Contaminant transport pathways between urban sewer networks and water supply wells

Madeline Gotkowitz
Ken Bradbury
Wisconsin Geological Survey

Mark Borchardt
USDA Agricultural Research Service

UW Extension Cooperative Extension

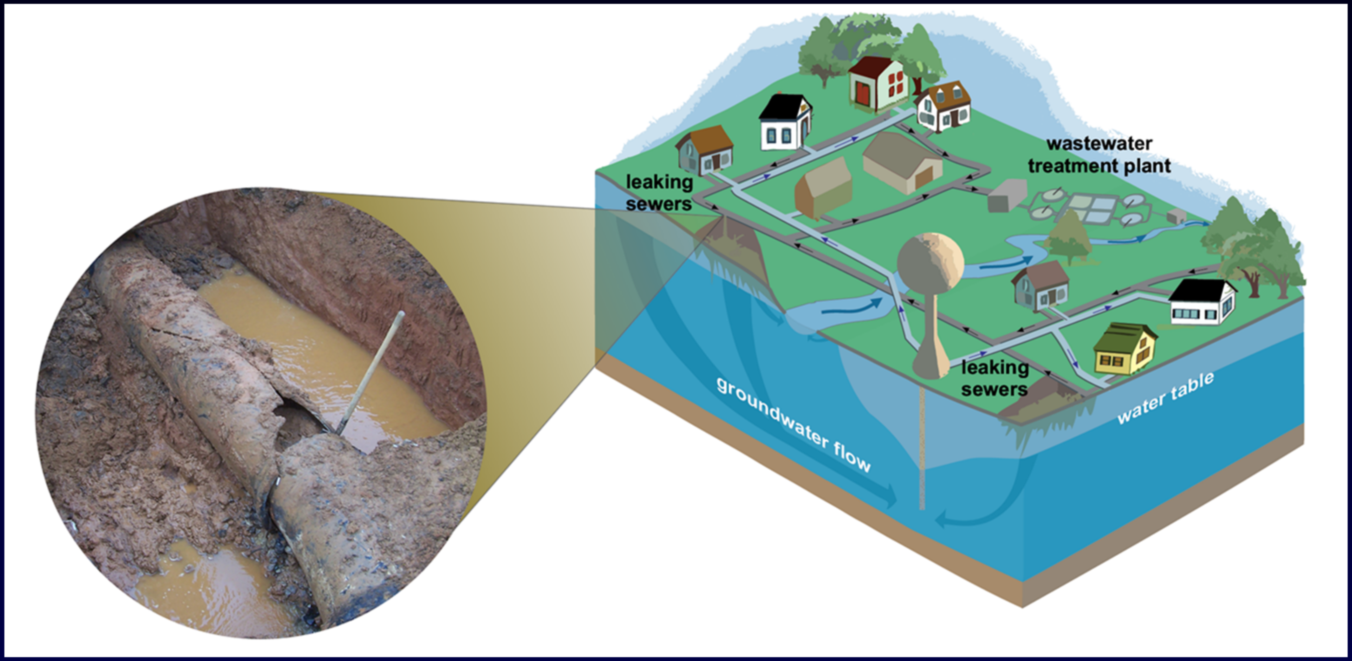
Wisconsin Geological & Natural History Survey

Acknowledgements

Field techs
J. Krause, B. Bradbury, J.Borchardt

Data management: P. Schoephoester, H. Davis
Lab support: H. Millen, J. Gonnering, S. Spencer
Collaborators: C. Gellash, J. Zhu, R. Hunt
Madison and Fitchburg Water Utilities
Madison Metropolitan Sewer District
EPA Science to Achieve Results (STAR) Program
Bureau of Drinking Water and Groundwater, WDNR

Sanitary sewers leak outward

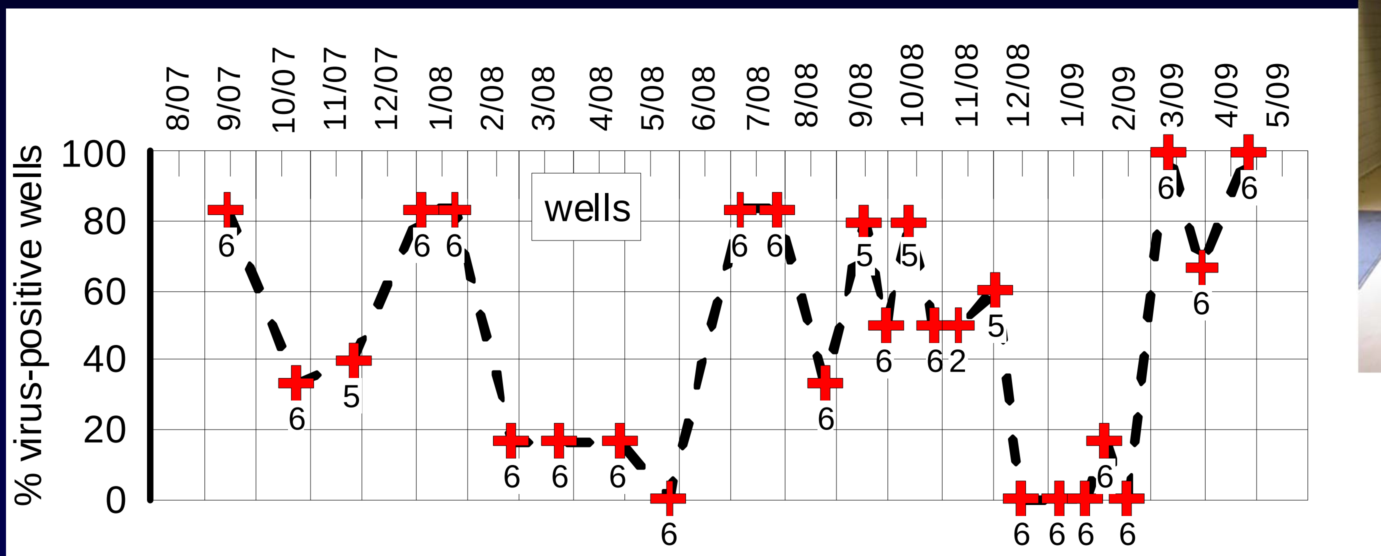


Sewage exfiltration rates: 0.3 to 300 gallons/hr/mile

Chisala and Lerner, 2008.

Are there impacts on urban groundwater…are there significant problems associated with aging underground pipes and our drinking water quality?

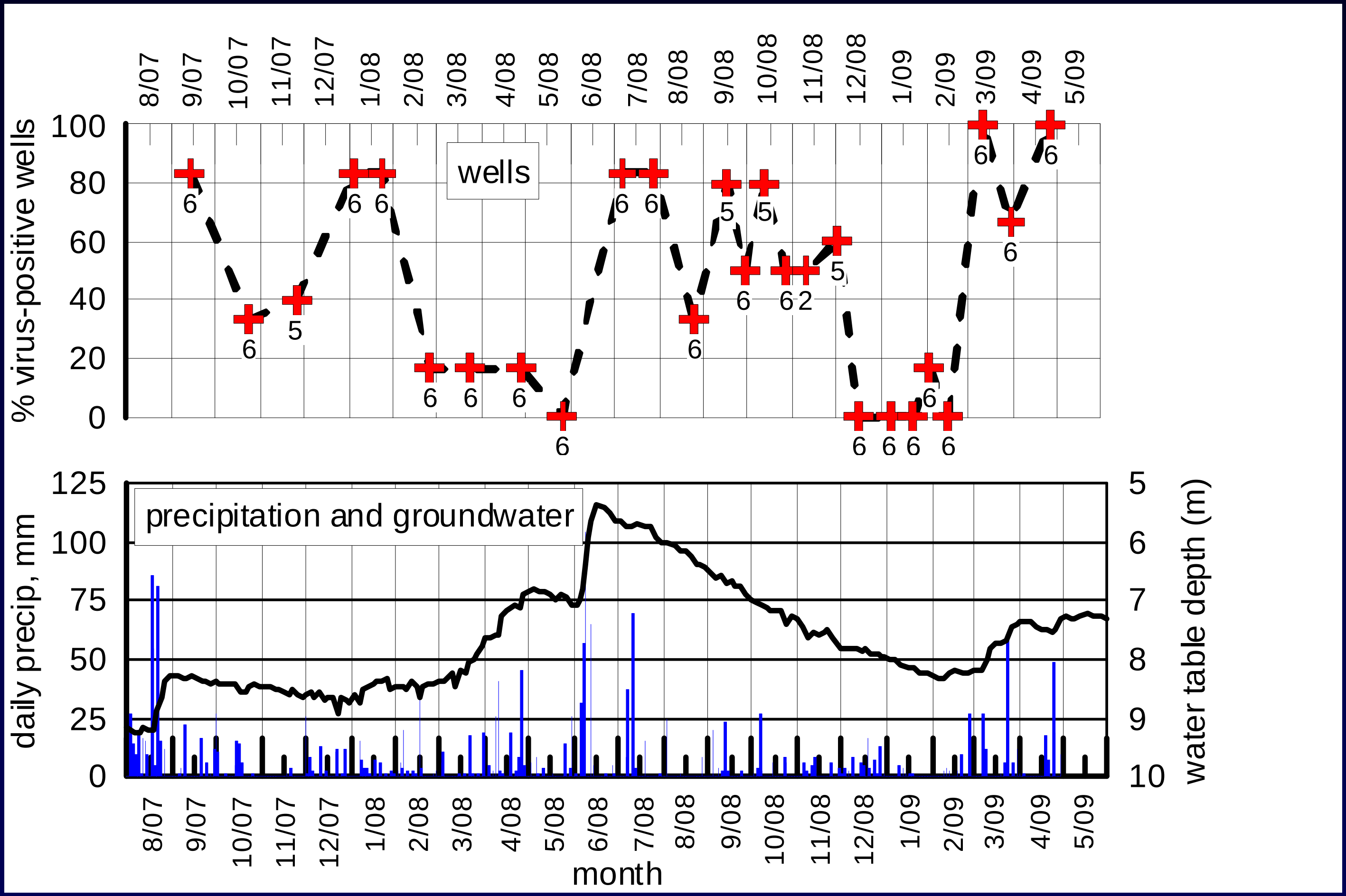
47% (70 of 148) samples collected from six deep public supply wells were virus positive



Overall detections varied over time, from no positive wells to 100% positive samples

Bradbury et al., *In Review*

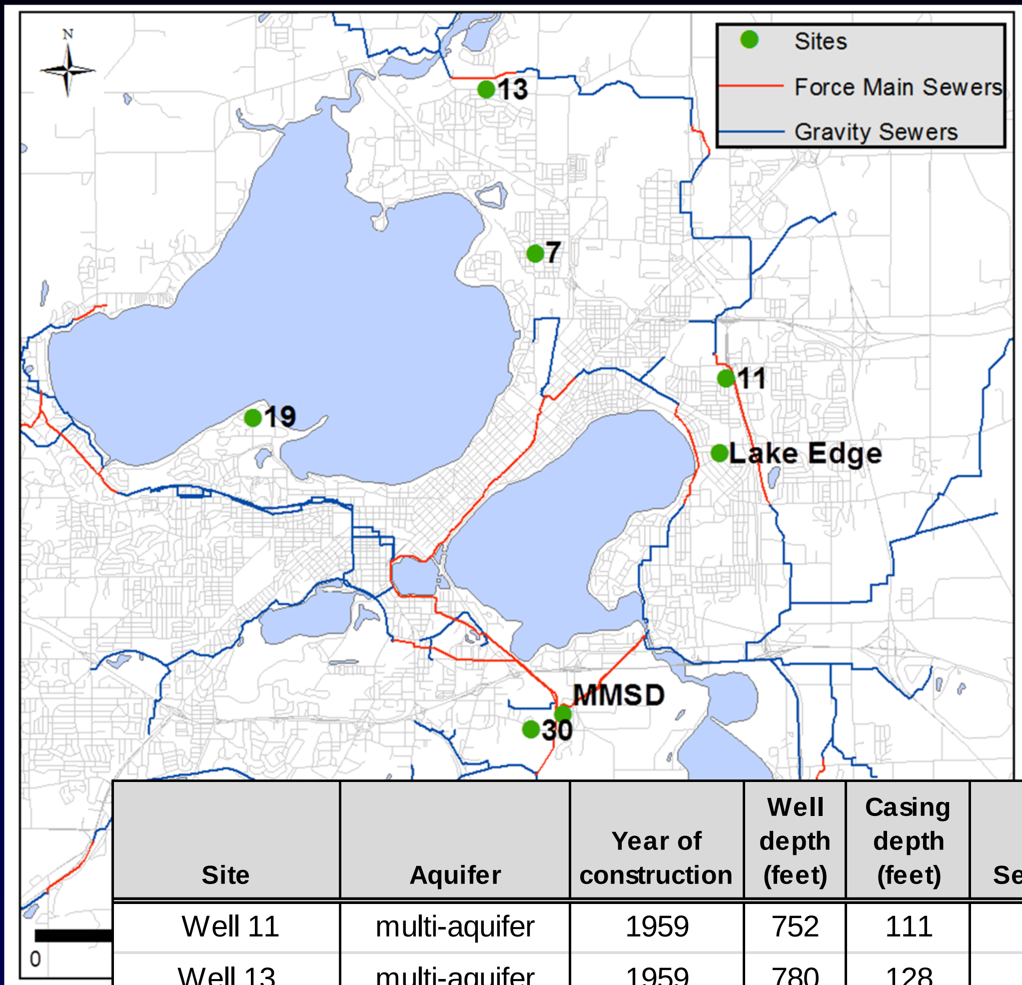
Groundwater recharge events correlate to virus detections, suggesting rapid transport



Bradbury et al., *In Review*

Project goals

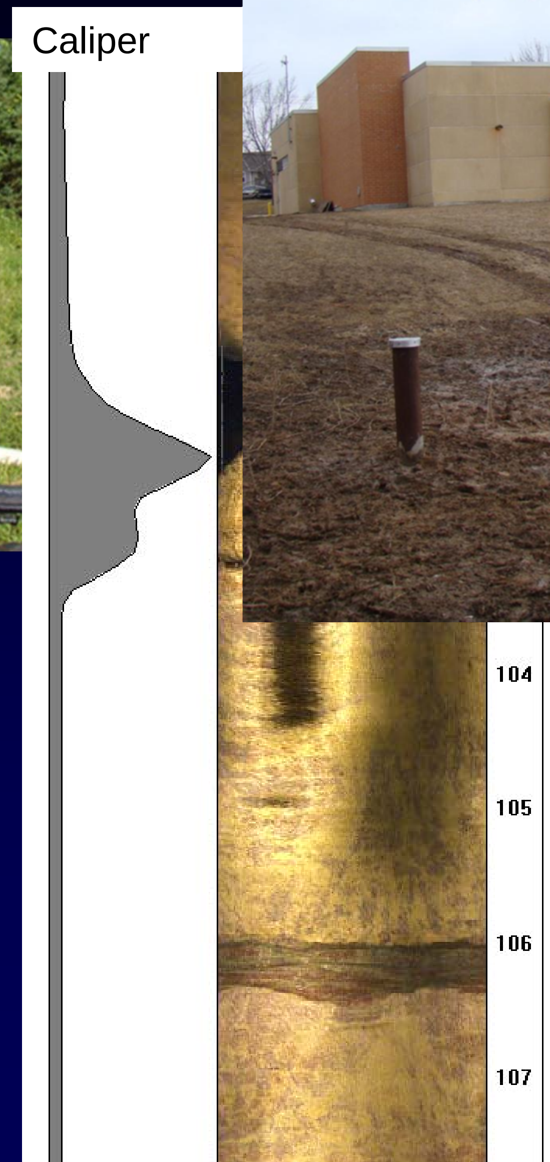
- *Quantify the temporal and spatial distribution of viruses in shallow groundwater*
- *Is there a relationship between viruses detections and conditions of near-by sewers?*
- *What is the nature of preferential pathways in the apparent rapid transport of viruses*



Study design

Site	Aquifer	Year of construction	Well depth (feet)	Casing depth (feet)	Sewer Age	Sewer Material	Tritium (TUs)	Chloride (mg/L)	Nitrate (mg/L)
Well 11	multi-aquifer	1959	752	111	1957	clay	5.5	44.2	2.5
Well 13	multi-aquifer	1959	780	128	1958	clay	1.6	7.8	1.7
Well 7	confined	1939	736	238	1939	clay	5.1	11.6	<0.1
Well 19	confined	1970	710	260	1960	clay	3.7	4.4	<0.1
Well 30	confined	2003	800	312	1997	plastic	0.4	3.6	<0.1
FB Well 11	confined	2007	1000	402	2000	plastic	0.04	2.4	<0.1
Lake Edge	NA	NA	NA	NA	1952	clay	6	9.2	1.5

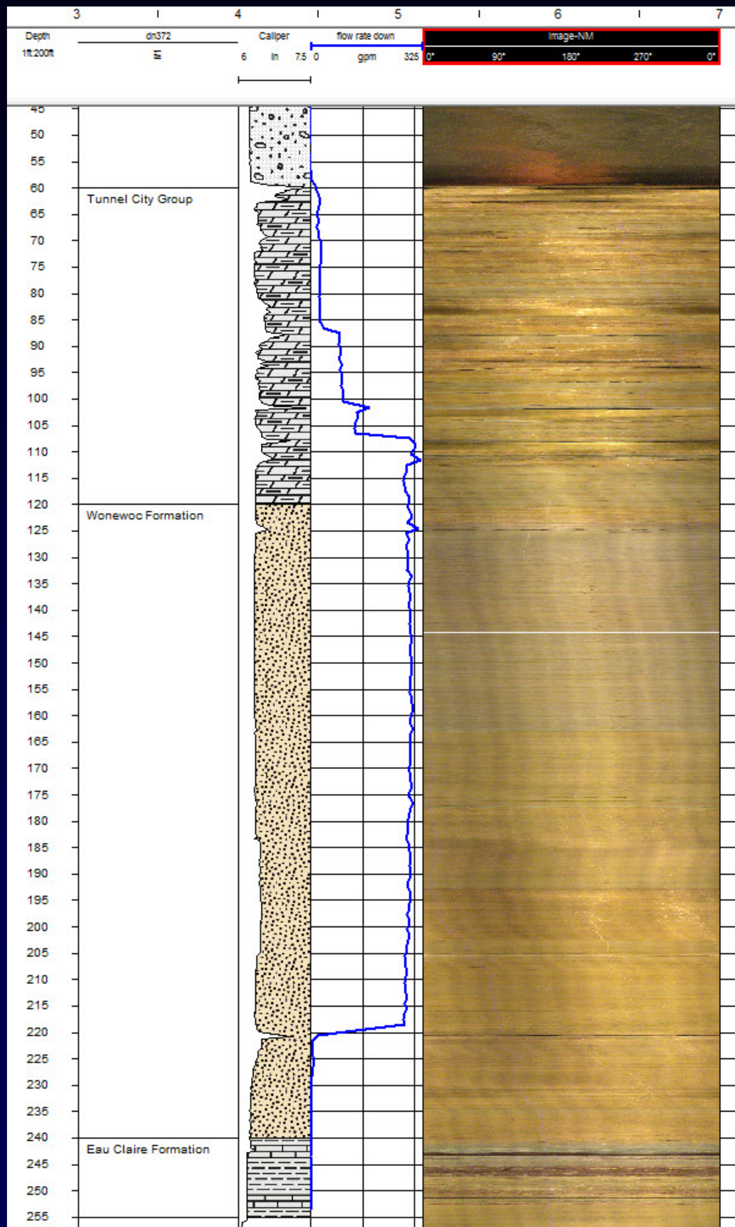
Site characterization and development

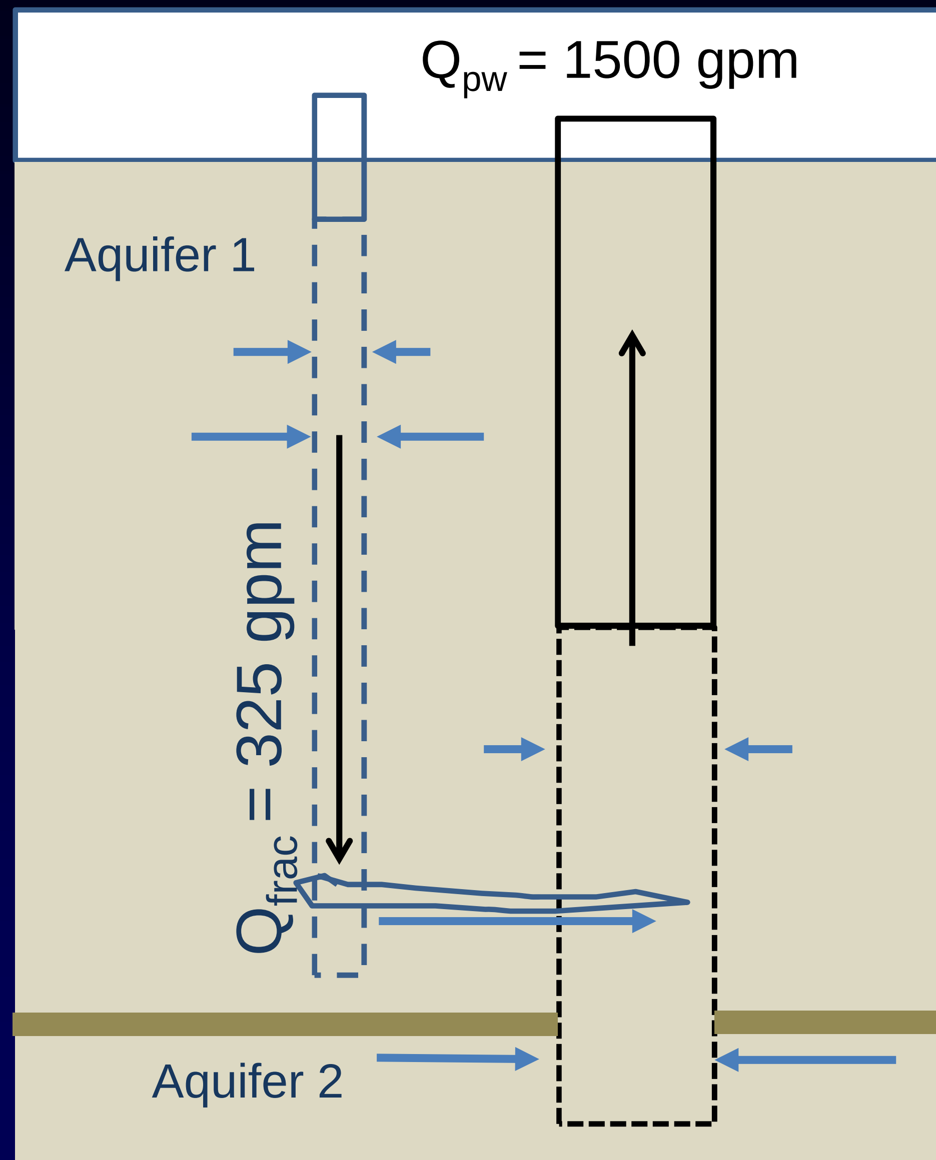


Preferential pathways

Well 13-1

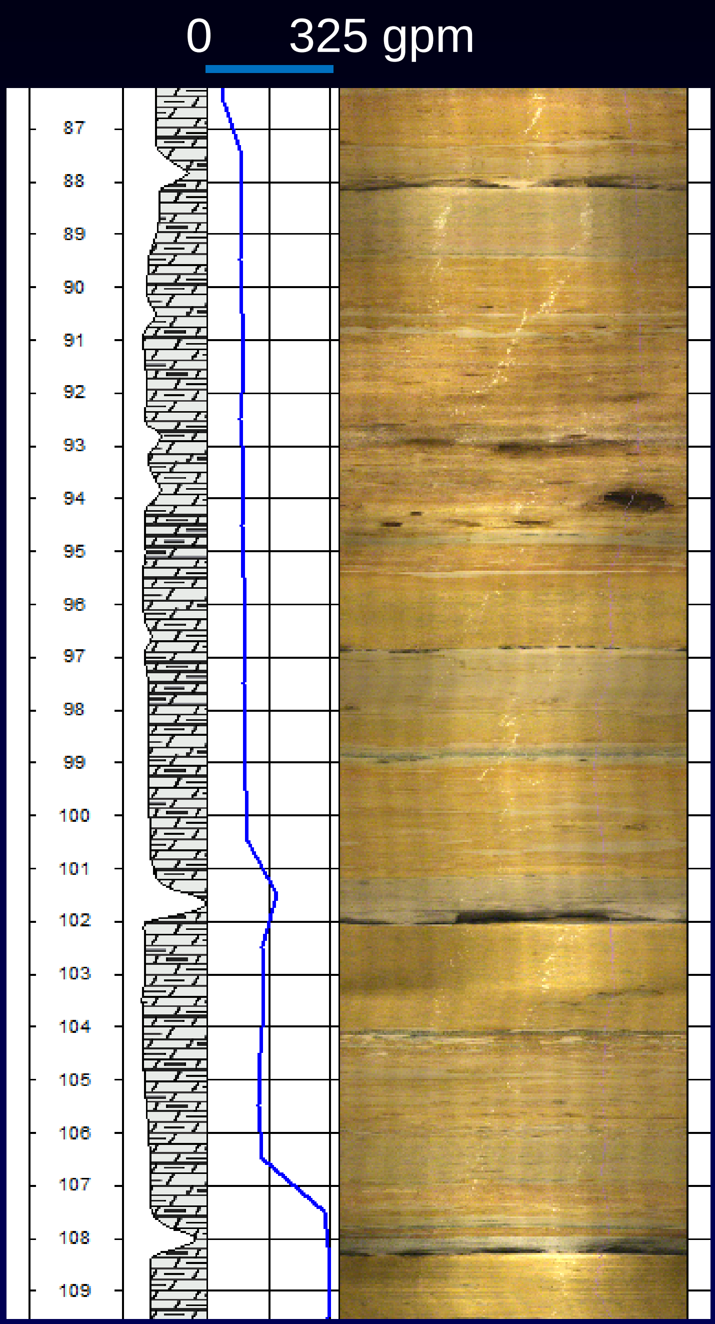
0 325 gpm

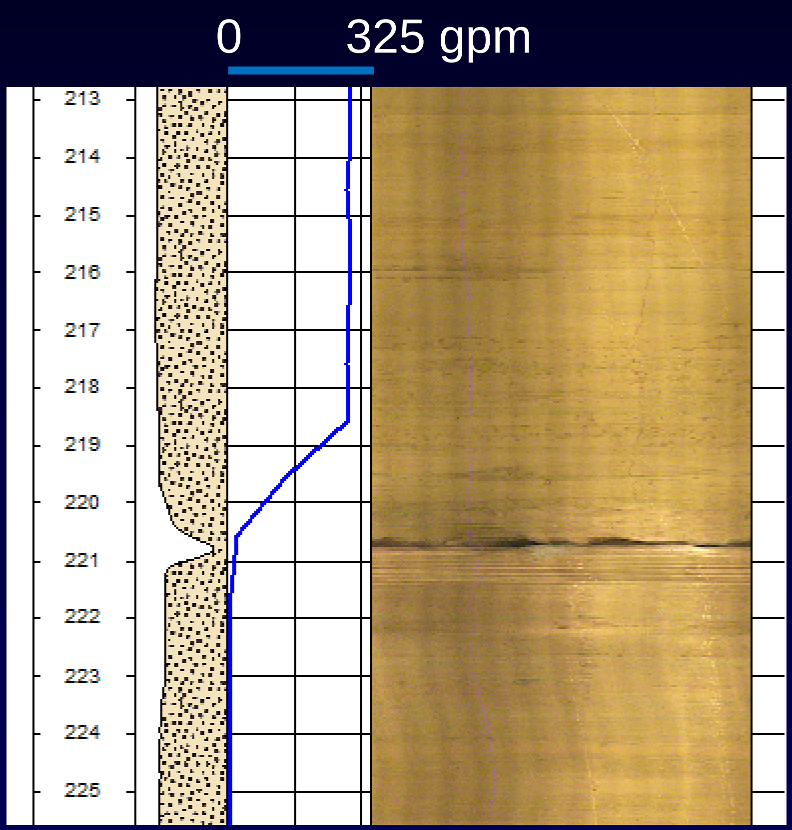




Well 13-1

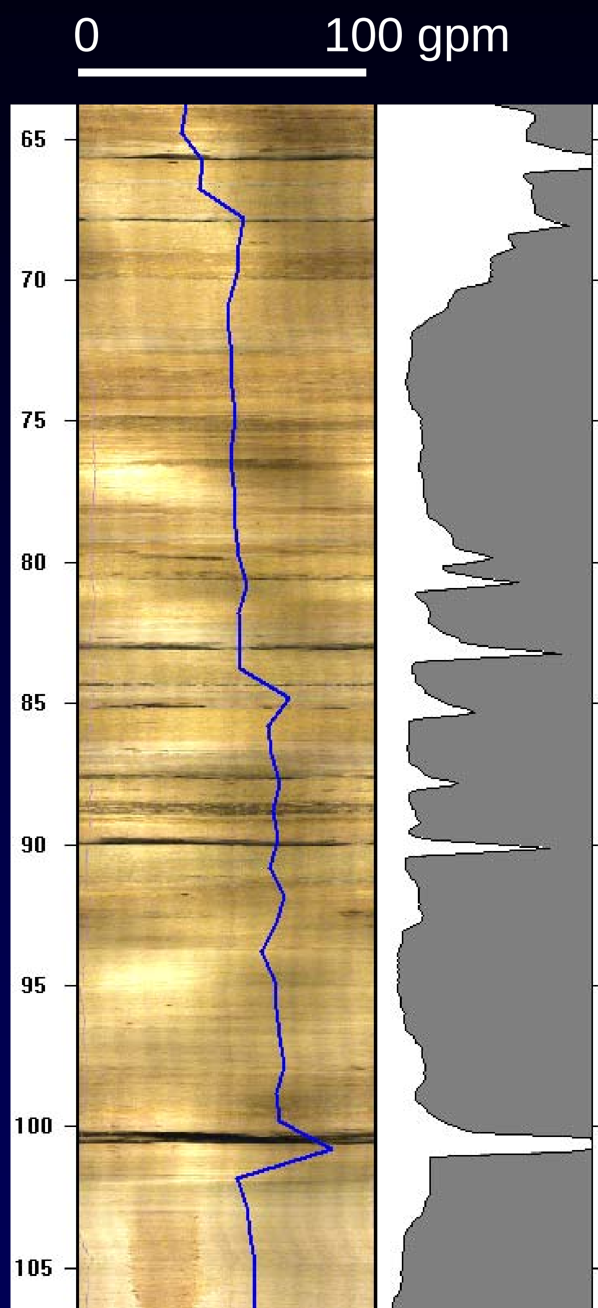
flow: positive values are downward

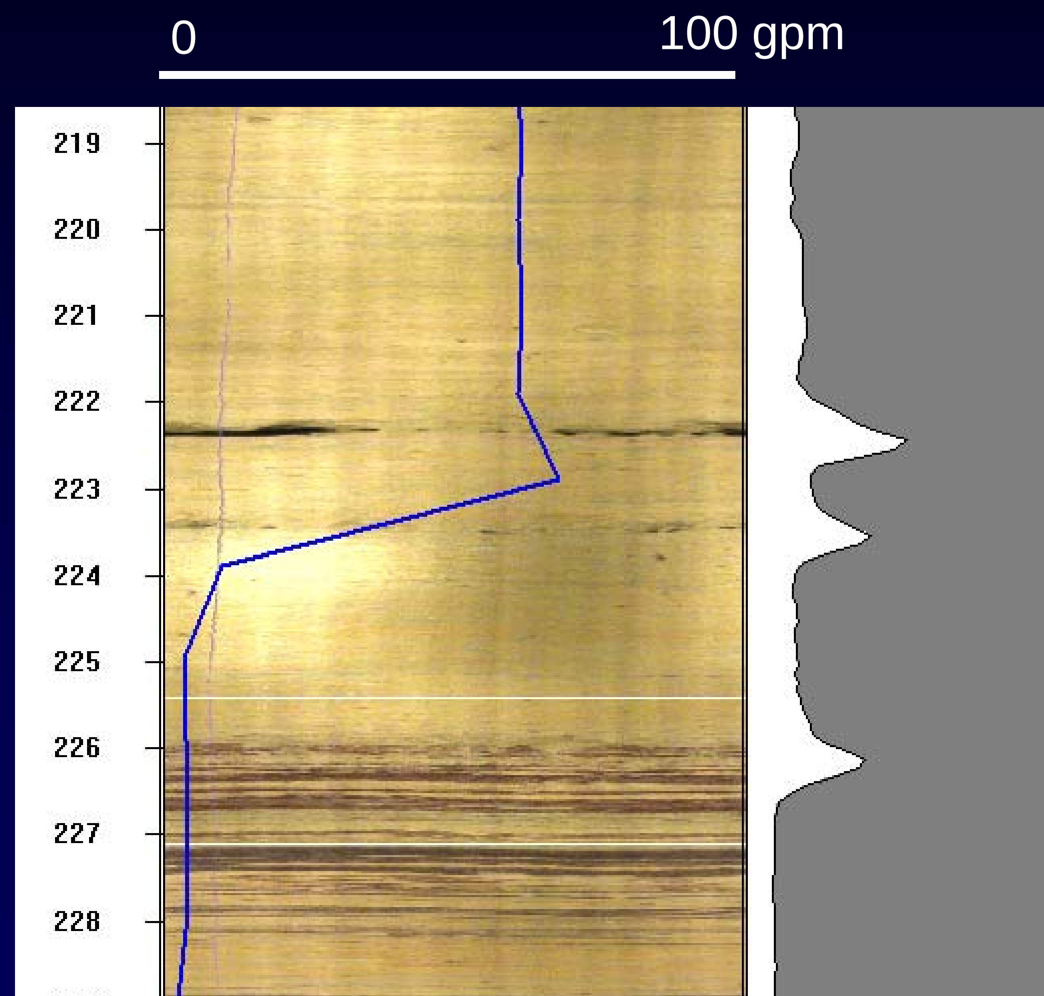


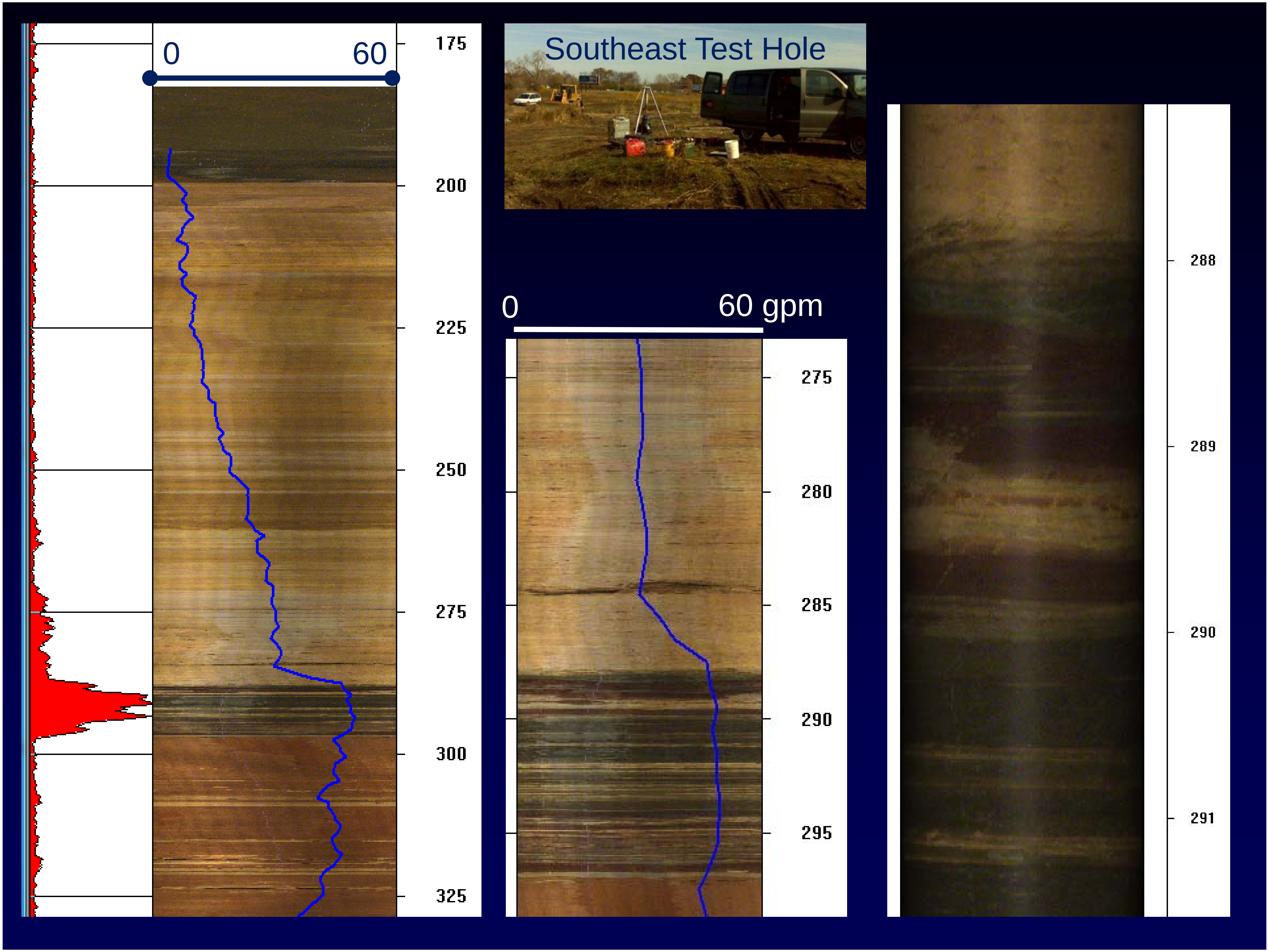


Well 11-1, non-pumping

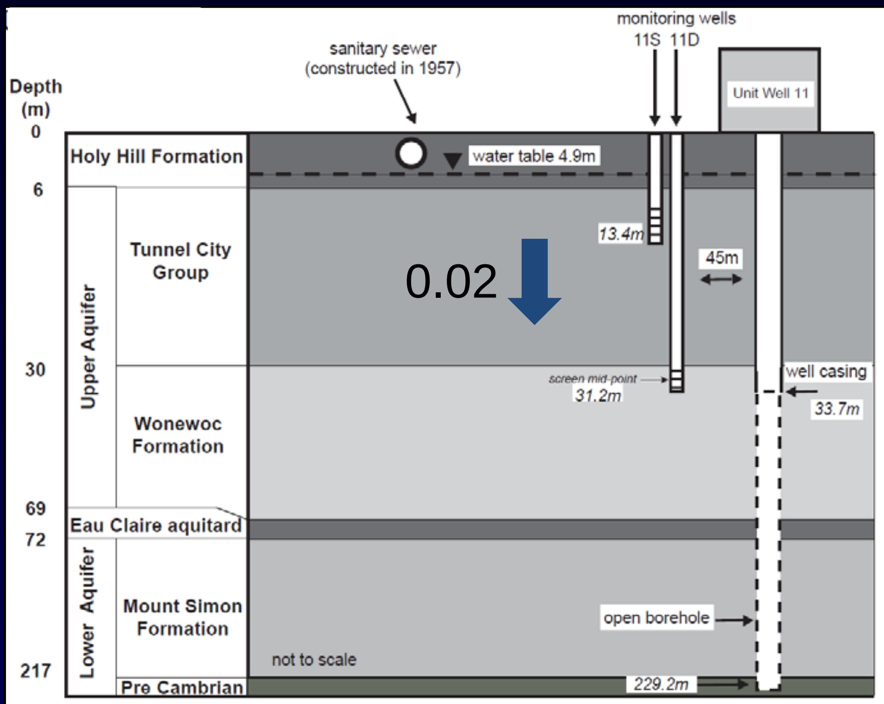
flow: positive is downward

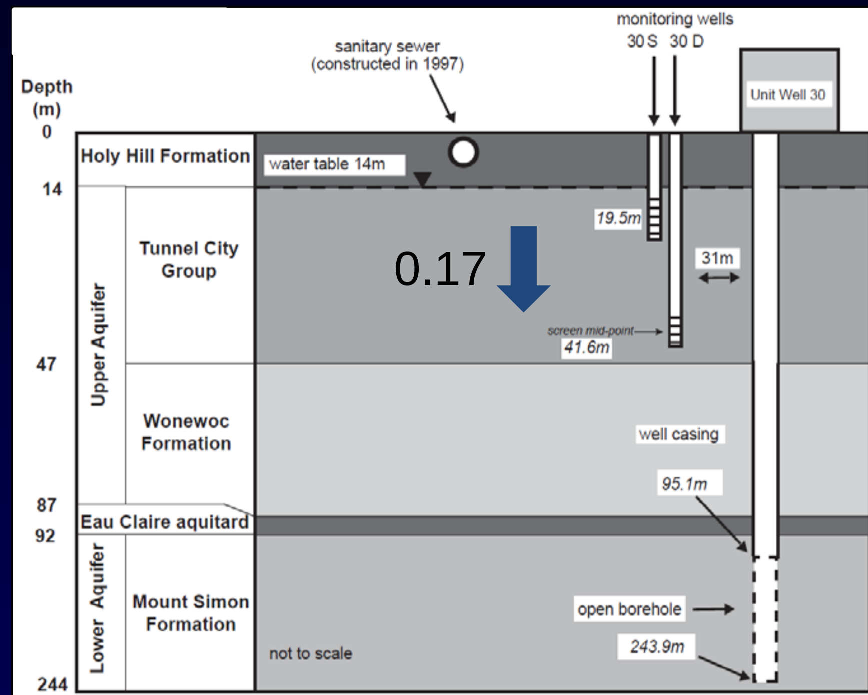




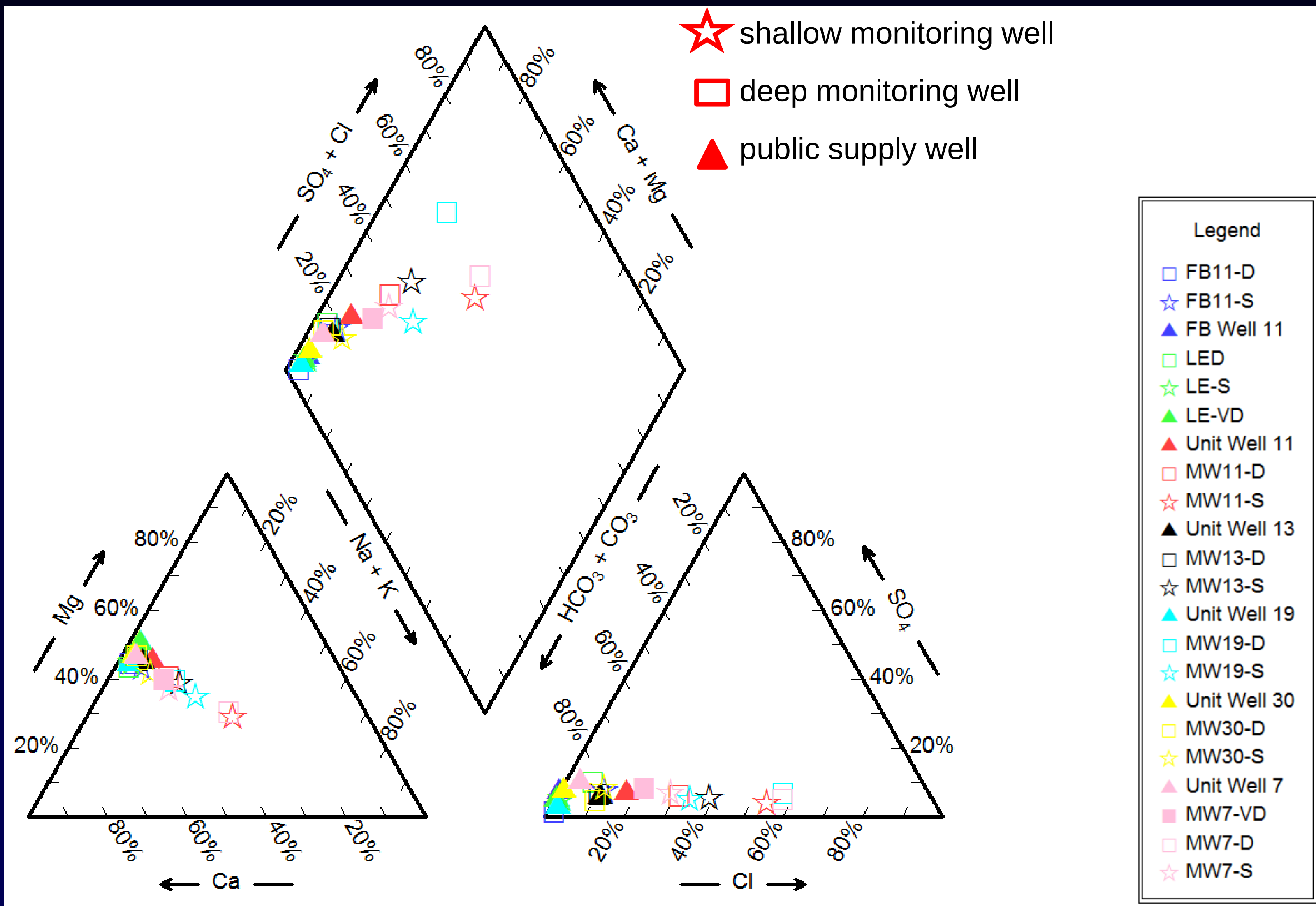

Southeast Test Hole
0
60
175
200
225
250
275
300
325
0
60 gpm
275
280
285
290
295
288
289
290
291

Monitoring network





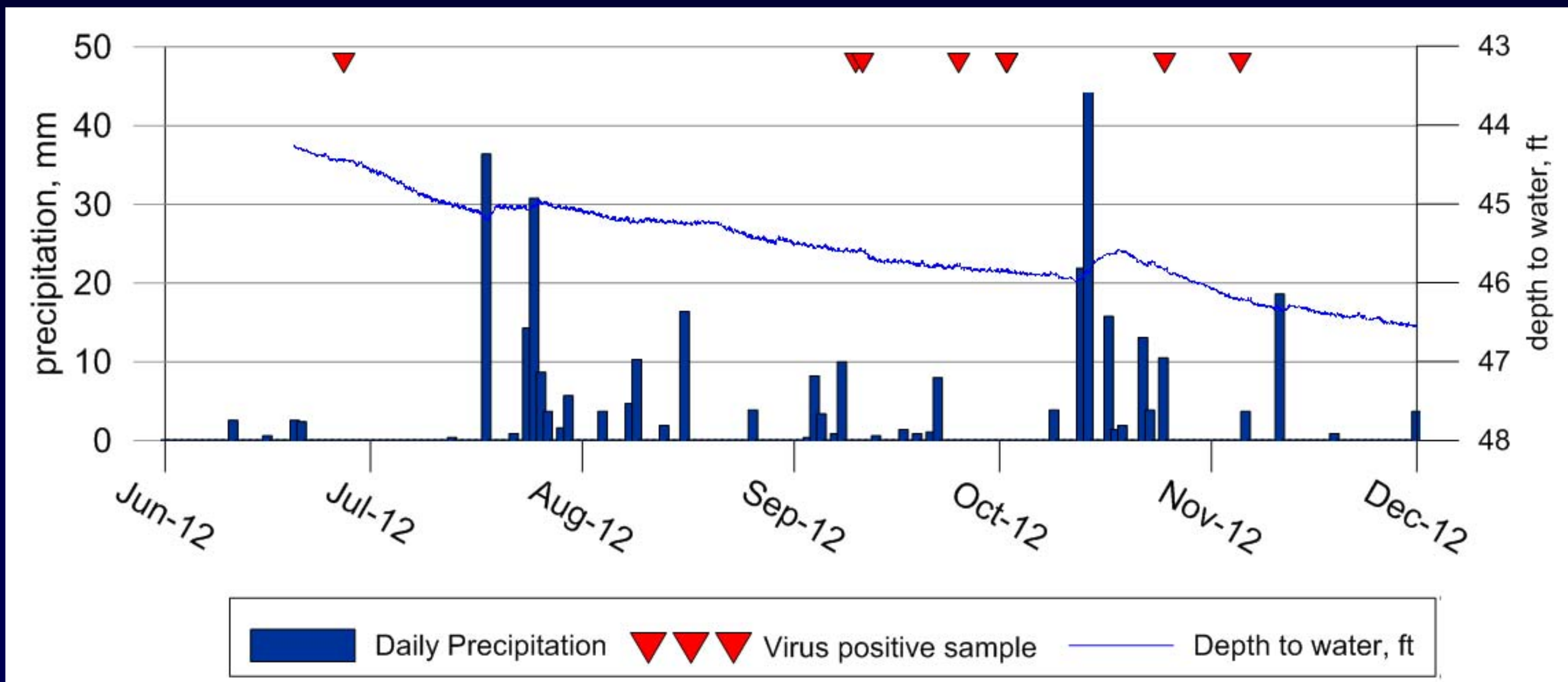
Water quality



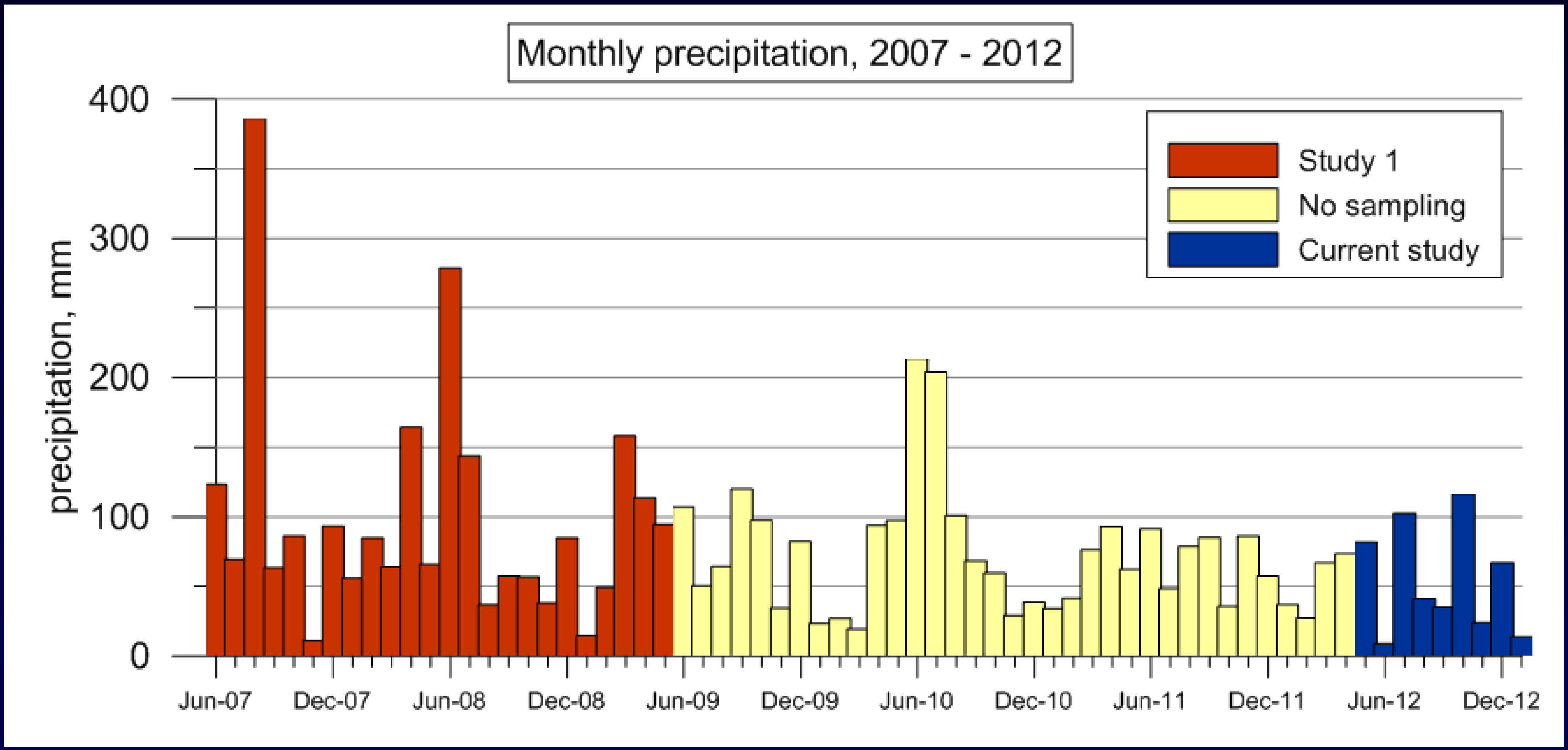
Preliminary virus detections

55% , 251 out of 456, of samples collected and analyzed

3.2% of the samples are virus positive *(47% positive in first study)*



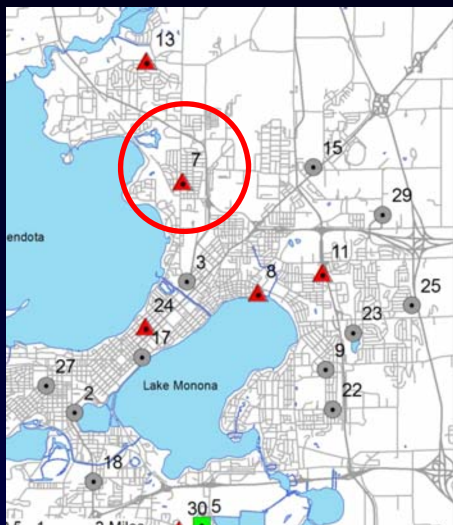
Does precipitation drrve sewer exfiltration?

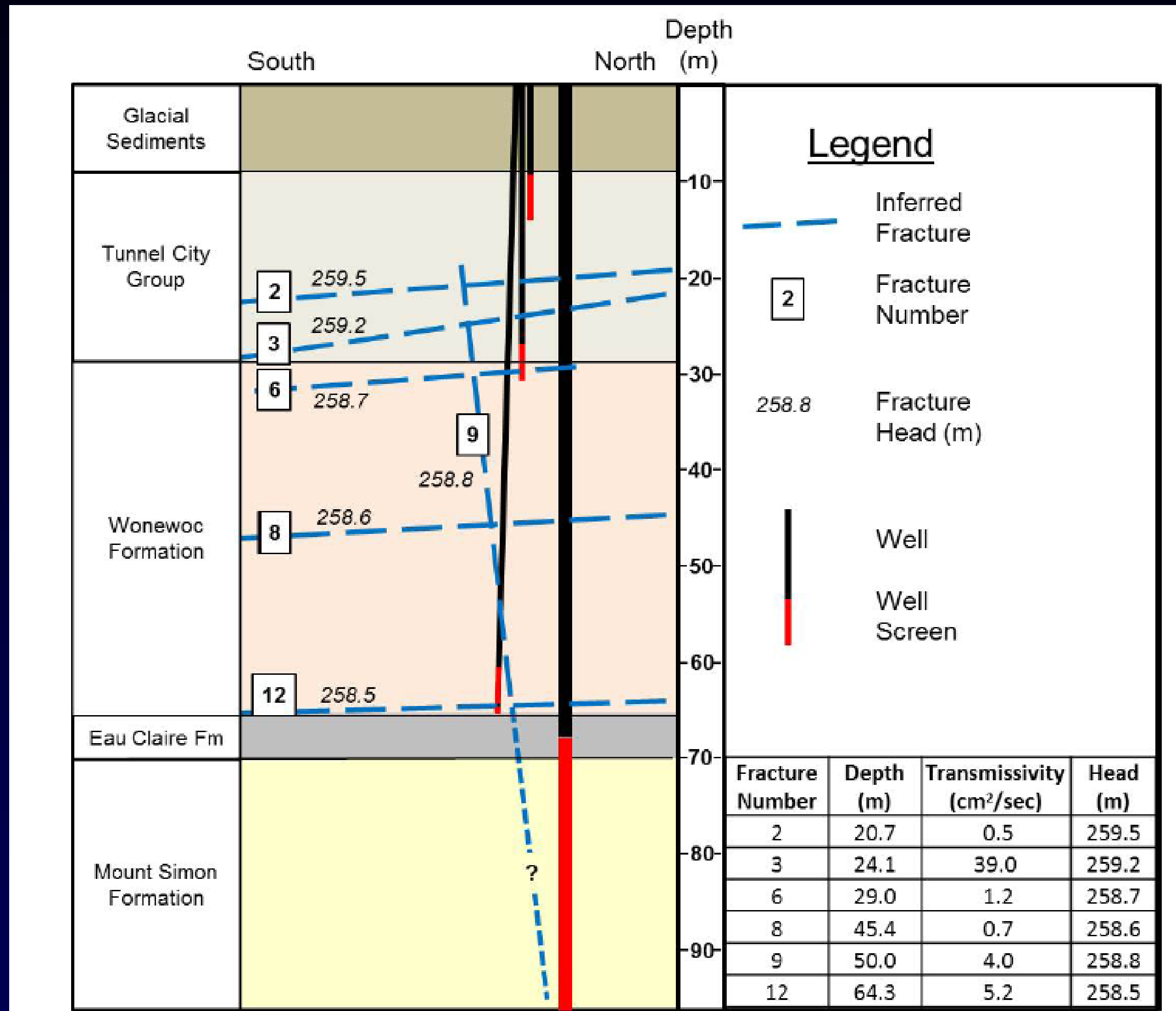


Some observations

1. Fractures and multi-aquifer wells in combination provide fast and high-volume preferential pathways in the urban environment
2. Lower virus detection rate than in previous work supports role of precipitation in sewer exfiltration
3. Rainy spring…

3) fractures





Fracture Number	Depth (m)	Transmissivity (cm²/sec)	Head (m)
2	20.7	0.5	259.5
3	24.1	39.0	259.2
6	29.0	1.2	258.7
8	45.4	0.7	258.6
9	50.0	4.0	258.8
12	64.3	5.2	258.5

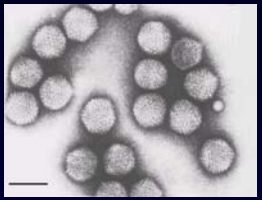
Gellasch et al., 2012

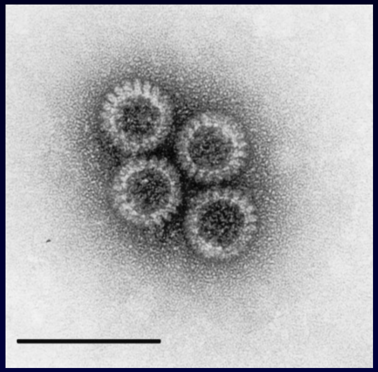
Not all public drinking water systems disinfect

- Federal Groundwater Rule: risk-based approach to pathogen contamination, relying on sanitary surveys and total coliform tests to identify susceptible wells
- Total coliform results do not have good correspondence with virus-positive tests
- About 12%, or 66, of the public groundwater systems in Wisconsin do not disinfect

Virus characteristics

- *Particulates and common diameters*
  - *Colloids (<0.2 um)*
  - *Bacteria (~.2 – 20 um)*
  - *Viruses (~50 nm, or 0.050 um)*
- *For comparison*
  - *Human hair (~50-100 um)*
  - *Rock fracture (1 um to > 1 mm)*





Viruses (e.g., adenovirus, enterovirus, rotavirus)

- *Viruses are much smaller than bacterial pathogens*
- *Virus survivability favored by low temp, moisture, absence of UV light*
- *Generally thought to survive for up to ~ 2 years in groundwater systems*
- *Virus retention in sediment and fractures influenced by flow rate, gradient, aperture size, surface chemistry of colloid and sediments*

2) along damaged or poorly sealed well casings or breaches in casings

Well casing, Benton, Wisconsin   Photo courtesy of DNR