GROUND WATER POLLUTION POTENTIAL OF MAHONING COUNTY, OHIO

BY

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ABSTRACT

A ground water pollution potential map of Mahoning County has been prepared using the DRASTIC mapping process. The DRASTIC system consists of two major elements: the designation of mappable units, termed hydrogeologic settings, and the superposition of a relative rating system for pollution potential.

Hydrogeologic settings form the basis of the system and incorporate the major hydrogeologic factors that affect and control ground water movement and occurrence including depth to water, net recharge, aquifer media, soil media, topography, impact of the vadose zone media, and hydraulic conductivity of the aquifer. These factors, which form the acronym DRASTIC, are incorporated into a relative ranking scheme that uses a combination of weights and ratings to produce a numerical value called the ground water pollution potential index. Hydrogeologic settings are combined with the pollution potential indexes to create units that can be graphically displayed on a map.

Ground water pollution potential analysis in Mahoning County resulted in a map with symbols and colors that illustrate areas of varying ground water contamination vulnerability. Eight hydrogeologic settings were identified in Mahoning County with computed ground water pollution potential indexes ranging from 76 to 168.

Mahoning County lies within the Glaciated Central hydrogeologic setting. Varying thicknesses of glacial till overlies Mahoning County. The county is crossed by numerous, primarily north-south trending, buried valleys. The buried valleys are variable. Some contain appreciable thicknesses of outwash sand and gravel, others are predominantly filled with fine-grained glacial till. Outside of the buried valleys, aquifers within glacial deposits are limited to thin lenses interbedded in glacial till. Yields from the unconsolidated aquifers typically average 10 to 25 gallons per minute (gpm) with yields over 100 gpm possible in select areas. Interbedded sandstones, shales, siltstones, limestones, and coals of the Pennsylvanian System or shales and sandstones of the Mississippian System comprise the aquifer in the majority of the county. Consolidated units are moderate to poor aquifers with typical yields ranging from 3 to 25 gpm. Yields up to 100 gpm are possible from some of the sandstone intervals in the Pennsylvanian Pottsville Group.

The ground water pollution potential mapping program optimizes the use of existing data to rank areas with respect to relative vulnerability to contamination. The ground water pollution potential map of Mahoning County has been prepared to assist planners, managers, and local officials in evaluating the potential for contamination from various sources of pollution. This information can be used to help direct resources and land use activities to appropriate areas, or to assist in protection, monitoring, and clean-up efforts.

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Map preparation and review:	Michael P. Angle
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INTRODUCTION

The need for protection and management of ground water resources in Ohio has been clearly recognized. Approximately 42 percent of Ohio citizens rely on ground water for drinking and household use from both municipal and private wells. Industry and agriculture also utilize significant quantities of ground water for processing and irrigation. In Ohio, approximately 750,000 rural households depend on private wells; 12,000 of these wells exist in Mahoning County.

The characteristics of the many aquifer systems in the state make ground water highly vulnerable to contamination. Measures to protect ground water from contamination usually cost less and create less impact on ground water users than clean up of a polluted aquifer. Based on these concerns for protection of the resource, staff of the Division of Water conducted a review of various mapping strategies useful for identifying vulnerable aquifer areas. They placed particular emphasis on reviewing mapping systems that would assist in state and local protection and management programs. Based on these factors and the quantity and quality of available data on ground water resources, the DRASTIC mapping process (Aller et al., 1987) was selected for application in the program.

Considerable interest in the mapping program followed successful production of a demonstration county map and led to the inclusion of the program as a recommended initiative in the Ohio Ground Water Protection and Management Strategy (Ohio EPA, 1986). Based on this recommendation, the Ohio General Assembly funded the mapping program. A dedicated mapping unit has been established in the Division of Water, Water Resources Section to implement the ground water pollution potential mapping program on a countywide basis in Ohio.

The purpose of this report and map is to aid in the protection of our ground water resources. This protection can be enhanced by understanding and implementing the results of this study, which utilizes the DRASTIC system of evaluating an area's potential for ground water pollution. The mapping program identifies areas that are vulnerable to contamination and displays this information graphically on maps. The system was not designed or intended to replace site-specific investigations, but rather to be used as a planning and management tool. The map and report can be combined with other information to assist in prioritizing local resources and in making land use decisions.

APPLICATIONS OF POLLUTION POTENTIAL MAPS

The pollution potential mapping program offers a wide variety of applications in many counties. The ground water pollution potential map of Mahoning County has been prepared to assist planners, managers, and state and local officials in evaluating the relative vulnerability of areas to ground water contamination from various sources of pollution. This information can be used to help direct resources and land use activities to appropriate areas, or to assist in protection, monitoring, and clean-up efforts.

An important application of the pollution potential maps for many areas will be assisting in county land use planning and resource expenditures related to solid waste disposal. A county may use the map to help identify areas that are suitable for disposal activities. Once these areas have been identified, a county can collect more site-specific information and combine this with other local factors to determine site suitability.

Pollution potential maps may be applied successfully where non-point source contamination is a concern. Non-point source contamination occurs where land use activities over large areas impact water quality. Maps providing information on relative vulnerability can be used to guide the selection and implementation of appropriate best management practices in different areas. Best management practices should be chosen based upon consideration of the chemical and physical processes that occur from the practice, and the effect these processes may have in areas of moderate to high vulnerability to contamination. For example, the use of agricultural best management practices that limit the infiltration of nitrates, or promote denitrification above the water table, would be beneficial to implement in areas of relatively high vulnerability to contamination.

A pollution potential map can assist in developing ground water protection strategies. By identifying areas more vulnerable to contamination, officials can direct resources to areas where special attention or protection efforts might be warranted. This information can be utilized effectively at the local level for integration into land use decisions and as an educational tool to promote public awareness of ground water resources. Pollution potential maps may be used to prioritize ground water monitoring and/or contamination clean-up efforts. Areas that are identified as being vulnerable to contamination may benefit from increased ground water monitoring for pollutants or from additional efforts to clean up an aquifer.

Individuals in the county who are familiar with specific land use and management problems will recognize other beneficial uses of the pollution potential maps. Planning commissions and zoning boards can use these maps to help make informed decisions about the development of areas within their jurisdiction. Developers proposing projects within ground water sensitive areas may be required to show how ground water will be protected.

Regardless of the application, emphasis must be placed on the fact that the system is not designed to replace a site-specific investigation. The strength of the system lies in its ability to make a "first-cut approximation" by identifying areas that are vulnerable to contamination. Any potential applications of the system should also recognize the assumptions inherent in the system.

SUMMARY OF THE DRASTIC MAPPING PROCESS

DRASTIC was developed by the National Ground Water Association for the United States Environmental Protection Agency. This system was chosen for implementation of a ground water pollution potential mapping program in Ohio. A detailed discussion of this system can be found in Aller et al. (1987).

The DRASTIC mapping system allows the pollution potential of any area to be evaluated systematically using existing information. Vulnerability to contamination is a combination of hydrogeologic factors, anthropogenic influences, and sources of contamination in any given area. The DRASTIC system focuses only on those hydrogeologic factors that influence ground water pollution potential. The system consists of two major elements: the designation of mappable units, termed hydrogeologic settings, and the superposition of a relative rating system to determine pollution potential.

The application of DRASTIC to an area requires the recognition of a set of assumptions made in the development of the system. DRASTIC evaluates the pollution potential of an area under the assumption that a contaminant with the mobility of water is introduced at the surface and flushed into the ground water by precipitation. Most important, DRASTIC cannot be applied to areas smaller than 100 acres in size and is not intended or designed to replace site-specific investigations.

Hydrogeologic Settings and Factors

To facilitate the designation of mappable units, the DRASTIC system used the framework of an existing classification system developed by Heath (1984), which divides the United States into 15 ground water regions based on the factors in a ground water system that affect occurrence and availability.

Within each major hydrogeologic region, smaller units representing specific hydrogeologic settings are identified. Hydrogeologic settings form the basis of the system and represent a composite description of the major geologic and hydrogeologic factors that control ground water movement into, through, and out of an area. A hydrogeologic setting represents a mappable unit with common hydrogeologic characteristics and, as a consequence, common vulnerability to contamination (Aller et al., 1987).

Figure 1 illustrates the format and description of a typical hydrogeologic setting found within Mahoning County. Inherent within each hydrogeologic setting are the physical characteristics that affect the ground water pollution potential. These characteristics or factors identified during the development of the DRASTIC system include:

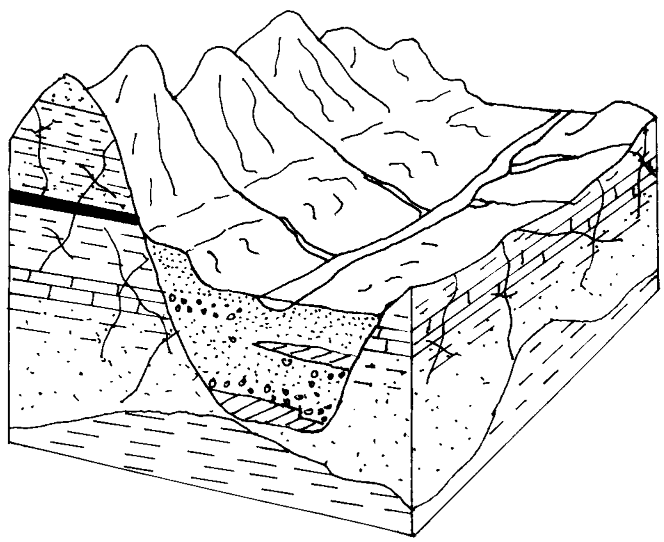
D	-	Depth to Water
R	-	Net Recharge
A	-	Aquifer Media
S	-	Soil Media
T	-	Topography
I	-	Impact of the Vadose Zone Media
C	-	Conductivity (Hydraulic) of the Aquifer

These factors incorporate concepts and mechanisms such as attenuation, retardation, and time or distance of travel of a contaminant with respect to the physical characteristics of the hydrogeologic setting. Broad consideration of these factors and mechanisms coupled with existing conditions in a setting provide a basis for determination of the area's relative vulnerability to contamination.

Depth to water is considered to be the depth from the ground surface to the water table in unconfined aquifer conditions or the depth to the top of the aquifer under confined aquifer conditions. The depth to water determines the distance a contaminant would have to travel before reaching the aquifer. The greater the distance the contaminant has to travel, the greater the opportunity for attenuation to occur or restriction of movement by relatively impermeable layers.

Net recharge is the total amount of water reaching the land surface that infiltrates the aquifer measured in inches per year. Recharge water is available to transport a contaminant from the surface into the aquifer and affects the quantity of water available for dilution and dispersion of a contaminant. Factors to be included in the determination of net recharge include contributions due to infiltration of precipitation, in addition to infiltration from rivers, streams and lakes, irrigation, and artificial recharge.

Aquifer media represents consolidated or unconsolidated rock material capable of yielding sufficient quantities of water for use. Aquifer media accounts for the various physical characteristics of the rock that provide mechanisms of attenuation, retardation, and flow pathways that affect a contaminant reaching and moving through an aquifer.



7D Buried Valley

This setting is characterized by thick deposits of sand and gravel that have been deposited in a former topographic low (usually a pre-glacial river valley) by glacial meltwater. Many of the buried valleys in Mahoning County underlie the broad, flat lying floodplains of modern rivers. The boundary between the buried valley and the adjacent bedrock upland is usually prominent. The buried valleys contain substantial thicknesses of permeable sand and gravel that serve as the aquifer. The aquifer is typically in hydraulic connection with the modern rivers. The vadose zone is typically composed of sand and gravel but significant amounts of silt and clay can be found in discrete areas. Silt loams, loams, and sandy loams are the typical soil types for this setting. Depth to water is typically less than 30 feet for areas adjacent to modern rivers, and between 30 to 50 feet for terraces that border the bedrock uplands. Recharge is generally high due to permeable soils and vadose zone materials, shallow depth to water, and the presence of surface streams.

Figure 1. Format and description of the hydrogeologic setting - 7D Buried Valley.

Soil media refers to the upper six feet of the unsaturated zone that is characterized by significant biological activity. The type of soil media influences the amount of recharge that can move through the soil column due to variations in soil permeability. Various soil types also have the ability to attenuate or retard a contaminant as it moves throughout the soil profile. Soil media is based on textural classifications of soils and considers relative thicknesses and attenuation characteristics of each profile within the soil.

Topography refers to the slope of the land expressed as percent slope. The slope of an area affects the likelihood that a contaminant will run off or be ponded and ultimately infiltrate into the subsurface. Topography also affects soil development and often can be used to help determine the direction and gradient of ground water flow under water table conditions.

The impact of the vadose zone media refers to the attenuation and retardation processes that can occur as a contaminant moves through the unsaturated zone above the aquifer. The vadose zone represents that area below the soil horizon and above the aquifer that is unsaturated or discontinuously saturated. Various attenuation, travel time, and distance mechanisms related to the types of geologic materials present can affect the movement of contaminants in the vadose zone. Where an aquifer is unconfined, the vadose zone media represents the materials below the soil horizon and above the water table. Under confined aquifer conditions, the vadose zone is simply referred to as a confining layer. The presence of the confining layer in the unsaturated zone has a significant impact on the pollution potential of the ground water in an area.

Hydraulic conductivity of an aquifer is a measure of the ability of the aquifer to transmit water, and is also related to ground water velocity and gradient. Hydraulic conductivity is dependent upon the amount and interconnectivity of void spaces and fractures within a consolidated or unconsolidated rock unit. Higher hydraulic conductivity typically corresponds to higher vulnerability to contamination. Hydraulic conductivity considers the capability for a contaminant that reaches an aquifer to be transported throughout that aquifer over time.

Weighting and Rating System

DRASTIC uses a numerical weighting and rating system that is combined with the DRASTIC factors to calculate a ground water pollution potential index or relative measure of vulnerability to contamination. The DRASTIC factors are weighted from 1 to 5 according to their relative importance to each other with regard to contamination potential (Table 1). Each factor is then divided into ranges or media types and assigned a rating from 1 to 10 based on their significance to pollution potential (Tables 2-8). The rating for each factor is selected based on available information and professional judgment. The selected rating for each factor is multiplied by the assigned weight for each factor. These numbers are summed to calculate the DRASTIC or pollution potential index.

Once a DRASTIC index has been calculated, it is possible to identify areas that are more likely to be susceptible to ground water contamination relative to other areas. The higher the DRASTIC index, the greater the vulnerability to contamination. The index generated provides only a relative evaluation tool and is not designed to produce absolute answers or to represent units of vulnerability. Pollution potential indexes of various settings should be compared to each other only with consideration of the factors that were evaluated in determining the vulnerability of the area.

Pesticide DRASTIC

A special version of DRASTIC was developed for use where the application of pesticides is a concern. The weights assigned to the DRASTIC factors were changed to reflect the processes that affect pesticide movement into the subsurface with particular emphasis on soils. Where other agricultural practices, such as the application of fertilizers, are a concern, general DRASTIC should be used to evaluate relative vulnerability to contamination. The process for calculating the Pesticide DRASTIC index is identical to the process used for calculating the general DRASTIC index. However, general DRASTIC and Pesticide DRASTIC numbers should not be compared because the conceptual basis in factor weighting and evaluation differs significantly. Table 1 lists the weights used for general and pesticide DRASTIC.

Table 1. Assigned weights for DRASTIC features

Feature	**General DRASTIC Weight**	**Pesticide DRASTIC Weight**
Depth to Water	5	5
Net Recharge	4	4
Aquifer Media	3	3
Soil Media	2	5
Topography	1	3
Impact of the Vadose Zone Media	5	4
Hydraulic Conductivity of the Aquifer	3	2

Table 2. Ranges and ratings for depth to water

Depth to Water (feet)	
Range	**Rating**
0-5	10
5-15	9
15-30	7
30-50	5
50-75	3
75-100	2
100+	1
Weight: 5	Pesticide Weight: 5

Table 3. Ranges and ratings for net recharge

Net Recharge (inches)	
Range	**Rating**
0-2	1
2-4	3
4-7	6
7-10	8
10+	9
Weight: 4	Pesticide Weight: 4

Table 4. Ranges and ratings for aquifer media

Aquifer Media		
Range	**Rating**	**Typical Rating**
Shale	1-3	2
Glacial Till	4-6	5
Sandstone	4-9	6
Limestone	4-9	6
Sand and Gravel	4-9	8
Interbedded Ss/Sh/Ls/Coal	2-10	9
Karst Limestone	9-10	10
Weight: 3	Pesticide Weight: 3	

Table 5. Ranges and ratings for soil media

Soil Media	
Range	**Rating**
Thin or Absent	10
Gravel	10
Sand	9
Peat	8
Shrink/Swell Clay	7
Sandy Loam	6
Loam	5
Silty Loam	4
Clay Loam	3
Muck	2
Clay	1
Weight: 2	Pesticide Weight: 5

Table 6. Ranges and ratings for topography

Topography (percent slope)	
Range	**Rating**
0-2	10
2-6	9
6-12	5
12-18	3
18+	1
Weight: 1	Pesticide Weight: 3

Table 7. Ranges and ratings for impact of the vadose zone media

Impact of the Vadose Zone Media		
Range	**Rating**	**Typical Rating**
Confining Layer	1	1
Silt/Clay	2-6	3
Shale	2-5	3
Limestone	2-7	6
Sandstone	4-8	6
Interbedded Ss/Sh/Ls/Coal	4-8	6
Sand and Gravel with Silt and Clay	4-8	6
Glacial Till	2-6	4
Sand and Gravel	6-9	8
Karst Limestone	8-10	10
Weight: 5	Pesticide Weight: 4	

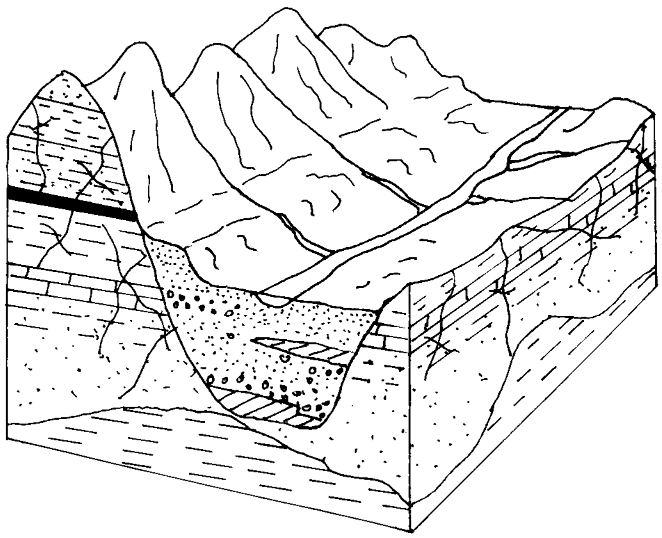
Table 8. Ranges and ratings for hydraulic conductivity

Hydraulic Conductivity (GPD/FT^2)	
Range	**Rating**
1-100	1
100-300	2
300-700	4
700-1000	6
1000-2000	8
2000+	10
Weight: 3	Pesticide Weight: 2

Integration of Hydrogeologic Settings and DRASTIC Factors

Figure 2 illustrates the hydrogeologic setting 7D1, Buried Valley, identified in mapping Mahoning County, and the pollution potential index calculated for the setting. Based on selected ratings for this setting, the pollution potential index is calculated to be 149. This numerical value has no intrinsic meaning, but can be readily compared to a value obtained for other settings in the county. DRASTIC indexes for typical hydrogeologic settings and values across the United States range from 45 to 223. The diversity of hydrogeologic conditions in Mahoning County produces settings with a wide range of vulnerability to ground water contamination. Calculated pollution potential indexes for the eight settings identified in the county range from 76 to 168.

Hydrogeologic settings identified in an area are combined with the pollution potential indexes to create units that can be graphically displayed on maps. Pollution potential analysis in Mahoning County resulted in a map with symbols and colors that illustrate areas of ground water vulnerability. The map describing the ground water pollution potential of Mahoning County is included with this report.



SETTING 7D1		GENERAL		
FEATURE	**RANGE**	**WEIGHT**	**RATING**	**NUMBER**
Depth to Water	15-30	5	7	35
Net Recharge	7-10	4	8	32
Aquifer Media	Sand & Gravel	3	7	21
Soil Media	Silt Loam	2	4	8
Topography	0-2%	1	10	10
Impact of Vadose Zone	Silt/Clay	5	5	25
Hydraulic Conductivity	700-1000	3	6	18
		DRASTIC	INDEX	149

Figure 2. Description of the hydrogeologic setting - 7D1 Buried Valley.

INTERPRETATION AND USE OF GROUND WATER POLLUTION POTENTIAL MAPS

The application of the DRASTIC system to evaluate an area's vulnerability to contamination produces hydrogeologic settings with corresponding pollution potential indexes. The higher the pollution potential index, the greater the susceptibility to contamination. This numeric value determined for one area can be compared to the pollution potential index calculated for another area.

The map accompanying this report displays both the hydrogeologic settings identified in the county and the associated pollution potential indexes calculated in those hydrogeologic settings. The symbols on the map represent the following information:

7D1 - defines the hydrogeologic region and setting

149 - defines the relative pollution potential

Here the first number (**7**) refers to the major hydrogeologic region and the upper case letter (**D**) refers to a specific hydrogeologic setting. The following number (**1**) references a certain set of DRASTIC parameters that are unique to this setting and are described in the corresponding setting chart. The number below the hydrogeologic setting (**149**) is the calculated pollution potential index for this unique setting. The charts for each setting provide a reference to show how the pollution potential index was derived.

The maps are color-coded using ranges depicted on the map legend. The color codes used are part of a national color-coding scheme developed to assist the user in gaining a general insight into the vulnerability of the ground water in the area. The color codes were chosen to represent the colors of the spectrum, with warm colors (red, orange, and yellow) representing areas of higher vulnerability (higher pollution potential indexes), and cool colors (greens, blues, and violet) representing areas of lower vulnerability to contamination. Large man-made features such as landfills, quarries, or strip mines have also been marked on the map for reference.

GENERAL INFORMATION ABOUT MAHONING COUNTY

Demographics

Mahoning County occupies approximately 419 square miles in northeastern Ohio (Figure 3). Mahoning County is bounded to the north by Trumbull County, to the west by Portage County, to the southwest by Stark County, to the south by Columbiana County, and to the east by Lawrence County and Mercer County, Pennsylvania.

The approximate population of Mahoning County, according to 2000 figures, is 263,884 (Ohio Department of Development, personal communication). Youngstown is the county seat and largest city and has an estimated population of 91,775 (Ohio Department of Development, personal communication). Roughly 40 percent of the county's land area is used for agricultural purposes. About 30 percent of the county is forested. The remaining 30 percent of the land area is used for urban, industrial, and residential purposes, strip mines, and reservoirs. These figures are based upon 1985 estimates obtained from the ODNR, Division of Real Estate and Land Management (REALM), Resource Analysis Program (formerly OCAP). More specific information may be obtained by contacting REALM.

Climate

The weather station at Canfield reports a mean annual temperature of 48.8 degrees Fahrenheit for a thirty-year (1961-1990) average (Owenby and Ezell, 1992). According to Harstine (1991), the average temperature is relatively constant across the county with a slight temperature increase to the west and south. Mahoning County is located in a region that is typically one of the coolest regions in Ohio. Mahoning County is too far removed from Lake Erie to receive any of the lake effect warmth. Higher elevations and many days of cloud cover may also account for these low average temperatures. The average annual precipitation recorded at the Canfield weather station is 35.97 inches based on the same thirty-year (1961-1990) period (Owenby and Ezell, 1992). Harstine (1991) shows that Mahoning County sits in an area of lower precipitation. The county is just to the south of the major band of high precipitation (i.e. "the snowbelt") that occupies much of Geauga County and northern Trumbull County.

Physiography and Topography

Mahoning County lies within the Glaciated Allegheny Plateau section of the Appalachian province (Frost, 1931 and Thornbury, 1965). According to Fenneman (1938), Mahoning County lies within the Southern New York Section of the Appalachian Plateau

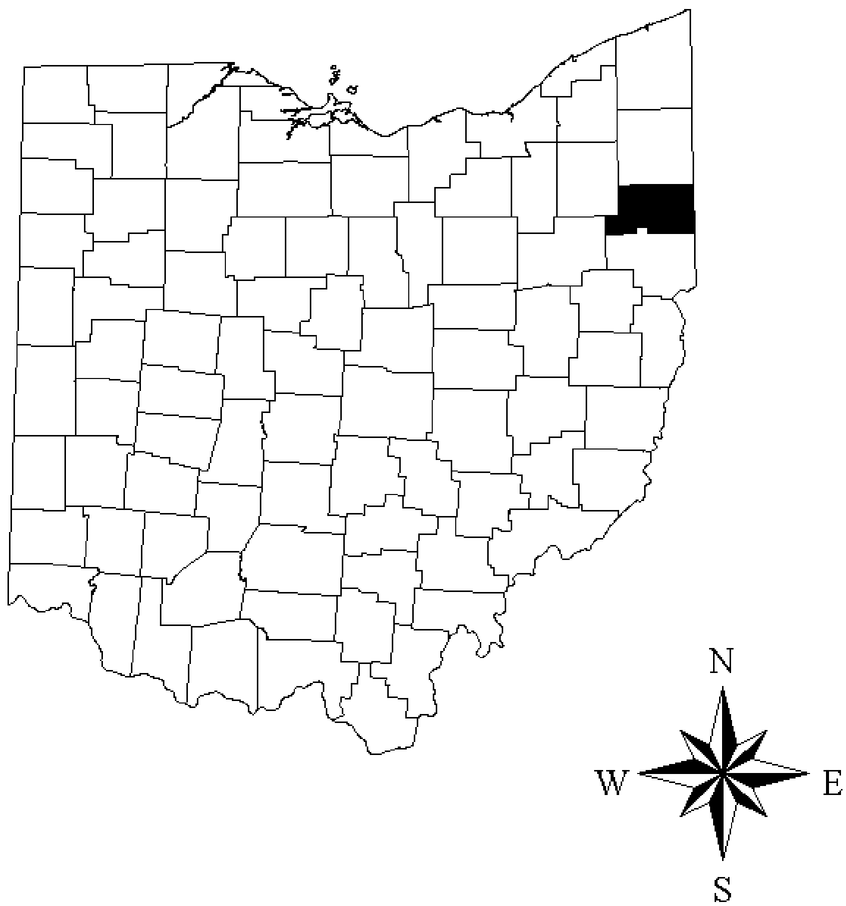


Figure 3. Location of Mahoning County, Ohio.

province. The glacial boundary lies roughly ten miles to the south of Mahoning County in Columbiana County. The highest elevation in the county is approximately 1,320 feet in Green Township and the lowest elevation is about 795 feet where the Mahoning River enters Pennsylvania south of Lowellville. The maximum relief throughout the county is over 500 feet. The greatest local relief is the roughly 300 to 350 feet along the valley walls of the Mahoning River southeast of Lowellville.

The western portion of the county has the lowest relief and is characterized by relatively flat to gently rolling topography. Relief increases and the topography becomes much steeper and more rugged in eastern Mahoning County. In western Mahoning County, end moraines and stream dissection control the rolling or hummocky nature of the topography. In eastern Mahoning County, the topography of the upland areas is bedrock-controlled. Eastern and central Mahoning County is characterized by numerous steep, circular to elongate ridges composed of resistant sandstone bedrock of the Pennsylvanian System. The common (accordant) elevations of many of these ridges are believed to be due to the resistance of common bedrock lithologies (Totten and White, 1987).

Modern Drainage

All of Mahoning County eventually drains into the Ohio River watershed. Figure 4 (Cummins, 1950) depicts the modern drainage pattern of Mahoning County. The Mahoning River roughly encircles the county and is the primary drainage for the majority of the county. The Mahoning River originates in northwestern Columbiana County and flows to the northwest, toward Alliance. The Mahoning River cuts across the southwestern corner of Smith Township and enters Stark County. Near Alliance, the river flows northeastward into Portage County. Damming the Mahoning River near the boundary between Portage County and Mahoning County created Berlin Reservoir. The course of the Mahoning River continues due north into Trumbull County. Lake Milton was constructed by damming the Mahoning River near the boundary between Trumbull County and Mahoning County. The Mahoning River continues north into central Trumbull County. North of Warren, near the divide between the Ohio River Basin and the Lake Erie Basin, the Mahoning River turns abruptly to the southeast. The Mahoning River re-enters Mahoning County near Youngstown and eventually enters Pennsylvania southeast of Lowellville.

Several important tributaries of the Mahoning River drain much of northern and central Mahoning County. There are two major streams named Mill Creek that empty into the Mahoning River. Mill Creek (west) originates in Goshen Township and flows northwest into Berlin Reservoir near the Portage County line. The source of Mill Creek (east) is south of the town of Columbiana. This tributary flows north, joining the Mahoning River in Youngstown. Meander Creek begins southwest of Canfield and flows due north. This stream is dammed in southern Trumbull County to form Meander Creek Reservoir. Meander Creek empties into the Mahoning River near Niles in Trumbull County. The headwaters of Yellow Creek are in Columbiana County. This stream flows north and is dammed in three places, forming Pine Lake, Evans Lake, and Lake Hamilton. Yellow Creek joins the Mahoning River in Youngstown. The source of Crab Creek is in Trumbull County. This southerly-flowing stream joins the Mahoning River in Youngstown. Dry Run originates in

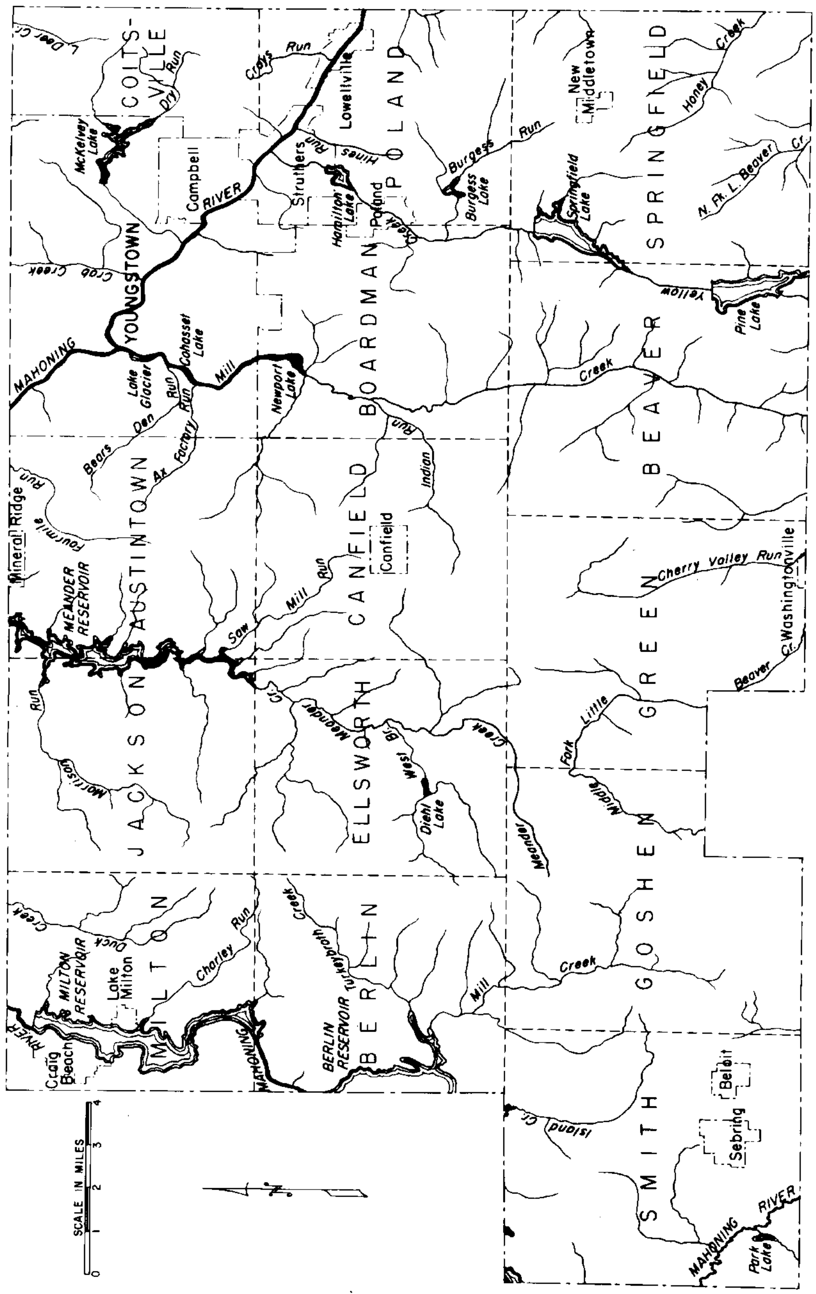


Figure 4. Map showing present drainage pattern in Mahoning County (after Cummins, 1950).

eastern Coitsville Township and flows due west where it is dammed to create McKelvey Lake. This tributary bends to the southwest and empties into the Mahoning River near Youngstown.

South-central and southeastern Mahoning County is part of the Little Beaver Creek watershed. Middle Fork Little Beaver Creek originates west of Salem and flows north then east, roughly encircling the city. This stream bends to the south, entering Columbiana County near Washingtonville. From its source area in northern Green Township, Cherry Valley flows south joining Middle Fork Little Beaver Creek in Washingtonville. The headwaters of East Branch Middle Fork Little Beaver Creek lie just to the east of Cherry Valley in Green Township. This tributary also flows southward into Columbiana County. North Fork Little Beaver Creek and its major tributary, Honey Creek, drain the southeastern corner of Mahoning County. Both streams flow southeastward, joining in Lawrence County, Pennsylvania. Northeastern Coitsville Township is drained by Little Deer Creek. This stream flows to the northwest and empties into the Shenango River near Sharon, Pennsylvania.

Pre- and Inter-Glacial Drainage and Topography

Stout and Lamborn (1924), Stephenson (1933), Stout et al. (1943), Cummins (1950), and Totten and White (1987) provide accounts of the pre-glacial and inter-glacial drainage and drainage changes in Mahoning County and adjacent areas. Drainage changes occurring over time in Mahoning County are numerous and complex and are still not totally understood. It is important to note that entire drainage systems, including tributaries, have changed and these various systems have been superimposed (overlapped) over time.

Stout et al. (1943) proposed that a northeasterly-flowing tributary of the Pittsburgh River drained the majority of Mahoning County (Figure 5). The Pittsburgh River flowed roughly northward from Pittsburgh and was the master stream draining this area (Stout et al., 1943 and Totten and White, 1987). Stout et al. (1943) also proposed that the Ravenna River drained the western margin of Mahoning County. The Ravenna River flowed northwestward through Portage County and Geauga County. Stout et al. (1943) speculated that these drainages, although not physically connected, were roughly time equivalent of the Teays River drainage system in south-central and western Ohio.

Previously, Stout and Lamborn (1924) and Stephenson (1933) had provided an alternative interpretation of the pre-glacial drainage of the area. These reports referred to the master stream draining this region as the ancestral Monongahela River. The ancestral Monongahela River flowed northward, approximately followed the course of the present Beaver River and Shenango River through western Pennsylvania (Stephenson, 1933). At Sharon Pennsylvania, the ancestral Monongahela River turned sharply to the southwest, flowing towards Hubbard. This stream cut the broad valley presently occupied by Crab Creek (Stephenson, 1933). Where modern Crab Creek valley joins the Mahoning River valley, the ancestral Monongahela River turned to the northwest, roughly following the course of the present Mahoning River (Stout and Lamborn, 1924 and Stephenson, 1933).

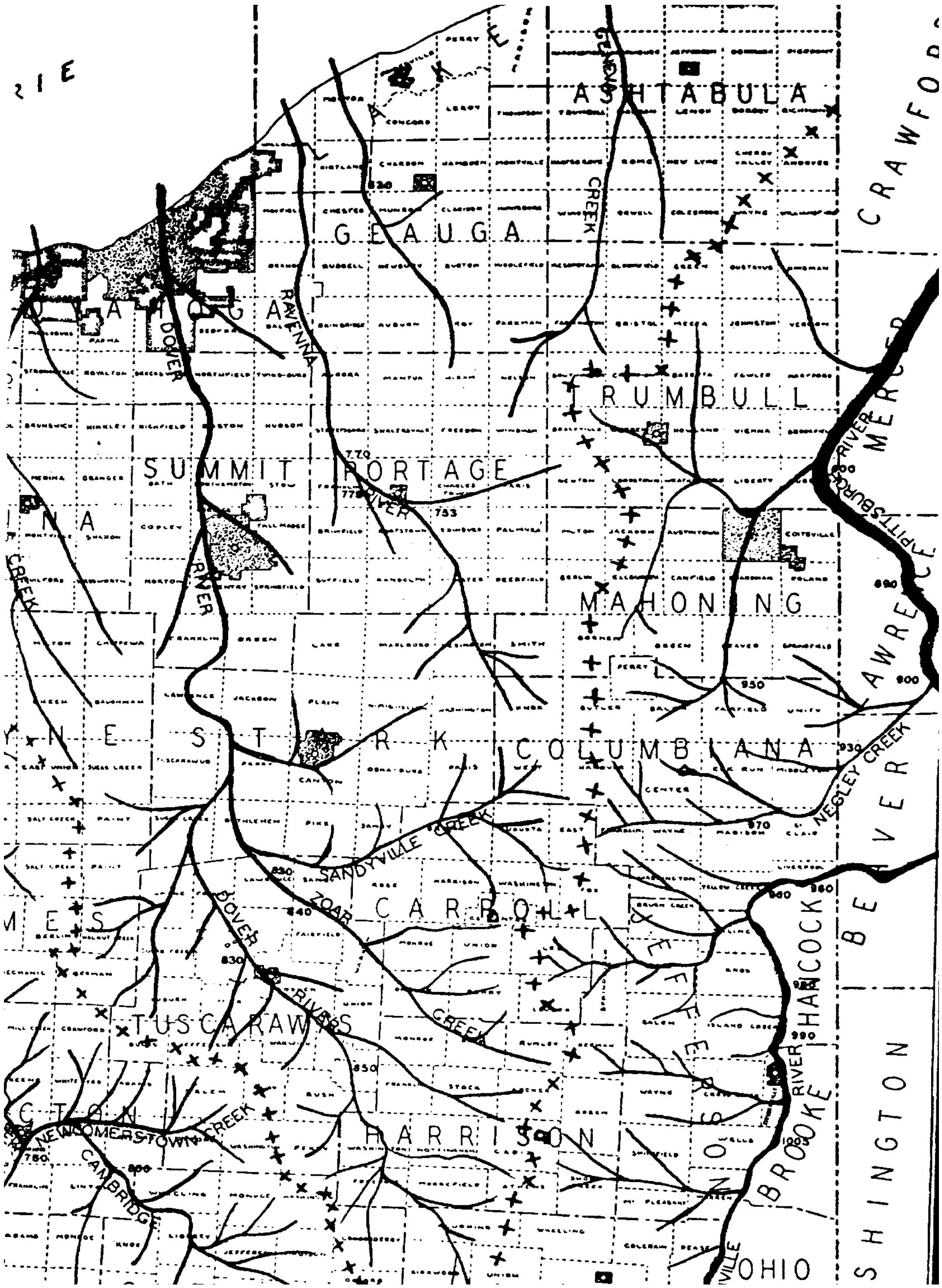


Figure 5. Pre-glacial (Teays Stage) drainage in Northeast Ohio (after Stout et al., 1943). The line of x's indicate the drainage divide.

The ancestral Monongahela River continued to flow north past Warren and eventually merged with the northerly-flowing, ancestral Grand River drainage system (Stephenson, 1933). The ancestral Monongahela River drainage system included many primarily northerly-flowing tributaries that drained Mahoning County.

As ice advanced through Ohio, the ancestral Monongahela drainage system was blocked. Flow backed up the main trunk valley as well as in many of the tributaries, forming several large lakes. Eventually spillways were created for these lakes, new stream channels were downcut, and new drainage systems evolved (Stout and Lamborn, 1924, Stephenson, 1933 and Cummins, 1950). This downcutting was believed to be relatively rapid and in many places the new channels were cut over 70 feet deeper than the pre-glacial valleys (Stout and Lamborn, 1924, Stephenson, 1933, and Cummins, 1950). This new drainage system is referred to as the Deep Stage due to this increased downcutting. In Mahoning County many of the Deep Stage channels closely followed the previously existing drainage ways. Regionally, a southerly-flowing system evolved with drainage toward the ancestral Ohio River. Many of the pre-existing valleys were filled or "buried" by thick sequences of glacial drift. Figure 6 (Cummins, 1950) depicts the location of the major buried valleys in Mahoning County. The drift created a new series of drainage divides. Drainage changes persisted throughout the later Illinoian and Wisconsinan ice advances.

Examples of the buried valleys include a deep, broad valley extending northward from Damascus and underlying present Mill Creek (west). This valley continues to the north, passing just east of Berlin Reservoir and underlying Lake Milton. A major buried valley underlies the Mahoning River in southwestern Smith Township. A tributary buried valley originating near Sebring and Beloit joins this trunk valley near Alliance. Underlying the Middle Fork Little Beaver Creek east of Salem and New Albany is a relatively deep buried valley that extends to the north, underlying Meander Creek and Meander Creek Reservoir. From Youngstown to Columbiana, a broad buried valley underlies Mill Creek (east). Smaller tributary valleys originate near the source of both modern Cherry Valley and East Branch Middle Fork Little Beaver Creek. These two valleys merge to create a deep valley that joins the master valley underlying Mill Creek (east) southeast of Canfield. A somewhat shallower buried valley underlies present Yellow Creek between Evans Lake and Youngstown. Finally, a deep, broad valley, which contained the ancestral Monongahela River, underlies modern Crab Creek.

The pre-glacial topography of Mahoning County was probably somewhat steeper and more rugged than the modern topography (Stout and Lamborn, 1924, Stephenson, 1933, and Cummins, 1950). The maximum relief and average local relief were also believed to be greater. Topography was controlled by resistant sandstone bedrock. Glaciation had the net effect of filling in valleys and smoothing-out the topography.

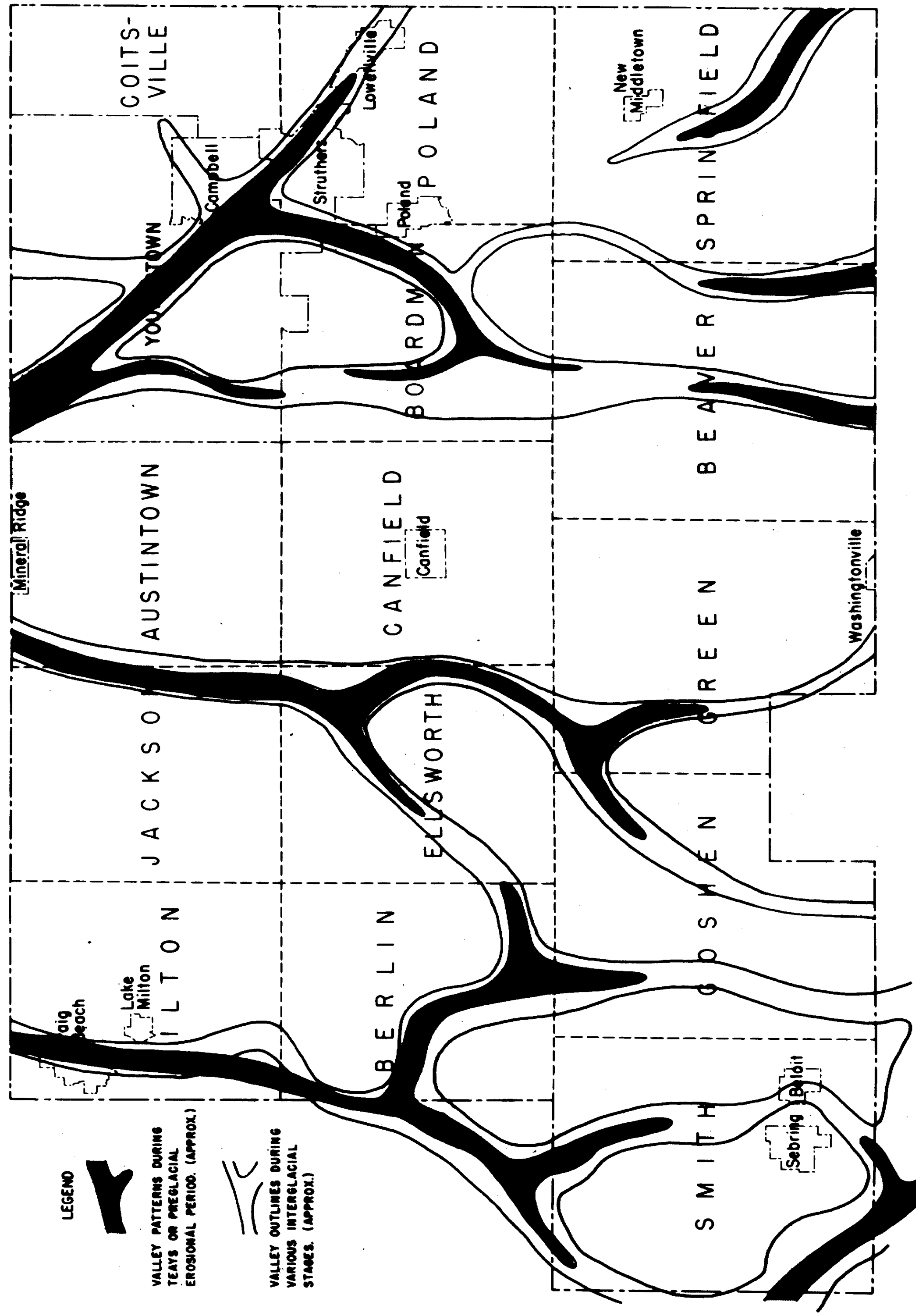


Figure 6. Approximate outlines of pre-glacial and inter-glacial buried valleys in Mahoning County, Ohio (after Cummins, 1950).

Glacial Geology

During the Pleistocene Epoch (2 million to 10,000 years before present (Y.B.P.)) several episodes of ice advance occurred in northeastern Ohio. Table 9 summarizes the Pleistocene deposits found in Mahoning County. Older ice advances that predate the most recent (Brunhes) magnetic reversal (about 730,000 Y.B.P.) are now commonly referred to as pre-Illinoian (formerly Kansan). Lessig and Rice (1962) reported encountering some weathered "Kansan-age" tills near Elkton in central Columbiana County. Weathered till closely resembling the pre-Illinoian Slippery Rock Till found in northwestern Pennsylvania has been identified in eastern Mahoning County (White et al., 1969). The age of these deposits has been disputed over time. The age and nature of many of the deposits found in the deeper buried valleys of Mahoning County are poorly understood.

The majority of the glacial deposits fall into four main types: (glacial) till, lacustrine, outwash, and ice-contact sand and gravel (kames). Buried valleys may contain a mix of all of these types of deposits. Drift is an older term that collectively refers to the entire sequence of glacial deposits.

Till is an unsorted, non-stratified (non-bedded), mixture of sand, gravel, silt, and clay deposited directly by the ice sheet. There are two main types or facies of glacial till. Lodgement till is "plastered-down" or "bulldozed" at the base of an actively moving ice sheet. Lodgement till tends to be relatively dense and compacted and pebbles typically are angular, broken, and have a preferred direction or orientation. "Hardpan" and "boulder-clay" are two common terms used for lodgement till. Ablation or "melt-out" till occurs as the ice sheet melts or stagnates away. Debris bands are laid down or stacked as the ice between the bands melts. Ablation till tends to be less dense, less compacted, and slightly coarser as meltwater commonly washes away some of the fine silt and clay.

At the land surface, till accounts for two primary landforms: ground moraine and end moraine. Ground moraine (till plain) is relatively flat to gently rolling. End moraines are more ridge-like, with terrain that is steeper and more rolling or hummocky. Cummins (1950) reported that the average till thickness in ground moraine areas was 10 to 20 feet. Streams tend to parallel the margins of the moraines, which helps to enhance the relief and steepness of these features. Locally, end moraines commonly serve as drainage divides. Totten and White (1987) have delineated the end moraines in Mahoning County in detail. Due to the complexity of the moraines in Mahoning County, the individual end moraines have not been named or differentiated. Totten and White (1987) and White (1982) do suggest that the majority of the end moraines are related to the Kent Moraine that is more readily identified in Portage County. In eastern Mahoning County, the topography is primarily bedrock-controlled and differentiating between ground moraine and end moraines is difficult.

End moraines commonly represent a thickening of till. Thicknesses of till in end moraines (not including drift in underlying buried valleys) ranges from roughly 40 to 80 feet. Such a thickening may have occurred along the edge of a glacier that was melting or "retreating". The ice would carry sediment to the edge where it would be deposited somewhat in conveyor-belt fashion. Conversely, an advancing ice sheet may deposit an end moraine. As the ice sheet hits an obstruction such as a hill or ridge, a thicker wedge of till is deposited. This wedge then serves as an obstruction for successive, over-riding ice sheets. Many of the end moraines in northeastern Ohio have "cores" formed of till older than the surficial till (Totten, 1969).

Wisconsinan-age deposits compose the surficial material across all of Mahoning County except along steep slopes where the bedrock crops-out at the surface. Illinoian-age till, referred to as the Mapledale Till by White (1982) and Totten and White (1987 underlies the Wisconsinan-age till through most of the county. Totten and White (1987) report that the underlying Illinoian-age glacial till was observed in at least three areas in Mahoning County. Moran (1967) also discussed the presence of Illinoian tills in eastern Mahoning County. Deposition of Illinoian deposits is believed to have occurred prior to 100,000 Y.B.P. Stephenson (1933) and Cummins (1950) discussed the possibility of Illinoian tills, outwash, and kame deposits at depth in eastern Mahoning County.

Ice sheets associated with the Grand River Lobe deposited Wisconsinan-age tills. The earliest Wisconsinan-age till was formerly believed to be the Altonian sub-stage Titusville Till (Table 9). The Titusville Till was proposed as being older than 40,000 Y.B.P. based upon radiocarbon (C^{14}) dates from exposures in northwestern Pennsylvania (White et al., 1969). Current thinking (Totten, 1987 and Eyles and Westgate, 1987) suggests that there was probably insufficient ice available in North America for a major ice advance into the Great Lakes area until the Late Wisconsinan Woodfordian sub-stage (approximately 25,000 Y.B.P.). The age of deposits previously determined to be early to mid-Wisconsinan in age is therefore being re-evaluated. Moran (1967) and Gross and Moran (1971) identified at least 5 sub-units of the Titusville Till. The Titusville Till tends to be very firm, compact, stony, and silty to sandy in nature. Sand and gravel lenses are commonly found interbedded within this till. The Titusville Till also contains a higher percentage of crystalline igneous and metamorphic pebbles and boulders that were transported from Canada. The Titusville Till extends across Mahoning County and is found in many exposures, excavations and strip-mined areas. In many upland areas, the Titusville Till appears to lie directly upon the bedrock and the underlying Illinoian Mapledale Till is lacking.

Table 9. Generalized Pleistocene stratigraphy of Mahoning County, Ohio

Epoch	**Age (years ago)**	**Stage**	**Grand River Lobe**
Pleistocene	25,000 to 70,000	Wisconsinan	Hiram Till Lavery Till Kent Till Titusville Till?
	70,000 to 120,000	Sangamonian	Lake and alluvial deposits
	120,000 to 730,000	Iliinoian	Titusville Till Mapledale Till
	730,000 to 2,000,000	Pre-Illinoian	Slippery Rock Till (sediments in deep buried valleys)

The Kent Till is the oldest of the Late Wisconsinan Woodfordian tills. This till extends across Mahoning County, but is only exposed at the surface in the far southeastern corner. The Kent Till is friable (loose), non-compact, sandy, and stony. Sand and gravel lenses are common in this till. Many of the kame and outwash deposits found in the county are associated with this till unit (Totten and White, 1987). The Kent Moraine is also primarily composed of the Kent Till (Winslow and White, 1966).

The Lavery Till is the surficial till found in much of southern, central, and eastern Mahoning County. The Lavery Till is moderately compact, dense, sparingly to moderately pebbly, and has a clayey-silty texture. Totten and White (1987) have delineated two separate areas where the Lavery Till is the surficial unit. In south-central and southeastern Mahoning County, the Lavery Till is considered as being thin, discontinuous and spotty. In these areas, the entire thickness of the Lavery Till is typically weathered as the till is thin. To the north and west, the Lavery Till is thicker and more continuous.

The Hiram Till is the youngest till encountered in Mahoning County. It is the surficial till found in western, northwestern, and north-central Mahoning County. The Hiram Till is relatively soft, non-compact, sparingly pebbly and has a silty-clay to clayey texture. It tends to be particularly fine-grained in western Mahoning County. The fine texture is probably due to the till eroding and incorporating lacustrine deposits or shale bedrock. The Hiram Till may have been deposited in a fairly wet environment transitional between lacustrine and an ablational environment.

Lacustrine deposits were created as a result of numerous shallow lakes forming. Within stream valleys, the damming of streams by advancing ice sheets formed lakes. Some buried valleys contain appreciable thicknesses of lacustrine deposits (Totten and White, 1987). A large area of surficial lacustrine deposits is found in Mill Creek (east). In ground moraine areas, lakes were formed as meltwater was trapped between the melting ice sheet and adjacent, previously-deposited moraines. In some low-lying areas, lakes formed as the ice melted quicker then drainage systems could evolve. Deposits from shallow, inter-morainal lakes are also referred to as slackwater deposits. Typically, lacustrine deposits are composed of fairly dense, cohesive, uniform silt and clay with minor amounts of fine sand. Thin bedding, referred to as laminations, is common in these deposits. Such sediments were deposited in quiet, low-energy environments with little or no current. Large areas of surficial lacustrine deposits in upland areas include areas northwest of Sebring, northeast of Beloit, and northeast of Beloit Center.

Outwash deposits are created by active deposition of sediments by meltwater streams. These deposits are generally bedded or stratified and are sorted. Outwash deposits in Mahoning County are predominantly located in stream valleys. Such deposits were referred to in earlier literature as valley trains. Sorting and degree of coarseness depend upon the nature and proximity of the melting ice sheet. Braided streams usually deposit outwash. Such streams have multiple channels that migrate across the width of the valley floor, leaving behind a complex record of deposition and erosion. As modern streams downcut, the older, now higher elevation, remnants of the original valley floor are called terraces. Totten and White (1987) and Lessig et al. (1971) have delineated some of the major terraces in the county. All of the surficial terraces were reported as being Wisconsinan in age (Totten and

White, 1987). White and Totten (1985) and Totten and White (1987) noted a difference in the coarseness and lithologies of the gravel between the Woodfordian and older Altonian (Titusville equivalent) outwash.

Kames and eskers are ice contact features. They are composed of masses of generally poorly-sorted sand and gravel with minor till, deposited in depressions, holes, tunnels, or other cavities in the ice. As the surrounding ice melts, a mound of sediment remains behind. Typically, these deposits may collapse or flow as the surrounding ice melts. These deposits may display high angle, distorted or tilted beds, faults, and folds. In Mahoning County, the majority of the kames are deposited along the margins or flanks of valleys, particularly within the headwaters of the drainage systems. These kames tend to coalesce together along the valley margins. Such features are referred to as kame terraces. They represent deposition of materials between the melting ice sheet and the bedrock and till slopes flanking the ice-filled valleys. A few isolated, knob-like kames are found in the uplands of south-central Mahoning County. Totten and White (1987) suggest that the majority of kames and kame terraces may be associated with the deposition of the Kent Moraine during the Woodfordian sub-stage.

Peat and muck are organic-rich deposits associated with low-lying depressional areas, bogs, kettles, and swamps. Muck is a dense, fine silt with a high content of organics and a dark black color. Peat is typically brownish and contains pieces of plant fibers, decaying wood, and mosses. The two deposits commonly occur together, along with lacustrine or slackwater clays and silts. The majority of these deposits are found along lower-lying portions of valley floors including margins of floodplains and terraces.

Bedrock Geology

Bedrock underlying Mahoning County belongs to the Mississippian and Pennsylvanian Systems. Table 10 summarizes the bedrock stratigraphy found in Mahoning County. Outcrops of rocks from the Mississippian System are limited to exposures near stream level where major tributaries join the Mahoning River in northeastern Mahoning County. There are many exposures of Pennsylvanian System bedrock, particularly along valley sides and in strip mines and quarries.

Rocks of the Mississippian System underlie the floors of the deeper buried valleys and are exposed along the Mahoning River in the vicinity of Youngstown (Stephenson, 1933 and Cummins, 1950). These rocks are interbedded fine-grained sandstones, siltstones, and shales of the Cuyahoga Formation (Stephenson, 1933 and Cummins, 1950). These rock units are composed of sediments deposited in quiet marine waters in an offshore, deltaic environment, not unlike the modern Mississippi River delta. These sediments were fine silts, clay and mud, with thin beds of sand deposited by storms, floods, or in stream channels. The Cuyahoga Formation has been subdivided into the Orangeville Shale, Sharpsville Sandstone, and the Meadville Shale elsewhere in northeastern Ohio (Winslow et al., 1953, Smith and White, 1953, and Winslow and White, 1966). Stephenson (1933) and Cummins (1950) reported that only the uppermost unit, the Meadville Shale, cropped out in Mahoning County. Larsen (1996, personal communication, O.D.N.R., Division of Geological Survey) suggested

Table 10. Bedrock stratigraphy of Mahoning County, Ohio

System	Group/Formation (Symbol)	Lithologic Description
Pennsylvanian	Pennsylvanian Undifferentiated (Pu)	Interbedded dirty sandstones, shales, and siltstones with thin coal, limestone, and clay layers. Poor aquifer with yields of less than 5 gpm. Found in the uplands throughout most of Mahoning County.
	Allegheny and Pottsville Groups (Pap) Allegheny-Upper Pottsville (Pa-up) Upper Freeport Lower Freeport Middle Kittanning Lower Kittanning Vanport Brookville Homewood Mercer	The Pap is typically gray to black interbedded sandstone, siltstone, and shale, with thin layers of limestone, coal and clay. Poor to moderate aquifer with yields from 0 to 25 gpm. The Pa-up is typically thin brown to gray sandstones, siltstones, shale and coal. Local thickness < 100 feet. Poor to moderate aquifer yielding 5-25 gpm. The Pa-up is limited to the northwest corner of the county.
	Pottsville Massillon through Sharon Formations (Pm-s)	The Massillon Formation is a coarse to medium grained gray-white cross-bedded sandstone. The Sharon is a loosely cemented, cross-bedded, coarse-grained gray to tan sandstone with conglomerate zones. This aquifer is less than 100 feet thick. The best bedrock aquifer in the area yields 5 to 25 gpm. Found in the upland areas in the northwest corner of Mahoning County. The Sharon Shale may separate the sandstone units in some areas.
Mississippian	Cuyahoga Formation (Mcg) Meadville Shale Sharpsville Sandstone Orangeville Shale	Gray to brown shale with thin sandstone and siltstone interbeds. Thickness is commonly greater than 100 feet. Yields range from 5 to 25 gpm. Found in deeper valleys of northern Mahoning County.
	Berea Sandstone	Fine to medium-grained light greenish-gray to brown sandstone. Thickness is typically less than 100 feet. Found in the subsurface only.

that due to lack of adequate surface exposures and sub-surface data that referring to all units collectively as the Cuyahoga Formation is most reasonable. Underlying the Cuyahoga Formation is the Berea Sandstone (see Table 10). Although this unit is not exposed at the surface, the Berea Sandstone has historically been a source of water, brine, and petroleum, especially gas (Cummins, 1950 and Rau, 1969).

The contact between rocks of the Mississippian System and the Pennsylvanian System is a major disconformity that represents a large interval of erosion. The elevation and nature of the contact is highly variable. Stephenson (1933) and Cummins (1950) mention an elevation difference of the contact exceeding 100 feet in northeastern Mahoning County, which suggests the differential nature of erosion and downcutting during the Pennsylvanian.

Rocks of the Pennsylvanian System include formations of both the Pottsville Group and the Allegheny Group (Table 10). The stratigraphy of these units is highly complex, variable, and is still relatively poorly understood. Historically, bedrock mapping in the Pennsylvanian System has focused on the identification of key economic beds, particularly coals, minor iron ores (Stout and Lamborn, 1924, Stephenson, 1933 and Cummins, 1950) and also certain shales used in the ceramic industry. These units also served as useful marker beds. Less emphasis was placed upon characterizing the entire sediment package between these key units (Collins, 1979 and Larsen, 1991). Recent stratigraphic work (Larsen, 1991 and Slucher and Rice, 1994) is placing increased emphasis upon marine marker beds and identifying key fossil assemblages. The Pottsville Group is primarily represented by interbedded shales, dirty sandstones, and siltstones along with thin but important coals, underclays, and limestones. Some of the shales contain nodular bands of iron ore that had great local economic significance in the Nineteenth Century. The basal formation is the Sharon Sandstone (Conglomerate), a thick, massive , coarse-grained sandstone containing conglomeratic zones comprised of bands of milky-white, rounded quartzite pebbles. This unit represents deposition in a relatively high-energy stream channel system. The Sharon Sandstone is a very resistant unit that caps many of the steep ridges in central and eastern Mahoning County. It is overlain by the Sharon (No.1) Coal and the Sharon Shale. In many locales, the Sharon Shale may be absent due to erosion. The Sharon Sandstone typically directly overlies the Cuyahoga Formation. Cummins (1950) reported that in portions of Coitsville Township, the entire sequence of the Cuyahoga Formation and the Sunbury Shale has been eroded away and that the Sharon Sandstone rests directly upon the Berea Sandstone.

Weedman (1990) provides an excellent account of the complex depositional environments that created the rocks of the Pennsylvanian System. These highly transitional environments included both terrestrial ("land-based") and marine derived sediments. The terrestrial environment was dominated by large river systems that featured broad alluvial plains upland from coastal areas. Stream channels and point bar deposits were the source of sandstones and conglomerates. Shales and siltstones were derived from fine-grained floodplain deposits. Freshwater limestones were deposited in shallow, rapidly-evaporating lakes and ponds found on the alluvial plain. The terrestrial environment was highly transitional with a marine environment over time. The position of the shoreline and the depth of water varied with the rate of sediment input into the basin, sea level, and the rate of subsidence. Subsidence refers to an uneven "settling" during the relatively rapid accumulation of sediments. In the Allegheny Group, sandstones and shales represent deltaic/shoreline environments. Marine limestones formed in slightly deeper waters that lacked clastic input from rivers and deltas. Coal and clay were deposited in two different environments. Coal was deposited in either a "back-barrier" environment along the shoreline or in "deltaic-plain" environment in swamps formed in abandoned river channels (Horne et al., 1978). Similarly, clay was deposited in either quiet lagoonal areas directly behind the shoreline or in abandoned "oxbow" river channels (Ferm, 1974).

The Sharon Shale, or if absent, the Sharon Sandstone underlay the quartz-rich Massillon (Connoquenessing) Sandstone. This unit is also relatively resistant and together with the Sharon Sandstone, may aid in creating a resistant cap of bedrock on ridge tops. The Massillon Sandstone is slightly finer-grained, dirtier (contains more matrix) than the Sharon and is usually thinner.

Overlying the Massillon Sandstone is the Mercer Formation. The Mercer Formation is a dark, silty, organic-rich shale that contains thin interbedded limestones, coals, and underclays. The Lower Mercer (No. 3) Coal, the Lower Mercer Limestone, and the Upper Mercer Limestone Bed are the primary marker beds for this interval.

The Homewood Sandstone is the uppermost Pottsville unit recognized in Mahoning County (Stephenson, 1933 and Cummins, 1950). It varies from a massive, fine-grained sandstone to a thin dirty sandstone or a sandy shale. The thickness of this formation varies considerably.

The Brookville (No.4) Coal is the basal unit of the Allegheny group (Stephenson, 1933 and Cummins, 1950). This thin unit is usually poorly exposed and is not commonly reported in the subsurface. The Clarion Sandstone is the first commonly encountered formation of the Allegheny Group. The Clarion Sandstone closely resembles the Homewood Sandstone and in many areas rests on top of the Homewood Sandstone (Stephenson, 1933 and Cummins, 1950). Because of these factors, the Homewood Sandstone and the Clarion Sandstone are treated as a "package" or as one unit in some areas.

The Vanport Limestone serves as a local marker bed. It achieves its greatest thickness and economic importance in Poland Township where it is a fairly massive, dense limestone. Further west, the Vanport grades into a dark, organic-rich shale and is of little economic significance.

The Lower Kittanning (No. 5) is the most economically important coal in Mahoning County. It is separated from the Middle Kittanning (No. 6) Coal by thin shales and clays. The Middle Kittanning has more limited exposure, is thin, and is of less economic importance.

The Lower Freeport Sandstone is a moderately thick relatively fine-grained sandstone found in southeastern Mahoning County. The overlying Upper Freeport Sandstone is very thin and is found capping a limited number of high ridge tops in southeastern Mahoning County (Cummins, 1950). The Upper Freeport represents the uppermost portion of the Pennsylvanian System sequence exposed in Mahoning County.

Ground Water Resources

Ground water in Mahoning County is obtained from both glacial (unconsolidated) and bedrock (consolidated) aquifers. Glacial deposits are utilized as the aquifer in the buried valleys. Sand and gravel outwash are also utilized in river valleys where the drift is of insufficient thickness to be considered a buried valley. Sand and gravel lenses interbedded with the glacial till are also utilized as aquifers in some moraine areas. In much of the upland areas of Mahoning County, the glacial deposits are either too thin or too fine-grained to serve as aquifers.

Glacial aquifers in Mahoning County are highly variable, particularly within the buried valleys. The aquifers range from thin, isolated, discontinuous lenses of sand and gravel interbedded in thick sequences of glacial till or lacustrine deposits to relatively thick, extensive outwash deposits. Yields obtained from outwash or alluvial deposits not associated with buried valleys range from 25 to 100 gpm (ODNR, Div. of Water Open File, Glacial State Aquifer Map, Cummins, 1950 and Crowell, 1979). Discontinuous sand and gravel lenses in areas of thinner drift (i.e. non-buried valley areas) typically have yields ranging from 10 to 25 gpm (Crowell, 1979).

Yields obtained from aquifers within buried valleys vary considerably. Areas containing thicker, more extensive sand and gravel outwash deposits, higher permeability soils, and modern streams have the capability of maximum yields exceeding 100 gpm from properly developed, large diameter wells (ODNR, Div. of Water Open File, Glacial State Aquifer Map and Crowell, 1979). Wells completed in outwash deposits in a few isolated locales, such as where Crab Creek joins the Mahoning River in Youngstown and the Mahoning River in southwestern Smith Township, may be capable of yields up to 500 gpm (ODNR, Div. of Water Open File, Glacial State Aquifer Map, Cummins, 1950 and Crowell, 1979). Test drilling may be necessary to confirm the presence of the higher-yielding sand and gravel deposits within the buried valleys (ODNR, Div. of Water Open File, Glacial State Aquifer Map and Crowell, 1979). Yields from somewhat finer, thinner sand and gravel deposits found along the margins or up tributaries of the major trunk buried valleys typically are less than 25 gpm (ODNR, Div. of Water Open File, Glacial State Aquifer Map and Crowell, 1979). Buried valleys that extend through present upland areas commonly have yields less than 15 gpm (ODNR, Div. of Water Open File, Glacial State Aquifer Map and Crowell, 1979). In these areas, the aquifer consists of thin, discontinuous sand and gravel lenses, soils are low permeability, and modern streams are absent or intermittent.

Yields obtained from bedrock aquifers are also variable. Cummins (1950) reported yields of over 50 gpm for the Berea Sandstone; however, the water is non-potable due to the near-brine concentration levels of chlorides (Cummins, 1950, Rau, 1969, and Sedam, 1973). The Berea Sandstone has potential use for limited industrial applications where the water quality is non-important. The Cuyahoga Formation is a relatively poor aquifer with yields averaging less than five gpm (ODNR, Div. of Water, Bedrock State Aquifer Map, Cummins, 1950 and Crowell, 1979).

The Sharon Sandstone is, on average, the highest-yielding bedrock formation in Mahoning County. Yields of 25 to 40 gpm are common, and large diameter wells in favorable locations are capable of sustaining yields up to 100 gpm (ODNR, Div. of Water, Bedrock State Aquifer Map, Cummins, 1950 and Crowell, 1979). Coarser-grained and conglomeratic zones within the Sharon may be slightly more permeable and have slightly higher yields. Yields are influenced by the number of fractures and bedding planes intersected by the wells (Stanley, 1973). The amount of fracturing tends to increase along hill slopes and valleys. This increase may be related to the stress relief as shown by Wyrick and Borchers (1981) and Kipp et al. (1983). The net result is that there is usually a decrease in depth to water (i.e.- a shallower static water level) and higher yields. Fracturing resulting from strip mining, blasting, or underground mining may produce similar results. Fracturing is also an influence on the direction of ground water flow (Schubert, 1980) and affects the amount of recharge.

Yields in the Massillon Sandstone generally average less than 50 gpm, with yields averaging from 10 to 25 gpm (ODNR, Div. of Water, Bedrock State Aquifer Map, Cummins, 1950, Sedam, 1973, and Crowell, 1979). The Homewood Sandstone and Clarion Sandstone typically have yields averaging 5 to 10 gpm (ODNR, Div. of Water, Bedrock State Aquifer Map, Cummins, 1950, Rau, 1973, and Crowell, 1979). Yields up to 10 gpm are possible from the Freeport Sandstone in areas where it has adequate thickness (ODNR, Div. of Water, Bedrock State Aquifer Map, Cummins, 1950 and Crowell, 1970). Yields in formations within the Allegheny Group commonly have lower yields due to the higher variability of the bedrock units and the fact that they typically occur at higher elevations and are therefore higher above stream base. The higher yields in the Pottsville Group also reflect the much higher proportion of coarse sandstone units (Sedam, 1973).

The yield in any particular area is dependent upon the number and type of formations drilled. Wells drilled in bedrock often intersect several aquifers or water producing zones. Sandstones and coals tend to be water-bearing units whereas underclays, mudstones, siltstones and shales tend to be aquitards that impede the flow of water. Limestones are typically thin, hard, and fine-grained and are generally poor aquifers. Thicker, fractured limestones however; are capable of producing suitable yields. Water tends to "perch" or collect on top of lower permeability units (e.g. shale) and move laterally along the base of an overlying unit with higher permeability (e.g. sandstone). Springs and seeps mark where these contacts meet the slope or land surface. Peffer (1991) demonstrated that shales can provide sufficient water to serve domestic needs and still behave as an aquitard.

Strip and Underground Mined Areas

The pollution potential of strip mined and underground mined areas was not evaluated in Mahoning County. Although *DRASTIC: A Standardized System for Evaluating Ground Water Pollution Using Hydrogeologic Settings* (Aller et al., 1987) does identify mining as a source of contamination, it does not discuss a methodology to evaluate the vulnerability of aquifers to contamination in these areas.

Many geologic and hydrogeologic changes occur in areas that have undergone or are undergoing mining or reclamation activities (Bonta et al., 1992 and Razem, 1983) The extent of these changes may not be known or may have a high degree of variability from one location to another.

Mining activities have the ability to affect all DRASTIC parameters. Tables 11 and 12 list the DRASTIC parameters and the possible impacts that mining may have on rating the parameters for strip mined and underground mined areas, respectively. These tables are not meant to be a comprehensive listing of the impacts of mining on the ground water systems. They are provided to illustrate the uncertainty of evaluating the pollution potential of mined areas.

Although the pollution potential of strip mined and underground mined areas was not evaluated, such areas were delineated. Only the most areally extensive areas were delineated on the Pollution Potential Map of Mahoning County. Delineations were based upon the *Soil Survey of Mahoning County* (Lessig et al., 1971), abandoned underground mine maps (ODNR, Division of Geological Survey, open file maps), and the U.S.G.S. 7 1/2 minute topographic maps. Site specific information for mined and reclaimed areas can be obtained from the ODNR, Division of Reclamation, the ODNR, Division of Geological Survey, and the U.S. Department of Interior, Division of Surface Mining. A wealth of information can also be obtained from Dr. Ann Harris at the Department of Geology, Youngstown State University.. Dr. Harris is an authority on the historical perspective of underground mining and has archived considerable data on underground mining in the greater Youngstown area. Her data was also used to check the delineations of the underground mines. She has noted that shafts interconnect a considerable number of the mines, unfortunately these features are too small in scale to be portrayed on the map. It is highly recommended that a site-specific study of the mined area and surrounding areas be conducted before further use of these areas.

Unmapped Areas

A large area of the Mahoning River Valley and adjoining Crab Creek Valley in the vicinity of Youngstown was not mapped. Well logs show that these areas contain upwards of 20 to 30 feet of fill. This fill is composed of bricks, demolition debris, slag and cinders from the steel industry, and spoils or overburden from nearby strip mines and quarries (Lessig et. al., 1971 and Totten and White, 1987). Dr. Ann Harris (personal communication, 1995, Youngstown State University) reported that similar materials were used in attempts to seal or fill many small mine shafts, adits, and both underground and surface mines in the greater Youngstown area. Many of these attempts were either incomplete or have subsequently undergone subsidence. Most of this fill dates back to the industrial expansion of Youngstown prior to and during the Second World War. In many of these areas, the soil, slope, vadose zone material, and recharge may be altered. In some of these areas, the static water level rises within the level of the fill material, thereby, the fill material may partially represent an uppermost aquifer. Because these conditions do not reflect natural conditions and because they are so variable, it was decided not to rate these areas. Any further activities conducted in these areas would require extensive site-specific study to determine their suitability.

Table 11. Potential factors influencing DRASTIC ratings for strip mined areas

Parameter	Impact of Activity/Effects on DRASTIC Ratings
Depth to water	Removal of material overlying the aquifer will decrease the depth to water (i.e. increase DRASTIC rating); removal of uppermost aquifer will increase the depth to water (i.e. decrease DRASTIC rating)
Net Recharge	Mineral extraction and reclamation could increase the degree of fracturing, increase the permeability of the vadose zone and soils and therefore increase the amount of recharge (i.e. increase DRASTIC rating); compaction of fine grained spoils could decrease the amount of recharge to the aquifer (i.e. decrease DRASTIC rating)
Aquifer media	Mineral extraction could remove the uppermost aquifer
Soil media	Removal of soils will provide less of a barrier for contaminant transport (i.e. increase soil rating); reclaimed soils may have a lower permeability than the original cover (i.e. decrease soil rating)
Topography	Strip mining can change the contour of the land surface making delineation of this parameter virtually impossible
Impact of the vadose zone	Fracturing of vadose zone media could increase the permeability (i.e. increase rating); compaction of spoils during reclamation could decrease the permeability (i.e. decrease rating)
Hydraulic Conductivity	Fracturing of aquifer media could increase the conductivity (i.e. increase DRASTIC rating)

Table 12. Potential factors influencing DRASTIC ratings for underground mined areas

Parameter	Impact of Activity/Effects on DRASTIC Ratings
Depth to water	Collapse of underground mines has the potential to fracture overlying confining units, therefore causing a dewatering of overlying aquifers (i.e. decrease rating)
Net Recharge	Fracturing of overlying strata can increase amount of recharge to the aquifer (i.e. increase rating)
Aquifer media	Upper aquifers could be dewatered and underground mine could become the aquifer
Soil media	Fractures may extend to the land surface
Topography	This factor will not be affected unless severe subsidence occurs
Impact of the vadose zone	Fracturing and air shafts in the vadose zone could increase the permeability and provide a direct conduit for contamination (i.e. increase rating)
Hydraulic Conductivity	Upper aquifers not dewatered as a result of fracturing or subsidence would have higher conductivity values; underground mines serving as the aquifer media will have high conductivity values (i.e. higher rating)

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APPENDIX A

DESCRIPTION OF THE LOGIC IN FACTOR SELECTION

<u>Depth to Water</u>

This factor was primarily evaluated using information from water well log records on file at the ODNR, Division of Water, Water Resources Section (WRS). Approximately 12,000 water well log records are on file for Mahoning County. Almost 4,500 of these logs have been located by WRS staff or by personnel contracted by the Mahoning County Health Department. Data from approximately 2,000 representative well logs were plotted on U.S.G.S. 7 1/2 minute topographic maps during the course of this project. Static water levels and information on the depth to saturated zones were taken from the well log records. An earlier, unpublished *Ground Water Resources Map of Mahoning County* (Cummins, 1950), the *Ground Water Resources Map of Mahoning County* (Crowell, 1979), and the reports of Rau (1969) and Sedam (1973) helped to provide generalized depth to water information throughout Mahoning County. Topographic and geomorphic trends were utilized to estimate the depth to water in areas where other data sources were lacking.

Depths of 5 to 15 feet (DRASTIC value =9) and 15 to 30 feet (7) were typical of areas paralleling smaller streams in the uplands and for floodplains flanking larger streams. Depths of 15 to 30 feet (7) were common for outwash terraces and for the buried valleys containing modern streams. Areas of ground moraine commonly had depths of water of 15 to 30 feet (7) or 30 to 50 feet (5). Areas covered by thin to moderate thicknesses (less than 40 feet) of glacial till commonly have depths of water averaging 15 to 30 feet (7). Depths of 30 to 50 feet were common along hill slopes and along the margins of valleys. Many of the areas mapped by Totten and White (1987) as kames, kame terraces, and end moraines were evaluated as having depths of water from 30 to 50 feet (5). Areas with depths ranging from 30 to 50 feet (5) are typically transitional between the upland divides and ridges and lower-lying stream valleys and floodplains. Areas with a moderate thickness of till (roughly 40 to 70 feet) typically have a depth to water ranging from 30 to 50 feet (5). Depths of 30 to 50 feet (5) were common in portions of buried valleys lacking or far-removed from modern streams.

Depths of 50 to 75 feet (3) were selected for isolated, steep, bedrock-controlled ridges and knolls. These areas typically exhibit some of the highest relief in Mahoning County. These ridges are commonly capped by resistant sandstone of the Pennsylvanian System.

Net Recharge

This factor was evaluated using many criteria including depth to water, topography, soil type, proximity of surface drainage, vadose zone material, and annual precipitation. General estimates of recharge provided by Pettyjohn and Henning (1979) and Dumouchelle and Schiefer (2002) proved to be helpful. Recharge values calculated for adjoining counties (Williams, 1990, Angle, 1991 and Angle, 1994) were also utilized.

Values of 7 to 10 inches per year (8) of recharge were selected for areas with highly permeable soils (e.g. sandy loams) and vadose zone materials (e.g. outwash), shallow depths to water, and gentle slopes. These areas typically occur on terraces or floodplains flanking modern streams. Areas having recharge values of 7 to 10 inches per year (8) contain extensive outwash deposits as the aquifer and are limited to either the 7D - Buried Valley hydrogeologic setting or the 7Ba - Outwash hydrogeologic setting.

Recharge values of 4 to 7 inches per year (6) were selected for the vast majority of the county. This range of recharge reflects moderate depths to water, moderate thicknesses of till, low to moderate permeability soils, and areas of moderate slope. These values were assigned to areas of end moraine and ground moraine, kames, some bedrock uplands and margins and tributaries of major buried valley systems.

Recharge values of 2 to 4 inches per year (3) were utilized in areas where the depth to water exceeded 50 feet, based upon static water levels. The majority of these areas contained moderate thicknesses of till, low permeability soils (e.g. clay loams), and moderately steep slopes. These rates were also commonly found in areas with steeper, bedrock-controlled topography and relatively high depths to water.

Aquifer Media

Information on aquifer media was obtained from the reports of Stout and Lamborn (1924), Stephenson (1933), Cummins (1950), Smith and White (1953), Winslow et al. (1953), Winslow and White (1966), Sedam (1973), Crowell (1979), Walker and Hartzell (1983), and Totten and White (1987). Open File Bedrock Reconnaissance Maps and Open File Bedrock Topography Maps, based upon U.S.G.S. 7-1/2 minute topographic maps from the ODNR, Division of Geological Survey proved helpful. The ODNR, Division of Water, Glacial State Aquifer Map and Bedrock State Aquifer Map were an important source of aquifer data. Open file bedrock topography maps from the ODNR, Division of Geological Survey proved invaluable in delineating buried valleys and mapping aquifer media. Regional bedrock topography is available from Cummins (1959) and Risser and Vormelker (1986) have generated a bedrock topography map for Mahoning County. Generalized bedrock topography contours also appear on the *Glacial Geology Map of Mahoning County* (Totten and White, 1987). Water well log records on file at the WRS were also an important source of data. Where more than one aquifer was present, the uppermost aquifer was rated.

The aquifer media rating for bedrock varied across the county. An aquifer rating of (6) was selected primarily for wells completed within the Pottsville Group. Although the Pottsville Group contains interbedded shales, sandstones, siltstones, underclays, limestones, and coal the massive sandstones are the primary aquifers. These sandstone aquifers include the Sharon Sandstone, the Massillon (Connoquenessing) Sandstone, and the Homewood/Clarion Sandstone. These sandstones contribute a high proportion of the total yield obtained from wells drilled into the Pottsville. Wells developed primarily within the interbedded sandstones, siltstones, shales, limestones, coal, and clay of the Allegheny Group or within the Mercer Formation of the Pottsville Group were given an aquifer media rating of (5). An aquifer media rating of (5) was also selected for wells encountering the interbedded sandstones, shales, and siltstones of the Mississippian Cuyahoga Formation. Shales and siltstones are predominant in the bedrock units assigned an aquifer media rating of (5) and sandstones tend to be dirtier, thinner, and finer-grained in these intervals.

Ratings for the aquifers in the glacial deposits also varied across Mahoning County. The thick, continuous, coarse, clean outwash deposits were given aquifer media ratings of (7) or (8). These highly-rated outwash deposits are limited to the 7D Buried Valley hydrogeologic setting. Aquifer media ratings of (8) were only utilized for outwash deposits occupying the buried valley containing the Mahoning River in the southwestern corner of Smith Township. This high-yielding aquifer extends into Stark County (Walker, 1988 and Williams, 1990). Aquifer media ratings of (6) were utilized for less continuous, finer-grained sand and gravel deposits and deposits containing finer silts and clays. The aquifer media rating of (6) was commonly utilized for many of the buried valleys, kames, and areas with thinner outwash and included the 7D - Buried Valley hydrogeologic setting and the 7Ba - Outwash hydrogeologic setting. For areas containing aquifers composed of thin, isolated, discontinuous lenses of sand and gravel interbedded in glacial till or lacustrine deposits or for exceptional fine-grained or dirty sands, an aquifer media rating of (5) was utilized. The aquifer media rating of (5) was assigned to some of the margins and tributary buried valleys within the 7D - Buried Valley hydrogeologic setting as well as in the 7Af - Sand and Gravel Interbedded in Glacial Till hydrogeologic setting and the 7Ed - Alluvium Over Glacial Till hydrogeologic setting.

Soil Media

This factor was primarily evaluated using data obtained from the *Soil Survey of Mahoning County* (Lessig et. al., 1971). Information on every indicated soil type was analyzed and appropriate ratings were selected. Computer-generated maps derived from digitized Soil Survey data were supplied by the ODNR, Division of Real Estate and Land Management (REALM), Resource Analysis Program (formerly OCAP). Table 13 lists the soil types encountered in Mahoning County and gives information on the soils' parent material or setting and the corresponding DRASTIC rating. The nature of the underlying glacial deposits and proximity to bedrock were two of the main factors influencing soil types in Mahoning County. Soil ratings were based upon the most restrictive layer or horizon within the soil profile.

Clay loam (3) and silt loam (4) were the two most common soil ratings utilized throughout Mahoning County. Clay loam (3) was encountered in most upland areas where the clay-rich Hiram Till and Lavery Till were the surficial materials. Clayey lacustrine/slackwater deposits also weather into clay loam (3) soils. In areas where the Lavery Till was thin, where the Kent Till was the surficial material, or where till thinly overlies bedrock, silt loam (4) soils were found. Silt loam (4) soils were also common in modern alluvium terraces, floodplains, and siltier lacustrine/slackwater deposits. Loam (5) soils were associated with areas of weathered, interbedded bedrock and with outwash terraces that contained higher proportion of fine-grained materials. Sandy loam (6) soils were developed in areas with coarser outwash terraces, kames, and very coarse alluvium. Weathered sandstone was another source of sandy loam (6) soils. Shrink-swell clay (7) was rated for many clay rich soils derived from exceptionally clayey slackwater, till, or water-deposited tills. Isolated areas of bogs, kettles, depression, and swamps contained peat (8) soils. These soils and features are usually associated with floodplains and terraces.

The Canfield, Frenchtown, Ravenna, Rittman, Wadsworth, and Wooster soils, all of which are derived from weathering till, contain fragipans. A fragipan is a dense, mineralized, impermeable zone found within a few feet of the ground surface. Fragipans may noticeably restrict the downward movement of water. The net effect of the fragipan is to reduce the overall permeability of a soil within a given textural range (Aller et. al., 1987). Hence, a soil with a loam texture (5) would be rated equivalent to a silt loam (4) and a soil with a silt loam (4) texture would be rated as a clay loam (3) due to the presence of the fragipan (Table 13).

Topography

Topography was evaluated by determining the percentage of slope obtained from the U.S.G.S. 7 1/2-minute (1:24,000 scale) quadrangle maps and from the *Soil Survey of Mahoning County* (Lessig et. al., 1971). Slopes of 0 to 2 percent (10) were selected for floodplains, flat-lying outwash terraces, and some areas of ground moraine. Slopes of 2 to 6 percent (9) were widespread through the county and include areas of both end moraine and ground moraine, terraces, as well as some areas with bedrock-controlled topography. Overall, slopes of 0 to 2 percent (10) and 2 to 6 percent (9) were found in stream valleys or in uplands in the northern and western portions of the county. Slopes of 6 to 12 percent (5) were utilized for steeper end moraines, moderately steep bedrock ridges, many kames, and areas adjacent to modern stream valleys that have undergone moderately high lateral erosion. Steeper slopes of 12 to 18 percent (3) or greater than 18 percent (1) were limited to areas of bedrock ridges, cliffs, and knobs. Such ridges are commonly capped by resistant sandstone bedrock units, especially the Sharon Sandstone and Massillon Sandstone.

Table 13. Mahoning County soils

Soil Name	Parent Material or Setting	DRASTIC Rating	Soil Media
Bennington	Till	3	Clay loam
Bogart	Outwash, kames	6	Sandy loam
Canedice	Clayey lacustrine	7	Shrink-swell clay
Canfield*	Loamy till	4	Silt loam
Cardington	Till	3	Clay loam
Carlisle Muck	Bogs, depressions	8	Peat
Chagrin	Coarse alluvium, outwash	6	Sandy loam
Chili	Outwash, kames	6	Sandy loam
Condit	Till	3	Clay loam
Damascus	Outwash	6	Sandy loam
Dekalb	Till over sandstone	6	Sandy loam
Ellsworth	Clayey till	3	Clay loam
Fitchville	Silty lacustrine	4	Silty loam
Frenchtown*	Clayey till	3	Clay loam
Geeburg	Clayey till	7	Shrink-swell clay
Glenford	Silty lacustrine	4	Silt loam
Hornell	Till over shale	3	Clay loam
Jimtown	Outwash, kame	6	Sandy loam
Kerston Muck	Clayey depressions	1	Clay
Lobdell	Coarse alluvium	5	Loam
Lorain	Clayey lacustrine, ponds	7	Shrink-swell clay
Loudenville	Till over sandstone and siltstone	5	Loam
Luray	Clayey lacustrine	3	Clay loam
Mahoning	Clayey till	3	Clay loam
Muskingum	Thick siltstone regolith	4	Silt loam
Olmsted	Coarse alluvium	6	Sandy loam
Orrville	Coarse alluvium	6	Sandy loam
Papakating	Fine alluvium	3	Clay loam
Ravenna*	Loamy till	4	Silt loam
Remsen	Clayey till	7	Shrink-swell clay
Rittman*	Silty till	3	Clay loam
Sebring	Silty lacustrine over till	4	Silt loam
Trumbull	Till	3	Clay loam
Wadsworth*	Silty till	3	Clay loam
Wayland	Alluvium	4	Silt loam
Wooster*	Loamy till	4	Silt loam

* - soil contains a fragipan

Impact of the Vadose Zone Media

Water well records on file at the WRS were a primary source of information on vadose zone media. Information on vadose zone media was obtained from the reports of Stout and Lamborn (1924), Stephenson (1933), Cummins (1950), Smith and White (1953), Winslow et al. (1953), Winslow and White (1966), Moran (1967), Sedam (1973), Crowell (1979), Walker and Hartzell (1983), and Totten and White (1987). Open File Bedrock

Reconnaissance Maps and Open File Bedrock Topography Maps, based upon U.S.G.S. 7-1/2 minute topographic maps from the ODNR, Division of Geological Survey proved helpful. The ODNR, Division of Water, Glacial State Aquifer Map and Bedrock State Aquifer Map were an important source of aquifer data. Regional bedrock topography is available from Cummins (1959), and Risser and Vormelker (1986) have generated a bedrock topography map for Mahoning County. Generalized bedrock topography contours also appear on the *Glacial Geology Map of Mahoning County* (Totten and White, 1987).

Till was chosen as the vadose zone material for much of Mahoning County. Typically a rating of (4) was selected for till. Totten and White (1987) delineated areas of "gravelly till" on the *Glacial Geology Map of Mahoning County*. These areas generally are adjacent to kames and kame terraces and are associated with the Kent Moraine and the Kent Till in general. Till in these areas was assigned a vadose zone rating of (5) and is referred to in the DRASTIC index charts as "sandy till". In many of the buried valleys and other areas containing outwash, sand and gravel with significant silt and clay were selected as the vadose zone material and ratings of (5) or (6) were used. These ratings varied upon the relative proportion of sand and gravel to silt and clay as well as the coarseness and degree of sorting within the units. Kames, kame terraces, and outwash terraces were similarly assigned ratings of (5) or (6). Silt and clay were selected as the vadose zone media for alluvium and floodplains that lacked underlying outwash. Vadose zone media ratings of (4) or (5) were chosen for these sediments. Silt and clay with a vadose zone media rating of (3) was assigned to areas with moderately thick clayey lacustrine, slackwater, or lakebed deposits. The majority of these deposits have shrink-swell clay soils that belong to the Remsen-Geeburg soil association.

Bedrock was selected as the vadose zone media for numerous areas in Mahoning County, particularly the northeastern portion of the county. A vadose zone rating of (6) was selected for bedrock units that have an aquifer media rating of (6). This rating was generally utilized for formations within the Pottsville Group containing abundant thicknesses of sandstone. Similarly, a vadose zone media rating of (5) was assigned to bedrock units that have an aquifer media rating of (5). This rating was generally utilized for rocks within the Cuyahoga Formation, portions of the Allegheny Group, and the Mercer Formation. Bedrock was utilized as the vadose zone media in the 7G - Thin Till Over Bedded Sedimentary Rock hydrogeologic setting

Hydraulic Conductivity

Very little published hydraulic conductivity data exists for Mahoning County. The regional bedrock studies of Rau (1969) and Sedam (1973) proved to be useful. Textbook tables (Freeze and Cherry, 1979, Fetter, 1980, and Driscoll, 1986) were useful in obtaining estimated values for a variety of aquifer materials. Additionally, values for hydraulic conductivities utilized in adjoining counties were extended into Mahoning County (Williams, 1990, Angle, 1991, and Angle, 1994).

Values for hydraulic conductivity roughly followed the aquifer ratings, i.e. the more highly-rated aquifers have higher hydraulic conductivities. For the sand and gravel aquifers, the hydraulic conductivity is a function of coarseness, stratification, sorting, and cleanliness (absence of fines). For discontinuous sand and gravel aquifers not associated with buried valleys and having an aquifer media rating of (5), a hydraulic conductivity of 100-300 gallons per day per square foot (gpd/ft^2) (2) was used. Buried valleys containing sand and gravel aquifers with an aquifer media rating of (5) were assigned a hydraulic conductivity of 300-700 gpd/ft^2 (4). A hydraulic conductivity value of 300-700 gpd/ft^2 (4) was used for sand and gravel aquifers with an aquifer media rating of (6). Sand and gravel aquifers with an aquifer media rating of (7) were assigned hydraulic conductivity ratings of 300-700 gpd/ft^2 (4) or 700-1,000 gpd/ft^2 (6). The sand and gravel aquifers with an aquifer media rating of (8) were assigned a hydraulic conductivity value of 1,000-2,000 gpd/ft^2 (8).

A hydraulic conductivity rating of 1-100 gpd/ft^2 (1) was selected for bedrock aquifers having an aquifer media rating of (5). For bedrock aquifers with an aquifer media rating of (6), a hydraulic conductivity range of 100-300 gpd/ft^2 (2) was used. The hydraulic conductivity ratings selected for the bedrock aquifers roughly follow the values derived by Sedam (1973).

APPENDIX B

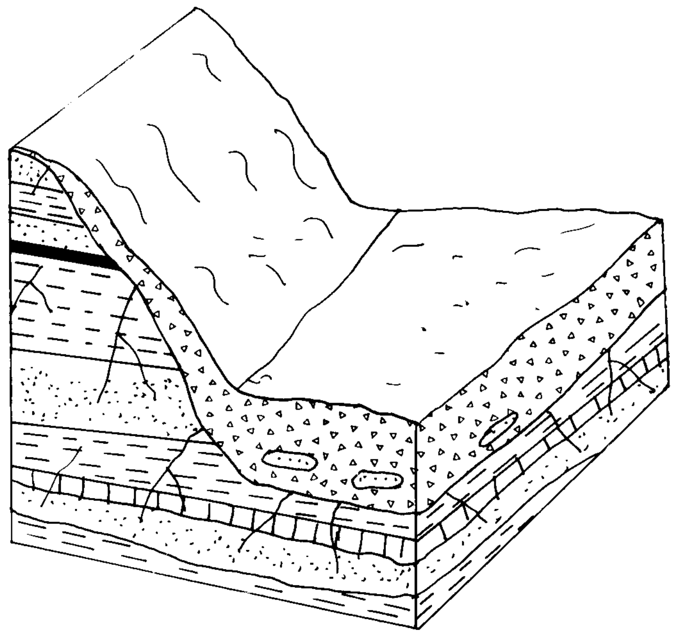
DESCRIPTION OF HYDROGEOLOGIC SETTINGS AND CHARTS

Ground water pollution potential mapping in Mahoning County resulted in the identification of eight hydrogeologic settings within the Glaciated Central Region. The list of these settings, the range of pollution potential indexes, and the number of index calculations for each setting are provided in Table 14. Computed pollution potential indexes for Mahoning County range from 76 to 168.

Table 14. Hydrogeologic settings mapped in Mahoning County, Ohio

Hydrogeologic Settings	Range of GWPP Indexes	Number of Index Calculations
7Aa - Glacial Till Over Bedded Sedimentary Rock	76-139	110
7Af – Sand and Gravel Interbedded in Glacial Till	108-112	2
7Ba – Outwash	129-158	12
7Bb – Outwash Over Bedded Sedimentary Rocks	119-140	9
7D - Buried Valley	106-168	64
7Ec - Alluvium Over Sedimentary Rock	120-147	14
7Ed – Alluvium Over Glacial Till	127-147	4
7G – Thin Till Over Bedded Sedimentary Rocks	99-134	20

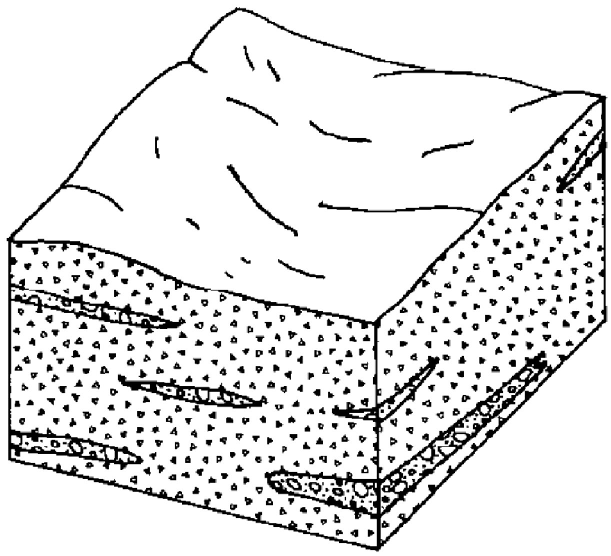
The following information provides a description of each hydrogeologic setting identified in the county, a block diagram illustrating the characteristics of the setting, and a listing of the charts for each unique combination of pollution potential indexes calculated for each setting. The charts provide information on how the ground water pollution potential index was derived and are a quick and easy reference for the accompanying ground water pollution potential map. A complete discussion of the rating and evaluation of each factor in the hydrogeologic settings is provided in Appendix A, Description of the Logic in Factor Selection.



7Aa Glacial Till Over Bedded Sedimentary Rocks

This hydrogeologic setting is variable and widespread across Mahoning County. Topography varies from rolling, low relief areas in the western portion of the county to steep, high relief areas in the eastern part of the county. The aquifer consists of thin interbedded shales, sandstones, siltstones, limestones, clay, and coal of the Pottsville Group and Allegheny Group of the Pennsylvanian System and interbedded shale, siltstones, and fine-grained sandstones of the Mississippian Cuyahoga Formation. Yields range from 3 to 25 gpm for wells completed in rocks of the Allegheny Group and Cuyahoga Formation to yields locally up to 100 gpm for massive, fractured sandstones in the Pottsville Group. Varying thicknesses of glacial till typically overlies the aquifer. This setting also contains numerous small areas where the till is overlain by thin, clay-rich lacustrine or slackwater deposits. The till cover has a typical thickness of 20 to 30 feet in ground moraine areas and may reach thicknesses of 70 feet within end moraines. The various till units commonly weather into either silt loams or clay loams. The depth to water is variable, averaging from 15 to 30 feet in western Mahoning County to 30 to 50 feet in southern and eastern Mahoning County. Recharge is moderate to low depending upon the slope, thickness of the till cover, and depth to water.

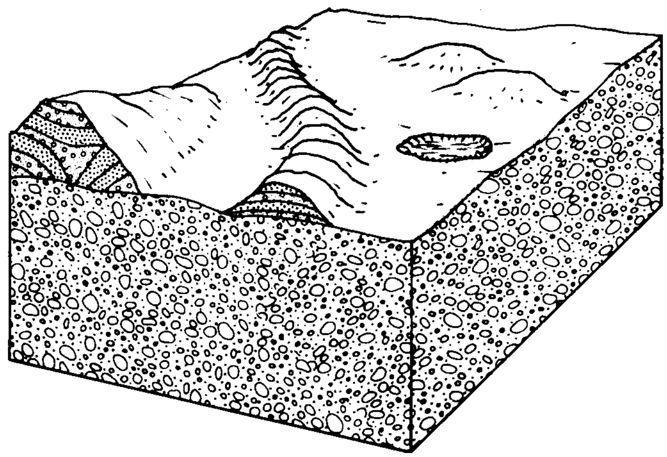
GWPP index values for the hydrogeologic setting of glacial till over bedded sedimentary rocks range from 76 to 139 with the total number of GWPP index calculations equaling 110.



7Af Sand and Gravel Interbedded in Glacial Till

This hydrogeologic setting is limited to a small area adjacent to the major buried valley underlying Yellow Creek, just east of Boardman, in eastern Mahoning County. The setting encompasses areas where sand and gravel lenses interbedded within till are the aquifer. The total thickness of drift in these areas is substantially less than that found in the 7D - Buried Valley hydrogeologic setting. This hydrogeologic setting is characterized by nearly flat-lying topography. Soils range from silt loam to sandy loam. The sand and gravel aquifers are typically thin, discontinuous lenses. Yields average 10 to 25 gpm and are adequate for domestic purposes. Till is the vadose zone media. Depth to water is moderate, averaging from 30 to 50 feet. Recharge is moderate due to the low relief, moderate depth to the water table, and the moderate thickness of the till.

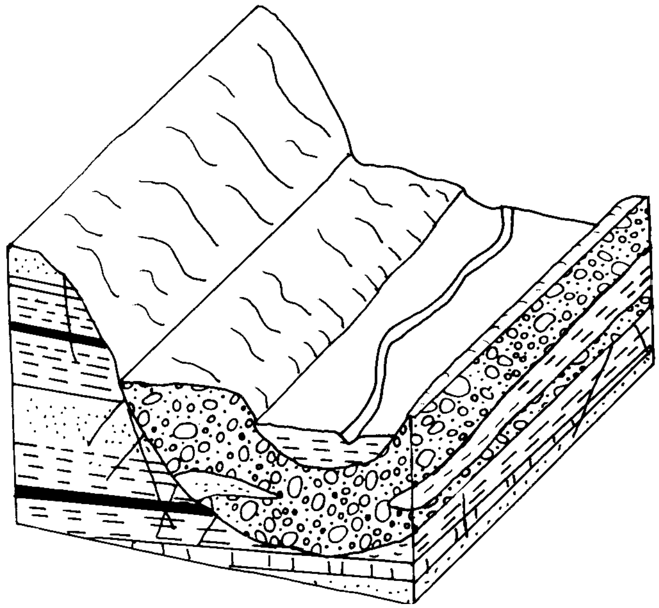
GWPP index values for the hydrogeologic setting of sand and gravel interbedded in glacial till range from 108 to 112 with the total number of GWPP index calculations equaling 2.



7Ba Outwash

This hydrogeologic setting consists of areas of outwash terraces that do not overlie buried valleys. Many of these areas contain modern streams and are located at the "head" or margins of buried valleys. This setting also encompasses some areas of kame terraces. This setting is characterized by flat-lying to gently rolling topography and low relief. The terraces usually occur at higher elevations than the modern floodplains. The aquifer consists of sand and gravel outwash deposits. Yields average 10 to 25 gpm with maximum local yields up to 100 gpm. Test drilling may be necessary to locate higher-yielding areas. Vadose zone media consists of bedded sandy to gravelly outwash interbedded with finer alluvial and lacustrine deposits. Depth to water is typically shallow and the aquifer may be in direct hydraulic connection with overlying streams. Soils vary from silt loam to sandy loam depending whether fine-grained alluvial material is capping the coarser outwash. Recharge is moderately high due to the relatively flat topography, relatively permeable soils and vadose media, and the shallow depth to water.

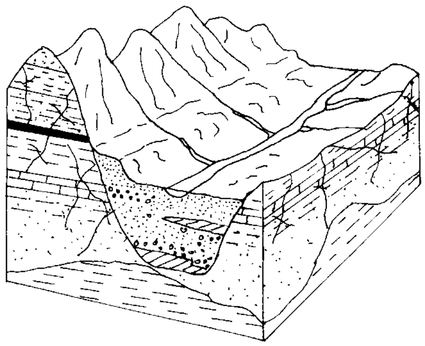
GWPP index values for the hydrogeologic setting of outwash range from 129 to 158 with the total number of GWPP index calculations equaling 12.



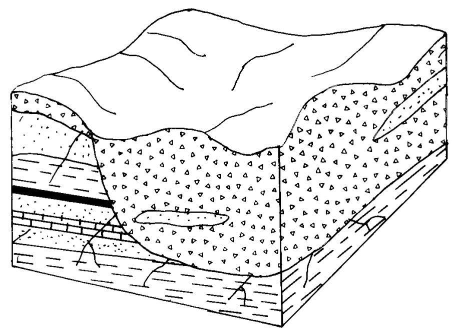
7Bb Outwash Over Bedded Sedimentary Rocks

This hydrogeologic setting consists of areas of thinner glacial drift underlying outwash or kame terraces. This setting is relatively similar to the 7Ba- Outwash hydrogeologic setting except that the outwash in the 7Bb setting is generally too thin to comprise the aquifer. The aquifer consists of the underlying, fractured, interbedded sandstones, shales, siltstones. limestones, and coals of the Pennsylvanian System. Yields typically range from 10 to 25 gpm. This setting typically flanks buried valleys or areas of thicker outwash included in the 7Ba - Outwash setting. Vadose zone media consists of bedded sand and gravel interlayered with finer alluvial and lacustrine deposits. Depth to water is typically shallow. The bedrock aquifer may or may not be in hydraulic connection with overlying streams. Soils are typically sandy loams. Recharge is moderately high due to the relatively flat topography, relatively permeable soils and vadose media, and the moderately shallow depth to water.

GWPP index values for the hydrogeologic setting of outwash over bedded sedimentary rocks ranges from 119 to 140 with the total number of GWPP index calculations equaling 9.



a)



b)

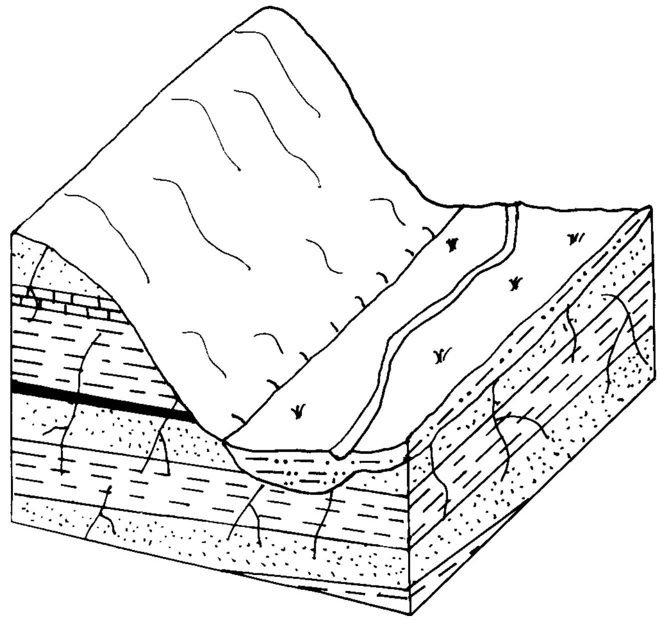
7D Buried Valleys

This hydrogeologic setting varied across Mahoning County. There were two common types or varieties of buried valleys within the county.

The first type of buried valley (block diagram a) is occupied by a modern stream valley, contains abundant outwash or kame deposits, and is easy to distinguish from the surrounding steep bedrock and till uplands. Valley floors are relatively flat and broad. These valleys contain variable thicknesses of sand and gravel outwash and finer-grained till and lacustrine deposits. The upper 20 to 30 feet is typically composed of sand and gravel outwash terraces or kames. Depth to water is typically less than 30 feet for the trunk of the valley and 30 to 50 feet for the margins. Yields up to 500 gpm have been reported for properly constructed and large diameter wells, typical yields are in the 25 to 100 gpm range. Streams are typically in direct hydraulic connection with the underlying aquifer. Soils are typically silt loams or sandy loams. Recharge is high due to the permeable soils and vadose media, flat topography, and shallow depth to water.

The second type of buried valley (block diagram b) extends across upland areas. They are not easily distinguished from the surrounding topography. Relief varies from moderate to highly rolling, especially in areas of end moraine. These valleys are usually not overlain by streams or only intermittent streams. The aquifer consists of thin lenses of sand and gravel interbedded in thick sequences of glacial till or lacustrine deposits. Yields commonly range from 10 to 25 gpm. Depth to water is typically from 30 to 50 feet. Soils are typically clay loams or silt loams derived from the weathering till. Till is the vadose zone media. Recharge is typically moderate to low because of the greater depth to water, lower permeability soils and vadose media, and steeper topography.

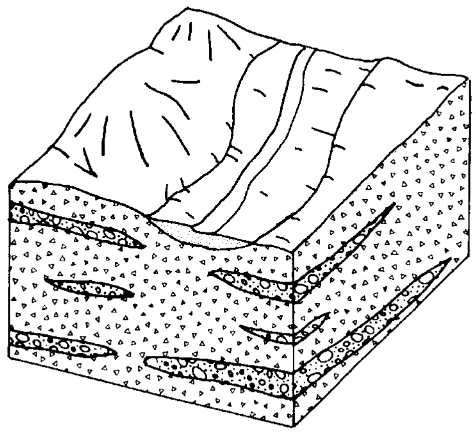
GWPP index values for the hydrogeologic setting of buried valley range from 106 to 168 with the total number of GWPP index calculations equaling 64.



7Ec Alluvium Over Bedded Sedimentary Rock

This hydrogeologic setting is predominantly found in upland areas of southern and eastern Mahoning County. This setting consists of small tributary streams in upland areas with thin glacial cover. Narrow, flat-bottomed stream valleys flanked by steeper, bedrock-controlled uplands characterize the setting. The aquifer consists of fractured, interbedded sandstones, shales, limestones and coals of the Pennsylvanian System and interbedded shales, siltstones, and fine-grained sandstones of the Mississippian System. Yields developed from the fractures and bedding planes of the bedrock range from 10 to 25 gpm. Soils vary but are usually silt loams. Vadose zone media is typically the silty alluvium. The depth to water is commonly shallow, averaging from 10 to 30 feet. The alluvium is commonly in direct hydraulic connection with the underlying aquifer. Recharge is moderate to high due to the shallow depth to water, flat-lying topography, proximity of modern streams, and the moderately low permeability of the soils, alluvium, and bedrock.

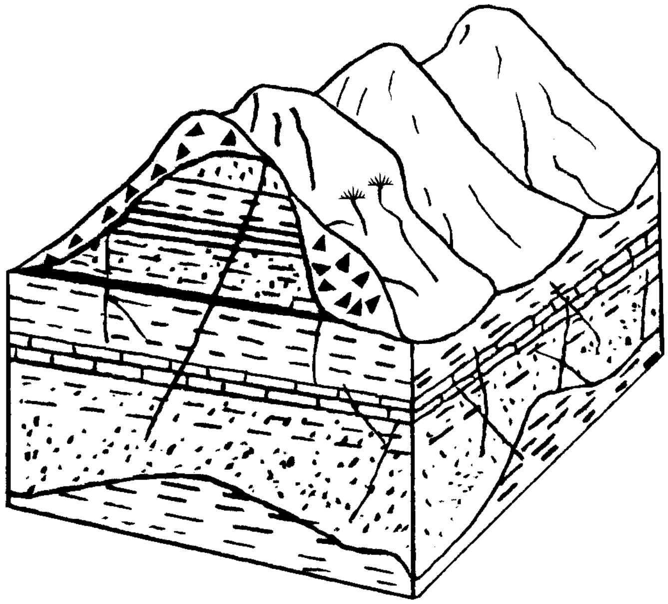
GWPP index values for the hydrogeologic setting of alluvium over bedded sedimentary rocks ranges from 120 to 147 with the total number of GWPP index calculations equaling 14.



7Ed Alluvium Over Glacial Till

This hydrogeologic setting is comprised of flat-lying floodplains and stream terraces containing thin to moderate thicknesses of modern alluvium . This setting is similar to the 7Af - Sand and Gravel Interbedded in Glacial Till setting except for the presence of the modern stream and related deposits. The stream may or may not be in direct hydraulic connection with the underlying sand and gravel lenses that constitute the aquifer. The surficial, silty alluvium is typically more permeable than the surrounding till. The alluvium is too thin to be considered the aquifer. Soils are typically silt loams. Yields commonly range from 10 to 25 gpm. Depth to water is typically shallow with depths averaging less than 30 feet. Recharge is moderate to low due to the shallow depth to water, flat-lying topography, and the relatively low permeability of the glacial till.

GWPP index values for the hydrogeologic setting Alluvium Over Glacial Till range from 127 to 147 with the total number of GWPP index calculations equaling 4.



7G Thin Till Over Bedded Sedimentary Rock

This hydrogeologic setting is characterized by relatively rugged topography and high relief. This setting primarily consists of steep, bedrock-controlled ridges flanking river valleys in the northeastern part of the county. Glacial till is absent or thinly overlies (less than 45 inches) the bedrock surface. Soils are typically sandy loams and are derived from weathering bedrock and the thin, remaining till. The aquifer consists of interbedded sandstones, shales, limestones, clay, and coal of the Pennsylvanian System or interbedded shales, siltstones, and fine-grained sandstones of the Mississippian System. The vadose zone media is also composed of the same fractured, interbedded sedimentary units. Depth to water is moderate with depths ranging from 20 to 50 feet. Yields range from 3 to 25 gpm. Recharge is moderate due to the steep slopes, the moderate depth to water, and relatively permeable soils and fractured vadose zone media.

GWPP index values for the hydrogeologic setting of thin till over bedded sedimentary rock range from 99 to 134 with the total number of GWPP index calculations equaling 20.

Table 15. Hydrogeologic Settings, DRASTIC Factors, and Ratings

Setting	Depth To Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% Slope)	Vadose Zone Media	Hydraulic Conductivity	Rating
7Aa001	30-50	4-7	interbedded ss/sh/ls/coal	Silty Loam	2-6	till	1-100	104
7Aa002	30-50	4-7	interbedded ss/sh/ls/coal	Clay Loam	0-2	till	1-100	103
7Aa003	30-50	4-7	interbedded ss/sh/ls/coal	Silty Loam	0-2	till	1-100	105
7Aa004	50-75	2-4	interbedded ss/sh/ls/coal	Silty Loam	6-12	till	1-100	78
7Aa005	30-50	4-7	interbedded ss/sh/ls/coal	Silty Loam	12-18	till	1-100	98
7Aa006	30-50	4-7	interbedded ss/sh/ls/coal	Sandy Loam	6-12	sandy till	1-100	109
7Aa007	50-75	2-4	interbedded ss/sh/ls/coal	Sandy Loam	6-12	till	1-100	82
7Aa008	30-50	4-7	interbedded ss/sh/ls/coal	Silty Loam	6-12	sandy till	1-100	105
7Aa009	50-75	2-4	interbedded ss/sh/ls/coal	Silty Loam	2-6	interbedded ss/sh/ls/coal	1-100	79
7Aa010	30-50	4-7	interbedded ss/sh/ls/coal	Silty Loam	6-12	till	1-100	100
7Aa011	15-30	4-7	interbedded ss/sh/ls/coal	Silty Loam	2-6	till	1-100	114
7Aa012	30-50	4-7	interbedded ss/sh/ls/coal	Silty Loam	0-2	till	1-100	102
7Aa013	50-75	2-4	interbedded ss/sh/ls/coal	Silty Loam	0-2	interbedded ss/sh/ls/coal	1-100	80
7Aa014	50-75	2-4	interbedded ss/sh/ls/coal	Silty Loam	0-2	interbedded ss/sh/ls/coal	1-100	83
7Aa015	30-50	4-7	interbedded ss/sh/ls/coal	Sandy Loam	2-6	sandy till	1-100	113
7Aa016	30-50	4-7	interbedded ss/sh/ls/coal	Silty Loam	2-6	sandy till	1-100	109
7Aa017	30-50	4-7	interbedded ss/sh/ls/coal	Loam	6-12	sandy till	1-100	107
7Aa018	30-50	4-7	interbedded ss/sh/ls/coal	Silty Loam	2-6	till	1-100	101
7Aa019	30-50	4-7	interbedded ss/sh/ls/coal	Sandy Loam	6-12	till	1-100	104
7Aa020	30-50	4-7	interbedded ss/sh/ls/coal	Sandy Loam	0-2	sandy till	1-100	114
7Aa021	5-15	4-7	interbedded ss/sh/ls/coal	Loam	12-18	till	100-300	132
7Aa022	50-75	2-4	interbedded ss/sh/ls/coal	Clay Loam	0-2	interbedded ss/sh/ls/coal	1-100	78
7Aa023	50-75	2-4	interbedded ss/sh/ls/coal	Silty Loam	2-6	till	1-100	82
7Aa024	30-50	4-7	interbedded ss/sh/ls/coal	Clay Loam	2-6	till	1-100	102

Setting	Depth To Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% Slope)	Vadose Zone Media	Hydraulic Conductivity	Rating
7Aa025	15-30	4-7	interbedded ss/sh/ls/coal	Silty Loam	0-2	till	1-100	115
7Aa026	15-30	4-7	interbedded ss/sh/ls/coal	Sandy Loam	2-6	sandy till	100-300	129
7Aa027	30-50	4-7	interbedded ss/sh/ls/coal	Silty Loam	2-6	till	100-300	110
7Aa028	15-30	4-7	interbedded ss/sh/ls/coal	Sandy Loam	2-6	sandy till	1-100	123
7Aa029	15-30	4-7	interbedded ss/sh/ls/coal	Silty Loam	2-6	sandy till	1-100	119
7Aa030	30-50	4-7	interbedded ss/sh/ls/coal	Silty Loam	0-2	till	100-300	111
7Aa031	5-15	4-7	interbedded ss/sh/ls/coal	Silty Loam	0-2	till	100-300	131
7Aa032	30-50	4-7	interbedded ss/sh/ls/coal	Sandy Loam	2-6	till	1-100	108
7Aa033	15-30	4-7	interbedded ss/sh/ls/coal	Sandy Loam	2-6	till	1-100	118
7Aa034	15-30	4-7	interbedded ss/sh/ls/coal	Sandy Loam	6-12	sandy till	1-100	119
7Aa035	15-30	4-7	interbedded ss/sh/ls/coal	Silty Loam	6-12	till	1-100	110
7Aa036	15-30	4-7	interbedded ss/sh/ls/coal	Sandy Loam	12-18	sandy till	1-100	117
7Aa037	15-30	4-7	interbedded ss/sh/ls/coal	Clay Loam	0-2	till	1-100	113
7Aa038	15-30	4-7	interbedded ss/sh/ls/coal	Clay Loam	2-6	till	1-100	112
7Aa039	15-30	4-7	interbedded ss/sh/ls/coal	Silty Loam	2-6	sandy till	100-300	125
7Aa040	15-30	4-7	interbedded ss/sh/ls/coal	Sandy Loam	6-12	sand + gvl w/silt + clay	100-300	125
7Aa041	15-30	4-7	interbedded ss/sh/ls/coal	Sandy Loam	6-12	till	100-300	120
7Aa042	15-30	4-7	interbedded ss/sh/ls/coal	Silty Loam	0-2	till	100-300	121
7Aa043	15-30	4-7	interbedded ss/sh/ls/coal	Silty Loam	6-12	sandy till	100-300	121
7Aa044	15-30	4-7	interbedded ss/sh/ls/coal	Clay Loam	0-2	till	100-300	119
7Aa045	15-30	4-7	interbedded ss/sh/ls/coal	Loam	0-2	sandy till	100-300	128
7Aa046	30-50	4-7	interbedded ss/sh/ls/coal	Sandy Loam	18+	till	1-100	100
7Aa047	30-50	4-7	interbedded ss/sh/ls/coal	Silty Loam	6-12	till	1-100	97
7Aa048	30-50	4-7	interbedded ss/sh/ls/coal	Silty Loam	12-18	till	1-100	95
7Aa049	30-50	4-7	interbedded ss/sh/ls/coal	Clay Loam	6-12	till	1-100	98
7Aa050	50-75	2-4	interbedded ss/sh/ls/coal	Clay Loam	2-6	till	1-100	80

Setting	Depth To Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% Slope)	Vadose Zone Media	Hydraulic Conductivity	Rating
7Aa051	50-75	2-4	interbedded ss/sh/ls/coal	Loam	6-12	till	1-100	80
7Aa052	15-30	4-7	interbedded ss/sh/ls/coal	Silty Loam	2-6	till	100-300	120
7Aa053	15-30	4-7	interbedded ss/sh/ls/coal	Clay Loam	2-6	till	100-300	118
7Aa054	30-50	4-7	interbedded ss/sh/ls/coal	Clay Loam	6-12	till	100-300	104
7Aa055	15-30	4-7	interbedded ss/sh/ls/coal	Clay Loam	2-6	sandy till	1-100	117
7Aa056	15-30	4-7	interbedded ss/sh/ls/coal	Clay Loam	2-6	till	1-100	115
7Aa057	30-50	4-7	interbedded ss/sh/ls/coal	Shrink/Swell Clay	0-2	silt/clay	1-100	106
7Aa058	15-30	4-7	interbedded ss/sh/ls/coal	Shrink/Swell Clay	2-6	silt/clay	100-300	121
7Aa059	15-30	4-7	interbedded ss/sh/ls/coal	Shrink/Swell Clay	6-12	silt/clay	1-100	111
7Aa060	15-30	4-7	interbedded ss/sh/ls/coal	Clay Loam	12-18	till	1-100	106
7Aa061	15-30	4-7	interbedded ss/sh/ls/coal	Silty Loam	12-18	till	1-100	108
7Aa062	30-50	4-7	interbedded ss/sh/ls/coal	Loam	12-18	sandy till	1-100	105
7Aa063	30-50	4-7	interbedded ss/sh/ls/coal	Silty Loam	18+	till	1-100	96
7Aa064	30-50	4-7	interbedded ss/sh/ls/coal	Sandy Loam	2-6	sandy till	100-300	119
7Aa065	50-75	2-4	interbedded ss/sh/ls/coal	Silty Loam	2-6	till	100-300	88
7Aa067	30-50	4-7	interbedded ss/sh/ls/coal	Clay Loam	2-6	till	100-300	108
7Aa068	30-50	4-7	interbedded ss/sh/ls/coal	Sandy Loam	12-18	sand + gvl w/silt + clay	1-100	107
7Aa069	15-30	4-7	interbedded ss/sh/ls/coal	Shrink/Swell Clay	0-2	silt/clay	1-100	116
7Aa070	15-30	4-7	interbedded ss/sh/ls/coal	Clay Loam	6-12	till	1-100	108
7Aa071	15-30	4-7	interbedded ss/sh/ls/coal	Sandy Loam	0-2	sandy till	1-100	124
7Aa072	30-50	4-7	interbedded ss/sh/ls/coal	Clay Loam	0-2	till	100-300	109
7Aa073	30-50	4-7	interbedded ss/sh/ls/coal	Shrink/Swell Clay	0-2	silt/clay	1-100	111
7Aa074	15-30	4-7	interbedded ss/sh/ls/coal	Shrink/Swell Clay	0-2	till	100-300	127
7Aa075	15-30	4-7	interbedded ss/sh/ls/coal	Clay Loam	6-12	till	100-300	114
7Aa076	15-30	4-7	interbedded ss/sh/ls/coal	Sandy Loam	2-6	till	100-300	124
7Aa077	30-50	4-7	interbedded ss/sh/ls/coal	Shrink/Swell Clay	0-2	till	100-300	117

Setting	Depth To Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% Slope)	Vadose Zone Media	Hydraulic Conductivity	Rating
7Aa078	30-50	4-7	interbedded ss/sh/ls/coal	Shrink/Swell Clay	0-2	silt/clay	100-300	112
7Aa079	15-30	4-7	interbedded ss/sh/ls/coal	Clay Loam	12-18	till	100-300	112
7Aa080	15-30	4-7	interbedded ss/sh/ls/coal	Shrink/Swell Clay	6-12	till	100-300	122
7Aa081	30-50	4-7	interbedded ss/sh/ls/coal	Shrink/Swell Clay	12-18	till	100-300	110
7Aa082	30-50	4-7	interbedded ss/sh/ls/coal	Shrink/Swell Clay	2-6	silt/clay	100-300	111
7Aa083	15-30	4-7	interbedded ss/sh/ls/coal	Shrink/Swell Clay	0-2	silt/clay	100-300	122
7Aa084	30-50	4-7	interbedded ss/sh/ls/coal	Shrink/Swell Clay	2-6	silt/clay	1-100	105
7Aa085	5-15	4-7	interbedded ss/sh/ls/coal	Shrink/Swell Clay	0-2	silt/clay	100-300	132
7Aa086	15-30	4-7	interbedded ss/sh/ls/coal	Sandy Loam	0-2	sandy till	100-300	130
7Aa087	30-50	4-7	interbedded ss/sh/ls/coal	Clay Loam	12-18	till	100-300	102
7Aa088	30-50	4-7	interbedded ss/sh/ls/coal	Sandy Loam	0-2	sandy till	100-300	120
7Aa089	15-30	4-7	interbedded ss/sh/ls/coal	Clay Loam	0-2	sandy till	100-300	124
7Aa090	15-30	4-7	interbedded ss/sh/ls/coal	Shrink/Swell Clay	6-12	silt/clay	100-300	117
7Aa091	15-30	4-7	interbedded ss/sh/ls/coal	Shrink/Swell Clay	12-18	silt/clay	1-100	109
7Aa092	50-75	2-4	interbedded ss/sh/ls/coal	Shrink/Swell Clay	0-2	silt/clay	100-300	90
7Aa093	30-50	4-7	interbedded ss/sh/ls/coal	Shrink/Swell Clay	6-12	silt/clay	100-300	107
7Aa094	15-30	4-7	interbedded ss/sh/ls/coal	Sandy Loam	12-18	sandy till	100-300	123
7Aa095	50-75	2-4	interbedded ss/sh/ls/coal	Clay Loam	0-2	till	100-300	87
7Aa096	50-75	2-4	interbedded ss/sh/ls/coal	Clay Loam	2-6	till	100-300	86
7Aa097	15-30	4-7	interbedded ss/sh/ls/coal	Loam	6-12	sandy till	1-100	117
7Aa098	30-50	4-7	interbedded ss/sh/ls/coal	Loam	2-6	till	100-300	112
7Aa099	30-50	4-7	interbedded ss/sh/ls/coal	Silty Loam	6-12	till	100-300	106
7Aa100	30-50	4-7	interbedded ss/sh/ls/coal	Sandy Loam	12-18	till	1-100	102
7Aa101	15-30	4-7	interbedded ss/sh/ls/coal	Sandy Loam	6-12	till	1-100	114
7Aa102	30-50	4-7	interbedded ss/sh/ls/coal	Clay Loam	12-18	till	1-100	96
7Aa103	30-50	4-7	interbedded ss/sh/ls/coal	Sandy Loam	6-12	sandy till	100-300	115

Setting	Depth To Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% Slope)	Vadose Zone Media	Hydraulic Conductivity	Rating
7Aa104	5-15	4-7	interbedded ss/sh/ls/coal	Clay Loam	0-2	till	100-300	129
7Aa105	5-15	4-7	interbedded ss/sh/ls/coal	Sandy Loam	2-6	sandy till	100-300	139
7Aa106	30-50	4-7	interbedded ss/sh/ls/coal	Loam	6-12	sandy till	100-300	113
7Aa107	50-75	2-4	interbedded ss/sh/ls/coal	Silty Loam	6-12	till	100-300	84
7Aa108	30-50	4-7	interbedded ss/sh/ls/coal	Silty Loam	12-18	till	100-300	104
7Af1	30-50	4-7	sand + gravel	Silty Loam	0-2	till	100-300	108
7Af2	30-50	4-7	sand + gravel	Sandy Loam	0-2	till	100-300	112
7Ba01	5-15	4-7	sand + gravel	Sandy Loam	0-2	sand + gvl w/silt + clay	300-700	143
7Ba02	15-30	4-7	sand + gravel	Sandy Loam	2-6	sand + gvl w/silt + clay	300-700	132
7Ba03	5-15	4-7	sand + gravel	Sandy Loam	0-2	sand + gvl w/silt + clay	300-700	148
7Ba04	5-15	4-7	sand + gravel	Silty Loam	0-2	sand + gvl w/silt + clay	300-700	139
7Ba05	15-30	4-7	sand + gravel	Shrink/Swell Clay	2-6	silt/clay	300-700	129
7Ba06	5-15	7-10	sand + gravel	Sandy Loam	0-2	sand + gvl w/silt + clay	300-700	151
7Ba07	15-30	7-10	sand + gravel	Sandy Loam	2-6	sand + gvl w/silt + clay	300-700	143
7Ba08	15-30	4-7	sand + gravel	Clay Loam	0-2	sand + gvl w/silt + clay	300-700	130
7Ba09	5-15	7-10	sand + gravel	Sandy Loam	0-2	sand + gvl w/silt + clay	300-700	154
7Ba10	5-15	7-10	sand + gravel	Loam	0-2	sand + gvl w/silt + clay	300-700	152
7Ba11	5-15	7-10	sand + gravel	Clay Loam	0-2	sand + gvl w/silt + clay	300-700	145
7Ba12	5-15	7-10	sand + gravel	Sandy Loam	2-6	sand + gvl w/silt + clay	300-700	158
7Bb1	5-15	4-7	interbedded ss/sh/ls/coal	Sandy Loam	0-2	sand + gvl w/silt + clay	1-100	134
7Bb2	15-30	4-7	interbedded ss/sh/ls/coal	Sandy Loam	2-6	sand + gvl w/silt + clay	1-100	123
7Bb3	15-30	4-7	interbedded ss/sh/ls/coal	Sandy Loam	0-2	sand + gvl w/silt + clay	1-100	124
7Bb4	5-15	4-7	interbedded ss/sh/ls/coal	Sandy Loam	2-6	sand + gvl w/silt + clay	1-100	133
7Bb5	15-30	4-7	interbedded ss/sh/ls/coal	Loam	0-2	sand + gvl w/silt + clay	1-100	122

Setting	Depth To Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% Slope)	Vadose Zone Media	Hydraulic Conductivity	Rating
7Bb6	15-30	4-7	interbedded ss/sh/ls/coal	Silty Loam	0-2	sand + gvl w/silt + clay	1-100	120
7Bb7	5-15	4-7	interbedded ss/sh/ls/coal	Sandy Loam	0-2	sand + gvl w/silt + clay	100-300	140
7Bb8	15-30	4-7	interbedded ss/sh/ls/coal	Sandy Loam	0-2	sand + gvl w/silt + clay	100-300	130
7Bb9	15-30	4-7	interbedded ss/sh/ls/coal	Sandy Loam	6-12	sand + gvl w/silt + clay	1-100	119
7D01	5-15	7-10	sand + gravel	Sandy Loam	0-2	sand + gvl w/silt + clay	300-700	151
7D02	5-15	7-10	sand + gravel	Sandy Loam	0-2	sand	300-700	159
7D03	5-15	7-10	sand + gravel	Peat	0-2	sand	300-700	163
7D04	15-30	4-7	sand + gravel	Silty Loam	2-6	sand + gvl w/silt + clay	300-700	131
7D05	5-15	7-10	sand + gravel	Peat	0-2	sand + gvl w/silt + clay	300-700	163
7D05	5-15	7-10	sand + gravel	Silty Loam	0-2	sand + gvl w/silt + clay	300-700	155
7D06	5-15	7-10	sand + gravel	Sandy Loam	0-2	sand + gvl w/silt + clay	700-1000	168
7D07	15-30	7-10	sand + gravel	Sandy Loam	2-6	sand + gvl w/silt + clay	300-700	148
7D08	30-50	4-7	sand + gravel	Silty Loam	2-6	sand + gvl w/silt + clay	300-700	121
7D09	15-30	4-7	sand + gravel	Silty Loam	2-6	sand + gvl w/silt + clay	300-700	128
7D10	5-15	7-10	sand + gravel	Clay Loam	0-2	sand + gvl w/silt + clay	300-700	145
7D11	15-30	4-7	sand + gravel	Sandy Loam	2-6	sand + gvl w/silt + clay	700-1000	149
7D12	15-30	4-7	sand + gravel	Silty Loam	2-6	till	300-700	123
7D13	5-15	7-10	sand + gravel	Silty Loam	0-2	sand + gvl w/silt + clay	700-1000	164
7D14	5-15	7-10	sand + gravel	Silty Loam	0-2	sand + gvl w/silt + clay	300-700	158
7D15	5-15	7-10	sand + gravel	Clay Loam	0-2	sand + gvl w/silt + clay	300-700	156
7D16	30-50	4-7	sand + gravel	Sandy Loam	2-6	sand + gvl w/silt + clay	300-700	125
7D17	5-15	7-10	sand + gravel	Sandy Loam	0-2	sand + gvl w/silt + clay	300-700	162
7D18	15-30	4-7	sand + gravel	Clay Loam	0-2	till	300-700	122
7D19	5-15	7-10	sand + gravel	Silty Loam	0-2	sand + gvl w/silt + clay	300-700	150
7D20	15-30	7-10	sand + gravel	Sandy Loam	2-6	sand + gvl w/silt + clay	300-700	143
7D21	15-30	4-7	sand + gravel	Clay Loam	2-6	silt/clay	300-700	124
7D21	15-30	4-7	sand + gravel	Clay Loam	2-6	till	300-700	124

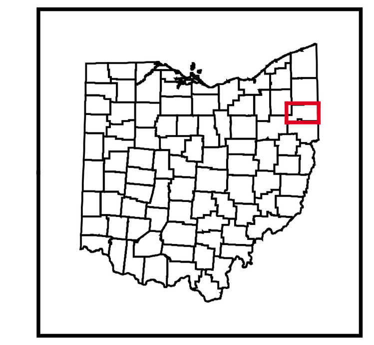
Setting	Depth To Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% Slope)	Vadose Zone Media	Hydraulic Conductivity	Rating
7D22	15-30	4-7	sand + gravel	Shrink/Swell Clay	2-6	silt/clay	300-700	132
7D23	15-30	4-7	sand + gravel	Shrink/Swell Clay	6-12	silt/clay	300-700	128
7D24	15-30	4-7	sand + gravel	Sandy Loam	6-12	sand + gvl w/silt + clay	300-700	131
7D25	15-30	7-10	sand + gravel	Sandy Loam	2-6	sand + gvl w/silt + clay	700-1000	157
7D26	15-30	7-10	sand + gravel	Sandy Loam	0-2	sand + gvl w/silt + clay	300-700	149
7D27	30-50	4-7	sand + gravel	Silty Loam	6-12	till	100-300	106
7D28	30-50	4-7	sand + gravel	Silty Loam	0-2	till	100-300	108
7D29	15-30	4-7	sand + gravel	Silty Loam	0-2	sand + gvl w/silt + clay	100-300	118
7D30	15-30	4-7	sand + gravel	Silty Loam	0-2	sand + gvl w/silt + clay	300-700	145
7D31	15-30	4-7	sand + gravel	Sandy Loam	0-2	sand + gvl w/silt + clay	300-700	136
7D32	15-30	4-7	sand + gravel	Sandy Loam	6-12	sand + gvl w/silt + clay	300-700	128
7D33	15-30	4-7	sand + gravel	Silty Loam	0-2	sand + gvl w/silt + clay	300-700	132
7D34	5-15	7-10	sand + gravel	Peat	0-2	sand	300-700	155
7D35	5-15	7-10	sand + gravel	Silty Loam	0-2	sand	300-700	147
7D36	30-50	4-7	sand + gravel	Silty Loam	6-12	sand + gvl w/silt + clay	300-700	114
7D37	5-15	7-10	sand + gravel	Loam	0-2	sand + gvl w/silt + clay	700-1000	166
7D38	30-50	4-7	sand + gravel	Clay Loam	2-6	till	300-700	111
7D39	15-30	4-7	interbedded ss/sh/ls/coal	Silty Loam	6-12	sand + gvl w/silt + clay	1-100	115
7D40	5-15	4-7	sand + gravel	Sandy Loam	0-2	sand + gvl w/silt + clay	300-700	146
7D41	15-30	4-7	sand + gravel	Sandy Loam	0-2	sand	300-700	133
7D42	15-30	4-7	sand + gravel	Silty Loam	0-2	sand + gvl w/silt + clay	1000-2000	150
7D43	15-30	4-7	sand + gravel	Shrink/Swell Clay	0-2	silt/clay	1000-2000	151
7D44	15-30	4-7	sand + gravel	Clay Loam	0-2	till	700-1000	134
7D45	5-15	7-10	sand + gravel	Silty Loam	0-2	sand + gvl w/silt + clay	1000-2000	168
7D46	15-30	4-7	sand + gravel	Shrink/Swell Clay	0-2	silt/clay	300-700	128
7D47	15-30	4-7	sand + gravel	Clay Loam	0-2	till	300-700	125
7D48	15-30	4-7	sand + gravel	Shrink/Swell Clay	0-2	silt/clay	300-700	125
7D49	15-30	4-7	sand + gravel	Clay Loam	0-2	till	100-300	119
7D50	5-15	4-7	sand + gravel	Shrink/Swell Clay	0-2	silt/clay	300-700	135

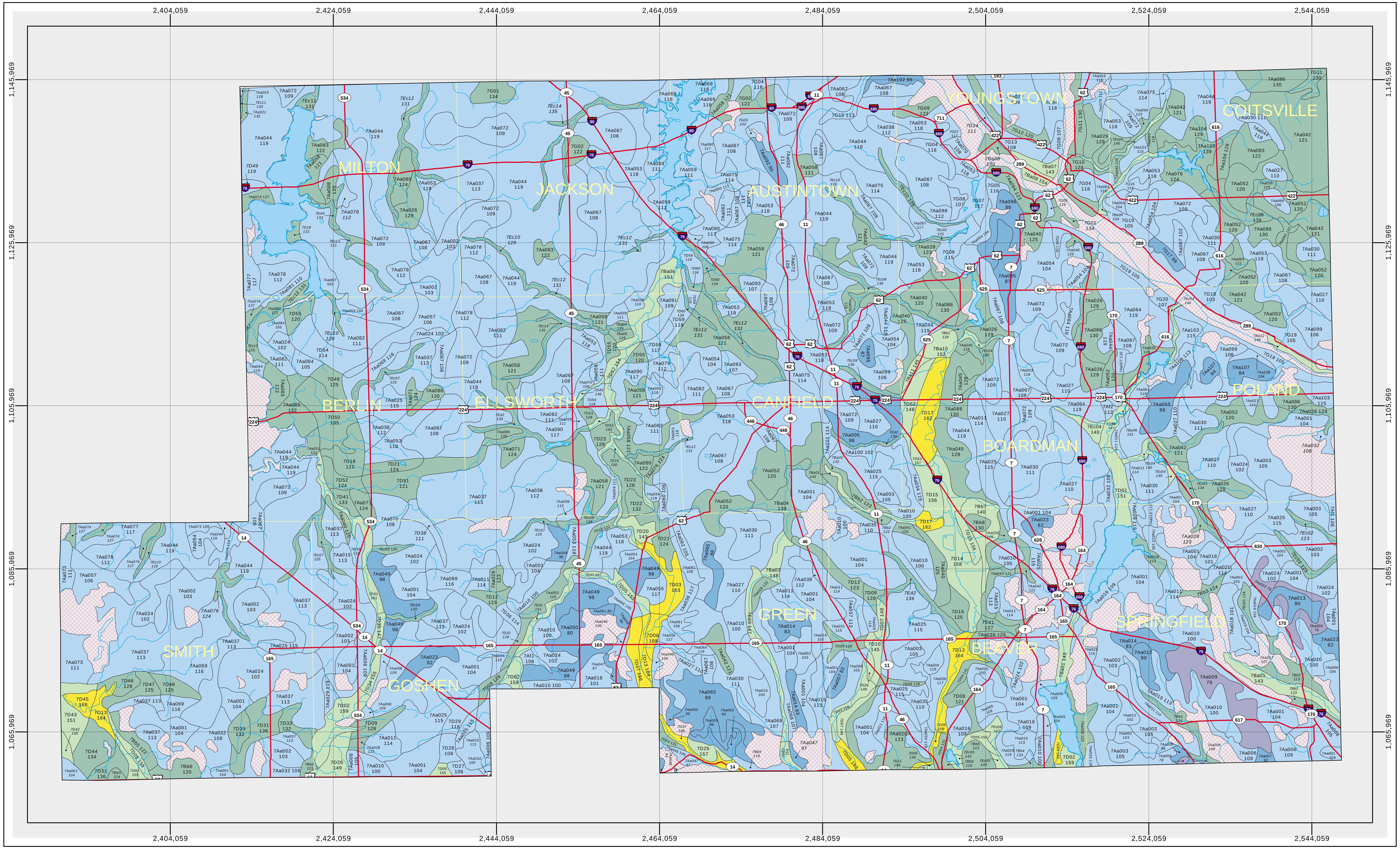
Setting	Depth To Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% Slope)	Vadose Zone Media	Hydraulic Conductivity	Rating
7D51	15-30	4-7	sand + gravel	Clay Loam	2-6	till	300-700	121
7D52	15-30	4-7	sand + gravel	Silty Loam	0-2	till	300-700	124
7D53	5-15	4-7	sand + gravel	Silty Loam	0-2	sand	300-700	142
7D54	30-50	4-7	sand + gravel	Shrink/Swell Clay	2-6	silt/clay	300-700	114
7D55	15-30	4-7	sand + gravel	Shrink/Swell Clay	6-12	silt/clay	300-700	120
7D56	30-50	4-7	sand + gravel	Shrink/Swell Clay	6-12	silt/clay	300-700	118
7D57	5-15	7-10	sand + gravel	Sandy Loam	0-2	sand	300-700	154
7D58	15-30	4-7	sand + gravel	Clay Loam	6-12	till	300-700	117
7D59	15-30	4-7	sand + gravel	Shrink/Swell Clay	12-18	silt/clay	300-700	118
7D60	5-15	4-7	sand + gravel	Silty Loam	0-2	till	300-700	134
7D61	5-15	7-10	sand + gravel	Sandy Loam	0-2	sand	300-700	157
7D62	5-15	7-10	sand + gravel	Clay Loam	0-2	sand + gvl w/silt + clay	300-700	148
7Ec01	15-30	4-7	interbedded ss/sh/ls/coal	Sandy Loam	0-2	sand + gvl w/silt + clay	1-100	124
7Ec02	5-15	4-7	interbedded ss/sh/ls/coal	Clay Loam	0-2	silt/clay	1-100	123
7Ec03	5-15	4-7	interbedded ss/sh/ls/coal	Sandy Loam	0-2	sand + gvl w/silt + clay	1-100	134
7Ec04	5-15	4-7	interbedded ss/sh/ls/coal	Sandy Loam	0-2	sand + gvl w/silt + clay	100-300	140
7Ec05	5-15	7-10	interbedded ss/sh/ls/coal	Silty Loam	0-2	sand + gvl w/silt + clay	1-100	143
7Ec06	5-15	7-10	interbedded ss/sh/ls/coal	Sandy Loam	0-2	sand + gvl w/silt + clay	1-100	147
7Ec07	5-15	4-7	interbedded ss/sh/ls/coal	Silty Loam	0-2	silt/clay	1-100	125
7Ec08	5-15	4-7	interbedded ss/sh/ls/coal	Silty Loam	0-2	sand + gvl w/silt + clay	100-300	136
7Ec09	15-30	4-7	interbedded ss/sh/ls/coal	Silty Loam	0-2	sand + gvl w/silt + clay	1-100	120
7Ec10	5-15	4-7	interbedded ss/sh/ls/coal	Clay Loam	0-2	silt/clay	100-300	129
7Ec11	5-15	4-7	interbedded ss/sh/ls/coal	Loam	0-2	silt/clay	100-300	133
7Ec12	5-15	4-7	interbedded ss/sh/ls/coal	Silty Loam	0-2	silt/clay	100-300	131
7Ec13	15-30	4-7	interbedded ss/sh/ls/coal	Silty Loam	0-2	silt/clay	100-300	121
7Ec14	5-15	4-7	interbedded ss/sh/ls/coal	Sandy Loam	0-2	silt/clay	100-300	135
7Ec15	5-15	4-7	interbedded ss/sh/ls/coal	Clay	0-2	till	100-300	125

Setting	Depth To Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% Slope)	Vadose Zone Media	Hydraulic Conductivity	Rating
7Ed1	15-30	4-7	sand + gravel	Silty Loam	6-12	sand + gvl w/silt + clay	300-700	127
7Ed2	5-15	4-7	sand + gravel	Silty Loam	0-2	sand + gvl w/silt + clay	300-700	139
7Ed3	5-15	7-10	sand + gravel	Silty Loam	0-2	sand + gvl w/silt + clay	300-700	147
7Ed4	15-30	4-7	sand + gravel	Sandy Loam	0-2	sand + gvl w/silt + clay	300-700	133
7G01	15-30	4-7	interbedded ss/sh/ls/coal	Sandy Loam	2-6	interbedded ss/sh/ls/coal	100-300	134
7G02	30-50	4-7	interbedded ss/sh/ls/coal	Loam	2-6	interbedded ss/sh/ls/coal	100-300	122
7G03	50-75	2-4	interbedded ss/sh/ls/coal	Sandy Loam	2-6	interbedded ss/sh/ls/coal	100-300	102
7G04	30-50	4-7	interbedded ss/sh/ls/coal	Sandy Loam	12-18	interbedded ss/sh/ls/coal	100-300	118
7G05	30-50	4-7	interbedded ss/sh/ls/coal	Loam	12-18	interbedded ss/sh/ls/coal	100-300	116
7G06	15-30	4-7	interbedded ss/sh/ls/coal	Loam	12-18	interbedded ss/sh/ls/coal	1-100	115
7G07	15-30	4-7	interbedded ss/sh/ls/coal	Sandy Loam	12-18	interbedded ss/sh/ls/coal	1-100	117
7G08	30-50	4-7	interbedded ss/sh/ls/coal	Loam	6-12	interbedded ss/sh/ls/coal	1-100	107
7G09	15-30	4-7	interbedded ss/sh/ls/coal	Clay Loam	12-18	interbedded ss/sh/ls/coal	100-300	122
7G10	15-30	4-7	interbedded ss/sh/ls/coal	Sandy Loam	12-18	interbedded ss/sh/ls/coal	100-300	128
7G11	15-30	4-7	interbedded ss/sh/ls/coal	Sandy Loam	6-12	interbedded ss/sh/ls/coal	100-300	130
7G12	30-50	4-7	interbedded ss/sh/ls/coal	Sandy Loam	6-12	interbedded ss/sh/ls/coal	100-300	120
7G13	30-50	4-7	interbedded ss/sh/ls/coal	Sandy Loam	6-12	interbedded ss/sh/ls/coal	1-100	109
7G14	30-50	4-7	interbedded ss/sh/ls/coal	Shrink/Swell Clay	6-12	interbedded ss/sh/ls/coal	1-100	111
7G15	15-30	4-7	interbedded ss/sh/ls/coal	Silty Loam	12-18	interbedded ss/sh/ls/coal	1-100	113
7G16	15-30	4-7	interbedded ss/sh/ls/coal	Sandy Loam	18+	interbedded ss/sh/ls/coal	1-100	115
7G17	30-50	4-7	interbedded ss/sh/ls/coal	Clay Loam	18+	interbedded ss/sh/ls/coal	1-100	99
7G18	30-50	4-7	interbedded ss/sh/ls/coal	Loam	18+	interbedded ss/sh/ls/coal	1-100	103
7G19	30-50	4-7	interbedded ss/sh/ls/coal	Sandy Loam	18+	interbedded ss/sh/ls/coal	1-100	105
7G20	30-50	4-7	interbedded ss/sh/ls/coal	Sandy Loam	12-18	interbedded ss/sh/ls/coal	1-100	107

Ground Water Pollution Potential of Mahoning County

by
Michael P. Angle
Ohio Department of Natural Resources





Ground Water Pollution Potential maps are designed to evaluate the susceptibility of ground water to contamination from surface sources. These maps are based on the DRASTIC system developed for the USEPA (Aller et al., 1987). The DRASTIC system consists of two major elements: the designation of mappable units, termed hydrogeologic settings, and a relative rating system for determining the ground water pollution potential within a hydrogeologic setting. The application of DRASTIC to an area requires the recognition of a set of assumptions made in the development of the system. The evaluation of pollution potential of an area assumes that a contaminant with the mobility of water is introduced at the surface and is flushed into the ground water by precipitation. DRASTIC is not designed to replace specific on-site investigations.

In DRASTIC mapping, hydrogeologic settings form the basis of the system and incorporate the major hydrogeologic factors that affect and control ground water movement and occurrence. The relative rating system is based on seven hydrogeologic factors: Depth to water, net Recharge, Aquifer media, Soil media, Topography, Impact of the vadose zone media, and hydraulic Conductivity. These factors form the acronym DRASTIC. The relative rating system uses a combination of weights and ratings to produce a numerical value called the ground water pollution potential index. Higher index values indicate higher susceptibility to ground water contamination. Polygons (outlined in black on the map at left) are regions where the hydrogeologic setting and the pollution potential index are combined to create a mappable unit with specific hydrogeologic characteristics, which determine the region's relative vulnerability to contamination. Additional information on the DRASTIC system, hydrogeologic settings, ratings, and weighting factors is included in the report.

Description of Map Symbols

Hydrogeologic Region → 7D24 ← Hydrogeologic Setting
170 ← Relative Pollution Potential

Legend

Colors are used to depict the ranges in the pollution potential indexes shown below. Warm colors (red, orange, yellow) represent areas of higher vulnerability (higher pollution potential indexes), while cool colors (green, blue, violet) represent areas of lower vulnerability to contamination (lower pollution potential indexes).

- Roads
- Streams
- Lakes
- Townships

Index Ranges

- Not Rated
- Less Than 79
- 80 - 99
- 100 - 119
- 120 - 139
- 140 - 159
- 160 - 179
- 180 - 199
- Greater Than 200

Black grid represents the State Plane South Coordinate System (NAD27, feet).

0 1 2 3 4 5 Miles

0 1 2 4 6 8 Kilometers

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