Potential Effects of Sea-Level Rise on the Hydrologic System of Cape Cod, Massachusetts

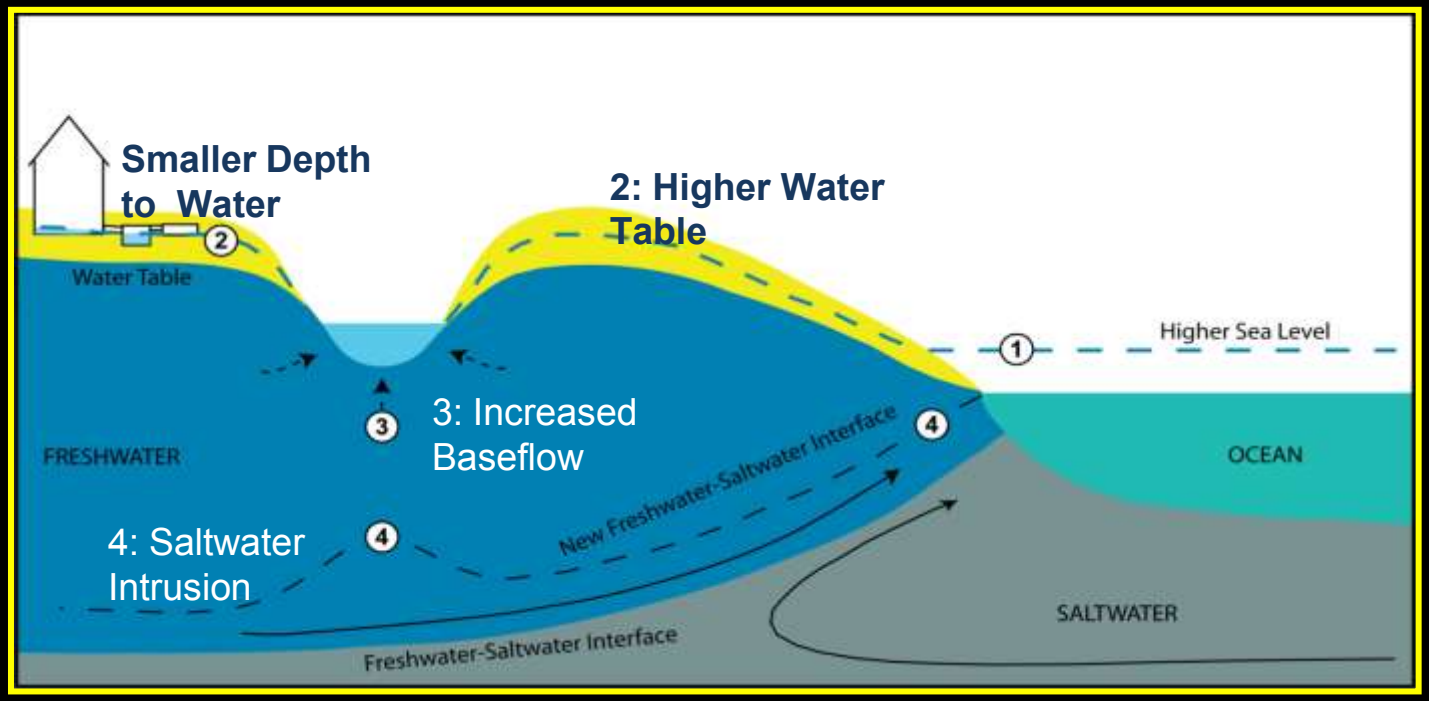
3rd Cape Coastal Conference, December 7, 2016

Climate Change and Sea Level Rise

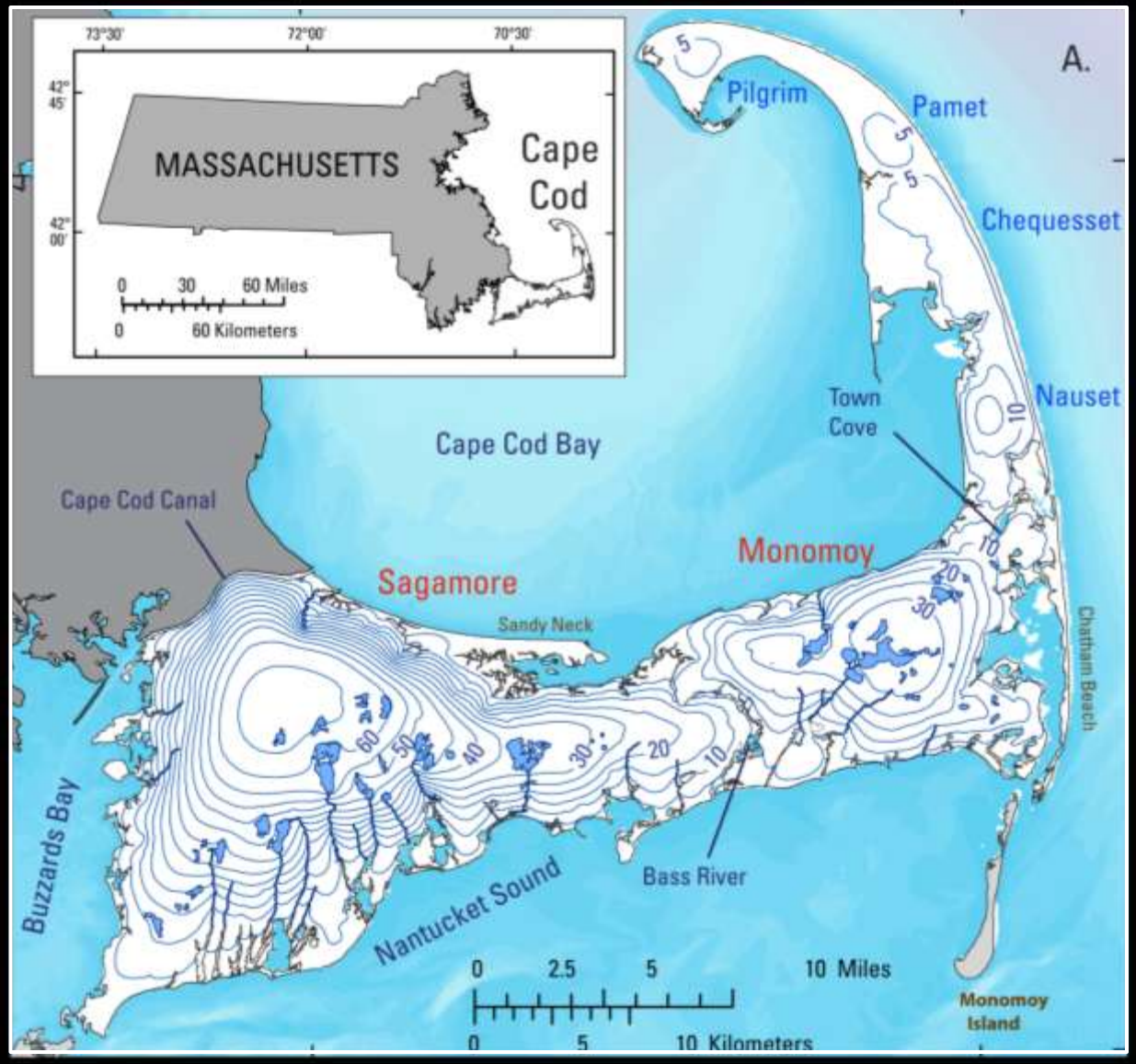
- Continued release of anthropogenic greenhouse gases is resulting in global warming, climate instability, and ***sea-level rise (SLR)***.
- Sea-level rise results from the thermal expansion of ocean water and melting of glacial ice
- Wide range of mean global sea-level-rise predictions (emission scenarios, ice-sheet dynamics)
- Sea-level rise will vary locally, Mid-Atlantic and Northeast US likely to be larger than the global mean
- Long-term effects of sea-level rise include:
  - Inundation of low-lying coastal areas
  - Alteration of coastal landforms
  - ***Effects on coastal aquifers***

Potential Effects of Sea-Level Rise

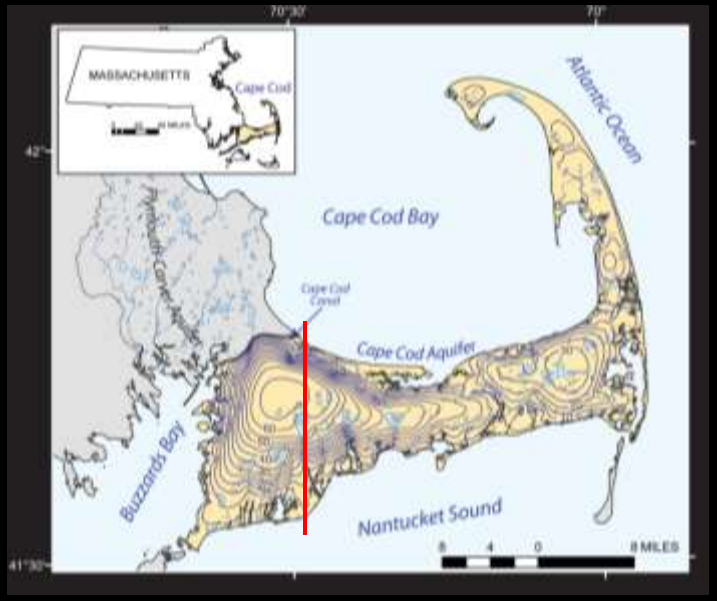
- Changes to the freshwater/saltwater interface (potential saltwater intrusion)
- Changes in groundwater discharge to streams and wetlands
- Increases in water-table altitudes (groundwater inundation)
- Effects on infrastructure (water-supply wells, septic systems, basements, roads)
- Factors affecting local sea-level-rise responses: coastal morphology, surface-water features, topography



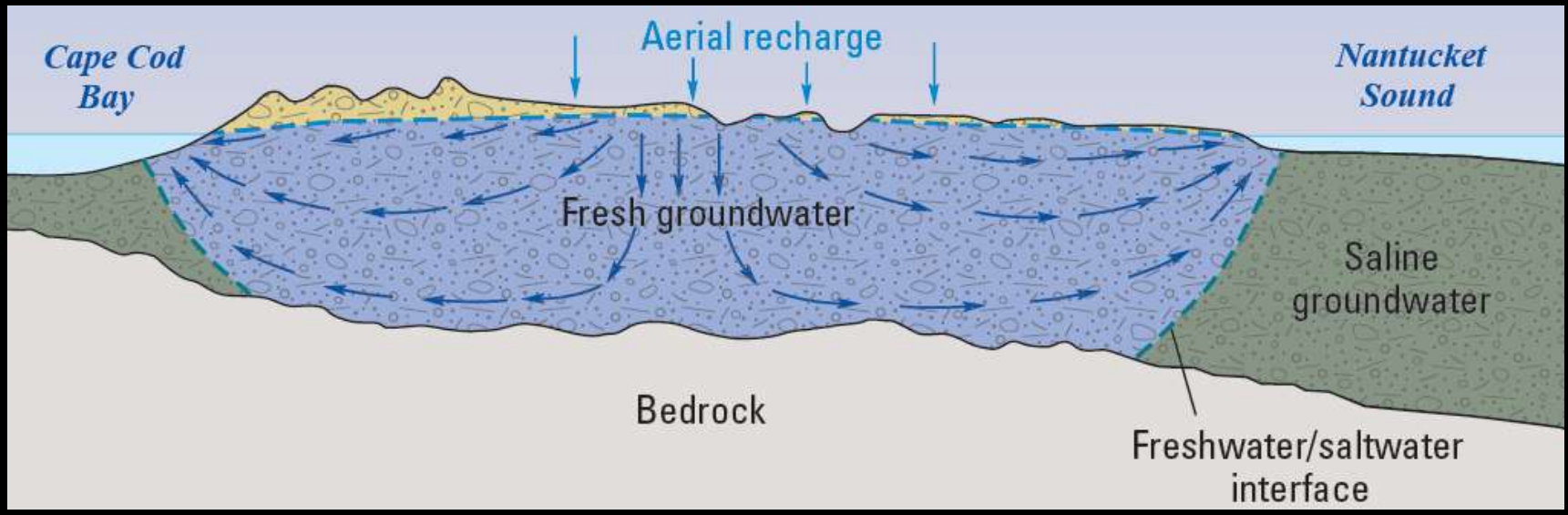
Location and Hydrography of Cape Cod, Massachusetts



Generalized Hydrologic Section, western Cape Cod



- Unconfined aquifer
- Precipitation is the sole-source of water to the aquifer
- Groundwater discharges into fresh and saltwater receptors
- Freshwater occurs at bedrock in most areas
- Fresh/saltwater interface in coastal areas



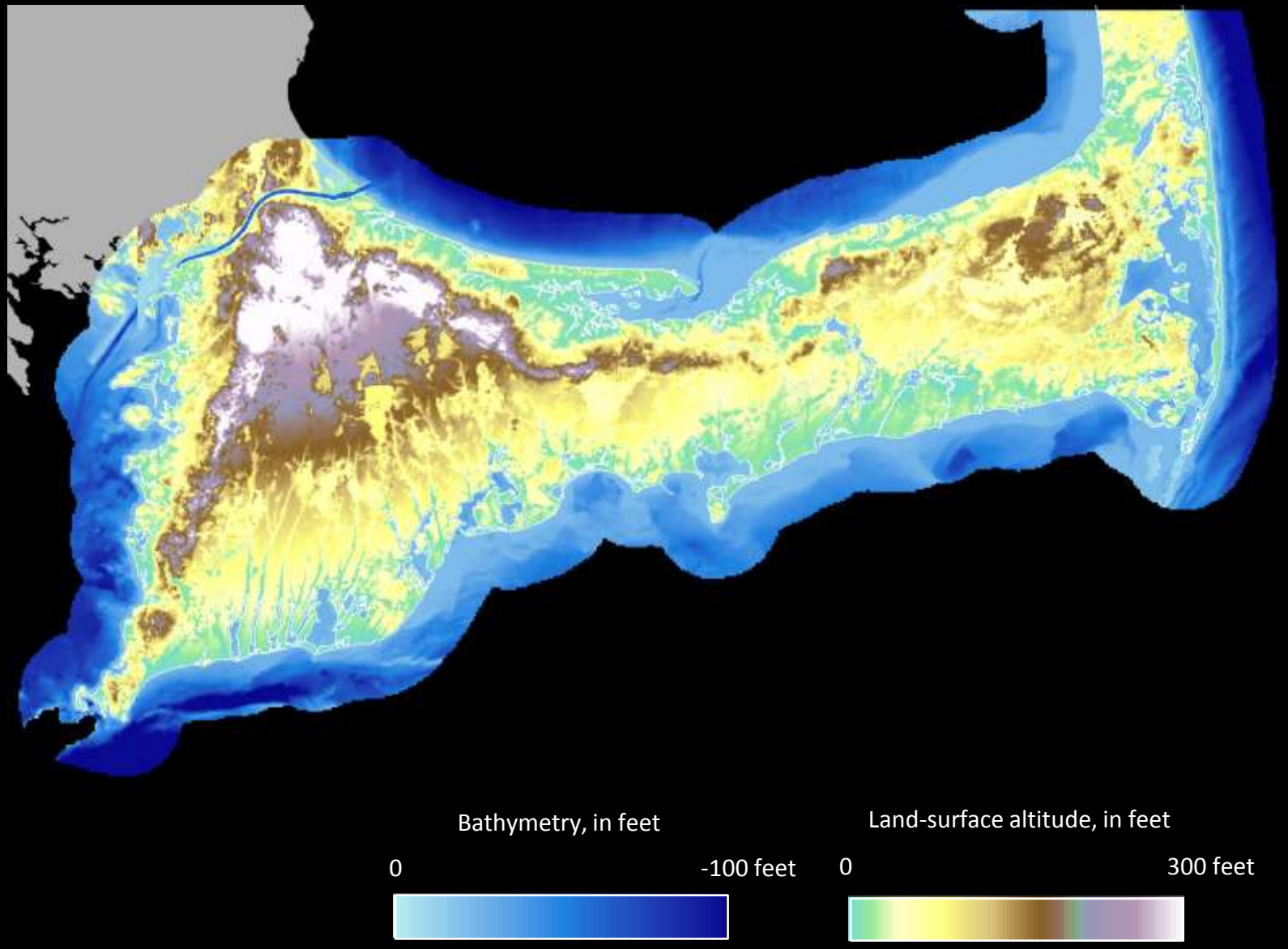
Approach

- Use land-surface data and numerical models to evaluate sea-level rise effects
- High resolution LiDar data
- Two sets of internally-consistent, steady-state numerical models:
  - 2D model capable of simulating a dynamic fresh/saltwater interface position
  - 3D model of ground-water-flow system capable of simulating water-table altitudes and streamflows
- Sea-level-rise scenarios of 0, 2, 4, and 6 feet above current sea level
  - 2 feet a general average for emission scenarios
  - 6 feet a near upper limit for scenarios including ice-sheet dynamics

LiDAR Data

- USGS 2011 Northeast LiDar data at 1-meter resolution
- 30-meter bathymetry from NOAA
- Geoprocessing to develop seamless mosaics
- Modifications to numerical models for different SLR scenarios :
  - Develop coastal morphologies
  - Modify hydrologic boundaries
- Estimate depth-to-water from LiDar data and simulated water-table altitude

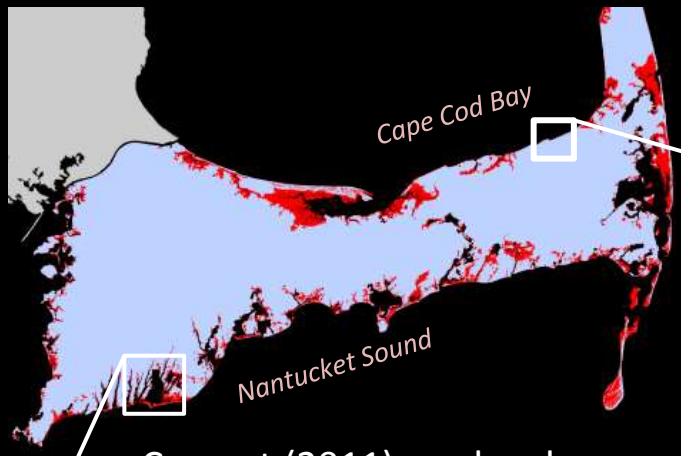
Topography and Bathymetry for Current (2011) Sea Level



Coastal Morphology Estimated from LiDAR Data

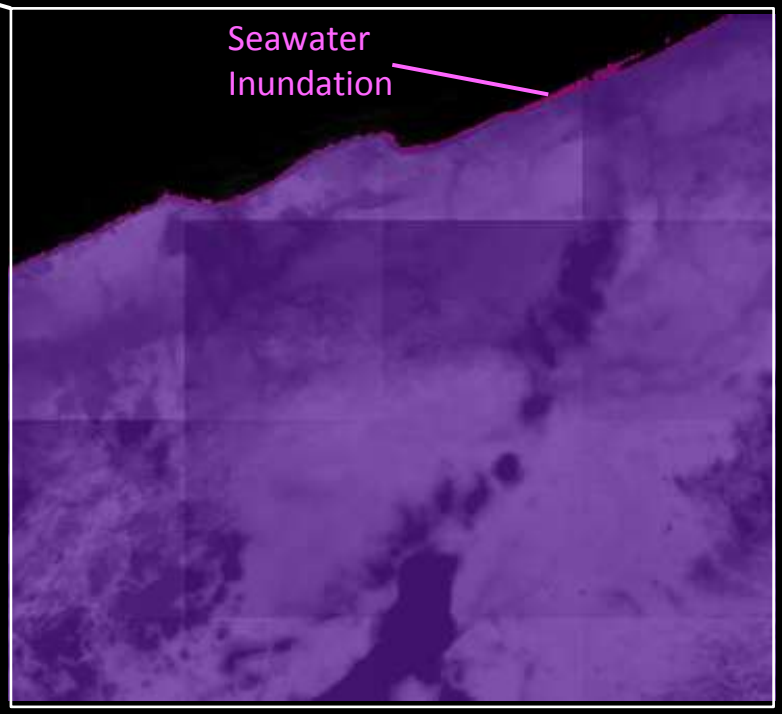
- Change in geometry of existing coastal boundaries
- Conversion from fresh to saline surface waters
- Landward migration of heads of tide in rivers

Coastal Morphology Estimated from LiDAR Data



Current (2011) sea level

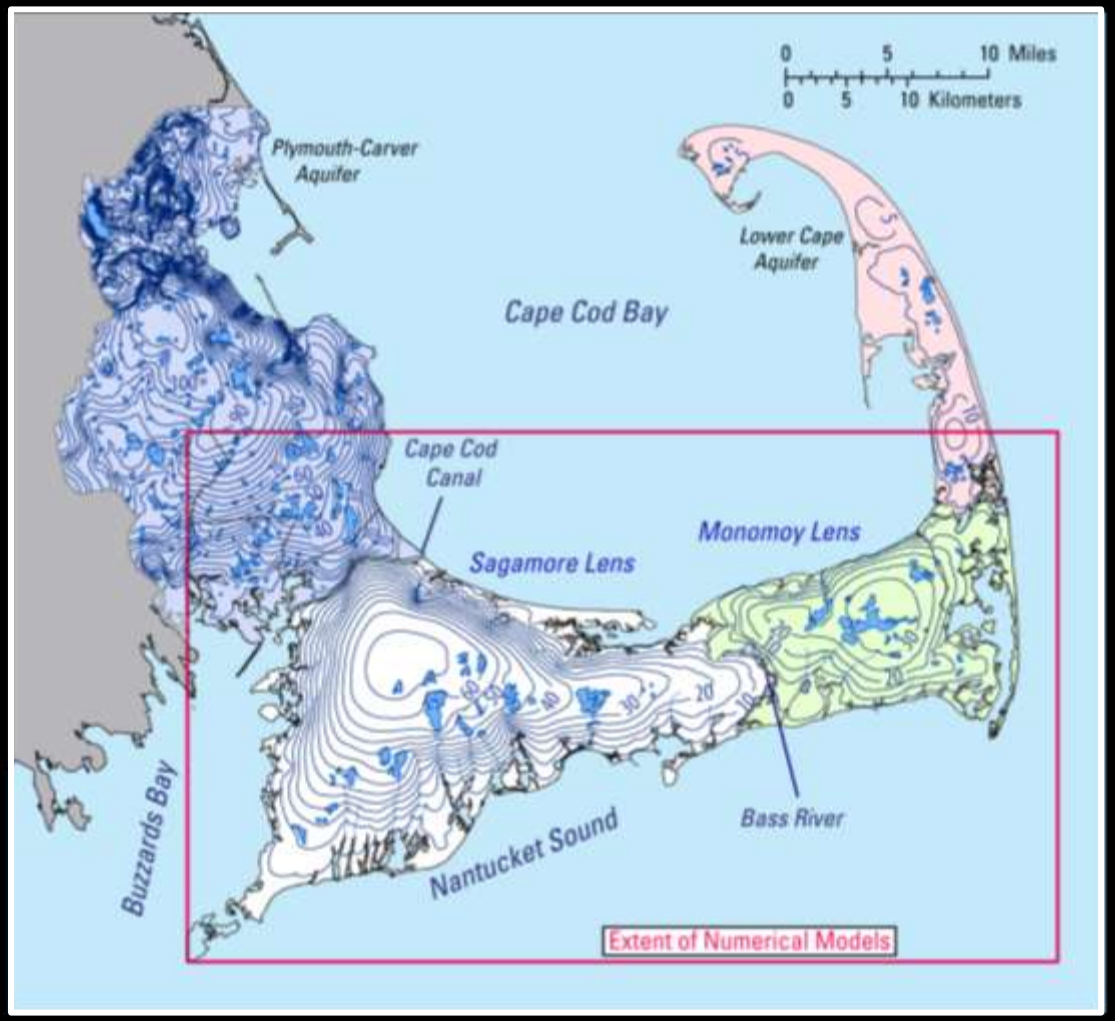
6-foot sea-level rise



Numerical Models

- Interface Model
  - Uses SWI Package to simulate FW/SW interface
  - 2D model: 100-ft discretization
  - Model produces 3D interface position
- Groundwater Flow Model
  - 3D model: 25 layers with variable thickness, 400-ft discretization
  - Incorporates simulated 3D interface as a no-flow boundary
  - Model inversely calibrated to water levels, streamflows, and a regional groundwater divide
- Modifications to each model for three sea-level scenarios: 0, 2, 4, and 6 feet above current sea level

Mid-Cape Cod Coastal Model



- Represents the Sagamore and Monomoy lenses; includes parts of adjacent aquifers
- MODFLOW-2005; SWI2
- Modified versions for each of three SLR scenarios: 0, 2, 4, and 6 feet

Potential Effects of Sea-Level Rise

- Changes to the freshwater/saltwater interface (potential saltwater intrusion)
- Changes in groundwater discharge to streams and wetlands
- Increases in water-table altitudes (groundwater inundation)
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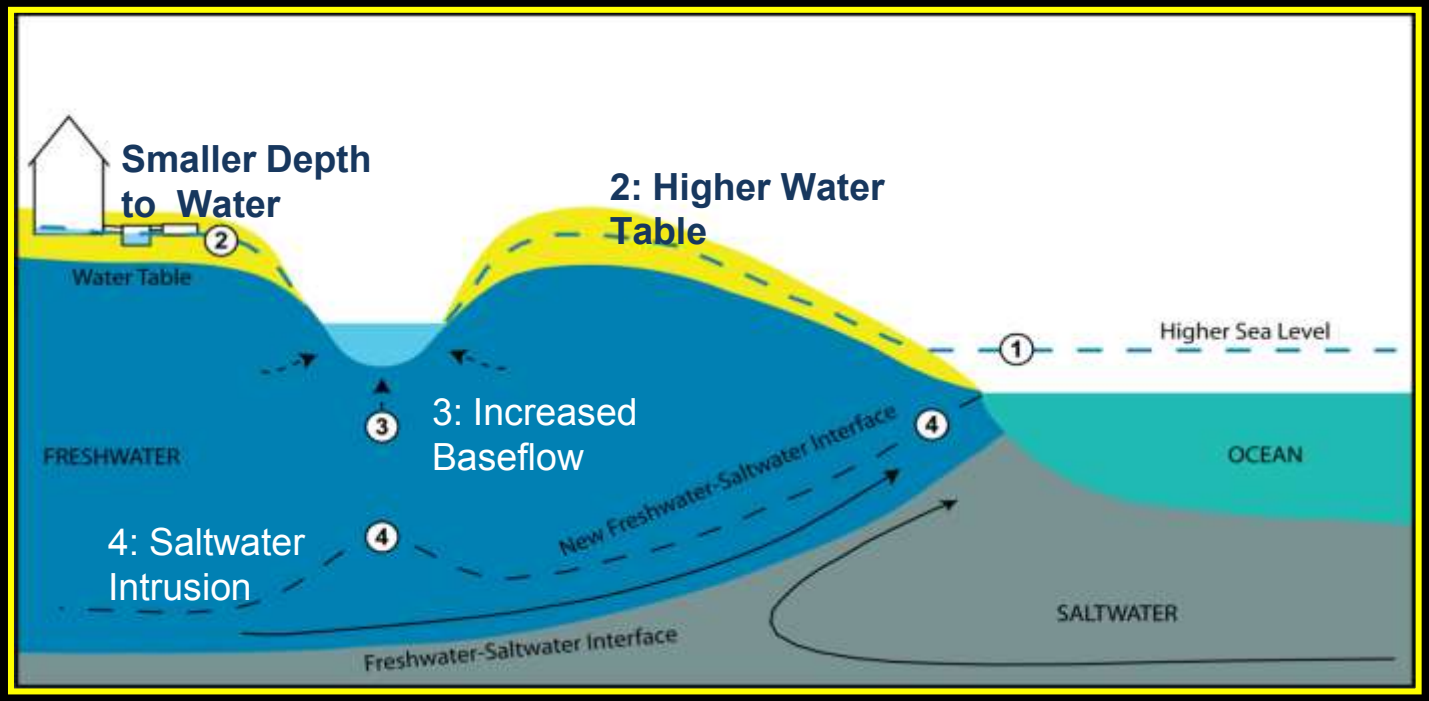
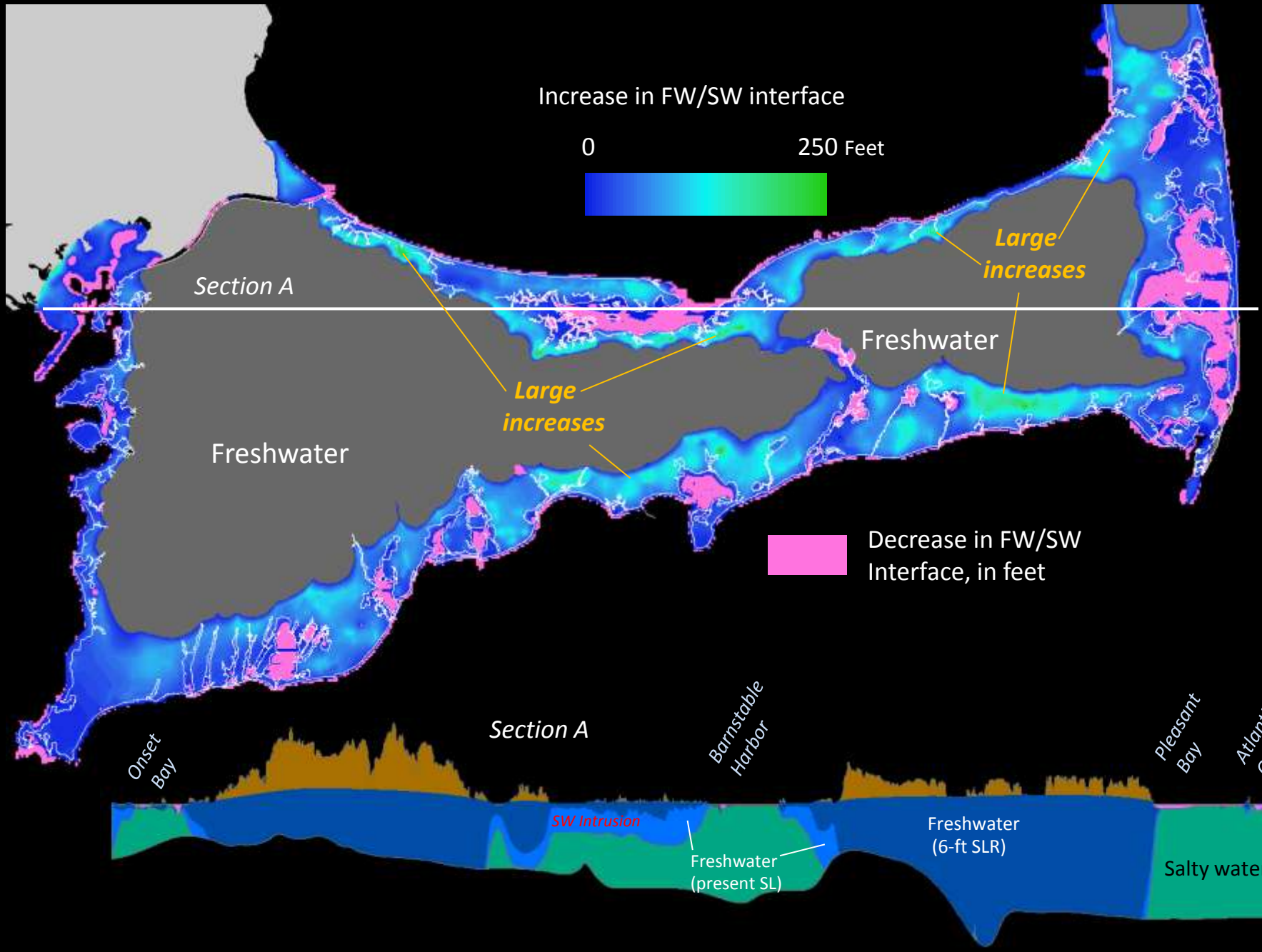


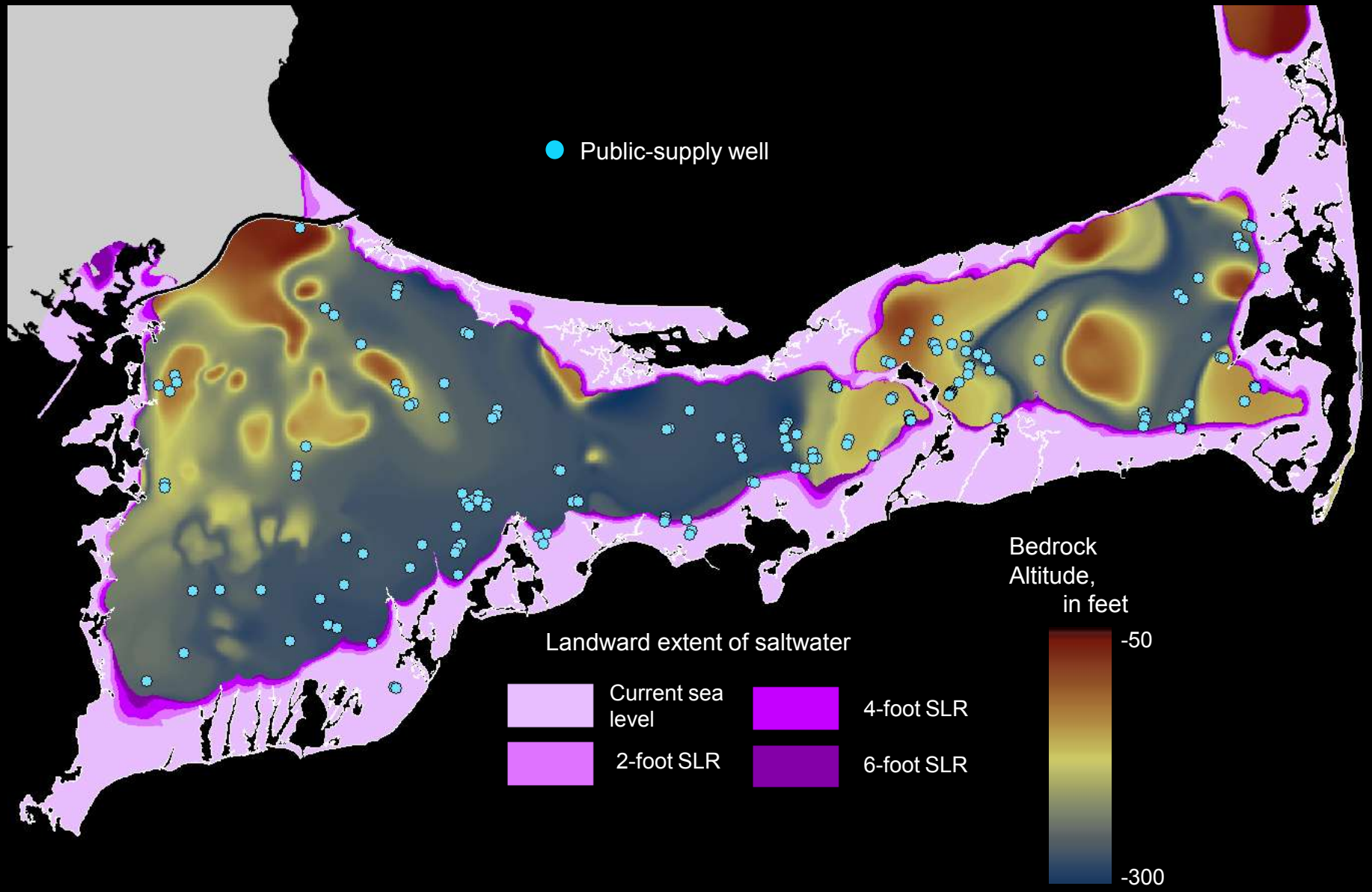
Effect of Sea-Level Rise on the Freshwater/Saltwater Interface

- Aquifer bounded laterally by salty groundwater
- Potential exists for saltwater intrusion
- Intrusion results from both lateral and vertical movement of the interface
- Groundwater is the sole source of drinking water

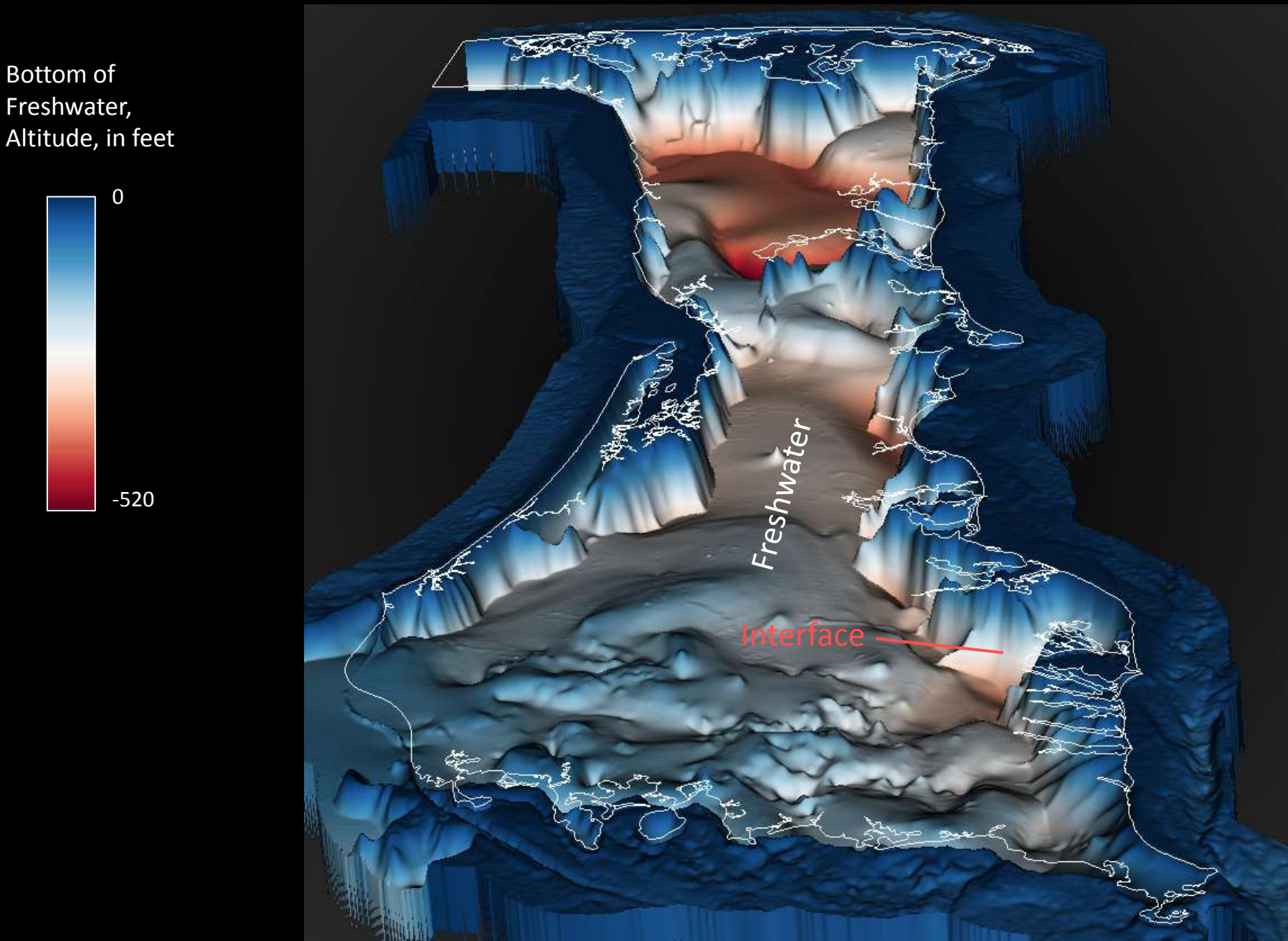
Vertical Change in FW/SW Interface Altitude: 6-foot Sea-Level Rise



Landward Extent of Saltwater: 0, 2, 4, and 6-foot Sea-Level Rise



Lower Altitude of Freshwater: Current Sea Level



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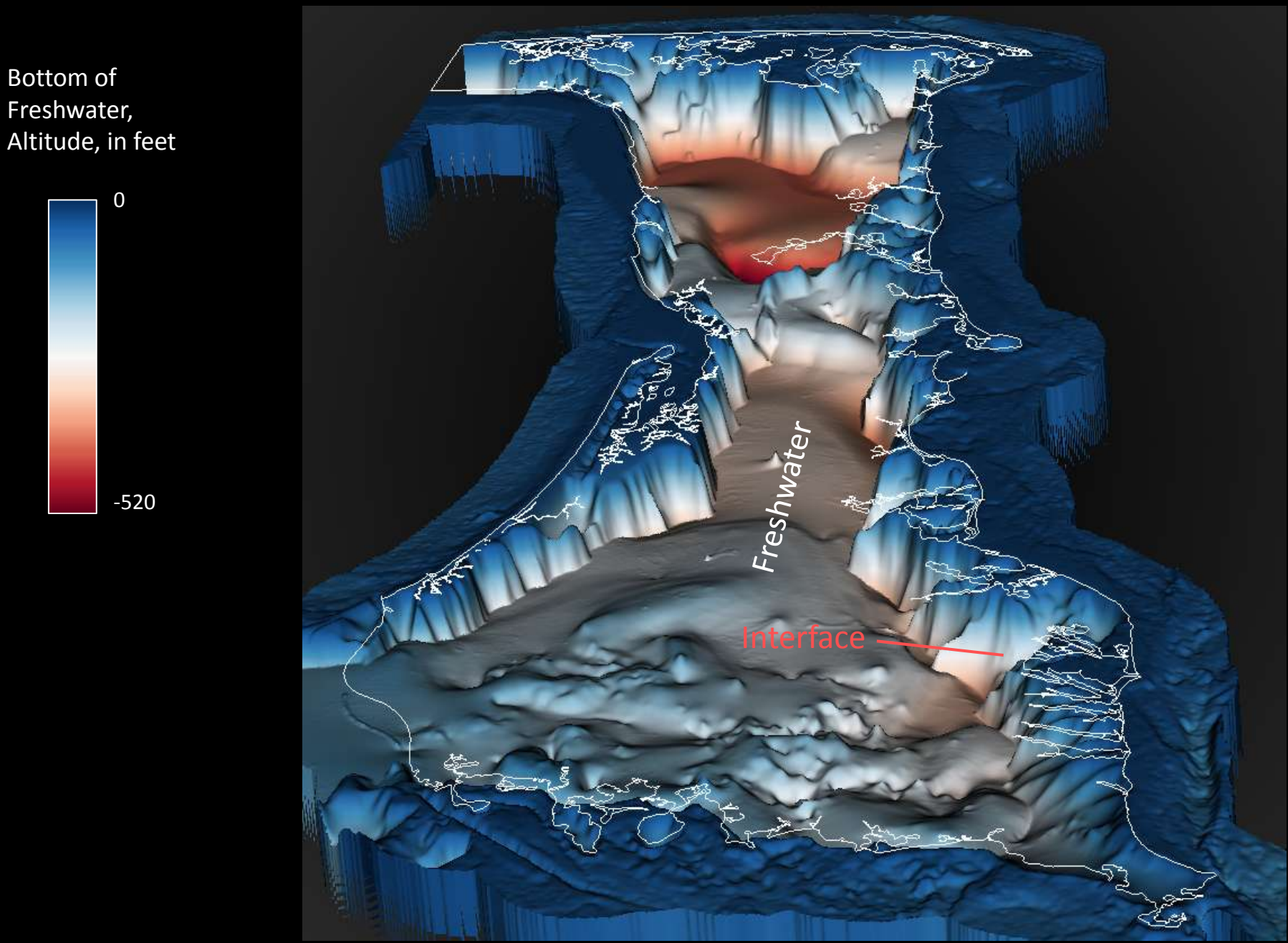

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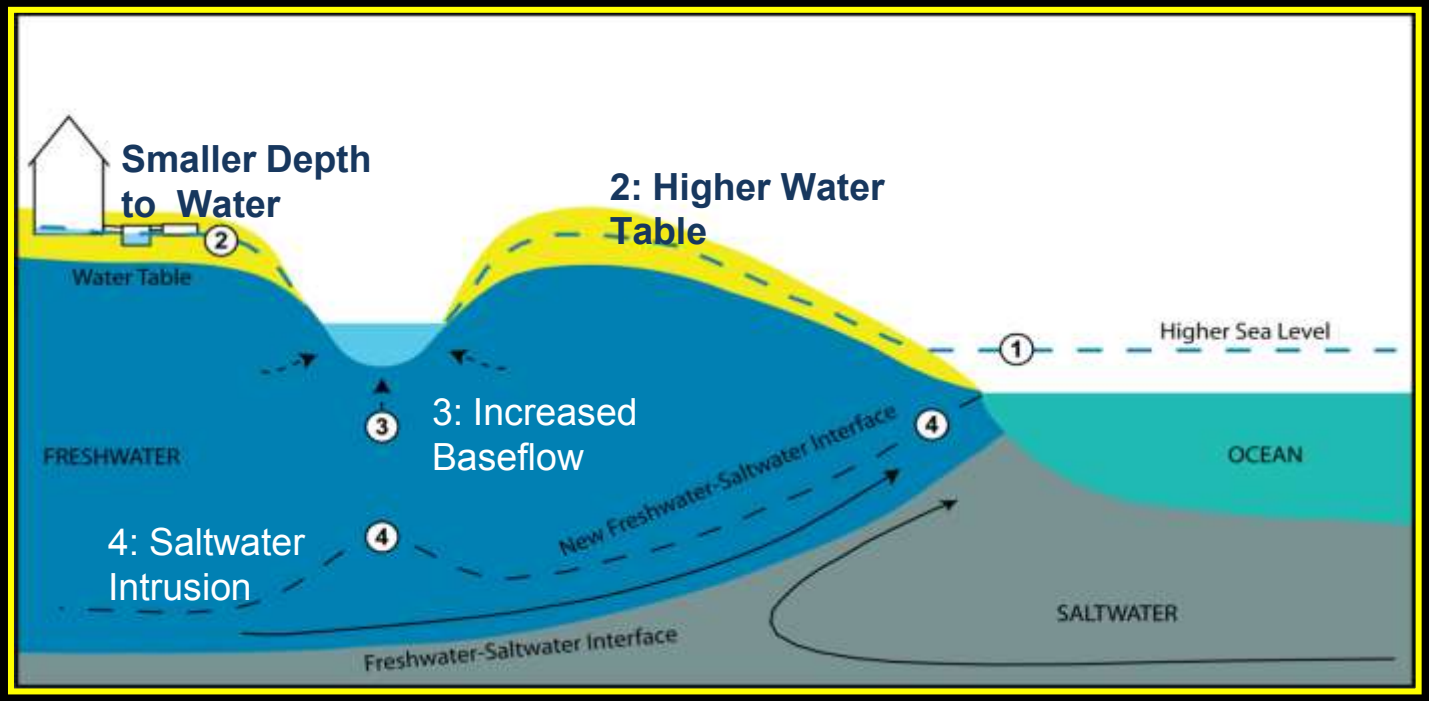
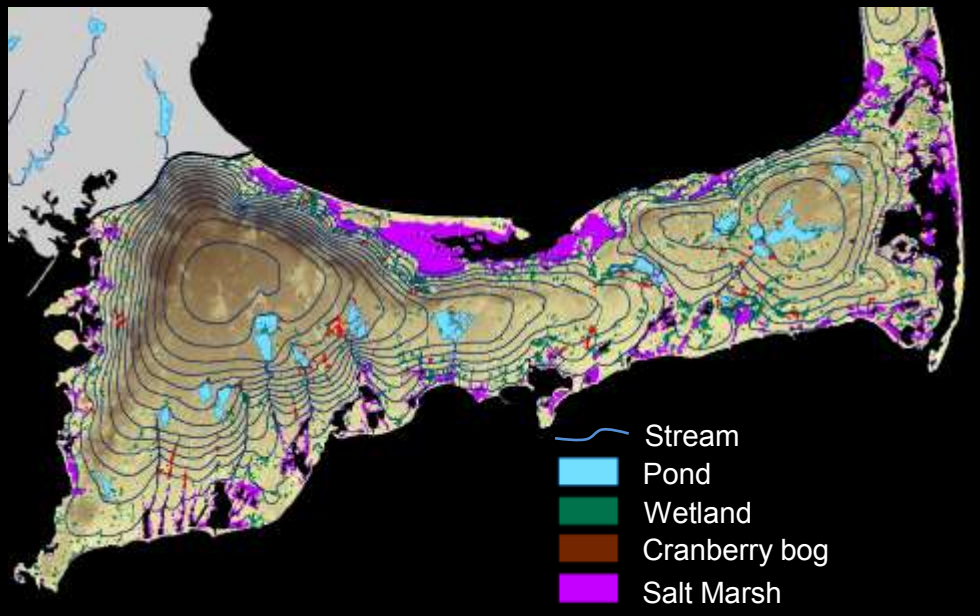


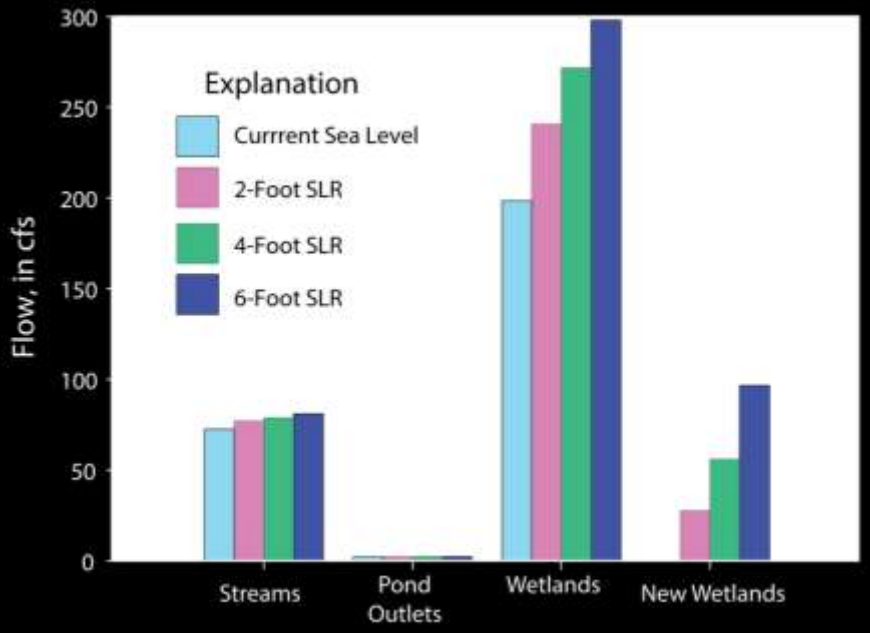
Factors Affecting SLR Responses on Cape Cod: Surface Waters

- Groundwater discharges into numerous streams, wetlands, and ponds with surface-water outlets
- Surface waters represent essentially fixed-altitude boundaries
- Sea-level rise will increase discharge which would limit increases in water-table altitude

Change in Freshwater Discharge

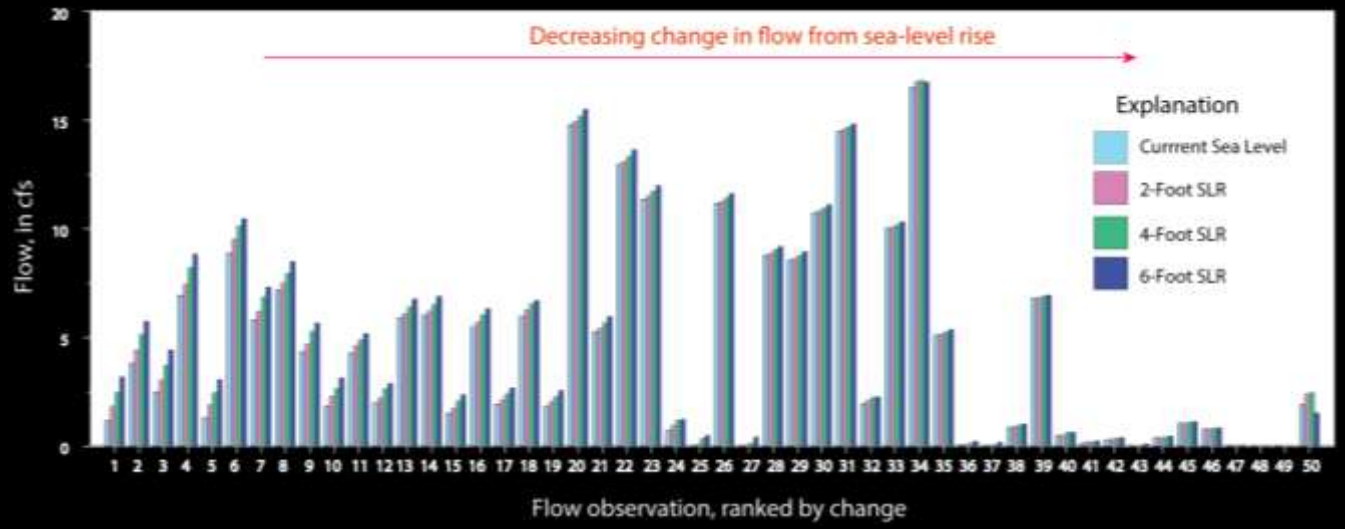


Freshwater receptors



Surface water

Streamflow sites



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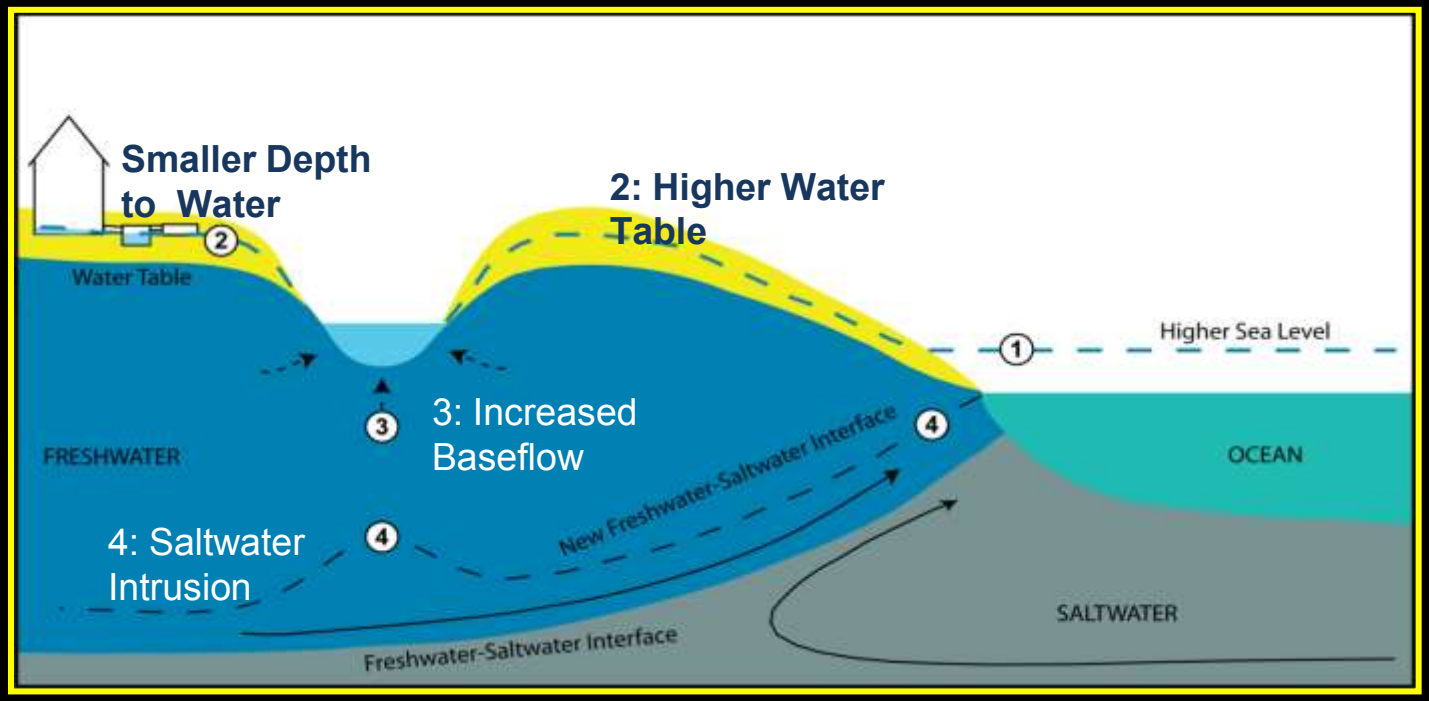
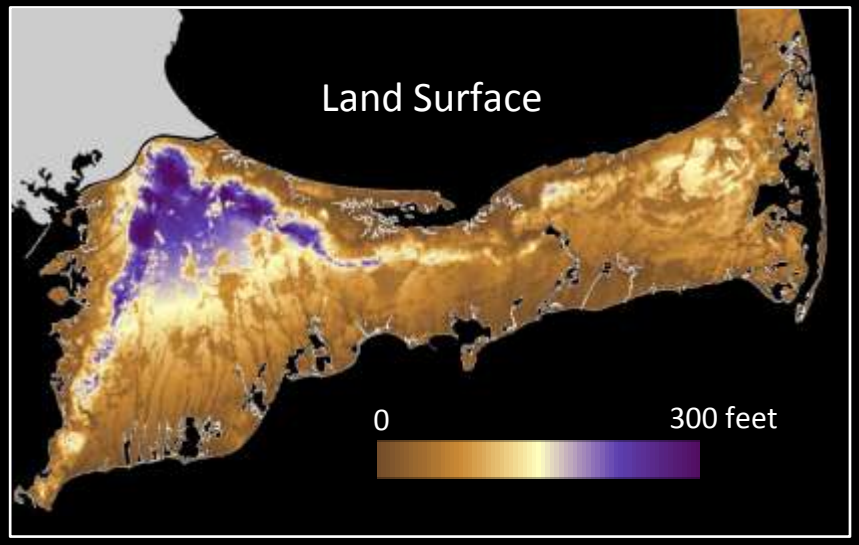


Water-Table Altitude and Depth to Water

- Increases in sea level causes an increase in water table altitude
- Depth to water decreases proportionally to the increase in water table
- Groundwater inundation in some areas
- Shallow depths to water can affect infrastructure

Depth to Water Estimated from Land and Water Table Surfaces



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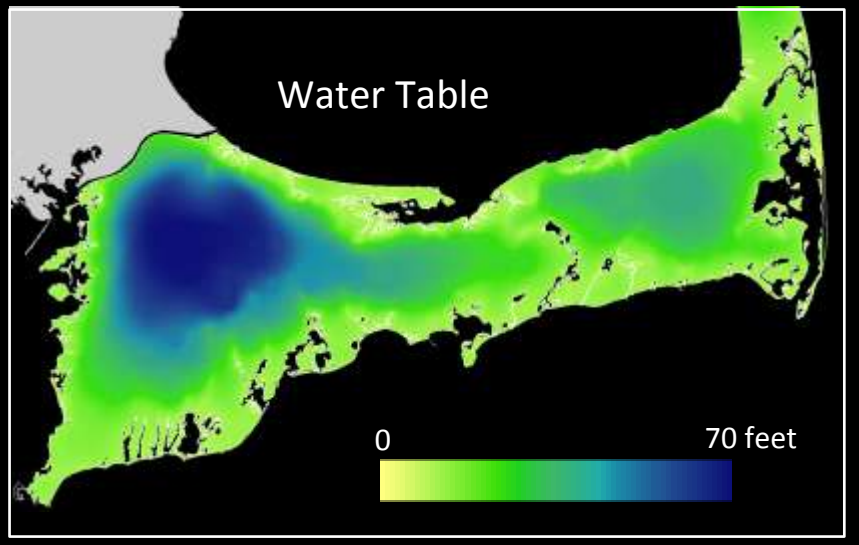

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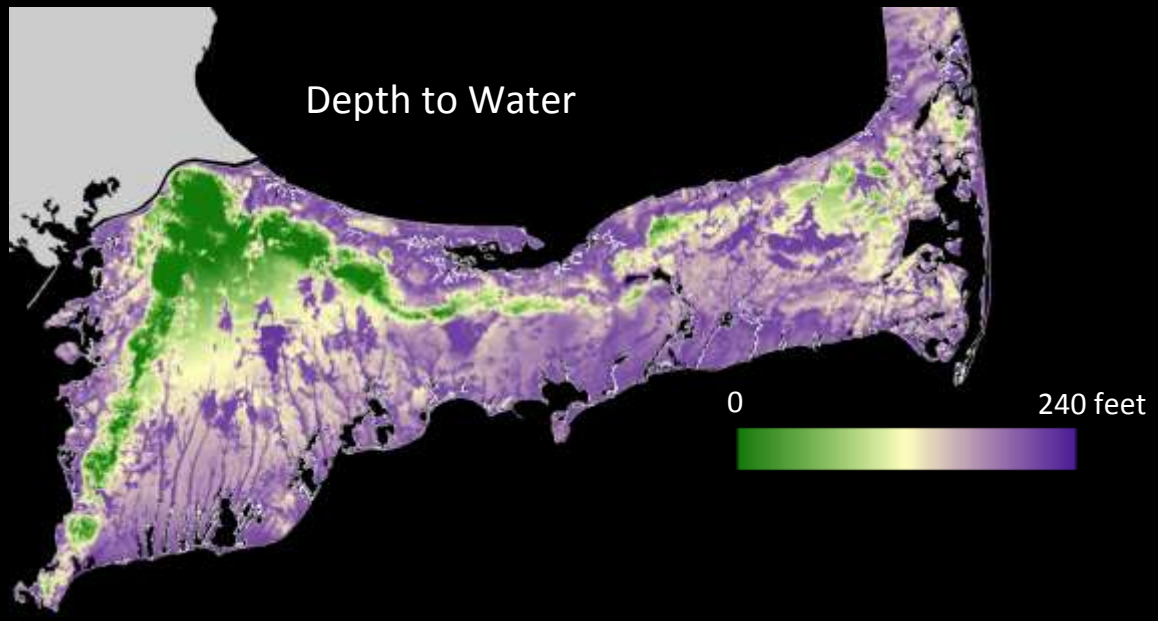
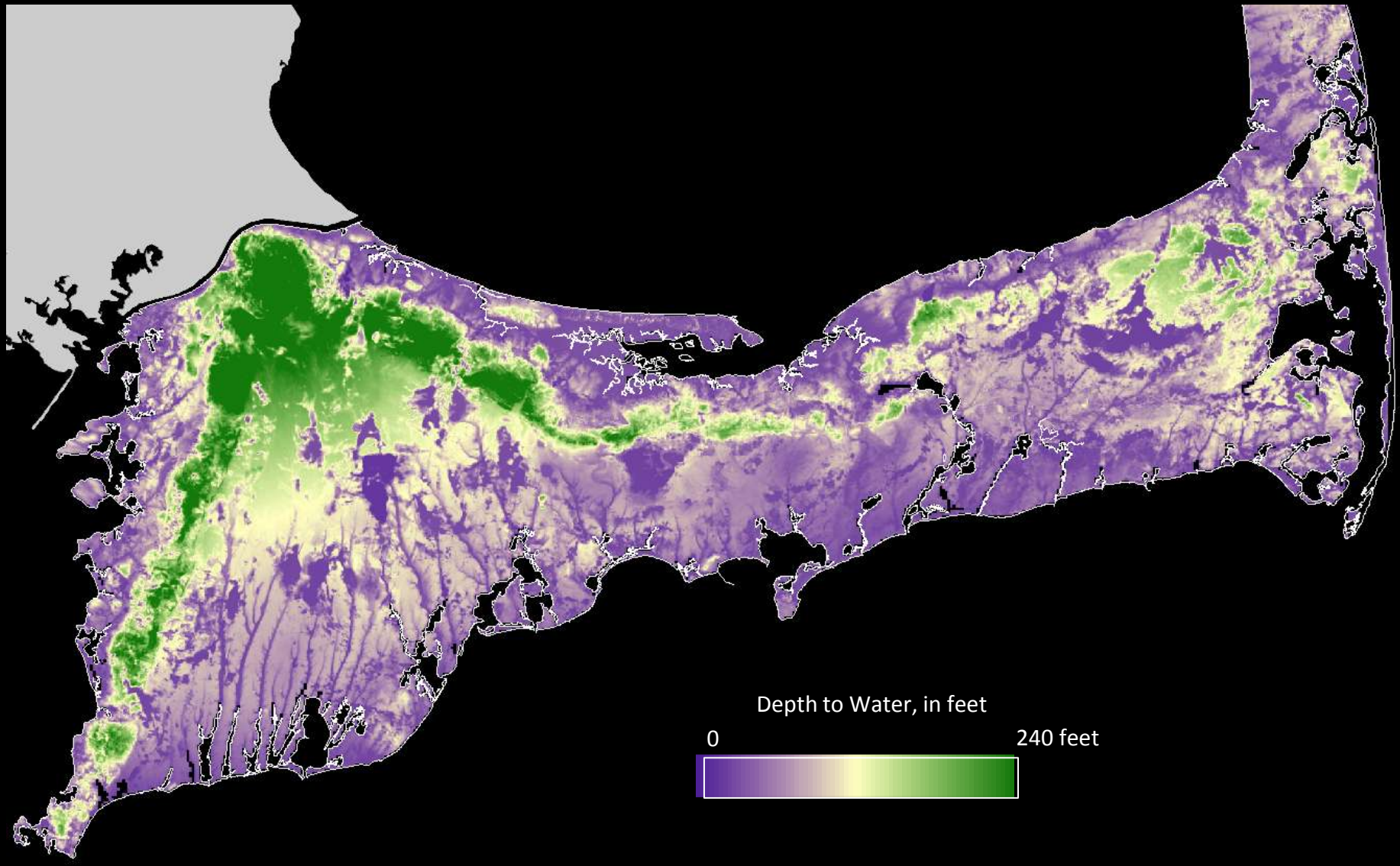
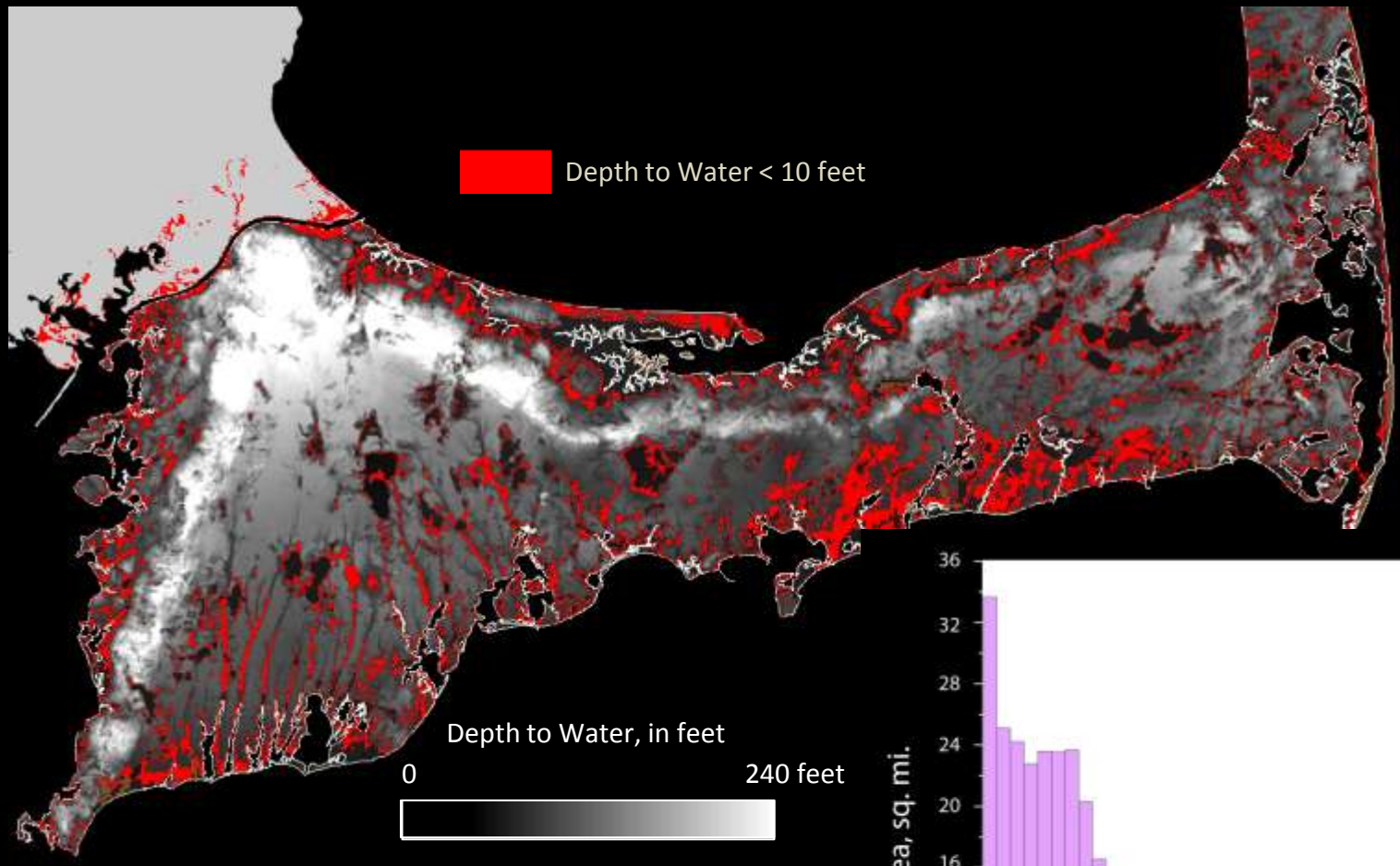
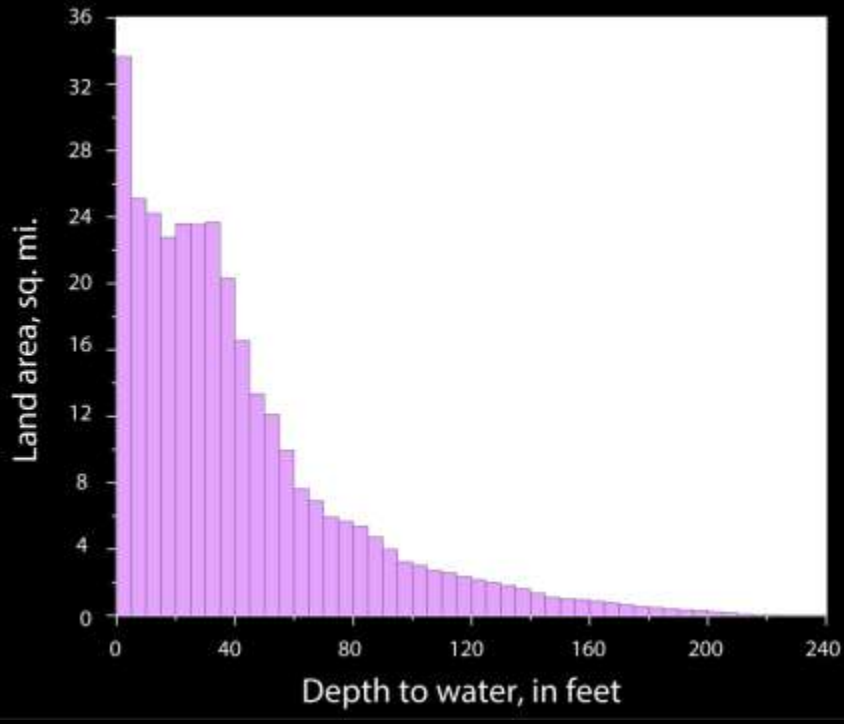


Estimated Depth to Water, Current Sea Level

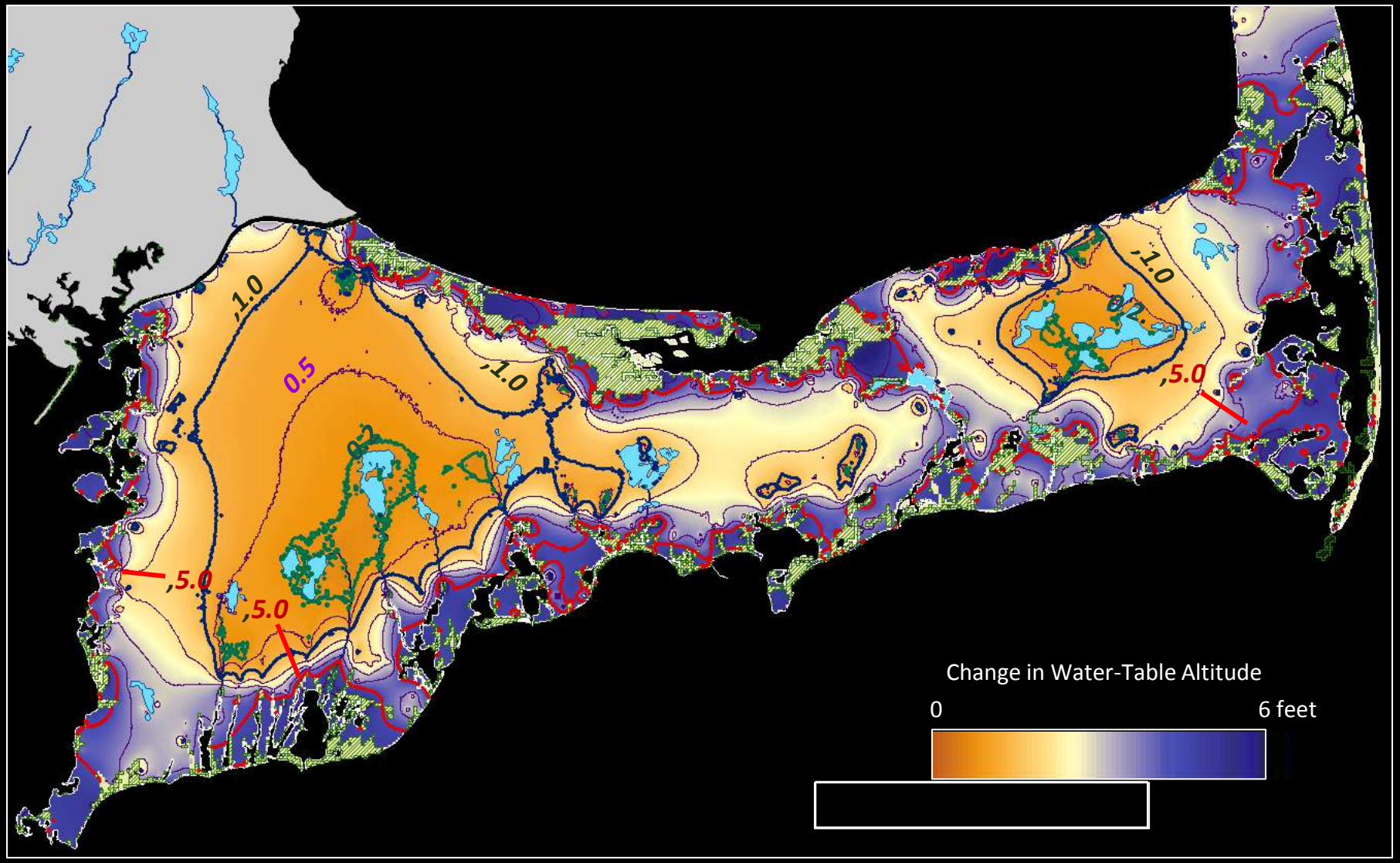


Depth to Water Less Than 10 Feet, 6-foot SLR





Change in Water Table Altitude, 6-foot Sea Level Rise



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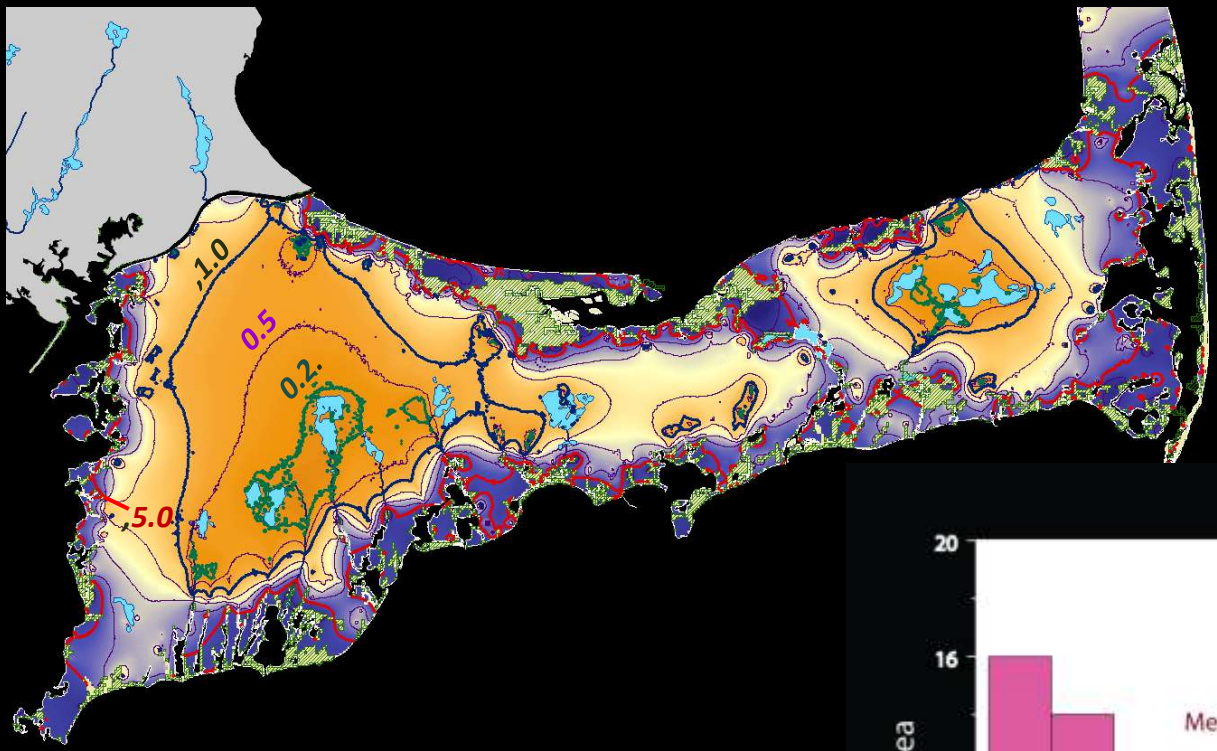
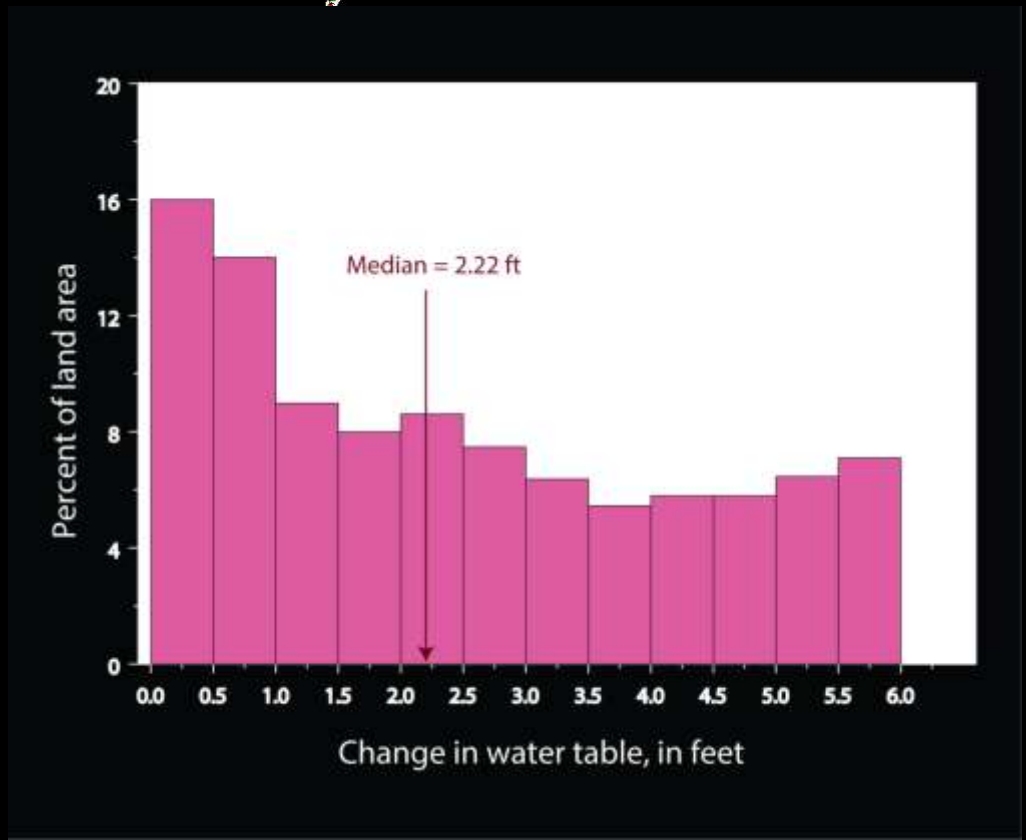


Change in Water-Table Altitude

0 6 feet



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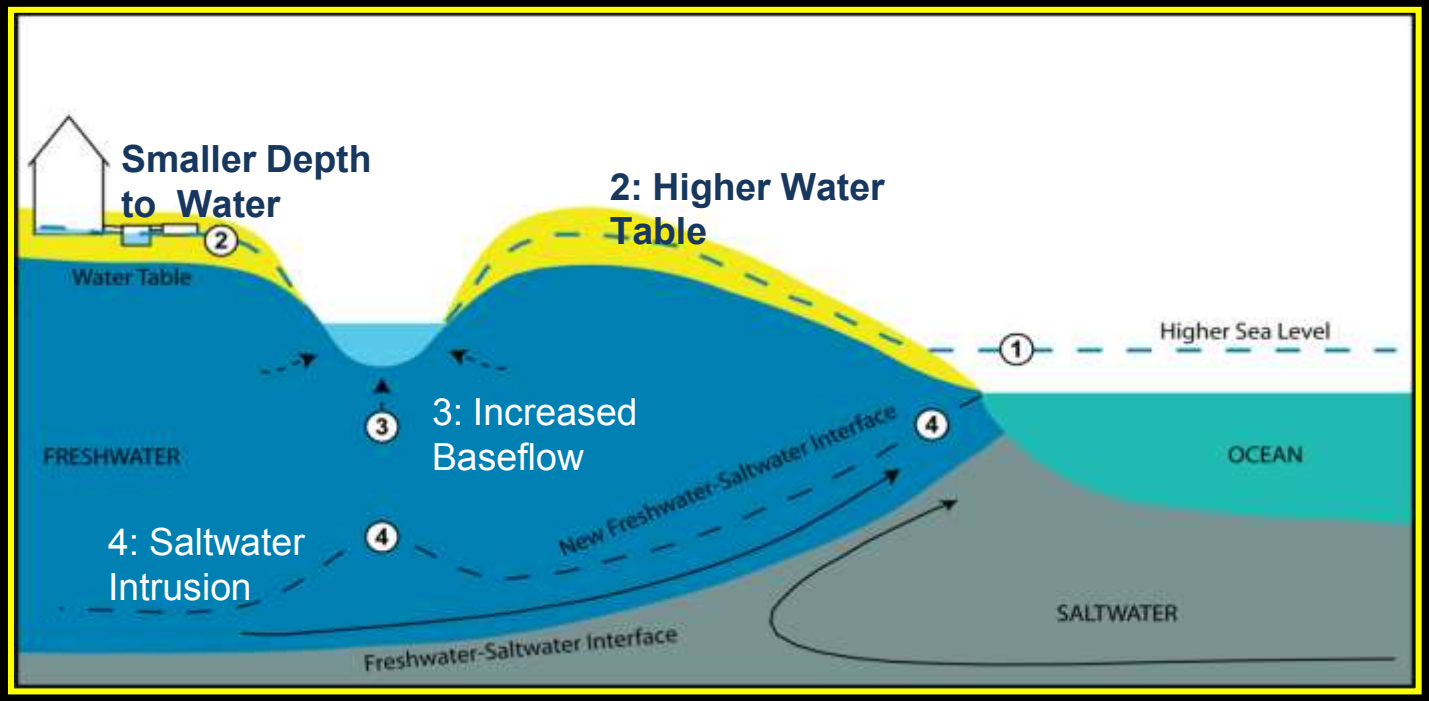
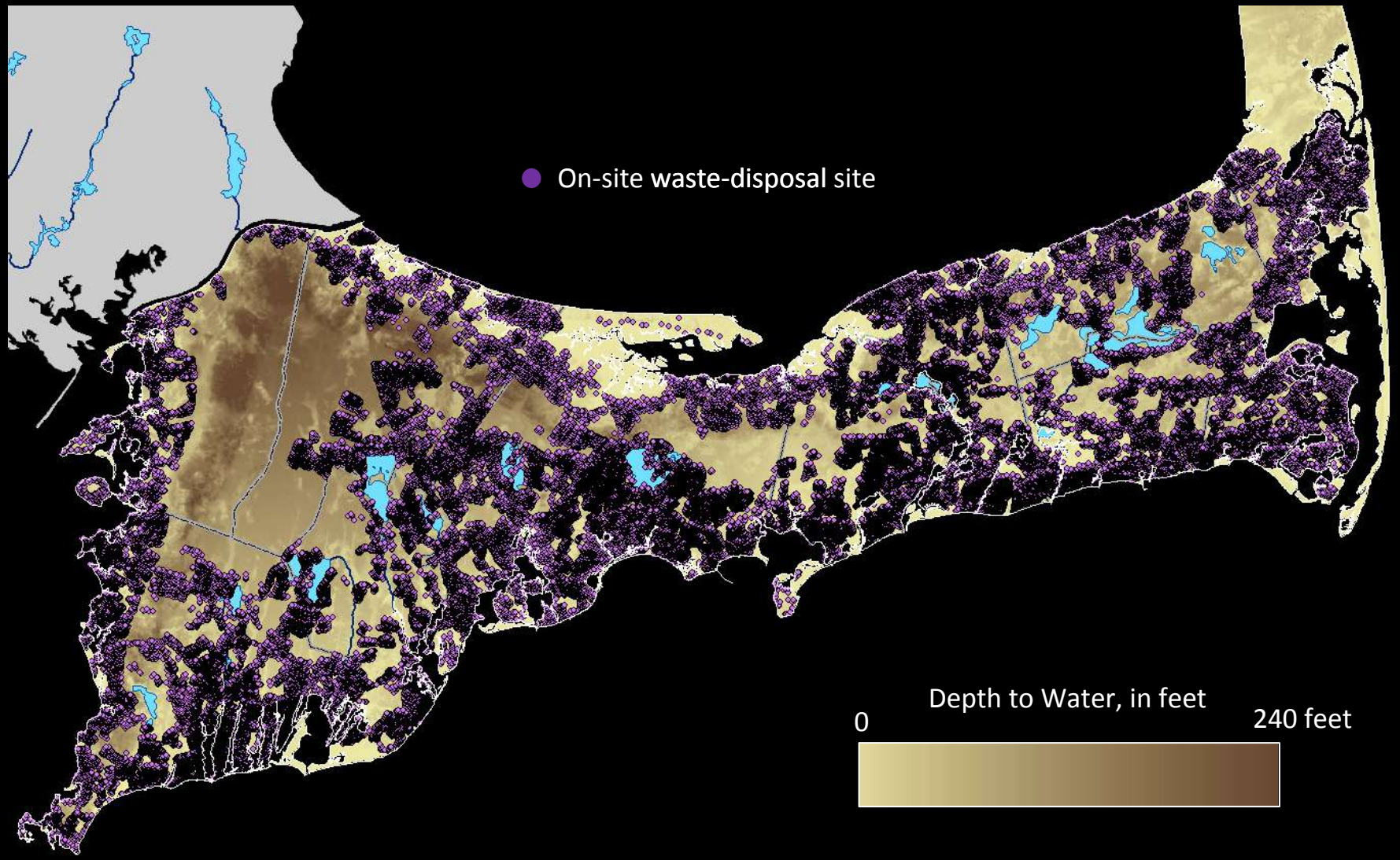


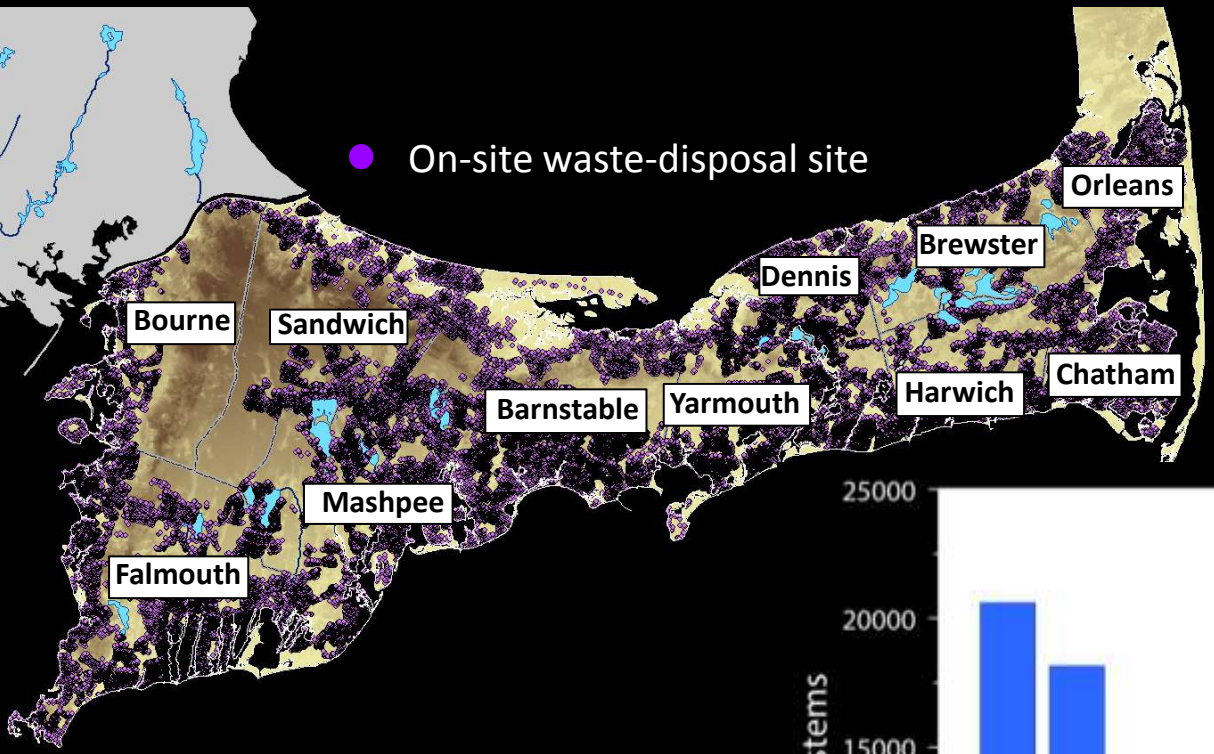
Effect of Sea-Level Rise on Septic Systems

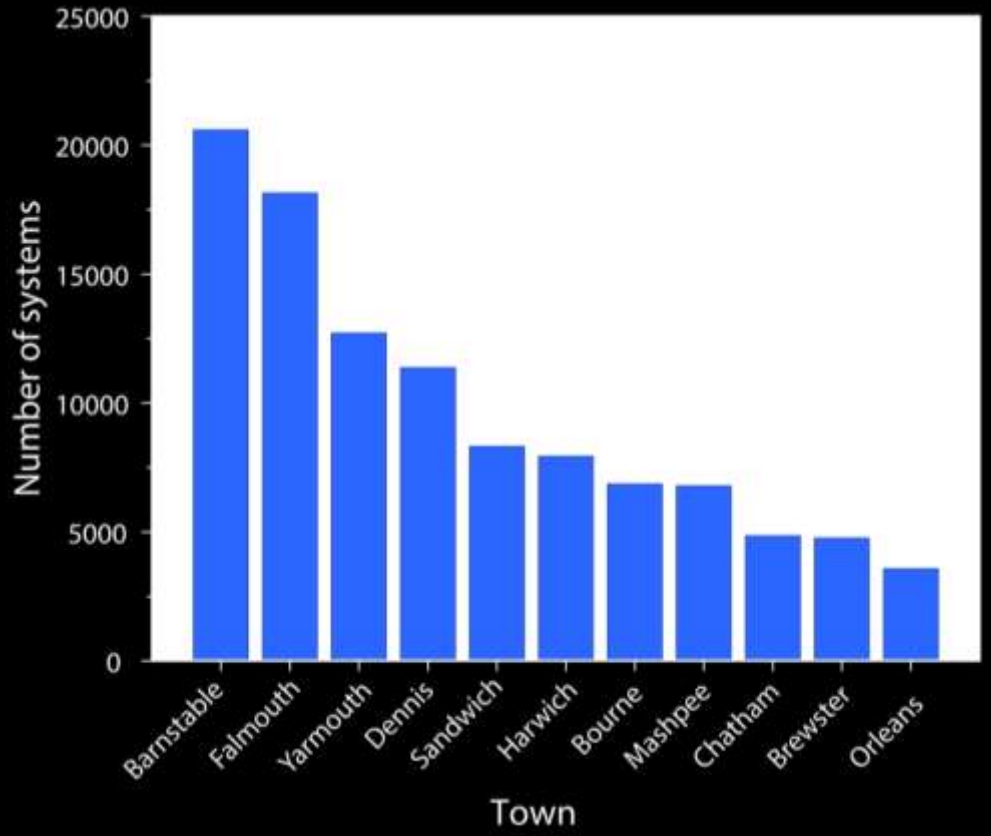
- About 106,000 septic systems within the study area (11 townships)
- Most septic systems are in coastal areas or near surface waters
- Septic systems susceptible to groundwater inundation arising from SLR
- A depth to water of 5 feet or less considered a minimum threshold

Location of On-Site Waste Disposal Systems



Location of On-Site Waste Disposal Systems by Town





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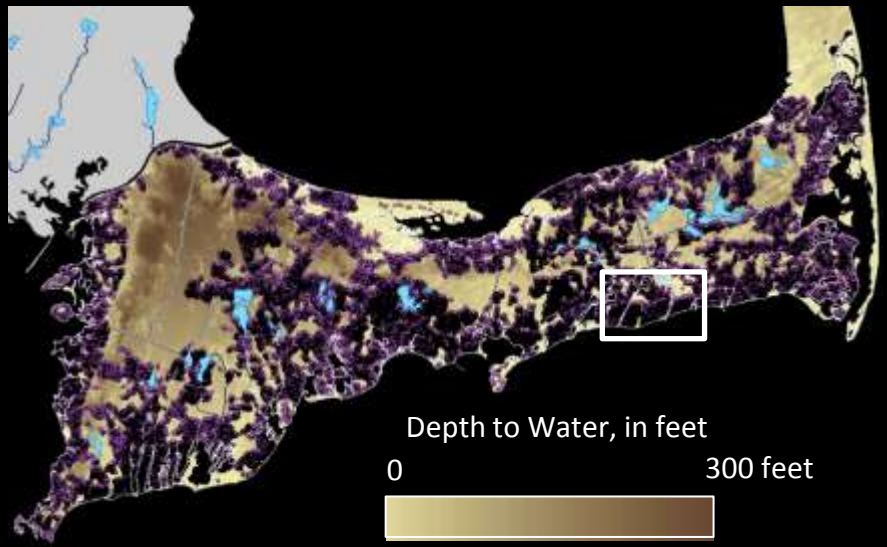
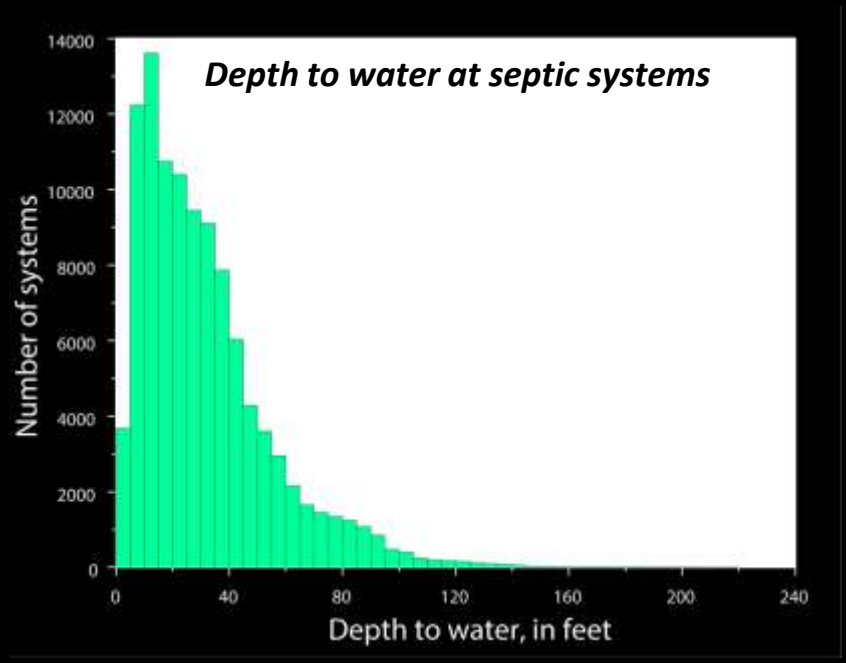
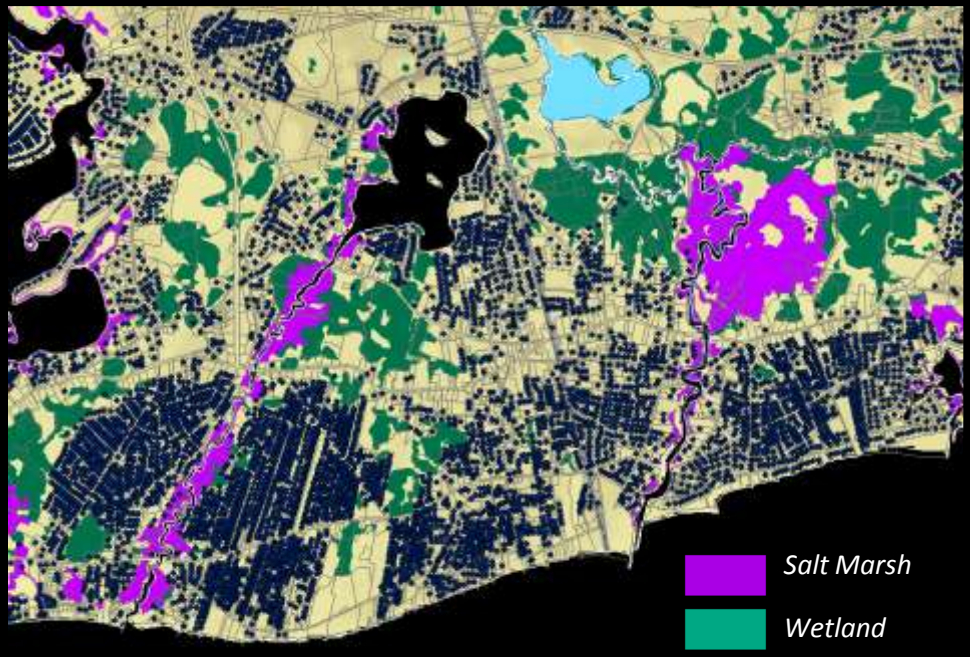
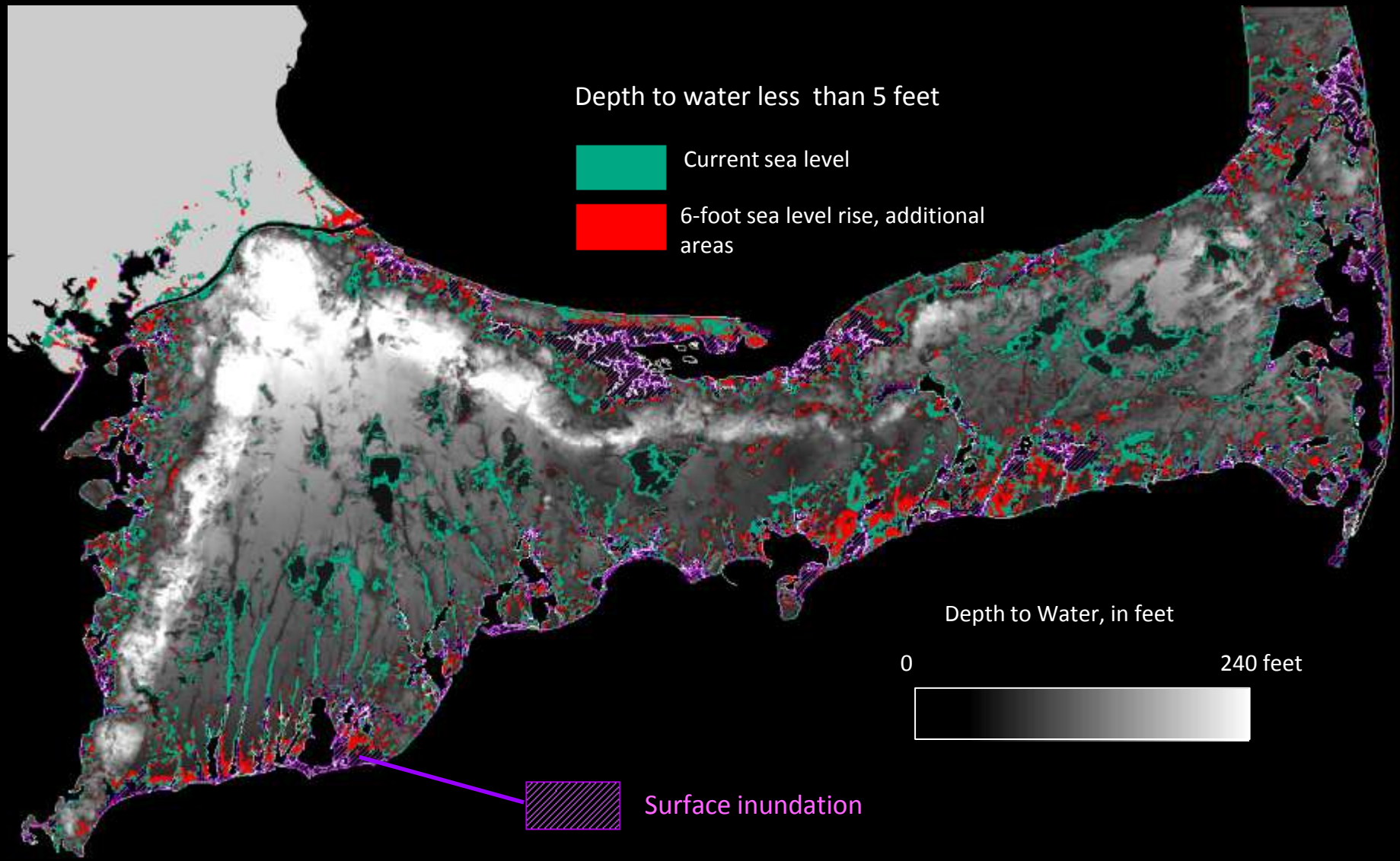


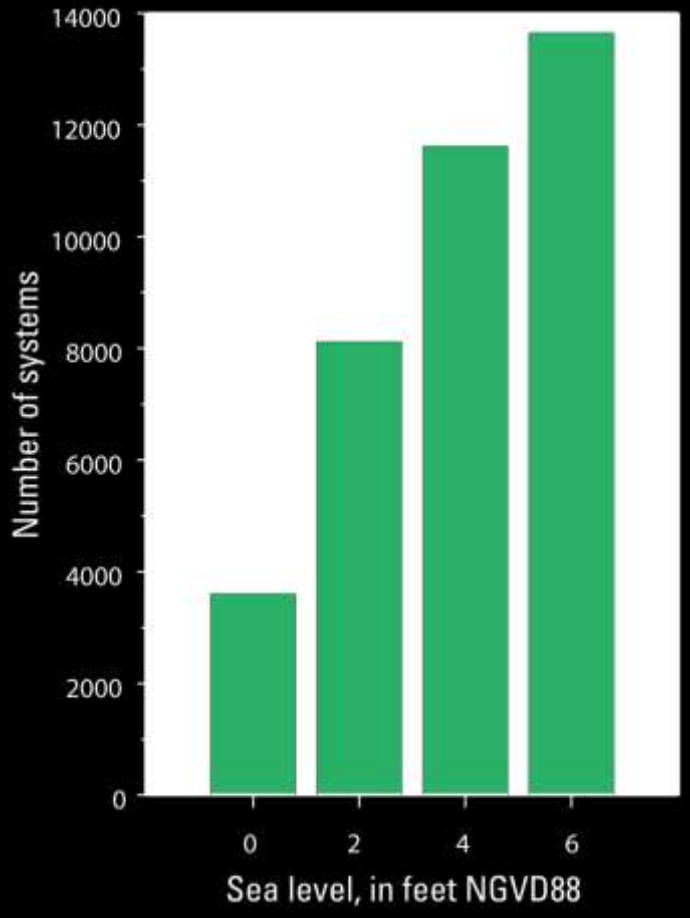


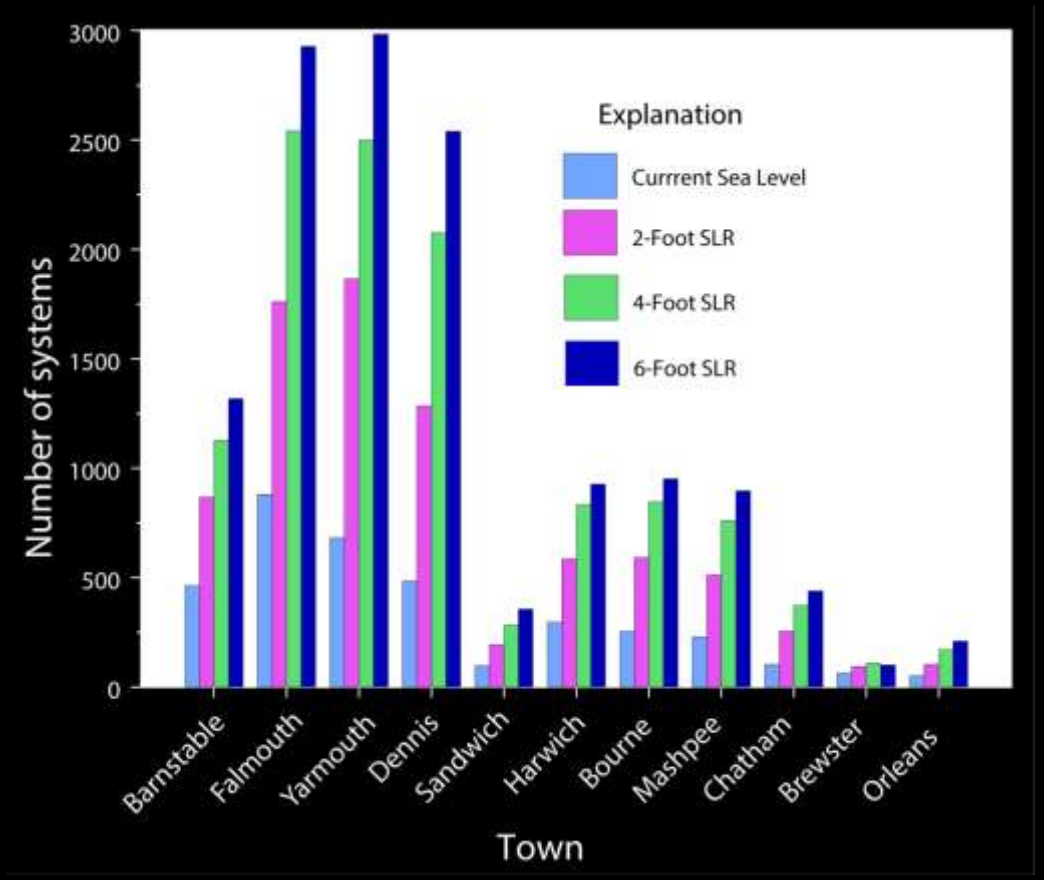


Change in Depth to Water Less Than 5 feet: 6-foot Sea Level Rise

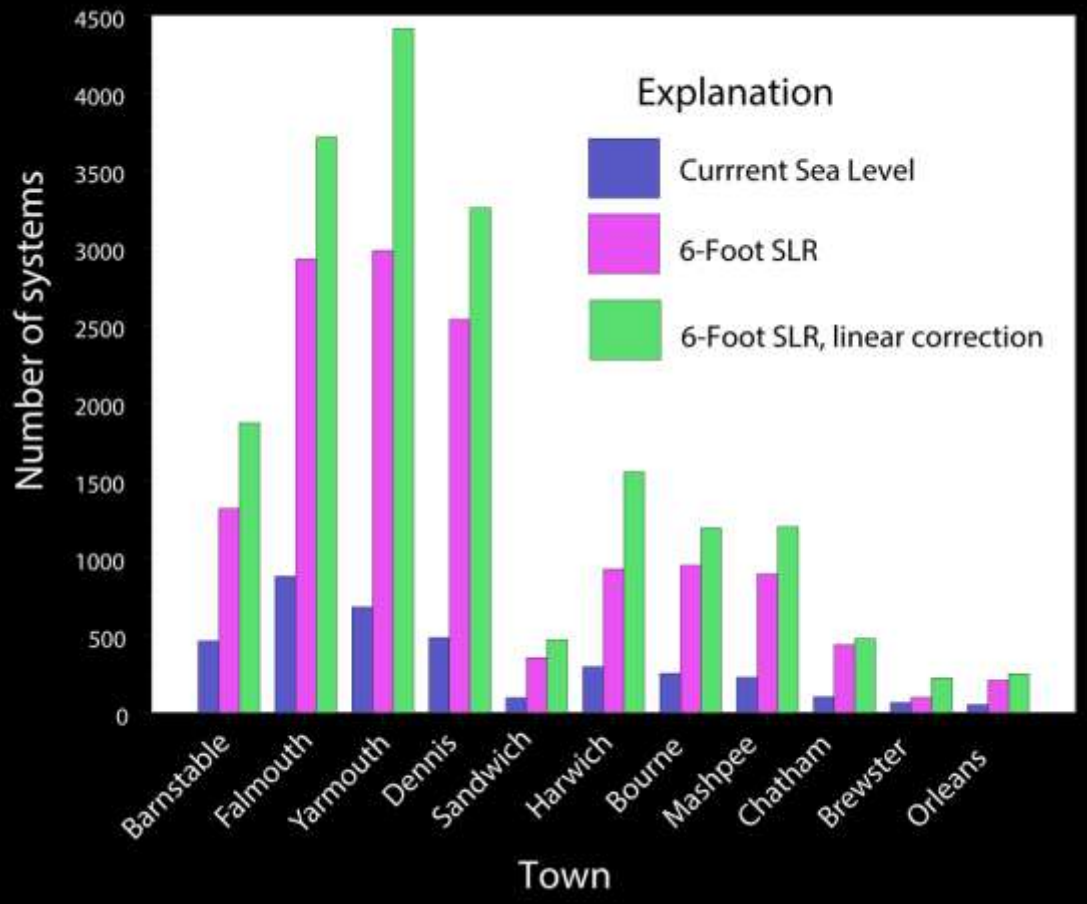


Septic-systems with Depth to Water less than 5 feet: Current Sea Level and a 2, 4, and 6-foot SLR

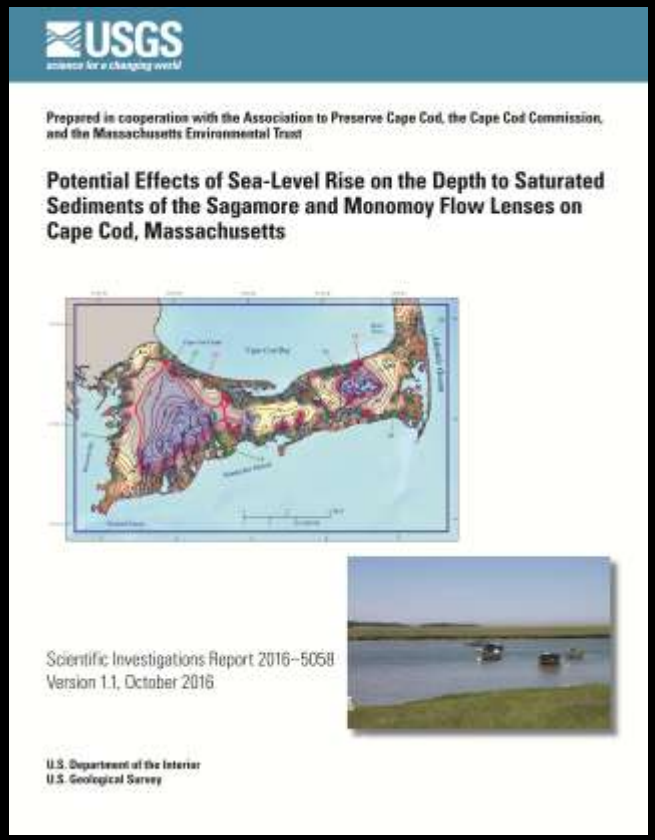




Septic-Systems with Depth to Water less than 5 feet: 6-foot SLR Using Linear Correction



Link to Report: SIR 2016-5058



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