CONTRACT REPORT 2020-03

Recent Trends in Chloride and Total Dissolved Solids in Silurian Wells in the Southwest Water Planning Group Region: Indicators of Groundwater Contamination within the Silurian Dolomite Aquifer

Walton R. Kelly

June 2020

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Illinois State Water Survey
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Abstract

The objective of this study was to assess whether chloride (Cl^-) and total dissolved solids (TDS) concentrations have continued to increase since 2005 in the Silurian shallow bedrock aquifer in the Southwest Water Planning Group (SWPG) region of Illinois (Will, Kendall, and Grundy Counties). Previous research has indicated that Cl^- and TDS concentrations have been increasing in Will County since the 1960s as a result of road salt runoff. Analysis of new data indicates that several community supply wells in the SWPG region that are finished in the Silurian dolomite aquifer show increasing Cl^- and TDS concentrations. The median increase in Cl^- concentrations was 2.5 mg/L per year, with a maximum of 10.4 mg/L per year. The most affected wells were in the northwestern part of Will County. Deeper wells tended to have lower concentrations. Some of the wells that were sampled over short time frames showed extreme variability, which suggests that contaminated water recharges seasonally and that there is minimal mixing in the aquifers.

As was shown in previous studies in the Chicago region, urbanization can seriously degrade the groundwater quality of unconfined aquifers. Increasing Cl^- concentrations in the region indicate that road salt runoff is reaching the Silurian dolomite aquifer, even to depths greater than 300 feet. Therefore, recharge from the surface is reaching the dolomite aquifer, passing through any till and sand and gravel layers above it. This connectivity between the land surface and the dolomite aquifer shows the vulnerability of the aquifer to surface contamination and the need to protect it.

Introduction

Deep sandstone bedrock aquifers are being pumped unsustainably in northeastern Illinois, particularly in the region surrounding Joliet. The Southwest Water Planning Group (SWPG) was formed to address the need for many communities and industries to find a new water source. SWPG currently comprises 12 municipalities, three major industrial water users, and Will County government. One of the alternative strategies to replace or supplement the deep sandstone aquifers is to increase reliance on shallower aquifers, primarily the Silurian shallow bedrock system, which is mainly fractured dolomite. Although the Silurian aquifer cannot provide adequate water for many affected municipalities and industries on account of geological constraints, it is an important source for many communities and domestic supplies in the region. For these communities, the main factor impinging on its use is water quality, specifically the increasing salinization due to road salt runoff.

In a study of shallow groundwater (< 300 feet) in northern Illinois, Panno et al. (2006) determined that naturally occurring chloride concentrations in shallow aquifers ranged from less than 1 to 15 milligrams per liter (mg/L). They suggested that concentrations greater than 15 mg/L indicated contamination from human sources. In 2005, the Illinois State Water Survey (ISWS) began a series of studies to examine changes in shallow groundwater quality due to road salt runoff in northeastern Illinois (Kelly 2005, Kelly 2008, Kelly et al. 2016, Kelly et al. 2012). These studies found increasing levels of total dissolved solids (TDS), chloride (Cl^-), and other ions in sand and gravel and shallow bedrock aquifers throughout the region. Kelly (2008) found that approximately 60 percent of shallow community supply wells (< 250 feet deep) had statistically significant increases in Cl^- concentrations, with an average increase of approximately 4 mg/L per year. This rate of increase was confirmed in a later study in Kane County (Kelly et al., 2016). The objective of this study was to assess more recently collected water quality data and determine where Cl^- and TDS concentrations were increasing in the Silurian shallow bedrock aquifer within the SWPG region.

The Silurian dolomite formation has been extensively weathered at the bedrock surface, producing secondary porosity in the form of enlarged fractures, cracks, and crevices, resulting in highly productive aquifers. The Silurian aquifer thickness varies greatly in the region. With a maximum thickness of around 500 feet in the southeastern comer of Will County, the aquifer rapidly thins toward the western border of Will County, where it has been eroded away (Roadcap et al. 1993). In parts of the region, basal sands and gravels lay directly atop the Silurian bedrock surface. Wells drilled at these locations can be three to four times more productive than wells drilled elsewhere (Csallany and Walton 1963). Areas where these basal sands and gravels are found may also be more vulnerable to surface-derived contamination, as they may provide pathways for migration to the Silurian aquifer. Figure 1 and Figure 2 show these locations in map and cross-sectional views. The cross section in Figure 2 was developed from the ISWS 9-layer groundwater flow model for the region (Abrams et al. 2018).

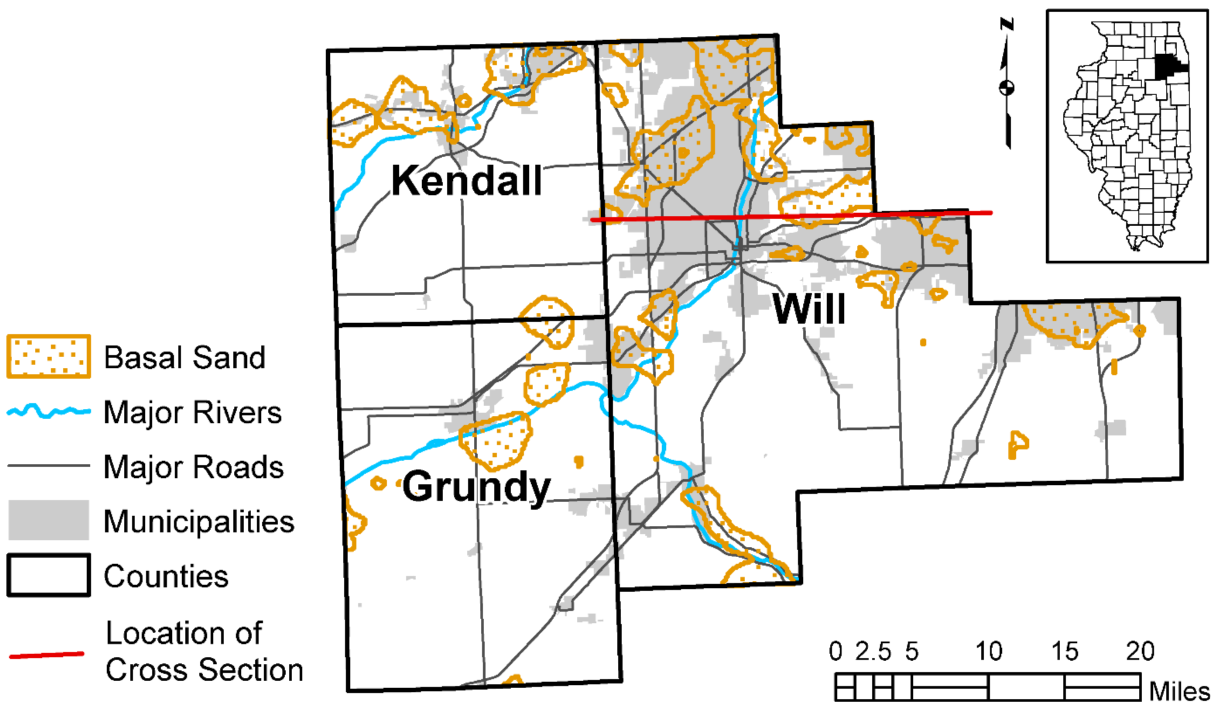

Figure 1. Three county study regions. Stippled areas show locations where basal sands (> 50% coarse material) lie directly on the Silurian dolomite. Red line shows cross section shown in Figure 2.

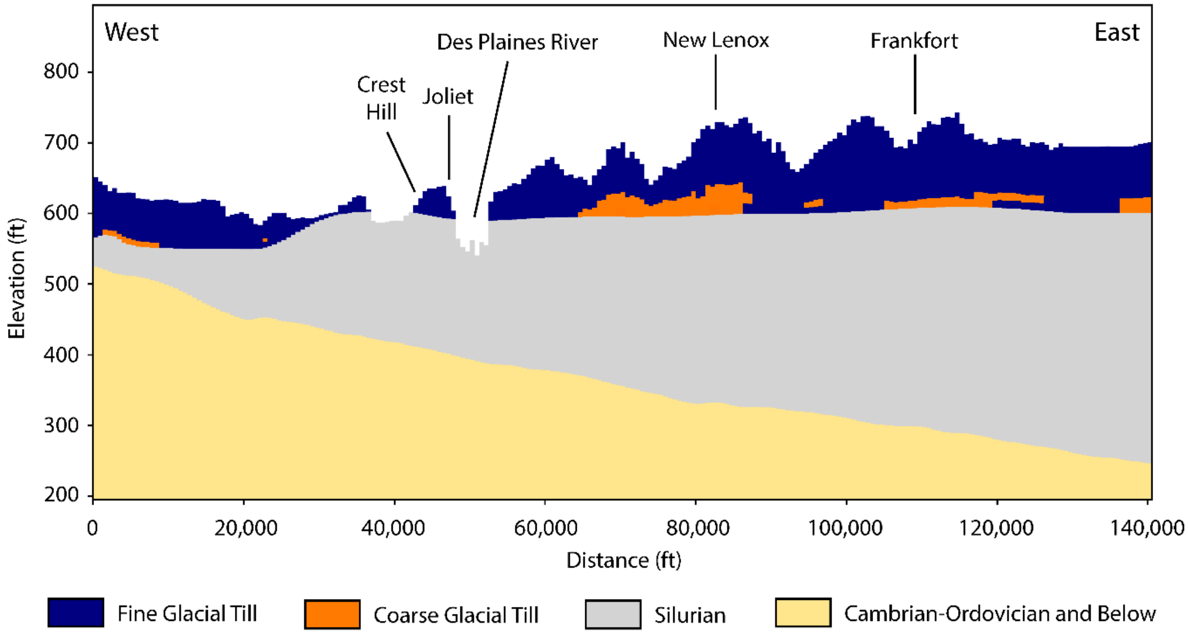

Figure 2. Geologic cross section in Will County showing shallow geology. Coarse glacial till represents material with > 50% coarse material. Note how Silurian dolomite thins moving from east to west. See Figure 1 for cross section location.

Acknowledgments

Mike Krasowski (ISWS) made the maps and cross section. Sam Panno (ISGS), Devin Mannix (ISWS), Cecilia Cullen (ISWS), and Daniel Abrams (ISWS) provided valuable peer reviews. Lisa Sheppard edited the report. Thank you to the community water supplies (Channahon, Joliet, Romeoville, and Shorewood) that supplied water quality data that helped this analysis considerably.

Procedures

This study relied on data collected by other entities; no new samples were collected. Most of the data used in this study resides in the ISWS Groundwater Quality Database (GWQDB). There are two primary sources of data in the GWQDB: (1) samples collected under the Illinois Environmental Protection Agency (IEPA) community supply well networks, and (2) samples analyzed by the ISWS Public Service Laboratory (PSL). The ISWS PSL data are primarily from private (domestic and commercial) wells and are generally collected by the well owner and shipped to PSL for analysis. There are some community supply well sample data in the ISWS PSL dataset, as well as data from samples collected by ISWS scientists as part of various research projects. An additional source of data was from samples collected by community water systems (CWS) in the SWPG region. Community water systems that sent sample data to the ISWS included the cities of Channahon, Joliet, Romeoville, and Shorewood.

The database was queried for samples between 1990 and 2020, providing 30 years of data. Previous studies looked at data prior to 1990, generally ending around 2005 (Kelly 2008, Kelly et al. 2012); the author chose not to duplicate those older results. The SWPG region is primarily in northwestern Will County, but also includes parts of Kendall and Grundy Counties, and we included all three counties in the search. The data were assessed to include only wells completed in the Silurian dolomite or shallower (sand and gravel) aquifers. These aquifers are hydraulically connected throughout most of the region, and it is likely that Silurian wells would be more vulnerable to contamination where there are connections to the overlying sand and gravel aquifers.

Community supply wells are assigned codes by the ISWS to indicate from which aquifers the communities get their water. Private wells generally are not coded in this way, but it was assumed that all domestic and commercial (not high capacity) wells in the query were open only to shallow aquifers, which in this region is generally less than 250 feet deep. This is a reasonable assumption in that it is too expensive for a domestic well owner to drill down to a deep bedrock aquifer in this region, except south of the fault, southwest of Shorewood and south of Channahon.

The entire dataset was divided into 10-year increments: 1990–1999, 2000–2009, and 2010–2019. The number of samples in each group were 279, 235, and 190, respectively. Because the data were not normally distributed, the non-parametric Kruskal-Wallis One Way ANOVA on Ranks with Dunn's Method for pairwise multiple comparison tests was used to compare groups. The tests were run using SigmaPlot for Windows Version 11.0 software. Because aquifer information was not available for many samples, no distinction was made between aquifers (Silurian vs. sand and gravel).

Individual community supply wells were evaluated where the data were available. Evaluations were limited to wells with a minimum of three samples collected since 2000 and at least one since 2010. The TDS data were used for cases in which the community water supply provided TDS but not Cl^- data. Trends were determined using the non-parametric Mann-Kendall test, a rank-based procedure, at the 95 percent confidence level (Helsel and Hirsch 2002). For wells that showed a significant increasing trend, a simple linear regression was done to estimate rates using the SLOPE and CORREL functions in Microsoft Excel.

There are limitations in evaluating these data that need to be noted. First, these are not random samples, but are primarily either community supply wells required to be sampled or private wells sampled at the discretion of the well owner. Second, there is variability in the location with time due to changes in population patterns and decisions regarding water sources. Third, many of the samples collected for ISWS PSL analysis were collected by the well owners and thus there is no guarantee they were collected properly, although this is less of a concern for Cl^- than for other ions and parameters. Fourth, including both private and community supply wells in the same analysis is not strictly legitimate. Community supply wells typically are drilled through the aquifer and thus have a much longer open interval than private wells, which are usually drilled just into the top of the aquifer. Thus, a communty supply well may be mixing waters of differing water chemistry, in effect mixing different waters, whereas water chemistry in private wells represents a much smaller region of the aquifer.

Results and Discussion

A box-and-whisker plot was used to visually compare the decadal data (Figure 3). Median values for Cl^- increased from 22.4 mg/L in 1990–1999 to 32.9 mg/L in 2000–2009 to 47.6 mg/L in 2010–2019. The ANOVA results indicated that both the 2000–2009 and 2010–2019 data populations were significantly greater than the 1990–1999 population ($P < 0.05$). The difference between 2000–2009 and 2010–2019 was not statistically significant. The data are plotted by decade on regional maps in Figure 4, Figure 5, and Figure 6. Please be aware of the different sample locations depending on the decade sampled. Figure 7 shows the same data as Figure 6 but includes the locations of basal sands.

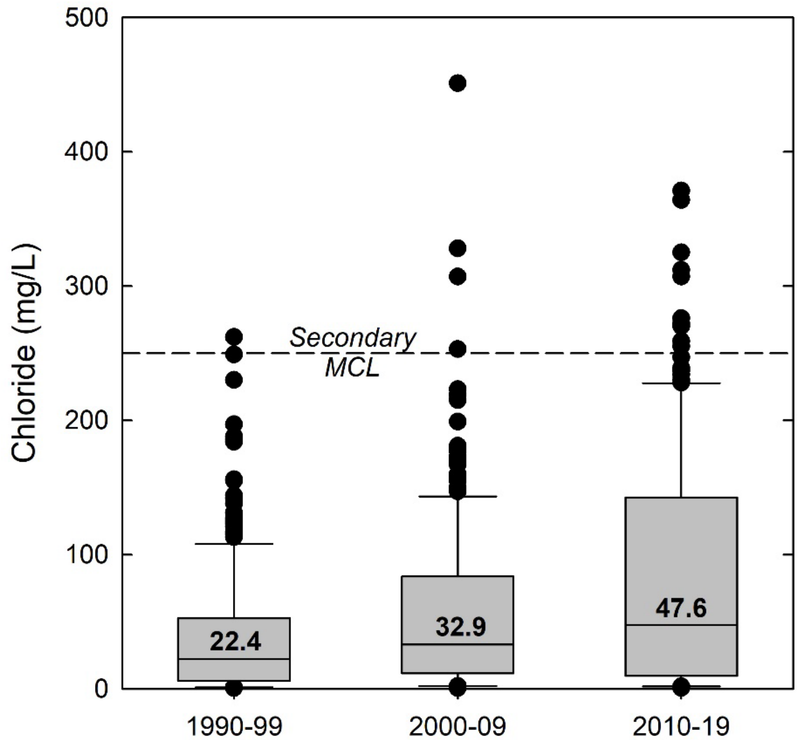

Figure 3. Box and whisker diagram for chloride data from ISWS GWQDB by decade. Line and value in middle of box indicates median value, top and bottom of box indicate 75th and 25th percentiles, top and bottom whiskers indicate 90th and 10th percentiles, and data points indicate outliers. Secondary standard for chloride (250 mg/L) indicated by dashed line.

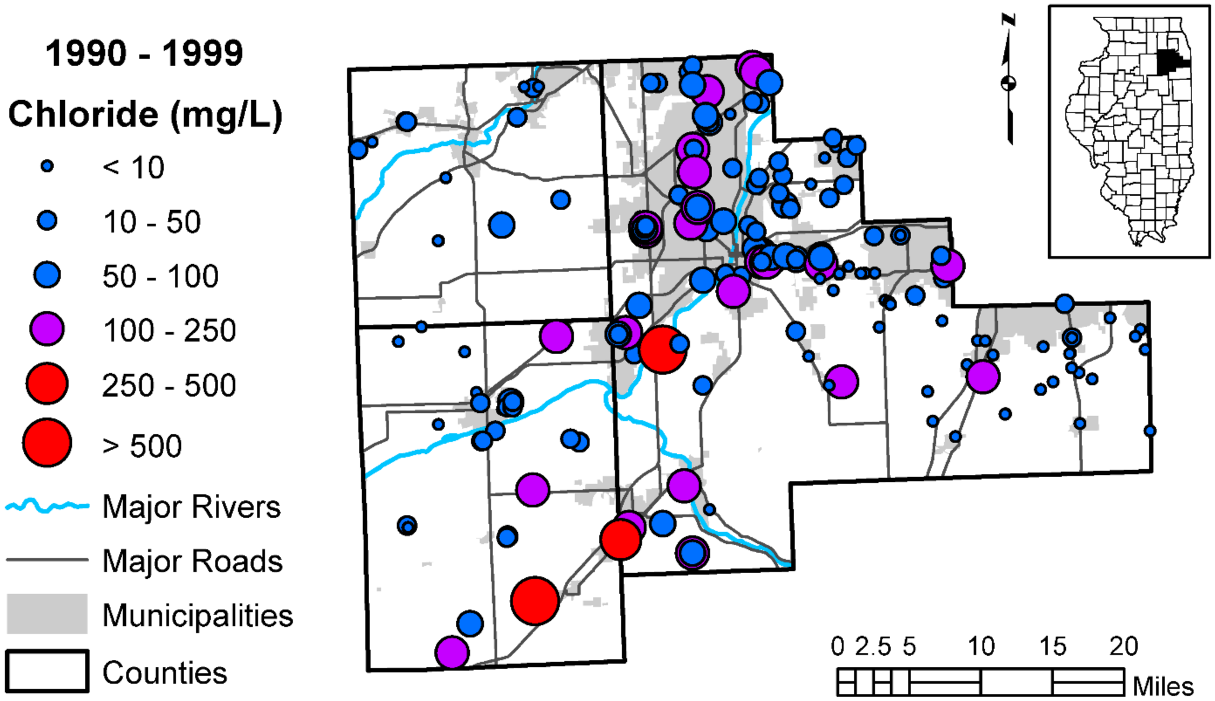

Figure 4. Chloride data from ISWS GWQDB for 1990–1999 time period. Red circles indicate chloride levels greater than the secondary MCL (250 mg/L).

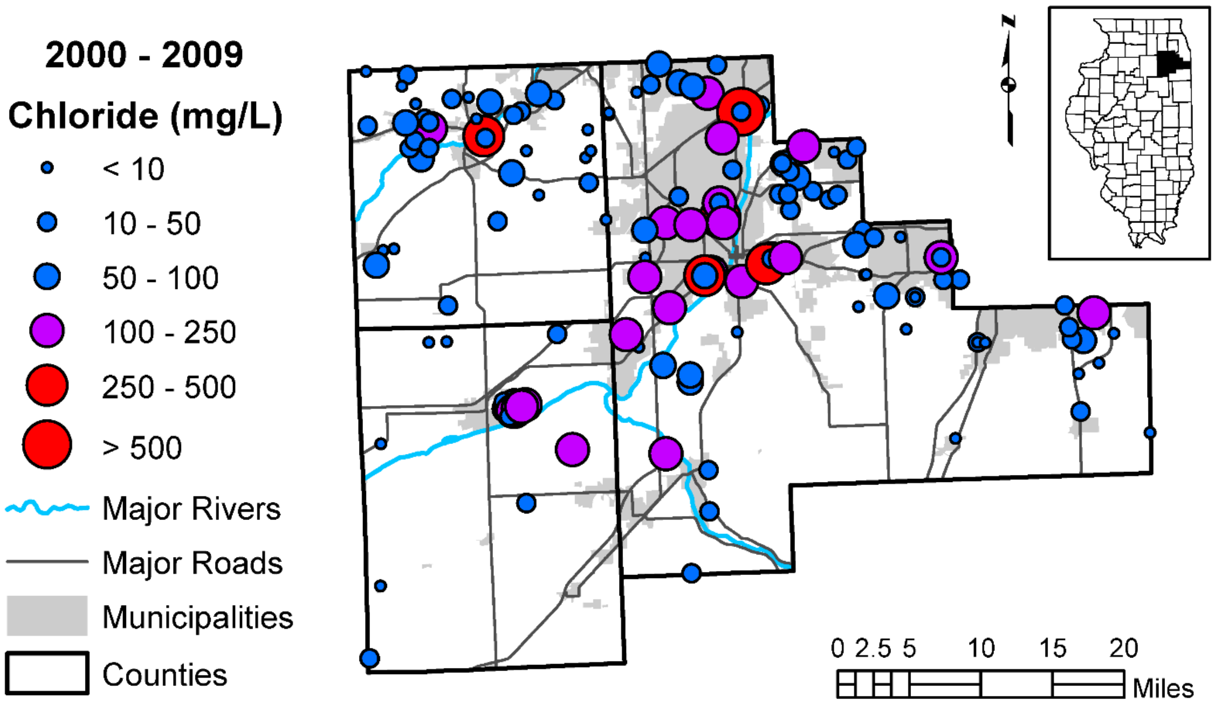

Figure 5. Chloride data from ISWS GWQDB for 2000–2009 time period. Red circles indicate chloride levels greater than the secondary MCL (250 mg/L).

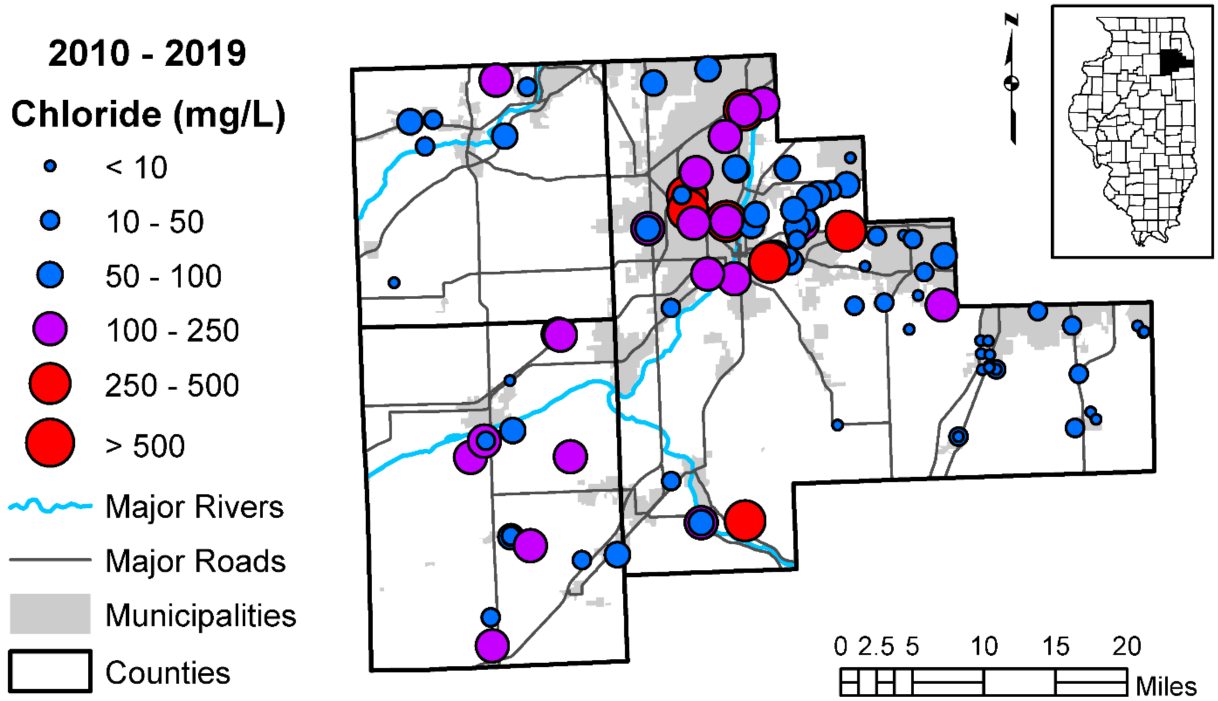

Figure 6. Chloride data from ISWS GWQDB for 2010–2019 time period. Red circles indicate chloride levels greater than the secondary MCL (250 mg/L).

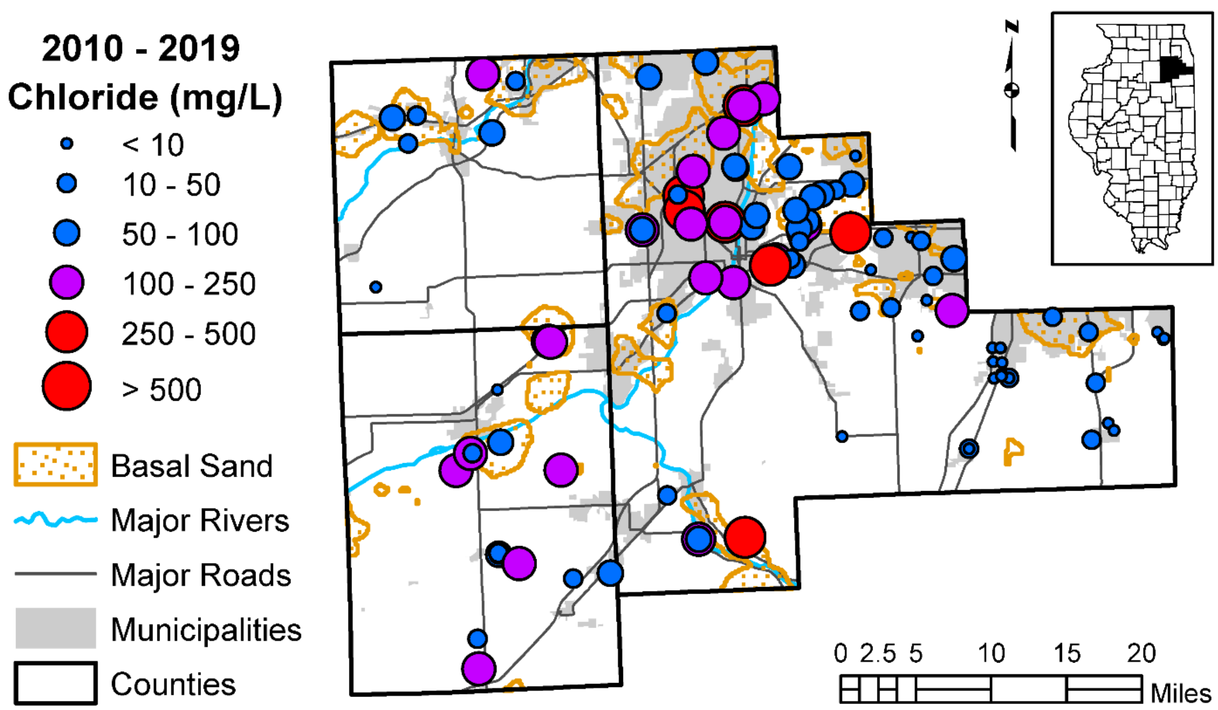

Figure 7. Chloride data from ISWS GWQDB for 2010–2019 time period. Red circles indicate chloride levels greater than the secondary MCL (250 mg/L). Stippled areas show where basal sand (> 50% coarse material) connects with the Silurian dolomite.

A total of 30 community supply wells from 18 suppliers met the criteria for trend evaluation (Table 1 and Table 2). Channahon and Romeoville provided TDS for some of their wells (Table 2). For wells impacted by road salt runoff, TDS is a good proxy for chloride (Figure 8). Twenty-eight of the wells were open to the Silurian dolomite shallow bedrock aquifer, and the other two (Channahon 3 and Plano 5) were open to shallower sand and gravel aquifers. Most wells were located in northwestern Will County, several were in more rural eastern Will County (Aqua IL-University Park, Beecher, Peotone), one was in Kendall County (Plano), and none were in Grundy County (Figure 9).

Table 1. Individual CWS wells evaluated for trends in chloride concentrations. Aquifer units determined by ISWS aquifer codes as reported in Illinois Water Inventory Program (IWIP) database maintained by the ISWS.

Community	Well No.	IEPA ID	Well Depth (ft)	Upper Unit	Lower Unit	P value[1]	Slope (mg/L/yr)[2]
Aqua IL-University Park	3	20455	457	Silurian	Maquoketa	0.548	-0.02
Aqua IL-University Park	6	20458	460	Silurian	Silurian	0.338	0.11
Beecher	4	00832	565	Silurian	Maquoketa	0.334	0.26
College View Subdv	3	20403	327	Silurian	Silurian	**0.006**	**2.51**
Crest Hill	1	20447	303	Silurian	Silurian	**0.002**	**8.55**
Crest Hill	9	01050	320	Silurian	Maquoketa	**0.002**	**4.17**
Crete	3	20460	263	Silurian	Silurian	**0.011**	**0.75**
Eastmoreland	1	20415	286	Silurian	Silurian	0.548	-1.19
Frankfort	5	20442	428	Silurian	Silurian	0.582	-0.30
Frankfort	8	20328	500	Silurian	Silurian	**0.002**	**1.17**
Frankfort	9	20329	505	Silurian	Maquoketa	0.062	1.56
IL Amer-Central States	1	20354	260	Silurian	Silurian	**0.003**	**0.76**
IL Amer-Homer Twp	3	20445	300	Silurian	Silurian	**0.003**	**2.06**
IL Amer-Homer Twp	8	20425	408	Silurian	Silurian	1.000	-0.63
Ingalls Park	2	20412	305	Silurian	Silurian	**0.002**	**6.27**
Mokena	4	20389	420	Silurian	Silurian	0.194	-0.67
Mokena	5	00152	355	Silurian	Silurian	0.904	0.03
Peotone	4	20436	300	Silurian	Silurian	**0.002**	**0.23**
Plano	5	20129	41	Sand & Gravel	Sand & Gravel	0.178	**1.23**
Rockdale	5	00176	285	Silurian	Silurian	0.904	-4.21
Romeoville	3	22126	160	Silurian	Silurian	**0.003**	**10.4**
Romeoville	5	22128	250	Silurian	Maquoketa	0.562	-15.6
Shorewood	5	00641	203	Silurian	Maquoketa	**0.013**	**2.58**
Utilities Inc-Cherry Hill	2	20330	260	Silurian	Silurian	1.000	-0.46

[1] Significant P values (< 0.05) for trend tests are bolded.
[2] Slope values in bold when $R^2 > 0.5$.

Table 2. Individual CWS wells evaluated for trends in TDS concentrations. Data supplied by CWS. Aquifer units determined by ISWS aquifer codes as reported in Illinois Water Inventory Program (IWIP) database maintained by the ISWS. NR = not reported.

Community	Well No.	IEPA ID	Well Depth (ft)[1]	Upper Unit	Lower Unit	P value[2]	Slope (mg/L/yr)[3]
Channahon	2	00384	NR	Sand & Gravel	Sand & Gravel	**0.001**	29.8
Romeoville	1	22124	160	Silurian	Silurian	**0.001**	**12.9**
Romeoville	5	22128	250	Silurian	Maquoketa	0.826	**26.8**
Romeoville	7	00621	300	Silurian	Silurian	0.139	36.6
Romeoville	8	00619	200	Silurian	Maquoketa	**-0.029**	**31.3**
Romeoville	9	00618	250	Silurian	Maquoketa	0.113	**14.6**
Romeoville	12	01281	245	Silurian	Silurian	-0.463	-36.8

[1] NR = not reported.
[2] Significant P values (< 0.05) for trend tests are bolded.
[3] Slope values in bold when $R^2 > 0.5$.

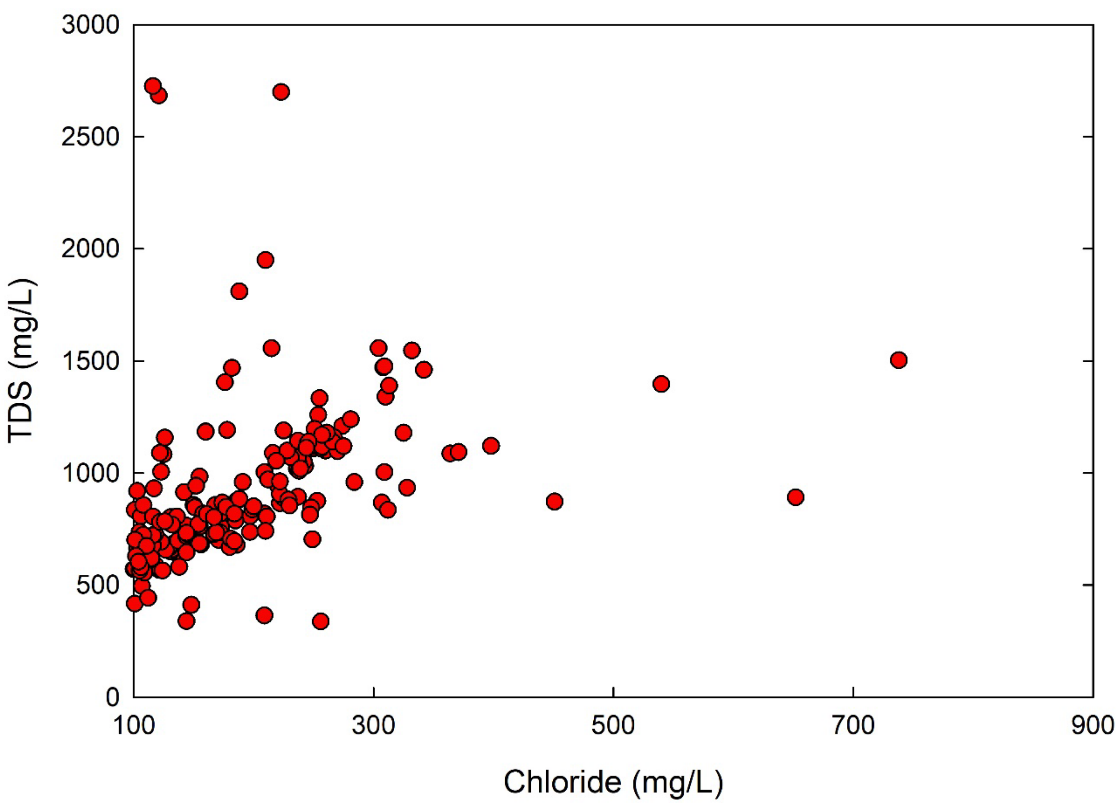

Figure 8. TDS vs. chloride concentrations for all samples from GWQDB with chloride concentrations > 100 mg/L

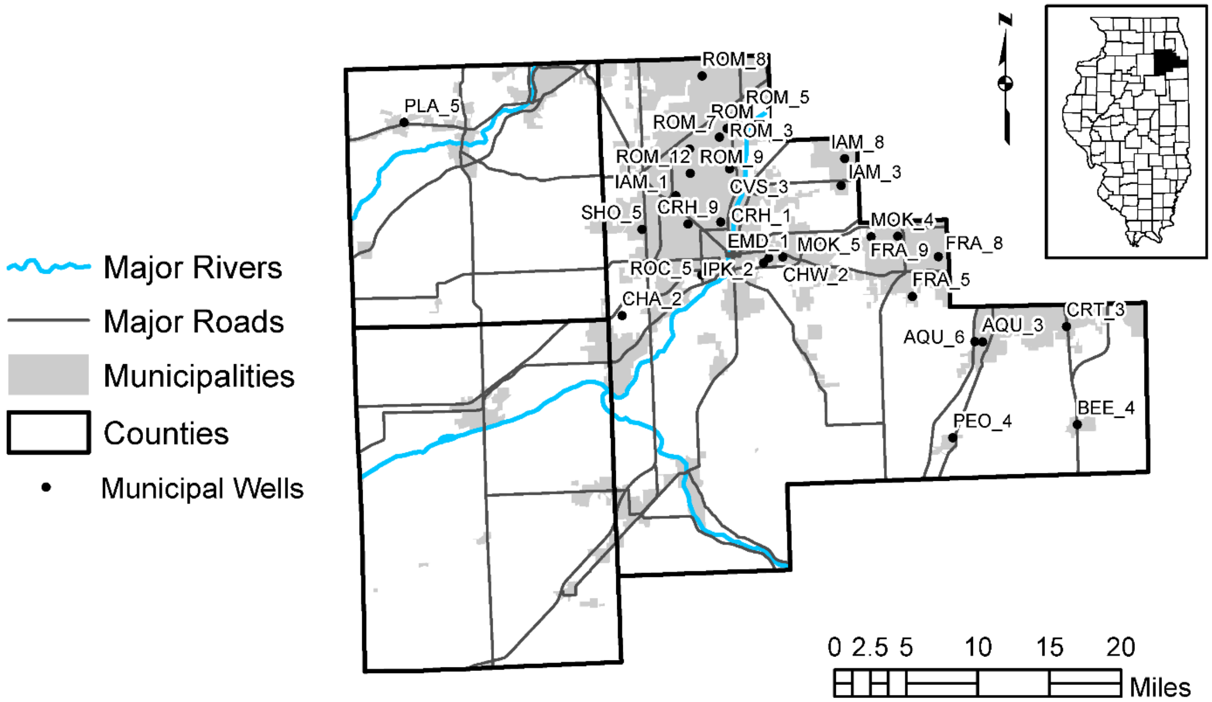

Figure 9. Location of community supply wells evaluated in this study

Chloride and TDS data are plotted for all 30 wells in Figures 10–12. Figure 10 shows wells where Cl^- concentrations were almost always below 100 mg/L, and Figure 11 shows wells where Cl^- concentrations exceeded 100 mg/L. Figure 12 shows TDS concentrations for Romeoville and Channahon wells provided by the communities. For most wells, chloride concentrations were greater than 15 mg/L, which Panno et al. (2006) suggested indicates human-derived contamination. Of the 24 wells tested for trends in Cl^- concentrations, 11 had significant positive trends ($P < 0.05$), i.e., increasing concentrations with time. For those 11 wells, the slope values ranged from 0.23 to 10.4 mg/L per year (mg/L/yr), with a median value of 2.51 mg/L/yr. Figure 13 shows the locations of the wells and their slope values. For the six wells tested for trends in TDS concentrations, two had significant positive trends and one had a significant negative trend (Romeoville 8). All three wells had positive slope values, however, ranging from 12.9 to 31.3 mg/L/yr. Romeoville sampled five of their Silurian wells weekly for 12 weeks in late 2017 (Figure 14). Chloride concentrations varied considerably during this period, by between 92 and 344 mg/L in individual wells. It is extremely unusual to find such large variability in any water quality parameter in groundwater. These results show the variability of the source term, i.e., that winter and spring thaws tend to produce a lot of meltwater that releases large slugs of salt into streams and shallow aquifers. During the rest of the year, the volumes of salt recharging to groundwater are much less. Romeoville also collected frequent samples (approximately bi-weekly) in 2019; they did not report Cl^- concentrations but did report TDS values. Again, there was considerable variability in concentrations; TDS varied between 78 and 577 mg/L in individual wells during the year (Figure 15).

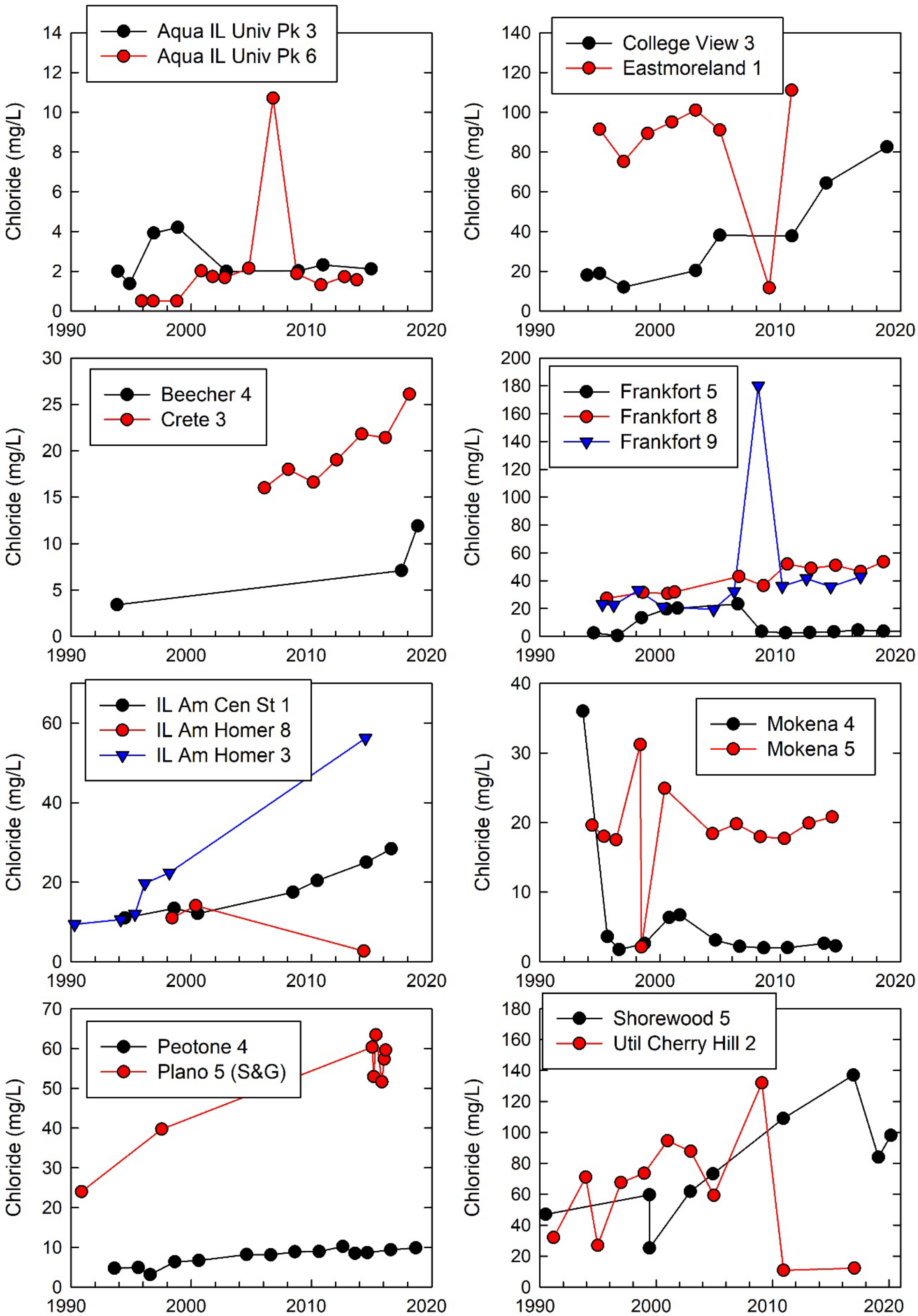

Figure 10. Chloride time series from 1990 for CWS wells that generally had chloride concentrations less than 100 mg/L

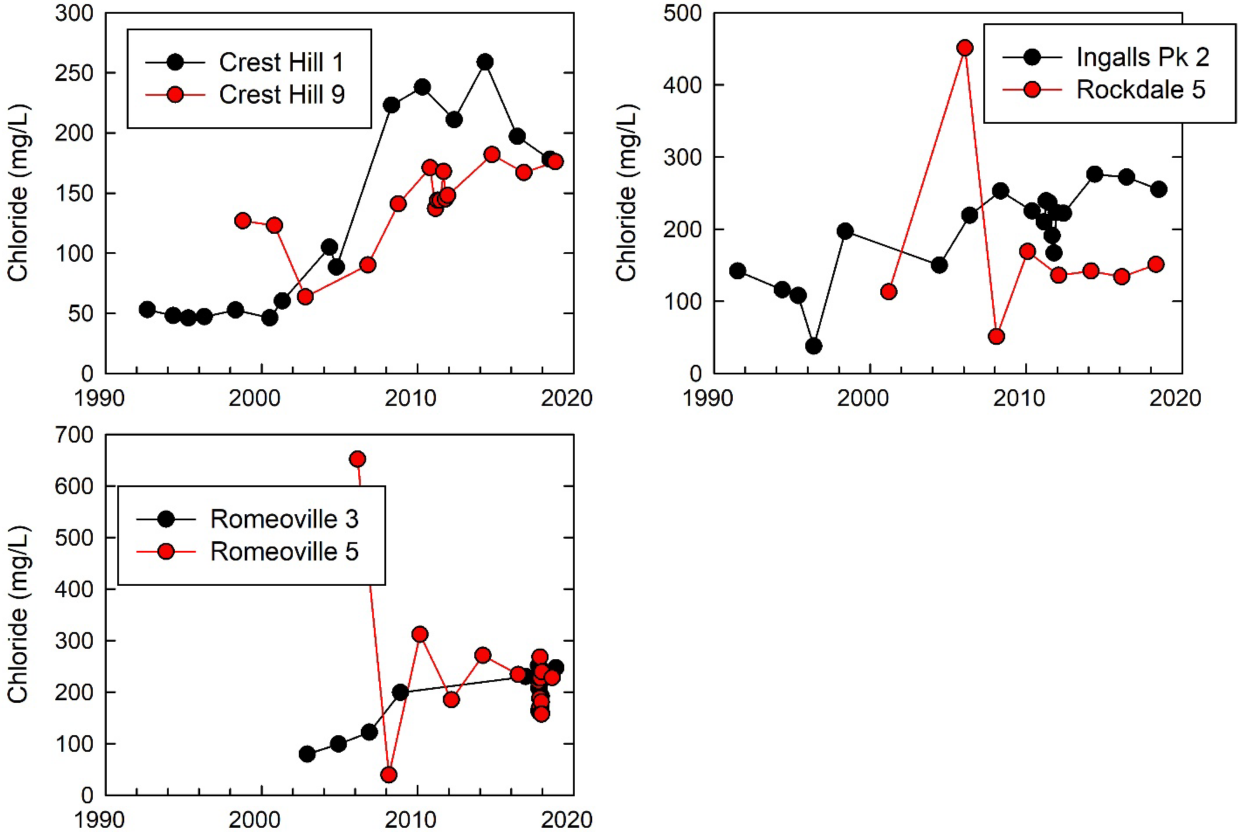

Figure 11. Chloride time series from 1990 for CWS wells that generally had chloride concentrations greater than 100 mg/L

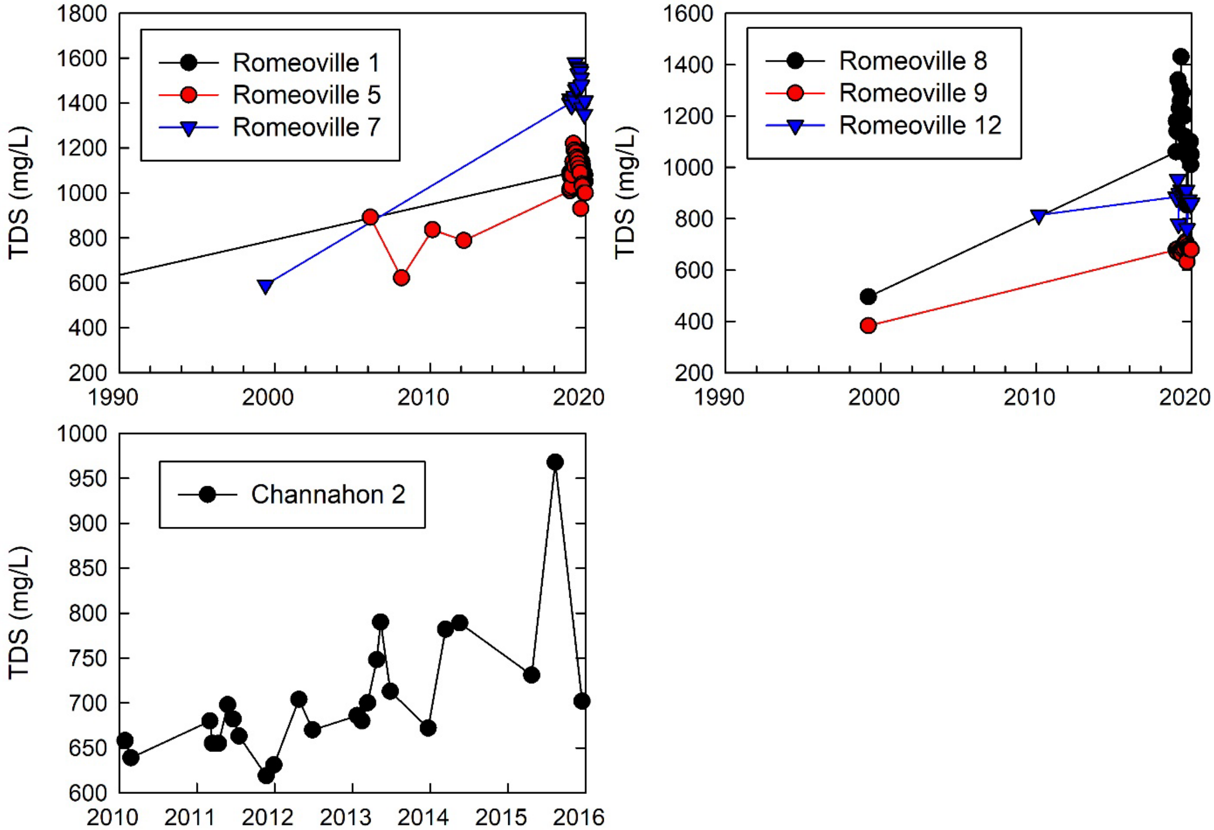

Figure 12. TDS time series from 1990 for CWS wells evaluated in this study

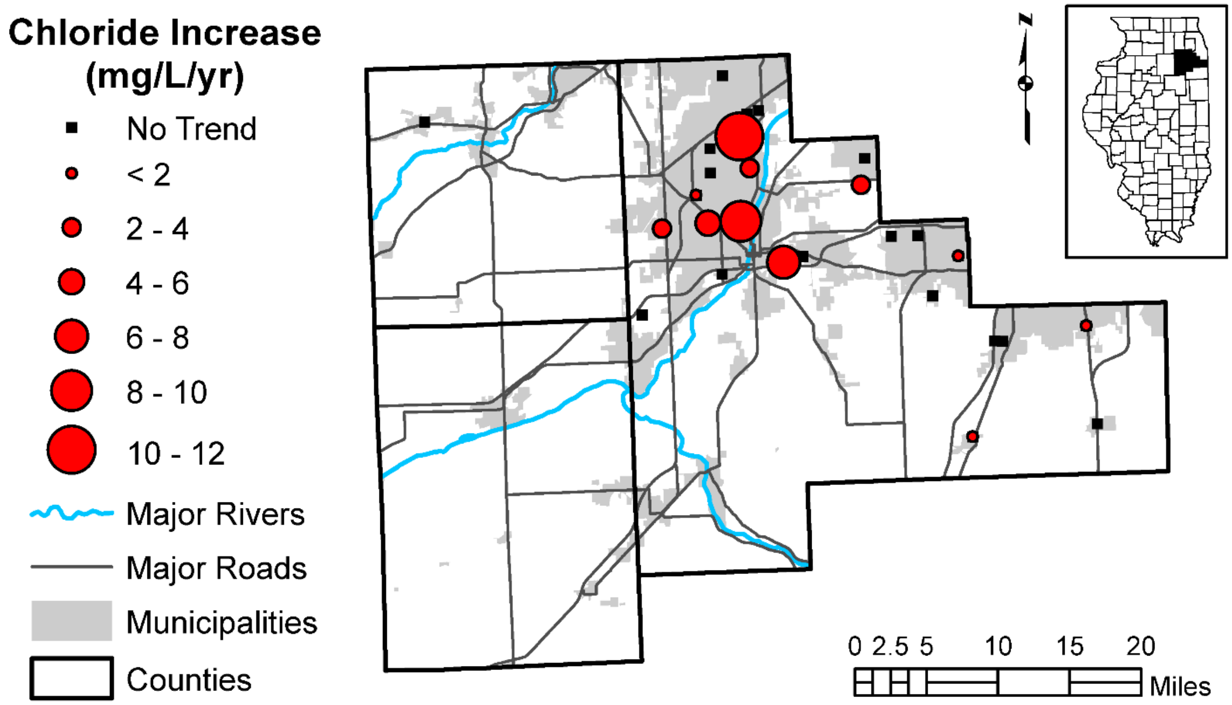

Figure 13. Changes in chloride concentrations for CWS wells evaluated in this study. Black squares indicate wells without significant trends.

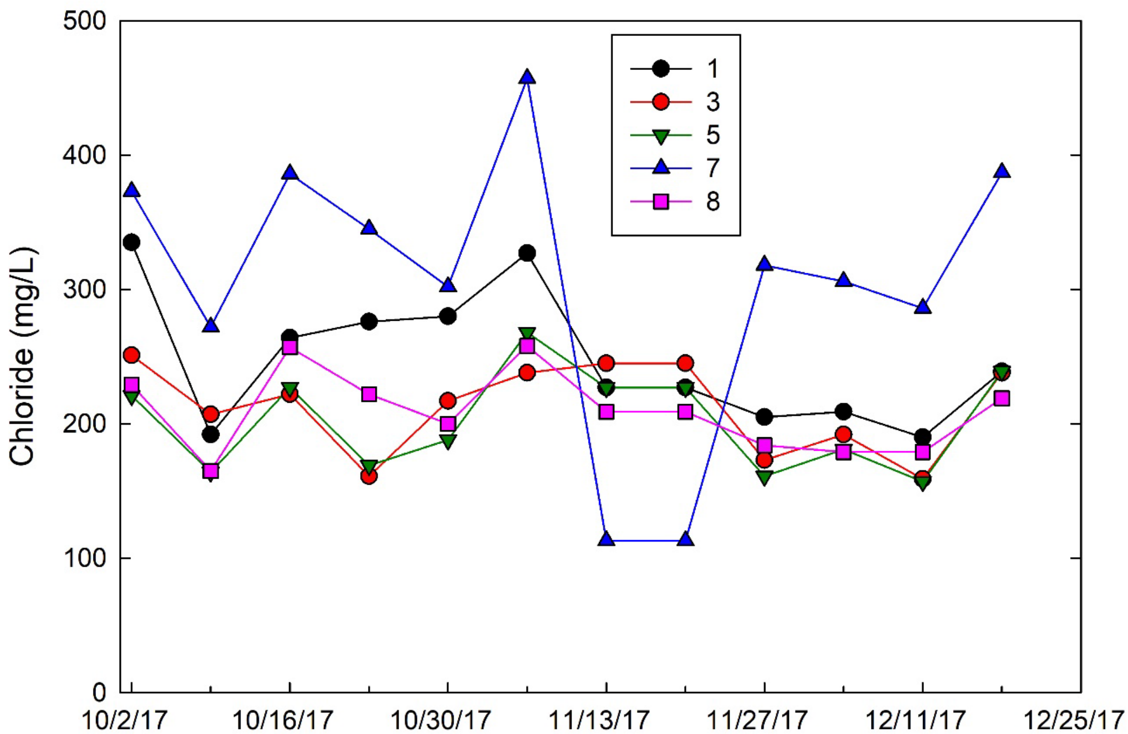

Figure 14. Chloride concentrations for Romeoville Silurian community supply wells sampled weekly during 2017

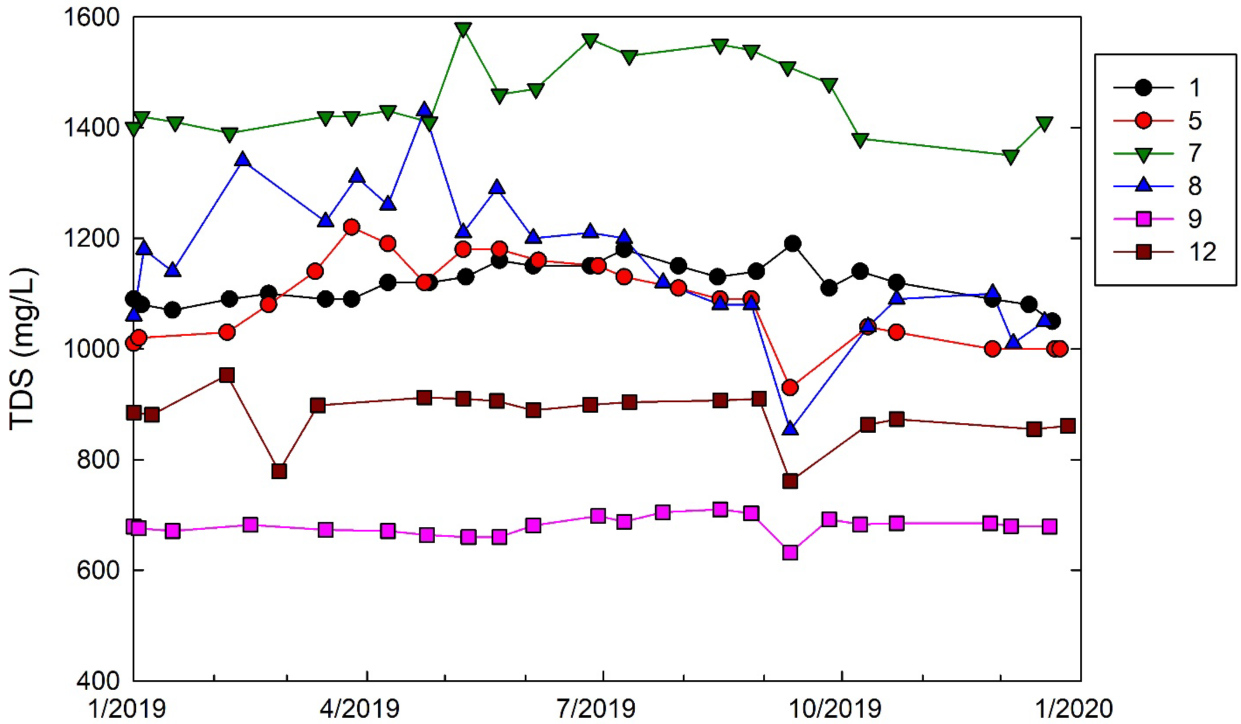

Figure 15. TDS concentrations for Romeoville Silurian community supply wells sampled frequently during 2019

The great variability in Cl^- and TDS concentrations in the Romeoville wells shows that even at these depths (160–300 feet), the groundwater has not mixed enough to remove the variability in the source terms. This also shows the difficulty in understanding the impacts and trends of road salt runoff without frequent sampling. For most of the wells we examined, samples were collected less than once a year.

Because the aquifers are being contaminated by surface activities, deeper wells should be less vulnerable to contamination, and previous research suggested this was the case (Kelly, 2008). A plot of the most recent Cl^- concentration measured in a well vs. its depth is shown in Figure 16. The deepest wells (> 400 ft) do tend to have relatively low Cl^- concentrations. Several of these wells are in the less developed eastern part of the county, so that may also help explain why they have relatively low Cl^- concentrations.

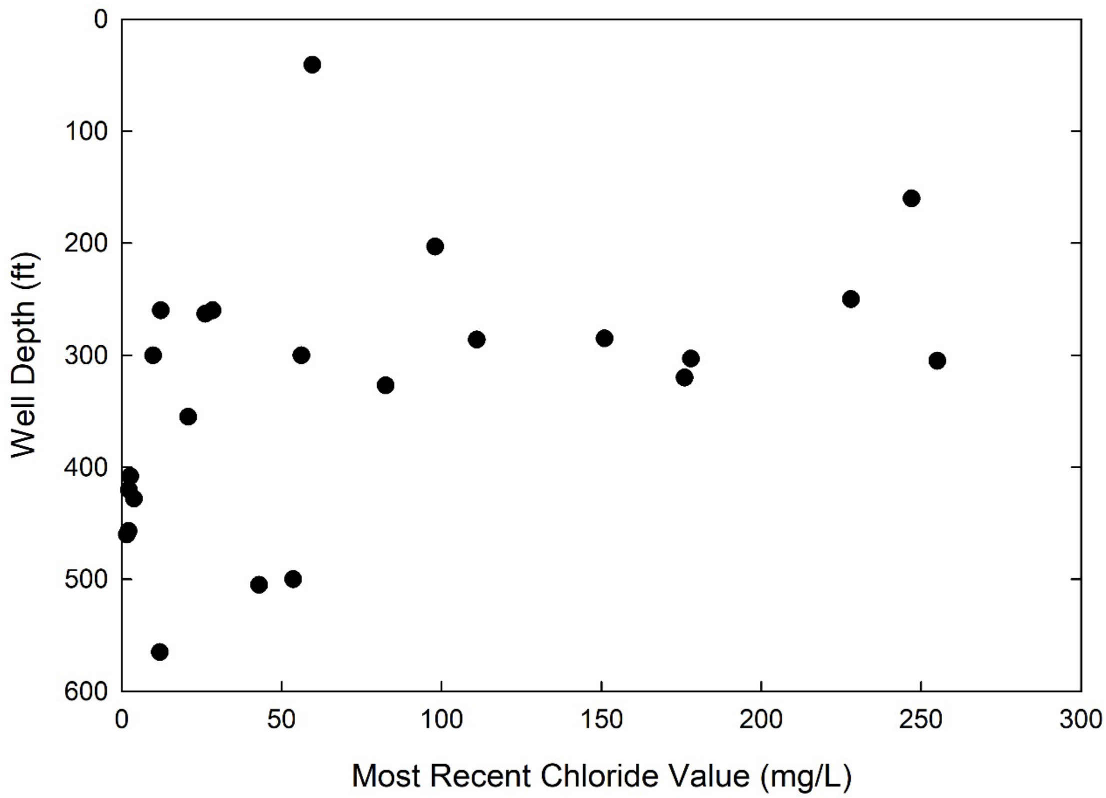

Figure 16. Well depth vs. most recent chloride value for wells examined in this study

Conclusions

Many community supply wells in the SWPG region finished in the Silurian dolomite aquifer show increasing Cl^- and TDS concentrations, most likely due to road salt runoff. The median increase in Cl^- concentrations for these wells was 2.5 mg/L/yr, with a maximum of 10.4 mg/L/yr. The most affected wells were in the northwestern part of Will County. Deeper wells tended to have lower concentrations.

One of the main findings of this study was the considerable variability in Cl^- and TDS concentrations in Romeoville wells sampled over short time frames in 2017 and 2019. We suspect this variability might also be found for other communities if more frequent samples were collected. Making predictions about concentration trends is difficult without more frequent sampling, and even then, the considerable noise in the data complicates matters.

As was shown in previous studies in the Chicago region, urbanization can seriously degrade the groundwater quality of unconfined aquifers. The increase in chloride concentrations in the region indicates that road salt runoff is reaching the Silurian dolomite aquifer, even to depths greater than 300 feet. This indicates that recharge from the surface is reaching the dolomite aquifer, passing through any till and sand and gravel layers above it. This connectivity between land surface and the dolomite aquifer shows the vulnerability of the aquifer to surface contamination and the need to protect it.

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