Ohio 2010 Integrated Report

Section N

An Overview of Ground Water Quality in Ohio

N1. Introduction

Section N summarizes water quality assessment data for Ohio's major aquifers based on information requested in the 2006 Integrated Reports Guidance and the 1997 Guidelines for Preparation of the Comprehensive State Water Quality Assessments.

Ground water protection programs for the state of Ohio are briefly summarized in Section N2 as required in section 106(e) of the Clean Water Act. Programs to monitor, evaluate, and protect ground water resources in Ohio are implemented by various state, federal, and local agencies. Ohio EPA is the designated agency for monitoring and evaluating ground water quality conditions and assessing ground water contamination problems for the state of Ohio. Within Ohio EPA, the Division of Drinking and Ground Waters (DDAGW) carries out these functions, and coordinates various ground water monitoring efforts within the agency and with other state programs through the Ohio Water Resources Council and the State Coordinating Committee on Ground Water. The program descriptions are significantly reduced from what was presented in past Ground Water Chapters in the belief that links to program based web pages provide access to the most current information.

Ohio's three major aquifer types are described in Section N3. Where possible the water quality data are associated with the major aquifer types. The aquifer descriptions allow the reader to associate water quality impacts with geologic settings.

Sections N4 and N5 summarize facilities with verified ground water contamination and identifying the major nonpoint sources of ground water contamination in Ohio. These data were obtained from various sources including: Ground Water Impacts Database (maintained by Ohio EPA, DDAGW); potential contaminant sources inventoried as part of the Source Water Assessment and Protection Program (SWAP); underground injection control sites documented in Ohio EPA – DDAGW and Ohio Department of Natural Resources (ODNR) – Division of Mineral Resource Management (DMRM) databases; leaking and formerly leaking underground storage tanks [from Bureau of Underground Storage Tank Regulations (BUSTR) databases]; and federal databases listing Department of Development/Department of Energy (DOD/DOE) facilities and National Priorities List/Comprehensive Environmental Response, Compensation, and Liability Act (NPL/CERCLA) sites. In many instances, these data are not associated with the geologic setting of the impacted aquifer, so statewide summaries are provided.

Section N6 summarizes ground water quality impairments by parameter within Ohio's major aquifers. Two primary data sets used to characterize Ohio's ground water quality in this analysis: ambient ground water quality data and drinking water compliance data for the public water systems (PWSs). The Ambient Ground Water Quality Monitoring Program is the DDAGW program created to monitor "raw" (untreated) ground water. The program's goal is the collection, maintenance, and analysis of raw ground water quality data to measure long-term changes in the water quality of Ohio's major aquifer systems. Ohio's public water system compliance monitoring data represents water quality for treated (post-processing) ground water and was used to characterize ground water quality within Ohio's major aquifers. Since Ohio does not have statewide ground water quality standards, comparisons to primary maximum contaminant (MCL) levels or secondary maximum contaminant levels (SMCL) for drinking water were used for the analysis.

Section N7 briefly discusses ground water-surface water interaction (GW-SW) and a few special studies that provide insight on the GW-SW interaction, which lead to suggestions for future ground water monitoring efforts. Section N8 presents some conclusions and recommendations for future direction concerning statewide ground water monitoring and protection of Ohio's major aquifers.

N2. Ohio's Ground Water Programs

Ohio Water Resources Council - On July 1, 2001, Governor Bob Taft established a permanent Ohio Water Resources Council (OWRC) with the mission: Guide the development and implementation of a dynamic process to advance the management of Ohio's water resources. The State Agency Coordination Group, with representatives from the state agencies dealing with water issues, was also established to serve as a technical resource for the OWRC. The current 10-year vision and four year action plan focuses on water resources in the following areas: data and information, education and outreach, water quality, water quantity, infrastructure and water hazards. http://www.dnr.state.oh.us/tabid/15378/default.aspx.

State Coordinating Committee on Ground Water - The State Coordinating Committee on Ground Water (SCCGW) was created in 1992 by the directors of the state agencies that have ground water program responsibilities. The purpose of the SCCGW is to promote and guide the implementation of coordinated, comprehensive, and effective ground water protection and management programs for Ohio. The SCCGW used the OWRC's four-year action plan to outline SCCGW priorities. Details on the SCCGW priority actions for data and information, education and outreach, watershed management, water quality, water quantity, water resource infrastructure, and water related natural hazards are provided on the SCCGW Web site (http://wwwapp.epa.ohio.gov/ddagw/SCCGW/index.html).

Ohio Ground Water Protection Programs - Programs to monitor, evaluate, and protect ground water resources in Ohio are administered by federal, state and local agencies. The Ohio EPA is the designated state ground water quality management agency. The ODNR Division of Water is responsible for the evaluation of the quantity of ground water resources. Ground water-related activities at the state level are also conducted by the Ohio Departments of Agriculture, Commerce (Division of State Fire Marshal), Health, and Transportation. The United States Geological Survey (USGS), Ohio Water Science Center, contributes to these efforts with water resource research. Table N-1 (Table 5-2, U.S. EPA 305(b) Guidelines, 1997) summarizes agencies responsible for administering the various ground water programs in Ohio.

Table N-1. Summary of Ohio ground water protection programs.

Programs or Activities	Check (✓)	Implementation Status	Responsible State Agency
Active SARA Title III Program	✓	E	OEPA - DERR
Ambient ground water monitoring system	✓	E	OEPA - DDAGW
Aquifer vulnerability assessment	✓	CE	ODNR – DSWR
Aquifer mapping	✓	CE	ODNR – DSWR
Aquifer characterization	✓	CE	OEPA – DDAGW ODNR – DSWR
Comprehensive data management system	✓	UD [a]	OWRC
Consolidated Cleanup Standards	NA		
Ground water Best Management Practices	✓	E	ODNR, ODA

Programs or Activities	Check (✓)	Implementation Status	Responsible State Agency
Ground water legislation	✓	UR [b]	All Agencies
Ground water classification	✓	E [c]	OEPA- DERR
Ground water quality standards (program specific)	✓	E [d]	OEPA
Interagency coordination for ground water protection initiatives	✓	E	OWRC, SCCGW
Nonpoint source controls	✓	CE	ODA, OEPA, ODNR
Pesticide State Management Plan	✓	E [e]	ODA
Pollution Prevention Program	✓	E	OEPA - OCAPP
Resource Conservation and Recovery Act (RCRA) Primacy	✓	E	OEPA - DHWM
Source Water Assessment Program	✓	E	OEPA - DDAGW
State Property Clean-up Programs	✓	E	OEPA - DERR
Susceptibility assessment for drinking water/wellhead protection	✓	E	OEPA
State septic system regulations	✓	UR [f]	ODH, OEPA
Underground storage tank installation requirements	✓	E	SFM/BUSTR
Underground Storage Tank Remediation Fund	✓	E [g]	SFM/BUSTR
Underground Storage Tank Permit Program	✓	E	SFM/BUSTR
Underground Injection Control Program	✓	E [h]	OEPA – DDAGW ODNR – DMRM
Well abandonment regulations	✓	E [i]	ODNR, OEPA DDAGW, ODH
Wellhead Protection Program (EPA-approved)	✓	E [j]	OEPA
Well installation regulations	✓	E [k]	OEPA, ODH

Table Notes: **E** – Established; **CE** - Continuing Effort; **UD** - Under Development; **UR** - Under Revision

[a] Data management occurring on an agency level, however, a web based GROUND WATER metadata site was developed to provide links to ground water quality data in Ohio. OWRC has proposed expanding this site to develop an Ohio Water Information Gateway.

[b] Rules are required to be reviewed every 5 years by state statute.

[c] Established through the Voluntary Action Program (VAP).

[d] Standards are program-specific; effort to establish Consolidated Cleanup Standards was not successful.

[e] ODA received cooperative commitment from other Ohio agencies for the Generic Pesticide Management Plan. The requirement for Specific Pesticide Management Plan was dropped.

[f] The Public Health Council sewage treatment system rules (residential and small flow, on-site systems) that became effective on Jan. 1, 2007 were rescinded as required by HB119. In compliance with HB 119, the director of Health adopted statewide interim sewage rules (OAC 3701-29) effective July 2, 2007. ODH has documented septic failure rates and is recommending revised 2007 design standards. Larger systems are regulated by Ohio EPA under separate regulations.

[g] Remediation funds are available from the Petroleum Underground Storage Tank Release Compensation Fund.

[h] Ohio EPA regulates Class I and V injection wells; ODNR regulates Class II and III injection wells.

[I] Technical Guidance for Sealing Unused Wells prepared by SCCGW (1996).

[j] Wellhead Protection Program has evolved to the Source Water Protection Program.

[k] Technical Guidance for Well Construction and Ground Water Protection prepared by SCCGW (2000). Ohio EPA new wells workgroup has revised requirements for approving new PWS wells which incorporate elements of the Source Water Protection Program and water quality into the well approval process.

Program Web Sites:

ODA - Ohio Department of Agriculture
- Pesticide and Fertilizer Regulation Program http://www.ohioagriculture.gov/pesticides/
- Livestock Environmental Permitting Program http://www.agri.ohio.gov/divs/LEPP/Lepp.aspx

ODH - Ohio Department of Health http://www.odh.ohio.gov/odhPrograms/eh/sewage/sewage1.aspx

ODNR - Ohio Department of Natural Resources http://www.dnr.state.oh.us/
- Division of Soil and Water Resources http://www.dnr.state.oh.us/soilandwater
- Division of Mineral Resources Management http://www.dnr.state.oh.us/mineral/default/tabid/10352/Default.aspx
- Division of Geologic Survey http://www.dnr.state.oh.us//geosurvey

Ohio EPA - Ohio Environmental Protection Agency http://www.epa.ohio.gov/
- Division of Drinking and Ground Waters http://www.epa.ohio.gov/ddagw/Home.aspx
- Division of Surface Water http://www.epa.ohio.gov/dsw/Home.aspx
- Office of Compliance Assistance and Pollution Prevention http://www.epa.ohio.gov/ocapp/Home.aspx
- Division of Emergency and Remedial Response http://www.epa.ohio.gov/derr/Home.aspx
- Division of Hazardous Waste Management http://www.epa.ohio.gov/dhwm/Home.aspx

OWRC – Ohio Water resource Council http://www.ohiodnr.com/tabid/15378/default.aspx

SCCGW – State Coordinating Committee on Ground Water http://wwwapp.epa.ohio.gov/ddagw/SCCGW/

SFM/BUSTR – State Fire Marshall/ Bureau of Underground Storage Tank Regulations http://www.com.ohio.gov/fire/bustMain.aspx

N3. Ohio's Major Aquifers

Ohio has abundant surface and ground water resources. Average rainfall ranges between 30 to 44 inches a year (increasing from northwest to southeast), which drives healthy stream flows. Infiltration of a small portion of this rainfall (3-16 inches) recharges the states aquifers and keeps the streams flowing between rains. Ohio's aquifers can be divided into three major types of productive aquifers as illustrated in Figure N-1. The sand and gravel valley aquifers (in blue) are distributed through the state. The valleys filled by these sands are cut into sandstone and shale in the eastern half of the state (in rose) and into carbonate aquifers (in greens) in the western half of the state. The sandstone and carbonate aquifers generally provide sufficient production for water wells except where dominated by shale, as in southwest and southeast Ohio.

Sand and Gravel Aquifers - The unconsolidated sand and gravel units, typically associated with buried valley aquifer systems, are Ohio's most productive water bearing formations or aquifers. These valleys were cut into the bedrock by pre-glacial and glacial streams and subsequently the valleys were back filled with deposits of sand, gravel and other glacial drift by glacial and alluvial processes as the glaciers advanced and receded. Buried valley aquifers are found beneath and adjacent to the Ohio River, its major tributaries, and other pre-glacial stream channels such as the Teays River. The distribution of these Quaternary sand and gravel units is presented as thin bands of blue in Figure N-1 (modified from ODNR Glacial Aquifer Maps, 2000). In addition to the buried valley aquifers, several other types of productive sand and gravel aquifers are included in Figure N-1. In the northwest corner of the state, the triangular area of sand and gravel units includes sheets of outwash or sand and gravel deposits that occur between sheets of glacial till. Present day stream processes deposit alluvial sand and gravel deposits that also serve as aquifers. Other geologic settings included in the sand and gravel aquifers are the outwash/kame and beach ridge deposits, including the Oak Opening Sands (large patches of sand and gravel in northwest Ohio.

Water production from the coarser grained and thicker sand and gravel deposits ranges up to 500 to 1,000 gallons per minute. Lower yields from sand and gravel aquifers are more common. The production rate depends on the type, distribution, permeability, and thickness of permeable glacial/alluvial deposits as well as on well construction parameters, such as well diameter and length of well screen.

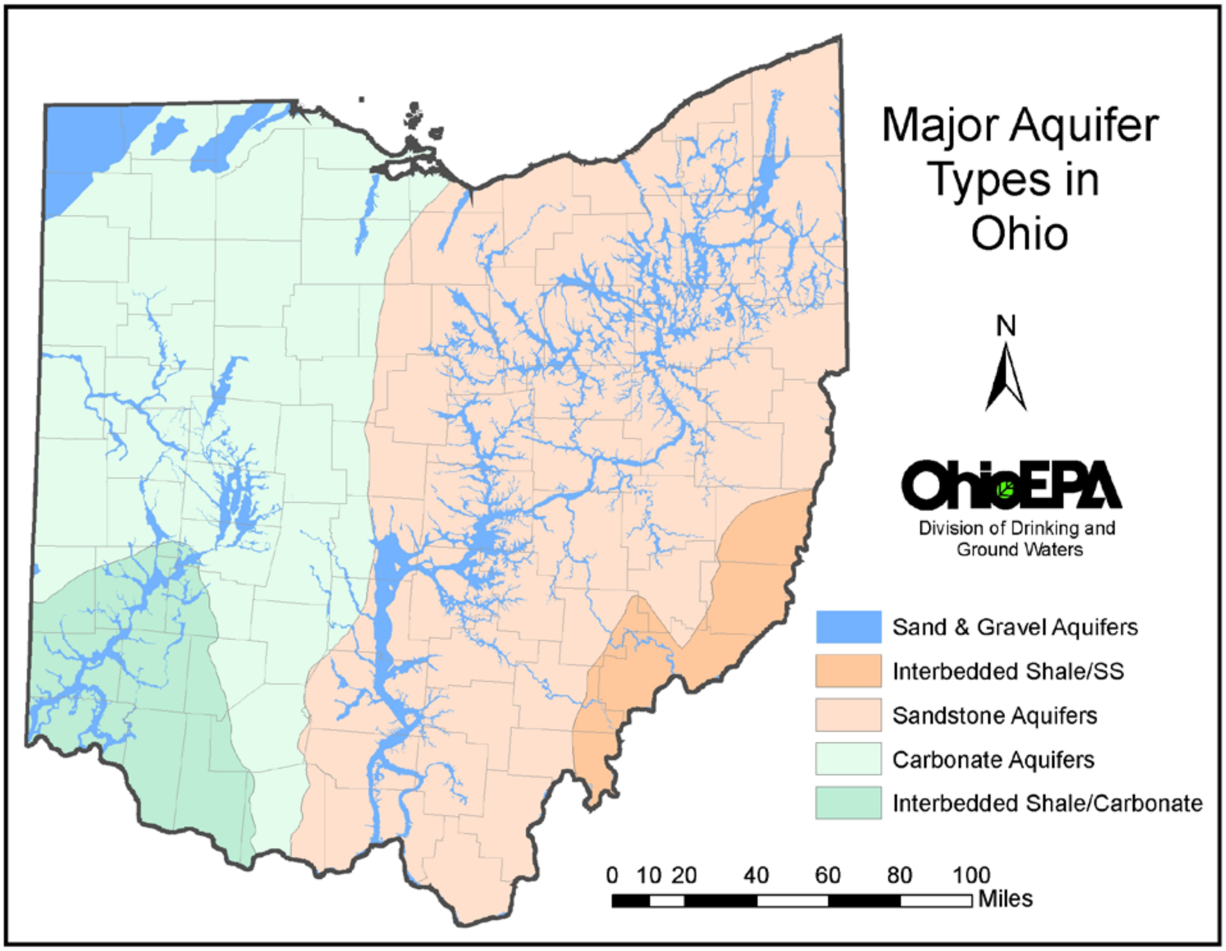

Figure N-1. Aquifer Types in Ohio modified from ODNR glacial and bedrock Aquifer Maps (ODNR, 2000).
Web site last viewed in 2009 (http://www.dnr.state.oh.us/water/samp/default/tabid/4218/Default.aspx).

Sandstone Aquifers - In the eastern half of Ohio, Mississippian and Pennsylvanian sandstone units are the dominant bedrock aquifers (Figure N-1). Upper Paleozoic siltstone, sandstone, and conglomerate formations (Mississippian to Permian age) in eastern Ohio occur as numerous layers of siltstone and sandstone of variable thickness and areal extent separated by layers of shale and minor amounts of limestone, clay and coal. The sandstone units generally dip a few degrees to the southeast, toward the Appalachian Basin. Some of the thicker sandstones and conglomerates are capable of yielding 50 to 100 gallons per minute, but 25 gallons a minute is a good yield for these aquifers. The more productive stratigraphic units include:

- Pennsylvanian Sharon through Massillon Formations, and the Homewood Sandstone within the Pottsville and Allegheny Groups - These sandstones were deposited on a stable coastal plain under conditions of rising sea level. These aquifers are most commonly used in the northern areas of Eastern Ohio. To the southeast, farther into the Appalachian Basin, the water in these units is generally too saline for drinking water.

- Mississippian Berea Sandstone, Cuyahoga Group, Logan and Blackhand Formations - These siltstones and sandstones with minor conglomerate were sorted and deposited in deltaic complexes from material eroded from the Acadian Mountains (Late Devonian uplift) to the east. These units also extend to the SE, farther into the Appalachian Basin, but as with the Pennsylvanian units, the water becomes too saline for drinking water.

In southeastern Ohio, Upper Pennsylvanian and Permian stratigraphic sections include low yielding aquifers. The bedrock consists of varied sequences of thin-bedded shales, limestones, sandstones, clays, and coals of the Pennsylvania, Conemaugh and Monongahela Groups and the Permian Dunkard Group. Yields below 5 gallons per minute are common in these areas (see http://www.dnr.state.oh.us/water/samp/default/tabid/4218/Default.aspx).

Carbonate Aquifers - Carbonate bedrock is the dominant aquifer in the western part of Ohio (Figure N-1). Middle Devonian and Silurian limestone and dolomite 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 units are associated with fractures and dissolution features that increase the fracture permeability of the carbonate bedrock. The high production aquifers, in order of deposition, are fractured or karst Silurian sub-Lockport/ Lockport Dolomite and equivalent units, the Salina Group, consisting of the Tymochtee and Greenfield Dolomites, and the Undifferentiated Salina Dolomite. The Devonian Delaware and Columbus Limestone, exposed along the eastern edge of the Silurian Dolomites, and equivalent Devonian units in the northwest corner of Ohio (Ten Mile Creek Dolomite, Silica formation, Dundee Limestone, and Detroit River Group) are productive carbonate aquifers. These carbonates were generally deposited in warm, shallow seas with limited input of sediment from continental sources. Where the Devonian limestone is overlain by 100 feet or more of Devonian shale, the water quality in the aquifer is poor and generally cannot be considered a drinking water source.

The southwestern portion of the state is underlain by inter-bedded lower Ordovician carbonates and shales. These undivided Ordovician units are dominated by shale (Figure N-1). As a result, well yields are generally less than 10 gallons per minute, and in many areas yields 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 low yielding aquifers are only practical for low volume water users, and consequently, this aquifer is not discussed further in this report. Another area with low yields is the region of Devonian shale that overlies the Columbus and Delaware Limestone aquifers. The narrow north-south trending area of the Devonian shale in central Ohio curves eastward along the Lake Erie shoreline. These shale bedrock units are poor aquifers yielding less than 5 gallons per minute. In addition, hydrogen sulfide is frequently present in these shales causing water quality problems.

N4. Facility-Specific Ground Water Contamination Summary

Table N-2 (based on Table 5-3, U.S. EPA 305(b) Guidelines, 1997) provides a summary of the facilities that have verified ground water contamination in Ohio. These data come from various state programs and the quality of these data varies from program to program. Because the specific hydrogeologic settings for many of these sites is not included in the databases or is unknown, only a statewide summary is provided. Additional information is provided below for each program or subset of sites listed in Table N-2.

Federal National Priorities List (NPL): Currently, 33 sites in Ohio are on the NPL, most of which (30) have been found to be affecting ground water quality. The primary contaminants in ground water from the NPL sites are volatile organic chemicals (VOCs) and heavy metals. There are also seven sites that are proposed to be added to the NPL, four of which have documented ground water contamination.

CERCLIS (non-NPL): Detailed information on the 386 CERCLIS sites in Ohio is not readily available. Therefore, the aquifer being impacted and the types of contaminants could not be determined.

DOD/DOE: The 105 facilities on this list are the Department of Defense (DOD)/Department of Energy (DOE) sites in Ohio, including those that are Formerly Used Defense Sites (FUDS) and Formerly Utilized Sites Remedial Action Program (FUSRAP) sites. Of these, 68 have had confirmed releases to ground water.

Leaking Underground Storage Tanks (LUST): In Ohio, underground storage tanks (USTs) are under the jurisdiction of the State Fire Marshal, Bureau of Underground Storage Tank Regulations (BUSTR). Current data from BUSTR indicates that more than 30,000 sites have been found to be leaking. Of these, 25,000 have been cleaned up and approximately 5,000 are still active - that is, they are still leaking or they are in the process of being remediated. Of the 5,000 or so active sites, about 700 have released contamination that affected ground water quality. The primary contaminants are petroleum products benzene, toluene, ethylbenzene, xylenes (BTEX).

RCRA Corrective Action: Currently, 167 facilities are in RCRA corrective action. All of these have confirmed releases to ground water. The primary contaminants in ground water from the RCRA sites are VOCs and heavy metals. This information was obtained from the Ground Water Impacts Database, an internal DDAGW tracking system for facilities that are affecting ground water in Ohio.

Underground Injection: There are five classes of underground injection wells:

- Class I wells inject hazardous wastes or other wastewaters beneath the lowermost aquifer;
- Class II wells inject brines and other fluids associated with oil and gas production beneath the lowermost aquifer;
- Class III wells inject fluids associated with solution mining of minerals beneath the lowermost aquifer;
- Class IV wells inject hazardous or radioactive wastes into or above aquifers (these wells are banned unless authorized under a federal or state ground water remediation project; there are none in Ohio);
- Class V wells comprise all of the injection wells not included in Classes I-IV.

The Ohio Department of Natural Resources, Division of Mineral Resource Management regulates Class II (370) and Class III (46) wells. Ohio EPA Division of Drinking and Ground Waters regulates Class I (10), Class IV (0), and Class V (+50,000) wells. Although owners and operators of Class V wells are required to register their wells, there are still many that are unknown and unregistered throughout the state.

State Sites: State sites include landfills, hazardous waste sites, unregulated sites (pre- RCRA), and sites investigated through the Voluntary Action Program (VAP). Ground water contamination summary information concerning many of these facilities is tracked in the Ground

Water Impacts Database, maintained by Ohio EPA DDAGW. The database currently consists of facilities that have adequate documentation to make a conclusion that a verified contaminant release to ground water has occurred. As of July 2009, the database contained 512 facilities that have a documented release to ground water. Of the 512 sites, 218 facilities have affected ground water quality within the uppermost aquifer or lower aquifer, the local aquifers that can be used as drinking water sources.

Table N-2. Ground water contamination summary.

Hydrogeologic Setting: Statewide
Data Reporting Period: As of July, 2009

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
NPL	33	33	30	Mostly VOCs and heavy metals; also, SVOCs, PCBs, PAHs and others
CERCLIS (non-NPL)	386	NA	NA	Varied
DOD/DOE	105[a]	68	68	Varied
LUST	~30,000[b]	~5,000	~700[c]	BTEX
RCRA Corrective Action	167	167	167	VOCs, heavy metals, PCBs, and others
Underground Injection	Class: I - 10 II - 370 III - 46 IV - 0 V - 50,000+	 0 0 0 0 NA	 0 0 0 0 NA	
State Sites	604[e]	512	218[f]	Varied
Nonpoint Sources	NA	NA	NA	

Notes:

NA - Numbers not available

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

[b] Includes active LUST sites and closed LUST sites (where the leaking tank has been removed and the contamination remediated). Source: Ohio's Bureau of Underground Storage Tank Regulations

[c] Facilities in Tier 2 or Tier 3 cleanup stages. Source: Ohio's Bureau of Underground Storage Tank Regulations

[d] Class II and Class III injection wells regulated by the Ohio Department of Natural Resources. Class IV injection wells are illegal in Ohio. The total number of Class V injection wells in Ohio is unknown.

[e] Facilities in Ohio EPAs Ground Water Impacts database

[f] The facility is considered to be contaminating ground water if the "Uppermost Aquifer" is noted to be impacted, found in Ohio EPAs Ground Water Impacts database

Figure N-2 illustrates the distribution of the facilities with verified ground water quality releases as recorded in the Ground Water Impacts Database. Several different types of saturated ground water zones or aquifers are identified for each facility depending on the program under which the facility is regulated and the zone being monitored. The monitored zones include but are not limited to urban setting designations, significant zone of saturation, uppermost aquifer. For the purpose of Figure N-2 (and state sites in Table N-2), contamination had to be present in either the uppermost aquifer or lower aquifer to be counted as having ground water contamination (218 facilities). The type of contaminants detected varies with the majority being VOCs and heavy metals. The majority of the facilities are concentrated near the large, urban areas, such as Cincinnati/Dayton in southwest Ohio, Columbus in central Ohio, and the Cleveland/Akron area in northeast Ohio. Of the 218 facilities, landfills are found to contribute the most to ground water contamination (118, 54%). Most likely, these are from older, unlined landfills, many of which are currently closed.

N5. Major Sources of Ground Water Contamination

Although available data show that much of Ohio's ground water is of high quality and has not been widely influenced by anthropogenic activities, individual cases of ground water contamination are documented every year from point (facility specific locations) 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 range of contaminants and a wide variety of land use activities across the state.

The ten major sources of ground water contamination in Ohio are indicated in Table N-3 (Table 5-3, U.S. EPA 305(b) Guidelines, 1997) by checks (✓). These data were obtained from two sources: Ohio's Source Water Assessment and Protection (SWAP) Program and DDAGW's Ground Water Impacts Database. The SWAP Program has completed an inventory of the potential sources of ground water contamination in the delineated Drinking Water Source Protection Areas. Ninety-nine percent (99%) of the active public water systems that use ground water have had an inventory conducted, an analysis of the aquifer's susceptibility contamination and whether the ground water quality has been impacted by anthropogenic activities. The Ground Water Impacts Database provides information regarding facilities in Ohio where contamination of ground water has been confirmed. These data were evaluated and those sources of highest concern were given a check mark (✓) in Table N-3.

Some of the "potentially high priority" sources, indicated by crosses (×), were selected based on professional knowledge of the types of sources that exist in Ohio. These sources, such as animal feedlots and mining, are limited in their extent and may not be sited close to public water system well fields and therefore do not rank in the top ten highest priority sources. However, in the parts of the state where they are prevalent, these sources may be a threat to ground water resources, especially at sites with sensitive hydrogeologic settings. The land use activities within the vulnerable areas have a greater potential of affecting the ground water quality.

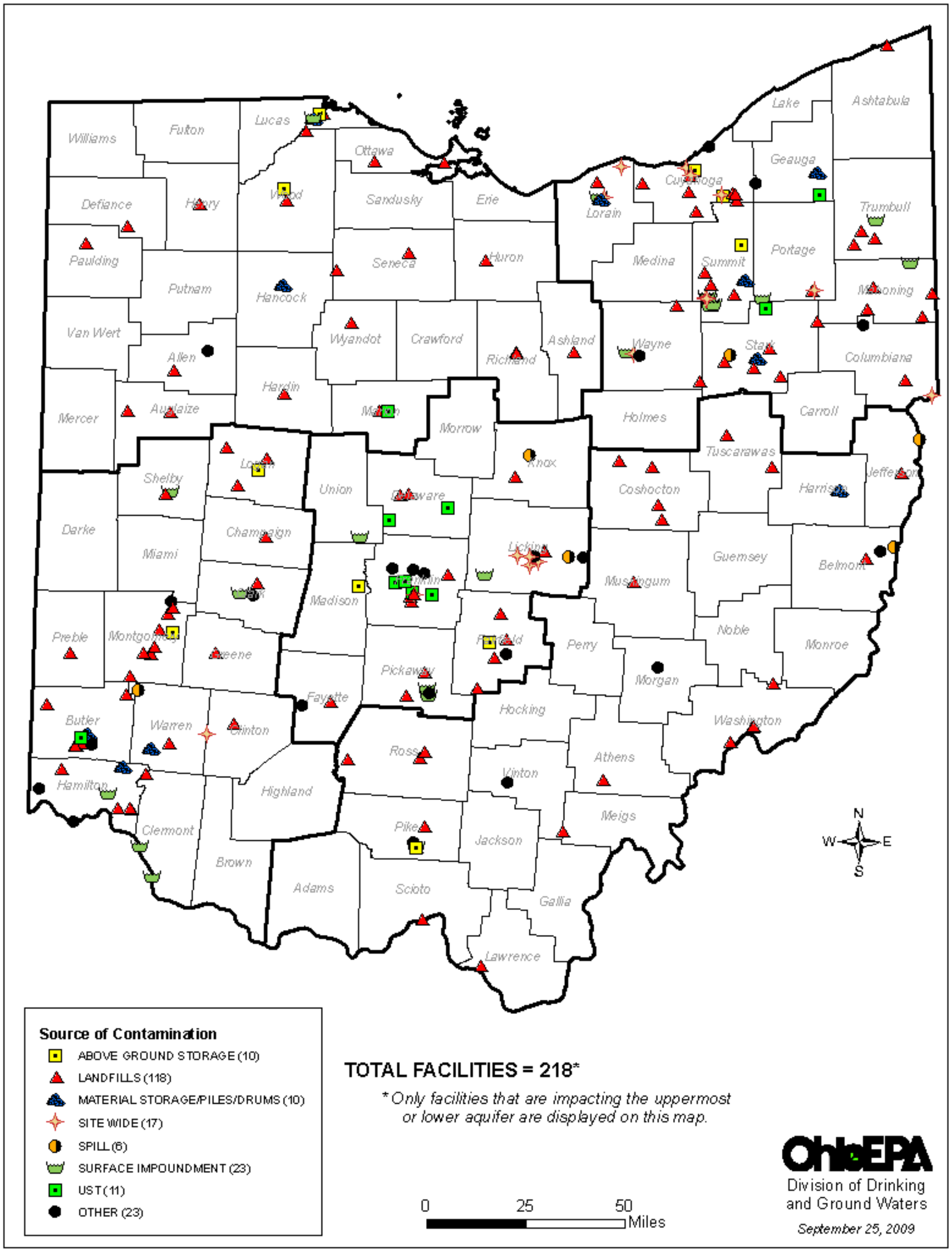

Figure N-2. Locations of facilities with documented ground water impacts in Ohio.

Table N-3. Major sources of ground water contamination.

Contaminant Source	Highest-Priority Sources	Factors Considered in Selecting a Contaminant Source	Contaminants
Agricultural Activities			
Agricultural chemical facilities			
Animal feedlots	×	6, 8	E, J, K, L
Drainage wells			
Fertilizer applications	✓	1, 2, 3, 4, 5	E, J, K, L
Irrigation practices			
Pesticide applications			
On-farm agricultural mixing and loading			
Land application of manure	✓	1, 3, 5	E, J, K, L
Storage and Treatment Activities			
Land application	×	6, 8	E, J, K, L
Material stockpiles	✓	6	H, M
Storage tanks (above/below ground)	✓	1, 2, 3, 4, 5, 6, 7	C, D, H, M
Surface impoundments	✓		G, H, M
Waste piles			
Waste tailings			
Disposal Activities			
Deep injection wells			
Landfills	✓	1, 2, 3, 4, 5, 6	A, B, C, D, H, J, K, L, M
Septic systems	✓	1, 2, 3, 4, 5, 6	E, H, J, K, L
Shallow injection wells	✓	1, 2, 3, 4, 5, 6, 8	C, D, G, H, M
Other			
Hazardous waste generators			
Hazardous waste sites	✓	1, 2, 3, 4, 5, 6, 7	A, B, C, D, H, I, M
Large industrial facilities			
Material transfer operations			
Mining and mine drainage	×	6, 8	G, H
Pipelines and sewer lines			
Salt storage and road salting	×	6	G
Spills	×	6	C, D, H, M
Transportation of materials			
Urban runoff (storm water management)	✓	2, 4	A, B, C, D, G, H
Small-scale manufacturing and repair shops			

Notes: (✓) Highest Priority; (×) Potentially High Priority
Factors and Contaminants codes on next page.

FACTORS
1. Human health and/or environmental risk (toxicity)
2. Size of the population at risk
3. Location of the sources relative to drinking water sources
4. Number and/or size of contaminant sources
5. Hydrogeologic sensitivity
6. State findings, other findings
7. Documented from mandatory reporting
8. Geographic distribution/occurrence

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 (VOCs)

Contaminant Source Discussion - The sources of contamination that are identified in Table N-3 as "highest priority" or "potentially high priority" are listed below in the order presented in the table. Each of these priority sources is discussed briefly to provide additional information on these threats to Ohio's ground water.

(✓) 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 contamination in ground water. Nitrate concentrations in ground water represent one of the better examples of the widespread distribution of nonpoint source pollution. Non-agricultural sources, such as lawn fertilization and septic systems, also contribute to localized ground water contamination. Public water systems utilizing sand and gravel aquifers have higher average nitrate levels than PWSs using sandstone and carbonate aquifers, primarily due to the higher vulnerability of the unconsolidated aquifers.

- **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. The growth of animal feeding operations and sewage treatment facilities increases the land application of manure and sludge that is being spread on fields as fertilizer.

- **Material Stockpiles:** A material stockpile can consist of almost any type of material. For example, it can include manure, biosolids, salt, or a hazardous substances or waste.

- **Storage Tanks (Underground and Above-ground):** The 1994 State of Ohio Non-Point 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 their hidden nature contributes to the lack of proper maintenance. There are around 700 USTs known to still be leaking or undergoing remediation in Ohio. Leaking above-ground storage tanks from commercial and industrial facilities are less of an issue in Ohio (there are only nine known to be contributing to ground water contamination from regulated facilities, most are hazardous waste sites), but the smaller fuel oil tanks used to heat individual homes may be a bigger concern. Many of these above ground tanks are old and rusty with no containment in the event of a leak or spill. Fuel oil tanks are found throughout Ohio, primarily in rural areas.

- **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 at older sites. Current siting and engineering requirements have improved this situation.

- **Landfills:** Currently there are about 118 landfills with documented ground water contamination in Ohio. This constitutes 54 percent of the facilities known to be affecting ground water quality based on information in Ohio EPA's Ground Water Quality Impacts database. Most likely, these are from older, unlined landfills, many of which are currently closed. The current siting, design, and construction standards for landfills are more stringent than twenty years ago, with the result that new landfills have significantly lower potential to impact ground water quality than older landfills.

- **Septic Systems:** Over 1,000,000 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 ground water which may supply water to nearby wells. Improperly operating and maintained septic systems are considered significant contributors to elevated nitrate levels in ground water in vulnerable geologic settings (e.g. shallow fractured bedrock).

- **Injection Wells:** Class V injection wells are widespread throughout the state, with some areas having a high concentration of wells. It is estimated that Ohio has over 50,000 class V injection wells. The fact that these wells are used to inject fluids directly into vulnerable aquifers in the State is the main cause for concern. These shallow injection wells provide a direct pathway for nonpoint source contamination and illegal waste disposal into vulnerable aquifers. Ohio has closed 571 motor vehicle waste disposal wells (e.g. oil, radiator fluids, etc) since 2000.

- **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. There are 167 hazardous waste facilities in Ohio known to be affecting ground water quality (including uppermost aquifer and significant zones of saturation).

- **Suburban /Urban Runoff:** With expanding suburban areas, nonpoint source contamination from suburban/urban runoff is an increasing source of ground water contamination, in contrast with most of the other sources discussed. In addition, the recent practice of constructing storm water retention basins increases the likelihood that storm water runoff infiltrates into ground water. Elevated chloride concentrations are documented in urban areas within glacial aquifers by Mullaney, Lorenz and Arntson (2009) and we see indications of positive trends in chloride concentrations in Ambient Ground Water Quality Monitoring data.

(✗) Potentially High Priority Sources

- **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 significant potential source of ground water contamination if the waste is not properly managed. 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.

- **Land Application (for wastewater treatment):** The concerns for land application of wastewater sludge are similar to the issues for land applying manure and sludge described above. The growth of sewage treatment facilities increases the land application of wastewater and sludge.

- **Mining and Mine Drainage:** The bedrock (Pennsylvanian Units) that underlies eastern Ohio includes 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 a 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 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:** Improper storage and use of salt as a deicing agent can affect ground water resources. The widespread use of salt or mixtures of salt and sand for deicing roads has been documented as a nonpoint source contributor of sodium and chlorine contamination of shallow ground water (Jones and Sroka, 1997; Mullaney, Lorenz and Arntson, 2009). Local impact of salt storage sites is significant in some areas. Alternative chemicals like acetate-based deicers in combination with reduced salt usage are being promoted in pollution prevention programs.

- **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. Several of the sources of leaks, such as LUST, storage facilities, and surface impoundments, are included with the Highest Priority Sources.

The major sources of ground water contamination listed include point and nonpoint sources in roughly equal proportions. In strict terms, a point source is a discharge from a discernable, confined and discrete conveyance, but in practical terms when assessing ground water quality, the distribution or spatial scale of a contaminant controls the designation of a source as point or nonpoint. For example, salt applied for de-icing along roads exhibits nonpoint source behavior, while salt stockpiles behave more like point sources with the potential for continual release of concentrated brine that may affect ground water quality. This dichotomy is typical of many agricultural contaminants, manure spreading versus storage, fertilizer application versus storage or mixing sites. In Ohio, we generally have better documentation of ground water contamination associated with point source contamination than nonpoint source contamination due to the extensive ground water monitoring programs at regulated facilities.

Rapid runoff in glacial tills areas overlying much of Ohio and drainage tiling have protected many of Ohio’s aquifers from traditional nonpoint source pollution sources such as nitrate, chloride, pesticides or bacteria. However, in sensitive aquifer settings (e.g. sand and gravel aquifers, shallow bedrock aquifer) indicators of nonpoint source pollution are more clearly identified in Ohio's ambient ground water quality monitoring program and the public water system compliance monitoring data. However, these monitoring programs do not focus on shallow aquifers, which have a higher likelihood of being influenced by nonpoint source pollution such as agricultural practices.

N6. Summary of Ground Water Quality by Aquifer

Tables N-4A and N-4B (Table 5-4, U.S. EPA 305(b) Guidelines, 1997) present the number of Ohio public water systems (PWSs) and the number of wells in the Ambient Ground Water Quality Monitoring Program (AGWQMP) at which the water quality exceeds the maximum contaminant levels (MCL) respectively. Compilation of these tables utilized two sources of ground water quality data: the AGWQMP data and PWS compliance monitoring data. The AGWQMP is the DDAGW program created to monitor "raw" (untreated) ground water. This program's goal is the collection, maintenance, and analysis of raw ground water quality data to measure long-term changes in the water quality of the Ohio's major aquifer systems. The compliance data for Ohio EPA's public water systems documents water quality for treated water (post processing) and is used primarily to track PWS compliance. However, parameters which are generally unaffected by standard treatment, such as nitrate, are frequently used to characterize Ohio's ground water quality.

Ohio does not have statewide ground water quality standards so data for the major aquifers are summarized using percentages of primary maximum contaminant level (MCL) or secondary maximum contaminant level (SCML) parameters. Primary MCLs are the highest level of a contaminant that is allowed in public drinking water and are set as close to MCL Goals (a health-based standard) as feasible using the best available treatment technology and economic considerations. Primary MCLs are enforceable standards. Secondary MCLs are non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water. Primary and secondary MCLs represent practical benchmarks for water quality characterization. Fifty percent of the MCL is used as a lower boundary for a "watch list" determination in Tables N-4A and N-4B. The PWSs or wells identified in this category may warrant monitoring to identify increasing trends. Exceedance of the MCL is used as the "impaired" category. Tables N-4A and N-4B were generated using the last 10 years of data (1999-2008) and mean concentrations of the parameters listed. Maximum concentrations of nitrate and nitrite are reported in these tables instead of averages, due to the acute nature of their health concerns.

Public Water System Compliance Data
Mean values were calculated from PWS compliance data for 1999-2008 to determine the number of PWSs the watch list and the impaired category. A ten year period of record was used to increase the statistical significance of the determination due to the infrequent sampling requirements (e.g. once per three year period) for public water systems. Listing in the impaired category may not match Safe Drinking Water Act regulatory determinations of a violation due to the method of calculation.

Table N-4A lists all parameters with MCLs (and SMCLs), the standard, and summarizes the number of PWSs in the watch list and impaired category for both raw and treated water quality data. The results for each parameter are divided in the major aquifer types. The total number of PWSs with data used in these determinations is presented to allow comparison of the total number of PWSs to those that exhibit elevated concentrations of MCL parameters. Beyond the requirement of a new well analysis, there are no requirements for collecting and reporting raw water data so, generally, the number of PWSs with raw water data is less than the number of PWSs with treated water data. The PWS data were linked to geologic settings using the DDAGW Source Water Assessment data, which allowed the breakout of the data by major aquifer.

Raw water monitoring data are not as numerous as treated water data since regulations are tied to treated water. Consequently, in this analysis any detection in raw water data was used to generate PWS averages. For treated water data, PWS averages were generated only if there were at least two detections of a parameter. The inorganic parameters that place numerous PWSs in the watch list and impaired category warrant additional analysis.

The number of PWSs in Table N-4A in the watch list and the impaired category are low; however, several parameters do exhibit higher numbers of PWSs in these groups. Fortunately, most of the parameters that exhibit elevated numbers of PWS in the watch list and impaired category are secondary MCLs. That is, the water quality impacts documented are mostly aesthetic issues and are not health based. Groups of parameters are discussed below.

Inorganic Parameters – Most of the inorganic data puts few PWSs on the watch list or in the impaired category. For treated water, many of the inorganic parameters, except **asbestos**, have no PWSs with mean concentrations that are greater than 50 % of the MCL. The asbestos MCL impairment is most likely tied to the treatment or distribution infrastructure as only six PWSs had detectable levels of asbestos. Relatively low numbers of PWSs exceed the Watch List category in treated water. These parameters include **antimony, barium, beryllium, cadmium**, **chromium, cyanide, fluoride, mercury, selenium, silver, thallium and zinc.** Factors limiting the number of PWSs in these categories include limited solubility of the substance in water, low crustal abundance, local geology, and possibly treatment. For example, fluoride has no PWSs that exceed the MCL, but 24 PWSs that draw water from carbonate aquifers exceed 50 percent of the MCL. This association is controlled by mineralization along fractures, including fluorite, identified in limestone in northwest Ohio. Several PWSs display elevated chloride concentrations, with the largest number being associated with the sandstone aquifers. This may be to be related to oil and gas production from sandstone reservoirs and associated brines, or from local salt storage facilities.

The number of PWSs with **arsenic** in raw water and treated water above the MCL (118 and 58 respectively) is consistent with the number of PWSs that DDAGW has worked with to reduce arsenic concentrations in order to meet the 2006 revised MCL of 10 µg/L. These sites are associated with reduced ground water and local areas of elevated naturally occurring arsenic. Sand and gravel and carbonate aquifers are more likely than the sandstone aquifers to exhibit arsenic impaired ground water. The number of PWS currently exceeding the arsenic MCL are less than what is listed in Table N4-A because numerous PWS have installed treatment to remove arsenic since 2006, but the exceedances prior to 2006 are still included in the ten years of data used to generated the PWS averages that are counted in the Table N4-A.

Table N-4A. Counts of PWSs where 1999-2008 mean values exceed 50% MCL (watch list) and 100% MCL (impaired). *Note: presented by major aquifer types.*

Chemical Group	Chemical	Standard Type	Standard	Major Aquifer	PWS Systems					
					Raw Water			Treated Water		
					Total # PWSs	Watch List >50 % - MCL	Impaired > MCL	Total # PWSs	Watch List > 50 % - MCL	Impaired > MCL
Inorganics	Antimony	MCL	6 µg/L	Sand & Gravel	192	2		712	14	
				Sandstone	219	4	1	702	16	
				Carbonate	173	2		497	8	
	Arsenic	MCL	10 µg/L	Sand & Gravel	247	48	66	692	73	38
				Sandstone	224	19	11	657	31	11
				Carbonate	210	45	41	460	67	29
	Asbestos	MCL	$7x10^6$ fibers/L	Sand & Gravel	13			227		
				Sandstone	5			126		1
				Carbonate	4			104		
	Barium	MCL	2 mg/L	Sand & Gravel	195	2		672	4	
				Sandstone	216	4		647	1	
				Carbonate	171	1	1	444	1	
	Beryllium	MCL	4 µg/L	Sand & Gravel	190	2		686	1	
				Sandstone	219			650		
				Carbonate	173			453		
	Cadmium	MCL	5 µg/L	Sand & Gravel	196		1	676	1	
				Sandstone	218		1	646	3	
				Carbonate	174			443		
	Chloride	SMCL	250 mg/L	Sand & Gravel	173	5	2	13	2	
				Sandstone	209	12	10	14	2	
				Carbonate	160	3	1	7		
	Chromium	MCL	0.1 mg/L	Sand & Gravel	193			674		
				Sandstone	217	2	1	647		
				Carbonate	174			440		
	Cyanide	MCL	0.2 mg/L	Sand & Gravel	182			656		
				Sandstone	215			627		
				Carbonate	171			422		

Chemical Group	Chemical	Standard Type	Standard	Major Aquifer	PWS Systems					
					Raw Water			Treated Water		
					Total # PWSs	Watch List >50 % - MCL	Impaired > MCL	Total # PWSs	Watch List > 50 % - MCL	Impaired > MCL
	Fluoride	MCL	4 mg/L	Sand & Gravel	197	1		688	5	
				Sandstone	218	1		651		
				Carbonate	177	18		455	24	
	Iron	SMCL	0.3 mg/L	Sand & Gravel	198	9	155	100	11	21
				Sandstone	214	34	131	44	7	8
				Carbonate	183	20	126	55	4	25
	Manganese	SMCL	0.05 mg/L	Sand & Gravel	177	35	99	84	12	14
				Sandstone	214	30	134	42	5	16
				Carbonate	159	36	42	32	7	7
	Mercury	MCL	2 µg/L	Sand & Gravel	191			675		
				Sandstone	219	1		646	1	
				Carbonate	173	1		444		
	Nitrate * (Max Value)	MCL	10 mg/L	Sand & Gravel	224	12	6	1572	91	29
				Sandstone	225	2	2	1907	53	8
				Carbonate	194	4	4	1468	48	14
	Nitrite * (Max Value)	MCL	1 mg/L	Sand & Gravel	213		1	1557	12	1
				Sandstone	220			1852	13	
				Carbonate	189			1455	12	
	Selenium	MCL	50 µg/L	Sand & Gravel	191			675		
				Sandstone	219			647		
				Carbonate	174	2		444		
	Silver	SMCL	0.1 mg/L	Sand & Gravel	169			11		
				Sandstone	210			13		
				Carbonate	160		1	5		
	Solids, Total Dissolved	SMCL	500 mg/L	Sand & Gravel	û	û	û	û	û	û
				Sandstone	û	û	û	û	û	û
				Carbonate	û	û	û	û	û	û

Chemical Group	Chemical	Standard Type	Standard	Major Aquifer	PWS Systems					
					Raw Water			Treated Water		
					Total # PWSs	Watch List >50 % - MCL	Impaired > MCL	Total # PWSs	Watch List > 50 % - MCL	Impaired > MCL
	Sulfate	SMCL	500 mg/L	Sand & Gravel	185	12	14	23	5	1
				Sandstone	217	12	12	13		1
				Carbonate	176	24	82	12	3	4
	Thallium	MCL	2 µg/L	Sand & Gravel	191	2	1	688	12	
				Sandstone	218		1	652	4	
				Carbonate	173			453	2	
	Zinc	SMCL	5.0 mg/L	Sand & Gravel	73			14		
				Sandstone	80			13		
				Carbonate	56			5		
Volatile Organic Chemicals	1,2-Dichloroethane	MCL	5 µg/L	Sand & Gravel	220			708		
				Sandstone	244			686		
				Carbonate	191			478		
	1,1-Dichloroethylene	MCL	7 µg/L	Sand & Gravel	220			708		
				Sandstone	244		1	686		
				Carbonate	191			478		
	1,2-Dichloropropane	MCL	5 µg/L	Sand & Gravel	222			708	1	
				Sandstone	244			686		
				Carbonate	191			478		
	Benzene	MCL	5 µg/L	Sand & Gravel	221	1		708		
				Sandstone	244			686		
				Carbonate	190			478		
	Carbon Tetrachloride	MCL	5 µg/L	Sand & Gravel	222			708		
				Sandstone	244		1	686		
				Carbonate	191			478		
	Cis-1,2-Dichloroethylene	MCL	70 µg/L	Sand & Gravel	222			708		
				Sandstone	244			686		
				Carbonate	191			478		

Chemical Group	Chemical	Standard Type	Standard	Major Aquifer	PWS Systems					
					Raw Water			Treated Water		
					Total # PWSs	Watch List >50 % - MCL	Impaired > MCL	Total # PWSs	Watch List > 50 % - MCL	Impaired > MCL
	Dichloromethane	MCL	5 µg/L	Sand & Gravel	220	2		709		1
				Sandstone	241	1		685		1
				Carbonate	190			475	2	
	Pentachlorophenol	MCL	1 µg/L	Sand & Gravel	3			94		
				Sandstone	û	û	û	37		
				Carbonate	1			20		
	Polychlorinated Biphenyls (PCB)	MCL	1 µg/L	Sand & Gravel	4			93		
				Sandstone	û	û	û	35		
				Carbonate	û	û	û	18	1	
	Styrene	MCL	0.1 mg/L	Sand & Gravel	222			708		
				Sandstone	244			686		
				Carbonate	191			478		
	Tetra-chloroethylene	MCL	5 µg/L	Sand & Gravel	222	1		708		
				Sandstone	244		1	686		1
				Carbonate	191			478		
	Trichloroethylene	MCL	5 µg/L	Sand & Gravel	222	1		708		
				Sandstone	244		1	686	1	
				Carbonate	190	1		478		
	Vinyl Chloride	MCL	2 µg/L	Sand & Gravel	222	4	1	708	1	1
				Sandstone	244			686		
				Carbonate	191			478		
Pesticides	Alachor	MCL	2 µg/L	Sand & Gravel	196			671		
				Sandstone	223			628		
				Carbonate	172			447		
	Atrazine	MCL	3 µg/L	Sand & Gravel	195			671		
				Sandstone	223			628		
				Carbonate	172			447		

Chemical Group	Chemical	Standard Type	Standard	Major Aquifer	PWS Systems					
					Raw Water			Treated Water		
					Total # PWSs	Watch List >50 % - MCL	Impaired > MCL	Total # PWSs	Watch List > 50 % - MCL	Impaired > MCL
	Simazine	MCL	4 µg/L	Sand & Gravel	195			671		
				Sandstone	223			628		
				Carbonate	172			447		
Radiological	Gross Alpha	MCL	15 pCi/L	Sand & Gravel	184			343		
				Sandstone	207	4		219		
				Carbonate	161	10	3	172		
	Gross Beta	MCL	4 mrem/yr**	Sand & Gravel	126			20	1	
				Sandstone	143			12		
				Carbonate	113			7		
	Radium 226	MCL	5 pCi/L ***	Sand & Gravel	12			4	1	
				Sandstone	13	1		12	1	
				Carbonate	30	6	1	19		
	Radium 228	MCL	5 pCi/L ***	Sand & Gravel	83			329		
				Sandstone	86	1		238	1	
				Carbonate	79	2		164		

û Indicates no data available
Blank spaces indicate no PWSs exceed the standards (zeros left out to highlight impacted PWSs).
* Numbers for nitrate and nitrite are based on maximum values to reflect the acute nature of contaminant
** If Gross Beta result is less than 50 pCi/L no conversion to mrem/yr is necessary - table used 50 pCi/L as standard.
*** MCL is for combined Radium 226 and Radium 228

Iron and manganese, with similar oxidation-reduction solubility controls as arsenic, also exhibit elevated numbers of PWSs in the watch list and impaired category of Table N-4A. These numbers are controlled by the increased solubility of iron and manganese in reduced waters. The deeper wells generally exhibit more reduced conditions (e.g., reduced interaction with the atmosphere) and consequently higher concentrations of iron and manganese. Iron and manganese have secondary MCLs and consequently not as many PWSs have collected data for these parameters. For manganese, it appears that the carbonate aquifer is least likely to exhibit concentrations above the SMCL. Because of treatment to remove iron, manganese and arsenic, the percentage of PWSs that exhibit impairments in raw water is significantly higher than in treated water.

Sulfate also has an SMCL and consequently less data exists for identifying water quality impacts. Nevertheless, a significant number of PWSs exhibit elevated sulfate concentrations. The carbonate aquifers exhibit the highest number of PWSs on the watch list and in the impaired category due to the presence of evaporates in the Salina Formation in northwest Ohio.

For **nitrate and nitrite,** the maximum values were used rather than average values to reflect the acute nature of the nitrogen MCLs. As a parameter that is stable in oxidized environments, nitrate is more likely to be present in shallower wells. Approximately five percent (243 PWS) have average concentrations of nitrate at 50 percent of the MCL or higher. Over 50 percent of these PWSs are located in sand and gravel aquifer settings. Fifty-one PWSs exceed the nitrate MCL and have been required to treat the source water or abandon the well. One PWS showed maximum nitrite (NO_2) values exceeding the MCL in treated water.

Organic Parameters – For the organic parameters, the mean concentration of treated water for only three parameters, **dichloromethane, tetrachloroethylene, and trichloroethylene,** have placed PWSs in the impaired category. These three parameters are common solvents and are in the top ten contaminants detected in PWSs as documented in the 2006 305(b) Ground Water Quality Report. **Dichloromethane** (methylene chloride) is a known lab contaminant but it is also possible that it can leach to ground water before it volatilizes, so it is included in Table N-4A. It should be noted there are 15 PWSs not using a production well or treating for volatile organic chemicals due to ground water contamination that are not identified in this analysis. It is somewhat reflected in the raw water sampling but these PWSs may be considered “impaired” if they did not treat to remove the contamination.

Pesticides - There is little evidence for ground water impairment by pesticides. As part of cooperative agreements with U.S. EPA, ODA’s Pesticide & Fertilizer Regulation Section completes an annual ground water sampling program in areas identified as sensitive to pesticide contamination. Samples are analyzed for a broad array of pesticide parent and degradation compounds. The focus of the 2009 sampling was a karst area in NE Seneca County in an area of intensive row crops and sensitive aquifers. The 2009 ODA results with no pesticide detections are consistent with Table N-4A.

Radiological Parameters – No PWSs are included listed in the impaired category for treated water due to radiological parameters, although several are included in the watch list. This is consistent with the Ohio’s geologic setting having few natural sources of radioactive nuclides. The exception are low concentrations of potassium in glacial tills, uranium associated with reduced geologic settings like the Ohio shale and coal deposits, and scattered thorium rich detrital grains in sandstones. Gross beta compliance monitoring focuses on anthropogenic sources of radiation.

Ambient Ground Water Quality Monitoring Data

Mean values were calculated from the AGWQMP data (raw water) over the past ten years to determine the number of wells in the watch list and impaired categories. The number of wells in the watch list and impaired categories are listed in Table N-4A by parameter and major aquifer for raw water. The number of wells with data used in the determinations is also presented to provide the relative number of wells that exhibit ground water quality with elevated concentrations of MCL parameters. A limited number of AGWMP wells require listing because of MCL exceedances, as was the case for the PWS compliance data.

Inorganic Parameters – The AGWQMP data does not collect data for **antimony, asbestos, beryllium, mercury, nitrite, silver, and thallium** so no comparison can be made to the PWS data. These parameters are not included in the AGWQMP analysis template due to their low concentrations in Ohio ground water. No wells have means that exceed the MCL or SMCL for **chromium, cyanide, fluoride, selenium, and zinc.** Several wells exceed 50 percent of the fluoride MCL. Most of these wells are producing water from the carbonate aquifer as was seen with PWSs in Table N-4A. A few AGWQMP well means are greater than 50 percent of the **barium** MCL but no impairments were identified. **Cadmium and chloride** have a few wells with averages that exceed the MCL or SMCL. Seventeen wells have chloride concentrations above 50 percent of the SMCL with the majority of these wells in extracting water from sand and gravel aquifers. The source of contamination is possibly due to use of salt for road deicing.

For **nitrate**, the maximum values were used rather than average values in order to reflect the acute nature of the nitrate MCL. Nitrate is stable in oxidized environments and is more likely to be detected in shallower wells that are in closer contact with the atmosphere. In the AGWQMP, the sand and gravel wells are generally the shallowest and consequently would be expected to exhibit the largest number of wells with maximum nitrate concentrations that exceed the nitrate MCL. This is the case with about 5 percent of the sand and gravel well exceeding 50 percent of the MCL. Only 1 percent of the carbonate wells are on the watch list and no sandstone wells are on the watch list. The AGWQMP tends to collect samples from higher production wells located deeper in the aquifer; consequently, it is not the best program to evaluate ground water quality in shallow (e.g. 10 to 50 feet), sensitive aquifer settings.

Arsenic, iron, manganese, total dissolved solids (TDS), and sulfate mean concentrations result in significant numbers of wells on the watch list and in the impaired category. These are the same parameters identified in the PWS compliance data with the addition of TDS. TDS is not required or collected for PWSs compliance data. Except for arsenic, all of these parameters have SMCLs so treatment is not required. However, iron and manganese treatment is required for community public water systems. Many PWSs remove iron with the additional benefit of manganese and arsenic removal due to similar geochemical controls of solubility. Sulfate in the AGWQMP is elevated in the carbonate aquifer due primarily to the presence of evaporates in the Salina Formation. The elevated TDS concentrations in raw water result from the long residence time for ground water that allows for dissolution of natural materials. Almost all the wells in carbonate aquifers, but only 30-35 percent of the wells in the sand and gravel and sandstone aquifers, exceed the SMCL for TDS. This is consistent with the high solubility of carbonate rocks and with the water quality data listed in Table 4 of the 2008 305(b) Report – Ohio's Ground Water Quality.

Organic Parameters – Detection of organic parameters at and above watch list concentrations is not common. Organic parameters detected at concentrations above the MCL include **carbon**

tetrachloride, dichloromethane (also a common lab contaminant), **tetrachloroethylene, trichloroethylene, and vinyl chloride**. These organic solvents were all detected in PWSs as listed in Table N-4A.

Pesticides – No pesticides were detected in the AGWQMP wells at concentrations above 50 percent of the MCL. The AGWQMP does not analyze for pesticides on a regular basis due to the lack of pesticide detections during several sampling rounds in the late 1990's. This sampling and consultations with the Ohio Department of Agriculture regarding their pesticide sampling results, lead to the decision that further pesticide data collection was not cost effective for the AGWQMP.

Radiological Parameters – Radiological parameters are not included in the AGWQMP Template for analysis.

Comparison of PWS and AGWQMP Data - Overall, we see similar trends in the PWS compliance data and the AGWQMP data. This confirms that the AGWQMP data are appropriate for identifying long-term trends in ground water quality of the major aquifers utilized by the PWSs. Thus, the AGWQMP goal of monitoring the ground water quality utilized by PWSs in Ohio is validated by these empirical data.

It is interesting to note that the ground water quality differences documented between the major aquifers in previous 305(b) reports (2008 305(b) Report, Table 4) are not obvious in Tables N-4A and N-4B. The major elements or components (Ca, Mg, Cl, Na, K, sulfate, and alkalinity) are generally the parameters utilized to identify water types. However, most of these parameters do not have MCLs. So MCL, and to a lesser extent SMCL, comparisons are limited in their capacity to delineate geochemical differences among aquifers.

Chloride and sulfate do have SMCLs and exhibit some significant differences between the major aquifers as noted above. The most recognizable geochemical differences between the major aquifers in Ohio relate to the concentrations of calcium, magnesium, bicarbonate, and strontium. These differences relate to the higher solubility of carbonate rocks and the long water-rock reaction time of ground water. The carbonate waters are characterized by elevated calcium, manganese, bicarbonate, and strontium compared to water in sandstone and sand and gravel aquifers. The higher percentages of PWSs that exhibit watch list and impaired category results for TDS and sulfate in the carbonate aquifers reflects the major element control of aquifer water quality. Treatment, such as softening, of PWS distributed water can help mask the differences of major aquifer water quality in treated water.

Table N-4B. Counts of wells where 1999-2009 mean values exceed 50% MCL (watch list) and 100% MCL (impaired). *Note: presented by major aquifer types.*

Chemical Group	Chemical	Standard Type	Standard	Major Aquifer	Ambient GW Quality Wells		
					Raw Water		
					Total # Wells	Watch List > 50 % - MCL	Impaired > MCL
Inorganic Parameters	Antimony	MCL	6 µg/L	Sand & Gravel	û	û	û
				Sandstone	1		
				Carbonate	û	û	û
	Arsenic	MCL	10 µg/L	Sand & Gravel	260	84	40
				Sandstone	63	8	2
				Carbonate	77	16	6
	Asbestos	MCL	7x10^{6} fibers/L	Sand & Gravel	û	û	û
				Sandstone	û	û	û
				Carbonate	û	û	û
	Barium	MCL	2 mg/L	Sand & Gravel	264	4	
				Sandstone	64	1	
				Carbonate	79		
	Beryllium	MCL	4 µg/L	Sand & Gravel	û	û	û
				Sandstone	û	û	û
				Carbonate	û	û	û
	Cadmium	MCL	5 µg/L	Sand & Gravel	232	1	1
				Sandstone	62		
				Carbonate	77		
	Chloride	SMCL	250 mg/L	Sand & Gravel	272	8	
				Sandstone	68	4	1
				Carbonate	81	3	1
	Chromium	MCL	0.1 mg/L	Sand & Gravel	254		
				Sandstone	64		
				Carbonate	79		
	Cyanide	MCL	0.2 mg/L	Sand & Gravel	77		
				Sandstone	19		
				Carbonate	28		
	Fluoride	MCL	4 mg/L	Sand & Gravel	219		
				Sandstone	57	1	
				Carbonate	68	5	
	Iron	SMCL	0.3 mg/L	Sand & Gravel	272	214	190
				Sandstone	68	51	45
				Carbonate	81	66	60
	Manganese	SMCL	0.05 mg/L	Sand & Gravel	268	223	198
				Sandstone	67	50	45
				Carbonate	80	32	12
	Mercury	MCL	2 µg/L	Sand & Gravel	6		
				Sandstone	û	û	û
				Carbonate	3		

Chemical Group	Chemical	Standard Type	Standard	Major Aquifer	Ambient GW Quality Wells Raw Water Total # Wells	Watch List > 50 % - MCL	Impaired > MCL
	Nitrate * (max values)	MCL	10 mg/L	Sand & Gravel	251	12	2
				Sandstone	63		
				Carbonate	77	1	1
	Nitrite * (max values)	MCL	1 mg/L	Sand & Gravel	û	û	û
				Sandstone	û	û	û
				Carbonate	û	û	û
	Selenium	MCL	50 µg/L	Sand & Gravel	224		
				Sandstone	60		
				Carbonate	65		
	Silver	SMCL	0.1 mg/L	Sand & Gravel	û	û	û
				Sandstone	û	û	û
				Carbonate	û	û	û
	Solids, Total Dissolved	SMCL	500 mg/L	Sand & Gravel	269	264	93
				Sandstone	66	56	18
				Carbonate	81	81	72
	Sulfate	SMCL	250 mg/L	Sand & Gravel	270	1	1
				Sandstone	68	6	2
				Carbonate	80	37	14
	Thallium	MCL	2 µg/L	Sand & Gravel	û	û	û
				Sandstone	û	û	û
				Carbonate	û	û	û
	Zinc	SMCL	5.0 mg/L	Sand & Gravel	229		
				Sandstone	61		
				Carbonate	65		
Volatile Organic Chemicals	1,2-Dichloro-ethane	MCL	5 µg/L	Sand & Gravel	827		
				Sandstone	186		
				Carbonate	270		
	1,1-Dichloro-ethylene	MCL	7 µg/L	Sand & Gravel	827		
				Sandstone	186		
				Carbonate	270		
	1,2-Dichloro-propane	MCL	5 µg/L	Sand & Gravel	827		
				Sandstone	186		
				Carbonate	270		
	Benzene	MCL	5 µg/L	Sand & Gravel	827		
				Sandstone	186		
				Carbonate	269		
	Carbon Tetrachloride	MCL	5 µg/L	Sand & Gravel	827	1	1
				Sandstone	186		
				Carbonate	270		
	Cis-1,2-Di-chloroethylene	MCL	70 µg/L	Sand & Gravel	827		
				Sandstone	186		

Chemical Group	Chemical	Standard Type	Standard	Major Aquifer	Ambient GW Quality Wells		
					Raw Water		
					Total # Wells	Watch List > 50 % - MCL	Impaired > MCL
				Carbonate	270		
	Dichloro-methane	MCL	5 µg/L	Sand & Gravel	827	3	2
				Sandstone	186		
				Carbonate	270	1	1
	Pentachloro-phenol	MCL	1 µg/L	Sand & Gravel	43		
				Sandstone	8		
				Carbonate	21		
	Polychlorinated Biphenyls (PCB)	MCL	1 µg/L	Sand & Gravel	û	û	û
				Sandstone	û	û	û
				Carbonate	û	û	û
	Styrene	MCL	0.1 mg/L	Sand & Gravel	827		
				Sandstone	186		
				Carbonate	270		
	Tetrachloro-ethylene	MCL	5 µg/L	Sand & Gravel	827	1	1
				Sandstone	186		
				Carbonate	270		
	Trichloro-ethylene	MCL	5 µg/L	Sand & Gravel	827		
				Sandstone	186		
				Carbonate	270	1	1
	Vinyl Chloride	SMCL	2 µg/L	Sand & Gravel	827	1	1
				Sandstone	186		
				Carbonate	270		
Pesticides	Alachor	MCL	2 µg/L	Sand & Gravel	15		
				Sandstone	4		
				Carbonate	4		
	Atrazine	MCL	3 µg/L	Sand & Gravel	15		
				Sandstone	4		
				Carbonate	4		
	Simazine	MCL	4 µg/L	Sand & Gravel	15		
				Sandstone	4		
				Carbonate	4		
Radiological	Gross Alpha	MCL	15 pCi/L	Sand & Gravel	û	û	û
				Sandstone	û	û	û
				Carbonate	û	û	û
	Gross Beta	MCL	4 mrem/yr	Sand & Gravel	û	û	û
				Sandstone	û	û	û
				Carbonate	û	û	û
	Radium 226	MCL	5 pCi/L **	Sand & Gravel	û	û	û
				Sandstone	û	û	û
				Carbonate	û	û	û

Chemical Group	Chemical	Standard Type	Standard	Major Aquifer	Ambient GW Quality Wells		
					Raw Water		
					Total # Wells	Watch List > 50 % - MCL	Impaired > MCL
	Radium 228	MCL	5 pCi/L **	Sand & Gravel	û	û	û
				Sandstone	û	û	û
				Carbonate	û	û	û

û Indicates no data available
Blank spaces indicate no wells exceed the standards (zeros left out to highlight impacted wells).
* Numbers for nitrate and nitrite are based on maximum values to reflect the acute nature of contaminant.
** MCL is for combined Radium 226 and Radium 228

N7. Ground Water-Surface Water Interaction

DDAGW special studies generally focus on the impacts of surface water recharge on ground water quality. However, the hydrogeologic cycle requires ground water-surface water interaction to flow in both directions. Two current special studies emphasize the potential for ground water discharge to influence surface water quality. Brief summaries of these studies are provided below.

A fluorescein dye trace study in northwest Wyandot County, Ohio, was conducted to determine ground water flow rates in the region. Dye was injected into a pool in the base of a 60 foot deep cave and was detected within days in wells, springs, and streams located up to 3 miles from the injection point. The preliminary data yield ground water flow rates to springs ranging from 48,000 – 53,000 feet per day and ground water flow rates to wells ranging from 1600-2600 feet per day. Elevated nitrate concentration of up to 16 mg/L in groundwater and surface water helped confirm the interaction between surface and ground water and the susceptibility of the local water resources to contamination from ground water recharge and discharge.

Ohio EPA, Division of Surface Water, discussed the role of ground water discharge on the western streams in the Grand River basin that have cut into sandstone bedrock. These stream segments exhibit high Ephemeroptera/Plecoptera/Trichoptera (EPT) taxa, elevated numbers of sensitive taxa, and the presence of cold water taxa, believed to be associated with elevated ground water contribution (*Biological and Water Quality Study of the Upper Grand River Watershed*, June 4, 2009; OHIO EPA Technical Report EAS/2009-6-5).

N8. Conclusions and Future Directions for Ground Water Protection

Ohio is fortunate that ground water is plentiful across the state. With the exceptions of a couple of local areas that exhibit effects of over pumping, decreasing static water levels have not been documented in extensive areas of the state. Although the quantity of ground water appears stable in Ohio, the documentation of ground water quality impacts in this document illustrate that continued protection of ground water resources is necessary. Ground water contamination can eliminate the potential use of water resources as easily as diminished quantities of ground water resources.

As documented in the previous sections, numerous sites exhibit ground water contamination from anthropogenic and natural point and nonpoint sources of pollution. The only alternative for natural sources of contamination that cause impairment of drinking water is to develop and install treatment that removes the contamination or to locate another source of water. The alternatives for managing anthropogenic sources of contamination are more numerous, with the most constructive approaches focusing on prevention of releases of the contamination that migrates to ground water. Instituting best management practices (especially for the use of fertilizers), implementing appropriate siting criteria for new waste storage and disposal sites, and improving design parameters of material storage and waste disposable facilities are proactive approaches to prevent releases of contamination to ground water. The discussion of ground water contamination sites listed in Table N-2 indicated that the contamination of ground water from landfills is associated with older sites. New design standards, improved siting criteria, and revised rules for ground water monitoring around landfills are being developed to improve ground water protection at landfills. These kind of proactive practices lead to sustainability of high quality ground water resources.

The completion of Source Water Assessment Reports for Ohio's public water systems has raised awareness of the ground water quality issues and has helped promoted source water protection planning. The complex nature of this planning identifies new issues, for instance ground water protection requirements for geothermal wells. SCCGW has just started to discuss appropriate guidance for the siting, construction and abandonment of geothermal wells as related to ground water protection.

The SWAP potential contaminant source inventory data was instrumental in identifying major sources on contamination as listed in Table N-3. Our documentation and regulation of point source (facility specific location) contamination is significantly better than documentation and regulation of nonpoint source contamination, as is the case elsewhere in the U.S. Nonpoint source contamination in combination with the SW-GW interaction is a significant threat to water quality resources. Ohio's ground water resources are reasonably well protected with widespread glaciated tills naturally protecting water supply aquifers and land drainage tiles that tend to transport agricultural contaminants more rapidly to surface waters rather than recharge deeper aquifers. Nonpoint source pollution is from surface water resources is the affecting the quality of ground water resources in sensitive areas. Ohio EPA continues to refine the determination of areas with sensitive aquifers and efforts to more effectively monitor shallow ground water resources in Ohio. Long-term efforts for protecting ground water quality need to focus protection programs in areas where aquifers are influenced by rapid recharge in shallow fractured bedrock, karst bedrock and sand and gravel aquifer settings.