University of Massachusetts Amherst
Hydrogeology

Massachusetts Groundwater Flooding Study

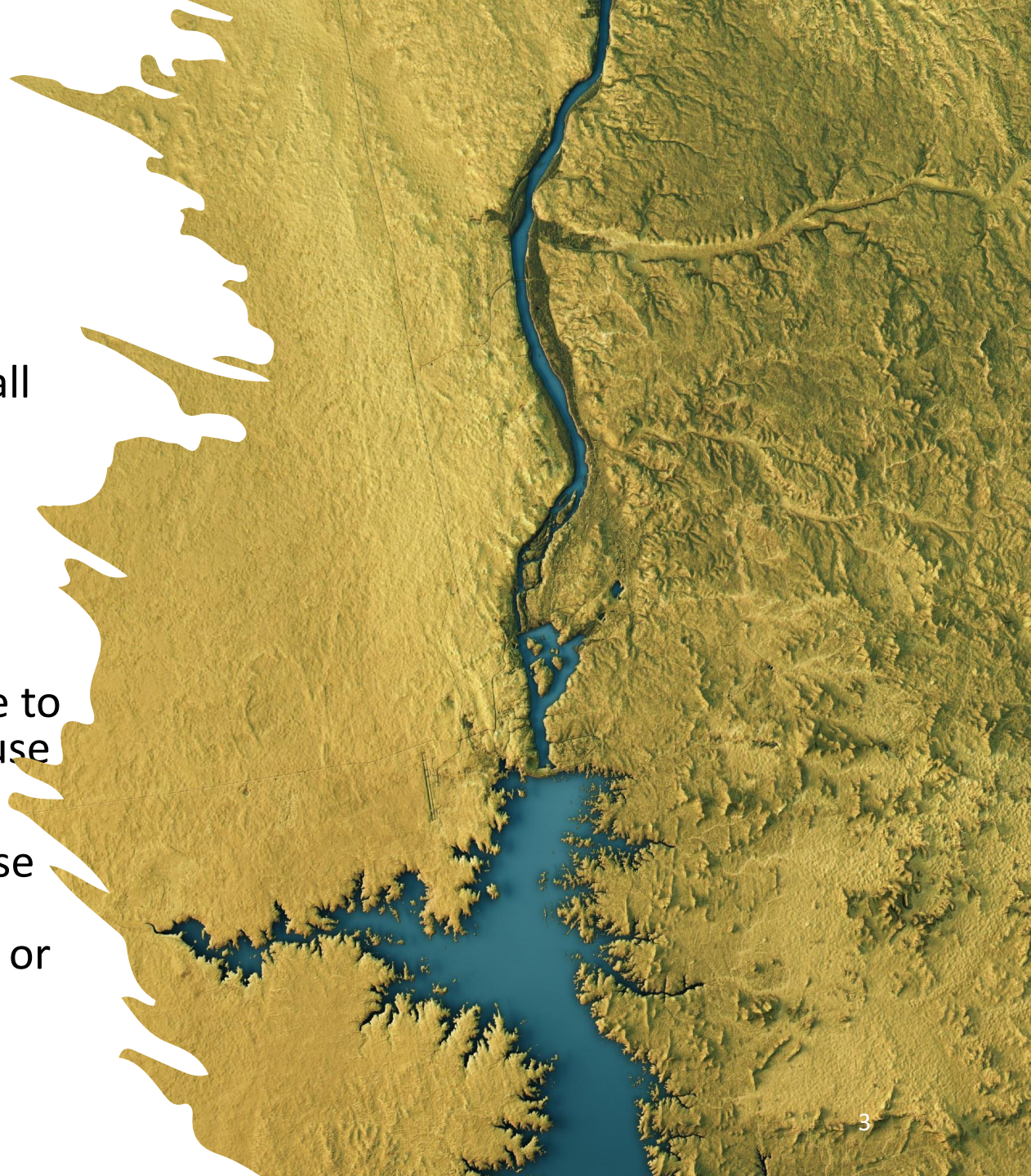
Funded by EEA State Hazard Mitigation and Climate Adaptation Plan

What is groundwater flooding?

Key Terms Defining Groundwater Flooding

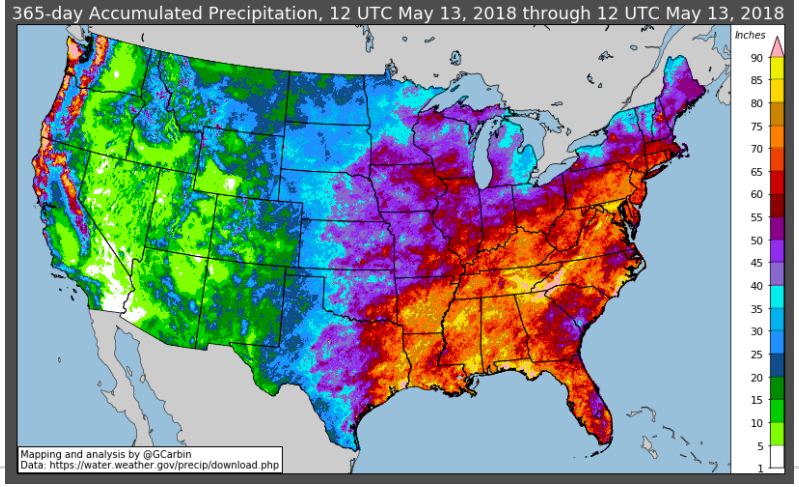
- **Groundwater rise:** Movement upward of the water table due to short or long-term fluctuations in rainfall recharge and/or river, ocean or tidal levels.
- **Groundwater shoaling:** Water table rise in the subsurface closer to, but not reaching, the land surface.
- **Groundwater emergence:** Discharge/outflow of groundwater at the surface from the subsurface due to the rise of the water table at a point (spring) or diffuse locations.
- **Groundwater flooding:** Temporary process of the rise of the water table resulting in a groundwater emergence where the water level surface intersects or goes above the land surface due to a changing condition.

Bosserelle et al., 2021, Earth's Future

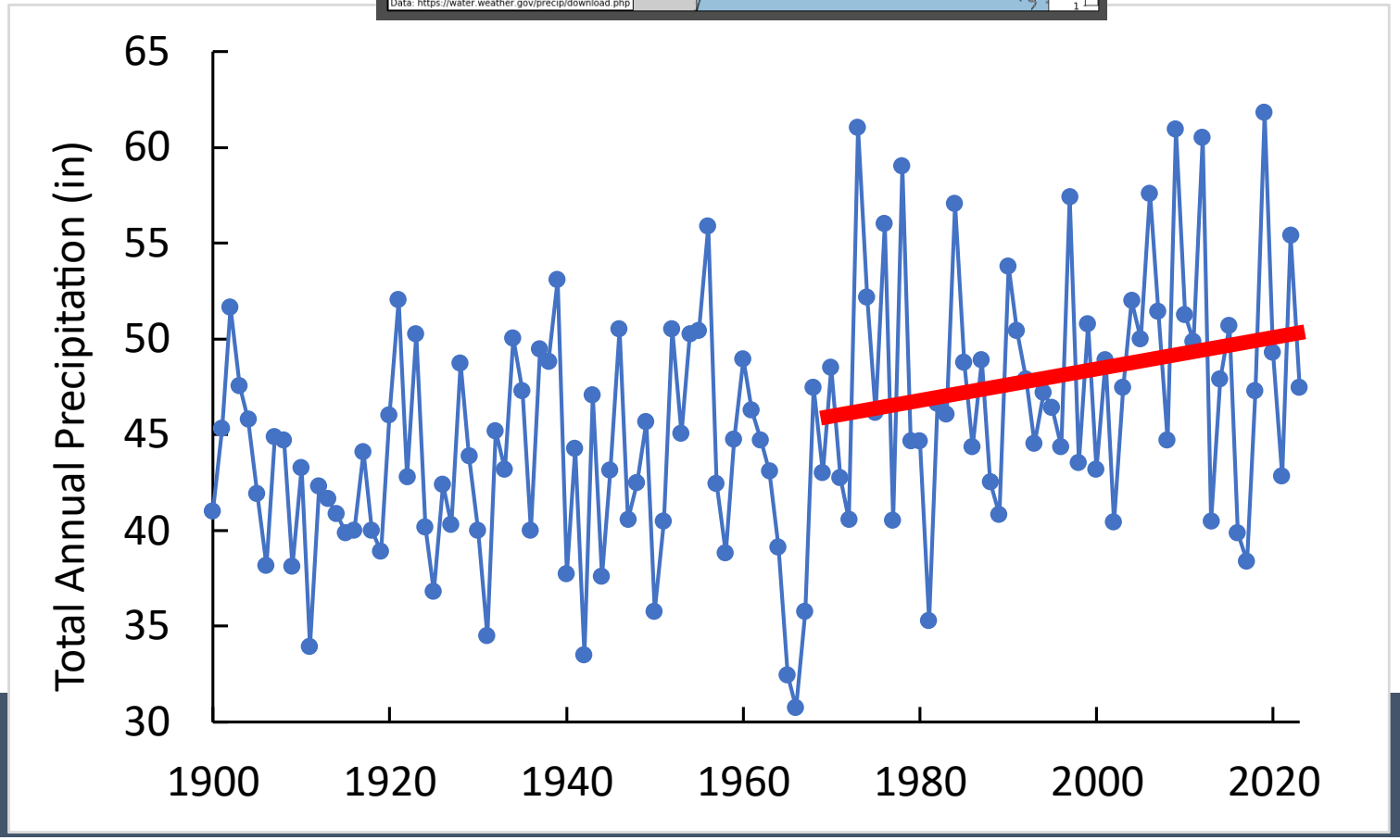


What evidence do we have for GW flooding and rising water tables in Massachusetts?

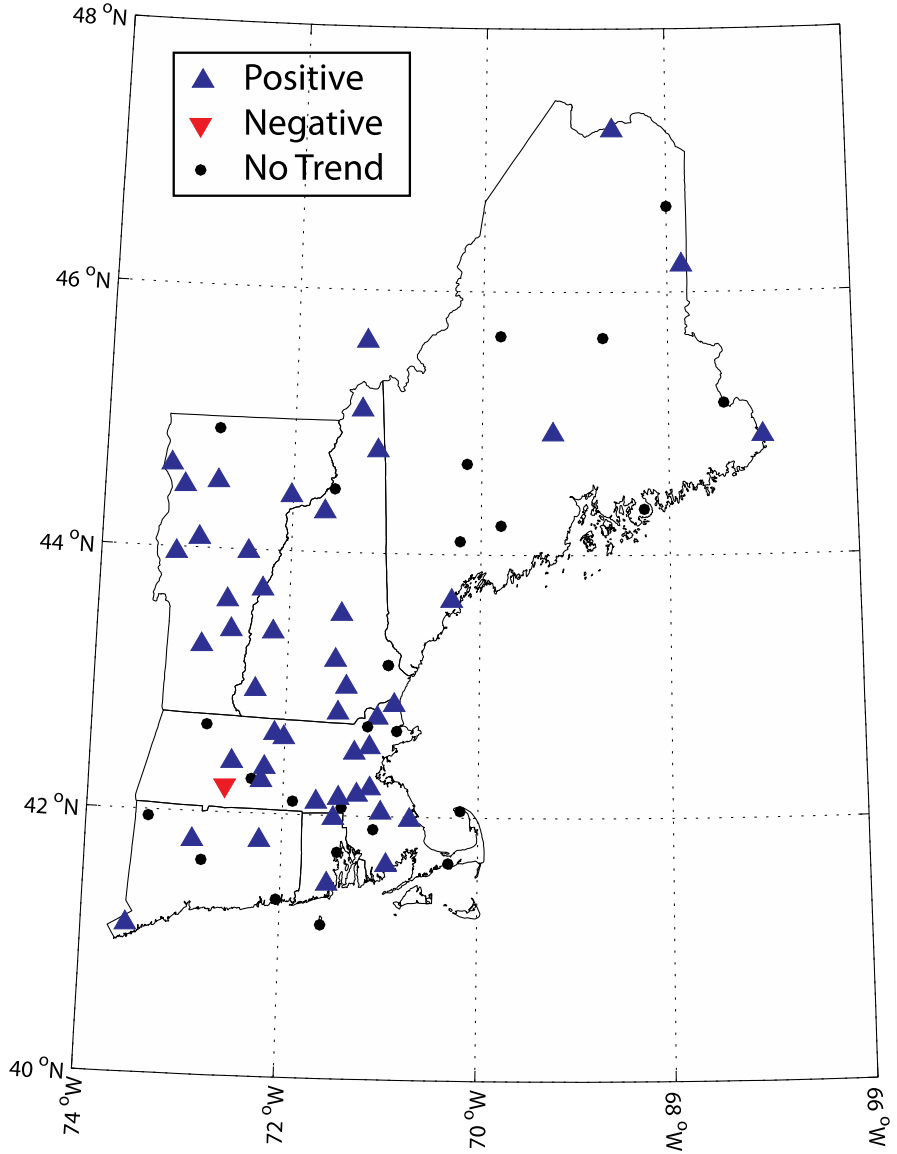
Precipitation Trends in S. New England, USA



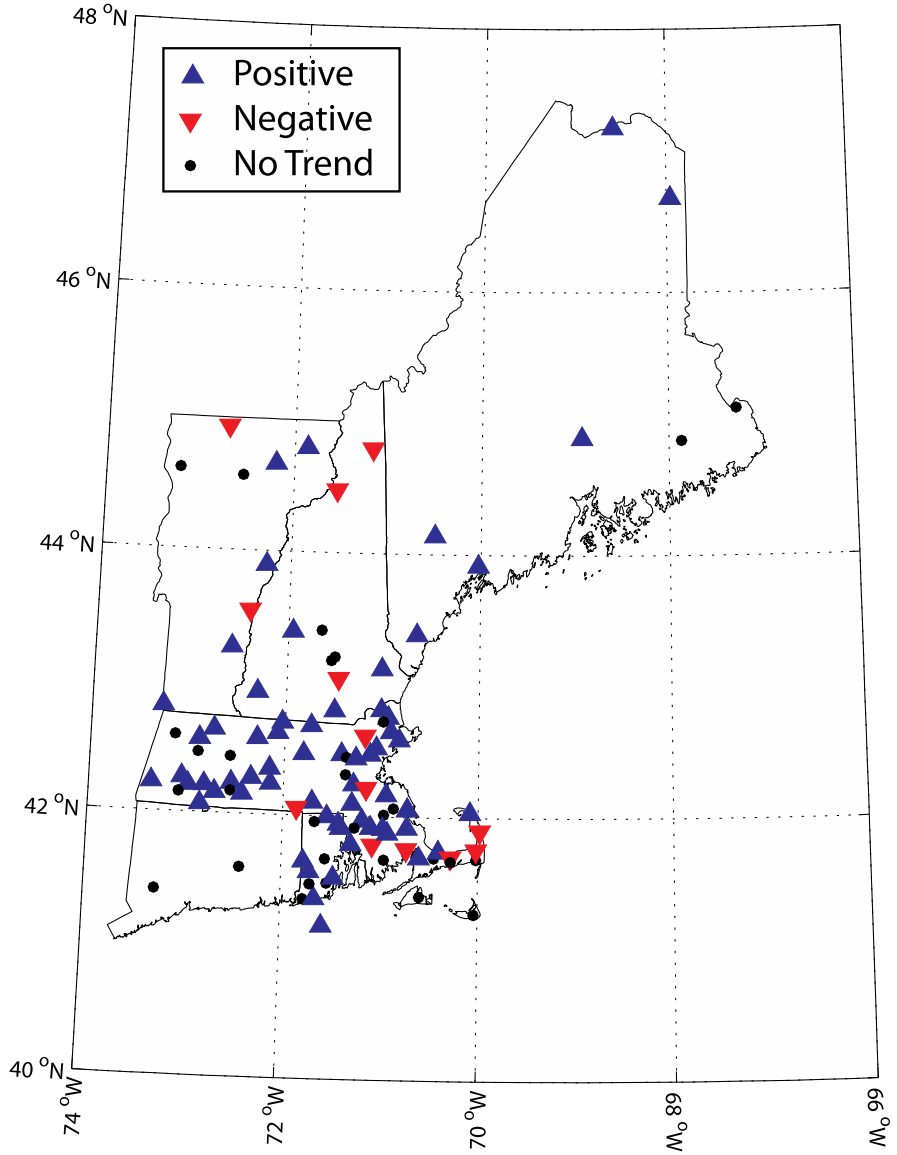
The southern New England region has experienced a ~30% increase in precipitation since the mid 1960's.



Precipitation Trends since 1960



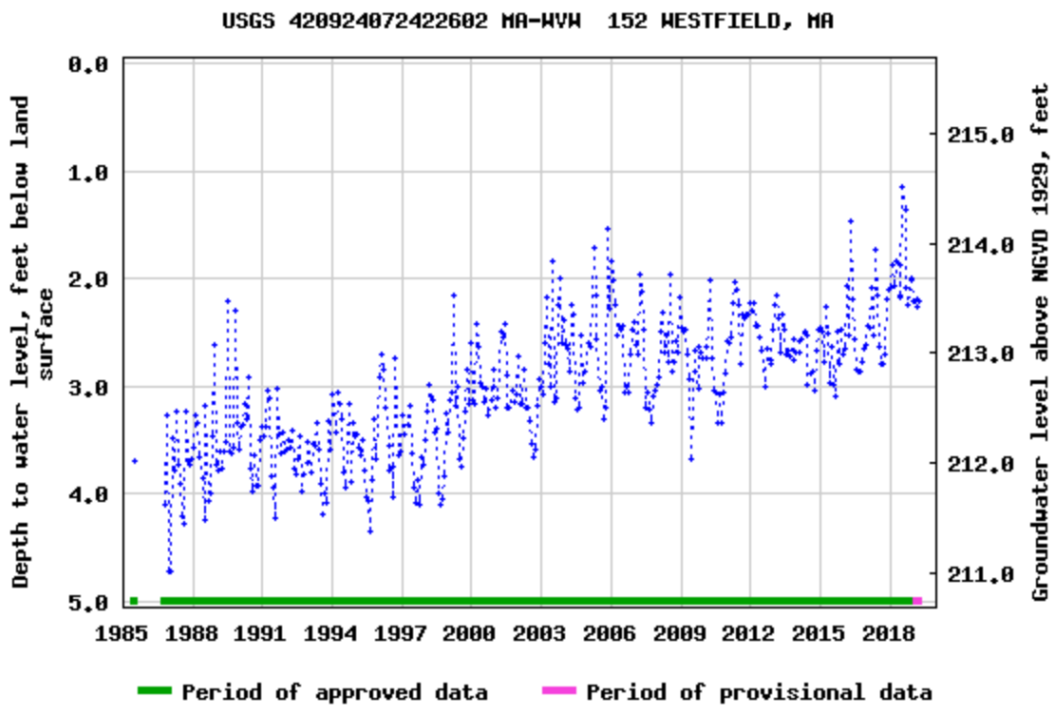
Groundwater Trends since 1970



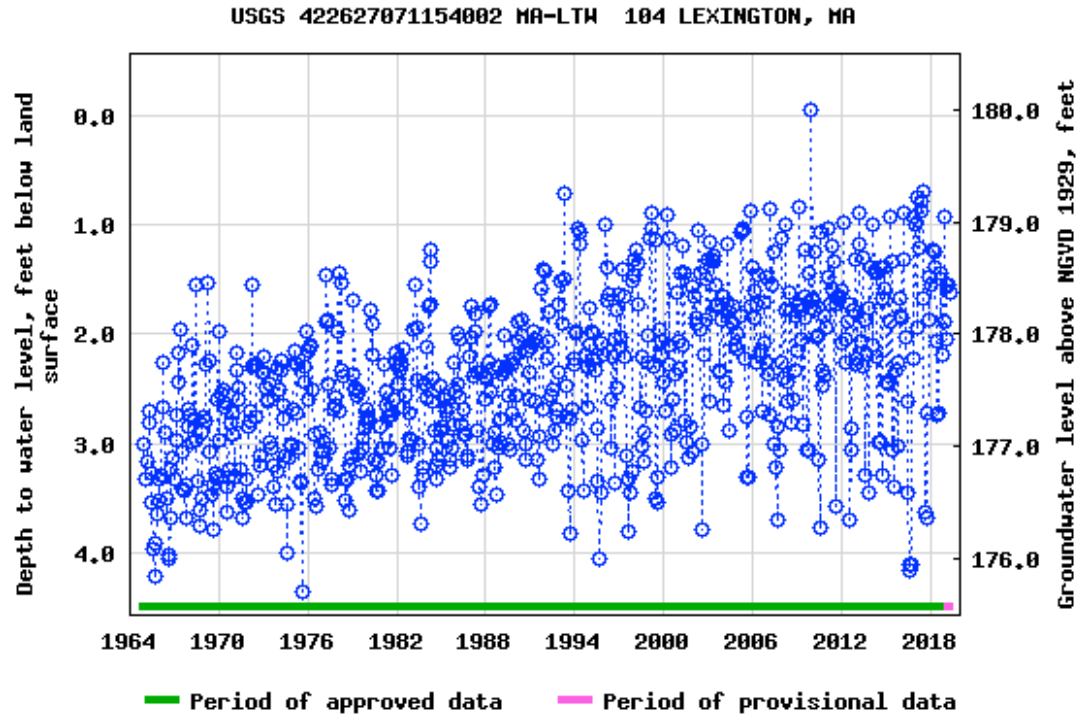
Majority of Groundwater Levels Across New England are Increasing

Majority of Groundwater Levels Across New England are Increasing

Western MA



Eastern MA

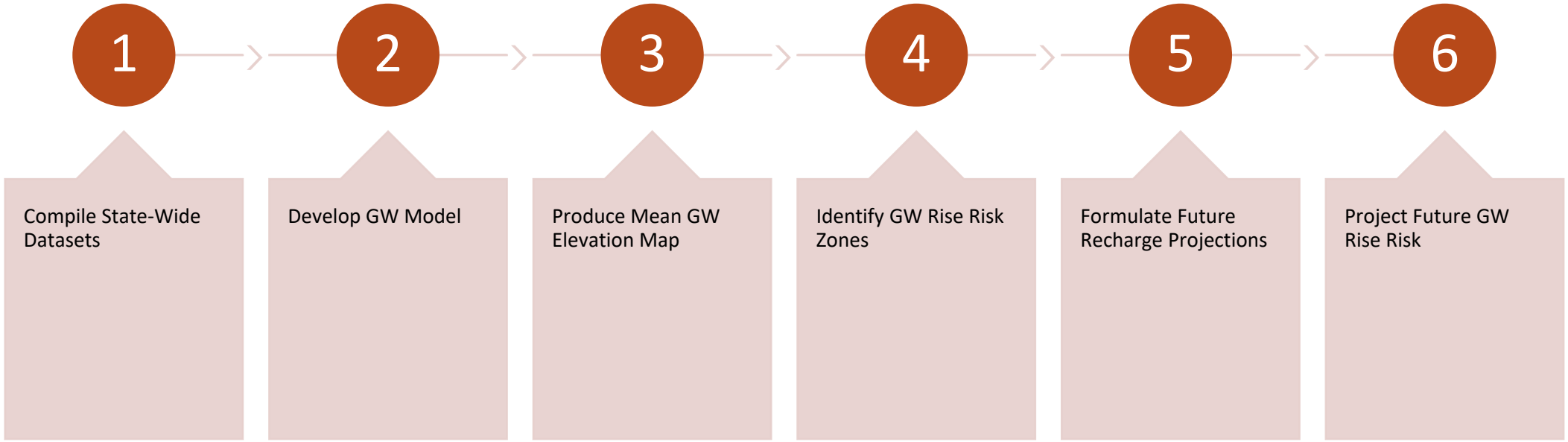


Massachusetts Groundwater Flooding Study

Project Objectives

- Map the modern water table depth across the Commonwealth
- Make probabilistic predictions of the likelihood of future groundwater rise impacts

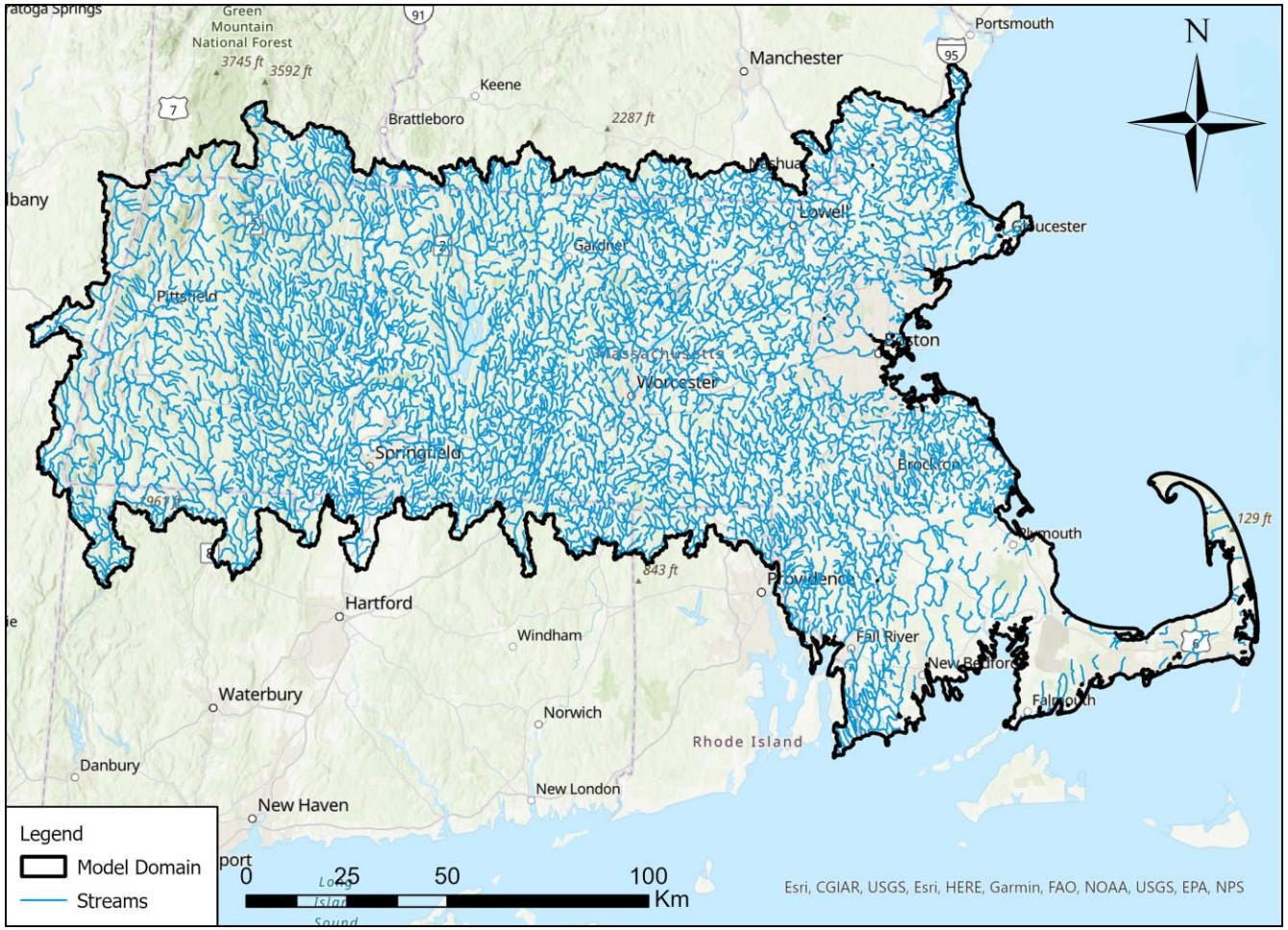
Project Tasks



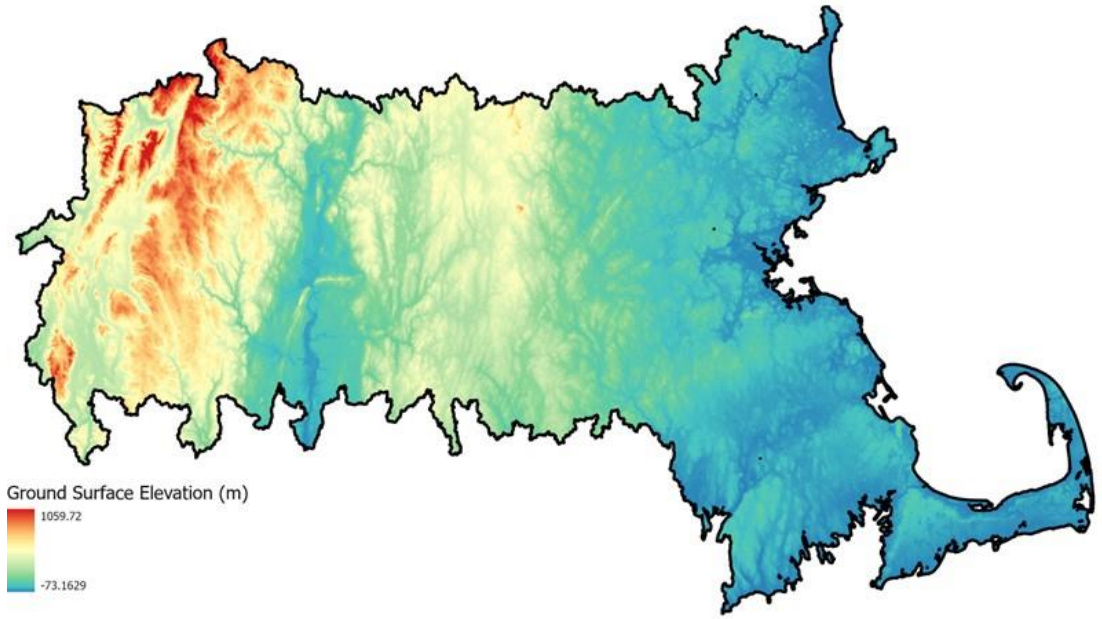
1. Datasets

Hydrography

- Source: USEPA National Hydrography Dataset Plus (NHDPlus) Version 2.1
- HUC12 Watersheds
- Rivers and streams (+1st order streams)
- Surface water bodies
- Ocean

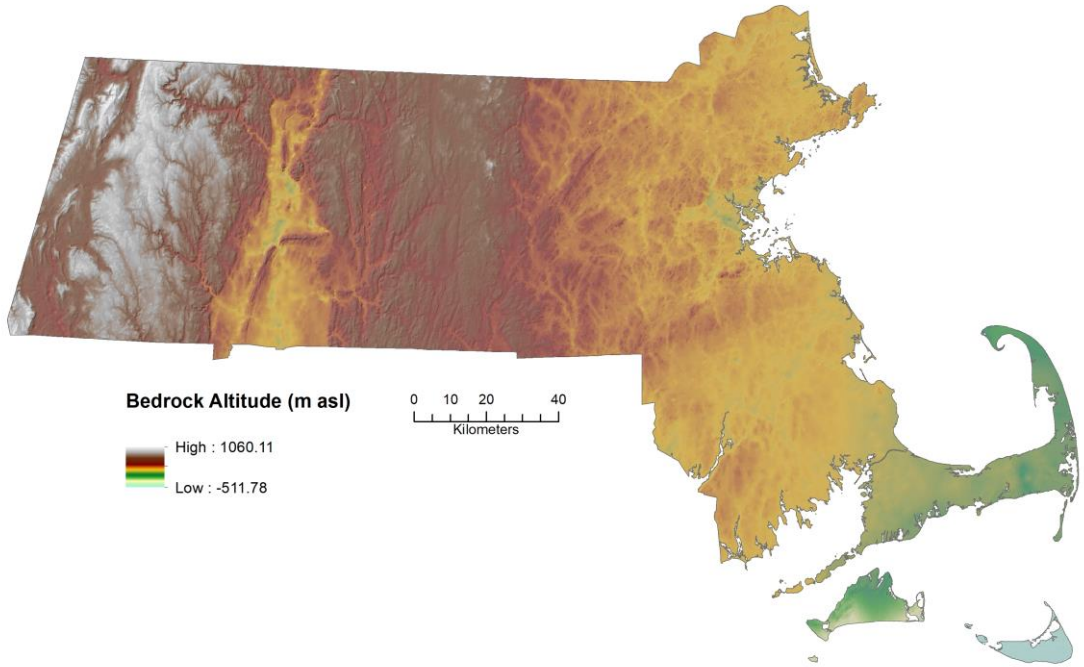


Topographic Digital Elevation Model



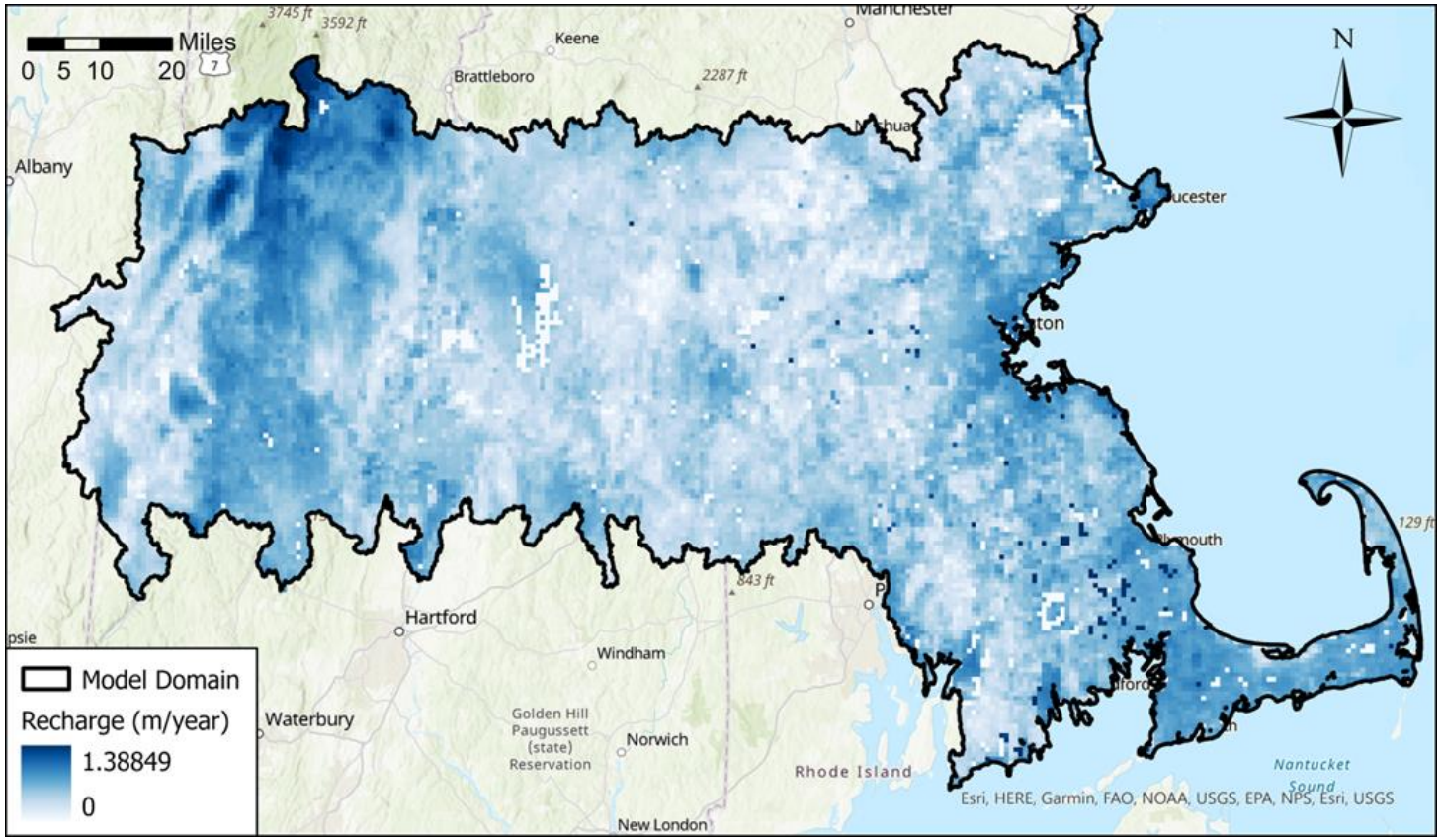
Source: USGS National Elevation Dataset (NED)

Bedrock Elevation Model



Source: MA Geological Survey

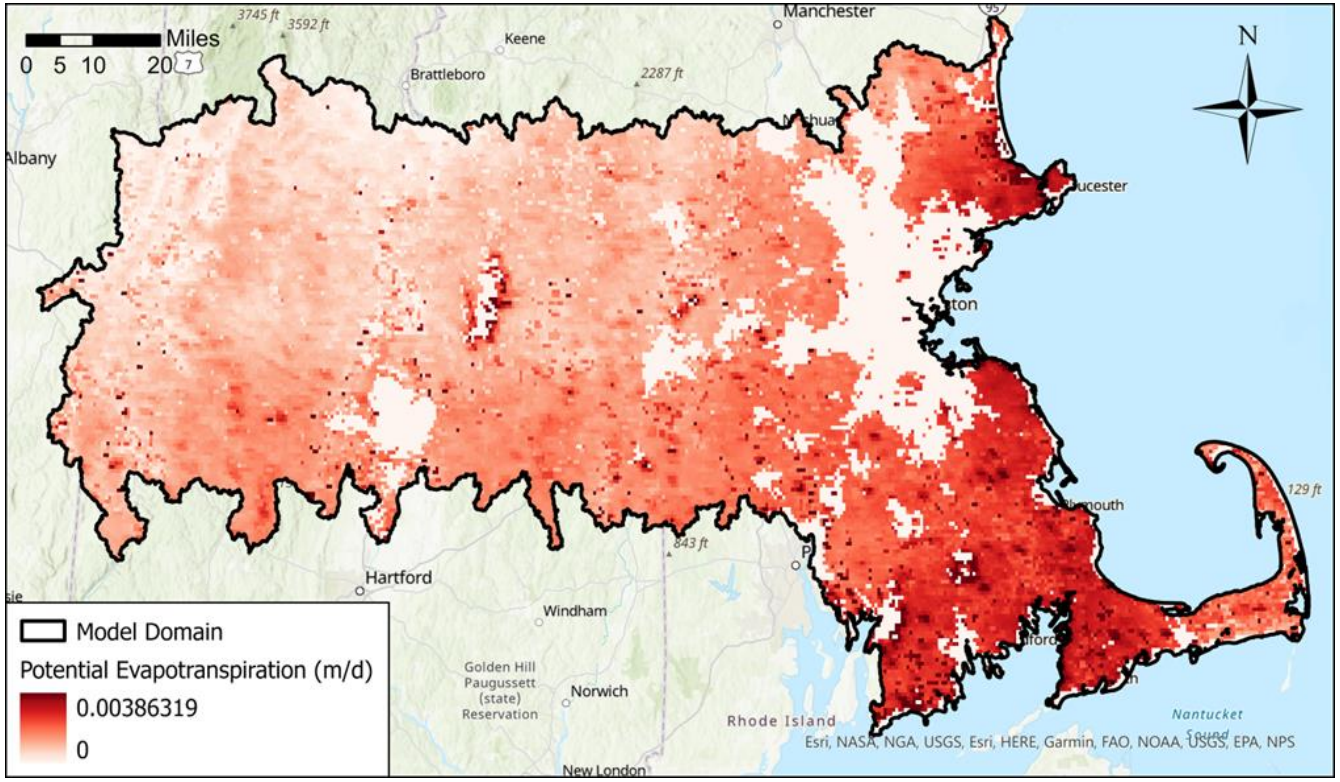
Aquifer Recharge

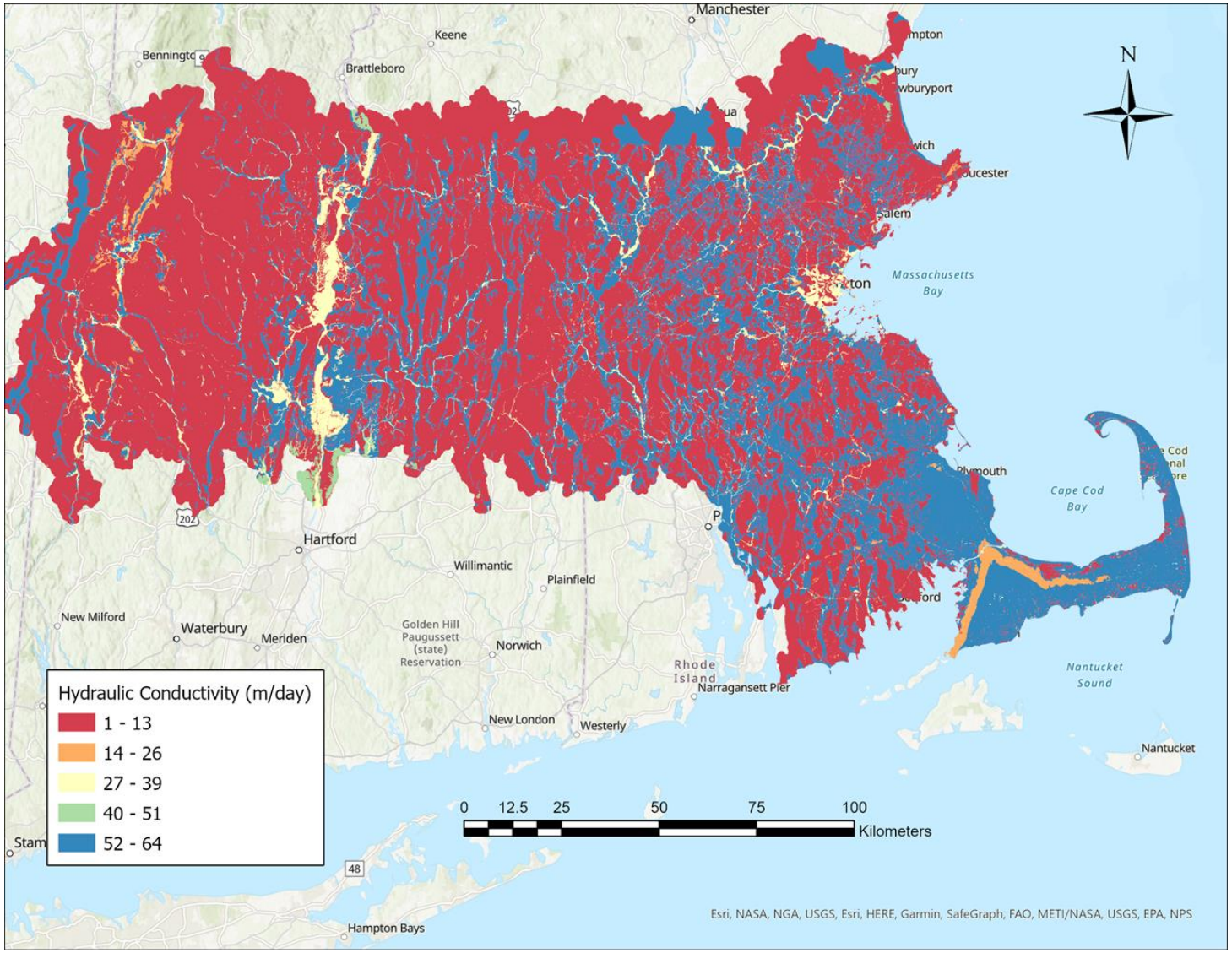


- Source: Reitz *et al.* (2017)
- Mean recharge for period 2000-2013

Potential Evapotranspiration

- Source: MassGIS, Fennessey and Vogel (1996)
- Modeled via modified Penman-Monteith method
- Initial evapotranspiration rate conditions for model





Hydraulic Conductivity (K)

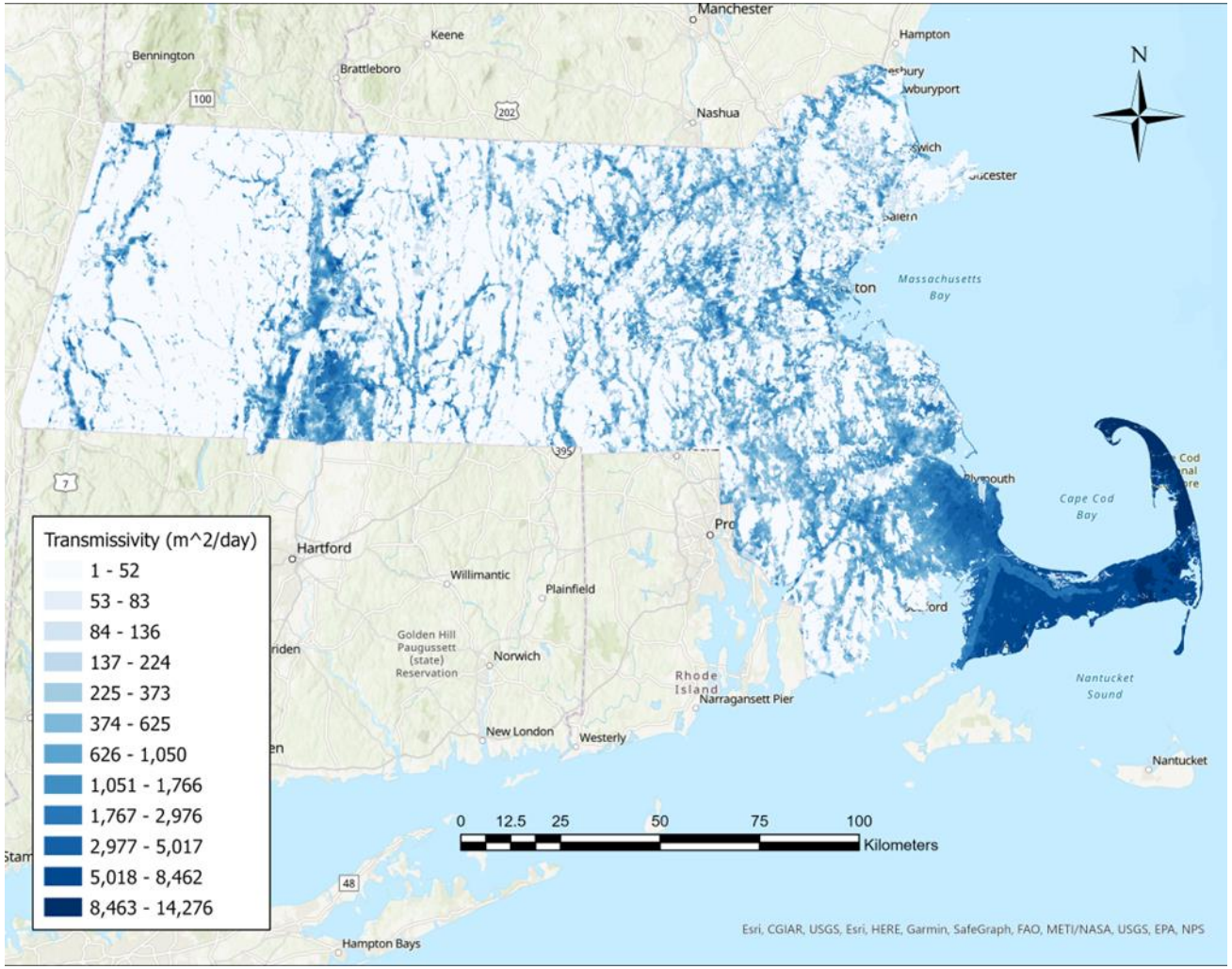
- Extracted K from USGS Reports in Plymouth[1], Cape Cod[2], South Hadley[3], Deerfield River Basin[4], Assabet River Basin[5], and Charles River Basin[6]
- Merged 1:24,000 MA surficial geology map with surficial geology from surrounding states
- Mapped K to surficial geologic units

1. Williams and Tasker, 1974; Masterson et al., 2009
2. Masterson et al., 1997
3. Garadedian and Stone, 2004
4. Friesz, 1996
5. DeSimone, 2004
6. DeSimone et al., 2002

Transmissivity

Calculated using:

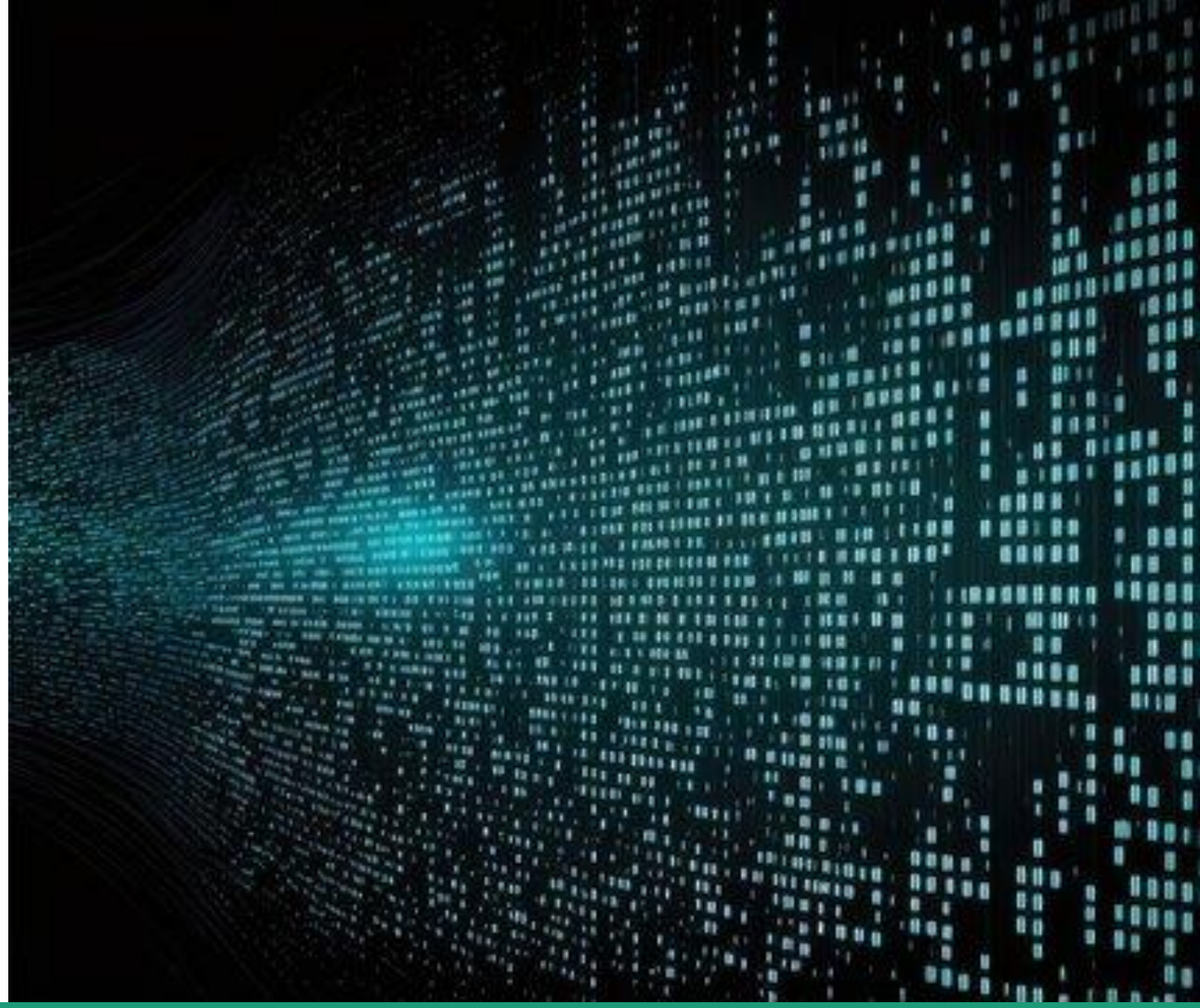
- Aquifer thickness
  - Surface elevation – bedrock elevation
- Hydraulic conductivity map from surficial geology



2. Groundwater Model

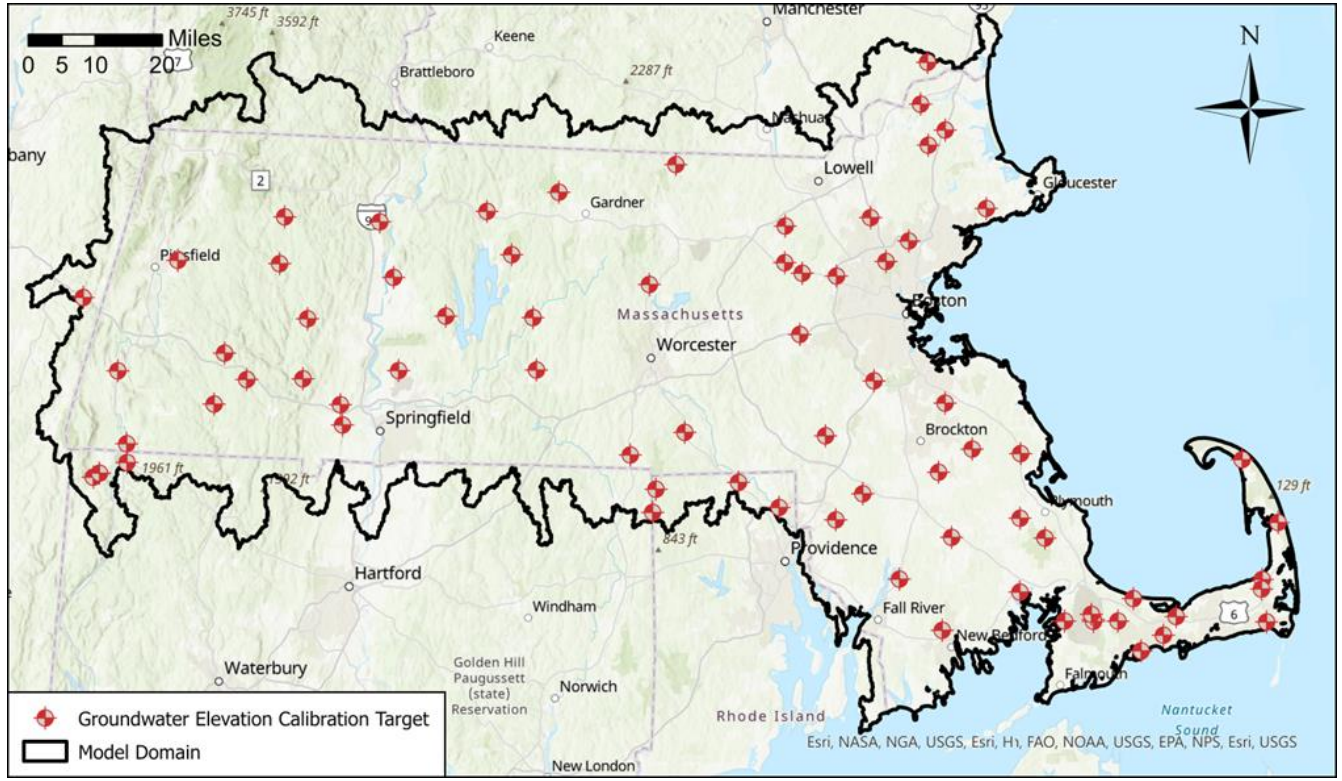
Developing a state-wide map of mean water table elevation

- MODFLOW 6 steady-state groundwater model
- 100m resolution
- Incorporate the following datasets:
  - Hydrography
  - Topographic Digital Elevation Model (DEM)
  - Bedrock elevation
  - Surficial hydraulic conductivity (this study)
  - Recharge
  - Potential Evapotranspiration (PET)
  - Mean groundwater elevations 2003-2010



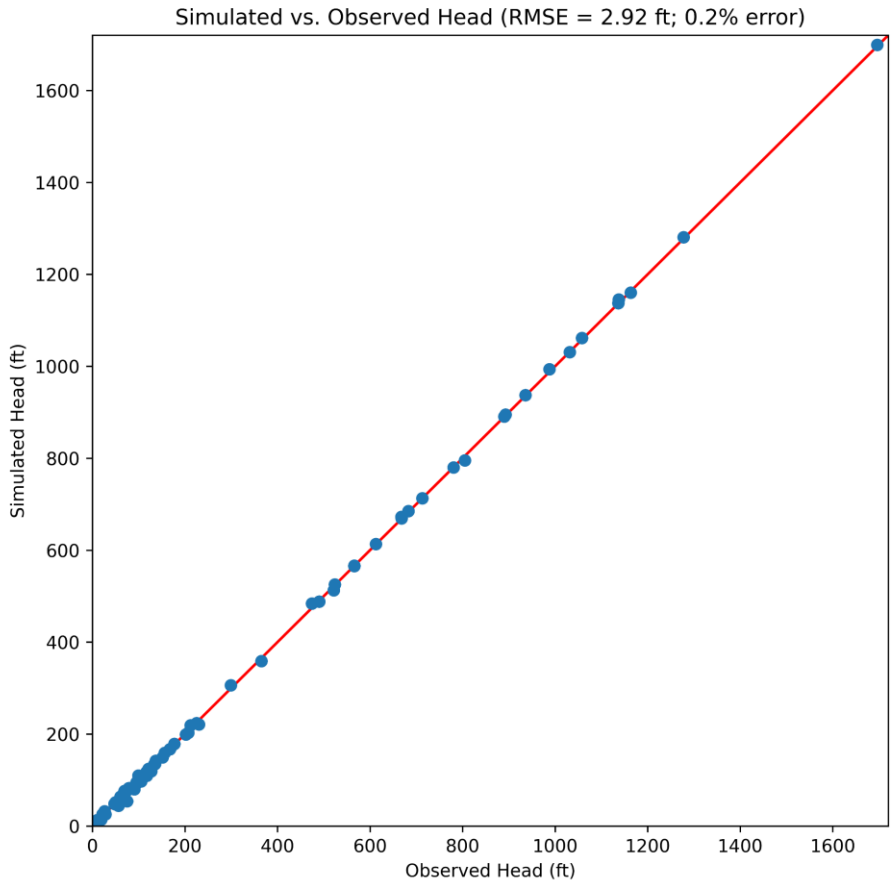
Calibration Dataset

- Sources:
  - National Ground-Water Monitoring Network (NGWMN)
  - DCR-USGS Long-Term Monitoring Network
- 66 locations
- Mean groundwater elevations for water years 2003-2010

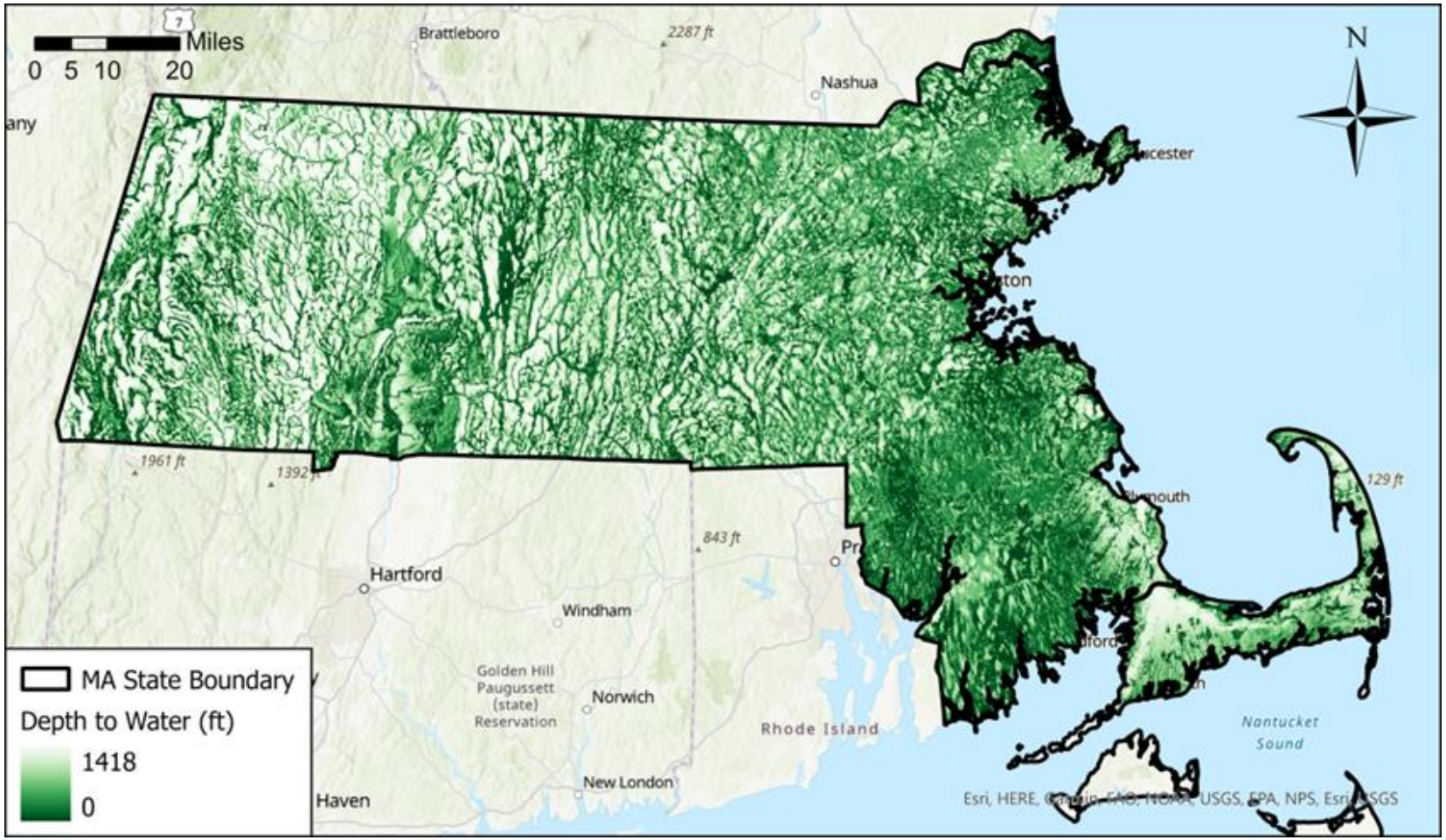


Model Calibration

- Automated calibration using PESTPP-IES
- Tuning Parameters:
  - Hydraulic Conductivity
  - Evapotranspiration Rate / Extinction Depth
  - Streambed Conductance
  - Recharge Rate



3. Mean Depth to Water Table 2003-2010



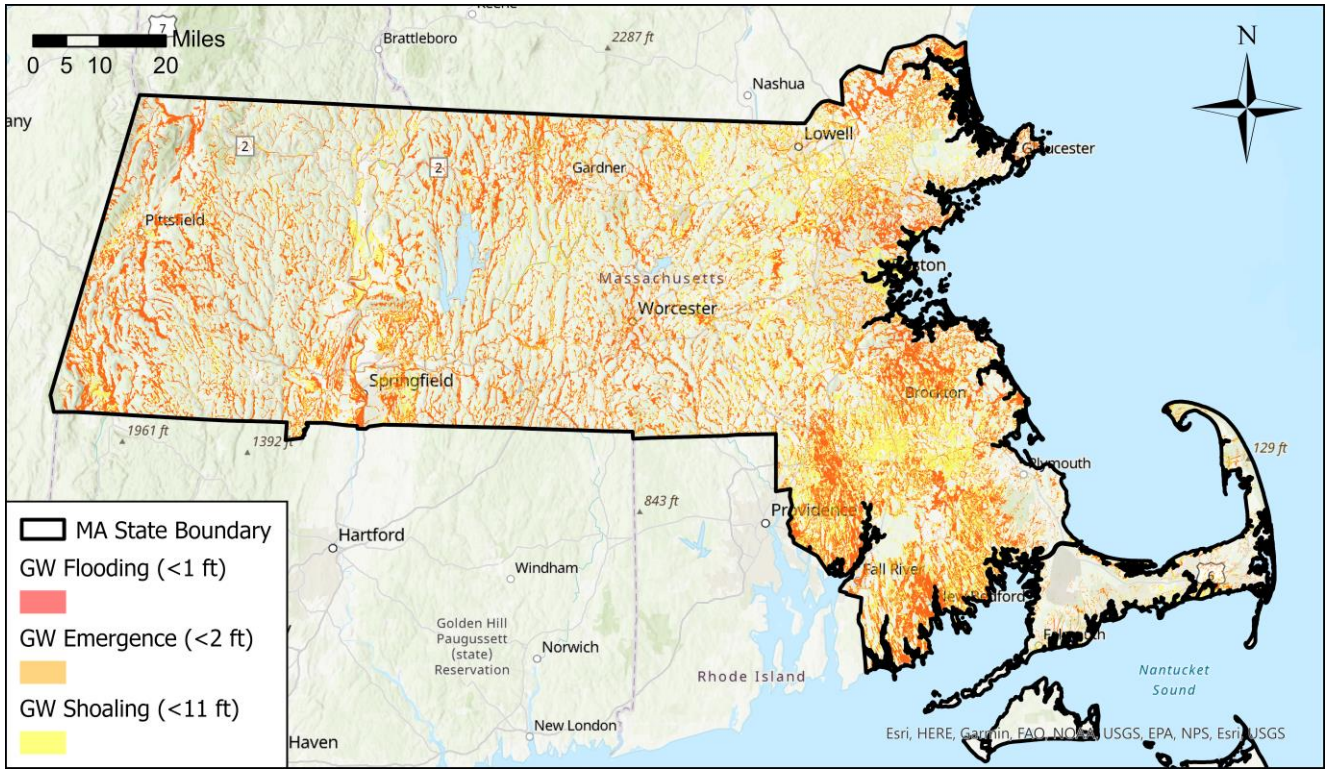
4. Groundwater Rise Risk Zones

Risk Zone Definitions

- Groundwater flooding – less than 1 foot
  - Groundwater reaching the land surface may occur due to the normal seasonal water table fluctuations
- Groundwater emergence - less than 2 feet
  - Groundwater reaching the land surface may occur due to extreme event driven water table increases
- Groundwater shoaling – less than 11 feet
  - Groundwater may intersect basements and other subsurface infrastructure

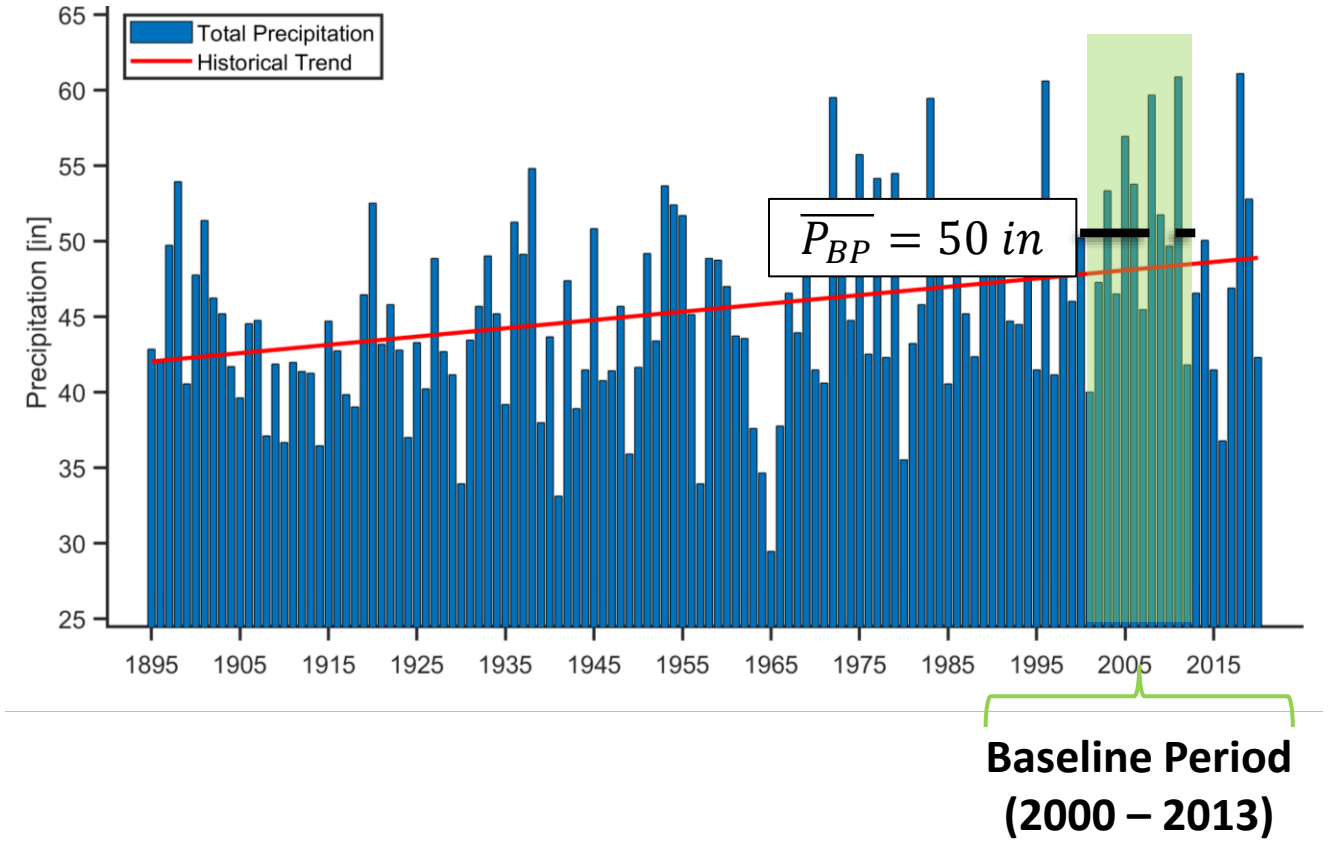
Groundwater Rise Risk Zones – Baseline (2003-2010)

- GW Flooding (<1 ft)
  - 1,439 mi^2 (19% of land area)
- GW Emergence (<2 ft)
  - 1,623 mi^2 (21% of land area)
- GW Shoaling (<11 ft)
  - 2,937 mi^2 (38% of land area)

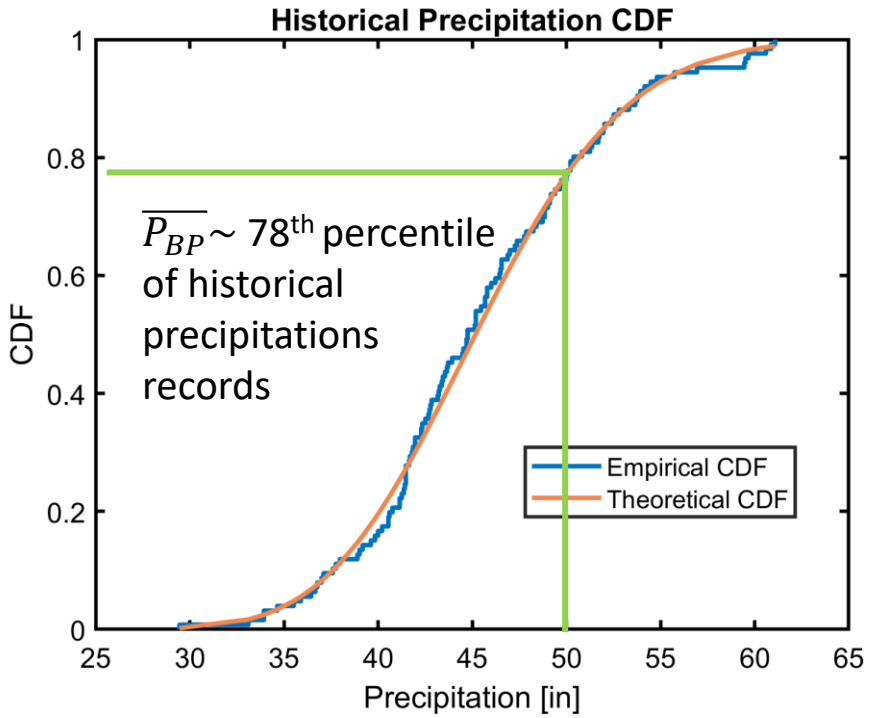


5. Recharge Projections

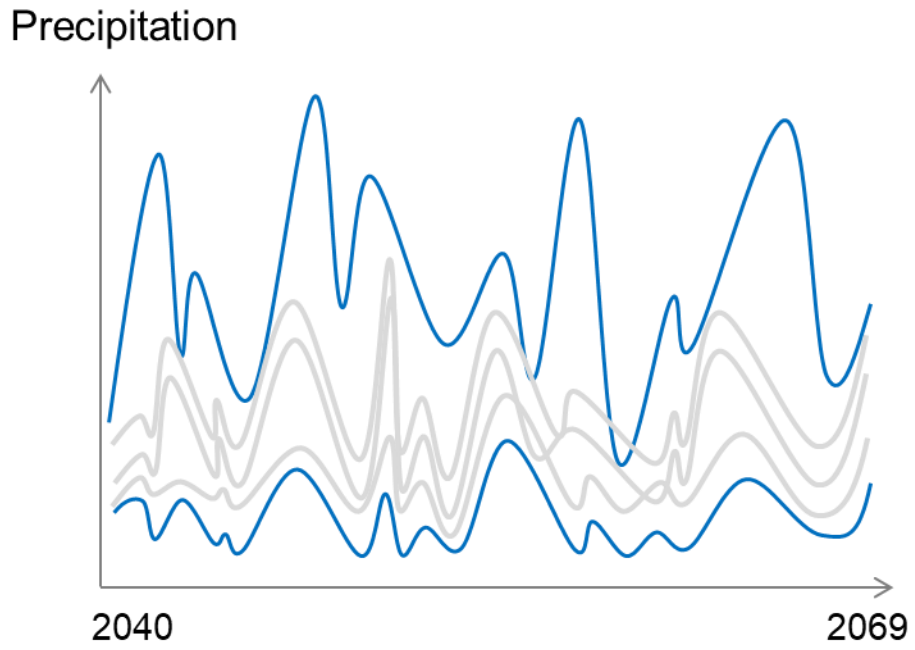
Historical Precipitation



- Cumulative Distribution Function (CDF)
  - $F_{P_i}(x) = P(P_i \leq x)$



Recharge scenarios based on precipitation projections



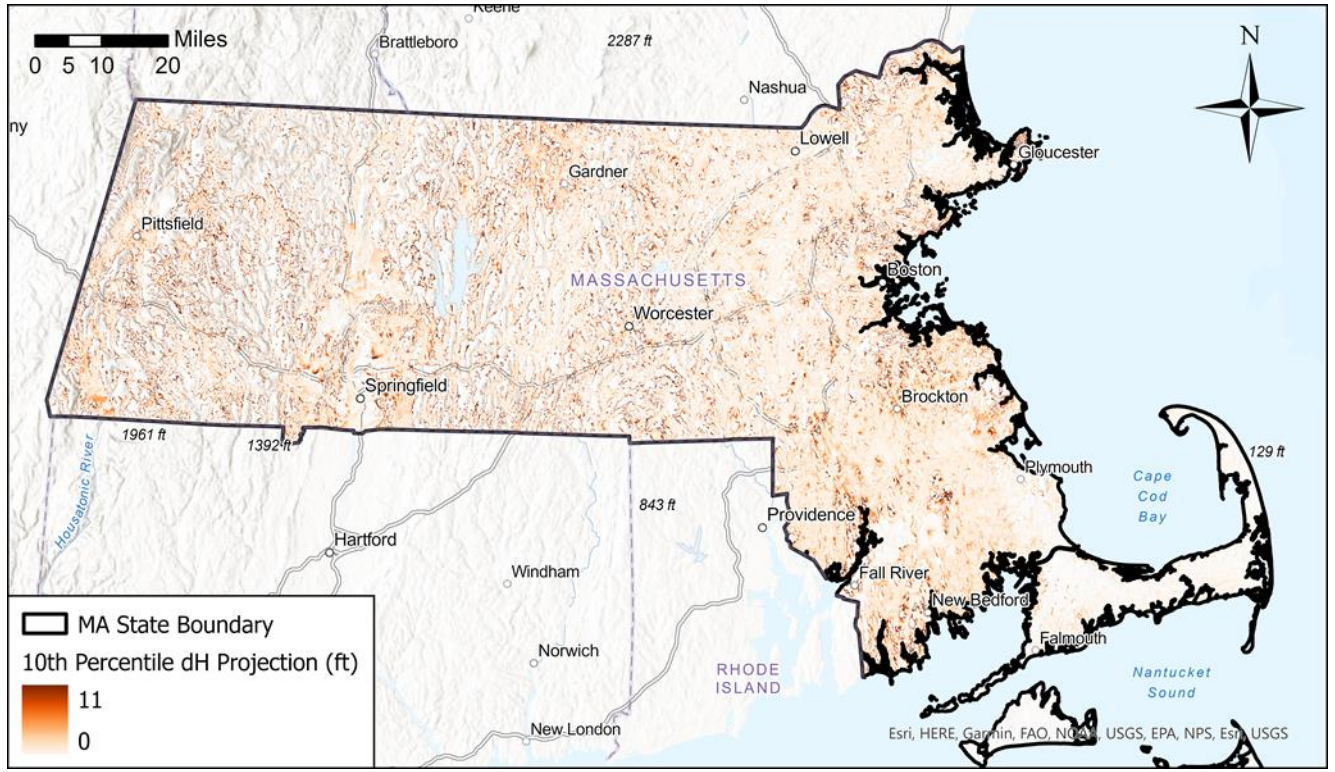
28 model runs from RCP 4.5 and RCP 8.5
(NOAA National Centers for Environmental Information | State Climate Summaries 2022 150-MA)

- 10th Percentile
  - 3% increase in precipitation
  - Baseline Recharge * 1.03
- 90th Percentile
  - 15% increase in precipitation
  - Baseline Recharge * 1.15

6. Groundwater Rise Risk Projections

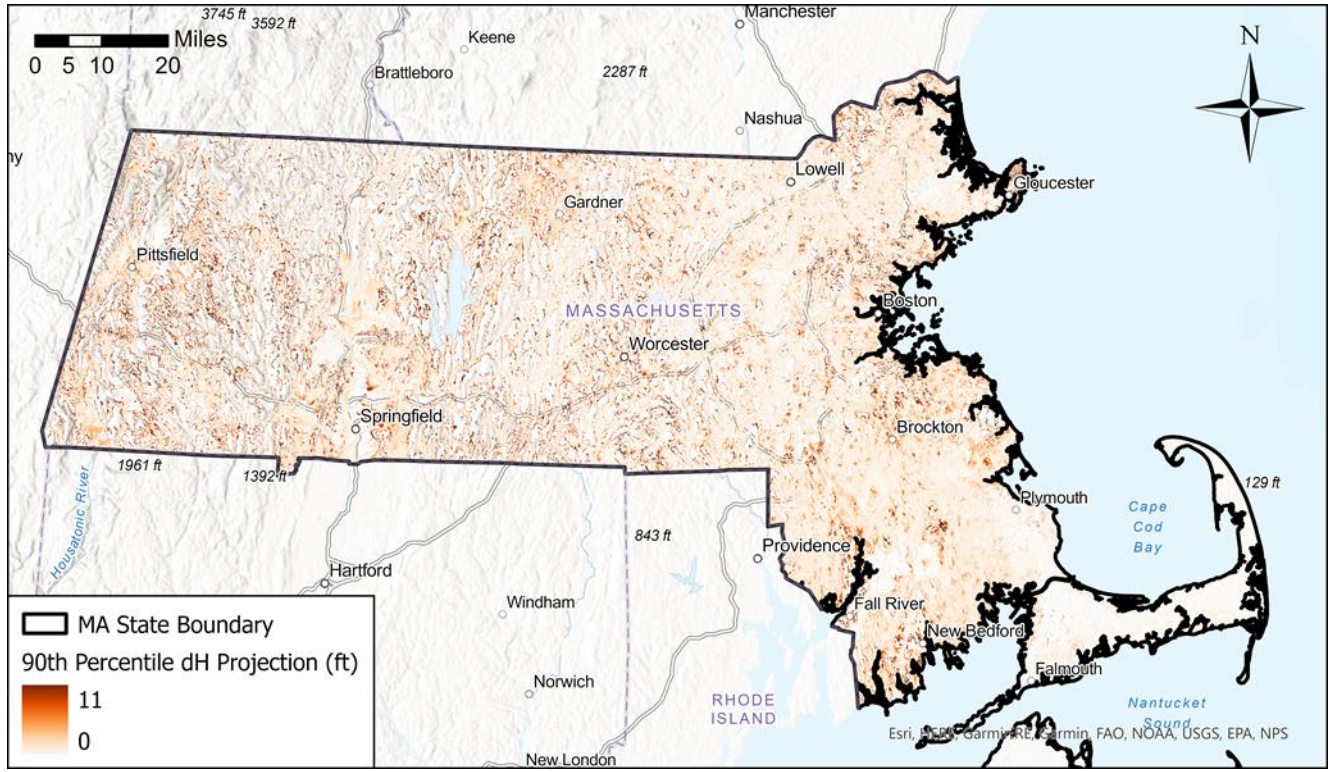
10th Percentile Groundwater Rise Projection

- Change in long-term mean groundwater elevation (dH) projection for the 10th Percentile scenario (3% increase in recharge)
- Groundwater within the Groundwater Rise Risk Zones may rise by an average of 0.14 ft
- Groundwater Flooding Risk Zone area increases by 115 mi^2 (8% increase)
- Groundwater Emergence Risk Zone area increases by 117 mi^2 (7% increase)
- Groundwater Shoaling Risk Zone area increases by 112 mi^2 (4% increase)

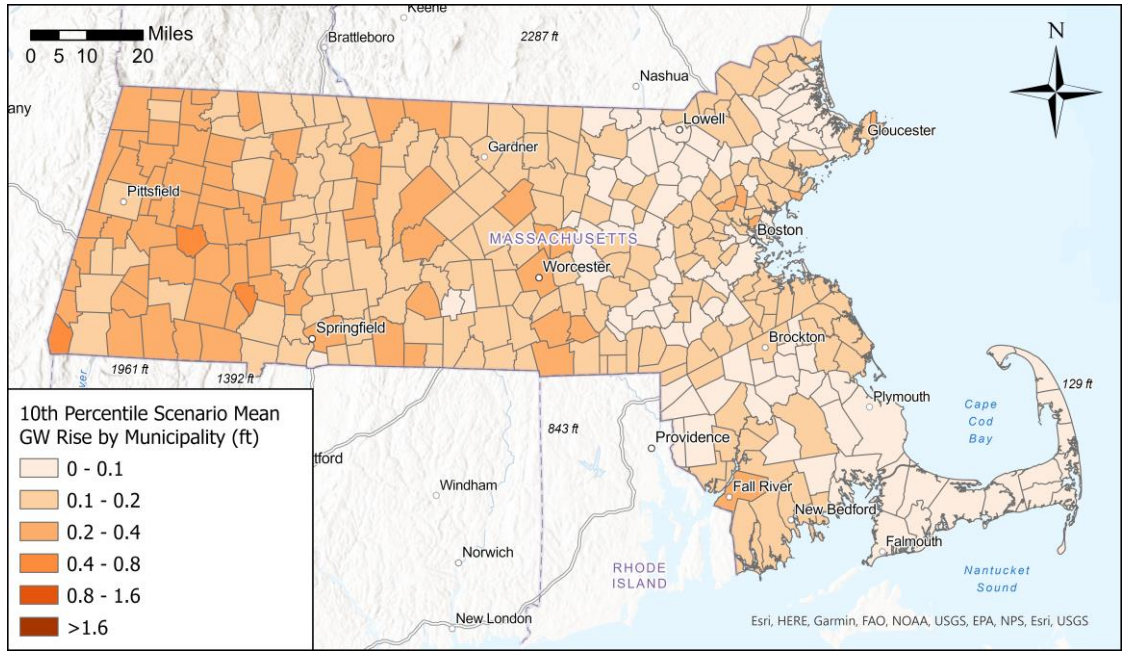


90th Percentile Groundwater Rise Projection

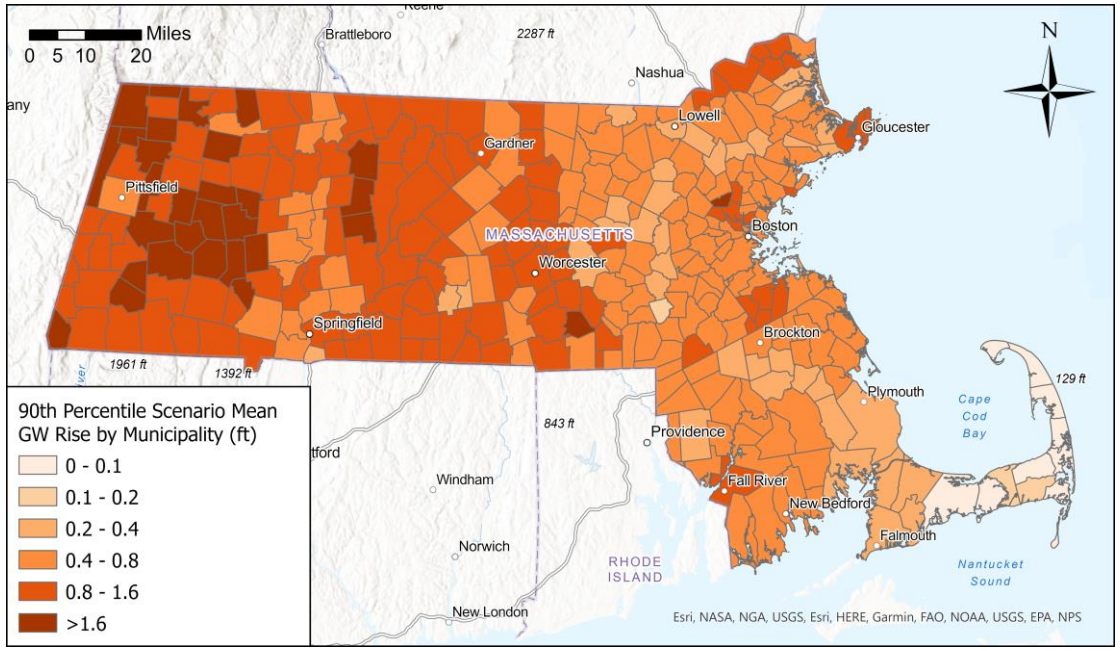
- dH projection for the 90th Percentile scenario (15% increase in recharge)
- Groundwater within the Groundwater Rise Risk Zones may rise by an average of 0.8 ft
- Groundwater Flooding Risk Zone area increases by 226 mi^2 (16% increase)
- Groundwater Emergence Risk Zone area increases by 230 mi^2 (14% increase)
- Groundwater Shoaling Risk Zone area increases by 237 mi^2 (8% increase)



10th Percentile Scenario



90th Percentile Scenario



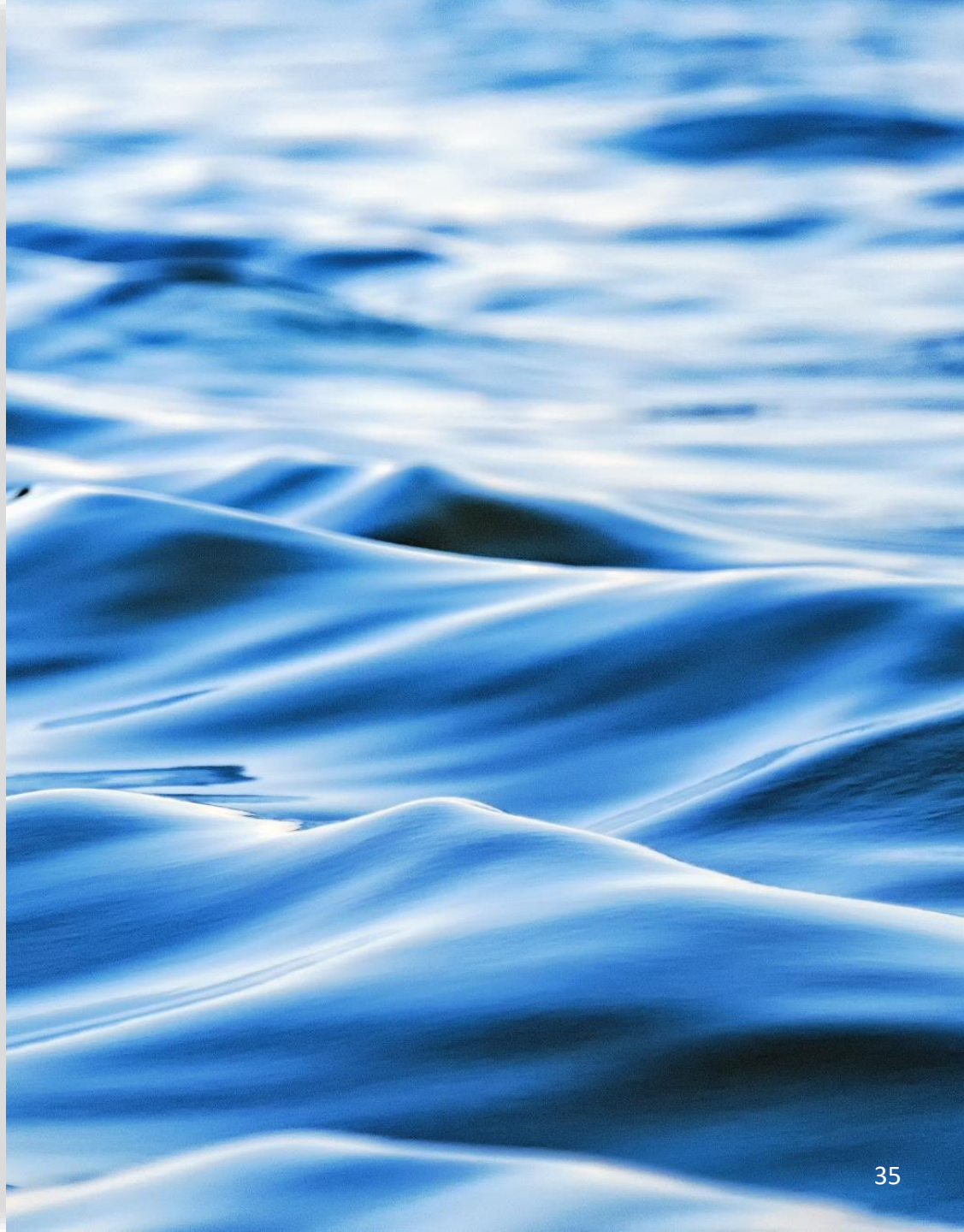
Summary

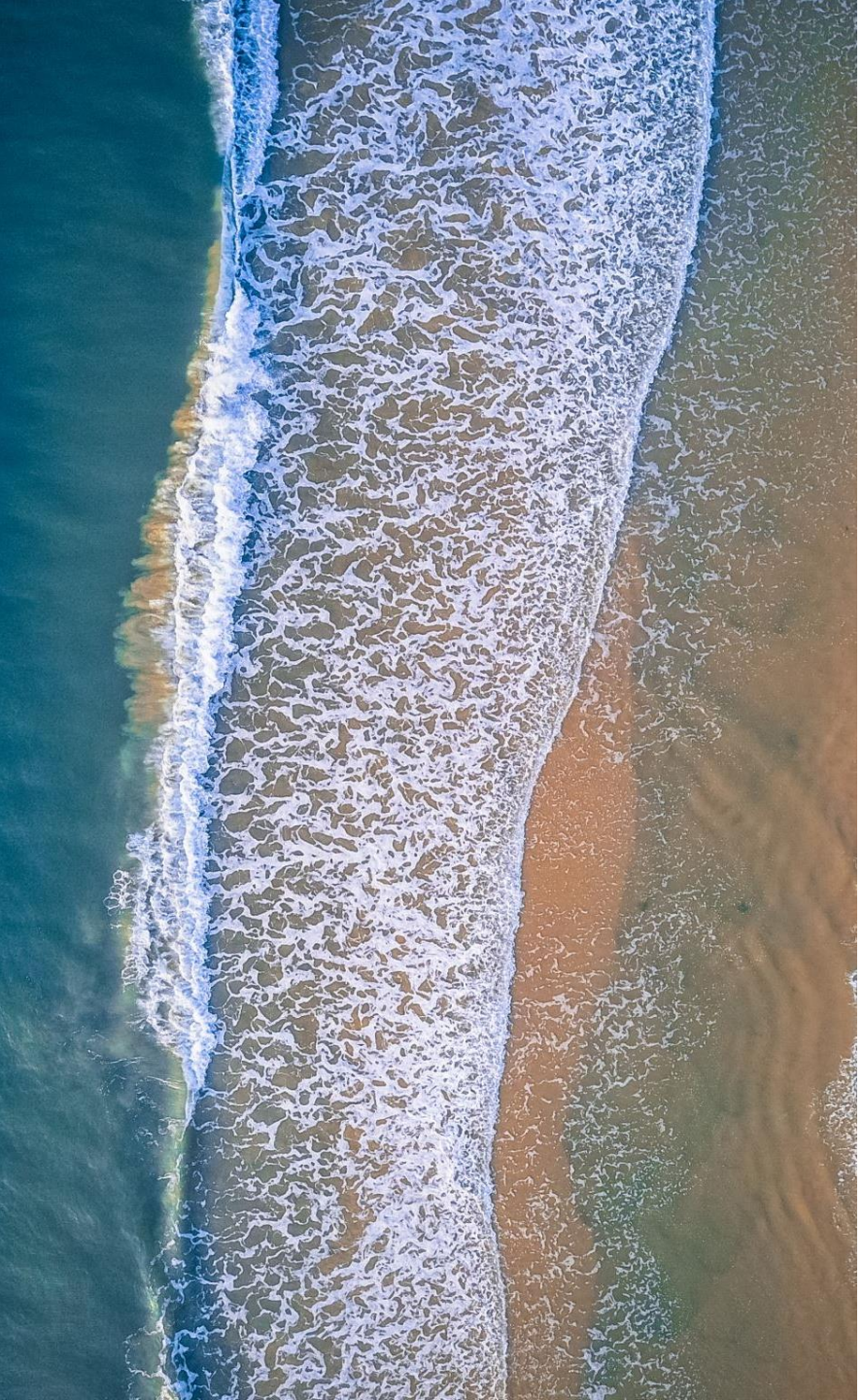
Conclusions

- Shallow groundwater will rise by an average of 0.14-0.8 ft
- Groundwater Rise Risk Zones will increase by:
  - Groundwater Flooding: 8-16%
  - Groundwater Emergence: 7-14%
  - Groundwater Shoaling: 4-8%
- Greatest risks occur in Western MA

Limitations and Appropriate Use

- Current model assessments consider long-term increases in mean GW levels
- Risk zones show areas where water table is most sensitive to rise
- Model cell size represents an area of approximately 2.5 acres –features smaller than this will not be represented well
- Model does not predict water table responses to seasonal or event-driven fluctuations





Phase 2 FY 24 – Next steps

- Publishing a Data explorer for hydrogeologic datasets
- Incorporation of coastal sea-level rise impacts on GW levels
- Assessing seasonal GW level responses using transient models
- Refinement of Recharge conditions used in model from climate-hydro risk project