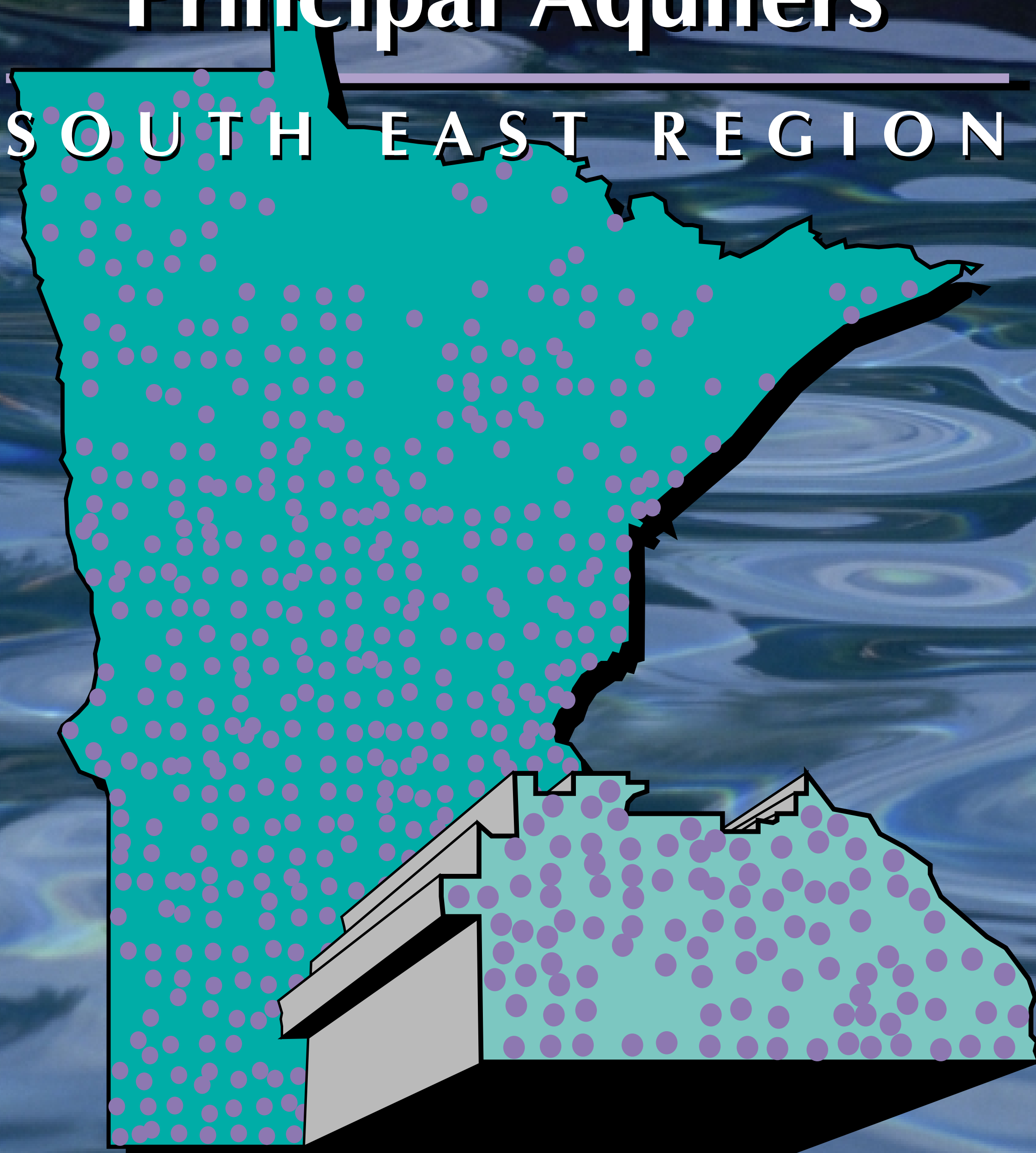
Baseline Water Quality of Minnesota's Principal Aquifers

SOUTH EAST REGION



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Baseline Water Quality of Minnesota's Principal Aquifers - Region 5, Southeast Minnesota

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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 MPCA Region 5 in southeast Minnesota. 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.

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 1992, 1993, and 1994, the Minnesota Pollution Control Agency's (MPCA) Ground Water Monitoring and Assessment Program (GWMAP) sampled 170 primarily domestic wells in MPCA Region 5, which encompasses southeast 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 were 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 spacings. 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, 34 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 30 different aquifers.

Ground water in the Paleozoic bedrock aquifers of Region 5 is generally very good. Locally, high concentrations of some trace elements such as cadmium, lead, and arsenic were observed in the Galena and Cedar Valley aquifers. These high concentrations are a function of the mineralogy of the geologic deposits. The eastern portions of the Prairie du Chien, Jordan, and Franconia aquifers are more highly oxidized than other parts of the aquifers, making them more responsive to recharge and sensitive to anthropogenic chemicals such as Volatile Organic Compounds (VOCs), nitrate, and lead. Water quality of the buried drift and Cretaceous aquifers is poor. Both aquifers have high concentrations of dissolved solids, boron, manganese, iron, and sulfate. The buried drift and Cretaceous aquifers appear to interact in the western part of Region 5, and water quality of buried drift aquifers in this area is particularly poor compared to water quality in these aquifers from the remainder of the region.

The primary research needs for Region 5 include:

- using water quality information to evaluate conceptual hydrologic models of the Paleozoic aquifers in Region 5;
- expanding the current understanding of spatial and temporal variability in water quality of the Paleozoic aquifers; this includes mapping recharge areas, identifying areas of conduit flow (fracture flow, flow through dissolution channels), and developing geochemical sensitivity models and maps for these aquifers.
- determining if a correlation exists between land use and the distribution of VOCs; and
- analyzing mineralogy of Upper Carbonate aquifers, particularly for cadmium, lead, and arsenic, and of Cretaceous and buried drift aquifers, particularly for boron and manganese.

The primary monitoring needs for Region 5 include:

- collecting additional samples for baseline analysis from the Cedar Valley, Cretaceous, and Franconia aquifers;
- assessing the need for an ambient network for VOCs and establishing a shallow ambient network for nitrates; and
- establishing consistent sampling and data storage protocol.

Bedrock hydrogeology of Region 5 is very complicated. This report focuses on ambient water quality in the principal aquifers of the region. The conclusions are not consistently linked to physical factors affecting water quality, but are primarily intended to provide information about the quality of water that people are drinking. There are numerous reports summarizing the physical hydrogeology of Region 5. Additional analysis of the baseline data, with an emphasis on physical processes, may be conducted more rigorously in subsequent papers.

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 5. Region 5 is located in southeast Minnesota and includes the counties of Blue Earth, Brown, Dodge, Faribault, Fillmore, Freeborn, Goodhue, Houston, Le Sueur, Martin, Mower, Nicollet, Olmstead, Rice, Sibley, Steele, Wabasha, Waseca, Watonwan, and Winona (Figure B.1). The regional office is located in Rochester.

The following information needs for Region 5 were identified in Myers et al., 1992:

- systematic monitoring of all aquifers;
- evaluate water quality trends;
- determine impacts of high volume wells on contaminant transport;
- determine impacts of underground storage tanks, storm water retention basins, landfills, improperly constructed wells, and abandoned wells on ground water quality;
- evaluate ground water-surface water interaction;
- evaluate interaction between bedrock and drift aquifers;
- collect agricultural use data.

Assistance needs were identified in the following areas:

- data interpretation;
- sampling procedures.

The baseline study conducted by GWMAP may be used to partly fulfill the informational needs of systematic monitoring of all aquifers (by providing a baseline or reference condition), evaluating potential impacts from pollution sources on drinking water wells, and evaluating interaction between drift and bedrock aquifers. The baseline study can assist with data interpretation through analysis of the data for the region, by describing analysis methods useful in local interpretation, and by providing comparisons between information from the baseline study and other hydrologic investigations from Region 5. Sampling methods described in MPCA (1996) assist in identifying and implementing sampling procedures.

This report provides baseline water quality information for Region 5. Comparisons are made between water quality in the principal aquifers of Region 5 to that in the remainder of the state. Significant differences in ground water quality between Region 5 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 water chemistry. Specific instances occur where water quality relates to potential effects on humans consuming ground water or general quality of 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. (1991) and MPCA (1994, 1995, and 1998a). A systematic grid design was implemented, with sampling nodes spaced at eleven mile intervals. We sampled all major aquifers with a suitable domestic well located within a nine square mile area centered on each grid node. The County Well Index (CWI)(Wahl and Tipping, 1991) provided information on wells within the sampling area. Table A.1 summarizes CWI aquifer codes. Wells were purged until stabilization criteria were met. 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 the Galena and Cedar Valley aquifers; in Figure B.5 for the Cretaceous aquifer; and in Figure B.6 for the buried drift aquifers. Sampling is summarized by aquifer in Table A.1 and for all data in Table A.2.

2. Analysis Methods

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

- establishing descriptive statistics (mean, median, minimum, etc.) for each parameter 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 chemicals and chemical parameters; and
- discussions for individual aquifers.

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 5. 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), St. Lawrence (CSTL), Maquoketa (OMAQ), and Platteville (OPVL) aquifers were small and no further discussion of these aquifers is presented in this section.

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 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 such as nitrate between two or more months. Concentrations of sampled chemicals and chemical parameters were compared between different aquifers.

Concentrations of many chemicals differed between aquifers. Median chemical concentrations were compared between the Franconia (CFRN), Jordan (CJDN), Cedar Valley (DCVA), Cretaceous (KRET), Galena (OGAL), Prairie du Chien (OPDC), St. Peter (OSTP), buried confined drift (QBAA), and buried unconfined drift (QBUU) aquifers. Results are summarized in Table A.20. P-values are included for each parameter. 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 the major ions (calcium, magnesium, sodium, potassium, chloride, sulfate, and bicarbonate) were highest in the Cretaceous aquifer and higher in the Quaternary aquifers than in Paleozoic aquifers. A similar pattern existed for boron, antimony, iron, manganese, strontium, and total suspended solids. Concentrations of major ions in Quaternary aquifers were correlated with those for the Cretaceous aquifer, suggesting an interaction between the two aquifers.
2. Concentrations of arsenic, selenium, and phosphate were elevated in the Quaternary aquifers. There was no apparent correlation between the three chemicals, although the highest arsenic concentrations were found along an east-west line across the northern portion of the region. This corresponds with an area consisting of stagnation moraines. Elevated arsenic concentrations have been observed in similar areas of Minnesota (Minnesota Pollution Control Agency, 1999). Reasons for the high arsenic concentrations in these areas is unknown (Soule, personal communication).
3. Concentrations of most chemicals were low in the Prairie du Chien aquifer compared to other aquifers. Concentrations of arsenic, barium, cadmium, chloride, copper, orthophosphate, and total organic carbon were high in the Galena aquifer. These were also chemicals which had

higher concentrations in the Cedar Valley aquifer compared to most aquifers. The Galena and Cedar Valley aquifers are both classified as Upper Carbonate aquifers.

4. The Jordan and Franconia aquifers had low concentrations of most chemicals compared to other aquifers, with the exception of aluminum, chromium, zinc, and dissolved oxygen.
5. Median nitrate concentrations were low in all aquifers, being above the reporting limit of 500 ug/L only in the Jordan aquifer. Reporting limits are listed in Table A.2.

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 (CIGL), Platteville (OPVL), and Maquoketa (OMAQ) aquifers to provide meaningful results. The drinking criteria for beryllium (0.08 ug/L) was exceeded once each in the Franconia (CFRN) and unconfined buried drift (QBUU) aquifers; boron (600 ug/L) once in the QBUU aquifer; cadmium (4 ug/L) once each in the Jordan (CJDN), Cedar Valley (DCVA), and Prairie du Chien (OPDC) aquifers and twice in the St. Peter (OSTP) aquifer; manganese (1000 ug/L) three times in the confined buried drift (QBAA) aquifer and twice in the QBUU aquifer; and nitrate (10000 ug/L) once each in the Galena (OGAL) and OPDC aquifers. There appear to be instances where concentrations of cadmium and manganese represent a potential health concern. Cadmium and manganese are discussed in sections 3.4.4 and 3.4.5.

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 concentrations exceeded the SMCL in 1, 11, 1, 8, 2, 2, 9, 10, 19, 16, 9, 1, 24, and 17 wells for the Franconia-Ironton-Galesville (CFIG), CFRN, CIGL, CJDN, Mount Simon (CMTS), St. Lawrence (CSTL), DCVA, Cretaceous (KRET), OGAL, OPDC, OSTP, OPVL, QBAA, and QBUU aquifers, respectively. The drinking criteria for lead (15 ug/L) was exceeded once in the CFRN aquifer. The SMCL for sulfate (250000 ug/L) was exceeded once each in the CIGL, CJDN, and OGAL aquifers, five times in the Cretaceous aquifer, six times in the QBUU aquifer, and nine times in the QBAA aquifer.

Some chemicals have the same toxic endpoint. For example, Table A.21 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. To make this calculation, a hazard index (HI) is used to add the contribution of each chemical with similar endpoints:

$$[HI_{endpoint} = C_{chemical\ 1}/HRL_{chemical1} + C_{chemical\ 2}/HRL_{chemical2} + ... + C_{chemical\ n}/HRL_{chemicaln}]$$

where C represents the concentration (ug/L) of a chemical. If the HI exceeds 1.0 in an individual well, 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. The calculations would therefore be potentially misleading. These calculations were made for statewide data and are reported in MPCA, 1998a.

3.4. Discussion of Individual Chemicals and Chemical Parameters

Although individual chemicals which exceeded their drinking criteria are discussed in Section 3.5, nitrate, arsenic, volatile organic compounds, cadmium, and manganese are discussed in greater detail below.

3.4.1. Nitrate

Median nitrate concentrations were below the reporting limit of 500 ug/L in all aquifers except the Jordan, which had a median concentration of 590 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 all detections occurring in the eastern third of the study area (Figure B.7). Detections of nitrate were distributed among each of the major aquifers. There were 19 detections of nitrate and the oxidation-reduction potential (Eh) in each of these wells exceeded 225 mV, with most exceeding 300 mV. At Eh values less than these, nitrate will undergo denitrification. Concentrations in all wells with an Eh of less than 225 mV were below the reporting limit of 500 ug/L. Approximately 50 percent of the samples containing no detectable nitrate had Eh values greater than 225 mV, indicating anthropogenic sources of nitrate are not uniform across the study area. The distribution of dissolved oxygen and Eh are illustrated in Figure B.7 and correlate with the distribution of nitrate.

Paleozoic aquifers are closest to the land surface in the eastern third of Region 5. Unconsolidated deposits are relatively thin or absent in these areas and consist predominantly of loess, which may be subject to rapid infiltration and recharge to underlying bedrock aquifers. These aquifers have been mapped as sensitive to pollution in various reports (Minnesota Geological Survey, 1984; Minnesota Department of Natural Resources 1996, 1997). Walsh (1992) and the Minnesota Pollution Control Agency (MPCA)(1998c) found strong correlations between nitrate concentration and thickness of deposits overlying the uppermost aquifer, with little nitrate found in aquifers having more than 70 feet of surficial material. This may be due to fractures within these deposits, which create conduits for rapid transport of water. The sensitivity of these aquifers appears to extend deeply into the aquifers, since most sampled wells were screened far below the top of the water table.

3.4.2. Volatile Organic Compounds

Results for Volatile Organic Compounds (VOCs) are summarized in Table A.26. The distribution of VOC detections is illustrated in Figure B.8. There were 17 wells in which a VOC was detected. This represents 10 percent of the sampled wells, which is close to the overall statewide rate of 11 percent (MPCA, 1998a). There were nine wells in which more than one VOC was detected, which is greater than the statewide rate of 2.1 percent. Thirty-three of the 45 total detections were chemicals commonly found in gasoline and fuel oils. These included nine detections for xylene, eight for toluene, seven for benzene, and nine for substituted benzenes. The detection rate for benzene is very high. Nine of the 45 total detections were halogenated aliphatic compounds. The remaining three detections were chloroform, which may represent a by-product of well disinfection or be naturally occurring.

Five of the wells with VOC detections were in the QBAA aquifer, four in the QBUU aquifer, three in the Cretaceous aquifer, two each in the Cedar Valley and Jordan aquifers, and one in the Maquoketa aquifer. The occurrence of VOCs was not associated with any sampled chemical parameter. Eh and concentrations of dissolved oxygen did not differ between samples with and without detectable VOCs. The frequency of tritium detections in wells with a detected VOC was 83 percent, while the frequency was 71 percent in wells with no detectable VOC. There was no significant difference in well depth or static water elevation in samples with and without a detectable VOC. The occurrence of VOCs in ground water appears to be somewhat random, being dependent on a source for the VOC.

There were no exceedances of drinking criteria. The high occurrence rate for benzene, toluene, xylene, and halogenated compounds, combined with the high rate of multiple exceedances for individual wells, indicates VOC contamination may be a concern in some locations in southeast Minnesota.

3.4.3. Arsenic

The Maximum Contaminant Level (MCL) of 50 ug/L was not exceeded in any well sampled in Region 5. The MCL is not strictly health-based, but considers factors such as treatability. A health-based value for arsenic is likely to be less than 10 ug/L, perhaps as a low as 2 or 3 ug/L. A drinking criteria this low would be approached or exceeded in many of the sampled wells. Median concentrations in the Mt. Simon, St. Lawrence, Cedar Valley, Galena, Quaternary buried artesian, and Quaternary buried undifferentiated aquifers were 3.9, 4.6, 2.6, 2.5, 3.2, and 5.8 ug/L, respectively.

Arsenic was correlated with iron (R^2 = 0.432), Eh (R^2 = -0.377), dissolved oxygen (R^2 = -0.305), nitrate (R^2 = -0.314), manganese (R^2 = 0.420), silicate (R^2 = 0.61), sodium (R^2 = 0.46), and total dissolved solids (R^2 = 0.38). Arsenic concentrations increase from east to west across Region 5. Arsenic may represent a potential health concern in Region 5.

3.4.4. Cadmium

The overall median concentration of cadmium in region 5 was 0.13 ug/L. There were, however, five exceedances of the HRL (4 ug/L). An additional 11 samples exceeded 2 ug/L. The median concentration in the Cedar Valley aquifer was 1.4 ug/L. The median concentration in the Galena aquifer was 0.63 ug/L. Median concentrations in all other aquifers were less than 0.20 ug/L. There were no strong correlations between cadmium and other chemicals, either for the entire data set or for the Upper Carbonate aquifers. Cadmium represents a health concern in the Upper Carbonate aquifers, but not in other aquifers. Additional investigation is needed to determine the source of the cadmium.

3.4.5. Manganese

The overall median concentration of manganese in Region 5 was 68 ug/L. The current HRL is 100 ug/L and the drinking standard we used in this report was 1000 ug/L. Five samples exceeded a concentration of 1000 ug/L and 68 samples exceeded a concentration of 100 ug/L. Two factors control the concentration of manganese in ground water. First is the concentration of manganese in geologic materials. Concentrations in the Galena and Cedar Valley aquifers, for example, were 21 and 59 ug/L, while concentrations in Cretaceous aquifers were 248 ug/L. Concentrations of manganese in these aquifers showed no correlation with oxidation-reduction (redox) conditions in the aquifer. The second factor is the redox status within an aquifer. Aquifers that are generally well protected, excluding the Cretaceous, showed strong corrleations between Eh and manganese concentrations. Manganese was poorly correlated with iron. Nitrate was not present in any sample in which manganese concentrations exceeded 50 ug/L. Manganese occupies a small redox window between nitrate and iron. As nitrate disappears, manganese becomes the electron source for microbes and it is reduced. It's concentration then increases in ground water. Between Eh values of about 200 and 250 mV, manganese concentrations steadily increase from less than 10 ug/L to over 100 ug/L. Manganese therefore represents a health concern in aquifers with reducing conditions. These occur primarily in the western part of Region 5, where increasing till thickness leads to greater confinement of aquifers and increasing residence times within ground water.

3.5. Aquifers

The hydrology and geology of Region 5 is described in numerous reports, although there is no specific report which encompasses the entire area. The Hydrologic Investigations Reports for the Lower Minnesota (Anderson et al., 1974), Root River (Broussard et al., 1975), Cedar River (Farrell et al., 1975), Zumbro River (Anderson et al., 1975), Cannon River (Anderson et al., 1974), and Blue Earth River (Anderson et al., 1974) watersheds provide information about climate, the water budget, surface water, and ground water. Precipitation across the region varies from about 29 inches in the west to 31 inches in the east. Annual runoff to surface rivers varies from about 4.5 inches in the west to more than 7.5 inches in the east. Annual recharge to surficial aquifers may be greater than these amounts and will vary widely with annual precipitation. The major rivers in the region are gaining streams in that they have a baseflow component (ground water discharges to them).

The hydrogeology of Region 5 is dominated by Paleozoic bedrock geology consisting primarily of limestone, dolomite, and sandstone. The primary aquifers in Region 5 include the Upper Carbonate Group (Galena and Cedar Valley carbonate aquifers), the St. Peter sandstone, the Prairie du Chien Group (carbonate aquifers), the Jordan sandstone, the Franconia Formation (a sandstone), the Ironton-Galesville Formation (sandstones), and the Mt. Simon sandstone. Thickness of glacial till through most of Region 5 is thin, except for the western third of the study area where deposits may be several hundred feet thick. Karst features can develop in areas where carbonate aquifers are located at or near the land surface, or they may occur deeply within bedrock. Karst significantly impacts ground water flow, with much of the flow occurring in a small volume of the aquifer material, travel times often being very short, and flow directions differing from surface drainage. In places where karst features have not developed, the bedrock aquifers act as more or less continuous units, with regional flow being to the major rivers in the area. Travel times within these aquifers range from a few years to more than 30000 years (Campion, personal communication). Aquifers in glacial material consist of buried sand and gravel alluvial deposits. The buried sand and gravel aquifers behave as a regional flow system in which ground water flow is toward the major rivers in the area, but individual aquifers are poorly connected hydrologically with each other. Cretaceous bedrock deposits occur in the western portion of Region 5 and are of limited importance as a source of drinking water.

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, but karst features are responsive to large precipitation events during the summer and autumn. Some recharge occurs in summer and autumn if precipitation is heavy and soils are saturated. Tipping (1994) indicates about 20 percent of annual precipitation (approximately 7 inches) percolates through the vadose zone and into ground water. 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, and permeability of glacial deposits.

Bedrock ground water systems are generally regional, and research has therefore focused on regional analyses. Examples of regional reports include Minnesota Department of Natural Resources (1997), Minnesota Geological Survey (1984), Minnesota Department of Natural Resources (1996), Tipping (1994), Ruhl and Wolf (1983), Ruhl and Wolf (1984), Ruhl et al. (1982), and Ruhl et al. (1983). Regional ground water resources are well described in these reports, partly because these aquifers are used heavily for industrial and domestic purposes. In addition to major ion chemistry, extensive sampling has been conducted for volatile organic compounds, pesticides, and age-dating. The aquifers considered in this report include buried sand and gravel, Cretaceous, Cedar Valley, Galena, St. Peter, Prairie du Chien, Jordan, and Franconia.

3.5.1. Buried Drift Aquifers

Well-sorted sand and gravel were deposited in bedrock valleys and as outwash plains by advancing and retreating glaciers. These deposits were subsequently covered by fine-textured deposits which act as confining units. Sand and gravel deposits are typically less than 30 feet thick and have limited potential supply for high capacity uses, but they yield sufficient quantities for domestic use. Sand and gravel aquifers are limited to the western third of Region 5 (Figure B.6). 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 undifferentiated (QBUU) aquifers. Statistical tests were performed between the QBAA and QBUU aquifers to determine if they had similar chemistry. Water quality of the two aquifers were similar, with no significant differences between the two aquifers in concentrations of major ions. The QBUU aquifer had a tendency for elevated concentrations of chemicals which are mobile in the vadose zone, such as chloride, selenium, and vanadium, while concentrations of phosphorus and some trace metals were greater in the QBAA aquifer. Because of the similar water quality of the two aquifers, they are treated as a single aquifer in this discussion. There was no attempt to identify the extent of confinement or depths of well screen in the wells sampled as part of the baseline analysis. Water quality information for buried and surficial drift aquifers in Region 5 is illustrated in Tables A.16 and A.17.

Despite the similarity between the QBAA and QBUU groups, water quality of the buried artesian aquifers (QBAA) in Region 5 differs from similar aquifers in other areas of the state. Concentrations of most chemicals were higher in Region 5, with an overall difference in concentration of +21%. The greatest differences were for boron (+51%), antimony (+52%), and sulfate (+92%). Water quality of the undifferentiated aquifers (QBUU) is very similar to statewide median concentrations for the same aquifers. This is because 18 of the 22 wells sampled statewide were located in this region.

There is limited information for glacial aquifers in Region 5. These aquifers are unimportant except in the extreme western portion of the study area, where the drift thickness exceeds several hundred feet.

Water quality information for buried drift aquifers from other studies conducted in Region 5 is illustrated in Table A.27. The data indicate GWMAP data are intermediate compared with data from other studies. There is considerable variability in the data, however, suggesting water quality varies widely in Region 5. For example, concentrations of iron, chloride, sulfate, and total dissolved solids are high in the Blue Earth River watershed (Anderson et al., 1974) and low in the Root River watershed (Broussard et al., 1975).

Water quality of drift aquifers in Region 5 is similar to water quality of Cretaceous aquifers and very different from Paleozoic aquifers. These results suggest some interaction between the Cretaceous and drift aquifers, or the importance of weathered Cretaceous material on water quality of the buried aquifers. Comparison of Figures B.5 and B.6 supports the idea of interaction, since most sampled drift and Cretaceous wells were in the western part of the region. Ground water in the drift aquifers is high in total dissolved solids and many trace elements, such as boron, zinc, cadmium, manganese, and vanadium, compared to similar aquifers statewide. Drinking water criteria for beryllium, boron, manganese, iron, and sulfate were exceeded in at least one sample from the drift aquifers. Each of these chemicals is discussed below.

Beryllium

The HRL of 0.08 ug/L was exceeded in one Quaternary well. The median concentration in buried artesian aquifers (QBAA) was below the reporting limit of 0.01 ug/L, while the median was 0.010 ug/L in buried undifferentiated aquifers (QBUU). Concentrations were greater in the QBUU wells compared to the QBAA wells, with the upper 95th percent confidence level concentration being 0.18 ug/L in QBUU wells. It is unclear what the source of the beryllium is, since no other aquifers had high beryllium concentrations.

Boron

Although the overall median boron concentration was 287 ug/L for the buried drift aquifers, there was only one exceedance (807 ug/L) of the drinking criteria (600 ug/L). The 95th percentile concentration was 493 ug/L. The strongest correlations of boron were with sodium (R^2 = 0.82), specific conductance (R^2 = 0.73), sodium (R^2 = 0.64), magnesium (R^2 = 0.58), calcium (R^2 = 0.54), and several of the trace metals (lead, cobalt, aluminum, and chromium). The distribution of boron appears to be strongly related to parent material. The single exceedance of the drinking standard was a well with a very high concentration of total suspended solids (904000 ug/L). Several other metals were at a high concentration in this well. Overall, boron concentrations are higher in the buried drift aquifer than in other aquifers of Region 5, but boron does not appear to represent a significant potential health concern in ground water.

Iron

All but three of the 44 wells sampled from the buried drift had iron concentrations exceeding the Secondary Maximum Contaminant Level of 300 ug/L. The median concentration in the buried drift aquifer was 1999 ug/L. The 95th percentile concentration was 7219 ug/L. Iron was not well correlated with any chemical parameter. The correlation coefficient with total suspended solids was 0.54. Iron concentrations in the buried drift aquifers of Region 5 are very high and associated water quality problems, such as staining of plumbing fixtures, are likely to occur.

Manganese

There were five exceedances of the drinking criteria (1000 ug/L) for manganese. The overall median concentration was 210 ug/L. Thirty-four of the 44 sampled wells had manganese concentrations exceeding the current Health Risk Limit of 100 ug/L. Correlations with other chemical or physical parameters were weak, except for Eh (R^2 = 0.56). This correlation is the opposite of what would be expected, since manganese concentrations generally increase with decreasing Eh. Manganese does not appear to represent a potential health concern in buried drift aquifers of Region 5.

Sulfate

There were six exceedances of the SMCL (500000 ug/L) for sulfate. The median sulfate concentration was 155640 ug/L. The strongest correlations of sulfate were with total dissolved solids (R^2 = 0.98), calcium (R^2 = 0.92), and magnesium (R^2 = 0.89). Sulfate accounts for approximately 40 percent of the anion charge in buried drift aquifers of Region 5. This compares with a value of less than 10 percent for the Paleozoic bedrock aquifers, but is similar to the value for Cretaceous bedrock. The primary source appears to be gypsum. Other sources include reduced sulfur in minerals, and organic sulfur.

3.5.2. Cretaceous Aquifer

The Cretaceous aquifer is limited to the extreme western portion of Region 5 (see Figure B.5). Cretaceous deposits consist of alternating layers of sandstone and shale, with aquifers located in the sandstone deposits. The aquifer is probably discontinuous in Region 5, consisting of separate deposits.

Data in Table A.10 indicates differences in water quality between the Cretaceous aquifers in Region 5 and those statewide. Higher concentrations of calcium, bicarbonate, and sulfate were observed in Region 5, but concentrations of sodium, chloride, potassium, and total dissolved solids were lower. Ground water quality in Cretaceous aquifers sampled in Region 5 is similar to buried drift aquifers of Region 5. This is most evident in iron and manganese concentrations. The data suggest some interaction between drift and Cretaceous aquifers.

There is limited information on water quality in the Cretaceous aquifer from other studies (Table A.34). There were exceedances of drinking criteria for iron and sulfate. In addition, median concentrations of boron and manganese were relatively high. These four chemicals are discussed below.

Sulfate

The SMCL of 500000 ug/L for sulfate was exceeded in two wells. The median concentration of sulfate was 281385 ug/L. Sulfate concentrations were correlated with calcium (R^2 = 0.964), magnesium (R^2 = 0.818), specific conductance (R^2 = 0.879), and total dissolved solids (R^2 = 0.879). Sulfate concentrations also increased from north to south. Calcium- and magnesium-sulfates appear to be the source for the sulfate. Sulfate, which has laxative effects, is an important ion in the Cretaceous aquifer and is a drinking water concern in Region 5.

Iron

The Secondary Maximum Contaminant Level (SMCL) of 300 ug/L for iron was exceeded in all 10 Cretaceous wells sampled in Region 5. The median concentration for iron was 3151 ug/L, which exceeds the SMCL by a factor of more than 10. Iron was not strongly correlated with other sampled parameters. Iron, which affects plumbing fixtures, is a concern in the Cretaceous aquifer, and there appear to be no effective management strategies for reducing iron concentrations.

Boron

No samples exceeded the Health Risk Limit of 600 ug/L for boron. The median concentration was 367 ug/L, however, which is high compared to most aquifers in the state. Statewide boron represents the most important potential health concern in Cretaceous aquifers. Boron was correlated with sodium (R^2 = 0.661). Since boron-bearing minerals also contain sodium, the results indicate parent materials are enriched in boron. Consequently, there are no effective management strategies for reducing boron concentrations in Cretaceous aquifers.

Manganese

No samples exceeded the drinking criteria of 1000 ug/L for manganese, although eight samples exceeded the current Health Risk Limit of 100 ug/L and the median concentration was 248 ug/L. This is higher than the statewide median concentration of 112 ug/L in Cretaceous aquifers. Manganese was correlated with calcium (R^2 = 0.697), sulfate (R^2 = 0.697), specific conductance (R^2 = 0.697), and total dissolved solids (R^2 = 0.697). Negative correlations were observed with trace metals. Manganese concentrations appear to be related to presence of relatively soluble carbonate- and sulfate-bearing minerals. Manganese does not represent a health concern in Cretaceous aquifers of Region 5.

3.5.3. Upper Carbonate Aquifers

The Upper Carbonate aquifer is comprised of five geologic formations. In ascending order, these are the Galena Group, Dubuque Formation, the Maquoketa Formation, the Wapsipinicon Group and the Cedar Valley Group. These formations are often considered to represent a single aquifer system, since they have similar hydrology. They were formed in

Paleozoic seas which occupied the Hollandale embayment. Ground water in these formations flows in fractures and solution channels. Sinkholes are a common feature of the landscape overlying the formations. Ground water discharges to regional streams and rivers.

Although these aquifers have similar hydrology and consist of water dominated by calcium, magnesium, and bicarbonate, there are significant differences in chemistry (MPCA, 1998a). Temperature, pH, Eh, specific conductance, and concentrations of calcium, magnesium, chloride, nitrate, iron, manganese, total organic carbon, suspended solids, and several trace inorganics differ between the individual formations. Thus, although there may be hydraulic connection between the aquifers, they cannot be treated as a single unit. The Galena and Cedar Valley aquifers comprise all but one sample collected from these formations. They are discussed separately below.

3.5.3.1. Galena Aquifer

The Galena aquifer shows high concentrations of most dissolved constituents compared to the Cedar Valley aquifer. The Maquoketa and Dubuque formations may act as confining units, resulting in greater residence times within the Galena aquifer. The data for tritium conflicts with this model, however. Tritium was detected in 6 of 7 samples collected from the Galena aquifer. Four of the wells with detectable tritium had concentrations between 1.8 and 10 tritium units, indicating a mixture of old and new water, while two samples had tritium concentrations greater than 10 tritium units, reflecting post-1953 water. The water chemistry of the Galena aquifer is difficult to explain, but is likely to be influenced by karst features.

Water quality information from other studies are illustrated in Table A.28. GWMAP data are similar to other data, although there is a limited amount of information for the Galena aquifer. Water quality criteria for iron and nitrate were exceeded in one and 19 wells, respectively. These chemicals are discussed individually below.

Iron

Nineteen of the 22 samples exceeded the SMCL of 300 ug/L. The median iron concentration was 1500 ug/L. Strongest correlations of iron were with Eh (R^2 = -0.60), dissolved oxygen (R^2 = -0.52), and total suspended solids (R^2 = 0.75). These results indicate iron will be a concern in most wells completed in the Galena aquifer, but that iron concentrations will increase with more reducing conditions and as the amount of suspended material increases. Filtering may thus reduce much of the iron.

Nitrate

There was one exceedance (30460 ug/L) of the Health Risk Limit (10000 ug/L) for nitrate. There were only two other detections of nitrate, and the estimated mean concentration in the Galena aquifer was 31 ug/L. The three wells with detectable nitrate had dissolved oxygen concentrations of 3390 ug/L or greater, an Eh of 293 mV or greater, and iron concentrations less than 150 ug/L. The highest Eh in the remaining 19 wells was 289 mV, with most values less than 200 mV. The results indicate that when oxidizing conditions are encountered in Galena wells, nitrate may be a concern.

3.5.3.2. Cedar Valley Aquifer

Where present, the Cedar Valley represents the uppermost bedrock formation in south-central Minnesota. It is subject to dissolution and karst has formed extensively where glacial materials are thin or absent. The aquifer shows relatively low concentrations of most dissolved solids, as would be expected in a rapid response system. Nitrate was not detected in any of the ten wells sampled from this aquifer, and tritium was detected in two of the three sampled wells at concentrations indicating waters of mixed age (between 1.8 and 10 tritium units). The median Eh value for this aquifer was 105 mV, indicating reducing conditions. Samples collected for this study appear to reflect ground water quality of less active portions of the aquifer. Hydraulically active areas should be characterized by oxidized water, detectable oxygen and nitrate, and low concentrations of dissolved solids, iron, and manganese.

Water quality information in the literature for the Cedar Valley aquifer is combined with information from the Galena aquifer (Table A.28). Consequently, concentrations of most dissolved constituents are slightly lower in the GWMAP data, which considers only the Cedar

Valley aquifer. The data from the two data sets are comparable, however. There were nine exceedances of the drinking criteria for iron and one exceedance for cadmium. These two chemicals are discussed below.

Cadmium

The Health Risk Limit of 4 ug/L for cadmium was exceeded in one well (36.67 ug/L). The median concentration was 1.4 ug/L, and four samples exceeded 2 ug/L. Cadmium was well correlated with aluminum (R^2 = 0.709), phosphorus (R^2 = 0.842), and beryllium (R^2 = -0.919). These results are difficult to interpret but may suggest the presence of minerals with high concentrations of cadmium. Cadmium appears to be present in sufficient quantities to represent a potential health concern in some portions of the Cedar Valley aquifer.

Iron

The SMCL of 300 ug/L for iron was exceeded in all but one well. The median concentration was 1612 ug/L, which is much greater than concentrations in the Prairie du Chien, Jordan, or St. Peter aquifers and similar to concentrations in drift aquifers. The strongest correlations were with depth (R^2 = 0.770), Eh (R^2 = -0.721), and total suspended solids (R^2 = 0.826). As expected, iron concentrations increase with more reducing conditions, and iron is primarily associated with suspended material in the aquifer. Filtering of ground water may significantly lower the concentrations of iron.

3.5.4. 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 based on measured heads within the aquifers, which often suggest there is no effective confining unit between the aquifers. Definitions based on hydraulics, however, ignore the actual movement of water within the aquifers and, in particular, attenuation properties and residence times of the aquifers. Comparisons of water quality in the three aquifers indicate significant differences in water quality (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.

3.5.4.1. 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. Unconsolidated deposits cover approximately 20 percent of the aquifer. The St. Peter formation is easily eroded and therefore is only rarely found at the land surface. The basal layer of the St. Peter formation acts as a confining unit (Ruhl and Wolf, 1983).

Water quality information from other studies are illustrated in Figure A.29. Concentrations of most chemicals are lower in the GWMAP data compared to the remaining studies. The reasons for this are unclear, since tritium was not detected in six of the eight wells sampled for tritium. Only one sample had a tritium concentration exceeding 10 tritium units, reflecting post-1953 water. These results suggest relatively old waters, which should have higher concentrations of dissolved solids because of increased residence times. The greater concentrations of chloride and nitrate in the data from the USGS study may reflect a sampling bias toward shallower wells than those sampled for the GWMAP baseline study.

Drinking water criteria were exceeded for iron and cadmium in nine and two samples, respectively. These chemicals are discussed below.

Cadmium

The HRL for cadmium (4 ug/L) was exceeded in two wells (13.42 and 5.82 ug/L). One additional well had a concentration of 3.08 ug/L, but the overall median concentration was 0.27 ug/L. Cadmium concentrations increased from west to east (R^2 = 0.767 for UTM-east coordinate) and with increasing depth to water (R^2 = 0.590). Cadmium was also correlated with aluminum (R^2 = 0.717), manganese (R^2 = -0.707), silicate (R^2 = -0.645), and sodium (R^2 = -0.579). These results suggest the presence of cadmium-bearing minerals in some locations of Region 5, possibly in the unsaturated zone. Aluminum-bearing minerals appear to be the source of the cadmium. Cadmium concentrations are generally low, but in isolated locations concentrations are elevated and may represent a potential health concern.

Iron

Nine of the 14 samples exceeded the SMCL of 300 ug/L for iron. The median concentration was 384 ug/L. Iron was not well correlated with any parameter except chloride (R^2 = -0.635). There were only four wells in which iron concentrations exceeded 1000 ug/L. Although iron exceeds the SMCL in the majority of samples, concentrations were low in the St. Peter aquifer compared to most other aquifers.

3.5.4.2. 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. Consequently, the formation may be as thick as 400 feet near the interior. The Prairie du Chien Formation is vuggy and fractured, with interbedded thin layers of shale.

Ground water flow is predominantly toward the Mississippi River. Recharge to the aquifer is greatest in the eastern part of Region 5, where the aquifer is close to or crops out at the land surface. The Prairie du Chien is an important aquifer in Region 5, but is vulnerable to contamination when overlying deposits of glacial till are thin or absent.

Concentrations of some chemicals from other studies of the Prairie du Chien aquifer are illustrated in Table A.30. GWMAP data are similar to other data, except that iron, chloride, and sulfate concentrations are lower for the GWMAP data. Concentrations of most chemicals in Region 5 are similar to statewide concentrations for the aquifer. However, this is partly due to 26 of the 36 statewide samples being collected in Region 5. The most noticeable difference is for chloride, which is considerably lower in Region 5 compared to the statewide median for the aquifer. This is because the remainder of the samples from the Prairie du Chien aquifer were collected in the Twin Cities Metropolitan Area, where there are likely to be significant impacts from road salt and industry.

There was one exceedance of drinking criteria for both nitrate and chloride, and 16 exceedances for iron. These chemicals are discussed below.

Nitrate

Nitrate was detected in nine samples, with the HRL of 10000 ug/L being exceeded in one well (10010 ug/L). Three samples exceeded 3000 ug/L. The strongest correlations of nitrate were with dissolved oxygen (R^2 = 0.426), Eh (R^2 = 0.612), iron (R^2 = -0.728), and manganese (R^2 = -0.667). Nitrate also increased from west to east (R^2 = 0.574). Chloride and tritium were good indicators of the presence of nitrate (R^2 = 0.691 and 0.806, respectively). Nitrate concentrations appear to be strongly correlated with recharge to the aquifer and represent a drinking water concern in the eastern portion of Region 5.

Cadmium

The HRL of 4 ug/L for cadmium was exceeded in one well (5.67 ug/L). Three additional samples exceeded 1 ug/L. The median concentration was 0.10 ug/L. Cadmium was most strongly correlated with dissolved oxygen (R^2 = 0.420), chloride (R^2 = 0.483), magnesium (R^2 = -0.417), alkalinity (R^2 = -0.497), sodium (R^2 = -0.432), and silicate (R^2 = -0.474). Cadmium concentrations also increased to the south and east. These results provide further support that the occurrence of cadmium in Paleozoic aquifers is related to the presence of cadmium-rich minerals, possibly in the unsaturated zone. In general, however, cadmium does not represent a drinking water concern in Region 5.

Iron

The SMCL of 300 ug/L for iron was exceeded in 16 of the 26 sampled wells. The overall median concentration was 615 ug/L. Four and eight samples, respectively, exceeded concentrations of 3000 and 1000 ug/L. Unlike other aquifers, there were several strong correlations for iron. These included nitrate (R^2 = -0.728), manganese (R^2 = 0.859), boron (R^2 = 0.568), chloride (R^2 = -0.541), Eh (R^2 = -0.526), and total suspended solids (R^2 = 0.589). Iron concentrations also increased from east to west (R^2 = 0.670). While iron was more prevalent in waters with high concentrations of suspended material, concentrations were more strongly related to oxidation-reduction conditions in the aquifer compared to other aquifers. The Prairie du Chien aquifer is a more highly oxidized aquifer than other Paleozoic aquifers. Concentrations of chemicals are probably correlated with thickness of overlying glacial or bedrock deposits.

3.5.4.3. 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. The Jordan aquifer is often considered to be hydraulically connected to the Prairie du Chien aquifer. 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.

Water quality criteria from different studies are compared in Table A.31. GWMAP-measured concentrations are somewhat lower than concentrations measured in other studies. The amount of data collected from other studies is very small, however. Twenty of the 31 total samples collected statewide from the Jordan were collected in Region 5. Consequently, concentrations of most chemicals in Region 5 are similar to concentrations measured statewide. Exceptions are for the oxidation-reduction parameters, which indicate the Jordan aquifer is much more highly oxidized in Region 5 than in other parts of the state. This is reflected by higher concentrations of dissolved oxygen and nitrate, higher Eh, and lower concentrations of manganese and iron in Region 5.

Drinking water criteria were exceeded once for cadmium and eight times for iron. These chemicals are discussed below.

Cadmium

The HRL of 4 ug/L for cadmium was exceeded in one well (4.57 ug/L). The overall median concentration was very low at 0.035 ug/L. Only one other sample exceeded 1 ug/L. Cadmium was not well correlated with any other measured parameter. Cadmium does not appear to be a drinking water concern in Region 5 within the Jordan aquifer.

Iron

The SMCL of 300 ug/L for iron was exceeded in eight wells. However, the data appeared to fall into two separate groups. Eight sampled wells had concentrations greater than 700 ug/L, while 12 samples had concentrations less than 100 ug/L. The chemistry of these two groups differed significantly, as illustrated in Table A.32. Samples with low iron concentrations are restricted to the eastern edge of Region 5 and are characterized by oxidized ground water and elevated concentrations of chloride and lead. High iron concentrations occur west of this area. Samples from these wells have high concentrations of manganese, potassium, suspended solids, and low Eh. The boundary between these two areas appears to correlate with the boundary between confined and unconfined portions of the Jordan aquifer, but additional analysis is needed to confirm this. The overall median concentration for the Jordan aquifer was 35 ug/L, which is by far the lowest median concentration measured for any aquifer in Region 5. There were several strong correlations for iron, including alkalinity (R^2 = 0.575), Eh (R^2 = -0.548), manganese (R^2 = 0.774), nitrate (R^2 = -0.574), potassium (R^2 = 0.834), and total suspended solids (R^2 = 0.841). Iron concentrations also increased from east to west (R^2 = -0.557). Occurrences of high iron concentrations in ground water appear to be related to oxidation-reduction conditions, with reducing waters having much greater concentrations.

3.5.5. 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. Data from the statewide baseline study indicates the chemistry of these aquifers is very similar. The discussion below treats them as a single unit.

The Franconia-Ironton-Galesville aquifer covers all of Region 5 except for the extreme western portion of the region. The Franconia, Ironton, and Galesville formations consist primarily of sandstones, although the Franconia Formation has some interbedded shale and layers of dolomitic sandstone. The Franconia Formation is often considered to be a confining unit, but sufficient quantities of water for domestic use can be obtained from the northern and northwestern part of Region 5. The Franconia Formation consists of four members, but there was no attempt to separate the GWMAP data into these different members. The Ironton Sandstone is a medium grained, moderately- to poorly-sorted quartzarenite. The Galesville Sandstone is mostly medium grained. The thickness of the Ironton-Galesville deposits average about 70 feet. Recharge to the aquifer primarily occurs from leakage through overlying bedrock deposits and, in the northwestern part of Region 5, through glacial till. Ground water discharges to the major rivers in Region 5 (Ruhl, et al., 1982).

GWMAP data are intermediate compared with data collected from other studies (Table A.33). Compared to overall statewide data, concentrations of most major cations and anions are lower in Region 5. The aquifer appears to be more oxidized in Region 5 than in other parts of the state, with a median Eh of about 250 mV, dissolved oxygen concentrations greater than 1000 ug/L, and low concentrations of manganese (median = 20 ug/L). Concentrations of many trace metals, such as cadmium, chromium, lead, and zinc are higher in Region 5, which is a pattern observed for the overlying Paleozoic aquifers.

Drinking standards for beryllium, iron, and lead were exceeded in one, 13, and one well, respectively. These chemicals are discussed below.

Beryllium

The HRL of 0.08 ug/L for beryllium was equaled in one well. Beryllium was detected in only three other wells and the mean concentration was less than 0.001 ug/L. Beryllium was not well correlated with other measured parameters. It does not appear to represent a drinking water concern in Region 5.

Iron

The SMCL of 300 ug/L for iron was exceeded in 12 of the 18 sampled wells. The median concentration was approximately 888 ug/L. Iron was correlated with several parameters, including boron (R^2 = 0.640), chloride (R^2 = -0.525), dissolved oxygen (R^2 = -0.560), manganese (R^2 = 0.806), nitrate (R^2 = -0.708), pH (R^2 = -0.589), potassium (R^2 = 0.650), sulfate (R^2 = 0.627), total suspended solids (R^2 = 0.853), and tritium (R^2 = -0.788). Iron concentrations also increased from east to west. These results support increasing concentrations of iron as ground water residence time increases and ground water becomes more reducing.

Lead

The Action Level of 15 ug/L for lead was exceeded in one well (27.58 ug/L). All other samples had concentrations of lead less than 2.5 ug/L. The median concentration was approximately 0.75 ug/L. Lead was correlated with alkalinity (R^2 = -0.713), boron (R^2 = -0.805), calcium (R^2 = -0.726), potassium (R^2 = -0.709), sodium (R^2 = -0.809), total dissolved solids (R^2 = -0.680), and total suspended solids (R^2 = -0.680). Concentrations of lead increased from west to east (R^2 = 0.715). Much of the lead observed in ground water appears to be due to anthropogenic sources, since concentrations decrease as residence time increases. There may be some concern with lead in drinking water in the eastern portion of Region 5.

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 5 in southeast Minnesota. Sample size was sufficient for the Franconia (CFRN), Jordan (CJDN), Galena (OGAL), Prairie du Chien (OPDC), St. Peter (OSTP), and buried drift (QBAA and QBUU) aquifers so that these values may serve as background concentrations for the aquifers in Region 5. Sample sizes for the Cedar Valley (DCVA) and Cretaceous (KRET) aquifers are somewhat limited, but may be useful as an indicator of background conditions.
2. There were differences in concentrations of many chemicals between different aquifers. Buried drift and Cretaceous aquifers had similar water quality. Concentrations of many parameters, including bicarbonate, boron, calcium, magnesium, manganese, sodium, sulfate,

and total dissolved solids, were much higher in these aquifers than in other aquifers. Concentrations of arsenic and silicate were highest in the buried drift aquifers. The Jordan, Franconia, and St. Peter aquifers had low concentrations of most parameters, including bicarbonate, chloride, iron, potassium, sodium, and total dissolved solids. Concentrations of dissolved oxygen and nitrate, and Eh, tend to be higher in these aquifers and the Prairie du Chien aquifer. These aquifers appear to be responsive to recharge, particularly along the eastern margin of these aquifers where thickness of overlying drift or bedrock aquifers is thin or absent. The Galena and Cedar Valley aquifers have chemistry different from the remaining aquifers. Concentrations of most chemicals are intermediate compared to the remaining aquifers, except for relatively high concentrations of aluminum, arsenic, and cadmium. Water quality in the buried drift, Cretaceous, Galena, and Cedar Valley aquifers was most affected by parent material, while the Prairie du Chien, Jordan, Franconia, and Galesville aquifers may be highly impacted by recharge.

3. Health-based drinking standards (HRL or HBV) were exceeded for the following compounds:
   - manganese - 5 exceedances in buried drift aquifers;
   - boron - 1 exceedance in the buried drift aquifer;
   - beryllium - 2 exceedances, one each in the Franconia and buried drift aquifers;
   - cadmium - 5 exceedances in Paleozoic bedrock aquifers; and
   - nitrate - 2 exceedances, one each in the Galena and Prairie du Chien aquifers.
4. Non-health based standards (MCL or SMCL) were exceeded for the following compounds:
   - iron - 130 exceedances, scattered among all aquifers;
   - sulfate - 8 exceedances in the Cretaceous and buried drift aquifers; and
   - lead - 1 exceedance in the Franconia aquifer.
5. Most samples collected statewide from the Paleozoic bedrock aquifers were collected in Region 5. Consequently, there are few differences in water quality of these aquifers in Region 5 compared to statewide concentrations. Exceptions include some of the trace metals, such as cadmium, lead, and zinc, which tend to be higher in Region 5, and the oxidation-reduction parameters, which reflect water that is more oxidized compared to statewide values. The results reflect specific mineralogy, particularly in the Galena and Cedar Valley aquifers, and influence of recharge, particularly along the eastern margin of the Prairie du Chien, Jordan,

and Franconia aquifers. Water quality in Cretaceous aquifers shows greater impacts from the overlying drift aquifers than for Cretaceous aquifers statewide. Concentrations of bicarbonate and calcium are higher in Region 5 compared to the remainder of the state, while concentrations of sodium, chloride, and potassium are lower. Concentrations of most trace elements are slightly lower compared to statewide concentrations. The interaction between buried drift and Cretaceous aquifers is evident in the water quality results for the buried drift. Concentrations of bicarbonate, calcium, iron, boron, sodium, and several trace elements are greater in the buried drift aquifers of Region 5 compared to similar aquifers statewide. Water quality in most aquifers of Region 5 is good, except for the buried drift aquifers and locations where the Paleozoic bedrock aquifers are close to the land surface. The primary trace elements of concern include cadmium in the Paleozoic bedrock aquifers and boron in the buried drift and Cretaceous aquifers. Iron concentrations exceeded or were near the drinking criteria in a high percentage of wells in all aquifers. Concentrations of sulfate were very high in the buried drift and Cretaceous aquifers.

6. Volatile organic compounds were detected in 17 wells or 10 percent of the samples. Compounds commonly associated with fuel oils (xylene, ethylbenzene, toluene, and benzene) accounted for about 80 percent of the total number of compounds detected. Halogenated compounds accounted for the majority of the remaining detections. Nine of the wells with a detectable VOC had more than one VOC present in the sample, which is much higher than the statewide rate for multiple detections. The distribution of VOCs in ground water of Region 5 differs from most other areas of the state because chemicals typical of fuel oils and industrial solvents account for nearly all the compounds detected. Individual wells may be at high risk from contamination. No drinking water criteria for VOCs were exceeded.

4.2. Research Recommendations

The objective of research is to provide information relating physical processes to water quality. Although research is typically conducted at small scales, results should have widespread application. GWMAP conducts research related to impacts of human activity on ground water quality. Research recommendations for Region 5 are discussed below.

1. The primary research need in Region 5 is a better understanding of the hydrogeology of the Paleozoic bedrock aquifers. This report provides information on ambient conditions in these aquifers, but does not address hydrologically sensitive portions of the aquifers. These include unconfined areas of the Prairie du Chien and Jordan aquifers, and the role of karst in ground water hydrology. Although considerable research is on-going in these areas, more information is needed on spatial and temporal variability in hydrologic processes such as recharge, discharge, and flow rates.
2. There has been considerable debate challenging the commonly held notion that many of the Paleozoic aquifers of southeast Minnesota are hydrologically connected. Water quality information suggests that the fate and transport of chemicals in ground water does not follow the traditional concepts of flow within these aquifers. Attempts to identify hydrologic units in southeast Minnesota should include assessment of water quality. This requires better control on where individual wells are completed and, for fractured bedrock, more control on seasonal variability in water quality.
3. Land use information needs to be collected to determine if there is a relationship between detection of VOCs and human activity.
4. Mineralogical analysis of some aquifers should be conducted to determine if water quality is related to mineralogy. Chemicals of greatest concern include cadmium and lead in the Upper Carbonate aquifers and boron in the Cretaceous and buried drift 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 5 are discussed below.

1. Baseline data : the baseline data for the buried confined drift (QBAA), Jordan (CJDN), Prairie du Chien (OPDC), and Galena (OGAL) aquifers are sufficient to be considered representative of background. These data can simply be updated over time. Data bases for the Franconia, Cedar Valley, and Cretaceous aquifers should be expanded 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. The following specific recommendations are made for baseline enhancement.

- Expand the database for the CFRN, KRET, and OGAL aquifers by about 10 wells each. Wells selected for sampling should have well logs and would preferably be grouted and finished below the middle of the aquifer. The wells do not need to be located within GWMAP grid cells. The parameter list includes major cations and anions and the inorganic trace elements. Wells located in karst bedrock should be avoided because of seasonal variability in the data.
- Sample for VOCs in approximately 100 additional wells in areas of Region 5 mapped as hydrologically sensitive. Land use information should be collected simultaneously.
- Analysis of the data should be conducted at approximately five to ten year intervals, provided data have been collected during this period. Analysis methods similar to those employed by GWMAP should be used.
- Data from other studies can be incorporated into the baseline data base. Field sampling methods must be documented and meet standard QA/QC protocol.

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 5. It is unclear, however, if the high incidence of VOC detections is related to human activity and what the potential health implications of VOCs are. An ambient network should not be established, therefore, until the link between human activity and incidence of VOC detections has been proven. Nitrates are generally considered to represent a concern in sensitive portions of the Paleozoic bedrock aquifers. Although the drinking criteria for nitrate was exceeded in just two wells, the strong correlations between nitrate and the oxidation-reduction parameters and with tritium indicate there are human impacts on nitrate concentrations in ground water. The GWMAP data is biased toward a low frequency of detection, because most sampled wells are completed in the lower half of the aquifer. A shallow monitoring network should be established in areas which are mapped as hydrologically sensitive and where nitrates have been observed in domestic wells.

3. Sampling, data management, and data analysis protocol should be established and documented. Protocol developed by other agencies or ground water groups can be utilized.

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Appendix A - Tables

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

Aquifer	Number of Samples
Franconia-Ironton-Galesville (CFIG)	1
Franconia (CFRN)	15
Ironton-Galesville (CIGL)	2
Jordan (CJDN)	20
Mt. Simon (CMTS)	2
St. Lawrence (CSTL)	2
Cedar Valley (DCVA)	10
Cretaceous (KRET)	10
Galena (OGAL)	22
Maquoketa (OMAQ)	1
Prairie du Chien (OPDC)	26
Platteville (OPVL)	1
St. Peter (OSTP)	14
Quaternary buried artesian aquifer (QBAA)	26
Quaternary buried undifferentiated aquifer (QBUU)	18

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

Parameter	No. of samples	No. of missing	Maximum reporting limit (ug/L)	No. detections above censoring value	No. censored values
Alkalinity	170	0	nnd[1]	170	0
Aluminum (Al)	168	2	0.060	142	26
Antimony (Sb)	168	2	0.008	126	42
Arsenic (As)	168	2	0.060	157	11
Barium (Ba)	170	0	1.4	170	0
Beryllium (Be)	168	2	0.010	48	120
Boron (B)	170	0	13	148	22
Bromide (Br)	168	2	0.20	2	166
Cadmium (Cd)	168	2	0.020	131	37
Calcium (Ca)	170	0	nnd	170	0
Chromium (Cr)	169	1	0.050	101	68
Chloride (Cl)	168	2	200	167	1
Cobalt (Co)	168	2	0.0020	168	0
Copper (Cu)	170	0	4.6	110	60
Dissolved Oxygen	170	0	300	97	73
Eh	170	0	nnd	170	0
Fluoride (F)[2]	145	25	[2]	145	0
Iron (Fe)	170	0	3.2	170	0
Lead (Pb)	168	2	0.03	153	15
Lithium (Li)	170	0	4.5	131	39
Magnesium (Mg)	170	0	nnd	170	0
Manganese (Mn)	170	0	0.90	155	15
Mercury (Hg)	166	4	0.10	9	157

Table A.2 Continued

Parameter	No. of samples	No. of missing	Maximum reporting limit (ug/L)	No. detections above censoring value	No. censored values
Molybdenum (Mo)	170	0	4.2	27	143
Nickel (Ni)	170	0	6.0	53	117
Nitrate-N (NO_3-N)	170	0	500	28	142
pH	170	0	nnd	135	35
$Phosphorus_{total}$	170	0	14.9	150	20
Potassium (K)	170	0	118.5	170	0
Rubidium (Rb)	170	0	555.5	14	156
Selenium (Se)	133	37	0.1	128	5
Silicate (Si)	170	0	nnd	170	0
Silver (Ag)	168	2	0.0090	26	142
Sodium (Na)	170	0	nnd	170	0
Specific Conductance	170	0	nnd	170	0
Strontium (Sr)	170	0	0.60	170	0
Sulfate	169	1	300	166	3
Sulfur (S)	170	0	21.8	170	0
Temperature	170	0	nnd	170	0
Thallium (Tl)	168	2	0.0050	92	76
Titanium (Ti)	170	0	0.0035	30	140
Total dissolved solids	167	3	nnd	167	0
Total organic carbon	169	1	500	163	6
Total phosphate	84	86	20	71	13
Total suspended solids	167	3	nnd	167	0
Vanadium (V)	170	0	2.5	115	55
Zinc (Zn)	170	0	2.7	166	4
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	-	-

Table A.2 Continued

Parameter	No. of samples	No. of missing	Maximum reporting limit (ug/L)	No. detections above censoring value	No. censored values
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	-	-
1,2-Dibromoethane	170	-	0.5	-	-
Ethylbenzene	170	-	0.2	-	-
Ethyl ether	170	-	2	-	-
Hexachlorobutadiene	170	-	0.5	-	-
Isopropylbenzene	170	-	0.5	-	-
Methylene chloride	170	-	0.5	-	-
Methyl ethyl ketone	170	-	10	-	-
Methyl isobutyl ketone	170	-	5	-	-
Methyl tertiary butyl ether	170	-	2	-	-
n-Butylbenzene	170	-	0.5	-	-
Naphthalene	170	-	0.5	-	-
n-Propylbenzene	170	-	0.5	-	-
o-Xylene	170	-	0.2	-	-
p&m-Xylene	170	-	0.2	-	-
p-Isopropyltoluene	170	-	0.5	-	-
sec-Butylbenzene	170	-	0.5	-	-
Styrene	170	-	0.5	-	-
tert-Butylbenzene	170	-	0.5	-	-
trans-1,2-Dichloroethene	170	-	0.1	-	-
trans-1,3-Dichloropropene	170	-	0.2	-	-
Trichloroethene	170	-	0.1	-	-
Trichlorofluoromethane	170	-	0.5	-	-
Tetrachloroethene	170	-	0.2	-	-
Tetrahydrofuran	170	-	10	-	-
Toluene	170	-	0.2	-	-
Vinyl chloride	170	-	0.5	-	-

[1] nnd = no samples were below the maximum reporting limit
[2] 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).

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Min	Max	State Median
						ug/L				ug/L
Alkalinity	1	0	ins[1]	ins	ins	467000	ins	ins	ins	330000
Aluminum	1	1	ins	ins	ins	< 0.060	ins	ins	ins	2.9
Antimony	1	1	ins	ins	ins	< 0.0080	ins	ins	ins	0.017
Arsenic	1	0	ins	ins	ins	1.9	ins	ins	ins	0.99
Barium	1	0	ins	ins	ins	28	ins	ins	ins	35
Beryllium	1	1	ins	ins	ins	< 0.010	ins	ins	ins	< 0.010
Boron	1	0	ins	ins	ins	162	ins	ins	ins	1163
Bromide	1	1	ins	ins	ins	< 0.20	ins	ins	ins	< 0.20
Cadmium	1	1	ins	ins	ins	< 0.020	ins	ins	ins	0.040
Calcium	1	0	ins	ins	ins	130435	ins	ins	ins	99107
Chloride	1	0	ins	ins	ins	350	ins	ins	ins	1310
Chromium	1	0	ins	ins	ins	1.1	ins	ins	ins	0.27
Cobalt	1	0	ins	ins	ins	0.49	ins	ins	ins	0.55
Copper	1	1	ins	ins	ins	< 4.6	ins	ins	ins	< 5.5
Dissolved oxygen	1	0	ins	ins	ins	18000	ins	ins	ins	< 300
Eh	1	0	ins	ins	ins	26	ins	ins	ins	140
Fluoride	1	0	ins	ins	ins	770	ins	ins	ins	325
Iron	1	0	ins	ins	ins	2550	ins	ins	ins	876
Lead	1	1	ins	ins	ins	< 0.030	ins	ins	ins	0.20
Lithium	1	0	ins	ins	ins	12	ins	ins	ins	6.2
Magnesium	1	0	ins	ins	ins	52959	ins	ins	ins	36044
Manganese	1	0	ins	ins	ins	17	ins	ins	ins	53
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	6.92	ins	ins	ins	7.20
Phosphorus	1	0	ins	ins	ins	46	ins	ins	ins	33
Potassium	1	0	ins	ins	ins	4099	ins	ins	ins	4099
Rubidium	1	1	ins	ins	ins	< 555.5	ins	ins	ins	< 555.5
Selenium	1	0	ins	ins	ins	8.1	ins	ins	ins	2.9
Silicate	1	0	ins	ins	ins	6233	ins	ins	ins	6233
Silver	1	1	ins	ins	ins	< 0.0090	ins	ins	ins	< 0.0090
Sodium	1	0	ins	ins	ins	42265	ins	ins	ins	10760
Specific Conductance	1	0	ins	ins	ins	980	ins	ins	ins	700
Strontium	1	0	ins	ins	ins	363	ins	ins	ins	363
Sulfate	1	0	ins	ins	ins	162090	ins	ins	ins	24330
Sulfur	1	0	ins	ins	ins	56024	ins	ins	ins	23426
Temperature	1	0	ins	ins	ins	9.7	ins	ins	ins	9.7
Thallium	1	1	ins	ins	ins	< 0.0050	ins	ins	ins	< 0.0050
Titanium	1	1	ins	ins	ins	< 0.0035	ins	ins	ins	< 0.0035

Table A.3 Continued

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Min	Max	State Median
Total dissolved solids	1	0	ins	ins	ins	732000	ins	ins	ins	428000
Total organic carbon	1	0	ins	ins	ins	7500	ins	ins	ins	1000
Total phosphate-P	1	0	ins	ins	ins	40	ins	ins	ins	< 20
Total suspended solids	1	0	ins	ins	ins	8000	ins	ins	ins	6000
Vanadium	1	1	ins	ins	ins	< 2.5	ins	ins	ins	4.9
Zinc	1	0	ins	ins	ins	32	ins	ins	ins	39

[1] ins = insufficient sample size

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

Parameter	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	15	0	normal	297000	342569	270000	538000	206000	538000	270000
Aluminum	14	1	log-censored	0.95	9.8	1.2	4.0	< 0.060	4.0	1.5
Antimony	14	3	log-censored	0.022	0.20	0.027	0.13	< 0.0080	0.13	0.012
Arsenic	14	3	log-censored	0.33	8.9	0.34	69	< 0.060	6.0	0.67
Barium	15	0	log-normal	52	103	46	210	2.1	210	48
Beryllium	14	11	log-censored	0.00094	0.015	< 0.010	0.080	< 0.010	0.08	< 0.010
Boron	15	5	log-censored	24	638	22	272	< 13	272	28
Bromide	15	15	ins	-	-	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20
Cadmium	14	4	log-censored	0.097	28	0.14	2.2	< 0.020	2.2	0.055
Calcium	15	0	log-normal	69088	83965	60334	116589	45905	116589	69745
Chloride	15	0	log-normal	1262	3156	440	22760	200	22760	1030
Chromium	14	3	log-censored	0.41	7.7	0.36	5.3	< 0.050	5.3	0.29
Cobalt	14	0	normal	0.58	0.91	0.48	1.3	0.21	1.2	0.58
Copper	15	9	log-censored	4.7	40	< 5.5	32	< 4.6	32	< 5.5
Dissolved oxygen	15	5	log-censored	1467	-	1830	105300	< 300	105300	< 300
Eh	15	0	normal	232	322	255	457	-30	457	213
Fluoride	12	0	normal	297	331	300	370	210	370	280
Iron	15	0	normal	1569	2085	888	4669	20	4669	856
Lead	14	2	log-censored	0.51	20	0.74	28	< 0.030	28	0.23
Lithium	15	8	log-censored	4.1	77	< 4.5	41	< 4.5	41	5.1
Magnesium	15	0	normal	30585	24944	30286	45351	16497	45351	30514
Manganese	15	2	log-censored	17	424	20	166	< 0.90	166	47
Mercury	14	13	ins	-	-	< 0.10	0.10	< 0.10	0.10	< 0.10
Molybdenum	15	13	ins	-	-	< 4.2	9.6	< 4.2	9.6	< 4.2
Nickel	15	9	log-censored	4.8	17	< 6.0	14	< 6.0	14	< 6.0
Nitrate-N	15	11	log-censored	141	11725	< 500	7850	< 500	7850	< 500
Ortho-phosphate-P	10	9	ins	-	-	< 5	10	< 5	10	< 5.0
pH	15	0	normal	7.25	7.46	7.30	7.83	6.9	7.83	7.34
Phosphorus	15	7	log-censored	14	658	16	696	< 14.9	696	29

Table A.4 Continued

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	90th percentile	Min	Max	State Median
Potassium	15	0	log-normal	1447	3436	1405	9321	153	9321	1691
Rubidium	15	14	ins	-	-	< 555.5	893	< 555.5	893	< 555.5
Selenium	10	1	log-censored	1.3	6.1	1.0	7.7	< 0.1	7.7	1.0
Silicate	15	0	normal	7812	11583	6133	14861	3601	14861	8291
Silver	14	8	log-censored	0.019	1.8	< 0.0090	0.78	< 0.0090	0.78	< 0.0090
Sodium	15	0	none	-	-	2310	40006	1627	40006	4997
Specific Conductance	15	0	normal	491	676	470	893	3	893	510
Strontium	15	0	none	-	-	74	1412	37	1412	110
Sulfate	15	0	log-normal	16088	29161	18150	67230	4560	67230	6330
Sulfur	15	0	normal	8971	16401	6931	28585	1463	28585	6948
Temperature	15	0	normal	9.90	10.2	9.90	11.0	9.00	11.0	9.8
Thallium	14	10	log-censored	0.00080	0.16	< 0.0050	0.090	< 0.005	0.090	< 0.0050
Titanium	15	12	log-censored	0.0023	0.010	< 0.0035	0.0087	< 0.0035	0.0087	< 0.0035
Total dissolved solids	14	0	normal	348357	431435	313000	616000	222000	616000	339000
Total organic carbon	15	2	log-censored	3387	34557	3800	16700	< 500	16700	2900
Total phosphate-P	5	2	ins	-	-	50	-	< 20	640	20
Total suspended solids	14	0	normal	5643	7978	4000	16000	1000	16000	3500
Vanadium	15	9	log-censored	3.4	17	< 4.7	12	< 4.7	12	< 4.7
Zinc	15	0	log-normal	89	298	146	1760	4.9	1760	88

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

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95h percentile	Min	Max	State Median
						ug/L		ug/L	ug/L	ug/L
Alkalinity	2	0	ins	ins	ins	333500	ins	271000	396000	353500
Aluminum	2	0	ins	ins	ins	0.44	ins	0.43	0.45	2.1
Antimony	2	0	ins	ins	ins	0.038	ins	0.013	0.062	0.019
Arsenic	2	0	ins	ins	ins	0.57	ins	0.40	0.74	0.65
Barium	2	0	ins	ins	ins	34	ins	19	49	47
Beryllium	2	1	ins	ins	ins	ins	ins	< 0.010	0.010	0.10
Boron	2	0	ins	ins	ins	82	ins	12	152	59
Bromide	2	2	ins	ins	ins	< 0.20	ins	< 0.20	< 0.2	< 0.20
Cadmium	2	0	ins	ins	ins	0.17	ins	0.15	0.19	0.090
Calcium	2	0	ins	ins	ins	103060	ins	51375	154746	89046
Chloride	2	0	ins	ins	ins	1615	ins	570	2660	1310
Chromium	2	1	ins	ins	ins	0.20	ins	< 0.050	0.35	0.27
Cobalt	2	0	ins	ins	ins	1.1	ins	0.38	1.8	0.72
Copper	2	1	ins	ins	ins	8.1	ins	< 5.5	11	10
Dissolved oxygen	2	1	ins	ins	ins	1140	ins	< 300	1990	< 300
Eh	2	0	ins	ins	ins	255	ins	228	282	207
Fluoride	2	0	ins	ins	ins	275	ins	200	350	245
Iron	2	0	ins	ins	ins	599	ins	256	942	1005

Table A.5 Continued

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95h percentile	Min	Max	State Median
Lead	2	0	ins	ins	ins	0.67	ins	0.050	1.3	0.88
Lithium	2	1	ins	ins	ins	9.6	ins	< 4.5	15	10
Magnesium	2	0	ins	ins	ins	37837	ins	29971	45702	32668
Manganese	2	0	ins	ins	ins	43	ins	11	75	136
Mercury	2	2	ins	ins	ins	< 0.10	ins	< 0.10	< 0.10	< 0.10
Molybdenum	2	2	ins	ins	ins	< 4.2	ins	< 4.2	< 4.2	< 4.2
Nickel	2	2	ins	ins	ins	< 6.0	ins	< 6.0	< 6.0	< 6.0
Nitrate-N	2	2	ins	ins	ins	< 500	ins	< 500	< 500	<500
Ortho-phosphate-P	1	1	ins	ins	ins	< 5.0	ins	ins	ins	< 5.0
pH	2	0	ins	ins	ins	7.19	ins	7.01	7.47	7.27
Phosphorus	2	1	ins	ins	ins	40	ins	< 14.9	65	57
Potassium	2	0	ins	ins	ins	3483	ins	837	6130	2564
Rubidium	2	2	ins	ins	ins	< 555.5	ins	< 555.5	< 555.5	< 555.5
Selenium	2	1	ins	ins	ins	0.95	ins	< 0.1	1.0	< 1.0
Silicate	2	0	ins	ins	ins	5553	ins	5439	5666	7059
Silver	2	0	ins	ins	ins	0.14	ins	0.010	0.26	0.025
Sodium	2	0	ins	ins	ins	35282	ins	1790	68775	9965
Specific Conductance	2	0	ins	ins	ins	847	ins	477	1217	651
Strontium	2	0	ins	ins	ins	422	ins	47	798	224
Sulfate-S	2	0	ins	ins	ins	57065	ins	5210	108920	8155
Sulfate	2	0	ins	ins	ins	171195	ins	15630	326760	8333
Sulfur	2	0	ins	ins	ins	59172	ins	5489	1129	10.3
Temperature	2	0	ins	ins	ins	10.5	ins	10.4	10.6	0.027
Thallium	2	1	ins	ins	ins	0.021	ins	< 0.0050	0.037	0.090
Titanium	2	2	ins	ins	ins	< 0.0035	ins	< 0.0035	< 0.0035	< 0.0035
Total dissolved solids	2	0	ins	ins	ins	638000	ins	264000	1012000	373000
Total organic carbon	2	0	ins	ins	ins	3600	ins	1900	5300	1654
Total phosphate-P	1	1	ins	ins	ins	< 20	ins	ins	ins	30
Total suspended solids	2	0	ins	ins	ins	3000	ins	1000	5000	5000
Vanadium	2	1	ins	ins	ins	ins	ins	< 2.5	10	6.7
Zinc	2	0	ins	ins	ins	150	ins	55	246	56

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

Parameter	No. of samples	No. values censored	Distribu-tion	Mean	UCL mean	Median	95th percent.	Min	Max	State Median
				ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
Alkalinity	20	0	normal	255800	281625	257000	393000	162000	395000	250000
Aluminum	20	6	log-censored	0.95	9.8	0.81	14	< 0.060	14	1.0
Antimony	20	10	log-censored	0.0089	0.078	0.0075	0.55	< 0.0080	0.056	0.0090
Arsenic	20	2	log-censored	0.59	9.9	0.50	17	< 0.060	18	0.58
Barium	20	0	log-normal	32	50	22	641	10	664	23
Beryllium	20	18	log-censored	0.000045	0.085	< 0.01	0.058	< 0.010	0.060	< 0.010

Table A.6 Continued

Parameter	No. of samples	No. values censored	Distribu-tion	Mean	UCL mean	Median	95th percent.	Min	Max	State Median
Boron	20	10	log-censored	11	381	14	293	< 13	297	19
Bromide	20	20	ins	-	-	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20
Cadmium	20	7	log-censored	0.037	5.5	0.035	4.5	< 0.020	4.6	0.060
Calcium	20	0	none	-	-	65727	136501	40118	137412	63229
Chloride	20	0	log-normal	1028	1522	975	8202	310	8370	950
Chromium	20	4	log-censored	0.49	3.7	0.66	1.7	< 0.050	1.7	0.59
Cobalt	20	0	normal	0.38	0.46	0.35	0.64	0.14	0.64	0.41
Copper	20	6	log-censored	8.5	44	9.2	38	< 4.6	39	8.1
Dissolved oxygen	20	6	log-censored	2916	91104	4340	91000	< 300	94500	500
Eh	20	0	normal	286	341	264	463	102	463	199
Fluoride	16	0	none	-	-	275	2510	150	2510	290
Iron	20	2	log-censored	82	29785	35	5692	< 3.2	5777	246
Lead	20	3	log-censored	0.59	11	0.51	10	< 0.030	11	0.40
Lithium	20	12	log-censored	3.6	54	< 4.5	42	< 4.5	43	< 4.5
Magnesium	20	0	log-normal	25316	28438	24105	44265	16978	44401	23845
Manganese	20	9	log-censored	11	673	7.9	353	< 0.90	362	27
Mercury	19	18	ins	-	-	< 0.10	0.17	< 0.10	0.17	< 0.10
Molybdenum	20	19	ins	-	-	< 4.2	5.1	< 4.2	5.1	< 4.2
Nickel	20	12	log-censored	5.5	9.3	< 6.0	9.1	< 6.0	9.2	< 6.0
Nitrate-N	20	5	log-censored	840	3370	595	2722	< 500	2740	< 500
Ortho-phosphate-P	16	8	log-censored	5.1	73	4.5	40	< 5.0	40	5.0
pH	20	0	none	-	-	7.31	8.66	1.50	8.69	7.34
Phosphorus	20	8	log-censored	24	290	25	217	< 14.9	220	25
Potassium	20	0	none	-	-	780	5577	120	5656	990
Rubidium	20	19	ins	-	-	< 555.5	1731	< 555.5	740	< 555.5
Selenium	10	0	normal	1.7	2.2	1.4	3.7	1.0	3.7	1.0
Silicate	20	0	log-normal	8177	9236	7972	15086	5880	15231	7971
Silver	20	17	log-censored	0.000027	0.29	< 0.0090	0.24	< 0.0090	0.25	< 0.0090
Sodium	20	0	none	-	-	2313	60913	1790	61464	2497
Specific Conductance	20	0	none	-	-	492	1196	3.0	1200	492
Strontium	20	0	none	-	-	63	754	27	765	69
Sulfate	20	0	none	-	-	18180	276834	2370	281370	6160
Sulfur	20	0	log-normal	5998	9806	6617	94940	972	96320	6607
Temperature	20	0	normal	9.68	10.0	9.6	11.1	8.3	11.1	9.8
Thallium	20	7	log-censored	0.035	0.20	0.018	0.19	< 0.005	0.19	0.018
Titanium	20	17	log-censored	0.0026	0.0071	< 0.0035	0.0069	< 0.0035	0.0070	< 0.035
Total dissolved solids	19	0	none	-	-	300000	828000	182000	828000	288000
Total organic carbon	20	3	log-censored	2463	24111	2400	17010	< 500	17400	1500
Total phosphate-P	4	0	ins	-	-	105	-	100	160	20
Total suspended solids	19	0	log-normal	3057	4606	4000	16000	1000	16000	3000
Vanadium	20	9	log-censored	3.3	13	< 2.5	10	< 2.5	10	< 4.7
Zinc	20	1	log-censored	5.1	73	59	1778	< 2.7	1858	51

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

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Min	Max	State Median
						ug/L		ug/L	ug/L	ug/L
Alkalinity	2	0	ins	ins	ins	407500	ins	327000	488000	257000
Aluminum	2	0	ins	ins	ins	0.84	ins	0.070	1.6	0.53
Antimony	2	0	ins	ins	ins	0.074	ins	0.063	0.084	0.016
Arsenic	2	0	ins	ins	ins	3.9	ins	0.29	7.4	1.6
Barium	2	0	ins	ins	ins	69	ins	32	107	57
Beryllium	2	0	ins	ins	ins	0.040	ins	0.030	0.050	< 0.10
Boron	2	0	ins	ins	ins	147	ins	145	150	33
Bromide	2	1	ins	ins	ins	ins	ins	< 0.20	0.55	< 0.20
Cadmium	2	1	ins	ins	ins	ins	ins	< 0.020	0.19	< 0.020
Calcium	2	0	ins	ins	ins	94833	ins	90263	99403	76615
Chloride	2	0	ins	ins	ins	49375	ins	380	98370	1010
Chromium	2	0	ins	ins	ins	0.26	ins	0.080	0.43	0.31
Cobalt	2	0	ins	ins	ins	0.86	ins	0.62	1.1	0.60
Copper	2	2	ins	ins	ins	< 4.6	ins	< 4.6	< 4.6	< 5.5
Dissolved oxygen	2	1	ins	ins	ins	475	ins	< 300	660	< 300
Eh	2	0	ins	ins	ins	180	ins	85	275	79
Fluoride	2	0	ins	ins	ins	315	ins	280	350	280
Iron	2	0	ins	ins	ins	4128	ins	2687	5569	1259
Lead	2	0	ins	ins	ins	0.37	ins	0.16	0.57	0.20
Lithium	2	1	ins	ins	ins	18	ins	< 4.5	33	< 4.5
Magnesium	2	0	ins	ins	ins	36632	ins	34197	39068	26883
Manganese	2	0	ins	ins	ins	159	ins	43	275	100
Mercury	2	2	ins	ins	ins	< 0.10	ins	< 0.10	< 0.10	< 0.10
Molybdenum	2	2	ins	ins	ins	< 4.2	ins	< 4.2	< 4.0	< 4.2
Nickel	2	2	ins	ins	ins	< 6.0	ins	< 6.0	< 6.0	< 6.0
Nitrate-N	2	2	ins	ins	ins	< 500	ins	< 500	< 500	< 500
pH	2	0	ins	ins	ins	7.18	ins	7.11	7.24	7.30
Phosphorus	2	0	ins	ins	ins	45	ins	39	51	64
Potassium	2	0	ins	ins	ins	4745	ins	3531	5960	1700
Rubidium	2	2	ins	ins	ins	< 555.5	ins	< 555.5	< 555.5	< 555.5
Selenium	2	1	ins	ins	ins	ins	ins	< 0.1	3.0	2.4
Silicate	2	0	ins	ins	ins	6545	ins	5674	7417	8567
Silver	2	1	ins	ins	ins	ins	ins	< 0.0090	0.33	< 0.0090
Sodium	2	0	ins	ins	ins	70703	ins	43516	97890	8085
Specific Conductance	2	0	ins	ins	ins	940	ins	830	1055	661
Strontium	2	0	ins	ins	ins	591	ins	382	800	159
Sulfate	2	0	ins	ins	ins	70710	ins	21870	1196	2450
Sulfur	2	0	ins	ins	ins	24481	ins	7971	40991	2732
Temperature	2	0	ins	ins	ins	11.5	ins	10.8	12.1	9.6
Thallium	2	0	ins	ins	ins	0.046	ins	0.045	0.046	0.0060

Table A.7 Continued.

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Min	Max	State Median
Titanium	2	2	ins	ins	ins	< 0.0035	ins	< 0.0035	< 0.0035	< 0.0035
Total dissolved solids	2	0	ins	ins	ins	581000	ins	484000	678000	374000
Total organic carbon	2	0	ins	ins	ins	2750	ins	2600	2900	2000
Total phosphate-P	2	2	ins	ins	ins	< 20	ins	< 20	< 20	< 20
Total suspended solids	2	0	ins	ins	ins	7000	ins	2000	12000	5000
Vanadium	2	2	ins	ins	ins	< 2.5	ins	< 2.5	< 2.5	< 4.7
Zinc	2	0	ins	ins	ins	161	ins	55	266	14

Table A.8 : Descriptive statistics for the St. Lawrence aquifer (CSTL).

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Min	Max	State Median
						ug/L		ug/L	ug/L	ug/L
Alkalinity	2	0	ins	ins	ins	474500	ins	431000	518000	450500
Aluminum	2	0	ins	ins	ins	1.2	ins	0.81	1.5	2.0
Antimony	2	0	ins	ins	ins	0.065	ins	0.024	0.11	0.065
Arsenic	2	0	ins	ins	ins	4.6	ins	0.41	8.9	4.6
Barium	2	0	ins	ins	ins	37	ins	32	42	37
Beryllium	2	1	ins	ins	ins	ins	ins	< 0.01	0.040	< 0.010
Boron	2	0	ins	ins	ins	273	ins	194	353	142
Bromide	2	2	ins	ins	ins	< 0.20	ins	< 0.20	< 0.2	< 0.20
Cadmium	2	0	ins	ins	ins	0.085	ins	0.050	0.12	0.085
Calcium	2	0	ins	ins	ins	117217	ins	81568	152865	97724
Chloride	2	0	ins	ins	ins	735	ins	580	890	980
Chromium	2	1	ins	ins	ins	ins	ins	< 0.050	0.060	0.13
Cobalt	2	0	ins	ins	ins	1.1	ins	0.84	1.4	0.77
Copper	2	1	ins	ins	ins	ins	ins	< 4.6	94	20
Dissolved oxygen	2	1	ins	ins	ins	ins	ins	< 300	730	375
Eh	2	0	ins	ins	ins	235	ins	211	259	208
Fluoride	2	0	ins	ins	ins	305	ins	290	320	305
Iron	2	0	ins	ins	ins	4676	ins	473	8880	3385
Lead	2	0	ins	ins	ins	2.7	ins	2.2	3.1	2.7
Lithium	2	0	ins	ins	ins	25	ins	22	28	15
Magnesium	2	0	ins	ins	ins	42395	ins	33475	51315	39958
Manganese	2	0	ins	ins	ins	61	ins	39	84	61
Mercury	2	2	ins	ins	ins	< 0.10	ins	< 0.10	< 0.10	< 0.10
Molybdenum	2	1	ins	ins	ins	ins	ins	< 4.2	8.2	4.8
Nickel	2	2	ins	ins	ins	< 6.0	ins	<6.0	< 6.0	6.0
Nitrate-N	2	2	ins	ins	ins	< 500	ins	< 500	< 500	< 500
pH	2	0	ins	ins	ins	7.00	ins	6.72	7.3	7.21
Phosphorus	2	0	ins	ins	ins	64	ins	46	82	64
Potassium	2	0	ins	ins	ins	3512	ins	3452	3571	3367
Rubidium	2	2	ins	ins	ins	< 555.5	ins	< 555.5	< 555.5	< 555.5

Table A.8 Continued.

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Min	Max	State Median
Selenium	2	0	ins	ins	ins	1.2	ins	1.0	1.4	1.0
Silicate	2	0	ins	ins	ins	13134	ins	12548	13720	11639
Silver	2	2	ins	ins	ins	< 0.0090	ins	< 0.0090	0.15	0.014
Sodium	2	0	ins	ins	ins	55551	ins	42331	68771	26940
Specific Conductance	2	0	ins	ins	ins	959	ins	820	1100	810
Strontium	2	0	ins	ins	ins	490	ins	341	639	381
Sulfate	2	0	ins	ins	ins	135105	ins	58620	211590	12020
Sulfur	2	0	ins	ins	ins	52671	ins	25726	79617	15416
Temperature	2	0	ins	ins	ins	9.70	ins	9.40	10.0	9.7
Thallium	2	1	ins	ins	ins	ins	ins	< 0.0050	0.060	0.018
Titanium	2	2	ins	ins	ins	< 0.0035	ins	< 0.0035	< 0.0035	< 0.0035
Total dissolved solids	2	0	ins	ins	ins	672000	ins	516000	828000	518000
Total organic carbon	2	0	ins	ins	ins	3450	ins	2700	4200	2650
Total phosphate-P	2	0	ins	ins	ins	35	ins	20	50	35
Total suspended solids	2	0	ins	ins	ins	11500	ins	1000	22000	8000
Vanadium	2	1	ins	ins	ins	ins	ins	< 2.5	5.4	7.2
Zinc	2	0	ins	ins	ins	285	ins	100	470	245

Table A.9 : Descriptive statistics for the Cedar Valley aquifer (DCVA).

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Min	Max	State Median
				ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
Alkalinity	10	0	normal	312600	356752	289500	421000	225000	421000	289500
Aluminum	10	1	log-censored	1.8	7.0	1.8	3.4	< 0.060	6.4	1.8
Antimony	10	3	log-censored	0.011	0.055	0.011	0.042	< 0.0080	0.042	0.011
Arsenic	10	0	normal	4.5	7.8	2.6	13	0.44	13	2.6
Barium	10	0	normal	190	256	168	331	66	331	168
Beryllium	10	4	log-censored	0.0092	0.077	0.010	0.050	< 0.010	0.050	0.010
Boron	10	0	log-normal	53	158	44	499	12	499	44
Bromide	9	9	ins	-	-	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20
Cadmium	10	0	normal	5.0	14	1.4	37	0.060	37	1.4
Calcium	10	0	normal	75643	84132	75524	95426	61286	95426	75524
Chloride	9	0	log-normal	870	1789	600	4720	410	4720	600
Chromium	10	6	log-censored	0.021	4.2	< 0.050	1.2	< 0.050	1.2	< 0.050
Cobalt	10	0	none	-	-	0.32	1.5	0.24	1.5	0.32
Copper	10	1	log-censored	10	29	9.3	21	< 4.6	21	9.3
Dissolved oxygen	10	4	log-censored	472	3351	450	1800	< 300	1800	450
Eh	10	0	normal	148	222	105	278	63	278	99
Fluoride	9	0	normal	256	279	270	300	210	300	270
Iron	10	0	normal	1752	2401	1612	3561	7.0	3561	1612
Lead	10	0	normal	0.47	0.82	0.39	1.1	0.060	1.1	0.39
Lithium	10	1	log-censored	12	122	11	95	< 4.5	95	11
Magnesium	10	0	normal	22362	26154	22465	29740	15711	29740	22465

Table A.9 Continued.

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Min	Max	State Median
Manganese	10	0	normal	83	125	90	156	9.1	156	90
Mercury	10	5	log-censored	0.093	0.10	0.095	0.23	< 0.10	0.23	< 0.10
Molybdenum	10	9	ins	-	-	< 4.2	4.9	< 4.2	4.9	< 4.2
Nickel	10	6	log-censored	6.6	10	< 6.0	9.2	< 6.0	9.2	< 6.0
Nitrate-N	10	10	ins	-	-	< 500	< 500	< 500	< 500	< 500
Ortho-phosphate-P	10	3	log-censored	18	36	15	170	< 5	170	15
pH	10	0	normal	7.13	7.20	7.12	7.34	6.94	7.34	7.12
Phosphorus	10	0	none	-	-	203	1120	16	1120	203
Potassium	10	0	normal	2036	3441	1318	5998	931	5998	1318
Rubidium	10	10	ins	-	-	< 555.5	< 555.5	< 555.5	< 555.5	< 555.5
Selenium	8	0	none	-	-	1.0	4.0	1.0	4.0	1.0
Silicate	10	0	normal	10904	12384	10666	13959	8544	13959	10666
Silver	10	8	log-censored	0.0080	0.018	< 0.0090	0.015	< 0.0090	0.015	< 0.0090
Sodium	10	0	none	-	-	6764	60355	4808	60355	6764
Specific Conductance	10	0	normal	576	689	534	828	440	828	534
Strontium	10	0	normal	213	327	151	519	97	519	151
Sulfate	10	0	normal	11928	21118	6675	39990	270	39990	2240
Sulfur	10	0	normal	4407	8030	2779	13394	488	13394	2779
Temperature	10	0	normal	9.18	9.44	9.25	9.70	8.7	9.7	9.25
Thallium	10	5	log-censored	0.0058	0.12	0.0050	0.061	< 0.0050	0.061	0.0050
Titanium	10	8	log-censored	0.0048	0.0051	< 0.0035	0.0050	< 0.0035	0.0050	< 0.0035
Total dissolved solids	9	0	normal	348111	416427	320000	500000	250000	500000	320000
Total organic carbon	10	0	normal	6292	9564	5250	11800	1500	11800	5250
Total suspended solids	9	0	normal	5889	8422	5000	14000	3000	14000	5000
Vanadium	10	5	log-censored	4.4	12	4.9	8.5	< 2.5	8.5	4.9
Zinc	10	0	log-normal	13	29	12	72	2.6	72	12

Table A.10 : Descriptive statistics for the Cretaceous aquifer (KRET).

Parameter	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	log-normal	418504	482785	414000	591000	331000	591000	356000
Aluminum	10	1	log-censored	0.87	32.8	0.91	36	< 0.060	36	1.5
Antimony	10	1	log-censored	0.049	0.18	0.051	0.15	< 0.0080	0.15	0.025
Arsenic	10	2	log-censored	0.73	16	0.79	8.2	< 0.060	8.2	1.3
Barium	10	0	none	-	-	29	402	12	402	20
Beryllium	10	7	log-censored	0.032	0.064	< 0.010	0.050	< 0.010	0.050	< 0.010
Boron	10	0	normal	371	500	367	571	122	571	410
Bromide	10	10	ins	-	-	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20
Cadmium	10	2	log-censored	0.084	2.6	0.11	0.82	< 0.020	0.82	0.050
Calcium	10	0	normal	160149	195789	155177	282426	82290	282426	132699
Chloride	10	0	normal	2315	3728	1675	4570	480	4570	5840

Table A.10 Continued.

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	90th percentile	Min	Max	State Median
Chromium	10	6	log-censored	0.044	1.2	< 0.050	0.60	< 0.050	0.60	0.14
Cobalt	10	0	normal	0.92	1.2	0.82	1.9	0.32	1.9	0.60
Copper	10	2	log-censored	8.1	30	7.6	25	< 4.6	25	13
Dissolved oxygen	10	8	log-censored	584	1365	< 300	1140	< 300	1140	< 300
Eh	10	0	normal	168	227	162	307	85	307	138
Fluoride	8	0	normal	395	450	385	520	310	520	431
Iron	10	0	normal	3050	3931	3151	5102	704	5102	1514
Lead	10	3	log-censored	0.24	11	0.30	3.7	< 0.03	3.7	0.45
Lithium	10	2	log-censored	25	68	30	44	< 4.5	44	35
Magnesium	10	0	normal	52932	58931	49655	100778	30972	100778	51635
Manganese	10	0	normal	334	654	248	970	24	967	112
Mercury	10	10	ins	-	-	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010
Molybdenum	10	10	ins	-	-	< 4.2	< 4.2	< 4.2	< 4.2	< 4.2
Nickel	10	9	ins	-	-	< 6.0	15	< 6.0	15	< 6.0
Nitrate-N	10	10	ins	-	-	< 500	< 500	< 500	< 500	< 500
pH	10	0	none	-	-	6.95	7.26	6.8	7.26	7.00
Phosphorus	10	0	log-normal	141	255	113	663	48	663	140
Potassium	10	0	normal	4574	5311	4737	58734	3032	5734	5474
Rubidium	10	10	ins	-	-	< 555.5	< 555.5	< 555.5	< 555.5	< 555.5
Selenium	10	4	log-censored	1.4	5.1	1.4	3.9	< 0.1	3.9	1.5
Silicate	10	0	normal	10597	12765	11092	13746	5857	13746	10955
Silver	10	10	ins	-	-	< 0.0090	< 0.0090	< 0.0090	< 0.0090	< 0.0090
Sodium	10	0	normal	62569	83199	64560	114195	6596	114195	76187
Specific Conductance	10	0	normal	1268	1517	1200	1917	820	2000	1436
Strontium	10	0	normal	816	947	748	1299	510	1299	754
Sulfate	10	0	normal	306693	466250	281385	728340	46890	728340	140130
Sulfur	10	0	normal	118602	179399	105463	286101	18477	286101	162675
Temperature	10	0	normal	10.0	10.7	9.95	11.7	9.70	11.7	10.0
Thallium	10	3	log-censored	0.018	0.080	0.017	0.054	< 0.0050	0.054	< 0.0050
Titanium	10	10	ins	-	-	< 0.0035	< 0.0035	< 0.0035	< 0.0035	< 0.0035
Total dissolved solids	10	0	normal	976200	1242835	945000	1716000	498000	1716000	1110000
Total organic carbon	10	0	normal	4900	7172	3900	10200	2100	10200	2800
Total phosphate-P	10	0	log-normal	71	33	55	570	10	570	50
Total suspended solids	10	0	normal	11000	14047	11000	18000	4000	18000	8000
Vanadium	10	0	normal	6.7	8.4	7.1	10	< 2.5	10	7.2
Zinc	10	0	log-normal	30	54	33	996	4.2	996	26

Table A.11 : Descriptive statistics for the Galena aquifer (OGAL).

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Min	Max	State Median
				ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
Alkalinity	22	0	normal	332227	362488	330000	430800	236000	435000	380000
Aluminum	22	5	log-censored	0.66	16	1.1	10	< 0.060	12	1.1
Antimony	22	9	log-censored	0.010	0.056	0.0090	0.040	< 0.0080	0.040	0.0090
Arsenic	22	1	log-censored	2.0	38	2.5	18	< 0.060	19	2.5
Barium	22	0	normal	162	212	148	392	8.3	397	148

Table A.11 Continued.

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Min	Max	State Median
Beryllium	22	16	log-censored	0.0063	0.024	< 0.010	0.020	< 0.010	0.020	< 0.010
Boron	22	0	none	-	-	43	540	16	567	43
Bromide	21	21	ins	-	-	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20
Cadmium	22	0	log-normal	0.51	0.98	0.63	3.0	0.040	3.1	0.63
Calcium	22	0	none	-	-	79932	139609	55363	139890	79932
Chloride	22	0	log-normal	1687	3534	1340	86288	220	95070	1340
Chromium	22	12	log-censored	0.060	0.86	< 0.050	0.75	< 0.050	0.81	< 0.050
Cobalt	22	0	log-normal	0.37	0.44	0.33	0.91	0.17	0.95	0.33
Copper	22	4	log-censored	8.5	44	12	41	< 4.6	43	11
Dissolved oxygen	22	12	log-censored	459	14326	< 300	15522	< 300	17140	< 300
Eh	22	0	log-normal	122	162	103	415	43	432	97
Fluoride	21	0	normal	320	360	310	478	220	480	460
Iron	22	0	normal	1596	2072	1500	3470	23	3517	1500
Lead	22	0	log-normal	0.23	0.42	0.23	5.4	0.030	6.1	0.060
Lithium	22	2	log-censored	15	75	14	60	< 4.5	62	14
Magnesium	22	0	log-normal	26613	30234	24238	57607	15357.1	60246	24237
Manganese	22	0	none	-	-	51	284	1.2	313	51
Mercury	21	21	ins	ins	-	< 0.010	< 0.010	< 0.10	< 0.10	< 0.10
Molybdenum	22	17	log-censored	3.9	7.4	< 4.2	6.7	< 4.2	6.8	< 4.2
Nickel	22	10	log-censored	6.3	13	6.3	13	< 6.0	14	< 6.0
Nitrate-N	22	19	log-censored	31	38503	< 500	26950	< 500	30460	< 500
Ortho-phosphate-P	19	2	log-censored	23	478	30	200	< 5.0	200	30
pH	22	0	none	-	-	7.17	7.43	5.85	7.44	7.17
Phosphorus	22	0	none	-	-	108	461	34	474	108
Potassium	22	0	log-normal	1934	2618	1789	16319	75	18309	1789
Rubidium	22	20	log-censored	653	662	< 555.5	661	< 555.5	661	< 555.5
Selenium	17	0	none	-	-	1.0	2.9	1.0	2.9	1.0
Silicate	22	0	normal	9757	10870	9780	13591	4491	13771	9780
Silver	22	21	ins	0.000027	0.29	< 0.0090	0.012	< 0.0090	0.013	< 0.0090
Sodium	22	0	log-normal	19476	350187	13465	145261	4310	145608	13465
Specific Conductance	22	0	log-normal	697	800	670	1424	430	1500	667
Strontium	22	0	normal	243	304	231	530	94	554	231
Sulfate	22	2	log-censored	18883	842796	29325	396335	< 300	427290	9776
Sulfur	22	0	log-normal	5806	15631	10853	137131	50	148668	10853
Temperature	22	0	none	-	-	9.1	10.9	8.6	11.1	9.1
Thallium	22	9	log-censored	0.0062	0.050	0.0060	0.0057	< 0.0050	0.062	0.0060
Titanium	22	14	log-censored	0.0028	0.0084	< 0.0035	0.0076	< 0.0035	0.0077	< 0.0035
Total dissolved solids	22	0	log-normal	439036	530029	385500	1180300	238000	1234000	385500
Total organic carbon	22	0	none	-	-	8900	72670	1500	77800	8900
Total phosphate-P	3	0	ins	-	-	40	-	20	150	40
Total suspended solids	22	0	log-normal	4130	5514	4000	12000	1000	12000	4000
Vanadium	22	3	log-censored	5.1	16	5.8	14	< 2.5	14	5.8
Zinc	22	0	log-normal	28	46	24	419	6.0	429	24

Table A.12 : Descriptive statistics for Maquoketa aquifer (OMAQ).

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Min	Max	State Median
						ug/L				ug/L
Alkalinity	1	0	ins	ins	ins	212000	ins	ins	ins	212000
Aluminum	1	0	ins	ins	ins	0.69	ins	ins	ins	0.69
Antimony	1	1	ins	ins	ins	< 0.0080	ins	ins	ins	< 0.0080
Arsenic	1	0	ins	ins	ins	0.84	ins	ins	ins	0.84
Barium	1	0	ins	ins	ins	90	ins	ins	ins	90
Beryllium	1	1	ins	ins	ins	< 0.010	ins	ins	ins	< 0.010
Boron	1	1	ins	ins	ins	< 13	ins	ins	ins	< 13
Bromide	1	1	ins	ins	ins	< 0.20	ins	ins	ins	< 0.20
Cadmium	1	1	ins	ins	ins	< 0.020	ins	ins	ins	< 0.020
Calcium	1	0	ins	ins	ins	57522	ins	ins	ins	57522
Chloride	1	0	ins	ins	ins	3330	ins	ins	ins	3330
Chromium	1	0	ins	ins	ins	0.10	ins	ins	ins	0.10
Cobalt	1	0	ins	ins	ins	0.25	ins	ins	ins	0.25
Copper	1	0	ins	ins	ins	26	ins	ins	ins	26
Dissolved oxygen	1	0	ins	ins	ins	6940	ins	ins	ins	6940
Eh	1	0	ins	ins	ins	272	ins	ins	ins	272
Iron	1	0	ins	ins	ins	47	ins	ins	ins	47
Lead	1	0	ins	ins	ins	0.32	ins	ins	ins	0.32
Lithium	1	0	ins	ins	ins	9.1	ins	ins	ins	9.1
Magnesium	1	0	ins	ins	ins	24639	ins	ins	ins	24639
Manganese	1	0	ins	ins	ins	13	ins	ins	ins	13
Mercury	1	0	ins	ins	ins	0.15	ins	ins	ins	0.15
Molybdenum	1	1	ins	ins	ins	< 4.2	ins	ins	ins	< 4.2
Nickel	1	0	ins	ins	ins	12	ins	ins	ins	12
Nitrate-N	1	0	ins	ins	ins	2030	ins	ins	ins	2030
Ortho-phosphate-P	1	0	ins	ins	ins	10	ins	ins	ins	10
pH	1	0	ins	ins	ins	7.35	ins	ins	ins	7.35
Phosphorus	1	0	ins	ins	ins	31	ins	ins	ins	31
Potassium	1	0	ins	ins	ins	734	ins	ins	ins	734
Rubidium	1	0	ins	ins	ins	656	ins	ins	ins	656
Selenium	1	0	ins	ins	ins	2.0	ins	ins	ins	2.0
Silicate	1	0	ins	ins	ins	7655	ins	ins	ins	7655
Silver	1	1	ins	ins	ins	< 0.0090	ins	ins	ins	< 0.0090
Sodium	1	0	ins	ins	ins	2177	ins	ins	ins	2177
Specific Conductance	1	0	ins	ins	ins	0.47	ins	ins	ins	0.47
Strontium	1	0	ins	ins	ins	47	ins	ins	ins	47
Sulfate-S	1	0	ins	ins	ins	5160	ins	ins	ins	5160
Sulfate	1	0	ins	ins	ins	15480	ins	ins	ins	15480
Sulfur	1	0	ins	ins	ins	5239	ins	ins	ins	5239
Temperature	1	0	ins	ins	ins	9.3	ins	ins	ins	9.3

Table A. 12 Continued.

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Min	Max	State Median
Thallium	1	1	ins	ins	ins	< 0.035	ins	ins	ins	< 0.035
Titanium	1	0	ins	ins	ins	0.0069	ins	ins	ins	0.0069
Total dissolved solids	1	0	ins	ins	ins	289000	ins	ins	ins	289000
Total organic carbon	1	0	ins	ins	ins	1100	ins	ins	ins	1100
Total suspended solids	1	0	ins	ins	ins	1000	ins	ins	ins	1000
Vanadium	1	0	ins	ins	ins	9.7	ins	ins	ins	9.7
Zinc	1	0	ins	ins	ins	10	ins	ins	ins	10

Table A.13 : Descriptive statistics for the Prairie du Chien aquifer (OPDC).

Parameter	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	26	0	normal	310769	357939	288500	463050	185000	469000	272000
Aluminum	25	5	log-censored	0.38	12	0.48	14	< 0.060	18	0.93
Antimony	25	4	log-censored	0.024	0.30	0.020	0.24	< 0.0080	0.25	0023
Arsenic	25	0	log-normal	0.52	0.95	0.47	10	0.080	12	0.46
Barium	26	0	log-normal	68	88	60	189	25	201	60
Beryllium	25	19	log-censored	0.0026	0.039	< 0.010	0.041	< 0.01	< 0.010	< 0.010
Boron	26	3	log-censored	53	685	57	461	< 13	523	30
Bromide	26	26	ins	-	-	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20
Cadmium	25	6	log-censored	0.094	5.0	0.10	4.6	< 0.020	5.7	0.075
Calcium	26	0	normal	82960	94554	80441	136135	34318	144905	80176
Chloride	26	0	log-normal	1871	3882	1255	162785	320	242480	2645
Chromium	25	4	log-censored	0.24	2.9	0.25	3.2	< 0.050	3.6	0.26
Cobalt	25	0	log-normal	0.47	0.69	0.34	4.1	0.15	4.7	0.44
Copper	26	12	log-censored	6.2	59	6.5	51	< 4.6	59	6.1
Dissolved oxygen	26	6	log-censored	835	19955	800	10050	< 300	10200	920
Eh	26	0	log-normal	246	286	257	612	97	702	251
Fluoride	22	0	log-normal	311	359	295	615	200	630	285
Iron	26	0	log-normal	408	1002	615	5583	3.8	6672	487
Lead	25	2	log-censored	0.56	12	0.68	4.7	< 0.030	4.9	0.50
Lithium	26	6	log-censored	9.0	48	9.2	45	< 4.5	50	7.7
Magnesium	26	0	normal	27809	32105	26104	44459	16033	45244	26492
Manganese	26	4	log-censored	20	1182	30	345	< 0.90	353	23
Mercury	25	24	ins	-	-	< 0.10	0.16	< 0.10	0.19	< 0.10
Molybdenum	26	23	log-censored	1.9	6.5	< 4.2	6.0	< 4.2	6.7	< 4.2
Nickel	26	16	log-censored	3.9	22	< 6.0	24	< 6.0	31	< 6.0
Nitrate-N	26	18	log-censored	399	12430	< 500	8677	< 500	10010	< 500
Ortho-phosphate-P	19	7	log-censored	9.2	99	10	60	< 5.0	60	10
pH	26	0	normal	7.17	7.28	7.17	7.60	6.7	7.6	7.25
Phosphorus	26	4	log-censored	40	296	46	263	< 14.9	265	34
Potassium	26	0	log-normal	2203	2887	1634	6659	551	7347	1700
Rubidium	26	23	log-censored	388	844	< 555.5	803	< 555.5	852	< 555.5

Table A.13 Continued.

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	90th percentile	Min	Max	State Median
Selenium	17	1	log-censored	1.3	3.5	1.0	3.7	< 0.1	3.7	1.0
Silicate	26	0	normal	7724	8886	8011	11941	3387	12432	8419
Silver	25	22	log-censored	0.0000035	0.33	< 0.0090	0.34	< 0.0090	0.48	< 0.0090
Sodium	26	0	log-normal	11212	19258	6146	95680	2013	96942	5763
Specific Conductance	26	0	none	-	-	598	1237	2	1400	598
Strontium	26	0	normal	210	296	155	548	82	571	13
Sulfate	26	0	log-normal	33281	46281	3014	163007	9870	185550	8750
Sulfur	26	0	log-normal	12086	16827	9977	61859	3538	73010	9508
Temperature	26	0	normal	9.18	9.59	9.25	10.7	6.4	10.7	9.5
Thallium	25	11	log-censored	0.0077	1.0	0.0060	0.42	< 0.0050	0.46	0.0095
Titanium	26	21	log-censored	0.0018	0.012	< 0.0035	0.0096	< 0.0035	0.011	< 0.0035
Total dissolved solids	26	0	normal	412654	494852	366500	797950	264000	799000	370500
Total organic carbon	26	1	log-censored	3648	31446	3850	29795	< 500	31300	2400
Total phosphate-P	7	1	log-censored	45	425	40	250	< 20	250	20
Total suspended solids	26	0	none	-	-	2000	19200	1000	22000	2000
Vanadium	26	10	log-censored	4.5	14	4.7	12	< 2.5	12	4.9
Zinc	26	1	log-censored	101	1397	95	1108	< 2.7	1372	79

Table A.14 : Descriptive statistics for the Platteville aquifer (OPVL).

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Min	Max	State Median
						ug/L				ug/L
Alkalinity	1	0	ins	ins	ins	283000	ins	ins	ins	329000
Aluminum	1	0	ins	ins	ins	0.32	ins	ins	ins	1.3
Antimony	1	0	ins	ins	ins	0.040	ins	ins	ins	0.040
Arsenic	1	0	ins	ins	ins	14	ins	ins	ins	4.2
Barium	1	0	ins	ins	ins	228	ins	ins	ins	173
Beryllium	1	0	ins	ins	ins	0.010	ins	ins	ins	< 0.010
Boron	1	0	ins	ins	ins	30	ins	ins	ins	30
Bromide	1	1	ins	ins	ins	< 0.20	ins	ins	ins	< 0.20
Cadmium	1	1	ins	ins	ins	< 0.020	ins	ins	ins	0.020
Calcium	1	0	ins	ins	ins	79425	ins	ins	ins	79425
Chloride	1	0	ins	ins	ins	4080	ins	ins	ins	12740
Chromium	1	1	ins	ins	ins	< 0.050	ins	ins	ins	< 0.050
Cobalt	1	0	ins	ins	ins	0.46	ins	ins	ins	0.46
Copper	1	1	ins	ins	ins	< 4.6	ins	ins	ins	17
Dissolved oxygen	1	1	ins	ins	ins	< 300	ins	ins	ins	< 300
Eh	1	0	ins	ins	ins	246	ins	ins	ins	100
Fluoride	1	0	ins	ins	ins	210	ins	ins	ins	230
Iron	1	0	ins	ins	ins	733	ins	ins	ins	733
Lead	1	0	ins	ins	ins	0.070	ins	ins	ins	0.44
Lithium	1	0	ins	ins	ins	5.9	ins	ins	ins	6.8
Magnesium	1	0	ins	ins	ins	27311	ins	ins	ins	43458

Table A.14 Continued.

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Min	Max	State Median
Manganese	1	0	ins	ins	ins	186	ins	ins	ins	186
Mercury	1	1	ins	ins	ins	< 10	ins	ins	ins	< 0.10
Molybdenum	1	0	ins	ins	ins	5.7	ins	ins	ins	4.7
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	7.30	ins	ins	ins	7.30
Phosphorus	1	0	ins	ins	ins	61	ins	ins	ins	61
Potassium	1	0	ins	ins	ins	1925	ins	ins	ins	2156
Rubidium	1	1	ins	ins	ins	< 555.5	ins	ins	ins	< 555.5
Selenium	1	0	ins	ins	ins	6.9	ins	ins	ins	1.0
Silicate	1	0	ins	ins	ins	12594	ins	ins	ins	14233
Silver	1	1	ins	ins	ins	< 0090	ins	ins	ins	0.051
Sodium	1	0	ins	ins	ins	7010	ins	ins	ins	6690
Specific Conductance	1	0	ins	ins	ins	568	ins	ins	ins	631
Strontium	1	0	ins	ins	ins	239	ins	ins	ins	239
Sulfate	1	0	ins	ins	ins	25380	ins	ins	ins	5440
Sulfur	1	0	ins	ins	ins	9637	ins	ins	ins	6221
Temperature	1	0	ins	ins	ins	10	ins	ins	ins	10.4
Thallium	1	1	ins	ins	ins	< 0050	ins	ins	ins	0.017
Titanium	1	1	ins	ins	ins	< 0035	ins	ins	ins	< 0.0035
Total dissolved solids	1	0	ins	ins	ins	325000	ins	ins	ins	352000
Total organic carbon	1	0	ins	ins	ins	3200	ins	ins	ins	1900
Total phosphate-P	1	0	ins	ins	ins	50	ins	ins	ins	50
Total suspended solids	1	0	ins	ins	ins	2000	ins	ins	ins	2000
Vanadium	1	1	ins	ins	ins	< 2.5	ins	ins	ins	< 4.7
Zinc	1	0	ins	ins	ins	20	ins	ins	ins	29

Table A.15 : Descriptive statistics for the St. Peter aquifer (OSTP).

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Min	Max	State Median
				ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
Alkalinity	14	0	normal	262786	316424	233000	398000	175000	398000	242000
Aluminum	14	3	log-censored	0.32	7.0	0.40	2.5	< 0.060	2.5	2.1
Antimony	14	6	log-censored	0.0081	0.11	0.0080	0.083	< 0.0080	0.083	0.0080
Arsenic	14	1	log-censored	0.50	6.2	0.57	3.3	< 0.060	3.3	0.53
Barium	14	0	log-normal	59	79	50	124	27	124	52
Beryllium	14	12	log-censored	0.00072	0.052	< 0.010	0.030	< 0.010	0.030	< 0.010
Boron	14	0	log-normal	83	136	53	266	12	266	42
Bromide	14	14	ins	-	-	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20
Cadmium	14	0	log-normal	0.24	0.94	0.27	13	0.01	13	0.080
Calcium	14	0	log-normal	77126	92236	69718	123474	54415	123474	72852
Chloride	14	0	log-normal	1253	2995	950	48030	310	48030	1230
Chromium	14	5	log-censored	0.11	0.60	0.13	0.69	< 0.050	0.69	0.18

Table A.15 Continued.

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Min	Max	State Median
Cobalt	14	0	log-normal	0.48	0.81	0.43	3.3	0.19	3.3	0.48
Copper	14	6	log-censored	11	101	12	71	< 4.6	71	10
Dissolved oxygen	14	4	log-censored	838	21103	700	10830	< 300	10830	470
Eh	14	0	normal	265	290	262	328	182	328	249
Fluoride	12	0	normal	353	441	330	630	210	630	310
Iron	14	0	log-normal	294	945	384	3531	5.4	3531	384
Lead	14	0	log-normal	0.28	0.55	0.28	1.2	0.040	1.2	0.25
Lithium	14	0	log-censored	8.8	35	8.9	27	4.4	27	7.9
Magnesium	14	0	normal	24649	29641	22362	36153	18272	36153	23382
Manganese	14	0	log-normal	35	109	29	882	1.1	882	31
Mercury	14	14	ins	-	-	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
Molybdenum	14	13	ins	-	-	< 4.2	4.2	< 4.2	4.2	< 4.2
Nickel	14	7	log-censored	8.2	14	6.3	12	< 6.0	12	< 6.0
Nitrate-N	14	13	ins	-	-	< 500	< 500	< 500	7320	< 500
Ortho-phosphate-P	10	5	log-censored	3.7	44	< 5.0	30	< 5.0	30	5.0
pH	14	0	none	-	-	7.18	7.45	4.4	7.45	7.25
Phosphorus	14	0	log-normal	35	56	32	170	16	170	40
Potassium	14	0	normal	2702	3796	2327	5214	1275	5214	1881
Rubidium	14	12	log-censored	578	635	< 555.5	627	< 555.5	627	< 555.5
Selenium	8	2	log-censored	1.1	6.7	1.0	5.4	< 1.0	5.4	1.0
Silicate	14	0	normal	6035	8127	5017	11953	3121	11953	8458
Silver	14	12	log-censored	0.00021	0.27	< 0.0090	0.11	< 0.0090	0.11	< 0.0090
Sodium	14	0	none	-	-	4394	73885	2296	73885	4207
Specific Conductance	14	0	none	-	-	488	939	418	939	526
Strontium	14	0	log-normal	195	260	169	500	67	500	143
Sulfate	14	0	log-normal	35278	63460	3182	161070	4440	161070	8130
Sulfur	14	0	log-normal	12615	22243	11578	58829	1792	58839	8558
Temperature	14	0	normal	9.45	9.78	9.5	10.1	6.6	10.1	9.8
Thallium	14	9	log-censored	0.0061	0.17	< 0.0050	0.11	< 0.0050	0.11	0.0080
Titanium	14	9	log-censored	0.0045	0.0056	< 0.0035	0.0054	< 0.0035	0.0054	< 0.0035
Total dissolved solids	14	0	none	-	-	292500	657000	257000	657000	312000
Total organic carbon	14	0	log-normal	3255	5786	2600	20000	600	20000	1900
Total phosphate-P	4	0	ins	-	-	35	-	10	70	50
Total suspended solids	14	0	log-normal	2885	4201	3000	8000	1000	8000	3000
Vanadium	14	6	log-censored	4.7	16	4.9	12	< 2.5	12	4.9
Zinc	14	0	log-normal	68	123	82	402	10	402	47

Table A.16 : Descriptive statistics for the Quaternary buried artesian aquifer (QBAA).

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Min	Max	State Median
				ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
Alkalinity	26	0	normal	415346	446339	417500	554350	260000	561000	328000
Aluminum	26	0	none	-	-	0.57	45	0.080	66	0.88

Table A.16 Continued.

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Min	Max	State Median
Antimony	26	4	log-censored	0.036	0.11	0.034	0.084	< 0.0080	0.085	0.011
Arsenic	26	1	log-censored	2.5	61	3.2	27	< 0.060	28	2.6
Barium	26	0	log-normal	58	83	60	455	134	618	61
Beryllium	26	21	log-censored	0.0032	0.022	< 0.010	0.023	< 0.010	0.030	< 0.010
Boron	26	0	normal	310	346	315	526	98	544	98
Bromide	26	25	ins	-	-	< 0.20	0.20	< 0.20	0.26	< 0.20
Cadmium	26	9	log-censored	0.077	1.2	0.085	0.81	< 0.020	0.83	< 0.020
Calcium	26	0	log-normal	122970	144777	120975	264722	64092	278909	79537
Chloride	26	1	log-censored	1079	11932	1035	16387	< 200	20730	2320
Chromium	26	16	log-censored	0.064	2.0	< 0.050	1.2	< 0.050	1.3	0.49
Cobalt	26	0	normal	1.0	1.2	0.79	2.7	0.31	3.0	0.46
Copper	26	10	log-censored	5.8	54	6.9	76	< 4.6	89	< 5.5
Dissolved oxygen	26	11	log-censored	483	4898	470	3480	< 300	3900	< 300
Eh	26	0	normal	192	227	172	452	22	468	158
Fluoride	23	0	log-normal	358	401	340	634	230	660	380
Iron	26	0	none	-	-	1906	9513	61	10592	1179
Lead	26	3	log-censored	0.20	2.8	0.26	2.4	< 0.030	3.0	0.18
Lithium	26	1	log-censored	28	179	35	125	< 4.5	143	14
Magnesium	26	0	normal	45716	51939	42426	85147	22528	92876	30515
Manganese	26	0	log-normal	225	350	188	1293	42	1296	131
Mercury	26	26	ins	-	-	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
Molybdenum	26	19	log-censored	3.1	13	< 4.2	12	< 4.2	12	< 4.2
Nickel	26	19	log-censored	13	16	< 6.0	14	< 6.0	16	< 6.0
Nitrate-N	26	26	ins	-	-	< 500	< 500	< 500	< 500	< 500
pH	26	0	normal	7.01	7.08	7.03	7.24	6.61	7.26	7.29
Phosphorus	26	0	none	-	-	139	1041	41	1215	102
Potassium	26	0	normal	4908	5900	4500	10746	1900	11825	3068
Rubidium	26	25	ins	-	-	< 555.5	604	< 555.5	630	< 555.5
Selenium	26	4	log-censored	2.5	14	2.6	11	< 0.1	12	2.4
Silicate	26	0	normal	12329	13474	13067	16213	5704	16823	11914
Silver	26	23	log-censored	0.00034	0.82	< 0.0090	0.67	< 0.0090	0.97	< 0.0090
Sodium	26	0	normal	60082	68853	51238	172324	9297	195164	18812
Specific Conductance	26	0	normal	1131	1223	1042	1885	582	1932	619
Strontium	26	0	log-normal	596	735	570	2099	312	2348	304
Sulfate	26	0	normal	236421	294708	187125	675771	930	698220	7300
Sulfur	26	0	normal	83501	102489	60051	249449	639	249897	8110
Temperature	26	0	none	-	-	10.0	12.5	9.2	12.5	8.9
Thallium	26	13	log-censored	0.0070	0.098	0.0055	0.079	< 0.0050	0.095	< 0.0050
Titanium	26	26	ins	-	-	< 0.0035	< 0.0035	< 0.0035	<0.0035	< 0.0035
Total dissolved solids	26	0	normal	822615	919728	740000	1595700	258000	1630000	430000
Total organic carbon	26	0	log-normal	3680	4682	3700	121395	1700	14600	2600
Total phosphate-P	26	3	log-censored	86	708	105	816	< 20	970	60
Total suspended solids	26	0	none	-	-	7000	23300	1000	24000	5000
Vanadium	26	8	log-censored	5.4	18	6.1	14	< 2.5	14	< 4.7
Zinc	26	1	log-censored	23	452	25	1333	< 2.7	1911	13

Table A.17 : Descriptive statistics for the Quaternary buried undifferentiated aquifer (QBUU).

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Min	Max	State Median
				ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
Alkalinity	18	0	none	-	-	395000	477000	275000	477000	385000
Aluminum	18	2	log-censored	0.48	72	0.35	1151	< 0.060	1151.33	0.36
Antimony	18	0	normal	0.063	0.083	0.056	0.13	0.020	0.13	0.056
Arsenic	18	1	log-censored	3.5	143	5.8	49	< 0.060	49	2.8
Barium	18	0	log-normal	57	82	54	164	13	164	52
Beryllium	18	8	log-censored	0.0096	0.18	0.010	0.16	< 0.010	0.16	< 0.010
Boron	18	0	normal	292	380	279	807	23	807	279
Bromide	18	18	ins	-	-	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20
Cadmium	18	2	log-censored	0.14	1.3	0.16	1.0	< 0.020	1.0	0.13
Calcium	18	0	log-normal	118522	125777	114917	279885	67839	279885	114917
Chloride	18	0	log-normal	1504	2791	1480	21330	200	21330	2185
Chromium	18	9	log-censored	0.064	3.9	0.060	8.0	< 0.050	8.0	0.060
Cobalt	18	0	log-normal	1.1	1.2	1.0	4.7	0.31	4.7	0.99
Copper	18	8	log-censored	4.9	96	5.7	98	< 4.6	98	< 5.5
Dissolved oxygen	18	11	log-censored	112	3605	< 300	305	< 300	3050	< 300
Eh	18	0	none	-	-	267	291	92	291	261
Fluoride	14	0	normal	332	379	335	520	200	520	330
Iron	18	0	normal	2458	2080	2080	9966	140	9966	2080
Lead	18	1	log-censored	0.27	8.1	0.27	9.5	< 0.030	9.5	0.27
Lithium	18	1	log-censored	32	164	36	112	< 4.5	112	36
Magnesium	18	0	normal	46487	52747	40397	101744	19260	101744	42087
Manganese	18	0	log-normal	235	362	222	1239	22	1239	205
Mercury	18	18	ins	-	-	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10
Molybdenum	18	13	log-censored	4.1	16	< 4.2	13	< 4.2	13	< 4.2
Nickel	18	17	ins	-	-	< 6.0	7.8	< 6.0	7.8	< 6.0
Nitrate-N	18	18	ins	-	-	< 500	< 500	< 500	< 500	< 500
pH	18	0	normal	7.03	7.14	7.03	7.29	6.71	7.29	7.10
Phosphorus	18	0	log-normal	87	119	81	677	20	677	80
Potassium	18	0	normal	4941	5877	4960	7661	2845	7661	4960
Rubidium	18	15	log-censored	481	698	<555.5	681	< 555.5	681	< 555.5
Selenium	18	6	log-censored	1.5	5.1	1.7	4.1	< 0.1	4.1	1.8
Silicate	18	0	normal	13038	14647	13548	15622	5859	15622	13548
Silver	18	16	log-censored	0.018	0.13	< 0.0090	0.12	< 0.0090	0.11	< 0.0090
Sodium	18	0	normal	57804	74552	41143	218891	3267	218891	47568
Specific Conductance	18	0	normal	996	1148	910	1781	2	1781	955
Strontium	18	0	normal	562	712	561	1060	142	1060	561
Sulfate	18	0	normal	202390	252392	127170	638380	15300	638370	42390
Sulfur	18	0	log-normal	45878	70146	43256	245539	5494	245559	43256
Temperature	18	0	normal	10.1	10.6	10.1	11.8	9.3	11.8	10.1
Thallium	18	5	log-censored	0.014	0.15	0.017	0.12	< 0.0050	0.12	0.011
Titanium	18	16	log-censored	0.0000028	0.12	< 0.0035	0.057	<0.0035	0.057	< 0.0035

Table A.17 Continued.

Parameter	No. of samples	No. values censored	Distribution	Mean	UCL mean	Median	95th percentile	Min	Max	State Median
Total dissolved solids	18	0	normal	755778	870928	608000	1494000	322000	1494000	608000
Total organic carbon	17	0	normal	4218	6089	3600	11200	1300	11200	3400
Total phosphate-P	18	2	log-censored	78	407	60	600	< 20	600	50
Total suspended solids	18	0	normal	56944	10912	8000	9.40	1000	904000	7000
Vanadium	18	6	log-censored	4.9	21	5.6	18	< 2.5	18	5.1
Zinc	18	0	log-normal	43	96	36	485	5.1	485	25

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

Chemical Parameter	CFRN		CJDN		DCVA		KRET		OPDC	
	a	b	a	b	a	b	a	b	a	b
Aluminum	-0.054	1.192	-0.329	1.758	0.582	0.699	-0.14	1.853	-0.96	1.775
Antimony	-3.801	1.122	-4.721	1.11	-4.503	0.816	-3.021	0.653	-3.731	1.287
Arsenic	-1.212	1.735	-0.531	1.443	-	-	-0.31	1.575	-	-
Beryllium	-	-	-10.014	3.853	-4.684	1.083	-3.434	0.347	-5.941	1.381
Boron	3.1781	1.6974	2.402	1.806	-	-	-	-	3.974	1.304
Cadmium	-2.333	1.889	-3.294	2.546	-	-	-2.48	1.749	-2.363	2.023
Chloride	-	-	-	-	-	-	-	-	-	-
Chromium	-0.903	1.5	-0.72	1.039	-3.88	2.714	-3.132	1.692	-1.42	1.264
Copper	1.5476	1.092	2.138	0.836	2.303	0.542	2.086	0.668	1.821	1.154
Dissolved oxygen	7.2910	2.552	7.978	1.756	6.157	1.000	6.37	0.433	6.728	1.619
Iron	-	-	4.41	3.006	-	-	-	-	-	-
Lead	-0.672	1.882	-0.528	1.508	-	-	-1.437	1.96	-0.581	1.544
Lithium	1.411	1.502	1.29	1.38	2.469	1.193	3.205	0.521	2.194	0.856
Manganese	2.833	1.65	2.366	2.115	-	-	-	-	3.016	2.071
Mercury	-	-	-	-	-2.38	0.617	-	-	-	-
Molybdenum	-	-	-	-	-	-	-	-	0.662	0.618
Nickel	1.5686	0.646	1.706	0.27	1.882	0.222	-	-	1.372	0.875
Nitrate-N	4.9488	2.256	6.733	0.709	3.428	3.638	-	-	5.99	1.754
Ortho-phosphate	-	-	1.633	1.358	-	-	-	-	2.217	1.211
Phosphorus	2.6391	1.982	3.169	1.276	-	-	-	-	3.695	1.018
Rubidium	-	-	-	-	-	-	-	-	5.96	0.397
Selenium	-	-	-	-	-	-	0.345	0.66	0.287	0.499
Silver	-3.944	2.318	-10.527	4.745	-4.831	0.408	-	-	-12.555	5.845
Sulfate	-	-	-	-	9.155	0.93	-	-	-	-
Thallium	-7.135	2.69	-3.365	0.895	-5.152	1.541	-4.000	0.755	-4.863	2.495
Titanium	-6.074	0.747	-5.937	0.507	-5.346	0.037	-	-	-6.328	0.957
Total organic carbon	8.1277	1.185	7.809	1.164	-	-	-	-	8.202	1.099
Total phosphate-P	-	-	-	-	-	-	-	-	3.807	4.044
Vanadium	-5.688	0.832	-5.709	0.696	-5.427	0.504	-	-	-5.403	0.580
Zinc	-	-	-	-	-	-	-	-	4.618	1.339

Table A.18 continued

Chemical Parameter	OGAL		OSTP		QBAA		QBUU	
	a	b	a	b	a	b	a	b
Aluminum	-0.414	1.624	-1.152	1.582	-	-	-0.739	2.562
Antimony	-4.562	0.857	-4.818	1.311	-3.806	0.816	-	-
Arsenic	0.702	1.491	-0.723	1.302	0.926	1.625	1.248	1.896
Beryllium	-5.067	0.62	-7.241	2.186	-5.74	0.993	-4.6510	1.492
Cadmium	-	-	-	-	-2.561	1.39	-1.974	1.148
Chromium	-2.896	1.398	-2.176	0.847	-2.742	1.765	-2.742	2.092
Copper	2.138	0.836	2.402	1.131	1.758	1.141	1.588	1.519
Dissolved oxygen	6.13	1.755	6.731	1.646	6.181	1.181	4.717	1.772
Lead	-	-	-	-	-	-	-1.318	1.74
Lithium	2.699	0.824	0.2178	0.701	3.325	0.951	3.46	0.836
Molybdenum	1.631	0.328	-	-	1.116	5.256	0.618	1.417
Nickel	1.843	0.376	2.11	0.269	1.593	0.604	-	-
Nitrate-N	3.428	3.638	-	-	-	-	-	-
Ortho-phosphate	3.122	1.555	1.31	1.263	-	-	-	-
Rubidium	6.481	0.007	6.359	0.048	6.359	0.048	6.176	0.19
Selenium	-	-	0.087	0.726	0.918	0.873	0.409	0.618
Silver	-10.527	4.745	-8.466	3.643	- 7.996	3.981	-4.041	1.026
Sulfate	9.846	1.938	-	-	-	-	-	-
Thallium	-5.085	1.108	-5.099	1.709	-4.959	1.347	-4.294	1.214
Titanium	-5.861	0.553	-5.413	0.119	-	-	-12.779	5.442
Total phosphate-P	-	-	1.09		-	-	1.149	3.873
Vanadium	-5.274	0.573	-5.366	0.637	-5.216	0.612	-5.316	0.755

Table A.19: Coefficients for data with a normal or log-normal distribution, for each aquifer and chemical. See MPCA, 1998a, for application of these coefficients.

Chemical Parameter	CFRN		CJDN		DCVA		KRET		OPDC	
	std. dev.	n	std. dev.	n	std. dev.	n	std. dev.	n	std. dev.	n
Alkalinity	88243	15	57746	20	6971	10	0.0679	10	80761	26
Arsenic	-	-	-	-	-	-	-	-	0.552	25
Barium	0.507	15	0.440	20	80.4	10	-	-	0.243	26
Boron	-	-	-	-	0.542	10	135	10	-	-
Cadmium	-	-	-	-	11.2	10	-	-	-	-
Calcium	0.133	15	-	-	9741	10	64946	10	22424	26
Chloride	0.531	15	0.381	20	0.408	9	1483	10	0.691	26
Cobalt	0.341	-	0.161	20	-	-	0.558	10	0.362	25
Eh	116	15	123	20	84.8	10	66.5	10	0.172	26
Fluoride	52.6	12	-	-	30.0	10	66.3	10	0.141	22

Table A.19 Continued.

Chemical Parameter	CFRN		CJDN		DCVA		KRET		OPDC	
	std. dev.	n	std. dev.	n	std. dev.	n	std. dev.	n	std. dev.	n
Iron	1612	15			1003	10	1446	10	0.877	26
Lead	-	-	-	-	0.400	10	-	-	-	-
Magnesium	8235	15	0.105	20	4513	10	20218	10	7700	26
Phosphorus	-	-	-	-	-	-	0.314	10	-	-
Potassium	0.429	15	-	-	1620	10	888	10	0.290	26
Selenium	-	-	0.842	20	-	-	-	-	-	-
Silicate	3558	15	0.118	20	1705	-	2359	10	2430	26
Sodium	-	-	-	-	-	-	28839	10	0.535	26
Specific conductance	254	15	-	-	131	10	391	10	-	-
Sulfate	0.302	15	-	-	-	-	252132	10	0.314	26
Sulfur	7472	15	-	-	4150	10	98105	10	0.306	26
Temperature	0.588	15	0.708	20	0.322	10	0.606	10	0.853	26
Total dissolved solids	127761	14	-	-	88876	10	432296	10	151321	26
Total organic carbon	-	-	-	-	4016	10	2781	10	-	-
Total phosphate	-	-	-	-	-	-	0.455	10	-	-
Total suspended solids	5183	15	-	-	3296	10	3916	10	-	-
Zinc	0.685	15	-	-	0.431	10	0.636	10	-	-

Table A.19 Continued

Chemical Parameter	OGAL		OSTP		QBAA		QBUU	
	std. dev.	n	std. dev.	n	std. dev.	n	std. dev.	n
Alkalinity	59685	22	71641	14	69931	26	-	-
Barium	102	22	0.191	14	0.359	26	0.294	18
Boron	-	-	0.388	14	126	26	187	18
Cadmium	0.614	22	1.04	14	-	-	-	-
Calcium	-	-	0.117	14	0.170	26	0.156	18
Chloride	0.705	22	0.562	14	0.651	26	0.558	18
Cobalt	0.165	22	0.338	14	97.5	26	0.305	18
Eh	0.277	22	-	-	-	-	-	-
Fluoride	86.9	22	-	-	0.102	23	78	18
Iron	928	22	0.762	14	-	-	2249	18
Lead	0.584	22	0.459	14	-	-	-	-
Magnesium	0.336	22	-	-	17023	26	20789	18
Manganese	-	-	0.737	14	0.446	26	0.506	18
Phosphorus	-	-	0.287	14	-	-	0.364	18
Potassium	0.351	22	-	-	2186	26	1381	18-
Silicate	2191	22	2811	14	2547	26	-	-

Table A.19 Continued.

Chemical Parameter	OGAL		OSTP		QBAA		QBUU	
	std. dev.	n	std. dev.	n	std. dev.	n	std. dev.	n
Sodium	0.563	22	-	-	42832	26	55039	18
Strontium	121	22	0.227	14	0.209	26	253	18
Sulfate	-	-	0.392	14	215413	26	198597	18
Sulfur	0.922	22	0.383	14	78896	26	0.459	18
Temperature	-	-	0.911	14	-	-	-	-
Total dissolved solids	0.177	22	-	-	277241	26	358190	18
Total organic carbon	-	-	0.414	14	0.252	26	2442	18
Total suspended solids	0.300	22	0.267	14	-	-	211456	18
Zinc	0.551	22	0.466	14	-	-	0.597	18

Table A.20 : Median concentrations, in ug/L, of sampled parameters for each of the major aquifers. The p-value indicates the probability that aquifers have equal concentrations.

Parameter	p-value	CFRN	CJDN	DCVA	KRET	OGAL
Alkalinity	0.000	270000 abc	257000 a	289500 bc	414000 d	330000 cd
Aluminum	0.149	1.2	0.81	1.8	0.91	1.1
Antimony	0.000	0.027 c	0.0075 b	0.011 b	0.051 d	0.0090 b
Arsenic	0.000	0.34 a	0.50 ab	2.6 c	0.79 abc	2.5 bc
Barium	0.000	46 ab	22 ab	168 d	29 ab	148 cd
Beryllium	0.012	< 0.01 ab	< 0.01 ab	0.010 b	< 0.010 ab	0.010 ab
Boron	0.000	22 ab	14 a	44 bc	367 e	43 cd
Bromide	0.821	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20
Cadmium	0.000	0.14 b	0.035 b	1.4 d	0.11 b	0.63 cd
Calcium	0.000	60334 a	65727 a	75524 ab	155177 c	79932 b
Chloride	0.235	440	975	600	1675	1340
Chromium	0.000	0.36 cd	0.66 cd	< 0.050 a	< 0.050 a	< 0.050 a
Cobalt	0.000	0.48 a	0.35 a	0.32 a	0.82 bc	0.33 a
Copper	0.291	< 5.4	9.2	9.3	7.6	12
Dissolved oxygen	0.002	1830 b	4340 b	450 ab	< 300 a	< 300 ab
Eh	0.000	255 cd	264 d	105 b	162 b	103 b
Fluoride	0.010	300 ab	275 ab	270 a	385 bc	310 ab
Iron	0.000	888 abc	35 a	1612 bcd	3151 d	1500 bcd
Lead	0.198	0.74	0.51	0.39	0.30	0.23
Lithium	0.000	4.4 a	< 4.5 a	11 bc	30 cde	14 bcd
Magnesium	0.000	30286 c	24105 ab	22465 a	49655 d	24238 ab
Manganese	0.000	20 ab	7.9 ab	90 c	248 d	51 bc
Mercury	0.000	0.10 a	< 0.10 a	0.095 b	< 0.010 a	< 0.010 a
Molybdenum	0.217	< 4.0	< 4.0	< 4.0	< 4.0	< 4.0
Nickel	0.130	< 6.0	< 6.0	< 6.0	< 6.0	6.3
Nitrate-N	0.000	< 500 a	595 b	< 500 a	< 500 a	< 500 a
Orthophosphate	0.001	< 5 a	< 5 ab	15 ab	-	30 b

Table A.20 Continued.

Parameter	p-value	CFRN	CJDN	DCVA	KRET	OGAL
pH	0.000	7.3 d	7.3 d	7.12 bcd	6.9 ab	7.17 cd
Phosphorus	0.000	16 a	25 a	203 b	113 b	108 b
Potassium	0.000	1405 ab	780 a	1318 ab	4737 c	1789 b
Rubidium	0.799	< 555.5	< 555.5	< 555.5	< 555.5	< 555.5
Selenium	0.034	1.0 a	1.4 a	1.0 a	1.4 a	1.0 a
Silicate	0.000	6133 ab	7972 bc	10666 cde	11092 cde	9780 cd
Silver	0.086	< 0.0090	< 0.0090	< 0.0090	< 0.0090	< 0.0090
Sodium	0.000	2310 a	2313 a	6764 bc	64560 d	13465 cd
Specific Conductance	0.000	470 a	492 a	534 ab	1200 d	670 c
Strontium	0.000	74 ab	63 a	151 bc	748 e	231 bc
Sulfate	0.000	18150 abc	18180 ab	6675 a	281385 d	29325 bc
Sulfur	0.000	6931 abc	6617 ab	2779 a	105463 d	10853 bc
Temperature	0.000	9.9 cd	9.6 bc	9.25 a	9.95 d	9.1 a
Thallium	0.120	< 0.0050	0.018	0.0050	0.017	0.0060
Titanium	0.059	< 0.0035	< 0.0035	< 0.0035	< 0.0035	< 0.0035
Total dissolved solids	0.000	313000 ab	300000 a	320000 ab	945000 d	385500 c
Total organic carbon	0.067	3800	2400	5250	3900	8900
Total phosphate-P	0.309	50	105	-	55	40
Total suspended solids	0.000	4000 abc	4000 ab	5000 abcd	11000 e	4000 abc
Vanadium	0.536	< 4.7	< 4.7	4.9	7.1	5.8
Zinc	0.000	146 d	59 bcd	12 a	33 abc	24 ab

Table A.20 continued

Parameter	OPDC	OSTP	QBAA	QBUU
	ug/L	ug/L	ug/L	ug/L
Alkalinity	288500 bc	233000 ab	417500 d	395000 d
Aluminum	0.48	0.40	0.57	0.35
Antimony	0.020 c	0.0080 b	0.034 c	0.056 d
Arsenic	0.47 a	0.57 a	3.2 c	5.8 c
Barium	60 bc	50 abc	60 abc	54 abc
Beryllium	< 0.010 ab	< 0.010 ab	< 0.010 ab	0.010 b
Boron	57 bc	53 bcd	315 e	279 e
Bromide	< 0.20	< 0.20	< 0.20	< 0.20
Cadmium	0.10 b	0.27 bc	0.085 b	0.16 bc
Calcium	80441 b	69718 ab	120975 c	114917 c
Chloride	1255	950	1035	1480
Chromium	0.25 bc	0.13 ab	< 0.050 ab	0.060 ab
Cobalt	0.34 a	0.43 a	0.79 c	1.0 c
Copper	6.5	12	6.9	5.7
Dissolved oxygen	800 d	700 d	470 bc	< 300 cd
Eh	257 d	262 d	172 bc	267 cd
Fluoride	295 ab	330 ab	340 b	335 ab
Iron	615 ab	384 ab	1906 cd	2080 cd
Lead	0.68	0.28	0.26	0.27

Table A.20 Continued.

Parameter	OPDC	OSTP	QBAA	QBUU
Lithium	9.2 ab	8.9 ab	35 de	36 e
Magnesium	26104 bc	22362 ab	42426 d	40397 d
Manganese	30 abc	29 bc	188 d	222 d
Mercury	< 0.10 a	< 0.10 a	< 0.10 a	< 0.10 a
Molybdenum	< 4.0	< 4.0	< 4.0	< 4.0
Nickel	< 6.0	6.3	< 6.0	< 6.0
Nitrate-N	< 500 a	< 500 a	< 500 a	< 500 a
Orthophosphate	10 ab	< 5.0 ab	-	-
pH	7.17 cd	7.18 bcd	7.03 abc	7.03 abc
Phosphorus	46 a	32 a	139 b	81 b
Potassium	1634 b	2327 b	4500 c	4960 c
Rubidium	< 555.5	< 555.5	< 555.5	<555.5
Selenium	1.0 a	1.0 a	2.6 ab	1.7 a
Silicate	8011 ab	5017 a	13067 ef	13548 f
Silver	0.0090	< 0.0090	< 0.0090	< 0.0090
Sodium	6146 bc	4394 ab	51238 d	41143 d
Specific Conductance	598 bc	488 a	1042 d	910 d
Strontium	155 bc	169 bc	570 e	561 de
Sulfate	3014 bc	3182 c	187125 d	127170 d
Sulfur	9977 bc	11578 c	60051 d	43256 d
Temperature	9.25 bc	9.5 ab	10 d	10.1 d
Thallium	0.0060	< 0.0050	0.0055	0.017
Titanium	< 0.0035	< 0.0035	< 0.0035	< 0.0035
Total dissolved solids	366500 bc	292500 ab	740000 d	608000 d
Total organic carbon	3850	2600	3700	3600
Total phosphate-P	40	35	105	60
Total suspended solids	2000 ab	3000 a	7000 cde	8000 bcde
Vanadium	4.7	4.9	6.1	5.6
Zinc	95 d	82 cd	25 ab	36 bcd

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

Parameter	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)	-	-	-

Table A.21 Continued.

Parameter	Criteria (ug/L)	Basis of criteria	Endpoint
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)	-	-	-
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

Parameter	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

Table A.21 Continued.

Parameter	Criteria (ug/L)	Basis of criteria	Endpoint
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.

Parameter	No. exceedances of criteria							
	CFRN	CJDN	DCVA	OGAL	OPDC	OSTP	QBAA	QBUU
Beryllium (Be)	1	-	-	-	-	-	-	1
Boron (B)	-	-	-	-	-	-	-	1
Cadmium (Cd)	-	1	1	-	1	2	-	-
Manganese (Mn)	-	-	-	-	-	-	3	2
Nitrate (NO_3)	-	-	-	1	1	-	-	-

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

Parameter	% exceedances of criteria							
	CFRN	CJDN	DCVA	OGAL	OPDC	OSTP	QBAA	QBUU
Beryllium (Be)	7	-	-	-	-	-	-	6
Boron (B)	-	-	-	-	-	-	-	6
Cadmium (Cd)	-	5	10	-	4	14	-	-
Manganese (Mn)	-	-	-	-	-	-	12	11
Nitrate (NO_3)	-	-	-	5	4	-	-	-

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

Parameter	No. exceedances of criteria													
	CFIG	CFRN	CIGL	CJDN	CMTS	CSTL	DCVA	KRET	OGAL	OPDC	OSTP	OPVL	QBAA	QBUU
Iron (Fe)	1	11	1	8	2	2	9	10	19	16	9	1	24	17
Lead (Pb)	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Sulfate (SO_4)	-	-	-	-	-	-	-	2	-	-	-	-	4	3

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

Parameter	% exceedances of criteria													
	CFIG	CFRN	CIGL	CJDN	CMTS	CSTL	DCVA	KRET	OGAL	OPDC	OSTP	OPVL	QBAA	QBUU
Iron (Fe)	100	73	50	40	100	100	90	100	86	62	64	100	92	94
Lead (Pb)	-	7	-	-	-	-	-	-	-	-	-	-	-	-
Sulfate (SO_4)	-	-	-	-	-	-	-	20	-	-	-	-	16	17

Table A.26 : Summary of VOC detections for Region 5.

Unique No.	Parameter	Concentration	Chemical class
1	1,1,1-trichloroethane	0.4	Halogenated aliphatic
2	1,2-dichloroethane	0.3	Halogenated aliphatic
3	benzene	0.5	BTEX
4	1,1,1-trichloroethane	0.8	Halogenated aliphatic
5	benzene	0.4	BTEX
5	toluene	0.2	BTEX
5	xylene	0.2	BTEX
6	chloroform	0.3	Trihalomethane
7	benzene	0.2	BTEX
7	toluene	0.2	BTEX
7	xylene	0.2	BTEX
7	1,1,1-trichloroethane	0.9	Halogenated aliphatic
8	benzene	3.5	BTEX
8	ethylbenzene	3.8	BTEX
8	isopropylbenzene	1.1	BTEX
8	n-butylbenzene	0.6	BTEX
8	n-propyl benzene	0.8	BTEX
8	p-isopropyltoluene	0.9	BTEX
8	styrene	1.9	BTEX
8	toluene	0.7	BTEX
8	xylene	0.8	BTEX
8	1,1,1-trichloroethane	0.6	Halogenated aliphatic

Table A.26 Continued.

Unique No.	Parameter	Concentration	Chemical class
9	trichloroethene	1	Halogenated aliphatic
10	benzene	0.7	BTEX
10	toluene	0.2	BTEX
10	xylene	0.3	BTEX
11	chloroform	0.1	Trihalomethane
12	benzene	0.7	BTEX
12	toluene	0.2	BTEX
12	xylene	0.3	BTEX
13	benzene	0.5	BTEX
13	xylene	0.2	BTEX
14	1,2,4-trimethylbenzene	1.2	BTEX
14	1,3,5-trimethylbenzene	0.5	BTEX
14	ethyl benzene	2.9	BTEX
14	toluene	20	BTEX
14	xylene	15	BTEX
14	1,1,1-trichloroethane	1.1	Halogenated aliphatic
14	1,1-dichloroethane	0.5	Halogenated aliphatic
14	cis-1,2 dichloroethene	1.5	Halogenated aliphatic
15	toluene	0.3	BTEX
15	xylene	0.2	BTEX
16	toluene	1	BTEX
16	xylene	0.9	BTEX
17	chloroform	2.6	Trihalomethane

Table A.27 : Comparison of water quality data for glacial drift aquifers from different literature sources for Southeast Minnesota. Concentrations represent median values, in ug/L (ppb)[1].

Parameter	USGS Atlas HA-526	DNR, 1997	USGS Atlas HA-525	USGS Atlas HA-543	USGS Atlas HA-548	GWMAP
No. Samples	24	23	20	5	5	18
Bicarbonate	-	390000	-	-	-	395000
Calcium	-	91000	-	-	-	114917
Chloride	4000	1610	2800	1600	35000	1480
Fluoride	-	-		-	-	335
Iron	2100	1910	1800	30	440	2080
Magnesium	-	34500	-	-	-	40397

Table A.27 Continued.

Parameter	USGS Atlas HA-526	DNR, 1997	USGS Atlas HA-525	USGS Atlas HA-543	USGS Atlas HA-548	GWMAP
Nitrate	-	< 10.	-	-	-	< 500
pH	-	7.29	-	-	-	7.03
Potassium	-	3360	-	-	-	4960
Sodium	-	12800	-	-	-	41143
Sulfate	120000	23500	450000	10000	47000	127170
Temperature	-	9.35	-	-	-	10.1
Total dissolved solids	530000	-	1180000	315000	410000	608000

1 Temperature in degrees Celsius, and pH in pH units

Table A.28 : Comparison of water quality data for the Galena aquifer from different literature sources for Southeast Minnesota. Concentrations represent median values, in ug/L (ppb)[1].

Parameter	USGS, 1984	USGS Atlas HA-525[2]	USGS Atlas HA-522[2]	USGS Atlas HA-552	USGS Atlas HA-543	USGS Atlas HA-548[2]	GWMAP
No. samples	41 to 52	7	3	7	2	3	22
Bicarbonate	329000	-	-	-	-	-	330000
Boron	60	-	-	-	-	-	43
Calcium	74000	-	-	-	-	-	79932
Chloride	2300	500	2000	2000	1800	21000	1340
Conductance	560	-	-	-	-	-	670
Fluoride	200	-	-	-	-	-	310
Iron	1200	1200	2100	1100	1500	360	1500
Magnesium	22000	-	-	-	-	-	24238
Manganese	20	-	-	-	-	-	51
Nitrate	430	-	-	-	-	-	< 500
pH	7.4	-	-	-	-	-	7.17
Potassium	2000	-	-	-	-	-	1789
Sodium	6000	-	-	-	-	-	13465
Sulfate	20000	76000	55000	14000	< 5000	25000	29325
Temperature	9.3	-	-	-	-	-	9.1
Total dissolved solids	336000	480000	504000	315000	360000	230000	385500

1 Specific Conductance in mmhos/cm, Temperature in degrees C, and pH in pH units.
2 Includes overlying limestone aquifers, such as the Cedar Valley

Table A.29 : Comparison of water quality data for the St. Peter aquifer from different literature sources for Southeast Minnesota. Concentrations represent median values, in ug/L (ppb)[1].

Parameter	USGS, 1965	USGS Hydro Atlas HA-522	USGS Atlas HA-543	USGS Atlas HA-552	USGS Atlas HA-548	GWMAP
No. samples	27 to 35	3	1	1	2	14
Bicarbonate	350000	-	-	-	-	233000
Boron	< 10	-	-	-	-	53
Calcium	77000	-	-	-	-	69718
Chloride	1700	1200	1400	1200	4000	950
Conductance	572	-	-	-	-	488
Fluoride	200	-	-	-	-	330
Iron	2400	2600	180	140	200	384
Magnesium	27000	-	-	-	-	22362
Manganese	80	-	-	-	-	29
Nitrate	360	-	-	-	-	< 500
pH	7.6	-	-	-	-	7.18
Potassium	2000	-	-	-	-	2327
Sodium	5200	-	-	-	-	4394
Sulfate	12000	< 1000	62000	33000	47000	3182
Temperature	11.0	-	-	-	-	9.5
Total dissolved solids	348000	350000	380000	-	205000	292500

1 Specific Conductance in mmhos/cm, Temperature in degrees C, and pH in pH units.

Table A.30 : Comparison of water quality data for the Prairie du Chien aquifer from different literature sources for Southeast Minnesota. Concentrations represent median values, in ug/L (ppb)[1].

Parameter	DNR, 1997	USGS Atlas HA-525	USGS Hydro Atlas HA-522[2]	USGS Atlas HA-543	USGS Atlas HA-548	USGS Atlas HA-552[2]	GWMAP
No. samples	54	8	20	4	6	7	26
Bicarbonate	302000	-	-	-	-	-	288500
Boron	-	-	-	-	-	-	57
Calcium	87500	-	-	-	-	-	80441
Chloride	870	1400	1500	3000	13000	700	1255
Conductance	477	-	-	-	-	-	598
Fluoride	-	-	180	30	160	700	295
Iron	1090	2800	-	-	-	-	615
Magnesium	30100	-	-	-	-	-	26104
Manganese	-	-	-	-	-	-	30

Table A.30 Continued.

Parameter	DNR, 1997	USGS Atlas HA-525	USGS Hydro Atlas HA-522[2]	USGS Atlas HA-543	USGS Atlas HA-548	USGS Atlas HA-552[2]	GWMAP
Nitrate	< 100	-	-	-	-	-	< 500
pH	7.23	-	-	-	-	-	7.17
Potassium	2240	-	-	-	-	-	1634
Sodium	6870	-	-	-	-	-	6146
Sulfate	17200	79000	28000	10000	19000	15000	3014
Temperature	9.3	-	-	-	-	-	9.25
Total dissolved solids	-	498000	350000	350000	360000	830000	366500

1 Specific Conductance in mmhos/cm, Temperature in degrees C, and pH in pH units.
2 Prairie du Chien and Jordan aquifers were combined

Table A.31 : Comparison of water quality data for the Jordan aquifer from different literature sources for Southeast Minnesota. Concentrations represent median values, in ug/L (ppb)1.

Parameter	USGS Atlas HA-526	USGS Atlas HA-586	USGS Hydro Atlas HA-522[2]	USGS Atlas HA-552[2]	USGS Atlas HA-548	USGS Atlas HA-543	GWMAP
No. of Samples	30	16	20	7	16	13	20
Chloride	2000	1200	1500	700	1800	< 1000	975
Iron	520	2200	180	700	50	350	35
Sulfate	7800	200000	28000	15000	15000	19000	18180
Total dissolved solids	300000	712000	350000	830000	280000	300000	300000

1 Temperature in degrees Celsius, and pH in pH units
2 Prairie du Chien and Jordan aquifers were combined

Table A.32 : Comparison of water quality in the Jordan aquifer for samples containing low iron concentrations and samples with high iron concentrations.

Chemical	Low iron group	High iron group
Sample size	12	8
Iron (ug/L)	13	2409
Eh (mV)	394	182
Dissolved oxygen (ug/L)	6350	< 300
Nitrate (ug/L)	1165	< 500
Manganese (ug/L)	< 0.8	77
Potassium (ug/L)	636	2126
Total suspended solids (ug/L)	1000	5500
Total organic carbon (ug/L)	1750	5000
Chloride (ug/L)	1040	720
Lead (ug/L)	0.70	0.30

Table A.33 : Comparison of water quality data for the Franconia aquifer from different literature sources for Southeast Minnesota. Concentrations represent median values, in ug/L (ppb)[1].

Parameter	DNR, 1997	USGS Atlas HA-526	USGS Atlas HA-525[2]	USGS Atlas HA-543	USGS Atlas HA-548	GWMAP
No. samples	5	1	12	12	3	14
Bicarbonate	398000	-	-	-	-	270000
Calcium	98200	-	-	-	-	60334
Chloride	880	1500	2400	61000	2400	440
Conductance	580	-	-	-	-	470
Iron	2100	1800	3000	520	260	888
Magnesium	36900	-	-	-	-	30286
pH	7.38	-	-	-	-	7.3
Potassium	2730	-	-	-	-	1405
Sodium	43800	-	-	-	-	2310
Sulfate	83100	130000	260000	27000	13000	18150
Temperature	9.7	-	-	-	-	9.9
Total dissolved solids	-	-	811000	-	300000	313000

1 Specific Conductance in mmhos/cm, Temperature in degrees C, and pH in pH units.
2 May include data for the Ironton-Galesville aquifer

Table A.34 : Comparison of water quality data for the Cretaceous aquifer from different literature sources for Southeast Minnesota. Concentrations represent median values, in ug/L (ppb)[1].

Parameter	USGS Hydro Atlas HA-525	GWMAP
No. samples	2	10
Chloride	2800	1675
Iron	1800	3151
Sulfate	885000	281385
Total dissolved solids	1570000	945000

1 Specific Conductance in mmhos/cm, Temperature in degrees C, and pH in pH units.

Appendix B - Figures

Figure B.1 : Location of Region 5.

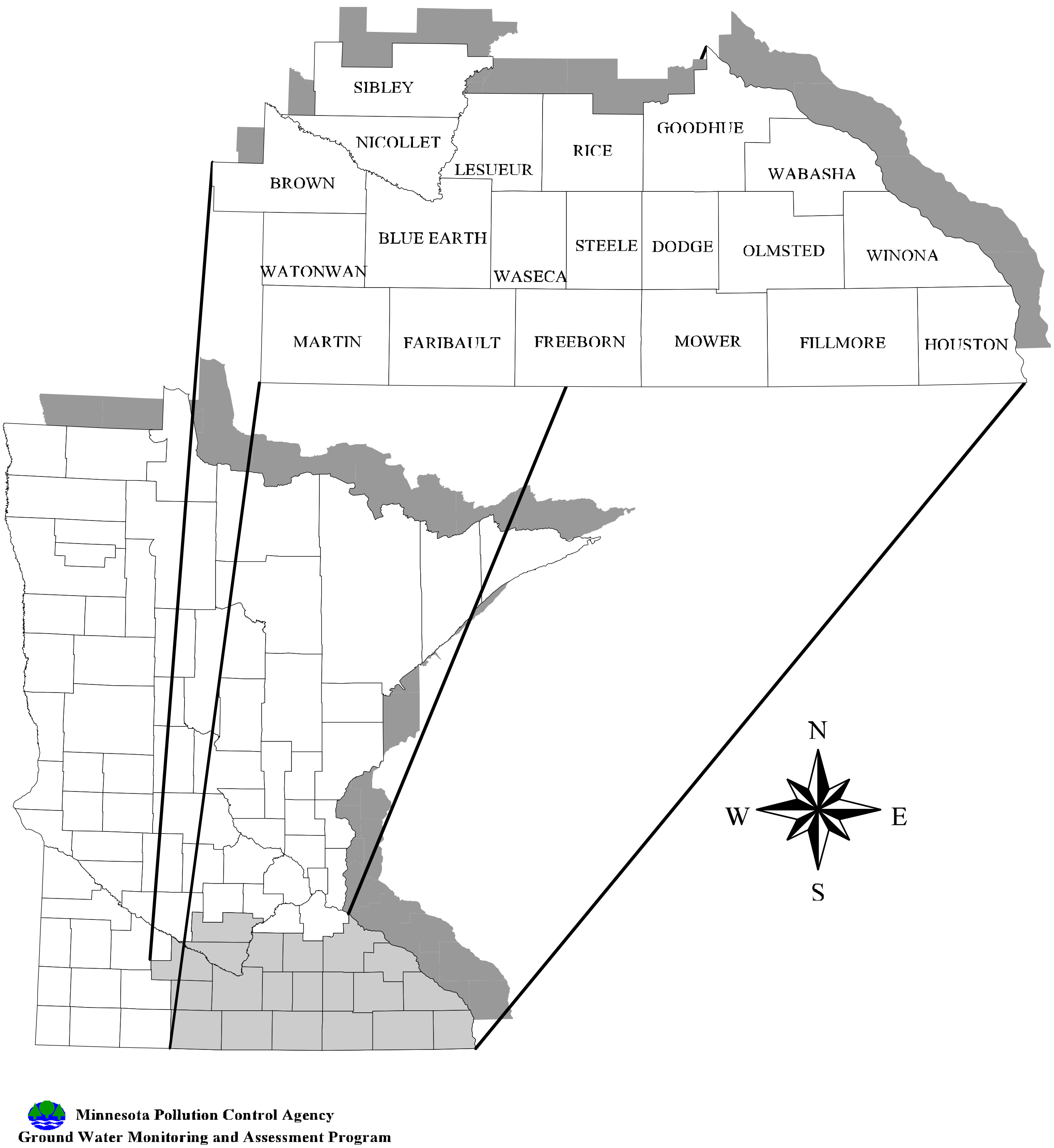

Figure B.2 : Location of sampled wells from the Franconia, Ironton, and Galesville aquifers.

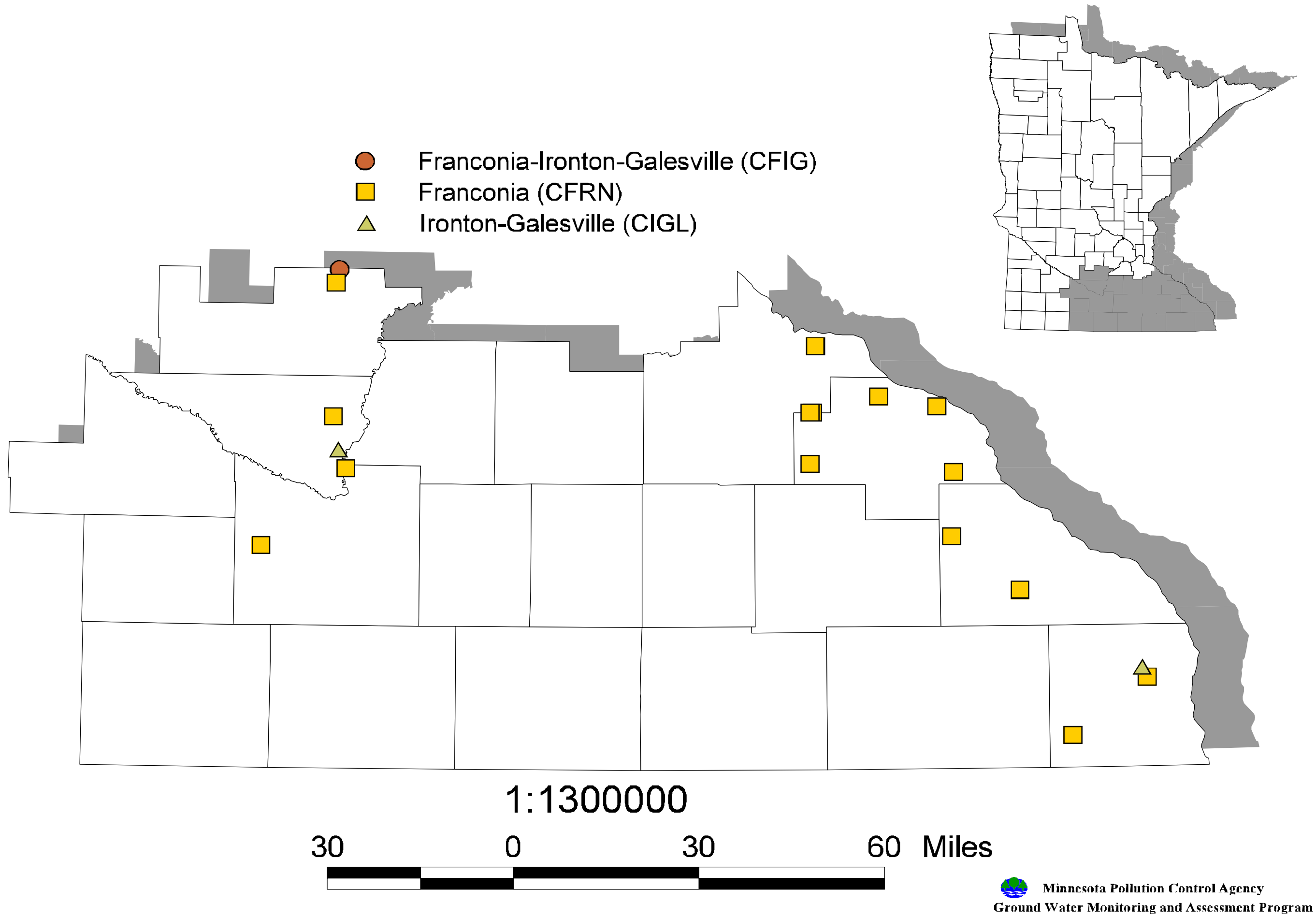

Figure B.3 : Location of sampled wells from the St. Peter, Prairie du Chien, and Jordan aquifers.

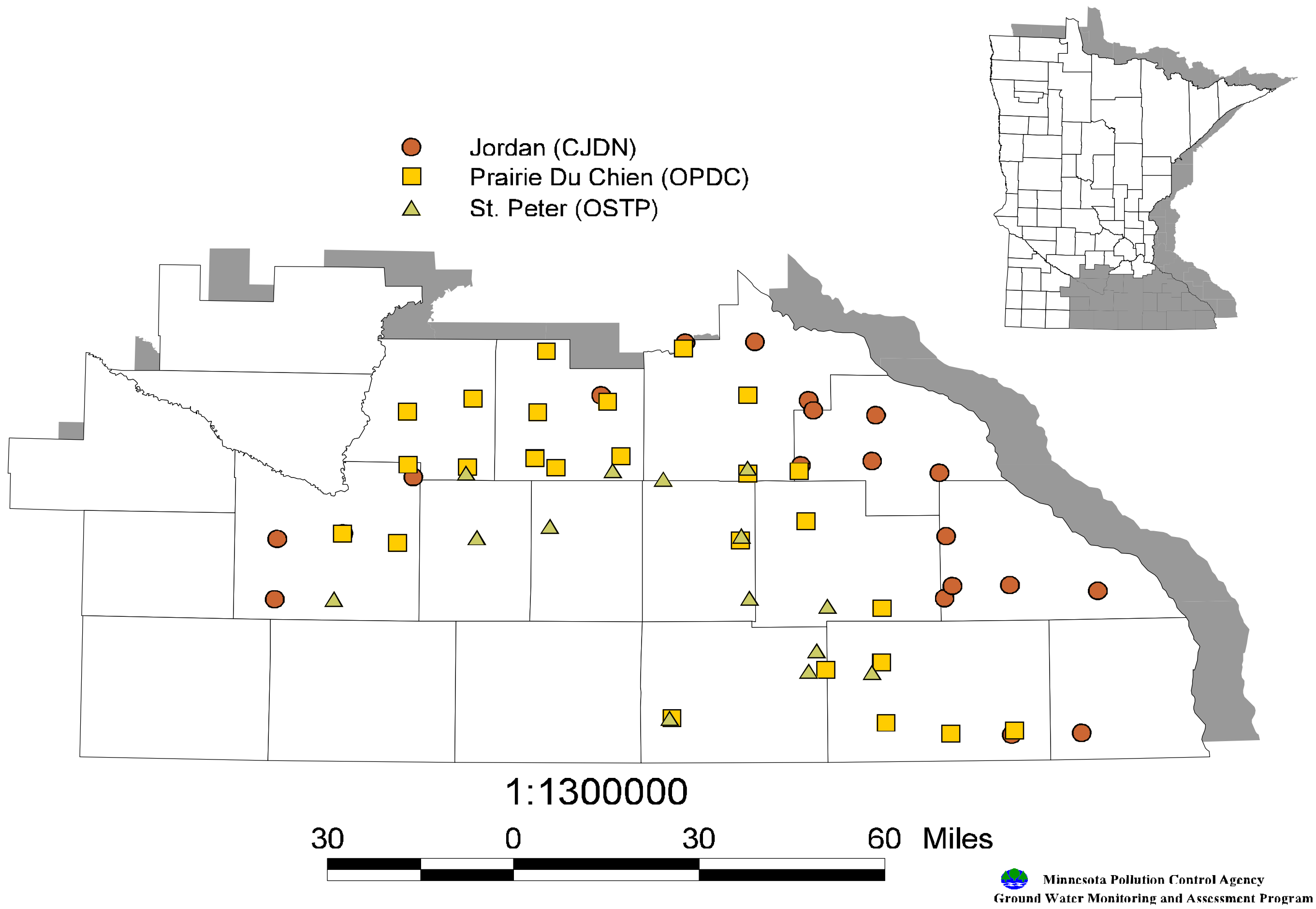

Figure B.4 : Location of sampled wells from the Galena and Cedar Valley aquifers.

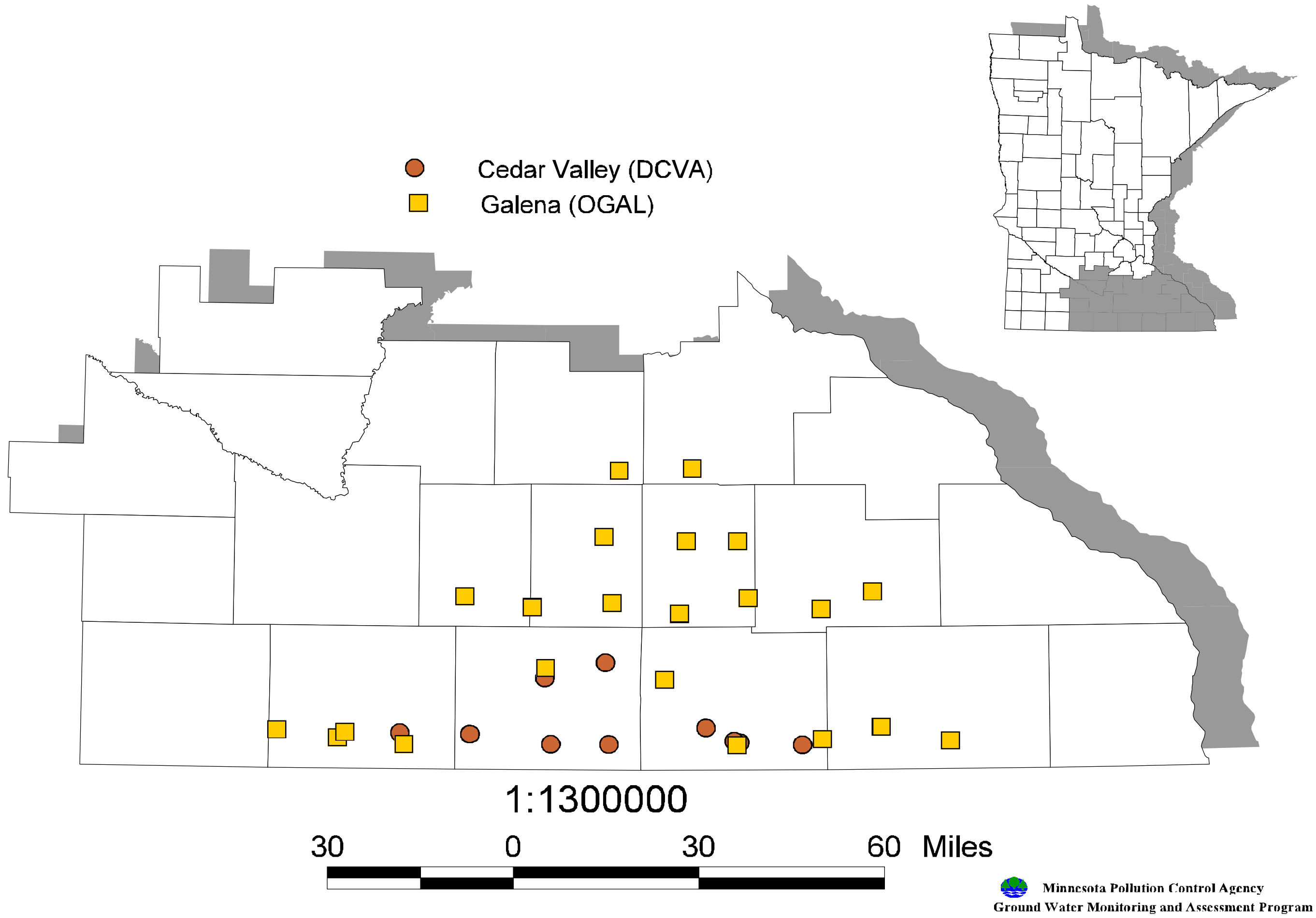

Figure B.5 : Location of sampled wells from the Cretaceous aquifer.

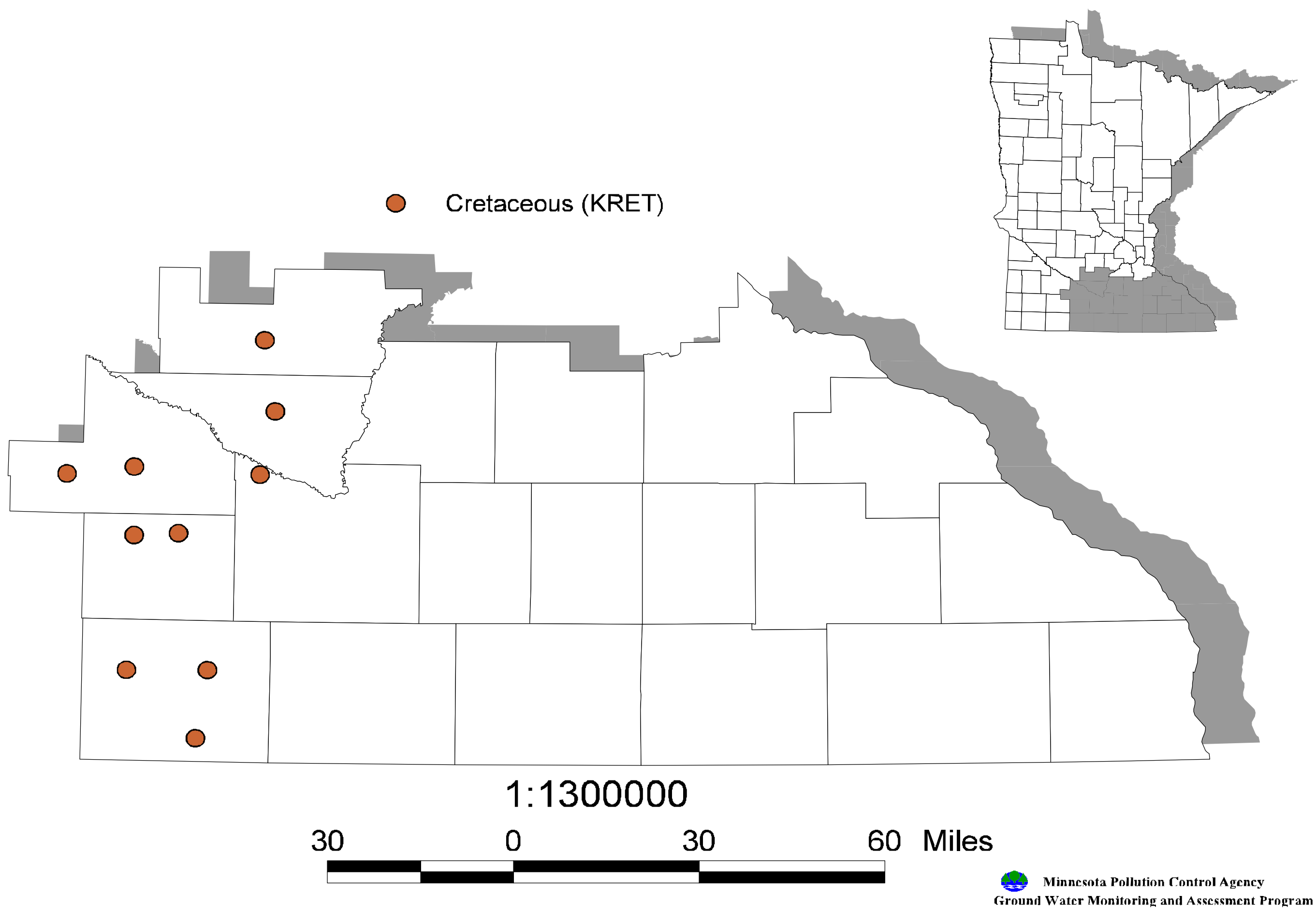

Figure B.6 : Location of sampled wells from the buried drift aquifers.

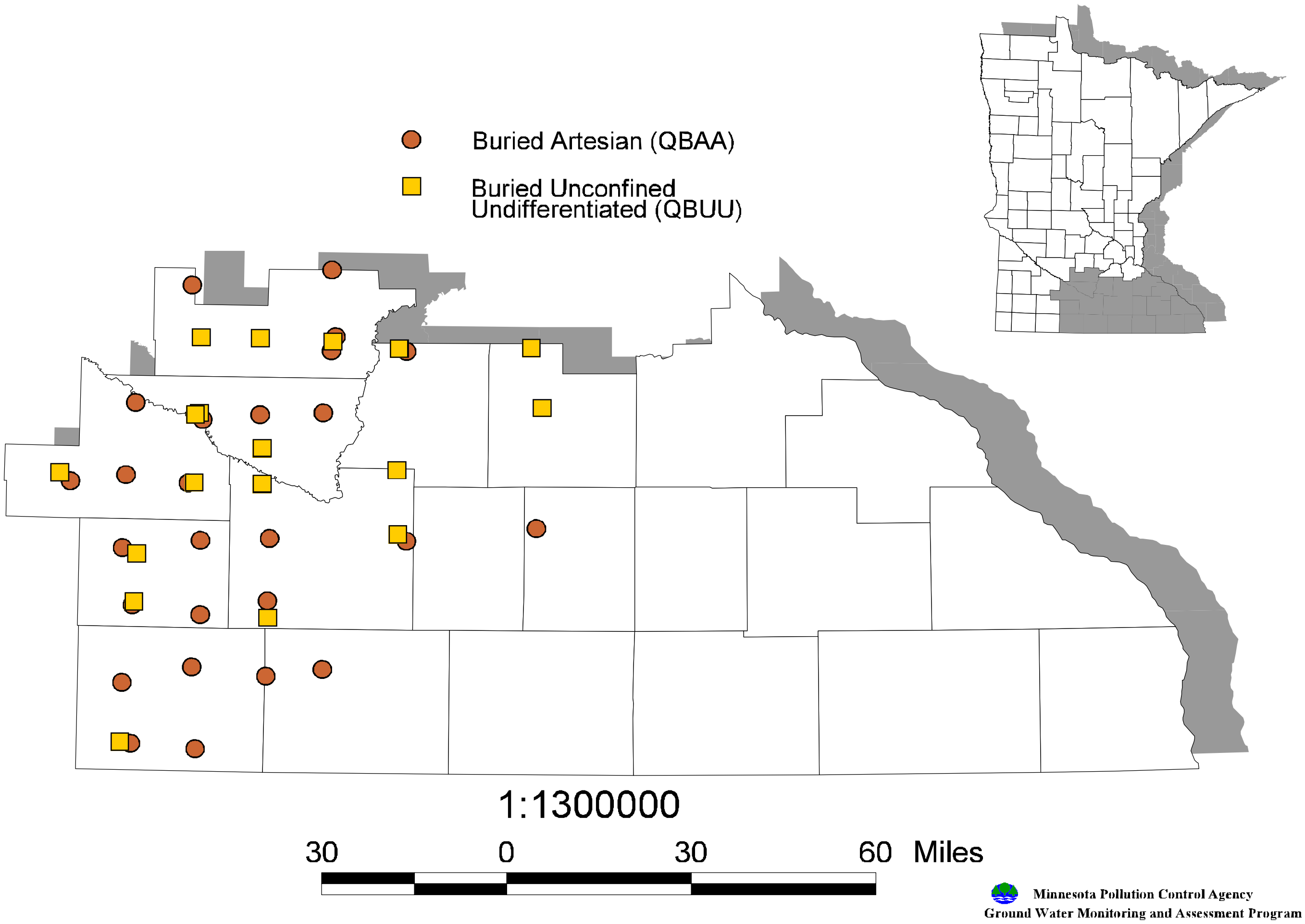

Figure B.7 : Distribution of Eh, nitrate, and dissolved oxygen in Region 5.

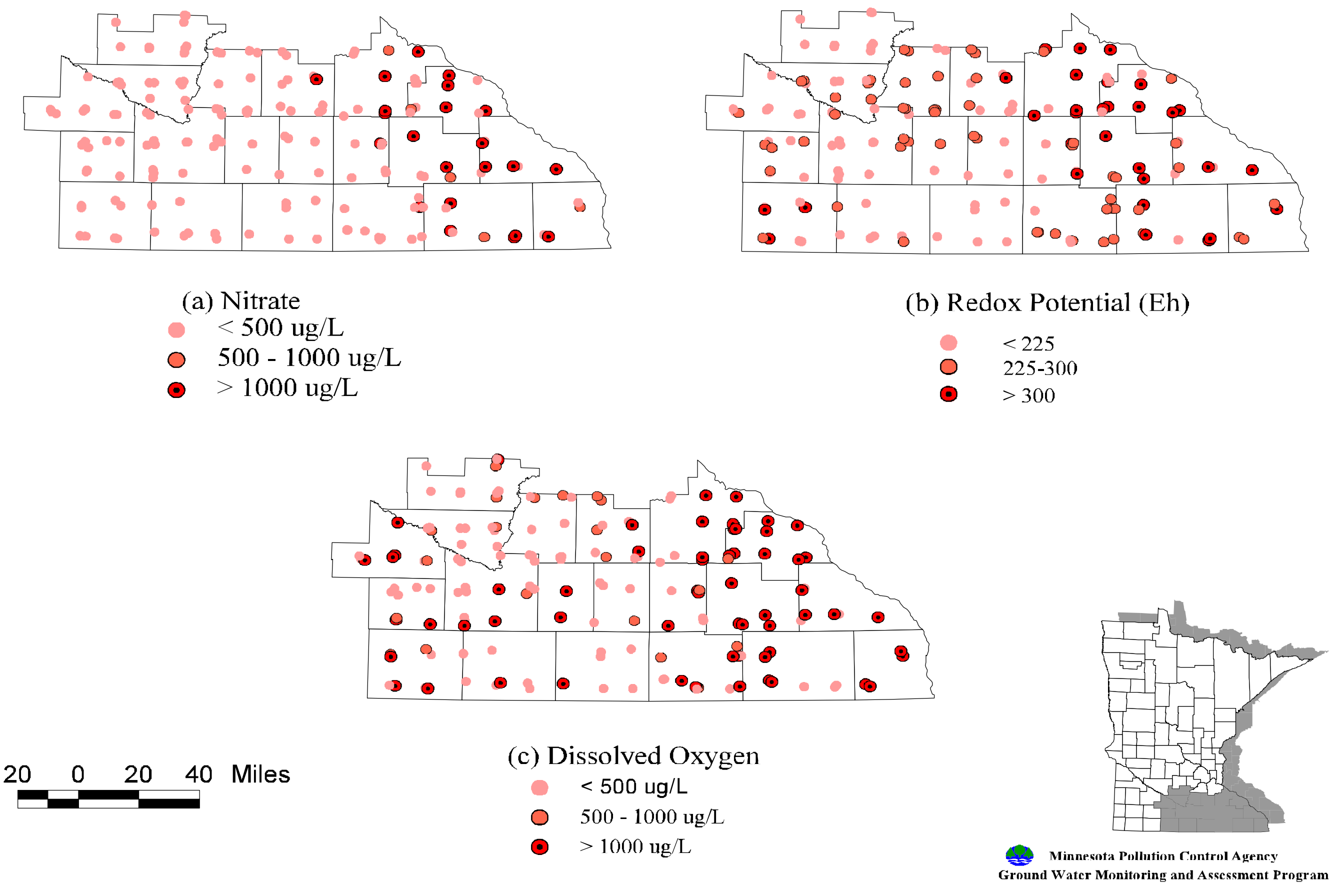

Figure B.8 : Distribution of VOCs in Region 5.