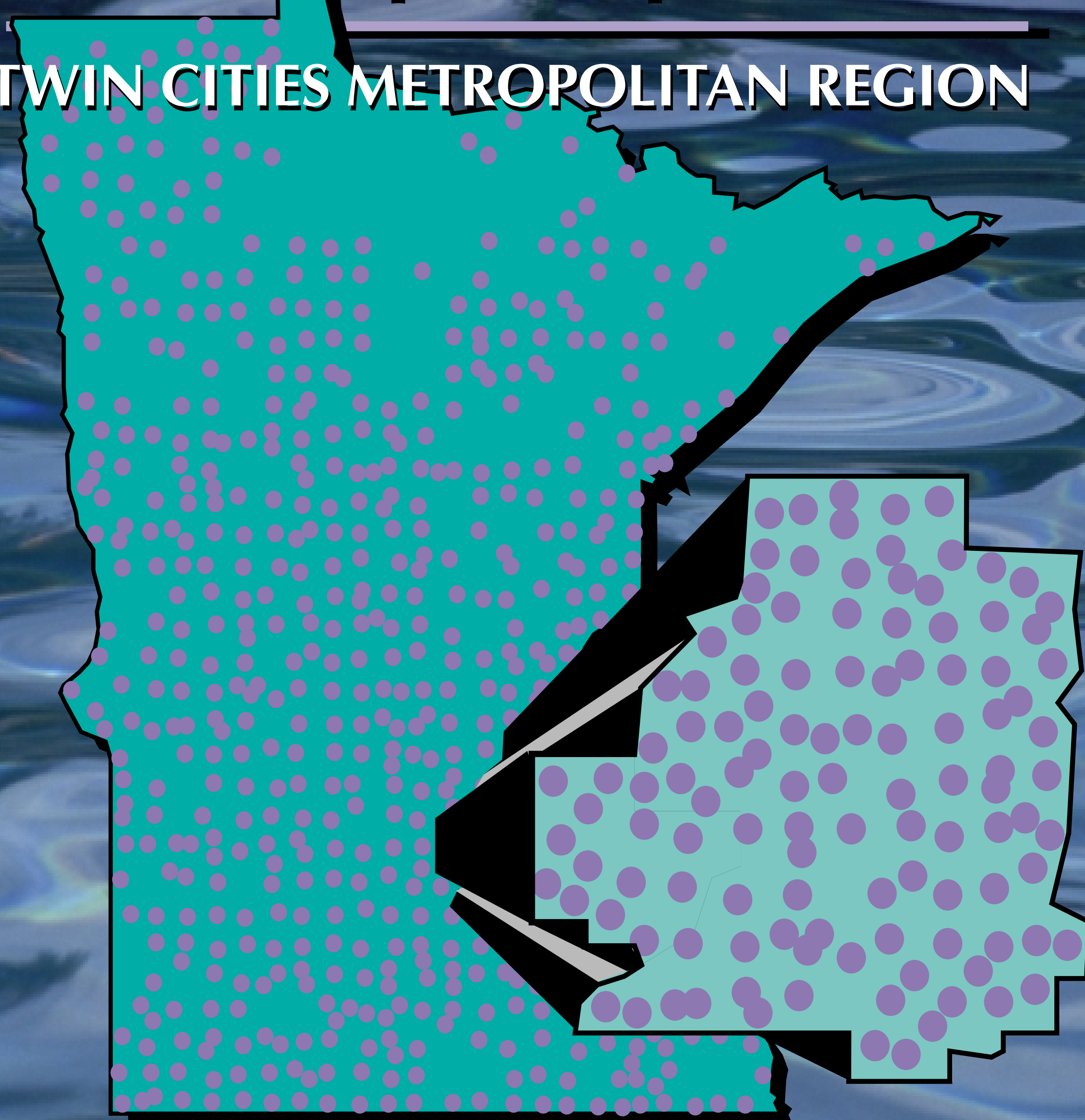
Baseline Water Quality of Minnesota's Principal Aquifers

TWIN CITIES METROPOLITAN REGION



Minnesota Pollution Control Agency

Baseline Water Quality of Minnesota's Principal Aquifers - Region 6, Twin Cities Metropolitan Area

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Environmental Outcomes Division
Environmental Outcomes Monitoring and Analysis Section
Ground Water and Toxics Monitoring Unit
520 Lafayette Road
St. Paul, Minnesota 55155-4194
(651) 296-6300 or (800) 657-3864

Prepared by

Ground Water Monitoring and Assessment Program (GWMAP)

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Foreword

Ground Water Monitoring and Assessment Program (GWMAP) staff believe the enclosed report represents a comprehensive study of water quality in the principal aquifers of the seven-county Twin Cities Metropolitan Area, which corresponds with Minnesota Pollution Control Agency (MPCA), Region 6. Information in this report, when used in conjunction with *Baseline Water Quality of Minnesota's Principal Aquifers* (MPCA, 1998a), can be used by water resource managers to identify baseline or background water quality conditions in areas or aquifers of concern, prioritize ground water problems, and assist in site decision-making, provided the limitations and assumptions outlined in the document are understood. Although data have been carefully analyzed, compiled, and reviewed independently, mistakes are inevitable with a data set this large. If mistakes are found in this report, please forward them to GWMAP staff. Errata sheets will be prepared as needed.

The report is divided into four parts. Part I briefly summarizes sample design and collection. Part II briefly describes analysis methods. Results and discussion are provided in Part III. Part IV includes a summary of results and recommendations.

List of Abbreviations

CWI - County Well Index

GWMAP - Ground Water Monitoring and Assessment Program

HBV - Health Based Value

HI - Hazard Index

HRL - Health Risk Limit

MCL - Maximum Contaminant Level

MPCA - Minnesota Pollution Control Agency

QA/QC - Quality Assurance/Quality Control

RLs - Reporting Limits

SMCL - Secondary Maximum Contaminant Level

USGS - United States Geological Survey

UTM - Universal Trans Mercator

VOC - Volatile Organic Compound

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Executive Summary

In 1993, 1994, and 1996 the Minnesota Pollution Control Agency's (MPCA) Ground Water Monitoring and Assessment Program (GWMAP) sampled 93 primarily domestic wells in MPCA Region 6, which encompasses the seven-county Twin Cities Metropolitan Area in eastern Minnesota. This sampling effort was part of the statewide baseline assessment (baseline study). The objectives of the baseline study were to determine water quality in Minnesota's principal aquifers, identify chemicals of potential concern to humans, and identify factors affecting the distribution of chemicals. An important benefit of this study was establishment of contacts with state and local ground water groups. GWMAP efforts in 1998 and 1999 are focused on providing information from the baseline study, helping ground water groups prioritize monitoring efforts, and assisting with sampling and analysis of ground water monitoring data at the state and local levels.

Samples were collected statewide from a grid at eleven-mile grid node spacing. One well was sampled from each aquifer located within a nine-square mile target area centered on each grid node. Sampling parameters included major cations and anions, trace inorganics, total organic carbon, volatile organic compounds, and field measurement of dissolved oxygen, oxidation-reduction potential, temperature, pH, alkalinity, and specific conductance. Statewide, 954 wells were sampled from thirty different aquifers.

Water quality varied between the major aquifers of Region 6. The Franconia aquifer had high concentrations of many chemicals, particularly the major ions. Ground water in this aquifer appears to be old and highly evolved geochemically. This contrasts with the Prairie du Chien aquifer, which is well oxygenated and susceptible to human activity, as evidence by elevated nitrate and chloride concentrations. The Jordan aquifer has good quality water, with low concentrations of dissolved solids compared to other aquifers. Water quality in the St. Peter aquifer varied widely, with half the samples showing oxygenated conditions and half showing strongly reducing conditions. The surficial drift aquifers showed impacts from humans, with concentrations of chloride, sodium, and some trace metals being high compared to other aquifers. There were few exceedances of drinking criteria, but this may be partly related to sampling bias, since few samples were collected from sensitive aquifers in the older, more industrialized portions of the Twin Cities.

There were two exceedances each of drinking water criteria for nitrate, selenium, and manganese. Water quality in the major aquifers was similar to water quality found in the same aquifers statewide. Volatile Organic Compounds (VOCs) were detected in only four wells, but there was more than one VOC in each of these wells. Chlorinated solvents and VOCs typically associated with fuel oils and gasoline accounted for nearly all the VOC detections. The results suggest there are local human impacts to some aquifers due to industrial activity, use of automobiles, leaking tanks, and other commercial uses of organic chemicals.

Research needs for Region 6 include:

1. Determining the overall distribution of VOCs in the major aquifers of the Twin Cities Metropolitan Area;

2. Identifying major plumes containing chlorinated solvents;

3. Determining relationships between land use and ground water quality, including evaluation of long-term changes in ground water quality, in the major aquifers of the Twin Cities; and

4. Determining the relationship between geology, particularly mineralogy, and water quality.

Monitoring needs for Region 6 include:

1. Expanding data bases for the Paleozoic and water table aquifers by approximately 10 wells each;

2. Incorporating data from regulated sites into the regional baseline data;
3. Employing models to assist in tracking plumes, particularly for chlorinated solvents;

4. Conducting ambient monitoring in aquifers impacted by humans, particularly for VOCs;

5. Establishing agency-wide sampling, data management, and data analysis protocol by an intra-agency group consisting of staff from all programs dealing with ground water cleanup and monitoring; and

6. Collect monitoring information on the distribution of pesticides and metabolites

The discussion of baseline water quality and chemistry presented in *Ground Water Quality of Minnesota's Principal Aquifers* (MPCA, 1998a) focused on statewide results. There was no attempt to explain differences in water quality between regions. Since ground water is largely managed on a regional basis, it is important to identify water quality issues at the regional level.

This report focuses on MPCA Region 6. Region 6 is located in eastern Minnesota and includes the Twin Cities Metropolitan Area counties of Anoka, Carver, Dakota, Hennepin, Ramsey, Scott, and Washington (Figure B.1). The MPCA regional office is located in St. Paul.

The following needs for Region 6 were identified in *The Redesign of the Ambient Ground Water Monitoring Program* (Myers et al., 1992) as meeting local government needs for groundwater information:

- water quality trends, especially organics;
- regional water quality assessment;
- water quantity assessments;
- statewide baseline data;
- ground water and surface water interactions; and
- impacts from gravel mining.

Assistance needs were identified in the following areas:

- data interpretation;
- program design for local aquifers (state should be responsible for major aquifers); and
- coordination of existing efforts.

The baseline study conducted by GWMAP may be used to fulfill the informational needs of regional water quality assessment and statewide baseline data. The baseline study can assist with data interpretation through analysis of the data for the region, and by describing analysis methods useful in local interpretation.

This report provides baseline water quality information for Region 6. Comparisons are made between water quality in the principal aquifers of Region 6 to that in the remainder of the state. Significant differences in ground water quality between Region 6 and the statewide data were determined, factors contributing to these differences were identified, and potential health implications were investigated. **NOTE: Water quality is a relative term which may have multiple meanings. In this report, water quality typically refers to the chemical nature of ground water, although the term is occasionally used in risk evaluations to describe potential effects on humans consuming ground water. The reader should be aware of these different applications of water quality.**

1. Baseline Design and Implementation

Design and implementation of the baseline study are described in Myers et al. (1992) and MPCA (1994, 1995, and 1998a). A systematic grid design was implemented, with sampling nodes spaced at eleven mile intervals. Samples were collected from all major aquifers where a suitable domestic well was located within a nine square mile area centered on each grid node. The County Well Index (CWI) (Wahl and Tipping, 1991) was used to determine suitability of wells within the sampling area. CWI aquifer codes are summarized in Table A.1. Wells were purged until field measurement of pH, temperature, and specific conductance stabilized to 0.1 pH unit, 0.1^{o}C, and 10% for three consecutive readings, with each reading being taken after approximately one well volume had been purged. Sampling parameters included field parameters (dissolved oxygen, oxidation-reduction potential, pH, temperature, specific conductance, and alkalinity) major cations and anions, volatile organic compounds (VOCs), total organic carbon, and 34 trace inorganic chemicals. Tritium and pesticides were sampled in select wells. Samples were not filtered. Rigorous analysis of the data was conducted. Sampling and analysis methods are described in MPCA 1996 and 1998b, respectively. Sample locations, by aquifer, are illustrated in Figure B.2 for the Franconia, Ironton, and Galesville aquifers; in Figure B.3 for the St. Peter, Jordan, and Prairie du Chien aquifers; in Figure B.4 for buried drift aquifers; and in Figure B.5 for water table drift aquifers. Sampling is summarized by aquifer in Table A.1 and for all data in Table A.2. Detailed aquifer descriptions are provided in Section 3.5.

2. Analysis Methods

Quality assurance/quality control analysis of the data are reported in MPCA (1998a). Data analysis consisted of

- establishing descriptive statistics (mean, median, minimum, etc.) for each chemical and each aquifer;

- conducting hypothesis tests between aquifers and different well diameter classes;

- conducting factor analysis related to the distribution of chemicals in the principal aquifers;

- conducting an analysis of health and risk.

Methods used in conducting these analyses are described in MPCA (1998b).

3. Results and Discussion

Results are separated into:

- descriptive statistics;
- group (hypothesis) tests;
- health and risk;
- discussions for individual aquifers;
- discussions for individual chemicals and chemical parameters.

3.1. Descriptive Summaries

Descriptive statistics include the number of samples, number of censored samples (samples below the maximum reporting limit), the type of distribution for the data, and the mean, upper 95th percent confidence limit of the mean, median, 90th or 95th percentile, minimum, and maximum concentrations. Results are summarized in Tables A.3 through A.17 for the fifteen aquifers sampled in Region 6. All concentrations are in ug/L (ppb) except for Eh (mV), temperature (^{o}C), pH (negative log of the hydrogen ion concentration), and specific conductance (umhos/cm). Sample sizes for the Franconia-Ironton-Galesville (CFIG), Ironton-Galesville (CIGL), Mt. Simon (CMTS), St. Lawrence-Franconia (CSLF), St. Lawrence (CSTL), Platteville (OPVL), St. Peter-Prairie du Chien (OSPC), and Precambrian (PCUU) aquifers were small and no further discussion of these aquifers is presented in this report.

Examples of how to use information from Tables A.3 through A.17 in site applications are provided in MPCA, 1998a. To use these data in site applications, the coefficients presented in Tables A.18 and A.19 will be needed. **Mean and median concentrations are considered to represent background concentrations with which**

site or other local water quality information can be compared. Upper 95th percent confidence limits and 90th or 95th percentiles represent extremes in the distribution for a chemical. The distribution of a chemical indicates whether concentrations need to be log-transformed and whether concentrations below the detection limit will be encountered during subsequent sampling.

3.2. Group Tests

Group tests are statistical tests which compare concentrations of a chemical or parameter in one group with concentrations in another group or groups. A group might be month of sampling, for example, and a group test might explore potential differences in concentrations of a chemical between two or more months. Concentrations of sampled chemicals and chemical parameters were compared between different aquifers.

Concentrations of many chemicals differed between different aquifers. Median chemical concentrations were compared between the Franconia (CFRN), Jordan (CJDN), Prairie du Chien (OPDC), St. Peter (OSTP), buried confined drift (QBAA), buried unconfined drift (QBUA), and surficial drift (QWTA) aquifers. Results are summarized in Table A.20. P-values are included for each chemical. The p-value indicates the probability that median concentrations between aquifers are equal. Median concentrations are given in ug/L (except for Eh, pH, temperature, and specific conductance).

Different median concentrations were observed for many chemicals. Some of these differences will be discussed in greater detail in the section for individual aquifers, but the primary conclusions are summarized below.

1. Concentrations of calcium, magnesium, sodium, sulfate, and bicarbonate were highest in the Franconia and buried drift aquifers. These aquifers are covered by glacial or Paleozoic deposits and are therefore well protected. Ground water residence times are likely to be long compared to other aquifers. The higher concentrations of these major ions may reflect increased dissolution of parent material.

2. Boron, iron, and arsenic concentrations were higher in the Franconia aquifer compared to other aquifers.

3. Concentrations of chloride and sodium were highest in the water table aquifer, possibly due to anthropogenic sources such as leaching of road salts, fertilizers, and animal wastes.

4. Eh was low in the Jordan and St. Peter aquifers. This contrasts with the Prairie du Chien aquifer, which had high Eh and low concentrations of iron and manganese, as would be expected in an oxidizing environment. It is unclear why the Prairie du Chien, which is positioned between the St. Peter and Jordan aquifers, would have such an oxidizing environment compared to these two aquifers. Degradation of organic compounds present in the aquifer as a result of human activity may impact oxidation-reduction conditions locally. These results may have implications for cleanup programs, since some chemicals such as vinyl chloride are persistent in reducing environments, while others such as trichloroethylene are persistent in oxidizing environments.

3.3. Health and Risk

Drinking water criteria for individual chemicals are summarized in Table A.21. The Health Risk Limit (HRL) and Health-Based Value (HBV) are health-based criteria. HRLs are defined in the following manner: *HRLs are promulgated concentrations of a ground water contaminant, in ug/L, which estimates the long-term exposure level which is unlikely to result in deleterious effects to humans. HRLs strictly incorporate factors related to human health* (Minn. R., Pts. 4717.7100 to 4717.7800). HBVs have a similar definition, with the exception that they are not promulgated and have not undergone rigorous external peer review. Drinking water criteria are calculated based on a standard adult (70 kg) ingestion rate of two liters of water per day. Uncertainty and other exposure pathways, such as showering, cooking, and inhalation of water vapor, are addressed through the use of safety factors. Lifetime exposure is assumed to apply to baseline data, since the sampled wells are used for domestic supply. Maximum Contaminant Levels

(MCLs) and Secondary Maximum Contaminant Levels (SMCLs) are not strictly health-based and may include factors such as treatability.

The number and percent of samples exceeding health-based ground water drinking criteria are summarized in Tables A.22 and A.23, respectively. **In anticipation of a change in the HRL for manganese from 100 ug/L to a value of 1000 ug/L or greater, the drinking criteria for manganese used in this report is modified from the HRL (MDH, 1997)**. Sample size was not sufficient for the Ironton-Galesville, Precambrian, and buried unconfined (QBUA) aquifers to provide meaningful results. No chemical appeared to represent a significant potential risk in any aquifer. The HRL of 10000 ug/L for nitrate was exceeded once each in the Prairie du Chien and buried drift aquifers. The drinking criteria of 1000 ug/L for manganese was exceeded once each in the St. Peter, buried drift, and water table aquifers. The HRL of 30 ug/L for selenium was exceeded twice in the water table aquifer.

The number and percent of samples exceeding non-health-based ground water drinking criteria are summarized in Tables A.24 and A.25, respectively. Non-health-based drinking criteria include chemicals with a Maximum Contaminant Level (MCL) or Secondary Maximum Contaminant Level (SMCL). Iron exceeded its SMCL in 67, 64, 40, 67, 65, and 50 percent of the sampled wells in the CFRN, CJDN, OPDC, OSTP, QBAA, and QWTA aquifers, respectively. Criteria were not exceeded for any other chemical.

Some chemicals have the same toxic endpoint. For example, Table A.18 indicates that barium and nitrate both affect the cardiovascular/blood system. A useful calculation is to estimate the probability that chemicals with the same endpoint will exceed drinking water criteria when assessed in a cumulative fashion. To make this calculation, a hazard index (HI) is used to add the contribution of each chemical with similar endpoints

$$[HI_{endpoint} = C_{chemical\ 1}/HRL_{chemcial1} + C_{chemical\ 2}/HRL_{chemcial2} + \ldots + C_{chemical\ n}/HRL_{chemcialn}]$$

where C represents the concentration (ug/L) of a chemical. If the HI exceeds 1.0 in an individual sample, further investigation is recommended to evaluate the potential factors controlling chemical concentrations and the validity of the exposure assumptions. These calculations were not made for this report, primarily because there are a limited number of samples for all aquifers except the buried drift. These calculations were made for statewide data and are reported in MPCA, 1998a.

3.4. Discussion of Individual Chemicals and Chemical Parameters

Concentrations of nitrate, chloride, volatile organic compounds (VOCs) and arsenic were sufficient to warrant additional discussion.

3.4.1. Nitrate

Median nitrate concentrations were below the reporting limit of 500 ug/L in all aquifers except the Prairie du Chien, which had a median concentration of 1650 ug/L. The Health Risk Limit of 10000 ug/L was exceeded in only two wells. Despite these results, there was a very strong spatial pattern to nitrate distribution, with most of the detections occurring in the eastern third of the study area (Figure B.6). Detections of nitrate were distributed among each of the major aquifers. There were 20 detections of nitrate and the median oxidation-reduction potential (Eh), dissolved oxygen, and chloride concentrations in these wells was 276 mV, 3330 ug/L, and 21560 ug/L, respectively. Tritium samples collected in 13 of the wells with detectable nitrate had concentrations exceeding 10 TU, reflecting recent water. Conversely, wells with no detectable nitrate had a median Eh of 115 mV and median dissolved oxygen and chloride concentrations of < 300 and 2250 ug/L, respectively. Only five of the 23 wells sampled for tritium and containing no detectable nitrate had tritium concentrations exceeding 10 TU. The results suggest that nitrogen inputs into aquifers of Region 6 are considerable. Under reducing conditions within these aquifers (low Eh, low dissolved oxygen concentration), nitrate will undergo denitrification and concentrations will be less than the reporting limit of 500 ug/L. These results are supported by the correlation with chloride. Elevated chloride concentrations are probably related to anthropogenic sources.

The spatial distribution of nitrate in Paleozoic bedrock aquifers is related to the proximity of these aquifers to the land surface. In the eastern third of Region 6, unconsolidated deposits overlying the bedrock aquifers are thin or absent. In these areas, the uppermost bedrock aquifer appears to be sensitive to pollution. Walsh (1992) and

MPCA (1998c) found strong correlations between nitrate concentration and thickness of deposits overlying the uppermost aquifer, with little nitrate found in aquifers overlain by more than 70 feet of unsaturated surficial material.

Even within surficial drift aquifers, nitrate concentrations were greatest in the eastern part of Region 6. There are large areas of shallow sand aquifers in Washington County, and nitrate may associated with agriculture and unsewered developments. The lack of high nitrate concentrations in the Anoka Sand Plain Aquifer (Hennepin and Anoka Counties) is surprising, since this area is often intensively farmed and irrigated. Well depths, static water elevations, and screened interval were not different in wells containing detectable nitrate and those with no detectable nitrate.

3.4.2. Chloride

Chloride does not represent a health concern in ground water. It is, however, a chemical tracer because it is not attenuated and moves freely with water. Chloride is also an indicator of human impacts, since it is found in road salt, fertilizer, human waste, and animal waste.

Median concentrations of chloride within the surficial drift aquifer were 24980 ug/L, which is significantly greater than the statewide concentration of 5810 ug/L. Chloride was most strongly correlated with other major cations and anions, such as sodium, calcium, and magnesium. The greatest chloride concentrations were found in the central part of Region 6, which is the oldest and most industrialized part of the Twin Cities Metropolitan area (Figure B.7). The density of roads is also greater in this area compared to other areas of Region 6. Road salts and decreased recharge in these areas may account for the elevated chloride concentrations. Chloride was not well correlated with Eh, nitrate concentration, or dissolved oxygen concentration. The distribution of chloride appears to primarily be related to road salt, since fertilizer and human wastes would also contribute nitrate to ground water. Chloride is therefore a good indicator of young water but not necessarily of contamination, especially if multiple contaminant sources exist.

3.4.3. Volatile Organic Compounds (VOCs)

VOC results are summarized in Table A.26. There were only four wells in which a VOC was detected (Figure B.8). This represents 4.3 percent of the sampled wells, which is less than the overall statewide rate of 11 percent. All four wells had more than one VOC detected. Statewide, only 2.6 percent of sampled wells had more than one VOC detected. All the detected VOCs were either halogenated aliphatic compounds or chemicals commonly associated with fuels oils and gasoline.

There was one VOC detection each in the Franconia, Prairie du Chien, St. Peter, and buried drift aquifers. The occurrence of VOCs was correlated with geochemical conditions in an aquifer. Each of the four wells with a detectable VOC had a tritium concentration of 19.3 TU or greater. There was detectable nitrate in each of these wells and Eh exceeded 250 mV in all four wells.

The VOC results for Region 6 differ from those for other regions. While the incidence of VOC detections was low, affected wells are more contaminated than wells from other parts of the state. Since most of the samples collected for Region 6 were outside sewered areas of the Twin Cities Metropolitan area, these results do not reflect water quality under much of the Twin Cities, including heavily industrialized areas. These data suggest more information is needed to determine the distribution and associated risk from VOCs in Region 6.

3.4.4. Arsenic

The Maximum Contaminant Level (MCL) of 50 ug/L was not exceeded in any well sampled in Region 6. The MCL is not strictly health-based, but considers factors such as treatability. A strictly health-based value for arsenic is likely to be less than 10 ug/L, perhaps as low as 2 or 3 ug/L. An arsenic concentration of 3.0 ug/L was exceeded in 22 percent of the sampled wells. Higher concentrations of arsenic occur almost exclusively in the St. Lawrence (median = 3.9 ug/L), Franconia (median = 2.3 ug/L), and buried drift (median = 2.1 ug/L) aquifers. The greatest concentrations also occur near the western edge of the study area (Figure B.9). Arsenic is more soluble under reducing conditions, but conditions within the Franconia and buried drift aquifers are not particularly reducing (Eh = 206 and 195 mV, respectively), suggesting some of the aquifer materials are enriched in arsenic. Correlations between arsenic and most other chemical parameters were weak, but significant correlations were observed with iron and suspended solids. Since the samples were not filtered, arsenic may be associated with suspended matter or metal oxides.

3.5. Aquifers

The hydrology and geology of Region 6 is described in numerous reports, although there is no specific report which encompasses the entire area. The Hydrologic Investigations Reports for the Lower St. Croix River (Lindholm et al., 1974), Crow River (Lindholm et al., 1974), Rum River (Ericson et al., 1974), and Lower Minnesota River (Anderson et al., 1974) watersheds provide information about climate, the water budget, surface water, and ground water. Annual precipitation is about 28.5 inches and is relatively uniform across the study area. Annual surface water runoff varies from about 3 inches in the west to more than 9 inches in the east. Annual recharge to surficial aquifers may be greater than these amounts and will vary widely with annual precipitation and local geology. The major rivers in the region are gaining streams in that they have a baseflow component (ground water discharges to them). County hydrologic atlases have been completed for Ramsey (Minnesota Geological Survey, 1992), Scott (Minnesota Geological Survey, 1982), Washington (1986), and Hennepin (Minnesota Geological Survey, 1989) counties, and a regional assessment of the Anoka Sand Plain (Minnesota Department of Natural Resources, 1993) has been completed.

The hydrogeology of the southern and eastern portions of Region 6 is dominated by Paleozoic bedrock geology consisting primarily of limestone, dolomite, and sandstone. In the northern part of the study area, surficial and buried drift aquifers are important sources of drinking water. The primary bedrock aquifers in Region 6 include the St. Peter sandstone, the Prairie du Chien Group (carbonate aquifers), the Jordan sandstone, and the Franconia sandstone. The bedrock aquifers more or less act as continuous units, with regional flow being to the major rivers in the area. Travel times within these aquifers range from a few years to several thousand years. Surficial and buried sand and gravel aquifers may behave as a regional flow system in which ground water flow is toward the major rivers in the area. Individual buried aquifers are poorly connected hydrologically with each other. The Mt. Simon and Ironton-Galesville aquifers are important sources of drinking water toward the northern and western portion of Region 6, where the Jordan aquifer is absent.

Ground water originates as precipitation which percolates through the soil and vadose zone and into the saturated zone (ground water). Most recharge originates in spring following snowmelt and prior to plant growth. Recharge to the different bedrock aquifers in the study area will vary widely with their vertical position relative to other bedrock units. In areas with sufficient thickness of overlying glacial deposits, the water table reflects, in a subdued way, surface topography. Ground-water flow is controlled by local factors such as topography, extent of fracturing and dissolution, permeability of glacial deposits, and local stresses such as pumping.

A limited amount of background water quality information exists for Region 6. This is partly due to the lack of wells for sampling in the older, residential and commercial areas of the region. Regional hydrologic studies in Region 6 were often conducted with limited budgets for water quality analysis. For these reasons, water quality information from other studies was not incorporated into this report. The aquifers considered in this report include surficial and buried sand and gravel, St. Peter, Prairie du Chien, Jordan, and Franconia. Locations of sampling points from these aquifers are summarized in Figures B.2 through B.5.

3.5.1. Surficial Drift Aquifers

The glacial geology of Region 6 is complex because most of the area was covered by ice from both the Superior and Des Moines lobes. The materials deposited by these ice sheets differ significantly. In addition, the Des Moines lobe overrode areas previously covered with material deposited by the Superior lobe, thus mixing materials deposited by the different ice sheets.

There are few surficial drift (QWTA) aquifers in the southern and western portions of Region 6. Surficial drift aquifers primarily occur in alluvium deposited along the major drainageways, such as the Mississippi, Minnesota, Crow, and St. Croix rivers (Minnesota Geological Survey, 1982). Surficial outwash deposits increase in frequency toward the northern part of the study area. Significant areas of surficial outwash occur in Hennepin, Anoka, and the western portion of Washington counties (Minnesota Geological Survey, 1989; Minnesota Department of Natural Resources, 1993).

Surficial drift aquifers appear to reflect impacts from humans, although data analysis is hampered by small sample size. This is partly due to a lack of wells drilled in sewered areas, which would be areas likely to show the greatest impacts from human activity. Concentrations of most chemicals are low compared to other aquifers in Region 6. Concentrations of chloride, sodium, zinc, copper, lead, and sulfate are higher in water table aquifers from Region 6 than in water table aquifers statewide. These may reflect inputs from human activity, including road salts (chloride and sodium), deposition of automotive emissions (lead), and industrial processes (copper and zinc).

Drinking water criteria were exceeded for manganese, iron, and selenium. These chemicals are discussed below.

Manganese

The drinking water criteria of 1000 ug/L for manganese was exceeded in one sample. The current HRL for manganese (100 ug/L) was exceeded in five samples. The overall median concentration for the aquifer was 111 ug/L. Manganese was correlated with copper (R^2 = 0.83), chloride (R^2 = 0.83), tritium (R^2 = 0.83), and static water elevation (R^2 = -0.50). These are not typical correlations for manganese, which generally increases with depth and as residence time increases.

Iron

The Secondary Maximum Contaminant Level (SMCL) for iron (300 ug/L) was exceeded in 50 percent (5 wells) of the samples. The median concentration of 225 ug/L is below the SMCL. There were significant correlations with many other chemicals. In general these indicated increasing iron concentrations in older, more reducing ground water and in water having high concentrations of organic carbon (R^2 = 0.97) and suspended solids (R^2 = 0.99). Samples were not filtered and dissolved concentrations of iron would be lower than the observed values. Iron concentrations in the surficial drift aquifer are low with respect to similar drift aquifers statewide and compared to different aquifers in Region 6.

Selenium

The HRL for selenium (30 ug/L) was exceeded in two samples. Selenium was not detected at a reporting limit of 1.0 ug/L in five of the nine samples and two of the samples had selenium concentrations at the reporting limit. There were no strong correlations between selenium and other chemicals. Water quality in the two wells with high concentrations did not differ from the remaining wells. The two wells were not geographically isolated from the remaining water table wells. There is no information in the database useful for identifying reasons for the elevated selenium concentrations in these two wells. It is possible the two higher occurrences of selenium are associated with particular geologic deposits, such as Des Moines Lobe till. Statewide, elevated concentrations of selenium were observed in Precambrian and Quaternary aquifers.

3.5.2. Buried Drift Aquifers

Well-sorted sand and gravel were deposited in bedrock valleys and as outwash plains by advancing and retreating glaciers. These deposits, which are typically less than 30 feet thick, were subsequently buried by fine textured material. Buried sand and gravel deposits comprise aquifers with limited potential supply for high capacity uses, but they yield sufficient quantities for domestic use. Buried aquifers occur throughout Region 6 except in the southeast portion of the region, where bedrock occurs close to the land surface. These aquifers are in general, protected from contamination resulting from human activity at the land surface.

Using the County Well Index (CWI) nomenclature, the buried drift group is comprised of artesian (QBAA) and unconfined (QBUA) aquifers. The unconfined aquifers are classified differently than water-table aquifers (QWTA) because more than 10 feet of confining material (e.g. clay) was encountered during drilling. The statewide baseline report (MPCA, 1998b) indicates that the QBUA group has water quality which is more similar to the surficial drift aquifers than to the buried artesian aquifers. Physically, this makes sense since the difference in thickness of confining material between QWTA and QBUA aquifers is arbitrary. Consequently, only the QBAA group is discussed in this section. Water quality information for the QBAA and QBUA groups is illustrated in Tables A.15 and A.16, respectively.

Water quality of the QBAA aquifers appears to be more similar to water quality of the overlying surficial drift aquifers than the underlying bedrock aquifers. Concentrations of zinc, manganese, and sulfate were higher in QBAA aquifers from Region 6 than in similar aquifers statewide. Concentrations of these chemicals were also elevated in the surficial drift aquifers. Overall, concentrations of most major cations and anions were higher in the buried drift aquifers than in other aquifers of Region 6. This may reflect older, more highly evolved ground water.

Water quality of buried drift aquifers in Region 6 is very good. There was one exceedance of the drinking criteria for nitrate and manganese and 13 exceedances of the SMCL for iron. These chemicals are discussed below.

Manganese

The HRL for manganese (100 ug/L) was exceeded in 13 of the 20 sampled wells, but the drinking criteria used in this report (1000 ug/L) was exceeded in only one well. There were no strong correlations of manganese with other chemicals. Most of the higher concentrations of manganese were clustered in the western portion of the study area, in Hennepin and Carver counties. The overall median concentration was 259 ug/L, which is much higher than the median concentration of 131 ug/L in similar aquifers statewide. If the drinking water criteria is raised to 1000 ug/L or more, manganese will not represent a health concern in Region 6.

Nitrate

The drinking water criteria of 10000 ug/L for nitrate was exceeded in one well. Nitrate was not detected in 15 of the 19 sampled wells. Three of the four wells with detectable nitrate had dissolved oxygen concentrations exceeding 1000 ug/L, while only two other wells in the study area had detectable dissolved oxygen. Samples with detectable nitrate were located in the eastern portion of the study area. This area is covered primarily by Superior lobe deposits, which may be more "permeable" than deposits of the Des Moines lobe (MPCA, 1998c). The strongest correlations of nitrate were with dissolved oxygen, tritium, and some of the more mobile elements such as antimony, chloride, and vanadium.

The areas in which nitrate was detected are a mix of residential development, unsewered developments and agricultural land. There are therefore sources of nitrogen in these areas. Nitrate is a potential health concern in these areas.

Iron

Iron exceeded its SMCL of 300 ug/L in 65 percent (13 wells) of the samples from the buried drift aquifer. The median concentration was 481 ug/L. This is well below the statewide median concentration of 1170 ug/L for similar aquifers. Iron was not well correlated with other chemicals except for total suspended solids ($R^2 = 0.94$). The samples collected for this study were not filtered and dissolved iron concentrations will be much lower, probably below the SMCL of 300 ug/L.

Iron, which stains plumbing fixtures, does not appear to represent a significant concern in ground water from buried drift aquifers in Region 6.

3.5.3. St. Peter, Prairie du Chien, and Jordan Aquifers

The St. Peter Sandstone, Prairie du Chien Formation (a carbonate formation), and Jordan Sandstone aquifers are often treated as a single aquifer. This grouping of aquifers is generally based on measured heads within the aquifers, which often suggest there is no effective confining unit between the aquifers. Recent studies, however, indicate when one aquifer is stressed there is often little hydraulic response in the adjacent aquifer. In addition, definitions based solely on hydraulics ignore the actual movement of chemicals within the aquifers since residence time and geochemistry change with depth. Comparisons of water quality in the three aquifers indicates significant differences in water quality between the three aquifers (MPCA, 1998b). In particular, specific conductance and concentrations of calcium, magnesium, potassium, sodium, chloride, nitrate, sulfate, total dissolved solids, and total suspended solids differ between the aquifers. These three aquifers are therefore treated individually in the discussion below.

3.5.3.1. St. Peter Aquifer

The St. Peter formation, which consists of fine- to medium-grained, well sorted quartzose sand, is separated from the Upper Carbonate formations by the Decorah Shale and the Platteville and Glenwood formations, which act as confining units. The St. Peter formation is easily eroded and therefore is only rarely found at the land surface. More often, the formation is covered by glacial deposits. The St. Peter formation is an important aquifer in the central portion of Region 6. The basal layer of the St. Peter formation can act as a confining unit when present, but the effectiveness of this layer varies considerably across the region (Ruhl and Wolf, 1983).

The water quality of the St. Peter aquifer is highly variable in Region 6. Concentrations of chloride are higher in Region 6 than the statewide median concentration for the St. Peter aquifer. This suggests some effect of human activity. However, Eh is lower and manganese concentrations higher compared to the statewide median for the St. Peter aquifer. These suggest older, more highly evolved water which should not reflect human effects. The data break into two distinct groups. One group of four wells had Eh values greater than 250 mV. Three of these wells had dissolved oxygen concentrations greater than 1000 ug/L, detectable nitrate, and tritium concentrations greater than 10 TU.

Chloride concentrations were also high in these wells. The other 5 wells had Eh values less than 50 mV and no detectable nitrate or dissolved oxygen. Concentrations of iron and manganese were very high in these five wells. All four samples with the high Eh values were located along the eastern or western margin of the study area, presumably in locations where the St. Peter is close to the land surface.

Drinking water criteria were exceeded for manganese and iron. These chemicals are discussed below.

Manganese

The drinking water criteria of 1000 ug/L was exceeded in one well (1019 ug/L). The distribution of manganese was very uneven in the study area. All five wells with the Eh values less than 50 mV had manganese concentrations which exceeded the current HRL of 100 ug/L. Concentrations in three of the four wells with Eh values greater than 250 mV had manganese concentrations less than 5 ug/L. Manganese concentrations were not well correlated with the other oxidation-reduction parameters (dissolved oxygen, nitrate, and iron), but were correlated with boron (R^2 = 0.94), dissolved solids (R^2 = 0.93), and suspended solids (R^2 = 0.84). These results suggest a relationship between increasing ground water residence time and manganese concentrations.

The source of the manganese is unclear. If the drinking criteria is raised to 1000 ug/L or more, manganese will not represent a drinking water concern in Region 6.

Iron

Iron exceeded its SMCL (300 ug/L) in 67 percent (6) of the sampled wells. The median concentration of 443 ug/L is slightly higher than the statewide rate of 384 ug/L for the St. Peter aquifer. All six exceedances of the criteria occurred in the western portion of the study area. The results are similar to those for manganese, with the aquifer being more susceptible to elevated iron concentrations in areas where the aquifer is well protected by confining layers. There were a number of significant correlations with other chemicals, but no apparent pattern to these correlations. For example, iron was positively correlated with zinc and negatively correlated with copper. As with other aquifers, iron was significantly correlated with suspended solids, indicating water filtration is a good mechanism for reducing iron concentrations.

3.5.3.2. Prairie du Chien Aquifer

The Prairie du Chien group comprises two principal formations, the Oneota dolomite and the overlying Shakopee formation. These consist of thin- to thick-bedded dolomite separated by the New Richmond sandstone. The Prairie du Chien formation was deposited when the interior of the Hollandale embayment was subsiding more rapidly than the margins. The formation may be as thick as 400 feet. The Prairie du Chien formation is vuggy and fractured, with interbedded thin layer of shale.

Ground water flow is predominantly toward the major rivers in the area, including the Mississippi, St. Croix, and Minnesota rivers. Recharge to the aquifer is greatest in the eastern part of Region 6, where the aquifer is close to or crops out at the land surface. The Prairie du Chien is an extremely important aquifer in Region 6, but is vulnerable to contamination when overlying deposits of glacial till or the St. Peter sandstone are thin or absent.

There was exceedance of drinking water criteria for nitrate and four exceedances for iron. These chemicals are discussed below.

Nitrate

The HRL of 10000 ug/L for nitrate was exceeded in one well. Nitrate was detected at concentrations greater than 1000 ug/L in six of the ten sampled wells. The overall median nitrate concentration for the Prairie du Chien aquifer was 1650 ug/L. This is well above the statewide median concentration, which was less than the reporting limit of 500 ug/L. Water from the Prairie du Chien aquifer is oxidized, with a median Eh of

263 mV and a median concentration of 1820 ug/L for oxygen. Nitrate is therefore stable in the aquifer.

Nitrate was most strongly correlated with dissolved oxygen (R^2 = 0.813), iron (R^2 = -0.417), manganese (R^2 = -0.452), Eh (R^2 = 0.547), tritium (R^2 = 0.491), total organic carbon (R^2 = -0.701), alkalinity (R^2 = -0.633), and potassium (R^2 = 0.780). These correlations indicate nitrate will be found in well oxygenated ground water, which is typically impacted by recharge. Nitrate inputs in Region 6 appear to be substantial, probably from a combination of rural and urban fertilizers, animal and human waste, industrial processes, and possibly atmospheric fallout. Nitrate concentrations increased from north to south. The correlation with potassium is interesting, since nitrate was either not correlated or negatively correlated with other major cations and anions. The nitrate correlation with potassium may be related to use of potassium in fertilizers.

Nitrate concentrations in areas of the Prairie du Chien aquifer impacted by recharge represent a potential drinking water concern. Because of the large number of different nitrate sources, additional information is needed to assess nitrate risk under different land use settings.

Iron

The SMCL of 300 ug/L for iron was exceeded in four wells. The overall median concentration of iron was 35 ug/L, which is well below the statewide median of 487 ug/L for the aquifer. In each of the four wells in which iron exceeded the drinking criteria, dissolved oxygen was below the reporting limit. In the remaining six wells, dissolved oxygen concentrations were greater than 1300 ug/L. Iron was correlated with dissolved oxygen (R^2 = -0.581), Eh (R^2 = -0.651), total suspended solids (R^2 = 0.757), and tritium (R^2 = -0.728). Iron, which stains plumbing fixtures, does not represent a concern in shallow, oxygenated portions of the Prairie du Chien aquifer.

3.5.3.3. Jordan Aquifer

The Jordan sandstone consists of a quartzose, fine- to medium-grained sandstone, ranging from massive or thick-bedded to thin-bedded. Like the Prairie du Chien aquifer, ground water flow is toward the Mississippi River. Concentrations of several chemicals, including bicarbonate, calcium, potassium, sodium, sulfate, and total dissolved solids, are significantly lower in the Jordan aquifer than in the Prairie du Chien aquifer, however.

The SMCL of 300 ug/L for iron was exceeded in seven samples. The median concentration was 345 ug/L. Iron was correlated with alkalinity ($R^2 = 0.903$), calcium ($R^2 = 0.864$), magnesium ($R^2 = 0.821$), total dissolved solids ($R^2 = 0.836$), and total suspended solids ($R^2 = 0.889$). These results reflect increasing concentrations of iron as ground water residence time increases, since concentrations of dissolved solids increase and ground water becomes more reducing with increasing residence time.

3.5.4. Franconia-Ironton-Galesville Aquifer

The Franconia Formation, Ironton Sandstone, and Galesville Sandstone are separated from the Jordan aquifer by the St. Lawrence Formation, which acts as a confining layer. As with other aquifers of Paleozoic age, these aquifers are often treated as a single hydrologic unit. Each aquifer consists of sandstone, although there are scattered layers of shale and dolomite within the Ironton and Galesville sandstones. Data from the statewide baseline study indicates the chemistry of these aquifers is very similar. There were no sampled chemicals which differed in concentration between the three formations, suggesting they may act as a single hydrologic unit. The discussion below treats them as a single unit. Consequently, the CFIG, CFRN, and CIGL aquifers are grouped together for this analysis.

The aquifer covers most of the study area except along the major rivers, where the formation was eroded and filled with glacial material. Ground water flow is similar to the overlying aquifers, with discharge to the major rivers in the area. The aquifer is separated from overlying aquifers by the St. Lawrence confining layer.

In general, the aquifer is covered by overlying glacial or Paleozoic deposits and is therefore well protected from direct leaching through the unsaturated zone. Ground water is typically reducing, with a median Eh of 198 mV and detectable concentrations of dissolved oxygen and nitrate in only two wells. Tritium was sampled in one of the two wells with detectable nitrate and the concentration exceeded 10 TU, reflecting recent water. Tritium concentrations were less than 10 TU in the remaining wells for the Franconia-Ironton-Galesville aquifer.

Concentrations of most major cations and anions are higher in the Franconia-Ironton-Galesville aquifer compared to other aquifers in Region 6. Despite this, ground water quality is generally good within the aquifer. The only chemical which exceeded a drinking criteria was iron.

Iron

Iron exceeded its SMCL of 300 ug/L in 87 percent (13 wells) of the sampled wells. The median concentration was 856 ug/L. The strongest correlation was with total suspended solids (R^2 = 0.94). Other correlations of iron were weak. The greatest concentrations of iron occurred north of the Minnesota River. There is insufficient geologic information for this area to evaluate the reasons for the observed distribution of iron.

The primary effects of iron are on plumbing fixtures, taste, and development of iron bacteria. Iron does appear to represent a potential concern in Region 6.

4. Summary and Recommendations

This chapter is divided into a section providing a summary of the results, a section providing recommendations for additional research, and a section providing monitoring recommendations.

4.1. Summary

1. Summary statistics (median, minimum, maximum, mean, 95th confidence limit, and 90th or 95th percentile concentrations) for a wide range of chemical parameters have been calculated for 15 aquifers sampled in MPCA Region 6 in the Twin Cities Metropolitan Area located in east-central Minnesota. Sample size was sufficient for the Franconia (CFRN), Jordan (CJDN), St. Peter (OSTP), Prairie du Chien (OPDC), buried artesian drift (QBAA), and surficial drift (QWTA) aquifers so that these values

may serve as initial estimates of background concentrations, although additional data should be collected for some of these aquifers due to small sample size. A high density grid supplemented the baseline study in Region 6, but additional sampling from over 100 wells indicated no change in descriptive statistics for the major aquifers.

2. There were differences in concentrations of many chemicals between different aquifers. The Franconia aquifer had high concentrations of many chemicals compared to other aquifers, including bicarbonate, calcium, magnesium, potassium, sodium, sulfate, iron, boron, and organic carbon. The buried drift aquifer also had high concentrations of many chemicals. Residence time and parent material appear to be the primary factors controlling water quality in these two aquifers. The Jordan aquifer had low concentrations of most chemicals compared to other aquifers. Only cadmium, silver, and zinc were elevated in this aquifer. Water quality in the Jordan is generally very good. The Prairie du Chien aquifer appears to be highly impacted by recent water (recharge). Eh and concentrations of dissolved oxygen, nitrate, and chloride were higher in the Prairie du Chien aquifer compared to other aquifers. The surficial drift aquifer showed some effects of human activity, with concentrations of sodium, chloride, and some trace metals such as copper being higher than concentrations in other aquifers. Water quality in the St. Peter aquifer was highly variable. This was best demonstrated by Eh, which was less than 40 mV in five wells and greater than 250 mV in four wells.

3. Health-based drinking water standards (HRL or HBV) were exceeded for the following compounds:

   - manganese - 2 exceedances, one each in the buried drift and St. Peter aquifers;
   - nitrate - 2 exceedances, one each in the buried drift and Prairie du Chien aquifers;
   - selenium - 2 exceedances in the surficial drift aquifer.

1. Non-health based standards (MCL or SMCL) were exceeded for the following compounds:

- iron - 41 exceedances, scattered among all aquifers.

2. Median concentrations of most chemicals in all aquifers of Region 6 were similar to statewide median concentrations for similar aquifers, but there were some aquifer-specific differences. Concentrations of most chemicals were higher in the Franconia aquifer in Region 6 compared to the Franconia aquifer statewide. Sodium and chloride were higher in the water table aquifers and sulfate was higher in all aquifers compared to statewide concentrations. The Prairie du Chien aquifer had higher concentrations of nitrate and dissolved oxygen compared to statewide values, while iron and manganese were lower. The Prairie du Chien aquifer in the Twin Cities Metropolitan Area appears to be readily recharged and is therefore sensitive to human activity at the land surface.
3. Volatile organic compounds were detected in 4 wells or 4.3 percent of the samples. Each well with a detectable VOC had more than one VOC detected. Chlorinated aliphatic compounds and substituted benzenes accounted for all of the VOC detections. No drinking water criteria for VOCs was exceeded. Despite the low frequency of detection compared to other regions of the state, individual wells which are vulnerable to contamination appear to be at greater risk from industrial sources compared to other regions in the state. An additional factor in this study was that very few samples were collected in the older, more heavily industrialized portions of the region because these areas are serviced with municipal water.

4.2. Research Recommendations

The Paleozoic aquifers of the Twin Cities Area have been extensively studied and modeled, and there is considerable information on the chemistry of these aquifers compared to other aquifers in Minnesota. However, this information is poorly organized. There are few studies discussing the attenuation properties of these aquifers with respect to contaminants. Surficial aquifers, although not as widely studied, suffer from the same information gaps with respect to water quality. The data set discussed in this report is biased toward not finding contamination, since the more industrialized portions of the region were sparsely sampled. Andrews et al. (1998) observed a high detection rate for VOCs and some trace metals under an older, more intensely developed residential/commercial portion of the Twin Cities. The fact that each of the four wells containing a detectable VOC contained more than one VOC, and that all detected VOCs are related to industrial processes, indicates a need for much more information on the distribution of VOCs in Twin Cities aquifers. Research recommendations for Region 6 are discussed below.

1. Determine the overall distribution of VOCs in the major aquifers of the Twin Cities Metropolitan Area and identify the locations of major plumes containing chlorinated solvents. Information from regulated sites should be compiled and used to complete this objective. This information must include upgradient wells which provide information on background concentrations of VOCs originating from nonpoint sources.
2. Determine relationships between land use and water quality in the major aquifers of the Twin Cities and evaluate changes in water quality under new or changing land uses. The primary chemicals of concern are VOCs. Chloride serves as an excellent indicator of human impacts.
3. Determine the relationship between water quality and geology. This primarily applies to trace elements which are occasionally found at higher concentrations in an aquifer, such as selenium in Quaternary aquifers.

4.3. Monitoring Needs

The objective of ground water monitoring is to provide information which can serve as a point of reference for ground water quality. Baseline monitoring is used to provide data which can be compared with site-specific or regional data. Ambient monitoring includes a time component and is intended to provide information regarding long-term trends in water quality of an aquifer. Monitoring needs for Region 6 are discussed below.

1. Baseline data : the baseline data for the buried confined drift (QBAA) aquifer is sufficient to be considered representative of background. These data can simply be updated over time. Data bases for the Paleozoic and water table aquifers should be

expanded by approximately 10 wells each and the data analyzed to establish baseline conditions. Information in this report provides an initial estimate of background water quality in these aquifers, but the values may change as additional data is incorporated. A proportionate amount of this data should be collected from older, more heavily industrialized areas of Region 6. A logical way of bridging the data gap would be to incorporate data from regulated sites. Because of the large number of sites associated with Superfund, the Voluntary Investigation and Cleanup Program, Resource Conservation and Recovery Act (RCRA), the closed Landfill Program, and the Tanks and Spills programs, there is potentially sufficient information to describe general water quality in the major aquifers of the Twin Cities. Coupled with models which have been developed for these aquifers, there is potential for tracking plumes with high concentrations of VOCs, particularly the more persistent and toxic chlorinated solvents.

2. Ambient monitoring : ambient monitoring is needed in aquifers impacted by humans. At this time, VOCs are the primary chemical of concern related to human activity in Region 6.

   The GWMAP baseline data provides very little insight into the occurrence and distribution of VOCs in ground water of Region 6 and is not useful for identifying the major plumes containing chlorinated solvents.

1. Pesticide sampling for the baseline study was inadequate to evaluate their distribution in the major aquifers. Reporting limits were high and analyte lists were limited to a few parent compounds. Pesticide sampling should include a variety of pesticides and metabolites, since a wide variety of chemicals may be used in a variable land use setting such as the Twin Cities. Andrews et al. (1997), for example, found detection rates of greater than 10 percent for prometon and tebuthiuron, which are commonly used for weed control in right-of-ways.
2. Agency-wide sampling, data management, and data analysis protocol should be established by an intra-Agency group consisting of staff from all programs dealing with ground water cleanup and monitoring.

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Appendix A - Tables

Table A.1 : Distribution of samples, by aquifer.

Aquifer	Number of Samples
Quaternary water table aquifer (QWTA)	10
Quaternary buried artesian aquifer (QBAA)	20
Quaternary buried undifferentiated aquifer (QBUU)	5
Platteville (OPVL)	2
St. Peter (OSTP)	9
St. Peter-Prairie du Chien (OSPC)	2
Prairie du Chien (OPDC)	10
Jordan (CJDN)	11
St. Lawrence (CSTL)	2
Franconia (CFRN)	9
Franconia-Ironton-Galesville (CFIG)	2
Ironton-Galesville (CIGL)	4
St. Lawrence-Franconia (CSLF)	4
Mt. Simon (CMTS)	2
Precambrian (PCUU)	1

Table A.2 : Summary information for all chemical parameters. Censoring values were established just below the maximum reporting limit.

Chemical	No. of samples	No. of missing	Maximum reporting limit (ug/L)	No. detections above censoring value	No. censored values
Alkalinity	93	0	1000	93	0
Aluminum (Al)	85	8	0.060	76	9
Antimony (Sb)	85	8	0.008	51	34
Arsenic (As)	85	8	0.060	84	1
Barium (Ba)	93	0	1.4	92	1
Beryllium (Be)	85	8	0.010	24	61
Bismuth (Bi)	69	14	0.040	3	66
Boron (B)	93	0	13	78	15
Bromide (Br)	93	0	0.20	0	93
Cadmium (Cd)	85	8	0.020	59	26
Calcium (Ca)	93	0	5	93	0
Cesium (Cs)	69	24	0.010	40	29
Chloride (Cl)	93	0	200	93	0
Chromium (Cr)	85	8	0.050	63	22
Cobalt (Co)	85	8	0.0020	85	0
Copper (Cu)	93	0	4.6	57	36
Dissolved Oxygen	93	0	300	27	66
Eh	93	0	-	93	0
Fluoride (F)[1]	36	57	[2]	36	0
Iron (Fe)	93	0	3.2	92	1
Lead (Pb)	85	8	0.03	85	0
Lithium (Li)	93	0	4.5	66	27
Magnesium (Mg)	93	0	120	93	0
Manganese (Mn)	93	0	0.90	77	16
Mercury (Hg)	16	77	0.10	0	16
Molybdenum (Mo)	93	0	4.2	18	75
Nickel (Ni)	93	0	6.0	22	71
Nitrate-N (NO_3-N)	92	1	500	21	71
pH	93	0	-	93	0
$Phosphorus_{total}$	93	0	14.9	88	5
Potassium (K)	93	0	118.5	93	0
Rubidium (Rb)	93	0	555.5	5	88
Selenium (Se)	86	7	0.1	42	44
Silicate (Si)	93	0	20	93	0
Silver (Ag)	85	8	0.0090	59	26
Sodium (Na)	93	0	60	93	0
Specific Conductance	93	0	10	93	0
Strontium (Sr)	93	0	0.60	93	0
Sulfate	93	0	300	93	0
Sulfur (S)	93	0	21.8	93	0
Temperature	93	0	-	93	0
Thallium (Tl)	85	8	0.0050	60	25
Tin (Sn)	69	24	0.040	33	36
Titanium (Ti)	93	0	0.0035	17	76
Total dissolved solids	93	0	-	93	0
Total organic carbon	93	0	500	91	2
Total phosphate	93	0	20	69	24
Total suspended solids	93	0	-	93	0

Table A2 continued.

Chemical	No. of samples	No. of missing	Maximum reporting limit (ug/L)	No. detections above censoring value	No. censored values
Vanadium (V)	93	0	4.7	54	39
Zinc (Zn)	93	0	2.7	93	0
Zirconium (Zr)	69	24	0.030	26	53
1,1-Dichloroethane	170	-	0.2	-	-
1,1-Dichloroethene	170	-	0.5	-	-
1,1-Dichloropropene	170	-	0.2	-	-
1,1,1-Trichloroethane	170	-	0.2	-	-
1,1,1,2-Tetrachloroethane	170	-	0.2	-	-
1,1,2-Trichloroethane	170	-	0.2	-	-
1,1,2,2-Tetrachloroethane	170	-	0.2	-	-
1,1,2-Trichlorotrifluoroethane	170	-	0.2	-	-
1,2-Dichlorobenzene	170	-	0.2	-	-
1,2-Dichloroethane	170	-	0.2	-	-
1,2-Dichloropropane	170	-	0.2	-	-
1,2,3-Trichlorobenzene	170	-	0.5	-	-
1,2,3-Trichloropropane	170	-	0.5	-	-
1,2,4-Trichlorobenzene	170	-	0.5	-	-
1,2,4-Trimethylbenzene	170	-	0.5	-	-
1,3-Dichlorobenzene	170	-	0.2	-	-
1,3-Dichloropropane	170	-	0.2	-	-
1,3,5-Trimethylbenzene	170	-	0.5	-	-
1,4-Dichlorobenzene	170	-	0.2	-	-
2,2-Dichloropropane	170	-	0.5	-	-
2-Chlorotoluene	170	-	0.5	-	-
4-Chlorotoluene	170	-	0.5	-	-
Acetone	170	-	20	-	-
Allyl chloride	170	-	0.5	-	-
Bromochloromethane	170	-	0.5	-	-
Bromodichloromethane	170	-	0.2	-	-
Benzene	170	-	0.2	-	-
Bromobenzene	170	-	0.2	-	-
Bromoform	170	-	0.5	-	-
Bromomethane	170	-	0.5	-	-
cis-1,2-Dichloroethene	170	-	0.2	-	-
cis-1,3-Dichloropropene	170	-	0.2	-	-
Carbon tetrachloride	170	-	0.2	-	-
Chlorodibromomethane	170	-	0.5	-	-
Chlorobenzene	170	-	0.2	-	-
Chloroethane	170	-	0.5	-	-
Chloroform	170	-	0.1	-	-
Chloromethane	170	-	0.5	-	-
1,2-Dibromo-3-chloropropane	170	-	0.5	-	-
Dibromomethane	170	-	0.5	-	-
Dichlorodifluoromethane	170	-	0.5	-	-
Dichlorofluoromethane	170	-	0.5	-	-

Table A.2 continued.

Chemical	No. of samples	No. of missing	Maximum reporting limit (ug/L)	No. detections above censoring value	No. censored values
1,2-Dibromoethane	93	-	0.5	-	-
Ethylbenzene	93	-	0.2	-	-
Ethyl ether	93	-	2	-	-
Hexachlorobutadiene	93	-	0.5	-	-
Isopropylbenzene	93	-	0.5	-	-
Methylene chloride	93	-	0.5	-	-
Methyl ethyl ketone	93	-	10	-	-
Methyl isobutyl ketone	93	-	5	-	-
Methyl tertiary butyl ether	93	-	2	-	-
n-Butylbenzene	93	-	0.5	-	-
Naphthalene	93	-	0.5	-	-
n-Propylbenzene	93	-	0.5	-	-
o-Xylene	93	-	0.2	-	-
p&m-Xylene	93	-	0.2	-	-
p-Isopropyltoluene	93	-	0.5	-	-
sec-Butylbenzene	93	-	0.5	-	-
Styrene	93	-	0.5	-	-
tert-Butylbenzene	93	-	0.5	-	-
trans-1,2-Dichloroethene	93	-	0.1	-	-
trans-1,3-Dichloropropene	93	-	0.2	-	-
Trichloroethene	93	-	0.1	-	-
Trichlorofluoromethane	93	-	0.5	-	-
Tetrachloroethene	93	-	0.2	-	-
Tetrahydrofuran	93	-	10	-	-
Toluene	93	-	0.2	-	-
Vinyl chloride	93	-	0.5	-	-

[1] Fluoride was censored at several detection limits. Censoring at the highest detection limit would result in only a few values above the censoring limit. Consequently, all non-detections were treated as missing data and removed from the data set.

Table A.3 : Descriptive statistics for the Franconia-Ironton-Galesville aquifer (CFIG).

Chemical	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	90 or 95th percentile	Min	Max	State Median
								ug/L	ug/L	ug/L
Alkalinity	2	ins	ins	ins	ins	ins	ins	244000	266000	330000
Aluminum	2	ins	ins	ins	ins	ins	ins	< 0.060	2.9	2.9
Antimony	2	ins	ins	ins	ins	ins	ins	0.017	0.030	0.017
Arsenic	2	ins	ins	ins	ins	ins	ins	0.29	0.99	0.99
Barium	2	ins	ins	ins	ins	ins	ins	35	58	35
Beryllium	2	ins	ins	ins	ins	ins	ins	< 0.010	< 0.010	< 0.010
Bismuth	1	ins	ins	ins	ins	ins	ins	< 0.040	-	< 0.040
Boron	2	ins	ins	ins	ins	ins	ins	113	250	1163
Bromide	2	ins	ins	ins	ins	ins	ins	< 0.20	< 0.20	< 0.20
Cadmium	2	ins	ins	ins	ins	ins	ins	0.040	0.090	0.040
Calcium	2	ins	ins	ins	ins	ins	ins	99107	103137	99107
Cesium	1	ins	ins	ins	ins	ins	ins	0.040	-	0.040
Chloride	2	ins	ins	ins	ins	ins	ins	1300	1310	1310
Chromium	2	ins	ins	ins	ins	ins	ins	0.27	2.0	0.27
Cobalt	2	ins	ins	ins	ins	ins	ins	0.51	0.55	0.55
Copper	2	ins	ins	ins	ins	ins	ins	< 5.5	< 5.5	< 5.5
Dissolved oxygen	2	ins	ins	ins	ins	ins	ins	< 300	1890	< 300
Eh	2	ins	ins	ins	ins	ins	ins	131	240	140
Fluoride	2	ins	ins	ins	ins	ins	ins	250	350	325
Iron	2	ins	ins	ins	ins	ins	ins	711	1425	876
Lead	2	ins	ins	ins	ins	ins	ins	0.20	0.33	0.20
Lithium	2	ins	ins	ins	ins	ins	ins	4.4	6.2	6.2
Magnesium	2	ins	ins	ins	ins	ins	ins	39676	36044	36044
Manganese	2	ins	ins	ins	ins	ins	ins	4.7	53	53
Mercury	1	ins	ins	ins	ins	ins	ins	< 0.10	-	< 0.10
Molybdenum	2	ins	ins	ins	ins	ins	ins	< 4.2	< 4.2	< 4.2
Nickel	2	ins	ins	ins	ins	ins	ins	< 6.0	< 6.0	< 6.0
Nitrate-N	2	ins	ins	ins	ins	ins	ins	< 500	< 500	< 500
pH	2	ins	ins	ins	ins	ins	ins	6.92	7.28	7.20
Phosphorus	2	ins	ins	ins	ins	ins	ins	27	33	33
Potassium	2	ins	ins	ins	ins	ins	ins	5153	7318	4099
Rubidium	2	ins	ins	ins	ins	ins	ins	< 555.2	< 555.2	< 555.5
Selenium	2	ins	ins	ins	ins	ins	ins	< 1.0	2.9	2.9
Silicate	2	ins	ins	ins	ins	ins	ins	4447	5589	6233
Silver	2	ins	ins	ins	ins	ins	ins	< 0.090	0.077	< 0.0090
Sodium	2	ins	ins	ins	ins	ins	ins	10760	17246	10760
Specific Conductance	2	ins	ins	ins	ins	ins	ins	700	818	700
Strontium	2	ins	ins	ins	ins	ins	ins	427	870	363
Sulfate	2	ins	ins	ins	ins	ins	ins	72990	87750	24330
Sulfur	2	ins	ins	ins	ins	ins	ins	23426	30312	23426
Temperature	2	ins	ins	ins	ins	ins	ins	10.9	11.8	9.7
Thallium	2	ins	ins	ins	ins	ins	ins	< 0.0050	< 0.0050	< 0.0050
Tin	1	ins	ins	ins	ins	ins	ins	0.16	-	0.16
Titanium	2	ins	ins	ins	ins	ins	ins	< 0.0035	< 0.0035	< 0.0035
Total dissolved solids	2	ins	ins	ins	ins	ins	ins	428000	496000	428000
Total organic carbon	2	ins	ins	ins	ins	ins	ins	800	1300	1000
Total phosphate-P	2	ins	ins	ins	ins	ins	ins	< 20	< 20	< 20

Table A.3 continued.

Chemical	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	90 or 95th percentile	Min	Max	State Median

Total suspended solids	2	ins	ins	ins	ins	ins	ins	4000	6000	6000
Vanadium	2	ins	ins	ins	ins	ins	ins	4.6	5.0	4.9
Zinc	2	ins	ins	ins	ins	ins	ins	134	96	39
Zirconium	1	ins	ins	ins	ins	ins	ins	0.050	-	0.050

[1] = insufficient sample size for analysis

Table A.4 : Descriptive statistics for the Franconia aquifer (CFRN).

Chemical	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	90 or 95th percentile	Min	Max	State Median
				ug/L	ug/L	ug/L		ug/L	ug/L	ug/L
Alkalinity	9	0	normal	320556	400777	330000	ins	155000	452000	270000
Aluminum	9	1	log-censored	0.022	21	3.7	ins	< 0.060	7.9	1.5
Antimony	9	3	log-censored	0.0019	4.4	0.011	ins	< 0.0080	0.048	0.012
Arsenic	9	0	normal	2.5	4.0	2.3	ins	0.17	5.1	0.67
Barium	9	0	normal	99	163	102	ins	14	263	48
Beryllium	9	7	log-censored	0.011	0.093	< 0.010	ins	< 0.010	< 0.010	< 0.010
Bismuth	7	7	ins	ins	ins	< 0.040	ins	< 0.040	< 0.040	< 0.040
Boron	9	0	normal	91	162	55	ins	15	299	28
Bromide	9	9	ins	ins	ins	< 0.20	ins	< 0.20	< 0.20	< 0.20
Cadmium	9	5	log-censored	0.070	0.15	< 0.020	ins	< 0.020	0.13	0.055
Calcium	9	0	normal	87574	104151	84659	ins	49520	126770	69745
Cesium	7	2	log-censored	0.013	0.076	0.010	ins	< 0.010	0.040	0.040
Chloride	9	0	log-normal	2850	12838	1200	ins	240	127350	1030
Chromium	9	1	log-censored	0.19	9.5	0.26	ins	< 0.050	3.7	0.29
Cobalt	9	0	normal	0.67	0.82	0.61	ins	0.43	1.0	0.58
Copper	9	5	log-censored	5.2	21	< 5.5	ins	< 5.5	15	< 5.5
Dissolved oxygen	9	8	ins	ins	ins	< 300	ins	< 300	5780	< 300
Eh	9	0	normal	176	246	206	ins	50	285	213
Fluoride	5	0	ins	-	-	270	ins	230	400	280
Iron	9	0	normal	1087	2106	583	ins	46	4152	856
Lead	9	0	log-normal	0.18	0.31	0.19	ins	0.060	0.75	0.23
Lithium	9	2	log-censored	7.5	76	8.3	ins	< 4.5	55	5.1
Magnesium	9	0	normal	33356	42199	32256	ins	17809	51185	30514
Manganese	9	1	log-censored	60	1074	67	ins	< 0.90	372	47
Mercury	2	2	ins	ins	ins	< 0.10	ins	< 0.10	< 0.10	< 0.10
Molybdenum	9	7	ins	ins	ins	< 4.2	ins	< 4.2	6.3	< 4.2
Nickel	9	9	ins	ins	ins	< 6.0	ins	< 6.0	< 6.0	< 6.0
Nitrate-N	9	7	ins	ins	ins	< 500	ins	< 500	6900	< 500
pH	9	0	normal	7.39	7.62	7.34	ins	6.92	7.96	7.34
Phosphorus	9	0	normal	73	139	37	ins	19	293	29
Potassium	9	0	normal	2681	3584	2580	ins	1299	4873	1691
Rubidium	9	8	ins	-	-	< 555.2	ins	< 555.2	638	< 555.5
Selenium	9	3	log-censored	0.96	3.3	1.0	ins	< 1.0	2.9	1.0
Silicate	9	0	normal	10474	12777	10818	ins	6058	15184	8291
Silver	9	5	log-censored	0.031	0.079	< 0.0090	ins	< 0.0090	0.070	< 0.0090
Sodium	9	0	normal	20876	32417	18663	ins	3016	51287	4997
Specific Conductance	9	0	normal	718	862	703	ins	421	951	510

Table A.4 continued.

Chemical	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	90 or 95th percentile	Min	Max	State Median
Strontium	9	0	normal	276	442	231	ins	98	747	110
Sulfate	9	0	normal	38473	66625	28170	ins	2280	122820	6330
Sulfur	9	0	normal	13492	23073	9891	ins	874	41634	6948

Temperature	9	0	normal	10.3	10.9	10.3	ins	9.1	11.5	9.8
Thallium	9	0	log-censored	0.0078	0.11	0.010	ins	< 0.0050	0.060	< 0.0050
Tin	7	3	log-censored	1.6	27	< 0.040	ins	< 0.040	0.18	0.20
Titanium	9	5	log-censored	0.011	8.1	< 0.0035	ins	< 0.0035	0.0058	< 0.0035
Total dissolved solids	9	0	normal	459111	568988	428000	ins	242000	700000	339000
Total organic carbon	9	0	normal	2289	3282	2000	ins	900	4500	2900
Total phosphate-P	9	2	log-censored	25	502	20	ins	< 20	630	20
Total suspended solids	9	0	normal	3778	6988	2000	ins	1000	14000	3500
Vanadium	9	4	log-censored	6.7	15	6.5	ins	< 4.7	12	< 4.7
Zinc	9	0	log-normal	30	97	22	ins	5.3	412	88
Zirconium	7	5	ins	ins	ins	< 0.030	ins	< 0.030	0.030	0.040

Table A.5 : Descriptive statistics for the Ironton-Galesville aquifer (CIGL).

Chemical	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	90 or 95h percentile	Min	Max	State Median
						ug/L		ug/L	ug/L	ug/L
Alkalinity	4	0	ins	ins	ins	387500	ins	267000	405000	405000
Aluminum	4	0	ins	ins	ins	4.4	ins	0.16	9.0	2.1
Antimony	4	1	ins	ins	ins	0.033	ins	< 0.0080	0.046	0.019
Arsenic	4	0	ins	ins	ins	0.81	ins	0.34	3.8	0.65
Barium	4	0	ins	ins	ins	88	ins	45	205	47
Beryllium	4	1	ins	ins	ins	0.025	ins	< 0.010	0.030	0.10
Bismuth	3	2	ins	ins	ins	< 0.040	ins	< 0.040	0.040	< 0.040
Boron	4	0	ins	ins	ins	79	ins	45	117	59
Bromide	4	4	ins	ins	ins	< 0.20	ins	< 0.20	< 0.20	< 0.20
Cadmium	4	1	ins	ins	ins	0.080	ins	< 0.020	0.27	0.090
Calcium	4	0	ins	ins	ins	94815	ins	61786	117640	89046
Cesium	3	1	ins	ins	ins	0.020	ins	< 0.010	0.040	0.020
Chloride	4	0	ins	ins	ins	1445	ins	770	2620	1310
Chromium	4	0	ins	ins	ins	0.27	ins	0.16	0.49	0.27
Cobalt	4	0	ins	ins	ins	0.72	ins	0.62	4.9	0.72
Copper	4	2	ins	ins	ins	7.5	ins	< 5.5	12	10
Dissolved oxygen	4	4	ins	ins	ins	< 300	ins	< 300	< 300	< 300
Eh	4	0	ins	ins	ins	176	ins	98	280	207
Fluoride	4	0	ins	ins	ins	245	ins	210	280	245
Iron	4	0	ins	ins	ins	2484	ins	596	4427	1005
Lead	4	0	ins	ins	ins	0.56	ins	0.070	1.7	0.88
Lithium	4	0	ins	ins	ins	10	ins	5.2	16	10
Magnesium	4	0	ins	ins	ins	35920	ins	20498	41566	32668
Manganese	4	0	ins	ins	ins	255	ins	49	549	136

Table A.5 continued.

Chemical	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	90 or 95h percentile	Min	Max	State Median
Mercury	1	1	ins	ins	ins	< 0.10	ins	< 0.10	< 0.10	< 0.10
Molybdenum	4	4	ins	ins	ins	< 4.2	ins	< 4.2	< 4.2	< 4.2
Nickel	4	2	ins	ins	ins	6.2	ins	< 6.0	11	< 6.0

Nitrate-N	4	4	ins	ins	ins	< 500	ins	< 500	< 500	<500
pH	4	0	ins	ins	ins	7.15	ins	7.01	7.71	7.27
Phosphorus	4	0	ins	ins	ins	47	ins	41	75	57
Potassium	4	0	ins	ins	ins	2913	ins	2444	3879	2564
Rubidium	4	3	ins	ins	ins	< 555.2	ins	< 555.2	631	< 555.5
Selenium	4	2	ins	ins	ins	1.7	ins	< 1.0	3.0	< 1.0
Silicate	4	0	ins	ins	ins	7456	ins	6583	10528	7059
Silver	4	1	ins	ins	ins	0.041	ins	< 0.0090	0.045	0.025
Sodium	4	0	ins	ins	ins	24150	ins	7895	44670	9965
Specific Conductance	4	0	ins	ins	ins	737	ins	465	982	651
Strontium	4	0	ins	ins	ins	281	ins	182	365	224
Sulfate	4	0	ins	ins	ins	63645	ins	1740	155640	8155
Sulfur	4	0	ins	ins	ins	21557	ins	567	56818	8333
Temperature	4	0	ins	ins	ins	10.5	ins	9.20	13.0	10.3
Thallium	4	1	ins	ins	ins	0.027	ins	< 0.0050	0.18	0.027
Tin	3	1	ins	ins	ins	0.050	ins	< 0.040	0.090	0.090
Titanium	4	3	ins	ins	ins	< 0.0035	ins	< 0.0035	0.0041	< 0.0035
Total dissolved solids	4	0	ins	ins	ins	464000	ins	272000	692000	373000
Total organic carbon	4	0	ins	ins	ins	1950	ins	1000	3200	1654
Total phosphate-P	4	0	ins	ins	ins	20	ins	10	40	30
Total suspended solids	4	0	ins	ins	ins	7500	ins	4000	11000	5000
Vanadium	4	0	ins	ins	ins	7.6	ins	4.6	11	6.7
Zinc	4	0	ins	ins	ins	118	ins	33	1132	56
Zirconium	3	2	ins	ins	ins	< 0.030	ins	< 0.030	0.040	< 0.030

Table A.6 : Descriptive statistics for the Jordan aquifer (CJDN).

Chemical	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	90 or 95th percent.	Min	Max	State Median
				ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
Alkalinity	11	0	normal	265500	346516	223000	453600	126000	467000	250000
Aluminum	10	1	log-censored	2.0	5.9	2.3	4.5	< 0.060	4.6	1.0
Antimony	10	4	log-censored	0.024	0.090	0.023	0.058	< 0.0080	0.059	0.0090
Arsenic	10	0	log-normal	0.78	1.9	0.71	10	0.15	11	0.58
Barium	11	0	normal	56	98	29	180	1.8	206	23
Beryllium	10	7	log-censored	0.0052	0.026	< 0.010	0.019	< 0.10	0.020	< 0.10
Bismuth	8	7	ins	-	-	< 0.040	0.080	< 0.040	0.080	< 0.040
Boron	11	2	log-censored	32	303	23	175	< 13	194	19
Bromide	11	11	ins	-	-	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20
Cadmium	10	1	log-censored	0.072	0.21	0.075	0.16	< 0.020	0.16	0.060
Calcium	11	0	normal	67526	88306	62713	107880	14031	109630	63229
Cesium	8	3	log-censored	0.0094	0.042	0.010	0.030	< 0.010	0.030	0.010

Table A.6 continued.

Chemical	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	90 or 95th percent.	Min	Max	State Median
Chloride	11	0	log-normal	1383	2852	820	9794	530	11020	950
Chromium	10	2	log-censored	0.48	5.6	0.46	2.7	< 0.050	2.9	0.59
Cobalt	10	0	normal	0.66	0.93	0.66	1.4	0.14	1.5	0.41

Copper	11	5	log-censored	5.3	74	5.9	57	< 5.5	68	8.1
Dissolved oxygen	11	7	log-censored	136	14625	< 300	6242	< 300	7510	500
Eh	11	0	normal	94	156	96	277	-1.02	281	199
Fluoride	3	0	ins	-	-	330	-	240	530	290
Iron	11	1	log-censored	5.7	36	345	2623	< 3.2	2661	246
Lead	10	0	normal	0.57	1.2	0.32	2.7	0.070	2.9	0.40
Lithium	11	4	log-censored	54	823	5.5	24	< 4.5	26	< 4.5
Magnesium	11	0	normal	26564	35745	22886	46730	3954	47548	23845
Manganese	11	2	log-censored	2.9	15	46	394	< 0.90	419	27
Mercury	2	2	ins	ins	ins	< 0.10	-	< 0.10	< 0.10	< 0.10
Molybdenum	11	7	log-censored	29	313	< 4.2	9.7	< 4.2	10	< 4.2
Nickel	11	9	ins	ins	ins	< 6.0	8.9	< 6.0	9.2	< 6.0
Nitrate-N	11	10	ins	ins	ins	< 500	7458	< 500	9200	< 500
pH	11	0	normal	7.37	7.52	7.43	7.64	6.99	7.65	7.34
Phosphorus	11	0	log-normal	38	72	32	215	15	242	25
Potassium	11	0	normal	1974	2931	1312	4494	899	4610	990
Rubidium	11	10	ins	ins	ins	< 555.2	578	< 555.2	584	< 555.2
Selenium	10	6	log-censored	0.48	13	< 1.0	5.5	< 1.0	5.7	1.0
Silicate	11	0	normal	8135	9496	7964	10900	5901	11056	7971
Silver	10	2	log-censored	0.030	0.19	0.036	0.14	< 0.0090	0.14	< 0.0090
Sodium	11	0	log-normal	6877	14119	3476	47729	2248	51209	2497
Specific Conductance	11	0	log-normal	0.60	0.68	492	923	240	951	492
Strontium	11	0	normal	158	256	95	439	39	489	69
Sulfate	11	0	log-normal	13759	34634	18570	93006	1260	108750	6160
Sulfur	11	0	log-normal	6222	14866	6580	36726	947	38858	6607
Temperature	11	0	normal	10.1	10.3	10.1	10.7	9.6	10.8	9.8
Thallium	10	2	log-censored	0.018	0.35	0.017	0.27	< 0.0050	0.30	0.018
Tin	8	4	log-censored	0.052	0.19	0.045	0.14	< 0.040	0.14	0.045
Titanium	11	9	ins	ins	ins	< 0.0035	0.0049	< 0.0035	0.0049	< 0.0035
Total dissolved solids	11	0	normal	330000	437586	284000	595200	148000	614000	288000
Total organic carbon	11	0	normal	1330	2004	900	3180	600	3300	1500
Total phosphate-P	11	6	log-censored	8.9	301	< 20	178	< 20	210	20
Total suspended solids	11	0	none	-	-	1000	7800	1000	8000	3000
Vanadium	11	6	log-censored	6.3	16	< 4.7	11	< 4.7	12	< 4.7
Zinc	11	0	log-normal	42	90	38	299	7.2	299	51
Zirconium	8	6	ins	ins	ins	< 0.030	0.070	< 0.030	0.070	< 0.030

Table A.7 : Descriptive statistics for the Mt. Simon aquifer (CMTS).

Chemical	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	90 or 95th percentile	Min	Max	State Median
								ug/L	ug/L	ug/L
Alkalinity	2	0	ins	ins	ins	ins	ins	311000	432000	257000
Aluminum	2	0	ins	ins	ins	ins	ins	0.17	3.5	0.53
Antimony	2	1	ins	ins	ins	ins	ins	< 0.0080	0.038	0.016
Arsenic	2	0	ins	ins	ins	ins	ins	0.39	2.8	1.6
Barium	2	0	ins	ins	ins	ins	ins	66	276	57
Beryllium	2	1	ins	ins	ins	ins	ins	< 0.010	0.020	< 0.010
Bismuth	1	1	ins	ins	ins	ins	ins	< 0.030	-	< 0.030
Boron	2	0	ins	ins	ins	ins	ins	128	140	33
Bromide	2	2	ins	ins	ins	ins	ins	< 0.20	< 0.20	< 0.20
Cadmium	2	2	ins	ins	ins	ins	ins	< 0.020	< 0.020	< 0.020
Calcium	2	0	ins	ins	ins	ins	ins	76615	98638	76615
Cesium	1	1	ins	ins	ins	ins	ins	< 0.050	-	0.025
Chloride	2	0	ins	ins	ins	ins	ins	1060	4600	1010
Chromium	2	1	ins	ins	ins	ins	ins	< 0.050	2.6	0.31
Cobalt	2	0	ins	ins	ins	ins	ins	0.42	0.68	0.60
Copper	2	1	ins	ins	ins	ins	ins	< 5.5	6.3	< 5.5
Dissolved oxygen	2	2	ins	ins	ins	ins	ins	< 300	< 300	< 300
Eh	2	0	ins	ins	ins	ins	ins	19	125	79
Fluoride	2	0	ins	ins	ins	ins	ins	230	370	280
Iron	2	0	ins	ins	ins	ins	ins	3705	1150	1259
Lead	2	0	ins	ins	ins	ins	ins	0.090	0.71	0.20
Lithium	2	0	ins	ins	ins	ins	ins	9.8	10	< 4.5
Magnesium	2	0	ins	ins	ins	ins	ins	41173	32379	26883
Manganese	2	0	ins	ins	ins	ins	ins	28	63	100
Mercury	1	1	ins	ins	ins	ins	ins	< 0.10	-	< 0.10
Molybdenum	2	2	ins	ins	ins	ins	ins	< 4.2	< 4.2	< 4.2
Nickel	2	2	ins	ins	ins	ins	ins	< 6.0	< 6.0	< 6.0
Nitrate-N	2	2	ins	ins	ins	ins	ins	< 500	< 500	< 500
pH	2	0	ins	ins	ins	ins	ins	7.37	7.37	7.30
Phosphorus	2	0	ins	ins	ins	ins	ins	64	558	64
Potassium	2	0	ins	ins	ins	ins	ins	2816	4703	1700
Rubidium	2	2	ins	ins	ins	ins	ins	< 555.2	< 555.2	< 555.2
Selenium	2	1	ins	ins	ins	ins	ins	< 1.0	1.0	2.4
Silicate	2	0	ins	ins	ins	ins	ins	5135	9010	8567
Silver	2	1	ins	ins	ins	ins	ins	< 0.0090	0.41	< 0.0090
Sodium	2	0	ins	ins	ins	ins	ins	28967	56059	8085
Specific Conductance	2	0	ins	ins	ins	ins	ins	700	991	661
Strontium	2	0	ins	ins	ins	ins	ins	453	499	159
Sulfate	2	0	ins	ins	ins	ins	ins	58440	117930	2450
Sulfur	2	0	ins	ins	ins	ins	ins	21926	39931	2732
Temperature	2	0	ins	ins	ins	ins	ins	9.3	9.4	9.6
Thallium	2	0	ins	ins	ins	ins	ins	0.0060	0.0080	0.0060
Tin	1	1	ins	ins	ins	ins	ins	< 0.040	-	0.10
Titanium	2	2	ins	ins	ins	ins	ins	< 0.0035	< 0.0035	< 0.0035
Total dissolved solids	2	0	ins	ins	ins	ins	ins	446000	642000	374000
Total organic carbon	2	0	ins	ins	ins	ins	ins	2300	3700	2000
Total phosphate-P	2	0	ins	ins	ins	ins	ins	40	710	40
Total suspended solids	2	0	ins	ins	ins	ins	ins	6000	6000	5000
Vanadium	2	1	ins	ins	ins	ins	ins	< 4.7	5.3	< 4.7

Table A.7 continued.

Chemical	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	90 or 95th percentile	Min	Max	State Median
Zinc	2	0	ins	ins	ins	ins	ins	6.7	93	14
Zirconium	1	1	ins	ins	ins	ins	ins	< 0.030	-	< 0.030

Table A.8 : Descriptive statistics for the St. Lawrence-Franconia aquifer (CSLF).

Chemical	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	90 or 95th percentile	Min	Max	State median
						ug/L		ug/L	ug/L	ug/L
Alkalinity	4	0	ins	ins	ins	257500	ins	181000	416000	257500
Aluminum (Al)	4	1	ins	ins	ins	1.2	ins	< 0.060	4.2	1.2
Antimony (Sb)	4	2	ins	ins	ins	0.012	ins	< 0.0080	0.026	0.012
Arsenic (As)	4	0	ins	ins	ins	3.9	ins	0.84	14	3.9
Barium (Ba)	4	0	ins	ins	ins	115	ins	20	212	115
Beryllium (Be)	4	4	ins	ins	ins	< 0.010	ins	< 0.010	< 0.010	< 0.010
Bismuth (Bi)	3	3	ins	ins	ins	< 0.040	ins	< 0.040	< 0.040	< 0.040
Boron (B)	4	2	ins	ins	ins	25	ins	< 13	279	25
Bromide (Br)	4	4	ins	ins	ins	< 0.20	ins	< 0.20	< 0.20	< 0.20
Cadmium (Cd)	4	1	ins	ins	ins	0.045	ins	< 0.020	0.11	0.045
Calcium (Ca)	4	0	ins	ins	ins	83603	ins	53769	111650	83603
Cesium (Cs)	3	2	ins	ins	ins	< 0.010	ins	< 0.010	0.020	< 0.010
Chloride (Cl)	4	0	ins	ins	ins	6580	ins	740	18340	6580
Chromium (Cr)	4	0	ins	ins	ins	0.15	ins	0.070	2.3	0.15
Cobalt (Co)	4	0	ins	ins	ins	0.67	ins	0.32	1.3	0.67
Copper (Cu)	4	1	ins	ins	ins	17	ins	< 5.5	40	17
Dissolved Oxygen	4	4	ins	ins	ins	< 300	ins	< 300	250	< 300
Eh	4	0	ins	ins	ins	53	ins	-201	249	53
Fluoride (F)	4	3	ins	ins	ins	380	ins	-	-	380
Iron (Fe)	4	0	ins	ins	ins	1863	ins	865	5114	1863
Lead (Pb)	4	0	ins	ins	ins	0.22	ins	0.19	0.55	0.22
Lithium (Li)	4	1	ins	ins	ins	11	ins	< 4.5	14	11
Magnesium (Mg)	4	0	ins	ins	ins	28739	ins	13069	44450	28739
Manganese (Mn)	4	0	ins	ins	ins	282	ins	80	938	282
Mercury (Hg)	1	1	ins	ins	ins	< 0.10	ins	< 0.10	< 0.10	< 0.10
Molybdenum (Mo)	4	4	ins	ins	ins	< 4.2	ins	< 4.2	< 4.2	<4.2
Nickel (Ni)	4	4	ins	ins	ins	< 6.0	ins	< 6.0	< 6.0	< 6.0
Nitrate (NO_3)	4	4	ins	ins	ins	< 500	ins	< 500	< 500	< 500
pH	4	0	ins	ins	ins	7.45	ins	7.26	7.66	7.45
$Phosphorus_{total}$	4	0	ins	ins	ins	117	ins	35	254	117
Potassium (K)	4	0	ins	ins	ins	1935	ins	900	3604	1935
Rubidium (Rb)	4	4	ins	ins	ins	< 555.2	ins	< 555.2	< 555.2	< 555.2
Selenium (Se)	4	1	ins	ins	ins	1.0	ins	< 1.0	8.1	1.0
Silcate (Si)	4	0	ins	ins	ins	12104	ins	7018	15416	12104
Silver (Ag)	4	2	ins	ins	ins	0.010	ins	< 0.0090	0.013	0.010
Sodium (Na)	4	0	ins	ins	ins	5258	ins	3232	79743	5258
Specific Conductance	4	0	ins	ins	ins	611	ins	384	1063	611
Strontium (Sr)	4	0	ins	ins	ins	165	ins	63	420	165
Sulfate (SO_4)	4	0	ins	ins	ins	22850	ins	2270	61440	22850
Sulfur (S)	4	0	ins	ins	ins	23610	ins	2630	63876	23610
Temperature	4	0	ins	ins	ins	10.5	ins	9.5	11.4	10.5
Thallium (Tl)	4	0	ins	ins	ins	0.015	ins	0.0060	0.022	0.015

Table A.8 continued.

Chemical	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	90 or 95th percentile	Min	Max	State median
Tin (Sn)	3	0	ins	ins	ins	0.070	ins	0.040	0.11	0.070
Titanium (Ti)	4	3	ins	ins	ins	< 0.0035	ins	< 0.0035	0.0045	< 0.0035
Total dissolved solids	4	0	ins	ins	ins	384000	ins	248000	708000	384000
Total organic carbon	4	0	ins	ins	ins	2000	ins	1400	2700	2000
Total phosphate	4	1	ins	ins	ins	90	ins	< 20	210	90
Total suspended solids	4	0	ins	ins	ins	4500	ins	3000	13000	4500
Vanadium (V)	4	2	ins	ins	ins	5.3	ins	< 4.7	9.4	5.3
Zinc (Zn)	4	0	ins	ins	ins	27	ins	6.3	60	27
Zirconium (Zr)	3	3	ins	ins	ins	< 0.030	ins	< 0.030	< 0.030	< 0.030

Table A.9 : Descriptive statistics for the St. Lawrence aquifer (CSTL).

Chemical	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	90 or 95th percentile	Min	Max	State Median
								ug/L	ug/L	ug/L
Alkalinity	2	0	ins	ins	ins	ins	ins	181000	470000	450500
Aluminum	2	0	ins	ins	ins	ins	ins	2.5	7.9	2.0
Antimony	2	1	ins	ins	ins	ins	ins	< 0.0080	0.12	0.065
Arsenic	2	0	ins	ins	ins	ins	ins	0.12	14	4.6
Barium	2	0	ins	ins	ins	ins	ins	8.9	270	37
Beryllium	2	1	ins	ins	ins	ins	ins	< 0.010	0.010	< 0.010
Bismuth	2	2	ins	ins	ins	ins	ins	< 0.040	< 0.040	< 0.040
Boron	2	0	ins	ins	ins	ins	ins	14	89	142
Bromide	2	2	ins	ins	ins	ins	ins	< 0.20	< 0.20	< 0.20
Cadmium	2	0	ins	ins	ins	ins	ins	0.050	0.17	0.085
Calcium	2	0	ins	ins	ins	ins	ins	48461	113880	97724
Cesium	2	1	ins	ins	ins	ins	ins	< 0.010	0.040	0.025
Chloride	2	0	ins	ins	ins	ins	ins	1070	1460	970
Chromium	2	0	ins	ins	ins	ins	ins	0.20	0.76	0.13
Cobalt	2	0	ins	ins	ins	ins	ins	0.45	0.71	0.77
Copper	2	0	ins	ins	ins	ins	ins	8.0	32	20
Dissolved oxygen	2	1	ins	ins	ins	ins	ins	< 300	750	375
Eh	2	0	ins	ins	ins	ins	ins	211	217	208
Iron	2	0	ins	ins	ins	ins	ins	62	6296	3385
Lead	2	0	ins	ins	ins	ins	ins	0.91	52	2.7
Lithium	2	0	ins	ins	ins	ins	ins	7.0	7.2	15
Magnesium	2	0	ins	ins	ins	ins	ins	18197	46441	39958
Manganese	2	0	ins	ins	ins	ins	ins	19	139	61
Molybdenum	2	1	ins	ins	ins	ins	ins	< 4.2	5.40	< 4.2
Nickel	2	0	ins	ins	ins	ins	ins	6.1	7.3	6.0
Nitrate-N	2	1	ins	ins	ins	ins	ins	< 500	1500	< 500
pH	2	0	ins	ins	ins	ins	ins	7.14	7.50	7.21
Phosphorus	2	0	ins	ins	ins	ins	ins	15	306	64
Potassium	2	0	ns	ns	ns	ns	ns	1123	3282	3367
Rubidium	2	2	ins	ins	ins	ins	ins	< 555.2	< 555.2	< 555.2

Table A.9 continued.

Chemical	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	90 or 95th percentile	Min	Max	State Median
Selenium	2	2	ins	ins	ins	ins	ins	< 1.0	< 1.0	1.0
Silicate	2	0	ins	ins	ins	ins	ins	6858	10731	11639
Silver	2	0	ins	ins	ins	ins	ins	0.010	0.017	0.014
Sodium	2	0	ins	ins	ins	ins	ins	2679	11549	26940
Specific Conductance	2	0	ins	ins	ins	ins	ins	368	808	0.81
Strontium	2	0	ins	ins	ins	ins	ins	59	420	381
Sulfate	2	0	ins	ins	ins	ins	ins	8580	13500	12020
Sulfur	2	0	ins	ins	ins	ins	ins	3016	5106	15416
Temperature	2	0	ins	ins	ins	ins	ins	9.1	10.3	9.7
Thallium	2	1	ins	ins	ins	ins	ins	< 0.0050	0.022	0.018
Tin	2	1	ins	ins	ins	ins	ins	< 0.040	0.93	0.48
Titanium	2	2	ins	ins	ins	ins	ins	< 0.0035	< 0.0035	< 0.0035
Total dissolved solids	2	0	ins	ins	ins	ins	ins	208000	520000	518000
Total organic carbon	2	0	ins	ins	ins	ins	ins	400	2600	2650
Total Phosphate	2	1	ins	ins	ins	ins	ins	< 20	260	35
Total suspended solids	2	0	ins	ins	ins	ins	ins	1000	15000	8000
Vanadium	2	0	ins	ins	ins	ins	ins	9.0	9.7	7.2
Zinc	2	0	ins	ins	ins	ins	ins	146	345	245
Zirconium	2	1	ins	ins	ins	ins	ins	< 0.030	0.050	0.035

Table A.10 : Descriptive statistics for the Prairie du Chien (OPDC).

Chemical	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	90 or 95th percentile	Min	Max	State Median
				ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
Alkalinity	10	0	normal	248000	316365	249500	413000	111000	413000	469000
Aluminum	9	0	normal	5.3	8.5	4.4	15	0.92	15	0.93
Antimony	9	2	log-censored	0.033	0.21	0.040	0.12	< 0.0080	0.12	0.023
Arsenic	9	1	log-censored	0.51	6.6	0.45	2.6	< 0.060	2.6	0.46
Barium	10	0	normal	95	158	70	250	5.1	259	60
Beryllium	9	8	ins	ins	ins	< 0.010	0.020	< 0.010	0.020	< 0.010
Bismuth	9	2	log-censored	20	40	< 0.040	< 0.040	< 0.040	< 0.040	< 0.040
Boron	10	0	normal	21	26	21	30	12	30	30
Bromide	10	10	ins	ins	ins	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20
Cadmium	9	2	log-censored	0.054	0.18	0.050	0.15	< 0.020	0.15	0.075
Calcium	10	0	normal	79963	94779	78942	112508	55461	113540	80176
Cesium	9	0	normal	0.026	0.032	0.030	0.040	0.010	0.040	0.030
Chloride	10	0	log-normal	11752	29833	9615	124461	2250	133280	2645
Chromium	9	2	log-censored	0.35	3.5	0.30	2.2	< 0.050	2.2	0.26
Cobalt	9	0	none	-	-	0.53	4.8	0.28	4.8	0.44
Copper	10	4	log-censored	6.7	16	6.1	12	< 5.5	12	6.1
Dissolved oxygen	10	4	log-censored	1899	12636	1820	6514	< 300	6550	920
Eh	10	0	none	-	-	263	327	-30	329	251
Fluoride	2	0	ins	ins	ins	210	-	210	210	285
Iron	10	0	log-normal	115	522	35	1975	5.8	2114	487
Lead	9	0	normal	0.35	0.58	0.21	0.92	0.060	0.92	0.50

Table A.10 continued.

Chemical	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	90 or 95th percentile	Min	Max	State Median
Lithium	10	4	log-censored	5.6	17	5.8	14	< 4.5	15	7.7
Magnesium	10	0	log-normal	29792	38574	26492	56074	20452	57023	26492
Manganese	10	5	log-censored	5.9	4909	0.90	434	< 0.90	451	23
Molybdenum	10	10	ins	ins	ins	< 4.2	< 4.2	< 4.2	< 4.2	< 4.2
Nickel	10	8	ins	ins	ins	< 6.0	9.5	< 6.0	10	< 6.0
Nitrate-N	10	4	log-censored	1547	30911	1650	14920	< 500	15700	< 500
pH	10	0	normal	7.39	7.56	7.46	7.67	7.00	7.68	7.25
Phosphorus	10	0	log-normal	36	69	31	150	15	151	34
Potassium	10	0	log-normal	1997	3284	1728	7778	900	8327	1700
Rubidium	10	10	ins	ins	ins	< 555.2	< 555.2	< 555.2	< 555.2	< 555.2
Selenium	9	5	log-censored	0.77	4.1	< 1.0	2.6	< 1.0	2.6	1.0
Silicate	10	0	normal	9957	11780	10321	15623	7044	15782	8419
Silver	9	0	normal	0.058	0.093	0.049	0.13	0.011	0.13	< 0.0090
Sodium	10	0	log-normal	5001	8610	4929	23381	2325	25168	5763
Specific Conductance	10	0	normal	631	777	590	1038	430	1100	597
Strontium	10	0	normal	137	207	103	329	61	341	13
Sulfate	10	0	normal	23660	32804	22425	45774	6720	47220	8750
Sulfur	10	0	log-normal	8228	14365	7777	28004	2560	29305	9508
Temperature	10	0	normal	10.1	10.4	10.0	10.9	9.5	10.9	9.5
Thallium	9	2	log-censored	0.017	0.31	0.017	0.15	< 0.0050	0.15	0.0095
Tin	9	4	log-censored	0.055	0.37	0.050	0.19	< 0.040	0.19	0.050
Titanium	10	9	ins	ins	ins	< 0.0035	0.0038	< 0.0035	0.0038	< 0.0035
Total dissolved solids	10	0	normal	402444	488915	395000	621600	274000	636000	370500
Total organic carbon	10	0	log-normal	1350	1898	1500	2090	600	2100	2400
Total phosphate-P	10	4	log-censored	18	181	20	114	< 20	120	20
Total suspended solids	10	0	normal	2778	4443	1500	6800	1000	7000	2000
Vanadium	10	3	log-censored	5.8	15	5.6	11	< 4.7	11	4.9
Zinc	10	0	normal	43	71	34	112	6.6	116	749
Zirconium	9	8	ins	ins	ins	< 0.030	0.040	< 0.030	0.040	< 0.030

Table A.11 : Descriptive statistics for the Platteville aquifer (OPVL).

Chemical	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	90 or 95th percentile	Min	Max	State Median
								ug/L	ug/L	ug/L
Alkalinity	2	0	ins	ins	ins	ins	ins	329000	354000	329000
Aluminum	2	0	ins	ins	ins	ins	ins	1.3	5.3	1.3
Antimony	2	1	ins	ins	ins	ins	ins	< 0.0080	0.04	0.040
Arsenic	2	1	ins	ins	ins	ins	ins	< 0.060	4.2	4.2
Barium	2	0	ins	ins	ins	ins	ins	138	173	173
Beryllium	2	2	ins	ins	ins	ins	ins	< 0.010	< 0.010	< 0.010
Bismuth	2	2	ins	ins	ins	ins	ins	< 0.040	< 0.040	0.050
Boron	2	0	ins	ins	ins	ins	ins	30	85	30
Bromide	2	2	ins	ins	ins	ins	ins	< 0.20	< 0.20	< 0.20

Table A.11 continued.

Chemical	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	90 or 95th percentile	Min	Max	State Median
Cadmium	2	1	ins	ins	ins	ins	ins	< 0.020	0.050	0.020
Calcium	2	0	ins	ins	ins	ins	ins	52628	93202	79425
Cesium	2	1	ins	ins	ins	ins	ins	< 0.010	0.020	0.015
Chloride	2	0	ins	ins	ins	ins	ins	12740	17510	12741
Chromium	2	1	ins	ins	ins	ins	ins	< 0.050	0.10	< 0.050
Cobalt	2	0	ins	ins	ins	ins	ins	0.41	1.2	0.46
Copper	2	1	ins	ins	ins	ins	ins	< 5.5	121	17
Dissolved oxygen	2	2	ins	ins	ins	ins	ins	< 300	< 300	< 300
Eh	2	0	ins	ins	ins	ins	ins	56	106	100
Fluoride	2	0	ins	ins	ins	ins	ins	230	270	230
Iron	2	0	ins	ins	ins	ins	ins	672	752	733
Lead	2	0	ins	ins	ins	ins	ins	0.44	0.96	0.44
Lithium	2	1	ins	ins	ins	ins	ins	< 4.5	7.3	6.8
Magnesium	2	0	ins	ins	ins	ins	ins	43458	52490	43458
Manganese	2	0	ins	ins	ins	ins	ins	27	305	186
Molybdenum	2	2	ins	ins	ins	ins	ins	< 4.2	< 4.2	4.7
Nickel	2	1	ins	ins	ins	ins	ins	< 6.0	10	< 6.0
Nitrate-N	2	2	ins	ins	ins	ins	ins	< 500	< 500	< 500
pH	2	0	ins	ins	ins	ins	ins	7.15	7.67	7.30
Phosphorus	2	0	ns	ns	ns	ns	ns	38	76	61
Potassium	2	0	ins	ins	ins	ins	ins	2156	3063	2156
Rubidium	2	2	ins	ins	ins	ins	ins	< 555.2	< 555.2	< 555.2
Selenium	2	1	ins	ins	ins	ins	ins	< 1.0	1.0	1.0
Silicate	2	0	ins	ins	ins	ins	ins	14233	14480	14233
Silver	2	0	ins	ins	ins	ins	ins	0.051	0.15	0.051
Sodium	2	0	ins	ins	ins	ins	ins	5931	6690	6690
Specific Conductance	2	0	ins	ins	ins	ins	ins	631	738	631
Strontium	2	0	ins	ins	ins	ins	ins	219	394	239
Sulfate	2	0	ins	ins	ins	ins	ins	5820	16320	5440
Sulfur	2	0	ins	ins	ins	ins	ins	2184	6221	6221
Temperature	2	0	ins	ins	ins	ins	ins	10.4	11.6	10.4
Thallium	2	1	ins	ins	ins	ins	ins	< 0.0050	0.059	0.017
Tin	2	1	ins	ins	ins	ins	ins	< 0.040	0.20	0.12
Titanium	2	1	ins	ins	ins	ins	ins	< 0.0035	0.0052	< 0.0035
Total dissolved solids	2	0	ins	ins	ins	ins	ins	352000	442000	352000
Total organic carbon	2	0	ins	ins	ins	ins	ins	1200	1900	1900
Total phosphate-P	2	0	ins	ins	ins	ins	ins	30	50	50
Total suspended solids	2	0	ins	ins	ins	ins	ins	2000	4000	2000
Vanadium	2	1	ins	ins	ins	ins	ins	< 4.7	13	< 4.7
Zinc	2	0	ins	ins	ins	ins	ins	29	43	29
Zirconium	2	1	ins	ins	ins	ins	ins	< 0.030	0.10	0.060

Table A.12 : Descriptive statistics for St. Peter-Prairie du Chien aquifer (OSPC).

Chemical	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	90 or 95th percentile	Min	Max	State Median
								ug/L	ug/L	ug/L
Alkalinity	2	0	ins	ins	ins	ins	ins	166000	348000	-
Barium (Ba)	2	0	ins	ins	ins	ins	ins	69	76	-
Boron (B)	2	1	ins	ins	ins	ins	ins	< 13	38	-
Bromide (Br)	2	2	ins	ins	ins	ins	ins	< 0.20	< 0.20	-
Calcium (Ca)	2	0	ins	ins	ins	ins	ins	52226	91875	-
Chloride (Cl)	2	0	ins	ins	ins	ins	ins	1720	14800	-
Copper (Cu)	2	1	ins	ins	ins	ins	ins	< 5.5	6.8	-
Dissolved Oxygen	2	1	ins	ins	ins	ins	ins	< 300	530	-
Eh	2	0	ins	ins	ins	ins	ins	75	251	-
Fluoride (F)[3]	2	1	ins	ins	ins	ins	ins	270	270	-
Iron (Fe)	2	0	ins	ins	ins	ins	ins	171	732	-
Lithium (Li)	2	1	ins	ins	ins	ins	ins	< 4.5	12	-
Magnesium (Mg)	2	0	ins	ins	ins	ins	ins	15933	36858	-
Manganese (Mn)	2	0	ins	ins	ins	ins	ins	365	398	-
Molybdenum (Mo)	2	2	ins	ins	ins	ins	ins	< 4.2	< 4.2	-
Nickel (Ni)	2	2	ins	ins	ins	ins	ins	< 6.0	< 6.0	-
Nitrate (NO_3)	2	2	ins	ins	ins	ins	ins	< 500	< 500	-
pH	2	0	ins	ins	ins	ins	ins	7.28	7.52	-
$Phosphorus_{total}$	2	0	ins	ins	ins	ins	ins	35	76	-
Potassium (K)	2	0	ins	ins	ins	ins	ins	1663	2809	-
Rubidium (Rb)	2	2	ins	ins	ins	ins	ins	< 555.2	< 555.2	-
Silcate (Si)	2	0	ins	ins	ins	ins	ins	6839	11788	-
Sodium (Na)	2	0	ins	ins	ins	ins	ins	3478	5424	-
Specific Conductance	2	0	ins	ins	ins	ins	ins	400	662	-
Strontium (Sr)	2	0	ins	ins	ins	ins	ins	68	260	-
Sulfate (SO_4)	2	0	ins	ins	ins	ins	ins	4000	11320	-
Sulfur (S)	2	0	ins	ins	ins	ins	ins	4310	11205	-
Temperature	2	0	ins	ins	ins	ins	ins	10.0	11.0	-
Titanium (Ti)	2	2	ins	ins	ins	ins	ins	< 0.0035	< 0.0035	-
Total dissolved solids	2	0	ins	ins	ins	ins	ins	288000	474000	-
Total organic carbon	2	0	ins	ins	ins	ins	ins	1000	2400	-
Total phosphate	2	0	ins	ins	ins	ins	ins	40	70	-
Total suspended solids	2	0	ins	ins	ins	ins	ins	2000	3000	-
Vanadium (V)	2	2	ins	ins	ins	ins	ins	< 4.7	< 4.7	-
Zinc (Zn)	2	0	ins	ins	ins	ins	ins	11	73	-

Table A.13 : Descriptive statistics for the St. Peter aquifer (OSTP).

Chemical	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	90 or 95th percentile	Min	Max	State Median
				ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
Alkalinity	9	0	normal	279444	346701	284000	399000	164000	399000	242000
Aluminum	9	0	normal	4.4	5.3	4.8	5.7	2.4	6	2.1
Antimony	9	3	log-censored	0.016	0.12	0.013	0.057	< 0.0080	0.057	0.0080
Arsenic	9	0				0.49	4.3	< 0.060	4.3	0.53
Barium	9	0	normal	86	130	91	165	5.4	165	52
Beryllium	9	6	ins	ins	ins	< 0.010	0.020	< 0.010	0.020	< 0.010
Bismuth	9	9	ins	ins	ins	< 0.040	< 0.040	< 0.040	< 0.040	< 0.040
Boron	9	2	log-censored	23	172	23	167	< 13	167	42
Bromide	9	9	ins	ins	ins	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20
Cadmium	9	1	log-censored	0.050	0.16	0.060	0.11	< 0.020	0.11	0.080
Calcium	9	0	normal	74423	82935	76373	88406	52866	88406	72852
Cesium	9	5	log-censored	0.018	0.038	< 0.010	0.030	< 0.010	0.030	< 0.010
Chloride	9	0	normal	5790	9599	4370	15480	780	15480	1230
Chromium	9	2	log-censored	0.35	3.5	0.39	1.8	< 0.050	1.8	0.15
Cobalt	9	0	normal	0.81	1.2	0.54	1.7	0.31	1.7	0.48
Copper	9	4	log-censored	10	36	8.9	25	< 5.5	25	10
Dissolved oxygen	9	7	ins	ins	ins	< 300	7480	< 300	7480	470
Eh	9	0	none	-	-	21	281	-47	281	249
Fluoride	2	0	ins	-	-	240	270	210	270	310
Iron	9	0	normal	570	996	443	1474	6.0	1474	384
Lead	9	0	normal	0.17	0.24	0.14	0.31	0.040	0.31	0.25
Lithium	9	4	log-censored	7.1	22	4.8	14	< 4.5	14	7.9
Magnesium	9	0	normal	29963	37780	26465	44471	18386	44471	23382
Manganese	9	2	log-censored	78	4879	201	1019	< 0.90	1019	31
Molybdenum	9	7	ins	ins	ins	< 4.2	9.0	< 4.2	9.0	< 4.2
Nickel	9	5	log-censored	7.9	14	< 6.0	12	< 6.0	12	< 6.0
Nitrate-N	9	6	log-censored	575	5807	< 500	3300	< 500	3300	< 500
pH	9	0	normal	7.42	7.55	7.45	7.64	7.12	7.64	7.25
Phosphorus	9	0	normal	102	149	93	235	28	235	40
Potassium	9	0	normal	2148	2851	1814	3792	1178	3792	1881
Rubidium	9	9	ins	ins	ins	< 555.2	< 555.2	< 555.2	< 555.2	< 555.2
Selenium	9	5	log-censored	0.69	7.1	< 1.0	4.0	< 1.0	4.0	1.0
Silicate	9	0	none	-	-	12145	13969	8281	13970	8458
Silver	9	1	log-censored	0.016	0.079	0.017	0.041	< 0.0090	0.04	< 0.0090
Sodium	9	0	none	-	-	4207	28147	2946	28147	4207
Specific Conductance	9	0	normal	569	658	569	726	380	726	526
Strontium	9	0	normal	141	216	116	383	60	383	143
Sulfate	9	0	normal	15897	22488	15000	25140	3690	25140	8130
Sulfur	9	0	log-normal	5574	11094	5492	29613	1542	29613	8558
Temperature	9	0	none	-	-	10.1	12.1	9.7	12.1	9.8
Thallium	9	2	log-censored	0.013	0.045	0.014	0.034	< 0.0050	0.03	0.0080
Tin	9	7	ins	ins	ins	< 0.040	0.17	< 0.040	0.17	< 0.040
Titanium	9	5	log-censored	0.0035	0.0082	< 0.0035	0.0068	< 0.0035	0.0068	< 0.0035

Table A.13 continued.

Chemical	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	90 or 95th percentile	Min	Max	State Median
Total dissolved solids	9	0	normal	354444	404489	332000	466000	252000	466000	312000
Total organic carbon	9	0	normal	1233	1702	1000	2200	600	2200	1900
Total phosphate-P	9	1	log-censored	56	273	60	190	< 20	190	50
Total suspended solids	9	0	normal	2556	3650	3000	5000	1000	5000	3000
Vanadium	9	3	log-censored	6.4	26	5.2	16	< 4.7	16	4.9
Zinc	9	0	log-normal	17	29	15	65	7.8	65	47
Zirconium	9	7	ins	ins	ins	< 0.030	0.21	< 0.030	0.210	< 0.030

Table A.14 : Descriptive statistics for the Precambrian aquifer (PCUU).

Chemical	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	90 or 95th percentile	Min	Max	State Median
						ug/L				ug/L
Alkalinity	1	0	ins	ins	ins	390000	ins	ins	ins	333000
Aluminum	1	1	ins	ins	ins	< 0.060	ins	ins	ins	< 0.060
Antimony	1	1	ins	ins	ins	< 0.0080	ins	ins	ins	< 0.0080
Arsenic	1	0	ins	ins	ins	2.8	ins	ins	ins	1.4
Barium	1	0	ins	ins	ins	59	ins	ins	ins	12
Beryllium	1	1	ins	ins	ins	< 0.010	ins	ins	ins	< 0.010
Boron	1	0	ins	ins	ins	271	ins	ins	ins	271
Bromide	1	1	ins	ins	ins	< 0.10	ins	ins	ins	< 0.20
Cadmium	1	1	ins	ins	ins	< 0.020	ins	ins	ins	< 0.020
Calcium	1	0	ins	ins	ins	102262	ins	ins	ins	102262
Chloride	1	0	ins	ins	ins	2120	ins	ins	ins	2120
Chromium	1	0	ins	ins	ins	1.5	ins	ins	ins	1.1
Cobalt	1	0	ins	ins	ins	1.0	ins	ins	ins	0.54
Copper	1	0	ins	ins	ins	5.5	ins	ins	ins	5.9
Dissolved oxygen	1	0	ins	ins	ins	1640	ins	ins	ins	1640
Eh	1	0	ins	ins	ins	28	ins	ins	ins	159
Fluoride	1	0	ins	ins	ins	410	ins	ins	ins	410
Iron	1	0	ins	ins	ins	1941	ins	ins	ins	1650
Lead	1	0	ins	ins	ins	0.25	ins	ins	ins	0.11
Lithium	1	0	ins	ins	ins	20	ins	ins	ins	20
Magnesium	1	0	ins	ins	ins	46382	ins	ins	ins	46382
Manganese	1	0	ins	ins	ins	390	ins	ins	ins	241
Mercury	1	1	ins	ins	ins	< 0.10	ins	ins	ins	< 0.10
Molybdenum	1	1	ins	ins	ins	< 4.2	ins	ins	ins	< 4.2
Nickel	1	1	ins	ins	ins	< 6.0	ins	ins	ins	< 6.0
Nitrate-N	1	1	ins	ins	ins	< 500	ins	ins	ins	< 500
pH	1	0	ins	ins	ins	7.22	ins	ins	ins	7.20
Phosphorus	1	0	ins	ins	ins	71	ins	ins	ins	70

Table A.14 continued.

Chemical	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	90 or 95th percentile	Min	Max	State Median
Potassium	1	0	ins	ins	ins	6551	ins	ins	ins	5629
Rubidium	1	1	ins	ins	ins	< 555.2	ins	ins	ins	< 555.2
Selenium	1	0	ins	ins	ins	8.1	ins	ins	ins	2.0
Silicate	1	0	ins	ins	ins	6227	ins	ins	ins	8621
Silver	1	1	ins	ins	ins	< 0.0090	ins	ins	ins	< 0.0090
Sodium	1	0	ins	ins	ins	63903	ins	ins	ins	63903
Specific Conductance	1	0	ins	ins	ins	1018	ins	ins	ins	162
Strontium	1	0	ins	ins	ins	743	ins	ins	ins	743
Sulfate	1	0	ins	ins	ins	174030	ins	ins	ins	58010
Sulfur	1	0	ins	ins	ins	60092	ins	ins	ins	60092
Temperature	1	0	ins	ins	ins	9.6	ins	ins	ins	9.6
Thallium	1	0	ins	ins	ins	0.014	ins	ins	ins	< 0.0050
Titanium	1	1	ins	ins	ins	< 0.0035	ins	ins	ins	< 0.0035
Total dissolved solids	1	0	ins	ins	ins	666000	ins	ins	ins	666000
Total organic carbon	1	0	ins	ins	ins	3400	ins	ins	ins	3000
Total phosphate-P	1	0	ins	ins	ins	40	ins	ins	ins	-
Total suspended solids	1	0	ins	ins	ins	6000	ins	ins	ins	4000
Vanadium	1	0	ins	ins	ins	4.8	ins	ins	ins	5.5
Zinc	1	0	ins	ins	ins	48	ins	ins	ins	8.0

Table A.15 : Descriptive statistics for the Quaternary buried artesian aquifer (QBAA).

Chemical	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	90 or 95th percentile	Min	Max	State Median
				ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
Alkalinity	20	0	normal	330722	388160	323000	558650	121000	565000	328000
Aluminum	18	4	log-censored	1.8	23	2.8	9.3	< 0.060	9.3	0.88
Antimony	18	4	log-censored	0.017	0.096	0.019	0.073	< 0.0080	0.073	0.011
Arsenic	18	0	log-normal	2.1	4.2	2.1	29	0.11	29	2.6
Barium	20	1	log-censored	79	84	79	299	< 1.4	301	61
Beryllium	18	12	log-censored	0.0058	0.035	< 0.010	0.030	< 0.010	0.030	< 0.030
Bismuth	11	11	ins	ins	ins	< 0.040	< 0.040	< 0.040	< 0.040	< 0.040
Boron	20	3	log-censored	41	726	36	558	< 13	576	98
Bromide	20	20	ins	ins	ins	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20
Cadmium	18	8	log-censored	0.030	0.25	0.030	0.19	< 0.020	0.19	< 0.020
Calcium	20	0	normal	83781	92850	85466	116643	45155	116930	79537
Cesium	11	8	log-censored	0.0056	0.046	< 0.010	0.030	< 0.010	0.030	< 0.010
Chloride	20	0	log-normal	3157	6176	2710	37277	450	37640	2320
Chromium	18	7	log-censored	0.32	5.3	0.24	2.6	< 0.050	2.6	0.49
Cobalt	18	0	normal	0.59	0.67	0.58	0.93	0.27	0.93	0.46
Copper	20	8	log-censored	6.0	82	6.4	109	< 5.5	113	< 5.5
Dissolved oxygen	20	16	log-censored	388	10599	< 300	8669	< 300	8900	< 300
Eh	20	0	normal	162	210	195	311	-9	313	158

Table A.15 continued.

Chemical	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	90 or 95th percentile	Min	Max	State Median
Fluoride	8	0	normal	273	320	260	360	200	360	380
Iron	20	0	log-normal	464	1112	481	5729	3.5	5837	1179
Lead	18	0	log-normal	0.24	0.41	0.24	1.6	0.030	1.6	0.18
Lithium	20	3	log-censored	8.9	78	8.6	60	< 4.5	60	14
Magnesium	20	0	normal	33152	38619	34331	49861	13283	50088	30515
Manganese	20	2	log-censored	191	1907	259	1200	< 0.90	1213	131
Mercury	7	7	ins	ins	ins	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
Molybdenum	20	15	log-censored	2.4	14	< 4.2	11	< 4.2	11	< 4.2
Nickel	20	15	log-censored	3.1	15	< 6.0	16	< 6.0	17	< 6.0
Nitrate-N	19	15	log-censored	17	26994	< 500	20800	< 500	20800	< 500
pH	20	0	normal	7.39	7.51	7.40	8.04	7.04	8.07	7.29
Phosphorus	20	0	log-normal	71	98	61	194	24	195	102
Potassium	20	0	normal	2946	3794	2768	7948	828	8099	3068
Rubidium	20	18	ins	ins	ins	< 555.2	1261	< 555.2	< 555.2	< 555.2
Selenium	19	8	log-censored	1.1	11	1.0	9.0	< 1.0	9.0	2.4
Silicate	20	0	normal	11965	13227	11986	16121	7609	16129	11914
Silver	18	6	log-censored	0.042	0.99	0.040	0.40	< 0.0090	0.40	< 0.0090
Sodium	20	0	log-normal	9266	15929	5764	58444	2757	59257	18812
Specific Conductance	20	0	normal	670	753	664	952	350	956	619
Strontium	20	0	normal	266	351	202	629	68	636	304
Sulfate	20	0	none	-	-	24375	93779	270	94020	7300
Sulfur	20	0	none	-	-	9478	1380733	21	1451700	8110
Temperature	20	0	normal	10.0	10.3	10.0	10.9	9.2	10.9	8.9
Thallium	18	11	log-censored	0.0052	0.077	< 0.0050	0.054	< 0.0050	0.054	< 0.0050
Tin	11	4	log-censored	0.063	0.68	0.06	0.56	< 0.040	0.56	0.060
Titanium	20	18	log-censored	0.00013	0.016	< 0.0035	0.012	< 0.0035	0.013	< 0.0035
Total dissolved solids	20	0	normal	431222	485404	443000	611900	256000	614000	430000
Total organic carbon	20	0	normal	2178	2918	1900	6470	500	6600	2600
Total phosphate-P	20	5	log-censored	39	325	40	208	< 20	210	60
Total suspended solids	20	0	normal	4111	5636	2500	10850	1000	11000	5000
Vanadium	20	10	log-censored	4.9	20	4.9	22	< 4.7	23	< 4.7
Zinc	20	0	log-normal	35	64	30	287	5.5	290	13
Zirconium	11	9	ins	ins	ins	< 0.030	0.27	< 0.030	0.27	< 0.030

Table A.16 : Descriptive statistics for the Quaternary buried unconfined aquifer (QBUA).

Chemical	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	90 or 95th percentile	Min	Max	State Median
						ug/L		ug/L	ug/L	ug/L
Alkalinity	5	0	ins	ins	ins	315000	ins	230000	442000	281000
Aluminum	4	0	ins	ins	ins	4.9	ins	1.3	6.2	0.91
Antimony	4	3	ins	ins	ins	< 0.0080	ins	< 0.0080	0.083	0.016
Arsenic	4	0	ins	ins	ins	1.0	ins	0.50	2.7	1.9
Barium	5	0	ins	ins	ins	182	ins	58	485	71
Beryllium	4	4	ins	ins	ins	< 0.010	ins	< 0.010	< 0.010	< 0.010

Table A.16 continued.

Chemical	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	90 or 95th percentile	Min	Max	State Median
Bismuth	4	4	ins	ins	ins	< 0.040	ins	< 0.040	< 0.040	< 0.040
Boron	5	0	ins	ins	ins	37	ins	22	84	23
Bromide	5	5	ins	ins	ins	< 0.20	ins	< 0.20	< 0.20	< 0.20
Cadmium	4	1	ins	ins	ins	0.040	ins	< 0.020	0.070	< 0.020
Calcium	5	0	ins	ins	ins	85053	ins	73412	136040	78821
Cesium	4	2	ins	ins	ins	0.010	ins	< 0.010	0.020	< 0.010
Chloride	5	0	ins	ins	ins	5880	ins	1560	29230	3625
Chromium	4	2	ins	ins	ins	0.070	ins	< 0.050	0.13	0.69
Cobalt	4	0	ins	ins	ins	0.64	ins	0.41	1.2	0.46
Copper	5	1	ins	ins	ins	17	ins	< 5.5	37	< 5.5
Dissolved oxygen	5	3	ins	ins	ins	< 300	ins	< 300	5250	< 300
Eh	5	0	ins	ins	ins	204	ins	55	255	220
Fluoride	2	0	ins	ins	ins	230	ins	220	240	305
Iron	5	0	ins	ins	ins	710	ins	27	7133	367
Lead	4	0	ins	ins	ins	0.42	ins	0.12	0.81	0.19
Lithium	5	0	ins	ins	ins	10	ins	5.0	21	7.1
Magnesium	5	0	ins	ins	ins	32465	ins	23832	48511	26539
Manganese	5	0	ins	ins	ins	502	ins	87	665	152
Molybdenum	5	2	ins	ins	ins	4.6	ins	< 4.2	6.90	< 4.2
Nickel	5	3	ins	ins	ins	< 6.0	ins	< 6.0	8.6	< 6.0
Nitrate-N	5	5	ins	ins	ins	< 500	ins	< 500	< 500	< 500
pH	5	0	ins	ins	ins	7.37	ins	7.09	7.61	7.20
Phosphorus	5	0	ins	ins	ins	58	ins	35	141	57
Potassium	5	0	ins	ins	ins	2620	ins	1613	3560	1796
Rubidium	5	5	ins	ins	ins	< 555.2	ins	< 555.2	< 555.2	< 555.2
Selenium	4	4	ins	ins	ins	< 1.0	ins	< 1.0	< 1.0	3.2
Silicate	5	0	ins	ins	ins	14086	ins	11228	14683	10867
Silver	4	3	ins	ins	ins	< 0.0090	ins	< 0.0090	0.039	< 0.0090
Sodium	5	0	ins	ins	ins	5116	ins	2084	19631	5906
Specific Conductance	5	0	ins	ins	ins	652	ins	567	912	533
Strontium	5	0	ins	ins	ins	207	ins	76	432	112
Sulfate	5	0	ins	ins	ins	38370	ins	22140	61230	5280
Sulfur	5	0	ins	ins	ins	14414	ins	7974	20004	5106
Temperature	5	0	ins	ins	ins	10.5	ins	9.5	10.7	8.8
Thallium	4	1	ins	ins	ins	0.011	ins	< 0.0050	0.015	< 0.030
Tin	4	3	ins	ins	ins	< 0.0040	ins	< 0.0040	0.080	0.060
Titanium	5	4	ins	ins	ins	< 0.0035	ins	< 0.0035	0.0064	< 0.0035
Total dissolved solids	5	0	ins	ins	ins	402000	ins	336000	574000	350000
Total organic carbon	5	0	ins	ins	ins	1500	ins	1200	1900	1900
Total phosphate-P	5	0	ins	ins	ins	40	ins	20	130	40
Total suspended solids	5	0	ins	ins	ins	4000	ins	1000	17000	2000
Vanadium	5	0	ins	ins	ins	7.4	ins	4.6	12	< 4.7
Zinc	5	0	ins	ins	ins	15	ins	8.7	51	12
Zirconium	4	3	ins	ins	ins	< 0.030	ins	< 0.030	0.070	< 0.030

Table A.17 : Descriptive statistics for the Quaternary water table aquifer (QWTA).

Chemical	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	90th percentile	Min	Max	State Median
				ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
Alkalinity	10	0	normal	239667	313021	220000	422600	134000	433000	237500
Aluminum	9	0	normal	4.5	6.0	4.8	7.6	1.3	8.6	1.2
Antimony	9	5	log-censored	0.032	0.087	< 0.0080	0.070	< 0.0080	0.070	0.017
Arsenic	9	0	log-normal	1.1	2.1	0.77	7.6	0.52	7.6	1.3
Barium	10	0	log-normal	94	208	74	787	3.8	787	85
Beryllium	9	5	log-censored	0.0082	0.024	< 0.010	0.020	< 0.010	0.020	< 0.010
Bismuth	9	9	ins	ins	ins	< 0.040	< 0.040	< 0.040	< 0.040	< 0.040
Boron	10	2	log-censored	26	54	25	44	< 13	44	24
Bromide	10	10	ins	ins	ins	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20
Cadmium	9	2	log-censored	0.044	0.29	0.040	0.24	< 0.020	0.24	< 0.020
Calcium	10	0	normal	80507	99570	72638	127010	52014	127010	74237
Cesium	9	5	log-censored	0.012	0.028	< 0.010	0.020	< 0.010	0.020	< 0.010
Chloride	10	0	normal	29242	42745	24980	56000	2140	56000	5810
Chromium	9	3	log-censored	0.11	2.7	0.11	1.3	< 0.050	1.3	0.55
Cobalt	9	0	normal	0.62	0.79	0.60	1.0	0.32	1.0	0.48
Copper	10	2	log-censored	8.8	63	8.8	90	< 5.5	90	6.3
Dissolved oxygen	10	7	log-censored	1220	8993	< 300	5780	< 300	5780	< 300
Eh	10	0	normal	186	266	187	351	32	351	187
Fluoride	1	0	ins	-	-	600	600	600	600	300
Iron	10	0	log-normal	231	1538	225	9315	4.7	9315	811
Lead	9	0	log-normal	0.25	0.76	0.34	5.2	0.040	5.2	0.18
Lithium	10	6	log-censored	3.4	29	< 4.5	22	< 4.5	22	5.7
Magnesium	10	0	normal	26364	36166	25436	47086	9324	47086	22224
Manganese	10	3	log-censored	108	2677	111	1205	< 0.90	1205	176
Molybdenum	10	10	ins	ins	ins	< 4.2	< 4.2	< 4.2	< 4.2	< 4.2
Nickel	10	8	ins	ins	ins	< 6.0	6.4	< 6.0	6.4	< 6.0
Nitrate-N	10	6	log-censored	1025	7049	< 500	4200	< 500		< 500
pH	10	0	normal	7.33	7.48	7.43	7.52	7.03	7.52	7.21
Phosphorus	10	0	log-normal	84	164	61	344	29	344	56
Potassium	10	0	log-normal	1805	2745	1635	5321	843	5321	1766
Rubidium	10	10	ins	ins	ins	< 555.2	< 555.2	< 555.2	< 555.2	< 555.2
Selenium	9	5	log-censored	0.19	3366	< 1.0	214	< 1.0	77	2.1
Silicate	10	0	normal	12168	15195	11308	21264	8713	21264	10819
Silver	9	2	log-censored	0.018	0.20	< 0.0090	0.14	< 0.0090	0.14	4200
Sodium	10	0	normal	7752	10635	7718	12442	2600	12442	4986
Specific Conductance	10	0	normal	616	773	553	964	367	843	465
Strontium	10	0	log-normal	117	191	84	387	56	387	105
Sulfate	10	0	normal	34943	45933	31905	54570	12690	54570	4250
Sulfur	10	0	normal	12422	16231	10826	18642	4572	18642	4603
Temperature	10	0	normal	10.5	11.0	10.4	11.6	9.6	11.6	8.8
Thallium	9	1	log-censored	0.012	0.082	0.010	0.070	< 0.0050	0.070	< 0.0050
Tin	9	5	log-censored	0.042	0.22	< 0.0040	0.14	< 0.0040	0.14	0.060
Titanium	10	8	ins	ins	ins	< 0.0035	0.0039	< 0.0035	0.0039	< 0.0035

Table A.17 continued.

Chemical	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	90th percentile	Min	Max	State Median
Total dissolved solids	10	0	normal	387333	479246	355000	574000	256000	574000	340000
Total organic carbon	10	1	log-censored	0.0029	0.0042	1450	7500	< 500	7500	2400
Total phosphate-P	10	0	log-normal	54	124	40	330	20	330	40
Total suspended solids	10	0	log-normal	3641	8119	3000	25000	1000	25000	4000
Vanadium	10	3	log-censored	6.5	13	6.6	11	< 4.7	11	5.4
Zinc	10	0	log-normal	36	103	32	312	3.2	312	12
Zirconium	9	7	ins	ins	ins	< 0.030	0.16	< 0.030	0.16	0.030

Table A.18: Coefficients for log-censored data from analysis of descriptive statistics, foreach aquifer and chemical. See MPCA, 1998a, for application of these coefficients.

Chemical Parameter	CFRN		CJDN		OPDC		OSTP		QBAA		QWTA	
	a	b	a	b	a	b	a	b	a	b	a	b
Aluminum	-	-	-	-	-	-	-	-	0.597	1.300	-3.451	0.515
Antimony	-4.473	1.069	-3.747	0.686	-3.412	0.935	-4.160	1.026	-4.072	0.883	-4.800	0.553
Arsenic	-	-	-	-	-0.666	1.303	-	-	-	-	-	-
Beryllium	-	-	-5.251	0.822	-	-	-	-	-5.152	0.924	-	-
Boron	-	-	3.470	1.144	2.975	0.368	3.127	1.030	3.703	1.472	3.251	0.374
Cadmium	-2.655	0.378	-2.630	0.543	-2.924	0.611	-2.998	0.580	-3.501	1.087	-3.115	0.957
Cesium	-4.355	0.908	-4.671	0.769	-	-	-4.026	0.387	-5.185	1.070	-4.458	0.456
Chromium	-1.658	1.995	-0.742	1.261	-1.061	1.183	-1.061	1.183	-1.152	1.442	-2.244	1.644
Copper	1.652	0.722	1.665	1.347	1.902	0.457	2.343	0.626	1.799	1.330	2.177	1.001
Dissolved oxygen	-	-	4.912	2.387	7.549	0.967	-	-	5.962	1.687	7.107	1.019
Lithium	2.012	1.184	1.732	0.944	1.717	0.576	1.961	0.586	2.181	1.109	1.230	1.082
Manganese	4.098	1.470	3.997	1.386	1.782	3.427	4.363	2.107	5.254	1.173	4.686	1.636
Molybdenum	-	-	1.070	0.822	-	-	-	-	0.884	0.887	-	-
Nickel	-	-	-	-	-	-	2.070	0.300	1.134	0.817	-	-
Nitrate-N	-	-	-	-	7.344	1.528	6.354	1.180	2.822	3.766	6.932	0.984
Phosphorus	-	-	3.354	1.220	-	-	-	-	-	-	-	-
Selenium	-0.040	0.631	-0.730	1.668	-0.258	0.848	-0.376	1.194	0.092	1.159	-1.651	4.986
Silver	-3.473	0.474	-3.513	0.947	-	-	-4.112	0.802	-3.181	1.617	-4.040	1.227
Thallium	-4.850	1.341	-4.032	1.524	-4.061	1.477	-4.348	0.639	-5.258	1.374	-4.399	0.966
Tin	-	-	-2.966	0.653	-2.902	0.980	-	-	-2.772	1.221	-3.166	0.837
Titanium	-	-	-	-	-	-	-5.663	0.439	-8.961	2.450	-5.853	0.198
Total phosphate-P	3.234	1.523	2.189	1.795	2.892	1.176	4.029	0.806	3.664	1.082	-	-
Vanadium	1.898	0.414	1.844	0.459	1.754	0.477	1.853	0.716	1.594	0.717	1.871	0.344

Table A.19: Coefficients for log-normal data from analysis of descriptive statistics, for each aquifer and chemical. See MPCA, 1998a, for application of these coefficients.

Chemical Parameter	CFRN		CJDN		OPDC		OSTP		QBAA		QWTA	
	std. dev.	n	std. dev.	n	std. dev.	n	std. dev.	n	std. dev.	n	std. dev.	n
Arsenic	1.955	9	0.5322	10	-	-	-	-	0.6190	18	0.3621	9
Barium	-	-	-	-	-	-	-	-	-	-	0.6112	10
Cesium	-	-	-	-	0.008819	9	-	-	-	-	-	-
Chloride	0.8504	9	0.4261	11	0.5295	10	-	-	0.6045	20	-	-
Chromium	-	-	-	-	0.7290	9	-	-	-	-	-	-
Cobalt	0.2012	9	0.3800	10	-	-	0.5437	9	0.1753	18	0.2181	9
Iron	-	-	-	-	0.9028	10	553	9	0.9376	20	1.142	10
Lead	0.3168	9	0.835	10	0.3053	9	0.08623	9	0.4734	18	1.658	9
Magnesium	-	-	-	-	0.1378	10	-	-	-	-	-	-
pH	0.3051	9	0.2108	11	0.2387	10	0.1661	9	0.2350	20	0.1743	10
Phosphorus	-	-	0.3911	11	0.3474	10	-	-	0.2994	20	0.3815	10
Potassium	-	-	-	-	0.2828	10	-	-	-	-	0.2432	10
Silver	-	-	-	-	0.04567	10	-	-	-	-	-	-
Sodium	-	-	0.4766	11	0.2934	10	-	-	0.4642	20	-	-
Specific Conductance	-	-	0.175	11	0.1787	10	-	-	-	-	-	-
Strontium	-	-	-	-	-	-	-	-	-	-	0.2720	10
Sulfate	-	-	0.5537	11	-	-	-	-	-	-	-	-
Sulfur	-	-	0.5345	11	0.3065	10	0.3889	9	-	-	-	-
Temperature	0.858	9	0.347	11	0.5461	10	-	-	0.5391	20	0.5739	10
Total organic carbon	-	-	-	-	0.1862	10	-	-	-	-	-	-
Total Phosphate	-	-	-	-	-	-	-	-	-	-	0.4459	10
Total suspended solids	-	-	-	-	-	-	-	-	-	-	0.4626	10
Zinc	0.6641	9	0.4840	11	-	-	0.2913	9	0.5312	20	0.5596	10

Table A.20 : Median concentrations, in ug/L, of sampled chemicals for each of the major aquifers. The p-value indicates the probability that aquifers have equal concentrations. Different letters within a row indicate different median concentrations between aquifers.

Chemical	p-value	CFRN	CJDN	OPDC	OSTP	QBAA	QWTA
		ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
Alkalinity	0.279	330000	223000	249500	284000	323000	220000
Aluminum	0.164	3.7	2.3	4.4	4.8	2.8	4.8
Antimony	0.787	0.011	0.023	0.040	0.013	0.019	< 0.0080
Arsenic	0.054	2.3	0.71	0.45	0.49	2.1	0.77
Barium	0.386	102	29	70	91	79	74
Beryllium	0.777	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Bismuth	0.344	< 0.040	< 0.040	< 0.040	< 0.040	< 0.040	< 0.040
Boron	0.216	55	23	21	23	36	25
Bromide	1.000	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	ins
Cadmium	0.575	< 0.020	0.075	0.050	0.060	0.030	0.040
Calcium	0.335	84659	62713	78942	76373	85466	72638
Cesium	0.017	0.010 ab	0.010 b	0.030 a	< 0.010 b	< 0.010 b	< 0.010 b
Chloride	0.000	1200 bc	820 c	9615 a	4370 b	2710 b	24980 a
Chromium	0.777	0.26	0.46	0.30	0.39	0.24	0.11
Cobalt	0.993	0.61	0.66	0.53	0.54	0.58	0.60
Copper	0.782	< 5.5	5.9	6.1	8.9	6.4	8.8
Dissolved oxygen	0.308	< 300	< 300	1820	< 300	< 300	< 300
Eh	0.204	206	96	263	21	195	187
Fluoride	0.179	270	330	210	240	260	600
Iron	0.629	583	345	35	443	481	225
Lead	0.640	0.19	0.32	0.21	0.14	0.24	0.34
Lithium	0.254	8.3	5.5	5.8	4.8	8.6	< 4.5
Magnesium	0.593	32256	22886	26492	26465	34331	25436
Manganese	0.241	67	46	0.90	201	259	111
Mercury	1.000	< 0.10	< 0.10	-	-	< 0.10	< 0.10
Molybdenum	0.202	< 4.2	< 4.2	< 4.2	< 4.2	< 4.2	< 4.2
Nickel	0.253	< 6.0	< 6.0	< 6.0	< 6.0	< 6.0	< 6.0
Nitrate-N	0.133	< 500	< 500	1650	< 500	< 500	< 500
pH	0.973	7.34	7.43	7.46	7.45	7.40	7.43
Phosphorus	0.018	37 bc	32 c	31 c	93 a	61 ab	61 ab
Potassium	0.281	2580	1312	1728	1814	2768	1635
Rubidium	0.686	< 555.2	< 555.2	< 555.2	< 555.2	< 555.2	< 555.2
Selenium	0.886	1.0	< 1.0	< 1.0	< 1.0	1.0	< 1.0
Silicate	0.007	10818 a	7964 b	10321 a	12145 a	11986 a	11308 a
Silver	0.261	< 0.0090	0.036	0.049	0.017	0.040	< 0.0090
Sodium	0.133	18663	3476	4929	4207	5764	7718
Specific Conductance	0.238	703	492	590	569	664	553
Strontium	0.048	231 a	95 b	103 b	116 b	202 a	84 b
Sulfate	0.150	28170	18570	22425	15000	24375	31905
Sulfur	0.510	9891	6580	7777	5492	9478	10826
Temperature	0.432	10.3	10.1	10.0	10.1	10.0	10.4
Thallium	0.167	0.010	0.017	0.017	0.014	< 0.0050	0.010
Tin	0.506	< 0.040	0.045	0.05	< 0.040		< 0.0040
Titanium	0.310	< 0.0035	< 0.0035	< 0.0035	< 0.0035	< 0.0035	< 0.0035
Total dissolved solids	0.131	428000	284000	395000	332000	443000	355000
Total organic carbon	0.143	2000	900	1500	1000	1900	1450
Total phosphate-P	0.050	20	< 20	20	60	40	40
Total suspended solids	0.797	2000	1000	1500	3000	2500	3000
Vanadium	0.925	6.5	5.0	5.6	5.2		6.6
Zinc	0.609	22	38	34	15	30	32
Zirconium	0.978	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030

Table A.21 : Summary of water quality criteria, basis of criteria, and endpoints, by chemical parameter.

Chemical	Criteria (ug/L)	Basis of criteria	Endpoint
Alkalinity	-	-	-
Aluminum (Al)	50	MCL	-
Antimony (Sb)	6	HRL	-
Arsenic (As)	50	MCL	Cancer
Barium (Ba)	2000	HRL	Cardiovascular/blood
Beryllium (Be)	0.08	HRL	Cancer
Boron (B)	600	HRL	Reproductive
Bromide (Br)	-	-	-
Cadmium (Cd)	4	HRL	Kidney
Calcium (Ca)	-	-	-
Chloride (Cl)	250000	SMCL	-
Chromium (Cr)	20000[1]	HRL	-
Cobalt (Co)	30	HBV	-
Copper (Cu)	1000	HBV	-
Dissolved Oxygen	-	-	-
Fluoride (F)	4000	MCL	-
Iron (Fe)	300	SMCL	-
Lead (Pb)	15	Action level at tap	-
Lithium (Li)	-	-	-
Magnesium (Mg)	-	-	-
Manganese (Mn)	100 (1000)[2]	HRL	Central nervous system
Mercury (Hg)	2	MCL	-
Molybdenum (Mo)	30	HBV	Kidney
Nickel (Ni)	100	HRL	-
Nitrate-N (NO_3-N)	10000	HRL	Cardiovascular/blood
Ortho-phosphate	-	-	-
pH	-	-	-
$Phosphorus_{total}$	-	-	-
Potassium (K)	-	-	-
Redox/Eh	-	-	-
Rubidium (Rb)	-	-	-
Selenium (Se)	30	HRL	-
Silicate (Si)	-	-	-
Silver (Ag)	30	HRL	-
Sodium (Na)	250000	SMCL	-
Specific Conductance	-	-	-
Strontium (Sr)	4000	HRL	Bone
Sulfate (SO_4)	500000	MCL	-
Sulfur (S)	-	-	-
Temperature	-	-	-
Thallium (Tl)	0.6	HRL	Gastrointestinal/liver
Titanium (Ti)	-	-	-
Total dissolved solids	-	-	-
Total organic carbon	-	-	-
Total phosphate	-	-	-
Total suspended solids	-	-	-
Vanadium (V)	50	HRL	-
Zinc (Zn)	2000	HRL	-

Table A.21 continued

Chemical	Criteria (ug/L)	Basis of criteria	Endpoint
1,1,1-trichloroethane	600	HRL	gi/liv
1,1-dichloroethane	70	HRL	kid
1,1-dichloroethene	6	HRL	gi/liv
1,2-dichloroethane	4	HRL	cancer
1,2-dichloropropane	5	HRL	cancer
acetone	700	HRL	cv/bld; liv
benzene	10	HRL	cancer
bromodichloromethane	6	HRL	cancer
chlorodibromomethane	-	-	-
chloroform	60	HRL	cancer
dichlorodifluoromethane	1000	HRL	body weight
dichlorofluoromethane	-	-	-
ethyl ether	1000	HRL	body weight
isopropylbenzene	-	-	-
xylene	10000	HRL	cns/pns
methyl ethyl ketone	4000	HRL	repro
methylene chloride	50	HRL	cancer
naphthalene	300	HRL	cv/bld
tetrachloroethene	7	HRL	cancer
tetrahydrofuran	100	HRL	gi/liv
toluene	1000	HRL	kid; gi/liv
trichloroethene	30	HRL	cancer
1,2,4-trimethylbenzene	-	-	-
1,3,5-trimethylbenzene	-	-	-
cis-1,2 dichloroethene	70	HRL	cv/bld
ethyl benzene	700	HRL	kid; gi/liv
n-butylbenzene	-	-	-
n-propyl benzene	-	-	-
p-isopropyltoluene	-	-	-
styrene	-	-	-
trichlorofluoromethane	-	-	-

[1] Trivalent chromium
[2] The current HRL for manganese is 100, but calculations were made using a value of 1000 ug/L (MDH, 1997)

Table A.22 : Number of samples exceeding health-based water quality criteria, by aquifer.

	Number of Exceedances			
Chemical	OPDC	OSTP	QBAA	QWTA
Manganese (Mn)	-	1	1	1
Nitrate (NO_3)	1	-	1	-
Selenium (Se)	-	-	-	2

Table A.23 : Percentage of samples exceeding health-based water quality criteria, by aquifer.

Chemical	Number of Exceedances			
	OPDC	OSTP	QBAA	QWTA
Manganese (Mn)	-	11	5	10
Nitrate (NO_3)	10	-	5	-
Selenium (Se)	-	-	-	20

Table A.24 : Number of samples exceeding non-health-based water quality criteria, by aquifer.

Chemical	Number of Exceedances					
	CFRN	CJDN	OPDC	OSTP	QBAA	QWTA
Iron(Fe)	6	7	4	6	13	5

Table A.25 : Percentage of samples exceeding non-health-based water quality criteria, by aquifer.

Chemical	Number of Exceedances					
	CFRN	CJDN	OPDC	OSTP	QBAA	QWTA
Iron(Fe)	67	64	40	67	65	50

Table A.26 : Summary of VOC detections for Region 6.

Unique No.	Chemical	Concentration	Chem_class
1	1,1-dichloroethene	0.5	Halogenated aliphatic
1	1,1,1-trichloroethane	10	Halogenated aliphatic
2	1,2-dichloroethane	0.2	Halogenated aliphatic
2	trichloroethene	0.2	Halogenated aliphatic
3	1,1-dichloroethene	0.6	Halogenated aliphatic
3	1,1,1-trichloroethane	10	Halogenated aliphatic
4	xylene	0.4	BTEX
4	ethylbenzene	0.2	BTEX
4	toluene	0.9	BTEX
4	tetrachloroethene	0.4	Halogenated aliphatic
4	1,1,1-trichloroethane	0.6	Halogenated aliphatic
4	1,1-dichloroethane	0.3	Halogenated aliphatic

Appendix B - Figures

1. Location of Region 6.
2. Locations of wells sampled from the Franconia (CFRN) and Ironton-Galesville (CIGL) aquifers.
3. Location of wells sampled from the St. Peter (OSTP), Prairie du Chien (OPDC), and Jordan (CJDN) aquifers.
4. Location of wells sampled from Quaternary, buried (QBAA) aquifers.
5. Location of wells sampled from Quaternary, water-table aquifers (QWTA).
6. Distribution of nitrate in Region 6.
7. Distribution of chloride in Region 6.
8. Distribution of Volatile Organic Compound detections in Region 6.
9. Distribution of Arsenic in Region 6.

Figure B.1 : Location of Region 6

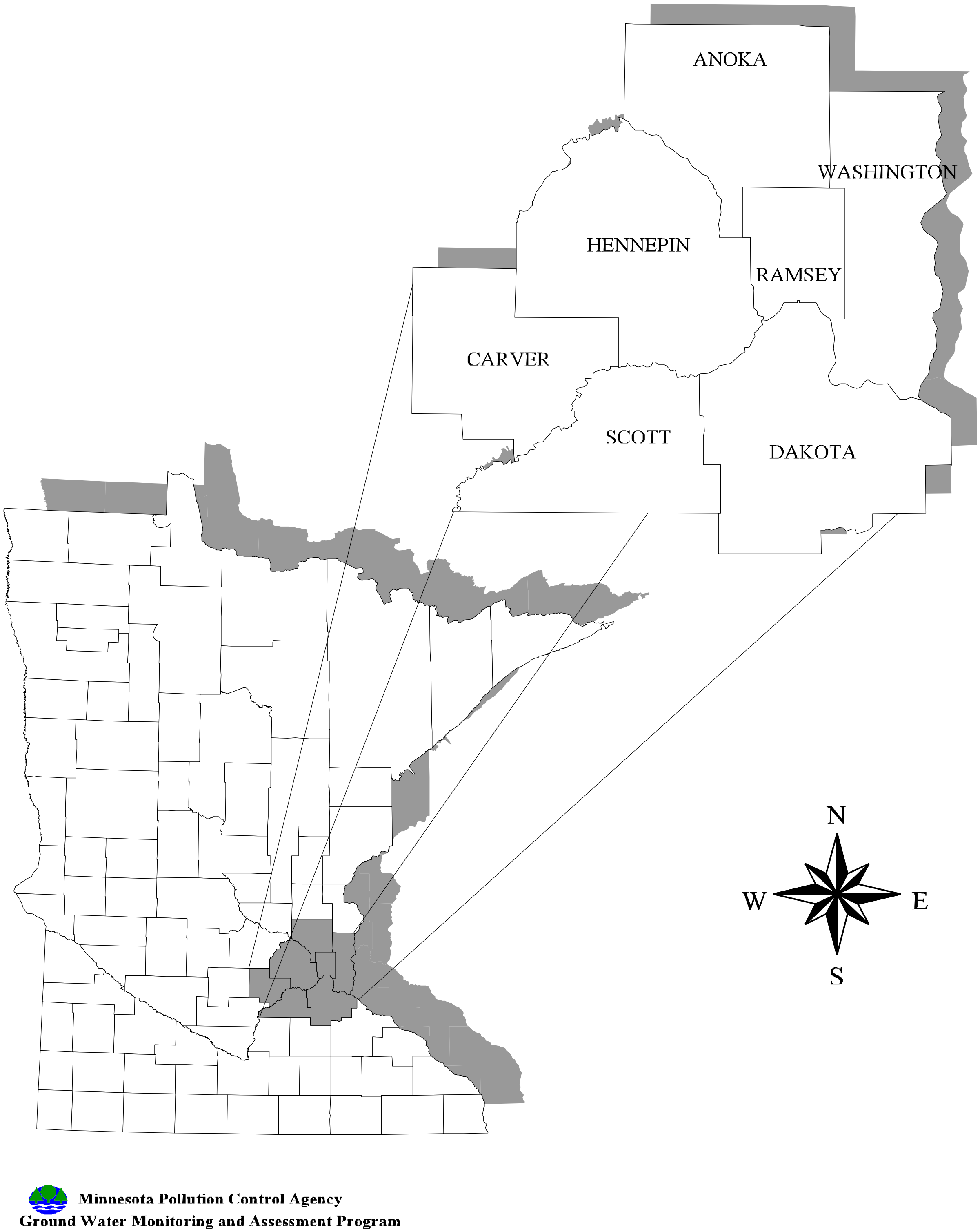

Figure B.2 : Location of wells sampled from the Franconia (CFRN) and Ironton-Galesville (CIGL) aquifers.

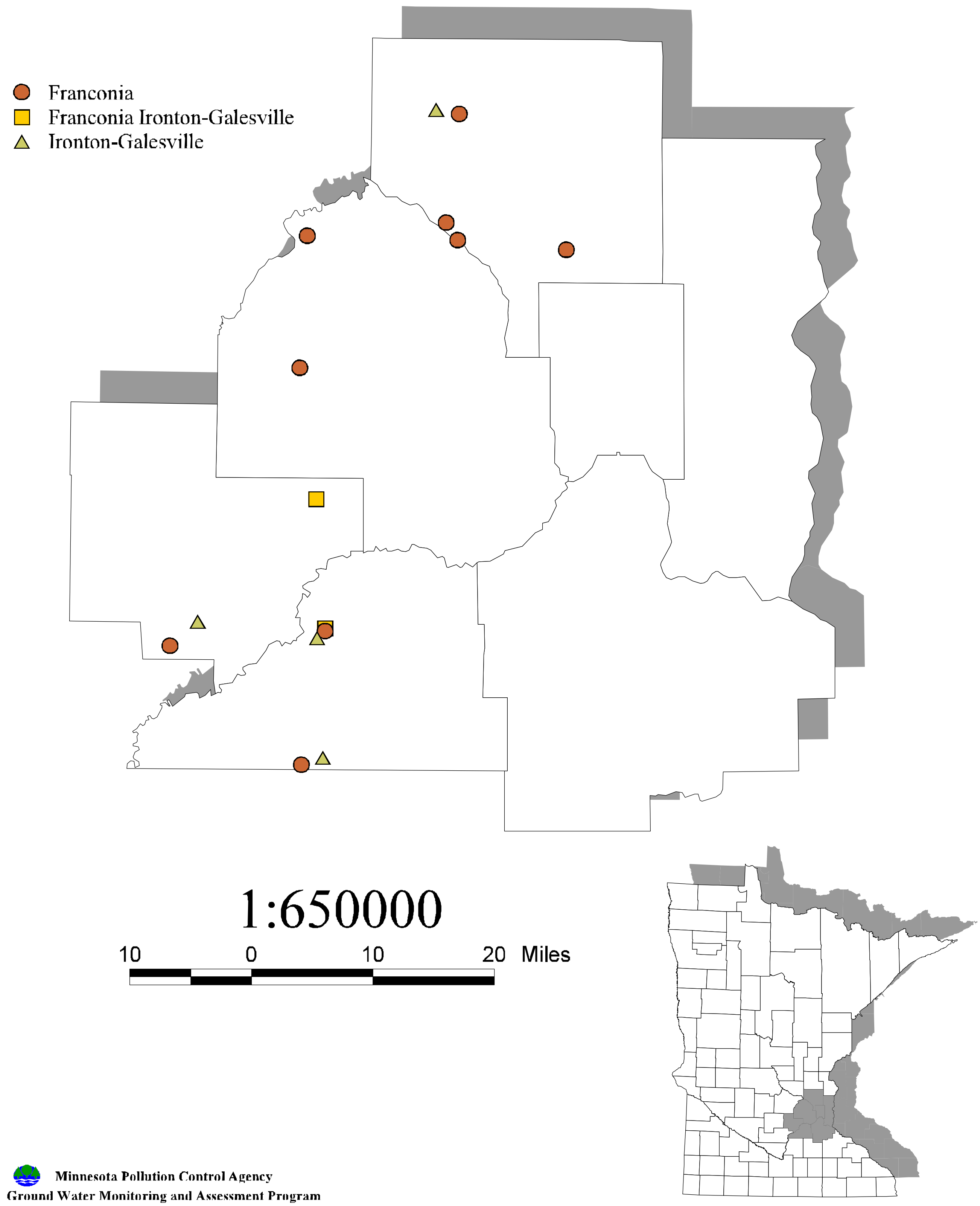

Figure B.3 : Location of wells sampled from the St. Peter (OSTP), Prairie du Chien (OPDC), and Jordan (CJDN) aquifers.

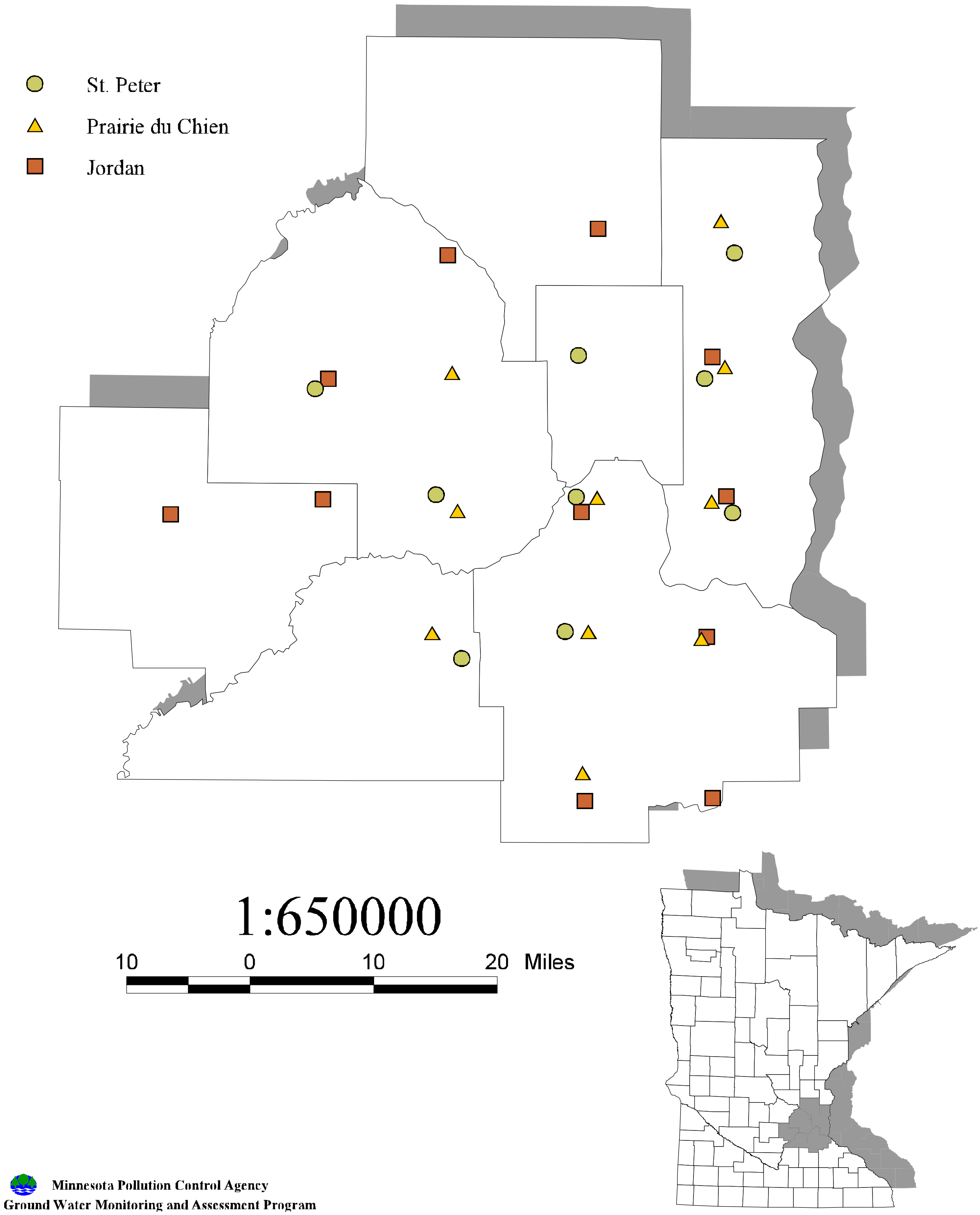

Figure B.4 : Location of wells sampled from Quaternary, buried (QBAA) aquifers.

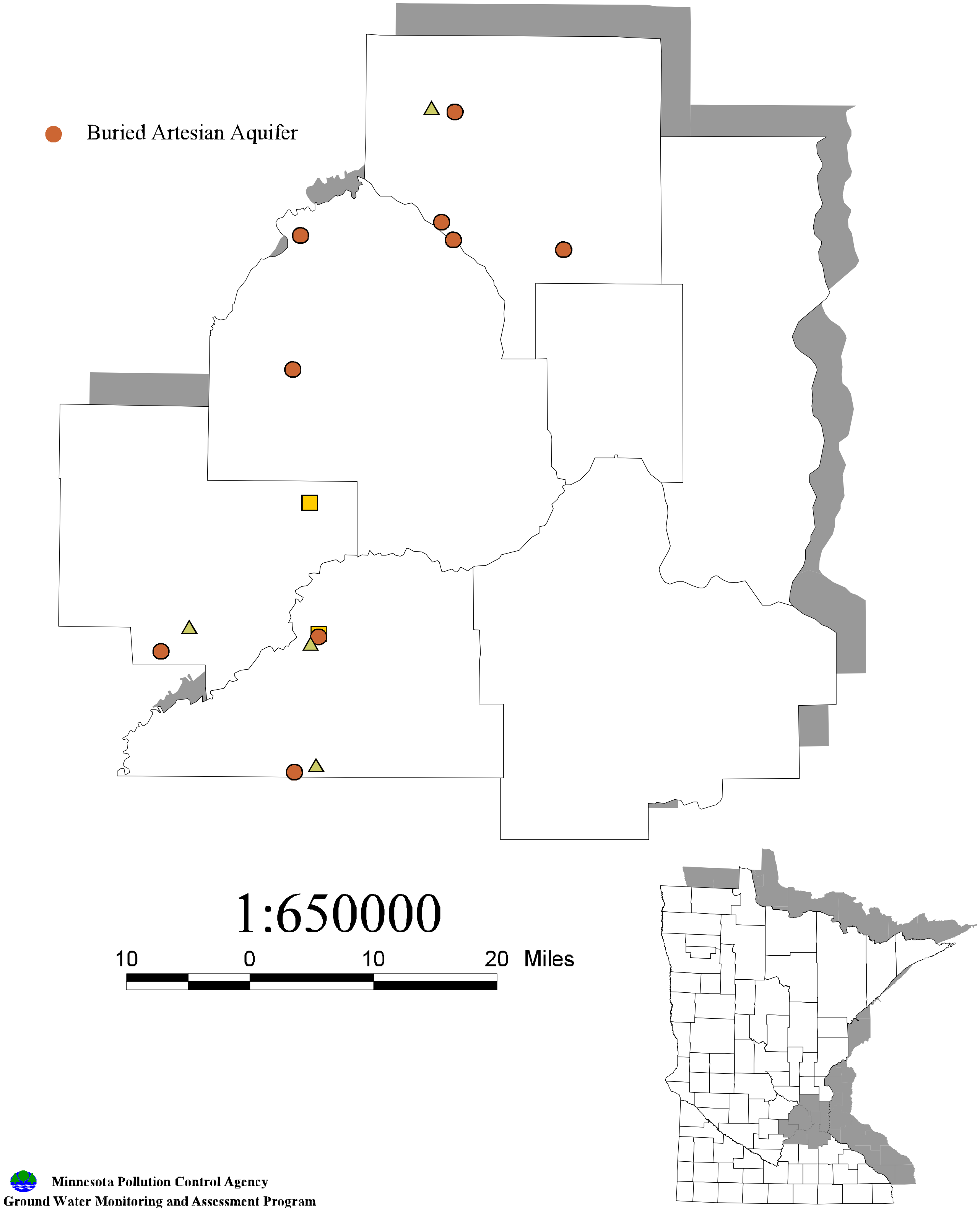

Figure B.5 : Location of wells sampled from Quaternary, water-table aquifers (QWTA).

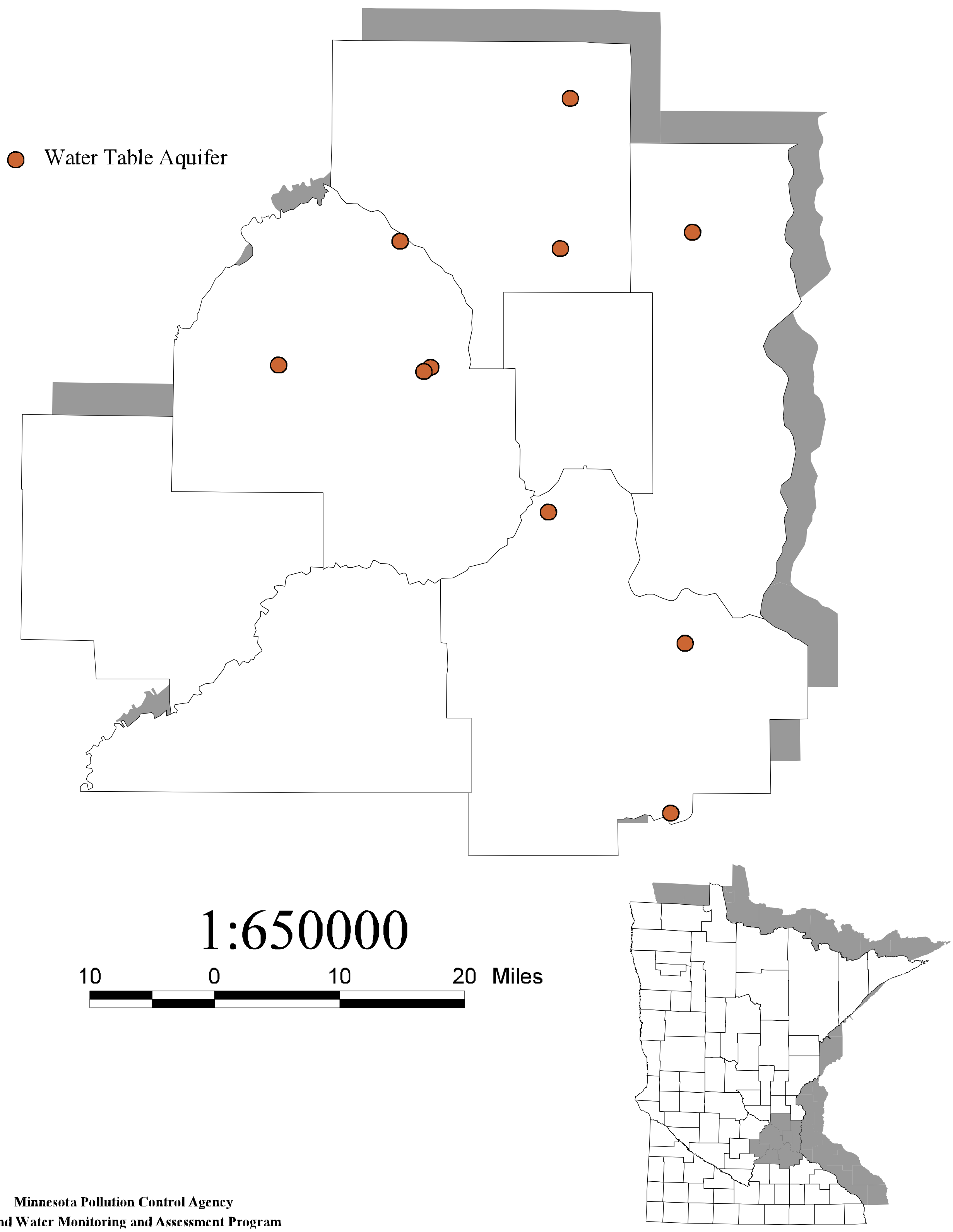

Figure B.6 : Distribution of nitrate in Region 6.

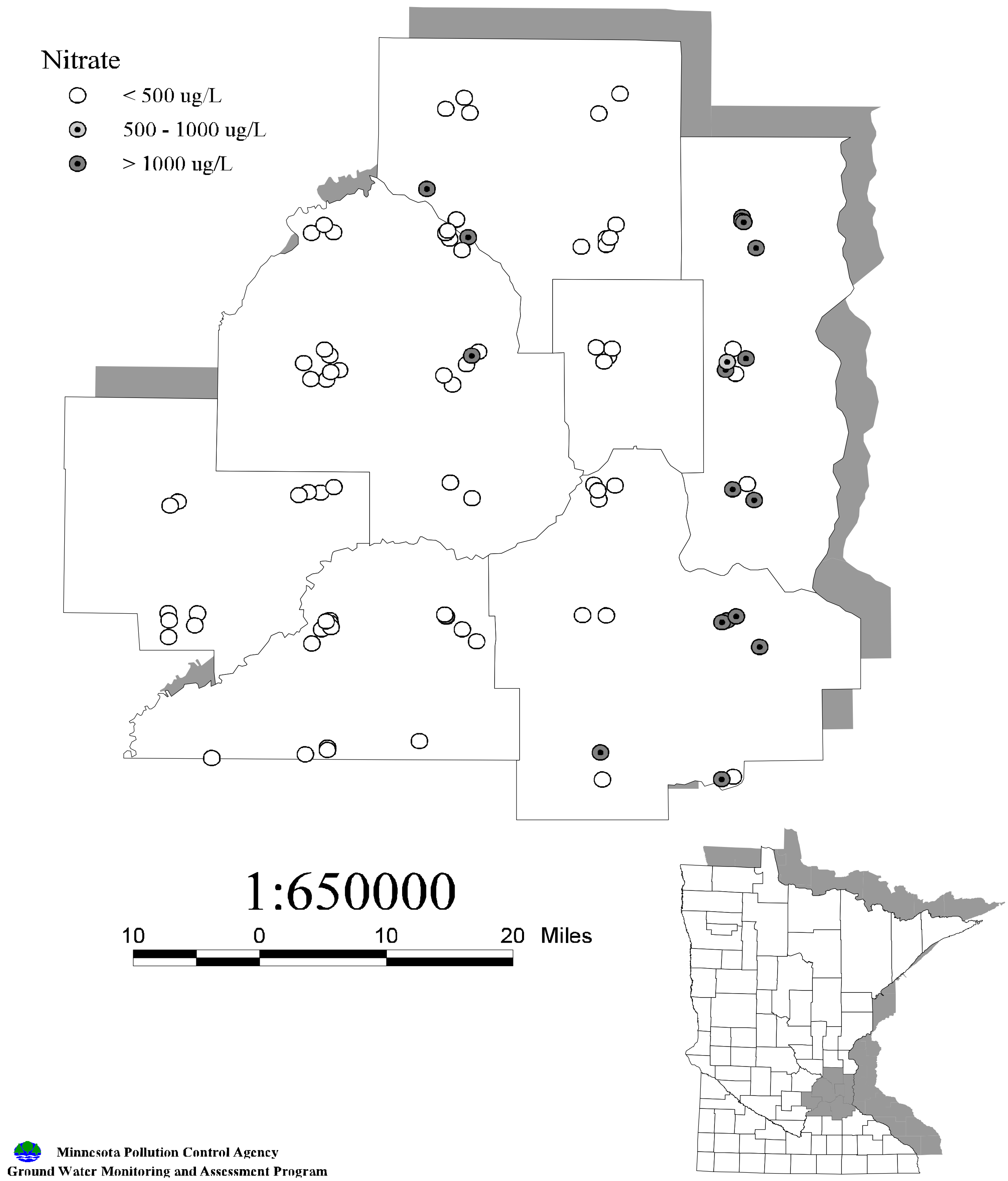

Figure B.7 : Distribution of chloride in Region 6.

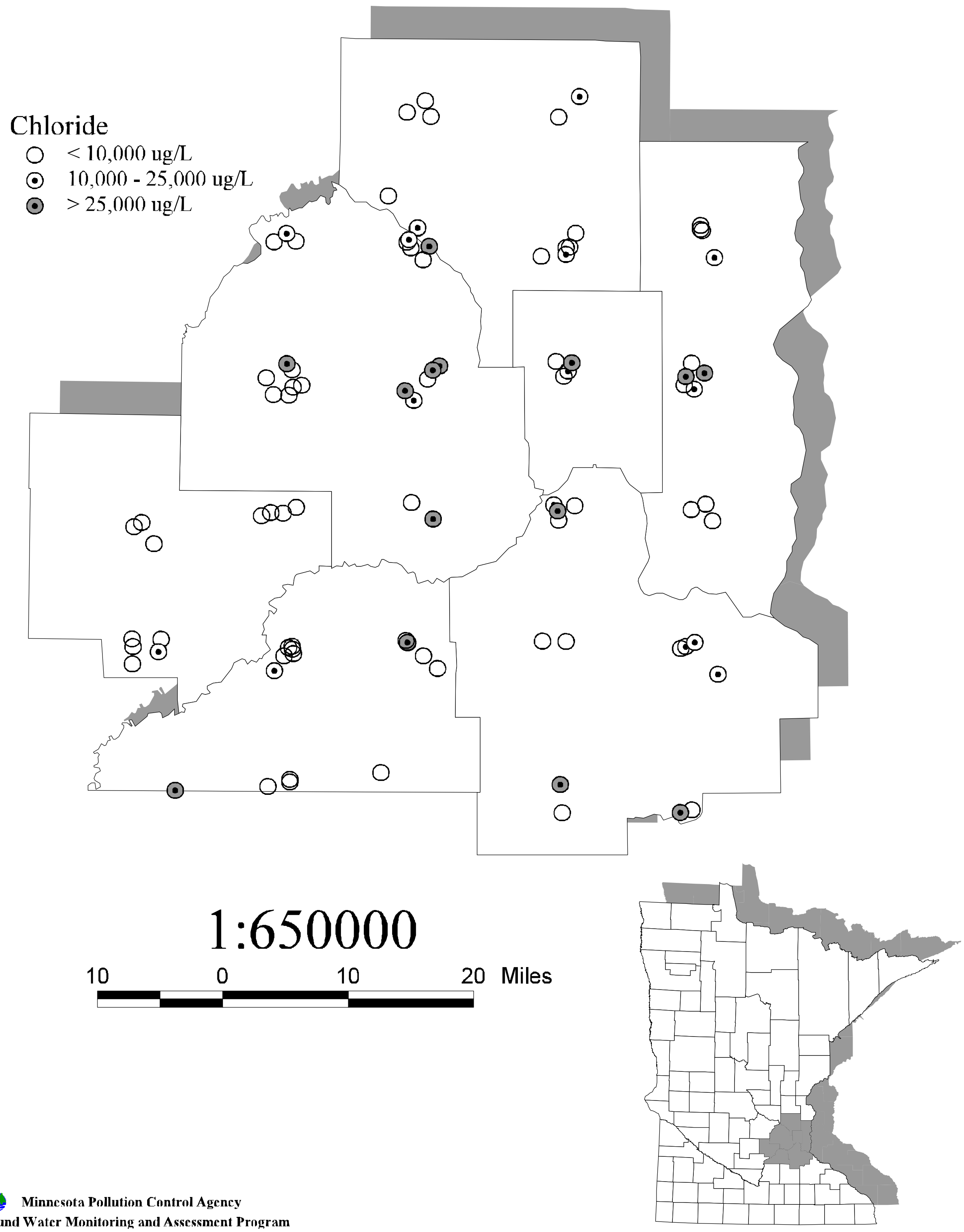

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Figure B.8 : Distribution of Volatile Organic Compound detections in Region 6.

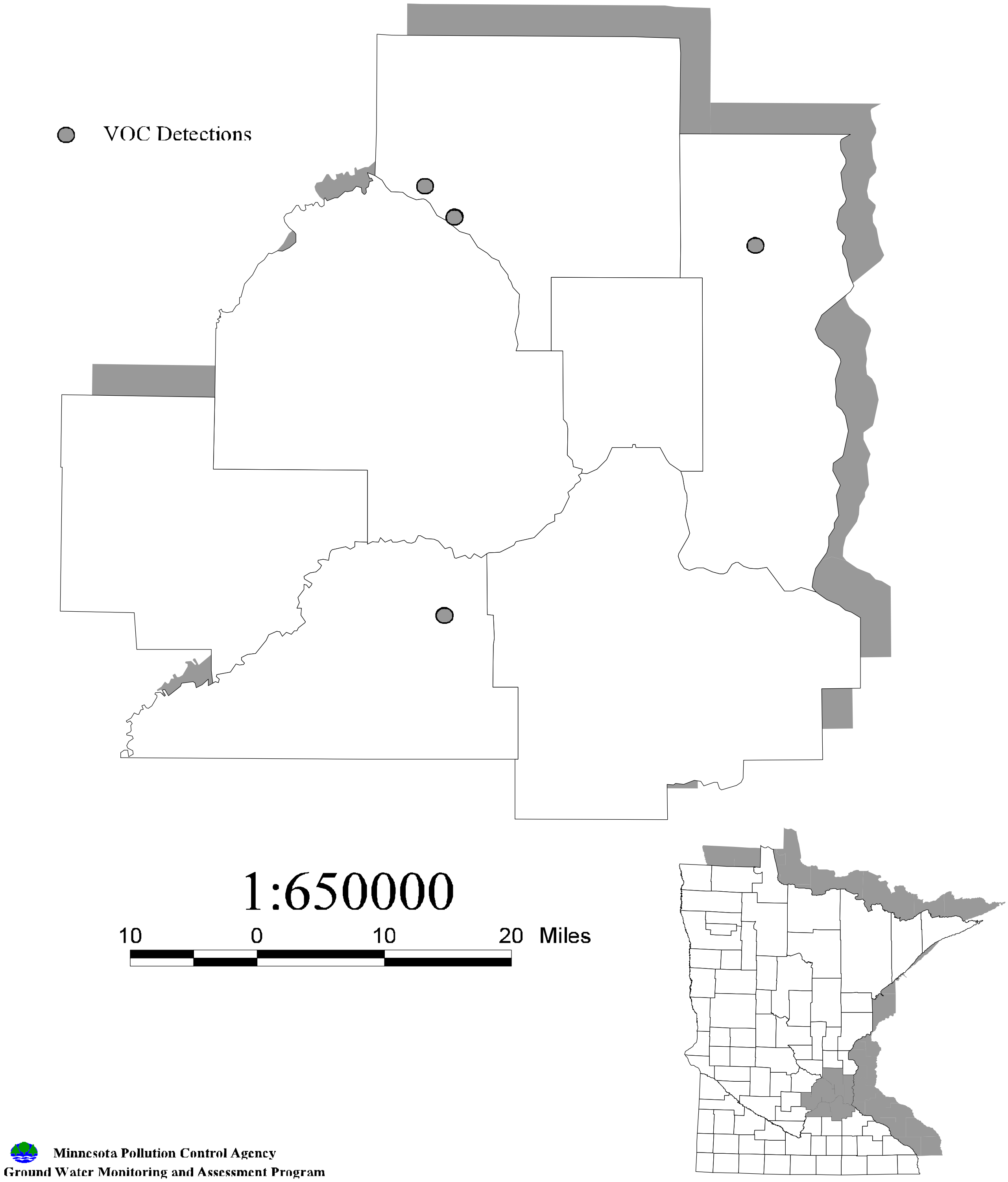

Figure B.9 : Distribution of arsenic in Region 6.