




Low-lying Roads: Falmouth

Project funded by the
Municipal Vulnerability
Preparedness Program



Purpose and Objectives of Workshop

- 
- **Review flood projections and impacts on roadways for the town under future scenarios**
 - **Discuss vulnerable low-lying roads or other transportation infrastructure**
 - **Prepare the town to address priority road segments for design and permitting**

Agenda

- Project Overview – CCC
- Vulnerability and Risk Assessment – WHG
- Results of Low-Lying Roads Screening & Prioritization – WHG
- Discussion – CCC & WHG
 - Town comments
- Next Steps – CCC
- Workshop concludes ~ 6:30 pm

Low-Lying Roads 2

5

TOWNS

Chatham
Falmouth
Harwich

Mashpee
Provincetown



Flooding vulnerability assessment of low-lying roads and transportation infrastructure



Support municipal road segment prioritization



Identify range of potential design solutions, costs

Work performed by Cape Cod Commission and Woods Hole Group



Hazards

Storms,
Sea Level Rise,
& Flooding



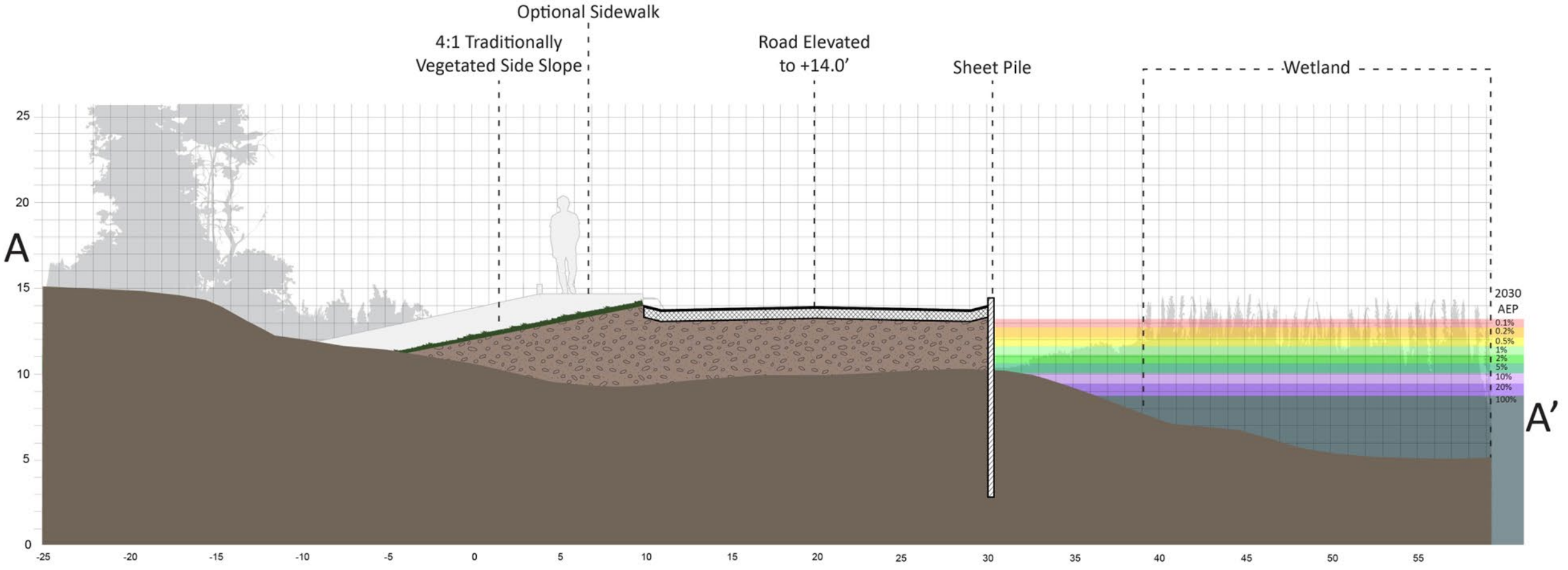
Adaptation Strategies



- | Gray Infrastructure, or Traditional Engineering Structures
- | Green Infrastructure, or Nature-based Solutions
- | Other approaches – Hybrid, Planned Relocation, Abandonment

ADAPTATION STRATEGIES

GRAY/TRADITIONAL ENGINEERING

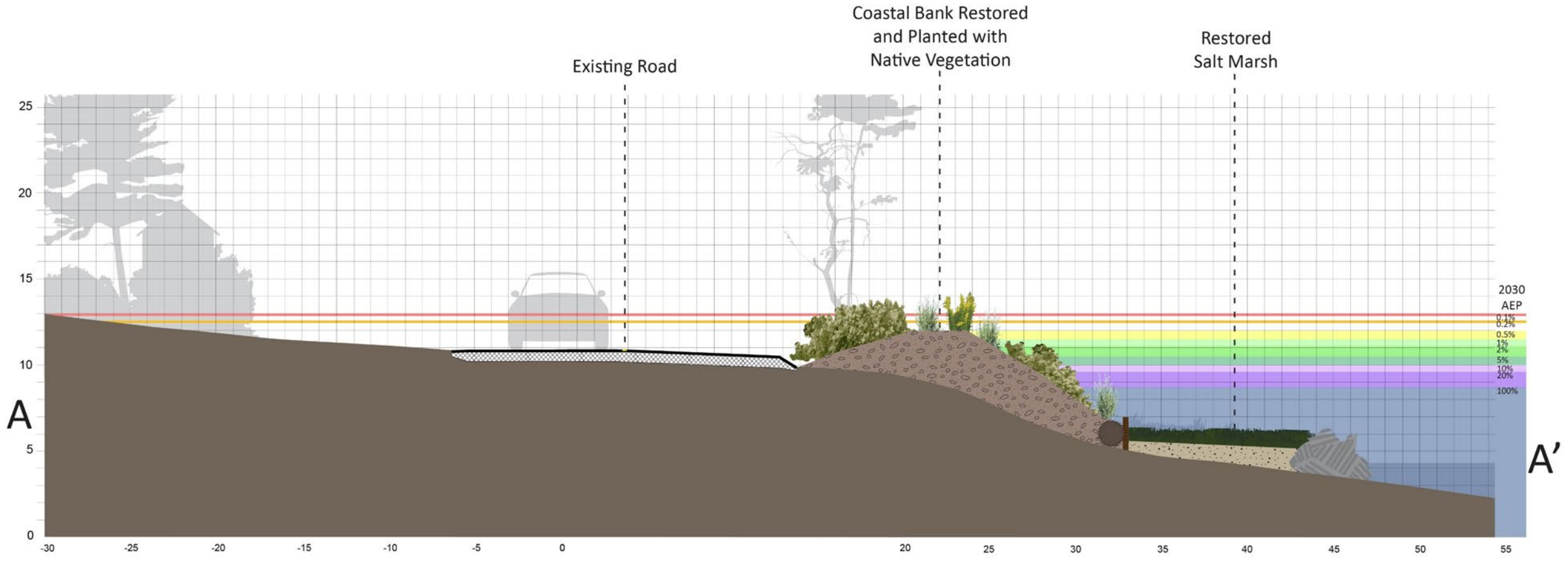




ADAPTATION STRATEGIES



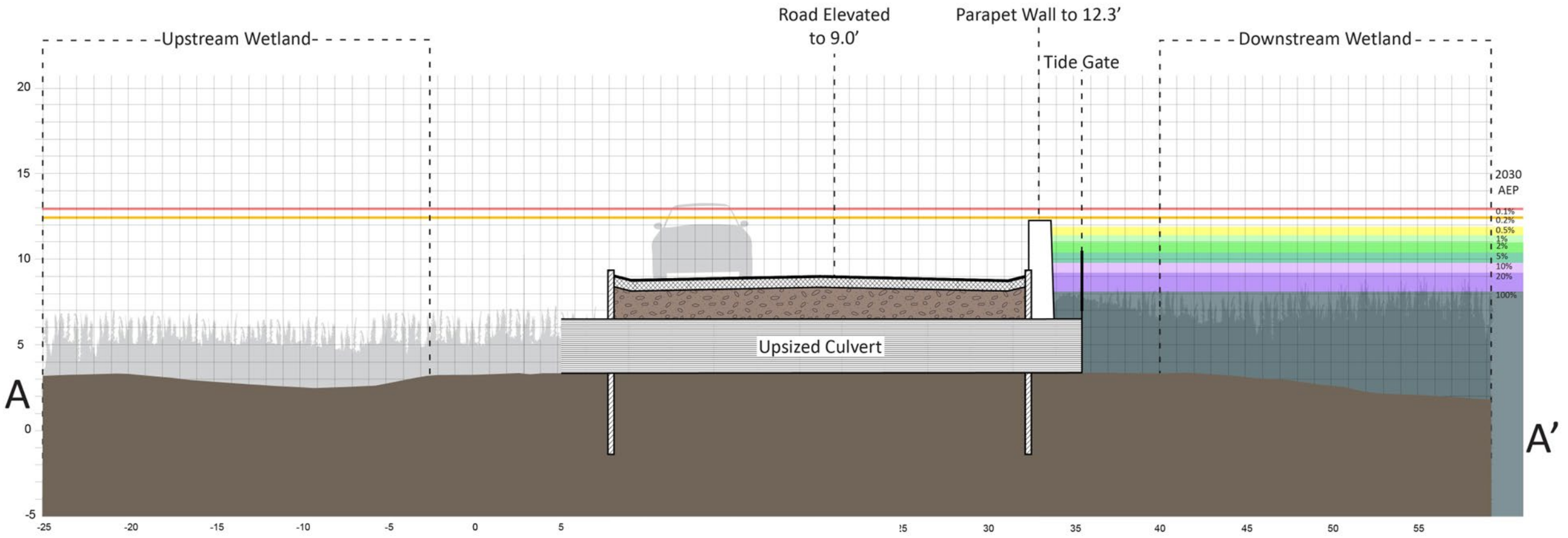
GREEN/NATURE-BASED SOLUTIONS



ADAPTATION STRATEGIES



HYBRID APPROACHES





PROJECT TIMELINE & ELEMENTS

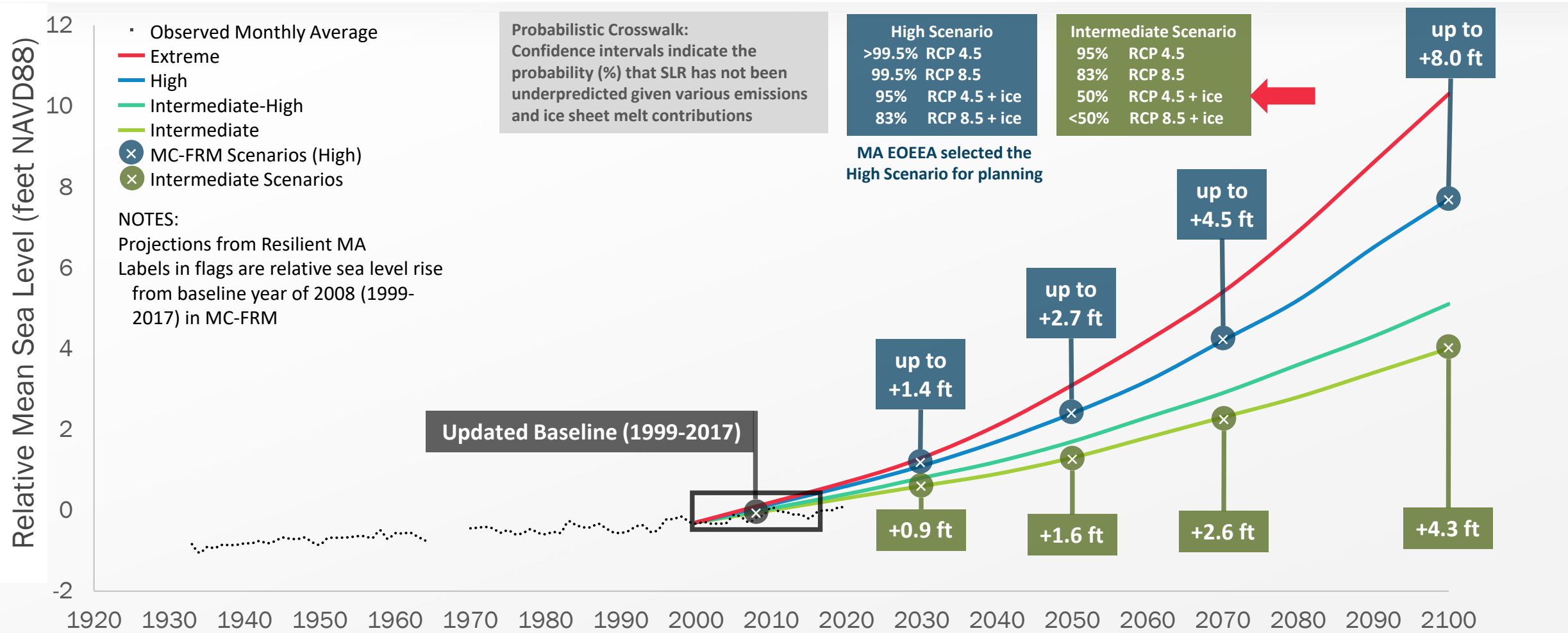


Questions?

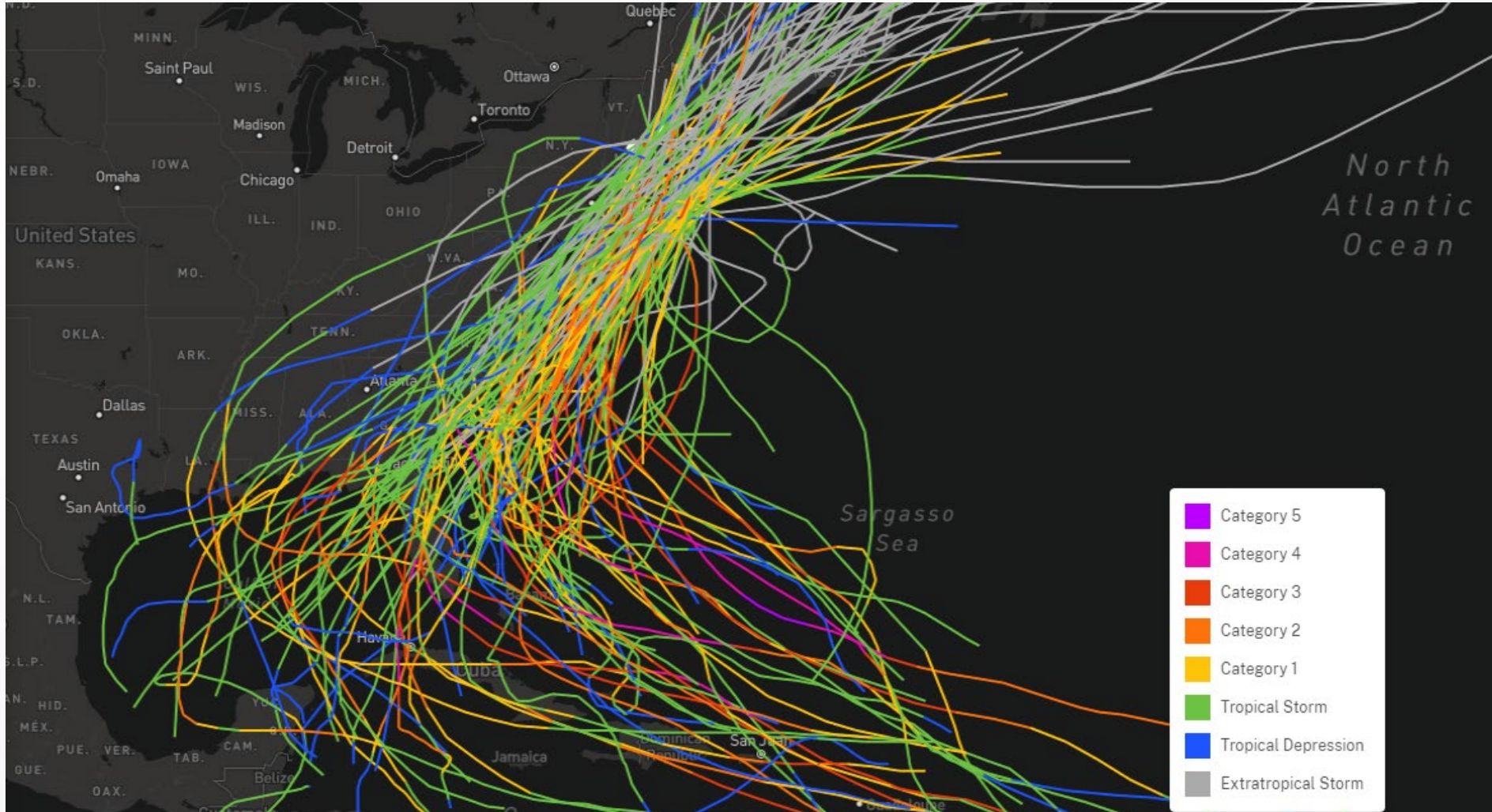
- Workshop Purpose or Objectives
- Low Lying Roads project
 - Key components
 - Vulnerability Assessment - Identify Potential Sites
 - Public Outreach and Engagement
 - Roadway Feasibility and Alternative Solutions
 - Solutions Identification
 - Timeline

MA EOEEA Probabilistic Sea Level Rise Projections

MC-FRM SOUTH (DeConto & Kopp, 2017)

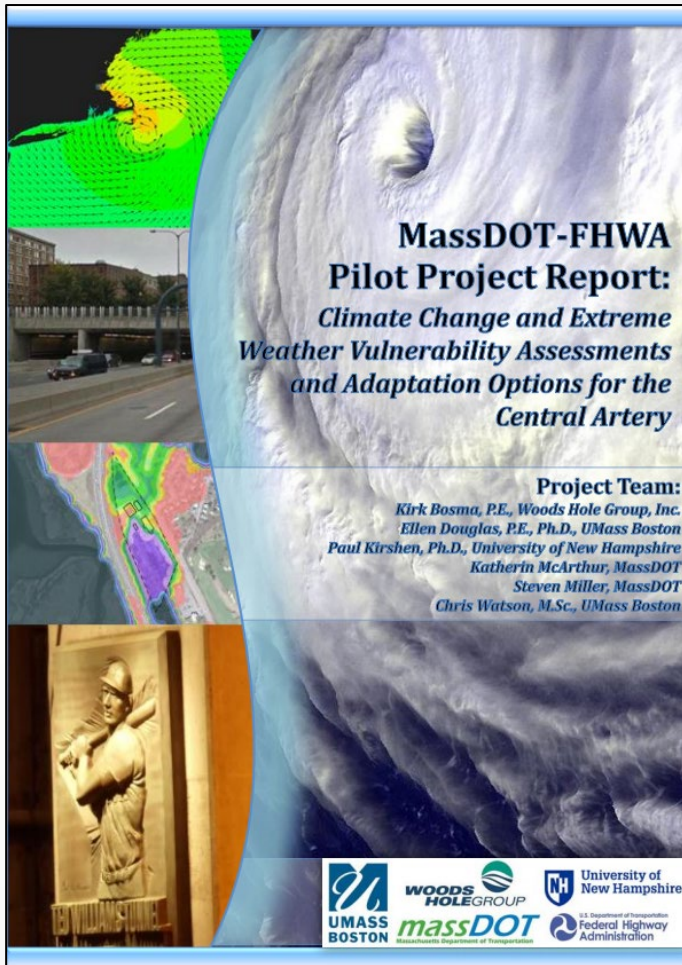


Tropical / Extra-tropical Storms



NOAA National Ocean Service

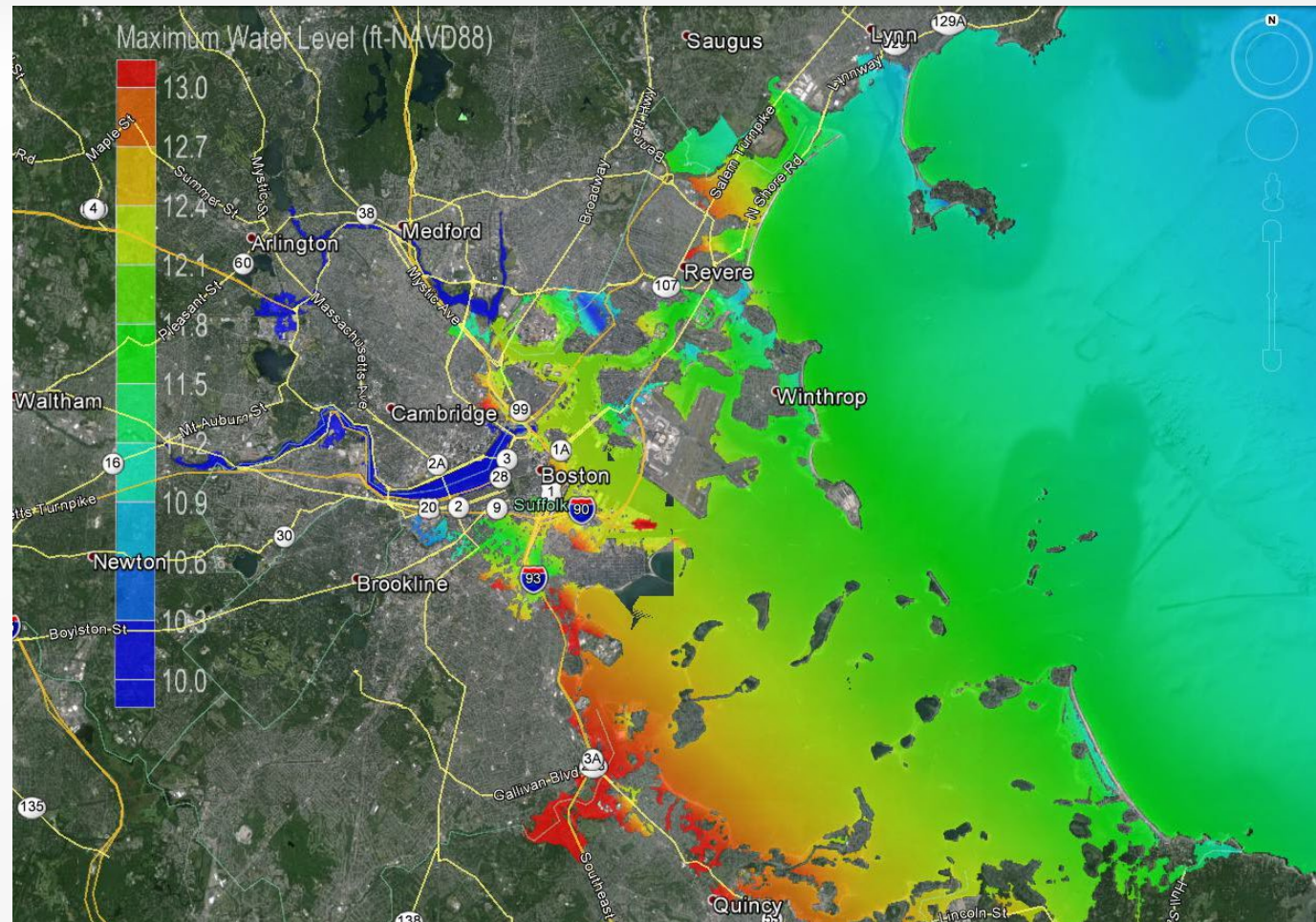
Why Hydrodynamic Modeling? Why Probabilistic?



**MassDOT-FHWA
Pilot Project Report:
Climate Change and Extreme
Weather Vulnerability Assessments
and Adaptation Options for the
Central Artery**

Project Team:
Kirk Bosma, P.E., Woods Hole Group, Inc.
Ellen Douglas, P.E., Ph.D., UMass Boston
Paul Kirshen, Ph.D., University of New Hampshire
Katherin McArthur, MassDOT
Steven Miller, MassDOT
Chris Watson, M.Sc., UMass Boston

UMASS BOSTON | WOODS HOLE GROUP | University of New Hampshire | U.S. Department of Transportation Federal Highway Administration



Massachusetts Coast Flood Risk Model (MC-FRM)

INPUTS



SEA LEVEL
RISE



TROPICAL / EXTRA-
TROPICAL STORMS



LANDSCAPE



ELEVATION



CHANGING
CLIMATE

PROBABILISTIC /
HYDRODYNAMIC
MODEL



Includes relevant physical processes:
sea level rise, tides, storm surge, wind, wave setup
/ run-up / overtopping, future climate scenarios

Future version to incorporate coastal erosion



FLOOD
PROBABILITY



FLOOD
DEPTH



FLOOD
DURATION



FLOOD
VOLUMES



FLOOD
PATHWAYS



WINDS



WAVES



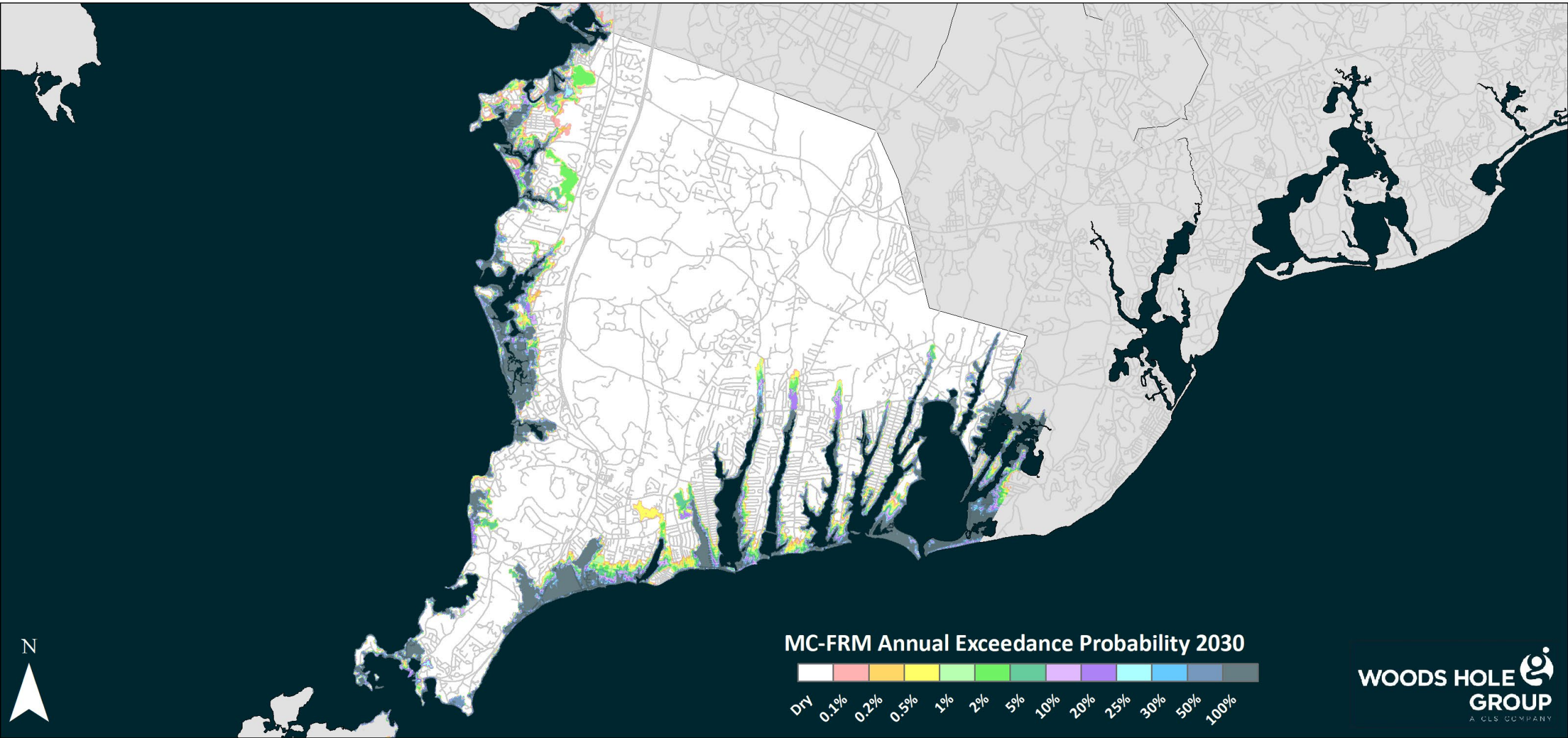
CURRENTS

OUTPUTS

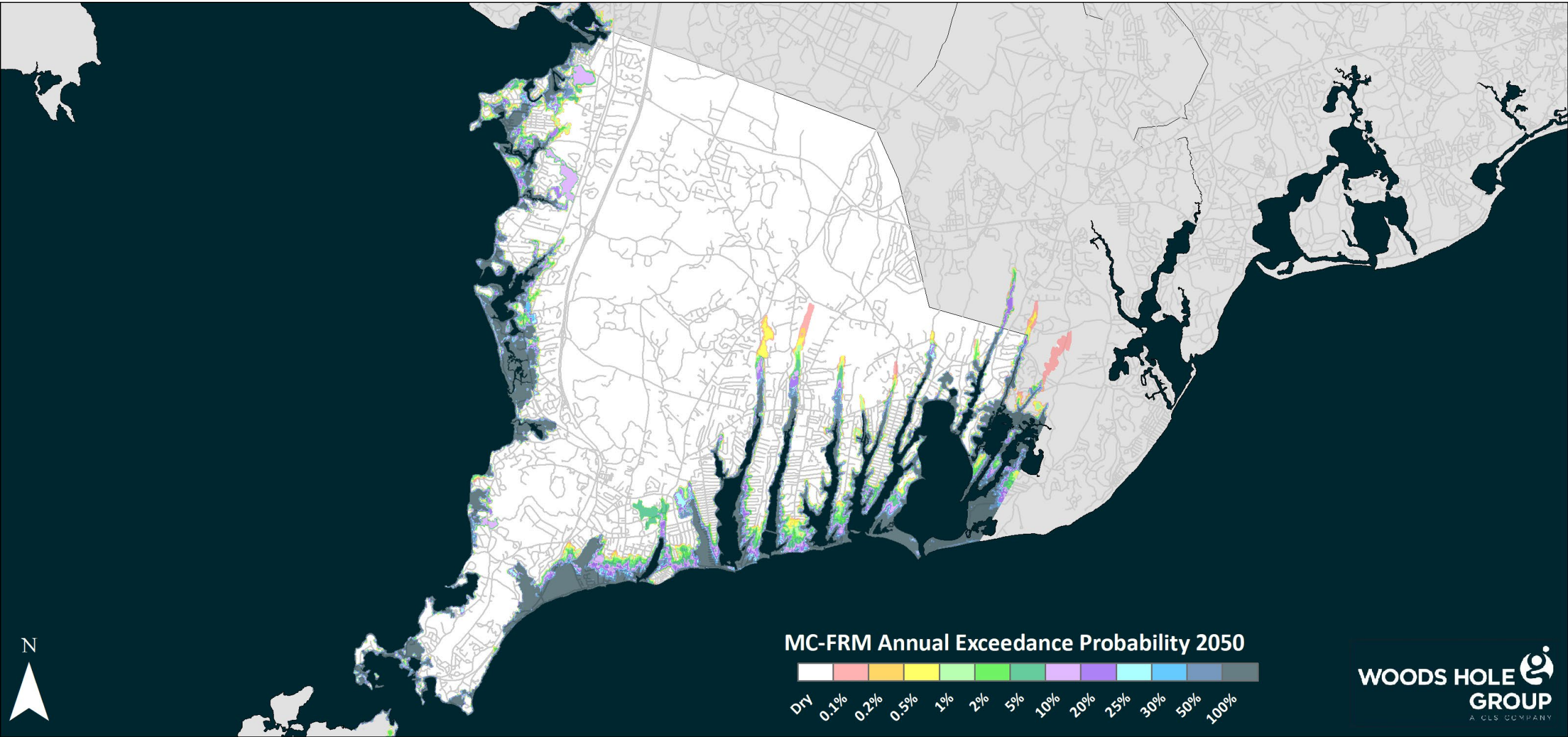
MC-FRM Resolution



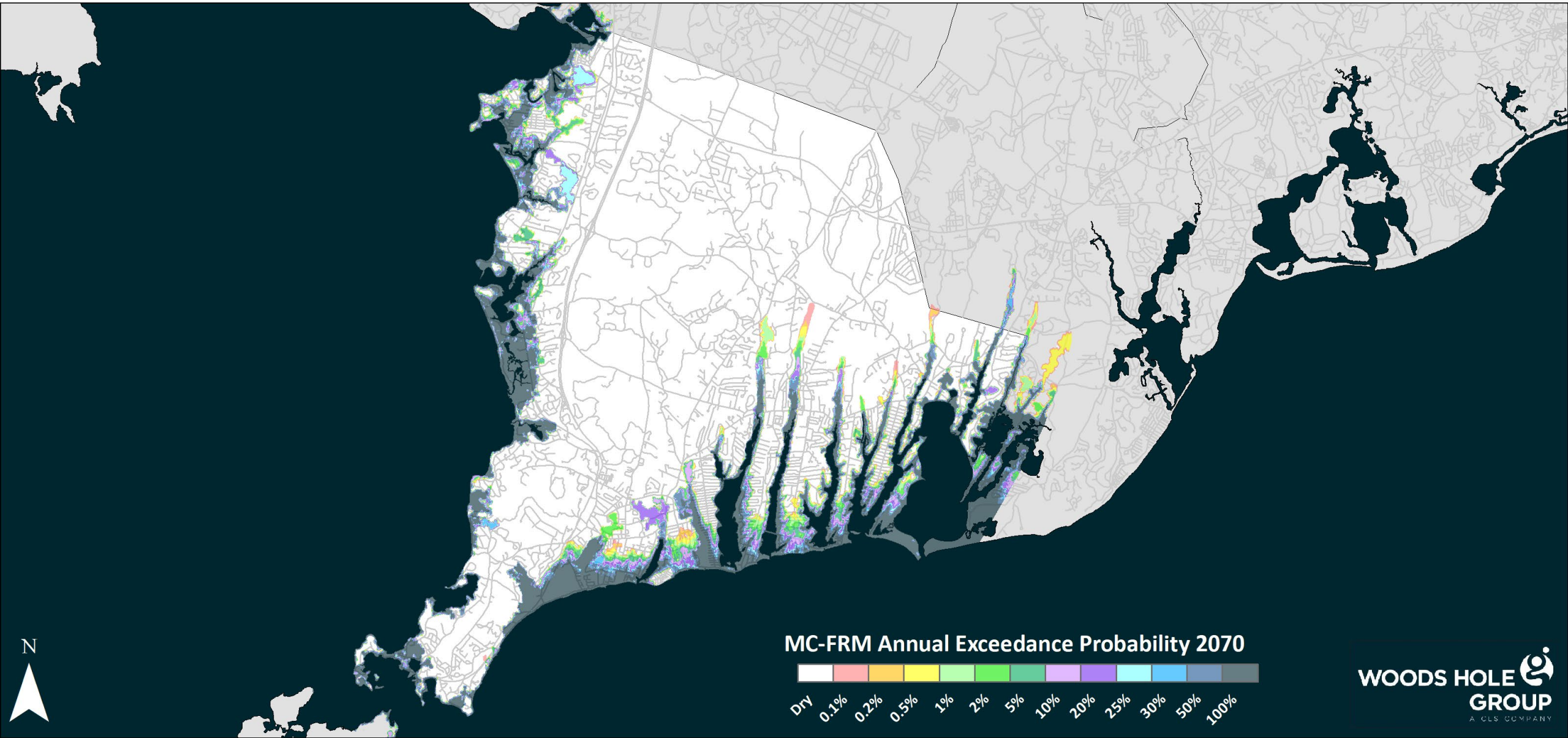
MC-FRM Annual Coastal Flood Exceedance Probability – 2030



MC-FRM Annual Coastal Flood Exceedance Probability – 2050



MC-FRM Annual Coastal Flood Exceedance Probability – 2070



MC-FRM Annual Exceedance Probabilities

	0.1%	1/1000
	0.2%	1/500
	0.5%	1/200
	1%	1/100
	2%	1/50
	5%	1/20
	10%	1/10
	20%	1/5
	25%	1/4
	30%	1/3.33
	50%	1/2
	100%	1/1

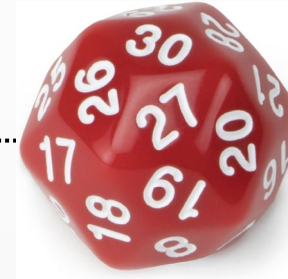


Image source: amazon.com/stores/Brybelly



Image source: dicegamedepot.com



Image source: dicegamedepot.com

Cumulative Probability

	AEP	Return	Cumulative Probability (P_e) of 1 or more events occurring over:			
			10-yrs	25-yrs	50-yrs	100-yrs
	0.1%	1/1000	1.0%	2.5%	4.9%	9.5%
	0.2%	1/500	2.0%	4.9%	9.5%	18.1%
	0.5%	1/200	4.9%	11.8%	22.2%	39.4%
	1%	1/100	9.6%	22.2%	39.5%	63.4%
	2%	1/50	18.3%	39.7%	63.6%	86.7%
	5%	1/20	40.1%	72.3%	92.3%	99.4%
	10%	1/10	65.1%	92.8%	99.5%	100%
	20%	1/5	89.3%	99.6%	100%	100%
	25%	1/4	94.4%	99.9%	100%	100%
	30%	1/3.33	97.2%	100%	100%	100%
	50%	1/2	99.9%	100%	100%	100%
	100%	1/1	100%	100%	100%	100%

Massachusetts Coast Flood Risk Model

SUMMARY

Hydrodynamically modeled projections

Sea level rise and storm surge – combined

Annual chance of flooding under 2030/2050/2070 climate conditions

QUESTIONS?



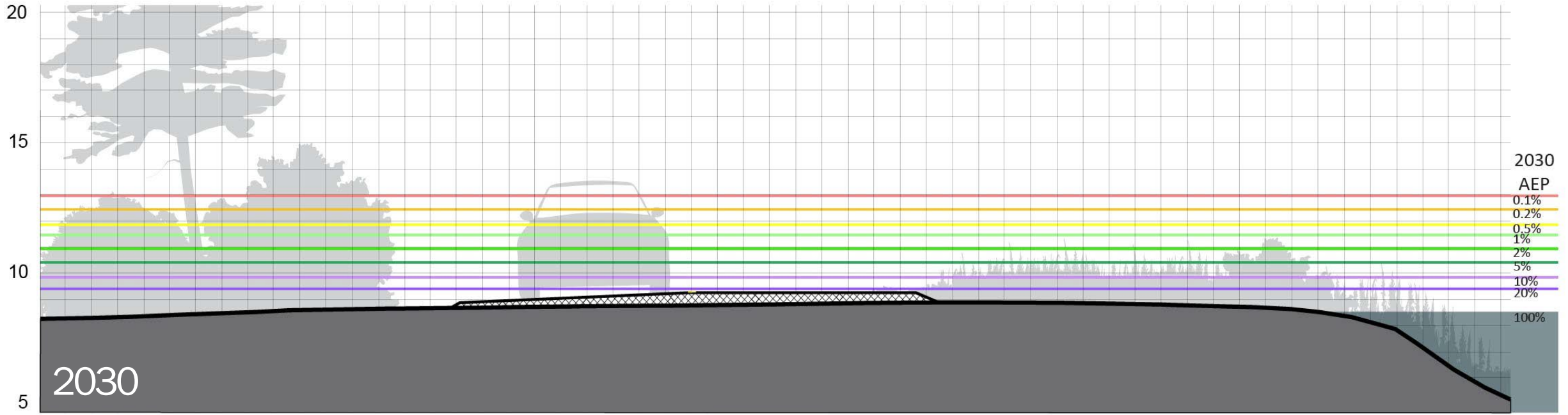
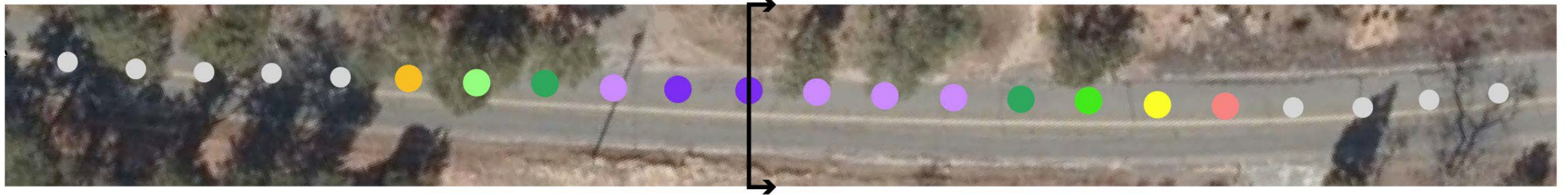
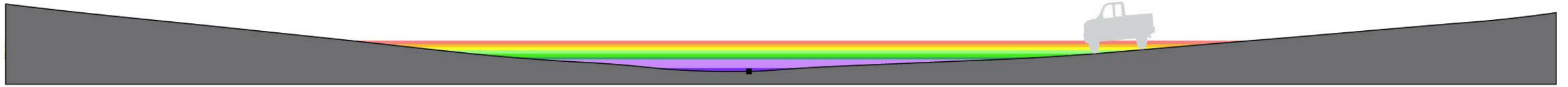
Cape Cod Low Lying Roads Vulnerability Assessment Methods

COASTAL FLOOD EXCEEDANCE PROBABILITY



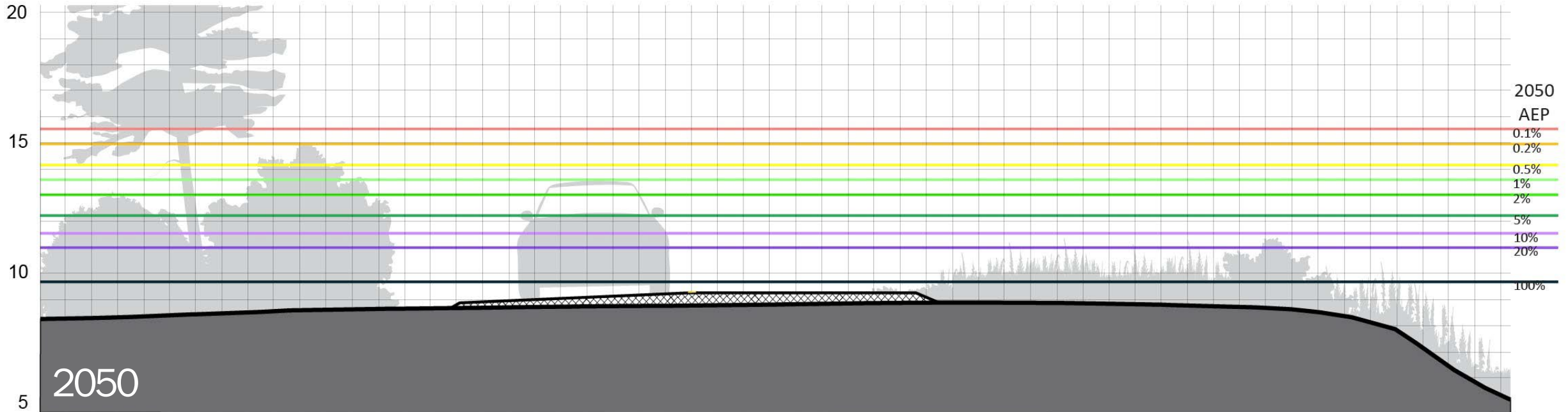
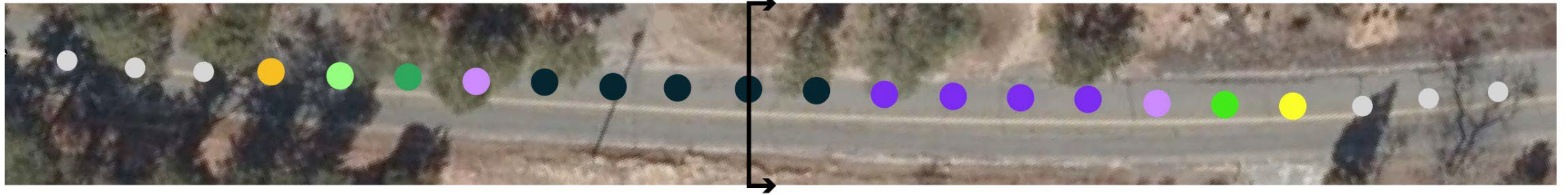
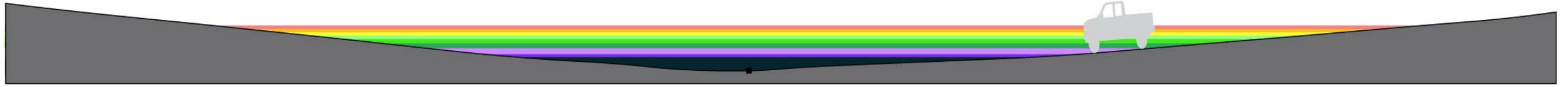
Cape Cod Low Lying Roads Vulnerability Assessment Methods

COASTAL FLOOD EXCEEDANCE PROBABILITY



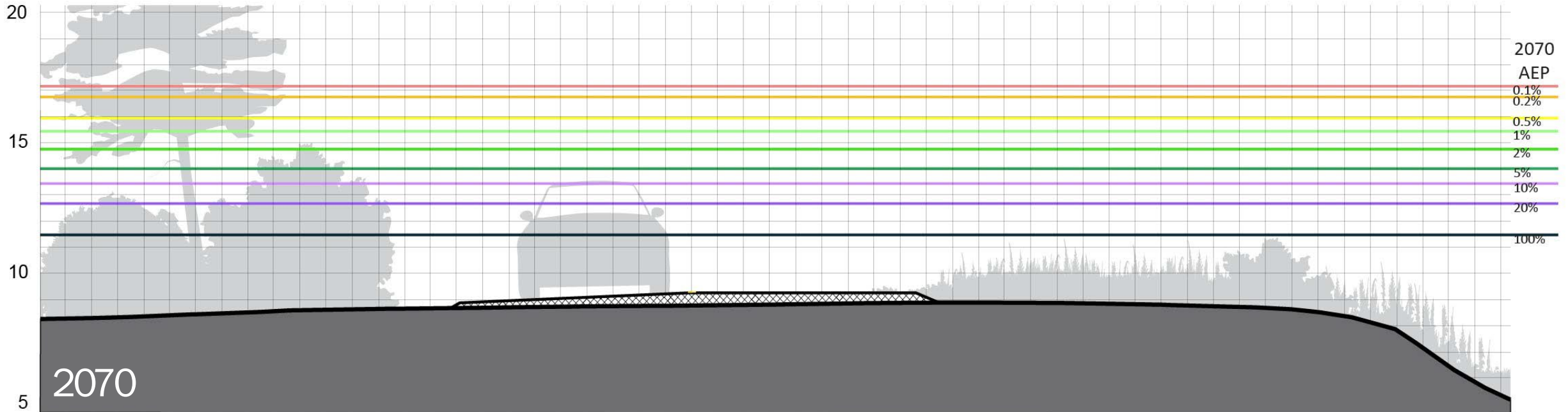
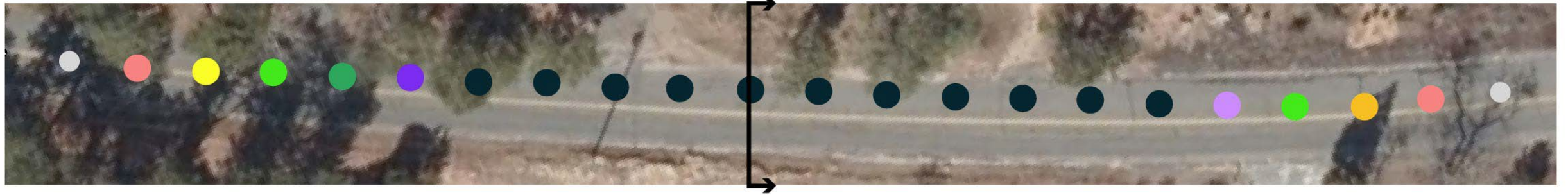
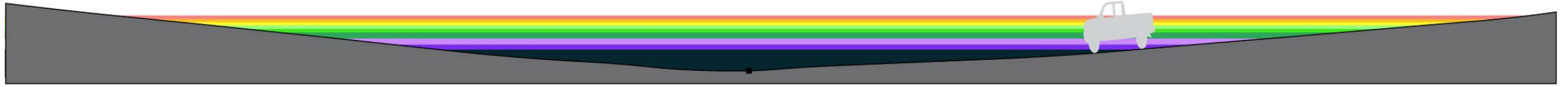
Cape Cod Low Lying Roads Vulnerability Assessment Methods

COASTAL FLOOD EXCEEDANCE PROBABILITY

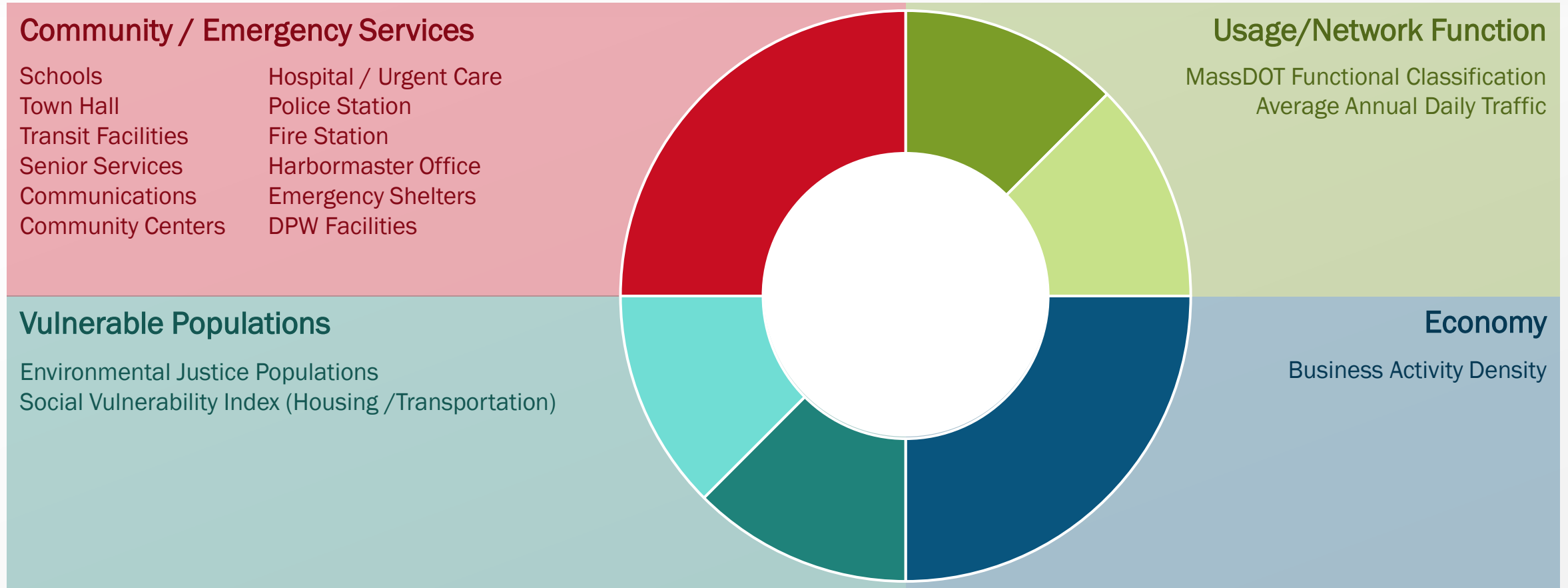


Cape Cod Low Lying Roads Vulnerability Assessment Methods

COASTAL FLOOD EXCEEDANCE PROBABILITY

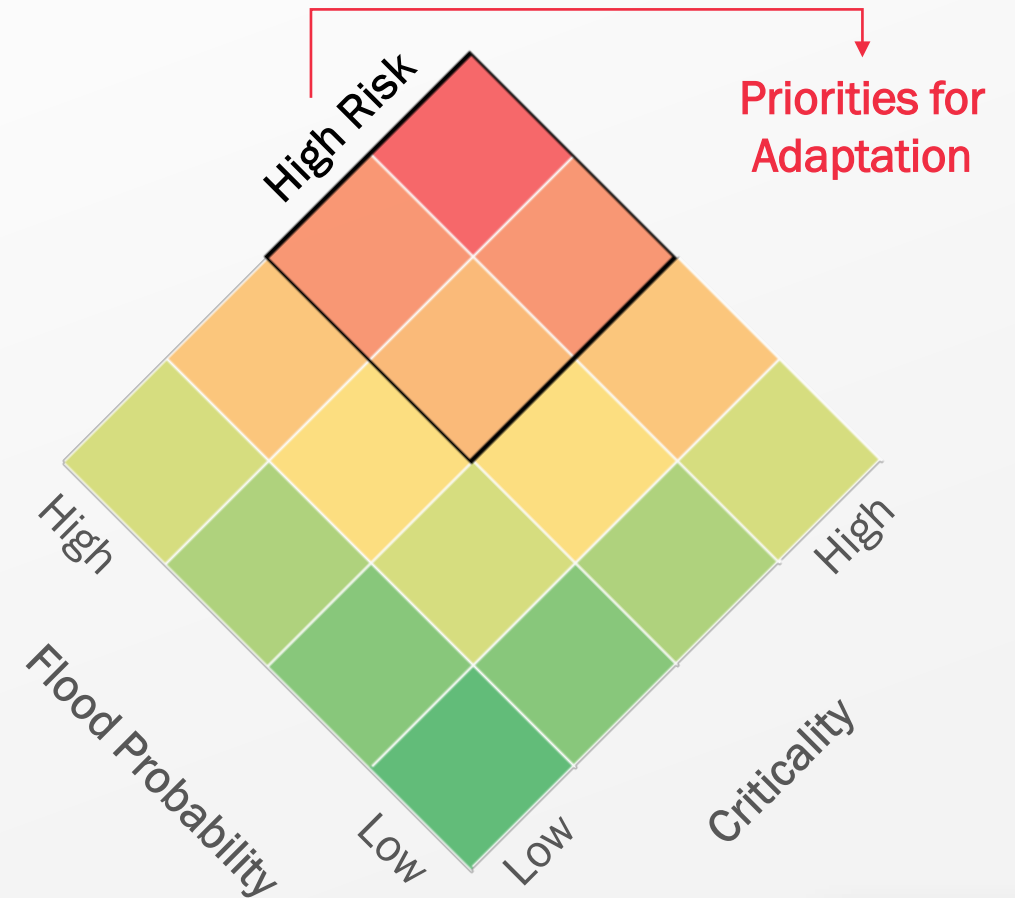


Cape Cod Low Lying Roads Criticality Scoring Framework



Cape Cod Low Lying Roads Risk Assessment Approach

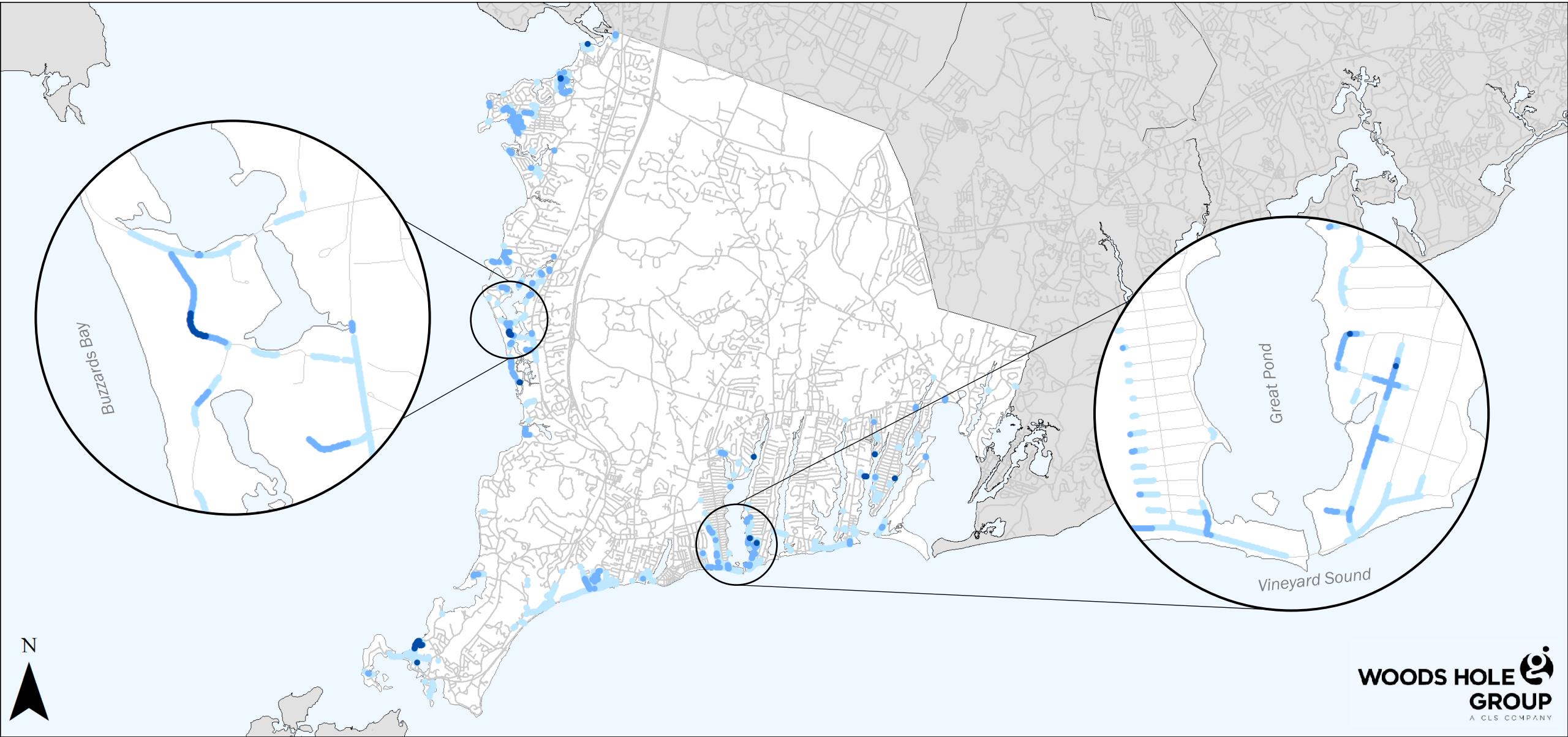
1. Extract roadway/bridge critical elevations (CEs)
2. Compile 2030/2050/2070 MC-FRM water surface elevations (WSEs)
3. Compare CEs to WSEs to determine flood probability
4. Score road segment criticality
5. **Probability * Criticality = Risk**
6. Prioritize high-risk road segments for community consideration



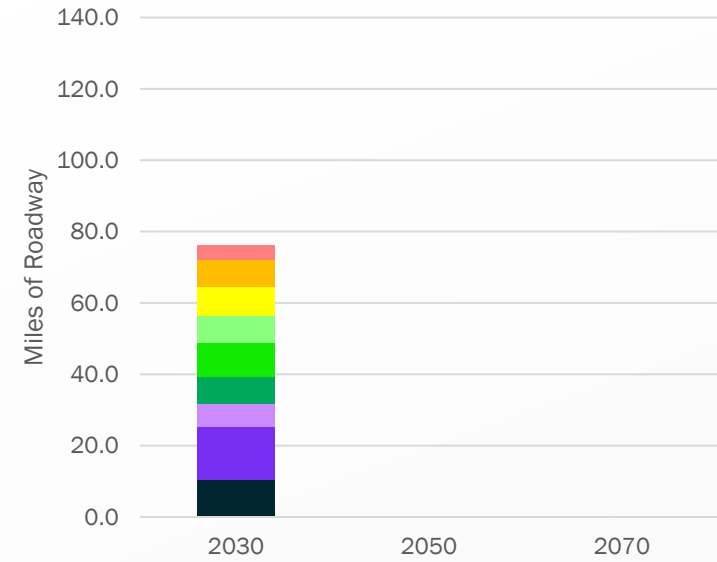
Low Lying Roads Nuisance Flooding

Road Surface Elevations Below MHW

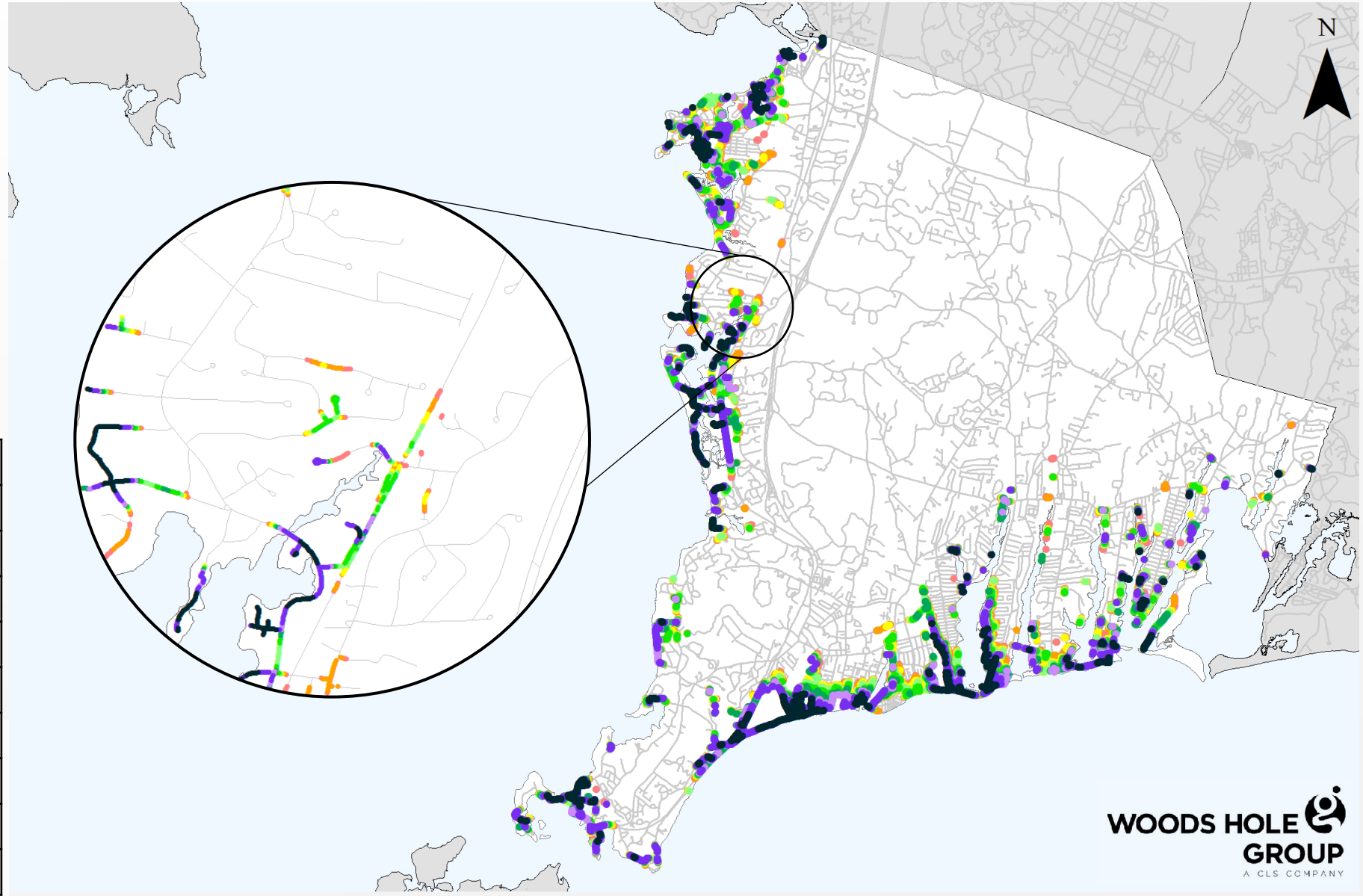
- 2070 (17.4 mi)
- 2050 (4.5 mi)
- 2030 (0.3 mi)



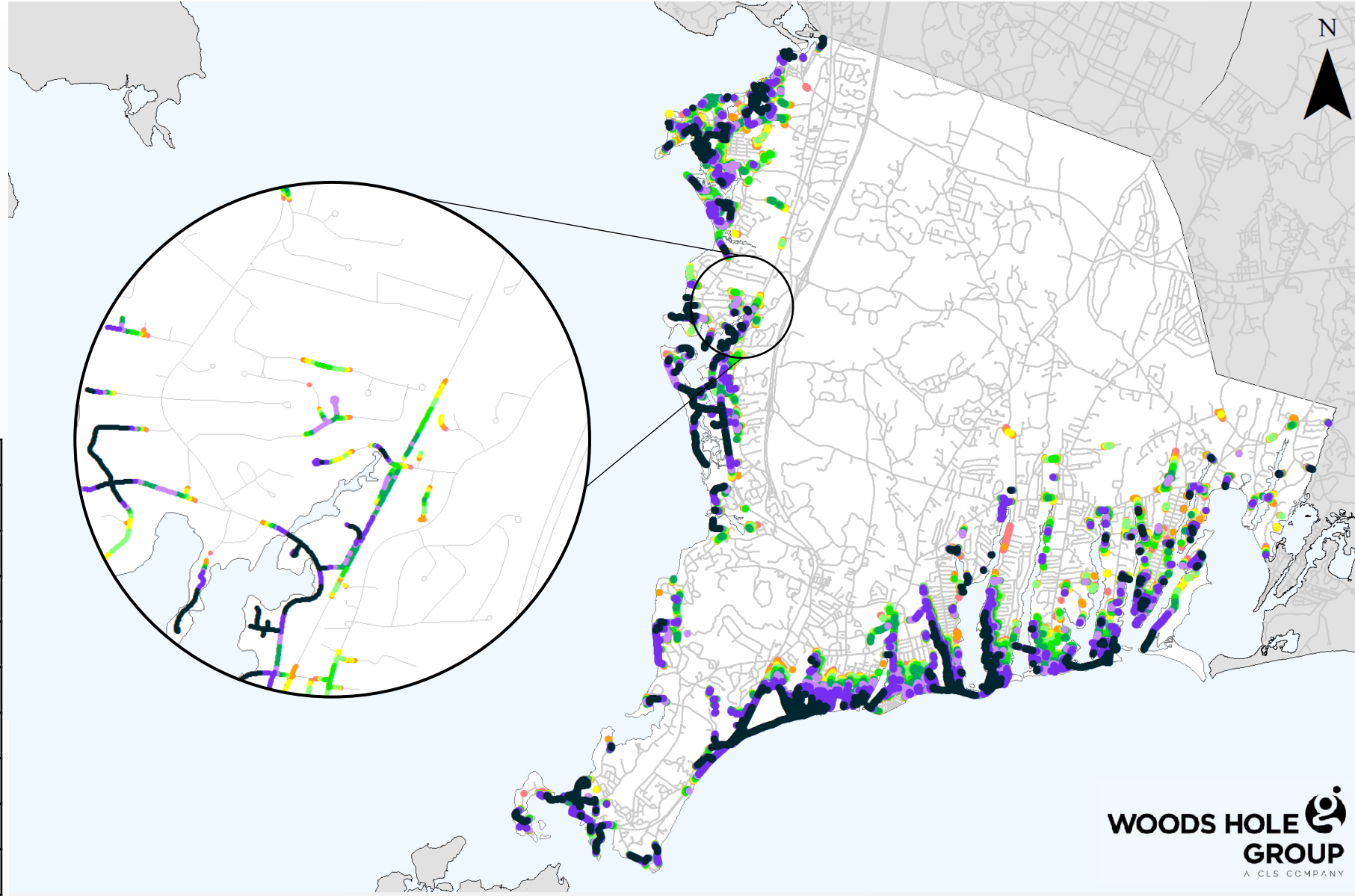
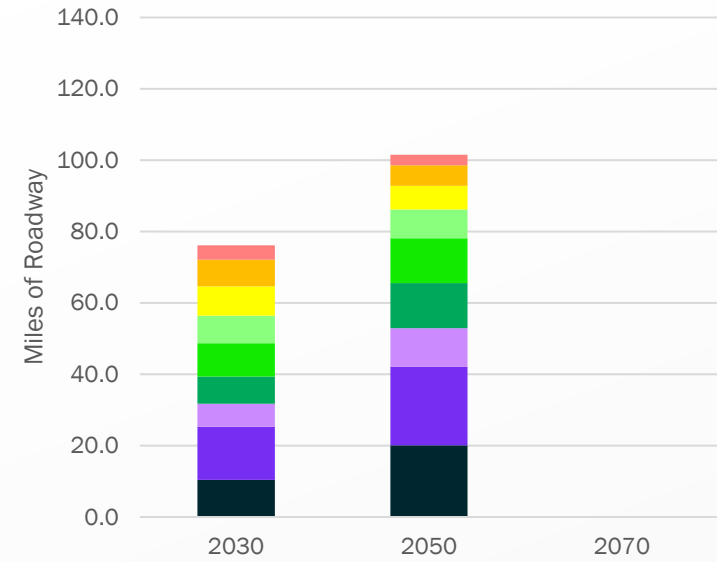
Low Lying Roads 2030 Flood Probability (Annual Exceedance Probability)



Flood Probability	Total Road Miles
0.1%	76.1
0.2%	72.1
0.5%	64.6
1%	56.4
2%	48.7
5%	39.3
10%	31.7
20%	25.3
100%	10.4

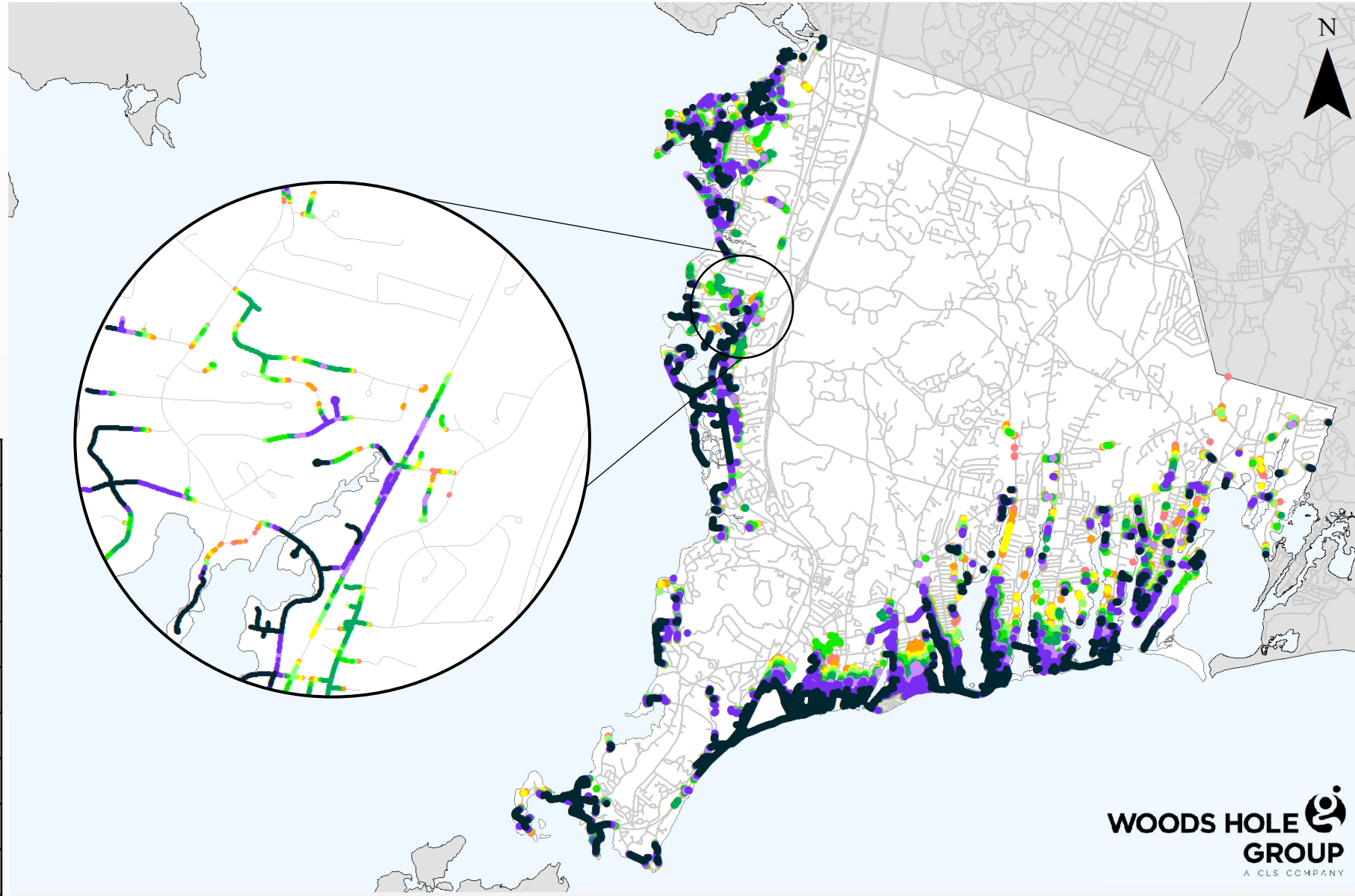
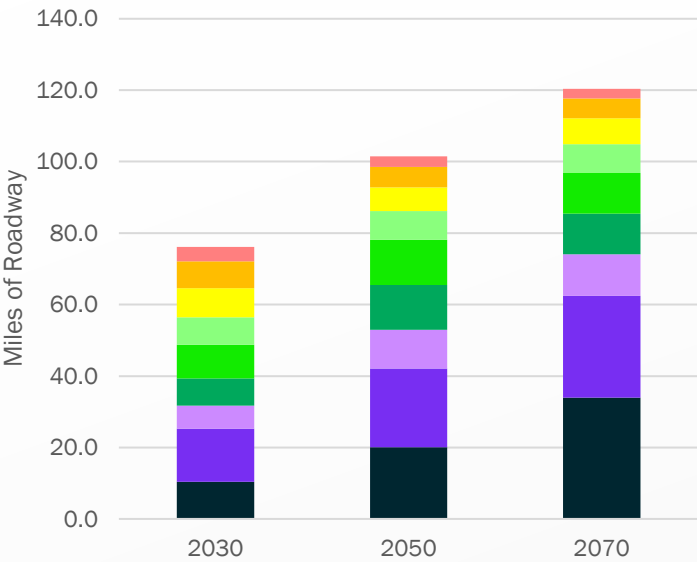


Low Lying Roads 2050 Flood Probability (Annual Exceedance Probability)



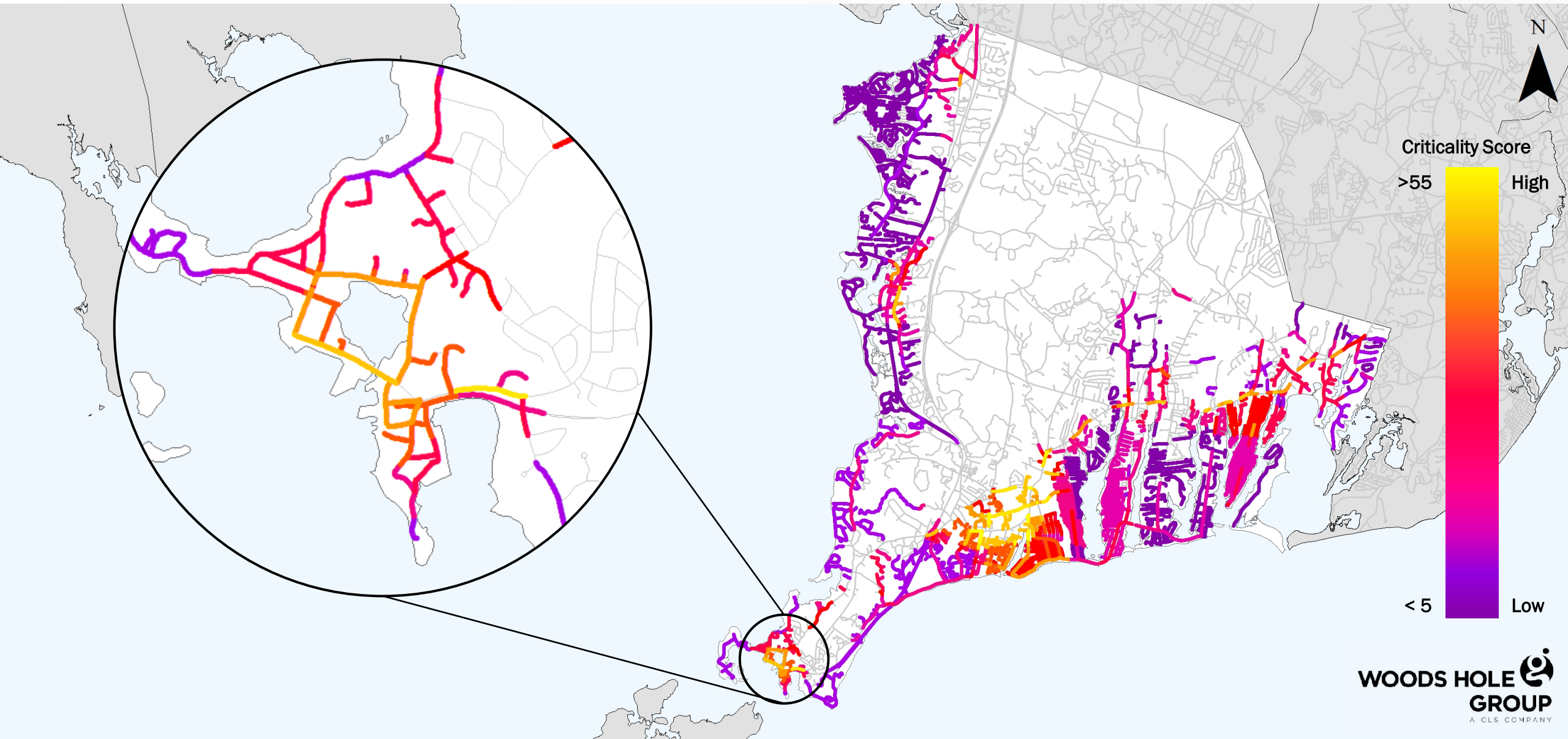
Flood Probability	Total Road Miles
0.1%	101.5
0.2%	98.5
0.5%	92.8
1%	86.2
2%	78.1
5%	65.5
10%	52.9
20%	42.1
100%	20.1

Low Lying Roads 2070 Flood Probability (Annual Exceedance Probability)



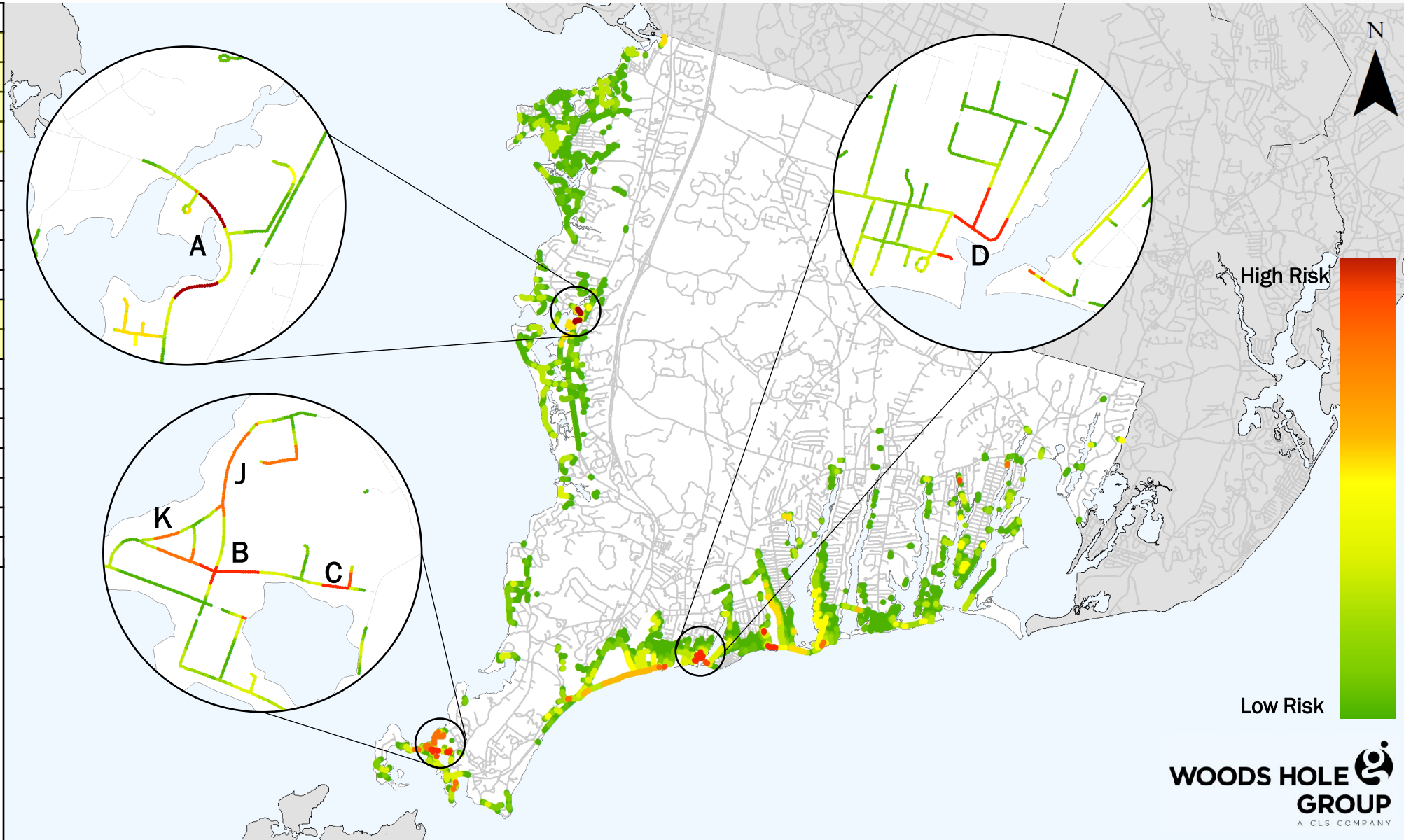
Flood Probability	Total Road Miles
0.1%	120.4
0.2%	117.7
0.5%	112.1
1%	104.9
2%	96.8
5%	85.4
10%	74.1
20%	62.4
100%	34.0

Low Lying Roads Criticality Scoring



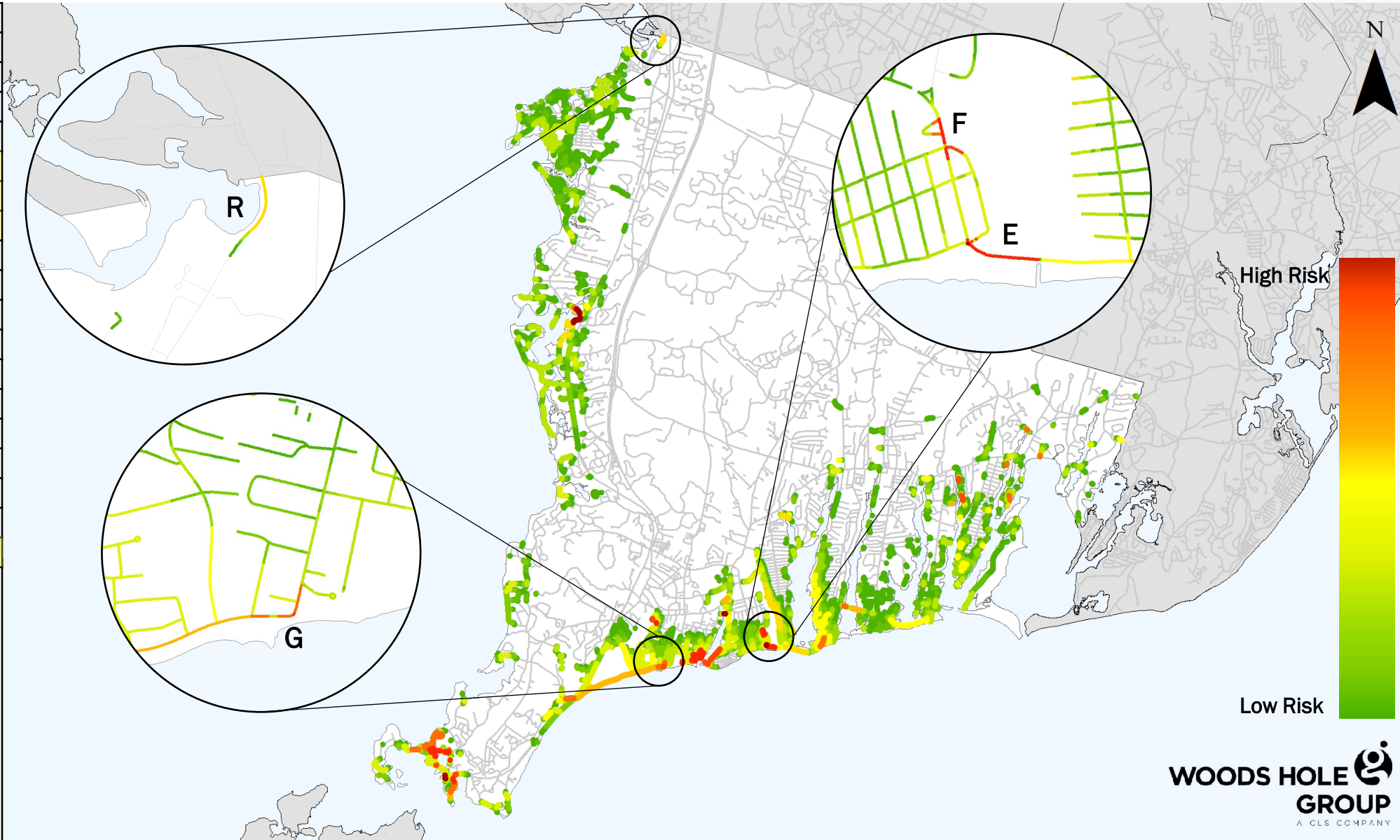
Low Lying Roads 2030 Risk Results

High Risk Road Segments	
A	Nashawena St
B	Millfield St West
C	Millfield St East
D	Clinton/Scranton Ave corner
E	Menauhant Rd at Little Pond
F	Jericho Path
G	Surf Dr East
H	Menauhant Rd at Acapesket Neck
I	Little Harbor Rd
J	Gardiner Rd
K	Gosnold Rd
L	Surf Dr West
M	Surf Dr Center
N	Menauhant Rd at Green Pond
O	Teaticket Path
P	Menauhant Rd at Great Pond
Q	Old Dock Rd
R	Garnet Ave



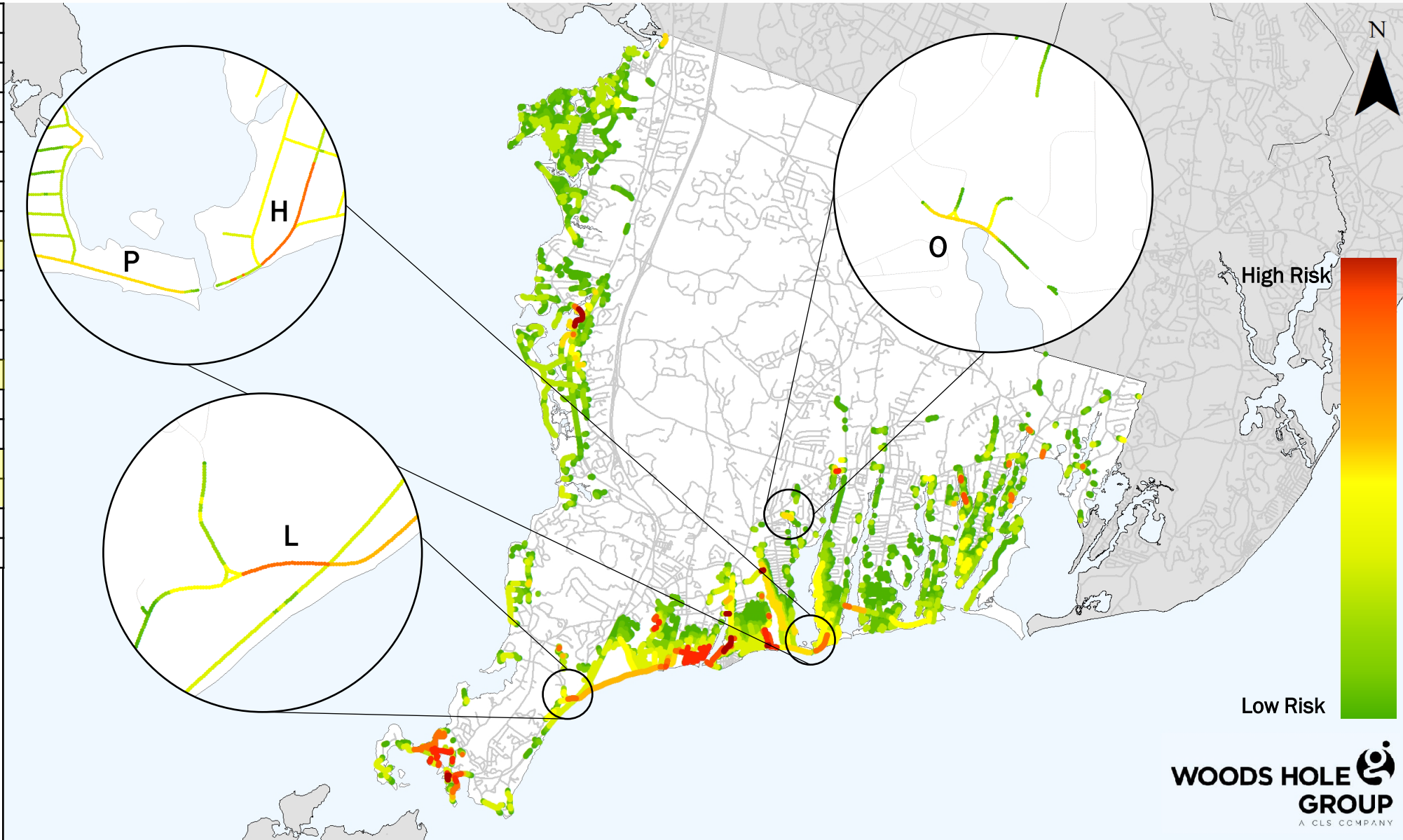
Low Lying Roads 2050 Risk Results

High Risk Road Segments	
A	Nashawena St
B	Millfield St West
C	Millfield St East
D	Clinton/Scranton Ave corner
E	Menauhant Rd at Little Pond
F	Jericho Path
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N	Menauhant Rd at Green Pond
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Low Lying Roads 2070 Risk Results

High Risk Road Segments	
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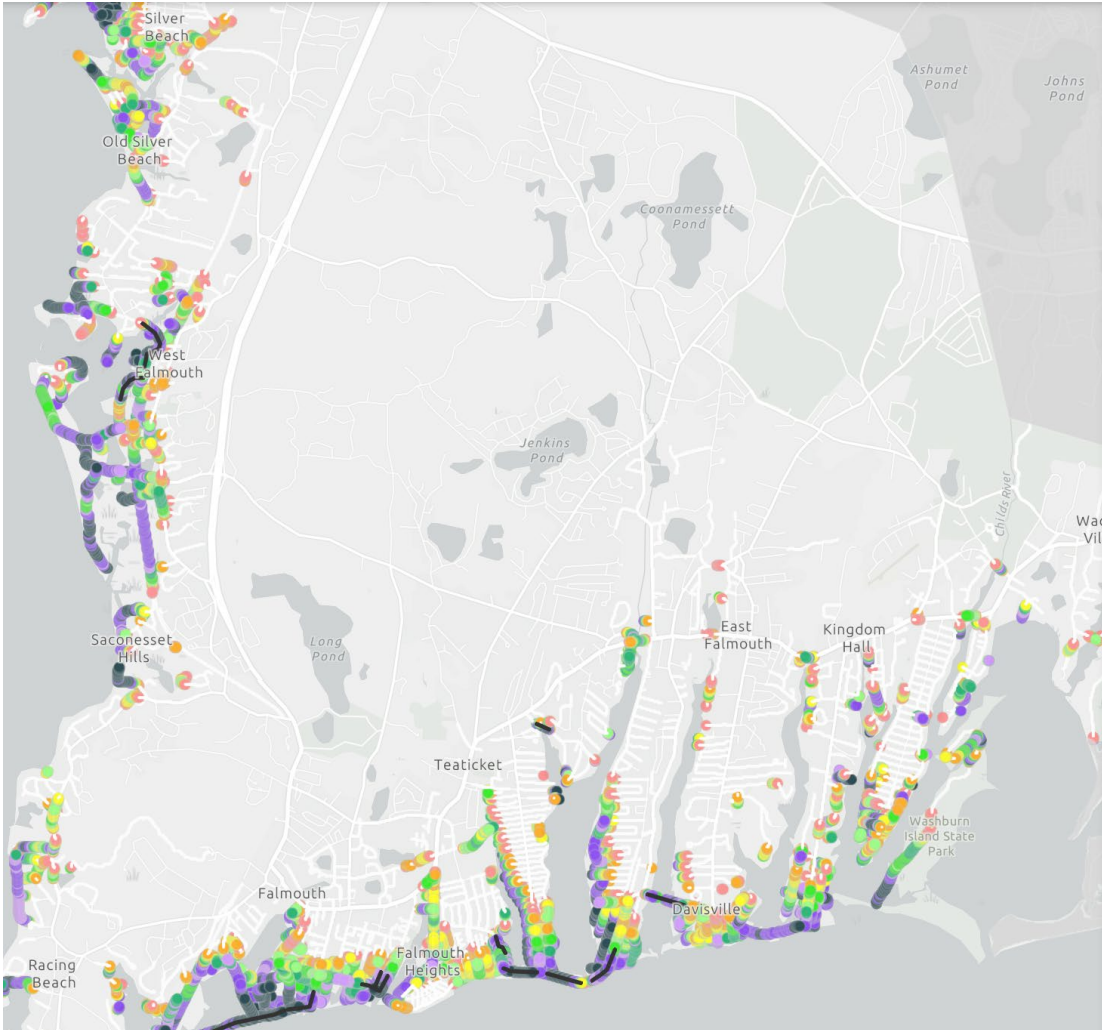
Summary of High Priority Road Segments

	Road Name	Length (ft)	Description	AEP 2030	Criticality Score	2030 Risk Score	Tidal Flooding Length (ft)		
							2030	2050	2070
A	Nashawena St	2140	along Snug Harbor	100	39	3900	0	180	1120
B	Millfield St West†	1520	west of Bell Tower including Spencer Baird Rd	100	38	3800	0	0	1400
C	Millfield St East†	480	east of Bell Tower to School St	100	38	3800	0	0	440
D	Clinton/Scranton Ave corner	1910	at Falmouth Harbor Entrance	100	35	3500	0	0	1300
E	Menauhant Rd at Little Pond	1200	behind Bristol Beach between Grand Ave and Maravista Ave	100	35	3500	0	540	1200
F	Jericho Path	500	at Little Pond between Lucerne Ave and Grand Ave	100	32	3200	0	20	340
G	Surf Dr East†	1310	corner of Surf Dr and Shore St at Town Beach	100	28	2800	0	0	440
H	Menauhant Rd at Acapesket Neck	1420	east of Great Pond Bridge to Bayview Ave	100	23	2300	0	0	900
I	Little Harbor Rd†	650	behind USCG Woods Hole	100	22	2200	0	0	460
J	Gardiner Rd†	1140	between Gosnold Rd and Park St	100	22	2200	360	480	1100
K	Gosnold Rd†	770	behind Stoney Beach	100	22	2200	0	0	440
L	Surf Dr West†	2090	between Oyster Pond Rd and Elm Rd	100	22	2200	0	0	1180
M	Surf Dr Center†	3820	along Salt Pond between Elm Rd and Bywater Ct	100	19	1900	0	20	4220
N	Menauhant Rd at Green Pond	1320	bridge between Acapesket Rd and Green Harbor Rd	100	17	1700	0	0	720
O	Teaticket Path	500	at top of Perch Pond between Norris Path and Seabrook Dr	100	17	1700	0	340	540
P	Menauhant Rd at Great Pond	1420	west of Great Pond Bridge to Maravista Ave	100	17	1700	0	40	1160
Q	Old Dock Rd	1260	by West Falmouth Harbor landing	100	17	1700	0	260	580
R	Garnet Ave	630	along Squeteague Harbor at Bourne line	100	17	1700	0	160	520

†Existing planning work underway

LOW LYING ROADS

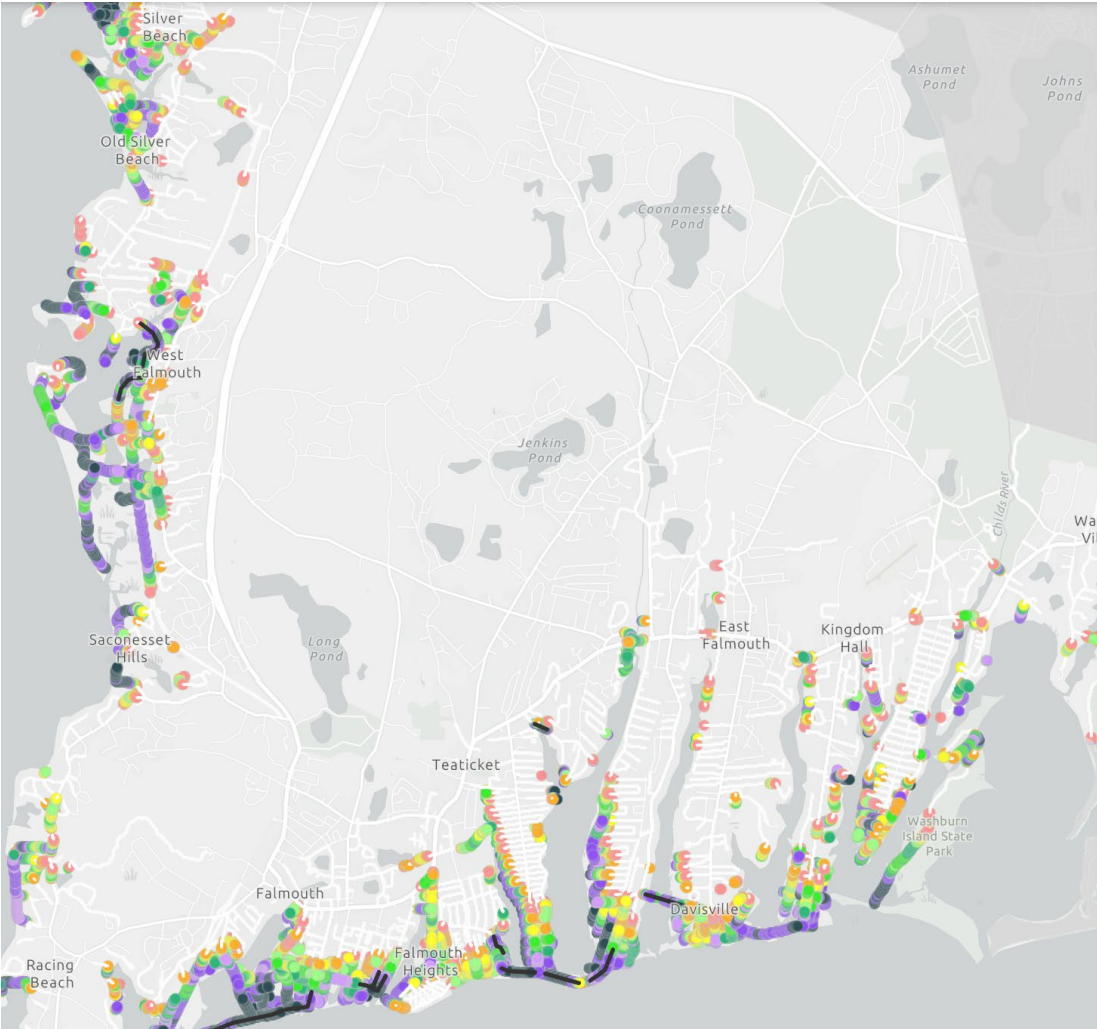
Group Discussion



DISCUSSION ORIENTATION

LOW LYING ROADS

Group Discussion



DISCUSSION QUESTIONS

1. Are you more concerned with high tide flooding or storm flooding?
2. What local knowledge or concerns can you bring to the discussion?
3. How would you prioritize these road segments?

Summary of High Priority Road Segments

	Road Name	Length (ft)	Description	AEP 2030	Criticality Score	2030 Risk Score	Tidal Flooding Length (ft)		
							2030	2050	2070
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J	Gardiner Rd†	1140	between Gosnold Rd and Park St	100	22	2200	360	480	1100
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L	Surf Dr West†	2090	between Oyster Pond Rd and Elm Rd	100	22	2200	0	0	1180
M	Surf Dr Center†	3820	along Salt Pond between Elm Rd and Bywater Ct	100	19	1900	0	20	4220
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R	Garnet Ave	630	along Squeteague Harbor at Bourne line	100	17	1700	0	160	520

†Existing planning work underway

NEXT STEPS

- Town staff to select 2 road segments
- Site visits and feasibility analysis
- 3 solutions + costs per segment
- 2nd Workshop date TBD – spring 2024
- Materials available to view on Low Lying Road webpage:
<https://www.capecodcommission.org/our-work/low-lying-roads-project/>



Low Lying Roads: Falmouth

Home > Work > Low Lying Roads: Falmouth

Start Date: 2023

[Low Lying Roads Project Homepage](#), learn more about the background and process.

Overview

Map Viewer

Overview

The Cape Cod Commission is working with all 15 Cape towns, including the **Town of Falmouth**, to examine vulnerabilities in the roadway network and identify solutions

NEXT MEETINGS

THURSDAY

MAY 18, 2023

Falmouth Low-lying Roads Public Meeting

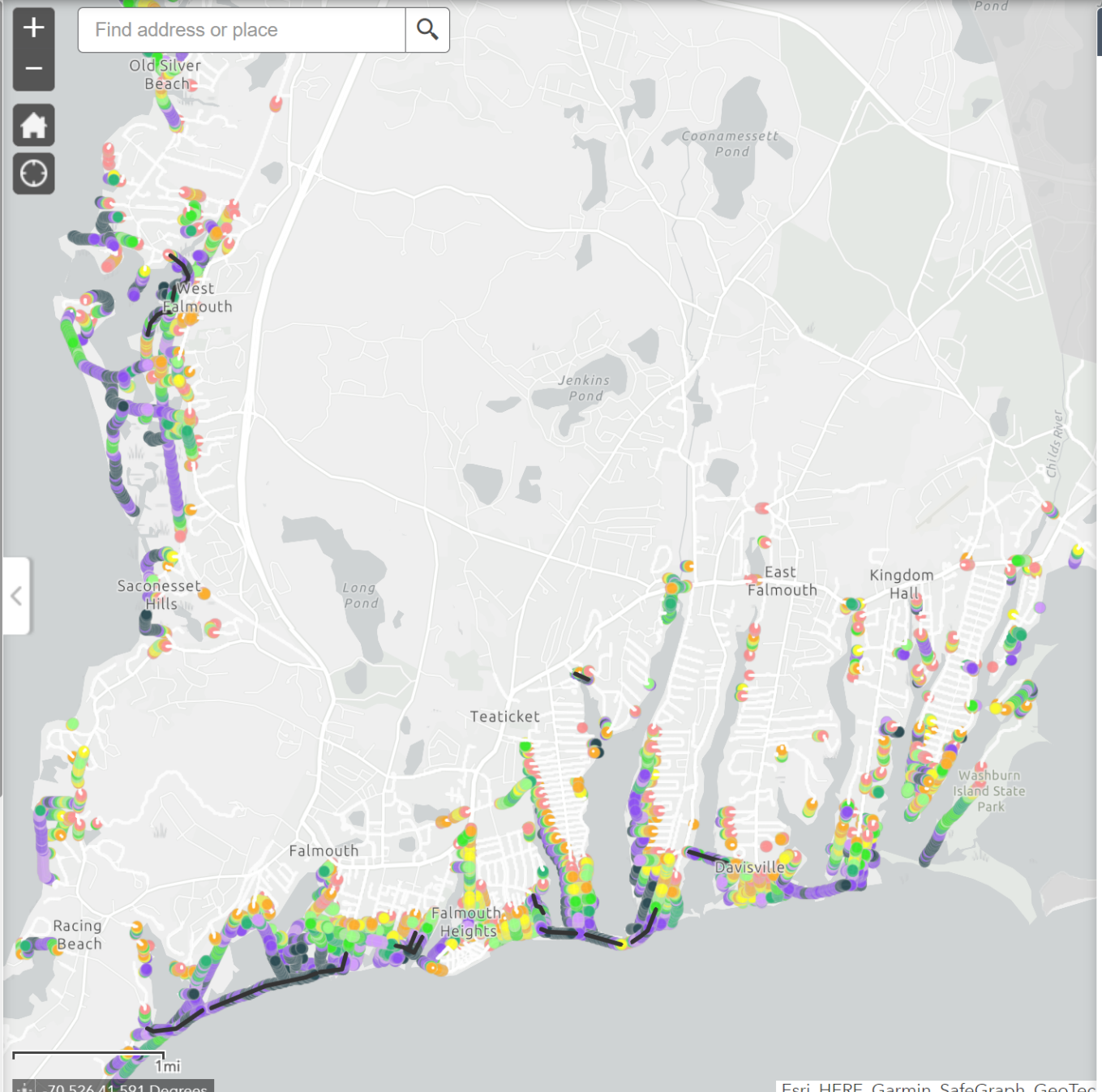
START TIME: 5:00 PM

ABOUT

With funding support from the Massachusetts Municipal Vulnerability Preparedness (MVP) program, the Commission has contracted with the Woods Hole Group (WHG) to conduct a vulnerability assessment of roadway segments, bridges, and culverts due to flooding from the combined effects of sea level rise and storm surge. WHG will employ the state-of-the-art Massachusetts Coast Flood Risk Model (MC FRM) to identify vulnerable road segments under different sea level rise scenarios and time scales. One output from this work is a projection of the probability and extent of flooding at defined future planning horizons, 2030, 2050, and 2070.

NAVIGATION

- Click the Legend to show the map key
 - Open the Layers to turn on more contextual features or create new suggestions
 - Use the Editor to provide feedback
 - Change Base Maps
 - Bookmarks help navigate Top Vulnerable Roads
 - Click on a feature to see more information. You may need to click through multiple pop ups
- (1 of 7)



Legend

Falmouth Top Vulnerable Roads



Coastal Erosion Comments



Coastal Flooding Comments



Town mask



Falmouth 2030 Inundation Probability

- Prob_2030
- 100% (Black circle)
 - 20% (Purple circle)
 - 10% (Light purple circle)
 - 5% (Green circle)
 - 2% (Light green circle)
 - 1% (Yellow-green circle)
 - 0.5% (Yellow circle)
 - 0.2% (Orange circle)
 - 0.1% (Red circle)
 - 0 (White circle)

Tell Us What You Think!

Are there roads in town that have FLOODING or EROSION issues? How high of a priority do you think it is to address the issue? Follow the steps below:

THANK YOU!
