Water Infrastructure Sustainability & Health in Alabama's Black Belt

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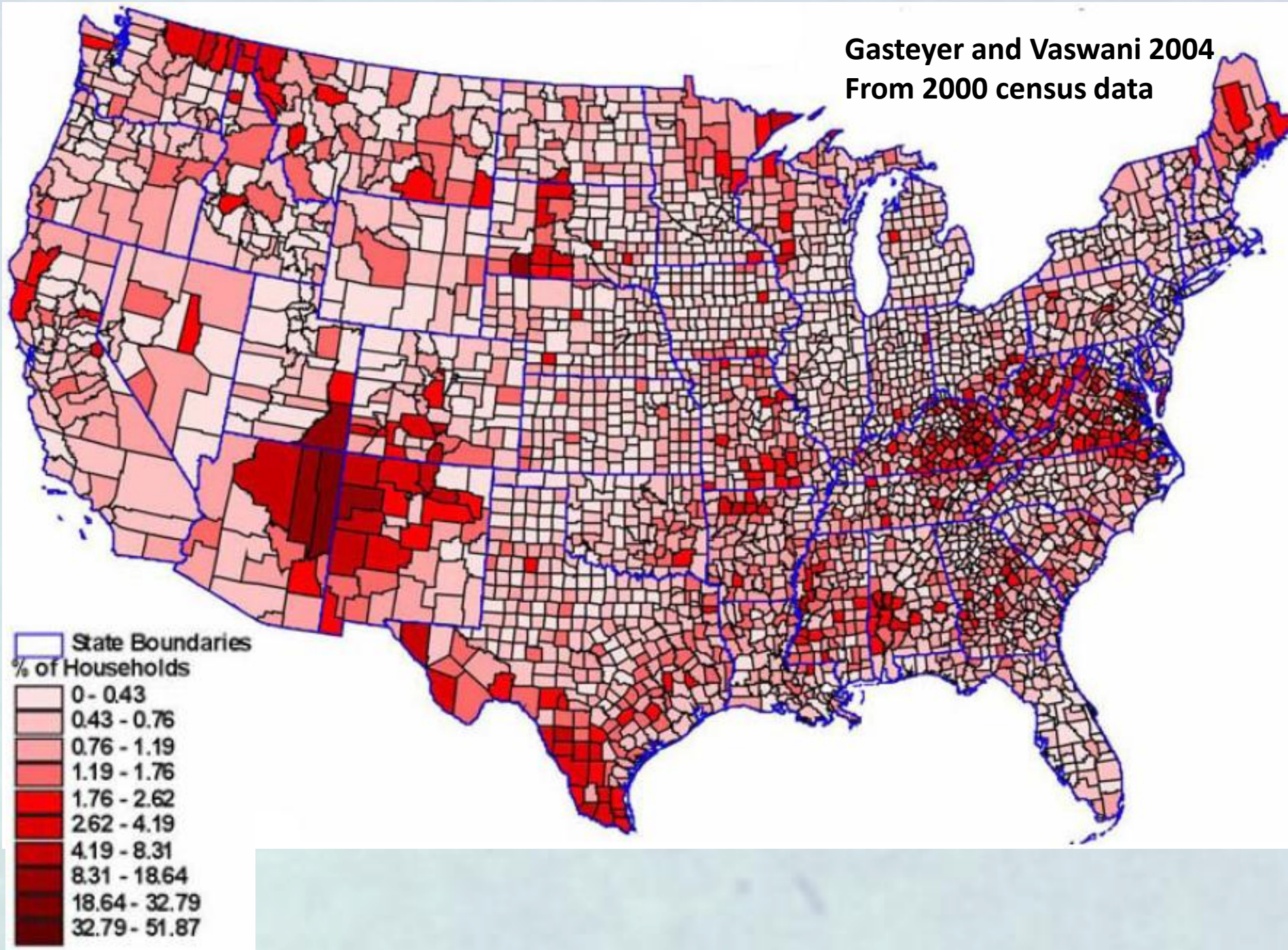
Outline

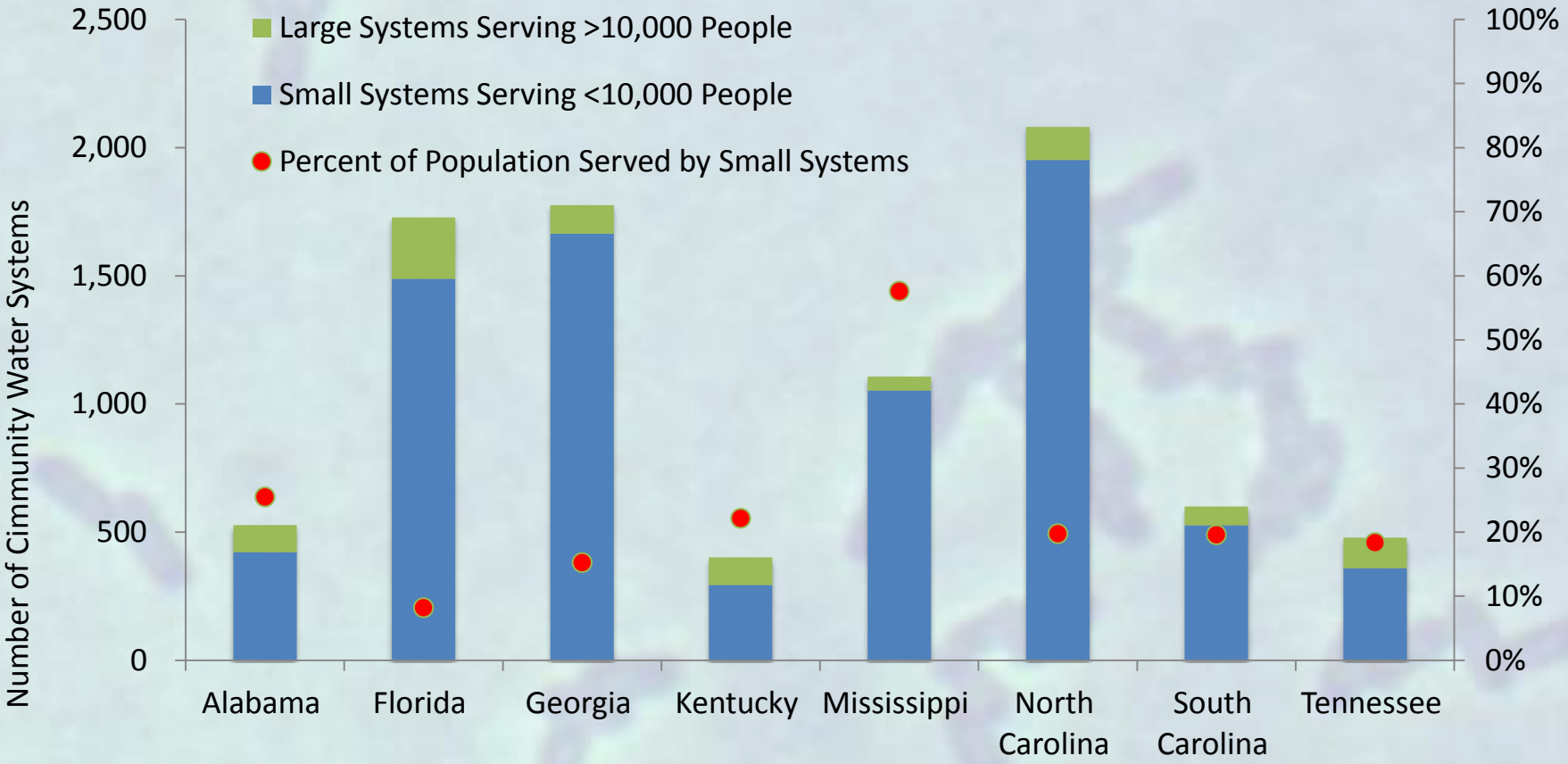
- Background and context: **Alabama's Black Belt**
- **Pilot data** and hypothesis generation
- **Goals**
- **Methods** overview
- Preliminary **data**
- **Next steps**


Gasteyer and Vaswani 2004
From 2000 census data
State Boundaries
% of Households
0 - 0.43
0.43 - 0.76
0.76 - 1.19
1.19 - 1.76
1.76 - 2.62
2.62 - 4.19
4.19 - 8.31
8.31 - 18.64
18.64 - 32.79
32.79 - 51.87

Rural water supplies

- **More than 94 percent of the nation's 156,000 public water systems serve <3,300 persons**
- **Disproportionate share of outbreaks related to microbial contamination**
- Face a variety of challenges:
  - Wide service areas and disperse populations
  - O & M challenges
  - Meeting regulatory requirements

Southeast's 8,700 community water systems serve 58.5 Million People



Source: EPA's 2011 SDWIS data analyzed by the Environmental Finance Center at the University of North Carolina, Shadi Eskaf

PWS Violations Alabama 1997-2012

Type of systems	Population served	Violations: HAA	Violations: TTHMs	Violations: coliform	Total violations	Total violations per 100,000 people
Large (10,001-100,000)	**4,136,225**	**15**	**28**	**100**	**143**	**3**
Top third per capita income	3,248,710	11	15	51	77	2
Middle third per capita income	664,795	4	5	21	30	5
Lower third per-capita income	222,720	0	8	28	36	16
Medium (3,301-10,000)	**1,027,417**	**38**	**69**	**160**	**267**	**26**
Top third per capita income	408,615	10	25	50	85	21
Middle third per capita income	384,255	23	23	58	104	27
Lower third per-capita income	234,547	5	21	52	78	33
Small (501-3,300)	**362,352**	**65**	**128**	**273**	**466**	**129**
Top third per capita income	124,756	13	25	70	108	87
Middle third per capita income	139,053	34	74	107	215	155
Lower third per-capita income	98,543	18	29	96	143	145
Very Small (<500)	**11,168**	**11**	**13**	**42**	**66**	**591**
Top third per capita income	2,547	6	1	9	16	628
Middle third per capita income	3,928	4	9	10	23	586
Lower third per-capita income	4,693	1	3	23	27	575
Total	**5,537,162**	**129**	**238**	**575**	**942**	**17**

> 8x

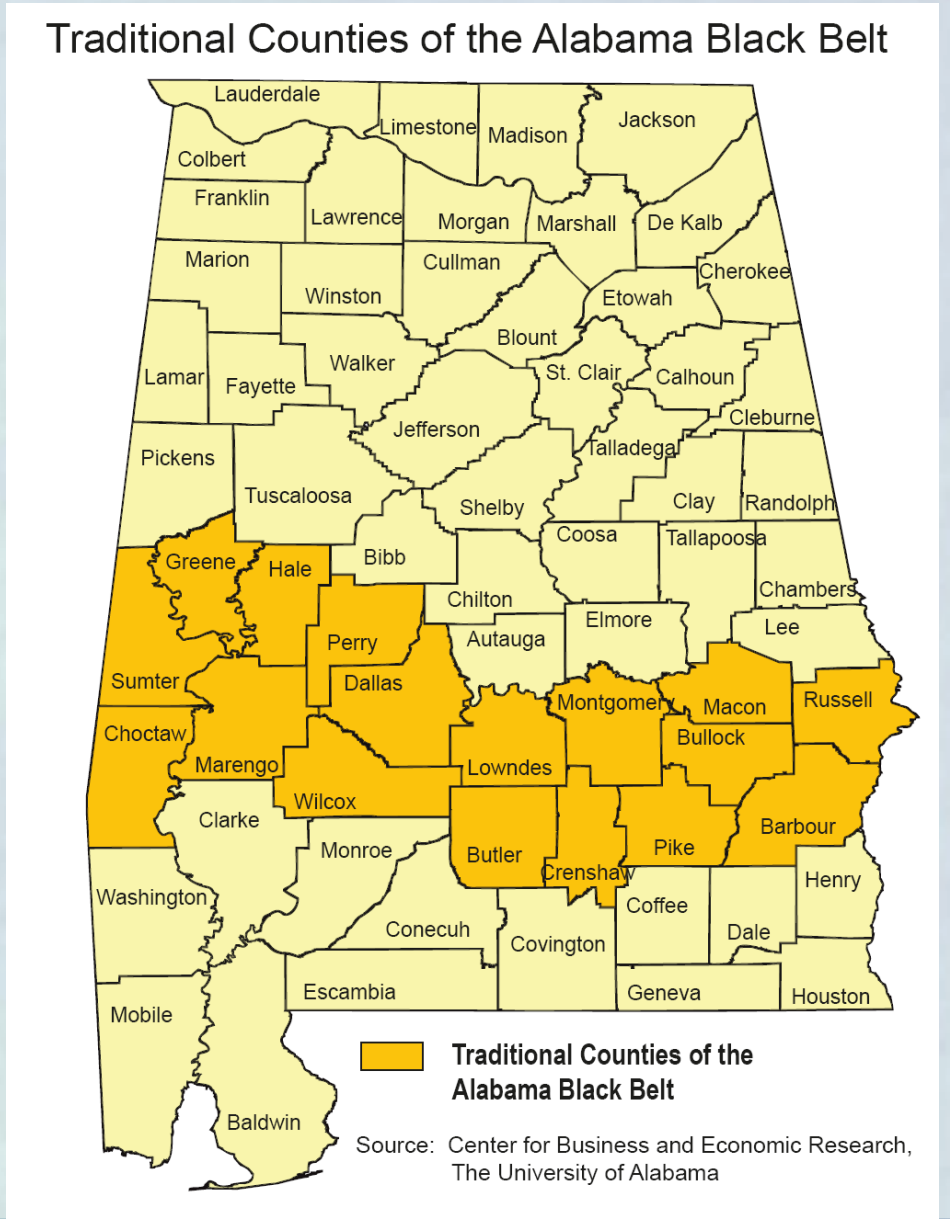
> 40x

197x

L Talebi

Alabama's Black Belt region

- **Common demographic and socio-economic characteristics**
  - High poverty
  - High unemployment
  - Decreasing population
  - High percentage of minorities
- **Common themes**
  - Decaying infrastructure
  - Poor access to basic services and health care
  - High percentage of vulnerable people (the young, elderly and infirm, HIV+)



Initial scoping assessment

- In collaboration with community partner
- Customer complaints: outages, cloudy or smelly water
- **High cost** to connect and tariffs
- **Alternatives are potentially unsafe** water sources (i.e. shallow wells near failing septic systems)
- **Poor septic access** and apparent function

Pilot study

- Pilot **cross-sectional study of 305 households in one county** to examine:
- (i) drinking water quality at the household level (both private wells and county public supply),
- (ii) possible associations between water infrastructure characteristics and drinking water quality, and
- (iii) risk of Highly Credible Gastrointestinal Illness (HCGI)

Results overview

- 8% of system samples positive for FC
- 30% of well samples positive for FC
- **No Cl in >35% of samples from the county water supply system**
  - **Cl presence associated with FC**
- Frequently intermittent service: 8% of households
- **Poor access to septic**
- Wells more likely to be contaminated

Results overview, continued

- 12 cases of GI illness among 507 people: **2.4% 7-day prevalence**
  - High risk
- Individuals **whose drinking water was found to contain ≥ 1 cfu/100 ml of FC were 4 times as likely to have also reported HCGI** in the previous 7 days as those whose water sample was negative for FC (<1 cfu/100 ml)
  - (OR 4.0, 95% CI 1.2 – 14)

Summary of pilot data

- Systems and wells **at risk** for microbiological contamination
- Onsite sanitation a (potentially big) problem
- **High prevalence of gastro-intestinal illness**
  - Suggestive evidence that water may play a role

Current study

- *2011 – 2015,* 14 water systems, 3 counties

EPA goals for this program

To:

- "**inform public health risk assessments** associated with **distribution vulnerability factors**", & to
- "inform **quantitative relationships between infrastructure conditions and public health risks** associated with continuous, intermittent, or episodic water quality deterioration or contamination"

Hypothesis	Approach
• Households with measured detectable pathogens and/or pathogen indicators are more likely to experience adverse health outcomes, including HCGI, when compared to households whose drinking water does not contain detectable levels of pathogens or pathogen indicators	• Prospective cohort study and QMRA
• Households reporting intermittent service, turbid water, or other indicators of poor system performance are more likely to experience HCGI versus households who do not report the same	• Prospective cohort study and QMRA

Hypothesis

- Households whose drinking water does not contain detectable levels of free chlorine are more likely to experience HCGI than those whose water contains detectable levels of free chlorine residual at the time of sampling

- Water supply system fecal contamination is related to poor wastewater handling, including septic system failures in the service area

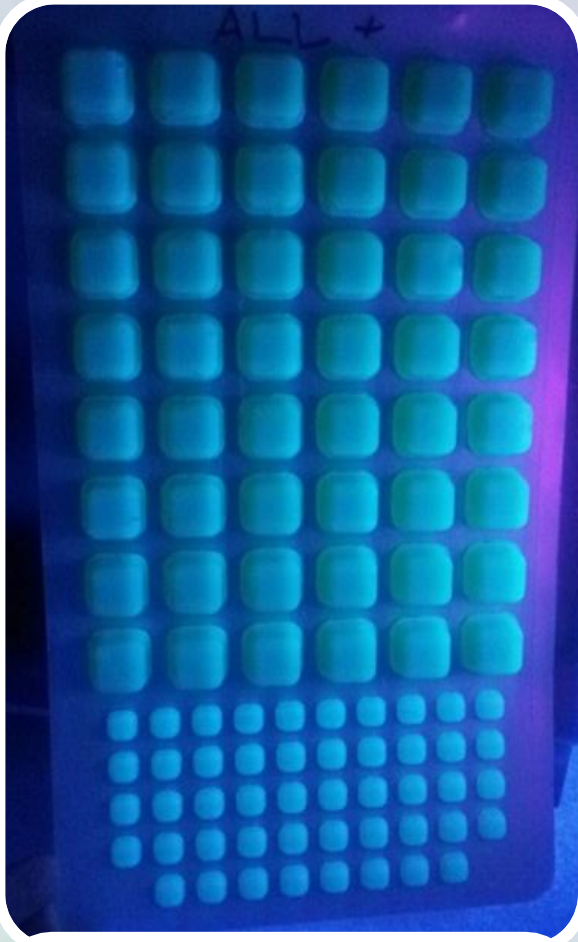
Approach

- Prospective cohort study and QMRA

- Septic surveys and MST

Goals

- 1. Assess system **performance and microbial water quality**
  - Fecal indicators and pathogens
- 2. GI illness associations
  - Directly measured (epidemiology)
  - Modeled using QMRA
- 3. Identify possible **transmission pathways**
- 4. Identify **risk mitigation** strategies
  - Working with operators



Methods

- Household-level **water quality data**
  - Microbiological indicators, pressure, Cl, pH, turbidity
- **Health GI measures**
  - HCGI health diaries & interviews
- Pathogens and indicators from concentrated ultrafiltration samples
  - *Cryptosporidium*, *Giardia*, norovirus, adenovirus, *Enterococcus*, *E. coli, potentially others*
- Microbial source tracking of all *E. coli* isolates
- **Other system-level data**
  - System modeling
  - Operation and maintenance
  - Infrastructure characteristics

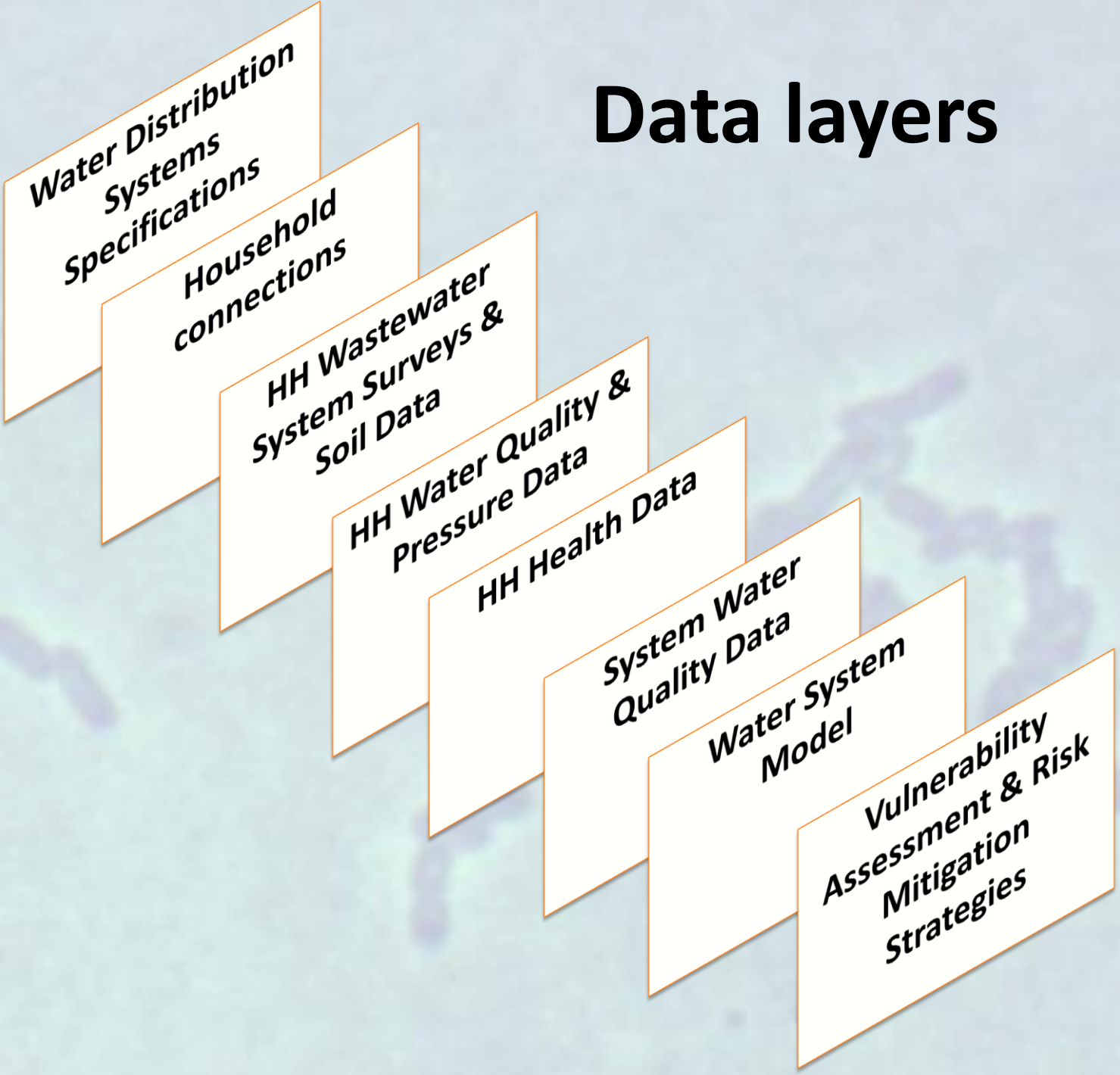
Methods, continued

- **Survey of 900 randomly selected connected households (300 in each county)**
  - Health outcomes
  - Grab and “flamed” drinking water samples
  - Septic access and function
  - Perceptions and water use
- Ongoing surveillance for health
- **Ongoing system-level sampling**
  - Selected households, key system points
  - Up to 10 sample points per system over 18 months

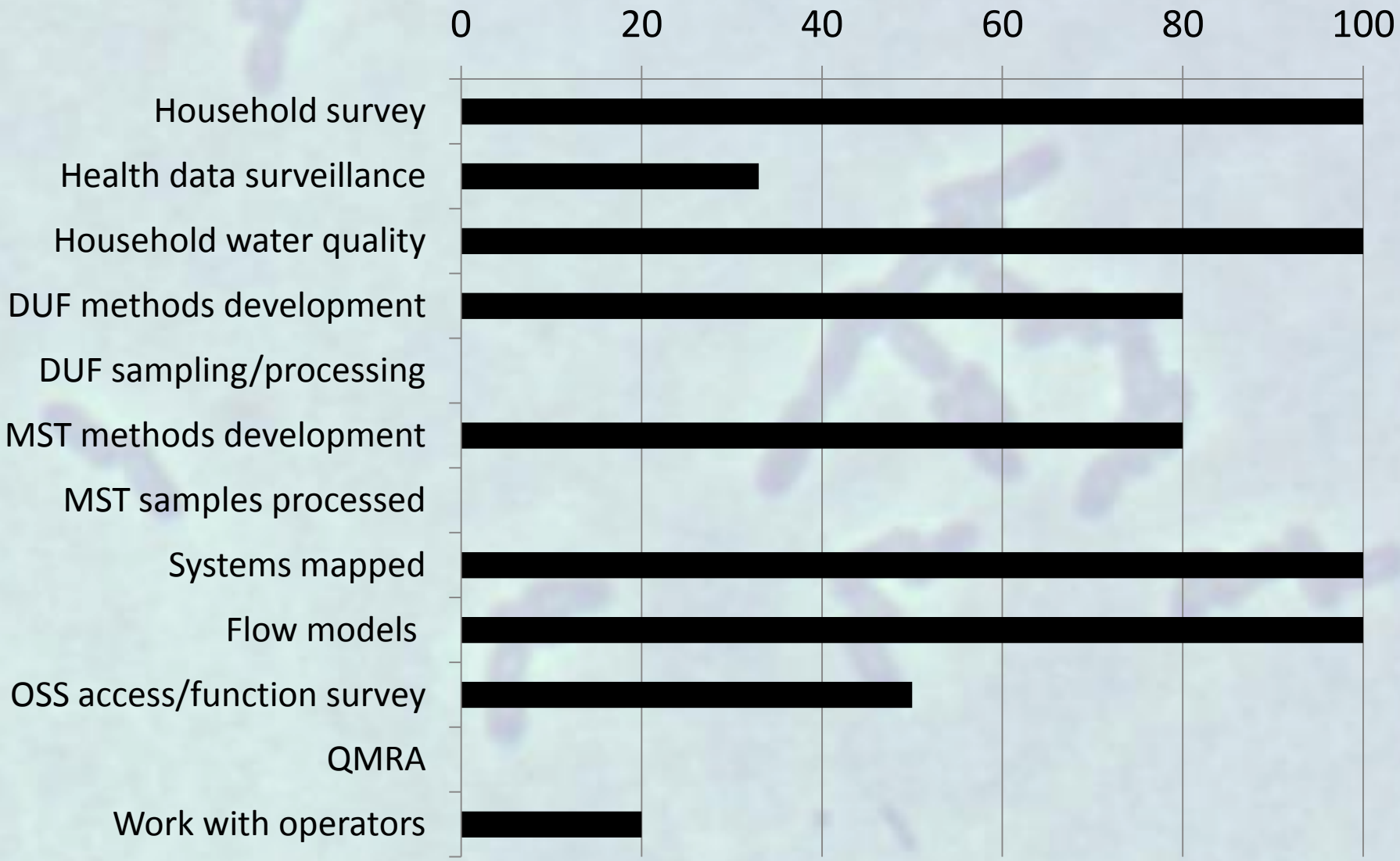
Onsite sanitation

- Systematic surveys of OSS function and access
  - Public records / survey
  - Previous study: 90% of septic systems in the Black Belt were failing (ADPH 1997)
- **Microbial source tracking** of *E. coli* isolates from drain fields
- Partner studies:
  - Household well samples
  - STHs
- **Technology innovation** for underserved communities
  - **<u>Urgent need</u>**

Data layers


Water Distribution Systems Specifications
Household connections
HH Wastewater System Surveys & Soil Data
HH Water Quality & Pressure Data
HH Health Data
System Water Quality Data
Water System Model
Vulnerability Assessment & Risk Mitigation Strategies

Progress – percent complete



Dead-end ultrafiltration

- UF of 100 l samples -> concentration -> storage at -80C -> DNA/RNA extraction & PCR
- Recovery experiments with *Giardia*, *Crypto* and *E. coli* done
- Sample collection beginning this month
- Sample site selection informed (in part) by:
  - EPANET flow models and
  - Data collected to date
- CDC and Emory input and collaboration

Microbial source tracking

- All *E. coli* isolates preserved in triplicate for MST
- Library complete
- 11 isolates so far

Preliminary results

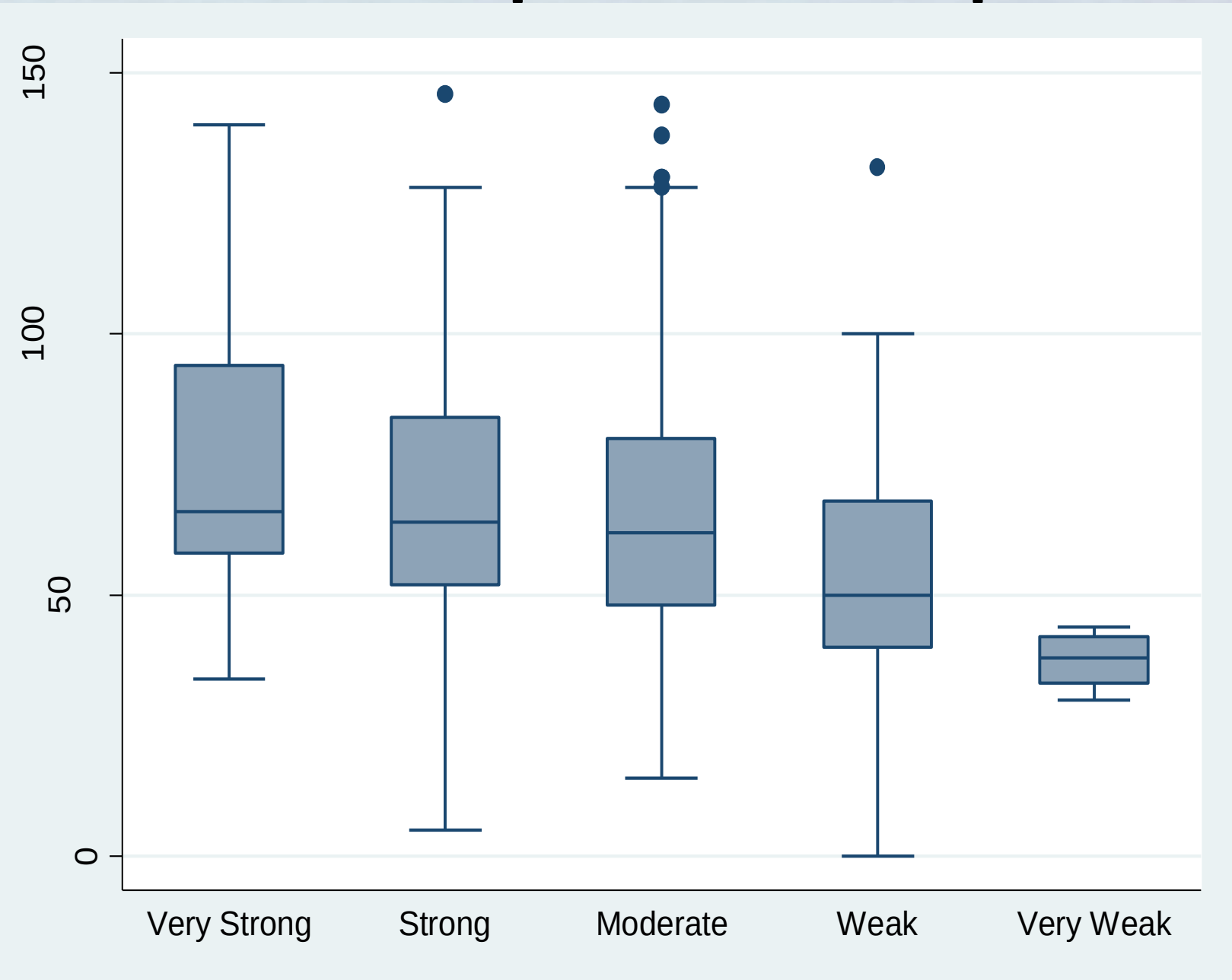
Bacterial Contamination	Any Symptoms (N=73)	Water Diarrhea (N=19)	Vomiting (N=31)
Flame Sample Negative for Total Coliforms (N=708)	N=59 (8.3%)	17 (2.4%)	N=26 (3.7%)
Flame Sample Positive for Total Coliforms (N=143)	N=14 (9.8%)	N=2 (1.4%)	N=5 (3.5%)
Pearson chi^2 p value	0.57	0.46	0.92

Bacterial Contamination	Any Symptoms (N=75)	Water Diarrhea (N=19)	Vomiting (N=31)
Grab Sample Negative for Total Coliforms (N=779)	N=65 (8.3%)	17 (2.2%)	N=27 (3.5%)
Grab Sample Positive for Total Coliforms (N=107)	N=10 (9.3%)	N=4 (3.7%)	N=4 (3.7%)
Pearson chi^2 p value	0.72	0.33	0.90

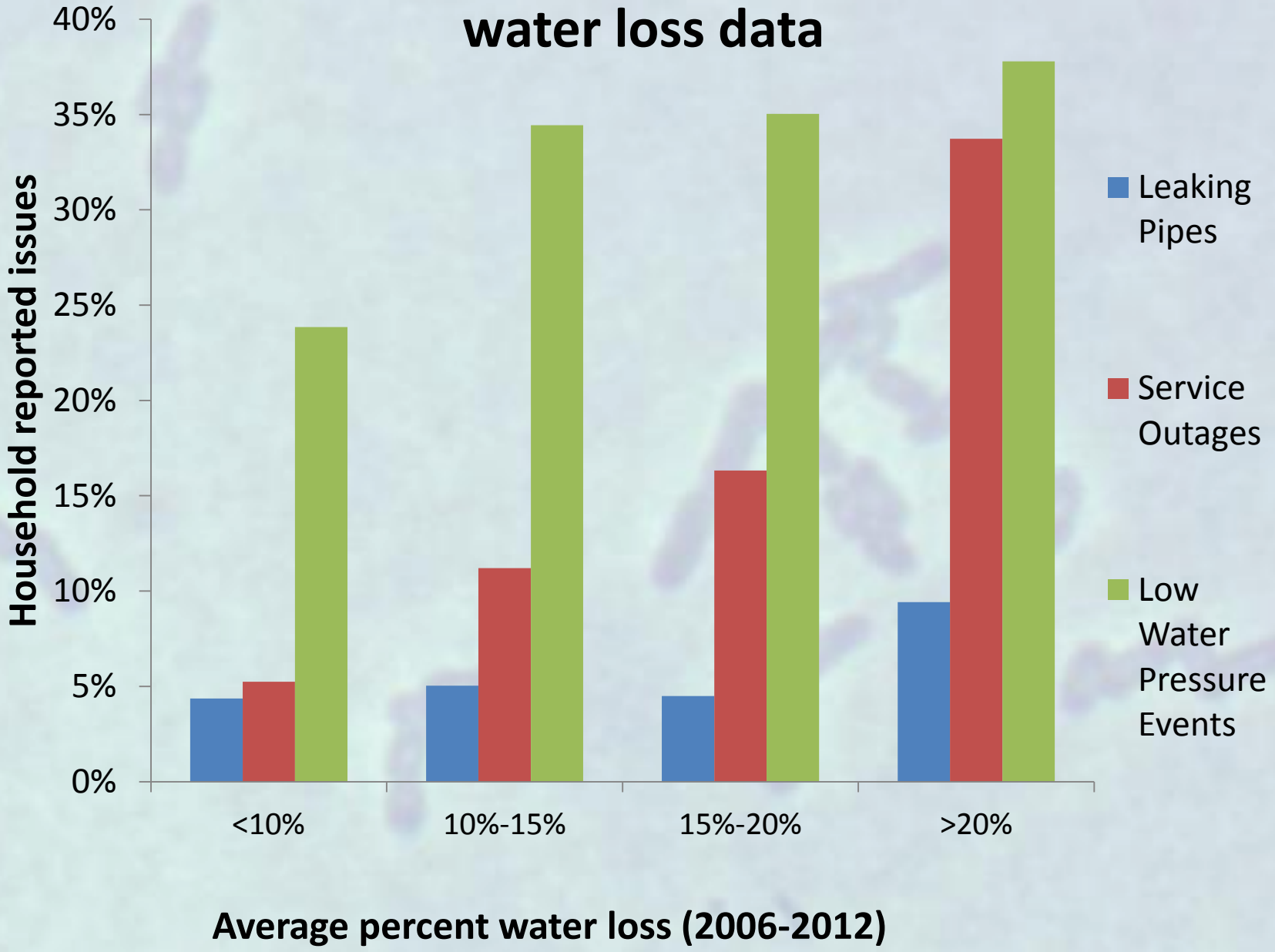
Total chlorine status of sample	Any Symptoms (N=75)	Water Diarrhea (N=21)	Vomiting (N=31)
Free chlorine absent (N=12)	N=3 (25%)	N=1 (8.3%)	N=2 (16.7%)
Free chlorine present (N=874)	N=72 (8.2%)	N=20 (2.3%)	N=29 (3.3%)
Pearson chi2 p value	0.038	0.17	0.012

Free chlorine status of sample	Any Symptoms (N=75)	Water Diarrhea (N=21)	Vomiting (N=31)
Free chlorine absent (N=32)	N=5 (15.6%)	N=1 (3.1%)	N=3 (9.4%)
Free chlorine present (N=855)	N=70 (8.2%)	N=20 (2.3%)	N=28 (3.3%)
Pearson chi2 p value	0.14	0.77	0.07

Measured vs reported water pressure



Household reported service interruptions vs water loss data



Water supply issue	Any symptoms	Any watery diarrhea	Any vomiting
Not experience low water pressure (557)	23 (4.1)	6 (1.1)	6 (1.1)
Yes low water pressure (317)	50 (5.8)	14 (4.4)	24 (7.6)
p value of chi^2 test	p <0.001	p =0.002	p <0.001

Water supply issue	Any symptoms	Any watery diarrhea	Any vomiting
No intermittent service (748)	50 (6.7)	10 (1.3)	20 (2.7)
Yes intermittent service (129)	24 (18.6)	11 (8.5)	11 (8.5)
Don’t know (18)	1 (5.6)	0 (0.0)	0 (0.0)
p value of chi^2 test	p <0.001	p <0.001	p =0.001

Free chlorine status of sample	Any Symptoms (N=75)	Water Diarrhea (N=21)	Vomiting (N=31)
Free chlorine absent (N=32)	N=5 (15.6%)	N=1 (3.1%)	N=3 (9.4%)
Free chlorine present (N=855)	N=70 (8.2%)	N=20 (2.3%)	N=28 (3.3%)
Pearson chi^2 p value	0.14	0.77	0.07

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Free chlorine absent (N=12)	N=3 (25%)	N=1 (8.3%)	N=2 (16.7%)
Free chlorine present (N=874)	N=72 (8.2%)	N=20 (2.3%)	N=29 (3.3%)
Pearson chi^2 p value	0.038	0.17	0.012

Water supply issue	Any symptoms	Any watery diarrhea	Any vomiting
Did not report a bad smell (707)	45 (6.4)	10 (1.4)	17 (2.4)
Yes report water has bad smell (155)	25 (16.1)	10 (6.5)	11 (7.1)
p value of chi^2 test	p <0.001	p <0.001	p =0.003

Water supply issue	Any symptoms	Any watery diarrhea	Any vomiting
Did not report a bad taste (651)	40 (6.1)	9 (1.4)	13 (2.0)
Yes reported water has bad taste (188)	28 (14.9)	10 (5.3)	15 (8.0)
p value of chi^2 test	p <0.001	p = 0.001	p <0.001

Water supply issue	Any symptoms	Any watery diarrhea	Any vomiting
Did not report an odd color to the water (712)	48 (6.7)	11 (1.5)	20 (2.8)
Yes reported an odd color to the water (153)	23 (15.0)	10 (6.5)	10 (6.5)
p value of chi^2 test	p = 0.001	p < 0.001	p = 0.022

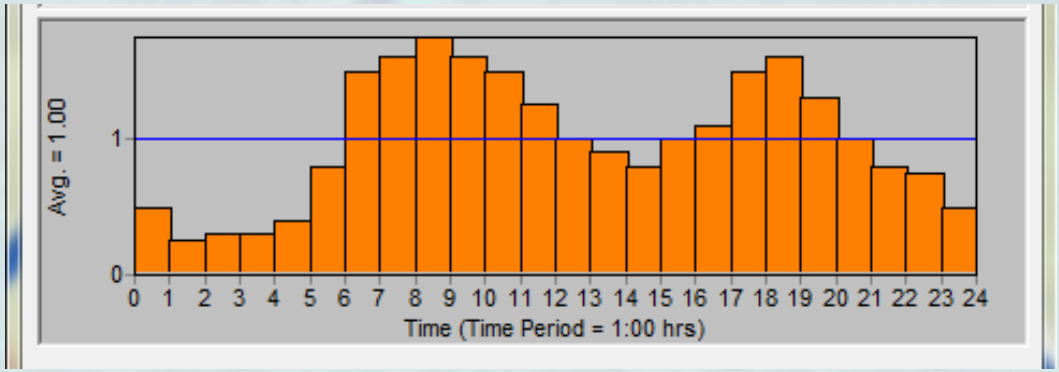
”Where does your waste go?”	Any symptoms	Any watery diarrhea	Any vomiting
To the ground (29)	1 (3.4)	0 (0.0)	0 (0.0)
Cess pool (18)	1 (5.6)	0 (0.0)	0 (0.0)
Septic system (590)	53 (9.0)	13 (2.2)	24 (4.1)
Sewer (231)	17 (7.4)	7 (3.0)	6 (2.6)
p-value chi^2 test	p=0.64	p = 0.65	p = 0.41

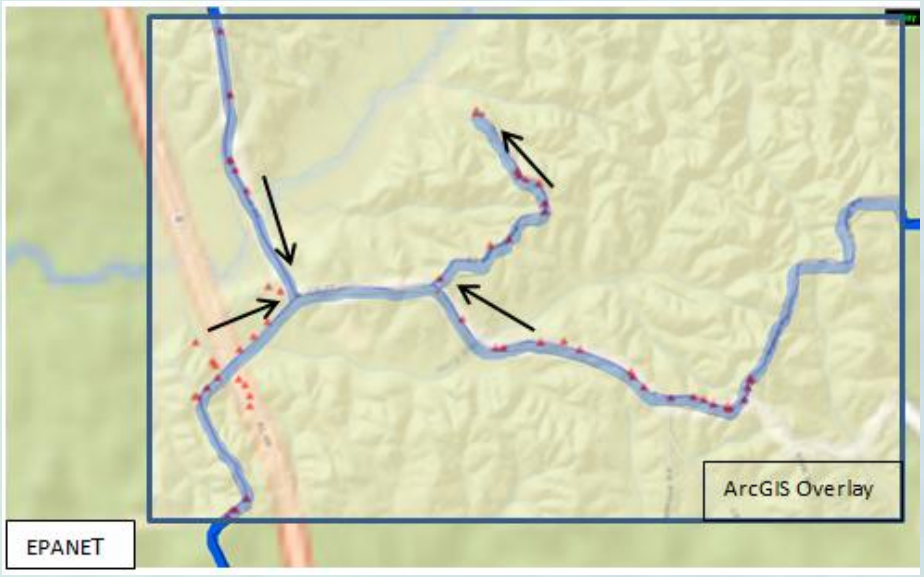
Septic Tank Serviced	Any symptoms	Any watery diarrhea	Any vomiting
More than four years ago (91)	10 (11.0)	4 (4.4)	4 (4.4)
Less than four year ago (112)	10 (8.9)	4 (3.6)	3 (2.7)
p value of chi^2 test	p =0.62	p = 0.76	p = 0.51

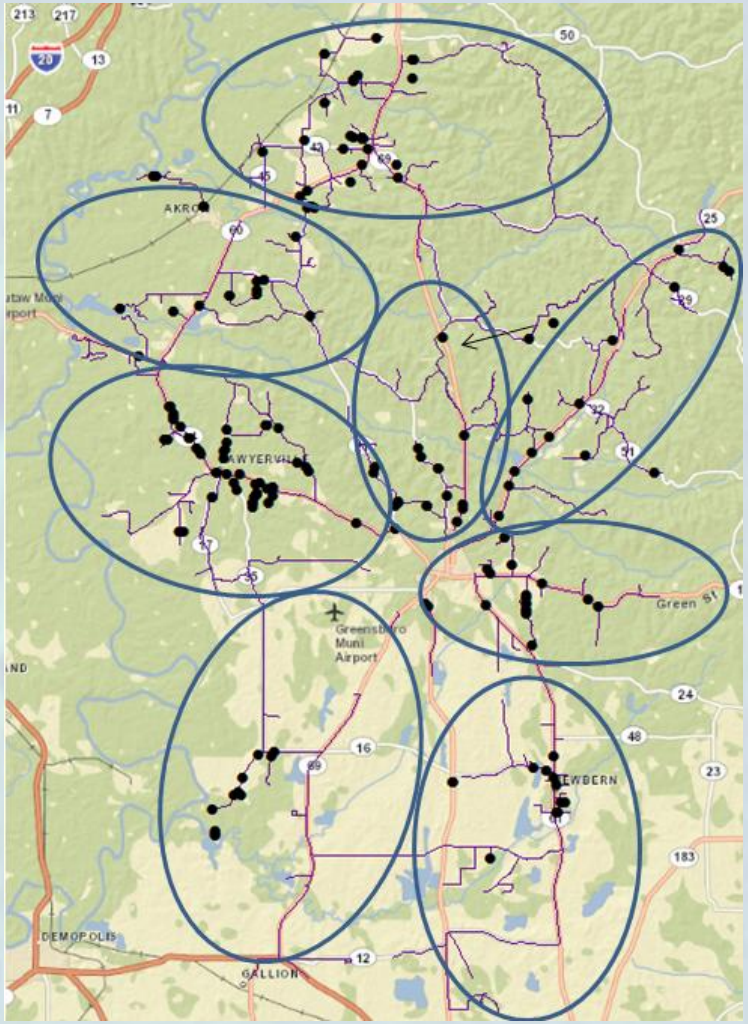
System data

- Flow modeling
- O&M records
- Existing monitoring data
- Offering PDHs to operators

Modeling EPA-Net, Arc-GIS overlay







Onsite sanitation (OSS)

- Low percentage of OSS systems have permits filed with ADPH
  - Systematic survey of OSS, D. Bunei MS work
  - 65% of people lack septic or have a system that is more than 25 years old
- No clear associations between measured OSS function indicators and health outcomes
- Homeowner age and low income associated with indicators of poor septic function in a systematic sub-study from one county
  - Olivia Johns MSc work
  - Also 75% of drain field surface samples positive for *E. coli* (not source tracked – but future sub-study will)

Summary

- **Relatively high percentage of samples positive for TC**, lower than expected number of *E. coli* positives
- Significant health **associations emerging** with some water quality measures, pressure, intermittent service, and subjective perceptions (unappealing taste, smell, color).
- Data collection and analysis **ongoing**
  - System-level samples are of central importance to study questions
- At-risk areas emerging when merging household and system data