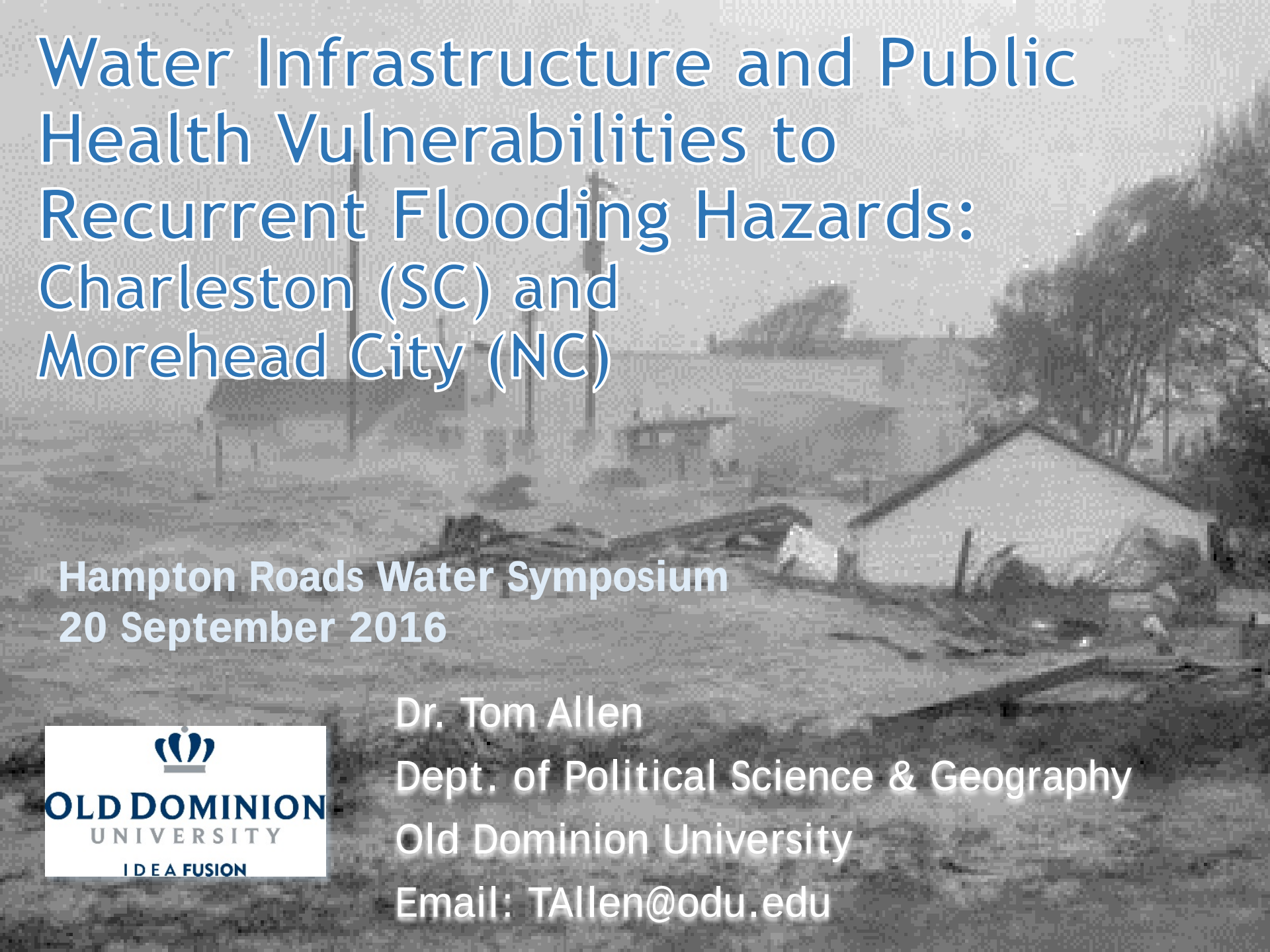
Water Infrastructure and Public Health Vulnerabilities to Recurrent Flooding Hazards: Charleston (SC) and Morehead City (NC)



Hampton Roads Water Symposium
20 September 2016

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Old Dominion University
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Two Cities with Recurrent Coastal Flooding

Morehead City

Charleston

Front Street, Beaufort, NC

NC Seafood Festival 2015

"Joaqueaster"

Source: KingTides NC Flickr https://www.flickr.com/photos/135620779@N07/with/21604340438/

Increasing Threats

- Coastal community water infrastructure is increasingly vulnerablility:
  - King tides
  - Storm surges
  - Urban flash flooding from extreme precipitation
  - Ground water elevation and salt water intrusion
  - Extreme heat
  - Mosquito and other vector-borne diseases
  - Water quality impairment and sanitation

Connecting Flooding and Community Health

Health Impacts

- Physical injuries (including drowning)
- Allergies (mold)
- Food and water-borne illnesses
- Food security
- Displacement
- Mental health issues
- Interruption of emergency services

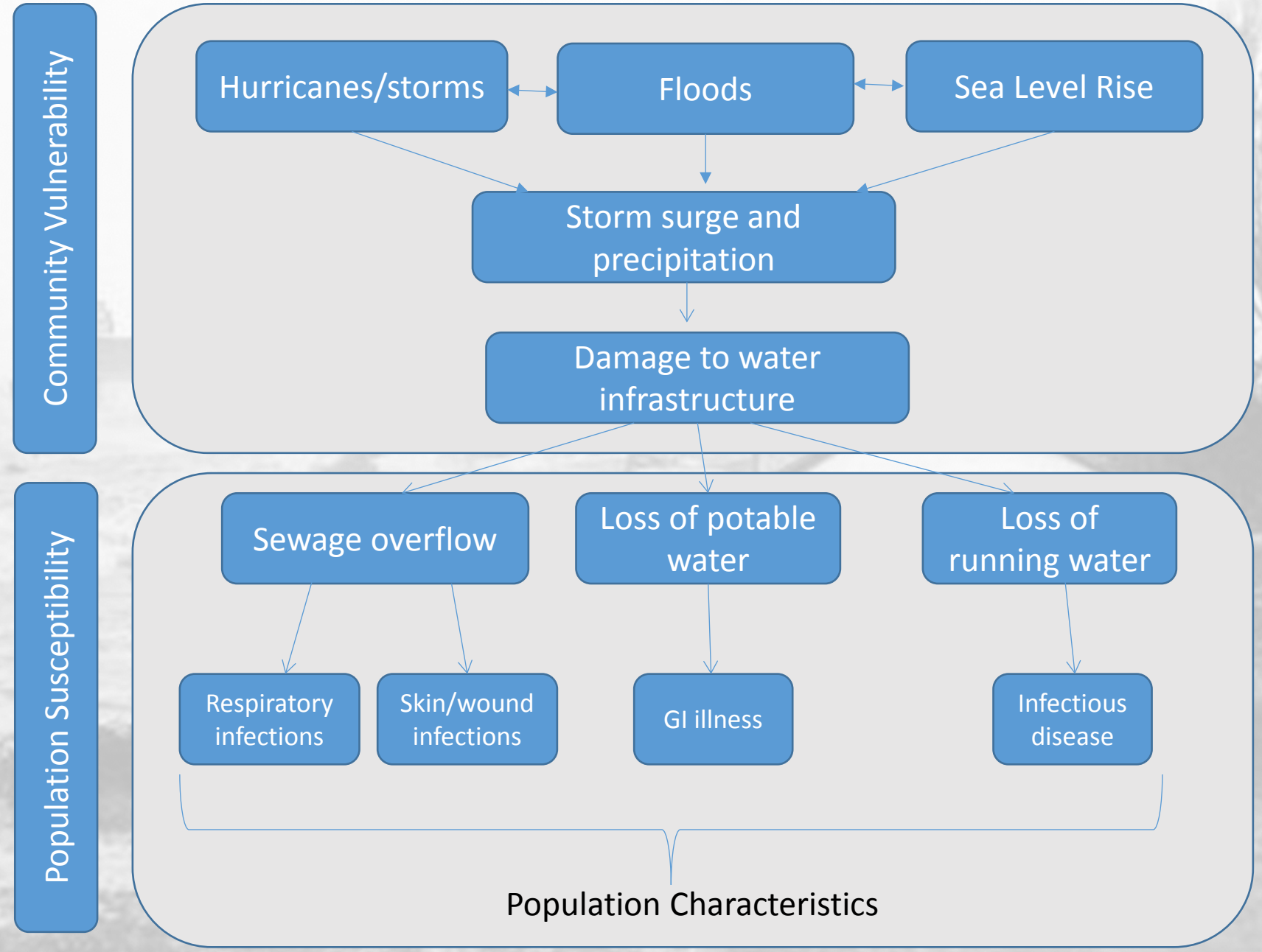
Impacts on Water Quality

- Disruption of and damage to water supply/sewage systems
- Overflow of toxic waste sites
- Waterborne infections
- Expanded range of vector habitats and vector borne diseases
- Contamination of recreational areas

Coastal Water Infrastructure

- Water supply
  - Wells, salinization, pumping and aquifer depression
- Wastewater
  - Sewage overflows
  - Onsite wastewater treatment systems
- Storm water
  - Contaminated runoff, nuisance flooding
- Green infrastructure
  - Ecosystem goods and services affecting health or flooding impacts

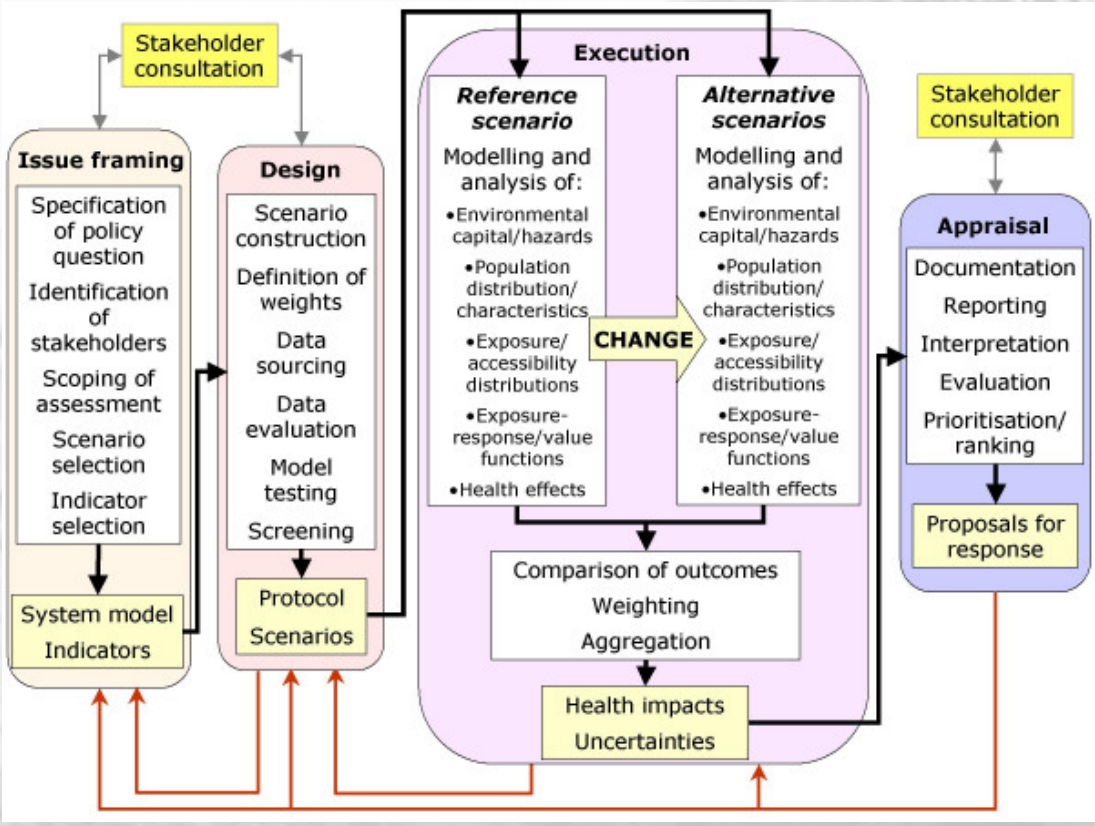
Logic Model


Community Vulnerability
Hurricanes/storms
Floods
Sea Level Rise
Storm surge and precipitation
Damage to water infrastructure
Population Susceptibility
Sewage overflow
Loss of potable water
Loss of running water
Respiratory infections
Skin/wound infections
GI illness
Infectious disease
Population Characteristics

Susceptibility Index

Likelihood of being affected by a particular hazard.

- To be shaped by stakeholders
- To include
  - Vulnerable populations
  - Vulnerable activities
  - Vulnerable infrastructure
- Vulnerable activities
  - Boating, kayaking, paddle-boarding
  - Fishing
  - Tourism facilities
  - Medical facilities
  - Transportation
  - Basic hygiene
- Information utility
  - Public health
  - Emergency management
  - Planning
  - Public utilities



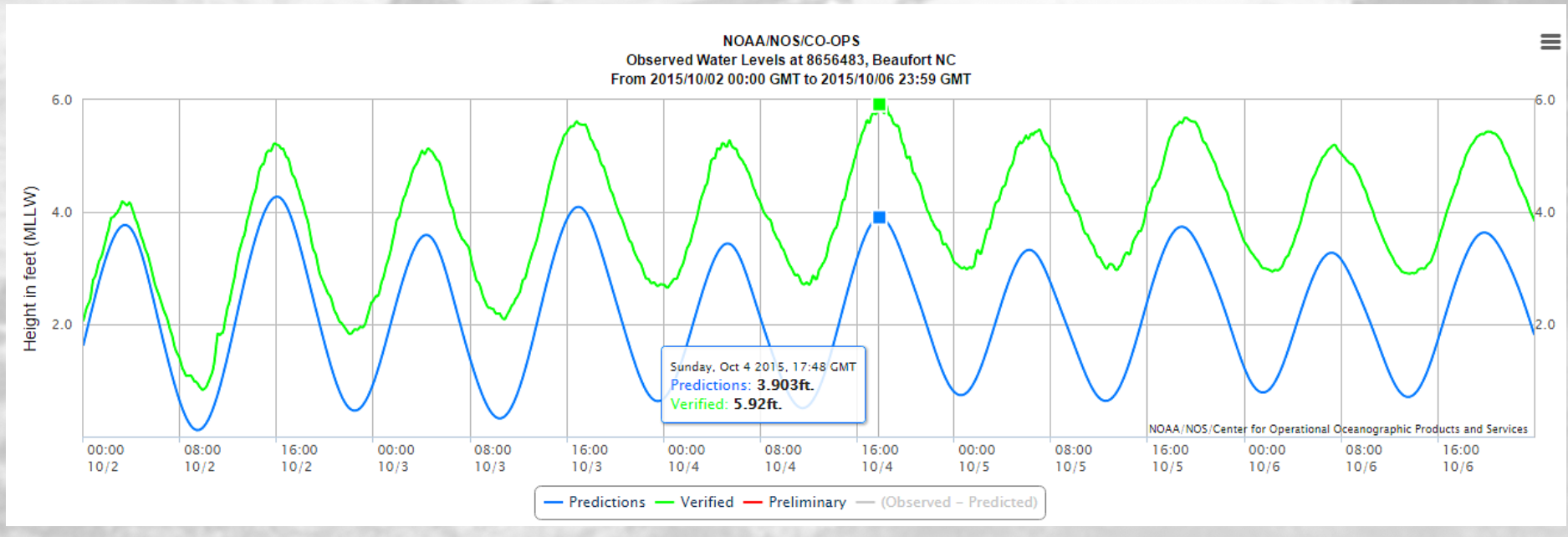
Briggs (2008) Integrated Environmental Health Impact Assessment

Geospatial Hazard Modeling

- Nuisance flooding
  - King tides
- Storm surges
  - SLOSH
- Extreme rainfall and storm water runoff
  - TauDEM Spatial Hydrology Model
- Onsite Wastewater Treatment Systems (OWTS)
  - Sea level rise
    - Marine inundation
    - Groundwater elevation
- Direct and indirect human health impacts
  - Mosquito blooms and infectious disease
  - Waterborne diseases
  - Shellfish sanitation and beach/waterway closures

Nuisance Flooding

"There has been a significant increase of nuisance flooding occurrences…largely in response to high regional RSLR rates (~3-5mm/yr) from vertical land subsidence…." (Sweet *et al.* 2014) and multi-decadal cycles of the North Atlantic and anomalies in the Gulf Stream (Ezer 2014)

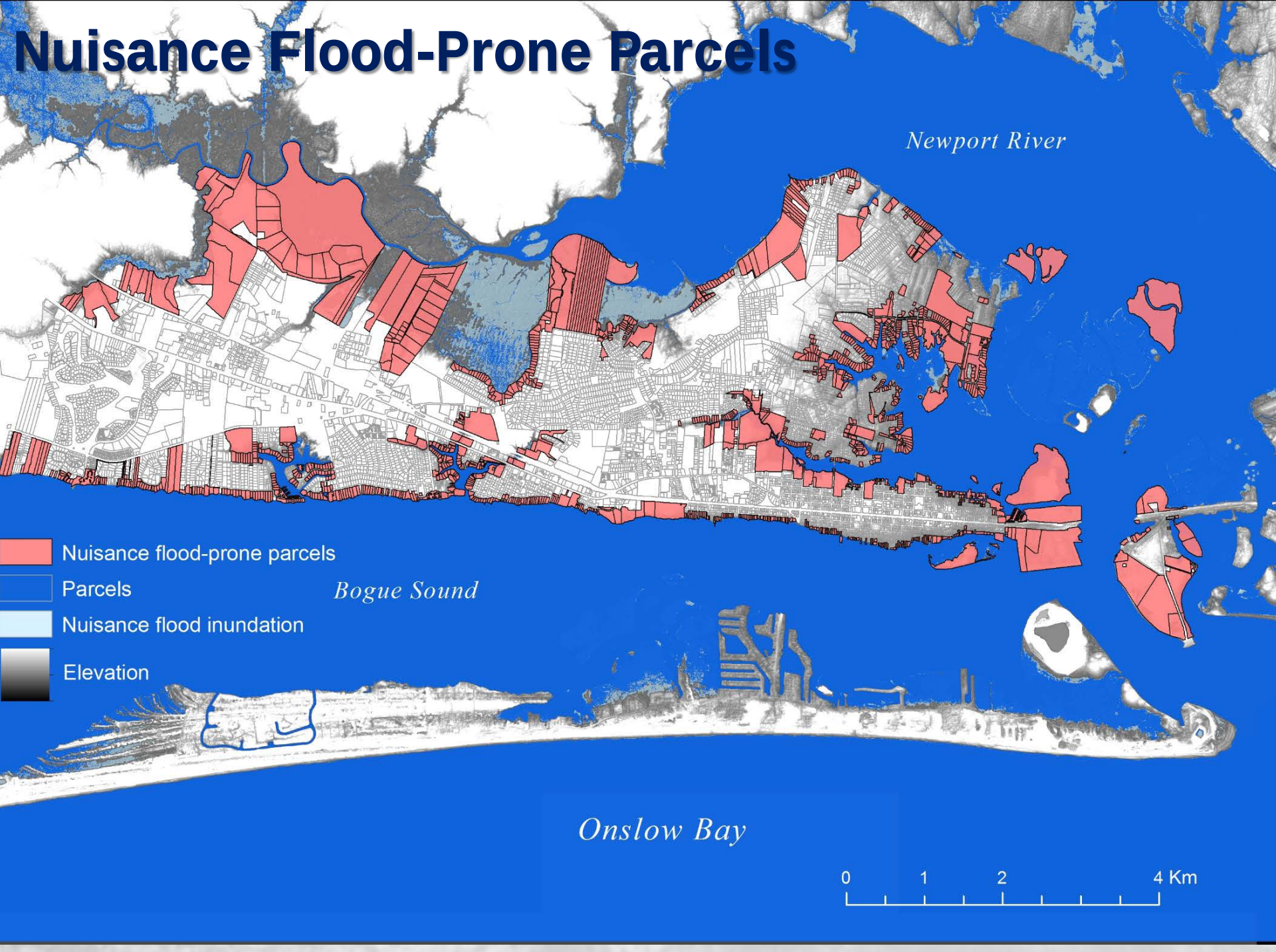


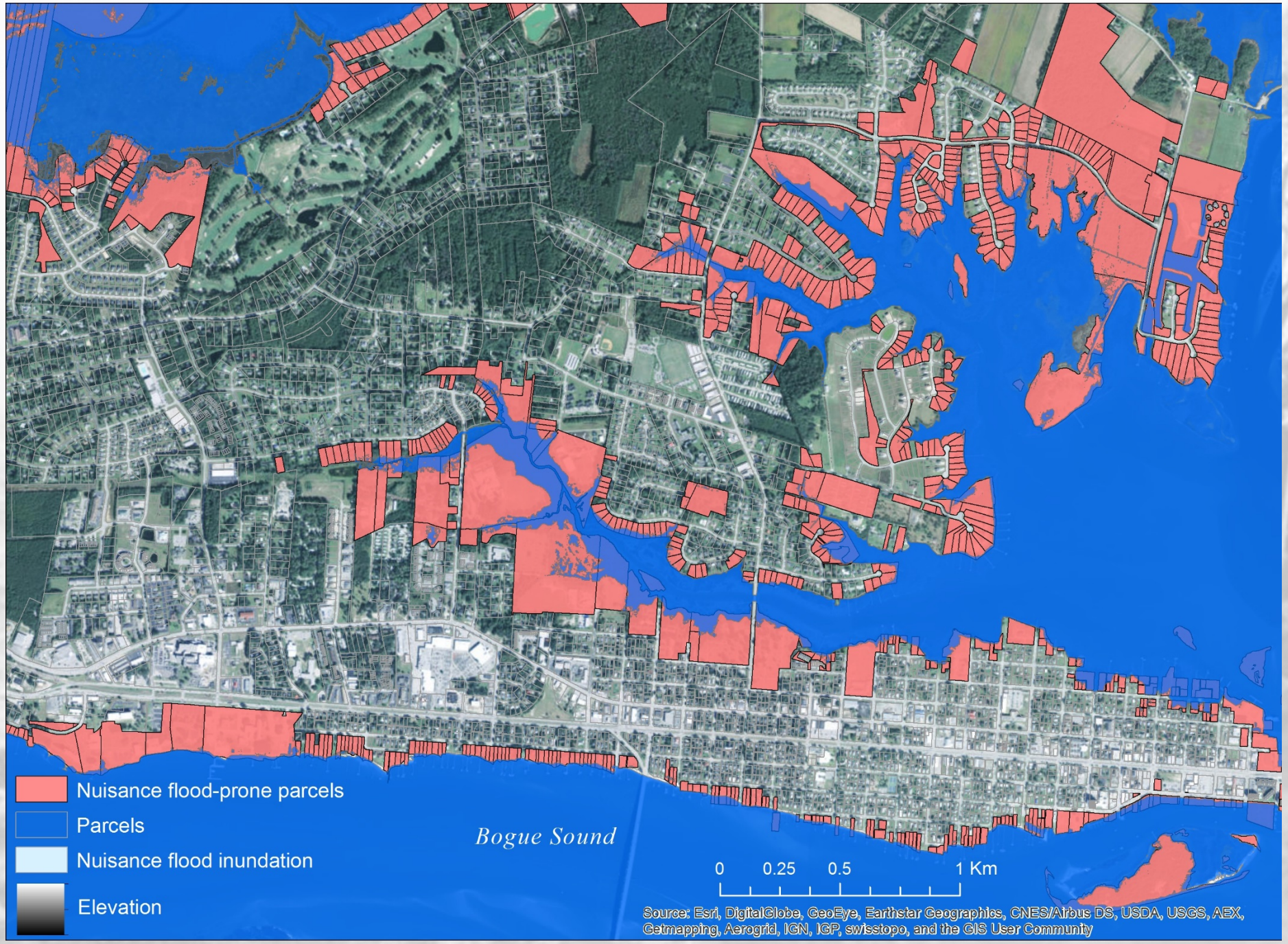
Nuisance Flooding

- Mean Higher High Water (MHHW) +0.29m
- Affects ~1,600 parcels directly (~10,000 city+ ETJ)
- $812M assessed value

Parcel Type	Parcel Count	% of Parcels	% of Area
Residential	5416	54.7	30.3
Condo	1088	11.0	0.4
Commercial	647	6.5	9.4
Townhouse	299	3.0	0.2
Mobile Home	155	1.6	2.6
Church	71	0.7	0.9
Apartment	26	0.3	0.4
School	27	0.3	1.3
Other	2169	21.9	54.5

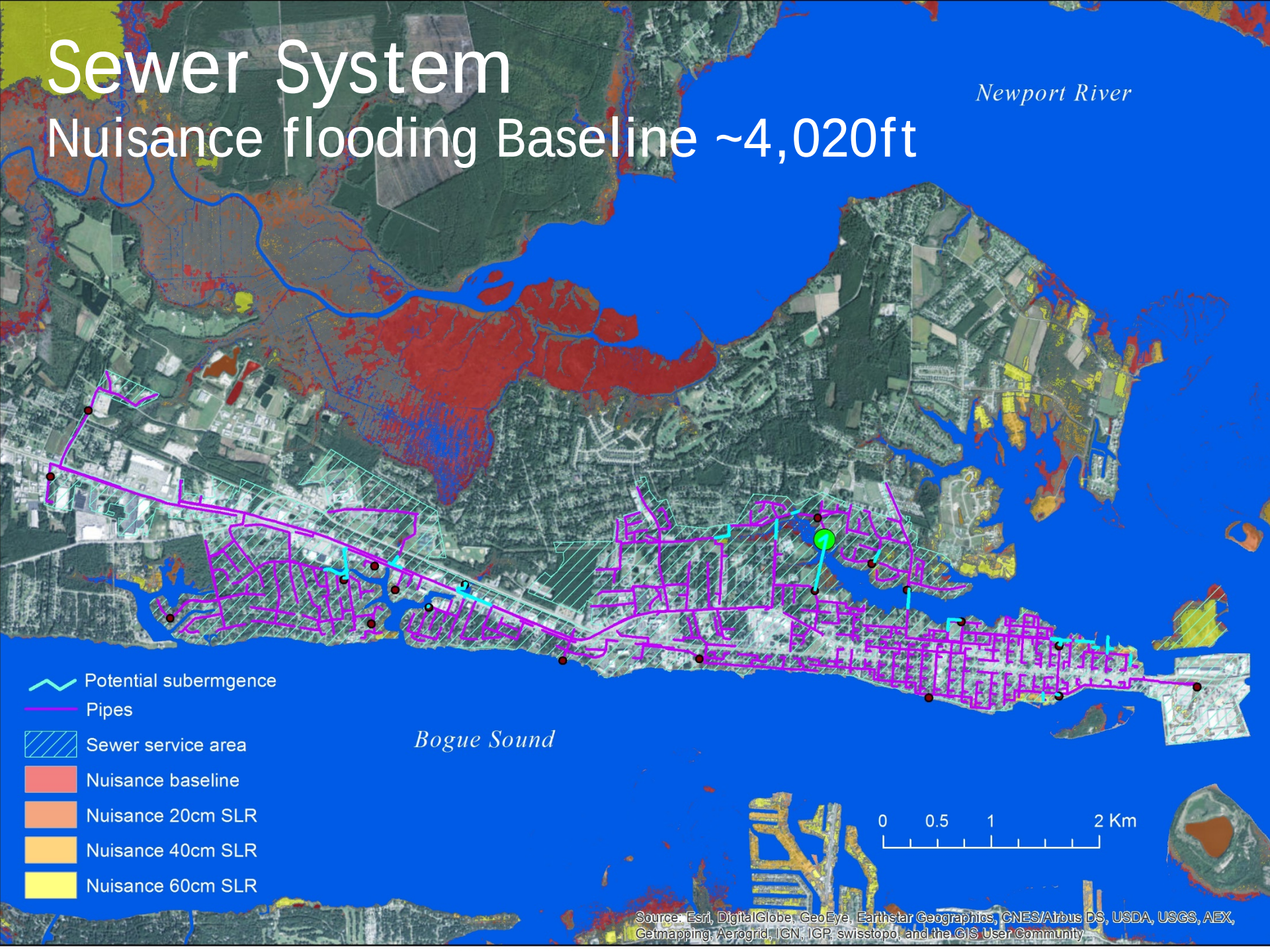
Nuisance Flood-Prone Parcels




Nuisance flood-prone parcels
Parcels
Nuisance flood inundation
Elevation
Bogue Sound
0
0.25
0.5
1 Km
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

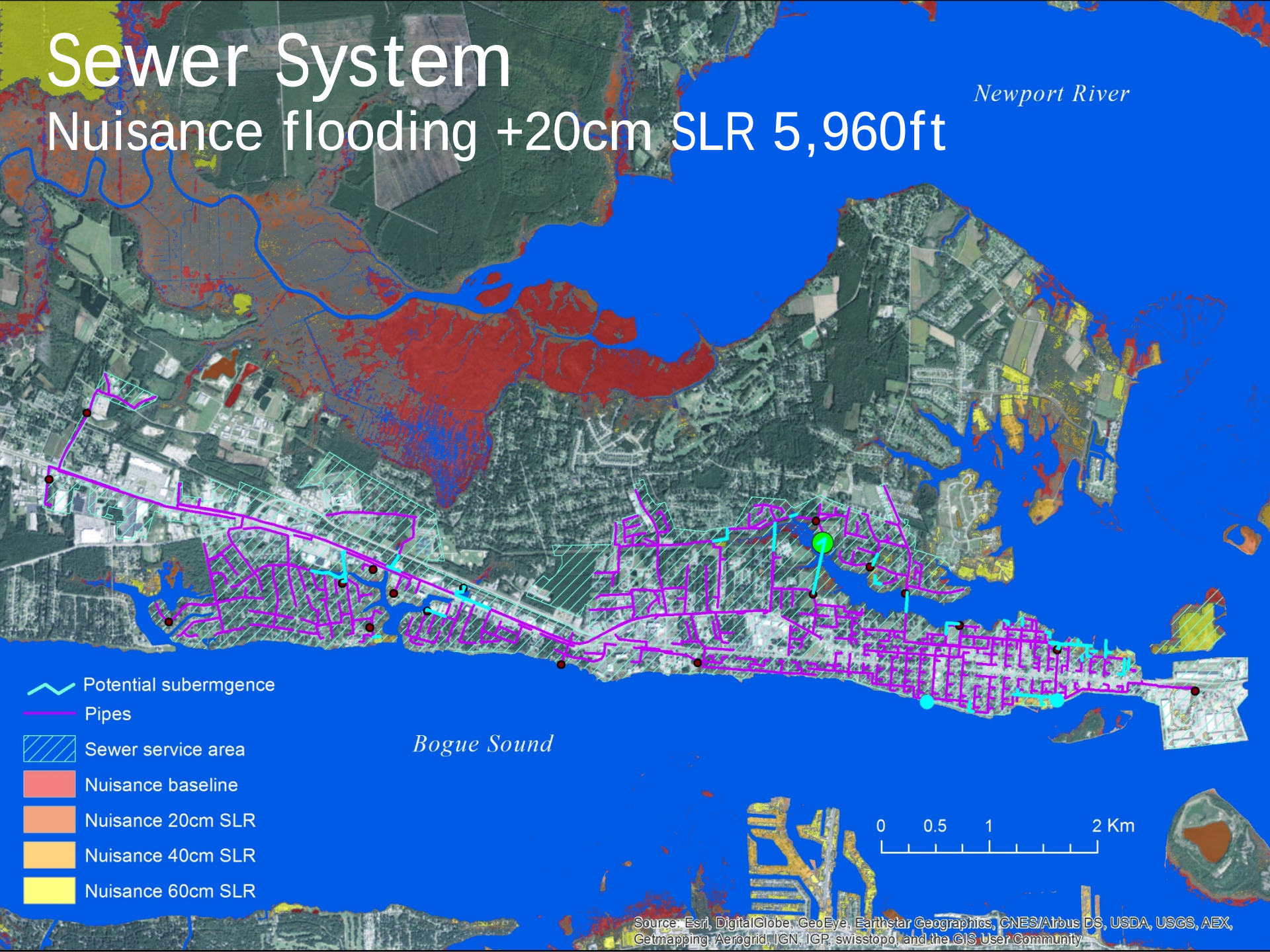
Sewer System

Nuisance flooding Baseline ~4,020ft



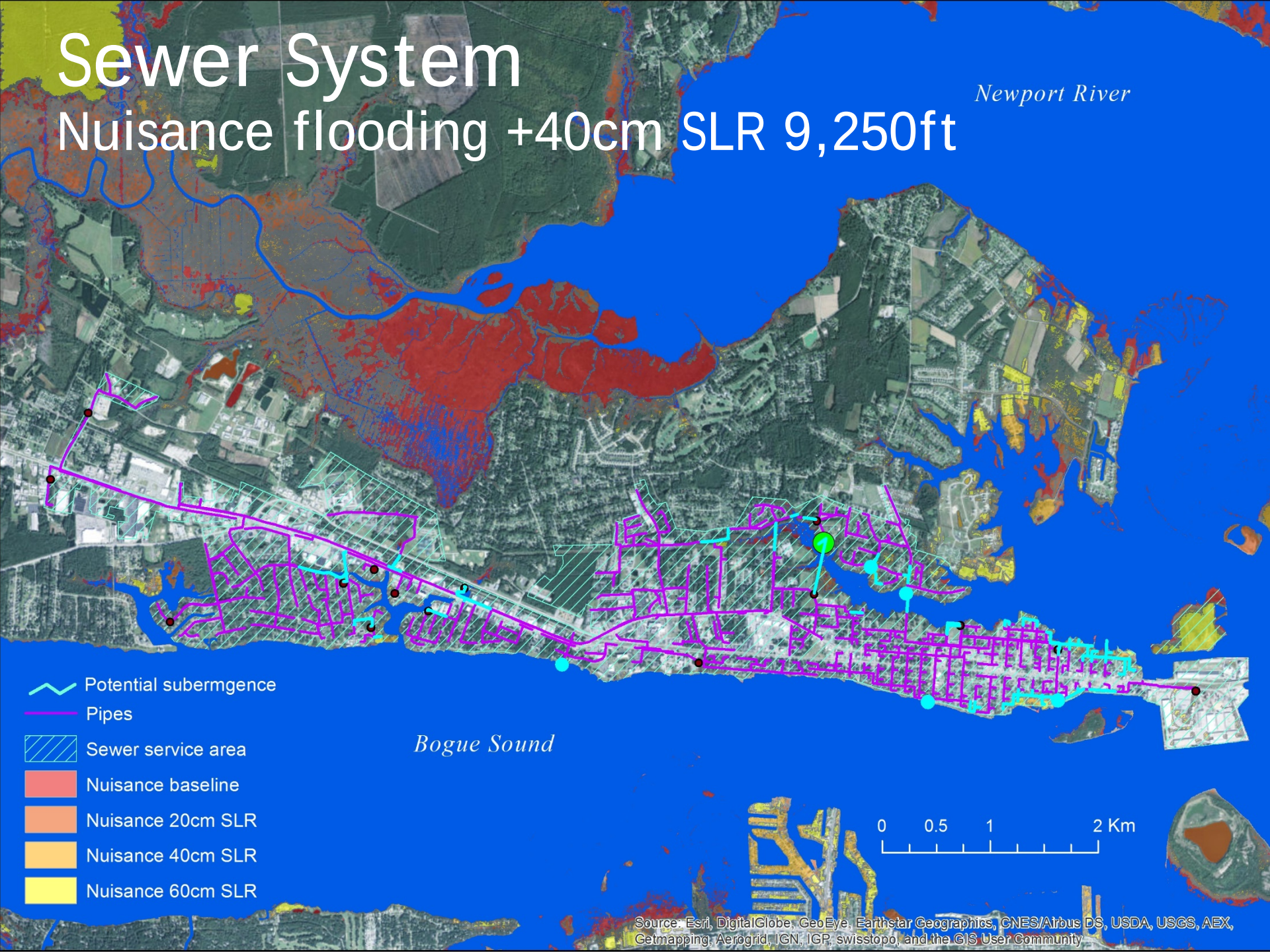
Sewer System

Nuisance flooding +20cm SLR 5,960ft



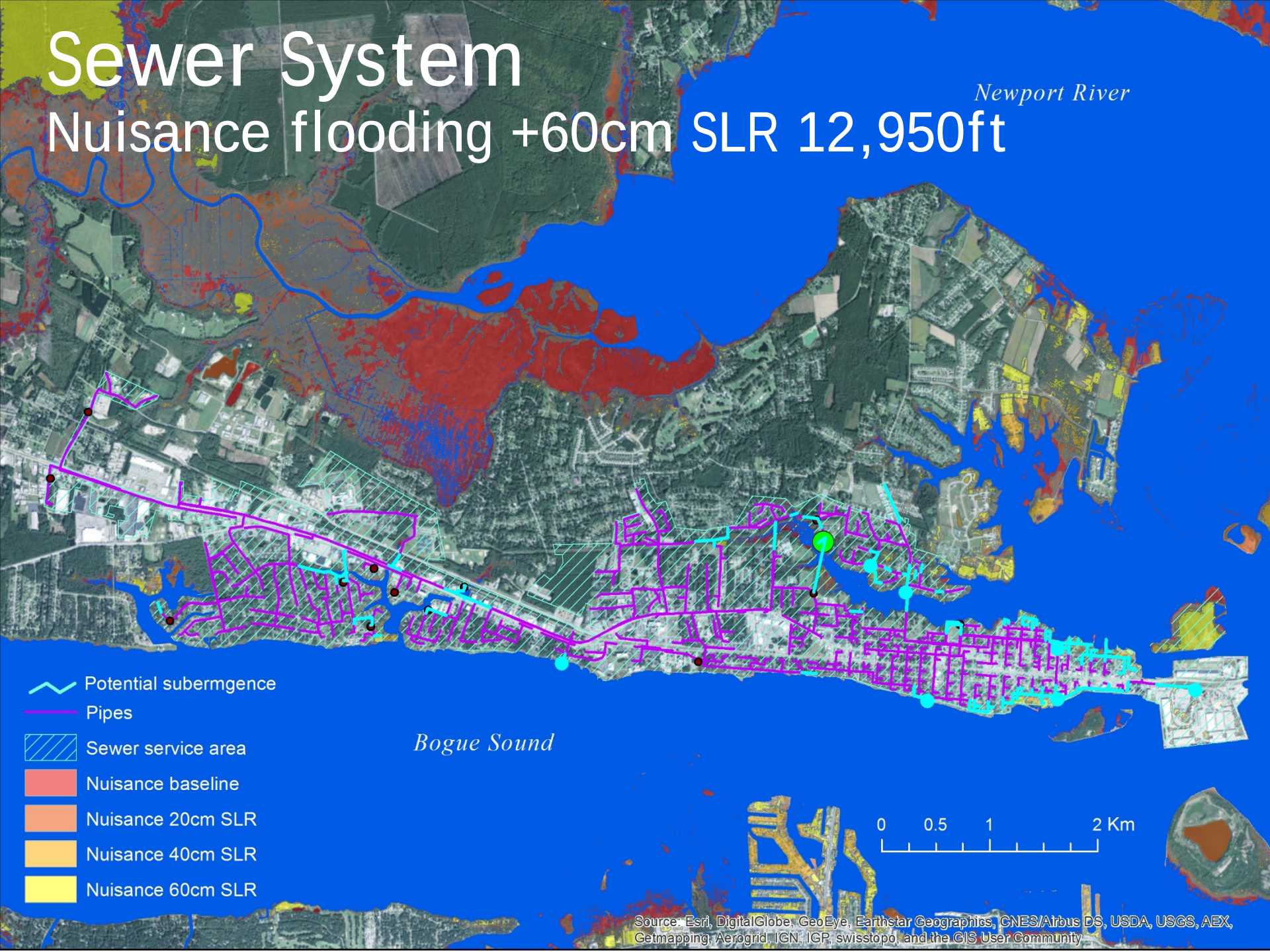
Sewer System

Nuisance flooding +40cm SLR 9,250ft

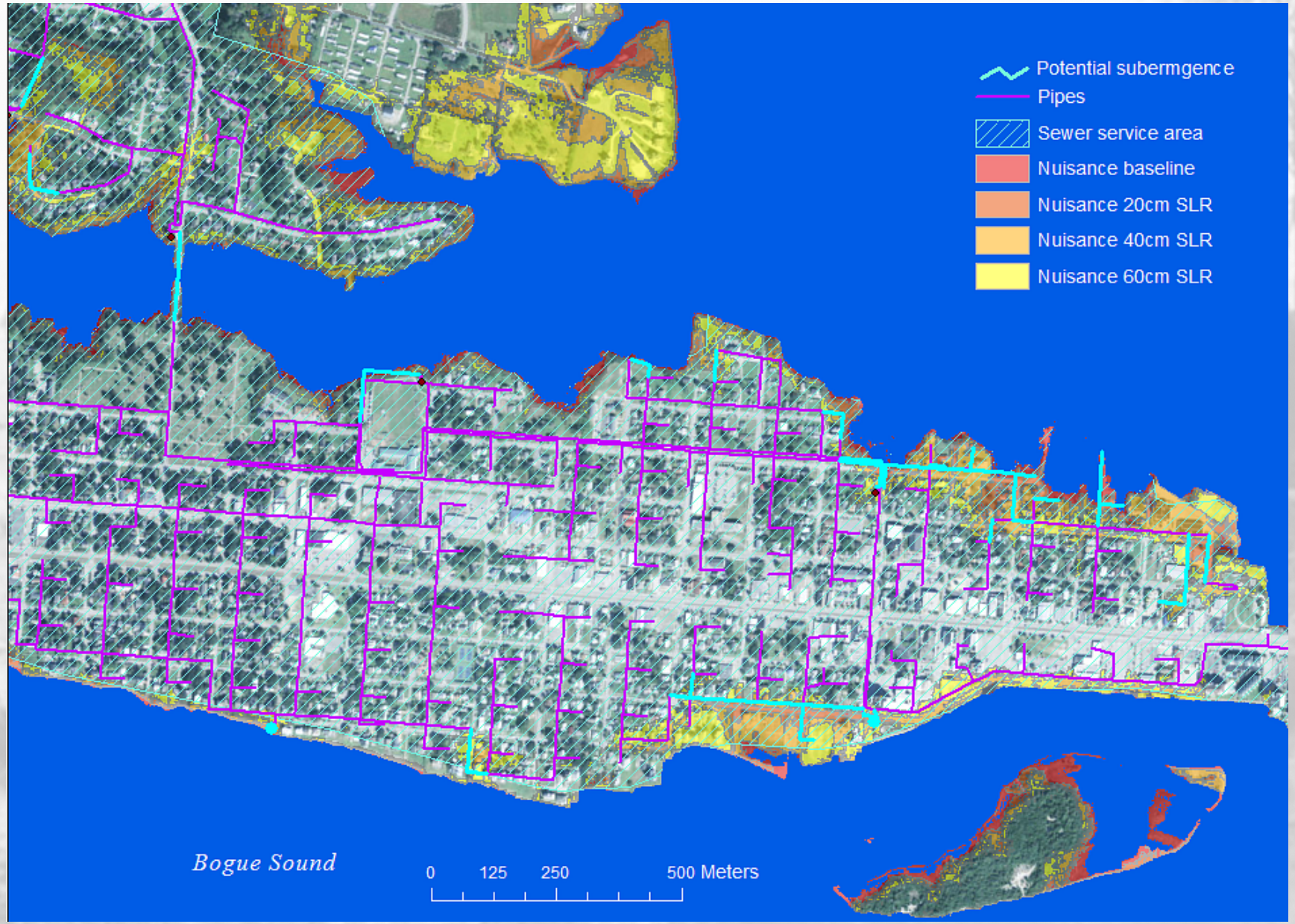


Sewer System

Nuisance flooding +60cm SLR 12,950ft

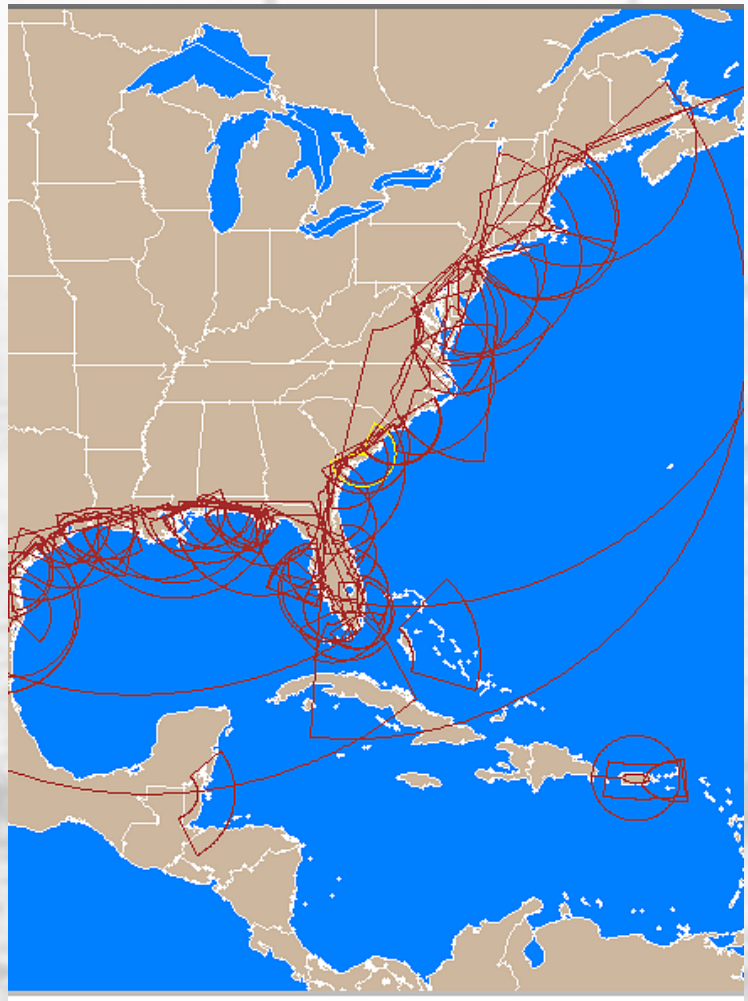


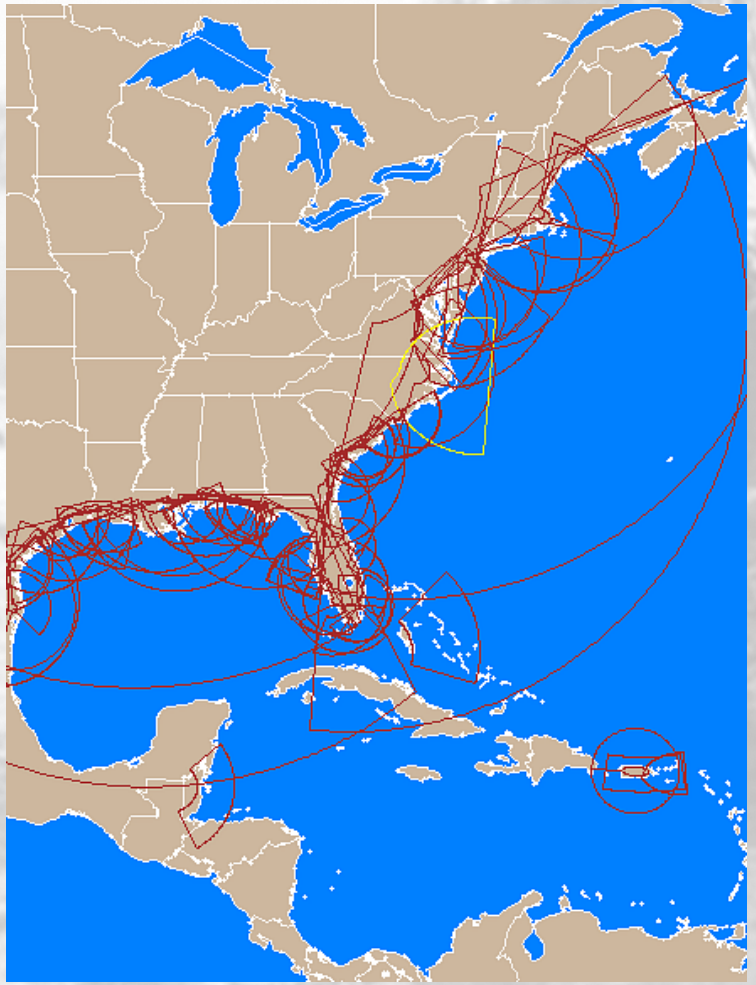
Zoom view- +20cm and 2 pump stations



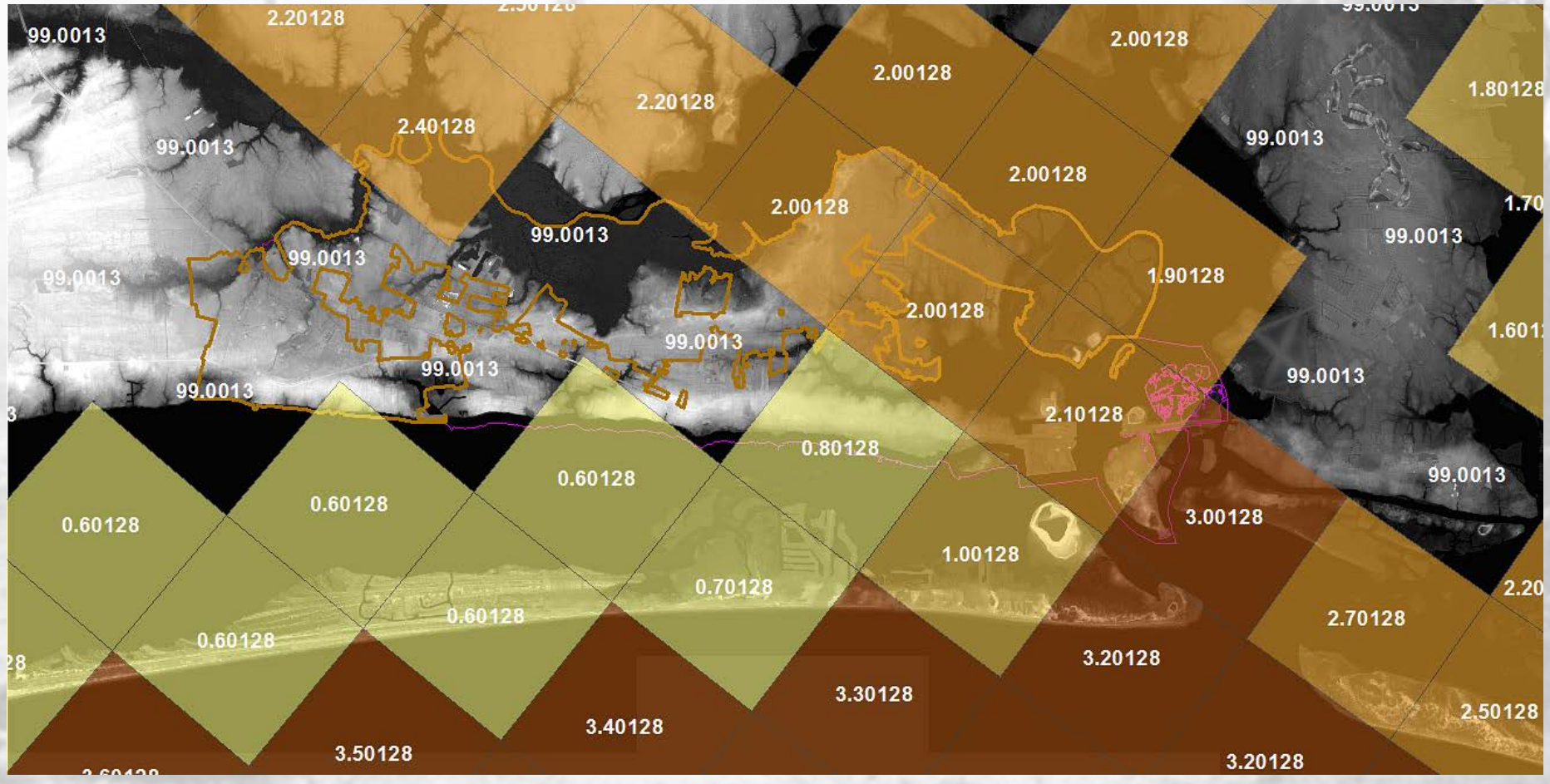
Storm Surge SLOSH Basins

Pamlico Sound (*ehatv2)* and Charleston Harbor (*hchs v2*)

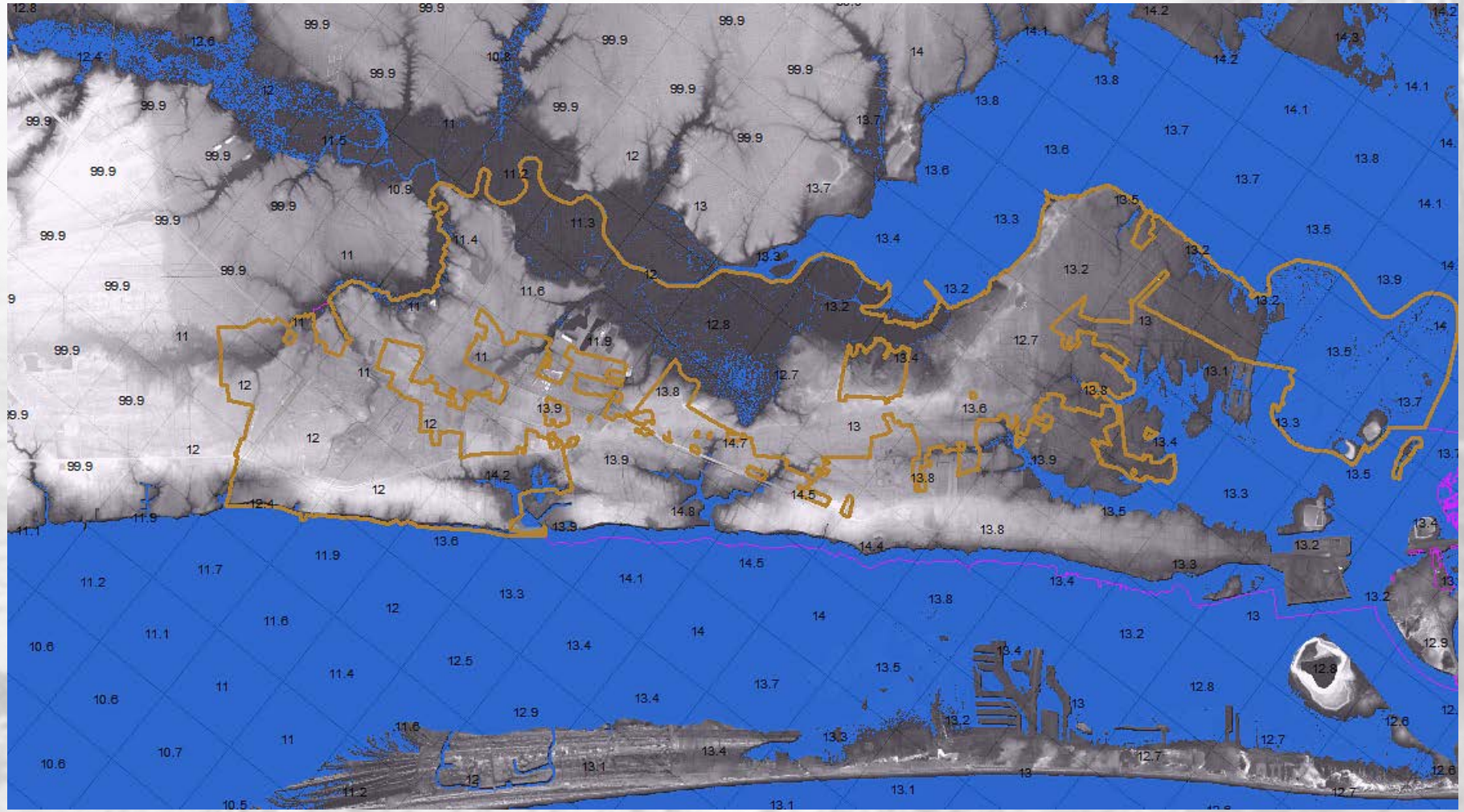




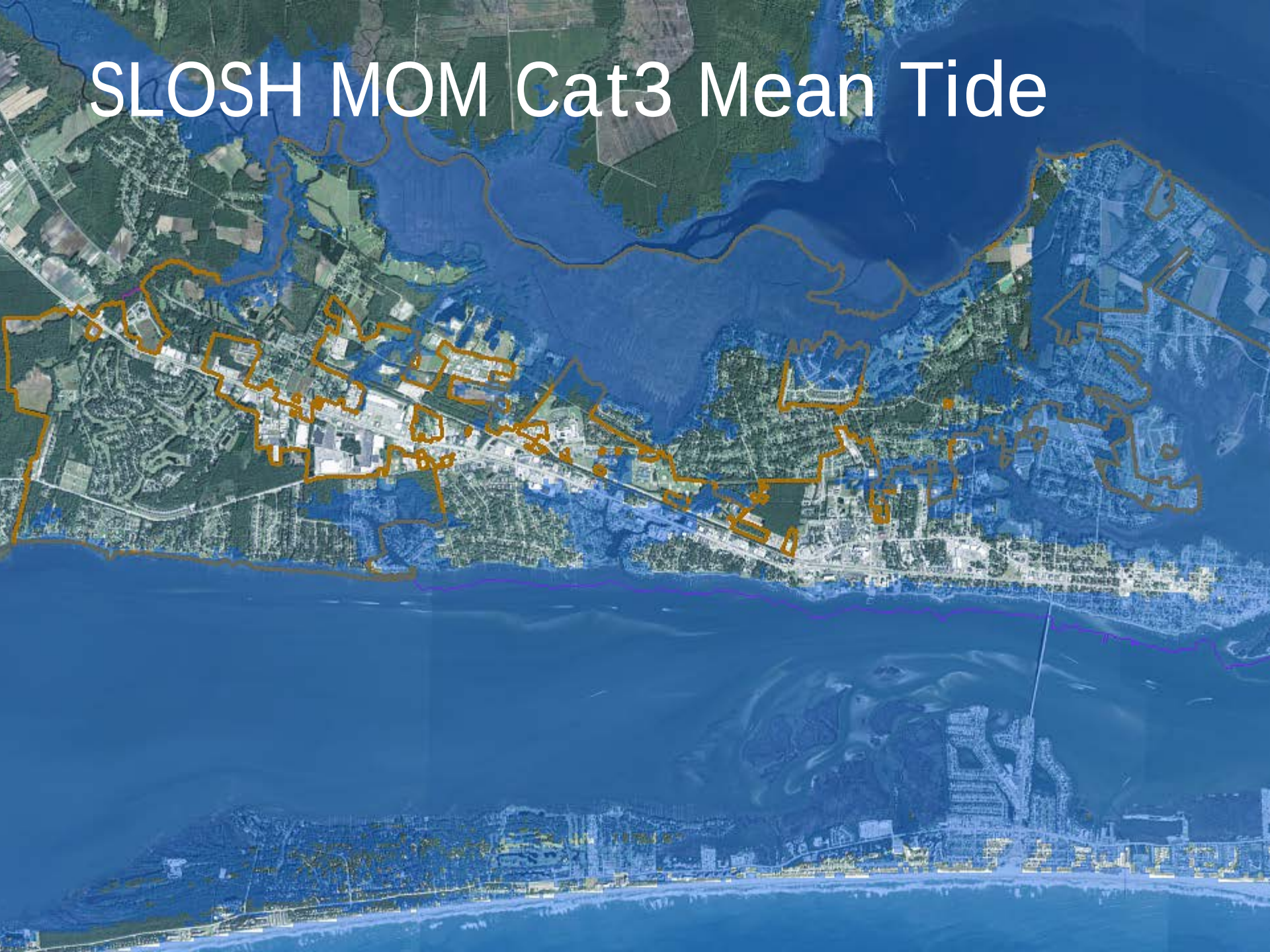
Downscaling SLOSH MOM Cat1 Storm Tide



SLOSH MOM Cat3 Mean tide inundation



SLOSH MOM Cat3 Mean Tide



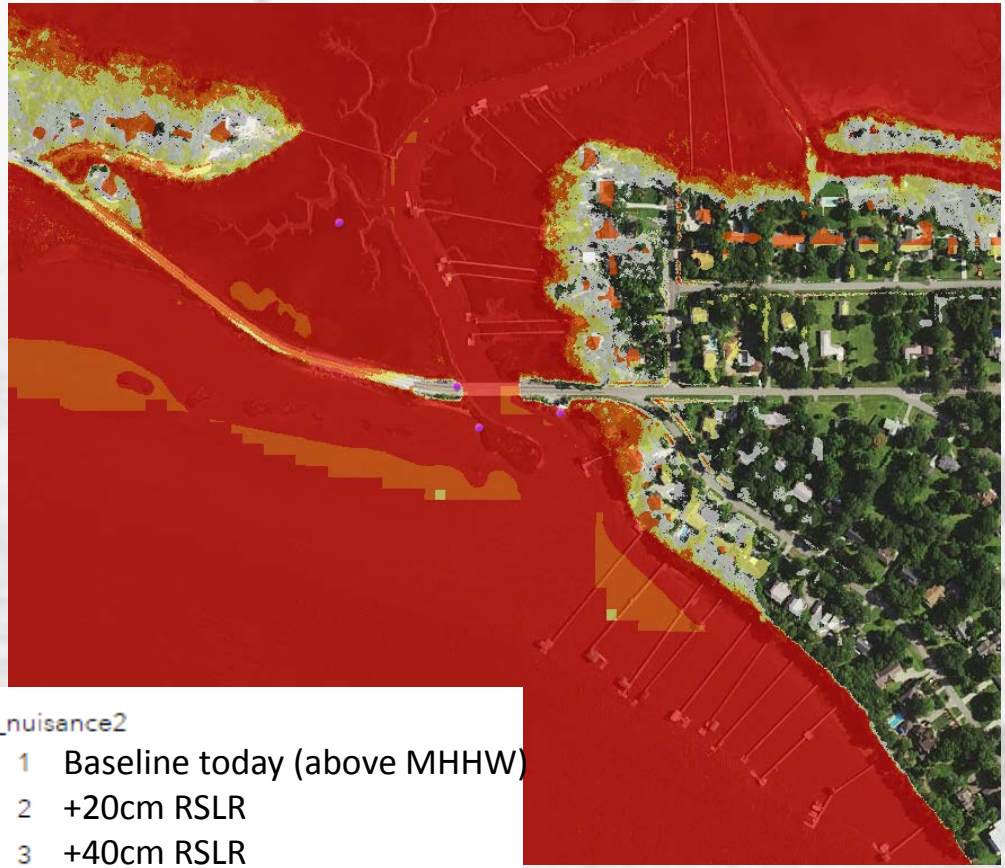
Calico Creek, MHC

N. 15th and Bridges St., MHC


Arendell St., MHC
QUALITY

Backflow and Tailwater

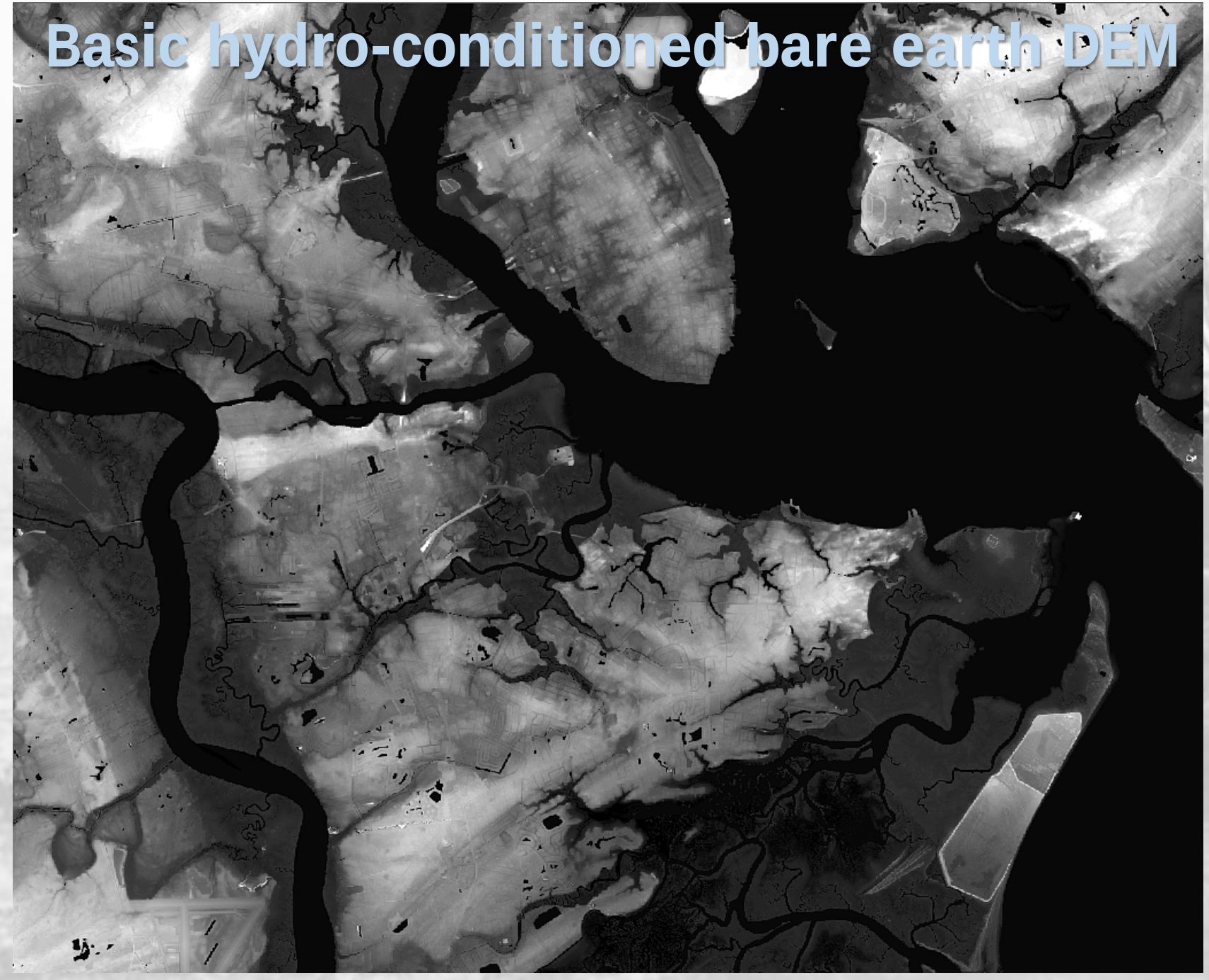
Charleston


CHS_nuisance2
1 Baseline today (above MHHW)
2 +20cm RSLR
3 +40cm RSLR
4 +60cm RSLR

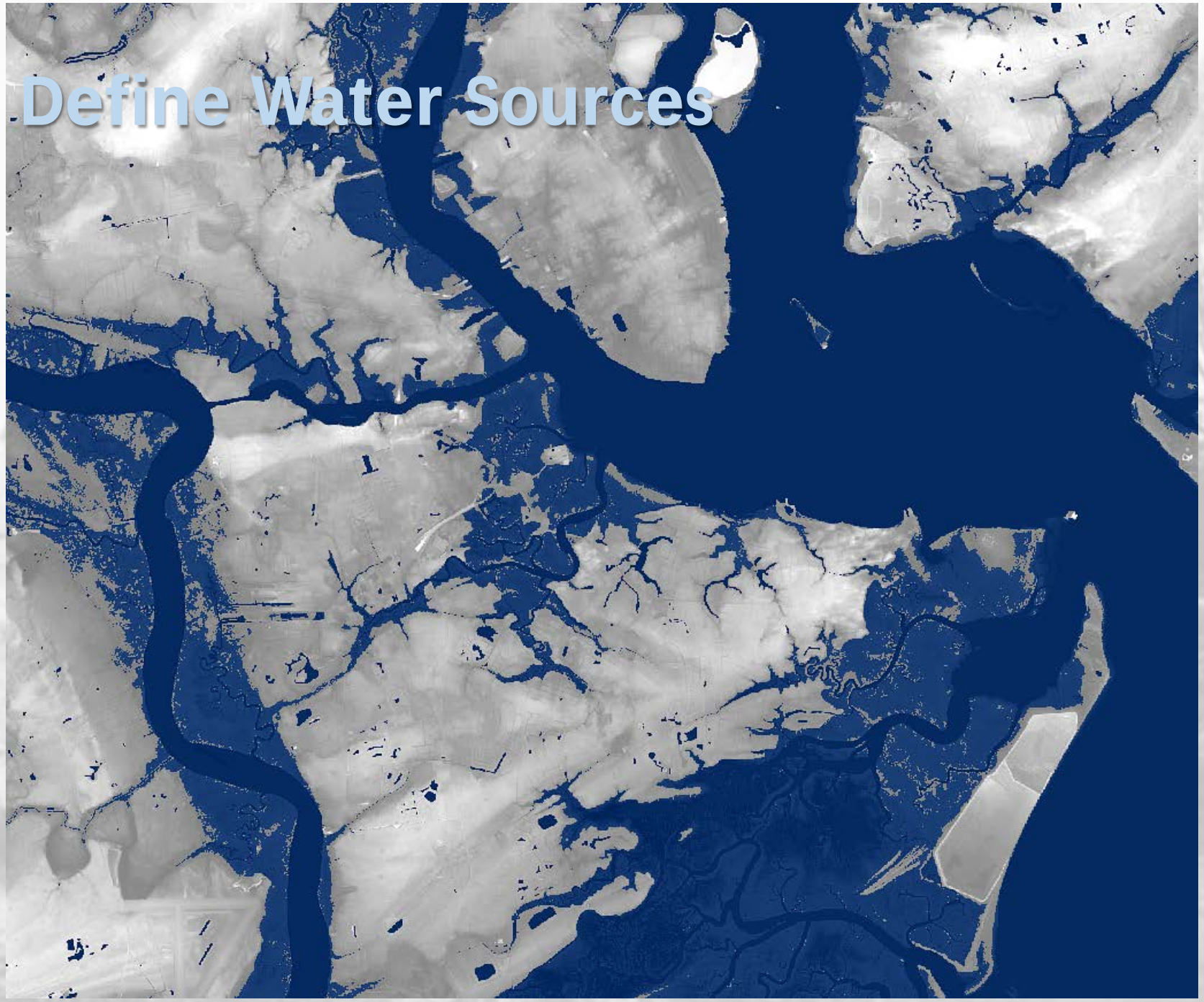
Hydro-Correction and -Conditioning DEMs

Culverts, Ditches and Microtopography

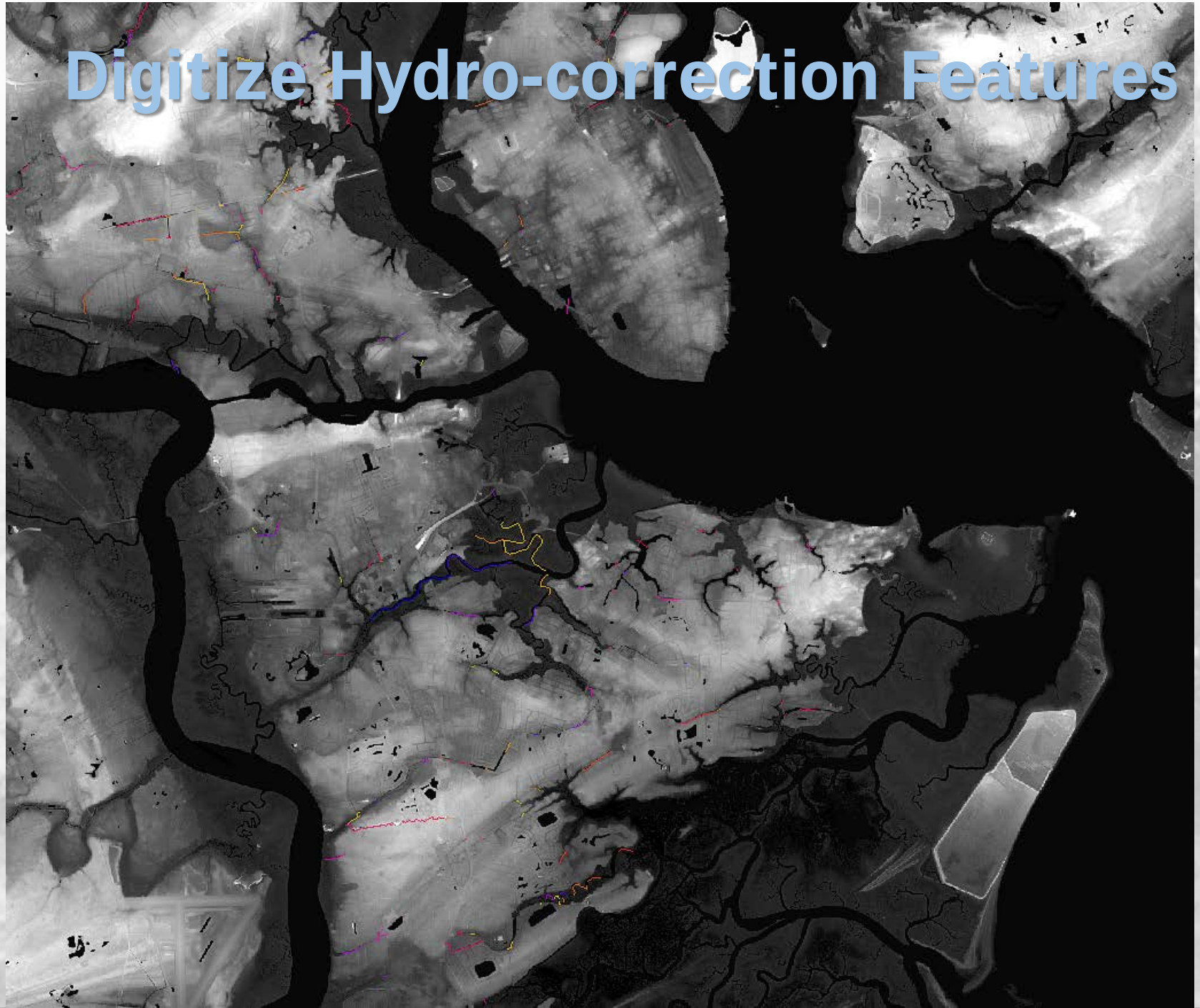
Basic hydro-conditioned bare earth DEM



Define Water Sources

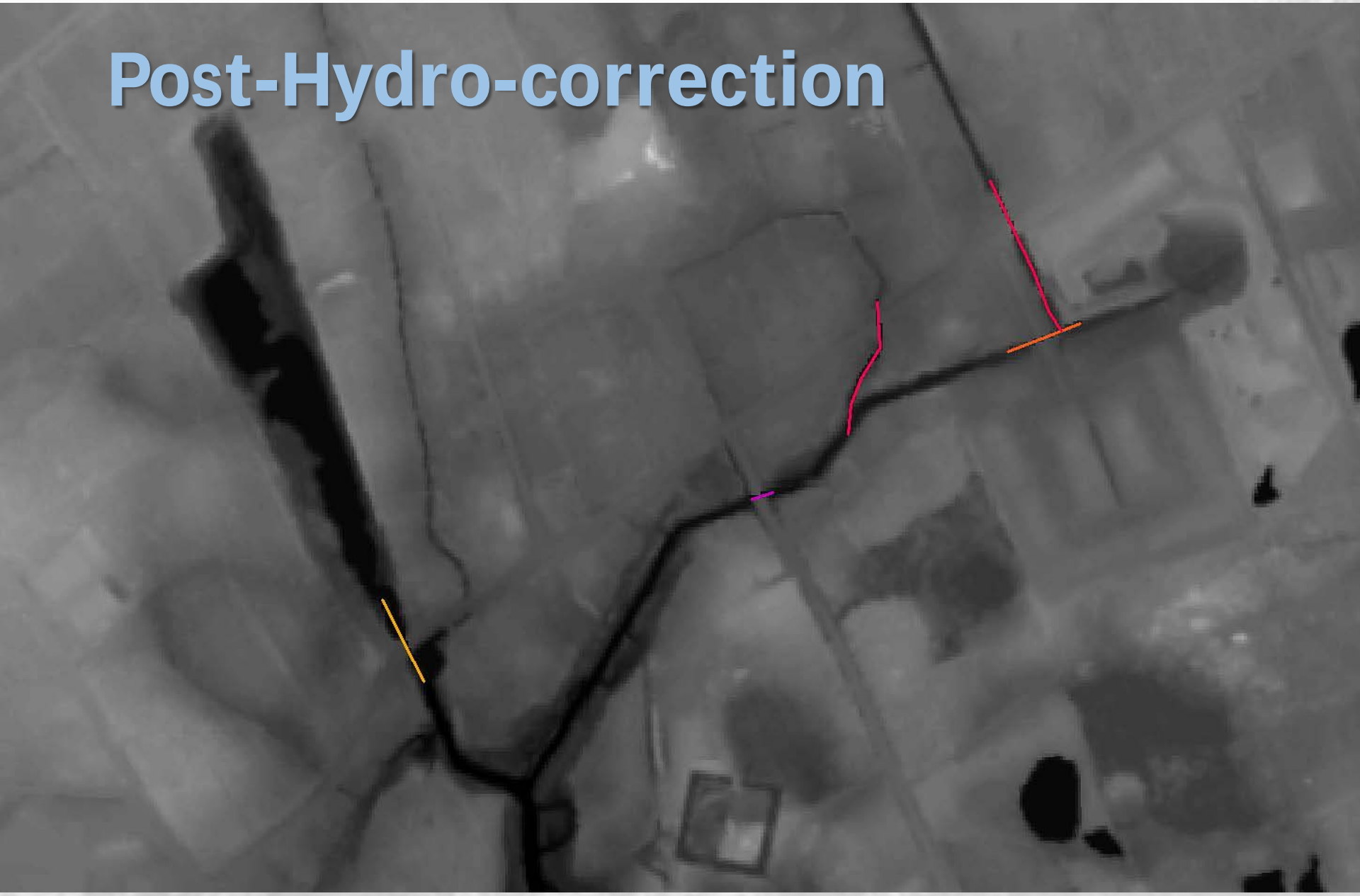


Digitize Hydro-correction Features

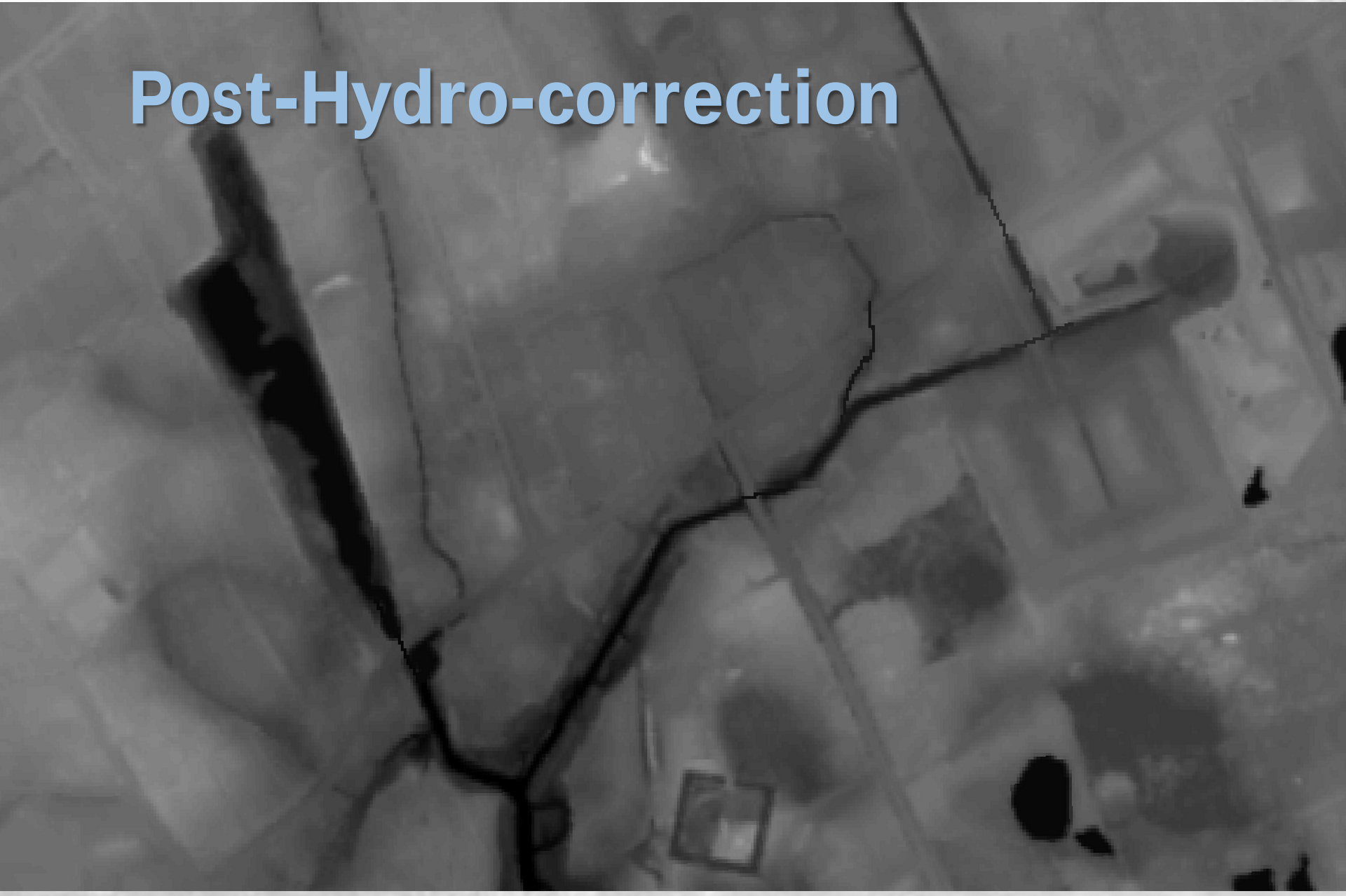



Pre-hydro-correction

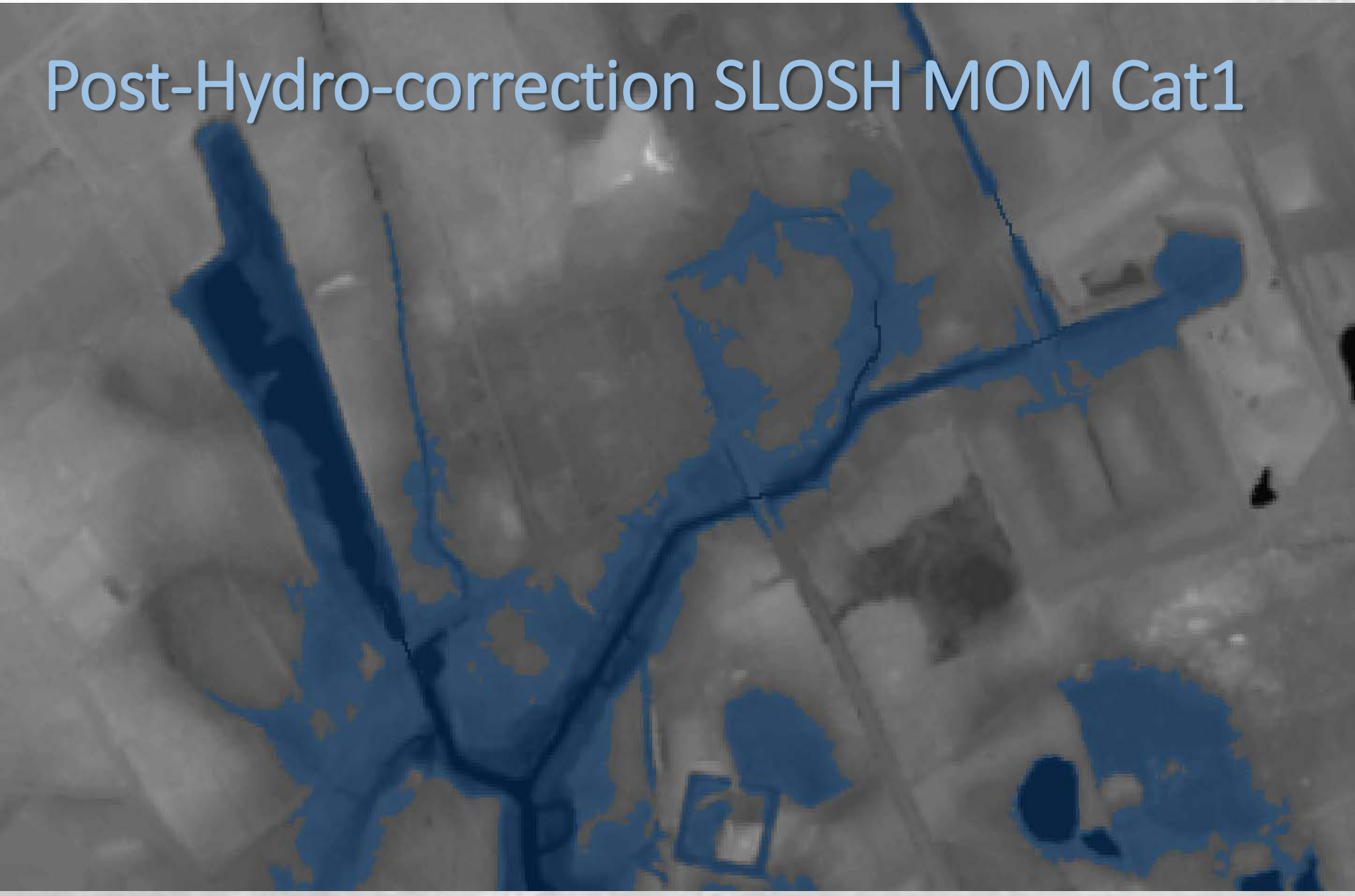
Post-Hydro-correction

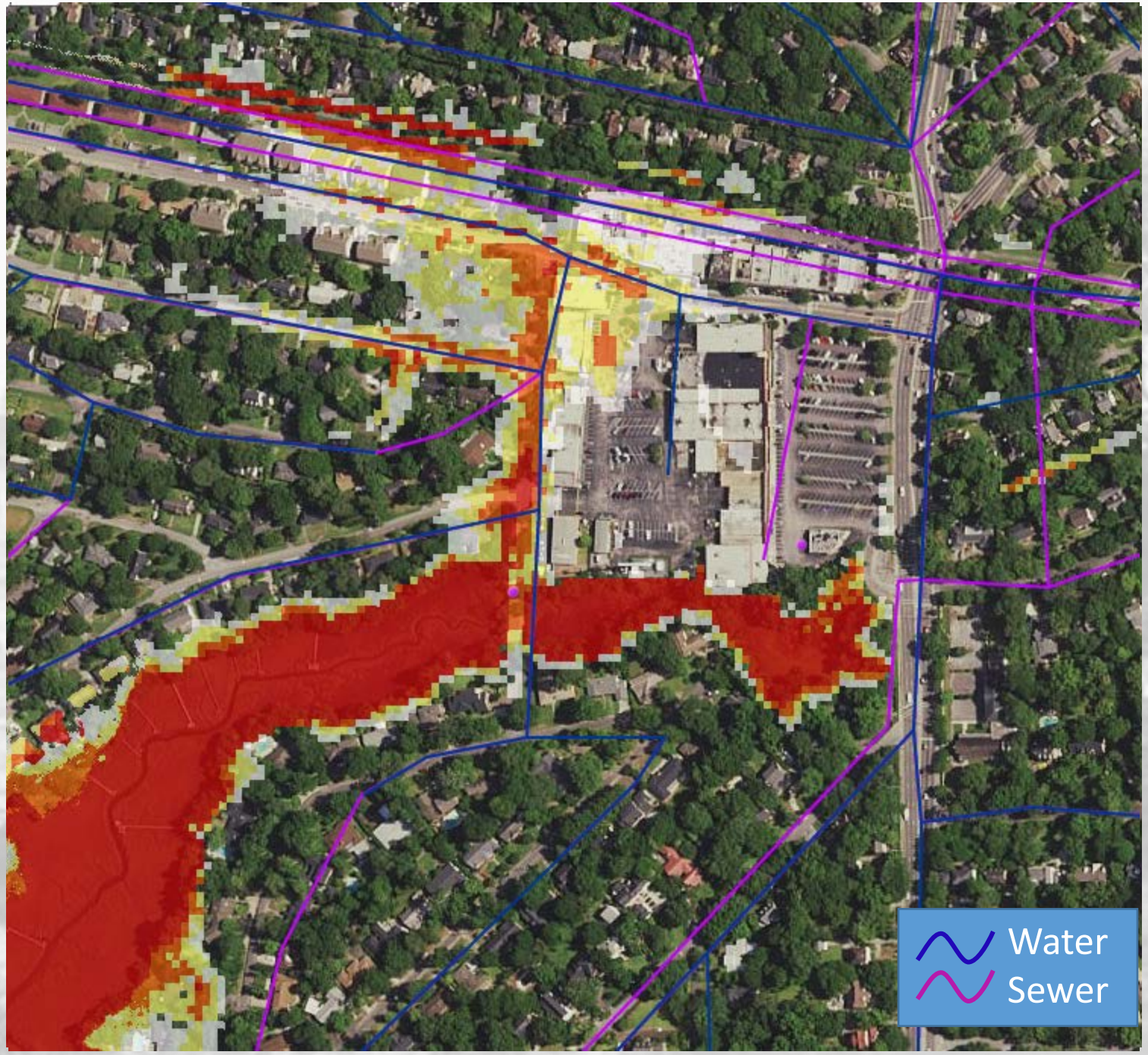


Post-Hydro-correction



Post-Hydro-correction SLOSH MOM Cat1

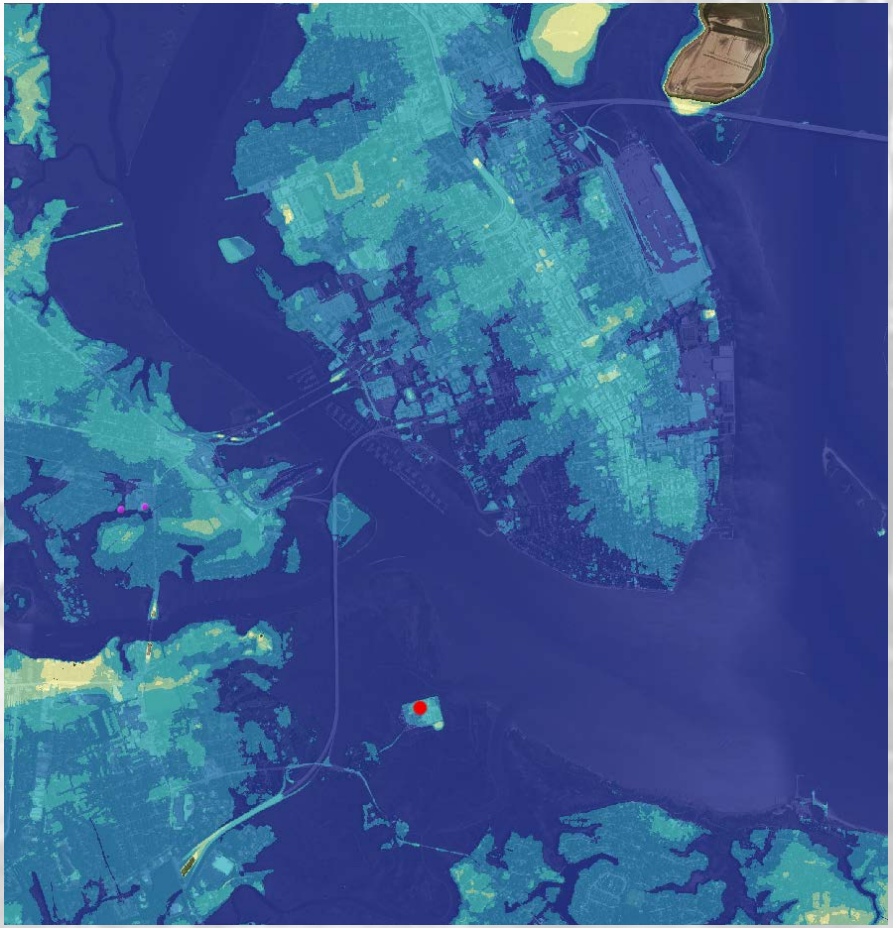



Water
Sewer

Charleston

Nuisance Flooding

SLOSH MOM Surges



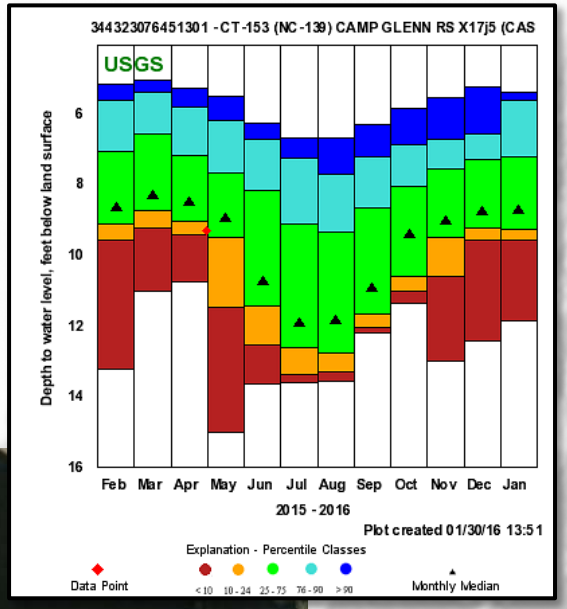
Onsite Wastewater Treatment Systems (OWTS), Climate Change and Sea Level Rise

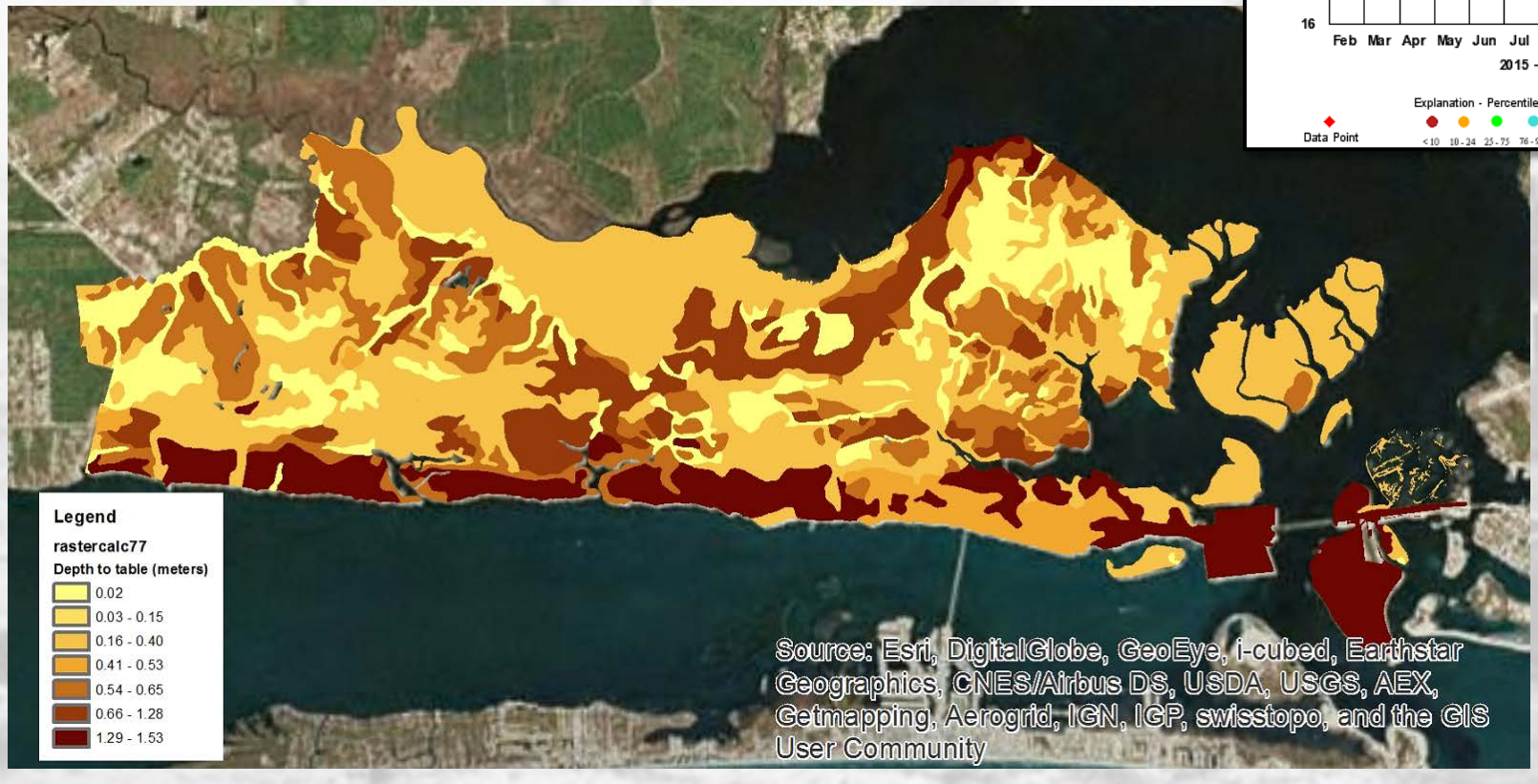
- Diminished volume of aerobic soil in vadose zone
- Lower O2 solubility and decrease in the vadose/freeboard zone
- Overall pathogen removal functions of OWTS to decline
- "..*the effects of climate change in humid regions receiving more precipitation and warmer temperatures are expected to result in complete loss of the infiltrative and water quality functions of OWTS.*"

Amador *et al.* (2014)

Amador, J., Loomis, G., Kalen, K. 2014. Soil-Based Onsite Wastewater Treatment and the Challenges of Climate Change. *Proceedings, Innovation in Soil-Based Onsite Wastewater Treatment*, Albuquerque, NM, April 7-8, 2014. (https://www.soils.org/files/meetings/specialized/full-conference-proceedings.pdf)

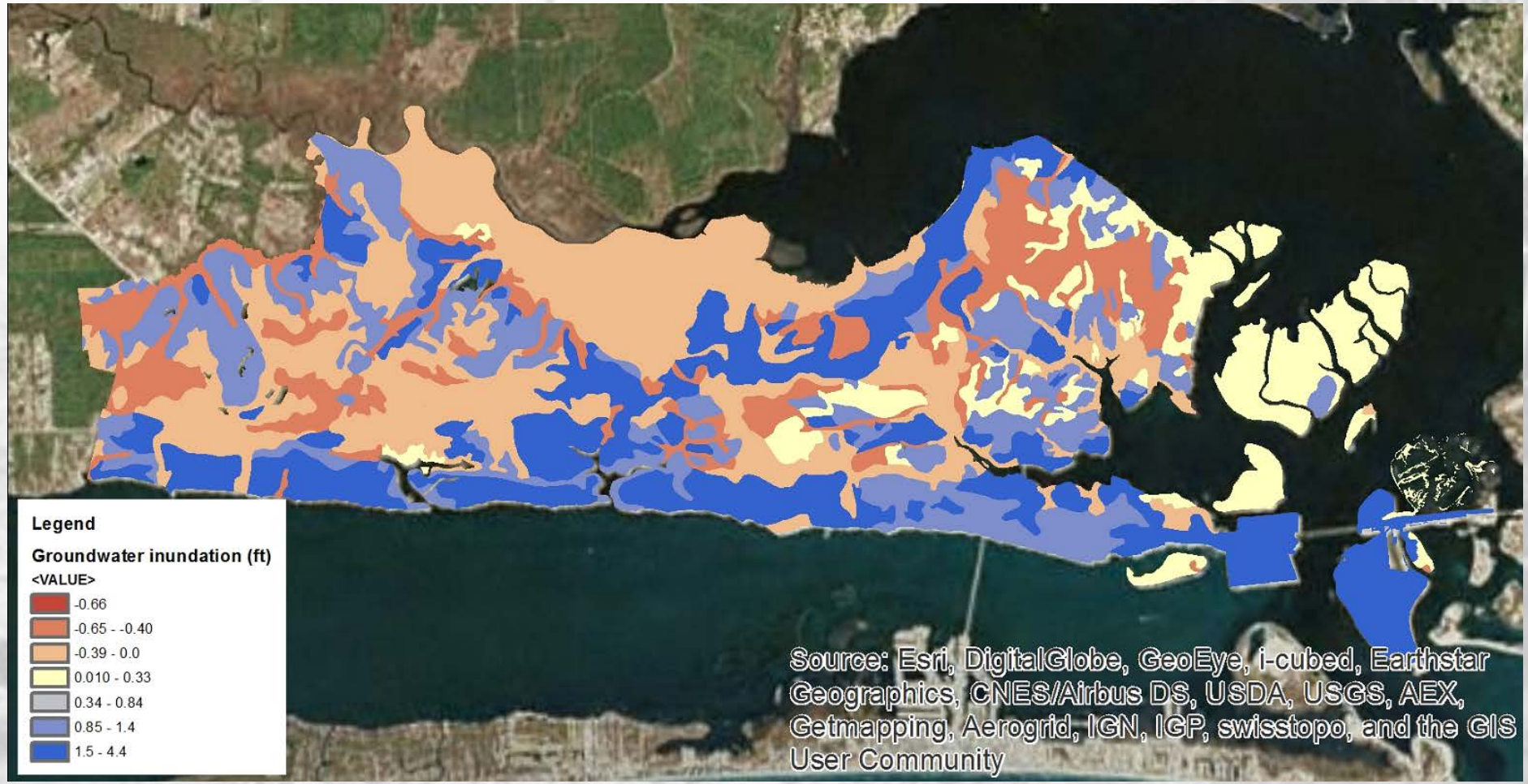
Soil Depth to Water Table



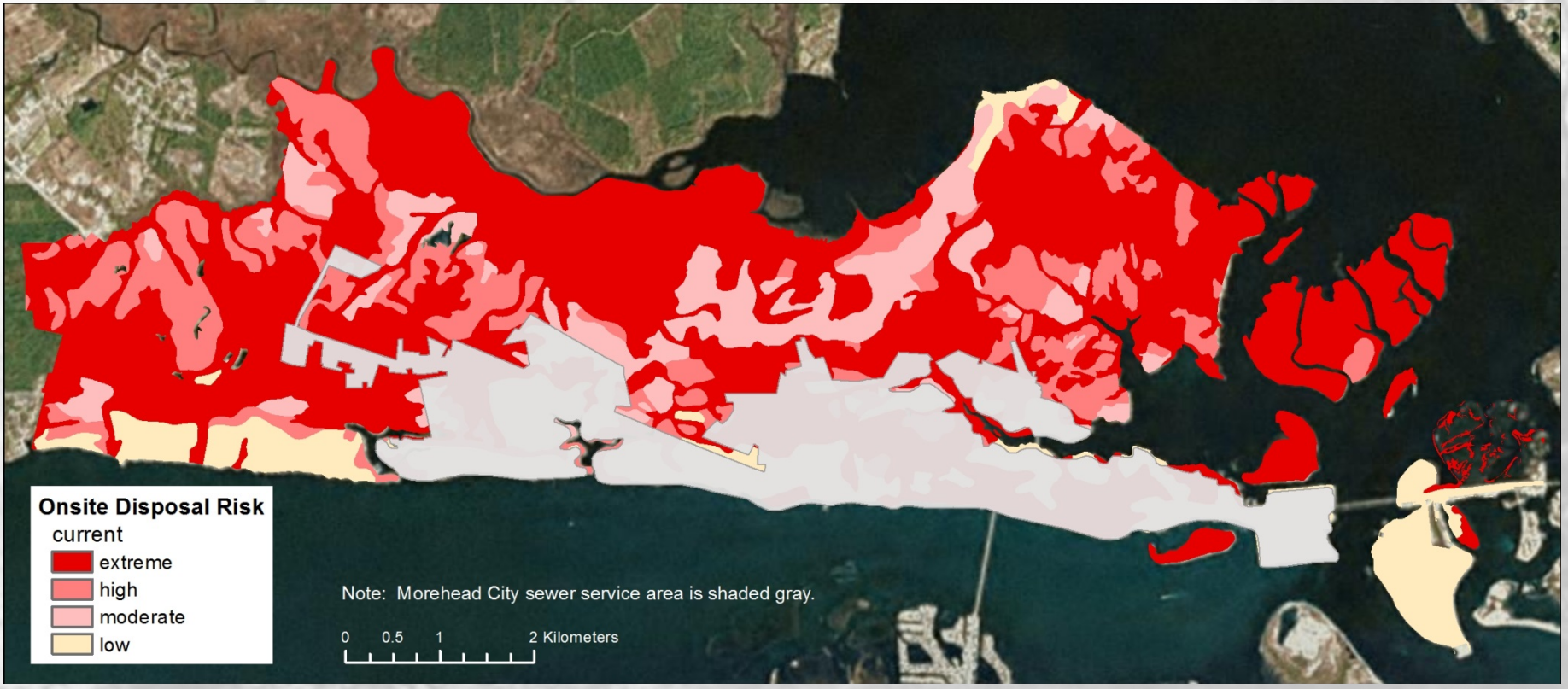


http://groundwaterwatch.usgs.gov/AWLSites.asp?S=344323076451301&ncd=

Groundwater Inundation of OWTS

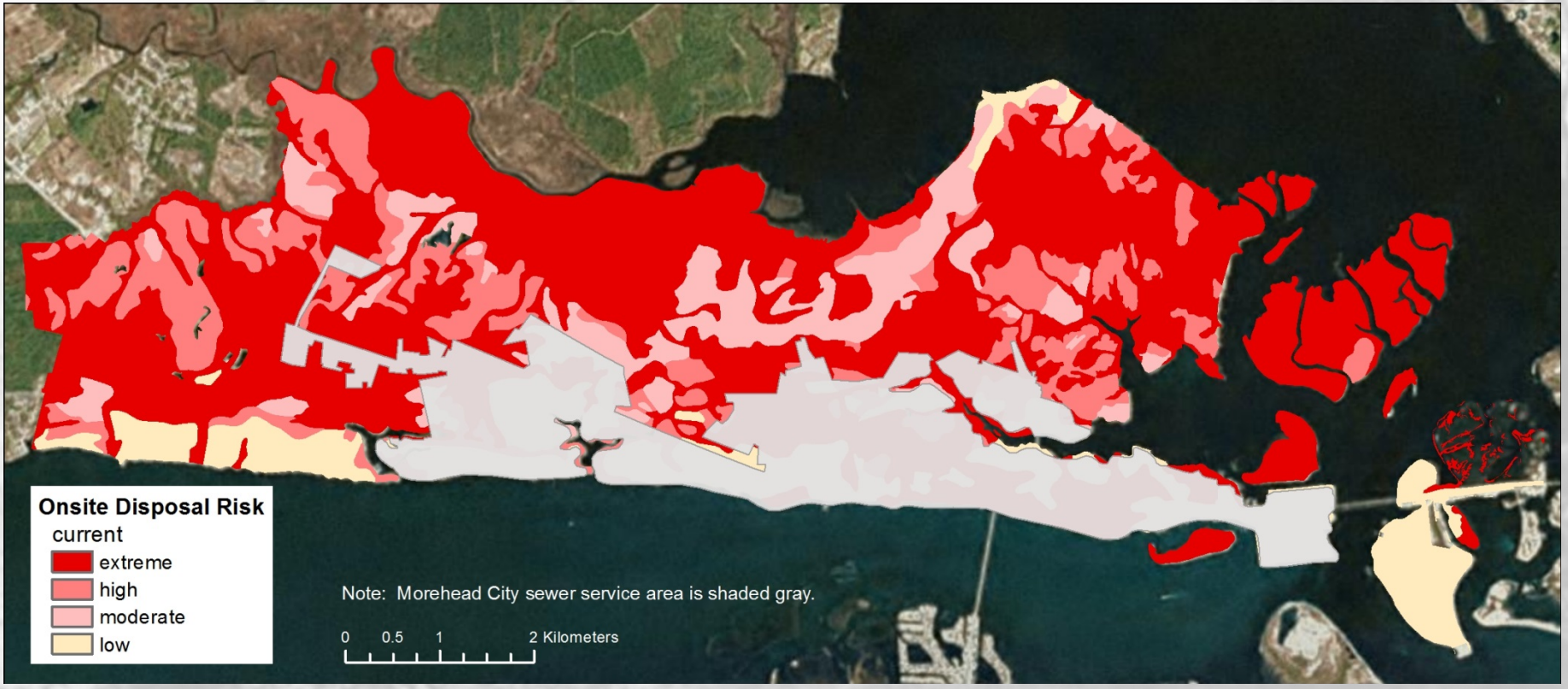


ETJ Onsite Wastewater Treatment Risk, current



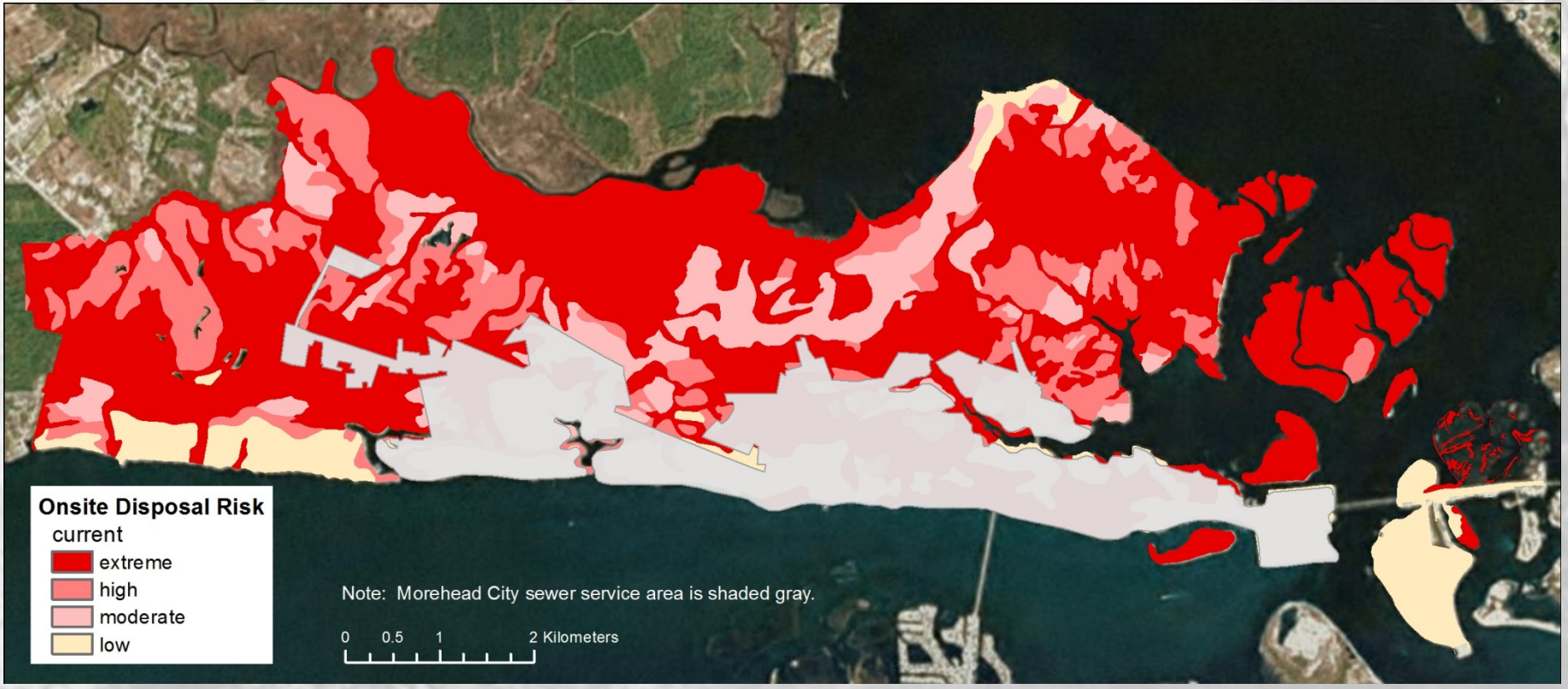
Note: Gray area is in Morehead City sewer coverage area..

ETJ Onsite Wastewater Treatment Risk, 20cm SLR



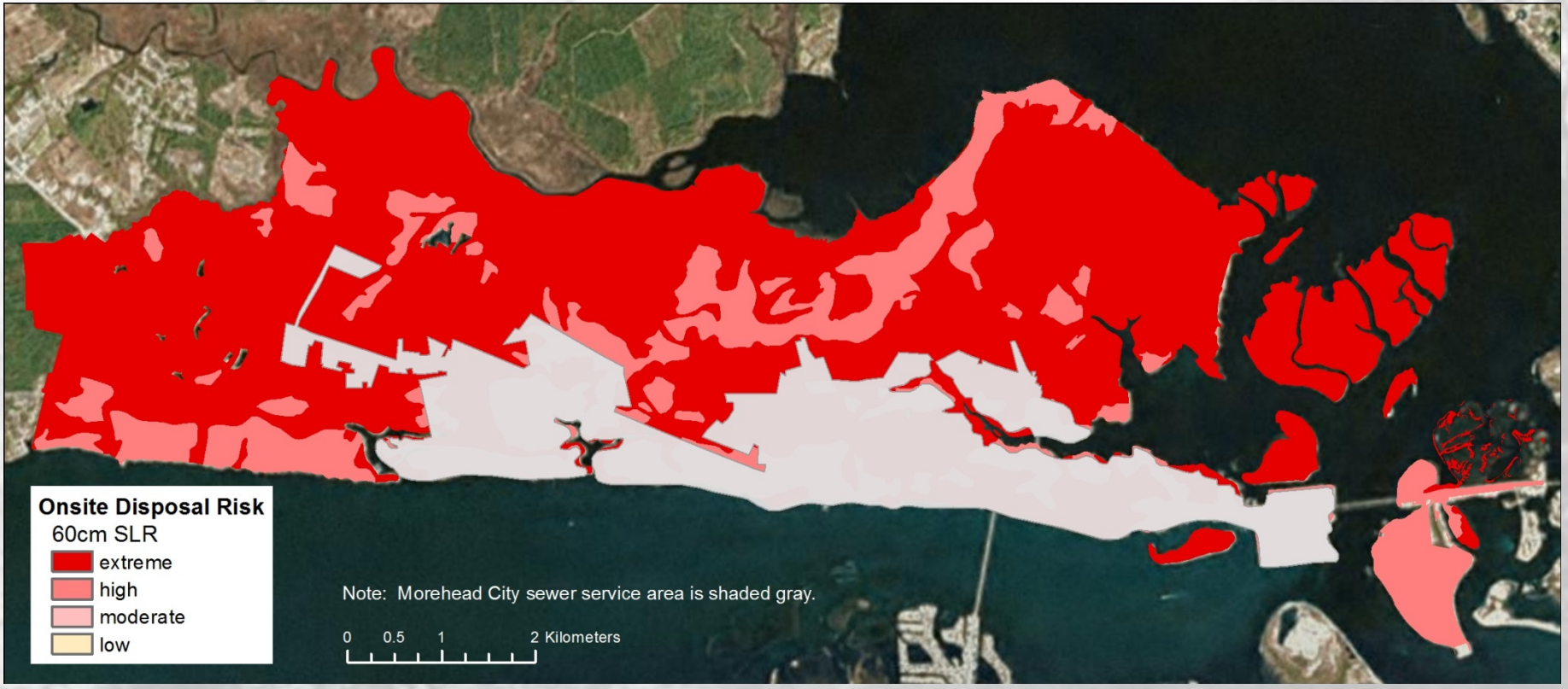
Note: Gray area is in Morehead City sewer coverage area..

ETJ Onsite Wastewater Treatment Risk, 40cm SLR



Note: Gray area is in Morehead City sewer coverage area..

ETJ Onsite Wastewater Treatment Risk, 60cm SLR



Note: Gray area is in Morehead City sewer coverage area..

Next Steps: Planning for Adaptation and Health Intervention

- **Scoping useful information for officials and the public**
  - Nuisance flood maps
  - Susceptibility index
  - Developing community tabletop exercise
  - Cross-cutting public health, planning, emergency mgt., and utilities
- **Infrastructure, Planning, and Public Health Interventions**
  - Retention ponds and wetlands increase water storage
  - Pervious surfaces and rain gardens increase infiltration, reducing run-off
  - Increasing capacity of stormwater system
  - Targeting surveillance and mosquito abatement
  - Model ordinance and codes

Conclusions

- Localized risk mapping for infrastructure and public health
- Spatial susceptibility
- Supporting local community adaptation and resilience
- Portability of GIS and modeling methods

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City of Charleston
Morehead City
East Carolina Univers
St. Louis University

Contact: Tom Allen TAllen@odu.e