

TEMPORAL CHANGES IN SHALLOW GROUND-WATER QUALITY IN NORTHEASTERN ILLINOIS: PRELIMINARY RESULTS

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ABSTRACT

The rapid increase in population and developed land in the Chicago, Illinois, metropolitan area has put a heavy demand on water resources. The water sources most likely to be exploited in this region over the next few decades are shallow aquifers. These shallow aquifers are vulnerable to surface-derived contaminants, and the increase in developed land may be increasing the rate at which ground-water quality is being degraded. Historical ground-water quality data from the Chicago metropolitan area is being evaluated for data quality and temporal trends. Preliminary results indicate increases in the concentrations of most major ions, especially chloride, both regionally and for individual wells. Chloride concentrations have increased by over 4 mg L⁻¹ yr⁻¹ in a significant number of municipal wells. Changes appear to be most rapid in the outermost counties of the Chicago metropolitan area.

INTRODUCTION

Population and infrastructure have grown tremendously in many urban/suburban areas in recent decades. This has put a heavy demand on water in these areas, a demand that is expected to continue to increase into the foreseeable future. The Chicago, Illinois, metropolitan area population has increased from about 5 million to greater than 7.7 million from 1950 to the present, and is projected to increase by 25% by 2020 (NIPC, 1999). Most of the growth is occurring in the outer collar counties, where the projected population increase is 70 to 100% by 2020 (NIPC, 1999). The amount of developed land has also been expanding; residential acreage increased by 46% between 1970 and 1990 (NIPC, 1996). Water use has increased about 27% from 1980 to 1992 and demand is expected to continue to grow as the population of the region increases (Kirk et al., 1982; Avery, 1999).

The principal sources of water for the Chicago metropolitan area are Lake Michigan and ground water. Illinois has used or exceeded its annual allotment of Lake Michigan water in recent years and an increased allocation in the future is extremely unlikely (Daniel Injerd, Illinois Dept. of Natural Resources, personal communication). Pumping of deep bedrock aquifers in the region has been at its sustainable limit since the early 1990s. The main additional sources of water to meet the anticipated increases in water demand are the shallow bedrock and overlying sand and gravel aquifers. A considerable amount of water (500 million gallons day⁻¹) is estimated to be

available in these shallow aquifers (Schicht et al., 1976); only a fraction of this water is presently being used.

Shallow unconfined aquifers, however, are vulnerable to surface contamination. Because of the relatively long residence time of ground water, the impact of long-term ground-water contamination is often not recognized until large volumes of water are affected. If shallow aquifers are going to be exploited for drinking water in the Chicago region, it is important to determine if their water quality is being degraded and the extent of any degradation. This baseline information is critical to developing strategies to protect these aquifers from future degradation.

Urban regions typically have many contamination sources. Because of large populations, landfills and septic systems are abundant in relatively small areas. Urban areas are generally centers of industrial activity, and thus a wide variety of waste effluents must be disposed. An important source of contamination in many northern U.S. and Canadian urban areas is road salt. Kelly and Roadcap (1994) identified many of these sources causing degradation of shallow ground-water quality in the Lake Calumet area of south Chicago. Some common contaminants found in urban/suburban areas include chloride (Cl^-), sulfate (SO_4^{2-}), nitrogen, total dissolved solids (TDS), various heavy metals, and volatile organic compounds (VOCs).

Increases in Cl^- concentrations in urban areas are generally the result of anthropogenic inputs, usually road-salt runoff, sewage effluent, or brine-waste disposal. Potential anthropogenic sources of SO_4^{2-} include industrial discharge, domestic sewage, urban and road drainage, and atmospheric deposition (Nraigu, 1978). TDS is a measure of the amount of material dissolved in water, and is a measure of the "freshness" of water; increasing levels in an aquifer are an indication that the aquifer is being contaminated.

Nitrogen species are common pollutants, and NO_3^- is probably the most widespread contaminant in ground water, mainly due to agricultural activities (Hallberg and Keeney, 1993). Elevated levels of ammonium (NH_4^+) are also sometimes found in contaminated areas, usually from septic systems, landfill leachates, or livestock. Atmospheric deposition of nitrogen can also be an important source. Nitrogen concentrations may actually decrease when rural landscapes are converted to urban/suburban areas, due to the elimination of farming activities. Some areas, however, may experience increased levels of nitrogen in ground water due to the presence of septic systems and landfills.

Sources of heavy metals to ground water include direct industrial discharge and landfill leachates. Metals may also enter solution via exchange with other cations from soils and aquifer material or increased dissolution of metal-containing minerals due to changes in water chemistry (i.e., changes in oxidation-reduction conditions, pH, etc.) (Drever, 1988).

The purpose of the present study is to examine historical ground-water quality data over a period of several decades from the Chicago metropolitan area, and determine what changes in water

quality have occurred over that period. The study is focusing on inorganic parameters, but organic contaminants are being considered where data are available. Additional objectives are to identify potential contaminant sources, predict future water quality, and determine if changes in chemistry are correlated with geological and land-use parameters.

LITERATURE REVIEW

Ground-Water Quality of Urban/Suburban Areas

A number of studies have investigated ground-water quality in urban areas and attempted to determine sources of contamination. A consistent finding is that water quality in urban areas is correlated with land use. For example, Eckhardt and Stackelberg (1995) and Bruce and McMahon (1996) found land use to be correlated with ground-water quality in suburban Long Island, New York, and Denver, respectively.

Two of the most common contaminants are Cl^- and SO_4^{2-} (Long and Saleem, 1974; Schicht, 1977; Eisen and Anderson, 1979). The source of Cl^- is often road salt, which has been linked to ground-water degradation in many urban and roadside areas (e.g., Huling and Hollocher, 1976; Pilon and Howard, 1987; Amrhein et al., 1992; Howard and Haynes, 1993). Because ground-water travel times are relatively slow, contaminants can persist long times in ground water. Howard et al. (1993) calculated that, even if road salting were stopped immediately in the Toronto area, it would be decades before the water quality in contaminated shallow aquifers recovered.

Landfill leachates can be sources of many contaminants to ground water, although the affected areas are relatively limited (Christensen et al., 1994). Concentrations of organic compounds can be very high (Rügge et al., 1995) and decreases in the oxidation-reduction potential (ORP) can mobilize toxic metals (Bjerg et al., 1995). Soils in industrial areas are commonly contaminated with heavy metals, which may potentially leach into shallow ground water (Kelly et al., 1996). Industrial activity may also be a source of volatile organic compounds (VOCs) to ground water (Wehrmann et al., 1988).

A difficulty in determining temporal degradation of ground-water quality is the lack of long-term chemical data and thus an understanding how water quality has or is changing. Because of this, the literature on temporal variations in ground-water quality is not extensive, especially in urban areas (Long and Saleem, 1974; Gibb and O'Hearn, 1980; Hull, 1984; Montgomery et al., 1987; Yee and Souza, 1987; Spruill, 1990). Some of these studies consider only two points in time (Long and Saleem, 1974) or one particular parameter (Spruill, 1990).

Ground-Water Quality in the Chicago Metropolitan Area

The ISWS has performed a number of studies in the Chicago region that have included data on shallow ground-water quality. Sasman et al. (1981) sampled 282 shallow wells in dolomite in

DuPage County in 1979. In undeveloped and newly developed areas, water quality was good, but deterioration of water quality in developed areas was observed. Visocky (1990) examined data from 30 sand-and-gravel wells in Kane County. While the water quality was generally good, concentrations of TDS, Cl⁻, and SO₄²⁻ were significantly higher in the shallow aquifers than the bedrock aquifers. Roadcap et al. (1993) sampled 186 shallow wells in Will and southern Cook Counties. They found that about 75% of the samples exceeded the secondary drinking water standard for TDS (500 mg/L); SO₄²⁻ and iron were also found to be elevated in most of the region.

Shallow ground water in the industrialized Calumet region of south Chicago is heavily polluted with many contaminants (Kelly and Roadcap, 1994; Duwelius et al., 1995). Significant contamination was found in almost all of the shallow ground-water wells. Contaminants included heavy metals, organic compounds (volatile organic compounds (VOCs) and methane), and inorganic ions (Cl⁻, SO₄²⁻, sodium (Na)). Ground water in certain parts of the Lake Calumet region also has the unusual problem of being extremely basic (pH > 11) due to dissolution of steel mill slag used as fill material.

Shallow aquifers in the Chicago area are becoming an increasingly important resource and will be heavily exploited in the coming decades. Water quality degradation has been observed in these aquifers in some developed areas, and the rapid increase in land development will bring more of the shallow aquifers under stress. Understanding the historical changes in ground-water quality is important to predicting future water quality problems and to help protect ground-water resources and avoid costly clean-ups.

PROCEDURES

Study Area

For the purposes of this study, the Chicago metropolitan area is considered to encompass six counties in Illinois: Cook, DuPage, Kane, Lake, McHenry, and Will (figure 1). This is an area of approximately 3,700 square miles with a population in excess of 7.7 million.

The shallow aquifers are in bedrock dolomite and overlying sand and gravel units. The surficial deposits in northeastern Illinois belong to the Wedron Formation and consist of unconsolidated deposits of Wisconsinan-age glacial till and outwash ranging in thickness from less than a foot to in excess of 400 feet (Willman and Frye, 1970). The glacial deposits are thickest in northwestern McHenry County. Deposits in excess of 200 feet are also found in central and eastern McHenry County, most of Lake County, northern Kane County, north-central DuPage County, and northwestern and west-central Cook County. The thinnest deposits are generally found in the central part of the study area, notably central DuPage and Cook Counties and northern and western Will County. Moderate to large supplies of ground water are generally found in sands and gravels in the Wedron Formation in the area. These units are found either at the surface or underlying or interbedded with glacial till. The best producing units tend to be the basal units, just above and in contact with bedrock, which in most of the region is Silurian dolomite.

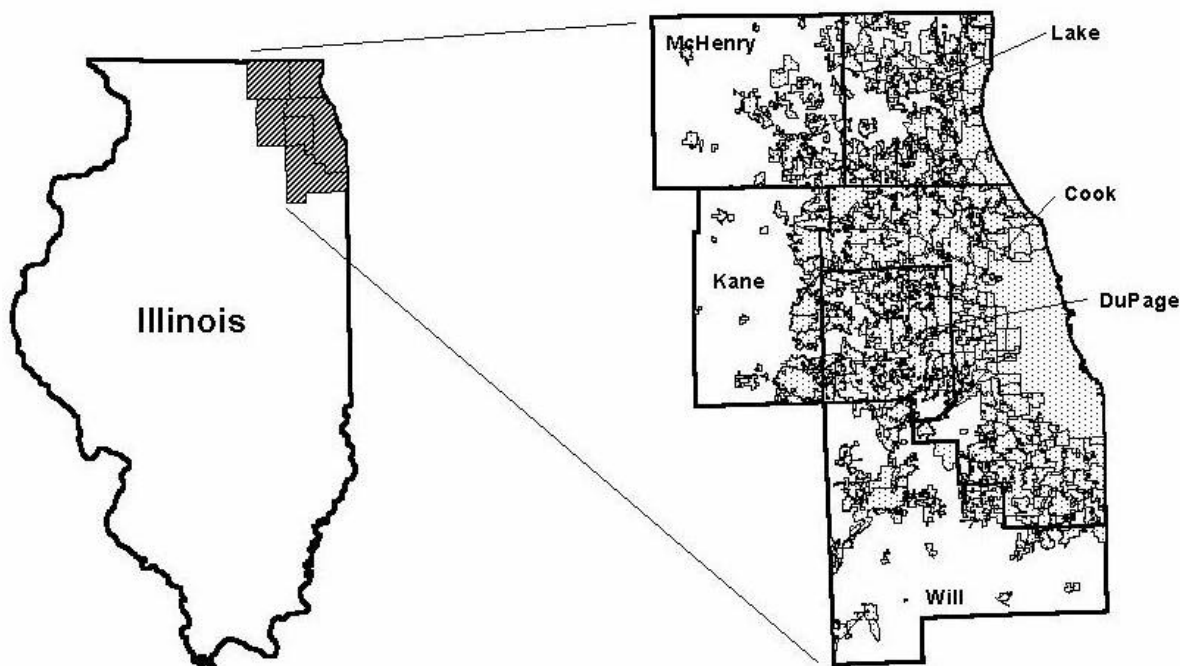


Figure 1. Study area. Dotted regions are incorporated areas.

Data Sources

Results presented here come from two major ground-water chemistry databases, the ISWS water-quality database and the Illinois Environmental Protection Agency (IEPA) ambient water-quality database. The ISWS database contains approximately 50,000 ground-water samples from more than 25,000 different wells in Illinois dating back to the early 1900s. The IEPA database includes approximately 2110 samples from 933 public wells in the six-county area of northeast Illinois, from 1980 to 1998. In this project, we are concentrating on the shallowest wells (< 200 ft). Of the 933 wells in the IEPA database, 253 are less than 200 feet deep and 46 are less than 100 feet deep; these are the wells that have been initially targeted for analysis.

Data Analysis

Complete analyses (i.e., having data for all major ions) from the ISWS and IEPA databases were evaluated using the cation-anion balance:

$$\%E = (\sum \text{cations} - \sum \text{anions} / \sum \text{cations} + \sum \text{anions}) * 100$$

where %E is percent error and the ion sums are calculated in milliequivalents per liter. Major cations include calcium (Ca), magnesium (Mg), Na, and potassium (K), and major anions include Cl^- , SO_4^{2-} , and bicarbonate (HCO_3^-). Other ions (e.g., iron, manganese, ammonium, nitrate,

fluoride, strontium) were included in the balance when their concentrations were significant. A percent error greater than $\pm 20\%$ was assumed to indicate an analytical or reporting error and the result would not be considered in statistical analyses. All complete samples in both databases passed this test. A small percentage of the samples ($< 5\%$) had incomplete major ion analyses and could not be evaluated with the ion balance. These data were still used for analysis but their lower reliability was noted.

Measured TDS concentrations were also evaluated by calculating TDS by summing the concentrations of all the analyzed elements and species (Hem, 1989). This was only possible for complete analyses. Measured values not within 80% of the calculated values were considered to be suspect and discarded. About 15% of the measured TDS values in the IEPA database were discarded (figure 2).

Preliminary analyses have focused on municipal wells and major ion data, especially Cl^- and TDS. The IEPA data were subdivided into five-year groupings starting in 1980 for preparation of box-and-whisker plots (because there are no 1999 data, the grouping starting in 1995 is for

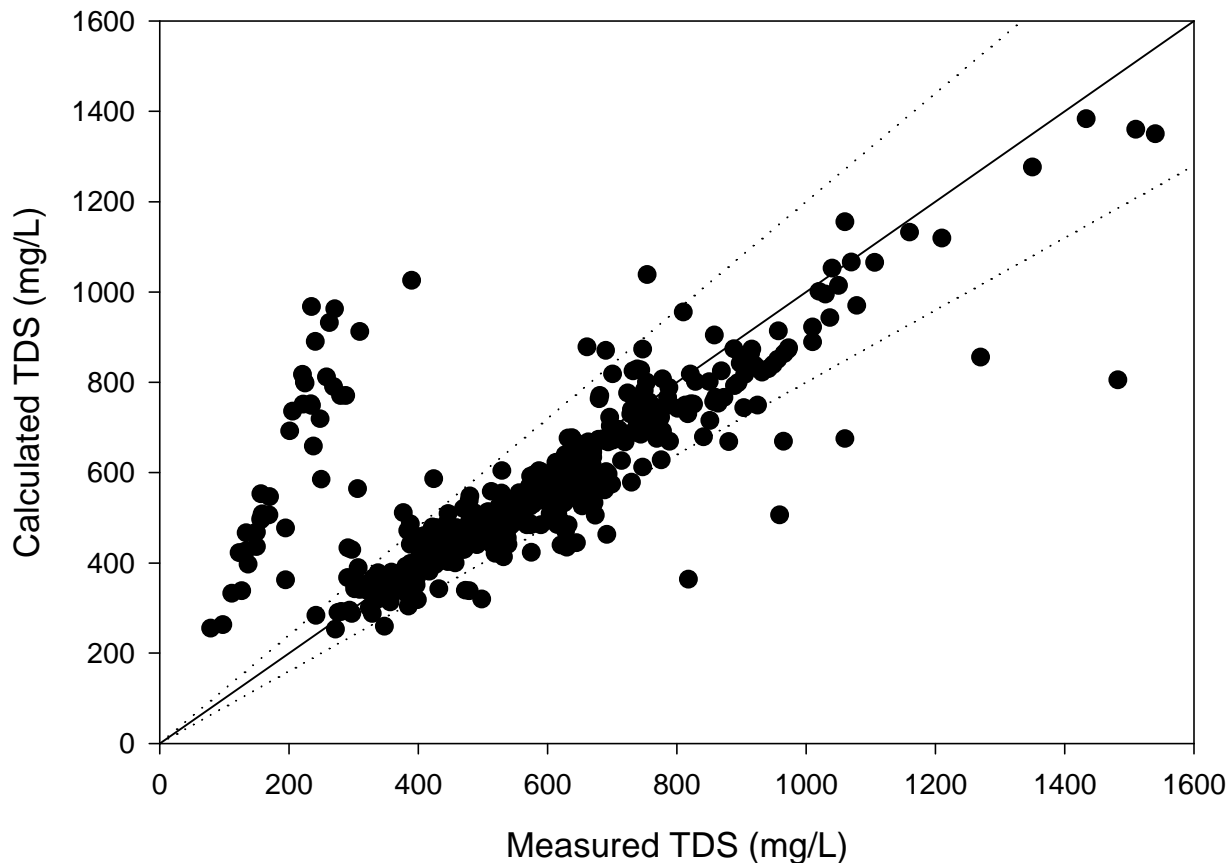


Figure 2. Comparison of measured and calculated values of TDS. Dotted lines represent the 80% difference between the values.

only four years). Wells were further subdivided by depth, less than 100 feet and between 100 and 200 feet. For several wells, multiple samples were taken in a single year. For these wells, concentrations for a single year were averaged so that data from a single year would not have an undue influence on the analyses. The data were graphically evaluated using box-and-whisker plots. Differences in median values were tested using the Kruskal-Wallis ANOVA on ranks and Mann-Whitney rank sum tests on median values using the SigmaStat® version 2.03 software (SPSS, 1997). The spread of the data were measured by the interquartile range (IQR), the difference between the 75th and 25th percentiles.

Wells for which Cl⁻ was analyzed three or more times over at least a five-year period were identified. A preliminary examination of the database revealed 54 municipal wells that meet this criterion (table 1). These data were plotted and linear regressions were performed using the software program SigmaPlot® version 6.00 (SPSS, 2000) to determine temporal trends in the Cl⁻ data for individual wells. For some wells, a period of little change was followed by a period of noticeable change. For these wells, the regressions were performed for the period of change.

Table 1. Trends in Cl⁻ concentrations in selected wells. Rate of change and r² values determined by linear regression; n is number of samples. Final Cl⁻ is concentration at end date.

County	Municipality	Well #	Depth (ft)	Rate (mg L ⁻¹ yr ⁻¹)	r ²	n	start	end	final Cl ⁻ (mg L ⁻¹)
Cook	Bartlett	1	200	0.86	0.754	9	1982	1998	35
	Bartlett	3	97	0.19	0.135	13	1960	1985	10
	Hoffmann Estates	22	119	0.87	0.872	12	1984	1992	25
	Mission Brook S.D.	4	170	-0.01	0.000	5	1985	1995	14
DuPage	Addison	7	85	3.39	0.931	10	1965	1987	77
	Addison	8	75	3.80	0.960	15	1967	1985	78
	Belmont-Highwood PWD	1	148	1.25	0.684	4	1982	1995	141
	Naperville	5	190	4.78	0.726	13	1982	1992	71
	Pleasant Ridge MHP	2	168	3.56	0.902	5	1988	1998	117
	Polo Dr/Saddle Rd Sbdv	2	200	0.51	0.084	4	1983	1997	144
	Vietzen MHP	1	135	-2.75	0.309	4	1988	1997	59
	Vietzen MHP	2	135	-2.27	0.234	4	1988	1996	57
Wheaton	2	184	3.91	0.923	13	1984	1992	94	
Kane	Carpentersville	5	183	1.17	0.543	4	1985	1998	37
	Carpentersville	6	179	2.47	0.843	18	1982	1998	61
	East Dundee	2	69	2.08	0.963	5	1958	1991	78
	Patterson MHP	1	80	3.27	0.824	6	1986	1998	87
	Subdivision Water Trust 1	3	196	0.57	0.903	6	1982	1998	14
	South Elgin	4	109	3.10	0.952	3	1982	1997	98
	South Elgin	5	68	2.25	0.698	4	1983	1997	92
	Sugar Grove	2	107	-2.05	0.355	8	1982	1992	64
Utl Inc Lake Marion	3	75	6.35	0.998	4	1982	1997	124	

Table 1 (continued). Trends in Cl⁻ concentrations in selected wells. Rate of change and r² values determined by linear regression; n is number of samples. Final Cl⁻ is concentration at end date.

County	Municipality	Well #	Depth (ft)	Rate (mg L ⁻¹ yr ⁻¹)	r ²	n	start	end	final Cl ⁻ (mg L ⁻¹)
Lake	Antioch	3	141	0.25	0.662	7	1982	1997	12
	Antioch	4	129	0.32	0.938	3	1982	1997	10
	Antioch	5	129	0.45	0.940	3	1982	1997	14
	Countryside Manor Sbdv	1	168	0.29	0.632	3	1983	1997	25
	Fields of Long Grove	1	165	-2.88	0.466	4	1993	1998	24
	Grandwood Park Sbdv	1	145	0.12	0.869	5	1982	1997	3
	Grandwood Park Sbdv	3	142	-0.02	0.110	5	1982	1998	1
	Holly Hock Hill MHP	1	126	-0.12	0.961	4	1987	1996	6
	Lake Villa	5	150	-0.46	0.691	4	1993	1998	<1
	Pekara Sbdv	2	155	0.31	0.271	6	1980	1998	10
	Pekara Sbdv	4	150	0.06	0.400	3	1987	1998	7
	Utl Inc Hilldale Manor	1	123	4.56	0.967	5	1982	1998	81
	McHenry	Algonquin	6	152	2.12	0.261	13	1993	1998
Algonquin		1	165	0.51	0.774	4	1982	1992	12
Cary		8	105	5.77	0.981	3	1984	1997	101
Fox River Grove		1	140	4.20	0.969	3	1982	1997	113
Fox River Grove		2	120	3.47	0.810	4	1982	1997	105
Harvard		3	71	5.18	0.668	6	1969	1985	101
Harvard		5	68	2.09	0.866	12	1958	1985	84
Harvard		6	197	1.08	0.864	16	1984	1998	24
Hebron		4	125	4.27	0.661	6	1986	1998	100
Huntley		4	63	1.83	0.856	4	1958	1985	62
Island Lake		104	122	2.78	0.965	3	1982	1991	59
Lakeland Park		2	85	1.03	0.399	6	1958	1982	34
Marengo		5	85	0.23	0.999	3	1978	1986	35
McHenry		2	60	2.90	0.117	11	1982	1998	182
McHenry		5	95	0.49	0.690	6	1982	1998	22
McHenry		6	131	1.80	0.619	6	1982	1998	44
Oakbrook Estates MHP		1	182	3.76	0.379	5	1986	1996	162
Union	3	80	62.80	0.772	13	1977	1989	612	
Will	Bollingbrook	10	170	4.27	0.747	6	1983	1998	83
	Citizens West Sub	12	157	3.57	0.494	4	1982	1998	156

RESULTS AND DISCUSSION

Grouped Data

Median concentrations of the major ions and TDS for the IEPA data are reported in tables 2 and 3 and box-and-whisker plots are shown in figure 3. There was an increase in median concentrations between the early 1980s and the late 1990s for the shallowest wells (< 100 ft) for TDS and all the major ions except Mg. However, the differences are only statistically significant for the Cl⁻ and Na data as measured using the ANOVA on ranks test; the 1990-1994 data are

Table 2. Median concentrations (mg/L) for major anions. Data are grouped in 5-year intervals and by depth.

Depth (ft)	Years	Chloride			Sulfate			Alkalinity		
		n	median	IQR	n	median	IQR	n	median	IQR
< 100	1980 - 1984	25	33	51.0	25	84	71.5	25	342	67.8
	1985 - 1989	47	44	59.0	47	94	122	32	348	66.5
	1990 - 1994	6	107	179	7	97	51.5	7	364	29.8
	1995 - 1998	11	92	64.5	11	97	92.5	11	369	61.8
100 - 200	1980 - 1984	141	11	37.5	141	94	101	141	321	78.4
	1985 - 1989	182	15	45.0	182	108.5	155	131	313	93.5
	1990 - 1994	50	35.1	72.8	47	105	91.0	50	325	47.0
	1995 - 1998	68	27	78.0	69	89	145	68	343	99.0

Table 3. Median concentrations (mg/L) for major cations and TDS. Data are grouped in 5-year intervals and by depth.

Depth (ft)	Years	Calcium			Magnesium			Sodium			TDS		
		n	median	IQR	n	median	IQR	n	median	IQR	n	median	IQR
< 100	1980 - 1984	25	101.3	29.0	25	53.5	11.1	25	17	18.9	25	552	155
	1985 - 1989	47	100	40.5	47	53	17.8	47	26	25.8	32	575	179
	1990 - 1994	7	121	28.9	7	62.3	24.6	7	39.5	94.5	6	696	432
	1995 - 1998	11	120	40.3	11	56	17.5	11	39	17.0	11	677	248
100 - 200	1980 - 1984	140	87	36.5	141	47.7	17.1	141	26	30.3	140	482	226
	1985 - 1989	182	84	34.0	182	49	18.0	182	30	37.0	131	534	249
	1990 - 1994	50	97	28.7	50	50.8	16.6	50	31.5	39.4	47	523	228
	1995 - 1998	69	91	42.8	69	50	14.0	69	43	31.0	67	561	277

significantly greater than the earlier data for both Cl⁻ and Na. There are limitations to comparing the data from the 1990s with the 1980s because there are substantially fewer samples from the 1990s, due to a decrease in the sampling frequency by IEPA. For the 100 - 200 ft wells, there was an increase in median concentrations for Cl⁻, Na, alkalinity, and TDS between the early 1980s and the late 1990s. Again, these differences as measured by ANOVA were statistically significant only for Cl⁻ and Na; for Cl⁻, both data groups from the 1990s were significantly greater than the 1980s groups, and for Na, the 1995-1998 data group is significantly greater than both groups from the 1980s. The rank sum test also indicated that the 1990-1994 Ca concentrations were significantly greater than for 1985-1989 and the 1995-1998 TDS concentrations were significantly greater than for 1980-1984.

Differences were also found for many of the ions as a function of depth. With the exception of Na and SO₄²⁻, all the ions and TDS had greater median concentrations in the shallower wells than the deeper ones for all date groupings. These differences were statistically significant at all times for Cl⁻, alkalinity, and Ca.

Chloride tends to have more spread, as indicated by greater IQR values, in the shallower wells, while SO₄²⁻ and alkalinity have more spread in the deeper wells. For the cations and TDS, the spread is usually greater in the deeper wells.

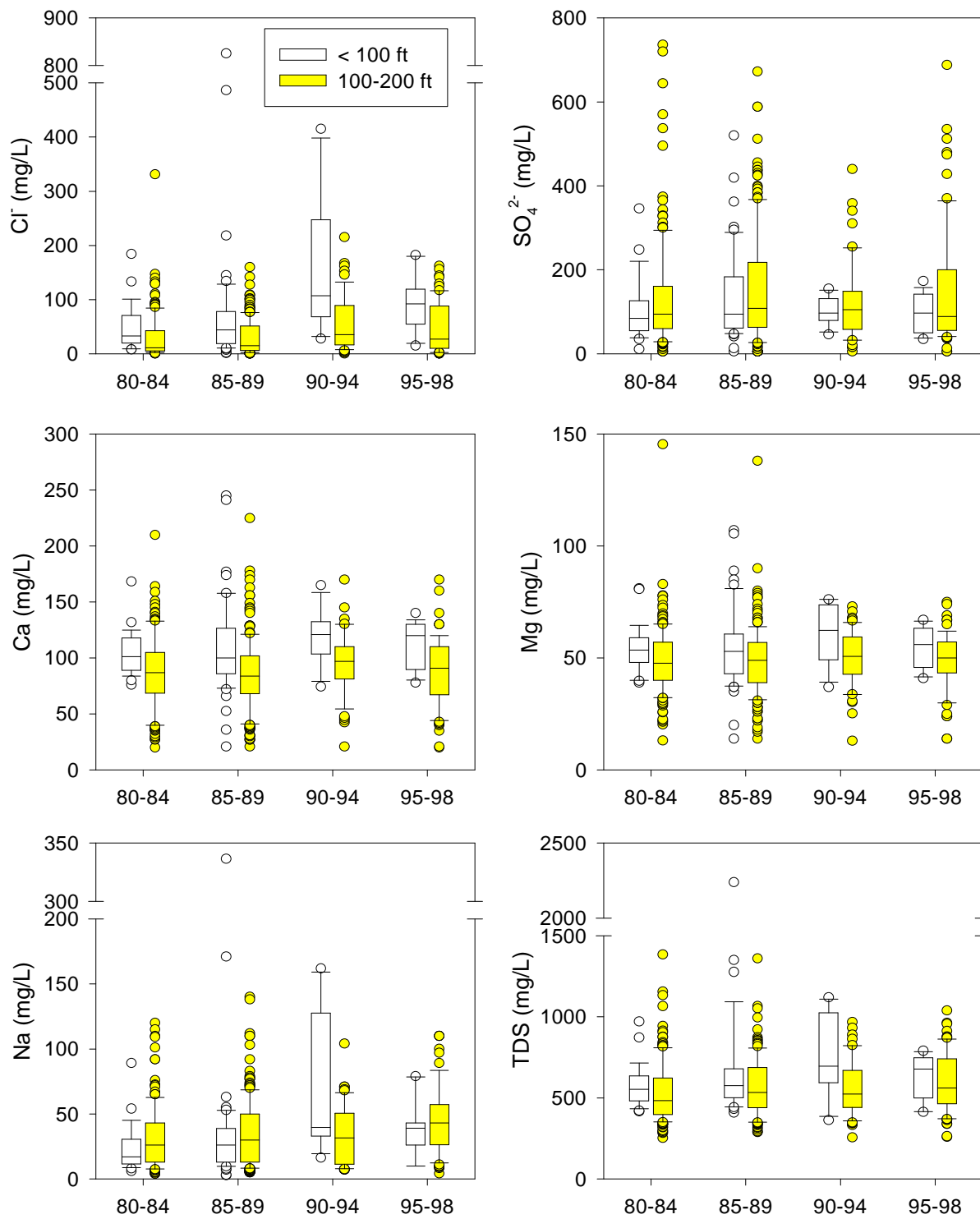


Figure 3. Box and whisker plots of IEPA municipal well data. Data are grouped into 5-year intervals except for the 1995-1998 group. Statistical values are reported in tables 2 and 3.

These evaluations are limited by several factors. As noted earlier, the number of samples is different among all the groupings, being especially low in the 1990-1994 less than 100 ft group. In addition, the identity of the wells in each group is not necessarily the same. Many of the wells sampled in the 1980s were not sampled in the 1990s. Thus the analyses are not as rigorous as they would be if the same wells were being compared over the entire period.

Individual Wells

Chloride results for the 54 individual wells having more than 3 analyses over at least a 5-year period are shown in figures 4 and 5. Chloride concentrations have increased with time in most of these wells. There is not a great amount of data prior to 1980, but it does appear that rates of change noticeably increased starting in the 1970s. One well, Union #3, showed a rapid and catastrophic degradation of water quality starting in the late 1970s, with Cl^- concentrations reaching levels in excess of 800 mg/L (figure 6). This was due to discharge of industrial effluent containing metal chlorides up-gradient of the well (Al Wehrmann, ISWS, personal communication).

Positive rates of change in Cl^- concentrations were calculated for 46 of the 54 wells. Thirty-one wells had rates greater than $1 \text{ mg L}^{-1} \text{ yr}^{-1}$, and 9 had rates greater than $4 \text{ mg L}^{-1} \text{ yr}^{-1}$ (table 1). These are average rates over the sampling period, and it is possible that present rates of increase may be greater for some wells.

The median rate of increase was greater in the shallower wells versus deeper wells (2.25 vs. $0.87 \text{ mg L}^{-1} \text{ yr}^{-1}$), although the difference was not statistically significant. This greater rate of change would be expected based on the assumption that the shallower wells are in general more susceptible to surface contamination.

There does seem to be some geographical control on the rate of change in Cl^- concentrations (figure 7). Wells in Cook and Lake Counties tend to have small or negative changes in Cl^- concentrations, while the outermost counties have the highest rates of change. This may reflect the rapid changes in land use occurring in the outermost counties. Cook and Lake Counties have been urban and residential areas for the longest times, and the streets and roads are generally curbed, which limits the recharge of contaminated water to ground water. Chloride concentrations in Cook and Lake Counties tend to be relatively low, generally less than 40 mg L^{-1} . It is not uncommon for wells in the outermost counties to have concentrations greater than 100 mg L^{-1} . There is less curbing in the outermost counties, and as increasing areas are being developed in the outermost counties, the quality of the recharge water is being affected. Another potential factor that may lead to relatively rapid contamination of ground water in these areas is that there are significant sand deposits in the collar counties, especially McHenry and Kane (Hansel and Johnson, 1996).

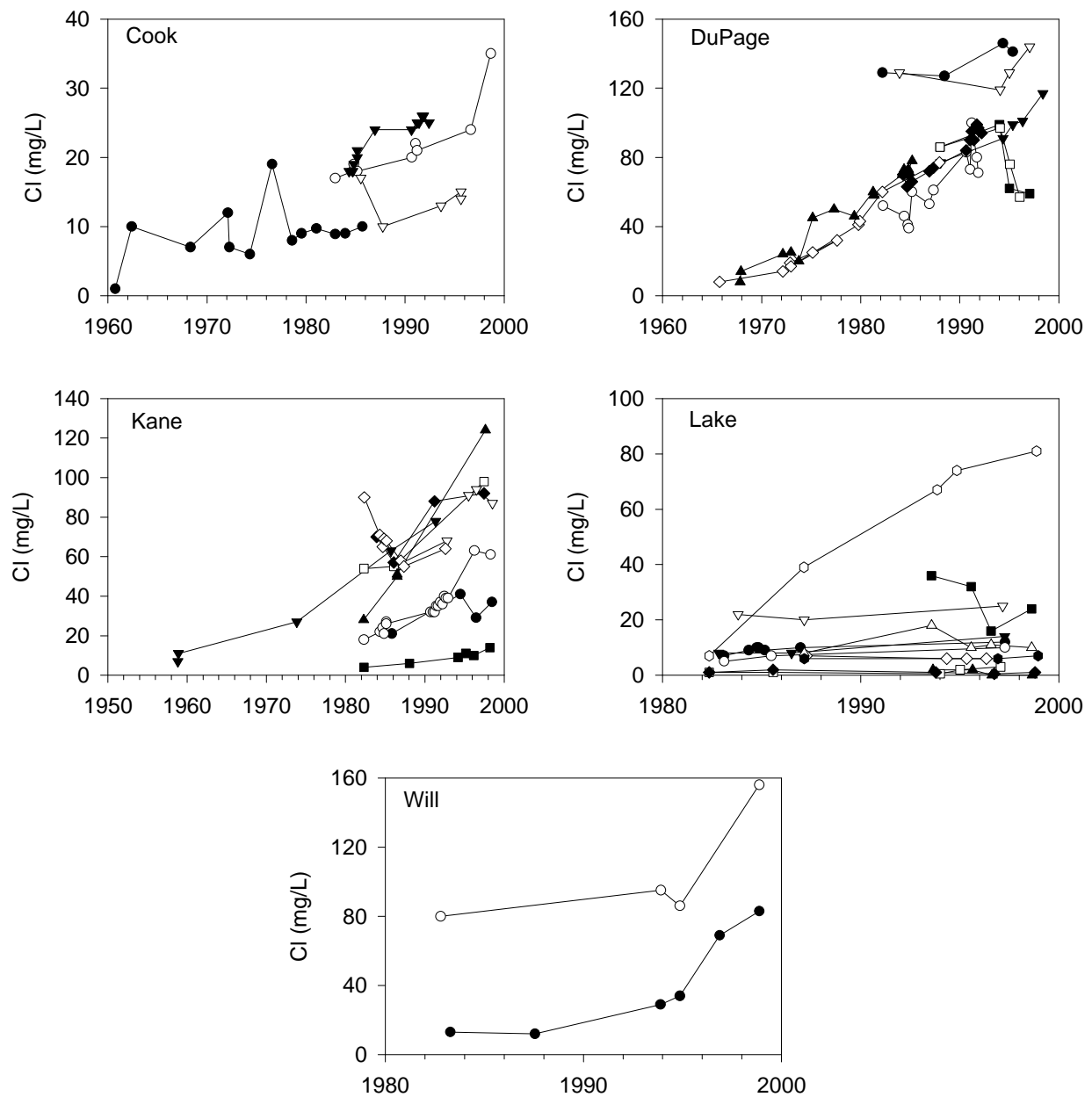


Figure 4. Chloride concentrations for individual municipal wells from the IEPA and ISWS databases.

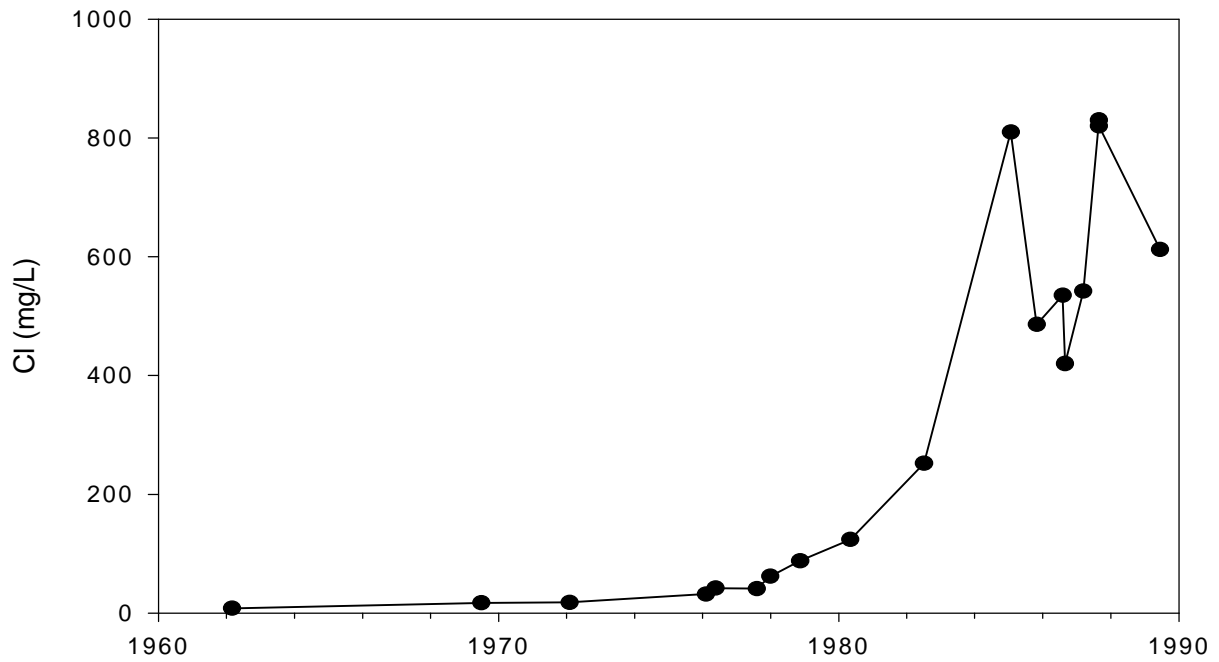


Figure 5. Chloride concentrations in Union well #3, McHenry County.

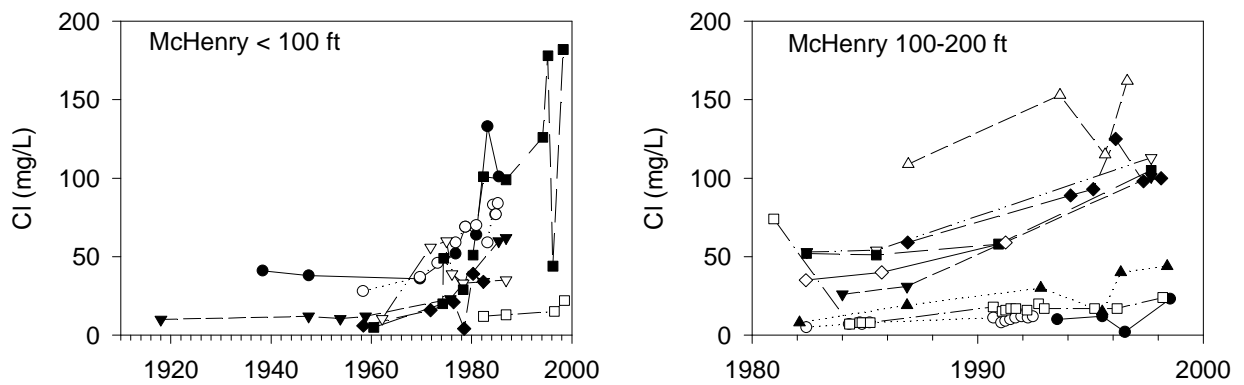


Figure 6. Chloride concentrations in individual municipal wells in McHenry County from the IEPA and ISWS databases.

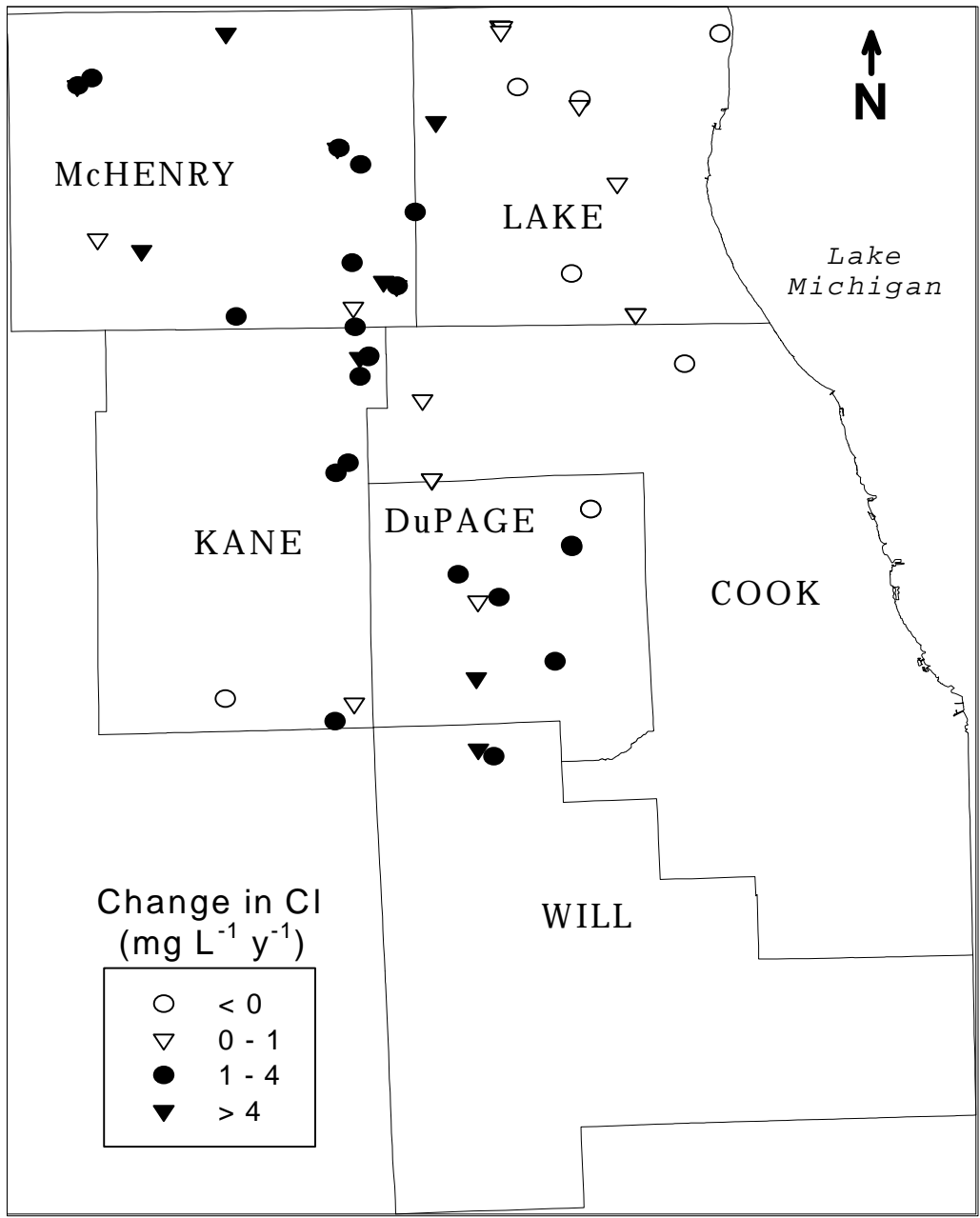


Figure 7. Rates of change in chloride concentrations for individual municipal wells in the IEPA and ISWS databases.

CONCLUSIONS

These preliminary results suggest that there has been degradation of shallow ground-water quality in northeastern Illinois. Concentrations are increasing for most major ions, especially Cl⁻, both regionally and for individual wells. Chloride concentrations are increasing by over 4 mg L⁻¹ yr⁻¹ in a significant number of municipal wells. Changes appear to be most rapid in the outermost counties of the Chicago metropolitan area. Although for most wells the observed changes are fairly small, the trends show no indication of leveling off. Because of slow travel times and long residence times in ground water, even if all sources of pollution were stopped today, peak concentrations of dissolved contaminants will almost surely be considerably higher in the future than they are now (Howard et al., 1993).

Work being planned in the second year of this project includes acquisition and evaluation of additional data sources, more regional analysis including private well data, and evaluation of changes for elements and species other than Cl⁻ for individual wells.

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