Re-thinking decentralized infrastructure as blue-green-grey infrastructure:
The need for industry-university partnerships

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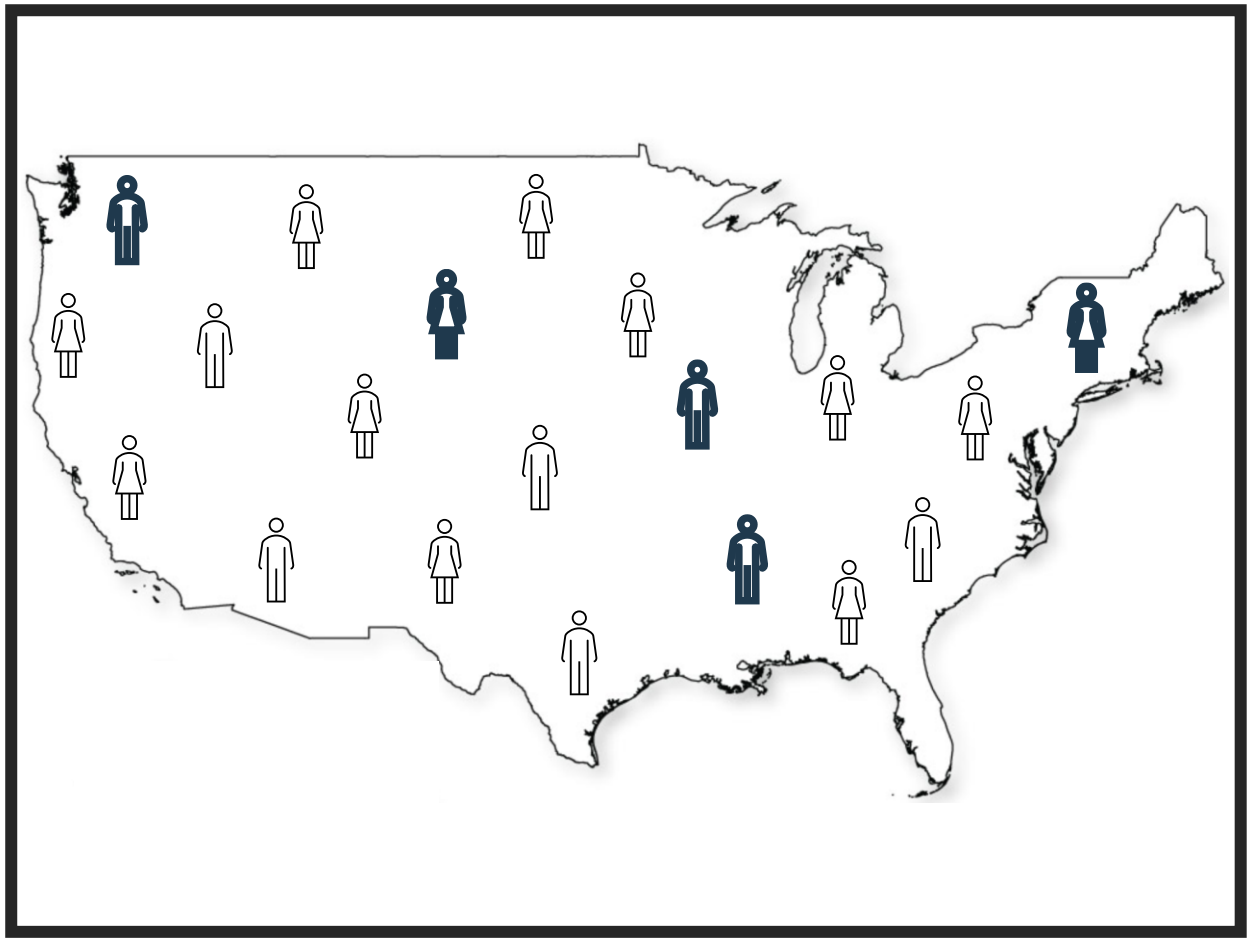
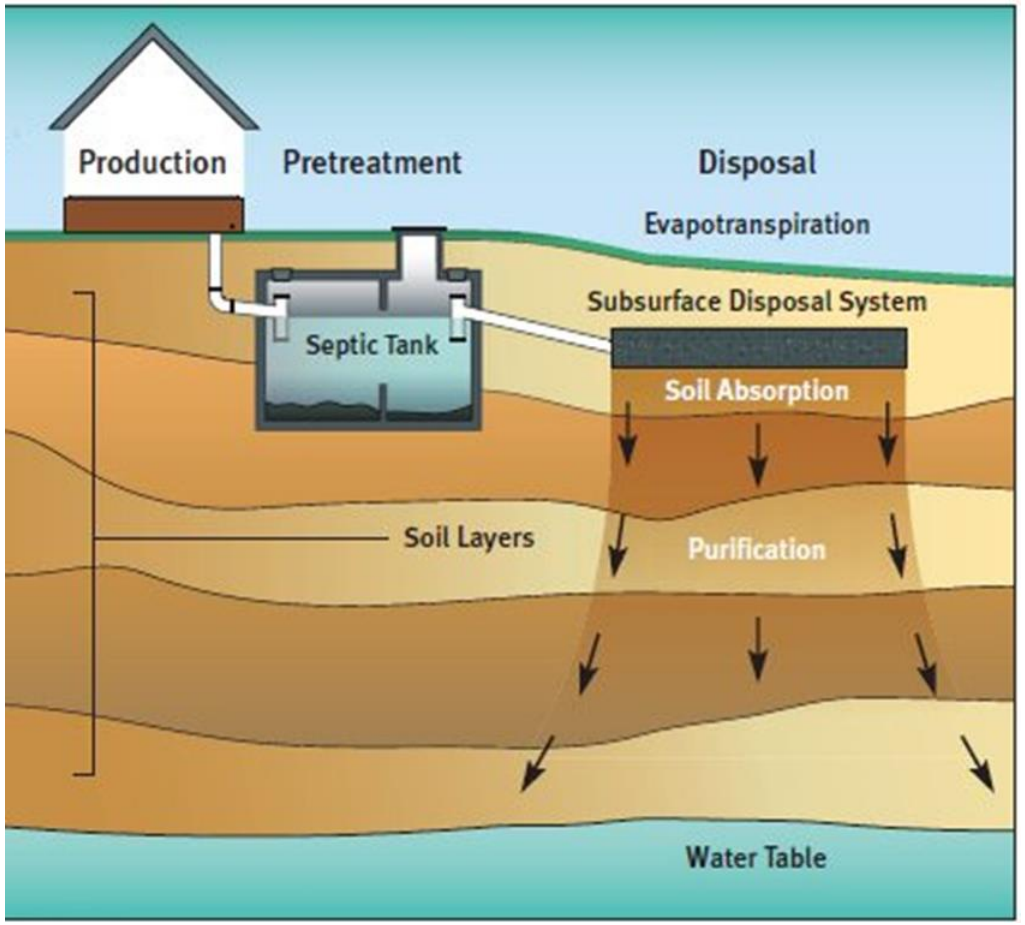


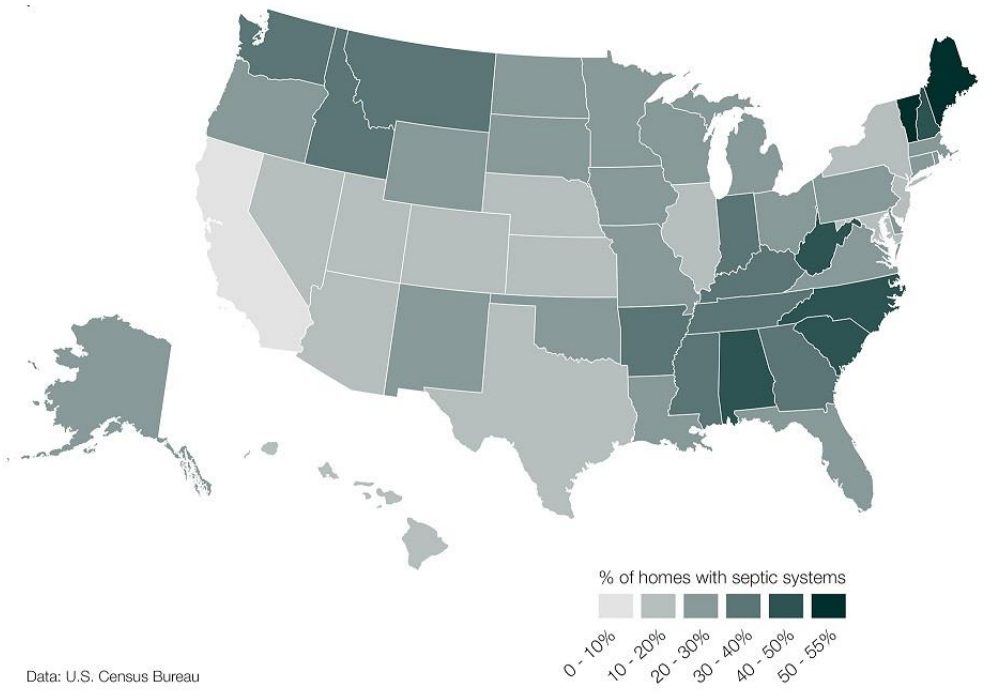
1/5 of Americans

US EPA 2002

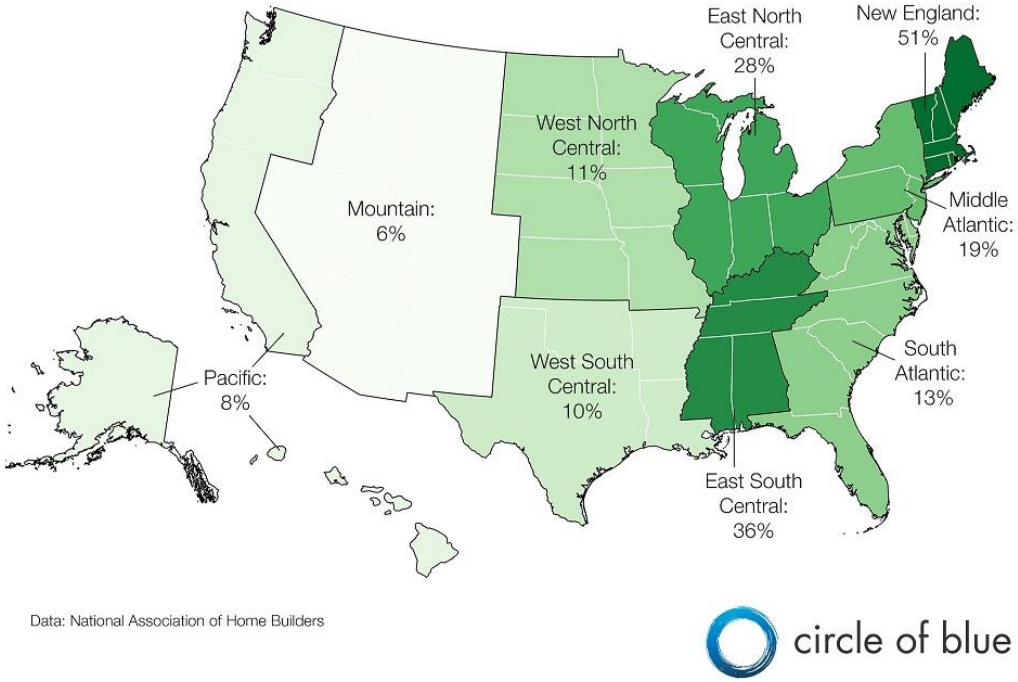


Proportion of homes on septic systems

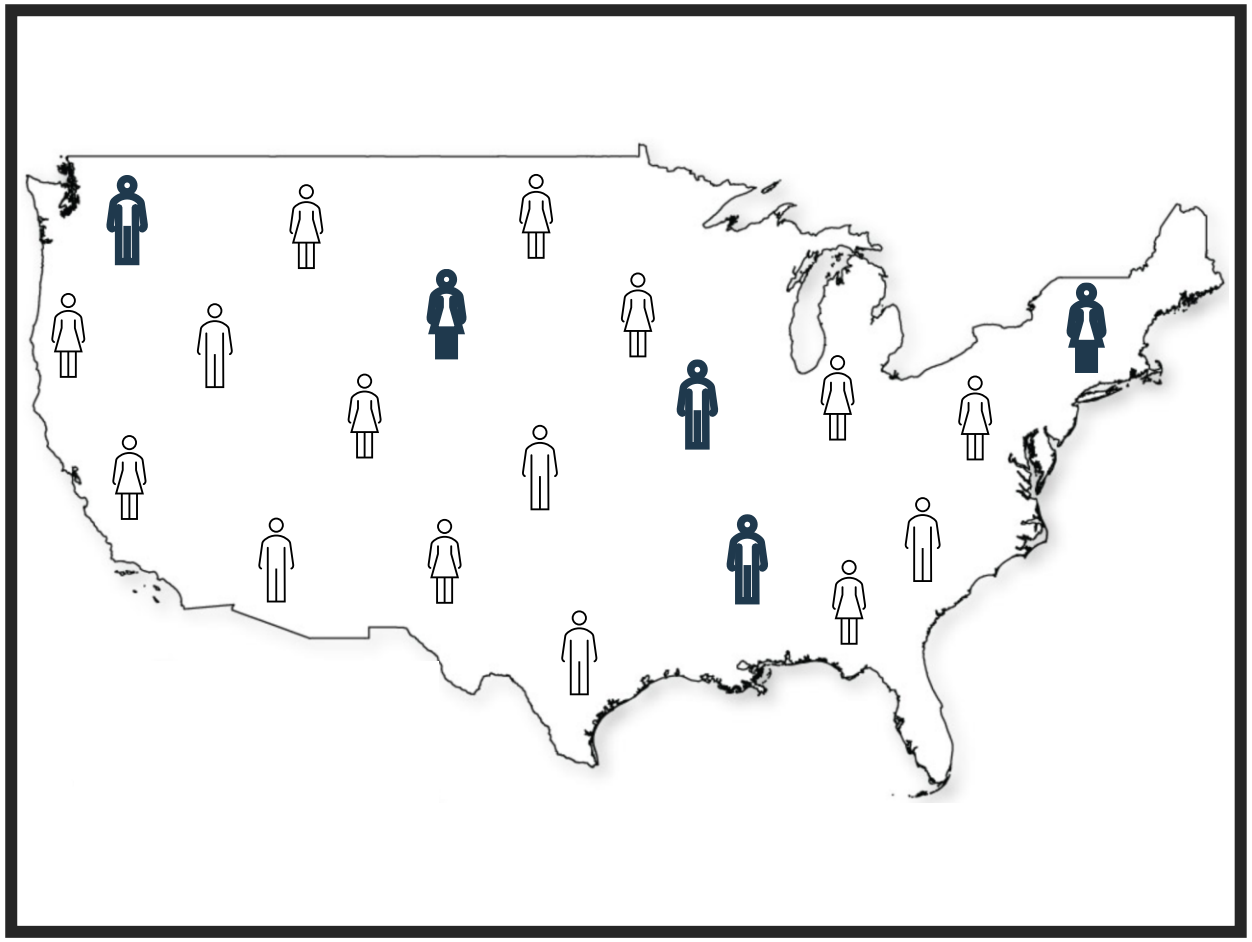
Portion of homes relying on a septic system or cesspool by state,1990.



Share of new homes built with septic systems by region, 2013.



Georgia- All counties are currently permitting septic systems.

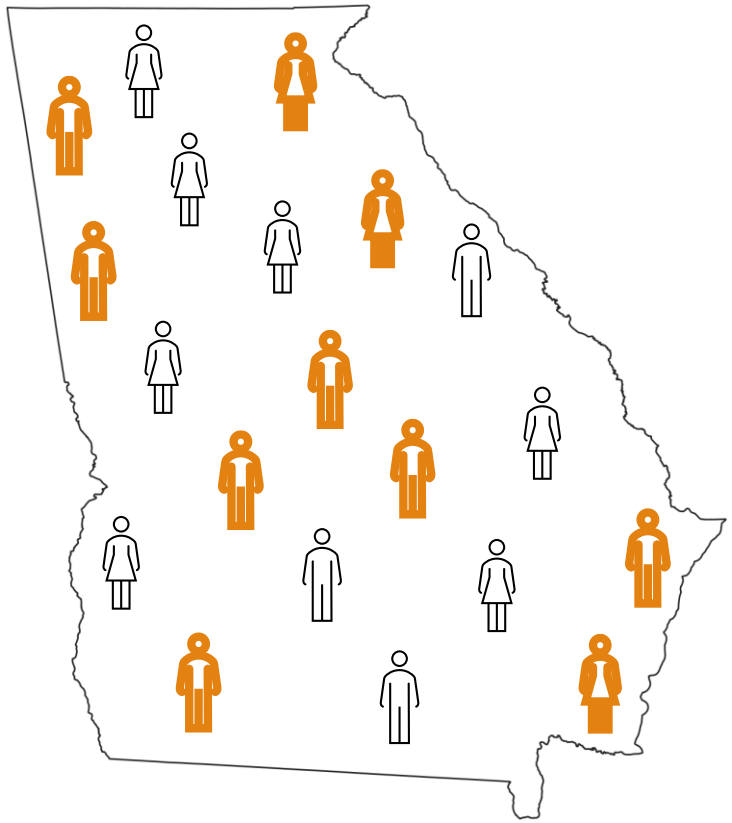


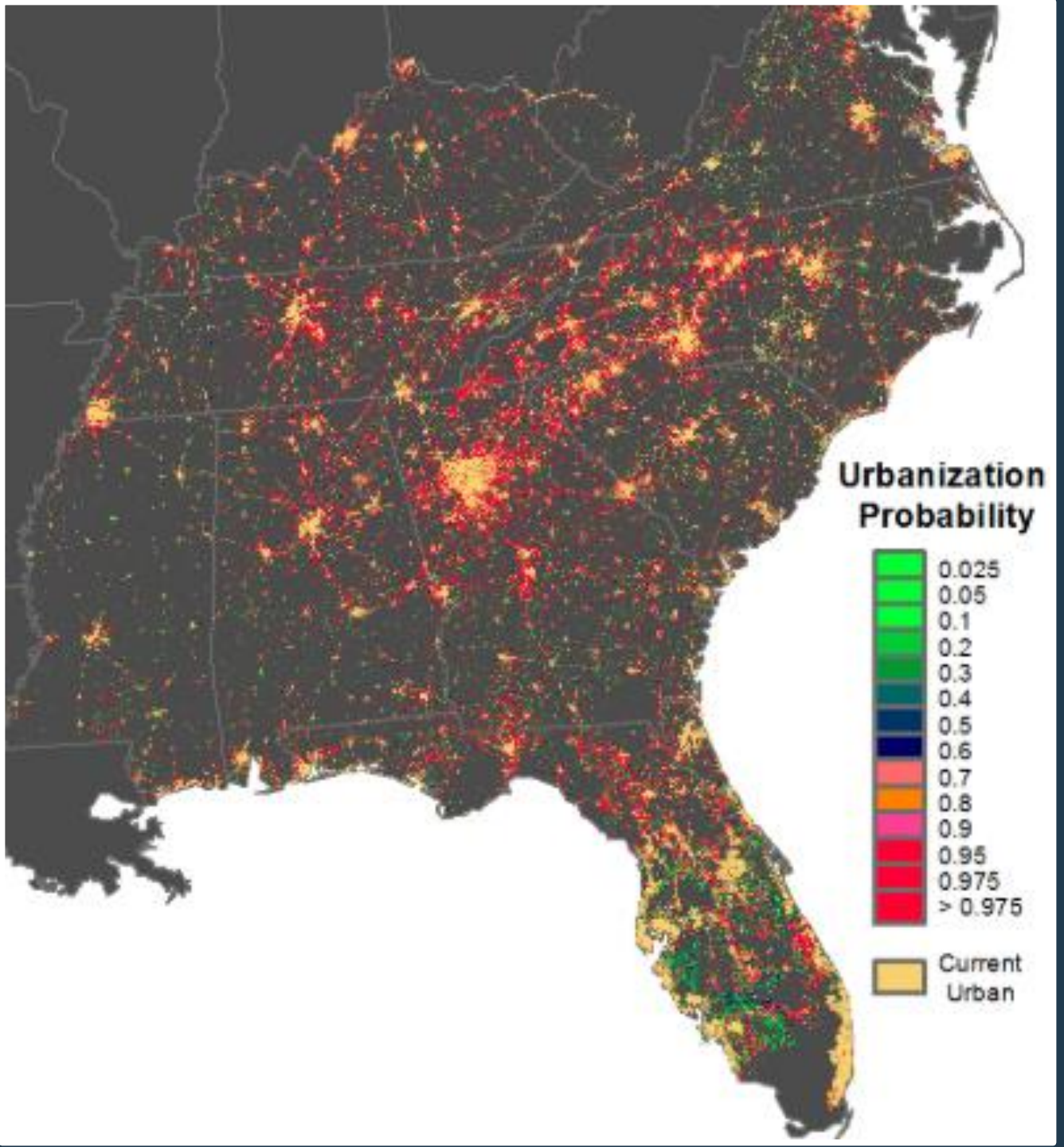
1/5 of Americans

US EPA 2002

1/2 of Georgians

US EPA 2012; US Census Bureau 2019





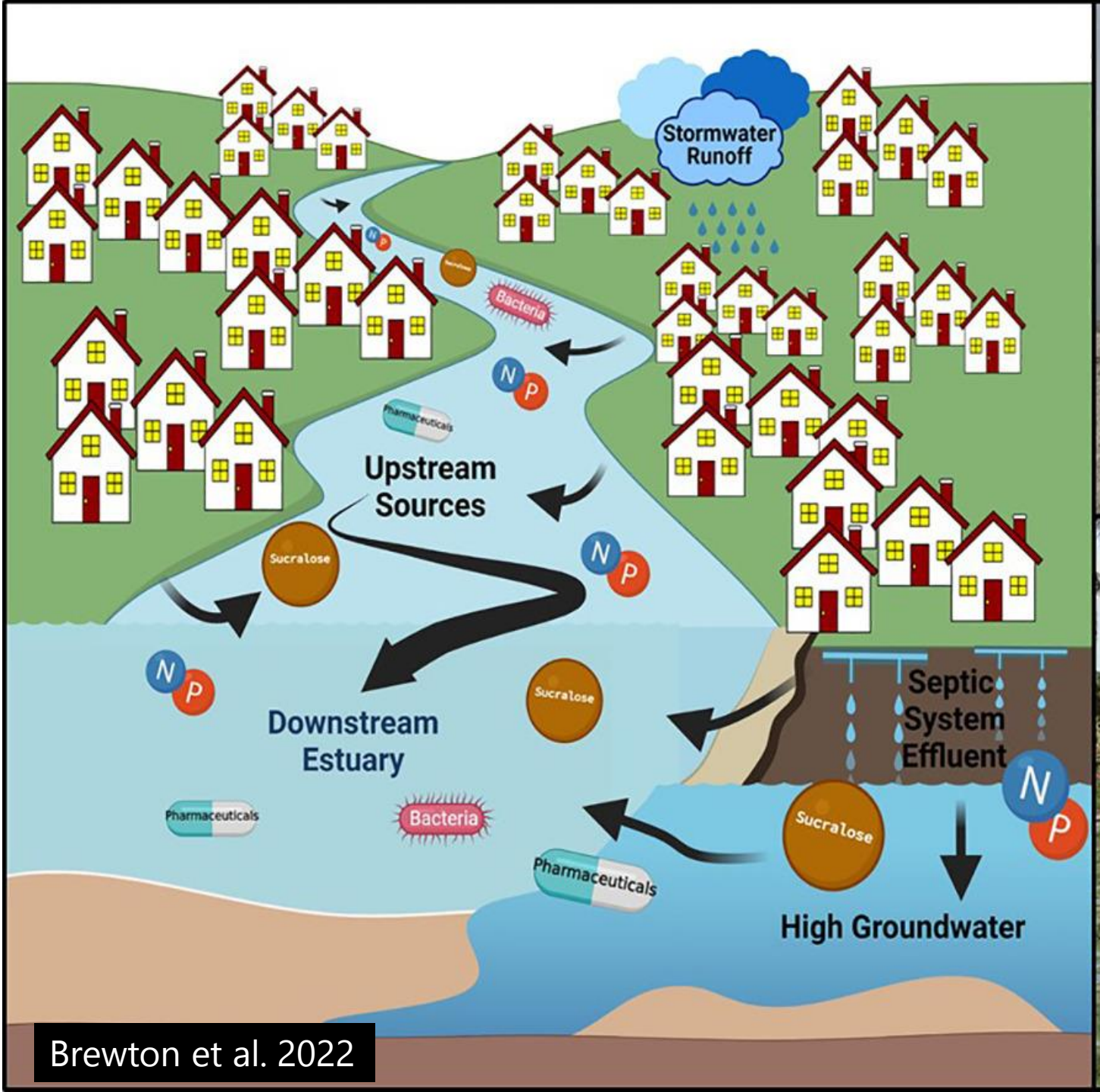
Growth in the Southeastern US

Largely in suburban areas

Outside central sewer collection

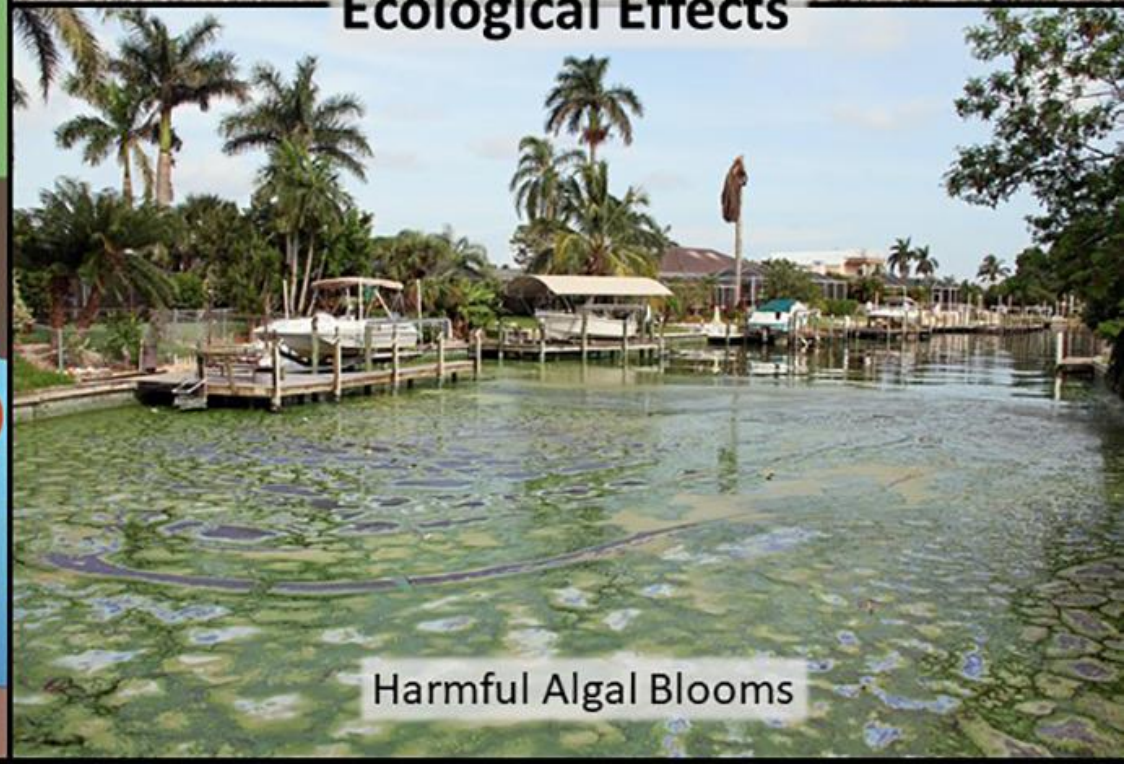
Second homes, new developments

≈15-20% new single-family homes (US Census Bureau 2020)



Brewton et al. 2022

Ecological Effects



Legacy issues

- **Brief History of Regulation**
  - Septic systems first started appearing in the U.S. in 1883 and became more popular post WWII in the 1940s.
  - 1970's – many cities began regulating their design, installation.
  - 1990's – Statewide regulation began to be considered.
  - Sewers will not replace septic systems everywhere.

Source: Van Delden On-Site Wastewater Systems, DPH, EPA

- **Legacy Issues**
  - Undersized and old systems as a result of little to no regulation for old systems.
  - Systems permitted under different rules due to lack of structure in permitting.
  - Old systems in low-income communities that may not have access to resources to maintain them.

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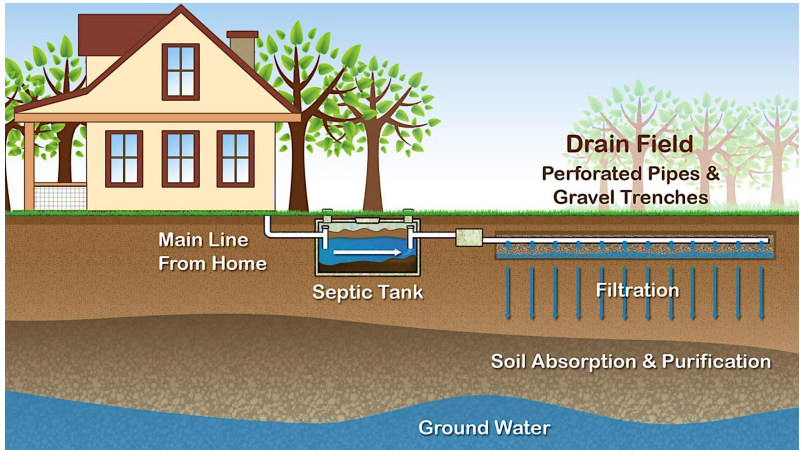
Systems at risk?

- Determining systems at risk now.
- Why are those systems at risk- environmental or socio-economic reasons?
- Will the number of at risk systems change as a result of climate change and sea level rise?
- Whose responsibility is it to fix the systems at risk?
- Where do we start?

Decentralized infrastructure is blue-green-grey infrastructure



- Weather
- Distance to water table
- Slope and distance to stream
- Physical and biological characteristics of the leach field
- Soil characteristics
- Home water use
- Septic system condition

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- Average distance to water table
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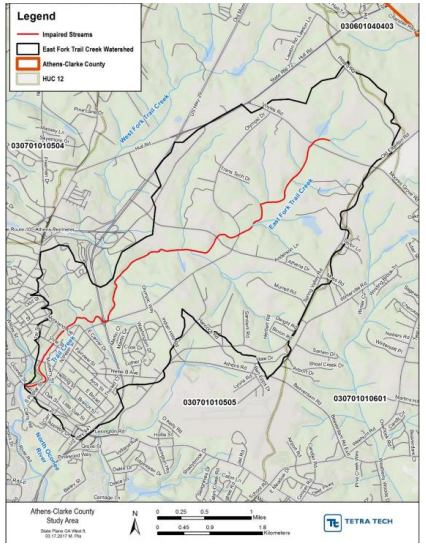
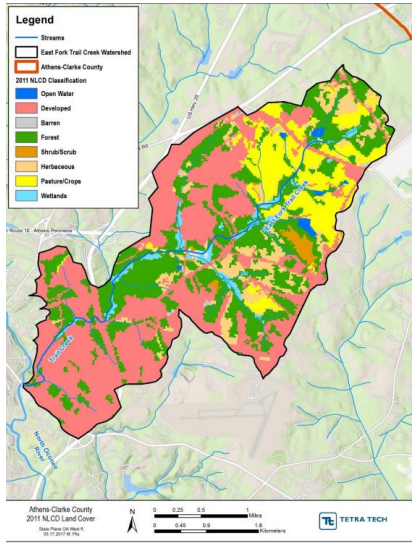
- Soil characteristics
- Land use
- Age and condition of tank clusters

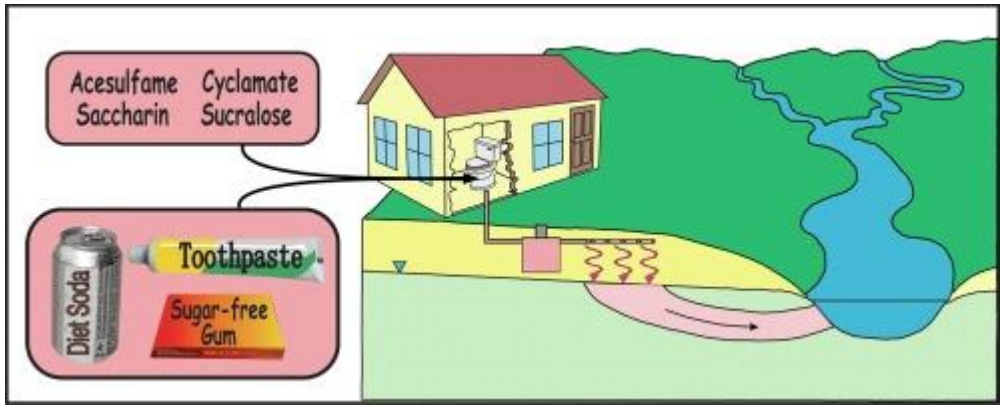




- Weather & climate
- Density and length of river networks
- Land use
- Soil characteristics
- Age and condition of infrastructure
- Septage disposal capabilities
- Water infrastructure investment

Evidence of septic effluent in streams and impact of climate variability

- Case study from Rural Southern Ontario (2008-2015)
  - Artificial sweeteners found in 91% streams.
  - Water derived from septic system effluent constituted upto 0.5% of streamflow.
  - About 13% of all septic effluent reached stream via groundwater.



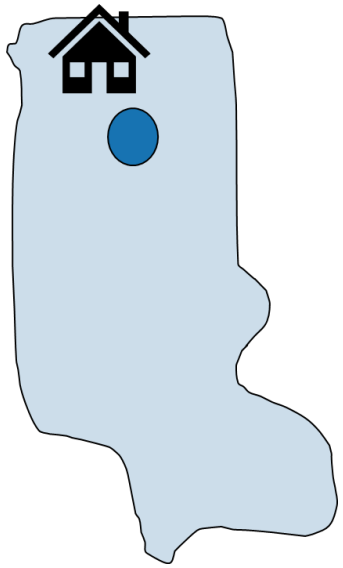
Spoelstra et al., 2020

What would happen in a drought year?

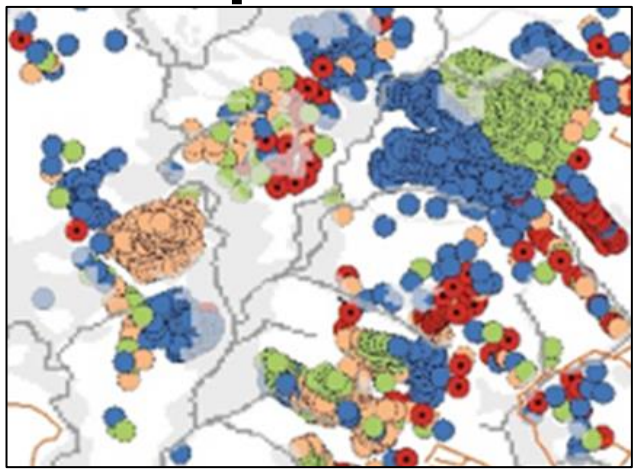
Today

- Blue-green-grey attributes of DWWTI at different spatial scales
- Assessing larger scale patterns in system failure
- Leach field function and failure
- Moving forward: partnerships to support clean water for healthy communities

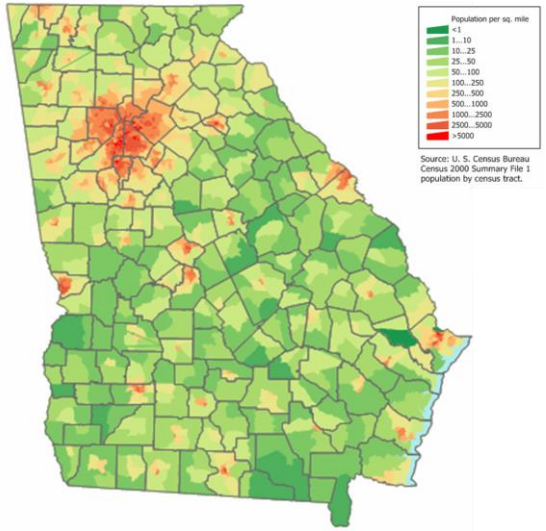
Parcel



Septicshed

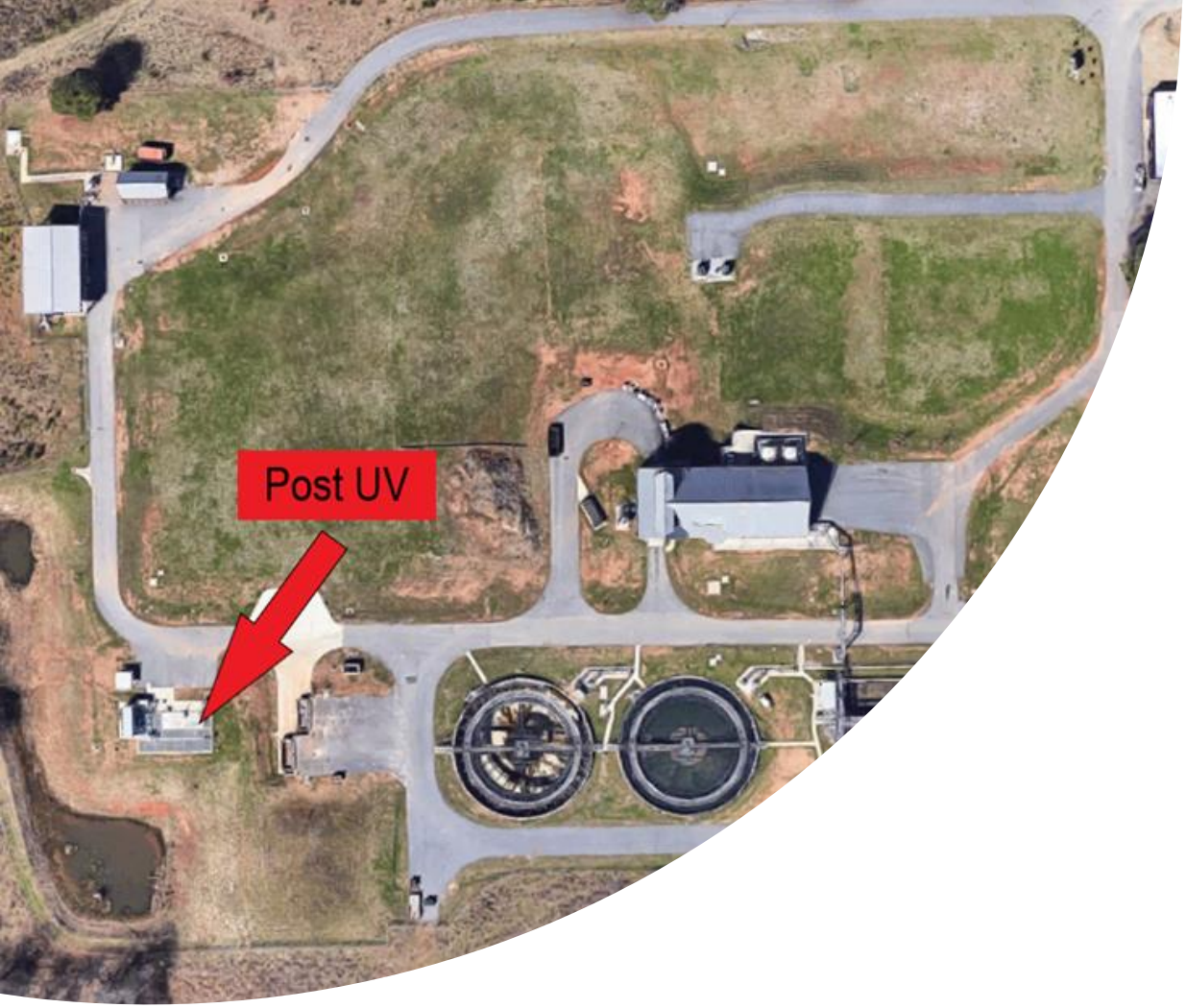


Municipality & State



Characteristics and (potential) resilience at multiple spatial scales

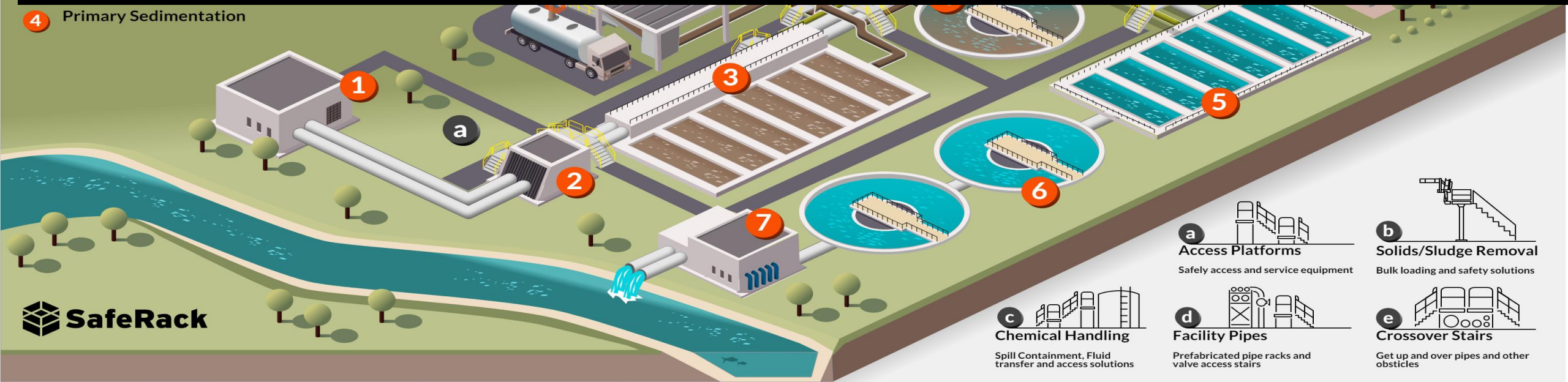
Treating septage is costly



SEPTAGE AFFECTS ALL ASPECTS OF WASTEWATER PLANT OPERATIONS

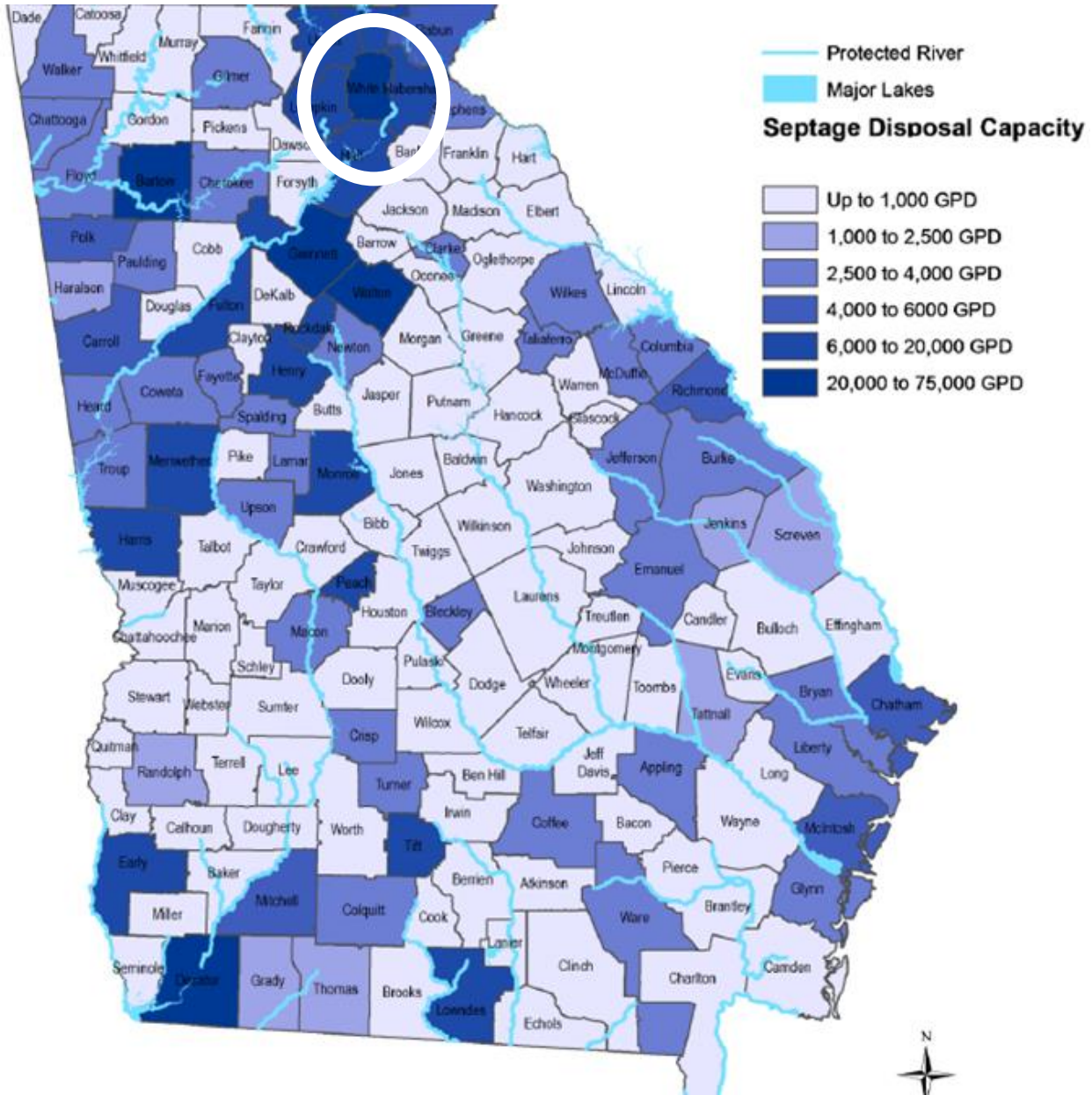
- Preliminary Treatment
- Primary Treatment
- Secondary Treatment
- Solids Handling
- Disposal Costs
- Chemical Costs
- Electrical Costs
- Odor Control
- Public Relations

Decentralized infrastructure is blue-green-grey infrastructure



State-level production of septage vs. demand for treatment

Septage Disposal Capacity



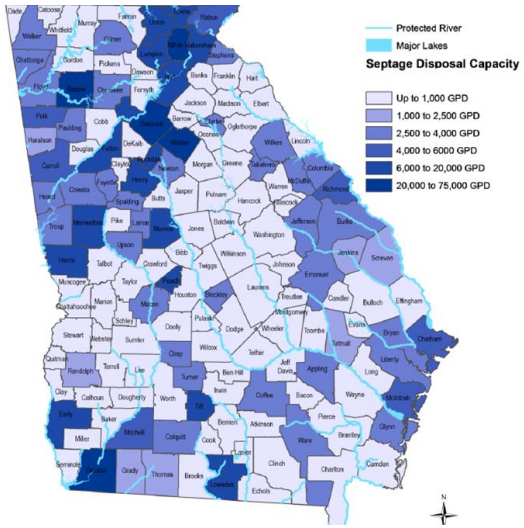
Each of the 322 NPDES permitted facilities in Georgia and the one private LAS permitted operation were contacted by postal mail and telephone to learn each facility's policies surrounding septage acceptance.

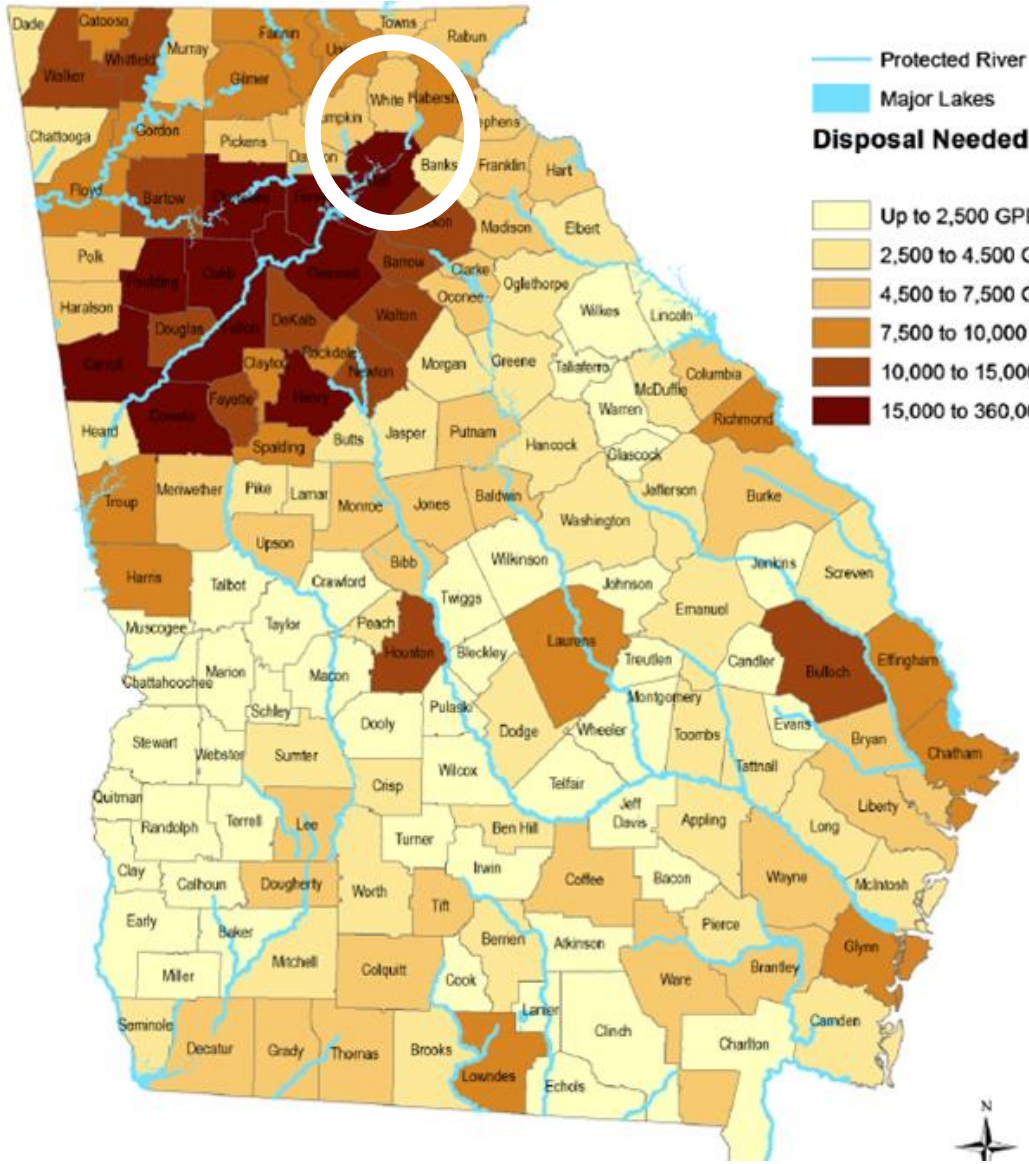
Information on septage acceptance was collected from 281 (86.5%) of the N=322 NPDES permitted facilities.

Average limit of 7,108.4 GPD

Private septage facility in White County was capable of accepting 150,000 gallons a day

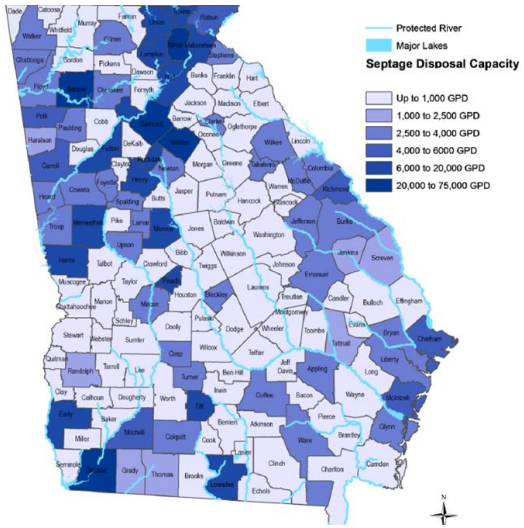
Septage Disposal Needs

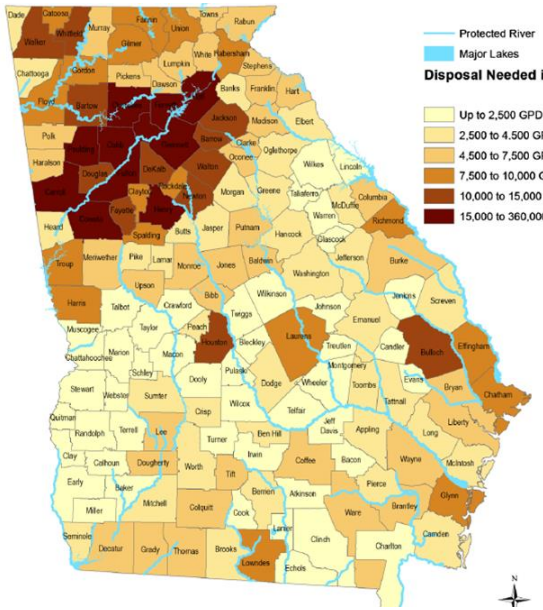


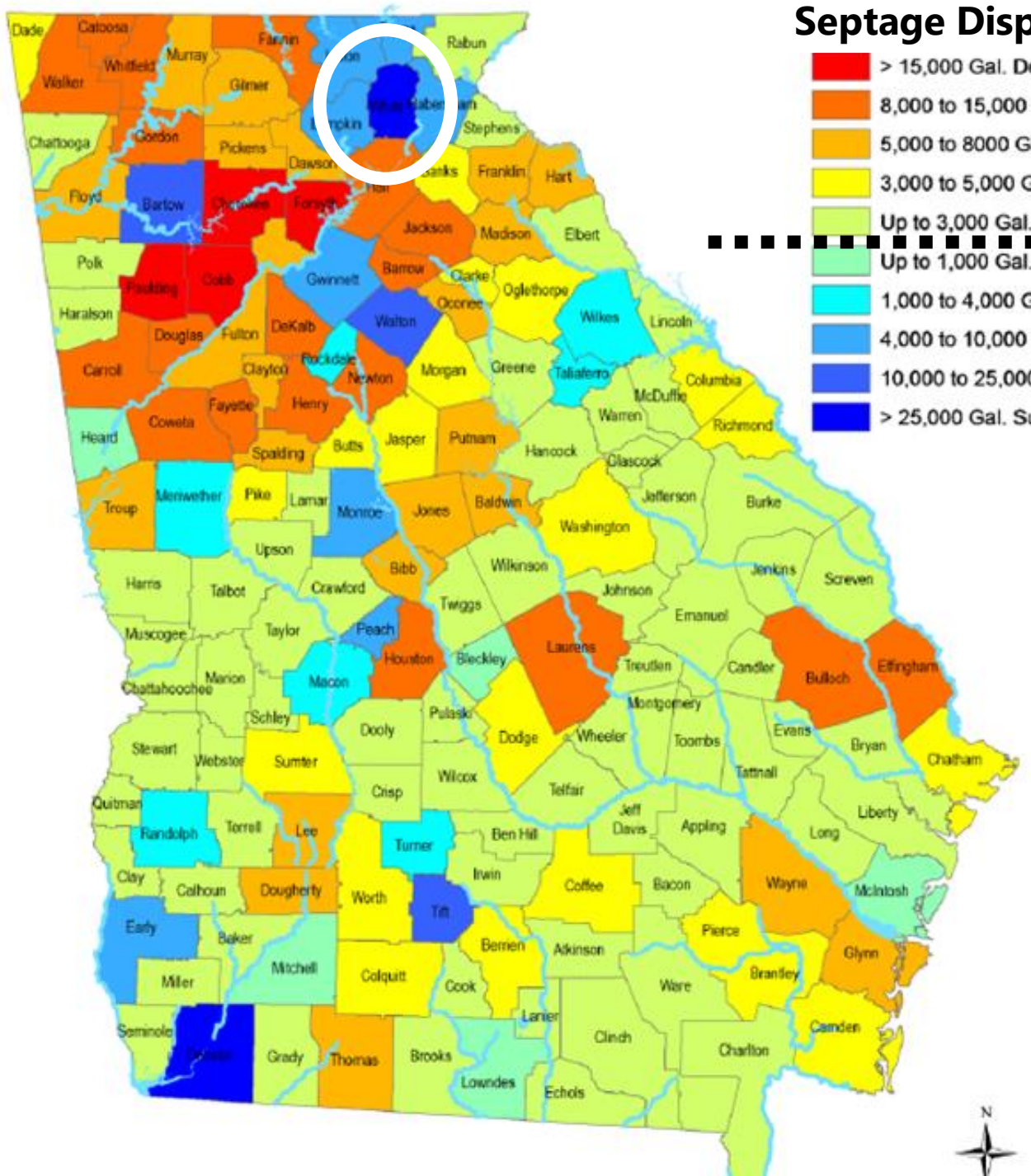


Demand estimates were based on the recommended septage removal schedule of every five years and a typical septic tank capacity of 1000 gallons.

The inventories of OWTS of all 159 Georgia counties included in this study were compiled by the combination of the 2007 inventory of system counts from each county conducted by EPD, with the sum of the new OWTS installations as reported to DPH by county health departments from 2007 through 2014.







Additional capacity to dispose of 76,969 gallons of septage per day, >28 million gallons per year

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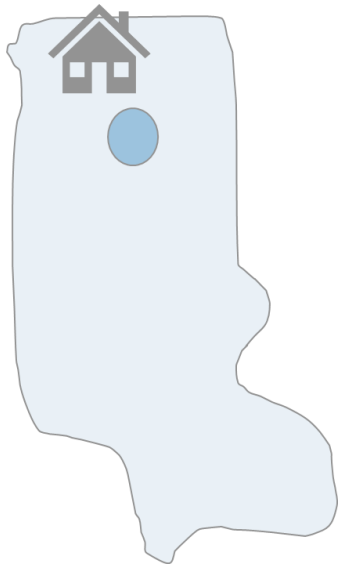
Parcel



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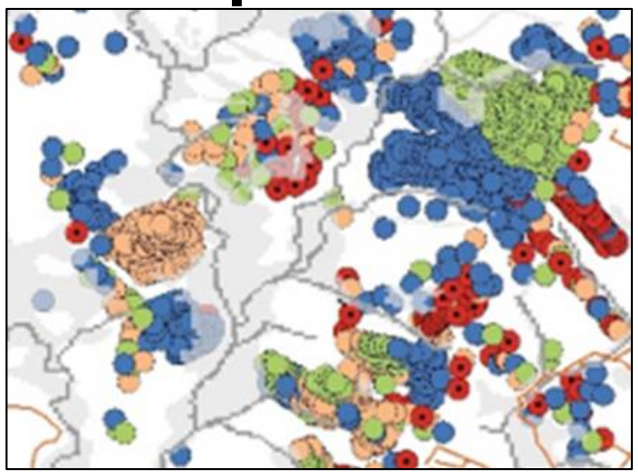

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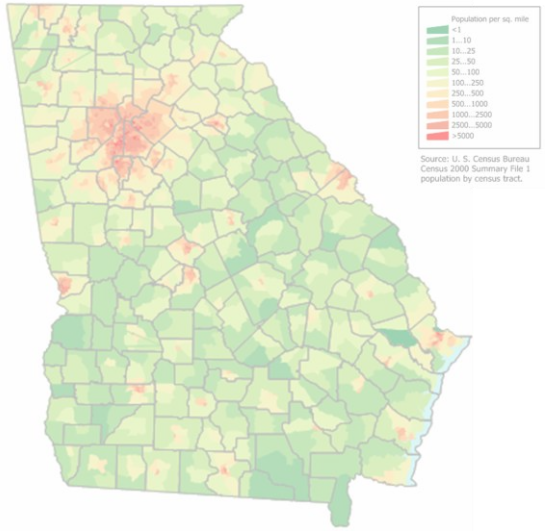
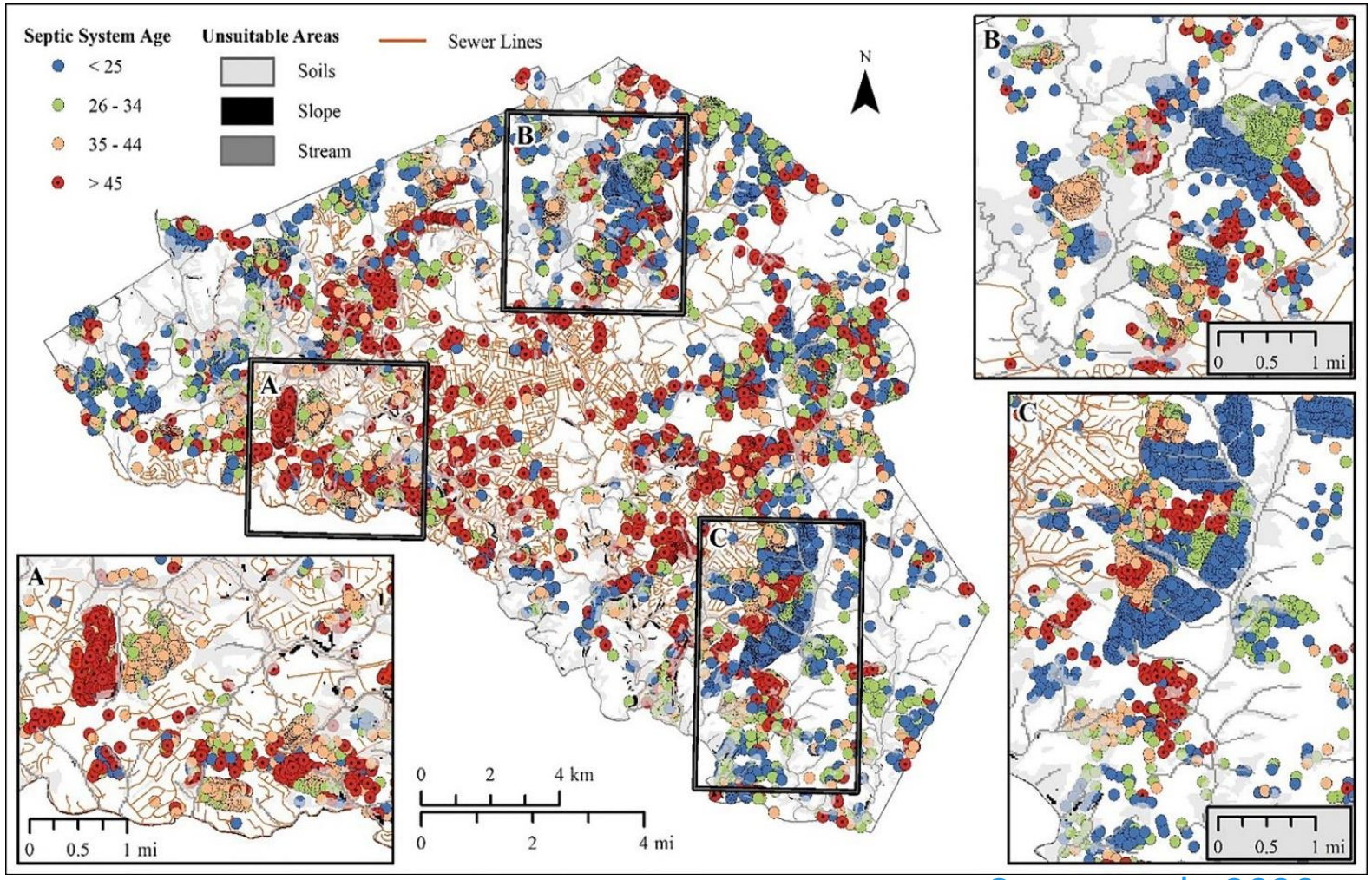


Characteristics and (potential) resilience at multiple spatial scales

What could a watershed with only septic systems look like? (a septicshed)



Capps et al., 2020

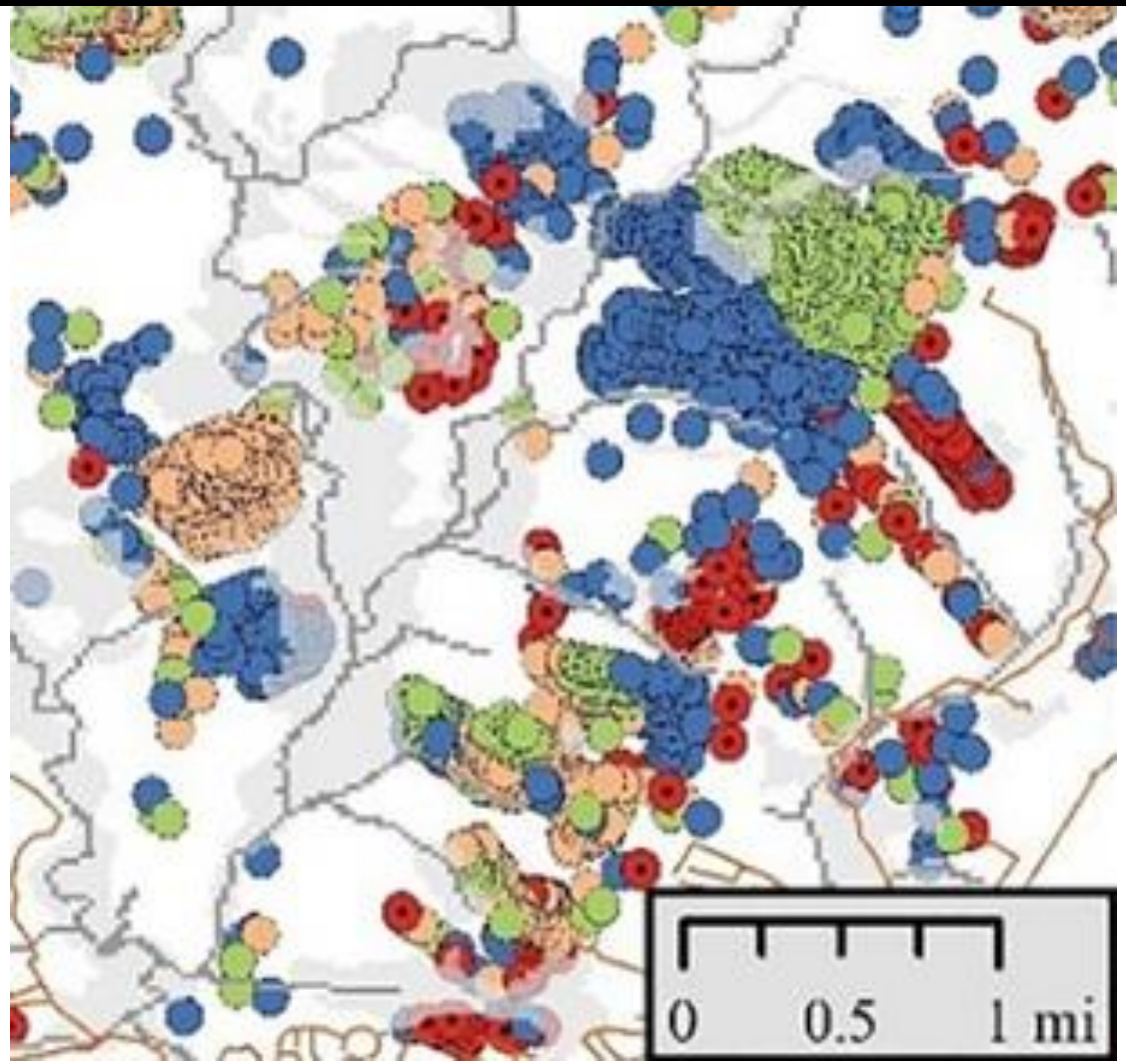
Failing septic systems are a non-point source of pollution.

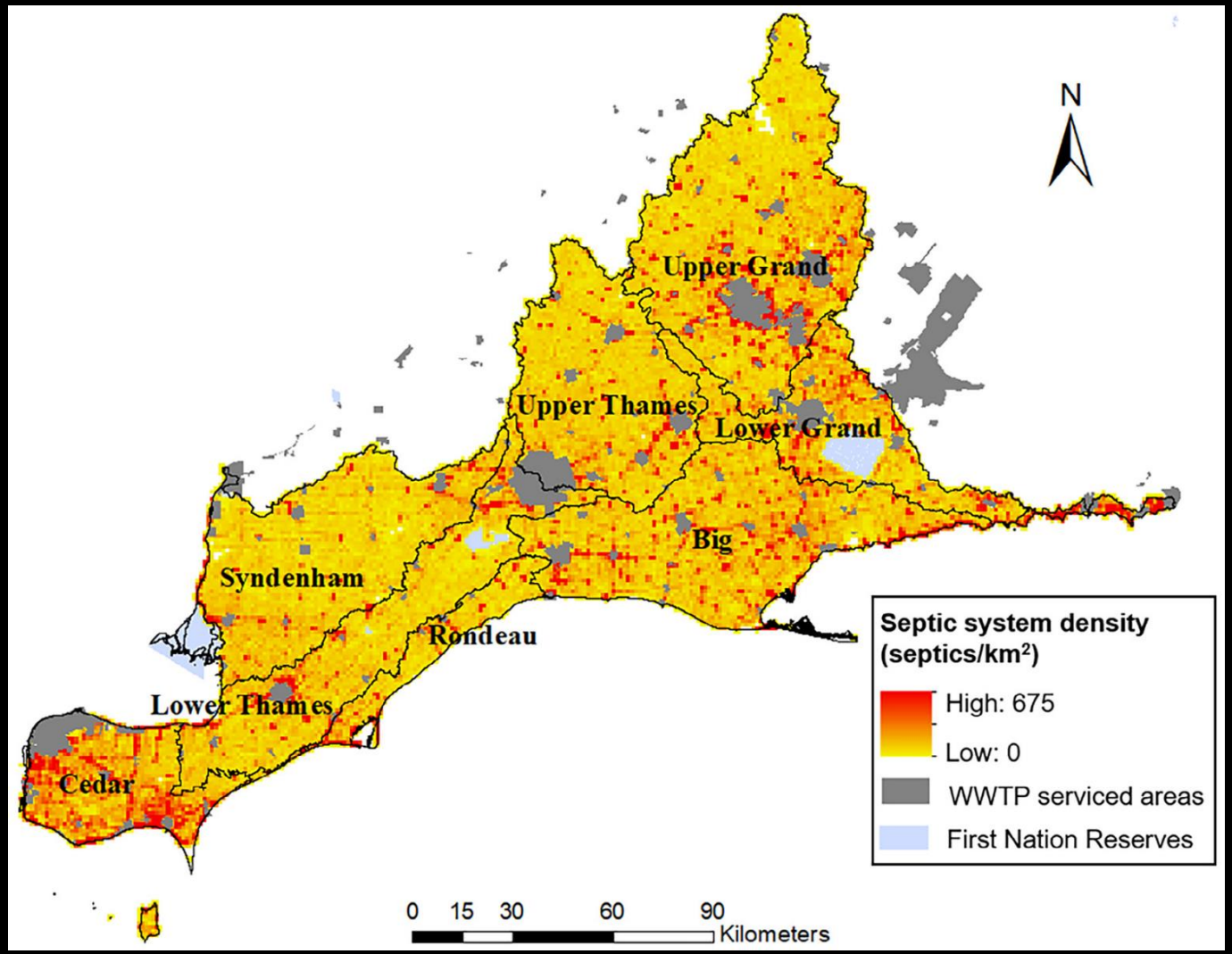
States and water management agencies are tasked with ‘fixing’ this problem.

But what systems really are the problem? Or could all systems be problems under certain conditions?

Decentralized infrastructure is blue-green-grey infrastructure

- Weather
- Average distance to water table
- Average slope and distance to stream
- Soil characteristics
- Land use
- Age and condition of tank clusters





Too many systems

Baseflow and specific conductance (Landers and Ankcorn 2008)

Nitrate concentrations (Oliver et al. 2014)

Fecal indicator bacteria (Ahmed et al. 2005)

Few "bad" systems?

Phosphorous concentrations
(Macintosh et al. 2011)

Indicator bacteria in surface waters and nitrate in surficial aquifers
(Geary and Lucas 2019)

Median housing age in US: 37 years
(ASCE 2021)

Lifespan of septic systems: 15-40 years
(US EPA 2017)

Types of failure

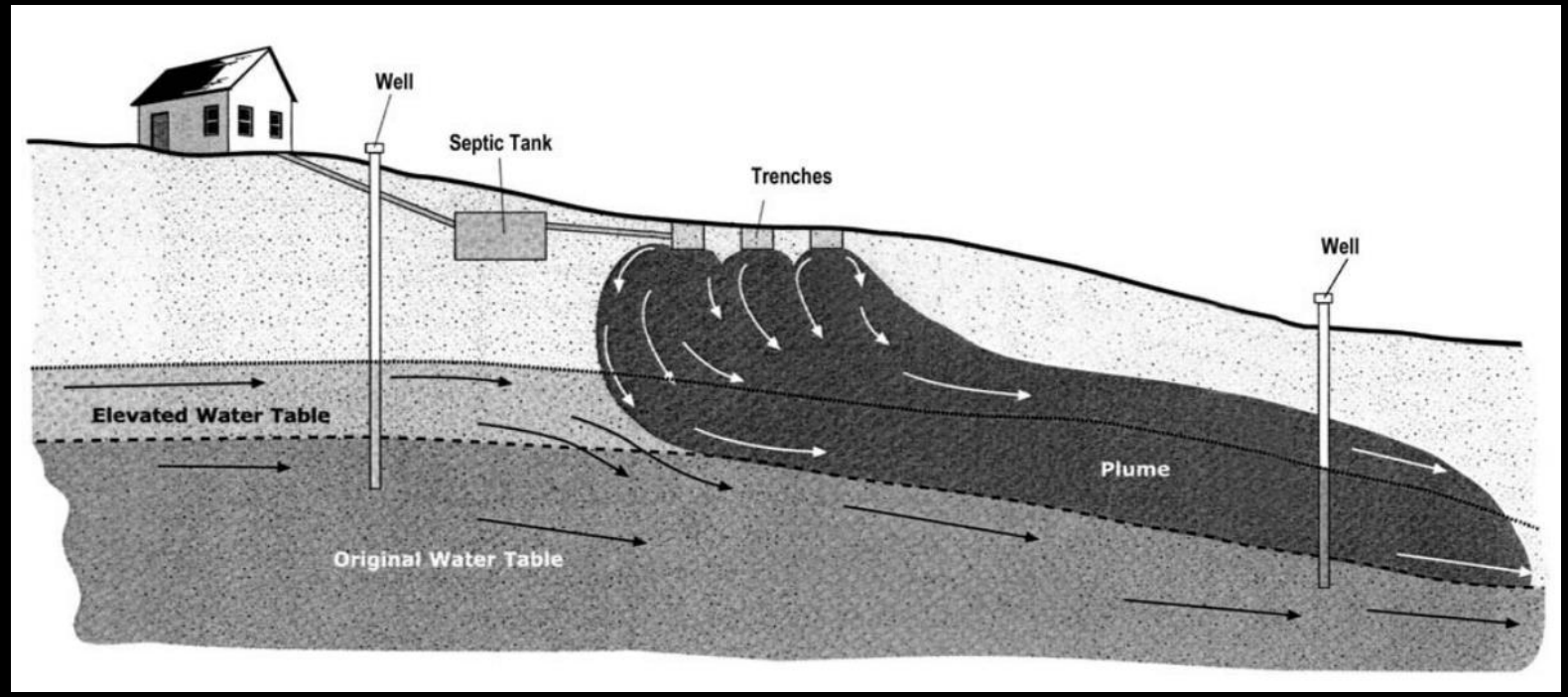
Acute

- System damage

Types of failure

Treatment

- Porous soils
- High water table



Types of failure

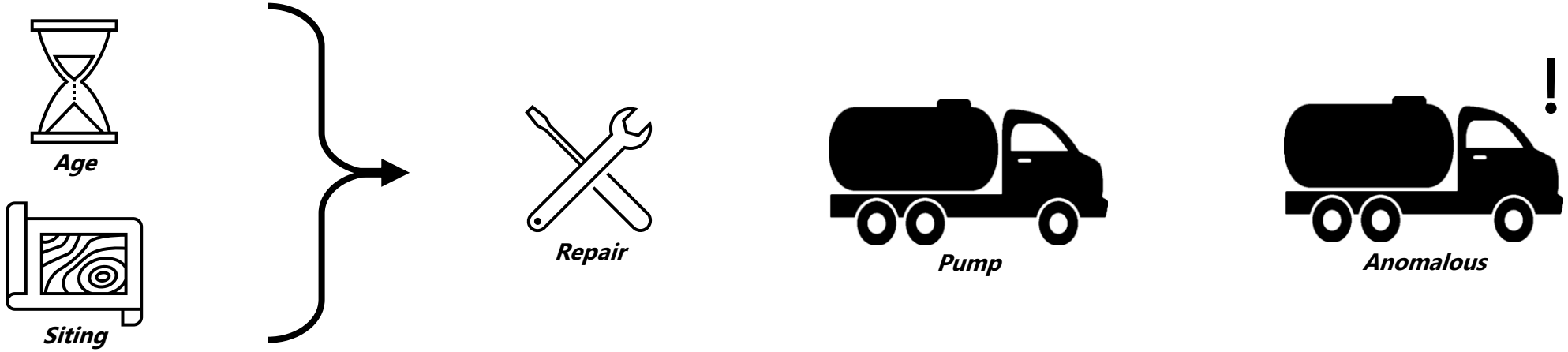
Hydraulic

- Low percolation rate
- Soil clogging
- System overuse
- Lack of maintenance

Today

- Blue-green-grey attributes of DWWTI at different spatial scales
- **Assessing larger scale patterns in system failure**
- Leach field function and failure
- Moving forward: partnerships to support clean water for healthy communities

What environmental variables may predict septic system repairs or pumping?



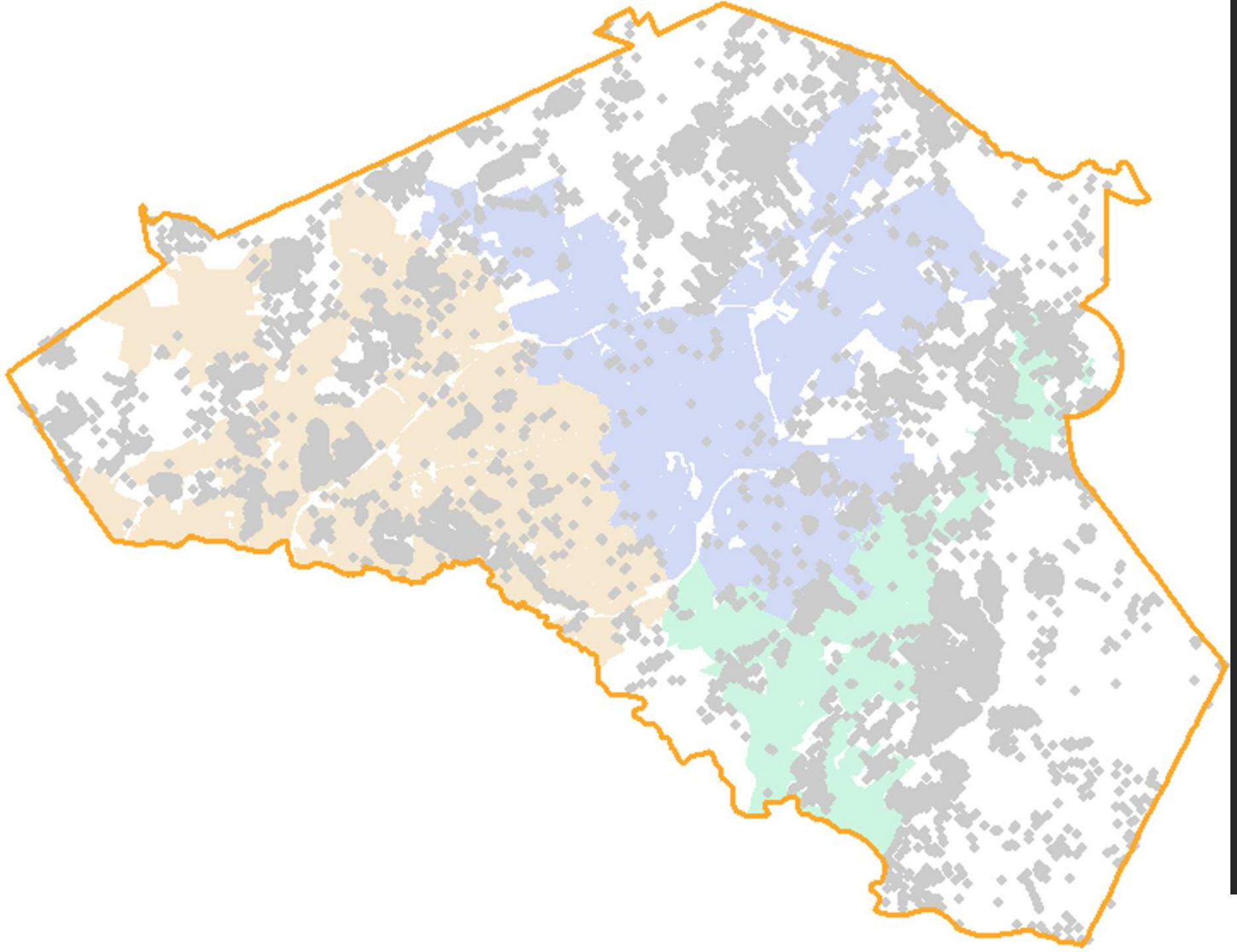
Pumping records

- Frequency
  - >1 pump
  - Typically once every 3-5 years

(US EPA 2020)

- Volume
  - Pumped volume > tank capacity

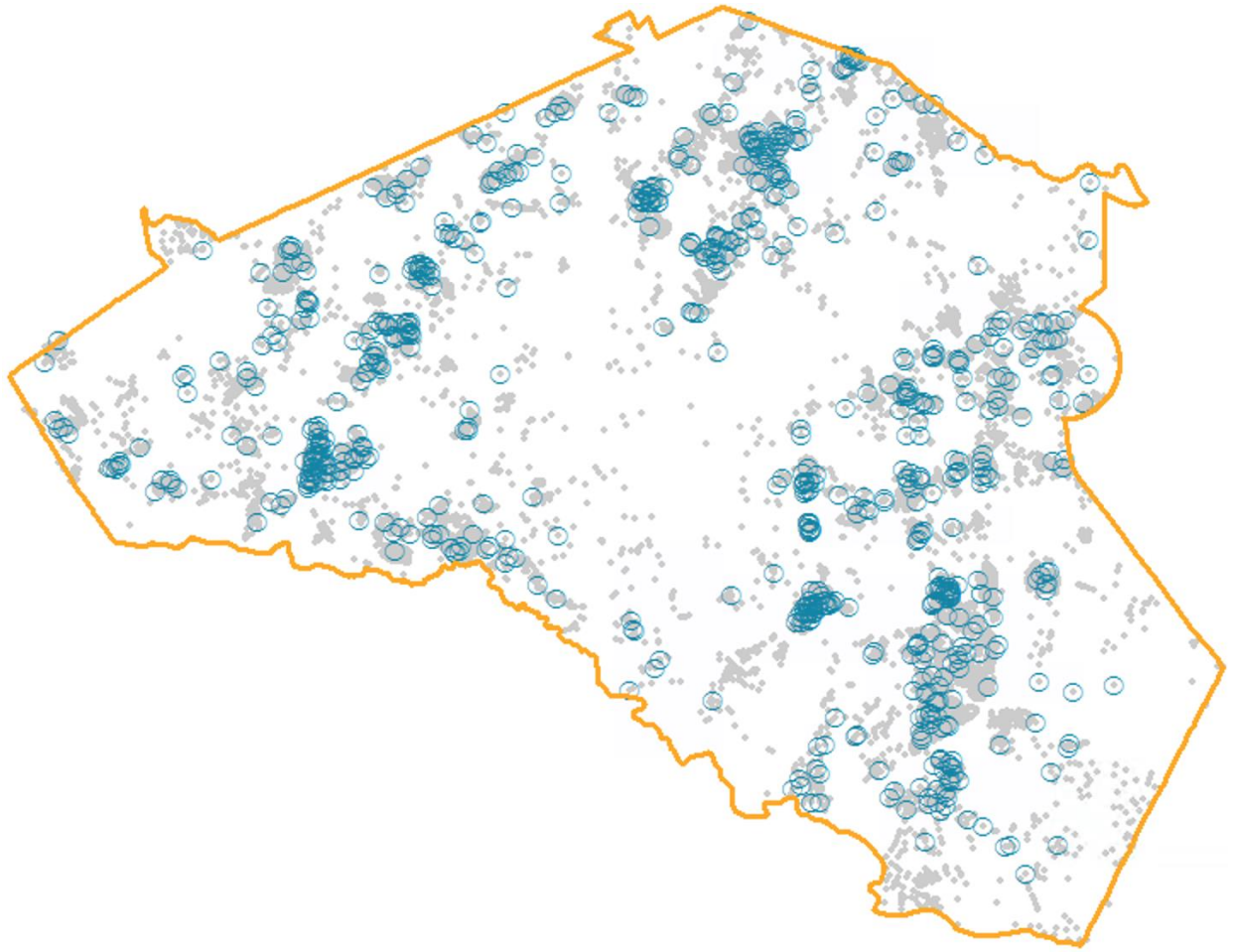
Anomalous



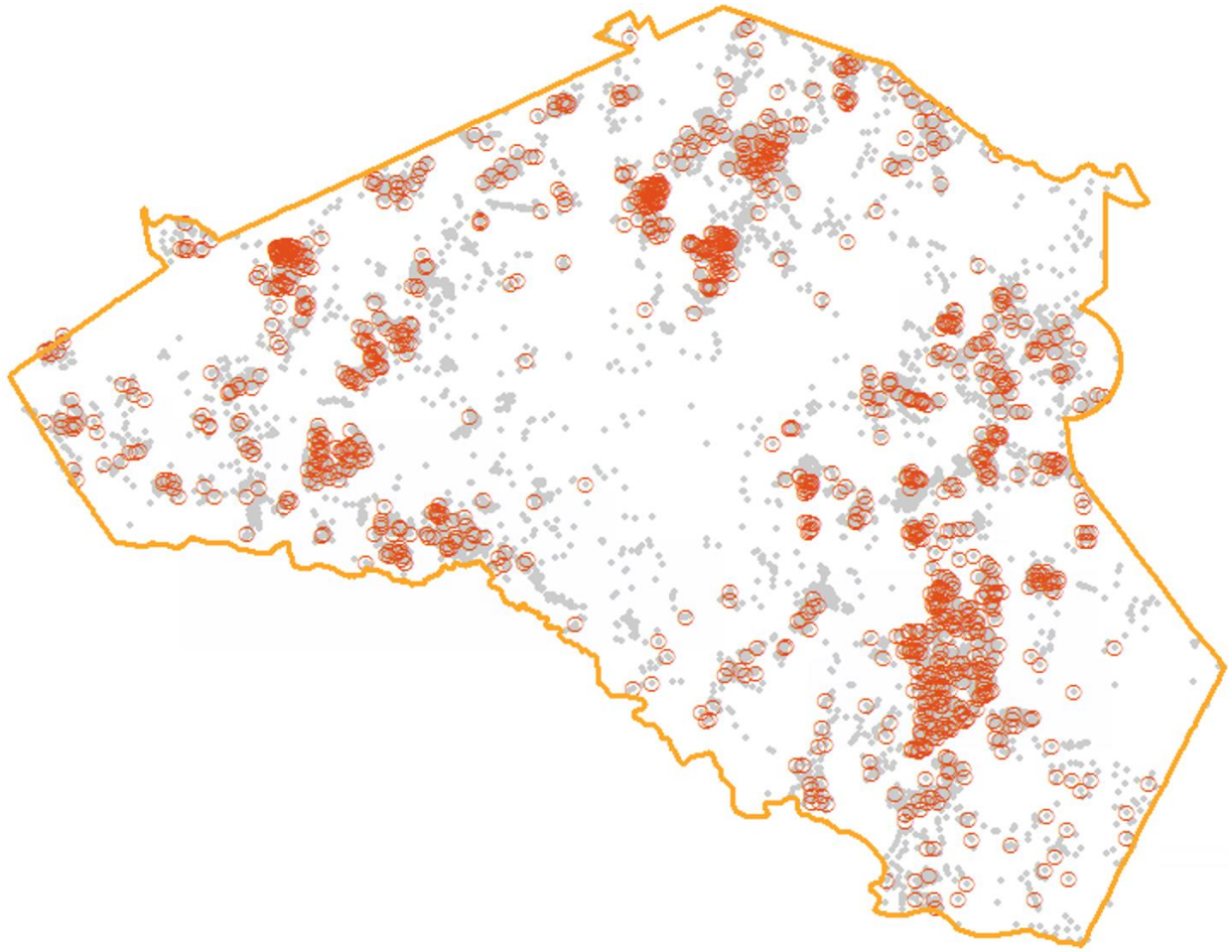
32,000
residents

9000
septic
systems

- Systems with **repair** records



Systems with **pumping** records



Pumping records: Jan. 2017 – Feb. 2020 (38 mos.)

- Frequency
  - >1 pump
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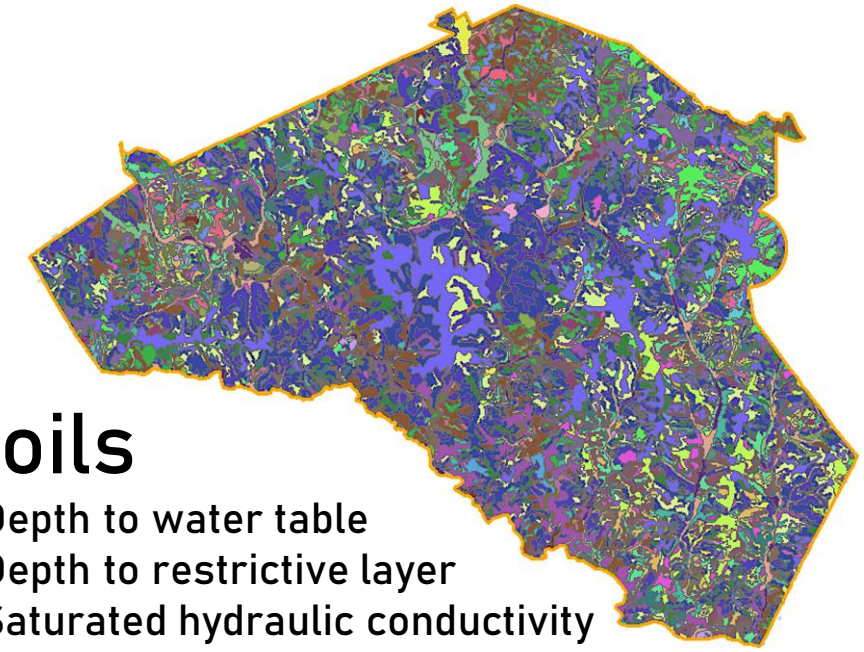
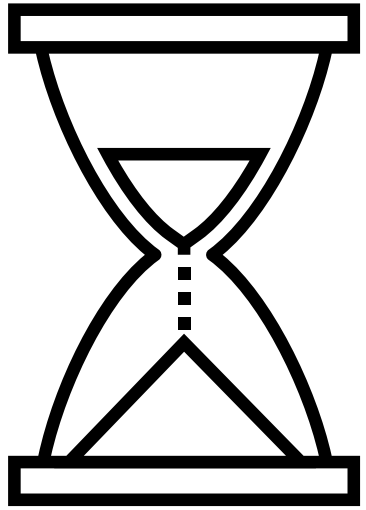
  (US EPA 2020)
- Volume
  - Pumped volume > tank capacity



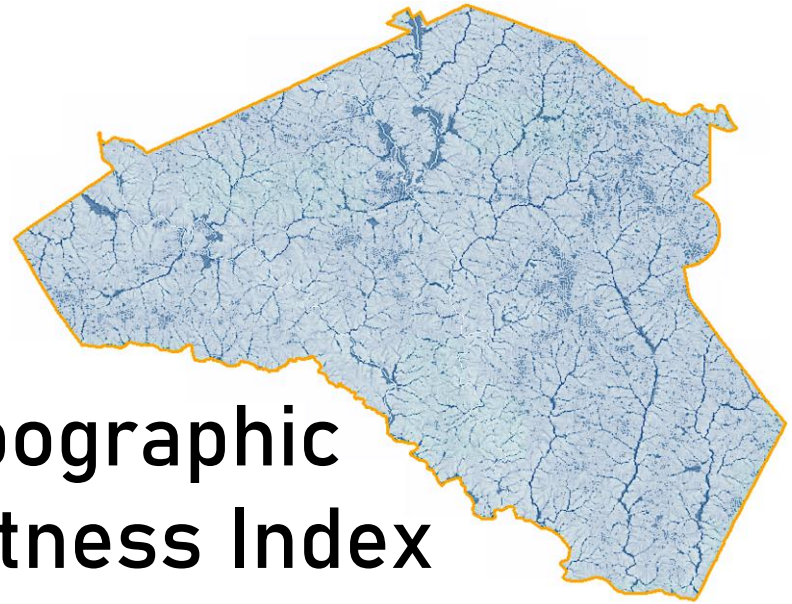
Soils

- Depth to water table
- Depth to restrictive layer
- Saturated hydraulic conductivity

Age



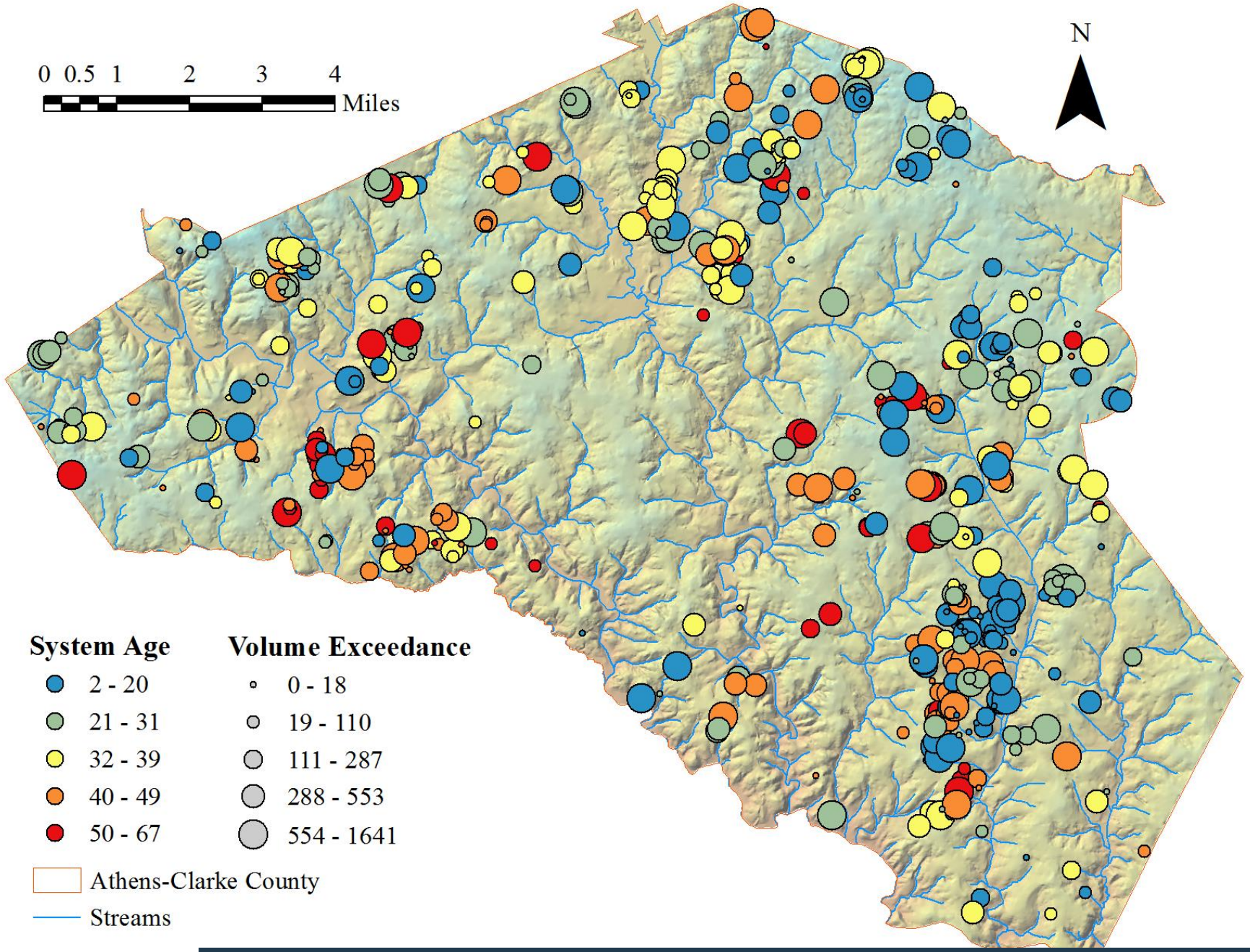
Distance to Stream



Topographic Wetness Index

Summary

- 7.9% of systems repaired; median age of 65 years
- 1605 pumping records from 1076 septic systems
- 12% of systems pumped; median age of 33 years
- 638 systems with anomalous pumping
  - 576 with volume exceedance
  - 218 were pumped more than once



Connelly, K. N., Wenger, S. J., Gaur, N., McDonald, J. M. B., Occhipinti, M., & Capps, K. A. (2023). Assessing relationships between onsite wastewater treatment system maintenance patterns and system-level variables. *Science of The Total Environment*, *870*, 161851.

Today

- Blue-green-grey attributes of DWWTI at different spatial scales
- Assessing larger scale patterns in system failure
- **Leach field function and failure**
- Moving forward: partnerships to support clean water for healthy communities

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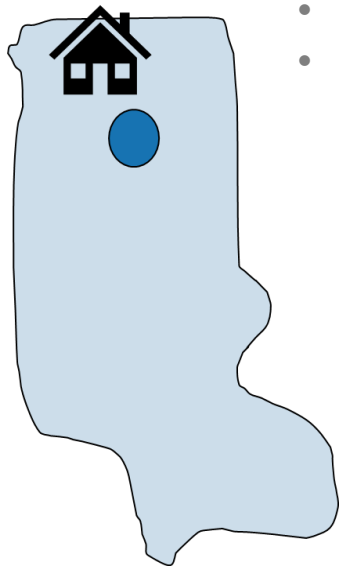
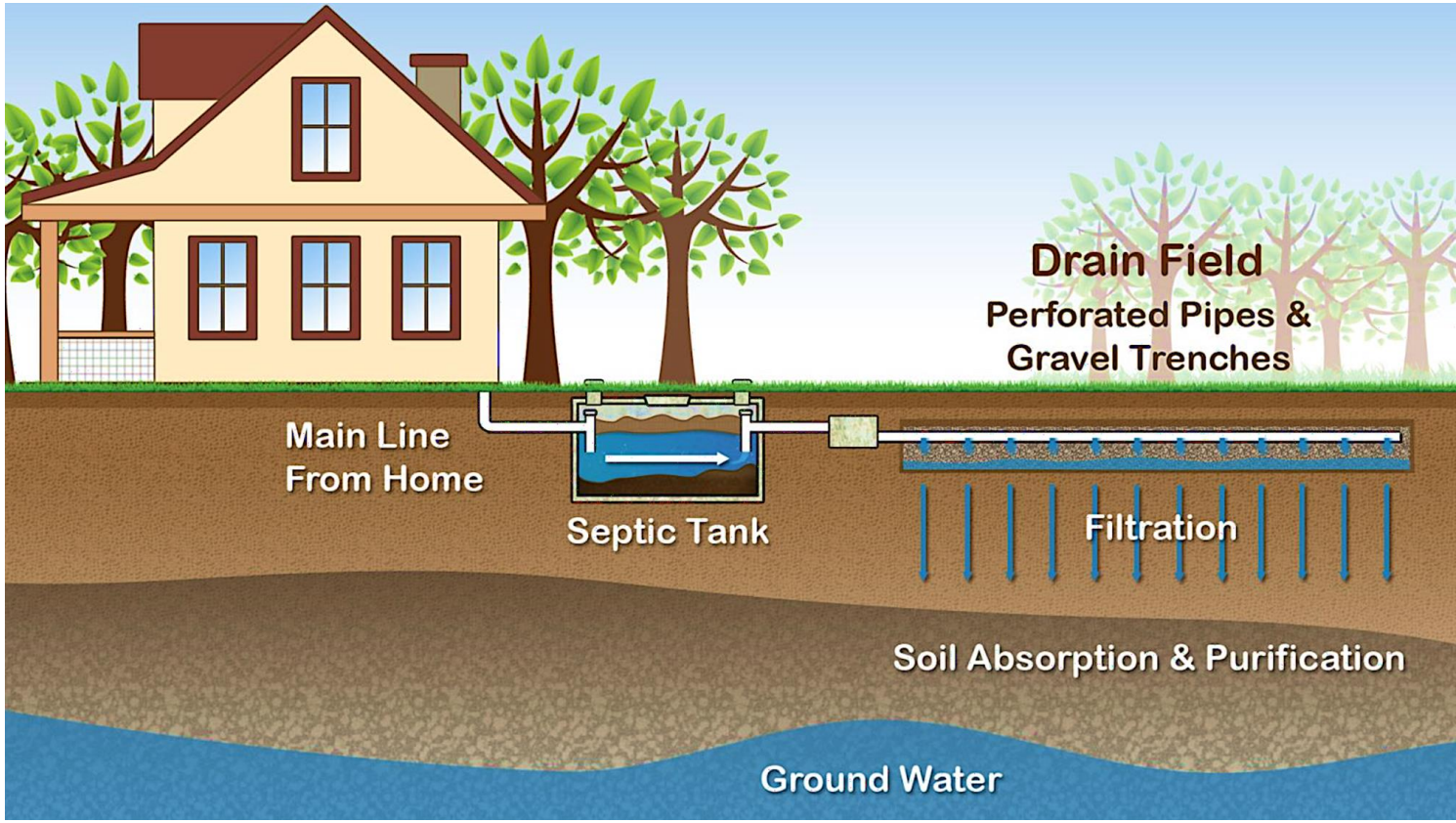
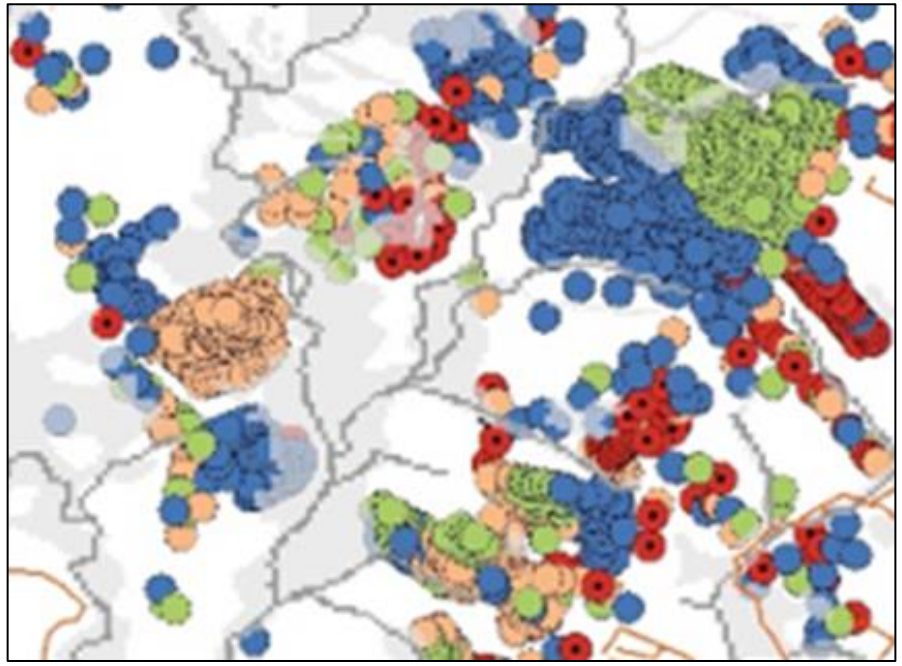


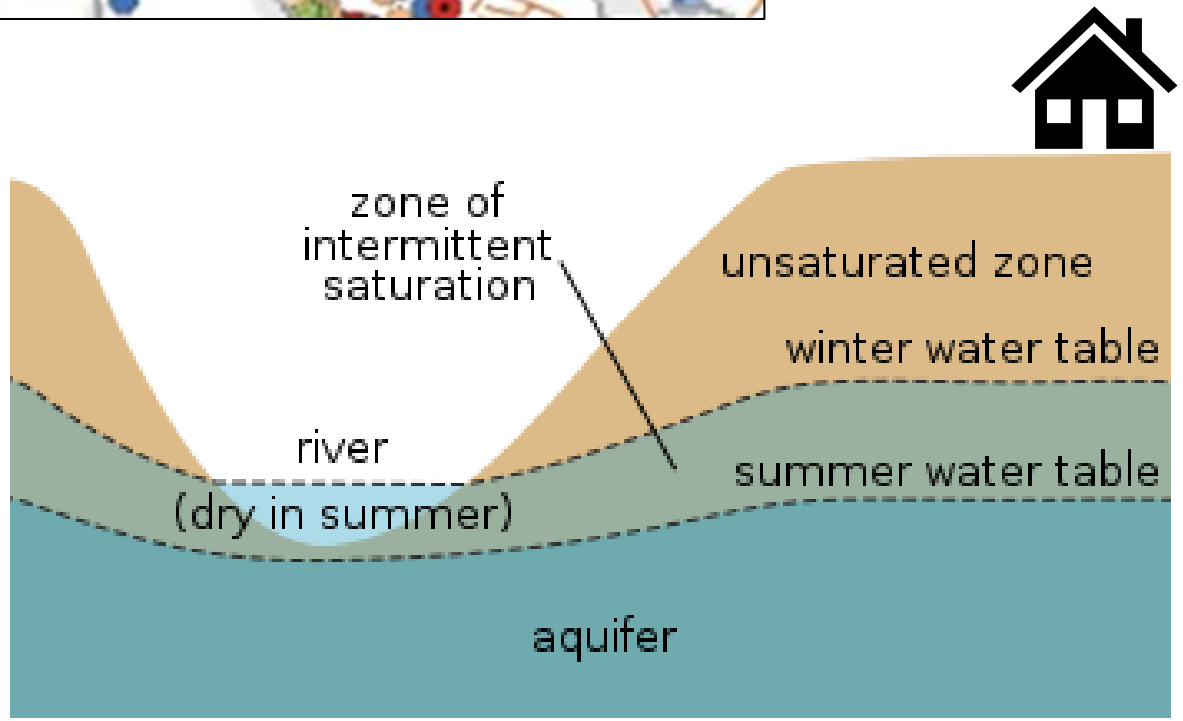


System Risk

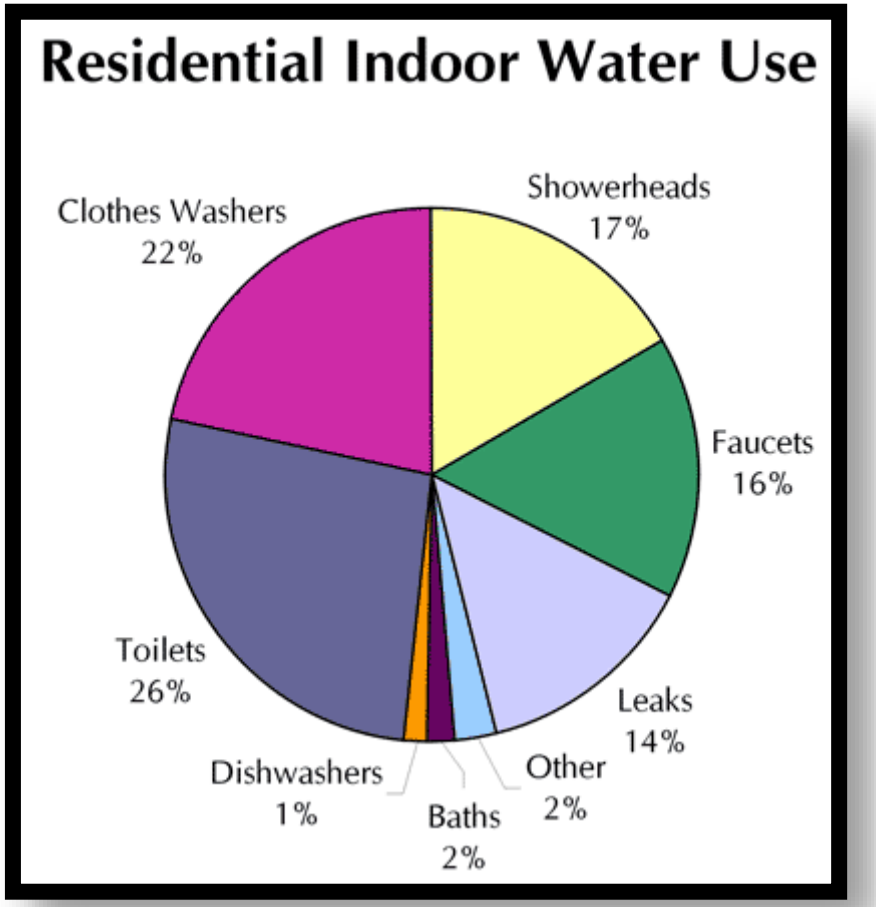
- Home water use
- System condition
  - Condition/Maintenance
  - Types of leach field
- Soils, and landscape location
- Weather and groundwater levels

How do these factors combine to create risk?





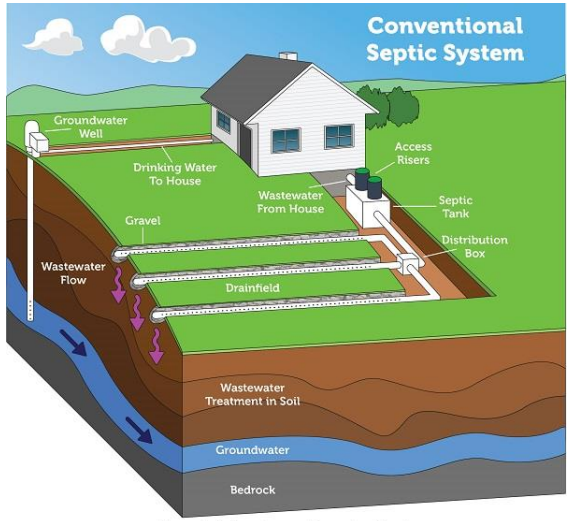
Home water use



Greensboro, NC

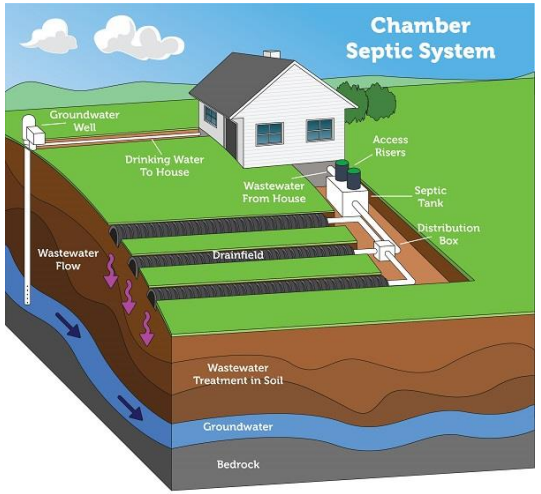
- Leaks can add upto 14% more into the system.

Types of leach fields



Please note: Septic systems vary. Diagram is not to scale.

Conventional



Please note: The ends of the chamber system lines are open for illustrative purposes only. In reality, and when properly installed, these lines are closed at the end. Septic systems vary. Diagram is not to scale.

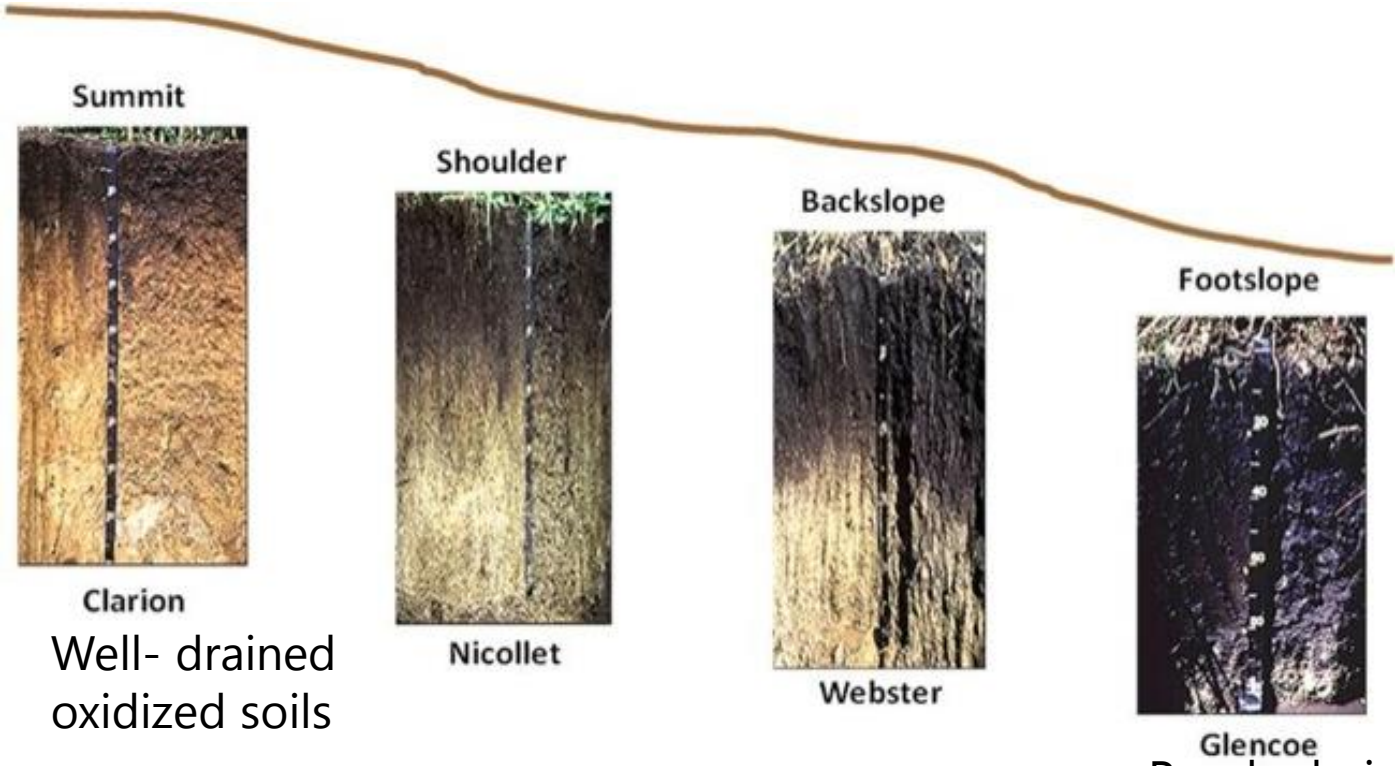
Different rates of failure?

Chamber

Image credits: https://web.uri.edu/owt/homeowners/understanding-septic-systems/


Image credits: https://www.septicplus.com/GravitySystem.htm

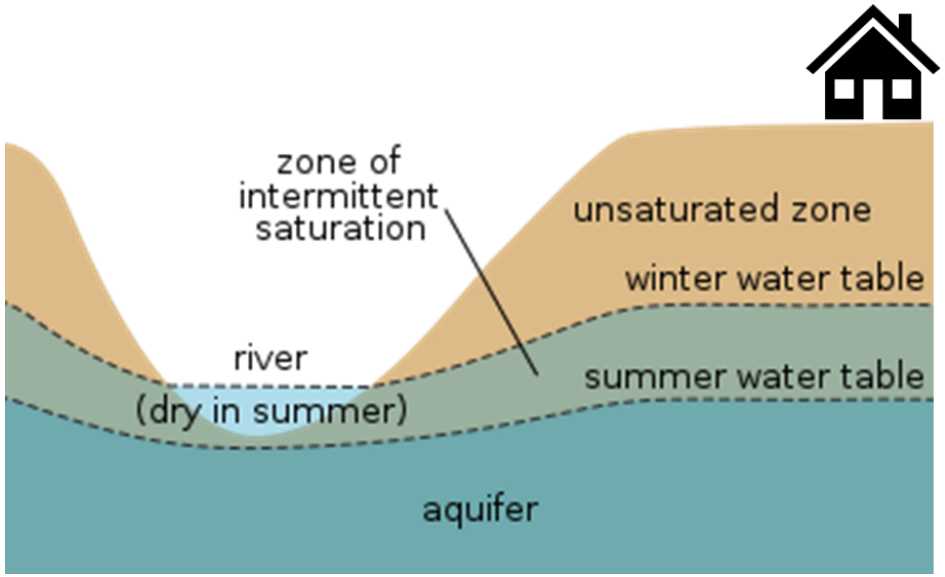
Soil variation with landscape location



Well- drained oxidized soils

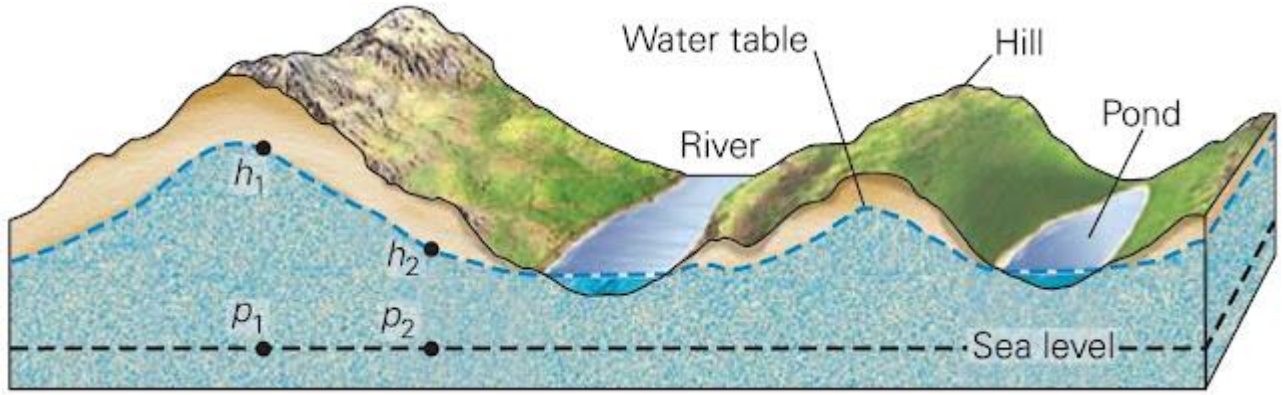
Poorly drained reduced soils

Swanson, H., 2003.

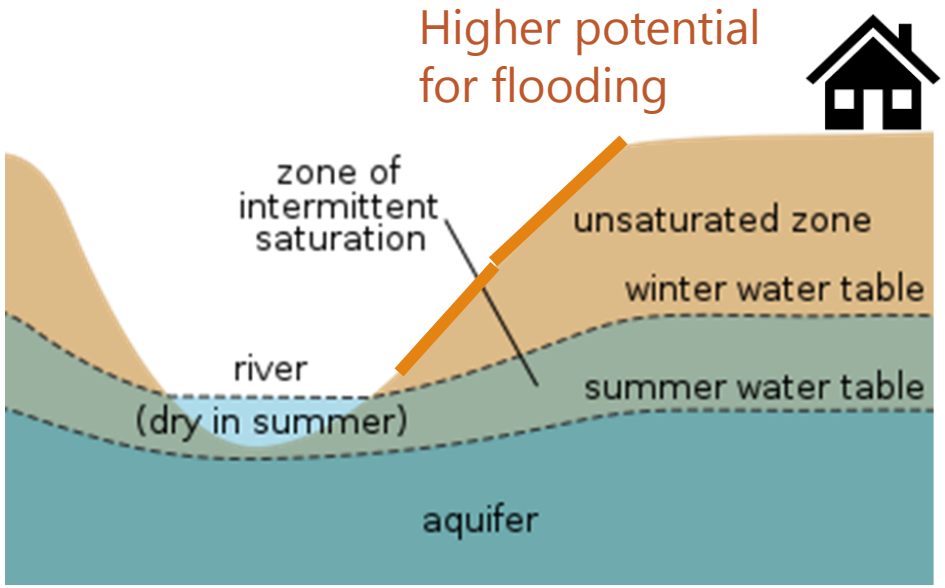


Variable soils, sub-surface conditions and landscape locations within a leach field make leach field failure a potential space-time process

Ground water profiles along hillslopes in different seasons



Learning geology



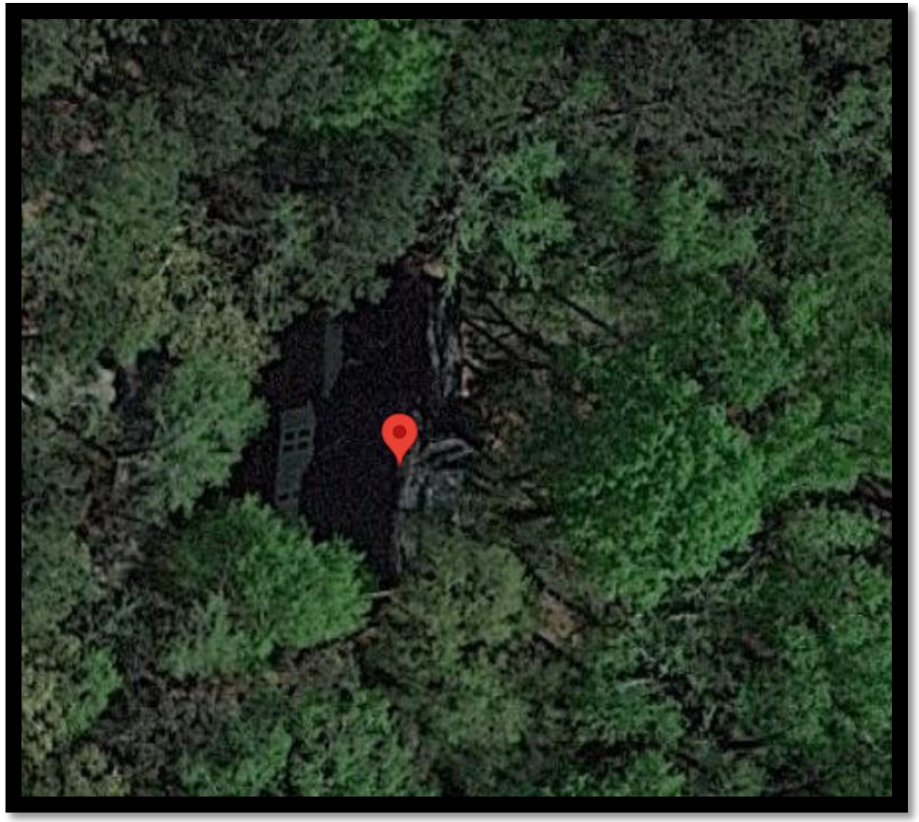
Wikipedia

Saturation excess flow alters flooding potential across landscape locations

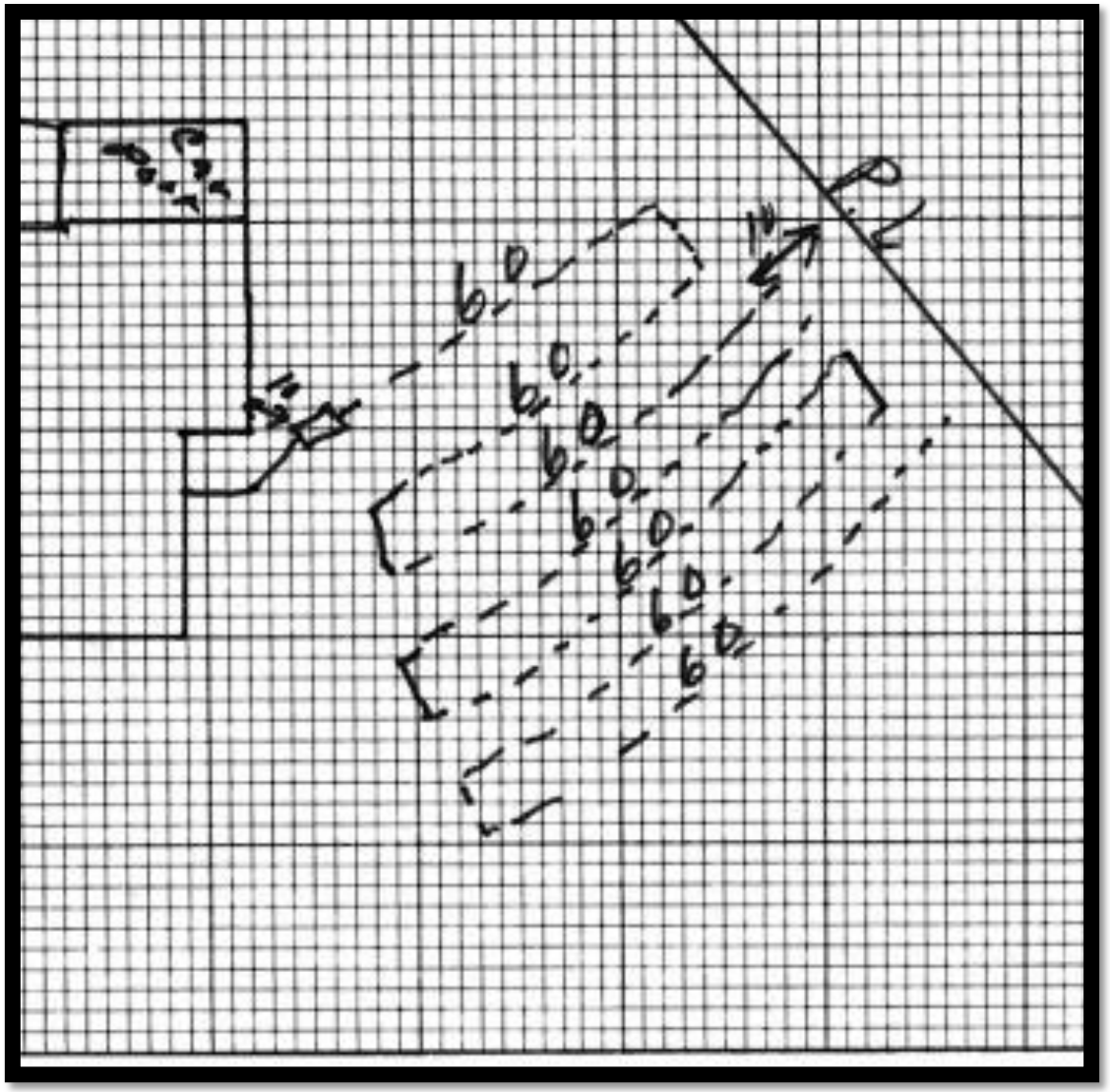
Research Approach

- Lots of variability in factors creating risk.
- Monitor effluent levels at a high spatial and temporal resolution.
- Correlate with environmental conditions.
- Case study of three houses

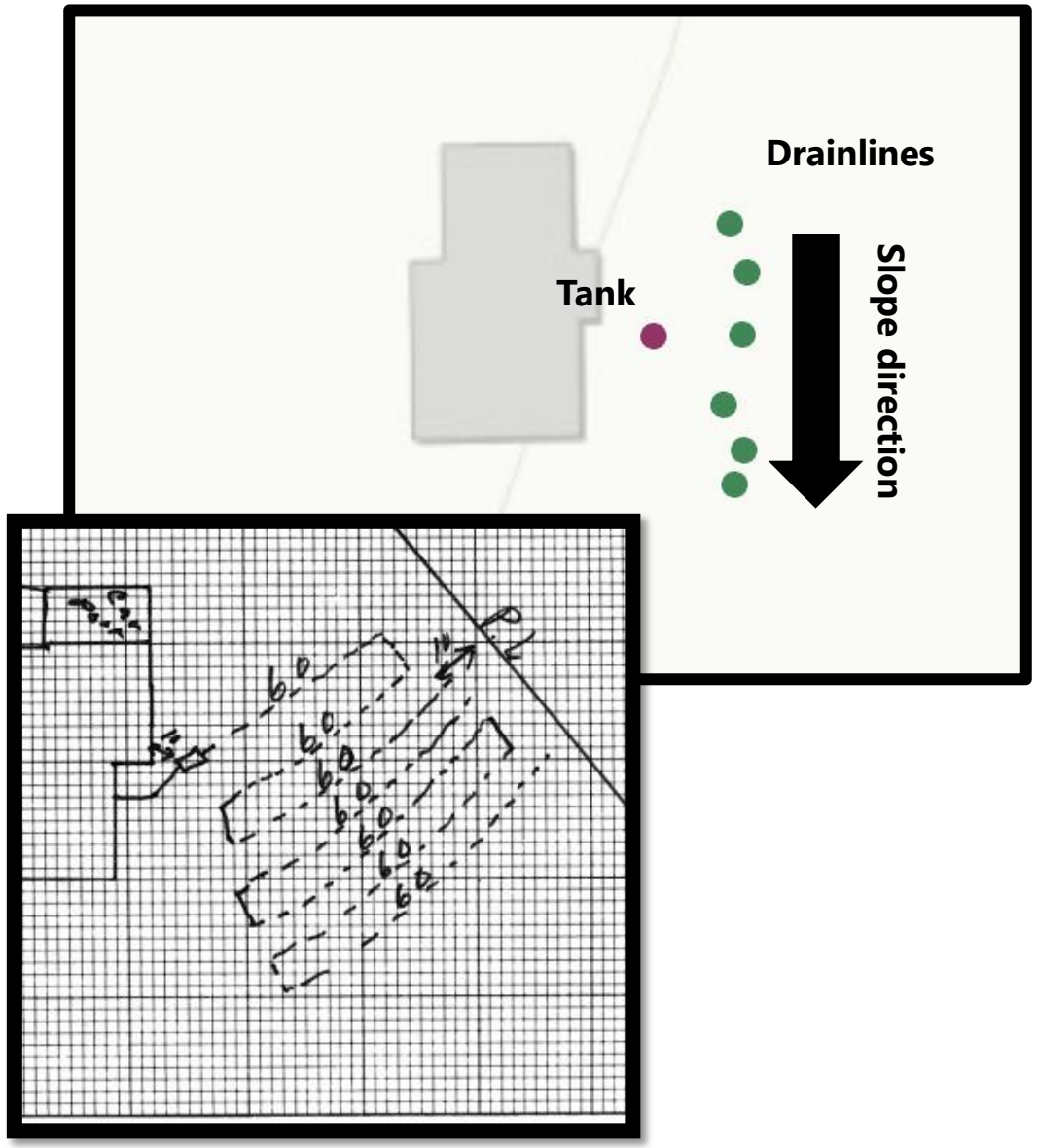
House 1

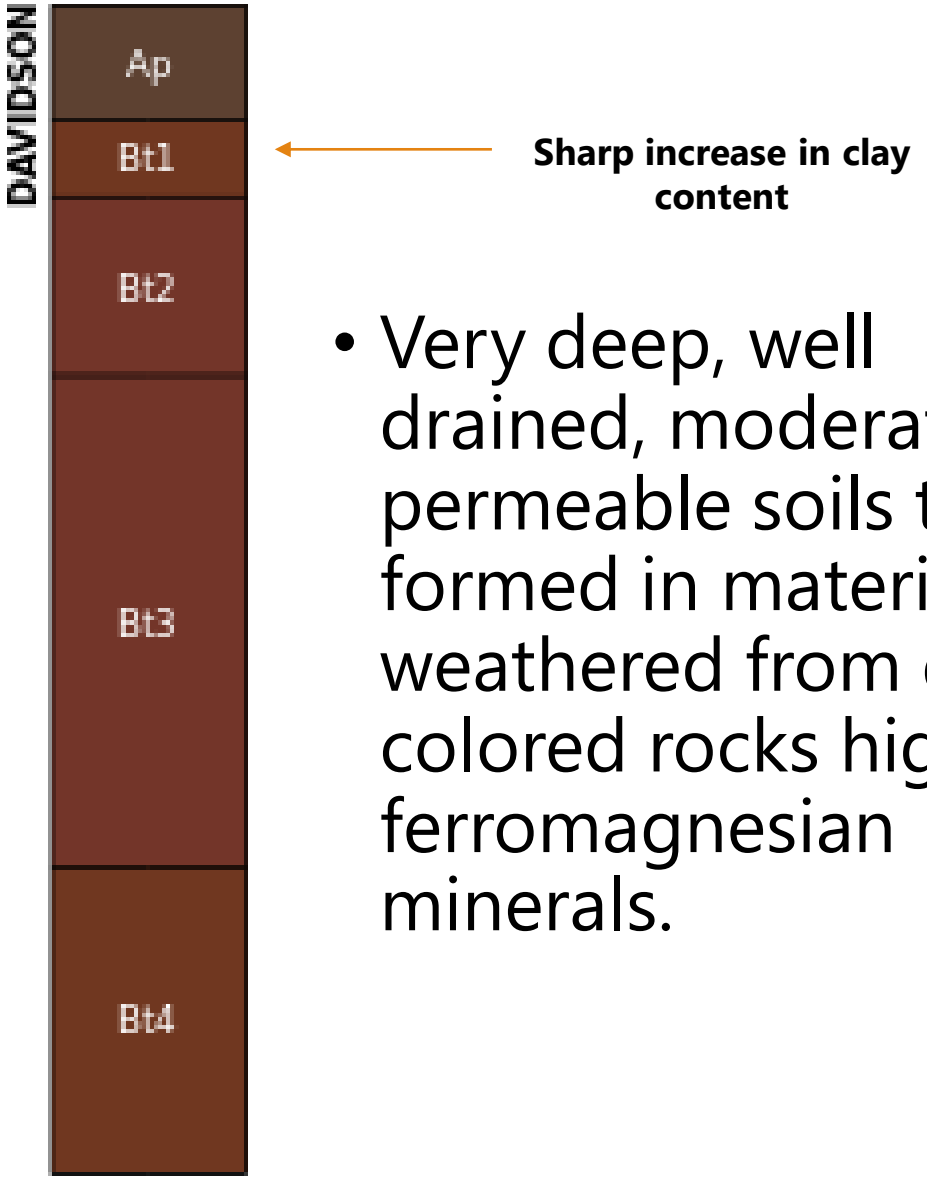


Conventional system with large trees on leach field



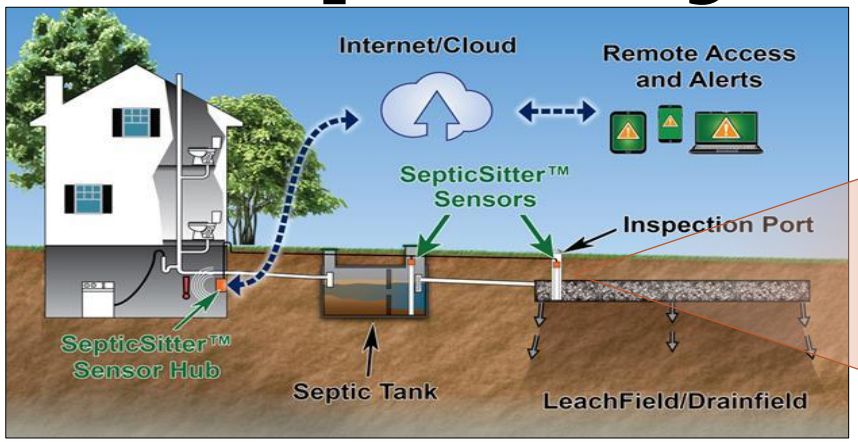
Soil (SSURGO) & landscape location

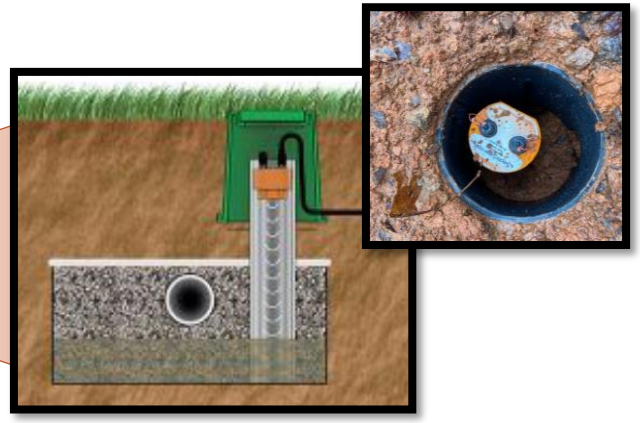


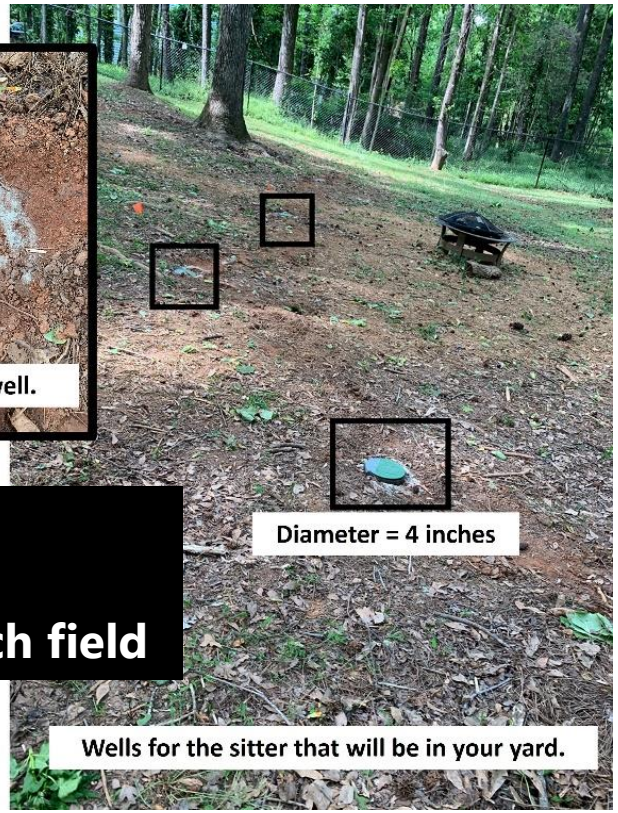


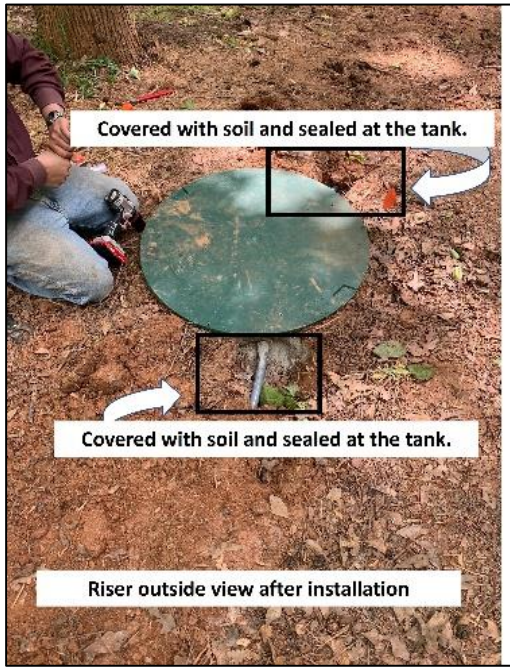
- Very deep, well drained, moderately permeable soils that formed in materials weathered from dark colored rocks high in ferromagnesian minerals.

Septic System Monitoring



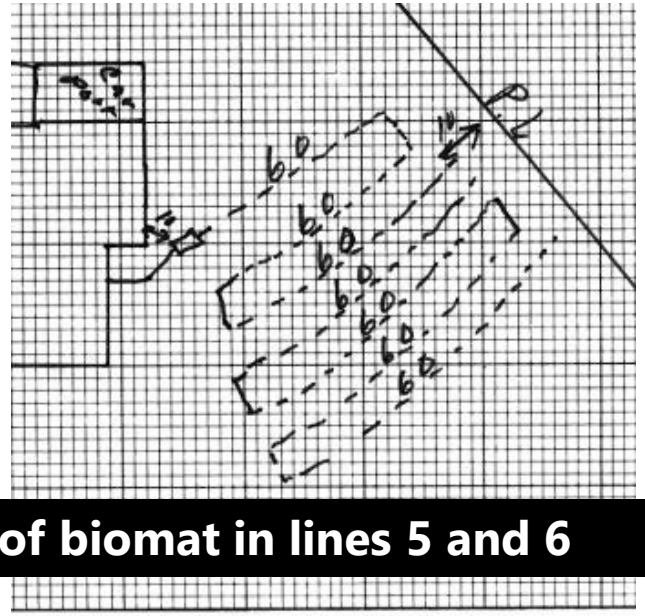




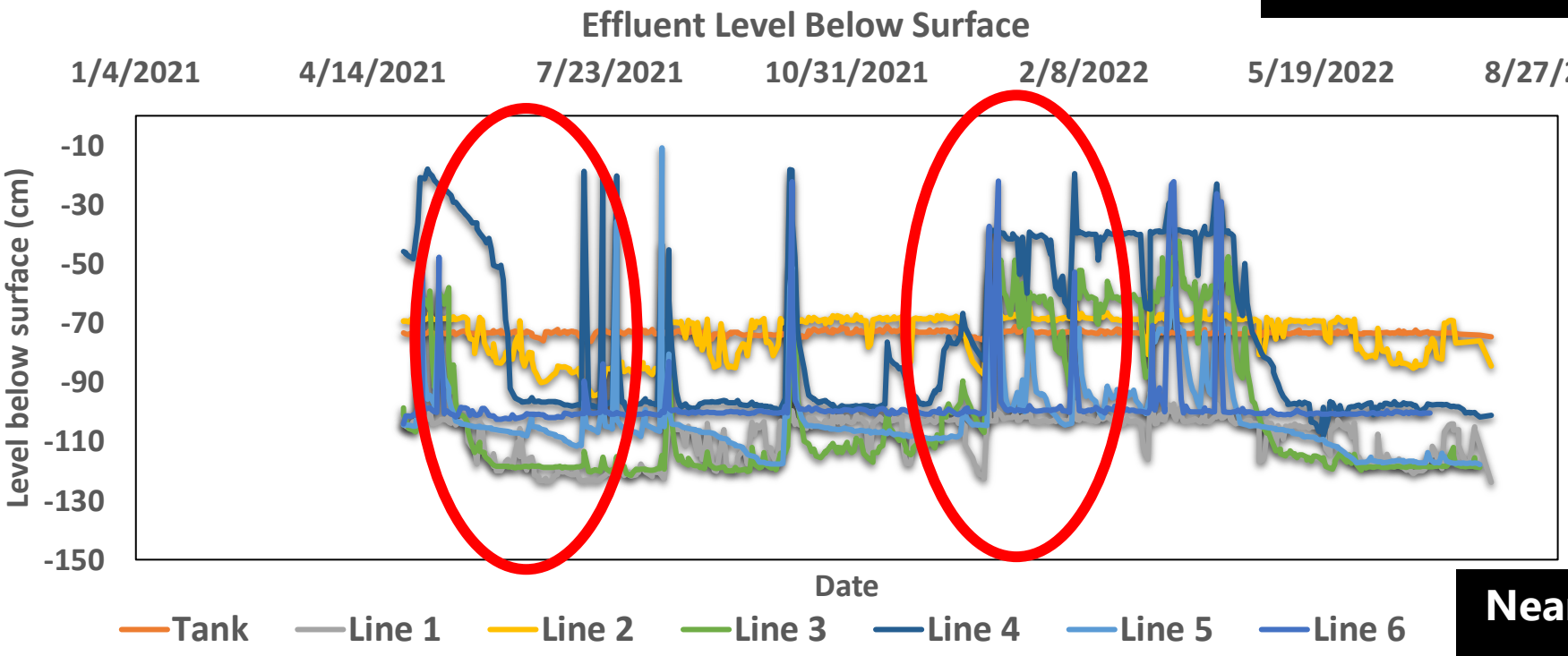


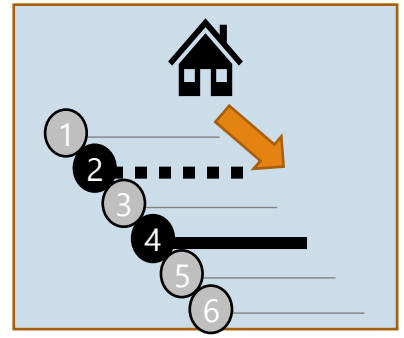
Effluent Levels in
1. **Tank**
2. **Each trench line in the leach field**

Temporal variation in septic effluent levels- House 1

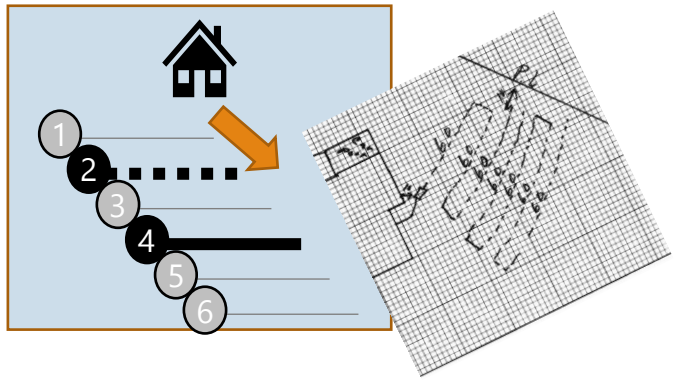


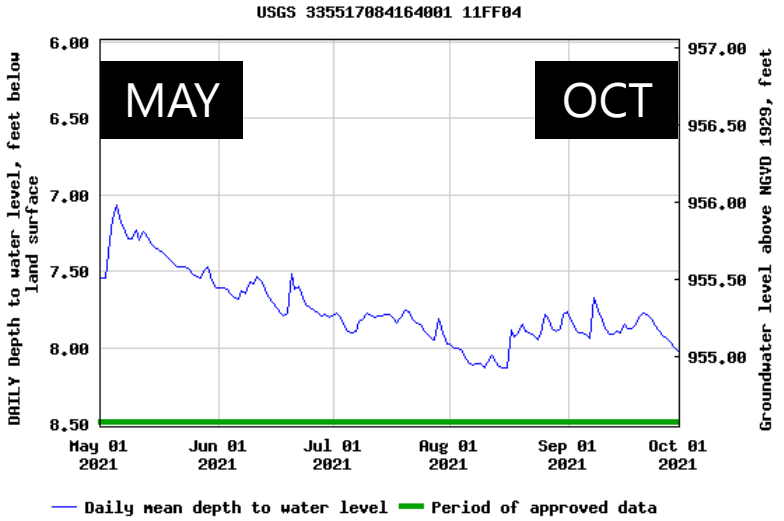
No evidence of biomat in lines 5 and 6

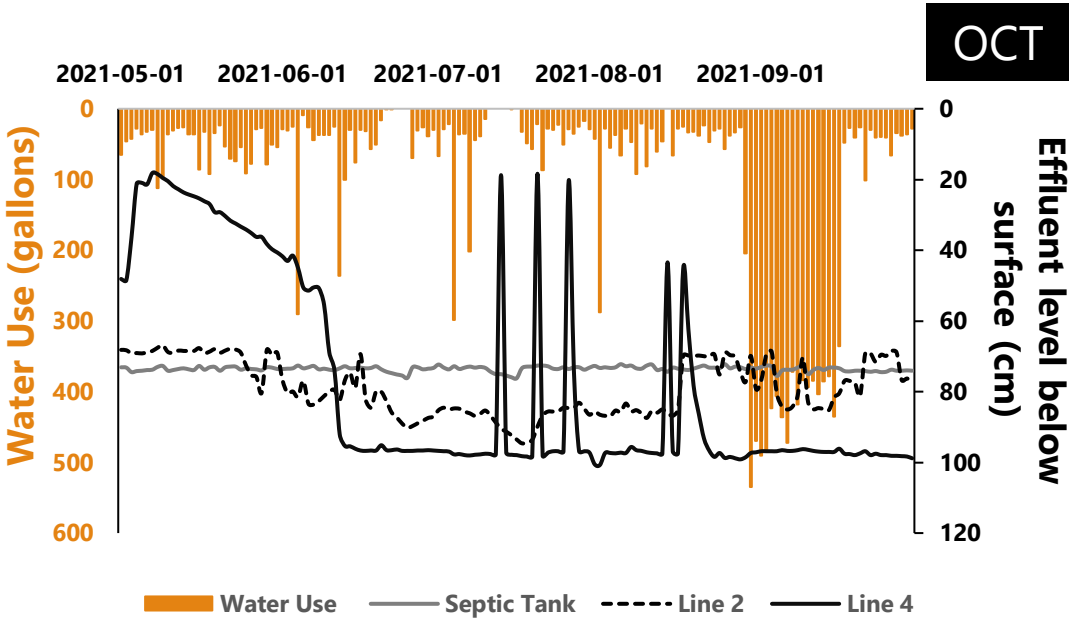


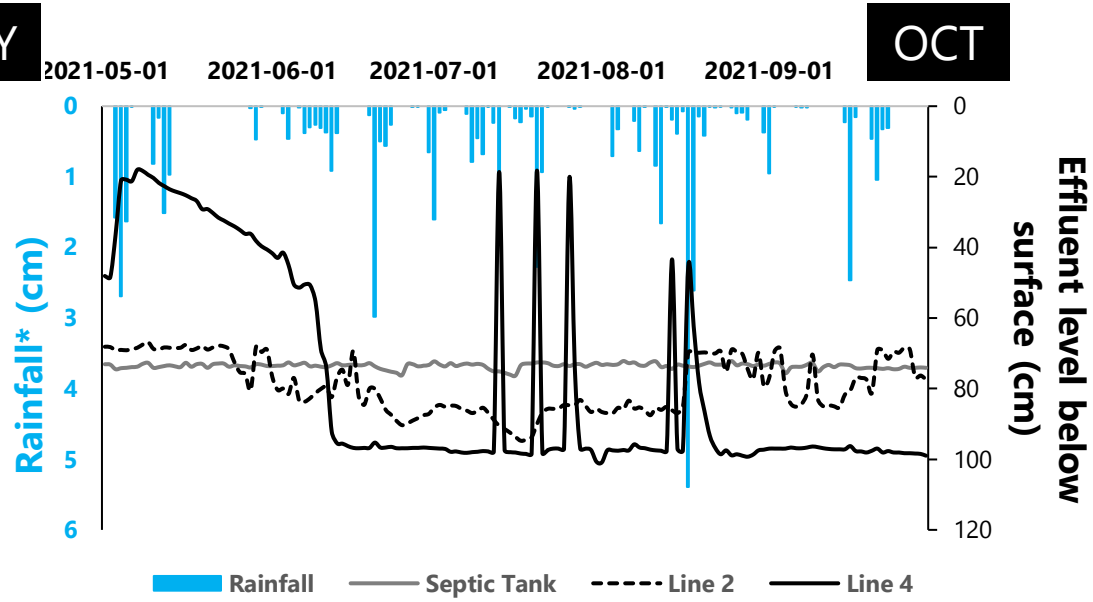


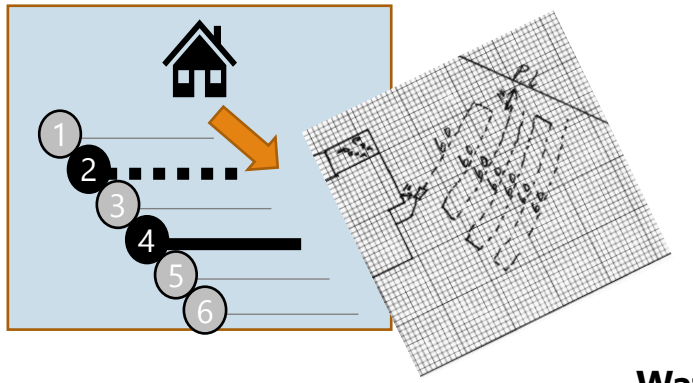
Near-failing conditions in drain lines that are downslope


1
2
3
4
5
6

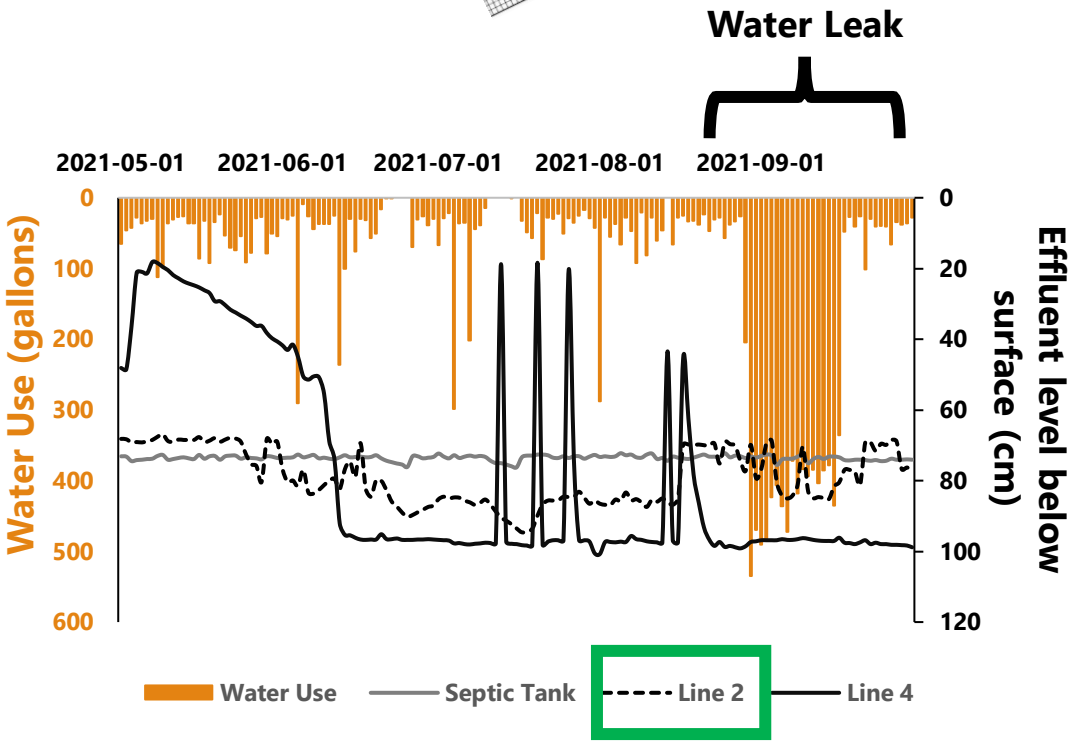

USGS 335517084164001 11FF04
MAY
OCT
DAILY Depth to water level, feet below land surface
Groundwater level above NGVD 1929, feet
6.00
6.50
7.00
7.50
8.00
8.50
957.00
956.50
956.00
955.50
955.00
May 01 2021
Jun 01 2021
Jul 01 2021
Aug 01 2021
Sep 01 2021
Oct 01 2021
Daily mean depth to water level
Period of approved data

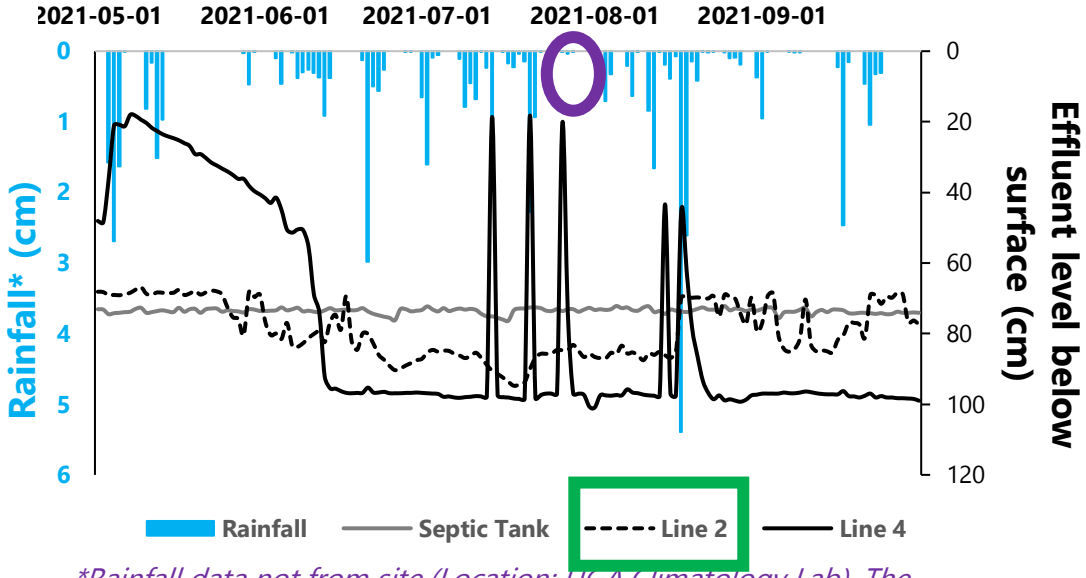

OCT
MAY
2021-05-01
2021-06-01
2021-07-01
2021-08-01
2021-09-01
Water Use (gallons)
0
100
200
300
400
500
600
Effluent level below surface (cm)
0
20
40
60
80
100
120
Water Use
Septic Tank
Line 2
Line 4


OCT
2021-05-01
2021-06-01
2021-07-01
2021-08-01
2021-09-01
Rainfall* (cm)
0
1
2
3
4
5
6
Effluent level below surface (cm)
0
20
40
60
80
100
120
Rainfall
Septic Tank
Line 2
Line 4

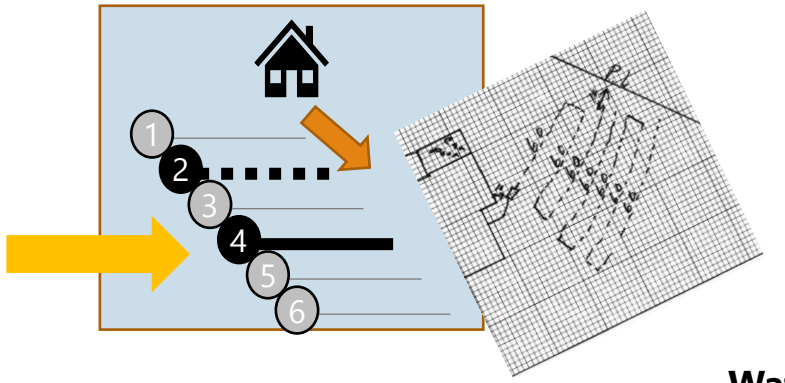


Unlike variation in line 4, line 2 maybe responding to water use in the home.



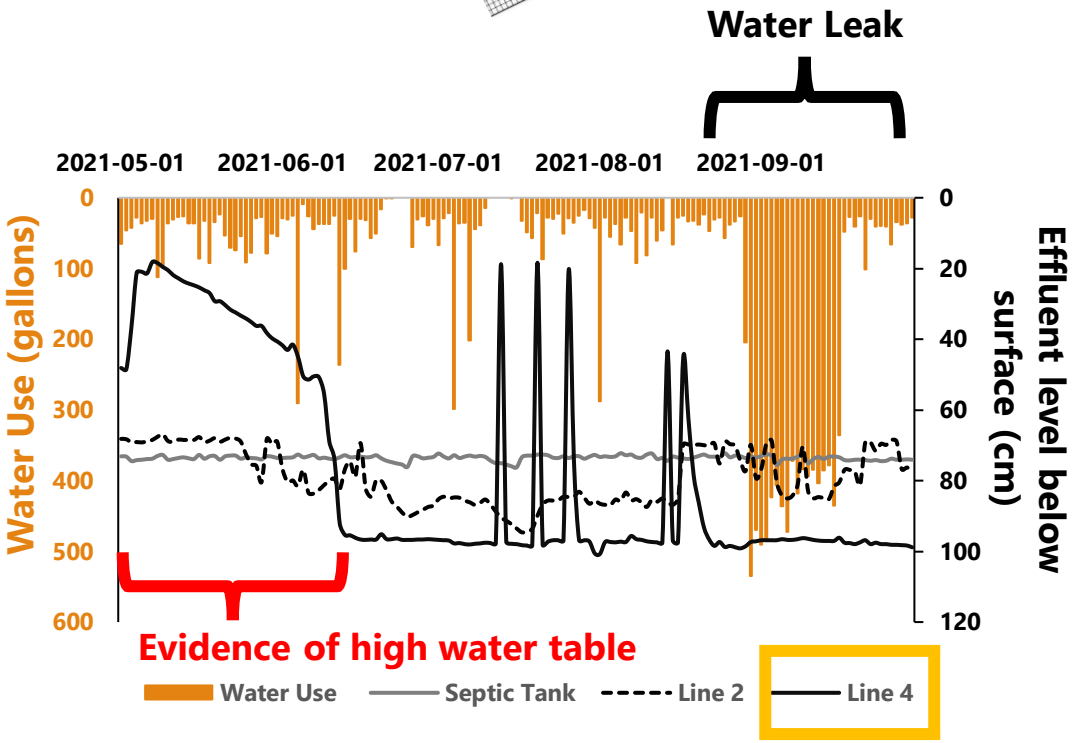


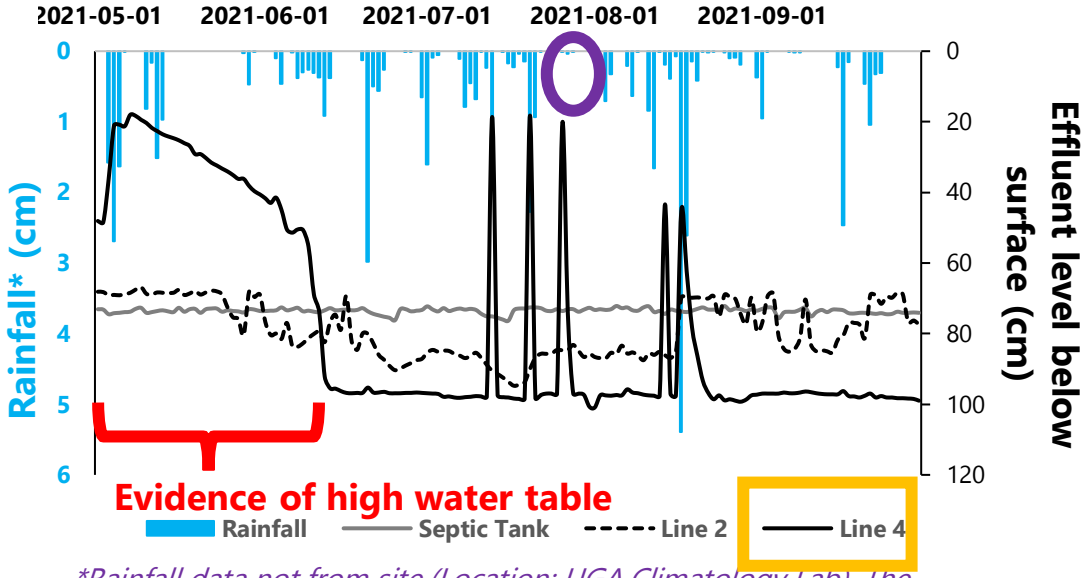
**Rainfall data not from site (Location: UGA Climatology Lab). The encircled data rainfall is likely not representative of our site since Athens often has highly localized rainfall events.*



Variation in line 4 is responding to weather events.

The duration of shallow effluent in the trench seems related to water table.



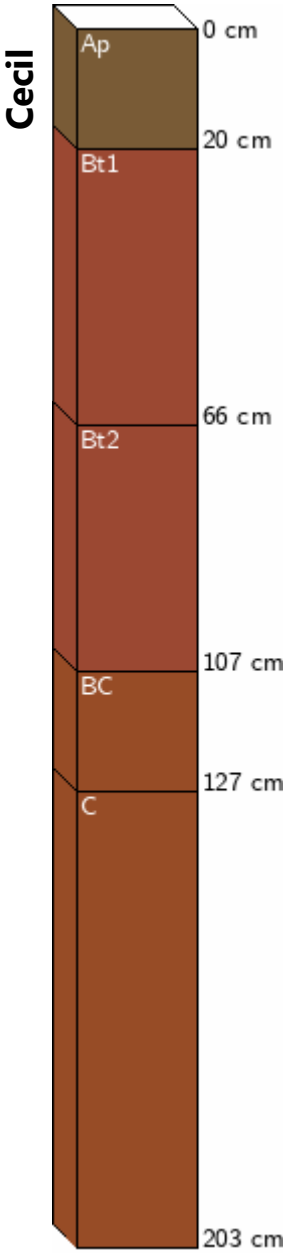


**Rainfall data not from site (Location: UGA Climatology Lab). The encircled data rainfall is likely not representative of our site since Athens often has highly localized rainfall events.*

Temporal variation in septic effluent levels- House 2

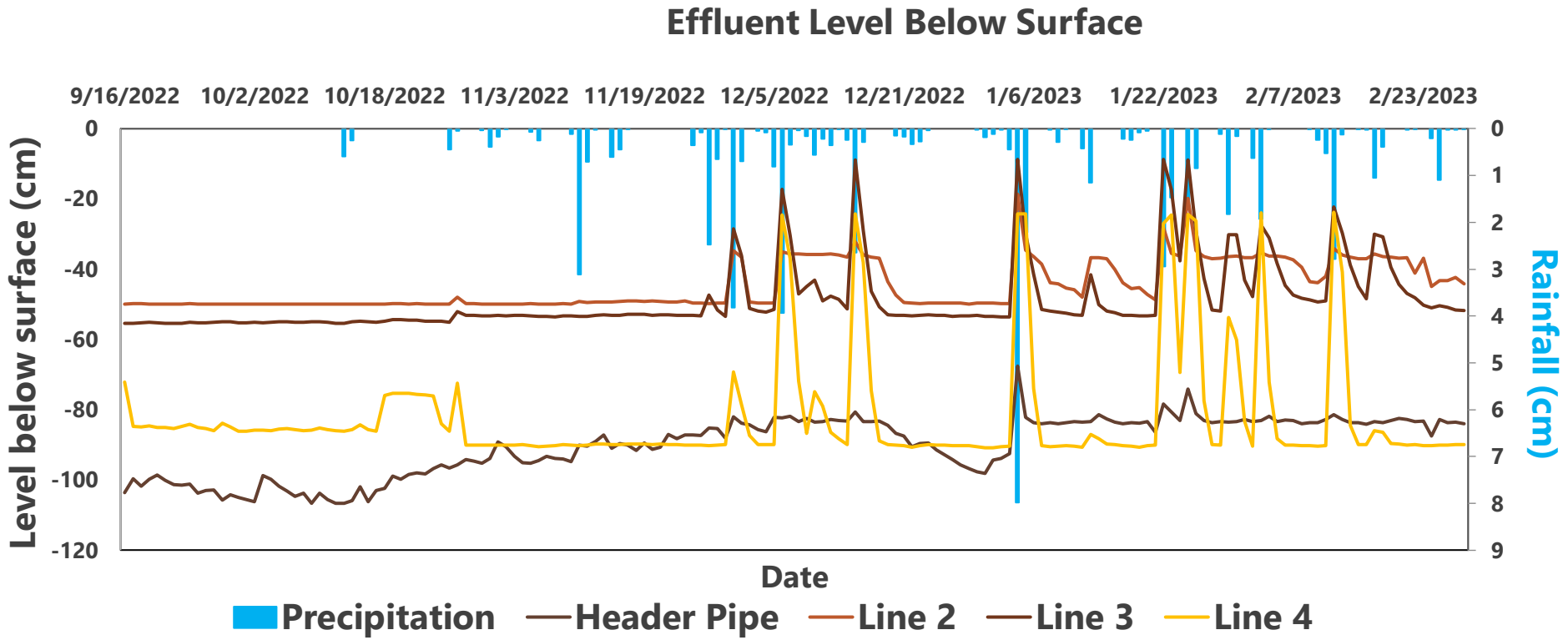
Terrace in backyard and leach field lies both within and outside the terrace

Header Pipe



Note: Points are not georeferenced in this image

Temporal variation in septic effluent levels- House 2



No evidence of biomat in any line except for header pipe

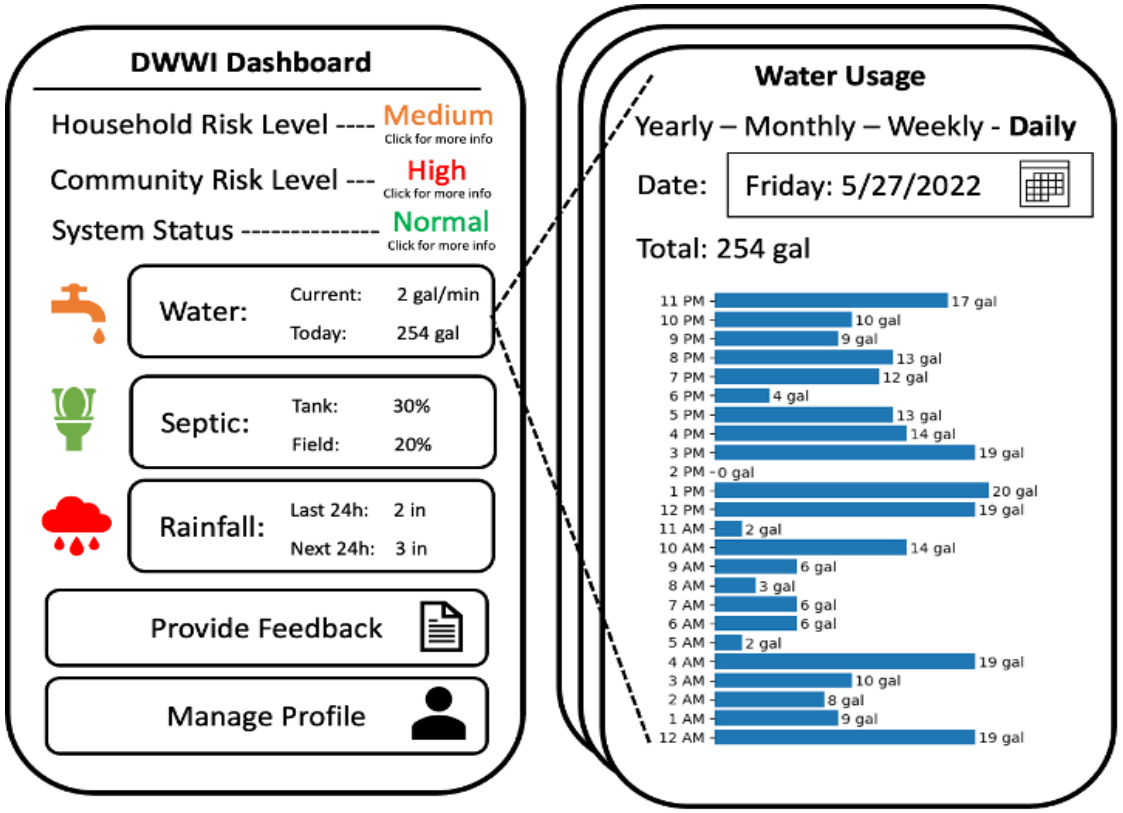
Should the header pipe be perforated?

Near-failing conditions in drain lines that are downslope

Inferences

- Not all drainlines are being used equally.
- Downslope drainlines for a well functioning system can also fail in response to high water table coupled with high rainfall but will not pollute the watersheds unless water use is sufficient to fill entire drainfield.
- Combining disparate data sources including groundwater levels, home water use and topography of the leach field may help identify conditions when certain systems may fail or an entire watershed is set to fail

SMART SEPTIC – Bringing septic systems into the 21st century



(*left*) Smart Septic dashboard (Homeowner interface). (*right*) Homeowner can click on water use and drill down further into water use per hour and appliance.

- Homeowner is empowered to manage water use and assess threat to home
- Similar interface for counties can aid resource allocation to prevent large scale pollution due to septic systems

UNIVERSITY OF GEORGIA

Thank you for listening!

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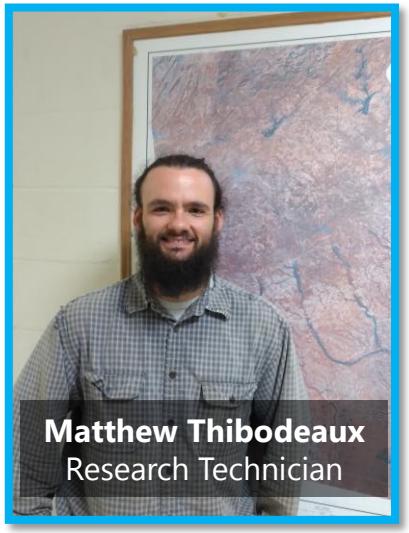
Dr. Jake McDonald
Dr. Rebecca Abney
Ms. Cheryl Shaw
Mr. David Bloyer
Mr. Daniel Johnson
Mr. Keith Higgs
Mr. Tim Callahan



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