Ohio's Ground Water Quality

2000 305(b) Report

JULY 2000

Ohio Environmental Protection Agency

Division of Drinking and Ground Waters

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Prepared by Ohio Environmental Protection Agency
Division of Drinking and Ground Waters

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July 31, 2000

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Cover Illustration: Graphic illustrates the main aquifer settings within Ohio, (see Figure 4, main document for specifics); courtesy of Ohio Department of Natural Resources, Division of Water, Statewide Aquifer Mapping Project.

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INTRODUCTION

Ohio Environmental Protection Agency (Ohio EPA) is the designated state ground water quality management agency for preventing and addressing ground water quality problems. To meet this responsibility, Ohio EPA characterizes ambient ground water quality conditions; identifies ground water contamination; determines cause and effect relationships; and recommends strategies for preventing contamination. The Division of Drinking and Ground Waters (DDAGW) has the lead role for these activities within Ohio EPA. In addition, DDAGW coordinates ground water monitoring efforts with other state programs. The 2000 305(b) report incorporates extensive efforts to improve the ambient water quality data used to characterize the quality of Ohio's ground water.

Efforts to improve Ohio's ability to characterize ground water quality since the last reporting period have focused on quality control of the ground water quality databases, improving our capabilities for manipulating the available data, entering older data into the water quality database, and including drinking water compliance data in water quality analysis. We have also worked to incorporate Geographical Information Systems (GIS) and other graphic tools to improve the analysis of the data and the presentation of the analytical results. The primary focus of these activities is to define background water quality for Ohio aquifers, identify natural variation in the state aquifers, and help locate sensitive hydrogeologic settings in the state. The goal is to utilize these water quality data to help identify areas where ground water quality has been affected by human activities.

This 305(b) Report allows Ohio EPA to document the progress that we have made in evaluating the water quality in the state aquifers. The report is organized to provide a summary of State ground water programs followed by a general description of the DDAGW's programs. Then a description of the major aquifer types in Ohio is provided. Analytical efforts of the Ground Water Quality Group to characterize the water quality of Ohio's three major aquifer types is consistent with U.S. EPA's request to assess the water quality for selected aquifers or hydrogeologic settings. In the Appendix , sources of contamination are discussed, state water programs are described, and four 305(b) tables are presented as requested by U.S. EPA: Major Sources of Ground Water Contamination; Summary of State Ground Water Protection Programs; Ground Water Contamination Survey; and Aquifer Monitoring Data. Data in these tables are presented on a statewide basis. We do not currently have sufficient locational information to associate contamination sites with aquifer types or hydrogeologic setting.

This report has been prepared by Chris Kenah, Kathy Musser, Linda Slattery, and Michael Slattery with input from other DDAGW staff and GIS specialists including Dick McClish, Brian Gara, and Rob Hanover. We gratefully acknowledge the numerous District Office staff who make this all possible through their water sample collection and field efforts.

OHIO GROUND WATER PROGRAMS

Programs to monitor, evaluate, and protect ground water resources in Ohio are carried out by various federal, state and local agencies. Ground water related activities at the state level are conducted by the Ohio Departments of Agriculture, Commerce (Division of State Fire Marshal), Health, Natural Resources, Transportation, and by the Ohio Environmental Protection Agency and Public Utilities Commission. The United States Geological Survey (USGS), Water Resources Division, contributes to these efforts with water resource research. Figure 1 illustrates the ground water monitoring programs in Ohio. The State Coordinating Committee on Ground Water (SCCGW) was created by the directors of these state agencies. The purpose of the SCCGW is to promote and guide the implementation of a coordinated, comprehensive, and effective ground water protection and management program for the state of Ohio. Ohio EPA is the lead agency in administering the SCCGW.

Ohio EPA ground water related activities include ground water quality monitoring and assessment, as well as evaluation, prevention and remediation of ground water pollution from existing and proposed waste disposal sites. Ohio EPA, DDAGW, functions as a technical support unit for other Ohio EPA programs by providing technical expertise on local hydrogeology and ground water quality. Specific activities of the ground water staff include: waste disposal treatment and storage site investigations; ground water complaint response; review of plans and site feasibility reports to insure adequate ground water protection; and surveillance at land disposal sites. The Division also maintains a statewide ground water quality monitoring program; oversees activities associated with underground injection wells (Class I and V); carries out the state public water supply supervision program; and is the lead office in developing and implementing Ohio's Source Water Protection Program (SWAP). Legal authority to support Ohio EPA ground water functions is included in Sections 6109, 6111, 3734, and 3745, Ohio Revised Code (ORC). Other divisions and units within Ohio EPA also have major ground water responsibilities including the Divisions of Surface Water, Solid and Infectious Waste, Hazardous Waste Management, and Emergency and Remedial Response.

The **Ohio Department of Natural Resources** (ODNR), Division of Water, is responsible for the quantitative evaluation of ground water resources. Specific functions include: ground water mapping; administering Ohio's well log and drilling report law; special hydrogeologic investigations; water quantity assessment; and technical assistance to municipalities, industries, and the general public regarding local geology, well drilling, and water development. Statutory authority for these activities is contained in Section 1521 and 1523, ORC. The Division of Water is also helping to collect existing hydrogeologic data from their files to help complete SWAP assessments. The Division of Water is working on computerization of the well log system and recently completed the State Aquifer Maps, both of which contribute to data available for evaluating ground water. The well log computerization is ongoing but currently well logs can be searched by address over the Internet. The Internet selection options for ODNR well logs will increase as the computerization efforts are completed. The State Aquifer Maps are GIS coverages that include a Glacial Aquifer Map with five attributes describing the aquifer (thickness, aquifer setting, yield, lithology, and local name) and multiple bedrock coverages with three attributes describing the aquifer (yield, thickness, and name). The Aquifer Maps are available as GIS coverages, and are a valuable tool for analysis of ground water resources in combination with other GIS based information, such as well location or water quality data.

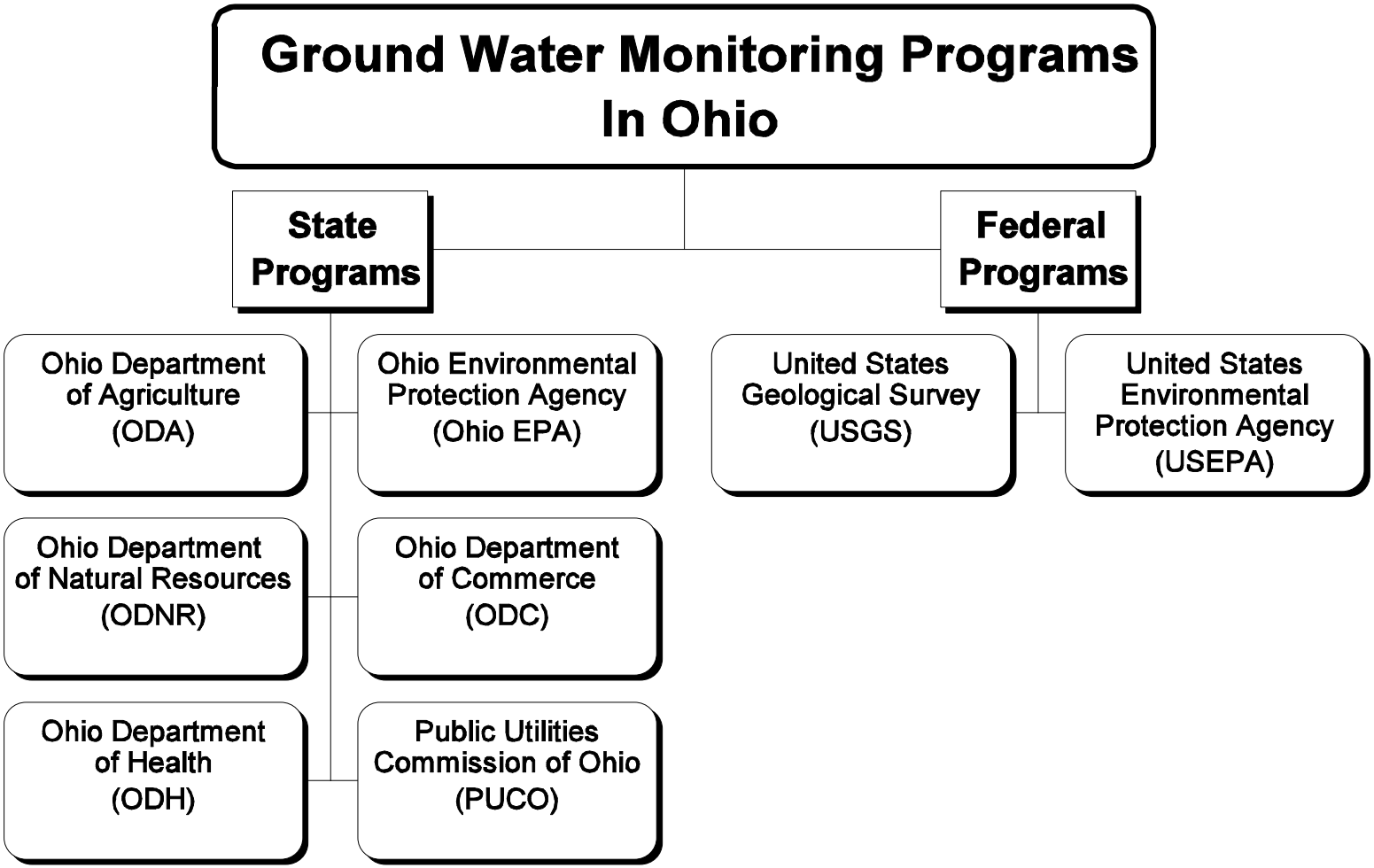
Ground Water Monitoring Programs In Ohio
State Programs
Federal Programs
Ohio Department of Agriculture (ODA)
Ohio Environmental Protection Agency (Ohio EPA)
Ohio Department of Natural Resources (ODNR)
Ohio Department of Commerce (ODC)
Ohio Department of Health (ODH)
Public Utilities Commission of Ohio (PUCO)
United States Geological Survey (USGS)
United States Environmental Protection Agency (USEPA)

Figure 1.

The ODNR Division of Mineral Resources Management, acting under authority of Section 1509, 1513, and 1514, ORC, administers rules and regulations to manage oil and gas reserves and to control pollution from activities associated with petroleum production. Major functions which directly relate to ground water protection include regulating well drilling, well casing, and well abandonment techniques; and regulating storage and disposal practices for associated waste fluids. The Division administers the State's underground injection control programs for mineral extraction wells, enhanced oil recovery operations, and brine disposal (Class II and III injection wells). Additionally, the Division oversees mining activities in the State and may require ground water monitoring and follow-up corrective actions around newly permitted coal strip mining areas.

Other divisions within ODNR also have ground water related responsibilities. The Division of Soil and Water Conservation (Section 1511, ORC) is responsible for developing programs which abate water pollution associated with soil erosion and animal waste handling activities. The Division of Geological Survey collects, interprets, and disseminates information on Ohio's bedrock and glacial geology. Ongoing programs for geologic mapping, geophysical testing, and test drilling provide a better understanding of the geologic framework of Ohio aquifers. The Division of Geological Survey recently produced a new Quaternary Geology of Ohio map, which is an extensive revision of the 1961 Glacial Map of Ohio, by Goldthwait, White, and Forsyth.

The **Ohio Department of Health** (ODH) is responsible for programs to regulate the siting, design, operation, and maintenance of private residential water supply systems and sewage disposal systems, which may have direct impacts upon local ground water quality and drinking water safety. ODH has developed rules governing specific well construction practices and a well permit system, effective January 1, 2000 (Chapter 3701-28, OAC). These rules are administered in cooperation with local health departments. Local health departments and ODH investigate complaints of private wells that are suspected of being contaminated. ODH programs are mandated by Section 3701 ORC, and include a registration program for private water system contractors.

In 1999, ODH investigated the distribution of arsenic in private wells in portions of Perry and Jackson Counties. With the growing awareness of arsenic in ground water, compliance sampling for public water systems that identified high arsenic values raised concern about private wells in these areas. Samples collected were analyzed for arsenic, total iron, phosphorous, nitrate, and total coliform. The studies found that all of the wells with detections were completed in the buried valley aquifer or in the sandstone formation immediately underlying the buried valley deposits. Additional studies are planned.

In the **Ohio Department of Commerce**, Division of State Fire Marshal, the Bureau of Underground Storage Tank Regulations (BUSTR) is responsible for registration of underground storage tanks (UST) for petroleum products and development of rules for underground tank installation, testing, and abandonment. BUSTR Staff investigate and direct UST removal and associated ground water clean-up activities in conjunction with local fire departments.

The **Ohio Department of Agriculture** (ODA) administers the Pesticide Regulation Section for programs regulating agricultural pesticides, and oversees pesticide applicator training programs. The department carries out limited testing of wells located at bulk pesticide storage and handling facilities, and has identified contaminated wells at some sites. ODA is the lead agency in developing the State Management

Plan for Pesticides to protect Ohio's ground waters from pesticide contamination. In 1999, ODA received verbal concurrence for the Pesticide Management Plan for the State of Ohio from U.S. EPA. Written approval is waiting on the cooperative commitment of the directors of ODH, ODNR, and Ohio EPA to implement the Pesticide Management Plan for the State of Ohio. In addition, various ODA divisions sample for pathogens in wells that produce water used in food processing.

The **USGS**, **Division of Water Resources**, efforts focus on collecting and interpreting ground water data to examine the sustainability of ground water resources. Relevant research includes description and evaluation of water resources, including mapping of water levels and ground water discharge of regional aquifers, local and regional modeling of ground water flow, local studies using Federal and State Co-operative funds, and the National Water Quality Assessment Program (NWQAP) as well as summary reports on national trends of water quality. The USGS is also helping to collect existing hydrogeologic data from their files to help complete SWAP assessments.

U.S. EPA collects ground water monitoring data at CERCLA sites for which they oversee cleanup and at RCRA sites that are permitted with the U.S. EPA. Federal legislation overseen by the U.S. EPA certainly drives much of the ground water monitoring and analysis completed in the state, such as the requirement for the 305(b) Report.

The **Office of Federal Facilities Oversight (OFFO)** collects ground water data from Federal facilities.

OHIO EPA GROUND WATER CHARACTERIZATION PROGRAM

Ohio EPA, DDAGW is responsible for characterizing Ohio's ground water quality. Ground water quality monitoring information is collected through the new well approval process for public water supply wells, compliance sampling for public drinking water systems, sampling of the ambient network wells, and various special studies. The division also receives water quality data collected from permitted solid waste, RCRA regulated hazardous waste sites, and Ohio EPA Division of Emergency and Remedial Response (DERR) sites. Significant progress is being made to utilize these water quality data to characterize Ohio's water quality. The goal is to employ water quality data to identify baseline water quality for the main aquifer types and to characterize the natural variation within the aquifer types on a regional and temporal basis. Then these data can be used to identify areas of contaminated ground water within Ohio. Once identified, areas of ground water impact can be investigated and analyzed to identify likely causes, in order to focus protection strategies in priority areas. A discussion of the major sources of contamination is included in the Appendix, U.S. EPA Table 5.1. Figure 2 illustrates the hierarchy of DDAGW water quality monitoring data.

The water quality analysis presented in this report utilizes the Ambient data and, to a lesser extent, public water system (PWS) compliance data. This focus reflects the quality and electronic availability of drinking water compliance data. Because of the importance of the Ambient and PWS compliance data to the water quality analysis presented in this report, these data are described in separate sections below. The other DDAGW ground water monitoring programs identified in Figure 2 will eventually contribute to the water quality characterization effort. DDAGW staff are evaluating and organizing historic data, collected primarily between 1973 and 1985**.** This includes data collected during complaint

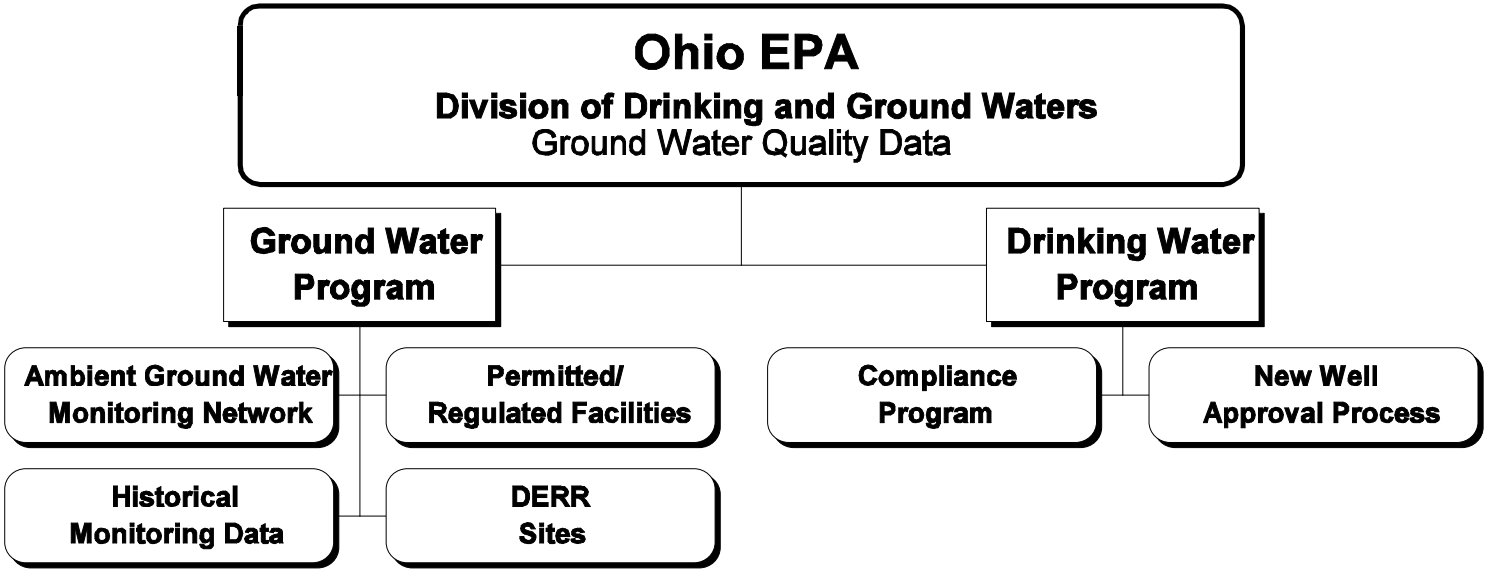
Ohio EPA
Division of Drinking and Ground Waters
Ground Water Quality Data
Ground Water Program
Drinking Water Program
Ambient Ground Water Monitoring Network
Permitted/ Regulated Facilities
Historical Monitoring Data
DERR Sites
Compliance Program
New Well Approval Process

Figure 2.

investigations, litigation sampling, and pollution source investigation sampling. Only data with accurate location and basic geologic information is being selected for entry into the database. To date, these historic data have not been incorporated in our water quality analysis. The monitoring data that DDAGW receives from permitted/regulated facilities and DERR sites are another untapped source of ground water quality information. Most of these data are submitted in standard format, but the effort to organize this information into a water quality database for statewide analysis has not been initiated. The Division completes special studies that focus on nonpoint sources such as arsenic, radon, pesticides or nitrates, which provide an additional source of data for water quality characterization. Finally, the required new public well analysis of raw water, which includes an extensive suite of parameters, provides an accurate characterization of water quality. In the case of transient public water systems, this new well sample is the only required monitoring, and a broad spectrum of geochemical parameters are reviewed.

Other Ohio EPA divisions have data relevant to ground water quality. The Division of Surface Water has extensive surface water sampling data that is important for evaluating ground water and surface water interactions. In addition, their nonpoint source programs collect data that are relevant to potential ground water impacts. The Division of Emergency and Remedial Response receives some ground water monitoring data from Voluntary Action Program sites that could be incorporated with ground water monitoring data from regulated sites. As DDAGW's Ground Water Quality Characterization Program matures, we will incorporate these additional data into our analysis.

Ambient Water Quality Data

As part of the effort to characterize general water quality conditions in Ohio, DDAGW maintains the Ambient Ground Water Monitoring Network. Data collection activities occur at the district offices, and compilation, database design, and data analysis are completed mainly in the central office. This program to sample raw water was originally established in 1967 to measure seasonal and annual changes in water quality in the state's major aquifers. The network initially consisted of 12 large production wells. The program expanded to 60 well stations in 1972 and continued at that level into the early 1980s. In 1986, the network was further expanded to around 90 stations. To provide better representation of the primary aquifers in Ohio, a large number of wells were added to the network in the late 1980s and early 1990s.

The program currently includes approximately 212 well stations at approximately 206 sites. The distribution of Ambient sites is illustrated in Figure 3. Of the total sites, roughly 181 (85 percent) are public water systems, and roughly 31 (15 percent) are industrial or commercial enterprises or private residents. Raw water is analyzed for inorganics every six or eighteen months depending on the total number of samples that have been collected and the stability of the geochemistry of major elements at the site. Table 1 lists the inorganic parameters for which Ambient samples are analyzed. Samples are analyzed for volatile organic compounds and semi-volatile organic compounds once every eighteen months.

To be included in the Ambient Monitoring Network, the production aquifer should not be impacted by localized spills or other local waste concerns. This is confirmed by reviewing the organic analysis results. Thirty-three wells had organic compounds detected between January 1, 1998, and December 31, 1999. Of these, 20 wells were impacted by potential disinfection by-products or laboratory contaminants. Only 13 wells revealed VOC's or pesticides above the detection level, and these were well below the Maximum Contaminant Level (MCL).

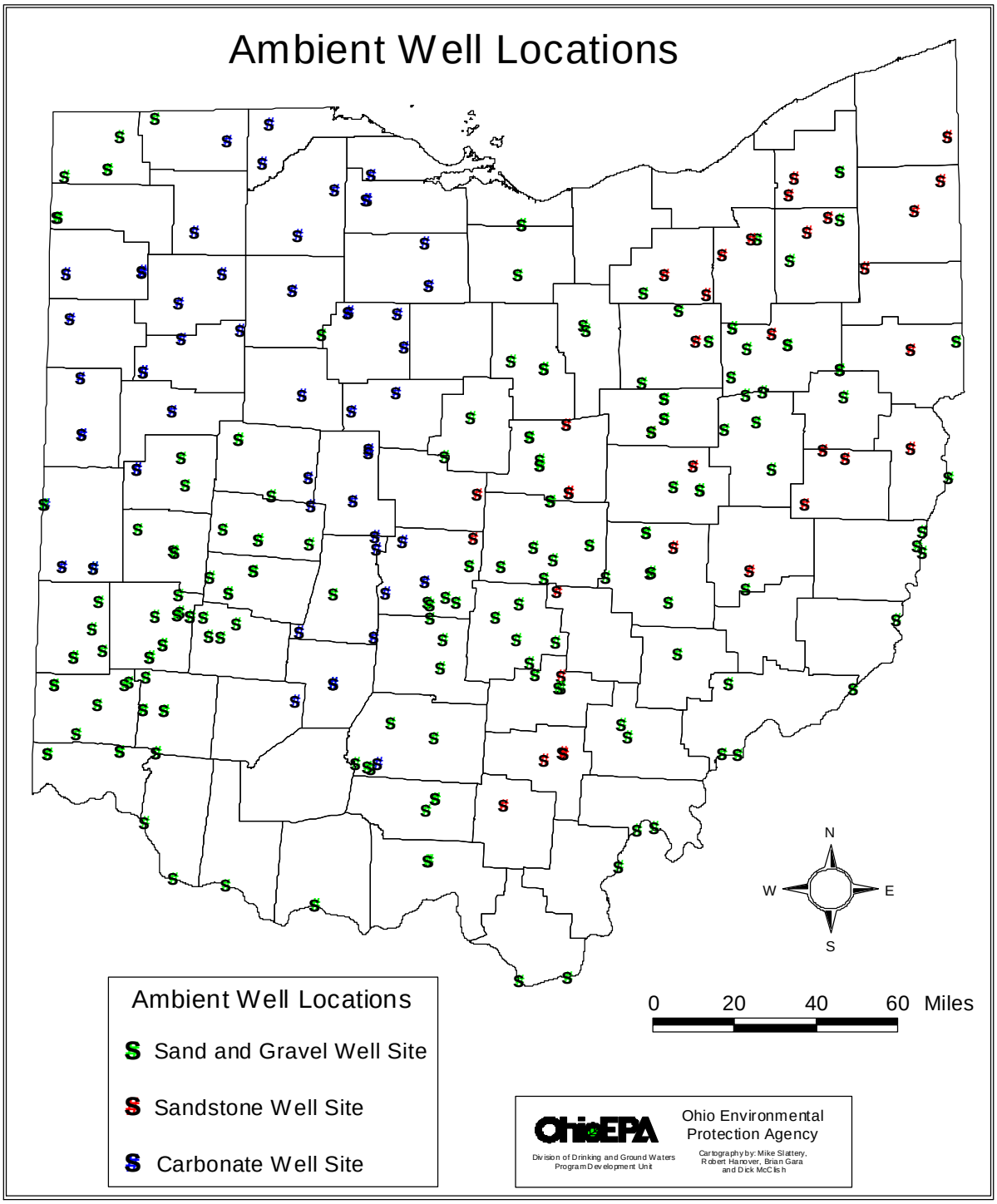
Ambient Well Locations
N
W
E
S
0
20
40
60
Miles
Ambient Well Locations
Sand and Gravel Well Site
Sandstone Well Site
Carbonate Well Site
OhioEPA
Division of Drinking and Ground Waters
Program Development Unit
Ohio Environmental
Protection Agency
Cartography by: Mike Slattery,
Robert Hanover, Brian Gara
and Dick McClish

Figure 3

.

Table 1

INORGANIC CHEMICAL PARAMETERS FOR AMBIENT MONITORING NETWORK WELLS	
PARAMETERS	**CURRENT DETECTION LIMITS**
Major Constituents	**mg/L**
Alkalinity, Total as $CaCO_3$	5
Calcium (Ca)	2
Chloride (Cl)	5
Hardness as $CaCO_3$	10
Magnesium (Mg)	1
Potassium (K)	2
Sodium (Na)	5
Sulfate (SO_4)	5
Total Dissolved Solids (TDS)	10
Trace Constituents	**µg/L**
Aluminum (Al)	200
Arsenic (As)	2
Barium (Ba)	15
Cadmium (Cd)	0.2
Chromium (Cr)	30
Copper (Cu)	10
Fluoride (F)	0.10 mg/L
Iron (Fe)	50
Lead (Pb)	2
Manganese (Mn)	10
Nickel (Ni)	40
Selenium (Se)	2
Strontium (Sr)	30
Tritium (^3H)	0.8 T.U.
Zinc (Zn)	10
Nutrients	**mg/L**
Ammonia (NH_3)	0.05
Chemical Oxygen Demand (COD)	10
Nitrate/Nitrite (as N)	0.10
Phosphorus (P)	0.05
Total Kjeldahl Nitrogen (as N)	0.2
Total Organic Carbon (TOC)	2
Field Analysis	**Relative Accuracy**
pH	± 0.02 S.U.
Specific Conductance (µmhos/cm)	± 0.5 %
Temperature	± 0.1 EC

Locational and lithologic information have been compiled for all of the 212 ambient wells currently in the ambient database for effective geochemical and GIS analysis. Two-thirds of the wells in the ambient network are developed in unconsolidated deposits, including cobble (1 site), gravel (8), sand (5), and sand and gravel (119). These four lithologies are grouped as the sand and gravel aquifers.

One-third of the network wells are production wells developed in bedrock aquifer systems. The sandstone (24), shale (2), and interbedded sand and shale (6) aquifers are included in the sandstone aquifer category. The dolostone (1), limestone (43), and interbedded carbonate and clastics (1) aquifers are included in the carbonate bedrock category. These broad categories are discussed in more detail in the "Major Aquifers Types" section that follows.

There are limitations to using Ambient data to characterize state-wide ground water quality. The most significant limitation is the range of well types (high-production public versus low-production public versus domestic). The bulk of the Ambient Monitoring Network wells are of the high-yield public water supply type. The high production wells in the unconsolidated units are generally deeper, and have long well screens. Bedrock wells are typically cased to the bedrock with open boreholes in the bedrock. These types of wells may allow a certain amount of natural mixing of waters between stratigraphic or hydro-stratigraphic units. Other possible sources of bias include the number and variety of sampling personnel and the somewhat irregular sampling frequencies. On the other hand, a single laboratory is used for all Ambient Program chemical measurements state-wide, providing strong analytical consistency. Despite these potential error sources, the data set quality is quite high; the geochemical variability between the aquifer types is easily discerned, as illustrated in the Ohio Water Quality Characterization Section of this report.

During the 1998-1999 reporting period for the 2000 305(b) Report, a significant effort has been made to increase the quality of the Ambient water quality database, develop standard procedures for data management, and to research and complete the header data associated with the Ambient wells. Although tedious, these efforts provide us with high confidence in the Ambient data. The following Ambient data management and QA/QC procedures have been completed:

- Sample tracking program has been developed to schedule sample collection for future sampling rounds;
- Procedure for electronic upload of laboratory inorganic water quality data was developed and implemented;
- Organic data entry procedures were finalized, and Ambient data for 1998 and 1999 were entered and QA/QC processed;
- Procedures for statistical analysis of censored data were selected and are being applied to the ambient data;
- A box plot procedure for identifying outliers was selected, and the application of this approach was used as a final QA/QC for the data to help identify transcription errors in the database;
- A procedure to evaluate the major element stability of a site using time trend analysis was established;
- A charge balance was calculated on each Ambient sample processed for the Spring 1999 sampling round to estimate the adequacy of analytical results. The mean, overall charge balance error for water samples from all three aquifer types was 4.2, well within the established acceptable range of less than fiver percent.

With this effort, the Ambient water quality data is the best raw water-quality data that DDAGW has to characterize statewide ground waters. Consequently, we have utilized them extensively in this report to characterize the water quality of the three major aquifer types in Ohio. The expertise of the GIS Staff and the development of expertise with data plotting programs are critical parts of the efforts to analyze these data and present them in effective ways.

Public Water System Data

ODH began water quality sampling and analysis of public water supplies in the early 1940s. With the formation of Ohio EPA in 1972, these duties were transferred to Ohio EPA. Samples of both raw and finished water from community water suppliers were collected and analyzed through the mid-1970s. The analyses provided a continuing record of public water supply quality to ensure that violations of recommended health (primary) or aesthetic (secondary) standards in drinking water were identified and corrected. Between 1950 and 1977, over 15,000 raw water chemical analyses of the State's public ground water supplies were obtained. Since around 1977, only finished (treated) water has been tested on a regular basis, and analyses are largely limited to primary (health related) drinking water parameters.

Even though public drinking water compliance sampling is targeted only at treated water, the wide distribution and large number of public water systems make these data useful in characterizing Ohio's ground water. The data from treated water (compliance sampling) and from an untreated public water supply are hereafter collectively referred to as public water system (PWS) data. In the case of nitrate and arsenic, we make the assumption that the treatment process does not significantly effect concentration of these elements in the sampled water.

Treated water from Ohio's public water systems is currently being monitored on a continuing basis in accordance with the Federal Safe Drinking Water Laws and Chapter 6109 of the ORC. Sampling is based on three year cycles, but sampling schedules for each contaminant group are different. Individual sampling schedules are produced for each public water supplier by DDAGW based on past sampling results and various waiver programs. Guidelines for public drinking water monitoring for ground water based systems are provided in Table 2.

Table 2.

Drinking Water Monitoring Requirements for Public Water Supply Wells.			
Contaminant Group	**Community PWS**	**Non-Transient, Non-Community PWS**	**Transient Non-Community PWS**
Radiological [a]	**Y**		
Trihalomethanes	**Y**		
Asbestos [b]	**Y**	**Y**	
Inorganic Constituents [c]	**Y**	**Y**	
Synthetic Organic Compounds (SOC's) [d]	**Y**	**Y**	
Volatile Organic Compounds (VOC's) [e]	**Y**	**Y**	
Lead and Copper [f]	**Y**	**Y**	
Microbiological [g]	**Y**	**Y**	**Y**
Nitrate and Nitrite [h]	**Y**	**Y**	**Y**

[a] Must monitor for gross alpha radioactivity once every three years. New community systems must complete four consecutive quarterly samples the first year of operation.
[b] Asbestos must be analyzed for once every nine years.
[c] Required to sample for 12 inorganic constituents every year
[d] Required to sample for 25 compounds. In the first quarter of 1999, all ground water community and non-transient non-community systems were required to sample for alachlor, atrazine, metalochlor, metribuzin and simazine. Systems that detected one of these pesticides will continue quarterly monitoring. If no detections were found, monitoring waivers were granted for the remainder of the three year cycle.
[e] Required to sample for 55 compounds. Initially, samples are required on a quarterly basis for one year, then a public water system can reduce sampling frequency to once a year. After three years of annual samples without VOC detections, sampling frequency can be reduced to once every three years.
[f] Action levels, not MCLs
[g] All ground water-based public water systems are required to monitor for total coliform at least once every quarter. A community system must sample for total coliform at least once per month.
[h] All ground water-based public water systems are required to monitor for nitrate and nitrite at least once per year. If the nitrate exceeds 50 percent of the MCL (i.e., 5 mg/L), or if nitrite exceeds 50 percent of the MCL (i.e., 0.5 mg/L), quarterly samples are required until the system is reliably and consistently below the MCL.

MAJOR AQUIFER TYPES

Ground water is a vital resource in Ohio. Approximately 1,100 of Ohio's 1,400 community water systems utilize ground water, including three of Ohio's largest cities (Dayton, Canton and Springfield). The cities of Columbus and Cincinnati use ground water to meet part of their daily water needs. Over 99 percent on the 4,500 non-community public water systems, (schools, small industries or businesses, service stations, golf courses, etc.) use ground water. In addition, nearly one million rural homes use ground water. The total number of Ohio residents who depend upon wells for drinking water and other domestic uses is approximately five million, and represents about 45 percent of the State's population. Ground water is important in meeting the demands of industry, agriculture, commercial establishments, and households. Total ground water pumped in Ohio for all uses is estimated at one billion gallons per day.

Three of the four major aquifers types illustrated in Figure 4 provide most of the ground water to Ohio citizens. The most productive aquifers are the sand and gravel units that occur in old stream valleys across the state. The sandstone bedrock aquifer setting provides water to the eastern portions of the state that do not use the sand and gravel units. The carbonate bedrock setting provides water to the western part of the state. The interbedded shale and carbonate aquifer is generally a very low-yielding set of formations, and its use is limited. The quantity of water obtained from wells is highly variable across the State and is dependent upon the local geology in the aquifer setting, and the users needs. Each of these aquifer settings is described in the following sections.

Sand and Gravel Aquifers

Ohio's most productive water bearing formations or aquifers are valley outwash deposits of sand and gravel that were deposited by glacial meltwater. They are found beneath and adjacent to the Ohio River, its major tributaries and other preglacial stream channels. The distribution of these Quaternary sand and gravel units is presented in a generalized manner as thin bands of material in Figure 4, which is simplified from the Glacial Aquifer Maps recently completed by ODNR. The Glacial Aquifer Maps provide high detail on the distribution of sand and gravel deposited by glacial and alluvial processes. Figure 4 illustrates the general distribution of the old river valleys cut by glacial meltwater and then filled in by glacial deposits as the glaciers receded. Because of their origin, the sand and gravel units are frequently referred to as buried valley aquifers, although this is not an accurate description of all the sand and gravel deposits that provide water to Ohio wells. For instance, in the northwest corner of the state, the wide area of sand and gravel units include sheets of outwash or gravel deposits that occur between glacial till sheets. Present day stream processes deposit alluvial sands and gravel deposits that can also be used as aquifers.

Water production from these sand and gravel units ranges from 500 to 1,000 gallons per minute in the coarser grained and thicker deposits. Lower yields from sand and gravel aquifers are more common. The production rate depends on the type, distribution, extent, and thickness of permeable glacial/alluvial deposits.

Sandstone Aquifers

In the eastern portions of Ohio where buried valley aquifers are not present, the common aquifer is sandstone (Figure 4). Upper Paleozoic sandstone and conglomerate formations (Permian to Mississippian age) in eastern Ohio occur as numerous individual layers of variable thickness and areal extent separated by layers of shale and other rock formations. The sandstone units generally dip a

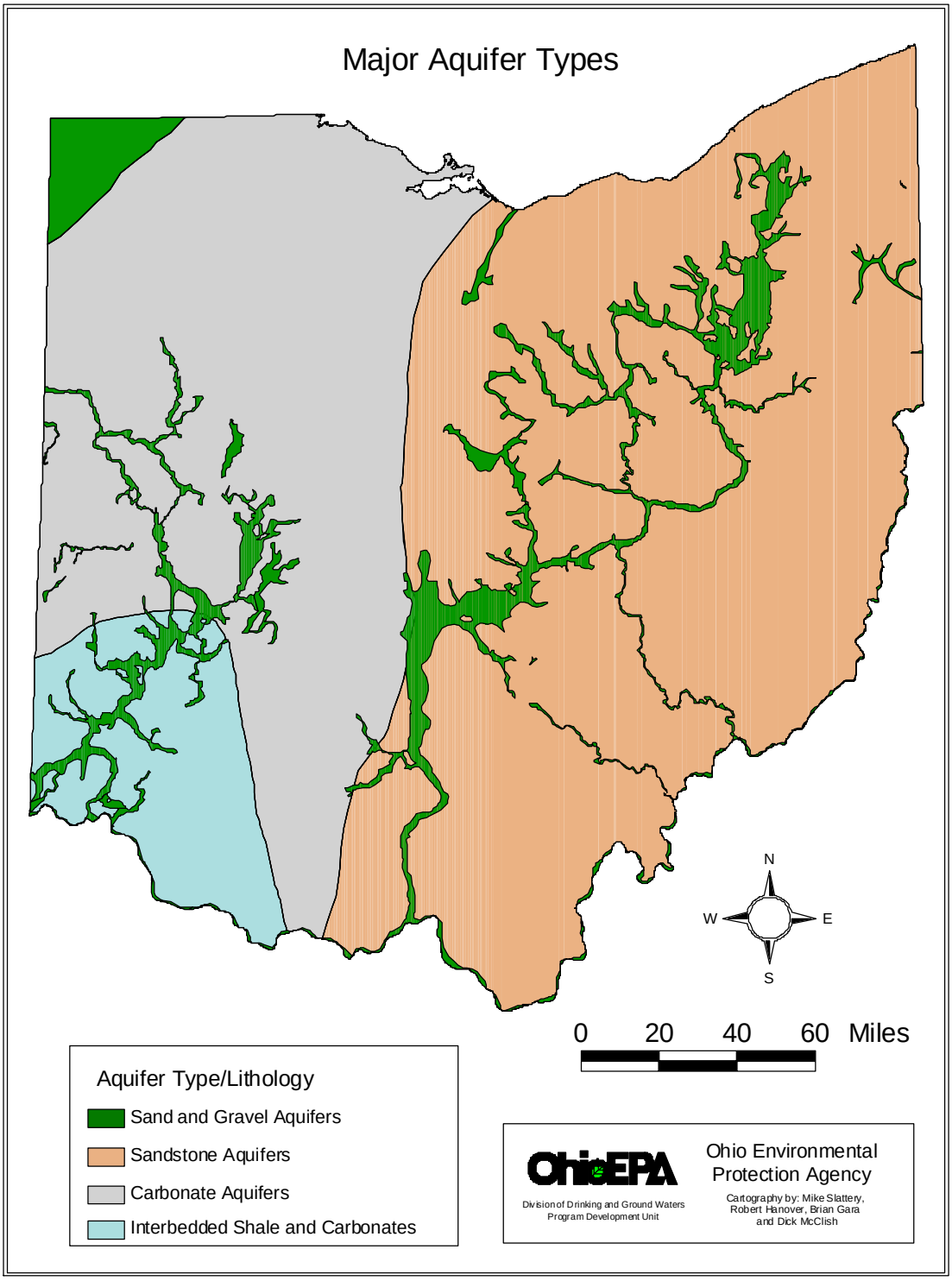

Figure 4. Modified from ODNR glacial aquifer map (ODNR, 2000).

few degrees to the southeast. Some of the thicker sandstones are capable of yielding 50 to 100 gallons per minute to individual wells.

In mny areas of southeastern Ohio productive sandstone aquifers are limited. The bedrock consists of massive shales or varied sequences of thin bedded shales, limestones, sandstones, clays, and coals, which do not yield much water to wells. A yield of two to three gallons per minute is not uncommon in these areas.

Carbonate Aquifers

The third major aquifer type is the carbonate bedrock which hosts the dominant aquifers in the western part of the state (Figure 4). Lower Devonian and Silurian limestones and dolomites reach a total thickness of 300 to 600 feet, and are capable of yielding from 100 to over 500 gallons of water per minute. Higher production is associated with fracture or dissolution features that increase the permeability of the carbonate bedrock.

Interbedded Shale and Carbonate Aquifers

In the southwestern portion of the state the interbedded shale and carbonate aquifer (Ordovician) is dominated by shale. These rocks have a relatively low potential for yielding ground water due to the predominance of shales and other impervious rocks. Well yields are generally less than 10 gallons per minute, and in many areas are less than one gallon per minute. In southwest Ohio, public water systems depend on the buried valley aquifers as the main ground water source. The interbedded shale and carbonate aquifer with low yields are only practical for low volume water users.

GROUND WATER QUALITY BY AQUIFER TYPE

Introduction

The overall ground water quality within the state of Ohio is described here using the Ambient Monitoring Network data base, consisting of nearly 2,700 water quality sampling events distributed across 212 sites (Figure 3). As described in the Major Aquifers Types section, the major aquifer settings are used to delineate the ground water quality between the unconsolidated sand and gravel units, sandstone bedrock, and carbonate bedrock (Figure 4). The majority of the wells used in this evaluation are production wells associated with public water supplies, usually developed within high-yield zones of generally good water quality. This is consistent with the aim of the Ambient Monitoring Network, which is to collect, analyze, and describe the background (ambient) ground water quality used by public water systems across the state.

Of the factors that contribute to the chemical makeup of ground water, the most significant are the composition of the recharge (percolation) water, the composition and nature of the aquifer solids, and the residence time of the ground water. These factors vary widely across the three main aquifers in Ohio, but some general observations on their effect on water quality are indicated based on aquifer types. In general, the initial composition of percolation water across the state is similar. Composition and solubility of soil materials, however, is highly variable across the state, leading to recharge waters with dissimilar initial compositions. Thus, the thick glacial tills (clayey soils) found across much of north, central, and west Ohio affect the initial percolation water quality much differently than the thin loess soils of southeast Ohio.

Increased residence time in an aquifer will typically lead to higher salinity and greater mineralization of the water, depending on the solubility of the available aquifer minerals. The sand and gravel units, for example, have typically shorter residence times, leading to lower salinities in these waters. These younger waters are generally more shallow, and, if affected by surface contamination, are more likely to still reflect this impact. Older, deeper waters, such as might be found in the carbonate system of northwestern Ohio may follow much longer flow paths, allowing the water ample time to fully equilibrate with the rock system. Figure 5 is a box plot indicating the distribution of well depths by aquifer type for the Ambient Monitoring Network. The median depth of the carbonate and sandstone systems are nearly the same, while the median depth for the sand and gravel units is about half as deep as the other two.

Parameter Means

Ground water across the state is generally of very high quality, as indicated by the mean aquifer geochemistry summarized in Table 3. This table provides the arithmetic mean, minimum value, maximum value, total number of samples, number of samples below the detection limit, and the percent censored for each parameter in each aquifer type as of December, 1999. The "percent censored" column records the percent of analyses measured below the current detection limit. The minimum value (column 4) in Table 3 may not always coincide with the modern detection limit (Table 2) due to changes over time in analytical methods and errors in data transcription. Estimates of the number and percentages of censored data (columns 7 and 8, Table 3) may be similarly affected.

The following analysis of Ambient Monitoring Network ground water quality data utilizes Maximum Contaminant Level (MCL) and Secondary Maximum Contaminant Level (SMCL) thresholds as convenient benchmarks for water quality comparisons. However, MCLs (regulated and enforceable) and

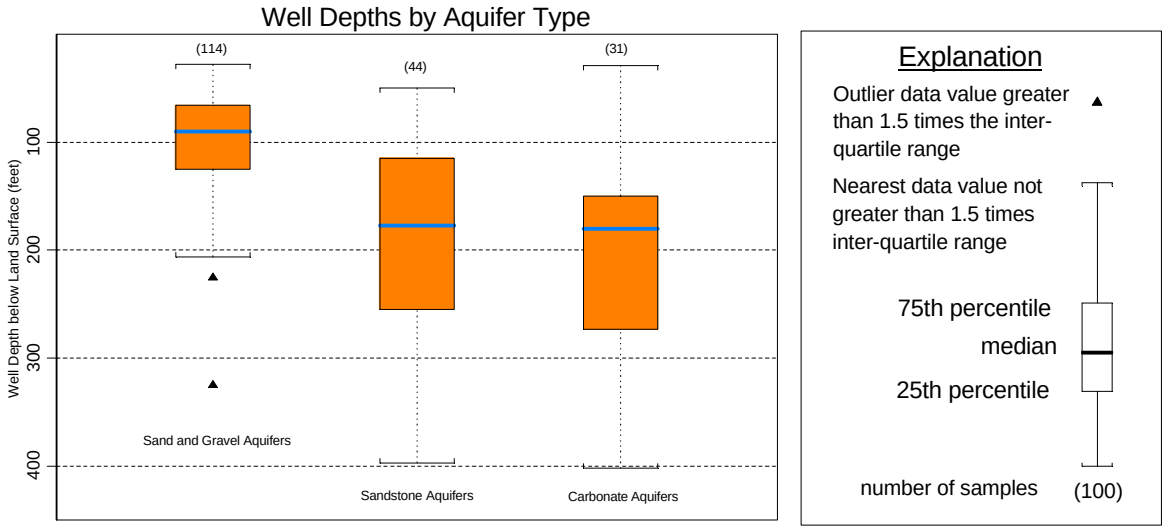

Figure 5

SMCLs (unregulated and unenforceable) are applied (in a regulatory sense) strictly to treated water at public water systems as an annual average. Since Ambient data are obtained entirely from raw (untreated) ground water, any exceedance of an MCL or SMCL by an Ambient data point has no legal or regulatory consequence. The usefulness of the following comparisons is only that MCLs and SMCLs are widely known, and thus represent a practical benchmark for discussion.

Eight of the enforceable primary drinking water standards with defined MCLs applicable to finished drinking water are monitored through the Ambient program. The MCLs are: arsenic (50 µg/L), barium (2 mg/L), cadmium (5 µg/L), chromium (100 µg/L), fluoride (4 mg/L), nickel 100 µg/L), nitrate-nitrite as N (10 mg/), and selenium (50 µg/L). Additionally, both lead (0.015 mg/L) and copper (1.3 mg/L) are covered by action levels for drinking water and are monitored by the program.

As indicated by Table 3, no chemical parameters exceed the MCL based on averages by aquifer type. Mean arsenic concentrations for all three aquifer systems were well below the MCL of 50µg/L (carbonate = 5.4 µg/L, sandstone = 2.5 µg/L, sand and gravel = 5.7 µg/L). Only a single (sand and gravel) station recorded a mean arsenic (As) concentration above the MCL. But proposed changes in the MCL raises concerns for those systems close to the newly suggested thresholds. Arsenic will thus be treated individually later in this report. Mean concentrations for barium, cadmium, chromium, fluoride, nickel, nitrate-nitrite, and selenium were also below the associated MCLs for these parameters within all three aquifer systems. Also, individual station means indicate no primary MCL exceedances for barium, cadmium, chromium, fluoride, nickel, and selenium. A single sand and gravel station mean exceeded the MCL for nitrate. Median nitrate concentrations for all three aquifer systems were less than 0.15 mg/L. Because nitrate-nitrite concentrations are useful indicators of anthropogenic (human activity) input, this parameter will also be discussed in a separate section in this report.

In addition to the eight primary drinking water standards, eight of the non-enforceable secondary drinking water standards with established SMCLs are monitored by the Ambient ground water program. Elevated levels of these parameters are related to aesthetic degradation of water quality. The SMCLs covered by this program are: aluminum (0.05 - 0.2 mg/L), chloride (250 mg/L), iron (0.3 mg/L),

Table 3. Ambient Network Data Summary by Major Aquifer as of December 31, 1999.

Parameter and Units	Major Aquifer	Mean Value	Minimum Value	Maximum Value	Number of Samples	Number Below Det. Limit	Percent Censored
FIELD PARAMETERS							
pH, Field S.U.	Sand and Gravel	7.31	5.8	8.9	1130	0	0
	Sandstone	7.23	5.9	8.6	181	0	0
	Carbonate	7.28	5.6	8.7	453	0	0
Specific Conductivity µmhos/cm	Sand and Gravel	523	1	1503	1209	0	0
	Sandstone	503	20	1276	192	0	0
	Carbonate	781	275	2330	467	0	0
Water Temperature Degrees C	Sand and Gravel	13.4	5.6	136.0	1272	0	0
	Sandstone	12.5	9.0	28.7	192	0	0
	Carbonate	13.4	7.7	65.0	472	0	0
MAJOR CONSTITUENTS							
Alkalinity, Total as $CaCO_3$ mg/L	Sand and Gravel	258	< 5.0	1500	1725	5	0
	Sandstone	220	< 5.0	496	295	0	0
	Carbonate	302	104.0	468	516	0	0
Calcium, Total mg/L	Sand and Gravel	89.5	< 2	300	1793	3	0
	Sandstone	62.6	< 2	163	311	2	1
	Carbonate	117.1	25	466	534	0	0
Chloride mg/L	Sand and Gravel	26.6	< 2.0	267	1774	50	3
	Sandstone	43.6	< 2.0	286	304	41	13
	Carbonate	23.0	< 2.0	299	501	33	7
Hardness, Total as $CaCO_3$ mg/L	Sand and Gravel	342	< 10	953	1174	4	0
	Sandstone	237	< 10	628	212	2	1
	Carbonate	492	99	1720	354	0	0
Magnesium, Total mg/L	Sand and Gravel	27.4	< 1	77	1797	5	0
	Sandstone	19.2	< 1	58	311	2	1
	Carbonate	48.4	9	134	535	1	0
Potassium, Total mg/L	Sand and Gravel	2.2	0.7	56.0	1654	187	11
	Sandstone	2.8	< 0.5	8.0	300	81	27
	Carbonate	2.7	0.8	8.4	484	9	2
Sodium, Total mg/L	Sand and Gravel	19.9	< 4	210	1799	35	2
	Sandstone	70.9	< 5	287	311	20	6
	Carbonate	32.4	< 5	131	535	11	2
Sulfate mg/L	Sand and Gravel	70.2	0.1	640	1777	10	1
	Sandstone	90.1	< 5.0	322	307	22	7
	Carbonate	216.9	< 5.0	1340	531	7	1
Total Dissolved Solids mg/L	Sand and Gravel	426	< 10	1650	1681	2	0
	Sandstone	450	< 10	1110	294	2	1
	Carbonate	667	320	2240	495	0	0
TRACE CONSTITUENTS							
Aluminum µg/L	Sand and Gravel	200.1	84.0	753	994	992	100
	Sandstone	200.4	< 200.0	234	251	249	99
	Carbonate	201.1	< 200.0	553	299	296	99
Arsenic, Total µg/L	Sand and Gravel	5.77	< 2.0	95	1628	823	51
	Sandstone	2.50	< 2.0	30	290	223	77
	Carbonate	5.44	< 2.0	21	499	317	64
Barium µg/L	Sand and Gravel	154.8	15.0	1440	1584	55	3
	Sandstone	93.4	15.0	1980	280	18	6
	Carbonate	77.2	7.0	346	497	52	10

Parameter and	Major Aquifer	Mean Value	Minimum Value	Maximum Value	Number of Samples	Number below Det. Limit	Percent Censored
	Sand and Gravel	0.21	< 0.2	5.0	1290	1270	98
Cadmium, Total	Sandstone	0.28	< 0.2	6.0	291	284	98
µg/L	Carbonate	0.23	< 0.2	10.2	473	463	98
	Sand and Gravel	25.6	< 10.0	50	1346	1330	99
Chromium, Total	Sandstone	26.9	< 10.0	30	297	293	99
µg/L	Carbonate	28.4	< 10.0	50	483	470	97
	Sand and Gravel	9.54	< 2.0	220	1111	941	85
Copper, Total	Sandstone	10.51	< 2.0	93	289	224	78
µg/L	Carbonate	11.24	< 2.0	270	335	234	70
	Sand and Gravel	0.37	< 0.1	2.3	846	79	9
Fluoride	Sandstone	0.32	< 0.1	1.2	220	23	10
mg/L	Carbonate	1.28	< 0.1	3.2	282	2	1
	Sand and Gravel	1169.8	< 50.0	29700	1786	333	19
Iron, Total	Sandstone	1382.7	< 50.0	17200	309	59	19
µg/L	Carbonate	1441.4	< 50.0	10200	536	75	14
	Sand and Gravel	2.65	< 2.0	101	1612	1445	90
Lead, Total	Sandstone	2.93	< 2.0	40	296	266	90
µg/L	Carbonate	2.69	< 2.0	167	453	385	85
	Sand and Gravel	158.3	5.3	5130	1697	255	15
Manganese, Total	Sandstone	166.3	9.0	1810	304	36	12
µg/L	Carbonate	24.9	10.0	300	489	162	33
	Sand and Gravel	34.7	< 1.0	74	1050	1042	99
Nickel, Total	Sandstone	37.1	< 20.0	144	262	249	95
µg/L	Carbonate	37.5	< 20.0	88	317	300	95
	Sand and Gravel	2.14	< 2.0	10	1154	1099	95
Selenium, Total	Sandstone	2.09	< 2.0	10	283	281	99
µg/L	Carbonate	2.06	< 2.0	10	316	298	94
	Sand and Gravel	1733.9	< 30.0	30800	1050	6	1
Strontium, Total	Sandstone	604.7	< 10.0	2120	256	3	1
µg/L	Carbonate	17232.2	< 30.0	59300	327	4	1
	Sand and Gravel	9.0	< 0.8	42	108	7	6
Tritium	Sandstone	8.3	< 0.8	22	26	5	19
T.U.	Carbonate	4.2	< 0.8	14	44	14	32
	Sand and Gravel	18.4	2.7	3620	1143	764	67
Zinc, Total	Sandstone	45.7	< 10.0	426	276	116	42
µg/L	Carbonate	37.2	< 10.0	2420	319	135	42
NUTRIENTS							
	Sand and Gravel	0.17	< 0.01	3.1	1735	634	37
Ammonia-N	Sandstone	0.38	< 0.05	2.2	302	92	30
mg/L	Carbonate	0.41	< 0.05	5.1	518	63	12
Chemical	Sand and Gravel	10.8	9.0	116	997	927	93
Oxygen Demand	Sandstone	10.8	< 10.0	55	245	229	93
mg/L	Carbonate	12.9	< 10.0	371	347	288	83
	Sand and Gravel	0.86	< 0.01	135.0	1590	974	61
NO2+NO3 as N	Sandstone	0.31	0.10	4.3	293	240	82
mg/L	Carbonate	0.21	< 0.05	30.5	491	466	95
	Sand and Gravel	0.10	< 0.05	10.0	1355	1009	74
Phosphorus, Total	Sandstone	0.11	< 0.05	4.4	247	148	60
mg/L	Carbonate	0.07	< 0.05	2.0	390	304	78
	Sand and Gravel	0.30	< 0.1	2.9	179	86	48
Total Kjeldahl N	Sandstone	0.59	0.2	2.2	63	29	46
mg/L	Carbonate	0.58	< 0.1	5.3	61	14	23
	Sand and Gravel	3.6	< 0.5	75	1106	997	90
Total Organic Carbon	Sandstone	2.8	< 0.5	13	247	235	95
mg/L	Carbonate	3.0	1.0	73	344	283	82

manganese (0.05 mg/L), pH (7-10.5 SU), sulfate (250 mg/L), total dissolved solids (TDS) (500 mg/L), and zinc (5 mg/L). Since these parameters are more closely related to general ground water quality, they will be discussed in the aquifer type sections below.

General Water Types

Based on major ion composition, the three general water types encountered are a calcium-bicarbonate type in the sand and gravel aquifers, a calcium-sodium-bicarbonate type in the sandstone aquifers, and a calcium-bicarbonate-sulfate type in the carbonate aquifers. This information is displayed graphically in Figure 6, which compares the mean major ion composition of the three aquifer systems. While all three

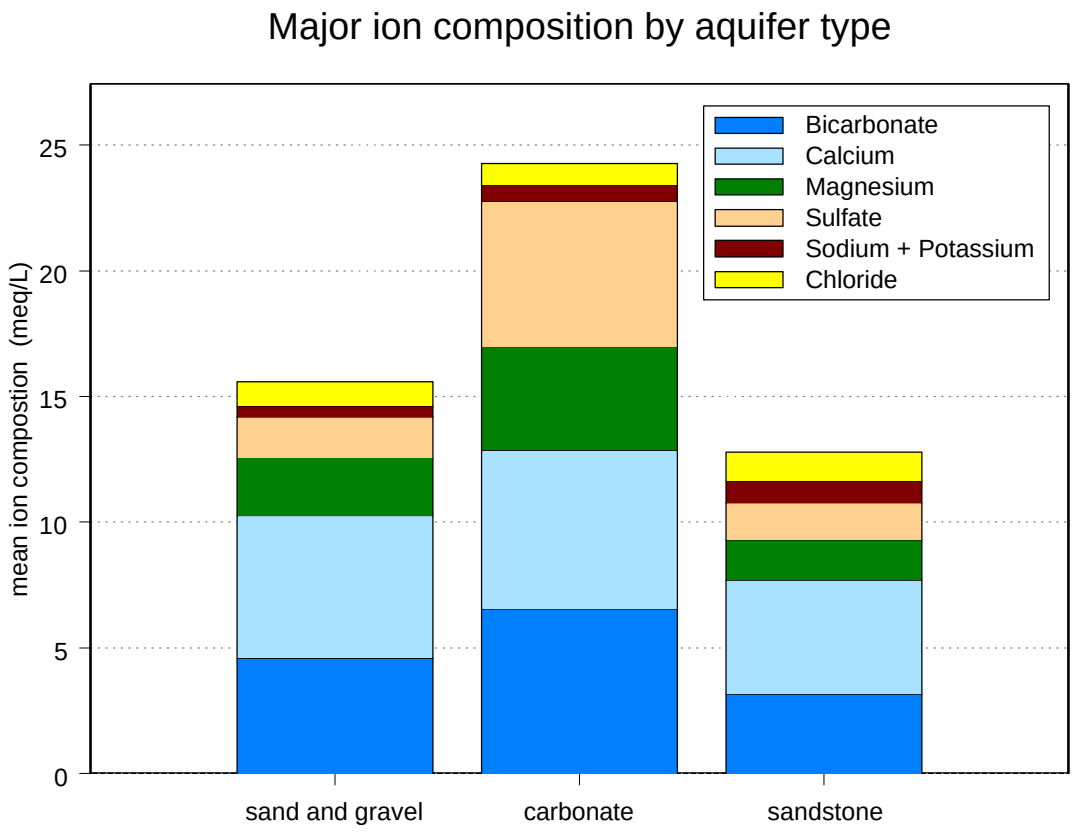

Figure 6.

water types are based on the calcium-bicarbonate model, the sandstone aquifer waters are highest in sodium and chloride. The carbonate ground waters have the highest bicarbonate, calcium, magnesium, and sulfate ion concentrations. Also notable is the fact that the carbonate waters have the highest mean ionic strength of the three aquifer types; this correlates well with the longer residence time within the carbonate system. The lower TDS of the sandstone aquifers is attributed to the higher silica sand and lower carbonate rock content in the sandstones. These same data are presented on a Piper diagram in Figure 7. This graphic provides a summary of cation data (left triangle), anion data (right triangle) and a composite diamond (center) to visually distinguish waters of different chemistries and origin.

The carbonate ground waters in Figure 7 (blue plotting points) trend toward a more sulfate-rich composition, reflecting the dissolution of strontium-, calcium-, and sulfate-bearing minerals. These waters

display a wide range of alkalinity concentrations. The overlap between the carbonate and sand and gravel aquifer water chemistries (green plotting points) is due to the fact that much of the aquifer material in the unconsolidated (sand and gravel) units is actually carbonate in origin. The sandstone water chemistry (red plotting points) reveals a higher mean sodium, potassium, and chloride content than the other two systems, indicating a probable natural source for these ions, apparently from dissolution of simple salts or matrix cements.

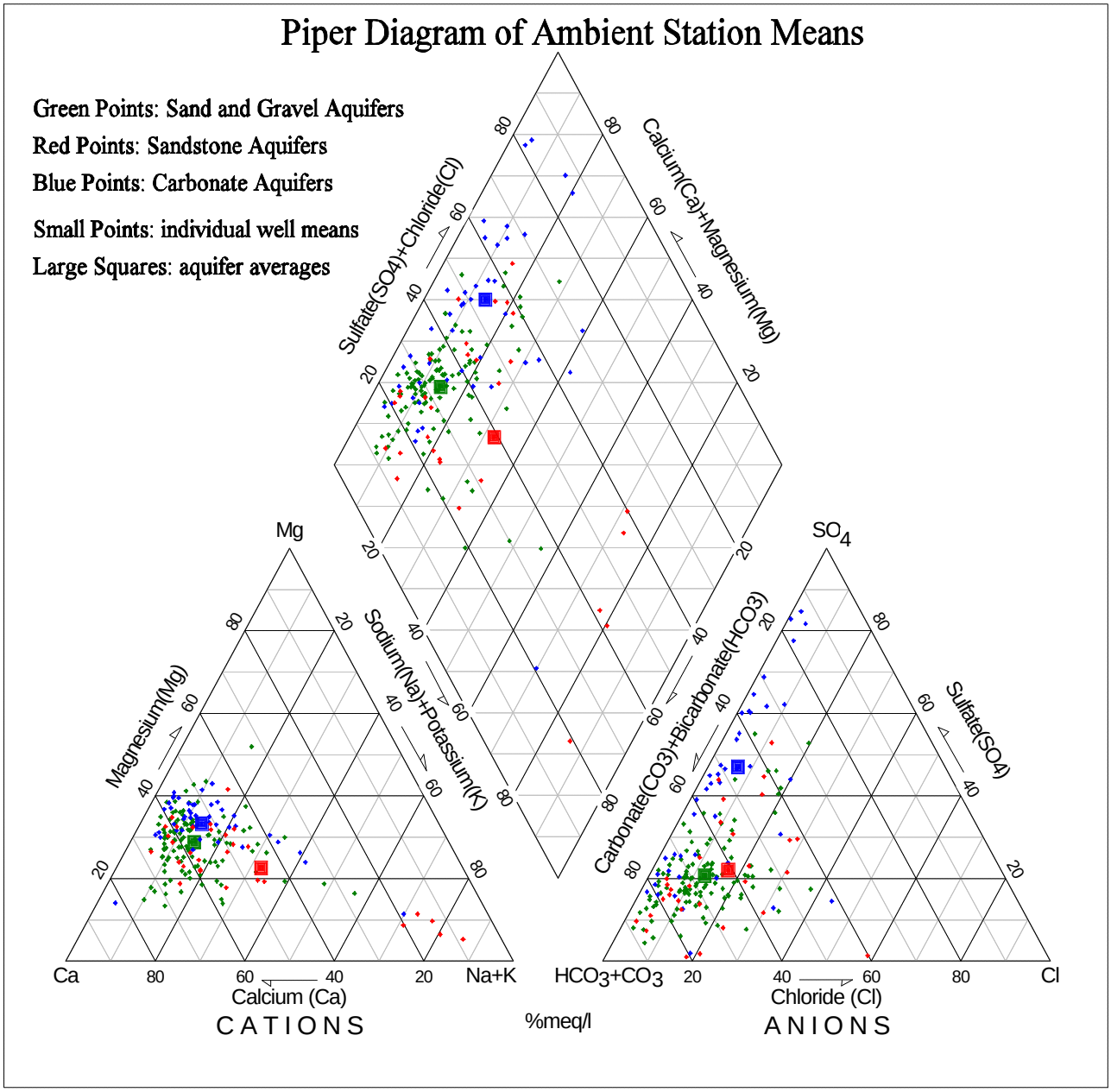

Figure 7.

Sand and Gravel Unit Ground Water Quality

The unconsolidated sand and gravel units, typically associated with the buried valley aquifer system, contain the highest water-yielding units across the state. These systems are superimposed upon the bedrock, and occur throughout much of the state (Figure 4). The Ambient database for this system consists of about 1,800 samples from 114 sites, and their mean water chemistry is summarized in Table 3. The ground water from this group of aquifers is characterized by relatively low TDS, zinc, fluoride, and sulfate. The sand and gravel aquifer waters are genetically similar to the carbonate bedrock waters, and display this similarity in their ground water chemistries. For example, the sand and gravel aquifer waters plot closely to the carbonate waters on the cation triangle of Figure 7; in the anion triangle of Figure 7, however, the carbonates are heavily influenced by the high sulfate concentrations. The mean total iron and manganese concentrations are 1170 µg/L, and 158 µg/L, both which exceed the SMCL of 300 µg/L and 50µg/L, respectively. Manganese increases in concentration, then decreases with depth for all three aquifer types, although this covariance is more pronounced in the shallower buried valley system, as illustrated in Figure 8.

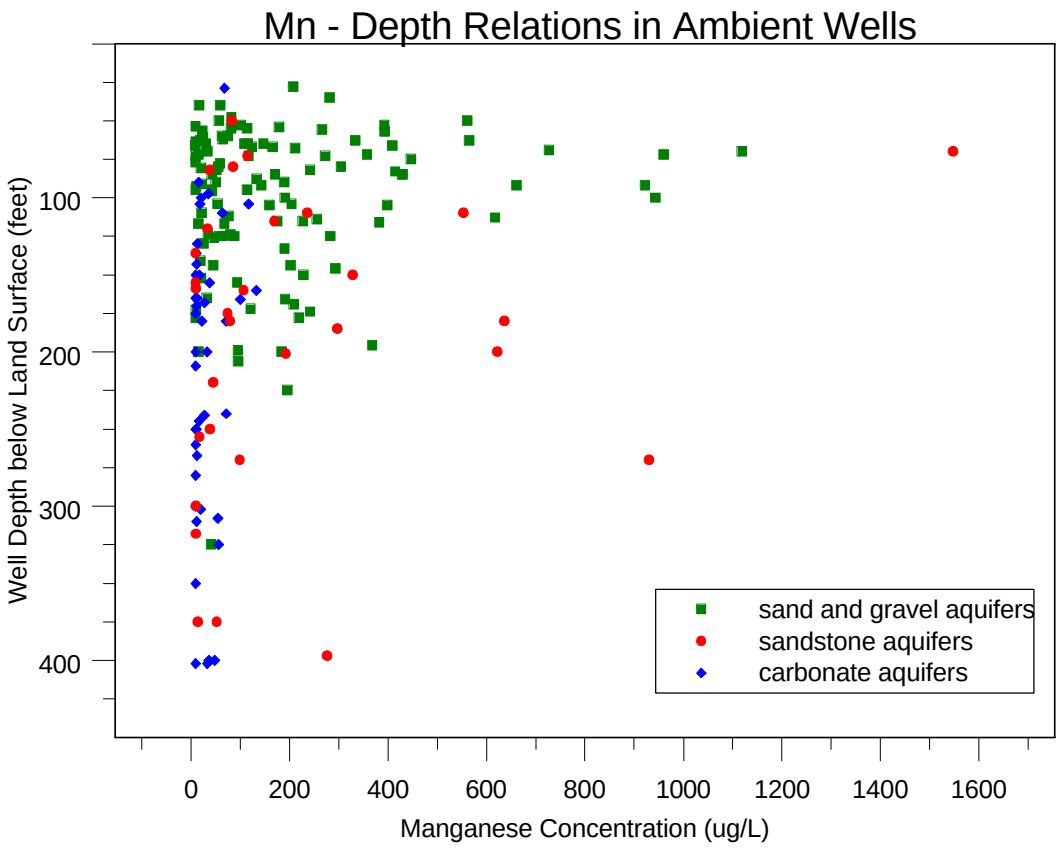

Figure 8.

A similar association with the sand and gravel aquifer is found to a lesser degree for other parameters with similar mobility characteristics such as iron, barium, and arsenic. Figure 9 illustrates the mean manganese concentrations for all current Ambient Monitoring Network sites across Ohio. One notable relationship displayed by this graphic is the association of elevated manganese concentrations with the sand and gravel aquifer system. Another interesting feature of Figures 8 and 9 is the even distribution of low Mn values throughout the carbonate system.

Carbonate Bedrock Aquifer Ground Water Quality

The bedrock of the Silurian/Devonian carbonate systems host the major aquifers in the western half of the state (Figure 4). The Ambient database for this system consists of about 500 samples from 44 sites. Most ground water in this host bedrock is of the calcium-bicarbonate-sulfate type, as depicted in the Piper diagram (Figure 7), and is slightly alkaline in pH. This aquifer type exhibits the greatest mean concentrations for calcium, magnesium, sulfate, TDS, alkalinity, strontium, iron, hardness, and conductivity of the three aquifer types. Mean hardness (about 500 mg/L) is at levels which typically require treatment to

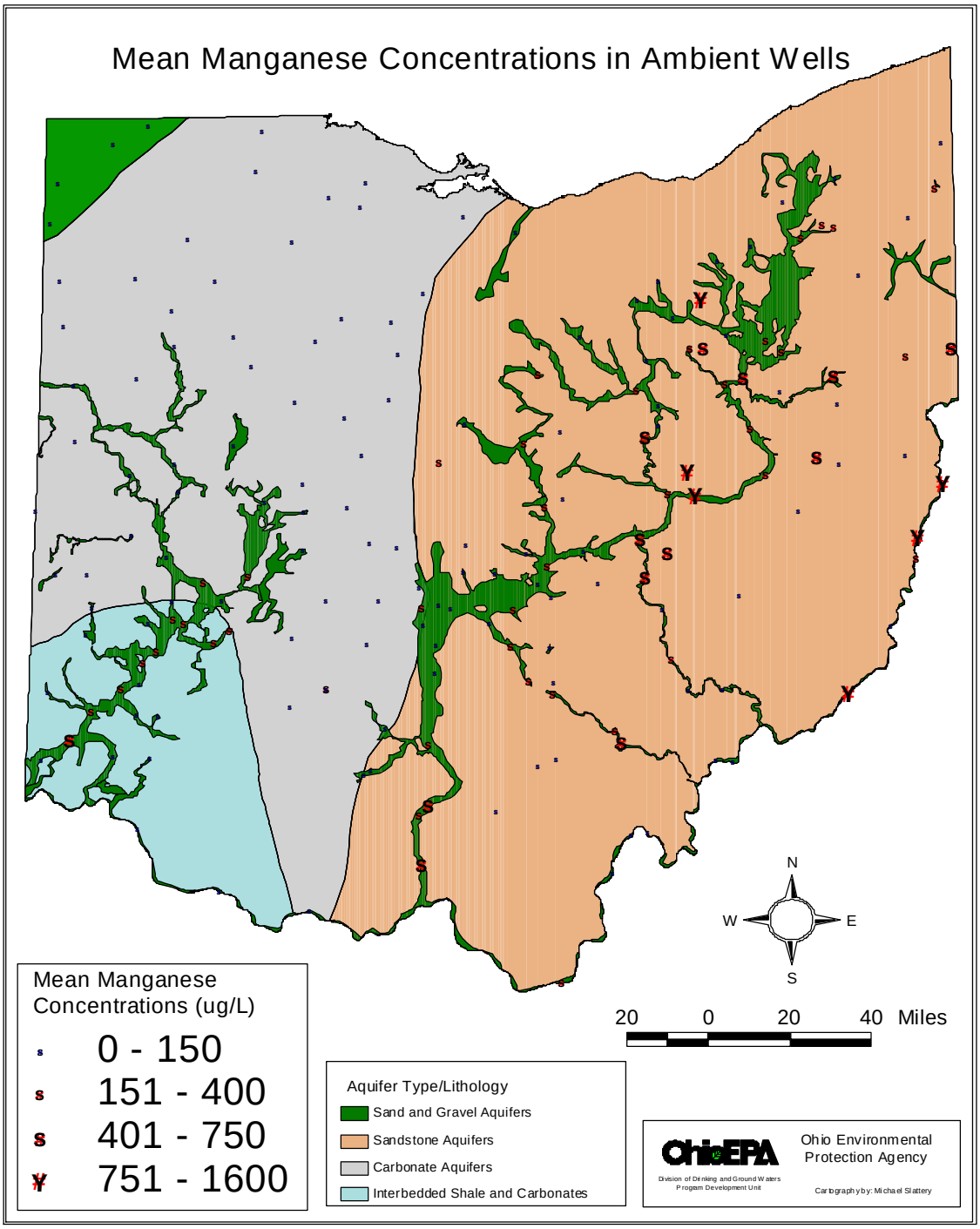

Figure 9.

remove calcium and magnesium in the finished water. The mean concentrations of TDS (667 mg/L) and iron (1441µg/L) are both above their respective SMCLs. While the mean carbonate aquifer concentration for sulfate (217 mg/L) is below the SMCL, 16 stations (36 percent) record mean SO_4^{2-} concentrations above 250 mg/L, with 3 stations (7 percent) above 750 mg/L. Fluoride is highest in the carbonate system and is probably controlled by the dissolution of F bearing minerals such as apatite and fluorite. Thus, the carbonate bedrock routinely displays ground water chemistry averages above secondary drinking water standards. These elevated measurements in the carbonate system relative to the other aquifer settings may be related to longer residence times within the system, as well as high solubilities of minerals in the host bedrock. Figure 10 illustrates the high mean TDS concentrations and increasing variability with well depth in the carbonate aquifer system compared to the other aquifer types. Figure 11 shows the state-wide spatial distribution of TDS across all three aquifer types.

Calcium and magnesium concentrations would be expected to be relatively high in a carbonate setting compared to the other rock types. The high sulfate averages may be the result of organics within the aquifer, the presence of iron sulfides, dissolution of gypsum/anhydrite, and/or elevated redox conditions. It is also common for longer flow paths to correlate with a chemical evolution towards higher mineralization, and the greater depth of the carbonate wells correlates well with the longer flow paths inferred for this aquifer system.

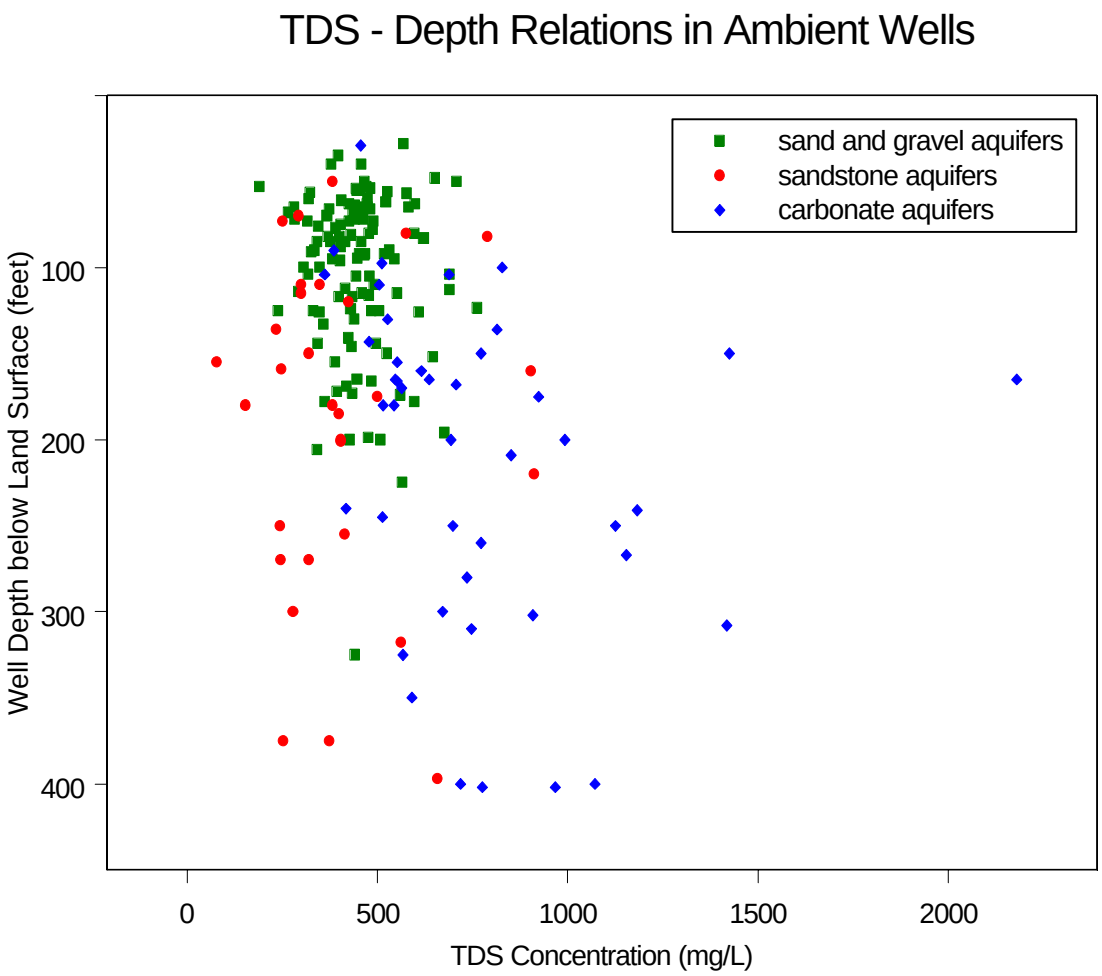

Figure 10.

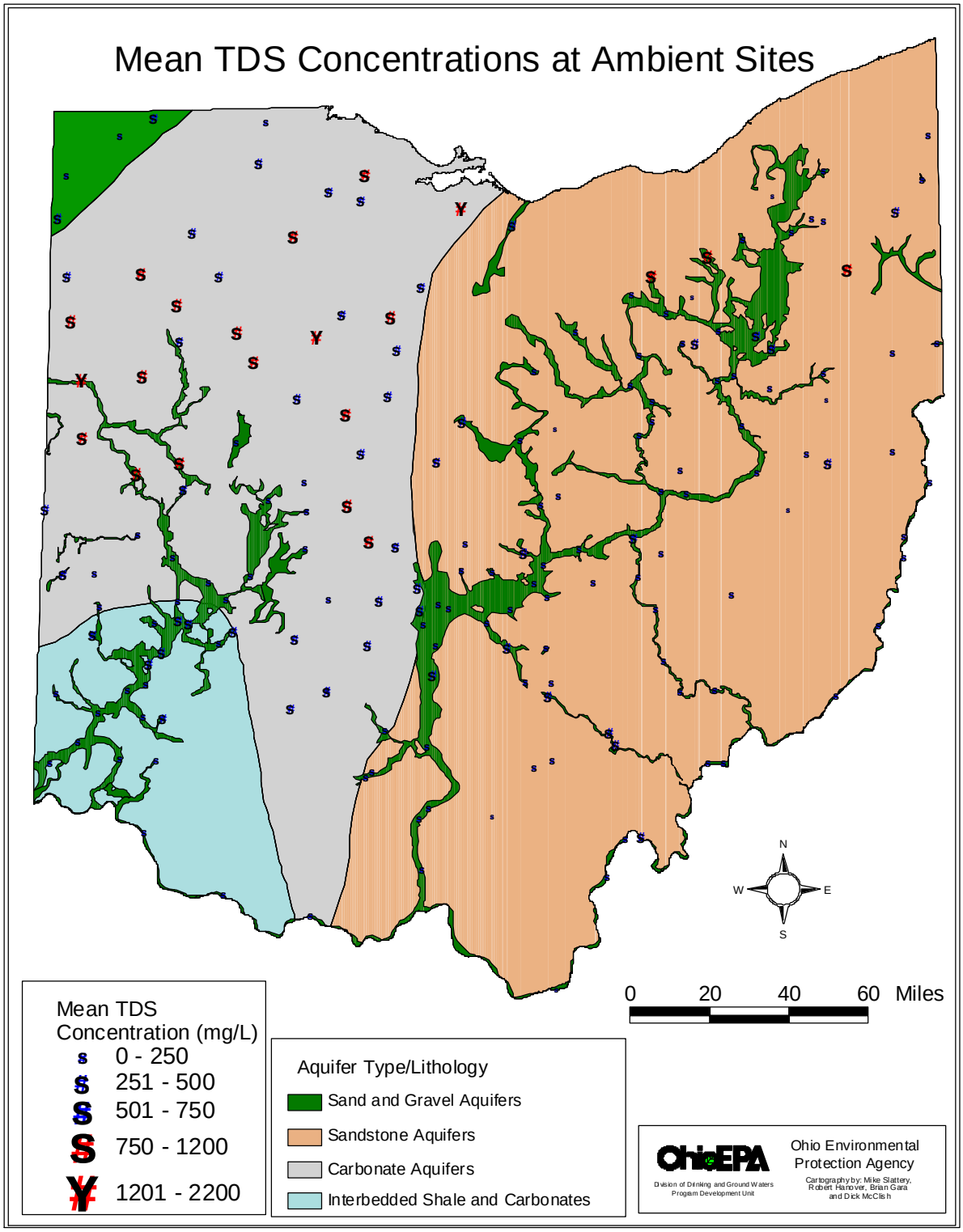
Mean TDS Concentrations at Ambient Sites
N
W
E
S
0
20
40
60
Miles
Mean TDS Concentration (mg/L)
0 - 250
251 - 500
501 - 750
750 - 1200
1201 - 2200
Aquifer Type/Lithology
Sand and Gravel Aquifers
Sandstone Aquifers
Carbonate Aquifers
Interbedded Shale and Carbonates
OhioEPA
Division of Drinking and Ground Waters
Program Development Unit
Ohio Environmental Protection Agency
Cartography by: Mike Slattery, Robert Hanover, Brian Gara and Dick McClish

Figure 11.

Among the important trace elements found in the Silurian/Devonian carbonates is strontium (carbonate aquifer mean = 17,200 µg/L), which is an order of magnitude greater than that of the sand (1,730 µg/L) and gravel system, and nearly 30 times greater that the sandstone system mean (600 µg/L). These levels of Sr are common throughout the carbonate system, and are attributed to the presence of the strontium sulfate mineral celestite ($SrSO_4$) within the limestone and dolomite of this system. The Sr/Ca ratio is a useful indicator of celestite, because when Sr is derived from rocks, the Sr/Ca ratio generally does not differ from that found in the host rock. Figure 12 shows the Sr concentration of all Ambient well means by aquifer type versus their respective Sr/Ca ratios (Sr is multiplied by 1000 in this ratio). Apparent in this graph are the elevated Sr/Ca ratios of the carbonate system ($Sr/Ca_{(carbonate)}$ ranges from about 7 to nearly 600) as

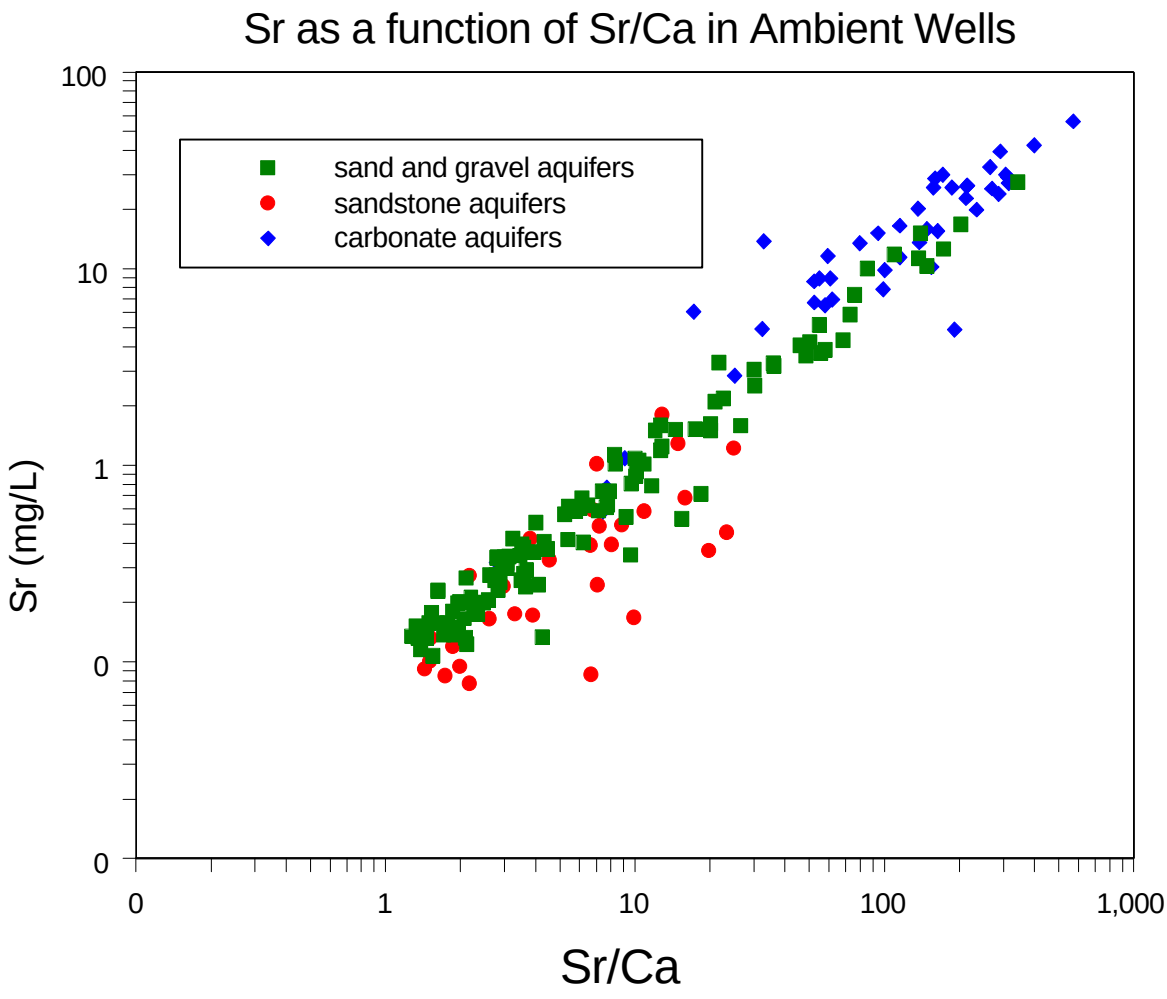

Figure 12

compared to $Sr/Ca_{(sandstone)}$ (1 to 20) and $Sr/Ca_{(sand\ and\ gravels)}$ (1 to 200). A representative limestone Sr/Ca ratio is around 1.5, while that for a calcareous shale is about 6 (Turekian and Kulp, 1956). The higher Sr/Ca values in the carbonate and sand and gravel units may also be due to the presence of $SrSO_4$ within the till layers overlying these aquifer systems.

Sandstone Bedrock Aquifer Ground Water Quality

The Mississippian/Pennsylvanian sandstone bedrock systems contain most of the major bedrock ground water wells in the eastern half of the state (Figure 4). The Ambient database for this system consists of about 325 samples from 31 sites whose mean water chemistry is provided in Table 3. These waters are characterized by low (bicarbonate) alkalinity, and moderately alkaline pH. The significant trend for some sandstone waters is toward increasing chloride and sodium composition seen in Figure 7, and suggests that these waters may have very long residence times, and/or may represent mixing with saline sodium-chloride type water expressed from bedrock shales or with deeper formation waters. Figure 13 illustrates the relationship between chloride concentration and well depth for all Ambient monitoring wells, and indicates that the deeper sandstone wells do acquire more salinity. A suggestion of a surface source for chloride in the

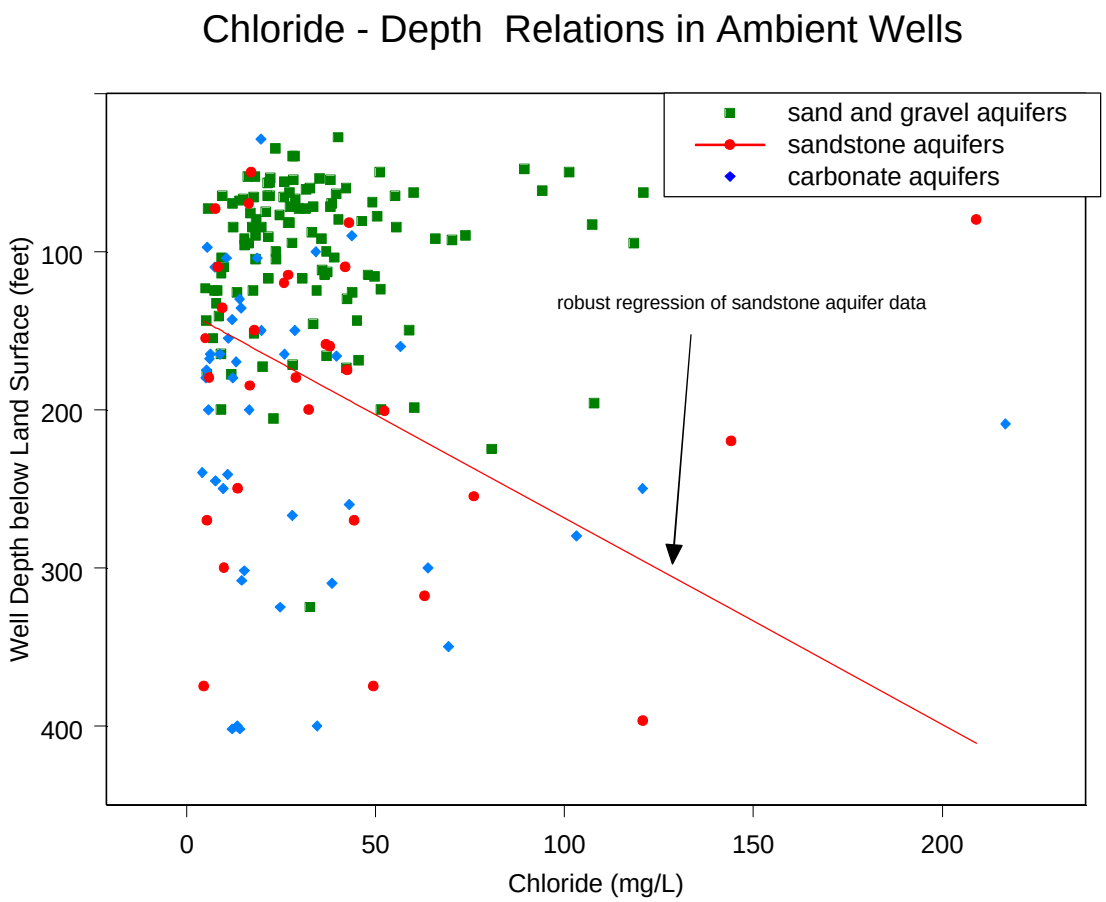

Figure 13.

Sand and Gravel aquifers exists in the relatively constant Cl concentrations for this aquifer setting (Figure 13). Elevated barium concentrations (range = 15 µg/L to 1980 µg/L, mean = 93 µg/L) in the sandstone aquifers supports the idea that some level of mixing is observed between the shallow, potable water and the deeper, saline waters. Barium-rich oil field formation waters tend to be low-sulfate waters; low sulfate concentrations are found in Ohio's sandstone waters, suggesting that barium might be released through sulfate reduction of barium sulfate.

NITRATE VARIATION AS AN INDICATOR OF AQUIFER SENSITIVITY TO IMPACT

Nitrate is a useful indicator of sensitive hydrogeologic settings because of its association with human activities. The distribution of the combined parameter nitrate-nitrite as N for both the Ambient and public water supply data sets is illustrated in Figure 14. The mean for this combined data set is 0.103 mg/L, and the median is 0.25 mg/L, with a current detection limit of 0.1 mg/L.

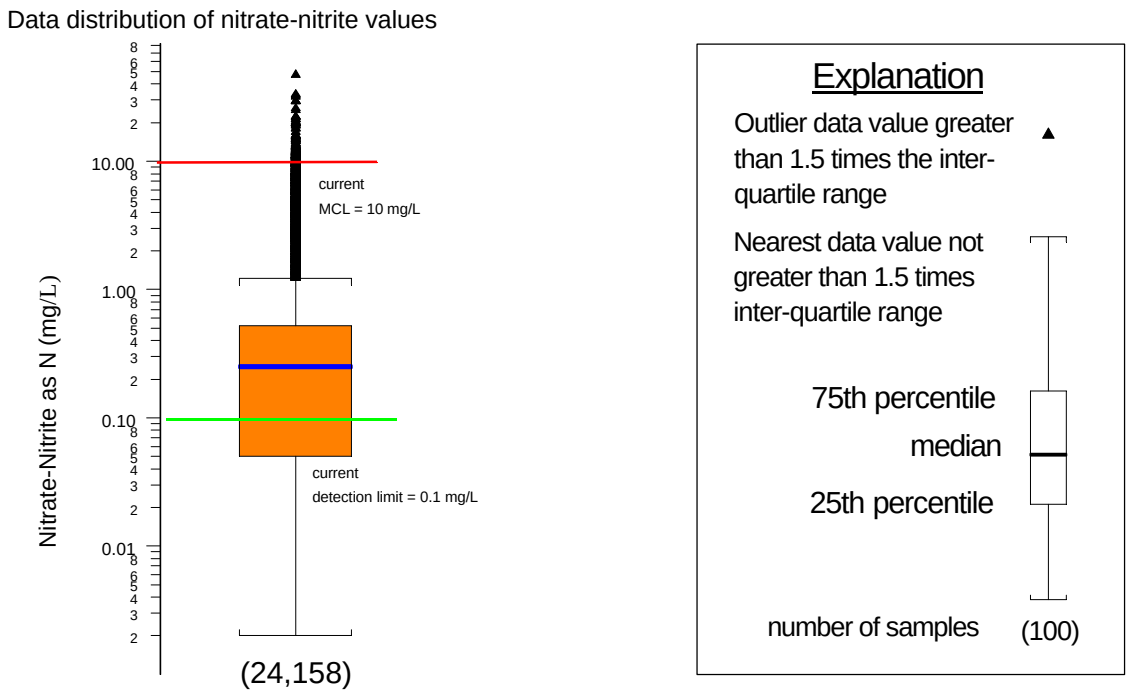

Figure 14.

A number of analyses are recorded above the MCL of 10 mg/L. If a PWS sample exceeds 5 mg/L, it is moved to a more frequent sampling schedule; thus the data above the MCL are biased toward those systems with higher nitrate values. Figure 15 illustrates the state-wide distribution of mean nitrate concentrations for public water systems with locations determined by Global Positioning Satellite methods. As noted before, the PWS data reflects treated water, but it is generally accepted that the standard treatments do not significantly alter nitrate-nitrite concentrations. Thus, the mixing of treated and untreated water in Figure 15 should not distort the relationship between aquifer type and nitrate concentration.

Madison and Brunett (1985) identified water samples with nitrate concentrations greater than 3.0 mg/L as indicating impacts by anthropogenic activities, including the management of animal wastes, the use of septic systems, and the application of fertilizer. There are nitrate values above 3.0 mg/L scattered throughout the state, but generally the highest density of high nitrate values occur in the sand and gravel aquifers. Similar relationships are illustrated in the mean NO_2 + NO_3 concentrations of the ambient

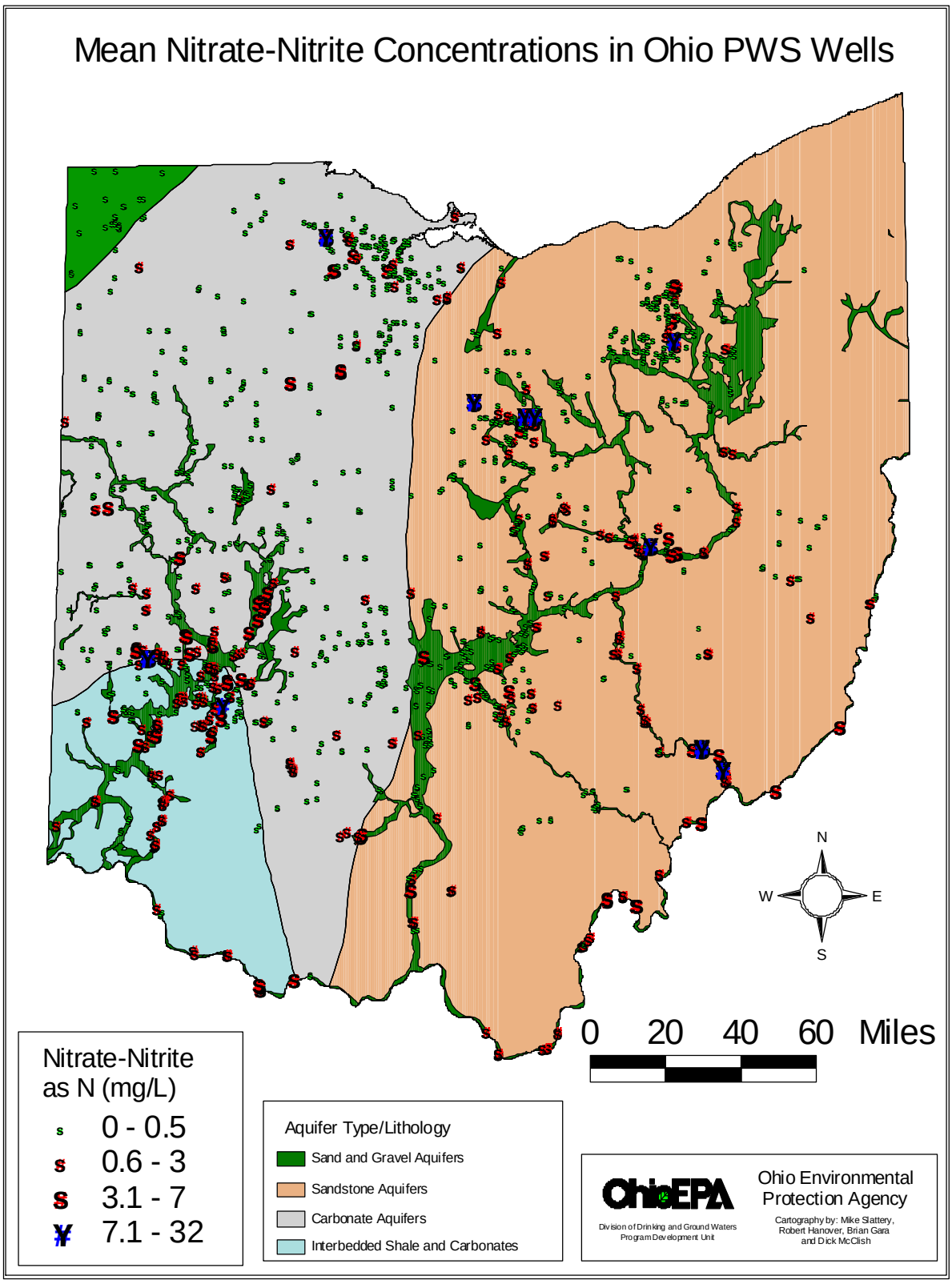
Mean Nitrate-Nitrite Concentrations in Ohio PWS Wells
N
W
E
S
0 20 40 60 Miles
Nitrate-Nitrite as N (mg/L)
0 - 0.5
0.6 - 3
3.1 - 7
7.1 - 32
Aquifer Type/Lithology
Sand and Gravel Aquifers
Sandstone Aquifers
Carbonate Aquifers
Interbedded Shale and Carbonates
OhioEPA
Division of Drinking and Ground Waters
Program Development Unit
Ohio Environmental Protection Agency
Cartography by: Mike Slattery, Robert Hanover, Brian Gara and Dick McClish

Figure 15.

water quality data (raw water). This sensitive nature of the sand and gravel aquifers is exhibited in Figure 16 , a plot of well depth versus the NO_2 + NO_3 concentration for the Ambient data. Most of the high nitrate concentrations occur in the sand and gravel aquifers, and there is a strong correlation of high concentrations to shallower well depths. Below depths of about 100 feet, the nitrate concentration decreases with depth. This is not surprising considering the permeable nature of the buried valley aquifers, the sandy soils that develop there, their shallow nature, and the fact that most nitrogen inputs are applied on or near the land surface.

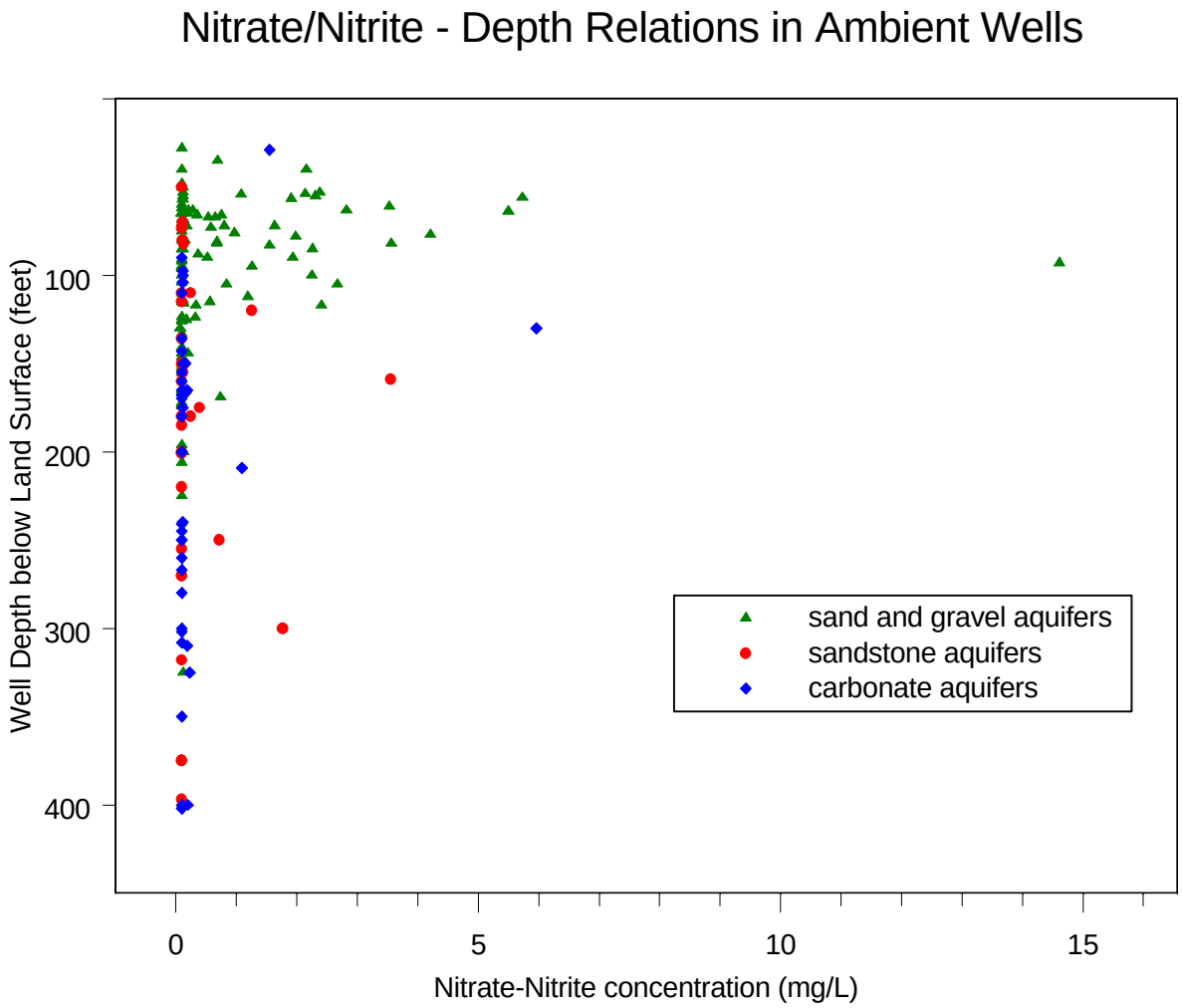

Figure 16.

The sandstone aquifer exhibits some higher concentrations of nitrate, but generally the values are low as illustrated in Figures 15 and 16. We interpret higher concentrations in the sandstone aquifers as the result of open bore holes leading to mixing of waters from shallower stratigraphic units. The increased relief in the southeastern part of the state increases the hydrologic head to transport surface inputs of nitrate through interbedded sandstone units. The low nitrogen concentrations in the sandstone aquifer suggests that the aquifer is not especially sensitive. This may be misleading because the application of nitrogen fertilizers and the population density in southeast Ohio is significantly less than that in northwest Ohio.

Generally, the nitrate levels in the carbonate aquifer are low, which is attributed to the thick glacial tills that

cover most of western Ohio. The higher values of nitrate in the carbonate aquifer are interpreted to be associated with areas of thin glacial cover over fractured bedrock or karst. The widespread agricultural land use and application of nitrogen fertilizers in western Ohio certainly provide nitrate sources. The fact that much of the area is drained by field tile helps to protect the ground water by cycling the nitrogen leached from the fields into surface water.

These data clearly document that the sand and gravel aquifers are the most sensitive of the three major aquifer types. This conclusion is supported by the tritium data that has been collected from the Ambient wells. Figure 17 illustrates the distribution of tritium values across Ohio. Values at or below the detection limit (0.8 tritium units) indicate that the water has had no contact with the atmosphere since the mid-1950's, suggesting an isolated aquifer. Most of the tritium samples from the sand and gravel aquifers exhibit results above the detection limit of tritium. This indicates the sensitive nature of the buried valley aquifers, although confined sand and gravel aquifers may be isolated, such as the buried Teays River Valley (west central Ohio). In contrast, the carbonate exhibits numerous sites with no tritium detection documenting the isolation that the overlying tills provide.

Certainly the sensitivity of any site is controlled by the local geologic setting, so site specific analysis is required to identify the aquifer sensitivity of any locality. For example, a confined sand and gravel aquifer with an extensive confining unit will not be sensitive, and these data illustrate this local variability. Nevertheless, the efforts to protect the ground water resources of the state of Ohio need to recognize the sensitive nature of the buried sand and gravel aquifers.

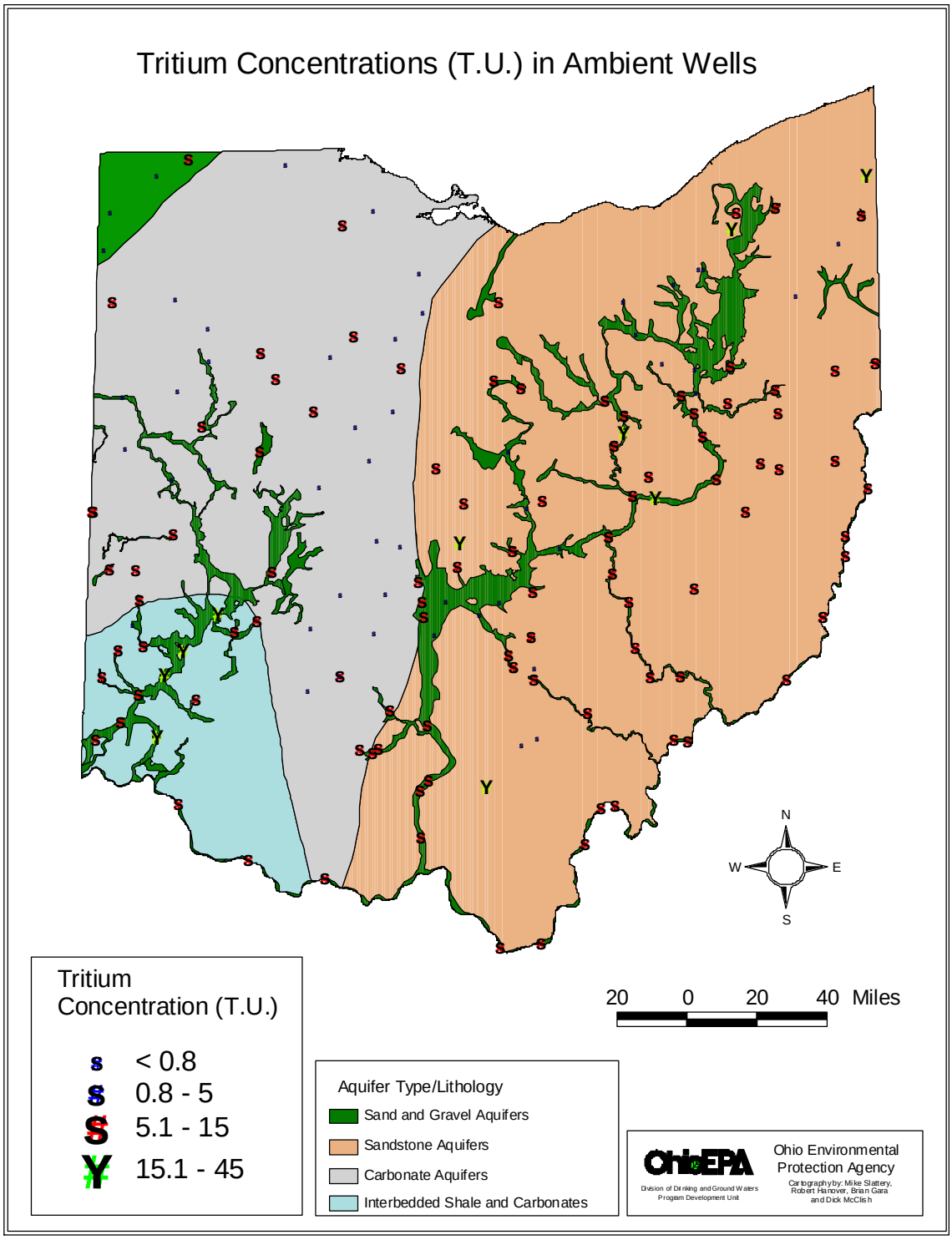
Tritium Concentrations (T.U.) in Ambient Wells
N
W
E
S
20 0 20 40 Miles
Tritium Concentration (T.U.)
< 0.8
0.8 - 5
5.1 - 15
15.1 - 45
Aquifer Type/Lithology
Sand and Gravel Aquifers
Sandstone Aquifers
Carbonate Aquifers
Interbedded Shale and Carbonates
OhioEPA
Division of Drinking and Ground Waters
Program Development Unit
Ohio Environmental Protection Agency
Cartography by: Mike Slattery, Robert Hanover, Brian Gara and Dick McClish

Figure 17.

VARIATION OF TOTAL ARSENIC IN OHIO PUBLIC WATER SYSTEMS

Arsenic in ground water can be a problem for PWSs, due to its known health effects. U.S. EPA set the Primary Drinking Water Standard at 50 µg/L, and recently has proposed to change this to 5 µg/L. The distribution of arsenic in ground water across Ohio is variable and complex, but can be summarized by identifying several important control mechanisms. These controls are inferred from data sets

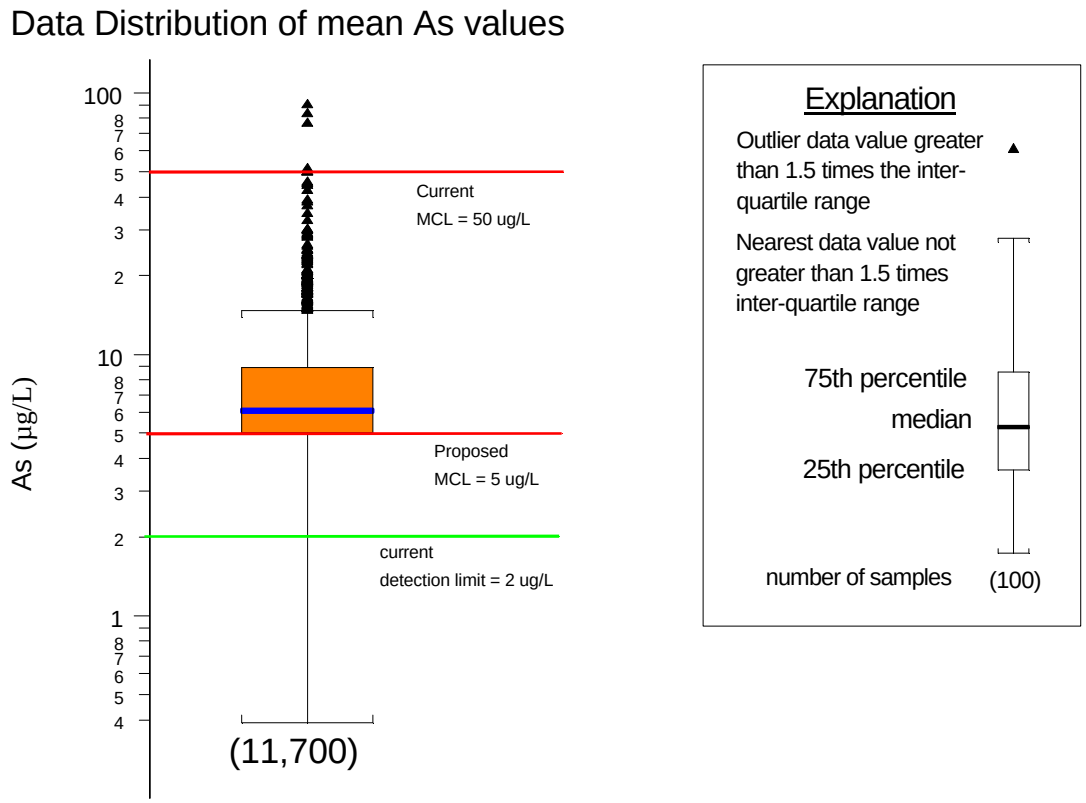

Figure 18.

gathered mostly from public water systems, notably the Ambient Monitoring Network, and PWS databases. Figure 18 illustrates the distribution of ground water As in Ohio for over 2,900 public water systems, combining over 11,700 measurements from both the Ambient and PWS systems (note the log scale for As). Arsenic measurements from raw and treated ground water samples from these PWSs in Ohio reveal only limited differences in As between the groups; thus, the data are combined for further analysis. The mean for this combined data sets is 7.2 µg/L, and the median is 6.1 µg/L, indicating a positive skewness due to the concentration of data near the main detection limit of 2 µg/L. The data are log-normally distributed, with a minimum value of 0.39 µg/L (an older sample with a different detection limit) and a maximum value of 90.1 µg/L.

Figure 19 presents the spatial distribution of mean As measurements across Ohio for the AMN system and PWS wells. The data are divided on Figure 19 into numerical ranges that correspond to the recently

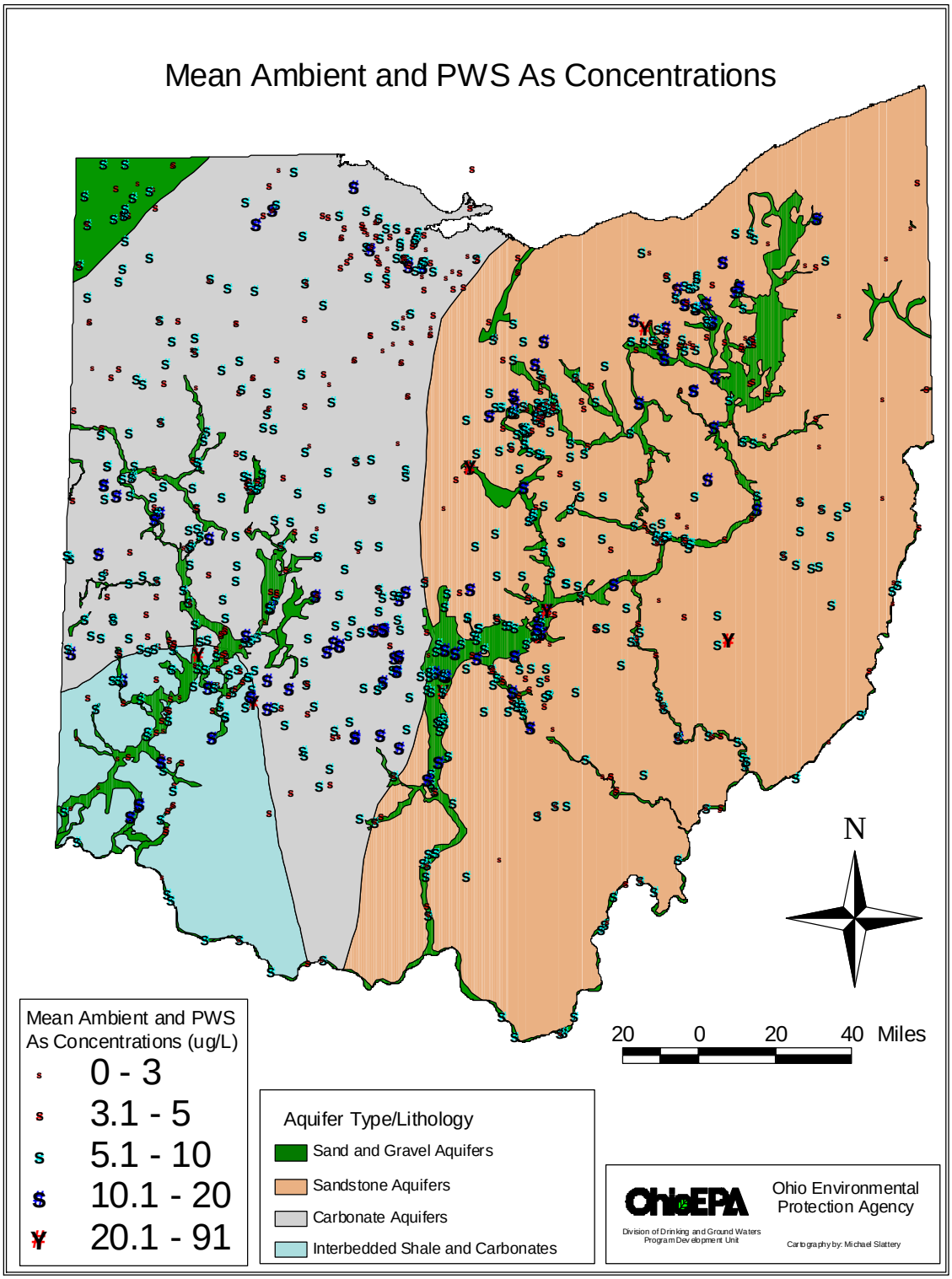
Mean Ambient and PWS As Concentrations
N
20 0 20 40 Miles
Mean Ambient and PWS As Concentrations (ug/L)
0 - 3
3.1 - 5
5.1 - 10
10.1 - 20
20.1 - 91
Aquifer Type/Lithology
Sand and Gravel Aquifers
Sandstone Aquifers
Carbonate Aquifers
Interbedded Shale and Carbonates
OhioEPA
Ohio Environmental Protection Agency
Division of Drinking and Ground Waters
Program Development Unit
Cartography by: Michael Slattery

Figure 19.

proposed (3 µg/L, 5µg/L, 10 µg/L) changes in the arsenic MCL. One of the clearest associations observable on Figure 19 (focus on the larger red dots) is the relationship between elevated As concentrations and wells developed in the sand and gravel unit aquifers. This correlation holds for both Ambient and PWS data. Also, the elevated As waters are apparently associated with the deeper portions of these buried valley settings.

The relationship between As, ground water, and aquifer solids is thought to be controlled mainly by the redox condition of the ground water and its effect on the dissolution of As bearing iron and manganese hydroxide minerals. If oxidizing conditions prevail in an aquifer, such as in a shallow setting relatively close in time and space to recharge waters, the waters will be less likely to dissolve the As bearing coatings. The origin of the As is thought to be from surface water passing though the young, yet unconsolidated sediments as they were buried and lithified. Arsenic is strongly adsorbed onto these hydroxide minerals, deposited as secondary coatings that cement the aquifer matrix. If reducing conditions then occur within the saturated zone, microbial degradation of organic matter will often lead to a series of reductive reactions, first consuming the available dissolved oxygen, followed by reduction of nitrate. Arsenic may then be released through the further reduction of the Fe and Mn-oxide cements bearing arsenic as a trace contaminant. The significant negative relationship found between NO_2 + NO_3 and As concentrations found in these waters supports this conclusion, suggesting that there is a low, minimum NO_2 + NO_3 ground water concentration which may be useful for identifying wells where the reduction of Fe and Mn oxides, and subsequent As release to ground water is not occurring.

Arsenic is found to increase with depth within the sand and gravel aquifers as shown in Figure 20 for the Ambient data. Most reducing ground water environments are found at some depth, which is a function of their separation from atmospheric contact (here a shallow confined system may be the exception). The As values above background appear in Figure 20 at about the 50-60 foot depth, and increase fairly regularly with depth at a rate of about 0.3 µg/L per 10 feet. Notable also is the lack of data points above about 10 µg/L As for the sandstone and carbonate systems. The single outlier (74 µg/L) is a shallow, 50 foot well.

The relationship between As levels and pumping rates for PWSs is not known at this time, but relationships described here suggest that the higher the well yield (e.g., sustained pump rate), the less likely a system is to encounter elevated As levels in ground water. This may be the case because a system under high pumping pressure is less likely to retain a reduced character over time. High-yield wells are set in permeable zones, and have the potential to be "refreshed" with oxygenated recharge in several ways: constant pumpage (bringing in foreign water), or significant draw-down in the well. It appears also that the occurrence of As has been correlated with low-yield wells (about 50 gpm or less). Perhaps the low-flow condition of a smaller well allows the ground water to more fully equilibrate with its reducing environment, with the resulting reduction of iron oxy-hydroxides releasing As.

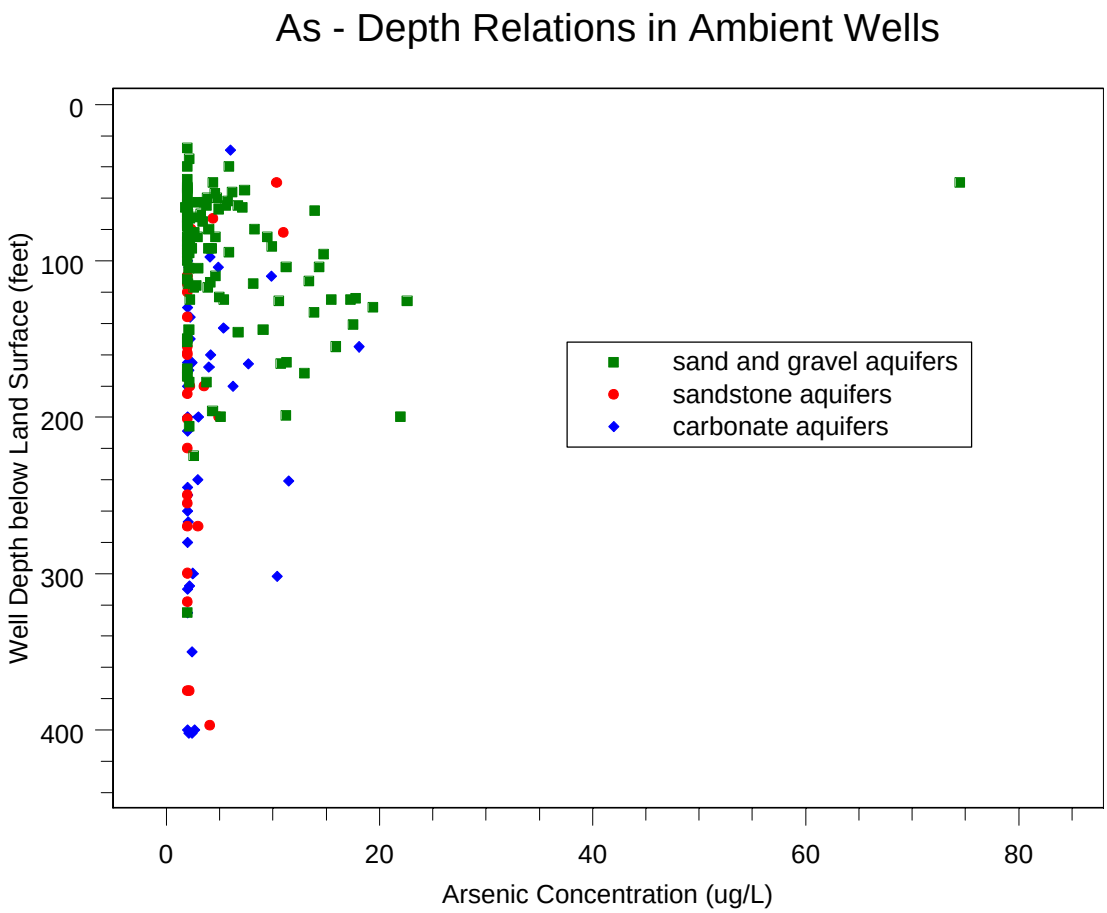

Figure 20.

CONCLUSION AND FUTURE FOCUS

The water quality analysis presented in the previous sections illustrates the progress that Ohio EPA, DDAGW has made in the last reporting period. We are pleased with this progress and it sets the stage for utilizing ground water quality data in support of division programs. We envision this support as focusing on several types of activity: helping to identify sensitive hydrogeologic settings or ground water areas; supporting new rule development; assisting in the SWAP sensitivity analyses; and generally increasing our understanding of the ground water resources of Ohio.

The Ambient Network Data Summary (Table 3) provides a summary of ground water chemistry that can be used to identify ground water that exhibits impacts from human activity, or which reveals significant natural variability useful for aquifer characterization. Additional efforts to characterize natural variation within each aquifer type will be completed to further refine our ability to identify anthropogenic impacts. The

identification of impacted ground water can then be used as a means to prioritize ground water protection activities. For example, once areas of impact are identified and confirmed, they can be targeted as priority areas for implementation of best management practices to protect the ground water through 319 grant funds. The resulting knowledge of sensitive hydrogeologic settings can be used to set broad priorities for ground water protection efforts or compliance activities. Our ability to focus effort on areas or PWSs with the greatest potential for impact becomes critical under the weight of numerous SDWA rules and finite resources. The Nitrate section of this report illustrates the power of water quality data to help identify sensitive hydrogeologic settings.

Federal rule development under the 1996 SDWA Amendments is a major task, and the ability to use ground water quality to help direct the effort is valuable. The option or requirement to target implementation to areas of more vulnerable PWSs (Class 5 Well Rule and Ground Water Rule) illustrates another need for identifying and evaluating sensitive ground water areas. The description of the state-wide total arsenic distribution, including the oxidation and reduction controls for this parameter, begins to illustrate how water quality data can be used to identify production settings in the state where there is likely to be a greater concentration of arsenic in the source water. There are many variables to consider, but these analyses point to significant elements that should allow the agency to set criteria for prioritizing wells of concern.

Raw and compliance water quality data will be used in the SWAP assessments to help identify susceptible public water systems on the basis that if water quality impacts are present, then contaminant sources and pathways for contaminant transport to the source water exist. This SWAP assessment process will provide site specific and regional data useful for analyzing water quality data associated with PWSs. These data include locational information, hydrogeologic setting information, well construction data, and aquifer hydrologic parameters, all housed in electronic databases. This information, collected in conjunction with completing SWAP assessments, increases the opportunity to establish detailed associations between geologic parameters and water quality data. Evaluations such as these can help to identify or confirm cause and effect relationships between potential sources of impact and the resulting ground water contamination in PWSs.

The collection and analysis of water quality data and supporting hydrogeologic setting data will increase our understanding of the ground water resources of Ohio. We plan to identify several areas with rapid recharge, and monitor temporal geochemical variation associated with seasonality. This effort will lead directly to understanding the local ground water and surface water interaction, and to a larger understanding of the nature of the water resources of Ohio. Other future activities include identifying additional parameters for Ambient Network Sampling to refine our characterization of the state aquifers. Finally, we seek to further develop and refine methods for data handling and analysis, and to improve our capabilities of sharing the water quality data with the public.

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APPENDIX

U. S. EPA 305(b) TABLES

MAJOR SOURCES OF CONTAMINATION - U. S. EPA Table 5.1

Although available data show that much of Ohio's ground water is of high quality and has not been widely impacted by human activities, individual cases of ground water contamination are documented every year from point and nonpoint sources. Ohio has a diverse economy and the state uses and produces a range of potential contaminants which are applied, stored, and disposed of on the land. Consequently, ground water quality is threatened by a wide range of contaminants and a wide variety of land use activities across the state.

The 2000 305(b) Guidance requests that Ohio identify the 10 main sources of ground water contamination. The 10 major sources of contamination are indicated in U. S. EPA Table 5.1 by checks (**T**). It is important to point out that this approach integrates extent and toxicity of contamination, which is not easy to do for multiple reasons. Different geographic areas of Ohio have different land use activities, consequently contamination that is a major source in one region may not be a major source when considering the entire State. For instance, coal mine waste piles are a significant contaminant source in southeastern Ohio, but are not in other parts of the state. The significantly variable hydrogeologic settings within the state make the vulnerability of some areas greater than others. The land use activities within the vulnerable areas have a greater potential of impacting the ground water. Both point sources and nonpoint sources of contamination are distributed through the state, but it is hard to evaluate whether the wide-spread low concentration nonpoint sources produce more impact on ground water than more concentrated, but less widespread, point sources. These points are raised to illustrate the subjective nature of U. S. EPA Table 5.1. Ohio EPA staff have tried to integrate these and other factors in a unbiased manner, but other groups may come up with other priority lists. Thus the fact that a contaminant source is not listed as a major contaminant source in the state does not mean that it is not significant locally or even regionally within the state. To provide some additional information, crosses (**Y**) indicate several additional categories of contamination that we considered as potentially top-10 priority sources.

Contaminant Source Discussion

Contamination sources that contain hazardous substances pose the greatest public health threat. However, on-lot sewage systems and mining activities that occur in great numbers or are prevalent throughout large areas of the state can impact large numbers of wells. The vulnerability of the local aquifers also influence the potential for ground water contamination. The shallow, unconfined buried valley aquifers are the most vulnerable of Ohio aquifers. Areas where little soil and/or glacial material cover overlies the carbonate aquifers are also vulnerable. Fortunately, the carbonate aquifers are generally overlain by glacial or other surface deposits that reduce the vulnerable nature of limestone aquifers. The bedrock sandstones appear to be the least vulnerable of Ohio aquifers.

U. S. EPA Table 5.1.

Contaminant Source	Ten Highest-Priority Sources (**T**)	Factors Considered in Selecting a Contaminant Source	Contaminants
Agricultural Activities			
Agricultural chemical facilities			
Animal feedlots	**Y**		
Drainage wells			
Fertilizer applications	**U**	A, B, C, D, E	E (J, K, L)
Irrigation practices	**Y**		
Pesticide applications			
On-farm agricultural mixing and loading procedures			
Land application of manure (unregulated)	**U**	A, D, E	E, J, K, L
Storage and Treatment Activities			
Land application (regulated or permitted)	**U**	A, C, D, E, H	E, J, K, L
Material stockpiles			
Storage tanks (above ground)			
Storage tanks (underground)	**U**	A, B, C, D, E, G	C, D, H
Surface impoundments	**Y**		
Waste piles	Y		
Waste tailings	Y		
Disposal Activities			
Deep injection wells			
Landfills	**U**	A, B, C, D, E	A, B, C, D, H, J, K, L
Septic systems	**U**	A, B, C, D, E	E, H, J, K, L
Shallow injection wells	**U**	A, B, C, D, E, H	C, D, G, H
Other			
Hazardous waste generators			
Hazardous waste sites	**U**	A, B, C, D, E, G	A, B, C, D, H, I
Large industrial facilities			
Material transfer operations			
Mining and mine drainage	Y		
Pipelines and sewer lines			
Salt storage and road salting	Y		
Salt water intrusion			

Spills	U	A, B, C, D, E, G	A, B, C, D, E, H, I, J, K, L
Transportation of materials			
Contaminant Source	Ten Highest-Priority Sources (T)	Factors Considered in Selecting a Contaminant Source	Contaminants
Urban runoff	U	B, D	A, B, C, D, G, H
Small-scale manufacturing and repair shops			
Other sources (please specify)			

Notes:
U - Highest Priority
Y - Potentially High Priority

FACTORS
A Human health and/or environmental risk (toxicity)
B Size of the population at risk
C Location of the sources relative to drinking water sources
D Number and/or size of contaminant sources
E Hydrogeologic sensitivity
F State findings, other findings
G Documented from mandatory reporting
H Geographic distribution/occurrence
I Other criteria

CONTAMINANTS
A Inorganic pesticides
B Organic pesticides
C Halogenated solvents
D Petroleum compounds
E Nitrate
F Fluoride
G Salinity/brine
H Metals
I Radionuclides
J Bacteria
K Protozoa
L Viruses
M Other

The sources of contamination that are identified in U.S. EPA Table 5.1 are listed alphabetically below. Each source of contamination identified in the table is discussed to provide additional information on these threats to Ohio's ground water. This list provides more specific information to enhance U.S. EPA Table 5.1.

- **Concentrated Animal Feeding Operations (CAFO):** It is difficult to identify ground water impacts associated with CAFOs. Nevertheless, the growth of these operations in numbers and size makes them a larger potential source of ground water contamination. In addition, these operations are increasingly visible to the public, both physically and in the media. The ground water threats associated with CAFOs are captured in other categories as well, such as manure and fertilizer application and surface impoundments, so they are not considered one of the 10 highest priority sources.

- **Fertilizer Applications**: Improper use and handling of fertilizers and animal wastes can cause ground water pollution. Animal waste used as fertilizer and chemical fertilizers contribute to nitrate values in ground water. It can be argued that nitrate values in ground water represent one of the better examples of the widespread distribution of impacted ground water, although it is important to point out that non-agricultural sources, such as lawn fertilization and septic systems, also contribute to ground water impacts from nitrate. Analysis of public water supply data documents a higher incidence of nitrate levels (well below the MCL) in sand and gravel public water systems, the most vulnerable of Ohio's aquifers.

- **Hazardous Waste Sites:** Ohio generates a large amount of hazardous waste. Industrial sites and other locations where hazardous waste is generated are not considered hazardous waste sites until hazardous waste has been spilled or released in some other manner. Hazardous waste sites are a serious threat to ground water. Thirty-two waste sites are on the National Priority List of the Superfund program. There are about 180 facilities that have Part A or Part B permits under the Resource Conservation and Recovery Act (RCRA Subtitle C), that are required to monitor for contamination in ground water because of their potential to affect ground water quality.

- **Injection Wells:** Class V injection wells are widespread throughout the state and exhibit a high density in several areas in the state. It is estimated that there are over 50,000 class V injection wells in the state of Ohio. The fact that these wells are used to inject fluids directly into some of the most vulnerable aquifers in the State is the main cause for concern. The nonpoint source origin of water flowing into Class V wells is variable and thus difficult to characterize in a state-wide analysis. Nevertheless, these shallow injection wells provide a direct pathway for non-point source contamination and illegal waste disposal into vulnerable aquifers.

- **Irrigation Practices:** The development of Total Maximum Daily Load (TMDL) and potential restrictions on National Pollution Discharge Elimination System (NPDES) permits is driving an increase in growth of sewage treatment facilities holding partially treated waste water in storage impoundments in combination with irrigation of this waste water. Irrigation in Ohio has been limited in the past, but the increase of irrigation with partially treated waste water has the potential to impact shallow aquifers, and so it has been included. This is an interesting example of the need for considering both ground water and surface water impacts in protection strategies.

- **Land Application of Manure and Sludge:** The concerns for land application of manure and sludge are similar to the issues of fertilizer application described above, with the addition of pathogen sources. Agriculture practices dominate much of Ohio's landscape, and the growth of animal feeding operations and sewage treatment facilities increases the land application of manure, as well as sludge that is being used as fertilizer.

- **Landfills:** Currently there are about 125 landfills with ground water monitoring in Ohio. In addition, there are approximately 200 construction and demolition sites that have submitted license applications but do not have ground water monitoring. Numerous abandoned landfills may pose potential ground water contamination threats, and many are included in

DERR's Remedial Response/VAP Sites List, which indicates a potentially significant impact of old landfills on ground water quality. The current siting, design, and construction standards for landfills are more stringent than just ten years ago, with the result that new landfills have significantly lower potential to impact ground water than older landfills.

- **Mining and Mine Drainage:** The Pennsylvanian Units that underlie eastern Ohio include significant coal resources, and the region continues to produce coal. The relatively high sulfur content of Ohio coal, concerns about acid rain, and clean air standards have resulted in reduction of Ohio coal production. The number of operating coal mines is decreasing more rapidly than total coal production, as production is concentrated in larger underground mines. The disruption of the stratigraphic units and oxidation of sulfides associated with coal mining produces the possibility of ground water contamination by acid mine waters. Acid mine waters are considered a significant threat to ground water resources in mined areas.

- **Salt Storage and Road Salting:** Storage and use of salt as a deicing agent can impact ground water resources. The widespread use of salt or mixtures of salt and sand for deicing roads has been documented as a major contributor of sodium and chlorine contamination of shallow ground water in a project co-sponsored by USGS and ODOT (Jones and Sroka, 1997). Alternative chemicals like acetate-based deicers in combination with reduced salt usage are being promoted as pollution prevention programs.

- **Septic Systems:** Over two hundred thousand household wastewater systems, primarily septic tanks and leach fields, are present throughout the rural and unsewered suburban areas of Ohio. A number of these systems are improperly located, poorly constructed, or inadequately maintained, and may cause bacterial and chemical contamination of nearby wells. Improperly operating septic systems are considered to be significant contributors to elevated nitrate levels in vulnerable aquifers.

- **Spills and Leaks:** Leaks and spills of hazardous substances from underground tanks, surface impoundments, bulk storage facilities, transmission lines, and accidents are major ground water pollution threats. More than a thousand leaks and spills that may pollute ground water are reported each year. This release of chemicals into the surface and near surface environment is certainly one of the greatest threats to ground water quality.

- **Storage Tanks, Underground:** The 1994 State of Ohio NonPoint Source Assessment Ground Water Component Report documented that ground water contamination at underground storage tanks (USTs) was a major source of ground water contamination. The large number of USTs and the hidden nature of the storage method contributes to the lack of proper maintenance. In wellhead protection areas USTs are one of the most common potential pollution sources identified. The many USTs exempted from Bureau of Underground Storage Tank Regulation (BUSTR) regulations are probably significant contributors to ground water contamination as a result of their number and limited maintenance.
- **Surface Impoundments:** Surface impoundments are one of the most common waste

disposal concerns at RCRA sites. Historically, surface impoundments have constituted a major source for ground water contamination. Older sites did not need to meet the same engineering standards as newer impoundments, and consequently the probability of fluids leaching to the ground water is greater. Current siting and engineering requirements have improved this situation, but the presence of saturated conditions provide pathways for contaminants to travel to the ground water.

- **Urban Runoff:** With expanding urban areas, nonpoint source contamination from urban areas is one of the sources of ground water contamination that is increasing, in contrast with most of the other sources discussed. In addition, the recent practice of constructing storm water retention basins increases the likelihood that urban runoff infiltrates into ground water.

- **Waste Piles and Tailings:** RCRA facilities have numerous waste piles and tailings that pose a threat to ground water, and coal mine tailings are present in some parts of the state. They have not been included as a major source of contamination because surface impoundments are more numerous.

Although this selection process is arbitrary, it identifies major sources of ground water contamination in Ohio. Overlap between these source groups, for instance the increased potential for ground water contamination where urban runoff is discharged into a Class V injection well, reflects the interrelated nature of ground water pollution and these sources. The 1994 State of Ohio NonPoint Source Assessment Ground Water Component Report is consistent with U. S. EPA Table 5.1, except above ground storage tanks/drums were identified as a significant source at numerous locations with ground water contamination. Finally, we want to emphasize that the location of sources relative to vulnerable aquifers is critical for ground water contamination to occur. For instance, deep injection wells are not considered a major source, because in Ohio the waste is not injected into potable waters and the regulations protect the shallower, useful aquifers. To evaluate the potential impact of these contamination sources on a local scale or site specific basis, it is critical that the source distribution is integrated with aquifer sensitivity (through DRASTIC type maps, or other sensitivity measures).

GROUND WATER PROTECTION PROGRAMS - U. S. EPA Table 5.2

Programs to monitor, evaluate, and protect ground water resources in Ohio are carried out by various federal, state and local agencies, and are summarized in the Ground Water Program section of this report. Ohio Departments of Agriculture, Commerce (Division of State Fire Marshal), Health, Natural Resources, Transportation, and the Ohio Environmental Protection Agency and Public Utilities Commission all complete ground water related activities. To promote and guide the implementation of a coordinated, comprehensive, and effective ground water protection and management program for the state of Ohio, the State Coordinating Committee on Ground Water Protection (SCCGW) was created by the directors of these state agencies. The Ohio EPA, DDAGW is the lead agency in administering the SCCGW.

U. S. EPA Table 5.2.

Programs or Activities	Check (**T**)	Implementation Status	Responsible State Agency
Active SARA Title III Program	**U**	E	OEPA
Ambient ground water monitoring system	**U**	E	OEPA
Aquifer vulnerability assessment	**U**	CE	ODNR, OEPA
Aquifer mapping	**U**	CE	ODNR
Aquifer characterization	**U**	CE	OEPA, ODNR
Comprehensive data management system	**NA**[a]		
Consolidated Cleanup Standards	U	UD	OEPA
EPA-endorsed Core Comprehensive State Ground Water Protection Program (CSGWPP)	U	UD	SCCGW
Ground water discharge permits	**U**	E	ODNR
Ground water Best Management Practices	**U**	E	ODNR, ODA
Ground water legislation	**U**	UR[b], UD[c]	ODNR, OEPA
Ground water classification	**U**	E[d], UD[c]	OEPA
Ground water quality standards	**U**	UD[c]	OEPA
Interagency coordination for ground water protection initiatives	**U**	E	SCCGW
Nonpoint source controls	**U**	CE	ODA, OEPA, ODNR
Pesticide State Management Plan	**U**	UD[e]	ODA
Pollution Prevention Program	**U**	E	OEPA
Resource Conservation and Recovery Act (RCRA) Primacy	**U**	E[f]	OEPA
Source Water Assessment Program	**U**	CE	OEPA
State Superfund	**U**	E	OEPA
Programs or Activities	Check (**T**)	Implementation Status	Responsible State Agency
State RCRA Program incorporating more stringent requirements than RCRA Primacy	**NA**		
State septic system regulations	**U**	E	ODH
Underground storage tank installation requirements	**U**	E	SFM/BUSTR
Underground Storage Tank Remediation Fund	**U**	E	SFM/BUSTR
Underground Storage Tank Permit Program	**U**	E	SFM/BUSTR

Underground Injection Control Program	**U**	E[g]	OEPA, ODNR
Vulnerability assessment for drinking water/wellhead protection	**U**	UD	OEPA
Well abandonment regulations	**U**	E[h]	ODNR, OEPA, ODH
Wellhead Protection Program (EPA-approved)	**U**	E	OEPA
Well installation regulations	**U**	E[i]	OEPA, ODH

Notes:
E - Established
CE - Continuing Effort
UD - Under Development
UR - Under Revision

ODA - Ohio Department of Agriculture
ODH - Ohio Department of Health
ODNR - Ohio Department of Natural Resources
OEPA - Ohio Environmental Protection Agency
SCCGW - State Coordinating Committee on Ground Water
SFM/BUSTR - State Fire Marshall, Bureau of Underground Storage Tank Regulations

[a] Data management occurring on an agency level. 319 proposal has been submitted by USGS with support from state agencies to develop a Ground Water Database to identify who has ground water data to promote use of existing water quality data.
[b] Rules, guidances and policies being updated per the Clean Water Act, Section 106.
[c] Being developed under the Consolidated Cleanup Standards.
[d] Established through the Voluntary Action Program (VAP).
[e] ODA is currently getting cooperative commitment from other Ohio agencies.
[f] RCRA primacy on all but RCRA corrective actions.
[g] Ohio EPA regulates Class I and V injection wells; ODNR regulates Class II and III injection wells.
[h] Technical Guidance for Sealing Unused Wells prepared by SCCGW (1996).
[I] Technical Guidance for Well Construction and Ground Water Protection prepared by SCCGW (Draft 1999).

U. S. EPA Table 5.2 summarizes the active ground water programs and activities across the state. The format for this table is provided in the Guidance for 2000 305(b) Reports. Individual programs that are parts of the activities listed are managed by various divisions within larger agencies. Many of the programs or activities listed have several state agencies that are responsible for specific aspects of the listed activities. The fact that numerous agencies are identified as managing elements of ground water related programs illustrates why the SCCGW plays such an important communication role. For instance, well abandonment is regulated by several agencies; ODH oversees private wells but public wells are overseen by Ohio EPA, while oil and gas wells are regulated by ODNR. Current regulations for private and public wells require that boreholes not converted into wells be sealed. It is not always clear when an unused well should be sealed. Ohio EPA has the authority to prescribe regulations for the drilling, maintenance, and abandonment of wells as deemed necessary by the director to prevent the contamination of underground waters in the state, as identified in the ORC 6111.42. This authority does not apply to private wells, which are regulated by the Ohio Department of Health and local health departments. As with many developing environmental programs, a cooperative approach for well abandonment is being instituted. The usefulness of the SCCGW

is illustrated by creation of a SCCGW Work Group to draft "Technical Guidelines for Well Construction and Ground Water Protection." The Well Construction Workgroup that drafted this document started in July 1996 and both Ohio EPA and the Ohio Department of Health have committed to have their well construction rules be consistent with the technical guidance (Draft, 1999).

GROUND WATER CONTAMINATION SUMMARY - U. S. EPA Table 5.3

U. S. EPA Table 5.3 provides additional information on ground water contamination in Ohio. It lists the number of sites in Ohio, both state and federal, that are actually or potentially contaminating the ground water. The 2000 305(b) Guidance requests that this table be completed on an aquifer or hydrogeologic setting basis. Ohio does not have geographically-referenced locations for the types of sources listed in U. S. EPA Table 5.3, and therefore can not locate them accurately on a map. Without accurate locations, we cannot correctly identify the aquifer or hydrogeologic setting. Therefore, U. S. EPA Table 5.3 is completed for the entire state. Efforts are being made to geo-locate many of the facilities that have ground water monitoring wells, which will allow an association of the facilities with aquifer type.

Ohio does not electronically track the number of sites with confirmed ground water contamination, so these numbers are typically not available. The number of underground injection sites with confirmed releases is listed as being not available because the design of an underground injection well is to release contaminants. It is believed that this column does not apply for underground injection.

U. S. EPA Table 5.3.

Hydrogeologic Setting: Statewide
Data Reporting Period: As of June 1, 2000

Source Type	Number of sites	Number of sites that are listed and/or have confirmed releases	Number of sites with confirmed ground water contamination	Contaminants	Number of site investigations (optional)	Number of sites stabilized or have had the source removed (optional)	Number of sites with corrective action plans (optional)	Number of sites with active remediation (optional)	Number of sites with cleanup completed (optional)
NPL	32	32	32	Varied					
CERCLIS (non-NPL)	238	238	NA	Varied					
DOD/DOE	39[a]	26	18	Varied					
LUST	26,143[b]	5,928[c]	NA	BTEX, Petroleum Hydrocarbons					
RCRA Corrective Action	123	123	123	Varied					
Underground Injection	I - 12 II - 479 III - 46 IV - <10 V - 50,000+	NA NA NA NA NA	0 0 0 0 NA	Varied Varied Varied Varied Varied					

Source Type	Number of sites	Number of sites that are listed and/or have confirmed releases	Number of sites with confirmed ground water contamination	Contaminants	Number of site investigations (optional)	Number of sites stabilized or have had the source removed (optional)	Number of sites with corrective action plans (optional)	Number of sites with active remediation (optional)	Number of sites with cleanup completed (optional)
State Sites	1496[d]	NA	NA	Varied					
Non-Point Sources	NA	NA	NA	NA					

Notes:

NA - Numbers not available

[a] Includes DOE, DOD, FUSRAP and FUD sites

[b] Includes closed sites - leaking tanks have been removed

[c] Only those site undergoing corrective action - leaking tanks have been removed

[d] Does not include NPL sites or federal facilities

AQUIFER MONITORING DATA -U. S. EPA Table 5.4

U.S. EPA Table 5.4 provides a description of the overall ground water quality data collected in Ohio from January 1, 1998, through December 31, 1999. The sources for this information were Ohio's Ambient ground water monitoring network database and the PWS database. Information was not available for the number of wells in sensitive or vulnerable areas for two reasons: first, accurate locations for Ohio's public water supply wells are not yet available. Ohio is in the process of having all of its public wells geographically located. Second, Ohio has not yet defined vulnerable or sensitive areas. These areas will be defined as the Source Water Assessment and Protection Program progresses, and susceptibility analyses are completed.

U. S. EPA Table 5.4.

Hydrogeologic Setting: Statewide
Data Reporting Period: January 1, 1998 through December 31, 1999

Monitoring Data Type	Total No. of Wells Used in the Assessment[a]	Parameter Groups	Number of Wells								
			No detections of parameters above MDLs or background levels		Nitrate concentrations range from background levels to less than or equal to 5 mg/l No detections of parameters other than nitrate above MDLs or background levels and/or located in areas that are sensitive or vulnerable		Nitrate ranges from greater than 5 to less than or equal to 10 mg/l Other parameters are detected at concentrations exceeding the MDL but are less than or equal to the MCLs[c]	Parameters are detected at concentrations exceeding the MCLs[c]	Number of Wells Removed from service[d,h]	Number of Wells Requiring Special Treatment[d,h]	Background parameters exceed MCLs
			ND	Number of wells in sensitive or vulnerable areas (optional)[b]	Nitrate ≤ 5mg/l VOC, SOC, and Other parameters not detected[c]	Number of wells in sensitive or vulnerable areas (optional)					
Ambient Monitoring Network (Optional)	166	VOC[e]	146	NA	64	NA	1	0	0	0	0
	167	SOC[e]	154	NA	68	NA	0	0	0	0	0
	207	NO_3[f]	129	NA	75	NA	2	1	0	0	0
Untreated Water Quality Data from Public Water Supply Wells	139	VOC[e]	79	NA	37	NA	1	0	8	10	0
	101	SOC[e]	70	NA	12	NA	3	0	0	0	0
	150	NO_3[f]	103	NA	44	NA	6	1	0	0	0
Finished Water Quality Data from Public Water Supply Wells	2123	VOC[e]	1851	NA	1692	NA	11	0	NA	NA	0
	2052	SOC[e]	2020	NA	1791	NA	3	0	NA	NA	0
	5462	NO_3[f]	2752	NA	1885	NA	149	28	NA	NA	0

Monitoring Data Type	Total No. of Wells Used in the Assessment[a]	Parameter Groups	Number of Wells								
			No detections of parameters above MDLs or background levels		Nitrate concentrations range from background levels to less than or equal to 5 mg/l No detections of parameters other than nitrate above MDLs or background levels and/or located in areas that are sensitive or vulnerable		Nitrate ranges from greater than 5 to less than or equal to 10 mg/l Other parameters are detected at concentrations exceeding the MDL but are less than or equal to the MCLs[c]	Parameters are detected at concentrations exceeding the MCLs[c]	Number of Wells Removed from service[d,h]	Number of Wells Requiring Special Treatment[d,h]	Background parameters exceed MCLs
			ND	Number of wells in sensitive or vulnerable areas (optional)[b]	Nitrate $\leq$ 5mg/l VOC, SOC, and Other parameters not detected[c]	Number of wells in sensitive or vulnerable areas (optional)					
Untreated Water Quality Data from Private or Unregulated Wells (optional)[g]	0	VOC									
		SOC									
		NO_3									
		Other									
Other Sources (optional)	0	VOC									
		SOC									
		NO_3									
		Other									

Notes:
[a] Total number of wells used for the Ambient monitoring network; total number of PWS's used for the Public Water Supply wells
[b] Ohio has not yet classified sensitive/vulnerable areas.
[c] Nitrate counts were given first priority. Total wells/PWS's for SOC's and VOC's are counted from within the nitrate data subset.
[d] Wells removed from service or wells requiring special treatment due to ground water contamination of nitrates, VOC's or SOC's.
[e] Total systems with VOC and SOC detections are looking at all detections (with the exception of trihalomethanes), not only those that are regulated.
[f] Nitrate data from both community and non-community public water supplies.
[g] Private wells are not under the jurisdiction of Ohio EPA; these wells are regulated by the Ohio Department of Health.
[h] Information only from three of the five district offices. Data applies only to the raw water.