

SUPPORTING INFORMATION

Microbial contamination of drinking water supplied by private wells after Hurricane Harvey

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Section S1. Sampling instructions from the University campaign

Collection Day and Sample Drop-off (Same Day)

1. Turn on the cold water only at the highest flow rate fixture (e.g., bathtub, wellhead tap) and flush for 5 minutes.
2. After 5 minutes, turn off the water.
3. Go to your kitchen tap. If your kitchen tap is not working, go to an outdoor tap.
4. Unpack the sample bottle from the plastic bag. Remove the cap from the bottle. Set the cap on the counter upside down, trying not to touch the inside of the cap or bottle.
5. Open the cold water tap and run the water for one minute.
6. At one minute, fill the bottle completely at full flow (as if you were filling a glass of water). Do not rinse the powder out of the container. Put the cap back on the bottle.
7. Turn off the water.
8. Complete the contact information and sampling form.
9. Place bottle and form back into the plastic bag. Bring your sample bag to the County Extension Office list on your sampling bag.

Section S2. University Round 1 survey

1. Where was your water sample collected? ☐ Kitchen tap ☐ Bathroom tap ☐ Bath tub/shower tap
☐ Outside spigot ☐ Wellhead ☐ Other (please describe): _____
2. Is your well system currently working (you have running water in the home)?
☐ Yes ☐ No ☐ Don't know
3. Have you used your well water since Hurricane Harvey?
☐ Yes ☐ No ☐ Don't know
If YES, roughly how many days have you been using your water? _____
4. How did you hear about this free testing opportunity?
☐ Email ☐ Radio announcement ☐ Info on FEMA site
☐ Television announcement ☐ Texas A&M website ☐ Family/neighbor
☐ Other (please describe): _____

WELL SYSTEM INFORMATION

5. Please describe the following to the best of your knowledge:
 - a. Type of private well: ☐ dug or bored well ☐ drilled well ☐ Don't know
 - b. What is the depth of the well? _____ feet ☐ Don't know
 - c. What year was well constructed? _____ ☐ Don't know
 - d. How many people in your home? _____ ☐ Don't know
 - e. How many homes are supplied? _____ ☐ Don't know
6. How long have you lived at your current residence? ☐ <1 year ☐ 3-5 years ☐ 10-15 years
☐ 1-2 years ☐ 6-10 years ☐ 20 or more years
7. Does anyone in your home drink the water from your kitchen tap?
☐ yes with filter/treatment ☐ yes but not with filter/treatment ☐ no
8. Do you have a septic system? ☐ Yes ☐ No ☐ Don't know
If YES, how often do you have your septic tank emptied? ☐ Haven't yet ☐ <1 year ☐ 1-2 years
☐ 3-5 years ☐ 6-10 years ☐ 10 or more years ☐ When problem
9. What water treatment devices are currently installed? **Check all that apply:**
☐ None ☐ Iron removal ☐ Chlorinator
☐ Sediment filter ☐ Acid neutralizer ☐ Water softener
☐ Reverse osmosis ☐ Ultraviolet (UV) light
☐ Activated carbon (charcoal) filter ☐ Other (please describe): _____
If you have treatment, is it: ☐ tap-mounted unit ☐ whole house filter ☐ mixture ☐ NA

FLOODING DURING HURRICANE HARVEY

10. Was there standing water in your home during Harvey? ☐ Yes ☐ No ☐ Don't know
If YES, how high did it get at its highest?
☐ Inches ☐ Ankle deep ☐ Knee deep ☐ Waist deep ☐ Above my head ☐ Don't know
11. Was your wellhead submerged under floodwater during Harvey? ☐ Yes ☐ No ☐ Don't know

12. Was your well system damaged during Harvey? ☐ Yes ☐ No ☐ Don't know

If YES, what was damaged? **Check all that apply:**

- ☐ Pipes broken in home ☐ Electrical problems with pump ☐ Pump clogged with debris
☐ Cover gone ☐ Cracks or damage to casing ☐ Other (please describe): _____

13. Was your septic system damaged during Harvey? ☐ Yes ☐ No ☐ Don't know ☐ Don't have septic

If YES, what was damaged? **Check all that apply:**

- ☐ Septic tank filled with floodwater ☐ Cover gone ☐ Drain field saturated
☐ Other (please describe): _____

14. Please indicate your level of agreement by circling the appropriate number (**1 = disagree; 5 = agree**).

AFTER THE FLOOD				
Disagree		Neutral		Agree
I feel my well water was safe to drink				
1	2	3	4	5
I feel my well water was safe for cooking				
1	2	3	4	5
I feel that my well water is safe for bathing				
1	2	3	4	5

WELL WATER TESTING AND WELL MAINTENANCE

15. Have you ever had your well system shock chlorinated? ☐ Yes ☐ No ☐ Don't know

If YES, when was the last time? _____

If NO, why not? **Check all that apply:**

- ☐ Too expensive ☐ Don't drink or cook with well water ☐ Not a priority
☐ Not a concern ☐ Don't know how to shock chlorinate ☐ Meant to but didn't
☐ Not sure of benefit ☐ Other (please describe): _____

16. Have you ever tested your well water? ☐ No ☐ Yes ☐ Don't know

If YES, was it with Texas A&M AgriLife Extension? ☐ No ☐ Yes ☐ Don't know

If NO, or you do not test as often as you would like, why not? **Check all that apply:**

- ☐ Too expensive ☐ Don't drink or cook with it ☐ Not a priority or concern
☐ No Transportation ☐ Don't know where to get it tested ☐ Other: _____

KNOWLEDGE, RESOURCES, INFORMATION AND BEHAVIOR

17. Please indicate your level of agreement by circling the appropriate number (**1 = disagree; 5 = agree**).

Disagree		Neutral		Agree
I am comfortable managing my well (testing, treating, and maintaining)				
1	2	3	4	5
I know where to find information about my well characteristics (e.g., depth, year constructed)				
1	2	3	4	5
I know where to find information about well water testing services				
1	2	3	4	5
I know where to find information about well water treatment systems				
1	2	3	4	5

FAMILY

18. What is your annual household income?

- | | | |
|--|---|---|
| <input type="checkbox"/> \$12,000 or below | <input type="checkbox"/> \$45,001 – \$65,000 | <input type="checkbox"/> \$100,001 or \$150,000 |
| <input type="checkbox"/> \$12,001 – \$24,000 | <input type="checkbox"/> \$65,001 – \$85,000 | <input type="checkbox"/> \$150,001 or above |
| <input type="checkbox"/> \$24,001 – \$45,000 | <input type="checkbox"/> \$85,001 – \$100,000 | <input type="checkbox"/> Prefer not to answer |

19. How would you describe the persons within your household? **Check all that apply.**

- | | | |
|---|---|---|
| <input type="checkbox"/> American Indian or Alaska Native | <input type="checkbox"/> Hispanic or Latino | <input type="checkbox"/> White or Caucasian |
| <input type="checkbox"/> Asian | <input type="checkbox"/> Pacific Islander | <input type="checkbox"/> Prefer not to answer |
| <input type="checkbox"/> Black or African American | <input type="checkbox"/> Two or more races | |

20. What is the highest level of education in the house?

- | | | |
|---|---|---|
| <input type="checkbox"/> Some high school | <input type="checkbox"/> Some college | <input type="checkbox"/> Post college (MS, PhD) |
| <input type="checkbox"/> High school graduate | <input type="checkbox"/> College graduate | <input type="checkbox"/> Prefer not to answer |

Section S3. University Round 2 survey

1. Where was your water sample collected? ☐ Kitchen tap ☐ Bathroom tap ☐ Bath tub/shower tap
☐ Outside spigot ☐ Wellhead ☐ Other (please describe): _____
2. Have you used your well water since Hurricane Harvey? ☐ Yes ☐ No ☐ Don't know
If YES, roughly how many days have you been using your water? _____ or ☐ Never stopped
3. Was your well system damaged during Harvey? ☐ Yes ☐ No ☐ Don't know
4. Was your well head submerged under floodwater during Harvey? ☐ Yes ☐ No ☐ Don't know
5. Was your septic system damaged during Harvey? ☐ Yes ☐ No ☐ Don't know
☐ Don't have septic system
6. Was your well disinfected (shock chlorinated) after Harvey? ☐ Yes, did it ourselves ☐ No
☐ Yes, hired someone ☐ Don't know
If YES, roughly how many days ago? _____
roughly how much bleach was used? _____
how many times have you disinfected your well? _____
7. What type of well do you have? ☐ Dug or bored well ☐ Drilled well ☐ Don't know/unsure
8. What is the well's depth, if known? _____ or ☐ Don't know
9. What year was the well constructed, if known? _____ or ☐ Don't know
10. Do you have water treatment installed? (*fill in all that apply*) ☐ Tap-mounted unit
☐ Unit within the frig
☐ Whole house filter
☐ I don't have treatment

Section S4. Characteristics of participations in University Round 1 testing campaign

As before most sampling (68.1%; n=410) was conducted in the first month of recovery. The median levels were 80.6 and 0.0 MPN for TC and EC (13.2 and 4.1 MPN among samples with detectable levels). Four wells had TC levels too numerous to count (TNCT; >2419.6 MPN) and one well had both TC and EC levels TNTC (Figure S2). Of the counties with equal to or more than 10 samples (10 to 171; n=10 counties; Table Section S4-1), TC rates varied from 20.0%-62.5% (median of 46.3%) and EC varied from 0.0%-19.2% (median of 10.3%). There was little (0.0-3.4%) exceedance of USEPA health-based drinking water standards (other than coliform bacteria; Table Section S4-2). However, water samples were collected after flushing, so contamination associated with the interior plumbing was not evaluated. Some water samples had iron and manganese above the USEPA aesthetic-based standards.

Most water samples were collected at the kitchen or bathroom (68.6%; n=413), with several collected from an outdoor spigot (e.g., wellhead tap; 25.7%) or non-drinking indoor water tap (2.2%). Treatment was installed in the majority of houses (51.2%, n=297), and when present, it was most commonly a water softener (43.8%) or sediment filter (25.6%). Residents rarely had treatment devices that treated for microbial contamination – 28 had a reverse osmosis unit (9.4%), 12 had continuous chlorinators (4.0%), and 1 had UV light (0.3%).

More participants reported being supplied by a drilled well (79.1%; n=476), and most wells were reported to be great than 100 ft. in depth (58.8%; n=330). Roughly 70% of systems supplied 2-4 people and 80.0% of participants had been living at the residence for at least five years. Among participants that responded (n=431), 40.8% reported a household income less than \$65,000 (Texas median income is \$59,570), with 14.2% reporting an income less than \$24,000 (Texas poverty level for one person is \$24,238). Approximately half (48.3%) of responding participants (n=549) reported having a college degree or higher. Responding participants (n=545) were predominately “White or Caucasian” (86.1%), with 6.4% self-identified as “Hispanic or Latino” and 5.7% as “Two or more races”.

Table Section S4-1. Coliform occurrence rate in counties with >10 samples

County	N	Occurrence rate	
		TC	EC
Chambers	18	27.8%	5.6%
Hardin	76	32.9%	10.5%
Harris	52	57.7%	19.2%
Liberty	40	60.0%	15.0%
Matagorda	10	20.0%	10.0%
Orange	40	55.0%	15.0%
Refugio	24	62.5%	4.2%
Victoria	102	44.1%	3.9%
Waller	27	25.9%	0.0%
Wharton	171	48.5%	18.1%

Table Section S4-2. Summary statistics of water quality parameters

Target water quality constituent	Standard		Number of observations	MRL	% <MRL	Mean	Median	90 th Percentile	Percent Exceeding
Arsenic, in µg/L	MCL	10 µg/L	413	0.5	19%	2.8	1.6	6.1	3.4%
Cadmium, in µg/L		5 µg/L	413	1.0	99%	0.5	0.5	0.5	0.2%
Chromium, in µg/L		100 µg/L	413	1.0	61%	8.6	0.5	5.4	1.0%
Fluoride, in mg/L		4.0 mg/L	326	0.01	13%	0.36	0.29	0.59	0.0%
Nitrate, in mg/L		10 mg/L	326	0.01	29%	0.69	0.11	1.32	1.2%
Uranium, in µg/L		30 µg/L	413	1.0	63%	2.1	0.5	3.9	0.7%
Total coliform, in cfu		ABSENT	602	0	54%	80.6	0.0	172.0	46.0%
<i>E. coli</i> , in cfu		ABSENT	602	0	88%	8.2	0.0	1.0	11.8%
Copper, in µg/L	Action Level	1,300 µg/L	413	1.0	19%	34.2	5.9	58.7	0.2%
Lead, in µg/L		15 µg/L	413	1.0	74%	3.6	0.5	4.2	3.6%
Chloride, in mg/L	SMCL	250 mg/L	326	0.01	0.3%	100.59	57.84	240.42	9.5%
Copper, in µg/L		1,000 µg/L	413	1.0	19%	34.2	5.9	58.7	0.5%
Fluoride, in mg/L		2.0 mg/L	326	10.0	13%	0.4	0.3	0.6	0.6%
Iron, in µg/L		300 µg/L	413	1.0	30%	343.1	46.8	768.3	22.0%
Manganese, in µg/L		50 µg/L	413	1.0	32%	42.0	7.3	109.6	22.5%
Sulfate, in mg/L		250 mg/L	326	0.01	6%	16.35	5.58	45.03	0.0%
Zinc, in µg/L		5,000 µg/L	413	5.0	20%	171.8	27.5	268.7	0.5%

MCL: Maximum Contaminant Levels – associated with risk to human health

SMCL: Secondary Maximum Contaminant Levels – associated with aesthetic considerations

MRL: Minimum reporting level

cfu: colony forming units

Table S1. Survey variables used in logistic regression

Variable	n	Type	Levels	Range	p-value	
					TC	EC
Survey Data Model						
County	582	Nominal	Name of county	-	0.99	1.00
# weeks used	596	Interval	Number of weeks	0-10	0.05	0.00
Flood Pixel 100m	587	Nominal	Yes; No	-	0.03	0.00
Flood Pixel 250m	587	Nominal	Yes; No	-	0.07	0.01
Flood Pixel 500m	587	Nominal	Yes; No	-	0.28	0.37
Flood Pixel 1000m	587	Nominal	Yes; No	-	0.23	0.63
CDC Code	583	Nominal	Urban; Rural	-	0.48	0.04
Q1. Sampling Location	581	Nominal	Drinking; Non-drinking	-	0.41	0.16
Q2. System working	594	Nominal	Yes; No; Don't Know	-	0.24	0.48
Q6A-well_type	494	Nominal	Drilled; Dug/Bored; Don't know	-	0.87	0.51
Q6B. Well depth	413	Nominal	Shallow; Deep	-	0.68	0.26
Q6C. Well year	417	Nominal	PreReg; PostReg	-	0.49	0.37
Q6D. # people on well	570	Nominal	Number of people; Don't know	0-11	0.99	1.00
Q6E. # homes on well	565	Nominal	Number of homes; Don't know	0-21	0.19	0.99
Q7. # years at residence	586	Interval	<1; 1-2; 3-5; 6-10; 10-15; 20+	-	0.31	0.63
Q8. Drink well water	591	Nominal	No; Yes with treatment; Yes without treatment	-	0.74	0.95
Q9. Have a septic	594	Nominal	Yes; No	-	0.98	1.00
Q9B. Empty septic (years)	549	Interval	<1; 1-2; 3-5; 6-10; 10+; When problem; Haven't yet	-	0.29	0.98
Q10A. No treatment	578	Nominal	Yes; No	-	0.41	0.99
Q10B. Sediment filter	579	Nominal	Yes; No	-	0.89	0.93
Q10C. Reserve Osmosis	579	Nominal	Yes; No	-	0.98	0.99
Q10D. Iron removal	580	Nominal	Yes; No	-	0.39	0.43
Q10E. Acid neutralizer	580	Nominal	Yes; No	-	Removed	
Q10F. UV light	580	Nominal	Yes; No	-	0.98	0.99
Q10G. Chlorinator	580	Nominal	Yes; No	-	0.16	0.73
Q10H. Water softener	580	Nominal	Yes; No	-	0.07	0.07
Q10I. Carbon unit	580	Nominal	Yes; No	-	0.57	0.34
Q11B. Height of floodwater observed in home	212	Interval	Inches; Knee Height; Waist deep; Above my head; Don't know	-	0.07	0.17
Q12. Submerged wellhead	476	Nominal	Yes; No; Don't Know	-	0.00	0.00
Q13. Damage to well	541	Nominal	Yes; No; Don't Know	-	0.97	0.98
Q14. Damaged to septic	510	Nominal	Yes; No; Don't Know	-	0.89	0.43
Q15G. Used water for cooking	580	Nominal	Yes; No	-	0.04	0.00
Q15H. Used water for drinking	579	Nominal	Yes; No	-	0.98	0.99
Q15I. Used water for bathing	580	Nominal	Yes; No	-	0.58	0.00
Q15J. Used water for pets	578	Nominal	Yes; No	-	0.99	0.99
Q15K. Used water for laundry	580	Nominal	Yes; No	-	0.35	0.00
Q15L. Used water for cleanup	580	Nominal	Yes; No	-	0.66	0.07
Q16E. Unfiltered well water	577	Nominal	Yes; No	-	0.56	0.06
Q16F. Bottled water	577	Nominal	Yes; No	-	0.09	0.01
Q16G. Filtered well water	576	Nominal	Yes; No	-	0.98	0.99

Q17D. Water safe for drinking	556	Interval	Likert scale	1-5	0.02	0.00
Q17E. Water safe for cooking	558	Interval	Likert scale	1-5	0.02	0.00
Q17F. Water safe for bathing	561	Interval	Likert scale	1-5	0.04	0.00
Q18B. Disinfected after	173	Nominal	Pre; Post	-	0.99	0.99
Q21B. Provide info about testing well	556	Nominal	Yes; No; Don't Know	-	0.57	0.99
Q22B. Provide info about treating well	547	Nominal	Yes; No; Don't Know	-	0.89	0.99
Q23B. Provide info about well maintenance	516	Nominal	Yes; No; Don't Know	-	0.73	0.90
Q24A. Comfortable managing well	577	Interval	Likert scale	1-5	0.37	0.15
Q24B. Know here to find info about well characteristics	571	Interval	Likert scale	1-5	0.81	0.44
Q24C. Know where to find info about testing	569	Interval	Likert scale	1-5	0.89	0.61
Q24D. Know where to find info about treatment	565	Interval	Likert scale	1-5	0.42	0.67
Q26. Household income	431	Interval	Levels 1-4	\$12,000 or below; \$12,001 - \$24,000; \$24,001 - \$45,000; \$45,001 - \$65,000; \$65,001 - \$85,000; \$85,001 - \$100,000; \$100,001 - \$150,000; \$150,001 or above	0.77	0.58
Q27. Household ethnicity	541	Nominal	American Indian or Alaska Native; Asian; Black or African American; Hispanic or Latino; Pacific Islander; Two or more races; White or Caucasian	-	0.98	0.99
Q28. Household education CODE	549	Nominal	Levels 1-5	Some High School; High School Graduate; Some College; College Graduate; Post College (MS, PhD)	0.71	0.40
Q30A. Someone sick from consuming well after	519	Nominal	Yes; No; Don't Know	-	0.54	0.98
Q31A. Someone sick from contacting water after	547	Nominal	Yes; No; Don't Know	-	0.54	0.04

Table S2. Water quality variables used in logistic regression

Variable	n	Type	Levels	Range	p-value	
Water Quality Data Model						
F	326	Ratio	Concentration (mg/L)	<0.01-2.8	0.59	0.12
Cl	326	Ratio	Concentration (mg/L)	<0.01-1,034.3	0.94	0.035
Br	326	Ratio	Concentration (mg/L)	<0.01-45.7	0.43	0.064
NO3	326	Ratio	Concentration (mg/L)	<0.01-24	0.38	0.64
PO4	326	Ratio	Concentration (mg/L)	<0.01-0.8	0.38	0.60
SO4	326	Ratio	Concentration (mg/L)	<0.01-214.6	0.96	0.74
Na	413	Ratio	Concentration (mg/L)	<0.05-1,475	0.01	<0.01
Mg	413	Ratio	Concentration (µg/L)	<10.0-39,690	0.15	0.27
Al	413	Ratio	Concentration (µg/L)	<5.0-5,945	0.61	0.50
Si	413	Ratio	Concentration (µg/L)	<5.0-26,800	0.45	0.00
P	413	Ratio	Concentration (µg/L)	<10.0-11,490	0.53	0.94
K	413	Ratio	Concentration (µg/L)	<10.0-57,610	0.73	0.36
Ca	413	Ratio	Concentration (µg/L)	<50-202,400	0.19	0.72
Ti	413	Ratio	Concentration (µg/L)	<1.0-87.2	0.67	0.19
V	413	Ratio	Concentration (µg/L)	<1.0-40	0.25	0.45
Cr	413	Ratio	Concentration (µg/L)	<1.0-1,233	0.86	0.35
Fe	413	Ratio	Concentration (µg/L)	<10.0-8,826	0.61	0.41
Mn	413	Ratio	Concentration (µg/L)	<1.0-1,412	0.61	<0.01
Co	413	Ratio	Concentration (µg/L)	<1.0-6.4	0.11	0.01
Ni	413	Ratio	Concentration (µg/L)	<1.0-39.8	0.81	0.72
Cu	413	Ratio	Concentration (µg/L)	<1.0-1,710	0.10	0.16
Zn	413	Ratio	Concentration (µg/L)	<5.0-10,470	0.09	0.88
As	413	Ratio	Concentration (µg/L)	<0.5-56.9	0.43	0.00
Se	413	Ratio	Concentration (µg/L)	<2.5-23.2	0.09	0.20
Br	413	Ratio	Concentration (µg/L)	<1.0-3,578	0.51	0.26
Sr	413	Ratio	Concentration (µg/L)	<1.0-1,572	0.13	0.27
Mo	413	Ratio	Concentration (µg/L)	<0.1-73.8	0.97	0.34
Ag	413	Ratio	Concentration (µg/L)	<1.0-7	0.98	0.99
Cd	413	Ratio	Concentration (µg/L)	<1.0-5.7	0.98	0.99
Sn	413	Ratio	Concentration (µg/L)	<1.0-9.7	0.90	0.14
Ba	413	Ratio	Concentration (µg/L)	<1.0-1,131	0.91	0.77
Pb	413	Ratio	Concentration (µg/L)	<1.0-372.1	0.97	0.87
U	413	Ratio	Concentration (µg/L)	<1.0-151.3	0.35	0.05
Hardness	413	Ratio	Concentration (µg/L)	<0.01-647	0.16	0.98

Table S3. Peak flooding dates derived from the US Geological Survey stream gage data

County	Peak Date
Aransas	8/18
Austin	8/22
Bee	8/26
Brazoria	9/12
Calhoun	8/28
Chambers	8/17
Childress	NA
Colorado	9/4
DeWitt	8/28
Galveston	8/24
Goliad	8/13
Gonzales	9/8
Hardin	8/31
Harris	9/13
Jackson	8/29
Jasper	9/1
Jefferson	8/26
La Salle	8/21
Lavaca	9/3
Liberty	8/31
Matagorda	9/7
Montgomery	9/1
Newton	9/2
Orange	8/30
Refugio	8/21
Sabine	NA
San Jacinto	8/31
San Patricio	8/6
Tyler	8/31
Victoria	8/25
Waller	9/2
Washington	8/22
Wharton	9/4

Table S4. Private well information in the 41 disaster declared counties

County	CDC classification	% of county inundated	Total population	Estimated well users	% population on well water	# of well users inundated	% of well users inundated
Aransas	3	65.2%	23,724	3,503	14.8%	452	12.9%
Austin	2	5.0%	31,504	9,739	30.9%	125	1.3%
Bastrop	2	0.5%	88,157	3,479	3.9%	6	0.2%
Bee	5	0.0%	33,240	9,301	28.0%	1	0.0%
Brazoria	2	31.9%	375,517	56,305	15.0%	2,922	5.2%
Caldwell	2	0.1%	42,593	2,340	5.5%	1	0.0%
Calhoun	5	62.9%	21,955	2,836	12.9%	324	11.4%
Chambers	2	50.6%	43,018	5,069	11.8%	822	16.2%
Colorado	6	5.3%	21,730	7,372	33.9%	91	1.2%
DeWitt	6	1.1%	20,938	6,999	33.4%	32	0.5%
Fayette	6	2.3%	25,857	8,109	31.4%	51	0.6%
Fort Bend	2	9.2%	779,600	27,008	3.5%	1,320	4.9%
Galveston	2	64.4%	337,503	16,514	4.9%	366	2.2%
Goliad	4	0.5%	7,791	3,664	47.0%	11	0.3%
Gonzales	6	0.7%	20,641	2,979	14.4%	3	0.1%
Grimes	6	2.3%	28,871	9,371	32.5%	67	0.7%
Hardin	3	0.2%	58,355	12,329	21.1%	19	0.2%
Harris	1	7.4%	4,686,778	106,039	2.3%	2,201	2.1%
Jackson	6	8.8%	15,234	4,426	29.1%	150	3.4%
Jasper	6	3.0%	36,407	12,846	35.3%	27	0.2%
Jefferson	3	47.5%	252,469	3,888	1.5%	497	12.8%
Karnes	6	0.0%	15,318	2,308	15.1%	0	0.0%
Kleberg	5	20.5%	32,295	2,491	7.7%	10	0.4%
Lavaca	6	0.9%	20,256	9,362	46.2%	30	0.3%
Lee	6	1.5%	17,366	2,222	12.8%	9	0.4%
Liberty	2	4.6%	86,495	19,448	22.5%	510	2.6%
Matagorda	5	40.9%	36,550	8,884	24.3%	634	7.1%
Montgomery	2	4.7%	594,453	47,896	8.1%	483	1.0%
Newton	3	0.8%	13,759	6,964	50.6%	17	0.2%
Nueces	3	30.7%	361,243	6,158	1.7%	60	1.0%
Orange	3	17.7%	84,862	28,197	33.2%	227	0.8%
Polk	6	5.6%	49,556	5,749	11.6%	271	4.7%
Refugio	6	13.3%	6,944	1,646	23.7%	126	7.7%
Sabine	6	17.6%	11,038	2,736	24.8%	338	12.3%
San Jacinto	6	10.4%	29,190	5,995	20.5%	158	2.6%
San Patricio	3	6.8%	65,920	7,321	11.1%	235	3.2%
Tyler	6	1.0%	22,437	5,714	25.5%	8	0.1%
Victoria	4	6.0%	92,025	15,179	16.5%	491	3.2%
Walker	5	3.3%	74,359	7,997	10.8%	61	0.8%
Waller	2	4.6%	53,305	8,921	16.7%	69	0.8%
Wharton	5	14.9%	41,093	16,719	40.7%	1,835	11.0%

CDC Codes – 1: Large central metro; 2: Large fringe metro; 3: Medium metro; 4: Small metro; 5: Micropolitan; 6: noncore

Table S5. Comparison of sampling rates by the three campaigns

Month	# samples				TC positive				EC positive			
	BHD	HHD	UR1	UR2	BHD	HHD	UR1	UR2	BHD	HHD	UR1	UR2
Aug	25	-	-	-	4	-	-	-	-	-	-	-
Sept	3040	1709	432	-	837	776	203	-	-	283	57	-
Oct	697	463	198	-	120	155	90	-	-	38	18	-
Nov	326	187	-	533	43	50	-	151	-	7	-	15
Dec	107	-	-	-	10	-	-	-	-	-	-	-
Jan	38	-	-	160	3	-	-	45	-	-	-	6
Feb	44	-	-	205	5	-	-	53	-	-	-	3
Mar	49	-	-	-	0	-	-	-	-	-	-	-
Apr	155	-	-	-	20	-	-	-	-	-	-	-
May	180	-	-	-	24	-	-	-	-	-	-	-
Jun	274	-	-	-	20	-	-	-	-	-	-	-
Total	4,935	2,359	630	898	1,086	981	293	249	-	328	75	24
	8,822				2,609				427			

BHD: Brazoria Health Department

HHD: Houston Health Department

UR1 University testing Round 1

UR2: University testing Round 2

Table S6. Private well testing results in the 41 disaster declared counties from the three campaigns

County	Total coliform		<i>E. coli</i>	
	n	% positive	n	% positive
Aransas	89	38.2%	89	38.2%
Austin	48	37.5%	47	10.6%
Bee	1	100.0%	1	100.0%
Brazoria	4,285	22.2%	34	11.8%
Caldwell	0	-	0	-
Calhoun	31	29.0%	31	29.0%
Chambers	73	27.4%	73	26.0%
Colorado	10	20.0%	9	22.2%
DeWitt	32	40.6%	32	40.6%
Fayette	1	0.0%	1	0.0%
Fort Bend	777	37.8%	702	9.4%
Galveston	216	19.0%	73	21.9%
Goliad	8	50.0%	8	50.0%
Gonzales	2	50.0%	2	50.0%
Grimes	1	0.0%	0	-
Hardin	124	31.5%	124	31.5%
Harris	1,455	41.6%	1,440	17.9%
Jackson	49	30.6%	49	30.6%
Jasper	28	39.3%	28	39.3%
Jefferson	40	45.0%	40	45.0%
Karnes	0	-	0	-
Lavaca	6	33.3%	6	33.3%
Lee	0	-	0	-
Liberty	67	41.8%	67	41.8%
Matagorda	140	22.1%	24	12.5%
Montgomery	14	50.0%	14	14.3%
Newton	25	44.0%	25	44.0%
Nueces	5	60.0%	5	60.0%
Orange	192	27.6%	192	27.6%
Polk	0	-	0	-
Refugio	38	52.6%	38	52.6%
Sabine	1	0.0%	1	0.0%
San Jacinto	7	14.3%	7	14.3%
San Patricio	19	57.9%	19	57.9%
Tyler	5	40.0%	5	40.0%
Victoria	139	43.2%	139	43.2%
Walker	2	0.0%	2	0.0%
Waller	92	40.2%	92	19.6%
Wharton	688	33.4%	389	31.9%

Table S7. Zip-code level private well testing results in the 41 disaster declared counties from the three campaigns

Zip Code	Total coliform		E. coli	
	n	% positive	n	% positive
75928	3	33.3%	3	33.3%
75931	3	33.3%	3	33.3%
75932	1	0.0%	1	0.0%
75933	5	40.0%	5	40.0%
75951	3	66.7%	3	66.7%
75956	6	66.7%	6	66.7%
75966	1	100.0%	1	100.0%
75979	1	100.0%	1	100.0%
76126	1	0.0%	1	0.0%
76849	1	0.0%	1	0.0%
77002	14	7.1%	14	0.0%
77003	1	0.0%	1	0.0%
77004	3	0.0%	3	0.0%
77005	5	60.0%	5	40.0%
77006	2	0.0%	2	0.0%
77008	1	0.0%	1	0.0%
77009	1	0.0%	1	0.0%
77015	7	0.0%	7	0.0%
77017	2	0.0%	2	0.0%
77023	1	0.0%	1	0.0%
77024	8	12.5%	8	0.0%
77025	2	0.0%	2	0.0%
77027	15	6.7%	15	0.0%
77029	2	50.0%	2	0.0%
77030	8	0.0%	8	0.0%
77032	6	50.0%	6	50.0%
77033	1	0.0%	1	0.0%
77034	6	0.0%	6	0.0%
77036	3	0.0%	3	0.0%
77037	28	50.0%	28	10.7%
77038	1	0.0%	1	0.0%
77039	35	48.6%	35	34.3%
77040	3	33.3%	3	0.0%
77041	10	50.0%	10	20.0%
77042	4	50.0%	4	50.0%
77044	31	48.4%	31	29.0%
77045	3	0.0%	3	0.0%
77047	5	0.0%	5	0.0%
77048	1	0.0%	1	0.0%
77049	2	0.0%	2	0.0%
77050	6	66.7%	6	33.3%
77054	22	4.5%	22	0.0%
77055	2	0.0%	2	0.0%
77057	4	0.0%	4	0.0%
77060	2	50.0%	2	50.0%
77063	1	100.0%	1	0.0%
77064	8	25.0%	8	0.0%
77065	77	61.0%	77	16.9%
77066	67	1.5%	67	0.0%
77068	5	20.0%	5	0.0%

77069	4	50.0%	4	50.0%
77070	9	33.3%	9	22.2%
77072	3	0.0%	3	0.0%
77073	1	0.0%	1	0.0%
77074	1	0.0%	1	0.0%
77075	1	0.0%	1	0.0%
77076	2	50.0%	2	0.0%
77079	9	11.1%	9	0.0%
77080	1	100.0%	1	100.0%
77081	2	0.0%	2	0.0%
77082	2	0.0%	2	0.0%
77083	1	0.0%	1	0.0%
77084	6	50.0%	6	50.0%
77086	5	80.0%	5	20.0%
77089	1	0.0%	1	0.0%
77090	1	100.0%	1	0.0%
77092	1	0.0%	1	0.0%
77093	5	40.0%	5	20.0%
77094	3	33.3%	3	0.0%
77096	2	0.0%	2	0.0%
77099	1	0.0%	1	0.0%
77249	1	100.0%	1	100.0%
77316	1	0.0%	1	0.0%
77327	4	50.0%	4	50.0%
77328	2	0.0%	2	0.0%
77336	22	45.5%	22	22.7%
77338	10	60.0%	10	50.0%
77339	1	0.0%	1	0.0%
77340	2	0.0%	2	0.0%
77354	5	80.0%	5	20.0%
77357	6	33.3%	6	0.0%
77371	6	16.7%	6	16.7%
77372	1	100.0%	1	100.0%
77373	3	100.0%	3	100.0%
77374	1	0.0%	1	0.0%
77375	11	63.6%	11	18.2%
77377	14	50.0%	14	0.0%
77379	21	0.0%	21	0.0%
77388	3	33.3%	3	0.0%
77389	1	0.0%	1	0.0%
77406	258	32.9%	258	9.3%
77407	2	50.0%	2	0.0%
77414	66	15.2%	10	0.0%
77415	7	0.0%	2	0.0%
77417	3	33.3%	3	0.0%
77419	1	0.0%	0	-
77420	76	32.9%	47	29.8%
77422	782	26.5%	3	0.0%
77423	27	59.3%	27	14.8%
77426	1	0.0%	1	0.0%
77427	3	66.7%	3	33.3%
77429	521	53.0%	521	21.3%
77430	88	45.5%	5	0.0%

77432	3	33.3%	2	0.0%
77433	13	38.5%	12	16.7%
77434	8	12.5%	8	12.5%
77435	67	31.3%	31	32.3%
77436	12	33.3%	6	50.0%
77437	40	15.0%	12	16.7%
77439	1	0.0%	1	0.0%
77441	16	50.0%	16	12.5%
77443	6	16.7%	1	100.0%
77444	38	10.5%	0	-
77445	39	25.6%	39	17.9%
77447	13	38.5%	13	23.1%
77448	2	0.0%	2	0.0%
77449	1	100.0%	1	0.0%
77454	1	0.0%	1	0.0%
77455	3	33.3%	3	33.3%
77456	3	66.7%	3	66.7%
77457	2	0.0%	2	0.0%
77459	24	41.7%	18	11.1%
77461	41	43.9%	41	2.4%
77463	3	33.3%	0	-
77464	3	33.3%	3	0.0%
77465	4	0.0%	3	0.0%
77467	7	28.6%	7	0.0%
77468	3	0.0%	1	0.0%
77469	27	33.3%	21	0.0%
77471	49	34.7%	46	8.7%
77474	11	36.4%	11	9.1%
77476	164	47.0%	164	11.6%
77478	2	0.0%	2	0.0%
77479	7	28.6%	7	0.0%
77480	188	28.2%	0	-
77481	22	45.5%	22	0.0%
77482	29	41.4%	4	25.0%
77484	14	35.7%	14	35.7%
77485	75	37.3%	74	12.2%
77486	109	30.3%	0	-
77488	474	35.9%	276	34.1%
77492	1	0.0%	1	0.0%
77493	34	55.9%	34	20.6%
77494	49	38.8%	49	6.1%
77496	1	0.0%	1	0.0%
77497	1	0.0%	1	0.0%
77498	1	0.0%	1	0.0%
77506	2	0.0%	2	0.0%
77507	6	0.0%	6	0.0%
77510	81	13.6%	29	13.8%
77511	226	34.1%	8	0.0%
77514	1	0.0%	1	0.0%
77515	1,605	28.7%	0	-
77516	22	54.5%	0	-
77517	72	13.9%	19	26.3%
77520	1	100.0%	1	100.0%

77521	79	29.1%	79	19.0%
77523	38	23.7%	38	21.1%
77531	116	24.1%	0	-
77532	219	47.9%	219	21.9%
77534	74	33.8%	0	-
77535	30	53.3%	30	53.3%
77536	4	0.0%	4	0.0%
77538	1	0.0%	1	0.0%
77539	23	30.4%	12	33.3%
77541	129	31.8%	0	-
77542	7	42.9%	0	-
77545	14	85.7%	13	46.2%
77546	1	100.0%	1	0.0%
77550	1	0.0%	1	0.0%
77555	0	-	0	-
77560	4	75.0%	4	75.0%
77562	10	20.0%	10	0.0%
77564	2	50.0%	2	50.0%
77565	2	50.0%	2	50.0%
77566	425	0.7%	5	60.0%
77573	1	100.0%	1	100.0%
77575	30	26.7%	30	26.7%
77577	56	0.0%	0	-
77578	44	6.8%	7	0.0%
77581	250	0.4%	2	0.0%
77583	265	0.4%	2	50.0%
77584	15	13.3%	5	0.0%
77585	3	66.7%	3	66.7%
77590	1	0.0%	1	0.0%
77591	7	14.3%	6	16.7%
77611	3	0.0%	3	0.0%
77612	1	100.0%	1	100.0%
77613	3	33.3%	3	33.3%
77619	1	100.0%	1	100.0%
77622	20	50.0%	20	50.0%
77624	1	0.0%	1	0.0%
77625	56	26.8%	56	26.8%
77629	1	0.0%	1	0.0%
77630	47	21.3%	47	21.3%
77632	59	44.1%	59	44.1%
77656	22	40.9%	22	40.9%
77657	20	35.0%	20	35.0%
77659	21	23.8%	21	23.8%
77661	5	40.0%	5	40.0%
77662	114	23.7%	114	23.7%
77663	2	50.0%	2	50.0%
77664	2	0.0%	2	0.0%
77665	27	25.9%	27	25.9%
77705	1	100.0%	1	100.0%
77713	6	50.0%	6	50.0%
77833	2	50.0%	2	50.0%
77834	3	0.0%	3	0.0%
77868	2	0.0%	0	-

77901	1	100.0%	1	100.0%
77904	38	36.8%	38	36.8%
77905	72	45.8%	72	45.8%
77954	27	40.7%	27	40.7%
77957	26	38.5%	26	38.5%
77961	2	0.0%	2	0.0%
77962	9	11.1%	9	11.1%
77963	3	33.3%	3	33.3%
77964	1	0.0%	1	0.0%
77968	24	33.3%	24	33.3%
77971	8	37.5%	8	37.5%
77974	1	100.0%	1	100.0%
77975	1	100.0%	1	100.0%
77979	26	26.9%	26	26.9%
77983	5	20.0%	5	20.0%
77988	6	83.3%	6	83.3%
77990	14	50.0%	14	50.0%
77991	1	0.0%	1	0.0%
77995	8	25.0%	8	25.0%
78132	1	0.0%	1	0.0%
78164	1	100.0%	1	100.0%
78233	1	0.0%	1	0.0%
78247	1	0.0%	1	0.0%
78336	29	51.7%	29	51.7%
78358	2	50.0%	2	50.0%
78377	12	58.3%	12	58.3%
78382	79	36.7%	79	36.7%
78387	4	75.0%	4	75.0%
78393	16	50.0%	16	50.0%
78629	1	100.0%	1	100.0%
78932	2	50.0%	2	0.0%
78934	2	50.0%	2	50.0%
78962	1	0.0%	1	0.0%
79331	1	0.0%	1	0.0%

Table S8. TC and EC screening data collected through TWON programming in 8-9 Texas Gulf Coast counties between 2013-2017.

	TC	EC
# samples	469	281
% positive	19.6%	3.9%
# clinics	9	8
# samples/clinic	18-188	18-70

TC: total coliform; EC: *E. coli*

Table S9. Linear regression model outputs

Total coliform: 3 campaigns (TC ~ Month)					<i>E. coli</i> : 3 campaigns (EC ~ Month)				
	Estimate	Std. Error	t-value	p-value		Estimate	Std. Error	t-value	p-value
Intercept	0.286	0.055	5.23	<0.001	Intercept	0.171	0.040	4.23	0.024
Month	-0.019	0.008	-2.31	0.046	Month	-0.024	0.008	-2.84	0.066
---					---				
Residual standard error: 0.08 on 9 degrees of freedom					Residual standard error: 0.04 on 3 degrees of freedom				
Multiple R ² : 0.37			Adjusted R ² : 0.30		Multiple R ² : 0.73			Adjusted R ² : 0.64	
F-statistic: 5.34 on 1 and 9 DF			p-value: 0.046		F-statistic: 8.06 on 1 and 3 DF			p-value: 0.06	
Total coliform: University campaign (TC ~ Week)					<i>E. coli</i> : University campaign (EC ~ Week)				
	Estimate	Std. Error	t-value	p-value		Estimate	Std. Error	t-value	p-value
Intercept	0.574	0.049	11.68	<0.001	Intercept	0.192	0.02	9.53	<0.001
Week	-0.027	0.006	-4.42	0.001	Week	-0.015	0.00	-6.09	<0.001
---					---				
Residual standard error: 0.09 on 10 degrees of freedom					Residual standard error: 0.04 on 10 degrees of freedom				
Multiple R ² : 0.66			Adjusted R ² : 0.63		Multiple R ² : 0.79			Adjusted R ² : 0.77	
F-statistic: 19.51 on 1 and 10 DF			p-value: 0.001		F-statistic: 37.14 on 1 and 10 DF			p-value: <0.001	

Table S10. Distribution of coliform contamination by weeks since peak flooding among participants in University testing

Week since peak flooding	n	% TC positive	% EC positive
0	46	58.7%	19.6%
1	2	50.0%	0.0%
2	102	43.1%	18.6%
3	39	61.5%	17.9%
4	198	42.4%	9.1%
5	89	51.7%	14.6%
6	58	29.3%	3.4%
7	11	45.5%	0.0%
8	54	46.3%	5.6%
9	50	22.0%	2.0%
10	70	34.3%	8.6%
11	98	23.5%	2.0%
12	82	29.3%	1.2%
13	137	21.9%	0.7%
14	8	50.0%	12.5%
15	17	29.4%	5.9%
16	0	-	-
17	0	-	-
18	0	-	-
19	0	-	-
20	1	0.0%	0.0%
21	17	11.8%	5.9%
22	45	33.3%	2.2%
23	115	21.7%	0.0%
24	11	0.0%	0.0%
25	34	32.4%	5.9%
26	47	34.0%	2.1%
27	0	-	-
28	1	0.0%	0.0%

TC: total coliform; EC: *E. coli*

Table S11. Odds ratio results from logistic regressions

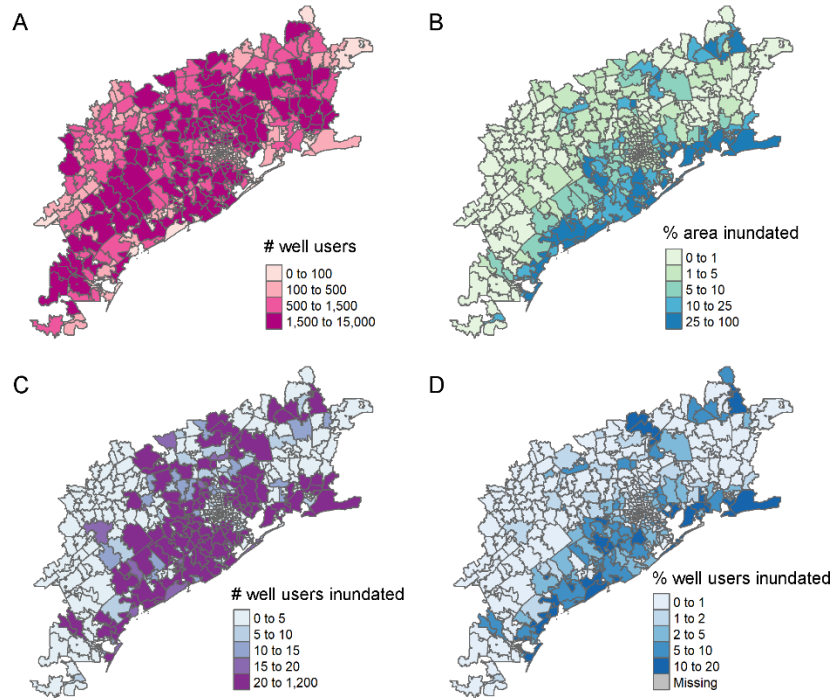
Variable	Total Coliform Detection				<i>E. coli</i> Detection			
	Odds Ratio	Lower Bound	Upper Bound	p-value	Odds Ratio	Lower Bound	Upper Bound	p-value
Survey Data Model Output								
Submerged wellhead	2.17	1.50	3.15	<0.001	8.53	4.25	19.06	<0.001
Within 100 m of flood pixel	1.68	1.04	2.72	0.03	2.97	1.61	5.31	<0.001
Within 250 m of flood pixel	1.42	0.97	2.10	0.07	2.05	1.18	3.50	0.01
Rural area	0.89	0.63	1.24	0.48	0.58	0.35	0.97	0.04
Resumed water use	0.93	0.86	1.00	0.05	0.78	0.68	0.89	0.00
Switched to bottled water	1.39	0.95	2.05	0.09	2.66	1.31	6.15	0.01
Water unsafe for drinking	1.14	1.02	1.27	0.02	1.43	1.19	1.75	<0.001
Water unsafe for cooking	1.14	1.02	1.27	0.02	1.39	1.18	1.67	<0.001
Not using for cooking	1.43	1.02	1.96	0.04	2.56	1.52	4.55	<0.001
Water unsafe for bathing	1.14	1.01	1.27	0.04	1.37	1.15	1.64	<0.001
Not using for bathing	1.11	0.76	1.61	0.58	2.27	1.32	3.85	<0.01
Not using for laundry	1.19	0.83	1.69	0.35	2.27	1.37	3.85	<0.01
Water Chemistry Data Model Output								
Cobalt	1.37	0.97	0.11	2.13	1.55	1.10	2.24	0.01
Arsenic	1.02	0.97	0.43	1.07	1.11	1.05	1.20	0.00
Uranium	1.02	0.99	0.35	1.08	1.07	1.01	1.15	0.05

Bold text indicates significant odds ratio value

Table S12. Well disinfection rates based on inundation proximity

Proximity to inundation	Within proximity				Not within proximity			
	Chlorinated		Not chlorinated		Chlorinated		Not chlorinated	
	n	%	n	%	n	%	n	%
100 m	37	46.8%	42	53.2%	157	20.0%	628	80.0%
250 m	64	41.8%	89	58.2%	130	18.3%	581	81.7%
500 m	91	31.4%	199	68.6%	103	17.9%	471	82.1%
1000 m	116	25.7%	335	74.3%	78	18.9%	335	81.1%

GEOSPATIAL MODELING DATA



CITIZEN SCIENCE SAMPLING DATA

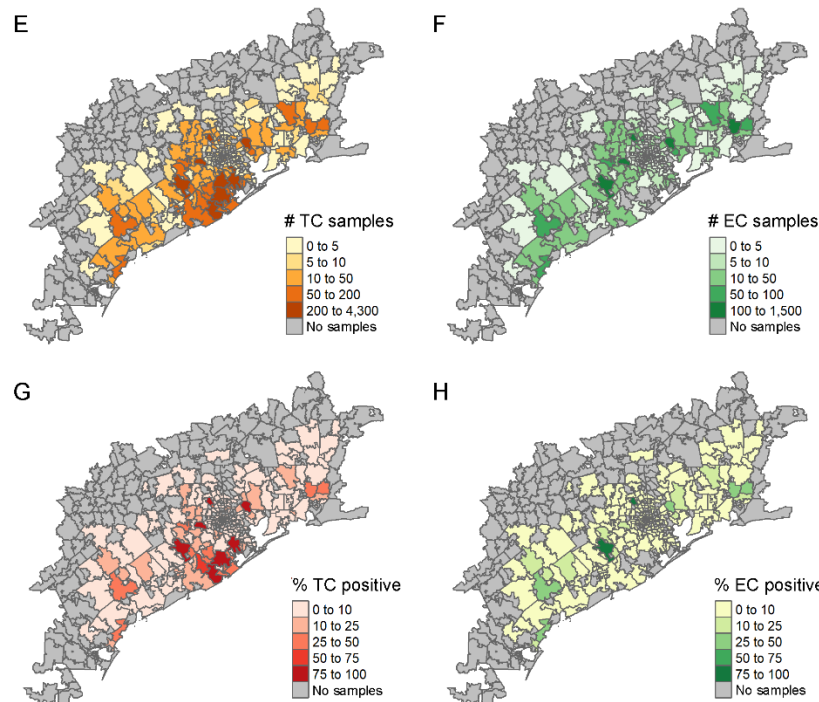


Figure S1. Spatial extent of flood impact on well users and associated contamination rates by zip code for (A) Total number of well users; (B) Percent of county flooded; (C) Total number of well users flooded; (D) Percent of well users flooded; (E) Total number of total coliform samples; (F) Total number of *E. coli* samples; (G) Percent of total coliform positive samples; and (H) Percent of *E. coli* positive samples. Well locations were derived from USGS well dataset²³ and inundation from the inundation dataset.²⁴ Samples reported were collected during the University and health department campaigns.

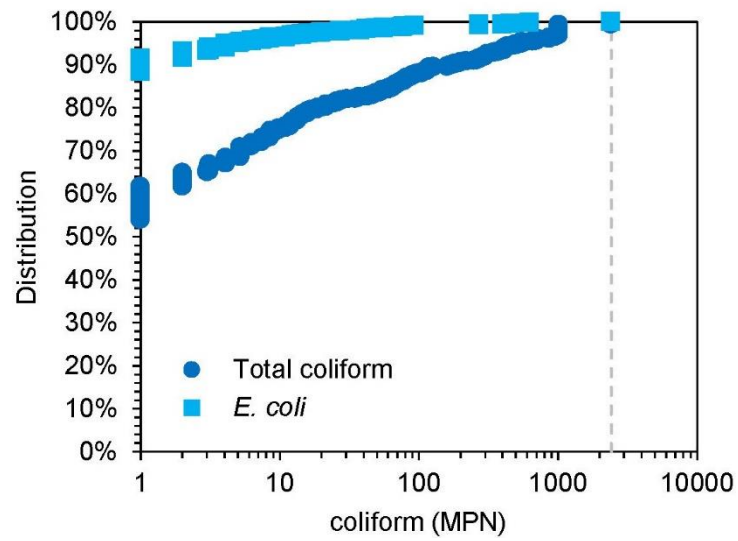


Figure S2. Cumulative distribution plot of total coliform and *E. coli* in Round 1. Dashed gray line indicates too numerous to count (TNTC; >2419.6 MPN); MPN: most probable number; n=602

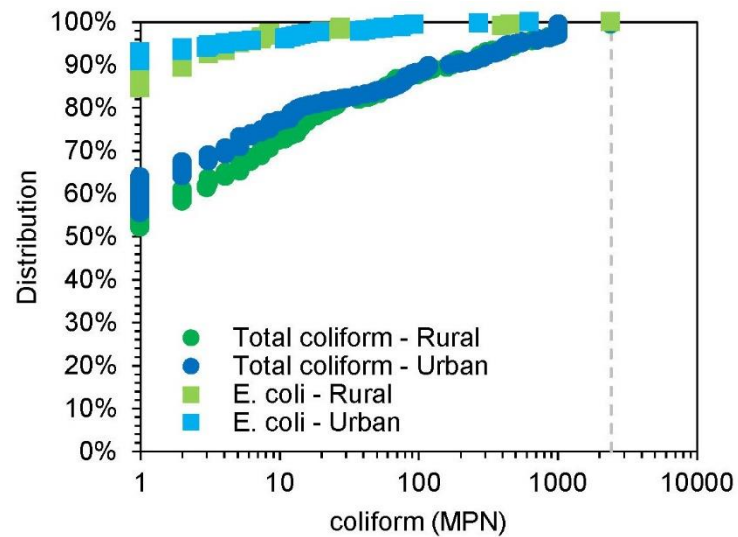


Figure S3. Cumulative distribution plot of total coliform and *E. coli* in Round 1 by rural and urban counties. Dashed gray line indicates too numerous to count (TNTC; >2419.6 MPN); MPN: most probable number; N=602, $n_{\text{rural}} = 228$, and $n_{\text{urban}}=374$

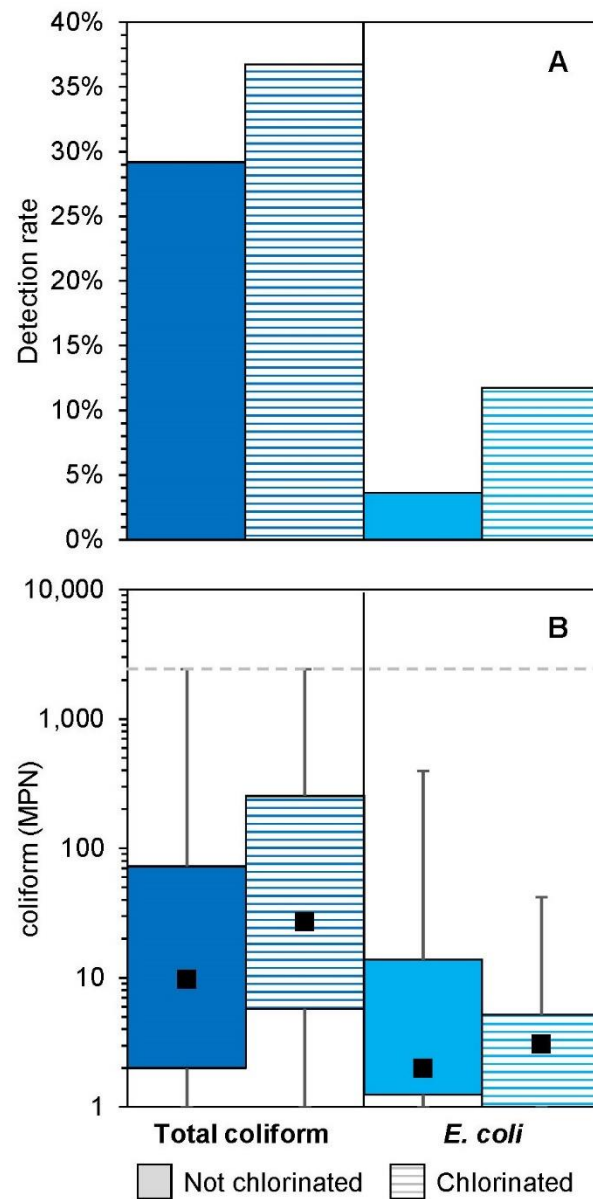


Figure S4. Total coliform and *E. coli* levels in chlorinated and non-chlorinated well water as (A) percent detected and (B) bacteria concentrations. Black square: median MPN value. Gray dashed line: too numerous to count (>2419.6 MPN).

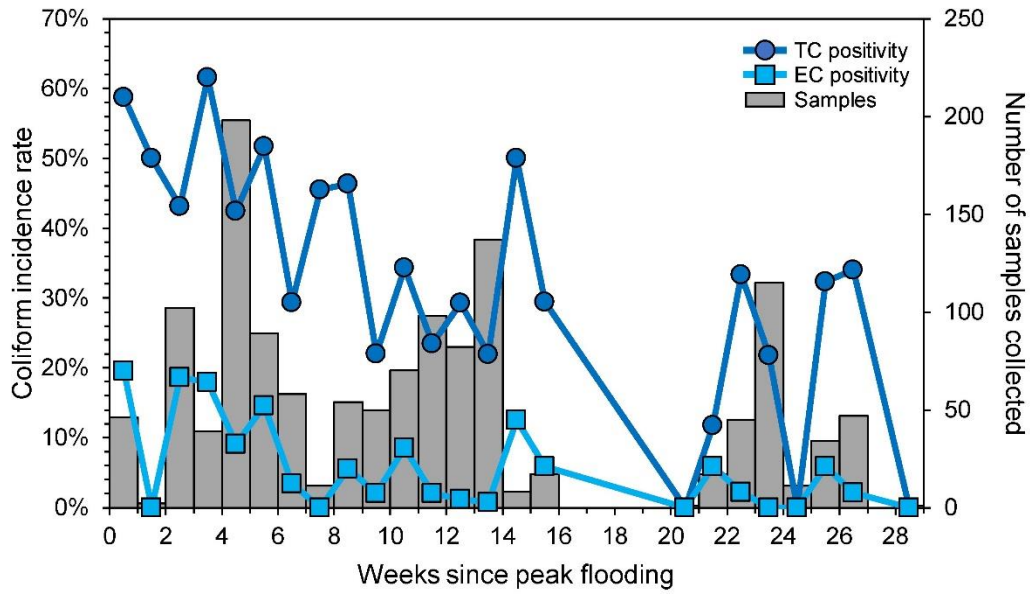


Figure S5. Number of samples and microbial contamination rates by weeks since peak flooding for Rounds 1 and 2 of the University testing through 28 weeks. TC: total coliform; EC: *E. coli*