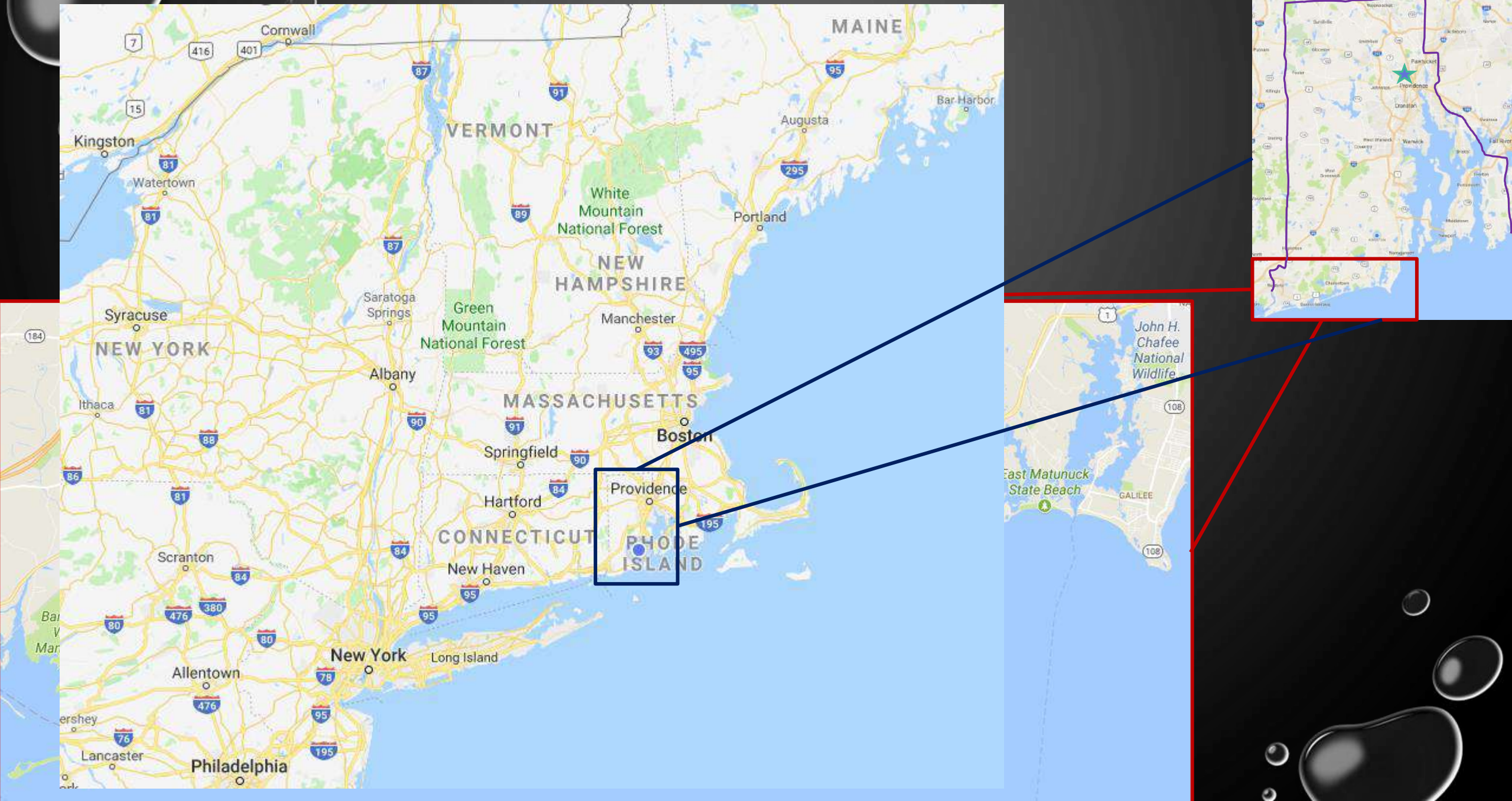
THE UNIVERSITY OF RHODE ISLAND
COLLEGE OF THE ENVIRONMENT AND LIFE SCIENCES

THE TIDE IS HIGH BUT I'M HOLDING ON

(HOW CLIMATE CHANGE IS AFFECTING ONSITE WASTEWATER TREATMENT SYSTEMS)

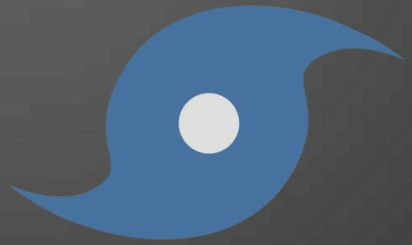
ALISSA COX, PHD & JOSE AMADOR, PHD

MARCH 31, 2021


Cornwall
MAINE
VERMONT
Kingston
Watertown
Bar Harbor
Augusta
Portland
White Mountain National Forest
NEW HAMPSHIRE
Saratoga Springs
Green Mountain National Forest
Manchester
Syracuse
NEW YORK
Albany
Ithaca
MASSACHUSETTS
Boston
Springfield
Providence
Hartford
CONNECTICUT
RHODE ISLAND
New Haven
Scranton
New York
Long Island
Allentown
Lancaster
Philadelphia
John H. Chafee National Wildlife
East Matunuck State Beach
GALILEE

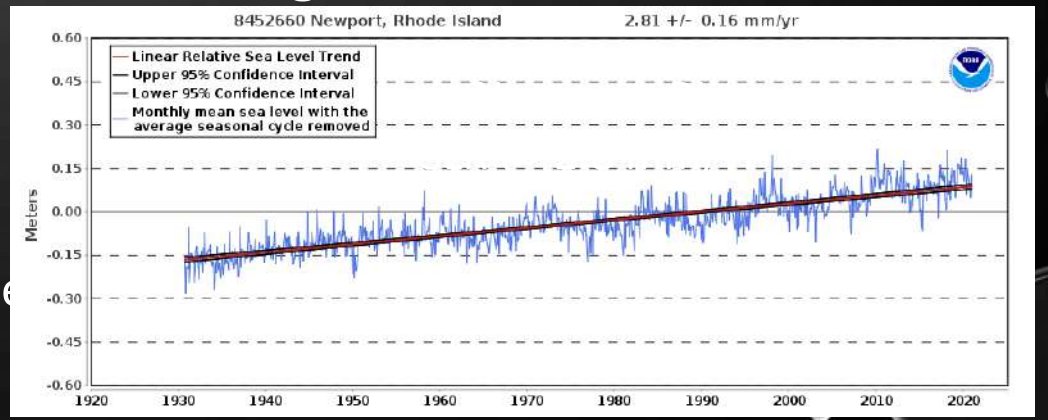
CLIMATE CHANGE'S EFFECTS ON SOUTHERN NEW ENGLAND COASTS

- Increased storm activity
  - More frequent
  - More intense
  - Trend expected to accelerate!
  - Result: Flooding & erosion



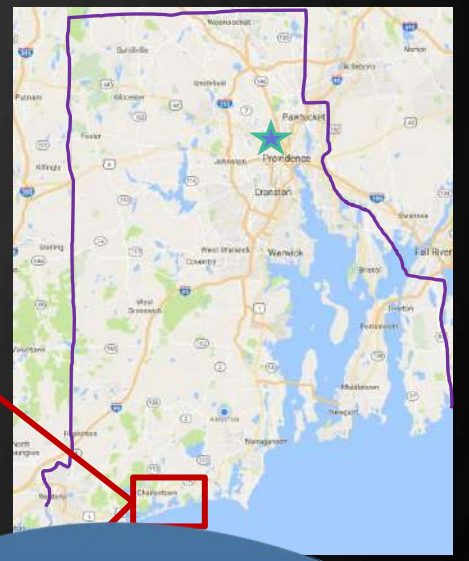
- Changes in precipitation patterns
  - Droughts & excess precipitation
  - Implications for groundwater tables

- Sea Level Rise
  - Makes everything worse!
  - More flooding
    - Surface flooding during storms & high tide e
    - Elevated groundwater tables



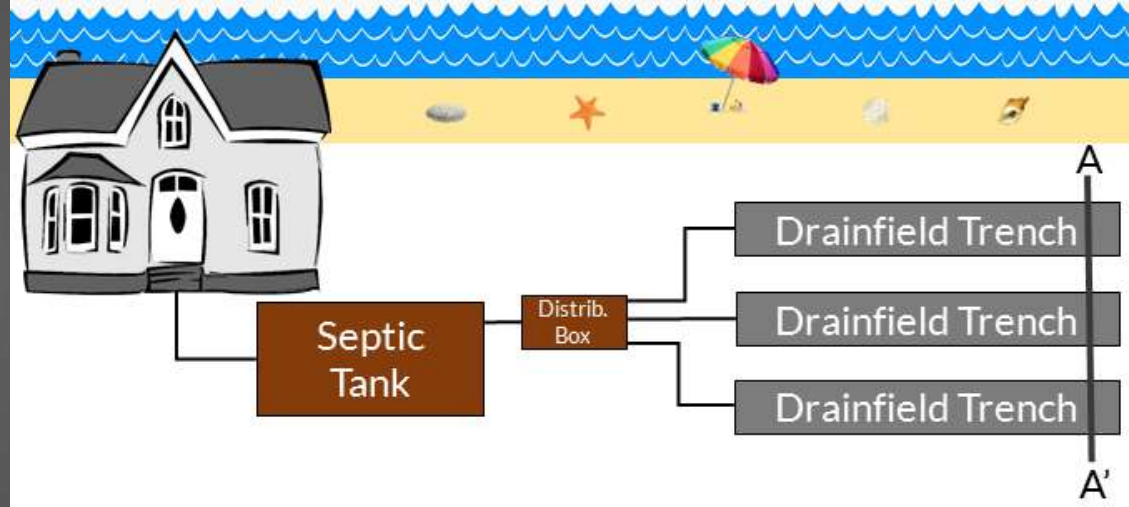
SEPTIC SYSTEMS EVERYWHERE!

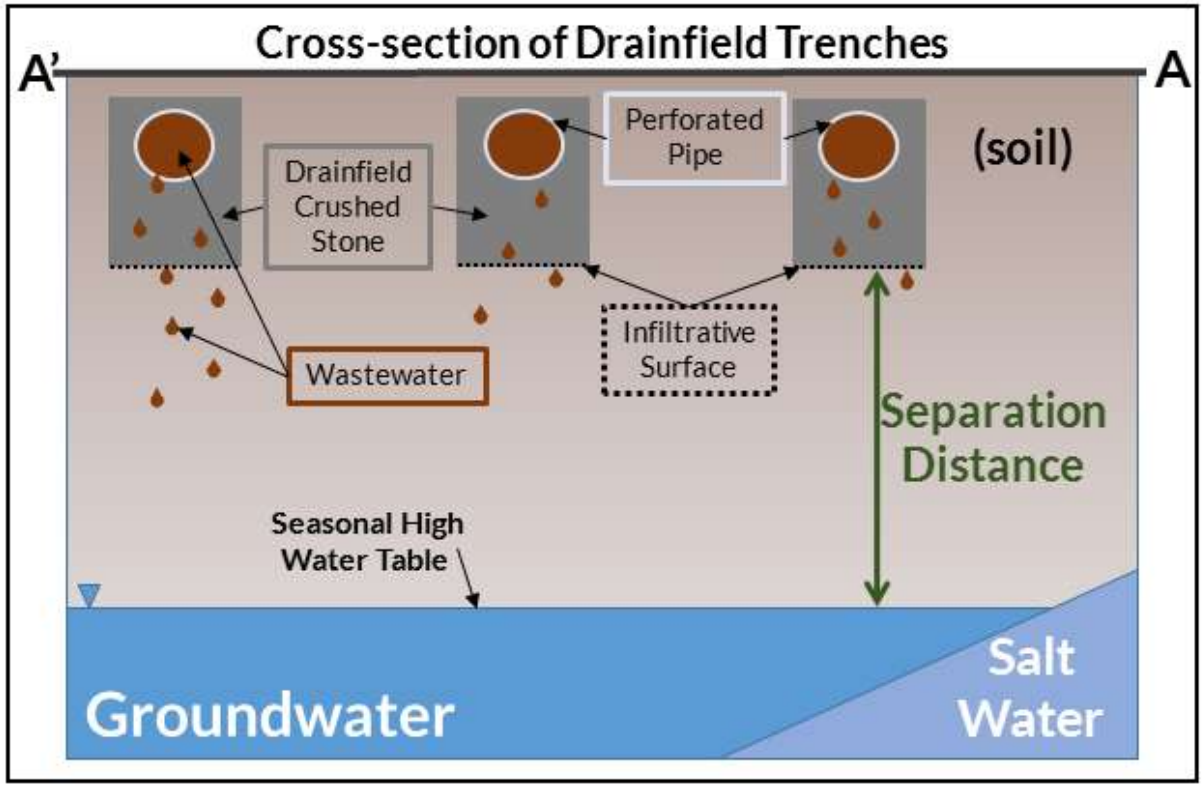
RI'S SOUTHERN COAST = DENSELY POPULATED & SERVED BY SEPTIC SYSTEMS

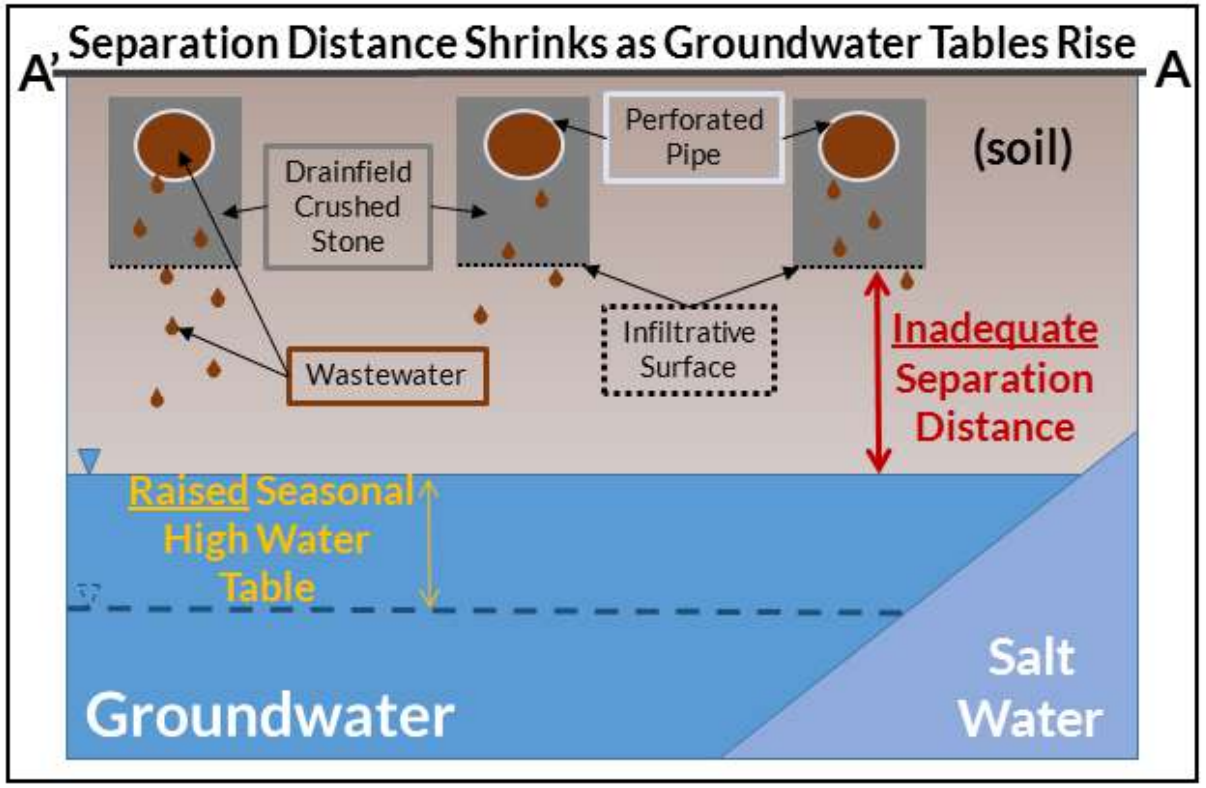



Coastal septic systems
Rising groundwater tables
Coastal storms

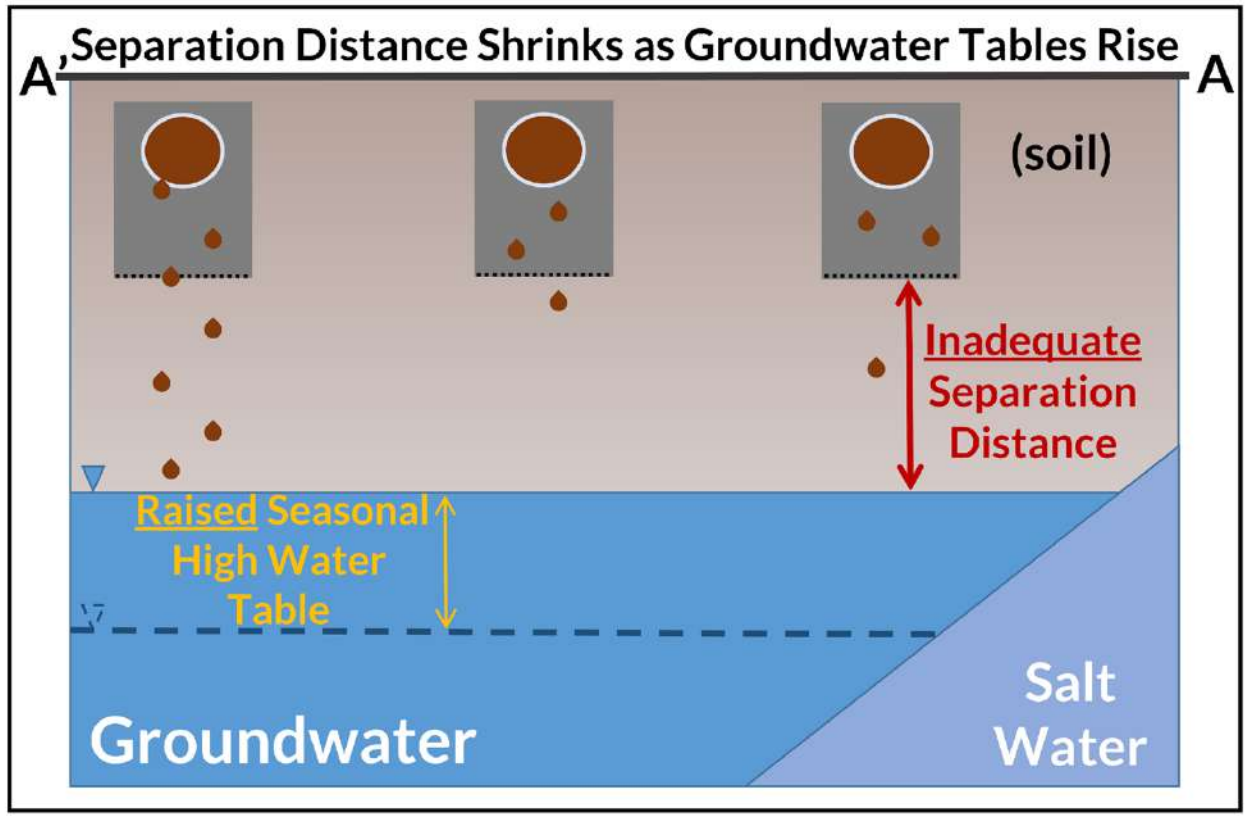
COASTAL SEPTIC SYSTEMS







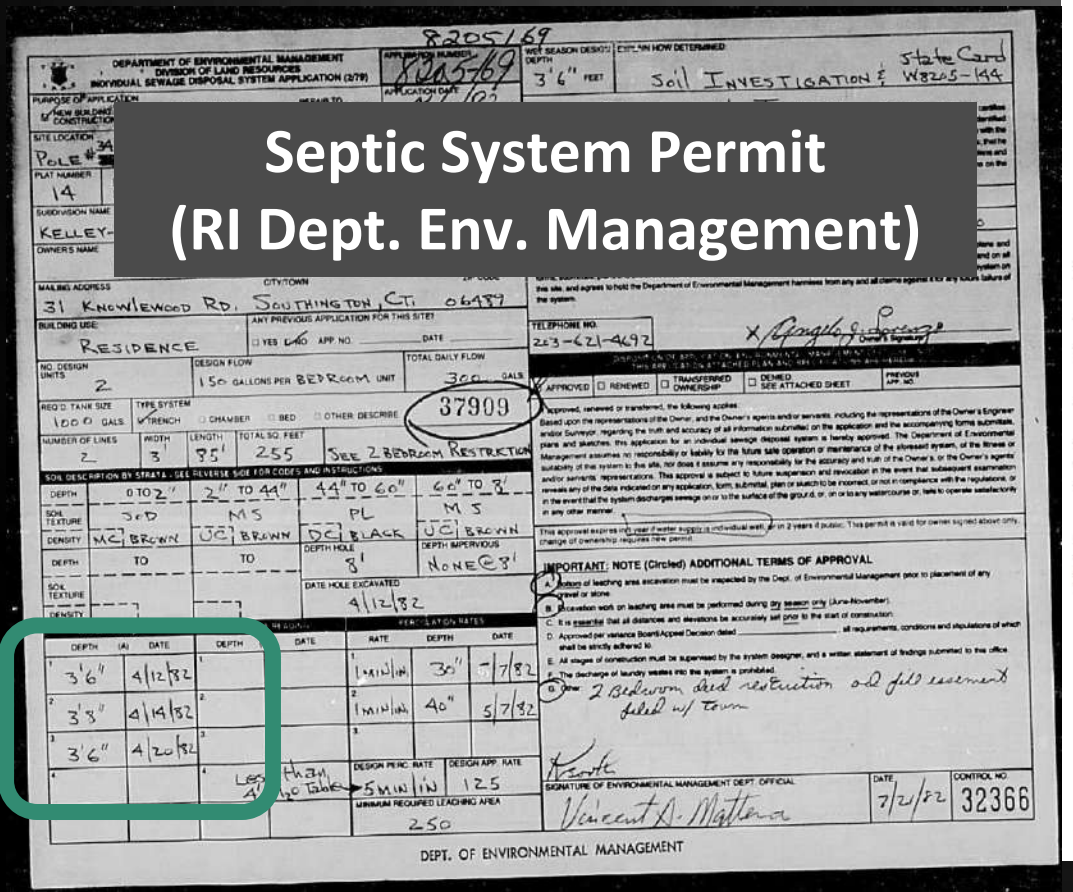
IS SEPARATION (DISTANCE) ANXIETY JUSTIFIED ALONG SOUTHERN RI COAST?

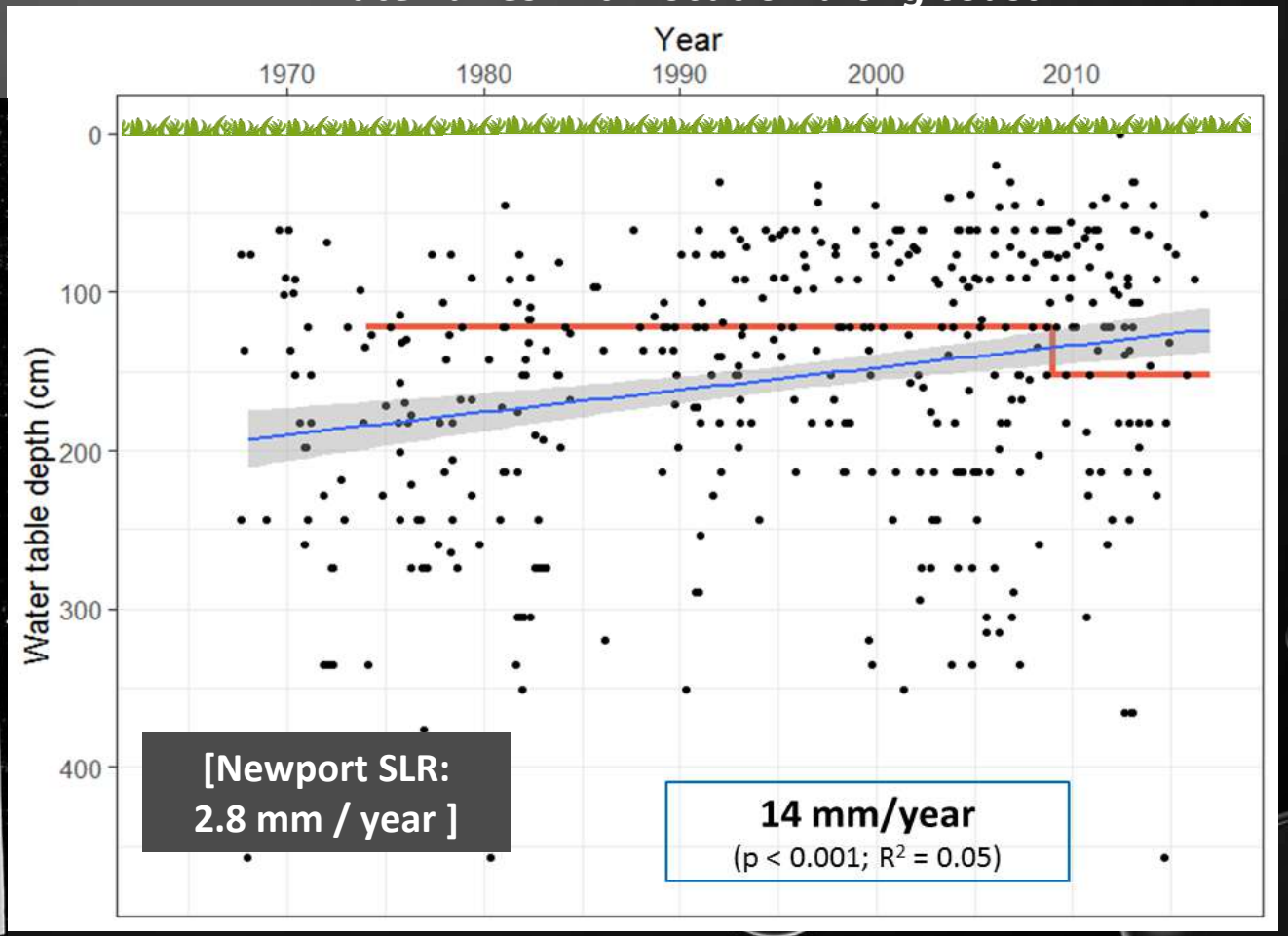


- APPROACH 1: LOOK AT HISTORIC DATA
- APPROACH 2: LOOK AT 10 EXISTING DRAINFIELDS IN THE FIELD

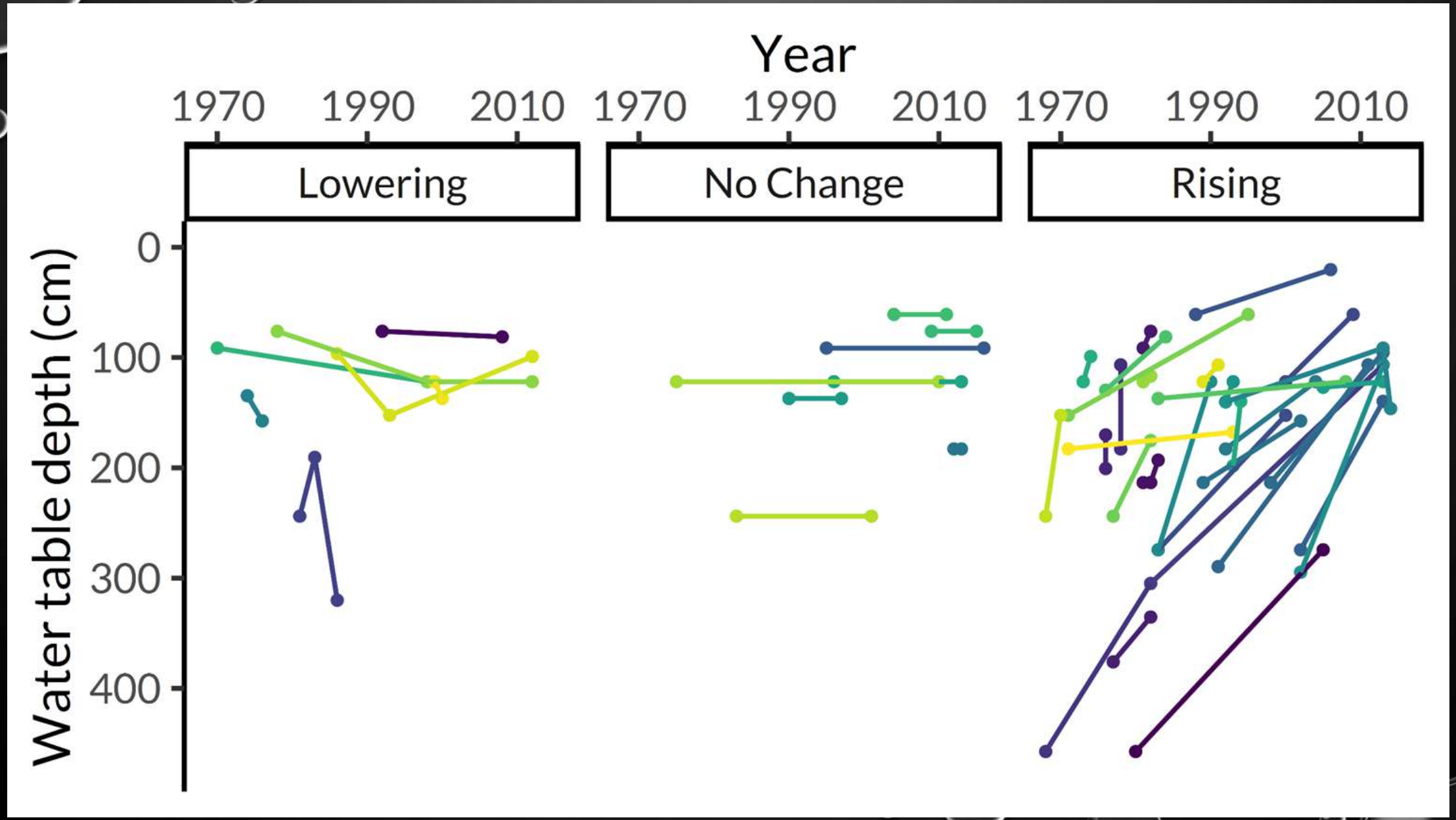
HISTORIC DATA: COASTAL GROUNDWATER TABLES IN SOUTHERN RI RISING

Rate varies with location along coast



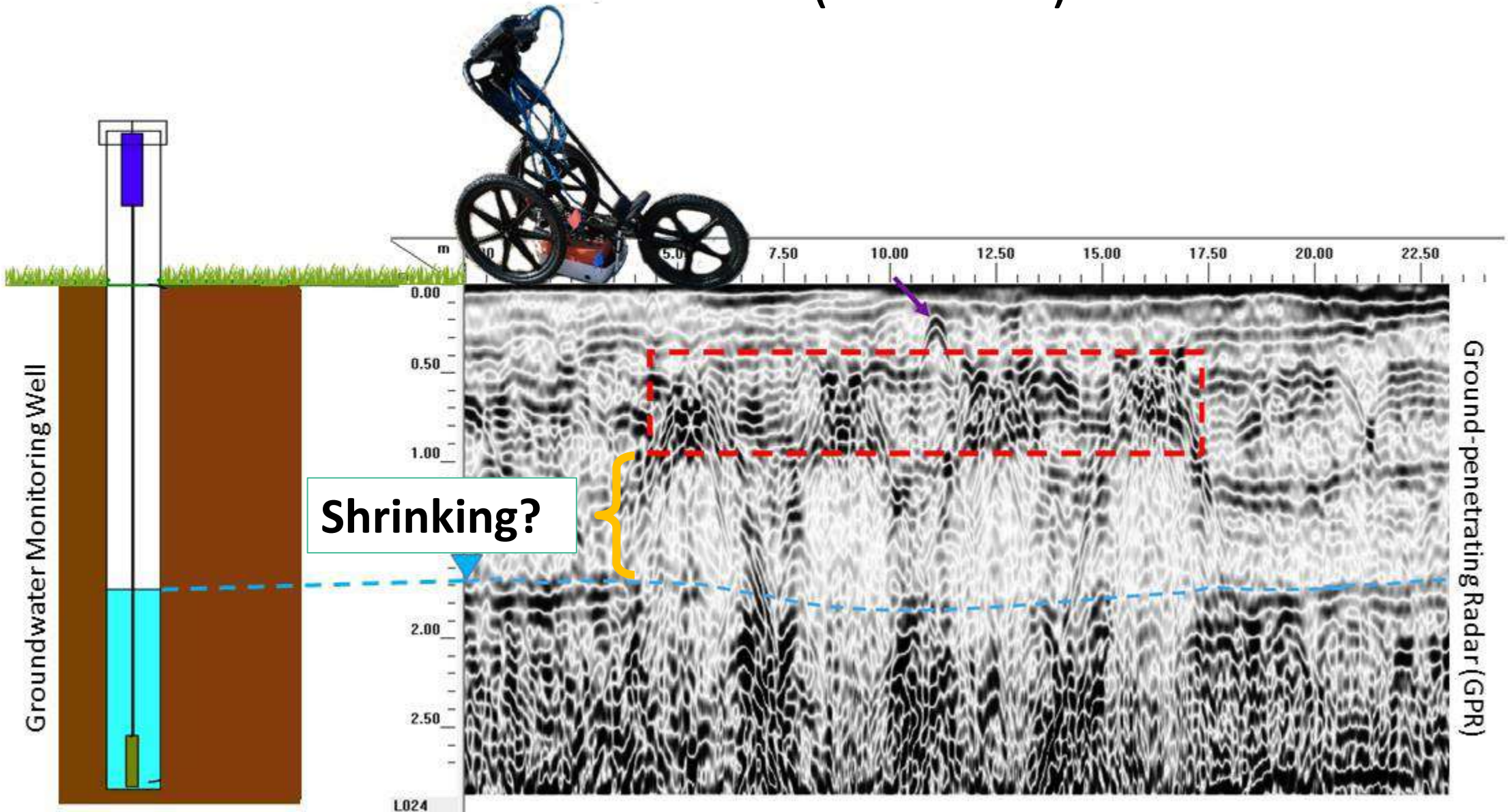


Cox et al. (2019)

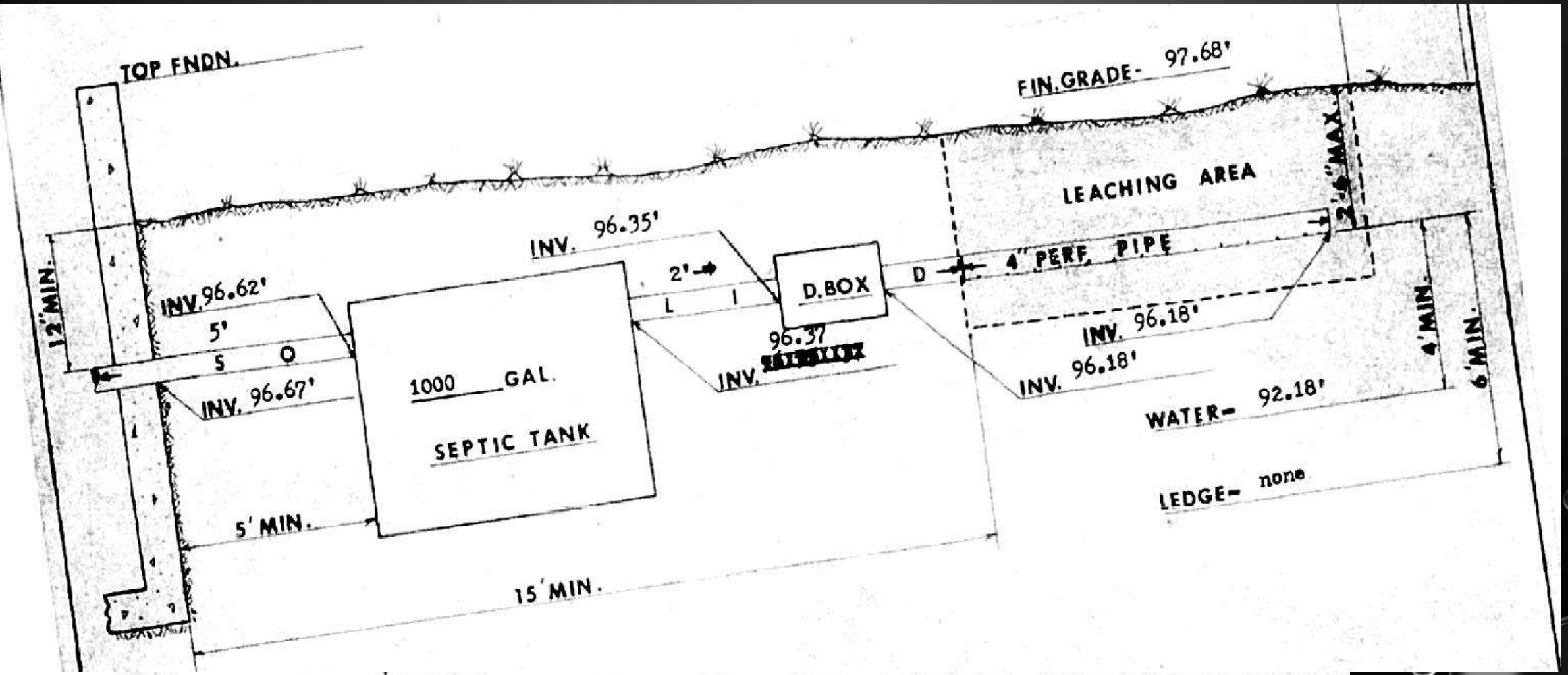


Cox et al. (2019)

INVESTIGATING GROUNDWATER TABLES AND SEPTIC SYSTEMS IN THE FIELD (10 SITES)

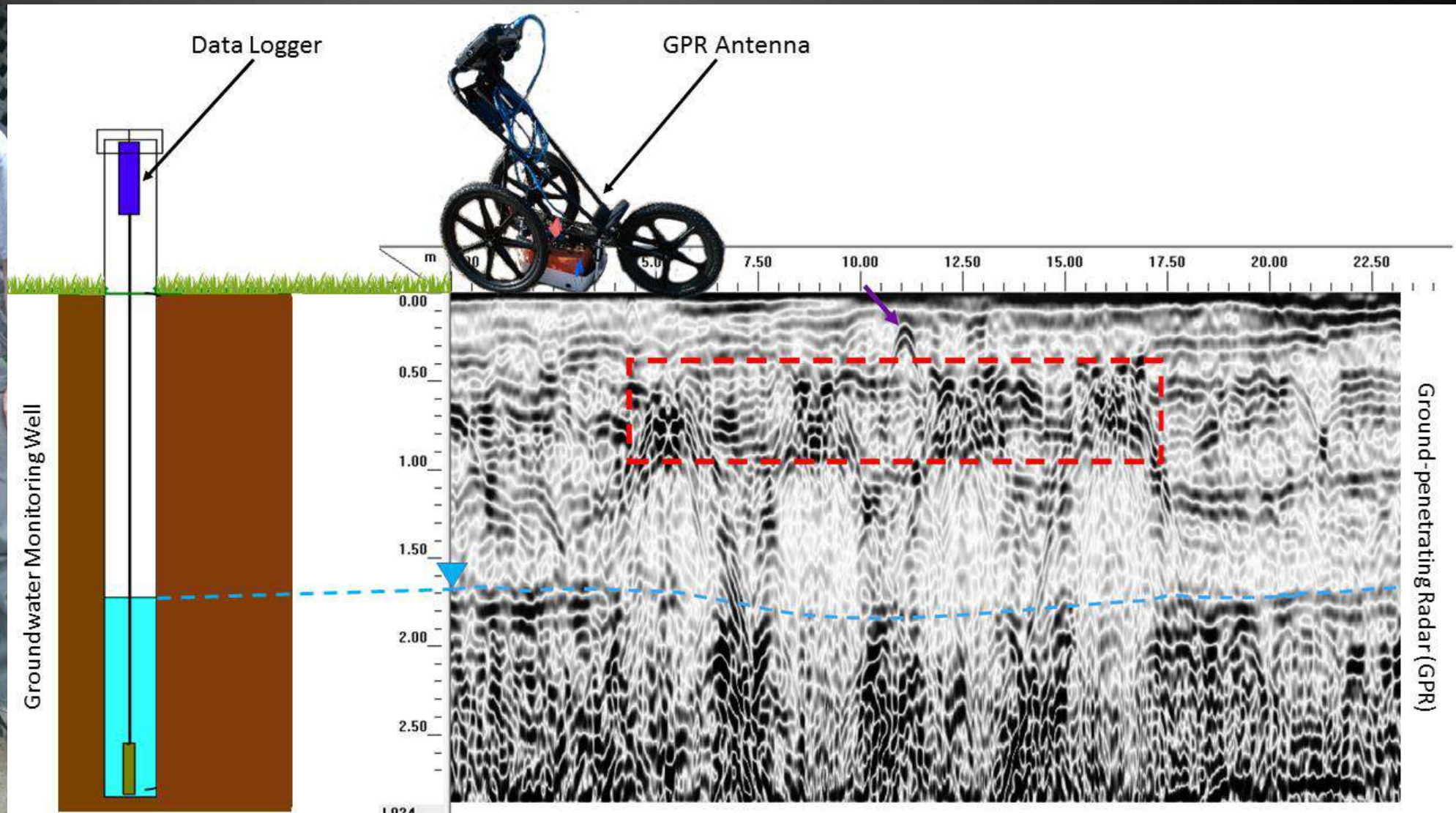


ASSESSING SEPARATION DISTANCE

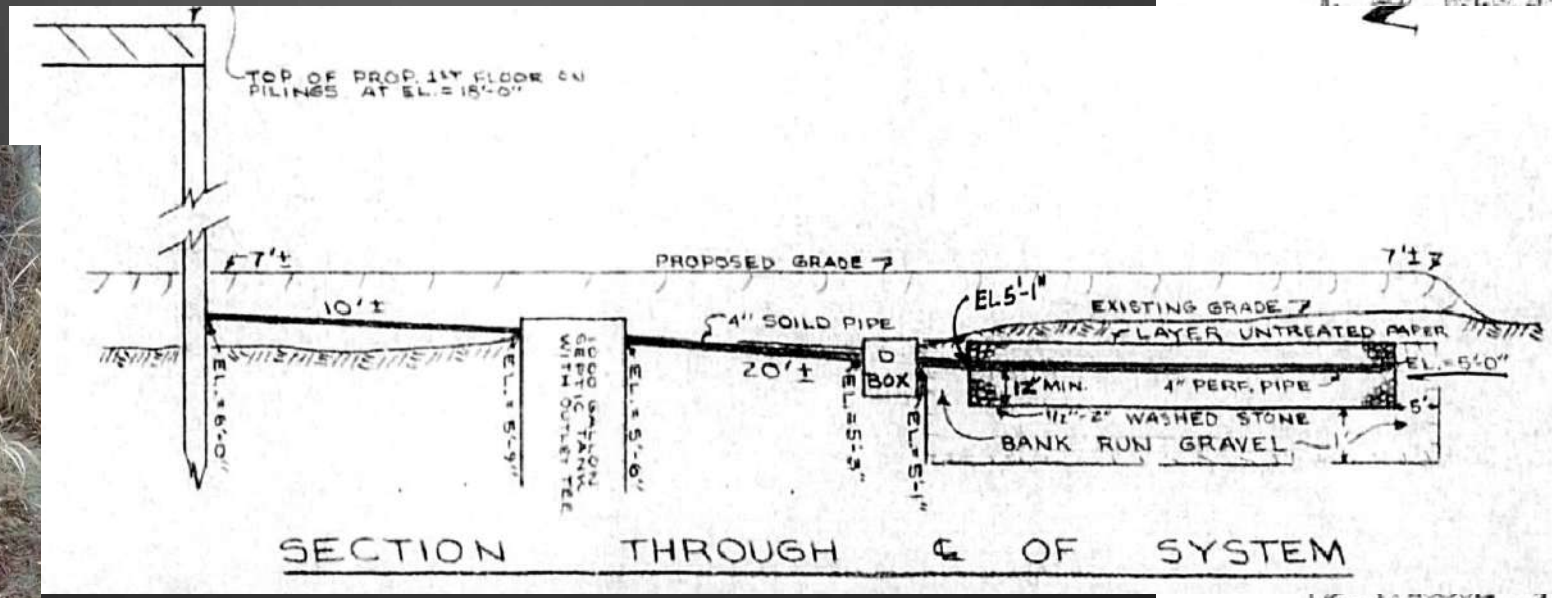


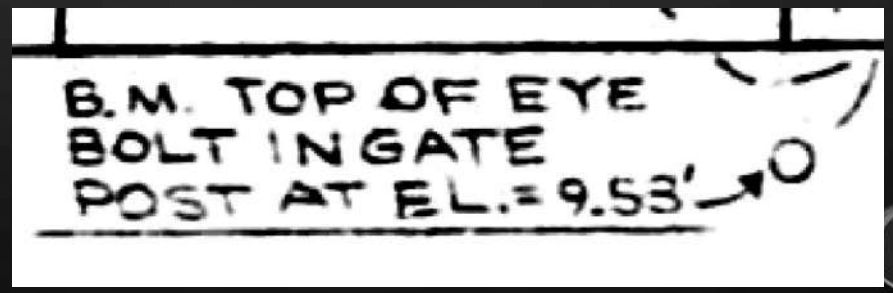
GROUND-PENETRATING RADAR (GPR)

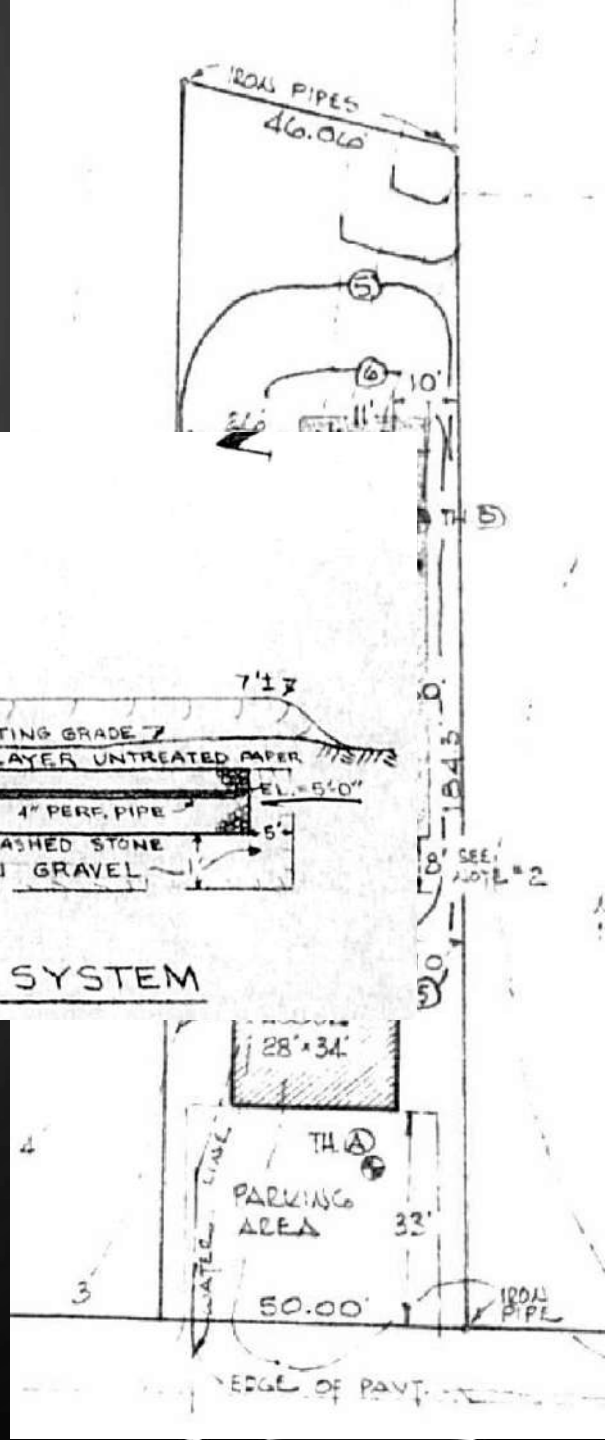
MONITORING WELLS

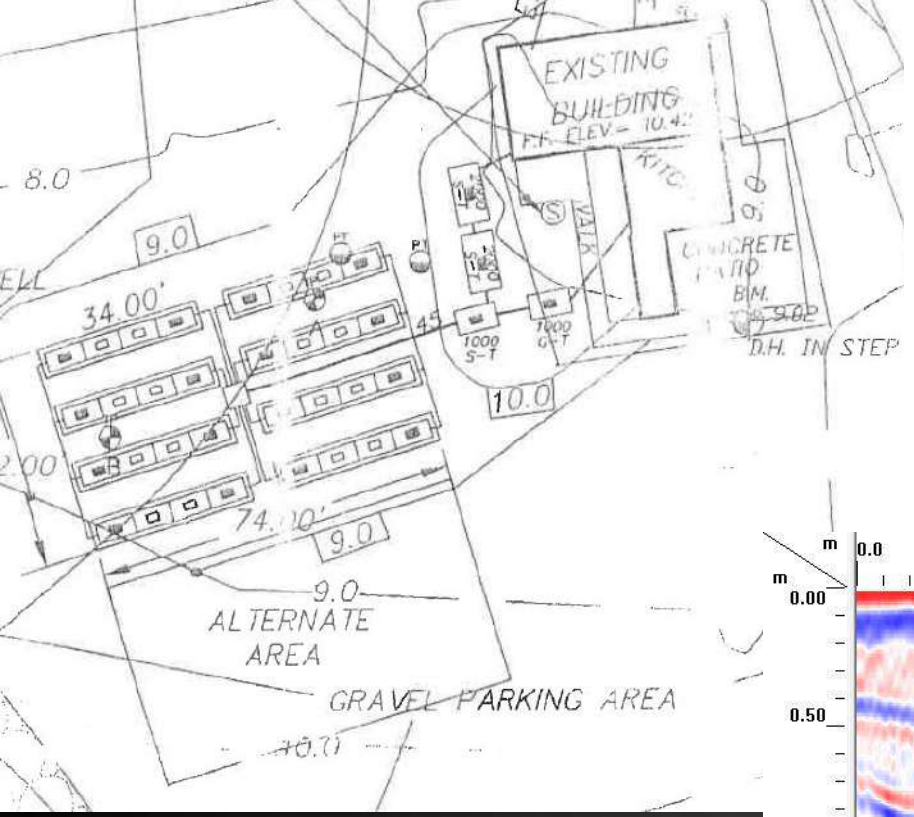


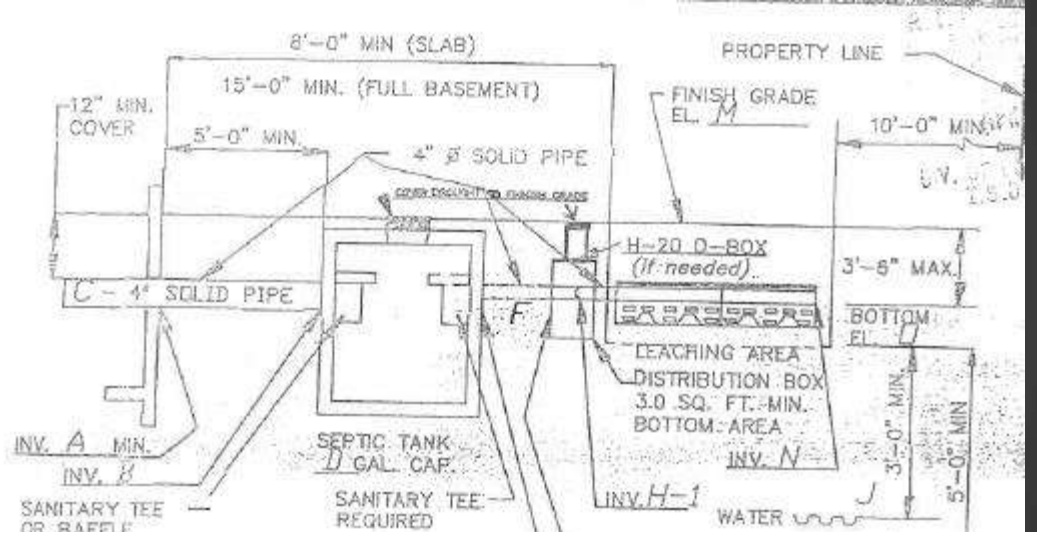
BENCHMARKS AND ELEVATIONS

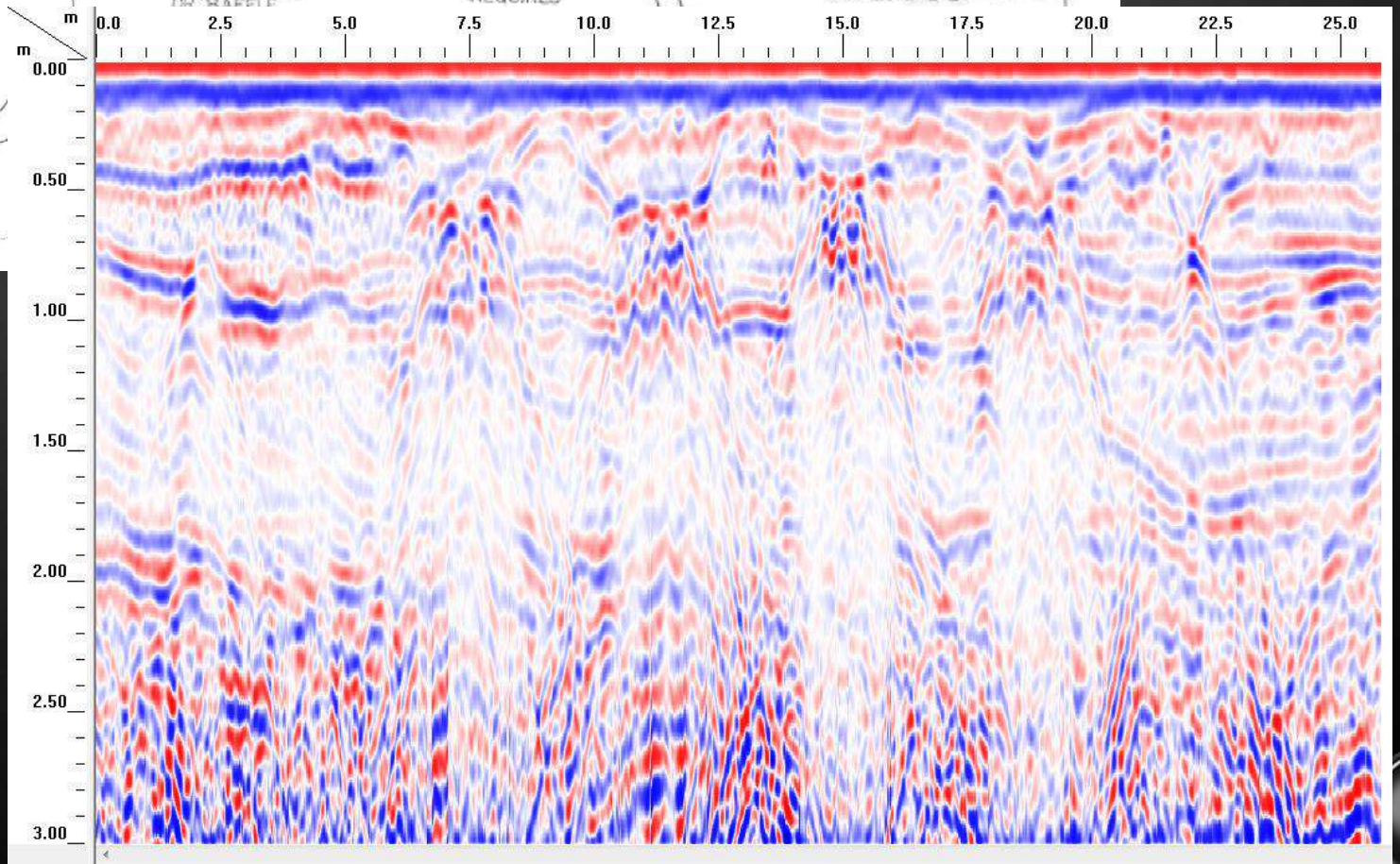




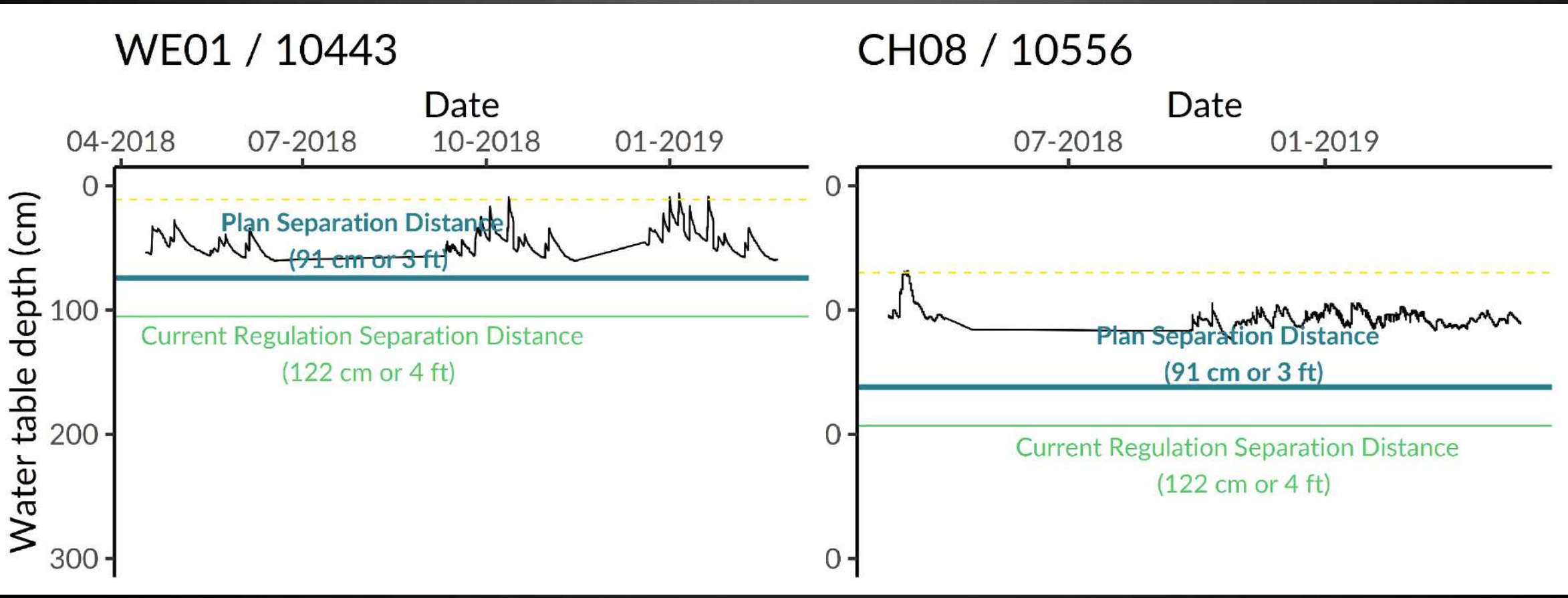



EXISTING
BUILDING
F.F. ELEV.= 10.4'
KITC
CONCRETE
PATIO
B.M.
S.O.P.
D.H. IN STEP
34.00'
74.10'
9.0
10.0
9.0
9.0
ALTERNATE
AREA
GRAVEL PARKING AREA


8'-0" MIN (SLAB)
15'-0" MIN. (FULL BASEMENT)
12" MIN.
COVER
5'-0" MIN.
4" Ø SOLID PIPE
PROPERTY LINE
FINISH GRADE
EL. M
10'-0" MIN.
H-20 D-BOX
(If needed)
3'-6" MAX.
C - 4" SOLID PIPE
F
BOTTOM
EL. D
LEACHING AREA
DISTRIBUTION BOX
3.0 SQ. FT. MIN.
BOTTOM AREA
INV. N
INV. A MIN.
INV. B
SEPTIC TANK
D GAL. CAP.
SANITARY TEE
REQUIRED
INV. H-1
SANITARY TEE
WATER
J
3'-0" MIN.
5'-0" MIN

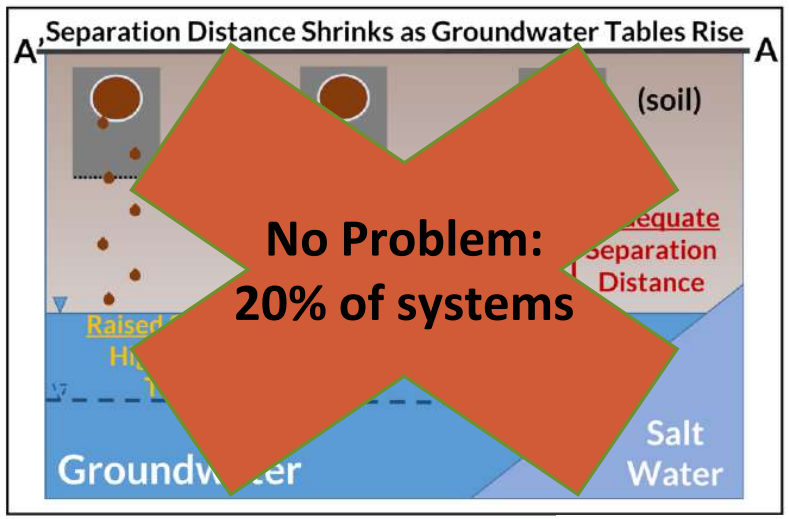

m
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0
m
0.00
0.50
1.00
1.50
2.00
2.50
3.00

WATER TABLE DATA

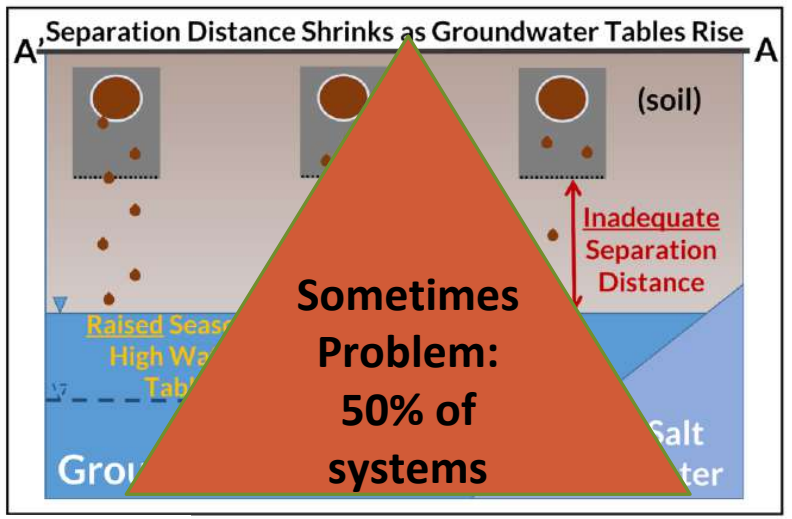


Cox et al. (2020A)

FIELD INVESTIGATIONS: IMPAIRED SEPARATION DISTANCE A COMMON PROBLEM

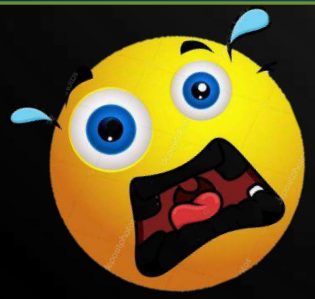


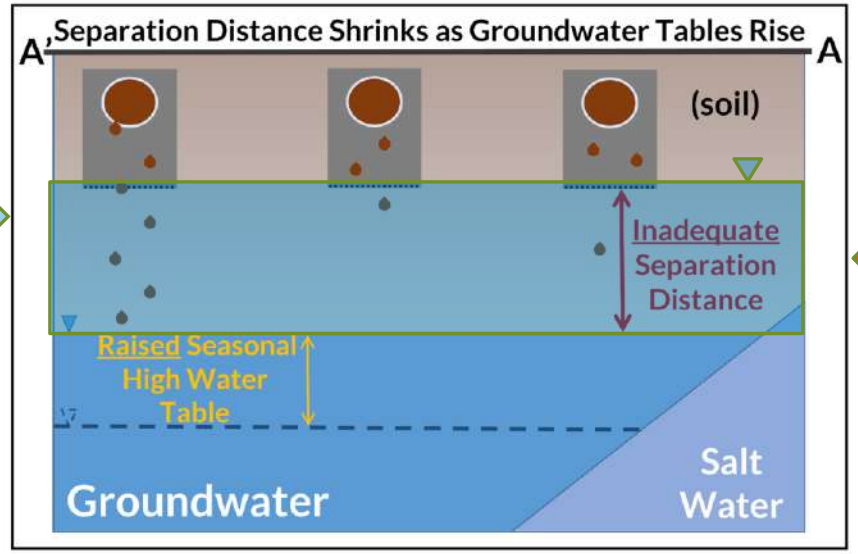
No Problem: 20% of systems



Sometimes Problem: 50% of systems

Water @ infiltrative surface 2% days

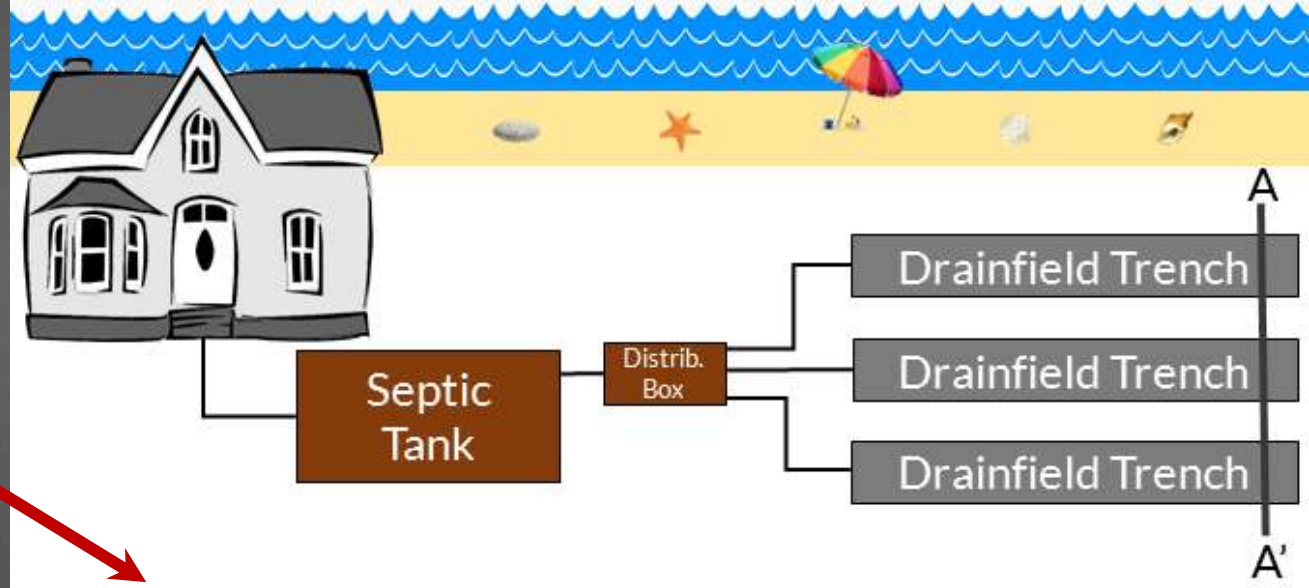


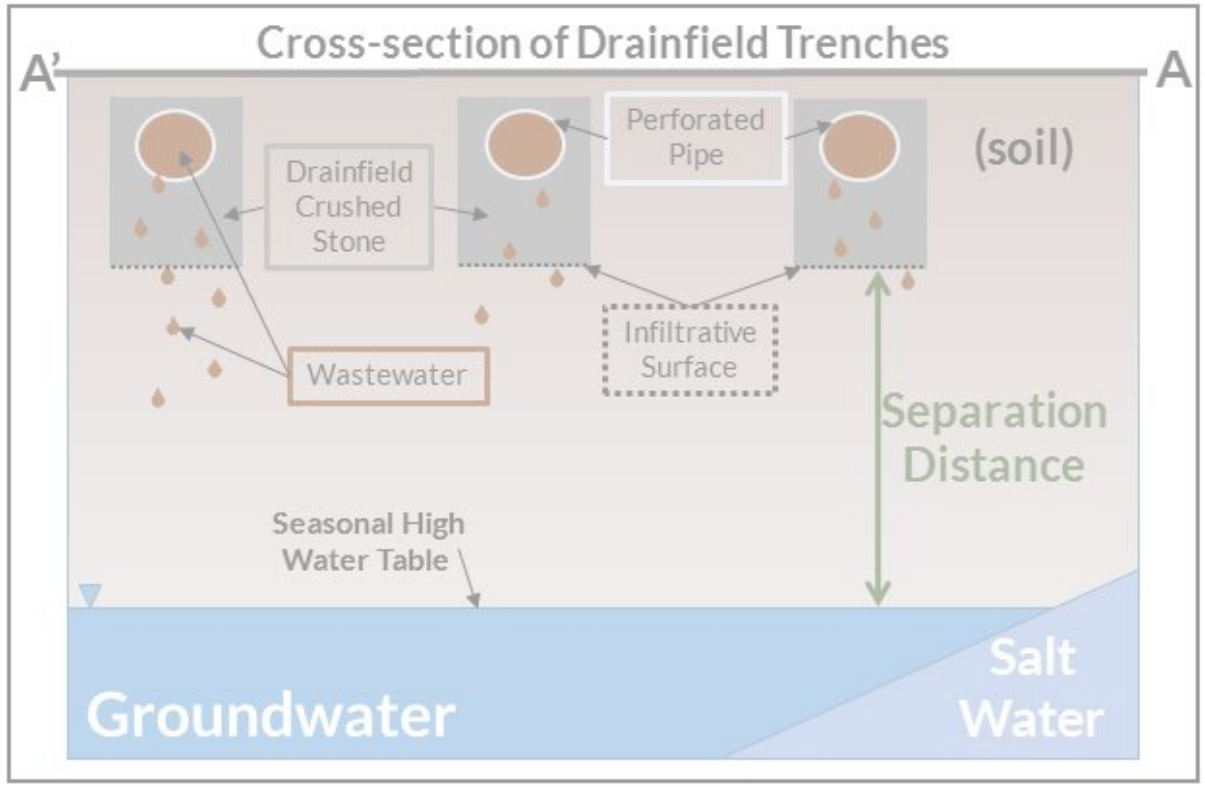


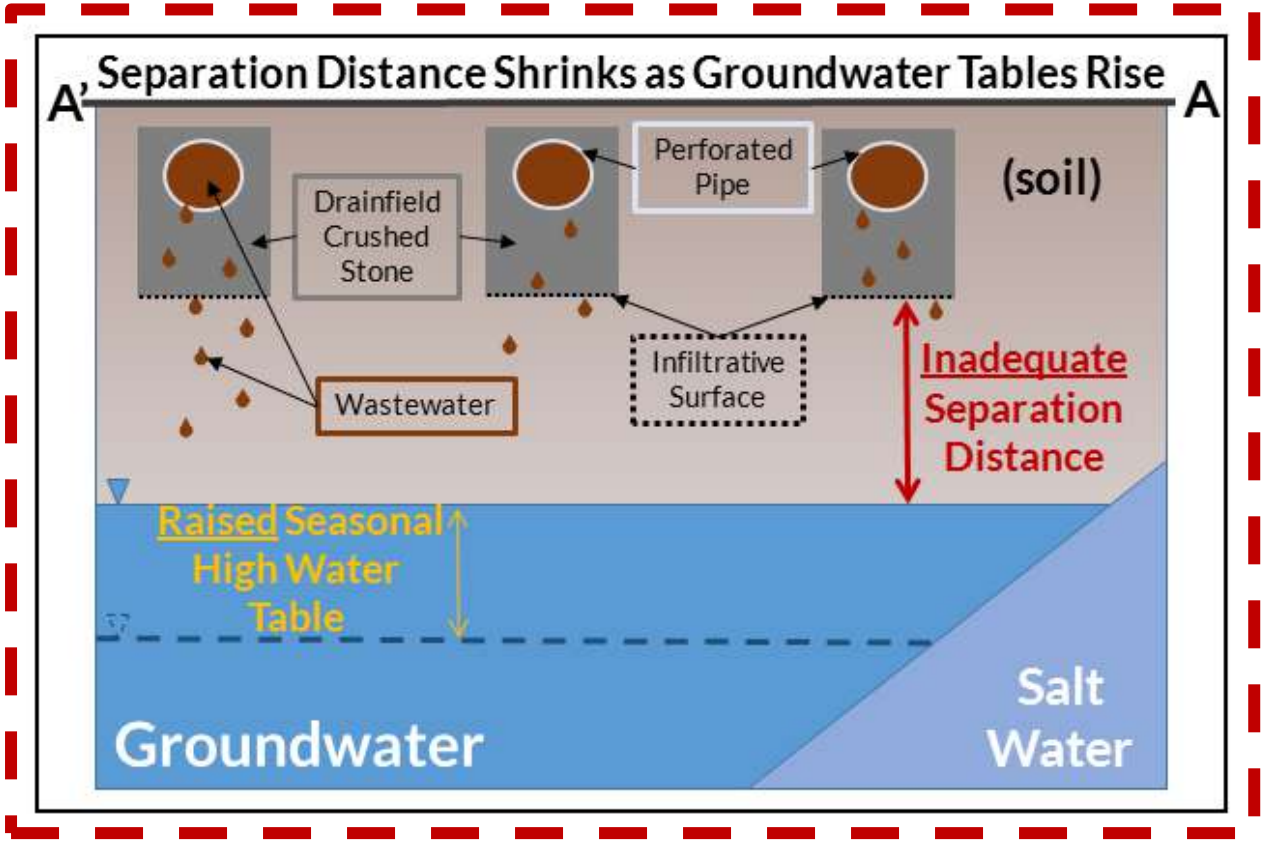
ALWAYS Problem: 30% of systems

Cox et al. (2020A)

IMPAIRED SEPARATION DISTANCE = CURRENT & FUTURE PROBLEM FOR SEPTIC SYSTEMS ALONG COAST!





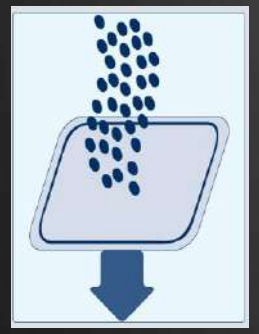


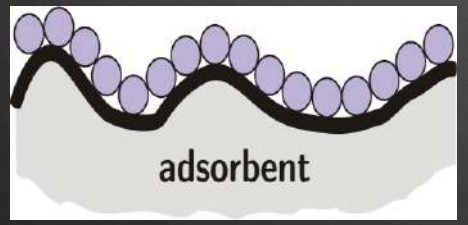
IMPAIRED SEPARATION DISTANCE … SO WHAT?!

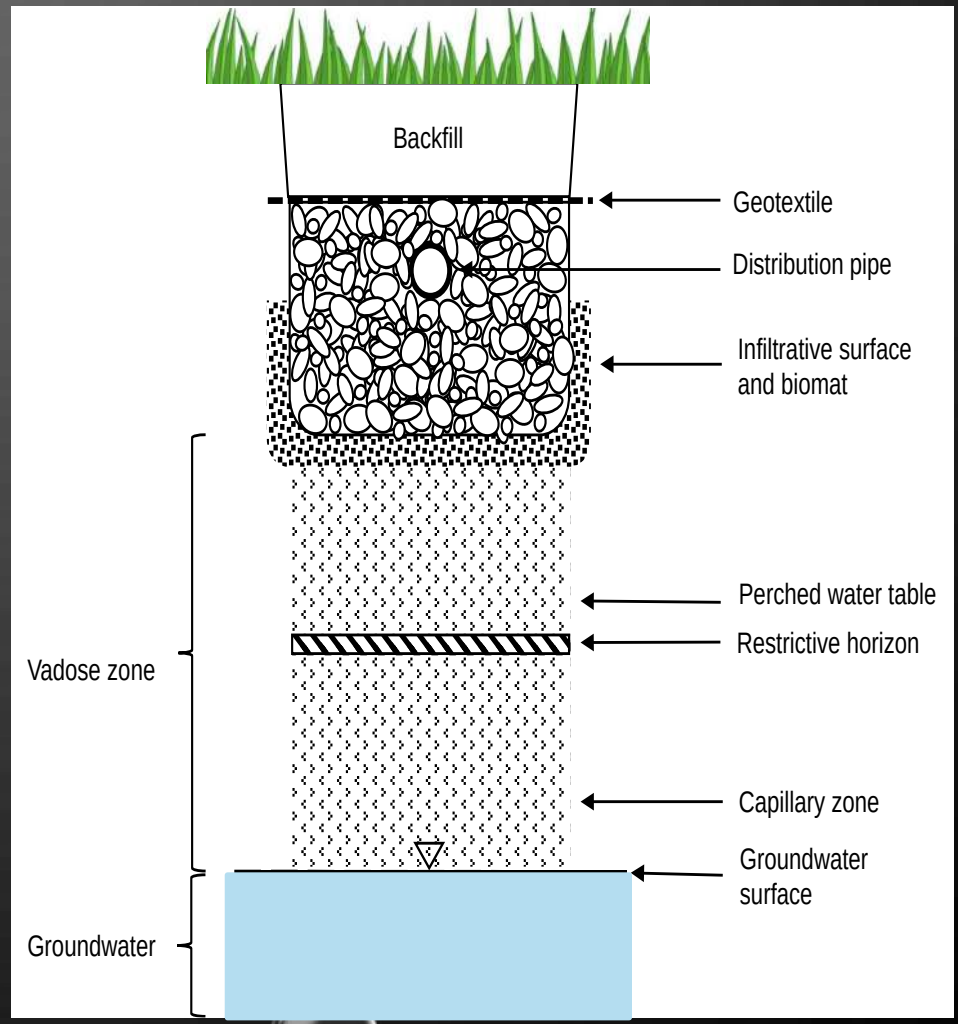
REMINDER:
WHAT DO WE WANT FROM OUR STA?

- Keep wastewater away from people
- Groundwater recharge/stream flow
- Remove
  - Suspended solids
  - BOD, N, P
  - Emerging pollutants
  - Pathogens

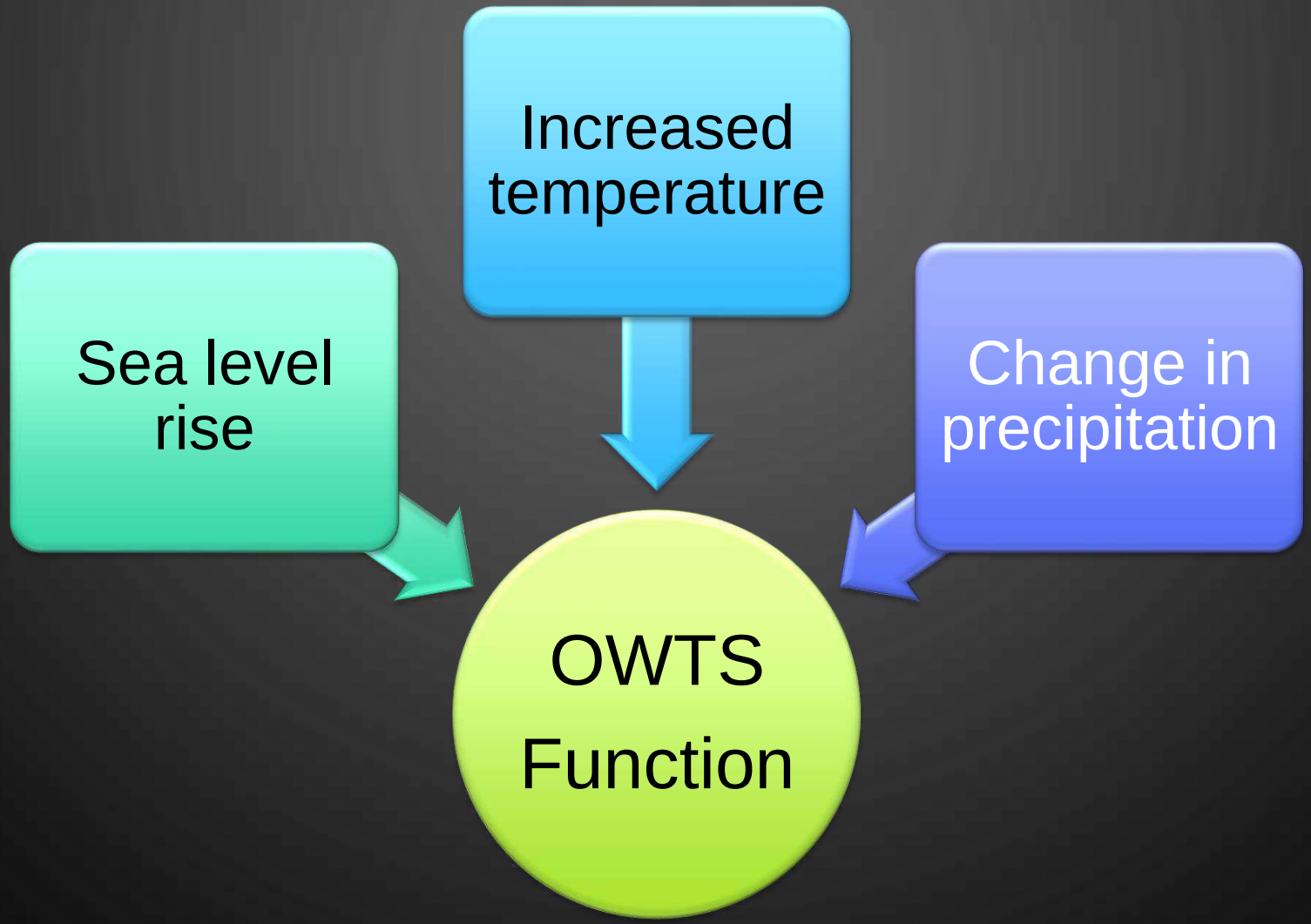
HOW DOES THE STA DO ITS THING?








°F
120
100
80
60
40
20
0
20
40
°C
50
40
30
20
10
0
10
20
30


Increased temperature
Sea level rise
Change in precipitation
OWTS Function

WHAT'S AFFECTED BY WATER AND HEAT?

WATER

- FILTRATION
- OXYGEN DIFFUSION
- MICROBIAL ACTIVITY
- PATHOGEN SURVIVAL
- REDOX POTENTIAL
- …

HEAT

- MICROBIAL ACTIVITY
- PATHOGEN SURVIVAL
- OXYGEN SOLUBILITY
- SPEED OF CHEMICAL REACTIONS
- …

Δ IN SOIL MOISTURE = Δ MICROBIAL ACTIVITY

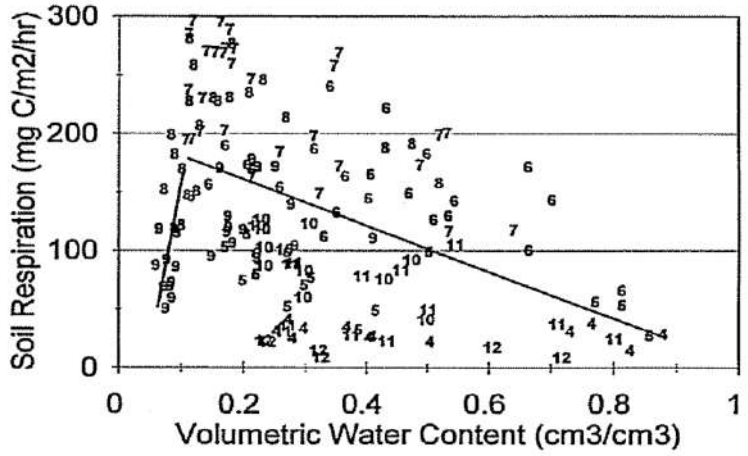


Fig. 7 Correlations of volumetric water content and soil respiration. The plotting symbol represents the month of the year that the measurements were made. Each datum is a mean of 3 or 4 TDR water content measurements and 6 flux measurements for a study area on a given date. The August (8) and September (9) data where water content was < 0.12 cm^3 cm^{-3} were fitted to the linear regression: flux $\alpha = -128 + (2852 \times$ water content$)$; $R^2 = 0.48$, which is significant at $\alpha = 0.05$ (d.f. $= 21$). The data from the rest of the year where water content was > 0.12 cm^3 cm^{-3} were fitted to the linear regression: flux $= 201 - (198 \times$ water content$)$; $R^2 = 0.22$, which is significant at $\alpha = 0.01$ (d.f. $= 131$).

Davidson et al. (1998)

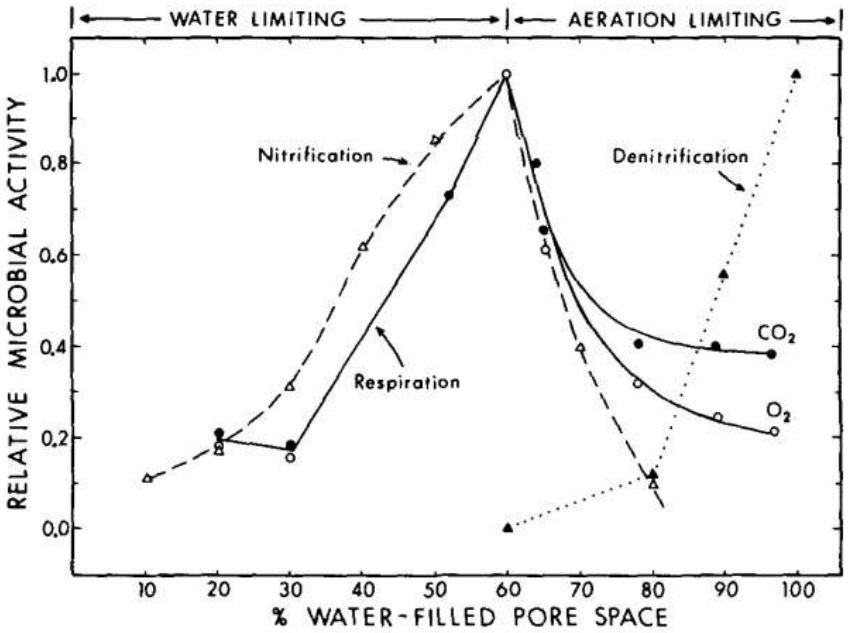
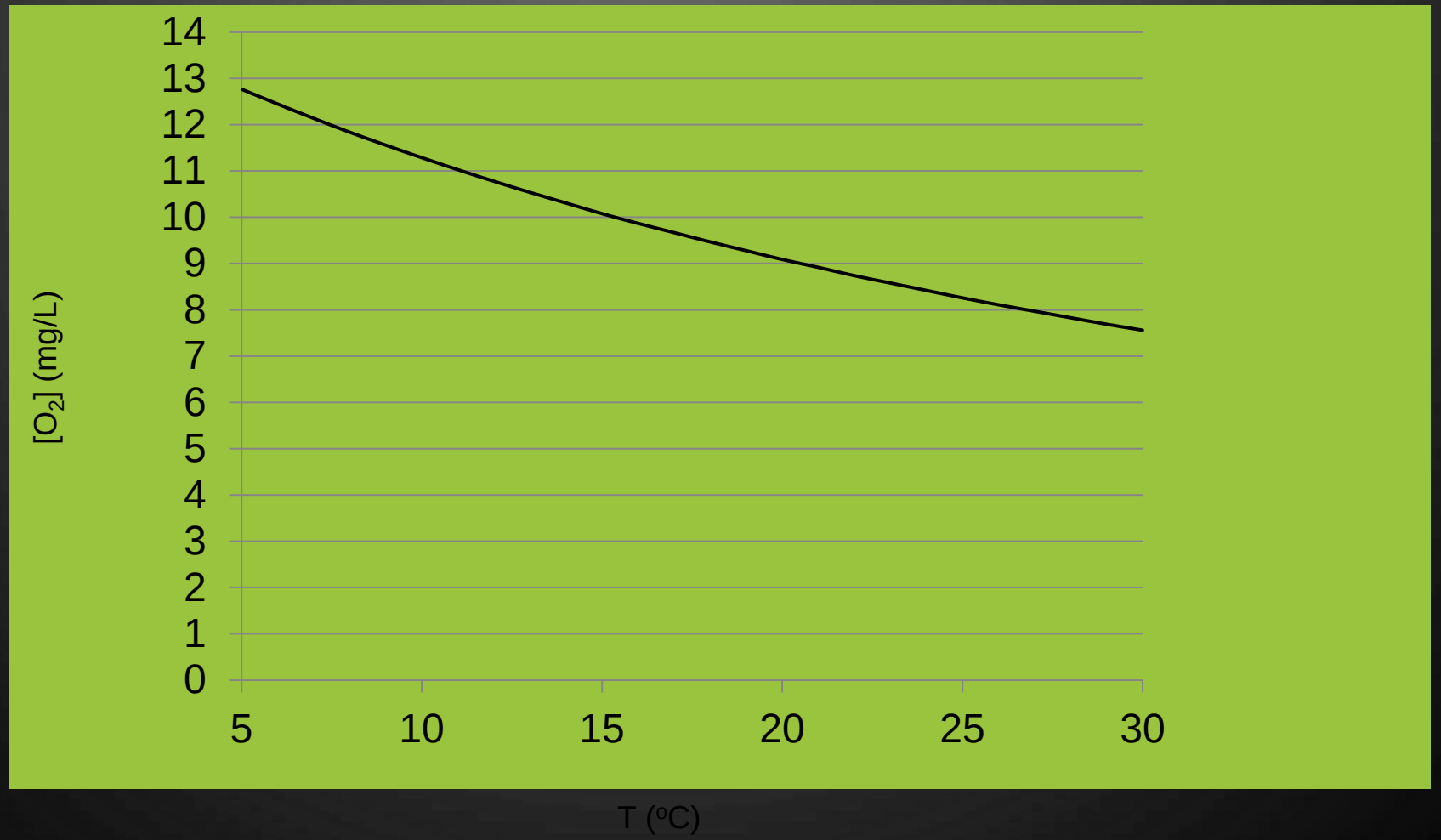
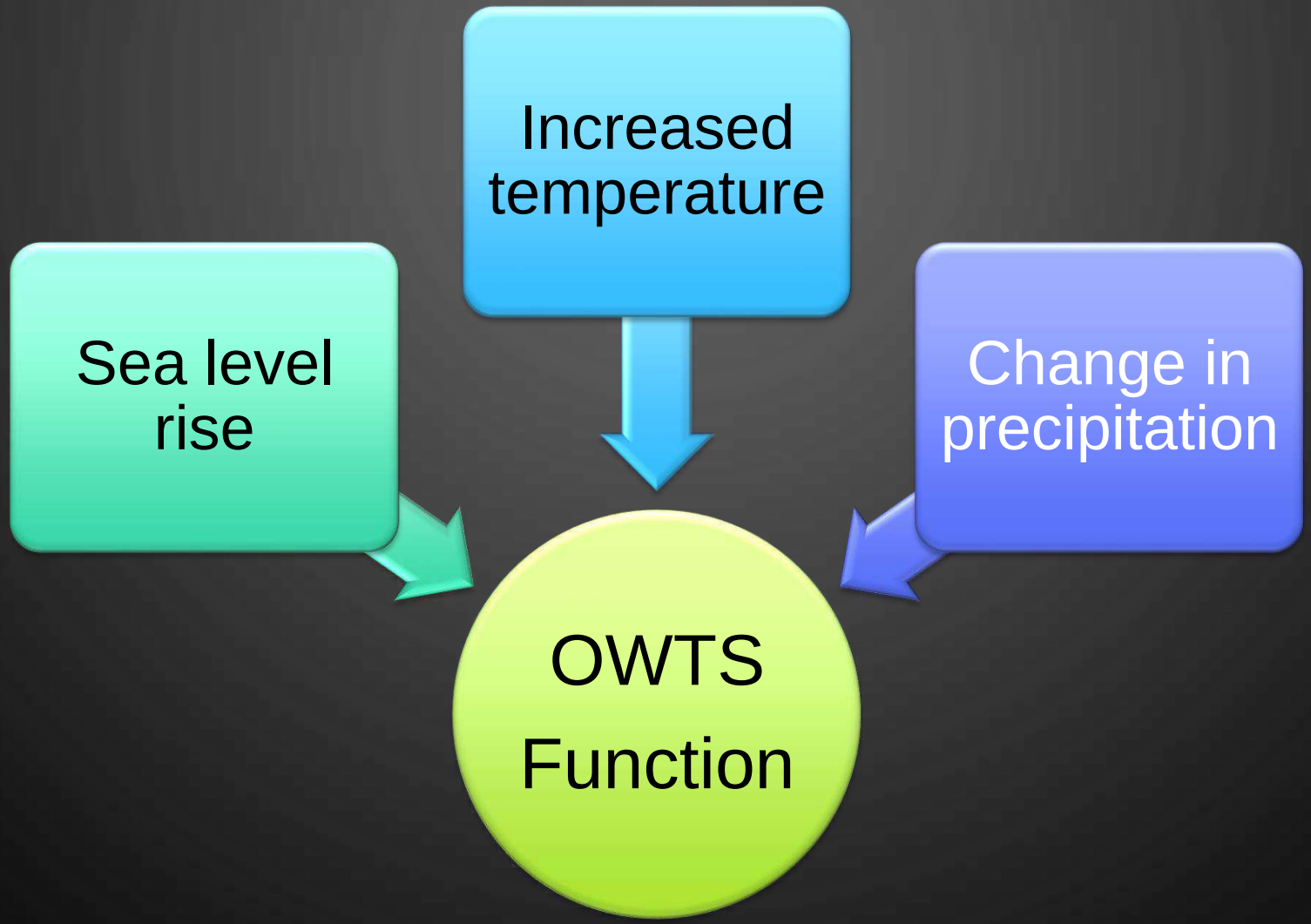


Fig. 1—The relationship between water-filled pore space and relative amount of microbial nitrification (after Greaves and Carter, 1920), denitrification (after Nommik, 1956), and respiration [O_2 uptake (○-○) and CO_2 production (●-●) as determined in this study]. Data for nitrification originally expressed as percentage water-holding capacity.

Linn and Doran (1984)

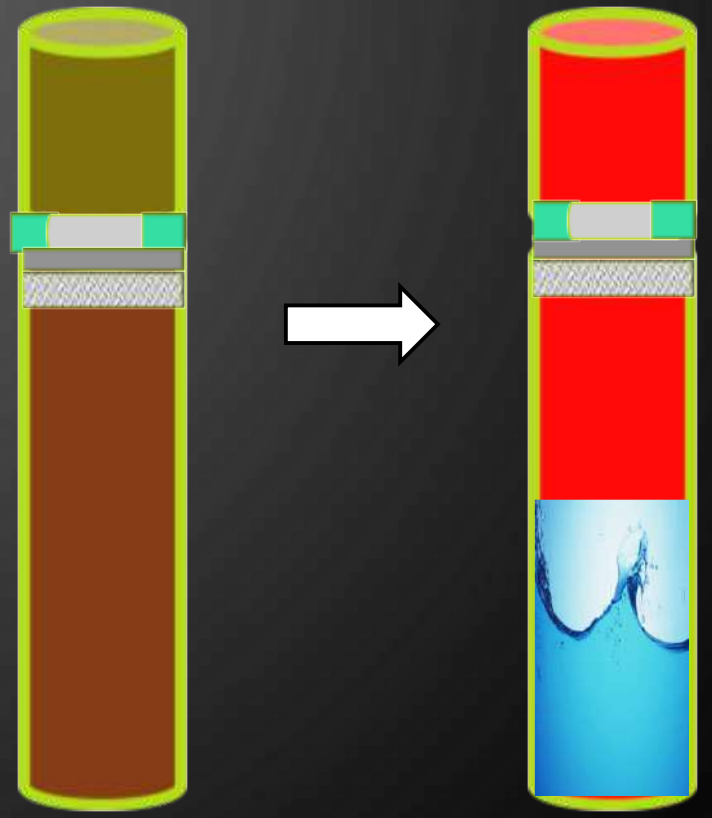
↑TEMPERATURE = LESS DISSOLVED O_2



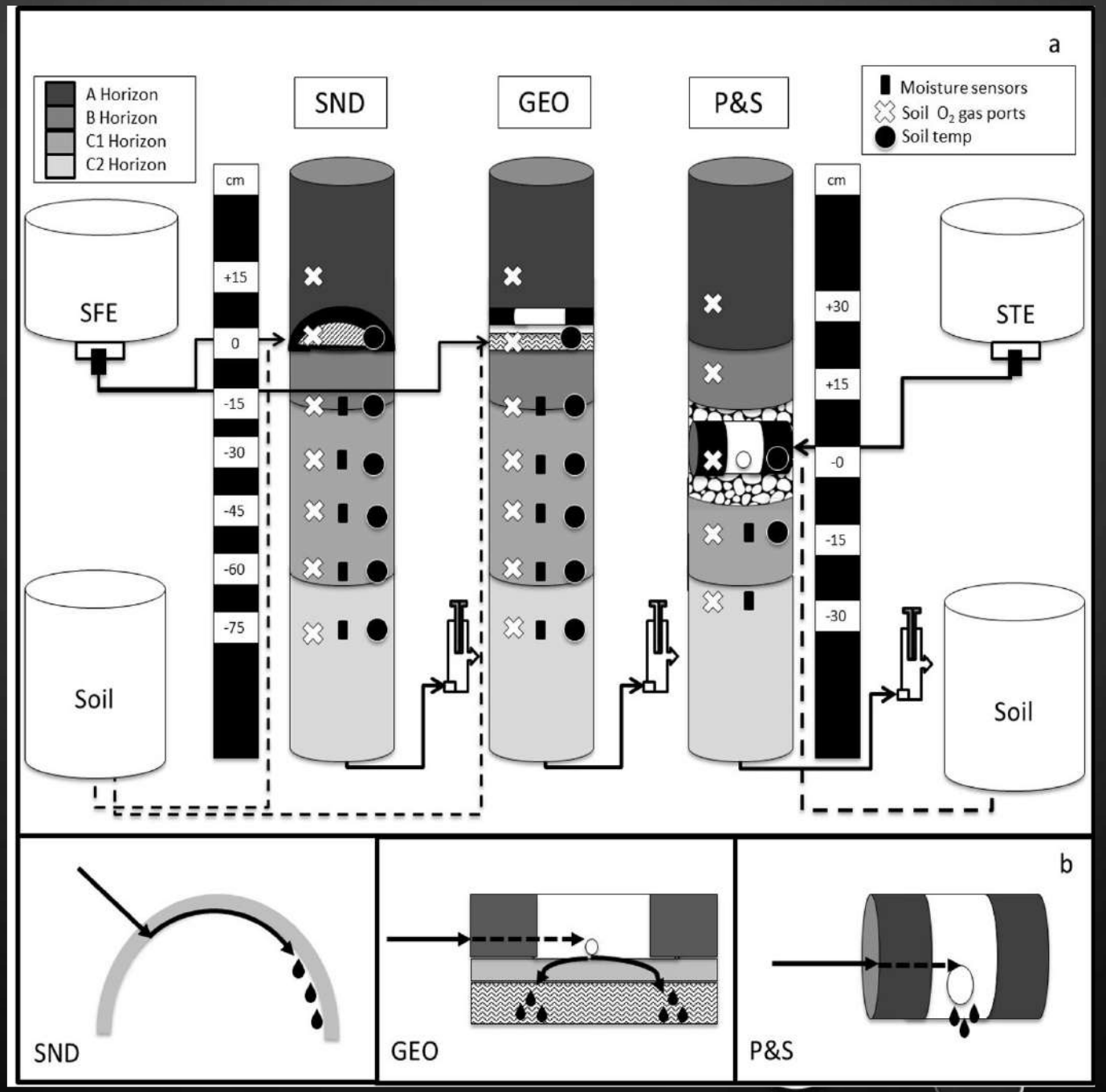

Increased temperature
Sea level rise
Change in precipitation
OWTS Function

HOW WILL CLIMATE CHANGE AFFECT STAs?

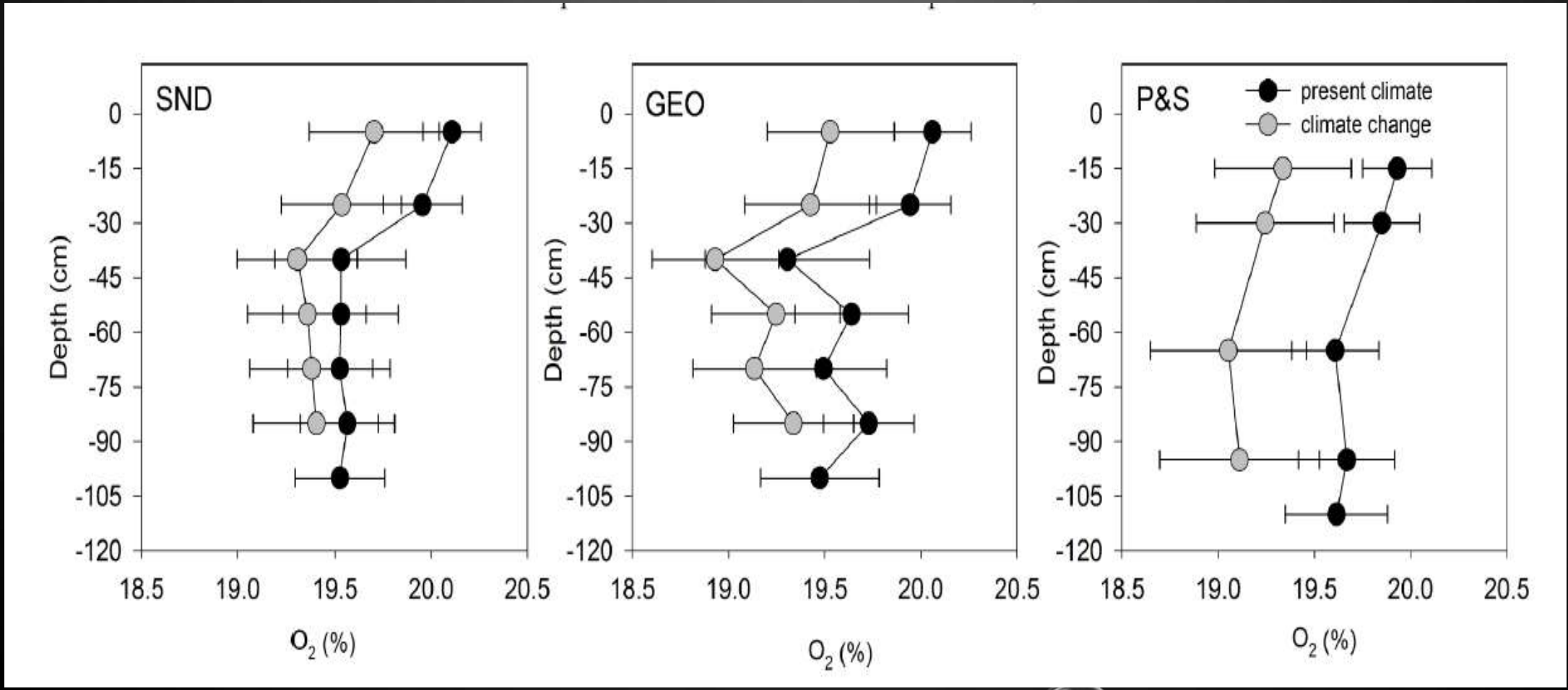
- Intact Soil Core Mesocosms
- Three Drainfield Types:
  - Pipe & stone – P&S
  - Shallow narrow – SND
  - Shallow narrow – GeoMat
- Climate Conditions:
  - Present climate: 70°F
  - Climate change: 77°F; Water table up 1 ft



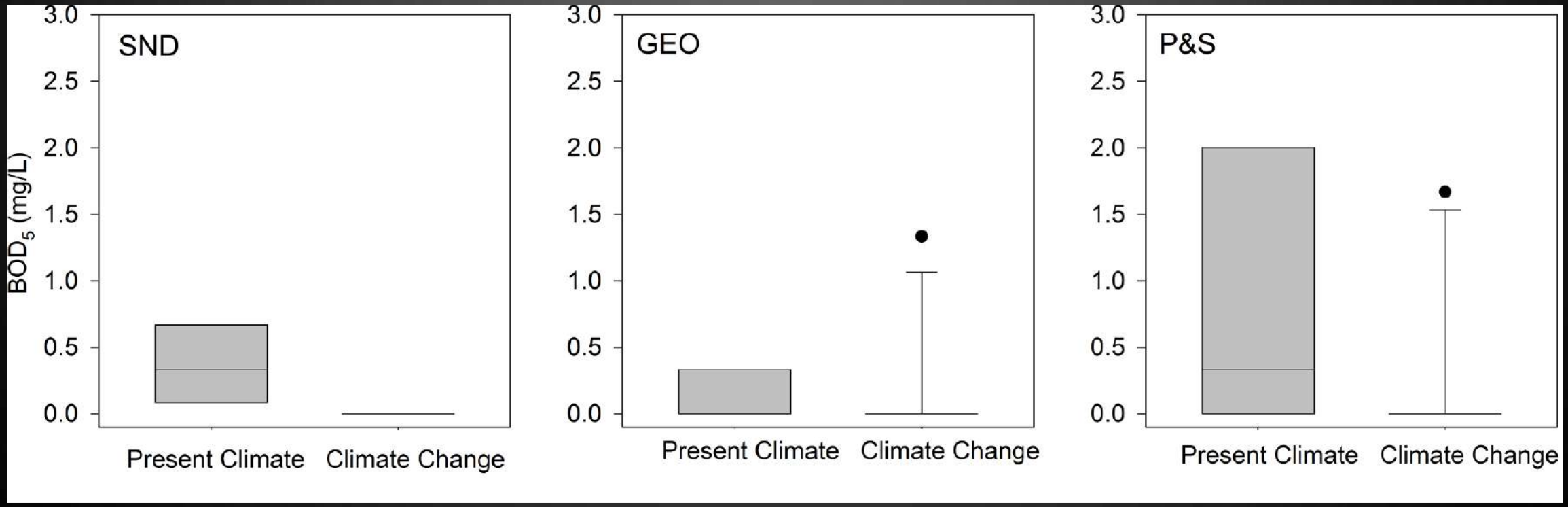
Cooper JA, Loomis GW, Amador JA (2016). Hell and High Water: Diminished Septic System Performance in Coastal Regions Due to Climate Change. PLoS ONE 11(9): e0162104. doi:10.1371/journal.pone.0162104


a
A Horizon
B Horizon
C1 Horizon
C2 Horizon
SND
GEO
P&S
Moisture sensors
Soil O_2 gas ports
Soil temp
cm
+15
0
-15
-30
-45
-60
-75
SFE
Soil
+30
-0
STE
b
SND
GEO
P&S

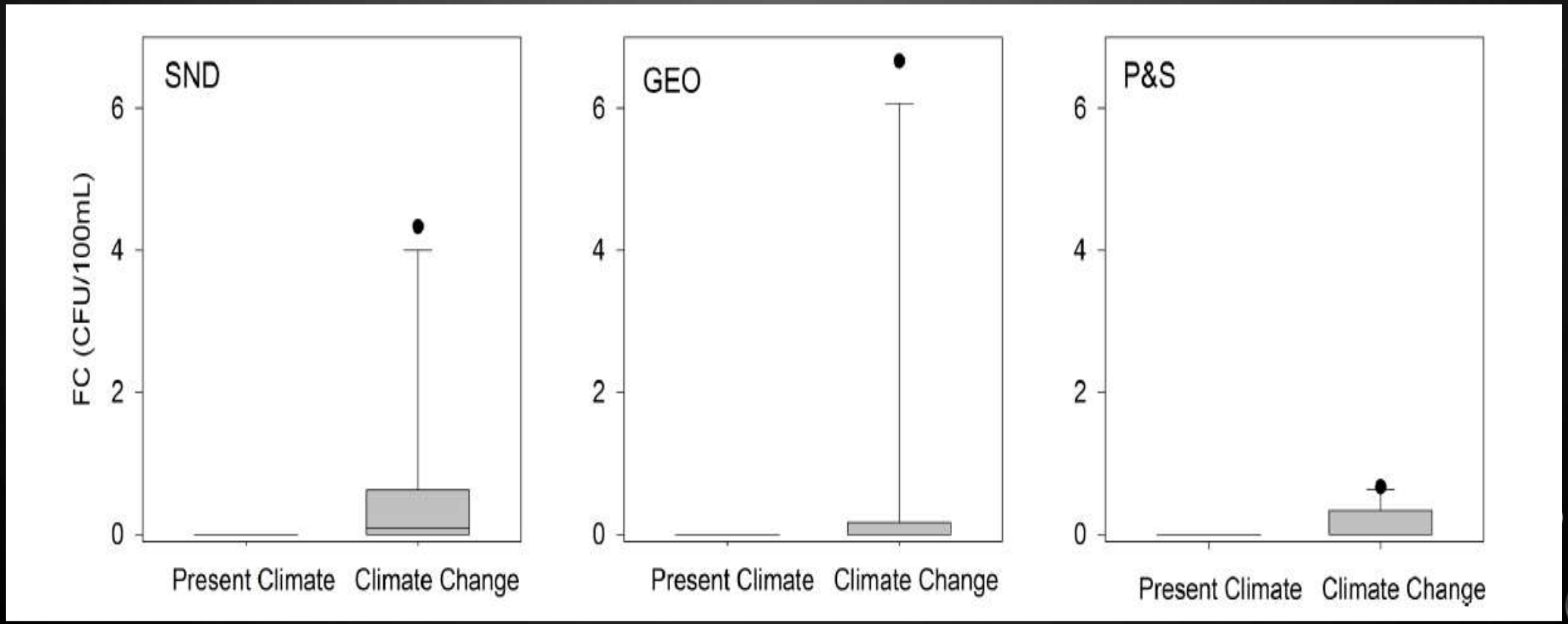
OXYGEN IN SOIL PORES



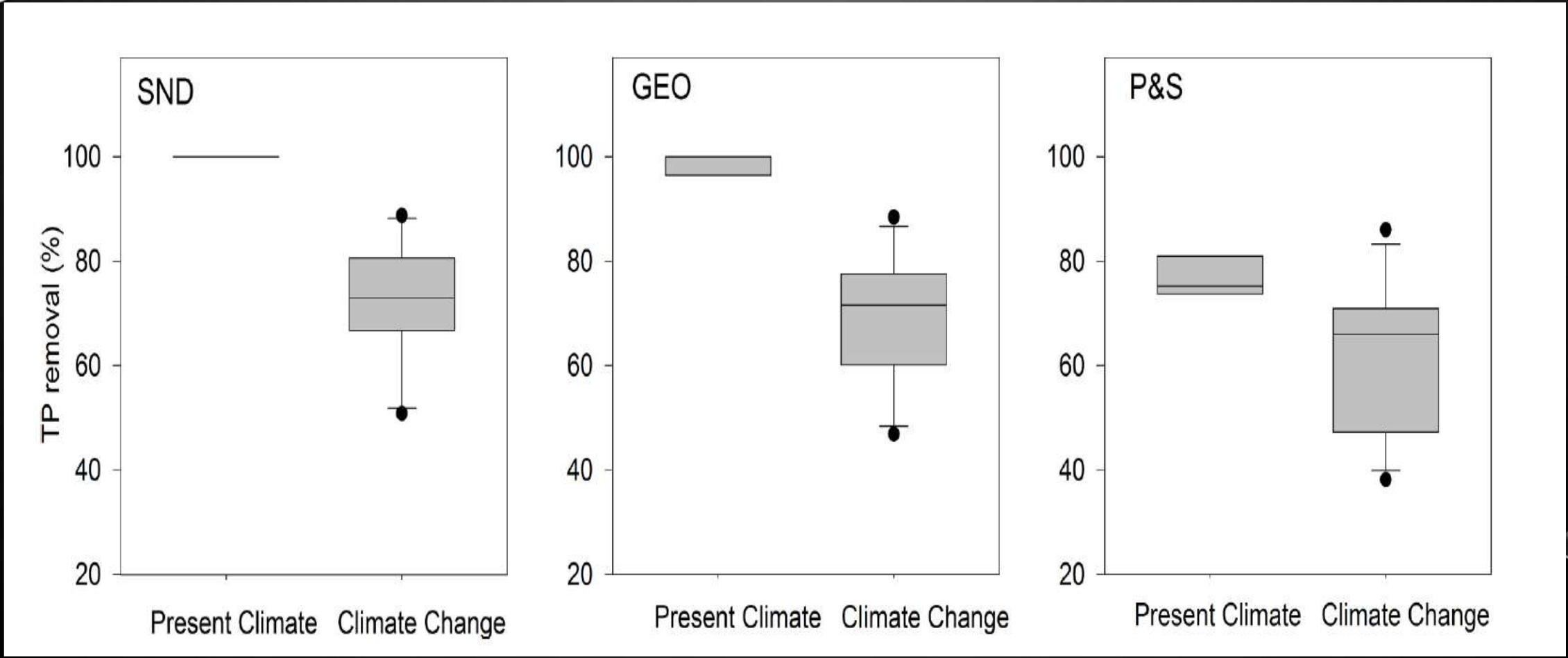
BOD_5


SND
GEO
P&S
BOD_5 (mg/L)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Present Climate
Climate Change

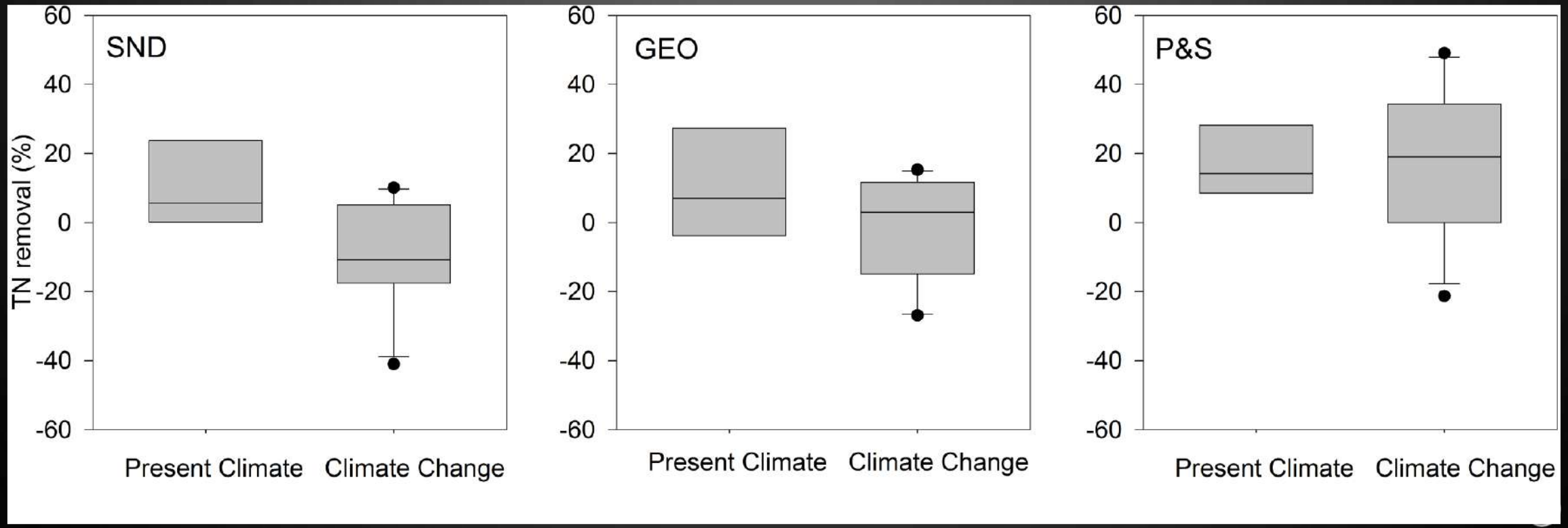
FECAL COLIFORM BACTERIA



PHOSPHORUS REMOVAL

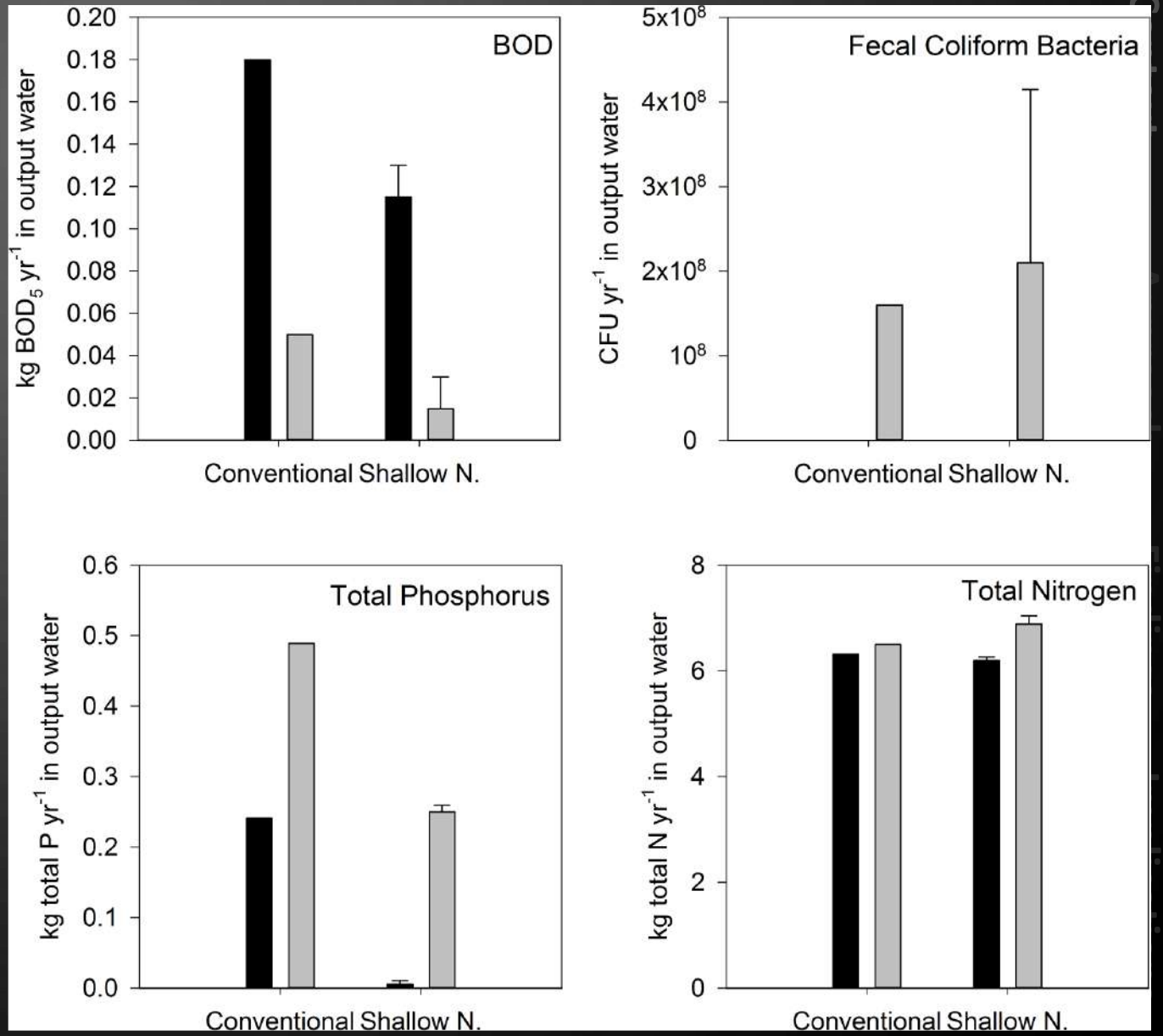


NITROGEN REMOVAL



- IMPAIRED SEPARATION DISTANCE (& HIGHER TEMPERATURE)…
  SO WHAT?!

  - Lower BOD
  - Increased FCB
  - Increased P
  - Some increase in N




Coastal septic systems
Rising groundwater tables
Coastal storms

COASTAL STORMS = EPIC DESTRUCTION!

Army Corps proposes raising homes

COASTAL STORMS – “PREPAREDNESS” … ?!

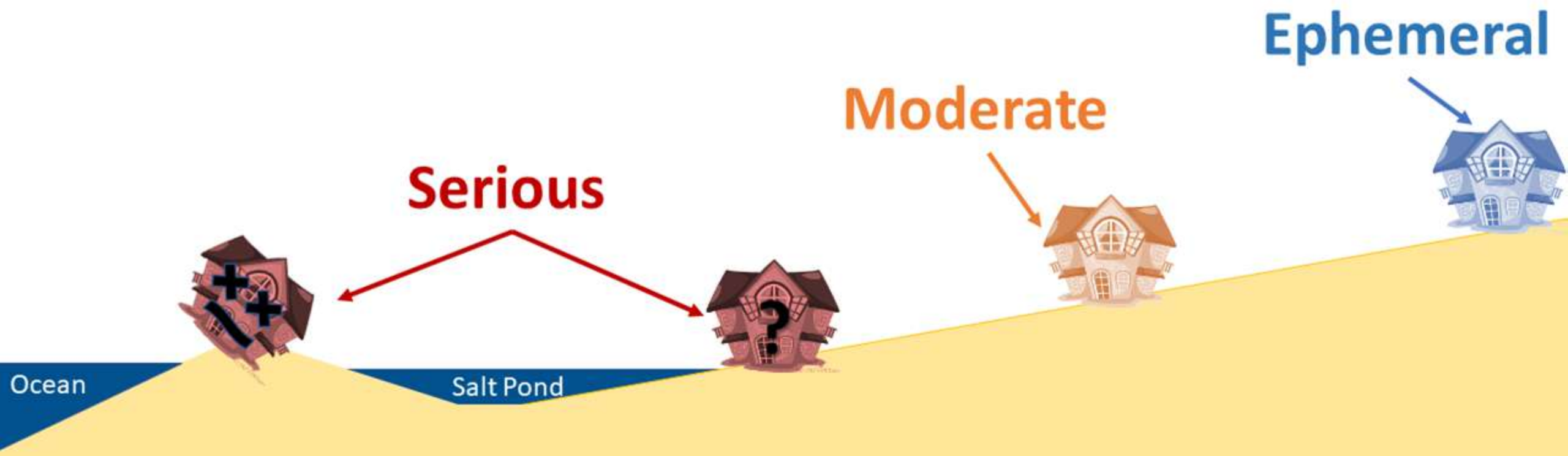
Septic Systems?!

Wells?!

(No public sewers along most of coast)

GOAL: QUANTIFY STORM IMPACTS!

- MODEL DIFFERENT STORM CONDITIONS ALONG SOUTHERN RI COAST…
- COUNT NUMBER OF SEPTIC SYSTEMS AFFECTED

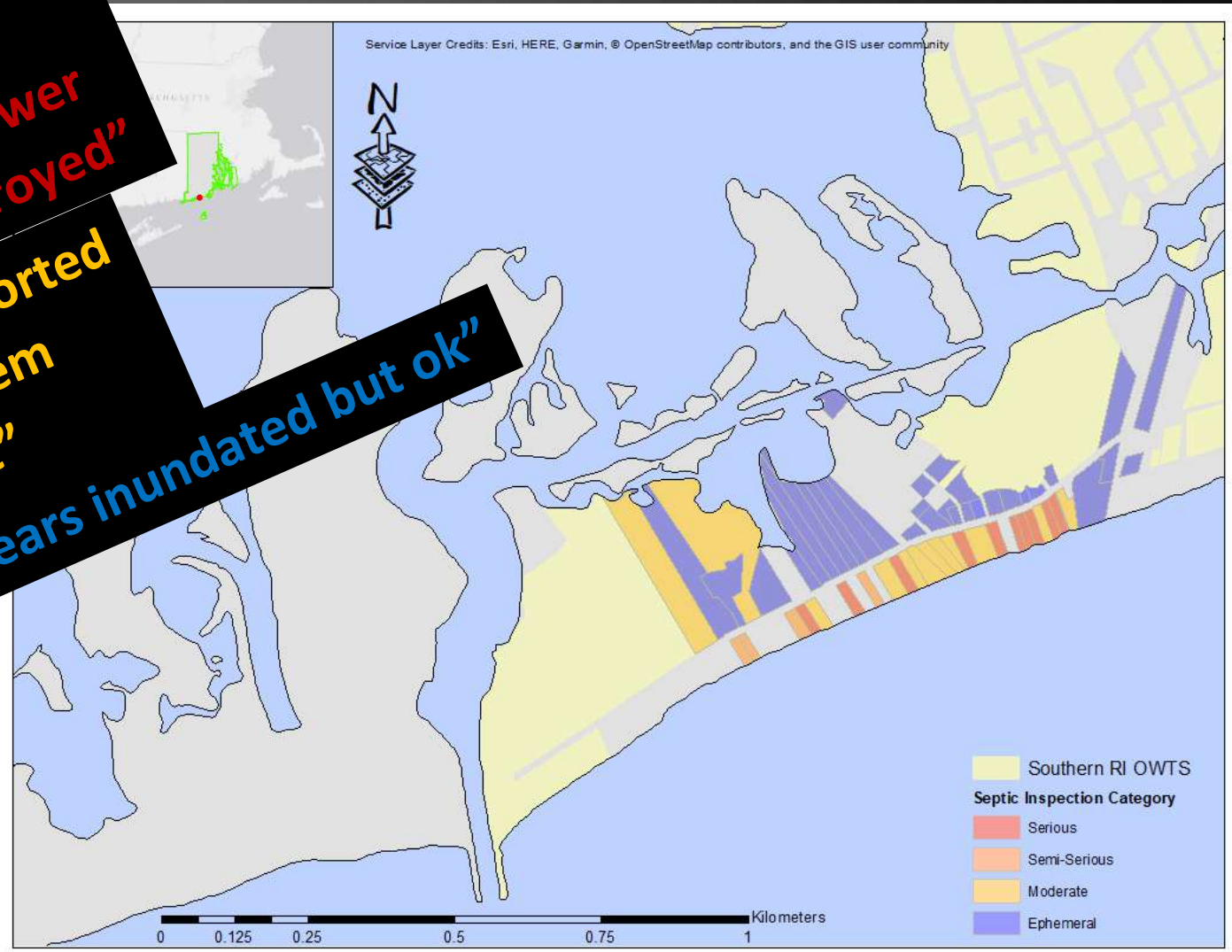


DAMAGE POST-SUPERSTORM SANDY (2012)

"fully exposed septic tank ocean side undermined, no outlet pipe, building sewer broken, covers off, tank full, likely destroyed"

"system in front, building sewer un-supported due to erosion, appears intact, system inundated, requires assessment"

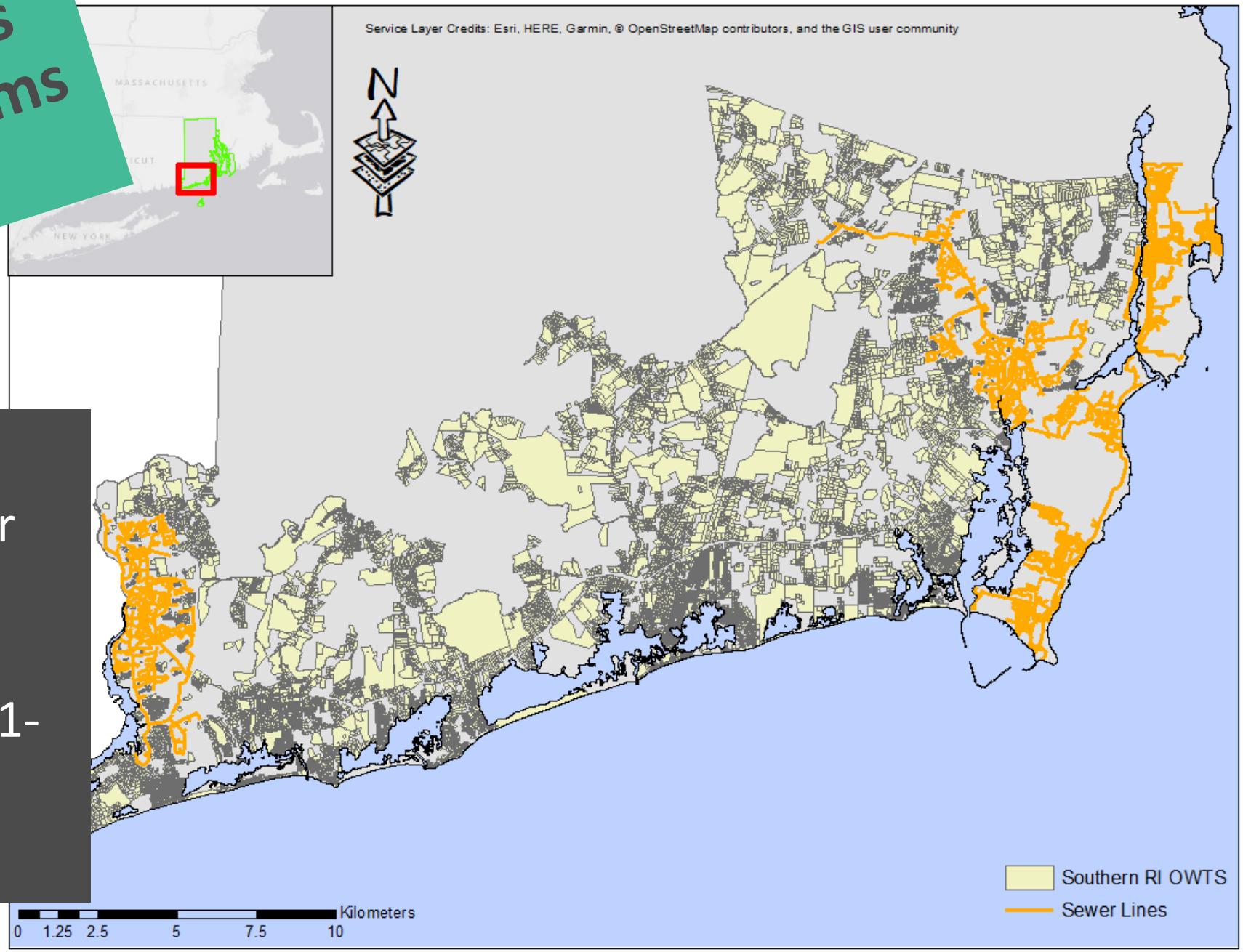
"building sewer ok, system appears inundated but ok"



17,760 Total Parcels rely on Septic Systems

+ Flood Maps
- 25, 50, 100 & 500-Year Storm Events
- Hurricane Worst Case Scenarios (Categories 1-4)

+ 2-foot Contour Lines



GIS – INTERSECTS…

- CREATED INTERSECTS OF SEPTIC SYSTEM PARCELS INUNDATED BY EACH STORM

Impact Category	Effect on Septic System	Duration
"Serious"	Major Repairs / Total Replacement	During Storm & Weeks – Months after Storm
"Moderate"	Minor Repairs	During Storm & Days – Weeks after Storm
"Ephemeral"	No Long-term Effects	During Storm

COASTAL STORM IMPACT SUMMARY (SOUTHERN RI COAST)

25-Y TO 500-Y STORM	HURRICANES (CAT 1 – 4)
• 3 – 4K SYSTEMS AFFECTED BY FLOODING	• 2 – 5K SYSTEMS AFFECTED BY FLOODING (?)
• ~200 SERIOUSLY IMPACTED	• ~200 SERIOUSLY IMPACTED
• ~ 65 MODERATELY IMPACTED	• ~ 65 MODERATELY IMPACTED
• REST EPHEMERALLY IMPACTED	• REST EPHEMERALLY IMPACTED

Require repairs!

+ 30cm SLR => + ~200 ephemerally impacted systems

Cox et al. (2020B)

WHY STORM DAMAGE IS CONCERNING FOR SEPTIC SYSTEMS…

- Septic system repairs & replacements…
  - Take weeks – months!
  - Expensive!
    - Repairs: $1k – $15k
    - Installing Advanced Treatment Tech: $23k – $30k

      …PER SYSTEM!
  - **<u>…what happens to wastewater in the meantime?</u>**

→ ???

Why worry?

Rising Groundwater Tables

Coastal septic systems

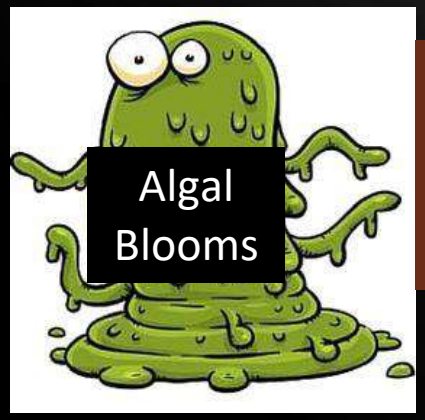
Coastal Storms

Failing / failed septic systems

Nutrient & Pathogen Pollution

Contaminated Coastal Waters

Environmental Health Problems



Contaminated wells

Human Health Problems

QUESTIONS?

Contact: alibba@uri.edu
@AlissaHCox

Contact: jamador@uri.edu
@URISoilMicro

Agricultural Experiment Station

USDA NIFA - NE 1545 Multi-state HATCH Project

NRCS Natural Resources Conservation Service

DEM RHODE ISLAND

TOWN OF CHARLESTOWN

CITATIONS

A. H. COX, G. W. LOOMIS & J. A. AMADOR. 2019. “PRELIMINARY EVIDENCE THAT RISING GROUNDWATER TABLES ARE THREATENING COASTAL SEPTIC SYSTEMS.” *JOURNAL OF SUSTAINABLE WATER IN THE BUILT ENVIRONMENT*. 5(4):04019007. DOI: 10.1061/JSWBAY.0000887

A. H. COX, D. SURABIAN, G. W. LOOMIS, J. D. TURENNE & J. A. AMADOR. 2020. “TEMPORAL VARIABILITY IN THE VERTICAL SEPARATION DISTANCE OF SEPTIC SYSTEM DRAINFIELDS ALONG THE SOUTHERN RHODE ISLAND COAST.” *WATER AIR & SOIL POLLUTION*. 231(107). DOI: 10.1007/S11270-020-04488-Z

A. H. COX, M. J. DOWLING, G. W. LOOMIS, S. E. ENGELHART & J. A. AMADOR. 2020. “GEOSPATIAL MODELING SUGGESTS THREATS FROM STORMY SEAS TO RHODE ISLAND’S COASTAL SEPTIC SYSTEMS.” *JOURNAL OF SUSTAINABLE WATER IN THE BUILT ENVIRONMENT*. 6(3):04020012. DOI: 10.1061/JSWBAY.0000917

J.A. COOPER, G.W. LOOMIS & J.A. AMADOR J(2016). HELL AND HIGH WATER: DIMINISHED SEPTIC SYSTEM PERFORMANCE IN COASTAL REGIONS DUE TO CLIMATE CHANGE. *PLOS ONE* 11(9): E0162104. DOI:10.1371/JOURNAL.PONE.0162104