GROUND WATER POLLUTION POTENTIAL OF TRUMBULL COUNTY, OHIO

BY

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GROUND WATER POLLUTION POTENTIAL REPORT NO. 75

OHIO DEPARTMENT OF NATURAL RESOURCES

DIVISION OF SOIL AND WATER RESOURCES

WATER RESOURCES SECTION

2010

This report was developed with financial assistance provided by the Coastal Zone Management Act of 1972, as amended, in award number NA05NO4191090 administered by the Office of Ocean and Coastal Resource Management, National Oceanic and Atmospheric Administration and the Ohio Coastal Management Program, administered by the Ohio Department of Natural Resources, Office of Coastal Management.

ABSTRACT

A ground water pollution potential map of Trumbull 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 Trumbull County resulted in a map with symbols and colors that illustrate areas of varying ground water contamination vulnerability. Eight hydrogeologic settings were identified in Trumbull County with computed ground water pollution potential indexes ranging from 74 to 170.

Trumbull County lies within the Glaciated Central hydrogeologic setting. Glacial till in varying thicknesses overlies Trumbull County. The county is crossed by two major buried valley systems, one trending north-south on the western border of the county, and the other runs northwest-southeast along the western and southern borders of the county. A third, smaller buried valley system runs along the eastern border of the county. The glacial deposits in the buried valleys range widely in composition. Some consist of appreciable thicknesses of outwash sand and gravel; others are predominantly fine-grained glacial till, or till containing significant sand and gravel. Outside of the buried valleys, aquifers within glacial deposits are limited to thin lenses interbedded in glacial till. Yields from the unconsolidated aquifers typically range from less than 5 up to 100 gallons per minute (gpm), with yields over 100 gpm possible in a select area in the southeastern corner of the county. Sandstones and shales of the Pennsylvanian and Mississippian Systems comprise the bedrock aquifer in the majority of the county, except the extreme southeastern corner of the county where the interbedded sandstones, shales, siltstones, limestones, and coals of the Pennsylvanian System are the aquifer. Consolidated units are moderate to poor aquifers with typical yields ranging from 5 to 25 gpm. Yields up to 100 gpm are possible from some of the sandstone intervals in the Pennsylvanian Massillon and Sharon Formations.

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 Trumbull 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 Trumbull County Ground Water Pollution Potential report and map involved the contribution and work of a number of individuals in the Division of Soil and Water Resources. 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:	Kathy Sprowls
GIS coverage production and review:	Robert Baker
Report production and review:	Kathy Sprowls
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; about 17,800 of these wells exist in Trumbull County.

The characteristics of the many aquifer systems in the state make ground water highly vulnerable to contamination. Measures to protect ground water from contamination usually cost less and create less impact on ground water users than clean up of a polluted aquifer. Based on these concerns for protection of the resource, staff of the Division of Soil and 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 Soil and Water, Water Resources Section to implement the ground water pollution potential mapping program on a countywide basis in Ohio.

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

APPLICATIONS OF POLLUTION POTENTIAL MAPS

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

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

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

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

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

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

SUMMARY OF THE DRASTIC MAPPING PROCESS

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

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

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

Hydrogeologic Settings and Factors

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

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

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

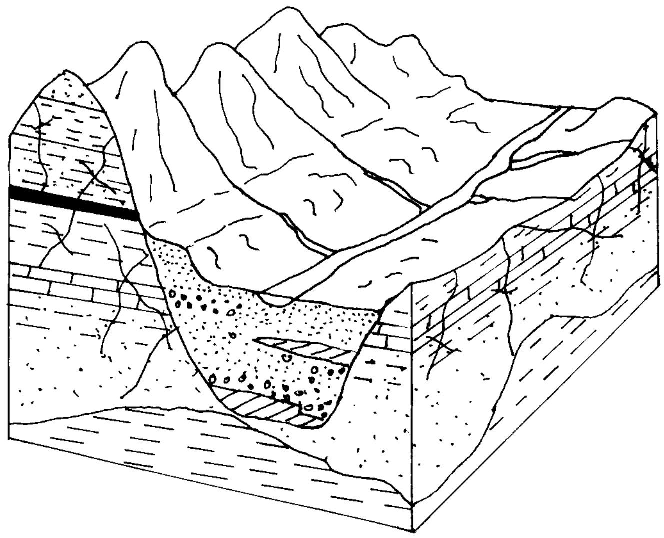
D	-	Depth to Water
R	-	Net Recharge
A	-	Aquifer Media
S	-	Soil Media
T	-	Topography
I	-	Impact of the Vadose Zone Media
C	-	Conductivity (Hydraulic) of the Aquifer

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

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

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

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



7D Buried Valley

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

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

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

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

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

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

Weighting and Rating System

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

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

Pesticide DRASTIC

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

Table 1. Assigned weights for DRASTIC features

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

Table 2. Ranges and ratings for depth to water

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

Table 3. Ranges and ratings for net recharge

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

Table 4. Ranges and ratings for aquifer media

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

Table 5. Ranges and ratings for soil media

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

Table 6. Ranges and ratings for topography

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

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

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

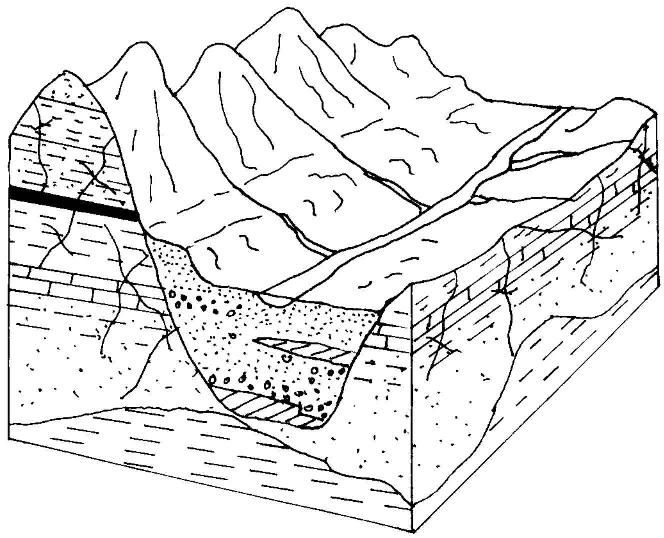
Table 8. Ranges and ratings for hydraulic conductivity

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

Integration of Hydrogeologic Settings and DRASTIC Factors

Figure 2 illustrates the hydrogeologic setting 7D1, Buried Valley, identified in mapping Trumbull 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 104. 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 Trumbull County produces settings with a wide range of vulnerability to ground water contamination. Calculated pollution potential indexes for the eight settings identified in the county range from 74 to 170.

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 Trumbull 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 Trumbull County is included with this report.



SETTING 7D1		GENERAL		
FEATURE	**RANGE**	**WEIGHT**	**RATING**	**NUMBER**
Depth to Water	50-75	5	3	15
Net Recharge	4-7	4	6	24
Aquifer Media	Sand & Gravel	3	6	18
Soil Media	Clay Loam	2	3	6
Topography	2-6%	1	9	9
Impact of Vadose Zone	Till	5	4	20
Hydraulic Conductivity	300-700	3	4	12
		DRASTIC	INDEX	104

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

INTERPRETATION AND USE OF GROUND WATER POLLUTION POTENTIAL MAPS

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

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

7D1 - defines the hydrogeologic region and setting

104 - defines the relative pollution potential

Here the first number (**7**) refers to the major hydrogeologic region and the upper case letter (**D**) refers to a specific hydrogeologic setting. The following number (**1**) references a certain set of DRASTIC parameters that are unique to this setting and are described in the corresponding setting chart. The number below the hydrogeologic setting (**104**) is the calculated pollution potential index for this unique setting. The charts for each setting provide a reference to show how the pollution potential index was derived.

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

GENERAL INFORMATION ABOUT TRUMBULL COUNTY

Demographics

Trumbull County occupies approximately 616 square miles in northeastern Ohio (Figure 3). Trumbull County is bounded to the north by Ashtabula County, to the west by Portage and Geauga Counties, to the south by Mahoning County, and to the east by Mercer County, Pennsylvania.

The approximate population of Trumbull County, according to 2007 figures, is 213,475 (Ohio Department of Development, 2007). Warren is the county seat and largest city and has an estimated population of 44,270 (Ohio Department of Development, 2007). Roughly 31 percent of the county's land area is used for agricultural purposes. About 42 percent of the county is forested. The remaining 27 percent of the land area is used for urban, industrial, and residential purposes, wetlands, strip mines, and reservoirs. These figures are based upon 2007 estimates obtained from the Ohio Department of Development, Ohio County Profiles.

Climate

The weather station at Warren reports a mean annual temperature of 47.9 degrees Fahrenheit for a thirty-year (1971-2000) average (National Oceanic and Atmospheric Administration (NOAA), 2000). According to Harstine (1991), the average temperature is relatively constant across the county with a slight temperature increase to the south and east. The average annual precipitation recorded at the Warren weather station is 37.8 inches based on the same thirty-year (1971-2000) period (NOAA, 2000). Northern Trumbull County is located in an area of higher precipitation known as the "snowbelt" (Harstine, 1991).

Physiography and Topography

Trumbull County lies within the Glaciated Allegheny Plateau section of the Appalachian Plateaus province. The northern half of the county lies within the Grand River Low Plateau section, while the southern half lies in the Killbuck-Glaciated Pittsburgh Plateau section (Brockman, 1998). Brockman, 1998 also shows a north-south trending area along the western border of the county that lies within the Grand River Finger-Lake Plain section of the Grand River Low Plateau region.

Figure 3. Location of Trumbull County, Ohio.

The highest elevation in the county is approximately 1,280 feet at Trautman Hill in Vernon Township, and the lowest elevation is approximately 800 feet in the Grand River Basin in Mesopotamia Township. The maximum relief throughout the county is about 480 feet.

Modern Drainage

Most of Trumbull County drains into the Ohio River watershed. The Mahoning River and its tributaries, Mosquito Creek, Eagle Creek, Meander Creek, and West Branch Mahoning River, are the primary drainage for the central, west-central, and southwestern portions of the county. The Mahoning River originates in northwestern Columbiana County and flows to the northwest, toward Alliance. It then continues north into central Trumbull County. North of Warren, near the divide between the Ohio River Basin and the Lake Erie Basin, the Mahoning River turns abruptly to the southeast. The Mahoning River re-enters Mahoning County near Youngstown and eventually enters Pennsylvania southeast of Lowellville.

The Shenango River and its tributaries drain the eastern third of Trumbull County. Its largest tributary, Pymatuning Creek, originates in Ashtabula County northwest of Andover. As it flows southeast through Kinsman and Vernon Townships, it is joined by other tributaries such as Stratton Creek and Mill Creek, and leaves the county at Orangeville to merge with the Shenango River. Yankee Creek and Little Yankee Creek meet the Shenango just south of Sharon, Pennsylvania where the Shenango continues on toward the Beaver River, and ultimately the Ohio River.

The northwestern third of the county is drained by the Grand River and its tributaries, which empty into Lake Erie. Two of the tributaries, Swine Creek and Dead Branch Grand River, drain Southington, Farmington, and Mesopotamia Townships on their way to join the Grand River.

Pre- and Inter-Glacial Drainage and Topography

Stout et al. (1943) proposed that southeasterly-flowing tributaries of the Pittsburgh River drained the majority of Trumbull County (Figure 4). The Pittsburgh River flowed roughly northward from Pittsburgh and was the master stream draining this area, eventually flowing into ancestral Lake Erie (Stout et al., 1943, and Totten and White, 1987). Stout et al. (1943) also proposed that a tributary of the Ravenna River drained the western margin of Trumbull County, while Geneva Creek drained the northwestern corner of the county. Geneva Creek had its headwaters near Garrettsville in Portage County and flowed north into what would become Lake Erie. The Ravenna River flowed northwestward through Portage County and Geauga County, and it too emptied into Lake Erie. Stout et al. (1943) speculated

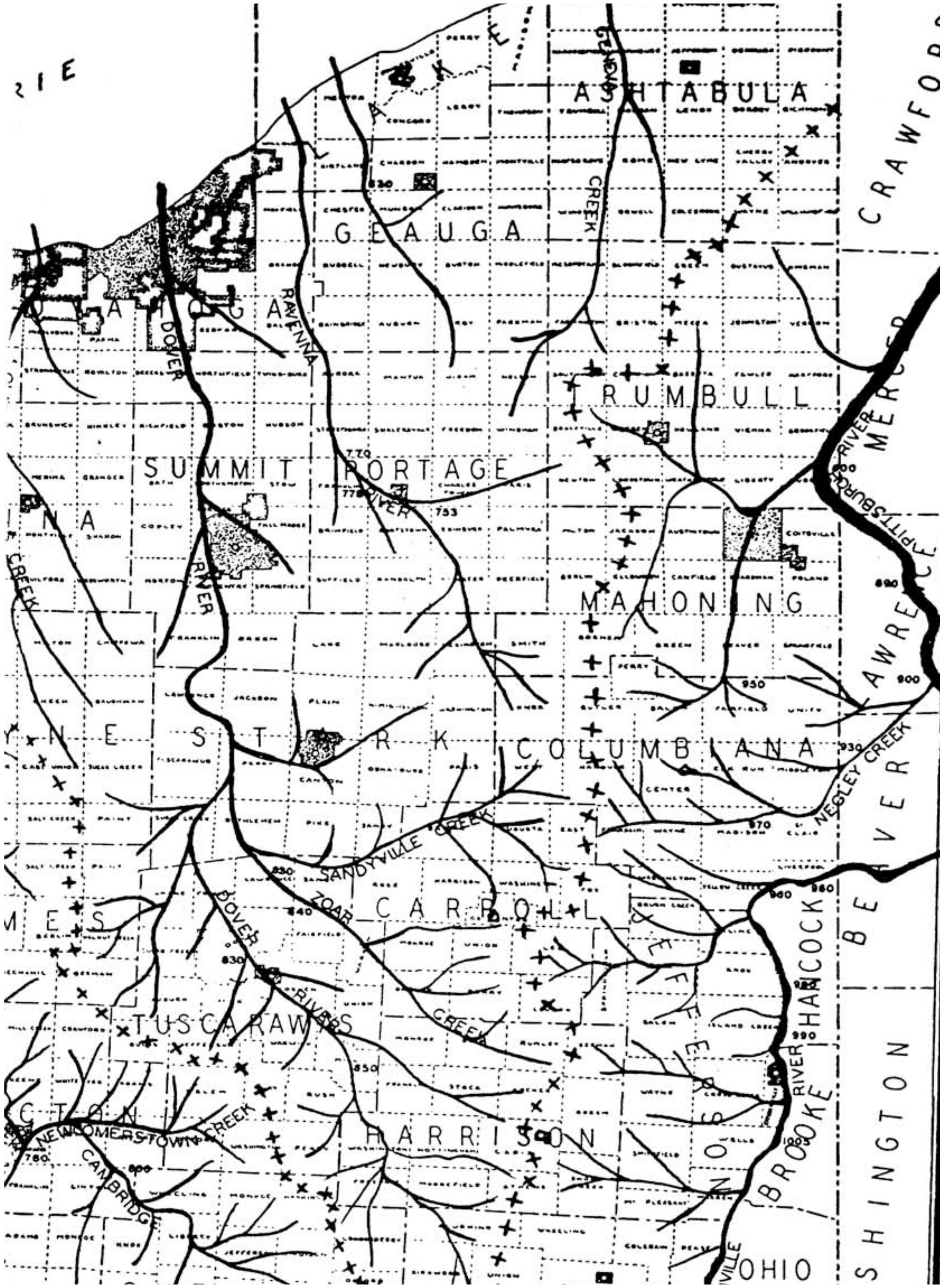


Figure 4. Pre-glacial (Teays Stage) drainage in Northeast Ohio (after Stout et al., 1943). The line of x's indicate the drainage divide.

that these drainages, although not physically connected, were roughly time equivalent of the Teays River drainage system in south-central and western Ohio.

As ice advanced through Ohio during the pre-Illinoain (Kansan) glaciations, the northerly drainage ways were blocked. Flow backed up the main trunk valley as well as in many of the tributaries, forming several large lakes. Eventually spillways were created for these lakes, new stream channels were downcut, and new drainage systems evolved. This downcutting was believed to be relatively rapid and in many places the new channels were cut deeper than the pre-glacial valleys (Stout et al., 1943). This new drainage system is referred to as the Deep Stage due to this increased downcutting. Many of the Deep Stage channels closely followed the previously existing drainage ways. Regionally, a southerly-flowing system evolved with drainage toward the ancestral Ohio River. Many of the pre-existing valleys were filled or "buried" by thick sequences of glacial drift. Principle examples of buried valleys are those that underlie present-day Pymatuning Creek, Mosquito Creek, and Grand River. Present-day Little Yankee Creek overlies part of a buried valley that trends southwest-northeast across Hubbard Township (Cummins, 1959 and White, 1971).

The pre-glacial topography of Trumbull County was probably somewhat steeper and more rugged than the modern topography. Bedrock outcrops were covered by deposits of till and sand and gravel left by glacial ice and meltwaters. Glaciation had the net effect of filling in valleys and smoothing-out the topography (Szmuc, 1953).

Glacial Geology

During the Pleistocene Epoch (2 million to 10,000 years before present (Y.B.P.)) several episodes of ice advance occurred in northeastern Ohio. Table 9 summarizes the Pleistocene deposits found in Trumbull County. The majority of the glacial deposits fall into four main types: (glacial) till, lacustrine, outwash, and ice-contact sand and gravel (kames). Buried valleys may contain a mix of all of these types of deposits. Drift is an older term that collectively refers to the entire sequence of glacial deposits.

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

At the land surface, till accounts for two primary landforms: ground moraine and end moraine. Ground moraine (till plain) is relatively flat to gently rolling. End moraines are

Table 9. Generalized Pleistocene stratigraphy of Trumbull County, Ohio

Epoch	Age (years ago)	Stage	Grand River Lobe
Pleistocene	25,000 to 70,000	Wisconsinan	Hiram Till Windham Sand Lavery Till Kent Till Titusville Till
	70,000 to 120,000	Sangamonian	Weathered soil
	120,000 to 730,000	Illinoian	Mapledale Till

more ridge-like, with terrain that is steeper and more rolling or hummocky. Streams tend to parallel the margins of the moraines, which helps to enhance the relief and steepness of these features. Locally, end moraines commonly serve as drainage divides. White (1971) has delineated the end moraines in Trumbull County in detail.

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

Wisconsinan-age deposits compose the surficial material across all of Trumbull County except along steep slopes where the bedrock crops-out at the surface. Illinoian-age till, referred to as the Mapledale Till by White (1971 and 1982) underlies the Wisconsinan-age till through most of the county. The underlying Illinoian-age glacial till was observed in a few exposures in Trumbull County (White, 1971), including an excavation 1 ½ miles southwest of Girard. Deposition of Illinoian deposits is believed to have occurred prior to 100,000 years before present (Y.B.P.).

Ice sheets associated with the Grand River Lobe deposited Wisconsinan-age tills. The earliest Wisconsinan-age till was formerly believed to be the Altonian sub-stage Titusville Till (Table 9). The Titusville Till was proposed as being older than 40,000 Y.B.P. based upon radiocarbon (C^{14}) dates from exposures in northwestern Pennsylvania (White et al., 1969). Current thinking (Totten, 1987 and Eyles and Westgate, 1987) suggests that there was probably insufficient ice available in North America for a major ice advance into the Great Lakes area until the Late Wisconsinan Woodfordian sub-stage (approximately 25,000 Y.B.P.). The age of deposits previously determined to be early to mid-Wisconsinan in age is therefore being re-evaluated. The Titusville Till is typically present in the subsurface in Trumbull County, though in some places it may be close to or at the surface where overlying tills are thin or absent. It tends to be compact, calcareous, pebbly, and sandy in nature, and it will weather to an olive brown color (White, 1971).

The Kent Till is the oldest of the Late Wisconsinan Woodfordian tills. This till is present in much of the subsurface in Trumbull County, but in many places in the eastern part of the county is at the surface due to the absence of the later Lavery Till. In some areas of the county, such as the Girard excavation, the Kent Till is missing completely. The Kent Till is sandy and moderately pebbly, and it weathers to a yellow-brown color (White, 1971). It is not as hard or compact as the underlying Titusville Till (White, 1982).

The Lavery Till is the surficial till found in eastern Trumbull County. It is also found in the subsurface beneath the Hiram Till in the central and northwestern parts of the county, where its typical thickness is less than 10 feet. The Lavery Till is dark brown, calcareous, sparingly to moderately pebbly, and has a clayey-silty texture. In southwestern Trumbull County, the Lavery Till is overlain by a thick sand layer called the Windham Sand (White, 1971 and 1982).

The Windham Sand is a fine-grained sand that ranges from a few inches to 10 feet or more thick. It lies between the Lavery and Hiram Tills in Braceville, Newton, Warren, and Lordstown Townships. In some areas where the Hiram Till is absent, the Windham Sand is the surface material. It was deposited by meltwater from the retreating ice of the Lavery Till in wide floodplains or shallow bodies of water (White, 1971 and 1982).

Late Woodfordian in age, the Hiram Till is the youngest till encountered in Trumbull County. It is the surficial till found in the western half of the county. The Hiram Till is very clay-rich, sparingly pebbly and rarely over 10 feet thick. It has the highest clay content of all the tills in Trumbull County, and in some areas it is difficult to distinguish it from lacustrine material (White, 1971).

Lacustrine deposits were created as a result of numerous shallow lakes forming. Within stream valleys, the damming of streams by advancing ice sheets formed lakes. Typically, lacustrine deposits are composed of fairly dense, cohesive, uniform silt and clay with minor amounts of fine sand. Thin bedding, referred to as laminations, is common in these deposits. Such sediments were deposited in quiet, low-energy environments with little or no current. A large area of surficial lacustrine deposits is found in the Grand River valley in parts of Mesopotamia, Bloomfield, and Farmington Townships. The silt and clay range in thickness from 30 to over 100 feet. The valley of Mosquito Creek also contains silt and clay, but much of it is covered by the Mosquito Creek Reservoir. Lacustrine silt and clay found in the valley of the Mahoning River in Braceville Township and the valley of Duck Creek in Newton, Lordstown, and Warren Townships are associated with glaciofluvial sand (White, 1971).

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 Trumbull County are predominantly located in stream valleys. Such deposits were referred to in earlier literature as valley trains. Sorting and degree of coarseness depend upon the nature and proximity of the melting ice sheet. Braided streams usually deposit outwash.

Such streams have multiple channels that migrate across the width of the valley floor, leaving behind a complex record of deposition and erosion. As modern streams downcut, the older, now higher elevation, remnants of the original valley floor are called terraces. Pymatuning Creek valley, the Mahoning River valley, the Mosquito Creek valley, Duck Creek, and Eagle Creek valleys all contain significant outwash deposits (White, 1971 and Hull, 1984).

Kames and eskers are ice contact features. They are composed of masses of generally poorly-sorted sand and gravel with minor till, deposited in depressions, holes, tunnels, or other cavities in the ice. As the surrounding ice melts, a mound of sediment remains behind. Typically, these deposits may collapse or flow as the surrounding ice melts. These deposits may display high angle, distorted or tilted beds, faults, and folds. In Trumbull County, the majority of the kames are deposited along the margins or flanks of valleys. These kames tend to coalesce together along the valley margins. Such features are referred to as kame terraces. They represent deposition of materials between the melting ice sheet and the bedrock and till slopes flanking the ice-filled valleys. Kame terraces can be found on the eastern side of the Pymatuning Creek valley, the western side of the Grand River valley, on both sides of the Yankee Run, Little Deer Creek, and Shenango River valleys. A few isolated, knob-like kames are found in Newton, Warren, Hubbard, and Bristol Townships (White, 1971 and Hull, 1984).

Bedrock Geology

Bedrock underlying Trumbull County belongs to the Devonian, Mississippian, and Pennsylvanian Systems. Table 10 summarizes the bedrock stratigraphy found in Trumbull County. The Devonian Ohio Shale underlies the floors of the deeper buried valleys beneath the Grand River and Pymatuning Creek. The Ohio Shale, which exceeds 100 feet in thickness (ODNR, Division of Water, Bedrock State Aquifer Map), consists of three members: the uppermost Cleveland Member, the middle Chagrin Member, and the lowermost Huron Member. The Cleveland Member is a black shale that is absent in Trumbull County and those surrounding it. The Chagrin Member consists of gray to greenish-gray shale, siltstone, and very fine-grained sandstone, and is the uppermost formation in the floor of the buried valleys named previously. It is thickest in the northeast portion of the state. The Huron Member is shale, mostly black, carbonaceous, and commonly contains calcareous concretions in the lower portion (Slucher et al., 2006).

Formerly classified as Mississippian in age, the Berea Sandstone and Bedford Shale, undivided, including the Cussewago Sandstone in Trumbull County, has been re-classified as Upper Devonian (Slucher et al., 2006). This unit underlies most of Trumbull County, with the exception of the northwest corner, extreme-west central border, and southwest corner, and can exceed 100 feet in thickness, though typically is much less (ODNR, Division of

Table 10. Bedrock stratigraphy of Trumbull County, Ohio

System	Group/Formation (Symbol)	Lithologic Description
Pennsylvanian	Allegheny and Pottsville Groups undifferentiated (Pap)	Shale, siltstone, sandstone, conglomerate, limestone, underclay, coal, and flint, color mainly gray to black. Sandstone is silty to pebbly, locally conglomeratic in lower 1/3 of unit. The Sharon sandstone is a loosely cemented, cross-bedded, coarse- to medium-grained gray-white to light reddish-tan sandstone with interbedded zones of pebbly conglomerate. Siltstone and shale is clayey to sandy, contain marine fossils. Limestone overlies coal or underclay beds. Unit contains economic coal, limestone, and underclay beds, top of unit mapped at top of Upper Freeport coal bed.
Mississippian	Cuyahoga Group (Mlc) including Shenango sandstone and shale	Consists of sandstone, siltstone, and shale interbeds typically gray or brown in color. Sandstone is silty to conglomeratic, occurs in thin to massive beds. Siltstone and shale occur in thin to thick beds, shale typically black in this area. Shenango sandstone and shale found only in eastern Trumbull County, sandstone medium to coarse-grained, shale is clayey and interbedded with siltstone. Color ranges from brown, yellow, and gray to almost white.
Devonian	Berea Sandstone Bedford Shale Cussewago Sandstone (Dbb)	The Berea Sandstone is a thin- to thick-bedded, fine to medium-grained light greenish-gray to brown sandstone. The Bedford Shale is a gray to brown to reddish-brown shale with thin interbeds of sandstone and siltstone. The Cussewago Sandstone is medium-grained, brown, poorly lithified sandstone. The Cussewago can be massive to crossbedded.
	Ohio Shale (Doh)	The Cleveland Member is a black shale that is absent in Trumbull County and those surrounding it. The Chagrin Member consists of gray to greenish-gray shale, siltstone, and very fine-grained sandstone. The Huron Member is shale, mostly black, carbonaceous, and commonly contains calcareous concretions in the lower portion

Water, Bedrock State Aquifer Map). The uppermost Berea Sandstone is gray to brown in color, and medium-grained to silty in texture. Its average thickness is about 40 feet in Trumbull County. The Bedford Shale can range in color from gray to red to brown, is silty to clayey in texture, and can contain siltstone and sandstone interbeds. It can range from 20 to 30 feet thick. The Cussewago Sandstone lies beneath the Bedford Shale except in south-central Trumbull County, where it lies directly beneath the Berea Sandstone (Rau, 1969). It is typically brown in color, pebbly, quartzose, and massive to crossbedded, and can range in thickness from less than 10 to over 100 feet thick (Rau, 1969 and Slucher et al., 2006).

The Mississippian System in Trumbull County is represented by the Cuyahoga Formation and includes the Shenango sandstone and shale. The Cuyahoga Formation contains interbedded sandstone, shale, and siltstone that can be found in all but the northwestern third of the county. The thickness of the formation in this area varies from less than 100 to over 300 feet (Szmuc, 1953, and ODNR, Division of Water, Bedrock State Aquifer Map). The sandstone ranges from silty to conglomeratic in texture, and occurs in thin to thick beds. The siltstone and shale occurs in thin to thick beds, and the shale in this area of the state is typically black in color. Found only in eastern Trumbull County, the Shenango sandstone and shale ranges in color from brown to gray to almost white. The shale is clayey with siltstone interbeds (Slucher et al., 2006). The sandstone is medium to coarse-grained and ranges in thickness from 15 to 40 feet (Szmuc, 1953). The Shenango sandstone and shale are the uppermost Mississippian formations in Trumbull County.

Rocks of the Pennsylvanian System include formations of both the Pottsville Group and the Allegheny Group (Table 10), and are found in the southeastern third and southwestern corner of the county. The Pottsville and Allegheny Groups are primarily represented by interbedded shales, dirty sandstones, and siltstones along with thin but economically important coals, underclays, and limestones. The basal formation is the Sharon Sandstone (Conglomerate), a thick, massive, coarse-grained sandstone containing conglomeratic zones comprised of bands of milky-white, rounded quartzite pebbles. This unit represents deposition in a relatively high-energy stream channel system. The Sharon Sandstone typically directly overlies the Cuyahoga Formation. The Upper Freeport coal bed represents the uppermost portion of the Pennsylvanian System sequence exposed in Trumbull County.

Ground Water Resources

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

Glacial aquifers in Trumbull County are highly variable, particularly within the buried valleys. The aquifers range from thin, isolated, discontinuous lenses of sand and gravel interbedded in thick sequences of glacial till or lacustrine deposits to relatively thick, extensive outwash deposits. Yields obtained from outwash or alluvial deposits not associated with buried valleys range from 10 to 25 gpm (ODNR, Division of Water Open File Glacial State Aquifer Map, and Haiker, 1996). Discontinuous sand and gravel lenses in areas of thinner drift (i.e. non-buried valley areas) typically have yields ranging from less than 5 to 25 gpm (ODNR, Division of Water Open File Glacial State Aquifer Map).

Yields obtained from aquifers within buried valleys vary considerably. Areas containing thicker, more extensive sand and gravel outwash deposits, higher permeability soils, and modern streams have the capability of maximum yields up to 500 gpm from properly developed, large diameter wells (ODNR, Division of Water Open File Glacial State Aquifer Map and Haiker, 1996). An example of this is the buried valley aquifer beneath the city of Hubbard. Wells completed in buried valley deposits beneath Little Yankee Run near Masury, the Mahoning River near Girard and Warren, and Duck Creek and the Mahoning River east of Newton Falls could yield from 25 to 100 gpm (ODNR, Division of Water Open File Glacial State Aquifer Map, Haiker, 1996). Test drilling may be necessary to confirm the presence of the higher-yielding sand and gravel deposits within the buried valleys. Yields from somewhat finer, thinner sand and gravel deposits found along the margins or up tributaries of the major trunk buried valleys typically are less than 25 gpm (ODNR, Division of Water Open File, Glacial State Aquifer Map and Haiker, 1996). Buried valleys that extend through present upland areas commonly have yields less than 10 gpm (ODNR, Division of Water Open File Glacial State Aquifer Map and Haiker, 1996). In these areas, the aquifer consists of thin, discontinuous sand and gravel lenses, soils are low permeability, and modern streams are absent or intermittent.

Yields obtained from bedrock aquifers are also variable. Rau (1969) reported yields of up to 50 gpm for the Berea Sandstone, with more common yields of 5 to 20 gpm. The Cussewago Sandstone also has the potential to yield 50 gpm, but typical yields are lower, 10 to 20. Wells penetrating both formations may yield more. Water quality may vary across the county; locally there are areas where the Berea is contaminated with oil and gas residue (Haiker, 1996 and Wilson, pers. comm.). The Cussewago may have a higher-than-desirable amount of total dissolved solids for some homeowners (Wilson, pers. comm.).

The Mississippian Cuyahoga Formation, with its interbedded sandstones, shales, and siltstones, can yield up to 25 gpm (ODNR, Division of Water, Bedrock State Aquifer Map and Haiker, 1996). There are no formations within this sequence that produce significantly higher yields than the others.

The Sharon Sandstone is the highest-yielding bedrock formation in the Allegheny Pottsville Group in Trumbull County. Yields of 25 to 50 gpm are common, and large diameter wells located in the southwest corner of the county could yield up to 100 gpm (ODNR, Division of Water, Bedrock State Aquifer Map and Haiker, 1996). Coarser-grained and conglomeratic zones within the Sharon may be slightly more permeable and have slightly higher yields. Yields in the Allegheny and Pottsville Groups, excluding the Sharon Sandstone, average from 5 to 25 gpm (ODNR, Division of Water, Bedrock State Aquifer Map and Haiker, 1996). Yields in formations within the Allegheny Group commonly have lower yields due to the higher variability of the bedrock units and the fact that they typically occur at higher elevations and are therefore higher above stream base. The higher yields in the Pottsville Group also reflect the much higher proportion of coarse sandstone units (Sedam, 1973).

The yield in any particular area is dependent upon the number and type of formations penetrated by the well. 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 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.

Yields are also influenced by the number of fractures and bedding planes intersected by the wells (Stanley, 1973). The amount of fracturing tends to increase along hill slopes and valleys. This increase may be related to the stress relief as shown by Wyrick and Borchers (1981) and Kipp et al. (1983). The net result is that there is usually a decrease in depth to water (i.e. a shallower static water level) and higher yields. Fracturing resulting from strip mining, blasting, or underground mining may produce similar results. Fracturing is also an influence on the direction of ground water flow (Schubert, 1980) and affects the amount of recharge.

Industrial Mineral Resources

During the late 1800's and early 1900's there were several underground coal mines operating in southeastern Trumbull County. The mines were extracting the Pennsylvanian Sharon #1 coal. Three of the largest mines were located in the area of Mineral Ridge, in an area just east of St. Rt. 193 near Girard, and in an area between St. Rt. 7 and Masury. Smaller operations were scattered throughout Brookfield, Hubbard, Liberty, and Vienna Townships. The last mine was closed in 1935, according to information from the Ohio Department of Natural Resources, Division of Geological Survey's Abandoned Mine Locator interactive map (found on their website, see references). The relationship between these mines and local ground water conditions is not known. The presence of abandoned underground mines may have little, or conversely, major effects on ground water. Determining the presence of underground mines and investigating their potential influence should be included as part of any extensive site-specific study in suspect areas. Table 11 lists the factors that could potentially influence the ratings for these underground mined areas.

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)

Other industrial minerals retrieved for economic purposes include sand and gravel, sandstone, and clay. The sand and gravel and clay are extracted from kame terrace deposits along the west side of the Grand River valley in Mesopotamia Township near the Ashtabula County border. A sandstone quarry on the east side of St. Rt. 7 just north of Hubbard is probably mining Pennsylvanian sandstone for building purposes (Ohio Department of Natural Resources, Division of Geological Survey, Interactive Map of Ohio Coal and Industrial Minerals, 2008). Large quarry pits or surface mines are typically not rated in the DRASTIC system because these areas no longer reflect natural conditions, and therefore cannot be evaluated using the DRASTIC criteria.

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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 ODNR, Division of Soil and Water Resources, Water Resources Section (WRS). Approximately 17,800 water well log records are on file for Trumbull County. Over 5600 of these logs have latitude/longitude or state X/Y coordinate data, which allows them to be located on a topographic map. Static water levels and information on the depth to saturated zones were taken from the well log records. The *Ground Water Resources Map of Trumbull County* (Haiker, 1996), and the report of Rau (1969) helped to provide generalized depth to water information throughout Trumbull County. Depth to water values calculated for adjoining counties (Aller et al., 1991, Aller et al., 1994, Angle, 1990, and Angle, 2003) were also utilized. Topographic and geomorphic trends were utilized to estimate the depth to water in areas where other data sources were lacking.

Depths of 5 to 15 feet (DRASTIC value =9) and 15 to 30 feet (7) were typical of areas paralleling smaller streams in the uplands and for floodplains flanking larger streams. Depths of 15 to 30 feet (7) were common for outwash terraces and for the buried valleys containing modern streams. Areas of ground moraine commonly had depths of water of 15 to 30 feet (7) or 30 to 50 feet (5). Areas covered by thin to moderate thicknesses (less than 40 feet) of glacial till commonly have depths of water averaging 15 to 30 feet (7). Depths of 30 to 50 feet (5) were common along hill slopes and along the margins of valleys. Many of the areas mapped by White (1971) as kames, kame terraces, and end moraines were evaluated as having depths of water from 30 to 50 feet (5). Other areas with depths ranging from 30 to 50 feet (5) are typically transitional between the upland divides and ridges and lower-lying stream valleys and floodplains. Areas with a moderate thickness of till (roughly 40 to 70 feet) typically have a depth to water ranging from 30 to 50 feet (5). Depths of 30 to 50 feet (5) were common in portions of buried valleys lacking or far-removed from modern streams.

Depths of 50 to 75 feet (3), 75 to 100 feet (2), and 100+ feet (1) were selected for, bedrock-controlled ridges and knolls. These areas typically exhibit some of the highest relief in Trumbull County.

Net Recharge

This factor was evaluated using many criteria including depth to water, topography, soil type, proximity of surface drainage, vadose zone material, and annual precipitation. General estimates of recharge provided by Pettyjohn and Henning (1979) and Dumouchelle and Schiefer (2002) proved to be helpful. Recharge values calculated for adjoining counties (Aller et al., 1991, Aller et al., 1994, Angle, 1990, and Angle, 2003) were also utilized.

Values of 7 to 10 inches per year (8) of recharge were selected for areas with highly permeable soils (e.g. sandy loams) and vadose zone materials (e.g. outwash), shallow depths to water, and gentle slopes. These areas typically occur on terraces or floodplains flanking modern streams. Areas having recharge values of 7 to 10 inches per year (8) contain outwash or coarse alluvial deposits as the aquifer and are primarily limited to the 7D - Buried Valley, the 7Ba Outwash, or the 7Eb River Alluvium Without Overbank Deposits hydrogeologic settings.

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

Recharge values of 2 to 4 inches per year (3) were utilized in areas where the depth to water exceeded 75 feet, based upon static water levels. The majority of these areas contained moderate thicknesses of till, low permeability soils (e.g. clay loams), and moderately steep slopes. These rates were also commonly found in areas with steeper, bedrock-controlled topography and relatively high depths to water.

Aquifer Media

Information on aquifer media was obtained from the works of Cummins (1950), Szmuc (1953), Rau (1969), White (1971), Sedam (1973), Angle (1990), Aller et al. (1991), Aller et al. (1994), Haiker (1996), Angle (2003) and Slucher et al. (2006). Open File Bedrock Reconnaissance Maps and Open File Bedrock Topography Maps, based upon U.S.G.S. 7-1/2 minute topographic maps from the ODNR, Division of Geological Survey proved helpful. The ODNR, Division of Soil and Water Resources Glacial State Aquifer Map and Bedrock State Aquifer Map were an important source of aquifer data. Open file bedrock topography maps from the ODNR, Division of Geological Survey proved invaluable in delineating buried valleys and mapping aquifer media. Generalized bedrock topography contours also appear on the *Glacial Geology Map of Trumbull County* (White, 1971). Water well log records on file at the WRS were also an important source of data.

The aquifer media rating for bedrock varied across the county. An aquifer rating of (6) was selected primarily for wells completed within the interbedded sandstones and shales of the Mississippian Cuyahoga Group. The Allegheny and Pottsville Groups contain interbedded shales, sandstones, siltstones, underclays, limestones, and coal; however, the massive sandstones are the primary aquifers. These sandstone aquifers include the Sharon Sandstone, the Massillon (Connoquenessing) Sandstone, and the Homewood/Clarion Sandstone. These sandstones contribute a high proportion of the total yield obtained from wells drilled into the Pottsville. An aquifer rating of (7) was chosen for the Pottsville sandstones; they are the uppermost formations in the southwest corner of the county. The

Devonian shale aquifer utilized along the northern boundary of the county was given a rating of (2). Ratings for the aquifers in the glacial deposits also varied across Trumbull County. The thick, continuous, coarse, clean outwash deposits were given aquifer media ratings of (7) or (8). These highly-rated outwash deposits are limited to the 7D Buried Valley hydrogeologic setting or the 7Ba Outwash setting. Aquifer media ratings of (6) were utilized for less continuous, finer-grained sand and gravel deposits and deposits containing finer silts and clays. The aquifer media rating of (6) was commonly utilized for many of the buried valleys, kames, and areas with thinner outwash and included the 7D Buried Valley hydrogeologic setting.

Soil Media

This factor was primarily evaluated using data obtained from the *United States Department of Agriculture, Natural Resource Conservation Service, Soil Data Mart OH155-Trumbull County, Ohio, 2007*. Information on every indicated soil type was analyzed and appropriate ratings were selected. Table 12 lists the soil types encountered in Trumbull County and gives information on the soils' parent material or setting and the corresponding DRASTIC rating. The nature of the underlying glacial deposits and proximity to bedrock were two of the main factors influencing soil types in Trumbull County. Soil ratings were based upon the most restrictive layer or horizon within the soil profile.

Clay loam (3) and silt loam (4) were the two most common soil ratings utilized throughout Trumbull County. Clay loam (3) was encountered in most upland areas where the clay-rich Hiram Till and Lavery Till were the surficial materials. Clayey lacustrine/slackwater deposits also weather into clay loam (3) soils. In areas where the Lavery Till was thin, where the Kent Till was the surficial material, or where till thinly overlies bedrock, silt loam (4) soils were found. Silt loam (4) soils were also common in modern alluvium terraces, floodplains, and siltier lacustrine/slackwater deposits. Loam (5) soils were associated with areas of weathered, interbedded bedrock and with outwash terraces that contained higher proportion of fine-grained materials. Sandy loam (6) soils were developed in areas with coarser outwash terraces, kames, and very coarse alluvium. Weathered sandstone was another source of sandy loam (6) soils. Shrink-swell clay (7) was rated for many clay rich soils derived from exceptionally clayey slackwater, till, or water-deposited tills. Sand (9) was rated in areas of Newton, Braceville, Warren, and Lordstown townships where the Hiram Till is absent and the Windham Sand is the surface material. Thin or absent (10) is used in the upland areas of northwestern and eastern Trumbull County where bedrock is nearly or totally exposed in steep stream valley walls.

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

Table 12. Trumbull County soils

Soil Name	Parent Material or Setting	DRASTIC Rating	Soil Media
Bogart	Outwash, kames	6	Sandy loam
Brecksville	Weathered shale	10	Thin/Absent
Cambridge*	Till	3	Clay loam
Canadice	Lacustrine	7	Shrink-swell clay
Caneadea	Lacustrine	7	Shrink-swell clay
Canfield*	Loamy till	4	Silt loam
Chenango	Outwash	10	Gravel
Chili	Outwash, kames	6	Sandy loam
Condit	Till	3	Clay loam
Damascus	Outwash	6	Sandy loam
Darien	Till	3	Clay loam
Ellsworth	Till	3	Clay loam
Elnora	Sandy outwash	6	Sandy loam
Fitchville	Lacustrine	4	Silt loam
Geeburg	Lacustrine/till	7	Shrink-swell clay
Glenford	Silty lacustrine	4	Silt loam
Haskins	Outwash over lacustrine/till	10	Gravel
Holly	Loamy alluvium	4	Silt loam
Jimtown	Outwash	6	Sandy loam
Lakin	Sandy outwash	9	Sand
Lorain	Clayey lacustrine	7	Shrink-swell clay
Lordstown	Till over sandstone	6	Sandy loam
Lordstown rock outcrop	Sandstone	10	Thin/Absent
Loudenville	Till over sandstone	5	Loam
Mahoning	Till	3	Clay loam
Mill	Loamy till	4	Silt loam
Mitiwanga	Till over sandstone	6	Sandy loam
Orrville	Loamy alluvium	4	Silt loam
Oshtemo	Outwash	6	Sandy loam
Otego	Silty alluvium	4	Silt loam
Pierpont*	Silty till	3	Clay loam
Platea*	Till	3	Clay loam
Ravenna*	Loamy till	4	Silt loam
Rawson	Outwash over lacustrine/till	10	Gravel
Red Hook	Outwash	10	Gravel
Remsen	Till	3	Clay loam
Rittman*	Silty till	3	Clay loam
Sebring	Lacustrine	3	Clay loam
Seward	Sandy outwash	6	Sandy loam
Tioga	Allluvium	6	Sandy loam
Trumbull	Till	3	Clay loam
Venango	Till	3	Clay loam
Wadsworth*	Silty till	3	Clay loam
Wooster*	Loamy till	4	Silt loam

*- soil contains a fragipan layer

and a soil with a silt loam (4) texture would be rated as a clay loam (3) due to the presence of the fragipan (Table 12).

Topography

Topography was evaluated by determining the percentage of slope obtained from digital elevations models (Ohio Geographically Referenced Information Program, 2007) and U.S.G.S. 7 1/2-minute (1:24,000 scale) quadrangle maps for Trumbull County. Slopes of 0 to 2 percent (10) were selected for floodplains, flat-lying outwash terraces, and some areas of ground moraine. Slopes of 2 to 6 percent (9) were widespread through the county and include areas of both end moraine and ground moraine, terraces, as well as some areas with bedrock-controlled topography. Overall, slopes of 0 to 2 percent (10) and 2 to 6 percent (9) were found in stream valleys or in uplands in the northern and western portions of the county. Slopes of 6 to 12 percent (5) were utilized for steeper end moraines, moderately steep bedrock ridges, many kames, and areas adjacent to modern stream valleys that have undergone moderately high lateral erosion. Steeper slopes of 12 to 18 percent (3) were limited to areas of bedrock ridges, cliffs, and knobs. Areas with steeper slopes are found in the eastern and southeastern portions of the county.

Impact of the Vadose Zone Media

Water well records on file at the WRS were a primary source of information on vadose zone media. Information on vadose zone media was obtained from the reports of Cummins (1950), Szmuc (1953), Rau (1969), White (1971), Sedam (1973), Angle (1990), Aller et al. (1991), Aller et al. (1994), Haiker (1996), Angle (2003) and Slucher et al. (2006). Open File Bedrock Reconnaissance Maps and Open File Bedrock Topography Maps, based upon U.S.G.S. 7-1/2 minute topographic maps from the ODNR, Division of Geological Survey proved helpful. The ODNR, Division of Soil and Water Resources Glacial State Aquifer Map and Bedrock State Aquifer Map were an important source of vadose zone data.

Till was chosen as the vadose zone material for much of Trumbull County. Typically a rating of (4) was selected for till. In many of the buried valleys and other areas containing outwash, sand and gravel with significant silt and clay were selected as the vadose zone material and a rating of (6) was used. Kames, kame terraces, and outwash terraces were similarly assigned a rating of (6). Silt and clay with a vadose zone media rating of (3) was assigned to areas with moderately thick clayey lacustrine, slackwater, or lakebed deposits.

Bedrock was selected as the vadose zone media for the few areas in Trumbull County with thin or absent soils, or areas in the 7G - Thin Till Over Bedded Sedimentary Rock hydrogeologic setting. A vadose zone rating of (4) was selected for these bedrock units due to the higher proportion of shale interbeds in these areas.

Hydraulic Conductivity

Very little published hydraulic conductivity data exists for Trumbull County. The regional bedrock studies of Rau (1969) and Sedam (1973) proved to be useful. Textbook tables (Freeze and Cherry, 1979, Fetter, 1980, and Driscoll, 1986) were useful in obtaining estimated values for a variety of aquifer materials. Additionally, values for hydraulic conductivities utilized in adjoining counties were extended into Trumbull County (Aller et al., 1991, Aller et al., 1994, Angle, 1990, and Angle, 2003).

Values for hydraulic conductivity roughly followed the aquifer ratings, i.e. the more highly-rated aquifers have higher hydraulic conductivities. For the sand and gravel aquifers, the hydraulic conductivity is a function of coarseness, stratification, sorting, and cleanliness (absence of fines). Buried valleys containing sand and gravel aquifers with an aquifer media rating of (6) were assigned a hydraulic conductivity of 300-700 gpd/ft^2 (4). Sand and gravel aquifers with an aquifer media rating of (7) were assigned hydraulic conductivity ratings of 300-700 gpd/ft^2 (4) or 700-1,000 gpd/ft^2 (6). The sand and gravel aquifers with an aquifer media rating of (8) were assigned a hydraulic conductivity value of 700-1,000 gpd/ft^2 (6).

A hydraulic conductivity rating of 1-100 gpd/ft^2 (1) was selected for the shale bedrock aquifer in the 7Ae Glacial Till Over Shale hydrogeologic setting. For bedrock aquifers with an aquifer media rating of (6), a hydraulic conductivity range of 100-300 gpd/ft^2 (2) was used. For the predominantly sandstone aquifer in the 7Ad Glacial Till Over Sandstone hydrogeologic setting, a hydraulic conductivity range of 300-700 gpd/ft^2 was used.

APPENDIX B

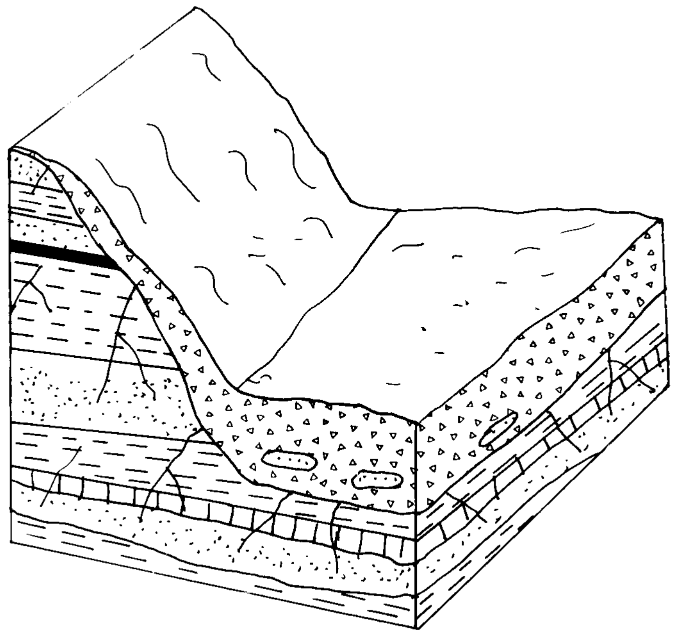
DESCRIPTION OF HYDROGEOLOGIC SETTINGS AND CHARTS

Ground water pollution potential mapping in Tumbull County resulted in the identification of eight hydrogeologic settings within the Glaciated Central Region. The list of these settings, the range of pollution potential indexes, and the number of index calculations for each setting are provided in Table 13. Computed pollution potential indexes for Trumbull County range from 74 to 170.

Table 13. Hydrogeologic settings mapped in Trumbull County, Ohio

Hydrogeologic Settings	Range of GWPP Indexes	Number of Index Calculations
7Aa - Glacial Till Over Bedded Sedimentary Rock	74-145	74
7Ad – Glacial Till Over Sandstone	130-154	14
7Ae – Glacial Till Over Shale	110-133	6
7Ba – Outwash	126-170	7
7D - Buried Valley	104-163	40
7Eb - River Alluvium Without Overbank Deposits	140-164	4
7Ec – Alluvium Over Bedded Sedimentary Rock	132-164	4
7G – Thin Till Over Bedded Sedimentary Rock	104-108	2

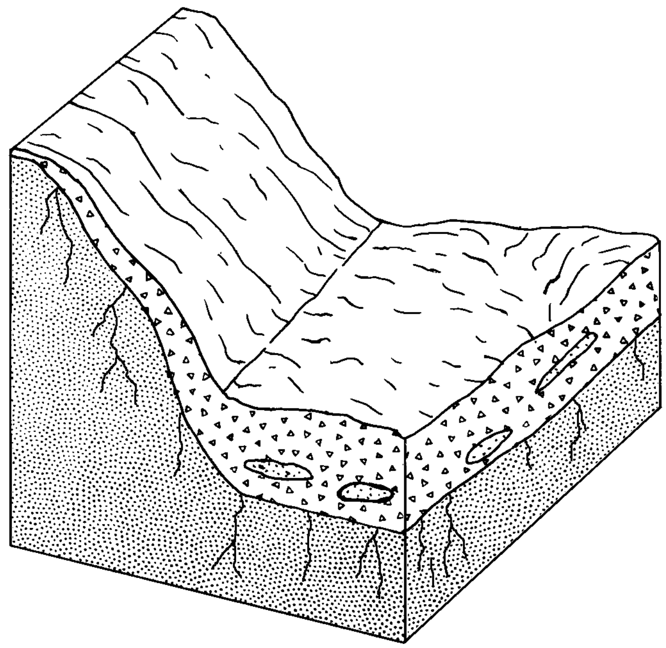
The following information provides a description of each hydrogeologic setting identified in the county, a block diagram illustrating the characteristics of the setting, and a listing of the charts for each unique combination of pollution potential indexes calculated for each setting. The charts provide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



7Aa Glacial Till Over Bedded Sedimentary Rocks

This hydrogeologic setting is variable and widespread across Trumbull County. Topography varies from rolling, low relief areas in the western portion of the county to steep, high relief areas in the eastern part of the county. The aquifer consists of thin interbedded shales, sandstones, siltstones, limestones, clay, and coal of the Pottsville and Allegheny Groups of the Pennsylvanian System, interbedded shale, siltstones, and sandstones of the Mississippian Cuyahoga Group (including the Shenango sandstone and shale), and the Devonian Berea Sandstone, Bedford Shale, Cussewago Sandstone, and Ohio Shale. Varying thicknesses of glacial till typically overlie the aquifer. The various till units commonly weather into either silt loams or clay loams. The depth to water varies widely across the county. Recharge is moderate to low depending upon the slope, thickness of the till cover, and depth to water.

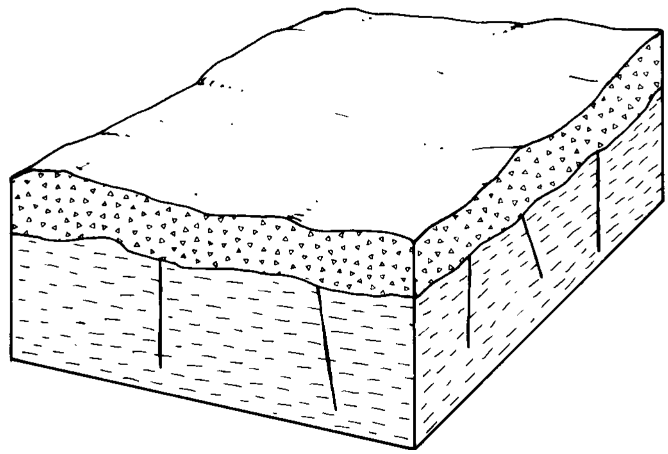
GWPP index values for the hydrogeologic setting of glacial till over bedded sedimentary rocks range from 74 to 145, with the total number of GWPP index calculations equaling 74.



7Ad Glacial Till over Sandstone

This setting is characterized by moderate to high relief. The topography varies from rolling hills to prominent ridges comprised of relatively flat-lying, resistant sandstone. The sandstones are generally fine-grained, though cemented conglomeratic zones are common in the Pennsylvanian Sharon Sandstone. The Massillon Sandstone is present as well, and both sandstones are the primary aquifer in the southwestern corner of Trumbull County. The sandstone is overlain by varying thicknesses of glacial till. Recharge is moderate, and depth to water depends on which aquifer is being used, the thickness of the overlying till, and whether the well is located on the crest of a ridge or the valley side.

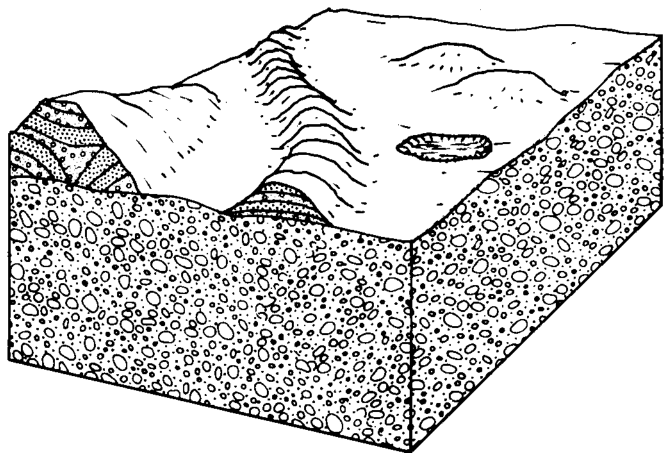
GWPP index values for the hydrogeologic setting of Glacial Till over Sandstone range from 130 to 154, with the total number of GWPP index calculations equaling 14.



7Ae Glacial Till over Shale

This hydrogeologic setting is found in northern Trumbull County in areas where the Devonian Ohio Shale is the only available aquifer. This setting is characterized by relatively flat-lying to gently rolling topography. Soils are clay loams, loams, or silt loams derived from the underlying tills. The vadose zone is till. Depths to water are commonly shallow, averaging less than 20 feet. Recharge is moderate to low due to the low permeability of the soils, vadose, and aquifer media itself and the very shallow depth to water.

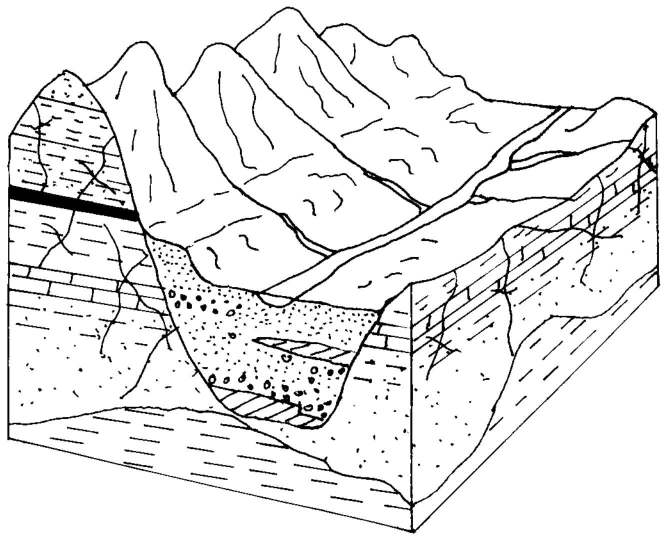
GWPP index values for the hydrogeologic setting of Glacial Till over Shale ranges from 110 to 133, with the total number of GWPP index calculations equaling 6.



7Ba Outwash

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

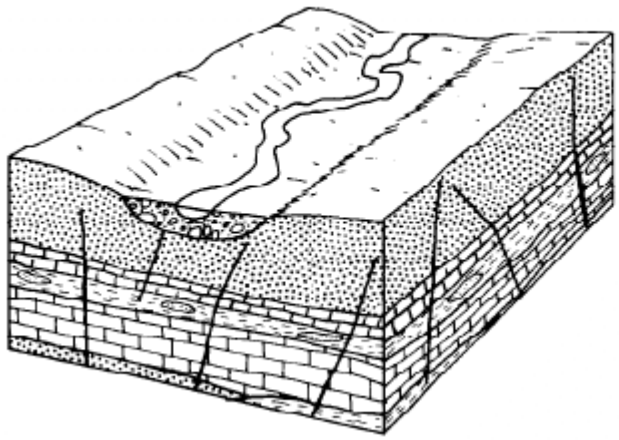
GWPP index values for the hydrogeologic setting of outwash range from 126 to 170, with the total number of GWPP index calculations equaling 7.



7D Buried Valley

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

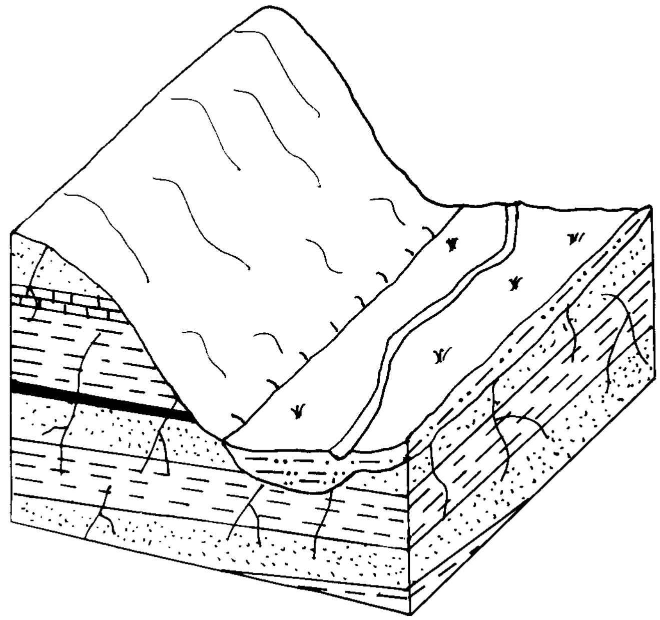
GWPP index values for the hydrogeologic setting of buried valley range from 104 to 163, with the total number of GWPP index calculations equaling 40.



<u>7Eb River Alluvium Without Overbank Deposits</u>

This hydrogeologic setting is characterized by flat-lying topography along limited areas of the floodplains of Swine Creek and Grand River in the northwest corner of the county, along Pymatuning Creek in the northeastern corner of the county, and along Yankee Creek in the east-central part of the county. Moderately thick, relatively coarse alluvium is found within these stream valleys. These valleys lack significant fine-grained overbank deposits. Recharge is relatively high and depth to water is typically 15 feet or less. The coarse alluvium (sand and gravel) aquifer is commonly in direct hydrologic contact with the surface stream. The alluvium may also serve as a source of recharge to the underlying fractured sedimentary rocks.

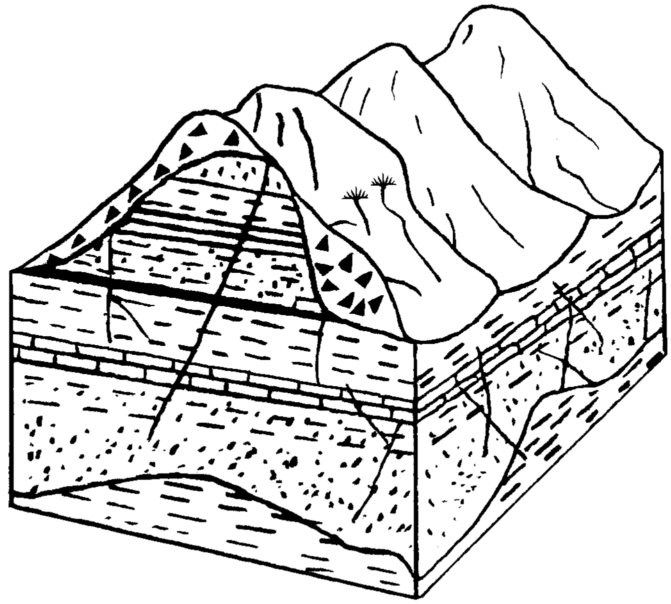
GWPP index values for the hydrogeologic setting of River Alluvium Without Overbank Deposits range from 140 to 164, with the total number of GWPP index calculations equaling 4.



7Ec Alluvium Over Bedded Sedimentary Rock

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

GWPP index values for the hydrogeologic setting of alluvium over bedded sedimentary rocks ranges from 132 to 164, with the total number of GWPP index calculations equaling 4.



7G Thin Till Over Bedded Sedimentary Rock

This hydrogeologic setting is characterized by relatively rugged topography and high relief. This setting primarily consists of steep, bedrock-controlled ridges flanking river valleys in the southeastern part of the county. Glacial till is absent or thinly overlies (less than 45 inches) the bedrock surface. Soils are typically sandy loams and are derived from weathering bedrock and the thin, remaining till. The aquifer consists of interbedded sandstones, shales, limestones, clay, and coal of the Pennsylvanian System or interbedded shales, siltstones, and fine-grained sandstones of the Mississippian System. The vadose zone media is also composed of the same fractured, interbedded sedimentary units. Depth to water is moderate with depths ranging from 30 to 50 feet. Recharge is moderate due to the steep slopes, the moderate depth to water, and relatively permeable soils and fractured vadose zone media.

GWPP index values for the hydrogeologic setting of Thin Till Over Bedded Sedimentary Rock range from 104 to 108, with the total number of GWPP index calculations equaling 2.

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
7Aa1	5-15	4-7	Interbedded sst & sh	Sandy loam	2-6	Till	100-300	134	164
7Aa2	30-50	4-7	Interbedded sst & sh	Clay loam	0-2	Till	100-300	109	132
7Aa3	50-75	4-7	Interbedded sst &sh	Clay loam	0-2	Till	100-300	99	122
7Aa4	5-15	4-7	Interbedded sst & sh	Clay loam	0-2	Till	100-300	129	152
7Aa5	5-15	4-7	Interbedded sst & sh	Clay loam	2-6	Till	100-300	128	149
7Aa6	5-15	4-7	Interbedded sst &sh	Silty loam	2-6	Till	100-300	130	154
7Aa7	5-15	4-7	Interbedded sst & sh	Clay loam	6-12	Till	100-300	124	137
7Aa8	5-15	4-7	Interbedded sst & sh	Thin/Absent	6-12	Interbedded sst & sh	100-300	138	172
7Aa9	5-15	4-7	Interbedded sst & sh	Thin/Absent	12-18	Interbedded sst & sh	100-300	136	166
7Aa10	5-15	4-7	Interbedded sst & sh	Loam	6-12	Till	100-300	128	147
7Aa11	30-50	4-7	Interbedded sst & sh	Clay loam	2-6	Till	100-300	108	129
7Aa12	30-50	4-7	Interbedded sst & sh	Silty loam	6-12	Till	100-300	106	122
7Aa13	30-50	4-7	Interbedded sst & sh	Silty loam	2-6	Till	100-300	110	134
7Aa14	30-50	4-7	Interbedded sst & sh	Thin/Absent	6-12	Interbedded sst & sh	100-300	118	152
7Aa15	30-50	4-7	Interbedded sst & sh	Sandy loam	6-12	Till	100-300	110	132
7Aa16	30-50	4-7	Interbedded sst & sh	Sandy loam	2-6	Till	100-300	114	144
7Aa17	30-50	4-7	Interbedded sst & sh	Clay loam	6-12	Till	100-300	104	117
7Aa18	30-50	4-7	Interbedded sst & sh	Clay loam	12-18	Till	100-300	102	111
7Aa19	5-15	4-7	Interbedded sst & sh	Loam	2-6	Till	100-300	132	159
7Aa20	30-50	4-7	Interbedded sst & sh	Loam	2-6	Till	100-300	112	139
7Aa21	50-75	4-7	Interbedded sst & sh	Clay loam	2-6	Till	100-300	98	119
7Aa22	50-75	4-7	Interbedded sst & sh	Silty loam	2-6	Till	100-300	100	124
7Aa23	30-50	4-7	Interbedded sst & sh	Sandy loam	2-6	Till	100-300	119	148
7Aa24	50-75	4-7	Interbedded sst & sh	Shrink/swell clay	2-6	Till	100-300	106	139
7Aa25	15-30	4-7	Interbedded sst & sh	Clay loam	0-2	Till	300-700	128	149
7Aa26	30-50	4-7	Interbedded sst & sh	Clay loam	2-6	Till	300-700	117	136

Setting	Depth to Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% slope)	Vadose Zone Media	Hydraulic Conductivity	Rating	Pesticide Rating
7Aa27	30-50	4-7	Interbedded sst & sh	Sandy loam	2-6	Till	300-700	123	151
7Aa28	15-30	4-7	Interbedded sst & sh	Sandy loam	0-2	Till	300-700	134	164
7Aa29	5-15	4-7	Interbedded sst & sh	Clay loam	0-2	Till	300-700	135	156
7Aa30	15-30	4-7	Interbedded sst & sh	Clay loam	2-6	Till	100-300	118	139
7Aa31	75-100	2-4	Interbedded sst & sh	Loam	2-6	Till	100-300	85	112
7Aa32	15-30	4-7	Interbedded sst & sh	Sandy loam	6-12	Till	100-300	120	142
7Aa33	30-50	4-7	Interbedded sst & sh	Clay loam	12-18	Till	100-300	102	111
7Aa34	15-30	4-7	Interbedded sst & sh	Clay loam	12-18	Till	100-300	112	121
7Aa35	100+	2-4	Interbedded sst & sh	Clay loam	2-6	Till	100-300	76	97
7Aa36	15-30	4-7	Interbedded sst & sh	Loam	12-18	Till	100-300	116	131
7Aa37	75-100	2-4	Interbedded sst & sh	Clay loam	2-6	Till	100-300	81	102
7Aa38	75-100	2-4	Interbedded sst & sh	Clay loam	0-2	Till	100-300	82	105
7Aa39	100+	2-4	Interbedded sst & sh	Clay loam	0-2	Till	100-300	77	100
7Aa40	75-100	2-4	Interbedded sst & sh	Silty loam	2-6	Till	100-300	83	107
7Aa41	100+	2-4	Interbedded sst & sh	Sandy loam	2-6	Till	100-300	82	112
7Aa42	75-100	2-4	Interbedded sst & sh	Sandy loam	2-6	Till	100-300	87	117
7Aa43	50-75	4-7	Interbedded sst & sh	Sandy loam	2-6	Till	100-300	104	134
7Aa44	15-30	4-7	Interbedded sst & sh	Shrink/swell clay	2-6	Till	100-300	126	159
7Aa45	100+	2-4	Interbedded sst & sh	Loam	2-6	Till	100-300	80	107
7Aa46	15-30	4-7	Interbedded sst & sh	Sandy loam	2-6	Till	100-300	124	154
7Aa47	15-30	4-7	Interbedded sst & sh	Silty loam	2-6	Till	100-300	120	144
7Aa48	30-50	4-7	Interbedded sst & sh	Sand	2-6	Till	100-300	120	159
7Aa49	15-30	4-7	Interbedded sst & sh	Sand	2-6	Till	100-300	130	169
7Aa50	15-30	4-7	Interbedded sst & sh	Clay loam	0-2	Till	100-300	119	142
7Aa51	15-30	4-7	Interbedded sst & sh	Sandy loam	0-2	Till	100-300	125	157
7Aa52	30-50	4-7	Interbedded sst & sh	Silty loam	6-12	Till	100-300	106	122
7Aa53	50-75	4-7	Interbedded sst & sh	Silty loam	6-12	Till	100-300	96	112

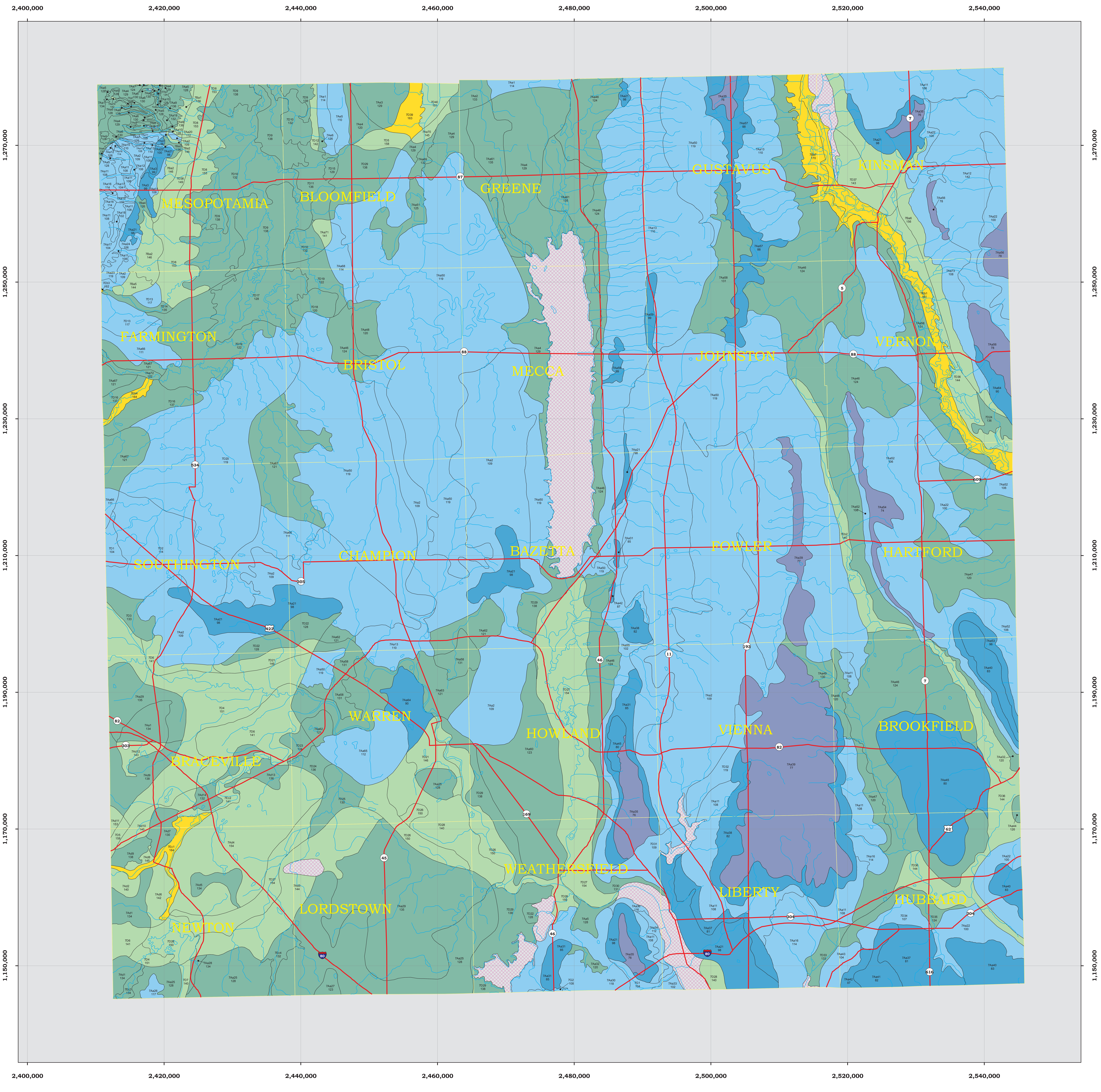
Setting	Depth to Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% slope)	Vadose Zone Media	Hydraulic Conductivity	Rating	Pesticide Rating
7Aa54	100+	2-4	Interbedded sst & sh	Silty loam	6-12	Till	100-300	74	90
7Aa55	50-75	4-7	Interbedded sst & sh	Loam	2-6	Till	100-300	102	129
7Aa56	100+	2-4	Interbedded sst & sh	Silty loam	2-6	Till	100-300	78	102
7Aa57	75-100	2-4	Interbedded sst & sh	Sandy loam	0-2	Till	100-300	88	120
7Aa58	15-30	4-7	Interbedded sst & sh	Sand	0-2	Till	100-300	131	172
7Aa59	50-75	4-7	Interbedded sst & sh	Clay loam	0-2	Till	100-300	99	122
7Aa60	15-30	4-7	Interbedded sst & sh	Loam	0-2	Till	100-300	123	152
7Aa61	5-15	4-7	Interbedded sst & sh	Sandy loam	0-2	Till	100-300	135	167
7Aa62	30-50	4-7	Interbedded sst & sh	Sand	0-2	Till	100-300	121	162
7Aa63	15-30	4-7	Interbedded sst & sh	Silty loam	0-2	Till	100-300	121	147
7Aa64	100+	4-7	Interbedded sst & sh	Sandy loam	6-12	Till	100-300	90	112
7Aa65	30-50	4-7	Interbedded sst & sh	Shrink/swell clay	0-2	Silt/clay	100-300	112	148
7Aa66	30-50	4-7	Interbedded sst & sh	Shrink/swell clay	2-6	Silt/clay	100-300	111	145
7Aa67	15-30	4-7	Interbedded sst & sh	Shrink/swell clay	2-6	Silt/clay	100-300	121	155
7Aa68	30-50	4-7	Interbedded sst & sh	Sandy loam	2-6	Till	100-300	114	144
7Aa69	5-15	4-7	Interbedded sst & sh	Shrink/swell clay	0-2	Silt/clay	100-300	132	168
7Aa70	0-5	7-10	Interbedded sst & sh	Shrink/swell clay	0-2	Silt/clay	100-300	145	181
7Aa71	5-15	4-7	Interbedded sst & sh	Sand	0-2	Till	100-300	141	182
7Aa72	15-30	4-7	Interbedded sst & sh	Loam	2-6	Till	100-300	122	149
7Aa73	30-50	4-7	Interbedded sst & sh	Loam	6-12	Till	100-300	108	127
7Aa74	5-15	4-7	Interbedded sst &sh	Thin/Absent	2-6	Interbedded sst & sh	100-300	142	184
7Ad1	15-30	4-7	Sandstone	Sandy loam	0-2	Till	300-700	134	164
7Ad2	5-15	4-7	Sandstone	Silty loam	0-2	Till	300-700	140	164
7Ad3	5-15	4-7	Sandstone	Sandy loam	0-2	Till	300-700	144	174
7Ad4	5-15	4-7	Sandstone	Sand	2-6	Till	300-700	154	190
7Ad5	15-30	4-7	Sandstone	Sandy loam	0-2	Till	300-700	134	164
7Ad6	5-15	4-7	Sandstone	Loam	0-2	Till	300-700	142	169
7Ad7	15-30	4-7	Sandstone	Silty loam	0-2	Till	300-700	130	154
7Ad8	15-30	4-7	Sandstone	Sand	0-2	Till	300-700	145	183
7Ad9	5-15	4-7	Sandstone	Clay loam	0-2	Till	300-700	138	159

Setting	Depth to Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% slope)	Vadose Zone Media	Hydraulic Conductivity	Rating	Pesticide Rating
7Ad10	5-15	4-7	Sandstone	Silty loam	0-2	Till	300-700	140	164
7Ad11	0-5	7-10	Sandstone	Silty loam	0-2	Till	300-700	153	177
7Ad12	5-15	4-7	Sandstone	Sandy loam	2-6	Till	300-700	143	171
7Ad13	15-30	4-7	Sandstone	Shrink/swell clay	0-2	Till	300-700	136	169
7Ad14	15-30	4-7	Sandstone	Loam	0-2	Till	300-700	132	159
7Ae1	5-15	4-7	Shale	Clay loam	0-2	Till	1-100	114	138
7Ae2	0-5	7-10	Shale	Sandy loam	0-2	Till	1-100	133	166
7Ae3	0-5	7-10	Shale	Silty loam	0-2	Till	1-100	129	156
7Ae4	5-15	4-7	Shale	Sandy loam	0-2	Till	1-100	120	153
7Ae5	15-30	4-7	Shale	Sandy loam	0-2	Till	1-100	110	143
7Ae6	5-15	4-7	Shale	Sand	0-2	Till	1-100	126	168
7Ba1	5-15	7-10	Sand & gravel	Sandy loam	6-12	Till	700-1000	156	174
7Ba2	30-50	7-10	Sand & gravel	Sandy loam	6-12	Sand & gravel w/silt & clay	700-1000	146	162
7Ba3	50-75	7-10	Sand & gravel	Sandy loam	6-12	Sand & gravel w/silt & clay	700-1000	136	152
7Ba4	50-75	7-10	Sand & gravel	Sandy loam	6-12	Till	700-1000	126	144
7Ba5	30-50	7-10	Sand & gravel	Clay loam	2-6	Sand & gravel w/silt & clay	700-1000	144	159
7Ba6	15-30	7-10	Sand & gravel	Sandy loam	6-12	Sand & gravel w/silt & clay	700-1000	156	172
7Ba7	5-15	7-10	Sand & gravel	Sandy loam	2-6	Sand & gravel w/silt & clay	700-1000	170	194
7D1	50-75	4-7	Sand & gravel	Clay loam	2-6	Till	300-700	104	123
7D2	30-50	4-7	Sand & gravel	Clay loam	2-6	Till	300-700	114	133
7D3	15-30	4-7	Sand & gravel	Shrink/swell clay	0-2	Till	300-700	133	166
7D4	5-15	4-7	Sand & gravel	Sandy loam	0-2	Sand & gravel w/silt & clay	300-700	151	179
7D5	0-5	7-10	Sand & gravel	Clay loam	0-2	Sand & gravel w/silt & clay	300-700	158	177
7D6	15-30	4-7	Sand & gravel	Sandy loam	0-2	Sand & gravel w/silt & clay	300-700	141	169

Setting	Depth to Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% slope)	Vadose Zone Media	Hydraulic Conductivity	Rating	Pesticide Rating
7D7	15-30	4-7	Sand & gravel	Silty loam	0-2	Sand & gravel w/silt & clay	300-700	140	162
7D8	5-15	4-7	Sand & gravel	Sandy loam	2-6	Sand & gravel w/silt & clay	300-700	153	179
7D9	5-15	4-7	Sand & gravel	Shrink/swell clay	0-2	Silt/clay	300-700	138	172
7D10	5-15	4-7	Sand & gravel	Silty loam	0-2	Silt/clay	300-700	132	157
7D11	5-15	4-7	Sand & gravel	Sandy loam	0-2	Silt/clay	300-700	136	167
7D12	5-15	4-7	Sand & gravel	Sand	0-2	Silt/clay	300-700	142	182
7D13	30-50	4-7	Sand & gravel	Shrink/swell clay	2-6	Silt/clay	300-700	117	149
7D14	5-15	4-7	Sand & gravel	Sandy loam	2-6	Silt/clay	300-700	135	164
7D15	5-15	4-7	Sand & gravel	Clay loam	2-6	Silt/clay	300-700	129	149
7D16	5-15	4-7	Sand & gravel	Shrink/swell clay	2-6	Silt/clay	300-700	137	169
7D17	15-30	4-7	Sand & gravel	Shrink/swell clay	0-2	Silt/clay	300-700	128	162
7D18	15-30	4-7	Sand & gravel	Clay loam	0-2	Silt/clay	300-700	120	142
7D19	15-30	4-7	Sand & gravel	Silty loam	0-2	Silt/clay	300-700	122	147
7D20	15-30	4-7	Sand & gravel	Clay loam	2-6	Silt/clay	300-700	119	139
7D21	15-30	4-7	Sand & gravel	Shrink/swell clay	0-2	Sand & gravel w/silt & clay	300-700	146	177
7D22	30-50	4-7	Sand & gravel	Clay loam	0-2	Sand & gravel w/silt & clay	300-700	128	147
7D23	30-50	4-7	Sand & gravel	Sandy loam	0-2	Sand & gravel w/silt & clay	300-700	134	162
7D24	30-50	4-7	Sand & gravel	Shrink/swell clay	0-2	Sand & gravel w/silt & clay	300-700	136	167
7D25	30-50	4-7	Sand & gravel	Silty loam	0-2	Sand & gravel w/silt & clay	300-700	130	152
7D26	5-15	4-7	Sand & gravel	Silty loam	0-2	Sand & gravel w/silt & clay	300-700	150	172
7D27	5-15	4-7	Sand & gravel	Sandy loam	0-2	Sand & gravel w/silt & clay	300-700	154	182
7D28	15-30	4-7	Sand & gravel	Silty loam	0-2	Sand & gravel w/silt & clay	300-700	140	162

Setting	Depth to Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% slope)	Vadose Zone Media	Hydraulic Conductivity	Rating	Pesticide Rating
7D29	15-30	4-7	Sand & gravel	Clay loam	0-2	Sand & gravel w/silt & clay	300-700	138	157
7D30	15-30	4-7	Sand & gravel	Sandy loam	6-12	Sand & gravel w/silt & clay	300-700	131	150
7D31	50-75	4-7	Sand & gravel	Clay loam	2-6	Sand & gravel w/silt & clay	300-700	109	127
7D32	30-50	4-7	Sand & gravel	Clay loam	2-6	Sand & gravel w/silt & clay	300-700	119	137
7D33	30-50	4-7	Sand & gravel	Sandy loam	2-6	Sand & gravel w/silt & clay	300-700	133	159
7D34	75-100	2-4	Sand & gravel	Sandy loam	0-2	Sand & gravel w/silt & clay	300-700	107	135
7D35	50-75	4-7	Sand & gravel	Sandy loam	0-2	Sand & gravel w/silt & clay	300-700	124	152
7D36	15-30	4-7	Sand & gravel	Sandy loam	0-2	Sand & gravel w/silt & clay	300-700	144	172
7D37	15-30	4-7	Sand & gravel	Sandy loam	2-6	Sand & gravel w/silt & clay	300-700	143	169
7D38	5-15	4-7	Sand & gravel	Sandy loam	6-12	Sand & gravel w/silt & clay	300-700	149	167
7D39	0-5	7-10	Sand & gravel	Silty loam	0-2	Sand & gravel w/silt & clay	300-700	163	185
7D40	0-5	7-10	Sand & gravel	Shrink/swell clay	0-2	Silt/clay	300-700	151	185
7Eb1	5-15	7-10	Sand & gravel	Silty loam	0-2	Sand & gravel w/silt & clay	700-1000	161	183
7Eb2	15-30	4-7	Interbedded sst & sh	Sandy loam	2-6	Sand & gravel w/silt & clay	300-700	140	166
7Eb3	5-15	7-10	Sand & gravel	Sandy loam	0-2	Sand & gravel w/silt & clay	300-700	162	190
7Eb4	5-15	7-10	Sand & gravel	Shrink/swell clay	0-2	Sand & gravel w/silt & clay	300-700	164	195
7Ec1	0-5	7-10	Sandstone	Sandy loam	0-2	Sand & gravel w/silt & clay	300-700	164	192
7Ec2	15-30	4-7	Interbedded sst & sh	Sandy loam	0-2	Sand & gravel w/silt & clay	300-700	141	169

Setting	Depth to Water (feet)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography (% slope)	Vadose Zone Media	Hydraulic Conductivity	Rating	Pesticide Rating
7Ec3	15-30	4-7	Sandstone	Sandy loam	0-2	Till	300-700	134	164
7Ec4	15-30	4-7	Sandstone	Loam	0-2	Till	300-700	132	159
7G1	30-50	4-7	Interbedded sst & sh	Silty loam	12-18	Till	100-300	104	116
7G2	30-50	4-7	Interbedded sst & sh	Loam	6-12	Interbedded sst & sh	100-300	108	127



Ground Water Pollution Potential of Trumbull County

by

Kathy Sprowls

Ohio Department of Natural Resources

Division of Soil and 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

147 ← 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

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 5

Miles

0 2 4 6 8

Kilometers

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July 2010

Cartography by Robert Baker