GROUND WATER POLLUTION POTENTIAL OF UNION COUNTY, OHIO

BY

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GROUND WATER POLLUTION POTENTIAL REPORT NO. 47

OHIO DEPARTMENT OF NATURAL RESOURCES

DIVISION OF WATER

WATER RESOURCES SECTION

2004

ABSTRACT

A ground water pollution potential map of Union 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 Union County resulted in a map with symbols and colors, which illustrate areas of varying ground water pollution potential indexes ranging from 94 to 171.

Union County lies entirely within the Glaciated Central hydrogeologic setting. Limestones and dolomites of the Silurian and Devonian Systems compose the aquifer in almost the entire 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 lenses interbedded in the glacial till locally serve as aquifers in portions of western Union County. 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 Union 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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ACKNOWLEDGEMENTS

The preparation of the Union County Ground Water Pollution Potential report and map involved the contribution and work of a number of individuals in the Division of Water. Grateful acknowledgement is given to the following individuals for their technical review and map production, text authorship, report editing, and preparation:

Map preparation and review:	Michael P. Angle Katherine Sprowls
GIS coverage production and review:	Paul Spahr
Report production and review:	Michael P. Angle
Report editing:	Katherine Sprowls

INTRODUCTION

The need for protection and management of ground water resources in Ohio has been clearly recognized. About 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; 7200 of these wells exist in Union 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 Union 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 Union 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

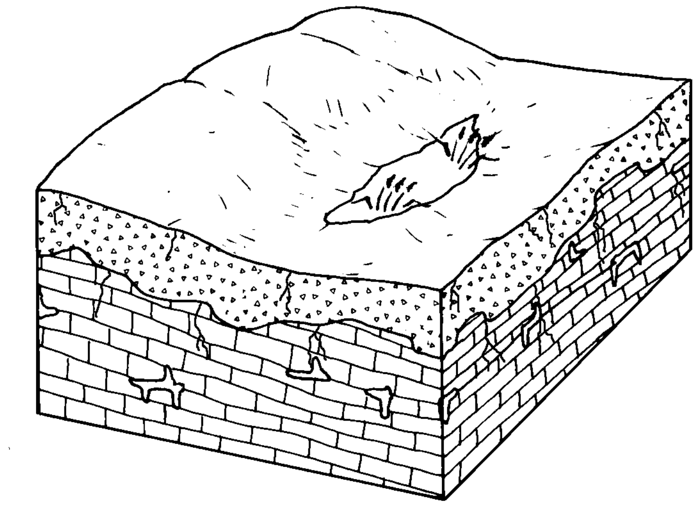
These factors incorporate concepts and mechanisms such as attenuation, retardation, and time or distance of travel of a contaminant with respect to the physical characteristics of the hydrogeologic setting. Broad consideration of these factors and mechanisms coupled with existing conditions in a setting 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 is widespread in Union County, especially in northern part of the county. The area is characterized by the 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 Silurian and/or Devonian limestones and dolomites. These carbonate rocks may contain significant solution features. Depth to water is typically shallow to moderate, ranging from 15 to 50 feet. Soils are variable but typically are clay loams derived from till. Maximum ground water yields greater than 100 gpm are possible from the Silurian Lockport, Tymochtee, Greenfield and Salina Groups. Yields range from 5 to 100 gpm for the Devonian carbonate units. Recharge is moderate due to the clayey nature of the soils and vadose zone and the relatively shallow depth to water and permeable nature of the bedrock aquifer.

GWPP index values for the hydrogeologic setting of Glacial Till over Solution Limestone range from 120 to 162, with the total number of GWPP index calculations equaling 37.

Figure 1. Format and description of the hydrogeologic setting – 7Ac 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	

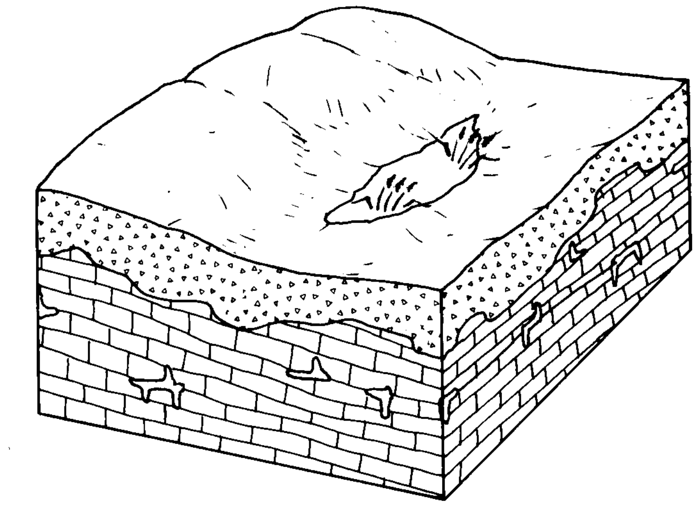
Table 8. Ranges and ratings for hydraulic conductivity

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, Till over Limestone, identified in mapping Union 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 147. This numerical value has no intrinsic meaning, but can be readily compared to a value obtained for other settings in the county. DRASTIC indexes for typical hydrogeologic settings and values across the United States range from 45 to 223. The diversity of hydrogeologic conditions in Union 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 94 to 171.

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 Union 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 Union County is included with this report.



SETTING 7Ac1		GENERAL		
FEATURE	**RANGE**	**WEIGHT**	**RATING**	**NUMBER**
Depth to Water	5-15	5	9	45
Net Recharge	4-7	4	6	24
Aquifer Media	Limestone	3	8	24
Soil Media	Clay Loam	2	3	6
Topography	0-2%	5	10	10
Impact of Vadose Zone	Till	5	4	20
Hydraulic Conductivity	700-1000	3	6	18
		DRASTIC	INDEX	147

Figure 2. Description of the hydrogeologic setting – 7Ac1 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
147 - 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 (**147**) 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 UNION COUNTY

Demographics

Union County occupies approximately 434 square miles (Waters and Matanzo, 1975) in north central Ohio (Figure 3). Union County is bounded to the northeast by Marion County, to the northwest by Hardin County, to the east by Delaware County, to the southeast by Franklin County, to the south by Madison County, to the southwest by Champaign County, and to the west by Logan County.

The approximate population of Union County, based upon year 2000 census estimates, is 40,909 (Department of Development, Ohio County Profiles, 2004). Marysville is the largest community and the county seat. Agriculture accounts for roughly 86 percent of the land usage in Marion County. Row crops are the primary agricultural land usage. Woodlands, industry, and residential are the other major land uses in the county. More specific information on land usage 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 51 degrees Fahrenheit for Union County. The average temperatures increase slightly towards the south. Harstine (1991) shows that precipitation approximately averages 36 to 37 inches per year for the county, with precipitation increasing towards the south. The mean annual precipitation for Marysville is 36.62 inches per year based upon a thirty-year (1971-2000) period National Oceanographic and Atmospheric Administration (NOAA), 2002). The mean annual temperature at Marysville for the same thirty-year period is 51.1 degrees Fahrenheit (NOAA, 2002).

Physiography and Topography

Union County lies within the Central Till Plains Lowland Province (Frost, 1931; Fenneman, 1938, and Bier, 1956). Brockman (1998) and Schiefer (2002) depict all of Union County except the far southern fringe as belonging in the Central Ohio Clayey Till Plain. This fringe, lying to the south of the Powell End Moraine, is part of the Darby Plain. Union County is characterized by flat ground moraine and intermorainal lakes separated by wide belts of hummocky end moraines.

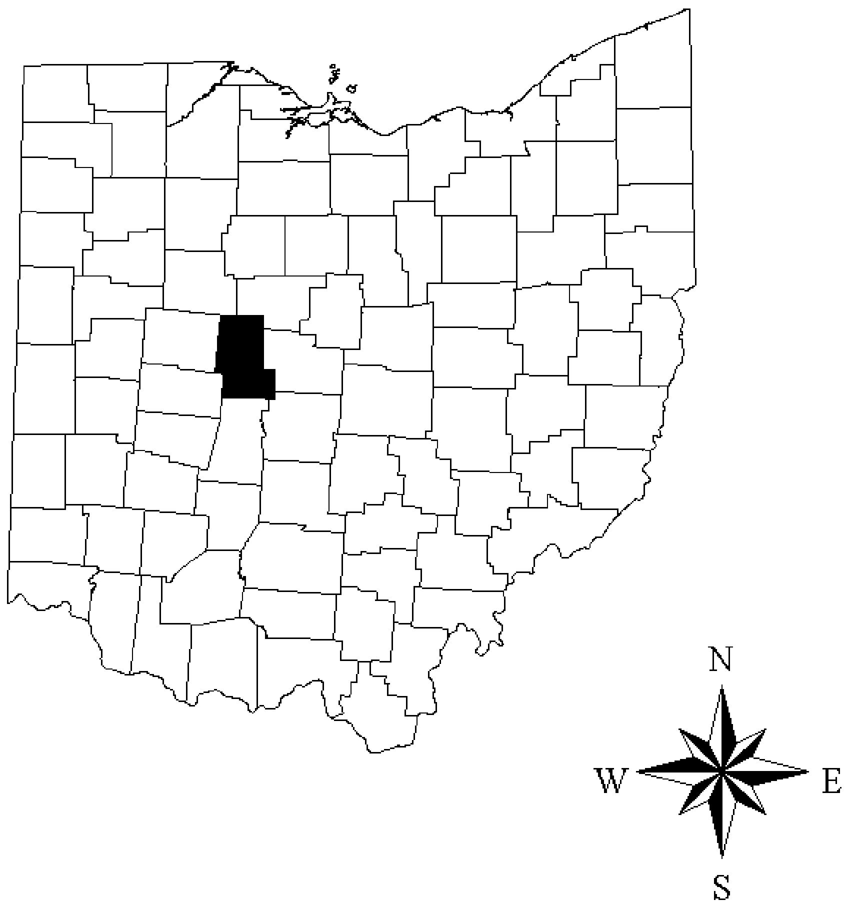


Figure 3. Location map of Union County, Ohio.

Modern Drainage

Union County lies south of the major drainage divide crossing north central Ohio; all of Union County drains toward the Ohio River. The majority of the county drains eastward toward the Scioto River. The major easterly flowing tributaries to the Scioto River (from north to south) include Rush Creek, Bokes Creek, Blues Creek, and Mill Creek. Darby Creek and Little Darby Creek drain the southern quarter of the county.

Pre- and Inter-Glacial Drainage Changes

The drainage patterns of Union 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 Union 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 stream for what is now the upper Ohio River Valley. Stout et al. (1943) proposed that a large, unnamed southwesterly-flowing tributary drained Union County (Figure 4).

As ice advanced through Ohio during the pre-Illinoian (Kansan) glaciations, northerly and western drainage ways were blocked. Flow backed-up these numerous tributaries, forming several large lakes. These lakes over-topped, creating spillways and cutting new channels. New drainage systems began to evolve (Stout et al., 1943). This down cutting 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 down cutting. Stout et al. (1943) suggested that southern Union County contained the headwaters of Springfield Creek, which in turn helped form the southwesterly flowing Middletown River (Figure 5). The Middletown River had a course similar to that of the present Mad River. Stout et al. (1943) proposed that the headwaters of easterly flowing tributaries of the Columbus River (Figure 5) formed in northern Union County. The Columbus River had a course somewhat similar to the present Scioto 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 Union County largely reflect the terrain resulting from the final Wisconsinan glacial advances. The modern drainage reflects the nature of landforms deposited during the Wisconsinan advances, particularly end moraines and intermorainal lakes.

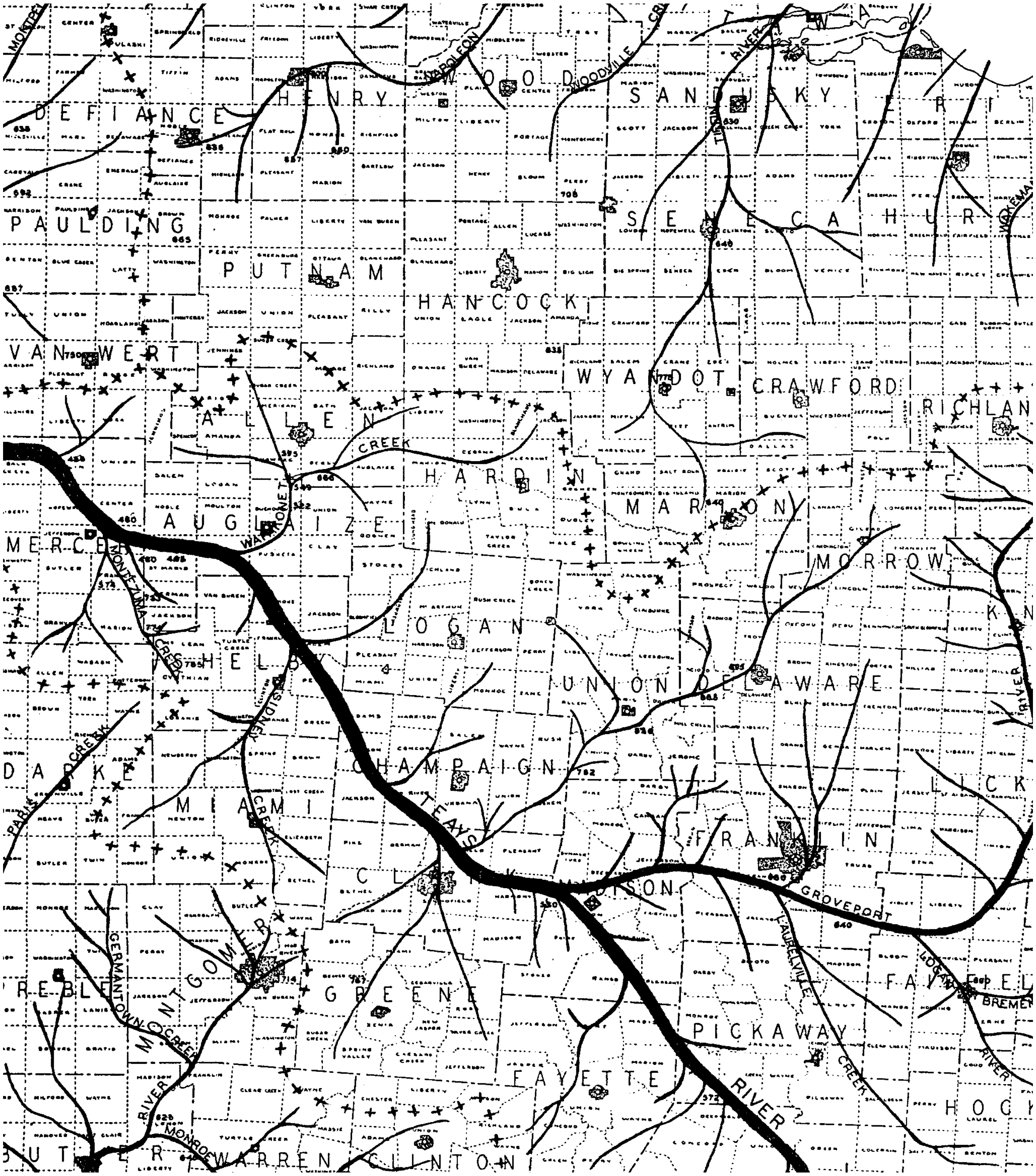


Figure 4. Teays Stage drainage in Union County (after Stout et al., 1943).

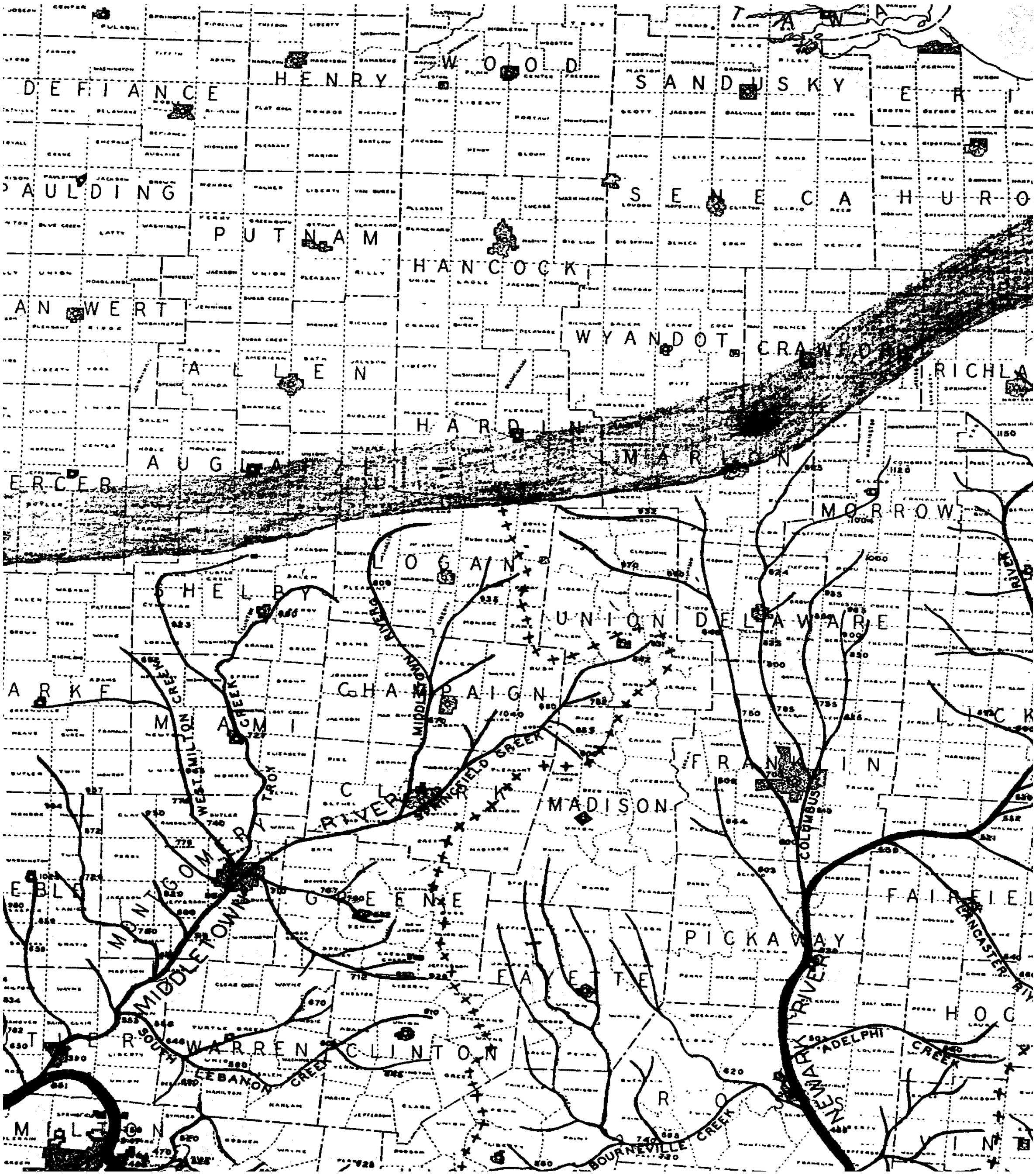


Figure 5. Deep Stage drainage in Union County (after Stout et al., 1943).

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), Forsyth (1967, 1968), Angle (1991), the Ohio Superconducting Super Collider ((SSC) State of Ohio, 1987), and Pavey et al. (1999) report that the last advance, the Late Wisconsinan Ice Sheet, deposited the surficial till in Union County. Evidence for the earlier glaciations is lacking or obscured.

The reports of Forsyth (1967, 1968), Angle (1991), and the Ohio SSC (Ohio SSC-State of Ohio, 1987) discuss the glacial deposits of Union County at length. Reports in neighboring Logan County (Forsyth, 1956, 1991) and Marion County (Totten, 1986) also provide valuable information on the glacial history of Union County. In a recent study; Russell (2002) reevaluated the lacustrine deposits related to the intermorainal lakes found in nearby Crawford County. His study was the basis for the delineation of the 7Fc-Intermorainal Lake Deposits hydrogeologic setting. Similar deposits are found in Union County. The *Soil Survey of Union County* (Waters and Matanzo, 1975) was used to make the delineations between the lakebeds and ground moraine. The exceptional flatness of these features and characteristics of poor drainage also proved useful in delineating the intermorainal lakes. The majority of the glacial deposits in Union County fall into four main types: (glacial) till, lacustrine deposits, outwash (valley train) deposits, and ice-contact sand and gravel (kames, eskers) 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 thickens in end moraines. Drift is thickest in the buried valleys found in southern Union County. There are isolated areas in Union County where the drift is very thin and the bedrock is very close 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. 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. There is evidence that some of the tills were deposited in a water-rich environment in Union County. These types of tills would be deposited when a relatively thin ice sheet would alternately float and ground depending on the water level of the lake and thickness of the ice sheet. Such tills may more closely resemble lacustrine deposits.

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). Numerous fractures in the till were noted in excavations associated with the construction of new U.S. Route 33 in the mid 1980's (Angle, unpublished notes, ODNR, Div. of Geological Survey). Of importance to the end moraines of Union County is the high proportion of sand and gravel units interbedded in the till. This is especially true with the St. Johns Moraine found in northern Union County. These units may overlap ("stack") enough to help aid in permeability. Fractures may also interconnect the sand and gravel lenses.

At the land surface, till accounts for two primary landforms: ground moraine and end moraine. Ground moraine (till plain) is relatively flat to gently rolling. End moraines are 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 St. Johns Moraine roughly parallels the boundary with Marion County. The Bokes Creek Moraine (Forsyth, 1956, 1968) occupies a broad area roughly flanking Bokes Creek in western and central Union County. The Broadway Moraine occupies a broad area between Bokes Creek and Mill Creek in western Union County and between Blues Creek and Mill Creek in eastern Union County. The Powell Moraine is a wide moraine occupying much of the land between Mill Creek and Darby Creek in southern Union County.

The various till units in Union County and adjoining Logan County have been discussed at length by Forsyth (1956, 1967, 1968, and 1991, and Angle, 1991). The various till units or "sheets" were differentiated by a number of means including the texture or grain particle size of the tills, the soil types associated with the tills, firmness and structure of the tills, and relative position between the various end moraines in the region. The methodology for naming tills in this region has evolved significantly over the years.

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 Marion County are mostly associated with Mill Creek southeast of Marysville and with Darby Creek. 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 Union County tend to be relatively low elevation and are at elevations just above the current floodplain. The outwash deposits in Union County tend to have a significant proportion of relatively fine-grained sand and silt layers. The outwash deposits flanking Mill Creek and Darby Creek are finer-grained than those found further south in Franklin County along Darby Creek and the Scioto River. This would seem to indicate that the sediments were deposited by relatively slow-moving meltwater. It is likely that the flow was partially restricted or blocked, perhaps by ice or while the ancestral Scioto River was cutting through a moraine further downstream (Totten, 1986).

Kames and eskers are ice contact features. They are composed of masses of generally poorly sorted sand and gravel with minor till, deposited in depressions, holes, tunnels, or other cavities in the ice. As the surrounding ice melts, a mound of sediment remains behind. Typically, these deposits may collapse or flow as the surrounding ice melts. These deposits may display high angle, distorted or tilted beds, faults, and folds. Kames are comprised of isolated or small groups of rounded mounds of dirty sand and gravel with minor till. Eskers are comprised of elongate, narrow, sinuous ridges of sand and gravel. Kame terraces are a linear belt of kames that have a similar appearance and a fairly uniform elevation. Kame terraces commonly flank valleys or streams. The best examples of ice contact deposits are small, isolated kames found in the southwestern corner of the county near Irwin (Pavey et al., 1999).

Southern Union County contains abundant kettles. The kettles are found within the area of the Darby Plain ("Darby Prairie"). The Darby Plain is a very flat area that lies south of Big Darby Creek and the Powell Moraine. Kettles are usually associated with areas of ablation where the ice sheet was actively melting. Melting blocks of ice formed these small, circular depressional features. As the ice block melted, it left behind a hole or low area surrounded by either till or outwash. Kettles may also reflect lows or "swales" in an end moraine which are flanked by highs or "swells". Kettles commonly contain standing water. The water may reflect the local water table conditions or may collect and perch local runoff. Kettles also contain peat and muck. Peat and muck are organic-rich deposits associated with low-lying depression areas, bogs, kettles, and swamps. Muck is dense, fine silt with a high content of organics and a dark black color. Peat is typically brownish and contains pieces of plant fibers, decaying wood, and mosses. The two deposits commonly occur together; the *Soil Survey of Union County* (Waters and Matanzo, 1975) shows organic deposits that have filled kettles. The kettles are typically underlain by either highly permeable sand and gravel outwash or by low permeability lacustrine silt and clay or till. Minor shallow kettles are found in the lakebed deposits associated with intermorainal lakes in western Union County.

Lacustrine deposits are composed of silty to clayey material found in intermorainal lake areas. These lakes are referred to as intermorainal lakes as they occupy low areas of ground moraine between end moraines. The lakes tend to become somewhat finer-grained near the center of the deposit or lake (Gregory, 1956, House, 1985, Totten, 1986, and Russell, 2002). Lacustrine deposits tend to be laminated (or varved) and contain various proportions of silts and clays. Thin layers of fine sand interbedded with the clayey to silty lacustrine deposits may reflect storm or flood events. Permeability is preferentially horizontal due to the laminations and water-laid nature of these sediments. The inherent vertical permeability is low; however, secondary porosity features such as fractures, joints, root channels, etc. help increase the vertical permeability. Thin layers of sand may occupy the margins of the lakes. These sands may reflect minor deltas that started to prograde into the lake, or they may mark the rough beginnings of a beach along the shoreline.

The lakes were created during the recession of the ice sheets. Meltwater was trapped between the receding ice sheet and end moraines. In some areas, meltwater may have been trapped between two end moraines, forming a lake. Additional ponding may have resulted from northerly-flowing, run-off fed streams that were blocked by the ice sheets. Run-off in general helped to fill these ponds. Eventually, some of these ponds may have overflowed their margins and began to cut an outlet. House (1985) and Russell (2002) theorized that as one lake overflowed, it would progressively cause the next lower elevation lake to overflow.

Alternatively, the headwaters of emerging streams may have cutback and created an outlet for the lakes. As the modern drainage system slowly developed, streams downcut through the series of end moraines, draining the lakes over time. Swampy bog and kettle areas replaced many of the lakes. Many of these features persist today or were recently drained for agriculture.

The largest, most prominent former lakebed occupies a large area south of Mill Creek and north of the Powell Moraine in western Union County. This lakebed is somewhat unusual in that it occupies a topographic high (relative to other features in the area). The surficial lacustrine deposits also encroach upon and cover some areas of end moraine. Perhaps the lake was formed as water was trapped between the prominent Bellefontaine Outlier highland in eastern Logan County and a very thick, high mass of ice somewhere east of Marysville. Glacial till in this area is unusually clayey (Forsyth, 1956, 1967, 1968, and 1991, Angle, 1991, and Waters and Matanzo, 1975). This is perhaps due to the till eroding and incorporating previously deposited lacustrine deposits, or that the tills were deposited in a watery environment where the ice sheet may have varied between floating or grounding.

Bedrock Geology

Bedrock underlying the surface of Union County belongs to the Silurian and Devonian Systems. Carbonate (limestone and dolomite) bedrock underlies the entire county. Table 9 summarizes the bedrock stratigraphy found in Union County. The ODNR, Division of 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 units encountered in Union County are the fossiliferous Devonian Columbus and Delaware Limestones. These Devonian carbonates are limited to southeastern Union County. These rocks were deposited in warm, high-energy seas and reef areas. The Columbus and Delaware Limestones tend to thin and the yields become proportionately lower further to the west. The uppermost Silurian unit is the Salina Undifferentiated Group, which consists of dolomites, fine-grained limestones, and some minor evaporite deposits such as gypsum. These rocks were deposited in warm, shallow tidal areas. Units of the Salina Undifferentiated Group tend to thin to the west and north.

Underlying the Salina Undifferentiated Group are rocks of the Silurian Tymochtee and Greenfield Formations, which were also deposited in warm, shallow seas. These two formations tend to become thinner along the margins of the deep buried valley system in southwestern Union County. The oldest unit typically encountered by water wells is the Silurian Lockport Group. Rocks of the Lockport are the uppermost bedrock unit in the northwestern corner of Union County and become progressively deeper to the east. The Lockport Group rocks were associated with tidal reefs deposited in warm, high-energy shallow seas. Yields typically remain constant across the county as well.

Table 9. Bedrock stratigraphy of Union County

System	Group/Formation (Symbol)	Lithologic Description
Devonian	Delaware and Columbus Limestones (Ddc)	The Delaware is a gray to brown thin-bedded to massive, argillaceous, carbonaceous limestone. The Columbus is a gray to brown, fossiliferous, massive-bedded limestone and dolomite. Karst features are common in the Columbus. These units are limited to the southeast corner of Union County. Thickness and yields for these formations decreases toward the west.
Silurian	Undifferentiated Salina Dolomite (Sus)	Gray to brown, thin-bedded, argillaceous dolomite. Thin evaporite zones common. This unit thins to the north and west. Yields may exceed 100 gpm when fractures or solution features are encountered.
	Tymochtee and Greenfield Dolomites (Stg)	Thin- to massive-bedded, olive-gray to yellowish-brown. The Tymochtee contains shale partings. The Greenfield has a laminated dolomite lithology. Thickness decreases to the southwest. Yields can be >100 gpm, especially in the Tymochtee.
	Lockport Dolomite (Sl)	White to medium gray, medium- to massive-bedded dolomite. Commonly contains cavernous solution zones. Thickness >100 feet. Yields can exceed 100 gpm, especially in cavernous or solution zones.

Ground Water Resources

Ground water in Union County is obtained from both unconsolidated (glacial-alluvial) and consolidated (bedrock) aquifers. Thin lenses of sand and gravel interbedded with till comprise the glacial aquifers in Union County. These thin sand and gravel aquifers are commonly associated with buried valley deposits and glacial complexes in southern Union County. Glacial complexes are areas of thick glacial drift that is predominantly comprised of thick, dense till (ODNR, Division of Water, Glacial State Aquifer Map, 2000). 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 generally 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 carbonate aquifer is an important regional aquifer for most of northwestern and north central Ohio and underlies all of Union County (ODNR, Div. of Water, 1970 and Schmidt, 1978). Completed water wells typically penetrate multiple bedrock units. Yields exceeding 100 gpm (ODNR, Div. of Water, Open File, Bedrock State Aquifer Map, 2000, ODNR, Div.

of Water, 1970, Norris and Fidler, 1973, and Schmidt, 1978) are available from deep, larger diameter wells drilled into the Silurian Salina Undifferentiated Group, the Tymochtee and Greenfield Dolomites, and the Lockport Dolomite. These formations extend across Union County. Yields for the Devonian Columbus and Delaware Limestones vary from 5-100 gpm (ODNR, Div. of Water, Open File, Bedrock State Aquifer Map, 2000, ODNR, Div. Of Water, 1970, Norris and Fidler, 1973, and Schmidt, 1978). The trend of increasing yields in deeper wells drilled into the carbonates is a generalization. The amount of fracturing, solution, and vuggy (porous) zones has great local importance. Deeper wells are also more likely to contain highly mineralized water and have objectionable water quality.

Yields from sand and gravel lenses interbedded with the fine-grained till averages 5 to 25 gpm (ODNR, Div. of Water, Glacial State Aquifer Map, 2000 and Schmidt, 1978). The sand and gravel may also directly overlie the bedrock and yield 5 to 25 gpm. The 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. Sand and gravel lenses are most commonly associated with areas of buried valleys or glacial complexes in southern Union County. It is important to note that thin sand and gravel lenses were encountered in a number of wells thoughout the county; however, in most cases, drillers widely prefer the underlying regional carbonate aquifer. The outwash deposits associated with Darby Creek and Mill Creek commonly are relatively thin and too close to the surface to comprise the aquifer.

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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 7,200 water well log records are on file for Union County. Data from roughly 1,500 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 *Ground Water Resources of Union County* (Schmidt, 1978) provided generalized depth to water information throughout the county. Depth to water trends mapped in adjoining Marion County (Angle, 2003), Franklin County (Angle, 1995), Madison County (Hallfrisch and Voytek, 1987), Logan County (Sprowls, 1995), and Champaign County (Jones, 1995) were used as a guideline. Topographic and geomorphic trends were utilized in areas where other sources of data were lacking.

Depths to water of 0 to 5 (10) were used for some limited floodplain areas adjacent to the headwaters of some minor streams. Depths of 5 to 15 feet (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 associated with the 7Ac-Glacial Till over Limestone setting. Depths to water of 30 to 50 feet (5) were utilized for the majority of the Broadway Moraine and the lower elevation margins of the Bokes Creek Moraine and Powell Moraine. The overlying cover of glacial till was thicker in most of these areas. Depths to water of 50 to 75 feet (3) were utilized for some higher elevation crests of the Broadway Moraine and Powell Moraine. Depths to water of 75 to 100 feet (2) were selected for limited portions of the Powell Moraine.

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. Recharge ratings from neighboring Marion County (Angle, 2003), Franklin County (Angle, 1995), Madison County (Hallfrisch and Voytek, 1987), Logan County (Sprowls, 1995), and Champaign County (Jones, 1995) were used as a guideline. Some localized recharge data was included in the investigation for the SSC site in Ohio (Ohio SSC-State of Ohio, 1987).

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 portions of Mill Creek and Big Darby Creek. Values of 4 to 7 inches per year (6) were used for areas with moderate recharge. These areas include the vast majority of Union County. Values of 2 to 4 inches per year (3) were utilized for limited, higher elevation crests of the Bokes Creek Moraine and Powell Moraine that have fairly thick till cover.

Aquifer Media

Information on evaluating aquifer media was obtained primarily from the *Ground Water Resources of Union County* (Schmidt, 1978). 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. Aquifer ratings from neighboring Marion County (Angle, 2003), Franklin County (Angle, 1995), Madison County (Hallfrisch and Voytek, 1987), Logan County (Sprowls, 1995), and Champaign County (Jones, 1995) were 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), 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 a report by the Division of Water (1970) on carbonate rocks in Northwestern Ohio and Norris and Fidler’s (1973) report on carbonates in southwestern Ohio. Additional aquifer information was obtained from the investigation for the proposed SSC site in Ohio (Ohio SSC-State of Ohio, 1987). Additional site-specific aquifer data, including reports by Wilson (1987), Stilson & Assoc. (1950), and Burgess & Niple (1978), provided valuable information. 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 the majority of Union County. A rating of (7) was applied to the Silurian and Devonian limestones that comprise the aquifer along the eastern margin of Union County. An aquifer rating of (8) was utilized for Silurian limestone aquifers in central and western Union County. An aquifer rating of (6) was selected for a limited number of limestone aquifers adjacent to Champaign County. Wells in this area typically are completed in the upper portion of the limestone and are relatively low-yielding compared to limestones in adjacent areas.

Sand and gravel was evaluated as the aquifer along the immediate eastern and western margins of Union County. 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 aquifers elsewhere were assigned a rating of (7), (6) or (5) depending upon how clean, coarse and thick the deposits were. 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 Union County* (Waters and Matanzo, 1975). 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 Union 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 Union County.

Shrink-swell (non-aggregated) clays (7) were selected for some thick, highly clayey soils. These soils included areas of lacustrine soils and water-modified till associated with the intermorainal lake west of Marysville and clayey alluvial ("oxbow") type deposits in northeastern Union County. Soils were considered to be sandy loam (6) for exposures of outwash terraces adjacent to Mill Creek and Big Darby Creek. Silt loam (4) was designated for most alluvial and floodplain deposits. Clay loam (3) soils were evaluated for the majority of the county including till overlying ground moraine and end moraine areas.

Topography

Topography, or percent slope, was evaluated using U.S.G.S. 7-1/2 minute quadrangle maps and the *Soil Survey of Union County* (Waters and Matanzo, 1975). Slopes of 0 to 2 percent (10) were selected for the majority of the settings in Union County due to the overall flat lying to gently rolling topography and low relief. Slopes of 2 to 6 percent (9) were assigned to most end moraines exhibiting hummocky terrain. Slopes of 6 to 12 percent (5) were selected for a limited number of areas where Blues Creek cut into the Broadway Moraine or where Big Darby Creek cut into the Powell Moraine.

Impact of the Vadose Zone Media

Information on evaluating vadose zone media was obtained primarily from the *Ground Water Resources of Union County* (Schmidt, 1978) 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. Vadose zone media ratings from neighboring Marion County (Angle, 2003), Franklin County (Angle, 1995), Madison County (Hallfrisch and Voytek, 1987), Logan County (Sprowls, 1995), and Champaign County (Jones, 1995) were 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 Union County* (Waters and Matanzo, 1975) provided valuable information on parent materials. The *Glacial Map of Ohio* (Goldthwait et al., 1961), and the *Quaternary Geology of Ohio* (Pavey et al., 1999) were useful in delineating vadose zone media. Additional vadose zone media information was obtained from the investigation for the

Table 10. Union County soils

Soil Name	Parent Material/ Setting	DRASTIC Rating	Soil Media
Algiers	Alluvium	4	Silt loam
Blount	Clayey till	3	Clay loam
Brookston	Loamy till	3	Clay loam
Celina	Loamy Till	3	Clay loam
Crosby	Loamy till	3	Clay loam
Eel	Alluvium	4	Silt loam
Fox	Outwash, kames	6	Sandy loam
Genesee	Alluvium	4	Silt loam
Henshaw	Alluvium, lacustrine terrace	4	Silt loam
Homer	Outwash	6	Sandy loam
Kane	Outwash terrace	6	Sandy loam
Kendalville	Thin outwash over ablation till	3	Clay loam
Lippincott	Outwash	6	Sandy loam
Miamian	Loamy till	3	Clay loam
Montgomery	Lacustrine terrace, oxbows	7	Shrink-swell clay
Morley	Clayey till	3	Clay loam
Muskego	Kettle, bogs	8	Peat
Nappanee	Water-modified till	7	Shrink-swell clay
Nolin	Alluvium	4	Silt loam
Odell	Lacustrine over ablation till	4	Silt Loam
Paulding	Clayey lacustrine	7	Shrink-swell clay
Pewamo	Clayey till, drainage ways	3	Clay loam
Ross	Alluvium	4	Silt loam
St. Clair	Clayey lacustrine	7	Shrink-swell clay
Shoals	Alluvium	4	Silt loam
Sleeth	Outwash, coarse alluvium	6	Sandy loam
Sloan	Alluvium	4	Silt loam
Warsaw	Outwash	6	Sandy loam
Westland	Outwash over ablation till	4	Silt loam
Wetzel	Ablation till, depressions	3	Clay loam

proposed SSC site in Ohio (Ohio SSC-State of Ohio, 1987).

The vadose zone media is a critical component of the overall DRASTIC rating in Union 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 Union County where the till covering the underlying limestone was very thin. Glacial till was given vadose zone media ratings of (6), (5), (4), or (3). A rating of (6) was applied to a limited number of areas where the till was thin, weathered, and fractured or contained a higher proportion of sand and gravel lenses. A vadose zone media rating of (5) was used for most areas where the thickness of till was thin to moderate and the depth to water was shallow. In these areas, it was assumed that the majority of the till was weathered and fractured. A vadose zone media rating of (4) was assigned to areas with moderate thicknesses of till and with moderate depths to water. A vadose zone media rating of (3) was selected for limited portions of the Powell Moraine where the till was quite thick and the depth to water was great. The rating of (3) is indicative of the semi-confined (but not truly confined) nature of the underlying limestone aquifer.

A vadose zone media rating of (5) or (6) was chosen for sand and gravel with significant silt and clay for alluvial and outwash terraces flanking portions of Mill Creek, Big Darby Creek, and along Big Swale Creek north of Richwood and Fulton Creek south of Richwood. Silt and clay with a vadose zone media rating of (5) was selected for most alluvial settings in the county. Silt and clay with a rating of (4) was applied to fine-grained alluvium associated with some minor tributary streams. Silt and clay (3) was selected for areas covered with thicker lacustrine deposits associated with the intermorainal lakes. Shrink-swell (non-aggregated) clay soils developed from these clayey sediments. Till/silt/clay was selected for the vadose zone media where thin lacustrine materials are draped over glacial till. A vadose zone media rating of (3) was applied to these fine-grained sediments.

Hydraulic Conductivity

Information on evaluating the hydraulic conductivity was obtained from the maps and report of the ODNR, Div. of Water, (1970), Norris and Fidler (1973), and the *Ground Water Resources of Union County* (Schmidt, 1978). 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. Hydraulic conductivity ratings from neighboring Marion County (Angle, 2003), Franklin County (Angle, 1995), Madison County (Hallfrisch and Voytek, 1987), Logan County (Sprowls, 1995), and Champaign County (Jones, 1995) were 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. Extensive hydraulic conductivity data was obtained from the investigation for the proposed SSC site in Ohio (Ohio SSC-State of Ohio, 1987). Additional site-specific hydraulic conductivity data includes reports by Wilson (1987), Stilson & Assoc. (1950), and Burgess & Niple (1978). 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. All of the sand and gravel aquifers were assigned a hydraulic conductivity rating of 300-700 (4) gallons per day per square foot (gpd/ft^2). Limestone aquifers along the northern, eastern, and southwestern margins of Union County were also assigned a hydraulic conductivity range of 300-700 gpd/ft^2 (4). Limestone aquifers in the central and western portions of the county were given a hydraulic conductivity rating of 700-1000 gpd/ft^2 (6) due to the high amount of fracturing and jointing. Most of the higher-yielding wells in Union County were located in the areas rated as having a higher range of hydraulic conductivity.

APPENDIX B

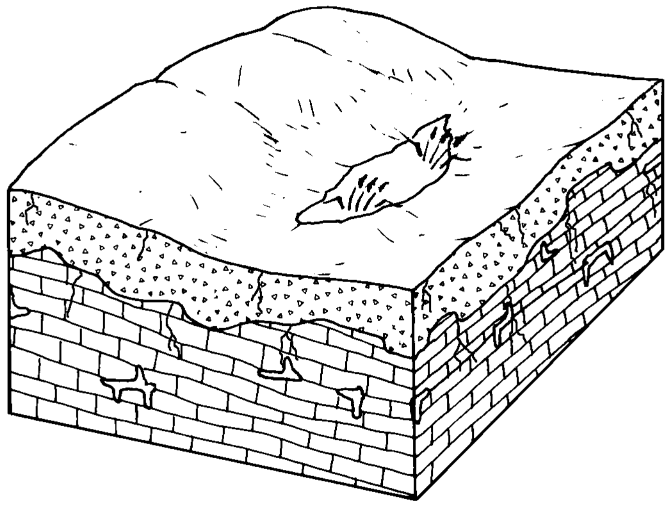
DESCRIPTION OF HYDROGEOLOGIC SETTINGS AND CHARTS

Ground water pollution potential mapping in Union County resulted in the identification of eight 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 Union County range from 94 to 171.

Table 11. Hydrogeologic settings mapped in Union County, Ohio

Hydrogeologic Settings	Range of GWPP Indexes	Number of Index Calculations
7 Ac-Glacial till over limestone	120-162	37
7Af-Sand and gravel interbedded in glacial till	121-135	4
7 C-Moraine	94-152	38
7D-Buried valley	115-125	2
7 Ec-Alluvium over sedimentary rock	138-171	27
7 Ed-Alluvium over glacial till	135-146	3
7 Fc-Intermorainal lake deposits	108-128	4
7 J-Glacial complex	118-147	8

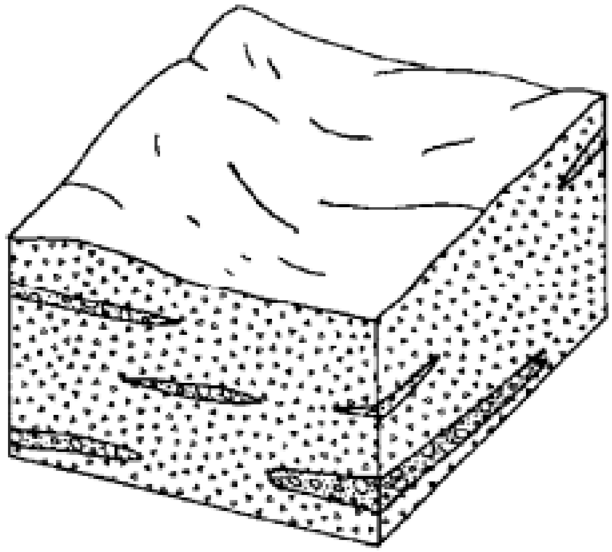
The following information provides a description of each hydrogeologic setting identified in the county, a block diagram illustrating the characteristics of the setting, and a listing of the charts for each unique combination of pollution potential indexes calculated for each setting. The charts provide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



<u>7Ac-Glacial Till over Limestone</u>

This hydrogeologic setting is widespread in Union County, especially in the northern part of the 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 Silurian and/or Devonian limestones and dolomites. These carbonate rocks may contain significant solution features. Depth to water is typically shallow to moderate, ranging from 15 to 50 feet. Soils are variable but typically are clay loams derived from till. Maximum ground water yields greater than 100 gpm are possible from the Silurian Lockport, Tymochtee, Greenfield and Salina Groups. Yields range from 5 to 100 gpm for the Devonian carbonate units. Recharge is moderate due to the clayey nature of the soils and vadose zone and the relatively shallow depth to water and permeable nature of the bedrock aquifer.

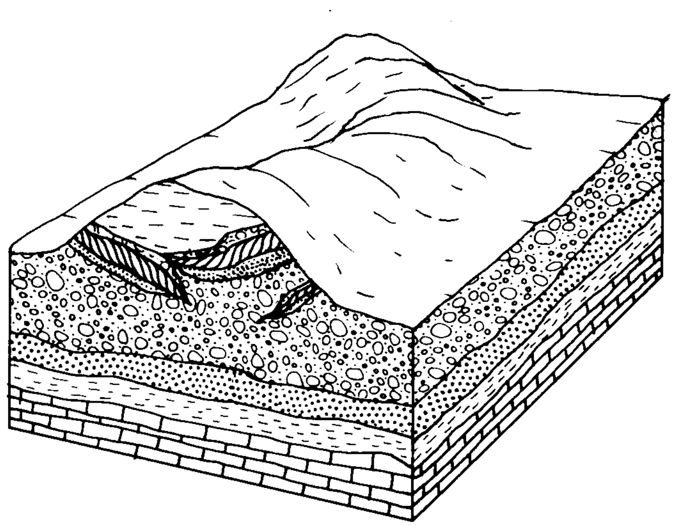
GWPP index values for the hydrogeologic setting of Glacial Till over Solution Limestone range from 120 to 162, with the total number of GWPP index calculations equaling 37.



7Af-Sand and Gravel Interbedded in Glacial Till

This hydrogeologic setting is limited to the southwestern corner of Union County adjacent to Champaign 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. Depth to water is usually shallow, averaging less than 30 feet. 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.

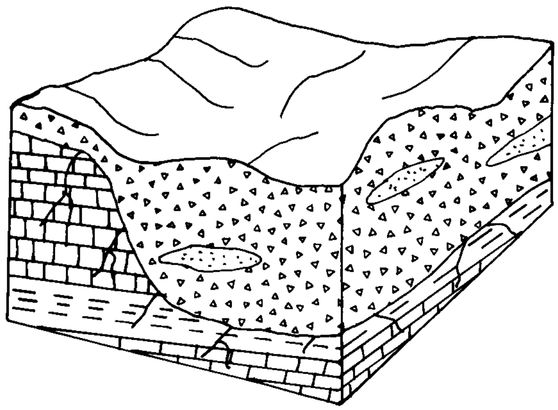
GWPP index values for the hydrogeologic setting of Sand and Gravel Interbedded in Glacial Till range from 121 to 135, with the total number of GWPP index calculations equaling 4.



<u>7C-Moraine</u>

This hydrogeologic setting consists of elongated, broad belts of end moraines that cross Union County. This setting is characterized by hummocky to rolling topography. Relief tends to become steeper near the margins of the moraine, especially if enhanced by the downcutting of an adjacent stream. Well log data shows that sand and gravel lenses within the moraine are typically not present or are very thin and isolated. The aquifer typically consists of limestone bedrock that underlies the till. Maximum ground water yields greater than 100 gpm are possible from the Silurian Lockport, Tymochtee, Greenfield and Salina Groups. Yields range from 5 to 100 gpm for the Devonian carbonate units. 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 variable and depends primarily upon how deep the underlying aquifer is. Soils are commonly clay loams. In limited areas, soils are shrink-swell clays that formed from thin lacustrine deposits where shallow intermorainal lakes overlapped upon the end moraine. Recharge is moderate to low depending upon how thick the till and how deep the underlying limestone is. The end moraines are the primary local sources of recharge. Overall, the St. Johns Moraine contains more sand and gravel than the Broadway Moraine, Powell Moraine, or Bokes Creek Moraine.

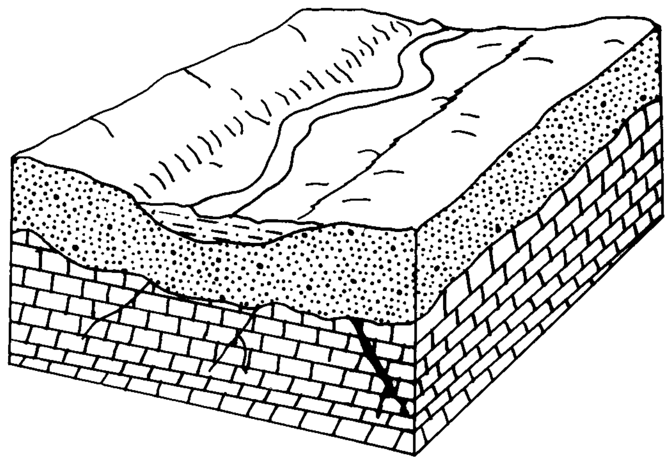
GWPP index values for the hydrogeologic setting of Moraine range from 94 to 152, with the total number of GWPP index calculations equaling 38.



<u>7D-Buried Valley</u>

This hydrogeologic setting is limited to the southeastern corner of Union 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. The aquifer consists of thinner, less continuous lenses of sand and gravel interbedded with thicker sequences of fine-grained glacial till. The setting is similar to the 7J-Glacial Complex except that the sand and gravel lenses are more numerous, more continuous in lateral extent, and constitute the aquifer. In the 7J setting, the underlying limestone is the aquifer. Yields from the sand and gravel lenses are commonly less than 25 gpm. Soils are usually clay loams derived from the overlying glacial till. Depths to water are typically shallow to moderate. Recharge is typically moderate due to the fine-grained nature of the soils and vadose zone media and the relatively shallow depth to the sand and gravel aquifers.

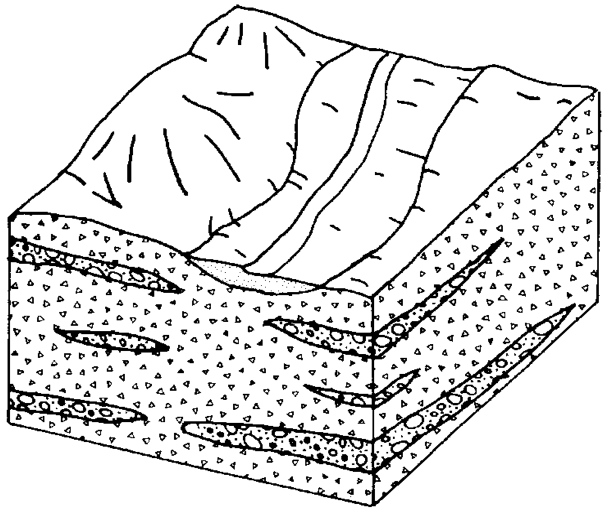
GWPP index values for the hydrogeologic setting of Buried Valley range from 115 to 125, with the total number of GWPP index calculations equaling 2.



7Ec-Alluvium over Sedimentary Rock

This hydrogeologic setting is common throughout Union County. 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 bedrock. The aquifers consist of Silurian and Devonian limestones. The vadose zone consists of the sandy to silty to clayey alluvial 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, Tymochtee, Greenfield and Salina Groups. Yields range from 5 to 100 gpm for the Devonian carbonate units. 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.

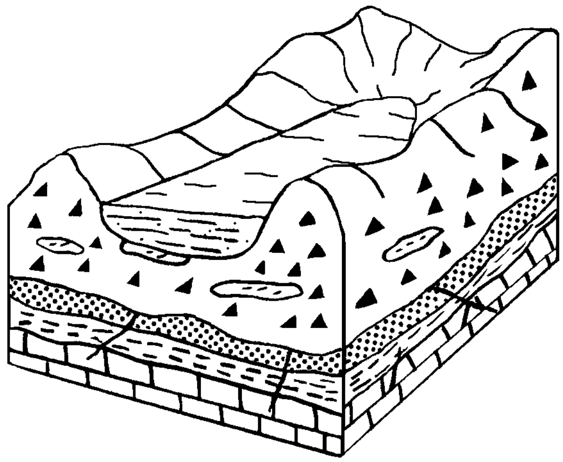
The GWPP index values for the hydrogeologic setting Alluvium over Sedimentary Rocks range from 138 to 171, with the total number of GWPP index calculations equaling 27.



7Ed-Alluvium Over Glacial Till

This hydrogeologic setting is comprised of flat-lying floodplains and stream terraces containing thin to moderate thicknesses of modern alluvium. This setting is similar to the 7Af–Sand and Gravel interbedded in Glacial Till setting except for the presence of the modern stream and related deposits. The 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 silt loams or sandy loams. 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.

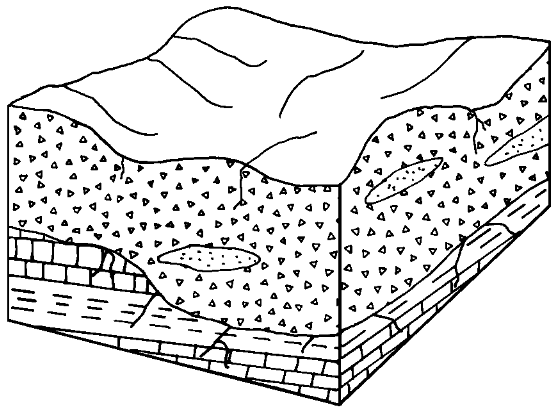
The GWPP index values for the hydrogeologic setting Alluvium Over Glacial Till range from 135 to 146, with the total number of GWPP index calculations equaling 3.



<u>7Fc-Intermorainal Lake Deposits</u>

This hydrogeologic setting is characterized by the flat-lying topography between end moraines and contains varying thicknesses of fine-grained lacustrine sediments. Surficial drainage is typically very poor; ponding is very common after rains. These sediments were deposited in shallow lakes formed between end moraines and the retreating ice sheets before the modern drainage system evolved. This setting occupies many of the low-lying areas within west central Union County. The vadose zone media consists of silty to clayey lacustrine sediments that overlie glacial till. The aquifer consists of the underlying limestone bedrock. Maximum ground water yields greater than 100 gpm are possible from the Silurian Lockport, Tymochtee, Greenfield and Salina Groups. Depth to water is commonly very shallow. Soils are shrink-swell (non-aggregated) clay derived from clayey lacustrine sediments. Recharge in this setting is low due to the relatively low permeability soils and vadose zone material.

GWPP index values for the hydrogeologic setting of Intermorainal Lake Deposits range from 108 to 128, with the total number of GWPP index calculations equaling 4.



7J-Glacial Complex

This setting is found in the southern half of Union 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. 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, most wells are completed in the limestone. Maximum ground water yields greater than 100 gpm are possible from the Silurian Lockport, Tymochtee, Greenfield and Salina Groups. The setting is similar to the 7D-Buried Valley except that the sand and gravel lenses are less common, less continuous in lateral extent, and the overall thickness of drift is somewhat less. In the 7J setting, the underlying limestone is the aquifer. Soils are usually clay loams derived from the overlying glacial till. Depths to water are typically shallow to moderate. 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 118 to 147, with the total number of GWPP index calculations equaling 8.

Table 12. Hydrogeologic Settings, DRASTIC Factors, and Ratings

Setting	Depth to Water	Recharge	Aquifer Media	Soil Media	Topography	Vadose Zone Media	Hydraulic Conductivity	Rating	Pesticide Rating_
7Ac01	5-15	4-7	limestone	Clay Loam	0-2	till	700-1000	147	166
7Ac02	5-15	4-7	limestone	Clay Loam	0-2	till	700-1000	152	170
7Ac03	15-30	4-7	limestone	Clay Loam	0-2	till	700-1000	142	160
7Ac04	0-5	4-7	limestone	Clay Loam	0-2	till	700-1000	152	171
7Ac05	0-5	4-7	limestone	Shrink-swell clay	0-2	till	700-1000	160	191
7Ac06	0-5	4-7	limestone	Sandy Loam	0-2	till	700-1000	158	186
7Ac07	15-30	4-7	limestone	Clay Loam	0-2	till	300-700	136	156
7Ac08	15-30	4-7	limestone	Clay Loam	0-2	till	300-700	133	153
7Ac09	15-30	4-7	limestone	Clay Loam	0-2	till	300-700	128	149
7Ac10	15-30	4-7	limestone	Clay Loam	2-6	till	700-1000	141	157
7Ac11	15-30	4-7	limestone	Clay Loam	2-6	lst/frac till	700-1000	146	161
7Ac12	15-30	4-7	limestone	Clay Loam	0-2	lst/frac till	700-1000	147	164
7Ac13	5-15	4-7	limestone	Clay Loam	0-2	till	300-700	146	166
7Ac14	5-15	4-7	limestone	Clay Loam	2-6	till	300-700	145	163
7Ac15	5-15	4-7	limestone	Sandy Loam	0-2	till	700-1000	153	181
7Ac16	15-30	4-7	limestone	Clay Loam	0-2	till	700-1000	137	156
7Ac17	15-30	4-7	limestone	Clay Loam	2-6	till	300-700	127	146
7Ac18	15-30	4-7	limestone	Clay Loam	2-6	till	300-700	132	150
7Ac19	5-15	4-7	limestone	Clay Loam	0-2	till	300-700	143	163
7Ac20	5-15	4-7	limestone	Clay Loam	0-2	lst/frac till	700-1000	157	174
7Ac21	0-5	4-7	limestone	Clay Loam	0-2	lst/frac till	700-1000	162	179
7Ac22	0-5	4-7	limestone	Clay Loam	0-2	till	300-700	151	171
7Ac23	0-5	4-7	limestone	Clay Loam	0-2	lst/frac till	300-700	153	172
7Ac24	5-15	4-7	limestone	Clay Loam	0-2	lst/frac till	300-700	148	167
7Ac25	30-50	4-7	limestone	Clay Loam	0-2	till	700-1000	132	150
7Ac26	0-5	4-7	limestone	Clay Loam	0-2	lst/frac till	300-700	156	175
7Ac27	5-15	4-7	limestone	Clay Loam	0-2	lst/frac till	300-700	151	170
7Ac28	15-30	4-7	limestone	Shrink-swell clay	0-2	till/silt/clay	700-1000	140	172
7Ac29	15-30	4-7	limestone	Clay Loam	0-2	lst/frac till	300-700	138	157
7Ac30	30-50	4-7	limestone	Clay Loam	2-6	till	300-700	120	139
7Ac31	15-30	4-7	limestone	Clay Loam	0-2	till	300-700	131	152
7Ac32	15-30	4-7	limestone	Clay Loam	0-2	till	700-1000	147	164
7Ac33	15-30	4-7	limestone	Sandy Loam	0-2	sd+gvl w/sl+cl	300-700	136	165
7Ac34	15-30	4-7	limestone	Sandy Loam	0-2	till	700-1000	148	175
7Ac35	15-30	4-7	limestone	Clay Loam	0-2	till	300-700	125	146
7Ac36	5-15	4-7	limestone	Clay Loam	0-2	till	300-700	135	156
7Ac37	30-50	4-7	limestone	Clay Loam	0-2	till	300-700	121	142
7Af1	15-30	4-7	sand and gravel	Clay Loam	2-6	till	300-700	121	140

Setting	Depth to Water	Recharge	Aquifer Media	Soil Media	Topography	Vadose Zone Media	Hydraulic Conductivity	Rating	Pesticide Rating_
7Af2	15-30	4-7	sand and gravel	Shrink-swell clay	2-6	till	300-700	132	163
7Af3	5-15	4-7	sand and gravel	Clay Loam	0-2	till	300-700	135	156
7Af4	15-30	4-7	sand and gravel	Clay Loam	0-2	till	300-700	125	146
7C01	15-30	4-7	limestone	Clay Loam	0-2	till	300-700	133	153
7C02	15-30	4-7	limestone	Clay Loam	0-2	till	300-700	138	157
7C03	15-30	4-7	limestone	Clay Loam	2-6	till	300-700	137	154
7C04	15-30	4-7	limestone	Clay Loam	0-2	till	700-1000	142	160
7C05	5-15	4-7	limestone	Clay Loam	0-2	till	700-1000	152	170
7C06	5-15	4-7	limestone	Clay Loam	0-2	till	700-1000	147	166
7C07	15-30	4-7	limestone	Clay Loam	0-2	till	700-1000	137	156
7C08	15-30	4-7	limestone	Clay Loam	2-6	till	700-1000	136	153
7C09	30-50	4-7	limestone	Clay Loam	0-2	till	700-1000	127	146
7C10	30-50	4-7	limestone	Clay Loam	0-2	till	700-1000	132	150
7C11	15-30	4-7	limestone	Clay Loam	2-6	till	700-1000	141	157
7C12	30-50	4-7	limestone	Clay Loam	2-6	till	700-1000	131	147
7C13	30-50	2-4	limestone	Shrink-swell clay	0-2	till	700-1000	123	154
7C14	50-75	2-4	limestone	Shrink-swell clay	0-2	till/silt/clay	700-1000	108	140
7C15	50-75	4-7	limestone	Clay Loam	0-2	till	700-1000	117	136
7C16	30-50	4-7	limestone	Clay Loam	6-12	till	700-1000	127	135
7C17	30-50	4-7	limestone	Clay Loam	6-12	till	300-700	121	131
7C18	30-50	4-7	limestone	Clay Loam	0-2	till	300-700	126	146
7C19	30-50	4-7	limestone	Clay Loam	0-2	till	300-700	123	143
7C20	30-50	4-7	limestone	Clay Loam	6-12	till	300-700	118	128
7C21	30-50	4-7	limestone	Clay Loam	2-6	till	300-700	122	140
7C22	15-30	4-7	limestone	Clay Loam	0-2	till	300-700	136	156
7C23	30-50	4-7	limestone	Clay Loam	2-6	till	700-1000	126	143
7C24	50-75	4-7	limestone	Clay Loam	2-6	till	700-1000	116	133
7C25	50-75	2-4	limestone	Clay Loam	0-2	till	700-1000	105	124
7C26	50-75	2-4	limestone	Clay Loam	2-6	till	700-1000	104	121
7C27	75-100	2-4	limestone	Clay Loam	2-6	till	700-1000	99	116
7C28	75-100	2-4	limestone	Clay Loam	2-6	till	700-1000	94	112
7C29	30-50	4-7	limestone	Clay Loam	2-6	till	300-700	120	139
7C30	50-75	2-4	limestone	Clay Loam	2-6	till	300-700	98	117
7C31	30-50	4-7	limestone	Clay Loam	2-6	till	300-700	117	136
7C32	30-50	4-7	limestone	Clay Loam	0-2	till	300-700	118	139
7C33	50-75	4-7	limestone	Clay Loam	2-6	till	300-700	107	126
7C34	50-75	2-4	limestone	Clay Loam	2-6	till	300-700	95	114
7C35	50-75	2-4	limestone	Clay Loam	0-2	till	300-700	96	117
7C36	15-30	4-7	limestone	Clay Loam	0-2	till	300-700	128	149

Setting	Depth to Water	Recharge	Aquifer Media	Soil Media	Topography	Vadose Zone Media	Hydraulic Conductivity	Rating	Pesticide Rating_
7C37	75-100	2-4	limestone	Shrink-swell clay	0-2	till/silt/clay	700-1000	103	135
7C38	50-75	2-4	limestone	Clay Loam	0-2	till	700-1000	100	120
7D1	15-30	4-7	sand and gravel	Clay Loam	0-2	till	300-700	125	146
7D2	30-50	4-7	sand and gravel	Clay Loam	0-2	till	300-700	115	136
7Ec01	5-15	4-7	limestone	Shrink-swell clay	0-2	silt/clay	700-1000	150	182
7Ec02	5-15	4-7	limestone	Silty Loam	0-2	silt/clay	700-1000	154	175
7Ec03	5-15	4-7	limestone	Silty Loam	0-2	silt/clay	300-700	148	171
7Ec04	0-5	4-7	limestone	Silty Loam	0-2	sd+gvl w/sl+cl	300-700	155	177
7Ec05	5-15	4-7	limestone	Sandy Loam	0-2	sd+gvl w/sl+cl	700-1000	158	185
7Ec06	5-15	4-7	limestone	Silty Loam	0-2	silt/clay	700-1000	149	171
7Ec07	5-15	4-7	limestone	Sandy Loam	0-2	silt/clay	700-1000	158	185
7Ec08	0-5	4-7	limestone	Shrink-swell clay	0-2	silt/clay	300-700	154	187
7Ec09	0-5	4-7	limestone	Sandy Loam	0-2	sd+gvl w/sl+cl	700-1000	168	194
7Ec10	0-5	4-7	limestone	Silty Loam	0-2	sd+gvl w/sl+cl	700-1000	159	180
7Ec11	0-5	4-7	limestone	Shrink-swell clay	0-2	silt/clay	700-1000	155	187
7Ec12	0-5	4-7	limestone	Silty Loam	0-2	sd+gvl w/sl+cl	700-1000	164	184
7Ec13	5-15	4-7	limestone	Shrink-swell clay	0-2	silt/clay	300-700	149	182
7Ec14	0-5	4-7	limestone	Silty Loam	0-2	sd+gvl w/sl+cl	300-700	150	173
7Ec15	5-15	4-7	limestone	Clay Loam	0-2	silt/clay	700-1000	152	170
7Ec16	0-5	4-7	limestone	Silty Loam	0-2	sd+gvl w/sl+cl	300-700	158	180
7Ec17	5-15	4-7	limestone	Silty Loam	0-2	silt/clay	300-700	145	168
7Ec18	5-15	7-10	limestone	Silty Loam	0-2	sd+gvl w/sl+cl	700-1000	167	187
7Ec19	5-15	7-10	limestone	Sandy Loam	0-2	sd+gvl w/sl+cl	700-1000	171	197
7Ec20	5-15	7-10	limestone	Silty Loam	0-2	sd+gvl w/sl+cl	300-700	161	183
7Ec21	5-15	7-10	limestone	Sandy Loam	0-2	sd+gvl w/sl+cl	300-700	162	190
7Ec22	5-15	7-10	limestone	Silty Loam	0-2	sd+gvl w/sl+cl	300-700	158	180
7Ec23	5-15	4-7	limestone	Clay Loam	0-2	silt/clay	300-700	138	159
7Ec24	5-15	4-7	limestone	Silty Loam	0-2	silt/clay	700-1000	151	172
7Ec25	5-15	7-10	limestone	Sandy Loam	0-2	sd+gvl w/sl+cl	300-700	165	193
7Ec26	15-30	7-10	limestone	Silty Loam	0-2	sd+gvl w/sl+cl	300-700	145	167
7Ec27	15-30	4-7	limestone	Silty Loam	0-2	sd+gvl w/sl+cl	700-1000	144	165

Setting	Depth to Water	Recharge	Aquifer Media	Soil Media	Topography	Vadose Zone Media	Hydraulic Conductivity	Rating	Pesticide Rating_
7Ed1	5-15	4-7	sand and gravel	Silty Loam	0-2	sd+gvl w/sl+cl	300-700	142	165
7Ed2	5-15	4-7	sand and gravel	Sandy Loam	0-2	sd+gvl w/sl+cl	300-700	146	175
7Ed3	15-30	4-7	sand and gravel	Silty Loam	0-2	sd+gvl w/sl+cl	300-700	135	158
7Fc1	15-30	2-4	limestone	Shrink-swell clay	0-2	silt/clay	700-1000	128	160
7Fc2	15-30	2-4	limestone	Shrink-swell clay	2-6	silt/clay	700-1000	127	157
7Fc3	30-50	2-4	limestone	Shrink-swell clay	0-2	silt/clay	700-1000	118	150
7Fc4	50-75	2-4	limestone	Shrink-swell clay	0-2	till/silt/clay	700-1000	108	140
7J1	30-50	4-7	limestone	Clay Loam	0-2	till	700-1000	127	146
7J2	30-50	4-7	limestone	Clay Loam	0-2	till	300-700	118	139
7J3	15-30	4-7	limestone	Clay Loam	0-2	till	700-1000	137	156
7J4	15-30	4-7	limestone	Clay Loam	0-2	till	300-700	131	152
7J5	15-30	4-7	limestone	Clay Loam	0-2	till	300-700	128	149
7J6	15-30	4-7	limestone	Sandy Loam	0-2	till	700-1000	143	171
7J7	15-30	4-7	sand and gravel	Clay Loam	0-2	till	300-700	125	146
7J8	5-15	4-7	limestone	Clay Loam	0-2	till	700-1000	147	166