# GROUND WATER POLLUTION POTENTIAL OF ERIE COUNTY, OHIO

**BY**

**KELLY C. SMITH**
**ERM-MIDWEST, INC**

**GROUND WATER POLLUTION POTENTIAL REPORT NO. 16**

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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.

Erie County lies within the central lowlands physiographic province and consists of two physiographic sections: the Eastern Lake Plains section and the Till Plains section (Fenneman, 1938). The county is covered by a variable thickness of glacial till, lacustrine deposits, and outwash. These unconsolidated glacial deposits are underlain by Bedford shale, Berea sandstone, and limestone. Ground water yields are dependant on the type of aquifer and vary greatly throughout the county. Pollution potential indexes are relatively low to moderate in areas of till or lacustrine cover over bedrock. Buried valleys containing sand and gravel aquifers and areas covered by outwash have moderate to high vulnerabilities.

Ground water pollution potential analysis in Erie County resulted in a map with symbols and colors which illustrate areas of varying ground water contamination vulnerability. Eleven hydrogeologic settings were identified in Erie County with computed ground water pollution potential indexes ranging from 79 to 211.

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 Erie County has been prepared to assist planners, managers, and local officials in evaluating the potential for contamination from various sources of pollution. This information can be used to help direct resources and land use activities to appropriate areas, or to assist in protection, monitoring, and clean-up efforts.

## TABLE OF CONTENTS

# LIST OF FIGURES

Number Page

## LIST OF TABLES

Number Page

# INTRODUCTION

The need for protection and management of ground water resources in Ohio has been clearly recognized. Approximately 42 per cent of Ohio citizens rely on ground water as a source for their drinking water and household use from both municipal and private wells. Industry and agriculture also utilize significant quantities of ground water for processing and crop irrigation. In Ohio, approximately 700,000 rural households depend on private wells; 2,600 of these wells exist in Erie 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 does. Based on these concerns for protection of the resource, 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.

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 ODNR, Division of Water, Ground Water Resources Section to implement the ground water pollution potential mapping program on a county-wide basis in Ohio.

ERM-Midwest, Inc. was selected by the Division of Water to assist in the timely production of these maps. Under the direct supervision of the Division of Water, ERM-Midwest, Inc. completed the pollution potential map for Erie County. All work has been extensively reviewed and field checked by both ERM-Midwest, Inc. and the Division of Water.

The purpose of this report and map is to aid in the protection of our ground water resources in Erie County. 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 groundwater 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 Erie 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.

Pollution potential maps may also 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 result 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 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 which 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 Erie County. Inherent within each hydrogeologic setting are the physical characteristics which 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

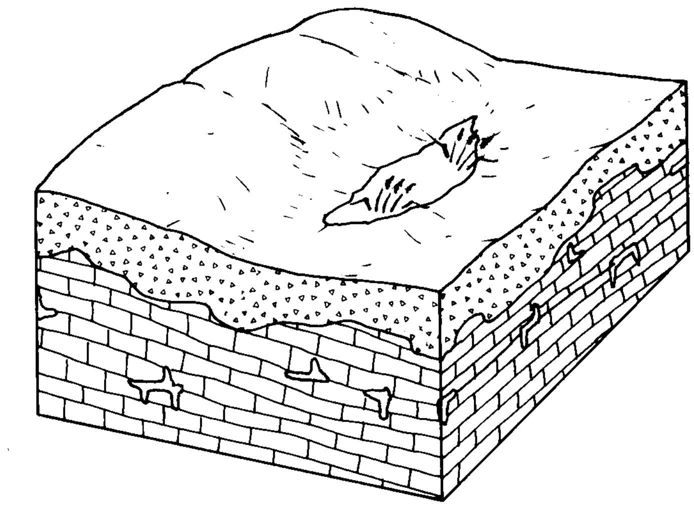
**C** - Conductivity (Hydraulic) of the Aquifer

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 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.

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.



7Ac Glacial Till Over Solution Limestone

This hydrogeologic setting is characterized by low topography and solution limestone which is covered by varying thicknesses of glacial till. The till is principally unsorted deposits which may be interbedded with loess or localized deposits of sand and gravel. Surficial deposits have usually weathered to a clay loam. Although ground water occurs in both the glacial deposits and in the underlying limestone, the limestone, which typically contains solution cavities, generally serves as the principal aquifer. The limestone is in direct hydraulic connection with the glacial till and the glacial till serves as a source of recharge for the underlying limestone. Although precipitation is abundant in most of the region, recharge is moderate because of the relatively low permeability of the overlying glacial till. Depth to water is extremely variable depending in part on the thickness of the glacial till, but is typically moderately deep.

Figure 1. Format and description of the hydrogeologic setting - 7Ac Glacial Till Over Solution Limestone.

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 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 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 judgement. 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. 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 |
| 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 | |

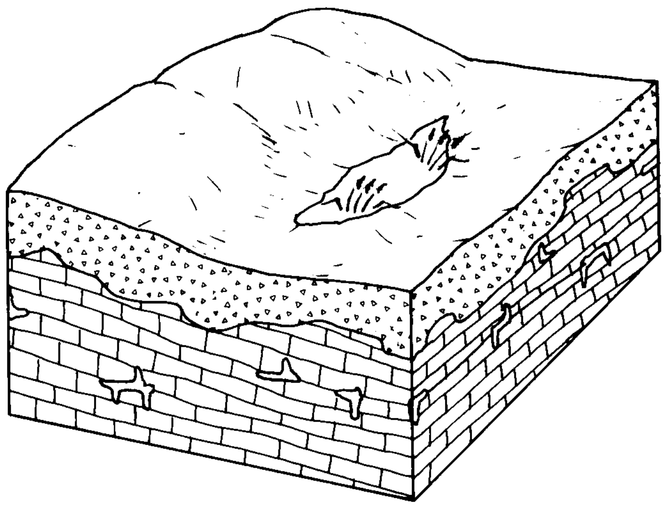
TABLE 8. RANGES AND RATINGS FOR HYDRAULIC CONDUCTIVITY

| 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 one hydrogeologic setting, 7Ac1 Glacial Till Over Solution Limestone, identified in mapping Erie 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 134. 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 Erie County produces settings with a wide range of vulnerability to ground water contamination. Calculated pollution potential indexes for the eleven settings identified in the county range from 79 to 211

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 Erie 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 Erie County is included with this report.



| SETTING 7Ac1 | | GENERAL | | |
|---|---|---|---|---|
| FEATURE | RANGE | WEIGHT | RATING | NUMBER |
| Depth to Water | 5'-15' | 5 | 9 | 45 |
| Net Recharge | 4"-7" | 4 | 6 | 24 |
| Aquifer Media | Massive Limestone | 3 | 6 | 18 |
| Soil Media | Clay Loam | 2 | 3 | 6 |
| Topography | 0-2% | 1 | 10 | 10 |
| Impact Vadose Zone | Glacial Till | 5 | 5 | 25 |
| Hydraulic Conductivity | 100-300 | 3 | 2 | 6 |
| | | DRASTIC | INDEX | 134 |

Figure 2. Description of the hydrogeologic setting - 7Ac Glacial Till Over Solution Limestone.

## 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:

7Ac 1 - defines the hydrogeologic region and setting
134 - defines the relative pollution potential

The first number (7) refers to the major hydrogeologic region, and the upper and lower case letters (Ac) refer to a specific hydrogeologic setting. The number (1) references a certain set of DRASTIC parameters that are unique to this setting and are described in the corresponding setting charts. The second number (134) 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 ERIE COUNTY

Erie County occupies an area of approximately 264 square miles in north-central Ohio (Figure 3). It is bounded on the north by Lake Erie, on the east by Lorain County, on the south by Huron County, and on the west by Sandusky County. The county seat is Sandusky. The population of the county in 1990, according to the Ohio Department of Development (1991), was 76,779. Erie county is primarily agricultural with 47 percent of the land used for crops and pasture (Ohio Department of Agriculture, 1992).

### Physiography

The physiography of Erie County consists of a mantle of unconsolidated glacial deposits overlying a sequence of relatively flat-lying sedimentary rocks. Topography of the county is generally flat to gently rolling except where rivers have cut into the surrounding countryside resulting in steep slopes, escarpments or both.

Erie County lies within the Central Lowlands physiographic province and consists of two physiographic sections: the Eastern Lake Plains section and the Till Plains section (Fenneman, 1938). The majority of the county is located in the Eastern Lake Plains section. This area is characterized by a gentle northward-sloping topography dominated by surficial deposits and landforms produced by ancient lacustrine (lake) processes. A small portion of the southeastern quarter of the county lies in the generally flat-lying to gently rolling Till Plains section, an area characterized by deposits and landforms produced by ancient glacial processes.

### Drainage and Climate

Erie County lies within the St. Lawrence drainage basin and is primarily drained by the Sandusky River and its tributaries. The county's surface drainage is divided into three major river basins in which 50.9% of the surface drainage occurs in the Pickeral Creek-Pipe Creek basins ( ODNR, 1966), 13.6% in the Huron River basin, 5.7% in the Vermillion River basin and the remaining 29.8% consists of minor tributary stream basins discharging directly into Lake Erie (K. Fortney, pers. comm.).

The climate in Erie County is typical of the temperate mid-continent region, characterized by a wide range between summer and winter temperatures and moderate amounts of precipitation. The average monthly precipitation at the U.S. Weather Bureau Station at Sandusky for the thirty year period from 1961 to 1990 ranged between 1.65 inches for February and 3.70 inches for July (U.S. Department of Commerce, 1992). The average annual precipitation for the county was 34.05 inches. The average annual temperature range for the same thirty year period was between 32.2°F (January) and 82.4°F (July) with an average annual temperature of 58.3°F (U.S. Department of Commerce, 1992).


Figure 3. Location of Erie County

## Glacial Geology

Approximately 2 million years ago, the Pleistocene Epoch commenced with a series of continental glaciations covering the northern half of North America. Four major glacial advances are known to have occurred on the continent: the Nebraskan (oldest), the Kansan, the Illinoian and the Wisconsian (youngest). In Ohio, evidence exists for three glacial periods: the pre-Illinoian, which includes Kansan and possibly Nebraskan periods but is not reliably dated (Norton et al., 1983); the Illinoian, which occurred at least 120,000 years ago; and the Wisconsinan, which occurred between 70,000 and 10,000 years ago (Fullerton, 1986).

Continental glaciation greatly altered much of Ohio's preglacial landscape by burying its topographic relief and drainage systems beneath a mantle of unconsolidated glacial deposits. This unconsolidated glacial mantle consists of both sorted and unsorted deposits of variable grain-size ranging from fine-grained lake deposits of silt and clay, to coarse-grained outwash deposits of cobbles and boulders.

Two groups of glacial deposits are commonly found in Erie County: glacial till, and lacustrine (lake) deposits (Goldthwait, et al., 1961). The general distribution of surficial glacial and lacustrine deposits in Erie County is illustrated in Figure 4. Glacial till is found throughout much of the county and consists of an unsorted mixture of silt and clay with variable amounts of sand and gravel. Glacial till is generally unsorted as a result of deposition directly from the ice sheet without any modification by glacial meltwater. Glacial till in this county creates a flat to gently-rolling ground moraine that covers much of the local bedrock topography.

As the last continental glaciation retreated from Ohio, meltwater impounded between the Great Lakes continental drainage divide and the retreating glacier created a series of ancient glacial lakes in northwest Ohio. Remnants of these ancient lakes are found throughout Erie County as a series of shoreline features and as clay-rich lake bottom (lacustrine) deposits.

Shoreline features in Erie County occur as either sandy beach ridge deposits or as erosional benches cut into bedrock or glacial till. Shorelines from all of the major glacial lake stages are present in Erie County, ranging from the earliest Lake Maumee stages to the present Lake Erie shoreline (Forsyth, 1959). Beach ridges generally occur as long, linear ridges of sand and gravel created during periods of stable lake water levels. Erosional benches are long low cliffs or terraces cut by wave action into the local bedrock or glacial till. Erosional benches are commonly found east of the Huron River along the Bedford Shale/Berea Sandstone contact creating a northeast-southwest trending embankment called the Berea Escarpment.

Lake bed deposits in Erie County consist of fine sand, silt, and clay deposited in the subaqueous environment of the glacial lakes. These deposits range from well-laminated sediments to massive, "reworked" glacial till. In Erie County, lacustrine bottom sediments appear to be limited to the region in front of the Lake Erie shoreline and range in thickness from thin veneers over glacial till and bedrock, to thick deposits in excess of 65 feet (Campbell, 1955).

Following the retreat of the lake levels to their present elevations, an extensive marsh-like prairie referred to as the Castalia Prairie developed in Margaretta Township of western Erie County. The prairie consists of interbedded peat and marl beds that have developed under the unusually saturated conditions of the area (Sears, 1967). The marl, consisting primarily of the mineral calcite, was commercially strip mined for many years for use in the manufacture of Portland cement.

In Huron and Milan Townships (Figure 4), a north-south trending buried valley occurs beneath the Huron River (Larsen, 1984a). This valley was deeply eroded into the underlying Ohio Shale during preglacial times and subsequently filled with unconsolidated glacial deposits. Depth to bedrock in the buried valley is known to range up to 160 feet below ground surface in the vicinity of Milan, Ohio (Ohio Department of Natural Resources, well logs; Larsen, 1984b).

## Bedrock Geology

Erie County is underlain by a relatively flat-lying sequence of Paleozoic sedimentary rocks consisting of limestone, shale, and sandstone. The bedrock in the county is a transitional sequence of rocks both in age and in lithology marking the change from the carbonate formations (limestone and dolomite) of western Ohio to the clastic (sandstone, shale, and coal) formations of eastern Ohio.

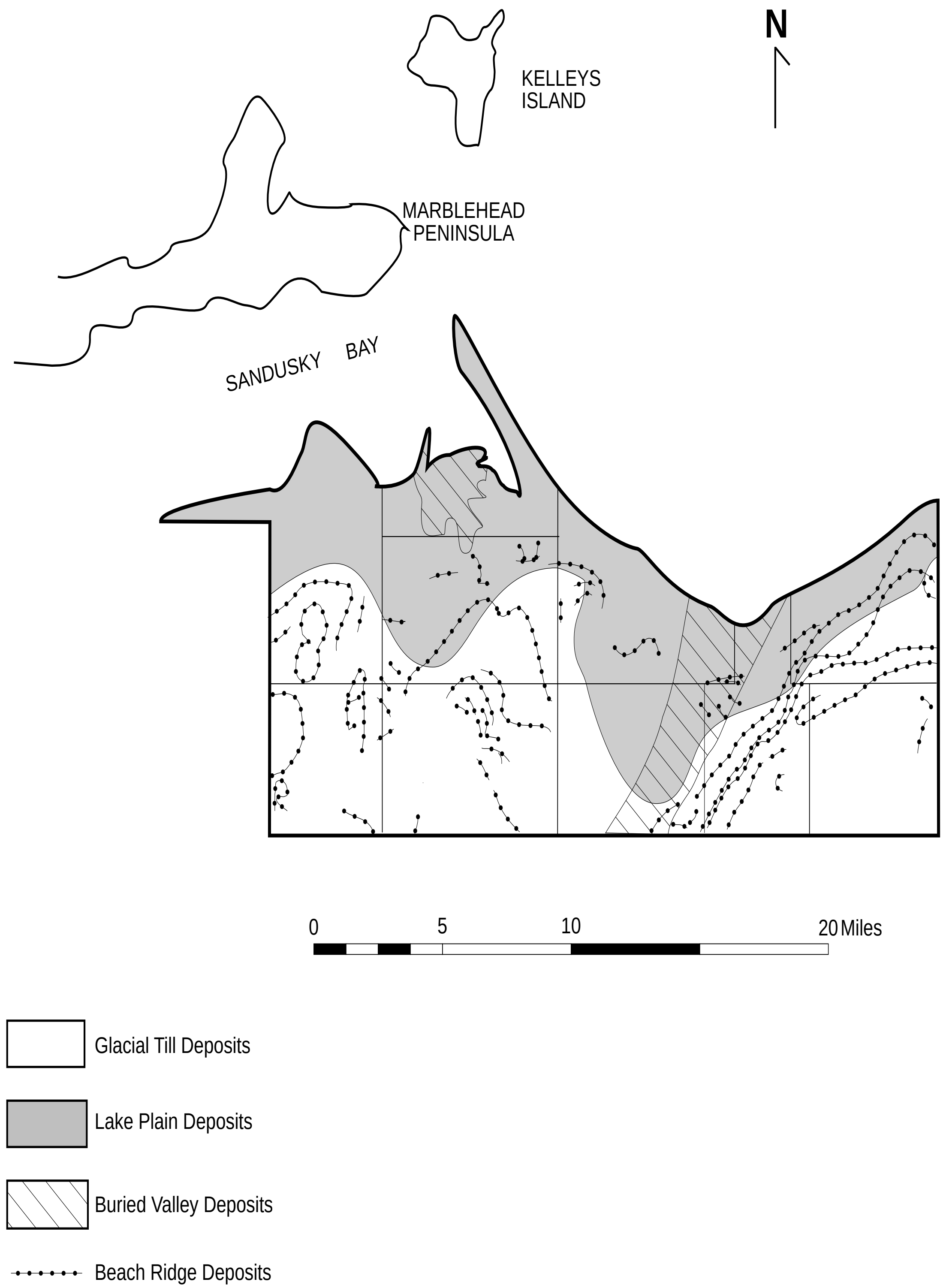



Figure 4. General Glacial Geology of Erie County, Ohio (adapted from Goldthwait, et al., 1961)

The oldest bedrock exposed in Erie County is Silurian dolomite outcropping in the northwestern corner of the county (Figure 5). The Silurian dolomite is overlain by younger Devonian limestone and shale formations in central Erie County which are in turn overlain by a younger Mississippian shale and sandstone sequence in eastern Erie County. The stratigraphic relationship of the formations underlying Erie County and their lithologic characteristics are depicted in Table 9.

The bedrock formations of Erie County lie on the eastern flank of a large regional structure referred to as the Findley Arch. The arch, a geologic structure resulting from tectonic forces, influenced the present configuration of bedrock formations in Ohio. The crest of the Findley Arch splits from the Cincinnati Arch in west-central Ohio and trends northeast towards Ontario, Canada. Bedrock formations on the eastern flank of the arch, including those of Erie County, dip gently southeast towards the ancient Appalachian Basin of eastern Ohio (ODNR, 1970).

The Silurian carbonate sequence of western Erie County is generally comprised of a micro-crystalline brown to gray argillaceous dolomite. Anhydrite and shale is commonly interbedded with the dolomite in certain localities throughout much of northwestern Ohio. The Devonian carbonates consist mainly of massive to thin-bedded brown to gray fossiliferous limestone and dolomite. Some thin shale beds occur intermittently within the Devonian carbonates, especially in the Delaware Formation (Stout, 1941).

The Devonian carbonates gradually change eastward into a thick shale sequence comprised of the following formations: the Plum Brook Shale, the Prout Limestone, and the Ohio Shale. The Plum Brook Shale-Prout Limestone sequence consists of a blue-gray, calcareous shale or mudstone overlain by a thin, fossiliferous limestone or dolomitic mudstone. Overlying the Plum Brook Shale-Prout Limestone sequence is the Ohio Shale, a black, fissile, siliceous shale with a high carbonaceous matter content and numerous pyrite/carbonate concretions (Hoover, 1960).

The Mississippian sequence begins with the Bedford Shale, a soft dark gray to reddish-brown shale containing thin beds of siltstone. The Berea Sandstone overlies the Bedford Shale and consists of a medium- to thin-bedded, fine-grained quartz sandstone. Ancient ripple marks formed by wave activity are commonly found at outcrops of the Berea Sandstone in Erie County. In addition, the Berea Sandstone of northern Ohio is highly variable in thickness, possibly because of scouring and filling of ancient river channels into and through the underlying Bedford Shale during the Lower Mississippian Period (Pepper, et al., 1954).

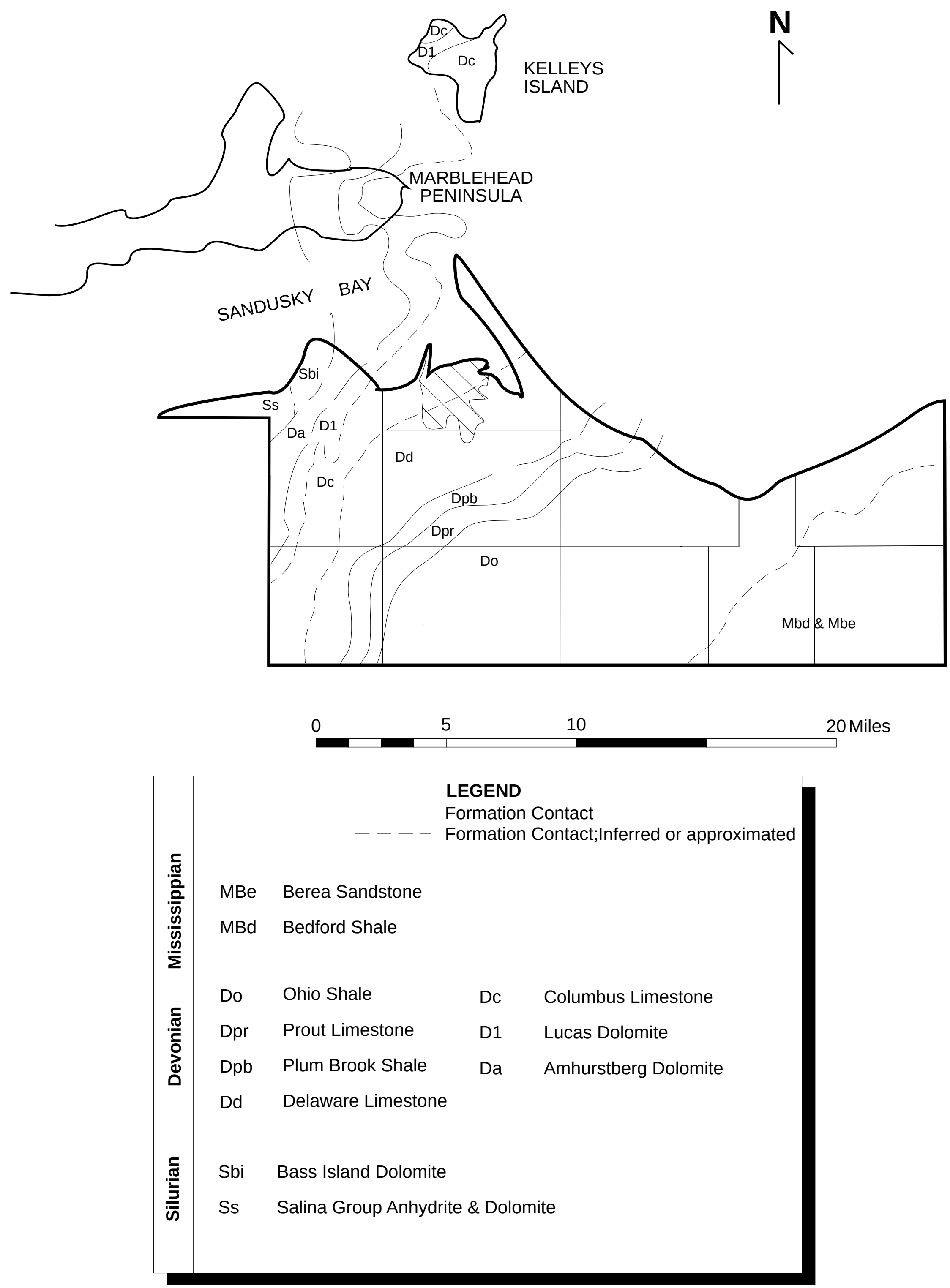



Figure 5. General Bedrock Geology of Erie County, Ohio. (adapted from Herdenorf and Braindech (1972) and Bownocker (1920)).

Table 9. Generalized Bedrock Statigraphy of Erie County, Ohio. (adapted from Stout, 1941 and ODNR, Div. of Geological Survey, 1987)

| Time-Stagraphic Units | | | Rock Units | |
|---|---|---|---|---|
| **System** | **Series** | **Group** | **Formation** | **Significant Members or Beds** |
| Mississ-ippian | | | Berea Sandstone | |
| | | | Bedford Shale | |
| DEVONIAN | Chau-tauquan | | Ohio Shale | Cleveland Shale<br>Chagrin Shale<br>Huron Shale |
| | Senecan | | Olentangy Shale (Central Ohio) / Prout Limestone Plum brook Shale (Northern Ohio) | |
| | Erian | | Delaware Limestone | |
| | Ulsterian | | Columbus Limestone | |
| | | Detroit River | Lucas Dolomite | |
| | | | Amherstburg Dolomite | |
| SILURIAN | Cayugan | | Bass Island Dolomite | |
| | | SALINA | G Unit (Anhydrite & Dolomite) | |

## Karst Geology

A unique geologic setting referred to as karst terrain is found in western Erie County. Karst terrain has distinctive relief and drainage resulting from the dissolution of limestone or dolomite by the action of surface and ground water (Bloom, 1978). Karst terrain typically has a strong underground drainage system ranging from fractures and minor solution channels to caverns with subterranean streams. Dolines (sinkholes), springs, sinking streams, ponors (shallow holes), and caves are surface expressions related to the underground drainage system.

Two karst features commonly found in western Erie County are sinkholes and springs (Tintera, 1980). Sinkholes or dolines are commonly found on top of the Columbus Cuesta, a large limestone plateau that trends northeast-southwest from Seneca County into Groton, Margaretta and Perkins Townships of Erie County. The sinkholes in Erie County are often very large, some covering many acres of land and resembling shallow valleys. Ohio's largest sinkhole is found in Erie County and measures nearly a mile in diameter.

Sinkholes act as points of concentrated recharge to the underlying carbonate aquifer by channeling precipitation into the subsurface (Kihn, 1988). The sinkholes are so effective in capturing and funnelling precipitation to the subsurface that natural surficial drainage features such as streams and rivers failed to develop in the karstic terrain of western Erie County (Norris, 1982).

Some of Ohio's most famous springs, known locally as "blue holes," are found in western Erie County. The Castalia Blue Hole is one of the best know examples of a karst spring in the county (Ver Steeg and Yunck, 1932). Other karst springs include Duck Pond Spring, Ransom Spring, Rockwell Spring, and the Castalia Trout Farm Spring (Kihn, 1988). In addition to sinkholes and springs, two caves known as Crystal Rock Cave and Brewery Cave occur in northwest Margaretta Township (White, 1926).

## Kelleys Island

Kelleys Island, a township of Erie County, is located approximately four miles north of Marblehead, Ohio and nine miles north of Sandusky, Ohio, in Lake Erie. The geology of the island consists of thin deposits of glacial drift overlying bedrock of Lower Devonian limestone and dolomite. The island's shoreline consists of either bedrock cliffs or cobble-sand beaches (Fisher, 1922).

Bedrock beneath Kelleys Island consists of the Lower Devonian Columbus Limestone overlying the Lucas Dolomite (Hatfield, 1988). The Columbus Limestone is a thin- to thick-bedded brown to gray fossiliferous limestone that gradually changes into a dolomite near the base of the formation. The Lucas Dolomite consists of a dark brown, thin- to thick-bedded, laminated dolomite with numerous carbonaceous seams and styolites. The Columbus Limestone underlies much of the island with the exception of outcrops of the Lucas Dolomite on the west and north shores of the island (Fisher, 1922).

Glacial deposits on Kelleys Island generally consist of a thin veneer of glacial till less than two feet thick; however, till deposits up to 20 feet thick are found near the north side of the island. In many places, the glacial till overlies glacial grooves and striations cut into the underlying Columbus Limestone. Other deposits include abandoned storm berm deposits consisting of imbricated (stacked) sequences of limestone cobbles exposed along a cliff on the northwest end of the island.

## Hydrogeology

The hydrogeologic system of Erie County consists of a highly productive limestone aquifer on the west and a poorly productive shale and sandstone aquifer to the east, both of which are overlain by glacial drift.

In northwest Ohio, a thick sequence of carbonate bedrock from the Devonian and Silurian Periods comprises a vast regional aquifer that serves as a primary source of ground water for the counties in this region (ODNR, 1970). Erie County lies on the eastern edge of this regional aquifer which comprises the western third of Erie County including Kelleys Island.

Ground water within the limestone and dolomite of the carbonate aquifer occurs in a network of interconnected fractures, bedding planes, and solution channels. Yields to individual wells drilled into the carbonate aquifer are highly variable, dependent upon the number of fractures and solution channels in the rock encountered by the well bore.

In Groton and Margaretta Townships, the carbonate aquifer is very karstic as evidenced by the numerous sinkholes in Groton Township and the many springs and artesian wells in Margaretta Township. Yields to wells in the karst region can range up to 1000 gallons per minute where wells intersect large cavernous solution cavities. The higher well yields can be attributed to the higher degree of dissolution within the carbonate aquifer in this area, providing greater capacity for the aquifer to store and transmit ground water to individual wells.

Prior to the construction of a sewage treatment facility by Bellevue in 1971, the carbonate aquifer was contaminated by the underground disposal of water-borne wastes and effluent through wells drilled into the aquifer. In 1961, the Ohio Division of Water, Ground Water Section, conducted a water quality study of the Bellevue-Castalia region. This study showed the contamination extended north through much of Groton and Margaretta Townships to Lake Erie (ODNR, 1961). A subsequent study by Sikora (1975) showed some improvement in the quality of the ground water within the carbonate aquifer since the construction of the sewage treatment facility by Bellvue.

A potentiometric surface map of the carbonate aquifer for western Erie County (Kihn, 1988) shows a general northward-trending slope, indicating regional ground water flow from sources of recharge south of Erie County towards points of discharge in Lake Erie. The northward flow of ground water towards Lake Erie has contributed to Bellevue's underground waste disposal facility having an impact on the ground water resources of western Erie County.

Well yields for the carbonate aquifer tend to decrease to the east as one moves away from the karst region of western Erie County towards the shale and sandstone bedrock of central and eastern Erie County. Well yields for the carbonate aquifer in Perkins and Sandusky townships generally range less than 20 gallons per minute although occasional higher yields have been obtained (Walker, 1986, and ODNR, 1967). The carbonate aquifer underlying Kelleys Island is a massive low-yielding limestone aquifer with known well yields up to 15 gallons per minute (Walker, 1986).

Well yields in the shale of central and northeastern Erie County are poor, generally measuring less than 2 gallons per minute. Despite the fine-grained texture of shale, the surface of shale outcrops can sometimes be highly fractured, giving the shale some capacity to store and transmit water.

Overlying the bedrock aquifers of Erie County is a mantle of glacial drift consisting of both glacial till and lacustrine deposits. Generally, the glacial drift is not considered a major aquifer in Erie County, although it does contain intermittent water-bearing lenses of sand and gravel.

Because of the high clay / silt content of glacial till, it usually has a low hydraulic conductivity and is a poor source of ground water. However, glacial till often has an interconnected network of vertical fractures which impart an enhanced capability for ground water flow and contaminant migration (Freeze and Cherry, 1979). In addition, water-bearing sand and gravel lenses in the till are a source of recharge to the underlying bedrock aquifers and occasionally a source of ground water for some domestic wells.

Another potential source of ground water from glacial drift is the buried valley occurring beneath the Huron River. Deposits of sand and gravel covered by a thick mantle of glacial till and lacustrine deposits occur at the bottom of the buried valley. Yields ranging up to 250 gallons per minute have been developed from the sand and gravel deposits (Walker, 1986).

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## APPENDIX A

### DESCRIPTION OF LOGIC IN FACTOR SELECTION

<u>Depth to Water</u>

Depth to water was evaluated using information obtained from well logs on file with the Ohio Department of Natural Resources, Division of Water, and from inferences based on the topographic expression of the land and surface water elevations.

Water levels in Erie County varied considerably with ranges of 0 to 5 feet, with a DRASTIC rating of ten (10), up to ranges of 75 to 100 feet with a DRASTIC rating of (2). Because of its close proximity to Lake Erie, depth to water generally ranged from 5 to 15 feet (9). Depth to water on Kelleys Island generally ranged from 5 to 15 feet (9), except for a small marsh on the northern side of the island which ranged 0 to 5 feet (10) and some bedrock highs with a range of 15 to 30 feet (7).

In the western half of the county, water levels in the karstic carbonate aquifer ranged from 0 to 100+ feet below ground surface. Depth to water in the karst aquifer can be divided into two regions. Water levels in the southwestern half are generally deep with ranges from 30 to 100 feet (ratings ranging from 5 to 2). The deep water levels in the karst aquifer result from a combination of recharge rates, high aquifer hydraulic conductivities, and high rates of ground water discharge through the springs of the northern karst region.

Conversely, water levels in the northwestern karst region of Erie County are very shallow or artesian with ranges of 0 to 5 feet (10) or 5 to 15 (9) feet. The shallow water levels result from the karst aquifer being confined by a thick cover of clay rich glacial drift. In response to a high hydrostatic pressure created by recharge from the south, the ground water flows to the surface through fissures or holes in the confining bed. The many springs or "blue holes" and flowing wells of Erie County occur in this northern karst region.

Depth to water along the Huron River Valley is generally deep ranging from 30 to 100 feet below the ground’s surface, (ratings 5 to 2). The deeper water levels appear to be a result of the Huron River becoming deeply entrenched into the glacial deposits of the buried valley. An elevation change of approximately 75 feet exists between the top of the valley and the Huron River. The deep entrenchment appears to have effectively dewatered the glacial deposits in the vicinity of the Huron River.

## Net Recharge

Recharge for much of the county was evaluated as ranging from 4 to 7 inches (4), based on recharge rates determined for the county's river basins as outlined in Pettyjohn and Henning (1979). Areas with sandy soils such as the beach ridges, river plains, and areas with thin or absent soils were given a higher recharge rate of 7 to 10 inches (8).

Recharge for the karst terrain of southwestern Erie County was evaluated as being 10 + inches (9) because of the numerous sinkholes present in the area. The sinkholes act as points of concentrated recharge by funnelling precipitation and surface water into the underlying carbonate aquifer (Kihn, 1988).

Aquifer

In Erie County, bedrock generally comprises the aquifer media. Three types of bedrock aquifers are commonly found in Erie County: a carbonate (limestone and dolomite) aquifer in western Erie County, a shale aquifer in northeastern, and central Erie County, and a sandstone aquifer in southeastern Erie County.

The carbonate aquifer of western Erie County can be subdivided into two general types: a karstic carbonate aquifer and a massive carbonate aquifer. The karstic carbonate aquifer was given a ten (10) rating because of numerous sinkholes, solution cavities and springs that comprise the karst aquifer system. The high rating reflects the fact that surface pollutants can quickly enter into the aquifer through the sinkholes, and once in the aquifer, the pollutants can move rapidly through the aquifer's network of solution cavities and caverns with little attenuation except perhaps for dilution. Therefore, surface activities releasing pollutants can potentially have a rapid impact on area water supplies.

The karstic property of the carbonate aquifer in western Erie County gradually decreases towards the central portion of Erie County. In order to reflect this gradual decrease, the carbonate aquifer is evaluated as a massive limestone aquifer and given first a rating of nine (9) followed by a rating of six (6) in central Erie County.

The shale bedrock aquifer of central and northeastern Erie County was given a rating of two (2) based upon the inference that the upper shale surface is weathered and fractured to some degree. This weathered zone gives an otherwise massive and nonwater-bearing shale formation some capacity to store and transmit ground water to domestic wells.

The sandstone aquifer of southeastern Erie County consists entirely of the Berea Sandstone, a medium- to thin-bedded, fine-grained, compact sandstone. Because the sandstone is fine-grained and compact, its capacity to be an effective aquifer with good storage and transmitting properties are reduced; therefore, the sandstone aquifer was given a rating of four (4).

## Soil Media

The classification of the soils are based upon the dominant soil properties as described in the soil survey for Erie County (Redmond, et al., 1971). The majority of soils in Erie County developed either on clay-rich deposits associated with the lake and till plains or on sand-rich deposits of the beach ridges. Soils developed on the glacial till of the till plains are generally classified as clay loams (3). Silt loam soils (4) are generally associated with deposits comprised of river alluvium, and sandy loam soils (6) and sand soils (9) are generally associated with the beaches and ancient beach ridges.

Soils developed on the clay-rich deposits of the lake plains were generally evaluated as a shrink/swell clay soil with a rating of seven (7). The shrink/swell clay soil rating was given to soil types that have a high shrink/swell potential, a low sand and gravel composition, and high plastic indices as detailed in Redmond, et al., (1971). Shrink/swell soils were commonly found in the northwestern quarter of the county.

A number of soils were classified as thin or absent (10) because of the close proximity of bedrock to the ground surface. This type of soil provides little protection for shallow bedrock aquifers against contamination introduced at the ground surface. Thin or absent soil types are commonly found in the karst region of southwestern Erie County and along the ancient shorelines where erosion by wave action has exposed shallow bedrock.

## Topography

Sources of information used to evaluate the topography of Erie County include Redmond, et al., 1971, and the USGS 7 1/2 minute topographic quadrangle maps.

Generally, the topography of Erie County is flat to gently rolling with slopes ranging from 0% to 2% (10). The low relief is due, in part, to the extensive cover of lacustrine and glacial deposits that have buried much of the preglacial bedrock topography.

Strong relief occurs in the vicinity of the Columbus Cuesta, a northeast trending highland plateau that rises above the surrounding lake plain in Groton Township. The cuesta, a former lakefront cliff comprised of flat-lying resistant limestone, abruptly drops in elevation on its north side (Norris, 1982). Topography along the cuesta is generally steep with slopes of 6% to 12% (5), 12% to 18% (3) and 18+% (1).

Escarpments with steep slopes and ranges of 6% to 12% (5), 12% to 18% (3), and 18+% (1) are also found along the Huron and Vermillion Rivers and their tributaries where these rivers have cut deeply into the surrounding country side. In addition, an area of highly dissected, hummocky topography with slopes ranging from 2% to 18% (ratings of 9 to 3) occurs west of the Huron River, between the cities of Huron and Milan. Because of the high variability in slopes over short distances in this area, the area was given an average range of 12% to 18% (3).

## Impact of the Vadose Zone Media

The vadose zone is defined as that zone between the ground surface and the water table which is unsaturated or discontinuously saturated. Depending upon the depth to ground water in any particular hydrogeologic setting, the vadose media can be comprised of a single geologic media such as glacial till or a combination of media such as glacial till overlying karst limestone or shale. To reflect this variability in vadose media, the dominant vadose media of the area in question may be given a range of rating values in order to assess the ratio of lower permeability media to higher permeability media.

For instance, glacial till is the material commonly comprising the vadose media in southern Erie County. For those areas with shallow water levels where glacial till comprises most or all of the material between ground surface and the water table, a low rating of three (3) or four (4) was given to the media. However, for deeper water levels where glacial till comprises only a fraction of the vadose media, the remainder being comprised of a second media such as sand and gravel or the bedrock aquifer media of the area, a higher rating, such as five (5) or six (6), was given to the vadose media.

The vadose media for the karst terrain of southwestern Erie County was evaluated as a karst limestone with a rating of ten (10). The high rating was given because sinkholes in the area can capture and quickly channel surface pollutants into the subsurface without significant attenuation to the contaminants. For areas with significant quantities of glacial till filling karst depressions, the vadose media was evaluated as karst limestone and given a rating of eight (8).

For areas where thin glacial drift deposits overlie a massive limestone aquifer, such as Kelleys Island, the vadose media was evaluated as massive limestone and given a rating of six (6).

In areas where shale dominated the vadose media, the media was evaluated as massive shale (5). Although shale is typically a fine-grained rock of low permeability, the five rating was assigned to reflect the increased secondary porosity that often results from weathering and fracturing of brittle, semi-competent shale deposits such as the Ohio and Bedford Formations.

For areas dominated by sandstone, the vadose media was evaluated as massive sandstone and given a rating of six (6). The lower rating for sandstone media was given because the Berea Sandstone is typically a compact, fine- to medium-grained sandstone (Pepper, et al., 1954), thus restricting its capacity to transmit fluids to the subsurface.

For the lake plains region of northern Erie County, the vadose media was evaluated as silt and clay with a rating range of two (2) to five (5) depending upon the ratio of silt/clay material to underlying bedrock comprising the vadose media. For marshes and swamps, the vadose media was evaluated as silt and clay and given a six rating (6) in order to reflect the presence of porous peat material from partially decayed marsh vegetation in the silt and clay deposits comprising the vadose media.

Vadose media for rivers and streams in Erie County were generally evaluated as "sand and gravel with significant silt and clay" and given ratings ranging from four (4) to eight (8). For beaches and beach ridges, the vadose media was generally evaluated as sand and gravel with rating ranges from seven (7) to nine (9). Ratings for both settings were established based upon the sand content of both the area well logs (Ohio Department of Natural Resources, Div. of Water) and the soil types occurring in each setting (Redmond, et al., 1971).

## Hydraulic Conductivity

The hydraulic conductivity of an aquifer is a measure of its ability to transmit ground water, and is, in part, a function of the media comprising the aquifer (i.e. sand and gravel, sandstone, limestone, etc.). Aquifers with significant silt and clay have low hydraulic conductivities, whereas aquifers that are porous and permeable (such as clean sands and gravels) or highly fractured and solutioned (such as cavernous or karst limestone ) have high hydraulic conductivities.

The hydraulic conductivity for the carbonate aquifer beneath Kelleys Island was evaluated as 100 to 300 gpd/ft sq. (2) based upon the low yields to wells reported throughout the island. The low hydraulic conductivity can be attributed to the generally massive and thick-bedded nature of the carbonate rocks beneath the island.

The karst aquifer of western Erie County was given a rating of 2000+ gpd/ft. sq. with a corresponding rating of ten (10). The high rating was given because the underground karst network of fractures and solution cavities transmit large quantities of ground water through springs in Margaretta Township. Ground water discharge rates for two springs in the township, Castalia "Blue Hole" and Duck Pond Springs, average approximately 4,000 and 6,500 gallons per minute (gpm) respectively (Kihn, 1988). In addition, yields from industrial wells completed in the karst aquifer commonly range up to 500 gpm.

A range of 1000 to 2000 gpd/ft sq. (8) was given to the limestone aquifer east of the karst region based upon the lower well yields associated with this area (Walker, 1986), and because karstic features such as sinkholes and springs gradually cease to occur in west-central Erie County.

The hydraulic conductivity of the shale bedrock aquifer in central and northeastern Erie County was evaluated as being 1 to 100 gpd/ft. sq. (1) based upon the known hydraulic properties of shale bedrock, a review of well logs, and Walker (1986).

The hydraulic conductivity of the Berea Sandstone aquifer in southeastern Erie County was evaluated as ranging from 1 to 100 gpd/ft. sq. (1). The low rating was given to the aquifer because the sandstone generally consists of a compact, fine-grained quartz sand, cemented with calcium carbonate. Yields to wells are low, seldom exceeding 10 gpm (Walker, 1986).

The hydraulic conductivity for the sand and gravel aquifer comprising the river alluvium was estimated to be in the 100-300 gpd/ft. sq. range (2). This is because the sand and gravel aquifers of the alluviel aquifers often contain a significant amount of silt and clay, thus reducing their capacity to transmit groundwater.

The sand and gravel aquifer media of the buried valley beneath the Huron River in Milan, Huron and Berlin Townships was evaluated as having a hydraulic conductivity ranging from 300 to 700 gpd/ft. sq. (4). Areas in the buried valley containing less permeable deposits, based on Ohio Department of Natural Resources well logs and Walker (1986), were evaluated as ranging from 100 to 300 gpd/ft. sq. (2).

The sand and gravel aquifer media of the Cedar Point sand spit was evaluated as ranging from 1000 to 2000 gpd/ft. sq. (8). The high rating was given based upon analysis of the sand comprising the spit, a well sorted, medium-grained to coarse-grained sand. Well-sorted sands often have higher hydraulic conductivities than poorly-sorted sands of a similar grain size range, because the pores of the well-sorted sands are not clogged by the silts, clays, and very fine sands often associated with the poorly-sorted sand fractions.

## APPENDIX B

## DESCRIPTION OF HYDROGEOLOGIC SETTINGS AND CHARTS

In mapping the pollution potential of Erie County, eleven hydrogeologic settings of 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 10. Computed pollution potential index values range from 79 to 211.

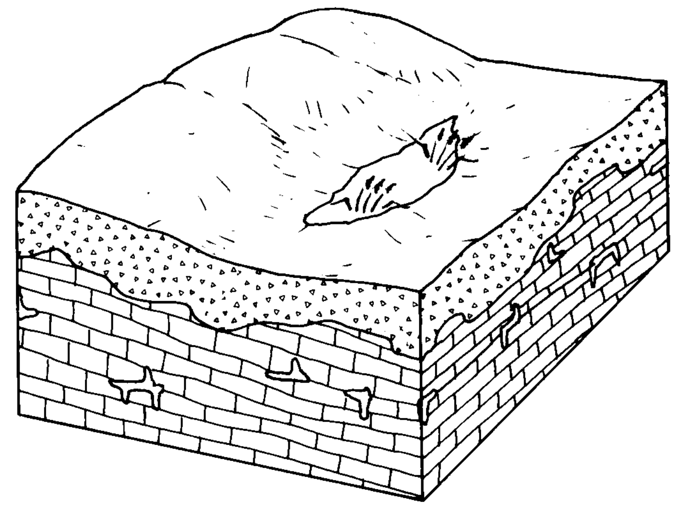
Table 10. Hydrogeologic Settings Mapped in Erie County, Ohio

| Hydrogeologic Settings | Range of GWPP Indexes | Number of Index Calculations |
|---|---|---|
| 7Ac Glacial Till over Solution Limestone | 129 to 205 | 34 |
| 7 Ad Glacial Till over Sandstone | 90 to 152 | 22 |
| 7 Ae Glacial Till over Massive Shale | 83 to 125 | 21 |
| 7Af Sand and Gravel Interbedded in Glacial Till | 90 to 133 | 10 |
| 7 D Buried Valley | 79 to 137 | 20 |
| 7Ec River Alluvium over Sedimentary Bedrock | 104 to 137 | 6 |
| 7Ed River Alluvium over Glacial Till | 132 to 178 | 7 |
| 7F Glacial Lake Plain Deposits | 92 to 195 | 52 |
| 7Gb Thin Glacial Till over Limestone | 166 to 211 | 19 |
| 7H Beaches, Beach Ridges, and Sand Dunes | 115 to 208 | 41 |
| 7I Marshes and Swamps | 147 to 195 | 3 |

The following charts are a schematic breakdown of each hydrogeologic setting mapped in Erie County. The charts provide information on how the ground water pollution potential indexes were derived and are a quick and easy reference for the accompanying ground water pollution potential map. The charts are grouped according to their respective hydrogeologic settings with an accompanying block diagram illustrating the characteristics of each setting. 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.

NOTE:

The Hydrogeologic settings; 7Ac 167, 7Ae 14, and 7H 23 appear with incorrect GWPP index values on the GWPP map. Please refer to the GWPP index tables in appendix B for the correct GWPP index values for those settings.



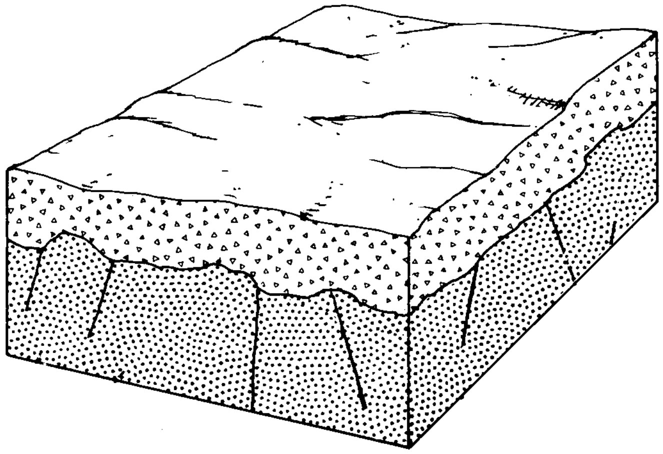
7Ac Glacial Till Over Solution Limestone

This hydrogeologic setting is characterized by low topography and solution limestone which is covered by varying thicknesses of glacial till. The till is principally unsorted deposits which may be interbedded with loess or localized deposits of sand and gravel. Surficial deposits have usually weathered to a clay loam. Although ground water occurs in both the glacial deposits and in the underlying limestone, the limestone, which typically contains solution cavities, generally serves as the principal aquifer. The limestone is in direct hydraulic connection with the glacial till and the glacial till serves as a source of recharge for the underlying limestone. Although precipitation is abundant in most of the region, recharge is moderate because of the relatively low permeability of the overlying glacial till. Depth to water is extremely variable depending in part on the thickness of the glacial till, but is typically moderately deep.

GWPP index values for the hydrogeologic setting of glacial till over solution limestone range from 129 to 205 with the total number of GWPP index calculations equaling 34.

| Setting | Depth to Water (ft) | Recharge (In/Yr) | Aquifer Media | Soil Media | Topography | Vadose Zone Media | Hydraulic Conductivity | Rating | Pest Rating |
|---|---|---|---|---|---|---|---|---|---|
| 7Ac1 | 5-15 | 4-7 | Massive Limestone | Clay Loam | 0-2 | Glacial Till | 100-300 | 134 | 156 |
| 7Ac2 | 5-15 | 7-10 | Massive Limestone | Thin or Absent | 0-2 | Massive Limestone | 100-300 | 161 | 203 |
| 7Ac3 | 0-5 | 4-7 | Massive Limestone | Clay Loam | 0-2 | Massive Limestone | 100-300 | 144 | 165 |
| 7Ac4 | 0-5 | 4-7 | Massive Limestone | Clay Loam | 0-2 | Glacial Till | 100-300 | 144 | 165 |
| 7Ac5 | 0-5 | 7-10 | Massive Limestone | Peat | 0-2 | Glacial Till | 100-300 | 167 | 202 |
| 7Ac6 | 15-30 | 4-7 | Massive Limestone | Clay Loam | 0-2 | Sand & Gravel | 100-300 | 129 | 150 |
| 7Ac7 | 75-100 | 10+ | Karst Limestone | Shrink-Swell (Aggregated) Clay | 0-2 | Karst Limestone | 2000+ | 180 | 201 |
| 7Ac8 | 5-15 | 4-7 | Massive Limestone | Shrink-Swell (Aggregated) Clay | 0-2 | Glacial Till | 1000-2000 | 171 | 198 |
| 7Ac9 | 15-30 | 4-7 | Massive Limestone | Shrink-Swell (Aggregated) Clay | 0-2 | Glacial Till | 1000-2000 | 161 | 188 |
| 7Ac10 | 30-50 | 10+ | Karst Limestone | Silt Loam | 0-2 | Karst Limestone | 2000+ | 189 | 201 |

| Setting | Depth to Water (ft) | Recharge (In/Yr) | Aquifer Media | Soil Media | Topography | Vadose Zone Media | Hydraulic Conductivity | Rating | Pest Rating |
|---|---|---|---|---|---|---|---|---|---|
| 7Ac11 | 15-30 | 4-7 | Massive Limestone | Clay Loam | 0-2 | Glacial Till | 1000-2000 | 153 | 168 |
| 7Ac12 | 15-30 | 4-7 | Massive Limestone | Shrink-Swell (Aggregated) Clay | 2-6 | Karst Limestone | 1000-2000 | 170 | 193 |
| 7Ac13 | 50-75 | 10+ | Karst Limestone | Shrink-Swell (Aggregated) Clay | 0-2 | Karst Limestone | 2000+ | 185 | 206 |
| 7Ac14 | 30-50 | 10+ | Karst Limestone | Clay Loam | 0-2 | Karst Limestone | 2000+ | 187 | 196 |
| 7Ac15 | 50-75 | 10+ | Karst Limestone | Silt Loam | 2-6 | Karst Limestone | 2000+ | 178 | 188 |
| 7Ac16 | 5-15 | 7-10 | Massive Limestone | Shrink-Swell (Aggregated) Clay | 0-2 | Karst Limestone | 1000-2000 | 189 | 214 |
| 7Ac17 | 5-15 | 4-7 | Massive Limestone | Silt Loam | 0-2 | Karst Limestone | 1000-2000 | 175 | 191 |
| 7Ac18 | 15-30 | 4-7 | Massive Limestone | Shrink-Swell (Aggregated) Clay | 0-2 | S & G w/ Sl & Cl | 1000-2000 | 166 | 192 |
| 7Ac19 | 15-30 | 4-7 | Massive Limestone | Shrink-Swell (Aggregated) Clay | 0-2 | Karst Limestone | 1000-2000 | 171 | 196 |
| 7Ac20 | 50-75 | 7-10 | Karst Limestone | Shrink-Swell (Aggregated) Clay | 2-6 | Karst Limestone | 2000+ | 170 | 191 |
| 7Ac21 | 15-30 | 4-7 | Massive Limestone | Silt Loam | 0-2 | Karst Limestone | 1000-2000 | 165 | 181 |
| 7Ac22 | 15-30 | 10+ | Karst Limestone | Silt Loam | 0-2 | Karst Limestone | 2000+ | 199 | 211 |
| 7Ac23 | 15-30 | 10+ | Karst Limestone | Shrink-Swell (Aggregated) Clay | 0-2 | Karst Limestone | 2000+ | 205 | 226 |
| 7Ac24 | 50-75 | 7-10 | Karst Limestone | Shrink-Swell (Aggregated) Clay | 0-2 | Karst Limestone | 2000+ | 171 | 194 |
| 7Ac25 | 15-30 | 10+ | Karst Limestone | Sandy Loam | 0-2 | Karst Limestone | 2000+ | 203 | 221 |
| 7Ac26 | 75-100 | 10+ | Karst Limestone | Clay Loam | 2-6 | Karst Limestone | 2000+ | 171 | 178 |
| 7Ac27 | 30-50 | 10+ | Karst Limestone | Shrink-Swell (Aggregated) Clay | 0-2 | Karst Limestone | 2000+ | 195 | 216 |
| 7Ac28 | 5-15 | 4-7 | Massive Limestone | Shrink-Swell (Aggregated) Clay | 0-2 | Karst Limestone | 1000-2000 | 191 | 214 |
| 7Ac29 | 50-75 | 10+ | Karst Limestone | Clay Loam | 0-2 | Karst Limestone | 2000+ | 177 | 186 |
| 7Ac30 | 15-30 | 4-7 | Karst Limestone | Silt Loam | 2-6 | Silt & Clay | 2000+ | 158 | 173 |
| 7Ac31 | 5-15 | 4-7 | Karst Limestone | Silt Loam | 2-6 | Silt & Clay | 2000+ | 168 | 183 |
| 7Ac32 | 30-50 | 7-10 | Karst Limestone | Sandy Loam | 2-6 | Karst Limestone | 2000+ | 178 | 196 |
| 7Ac33 | 50-75 | 7-10 | Karst Limestone | Sandy Loam | 2-6 | Karst Limestone | 2000+ | 168 | 186 |
| 7Ac34 | 50-75 | 10+ | Karst Limestone | Sandy Loam | 2-6 | Karst Limestone | 2000+ | 182 | 198 |



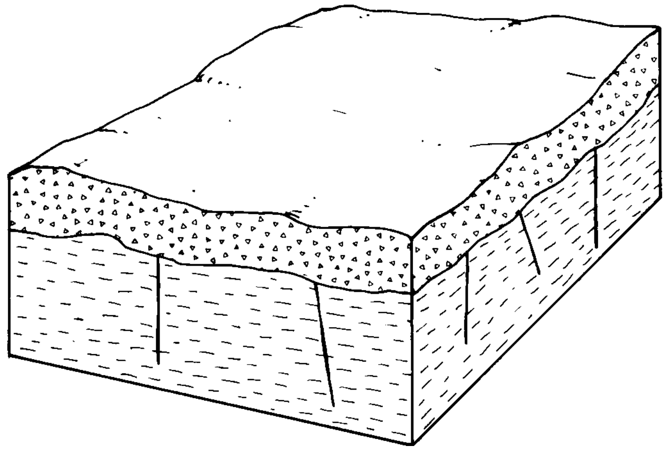
## 7Ad Glacial Till Over Sandstone

This hydrologic setting is characterized by low topography and relatively flat-lying, fractured sandstones which are covered by varing thicknesses of glacial till. The till is principally unsorted deposits which may be interbedded with loess or localized deposits of sand and gravel. Although ground water occurs in both the glacial deposits and in the intersecting bedrock fractures, the bedrock is typically the principal aquifer. The glacial till serves as a source of recharge to the underlying bedrock. Although precipitation is abundant in most of the region, recharge is moderate because of the glacial tills which typically weather to clay loam. Depth to water is extremely variable, depending in part on the thickness of the glacial till, but averages around 40 feet.

GWPP index values for the hydrogeologic setting of glacial till over sandstone range from 90 to 152 with the total number of GWPP index calculations equaling 20.

| Setting | Depth to Water (ft) | Recharge (In/Yr) | Aquifer Media | Soil Media | Topography | Vadose Zone Media | Hydraulic Conductivity | Rating | Pest Rating |
|---|---|---|---|---|---|---|---|---|---|
| 7Ad1 | 5-15 | 4-7 | Massive Sandstone | Clay Loam | 0-2 | Glacial Till | 1-100 | 125 | 148 |
| 7Ad2 | 15-30 | 4-7 | Massive Sandstone | Loam | 0-2 | Glacial Till | 1-100 | 124 | 152 |
| 7Ad3 | 5-15 | 4-7 | Massive Sandstone | Clay Loam | 2-6 | Glacial Till | 1-100 | 129 | 149 |
| 7Ad4 | 5-15 | 4-7 | Massive Sandstone | Sandy Loam | 0-2 | Glacial Till | 1-100 | 136 | 167 |
| 7Ad5 | 5-15 | 4-7 | Massive Sandstone | Clay Loam | 0-2 | Glacial Till | 1-100 | 130 | 152 |
| 7Ad6 | 5-15 | 4-7 | Massive Sandstone | Clay Loam | 0-2 | Glacial Till | 1-100 | 115 | 140 |
| 7Ad7 | 15-30 | 4-7 | Massive Sandstone | Clay Loam | 0-2 | Glacial Till | 1-100 | 110 | 134 |
| 7Ad8 | 5-15 | 4-7 | Massive Sandstone | Clay Loam | 0-2 | Glacial Till | 1-100 | 125 | 148 |
| 7Ad9 | 5-15 | 4-7 | Massive Sandstone | Clay Loam | 2-6 | Glacial Till | 1-100 | 124 | 145 |
| 7Ad10 | 15-30 | 2-4 | Massive Sandstone | Clay Loam | 0-2 | Glacial Till | 1-100 | 93 | 118 |
| 7Ad11 | 15-30 | 4-7 | Massive Sandstone | Clay Loam | 0-2 | Glacial Till | 1-100 | 115 | 138 |
| 7Ad12 | 15-30 | 7-10 | Massive Sandstone | Sand | 2-6 | S & G w/ Sl & Cl | 1-100 | 144 | 181 |
| 7Ad13 | 15-30 | 4-7 | Massive Sandstone | Clay Loam | 0-2 | Sandstone | 1-100 | 120 | 142 |
| 7Ad14 | 15-30 | 7-10 | Massive Sandstone | Sandy Loam | 2-6 | Sand & Gravel | 1-100 | 143 | 170 |
| 7Ad15 | 5-15 | 4-7 | Massive Sandstone | Clay Loam | 2-6 | Sandstone | 1-100 | 129 | 149 |
| 7Ad16 | 5-15 | 4-7 | Massive Sandstone | Sandy Loam | 2-6 | Glacial Till | 1-100 | 135 | 164 |
| 7Ad17 | 5-15 | 4-7 | Sandstone | Sand | 0-2 | Sand & Gravel | 1-100 | 152 | 190 |
| 7Ad18 | 15-30 | 2-4 | Massive Sandstone | Sandy Loam | 18+ | Glacial Till | 1-100 | 90 | 106 |

| Setting | Depth to Water (ft) | Recharge (In/Yr) | Aquifer Media | Soil Media | Topography | Vadose Zone Media | Hydraulic Conductivity | Rating | Pest Rating |
|---|---|---|---|---|---|---|---|---|---|
| 7Ad19 | 15-30 | 4-7 | Massive Sandstone | Clay Loam | 0-2 | Sandstone | 1-100 | 120 | 142 |
| 7Ad20 | 5-15 | 4-7 | Sandstone | Silt Loam | 2-6 | Glacial Till | 1-100 | 116 | 142 |
| 7Ad21 | 15-30 | 2-4 | Sandstone | Silt Loam | 2-6 | Glacial Till | 1-100 | 94 | 120 |
| 7Ad22 | 5-15 | 4-7 | Sandstone | Silt Loam | 2-6 | Sand & Gravel | 1-100 | 141 | 162 |

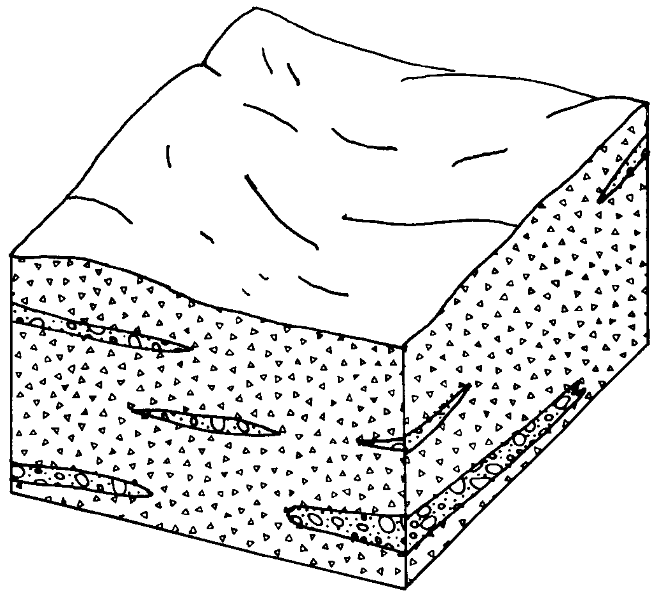


7Ae Glacial Till Over Massive Shale

This hydrogeologic setting is similar to (7Ad) Glacial Till Over Sandstone except that varying thicknesses of till overlie fractured, flat-lying shales. The till is principally unsorted deposits with interbedded lenses of loess and sand and gravel. Ground water is derived from either localized sources in the overlying till or from deeper, more permeable formations. The shale is relatively impermeable and does not serve as a source of ground water. Although precipitation is abundant, recharge is minimal from the till to deeper formations and occurs only by leakage of water through the fractures.

GWPP index values for the hydrogeologic setting of glacial till over massive shale range from 95 to 125 with the total number of GWPP index calculations equaling 17.

| Setting | Depth to Water (ft) | Recharge (In/Yr) | Aquifer Media | Soil Media | Topography | Vadose Zone Media | Hydraulic Conductivity | Rating | Pest Rating |
|---|---|---|---|---|---|---|---|---|---|
| 7Ae1 | 5-15 | 4-7 | Shale | Clay Loam | 0-2 | Glacial Till | 1-100 | 109 | 156 |
| 7Ae2 | 5-15 | 4-7 | Shale | Thin or Absent | 0-2 | Massive Shale | 1-100 | 133 | 177 |
| 7Ae3 | 5-15 | 4-7 | Shale | Shrink-Swell (Aggregated) Clay | 0-2 | Glacial Till | 1-100 | 117 | 154 |
| 7Ae4 | 5-15 | 4-7 | Shale | Silt Loam | 0-2 | Glacial Till | 1-100 | 111 | 139 |
| 7Ae5 | 15-30 | 4-7 | Shale | Clay Loam | 0-2 | Glacial Till | 1-100 | 99 | 124 |
| 7Ae6 | 5-15 | 4-7 | Shale | Clay Loam | 0-2 | Glacial Till | 1-100 | 124 | 146 |
| 7Ae7 | 5-15 | 4-7 | Shale | Clay Loam | 0-2 | Glacial Till | 1-100 | 119 | 142 |
| 7Ae8 | 5-15 | 4-7 | Shale | Sandy Loam | 0-2 | Glacial Till | 1-100 | 125 | 157 |
| 7Ae9 | 15-30 | 4-7 | Shale | Clay Loam | 0-2 | Glacial Till | 1-100 | 109 | 132 |
| 7Ae10 | 15-30 | 4-7 | Shale | Sandy Loam | 0-2 | Glacial Till | 1-100 | 120 | 151 |
| 7Ae11 | 5-15 | 4-7 | Shale | Clay Loam | 0-2 | Glacial Till | 1-100 | 112 | 137 |
| 7Ae12 | 5-15 | 4-7 | Shale | Clay Loam | 2-6 | Glacial Till | 1-100 | 111 | 134 |
| 7Ae13 | 5-15 | 4-7 | Shale | Silt Loam | 0-2 | Glacial Till | 1-100 | 114 | 142 |
| 7Ae14 | 5-15 | 4-7 | Shale | Clay Loam | 0-2 | Glacial Till | 1-100 | 117 | 141 |
| 7Ae15 | 5-15 | 4-7 | Shale | Thin or Absent | 0-2 | Glacial Till | 1-100 | 123 | 169 |
| 7Ae16 | 15-30 | 4-7 | Shale | Sandy Loam | 6-12 | Glacial Till | 1-100 | 110 | 132 |
| 7Ae17 | 5-15 | 2-4 | Shale | Clay Loam | 18+ | Glacial Till | 1-100 | 95 | 100 |
| 7Ae18 | 5-15 | 4-7 | Shale | Loam | 0-2 | Glacial Till | 1-100 | 113 | 144 |
| 7Ae19 | 15-30 | 4-7 | Shale | Sandy Loam | 2-6 | Glacial Till | 1-100 | 104 | 136 |
| 7Ae20 | 30-50 | 2-4 | Shale | Sandy Loam | 0-2 | Glacial Till | 1-100 | 83 | 117 |
| 7Ae21 | 5-15 | 4-7 | Shale | Loam | 0-2 | Glacial Till | 1-100 | 123 | 152 |

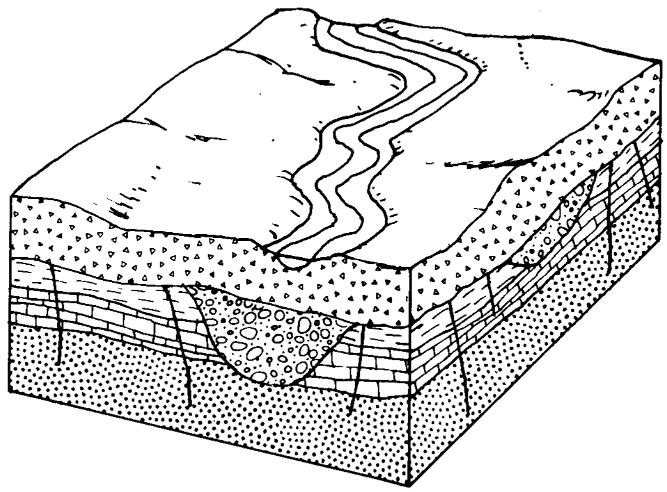


## 7Af Sand and Gravel Interbedded in Glacial Till

This hydrogeologic setting is characterized by low relief and sand and gravel deposits interbedded in glacial till. The till is composed primarily of clay with varying amounts of unsorted silt, sand, and gravel. The sand and gravel may be relatively thin and discontinuous, lens-shaped bodies, or thick layers which cover a large area. The thick units are usually confined to common horizons within the till. Ground water occurs in both the till and the sand and gravel; however, the sand and gravel serves as the principal aquifer. Recharge to the sand and gravel is primarily due to infiltration of precipitation through the till. Depth to water is highly variable, but averages around 30 feet. Soils are typically described as clay loams.

GWPP index values for the hydrogeologic setting of sand and gravel interbedded in glacial till range from 90 to 133 with the total number of GWPP index calculations equaling 7.

| Setting | Depth to Water (ft) | Recharge (In/Yr) | Aquifer Media | Soil Media | Topography | Vadose Zone Media | Hydraulic Conductivity | Rating | Pest Rating |
|---|---|---|---|---|---|---|---|---|---|
| 7Af1 | 15-30 | 2-4 | Sand & Gravel | Clay Loam | 0-2 | Glacial Till | 1-100 | 101 | 125 |
| 7Af2 | 15-30 | 2-4 | Sand & Gravel | Clay Loam | 2-6 | Glacial Till | 1-100 | 100 | 122 |
| 7Af3 | 30-50 | 2-4 | Sand & Gravel | Clay Loam | 2-6 | Glacial Till | 1-100 | 90 | 112 |
| 7Af4 | 15-30 | 4-7 | Sand & Gravel | Clay Loam | 0-2 | Glacial Till | 300-700 | 127 | 147 |
| 7Af5 | 15-30 | 4-7 | Sand & Gravel | Sandy Loam | 0-2 | Glacial Till | 300-700 | 133 | 162 |
| 7Af6 | 15-30 | 2-4 | Sand & Gravel | Clay Loam | 18+ | Glacial Till | 300-700 | 106 | 108 |
| 7Af7 | 5-15 | 4-7 | Sand & Gravel | Clay Loam | 0-2 | Glacial Till | 100-300 | 126 | 149 |
| 7Af8 | 30-50 | 4-7 | Sand & Gravel | Sandy Loam | 18+ | Glacial Till | 100-300 | 98 | 113 |
| 7Af9 | 15-30 | 4-7 | Sand & Gravel | Sandy Loam | 0-2 | Glacial Till | 100-300 | 117 | 150 |
| 7Af10 | 15-30 | 4-7 | Sand & Gravel | Silt Loam | 2-6 | S & G w/ Sl & Cl | 1-100 | 114 | 139 |

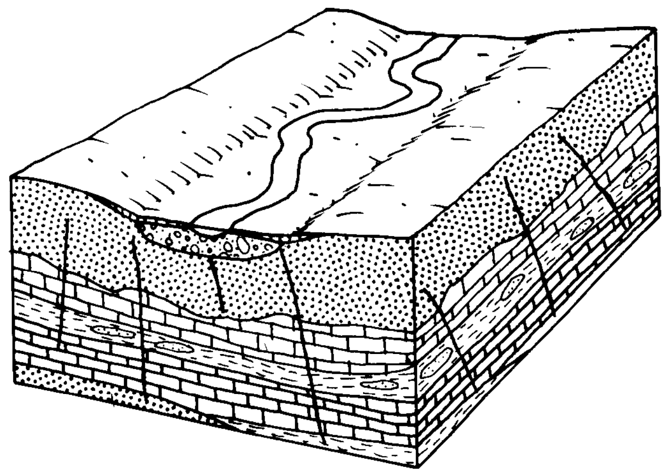


7D Buried Valley

This hydrogeologic 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 meltwaters. These deposits are capable of yielding large quanties 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. Soils are typically a sandy loam. Recharge to the sand and gravel is moderate and water levels are commonly relatively shallow, although they may be quite variable.

GWPP index values for the hydrogeologic setting of buried valley range from 76 to 146 with the total number of GWPP index calculations equaling 18.

| Setting | Depth to Water (ft) | Recharge (In/Yr) | Aquifer Media | Soil Media | Topography | Vadose Zone Media | Hydraulic Conductivity | Rating | Pest Rating |
|---|---|---|---|---|---|---|---|---|---|
| 7D1 | 50-75 | 2-4 | Sand & Gravel | Sand | 0-2 | Silt & Clay | 300-700 | 100 | 140 |
| 7D2 | 75-100 | 2-4 | Sand & Gravel | Sand | 0-2 | Silt & Clay | 300-700 | 93 | 134 |
| 7D3 | 50-75 | 2-4 | Sand & Gravel | Clay Loam | 18+ | Silt & Clay | 300-700 | 79 | 83 |
| 7D4 | 50-75 | 2-4 | Sand & Gravel | Clay Loam | 0-2 | Silt & Clay | 300-700 | 88 | 110 |
| 7D5 | 50-75 | 2-4 | Sand & Gravel | Silt Loam | 0-2 | Silt & Clay | 300-700 | 90 | 115 |
| 7D6 | 30-50 | 2-4 | Sand & Gravel | Silt Loam | 0-2 | Silt & Clay | 100-300 | 91 | 118 |
| 7D7 | 30-50 | 2-4 | Sand & Gravel | Sand | 0-2 | Silt & Clay | 100-300 | 101 | 143 |
| 7D8 | 30-50 | 2-4 | Sand & Gravel | Clay Loam | 0-2 | Silt & Clay | 300-700 | 98 | 120 |
| 7D9 | 30-50 | 2-4 | Sand & Gravel | Clay Loam | 12-18 | Silt & Clay | 100-300 | 82 | 92 |
| 7D10 | 30-50 | 2-4 | Sand & Gravel | Sand | 2-6 | Silt & Clay | 100-300 | 100 | 140 |
| 7D11 | 30-50 | 2-4 | Sand & Gravel | Silt Loam | 12-18 | Silt & Clay | 100-300 | 84 | 97 |
| 7D12 | 30-50 | 2-4 | Sand & Gravel | Clay Loam | 2-6 | Silt & Clay | 100-300 | 93 | 114 |
| 7D13 | 30-50 | 4-7 | Sand & Gravel | Sandy Loam | 12-18 | S & G w/ Sl & Cl | 100-300 | 110 | 127 |
| 7D14 | 15-30 | 2-4 | Sand & Gravel | Silt Loam | 2-6 | Silt & Clay | 100-300 | 105 | 129 |
| 7D15 | 15-30 | 2-4 | Sand & Gravel | Clay Loam | 0-2 | Silt & Clay | 100-300 | 104 | 127 |
| 7D16 | 15-30 | 4-7 | Sand & Gravel | Sand | 2-6 | S & G w/ Sl & Cl | 100-300 | 137 | 174 |
| 7D17 | 15-30 | 2-4 | Sand & Gravel | Silt Loam | 12-18 | Silt & Clay | 300-700 | 108 | 118 |
| 7D18 | 15-30 | 2-4 | Sand & Gravel | Silt Loam | 0-2 | Silt & Clay | 300-700 | 115 | 139 |
| 7D19 | 30-50 | 2-4 | Sand & Gravel | Sand | 0-2 | Silt & Clay | 300-700 | 110 | 150 |
| 7D20 | 30-50 | 2-4 | Sand & Gravel | Silt Loam | 0-2 | Silt & Clay | 300-700 | 100 | 125 |

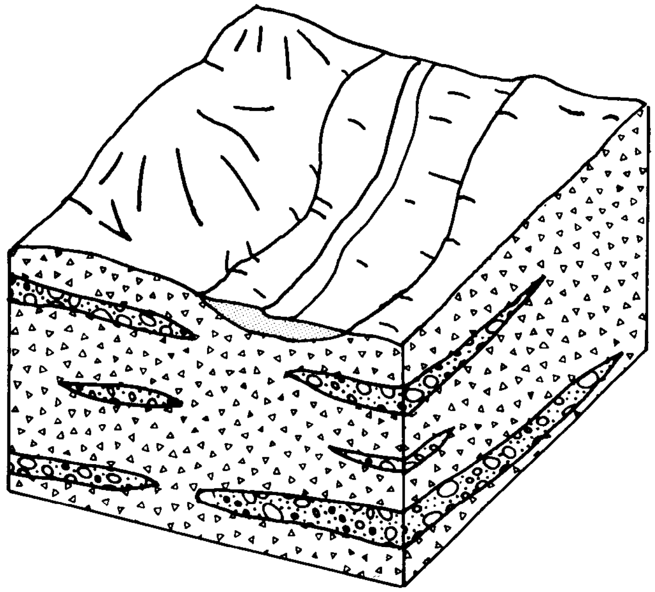


7Ec Alluvium Over Sedimentary Rock

This hydrogeologic setting is characterized by low relief with thin to moderate thicknesses of modern, stream-deposited alluvium. The alluvium is composed of silt, sand, gravel, and clay. Depth to water is shallow, and the stream is usually in hydraulic contact with the alluvial deposits. The alluvial deposits are underlain by fractured sandstone, limestone, shale, or bedded sedimentary sequences. These rocks are described in settings 7Ac, 7Ad, 7Ae, and 7Gb. Usually the upper, weathered portion of the bedrock serves as the principal aquifer in this setting. The alluvial deposits may serve as a source of recharge to the bedrock. Soils are typically silty loams.

GWPP index values for the hydrogeologic setting of alluvium over sedimentary rock range from 104 to 137 with the total number of GWPP index calculations equaling 6.

| Setting | Depth to Water (ft) | Recharge (In/Yr) | Aquifer Media | Soil Media | Topography | Vadose Zone Media | Hydraulic Conductivity | Rating | Pest Rating |
|---|---|---|---|---|---|---|---|---|---|
| 7Ec1 | 5-15 | 2-4 | Shale | Silt Loam | 18+ | S & G w/ Sl & Cl | 1-100 | 105 | 112 |
| 7Ec2 | 5-15 | 4-7 | Shale | Silt Loam | 0-2 | S & G w/ Sl & Cl | 1-100 | 126 | 151 |
| 7Ec3 | 5-15 | 4-7 | Sandstone | Clay Loam | 18+ | S & G w/ Sl & Cl | 1-100 | 126 | 129 |
| 7Ec4 | 5-15 | 7-10 | Shale | Silt Loam | 12-18 | Sand & Gravel | 1-100 | 137 | 146 |
| 7Ec5 | 0-5 | 4-7 | Shale | Silt Loam | 0-2 | S & G w/ Sl & Cl | 1-100 | 131 | 156 |
| 7Ec6 | 5-15 | 2-4 | Shale | Silt Loam | 0-2 | S & G w/ Sl & Cl | 1-100 | 104 | 131 |

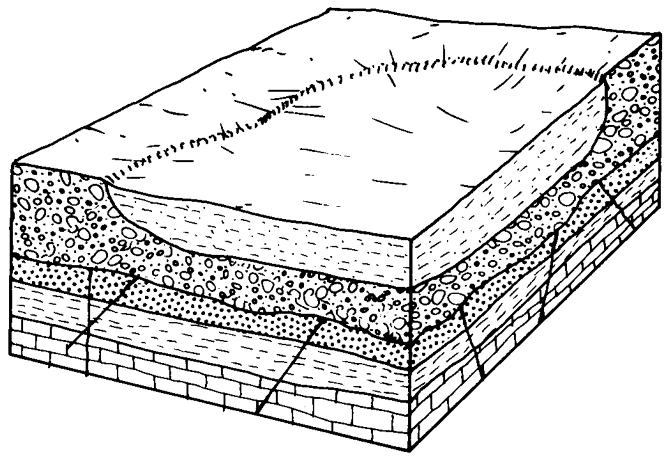


7Ed Alluvium Over Glacial Till

This hydrogeologic setting is characterized by low relief with thin to moderate thicknesses of modern, stream-deposited alluvium overlying glacial till. The alluvium is composed of silt, sand, gravel, and clay. The underlying sand and gravel lenses within the till serve as the aquifer. The depth to the water table is shallow, and the stream is usually in hydraulic connection with the alluvial deposits. Soils are typically classified as silty loams. The underlying till is described in setting 7Af. The alluvial deposits serve as a source of recharge for the sand and gravel lenses within the till. Recharge is moderately high.

GWPP index values for the hydrogeologic setting of alluvium over glacial till range from 129 to 178 with the total number of GWPP index calculations equaling 6.

| Setting | Depth to Water (ft) | Recharge (In/Yr) | Aquifer Media | Soil Media | Topography | Vadose Zone Media | Hydraulic Conductivity | Rating | Pest Rating |
|---|---|---|---|---|---|---|---|---|---|
| 7Ed1 | 5-15 | 4-7 | Sand & Gravel | Silt Loam | 18+ | S & G w/ Sl & Cl | 300-700 | 138 | 142 |
| 7Ed2 | 5-15 | 4-7 | Sand & Gravel | Silt Loam | 0-2 | S & G w/ Sl & Cl | 300-700 | 152 | 173 |
| 7Ed3 | 0-5 | 7-10 | Sand & Gravel | Peat | 0-2 | S & G w/ Sl & Cl | 300-700 | 178 | 210 |
| 7Ed4 | 15-30 | 4-7 | Sand & Gravel | Silt Loam | 6-12 | S & G w/ Sl & Cl | 300-700 | 132 | 144 |
| 7Ed5 | 5-15 | 4-7 | Sand & Gravel | Silt Loam | 6-12 | S & G w/ Sl & Cl | 100-300 | 133 | 147 |
| 7Ed6 | 5-15 | 4-7 | Sand & Gravel | Silt Loam | 2-6 | S & G w/ Sl & Cl | 300-700 | 138 | 159 |
| 7Ed7 | 5-15 | 4-7 | Sand & Gravel | Silt Loam | 0-2 | S & G w/ Sl & Cl | 100-300 | 133 | 158 |



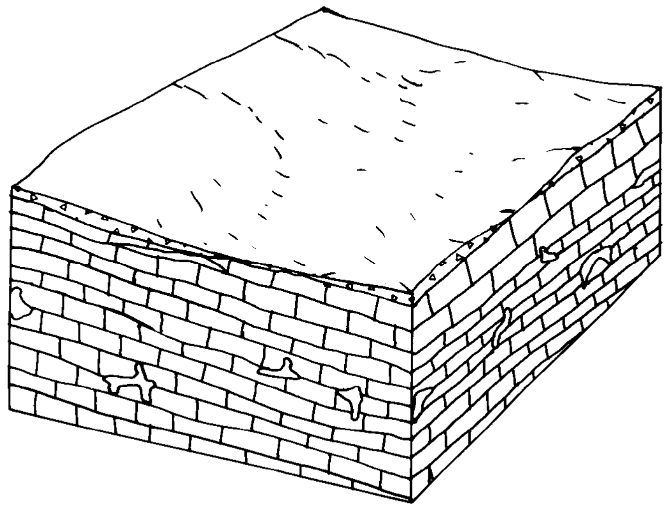
7F Glacial Lake Deposits

This hydrogeologic setting is characterized by flat topography and varying thicknesses of fine-graned sediments that overlie sequences of fractured sedimentary rocks. The deposits are composed of fine-grained silts and clays interlayered with fine sand that settled out in glacial lakes and exhibit alternating layers relating to seasonal fluctuations. As a consequence of the thin, alternating layers there is a substantial difference between the vertical and horizontal permeability with the horizontal commonly two or more orders of magnitude greater than the vertical. Due to their fine-grained nature, these deposits typically weather to organic-rich sandy loam with a range in permeabilities reflecting variations in sand content. Underlying glacial deposits or bedrock serve as the major source of ground water in the region. Although precipitation is abundant, recharge is controlled by the permeability of the surface clays; however, in all instances recharge is moderately high because of the impact of the low topography. Water levels are variable, depending on the thickness of the lake sediments and the underlying materials.

GWPP index values for the hydrogeologic setting of glacial lake deposits range from 92 to 195 with the total number of GWPP index calculations equaling 52.

| Setting | Depth to Water (ft) | Recharge (In/Yr) | Aquifer Media | Soil Media | Topography | Vadose Zone Media | Hydraulic Conductivity | Rating | Pest Rating |
|---|---|---|---|---|---|---|---|---|---|
| 7F1 | 5-15 | 7-10 | Massive Limestone | Thin or Absent | 0-2 | Karst Limestone | 1000-2000 | 195 | 229 |
| 7F2 | 5-15 | 4-7 | Massive Limestone | Silt Loam | 0-2 | S & G w/ Sl & Cl | 1000-2000 | 165 | 183 |
| 7F3 | 5-15 | 4-7 | Massive Limestone | Silt Loam | 2-6 | S & G w/ Sl & Cl | 1000-2000 | 164 | 180 |
| 7F4 | 5-15 | 4-7 | Massive Limestone | Clay Loam | 2-6 | S & G w/ Sl & Cl | 1000-2000 | 162 | 175 |
| 7F5 | 5-15 | 4-7 | Massive Limestone | Clay Loam | 0-2 | S & G w/ Sl & Cl | 700-1000 | 151 | 168 |
| 7F6 | 5-15 | 4-7 | Massive Limestone | Shrink-Swell (Aggregated) Clay | 0-2 | S & G w/ Sl & Cl | 700-1000 | 159 | 188 |
| 7F7 | 5-15 | 7-10 | Massive Limestone | Thin or Absent | 0-2 | Massive Limestone | 700-1000 | 178 | 215 |
| 7F8 | 5-15 | 4-7 | Massive Limestone | Silt Loam | 0-2 | S & G w/ Sl & Cl | 700-1000 | 148 | 169 |
| 7F9 | 5-15 | 4-7 | Massive Limestone | Clay Loam | 0-2 | S & G w/ Sl & Cl | 700-1000 | 146 | 164 |
| 7F10 | 5-15 | 4-7 | Massive Limestone | Clay Loam | 2-6 | S & G w/ Sl & Cl | 700-1000 | 145 | 161 |
| 7F11 | 5-15 | 4-7 | Massive Limestone | Silt Loam | 0-2 | S & G w/ Sl & Cl | 1000-2000 | 160 | 179 |
| 7F12 | 5-15 | 4-7 | Massive Limestone | Clay Loam | 0-2 | S & G w/ Sl & Cl | 1000-2000 | 158 | 174 |
| 7F13 | 5-15 | 4-7 | Massive Limestone | Clay Loam | 0-2 | Karst Limestone | 1000-2000 | 173 | 186 |

| Setting | Depth to Water (ft) | Recharge (In/Yr) | Aquifer Media | Soil Media | Topography | Vadose Zone Media | Hydraulic Conductivity | Rating | Pest Rating |
|---|---|---|---|---|---|---|---|---|---|
| 7F14 | 0-5 | 2-4 | Karst Limestone | Shrink-Swell (Aggregated) Clay | 0-2 | Silt & Clay | 2000+ | 153 | 182 |
| 7F15 | 5-15 | 4-7 | Massive Limestone | Silt Loam | 0-2 | Karst Limestone | 1000-2000 | 175 | 191 |
| 7F16 | 5-15 | 4-7 | Massive Limestone | Clay Loam | 0-2 | S & G w/ Sl & Cl | 1000-2000 | 163 | 178 |
| 7F17 | 5-15 | 4-7 | Massive Limestone | Shrink-Swell (Aggregated) Clay | 0-2 | S & G w/ Sl & Cl | 1000-2000 | 171 | 198 |
| 7F18 | 5-15 | 4-7 | Massive Limestone | Shrink-Swell (Aggregated) Clay | 0-2 | S & G w/ Sl & Cl | 1000-2000 | 176 | 202 |
| 7F19 | 5-15 | 2-4 | Karst Limestone | Shrink-Swell (Aggregated) Clay | 0-2 | Silt & Clay | 2000+ | 148 | 177 |
| 7F20 | 5-15 | 4-7 | Karst Limestone | Clay Loam | 2-6 | Silt & Clay | 2000+ | 164 | 177 |
| 7F21 | 5-15 | 4-7 | Massive Limestone | Shrink-Swell (Aggregated) Clay | 0-2 | Karst Limestone | 1000-2000 | 191 | 214 |
| 7F22 | 5-15 | 2-4 | Karst Limestone | Clay Loam | 0-2 | Silt & Clay | 2000+ | 150 | 165 |
| 7F23 | 0-5 | 2-4 | Karst Limestone | Sand | 0-2 | Silt & Clay | 2000+ | 157 | 192 |
| 7F24 | 0-5 | 2-4 | Karst Limestone | Shrink-Swell (Aggregated) Clay | 0-2 | Silt & Clay | 2000+ | 163 | 190 |
| 7F25 | 5-15 | 4-7 | Shale | Clay Loam | 2-6 | S & G w/ Sl & Cl | 1-100 | 123 | 143 |
| 7F26 | 5-15 | 4-7 | Sandstone | Clay Loam | 0-2 | S & G w/ Sl & Cl | 1-100 | 130 | 152 |
| 7F27 | 0-5 | 2-4 | Karst Limestone | Silt Loam | 0-2 | Silt & Clay | 2000+ | 147 | 167 |
| 7F28 | 5-15 | 2-4 | Karst Limestone | Sand | 0-2 | Silt & Clay | 2000+ | 152 | 187 |
| 7F29 | 30-50 | 4-7 | Karst Limestone | Sand | 2-6 | Silt & Clay | 2000+ | 161 | 191 |
| 7F30 | 5-15 | 4-7 | Shale | Silt Loam | 0-2 | Silt & Clay | 1-100 | 116 | 143 |
| 7F31 | 5-15 | 4-7 | Shale | Silt Loam | 2-6 | Silt & Clay | 1-100 | 115 | 140 |
| 7F32 | 5-15 | 4-7 | Shale | Thin or Absent | 2-6 | Shale | 1-100 | 132 | 174 |
| 7F33 | 5-15 | 4-7 | Shale | Clay Loam | 0-2 | Silt & Clay | 1-100 | 114 | 138 |
| 7F34 | 5-15 | 4-7 | Shale | Clay Loam | 2-6 | Silt & Clay | 1-100 | 113 | 135 |
| 7F35 | 5-15 | 4-7 | Shale | Shrink-Swell (Aggregated) Clay | 0-2 | Silt & Clay | 1-100 | 122 | 158 |
| 7F36 | 15-30 | 2-4 | Sand & Gravel | Silt Loam | 12-18 | Silt & Clay | 100-300 | 99 | 111 |
| 7F37 | 15-30 | 2-4 | Sand & Gravel | Clay Loam | 12-18 | Silt & Clay | 100-300 | 97 | 106 |
| 7F38 | 15-30 | 4-7 | Sand & Gravel | Silt Loam | 2-6 | Silt & Clay | 100-300 | 117 | 141 |
| 7F39 | 15-30 | 4-7 | Sand & Gravel | Silt Loam | 0-2 | Silt & Clay | 100-300 | 118 | 144 |
| 7F40 | 15-30 | 4-7 | Sand & Gravel | Clay Loam | 0-2 | Silt & Clay | 100-300 | 116 | 139 |
| 7F41 | 5-15 | 4-7 | Sand & Gravel | Silt Loam | 0-2 | Silt & Clay | 100-300 | 128 | 154 |
| 7F42 | 5-15 | 2-4 | Sand & Gravel | Silt Loam | 6-12 | Silt & Clay | 100-300 | 111 | 127 |
| 7F43 | 5-15 | 2-4 | Shale | Silt Loam | 0-2 | Silt & Clay | 1-100 | 99 | 127 |
| 7F44 | 5-15 | 2-4 | Shale | Clay Loam | 0-2 | Silt & Clay | 1-100 | 97 | 122 |
| 7F45 | 5-15 | 2-4 | Shale | Loam | 0-2 | S & G w/ Sl & Cl | 1-100 | 106 | 136 |
| 7F46 | 5-15 | 2-4 | Shale | Clay Loam | 0-2 | S & G w/ Sl & Cl | 1-100 | 102 | 126 |
| 7F47 | 15-30 | 2-4 | Sand & Gravel | Clay Loam | 0-2 | S & G w/ Sl & Cl | 1-100 | 101 | 125 |
| 7F48 | 15-30 | 2-4 | Sand & Gravel | Clay Loam | 18+ | S & G w/ Sl & Cl | 1-100 | 92 | 98 |
| 7F49 | 15-30 | 2-4 | Shale | Silt Loam | 0-2 | S & G w/ Sl & Cl | 1-100 | 94 | 121 |
| 7F50 | 5-15 | 4-7 | Shale | Silt Loam | 0-2 | S & G w/ Sl & Cl | 1-100 | 126 | 151 |
| 7F51 | 5-15 | 4-7 | Sandstone | Silt Loam | 0-2 | S & G w/ Sl & Cl | 1-100 | 132 | 157 |
| 7F52 | 5-15 | 4-7 | Shale | Clay Loam | 0-2 | S & G w/ Sl & Cl | 1-100 | 124 | 146 |



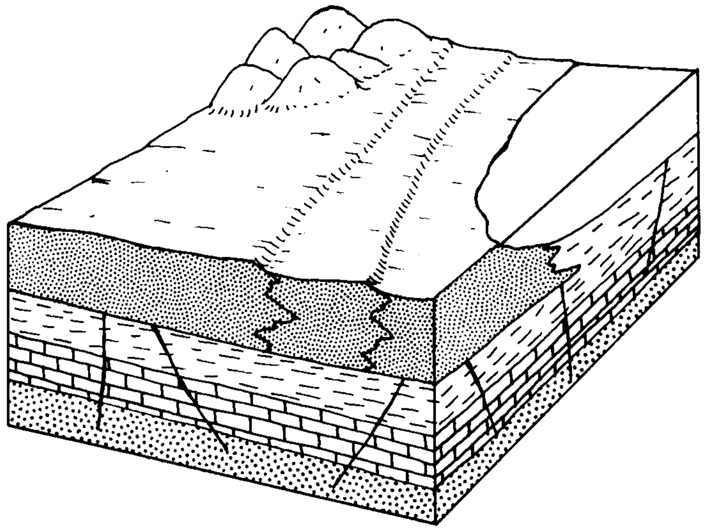
## 7Gb Thin Till Over Limestone

This hydrogeologic setting is characterized by thin deposits of glacial till overlying limestone bedrock. In some areas the limestone is directly overlain by shale. The till and soil are usually very thin or absent in areas of steep relief. Till consists primarily of clay with little, if any, sand and gravel and does not serve as a source of water. Ground water is obtained from the upper, weathered, and solutioned portion of the limestone. Recharge is generally low due to the steep relief and the presence of restrictive shale. Depth to water is fairly shallow where the shale is absent, but deepens with increased thickness of shale.

GWPP index values for the hydrogeologic setting of thin till over limestone range from 166 to 211 with the total number of GWPP index calculations equaling 19.

| Setting | Depth to Water (ft) | Recharge (In/Yr) | Aquifer Media | Soil Media | Topography | Vadose Zone Media | Hydraulic Conductivity | Rating | Pest Rating |
|---|---|---|---|---|---|---|---|---|---|
| 7Gb1 | 15-30 | 4-7 | Karst Limestone | Thin or Absent | 2-6 | Karst Limestone | 2000+ | 198 | 226 |
| 7Gb2 | 5-15 | 7-10 | Massive Limestone | Thin or Absent | 0-2 | Karst Limestone | 1000-2000 | 195 | 229 |
| 7Gb3 | 15-30 | 4-7 | Massive Limestone | Thin or Absent | 2-6 | Karst Limestone | 1000-2000 | 176 | 208 |
| 7Gb4 | 15-30 | 7-10 | Massive Limestone | Thin or Absent | 0-2 | Karst Limestone | 1000-2000 | 185 | 219 |
| 7Gb5 | 30-50 | 4-7 | Massive Limestone | Thin or Absent | 2-6 | Karst Limestone | 1000-2000 | 166 | 198 |
| 7Gb6 | 5-15 | 4-7 | Massive Limestone | Thin or Absent | 2-6 | Karst Limestone | 1000-2000 | 186 | 218 |
| 7Gb7 | 5-15 | 7-10 | Massive Limestone | Thin or Absent | 0-2 | Karst Limestone | 1000-2000 | 195 | 229 |
| 7Gb8 | 15-30 | 10+ | Karst Limestone | Thin or Absent | 2-6 | Karst Limestone | 2000+ | 210 | 238 |
| 7Gb9 | 30-50 | 10+ | Karst Limestone | Thin or Absent | 2-6 | Karst Limestone | 2000+ | 200 | 228 |
| 7Gb10 | 5-15 | 7-10 | Massive Limestone | Thin or Absent | 2-6 | Karst Limestone | 1000-2000 | 194 | 226 |
| 7Gb11 | 15-30 | 10+ | Karst Limestone | Thin or Absent | 0-2 | Karst Limestone | 2000+ | 211 | 241 |
| 7Gb12 | 50-75 | 10+ | Karst Limestone | Thin or Absent | 2-6 | Karst Limestone | 2000+ | 190 | 218 |
| 7Gb13 | 75-100 | 10+ | Karst Limestone | Thin or Absent | 2-6 | Karst Limestone | 2000+ | 185 | 213 |
| 7Gb14 | 50-75 | 4-7 | Karst Limestone | Thin or Absent | 12-18 | Karst Limestone | 2000+ | 172 | 188 |

| Setting | Depth to Water (ft) | Recharge (In/Yr) | Aquifer Media | Soil Media | Topography | Vadose Zone Media | Hydraulic Conductivity | Rating | Pest Rating |
|---|---|---|---|---|---|---|---|---|---|
| 7Gb15 | 75-100 | 4-7 | Karst Limestone | Thin or Absent | 12-18 | Karst Limestone | 2000+ | 167 | 183 |
| 7Gb16 | 75-100 | 10+ | Karst Limestone | Thin or Absent | 0-2 | Karst Limestone | 2000+ | 186 | 216 |
| 7Gb17 | 50-75 | 10+ | Karst Limestone | Thin or Absent | 0-2 | Karst Limestone | 2000+ | 191 | 221 |
| 7Gb18 | 30-50 | 4-7 | Karst Limestone | Thin or Absent | 12-18 | Karst Limestone | 2000+ | 182 | 198 |
| 7Gb19 | 75-100 | 10+ | Karst Limestone | Thin or Absent | 6-12 | Karst Limestone | 2000+ | 181 | 201 |



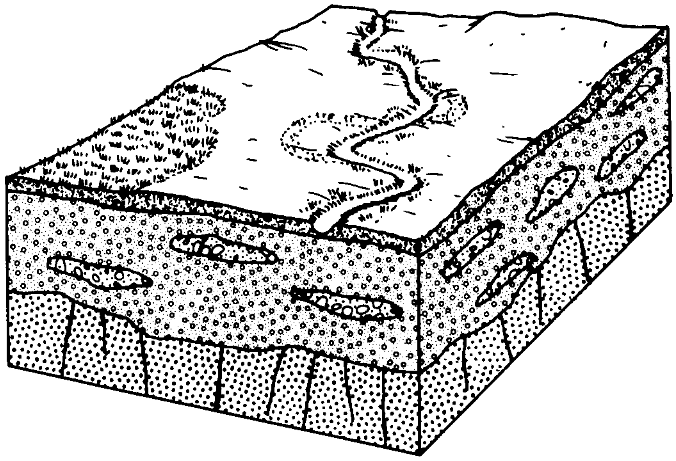
7H Beaches, Beach Ridges and Sand Dunes

This hydrogeologic setting is characterized by low relief, sandy surface soil that is predominantly silica sand, extremely high infiltration rates, and low sorptive capacity in the thin vadose zone. The water table is very shallow beneath the beaches bordering the Great Lakes. These beaches are commonly ground-water discharge areas. The water table is slightly deeper beneath the rolling dune topography and the vestigial inland beach ridges. All of these areas serve as recharge sources for the underlying sedimentary bedrock aquifers, and they often serve as local sources of water supply.

GWPP index values for the hydrogeologic setting of beaches, beach ridges and sand dunes range from 115 to 200 with the total number of GWPP index calculations equaling 41.

| Setting | Depth to Water (ft) | Recharge (In/Yr) | Aquifer Media | Soil Media | Topography | Vadose Zone Media | Hydraulic Conductivity | Rating | Pest Rating |
|---|---|---|---|---|---|---|---|---|---|
| 7H1 | 0-5 | 7-10 | Sand & Gravel | Sand | 0-2 | Sand & Gravel | 700-1000 | 200 | 232 |
| 7H2 | 5-15 | 7-10 | Massive Limestone | Sand | 0-2 | Sand & Gravel | 1000-2000 | 188 | 220 |
| 7H3 | 5-15 | 7-10 | Massive Limestone | Sand | 2-6 | Sand & Gravel | 1000-2000 | 187 | 217 |
| 7H4 | 5-15 | 7-10 | Massive Limestone | Sand | 0-2 | Sand & Gravel | 700-1000 | 176 | 210 |
| 7H5 | 5-15 | 7-10 | Massive Limestone | Sandy Loam | 0-2 | Sand & Gravel | 700-1000 | 170 | 195 |
| 7H6 | 5-15 | 7-10 | Shale | Sand | 2-6 | Sand & Gravel | 1-100 | 148 | 185 |
| 7H7 | 15-30 | 7-10 | Massive Limestone | Sand | 0-2 | Sand & Gravel | 1000-2000 | 178 | 210 |
| 7H8 | 5-15 | 7-10 | Massive Limestone | Sand | 0-2 | Karst Limestone | 1000-2000 | 193 | 224 |
| 7H9 | 5-15 | 7-10 | Massive Limestone | Sandy Loam | 0-2 | Sand & Gravel | 1000-2000 | 182 | 205 |
| 7H10 | 15-30 | 10+ | Karst Limestone | Sand | 2-6 | Karst Limestone | 2000+ | 208 | 233 |
| 7H11 | 75-100 | 10+ | Karst Limestone | Sand | 2-6 | Karst Limestone | 2000+ | 183 | 208 |
| 7H12 | 5-15 | 4-7 | Sandstone | Loam | 0-2 | S & G w/ Sl & Cl | 1-100 | 139 | 166 |
| 7H13 | 30-50 | 4-7 | Massive Limestone | Sand | 12-18 | Karst Limestone | 1000-2000 | 158 | 175 |
| 7H14 | 15-30 | 4-7 | Massive Limestone | Sandy Loam | 2-6 | S & G w/ Sl & Cl | 1000-2000 | 158 | 180 |
| 7H15 | 30-50 | 4-7 | Karst Limestone | Sand | 6-12 | Karst Limestone | 2000+ | 182 | 199 |
| 7H16 | 50-75 | 4-7 | Karst Limestone | Sand | 18+ | Karst Limestone | 2000+ | 168 | 177 |
| 7H17 | 50-75 | 4-7 | Karst Limestone | Sand | 2-6 | Karst Limestone | 2000+ | 176 | 201 |
| 7H18 | 5-15 | 7-10 | Shale | Sand | 2-6 | Sand & Gravel | 1-100 | 148 | 185 |
| 7H19 | 5-15 | 4-7 | Shale | Sand | 0-2 | S & G w/ Sl & Cl | 1-100 | 131 | 172 |
| 7H20 | 5-15 | 4-7 | Shale | Sandy Loam | 2-6 | Sand & Gravel | 1-100 | 134 | 162 |
| 7H21 | 5-15 | 4-7 | Shale | Sandy Loam | 0-2 | Sand & Gravel | 1-100 | 135 | 165 |
| 7H22 | 15-30 | 4-7 | Sand & Gravel | Sandy Loam | 0-2 | S & G w/ Sl & Cl | 100-300 | 130 | 161 |

| Setting | Depth to Water (ft) | Recharge (In/Yr) | Aquifer Media | Soil Media | Topography | Vadose Zone Media | Hydraulic Conductivity | Rating | Pest Rating |
|---|---|---|---|---|---|---|---|---|---|
| 7H23 | 15-30 | 4-7 | Sand & Gravel | Sand | 0-2 | S & G w/ Sl & Cl | 100-300 | 136 | 176 |
| 7H24 | 15-30 | 4-7 | Shale | Sandy Loam | 0-2 | S & G w/ Sl & Cl | 1-100 | 115 | 147 |
| 7H25 | 15-30 | 4-7 | Sand & Gravel | Sand | 2-6 | Sand & Gravel | 100-300 | 145 | 181 |
| 7H26 | 5-15 | 7-10 | Shale | Sand | 2-6 | Sand & Gravel | 1-100 | 153 | 189 |
| 7H27 | 5-15 | 7-10 | Shale | Sandy Loam | 2-6 | Sand & Gravel | 1-100 | 147 | 174 |
| 7H28 | 5-15 | 4-7 | Shale | Loam | 0-2 | Sand & Gravel | 1-100 | 138 | 164 |
| 7H29 | 15-30 | 7-10 | Shale | Sand | 2-6 | Sand & Gravel | 1-100 | 143 | 179 |
| 7H30 | 5-15 | 7-10 | Sandstone | Sandy Loam | 2-6 | Sand & Gravel | 1-100 | 153 | 180 |
| 7H31 | 5-15 | 7-10 | Sandstone | Sand | 2-6 | Sand & Gravel | 1-100 | 159 | 195 |
| 7H32 | 15-30 | 7-10 | Sandstone | Sand | 2-6 | Sand & Gravel | 1-100 | 149 | 185 |
| 7H33 | 15-30 | 4-7 | Sandstone | Sand | 12-18 | Sand & Gravel | 1-100 | 135 | 159 |
| 7H34 | 15-30 | 7-10 | Sandstone | Sandy Loam | 2-6 | Sand & Gravel | 1-100 | 143 | 170 |
| 7H35 | 5-15 | 7-10 | Shale | Sandy Loam | 0-2 | Sand & Gravel | 1-100 | 148 | 177 |
| 7H36 | 5-15 | 4-7 | Shale | Loam | 0-2 | Sand & Gravel | 1-100 | 138 | 164 |
| 7H37 | 5-15 | 4-7 | Shale | Thin or Absent | 12-18 | Shale | 1-100 | 126 | 156 |
| 7H38 | 5-15 | 4-7 | Shale | Sand | 12-18 | Sand & Gravel | 1-100 | 139 | 163 |
| 7H39 | 15-30 | 4-7 | Shale | Sandy Loam | 0-2 | Sand & Gravel | 1-100 | 120 | 151 |
| 7H40 | 5-15 | 7-10 | Sandstone | Sandy Loam | 0-2 | Sand & Gravel | 1-100 | 154 | 183 |
| 7H41 | 5-15 | 7-10 | Sandstone | Thin or Absent | 2-6 | Sandstone | 1-100 | 151 | 192 |



7I Swamp / Marsh

This hydrogeologic setting is characterized by low topographic relief, high water levels and high organic silt and clay deposits. These wetlands occur along the courses of floodplains and in upland areas as a result of vertically restricted drainage. Common features of upland wetlands include those characteristics attributable to glacial activity such as filled-in glacial lakes, potholes, and cranberry bogs. Recharge is moderate in most of the region due to restriction by clay-rich soils and limited by precipitation. The swamp deposits very rarely serve as significant aquifers but frequently recharge the underlying sand and gravel or bedrock aquifers.

GWPP index values for the hydrogeologic setting of swamp / marsh range from 147 to 175 with the total number of GWPP index calculations equaling 3.

| Setting | Depth to Water (ft) | Recharge (In/Yr) | Aquifer Media | Soil Media | Topography | Vadose Zone Media | Hydraulic Conductivity | Rating | Pest Rating |
|---|---|---|---|---|---|---|---|---|---|
| 7I1 | 0-5 | 7-10 | Massive Limestone | Peat | 0-2 | Silt & Clay | 700-1000 | 174 | 206 |
| 7I2 | 0-5 | 7-10 | Karst Limestone | Peat | 0-2 | Silt & Clay | 2000+ | 195 | 223 |
| 7I3 | 0-5 | 7-10 | Shale | Peat | 0-2 | Silt & Clay | 1-100 | 147 | 184 |

**ERRATA SHEET**
**ERIE COUNTY**

## Ground Water Pollution Potential ReportNo. 16

Label error on map:

“7Ac2 “ (Directly above the township name OXFORD) should be “7Ae2”.

# Ground-Water Pollution Potential of ERIE COUNTY

by
Kelly C. Smith
ERM-Midwest, Inc.

Prepared in cooperation with
Ohio Department of Natural Resources, Division of Water

1 0 1 2 Miles
1 0 1 2 Kilometers
CONTOUR INTERVAL 5 FEET

County Line
Township Line
Incorporated City Limit

**Pollution Potential Index Range**

| | |
|---|---|
| Higher | 200+ |
| | 180 - 199 |
| | 160 - 179 |
| to | 140 - 159 |
| | 120 - 139 |
| | 100 - 119 |
| | 80 - 99 |
| Lower | <79 |

**Description of Map Symbols**

Hydrogeologic Region → 7Ad 6 ← Hydrogeologic Setting
98 ← Relative Pollution Potential

Gravel Pit / Quarry

**Hydrogeologic Settings**

- 7Ac - Glacial Till Over Solution Limestone
- 7Ad - Glacial Till Over Sandstone
- 7Ae - Glacial Till Over Shale
- 7Af - Sand and Gravel Interbedded in Glacial Till
- 7D - Buried Valley
- 7Ec - River Alluvium Over Sedimentary Bedrock
- 7Ed - River Alluvium Over Glacial Till
- 7F - Glacial Lake Plain Deposits
- 7Gb - Thin Glacial Till Over Limestone
- 7H - Beaches, Beach Ridges and Sand Dunes
- 7I - Marshes and Swamps

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)".

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 Erie County", GWPP Report No. 16, Ohio Department of Natural Resources, Division of Water.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Ground-Water Resources Section
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Columbus, Ohio 43224

David S. Orr, Cartographer

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Publication date: 9/90

ODNR Ohio Department of Natural Resources
Richard F. Celeste, Governor
Joseph J. Sommer, Director