Glacial Geology and Groundwater Resources of Plymouth

What's with all this sand?

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Groundwater Myths

1. Always flows from north to south
2. Is 1000's of years old
3. Is not a significant source of water
4. Is not a renewable resource
5. Groundwater and surface water are not related
6. Not safe to drink
7. Always safe to drink
8. Artesian water is special – highest quality water
9. Occurs in underground lakes and rivers (except in karst)
10. Plymouth GW comes from the White Mtns. in NH

Topics

- Glacial Geology
  - How the sand got here
- Groundwater
  - Hydrologic Cycle
  - Groundwater occurrence & flow
  - Groundwater supply
  - Groundwater contamination

  - Groundwater use regulation in MA
  - Saltwater intrusion

Unique Environmental Features in Plymouth

- They’ve got a lot to do with the geology
  - Coastal Pine Barrens
  - Knob & Kettle topography
  - Ponds, bays, estuaries, coastal wetlands
  - State-designated areas of critical environmental concern:
    - Ellisville Harbor
    - Herring River watershed
  - Productive groundwater resource (PCKD Aquifer)
  - Cranberry cultivation

Continental Glaciation

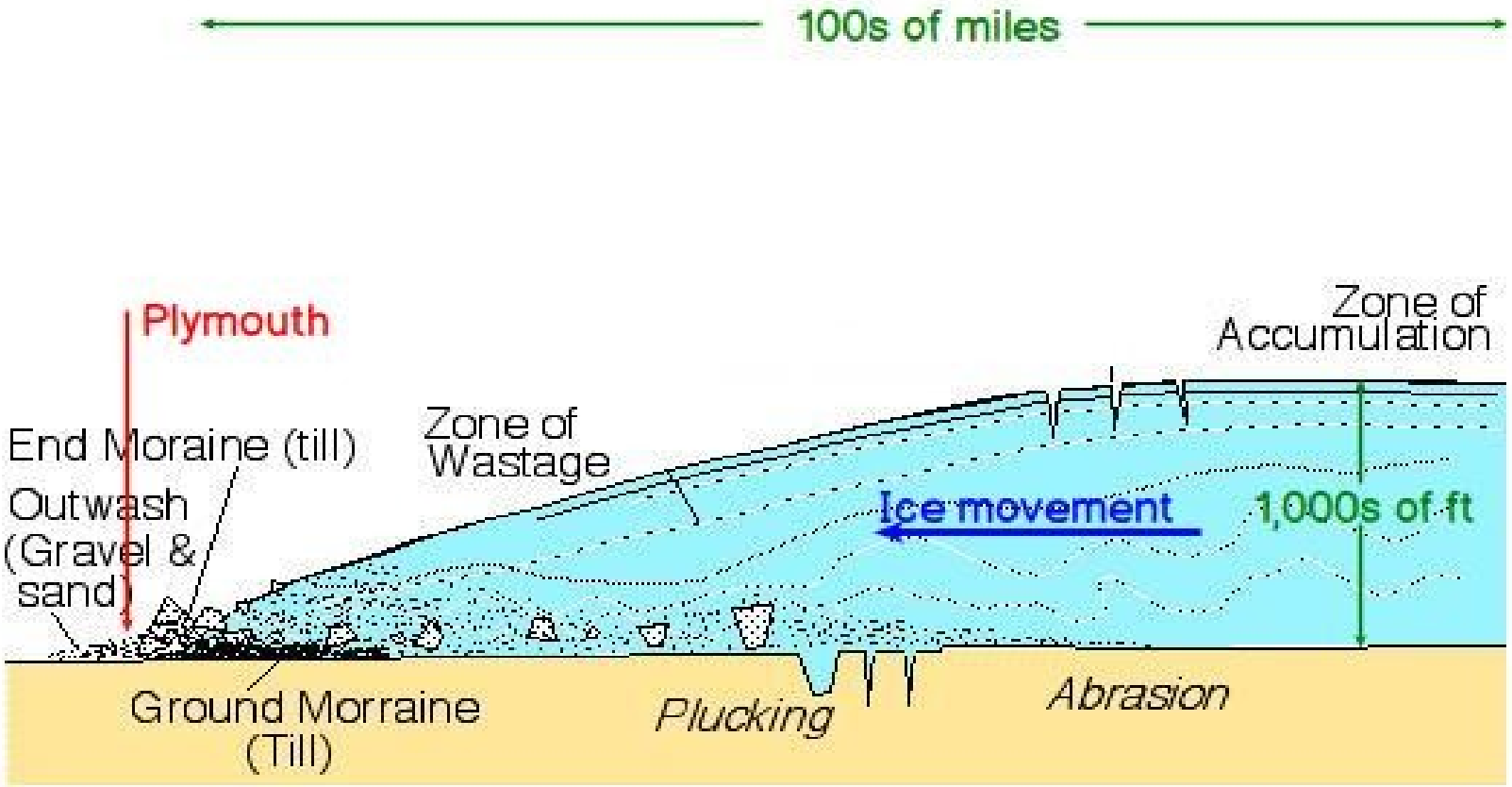
- Pleistocene epoch
  - 2.58 M to 11,700 yrs. ago
  - Last major glacial advance 129,000 to 11,700 yrs. ago
- Profoundly influenced our landscape
  - Erosion and deposition of material over large areas
  - Creation of ponds and lakes
  - Sea level dropped > 400 feet from current
  - River system modification
- Maximum ice advances in Plymouth area: approx. 28,000 to 18,000 y.a.
- Sand deposition from post-glacial meltwater

What is Glaciation?

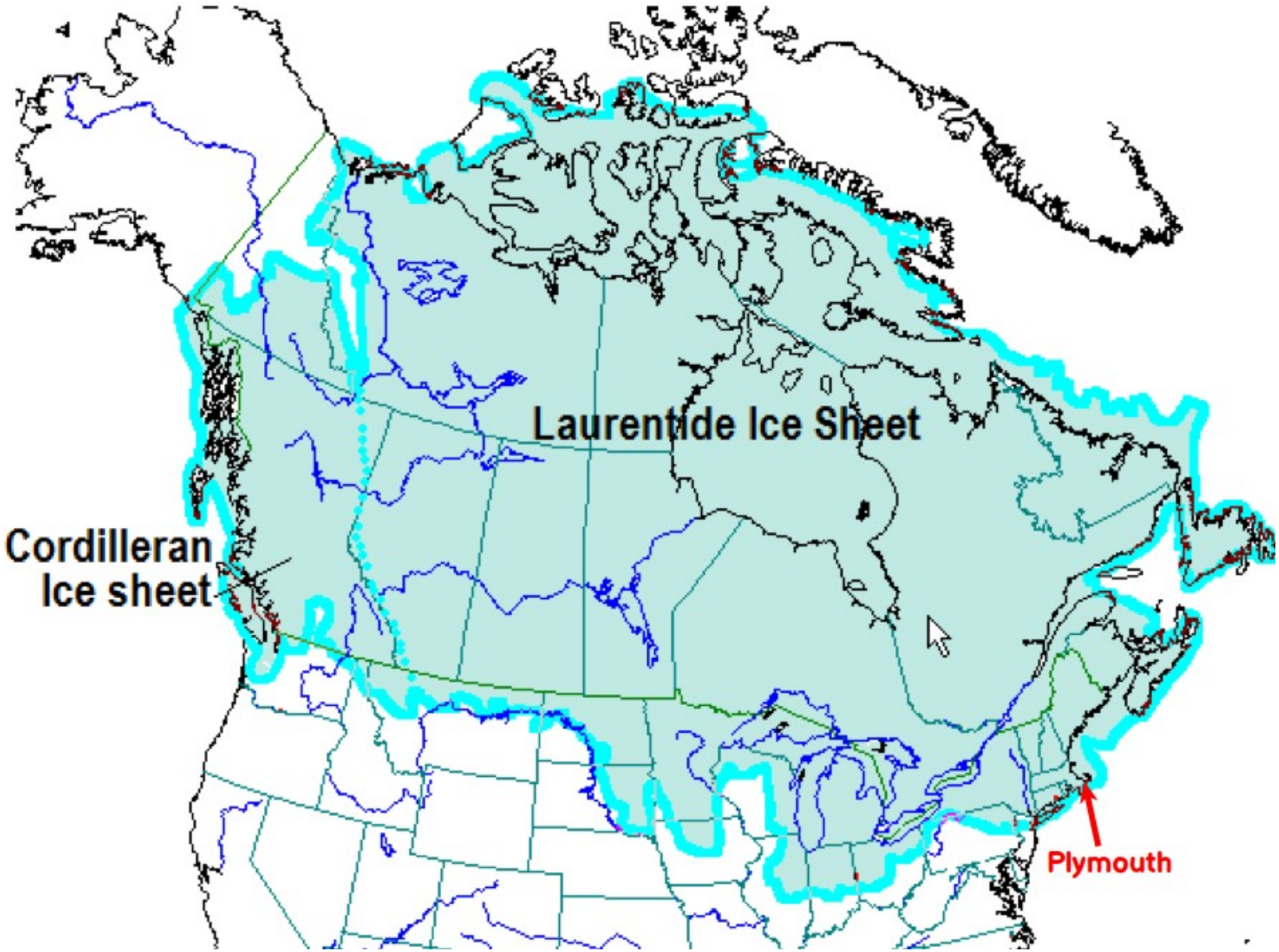
- Persistent body of dense ice that moves constantly under its own weight:
  - When net snow accumulation exceeds melting/sublimation over time
  - Temps at ice margin (Plymouth): only ~6°C lower than current
  - Glacial ice slowly deforms and flows southward
  - Abrade rock and debris from underlying materials to create landforms, e.g., moraines, outwash plains
- Two types:
  - Continental
  - Alpine

Continental Glacier

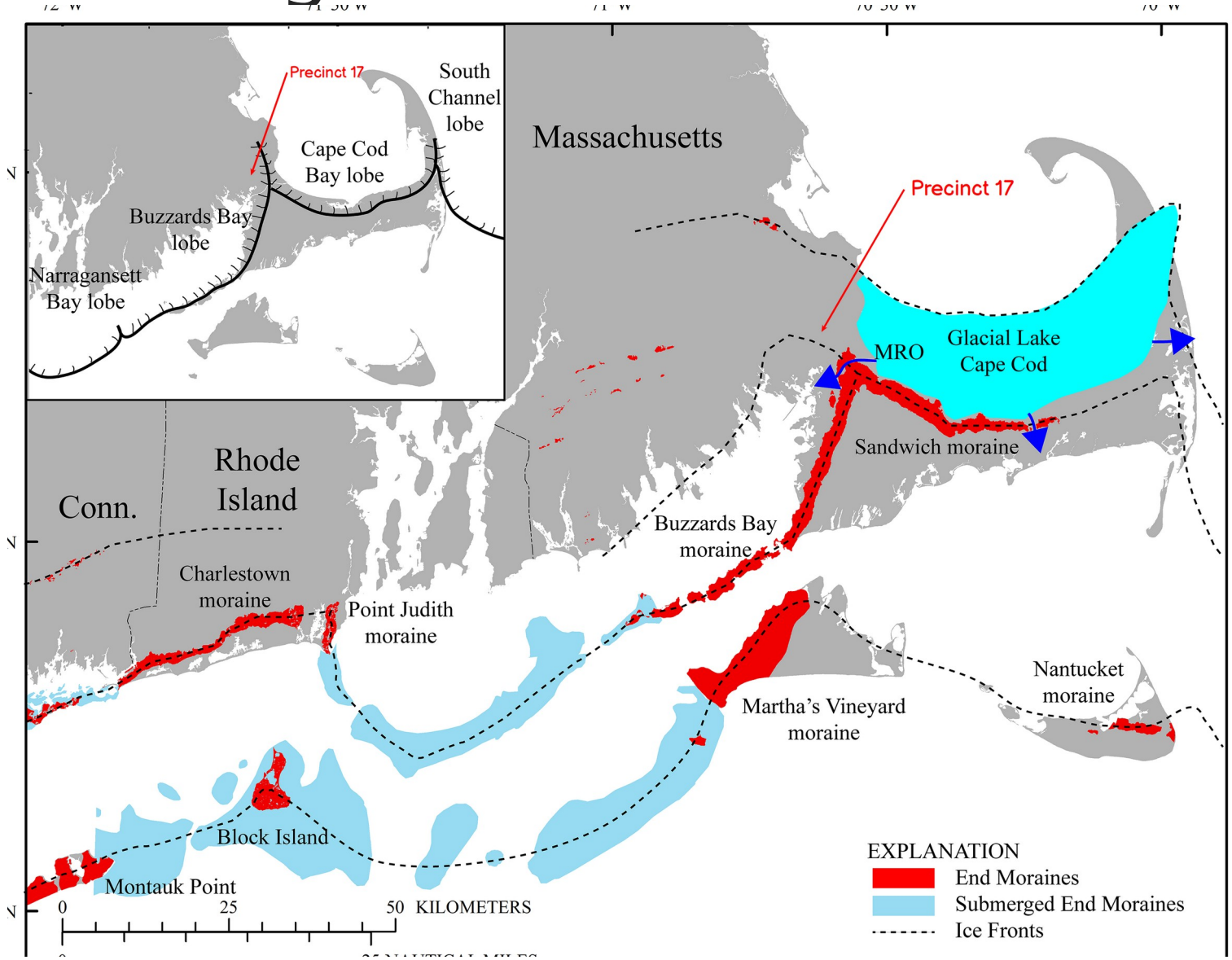
Principles of Continental Glaciation



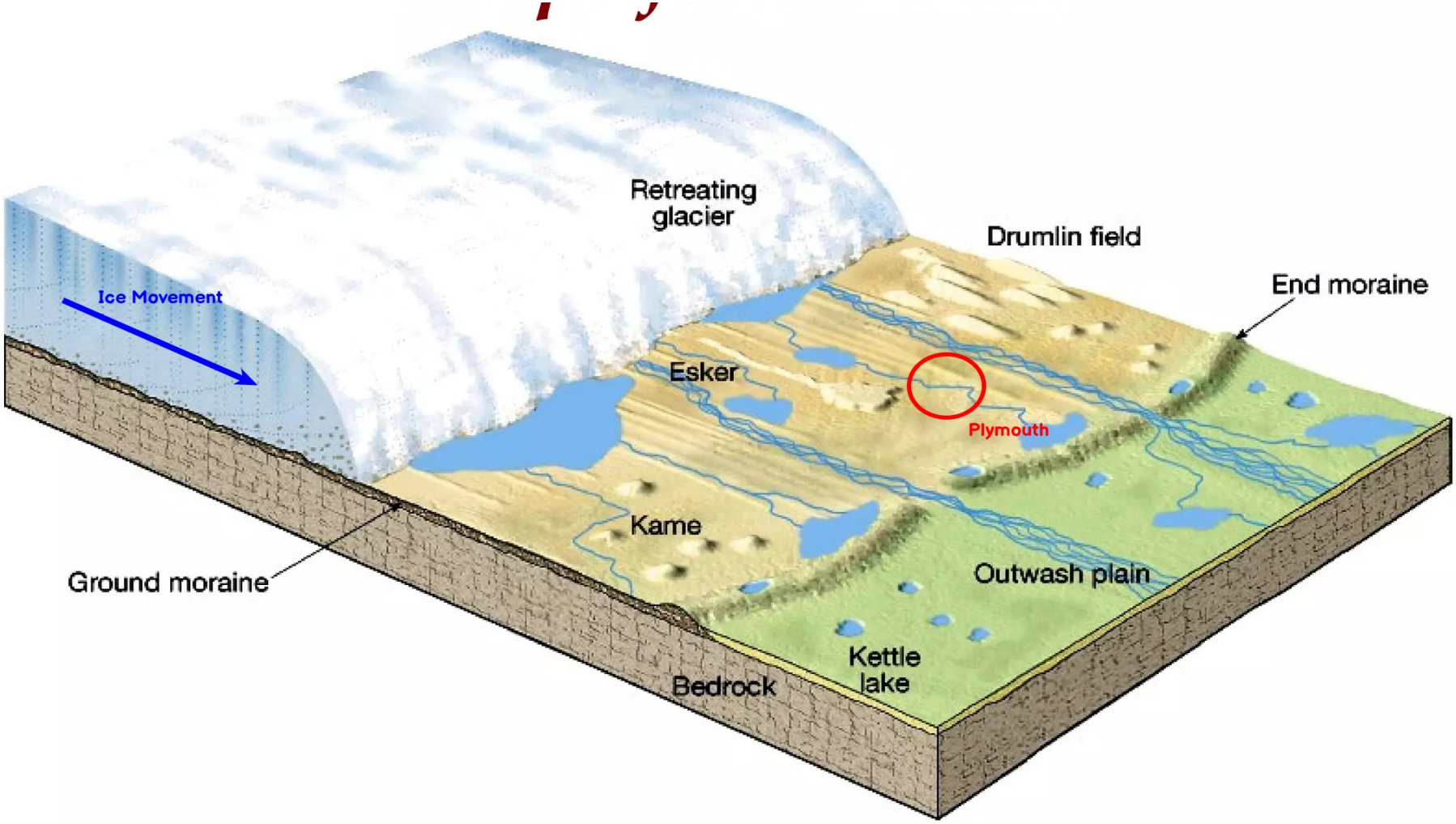
Continental Glaciation in North America



SE New England Glacial Features



Glacial Deposits

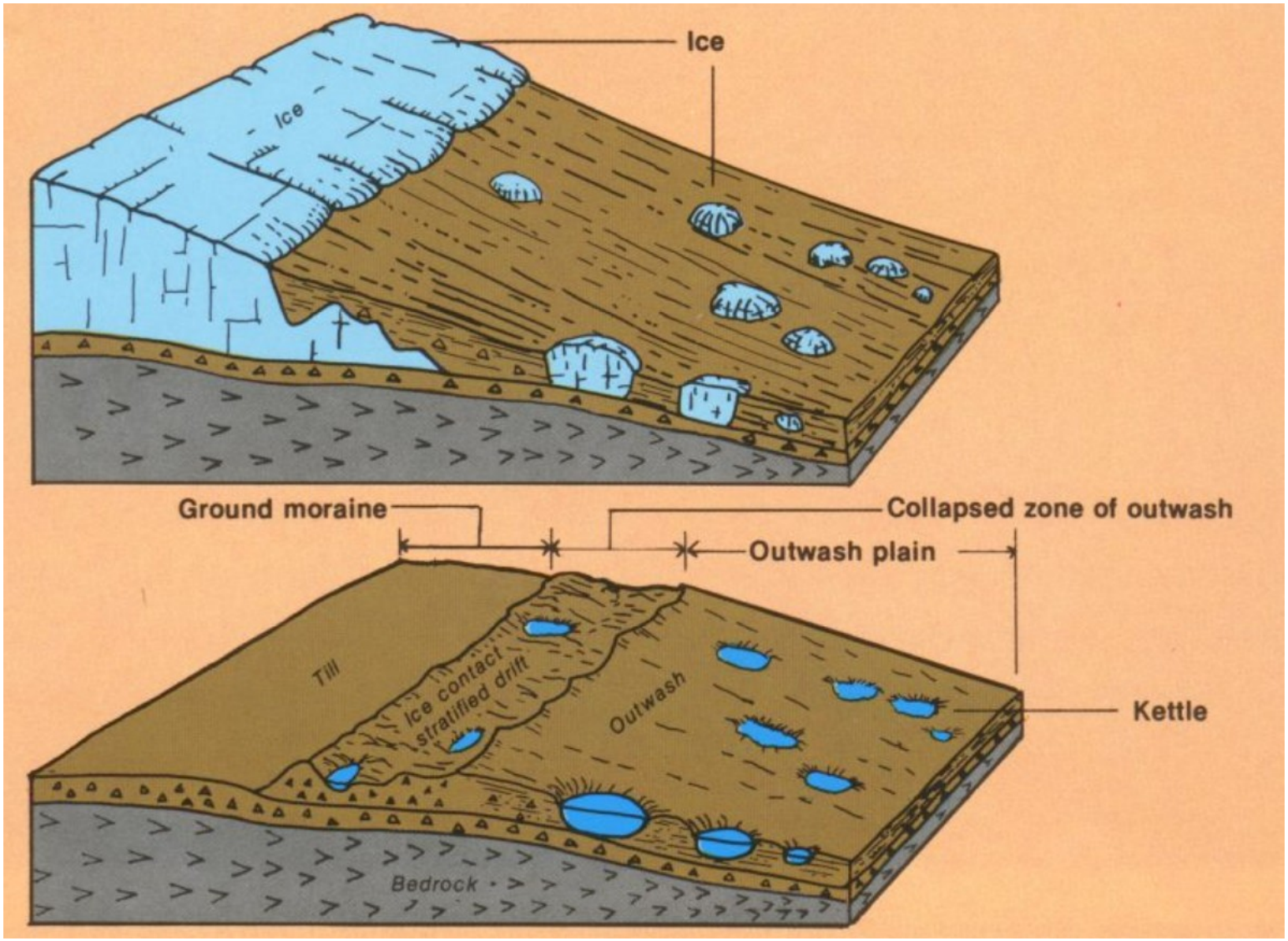


Continental Glacier Ice Front

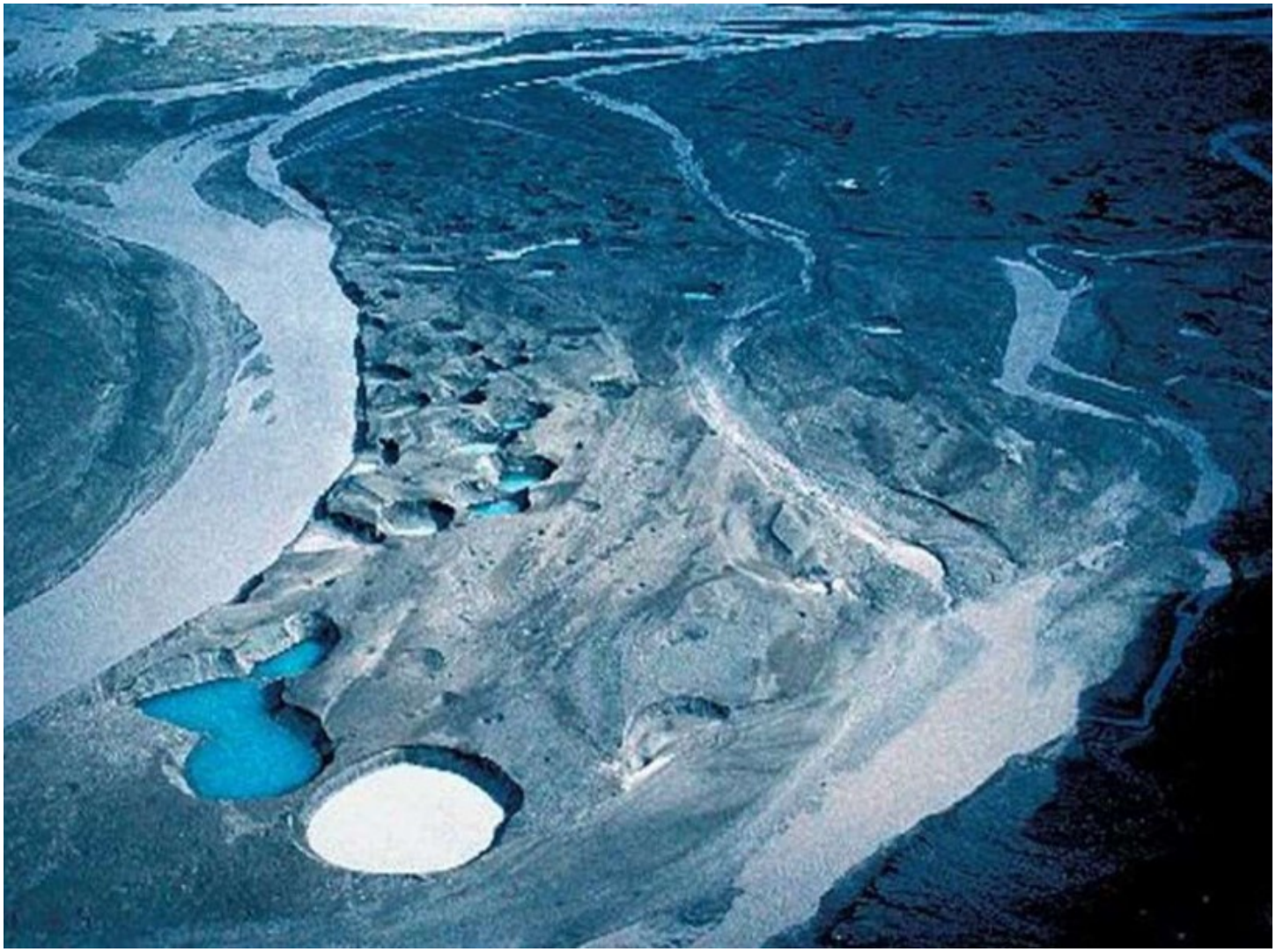
What Plymouth looked like 20,000 y.a

Receding Glacier Photo

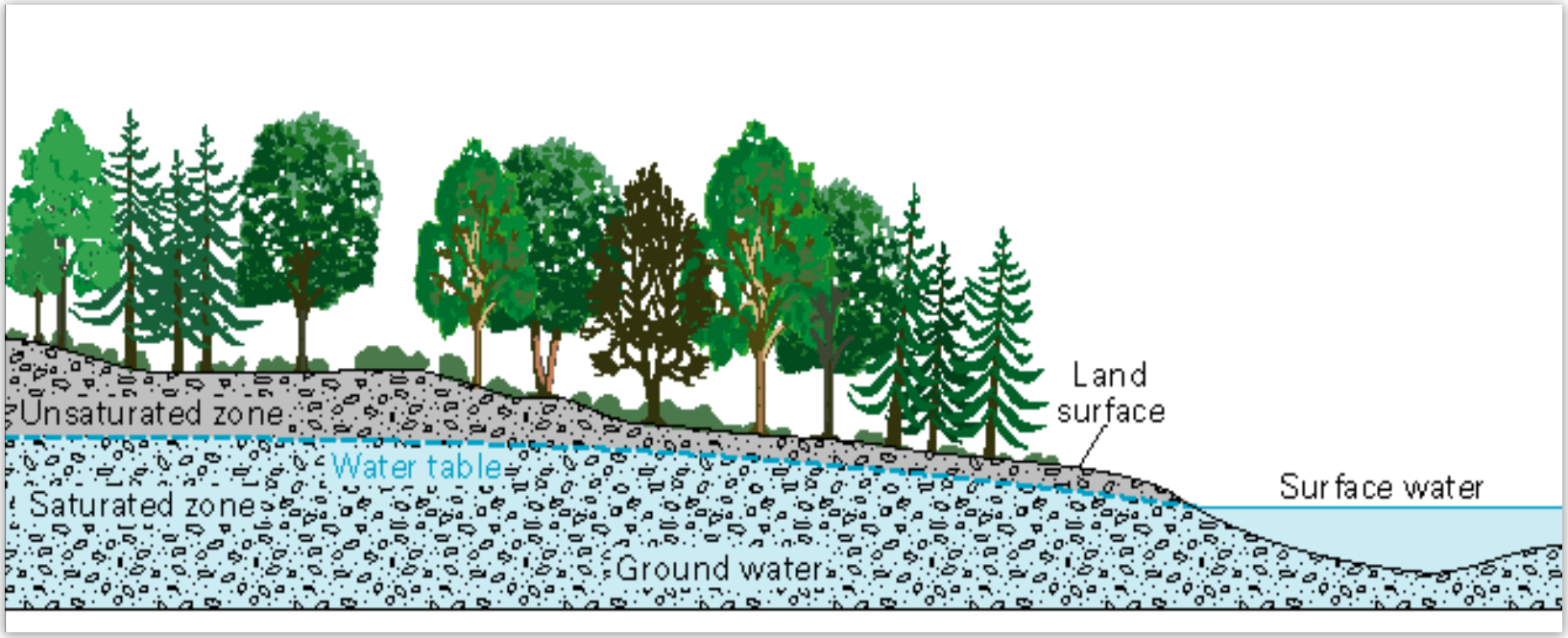
Kettle Formation



Kettle Formation

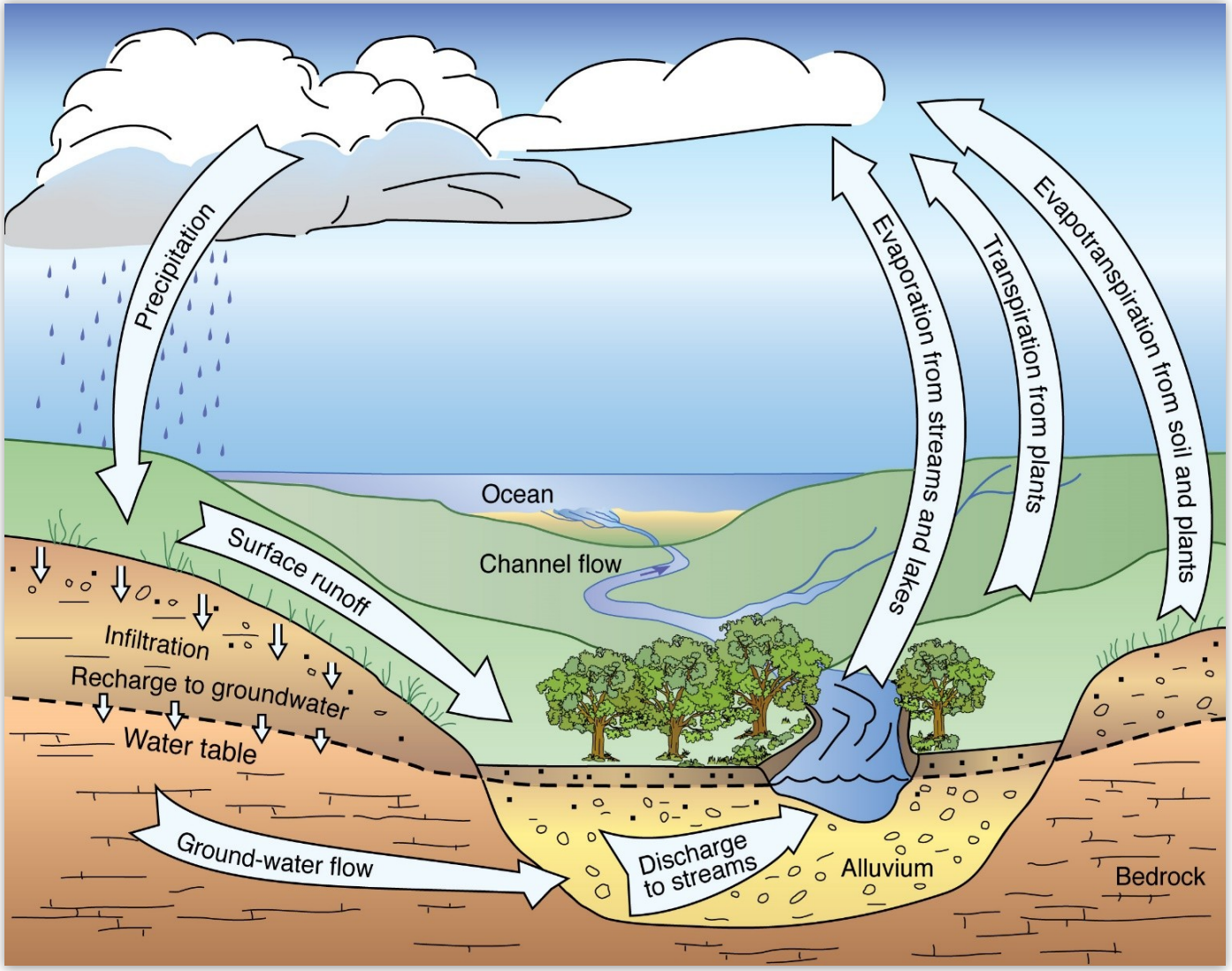


What is Groundwater?

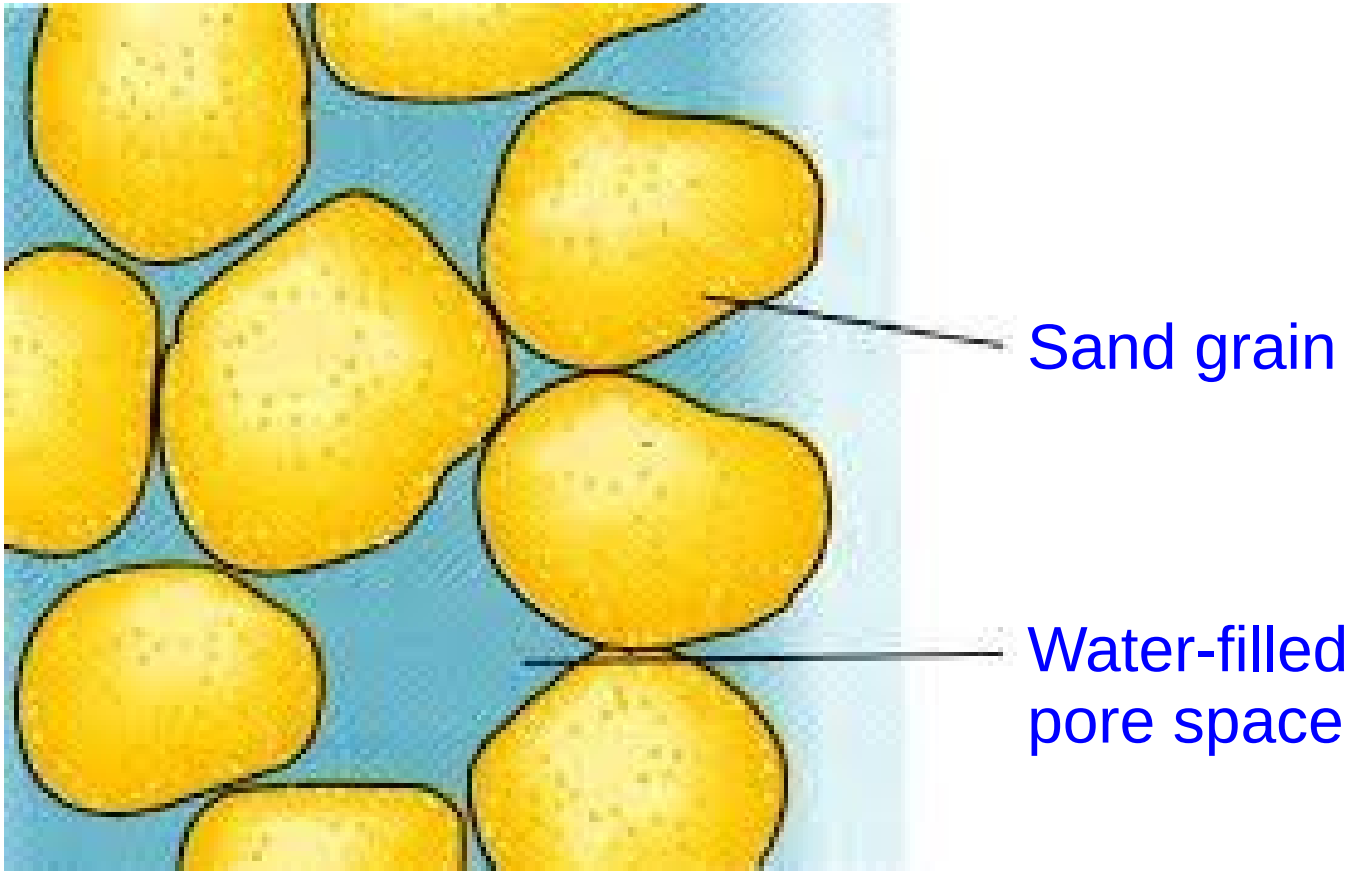


Water beneath Earth's surface contained in soil pore spaces and in the fractures of bedrock.

Hydrologic Cycle



Groundwater Occurrence in Plymouth

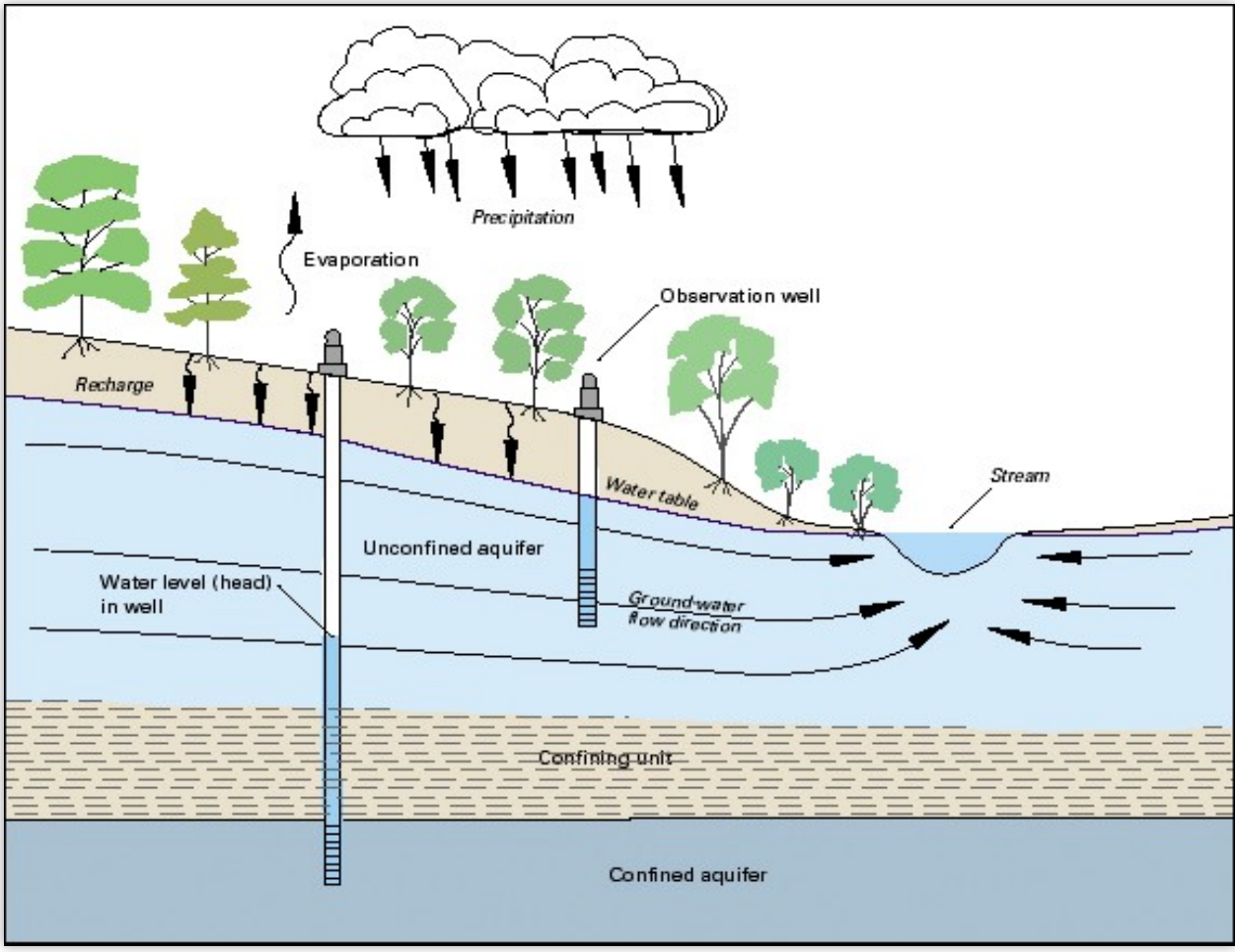


Groundwater Recharge

- Water that moves from the land surface or unsaturated zone into the saturated zone.
- Usually occurs in the vadose zone below plant roots.
- Sources can be water infiltration from:
  - Rainfall
  - Snow melt
  - Surface water – losing streams
  - Wastewater return flows
- Infiltration may be impeded by human activities:
  - Pavement
  - Buildings
  - Landscaping
- May be artificially induced

What is an Aquifer?

- A unit containing sufficient saturated permeable material to yield significant quantities of water to wells
- Example: PCKD Aquifer in Plymouth



Groundwater Flow

- Groundwater within an aquifer does not stand still:
  - Flows due to gravity and pressure
    - From regions of higher hydraulic head to regions of lower hydraulic head
    - Unconfined aquifers always flow from high *(e.g., Myles Standish State Forest)* to low points *(Town Brook, Eel River)* due to gravity
  - Large surface water bodies usually represent ultimate discharge areas for regional groundwater *(Cape Cod Bay & Buzzards Bay)*

Groundwater Discharge

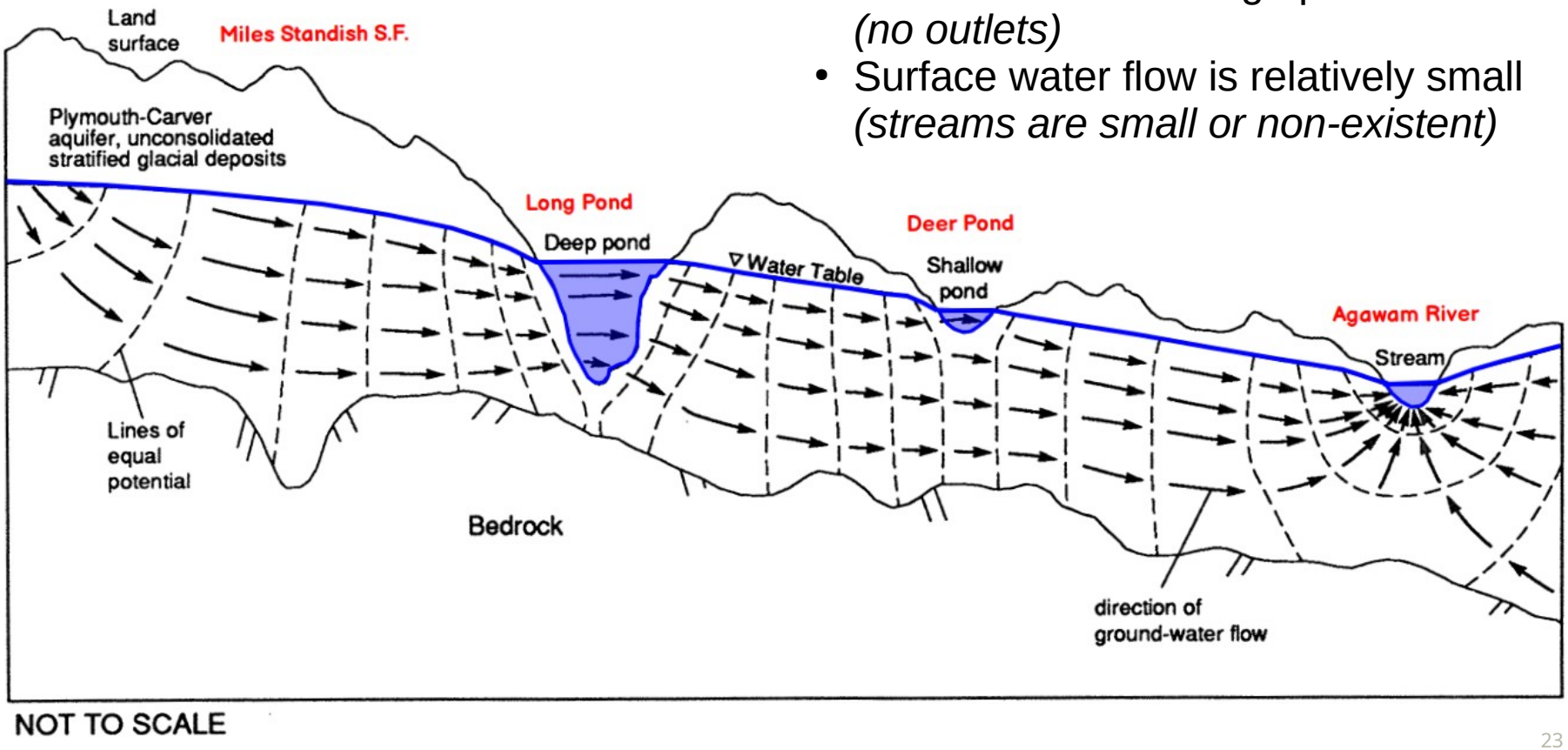
Movement of groundwater from the subsurface to the surface

- Natural flows to:
  - Oceans – *Cape Cod Bay & Buzzards Bay*
  - Lakes/ponds
  - Rivers/streams – *Town Brook, Eel River*
  - Surface Springs – *not many in Plymouth*
- Human-induced groundwater discharge to:
  - Wells
  - Drains

Conceptual Groundwater Flow in Plymouth area

Due to presence of transmissive sand:

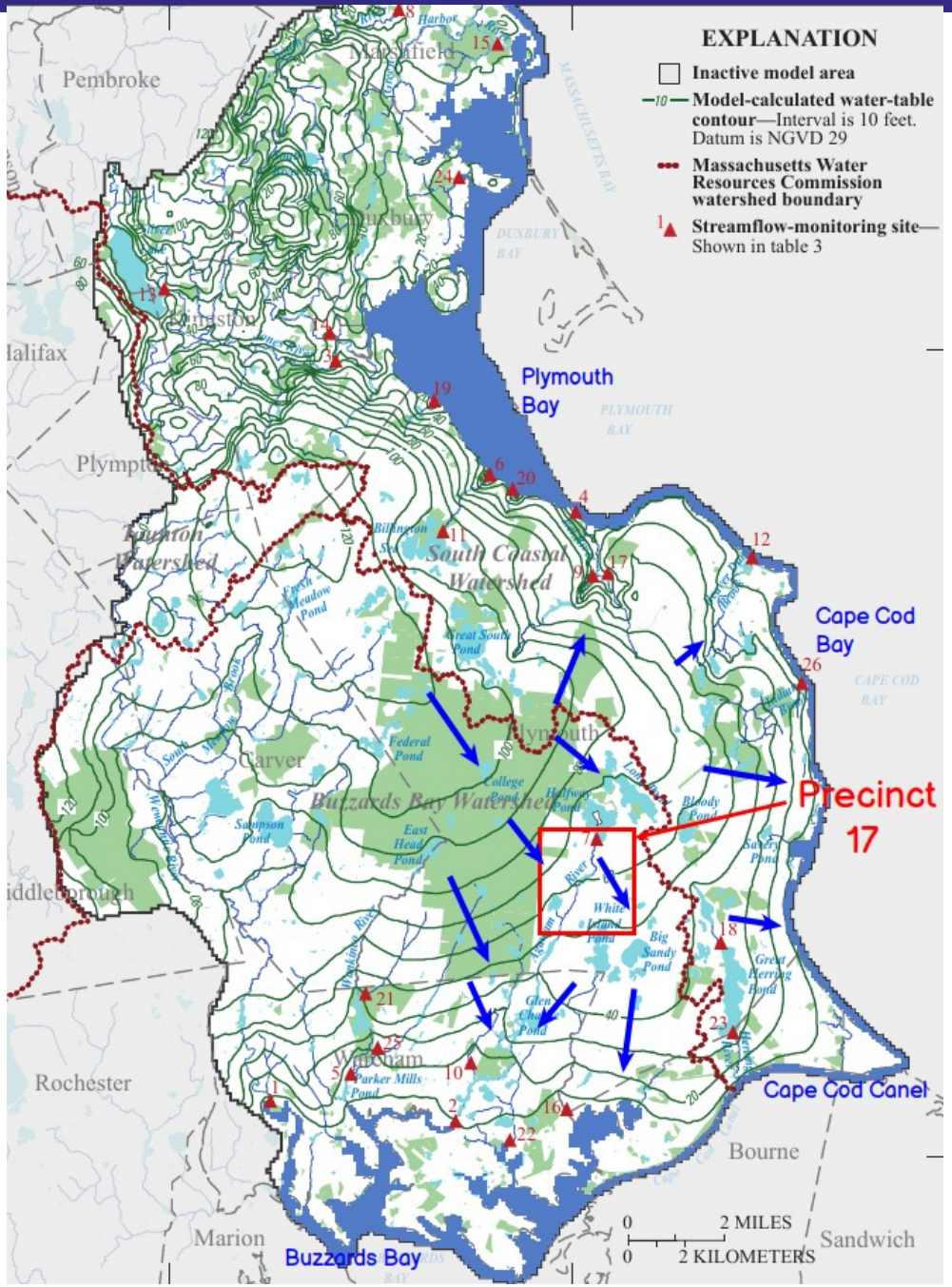
- Most water area flows in the subsurface *(as groundwater)*
- Numerous flow-through ponds *(no outlets)*
- Surface water flow is relatively small *(streams are small or non-existent)*



Plymouth/Carver/Kingston/ Duxbury (PCKD) Aquifer

- Composed primarily of glacial outwash sands
  - Very transmissive aquifer
  - Laterally extensive under the four Towns & parts of others incl. Wareham
  - Thickness to to more than 200 feet
- 2nd largest aquifer in Massachusetts
- Underlying bedrock yields essentially no groundwater

Water Table Surface Contour Map: PCKD Aquifer

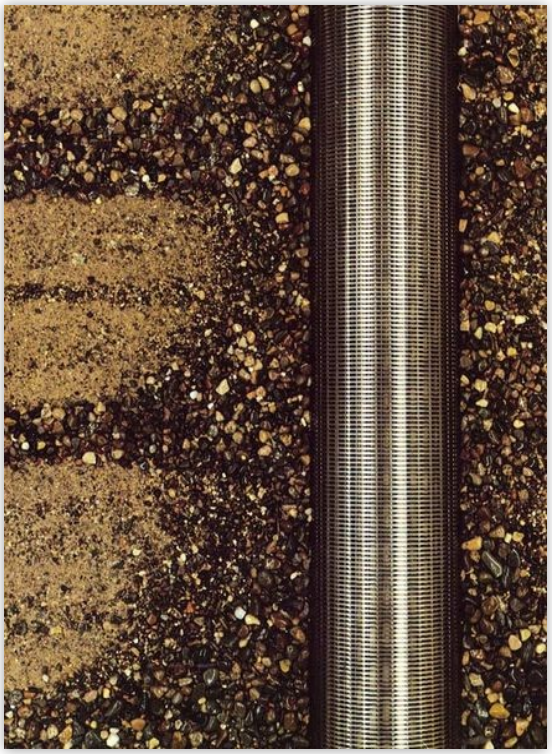


From: USGS GW Model Report for PCKD Aquifer, 2009

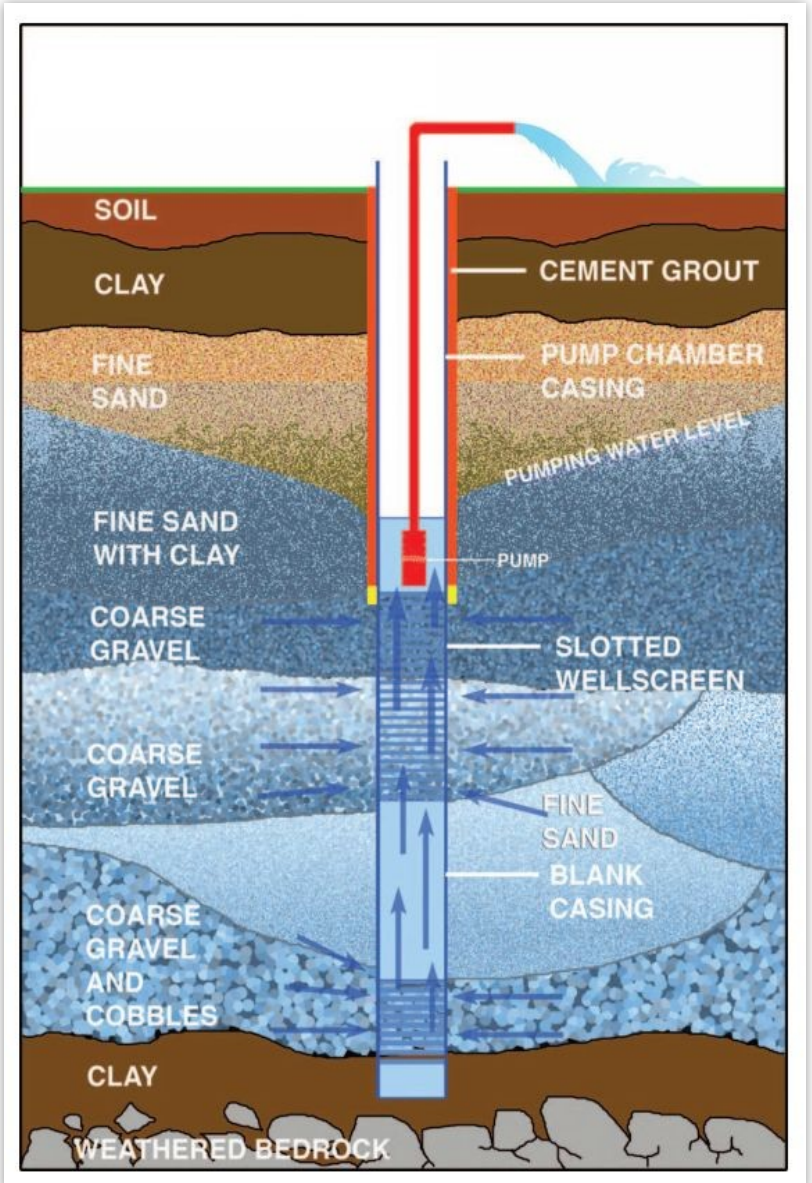
Groundwater Resource Impacts in PCKD Aquifer

- Localized over-pumping of groundwater can impact groundwater-fed surface water levels
  - Ponds
  - Rivers & Streams
  - Wetlands
- Treated wastewater infiltration can mitigate groundwater level declines
- Land use can impact:
  - Groundwater quality
  - Groundwater Infiltration

Water Supply Wells with Wellscreens

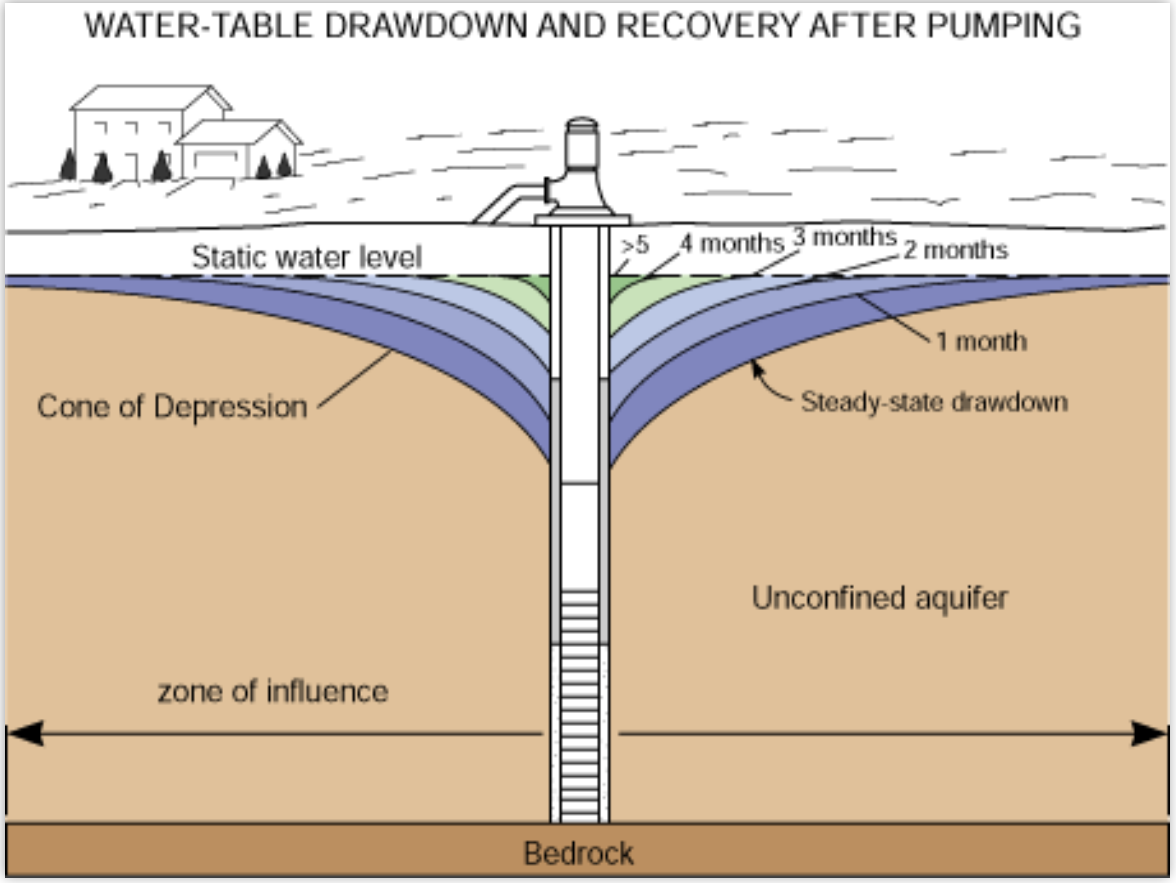


Agawam Water Co. wells are constructed in this manner

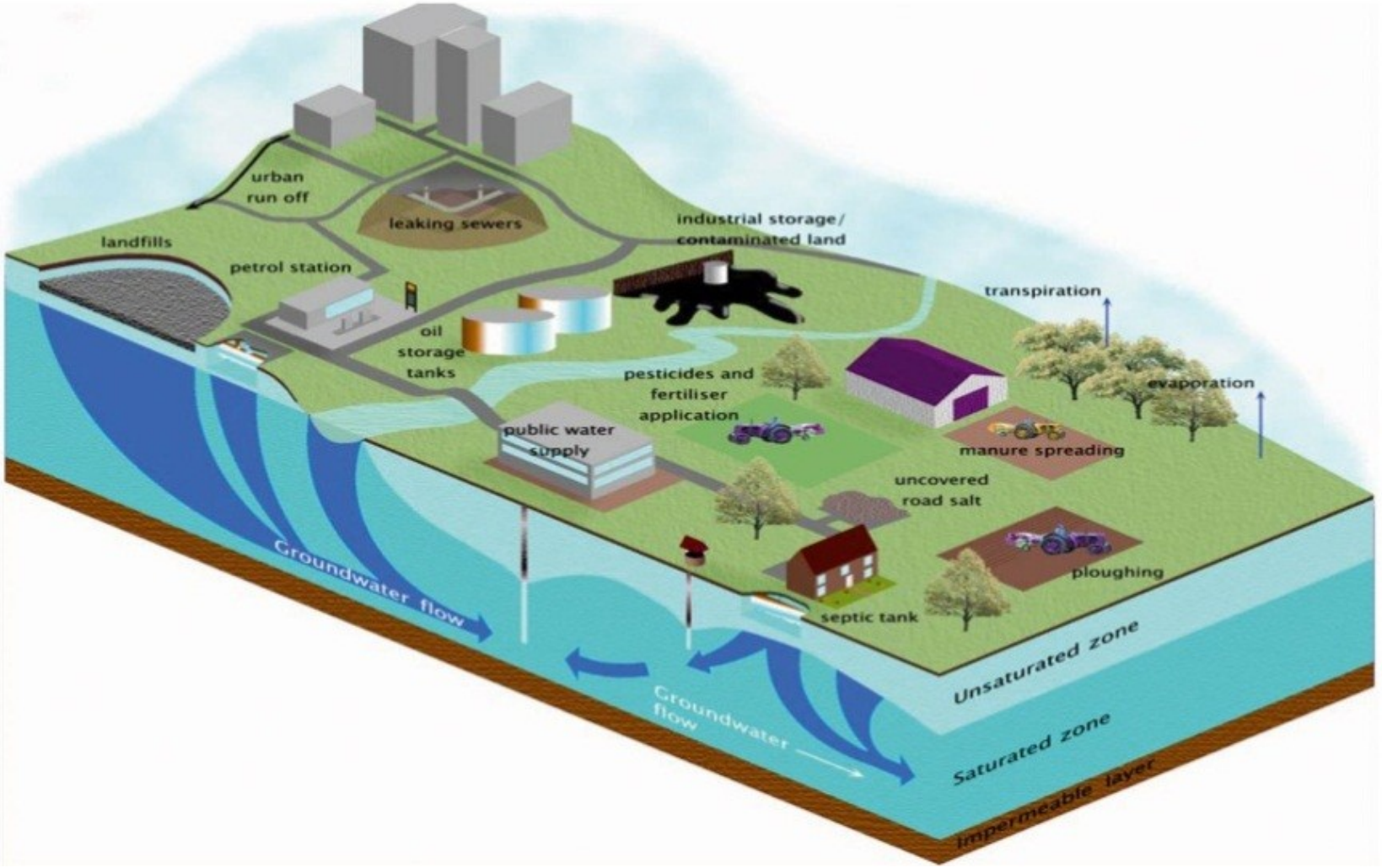


Groundwater Drawdown

Reduction in head observed at a well in an aquifer in response to pumping from a well.



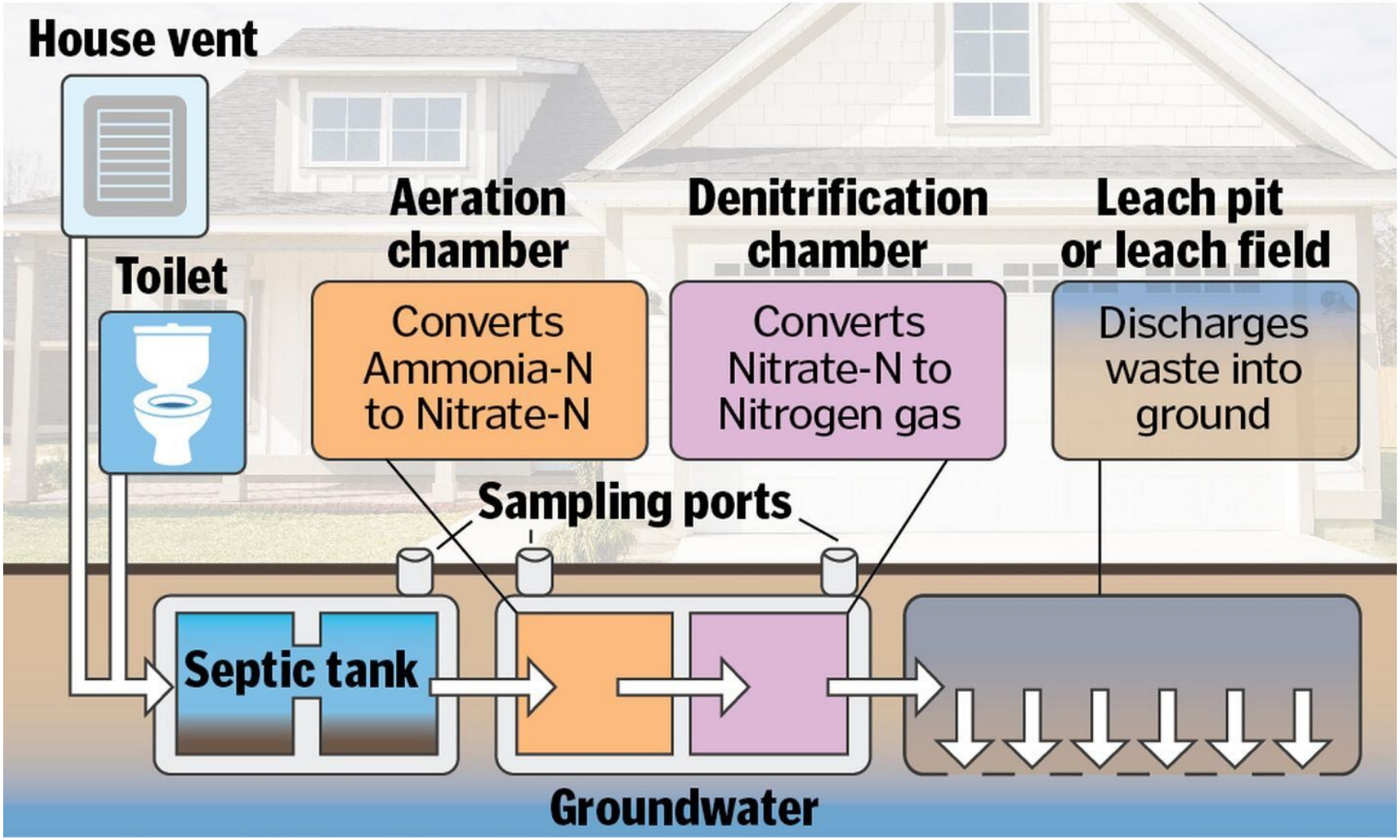
Potential Groundwater Contamination Sources



Title 5 2023 Amendments - Septic

- To reduce nitrogen loading in Nitrogen-sensitive areas:
  - 30 Cape Cod watersheds draining to Buzzards Bay, Nantucket Sound, Wellfeet Harbor
  - Potential future expansions to South Coast - very limited areas of Plymouth
- Requirement:
  - Watershed Permitting OR
  - Upgrade to Nitrogen-reducing Septic
    - Existing systems – within 5 years
    - New construction

Advanced Septic Systems



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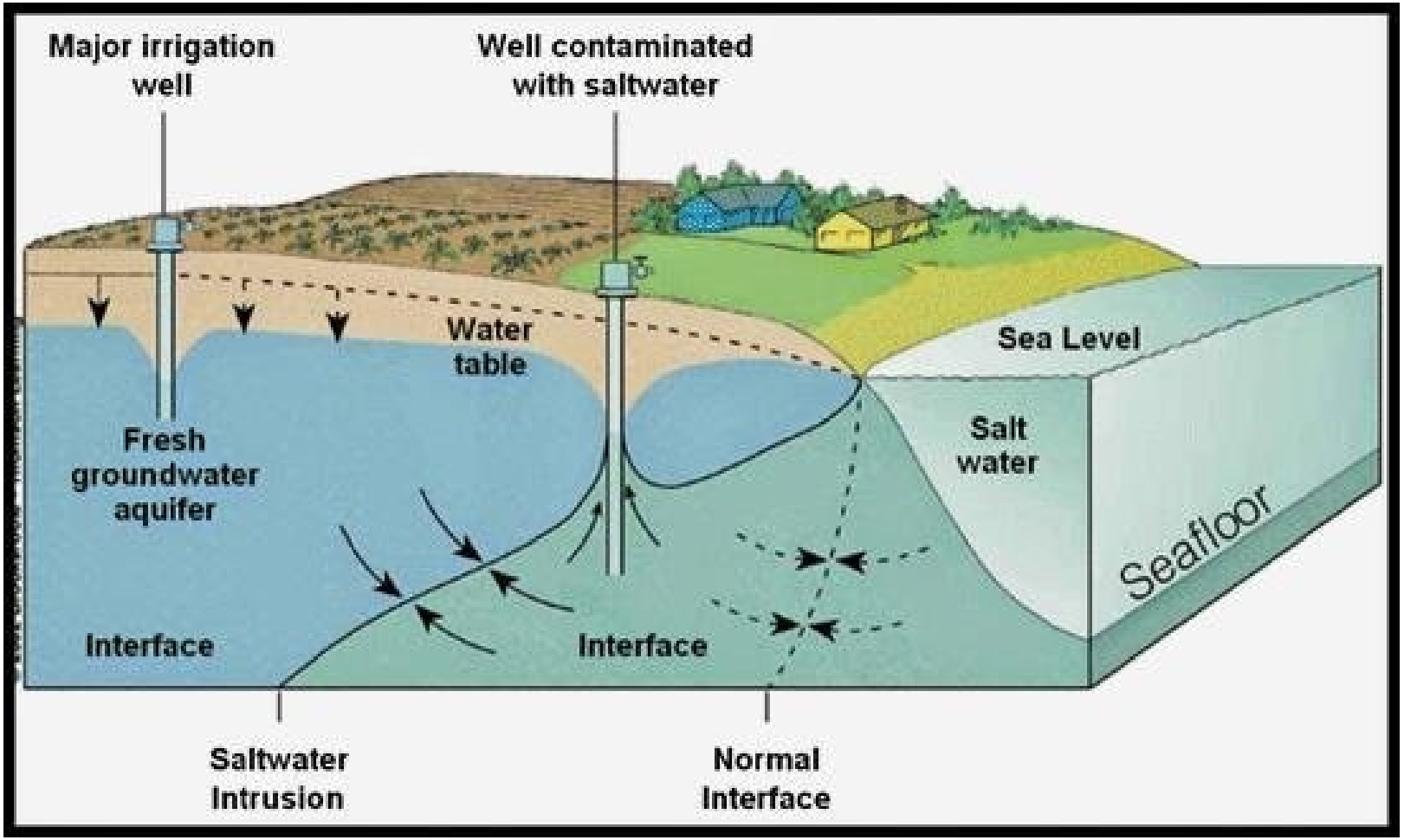
Questions?

Salt (Sea) Water Intrusion



Salt Water Intrusion in Plymouth

- Studied by Boutt, et al (USGS, 2023)
- Salt water intrusion currently occurs in limited areas very close to shore
- Projected sea water rise may may induce limited onshore migration of salt water interface (approx. 200 m)

Water Utility Regulation in MA

- Regulated by two state agencies
  - MassDEP
  - Dept. of Public Utilities
- Private water companies, e.g., Agawam Water Co., regulated same as municipal utilities

Groundwater Use Regulation

- Water Mgmt. Act [21G] Permitting
  - Provide safe yield in Buzzards Bay basin (South Plymouth) per new sustainable water mgmt regs (2014)
    - Safe yield: 148.4 mg/d
    - Allocated withdrawal: 83.78 mg/d
  - Protection of other water sources
  - Existing water resource mgmt plans
  - Water conservation performance standards
  - Mitigating impacts of increased withdrawals

Massachusetts Wellhead Protection Areas *[310 CMR 22.02]*

- Zone I:
  - Protective radius around the wellhead
  - 400 ft around wells >100,000 g/d
- Zone II:
  - Area of aquifer that contributes water under extreme drought conditions.
  - Determined by groundwater modeling and approved by the MaDEP
- Zone III:
  - Area beyond Zone II to which surface water drains into Zone II area

Zone I Land Use Restrictions

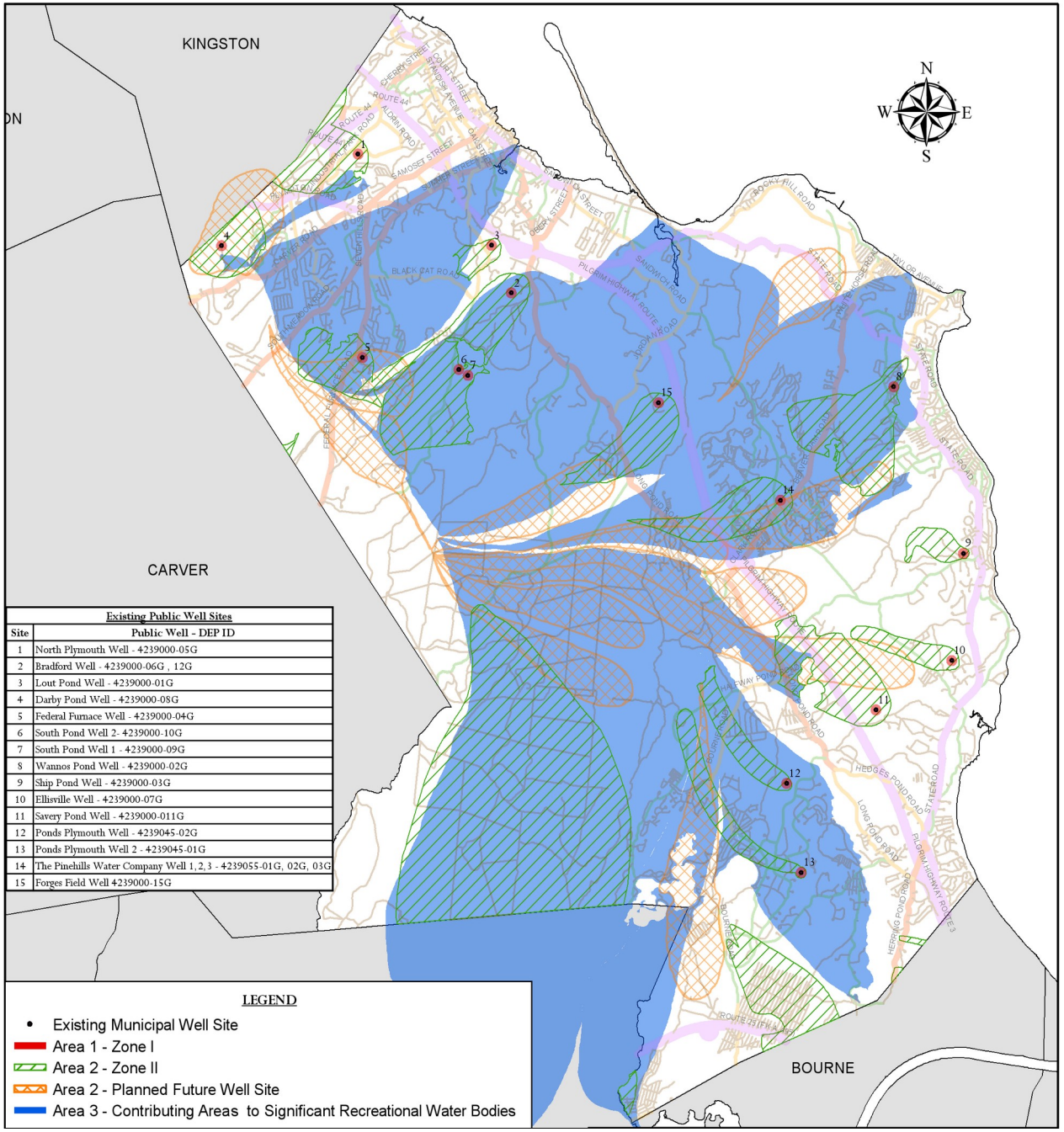
- Land must be owned/controlled by water supplier
- Land uses is limited to those directly related to drinking water provision, e.g., water supply well and associated mechanical and electrical equipment

Zone II & III Land Use Restrictions

- Zoning and non-zoning controls:
  - Prohibitions:
    Landfills; junkyards; stockpiling or disposal of snow & ice containing road salt; bulk petroleum storage; WWTPs; hazardous waste generation, treatment, storage, disposal; industrial floor drain discharge
  - Conditional Limitations:
    Storage of wastes, chemicals, salt, fertilizer, or manure; soil removal; installation of impervious surfaces (>15% of area)

Plymouth Aquifer Protection Map (2020)

Showing Town of Plymouth public water supply wells



Zone II Cross Section