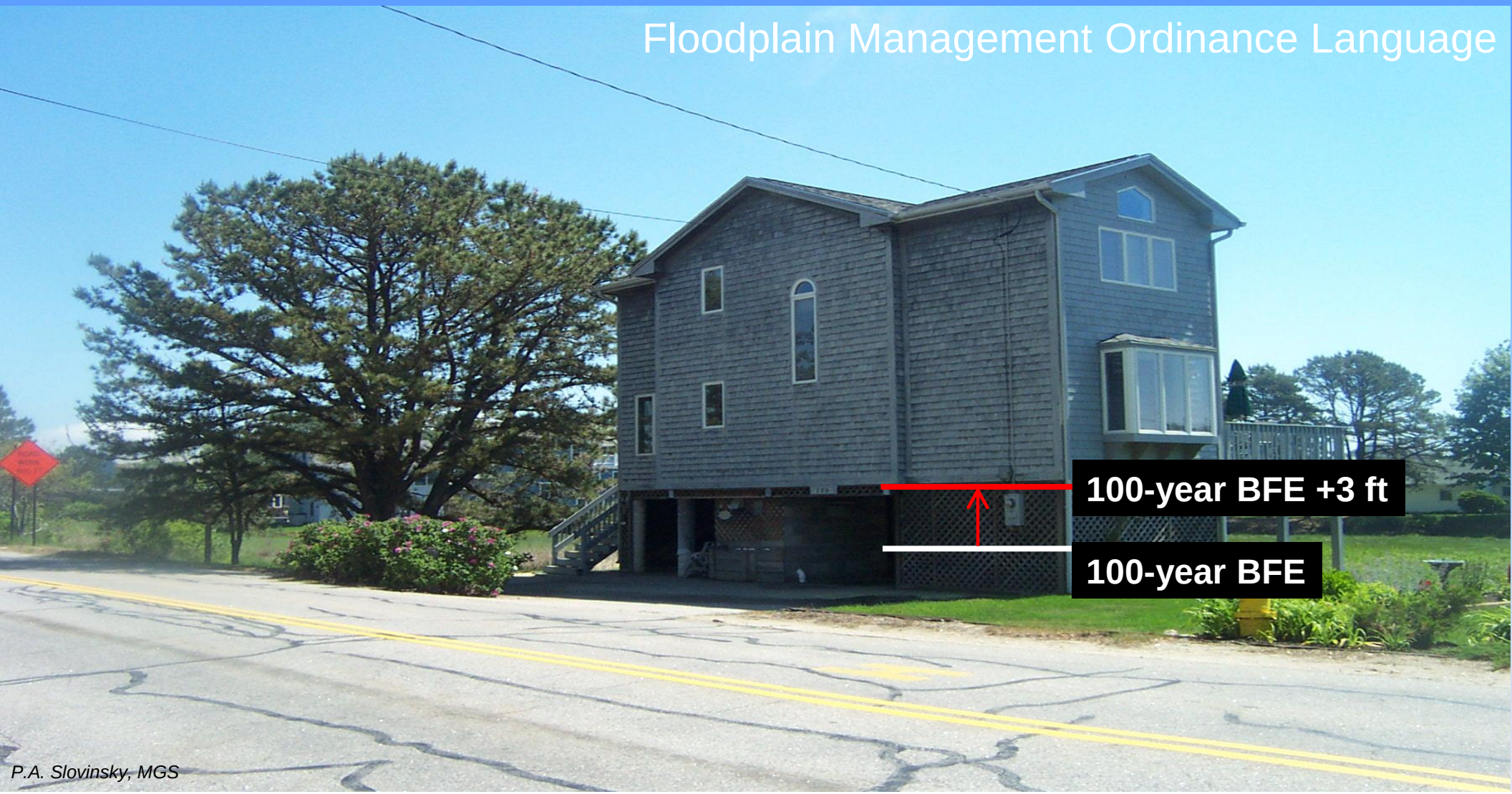
Adapt - Use hazard data and regulatory and land conservation mechanisms (existing and new) *to adapt development in high-hazard coastal areas*

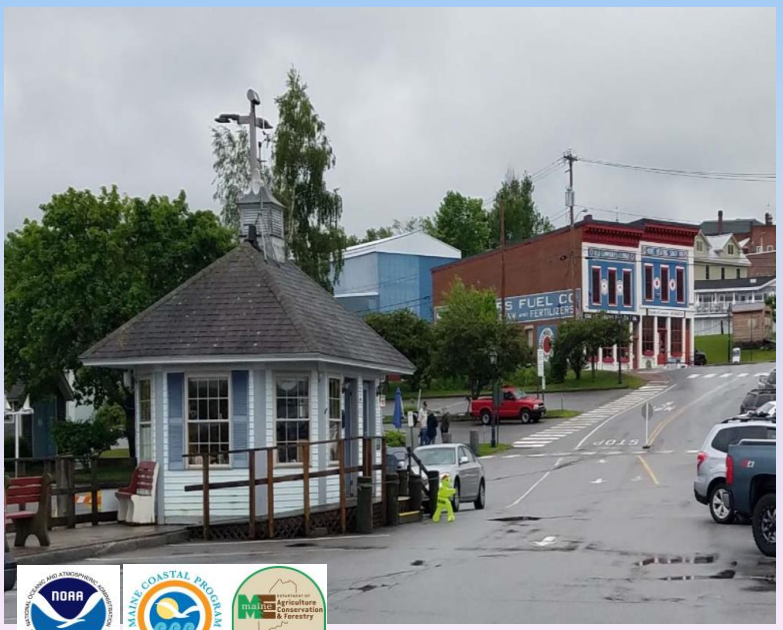


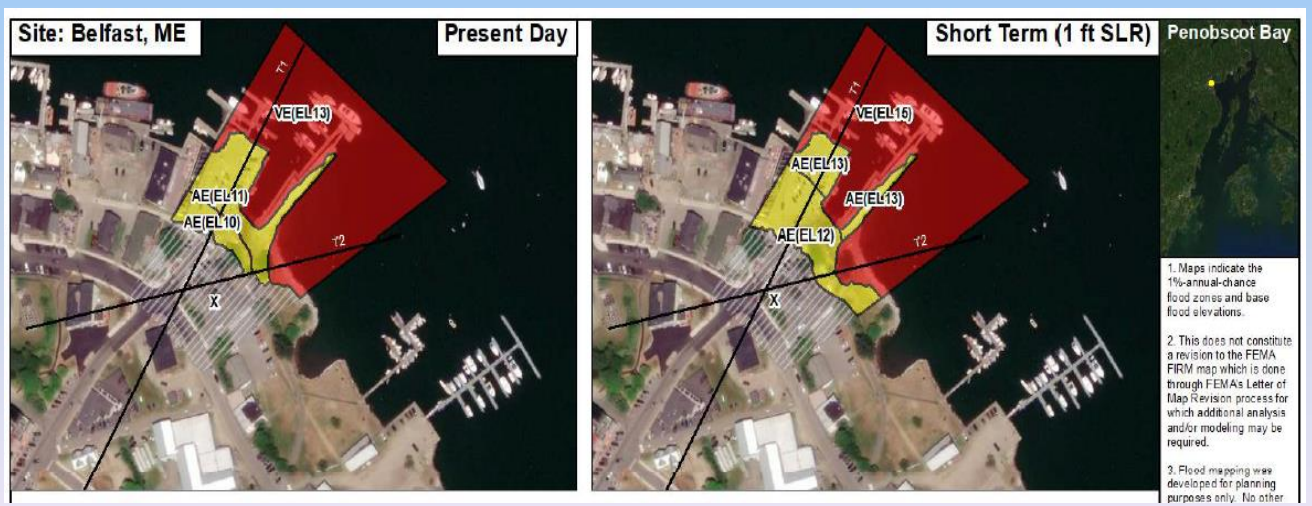
Some communities have increased ordinances to require <u>three feet above the 100-year BFE</u>.

Adapt – Adapt critical coastal water-based infrastructure using transferable vulnerability and adaptation assessment methods.

Penobscot Bay Working Waterfront Study – Public Landing, Belfast

Facility			Inundation above Elevation of Facility															
Description			Present Day				Short Term Scenario				Mid Term Scenario				Long Term Scenario			
			MHHW	HAT	1% Stillwater	BFE	MHHW	HAT	1% Stillwater	BFE	MHHW	HAT	1% Stillwater	BFE	MHHW	HAT	1% Stillwater	BFE
	Elevation (ft) to NAVD88		[ft]	[ft]	[ft]	[ft]	[ft]	[ft]	[ft]	[ft]	[ft]	[ft]	[ft]	[ft]	[ft]	[ft]	[ft]	[ft]
Harbor Master's Office	Adjacent Grade	8.97 ft			0.73	2			1.73	4.03		0.53	2.73	5.03	0.23	2.53	4.73	8.53
	Lowest Horizontal	10.01 ft				1			0.69	2.99			1.69	3.99		1.49	3.69	7.49
	Lowest Opening	10.3 ft				0.7			0.4	2.7			1.4	3.7		1.2	3.4	7.2

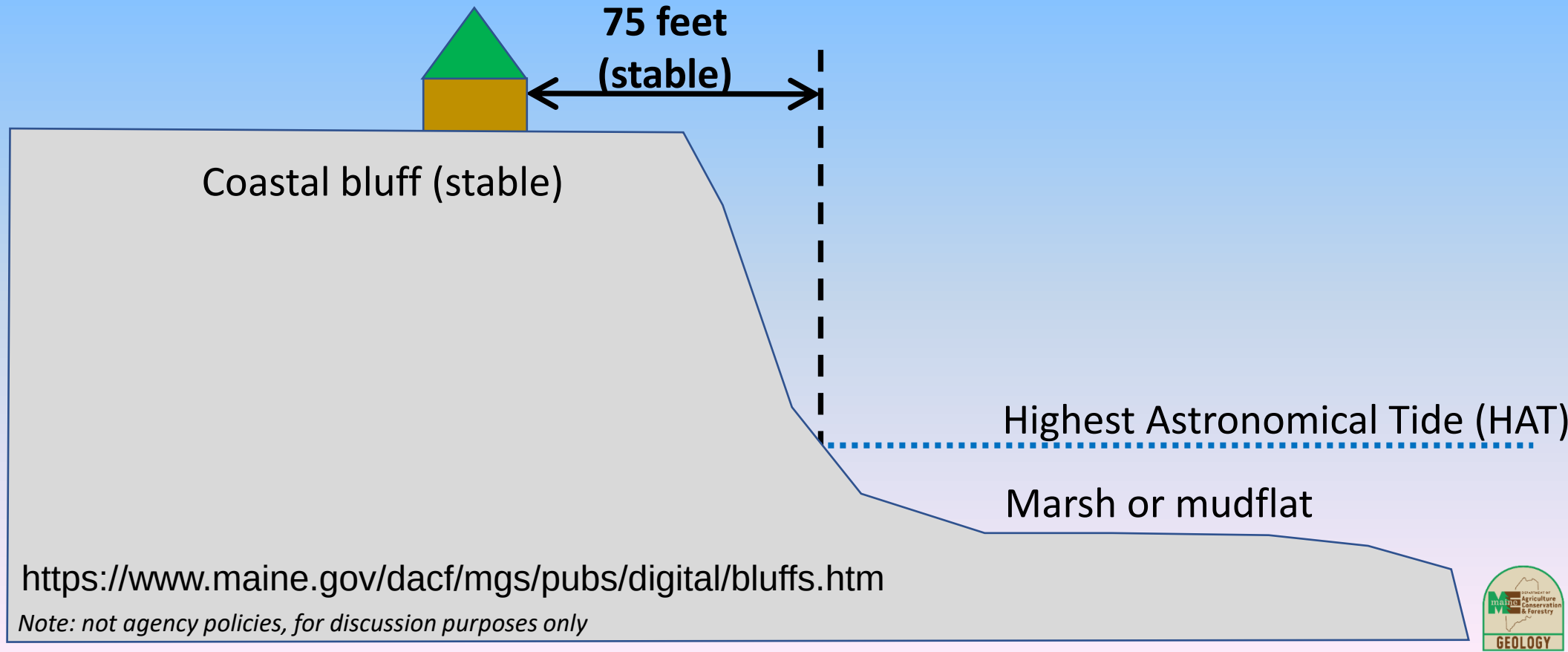




https://www.maine.gov/dmr/mcp/news/

Avoid/Adapt - Use hazard data and regulatory and mechanisms (existing and new) *to adapt development in high-hazard coastal areas – Coastal Bluffs and Shoreland Zoning and MGS Coastal Bluff Maps.*

Currently, minimum setbacks for ***stable bluffs are 75 feet from the highest astronomical tide.***

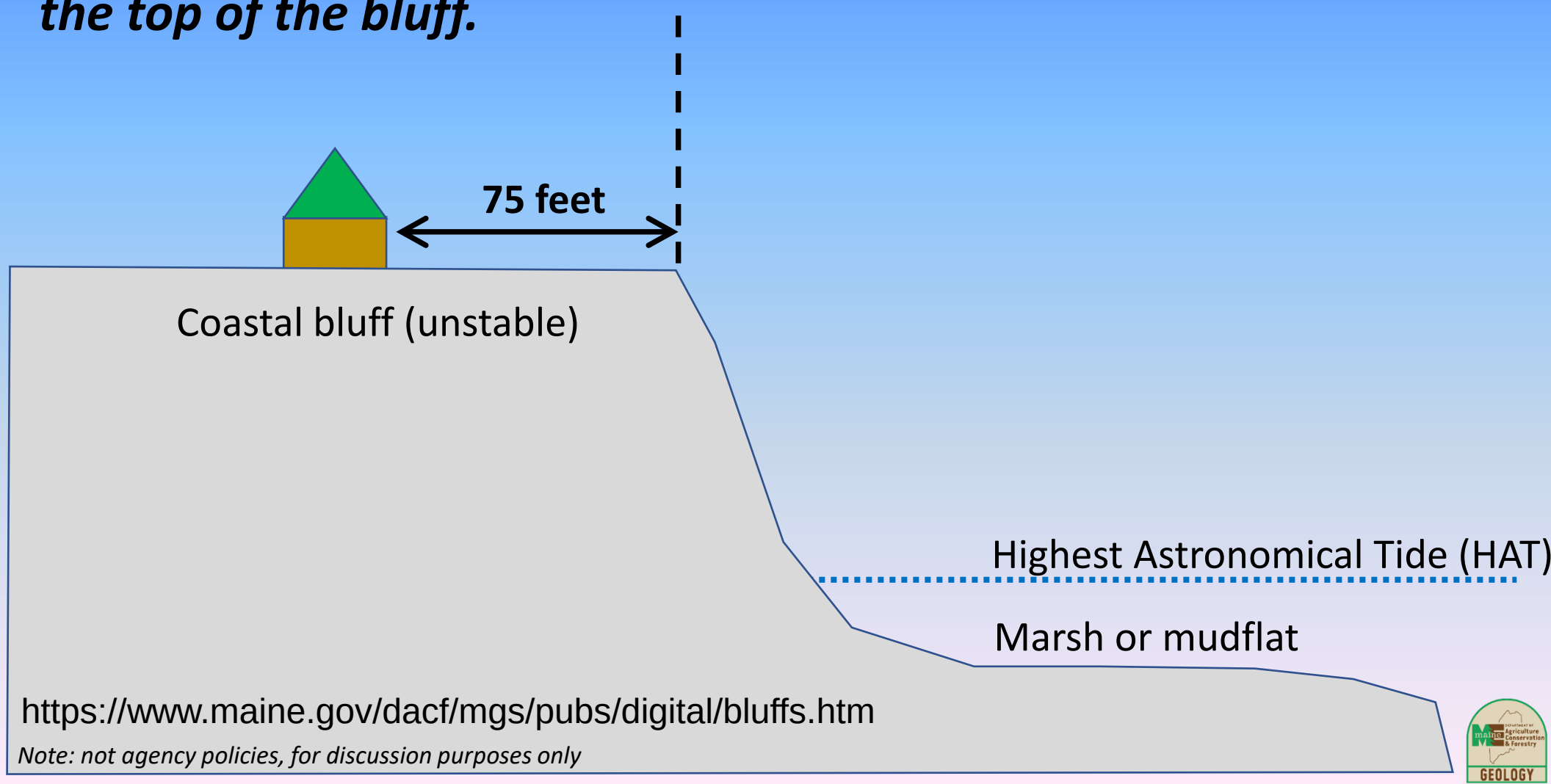


https://www.maine.gov/dacf/mgs/pubs/digital/bluffs.htm

Note: not agency policies, for discussion purposes only

Avoid/Adapt - Use hazard data and regulatory and mechanisms (existing and new) *to adapt development in high-hazard coastal areas – Coastal Bluffs and Shoreland Zoning and MGS Coastal Bluff Maps.*

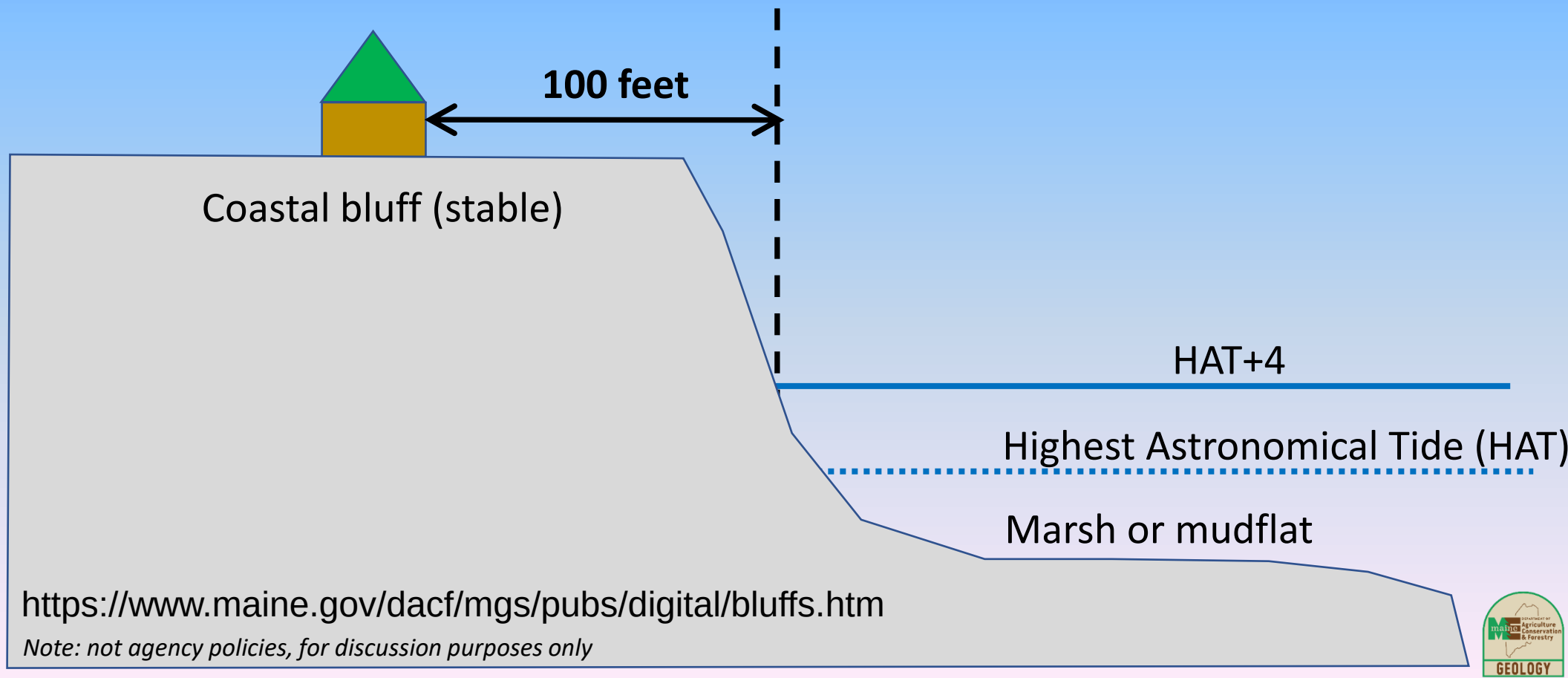
Currently, minimum setbacks for ***unstable bluffs are 75 feet from the top of the bluff.***



https://www.maine.gov/dacf/mgs/pubs/digital/bluffs.htm

Note: not agency policies, for discussion purposes only

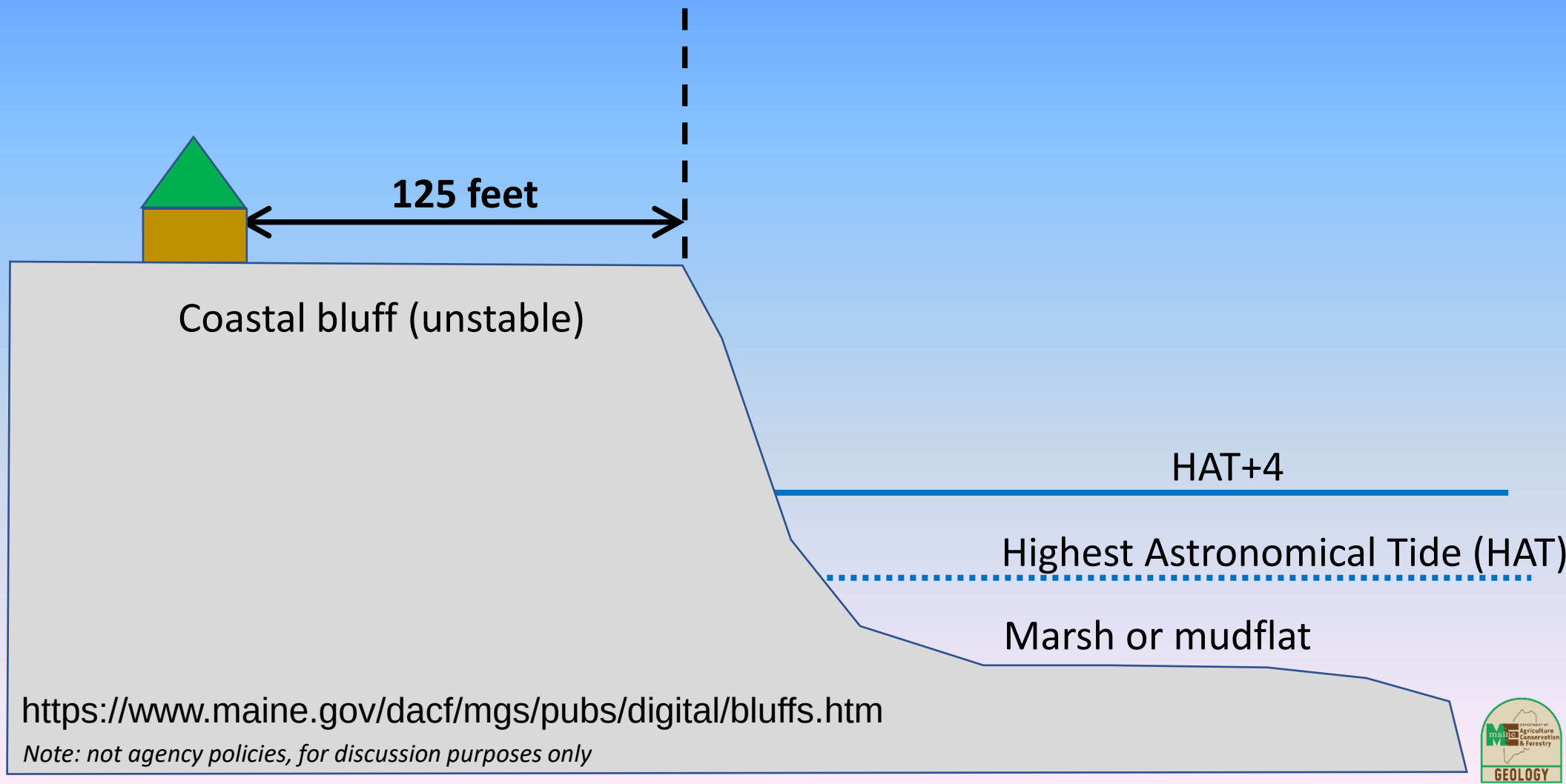
Avoid/Adapt - *Consider **larger setbacks (e.g., 100 feet) for stable bluff areas to account for future instability due to storms and sea level rise and establishing setbacks from a higher starting point** (for example, HAT+4 feet SLR).*



https://www.maine.gov/dacf/mgs/pubs/digital/bluffs.htm

Note: not agency policies, for discussion purposes only

Avoid/Adapt - *Consider* ***wider setbacks (e.g., 125 feet) along unstable bluffs to account for further instability due to future erosion and sea level rise.***



https://www.maine.gov/dacf/mgs/pubs/digital/bluffs.htm

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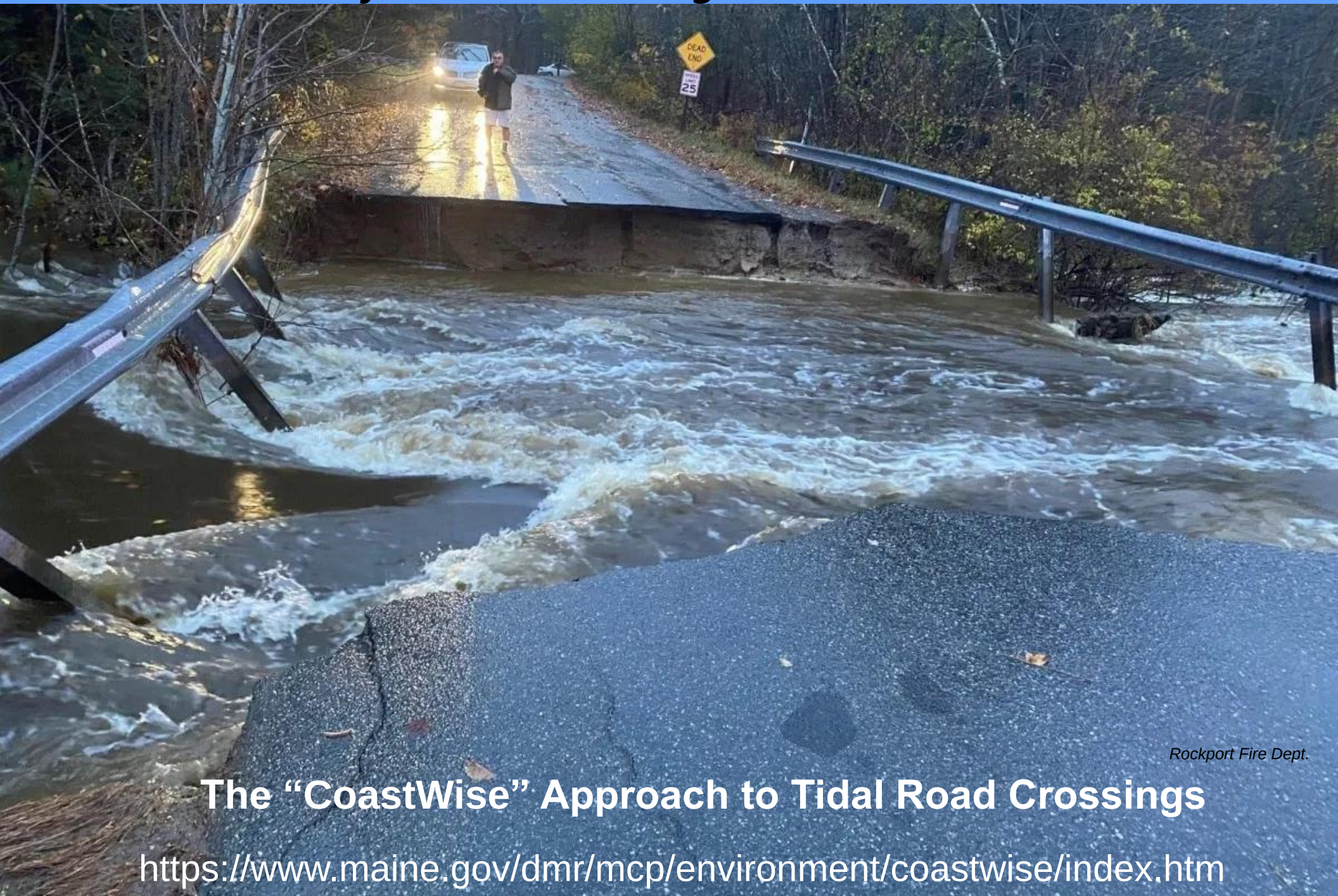
Adapt - Use best available scientific guidance *to adapt infrastructure in high-hazard areas*



Rockport Fire Dept.

The "CoastWise" Approach to Tidal Road Crossings

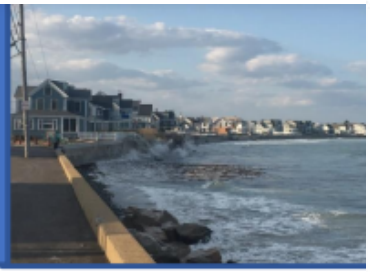
https://www.maine.gov/dmr/mcp/environment/coastwise/index.htm

Transferable Work to help guide Avoid and Adapt Actions

FACT SHEET

MUNICIPAL GUIDANCE FOR COASTAL RESILIENCE:

Model Ordinance Language For Maine Municipalities



Building climate resilience is essential for communities' well-being and local action is critical for addressing the impacts of climate change and coastal hazards. Municipal land use planning and regulations are indispensable tools for enhancing local climate resilience. Where and how communities accommodate growth and development affects the exposure of people and property to natural hazards, as well as the health of the natural environment. Maine's home rule status offers valuable opportunities for municipalities to adopt creative, innovative, and flexible land use solutions that address coastal hazards and are tailored to local needs and conditions.

The ***Municipal Guidance for Coastal Resilience: Model Ordinance Language for Maine Municipalities*** document was developed to support municipal staff and planning boards integrate resilience measures into land use regulations. The document provides a menu of land use provisions and resilience measures that municipalities can incorporate into existing ordinances or combine for a standalone coastal resilience ordinance.

Municipal Guidance for Coastal Resilience offers suggested resilience measures to integrate into existing ordinances, including:

- **Floodplain Management**
- **Shoreland Zoning**
- **Subdivision and Site Plan Review**
- **Zoning**

Benefits of *Municipal Guidance for Coastal Resilience: Model Ordinance Language for Maine Municipalities*

- Designed to allow a municipality to select resilience-based land use approaches that address local conditions, hazards, and needs.
- Provides specific yet customizable language that municipalities can integrate into land use regulations to enhance coastal resilience.
- Fosters the implementation of resilience strategies that protect people, property, and the natural environment from evolving coastal hazards.
- Facilitates land use planning that accounts for climate change impacts, minimizes risk from those impacts, and is designed for flexibility and adaptability to changing environmental conditions.
- Supports consistency in land use requirements between municipalities.

The *Municipal Guidance for Coastal Resilience* document includes:

- Hazards and topics to consider when amending existing municipal ordinance(s).
- Technical ordinance language
- Examples of resilience ordinance measures from other communities.
- Resources for understanding, identifying, and mapping coastal hazards and climate change impacts.

Click here to access The Municipal Guidance for Coastal Resilience document (*available on SMPDC's Website*)

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SMPDC FB

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MUNICIPAL GUIDANCE

for COASTAL RESILIENCE

Model Ordinance Language for Maine Municipalities

April 2022

PREPARED BY THE SOUTHERN MAINE PLANNING AND DEVELOPMENT COMMISSION
AND FB ENVIRONMENTAL ASSOCIATES

SMPDC FB

https://smpdc.org/coastal

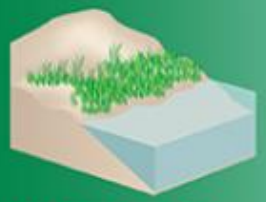
maine GEOLOGY

Protect - Use green, green-gray, and gray approaches to protect vulnerable shoreline areas, depending on wave energy, erosion and flood vulnerability, criticality and other factors.

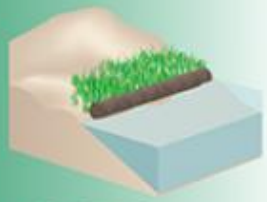
HOW GREEN OR GRAY SHOULD YOUR SHORELINE SOLUTION BE?

GREEN - SOFTER TECHNIQUES ⟷ **GRAY - HARDER TECHNIQUES**

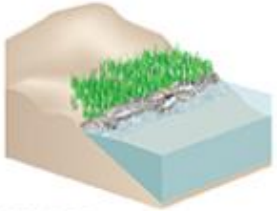
Living Shorelines



VEGETATION ONLY - Provides a buffer to upland areas and breaks small waves. Suitable for low wave energy environments.



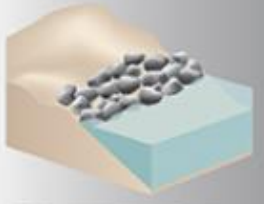
EDGING - Added structure holds the toe of existing or vegetated slope in place. Suitable for most areas except high wave energy environments.



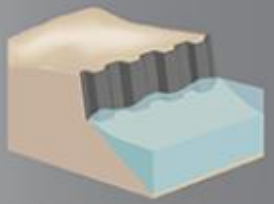
SILLS - Parallel to vegetated shoreline, reduces wave energy, and prevents erosion. Suitable for most areas except high wave energy environments.

Coastal Structures

BREAKWATER - (vegetation optional) - Offshore structures intended to break waves, reducing the force of wave action, and encourage sediment accretion. Suitable for most areas.



REVETMENT - Lays over the slope of the shoreline and protects it from erosion and waves. Suitable for sites with existing hardened shoreline structures.



BULKHEAD - Vertical wall parallel to the shoreline intended to hold soil in place. Suitable for high energy settings and sites with existing hard shoreline structures.

Courtesy of NOAA

GEOLOGY

Protect – Consider the use of *living shorelines* in appropriate areas.

Piloting Living Shorelines in New England

Wagon Hill Farm, Durham, New Hampshire

https://www.northeastoceancouncil.org/committees/coastal-hazards-resilience/living-shorelines-group/

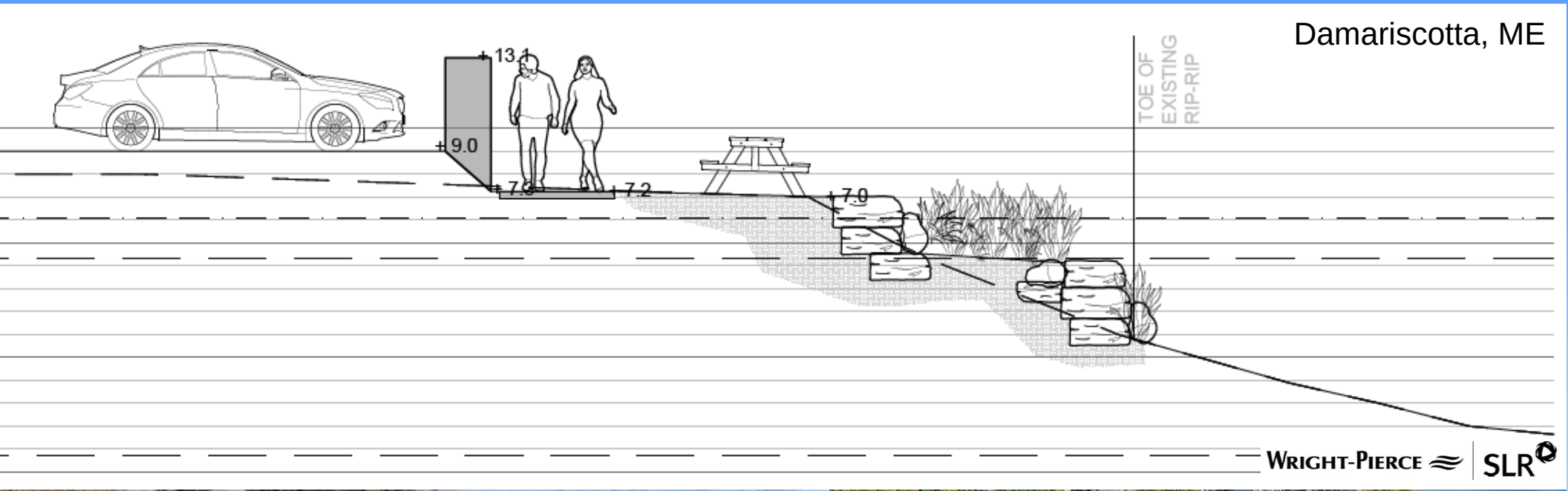
Protect – Consider using green/gray shoreline protection structures *before* using solely gray shoreline protection structures. Incorporate native vegetation to the maximum extent practicable.

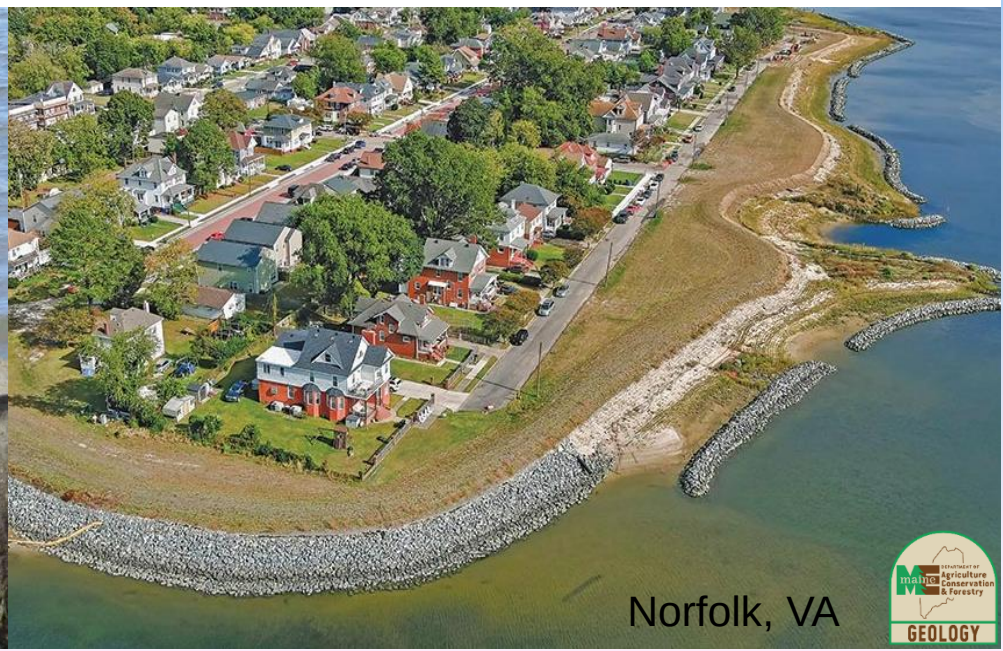
Freeport, ME, MEDEP

Protect – Consider requiring that if regrading is part of a shoreline protection project, *that sediment is beneficially placed at the toe of the structure to simulate natural erosion of the bluff.*

Bunganuc Bluff, Brunswick, ME, Walsh Engineering

Protect – In heavily developed areas, the use of gray shoreline protection structures should be in conjunction with nearshore reefs or integrated living shorelines to enhance habitat.





Relocate – **In certain areas that will have unsustainable flooding, erosion, and potential losses, consider the use of *strategic relocation of infrastructure and/or the use of rolling easements.***

Brunswick, ME, P. Slovinsky, MGS

Additional Useful Resources and Links

MGS Hazards
https://www.maine.gov/dacf/mgs/hazards/index.shtml

MGS Sea Level Rise Ticker and Dashboard
https://www.maine.gov/dacf/mgs/hazards/slr_ticker/index.html
https://www.maine.gov/dacf/mgs/hazards/slr_ticker/slr_dashboard.html

MGS Living Shorelines in Maine
https://www.maine.gov/dacf/mgs/explore/marine/living-shorelines/

Northeast Regional Ocean Council Living Shoreline Workgroup
https://www.northeastoceancouncil.org/committees/coastal-hazards-resilience/living-shorelines-group/

Maine Flood Resilience Checklist
https://digitalmaine.com/mgs_publications/521/

TNC Coastal Risk Explorer and Habitat Explorer
https://maps.coastalresilience.org/maine/

Thank you

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