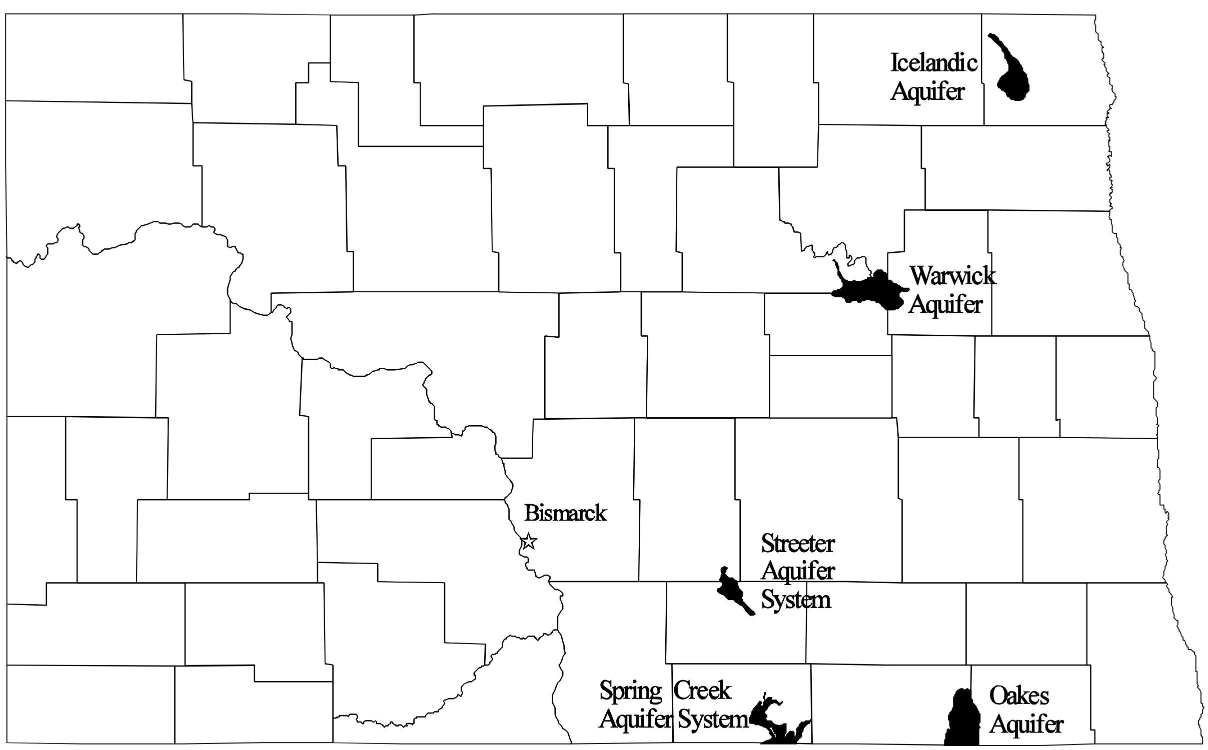
North Dakota Groundwater Monitoring Program

1997 Report



North Dakota Department of Health
Division of Water Quality

North Dakota Groundwater Monitoring Program

1997 Report

Edward T. Schafer, Governor
Murray G. Sagsveen, State Health Officer

Prepared by
Norene Bartelson, Environmental Scientist
William Gunnerson, Environmental Scientist

North Dakota Department of Health
Division of Water Quality
1200 Missouri Ave.
Bismarck, N.D. 58506-5520
701.328.5210

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ABSTRACT

To determine if there is agricultural chemical contamination of groundwater occurring in North Dakota, an aquifer monitoring program was developed by the North Dakota Department of Health (NDDoH), Division of Water Quality. In 1997, monitoring was conducted in five aquifers: the Icelandic, Oakes, and Warwick aquifers, which were initially sampled as part of the ambient groundwater monitoring program in 1992; and the Spring Creek and Streeter aquifers which were sampled for the first time as part of this program.

All five aquifers consist primarily of sand and/or gravel and have fairly shallow water tables; several increasingly are being used for irrigation. A total of 179 wells were sampled for general anion and cation chemistry, nitrate and nitrite, and 60 selected pesticides or degradation products. Seven wells--about four percent--contained detectable concentrations of pesticides in the initial samples. Follow-up samples were collected from all seven wells. Four wells with initial pesticide detections did not exhibit pesticide detections in follow-up samples. Picloram was detected in two wells in both the initial and follow-up samples. The pesticide compounds detected by laboratory analysis were bentazon; 2,4-D; 3,5 dichlorobenzoic acid; endrin; endrin aldehyde; endrin ketone; heptachlor epoxide; MCPA; pentachlorophenol and picloram. Most of the concentrations of the detected pesticides were far below their respective maximum contaminant level or health advisory level. However, concentrations of two of the detected pesticides, pentachlorophenol and MCPA, were above their MCLs. The highest concentration of a detected pesticide, with respect to a health-based standard, was 1,380 percent of its health advisory level. The wells with pesticide detections were located in the Icelandic, Oakes, and Warwick aquifers. Overall, pesticide contamination in these aquifers is limited in extent.

Nitrate plus nitrite as nitrogen (N) was detected above 0.05 milligrams per liter in 57 wells, or 32 percent of the wells sampled. Concentrations in 13 wells, 7 percent, exceeded the maximum contaminant level of 10 milligrams per liter. Based on sampling site inventories, many of the nitrate detections were associated with shallow well depth, masonry casing, large-diameter wells, and/or near chemical usage, feed lots, or septic systems. Based upon site inventories, a majority of the pesticide and nitrate detections are believed to be associated with point sources of contamination.

ACKNOWLEDGMENTS

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INTRODUCTION AND PURPOSE

The maintenance of a baseline description of groundwater quality is an essential element of a statewide comprehensive groundwater protection program. In recent years, concern for the quality of our environment and drinking water has increased as we learn that many states in the country have experienced groundwater contamination from a variety of point and nonpoint sources of pollution. Typically in North Dakota, available groundwater resources underlie agricultural areas; however, limited data exists to evaluate whether agricultural chemicals have impacted groundwater quality of the state on a broad scale. The goal of this project is to provide data relating to the overall quality of North Dakota's groundwater resources, with an emphasis on agricultural chemicals. Since 1992, several aquifers have been monitored each year of the project. Aquifers are resampled every five years in an effort to determine groundwater quality trends. Monitoring is conducted through the use of existing domestic wells, monitoring wells, livestock wells, public supply wells, and irrigation wells that meet construction standards and sampling requirements described later in this report.

Monitoring conducted in 1996 marked the completion of the first-round monitoring for 45 of the highest priority glacial drift aquifers in North Dakota. In 1997, the Icelandic, Oakes, and Warwick aquifers were sampled for the second time since the1992 initiation of the monitoring program. Spring Creek and Streeter aquifers also were added to the sampling schedule in 1997 (Figure 1). These five aquifers are composed primarily of sand and/or gravel and have shallow water tables ranging from just below the ground surface to approximately 50 feet below grade. Several are increasingly being used for irrigation. Wells included in the study were sampled during May through October 1997. Results from the monitoring will provide useful information about the overall quality of groundwater in the state.

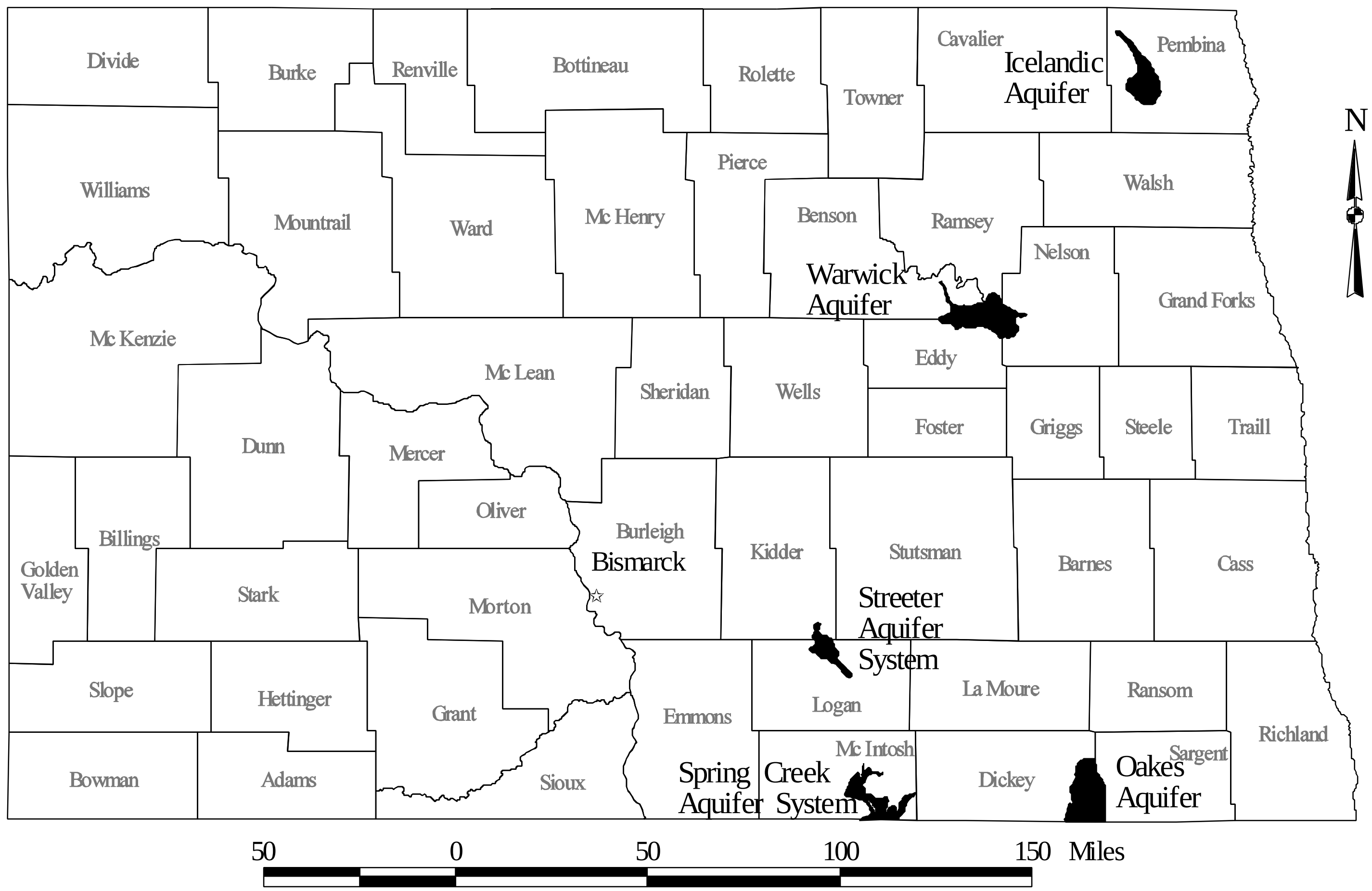


FIGURE 1. Locations of aquifers sampled in 1997 for the North Dakota Groundwater Monitoring Program

SUMMARY OF PREVIOUS INVESTIGATIONS

In recent years, several studies have been initiated to determine the presence and extent of pesticides in groundwater. The United States Environmental Protection Agency (EPA) (1992) conducted the National Pesticide Survey between 1988 and 1990 to determine the frequency and concentration of pesticides and nitrates in private and public drinking water wells. The survey investigated the association of pesticide detections with various factors such as pesticide use and groundwater vulnerability. For the survey, EPA sampled 566 community water system and 783 rural domestic drinking water wells throughout the nation for the presence of 126 pesticides and degradates, as well as nitrate. Of the analytes, 17 were detected in the survey, with five detected at levels above their respective Maximum Contaminant Level (MCL) or Health Advisory Level (HAL). Based on its findings, EPA estimated that approximately 9,850 (10 percent) community water system and 446,000 (4 percent) rural domestic wells in the United States contained concentrations of at least one pesticide above the minimum reporting level.

Glatt (1985) conducted a study of selected private and public wells to determine the presence of picloram in groundwater in Rolette County, N.D. Of the 126 water samples collected, picloram was found in 11 samples, ranging from less than 0.02 to 0.85 micrograms per liter (μg/l). All positive sites were retested, with picloram concentrations confirmed in four wells, ranging from 0.05 to 3.56μg/l.

In 1986, Glatt sampled 92 municipal drinking water supply systems, with at least one municipal system sampled in 52 of the 53 counties in North Dakota. Water samples were analyzed for one or more of the following agricultural pesticides: aldicarb, fenvalerate, picloram, methyl parathion, and 2,4-D. At least one of the five agricultural chemicals was detected in 10 of the water systems. Picloram, with concentrations ranging from 0.08 to 1.46 μg/l, was the pesticide detected in seven of the 10 positive sample locations. Three separate municipal drinking water systems had possible detections of ethyl parathion (less than 0.02 μg/l), methyl parathion (less than 0.04 μg/l), and trifluralin (less than 0.03 μg/l), respectively.

Murphy and Greene (1992) investigated the presence of picloram and 2,4-D on four tracts of land owned by the United States Bureau of Land Management in the Denbigh Sand Hills of McHenry

County, N.D. A total of 68 groundwater samples and 33 sediment samples were collected. The concentrations of picloram detected in groundwater ranged from 0.07 to 107 μg/l, and from 10 to 160 μg/l in the sediment. Concentrations of 2,4-D in groundwater ranged from 0.09 to 2.19 μg/l, and up to 20 μg/l in sediment samples.

Montgomery et al. (1988) collected baseline information from the Oakes aquifer for the purpose of assessing the environmental impact involving the Garrison Diversion Irrigation Project transfer of Missouri River water to the James River. A 31-square-kilometer test site was developed by the United States Bureau of Reclamation, with the installation of 98 observation wells on a 0.8-kilometer grid, four large drainage lysimeters, and 70 kilometers of slotted, plastic drain pipe. A total of 229 water samples were collected from the observation wells, lysimeters and manholes constructed in the drains for the period 1985 through 1987. Samples were analyzed for the presence of four commonly used herbicides: alachlor, metolachlor, simazine and atrazine. Concentrations of alachlor were detected in six of the 229 samples, ranging from a trace (0.2 μg/l) to 1.2 μg/l. Three of the detections were from samples of the same well collected during three different sampling episodes. The other three detections were from two lysimeters and a drain manhole. No detections of the other three herbicides were confirmed in any of the samples.

In a statewide study of 346 community and non-transient, non-community public water systems, Abel (1992) surveyed for the presence of certain regulated and non-regulated Volatile Organic Compounds (VOCs). In addition, those systems deriving their water supply from groundwater were tested for 14 herbicides and six insecticides, selected on the basis of their use in North Dakota, and their mobility and persistence in soil. Two pesticides, alachlor (0.55 μg/l) and picloram (1.99 μg/l), were detected, representing less than 1 percent of the systems in the study.

During the first four years of the Ambient Groundwater Monitoring Program, Radig and Bartelson (1992, 1993, 1994 and 1995) completed monitoring of 30 glacial drift aquifers.

During the 1992 sampling season, Radig and Bartelson (1992) sampled 137 wells in the Oakes, Warwick, and Icelandic aquifers for general inorganic chemistry, nitrate plus nitrite, and 44 selected pesticides. The established protocol for the study has been followed in succeeding years of the North Dakota Groundwater Monitoring Program. Only three of the 137 wells contained detectable pesticide concentrations, all of which were considerably below their respective MCL or HAL. Nitrate plus nitrite was detected in 37 wells and was above the 10 milligrams per liter (mg/l) as nitrogen (N) MCL in eight wells. Site surveys indicated that all of the pesticide detections and most of the nitrate plus nitrite detections were suspected to be associated with a point source of contamination.

During the 1993 sampling season, Radig and Bartelson (1993) sampled 117 wells in the Denbigh, Elk Valley, Fordville, Inkster, Lake Souris and Shell Valley aquifers. Twenty-one of the 117 wells contained detectable pesticide concentrations, all of which were considerably below their respective MCL or HAL. Seven of the wells had confirmed detections of the same pesticide in follow-up sampling events. Nitrate plus nitrite was detected in 37 wells, but was above the 10 mg/l (N) MCL in only three wells. Site surveys indicated that many of the pesticide detections and most of the nitrate plus nitrite detections were suspected to be associated with a point source of contamination.

During the 1994 sampling season, Radig and Bartelson (1994) sampled 149 wells in the Galesburg/Page, Hankinson, Marstonmoor Plain, Milnor Channel, Sand Prairie and Sheyenne Delta aquifers. Twenty-six of the 149 wells contained detectable pesticide concentrations, all below their respective MCL or HAL. Nitrate plus nitrite was detected in 84 wells, with only four samples above the 10 mg/l (N) MCL. Site surveys indicated that many of the pesticide detections and over one-half of the nitrate plus nitrite detections were suspected to be associated with a point source of contamination.

During the 1995 sampling season, Radig and Bartelson (1995) sampled 186 wells in 15 aquifers, including the Bismarck, Burnt Creek, Glenview, Wagonsport, Painted Woods Lake, Missouri River, Lake Nettie, Manfred, Carrington, Juanita Lake, Edgeley, LaMoure, Englevale, Guelph and Strasburg aquifers. Pesticides were detected in five wells, all at concentrations less than 5 percent of any health-based standards. Three of the five wells had confirmed detections of the same pesticide in follow-up sampling events. Nitrate plus nitrite was detected in 81 wells, with concentrations in 10 of the wells greater than the MCL. As in previous investigations, most detections are suspected of being associated with a point source.

Bartelson and Gunnerson (1996), continuing the North Dakota Groundwater Monitoring Program, reported finding eight wells with detectable concentrations of at least one pesticide, out of a total of 163 wells sampled in 15 aquifers. Seven pesticide compounds were identified in the initial samples collected; two pesticides were confirmed in follow-up samples. Most detected concentrations were well below any health-based standards; however, one pesticide, dinoseb, was detected at a concentration greater than two and one-half times the MCL. This detection was determined to be the result of back-siphoning while filling a sprayer. Dinoseb was not detected in a follow-up sample collected from the well. Nitrate plus nitrite was detected in 93 wells; nitrate concentrations in 12 wells were greater than the MCL.

Schuh et al. (1995) investigated the relationship between groundwater recharge and agricultural chemical movement. The investigation was conducted in a crop production plot at the Carrington Research Extension Center in Foster County, N.D., to assess the impact of pesticides on the Carrington aquifer, a buried sand and gravel deposit existing primarily under confined conditions. Monitoring wells were installed around the plot and nested at three depths: in the vadose zone, in the saturated overlying till, and at the top of the aquifer. Low concentrations of pesticides were detected at all sampling depths; however, detections were generally sporadic and spatially and temporally discontinuous. Most pesticide detections were below levels of toxicological concern, and there was no evidence of pesticide accumulation in the saturated till or the Carrington aquifer. In general, the investigators concluded that pesticide detections corresponded to periods of recharge and were depression-focused.

STUDY DESIGN

The North Dakota Groundwater Monitoring Program is designed to provide a consistent approach to water quality determinations by defining target populations and criteria for sample site selection.

Target Population

The target population, or set of environmental units, which this study addresses, includes all groundwater wells capable of producing significant amounts of water. Statistically, it is impossible to use a whole aquifer as the target population for a monitoring study because it is impossible to take an "overall" sample of an aquifer. Groundwater samples must be collected from wells or springs; therefore, the population that most closely correlates to the overall quality of an aquifer is the set of all wells completed in an aquifer.

Criteria for Acceptable Sampling Points

Because of the necessity to produce reliable and representative data, some limitations were put on the target population. A number of criteria were used to determine whether a well was acceptable for use as a sampling point. These criteria were used to ensure that the sample would be representative of groundwater in that area, and that there was data available to determine relationships between well and/or site characteristics and groundwater quality. The criteria used include:

- Wells capable of being pumped dry by small capacity pumps (one to two gallons per minute), or which can be bailed dry, were not included in the target population;

- The well must have a drilling and well completion log available to document the construction of the well and the geology of the aquifer material at the site;

- The well must be accessible and open for bailing or have an operable pump installed;

- The well must be capable of being sampled before any treatment of the water occurs; and,

- Permission of the owner or other responsible person must be received before the well may be sampled.

Sampling Grid

In an ideal monitoring program, every population unit in the target population would be sampled. However, due to the practical constraints of time, budget and personnel, not all wells could be sampled. A sampling grid was used, based on township, range and section boundaries. The size of a grid unit was one section, normally one square mile. Sections which only partially overlie an aquifer were included with that aquifer if they contained an acceptable sampling point.

Using Gilbert's (1987) method of determining "hot spots," a circular area of non-point source contamination with a radius of 0.56 miles has a 90 percent chance of being detecting by a one-mile-square uniform sampling grid. Because the sampling grid was not precisely uniform (the sample point could be anywhere within the grid block), the size of this 90 percent-confidence detection circle would be slightly more or less than 0.56 miles.

Selection of Sampling Points

A maximum of one well from each section was sampled for this survey. The shallowest well that met the sampling criteria and was nearest the center of the section was selected for sampling. Based on previous sampling results (only one questionable pesticide detection), wells with a depth greater than 100 feet generally were not sampled. Whenever possible, an alternative well was chosen for sampling in case the first selection was not capable of being sampled.

The only bias built into the monitoring program was toward shallower wells rather than deeper wells, and toward newer wells rather than older wells, because drilling logs were not required prior to enactment of the North Dakota Water Well Construction Code in 1971. The other characteristics of the sample site, such as water use and nearby land use, were strictly random.

Criteria for Selecting Aquifers

Radig (1997a) developed a system of prioritizing aquifers in the state which may have the highest potential for groundwater pollution. The Geographic Targeting System for identifying those aquifers is based on the DRASTIC groundwater vulnerability assessment model (Aller et al., 1987), as well as components for agricultural chemical usage and risk. The acronym DRASTIC stands for **d**epth to groundwater, **r**echarge, **a**quifer media, **s**oil media, **t**opography, **i**mpact of the vadose zone, and hydraulic **c**onductivity. These parameters are considered important in the transport of contaminants to groundwater. The Geographic Targeting System does not evaluate small areas within aquifers to determine recharge zones or critical areas, but rather evaluates aquifers as whole units to determine their relative average pollution potential. In some cases, large aquifers were subdivided into hydrogeologic settings with similar characteristics to aid in the evaluation process. Aquifers are chosen for groundwater monitoring based on a combination of their pollution potential and the volume of groundwater that is withdrawn from the aquifer for beneficial uses, such as drinking water supplies or irrigation. Aquifers are periodically re-evaluated for factors such as permitted water usage; therefore, an aquifer's ranking in the targeting system may move up or down accordingly.

Temporal Variability

All wells from which there was a pesticide detection in the initial sample are normally resampled at least once for confirmation purposes. Wells with sample analyses that exhibit a laboratory chromatographic peak below minimum detection limits, but which resembles a peak caused by pesticides, also will be resampled.

LOCATION NUMBERING SYSTEM

The wells and other data collection points mentioned in this report are numbered according to a system based upon the location in the public land classification of the U.S. Bureau of Land Management. The system is illustrated in Figure 2. The first numeral in the illustration denotes the township north of a base line, the second numeral denotes the range west of the fifth principal meridian, and the third numeral denotes the section in which the well is located. The letters A, B, C, and D designate the northeast, northwest, southwest and southeast quarter section, quarter-quarter section and quarter-quarter-quarter section (10-acre tract), respectively. For example, well 161-55-15DAB is in the NW$^{1}/_{4}$NE$^{1}/_{4}$SE$^{1}/_{4}$ of section 15, T. 161 N., R. 55 W. Consecutive end digits are added if more than one well or data collection point is within a given tract. Site

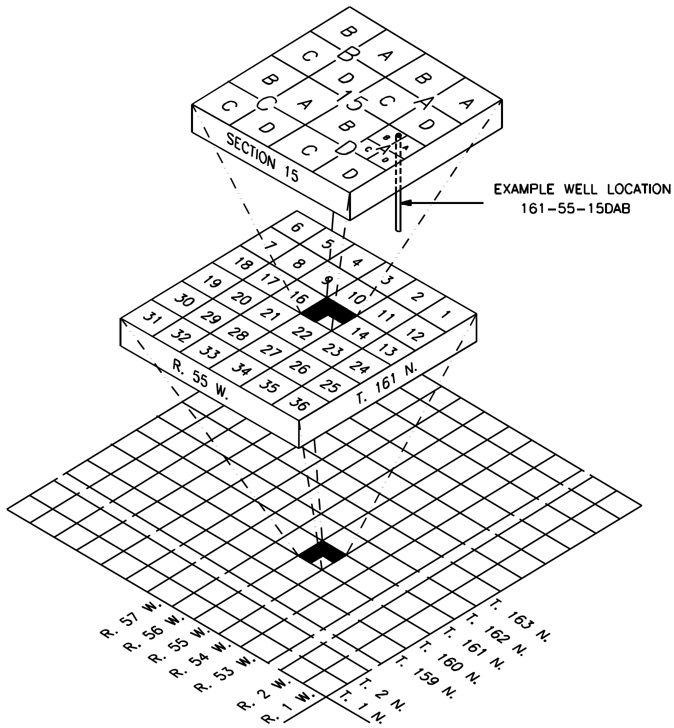


FIGURE 2. System of numbering wells, test holes and springs

identification numbers used for this study are the township, range, section and quarter digits combined without any dashes.

QUALITY ASSURANCE / QUALITY CONTROL METHODS

The objective of a groundwater monitoring program is to produce data that is valid, accurate, complete, representative of the medium being sampled, and comparable with other data. In view of this objective, a set of Standard Operating Procedures was developed and followed to encompass every aspect of groundwater monitoring, including sample collection, handling, preservation, field monitoring and uniform standards for the analysis and reporting of chemical data. Included in these procedures are certain methods for providing Quality Assurance/Quality Control (QA/QC). The Standard Operating Procedures used for this project include (1) locating the well site and collecting latitude/longitude data, (2) surveying well owners and filling out the field report form, (3) measuring water levels, (4) measuring temperature, pH, and conductivity, (5) well purging, (6) the use and maintenance of sampling mechanisms, and (7) collecting and preserving groundwater samples. Field sampling personnel were required to be familiar with these procedures and to have appropriate instruction manuals available for reference in the field. The project leader also served as the quality assurance representative, providing quality assurance oversight for the project.

A number of quality control checks were used in the field, including equipment calibration; submittal of field duplicate samples to establish sampling and laboratory precision; blank samples to assure noninterference with preservatives, sampling equipment or sample containers; and the use of standard solutions, reagents and lab-packaged vials of preservatives. A field duplicate sample and a field blank sample were collected with approximately one out of every 10 water chemistry samples collected. A notation was made in the site inventory form that the sample was a duplicate or a blank. The laboratory was not informed which samples were duplicates or blanks.

All equipment was inspected prior to departure for the field. Conductivity and pH meters were calibrated according to the manufacturer's specifications using standard solutions. Meters were calibrated daily and during sampling activities when necessary. Teflon bailers and Teflon pump tubing were used to prevent adsorption of pesticides on the sampler material and to facilitate effective cleanup.

All wells were purged prior to sampling to ensure that groundwater samples were representative of the aquifer. Purging the well removes stagnant groundwater in the well casing that may possess chemical and physical characteristics which are not representative of the aquifer water quality. Monitoring wells were purged by removing a minimum of three well volumes of water, and until stabilized readings of electrical conductivity, pH and temperature were obtained. Water pumps in wells for domestic, livestock and irrigation uses were allowed to run a minimum of five minutes prior to sample collection to increase the likelihood of collecting a representative sample.

To minimize cross-contamination of samples, the bailers and other equipment were decontaminated after sampling each well. Because the focus of this study was on pesticides (organics), decontamination procedures were followed that were appropriate for these parameters. The equipment was first washed with alconox, a non-phosphate detergent, then rinsed with deionized water. This was followed by an acetone rinse and then a hexane rinse. Disposable latex lab gloves were worn throughout sampling and decontamination processes to prevent contaminants from the skin from coming in contact with the sample and to protect the skin from the acetone and hexane rinses. Water level measurement tapes were rinsed with deionized water between measuring events. The gloves and the nylon cord used on the bailers were discarded and replaced after each well was sampled. Sample bottles were double-rinsed with sample medium, or, for blank samples, with deionized water. All samples were appropriately preserved, packed in ice and transported to the laboratory as necessary to comply with appropriate analytical holding times.

Prescribed field procedures, site inventory forms (Appendix A), and labels were used to ensure the orderly and consistent handling of all data collected. At the time of sample collection, field data and associated descriptive information were recorded on the site inventory form. This form includes information on the site location, well or location ID number, sampler(s), date and time of sample collection, method of sample collection, sampling equipment used, and well-purging data. Immediately prior to collecting the sample, the sample container was labeled with the well or location ID number, date, time and name or initials of sampler(s). Field data recorded in the laboratory report was checked against site inventory forms for accuracy.

All samples were analyzed by the North Dakota Department of Health, Division of Chemistry (NDDoH-DC), utilizing EPA-approved analytical methods. Sample custody procedures, analytical methods used in the analysis of samples, and calibration procedures for the NDDoH-DC laboratory are included in the NDDoH-DC Quality Assurance Program Plan (1997).

HYDROGEOLOGIC DESCRIPTIONS OF THE AQUIFERS

Icelandic Aquifer

Named after Icelandic State Park, the Icelandic aquifer underlies approximately 82 square miles in western Pembina County. It is an elongate feature extending from near Walhalla, where it is little more than a mile wide, southeast for about 20 miles, flaring out into a fan shape approximately nine miles across at its widest point. Refer to Figure 1 and Figure C-1 for plan views of the aquifer's location and areal extent.

Pembina County is located in the Central Lowlands physiographic province. All but the extreme southwest corner of the county lies within a district of the province designated the Lake Agassiz Plain, commonly known as the Red River Valley. This flat plain slopes gently to the northeast at less than five feet per mile and marks the extent of glacial Lake Agassiz in North Dakota (Hutchinson, 1977).

The northern portion of the Icelandic aquifer is bordered by the steep northeastern face of the Pembina Delta. This feature, also known as the Campbell Scarp, marks a former shoreline or strandline of Lake Agassiz in northwestern Pembina County. These deltaic deposits, which provided the primary source material for the Icelandic aquifer, were deposited by longshore currents moving along the eastern edge of the Pembina Delta. The currents formed large spit deposits to the south and east of the delta, which comprise the present-day aquifer (Arndt, 1975; Hutchinson, 1977).

The Icelandic aquifer is a water table aquifer underlain by a confining clay layer, and consists of predominantly very fine to medium sand interbedded with some silt and clay. Due to wave activity during deposition, most of the finer silt and clay particles were transported lakeward. Therefore, the aquifer materials, in general, become finer grained from north to south and from west to east, and there is a gradual change from fine sand to silt near the southern and eastern margins (Hutchinson, 1977).

According to Arndt (1975), the deposits comprising the Icelandic aquifer range from less than six feet thick east of Hensel, near the southeastern edge of the aquifer, to more than 50 feet thick southeast of Walhalla. Hutchinson (1977) reports a somewhat greater thickness, with a maximum saturated thickness of approximately 70 feet and an average saturated thickness of 30 feet. He estimates approximately 240,000 acre-feet of water are available from storage. The main source of recharge to the Icelandic aquifer is direct infiltration of precipitation and snowmelt. Discharge occurs primarily through underflow into adjacent glacial lake deposits to the east, flow into the Tongue River, evapotranspiration, and pumpage of wells (Hutchinson, 1977).

Oakes Aquifer

The Oakes aquifer is located in southeastern North Dakota and extends into South Dakota. The North Dakota portion of the aquifer lies in southeastern Dickey and southwestern Sargent counties. In Dickey County, the James River marks the western boundary of the aquifer, while the northern boundary coincides with the dividing line between T.131 N. and T. 132 N. Refer to Figure 1 and Figure C-2 for plan views of the aquifer's location and areal extent.

The Oakes aquifer lies in an area that was entirely glaciated, with the surficial Pleistocene glacial and Holocene deposits overlying the Cretaceous Niobrara or, in a few isolated locations, the Pierre Shale bedrock formations. Collectively, all sediment relating to glacial deposition has been designated the Coleharbor Group by Bluemle (1979). The glacial deposits consist of till, meltwater sediment and lake plain sediments. Covering the glacial sediments in much of the area is the eolian, or wind-blown, sediment of the Oahe Formation, named by Bluemle (1979) for Holocene deposits, primarily river, pond, eolian and mass-movement sediments.

According to Armstrong (1980, 1982), the Oakes aquifer was deposited in two stages. The first stage was the deposition of valley fill. The subsequent blockage of the valley in South Dakota led to the formation of glacial Lake Dakota, which extended from the point of blockage to approximately three miles north of Oakes. This was the second stage of aquifer formation and resulted in the deposition of deltaic and lake deposits that comprise much of the surface sediments of the Oakes aquifer. Shaver (1988) identified four depositional facies within the

Oakes aquifer: deltaic sand and gravel deposits up to about 80 feet thick in the northern part of the aquifer near Oakes; medium sand lacustrine deposits with a maximum thickness of 60 feet in the central part of the lake plain, grading to fine to very fine silty sand, clayey silt, and silty clay south of Ludden; channel-fill sand and gravel deposits approximately 200 feet thick in a glacial outwash channel located along the eastern margin of the lake plain; and eolian fine sand and silt ranging from less than one foot to approximately 50 feet thick covering much of the lake plain.

In Dickey County, the Oakes aquifer is approximately 11 miles wide at its widest point and as much as 18 miles long, underlying an area of about 93 square miles. In Sargent County, the aquifer is about two to three miles wide and 11 miles long, and underlies about 33 square miles. There is considerable variation in the thickness of the aquifer; the saturated thickness ranges from approximately two to 99 feet, with 30 feet the average. Armstrong (1980) estimates there are approximately 268,000 acre-feet of water available from storage from the Oakes aquifer.

The Oakes aquifer is generally a water table aquifer; leaky-confined conditions occur where channel-fill deposits are overlain by lacustrine silt and clay (Shaver, 1988). In the northern part, the Oakes aquifer overlies the Spiritwood aquifer system, with approximately 40 feet of clay, silt or till separating the two aquifers. According to Armstrong (1980), there is apparently some leakage from the Oakes to the Spiritwood aquifer. In the northeastern part, the Oakes aquifer is covered by a younger till (Armstrong, 1980), indicating that perhaps locally it is under semi-confined conditions.

Recharge occurs primarily through the direct infiltration of precipitation and snowmelt. Discharge occurs through evapotranspiration, pumpage and leakage into the Spiritwood aquifer system (Armstrong, 1980). According to Shaver (1988), groundwater flow is generally from east to west, toward the James River valley; however, recent sandy, silty clay flood-plain deposits that truncate the western flank of the aquifer result in negligible discharge to the James River.

Warwick Aquifer

The Warwick aquifer is located in southeastern Benson and northeastern Eddy counties. Bounded on the north by the North Viking End Moraine and on the west by the McHenry End Moraine, the aquifer extends south to the Sheyenne River valley. For plan views of the aquifer's location and areal extent, refer to Figure 1 and Figure C-3.

The Warwick aquifer lies within an area referred to by Paulson and Akin (1964) as the Warwick outwash plain, a flat plain that slopes gently to the south and east. The Warwick outwash plain exhibits characteristic glacial features such as numerous kettle lakes, some quite large; low hills or knobs of ground moraine; poorly integrated drainage; and the presence of glacial drift in varying thicknesses. Near Hamar, sand dunes create a hummocky terrain.

The Warwick aquifer consists predominantly of fine to coarse sand glacial outwash deposits. Beds of gravel and of clay and silt, found locally, vary in lateral extent and depth. Randich (1977) states that these deposits were transported by meltwater from glaciers and, for the most part, were deposited beyond the end moraines associated with the glaciers. Based on test holes and wells, the thickness of the deposits has been estimated to range from approximately 20 to 200 feet, with an average thickness of 74 feet (Randich, 1977) to 94 feet (Paulson and Akin, 1964). These outwash deposits generally overlie the Cretaceous Pierre Shale or, locally, glacial till and associated sand and gravel deposits. The Warwick aquifer underlies approximately 30 square miles of eastern Benson County (Randich, 1977) and 24 square miles in northeastern Eddy County (Trapp, 1968).

Approximately 300,000 acre-feet of water are available from storage in the Benson County portion of the aquifer (Randich, 1977) and 180,000 acre-feet from storage in the Eddy County portion (Trapp, 1968). Due to the slope of the water table and thinning and decreased permeability of deposits in the southern portion, the aquifer is restricted approximately to the north halves of T. 150 N., R. 62 and 63 W. in Eddy County, even though the outwash deposits extend to the Sheyenne River valley (Trapp, 1968).

In the western portion of the aquifer in the vicinity of the Devils Lake municipal water supply wells, Paulson and Akin (1964) report a "leaky" aquifer system consisting of a shallow water table aquifer and a deeper, highly permeable, sand and gravel aquifer. These aquifers, both located in the Warwick outwash deposits, are separated by a less permeable, semi-confining layer that allows mixing between the two aquifers. The Devils Lake municipal wells are supplied by the lower aquifer. According to Randich (1977), the aquifer is underlain by part of the Spiritwood aquifer system northeast of Warwick. In Eddy County, most of the Warwick aquifer is a water-table aquifer (Trapp, 1968).

The primary source of recharge to the Warwick aquifer is through direct infiltration of precipitation and snowmelt. Groundwater flow direction is generally south toward the Sheyenne River (Randich, 1977).

Spring Creek Aquifer

According to Klausing (1981), the Spring Creek aquifer system is a complex system of buried-valley and buried-outwash sand and gravel deposits underlying approximately 88 square miles in southeastern McIntosh County and extending into South Dakota. Refer to Figure 1 and Figure C-4 for plan views of the aquifer's location and areal extent. Near the South Dakota border these deposits merge, forming a vertical sequence of four laterally extensive aquifers. The aquifer materials are predominantly coarse to very coarse gravelly sand. Locally, the uppermost aquifer has been exposed by erosion. The maximum aggregate thickness of the aquifer is about 90 feet, and the average saturated aggregate thickness is about 40 feet (Klausing, 1981). The aquifer is generally confined, although the upper aquifer may be under water-table conditions, locally.

Discharge from the Spring Creek aquifer is by seepage into lakes and sloughs, evapotranspiration, and pumping of wells. Recharge is primarily from infiltration of precipitation, and from potholes and sloughs. Klausing (1981) estimates approximately 329,000 acre-feet of water would be available to wells from the Spring Creek aquifer.

Streeter Aquifer

The Streeter aquifer underlies a glacial outwash plain in north-central Logan County, known locally as Streeter Flats (Wanek, 1983). Refer to Figure 1 and Figure C-5 for plan views of the aquifer's location and areal extent. Streeter Flats is bordered by the Gary End Moraine on the northeast and by the Altamont End Moraine on the southwest. The Streeter aquifer is actually an aquifer system consisting of a small, buried-valley aquifer and a surficial-outwash aquifer, separated by approximately 40 to 120 feet of glacial till and lacustrine deposits. It has an areal extent of about 31 square miles. The buried-valley portion of the aquifer underlies about eight square miles in the northern part of the aquifer (Klausing, 1983). The shallow, surficial-outwash aquifer is the focus of the remainder of the discussion on the Streeter aquifer.

The outwash in the Streeter aquifer is generally intermixed sand and gravel; however, locally it may be either sand or gravel (Klausing, 1983). Wanek (1983) further states that the outwash sand and gravel is graded with few fines. The thickness of the outwash deposits ranges from zero to about 60 feet, with an average saturated thickness of approximately 29 feet (Klausing, 1983). The Streeter outwash aquifer is generally a water table aquifer; however, according to Klausing (1983), silt and clay beds present locally in the middle of the aquifer act as confining layers, particularly in the northwestern part of the aquifer.

Water is discharged from the Streeter aquifer by pumping of wells--mainly irrigation wells, but also by domestic and stock wells; by evapotranspiration; and by discharging into Alkaline Lake, north of the Kidder-Logan County border (Klausing, 1983; Wanek, 1983). Recharge is through direct infiltration of precipitation and runoff from the adjacent moraines that drain onto the Streeter Flats (Wanek, 1983). It is estimated that about 86,000 acre-feet of water in the Streeter outwash is available to wells (Klausing, 1983).

DESCRIPTION OF SITE CHARACTERISTICS

Site Inventory

A site inventory form was developed to collect data that would assist in the interpretation of the analytical results. The form was intended to record conditions around the well that may have an influence on the quality of the groundwater in the area. The form contains sections on well characteristics, activities performed and conditions around the well, as well as the parameters measured during the well-purging process. A copy of the form is included as Appendix A.

The site inventory form was completed by the field personnel who collected the sample(s) at each site. If the collection point was a private domestic, stock or irrigation well, or a public water supply well, an interview was conducted with the owner or other responsible person to obtain as much site-specific information as was available. If the collection point was a government agency monitoring well, the collector completed as much of the inventory form as possible from field observation. When possible, drilling log information, such as well depth and diameter, was measured and verified. Water level measurements recorded were those measured at the time of sampling, or those currently reported by the owner in the case of private wells. Water levels from the drilling logs were not entered on the site inventory form unless more current information was unavailable. Site characteristics recorded were those within approximately one-eighth mile or less of the well.

Information from the site inventory forms was entered into a database that was used to relate the field information with the analytical results of the water sampling. The maps on the forms were not entered graphically in the database; however, distance information to potential contaminant sources was included. The field sheets are retained by the Division of Water Quality.

Well Characteristics

Eighty-two percent of wells sampled for this study were monitoring wells, and 13 percent were private domestic wells. Most of these were small-diameter wells (less than six inches in diameter) and constructed of PVC casing. Other types of wells sampled include public water supply, livestock and irrigation wells, constructed of a variety of materials. The wells varied in depth below ground surface and below the water table. The shallowest well sampled had a total depth of eight feet; the deepest well was 110 feet deep. A number of wells were screened across or very near the water table, while the deepest screened interval was approximately 103 feet below the water table. The age of the wells was generally less than 25 years because of the study restriction requiring all wells to have a well-construction log. Table 1 contains a summary of well characteristics for all five aquifers included in this report. Tables of well characteristics for each aquifer are located in Appendix D.

TABLE 1
General Well Construction Statistics
For All Aquifers Sampled 1997

AQUIFER	#	PERCENT
ICELANDIC :	34	19.0
OAKES :	81	45.3
SPRING CREEK :	4	2.2
STREETER :	28	15.6
WARWICK :	32	17.9
Total :	179	

DEPTH OF WELL	#	PERCENT
< 20 Ft. :	50	27.9 %
20 - 50 Ft. :	98	54.7 %
> 50 Ft. :	30	16.8 %
Unknown :	1	0.6 %

DIAMETER OF WELL	#	PERCENT
< 6 in. :	161	89.9 %
6 - 18 in. :	7	3.9 %
> 18 in. :	9	5.0 %
Unknown :	2	1.1 %

CASING MATERIAL	#	PERCENT
Plastic (PVC or ABS) :	149	83.2 %
Concrete/Brick/Stone :	11	6.1 %
Metallic :	13	7.3 %
Other :	6	3.4 %

DEPTH TO TOP OF SCREENED INTERVAL	#	PERCENT
< 20 Ft. :	85	47.5 %
20 - 50 Ft. :	62	34.6 %
> 50 Ft. :	20	11.2 %
Unknown :	12	6.7 %

DISTANCE FROM WATER TABLE TO TOP OF SCREEN	#	PERCENT
< 10 Ft. :	44	24.6 %
10 - 30 Ft. :	79	44.1 %
> 30 Ft. :	29	16.2 %
Unknown :	27	15.1 %

TYPE OF WELL	#	PERCENT
Monitoring :	146	81.6 %
Private/Domestic :	23	12.8 %
Livestock :	4	2.2 %
Public Supply :	5	2.8 %
Irrigation :	1	0.6 %
Other :	0	0.0 %

is the number of wells in the category.
% is the percentage of wells in the category.

Site Characteristics

Wells were sampled from a variety of general settings, including fields, pastures, farmyards, Conservation Reserve Program (CRP) acres, roadsides and within town boundaries. Often the sites had characteristics of more than one type of general setting; for example, a well located on the boundary of a farmyard and a pasture, adjacent to a road ditch. In 1995, an additional data field was added to the site inventory form to include a secondary general setting to help account for wells with characteristics of more than one setting. Only wells located near chemical application areas or storage/mixing sites verified by the owner or applicator were recorded as such on the site inventory form and in the database. However, many more wells than verified in the field probably have had chemical application, storage or mixing performed near them. For instance, landowner information on chemical history was rarely available for monitoring wells.

WATER QUALITY ANALYSES

Analytes of Concern

According to a 1992 State Water Commission survey of North Dakota residents, the most important water-related issue is protecting groundwater from contamination. Agricultural chemicals are perceived as a threat to groundwater quality, and wide-spread contamination problems have occurred in other states. The main analytes of concern for this study are agricultural pesticides. The general inorganic chemical nature of each groundwater sample also was determined. Each sample was analyzed for general anions and cations, total nitrate plus nitrite as nitrogen (N), 39 base-neutral pesticides, 13 chlorinated pesticides, and eight carbamate pesticides (Table 2). These three pesticide groups are included in the Safe Drinking Water Act, Phase II/V, sampling requirements. By analyzing for the same pesticides as community water systems, results from this study can be correlated more easily with community water system sampling results.

TABLE 2
Summary of Analytical Parameters

Analyte Group	Parameter Analyzed	NDDoH, DC Quantification Limit*	Sample Preservation	Holding Time
Minerals	Chloride	1.0 mg/l	Stored at 4°C	14-28 days, varies with parameter
	Fluoride	0.01		
	Sulfate	3.0		
	Carbonate (CO3)	1.0		
	Bicarbonate (HCO3)	1.0		
	Hydroxide (OH)	1.0		
	Total Alkalinity	2.0		
	Total Hardness			
	TDS			
	Laboratory Conductivity			
	Laboratory pH			
	Percent Sodium			
	Sodium Adsorption Ratio			
	Turbidity			
ICP Metals	Sodium	0.1 mg/l	2 ml nitric acid to pH 2 and stored at 4°C	6 months
	Magnesium	0.1		
	Potassium	1.0		
	Calcium	0.030		
	Manganese	0.002		
	Iron	0.007		
Nitrate	Nitrate plus Nitrite	0.05 mg/l (N)	2 ml sulfuric acid to pH 2 and stored at 4°C	28 days

*Quanitification limits for 1 full liter of clean sample.

TABLE 2 (continued)
Summary of Analytical Parameters

Analyte Group	Parameter Analyzed	NDDoH, DC Quantification Limit*	Sample Preservation	Holding Time
Pesticides	Aldrin	0.010 μg/l	Stored at 4°C	7 days
Group I	BHC-Alpha	0.010		
Base-Neutral	BHC-Beta	0.010		
Organics	BHC-Delta	0.01		
	BHC-Gamma (Lindane)	0.010		
	DDD (or TDE)	0.010		
	DDE (degradate of DDT)	0.010		
	DDT	0.025		
	Dieldrin	0.010		
	Endosulfan I	0.010		
	Endosulfan II	0.010		
	Endosulfan Sulfate	0.010		
	Endrin	0.010		
	Endrin Aldehyde	0.02		
	Heptachlor	0.010		
	Heptachlor Epoxide	0.010		
	Methoxychlor	0.100		
	Diclofop (Hoelon)	1.00		
	Toxaphene	1.0		
	Chlordane (gamma)	0.010		
	Chlordane (alpha)	0.010		
	trans-Nonachlor	0.010		
	Endrin Ketone	0.025		
	Alachlor	0.200		
	Chlorpyrifos	1.00		
	Diazinon	0.10		
	Malathion	0.040		
	Ethyl Parathion	0.450		
	Methyl Parathion	0.450		
	Fenvalerate	0.400		
	Cyanazine	0.050		
	Triallate (Fargo)	0.010		
	Trifluralin (Treflan)	0.010		
	Simazine	0.450		
	Ethylfluralin	0.010		
	Atrazine	0.250		
	Pendimethalin (Prowl)	0.010		
	Metribuzin	0.020		
	Metolachlor	0.080		
Group II	2,4-D	0.10 μg/l	Stored at 4°C	14 days
Chlorinated	Dicamba	0.10		
Herbicides	Dinoseb	0.20		
	MCPA	50.0		
	Picloram (Tordon)	0.10		
	2,4,5-T	0.15		
	2,4,5-TP (Silvex)	0.20		
	Pentachlorophenol	0.04		
	Acifluorfen	0.05		
	3,5 Dichlorobenzoic Acid	0.05		
	Bromoxynil	0.10		
	Bentazon	0.500		
	Dichlorprop	0.200		
Group III	Aldicarb	0.500 μg/l	1.33 ml carbamate buffer	28 days
Carbamates	Aldicarb Sulfoxide	0.50	(76% water, 13.3% mono-	
	Aldicarb Sulfone	0.50	chloroacetic acid, 5.6% acetic	
	Oxamyl	0.50	acid, 5.1% potassium hydroxide)	
	Carbofuran	0.50	to pH of 3.1 and stored between	
	3-Hydroxycarbofuran	0.500	8 and 25°C	
	Methomyl	0.500		
	Carbaryl	0.50		

Significance of Selected Constituents

Interpretation of water quality is dependent upon many factors, including the intended use of the water. Several water-quality parameters may be detrimental to health or may cause undesirable aesthetic effects, which may be considered unsatisfactory to some, while others may see little or no adverse effect for nearly all uses. In view of possible adverse and/or undesirable effects, the U.S. EPA has established drinking water regulations for concentrations of certain elements for water that is delivered to users of a public water system. These standards are classified as either primary or secondary drinking water regulations. Primary drinking water regulations are federally enforceable regulations for specific contaminants that are potentially harmful to human health and are defined by a Maximum Contaminant Level (MCL). Although MCLs are not enforced for private water supplies, they are sometimes applied as a cleanup goal when remediation of contaminated groundwater is needed. Secondary drinking water regulations vary from state to state and are not federally enforceable. In contrast to the primary regulations, the secondary regulations are defined by Secondary Maximum Contaminant Levels (SMCL) and are designed to protect public welfare. SMCLs are only recommended limits, and North Dakota public water systems are not required to comply with them.

Of the general chemistry parameters included in primary drinking water regulations, nitrate is of primary concern. Health effects associated with drinking nitrate-contaminated water include methemoglobinemia, commonly called "blue baby syndrome," in infants. The MCL for nitrate plus nitrite as nitrogen (N), hereinafter referred to as nitrate, is 10 mg/l. The potential health effects of nitrates are discussed in detail in Appendix E, the Health Advisory section.

Fluoride is also included in the primary drinking water regulations. Most fluoride compounds have a low solubility; therefore, fluoride usually occurs only in small amounts in natural water. Many municipal water systems add fluoride to their drinking water. Within certain limits, fluoride in drinking water has been shown to reduce the formation of cavities in children. Optimum fluoride concentrations are region-specific and are dependent on the annual average of maximum daily air temperatures. An excess of fluoride may produce skeletal damage and dental fluorosis (a brownish discoloration of the teeth). The MCL for fluoride has been set at 4 mg/l;

however, the SMCL is 2 mg/l. Some groundwater in North Dakota has naturally-occurring fluoride concentrations that exceed the MCL.

The chemical constituents included under the secondary drinking water regulations of interest for this report include iron, manganese, sulfate, chloride, and the physical properties of hardness and Total Dissolved Solids (TDS). Although generally not a health concern, elevated concentrations of these constituents may cause unpleasant side effects and/or aesthetic qualities.

Although high concentrations of iron and manganese do not appear to present a health hazard, concentrations greater than the recommended limits may cause rust, brown or black stains on laundry, plumbing fixtures, sinks and utensils. A metallic taste may be present, and the elements may affect the taste of beverages made from the water. The SMCL for iron is 0.3 mg/l, and 0.05 mg/l for manganese.

Water containing high levels of sulfate may have a laxative effect on people unaccustomed to the water. These effects vary with the individual and appear to last only until one becomes accustomed to drinking the water. High sulfate content also affects the taste of water and will form a hard scale in boilers and heat exchangers. For these reasons, the SMCL is 250 mg/l.

High concentrations of chloride may result in an objectionable salty taste in water and the corrosion of plumbing in the hot water system. Water high in chloride may also produce a laxative effect. An SMCL of 250 mg/l has been recommended for chloride, although at this level few people will notice a salty taste. Higher concentrations do not appear to cause adverse health effects. An increase in the normal chloride content of water may indicate possible contamination from human sewage, feedlots or industrial wastes.

The TDS content of water is a measure of the total quantity of mineral matter present. Generally, the more highly mineralized the water, the more distinctive its taste. Water high in minerals may also deteriorate plumbing and appliances. It is recommended that water containing more than 500 mg/l dissolved solids not be used if other less mineralized supplies are available. This does not mean, however, that water containing more than 500 mg/l concentration of TDS is unusable. Exclusive of most treated public supplies, the Missouri River, a few fresh lakes, and scattered wells, very few water supplies in North Dakota contain less than the SMCL of 500 mg/l.

Conductivity, closely related to the TDS content of water, is a measure of the conductance of water to an electrical current. Conductivity is reported as micromhos per centimeter (μmhos/cm). TDS, in mg/l, is approximately 70 percent of the conductivity.

Hardness also is related to the TDS, and, as used in this report, refers to calcium and magnesium hardness. Hard water has no known adverse health effects and may be more palatable than soft water. Hard water is primarily of concern because it requires more soap for effective cleaning, forms scum and curd, causes yellowing of fabrics, toughens vegetables cooked in the water, and forms scales in boilers, water heaters, pipes, and cooking utensils. Based on the U.S. Geological Survey classification (Klausing, 1979), water having a hardness of less than 60 mg/l (measured as calcium carbonate, CaCO3) is considered soft, 61 to 120 mg/l is moderately hard, 121 to 180 mg/l is hard, and more than 180 mg/l is very hard. According to this classification, the hardness of good quality water should not exceed 270 mg/l. Because North Dakota groundwater is typically more mineralized than groundwater from other parts of the U.S., the NDDoH-DC uses a hardness classification that is tailored to North Dakota groundwater. The NDDoH-DC classification provides an interpretation of hardness relative to North Dakota groundwater, as follows: less than 75 mg/l (measured as calcium carbonate, $CaCO_3$) is considered low hardness, 76 to 150 mg/l is fairly low, 151 to 225 mg/l is satisfactory, 226 to 325 mg/l is average, 326 to 450 mg/l is high, and more than 450 mg/l is very high. The interpretation of hardness for groundwater samples collected for the North Dakota Groundwater Monitoring Program is based on the NDDoH-DC hardness classification. Water softer than 30 to 50 mg/l may be corrosive to piping, depending on other factors such as pH, alkalinity, temperature and dissolved-oxygen content.

There is no MCL or SMCL for sodium; however, high sodium content in water may be a concern for those people who must limit their dietary intake of sodium. The contribution of sodium in drinking water is normally small compared to other sources, such as consumption of sodium chloride, or table salt. A standard for public water supplies of no more than 100 mg/l sodium has been suggested to ensure that the water supply adds no more than 10 percent of the average person's total sodium intake, or an even more conservative standard of 20 mg/l to protect heart and kidney patients. High concentrations of sodium will reduce the suitability of water for irrigation or watering house plants. High concentrations of sodium in water may alter the soil chemistry and physical properties, possibly creating deleterious conditions for plant growth. Softening water by ion exchange or lime-soda ash processes will increase the sodium content.

Groundwater types, such as calcium bicarbonate and sodium chloride-bicarbonate, are classified based on chemical analyses and represent the predominant cation (sodium, calcium or magnesium) and anion (bicarbonate, sulfate or chloride) expressed in milliequivalents per liter. When two or more cations or anions are present in nearly equal concentrations, it is referred to as a mixed chemical type.

MONITORING RESULTS

A total of 179 wells from all five aquifers were sampled for general cation and anion chemistry, total nitrate plus nitrite, and 60 selected pesticides and pesticide degradation products. The NDDoH-DC laboratory performed the analyses for all samples.

Seven wells, or 4 percent of the wells sampled from the five aquifers, contained detectable concentrations of at least one pesticide. The Icelandic and Warwick aquifers each had two wells with pesticide detections, and the Oakes aquifer had three wells with pesticide detections. It is noted that between 1992 and 1997, method detection levels for many of the analytes decreased, while the number of pesticide analytes increased from 44 to 60. Therefore, several of the pesticides detected in 1997 would not have been observed using 1992 detection levels and analyte lists. Table 3 lists all detections of pesticides, including the results of follow-up sampling.

Ten pesticide compounds were positively identified by laboratory analysis: bentazon, 2,4-D, 3,5 dichlorobenzoic acid, endrin, endrin aldehyde, endrin ketone, heptachlor epoxide, MCPA, pentachlorophenol and picloram. Two pesticides, endrin and picloram, were confirmed in follow-up samples. Two pesticides were detected at concentrations above their respective HAL or MCL: pentachlorophenol was detected at 1.36 μg/l , or 136 percent of the MCL; and MCPA was detected in two samples at concentrations of 138 and 63.5 μg/l, or 1,380 and 635 percent of

TABLE 3
Summary of Pesticide Detection Data
For All Aquifers Sampled in 1997

LOCATION/ WELL ID NUM.	AQUIFER	DATE	CHEMICAL DETECTED	HAL* or MCL(ug/l)	DETECTED CONC.(ug/l)	% of HAL or MCL	SAMPLE TYPE
16105524AAC1	ICELANDIC	06/18/97	2,4-D	70.000	1.700	2.429	R
16105524AAC1	ICELANDIC	06/18/97	3,5 Dichlorobenzoic Acid	None	1.530		R
16105524AAC1	ICELANDIC	09/09/97	None				R
16105530AAC	ICELANDIC	06/17/97	Endrin	2.000	0.042	2.100	R
16105530AAC	ICELANDIC	09/09/97	MCPA	10.000*	138.000	1380.0	R
16105530AAC	ICELANDIC	10/30/97	Endrin	2.000	0.085	4.250	R
16105530AAC	ICELANDIC	10/30/97	Heptachlor Epoxide	0.200	0.017	8.500	R
16105530AAC	ICELANDIC	10/30/97	Endrin Ketone	None	0.046		R
12905915CBB	OAKES	07/01/97	2,4-D	70.000	0.500	0.714	R
12905915CBB	OAKES	07/01/97	Pentachlorophenol	1.000	1.360	136.00	R
12905915CBB	OAKES	08/14/97	None				R
13105909CCC	OAKES	05/21/97	Bentazon	20.000*	1.360	6.800	R
13105909CCC	OAKES	08/07/97	None				R
13105929ACC	OAKES	06/03/97	Endrin Aldehyde	None	0.030		R
13105929ACC	OAKES	09/10/97	MCPA	10.000*	63.500	635.00	B
13105929ACC	OAKES	10/29/97	None				R
15006310CDD	WARWICK	07/08/97	Picloram	500.000	0.650	0.130	R
15006310CDD	WARWICK	09/09/97	Picloram	500.000	1.300	0.260	R
15106335CCC	WARWICK	07/08/97	Picloram	500.000	3.110	0.622	R
15106335CCC	WARWICK	09/09/97	Picloram	500.000	4.040	0.808	R

Sample Type: R = Regular Sample; D = Duplicate Sample; B = Blank Sample

the HAL, respectively. Both samples with MCPA were follow-up samples collected to confirm the presence of other pesticides found in the initial samples. The two samples were collected a day apart and from different aquifers; however, they were collected by the same person, transported in the same vehicle, and were analyzed in the same batch. Of note, one of the samples with MCPA was a field blank sample collected along with a regular sample. Laboratory interference or sampling error are suspected in both of these detections. Both wells with MCPA were sampled a third time; MCPA was not detected in either well during the third sampling. Pentachlorophenol was also not detected during follow-up sampling. A discussion of the pesticide detections in each well follows in sections addressing individual aquifers.

Fifty-seven wells, or 32 percent of the 179 wells sampled, had nitrate greater than the detection limit of 0.05 mg/l (N) in at least one sample collected. Over one-third of the samples with detectable nitrate were at trace levels near the detection limit. Samples from 13 wells, or 7 percent of the total wells sampled, were greater than the 10 mg/l (N) MCL. A discussion of the nitrate detections in each well that exceeded the MCL follows in sections addressing individual aquifers.

Complete general inorganic chemical results, including nitrates, are listed for each aquifer in Appendix B. Also included with the analyses are the minimum, maximum, mean, median and standard deviation values for each parameter. Aquifer maps showing the sample locations are found in Appendix C. Descriptions of the characteristics and possible health effects of the detected pesticides and nitrates are found in Appendix E.

Icelandic Aquifer

Thirty-eight samples were collected from 34 wells in the Icelandic aquifer. The water in the Icelandic aquifer is primarily a calcium bicarbonate type. The samples were high in iron and manganese, and low in dissolved solids, sulfate, and sodium. Almost one-half of the samples from the Icelandic aquifer had no sodium detected. Median hardness was average at 307 mg/l as $CaCo_3$.

Pesticides were detected in samples from two wells in the Icelandic aquifer. The initial sample from well 16105524AAC1 had detectable concentrations of two pesticides: 2,4-D at 1.7μg/l, or 2.43 percent of the MCL, and 3,5-dichlorobenzoic acid at a concentration of 1.53 μg/l. There is no MCL or HAL for 3,5-dichlorobenzoic acid. No pesticides were detected in either a regular or a duplicate sample collected for follow-up confirmation purposes. This is a private well in a farmyard, used only for watering the lawn and garden. It is a 48-inch-diameter, masonry-cased well that is 12 feet deep. The screened interval is reported to be from nine to 12 feet. The well was first sampled for this program in 1992, at which time no pesticides were detected; however, the well has been consistently high in nitrates, ranging from 84.3 to 105 mg/l (N). Although the well is located on a farmstead, the current owners are not engaged in agriculture, either farming or raising livestock, although these practices probably occurred in the past. The only agricultural chemical reportedly stored or used on the farm is 2,4-D amine for the control of dandelions. The well is reportedly within 100 feet of CRP land, and within 100 feet to one-eighth mile of the septic system.

Another well in the Icelandic aquifer, 16105530AAC, initially had a detection of endrin at a concentration of 0.042 μg/l, or 2.1 percent of the MCL, set at 2.0 μg/l. A follow-up sample collected from the well did not detect endrin; however, MCPA was detected at 138 μg/l. This represents 1,380 percent of the HAL, set at 10 μg/l, and is the highest concentration of a pesticide detected, from a health-based standard, since the monitoring program began. (Of note, the pesticide analysis is normally run on a gas chromatograph [GC] with electron capture detector with a minimum detection limit for MCPA of 50 μg/l, a level five times the HAL. When detected at or above this level, the detection is confirmed on the mass spectrometer, with a minimum detection limit of 10 μg/l, although it may also be detected at concentrations lower than 10 μg/l.) Because of the high level of MCPA detected, the well was sampled a third time. No MCPA was detected in the third sample; however, endrin was again detected at a concentration of 0.085 μg/l, or 4.25 percent of the MCL, along with heptachlor epoxide at 0.017 μg/l, or 8.5 percent of the MCL, and endrin ketone at 0.046 μg/l. There is no MCL for endrin ketone. This well is a 36-inch-diameter well constructed with masonry casing, located in a farmyard. The well depth is 12 feet, and has a screened interval from nine to 12 feet. The reported water level is about five feet below ground surface. The well is listed as a livestock well, although there has not been any livestock there for some time. However, it is within one-eighth mile of the barn and pasture, the septic system and CRP land, which are all reportedly at the same elevation as the well. This well was also sampled in 1992 for this program; no pesticides were detected in the well at that time. Because of the elevated concentration of MCPA in the stock well, a domestic well located on the farmstead was also sampled; no pesticides were detected in the domestic well.

Fourteen (41 percent) of the 34 wells sampled in the Icelandic aquifer contained detectable levels of nitrate. One well (3 percent), had a concentration above the 10 mg/l (N) MCL. This well, 16105524ACC1, is discussed above. The initial sample collected from the well had a nitrate concentration of 90.9 mg/l (N). During follow-up sampling, both a regular and a duplicate sample were collected; the concentration of nitrate in the regular sample was 84.3 mg/l (N), and in the duplicate, 88 mg/l (N). In 1997, the NDDoH installed a well nest consisting of two, two-inch-diameter PVC monitoring wells downgradient of the lawn-watering well. The shallow well of the nest is screened from 10 to 20 feet; the deep well is screened from 20 to 40 feet. Nitrate was not detected in either well.

Resampling aquifers on a five-year cycle through the monitoring program provides an opportunity to assess the temporal variability of pesticide and nitrate detections in individual wells. Figure 3 compares percentages of nitrate detections in the Icelandic aquifer for the years 1992 and 1997. The first two columns depict the percentages of nitrate detections for all wells sampled for those years; the last two columns are a direct comparison of the 13 wells sampled in both years. Overall, the percentage of wells with nitrate detections decreased in 1997. This decrease was due entirely to smaller percentages of wells with high and intermediate detections; the percentage of wells with nitrate detections below 1.0 mg/l (N) increased slightly.

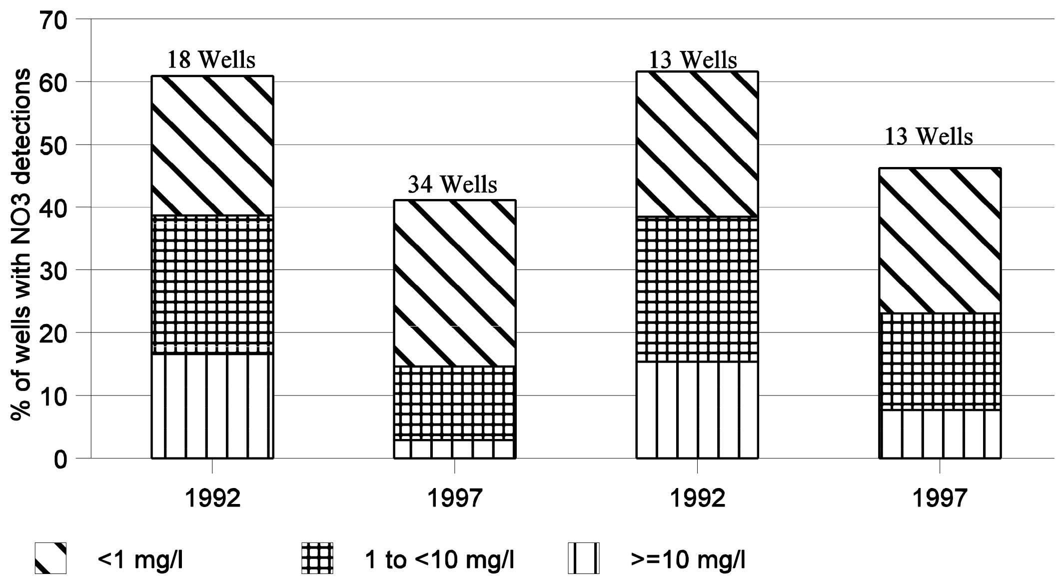


FIGURE 3. Graph of nitrate detections in the Icelandic aquifer for the years 1992 and 1997

In 1992, 18 wells were sampled in the Icelandic aquifer. Eleven wells, or 61 percent, had detectable concentrations of nitrate. Three wells, 17 percent, had nitrate concentrations above the 10 mg/l (N) MCL. One of the wells with nitrate above the MCL also had the only detection of pesticides in the Icelandic aquifer during the 1992 sampling. This well was not accessible for sampling in 1997.

In all, 13 of the 18 wells initially sampled in 1992 were resampled in 1997. As shown in Figure 3, the percentages of nitrate detections in these 13 wells also decreased overall, again due to decreased percentages of wells with high and intermediate nitrate concentrations. Table 4 lists all 13 wells sampled in both years, along with the nitrate concentrations detected in the wells. Five of the 13 wells had no nitrate detections either in 1992 or in 1997. Of the 13 wells, six of those that had nitrate detections in 1992 had decreases in nitrate concentrations in 1997, two to non-detectable levels, including one well which was previously above the MCL. Two wells had negligible increases in nitrate concentrations, from 0.03 to 0.16 mg/l (N) in one well, and from 0.01 to 0.07 mg/l (N) in the other well.

In 1992, two pesticides were detected in one of the 18 wells sampled in the Icelandic aquifer, or 5.5 percent of the wells; in 1997, six pesticides were detected in two of the 34 wells sampled, or 5.9 percent of the wells. About one-half of the pesticide analytes detected in the Icelandic aquifer in 1997 would not have been observed using the analyte list and detection levels of 1992.

TABLE 4
Summary of Nitrate Concentrations
in the Wells in the Icelandic Aquifer Sampled in Both 1992 and 1997
(In milligrams per liter [mg/l])

Well ID #		Type of Well	1992	1997
1.	160 056 02 ACB	Domestic	8.50	5.14
2.	161 055 14 ABC	Domestic	0.00	0.00
3.	161 055 15 CBB	Public	0.00	0.00
4.	161 055 16 DBB	Monitoring	0.00	0.00
5.	161 055 21 DBB	Public	1.20	0.21
6.	161 055 22 BCC	Public	0.01	0.00
7.	161 055 24 AAC1	Lawn Watering	105.0	90.9
8.	161 055 27 BBC	Public	0.00	0.00
9.	161 055 28 AAC	Public	0.00	0.00
10.	161 055 30 AAC	Livestock	3.06	2.37
11.	161 055 35 DBB	Domestic	0.03	0.16
12.	162 055 28 BCC	Domestic	0.01	0.07
13.	162 056 02 DAC1	Domestic	11.6	0.00

Areas of point source impact do not appear to have a widespread nonpoint impact affecting beneficial uses. Based upon the water quality information collected as part of this study, there does not appear to be a significant change in the Icelandic aquifer from 1992 to 1997.

Oakes Aquifer

Eighty-five samples were collected from 81 wells in the Oakes aquifer in 1997. The water in the Oakes aquifer is generally a calcium bicarbonate type; however, several of the water samples indicated a mixed water chemistry. The water sample from 12905935BBB was extremely high in many parameters including sodium, magnesium, potassium, chloride, sulfate, TDS, hardness and conductivity. The levels of sodium and chloride in the water may indicate leakage from a Dakota well, as Armstrong (1980, p.41) suggests for another well in the Oakes aquifer. Several other samples from the Oakes aquifer had high levels of total dissolved solids. Shaver (1988;1996), citing the large variations in hydrochemistry within an aquifer, has identified four areas in the Oakes aquifer where concentrations of TDS are less than 300 mg/l; these areas coincide with regional, land-surface topographic highs, which represent areas of recharge. Shaver (1988;1996) also has identified areas within the aquifer with marked increases in TDS concentrations, which coincide with topographic depressions and which represent groundwater discharge areas--primarily by evapotranspiration. The samples with elevated TDS concentrations collected for this study generally correlate with Shaver's groundwater discharge areas.

In general, the water from the Oakes aquifer is low in sodium, with high iron, manganese and TDS concentrations. Approximately one-fifth of the samples had sulfate concentrations above 250 mg/l. Median hardness was high at 392 mg/l $CaCo_3$.

In 1997, the Oakes aquifer had three wells with detectable levels of pesticides. In the initial sample, well 12905915CBB had detections of two pesticides, 2,4-D and pentachlorophenol. The detected concentration of 2,4-D was 0.5 μg/l, or 0.714 percent of the MCL; and of pentachlorophenol (PCP), 1.36 μg/l, or 136 percent of the MCL. The MCLs for 2,4-D and PCP are 70 and 1.0 μg/l, respectively. Neither pesticide was detected in follow-up sampling. This well is a two-inch-diameter monitoring well constructed of PVC. The well, constructed in 1983, is 17.8 feet deep with a screened interval of 15.6 to 17.8 feet, and a water level of approximately four feet below ground surface. The well was reported to be alongside a trail on a section line, and within 100 feet of a pasture, a field of irrigated row crops, and surface water consisting of a small wetland.

Well 13105909CCC had a detection of bentazon at a concentration of 1.36 μg/l, or 6.8 percent of the HAL. The HAL for bentazon is 20 μg/l. No pesticides were detected in the follow-up sample collected from the well. This well is a private domestic well located in a housing development approximately one mile from town, in which the residents have their own wells and septic systems. It is a two-inch-diameter well constructed of PVC in 1984. The well is 30 feet deep, with a screened interval of 22 to 30 feet. The water level at the time the well was constructed was about 15 feet below ground surface. There is reportedly a slight depression around the well. The well is located within 100 feet of row cropping and a septic system. Fertilizer and 2,4-D are applied to the yard as part of the normal lawn maintenance.

The third well, numbered 13105929ACC, had an initial detection of endrin aldehyde. The detected concentration was 0.03 μg/l. There is no MCL or HAL for endrin aldehyde. In follow-up confirmation resampling of the well, no pesticides were detected in the regular sample. However, MCPA was detected in a field blank sample collected along with the regular sample at the well location. The level of MCPA detected in the sample was 63.5 μg/l, or 635 percent of the HAL, set at 10 μg/l. This is over six times the minimum detection limit of 10 μg/l for MCPA, so it is unlikely that this is a false positive reading. Because of the high concentration detected and suspected QA/QC concerns, the well was sampled a third time with no pesticides being detected in the sample. As stated previously, MCPA was also detected in a sample collected in the Icelandic aquifer. The two samples were collected a day apart by the same person, were transported in the same vehicle, and were analyzed in the same laboratory batch. The well in the Oakes aquifer with the MCPA detection is a four-inch-diameter well, constructed in 1983 of PVC, and screened from 31 to 36 feet. The well is located within the city of Oakes, and is used only in the summer for watering the lawn.

Fifteen wells, about 19 percent, of the 81 wells sampled in the Oakes aquifer contained detectable concentrations of nitrate. Concentrations in four wells, or 5 percent of the total wells, were above the 10 mg/l (N) MCL. One of the wells with a pesticide detection, 13105909CCC, had a nitrate concentration of 11.8 mg/l (N). This domestic well also was sampled in 1992 with a nitrate concentration at that time of 1.9 mg/l (N). The other three wells with nitrate concentrations above the MCL were all two-inch-diameter monitoring wells constructed of PVC. Well depths ranged from 13 to 21 feet, and the water level in all three wells was less than three feet below ground surface. Two of the wells were reported as being within 100 feet of row crops and surface water, and two were reportedly within one-eighth mile of a pasture. None of the wells were near land that was being irrigated. Two of the monitoring wells with elevated levels of nitrates were also sampled in 1992. At that time, nitrate was found in both a regular and a duplicate sample from one of the wells at concentrations of 43.8 and 46.6 mg/l (N), respectively. The concentration detected in 1997 was 43.4 mg/l (N). The 1997 nitrate concentration in the other well was 21.3 mg/l (N); while in 1992 it was determined to be 31.6 mg/l (N).

Many of the wells sampled in 1992 were inaccessible in 1997 due to wet conditions. A few wells previously sampled could not be found and were presumably either abandoned or accidentally destroyed, and some wells had missing caps or had sustained damage that compromised the integrity of the well. In all, 47 of the 103 wells sampled in the Oakes aquifer in 1992 were resampled in 1997. Figure 4 compares the percentages of nitrate detections in the Oakes aquifer for the years 1992 and 1997. The first two columns depict the percentages of wells with nitrate detections for all wells sampled for those years; the last two columns are a direct comparison of the 47 wells sampled in both years. In 1992, 19 wells, or about 18 percent of the 103 wells sampled in the Oakes aquifer, contained detectable levels of nitrates. Three wells, about 3 percent, had nitrate concentrations greater than the MCL; two of the three wells also were sampled in 1997 and are discussed above.

As shown in Figure 4, the overall percentage of wells with nitrate detections did not change significantly, whether comparing total wells sampled in the two years, or comparing just the 47 wells sampled both years. However, when comparing the 47 wells, the percentage of wells with intermediate nitrate concentrations decreased in 1997, along with a corresponding increase in wells with low and high concentrations. Table 5 lists all 47 wells sampled in both years, along with the nitrate concentrations detected in the wells. Thirty-seven of the 47 wells had no initial detections of nitrates in 1992; 35 of the 37 wells also had no detections in 1997. Nitrates were detected in the other two wells, although at concentrations less than 2.0 mg/l (N). Of the 10 wells that had nitrate detections in 1992, seven had decreased nitrate concentrations in 1997, one well to levels below the detection limit; concentrations increased in the other three wells, two to levels above the MCL.

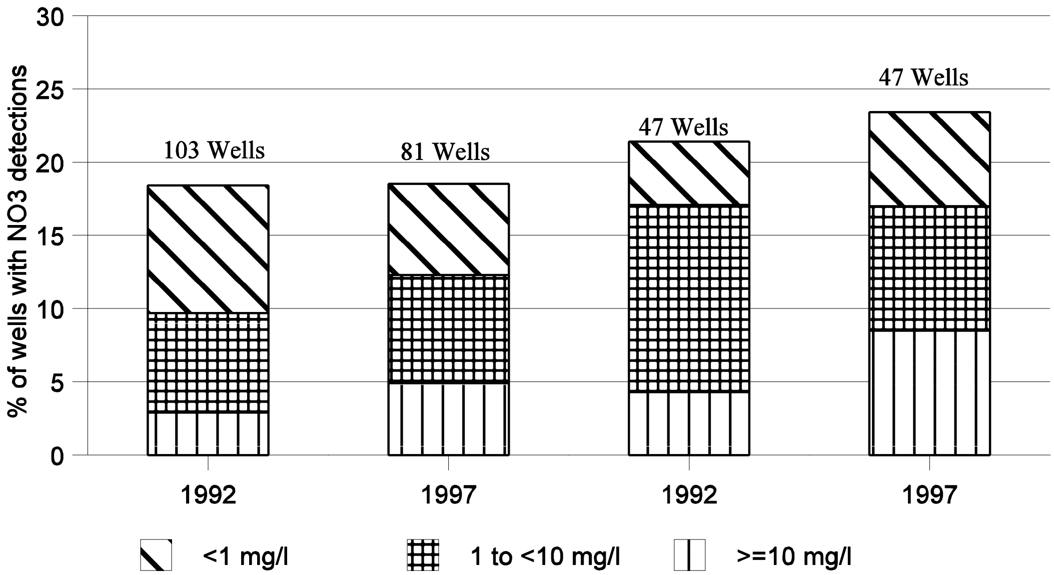


FIGURE 4. Graph of nitrate detections in the Oakes aquifer for the years 1992 and 1997

In 1992, two pesticides were detected in one well in the Oakes aquifer; this represents less than 1 percent of the total wells sampled in the aquifer that year. The well with the initial pesticide detection in 1992 could not be accessed for sampling in 1997. In 1997, five pesticides were detected in three wells sampled in the Oakes aquifer (approximately 4 percent). Due to changes in the program from 1992 to 1997, which included an increase in the number of analytical parameters and a decrease in method detection limits, it is possible that many of the pesticides detected in 1997 would not have been observed in 1992.

TABLE 5
Summary of Nitrate Concentrations
in the Wells in the Oakes Aquifer Sampled in Both 1992 and in 1997
(In milligrams per liter [mg/l])

Well ID #		Type of Well	1992	1997
1.	129 058 07 CCC	Monitoring	0.00	0.00
2.	129 058 08 BBB	Monitoring	0.00	0.00
3.	129 059 08 ABB	Monitoring	0.00	0.00
4.	129 059 10 BAA	Monitoring	0.00	0.09
5.	129 059 12 AAB3	Monitoring	1.79	1.21
6.	129 059 14 BBB	Monitoring	0.00	0.00
7.	129 059 15 CBB	Monitoring	0.00	0.00
8.	129 059 19 CDD	Monitoring	0.00	0.00
9.	129 059 21 CBB	Monitoring	0.00	1.62
10.	129 059 26 DDD	Monitoring	0.00	0.00
11.	129 059 29 DDD2	Monitoring	43.8	43.4
12.	129 059 31 DCC	Monitoring	31.6	21.3
13.	129 059 35 BBB	Monitoring	0.40	0.28
14.	129 060 01 DDD	Monitoring	0.00	0.00
15.	129 060 36 DAA	Monitoring	0.00	0.00
16.	130 058 08 CDD2	Monitoring	0.00	0.00
17.	130 058 17 BCC2	Monitoring	0.00	0.00
18.	130 058 19 ADD	Monitoring	0.00	0.00
19.	130 058 20 CCC2	Monitoring	0.00	0.00
20.	130 058 21 BBA	Monitoring	0.00	0.00
21.	130 058 29 CDC3	Monitoring	3.08	12.5
22.	130 059 04 CAA	Monitoring	0.00	0.00
23.	130 059 05 DBB	Monitoring	0.00	0.00
24.	130 059 09 ACC2	Monitoring	0.00	0.00
25.	130 059 10 DBB	Monitoring	0.00	0.00

TABLE 5 (continued)
Summary of Nitrate Concentrations
in the Wells in the Oakes Aquifer Sampled in Both 1992 and 1997
(In milligrams per liter [mg/l])

Well ID #		Type of Well	1992	1997
26.	130 059 15 CAA	Monitoring	0.00	0.00
27.	130 059 16 CAA1	Monitoring	0.00	0.00
28.	130 059 20 ADD	Monitoring	3.98	1.92
29.	130 059 21 DDD2	Monitoring	0.00	0.00
30.	130 059 22 CAA	Monitoring	0.00	0.00
31.	130 059 25 CBB	Monitoring	0.00	0.00
32.	130 059 28 DBB1	Monitoring	0.00	0.00
33.	130 059 29 ACC2	Monitoring	0.00	0.00
34.	130 059 30 DCC	Monitoring	0.00	0.00
35.	130 059 33 DAA	Monitoring	0.00	0.00
36.	130 059 35 ABB	Monitoring	0.00	0.00
37.	131 058 31 DBB	Domestic	0.00	0.00
38.	131 059 09 CCC	Domestic	1.90	11.8
39.	131 059 20 AAD	Monitoring	3.79	0.14
40.	131 059 24 CDC	Domestic	0.00	0.00
41.	131 059 27 BDD	Monitoring	0.00	0.00
42.	131 059 28 CBB2	Domestic	0.00	0.00
43.	131 059 29 ACC	Domestic	6.05	7.28
44.	131 059 33 DBB	Monitoring	0.14	0.00
45.	131 059 34 DAA	Monitoring	0.00	0.00
46.	131 059 35 DCC	Monitoring	0.00	0.00
47.	131 059 36 BBB2	Domestic	0.00	0.00

Warwick Aquifer

Thirty-four samples were collected from 32 wells in the Warwick aquifer in 1997. The water in the Warwick aquifer is a calcium bicarbonate type. It is low in sodium, sulfate, chloride and TDS, and high in iron and manganese. The median hardness was 274 mg/l, as $CaCo_3$.

Pesticides were detected in samples from two wells in the Warwick aquifer. Well 15006310CDD contained picloram at a concentration of 0.65 μg/l in the initial sample collected, and 1.3 μg/l in the follow-up sample. These concentrations represent 0.13 and 0.26 percent of the MCL, respectively. This well is a two-inch-diameter monitoring well installed by the NDDH approximately one month prior to sampling. Installed to provide better coverage of the aquifer for the monitoring program, the well is constructed of PVC, with a well depth of 28 feet and a screened interval of 18 to 28 feet. The depth to water in the well was about 21 feet below ground surface. The well is located on CRP or hayland and within 100 feet of a pasture.

Picloram was also detected in well 15106335CCC at an initial concentration of 3.11 μg/l, and at 4.04 μg/l in the follow-up sample, or 0.622 and 0.808 percent of the MCL, respectively. This well is also a monitoring well, 1.25 inches in diameter, with a well depth of 24 feet and screened at 19 to 24 feet. The water level in the well was about seven feet below ground surface. The primary setting of the well is in a pasture; the well also is located near CRP land.

Seventeen wells, or 53 percent of the total wells sampled in the Warwick aquifer, contained detectable nitrate concentrations. Six of the wells, about 19 percent, had concentrations greater than or equal to the MCL of 10 mg/l (N). All six wells with elevated nitrate concentrations were two-inch-diameter, PVC monitoring wells. Well depths in the six wells ranged from 14 to 36 feet; water levels were from approximately six to 25 feet below ground surface. Two of the wells are a nested pair (15106216BCC1 and 15106216BCC2), 30 and 36 feet deep, respectively, located in a field of small grains and within 100 feet to one-eighth mile of irrigation. These wells were installed in the fall of 1992 for the Low Energy Precision Application (LEPA) irrigation monitoring project conducted by the NDDoH between 1993 and 1996. Nitrate concentrations in the shallower well during the project period ranged from 3.02 to 31.1 mg/l (N), and in the deeper well from 1.14 to 28 mg/l (N). The nitrate concentrations measured in the wells in 1997 were 31.6 and 25.5 mg/l (N), respectively.

Three of the other wells with nitrate concentrations above the MCL also were installed for the LEPA project. The depths of the wells were 14, 15.5, and 33 feet below ground level. All three wells were located in fields of small grains. In addition, one was near CRP land, and another was near hayland. Between 1993 and 1996, nitrate concentrations in the 14-foot well, 15106216ADA1, ranged from below the detection limit to 32 mg/l (N). The concentration detected in the well in 1997 was 13.5 mg/l (N). Between 1993 and 1996, the nitrate concentration in the 15.5-foot well, 15106325ABA1, ranged from 1 to 45.7 mg/l (N); in 1997 the concentration was 24.2 mg/l (N). In the 33-foot well, 15106217ADA1, the concentrations detected between 1993 and 1996 ranged from 4.08 to 51 mg/l (N). The concentration detected in 1997 was 30.9 mg/l (N).

The sixth well with a nitrate detection above the MCL was a flush-mount well located in a road ditch alongside a field of beans. The well was also near CRP, a pasture and a grain field that was being irrigated at the time of sampling. It is questionable whether this well would meet today's well-construction requirements. The surface construction of the well is a concrete ground surface seal approximately 18 inches across. The casing is centered in the concrete, with the top of the casing approximately even with the top of the concrete, at which point the cover screws directly into the top of the casing. The well is constructed of PVC. The well is 23 feet below ground surface, with a screened interval of 18 to 23 feet. The water level was approximately 12 feet below the ground. The nitrate concentration in the well was 25 mg/l (N).

Two wells with pesticide detections were identified in the Warwick aquifer in 1997, compared to one well with a pesticide detection in 1992. However, because there were almost twice as many wells sampled in 1997, the percentage of wells with pesticide detections remained relatively the same. Picloram was also the pesticide detected in the Warwick aquifer in 1992.

Figure 5 compares percentages of wells with nitrate concentrations in the Warwick aquifer for the years 1992 and 1997. In 1992, seven wells, or 44 percent of the wells sampled in the Warwick aquifer, contained nitrate concentrations. Samples from three wells, or 19 percent, contained nitrate concentrations in excess of the 10 mg/l (N) MCL. In all, 13 of the 16 wells initially sampled in the Warwick aquifer in 1992 were resampled in 1997. As shown in Figure 5, the overall percentage of wells with nitrate detections increased from 1992 to 1997. The most notable change was an increase in the percentage of wells with intermediate nitrate detections. This also is noted, along with an accompanying decrease in low concentration detections, when comparing just the 13 wells sampled in both years. Table 6 lists all 13 wells sampled in both years, along with the nitrate concentrations detected in the wells. Six of the 13 wells did not have any nitrate detections in 1992; five of the six wells had no nitrate detections in 1997. Nitrate was detected in the sixth well at 1.0 mg/l (N). All seven wells with nitrate detections in 1992 were resampled in 1997. Concentrations increased in four of the wells, including the three wells discussed previously--15106216ADA1, 15106217ADA1 and 15106325ABA1--although the only apparent increase of significance was in the latter well. Concentrations decreased in the remaining three wells, one to non-detectable levels.

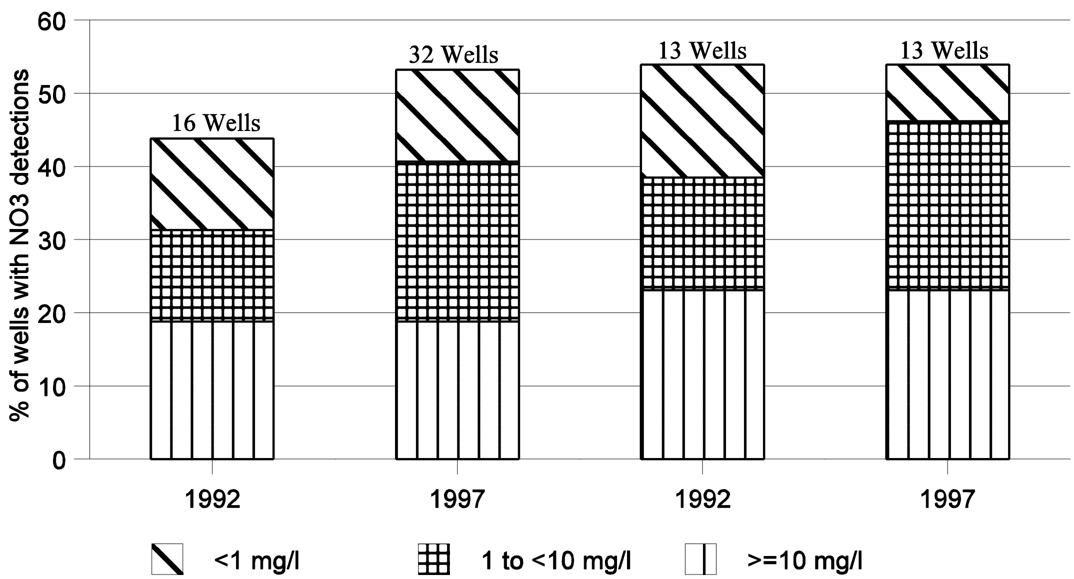


FIGURE 5. Graph of nitrate detections in the Warwick aquifer for the years 1992 and 1997

TABLE 6
Summary of Nitrate Concentrations
in the Wells in the Warwick Aquifer Sampled in Both 1992 and 1997
(In milligrams per liter [mg/l])

Well ID #		Type of Well	1992	1997
1.	150 062 03 ABC	Domestic	0.00	1.00
2.	150 062 06 DAA	Monitoring	0.77	0.00
3.	150 062 07 DAA	Monitoring	0.00	0.00
4.	150 062 10 DBC	Monitoring	0.00	0.00
5.	150 063 06 DDD	Livestock	0.28	0.05
6.	151 062 15 CCC	Monitoring	6.70	1.23
7.	151 062 16 ADA1	Monitoring	13.2	13.5
8.	151 062 17 ADA1	Monitoring	29.1	30.9
9.	151 062 23 ABB3	Monitoring	0.00	0.00
10.	151 062 24 CCC3	Monitoring	0.00	0.00
11.	151 063 17 ABC	Domestic	0.00	0.00
12.	151 063 22 BDA	Domestic	2.44	2.94
13.	151 063 25 ABA1	Monitoring	10.0	24.2

Spring Creek Aquifer

Only four wells were sampled in the Spring Creek aquifer. The water is a calcium bicarbonate type, high in iron and manganese, and relatively low in sodium. Two of the samples were above the recommended levels for sulfates and total dissolved solids. Median hardness is high at 430 mg/l as $CaCo_3$.

There were no pesticide or nitrate detections in the samples from the Spring Creek aquifer.

Streeter Aquifer

Samples were collected from 28 wells in the Streeter Aquifer. The dominant cation is calcium and the dominant anion is bicarbonate. The water is high in iron and manganese, but within the recommended limits for sulfate and TDS. Median hardness was 291 mg/l as $CaCo_3$.

No pesticides were detected in the samples from the Streeter aquifer.

Samples from 11 wells contained detectable levels of nitrate. Samples from two wells were above the MCL of 10 mg/l (N). Both wells are large-diameter (24-inch) wells constructed of masonry casing and are located in farmyards and within 100 feet of a feedlot. Well 13506909CCC is used for domestic purposes and watering livestock. The depth of the well is 33 feet below ground surface. The water level reported in the well at the time of installation was approximately 15 feet. The well is located near a septic system, a grain field and hayland. The concentration of nitrate in this well was 15.8 mg/l (N). The second well, 13607004BDB, is used for watering livestock and is near a pasture and CRP acres. This well is 24 feet deep, with a screened interval of 17 to 24 feet. The nitrate concentration in this well was 43.4 mg/l (N).

Well Construction / Water Quality Relationships

Relationships between pesticide and nitrate detections and most well characteristics are difficult to define from these sample results. This is especially true for pesticides because of the very low overall percentage of detections in relation to the total sample population. When trying to relate well-construction characteristics to a small subset population of detections, percentages change rapidly and confidence levels are low. See Table 7 for a summary of statistics on well construction related to pesticide and nitrate plus nitrite detections in this survey. Appendix D contains these summary statistics for each aquifer.

In general, the depth of the well, the depth to the top of the screened interval, and the distance from the water table to the top of the screen seemed to show a relationship to pesticide and nitrate detections. The percentage of pesticide and nitrate detections was greatest in wells that were less than 20 feet deep, in wells in which the top of the screened interval was less than 20

TABLE 7
Pesticide and Nitrate Plus Nitrite Detections Related to Well Construction
For All Aquifers Sampled in 1997

NUMBER OF DETECTIONS		#	PERCENT
Wells with only pesticide detections	:	1	0.6 %
Wells with only nitrate detections	:	51	28.5 %
Wells with pesticide & nitrate detections	:	6	3.4 %
Wells with nitrate > 10 mg/L	:	13	7.3 %

Total number of wells in sample population : 179

AQUIFER	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
ICELANDIC :	34	19.0	2	5.9	14	41.2
OAKES :	81	45.3	3	3.7	15	18.5
SPRING CREEK :	4	2.2	0	0.0	0	0.0
STREETER :	28	15.6	0	0.0	11	39.3
WARWICK :	32	17.9	2	6.3	17	53.1

DEPTH OF WELLS	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
< 20 Ft. :	50	27.9	3	6.0	22	44.0
20 - 50 Ft. :	98	54.7	4	4.1	31	31.6
> 50 Ft. :	30	16.8	0	0.0	3	10.0
Unknown :	1	0.6	0	0.0	1	100.0

DIAMETER OF WELL	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
< 6 in. :	161	89.9	6	3.7	47	29.2
6 - 18 in. :	7	3.9	0	0.0	2	28.6
> 18 in. :	9	5.0	1	11.1	6	66.7
Unknown :	2	1.1	0	0.0	2	100.0

is the number of wells or detections in that category.
% is the percentage of wells or detections in that category.

CASING MATERIAL	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
Plastic(PVC or ABS) :	149	83.2	4	2.7	40	26.8
Concrete/Brick/Stone :	13	7.3	2	15.4	10	76.9
Metallic :	11	6.1	0	0.0	4	36.4
Other :	6	3.4	1	16.7	3	50.0

DEPTH TO TOP OF SCREENED INTERVAL	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
< 20 Ft. :	85	47.5	5	5.9	34	40.0
20 - 50 Ft. :	62	34.6	2	3.2	16	25.8
> 50 Ft. :	20	11.2	0	0.0	1	5.0
Unknown :	12	6.7	0	0.0	6	50.0

DISTANCE FROM WATER TABLE TO TOP OF SCREEN	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
< 10 Ft. :	44	24.6	1	2.3	27	61.4
10 - 30 Ft. :	79	44.1	2	2.5	15	19.0
> 30 Ft. :	29	16.2	0	0.0	1	3.4
Unknown :	27	15.1	4	14.8	14	51.9

TYPE OF WELL	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
Monitoring :	146	81.6	3	2.1	39	26.7
Private/Domestic :	23	12.8	2	8.7	12	52.2
Livestock :	4	2.2	1	25.0	4	100.0
Public Supply :	5	2.8	0	0.0	1	20.0
Irrigation :	1	0.6	1	100.0	1	100.0
Other :	0	0.0	0	*****	0	*****

feet deep, and in wells in which the water table was less than 10 feet from the top of the screen. The percentage of pesticide and nitrate detections generally decreased as well-depth increased, as depth to the top of the screened interval increased, and as the distance from the water table to the top of the screen increased.

The nitrate detections for 1992 are generally consistent with the above findings. There were only three pesticide detections that year; therefore, it was impossible to determine relationships between pesticide detections and well-construction characteristics.
More detailed relationships between well characteristics and nitrate are generally easier to define because of the much higher percentage of nitrate detections. However, the 1997 nitrate

detections do not appear to show the clear relationships to well construction as in some previous years. The relationship between the intervals of nitrate concentrations and various well characteristics is shown graphically in Figures 6 through 9. The number of wells sampled in each category is shown at the top of the columns in the graphs.

Figure 6 depicts the percentage of nitrate detections versus well depth for various detection concentration intervals. The highest overall percentage of nitrate detections occurred in wells less than 20 feet deep. In general, the percentage of nitrate detections for all concentration intervals increased with decreasing well depth, except for the greater than 10.0 mg/l (N) interval, a slightly greater percentage of which was in wells 20 to 50 feet deep. This may be partly due to the fact that almost twice as many wells were sampled in the intermediate depth category than in the shallow depth category.

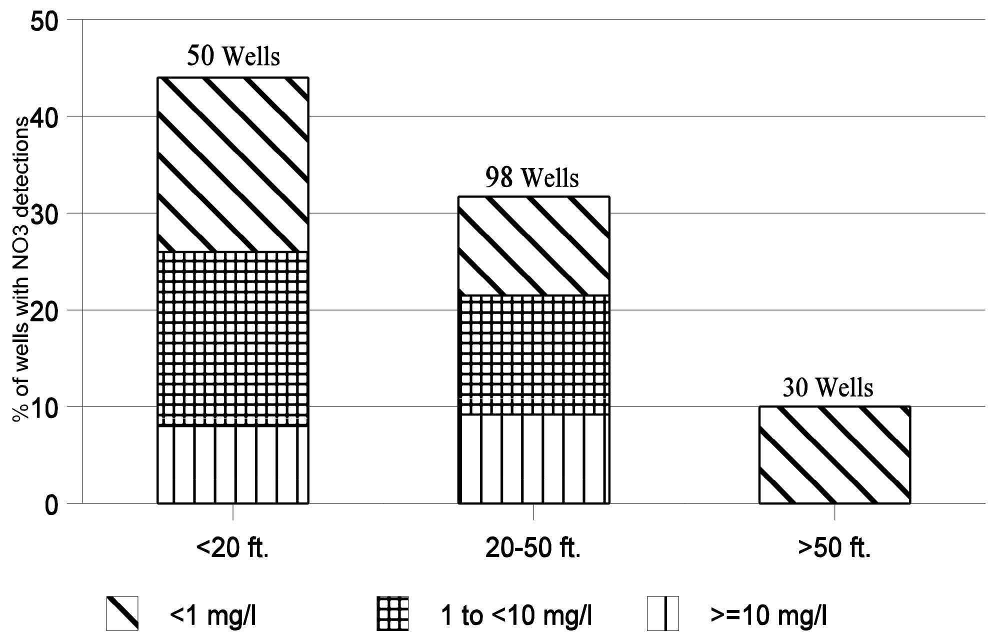


FIGURE 6. Graph of nitrate detections vs. well depth

Figure 7 depicts the percentage of nitrate detections versus well casing material for various concentration intervals. Masonry-cased wells had the highest overall percentage of nitrate detections in this survey, as well as the highest percentages of low concentration and high concentration detections. The greatest percentages of the intermediate concentrations were most often detected in metallic-cased wells; however, there were no nitrate detections at or above 10 mg/l (N) in these wells. It should be noted that the overwhelming majority of wells sampled were plastic-cased; therefore, comparisons of percentages are less precise than desired.

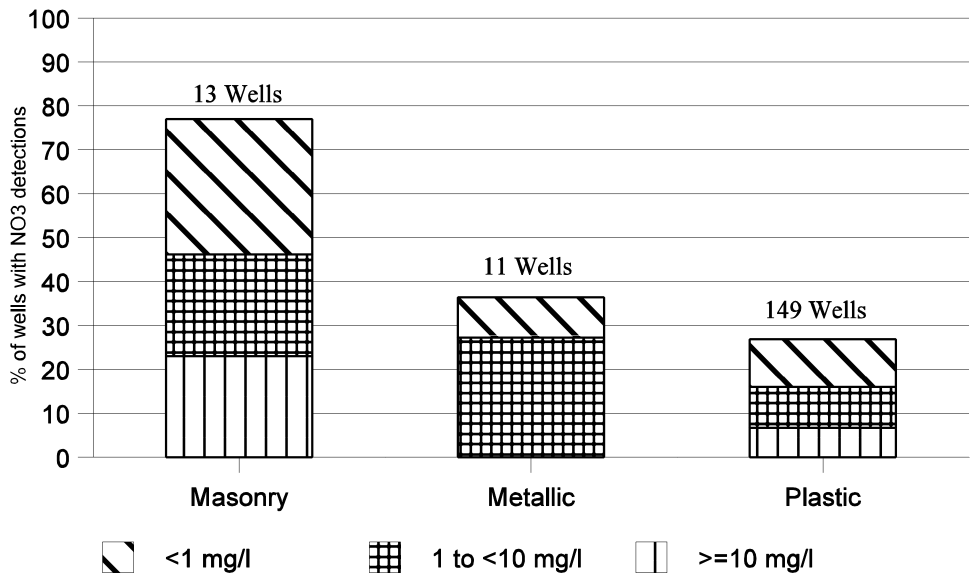


FIGURE 7. Graph of nitrate detections vs. casing material

There was also an apparent correlation between nitrate detections and well diameter, as depicted in Figure 8; however, this relationship did not follow through for all concentration intervals. Again, it should be noted that the overwhelming majority of wells sampled fall into one category: less than six inches in diameter. Wells greater than 18 inches in diameter had the highest overall percentage of nitrate plus nitrite detections, as well as the highest percentages of detections less than 1.0 mg/l (N) and greater than 10.0 mg/l (N).

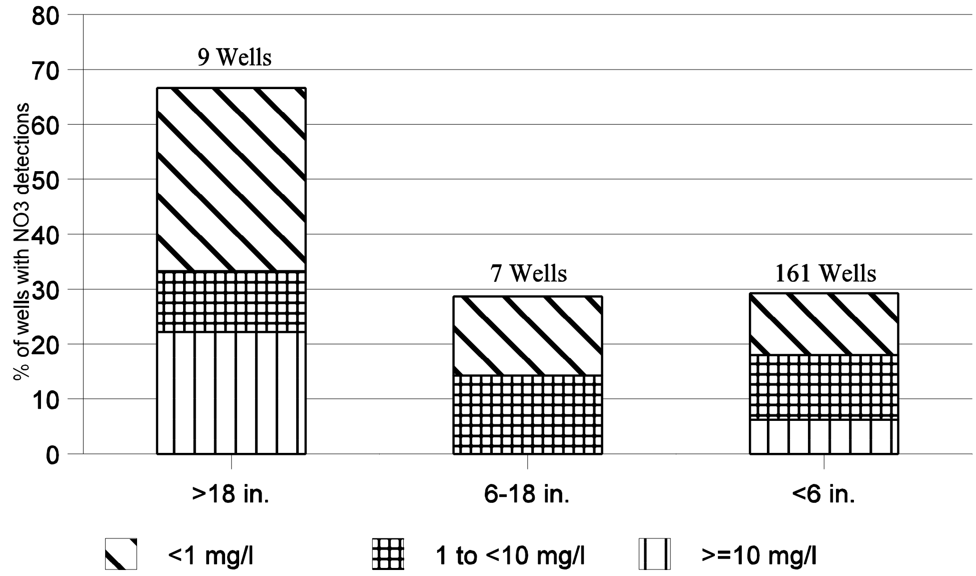


FIGURE 8. Graph of nitrate detections vs. well diameter

Figure 9 depicts the percentage of nitrate detections versus well type for various concentration intervals. Livestock, irrigation and public supply wells are not depicted on the graph because very few of these wells were sampled. Private/domestic wells had the highest overall percentage of nitrate detections, as well as the highest percentages for all concentration intervals.

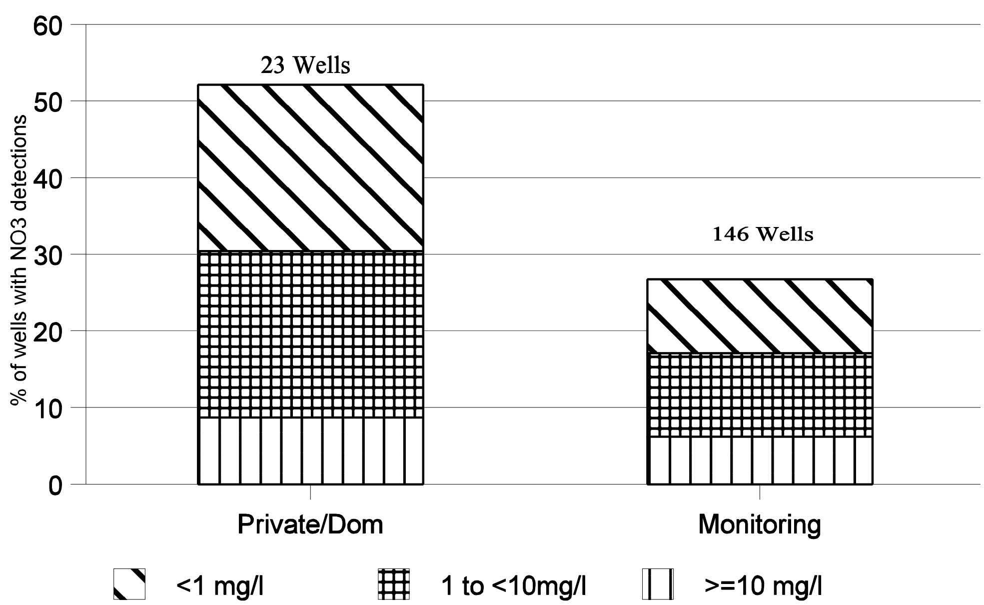


FIGURE 9. Graph of nitrate detections vs. type of well

Low concentration detections of nitrate correspond less closely to the various well construction factors than higher concentrations. Higher concentration detections are more likely to result from point sources of pollution, rather than non-point sources, which may explain the relationship between high nitrate concentration detections and well construction. Detections resulting from non-point sources likely may occur regardless of well construction characteristics because of the widespread nature of non-point nitrate contamination. This study, however, did not identify whether any individual detection is caused by point or non-point sources.

Site Inventory Data / Water Quality Relationships

Based on the information collected as part of this survey, it is difficult to relate pesticide detections to well construction characteristics or land use. The total number of pesticide detections is too low to arrive at relationships with any degree of confidence. It also was attempted to relate the distance from the well of certain site characteristics to pesticide and nitrate detections. This was also largely inconclusive because of the small number of detections related to each site characteristic. Refer to Table 8 for a summary of statistics on pesticide and nitrate detections related to site-inventory characteristics. Appendix D contains these summary statistics for each aquifer.

TABLE 8
Pesticide and Nitrate Plus Nitrite Detections Related to Site Inventory Data
For All Aquifers Sampled in 1997

NUMBER OF DETECTIONS		#	PERCENT
Wells with only pesticide detections	:	1	0.6 %
Wells with only nitrate detections	:	51	28.5 %
Wells with pesticide & nitrate detections	:	6	3.4 %
Wells with nitrate > 10 mg/L	:	13	7.3 %

Total number of wells in sample population : 179

AQUIFER	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
ICELANDIC :	34	19.0	2	5.9	14	41.2
OAKES :	81	45.3	3	3.7	15	18.5
SPRING CREEK :	4	2.2	0	0.0	0	0.0
STREETER :	28	15.6	0	0.0	11	39.3
WARWICK :	32	17.9	2	6.3	17	53.1

GENERAL SETTING	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
Farm Yard :	29	16.2	2	6.9	15	51.7
Field :	89	49.7	1	1.1	23	25.8
Pasture :	43	24.0	2	4.7	16	37.2
C.R.P. :	39	21.8	1	2.6	9	23.1
Roadside :	71	39.7	2	2.8	22	31.0
Town :	3	1.7	1	33.3	2	66.7

NEARBY FACTORS OF POSSIBLE INFLUENCE	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
Near Irrigation :	49	27.4	1	2.0	12	24.5
Near Feed Lot :	26	14.5	1	3.8	14	53.8
Near Disposal Area :	1	0.6	0	0.0	1	100.0
Near Septic System :	38	21.2	3	7.9	17	44.7
Near Surface Water :	65	36.3	1	1.5	18	27.7
Well in Depression :	0	0.0	0	*****	0	*****
Near Chemical Usage :	26	14.5	5	19.2	17	65.4
Other :	6	3.4	0	0.0	0	0.0

NEAR IRRIGATION	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	19	10.6	1	5.3	5	26.3
100 ft. - 1/8 mile :	30	16.8	0	0.0	7	23.3

NEAR A FEED LOT	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	16	8.9	1	6.3	10	62.5
100 ft. - 1/8 mile :	10	5.6	0	0.0	4	40.0

NEAR DISPOSAL AREA	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	0	0.0	0	*****	0	*****
100 ft. - 1/8 mile :	1	0.6	0	0.0	1	100.0

NEAR SEPTIC SYSTEM	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	22	12.3	2	9.1	13	59.1
100 ft. - 1/8 mile :	16	8.9	1	6.3	4	25.0

NEAR SURFACE WATER	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	35	19.6	1	2.9	4	11.4
100 ft. - 1/8 mile :	30	16.8	0	0.0	14	46.7

DEPRESSION AROUND WELL	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
Yes :	0	0.0	0	*****	0	*****
No :	179	100.0	7	3.9	57	31.8
Unknown :	0	0.0	0	*****	0	*****

NEAR CHEMICAL USAGE, MIXING, OR STORAGE	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
Pesticides :	9	5.0	3	33.3	6	66.7
Fertilizer :	6	3.4	1	16.7	4	66.7
Petroleum :	8	4.5	0	0.0	6	75.0
Other :	3	1.7	1	33.3	1	33.3

NEAR PESTICIDE USAGE, MIXING, OR STORAGE	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	6	3.4	3	50.0	4	66.7
100 ft. - 1/8 mile :	3	1.7	0	0.0	2	66.7

NEAR FERTILIZER USAGE, MIXING, OR STORAGE	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	2	1.1	1	50.0	1	50.0
100 ft. - 1/8 mile :	4	2.2	0	0.0	3	75.0

NEAR PETROLEUM STORAGE	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	5	2.8	0	0.0	3	60.0
100 ft. - 1/8 mile :	3	1.7	0	0.0	3	100.0

CROPS CLOSE TO WELL	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
Small Grains :	77	43.0	1	1.3	30	39.0
Row Crops :	77	43.0	2	2.6	25	32.5
Hay :	31	17.3	0	0.0	12	38.7
Pasture :	84	46.9	4	4.8	32	38.1
C.R.P. :	63	35.2	5	7.9	20	31.7

TABLE 8 (continued)
Pesticide and Nitrate Plus Nitrite Detections
Related to Site Inventory Data
For All Aquifers Sampled in 1997

NEAR SMALL GRAIN CROPS	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	50	27.9	1	2.0	17	34.0
100 ft. - 1/8 mile :	27	15.1	0	0.0	13	48.1

NEAR ROW CROPS	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	44	24.6	2	4.5	17	38.6
100 ft. - 1/8 mile :	33	18.4	0	0.0	8	24.2

NEAR HAY CROPS	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	16	8.9	0	0.0	3	18.8
100 ft. - 1/8 mile :	15	8.4	0	0.0	9	60.0

NEAR PASTURE	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	58	32.4	4	6.9	22	37.9
100 ft. - 1/8 mile :	26	14.5	0	0.0	10	38.5

NEAR C.R.P.	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	49	27.4	2	4.1	11	22.4
100 ft. - 1/8 mile :	14	7.8	3	21.4	9	64.3

is the number of wells or detections in that category.
% is the percentage of wells or detections in that category.

Because of the greater number of nitrate detections compared to pesticide detections, however, it was possible to relate nitrate detections to site-inventory data, as depicted in Figures 10 through 12. Figure 10 depicts the percentage of nitrate plus nitrite detections versus general setting at various nitrate concentrations. The general setting of a well located in a farmyard had the greatest percentage of nitrate detections at 52 percent. Farmyards also had the highest percentages of wells with nitrate detections less than 1.0 mg/l (N), and those exceeding the nitrate MCL of 10 mg/l (N). Often the sites had characteristics of more than one type of general setting; for example, a well located on the boundary of a farmyard and a pasture, adjacent to a road ditch. In 1995, an additional general setting data field was added to the inventory form and to the database to help account for wells with characteristics of more than one setting.

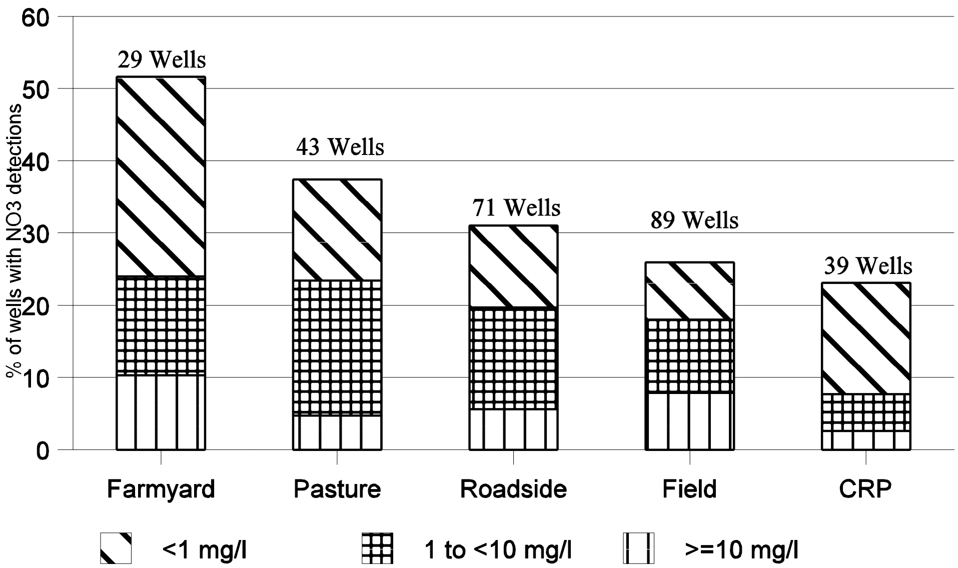


FIGURE 10. Graph of nitrate detections vs. general setting

An attempt was made to relate various factors of land use and their distance from the well to greater percentages of pesticide and nitrate detections. Shorter distance from the well did seem to correspond to greater percentages of pesticide and nitrate detections to chemical usage, mixing or storage areas; and greater percentages of nitrate detections to feedlots and septic systems. As depicted in Figure 11, close proximity to areas of chemical usage was associated with the greatest overall percentage of nitrate detections at 65 percent, and with the greatest percentage of wells exceeding the 10 mg/l (N) nitrate MCL, at 27 percent. Landowners around monitoring wells generally were not interviewed; therefore, numbers relating to verified chemical or fertilizer usage, mixing and storage are greatly understated. In addition, landowners that were interviewed rarely indicated chemical or fertilizer usage, mixing or storage in areas surrounding privately-owned domestic, stock or irrigation wells, although it could be assumed that these activities probably have occurred more often than was reported.

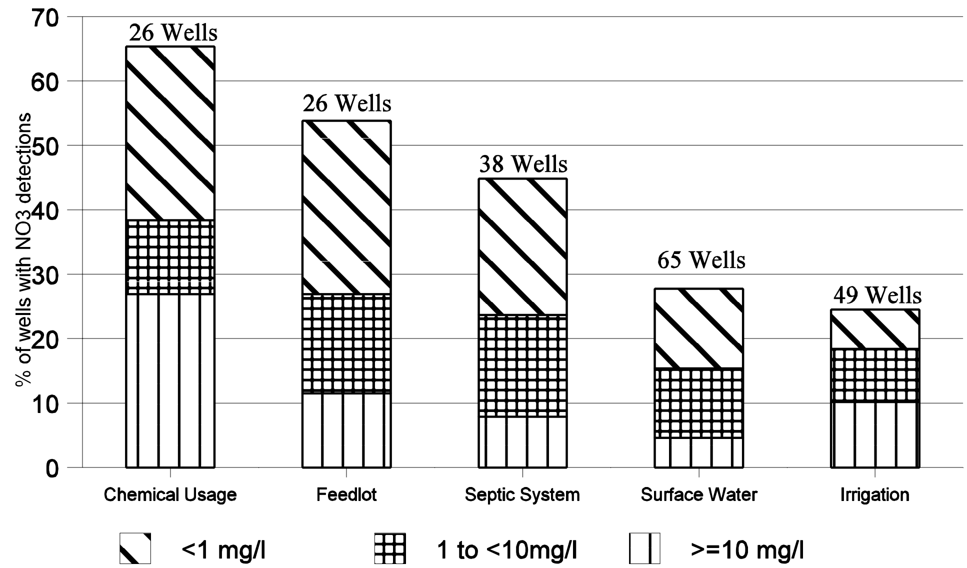


FIGURE 11. Graph of nitrate detections vs. other factors of possible influence within one-eighth mile of the well

As depicted in Figure 12, there were not great differences in overall percentages of nitrate detections for the various crop types, nor in the percentages of the concentration intervals from one crop to another. Distances from specific crop types to the well did not seem to relate well with greater percentages of pesticide or nitrate detections, except for row crops (Table 8).

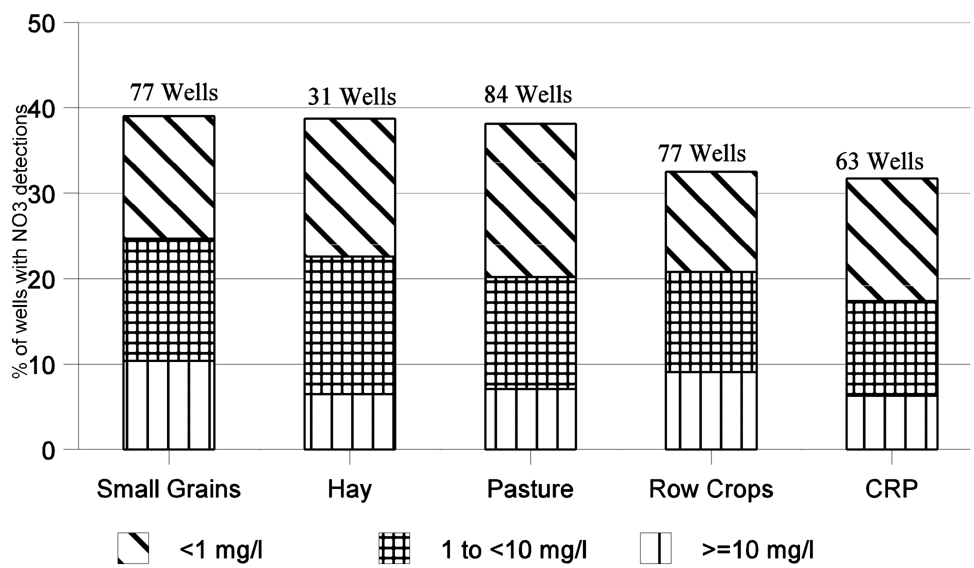


FIGURE 12. Graph of nitrate detections vs. crop type

It must be stated that the relationship of two variables, in this case the occurrence of greater percentages of nitrate detections related to various well-construction or site-inventory factors, does not necessarily imply a cause and effect relationship. None of the well-construction and site-inventory factors are necessarily independent, and some may have a cumulative effect on water quality. Within this study there is not enough specific data to determine all of the interrelationships of the factors. There are also factors that are inadequately accounted for, or not accounted for at all, such as chemical usage and precipitation. A higher percentage of nitrate detections for any one factor indicates only that there is a somewhat higher possibility of that factor having an influence on water quality in this sample population. It should be noted that statistical analysis and comparison of the various factors performed on the sample set as a whole and on each of several subset populations for the first five-year monitoring cycle, 1992-1996, determined that many of the nitrate-detection relationships remain when looking at larger groups of wells.

SUMMARY AND CONCLUSIONS

One hundred seventy-nine wells from five glacial drift aquifers were sampled for general anion and cation chemistry, nitrate plus nitrite, and 60 selected pesticides. A total of seven wells, or 4 percent of the wells sampled, contained detectable concentrations of pesticides in at least one of the sampling periods. Ten pesticide species were positively identified by laboratory analysis: bentazon; 2,4-D; 3,5 dichlorobenzoic acid; endrin; endrin aldehyde; endrin ketone; heptachlor epoxide; MCPA; pentachlorophenol; and picloram. Picloram was the most commonly detected pesticide.

Most concentrations of the detected pesticides were far below their respective MCLs; however, two pesticides, pentachlorophenol and MCPA, were detected at concentrations above their respective MCL or HAL. Pentachlorophenol was detected in an initial sample collected from a well at a concentration 136 percent of the MCL; it was not detected in follow-up sampling. MCPA was detected in two unrelated samples, one a regular sample, the other a field blank sample--at concentrations 1,380 percent and 635 percent of the HAL, respectively. Both samples were follow-up samples collected to confirm previous detections of other pesticides in the two wells. When the wells were sampled a third time, MCPA was not detected in either sample. This is the first time MCPA has been detected in any samples collected for the monitoring program. Based upon past monitoring results, its detection in two unrelated samples--one of which is a field blank sample--at such high concentrations is indicative of a point source of contamination, or laboratory or sampling error. The two samples were collected in different aquifers a day apart; however, they were collected during the same sample run, by the same person, transported in the same vehicle (and possibly in the same cooler), and analyzed in the same batch. All concentrations of picloram, which is the pesticide found most frequently and most often confirmed in follow-up sampling, were less than 1 percent of the MCL. Other pesticide concentrations detected ranged from 0.714 percent to 8.5 percent of the MCL or HAL.

Nitrate was found above the 0.05 mg/l (N) minimum detection limit in 57 wells, or 32 percent of the wells sampled. The concentration of nitrate was above the 10 mg/l (N) MCL in 13 wells, or 7 percent of the total wells sampled. Of the wells with nitrate detections, almost 40 percent were between 0.05 and 1.0 mg/l (N). The majority of nitrate detections appear to be associated with point sources of contamination, although several detections seem to be associated with nonpoint source activities or could not be identified as either point or nonpoint source. In general, the higher concentrations of nitrate were associated with point sources. Shallow depth of the well, masonry casing, large-diameter wells, and proximity to areas of chemical usage, feedlots and septic systems are the factors with the highest percentages of nitrate detections.

In 1997, the Icelandic, Oakes and Warwick aquifers underwent their first five-year resampling since 1992. An attempt was made to resample the same wells; however, this was not always possible. In some cases the well was no longer in existence or had been damaged so that the integrity of the well was in question, and many of the wells originally sampled could not be reached because of wet conditions. In 1997, seven wells, or about 4 percent of the 179 total wells sampled, had pesticide detections. All wells with pesticide detections in 1997 were in the three aquifers originally sampled in 1992: the Icelandic, Oakes and Warwick aquifers. If the preceding figures are adjusted to include only the original three aquifers, 5 percent of the 147 wells sampled in the three aquifers had pesticide detections.

Based on a change in the number of analytes and their method detection limits, a direct correlation of pesticide detections may be misleading. Using the detection limits of 1992, detections in three of the above wells would not have been observed. In addition, the list of pesticide analytes has increased from the initial list of 44 pesticides to 60 pesticides. Six of the pesticides or pesticide degradation products detected in 1997 were not even analyzed for in 1992. Allowing for this, two additional wells which had pesticide detections in 1997 would not have had pesticide detections in 1992. Therefore, it is possible that the pesticide detections in only two of the seven wells, or less than 2 percent, would have been observed in 1992.

Based upon the data collected, pesticide contamination of groundwater in the Icelandic, Oakes, Warwick, Spring Creek and Streeter aquifers is minor in extent and severity. Resampling of wells shows that the occurrence of pesticides in this study, even in the same well, is highly variable and often of short duration. Nitrate contamination in these aquifers appears to be similar to that encountered in aquifers monitored previously; however, nitrate concentrations in specific individual wells have the potential to cause adverse health impacts to those well users.

Because of the apparent relationship between contaminant detections and several well-construction and/or site-activity factors, it is recommended that nonpoint and especially point source activities should be conducted carefully to prevent future contamination. Placement of drinking water wells should avoid areas of potential point sources of contamination, and they should be constructed to prevent direct contamination of the well from surface activities.

SELECTED REFERENCES

Abel, C.A., 1992. North Dakota VOC/Pesticide Study: Proceedings North Dakota Water Quality Symposium, pp. 369-374.

Aller, T., T. Bennett, J.H. Lehr, R.J. Petty, and G. Hackett, 1987. DRASTIC: A Standardized System for Evaluating Groundwater Pollution Potential Using Hydrogeologic Settings, U.S. Environmental Protection Agency, EPA/600/2-87/035, 622 p.

Armstrong, C.A., 1980. Geology and ground-water resources of Dickey and LaMoure Counties, North Dakota; Part III, Ground-water resources: North Dakota State Water Commission County Ground-water Studies 28 and North Dakota Geological Survey Bulletin 70, 61 p.

___, 1982. Geology and ground-water resources of Ransom and Sargent Counties, North Dakota; Part III, Ground-water resources: North Dakota State Water Commission County Ground-water Studies 31 and North Dakota Geological Survey Bulletin 69, 51 p.

Arndt, B. Michael, 1975. Geology and ground-water resources of Cavalier and Pembina Counties, North Dakota; Part I, Geology: North Dakota State Water Commission County Ground-water Studies 20 and North Dakota Geological Survey Bulletin 62, 68 p.

Bartelson, Norene, and William Gunnerson, 1996. North Dakota Groundwater Monitoring Program, 1996 Report. North Dakota Department of Health, Division of Water Quality, 131 p.

Bluemle, John P., 1979. Geology and ground-water resources of Dickey and LaMoure Counties, North Dakota; Part I, Geology: North Dakota State Water Commission County Ground Water Studies 28 and North Dakota Geological Survey Bulletin 70, 72 p.

Carlson, C.G., and T.F. Freers, 1975. Geology and ground-water resources of Benson and Pierce Counties, North Dakota; Part I, Geology: North Dakota State Water Commission County Ground-water Studies 18 and North Dakota Geological Survey Bulletin 59, 32 p.

Cline, Royce, and Steve Pusc, 1990. Natural variations of ground-water quality in North Dakota: Proceedings North Dakota Water Quality Symposium, pp. 30-47.

Farm Chemicals Handbook '97, 1997. Meister Publishing Company.

Gilbert, R.O., 1987. Statistical Methods for Environmental Pollution Monitoring, Van Nostrand Reinhold, pp. 121-127.

Glatt, L. David, 1985. Groundwater investigation to determine the occurrence of picloram in selected well sites of Rolette County, North Dakota: North Dakota State Department of Health Report, December, 35 p.

___, 1986. Pesticide and herbicide survey of selected municipal drinking water systems in North Dakota: North Dakota State Department of Health Report, February, 34 p.

Hutchinson, R.D., 1977. Geology and ground-water resources of Cavalier and Pembina Counties, North Dakota; Part III, Ground-water resources: North Dakota State Water Commission County Ground-water Studies 20 and North Dakota Geological Survey Bulletin 62, 68 p.

Klausing, Robert L., 1979. Geology and ground-water resources of McIntosh County, North Dakota; Part II, Ground-water basic data: North Dakota State Water Commission County Ground-water Studies 30 and North Dakota Geological Survey Bulletin 73, 458 p.

___, 1981. Geology and ground-water resources of McIntosh County, North Dakota; Part III, Ground-water resources: North Dakota State Water Commission County Ground-water Studies 30 and North Dakota Geological Survey Bulletin 73, 37 p.

___, 1983. Geology and ground-water resources of Logan County, North Dakota; Part III, Ground-water resources: North Dakota State Water Commission County Ground-water Studies 34 and North Dakota Geological Survey Bulletin 77, 42 p.

Montgomery, B.R., Lyle Prunty, A.E. Mathison, E.C. Stegman, and W. Albus, 1988. Nitrate and pesticide concentrations in shallow aquifers underlying sandy soils: Proceedings North Dakota Groundwater Quality Symposium, pp.76-100.

Murphy, Edward C., and Earl A. Greene, 1992. The occurrence of picloram (Tordon) and 2,4-D in groundwater in the Denbigh Sand Hills, McHenry County, North Dakota: North Dakota Geological Survey Report of Investigation No. 95, 40 p.

North Dakota Agricultural Statistics Service, 1991. North Dakota Agricultural Statistics, Ag Statistics No. 60, p. 100.

___, 1998. North Dakota Agricultural Statistics, Ag Statistics No. 67, 132 p.

North Dakota Department of Health-Division of Chemistry, 1997. Quality Assurance Program Plan.

Paulson, Q.F., and P.D. Akin, 1964. Ground-water resources of the Devils Lake area, Benson, Ramsey, and Eddy Counties, North Dakota: North Dakota State Water Conservation Commission Ground-water Studies No. 56, 211 p.

Radig, Scott, and Norene Bartelson, 1992. North Dakota Groundwater Monitoring Program, 1992 Report. North Dakota State Department of Health and Consolidated Laboratories, Division of Water Quality, 58 p.

___, 1993. North Dakota Groundwater Monitoring Program, 1993 Report. North Dakota State Department of Health and Consolidated Laboratories, Division of Water Quality, 93 p.

___, 1994. North Dakota Groundwater Monitoring Program, 1994 Report. North Dakota State Department of Health and Consolidated Laboratories, Division of Water Quality, 93 p.

___, 1995. North Dakota Groundwater Monitoring Program, 1995 Report. North Dakota State Department of Health and Consolidated Laboratories, Division of Water Quality, 112 p.

Randich, P.G., 1977. Geology and ground-water resources of Benson and Pierce Counties, North Dakota; Part III, Ground-water resources: North Dakota State Water Commission County Ground-water Studies 18 and North Dakota Geological Survey Bulletin 59, 76 p.

State Water Commission, 1992. Communications Committee 1992 Survey of North Dakota Citizens.

Shaver, Robert B., 1988. Water chemistry variation in aquifers of glacial origin, in North Dakota: Proceedings North Dakota Groundwater Quality Symposium, pp. 24-49.

___, 1996. Spatial and temporal hydrochemical variations in ground water in the Oakes aquifer, southeastern North Dakota: Proceedings North Dakota Water Quality Symposium, pp. 56-71.

Trapp, Henry, Jr., 1968. Geology and ground-water resources of Eddy and Foster Counties, North Dakota; Part III, Ground-water resources: North Dakota State Water Commission County Ground-water Studies 5 and North Dakota Geological Survey Bulletin 44, 110 p.

U.S. Environmental Protection Agency, 1990. National pesticide survey phase I report: EPA 570/9-90-015, November, 98 p.

___, 1992. National pesticide survey phase II report: January, 169 p.

___, Office of Drinking Water, 1988. Bentazon health advisory, August, 21 p.

___, 1987. 2,4-Dichlorophenoxyacetic acid (2.4-D) health advisory, March 31, 21 p.

___, 1987. Endrin health advisory, March 31, 18 p.

___, 1987. Heptachlor and heptachlor epoxide health advisory, March 31, 21 p.

___, 1988. MCPA health advisory, August, 17 p.

___, 1987. Nitrate/Nitrite health Advisory, March 31, 18 p.

___, 1987. Pentachlorophenol health Advisory, March 31, 16 p.

___, 1987. Picloram health Advisory, March 31, 18 p.

Wanek, Alan, 1983. Streeter aquifer interim report. North Dakota State Water Commission.

Zollinger, R.K., Greg K. Dahl, Marcia P. McMullen, Philip Glogoza, Alan G. Dexter, Scott A. Fitterer, G. Eric Waldhaus, and Kara Ignaszewski, 1998. Pesticide use and pest management practices for major crops in North Dakota, 1996. North Dakota State University in cooperation with North Dakota Agricultural Statistics Service, Extension Report No. 43, 79 p.

APPENDIX A

Site Inventory Form

AMBIENT GROUNDWATER MONITORING
SITE INVENTORY

Site ID/Sample #____________________ Project Code______ Sample Type(s): **Reg. Dup. Blank**
Date___________ Time________ D/B Time_______ Collector(s)______________________________
Analyses: **Pesticides Carbamates Metals Gen. Chem**
Nitrates All of the Above Other_____________________________________
Weather Conditions____
Latitude/Longitude Field Reading____
Comments:

OWNER INFORMATION

Owner____ Renter: **Yes No**
c/o____
Address____ Phone# (____)______-___________
City____ State_________ Zip Code___________
Contact Person__________________________________ Rel. To owner____________________
Comments:

WELL INFORMATION

Well name or # other than ID____
Casing diameter________________________ Completed well depth________________________
Casing material: **PVC Stainless Steel Iron Wood Masonry Other**________________
Pump type: **Bailer Submersible Jet Hand/Windmill Bladder Other**________________
Ground elevation______________________ Date constructed______________________________
Top open interval______________________ Bottom open interval___________________________
Water use: **Domestic Public Stock Observation Irrigation Industrial Other**____________
Well construction: **Rotary Bored/Auger Dug Sand Point Cable Other**___________________
Well is used: **Daily Seasonally Backup Observation Other**____________________
Protective cap: **Yes No Unknown** Properly sealed: **Yes No Unknown**
Sampling point________________________ Aquifer_______________________________________
County_______________________________ Driller_______________________________________
Comments:

SITE DATA

Depression aound casing: **Yes No Unknown**
Near irrigation: **Yes No Unknown** Distance: **0-100' 100'-1/8 mile**
Recent precipitation: **Yes No Unknown** Amount_________________________________
Topography: **Flat Sloping Rolling Hilly Other**____________________________
Comments:

CHEMICAL USAGE NEAR WELL

Pesticides **Fertilizer** **Petroleum - UST, AST** **Other**__________________________
Chemical name__________________________ Date put in area_____________________________
Store__________ **Mix**__________ **Load**_________ **Apply**_________ **Dispose**__________
Gradient from well: **Up** **Down** **Both** **Even** Distance from well: **0-100'** **100'-1/8 mile**

Pesticides **Fertilizer** **Petroleum - UST, AST** **Other**__________________________
Chemical name__________________________ Date put in area_____________________________

Store__________ **Mix**__________ **Load**_________ **Apply**_________ **Dispose**__________
Gradient from well: **Up** **Down** **Both** **Even** Distance from well: **0-100'** **100'-1/8 mile**

Pesticides **Fertilizer** **Petroleum - UST, AST** **Other**_______________
Chemical name_________________________ Date put in area_______________________
Store__________ **Mix**__________ **Load**_________ **Apply**_________ **Dispose**__________
Gradient from well: **Up** **Down** **Both** **Even** Distance from well: **0-100'** **100'-1/8 mile**

Comments:

Have there been any nearby chemical spills? **Yes** **No** **Unknown**
Gradient from well: **Up** **Down** **Both** **Even** Distance from well: **0-100'** **100'-1/8 mile**
Recent change in water quality? **Yes** **No** **Unknown** When? _____________________
Taste **Odor** **Color** **Appearance** **Other**__________________________
Previous chemical/bacteriological analyses? **Yes** **No** **Unknown**
Results:____
Comments:

CROPS NEAR WELL

Small Grains **Row Crops** **Hay** **Pasture** **CRP**
Gradient from well: **Up** **Down** **Both** **Even** Distance from well: **0-100'** **100'-1/8 mile**

Small Grains **Row Crops** **Hay** **Pasture** **CRP**
Gradient from well: **Up** **Down** **Both** **Even** Distance from well: **0-100'** **100'-1/8 mile**

Small Grains **Row Crops** **Hay** **Pasture** **CRP**
Gradient from well: **Up** **Down** **Both** **Even** Distance from well: **0-100'** **100'-1/8 mile**

Small Grains **Row Crops** **Hay** **Pasture** **CRP**
Gradient from well: **Up** **Down** **Both** **Even** Distance from well: **0-100'** **100'-1/8 mile**

Comments:

NEARBY FACTORS OF POSSIBLE INFLUENCE

Feedlots **Disposal area** **Septic system** **Surface water** **Other**__________________
Gradient from well: **Up** **Down** **Both** **Even** Distance from well: **0-100'** **100'-1/8 mile**

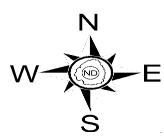
Feedlots **Disposal area** **Septic system** **Surface water** **Other**__________________
Gradient from well: **Up** **Down** **Both** **Even** Distance from well: **0-100'** **100'-1/8 mile**

Feedlots **Disposal area** **Septic system** **Surface water** **Other**__________________
Gradient from well: **Up** **Down** **Both** **Even** Distance from well: **0-100'** **100'-1/8 mile**

Feedlots **Disposal area** **Septic system** **Surface water** **Other**__________________
Gradient from well: **Up** **Down** **Both** **Even** Distance from well: **0-100'** **100'-1/8 mile**

Feedlots **Disposal area** **Septic system** **Surface water** **Other**__________________
Gradient from well: **Up** **Down** **Both** **Even** Distance from well: **0-100'** **100'-1/8 mile**

Comments:



Comments:

Draw a general map of the area - section / ¼ section / farmsite / etc. Locate wells, buildings, crops, and other operations that may impact water quality.

WELL STABILIZATION DATA

Site ID/Sample #_______________________________________ Date_________________________
Type of pump______________________________ Pumping rate____________________________
Regular sample time___________________________ Duplicate/Blank sample time______________

Time	Temperature	pH	Temperature-corrected Conductivity (μmhos/cm)	Volume of Water Removed From Well (Cumulative)

Well depth from top of casing*
-Casing length from top to ground
= Well depth

Water level from top of casing
-Casing length from top to ground
= Depth to water

Well depth ______________
-Depth to water ______________
=Lineal feet ______________ X ________ = ___________ (Volume of water in casing)

(*Measurements to nearest 0.01 ft. before pumping or bailing)

Calculate one well volume using the table below:

Well diameter in inches:	¾	1	1 ¼	1 ½	2	3	4	6
Gallons per lineal foot of water in well:	0.023	0.04	0.06	0.09	0.16	0.37	0.67	1.47
Liters per lineal foot of water in well:	0.087	0.15	0.24	0.34	0.60	1.4	2.53	5.56

(Gallons x 3.7853 = liters
Liters x.2642 = gallons)

WELL SETTING

Primary setting: **Farmyard** **Field** **Pasture** **CRP** **Roadside** **Town**
Secondary setting: **Farmyard** **Field** **Pasture** **CRP** **Roadside** **Town**

Color______________________________ Appearance____________________________
Odor______________________________ Taste__________________________________
Comments:

APPENDIX B

General Inorganic Water Quality Analyses

*** Icelandic Aquifer ***

WELL ID (TRSQ)	Na	Mg	SiO2	K	Ca	Mn	Fe	Cl	F	pH	CO3	HCO3	OH	Alk.	Cond.	SO4	NO3	CaCO3	Hard.	Turb.	% Na	SAR	TDS
16005505CCD	1.2	35.1	38.9	3.2	113.	2.54	16.7	16.6	0.29	7.37	< 1	412.	< 1	337.	752.	66.	< 0.05	427.	25.	145.	0.6	0.03	440.
16005508DDD	< 0.1	18.8	122.	1.7	76.6	15.7	255.	1.4	0.26	7.42	< 1	329.	< 1	269.	457.	58.	< 0.05	269.	16.	1200	0.1	0.00	321.
16005514BBC	11.0	36.0	16.7	1.7	78.1	17.5	445.	3.4	0.45	7.48	< 1	419.	< 1	343.	610.	20.	< 0.05	343.	20.	2500	6.4	0.26	359.
16005520BBB	113.	128.	95.4	4.3	134.	11.9	145.	21.4	1.02	7.39	< 1	822.	< 1	673.	1750	387.	2.19	862.	50.	980.	22.0	1.67	1200
16005529BBB	83.9	86.4	36.7	3.4	184.	15.1	219.	29.3	0.99	7.30	< 1	583.	< 1	477.	1560	404.	0.05	816.	48.	4500	18.1	1.28	1080
16005602ACB	33.7	54.7	21.2	10.6	162.	0.070	0.038	22.7	0.61	7.47	< 1	337.	< 1	276.	1350	430.	5.14	630.	37.	1.50	10.2	0.58	905.
16005602BDA	545.	467.	6.25	5.8	572.	29.3	532.	245.	2.21	7.12	< 1	723.	< 1	592.	6040	3380	< 0.05	3350	196.	3500	26.0	4.09	5570
16105431CCA2	1.0	12.8	21.5	3.9	62.9	0.003	0.445	3.2	0.24	7.74	< 1	235.	< 1	192.	386.	5.	0.38	210.	12.	2.30	1.0	0.03	208.
16105431CCD	0.3	28.0	23.7	2.0	116.	5.29	116.	1.9	0.23	7.28	< 1	438.	< 1	359.	683.	55.	0.12	405.	24.	1600	0.2	0.01	421.
16105503DDD	< 0.1	16.2	28.5	2.1	73.9	5.45	40.4	< 1	0.25	7.64	< 1	300.	< 1	246.	446.	13.	< 0.05	251.	15.	320.	0.1	0.00	256.
16105504DDD	< 0.1	17.3	24.5	1.5	59.9	0.441	2.53	< 1	0.16	7.46	< 1	217.	< 1	178.	416.	54.	< 0.05	221.	13.	25.0	0.1	0.00	243.
16105510DBC	< 0.1	13.9	31.1	< 1	66.1	1.11	17.1	< 1	0.24	7.59	< 1	226.	< 1	185.	395.	26.	< 0.05	222.	13.	165.	0.1	0.00	222.
16105514ABC	< 0.1	23.4	23.9	1.2	105.	0.275	0.181	5.3	0.30	7.34	< 1	374.	< 1	306.	696.	70.	< 0.05	359.	21.	3.90	0.1	0.00	391.
16105515CBB	< 0.1	13.0	24.9	1.1	53.4	0.450	0.354	1.7	0.16	7.62	< 1	202.	< 1	165.	393.	42.	< 0.05	187.	11.	3.20	0.1	0.00	213.
16105516DBB	< 0.1	11.7	26.9	1.0	49.5	0.436	0.928	< 1	0.14	7.63	< 1	204.	< 1	167.	359.	23.	< 0.05	172.	10.	8.40	0.1	0.00	189.
16105517DDD	< 0.1	16.9	45.8	2.5	64.9	0.654	10.9	< 1	0.14	7.64	< 1	264.	< 1	216.	396.	< 3	< 0.05	232.	14.	160.	0.1	0.00	221.
16105520AAB	0.1	13.0	27.3	1.6	62.4	0.335	0.936	1.0	0.15	7.76	< 1	279.	< 1	229.	437.	8.	< 0.05	209.	12.	5.80	0.1	0.00	226.
16105521DBB	< 0.1	12.4	25.5	1.1	56.8	0.399	1.14	< 1	0.20	7.64	< 1	218.	< 1	179.	399.	31.	0.21	193.	11.	9.00	0.1	0.00	213.
16105522BCC	< 0.1	11.8	27.2	1.1	46.7	0.551	2.13	< 1	0.13	7.53	< 1	185.	< 1	152.	350.	33.	< 0.05	165.	10.	19.0	0.1	0.00	187.
16105524AAC1	52.3	43.9	23.3	413.	108.	0.336	0.182	59.2	0.25	7.34	< 1	730.	< 1	598.	2420	186.	90.9	451.	26.	5.50	10.4	1.07	1630
16105524AAC1	39.4	33.6	27.0	411.	87.1	0.190	0.113	66.5	0.19	7.45	< 1	617.	< 1	505.	2170	152.	84.3	356.	21.	1.50	8.8	0.91	1470
16105524ADA1	6.1	47.2	46.7	4.3	141.	1.27	15.6	41.7	0.24	7.21	< 1	392.	< 1	321.	859.	106.	< 0.05	547.	32.	170.	2.3	0.11	541.
16105524ADA2	14.1	20.6	26.9	3.4	74.4	0.745	4.48	2.6	0.23	7.36	< 1	363.	< 1	297.	547.	< 3	< 0.05	271.	16.	31.0	10.0	0.37	299.
16105527BBC	< 0.1	10.5	26.9	1.7	50.5	0.469	1.91	< 1	0.23	7.62	< 1	226.	< 1	185.	374.	9.	< 0.05	169.	10.	19.0	0.1	0.00	186.
16105528AAC	< 0.1	13.4	32.5	1.7	61.5	0.517	1.45	3.0	0.24	7.62	< 1	210.	< 1	172.	383.	27.	< 0.05	209.	12.	14.0	0.1	0.00	212.
16105529CBC	< 0.1	13.3	28.1	1.3	51.7	0.626	1.02	< 1	0.20	7.67	< 1	218.	< 1	179.	391.	29.	< 0.05	184.	11.	8.70	0.1	0.00	206.
16105530AAC	< 0.1	12.0	17.5	13.9	63.5	0.844	0.093	4.4	0.18	7.78	< 1	261.	< 1	214.	482.	18.	3.36	208.	12.	2.00	0.1	0.00	257.
16105530AAC	< 0.1	21.0	25.0	20.5	99.1	7.60	0.016	6.6	0.14	7.84	< 1	387.	< 1	317.	655.	21.	2.37	334.	20.	1.90	0.1	0.00	371.
16105530AAC	3.8	24.1	18.0	34.9	107.	0.354	0.088	19.2		7.48	< 1	416.	< 1	341.	816.	60.	2.97	367.	21.	2.00	2.0	0.09	469.
16105530AAC2	< 0.1	15.7	28.0	1.6	70.6	0.104	< 0.007	2.4		7.38	< 1	301.	< 1	247.	478.	13.	< 0.05	241.	14.	1.00	0.1	0.00	254.
16105531BBB	37.7	18.7	28.1	3.8	79.6	0.326	2.39	25.7	0.35	7.53	< 1	428.	< 1	351.	704.	14.	< 0.05	276.	16.	19.0	22.5	0.99	392.
16105534DDD	14.2	37.2	22.9	20.3	113.	15.5	231.	3.7	0.24	7.66	< 1	452.	< 1	370.	809.	94.	0.21	436.	25.	2050	6.2	0.30	508.
16105535DBB	4.8	34.3	18.7	11.0	104.	1.36	0.068	25.8	0.34	7.25	< 1	415.	< 1	340.	857.	91.	0.16	401.	23.	3.00	2.4	0.10	478.
16205528BCC	< 0.1	30.7	31.7	1.0	107.	0.090	0.048	6.3	0.29	7.35	< 1	445.	< 1	364.	763.	54.	0.07	394.	23.	4.90	0.1	0.00	421.
16205530DDD	1.0	18.9	21.9	3.6	80.4	0.168	0.022	3.3	0.28	7.47	< 1	373.	< 1	305.	588.	14.	0.13	279.	16.	3.90	0.8	0.03	308.
16205602DAC1	5.4	55.8	29.4	3.4	157.	0.844	0.727	20.4	0.42	7.38	< 1	552.	< 1	452.	1210	219.		622.	36.	7.00	1.8	0.09	735.
16205602DAC1	5.1	59.0	33.7	3.2	170.	1.76	0.846	18.0	0.48	7.22	< 1	573.	< 1	469.	1190	209.	< 0.05	668.	39.	6.20	1.6	0.09	749.
16205602DAC2	0.3	29.9	24.8	2.3	124.	0.206	0.122	4.0	0.32	7.42	< 1	510.	< 1	418.	836.	41.	1.96	433.	25.	1.40	0.1	0.01	463.
MINIMUM	< 0.1	10.5	6.25	< 1	46.7	0.003	< 0.007	< 1	0.13	7.12	< 1	185.	< 1	152.	350.	< 3	< 0.05	165.	10.	1.00	0.1	0.00	186.
MAXIMUM	545.	467.	122.	413.	572.	29.3	532.	245.	2.21	7.84	< 1	822.	< 1	673.	6040	3380	90.9	3350	196.	4500	26.0	4.09	5570
MEAN	25.6	41.0	31.0	26.5	104.9	3.706	54.37	17.6	0.36	7.49	0.5	385	0.5	315	905.4	170	5.27	431	25	461	4.1	0.3	600
MEDIAN	0.3	20.8	26.9	2.9	80.0	0.589	1.08	3.6	0.24	7.47	0.5	374	0.5	306	632.5	42	0.05	307	18	9	0.2	0.0	365
STDDEV	89.9	74.7	20.2	92.3	85.9	6.645	124.35	41.1	0.38	0.17	0.0	162	0.0	132	990.8	546	20.00	518	30	1041	7.1	0.8	901

All units reported in mg/l except: pH, Conductivity (umhos/cm), Hardness (gr/gal), Turbidity (NTU), % Na (%), and SAR (Sodium Adsorption ration).
CaCO3 is total hardness measured as calcium carbonate.

*** Oakes Aquifer ***

WELL ID (TRSQ)	Na	Mg	SiO2	K	Ca	Mn	Fe	Cl	F	pH	CO3	HCO3	OH	Alk.	Cond.	SO4	NO3	CaCO3	Hard.	Turb.	% Na	SAR	TDS
12905807CCC	13.9	21.2	33.6	4.5	76.4	0.264	1.15	9.7	0.30	6.98	< 1	343.	< 1	281.	568.	15.	< 0.05	278.	16.	12.0	9.6	0.36	312.
12905808BBB	2.1	21.9	21.9	2.4	72.3	0.488	2.89	3.0	0.29	6.94	< 1	269.	< 1	220.	508.	55.	< 0.05	271.	16.	29.0	1.6	0.06	291.
12905818CCC2	23.5	64.1	31.3	7.8	74.4	1.93	2.90	3.0	0.44	7.17	< 1	662.	< 1	542.	948.	8.	6.07	450.	26.	23.0	10.0	0.48	536.
12905830ABB	0.6	20.5	27.3	2.7	81.3	1.08	8.88	1.3	0.18	7.64	< 1	281.	< 1	230.	473.	34.	< 0.05	288.	17.	1000	0.4	0.02	281.
12905831BCC	3.1	33.0	34.6	2.0	94.9	0.930	3.87	20.4	0.36	7.53	< 1	278.	< 1	228.	719.	135.	< 0.05	373.	22.	39.0	1.8	0.07	427.
12905901DDD2	7.3	24.3	48.4	5.6	81.3	1.40	15.1	6.3	0.21	7.64	< 1	320.	< 1	262.	503.	8.	< 0.05	303.	18.	180.	4.8	0.18	293.
12905904BAA	12.2	36.8	28.0	2.9	98.3	1.18	3.64	21.4	0.26	7.47	< 1	325.	< 1	266.	775.	132.	< 0.05	397.	23.	16.0	6.2	0.27	466.
12905905CBC	16.8	25.8	32.7	4.6	84.6	0.922	8.32	10.9	0.43	7.49	< 1	371.	< 1	304.	681.	48.	< 0.05	318.	19.	54.0	10.1	0.41	376.
12905908ABB	10.5	35.5	25.5	3.2	88.2	1.85	3.74	5.8	0.43	7.56	< 1	408.	< 1	334.	724.	63.	< 0.05	367.	21.	27.0	5.8	0.24	409.
12905909BCC	14.9	39.1	24.2	4.7	170.	7.09	189.	2.9	0.49	7.58	< 1	370.	< 1	303.	1000	264.	< 0.05	586.	34.	2600	5.2	0.27	680.
12905910BAA	127.	34.9	29.6	6.4	137.	1.31	6.52	47.5	0.42	7.06	< 1	685.	< 1	561.	1460	190.	0.09	486.	28.	45.0	35.7	2.50	883.
12905912AAB3	15.7	22.6	21.8	2.5	55.6	0.217	0.277	13.8	0.76	7.33	< 1	288.	< 1	236.	564.	40.	1.21	232.	14.	6.10	12.6	0.45	299.
12905914BBB	49.2	19.1	29.4	7.3	64.3	0.518	1.91	18.3	0.29	7.02	< 1	358.	< 1	293.	714.	74.	< 0.05	239.	14.	18.0	30.0	1.38	411.
12905915CBB	43.7	27.2	20.7	15.1	83.8	0.466	3.09	12.3	0.37	7.33	< 1	433.	< 1	355.	844.	90.	< 0.05	321.	19.	23.0	21.7	1.06	487.
12905915CBB	43.3	28.8	19.5	15.8	90.6	0.633	2.49	11.2		7.08	< 1	437.	< 1	358.	869.	98.	< 0.05	345.	20.	14.0	20.4	1.01	505.
12905917DCC	94.0	40.6	29.1	7.8	94.4	1.06	1.33	36.1	0.22	7.28	< 1	484.	< 1	396.	1230	234.	< 0.05	403.	24.	16.0	33.0	2.04	747.
12905919CDD	31.2	80.3	39.4	2.9	188.	1.25	10.5	9.2	0.29	7.29	< 1	698.	< 1	572.	1270	151.	< 0.05	800.	47.	150.	7.7	0.48	809.
12905920CCC2	6.5	42.2	28.4	2.8	91.4	3.42	66.3	5.9	0.57	7.66	< 1	406.	< 1	333.	684.	56.	< 0.05	402.	23.	160.	3.4	0.14	407.
12905921CBB	245.	307.	22.1	18.8	531.	72.8	1570	15.6	0.45	6.82	< 1	496.	< 1	406.	4220	2710	1.62	2590	151.	35000	16.9	2.09	4080
12905925AAA2	3.0	17.0	33.3	2.3	68.7	0.811	2.77	2.5	0.28	7.52	< 1	273.	< 1	224.	457.	23.	< 0.05	242.	14.	22.0	2.6	0.08	253.
12905926DDD	51.4	53.1	36.4	9.8	175.	1.20	18.7	25.4	0.28	7.26	< 1	787.	< 1	645.	1190	42.	< 0.05	656.	38.	110.	14.3	0.87	746.
12905928BAA	817.	688.	12.3	26.1	173.	11.3	361.	128.	0.34	7.84	< 1	469.	< 1	384.	6790	4220	0.67	3260	191.	4100	34.9	6.22	6290
12905929DDD2	27.4	78.5	53.8	1.9	58.7	0.861	25.6	2.4	1.06	7.84	< 1	381.	< 1	312.	944.	34.	43.4	470.	27.	220.	11.2	0.55	586.
12905931DCC	25.8	47.2	46.0	5.0	116.	0.199	14.3	7.2	1.13	7.05	< 1	396.	< 1	324.	888.	74.	21.3	484.	28.	135.	10.2	0.51	567.
12905932CDD	277.	222.	32.4	11.8	432.	2.73	42.7	254.	0.49	7.09	< 1	456.	< 1	373.	3690	1580	< 0.05	1990	116.	300.	23.0	2.70	3000
12905933DAA	19.3	95.7	98.7	5.4	166.	0.743	71.0	2.0	0.59	7.60	< 1	332.	< 1	272.	1360	498.	6.89	809.	47.	1250	4.9	0.30	983.
12905935BBB	6000	1620	56.4	94.8	430.	0.460	31.8	1080	1.25	7.46	< 1	710.	< 1	581.	26100	18500	< 0.05	7740	452.	800.	62.3	29.6	28100
12906001DDD	17.7	64.7	27.2	3.0	155.	0.521	1.13	155.	0.21	6.95	< 1	449.	< 1	368.	1420	186.	< 0.05	654.	38.	6.00	5.5	0.30	805.
12906036DAA	21.6	56.3	27.2	5.1	168.	2.66	36.9	8.3	0.50	7.07	< 1	455.	< 1	373.	1150	291.	< 0.05	652.	38.	290.	6.6	0.37	777.
13005807DAA	17.5	37.4	67.0	8.1	130.	3.55	78.2	2.8	0.23	7.33	< 1	407.	< 1	333.	907.	178.	< 0.05	479.	28.	550.	7.2	0.35	576.
13005808CDD2	4.7	33.0	30.9	6.4	120.	0.677	3.68	6.9	0.34	6.86	< 1	387.	< 1	317.	851.	144.	< 0.05	436.	25.	32.5	2.2	0.10	508.
13005817BCC2	18.7	37.6	27.3	5.4	114.	0.807	0.263	21.2	0.22	6.98	< 1	429.	< 1	351.	964.	152.	< 0.05	440.	26.	2.90	8.3	0.39	562.
13005818DDD2	13.8	19.5	29.0	4.8	77.4	0.716	4.15	2.8	0.37	7.46	< 1	338.	< 1	277.	527.	22.	< 0.05	274.	16.	32.0	9.6	0.36	309.
13005819ADD	7.3	29.6	33.5	4.3	86.0	0.712	3.70	2.6	0.22	7.52	< 1	437.	< 1	358.	682.	22.	< 0.05	337.	20.	27.0	4.4	0.17	369.
13005820CCC2	3.3	27.1	28.8	1.4	66.6	0.550	1.03	11.3	0.37	6.97	< 1	312.	< 1	256.	583.	44.	< 0.05	278.	16.	12.5	2.5	0.09	309.
13005821BBA	9.0	31.8	30.7	5.9	103.	0.670	2.44	2.6	0.35	7.08	< 1	413.	< 1	338.	808.	110.	< 0.05	388.	23.	39.0	4.7	0.20	468.
13005829CDC3	0.3	28.8	23.8	< 1	106.	0.002	0.335	32.1	0.14	7.63	< 1	322.	< 1	264.	822.	67.	12.5	384.	22.	7.50	0.2	0.01	451.
13005831ADD	1.2	13.8	24.1	4.4	81.7	0.513	5.53	< 1	0.23	7.52	< 1	330.	< 1	270.	501.	6.	0.10	261.	15.	87.5	1.0	0.03	273.
13005901DDD	110.	80.9	29.8	11.1	246.	2.32	5.45	4.4	0.25	7.17	< 1	515.	< 1	422.	2060	823.	< 0.05	948.	55.	37.0	19.8	1.55	1530
13005902CBB4	602.	240.	25.9	15.7	176.	0.574	6.32	77.6	0.47	7.52	< 1	603.	< 1	494.	4920	2500	< 0.05	1430	83.	68.0	47.4	6.93	3910
13005903CBB	53.4	10.9	24.2	5.1	27.2	0.280	2.88	2.0	0.62	7.84	< 1	283.	< 1	232.	455.	11.	< 0.05	113.	7.	28.0	49.2	2.19	251.
13005904CAA	37.0	34.1	28.0	5.3	105.	0.717	2.77	21.1	0.24	7.01	< 1	396.	< 1	324.	1010	199.	< 0.05	403.	24.	26.0	16.4	0.80	599.
13005905DBB	24.6	26.3	35.6	5.3	76.6	0.708	6.89	12.8	0.18	7.11	< 1	374.	< 1	306.	680.	47.	< 0.05	300.	18.	82.0	14.8	0.62	379.
13005908AAA2	12.9	8.6	30.7	1.7	26.3	0.168	1.74	< 1	0.46	7.65	< 1	155.	< 1	127.	241.	6.	< 0.05	101.	6.	7.10	21.3	0.56	135.
13005909ACC	93.0	28.6	28.3	11.2	69.6	1.34	8.35	17.5	0.21	7.30	< 1	536.	< 1	439.	1020	88.	< 0.05	292.	17.	54.0	39.7	2.37	574.
13005910DBB	58.0	26.7	28.2	5.3	80.7	0.651	1.53	39.9	0.51	7.02	< 1	330.	< 1	270.	922.	160.	< 0.05	312.	18.	11.0	28.3	1.43	535.

All units reported in mg/l except: pH, Conductivity (umhos/cm), Hardness (gr/gal), Turbidity (NTU), % Na (%), and SAR (Sodium Adsorption ration).
CaCO3 is total hardness measured as calcium carbonate.

*** Oakes Aquifer (continued)***

WELL ID (TRSQ)	Na	Mg	SiO2	K	Ca	Mn	Fe	Cl	F	pH	CO3	HCO3	OH	Alk.	Cond.	SO4	NO3	CaCO3	Hard.	Turb.	% Na	SAR	TDS
13005911CDD	3.4	13.0	29.9	1.5	61.5	0.660	1.87	2.4	0.56	7.52	< 1	176.	< 1	144.	448.	84.	< 0.05	207.	12.	11.0	3.4	0.10	255.
13005915CAA	14.8	36.0	26.6	5.6	74.4	1.20	2.64	5.8	0.18	7.06	< 1	389.	< 1	319.	757.	97.	< 0.05	334.	20.	19.0	8.6	0.35	427.
13005916CAA1	6.1	35.2	27.5	2.6	113.	1.13	0.886	17.3	0.23	7.45	< 1	312.	< 1	256.	855.	193.	< 0.05	427.	25.	8.90	3.0	0.13	523.
13005920ADD	27.0	36.5	20.6	4.7	98.8	0.471	1.55	25.1	0.25	6.98	< 1	406.	< 1	333.	900.	120.	1.92	397.	23.	22.0	12.7	0.59	523.
13005920BBB	70.6	20.8	29.7	9.4	73.6	0.292	0.879	15.9	0.24	7.13	< 1	451.	< 1	369.	847.	73.	< 0.05	270.	16.	16.0	35.2	1.87	488.
13005921DDD2	39.5	36.2	27.0	9.1	93.6	0.516	2.98	10.1	0.31	6.98	< 1	392.	< 1	321.	958.	192.	< 0.05	383.	22.	25.5	17.8	0.88	576.
13005922CAA	12.0	41.9	31.0	5.7	93.7	1.35	6.73	38.2	0.22	6.73	< 1	341.	< 1	279.	883.	157.	< 0.05	407.	24.	24.0	5.9	0.26	519.
13005923BBB2	4.8	29.1	28.0	3.4	99.5	1.31	4.69	6.7	0.56	7.40	< 1	257.	< 1	210.	677.	132.	< 0.05	368.	22.	29.0	2.7	0.11	404.
13005924DDD2	3.1	12.7	35.1	2.1	50.2	0.641	7.35	2.0	0.22	7.24	< 1	202.	< 1	165.	329.	11.	< 0.05	178.	10.	85.0	3.6	0.10	183.
13005925CBB	11.2	30.1	28.6	3.3	97.0	1.22	6.36	6.8	0.42	7.35	< 1	392.	< 1	321.	799.	112.	< 0.05	366.	21.	54.0	6.1	0.25	456.
13005926CCC3	6.3	31.5	26.6	4.8	78.2	0.552	0.330	5.4	0.23	7.42	< 1	305.	< 1	250.	676.	105.	< 0.05	325.	19.	3.20	4.0	0.15	384.
13005928DBB1	58.9	62.7	24.8	8.6	150.	1.15	5.22	23.6	0.30	7.15	< 1	573.	< 1	469.	1300	228.	< 0.05	633.	37.	44.0	16.5	1.02	816.
13005929ACC2	67.7	33.9	28.8	6.1	96.2	0.823	2.97	12.4	0.29	7.08	< 1	488.	< 1	400.	1040	167.	< 0.05	380.	22.	23.0	27.4	1.51	626.
13005930DCC	50.7	31.1	29.7	5.3	96.3	1.01	6.68	13.3	0.36	7.08	< 1	524.	< 1	429.	918.	67.	< 0.05	369.	22.	69.0	22.6	1.15	524.
13005931DDD	261.	155.	26.9	21.4	379.	1.50	6.68	196.	0.15	7.31	< 1	1110	< 1	909.	3660	1150	< 0.05	1590	93.	56.0	25.9	2.85	2710
13005932DAA	47.6	43.5	25.9	7.9	111.	0.726	2.81	31.5	0.30	7.39	< 1	553.	< 1	453.	1100	130.	< 0.05	457.	27.	28.0	18.1	0.97	646.
13005933DAA	8.8	35.2	26.4	2.6	76.2	0.934	3.39	12.0	0.30	6.77	< 1	270.	< 1	221.	741.	155.	< 0.05	335.	20.	27.0	5.3	0.21	425.
13005934ADD	13.8	25.2	26.6	3.7	63.9	1.52	2.48	4.9	0.36	7.37	< 1	326.	< 1	267.	610.	61.	< 0.05	263.	15.	27.0	10.0	0.37	335.
13005935ABB	13.9	28.3	29.9	3.7	91.3	0.813	0.832	17.0	0.52	6.92	< 1	268.	< 1	219.	675.	116.	< 0.05	345.	20.	5.80	7.9	0.33	404.
13105831DBB	37.3	64.1	25.6	9.2	239.	1.42	2.94	14.5	0.25	7.13	< 1	364.	< 1	298.	1510	576.	< 0.05	861.	50.	31.0	8.5	0.55	1120
13105909CCC	31.3	42.0	28.2	3.4	106.	0.167	0.025	29.9	0.17	6.90	< 1	291.	< 1	238.	914.	164.	11.8	438.	26.	< 1	13.3	0.65	574.
13105915AAA2	11.2	82.9	56.0	8.7	224.	2.88	29.5	69.9	0.11	6.86	< 1	348.	< 1	285.	1500	489.	< 0.05	901.	53.	175.	2.6	0.16	1060
13105920AAD	5.2	27.2	25.1	3.0	86.8	0.485	0.486	12.3	0.19	7.31	< 1	295.	< 1	242.	691.	106.	0.14	329.	19.	5.60	3.3	0.12	388.
13105920AAD	16.4	27.3	32.0	4.5	101.	0.878	1.91	10.0	0.13	7.41	< 1	382.	< 1	313.	793.	114.	< 0.05	365.	21.	24.0	8.7	0.37	463.
13105922CBB2	6.4	33.4	26.3	5.4	112.	0.807	0.239	18.6	0.21	7.10	< 1	285.	< 1	233.	838.	194.	< 0.05	417.	24.	2.70	3.2	0.14	512.
13105924CDC	80.4	21.7	32.4	7.2	58.9	0.030	1.87	16.0	0.45	7.32	< 1	437.	< 1	358.	844.	85.	< 0.05	237.	14.	18.0	41.5	2.27	487.
13105925BBB2	264.	361.	24.4	18.1	378.	0.408	0.605	22.2	0.29	6.95	< 1	374.	< 1	306.	4620	2950	< 0.05	2430	142.	7.60	18.9	2.33	4180
13105926BCB2	5.2	17.1	28.4	5.1	61.3	0.270	19.2	2.1	0.21	7.35	< 1	303.	< 1	248.	483.	13.	< 0.05	224.	13.	65.0	4.7	0.15	255.
13105927BDD	< 0.1	12.5	26.8	< 1	28.6	0.345	0.129	6.6	0.36	7.10	< 1	132.	< 1	108.	248.	13.	< 0.05	123.	7.	3.00	0.2	0.00	129.
13105928CBB2	24.9	31.6	31.7	6.3	106.	0.498	6.91	19.6	0.35	6.74	< 1	366.	< 1	300.	817.	115.	< 0.05	395.	23.	32.0	11.8	0.54	486.
13105928CBD	4.6	53.8	85.4	6.1	110.	94.7	533.	8.4	0.21	7.40	< 1	399.	< 1	327.	911.	123.	< 0.05	496.	29.	2100	1.9	0.09	505.
13105929ACC	22.1	33.5	27.2	3.4	103.	0.612	< 0.007	25.6	0.17	7.31	< 1	350.	< 1	287.	901.	143.	7.28	395.	23.	< 1	10.7	0.48	537.
13105929ACC	25.3	34.6	29.4	3.4	110.	0.610	< 0.007	27.6	0.11	7.41	< 1	353.	< 1	289.	925.	152.	7.19	417.	24.	1.00	11.5	0.54	561.
13105929ACC	13.5	37.0	30.8	2.7	114.	0.458	0.018	26.1							906.	144.	8.47	437.	26.	< 1	6.2	0.28	562.
13105932DCC2	172.	37.0	26.6	9.6	115.	0.430	3.76	22.3	0.20	7.35	< 1	495.	< 1	405.	1600	450.	< 0.05	440.	26.	33.0	45.2	3.57	1050
13105933DBB	4.0	53.1	23.9	2.6	156.	0.403	0.437	49.3	0.16	6.95	< 1	176.	< 1	144.	1200	458.	< 0.05	609.	36.	1.50	1.4	0.07	812.
13105934DAA	28.5	52.5	26.1	10.2	73.7	1.33	1.87	4.3	0.33	6.77	< 1	398.	< 1	326.	928.	181.	< 0.05	400.	23.	16.0	13.0	0.62	548.
13105935DCC	24.0	30.7	25.9	4.5	96.1	0.673	0.355	5.2	0.31	7.00	< 1	430.	< 1	352.	838.	107.	< 0.05	367.	21.	3.30	12.2	0.55	481.
13105936BBB2	18.1	39.9	27.4	5.0	126.	0.635	0.735	14.1	0.31	6.86	< 1	350.	< 1	287.	1060	277.	< 0.05	479.	28.	3.00	7.5	0.36	655.
MINIMUM	< 0.1	8.6	12.3	< 1	26.3	0.002	< 0.007	< 1	0.11	6.73	< 1	132.	< 1	108.	241.	6.	< 0.05	101.	6.	< 1	0.2	0.00	129.
MAXIMUM	6000	1620	98.7	94.8	531.	94.7	1570	1080	1.25	7.84	< 1	1110	< 1	909.	26100	18500	43.4	7740	452.	35000	62.3	29.6	28100
MEAN	125.9	75.8	31.4	7.3	122.5	3.106	39.46	35.7	0.35	7.24	0.5	400	0.5	327	1434.3	529	1.42	618	36	605	13.6	1.2	1102
MEDIAN	17.9	34.0	28.4	5.1	96.3	0.735	3.04	12.3	0.30	7.28	0.5	381	0.5	312	862.0	118	0.05	392	23	27	9.2	0.4	510
STDDEV	659.6	193.1	12.6	10.7	89.6	12.869	183.93	122.1	0.20	0.27	0.0	145	0.0	119	2924.9	2099	5.59	945	55	3844	13.1	3.4	3140

All units reported in mg/l except: pH, Conductivity (umhos/cm), Hardness (gr/gal), Turbidity (NTU), % Na (%), and SAR (Sodium Adsorption ration).
CaCO3 is total hardness measured as calcium carbonate.

*** Warwick Aquifer ***

WELL ID (TRSQ)	Na	Mg	SiO2	K	Ca	Mn	Fe	Cl	F	pH	CO3	HCO3	OH	Alk.	Cond.	SO4	NO3	CaCO3	Hard.	Turb.	% Na	SAR	TDS
15006203ABC	25.2	23.8	24.1	2.3	94.3	1.16	0.061	4.6	0.20	7.45	< 1	442.	< 1	362.	782.	56.	1.00	334.	19.	1.20	13.9	0.60	430.
15006206DAA	0.6	21.6	28.4	< 1	95.6	0.171	1.34	< 1	0.18	7.55	< 1	388.	< 1	318.	586.	11.	< 0.05	328.	19.	8.20	0.4	0.01	324.
15006207DAA	2.9	17.1	33.1	2.1	56.3	0.542	3.93	< 1	0.21	7.36	< 1	272.	< 1	223.	426.	10.	< 0.05	211.	12.	34.0	2.9	0.09	225.
15006210DBC	1.7	11.7	26.3	1.7	47.8	1.00	0.804	< 1	0.24	7.55	< 1	207.	< 1	170.	369.	24.	< 0.05	168.	10.	9.80	2.1	0.06	192.
15006304BBA	3.0	18.4	35.6	1.7	57.9	2.92	13.6	6.7	0.32	7.56	< 1	236.	< 1	193.	405.	18.	0.65	220.	13.	80.0	2.8	0.09	227.
15006306DDD	26.5	23.3	26.5	4.7	86.6	0.467	0.061	13.6	0.23	7.59	< 1	361.	< 1	296.	748.	93.	0.05	312.	18.	27.0	15.3	0.65	428.
15006310CDD	0.2	13.7	26.0	< 1	51.1	0.102	2.11	< 1	0.17	7.67	< 1	227.	< 1	186.	377.	6.	2.89	184.	11.	15.0	0.2	0.01	200.
15006310CDD	< 0.1	13.9	26.7	< 1	52.8	0.004	0.273	1.3	0.12	7.43	< 1	228.	< 1	187.	392.	6.	4.78	189.	11.	2.10	0.1	0.00	211.
15006313BBB1	2.2	39.2	18.4	1.7	50.5	0.033	0.673	< 1	0.28	7.43	< 1	293.	< 1	240.	500.	27.	2.51	288.	17.	5.10	1.6	0.06	279.
15006313BBB2	3.7	20.0	27.4	3.1	64.5	0.508	0.312	1.3	0.23	7.51	< 1	285.	< 1	233.	501.	38.	0.24	244.	14.	5.90	3.1	0.10	274.
15106215CCC	2.7	28.0	22.9	2.4	85.6	0.397	0.091	7.1	0.30	7.75	< 1	297.	< 1	243.	651.	103.	1.23	329.	19.	2.90	1.7	0.06	383.
15106216ADA1	2.7	32.4	31.7	1.1	79.2	0.478	2.90	10.4	0.29	7.65	< 1	273.	< 1	224.	719.	76.	13.5	331.	19.	22.0	1.7	0.06	398.
15106216ADA2	4.4	19.0	28.8	3.4	74.5	0.580	0.238	2.5	0.29	7.67	< 1	314.	< 1	257.	547.	43.	< 0.05	264.	15.	3.30	3.4	0.12	304.
15106216BCC1	5.5	30.9	32.2	3.3	94.5	1.11	4.20	15.3	0.24	7.68	< 1	267.	< 1	219.	803.	74.	31.6	363.	21.	18.0	3.1	0.13	498.
15106216BCC2	5.3	32.2	25.4	3.4	104.	0.137	0.436	16.1	0.25	7.53	< 1	286.	< 1	234.	852.	111.	25.5	393.	23.	6.50	2.8	0.12	528.
15106217ADA1	11.9	31.7	29.8	3.6	120.	0.386	1.50	10.1	0.31	8.00	< 1	289.	< 1	237.	904.	98.	30.9	430.	25.	15.0	5.6	0.25	557.
15106217ADA2	29.6	21.0	31.7	6.3	74.1	0.496	0.203	3.4	0.26	7.57	< 1	352.	< 1	288.	652.	67.	< 0.05	272.	16.	3.40	18.6	0.78	377.
15106219ABB	4.2	17.8	28.1	2.2	62.5	0.509	8.86	1.5	0.20	7.64	< 1	227.	< 1	186.	477.	66.	< 0.05	229.	13.	46.0	3.8	0.12	268.
15106220DAD2	2.5	14.7	27.6	2.1	56.7	0.677	0.633	1.2	0.23	7.61	< 1	256.	< 1	210.	433.	24.	< 0.05	202.	12.	14.0	2.6	0.08	229.
15106223ABB3	2.2	23.7	28.8	1.7	84.4	0.384	0.556	15.4	0.30	7.90	< 1	261.	< 1	214.	610.	91.	< 0.05	309.	18.	6.40	1.5	0.05	349.
15106224CCC3	0.4	19.2	25.1	5.8	82.7	4.81	0.591	< 1	0.10	7.05	< 1	382.	< 1	313.	580.	< 3	< 0.05	286.	17.	5.60	0.3	0.01	302.
15106225DAA3	3.3	33.7	24.7	2.3	107.	< 0.002	0.011	30.3	0.20	7.55	< 1	287.	< 1	235.	868.	90.	25.0	406.	24.	1.60	1.7	0.07	521.
15106225DAA4	2.0	21.2	29.7	2.0	51.3	0.782	2.85	2.6	0.28	7.70	< 1	257.	< 1	210.	427.	10.	2.18	215.	13.	35.0	1.9	0.06	227.
15106227AAA1	22.3	23.0	22.6	5.1	85.1	1.18	3.35	3.5	0.30	7.56	< 1	348.	< 1	285.	605.	44.	< 0.05	307.	18.	57.0	13.3	0.55	357.
15106317ABC	45.3	6.5	28.0	2.0	31.2	0.245	0.471	2.0	0.13	7.56	< 1	240.	< 1	197.	420.	26.	< 0.05	105.	6.	9.00	47.7	1.92	233.
15106320DDC	2.8	37.4	35.3	2.9	91.6	0.611	14.8	3.0	0.20	7.54	< 1	275.	< 1	225.	692.	154.	< 0.05	383.	22.	85.0	1.5	0.06	429.
15106322BDA	10.5	16.8	23.1	1.4	51.3	0.115	0.014	7.2	0.25	7.60	< 1	232.	< 1	190.	469.	38.	2.94	197.	12.	2.30	10.2	0.32	255.
15106325ABA1	6.0	25.7	61.1	3.1	83.3	1.62	22.0	11.5	0.20	7.62	< 1	207.	< 1	170.	606.	50.	24.2	314.	18.	195.	3.9	0.15	391.
15106325ABA2	2.1	20.1	23.4	1.5	73.2	0.318	0.150	6.9	0.22	7.62	< 1	260.	< 1	213.	558.	80.	< 0.05	266.	16.	3.20	1.7	0.06	314.
15106329DCC	39.5	25.2	32.2	6.5	39.6	0.196	1.07	1.7	0.22	7.88	< 1	314.	< 1	257.	590.	64.	< 0.05	203.	12.	5.60	28.8	1.21	333.
15106330ACC	83.2	28.3	35.3	15.8	97.2	1.28	3.23	9.6	0.21	7.72	< 1	511.	< 1	419.	934.	101.	< 0.05	359.	21.	350.	32.2	1.91	589.
15106334CCC	2.0	19.1	24.6	< 1	71.9	0.078	0.265	4.4	0.20	7.61	< 1	294.	< 1	241.	512.	35.	1.07	258.	15.	3.40	1.6	0.05	285.
15106335CCC	6.8	23.5	20.4	2.8	69.5	1.51	58.1	< 1	0.19	7.55	< 1	273.	< 1	224.	495.	44.	0.13	270.	16.	370.	5.1	0.18	285.
15106335CCC	6.5	23.8	32.8	3.0	71.3	0.294	0.824	2.2	0.14	7.50	< 1	280.	< 1	229.	512.	54.	< 0.05	276.	16.	800.	4.8	0.17	301.
MINIMUM	< 0.1	6.5	18.4	< 1	31.2	< 0.002	0.011	< 1	0.10	7.05	< 1	207.	< 1	170.	369.	< 3	< 0.05	105.	6.	1.20	0.1	0.00	192.
MAXIMUM	83.2	39.2	61.1	15.8	120.	4.81	58.1	30.3	0.32	8.00	< 1	511.	< 1	419.	934.	154.	31.6	430.	25.	800.	47.7	1.92	589.
MEAN	10.9	22.9	28.8	3.0	73.5	0.738	4.43	5.9	0.23	7.59	0.5	292	0.5	239	588.3	54	5.02	278	16	66	7.1	0.3	338
MEDIAN	3.5	22.3	27.8	2.3	73.7	0.487	0.74	3.2	0.23	7.58	0.5	278	0.5	227	569.0	47	0.09	274	16	9	2.9	0.1	309
STDDEV	17.2	7.4	7.1	2.7	20.8	0.933	10.67	6.5	0.06	0.16	0.0	66	0.0	54	160.3	37	9.84	75	4	157	10.6	0.5	108

All units reported in mg/l except: pH, Conductivity (umhos/cm), Hardness (gr/gal), Turbidity (NTU), % Na (%), and SAR (Sodium Adsorption ration).
CaCO3 is total hardness measured as calcium carbonate.

*** Spring Creek Aquifer ***

WELL ID (TRSQ)	Na	Mg	SiO2	K	Ca	Mn	Fe	Cl	F	pH	CO3	HCO3	OH	Alk.	Cond.	SO4	NO3	CaCO3	Hard.	Turb.	% Na	SAR	TDS
12906809CCB2	13.3	26.9	33.9	7.3	109.	1.36	7.47	6.8	0.27	7.18	< 1	426.	< 1	349.	793.	76.	< 0.05	383.	22.	40.0	6.8	0.30	451.
12906903AAA2	26.9	40.4	27.2	7.2	124.	1.65	5.33	20.4	0.25	7.19	< 1	334.	< 1	274.	1000	254.	< 0.05	476.	28.	46.0	10.7	0.54	640.
13006910BBB	23.9	25.1	26.8	6.9	75.8	1.07	11.0	2.7		7.19	< 1	392.	< 1	321.	711.	70.	< 0.05	293.	17.	90.0	14.6	0.61	400.
13006921BBB2	104.	46.5	30.0	7.0	120.	0.593	3.83	14.4		7.21	< 1	483.	< 1	396.	1380	373.	< 0.05	491.	29.	34.0	31.0	2.04	905.
MINIMUM	13.3	25.1	26.8	6.9	75.8	0.593	3.83	2.7	0.25	7.18	< 1	334.	< 1	274.	711.	70.	< 0.05	293.	17.	34.0	6.8	0.30	400.
MAXIMUM	104.	46.5	33.9	7.3	124.	1.65	11.0	20.4	0.27	7.21	< 1	483.	< 1	396.	1380	373.	< 0.05	491.	29.	90.0	31.0	2.04	905.
MEAN	42.0	34.7	29.5	7.1	107.2	1.168	6.91	11.1	0.26	7.19	0.5	409	0.5	335	971.0	193	0.05	411	24	53	15.8	0.9	599
MEDIAN	25.4	33.7	28.6	7.1	114.5	1.215	6.40	10.6	0.26	7.19	0.5	409	0.5	335	896.5	165	0.05	430	25	43	12.7	0.6	546
STDDEV	41.7	10.4	3.3	0.2	21.9	0.451	3.11	7.9	0.01	0.01	0.0	62	0.0	51	298.6	147	0.00	92	6	25	10.6	0.8	229

*** Streeter Aquifer ***

WELL ID (TRSQ)	Na	Mg	SiO2	K	Ca	Mn	Fe	Cl	F	pH	CO3	HCO3	OH	Alk.	Cond.	SO4	NO3	CaCO3	Hard.	Turb.	% Na	SAR	TDS
13506906CCC	73.3	43.4	31.6	10.8	79.7	1.35	5.19	9.0	0.27	7.42	< 1	541.	< 1	443.	1020	114.	< 0.05	378.	22.	47.0	28.8	1.64	599.
13506907DDD	5.1	30.9	29.3	1.5	92.8	0.096	3.70	17.4	0.26	7.43	< 1	359.	< 1	294.	690.	28.	5.96	359.	21.	45.0	3.0	0.12	381.
13506909CCC	54.2	94.4	23.9	12.0	182.	0.992	0.376	98.6	0.30	7.26	< 1	467.	< 1	382.	1850	470.	15.8	843.	49.	6.10	12.0	0.81	1210
13506921BAB2	28.1	17.5	31.6	6.4	69.1	2.69	16.0	6.2	0.35	7.55	< 1	289.	< 1	237.	549.	57.	< 0.05	245.	14.	235.	19.4	0.78	329.
13506934BBB	56.2	39.9	27.8	9.2	185.	1.00	3.59	33.1	0.37	7.24	< 1	360.	< 1	295.	1400	443.	< 0.05	627.	37.	29.0	16.0	0.98	946.
13606918CCC2	42.7	45.0	27.4	5.1	137.	0.997	9.60	15.1	0.26	7.26	< 1	393.	< 1	322.	1150	305.	< 0.05	528.	31.	72.0	14.7	0.81	746.
13606931DCC	63.7	38.2	20.9	7.4	111.	0.548	0.020	103.	0.14	7.39	< 1	367.	< 1	301.	1170	165.	0.60	435.	25.	< 1	23.7	1.33	674.
13607002BBB	9.9	42.3	26.4	4.2	97.2	9.58	298.	4.0	0.16	7.38	< 1	286.	< 1	234.	735.	158.	0.14	417.	24.	2200	4.8	0.21	459.
13607003ABB	3.6	21.0	28.8	2.7	52.8	2.32	81.7	< 1	0.21	7.84	< 1	242.	< 1	198.	397.	21.	2.18	218.	13.	320.	3.4	0.11	233.
13607004BDB	24.7	52.2	27.9	49.4	123.	0.040	0.085	63.3	0.21	7.27	< 1	441.	< 1	361.	1340	88.	43.4	522.	31.	1.00	8.4	0.47	813.
13607005AAD	8.2	22.6	25.5	< 1	49.6	1.12	55.9	< 1	0.30	7.63	< 1	269.	< 1	220.	398.	3.	< 0.05	217.	13.	290.	7.5	0.24	220.
13607006BBB	17.1	20.7	28.6	3.6	63.6	0.955	2.61	2.9	0.23	7.51	< 1	271.	< 1	222.	574.	80.	< 0.05	244.	14.	27.0	13.0	0.48	324.
13607007BBB	35.9	31.2	39.1	8.1	114.	2.89	13.7	8.2	0.23	7.51	< 1	349.	< 1	286.	777.	126.	< 0.05	413.	24.	200.	15.5	0.77	497.
13607008BBB	24.4	27.7	36.0	4.7	74.1	1.53	4.16	2.9	0.21	7.70	< 1	287.	< 1	235.	640.	106.	< 0.05	299.	17.	90.0	14.8	0.61	383.
13607009DDA	10.1	22.5	28.5	2.7	71.7	0.927	0.059	2.8	0.24	7.40	< 1	271.	< 1	222.	588.	91.	< 0.05	272.	16.	2.10	7.4	0.27	336.
13607010DCD	13.5	20.3	28.4	3.2	68.5	0.923	0.024	3.8	0.18	7.57	< 1	282.	< 1	231.	595.	83.	< 0.05	255.	15.	< 1	10.1	0.37	333.
13607015AAA3	1.8	18.7	24.5	1.3	60.7	< 0.002	0.115	< 1	0.18	7.77	< 1	251.	< 1	206.	465.	20.	5.44	229.	13.	1.00	1.7	0.05	253.
13607016BBB2	24.7	24.9	27.5	4.3	59.7	0.896	2.44	3.1	0.24	7.51	< 1	298.	< 1	244.	632.	87.	0.05	252.	15.	24.0	17.2	0.68	353.
13607017DDD2	9.2	20.7	27.7	2.7	62.2	0.794	1.93	2.0	0.24	7.54	< 1	242.	< 1	198.	552.	92.	< 0.05	241.	14.	19.0	7.5	0.26	310.
13607018BBB	30.5	25.4	24.7	7.8	46.4	3.29	0.975	3.3	0.25	7.30	< 1	316.	< 1	259.	589.	59.	< 0.05	221.	13.	16.0	22.3	0.89	330.
13607020DDA	1.3	37.2	28.3	< 1	49.1	4.55	99.0	2.5	0.32	7.80	< 1	281.	< 1	230.	477.	26.	4.28	276.	16.	850.	1.0	0.03	277.
13607022CCC	16.5	26.1	32.8	3.7	80.1	0.824	2.68	3.3	0.23	7.47	< 1	249.	< 1	204.	624.	130.	< 0.05	308.	18.	39.0	10.3	0.41	384.
13607023BBB	15.2	29.2	35.0	3.4	85.1	3.14	23.4	7.1	0.23	7.46	< 1	275.	< 1	225.	630.	111.	< 0.05	333.	19.	27.0	8.9	0.36	389.
13607025ABB	8.0	21.6	30.2	6.3	64.9	3.25	5.50	1.4	0.26	7.55	< 1	266.	< 1	218.	518.	50.	1.09	251.	15.	57.0	6.3	0.22	290.
13607026CCB	21.5	26.4	28.1	3.9	78.8	0.640	2.02	2.8	0.24	7.57	< 1	251.	< 1	206.	668.	145.	0.57	306.	18.	40.0	13.0	0.53	407.
13707015CCC	22.5	33.4	46.0	7.9	101.	20.0	275.	3.0	0.32	7.56	< 1	383.	< 1	314.	767.	126.	< 0.05	390.	23.	8800	10.9	0.50	485.
13707023DAD	75.7	12.5	29.2	4.0	30.1	0.350	0.543	4.7	0.64	7.72	< 1	333.	< 1	273.	594.	53.	< 0.05	127.	7.	17.0	55.4	2.92	346.
13707035AAA	5.7	23.5	27.8	3.0	74.1	0.759	2.06	< 1	0.17	7.63	< 1	256.	< 1	210.	530.	86.	< 0.05	282.	16.	39.0	4.1	0.15	321.
MINIMUM	1.3	12.5	20.9	< 1	30.1	< 0.002	0.020	< 1	0.14	7.24	< 1	242.	< 1	198.	397.	3.	< 0.05	127.	7.	< 1	1.0	0.03	220.
MAXIMUM	75.7	94.4	46.0	49.4	185.	20.0	298.	103.	0.64	7.84	< 1	541.	< 1	443.	1850	470.	43.4	843.	49.	8800	55.4	2.92	1210
MEAN	25.1	31.1	29.4	6.4	84.4	2.373	32.51	14.5	0.26	7.51	0.5	317	0.5	260	747.1	119	2.85	339	20	482	12.9	0.6	451
MEDIAN	19.3	26.3	28.4	4.1	74.1	0.995	3.14	3.3	0.24	7.51	0.5	287	0.5	235	627.0	90	0.05	291	17	39	10.6	0.5	367
STDDEV	21.7	15.7	5.0	8.9	37.1	3.951	75.93	27.5	0.09	0.17	0.0	75	0.0	61	342.9	112	8.60	149	9	1687	10.8	0.6	233

All units reported in mg/l except: pH, Conductivity (umhos/cm), Hardness (gr/gal), Turbidity (NTU), % Na (%), and SAR (Sodium Adsorption ration).
CaCO3 is total hardness measured as calcium carbonate.

APPENDIX C

Aquifer Maps Showing Sample Locations

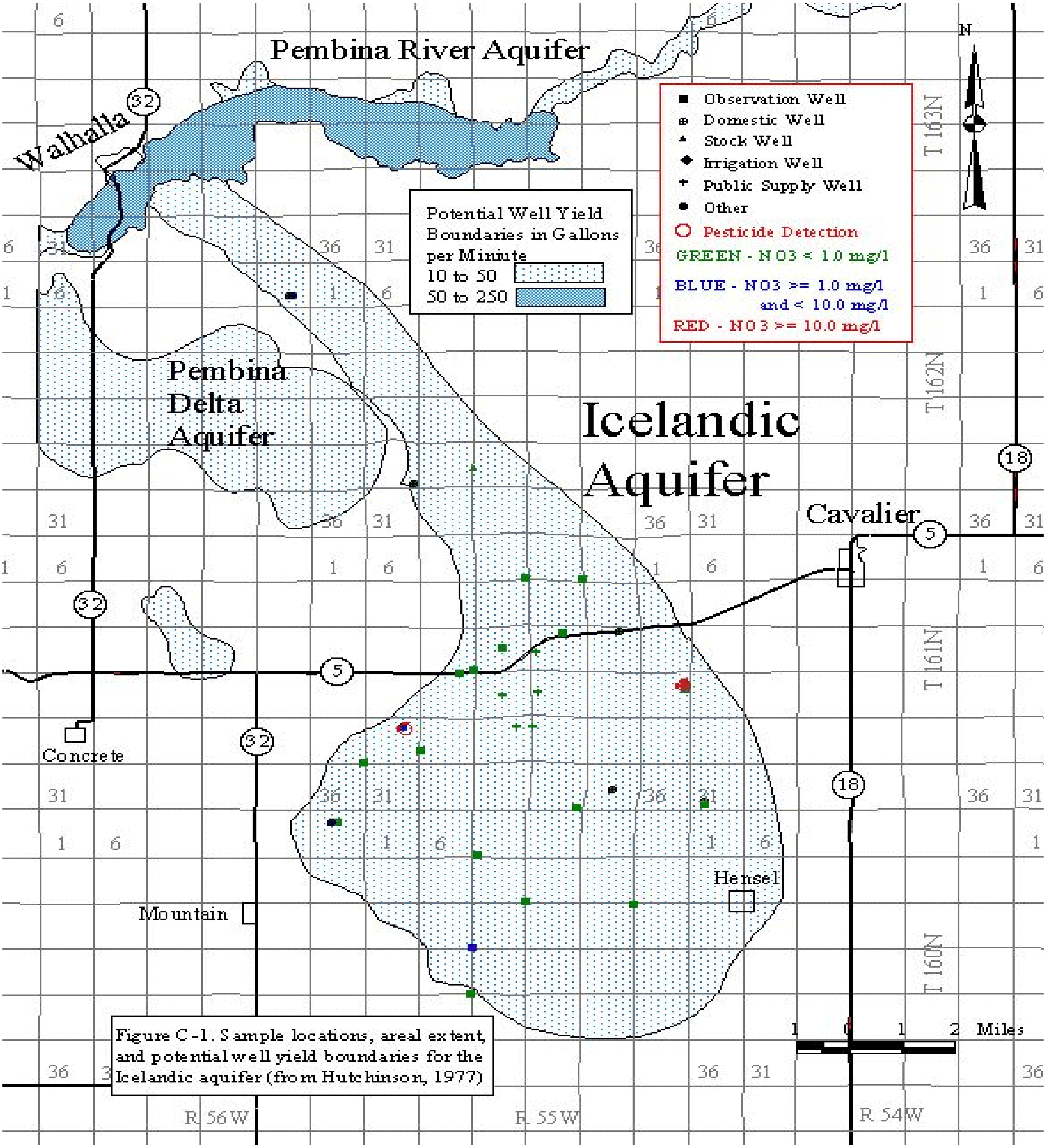


Figure C-1. Sample locations, areal extent, and potential well yield boundaries for the Icelandic aquifer (from Hutchinson, 1977)

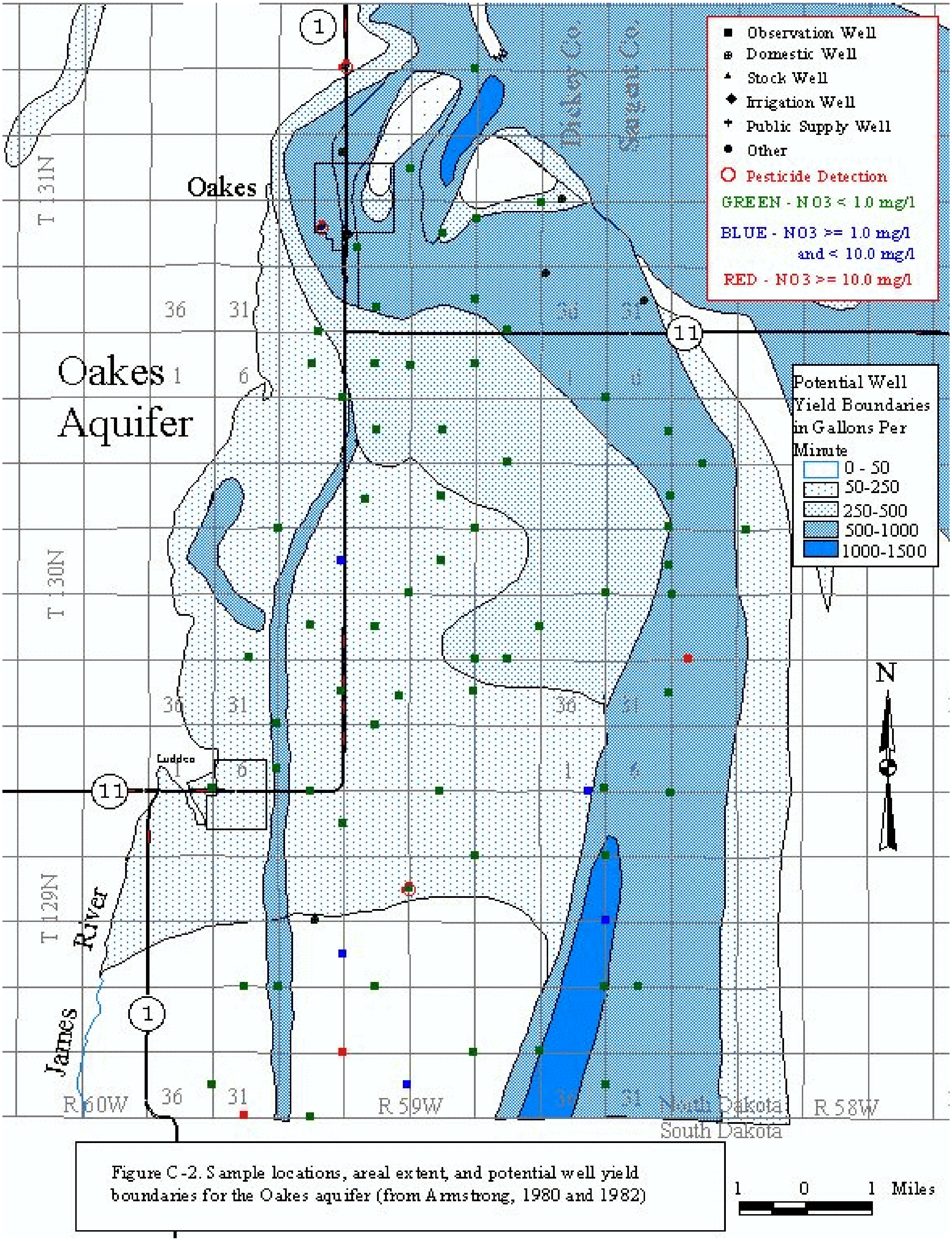


Figure C-2. Sample locations, areal extent, and potential well yield boundaries for the Oakes aquifer (from Armstrong, 1980 and 1982)

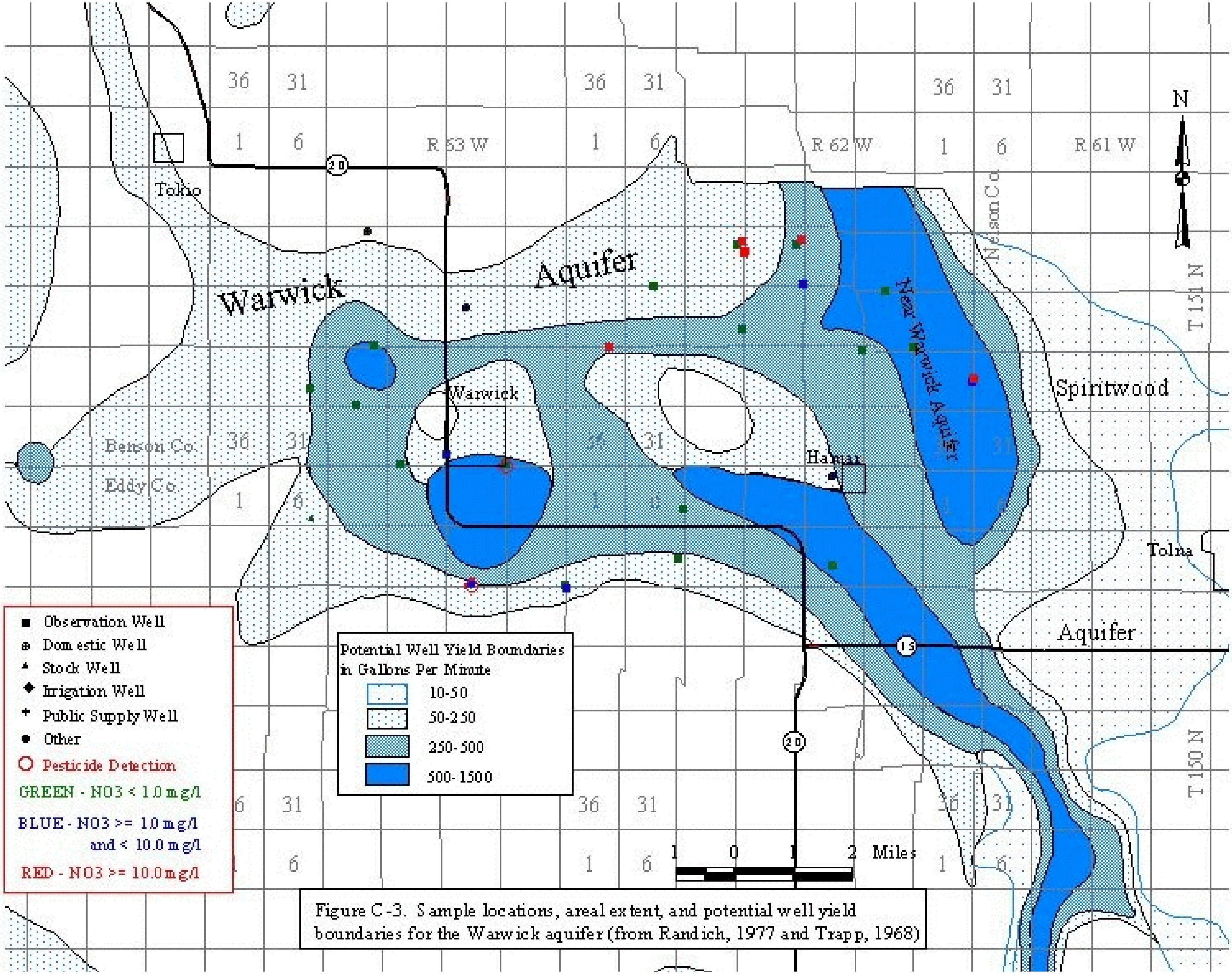


Figure C-3. Sample locations, areal extent, and potential well yield boundaries for the Warwick aquifer (from Randich, 1977 and Trapp, 1968)

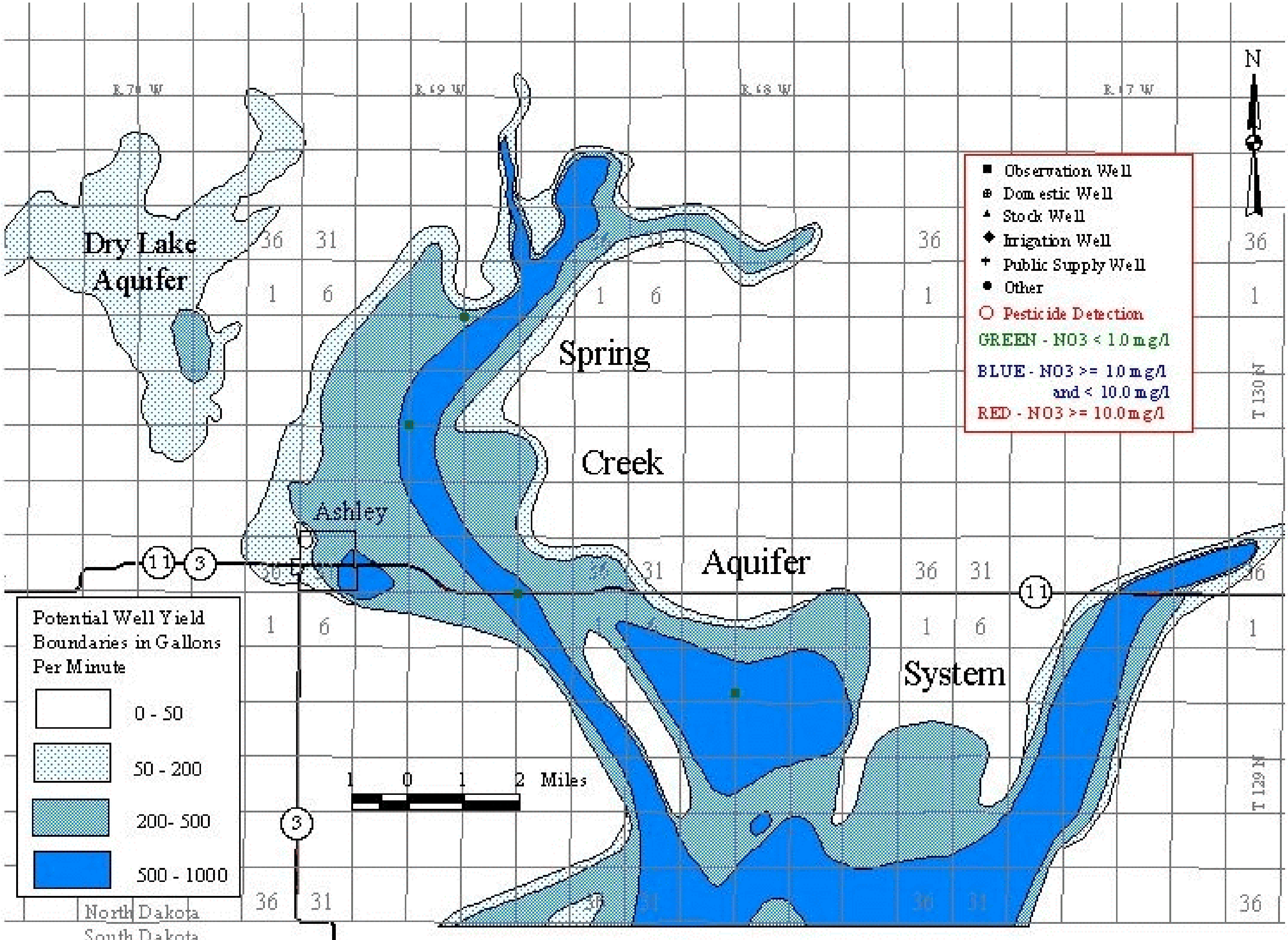


Figure C-4. Sample locations, areal extent, and potential well yield boundaries for the Spring Creek aquifer (from Klausing, 1981)

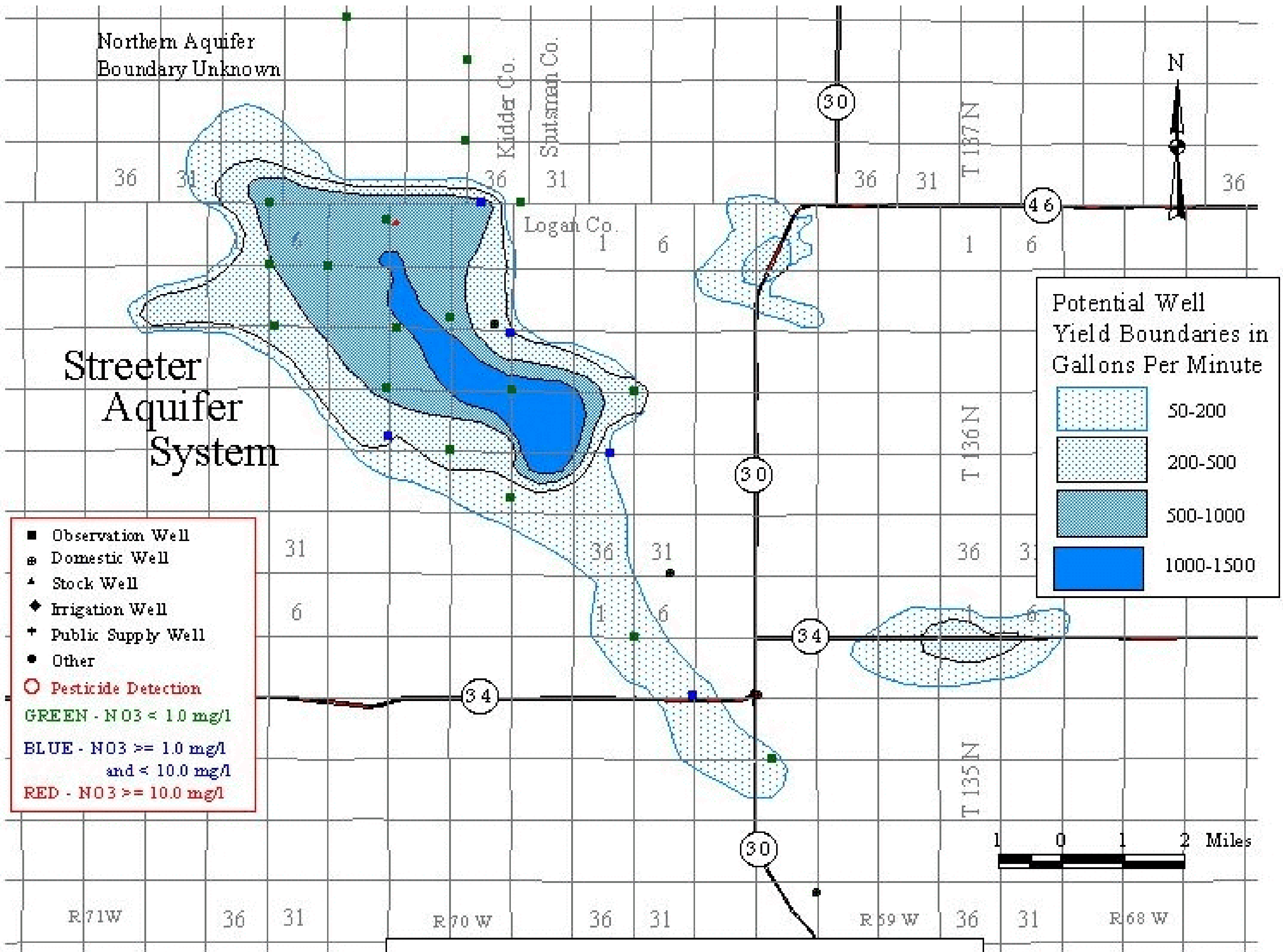


Figure C-5. Sample locations, areal extent, and potential well yield boundaries for the Streeter aquifer system (from Klausing, 1983)

APPENDIX D

Summary Tables
for Well-Construction and Site -Inventory Characteristics
Related to Pesticide and Nitrate /Nitrite Detections for Each Aquifer

Pesticide and Nitrate Plus Nitrite Detections
Related to Well Construction
For the Icelandic Aquifer

Wells with only pesticide detections	:	0	0.0 %
Wells with only nitrate detections	:	12	35.3 %
Wells with pesticide & nitrate detections	:	2	5.9 %
Wells with nitrate > 10 mg/L	:	1	2.9 %

Total number of wells in sample population : 34

DEPTH OF WELLS	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
< 20 Ft. :	13	38.2	2	15.4	10	76.9
20 - 50 Ft. :	12	35.3	0	0.0	2	16.7
> 50 Ft. :	8	23.5	0	0.0	1	12.5
Unknown :	1	2.9	0	0.0	1	100.0

DEPTH TO TOP OF SCREENED INTERVAL	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
< 20 Ft. :	14	41.2	2	14.3	8	57.1
20 - 50 Ft. :	9	26.5	0	0.0	1	11.1
> 50 Ft. :	7	20.6	0	0.0	1	14.3
Unknown :	4	11.8	0	0.0	4	100.0

DIAMETER OF WELL	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
< 6 in. :	21	61.8	1	4.8	8	38.1
6 - 18 in. :	5	14.7	0	0.0	1	20.0
> 18 in. :	7	20.6	1	14.3	4	57.1
Unknown :	1	2.9	0	0.0	1	100.0

DISTANCE FROM WATER TABLE TO TOP OF SCREEN	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
< 10 Ft. :	7	20.6	0	0.0	5	71.4
10 - 30 Ft. :	5	14.7	0	0.0	0	0.0
> 30 Ft. :	6	17.6	0	0.0	0	0.0
Unknown :	16	47.1	2	12.5	9	56.3

CASING MATERIAL	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
Plastic(PVC or ABS) :	18	52.9	0	0.0	5	27.8
Concrete/Brick/Stone :	11	32.4	2	18.2	8	72.7
Metallic :	5	14.7	0	0.0	1	20.0
Other :	0	0.0	0	*****	0	*****

TYPE OF WELL	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
Monitoring :	18	52.9	0	0.0	5	27.8
Private/Domestic :	8	23.5	0	0.0	5	62.5
Livestock :	2	5.9	1	50.0	2	100.0
Public Supply :	5	14.7	0	0.0	1	20.0
Irrigation :	1	2.9	1	100.0	1	100.0
Other :	0	0.0	0	*****	0	*****

Pesticide and Nitrate Plus Nitrite Detections
Related to Well Construction
For the Oakes Aquifer

Wells with only pesticide detections	:	1	1.2 %
Wells with only nitrate detections	:	13	16.0 %
Wells with pesticide & nitrate detections	:	2	2.5 %
Wells with nitrate > 10 mg/L	:	4	4.9 %

Total number of wells in sample population : 81

DEPTH OF WELLS	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
< 20 Ft. :	27	33.3	1	3.7	6	22.2
20 - 50 Ft. :	47	58.0	2	4.3	8	17.0
> 50 Ft. :	7	8.6	0	0.0	1	14.3
Unknown :	0	0.0	0	*****	0	*****

DEPTH TO TOP OF SCREENED INTERVAL	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
< 20 Ft. :	51	63.0	1	2.0	12	23.5
20 - 50 Ft. :	24	29.6	2	8.3	3	12.5
> 50 Ft. :	3	3.7	0	0.0	0	0.0
Unknown :	3	3.7	0	0.0	0	0.0

DIAMETER OF WELL	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
< 6 in. :	80	98.8	3	3.8	15	18.8
6 - 18 in. :	1	1.2	0	0.0	0	0.0
> 18 in. :	0	0.0	0	*****	0	*****
Unknown :	0	0.0	0	*****	0	*****

DISTANCE FROM WATER TABLE TO TOP OF SCREEN	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
< 10 Ft. :	12	14.8	0	0.0	3	25.0
10 - 30 Ft. :	52	64.2	1	1.9	9	17.3
> 30 Ft. :	9	11.1	0	0.0	0	0.0
Unknown :	8	9.9	2	25.0	3	37.5

CASING MATERIAL	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
Plastic(PVC or ABS) :	78	96.3	3	3.8	15	19.2
Concrete/Brick/Stone :	0	0.0	0	*****	0	*****
Metallic :	1	1.2	0	0.0	0	0.0
Other :	2	2.5	0	0.0	0	0.0

TYPE OF WELL	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
Monitoring :	73	90.1	1	1.4	12	16.4
Private/Domestic :	8	9.9	2	25.0	3	37.5
Livestock :	0	0.0	0	*****	0	*****
Public Supply :	0	0.0	0	*****	0	*****
Irrigation :	0	0.0	0	*****	0	*****
Other :	0	0.0	0	*****	0	*****

is the number of wells or detections in that category.
% is the percentage of wells or detections in that category.

Pesticide and Nitrate Plus Nitrite Detections
Related to Well Construction
For the Warwick Aquifer

Wells with only pesticide detections	:	0	0.0 %
Wells with only nitrate detections	:	15	46.9 %
Wells with pesticide & nitrate detections	:	2	6.3 %
Wells with nitrate > 10 mg/L	:	6	18.8 %

Total number of wells in sample population : 32

DEPTH OF WELLS	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
< 20 Ft. :	7	21.9	0	0.0	4	57.1
20 - 50 Ft. :	22	68.8	2	9.1	13	59.1
> 50 Ft. :	3	9.4	0	0.0	0	0.0
Unknown :	0	0.0	0	*****	0	*****

DIAMETER OF WELL	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
< 6 in. :	30	93.8	2	6.7	15	50.0
6 - 18 in. :	1	3.1	0	0.0	1	100.0
> 18 in. :	0	0.0	0	*****	0	*****
Unknown :	1	3.1	0	0.0	1	100.0

CASING MATERIAL	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
Plastic(PVC or ABS) :	26	81.3	1	3.8	13	50.0
Concrete/Brick/Stone :	0	0.0	0	*****	0	*****
Metallic :	2	6.3	0	0.0	1	50.0
Other :	4	12.5	1	25.0	3	75.0

DEPTH TO TOP OF SCREENED INTERVAL	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
< 20 Ft. :	16	50.0	2	12.5	11	68.8
20 - 50 Ft. :	9	28.1	0	0.0	4	44.4
> 50 Ft. :	2	6.3	0	0.0	0	0.0
Unknown :	5	15.6	0	0.0	2	40.0

DISTANCE FROM WATER TABLE TO TOP OF SCREEN	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
< 10 Ft. :	18	56.3	1	5.6	13	72.2
10 - 30 Ft. :	9	28.1	1	11.1	2	22.2
> 30 Ft. :	2	6.3	0	0.0	0	0.0
Unknown :	3	9.4	0	0.0	2	66.7

TYPE OF WELL	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
Monitoring :	28	87.5	2	7.1	14	50.0
Private/Domestic :	3	9.4	0	0.0	2	66.7
Livestock :	1	3.1	0	0.0	1	100.0
Public Supply :	0	0.0	0	*****	0	*****
Irrigation :	0	0.0	0	*****	0	*****
Other :	0	0.0	0	*****	0	*****

Pesticide and Nitrate Plus Nitrite Detections
Related to Well Construction
For the Spring Creek Aquifer

Wells with only pesticide detections	:	0	0.0 %
Wells with only nitrate detections	:	0	0.0 %
Wells with pesticide & nitrate detections	:	0	0.0 %
Wells with nitrate > 10 mg/L	:	0	0.0 %

Total number of wells in sample population : 4

DEPTH OF WELLS	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
< 20 Ft. :	0	0.0	0	*****	0	*****
20 - 50 Ft. :	0	0.0	0	*****	0	*****
> 50 Ft. :	4	100.0	0	0.0	0	0.0
Unknown :	0	0.0	0	*****	0	*****

DIAMETER OF WELL	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
< 6 in. :	4	100.0	0	0.0	0	0.0
6 - 18 in. :	0	0.0	0	*****	0	*****
> 18 in. :	0	0.0	0	*****	0	*****
Unknown :	0	0.0	0	*****	0	*****

CASING MATERIAL	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
Plastic(PVC or ABS) :	4	100.0	0	0.0	0	0.0
Concrete/Brick/Stone :	0	0.0	0	*****	0	*****
Metallic :	0	0.0	0	*****	0	*****
Other :	0	0.0	0	*****	0	*****

DEPTH TO TOP OF SCREENED INTERVAL	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
< 20 Ft. :	0	0.0	0	*****	0	*****
20 - 50 Ft. :	1	25.0	0	0.0	0	0.0
> 50 Ft. :	3	75.0	0	0.0	0	0.0
Unknown :	0	0.0	0	*****	0	*****

DISTANCE FROM WATER TABLE TO TOP OF SCREEN	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
< 10 Ft. :	0	0.0	0	*****	0	*****
10 - 30 Ft. :	2	50.0	0	0.0	0	0.0
> 30 Ft. :	2	50.0	0	0.0	0	0.0
Unknown :	0	0.0	0	*****	0	*****

TYPE OF WELL	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
Monitoring :	4	100.0	0	0.0	0	0.0
Private/Domestic :	0	0.0	0	*****	0	*****
Livestock :	0	0.0	0	*****	0	*****
Public Supply :	0	0.0	0	*****	0	*****
Irrigation :	0	0.0	0	*****	0	*****
Other :	0	0.0	0	*****	0	*****

is the number of wells or detections in that category.
% is the percentage of wells or detections in that category

Pesticide and Nitrate Plus Nitrite Detections
Related to Well Construction
For the Streeter Aquifer

Wells with only pesticide detections	:	0	0.0 %
Wells with only nitrate detections	:	11	39.3 %
Wells with pesticide & nitrate detections	:	0	0.0 %
Wells with nitrate > 10 mg/L	:	2	7.1 %

Total number of wells in sample population : 28

DEPTH OF WELLS	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
< 20 Ft. :	3	10.7	0	0.0	2	66.7
20 - 50 Ft. :	17	60.7	0	0.0	8	47.1
> 50 Ft. :	8	28.6	0	0.0	1	12.5
Unknown :	0	0.0	0	*****	0	*****

DEPTH TO TOP OF SCREENED INTERVAL	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
< 20 Ft. :	4	14.3	0	0.0	3	75.0
20 - 50 Ft. :	19	67.9	0	0.0	8	42.1
> 50 Ft. :	5	17.9	0	0.0	0	0.0
Unknown :	0	0.0	0	*****	0	*****

DIAMETER OF WELL	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
< 6 in. :	26	92.9	0	0.0	9	34.6
6 - 18 in. :	0	0.0	0	*****	0	*****
> 18 in. :	2	7.1	0	0.0	2	100.0
Unknown :	0	0.0	0	*****	0	*****

DISTANCE FROM WATER TABLE TO TOP OF SCREEN	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
< 10 Ft. :	7	25.0	0	0.0	6	85.7
10 - 30 Ft. :	11	39.3	0	0.0	4	36.4
> 30 Ft. :	10	35.7	0	0.0	1	10.0
Unknown :	0	0.0	0	*****	0	*****

CASING MATERIAL	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
Plastic(PVC or ABS) :	23	82.1	0	0.0	7	30.4
Concrete/Brick/Stone :	2	7.1	0	0.0	2	100.0
Metallic :	3	10.7	0	0.0	2	66.7
Other :	0	0.0	0	*****	0	*****

TYPE OF WELL	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
Monitoring :	23	82.1	0	0.0	8	34.8
Private/Domestic :	4	14.3	0	0.0	2	50.0
Livestock :	1	3.6	0	0.0	1	100.0
Public Supply :	0	0.0	0	*****	0	*****
Irrigation :	0	0.0	0	*****	0	*****
Other :	0	0.0	0	*****	0	*****

is the number of wells or detections in that category.
% is the percentage of wells or detections in that category.

Pesticide and Nitrate Plus Nitrite Detections
Related to Site Inventory Data
For the Icelandic Aquifer

Wells with only pesticide detections	:	0	0.0 %
Wells with only nitrate detections	:	12	35.3 %
Wells with pesticide & nitrate detections	:	2	5.9 %
Wells with nitrate > 10 mg/L	:	1	2.9 %

Total number of wells in sample population : 34

GENERAL SETTING	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
Farm Yard :	14	41.2	2	14.3	9	64.3
Field :	11	32.4	0	0.0	6	54.5
Pasture :	5	14.7	0	0.0	2	40.0
C.R.P. :	12	35.3	0	0.0	2	16.7
Roadside :	11	32.4	0	0.0	2	18.2
Town :	0	0.0	0	*****	0	*****

NEARBY FACTORS OF POSSIBLE INFLUENCE	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
Near Irrigation :	4	11.8	1	25.0	1	25.0
Near Feed Lot :	6	17.6	1	16.7	5	83.3
Near Disposal Area :	0	0.0	0	*****	0	*****
Near Septic System :	15	44.1	2	13.3	8	53.3
Near Surface Water :	5	14.7	0	0.0	3	60.0
Well in Depression :	0	0.0	0	*****	0	*****
Near Chemical Usage :	10	29.4	3	30.0	7	70.0
Other :	1	2.9	0	0.0	0	0.0

NEAR IRRIGATION	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	1	2.9	1	100.0	1	100.0
100 ft. - 1/8 mile :	3	8.8	0	0.0	0	0.0

NEAR A FEED LOT	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	4	11.8	1	25.0	3	75.0
100 ft. - 1/8 mile :	2	5.9	0	0.0	2	100.0

NEAR DISPOSAL AREA	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	0	0.0	0	*****	0	*****
100 ft. - 1/8 mile :	0	0.0	0	*****	0	*****

NEAR SEPTIC SYSTEM	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	9	26.5	1	11.1	6	66.7
100 ft. - 1/8 mile :	6	17.6	1	16.7	2	33.3

NEAR SURFACE WATER	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	2	5.9	0	0.0	1	50.0
100 ft. - 1/8 mile :	3	8.8	0	0.0	2	66.7

DEPRESSION AROUND WELL	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
Yes :	0	0.0	0	*****	0	*****
No :	34	100.0	2	5.9	14	41.2
Unknown :	0	0.0	0	*****	0	*****

NEAR CHEMICAL USAGE, MIXING, OR STORAGE	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
Pesticides :	4	11.8	2	50.0	3	75.0
Fertilizer :	3	8.8	0	0.0	1	33.3
Petroleum :	2	5.9	0	0.0	2	100.0
Other :	1	2.9	1	100.0	1	100.0

NEAR PESTICIDE USAGE, MIXING, OR STORAGE	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	3	8.8	2	66.7	3	100.0
100 ft. - 1/8 mile :	1	2.9	0	0.0	0	0.0

NEAR FERTILIZER USAGE, MIXING, OR STORAGE	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	1	2.9	0	0.0	0	0.0
100 ft. - 1/8 mile :	2	5.9	0	0.0	1	50.0

NEAR PETROLEUM STORAGE	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	1	2.9	0	0.0	1	100.0
100 ft. - 1/8 mile :	1	2.9	0	0.0	1	100.0

CROPS CLOSE TO WELL	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
Small Grains :	19	55.9	1	5.3	10	52.6
Row Crops :	7	20.6	0	0.0	6	85.7
Hay :	3	8.8	0	0.0	2	66.7
Pasture :	18	52.9	1	5.6	9	50.0
C.R.P. :	18	52.9	2	11.1	5	27.8

NEAR SMALL GRAIN CROPS	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	11	32.4	1	9.1	5	45.5
100 ft. - 1/8 mile :	8	23.5	0	0.0	5	62.5

NEAR ROW CROPS	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	2	5.9	0	0.0	1	50.0
100 ft. - 1/8 mile :	5	14.7	0	0.0	5	100.0

NEAR HAY CROPS	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	0	0.0	0	*****	0	*****
100 ft. - 1/8 mile :	3	8.8	0	0.0	2	66.7

NEAR PASTURE	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	10	29.4	1	10.0	5	50.0
100 ft. - 1/8 mile :	8	23.5	0	0.0	4	50.0

NEAR C.R.P.	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	15	44.1	1	6.7	3	20.0
100 ft. - 1/8 mile :	3	8.8	1	33.3	2	66.7

is the number of wells or detections in that category.
% is the percentage of wells or detections in that category.

Pesticide and Nitrate Plus Nitrite Detections
Related to Site Inventory Data
For the Oakes Aquifer

Wells with only pesticide detections	:	1	1.2 %
Wells with only nitrate detections	:	13	16.0 %
Wells with pesticide & nitrate detections	:	2	2.5 %
Wells with nitrate > 10 mg/L	:	4	4.9 %

Total number of wells in sample population : 81

GENERAL SETTING	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
Farm Yard :	7	8.6	0	0.0	1	14.3
Field :	45	55.6	1	2.2	4	8.9
Pasture :	23	28.4	0	0.0	6	26.1
C.R.P. :	8	9.9	0	0.0	2	25.0
Roadside :	24	29.6	1	4.2	5	20.8
Town :	2	2.5	1	50.0	1	50.0

NEARBY FACTORS OF POSSIBLE INFLUENCE	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
Near Irrigation :	29	35.8	0	0.0	1	3.4
Near Feed Lot :	9	11.1	0	0.0	2	22.2
Near Disposal Area :	0	0.0	0	*****	0	*****
Near Septic System :	10	12.3	1	10.0	2	20.0
Near Surface Water :	38	46.9	1	2.6	8	21.1
Well in Depression :	0	0.0	0	*****	0	*****
Near Chemical Usage :	8	9.9	2	25.0	3	37.5
Other :	5	6.2	0	0.0	0	0.0

NEAR IRRIGATION	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	11	13.6	0	0.0	0	0.0
100 ft. - 1/8 mile :	18	22.2	0	0.0	1	5.6

NEAR A FEED LOT	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	6	7.4	0	0.0	2	33.3
100 ft. - 1/8 mile :	3	3.7	0	0.0	0	0.0

NEAR DISPOSAL AREA	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	0	0.0	0	*****	0	*****
100 ft. - 1/8 mile :	0	0.0	0	*****	0	*****

NEAR SEPTIC SYSTEM	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	4	4.9	1	25.0	2	50.0
100 ft. - 1/8 mile :	6	7.4	0	0.0	0	0.0

NEAR SURFACE WATER	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	27	33.3	1	3.7	3	11.1
100 ft. - 1/8 mile :	11	13.6	0	0.0	5	45.5

DEPRESSION AROUND WELL	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
Yes :	0	0.0	0	*****	0	*****
No :	81	100.0	3	3.7	15	18.5
Unknown :	0	0.0	0	*****	0	*****

NEAR CHEMICAL USAGE, MIXING, OR STORAGE	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
Pesticides :	3	3.7	1	33.3	1	33.3
Fertilizer :	1	1.2	1	100.0	1	100.0
Petroleum :	2	2.5	0	0.0	1	50.0
Other :	2	2.5	0	0.0	0	0.0

NEAR PESTICIDE USAGE, MIXING, OR STORAGE	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	3	3.7	1	33.3	1	33.3
100 ft. - 1/8 mile :	0	0.0	0	*****	0	*****

NEAR FERTILIZER USAGE, MIXING, OR STORAGE	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	1	1.2	1	100.0	1	100.0
100 ft. - 1/8 mile :	0	0.0	0	*****	0	*****

NEAR PETROLEUM STORAGE	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	1	1.2	0	0.0	0	0.0
100 ft. - 1/8 mile :	1	1.2	0	0.0	1	100.0

CROPS CLOSE TO WELL	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
Small Grains :	19	23.5	0	0.0	3	15.8
Row Crops :	54	66.7	2	3.7	11	20.4
Hay :	12	14.8	0	0.0	2	16.7
Pasture :	36	44.4	1	2.8	8	22.2
C.R.P. :	16	19.8	1	6.3	2	12.5

NEAR SMALL GRAIN CROPS	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	11	13.6	0	0.0	1	9.1
100 ft. - 1/8 mile :	8	9.9	0	0.0	2	25.0

NEAR ROW CROPS	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	35	43.2	2	5.7	10	28.6
100 ft. - 1/8 mile :	19	23.5	0	0.0	1	5.3

NEAR HAY CROPS	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	10	12.3	0	0.0	2	20.0
100 ft. - 1/8 mile :	2	2.5	0	0.0	0	0.0

NEAR PASTURE	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	29	35.8	1	3.4	8	27.6
100 ft. - 1/8 mile :	7	8.6	0	0.0	0	0.0

NEAR C.R.P.	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	13	16.0	0	0.0	1	7.7
100 ft. - 1/8 mile :	3	3.7	1	33.3	1	33.3

is the number of wells or detections in that category.
% is the percentage of wells or detections in that category.

Pesticide and Nitrate Plus Nitrite Detections
Related to Site Inventory Data
For the Warwick Aquifer

Wells with only pesticide detections	:	0	0.0 %
Wells with only nitrate detections	:	15	46.9 %
Wells with pesticide & nitrate detections	:	2	6.3 %
Wells with nitrate > 10 mg/L	:	6	18.8 %

Total number of wells in sample population : 32

GENERAL SETTING	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
Farm Yard :	3	9.4	0	0.0	2	66.7
Field :	18	56.3	0	0.0	9	50.0
Pasture :	9	28.1	2	22.2	5	55.6
C.R.P. :	7	21.9	1	14.3	2	28.6
Roadside :	13	40.6	1	7.7	8	61.5
Town :	1	3.1	0	0.0	1	100.0

NEARBY FACTORS OF POSSIBLE INFLUENCE	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
Near Irrigation :	12	37.5	0	0.0	8	66.7
Near Feed Lot :	5	15.6	0	0.0	3	60.0
Near Disposal Area :	0	0.0	0	*****	0	*****
Near Septic System :	7	21.9	0	0.0	4	57.1
Near Surface Water :	11	34.4	0	0.0	4	36.4
Well in Depression :	0	0.0	0	*****	0	*****
Near Chemical Usage :	1	3.1	0	0.0	1	100.0
Other :	0	0.0	0	*****	0	*****

NEAR IRRIGATION	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	6	18.8	0	0.0	3	50.0
100 ft. - 1/8 mile :	6	18.8	0	0.0	5	83.3

NEAR A FEED LOT	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	2	6.3	0	0.0	2	100.0
100 ft. - 1/8 mile :	3	9.4	0	0.0	1	33.3

NEAR DISPOSAL AREA	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	0	0.0	0	*****	0	*****
100 ft. - 1/8 mile :	0	0.0	0	*****	0	*****

NEAR SEPTIC SYSTEM	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	5	15.6	0	0.0	3	60.0
100 ft. - 1/8 mile :	2	6.3	0	0.0	1	50.0

NEAR SURFACE WATER	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	3	9.4	0	0.0	0	0.0
100 ft. - 1/8 mile :	8	25.0	0	0.0	4	50.0

DEPRESSION AROUND WELL	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
Yes :	0	0.0	0	*****	0	*****
No :	32	100.0	2	6.3	17	53.1
Unknown :	0	0.0	0	*****	0	*****

is the number of wells or detections in that category.
% is the percentage of wells or detections in that category.

NEAR CHEMICAL USAGE, MIXING, OR STORAGE	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
Pesticides :	0	0.0	0	*****	0	*****
Fertilizer :	0	0.0	0	*****	0	*****
Petroleum :	1	3.1	0	0.0	1	100.0
Other :	0	0.0	0	*****	0	*****

NEAR PESTICIDE USAGE, MIXING, OR STORAGE	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	0	0.0	0	*****	0	*****
100 ft. - 1/8 mile :	0	0.0	0	*****	0	*****

NEAR FERTILIZER USAGE, MIXING, OR STORAGE	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	0	0.0	0	*****	0	*****
100 ft. - 1/8 mile :	0	0.0	0	*****	0	*****

NEAR PETROLEUM STORAGE	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	1	3.1	0	0.0	1	100.0
100 ft. - 1/8 mile :	0	0.0	0	*****	0	*****

CROPS CLOSE TO WELL	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
Small Grains :	24	75.0	0	0.0	13	54.2
Row Crops :	11	34.4	0	0.0	7	63.6
Hay :	7	21.9	0	0.0	5	71.4
Pasture :	16	50.0	2	12.5	10	62.5
C.R.P. :	11	34.4	2	18.2	6	54.5

NEAR SMALL GRAIN CROPS	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	17	53.1	0	0.0	8	47.1
100 ft. - 1/8 mile :	7	21.9	0	0.0	5	71.4

NEAR ROW CROPS	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	5	15.6	0	0.0	5	100.0
100 ft. - 1/8 mile :	6	18.8	0	0.0	2	33.3

NEAR HAY CROPS	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	2	6.3	0	0.0	1	50.0
100 ft. - 1/8 mile :	5	15.6	0	0.0	4	80.0

NEAR PASTURE	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	11	34.4	2	18.2	6	54.5
100 ft. - 1/8 mile :	5	15.6	0	0.0	4	80.0

NEAR C.R.P.	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	8	25.0	1	12.5	3	37.5
100 ft. - 1/8 mile :	3	9.4	1	33.3	3	100.0

Pesticide and Nitrate Plus Nitrite Detections
Related to Site Inventory Data
For the Spring Creek Aquifer

Wells with only pesticide detections	:	0	0.0 %
Wells with only nitrate detections	:	0	0.0 %
Wells with pesticide & nitrate detections	:	0	0.0 %
Wells with nitrate > 10 mg/L	:	0	0.0 %

Total number of wells in sample population : 4

GENERAL SETTING	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
Farm Yard :	0	0.0	0	*****	0	*****
Field :	3	75.0	0	0.0	0	0.0
Pasture :	1	25.0	0	0.0	0	0.0
C.R.P. :	0	0.0	0	*****	0	*****
Roadside :	4	100.0	0	0.0	0	0.0
Town :	0	0.0	0	*****	0	*****

NEARBY FACTORS OF POSSIBLE INFLUENCE	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
Near Irrigation :	0	0.0	0	*****	0	*****
Near Feed Lot :	0	0.0	0	*****	0	*****
Near Disposal Area :	0	0.0	0	*****	0	*****
Near Septic System :	0	0.0	0	*****	0	*****
Near Surface Water :	2	50.0	0	0.0	0	0.0
Well in Depression :	0	0.0	0	*****	0	*****
Near Chemical Usage :	0	0.0	0	*****	0	*****
Other :	0	0.0	0	*****	0	*****

NEAR IRRIGATION	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	0	0.0	0	*****	0	*****
100 ft. - 1/8 mile :	0	0.0	0	*****	0	*****

NEAR A FEED LOT	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	0	0.0	0	*****	0	*****
100 ft. - 1/8 mile :	0	0.0	0	*****	0	*****

NEAR DISPOSAL AREA	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	0	0.0	0	*****	0	*****
100 ft. - 1/8 mile :	0	0.0	0	*****	0	*****

NEAR SEPTIC SYSTEM	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	0	0.0	0	*****	0	*****
100 ft. - 1/8 mile :	0	0.0	0	*****	0	*****

NEAR SURFACE WATER	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	0	0.0	0	*****	0	*****
100 ft. - 1/8 mile :	2	50.0	0	0.0	0	0.0

DEPRESSION AROUND WELL	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
Yes :	0	0.0	0	*****	0	*****
No :	4	100.0	0	0.0	0	0.0
Unknown :	0	0.0	0	*****	0	*****

NEAR CHEMICAL USAGE, MIXING, OR STORAGE	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
Pesticides :	0	0.0	0	*****	0	*****
Fertilizer :	0	0.0	0	*****	0	*****
Petroleum :	0	0.0	0	*****	0	*****
Other :	0	0.0	0	*****	0	*****

NEAR PESTICIDE USAGE, MIXING, OR STORAGE	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	0	0.0	0	*****	0	*****
100 ft. - 1/8 mile :	0	0.0	0	*****	0	*****

NEAR FERTILIZER USAGE, MIXING, OR STORAGE	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	0	0.0	0	*****	0	*****
100 ft. - 1/8 mile :	0	0.0	0	*****	0	*****

NEAR PETROLEUM STORAGE	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	0	0.0	0	*****	0	*****
100 ft. - 1/8 mile :	0	0.0	0	*****	0	*****

CROPS CLOSE TO WELL	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
Small Grains :	2	50.0	0	0.0	0	0.0
Row Crops :	1	25.0	0	0.0	0	0.0
Hay :	3	75.0	0	0.0	0	0.0
Pasture :	3	75.0	0	0.0	0	0.0
C.R.P. :	0	0.0	0	*****	0	*****

NEAR SMALL GRAIN CROPS	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	2	50.0	0	0.0	0	0.0
100 ft. - 1/8 mile :	0	0.0	0	*****	0	*****

NEAR ROW CROPS	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	1	25.0	0	0.0	0	0.0
100 ft. - 1/8 mile :	0	0.0	0	*****	0	*****

NEAR HAY CROPS	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	3	75.0	0	0.0	0	0.0
100 ft. - 1/8 mile :	0	0.0	0	*****	0	*****

NEAR PASTURE	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	2	50.0	0	0.0	0	0.0
100 ft. - 1/8 mile :	1	25.0	0	0.0	0	0.0

NEAR C.R.P.	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	0	0.0	0	*****	0	*****
100 ft. - 1/8 mile :	0	0.0	0	*****	0	*****

is the number of wells or detections in that category.
% is the percentage of wells or detections in that category.

Pesticide and Nitrate Plus Nitrite Detections
Related to Site Inventory Data
For the Streeter Aquifer

Wells with only pesticide detections	:	0	0.0 %
Wells with only nitrate detections	:	11	39.3 %
Wells with pesticide & nitrate detections	:	0	0.0 %
Wells with nitrate > 10 mg/L	:	2	7.1 %

Total number of wells in sample population : 28

GENERAL SETTING	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
Farm Yard :	5	17.9	0	0.0	3	60.0
Field :	12	42.9	0	0.0	4	33.3
Pasture :	5	17.9	0	0.0	3	60.0
C.R.P. :	12	42.9	0	0.0	3	25.0
Roadside :	19	67.9	0	0.0	7	36.8
Town :	0	0.0	0	*****	0	*****

NEARBY FACTORS OF POSSIBLE INFLUENCE	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
Near Irrigation :	4	14.3	0	0.0	2	50.0
Near Feed Lot :	6	21.4	0	0.0	4	66.7
Near Disposal Area :	1	3.6	0	0.0	1	100.0
Near Septic System :	6	21.4	0	0.0	3	50.0
Near Surface Water :	9	32.1	0	0.0	3	33.3
Well in Depression :	0	0.0	0	*****	0	*****
Near Chemical Usage :	7	25.0	0	0.0	6	85.7
Other :	0	0.0	0	*****	0	*****

NEAR IRRIGATION	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	1	3.6	0	0.0	1	100.0
100 ft. - 1/8 mile :	3	10.7	0	0.0	1	33.3

NEAR A FEED LOT	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	4	14.3	0	0.0	3	75.0
100 ft. - 1/8 mile :	2	7.1	0	0.0	1	50.0

NEAR DISPOSAL AREA	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	0	0.0	0	*****	0	*****
100 ft. - 1/8 mile :	1	3.6	0	0.0	1	100.0

NEAR SEPTIC SYSTEM	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	4	14.3	0	0.0	2	50.0
100 ft. - 1/8 mile :	2	7.1	0	0.0	1	50.0

NEAR SURFACE WATER	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	3	10.7	0	0.0	0	0.0
100 ft. - 1/8 mile :	6	21.4	0	0.0	3	50.0

DEPRESSION AROUND WELL	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
Yes :	0	0.0	0	*****	0	*****
No :	28	100.0	0	0.0	11	39.3
Unknown :	0	0.0	0	*****	0	*****

NEAR CHEMICAL USAGE, MIXING, OR STORAGE	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
Pesticides :	2	7.1	0	0.0	2	100.0
Fertilizer :	2	7.1	0	0.0	2	100.0
Petroleum :	3	10.7	0	0.0	2	66.7
Other :	0	0.0	0	*****	0	*****

NEAR PESTICIDE USAGE, MIXING, OR STORAGE	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	0	0.0	0	*****	0	*****
100 ft. - 1/8 mile :	2	7.1	0	0.0	2	100.0

NEAR FERTILIZER USAGE, MIXING, OR STORAGE	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	0	0.0	0	*****	0	*****
100 ft. - 1/8 mile :	2	7.1	0	0.0	2	100.0

NEAR PETROLEUM STORAGE	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	2	7.1	0	0.0	1	50.0
100 ft. - 1/8 mile :	1	3.6	0	0.0	1	100.0

CROPS CLOSE TO WELL	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
Small Grains :	13	46.4	0	0.0	4	30.8
Row Crops :	4	14.3	0	0.0	1	25.0
Hay :	6	21.4	0	0.0	3	50.0
Pasture :	11	39.3	0	0.0	5	45.5
C.R.P. :	18	64.3	0	0.0	7	38.9

NEAR SMALL GRAIN CROPS	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	9	32.1	0	0.0	3	33.3
100 ft. - 1/8 mile :	4	14.3	0	0.0	1	25.0

NEAR ROW CROPS	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	1	3.6	0	0.0	1	100.0
100 ft. - 1/8 mile :	3	10.7	0	0.0	0	0.0

NEAR HAY CROPS	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	1	3.6	0	0.0	0	0.0
100 ft. - 1/8 mile :	5	17.9	0	0.0	3	60.0

NEAR PASTURE	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	6	21.4	0	0.0	3	50.0
100 ft. - 1/8 mile :	5	17.9	0	0.0	2	40.0

NEAR C.R.P.	#	%	# PEST. DET.	% PEST. DET.	# NO3 DET.	% NO3 DET.
0 - 100 ft. :	13	46.4	0	0.0	4	30.8
100 ft. - 1/8 mile :	5	17.9	0	0.0	3	60.0

is the number of wells or detections in that category.
% is the percentage of wells or detections in that category.

APPENDIX E

Health Advisories

HEALTH ADVISORIES

The Health Advisory Program, sponsored by EPA's Office of Drinking Water, provides information on the health effects, analytical methodology and treatment technology that would be useful in dealing with contamination of water resources. Health advisories describe nonregulatory concentrations of drinking water contaminants called HALs, at which adverse health effects would not be anticipated to occur over specific exposure durations. HALs contain a margin of safety to protect sensitive members of the population. Health advisories serve as informal technical guidelines to assist in protecting public health. They are not to be construed as legally enforceable federal standards. The HALs are subject to change as new information becomes available.

The Safe Drinking Water Act has specified MCLs for a variety of organic and inorganic constituents. MCLs are enforceable for Public Water Systems, but are not enforceable for private or individual water systems. HALs and MCLs do not address other beneficial uses of water such as irrigation or discharge to surface water.

The development of HALs and MCLs is based on essentially the same criteria. HALs are developed for One-day, Ten-day, Longer-term (approximately seven years or 10 percent of an individual's lifetime), and Lifetime exposures. The Lifetime Exposure HAL includes a factor to account for exposure to the contaminant from sources other than drinking water. An MCL is essentially the same as a Lifetime Exposure HAL.

Seven pesticides or pesticide degradation products, as well as nitrate plus nitrite, were detected in samples collected for this study. A summary of health advisory information for these contaminants follows. All information included is from EPA, Office of Drinking Water, health advisory bulletins; the *Farm Chemicals Handbook '97*; the *Handbook of Environmental Data on Organic Chemicals*; the *Merck Index*; the *International Union of Pure and Applied Chemistry* (IUPAC); and *Pesticide Use and Pest Management Practices for Major Crops in North Dakota*, 1996.

Bentazon

Common names: Common trade names for bentazon are Basagran, Bendioxide and Bentazone.

Chemical formula: The empirical chemical formula for bentazon is $C_{10}H_{12}N_2O_3S$. Its composition is 3-(1methylethyl)-1H-2,1,3-benzothiadiazin-4(3H)-one,2,2-dioxide (IUPAC).

Physical properties: At room temperature, bentazon is a crystalline powder that has no odor or color. It has a solubility of 500 mg/l and a melting point in the range of 137^0C to 139^0C. The retail formulation is a soluble concentrate.

Uses and occurrence: Bentazon is a selective herbicide that controls a number of broadleaf and sedge weeds. It is used primarily in most gramineous and many large-seeded leguminous crops. In 1996, bentazon was applied to approximately 577,300 acres in North Dakota (Zollinger et al., 1998).

Environmental fate: Bentazon is a very mobile chemical in soil and water. It is hydrolyzed poorly and undergoes photodecomposition very slowly, but is degraded rapidly by bacteria and fungi. The speed of degradation is decreased by decreasing temperature. The half-life of bentazon under these conditions is less than one month.

Health effects: Small doses of bentazon are almost completely absorbed when ingested by mammals. It is not metabolized significantly in the body, however, small traces of two unidentified metabolites have been detected. Approximately 92 percent of the ingested bentazon passes through the body and is excreted. No information on the health effects of this chemical in the human body was available. The LD_{50} for various species of animals, however, ranged from approximately 500 to 1,100 mg/kg. No valid data was available to make a determination of the carcinogenic potential of bentazon. Because of this, bentazon has been included in Group D: Not Classifiable. This group is generally used for substances with inadequate or no human and animal evidence of carcinogenicity.

Health advisory level: The lifetime HAL for bentazon has been set at 0.02 mg/l (20 μg/l or 20 ppb).

Treatment technologies: No information was available on treatment technologies used to effectively remove bentazon from contaminated water.

2,4-Dichlorophenoxyacetic Acid (2,4-D)

Common names: Trade names for 2,4-D are 2,4-D; Amoxone; Aqua-Kleen; Chloroxone; and Weed-B-Gone.

Chemical formula: The empirical chemical formula for 2,4-D is $C_8H_6O_3Cl_2$. The composition for 2,4-D is 2,4-dichlorophenoxyacetic acid (IUPAC).

Physical properties: 2,4-D is a white crystalline powder. The melting point of 2,4-D is 140.5^0C. It is only slightly soluble in water (540 mg/l) and petroleum distillate; however, it is soluble in organic solvents and alcohols. The acid is not used customarily by itself, but usually as an amine, salt or ester. The esters are soluble in oils, and the amine salts are soluble in water. Retail formulations include the emulsion form (esters); aqueous solutions (salts); and amines, of which the amine in largest production is the dimethylamine salt. As with amines which form salts with the 2,4-D acid, esters are made with a wide variety of alcohols.

Uses and occurrence: 2,4-D is a selective, systemic herbicide widely used in North Dakota to control broadleaf weeds in wheat, barley, oats, flax, corn, sunflower, soybeans, dry beans, potatoes, alfalfa and other hay, pasture, summer fallow and CRP. 2,4-D is the most widely used herbicide in North Dakota--in 1996, it was applied, alone, to 7,907,100 acres, or 19.1 percent of the agricultural acres in the state (Zollinger et al., 1998). In conjunction with other chemicals, it was applied to an additional 1,425,000 acres.

Environmental fate: 2,4-D is degraded in the environment and is not considered to be a persistent compound. It is metabolized by plants, is readily degraded by soil bacteria, and undergoes hydrolysis under environmental conditions. The half-life of 2,4-D is reported to be from one to six weeks in soil. Once in the soil, 2,4-D and some of its salts and esters have been demonstrated to migrate. 2,4-D does not tend to accumulate in soils and is reported not to bioaccumulate in plants and animals. Many broadleaf crops are extremely sensitive to 2,4-D.

Health effects: 2,4-D is absorbed almost completely after ingestion. 2,4-D acid is distributed into blood, liver, kidney, heart, lungs and spleen, with lower levels occurring in muscle and brain. The data indicate that 2,4-D does not undergo biotransformation to any great extent. A male agricultural student who ingested at least six grams of a commercial herbicide preparation of the dimethyl amine salt of 2,4-D died after vomiting and convulsions. Pathological examination showed degenerative ganglion cell changes in the brain. Occupational exposure to 2,4-D has resulted in reduced nerve conduction velocities. Case-controlled epidemiological studies of populations in Scandinavian countries exposed to the phenoxy herbicides indicate excess risk of the development of soft-tissue sarcomas and malignant lymphomas. Acute oral LD_{50} values of approximately 350 to 1,000 mg/kg of 2,4-D acid have been reported for small mammals. An LD_{50} of 100 mg/kg in dogs was reported. 2,4-D is classified in Group D: Not Classifiable. This category is for agents with inadequate or no human and animal evidence of carcinogenicity.

Health advisory level: The MCL and the lifetime HAL for 2,4-D have been set at 0.07 mg/l (70μg/l or 70 ppb).

Treatment technologies: Treatment technologies capable of removing 2,4-D from drinking water are adsorption by granular or powdered carbon and reverse osmosis.

3,5 Dichlorobenzoic Acid

Attempts to find information on this compound have proved to be unsuccessful. It appears to be a pesticide degradation product; however, of which pesticide is uncertain.

Endrin, Endrin Aldehyde, and Endrin Ketone

Common names: Endrex and Hexadrin.

Chemical formula: The empirical chemical formula for endrin is $C_{12}H_8Cl_6O$. Its composition is 3,4,5,6,9,9-Hexachloro-1a,2,2a,3,6,6a,7,-7a-octahydro-2,7:3,6-dimethanonaphth[2,3-b]oxirene; 1,2,3-4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-endo,endo-1,4:5,8-dimethanonaphthalene.

Physical properties: Endrin is a colorless, crystalline solid. The crystals decompose, or melt, at 245^0C. Endrin has a water solubility of 0.24 mg/l at 25^0C. Retail formulations include emulsifiable concentrate, wettable powder, and dust.

Uses and occurrence: Endrin is an insecticide once widely used in the United States. In 1979, the U.S. EPA canceled the use of endrin for a number of uses, and registration for new uses of endrin was denied. Endrin is presently registered only for the control of cutworms, grasshoppers and moles. The manufacture of endrin was discontinued in 1987 by Shell International Chemical Co., Ltd. Endrin aldehyde and endrin ketone are degradation products of endrin.

Environmental fate: Endrin is considered to be a persistent compound. Endrin is biodegraded poorly, and, once in the ground, endrin rapidly binds onto soils and migrates slowly. Endrin has the potential for bioaccumulation.

Health effects: Endrin is a central nervous system depressant and hepatotoxin. There is no antidote for endrin poisoning. Endrin is distributed in the fat, liver, brain and kidneys of mammals (both animal and human), and is metabolized rapidly. Endrin residues decline rapidly after cessation of exposure; however, both wild and domestic birds store endrin in various body tissues, especially fat. Exposure to endrin may cause sudden convulsions, headache, dizziness, sleepiness, weakness, nausea, vomiting, insomnia, agitation, mental confusion and loss of appetite. A number of deaths have occurred from swallowing endrin. Cases of fatal endrin poisoning have been reported from intentional and accidental ingestion. The time periods from administration of the pesticide to death ranged from one to six months. Endrin ingestion with milk or alcohol appeared to increase toxicity, as death occurred within an hour or two, possibly due to more rapid absorption through the GI tract. An oral LD_{50} value of 7 to 15 mg/kg has been reported in rats. Endrin is classified in Group D: Not Classifiable. This category is used for substances with inadequate or no human and animal evidence of carcinogenicity.

Health advisory level: The MCL and lifetime HAL for endrin have been set at 0.002 mg/l (2 μg/l or 2 ppb).

Treatment technologies: Treatment technologies which are capable of removing endrin from drinking water include adsorption by activated carbon--both granular and powdered--air-stripping, reverse osmosis and coagulation/filtration.

Heptachlor and Heptachlor Epoxide

Common names: Drinox, Gold Crest H-60 and Heptox. Combinations: Termide (with chlordane).

Chemical formula: The empirical chemical formula for heptachlor is $C_{10}H_5Cl_7$. The structural formula for heptachlor is 1,4,5,6,7,8,8-heptachloro-3a.4.7.7a-tetrahydro-4,7-methanoindene.

Physical properties: Heptachlor is a white, crystalline solid. It has a melting point of 95^0C to 96^0C. It is practically insoluble in water (0.056 mg/l at 25^0C.), and readily soluble in most organic solvents. Retail formulations include emulsifiable concentrate and oil solution. Dry formulations were discontinued by Velsicol in the mid-1970s.

Uses and occurrence: Heptachlor is an insecticide which in the past has been used on corn, alfalfa, hay and vegetables; as a termiticide; and as an insecticide for the control of the cotton boll weevil. During the mid-1970s, use of heptachlor on food crops was phased out due to the persistence of the chemical and its epoxide. The EPA canceled registration of pesticides containing this compound with the exception of its use through subsurface ground insertion for termite control and the dipping of roots or tops of non-food plants. In the United States, Termide sales have been halted per Velsicol and EPA agreement pending tests following specific application procedures. Heptachlor 5% granules are registered for the control of fire ants in cable closures. Heptachlor epoxide is a degradation product of heptachlor.

Environmental fate: Heptachlor is considered to be a moderately persistent compound, with a half-life in soil of six months. However, heptachlor is biotransformed, or degraded, to an epoxide which is very resistant to further biological or chemical change. The half-lives of heptachlor epoxide in various soils have been reported to be as long as several years. Heptachlor and its epoxide bind to soil and migrate slowly.

Health effects: Heptachlor poisoning may occur by ingestion, inhalation or skin contamination. In rats, heptachlor was absorbed rapidly from the gastrointestinal tract. Heptachlor stimulates the central nervous system; depression and paralysis may follow. Liver damage is a possible late manifestation. Anemia and leukemia are associated with inhalation and dermal exposure of humans to heptachlor. In a group of 1,403 male workers employed for approximately six years in the production of chlordane and heptachlor, there was a non-significant increased incidence of lung cancer and a statistically significant increased incidence of cerebrovascular disease. Heptachlor epoxide was detected in tissue samples from 77 autopsies performed from 1966 to 1968. In rat studies, the incidence of hepatocellular carcinomas was significant. Heptachlor is grouped in B2: Probable Human Carcinogen. This category is for agents for which there is sufficient evidence from animal studies but inadequate evidence from human studies.

Health advisory level: The MCL for heptachlor is 0.0004 mg/l (0.4 μg/l or 0.4 ppb). The MCL for heptachlor epoxide is 0.0002 mg/l (0.2 μg/l or 0.2 ppb).

Treatment technologies: Treatment technologies for the removal of heptachlor from drinking water have not been extensively evaluated (except on an experimental level). An evaluation of some of the physical and/or chemical properties of heptachlor indicates that the following techniques would be candidates for further investigation: adsorption by granular-activated carbon, and ozone or ozone/ultraviolet oxidation.

MCPA

Common names: Trade names for MCPA include MCPA, MCP, Agroxone, Hormotuho and Metaxon.

Chemical formula: The empirical chemical formula for MCPA is $C_9H_9O_3Cl$. The structural formula is (4-chloro-2-methylphenoxy)-acetic acid.

Physical properties: MCPA is the same as 2,4-D except for the replacement of one chlorine atom by a methyl group. MCPA is a white to light-brown solid, flakes, crystal powder or liquid. It has a melting point of 114^0C to 199^0C, and a solubility of 150 g/l in ethanol at 20^0C to 25^0C; in acetone, >200 g/l; in water, 825 mg/l. Retail formulations of MCPA include potassium, sodium, dimethylamine salts (water soluble concentrates), and emulsifiable concentrates. Some or all applications of MCPA may be classified as Restricted Use Pesticide.

Uses and occurrences: MCPA is a hormone-type herbicide used in small grains, rice, peas, grassland, sugar cane, tree crops, turf and noncrop areas for post-emergent control of many annual and perennial broadleaf weeds. In 1996, MCPA was applied, either alone or in conjunction with other pesticides, to 4,088,600 agricultural acres in North Dakota (Zollinger et al, 1998).

Environmental fate: MCPA dissipates rapidly in water, but residue levels in soil remain unchanged. MCPA would be expected to leach readily in most soils. Mobility in soil increases as organic-matter content decreases, possibly due to adsorption of MCPA to organic matter. In aqueous solution in sunlight, MCPA has a half-life of 20 to 24 days.

Health effects: MCPA is metabolized in the liver. In small mammals, oral exposure to MCPA produced growth retardation; increases in kidney weights; cell changes in the liver and kidneys; and bone marrow, liver and kidney damage. In human studies, volunteers ingested five milligrams of MCPA; approximately 50 percent of the dose was detected in the urine within several days. Urinary levels were not detectable on the fifth day following exposure. In case reports of attempted suicide by ingestion of MCPA, symptoms included pinpoint pupils, diminished or absent reflexes, low blood pressure, spasms, unconsciousness and death. In one case of occupational exposure to MCPA, a farm worker involved in spraying operations exhibited reversible aplastic anemia, muscular weakness, hemorrhagic gastritis and signs of slight liver damage. In a follow-up study of the exposed farmer, the occurrence of acute myelomonocytic leukemia was reported. Acute oral LD_{50} values of 550 to 700 mg/kg have been reported in mice and rats. MCPA has been classified in Group E: no evidence of carcinogenicity for humans. This group is used for agents for which there is no evidence of carcinogenicity in at least two adequate animal tests in different species *or* in inadequate epidemiologic and animal studies.

Health advisory level: The HAL for MCPA is 0.01 mg/l (10 μg/l or 10 ppb).

Treatment technologies: Oxidation by ozone may be a possible MCPA removal technique.

Pentachlorophenol

Common names: Trade names for pentachlorophenol include PCP, sodium pentachlorophenoxide, Permatox 101, Permatox 181, Dowicide G-ST, Pentacon, Pentwar, GLAZD and Weedone.

Chemical formula: The empirical chemical formula for pentachlorophenol is C_6Cl_5OH. Its composition is pentachlorohydroxybenzene.

Physical properties: Pentachlorophenol is a synthetic chlorinated organic herbicide. Pure pentachlorophenol is in the form of white- to buff-color crystals, beads or powder. It has a melting point of 174 ^{0}C or 191^{0}C (anhydrous), and a freezing point of 174^{0}C for technical pentachlorophenol. At room temperature, its solubility in water is 14 mg/l. Retail formulations include blocks, flakes, liquid concentrate or ready-to-use petroleum solutions. Pentachlorophenol, commonly called “penta” or PCP, as a formulated product is to be applied with a hydrocarbon diluent or as an emulsifiable solution. It is usually applied to wood products after dilution to a 5 percent solution with solvents such as mineral spirits, No. 2 fuel oil or kerosene.

Uses and occurrence: Pentachlorophenol was once one of the most widely used chemicals. PCP is a herbicide, antimicrobial agent, disinfectant, mossicide and defoliant. Its major uses are as a wood preservative for fungus decay; termite or Lyctus beetle attack; and as a molluscicide for snail carriers of larval human-blood flukes causing schistosomiasis in Egypt. In 1985, PCP production was 35 million pounds. In the U.S., PCP is a Restricted Use Pesticide as a wood preservative. Since 1987, wood preservatives and other pesticides containing pentachorophenol are no longer available for home and garden use. Currently, the principal use for pentachlorophenol is as a commercial wood preservative for power line poles, cross arms and fence posts.

Environmental fate: PCP is very persistent in some soils with half-lives of up to five years reported. PCP is rapidly degraded by sunlight: the half-life for photolysis of pentachlorophenol in water is reported to be less than one hour. PCP is degraded by soil bacteria under some conditions; biodegradation may take several weeks or longer. Depending upon soil conditions, half the pentachorophenol will be broken down by soil organisms in about two months. Migration occurs in neutral to alkaline soils. The occurrence of pentachlorophenol in ground and surface waters is rare.

Health effects: PCP is absorbed readily following oral, dermal or inhalation exposure. Once absorbed, PCP is distributed throughout the body, accumulating in the liver, kidneys, brain, spleen and fat. It apparently is metabolized readily, since a large portion of the administered dose is excreted unchanged by all species tested. The major route of elimination is in the urine, with feces as a minor route. Acute exposure in experimental mammals results in an initial rise in body temperature and respiration rate. The body temperature may increase to dangerous levels, causing injury to various organs and tissues and even death. Respiration then becomes slower and dyspneic as coma develops. Death is characterized by cardiac and muscular collapse with terminal asphyxial convulsions. An immediate and pronounced rigor mortis often is noted. Oral LD_{50} values ranging from 27 to over 300 mg/kg have been reported, with no species being noticeably more susceptible than any other. Human exposure to PCP results in local irritation, systemic effects, and, in a limited number of people, an allergic reaction. PCP poisoning is characterized by profuse sweating, often accompanied by fever, weight loss and gastrointestinal complaints. Liver and kidney involvement have been indicated in cases of fatal poisoning. PCP may affect reproduction in humans or cause harm to unborn babies. PCP is classified in Group B2: Probable Human Carcinogen. This group is used for agents for which there is sufficient evidence of carcinogenicity from animal studies.

Health advisory level: The MCL for pentachlorophenol is 0.001 mg/l (1μg/l or 1 ppb).

Treatment technologies: Treatment technologies which may be effective for PCP include adsorption with granular activated carbon. The use of aeration also has been considered.

Picloram

Common names: The most common trade name for picloram is Tordon. Other trade names include Amdon, ACTP, Borolin and K-Pin.

Chemical formula: The empirical chemical formula for picloram is $C_6H_3Cl_3N_2O_2$. The structural formula is 4-amino-3,5,6-trichloropicolinic acid.

Physical properties: At room temperature picloram is a white powder. At 215^0 C, picloram decomposes before it melts. It has a solubility of 430 mg/l at 20^0 C, with a slight chlorine-like odor. Retail formulations include water-soluble liquid and granules.

Uses and occurrence: Picloram is used as a broad-spectrum herbicide for the control of broad-leafed and woody plants in rangelands, pastures, small grains, and rights-of-way for power lines and roadways. In 1996 it was applied to approximately 280,600 acres in North Dakota (Zollinger et al., 1998).

Environmental fate: The main processes for dissipation of picloram in the environment are photodegradation and aerobic soil degradation. Photodegradation occurs rapidly in water, but is somewhat slower on a soil surface. Hydrolysis of picloram is very slow. Laboratory studies have shown that under aerobic soil conditions, the half-life of picloram is dependent upon the applied concentration and the temperature and moisture of the soil. Field tests have indicated that picloram's half-life varies from about one month to several months. Following normal agricultural, forestry or industrial applications, long-term accumulation of picloram in the soil generally does not occur. Under anaerobic conditions picloram has been shown to be quite stable, with very little degradation.

Health effects: Picloram is readily absorbed by mammals through the gastrointestinal tract. It is not metabolized significantly in the body, however, and 90 percent to 95 percent passes through the body within about two days. The acute oral toxicity of picloram is low. Lethal doses have been estimated in a number of species, with LD_{50} values ranging from 2,000 to 4,000 mg/kg. In a study of mice there was no indication of a carcinogenic response from dietary exposure. A rat study was negative for carcinogenic effects in males; however, females exhibited an increase in neoplastic nodules. Picloram has been included in Group D: Not Classified. This group is generally used for substances with inadequate human and animal evidence of carcinogenicity or for which no data are available.

Health advisory level: The MCL for picloram has been set at 0.5 mg/l (500 ug/l or 500 ppb).

Treatment technologies: No information was found on treatment technologies capable of effectively removing picloram from drinking water.

Nitrate and Nitrite

Chemical formula: NO_3 and NO_2

Uses and occurrence: The major use of nitrate and nitrite is in inorganic fertilizers. They also may be derived from septic systems, feedlots or areas with heavy manure loading, or from the decomposition of other organic materials. Nitrates and nitrites also are used extensively in the manufacture of explosives and in the curing of meats. The North Dakota Agricultural Statistics Service (1991) reported that 729,355 gross tons of fertilizer were applied in North Dakota in 1990, with 278,086 tons of that being nitrogen nutrient content. By comparison, 1,332,778 gross tons of fertilizer were applied in 1997, with 594,686 tons of that being nitrogen nutrient content (North Dakota Agricultural Statistics Service, 1998).

Environmental fate: Nitrates and nitrites in groundwater have been shown to degrade or dissipate with depth in an aquifer. The rates vary widely, depending on temperature and other factors. The exact processes are not completely understood. Because nitrite is easily oxidized to form nitrate, nitrate predominates in groundwater. Nitrate and nitrite ions are very mobile in soil and groundwater.

Health effects: Ingestion of nitrates and nitrites has resulted in a condition known as methemoglobinemia, which is sometimes referred to as "blue baby syndrome." Methemoglobinemia is caused by the reaction of nitrite (not nitrate) with red blood cells to form methemoglobin, which does not carry oxygen as normal hemoglobin does. This may result in anoxemia and cyanosis and, in severe cases, may be fatal.

While nitrate is readily excreted by the kidneys and is not directly metabolized in the human body, it is metabolized by bacteria in humans. In adults, high acidity levels in the gastrointestinal tract limit the number of nitrate-reducing bacteria; however, the lower gastrointestinal acidity levels in infants allow greater numbers of these bacteria to survive. These bacteria convert nitrate into nitrite, which is absorbed by the bloodstream. The oxygen starvation condition resulting from high concentrations of methemoglobin in the bloodstream will cause an infant's skin to have a bluish color. This is the reason methemoglobinemia is sometimes called blue baby syndrome. As an infant grows older, numbers of nitrate-reducing bacteria decrease, and chances for developing methemoglobinemia decrease as well.

Health advisory level: Nitrate is toxic because it can be converted to nitrite and the total toxicity of the two is additive. Therefore, nitrate and nitrite cannot be considered independently. The MCL for nitrite in drinking water is 1.0 mg/l as nitrogen. The MCL for nitrate is 10.0 mg/l (N), as is the MCL for total nitrate plus nitrite (N). These levels have been set to protect infants. Adults can safely ingest greater concentrations than this, and ruminant animals (cattle, sheep, etc.) can normally consume concentrations up to 100.0 mg/l.

Treatment technologies: Methods to remove nitrate from drinking water include distillation and reverse osmosis.

APPENDIX F

List of Abbreviations and Acronyms

DC	Division of Chemistry
EPA	Environmental Protection Agency
HAL	health advisory level
IUPAC	International Union of Pure and Applied Chemistry
MCL	maximum contaminant level
mg/l	milligrams per liter, equivalent to ppm or 1000 μg/l (liquid volume measurement)
N	(as) nitrogen
NDDoH	North Dakota Department of Health
NO_3	nitrate plus nitrite
ppb	parts per billion
ppm	parts per million
QA/QC	Quality Assurance/Quality Control
μg/l	micrograms per liter, equivalent to ppb or 0.001 mg/l (liquid volume measurement)
μmhos/cm	micromhos per centimeter