GROUND WATER POLLUTION POTENTIAL OF HAMILTON COUNTY, OHIO

BY

UNIVERSITY OF CINCINNATI
GROUNDWATER RESEARCH CENTER

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ABSTRACT

A ground water pollution potential mapping program for Ohio has been developed under the direction of the Division of Water, Ohio Department of Natural Resources, 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 mapping in Hamilton County resulted in a map with symbols and colors that illustrate areas of varying ground water contamination vulnerability. Three hydrogeologic settings were identified in Hamilton County with computed ground water pollution potential indexes ranging from 77 to 201.

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 Hamilton 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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Groundwater Research Center

INTRODUCTION

The need for protection and management of ground water resources in Ohio has been clearly recognized. About 42 per cent of Ohio citizens rely on ground water for their drinking and household uses from both municipal and private wells. Industry and agriculture also utilize significant quantities of ground water for processing and irrigation. In Ohio, approximately 700,000 rural households depend on private wells; approximately 1,500 of these wells exist in Hamilton County.

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

Considerable interest in the mapping program followed successful production of a demonstration county map and led to the inclusion of the program as a recommended initiative in the Ohio Ground Water Protection and Management Strategy (Ohio EPA, 1986). Based on this recommendation, the Ohio General Assembly funded the mapping program. A dedicated mapping unit has been established in the Division of Water, Ground 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 partly 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 more or less 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 results of 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 Hamilton 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 to assist 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 more or less suitable for land 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.

A pollution potential map can also 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 also 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.

Other beneficial uses of the pollution potential maps will be recognized by individuals in the county who are familiar with specific land use and management problems. Planning commissions and zoning boards can use these maps to help make informed decisions about the development of areas within their jurisdiction. Developments proposed to occur 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

The system chosen for implementation of a ground water pollution potential mapping program in Ohio, DRASTIC, was developed by the National Water Well Association for the United States Environmental Protection Agency. 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. The vulnerability of an area 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 assuming a contaminant with the mobility of water, introduced at the surface, and flushed into the ground water by precipitation. Most important, DRASTIC cannot be applied to areas smaller than one hundred 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 fifteen 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 Hamilton 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

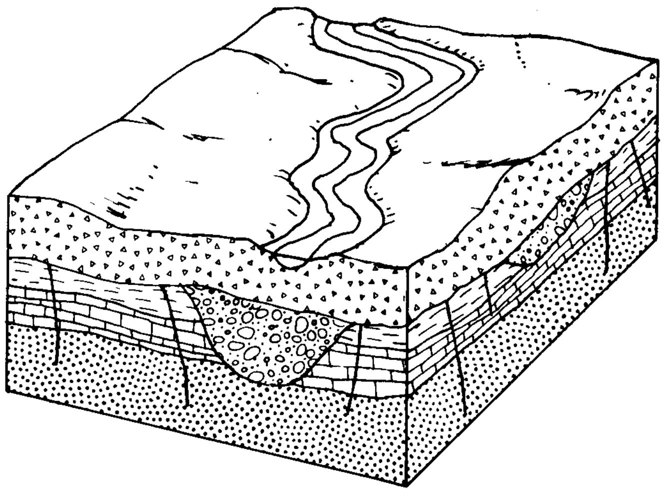
C - Conductivity (Hydraulic) of the Aquifer

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.

<u>Depth to water</u> 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.

<u>Net recharge</u> is the total amount of water reaching the land surface that infiltrates into the aquifer measured in inches per year. Recharge water is available to transport a contaminant from the surface into the aquifer and also 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.

<u>Aquifer media</u> 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 hydrogeologic setting is characterized by thick layers of sand and gravel that have been deposited in a former topographic low (usually a pre-glacial river valley) by glacial meltwaters. These deposits are capable of yielding large quantities of ground water. The deposits may or may not underlie a present day river and may or may not be in direct hydraulic connection with a stream. Glacial till or recent alluvium often overlies the buried valley. Usually the deposits are several times more permeable than the surrounding bedrock, with finer-grained alluvium covering the underlying sand and gravel. Recharge to the sand and gravel is moderate to high and water levels are commonly relatively shallow although in some areas they may be quite variable.

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 can influence 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 through 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 amount of slope in an area affects the likelihood that a contaminant will run off from an area 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 significantly impacts the pollution potential of the ground water in an area.

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

Weighting and Rating System

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

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

Pesticide DRASTIC

A special version of DRASTIC was developed to be used 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. 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 significantly differs.

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
Massive Shale	1-3	2
Metamorphic / Igneous	2-5	3
Weathered Metamorphic / Igneous	3-5	4
Glacial Till	4-6	5
Bedded Sandstone, Limestone and Shale Sequences	5-9	6
Massive Sandstone	4-9	6
Massive Limestone	4-9	6
Sand and Gravel	4-9	8
Basalt	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
Shrinking and / or Aggregated Clay	7
Sandy Loam	6
Loam	5
Silty Loam	4
Clay Loam	3
Muck	2
Nonshrinking and Nonaggregated 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
Bedded Limestone, Sandstone, Shale	4-8	6
Sand and Gravel with significant Silt and Clay	4-8	6
Metamorphic/Igneous	2-8	4
Sand and Gravel	6-9	8
Basalt	2-10	9
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 7G1 Thin Till Over Bedded Sedimentary Rock, identified in mapping Hamilton 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 86. 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 Hamilton County produces settings with a wide range of vulnerability to ground water contamination. Calculated pollution potential indexes for the three settings identified in the county range from 77 to 201.

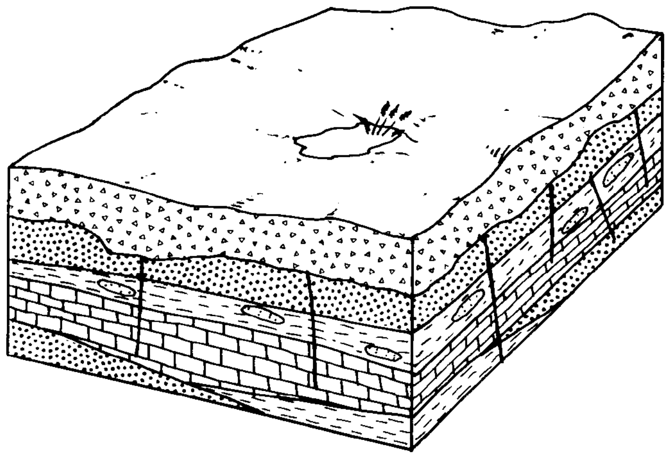
Hydrogeologic settings identified in an area are combined with the pollution potential indexes to create units that can be graphically displayed on maps. Pollution potential mapping in Hamilton County resulted in a map with symbols and colors that illustrate areas of ground water vulnerability. The map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

INTERPRETATION AND USE OF A GROUND WATER POLLUTION POTENTIAL MAP

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

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

7Af6 - defines the hydrogeologic region and setting
118 - defines the relative pollution potential



SETTING 7G1		GENERAL		
FEATURE	RANGE	WEIGHT	RATING	NUMBER
Depth to Water	30-50	5	5	25
Net Recharge	4-7	4	3	12
Aquifer Media	Bedded Ls & Sh	3	3	9
Soil Media	Shrink/swell clay	2	7	14
Topography	12-18%	1	3	3
Impact Vadose Zone	Ls, Sh & Cl	5	4	20
Hydraulic Conductivity	1-100	3	1	3
		GWPP	INDEX	86

Figure 2. Description of the hydrogeologic setting 7G1 Thin Till Over Bedded Sedimentary Rocks.

Here the first number refers to the major hydrogeologic region and the upper and lower case letters refer to a specific hydrogeologic setting. The following number references a certain set of DRASTIC parameters that are unique to this setting and are described in the corresponding setting chart. The second number (118) 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 in an area.

The maps are color-coded using ranges depicted on the map legend. The color codes used are part of a national color coding scheme developed to assist the user in gaining a general insight into the vulnerability of the ground water in the area. The color codes were chosen to represent the colors of the spectrum, with warm colors (red, orange and yellow), representing areas of higher vulnerability (higher pollution potential indexes), and cool colors (greens, blues, and violet), representing areas of lower vulnerability to contamination.

The map also includes information on the locations of selected observation wells. Available information on these observation wells is referenced in Appendix A, Description of the Logic in Factor Selection. Large man-made features such as landfills, quarries or strip mines have also been marked on the map for reference.

GENERAL INFORMATION ABOUT HAMILTON COUNTY

Physiography

Hamilton County lies within the Till Plains section of the Central Lowland physiographic province. The county is characterized by rolling uplands dissected by broad valleys. The uplands are composed of Late Ordovician shale and limestone bedrock and are covered by thin till deposits. The valleys are filled with thick deposits of glacial and fluvial origin. The area was once a gently rolling plain known as the Lexington Peneplain before the glacial and fluvial systems carved the valleys in the bedrock and subsequently deposited the materials that now fill the valleys (Feneman, 1938). .

All of Hamilton County lies within the Ohio River drainage basin. Principal tributaries to the Ohio River that flow through the county include the Whitewater River, Mill Creek, the Great Miami River and the Little Miami River.

The South West Region of the state, which includes all of Hamilton County, had a fifty-year (1931- 1980) average annual precipitation of 40.27 inches. The average temperature for the same period was 53.4 degrees Fahrenheit (U.S. Department of Commerce, 1982). The Cincinnati Abbe U.S. Weather Bureau Station recorded a 30-year (1951-1980) average precipitation of 40.10 inches per year; and an average annual temperature of 54.5 degrees Fahrenheit for the same period (U.S. Department of Commerce, 1981).

Bedrock Geology

The bedrock in Hamilton County consists of interbedded limestones and shales of Late Ordovician age. These rocks were deposited as sediments at the bottom of shallow seas, and are known worldwide for their abundance of well-preserved fossils. The bedrock units within Hamilton County are essentially flat and are used as the reference section for the Late Ordovician of North America (Figure 2).

Figure 3. Location of Hamilton County, Ohio.

Table 9. Generalized Bedrock Stratigraphy of Hamilton County, Ohio (modified from Swinford, in progress)

SYSTEM	FORMATION and MEMBER		ROCK TYPE
ORDOVICIAN	Waynesville Formation		Interbedded shale and limestone (shale 65% or more of unit)
	Arnhelm Formation		Interbedded limestone and shale
	Grant Lake Limestone	Mt . Auburn Member	Limestone and shale (shale 60% or more of unit)
		Coryville Member	Interbedded limestone and shale (shale 60% or more of unit)
		Bellevue Member	Limestone
	Miamitown Shale		Interbedded shale and limestone (shale 75% or more of unit)
	Fairview Formation		Interbedded shale and limestone (shale 60% or more of unit)
	Kope Formation		Interbedded shale and limestone (shale 75% or more of unit)

Glacial Geology

The uplands of Hamilton County are dissected by valley systems formed by glacial and fluvial processes. The four largest valley systems are the Whitewater, Great Miami, Mill Creek, and Little Miami. The streams presently in these valleys are referred to as underfit because they are too small to have cut the valley in which they lie. The glacial history of these valleys dates back at least to the Pleistocene epoch, which began approximately 2,000,000 years before present. During the Pleistocene, there were at least three major glacial events in this part of the state including the Pre-Illinoian (Kansan), Illinoian, and Wisconsinan glacial periods.

Prior to the advent of Pleistocene glaciation, the dominant river system in Ohio was the Teays River. The headwaters of the Teays originated in the Piedmont region of Virginia and North Carolina and followed a northwesterly course across what is now the east central portion of the United States. The Teays entered Ohio just east of Portsmouth in Scioto County and continued in a northwesterly course across Ohio, exiting the state just west of Celina in Mercer County (Stout, et al., 1943).

During the millions of years of its existence, the Teays River and its tributaries, cut deep valleys into the bedrock over which it flowed. Subsurface data indicates that the Teays valley has cut over 400 feet into the bedrock in some areas in Ohio (Cummins, 1959); however, in Hamilton County, the Teays-age tributaries cut valleys no more than 150 feet deep (Brockman, 1989).

Although the Teays River itself did not flow through Hamilton county, several tributaries to the Teays did. One of the main tributaries flowed to the northwest from the area of the present day Little Miami valley through the Norwood area and up the Mill Creek valley. Another tributary flowed northward in the current Great Miami River valley (Klaer and Thomeson, 1948).

Flow in the Teays River came to a halt with the beginning of Pleistocene glaciation. Glacial ice, possibly of Kansan age, dammed the river, causing water to stagnate and pond within the valleys cut by the river and its tributaries. Large quantities of silt and clay were washed into the glacial lake and filled a large portion of many of the valleys.

After a period of time, water dammed within the Teays overflowed the valley walls and initiated a new drainage network. This network is commonly called the Deep Stage system because streams at this time eroded extremely deep channels into the bedrock. During Deep Stage time the tributary channels the former Teays River in Hamilton County that had not been buried by glacial material were widened and deepened.

During subsequent periods of glaciation, Hamilton County was completely covered by ice. When the glaciers retreated northward, the major streams derived from the melting ice deposited large quantities of sand and gravel within the bedrock valleys eroded by the Teays tributaries and modified during Deep Stage time. Many of these deposits are now below the present day water table and serve as aquifers for dozens of high capacity industrial and municipal wells.

The uplands areas of Hamilton County are covered by a mantle of glacial till, deposited during the pre-Illinoian (Kansan), Illinoian and Wisconsinan glacial periods, that is typically 50 feet or less in thickness (Brockman, 1988). Pre-Illinoian (Kansan) till covers the southern and central portions of Hamilton County and represent some of the oldest known glacial deposits in the state. Till of Illinoian age overlies the central and southeastern portions of the county. This till is typically capped by a layer of wind blown silt (loess) and may be discontinuous or absent in some areas. Wisconsinan tills occur in the extreme northern part of the county and include both ground moraine deposits and portions of the Hartwell end moraine (Goldthwait, et al., 1961).

Hydrogeology

The primary aquifers within Hamilton County occur in the major buried valleys that contain varying deposits of sand and gravel, silts and clays. These aquifers are composed of sands and gravels deposited by glacial meltwaters during the Pleistocene Epoch. Well fields supplying significant quantities of ground water to both municipalities and industries have been developed in Hamilton County in the buried valley systems. The buried valleys beneath the Great Miami River, the Ohio River, and some areas of the Whitewater River contain coarse deposits of sand and gravel that are capable of producing yields of up to 1,000 gallons per minute (Walker, 1986). The characteristics of the buried valley aquifers in this area have been described in Dames and Moore (1971); Klaer and Thomeson (1948); Lewis, (1968); Spieker and Durrell (1961); and Spieker (1968).

Other buried valleys within the county are also capable of supplying significant quantities of ground water. Well-sorted sand and gravel deposits in both the Little Miami and Mill Creek valleys produce up to 500 gallons per minute from properly developed wells. Lesser yields of 10 to 100 gallons per minute may be obtained near the edges of these buried valleys from sand and gravel lenses interbedded with silts and clays. These deposits are typically less permeable and limited in areal extent and thickness. In some tributaries and abandoned channels of the preglacial and interglacial drainage system, sand and gravel lenses interbedded within clay deposits yield from 3 to 10 gallons per minute to domestic wells.

Outside of the buried valley areas, limited ground water supplies are available from the Ordovician limestone-shale sequence. The bedrock consists of interbedded plastic shales and limestones that are only capable of supplying up to 3 gallons per minute (Walker, 1986). Wells in these formations may experience seasonal losses of water and dry wells are not uncommon. Where ground water is present in the bedrock, it usually occurs in the upper few feet of weathered material or in fractures and bedding planes within the bedrock. The overlying glacial till is usually less than 50 feet thick and generally consists of silts and clays. Occasional sand and gravel lenses in the till can occur locally and may provide limited yields to domestic wells (Walker, 1986).

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APPENDIX A

DESCRIPTION OF THE LOGIC IN FACTOR SELECTION

Depth to Water

The primary source of data used to determine the depth to water was approximately 1450 well logs on file with the Ohio Department of Natural Resources, Division of Water. The majority of the logs were located in the buried valleys, with fewer logs located in the uplands areas. In areas with little or no depth to water data, interpretation of surficial geology and topography were used to determine a depth to water rating.

Site specific depth to water information was also obtained from Spieker (1968), Razem (1988), Klaer and Thompson (1948), Lewis (1968), and OKI (1988). In areas with little or no depth to water data, interpretation of surficial geology and topography were used to determine a depth to water rating.

In the hydrogeologic setting, 7D Buried Valley, depth to water generally ranged from 5-15 feet (9) to 30-50 feet (5). Depth to water in the buried valleys varied with distance from the river, and topography. Buried Valley setting 7D21 was evaluated as a confined aquifer due to the presence of thick clays overlying water-bearing sands and gravels in the Norwood Trough. The depth to water in this setting was assigned a value of 100+ feet (1), the distance to the top of the aquifer.

Depth to water in the setting, 7G Thin Till Over Bedded Sedimentary Rocks, varied from 5-15 (9) to 30-50 feet (5) and was reflective of fluctuations in the thickness of the overlying glacial till and variations in topography. Depth to water ranged from 15-30 feet (7) to 30-50 feet (5) in setting 7Ea, River Alluvium with Overbank Deposits. As with the Buried Valley setting, depth to water in this setting varied with distance from the river, and topography.

Net Recharge

Very few quantitative studies of aquifer recharge have been conducted in southwestern Ohio. Calculated recharge values for the buried valley deposits in Hamilton and other surrounding counties are listed in Table 10. Recharge values for the buried valley aquifers were selected based on this information, the proximity to the river, professional judgment and evaluation of other hydrogeologic factors especially soil type and topography. Values for recharge to the buried valley aquifer ranged from 4-7 inches (6) to 10+ inches (9), except in setting 7D21 where recharge was restricted to 0-2 inches (1) due to the presence of a confining layer.

Table 10. Locations and Values For Net Recharge For the Valley Train Deposits In Southwestern Ohio

Location	**Net Recharge (inches/year)**	**Reference**
Big Bend Well Field (SWOWC) adjacent to Great Miami River, near Ross	12	Lewis, 1968
Area adjacent to Mad River near Fairborn, Greene Co	12	Walton and Scuddy, 1960
Area adjacent to Great Miami River near Troy, Miami Co	12	Plummer, 1971

No published values for recharge to the limestone and shale bedrock aquifer are available. Based on professional judgment and evaluation of other hydrogeologic factors, a representative value of 2 to 4 inches per year (3) was selected for this aquifer.

Aquifer Media

Information for this parameter was taken from the water well logs on file with the Ohio Department of Natural Resources, Division of Water, unpublished Masters theses, personal communications, and from Dames and Moore (1971); Klaer and Thomeson (1948); Lewis (1968); Norris and Spieker (1966); Plummer (1971); Razem (1988); Spieker and Durrell (1961); Spieker (1968); Walker (1986); Walton and Scudder (1960); and Watkins (1971).

Within the buried valleys and along the Ohio River, the aquifers consist of thick glacial and fluvial sand and gravel units with interbedded layers of clay, and till of varying lateral extent. These deposits were assigned aquifer media ratings of 8 or 9 based on the relatively coarse nature of the aquifers and the generally low silt/clay content within the sand and gravel units.

The limestone and shale bedrock is the predominant aquifer underlying the upland areas in Hamilton County. Aquifer media ratings of 2 or 3 were assigned to these units because of their very low permeability and high clay content in both units.

Soil Media

The Hamilton County Soil Survey (Lerch, et al., 1982) was used to evaluate the soil media. The survey contains mapped aerial photographs and extensive descriptions of the soil units and profiles. The most significant soil horizon in the soil profile was chosen for the soil media parameter.

Soils overlying the hydrogeologic setting 7D Buried Valley were highly variable and ranged from clay loam (3), to sand (9). In the hydrogeologic setting 7Ea River Alluvium with Overbank Deposits, three of the four settings, 7Eal through 7Ea3, had silt loam soils (4); while the fourth setting, 7Ea4, had loam soils (5).

Three soil types, clay loam (3), silt loam (4), and shrink/swell clay (7), cover most of the hydrogeologic setting 7G Thin Till Over Bedded Sedimentary Rocks. Only a few small areas within this setting have loam (5) soils.

The clay loam, silt loam and loam soil ratings are found predominantly in areas where the soil profile is relatively thick. In areas where the soils are relatively thin and have at least a moderate shrink/swell potential, or any area with a soil with a high shrink/swell potential, a shrink/swell clay rating was assigned.

Topography

Percent slope was determined using 7 1/2 minute United States Geological Survey topographic quadrangle maps. Topography and slope within Hamilton County are highly variable; ranging from 0-2 percent (10) within large portions of stream flood plains and on ridge top plateaus, to well over 18 percent (1) along steep hillsides.

Impact of the Vadose Zone Media

The rating selected for the vadose zone media in the hydrogeologic setting 7G Thin Till Over Bedded Sedimentary Rock, varied based on an evaluation of the depth to water, the thickness of the glacial till and the composition of the vadose zone materials. Vadose zone parameter values ranged from clay, shale and limestone (3 or 4), silt and clay (4), to shale and limestone (4).

Impact of the vadose zone for the buried valley setting (7D) was evaluated as either sand and gravel with a rating of 8 or 9, sand and gravel with significant silt and clay with a rating of 4 to 7, or confining layer with a rating of 1. The distinction between sand and gravel, and sand and gravel with silt and clay was based on well log data, sieve analyses, and published and unpublished reports on the buried valley aquifer (Lewis, 1968; Plummer, 1971; Razem, 1988; Spieker and Durrell, 1961; Spieker, 1968; Walton and Scudder, 1960; Watkins, 1971). Vadose zone media for the river alluvium with overbank deposits were assigned ratings of 8 or 9, sand and gravel.

Hydraulic Conductivity

Published values for hydraulic conductivity are available for the sand and gravel aquifers contained within the buried valleys. Hydraulic conductivities for the buried valley aquifers range from 1000-2000 gpd/ft^2 (8) to 2000+ gpd/ft^2 (9) (Lewis, 1968; Spieker, 1968; Walton and Scuddy, 1960). Published values for hydraulic conductivity of the buried valley aquifer within the Norwood trough are not available, however, based on other geologic and hydrogeologic factors, a value of 1000-2000 gpd/ft^2 (8) was felt to be representative for this aquifer.

Information contained within several publications (Spieker and Durrell, 1961; OKI, 1988) and ground water yield data taken from water well logs was used to evaluate the hydraulic conductivity of the limestone and shale bedrock aquifer. Hydraulic conductivities were estimated at 1-100 gpd/ft^2 (1) due to the characteristics of the formations. Spieker and Durrell (1961) note that "water occurs along bedding planes and fractures but its distribution is highly erratic and difficult to predict"..."barely enough for farm or domestic use".

APPENDIX B

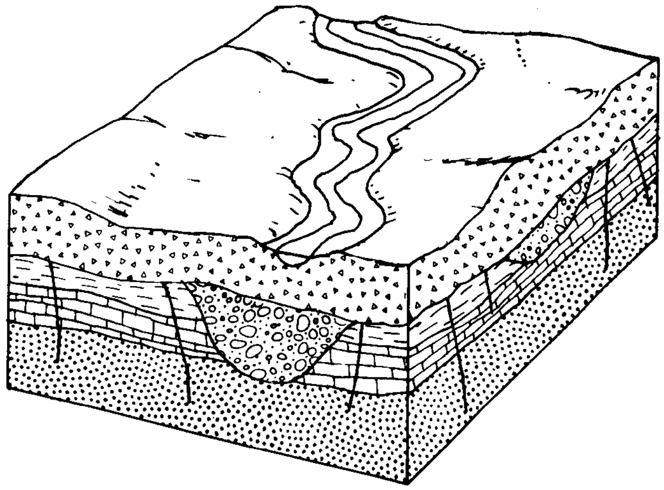
DESCRIPTION OF HYDROGEOLOGIC SETTINGS AND CHARTS

In the pollution potential mapping of Hamilton County, three hydrogeologic settings, all within the Glaciated Central Region, were identified. The list of these settings, the range of pollution potential index calculations and the number of pollution potential index calculations for each setting are provided in Table 11. Computed pollution potential index values range from 77 to 201.

Table 11. Hydrogeologic Settings Mapped in Hamilton County, Ohio

Hydrogeologic Settings	Range of GWPP Indexes	Number of Index Calculations
7D Buried Valley	77-201	25
7Ee River Alluvium with Overbank Deposits	181-191	4
7G Thin Till Over Bedded Sedimentary Rock	80-104	25

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 setting is provided in Appendix A, Description of the Logic in Factor Selection.

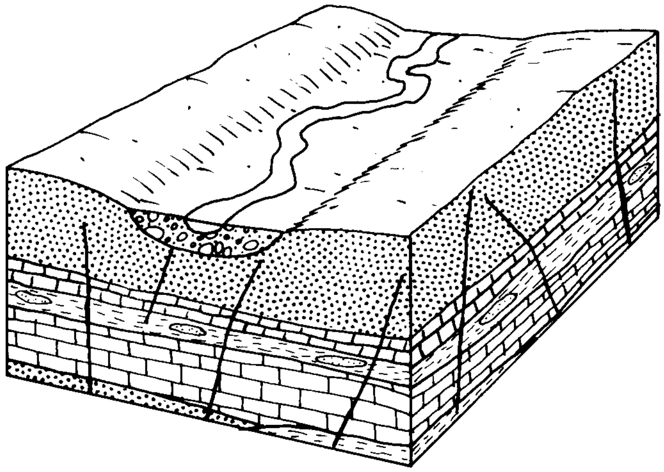


7D Buried Valley

This hydrogeologic setting is characterized by thick layers of sand and gravel that have been deposited in a former topographic low (usually a pre-glacial river valley) by glacial meltwaters. These deposits are capable of yielding large quantities of ground water. The deposits may or may not underlie a present day river and may or may not be in direct hydraulic connection with a stream. Glacial till or recent alluvium often overlies the buried valley. Usually the deposits are several times more permeable than the surrounding bedrock, with finer-grained alluvium covering the underlying sand and gravel. Recharge to the sand and gravel is moderate to high and water levels are commonly relatively shallow although in some areas they may be quite variable.

7D Buried Valley Settings Table.

Setting	Depth to Water (feet)	Recharge (in./yr.)	Aquifer Media	Soil Media	Topography (% Slope)	Vadose Zone Media	Hydro. Cond. (gpd/ft^2)	Rating	Pesticide Rating
7D01	30-50	7-10	sand & gravel	Sandy Loam	0-2	sand and gravel	1000-2000	167	189
7D02	30-50	7-10	sand & gravel	Loam	0-2	sand and gravel	2000+	179	195
7D03	30-50	7-10	sand & gravel	Loam	0-2	s & g w/ sl & cl	1000-2000	160	180
7D04	30-50	4-7	sand & gravel	Silty Loam	0-2	s & g w/ sl & cl	1000-2000	150	167
7D05	30-50	7-10	sand & gravel	Silty Loam	0-2	sand and gravel	2000+	177	190
7D06	30-50	10+	sand & gravel	Loam	0-2	sand and gravel	2000+	183	199
7D07	15-30	10+	sand & gravel	Loam	0-2	sand and gravel	2000+	193	209
7D08	15-30	10+	sand & gravel	Silty Loam	0-2	sand and gravel	2000+	191	204
7D09	15-30	7-10	sand & gravel	Clay Loam	0-2	s & g w/ sl & cl	1000-2000	161	176
7D10	15-30	10+	sand & gravel	Loam	0-2	sand and gravel	2000+	188	205
7D11	15-30	10+	sand & gravel	Sandy Loam	0-2	sand and gravel	2000+	195	214
7D12	15-30	7-10	sand & gravel	Loam	0-2	sand and gravel	2000+	181	198
7D13	30-50	7-10	sand & gravel	Silty Loam	0-2	s & g w/ sl & cl	1000-2000	143	163
7D14	30-50	7-10	sand & gravel	Clay Loam	0-2	s & g w/ sl & cl	1000-2000	151	166
7D15	5-15	7-10	sand & gravel	Silty Loam	0-2	s & g w/ sl & cl	1000-2000	173	191
7D16	5-15	7-10	Sand & gravel	Silty Loam	0-2	s & g w/ sl & cl	2000+	192	206
7D17	15-30	7-10	sand & gravel	Silty Loam	0-2	sand and gravel	2000+	182	196
7D18	15-30	7-10	sand & gravel	Loam	0-2	sand and gravel	700-1000	184	193
7D19	15-30	10+	sand & gravel	Sand	0-2	sand and gravel	2000+	201	229
7D20	5-15	10+	sand & gravel	Silty Loam	0-2	sand and gravel	2000+	196	210
7D21	100+	0-2	sand & gravel	Clay Loam	2-6	confined	1000-2000	77	95
7D22	5-15	4-7	sand & gravel	Clay Loam	0-2	s & g w/ sl & cl	1000-2000	158	174
7D23	15-30	4-7	sand & gravel	Loam	0-2	s & g w/ sl & cl	1000-2000	157	178
7D24	30-50	7-10	sand & gravel	Sandy Loam	0-2	sand and gravel	1000-2000	162	185
7D25	15-30	7-10	sand & gravel	Loam	0-2	s & g w/ sl & cl	1000-2000	170	190

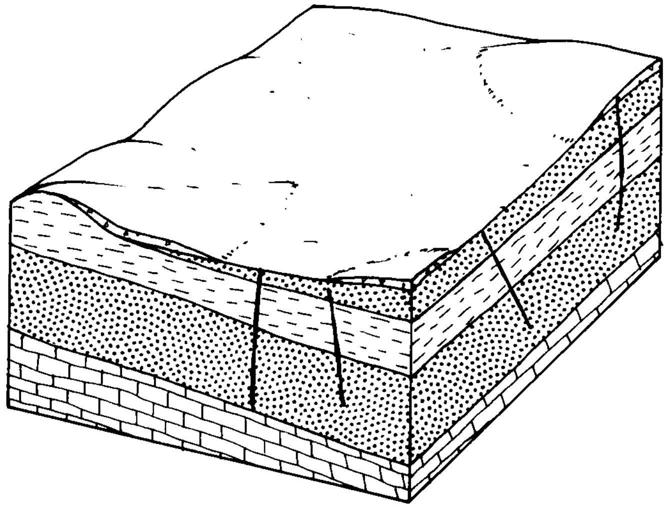


7Ea River Alluvium with Overbank Deposits

This hydrogeologic setting is characterized by low topography and thin to moderately thick layers of flood-deposited alluvium along portions of the river valley. The alluvium is underlain by fractured bedrock of sedimentary origin. Water is obtained from sand and gravel layers which are interbedded with finer grained alluvial deposits. The floodplain is covered by overbank deposits of varying thicknesses of fine-grained silt and clay. Water levels are moderately shallow. Ground water is usually in direct hydraulic contact with the surface stream. The alluvium serves as a significant source of water and may also be in direct hydraulic connection with the underlying sedimentary rocks.

7Ea River Alluvium with Overbank Deposits Settings Table

Setting	Depth to Water (feet)	Recharge (in./yr.)	Aquifer Media	Soil Media	Topography (% Slope)	Vadose Zone Media	Hydro. Cond. (gpd/ft^2)	Rating	Pesticide Rating
7Ea1	15-30	10+	sand & gravel	Silty Loam	0-2	sand and gravel	2000+	191	204
7Ea2	15-30	7-10	sand & gravel	Silty Loam	0-2	sand and gravel	2000+	182	196
7Ea3	30-50	10+	sand & gravel	Silty Loam	0-2	sand and gravel	2000+	181	194
7Ea4	15-30	7-10	sand & gravel	Loam	0-2	sand and gravel	2000+	184	201



7G Thin Till Over Bedded Sedimentary Rock

This hydrogeologic setting is characterized by moderate to low topography and deposits of thin glacial till overlying alternating layers of fractured, consolidated sedimentary rocks. The till is primarily unsorted deposits of clay, sand and gravel. Although ground water occurs in both the till and in the intersecting fractures of the bedrock, the bedrock is the principal aquifer. The glacial till serves as the source of recharge to the underlying bedrock. Although precipitation is abundant in most of the region, recharge is moderate because of the glacial tills and clayey soils. Water levels are extremely variable, but usually moderate.

7G Thin Till Over Bedded Sedimentary Rock Settings Table.

Setting	Depth to Water (feet)	Recharge (in./yr.)	Aquifer Media	Soil Media	Topography (% Slope)	Vadose Zone Media	Hydro. Cond. (gpd/ft^2)	Rating	Pesticide Rating
7G01	30-50	2-4	interbedded ls & sh	Shrink-swell (aggregated) clay	12-18	shale & clay	1-100	86	108
7G02	30-50	2-4	interbedded ls & sh	Shrink-swell (aggregated) clay	6-12	shale & clay	1-100	88	114
7G03	15-30	2-4	interbedded ls & sh	Shrink-swell (aggregated) clay	18+	shale & clay	1-100	94	112
7G04	30-50	2-4	interbedded ls & sh	Silty Loam	6-12	shale & clay	1-100	82	99
7G05	15-30	2-4	interbedded ls & sh	Shrink-swell (aggregated) clay	12-18	shale & clay	1-100	96	118
7G06	15-30	2-4	interbedded ls & sh	Shrink-swell (aggregated) clay	6-12	shale & clay	1-100	98	124
7G07	15-30	2-4	interbedded ls & sh	Clay Loam	6-12	shale & clay	1-100	90	104
7G08	5-15	2-4	interbedded ls & sh	Shrink-swell (aggregated) clay	18+	shale & clay	1-100	104	122
7G09	30-50	2-4	interbedded ls & sh	Shrink-swell (aggregated) clay	18+	shale & clay	1-100	84	102
7G10	15-30	2-4	interbedded ls & sh	Silty Loam	6-12	shale & clay	1-100	92	109
7G11	15-30	2-4	interbedded ls & sh	Clay Loam	0-2	shale & clay	1-100	95	119
7G12	15-30	2-4	interbedded ls & sh	Shrink-swell (aggregated) clay	18+	shale & clay	1-100	86	105
7G13	15-30	2-4	interbedded ls & sh	Shrink-swell (aggregated) clay	6-12	shale & clay	1-100	90	117
7G14	15-30	2-4	interbedded ls & sh	Clay Loam	2-6	shale & clay	1-100	94	116
7G15	30-50	2-4	Interbedded ls & sh	Silty loam	12-18	Shale & clay	1-100	80	87
7G16	15-30	2-4	interbedded ls & sh	Clay Loam	0-2	silt/clay	1-100	95	119
7G17	15-30	2-4	interbedded ls & sh	Silty Loam	2-6	silt/clay	1-100	96	121
7G18	30-50	2-4	Interbedded ls & sh	Loam	6-12	Silt/clay	1-100	90	100
7G19	15-30	2-4	interbedded ls & sh	Silty Loam	0-2	silt/clay	1-100	97	124
7G20	15-30	2-4	interbedded ls & sh	Clay Loam	2-6	silt/clay	1-100	94	116
7G21	15-30	2-4	interbedded ls & sh	Clay Loam	12-18	shale & clay	1-100	88	98
7G22	15-30	2-4	interbedded	Clay Loam	6-12	silt/clay	1-100	90	104

			ls & sh						
7G23	15-30	2-4	interbedded ls & sh	Shrink-swell (aggregated) clay	6-12	silt/clay	1-100	98	124
7G24	15-30	2-4	interbedded ls & sh	Clay Loam	6-12	shale & clay	1-100	82	89
7G25	15-30	2-4	Interbedded ls & sh	Silty Loam	0-2	Shale & clay	1-100	89	107

Ground-Water Pollution Potential of Hamilton County

by
University of Cincinnati
Groundwater Research Center

Prepared in Cooperation with
Ohio Department of Natural Resources Division of Water

Miles: 1 0 1 2

Kilometers: 1 0 1 2

CONTOUR INTERVAL 10 FEET

County Line

Township Line

Cincinnati City Limit

Pollution Potential Index Range

Higher	200+
	180 - 199
	160 - 179
to	140 - 159
	100 - 119
	80 - 99
Lower	<79

Description of Map Symbols

Hydrogeologic Region → 7Ad 6 ← Hydrogeologic Setting

98 ← Relative Pollution Potential

Landfill

Gravel Pit / Quarry

Confined Aquifer

Observation Well Site **

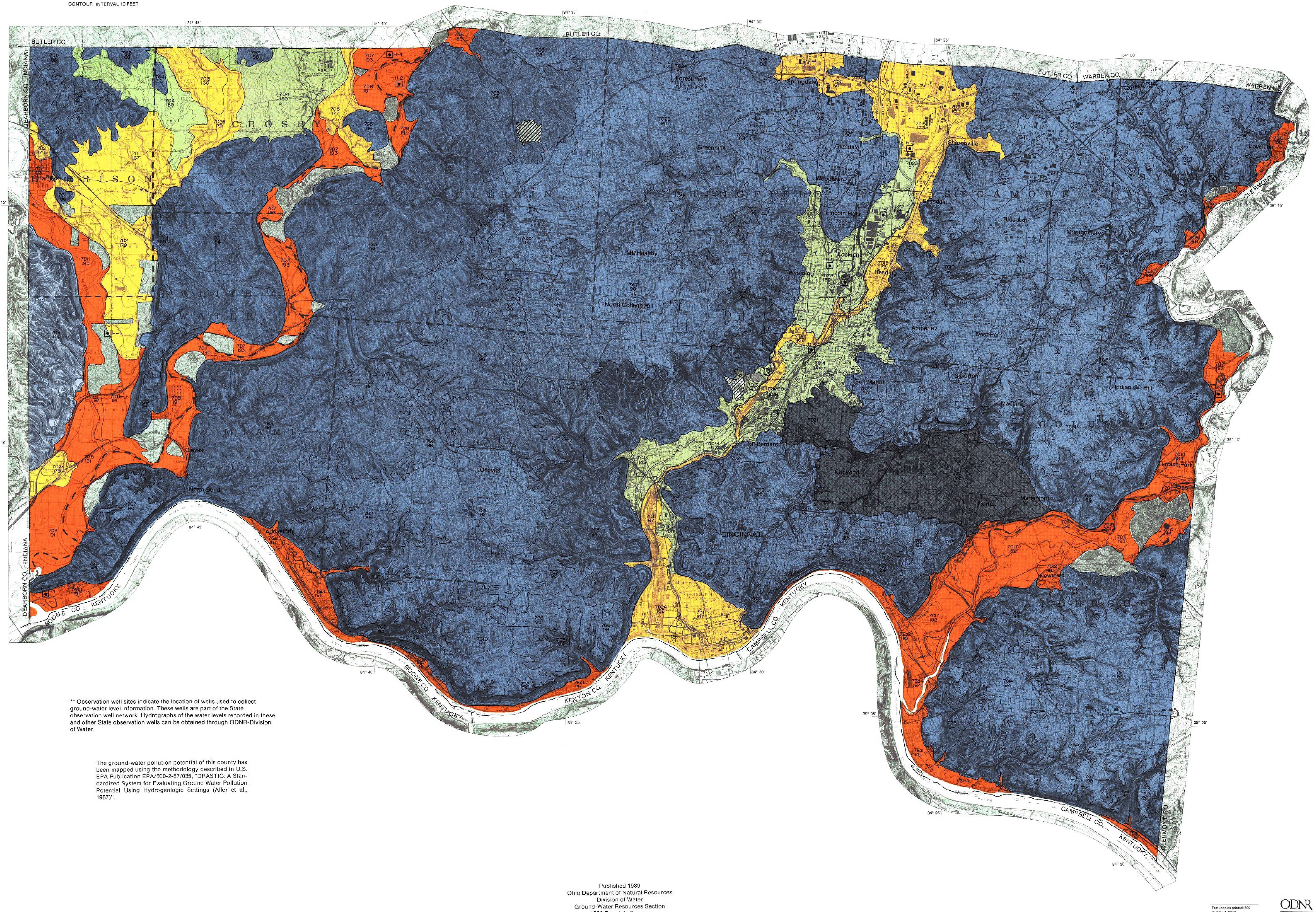
Hydrogeologic Settings

7D - Buried Valley

7Ea - River Alluvium with Overbank Deposits

7G - Thin Till Over Bedded Sedimentary Rocks

A more detailed description of the hydrogeologic settings and the evaluation of the pollution potential may be found in the publication "Ground-Water Pollution Potential of Hamilton County Ohio", GWPP Report No. 7 Ohio Dept. of Natural Resources, Division of Water.



** Observation well sites indicate the location of wells used to collect ground-water level information. These wells are part of the State observation well network. Hydrographs of the water levels recorded in these and other State observation wells can be obtained through ODNR-Division of Water.

The ground-water pollution potential of this county has been mapped using the methodology described in U.S. EPA Publication EPA/600-2-87/035, "DRASTIC: A Standardized System for Evaluating Ground Water Pollution Potential Using Hydrogeologic Settings (Aller et al., 1987)".

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Naturally OHIO the heart of it all!

ERRATA SHEET HAMILTON COUNTY
Ground Water Pollution Potential No. 7

Changes on Map and Tables

Hydrogeologic setting 7D18 GWPP Index should change from 184 to 172.