GROUND WATER POLLUTION POTENTIAL OF NOBLE COUNTY, OHIO

BY

KATHY SPROWLS

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ABSTRACT

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

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

Ground water pollution potential analysis in Noble County resulted in a map with symbols and colors that illustrate areas of varying ground water contamination vulnerability. Five hydrogeologic settings were identified in Noble County with computed ground water pollution potential indexes ranging from 61 to 126.

Noble County lies within the Nonglaciated Central hydrogeologic setting. Yields of up to 3 gallons per minute (gpm) are obtained from wells drilled in fill along stream valleys consisting of clay with occasional thin lenses of sand and gravel. Yields vary based on the thickness and extent of the sand and gravel lenses.

The consolidated, bedrock formations throughout the county are generally poor aquifers. Overall, yields tend to be slightly better adjacent to stream valleys and worse along ridge tops. Yields obtained from wells drilled in the dirty sandstones, shales, mudstones, and limestones of the Pennsylvanian Conemaugh and Monongahela Groups, as well as the Pennsylvanian to Lower Permian Dunkard Group, typically have meager yields averaging less than 3 gpm.

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 Noble 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.

TABLE OF CONTENTS

LIST OF FIGURES

Number | Page

LIST OF TABLES

ACKNOWLEDGEMENTS

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

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Report editing:	Kathy Sprowls James Raab

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; 1,134 of these wells exist in Noble 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 Ohio Department of Natural Resources (ODNR), Division of Water (now Division of Water Resources) 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 Resources 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 Noble 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 Noble 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

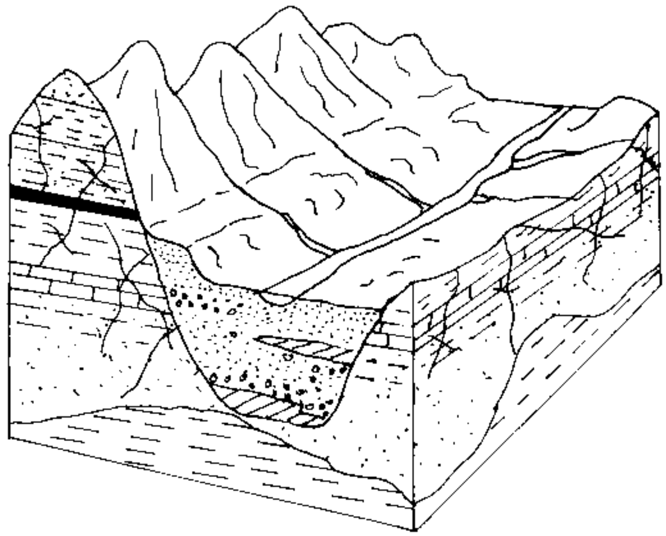
These factors incorporate concepts and mechanisms such as attenuation, retardation, and time or distance of travel of a contaminant with respect to the physical characteristics of the hydrogeologic setting. Broad consideration of these factors and mechanisms coupled with existing conditions in a setting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



7D Buried Valley

This hydrogeologic setting is limited to deposits found underlying Buffalo Creek just south of the Guernsey-Noble county line and Pleasant City. Broad, flat-lying floodplains and gently sloping terraces characterize the setting. Depths to water are typically less than 30 feet. The aquifer is composed of variable thicknesses of sand and gravel interbedded with finer-grained alluvium and lacustrine deposits. The modern stream may be in direct hydraulic connection with the underlying aquifer. Soils on floodplains are silt loams derived from modern alluvium. Recharge is typically relatively high due to the flat-lying topography, shallow depth to water, and the higher permeability of the soils, vadose zone materials, and aquifer.

The GWPP index value for the hydrogeologic setting of Buried Valley is 126, with the total number of GWPP index calculations equaling 1.

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

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. Greater vulnerability to contamination is indicated by a higher DRASTIC index. 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	

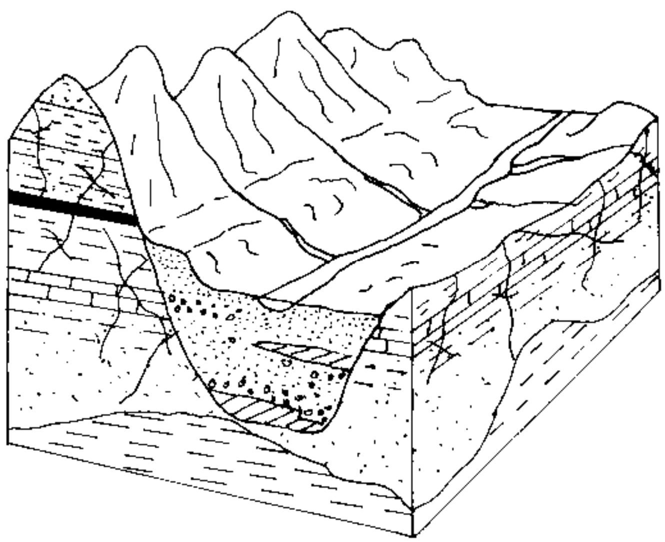
Table 8. Ranges and ratings for hydraulic conductivity

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 7D1, Buried Valley, identified in mapping Noble 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 126. 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. Calculated pollution potential indexes for the 5 settings identified in Noble County range from 61 to 126.

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 Noble 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 Noble County is included with this report.



SETTING 7D1		GENERAL		
FEATURE	**RANGE**	**WEIGHT**	**RATING**	**NUMBER**
Depth to Water	15-30	5	7	35
Net Recharge	4-7	4	6	24
Aquifer Media	Sand & Gravel	3	6	18
Soil Media	Silty Loam	2	4	8
Topography	0-2%	1	10	10
Impact of Vadose Zone	Sand & Gravel w/Silt & Clay	5	5	25
Hydraulic Conductivity	100-300	3	2	6
		DRASTIC	INDEX	126

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

INTERPRETATION AND USE OF GROUND WATER POLLUTION POTENTIAL MAPS

The application of the DRASTIC system to evaluate an area's vulnerability to contamination produces hydrogeologic settings with corresponding pollution potential indexes. The 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:

7D1 - defines the hydrogeologic region and setting
126 - defines the relative pollution potential

Here the first number (**7**) refers to the major hydrogeologic region and the upper case letters (**D**) refer 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 (**126**) 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 not color-coded.

GENERAL INFORMATION ABOUT NOBLE COUNTY

Demographics

Noble County occupies approximately 399 square miles in southeastern Ohio (Figure 3). Noble County is bounded to the north by Guernsey County, to the northeast by Belmont County, to the east by Monroe County, to the south by Washington County, to the northwest by Muskingum County, and to the west by Morgan County.

The approximate population of Noble County, based upon 2012 estimates, is 14,579 (Department of Development, Ohio County Profiles, 2012). Caldwell is the largest community and the county seat. Forest is the major land use in the county. Agriculture is also an important land use, followed by pasture. Strip mining has historically been an important land use in the northwestern and southeastern portion of the county.

Climate

The *Hydrologic Atlas for Ohio* (Harstine, 1991) reports an average annual temperature of approximately 52 degrees Fahrenheit for Noble County. The average temperature increases slightly towards the southwest and decreases slightly towards the northeast. The majority of the county receives approximately 40 inches per year of precipitation, but this amount decreases slightly in the west central portion of the county (Harstine, 1991). The mean annual precipitation for Caldwell is 38.21 inches per year based upon a thirty-year (1971-2000) period. The mean annual temperature at Caldwell for the same thirty-year period is 51.6 degrees Fahrenheit (U. S. Department of Commerce, 2002).

Physiography and Topography

Noble County lies entirely within the Allegheny Plateaus section of the Appalachian Plateaus Province (Frost, 1931, Fenneman, 1938, and Brockman, 1998). The Allegheny Plateaus section is subdivided into regions; Noble County is included within the Marietta Plateau Region. This region is characterized by high relief and rugged topography, featuring narrow ridges, steep slopes, a high degree of stream dissection, and fine-grained bedrock sequences.

Figure 3. Location of Noble County, Ohio.

Modern Drainage

The northeastern third of Noble County is drained by tributaries of Wills Creek including Buffalo Creek, Seneca Fork, Beaver Creek, South Fork and Glady Run. These tributaries join Wills Creek, which flows north through central Guernsey County and then turns westward, emptying into the Muskingum River at the Muskingum County–Coshocton County boundary. The central third of Noble County is drained primarily by West Fork Duck Creek and East Fork Duck Creek. East Fork Duck Creek joins West Fork Duck Creek in northwestern Washington County. West Fork Duck Creek then flows south and empties into the Ohio River. The western third of Noble County is drained by several tributaries of the Muskingum River: Olive Green Creek, Sharon Fork, Keith Fork, Big Run, and Cat Creek. The Muskingum River then flows south to join the Ohio River.

Pre- and Inter-Glacial Drainage Changes

Noble County lies entirely beyond the glacial boundary; however, the drainage patterns of the county changed greatly 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 Noble County and adjacent counties.

Prior to glaciation, the Teays River System drained southeastern Ohio (Figure 4). The Cambridge River and its tributaries drained the northern half of Noble County (Stout et al., 1943 and Stout, 1918). It flowed to the northwest following, in part, the present day course of Wills Creek. Eventually its course turned westward, emptying into the Groveport River near present day Newark. The Groveport River was an important eastern tributary of Teays River. Southern Noble County was drained by Barlow Creek and Whipple Creek, which eventually emptied into the Marietta River, which flowed into the Teays River.

As ice advanced through Ohio during the pre-Illinoian (Kansan) glaciation, the Teays Drainage System was blocked. Flow backed-up in the main trunk of the Teays River Valley as well as in many 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 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 (Figure 5) is referred to as the Deep Stage due to this increased downcutting. A new trunk stream referred to as the Newark River down-cut and its headwaters eroded eastward, eventually extending to the city of Coshocton. Plainfield Creek, a northwesterly flowing tributary that closely followed the course of the Teays Stage Cambridge River, drained the northern third of Noble County and joined the Newark River near West Lafayette. The southern two-thirds of Noble County was drained by Lowell Creek, which then emptied into the Pomeroy River. This area was also drained by an un-named tributary of the Pomeroy River that followed the course of the Teays Stage Whipple Creek. The Pomeroy River flowed west to join the Cincinnati River. During this time, the ancestral Ohio River became established.

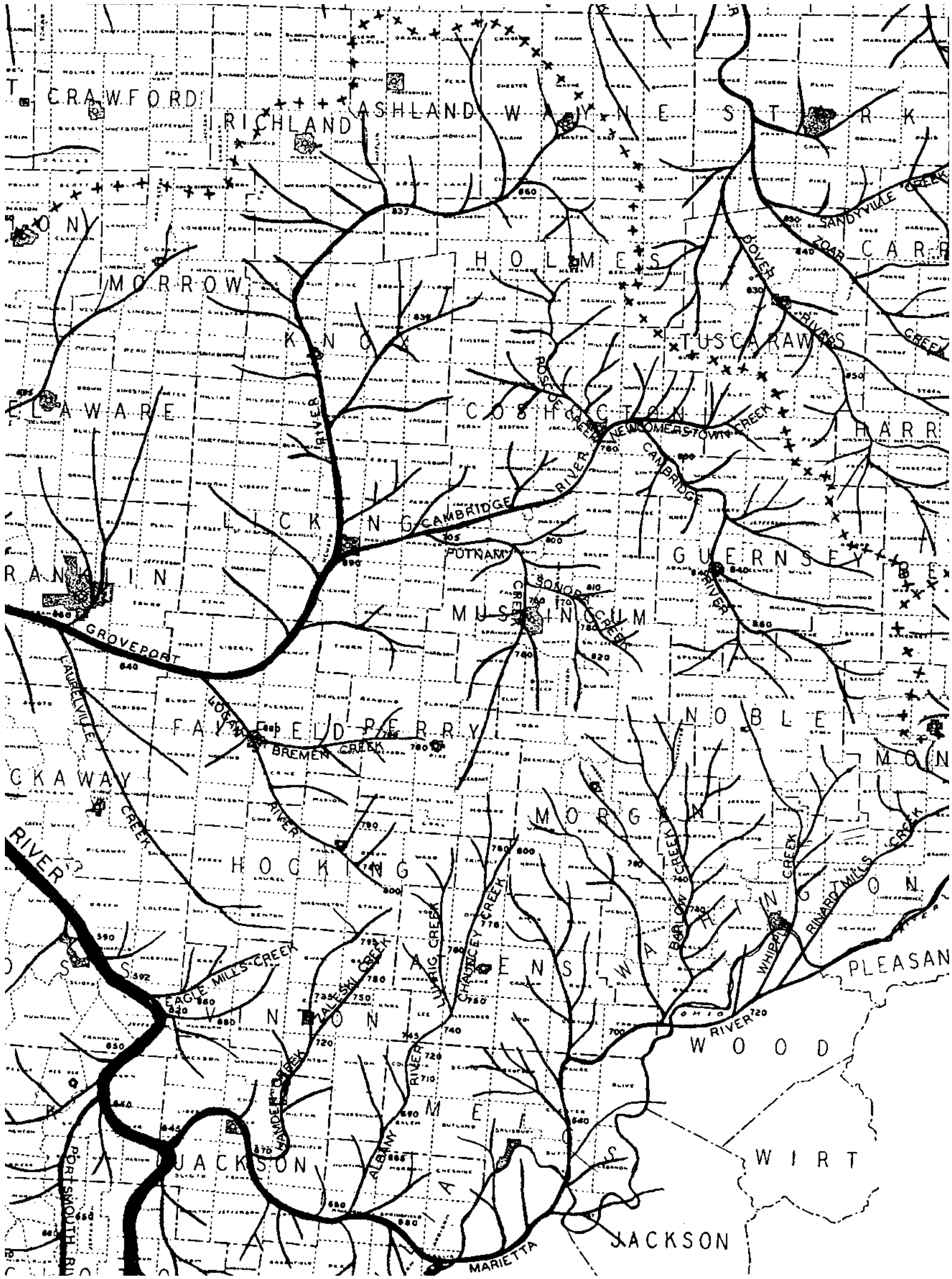


Figure 4. Pre-glacial Teays Stage drainage (after Stout et al., 1943).

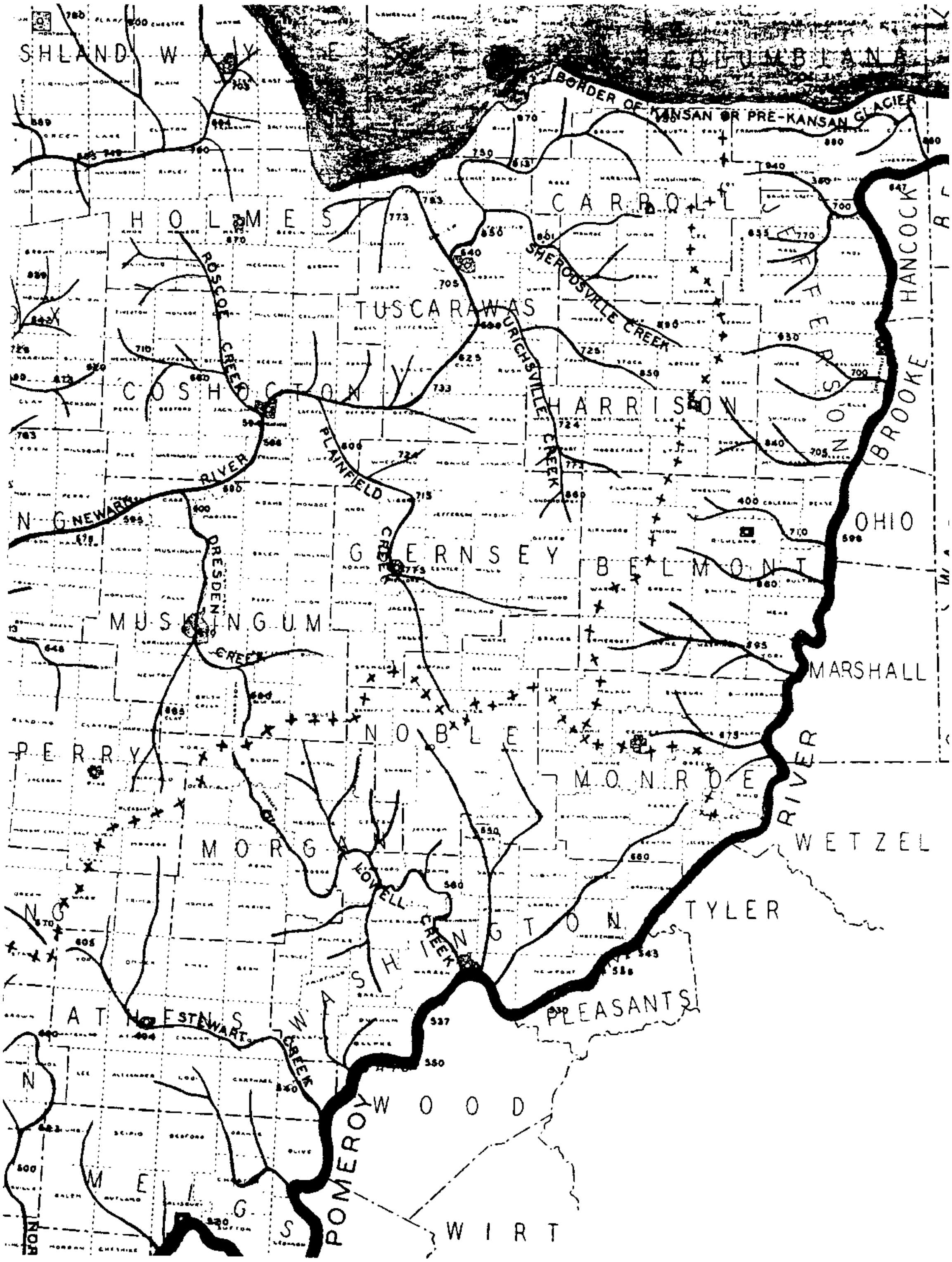


Figure 5. Deep Stage drainage (after Stout et al., 1943).

The Illinoian ice advance brought further changes to the drainage systems (Figure 6). Opinions as to the nature of drainage changes as a result of the advancing Illinoian ice front differ. Stout et al. (1943) determined that Illinoian ice either did not advance into northeastern Ohio, or at least advanced at a different time than in western Ohio. As the Illinoian ice sheet advanced eastward from central Ohio, the Newark River was blocked in Licking County. The waters of the blocked drainage rose and eventually were diverted to the north; basically re-occupying the channel of the former Dover River. At this time, drainage to the north was possible, as advancing Illinoian ice did not block this area. This northerly flowing trunk stream was referred to as the Massillon River (Stout et al., 1943). Headwaters for Kimbolton Creek, a northwesterly-flowing tributary to the Ashcraft Creek (which in turn flowed into the Massillon River), drained northern Noble County. Central and southern Noble County was drained by Beverly Creek, which followed the course of Deep Stage Lowell Creek, and another un-named tributary. Both of these emptied into the New Martinsville River. Lamborn (1956) and DeLong and White (1963) proposed that Illinoian ice did advance into northeastern Ohio and blocked drainage northward. They proposed that drainage was still primarily to the southwest through the Newark River.

The massive volumes of meltwater produced during the Wisconsinan (most recent) ice advance eventually breached the col near Eagleport (Norling, 1958). This led to the establishment of the modern Muskingum River System (Stout et al., 1943 and Norling, 1958). Present-day tributaries of the Muskingum River drain most of Noble County.

Glacial Geology

The majority of the glacially-related deposits are limited to the ancestral stream channels (Walker, 1991; Pavey et al., 1999; and ODNR, Division of Water Resources, Open File Glacial State Aquifer Map). Ancestral stream channels filled with glacial/alluvial sediments are referred to as buried valleys. The buried valleys are filled with differing sequences of coarse sand and gravel outwash, finer-grained lacustrine and modern, silty alluvial or floodplain deposits. These deposits vary with the energy level of the streams at that time. Streams leading away from melting glaciers are high energy and deposit coarser outwash. Outwash contains interbedded layers of sand and gravel deposited by a braided stream system. Streams that are blocked by ice or by thick channel deposits tend to be ponded and fill with finer-grained sediments. Modern tributaries, which lead into streams overlying the buried valleys, tend to contain variable thicknesses of sand, gravel, and silty alluvium.

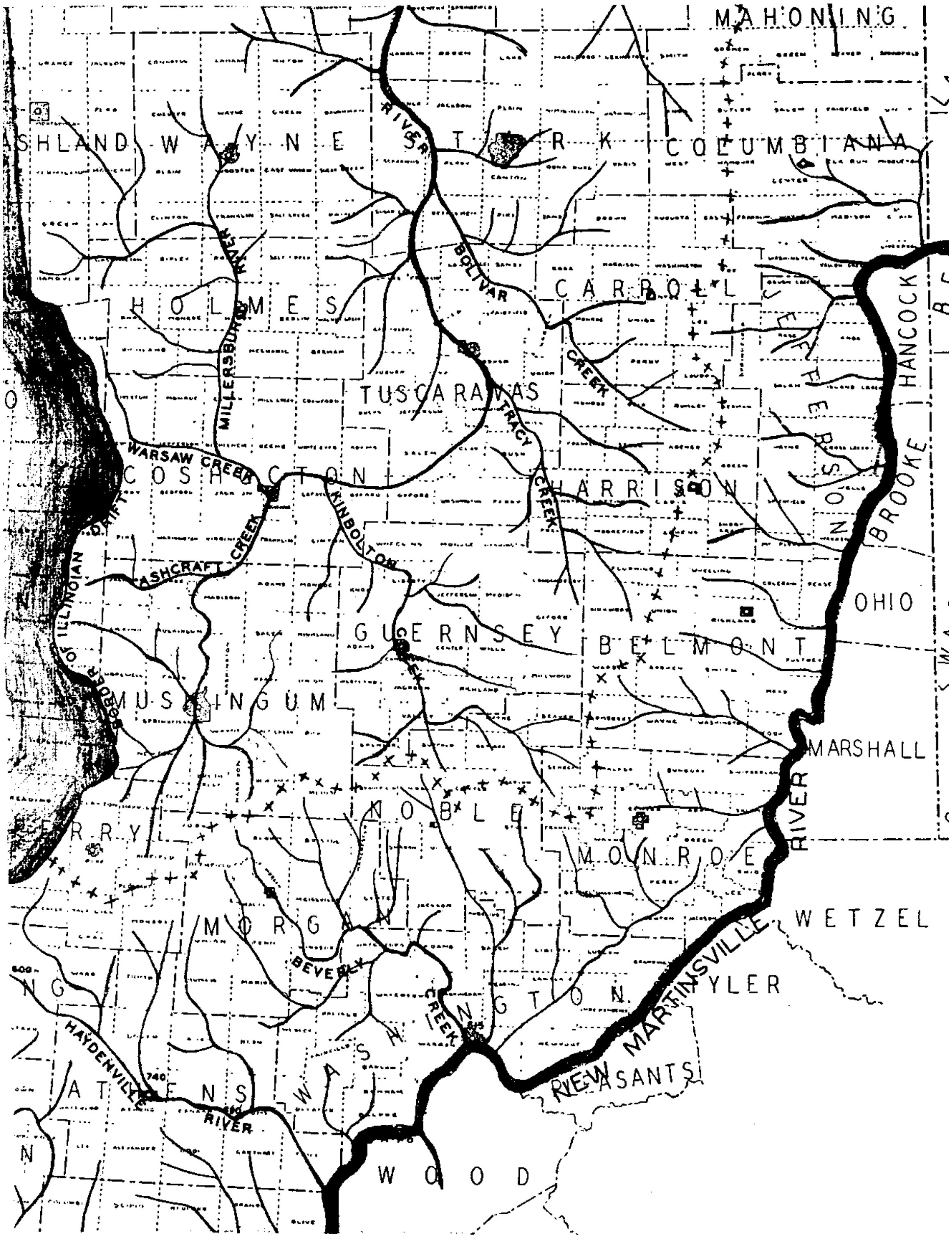


Figure 6. Illinoian-age drainage (after Stout et al., 1943).

Bedrock Geology

Bedrock exposed at the surface in Noble County belongs to the Pennsylvanian and Lower Permian Systems. Table 9 summarizes the bedrock stratigraphy found in Noble County. The oldest rocks exposed in Noble County are part of the Pennsylvanian Conemaugh Group, and are the uppermost formation in the north-central to northeastern portion of the county, and underlying the flood plains of Duck Creek, Buffalo Creek, and Seneca Fork to the south and east. These rocks include interbedded dirty sandstones, shales, siltstones, mudstones, and thin limestones and coals. Rocks of the Pennsylvanian Monongahela Group are uppermost in much of the south-central, southeastern, and eastern parts of the county, as well as the western border. These rocks include interbedded sandstones, shales, siltstones, mudstones, limestones, and some economic coal beds. The formations of the Pennsylvanian and Lower Permian Dunkard Group consist of clayey to silty mudstones, shale, siltstone, sandstone, and sparse thin beds of limestone and coal. The rocks are found on ridgetops in the extreme northwestern, southwestern, and southeastern portions of the county.

Weedman (1990) provides an excellent account of the complex depositional environments that created the rocks of the Pennsylvanian System. These highly transitional environments included both terrestrial ("land-based") and marine-derived sediments. The terrestrial environment was dominated by large river systems featuring broad alluvial plains upland from coastal areas. Stream channels and point bar deposits were the source of sandstones and conglomerates. Shales and siltstones were derived from fine-grained floodplain deposits. Freshwater limestones were deposited in shallow, rapidly evaporating lakes and ponds found on the alluvial plain. The terrestrial environment was highly transitional with a marine environment over time. The position of the shoreline and the depth of water varied with the rate of sediment input into the basin, sea level, and the rate of subsidence. Subsidence refers to an uneven "settling" during the relatively rapid accumulation of sediments.

Table 9. Bedrock stratigraphy of Noble County, Ohio (after Slucher et al., 2006)

System	Group/Formation (Symbol)	Lithologic Description
Lower Permian Pennsylvanian	Dunkard Group (Pd)	Gray, green, and black clayey to silty mudstone, shale, siltstone, sandstone, and sparse thin beds of non-marine limestone and coal. Sandstone is locally conglomeratic and calcareous; mudstone, shale, and siltstone are locally calcareous. Plant fossils are present locally. Mudstone is subject to severe surface weathering and prone to landslides in outcrop.
Pennsylvanian	Monongahela Group (Pm)	Red, gray, green, purple, yellow to black interbedded shale, siltstone, sandstone, mudstone, limestone and coal. Shale, siltstone, sandstone, and mudstone are clayey to silty, and locally calcareous. Mudstones are subject to severe surface weathering, landslides are common where unit crops out. Unit contains economic coal beds.
	Conemaugh Group (Pc)	Red, gray, green, purple, yellow to black interbedded shale, siltstone, sandstone, mudstone, limestone and coal. Shale, siltstone, sandstone, and mudstone are clayey to silty, and locally calcareous. Marine shale, limestone, and/or flinty limestone intervals are common in lower one-half of unit; non-marine limestone intervals mostly in upper one-half of unit. Coal beds are thin and rarely economic.

Ground Water Resources

Ground water in Noble County is obtained primarily from consolidated (bedrock) aquifers. Unconsolidated (glacial-alluvial) aquifers are limited to the main trunk of Buffalo Creek and West Fork Duck Creek near Caldwell.

Yields of up to 3 gallons per minute (gpm) are obtained from wells drilled in fill along stream valleys consisting of clay with occasional thin lenses of sand and gravel (Walker, 1991 and ODNR, Division of Water Resources, Open File Glacial State Aquifer Map). Yields vary based on the thickness and extent of the sand and gravel lenses.

Yields from the consolidated, bedrock aquifers throughout the county vary to a small degree. Overall, yields tend to be somewhat better adjacent to stream valleys and poorer along ridge tops. Yields obtained from wells drilled in the sandstones, shales, mudstones, and limestones of the Conemaugh Group, Monongahela Group, and Dunkard Group typically have meager yields averaging less than 3 gpm (Walker, 1991 and ODNR, Division of Water Resources, Open File Bedrock State Aquifer Map).

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

The number of fractures and bedding planes intersected by the well also influences yields. The amount of fracturing tends to be greater in the valley bottoms than at the ridge tops. This increase may be related to stress relief, as shown by Wyrick and Borchers (1981) and Kipp et al. (1983). The net result is that there is usually a decrease in the depth to water (i.e. a shallower static water level) and slightly higher yields. Fracturing is also an influence on the direction of ground water flow (Schubert, 1980) and affects the amount of recharge.

Strip and Underground Mined Areas

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

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

Mining and reclamation activities have the ability to affect all DRASTIC parameters. DRASTIC parameters and the possible impacts that mining may have on rating the parameters in strip-mined and underground mined areas are listed in Tables 10 and 11. These tables are not meant to be a comprehensive listing of the impacts of mining on ground water systems. They are provided to illustrate the uncertainty of evaluating the pollution potential of mined areas.

Although the pollution potential of strip and abandoned/active underground mined areas were not evaluated, they were delineated. Only the most prominent and conspicuous mined areas were delineated on the *Ground Water Pollution Potential Map of Noble County*. Delineations of mined areas were made using information from the *Soil Survey of Noble County* (Waters et al., 1990), abandoned underground mine maps (ODNR, Division of Geological Survey), and the Noble County portion of U.S.G.S. 7-1/2 minute quadrangle maps. Site-specific information for mined area can be obtained from the ODNR, Division of Geological Survey and Division of Mineral Resources Management.

Table 10. Potential factors influencing DRASTIC ratings for strip mined areas

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

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

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

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APPENDIX A
DESCRIPTION OF THE LOGIC IN FACTOR SELECTION

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 Resources. There are 1,134 water well log records on file for Noble County. Static water levels and information as to the depths at which water was encountered were taken from approximately 655 of these records. The *Ground Water Resources of Noble County* (Walker, 1991) provided generalized depth to water information throughout the county. Depth to water trends mapped in adjoining Morgan County (Angle et al., 2001) Washington County (Angle et al., 2002), Muskingum County (Angle et al., 2001), Belmont County (Angle et al., 2002), and Guernsey County (Sprowls, 2015) were helpful. Topographic and geomorphic trends were utilized in areas where other sources of data were lacking.

Depths to water of 5 to 15 feet (DRASTIC rating = 9) were typical of areas immediately adjacent to Buffalo Creek and other major streams. Depths of 15 to 30 feet (7) were used for stream terraces adjacent to major streams and along smaller tributaries. Depths of 30 to 50 feet (5) were utilized for the headwaters of upland tributaries and many moderately sloping areas. Depths to water of 50 to 75 feet were utilized for steeper slopes and lower ridge tops common throughout much of the county. Depths to water of 75 to 100 feet (2) were applied to very high, isolated ridge tops. These ridge tops are usually capped by thick sequences of fine-grained Pennsylvanian rocks.

Net Recharge

Net 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) proved to be helpful.

Values of 4 to 7 inches per year (6) were used for areas with moderate recharge. These include limited areas of the buried valley underlying Buffalo Creek, as well as tributary and upland streams. These areas tend to have moderately shallow depths to water, surficial streams, and moderately permeable soils. Bedrock in these areas of stream valleys tends to be fractured. Values of 2 to 4 inches per year (3) were utilized for almost all upland slopes and ridge tops. The low permeability of the fine-grained soils and bedrock, the greater depths to water, and the high amount of run-off due to the steep slopes were the major factors for assigning the low recharge values.

Aquifer Media

Information on aquifer media was obtained from the reports of Stout et al. (1943) and Walker (1991). Mapping in adjoining Morgan County (Angle et al., 2001), Muskingum County (Angle et al., 2001), Washington County (Angle et al., 2002), Belmont County (Angle et al., 2002), and Guernsey County (Sprowls, 2015) proved useful as a guideline for evaluating aquifers. Open File Bedrock Reconnaissance Maps based upon U.S.G.S. 7-1/2 minute topographic maps from the ODNR, Division of Geological Survey proved helpful. The ODNR, Division of Water Resources Glacial State Aquifer Map and Bedrock State Aquifer Map were important sources of aquifer data. Water well log and drilling report records on file at the ODNR, Division of Water Resources, were the primary source of aquifer information.

An aquifer rating of (6) was selected for the fairly clean, moderately well-sorted sand and gravel deposits underlying a limited area of Buffalo Creek just south of the Noble County – Guernsey County border. An aquifer rating of (4) was used for select consolidated bedrock aquifers underlying modern streams. An aquifer rating of (3) was used for the majority of the ground water – poor bedrock aquifers associated with the Pennsylvanian undivided (Monongahela and Conemaugh Groups) and the Pennsylvanian – Lower Permian Dunkard Group.

Soils

Soils were mapped using the data obtained from the *Soil Survey of Noble County* (Waters and Roth, 1990) and the USDA Natural Resource Conservation Service Geospatial Data Gateway website. 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. Table 12 is a list of the soils, parent materials, setting, and corresponding DRASTIC values for Noble County.

Table 12. Noble County soils

Soil Name	Parent Material/Setting	DRASTIC Rating	Soil Media
Barkcamp	Strip mine spoil	NR	
Berks	Shale, siltstone, sandstone residuum	10	Thin/Absent
Bethesda	Strip mine spoil	NR	
Brookside	Limestone, shale, siltstone, sandstone colluvium	7	Shrink/swell clay
Brookside-Vandalia	Limestone, shale, siltstone, sandstone colluvium	7	Shrink/swell clay
Chagrin	Alluvium	4	Silty loam
Dekalb	Sandstone colluvium and residuum	10	Shrink/swell clay
Elba	Limestone, calcareous shale residuum	7	Shrink/swell clay
Elba-Guernsey	Siltstone, shale, limestone residuum	7	Shrink/swell clay
Enoch	Strip mine spoil	NR	
Gilpin	Sandstone, siltstone, shale residuum	10	Thin/Absent
Gilpin-Upshur	Sandstone, siltstone, shale residuum	10	Thin/Absent
Guernsey	Siltstone, shale, limestone colluvium and residuum	7	Shrink/swell clay
Guernsey-Upshur	Siltstone, shale, limestone colluvium and residuum	7	Shrink/swell clay
Hartshorn	Alluvium on floodplains	6	Sandy loam
Kinnick-Linside	Alluvium	4	Silty loam
Linside	Alluvium on floodplains	4	Silty loam
Lowell	Limestone, siltstone, shale residuum	7	Shrink/swell clay
Lowell-Elba	Limestone, siltstone, shale residuum	7	Shrink/swell clay
Lowell-Gilpin	Limestone, siltstone, shale, sandstone residuum	10	Thin/Absent
Lowell-Upshur	Limestone, siltstone, shale residuum and colluvium	7	Shrink/swell clay
Lowell-Westmoreland	Bedrock residuum	3	Clay loam
Morristown	Strip mine spoil	NR	
Newark	Recent mixed alluvium	4	Silty loam
Nolin	Alluvium	4	Silty loam
Omulga*	Loess or alluvium over lacustrine	3	Clay loam
Otwell	Alluvium	4	Silty loam
Richland	Colluvium	5	Loam
Sarahsville	Clayey lacustrine sediments or alluvium w/clayey residuum	7	Shrink/swell clay
Udorthents/pits	Strip mine spoil	NR	
Upshur	Shale colluvium and residuum	7	Shrink/swell clay
Vandalia	Shale and siltstone colluvium	7	Shrink/swell clay
Vandalia-Guernsey	Shale, siltstone, limestone colluvium and residuum	7	Shrink/swell clay
Wellston	Alluvium	4	Silty loam
Westmoreland	Bedrock residuum	3	Clay loam
Woodsfield	Loess and bedrock residuum	7	Shrink/swell clay
Zanesville*	Loess and bedrock residuum	3	Clay loam

* denotes soils containing fragipan

Soils were considered to be Thin/absent (10) along many steep ridge tops and slopes where bedrock was exposed. Shrink/swell clays (7) were rated for upland areas having very clayey shale and mudstone bedrock residuum. Sandy loam soils (6) were selected for some alluvial deposits in tributary valleys. Loam (5) was chosen for some soils on gentle slopes along smaller tributaries. Silt loam (4) soils were evaluated for silty shale and siltstone residuum on slopes and ridge tops and also for silty alluvial and lacustrine deposits on floodplains. Silt loam (4) was selected for soils developed on the loess-capped uplands and terraces. Clay loam (3) soils were evaluated for fine-grained bedrock residuum as well as finer-grained alluvial deposits in floodplains.

Certain soils in Noble County contain fragipans. A fragipan is a dense, impermeable zone found within certain loamy, till-derived soils. The net effect of the fragipan is to reduce the overall permeability of a soil within a given textural range (Aller et al., 1987). Hence, a soil with a loam (5) texture would be evaluated as a silt loam (4), and a soil with a silt loam (4) texture would be evaluated as a clay loam (3) due to the presence of a fragipan.

Topography

Topography, or percent slope, was evaluated using U.S.G.S. 7-1/2 minute quadrangle maps and the digital elevation model for Noble County (Ohio Statewide Imagery Program, 2015). Slopes of 0 to 2 percent (10) and 2 to 6 percent (9) were selected for flat-lying floodplains, valley floors, and terraces. Slopes of 2 to 6 percent (9) and 6 to 12 percent (5) used for gentler, more rounded ridge tops. Slopes of 6 to 12 percent (5) were also used for less steep ridges, typically those flanking broader valleys and in areas with less resistant bedrock types. Slopes of 12 to 18 percent (3) and greater than 18 percent (1) were selected for steeper slopes in high relief, upland areas.

Impact of the Vadose Zone Media

Information on vadose zone media was obtained from the reports of Stout (1918), Stout et al. (1943), and Walker (1992). Mapping in adjoining Morgan County (Angle et al., 2001), Muskingum County (Angle et al., 2001), Washington County (Angle et al., 2002), Belmont County (Angle et al., 2002), and Guernsey County (Sprowls, 2015) proved useful as a guideline for evaluating aquifers. Open File Bedrock Reconnaissance Maps based upon U.S.G.S. 7-1/2 minute topographic maps from the ODNR, Division of Geological Survey proved helpful. The ODNR, Division of Water Resources Glacial State Aquifer Map and Bedrock State Aquifer Map were important sources of vadose zone data. Water well log and drilling report records on file at the ODNR, Division of Water Resources were the primary source of vadose zone information. Information on parent materials derived from the *Soil Survey of Noble County* (Waters and Roth, 1990), also proved useful in evaluating vadose zone materials.

Vadose zone media was given a rating of (5) for sand and gravel interbedded with silt and clay layers for the buried valley underlying Buffalo Creek. Silt and clay with ratings of (3) and (4) were selected for vadose zone media for floodplains in many tributary valleys. The ratings were dependent on the proportion of sand and gravel to the finer-grained alluvial and lacustrine deposits.

Vadose zone media was given a rating of (4) for the interbedded sandstone, shales, limestones, and coals of the Pennsylvanian System rocks that underlie the broader, upland stream valleys. It was determined that these rocks may contain more fracturing that is reflected by slightly higher yields in these areas. A vadose zone rating of (3) was utilized for the interbedded bedrock in ridge tops and higher slopes.

Hydraulic Conductivity

Published data for hydraulic conductivity for Noble County was found lacking. Information from Walker (1991), the ODNR, Division of Water Resources Glacial State Aquifer Map and Bedrock State Aquifer Map, as well as water well log and drilling report records on file at the ODNR, Division of Water Resources, were the primary sources of information. Hydraulic conductivity values utilized in adjoining Morgan County (Angle et al., 2001), Muskingum County (Angle et al., 2001), Washington County (Angle et al., 2002), Belmont County (Angle et al., 2002), and Guernsey County (Sprowls, 2015) proved to be a useful guideline. Textbook tables (Freeze and Cherry, Fetter, 1980, and Driscoll, 1986) were useful in obtaining estimated values for hydraulic conductivity in a variety of sediments.

For the sand and gravel deposits in the buried valley underlying Buffalo Creek, hydraulic conductivities of 100-300 gpd/ft^2 (2) were used. In these deposits, thin sand and gravel lenses were interbedded with finer-grained materials. Select bedrock aquifers underlying alluvial deposits in the flood plain of West Fork Duck Creek were also given a hydraulic conductivity of (2) as the aquifer may be in direct hydraulic connection with the overlying deposits.

Most of the bedrock aquifers in Noble County were evaluated as having hydraulic conductivity values ranging from 1-100 gpd/ft^2 (1) due to the overall low permeability of these interbedded sedimentary rocks.

APPENDIX B

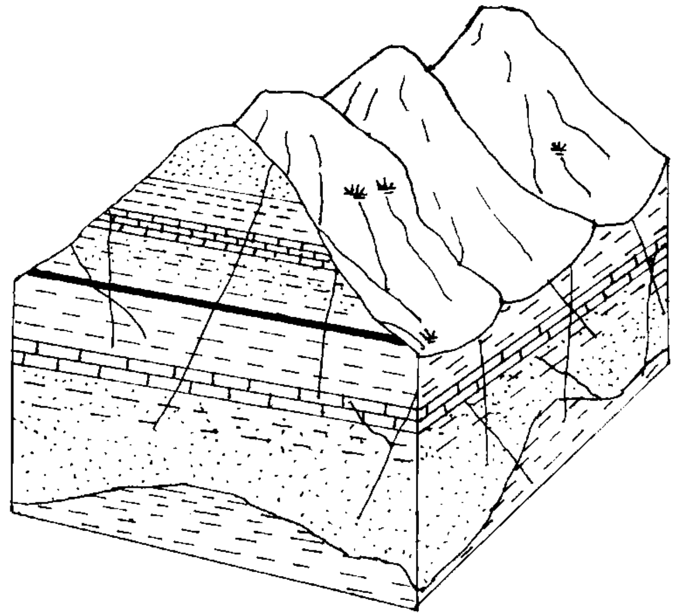
DESCRIPTION OF HYDROGEOLOGIC SETTINGS AND CHARTS

Ground water pollution potential mapping in Noble County resulted in the identification of five hydrogeologic settings within the Nonglaciated 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 13. Pollution potential indexes calculated for Noble County range from 61 to 126.

Table 13. Hydrogeologic settings mapped in Noble County, Ohio

Hydrogeologic Settings	Range of GWPP Indexes	Number of Index Calculations
6Da - Alternating Sandstone, Limestone, Shale-Thin Regolith	61-93	28
6Fa-River Alluvium With Overbank Deposits	103-119	8
6Fb - River Alluvium Without Overbank Deposits	103-112	5
7D - Buried Valley	126	1
7Fa - Glacial Lakes and Slackwater Terraces	99-125	6

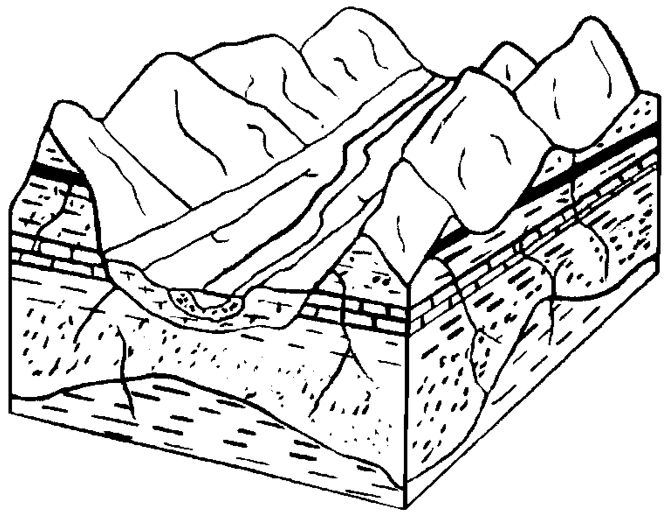
The following information provides a description of each hydrogeologic setting identified in the county, a block diagram illustrating the characteristics of the setting, and a listing of the charts for each unique combination of pollution potential indexes calculated for each setting. The charts provide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



6Da Alternating Sandstone, Limestone, Shale – Thin Regolith

This hydrogeologic setting is widespread, encompassing most upland areas in Noble County. The area is characterized by high relief with broad, steep slopes and narrow, somewhat flatter ridge tops. The vadose zone and aquifers consist of slightly dipping, fractured, alternating sequences of dirty sandstones, shales, thin limestones, clays, and coals of the Pennsylvanian and Lower Permian Systems. Multiple aquifers are typically present. Depth to water is generally deep; shallower perched zones may overlie low permeability shales, limestones, and clays. Soils are generally thin to absent on steeper slopes. On gentler slopes, soils vary with the bedrock lithology. Small supplies of ground water are obtained from intersecting bedding planes or vertical fractures. Recharge is limited due to the steep slopes, deep aquifers, and layers of impermeable bedrock.

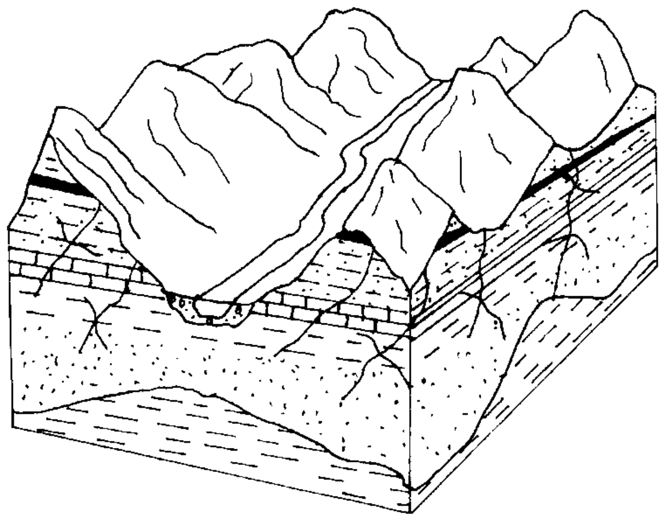
GWPP index values for the hydrogeologic setting of Alternating Sandstone, Limestone, Shale – Thin Regolith range from 61 to 93, with the total number of GWPP index calculations equaling 28.



6Fa River Alluvium with Overbank Deposits

This hydrogeologic setting is typically found in tributary valleys throughout Noble County. This setting is somewhat similar to the 7Fa Glacial Lakes and Slackwater Terraces setting; however, the valleys and floodplains are narrower and the alluvial deposits are much thinner. Areas in this setting are similar to the adjacent uplands, which belong to the 6Da Alternating Sandstone, Limestone, Shale - Thin Regolith setting. Narrow, relatively flat-bottomed stream valleys flanked by steep bedrock ridges characterize the setting. Depth to water is usually shallow, averaging less than 30 feet. Soils are generally silt loams. The alluvium is composed primarily of fine-grained floodplain ("overbank") sediments. The alluvial deposits are typically saturated; however, the alluvium is too thin to be utilized as an aquifer. The aquifer is the underlying dirty sandstones, shales, thin limestones, mudstones, clays and coals of the Pennsylvanian and Lower Permian Systems. In most areas, the alluvium is in direct connection with the underlying bedrock aquifers. Recharge is moderate due to the relatively shallow depth to water, flatter topography, and the relatively low permeability of the bedrock. Recharge is higher than the surrounding uplands.

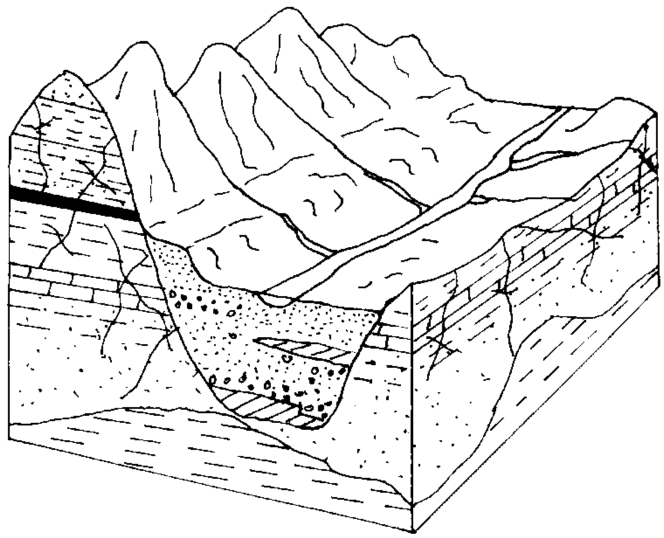
GWPP index values for the hydrogeologic setting of River Alluvium with Overbank Deposits range from 103 to 119, with the total number of GWPP index calculations equaling 8.



6Fb River Alluvium without Overbank Deposits

This hydrogeologic setting is limited to the headwaters of small tributary valleys in the uplands throughout Noble County. This setting is somewhat similar to the 6Fa River Alluvium with Overbank Deposits setting; however, the valleys and floodplains are narrower, terraces are absent, and the alluvial deposits are much thinner and coarser-grained. Areas in this setting are similar to the adjacent uplands, which belong to the 6Da Alternating Sandstone, Limestone, Shale - Thin Regolith setting. The headwaters of narrow, relatively flat-bottomed stream valleys flanked by steep bedrock ridges characterize the setting. Depth to water is usually moderate, averaging less than 50 feet. Soils are generally silt loams. The alluvium is composed primarily of fine-grained to coarse-grained sediments. The alluvial deposits are typically saturated; however, the alluvium is too thin to be utilized as an aquifer. The aquifer is the underlying dirty sandstones, shales, thin limestones, mudstones, clays and coals of the Pennsylvanian and Lower Permian Systems. In most areas, the alluvium is in direct connection with the underlying bedrock aquifers. Recharge is moderate due to the relatively shallow depth to water, flatter topography, and the relatively low permeability of the bedrock. Recharge is higher than in the surrounding uplands.

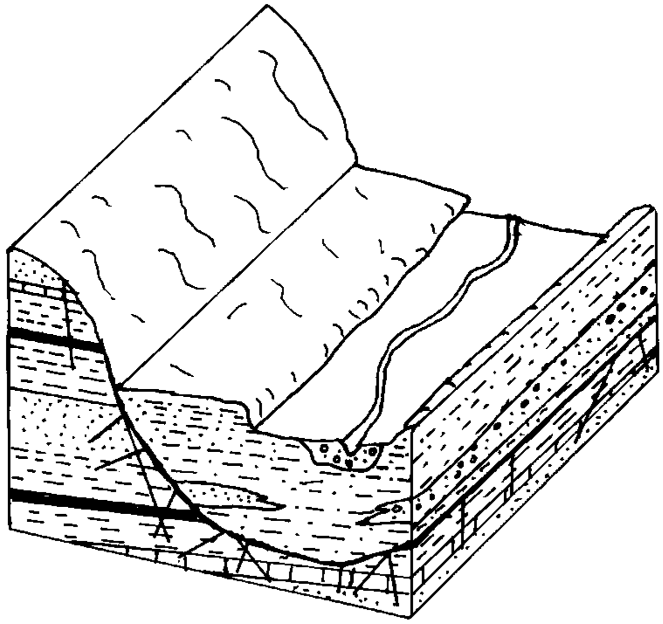
GWPP index values for the hydrogeologic setting of River Alluvium without Overbank Deposits range from 103 to 112, with the total number of GWPP index calculations equaling 5.



7D Buried Valley

This hydrogeologic setting is limited to deposits found underlying Buffalo Creek just south of the Guernsey-Noble county line and Pleasant City. Broad, flat-lying floodplains and gently sloping terraces characterize the setting. Depths to water are typically less than 30 feet. The aquifer is composed of variable thicknesses of sand and gravel interbedded with finer-grained alluvium and lacustrine deposits. The modern stream may be in direct hydraulic connection with the underlying aquifer. Soils on floodplains are silt loams derived from modern alluvium. Recharge is typically relatively high due to the flat-lying topography, shallow depth to water, and the higher permeability of the soils, vadose zone materials, and aquifer.

The GWPP index value for the hydrogeologic setting of Buried Valley is 126, with the total number of GWPP index calculations equaling 1.



7Fa Glacial Lakes and Slackwater Terraces

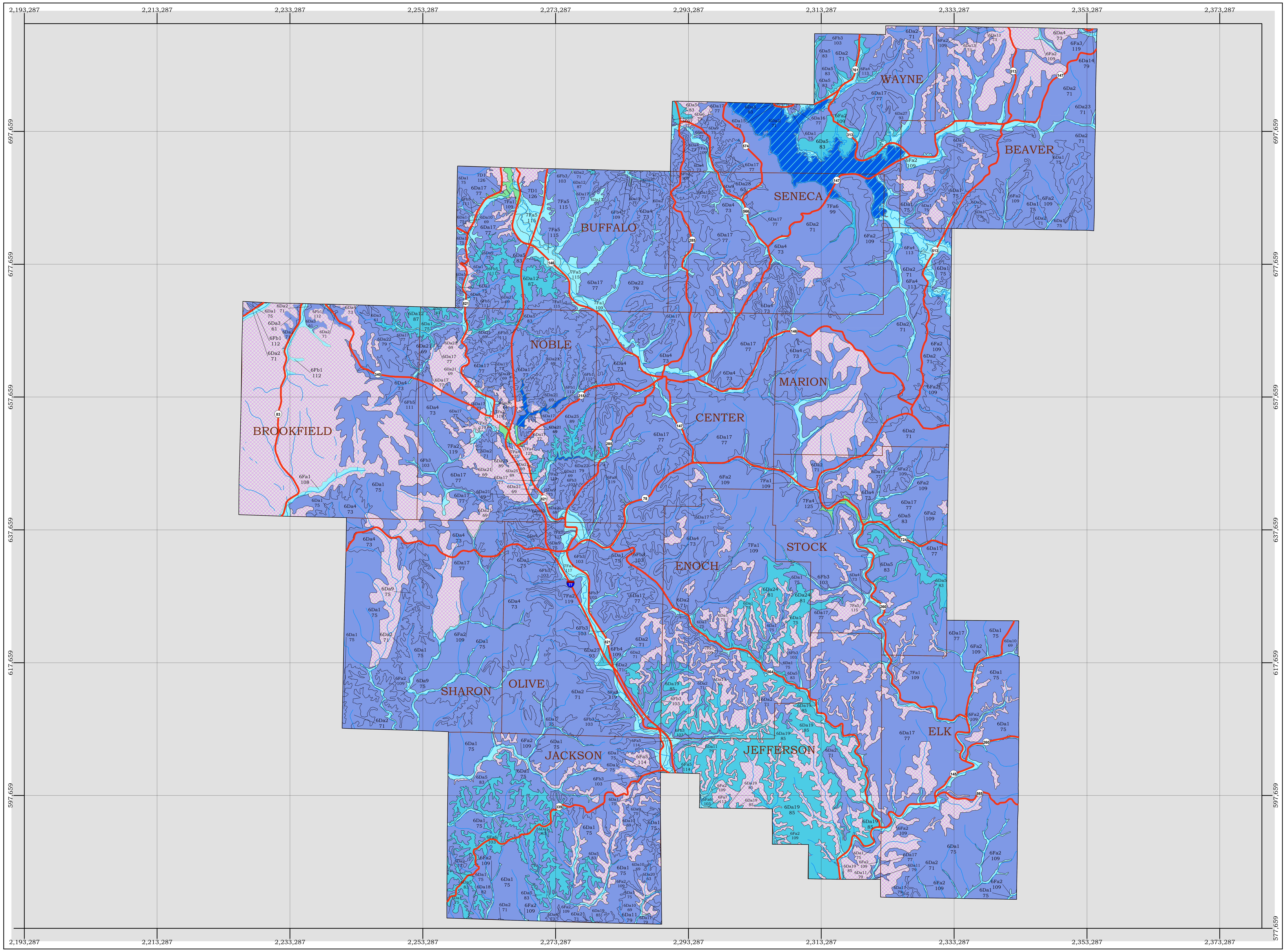
Flat-lying areas that were formed in low velocity water of glacial and slack water lakes that filled pre-existing drainage systems characterize this setting. These areas are typically dissected by modern streams and contain remnant low-lying terraces. These streams include Buffalo Creek, West Fork Duck Creek, and their tributaries. The valleys are typically broader and contain thicker deposits than the somewhat similar 6Fa River Alluvium with Overbank Deposits. The setting is bordered by steep bedrock uplands. The deposits are not as thick or as coarse as in adjacent 7D Buried Valley settings. The aquifer consists of thin sand and gravel lenses interbedded with finer lacustrine and alluvial deposits. If sand and gravel is not encountered, wells are completed in the underlying interbedded sedimentary rock. Depth to water is commonly shallow due to the presence of streams found within this setting. Vadose zone material consists of silty alluvium. Soils are silt loams. Recharge in this setting is moderate due to the relatively shallow depth to water, flat-lying topography, and the moderate to low permeability soils, vadose, and underlying bedrock.

GWPP index values for the hydrogeologic setting of Glacial Lakes and Slackwater Terraces range from 99 to 125, with the total number of GWPP index calculations equaling 6.

Table 14. Hydrogeologic Settings, DRASTIC Factors, and Ratings

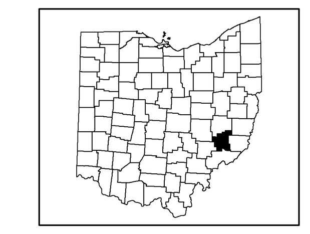
Setting	Depth To Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% slope)	Vadose Zone Media	Hydraulic Conductivity	Rating	Pesticide Rating
6Da1	50-75	2-4	Interbedded sst/sh/lst/coal	Thin/Absent Gravel	18+	Interbedded sst/sh/lst/coal	1-100	75	103
6Da2	50-75	2-4	Interbedded sst/sh/lst/coal	Shrink/Swell Clay	12-18	Interbedded sst/sh/lst/coal	1-100	71	94
6Da3	50-75	2-4	Interbedded sst/sh/lst/coal	Clay Loam	18+	Interbedded sst/sh/lst/coal	1-100	61	68
6Da4	50-75	2-4	Interbedded sst/sh/lst/coal	Shrink/Swell Clay	6-12	Interbedded sst/sh/lst/coal	1-100	73	100
6Da5	30-50	2-4	Interbedded sst/sh/lst/coal	Shrink/Swell Clay	6-12	Interbedded sst/sh/lst/coal	1-100	83	110
6Da6	30-50	2-4	Interbedded sst/sh/lst/coal	Clay Loam	2-6	Interbedded sst/sh/lst/coal	1-100	79	102
6Da7	30-50	2-4	Interbedded sst/sh/lst/coal	Silty Loam	6-12	Interbedded sst/sh/lst/coal	1-100	77	95
6Da8	50-75	2-4	Interbedded sst/sh/lst/coal	Silty Loam	2-6	Interbedded sst/sh/lst/coal	1-100	71	97
6Da9	30-50	2-4	Interbedded sst/sh/lst/coal	Clay Loam	6-12	Interbedded sst/sh/lst/coal	1-100	75	90
6Da10	50-75	2-4	Interbedded sst/sh/lst/coal	Shrink/Swell Clay	18+	Interbedded sst/sh/lst/coal	1-100	69	88
6Da11	30-50	2-4	Interbedded sst/sh/lst/coal	Shrink/Swell Clay	18+	Interbedded sst/sh/lst/coal	1-100	79	98
6Da12	30-50	2-4	Interbedded sst/sh/lst/coal	Shrink/Swell Clay	2-6	Interbedded sst/sh/lst/coal	1-100	87	122
6Da13	30-50	2-4	Interbedded sst/sh/lst/coal	Clay Loam	12-18	Interbedded sst/sh/lst/coal	1-100	73	84
6Da14	30-50	2-4	Interbedded sst/sh/lst/coal	Loam	6-12	Interbedded sst/sh/lst/coal	1-100	79	100
6Da15	75-100	2-4	Interbedded sst/sh/lst/coal	Thin/Absent Gravel	12-18	Interbedded sst/sh/lst/coal	1-100	72	104
6Da16	50-75	2-4	Interbedded sst/sh/lst/coal	Shrink/Swell Clay	2-6	Interbedded sst/sh/lst/coal	1-100	77	112
6Da17	50-75	2-4	Interbedded sst/sh/lst/coal	Thin/Absent Gravel	12-18	Interbedded sst/sh/lst/coal	1-100	77	109
6Da18	30-50	2-4	Interbedded sst/sh/lst/coal	Silty Loam	0-2	Interbedded sst/sh/lst/coal	1-100	82	110
6Da19	30-50	2-4	Interbedded sst/sh/lst/coal	Thin/Absent Gravel	18+	Interbedded sst/sh/lst/coal	1-100	85	113
6Da20	50-75	2-4	Interbedded sst/sh/lst/coal	Clay Loam	12-18	Interbedded sst/sh/lst/coal	1-100	63	74
6Da21	50-75	2-4	Interbedded sst/sh/lst/coal	Clay Loam	2-6	Interbedded sst/sh/lst/coal	1-100	69	92
6Da22	50-75	2-4	Interbedded sst/sh/lst/coal	Thin/Absent Gravel	6-12	Interbedded sst/sh/lst/coal	1-100	79	115
6Da23	30-50	2-4	Interbedded sst/sh/lst/coal	Clay Loam	18+	Interbedded sst/sh/lst/coal	1-100	71	78
6Da24	30-50	2-4	Interbedded sst/sh/lst/coal	Shrink/Swell Clay	12-18	Interbedded sst/sh/lst/coal	1-100	81	104
6Da25	30-50	2-4	Interbedded sst/sh/lst/coal	Thin/Absent Gravel	6-12	Interbedded sst/sh/lst/coal	1-100	89	125
6Da26	75-100	2-4	Interbedded sst/sh/lst/coal	Clay Loam	2-6	Interbedded sst/sh/lst/coal	1-100	64	87
6Da27	15-30	2-4	Interbedded sst/sh/lst/coal	Shrink/Swell Clay	6-12	Interbedded sst/sh/lst/coal	1-100	93	120

Setting	Depth To Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% slope)	Vadose Zone Media	Hydraulic Conductivity	Rating	Pesticide Rating
6Da28	50-75	2-4	Interbedded sst/sh/lst/coal	Clay Loam	6-12	Interbedded sst/sh/lst/coal	1-100	65	80
6Fa1	15-30	4-7	Interbedded sst/sh/lst/coal	Silty Loam	2-6	Interbedded sst/sh/lst/coal	1-100	108	133
6Fa2	15-30	4-7	Interbedded sst/sh/lst/coal	Silty Loam	0-2	Silt/clay	1-100	109	136
6Fa3	5-15	4-7	Interbedded sst/sh/lst/coal	Silty Loam	0-2	Interbedded sst/sh/lst/coal	1-100	119	146
6Fa4	15-30	4-7	Interbedded sst/sh/lst/coal	Shrink/Swell Clay	0-2	Silt/clay	1-100	113	150
6Fa5	15-30	4-7	Interbedded sst/sh/lst/coal	Shrink/Swell Clay	2-6	Silt/clay	1-100	114	148
6Fa6	15-30	4-7	Interbedded sst/sh/lst/coal	Clay	0-2	Silt/clay	1-100	103	121
6Fa7	15-30	4-7	Interbedded sst/sh/lst/coal	Sandy Loam	0-2	Silt/clay	1-100	113	146
6Fa8	5-15	4-7	Interbedded sst/sh/lst/coal	Silty Loam	0-2	Silt/clay	1-100	119	146
6Fb1	15-30	4-7	Interbedded sst/sh/lst/coal	Silty Loam	0-2	Interbedded sst/sh/lst/coal	1-100	112	139
6Fb2	15-30	4-7	Interbedded sst/sh/lst/coal	Silty Loam	2-6	Silt/clay	1-100	108	133
6Fb3	15-30	4-7	Interbedded sst/sh/lst/coal	Silty Loam	2-6	Interbedded sst/sh/lst/coal	1-100	103	129
6Fb4	15-30	4-7	Interbedded sst/sh/lst/coal	Shrink/Swell Clay	2-6	Interbedded sst/sh/lst/coal	1-100	109	144
6Fb5	15-30	4-7	Interbedded sst/sh/lst/coal	Silty Loam	2-6	Silt/clay	100-300	111	135
7D1	15-30	4-7	Sand & gravel	Silty Loam	0-2	Sand & gravel w/silt & clay	100-300	126	151
7Fa1	15-30	4-7	Interbedded sst/sh/lst/coal	Silty Loam	0-2	Silt/clay	1-100	109	136
7Fa2	5-15	4-7	Interbedded sst/sh/lst/coal	Silty Loam	0-2	Silt/clay	1-100	119	146
7Fa3	5-15	4-7	Interbedded sst/sh/lst/coal	Clay Loam	0-2	Silt/clay	1-100	117	141
7Fa4	5-15	4-7	Interbedded sst/sh/lst/coal	Shrink/Swell Clay	0-2	Silt/clay	1-100	125	161
7Fa5	15-30	4-7	Interbedded sst/sh/lst/coal	Shrink/Swell Clay	0-2	Silt/clay	1-100	115	151
7Fa6	30-50	4-7	Interbedded sst/sh/lst/coal	Silty Loam	0-2	Silt/clay	1-100	99	126



Ground Water Pollution Potential of Noble County

by
Kathy Sprowls, 2015
Ohio Department of Natural Resources
Division of Water 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

N

Index Ranges

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

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

0 1 2 3 4
Miles

0 1 2 3 4 5 6
Kilometers

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

Cartography by Kathy Sprowls, 2015