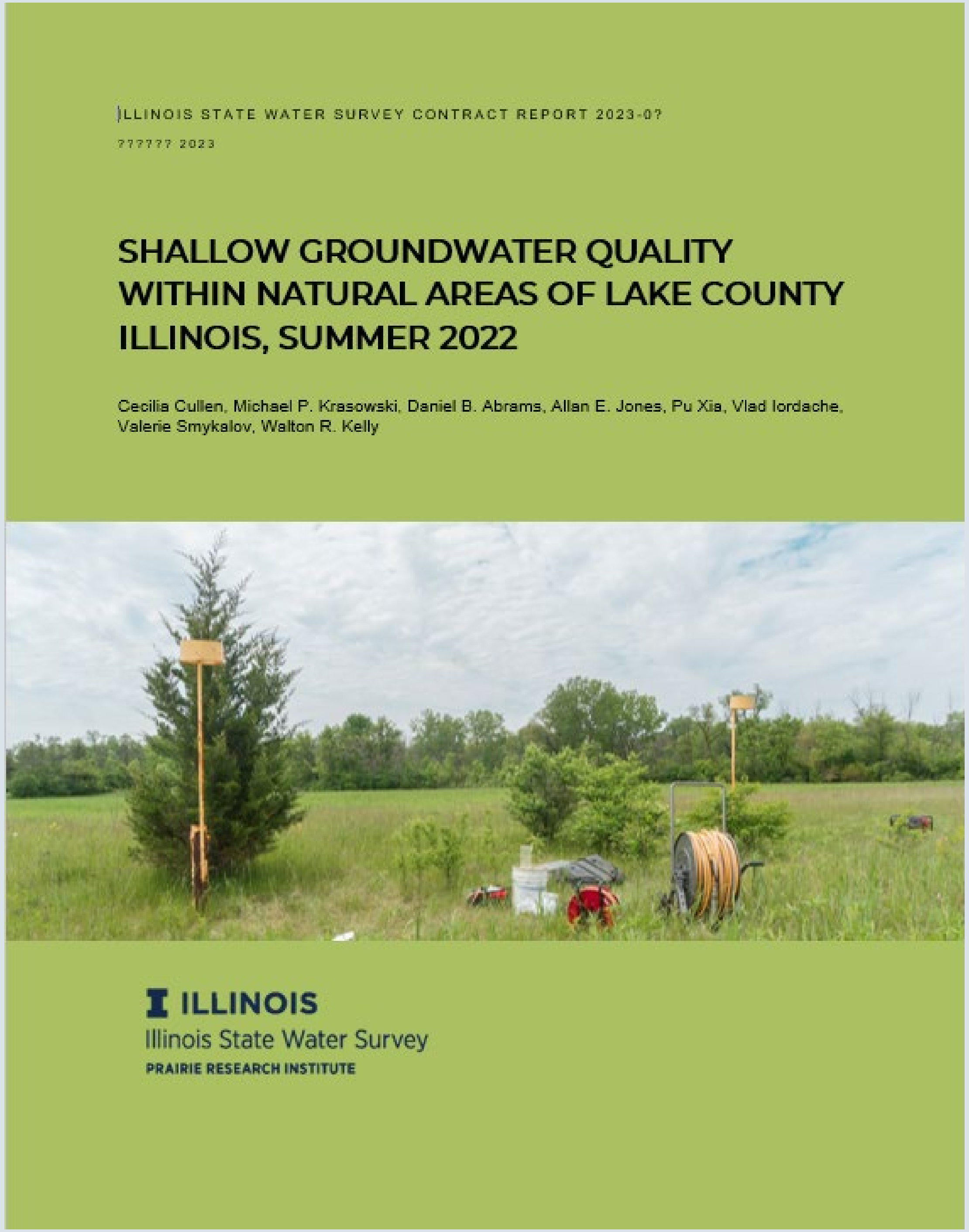
Results from a Summer 2022 ISWS study of groundwater quality in Lake County's shallow aquifer

Cecilia Cullen, Michael Krasowski, Daniel Abrams, Allan Jones, Pu Xia, Vlad Iordache, Valerie Smykalov, and Walt Kelly

NWPA Meeting
June 27, 2023



ISWS Upcoming Report Line-Up

- Rock River Region Report *– out this month*
- Lower Illinois Report *– out this month*
- Supply and Demand Report *– coming soon!*
- Model Update Report *– coming soon!*
- Lake County Report
- Sugar Grove Sampling Report *– out this fall*
- 2021 Synoptic Water Level Report *– out this fall*

Lake County

- Data from 30 monitoring wells
- Data from 13 community wells
- Looking into past ISWS water quality reports in the county from 1935 and 1976

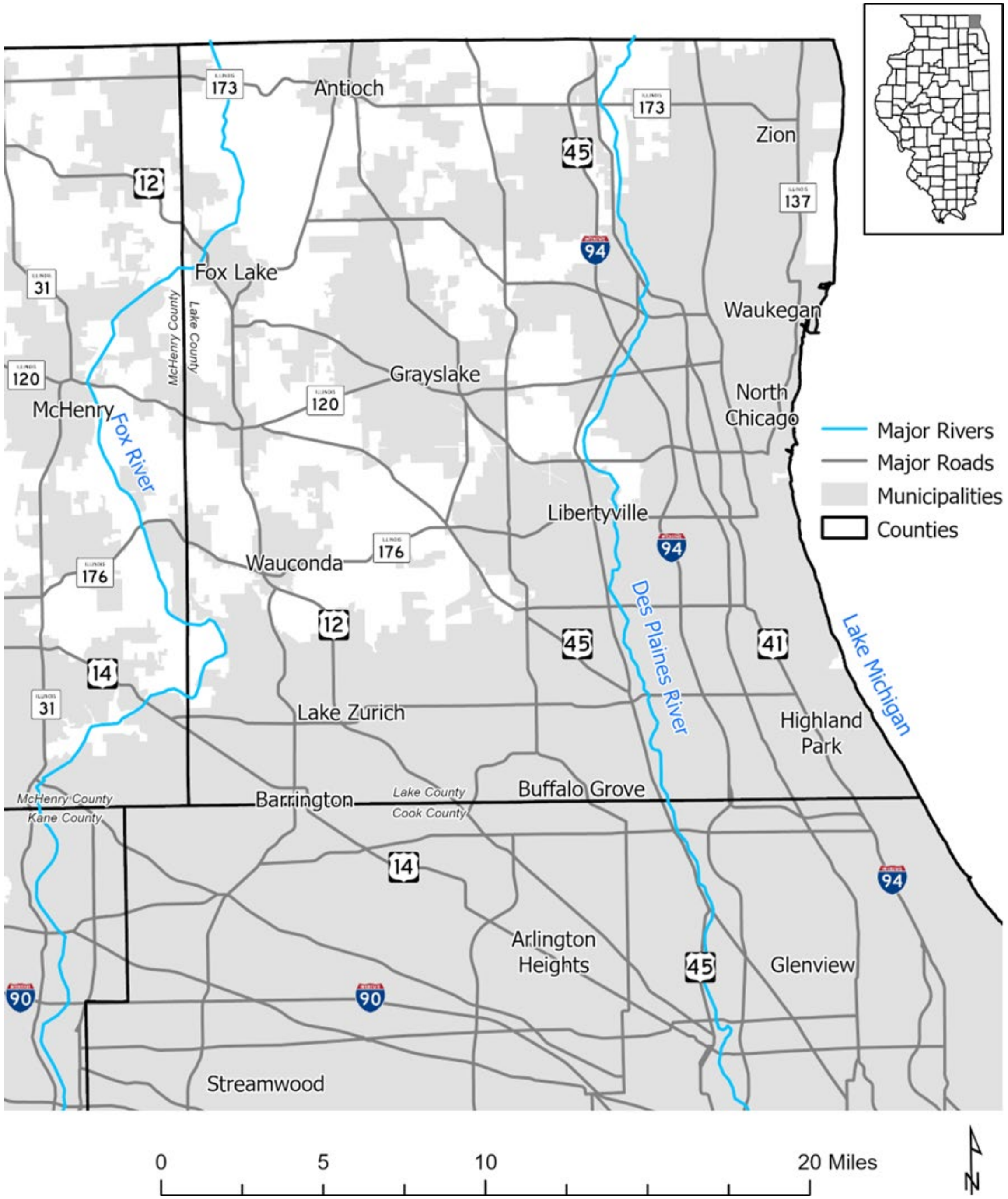


Figure credit: Michael Krasowski, ISWS

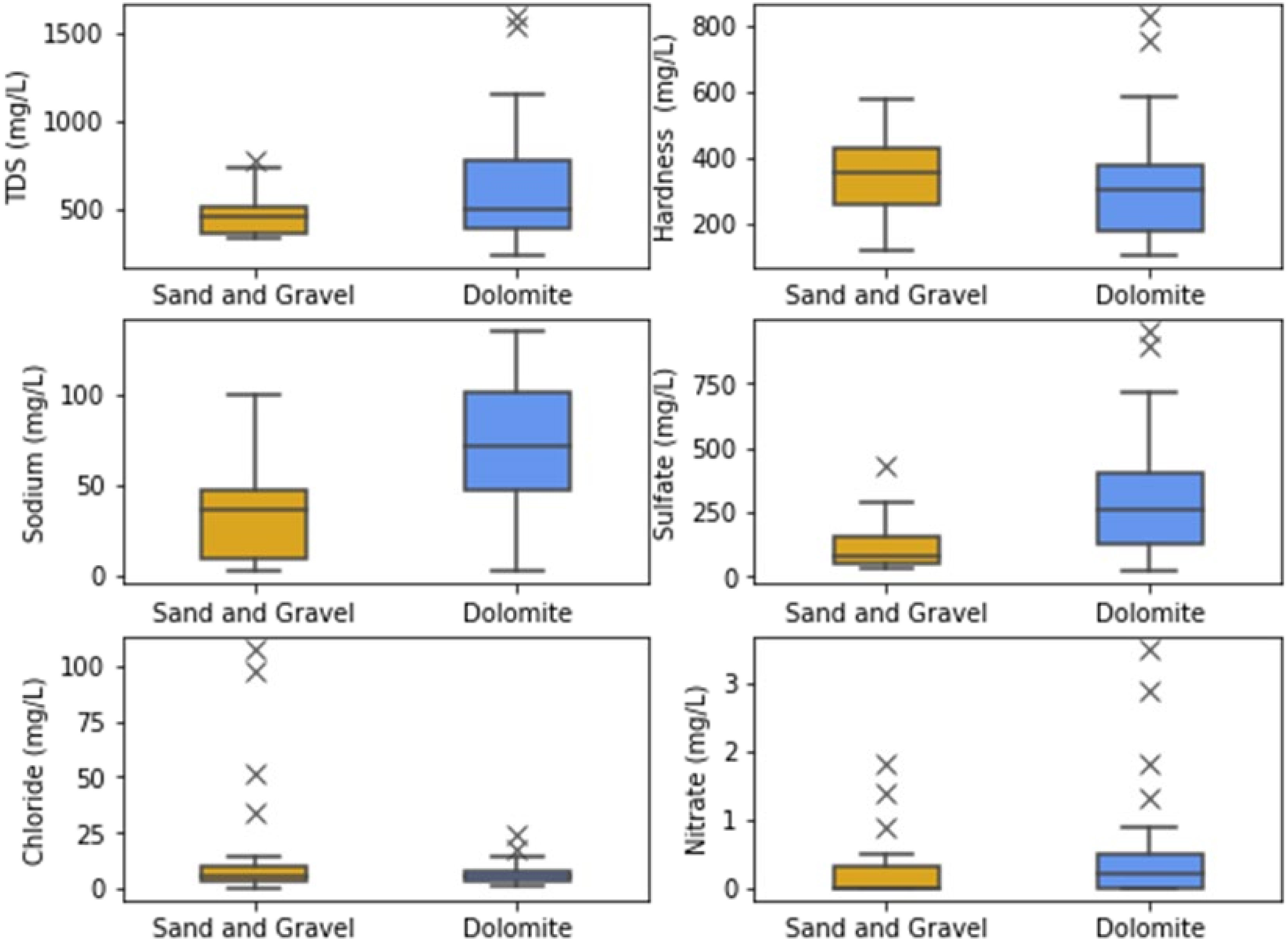
Past ISWS Results

		Glacial Deposits[1] ISWS (1935) *n = 54* Woller and Gibbs (1976) *n = 25*			Dolomite[2] ISWS (1935) *n = 169,* Woller and Gibbs (1976) *n = 37*		
		low	med.[3]	high	low	med.[3]	high
1935	Total Dissolved Solids[4]	193	406	1753	188	410	1693
	Hardness	58	344	977	7	145	943
	Sodium(K+)[5]	1	58	153	2	95	558
	Sulfate	3	185	1103	1	116	1078
	Chloride	1	4	22	2	9	325
1976	Total Dissolved Solids	329	453	770	230	490	1602
	Hardness	120	358	580	104	306	831
	Sodium	2.1	36	100	3	72	135
	Sulfate	32.7	76	430	17	254	950
	Chloride	0	5	108	1	5	24
	Nitrate	0	0	1.8	0	0.2	3.5

[1]In the ISWS report (1935) glacial deposits were referred to as 'Drift' [2]Referred to as 'Niagara' in the report [3]As worded in the report, presumably median [4]Referred to as 'residue' in the report [5]Combined values for sodium and potassium, since potassium is generally low in groundwater, this value is mostly representative the concentration of sodium

1976 Results

- In 1976 chloride was beginning to be elevated in the sand and gravel
- Sulfate and sodium are higher in the dolomite
- Nitrate observations at background except for a few outliers above 3 mg/L
- Median hardness higher in the sand and gravel aquifers



Lake County Groundwater Use

Reported to IWIP

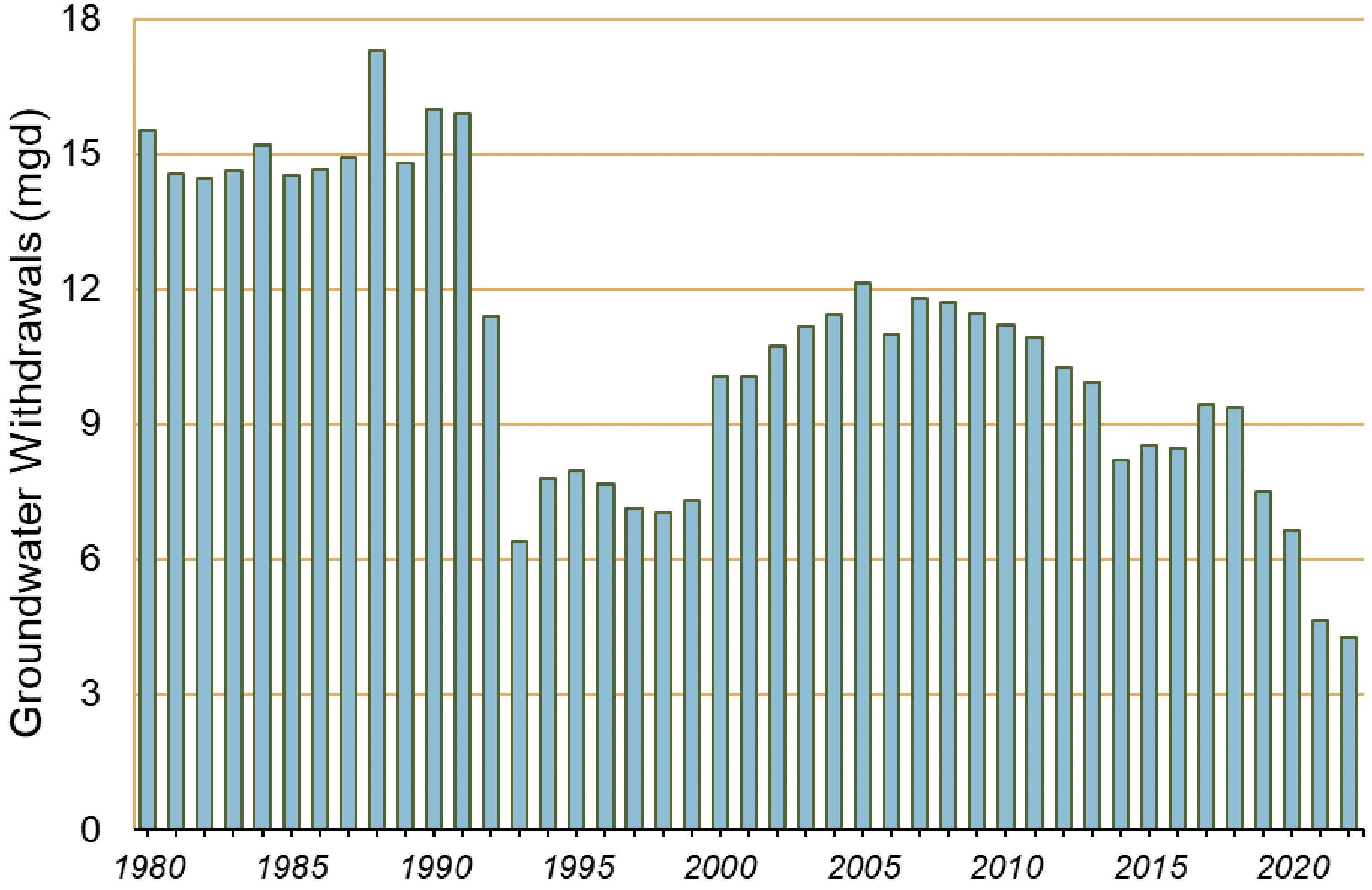


Figure credit: Cecilia Cullen and Vlad Iordache, ISWS

Glacial Drift Thickness (ft)

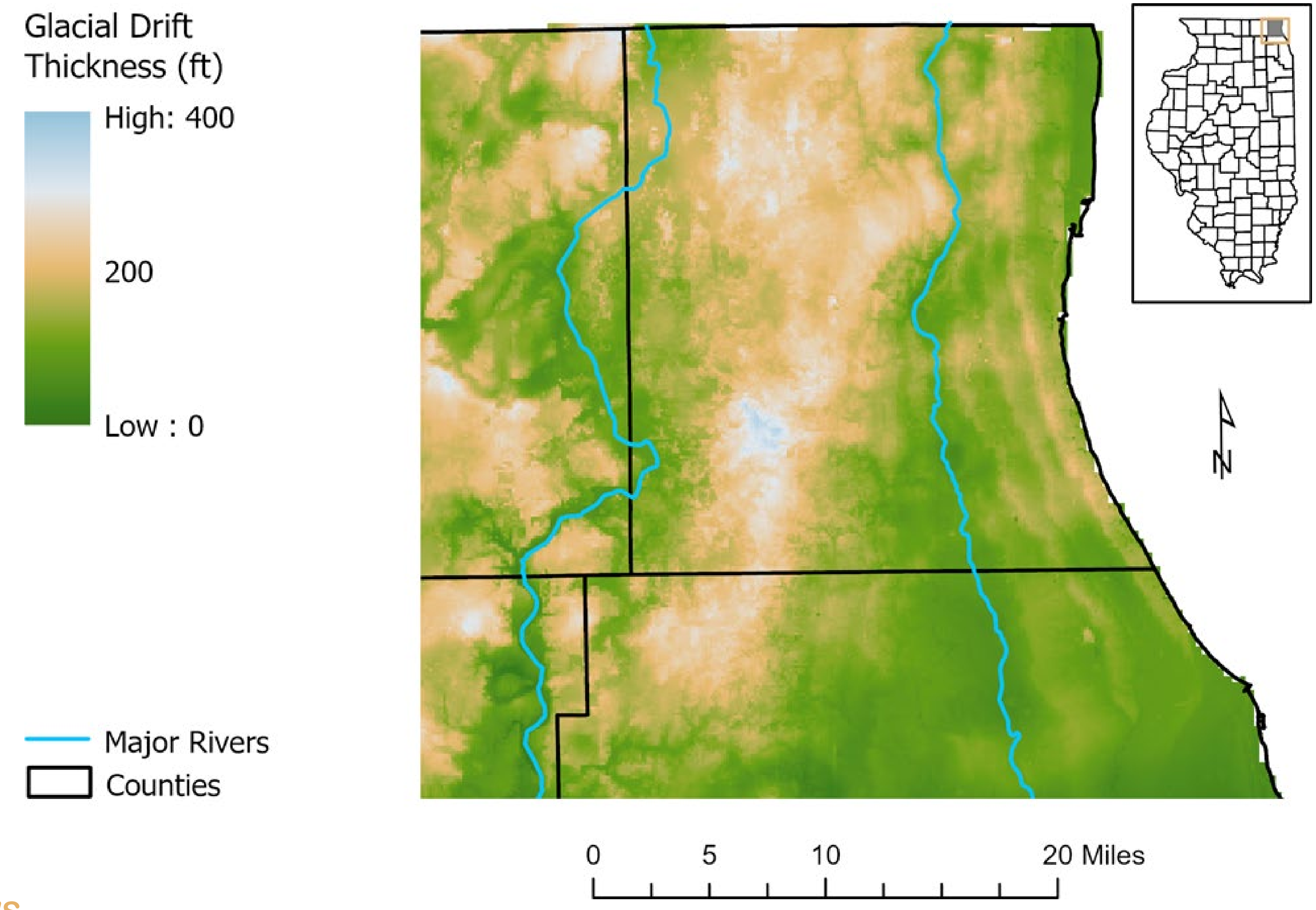


Figure credit: Michael Krasowski, ISWS

Transmissivity Distribution (ft²/day)

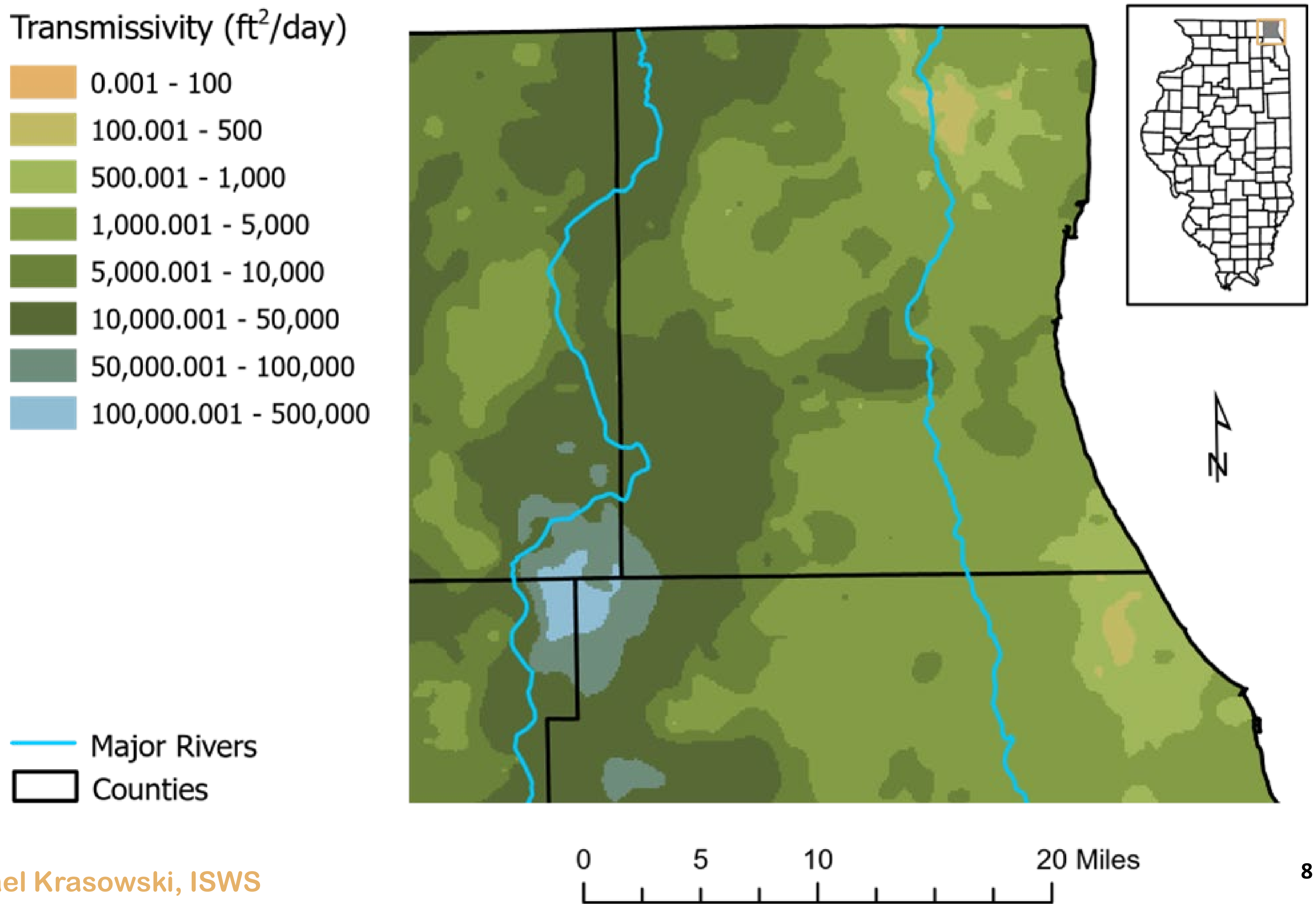


Figure credit: Daniel Abrams and Michael Krasowski, ISWS

Land Use

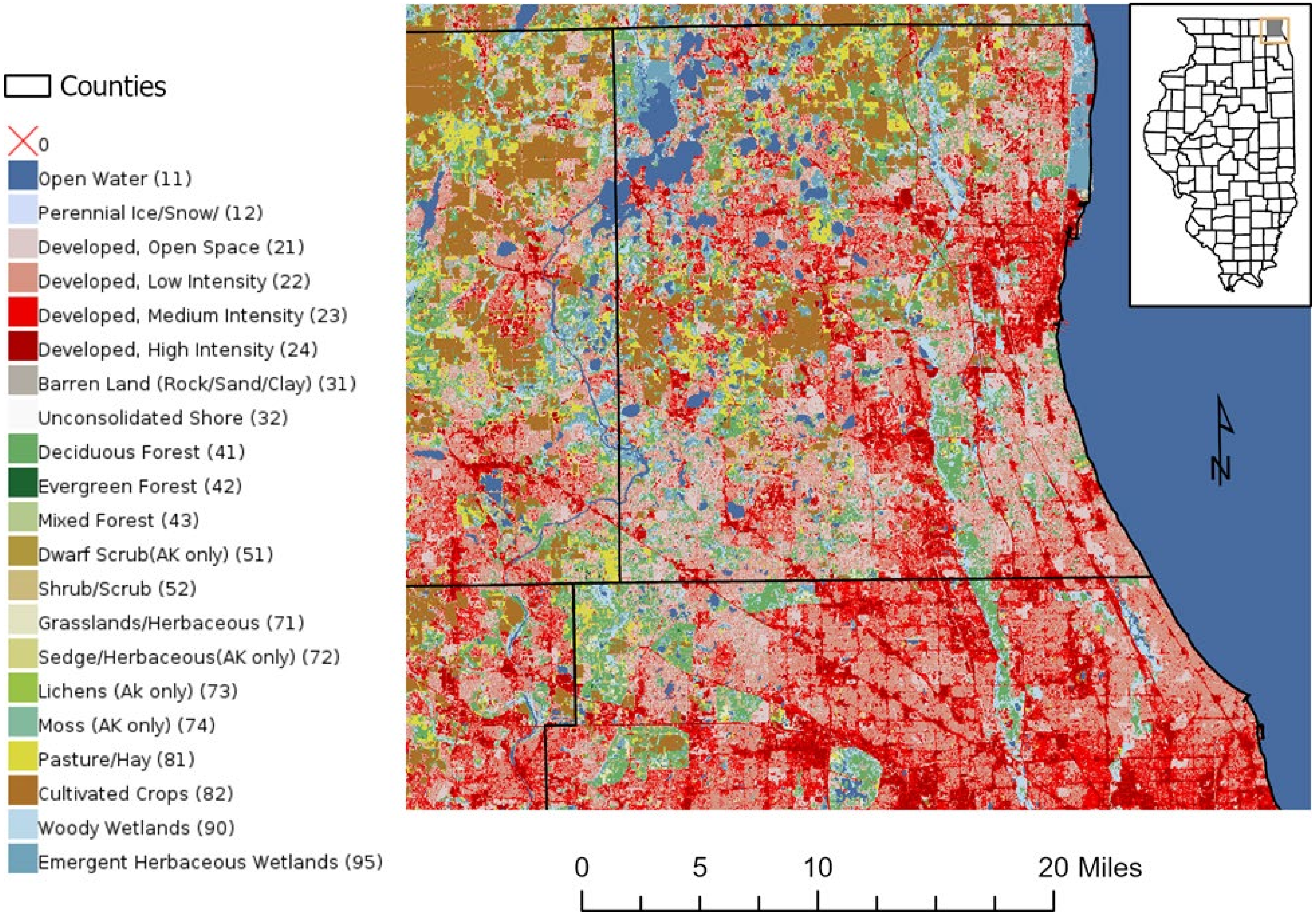
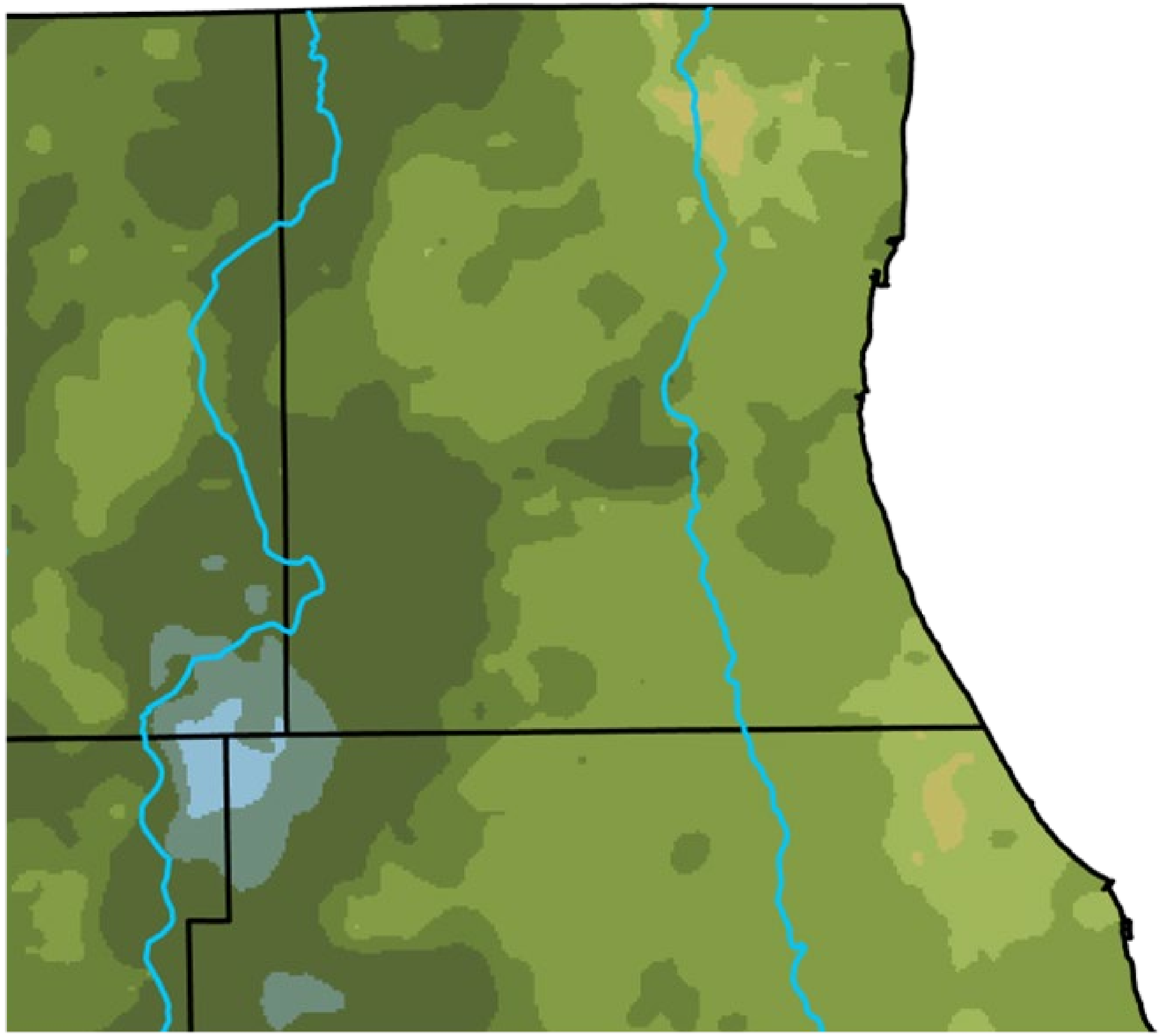
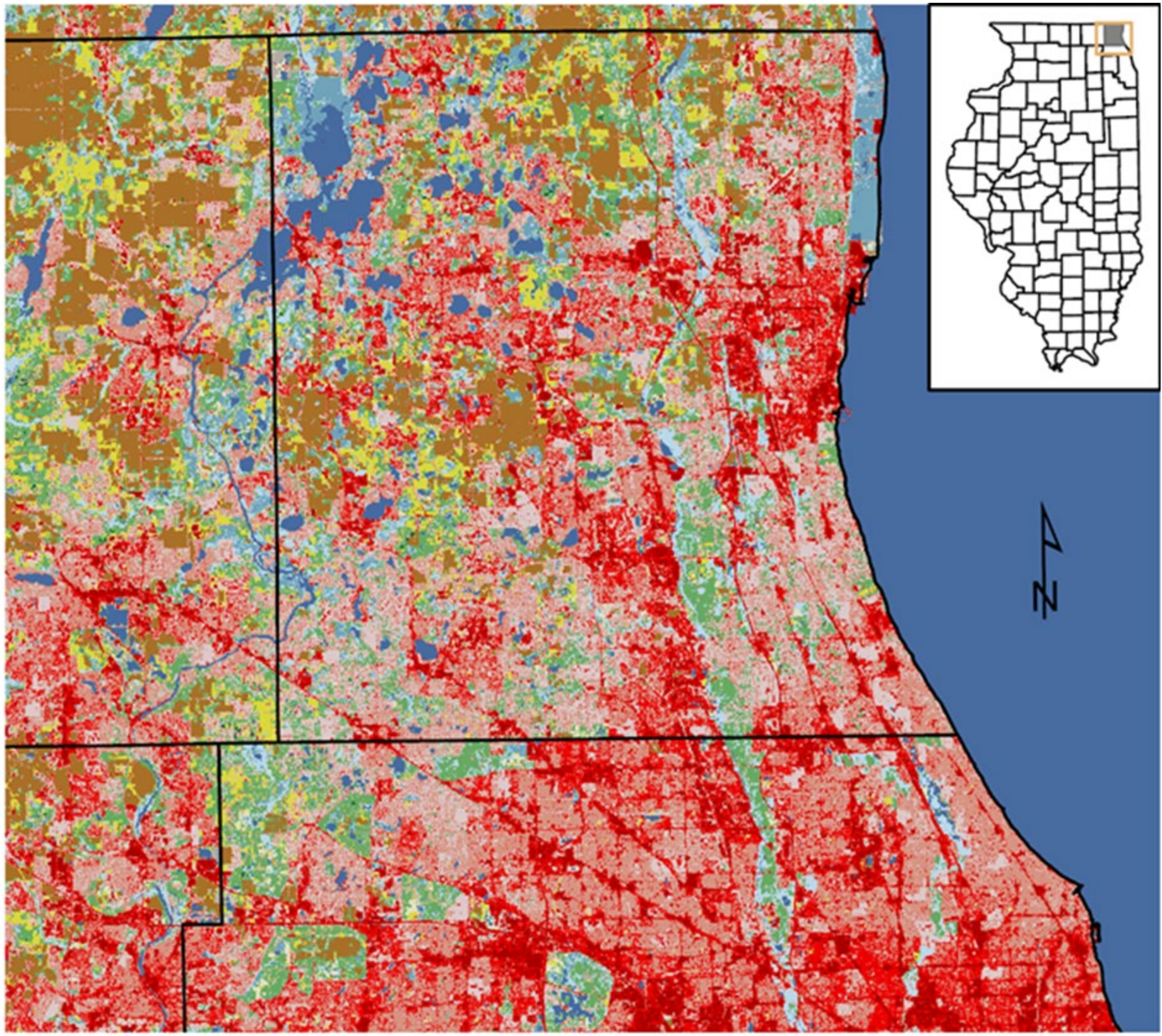


Figure credit: Michael Krasowski, ISWS (data from Dewitz and U.S. Geological Survey, 2021)

Geology and Land Use



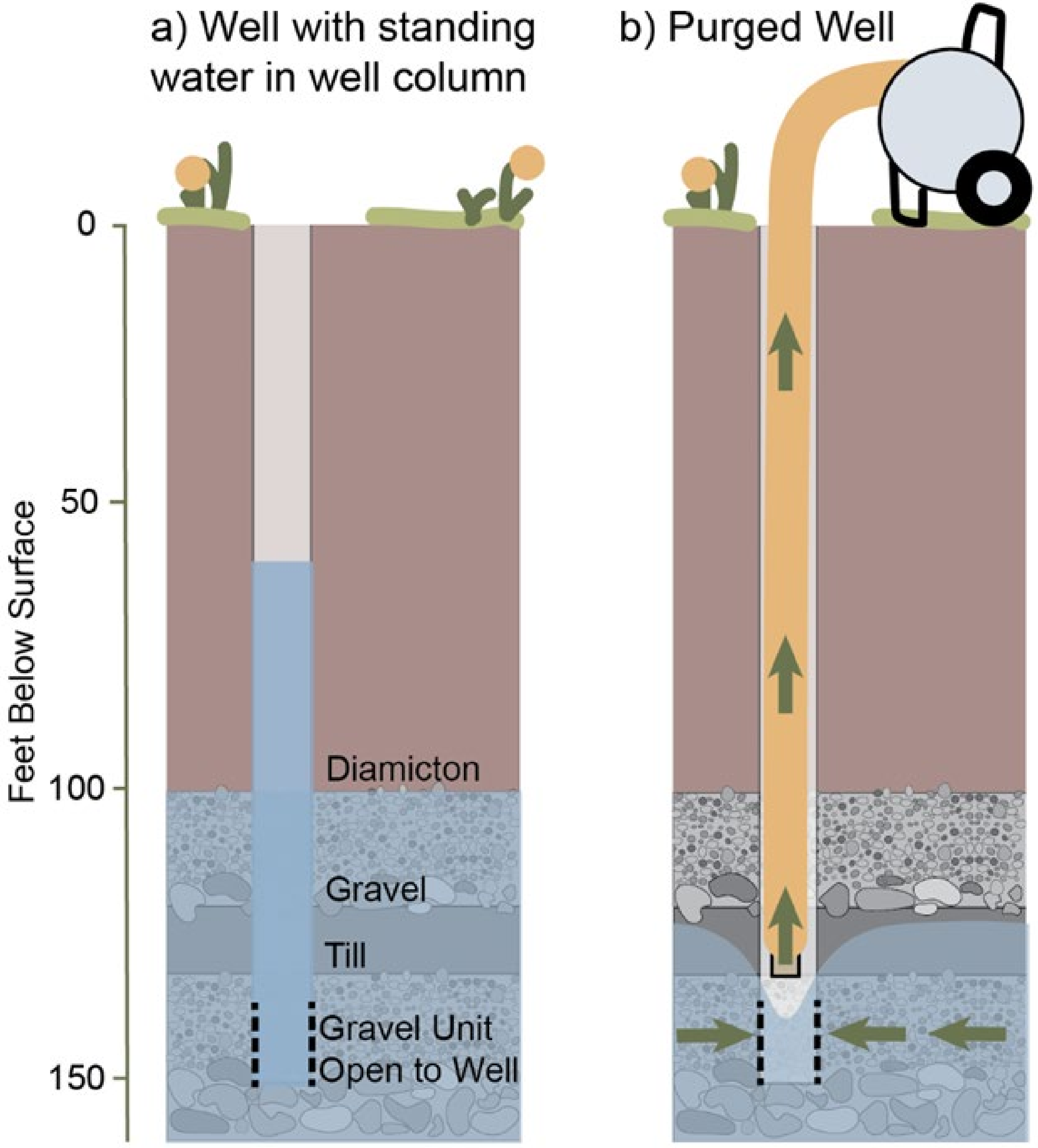


Process

- The wells we sampled were in forest preserves and other natural areas
- These were drilled by the Illinois State Geological Survey (ISGS)
- Wells do not have pump or electricity, so we had to bring our own submersible pump and generator
- Most wells in Lake County, some in McHenry and Cook Counties

Photo credit: Allan Jones, ISWS

To collect a sample that represents aquifer conditions, purging the well is critical



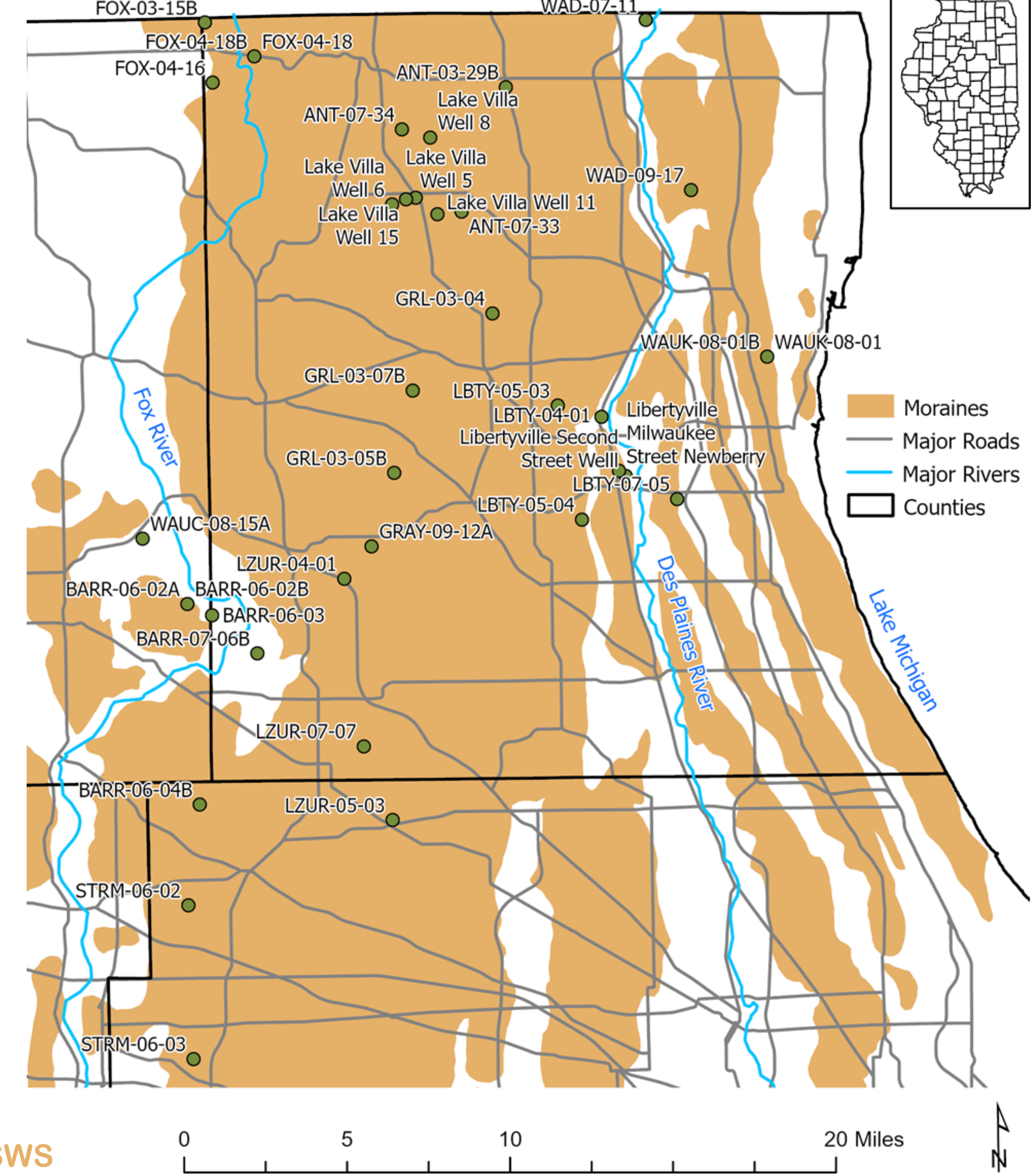


Figure credit: Michael Krasowski, ISWS

Well	Screen Bottom (ft)	Amount sand/gravel (ft)	Open to	Chloride[1] (mg/L)	Chloride source[2]	Sodium[3] (mg/L)	Hardness[4] (mg/L of $CaCO_3$)	Predominant Redox Processes[5]
ANT-03-29B	84	-[6]	-	Moderate	-	Low	Very Hard	Iron(III)/Sulfate Reduction
ANT-07-33	130	33	Gravel	Low	-	Elevated	Very Hard	Iron(III)/Sulfate Reduction
ANT-07-34	145	11	Gravel	Background	-	Elevated	Hard	Iron(III)/Sulfate Reduction
BARR-06-02A	90	65	Diamicton	Background	-	Low	Very Hard	Iron(III)/Sulfate Reduction[7]
BARR-06-02B	66	65	Gravel	High	-	High	Extremely hard	Nitrate Reduction[7]
BARR-06-03	60	60	Gravel	High	-	High	Extremely hard	Nitrate Reduction[7]
BARR-06-04B	48	48	Sand	Low	-	Low	Very Hard	Iron(III)/Sulfate Reduction[7]
BARR-07-06B	134	-	-	Background	-	Low	Very Hard	Iron(III)/Sulfate Reduction[7]
FOX-03-15B	239	-	Sand and gravel	Background	-	Low	Very Hard	Iron(III)/Sulfate Reduction
FOX-04-16	98	88	Sand and gravel	Low	-	Low	Very Hard	Iron(III)/Sulfate Reduction
FOX-04-18	148	44	Bedrock	Background	-	Elevated	Moderate	Suboxic
FOX-04-18B	83	-	Sand and gravel	Background	-	Low	Very Hard	Methanogenesis
GRAY-09-12A	245	166	Gravel	Low	-	Low	Very Hard	Iron(III)/Sulfate Reduction
GRL-03-04	250	82	Bedrock	Background	-	High	Moderate	Oxic
GRL-03-05B	149	-	Sand and gravel	Background	Precipitation	Elevated	Hard	Iron(III)/Sulfate Reduction
GRL-03-07B	120	-	Sand and gravel	Background	-	Low	Extremely hard	Iron(III)/Sulfate Reduction
LBTY-04-01	61	9	Sand	Background	-	Elevated	Hard	Iron(III)/Sulfate Reduction
LBTY-05-03	133	0	Sand	Background	-	Elevated	Moderate	Iron(III)/Sulfate Reduction
LBTY-05-04	165	17	Gravel on bedrock	Background	Precipitation	High	Soft	Iron(III)/Sulfate Reduction
LBTY-07-05	94	7	Sand	Background	-	Elevated	Extremely hard	Iron(III)/Sulfate Reduction
LZUR-04-01	270	17	Gravel	Background	-	Low	Very Hard	Iron(III)/Sulfate Reduction
LZUR-05-03	225	0	Gravel	Background	-	Elevated	Very Hard	Suboxic
LZUR-07-07	160	3	Gravel	Low	-	Low	Very Hard	Iron(III)/Sulfate Reduction[7]
STRM-06-02	111	90	Sand and gravel	Low	-	Low	Extremely hard	Iron(III)/Sulfate Reduction
STRM-06-03	110	29	Sand and gravel	Background	-	Low	Very Hard	Methanogenesis
WAD-07-11	185	3	Sand and gravel	Background	Precipitation	Elevated	Moderate	Iron(III)/Sulfate Reduction
WAD-09-17	206	0	Bedrock	Background	Precipitation	High	Soft	Suboxic
WAUC-08-15A	192	75	Gravel	Background	-	Low	Hard	Methanogenesis
WAUK-08-01	165	12	Sand	Background	-	Elevated	Moderate	Iron(III)/Sulfate Reduction
WAUK-08-01B	76	0	Gravel	Background	-	Elevated	Very Hard	Iron(III)/Sulfate Reduction

[1]Follows recent ISWS classification of chloride as Background (< 15 mg/L), Low (15 – 50 mg/L), Moderate (50 – 100), High (100 – 250 mg/L) and Excessive (> 250 mg/L) [2]Uses chloride – bromide ratios to determine source following relationships (Panno et al., 2006a) [3]Sodium classification from 2023 HEAL letter report ‘Understanding Your Water Quality’ [4]Hardness classification from 2023 HEAL letter report ‘Understanding Your Water Quality’ [5]Clasification from Chapelle et al., 2009 [6]Dash(-) indicates that is field was unknown, not available, or undeterminable [7]Dissolved oxygen levels were high (> 0.5 mg/L) and not in accord with oxic conditions; the well was likely not sufficiently purged and the DO was assumed to be 0.5 mg/L

Nitrate Distribution

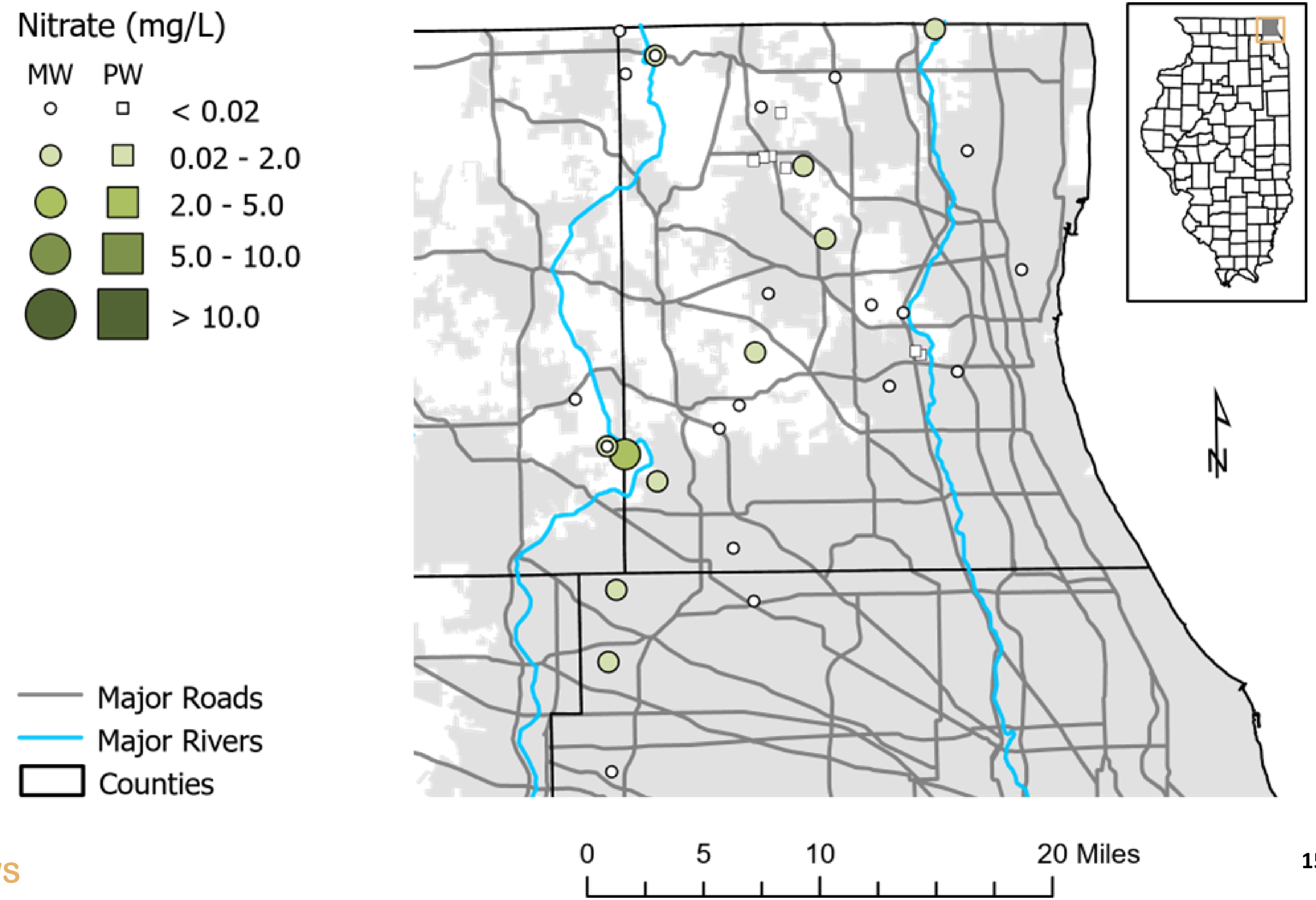


Figure credit: Michael Krasowski, ISWS

Chloride Distribution

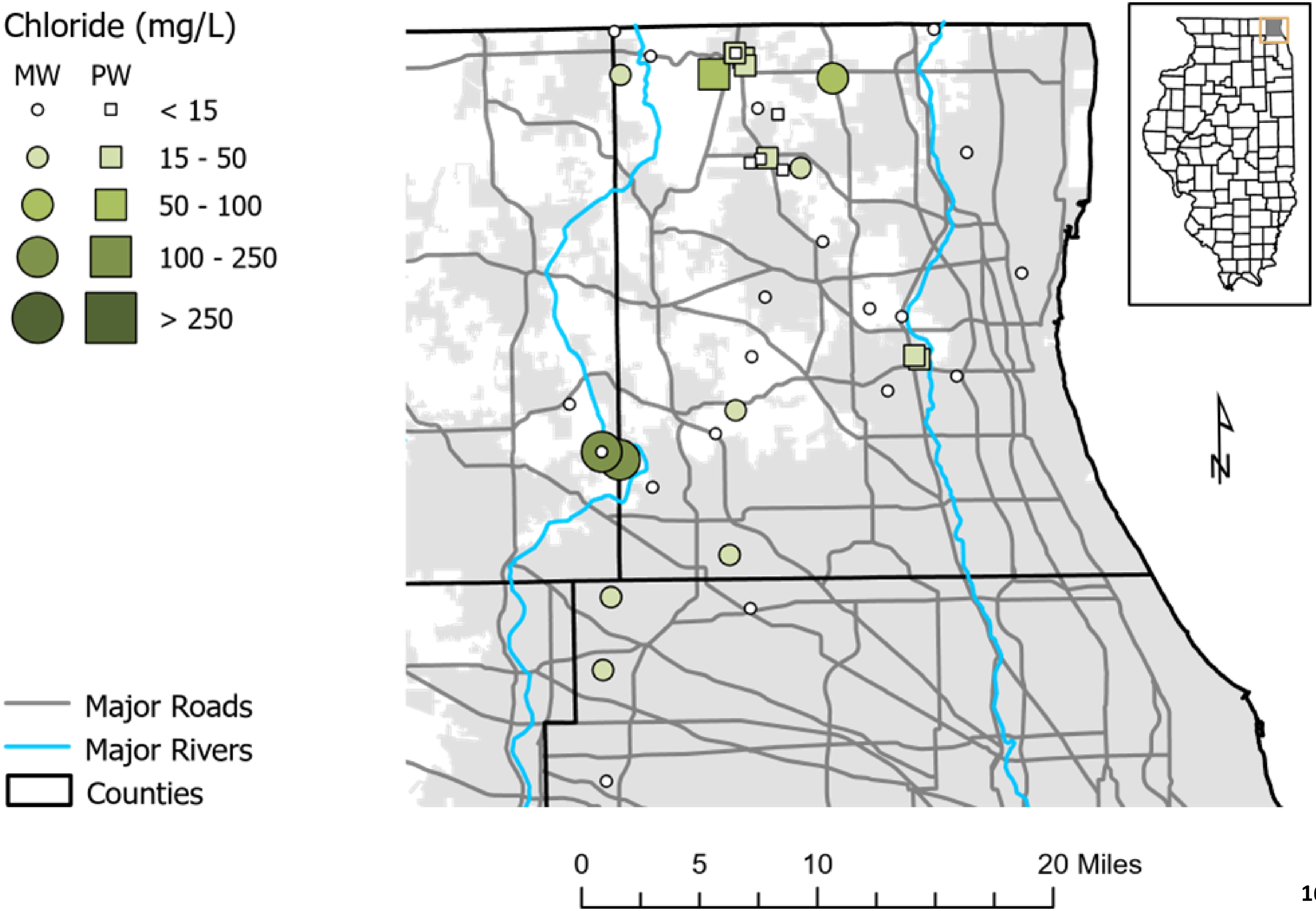
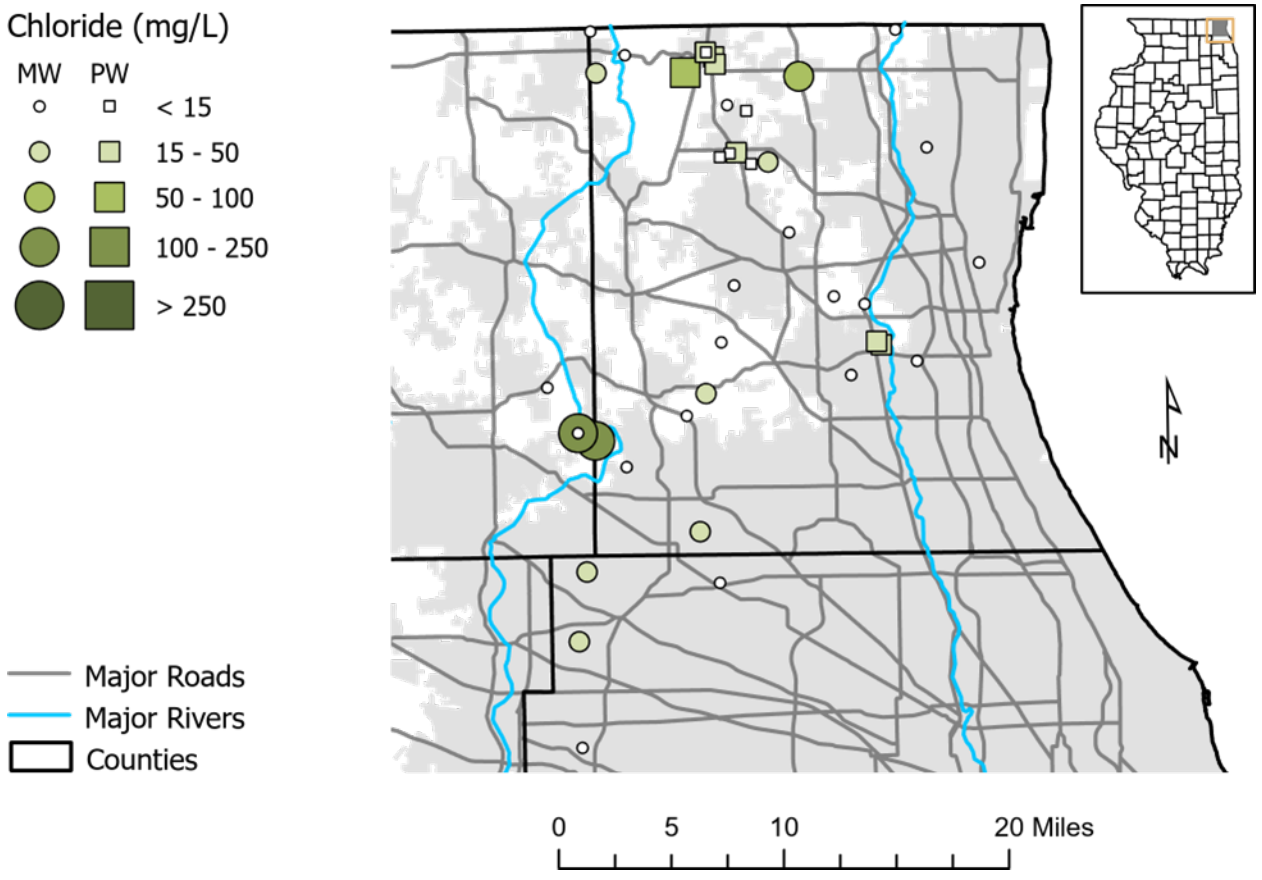


Figure credit: Michael Krasowski, ISWS

Chloride, nitrate, phosphorous (common IL surficial contaminants) are low



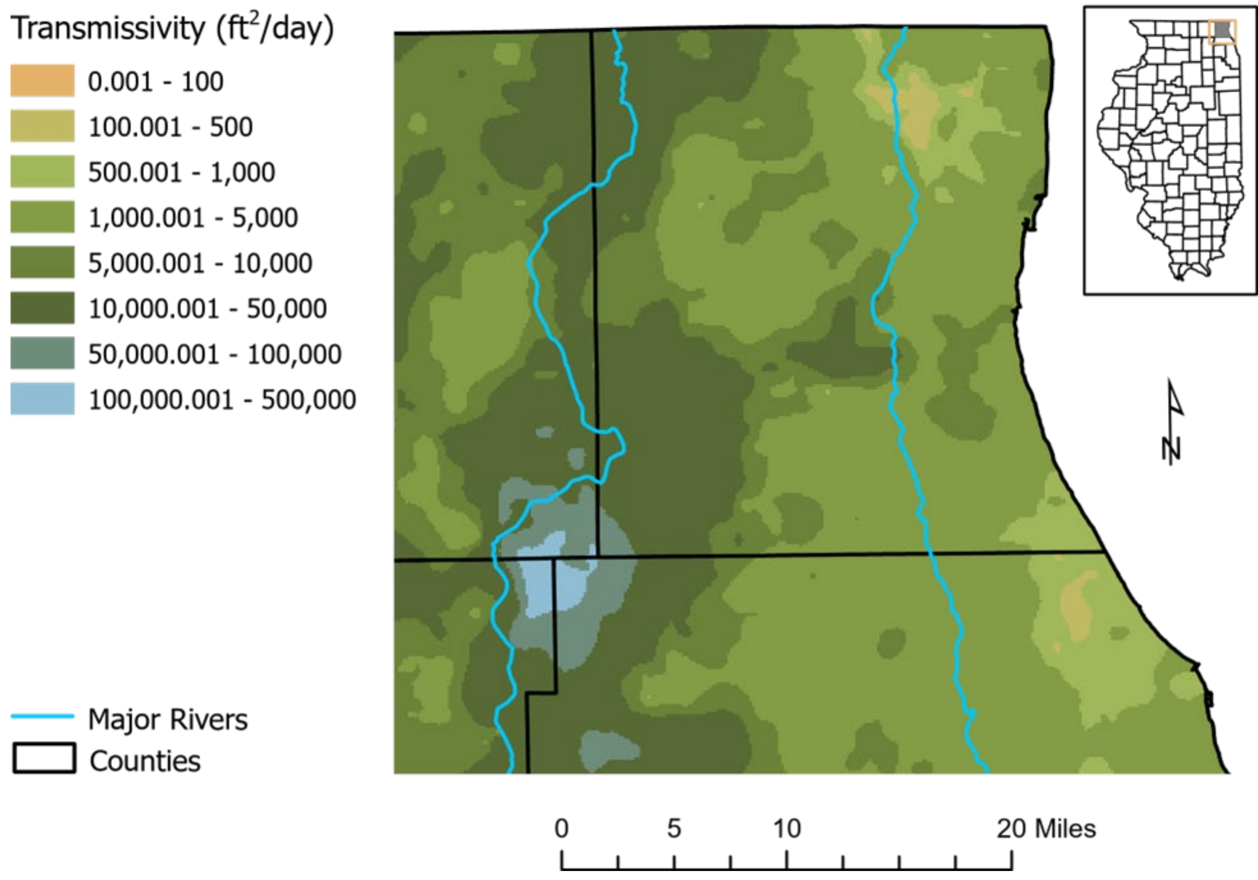
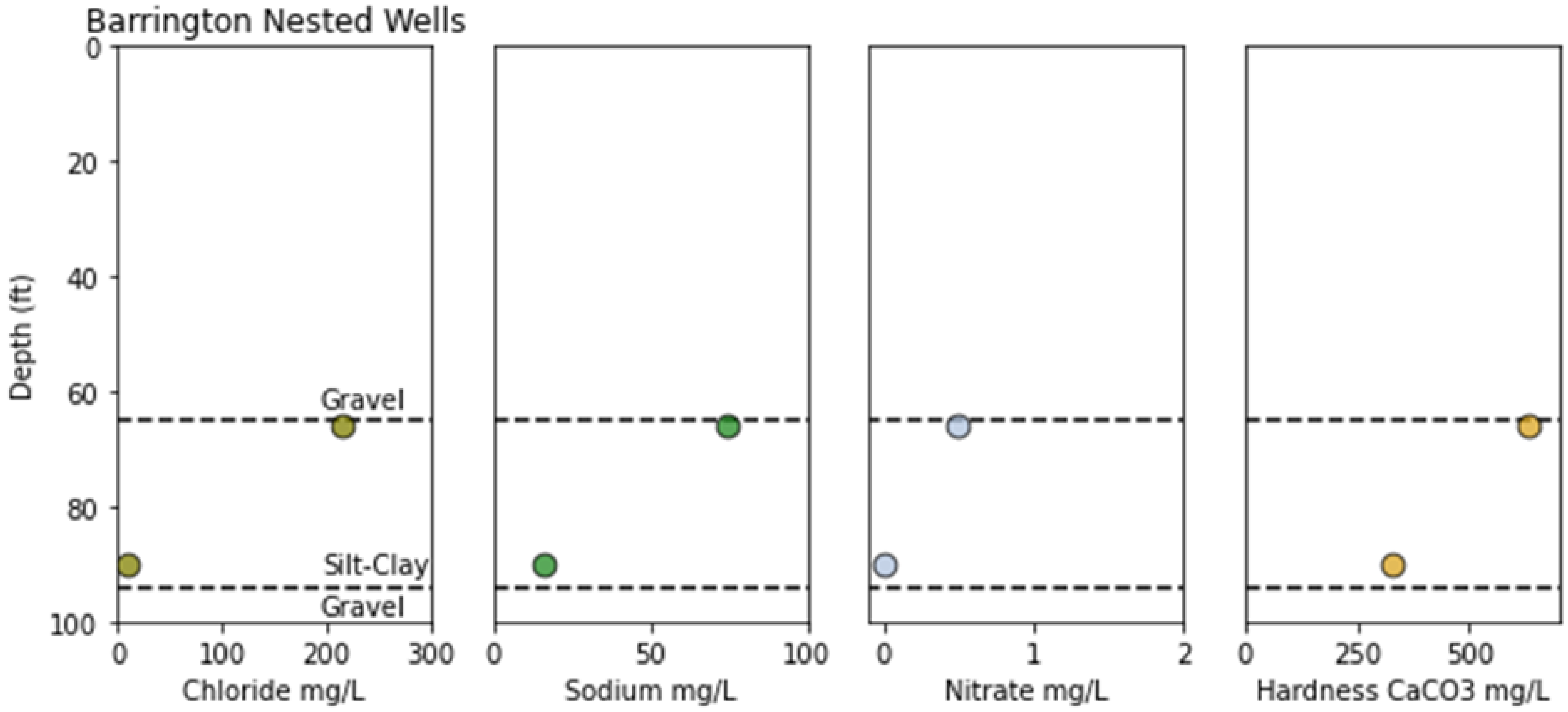


Figure credit: Michael Krasowski, ISWS

The abundant silts and clays seal out surficial contaminants



Nested well example

Sodium Distribution

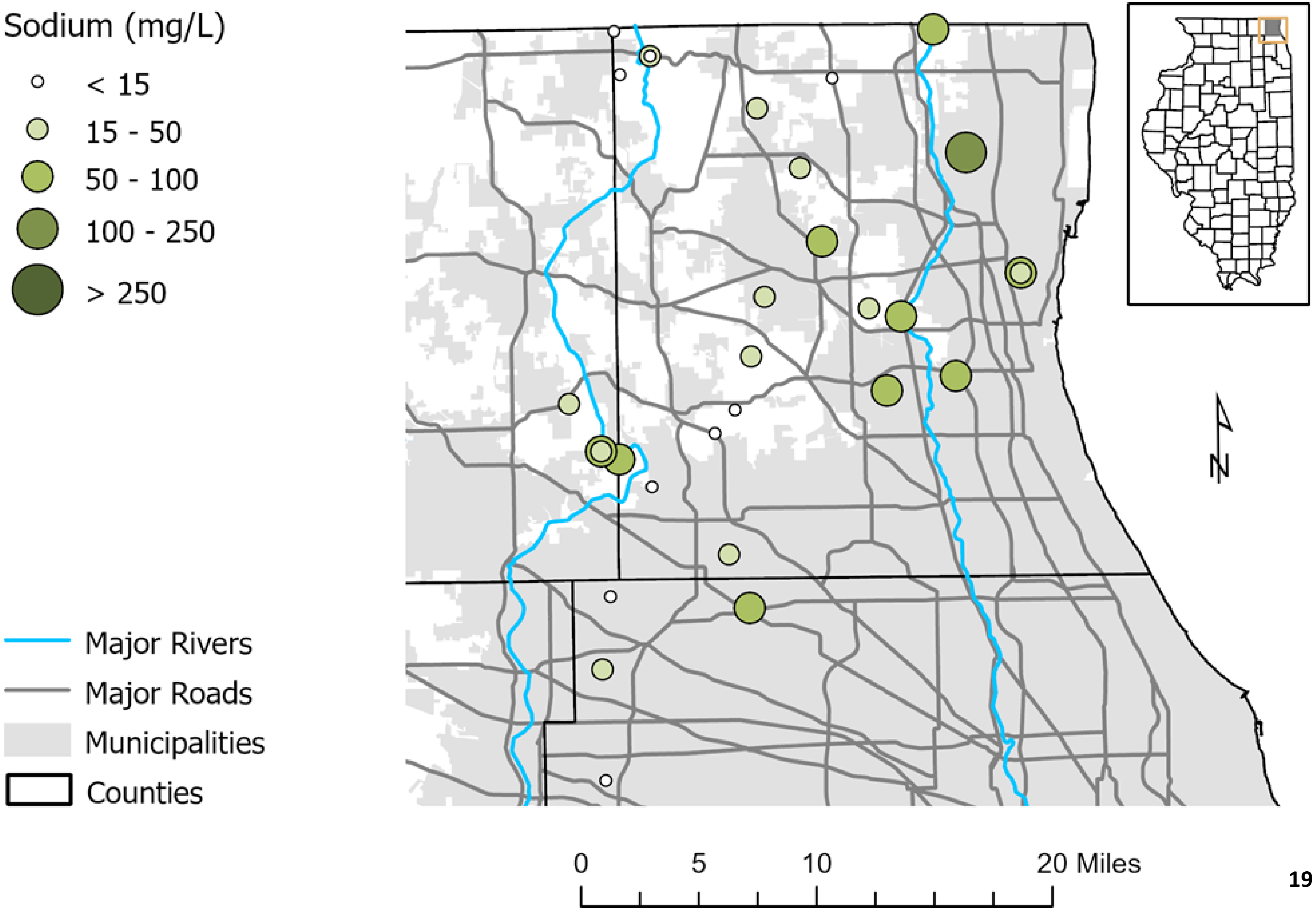
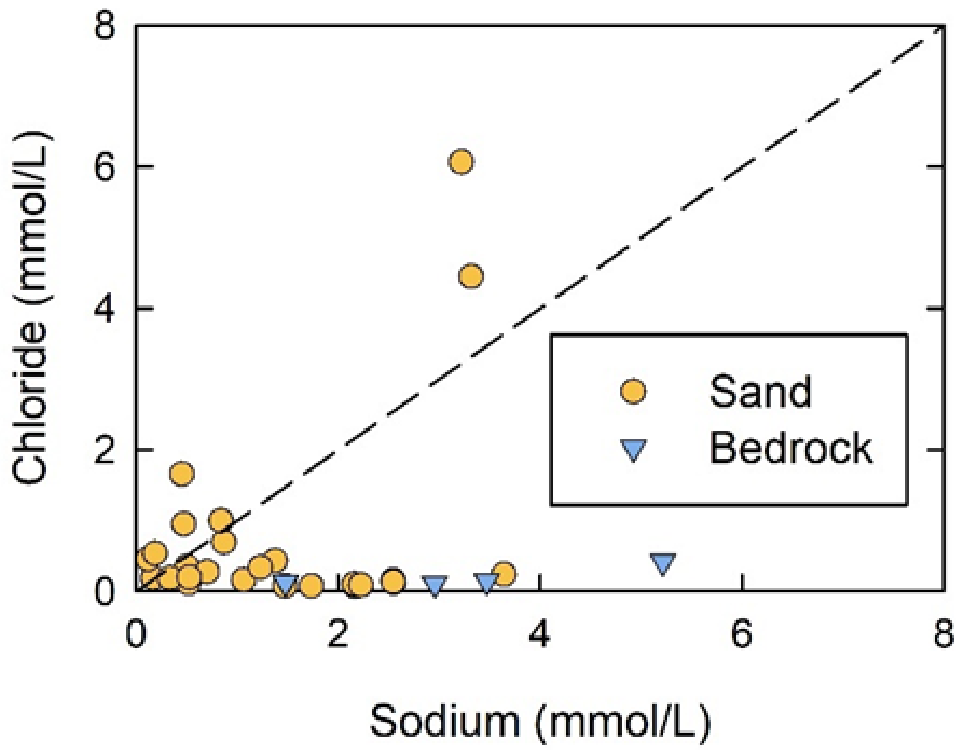
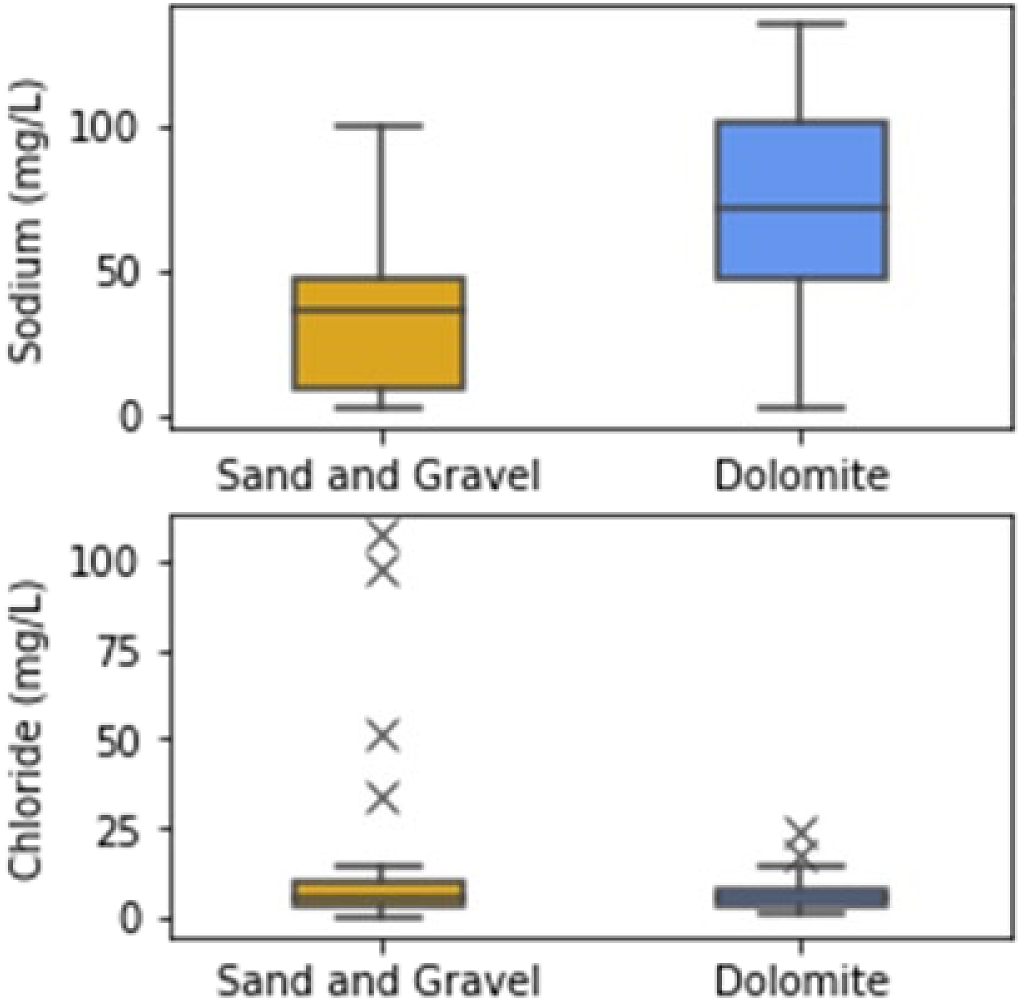


Figure credit: Michael Krasowski, ISWS

Data from Woller and Gibbs 1976

Sodium is sometimes high where chloride is low



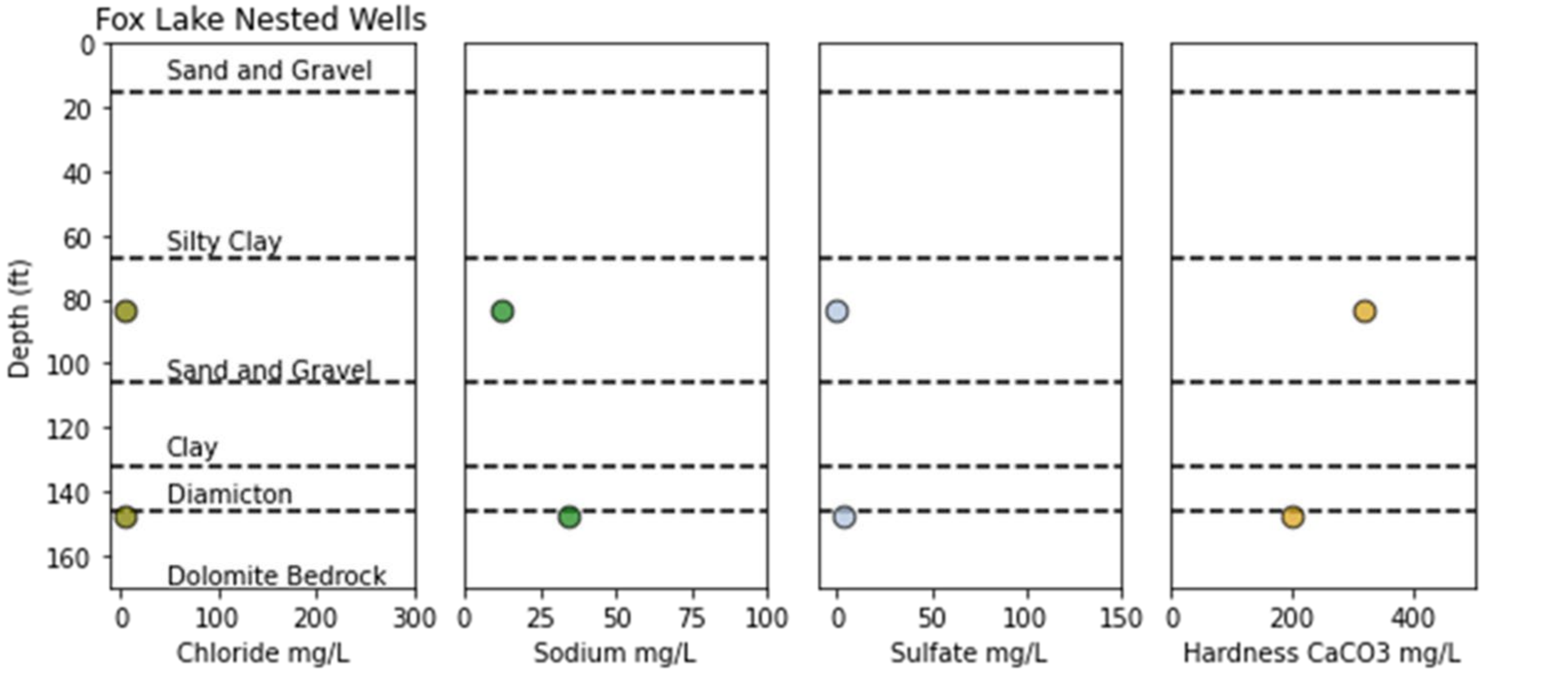


This was also observed in 1935 and 1976 ISWS studies AND in Racine County directly north in Wisconsin in two of their studies.

Some of the high sodium is natural (geogenic).

Figure credit (left): Walt Kelly, ISWS

Sodium can increase with depth at a site

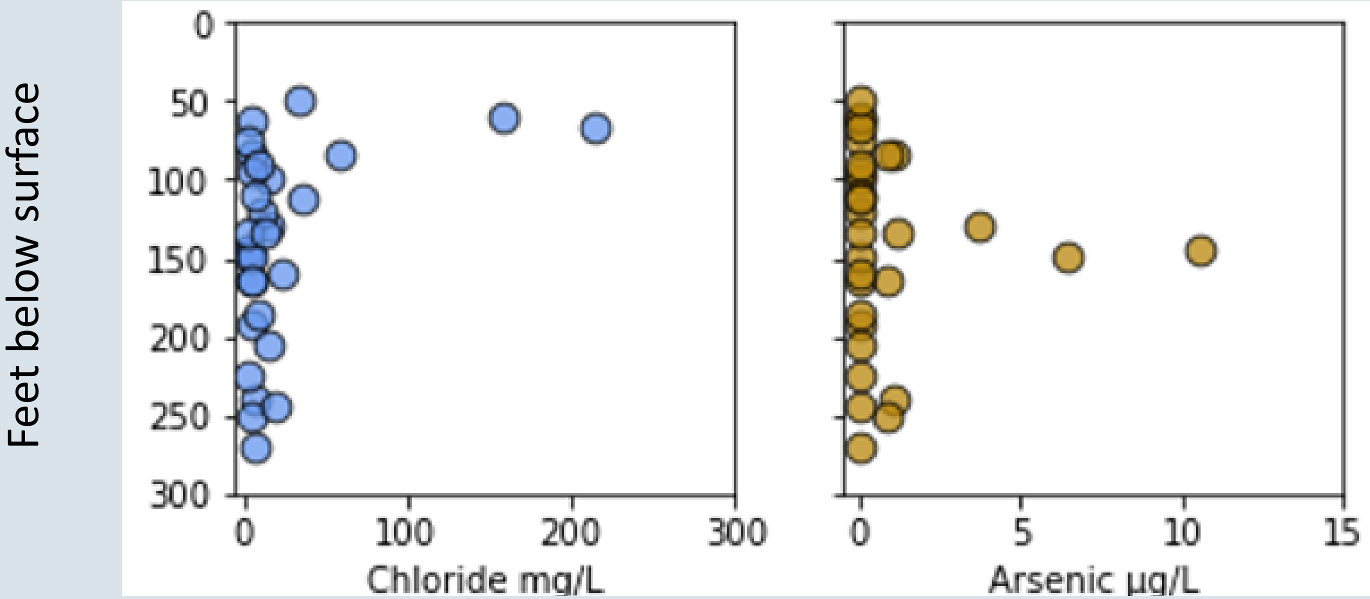


Nested well example

Well	Primary Standards												Secondary Standards										
	Antimony[1]	Arsenic	Barium	Beryllium	Cadmium	Chromium	Copper	Fluoride	Lead[2]	Nitrate	Selenium[3]	Thallium[4]	Aluminum	Chloride	Copper	Corrosivity[5]	Fluoride	Iron	Manganese	pH	Sulfate	TDS	Zinc
ANT-03-29B	?								?		?	?						X					
ANT-07-33	?								?		?	?						X					
ANT-07-34	?	X							?		?	?						X					
BARR-06-02A	?								?		?	?						X					
BARR-06-02B	?								?		?	?										X	
BARR-06-03	?								?		?	?										X	
BARR-06-04B	?								?		?	?						X					
BARR-07-06B	?								?		?	?						X					
FOX-03-15B	?								?		?	?						X					
FOX-04-16	?								?		?	?						X					
FOX-04-18	?								?		?	?											
FOX-04-18B	?								?		?	?						X	X				
GRAY-09-12A	?								?		?	?						X					
GRL-03-04	?								?		?	?											
GRL-03-05B	?								?		?	?											
GRL-03-07B	?								?		?	?						X				X	
LBTY-04-01	?								?		?	?				X							
LBTY-05-03	?								?		?	?											
LBTY-05-04	?								?		?	?											
LBTY-07-05	?								?		?	?				X		X			X	X	
LZUR-04-01	?								?		?	?						X					
LZUR-05-03	?								?		?	?				X					X	X	
LZUR-07-07	?								?		?	?						X					
STRM-06-02	?								?		?	?						X	X			X	
STRM-06-03	?								?		?	?						X					
WAD-07-11	?								?		?	?											
WAD-09-17	?								?		?	?				X				X			
WAUC-08-15A	?								?		?	?						X					
WAUK-08-01	?								?		?	?											
WAUK-08-01B	?								?		?	?						X					

One site had arsenic higher than 10 ppb (the EPA standard)

	Primary Standards											
Well	Antimony[1]	Arsenic	Barium	Beryllium	Cadmium	Chromium	Copper	Fluoride	Lead[2]	Nitrate	Selenium[3]	Thallium[4]
ANT-03-29B	?								?		?	?
ANT-07-33	?								?		?	?
ANT-07-34	?	X							?		?	?
BARR-06-02A	?								?		?	?
BARR-06-02B	?								?		?	?
BARR-06-03	?								?		?	?
BARR-06-04B	?								?		?	?
BARR-07-06B	?								?		?	?
FOX-03-15B	?								?		?	?
FOX-04-16	?								?		?	?
FOX-04-18	?								?		?	?
FOX-04-18B	?								?		?	?
GRAY-09-12A	?								?		?	?
GRL-03-04	?								?		?	?
GRL-03-05B	?								?		?	?
GRL-03-07B	?								?		?	?
LBTY-04-01	?								?		?	?
LBTY-05-03	?								?		?	?
LBTY-05-04	?								?		?	?
LBTY-07-05	?								?		?	?
LZUR-04-01	?								?		?	?
LZUR-05-03	?								?		?	?
LZUR-07-07	?								?		?	?
STRM-06-02	?								?		?	?
STRM-06-03	?								?		?	?
WAD-07-11	?								?		?	?
WAD-09-17	?								?		?	?
WAUC-08-15A	?								?		?	?
WAUK-08-01	?								?		?	?
WAUK-08-01B	?								?		?	?



Higher arsenic appears to occur in a sand/gravel unit called the Beverly Tongue

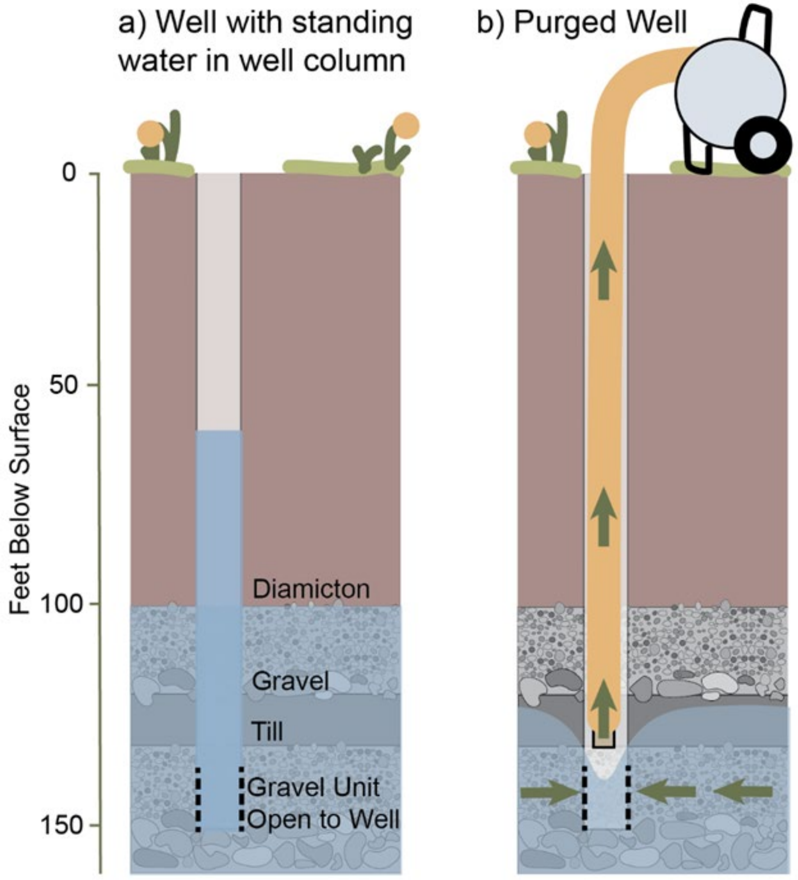
Community Results (anions only)

Well Name	Well Depth (ft)	Well open to	Chloride[1]	Chloride Source[2]
Libertyville Second Street Well	251	Dolomite	Low	Road salt and septic effluent
Libertyville Milwaukee Street Newberry	227	Dolomite	Low	Road salt and septic effluent
Lake Villa Well 5	150	Sand	Low	Unknown
Lake Villa Well 15	158	Sand	Background	Unknown
Lake Villa Well 8	235	Sand	Background	Precipitation
Lake Villa Well 11	235	Sand	Background	Unknown
Lake Villa Well 6	195	Sand	Background	Unknown
Antioch 1	216	Sand	Background	Unknown
Antioch 2	232	Glacial Drift	Background	Unknown
Antioch 3	150	Sand	Low	Unknown
Antioch 5	131	Gravel	Low	Unknown
Antioch 6	229	Glacial Drift	Low	Unknown
Antioch 7	155	Sand	Moderate	Unknown

[1]Follows recent ISWS classification of chloride as Background (< 15 mg/L), Low (15 – 50 mg/L), Moderate (50 – 100), High (100 – 250 mg/L) and Excessive (> 250 mg/L) [2]Chloride – bromide ratios used to determine source following relationships (Panno et al., 2006a)

Overall Results

- The clay/silt layers in areas of low transmissivity keep chloride in the aquifer low even when land use is urban
- Sodium and sulfate are naturally elevated in some wells
- Arsenic concentrations are observably higher in the Beverly Tongue sand/gravel outwash layer
- Nested well sites show that water quality can vary at depth in interesting ways



Also anticipated to be in the report

- Results of PFAS analyses at eight of the wells (not back from the lab yet)
- Water isotope results can commentary on timing of recharge of groundwater in Lake County
- More figures, maps, interpretations

New Questions

- **What is the source of elevated sodium in the dolomite?** This has long been a mystery
- **Is arsenic high in homeowners wells open to the Beverly Tongue?** This is first ISWS study in Lake County that was able to look into arsenic. In Central Illinois, Walt led a study that found high arsenic in a glacial sand/gravel outwash unit. How pervasive is this in homeowners' wells?
- **Are chloride and nitrate concentrations in groundwater problematic are wells in the highly transmissive BACOG area?** In early talks with BACOG leaders about the possibility of exploring this question more

Thank you for your attention NWPA

Questions? (email me at ccullen3@illinois.edu)

We are trying to find a home for this report, so let us know of people who would be interested in being emailed a copy once published, thanks!