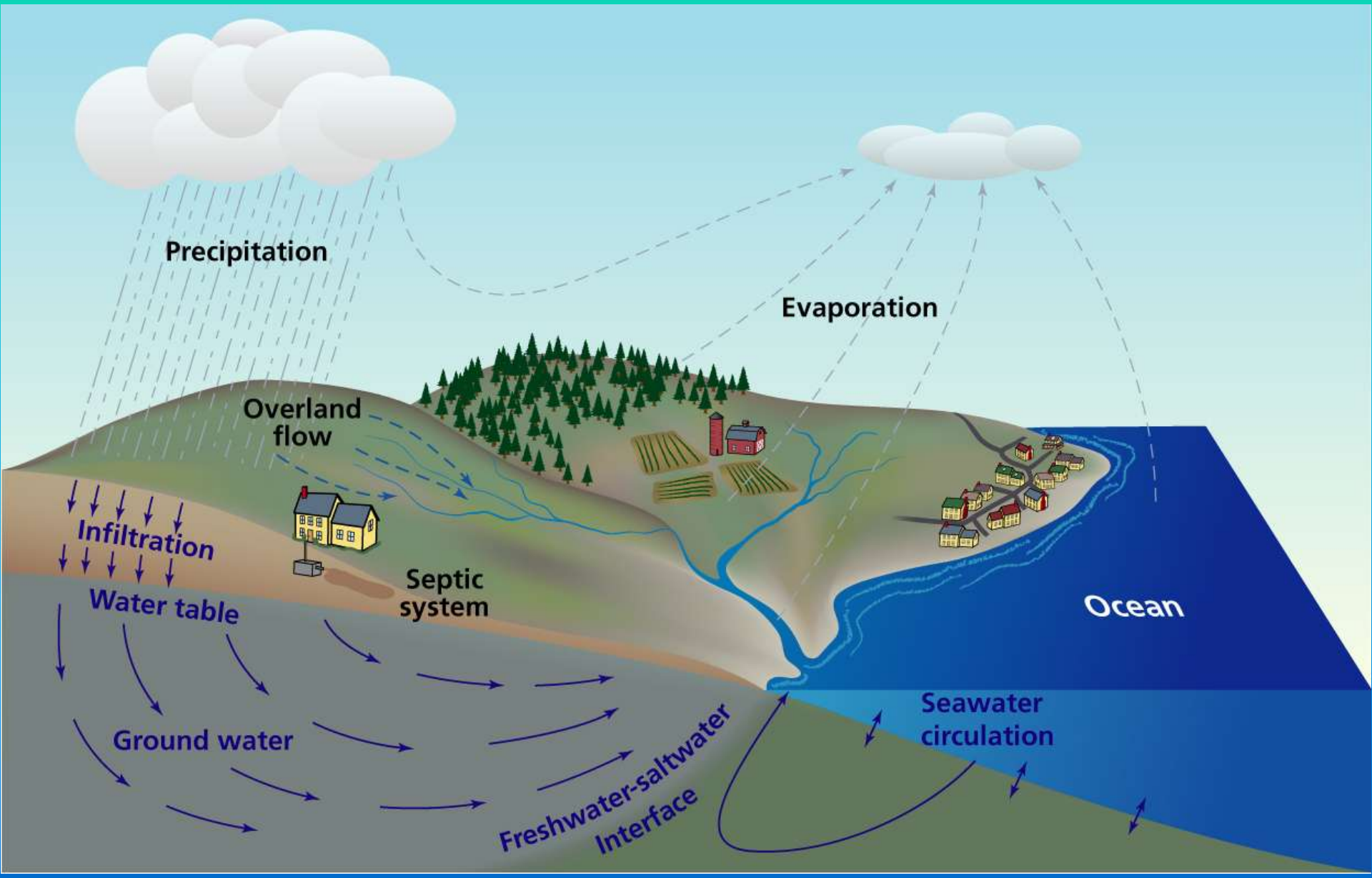
The Subterranean Estuary: An Unseen and Overlooked Boundary Between the Land and the Sea

Matt Charette

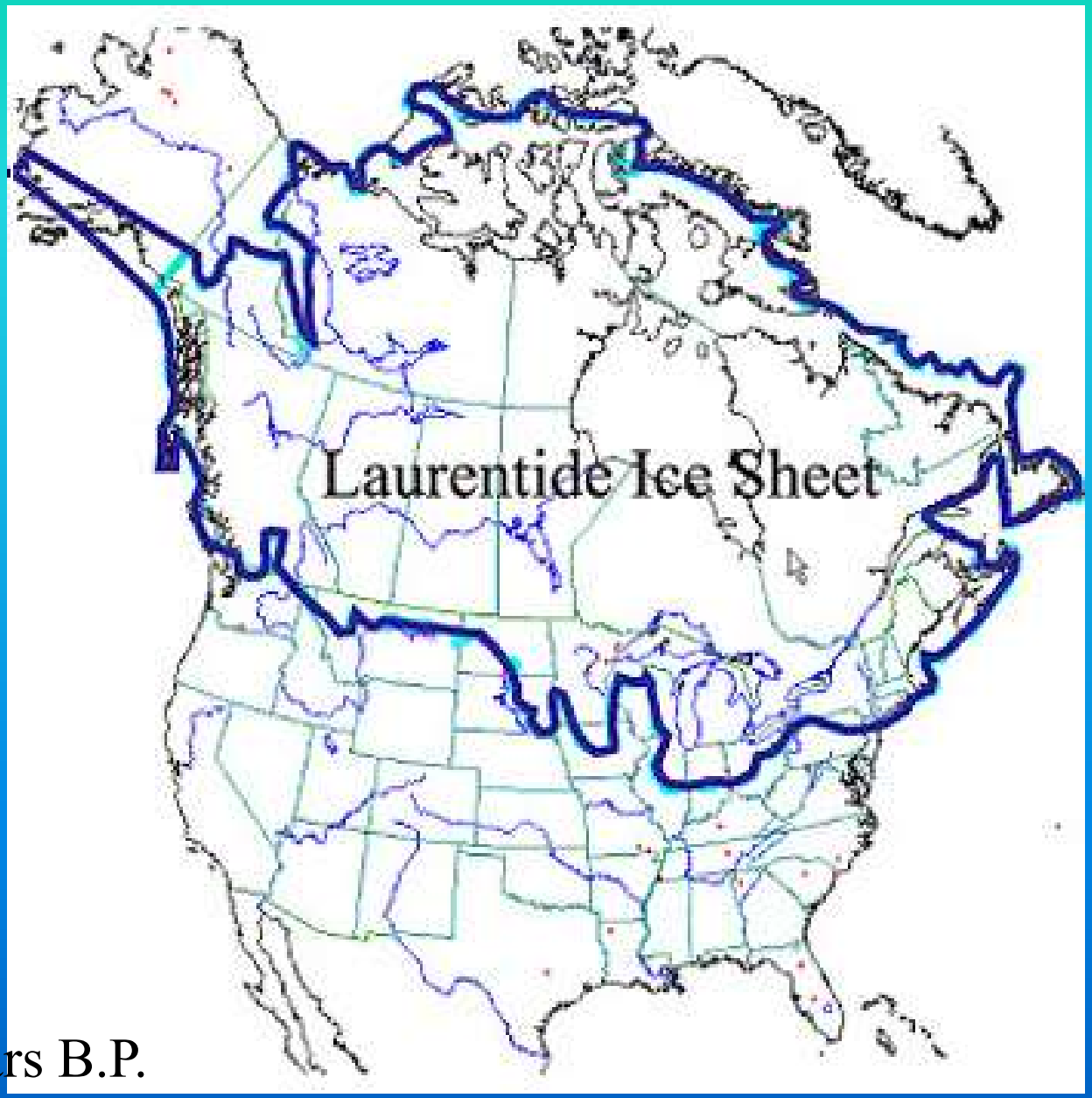
Department of Marine Chemistry and Geochemistry

Woods Hole Oceanographic Institution


Precipitation
Evaporation
Overland flow
Infiltration
Water table
Septic system
Ocean
Ground water
Seawater circulation
Freshwater-saltwater Interface

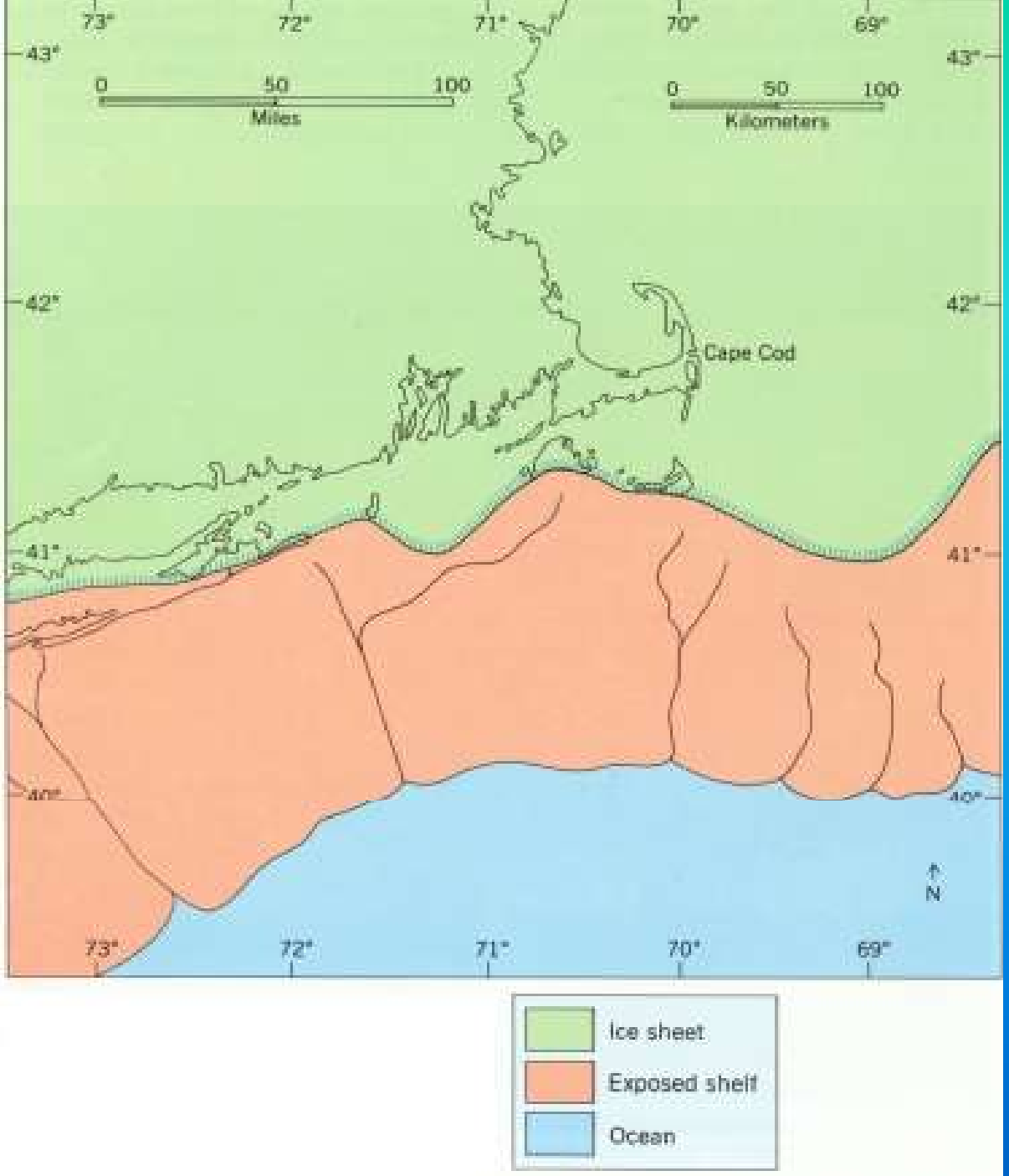
My 3000 Mile Journey to Waquoit Bay

Geologic History of Cape Cod

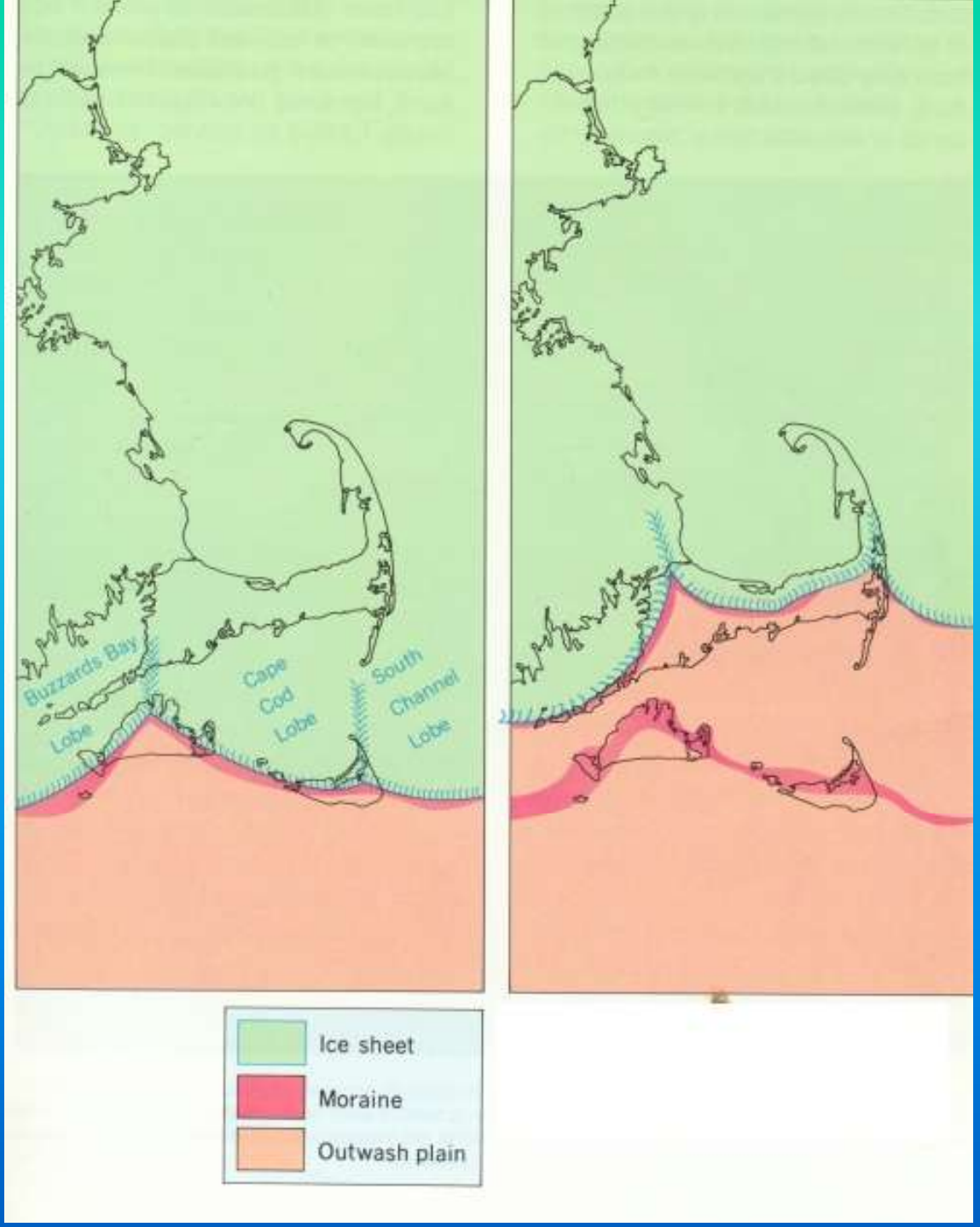


23,000 years B.P.

U. California San Diego

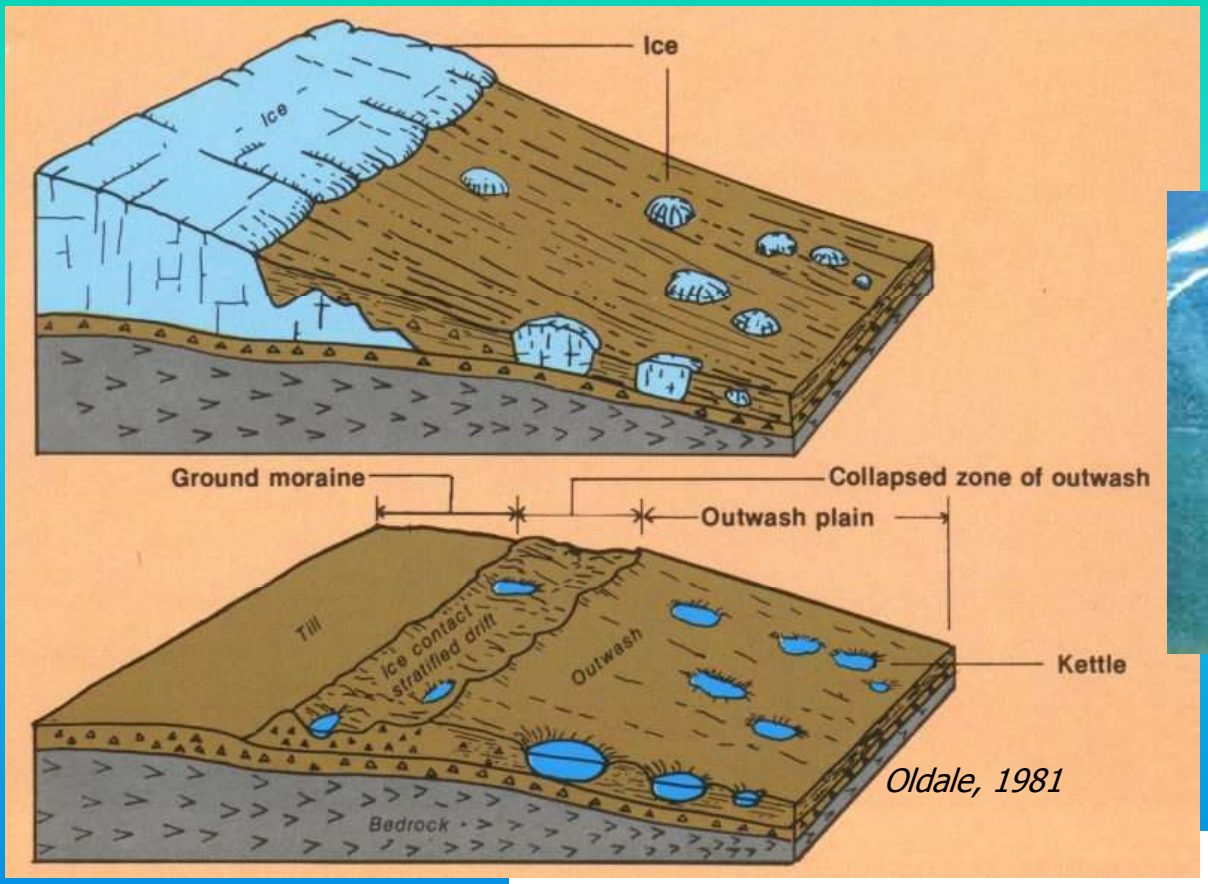

73°
72°
71°
70°
69°
43°
42°
41°
40°
0
50
100
Miles
0
50
100
Kilometers
Cape Cod
N
Ice sheet
Exposed shelf
Ocean

Oldale, 1981


Buzzards Bay Lobe
Cape Cod Lobe
South Channel Lobe
Ice sheet
Moraine
Outwash plain

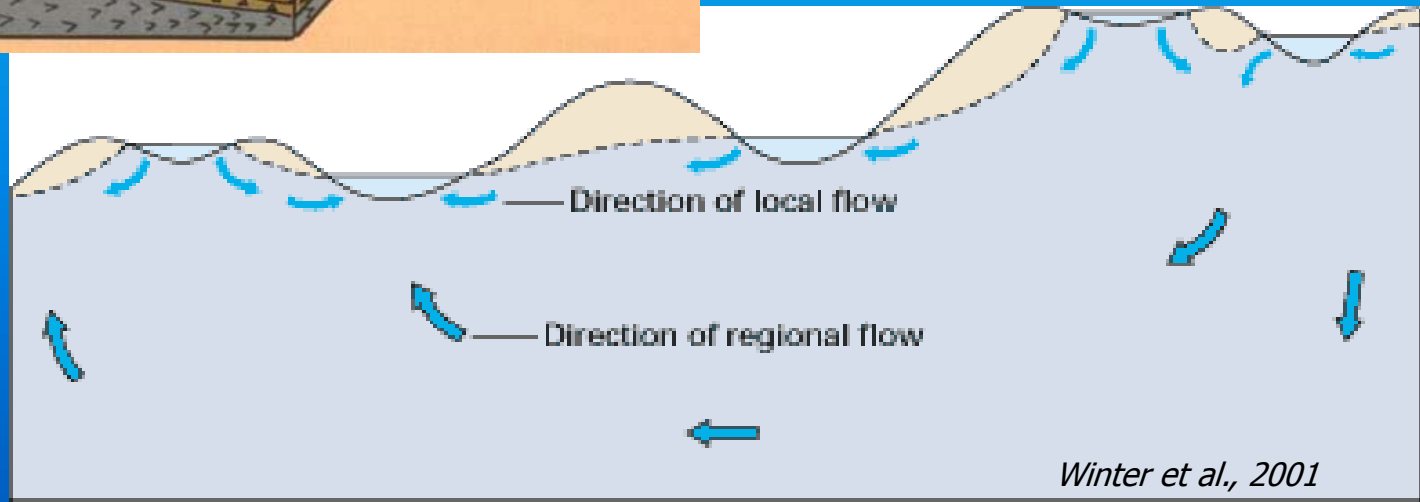
Oldale, 1981

Kettle Ponds



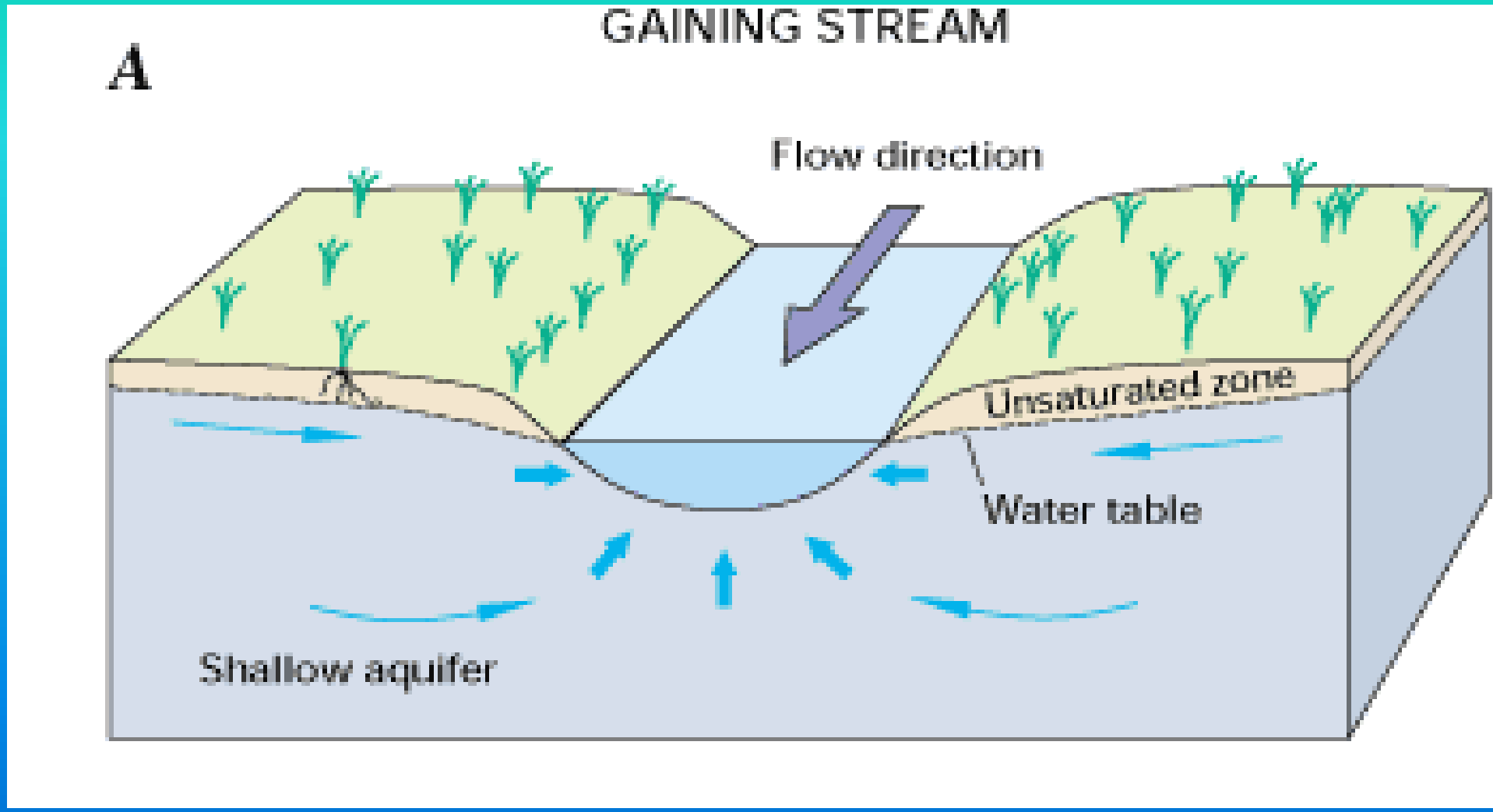
Oldale, 1981

Great Pond, Wellfleet

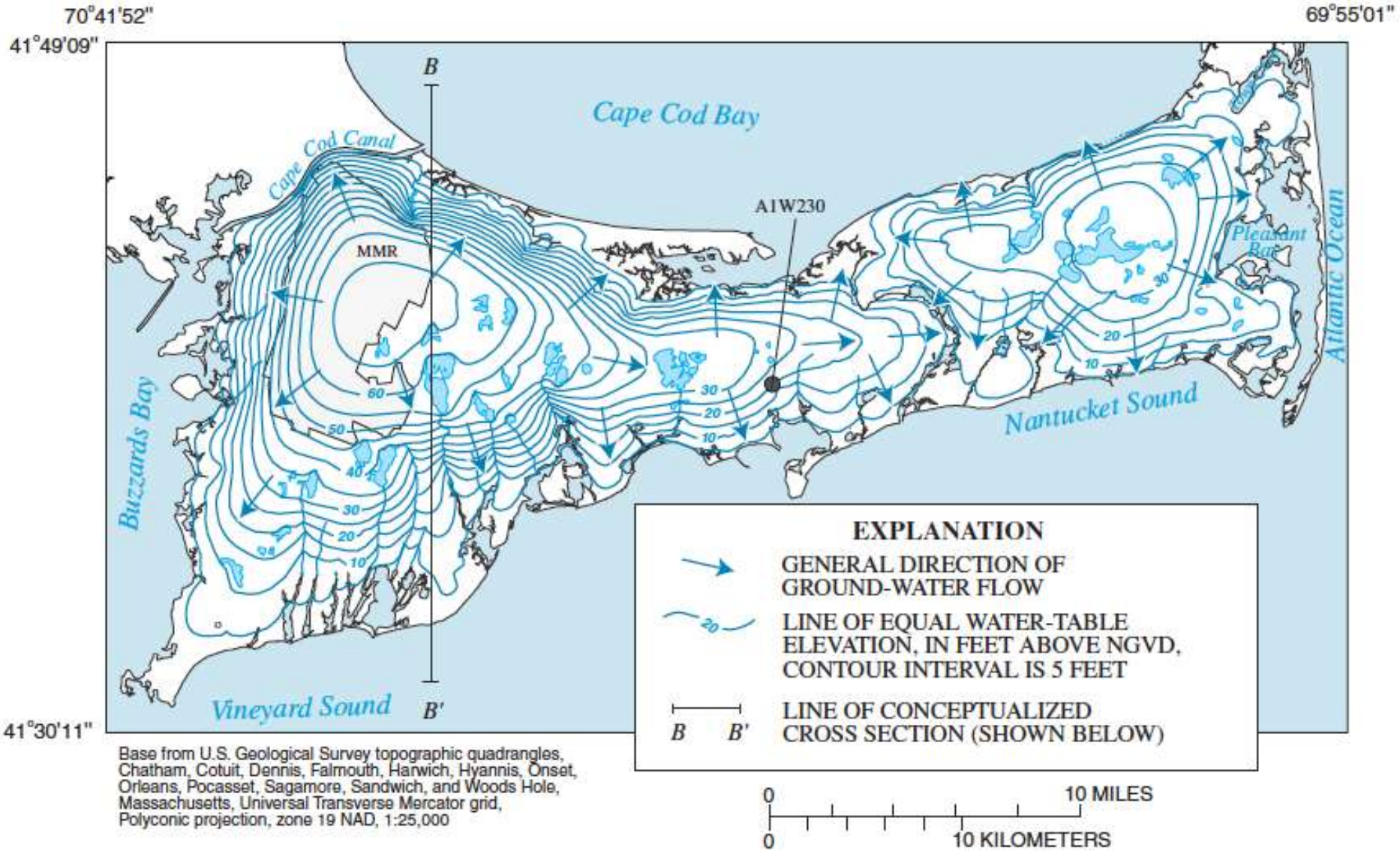


Winter et al., 2001

Rivers on Cape Cod

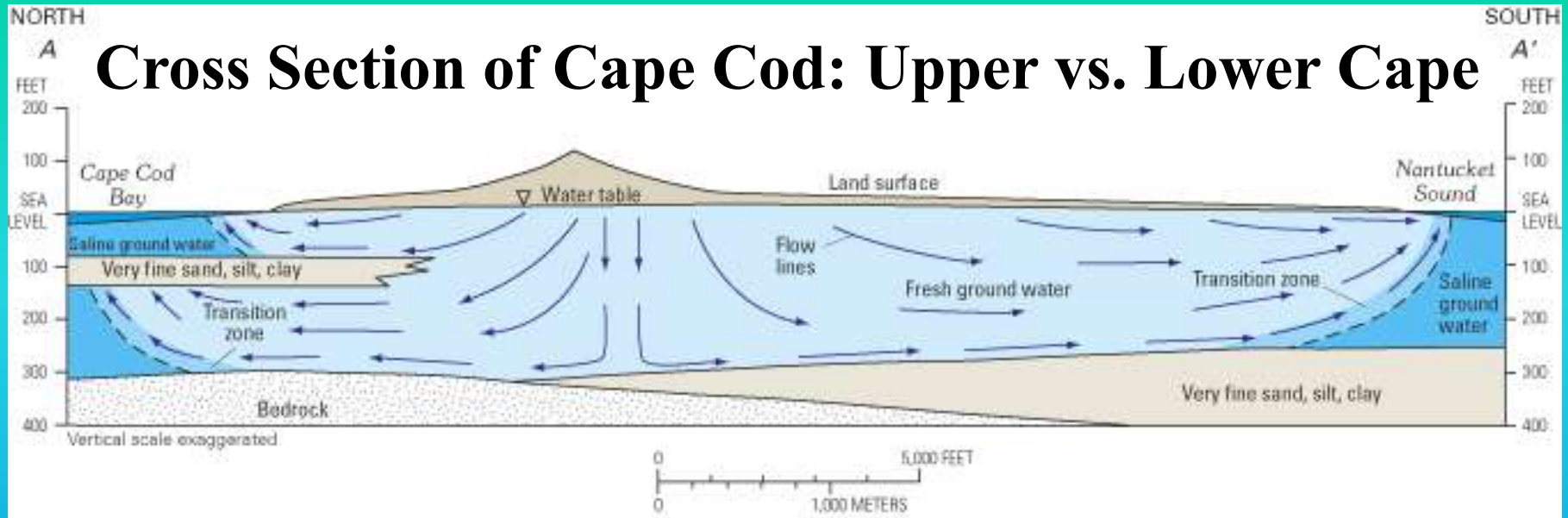


Winter et al., 2001



Base from U.S. Geological Survey topographic quadrangles, Chatham, Cotuit, Dennis, Falmouth, Harwich, Hyannis, Onset, Orleans, Pocasset, Sagamore, Sandwich, and Woods Hole, Massachusetts, Universal Transverse Mercator grid, Polyconic projection, zone 19 NAD, 1:25,000

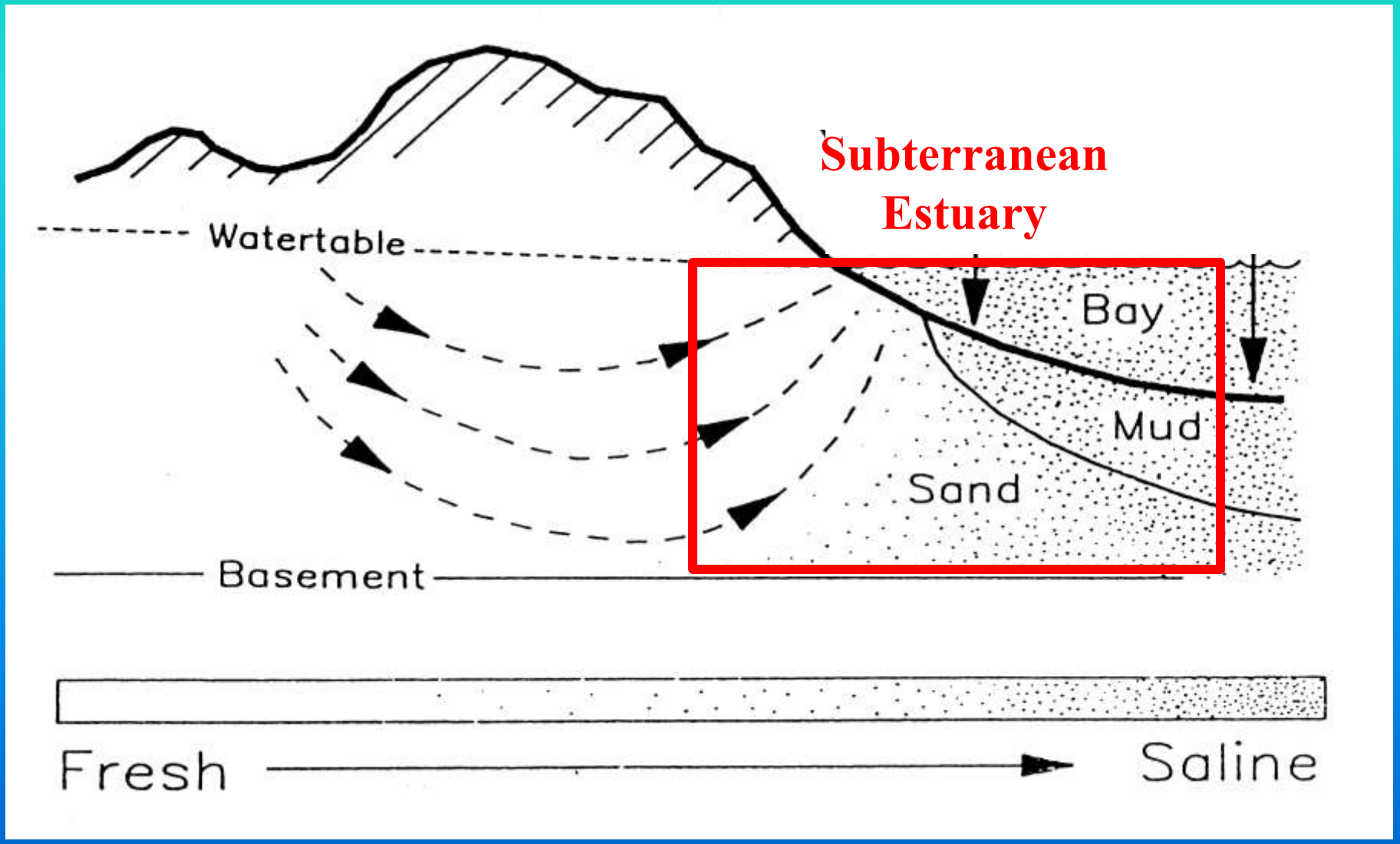
Cross Section of Cape Cod: Upper vs. Lower Cape



sea level refers to National Geodetic Vertical Datum of 1929

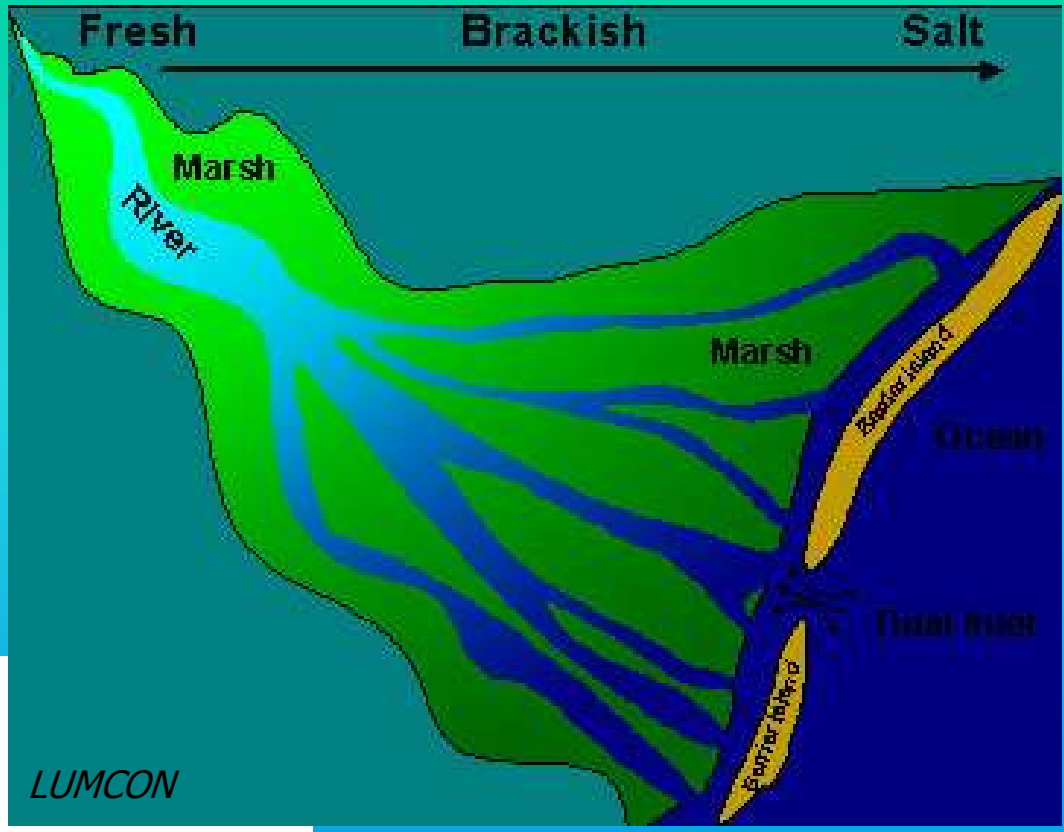
Barlow, 2003

Submarine Groundwater Discharge (SGD)

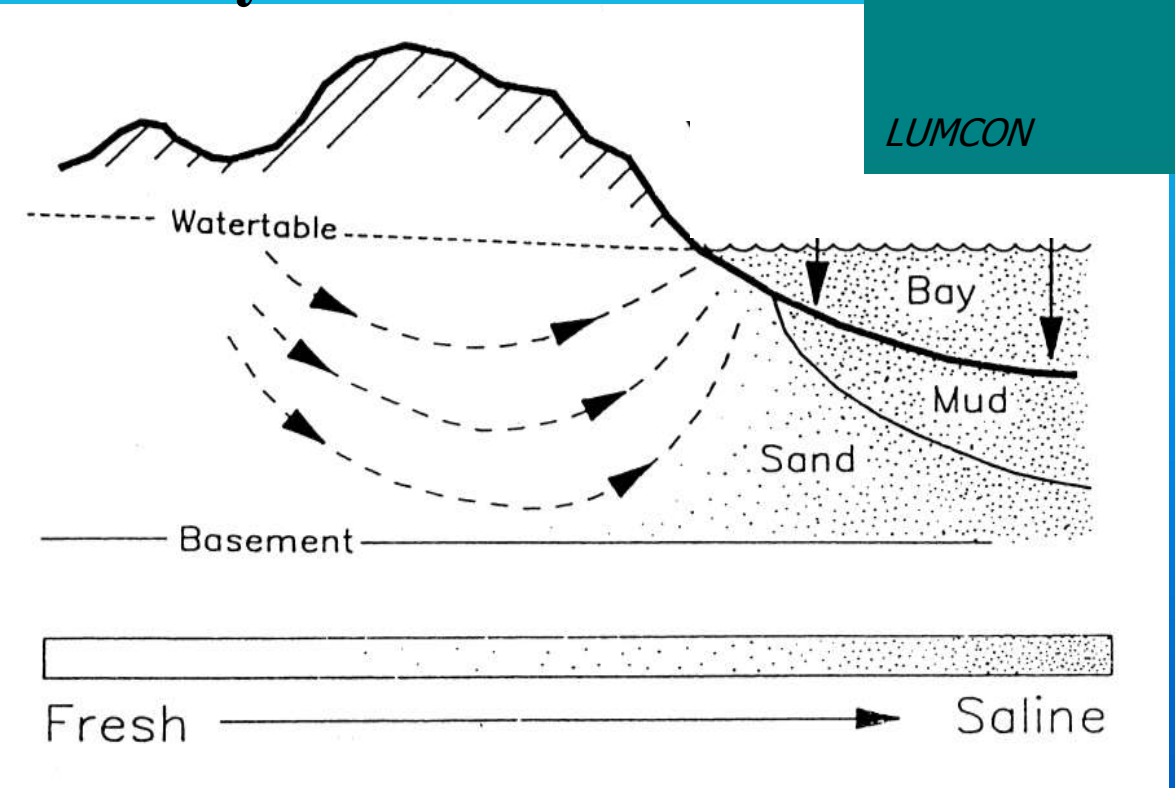


Valiela et al. (1992)

Surface Estuary

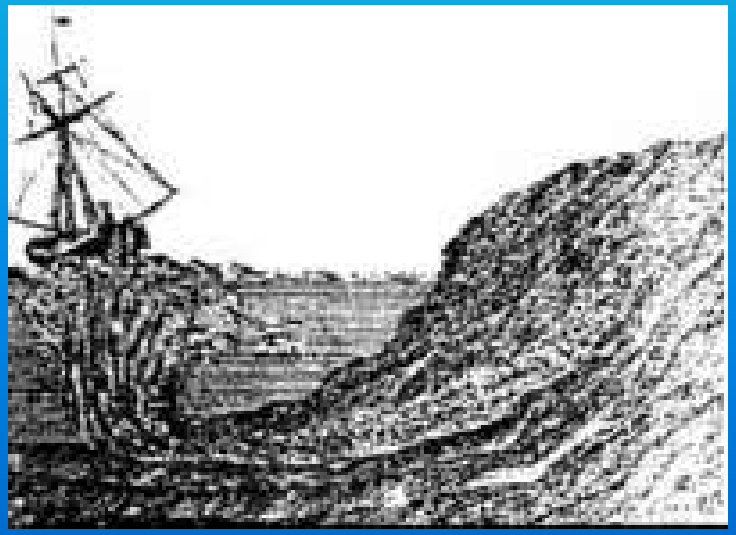


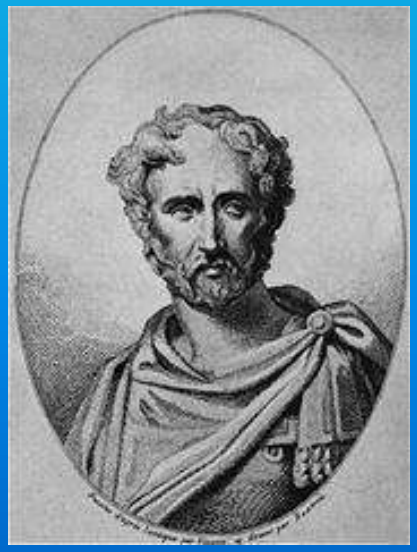
Subterranean Estuary



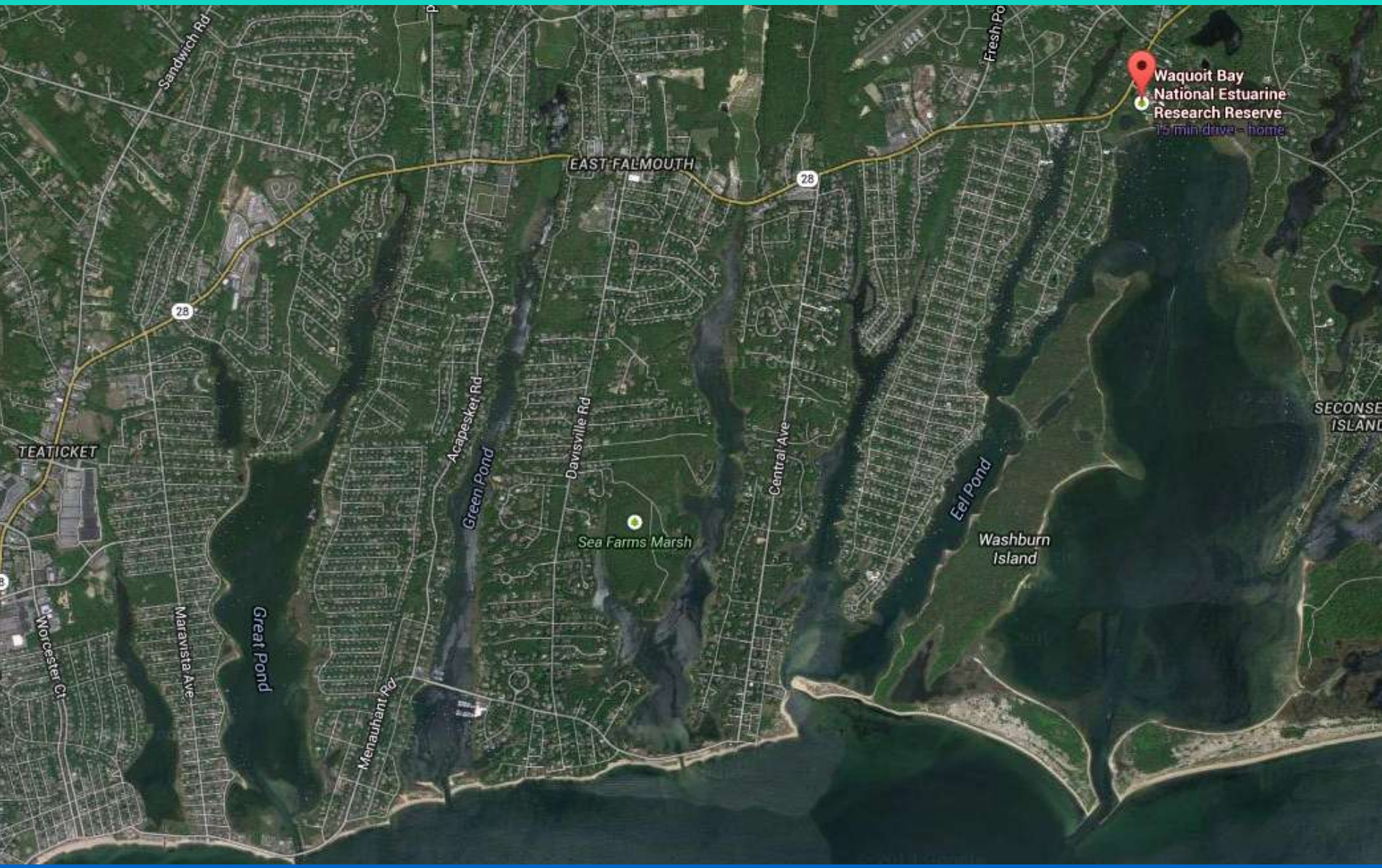
Valiela et al. (1992)

History of Submarine Groundwater Discharge and the Subterranean Estuary in Ocean Sciences



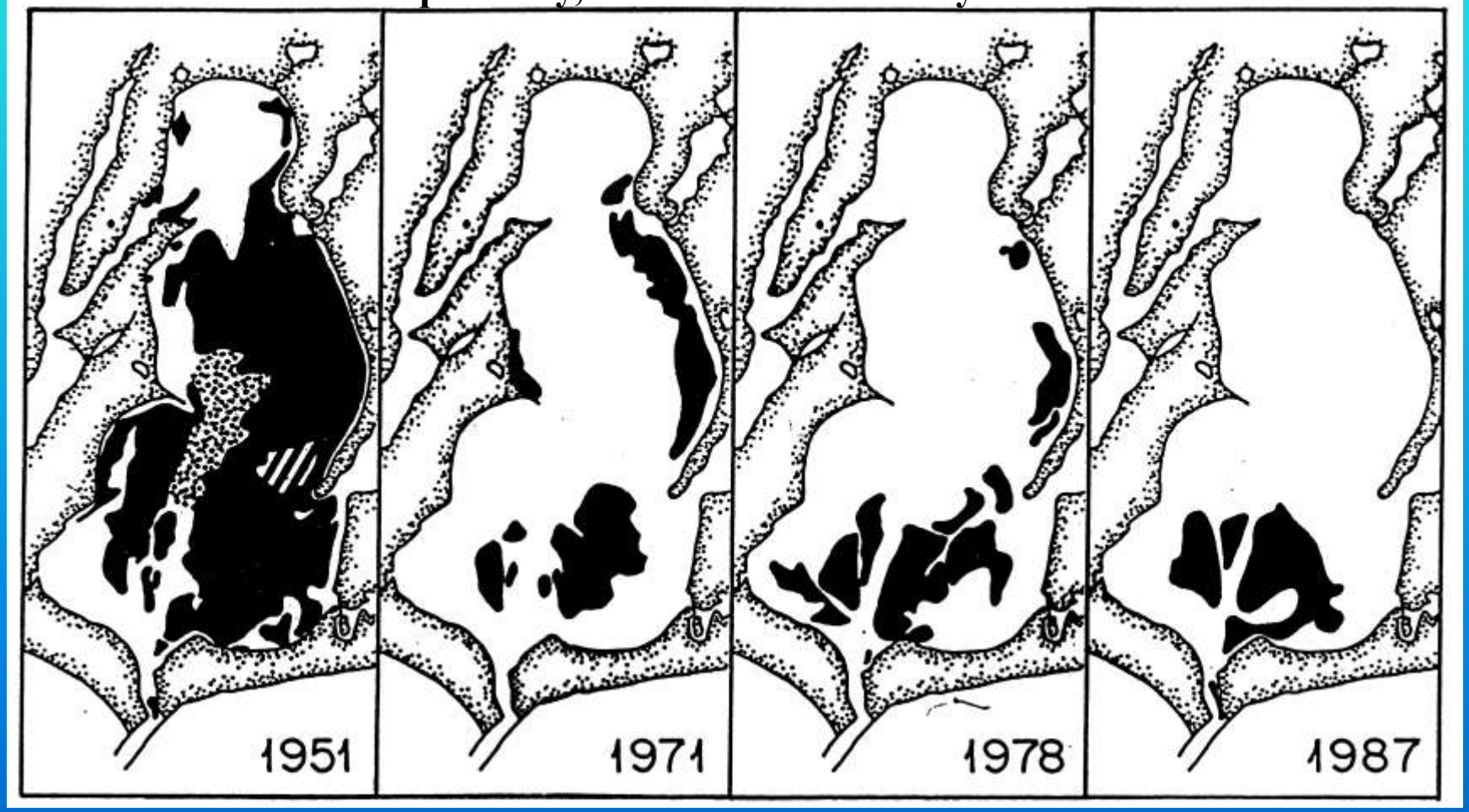


Housing Density at and Around Waquoit Bay



Consequences of Groundwater-Derived Nutrient Over-enrichment in a Coastal Embayment

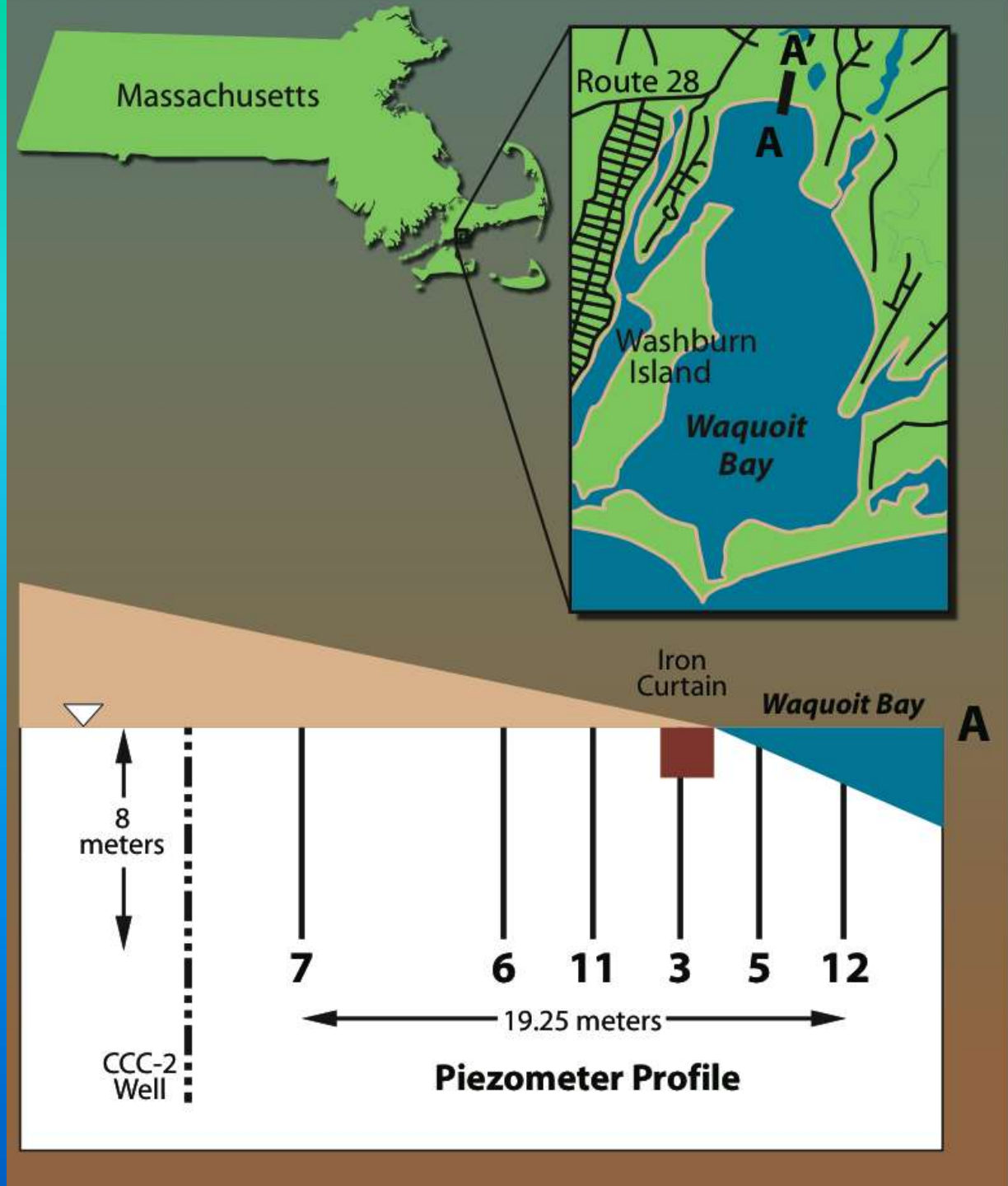
Waquoit Bay, MA Eel Grass Density: 1951-1987



Valiela et al. (1992)

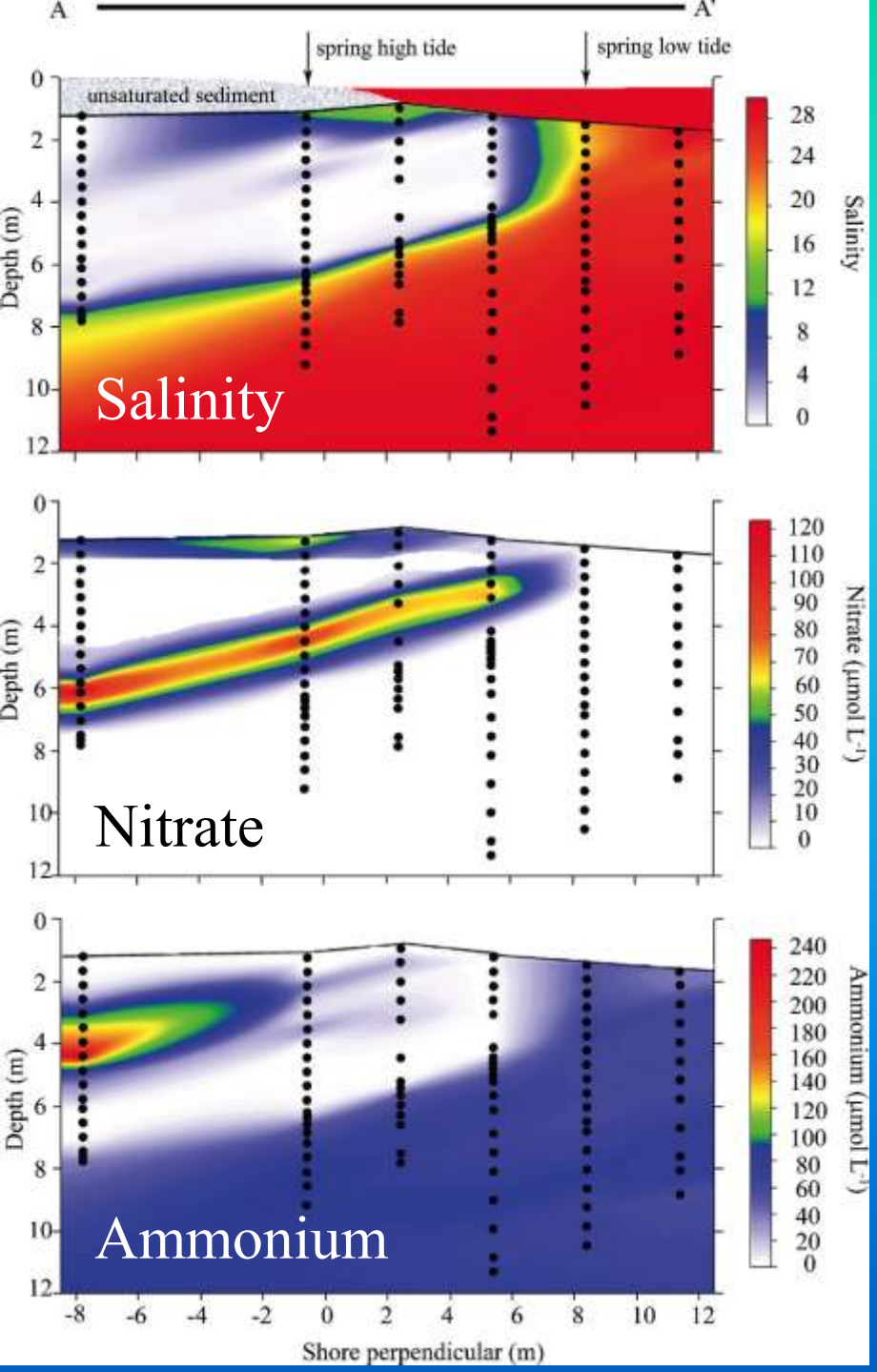
Mulligan and Charette, 2006

Typical Subterranean Estuary Sampling Program



Subterranean Estuary Sampling Methods

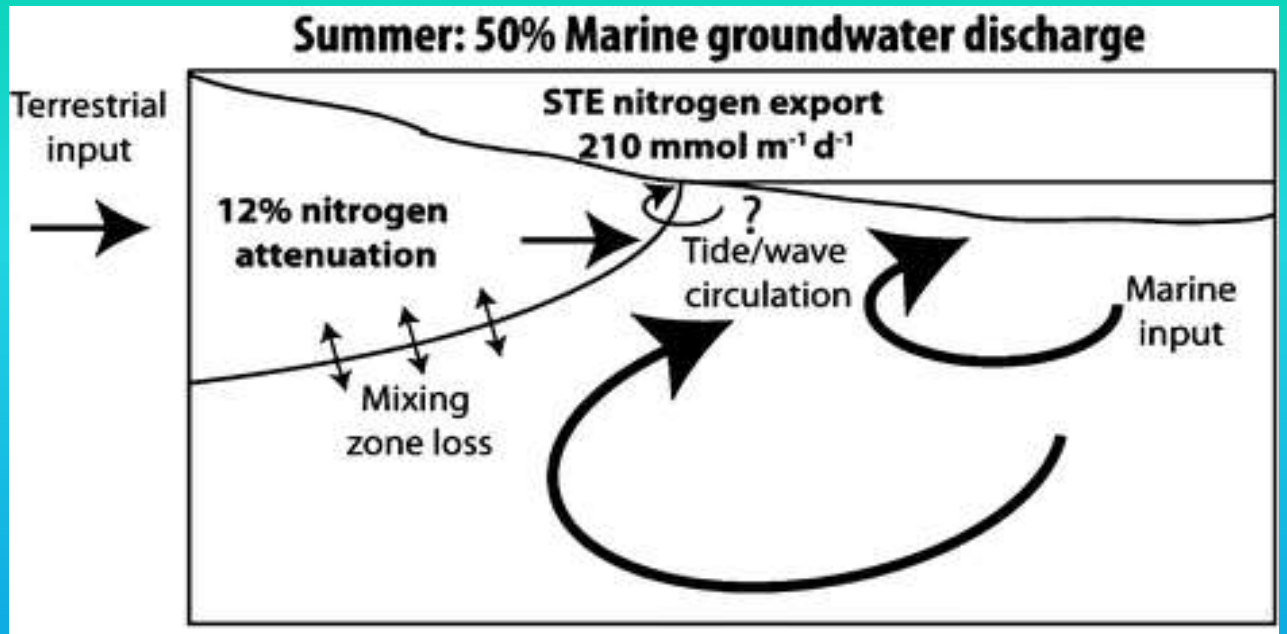
Subterranean Estuary Studies at Waquoit Bay (1999-present)



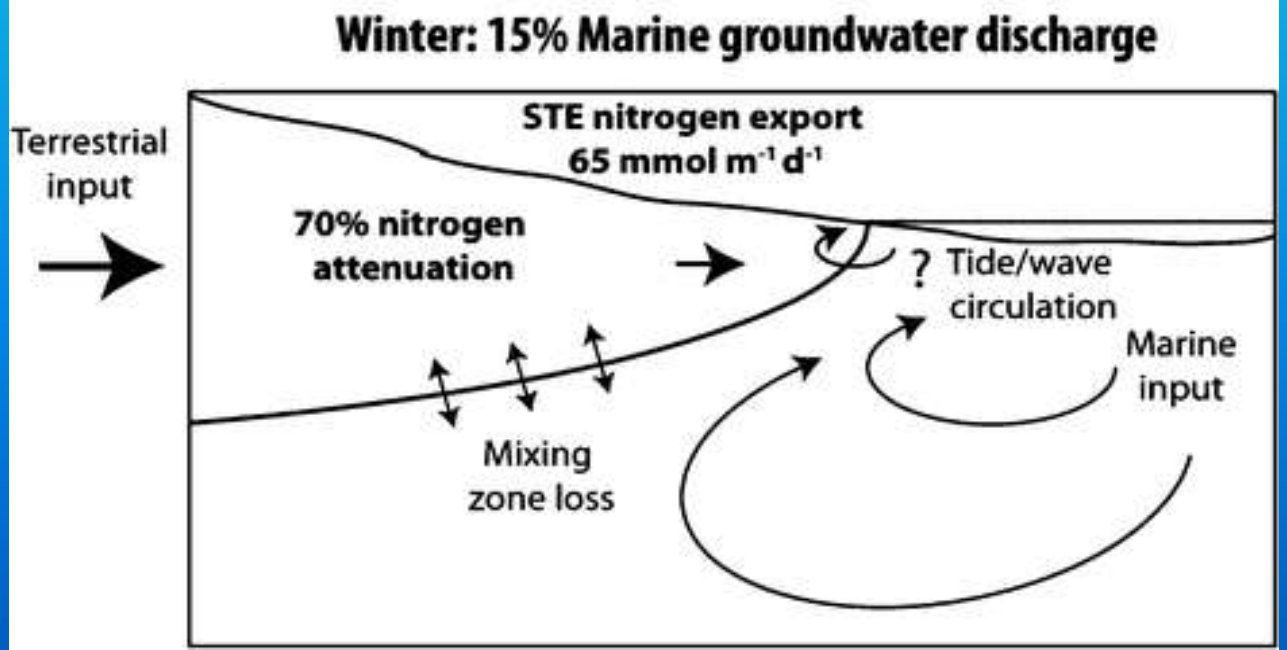
Nitrogen Distribution in the Waquoit Bay Subterranean Estuary

Kroeger and Charette (2008)

Nitrogen Behavior in the Subterranean Estuary



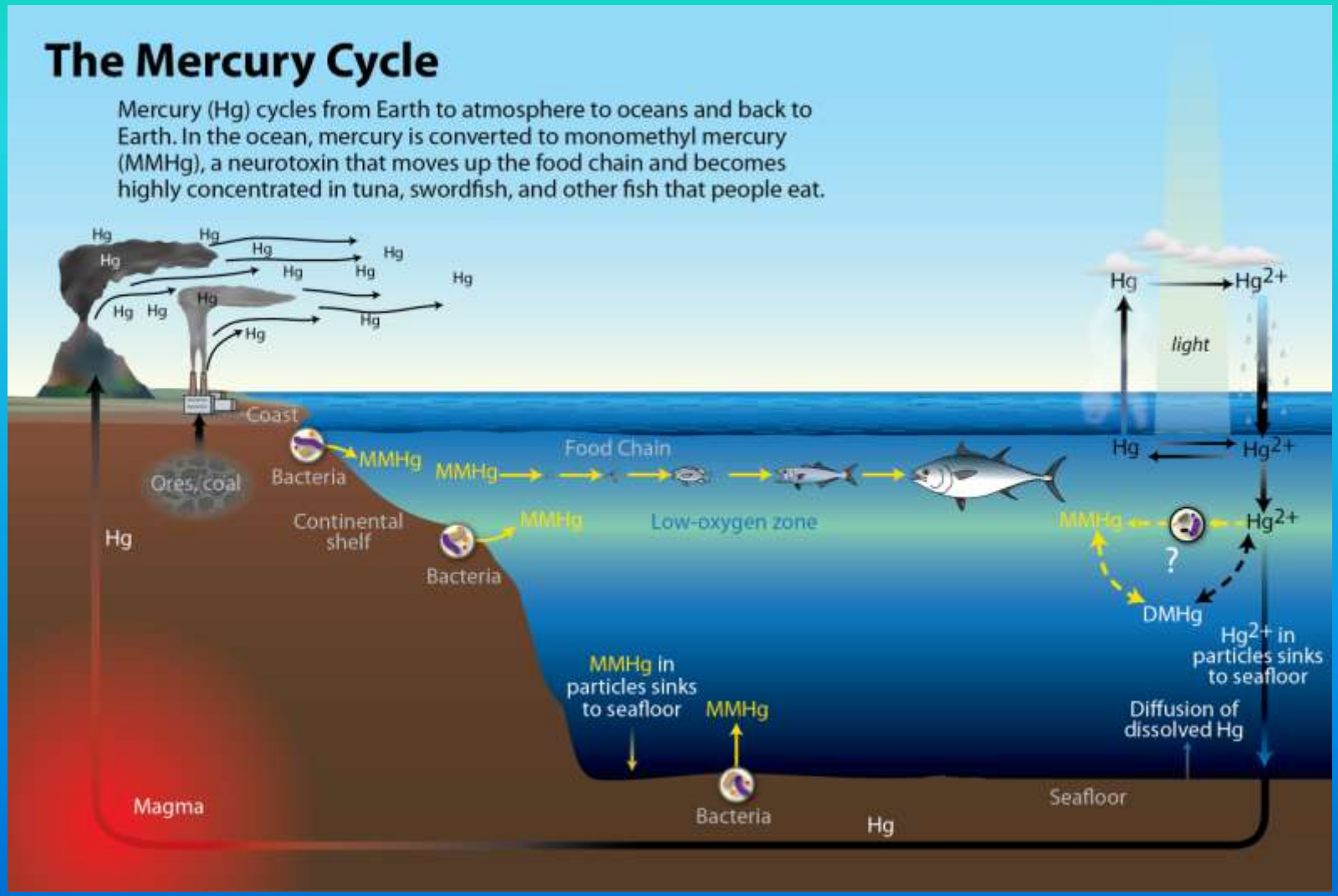
Summer



Winter

Gonneea and Charette (2014)

Groundwater as a Source of Mercury to the Ocean



Groundwater fills bay with mercury

■ WHOI researchers track a new path for high levels of pollution in Waquoit Bay.

By MARY ANN BRAGG
STAFF WRITER

Contaminated groundwater is producing high levels of mercury in Waquoit Bay, according to research released yesterday by the Woods Hole Oceanographic Institution.

In a unique approach, the research focuses on total mercury rather than the more biologically dangerous form of the heavy metal called methyl mercury, which accumulates in fish, according to Woods Hole marine chemist Matt Charette and researcher Sharon Bone.

"Until we look at that fraction of the mercury, and how that's cycling within the bay, we really don't know if there's cause for concern," Charette said of the potential for methyl mercury contamination in Waquoit Bay.

The research was published in the online version of the journal Environmental Science and Technology.

According to the federal Centers for Disease Control and Prevention, the human nervous system is sensitive to all forms of mercury and exposure to the toxic metal can lead to permanent brain damage.

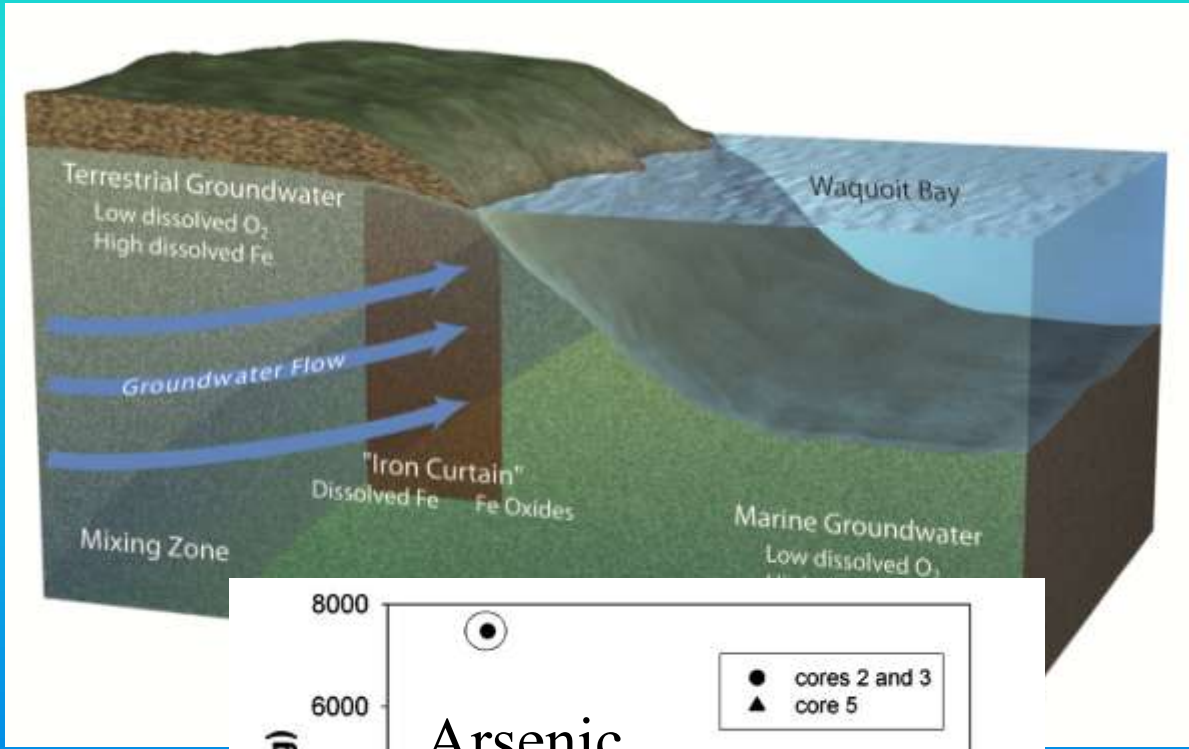
Charette said the Waquoit

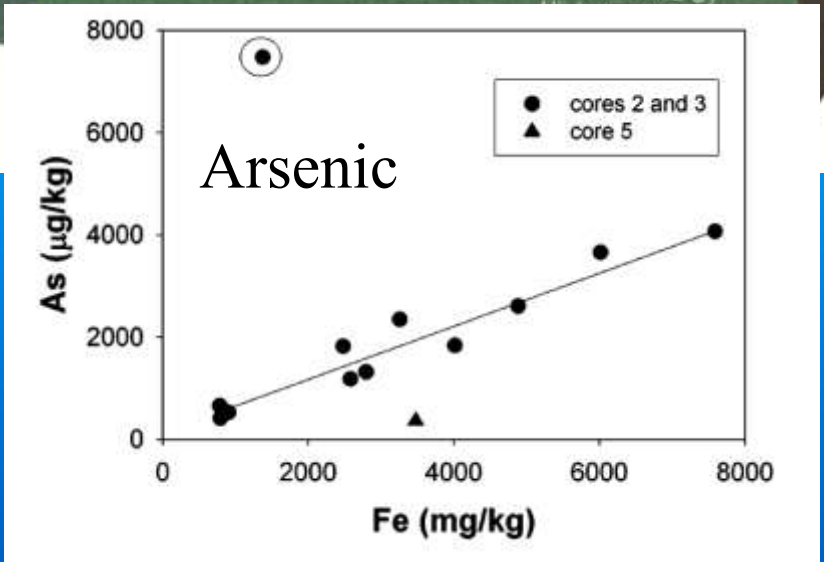
Please see MERCURY /A-12

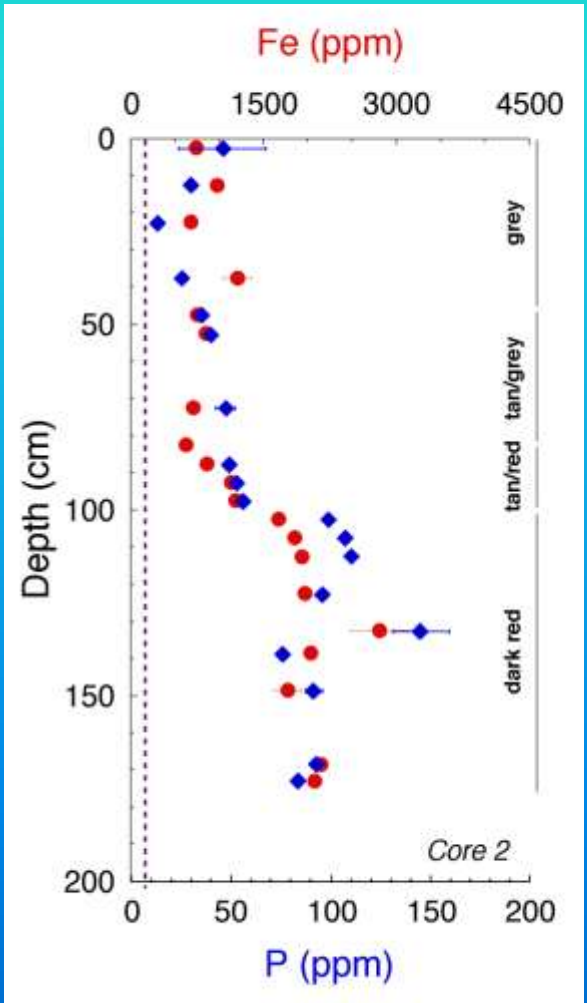
Cape Cod Times
Mar. 22, 2007

The ‘Iron Curtain’ at Waquoit Bay

Iron Curtain as a Natural Permeable Reactive Barrier for Contaminant Removal from Groundwater





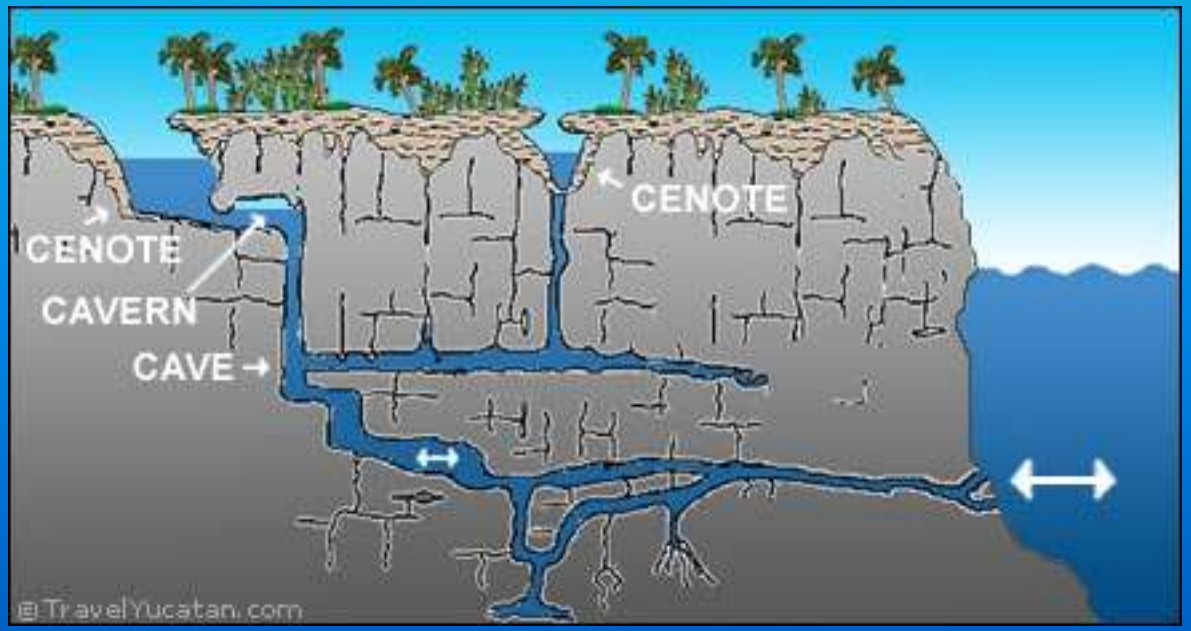


Phosphorous

Beyond Waquoit Bay

Florida Everglades

Yucatan Peninsula, Mexico



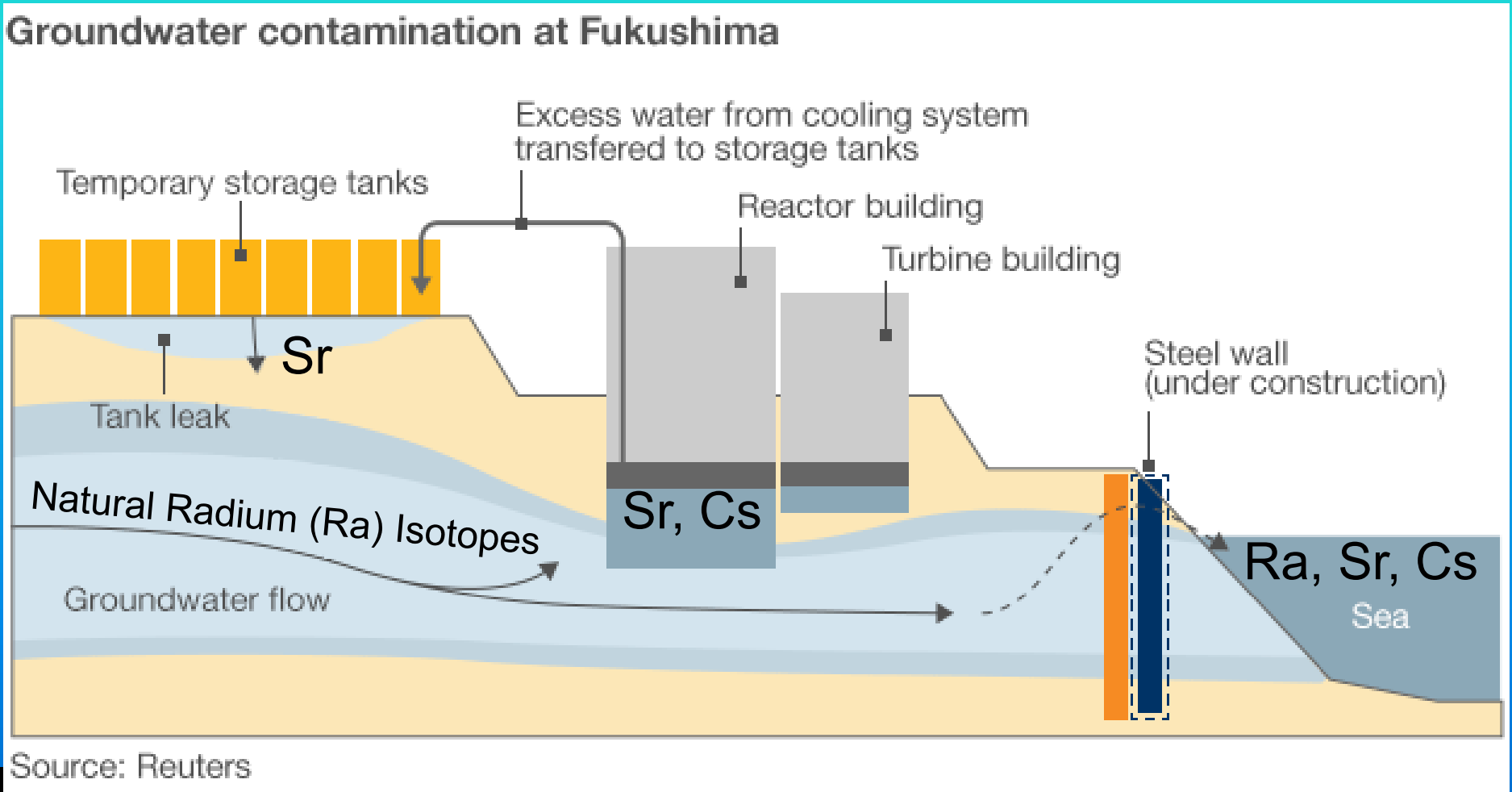
Guam (Northern Mariana Islands)

Tumon Bay, Guam

Tumon Bay, Guam

Fukushima Daichi Nuclear Power Plant

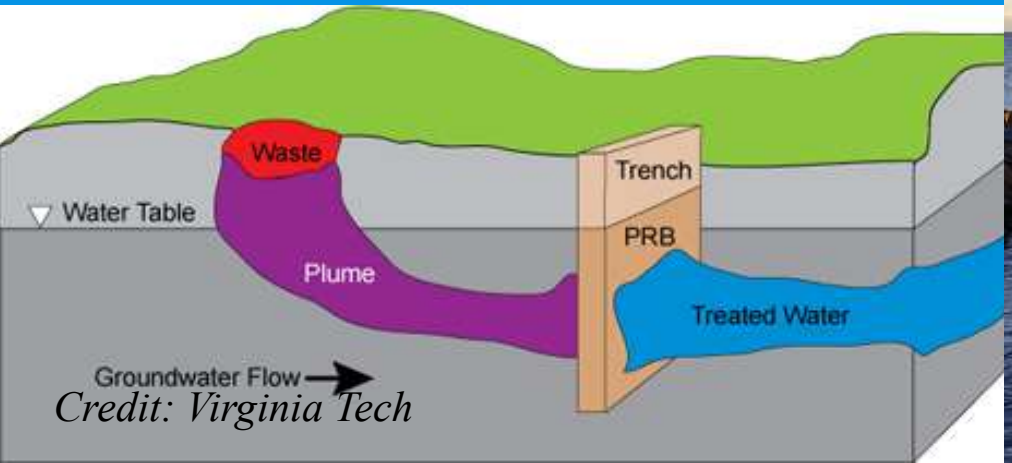
Fukushima



Cesium=Cs Strontium=Sr

Greenland Ice Sheet

Nitrogen Management on Cape Cod



Credit: Virginia Tech

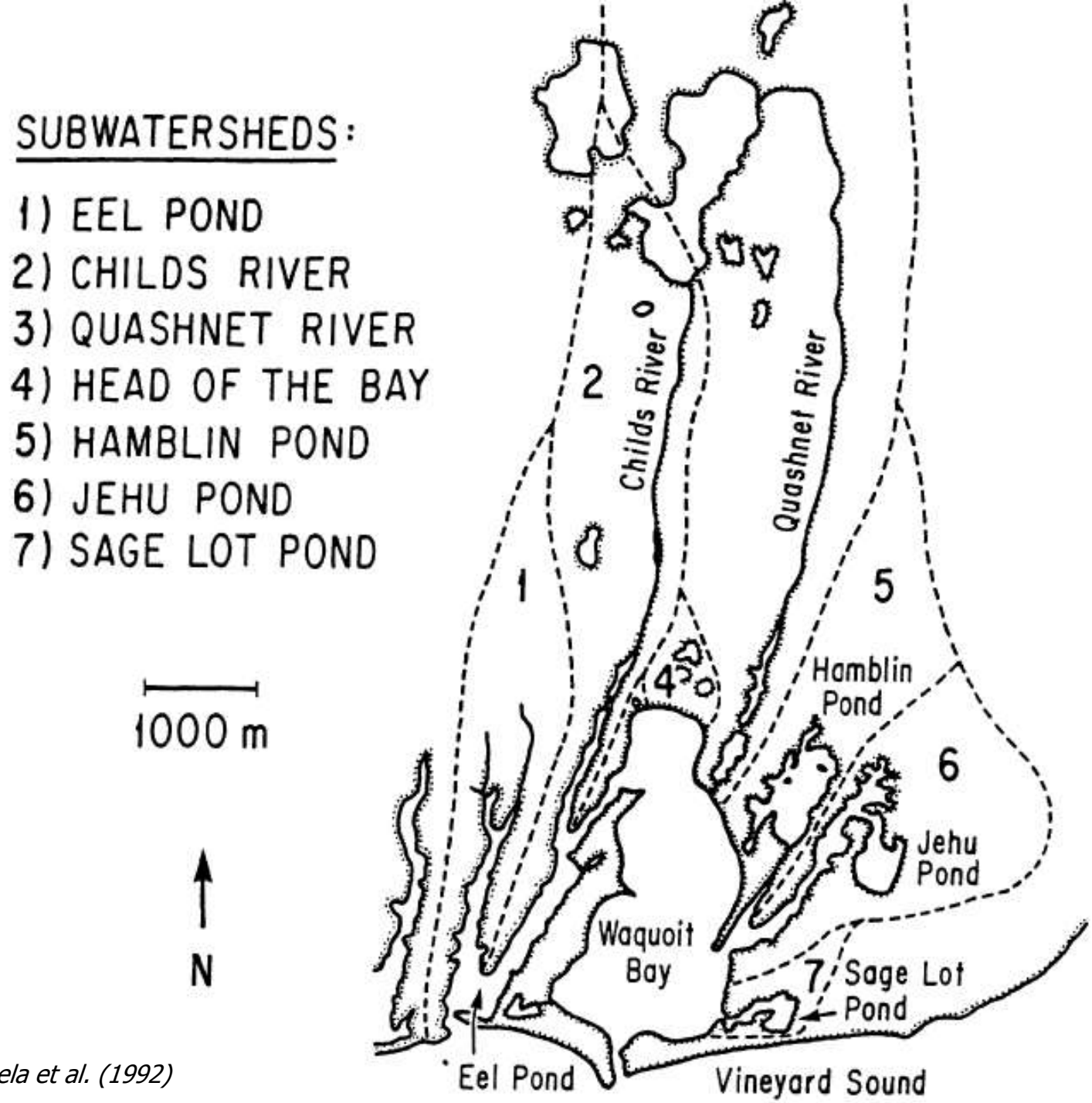
Take Home Messages

•Groundwater is the sole freshwater resource on Cape Cod

• Freshwater on Cape Cod enters the ocean through groundwater-fed rivers or submarine groundwater discharge

• Submarine groundwater discharge of nutrients has lead to eutrophication of estuaries

• Subterranean estuaries can act as filter for groundwater-derived chemical inputs to the marine environment



Valiela et al. (1992)

Aerial Photo of Waquoit Bay

TABLE 2. Nitrogen contributions (kg N yr^{-1}) by precipitation and septic systems, and N loading to water table and hence to estuaries.

	Subwatersheds		
	Childs River	Quashet River	Sage Lot Pond
Calculated DIN conc (M)[a]	160	3.6	6.2
Measured DIN conc (M) in well point samples (geometric mean)	132.7	4.2	15.1

[a] Assuming that seepage plus stream flow equals recharge.

Valiela et al. (1992)