GROUND WATER POLLUTION POTENTIAL OF MADISON COUNTY, OHIO
(AFTER HALLFRISCH AND VOYTEK, 1987)

BY

MICHAEL P. ANGLE AND KELLY BARRETT

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ABSTRACT

A ground water pollution potential map of Madison 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 incorporate hydrogeologic factors that 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 Madison County resulted in a map with symbols and colors, which illustrate areas of varying ground water pollution potential indexes ranging from 88 to 179.

Madison County lies entirely within the Glaciated Central hydrogeologic setting. Limestones and dolomites of the Silurian and Devonian Systems compose the aquifer in most of Madison County. Yields in the uppermost carbonate aquifers range from 5 to 100 gallons per minute (gpm). Yields over 100 gpm are possible from larger diameter wells drilled deeper into the limestone.

Sand and gravel outwash and alluvial deposits adjacent to portions of Deer Creek and Little Darby Creek and associated with the Teays Valley are capable of producing yields up to 100 gpm and 500 gpm respectively from large diameter wells. Sand and gravel lenses interbedded in the glacial till locally serve as aquifers in areas of eastern Madison County adjacent to Deer Creek, Little Darby Creek and Big Darby Creek and associated with the Teays Valley. Yields for these sand and gravel lenses range from 5 to 25 gpm. Sand and gravel lenses are more common in areas of thicker drift. The sand and gravel lenses may lie directly on top of the limestone bedrock and serve as the aquifer or provide additional recharge to the underlying bedrock.

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 Madison 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 Kelly Barrett
GIS coverage production and review:	Paul Spahr David Pitzer
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The original Ground Water Pollution Potential of Madison County by Hallfrisch and Voytek, (1987) represented Ohio's initial pilot project for the county-wide ground water pollution potential mapping program using the DRASTIC system. In the process of creating a digital version of the map, it was decided to update the map to better fit the trends, mapping style, and format of recently completed surrounding counties.

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; 5,000 of these wells exist in Madison 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 remediation 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 Madison 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 Madison 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

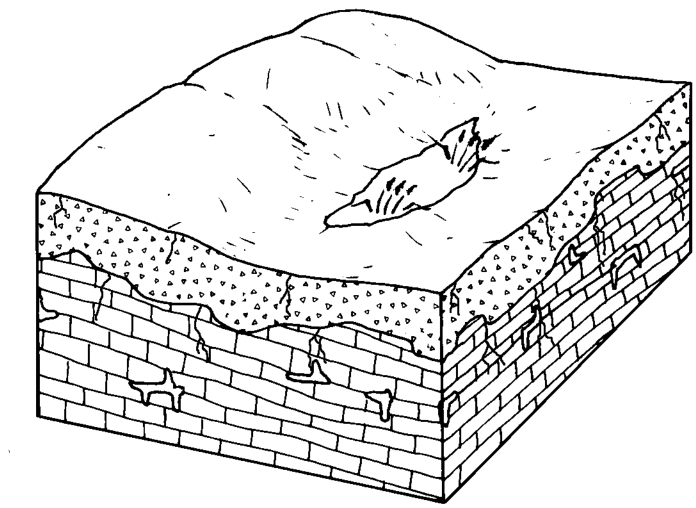
These factors incorporate concepts and mechanisms such as attenuation, retardation, and time or distance of travel of a contaminant with respect to the physical characteristics of the hydrogeologic setting. Broad consideration of these factors and mechanisms coupled with existing conditions in a setting 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.

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.



7Ac-Glacial Till over Limestone

This hydrogeologic setting covers a quarter of Madison County. The area is characterized by flat-lying topography and low relief associated with ground moraine. The vadose zone consists primarily of silty to clayey glacial till. The till may be fractured or jointed, particularly in areas where it is predominantly thin and weathered. Where the till is very thin, fractured limestone is considered to partially be the vadose zone media. The aquifer is composed of fractured Devonian and Silurian limestones and dolomites. These carbonate rocks may contain significant solution features. Depth to water is variable. Soils are typically clay loams derived from till. Maximum ground water yields greater than 100 gpm are possible from the Salina Group in portions of eastern Madison County. Yields decline to the west and south as the higher-yielding Silurian units thin in these directions. Yields average 5 to 25 gpm in the north central and south central portions of the county and less than 5 gpm in small pockets toward the northwest and in the Columbus Limestone. The amount of recharge reflects the vadose zone media and depth to water trends. Areas with higher recharge rates typically have coarser vadose zone materials and shallower depths to water.

GWPP index values for the hydrogeologic setting of Glacial Till over Limestone range from 93 to 157, with the total number of GWPP index calculations equaling 35.

Figure 1. Format and description of the hydrogeologic setting – 7Ac Glacial Till over Limestone.

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/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	

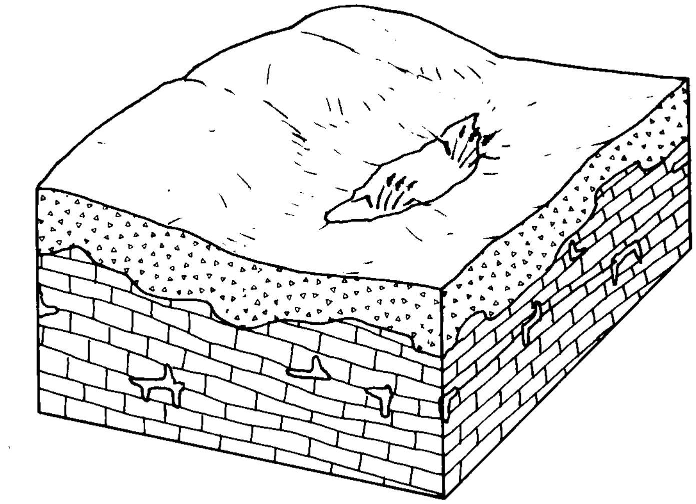
Table 8. Ranges and ratings for hydraulic conductivity

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 7Ac1, Glacial Till over Limestone, identified in mapping Madison 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 142. This numerical value has no intrinsic meaning, but can readily be 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 Madison County produces settings with a wide range of vulnerability to ground water contamination. Calculated pollution potential indexes for the nine settings identified in the county range from 88 to 179.

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 Madison 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 Madison County is included with this report.



SETTING 7Ac1		GENERAL		
FEATURE	**RANGE**	**WEIGHT**	**RATING**	**NUMBER**
Depth to Water	15-30	5	7	35
Net Recharge	4-7	4	6	24
Aquifer Media	Limestone	3	8	24
Soil Media	Clay Loam	2	3	6
Topography	0-2%	1	10	10
Impact of Vadose Zone	Till	5	5	25
Hydraulic Conductivity	700-1000	3	6	18
		DRASTIC	INDEX	142

Figure 2. Description of the hydrogeologic setting – 7Ac1 Glacial Till over Limestone.

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 susceptibility to contamination is greater as the pollution potential index increases. 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:

7Ac1 - defines the hydrogeologic region and setting
142 - defines the relative pollution potential

Here the first number (**7**) refers to the major hydrogeologic region and the upper case letter and lower case letter (**Ac**) 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 second number (**142**) 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. The maps also delineate large man-made and natural features such as lakes, landfills, quarries, and strip mines, but these areas are not rated and therefore are not color-coded.

GENERAL INFORMATION ABOUT MADISON COUNTY

Demographics

Madison County occupies approximately 463 square miles (Gerken and Scherzinger, 1981) in central Ohio (Figure 3). Madison County is bounded to the north by Union County, to the northeast by Franklin County, to the southeast by Pickaway County, to the south by Fayette County, to the southwest by Greene County, to the west by Clark County, and to the northwest by Champaign County.

The approximate population of Madison County, based upon year 2000 census estimates, is 40,213 (Department of Development, Ohio County Profiles, 2004). London is the largest community and the county seat. Agriculture accounts for roughly 93 percent of the land use in Madison County. Row crops are the primary agricultural land use. Woodland is the other major land coverage in the county. More specific information on land use can be obtained from the Ohio Department of Natural Resources, Division of Real Estate and Land Management (REALM), Resource Analysis Program (formerly OCAP).

Climate

The *Hydrologic Atlas for Ohio* (Harstine, 1991) reports an average annual temperature of approximately 52 degrees Fahrenheit for Madison County. The average temperatures increase slightly towards the south. Harstine (1991) shows that precipitation ranges from 38 to 39 inches per year for the county, with precipitation increasing towards the south. The mean annual precipitation for London is 38.39 inches per year based upon a thirty-year (1971-2000) period (National Oceanographic and Atmospheric Administration (NOAA), 2002). The mean annual temperature at London for the same thirty-year period is 50.1 degrees Fahrenheit (NOAA, 2002).

Physiography and Topography

Madison County lies within the Central Till Plains Lowland Province (Frost, 1931, Fenneman, 1938, and Bier, 1956). Brockman (1998) and Schiefer (2002) assign all of Madison County, except a small sliver to the south, as belonging in the Darby Plain District of the Southern Ohio Loamy Till Plain Region. The southern “sliver” area is characterized as being the Mad River Interlobate Plain District, another part of the general Southern Ohio Loamy Till Plain Region. Madison County is characterized by flat ground moraine separated by wide belts of hummocky end moraines. In the western part of the county, these end moraines begin to converge toward the north. There is a large concentration of boulders associated with the Bloomingburg end moraine found at the surface in the area of the convergence.

Figure 3. Location map of Madison County, Ohio.

Modern Drainage

Madison County lies south of the major drainage divide crossing north central Ohio; all of Madison County drains toward the Ohio River. The majority of the county's area lies just east of the major drainage divide between the Scioto River drainage basin and the Great and Little Miami River drainage basins. The extreme southwest corner of Madison county lies within the Little Miami River drainage basin. The major southeasterly flowing tributaries to the Scioto River (from northeast to southwest) include Big Darby Creek, Little Darby Creek, Spring Fork of Little Darby Creek, Deer Creek, Walnut Run, Bradford Creek, Paint Creek, and Sugar Creek.

Pre- and Inter-Glacial Drainage Changes

The drainage patterns of Madison County have changed significantly as a result of the multiple glaciations. The drainage changes are complex and not yet fully understood. More research and data are necessary in both Madison County and adjacent counties. Particularly, well log data for deeper wells that penetrate the entire drift thickness would be helpful in making interpretations. This would allow a more accurate reconstruction of the system of buried valleys and former drainage channels for the county.

Prior to glaciation, the drainage in Ohio is referred to as the Teays Stage. The Teays River drained the southern and western two thirds of the state and was the master river for what is now the upper Ohio River Valley. The resulting valley is not visible at the surface but can be recognized on the bedrock surface using various techniques. The Teays River entered Ohio near Portsmouth and flowed northward, roughly following a course similar to the modern Scioto River. The Teays River then turned sharply westward in northern Pickaway County. Stout et al. (1943) showed the northwesterly flowing, main trunk of the Teays River valley crossing from the southeastern corner of the county and turning toward the north central boundary with Clark County to its exit (Figure 4). Later, Norris and Spicer (1958) and Cummins (1959) depicted the main trunk of the Teays River turning westward farther east than Madison County, near Harrisburg. Modern bedrock topography data compiled by the ODNR, Division of Geological Survey, agrees with Cummins (1959) work. Also, Hoyng (1988 and 1992) used geophysical surveys to better determine the orientation and depth of the Teays River Valley System, especially the major tributaries. From eastern Madison County, the Teays River flowed roughly northwest towards present Grand Lake St. Mary's and then continued due west into Indiana. During the Teays Drainage stage, the Groveport River and several of its smaller tributaries drained Madison County to the west until converging with the Teays River near the present location of London (Stout et al, 1943). At some locations these valleys have over 300 feet of bedrock relief (Norris, 1959).

As ice advanced through Ohio during the pre-Illinoian (Kansan) glaciations, northern and western drainage ways were blocked. Flow backed up these numerous tributaries, forming

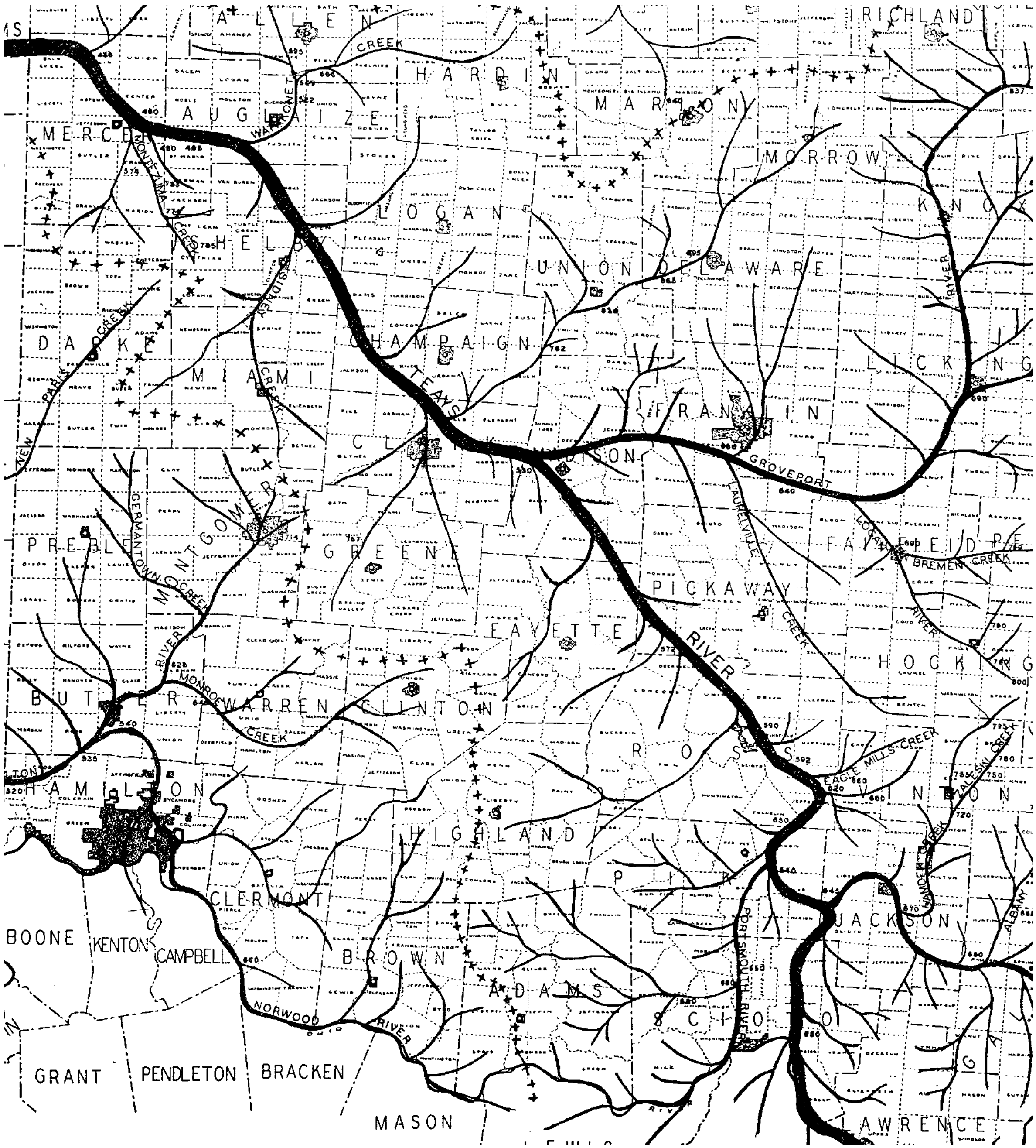


Figure 4. Teays Stage drainage in Madison County (after Stout et al., 1943).

several large lakes. These lakes over-topped, creating spillways and cutting new channels. New drainage systems began to evolve (Stout et al., 1943). Downcutting by these new streams was believed to be relatively rapid and, in many places, the new channels were cut over 100 feet deeper than the previous Teays River System valleys. The new drainage system is referred to as the Deep Stage due to this increased downcutting. In south central Ohio, the new spillways and channels flowed southward, reversing their former flow direction. The main trunk stream was referred to as the Newark River (Stout et al, 1943) which roughly followed a course similar to the modern Scioto River just to the west of the former Teays channel (Figure 5). Tributaries of the Newark River drained most of Madison County. These tributaries could have included a number of southerly flowing tributaries that fed Bourneville Creek, southeastern tributaries that fed the Columbus River, or both. The path of Bourneville Creek closely followed a course similar to modern Paint Creek in Ross County. The Columbus River had a course somewhat comparable to the present Scioto River. Stout et al. (1943) suggested that the northwestern corner of the county was part of the Middletown River drainage. The Middletown River had a course like that of the present Mad River.

The Illinoian ice advance had a continued effect on drainage patterns. Former drainage channels were blocked and filled, and the ancestral Scioto River drainage became better established. The modern drainage patterns of Madison County largely reflect the terrain resulting from the final Wisconsinan glacial advances, particularly end moraines in the western portion of the county.

Glacial Geology

During the Pleistocene Epoch (2 million to 10,000 years before present (Y.B.P.)) several episodes of ice advance occurred in northwestern Ohio. 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). Goldthwait et al. (1961), Pavey et al. (1999), and Brockman et al. (2004) report that the last advance, the Late Wisconsinan Ice Sheet, deposited the surficial till in Madison County. Evidence for the earlier glaciations is lacking or obscured.

Norris (1959) and Norris and Spicer (1958) describe the glacial deposits of Madison County at length. The majority of the glacial deposits in Madison County fall into two main types: (glacial) till and outwash (valley train) deposits. Drift is an older term that collectively refers to the entire sequence of glacial deposits. Overall, drift is thinner in areas of ground moraine and thicker in end moraines. Drift is thick in much of Madison County. There are areas in south and northeastern Madison County where the drift is thinner and the bedrock is closer to the ground surface (ODNR, Division of Geological Survey, Open File Bedrock Topography and ODNR, Division of Water, Glacial State Aquifer Map, 2000).

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:

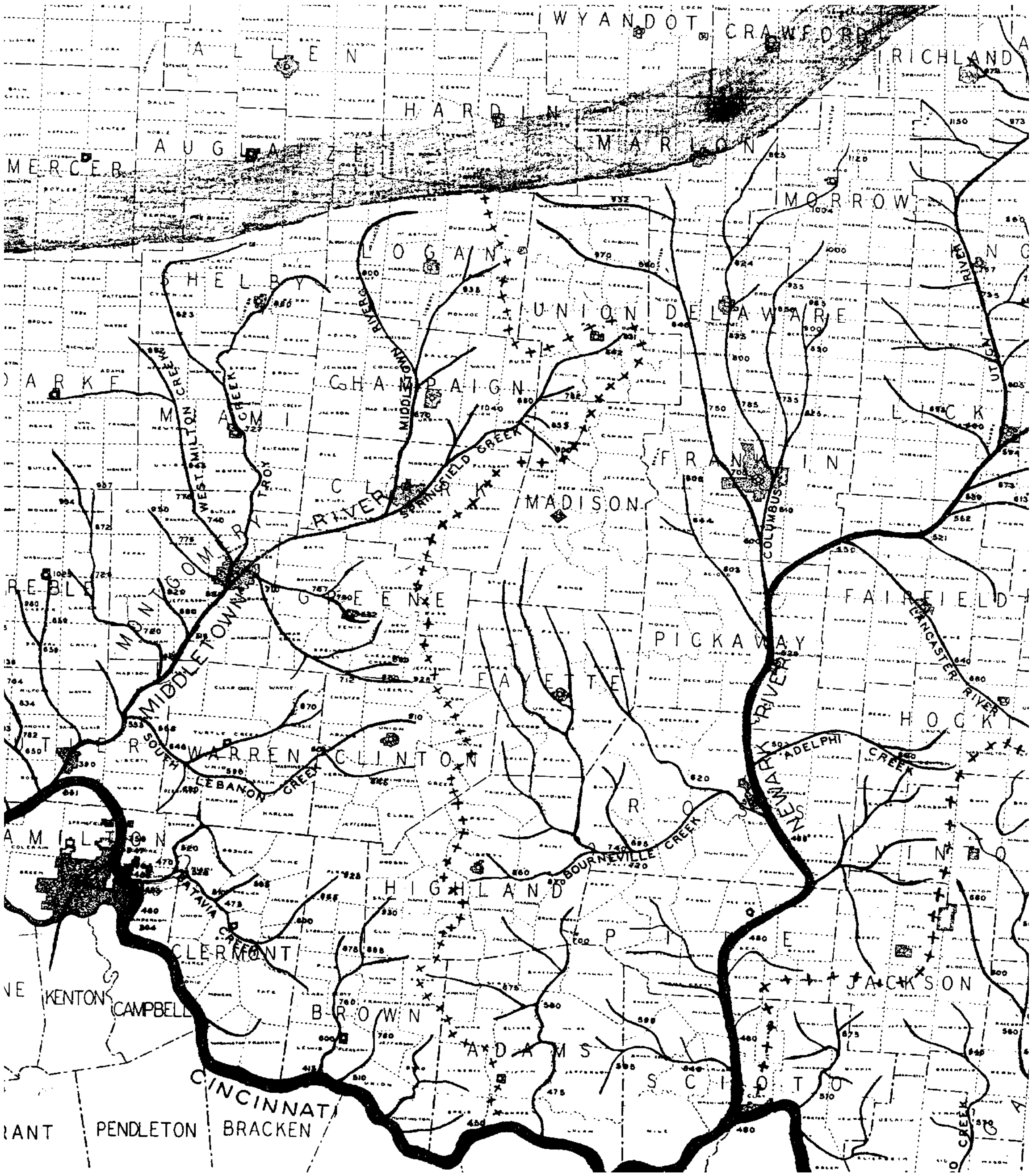


Figure 5. Deep Stage drainage in Madison County (after Stout et al., 1943).

lodgement till and ablation 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 or 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. Lloyd (1998) discusses the mineralogy and the stratigraphy of tills of central Madison County in great detail.

Till has relatively low inherent permeability. Permeability in till is in part dependent upon the primary porosity of the till, which reflects how fine-textured the particular till is. Vertical permeability in till is controlled largely by factors influencing the secondary porosity such as fractures (joints), worm burrows, root channels, sand seams, etc. (Brockman and Szabo, 2000 and Haefner, 2000). Fractures may also interconnect the sand and gravel lenses.

At the land surface, till accounts for two primary landforms: ground moraine and end moraine. End moraines are ridge-like, with terrain that is steeper and more rolling or hummocky. End moraines commonly serve as a local drainage divide due to their ridge-like nature. The London Moraine forms a crescent from the northwest corner to the east central boundary of Madison County where Franklin County and Pickaway County meet. The wide Bloomingburg Moraine occurs intermittently in the southwestern portion of Madison County associated with boulder belts. The Esboro Moraine occurs even further to the southwest of Madison County. At the southwest corner with Greene County and Clark County the Esboro Moraine meets the Reesville and Glendon Moraines and are indistinguishable. There is some occurrence of a boulder belt in this area.

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 Madison County are mostly associated with larger streams like Deer Creek and Little and Big Darby Creeks in the north central and northeastern portions of the county. Outwash deposits associated with stream valleys 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 deposited the outwash. Such streams have multiple channels, which migrate across the width of the valley floor, leaving behind a complex record of deposition and erosion. Deposition of outwash may precede an advancing ice sheet or be associated with a melting ice sheet. As modern streams downcut, the older, now higher elevation remnants of the original valley floor are called terraces. Terraces in Madison County tend to be relatively low elevation and are at elevations just above the current floodplain.

Bedrock Geology

Bedrock underlying the surface of Madison County belongs to Devonian and Silurian Systems. Carbonate (limestone and dolomite) bedrock underlies most of the county. Table 9 summarizes the bedrock stratigraphy found in Madison County. The ODNR, Division of

Table 9. Bedrock stratigraphy of Madison County

System	Group/Formation (Symbol)	Lithologic Description
Devonian	Columbus Limestone (Ddc)	Gray to brown, fossiliferous, massive-bedded limestone and dolomite. This unit occurs to the east in small pockets. Yields range from 5 to 25 gpm.
Silurian	Undifferentiated Salina Dolomite (Sus)	Gray to brown, thin-bedded, argillaceous dolomite. Thin evaporite zones common. This unit occurs in east and central portions of the county. Yields range from 0 to over 100 gpm depending on thickness.
	Tymochtee and Greenfield Dolomites (Stg)	Thin- to massive-bedded, olive-gray to yellowish-brown dolomite. The Tymochtee contains shale partings. The Greenfield has a laminated dolomite lithology. Thickness decreases to the southwest. Yields range from 0 to >100 gpm and decline to the west. Yields also decline in association with the buried valley system in the east central and southeastern portions of the county. These are also found along the eastern portion of the county.
	Lockport Dolomite (Sl)	White to medium gray, medium- to massive-bedded dolomite. Associated with the buried valley system in the east central and southeastern portions of the county. Commonly contains cavernous solution zones. Thickness >100 feet and yields vary from 0 to >100 gpm. Yields from large diameter wells may exceed 100 gpm. Both yield and thickness decrease towards the axis of the buried valley.
	Cedarville Dolomite, Springfield Dolomite, Euphemia Dolomite undivided (Scse)	The Cedarville is a white to gray, massive-bedded dolomite. The Springfield Dolomite is gray to tan, with massive bedding that weathers to a layered brick-like bedding. The Euphemia is a gray to bluish gray dolomite with massive bedding. Occurs in the southwest portion of the county. Yields are 5 to 25 gallons per minute.
	Massie Shale, Laurel Dolomite, Osgood Shale, Dayton Limestone, Brassfield Limestone undivided (Sm-b)	The shales are gray to blue gray with minor limestone and dolomite, thin- to thick-bedded. The Laurel is a gray to tan argillaceous dolomite that is thin- to medium-bedded. The Dayton is a gray to bluish gray medium- to thick-bedded dolomitic limestone. The Brassfield is a white to pink argillaceous limestone that is thin- to medium-bedded. Occurs in southwest Madison County. Yields are less than 5 gpm.
Ordovician	Undivided (Ou)	Gray shale with interbedded dolomite and limestone. Yields are less than 5 gpm. Associated with the deep buried valley system in east central Madison County.

Geological Survey has Open-File Reconnaissance Bedrock Geological Maps completed at a 1:24,000 scale on USGS topographic map bases available for the entire county. The ODNR, Division of Water has Open File Bedrock State Aquifer maps available for the county also.

The youngest unit encountered in Madison County is the fossiliferous Devonian Columbus Limestone. The Columbus is a gray to brown, fossiliferous, massive-bedded limestone and dolomite. It is limited to small areas in eastern Madison County. It was deposited in warm, high-energy seas and reef areas and is less than 100 feet thick. Yields range from 5 to 25 gpm. Yields are somewhat limited due to the thin nature of the unit.

The uppermost Silurian unit is the Undifferentiated Salina Dolomite, which consists of dolomite, fine-grained limestone, and some minor evaporite deposits such as gypsum. These rocks were deposited in warm, shallow tidal areas. Units of the Undifferentiated Salina Dolomite occur in the east and central areas of the county and tend to thin to the west and north. Yield ranges from 0 to 5 gpm to greater than 100 gpm. Yields decrease to the west and in association with the deep buried valley system.

Underlying the Undifferentiated Salina Dolomite are the dolomites and minor shale of the Silurian Tymochtee and Greenfield Formations, which were also deposited in warm, shallow seas. These formations are thin-to massive-bedded dolomites, olive gray to yellow brown in color. The Tymochtee and Greenfield Formations are thickest and produce the highest yields to the northeast. These two formations tend to become thinner along the margins of the deep buried valley system in central and southeastern Madison County. It occurs along most of the eastern portion of the county. Yield ranges from less than 0 to 5 gpm to over 100 gpm.

The Lockport Dolomite was associated with tidal reefs deposited in warm, high-energy shallow seas. The rocks are light-colored massive dolomites. The Lockport has been mapped along the buried valley system in central and southwestern Madison County. Yields range from 5 to 25 gpm to greater than 100 gpm and decrease towards the axis of the buried valley.

The Cedarville Dolomite, Springfield Dolomite, and Euphemia Dolomite have been grouped and mapped together. The units are roughly time-equivalent to the Lockport Group. These units are variable, thin, darker-colored, massive dolomites. They are mapped in southwestern Madison County. Yields are typically 5 to 25 gpm.

The base of the Silurian consists of Massie Shale, Laurel Dolomite, Osgood Shale, and Brassfield Limestone that have been grouped and mapped together. These units vary from bluish shales to gray, massive, dense dolomites. These units are found in southwestern Madison County with yields of 0 to 5 gpm. The low yields partially reflect the thin nature of these units locally.

The Ordovician undivided group forms the base of the geologic column. This unit consists of gray, thin- to medium-bedded shale with interbedded dolomite and limestone. Meager yields (0 to 5 gpm) are available from the upper fractured portion of the aquifer. It occurs in the axis of the deep buried valley system in east-central Madison County. The Ordovician bedrock is not considered to be a useable aquifer in Madison County.

Ground Water Resources

Ground water in Madison County is obtained from both unconsolidated (glacial-alluvial) and consolidated (bedrock) aquifers. The relatively thick, clean outwash deposits along portions of Little Darby Creek and along Deer Creek are among the highest–producing aquifers in Madison County. The outwash deposits associated with the deep buried valley system in the east-central portion of the county is also a very high-producing aquifer. Yields of 100 to 500 gpm (ODNR, Division of Water, Glacial State Aquifer Map, 2000 and Hallfrisch, 1994) can be obtained from properly constructed, large diameter wells completed in these units less than 300 feet deep (Haiker and Raab, 1994). Yields of 25 to 100 gpm can be obtained from sandy outwash and alluvial deposits flanking the Big Darby Creek and most of Little Darby Creek in north-central and northeastern Madison County (ODNR, Division of Water, Glacial State Aquifer Map, 2000).

Thin lenses of sand and gravel interbedded with till comprise the glacial aquifers in most of Madison County. Yields from sand and gravel lenses interbedded with the fine-grained till average 5 to 25 gpm (ODNR, Div. of Water, Glacial State Aquifer Map, 2000). These thin sand and gravel aquifers are commonly associated with areas of ground moraine, end moraine and glacial complexes. Glacial complexes are areas of thick glacial drift that are predominantly comprised of thick, dense till (ODNR, Division of Water, Glacial State Aquifer Map, 2000 and Hallfrisch, 1994). Complexes typically lack surface expression, unlike end moraines and some buried valleys. Modern perennial streams usually do not overlie complexes and they commonly lack major outwash and ice contact deposits. Sand and gravel lenses can directly overlie the carbonate bedrock. These lenses may serve as an aquifer or, more commonly, serve as an extra source of recharge to the underlying fractured bedrock. The sand and gravel may also directly overlie the bedrock and yield 5 to 25 gpm. Drillers may penetrate the bedrock directly below the sand and gravel. In such cases the bedrock acts as a “screen” to help filter fines out of the gravel.

The carbonate aquifer is an important regional aquifer for most of western and west-central Ohio and underlies most of Madison County (Norris and Fidler, 1973 and Hallfrisch, 1994). Completed water wells typically penetrate multiple bedrock units. Yields exceeding 100 gpm (ODNR, Div. of Water, Open File, Bedrock State Aquifer Map, 2000, Norris and Fidler, 1973, and Hallfrisch, 1994) are available from deep (up to 400 feet), larger diameter wells drilled into Silurian and Devonian rocks. Most wells developed in these formations obtain water in the top few feet from crevices created or enlarged through weathering when the rocks were exposed at the surface (Norris, 1959). Silurian units include Salina Undifferentiated Group, the Tymochtee and Greenfield Dolomites, and the Lockport Dolomite that underlie the majority of Madison County. Yields from these formations decrease markedly to the south and west as these aquifers thin considerably in these directions. (ODNR, Div. of Water, Open File, Bedrock State Aquifer Map, 2000, Norris and Fidler, 1973, Hallfrisch, 1994, and Haiker and Raab, 1994). The Silurian Cedarville Dolomite, Springfield Dolomite, and Euphemia Dolomite are found in southwestern Madison

County and yield 5 to 25 gpm (ODNR, Div. of Water, Open File, Bedrock State Aquifer Map, 2000, Norris and Fidler, 1973, and Hallfrisch, 1994). The Massie Shale, Laurel Dolomite, Osgood Shale, and Brassfield Limestone are found in the most southwestern portion of Madison County. The yields drop significantly for these units, averaging less than 10 gpm (ODNR, Div. of Water, Open File, Bedrock State Aquifer Map, 2000, Norris and Fidler, 1973, and Hallfrisch, 1994). The amount of fracturing, solution, and vuggy (porous) zones has great local importance.

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APPENDIX A
DESCRIPTION OF THE LOGIC IN FACTOR SELECTION

Depth to Water

This factor was primarily evaluated using information from water well log records on file at the Ohio Department of Natural Resources (ODNR), Division of Water, Water Resources Section (WRS). Approximately 5,000 water well log records are on file for Madison County. Data from roughly 1,300 located water well log records were analyzed and plotted on U.S.G.S. 7-1/2 minute topographic maps during the course of the project. Static water levels and information as to the depths at which water was encountered were taken from these records. The original *Ground Water Pollution Potential of Madison County* (Hallfrisch and Voytek, 1987) was an important guide for evaluating depth to water. The *Ground Water Resources of Madison County* (Hallfrisch, 1994) provided generalized depth to water information throughout the county. Depth to water trends mapped in adjoining Champaign County (Jones, 1995), Clark County (Vormelker et al., 1995), Fayette County (Angle, 2004), Franklin County (Angle, 1995), Greene County (Jones, 1995), Pickaway County (Sugar, 1990), and Union County (Angle, 2004) were used as a guideline. Topographic and geomorphic trends were utilized in areas where other sources of data were lacking.

Depths to water of 5 to 15 feet (with DRASTIC rating of 9) were selected for most of the alluvial settings and some areas of lower elevation ground moraine. Depths to water of 15 to 30 feet (7) were used for most areas of ground moraine throughout the county. Depths to water of 30 to 50 feet (5) were utilized for the majority of end moraines and complexes. Depths to water of 50 to 75 feet (3) were typically used for glacial complex where till is thick.

Net Recharge

Recharge is the precipitation that reaches the aquifer after evapotranspiration and run-off. This factor was evaluated using many criteria, including depth to water, topography, soil type, surface drainage, vadose zone material, aquifer type, and annual precipitation. General estimates of recharge provided by Pettyjohn and Henning (1979) and Dumouchelle and Schiefer (2002) proved to be helpful. The original Ground Water Pollution potential of Madison County (Hallfrisch and Voytek, 1987) was an important guide for evaluating recharge. Recharge information from Champaign County (Jones, 1995), Clark County (Vormelker et al., 1995), Fayette County (Angle, 2004), Franklin County (Angle, 1995), Greene County (Jones, 1995), Pickaway County (Sugar, 1990), and Union County (Angle, 2004) was used as a guideline.

Values of 7 to 10 inches per year (8) were used for areas of high recharge. Such areas were limited to low-lying outwash terraces flanking Deer Creek and Big and Little Darby Creeks. Values of 4 to 7 inches per year (6) were used for areas with moderate recharge. These areas include the vast majority of Madison County. Values of 2 to 4 inches per year (3) were utilized for areas of thick drift that also have depths of water greater than 75 feet. These are usually found in the east-central portion of Madison County.

Aquifer Media

Information on evaluating aquifer media was obtained primarily from the *Ground Water Resources of Madison County* (Hallfrisch, 1994). 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 original *Ground Water Pollution Potential of Madison County* (Hallfrisch and Voytek, 1987) was an important guide for evaluating aquifer media. Aquifer ratings from neighboring Champaign County (Jones, 1995), Clark County (Vormelker et al., 1995), Fayette County (Angle, 2004), Franklin County (Angle, 1995), Greene County (Jones, 1995), Pickaway County (Sugar, 1990), and Union County (Angle, 2004) were also used as a guideline. The ODNR, Division of Water, Glacial State Aquifer Map (2000) and Bedrock State Aquifer Map (2000) were an important source of aquifer data. The *Glacial Map of Ohio* (Goldthwait et al., 1961), *Surficial Geology of the Springfield 30 x 60 Minute Quadrangle* (Brockman et al., 2004) and the *Quaternary Geology of Ohio* (Pavey et al., 1999) provided useful information on the nature of the glacial aquifers and the delineation of the hydrogeologic settings. Additional information on limestone aquifers was obtained from Norris and Fidler's (1973) report on carbonates in southwestern Ohio. Development and the need for increased ground water supply spurred a number of site-specific aquifer tests and reports in the vicinity of I-70 and the area around London Correctional Institute and London Fish Hatchery. These reports include those of Eagon (1973), Weatherington-Rice (1984), Peterson et al. (1990), and Haiker and Raab (1994). Well log records on file at the ODNR, Division of Water, were the primary source of aquifer information.

All of the bedrock and most of the interbedded lenses of sand and gravel are semi-confined or leaky; however, for the purposes of DRASTIC, they have been evaluated as being unconfined (Aller et al., 1987). Limestone was evaluated as the aquifer for approximately half of Madison County, particularly the northeastern and southern portions. An aquifer rating of (8) was applied to the high-yielding Columbus Limestone and Undifferentiated Salina Dolomite in the far northeastern and southeastern portions of the county. This rating applies to most of the carbonate aquifers in Madison County. An aquifer rating of (7) was applied to the Tymochtee and Greenfield Dolomites and Undifferentiated Salina Dolomite in the south central part of Madison County associated with ground and end moraine. An aquifer rating of (6) was selected for Undifferentiated Salina Dolomite, Tymochtee and Greenfield Dolomites, and Cedarville Dolomite, Springfield Dolomite, and Euphemia Dolomite in southwestern Madison County. Yields for the Undifferentiated Salina Dolomite and the Tymochtee and Greenfield Dolomites decrease to the southwest as these units become quite thin. Deeper wells must utilize the underlying, lower yielding units in this area.

Sand and gravel was given a rating of (8) for the high-yielding outwash deposits adjacent to Deer Creek and portion of Little Darby Creek. A rating of (8) was also applied to the buried valley system in west central Madison County where deposits include sand and gravel.

Buried valley deposits with fewer sand and gravel lenses were given a rating of (7), and branch out from the area with a rating of (8) to the northeast and southeast. Other sand and gravel deposits adjacent to Little Darby Creek and its tributaries were given an aquifer media rating of (7). An aquifer rating of (4) was applied to a minor buried valley in southwestern Madison County in which the well logs only show minimal sand and gravel. Sand and gravel was selected as the aquifer for the 7Af-Sand and Gravel Interbedded in Glacial Till, 7D-Buried Valley, and 7Ed-Alluvium over Glacial Till settings. Sand and gravel was chosen for the aquifer for portions of the 7C- Moraine and 7J-Glacial Complex settings. An aquifer rating of (6) was assigned to sand and gravel deposits found in all the above settings. Yields and drawdown data reported on water well log records were also used to help evaluate the sand and gravel deposits.

Soils

Soils were mapped using the data obtained from the *Soil Survey of Madison County* (Gerken and Scherzinger, 1981). Each soil type was evaluated and given a rating for soil media. Evaluations were based upon the texture, permeability, and shrink-swell potential for each soil material. Special emphasis is placed upon determining the most restrictive layer. The soils of Madison County showed a high degree of variability. This is a reflection of the parent material. Table 10 is a list of the soils, parent materials, setting, and corresponding DRASTIC values for Madison County.

Peat (8) was selected for some minor depressions and kettles associated with the flat lying ground moraine in northeastern Madison County. This area has been referred to as the Darby Prairie. Most of these areas are so small that they do not meet the criteria of 100 acres necessary to make them a mappable size unit as specified by the DRASTIC system (Aller, et al, 1987). Soils were considered to be sandy loam (6) for terraces and floodplains associated with several major trunk streams in central and south Madison County. This includes Deer Creek, North Fork of Paint Creek, Paint Creek, Sugar Creek and portions of Little Darby Creek. Loam (5) was applied to small areas along streams containing coarse alluvium. Loam (5) was also evaluated for some thin tills overlying coarse outwash. Silt loam (4) was selected for thin alluvial soils found adjacent to streams including Big Darby Creek, most of Little Darby Creek, and portions of Point Creek and Deer Creek. Clay loam (3) soils were evaluated for the majority of the county including till overlying ground moraine, end moraine, and areas mapped as glacial complex.

Topography

Topography, or percent slope, was evaluated using U.S.G.S. 7-1/2 minute quadrangle maps and the *Soil Survey of Madison County* (Gerken and Scherzinger, 1981). Slopes of 0 to 2 percent (10) were selected for the majority of the settings in Madison County due to the overall flat lying to gently rolling topography and low relief. Slopes of 2 to 6 percent (9) were assigned to some end moraines exhibiting hummocky terrain. Slopes of 6 to 12 percent (5)

Table 10. Madison County soils

Soil Name	Parent Material/ Setting	DRASTIC Rating	Soil Media
Carlisle	Peat/Muck in upland depressions	8	Peat
Crosby	Loamy till in upland drainage	3	Clay loam
Crosby-Lewisburg	Loamy/silty till	3	Clay loam
Eldean	Outwash plains or stream terraces	6	Sandy loam
Kendalville	Thin outwash over ablation till	5	Loam
Kokomo	Till depression/prairie	3	Clay loam
Lewisburg-Celina	Till of ground or end moraine	3	Clay loam
Medway	Alluvium with outwash	4	Silt loam
Miamian	Loamy till on stream terraces	3	Clay loam
Miamian-Eldean	Outwash/kame associated with end moraine	6	Sandy loam
Odell-Lewisburg	Silty clay loam	3	Clay loam
Patton	Silty lacustrine, ponds	4	Silt loam
Ross	Alluvium	4	Silt loam
Sloan	Alluvium	4	Silt loam
Thackery	Alluvium over outwash terrace	5	Loam
Wea	Loess/prairie over outwash	6	Sandy loam
Westland	Outwash over ablation till	6	Sandy loam

were selected for a limited number of upland areas in Madison County along Deer Creek and its tributaries. These areas have undergone a higher level of stream dissection. Slopes of 12 to 18 percent (3) and slopes greater than 18 percent (1) were designated to several small areas that have been heavily dissected by streams in western Madison County.

Impact of the Vadose Zone Media

Information on evaluating vadose zone media was obtained primarily from the Ground Water Resources of Madison County (Hallfrisch, 1994) and water well log records on file at the ODNR, Division of Water. 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 original *Ground Water Pollution Potential of Madison County* (Hallfrisch and Voytek, 1987) was an important guide for evaluating vadose zone media. Vadose zone media ratings from neighboring Champaign County (Jones, 1995), Clark County (Vormelker et al., 1995), Fayette County (Angle, 2004), Franklin County (Angle, 1995), Greene County (Jones, 1995), Pickaway County (Sugar, 1990), and Union County (Angle, 2004) were also used as a guideline. The ODNR, Division of Water, Glacial State Aquifer Map (2000) and Bedrock State Aquifer Map (2000) were important sources of vadose zone media data. The *Soil Survey of Madison County* (Gerken and Scherzinger, 1981) provided valuable information on parent materials. The *Glacial Map of Ohio* (Goldthwait et al., 1961), the *Surficial Geology of the Springfield 30 x 60 Minute Quadrangle* (Brockman et al., 2004), and the *Quaternary Geology of Ohio* (Pavey et al., 1999) were useful in delineating vadose zone media. Site investigations (WW Engineering & Science, 1991 and Lloyd, 1998) were useful in interpreting vadose zone media.

The vadose zone media is a critical component of the overall DRASTIC rating in Madison County. The rating varies with the restrictive properties of the various glacial materials. The higher the proportion of silt and clay and the greater the compaction (density) of the sediments, the lower the permeability and the lower the vadose zone media are rated.

Limestone/fractured till with a vadose zone media rating of (6) was selected for parts of Madison County where the till covering the underlying limestone was very thin. Glacial till was given a vadose zone media ratings of (5) for most areas of ground moraine and end moraine. In these areas the thickness of till was thin to moderate and the depth to water was shallow. The majority of the till in the sequence was weathered and fractured. A vadose zone media rating of (4) was assigned to areas with a greater thickness of till and with moderate depths to water. This rating was commonly used in the 7J-Glacial Complex hydrogeologic setting and for areas of thicker end moraines in the 7C-Moraine hydrogeologic setting. Till (3) was selected for areas of glacial complex where till is very thick. These areas correspond to some of the deeper portions of the Teays River buried valley system.

Sand and gravel with a vadose rating of (8) was selected for a limited number of areas where clean outwash deposits were at the land surface. A vadose zone media rating of (7) was chosen for sand and gravel with significant silt and clay for alluvial and outwash terraces flanking the wider, southern portions of Deer Creek, Little Darby Creek and Big Darby

Creek. Sand and gravel with significant silt and clay was used for areas having sandy loam soils. A vadose zone media rating of (6) was selected for sand and gravel with significant silt and clay for the upper reaches of these larger streams. A vadose zone media rating of (5) was assigned for sand and gravel with significant silt and clay along the remaining streams.

Silt and clay with a vadose zone media rating of (5) was selected for alluvium found in minor tributary streams through out the county.

Hydraulic Conductivity

Information on evaluating the hydraulic conductivity was obtained from the maps and report of the Norris and Fidler (1973), and the *Ground Water Resources of Madison County* (Hallfrisch, 1994). 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 original *Ground Water Pollution Potential of Madison County* (Hallfrisch and Voytek, 1987) was an important guide for evaluating hydraulic conductivity. Hydraulic conductivity ratings from neighboring Champaign County (Jones, 1995), Clark County (Vormelker et al., 1995), Fayette County (Angle, 2004), Franklin County (Angle, 1995), Greene County (Jones, 1995), Pickaway County (Sugar, 1990), and Union County (Angle, 2004) were also used as a guideline. The ODNR, Division of Water, Glacial State Aquifer Map (2000) and Bedrock State Aquifer Map (2000) were important sources of hydraulic conductivity data. Additional site-specific hydraulic conductivity data includes reports by Eagon (1973), Weatherington-Rice (1984), Peterson et al. (1990), and Haiker and Raab (1994). Water well log records on file at the ODNR, Division of Water, were also used to help determine hydraulic conductivity. Textbook tables (Freeze and Cherry, 1979, Fetter, 1980, and Driscoll, 1986) were useful in obtaining estimated values for hydraulic conductivity in a variety of aquifers.

Values for hydraulic conductivity correspond to aquifer ratings; i.e., the more highly rated aquifers have higher values for hydraulic conductivity. The majority of the sand and gravel aquifers were given a hydraulic conductivity rating of 700-1000 (6) or 300-700 gallons per day per square foot (gpd/ft^2) (4). Sand and gravel with an aquifer rating of (4) were given a hydraulic conductivity rating of 100-300 gpd/ft^2 (2). Decreasing hydraulic conductivity values indicate decreasing permeability, porosity, a lack of sorting, being poorly bedded, and the sand and gravel being “dirtier” (containing more fine-grained particles).

Limestone with aquifer ratings of (8) and (7) were given a hydraulic conductivity rating of 700-1000 (6) or 300-700 gpd/ft^2 (4). The lower hydraulic conductivity rating was given to areas containing thicker Devonian Delaware Limestone. Limestone in southwestern Madison County with an aquifer rating of (6) was given a hydraulic conductivity rating of 700-1000 gpd/ft^2 (6) or 300-700 gpd/ft^2 (4). Decreasing hydraulic conductivity values in carbonate aquifers indicate reductions in permeability and solution features, being less “vuggy” (porous), and being less fractured or jointed.

APPENDIX B

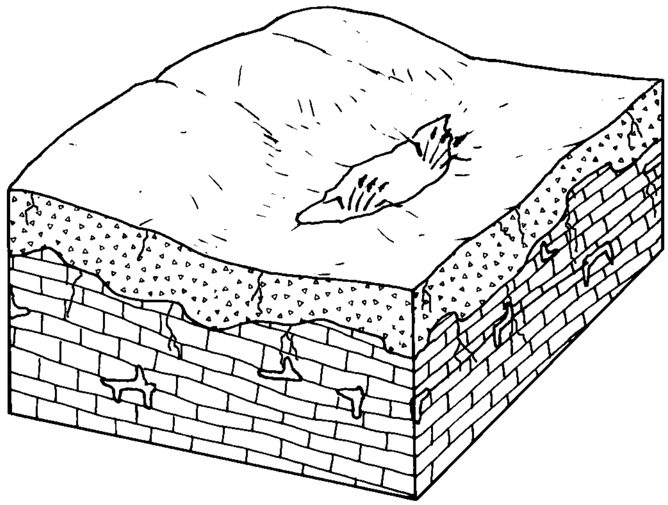
DESCRIPTION OF HYDROGEOLOGIC SETTINGS AND CHARTS

Ground water pollution potential mapping in Madison County resulted in the identification of nine hydrogeologic settings within the Glaciated Central Region. The list of these settings, the range of pollution potential index calculations, and the number of index calculations for each setting are provided in Table 11. Computed pollution potential indexes for Madison County range from 88 to 179.

Table 11. Hydrogeologic settings mapped in Madison County, Ohio

Hydrogeologic Settings	Range of GWPP Indexes	Number of Index Calculations
7Ac-Glacial till over limestone	93-157	35
7Af-Sand and gravel interbedded in glacial till	105-146	13
7Bc-Outwash over limestone	160-172	4
7Bd-Outwash over glacial till	179	1
7C-Moraine	121-151	8
7D-Buried valley	88-176	55
7Ec-Alluvium over sedimentary rock	142-165	13
7Ed-Alluvium over glacial till	136-168	12
7J-Glacial complex	98-156	52

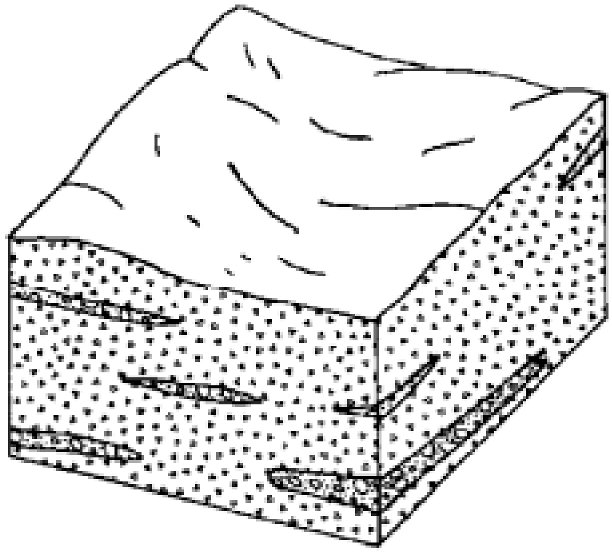
The following information provides a description of each hydrogeologic setting identified in the county, a block diagram illustrating the characteristics of the setting, and a listing of the charts for each unique combination of pollution potential indexes calculated for each setting. The charts provide 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.



7Ac-Glacial Till over Limestone

This hydrogeologic setting covers a quarter of Madison County. The area is characterized by flat-lying topography and low relief associated with ground moraine. The vadose zone consists primarily of silty to clayey glacial till. The till may be fractured or jointed, particularly in areas where it is predominantly thin and weathered. Where the till is very thin, fractured limestone is considered to partially be the vadose zone media. The aquifer is composed of fractured Devonian and Silurian limestones and dolomites. These carbonate rocks may contain significant solution features. Depth to water is variable. Soils are typically clay loams derived from till. Maximum ground water yields greater than 100 gpm are possible from the Salina Groups in portions of eastern Madison County. Yields decline to the west and south as the higher-yielding Silurian units thin in these directions. Yields average 5 to 25 gpm in the north central and south central portions of the county and less than 5 gpm in small pockets toward the northwest and in the Columbus Limestone. The amount of recharge reflects the vadose zone media and depth to water trends. Areas with higher recharge rates typically have coarser vadose zone materials and shallower depths to water.

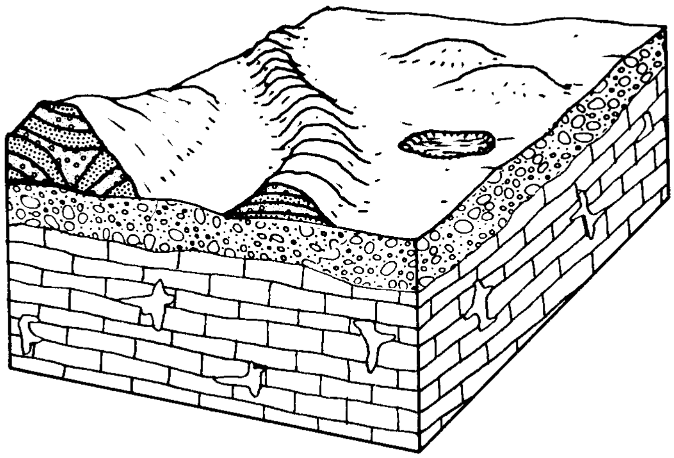
GWPP index values for the hydrogeologic setting of Glacial Till over Limestone range from 93 to 157, with the total number of GWPP index calculations equaling 35.



7Af-Sand and Gravel Interbedded in Glacial Till

This hydrogeologic setting is located in northern and southern Madison County. The area is characterized by flat lying topography and low relief. The setting is commonly associated with areas of ground moraine. The vadose zone is composed of silty to clayey glacial till. The till may be fractured or jointed, particularly in areas where it is predominantly thin and weathered. In areas bordering Pickaway County the till may be referred to as sand and gravel with significant silt and clay. This was done to match this county with the older map and report that did not recognize till as a vadose zone media. Depth to water is usually variable. Soils are generally clay loams. The aquifer consists of thin lenses of sand and gravel interbedded in the glacial till. Ground water yields range from 5 to 25 gpm. Recharge is moderate due to the relatively low permeability of the clayey soils and vadose zone material and the relative shallow depth to the sand and gravel aquifers.

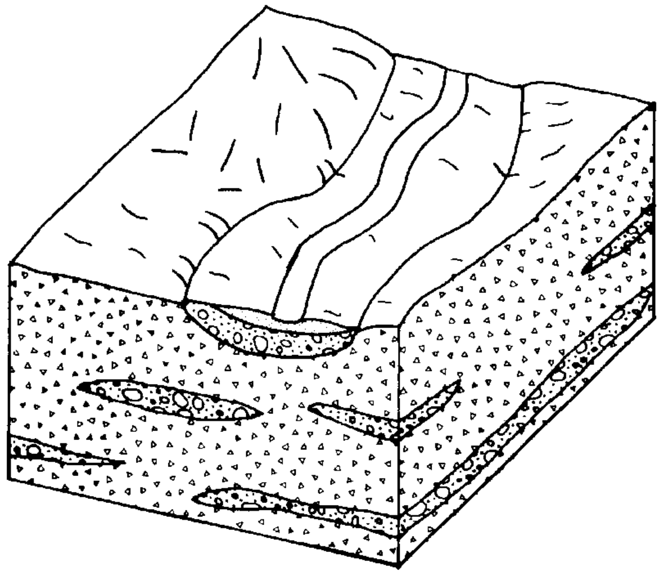
GWPP index values for the hydrogeologic setting of Sand and Gravel Interbedded in Glacial Till range from 105 to 146, with the total number of GWPP index calculations equaling 13.



7Bc Outwash over Limestone

This hydrogeologic setting is limited to eastern Madison County along the Big Darby Creek where sand and gravel overlie the limestone bedrock. Topography is relatively flat. The sand and gravel is too thin to comprise the aquifer, therefore ground water is obtained from the underlying limestone bedrock. The sand and gravel with silt and clay till composes the vadose zone. Precipitation moving through the outwash recharges the bedrock. Yields of 100 to 500 gpm may be obtained from the underlying limestone. The number of fractures and solution features encountered within the limestone help to determine the yield. Depth to water is generally less than 20 feet. Soils are sandy loams or silt loams. Recharge is moderately high due to the permeable soils and vadose, the shallow depth to water, and the flat topography.

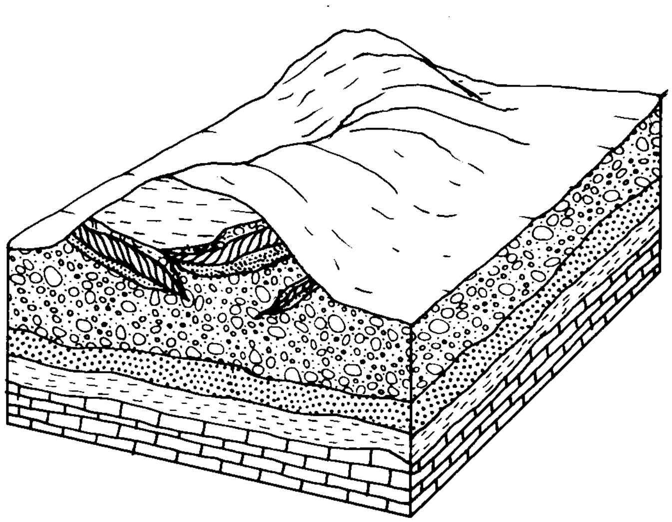
The GWPP index values for the hydrogeologic setting Outwash over Limestone range from 160 to 172, with the total number of calculations equaling 4.



7Bd Outwash over Glacial Till

This hydrogeologic setting is limited to a small area in southeastern Madison County along Deer Creek. Topography is relatively flat. The glacial till is very thick and is overlain with a thin layer of alluvium and outwash. The sand and gravel compose the vadose zone. Wells completed in this setting typically yield 5 to 25 gpm obtained from thin sand and gravel lenses interbedded in the till. With test drilling, large diameter wells may yield 100 to 500 gpm if thicker layers of sand and gravel are encountered in the till. Depth to water is generally less than 15 feet. Soils are loam. Recharge is moderately high due to the permeable soils and vadose, the shallow depth to water, and the flat topography.

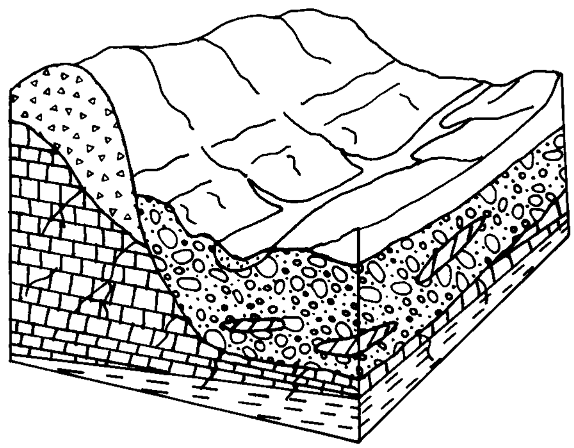
The GWPP index value for the hydrogeologic setting Outwash over Glacial Till is 179, with the total number of calculations equaling 1.



7C-Moraine

This hydrogeologic setting consists of minor portions of end moraines fringing southern Madison County. End moraines were mapped in this area because they represented a significant thickening of till in comparison to surrounding ground moraine. Farther north in Madison County moraines were not mapped separately due to the overall very thick sequence of till throughout that region. This setting is characterized by hummocky to rolling topography. Most wells are completed in sand and gravel lenses within the moraine. Yields from these sand and gravel wells average 5 to 25 gpm. Wells are completed in the underlying limestone and dolomite bedrock in areas where there is not an adequate thickness of sand and gravel in which to develop a well. The vadose zone is composed of loamy to clayey glacial till. The till may be fractured or jointed, particularly in areas where it is predominantly thin and weathered. Depth to water is shallow to moderate and depends primarily upon how deep the underlying aquifer is. Soils are commonly clay loams. Recharge is moderate due to the relatively low permeability of the clayey soils and vadose zone material and the relative shallow depth to the aquifers. The end moraines serve as an area of local recharge.

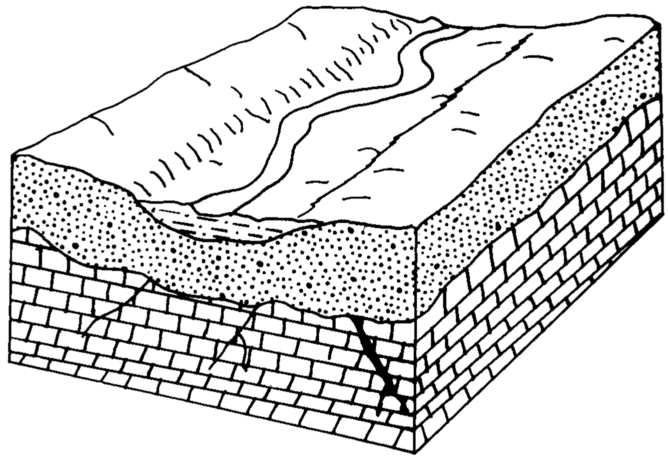
GWPP index values for the hydrogeologic setting of Moraine range from 121 to 151, with the total number of GWPP index calculations equaling 8.



7D-Buried Valley

This hydrogeologic setting is common throughout central Madison County. The surface topography is flat and has low relief. The Teays River valley is the significant buried valley in the west-central portion with arms toward the northeast and southeast. Smaller buried valleys underlay modern Deer Creek and Little Darby Creek. The aquifer consists of relatively coarse, thick, clean sand and gravel outwash. Yields from the sand and gravel outwash can be as great as 100 gpm for large diameter wells in portions of the Teays River valley and stretches along Deer Creek and Little Darby Creek. Yields range from 5-25 gpm to 25-100 gpm for the remaining areas. Soils are variable due to the varying nature of parent materials in the floodplains and terraces. Depths to water are typically shallow to moderate. Recharge is typically high due to the relatively permeable soils, vadose, and aquifer materials, shallow depth to water, and the influence of modern overlying streams that might be hydraulically connected to the sand and gravel aquifers.

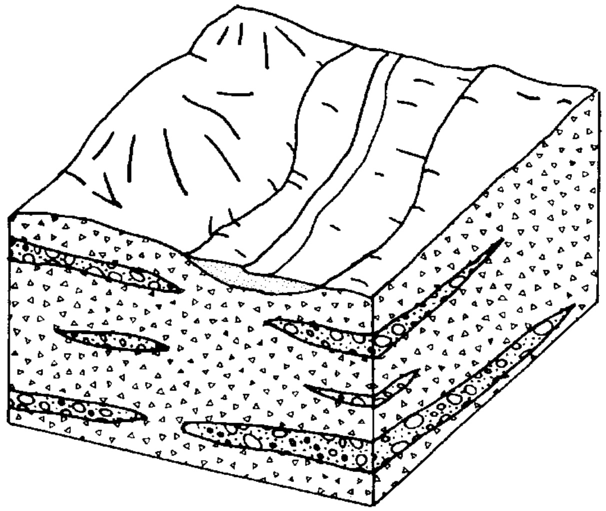
GWPP index values for the hydrogeologic setting of Buried Valley range from 88 to 176, with the total number of GWPP index calculations equaling 55.



7Ec-Alluvium over Sedimentary Rock

This hydrogeologic setting occurs in northern and southern Madison County in areas of thinner glacial drift. 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 7Ed-Alluvium over Glacial Till except that the underlying aquifers consist of limestone bedrock. The aquifers consist of Devonian or Silurian limestones. The vadose zone consists of sandy and silty to sand and gravel deposits. Soils are variable due to the varying texture of the alluvial materials and are usually silt loams or sandy loams. Depth to water is commonly very shallow, averaging less than 20 feet. The alluvium may be in direct hydraulic connection with the underlying bedrock or there may be thin till or lacustrine deposits in between. Maximum ground water yields greater than 100 gpm are possible from the Silurian Lockport and Salina Groups in central Madison County. Yields decline in the southwest corner of the county as the higher-yielding Silurian units thin in these directions. Yields average 5 to 25 gpm. Recharge is typically moderately high due to the flat-lying topography, shallow depth to water, the moderate permeability of the soils and vadose zone media, and the relatively high permeability of the underlying bedrock.

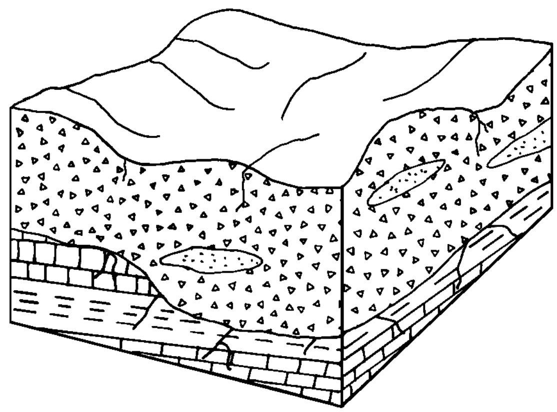
The GWPP index values for the hydrogeologic setting Alluvium over Sedimentary Rocks range from 142 to 165, with the total number of GWPP index calculations equaling 13.



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 most common in areas of thicker drift throughout Madison County. 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 setting is also similar to the 7Ec-Alluvium over Sedimentary Rock except that the underlying aquifer consists of shallow sand and gravel lenses instead of bedrock. 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 to sandy alluvium is typically more permeable than the underlying till. The alluvium is too thin to be considered the aquifer. The vadose zone consists of the sandy to silty to clayey alluvial deposits. Soils are variable. Yields commonly range from 5 to 25 gpm from the sand and gravel lenses. Depth to water is typically shallow with depths averaging less than 20 feet. Recharge is moderately high due to the shallow depth to water, flat-lying topography, and the moderate permeability of the glacial till and alluvium.

The GWPP index values for the hydrogeologic setting Alluvium over Glacial Till range from 136 to 168, with the total number of GWPP index calculations equaling 12.



7J-Glacial Complex

This setting is widespread throughout Madison County. The surface topography is flat and has low relief. Modern streams typically do not overly these deposits. The setting is characterized by a thick sequence of glacial till. It is adjacent to the 7D-Buried Valley setting in many areas. The aquifer consists of thinner, less continuous lenses of sand and gravel interbedded with thicker sequences of fine-grained glacial till or the underlying limestone bedrock. Due to the high-yielding nature of the Silurian limestones, many wells are completed in the limestone. Maximum ground water yields greater than 100 gpm are possible from the underlying limestone and dolomite. Wells completed in sand and gravel lenses in this setting have average yields of 5 to 25 gpm. Soils are usually clay loams derived from the underlying glacial till. Depths to water are variable and depend upon how deep the aquifer is and the thickness of till. Recharge is typically moderate to low due to the fine-grained nature of the soils and vadose zone media and the moderate depth to the limestone aquifers.

GWPP index values for the hydrogeologic setting of Glacial Complex range from 98 to 156, with the total number of GWPP index calculations equaling 52.

Table 12. 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	Pesticide Rating_
7Ac1	15-30	4-7	limestone	Clay Loam	0-2	till	700-1000	142	160
7Ac2	5-15	4-7	limestone	Clay Loam	0-2	till	700-1000	152	170
7Ac3	15-30	4-7	limestone	Silty Loam	0-2	till	700-1000	144	165
7Ac4	15-30	4-7	limestone	Clay Loam	2-6	till	700-1000	141	157
7Ac5	5-15	4-7	limestone	Clay Loam	2-6	till	700-1000	151	167
7Ac6	30-50	4-7	limestone	Clay Loam	0-2	till	700-1000	132	150
7Ac7	15-30	4-7	limestone	Clay Loam	0-2	till	700-1000	147	164
7Ac8	5-15	4-7	limestone	Clay Loam	0-2	lst/frac till	700-1000	157	174
7Ac9	5-15	4-7	limestone	Clay Loam	0-2	till	300-700	146	166
7Ac10	5-15	4-7	limestone	Clay Loam	2-6	till	300-700	145	163
7Ac11	15-30	4-7	limestone	Clay Loam	2-6	till	300-700	135	153
7Ac12	30-50	4-7	limestone	Clay Loam	2-6	till	700-1000	131	147
7Ac13	15-30	4-7	limestone	Loam	2-6	sd + gvl w/sl + cl	300-700	139	163
7Ac14	15-30	4-7	limestone	Clay Loam	2-6	till	300-700	130	149
7Ac15	30-50	4-7	limestone	Clay Loam	0-2	till	300-700	121	142
7Ac16	30-50	4-7	limestone	Clay Loam	0-2	till	300-700	126	146
7Ac17	15-30	4-7	limestone	Clay Loam	0-2	till	300-700	136	156
7Ac18	30-50	4-7	limestone	Clay Loam	2-6	till	700-1000	125	141
7Ac19	50-75	2-4	limestone	Clay Loam	0-2	till	700-1000	105	124
7Ac20	30-50	4-7	limestone	Clay Loam	6-12	till	300-700	116	127
7Ac21	50-75	2-4	limestone	Clay Loam	0-2	till	300-700	94	116
7Ac22	50-75	2-4	limestone	Clay Loam	2-6	till	300-700	93	113
7Ac23	30-50	4-7	limestone	Clay Loam	2-6	till	300-700	125	143
7Ac24	50-75	2-4	limestone	Clay Loam	0-2	till	300-700	99	120
7Ac25	50-75	2-4	limestone	Clay Loam	2-6	till	700-1000	104	121
7Ac26	15-30	4-7	limestone	Clay Loam	0-2	till	700-1000	136	154
7Ac27	30-50	4-7	limestone	Clay Loam	2-6	till	300-700	120	139
7Ac28	30-50	4-7	limestone	Clay Loam	6-12	till	700-1000	127	135
7Ac29	5-15	4-7	limestone	Clay Loam	2-6	till	700-1000	148	164
7Ac30	15-30	4-7	limestone	Clay Loam	2-6	till	700-1000	138	154
7Ac31	15-30	4-7	limestone	Clay Loam	0-2	till	700-1000	139	157
7Ac32	15-30	4-7	limestone	Clay Loam	6-12	till	700-1000	134	142
7Ac33	30-50	4-7	limestone	Clay Loam	2-6	till	700-1000	128	144
7Ac34	15-30	4-7	limestone	Clay Loam	2-6	till	700-1000	135	151
7Ac35	15-30	4-7	limestone	Clay Loam	0-2	till	700-1000	134	153
7Af1	15-30	4-7	sand and gravel	Clay Loam	0-2	till	300-700	125	146
7Af2	15-30	4-7	sand and gravel	Loam	0-2	till	300-700	129	156

Setting	Depth to Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% slope)	Vadose Zone Media	Hydraulic Conductivity	Rating	Pesticide Rating_
7Af3	5-15	4-7	sand and gravel	Clay Loam	0-2	till	700-1000	146	164
7Af4	5-15	4-7	sand and gravel	Clay Loam	2-6	till	700-1000	145	161
7Af5	15-30	4-7	sand and gravel	Clay Loam	0-2	till	700-1000	136	154
7Af6	15-30	4-7	sand and gravel	Clay Loam	2-6	till	700-1000	135	151
7Af7	30-50	4-7	sand and gravel	Clay Loam	0-2	till	700-1000	126	144
7Af8	30-50	4-7	sand and gravel	Clay Loam	2-6	till	700-1000	125	141
7Af9	50-75	4-7	sand and gravel	Clay Loam	0-2	sd + gvl w/sl + cl	300-700	105	126
7Af10	30-50	4-7	sand and gravel	Clay Loam	0-2	sd + gvl w/sl + cl	300-700	115	136
7Af11	15-30	4-7	sand and gravel	Clay Loam	2-6	sd + gvl w/sl + cl	300-700	124	143
7Af12	30-50	4-7	sand and gravel	Clay Loam	6-12	till	700-1000	121	129
7Af13	15-30	4-7	sand and gravel	Clay Loam	0-2	till	300-700	133	153
7Bc1	5-15	7-10	limestone	Silty Loam	0-2	sd + gvl w/sl + cl	700-1000	172	191
7Bc2	15-30	7-10	limestone	Loam	0-2	sd + gvl w/sl + cl	700-1000	164	186
7Bc3	5-15	7-10	limestone	Sandy Loam	0-2	sd + gvl w/sl + cl	700-1000	171	197
7Bc4	15-30	7-10	limestone	Sandy Loam	2-6	sd + gvl w/sl + cl	700-1000	160	184
7Bd1	5-15	7-10	sand and gravel	Loam	0-2	sand and gravel	700-1000	179	200
7C1	5-15	4-7	sand and gravel	Clay Loam	2-6	till	300-700	139	157
7C2	5-15	4-7	sand and gravel	Clay Loam	0-2	till	300-700	140	160
7C3	5-15	4-7	limestone	Clay Loam	2-6	till	700-1000	151	167
7C4	15-30	4-7	limestone	Clay Loam	2-6	till	700-1000	135	151
7C5	15-30	4-7	limestone	Clay Loam	0-2	till	700-1000	136	154
7C6	30-50	4-7	limestone	Clay Loam	2-6	till	700-1000	125	141
7C7	30-50	4-7	limestone	Clay Loam	0-2	till	700-1000	126	144
7C8	30-50	4-7	limestone	Clay Loam	0-2	till	700-1000	121	140
7D1	15-30	4-7	sand and gravel	Loam	2-6	till	300-700	128	153
7D2	5-15	7-10	sand and gravel	Silty Loam	0-2	sd + gvl w/sl + cl	700-1000	164	184
7D3	5-15	7-10	sand and gravel	Sandy Loam	0-2	sd + gvl w/sl + cl	700-1000	168	194

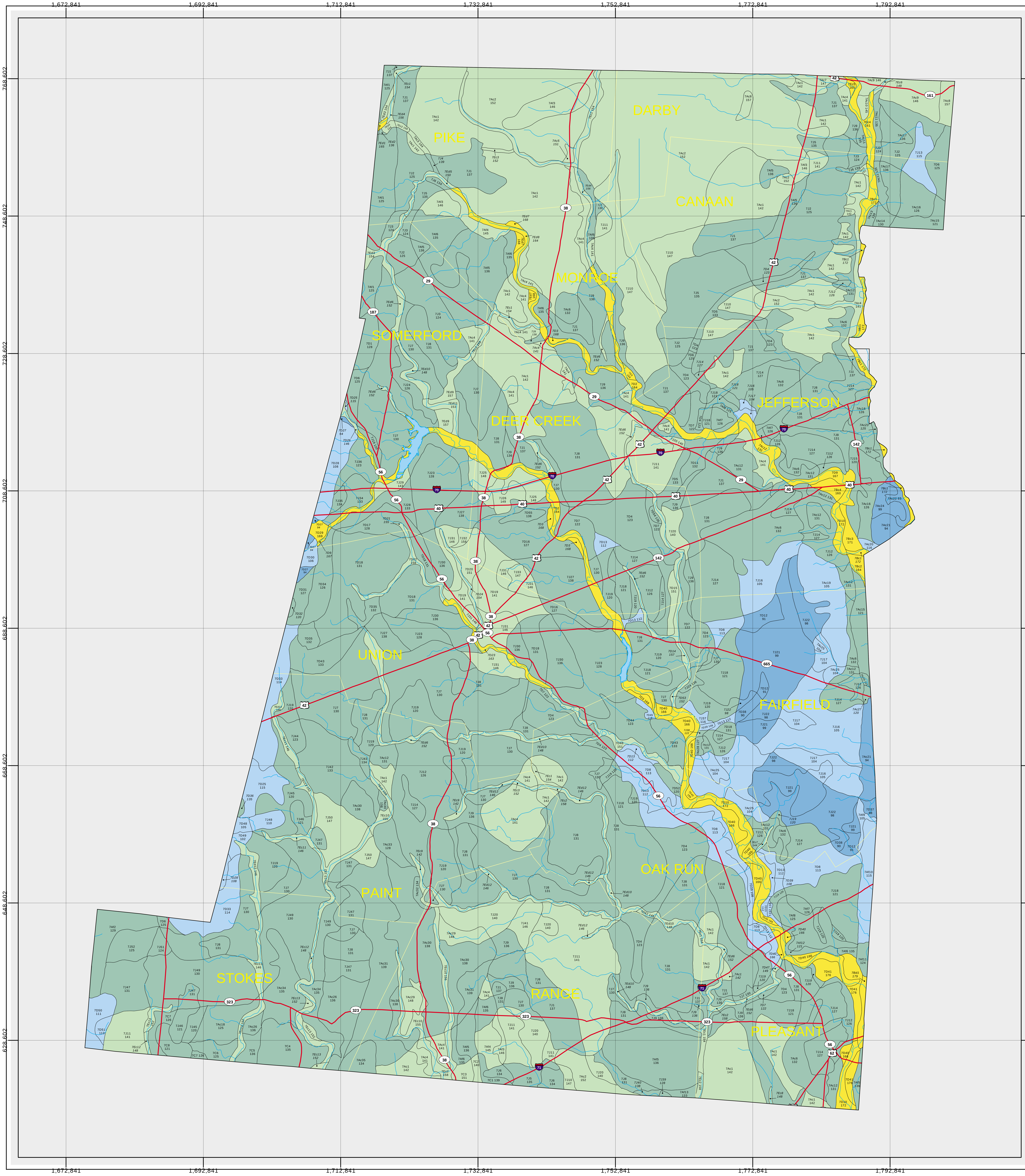
Setting	Depth to Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% slope)	Vadose Zone Media	Hydraulic Conductivity	Rating	Pesticide Rating_
7D4	15-30	4-7	sand and gravel	Clay Loam	0-2	till	300-700	123	145
7D5	5-15	4-7	sand and gravel	Clay Loam	0-2	till	300-700	133	155
7D6	15-30	4-7	sand and gravel	Clay Loam	0-2	till	300-700	125	146
7D7	15-30	4-7	sand and gravel	Clay Loam	2-6	till	300-700	122	142
7D8	30-50	4-7	sand and gravel	Clay Loam	0-2	till	300-700	113	135
7D9	5-15	7-10	sand and gravel	Silty Loam	0-2	sd + gvl w/sl + cl	700-1000	167	187
7D10	5-15	7-10	sand and gravel	Silty Loam	0-2	sd + gvl w/sl + cl	700-1000	172	191
7D11	5-15	4-7	sand and gravel	Clay Loam	2-6	till	300-700	132	152
7D12	50-75	2-4	sand and gravel	Clay Loam	0-2	till	300-700	91	113
7D13	30-50	4-7	sand and gravel	Clay Loam	2-6	till	300-700	112	132
7D14	5-15	4-7	sand and gravel	Sandy Loam	0-2	sd + gvl w/sl + cl	700-1000	157	183
7D15	5-15	4-7	sand and gravel	Sandy Loam	2-6	sd + gvl w/sl + cl	700-1000	151	176
7D16	15-30	4-7	sand and gravel	Clay Loam	2-6	till	300-700	127	146
7D17	30-50	4-7	sand and gravel	Clay Loam	2-6	till	700-1000	128	144
7D18	30-50	4-7	sand and gravel	Clay Loam	2-6	till	700-1000	131	147
7D19	15-30	4-7	sand and gravel	Clay Loam	2-6	till	700-1000	141	157
7D20	5-15	4-7	sand and gravel	Clay Loam	2-6	till	700-1000	151	167
7D21	5-15	4-7	sand and gravel	Sandy Loam	0-2	sd + gvl w/sl + cl	700-1000	155	182
7D22	5-15	4-7	sand and gravel	Sandy Loam	0-2	sd + gvl w/sl + cl	700-1000	158	185
7D23	5-15	4-7	sand and gravel	Sandy Loam	0-2	sd + gvl w/sl + cl	700-1000	163	189
7D24	5-15	4-7	sand and gravel	Silty Loam	0-2	silt/clay	700-1000	154	175
7D25	30-50	4-7	sand and gravel	Clay Loam	0-2	sd + gvl w/sl + cl	300-700	115	136
7D26	5-15	4-7	sand and gravel	Loam	2-6	sd + gvl w/sl + cl	300-700	146	170
7D27	30-50	2-4	sand and gravel	Clay Loam	18+	till	300-700	94	97
7D28	30-50	4-7	sand and gravel	Clay Loam	12-18	till	300-700	108	115
7D29	15-30	7-10	sand and gravel	Loam	0-2	sand and gravel	700-1000	169	190
7D30	30-50	4-7	sand and gravel	Clay Loam	18+	till	300-700	106	109

Setting	Depth to Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% slope)	Vadose Zone Media	Hydraulic Conductivity	Rating	Pesticide Rating_
7D31	30-50	4-7	sand and gravel	Clay Loam	0-2	till	700-1000	127	146
7D32	30-50	4-7	sand and gravel	Clay Loam	12-18	till	700-1000	120	125
7D33	30-50	4-7	sand and gravel	Clay Loam	2-6	till	300-700	114	133
7D34	30-50	4-7	sand and gravel	Clay Loam	2-6	till	700-1000	126	143
7D35	30-50	4-7	sand and gravel	Clay Loam	0-2	till	700-1000	132	150
7D36	5-15	4-7	sand and gravel	Clay Loam	0-2	till	300-700	135	156
7D37	50-75	2-4	sand and gravel	Clay Loam	0-2	till	300-700	88	110
7D38	50-75	2-4	sand and gravel	Clay Loam	2-6	till	300-700	90	110
7D39	30-50	4-7	sand and gravel	Clay Loam	6-12	till	300-700	108	120
7D40	15-30	7-10	sand and gravel	Sandy Loam	0-2	sd + gvl w/sl + cl	700-1000	166	191
7D41	5-15	7-10	sand and gravel	Sandy Loam	0-2	sd + gvl w/sl + cl	700-1000	176	201
7D42	5-15	4-7	sand and gravel	Silty Loam	0-2	sd + gvl w/sl + cl	300-700	145	165
7D43	15-30	4-7	sand and gravel	Clay Loam	2-6	till	700-1000	133	150
7D44	30-50	4-7	sand and gravel	Clay Loam	2-6	till	700-1000	123	140
7D45	30-50	4-7	sand and gravel	Clay Loam	6-12	till	700-1000	119	128
7D46	5-15	4-7	sand and gravel	Silty Loam	0-2	sd + gvl w/sl + cl	700-1000	151	172
7D47	5-15	4-7	sand and gravel	Sandy Loam	0-2	sd + gvl w/sl + cl	300-700	149	178
7D48	50-75	4-7	sand and gravel	Clay Loam	0-2	till	300-700	105	126
7D49	30-50	2-4	sand and gravel	Clay Loam	2-6	till	300-700	102	121
7D50	5-15	2-4	sand and gravel	Clay Loam	0-2	till	100-300	111	134
7D51	15-30	4-7	sand and gravel	Clay Loam	0-2	till	100-300	113	136
7D52	30-50	4-7	sand and gravel	Clay Loam	2-6	till	700-1000	120	137
7D53	5-15	4-7	sand and gravel	Sandy Loam	0-2	sd + gvl w/sl + cl	700-1000	152	179
7D54	15-30	4-7	sand and gravel	Clay Loam	2-6	till	700-1000	135	151
7D55	15-30	4-7	sand and gravel	Clay Loam	2-6	till	700-1000	138	154
7Ec1	5-15	4-7	limestone	Silty Loam	0-2	silt/clay	700-1000	154	175

Setting	Depth to Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% slope)	Vadose Zone Media	Hydraulic Conductivity	Rating	Pesticide Rating_
7Ec2	5-15	4-7	limestone	Sandy Loam	0-2	sd + gvl w/sl + cl	700-1000	158	185
7Ec3	5-15	4-7	limestone	Clay Loam	0-2	silt/clay	700-1000	152	170
7Ec4	5-15	7-10	limestone	Silty Loam	0-2	sd + gvl w/sl + cl	300-700	161	183
7Ec5	5-15	7-10	limestone	Sandy Loam	0-2	sd + gvl w/sl + cl	300-700	165	193
7Ec6	5-15	4-7	limestone	Silty Loam	0-2	silt/clay	300-700	148	171
7Ec7	15-30	4-7	limestone	Silty Loam	0-2	silt/clay	700-1000	144	165
7Ec8	15-30	4-7	limestone	Sandy Loam	0-2	sd + gvl w/sl + cl	700-1000	148	175
7Ec9	15-30	4-7	limestone	Clay Loam	0-2	silt/clay	700-1000	142	160
7Ec10	5-15	4-7	limestone	Sandy Loam	0-2	sd + gvl w/sl + cl	700-1000	155	182
7Ec11	5-15	4-7	limestone	Clay Loam	0-2	silt/clay	700-1000	146	164
7Ec12	5-15	4-7	limestone	Silty Loam	0-2	silt/clay	700-1000	148	169
7Ec13	5-15	4-7	limestone	Sandy Loam	0-2	sd + gvl w/sl + cl	700-1000	152	179
7Ed1	5-15	7-10	sand and gravel	Silty Loam	0-2	sand and gravel	300-700	165	185
7Ed2	15-30	4-7	sand and gravel	Sandy Loam	0-2	sd + gvl w/sl + cl	300-700	136	165
7Ed3	5-15	7-10	sand and gravel	Sandy Loam	0-2	till	300-700	154	183
7Ed4	5-15	7-10	sand and gravel	Silty Loam	0-2	sd + gvl w/sl + cl	700-1000	156	177
7Ed5	5-15	7-10	sand and gravel	Silty Loam	0-2	sd + gvl w/sl + cl	300-700	150	173
7Ed6	5-15	4-7	sand and gravel	Sandy Loam	0-2	sd + gvl w/sl + cl	700-1000	152	179
7Ed7	5-15	7-10	sand and gravel	Sandy Loam	0-2	sd + gvl w/sl + cl	700-1000	168	194
7Ed8	5-15	7-10	sand and gravel	Silty Loam	0-2	sd + gvl w/sl + cl	700-1000	164	184
7Ed9	5-15	4-7	sand and gravel	Sandy Loam	0-2	sd + gvl w/sl + cl	700-1000	157	183
7Ed10	5-15	4-7	sand and gravel	Silty Loam	0-2	sd + gvl w/sl + cl	700-1000	148	169
7Ed11	5-15	4-7	sand and gravel	Silty Loam	0-2	sd + gvl w/sl + cl	700-1000	153	173
7Ed12	5-15	4-7	sand and gravel	Clay Loam	0-2	silt/clay	700-1000	146	164
7J1	15-30	4-7	limestone	Clay Loam	0-2	till	700-1000	137	156
7J2	15-30	4-7	sand and gravel	Clay Loam	0-2	till	300-700	125	146
7J3	15-30	4-7	sand and gravel	Clay Loam	2-6	till	300-700	124	143
7J4	15-30	4-7	limestone	Silty Loam	0-2	till	700-1000	139	161

Setting	Depth to Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% slope)	Vadose Zone Media	Hydraulic Conductivity	Rating	Pesticide Rating_
7J5	5-15	4-7	sand and gravel	Clay Loam	0-2	till	300-700	135	156
7J6	5-15	4-7	sand and gravel	Clay Loam	2-6	till	300-700	134	153
7J7	15-30	4-7	sand and gravel	Clay Loam	2-6	till	700-1000	130	147
7J8	15-30	4-7	sand and gravel	Clay Loam	0-2	till	700-1000	131	150
7J9	15-30	4-7	limestone	Clay Loam	2-6	till	700-1000	136	153
7J10	5-15	4-7	limestone	Clay Loam	0-2	till	700-1000	147	166
7J11	5-15	4-7	sand and gravel	Clay Loam	0-2	till	700-1000	141	160
7J12	30-50	4-7	limestone	Clay Loam	2-6	till	700-1000	126	143
7J13	30-50	4-7	sand and gravel	Clay Loam	0-2	till	300-700	115	136
7J14	30-50	4-7	limestone	Clay Loam	0-2	till	700-1000	127	146
7J15	30-50	4-7	limestone	Clay Loam	2-6	till	300-700	120	139
7J16	50-75	2-4	limestone	Clay Loam	0-2	till	700-1000	105	124
7J17	50-75	2-4	limestone	Clay Loam	2-6	till	700-1000	104	121
7J18	30-50	4-7	sand and gravel	Clay Loam	0-2	till	700-1000	121	140
7J19	30-50	4-7	sand and gravel	Clay Loam	2-6	till	700-1000	120	137
7J20	5-15	4-7	sand and gravel	Clay Loam	2-6	till	700-1000	140	157
7J21	50-75	2-4	sand and gravel	Clay Loam	0-2	till	700-1000	99	118
7J22	50-75	2-4	sand and gravel	Clay Loam	2-6	till	700-1000	98	115
7J23	30-50	4-7	sand and gravel	Clay Loam	2-6	till	700-1000	128	144
7J24	15-30	4-7	sand and gravel	Clay Loam	6-12	till	700-1000	126	135
7J25	5-15	4-7	sand and gravel	Clay Loam	2-6	till	700-1000	148	164
7J26	5-15	4-7	sand and gravel	Clay Loam	0-2	till	700-1000	149	167
7J27	15-30	4-7	sand and gravel	Clay Loam	2-6	till	700-1000	138	154
7J28	30-50	4-7	sand and gravel	Clay Loam	2-6	till	700-1000	133	148
7J29	15-30	4-7	sand and gravel	Clay Loam	2-6	till	700-1000	143	158
7J30	30-50	4-7	sand and gravel	Clay Loam	2-6	till	700-1000	136	151
7J31	15-30	4-7	sand and gravel	Clay Loam	2-6	till	700-1000	146	161
7J32	5-15	4-7	sand and gravel	Clay Loam	2-6	till	700-1000	156	171
7J33	15-30	4-7	sand and gravel	Clay Loam	0-2	till	700-1000	147	164

Setting	Depth to Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% slope)	Vadose Zone Media	Hydraulic Conductivity	Rating	Pesticide Rating_
7J34	15-30	4-7	sand and gravel	Clay Loam	2-6	till	700-1000	133	150
7J35	15-30	4-7	sand and gravel	Clay Loam	0-2	till	700-1000	134	153
7J36	30-50	4-7	sand and gravel	Clay Loam	2-6	till	700-1000	123	140
7J37	30-50	4-7	sand and gravel	Clay Loam	6-12	till	700-1000	116	125
7J38	30-50	4-7	limestone	Clay Loam	6-12	till	700-1000	122	131
7J39	15-30	4-7	sand and gravel	Clay Loam	0-2	till	300-700	128	149
7J40	5-15	4-7	sand and gravel	Clay Loam	0-2	till	300-700	138	159
7J41	5-15	4-7	limestone	Clay Loam	2-6	till	700-1000	146	163
7J42	15-30	4-7	limestone	Clay Loam	2-6	till	700-1000	133	150
7J43	15-30	4-7	limestone	Clay Loam	0-2	till	700-1000	134	153
7J44	30-50	4-7	limestone	Clay Loam	2-6	till	700-1000	123	140
7J45	30-50	4-7	limestone	Clay Loam	2-6	till	700-1000	120	137
7J46	30-50	4-7	limestone	Clay Loam	0-2	till	700-1000	121	140
7J47	15-30	4-7	limestone	Clay Loam	0-2	till	700-1000	131	150
7J48	50-75	4-7	limestone	Clay Loam	2-6	till	700-1000	110	127
7J49	15-30	4-7	limestone	Clay Loam	2-6	till	700-1000	130	147
7J50	5-15	4-7	limestone	Sandy Loam	0-2	till	700-1000	147	175
7J51	15-30	4-7	limestone	Clay Loam	2-6	till	300-700	124	143
7J52	15-30	4-7	limestone	Clay Loam	0-2	till	300-700	125	146



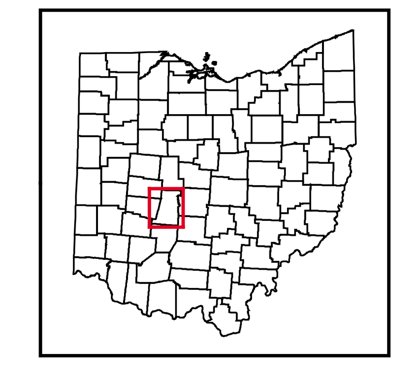
Ground Water Pollution Potential of Madison County

after Hallfrisch and Voytek, 1987

by

Mike Angle and Kelly Barrett

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

N

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

Ohio Department of Natural Resources
Division of Water
Ground Water Resources Section
2045 Morse Road
Columbus Ohio 43229-6605
www.dnr.state.oh.us
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