GROUND WATER POLLUTION POTENTIAL OF SANDUSKY COUNTY, OHIO

BY

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ABSTRACT

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

Hydrogeologic settings incorporate the major hydrogeologic factors that control ground water movement and occurrence including depth to water, net recharge, aquifer media, soil media, topography, impact of the vadose zone media, and hydraulic conductivity of the aquifer. The relative ranking scheme uses a combination of weights and ratings to produce a numerical value called the pollution potential index that helps prioritize areas with respect to ground water contamination vulnerability. Hydrogeologic settings and the corresponding pollution potential indexes are displayed graphically on maps.

Both general and pesticide DRASTIC maps were prepared for Sandusky County. General DRASTIC evaluates an area's relative susceptibility to a contaminant that has the mobility of water, whereas, pesticide DRASTIC evaluates areas with respect to ground water contamination vulnerabiltiy to pesticides.

Sandusky County lies within the Glaciated Central hydrogeologic region. The county is covered by variable thicknesses of glacial till, lacustrine deposits and beach ridges. The glacial deposits are underlain by limestones and dolomites that are capable of supplying large quantities of ground water. Pollution potential indexes are relatively low to moderate in areas of thick till or lacustrine cover. Karst limestone occurs in the eastern portion of the County representing areas of very high vulnerability to contamination. The County is crossed by a buried valley that contains sands and gravels overlain by tills that has a moderate vulnerability to contamination. Beach ridges and areas of shallow bedrock also exhibit a relatively high vulnerabiltiy. Eight hydrogeologic settings were identified in Sandusky County with computed ground water pollution potential indexes ranging from 99 to 197 for general DRASTIC and 122 to 218 for pesticide DRASTIC.

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

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INTRODUCTION

The need for protection and management of ground water resources in Ohio has been clearly recognized. About 42 per cent of Ohio citizens rely on ground water for their drinking and household uses from both municipal and private wells. Industry and agriculture also utilize significant quantities of ground water for processing and irrigation. In Ohio, approximately 700,000 rural households depend on private wells; about 4,500 of these wells exist in Sandusky 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 cleanup of a polluted aquifer. Based on these concerns for protection of the resource, staff of the Division of Water conducted a review of various mapping strategies useful for identifying vulnerable aquifer areas. They placed particular emphasis on reviewing mapping systems that would assist in state and local protection and management programs. Based on these factors and the quantity and quality of available data on ground water resources, the DRASTIC mapping process (Aller et al., 1987) was selected for application in the program.

Considerable interest in the mapping program followed successful production of a demonstration county map and led to the inclusion of the program as a recommended initiative in the Ohio Ground Water Protection and Management Strategy (Ohio EPA, 1986). Based on this recommendation, the Ohio General Assembly funded the mapping program. A dedicated mapping unit has been established in the Division of Water, Ground Water Resources Section, to implement the ground water pollution potential mapping program on a county-wide basis in Ohio.

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

APPLICATIONS OF POLLUTION POTENTIAL MAPS

The pollution potential mapping program offers a wide variety of applications in many counties. The general and pesticide ground water pollution potential maps of Sandusky County have 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 cleanup 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 sucessfully where non-point source contamination is a concern. Non-point source contamination occurs where land use activities over large areas impact water quality. Maps providing information on relative vulnerability can be used to guide the selection and implementation of appropriate best management practices in different areas. Best management practices should be chosen based upon consideration of the chemical and physical processes that occur from the practice, and the effect these processes may have in areas of moderate to high vulnerability to contamination. For example, the use of agricultural best management practices that limit the infiltration of nitrates, or promote denitrification above the water table, would be benefical 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 cleanup 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.

A specialized version of the DRASTIC mapping process, known as pesticide DRASTIC, has also been produced in Sandusky County. Pesticide DRASTIC evaluates an areas relative vulnerability to contamination by pesticides through consideration of important processes that offset pesticide fate and transport. Maps produced using both general and pesticide DRASTIC are located in the pocket at the end of this report.

Hydrogeologic Settings and Factors

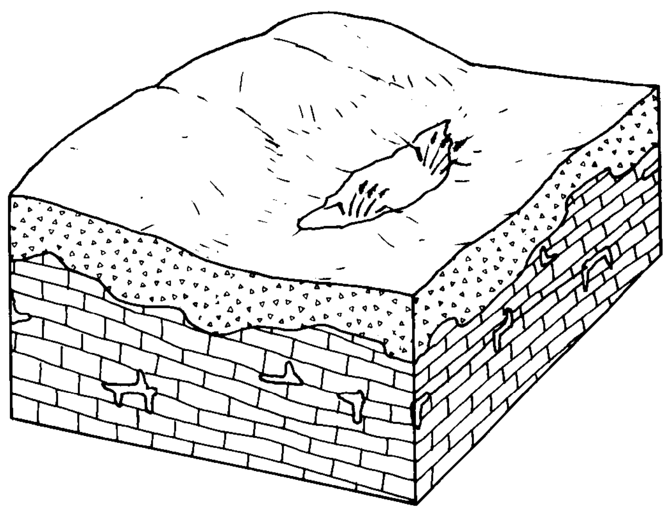
To facilitate the designation of mappable units, the DRASTIC system uses the framework of an existing classification system developed by Heath (1984), which divides the United States into fifteen ground water regions based on the factors in a ground water system that affect occurrence and availability.

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 Sandusky 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. Both forms of DRASTIC (general and pesticide) evaluate the same seven factors in the same way.



7Ac Glacial Till Over Solution Limestone

This hydrogeologic setting is characterized by low relief and limestone or dolomite bedrock which is covered by varying thicknesses of glacial till. The till is a principally unsorted deposit which may be locally interbedded with sand, gravel, or silt. Surficial deposits have usually weathered to a high shrink-swell (aggregated) clay or clay loam. The uppermost till surface may have been slightly modified or obscured by ancient lakeshore processes. Although ground water occurs in both the glacial deposits and in the underlying bedrock, the limestone or dolomite constitutes the principal aquifer. The carbonate (limestone and dolomite) units are variable, including karst limestones with well developed networks of solution channels; solution limestone, which has somewhat less well developed solution cavities; and massive limestones which are highly fractured, but lack appreciable solution features. The limestone is in direct contact with the overlying till and the till serves as a source of recharge. Recharge is moderate due to the clayey nature of the overlying till, but may be high in areas where the tills are thin. Depth to water is extremely variable, but is generally quite shallow in areas of massive and solution limestone and very deep in the regions of karst limestone. Localized, regions of ground water discharge exist. These regions are characterized by flowing (artesian) wells.

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

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 mediaaccounts for the various physical characteristics of the rock that provide mechanisms of attenuation, retardation and flow pathways that affect a contaminant reaching and moving through an aquifer.

Soil media refers to the upper six feet of the unsaturated zone that is characterized by significant biological activity. The type of soil media 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 significantly differs. 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	

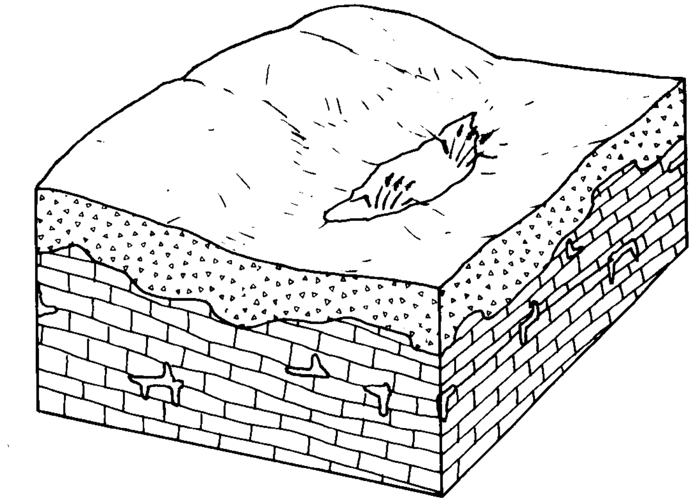
TABLE 8. RANGES AND RATINGS FOR HYDRAULIC CONDUCTIVITY

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 the hydrogeologic setting 7Ac1 Glacial Till Over Solution Limestone, identified in mapping Sandusky County, and the pollution potential indexes calculated for the setting by both general and pesticide DRASTIC. Based on selected ratings for this setting, the pollution potential index is calculated to be 180 for general DRASTIC and 201 for pesticide DRASTIC. These numerical values have no intrinsic meaning, but can be readily compared to values obtained for other settings in the county. DRASTIC indexes for typical hydrogeologic settings and values across the United States range from 65 to 223. The diversity of hydrogeologic conditions in Sandusky County produces settings with a wide range of vulnerability to ground water contamination. Calculated pollution potential indexes for the eight settings identified in the county range from 99 to 197 for general DRASTIC, and from 122 to 218 for pesticide DRASTIC.

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



SETTING 7Ac1		GENERAL		
FEATURE	RANGE	WEIGHT	RATING	NUMBER
Depth to Water	75-100	5	2	10
Net Recharge	10+	4	9	36
Aquifer Media	Karst Limestone	3	10	30
Soil Media	shrink/swell clay	2	7	14
Topography	0-2%	1	10	10
Impact Vadose Zone	Karst Limestone	5	10	50
Hydraulic Conductivity	2000+	3	10	30
		DRASTIC	INDEX	180

SETTING 7Ac1		PESTICIDE		
FEATURE	RANGE	WEIGHT	RATING	NUMBER
Depth to Water	75-100	5	2	10
Net Recharge	10+	4	9	36
Aquifer Media	Karst Limestone	3	10	30
Soil Media	shrink/swell clay	5	7	35
Topography	0-2%	3	10	30
Impact Vadose Zone	Karst Limestone	4	10	40
Hydraulic Conductivity	2000+	2	10	20
		DRASTIC	INDEX	201

Figure 2. Description of the hydrogeologic setting - 7Ac1 Glacial Till Over Solution Limestone (general DRASTIC and pesticide DRASTIC).

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

7Ac1 - defines the hydrogeologic region and setting
180 - defines the relative pollution potential

Here 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 following number (1) references a certain set of DRASTIC parameters that are unique to this setting and are described in the corresponding setting chart. The second number (180) 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 maps also include 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 SANDUSKY COUNTY

Sandusky County occupies an area of approximately 409 square miles in north-central Ohio. It is bounded on the east by Erie County, to the southeast by Huron County, on the south by Seneca County, on the west by Wood County, and on the north by Ottawa County and Sandusky Bay. The northerly-flowing Sandusky River effectively cuts the county in half. Figure 3 shows the location of Sandusky County.

The 1988 estimated population for Sandusky County was 62,200 (Ohio Department of Development, 1990). Most of the population is concentrated in the central and eastern portions of the county. Fremont, Bellevue, and Clyde are the major incorporated areas. Agriculture accounts for 85% of the land usage in Sandusky County. Land use in the remainder of the county is primarily a mixture of commercial (including quarrying) and residential.

Physiography

Sandusky County lies within the Central Lowlands physiographic province (Fenneman, 1938). The extreme southeastern corner of the county falls on the margin of the rolling Till Plains Section of the Central Lowlands Province, whereas the majority of the county falls within the gently northward sloping Eastern Lake Plains Section of the Central Lowlands Province.

The ancient lakes which covered much of northern Ohio following the last glaciation had a profound influence on the surficial deposits and topography of Sandusky County. Lake and shoreline processes and deposits tended to erode or obscure the previous glacial and bedrock features.

Overall, the topography is relatively flat and low-lying. Isolated bedrock highs and beach ridges do provide some local topographic relief. The Columbus Escarpment or Cuesta in far southeastern Sandusky County forms a relatively prominent rise (Forsyth, 1983). This region features an irregular surface accentuated by prominent sinkholes in the Columbus Limestone.

SANDUSKY COUNTY

Figure 3. Location of Sandusky County, Ohio.

Climate

Sandusky County has a thirty year (1951-1980) average annual precipitation of 32.78 inches (U.S. Department of Commerce, 1982). Mean annual temperature for the Fremont area over the some period was 50.43 F. This climate is typical for north central Ohio adjacent to Lake Erie.

Modern Drainage

The modern drainage of Sandusky County is dominated by the Sandusky River which empties into Sandusky Bay, an estuary of Lake Erie. Rising water levels in the lake flooded the lower portions of the Sandusky River during the last few thousand years (Calkin and Feenstra, 1985).

Streams east of the Sandusky River flow northwards towards Sandusky Bay in a radial fashion. Streams between the Sandusky River and Muddy Creek also tend to converge radially toward Sandusky Bay. Nine Mile Creek and drainages to the west and north tend to be roughly parallel and flow eastwards, eventually merging with either Toussaint Creek or the Portage River.

The area of the Columbus Escarpment is virtually devoid of stream drainage. Drainage within this area is internal; that is, water drains downwards through sinkholes instead of flowing within surficial drainage channels.

Pre-glacial and Glacial Drainage

Little study has been conducted regardingdrainage patterns in pre-glacial times. Stout and others (1943) reported two major pre-glacial rivers, the Tiffin River (which approximately followed the course of modern Muddy Creek) and the Woodville River (which approximately followed the course of the modern Portage River). However, the bedrock topography maps of Larsen (1984a, b) and Hoover (1982) do not substantiate Stout's work. Their later research is based upon significantly more data points and also incorporates a better understanding of the regional geology. Both studies indicate the presence of a buried valley system almost directly below modern Green Creek.

Kihn (1988) discussed the pre-glacial Erigan River which flowed just west of Bellevue and then veered eastward into Erie County south of Castalia. Kihn proposed that the Erigan River was responsible for creating the narrow, prominent ridge of the Columbus Cuesta.

Flow in all of the above mentioned streams would have been blocked by advancing glacial ice; however, there is no evidence for drainage reversals in Sandusky County. Therefore, streams probably continued flowing northward because of the basin-like nature of the topography. Lakes formed around the margin of the ice sheet. As the climate warmed, the ice may have eventually floated as these lakes merged and the basin filled with water.

Bedrock Geology and Hydrogeology

Bedrock formations underlying Sandusky County are comprised of Devonian and Silurian aged limestones and dolomites (Table 9). These carbonate units, which reach thicknesses of several hundred feet in western Sandusky County, represent the regional aquifer. Both the limestones and dolomites were deposited in shallow seas and coastal regions. Porosity in these units is largely controlled by complex networks of fractures and joints. Dissolution of gypsum, anhydrite, and calcite along discrete zones (i.e. fractures, bedding planes and bioturbated beds) also greatly enhances the porosity and permeability of these formations.

The youngest unit is the Devonian Age, Columbus Limestone (Table 9), which is found in the extreme southeastern corner of Sandusky County. This resistant unit forms the prominent ridge of the Columbus Cuesta. In the Bellevue-Castalia regions, this unit features the most spectacular karst topography in Ohio. A karst terrain has distinctive characteristics of relief and drainage resulting from the dissolution of limestone or dolomite by the action of surface and ground water. Karst terrain typically has a well developed underground drainage network ranging from fractures and minor solution channels to caverns with subterranean streams. Dolines (sinkholes), springs, sinking streams, ponors (swallow holes), and caves are surface expressions related to the underground drainage network. Tintera (1980) and Norris (1982) have carefully documented the sinkholes and collapse features in the area. Sikora (1975) and Kihn (1988) discussed the complicated ground water flow systems in this karst region.

TABLE 9. BEDROCK STRATIGRAPHY OF SANDUSKY COUNTY, OHIO

SYSTEM	GROUP	FORMATION	DESCRIPTION
DEVONIAN		Columbus	Limestone, light gray-buff, thin to massive bedded, fossiliferous, highly solutioned, Karstic
	DETROIT RIVER	Lucas	Dolomite, massive bedded, highly solutioned, fractured, fossiliferous
		Amherstberg	Dolomite, massive bedded, solutioned
SILURIAN	SALINA	undifferentiated (Put-In-Bay*) (Bass Islands*) (Raisin River*)	Dolomite, thin to massive bedded, argillaceous to shaly layers, granular, vesicular ("vuggy") layers, contains zones of gypsum and anhydrite, minor solution zones, some fracturing
	LOCKPORT	undifferentiated (Guelph*)	Dolomite, massive, fossiliferous, some porous zones

*Denotes older terminolgy having historical significance. Current preference is to leave the Salina and Lockport undifferentiated.

The Columbus Limestone is an excellent, high yielding aquifer due to the degree of solutioning along fractures, the number of fractures, and the presence of porous ("vuggy") zones. Ground water yields from 500-1000+ gallons per minute are obtainable from large diameter wells (Ohio Department of Natural Resources, Division of Water, 1970; Schmidt, 1980; Hoover, 1982). Flow through the solution channels can be quite rapid (Sikora, 1975 and Kihn, 1988). Recharge rates to the aquifer are very high and water level fluctuations are pronounced and common (Kihn, 1988 and Breen, 1989).

Lying directly to the west of the Columbus Limestone is the Detroit River Group which is subdivided into two dolomitic formations, the Lucas and the Amherstberg. While these formations lack the karst topography developed in the Columbus Limestone, they still exhibit a major network of solution- enhanced fractures. Yields range from 500 to 1000 gallons per minute (Ohio Department on Natural Resources, Division of Water, 1970; Schmidt, 1980; Hoover, 1982). Miller's Blue Hole, a major flowing spring in Riley Township, flows at a rate just over 1000 gallons per minute from this formation (Kihn, 1988).

The stratigraphy of the Silurian carbonate units occurring immediately west of the Detroit River Group is controversial and has not been resolved. The units are all dolomitic in nature; however, the amount of fracturing, vuggy zones, and evaporite (gypsum, anhydrite) beds are variable. Herdendorf and Braidech (1972) have subdivided the area into the Raisin River and Put-in-Bay Groups. Kihn (1988) and Hoover (1982) refer to the Bass Islands Group which they subdivide into numerous formations. The currently accepted scheme (Mac Swinford, personal communications; Division of Geological Survey) is that of Janssens (1977). Janssens refers to all of these units as belonging to the undifferentiated Salina Group. Upper Salina units east of the Sandusky River yield a maximum of 1000 gallons per minute. Salina units in the Fremont region and west of the Sandusky River north of Fremont have lower yields with a maximum of 600 gallons per minute (O.D.N.R., Division of Water, 1970 and Schmidt, 1980).

Western Sandusky County is underlain by the oldest bedrock units in the area, the Lockport Group (formerly referred to as the Guelph). This massive, fine-grained dolomite lacks the degree of fracturing and solution that the younger units possess. The Lockport Group has a correspondingly lower maximum yield of 100 gallons per minute.

Yields for typical domestic wells in Sandusky County follow the pattern of the maximum yields. Domestic wells generally produce under 5 gallons per minute from the Lockport, average about 10 to 15 gallons per minute from the Salina, and yield over 20 gallons per minute from the younger units in eastern Sandusky County.

Glacial Geology and Hydrogeology

During the Pleistocene Epoch (2 million to 10,000 years ago) at least four major episodes of glaciation, referred to as stages, occurred in north-central North America (Table 10). Each stage underwent numerous periods of advance and retreat referred to as sub-stages. Each sub-stage brought complex changes to Sandusky County. Bedrock and unconsolidated deposits were eroded, drainage-ways were blocked, and deposition of varying thicknesses of till, sand, and gravel took place.

Direct evidence for only the most recent glacial stage, the Wisconsinan, exists in Sandusky County. Evidence for earlier glaciations is lacking or obscured. The stratigraphic relation of the Pleistocene units in Sandusky County is given in Table 10.

Till is an unconsolidated, poorly-sorted, non-stratified (layered) mixture of clay, silt, sand, and gravel directly deposited by ice. Actively moving ice deposits highly compacted (dense) lodgement till, whereas stagnating, non-moving ice deposits less compacted ablation (melt-out) till. There is evidence that some of the tills were deposited in a water environment in Sandusky County. These types of tills would be deposited when a relatively thin ice sheet would alternately float and ground depending on the water level of the adjacent lake.

Till thickness averages under 20 feet in western Sandusky County (Larsen, 1984a, b). In central and northern Sandusky County, deltaic and lacustrine deposits obscure the till. Between Fremont and Castalia, the total till thickness approaches 80 feet. Along the Columbus Escarpment, the till thins to less than 20 feet (Larsen, 1984a, b). Much of the original thickness of the till deposited in Sandusky County was removed by subsequent glaciations and by wave activity associated with post glacial lakes.

The original land surface created by till deposition in Sandusky County is largely obscured by lake deposits or was eroded by wave action. Classical till features such as ground moraine or end moraines are not detectable in Sandusky County. The till surface may be referred to as wave-planed till or water-modified till (Forsyth, 1965). Wave erosion (Angle, 1988a) is probably largely responsible for the abundance of shallow and exposed bedrock in Sandusky County.

TABLE 10. GENERALIZED PLEISTOCENE (GLACIAL) STRATIGRAPHY OF SANDUSKY COUNTY.

EPOCH	STAGE		SUB-STAGE	UNIT OR INTERVAL	DESCRIPTION
PLEISTOCENE	WISCONSINAN	LATE	Woodfordian	Hiram Till	Clayey, non-compact, sparsely pebbly
				Hayesville Till	Clayey, moderately compact, and pebbly
				Upper Millbrook Till*	Compact, firm, fractured, silty, stony
				Middle Millbrook Till*	Compact, firm, fractured, clayey, to moderately stony
		MIDDLE	Farmdalian	unknown	
		EARLY	Altonian	Millbrook Till ?*	
	SANGAMONIAN			unknown	
	ILLINOIAN			Millbrook Till ?*	
	PRE-ILLINOIAN				not exposed

*Age of the Millbrook Till is unknown Units may span a considerable interval of time.Four till units have been identified in Sandusky County (Angle, 1988b). The youngest till is the sparsely pebbly, very clayey, non-compact Hiram Till. Underlying the Hiram is the slightly firmer, more pebbly Hayesville Till. These two tills are relatively similar and may be hard to differentiate upon examination. Together, they comprise the surficial till. These units weather into clay loams or into aggregated (shrink/swell) clays. These tills were deposited between 14,500 and 19,000 years before present (y.b.p.) (Fullerton, 1980) and are therefore late Wisconsinan (Woodfordian) in age.

Underlying the Hayesville Till are two different older till units. These deposits are known as the Millbrook Tills and include a very silty, stony and compact "upper" Millbrook and the clayey, less stony, compact "middle" Millbrook. The various subunits of the Millbrook have not been formally divided (Angle, 1988b) into subunits. The age of the various Millbrook units is also under question and may span both the Illinoian and Wisconsinan stages (Totten, 1988) elsewhere in Ohio. The "upper" Millbrook Till is found near the surface along beach ridges between Clyde and Castalia. This till is generally found at least 5 feet below the ground surface, is quite resistant to erosion. The "middle" Millbrook is only observed in deep river valleys and excavations. The Millbrook Tills are more persistently jointed and fractured, and contain more sand, gravel, and silt lenses than the overlying Hiram and Hayesville Till.

The tills of Sandusky County do not constitute a regional aquifer. Lenses of sand and gravel within or between till units comprise a limited local aquifer suitable only for domestic use. Wells developed in these aquifers are predominantly found between Green Springs and Clyde. Yields are typically under 10 gallons per minute.

The Buried Valley

As the glaciers advanced and receded in Sandusky County, large volumes of meltwater drained through existing river and stream valleys. Meltwater from the glaciers carried large quantities of sand, gravel, silt and clay. This material was sorted by running water and deposited in layers, filling the valley with interbedded deposits of sand and gravel, silt and clay. Larsen (1984a, b), Hoover (1982), and Schmidt (1980), indicate the presence of a buried valley with a central axis almost directly underlying Green Creek. The head of the valley is in central Seneca County near Tiffin. The valley was filled with various layers of sand, gravel, silt, clay, and till. Generally, surficial sands and gravels are underlain by silt and then till. Between the till and the bedrock surface are thick zones of saturated fine sands and gravels. From the Tiffin area northward into southern Sandusky County, the basal gravel within the buried valley is commonly utilized as an aquifer. Farther northward in Sandusky County, the deposits tend to become finer-grained and more effort is necessary to properly develop water wells. In this area of northern Sandusky County, the underlying bedrock is utilized as the aquifer.

Deglaciation and post-glacial lakes.

The Lake Plains region of Ohio was flooded immediately upon the melting of the glaciers because of its basin-like topography. River flow into the basin also contributed to the formation of lakes. Lake levels were controlled by various drainage outlets in Indiana, Michigan, and New York.

This series of lakes, from ancestral to modern Lake Erie, had a profound influence on the surficial deposits and geomorphology of the region. Shallow, lake wave activity had a major erosional effect on topography, cutting steep cliffs ("scarps") when the water level remained constant causing a beveling of the topography. Clays and silts were deposited in quieter, deeper portions of the lake. In the shallower areas, beaches and bars were formed. Some of the beach sands and gravel were derived from in-situ wave erosion of the till and bedrock (Anderhalt, 1983); the remainder was transported and redeposited by local rivers.

The ancestral Sandusky River created a sequence of deltas in central Sandusky County (Angle, 1987). These deltas corresponded with the various lake levels (Table 11) and were a major source of sediment for beach ridge formation (Angle, 1987 and Angle, 1988a). Near the mouth of the river, coarser sands and gravels were deposited. Farther out into the lake, finer sands, silts, and eventually clays were deposited. Thin layers of sand interbedded in the silts and clays may represent higher energy episodes such as storms or floods. When sediment loads exceeded wave erosion, the deltas tended to both aggrade (build upwards or thicken) and prograde (build outwards). When wave erosion was pronounced, deltas were diminished.

The major beach levels in Sandusky County are listed in Table 11. The evidence for these beaches is variable; some are represented by sand and gravel ridges, others are documented by wave-cut cliffs in till or bedrock. The beaches in eastern Sandusky County are linear, more continuous, and contain thicker sands and gravels. Beach ridges in western Sandusky County are rather discontinuous and irregular; they tend to wrap around and connect bedrock highs (Angle, 1988a). The beach deposits also tend to be thinner as well. Differences in slope, sediment supply, and the presence of bedrock highs account for the differing nature of beaches across the county.

TABLE 11. LAKE LEVEL SEQUENCE (after Hough, 1958 and Forsyth, 1973)

Lake Stage	Age (Years B. P.)	Elevation (ft.)	Outlet	Found in Sandusky Co.
Erie (Modern)	4,000	573	Niagara	no
Algonquin	>12,000	605	Grand River, Mich. or Mohawk River, N.Y.	no
Lundy	>12,200	?	Grand River, Mich. or Mohawk River, N.Y.	no
(Elkton)		615	Grand River, Mich. or Mohawk River, N.Y.	yes
(Dana)		620	Grand River, Mich. or Mohawk River, N.Y.	yes
(Grassmere)		640	Grand River, Mich.	no
Lower Warren		675	Grand River, Mich. or Mohawk River, N.Y.	yes
Wayne		655-660	Grand River, Mich. or Mohawk River, N.Y.	yes
Upper Warren	<13,000	685-690	Grand River, Mich.	no
Whittlesey	>13,000	735	Grand River, Mich.	no
Lower Arkona		700	Grand River, Mich.	no
Upper Arkona		710-715	Grand River, Mich.	no
Middle Maumee	14,000	775-780	Wabash River, Ind.	no
Lower Maumee		760	Grand River, Mich.	no
Upper Maumee		800	Wabash River Ind.	no

(Table 11 depicts the lake sequence used in this text, the approximate age of these events, the water level elevation, the outlet controlling the water level, and whether the lake level corresponds to elevations found in the deltaic sequences of Sandusky County.)

There are two basic theories on the behavior of lake levels of ancestral Lake Erie over time. Leverett and Taylor (1915), Hough (1958), and Forsyth (1959, 1973) ascribe to the theory that the lake level did not continuously fall, but instead went through intermittent periods of rising and falling levels controlled by ice blockage of the various outlets during periods of ice advance. Totten (1982; 1985) disagrees and cites evidence for a continuously falling lake level with no interruptions caused by blockage of different outlets.

The beaches associated with ancestral Lake Erie formed over a relatively short time period between 13,500 and 12,000 y.b.p. At approximately 12,000 y.b.p., ice retreated from western New York and the Niagara River outlet opened. Isostatic depression, a phenomenon created by the weight of the overlying ice, had lowered the elevation of the region by as much as 150 feet (Calkin, 1970). The depression in elevation caused the lake to almost entire drain. As the Niagara area rebounded, the outlet elevation slowly rose and modern Lake Erie deepened. Approximately 3000 - 4000 y.b.p., the western basin of Lake Erie (including Sandusky Bay) flooded as a result of increased drainage from the Lake Superior region and increased precipitation (Calkin and Feenstra, 1985).

Sand dunes in Sandusky County closely parallel and were derived from the beaches. Sand dunes cap many of the beach ridges and the two features can be hard to distinguish. Blowing sands are a problem in Sandusky County.

The origin of the marl and peat in the Castalia-Vickery region is also subject to debate. Deposition may have occurred at the bottom of glacial lakes or from precipitation at the surface along springs and seeps. While the peat deposits have been primarily mined out, the marl deposits remain impressive.

During the time of the early settlement of Sandusky County, much of northwest Ohio was within the Great Black Swamp (Kaatz, 1955). Settlement and transportation was limited to the beaches and dunes; other areas weren't inhabited until the swamp was drained artificially in the 1870's.

The beach and deltaic deposits, while highly permeable, are far too thin and close to the surface to be utilized as aquifers. Deeper underlying gravels or bedrock in these regions serve as the aquifer. The lacustrine silts and clays also do not constitute an aquifer. Both bedrock and limited lenses of deep gravels are utilized in the areas adjacent to Sandusky Bay.

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APPENDIX A

DESCRIPTION OF THE LOGIC IN FACTOR SELECTION

Depth to Water

This factor was primarily evaluated using information from water well logs on file at the Ohio Department of Natural Resources, Division of Water. Approximately 10,000 water well logs are on file for Sandusky County. The Ground-Water Resources Map of Sandusky County (Schmidt, 1980) and the study of Breen (1989) provided useful information on depth to water. The theses of Palumbo (1974), Sikora (1975), Hoover (1982), and Kihn (1988) also provided useful data.

Depth to water in most of Sandusky County is relatively shallow. Depth to water west of the Sandusky River is generally under fifteen feet except for a few isolated bedrock highs. Depths under 30 feet are common in the deltaic areas of central Sandusky County. Depths to water in areas adjacent to major streams are almost always under 15 feet. Depths to water above 30 feet are found in portions of the buried valley just east of Fremont and along the beach ridges to the northeast of Clyde. Depth to water in the area of the Columbus Escarpment near Bellevue varies from 50 feet to over 110 feet. The potentiometric surface undergoes tremendous fluctuations in this region, both seasonally, and from year to year. Sikora (1975), Kihn (1988), and Breen (1989) discuss the complex hydrogeology of the Bellevue region. The average water depth in the majority of wells was used to determine the depth to water in this region.

There are regions of flowing water wells where the depth to water is very shallow (less than 5 feet). The area roughly north of State Route 412 and east of Green Creek has numerous flowing (artesian) wells in addition to springs and seeps. The region just west of Clyde trending northwards toward the turnpike also contains a significant number of flowing wells. The number of flowing wells developed in sand & gravel and limestone is almost equal.

Technically, the artesian wells could have been considered confined aquifers, which would have given an average depth of 60 feet based on the depth to the top of the aquifer. However, there was evidence from well logs that the entire thickness of unconsolidated deposits is saturated. In addition, one must take into account the natural high water table, poor surface drainage, and overall environmental sensitivity of the area. For this reason the 0-5 feet (DRASTIC rating of 10) was utilized.

Net Recharge

This factor was evaluated using many criteria including, topography, vadose zone material, soil type and annual precipitation values. Net recharge is the amount of water (precipitation) that infiltrates and replenishes the aquifers; however, most precipitation is lost to runoff and evapotranspiration. Precipitation averages about 33 inches per year for Sandusky County (U.S. Department of Commerce, 1982); the amount of this total actually available as recharge varies considerably throughout the County.

An average recharge value of 4-7 inches per year (6) was assigned for the majority of Sandusky County, particularly western and central Sandusky County. This value was utilized, in part, as a result of Pettyjohn and Henning's (1979) study which specified an average recharge of 4.5-6.0 inches per year for the Sandusky River Basin. Smith and Voytek (1989) also used this value for neighboring Seneca County. This recharge value considers the permeable nature of typical sandy loam and high shrink-swell (aggregated) clay soils, and the flat, low-lying topography which generally has low runoff.

Recharge rates in the (7Ec) Alluvium over Sedimentary Rocks (limestone) setting varied from 4-7 inches per year (6) to 7-10 inches per year (8) depending upon the thickness of the alluvium, and the relative coarseness of the alluvial deposits.

In the areas of the (7F) Glacial Lake Deposits setting, a recharge value of 2-4 inches per year (3) was utilized, primarily due to the extremely clayey, impermeable nature of these deposits. This lower recharge value was also used in the areas of discharging (flowing) wells as the overall ground water flow gradient toward the surface.

Sandusky County also contains many areas with high average recharge values. Some segments of the Sandusky River and other major streams were found to be hydraulically connected to the underlying aquifers. An average recharge value of 7-10 inches per year (8) was assigned to these areas. The numerous locations where bedrock is shallow (close to the surface) in western Sandusky County were also assigned a recharge of 7-10 inches per year.

The region of highly solutioned karst limestone in southeastern Sandusky County was assigned overall high recharge values. The ability for water to move through the network of solution channels and fractures accounts for the greater (and more rapid) recharge. Internal surface drainage in the area (i.e. through sinkholes) causes high recharge to the aquifer. Precipitation runs off the land surface and into sinkholes instead of draining into streams leading from the vicinity. Additionally, the Bellevue region historically has had numerous drainage wells drilled as drains for storm water and sanitary waste disposal (Division of Water, 1961; Sikora, 1975, and Hoover, 1982). These drainage wells tend to augment the natural recharge and drainage. Where the overlying cover of till was thin (<15 feet) a recharge value greater then 10 inches per year (DRASTIC rating 9) was assigned to the karst region. A recharge value of 7-10 inches per year was assigned where the overlying till was over 15 feet thick.

Aquifer Media

In Sandusky County, the carbonate (limestone and dolomite) bedrock comprises the regional aquifer. The vast majority of domestic wells and all of the municipal and industrial wells are developed in these units. Locally, wells developed in sand and gravel are suitable for domestic needs. Sand and gravel deposits developed for domestic use are most commonly foun in the region between Green Springs and Clyde and the area between White's Landing and Vickery. The primary data source for determining the aquifer media were the water well logs on file at the ODNR Division of Water. Other sources included Division of Water (1970), Schmidt (1980), and the studies of Sikora (1975), Hoover (1982), Kihn (1988), and Breen (1989).

The aquifer media rating for the bedrock varied significantly across the county. The aquifer characteristics of the carbonates vary both between units and within individual units. The Columbus Limestone in southeastern Sandusky County was considered a true karst limestone and given a rating of 10 based on the network of solution features.

The rocks of the Detroit River Group and the uppermost portions of the Salina Formation were evaluated as massive limestone and were given a rating of 9. These rocks lack some of the true karst characteristics of the Columbus Limestone, but still possess some major solution pathways and contain appreciable amounts of water.

The vast majority of the Salina Formation is a massive limestone and was given a rating of 8. The Salina tends to be highly fractured; ancestral and modern drainage systems commonly align themselves with the fracture trends. The Salina underlies the buried valley area and may have experienced more intensive erosion of its surface by glacial melt-water. While the overlying sands and gravels in the valley are not necessarily good producers and may be difficult to develop, they are hydraulically connected with the Salina and help supply water to the bedrock. Conversely, along the valley walls, the Salina probably recharges the sand and gravel lenses. The degree of interconnection between the units is complex and important.

The massive Lockport Dolomite is generally considered the lowest yielding carbonate unit in Sandusky County (Division of Water, 1970; Schmidt, 1980). The vuggy and fractured zones in the Lockport are not as continuous as those in the Salina and Detroit River units. The Lockport was given a rating of 7 throughout western Sandusky County. Smith and Voytek (1989) rated a small portion of the Lockport as an 8 where it underlies the Sandusky River due to a higher degree of fracturing. This narrow zone of increased fracturing extends northward to Fremont.

The sand and gravel units were typically not evaluated as the local aquifer. Except in a few limited areas, it was difficult to ascertain the continuity of the sand and gravel units. Based upon available well log data, separation of discontinuous lenses from major producing layers was difficult. In many areas where sand and gravel was noticeable in the well logs, the well was developed in the underlying bedrock. Development in the bedrock may reflect the well driller's preference for a guaranteed water supply in bedrock. The unconsolidated units do seem to noticeably fine northwards, particularly within the buried valley. The most important reason for not emphasizing sand and gravel as an aquifer was that the carbonates in the region carry a much higher aquifer rating and hydrologic conductivity than the overlying sand and gravel units. Although the carbonates represent the true regional aquifer, the sand and gravel units are hydraulically connected to the underlying bedrock. Therefore, once a contaminant enters the sand and gravel, it will eventually enter the regional bedrock aquifer which would in turn serve as a medium for further contaminant transport. In other words, the underlying (bedrock) aquifer is more sensitive and is much more significant over a larger area.

Sand and gravel was rated as an aquifer in a few localized areas. In the Green Springs vicinity, sands and gravels within the Buried Valley (7D) hydrogeologic setting were given an aquifer rating of 6 (Smith and Voytek, 1989). These sand and gravel deposits appear to be relatively continuous; however, they are not particularly coarse or thick. Adjacent to the buried valley, the sand and gravels become less laterally continuous and more lense-like in nature. The Sand and Gravel Interbedded in Glacial Till hydrogeologic setting (7Af) was utilized for these deposits and an aquifer media rating of 5 was assigned. The sand and gravel within the beach ridge deposits served as a limited aquifer just west of Bellevue and in neighboring Seneca County (Smith and Voytek, 1989). These sand and gravel deposits were given an aquifer rating of 8.

Soil Media

This factor was primarily evaluated by using the Soil Survey for Sandusky County (Ernst and Hunter, 1987). Information on every indicated soil type was analyzed and appropriate ratings were selected. Computer-generated maps derived from digitized data were supplied by the ODNR, Division of Soil and Water Conservation, Ohio Capability Analysis Program (OCAP). These maps were useful in delineating the various soils. Information on the surficial materials of Sandusky County based upon research by the ODNR, Division of Geological Survey also proved to be very helpful.

The soils in Sandusky County reflect the heavy influence of both glaciation and subsequent shoreline and lacustrine (lake) processes (Ernst and Hunter, 1987; Angle 1988b). The presence of shallow bedrock over much of western and far southeastern Sandusky County also had a profound effect on soils. Alluvial soils are derived from stream deposits associated with the floodplains of modern stream valleys. The marl and associated peat deposits found in northeastern Sandusky County produce unique, localized soils. Table 12 lists the soil types encountered in Sandusky County, and gives information on the soil's parent material or setting and the corresponding DRASTIC index.

High shrink-swell (aggregated) clay soils (7) are the most prevalent soil type in Sandusky County. These soils contain a high proportion of expandable clay minerals and are overall very clayey in nature. During extreme dry periods (i.e., the 1988 drought) they desiccate (dry-out) and shrink, creating large cracks which effectively serve as pathways for any contaminant. Upon wetting, the clay will expand (swell), eventually "healing" the cracks. During periods of high to normal wetness high shrink-swell soils will be relatively impermeable and behave similar to clay loam soils.

These soils are derived from the weathering of both the wave-planed (water-modified) glacial till as well as lacustrine deposited clays and silts. Till overlying shallow bedrock commonly appears to be more weathered and exhibits high shrink-swell tendencies.

Marl soils are somewhat of a unique case as they are not categorized by the DRASTIC system. Due to their coarse, permeable nature and their common association with sensitive wetland areas and springs, marl soils were given a rating of 9.

TABLE 12. SANDUSKY COUNTY SOILS

Soil Name	Parent Material or Setting	DRASTIC Rating	Soil Media
Belmore	beach	6	sandy loam
Bennington	till	3	clay loam
Bixler	delta, beach	6	sandy loam
Blount	till	3	clay loam
Bono	lakebed	7	shrink/swell clay
Castalia	limestone bedrock	10	thin or absent
Colwood	delta	4	silt loam
Del Rey	lakebed	3	clay loam
Dixboro-Kibbie	delta, beach	6	sandy loam
Dunbridge	beach, bedrock	6	sandy loam
Fulton	lakebed	7	shrink/swell clay
Gilford	delta, beach	6	sandy loam
Glenford	lakebed,delta	4	silt loam
Glynwood	till	3	clay loam
Granby	dune, beach	9	sand
Haskins	till	4	silt loam
Hoytville	till	7	shrink/swell clay
Kibbie	delta	4	silt loam
Lenawee	lakebed	3	clay loam
Lucas	lakebed	7	shrink/swell clay
Mentor	delta, alluvium	4	silt loam
Mermill	till, lakebed	3	clay loam
Millsdale	till, bedrock	7	shrink/swell clay
Nappanee	till	7	shrink/swell clay
Pewamo	till	3	clay loam
Rimer	beach, dune	6	sandy loam
Rossburg	alluvium	5	loam
Sandusky	marl	9	marl
Saylesville	till, lakebed	3	clay loam
Seward	beach, dune	6	sandy loam
Shoals	alluvium	4	silt loam
Spinks	beach, dune	9	sand
Tedrow	beach, dune	9	sand
Tedrow-Dixboro	beach	9	sand
Toledo	lakebed	7	shrink/swell clay
Weyers	marl	9	marl

Areas where the bedrock is extremely close to the surface, soils were considered as being thin or absent and given a rating of 10. Clay loam soils (3) derived from lake deposits are found just southeast of Fremont. Loam (5), silty loam (4), and sandy loam (6) soils are associated with the deltas in central Sandusky County as well as along marginal beach ridge areas. Sandy soils (9) are associated with the better developed beach ridges and dunes. The alluvial soils in river and stream valleys were typically rated as silt loams (4).

Topography

Topography was analyzed by determining the percentage of slope obtained from USGS 7-1/2 minute quadrangle maps and from the Soil Survey of Sandusky County (Ernst and Hunter, 1987).

Impact of the Vadose Zone Material

This factor was determined using information obtained from water well logs on file at ODNR, Division of Water, and from the studies of Schmidt (1980), Hoover (1982); Kihn (1987), and Angle (1987; 1988a; b). The impact of the vadose zone media primarily reflects the nature and thickness of material between the bottom of the soil profile and the potentiometric surface or static water level. Emphasis is placed on the zone (unit) which will be the most effective in retarding the downward movement of a contaminant. Where the water table is extremely close to the surface, the soil may have to be interpreted as the vadose zone media. The impact of the vadose zone media was probably the single most complex parameter in Sandusky County. A variable sequence of differing materials commonly comprises the vadose media and the thickness and nature of these deposits is critical.

Till is the most widespread vadose zone material in Sandusky County. Till is commonly the vadose zone media in not only the Till over Limestone (7Ac) hydrogeologic setting but also associated with the beach and alluvial settings as well. Typically approximately 10 feet of clayey Hiram and Hayesville Till overlie the siltier, more highly-fractured "upper" Millbrook Till, particularly in western Sandusky County. The average till was rated as a 4; however, there are numerous exceptions to this rating; evaluations were made on a case-by-case basis. In many areas adjacent to beaches, wave erosion has stripped away the upper clayey tills and has exposed the underlying loamier tills. The vadose zone was given a rating of 5 in these locales. Similarly, where weathered till was found over shallow bedrock, but where the bedrock was not close enough to the surface to be considered the vadose zone media, a rating of 5 was assigned.

Silt and clay is a common vadose zone material in much of northern and central Sandusky County. Silt and clay was considered to be the vadose material in the Glacial Lake Deposits (7F) hydrogelogic setting, in the finer grained deltaic areas, and in the northernmost portions of the Buried Valley (7D) hydrogeologic setting. Within the Glacial Lake Deposits hydrogeologic setting, silt and clay was typically rated as a 2 due to their impermeable nature and the tendency for water to move horizontally and not vertically through these deposits. The silt and clay was rated as a 3 in the narrow transitional zone where thin lake sediments overlap glacial till. In the siltier deltaic areas (Angle, 1987) just southeast and to the north of Fremont, the rating for silt and clay varied between 3 and 4. Within the Buried Valley hydrogeologic setting, it became difficult to determine from the well log description whether the vadose zone media was till or silt and clay. As a compromise, the vadose was designated as silt and clay and given a rating of 4. The silt and clay vadose zone media for the Swamp Marsh (7I) hydrogeologic setting was given the maximum silt and clay rating of 6 in the sensitive wetland areas adjacent to Sandusky Bay,.

Silt and clay was considered to be the vadose media within the alluvial deposits in northern Sandusky County. Ratings of 3, 4 and 5 were assigned to these deposits based upon their coarseness and thickness. Sand and gravel deposits along the Sandusky River in southern Sandusky County, were given a rating of 8. As these deposits fined northward towards Fremont, they were evaluated as sand and gravel with significant silt and clay and given a rating of 5 and 6.

Within the Beaches, Beach Ridges, Deltas, and Dunes (7H) hydrogeologic setting, sand and gravel beach deposits typically overlie till, and less commonly, overlie silty lacustrine deposits or bedrock. The thickness and nature of the sand and gravel deposits are crucial factors in determining the vadose zone media rating. The shallower (higher) the water table and the thicker the beach deposits, the greater the proportion of sand and gravel comprising the vadose zone becomes. Where sand and gravel are the dominant vadose material, ratings of 6, 7, and 8 were used. Where the deposits within the vadose zone were transitional between sand and gravel and the underlying till, clay, or silt, the selected vadose zone media was sand and gravel with significant silt and clay, and the ratings ranged between 5 and 6. The beach deposits in these areas are typically thinner, poorer sorted, and finer then in areas where sand and gravel was selected as the vadose zone media.

Sand and gravel was also selected as the vadose zone media for the Sand and Gravel Interbedded in Glacial Till (7Af) hydrogeologic setting. A rating of 8 was ascribed to these coarse sands and gravels in extreme south-central Sandusky County. Similarly, sand and gravel was selected as the vadose media for the extreme southern portion of the Buried Valley (7D) hydrogeologic setting. As these coarse deposits tend to become thinner and finer-grained northwards, the vadose media was designated as being sand and gravel with significant silt and clay and ratings of 5 and 6 were utilized.

Karst limestone was determined to be the vadose zone media in the southeastern portion of the county,. This media was selected due to the great depth of the water table and the extremely high permeability along the solution channels. Where the till was less then 10 feet thick, the karst limestone was given a rating of 10. Where the till cover was thicker, karst limestone was still considered as the vadose media; however, the rating was lowered to 8 or 9. In western Sandusky County, where the massive limestones were at or nearby the surface, a vadose media rating of 7 was applied.

Hydraulic Conductivity

Hydraulic conductivity was estimated from the reports of Division of Water (1970), Schmidt (1980), Hoover (1982), and Kihn (1988). Textbook tables (Freeze and Cherry, 1979; Fetter, 1980) were useful in obtaining an estimated range of values for a variety of deposits.

The unconsolidated sand and gravel deposits generally received moderate hydraulic conductivity values. The values correspond with those utilized in neighboring Seneca County (Smith and Voytek, 1989). The values all fell within the range of 300-700 gallons per day/ft^2 (4).

Hydraulic conductivity ratings varied considerably between (and even within) the various carbonate bedrock units. Values for the Columbus Limestone under ideal conditions were found to exceed 2000 gpd/ft^2. (Ohio Department of Natural Resources, 1970), hence a DRASTIC rating of 10 was utilized. The Detroit River Group (Amherstberg and Lucas), and the uppermost unit of the Salina were also evaluated as having hydraulic conductivities over 2000 gpd/ft^2. These values were selected based partly upon the high yields from artesian wells and springs in the major areas of ground water discharge (flowing wells). West of the Buried Valley (7D) hydrogeologic setting (which roughly underlies Green Creek), these units appear to be lower yielding. Perhaps there is less fracturing and solutioning, or some of the discrete water producing zones might be absent. These areas were assigned hydraulic conductivity values ranging from 1000-2000 gpd/$ft.^2$ (8).

The massive, relatively high-yielding Salina Formation in central Sandusky County has hydraulic conductivity values within the 300-700 gpd/ft^2. range (4). Hydraulic conductivity for the lower yielding Lockport Formation was estimated as being from 100-300 gpd/ft^2 (2).

APPENDIX B

DESCRIPTION OF HYDROGEOLOGIC SETTINGS AND CHARTS FOR DRASTIC

TABLE 13. HYDROGEOLOGIC SETTINGS MAPPED IN SANDUSKY COUNTY, OHIO FOR GENERAL DRASTIC

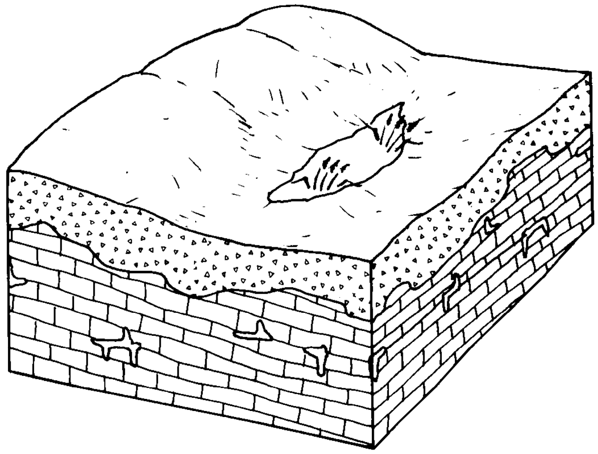
Hydrogeologic Settings	Range of GWPP Indexes	Number of Index Calculations
7Ac - Glacial Till Over Solution Limestone	117-182	81
7Af - Sand & Gravel Interbedded in Glacial Till	144-164	6
7D - Buried Valley	130-179	36
7Ec - Alluvium Over Bedded Sedimentary Rock	128-182	22
7F - Glacial Lake Deposits	99-158	46
7Gb - Thin Till Over Limestone	158-186	8
7H - Beaches, Beach Ridges, Deltas, and Dunes	105-197	60
7I - Swamp/Marsh	172-193	3

TABLE 14. HYDROGEOLOGIC SETTINGS MAPPED IN SANDUSKY COUNTY, OHIO, FOR PESTICIDE DRASTIC*

Hydrogeologic Settings	Range of Pesticide GWPP Indexes	Number of Index Calculations
7Ac - Glacial Till Over Solution Limestone	146-209	81
7Af - Sand & Gravel Interbedded in Glacial Till	164-179	6
7D - Buried Valley	139-211	36
7Ec - Alluvium Over Bedded Sedimentary Rock	153-199	22
7F - Glacial Lake Deposits	122-192	46
7Gb - Thin Till Over Limestone	197-216	8
7H - Beaches, Beach Ridges, Deltas, and Dunes	128-214	60
7I - Swamp/Marshe	203-218	3

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

* Page eight contains a discussion on Pesticide DRASTIC.

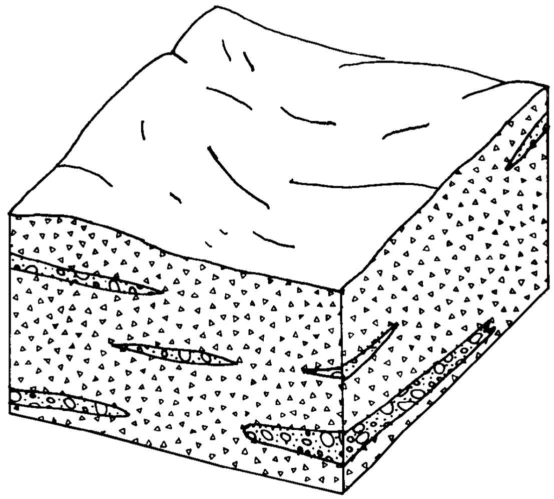


7Ac Glacial Till Over Solution Limestone

This hydrogeologic setting is characterized by low relief and limestone or dolomite bedrock which is covered by varying thicknesses of glacial till. The till is a principally unsorted deposit which may be locally interbedded with sand, gravel, or silt. Surficial deposits have usually weathered to a high shrink-swell (aggregated) clay or clay loam. The uppermost till surface may have been slightly modified or obscured by ancient lakeshore processes. Although ground water occurs in both the glacial deposits and in the underlying bedrock, the limestone or dolomite constitutes the principal aquifer. The carbonate (limestone and dolomite) units are variable, including karst limestones with well developed networks of solution channels; solution limestone, which has somewhat less well developed solution cavities; and massive limestones which are highly fractured, but lack appreciable solution features. The limestone is in direct contact with the overlying till and the till serves as a source of recharge. Recharge is moderate due to the clayey nature of the overlying till, but may be high in areas where the tills are thin. Depth to water is extremely variable, but is generally quite shallow in areas of massive and solution limestone and very deep in the regions of karst limestone. Localized, regions of ground water discharge exist. These regions are characterized by flowing (artesian) wells.

Setting	Depth to Water (ft)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography	Vadose Zone Media	Hydraulic Conductivity	Rating	Pest Rating
7Ac1	75-100	10+	Karst Limestone	Shrink/Swell Clay	0-2	Karst Limestone	2000+	180	201
7Ac2	75-100	10+	Karst Limestone	Clay Loam	0-2	Karst Limestone	2000+	172	181
7Ac3	75-100	7-10	Karst Limestone	Silt Loam	0-2	Karst Limestone	2000+	160	174
7Ac4	50-75	7-10	Karst Limestone	Silt Loam	0-2	Till	2000+	155	171
7Ac5	50-75	7-10	Karst Limestone	Shrink/Swell Clay	0-2	Karst Limestone	2000+	171	194
7Ac6	50-75	7-10	Karst Limestone	Silt Loam	0-2	Karst Limestone	2000+	165	179
7Ac7	75-100	7-10	Karst Limestone	Sandy Loam	0-2	Karst Limestone	2000+	164	184
7Ac8	75-100	7-10	Karst Limestone	Silt Loam	2-6	Karst Limestone	2000+	169	179
7Ac9	75-100	7-10	Karst Limestone	Sandy Loam	2-6	Karst Limestone	2000+	163	181
7Ac10	75-100	7-10	Karst Limestone	Clay Loam	0-2	Karst Limestone	2000+	158	169
7Ac11	50-75	7-10	Karst Limestone	Loam	0-2	Karst Limestone	2000+	172	188
7Ac12	75-100	10+	Karst Limestone	Clay Loam	2-6	Karst Limestone	2000+	171	178
7Ac13	50-75	7-10	Karst Limestone	Sandy Loam	2-6	Karst Limestone	2000+	168	186
7Ac14	30-50	7-10	Karst Limestone	Clay Loam	0-2	Karst Limestone	2000+	173	184
7Ac15	75-100	7-10	Karst Limestone	Thin or Absent	2-6	Karst Limestone	2000+	181	209
7Ac16	75-100	7-10	Karst Limestone	Clay Loam	2-6	Karst Limestone	2000+	157	166
7Ac17	75-100	7-10	Karst Limestone	Shrink/Swell Clay	0-2	Karst Limestone	2000+	166	189
7Ac18	75-100	10+	Karst Limestone	Sandy Loam	2-6	Karst Limestone	2000+	177	193
7Ac19	50-75	10+	Karst Limestone	Sandy Loam	2-6	Karst Limestone	2000+	182	198
7Ac20	50-75	10+	Karst Limestone	Silt Loam	2-6	Karst Limestone	2000+	178	188
7Ac21	50-75	7-10	Karst Limestone	Shrink/Swell Clay	2-6	Karst Limestone	2000+	170	191
7Ac22	30-50	7-10	Karst Limestone	Sandy Loam	2-6	Karst Limestone	2000+	178	196

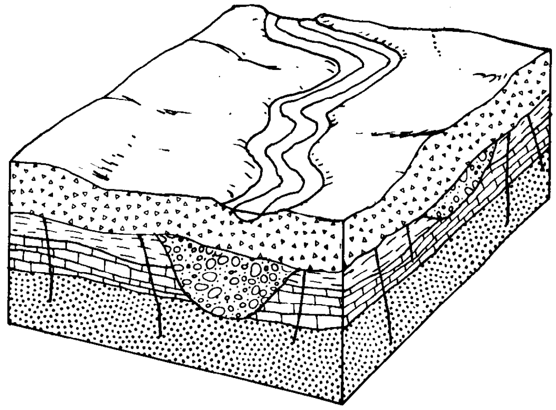
Setting	Depth to Water (ft)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography	Vadose Zone Media	Hydraulic Conductivity	Rating	Pest Rating
7Ac23	30-50	4-7	Solution Limestone	Shrink/Swell Clay	2-6	Till	2000+	154	178
7Ac24	15-30	4-7	Solution Limestone	Silt Loam	0-2	Till	2000+	154	172
7Ac25	50-75	4-7	Solution Limestone	Shrink/Swell Clay	0-2	Till	2000+	140	167
7Ac26	50-75	4-7	Solution Limestone	Sandy Loam	0-2	Till	2000+	138	162
7Ac27	5-15	4-7	Solution Limestone	Silt Loam	0-2	Till	2000+	164	182
7Ac28	15-30	4-7	Solution Limestone	Silt Loam	2-6	Till	2000+	158	173
7Ac29	5-15	4-7	Solution Limestone	Silt Loam	2-6	Till	2000+	168	183
7Ac30	75-100	4-7	Solution Limestone	Shrink/Swell Clay	0-2	Till	2000+	135	162
7Ac31	75-100	4-7	Solution Limestone	Sandy Loam	0-2	Till	2000+	133	157
7Ac32	50-75	4-7	Solution Limestone	Sandy Loam	2-6	Till	2000+	137	159
7Ac33	30-50	7-10	Solution Limestone	Shrink/Swell Clay	0-2	Karst Limestone	2000+	181	204
7Ac34	50-75	7-10	Solution Limestone	Sandy Loam	0-2	Karst Limestone	2000+	169	189
7Ac35	50-75	7-10	Solution Limestone	Clay Loam	0-2	Karst Limestone	2000+	163	174
7Ac36	30-50	7-10	Karst Limestone	Loam	2-6	Karst Limestone	2000+	176	191
7Ac37	30-50	7-10	Karst Limestone	Clay Loam	2-6	Karst Limestone	2000+	172	181
7Ac38	30-50	7-10	Karst Limestone	Silt Loam	0-2	Karst Limestone	2000+	175	189
7Ac39	30-50	7-10	Karst Limestone	Silt Loam	2-6	Karst Limestone	2000+	174	186
7Ac40	30-50	4-7	Solution Limestone	Silt Loam	0-2	Till	2000+	149	166
7Ac41	15-30	4-7	Solution Limestone	Silt Loam	0-2	Till	2000+	159	176
7Ac42	15-30	4-7	Solution Limestone	Clay Loam	0-2	Till	2000+	157	171
7Ac43	30-50	4-7	Solution Limestone	Shrink/Swell Clay	0-2	Till	2000+	150	177
7Ac44	30-50	4-7	Solution Limestone	Sandy Loam	0-2	Till	2000+	148	172
7Ac45	30-50	7-10	Solution Limestone	Sandy Loam	2-6	Karst Limestone	2000+	180	197
7Ac46	30-50	7-10	Solution Limestone	Shrink/Swell Clay	6-12	Karst Limestone	2000+	178	190
7Ac47	15-30	4-7	Solution Limestone	Shrink/Swell Clay	0-2	Till	2000+	160	187
7Ac48	15-30	4-7	Solution Limestone	Sandy Loam	0-2	Till	2000+	158	182
7Ac49	30-50	4-7	Solution Limestone	Sandy Loam	2-6	Till	2000+	147	169
7Ac50	30-50	4-7	Solution Limestone	Silt Loam	2-6	Till	2000+	148	163
7Ac51	30-50	4-7	Solution Limestone	Sandy Loam	2-6	Till	2000+	152	173
7Ac52	5-15	4-7	Solution Limestone	Silt Loam	0-2	Till	2000+	169	186
7Ac53	5-15	4-7	Solution Limestone	Shrink/Swell Clay	0-2	Till	2000+	170	197
7Ac54	5-15	4-7	Solution Limestone	Silt Loam	2-6	Till	2000+	163	179
7Ac55	0-5	4-7	Solution Limestone	Silt Loam	2-6	Till	2000+	168	184
7Ac56	0-5	4-7	Solution Limestone	Silt Loam	2-6	Till	2000+	169	187
7Ac57	0-5	4-7	Solution Limestone	Shrink/Swell Clay	0-2	Till	2000+	175	202
7Ac58	5-15	4-7	Solution Limestone	Clay Loam	0-2	Till	2000+	162	177
7Ac59	0-5	4-7	Solution Limestone	Clay Loam	0-2	Till	2000+	167	182
7Ac60	0-5	4-7	Solution Limestone	Shrink/Swell Clay	0-2	Till	2000+	180	206
7Ac61	5-15	4-7	Solution Limestone	Shrink/Swell Clay	0-2	Till	2000+	175	201
7Ac62	15-30	4-7	Solution Limestone	Shrink/Swell Clay	0-2	Till	2000+	165	191
7Ac63	0-5	4-7	Solution Limestone	Clay Loam	0-2	Till	2000+	172	186
7Ac64	0-5	4-7	Solution Limestone	Sandy Loam	0-2	Till	2000+	178	201
7Ac65	5-15	4-7	Massive Limestone	Shrink/Swell Clay	0-2	Till	100-300	140	175
7Ac66	5-15	4-7	Massive Limestone	Shrink/Swell Clay	0-2	Till	100-300	145	179
7Ac67	5-15	4-7	Massive Limestone	Clay Loam	0-2	Till	100-300	132	155
7Ac68	15-30	4-7	Massive Limestone	Silt Loam	0-2	Till	100-300	124	150
7Ac69	15-30	4-7	Massive Limestone	Shrink/Swell Clay	0-2	Till	100-300	130	165
7Ac70	0-5	4-7	Massive Limestone	Shrink/Swell Clay	0-2	Till	100-300	145	180
7Ac71	0-5	4-7	Massive Limestone	Clay Loam	0-2	Till	100-300	137	160
7Ac72	15-30	4-7	Massive Limestone	Clay Loam	0-2	Till	100-300	127	149
7Ac73	5-15	4-7	Massive Limestone	Sandy Loam	0-2	Till	100-300	143	174
7Ac74	5-15	4-7	Massive Limestone	Silt Loam	0-2	Till	100-300	139	164
7Ac75	15-30	4-7	Massive Limestone	Shrink/Swell Clay	0-2	Till	100-300	135	169
7Ac76	5-15	4-7	Massive Limestone	Silt Loam	0-2	Till	100-300	134	160
7Ac77	5-15	4-7	Massive Limestone	Sandy Loam	0-2	Till	100-300	138	170
7Ac78	15-30	4-7	Massive Limestone	Shrink/Swell Clay	0-2	Till	100-300	140	173
7Ac79	15-30	4-7	Massive Limestone	Silt Loam	0-2	Sand & Gravel w/ sig Silt/Clay	100-300	129	154
7Ac80	30-50	2-4	Massive Limestone	Shrink/Swell Clay	0-2	Till	300-700	117	150
7Ac81	15-30	4-7	Massive Limestone	Shrink/Swell Clay	0-2	Till	300-700	139	172



7Af Sand and Gravel Interbedded in Glacial Till

This hydrogeologic setting is characterized by low relief and contains varying thicknesses of glacial till overlying flat-lying limestone. The till is primarily unsorted silt and clay with minor amounts of sand and gravel. Soils are extremely variable as the till is generally obscured by thin deltaic deposits. Ground water occurs in both the sand and gravel deposits and in the till; however, the sand and gravel constitutes the local aquifer. The sand and gravel exists in thin discontinuous lenses and sheets which cover a limited area and may locally overlie the limestone. The areas containing appreciable amounts of sand and gravel appear to be adjacent to the buried valley. Recharge is from percolation through the surficial sand and till and is dependent upon fracturing and the interconnection of the sand and gravel lenses. Depth to water averages between 10 and 25 feet.

Setting	Depth to Water (ft)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography	Vadose Zone Media	Hydraulic Conductivity	Rating	Pest Rating
7Af1	15-30	4-7	Sand & Gravel	Silt Loam	0-2	Sand & Gravel	300-700	144	164
7Af2	15-30	4-7	Sand & Gravel	Shrink/Swell Clay	0-2	Sand & Gravel	300-700	150	179
7Af3	5-15	4-7	Sand & Gravel	Silt Loam	0-2	Sand & Gravel	300-700	154	174
7Af4	5-15	4-7	Sand & Gravel	Sand	0-2	Sand & Gravel	300-700	164	199
7Af5	15-30	4-7	Sand & Gravel	Sandy Loam	0-2	Sand & Gravel	300-700	148	174
7Af6	5-15	4-7	Sand & Gravel	Silt Loam	0-2	Sand & Gravel	300-700	154	174

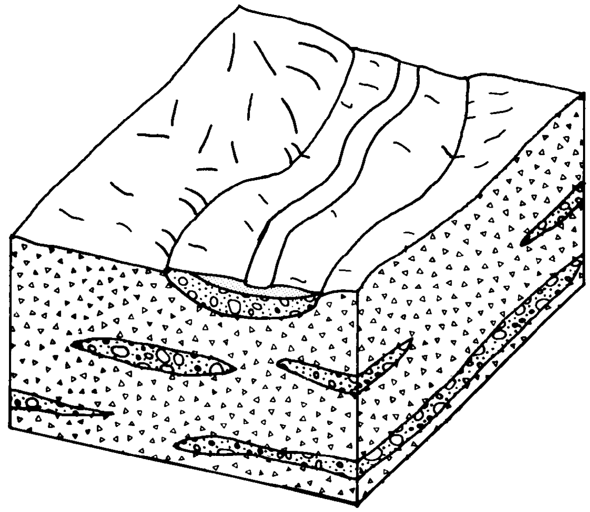


7D Buried Valley

This hydrogeologic setting is characterized by varying thicknesses of glacial till, silt, sand and gravel that have been deposited in a former topographic low (presumably pre-glacial or inter-glacial in origin). Unconsolidated deposits in the buried valley system probably receive some additional recharge from the modern river. Surficial soils are extremely variable in this setting. Typically, thin surficial sands overlie a sequence of lacustrine silt, glacial till, fine sand, and gravel. Underlying the basal sands and gravels is fractured limestone. Where the sand and gravel deposits are coarser, they are used as the primary aquifer. Where the sands become fine, the limestone is utilized as the aquifer. Water levels are variable but generally range between 15 and 50 feet. The sands and gravels are hydraulically connected to the limestone and probably provide recharge to the bedrock formations.

Setting	Depth to Water (ft)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography	Vadose Zone Media	Hydraulic Conductivity	Rating	Pest Rating
7D1	5-15	4-7	Sand & Gravel	Shrink/Swell Clay	0-2	Sand & Gravel	300-700	163	192
7D2	5-15	4-7	Sand & Gravel	Sandy Loam	0-2	Sand & Gravel	300-700	161	187
7D3	5-15	4-7	Sand & Gravel	Silt Loam	0-2	Sand & Gravel	300-700	157	177
7D4	15-30	4-7	Sand & Gravel	Silt Loam	0-2	Sand & Gravel	300-700	147	167
7D5	5-15	4-7	Sand & Gravel	Sand	0-2	Sand & Gravel	300-700	167	202
7D6	15-30	4-7	Sand & Gravel	Sand	0-2	Sand & Gravel	300-700	157	192
7D7	5-15	4-7	Solution Limestone	Sandy Loam	2-6	Sand and Gravel w/ sig Silt/Clay	2000+	177	197
7D8	30-50	4-7	Solution Limestone	Sand	0-2	Sand and Gravel w/ sig Silt/Clay	300-700	164	195
7D9	15-30	4-7	Solution Limestone	Sandy Loam	0-2	Sand and Gravel w/ sig Silt/Clay	2000+	168	190
7D10	5-15	4-7	Solution Limestone	Sand	0-2	Sand and Gravel w/ sig Silt/Clay	2000+	179	211
7D11	15-30	4-7	Solution Limestone	Shrink/Swell Clay	0-2	Sand and Gravel w/ sig Silt/Clay	2000+	165	191
7D12	15-30	4-7	Solution Limestone	Clay Loam	2-6	Silt/Clay	2000+	151	164
7D13	30-50	2-4	Solution Limestone	Shrink/Swell Clay	0-2	Silt/Clay	2000+	138	165
7D14	30-50	2-4	Solution Limestone	Clay Loam	0-2	Silt/Clay	2000+	130	145
7D15	15-30	2-4	Solution Limestone	Clay Loam	0-2	Silt/Clay	2000+	140	155
7D16	30-50	4-7	Solution Limestone	Sandy Loam	0-2	Sand and Gravel w/ sig Silt/Clay	2000+	158	180
7D17	30-50	4-7	Solution Limestone	Shrink/Swell Clay	0-2	Silt/Clay	2000+	155	181
7D18	15-30	2-4	Solution Limestone	Clay Loam	0-2	Silt/Clay	2000+	135	151
7D19	30-50	4-7	Solution Limestone	Sandy Loam	0-2	Silt/Clay	2000+	153	176
7D20	5-15	2-4	Solution Limestone	Clay Loam	0-2	Silt/Clay	2000+	150	165

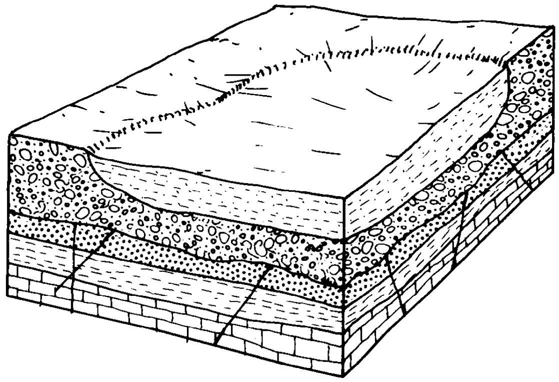
Setting	Depth to Water (ft)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography	Vadose Zone Media	Hydraulic Conductivity	Rating	Pest Rating
7D21	5-15	2-4	Solution Limestone	Clay Loam	0-2	Silt/Clay	2000+	145	161
7D22	5-15	2-4	Solution Limestone	Silt Loam	0-2	Silt/Clay	2000+	147	174
7D23	0-5	4-7	Solution Limestone	Silt Loam	0-2	Silt/Clay	2000+	164	183
7D24	15-30	2-4	Solution Limestone	Silt Loam	0-2	Silt/Clay	2000+	137	156
7D25	0-5	4-7	Solution Limestone	Clay Loam	0-2	Silt/Clay	2000+	162	178
7D26	15-30	4-7	Solution Limestone	Sandy Loam	2-6	Silt/Clay	2000+	157	179
7D27	0-5	2-4	Solution Limestone	Shrink/Swell Clay	0-2	Silt/Clay	2000+	158	186
7D28	0-5	2-4	Solution Limestone	Shrink/Swell Clay	0-2	Silt/Clay	2000+	153	182
7D29	0-5	2-4	Solution Limestone	Silt Loam	0-2	Silt/Clay	2000+	147	167
7D30	0-5	2-4	Solution Limestone	Clay Loam	0-2	Silt/Clay	2000+	145	162
7D31	5-15	2-4	Solution Limestone	Clay Loam	0-2	Silt/Clay	2000+	140	157
7D32	15-30	4-7	Solution Limestone	Sand	2-6	Silt/Clay	2000+	163	194
7D33	15-30	2-4	Solution Limestone	Sandy Loam	0-2	Silt/Clay	2000+	141	166
7D34	5-15	4-7	Solution Limestone	Sandy Loam	0-2	Sand and Gravel w/ sig Silt/Clay	2000+	178	200
7D35	5-15	4-7	Solution Limestone	Silt Loam	0-2	Silt/Clay	2000+	169	186
7D36	5-15	4-7	Solution Limestone	Silt Loam	0-2	Silt/Clay	2000+	164	182



7Ec Alluvium over Bedded Sedimentary Rock (Limestone)

This hydrogeologic setting is characterized by stream valleys, ranging from the Sandusky River to smaller streams and tributaries. The silty to loamy alluvium typically is more permeable then the surrounding till or lake bed deposits. The alluvium overlies varying thicknesses of till, lake bed or deltaic deposits which in turn overlies the limestone which constitutes the principal aquifer. Recharge is enhanced by the overlying streams and water levels are typically shallow, averaging under 20 feet.

Setting	Depth to Water (ft)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography	Vadose Zone Media	Hydraulic Conductivity	Rating	Pest Rating
7Ec1	15-30	4-7	Solution Limestone	Silt Loam	0-2	Silt/Clay	2000+	164	180
7Ec2	5-15	7-10	Solution Limestone	Silt Loam	0-2	Silt/Clay	2000+	182	198
7Ec3	0-5	7-10	Solution Limestone	Silt Loam	0-2	Silt/Clay	2000+	182	199
7Ec4	5-15	4-7	Solution Limestone	Silt Loam	0-2	Silt/Clay	2000+	169	186
7Ec5	5-15	7-10	Massive Limestone	Loam	0-2	Silt/Clay	300-700	158	184
7Ec6	5-15	7-10	Massive Limestone	Sandy Loam	0-2	Sand and Gravel w/ sig Silt/Clay	100-300	159	189
7Ec7	5-15	7-10	Massive Limestone	Loam	0-2	Sand and Gravel w/ sig Silt/Clay	100-300	157	184
7Ec8	5-15	4-7	Solution Limestone	Silt Loam	0-2	Silt/Clay	1000-2000	163	182
7Ec9	5-15	4-7	Massive Limestone	Loam	0-2	Silt/Clay	300-700	145	172
7Ec10	5-15	4-7	Solution Limestone	Silt Loam	0-2	Silt/Clay	1000-2000	158	178
7Ec11	5-15	4-7	Massive Limestone	Silt Loam	0-2	Silt/Clay	300-700	143	167
7Ec12	0-5	4-7	Solution Limestone	Silt Loam	0-2	Silt/Clay	1000-2000	150	179
7Ec13	5-15	4-7	Massive Limestone	Shrink/Swell Clay	0-2	Silt/Clay	300-700	144	178
7Ec14	15-30	4-7	Massive Limestone	Silt Loam	0-2	Silt/Clay	300-700	128	153
7Ec15	5-15	4-7	Massive Limestone	Silt Loam	0-2	Silt/Clay	300-700	138	163
7Ec16	5-15	4-7	Solution Limestone	Silt Loam	0-2	Silt/Clay	1000-2000	153	174
7Ec17	0-5	4-7	Solution Limestone	Shrink/Swell Clay	0-2	Silt/Clay	1000-2000	164	194
7Ec18	5-15	4-7	Massive Limestone	Silt Loam	0-2	Silt/Clay	100-300	134	160
7Ec19	0-5	4-7	Massive Limestone	Silt Loam	0-2	Silt/Clay	100-300	144	169
7Ec20	0-5	7-10	Massive Limestone	Loam	0-2	Silt/Clay	100-300	154	182
7Ec21	5-15	7-10	Massive Limestone	Loam	0-2	Silt/Clay	100-300	149	177
7Ec22	0-5	7-10	Massive Limestone	Silt Loam	0-2	Sand & Gravel	100-300	170	192

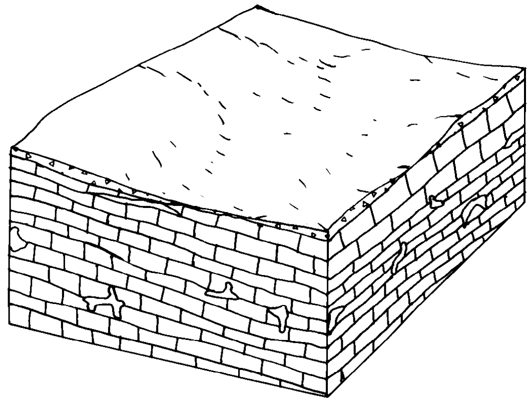


7F Glacial Lake Deposits

This hydrogeologic setting is characterized by very low relief, flat-lying topography and very poor surficial drainage. Variable thicknesses of fine-grained deposits overlie a sequence of till, fine sand, and limestone. The limestone serves as the regional aquifer; locally, the sands and gravels supply yields suitable for domestic wells. The lake bed and fine deltaic deposits are composed of sequences of fine clay and silt alternating with fine sand. As a consequence of the thin alternating layers, the horizontal permeability of these deposits is probably of much greater magnitude then the vertical permeability. Due to their fine-grained nature, these deposits weather into clay loams, silt loams, and high shrink-swell (aggregated) clays depending upon their clay content. Recharge is moderately low due to the impermeable nature of these deposits. Depth to water is extremely shallow (typically under 15 feet) due to the proximity of Sandusky Bay. In eastern Sandusky County, this area serves as a region of ground water discharge containing numerous flowing (artesian) wells and springs. Permeable, carbonate-rich marl is deposited locally around some of these springs.

Setting	Depth to Water (ft)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography	Vadose Zone Media	Hydraulic Conductivity	Rating	Pest Rating
7F1	0-5	2-4	Solution Limestone	Silt Loam	0-2	Silt/Clay	2000+	147	167
7F2	0-5	2-4	Solution Limestone	Marl	0-2	Silt/Clay	2000+	157	192
7F3	0-5	2-4	Solution Limestone	Clay Loam	0-2	Silt/Clay	2000+	145	162
7F4	0-5	2-4	Solution Limestone	Shrink/Swell Clay	0-2	Silt/Clay	2000+	153	182
7F5	0-5	2-4	Solution Limestone	Clay Loam	0-2	Silt/Clay	2000+	150	166
7F6	5-15	2-4	Solution Limestone	Clay Loam	0-2	Silt/Clay	2000+	145	161
7F7	0-5	2-4	Solution Limestone	Shrink/Swell Clay	0-2	Silt/Clay	2000+	158	186
7F8	5-15	2-4	Solution Limestone	Shrink/Swell Clay	0-2	Silt/Clay	2000+	153	181
7F9	0-5	2-4	Solution Limestone	Silt Loam	0-2	Silt/Clay	2000+	152	171
7F10	30-50	2-4	Solution Limestone	Clay Loam	0-2	Silt/Clay	1000-2000	119	137
7F11	30-50	2-4	Solution Limestone	Silt Loam	0-2	Silt/Clay	1000-2000	121	142
7F12	15-30	2-4	Solution Limestone	Clay Loam	0-2	Silt/Clay	1000-2000	129	147
7F13	30-50	2-4	Solution Limestone	Clay Loam	0-2	Silt/Clay	1000-2000	124	141
7F14	30-50	2-4	Solution Limestone	Silt Loam	0-2	Silt/Clay	1000-2000	126	146
7F15	15-30	2-4	Massive Limestone	Silt Loam	0-2	Silt/Clay	300-700	121	145
7F16	30-50	2-4	Massive Limestone	Silt Loam	0-2	Silt/Clay	300-700	111	135
7F17	30-50	2-4	Massive Limestone	Clay Loam	0-2	Silt/Clay	300-700	104	126
7F18	30-50	2-4	Massive Limestone	Clay Loam	0-2	Silt/Clay	300-700	99	122
7F19	15-30	2-4	Solution Limestone	Clay Loam	0-2	Silt/Clay	1000-2000	124	143
7F20	5-15	2-4	Solution Limestone	Clay Loam	0-2	Silt/Clay	1000-2000	134	153
7F21	5-15	2-4	Solution Limestone	Loam	0-2	Silt/Clay	1000-2000	143	167

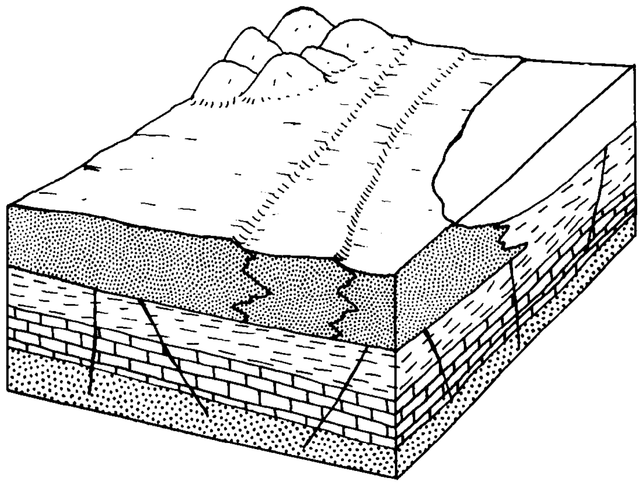
Setting	Depth to Water (ft)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography	Vadose Zone Media	Hydraulic Conductivity	Rating	Pest Rating
7F22	5-15	2-4	Solution Limestone	Shrink/Swell Clay	0-2	Silt/Clay	1000-2000	142	173
7F23	15-30	2-4	Massive Limestone	Clay Loam	0-2	Silt/Clay	300-700	109	132
7F24	0-5	2-4	Solution Limestone	Shrink/Swell Clay	0-2	Silt/Clay	1000-2000	147	178
7F25	0-5	2-4	Solution Limestone	Clay Loam	0-2	Silt/Clay	1000-2000	139	158
7F26	15-30	2-4	Massive Limestone	Clay Loam	0-2	Silt/Clay	300-700	114	136
7F27	5-15	2-4	Massive Limestone	Shrink/Swell Clay	0-2	Silt/Clay	300-700	127	162
7F28	5-15	2-4	Massive Limestone	Silt Loam	0-2	Silt/Clay	300-700	121	147
7F29	5-15	2-4	Massive Limestone	Clay Loam	0-2	Silt/Clay	300-700	119	142
7F30	15-30	2-4	Massive Limestone	Shrink/Swell Clay	0-2	Silt/Clay	300-700	117	152
7F31	15-30	2-4	Massive Limestone	Silt Loam	0-2	Silt/Clay	300-700	111	137
7F32	15-30	2-4	Massive Limestone	Clay Loam	0-2	Silt/Clay	300-700	109	132
7F33	15-30	2-4	Massive Limestone	Sandy Loam	0-2	Silt/Clay	300-700	115	147
7F34	15-30	2-4	Massive Limestone	Silt Loam	0-2	Silt/Clay	300-700	116	141
7F35	5-15	2-4	Massive Limestone	Silt Loam	0-2	Silt/Clay	300-700	126	151
7F36	5-15	2-4	Massive Limestone	Sandy Loam	0-2	Silt/Clay	300-700	130	161
7F37	5-15	2-4	Massive Limestone	Clay Loam	0-2	Silt/Clay	300-700	124	146
7F38	5-15	2-4	Massive Limestone	Clay Loam	0-2	Silt/Clay	100-300	115	139
7F39	5-15	2-4	Massive Limestone	Shrink/Swell Clay	0-2	Silt/Clay	100-300	123	159
7F40	5-15	2-4	Massive Limestone	Sandy Loam	0-2	Silt/Clay	100-300	121	154
7F41	5-15	2-4	Massive Limestone	Silt Loam	0-2	Silt/Clay	100-300	117	144
7F42	15-30	2-4	Massive Limestone	Silt Loam	0-2	Silt/Clay	100-300	112	138
7F43	15-30	2-4	Massive Limestone	Clay Loam	0-2	Silt/Clay	100-300	100	125
7F44	15-30	2-4	Massive Limestone	Shrink/Swell Clay	0-2	Silt/Clay	100-300	108	145
7F45	15-30	2-4	Massive Limestone	Silt Loam	0-2	Silt/Clay	100-300	102	130
7F46	15-30	2-4	Massive Limestone	Clay Loam	0-2	Silt/Clay	100-300	105	129



7Gb Thin Till over Limestone

This hydrogeologic setting is characterized by generally low relief ranging from very flat-lying regions to small ridges or knobs. The overlying glacial till is patchy, thin, and may be totally absent in some areas. Wave activity from post-glacial lakes has stripped the surficial till cover from these bedrock highs. The remaining till is commonly thin and highly weathered and fractured. Soils are thin to absent and reflect the residual bedrock. Recharge to the underlying bedrock is very rapid as the bedrock is exposed at or near the surface. In western Sandusky County depth to water is under 25 feet; depth to water in south eastern Sandusky County is variable, but generally is deeper.

Setting	Depth to Water (ft)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography	Vadose Zone Media	Hydraulic Conductivity	Rating	Pest Rating
7Gb1	75-100	10+	Karst Limestone	Thin or Absent	0-2	Karst Limestone	2000+	186	216
7Gb2	75-100	10+	Karst Limestone	Thin or Absent	6-12	Karst Limestone	2000+	181	201
7Gb3	5-15	7-10	Massive Limestone	Thin or Absent	0-2	Limestone	100-300	169	210
7Gb4	15-30	7-10	Massive Limestone	Thin or Absent	2-6	Limestone	100-300	158	197
7Gb5	15-30	7-10	Massive Limestone	Thin or Absent	0-2	Limestone	100-300	159	200
7Gb6	5-15	7-10	Massive Limestone	Thin or Absent	2-6	Limestone	100-300	168	207
7Gb7	0-5	7-10	Massive Limestone	Thin or Absent	0-2	Limestone	100-300	174	215
7Gb8	15-30	7-10	Massive Limestone	Thin or Absent	0-2	Limestone	300-700	168	207

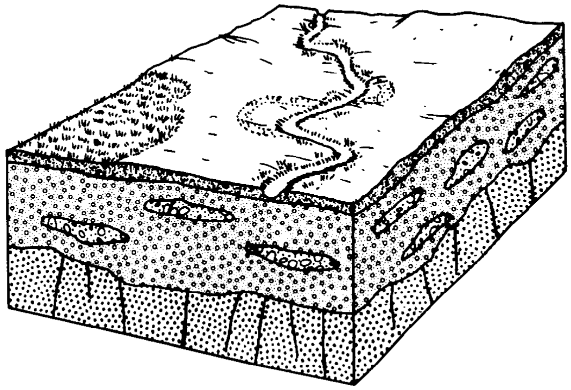


7H Beaches, Beach Ridges, Deltas, and Sand Dunes

This hydrogeologic setting is characterized by low relief, sandy surface soils, and high infiltration rates and low sorptive capacity. These deposits tend to be relatively thick in central and eastern Sandusky County and are thin in western Sandusky County. Sandy, deltaic deposits are common to the Green Springs-Fremont region. Beaches in eastern Sandusky County are much more continuous and linear then in western Sandusky County. These sandy deposits are underlain by fine till or lake bed deposits which in turn overlie limestone. The surficial sandy deposits do not constitute an aquifer, the source of ground water is the limestone or thin gravels between the limestone and till. Depth to water is highly variable throughout the region. Depths tend to be shallow in western Sandusky County, deep in eastern Sandusky County and vary by the thickness of drift in central Sandusky County.

Setting	Depth to Water (ft)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography	Vadose Zone Media	Hydraulic Conductivity	Rating	Pest Rating
7H1	50-75	10+	Karst Limestone	Sand	2-6	Karst Limestone	2000+	188	213
7H2	30-50	4-7	Solution Limestone	Sand	2-6	Till	2000+	158	188
7H3	50-75	4-7	Solution Limestone	Sand	2-6	Till	2000+	148	178
7H4	75-100	7-10	Karst Limestone	Sandy Loam	2-6	Karst Limestone	2000+	163	181
7H5	50-75	7-10	Karst Limestone	Sandy Loam	0-2	Sand & Gravel	2000+	169	189
7H6	75-100	7-10	Karst Limestone	Sand	2-6	Karst Limestone	2000+	169	196
7H7	50-75	7-10	Karst Limestone	Sand	0-2	Karst Limestone	2000+	175	204
7H8	50-75	7-10	Karst Limestone	Sandy Loam	2-6	Karst Limestone	2000+	168	186
7H9	30-50	7-10	Karst Limestone	Sand	0-2	Sand & Gravel	2000+	185	214
7H10	50-75	7-10	Karst Limestone	Sand	2-6	Karst Limestone	2000+	174	201
7H11	30-50	7-10	Karst Limestone	Sand	2-6	Karst Limestone	2000+	184	211
7H12	30-50	7-10	Sand & Gravel	Sand	2-6	Sand & Gravel	300-700	160	193
7H13	30-50	7-10	Sand & Gravel	Sandy Loam	2-6	Sand & Gravel	300-700	154	178
7H14	30-50	7-10	Sand & Gravel	Silt Loam	0-2	Sand & Gravel	300-700	151	171
7H15	30-50	4-7	Solution Limestone	Sandy Loam	2-6	Till	2000+	152	173
7H16	30-50	4-7	Solution Limestone	Sand	2-6	Sand and Gravel w/ sig Silt/Clay	2000+	163	192
7H17	15-30	4-7	Solution Limestone	Sandy Loam	0-2	Sand and Gravel w/ sig Silt/Clay	2000+	168	190
7H18	30-50	4-7	Solution Limestone	Sandy Loam	0-2	Sand and Gravel w/ sig Silt/Clay	2000+	158	180
7H19	15-30	4-7	Solution Limestone	Sand	2-6	Sand and Gravel w/ sig Silt/Clay	2000+	173	202
7H20	15-30	4-7	Solution Limestone	Sand	0-2	Till	2000+	164	197
7H21	5-15	4-7	Solution Limestone	Sand	2-6	Sand & Gravel	2000+	183	212

Setting	Depth to Water (ft)	Recharge (In/Yr)	Aquifer Media	Soil Media	Topography	Vadose Zone Media	Hydraulic Conductivity	Rating	Pest Rating
7H22	0-5	4-7	Solution Limestone	Sandy Loam	2-6	Sand & Gravel	2000+	182	202
7H23	15-30	4-7	Solution Limestone	Sandy Loam	2-6	Sand and Gravel w/ sig Silt/Clay	2000+	167	187
7H24	0-5	7-10	Solution Limestone	Sand	0-2	Sand & Gravel	2000+	197	228
7H25	30-50	4-7	Solution Limestone	Sandy Loam	0-2	Sand and Gravel w/ sig Silt/Clay	1000-2000	147	172
7H26	30-50	4-7	Solution Limestone	Sand	2-6	Sand and Gravel w/ sig Silt/Clay	1000-2000	152	184
7H27	30-50	4-7	Solution Limestone	Silt Loam	0-2	Sand and Gravel w/ sig Silt/Clay	1000-2000	143	162
7H28	15-30	4-7	Solution Limestone	Silt Loam	2-6	Sand and Gravel w/ sig Silt/Clay	1000-2000	152	169
7H29	15-30	4-7	Solution Limestone	Sandy Loam	0-2	Sand and Gravel w/ sig Silt/Clay	1000-2000	157	182
7H30	15-30	4-7	Solution Limestone	Sand	0-2	Sand and Gravel w/ sig Silt/Clay	1000-2000	163	197
7H31	15-30	4-7	Massive Limestone	Sandy Loam	0-2	Sand and Gravel w/ sig Silt/Clay	300-700	142	171
7H32	15-30	4-7	Massive Limestone	Sand	0-2	Sand and Gravel w/ sig Silt/Clay	300-700	148	186
7H33	30-50	4-7	Massive Limestone	Sandy Loam	0-2	Sand and Gravel w/ sig Silt/Clay	300-700	132	161
7H34	30-50	2-4	Massive Limestone	Silt Loam	0-2	Silt/Clay	300-700	106	131
7H35	30-50	2-4	Massive Limestone	Sandy Loam	0-2	Silt/Clay	300-700	110	141
7H36	30-50	2-4	Solution Limestone	Sandy Loam	0-2	Silt/Clay	1000-2000	125	152
7H37	15-30	2-4	Massive Limestone	Sandy Loam	0-2	Silt/Clay	300-700	120	151
7H38	15-30	2-4	Massive Limestone	Silt Loam	0-2	Silt/Clay	300-700	116	141
7H39	30-50	2-4	Massive Limestone	Silt Loam	2-6	Silt/Clay	300-700	105	128
7H40	15-30	2-4	Massive Limestone	Silt Loam	2-6	Silt/Clay	300-700	115	138
7H41	30-50	2-4	Solution Limestone	Silt Loam	0-2	Silt/Clay	1000-2000	121	142
7H42	30-50	4-7	Solution Limestone	Sandy Loam	0-2	Till	2000+	153	176
7H43	5-15	7-10	Massive Limestone	Sandy Loam	0-2	Sand and Gravel w/ sig Silt/Clay	100-300	161	190
7H44	5-15	7-10	Massive Limestone	Sandy Loam	0-2	Sand and Gravel w/ sig Silt/Clay	100-300	156	186
7H45	15-30	7-10	Massive Limestone	Sand	2-6	Sand and Gravel w/ sig Silt/Clay	100-300	156	192
7H46	15-30	4-7	Massive Limestone	Sandy Loam	2-6	Sand and Gravel w/ sig Silt/Clay	100-300	137	165
7H47	0-5	4-7	Massive Limestone	Sandy Loam	0-2	Sand and Gravel w/ sig Silt/Clay	100-300	153	183
7H48	5-15	7-10	Massive Limestone	Sand	2-6	Sand & Gravel	100-300	171	206
7H49	15-30	7-10	Massive Limestone	Sand	2-6	Sand & Gravel	100-300	161	196
7H50	15-30	4-7	Massive Limestone	Sand	0-2	Sand and Gravel w/ sig Silt/Clay	100-300	144	183
7H51	5-15	7-10	Massive Limestone	Sand	0-2	Sand and Gravel w/ sig Silt/Clay	100-300	162	201
7H52	0-5	7-10	Massive Limestone	Sand	2-6	Sand & Gravel	100-300	176	211
7H53	5-15	7-10	Massive Limestone	Sand	0-2	Sand & Gravel	100-300	172	209
7H54	15-30	4-7	Massive Limestone	Sandy Loam	0-2	Till	100-300	133	164
7H55	15-30	4-7	Massive Limestone	Silt Loam	0-2	Till	100-300	129	154
7H56	5-15	4-7	Massive Limestone	Loam	0-2	Till	100-300	136	165
7H57	15-30	4-7	Massive Limestone	Sandy Loam	0-2	Till	300-700	147	175
7H58	15-30	4-7	Massive Limestone	Sand	0-2	Till	100-300	139	179
7H59	5-15	4-7	Massive Limestone	Silt Loam	2-6	Till	300-700	147	168
7H60	5-15	4-7	Massive Limestone	Sandy Loam	2-6	Sand and Gravel w/ sig Silt/Clay	300-700	156	182



7I Swamp / Marsh

This hydrogeologic setting is characterized by extremely low topographic relief and poor drainage. This setting represents the extremely sensitive wetlands immediately adjacent to Sandusky Bay. Soils are a mixture of silts and clays and also contain appreciable organic detritus and peats. The soils are high shrink / swell clay and are particularly susceptible to desecration during dry periods. The water table is generally very near the surface due to the proximity of Sandusky Bay and recharge is relatively high to the local water table. Ground water predominantly comes from the underlying limestone.

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	Solution Limestone	Shrink/Swell Clay	0-2	Silt/Clay	2000+	193	218
7I2	0-5	7-10	Solution Limestone	Silt Loam	0-2	Silt/Clay	2000+	187	203
7I3	0-5	7-10	Massive Limestone	Shrink/Swell Clay	0-2	Silt/Clay	300-700	172	203

Ground-Water Pollution Potential of SANDUSKY COUNTY

by
Michael P. Angle

1 0 1 2 Miles
1 0 1 2 Kilometers

CONTOUR INTERVAL 5 FEET

Pollution Potential Index Range

Higher	180 - 199
	160 - 179
to	140 - 159
	120 - 139
	100 - 119
Lower	80 - 99

County Line
Township Line
Incorporated City Limit

Description of Map Symbols

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

Gravel Pit / Quarry

Observation Well Site**

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

Hydrogeologic Settings

- 7Ac Glacial Till Over Limestone
- 7Af Sand and Gravel Interbedded in Glacial Till
- 7D Buried Valley
- 7Ec Alluvium Over Sedimentary Rocks (Limestone)
- 7F Glacial Lake Deposits
- 7Gb Thin Till Over Limestone
- 7H Beaches, Beach Ridges, Deltas and Dunes
- 7I Swamps/Marshes

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 Sandusky County", GWPP Report No. 19, Ohio Department of Natural Resources, Division of Water.

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

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ODNR Ohio Department of Natural Resources
Richard F. Celeste Governor
Joseph J. Sommer Director
Naturally OHIO the heart of it all!

(Pesticide) Ground-Water Pollution Potential of SANDUSKY COUNTY

by
Michael P. Angle

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)".

Hydrogeologic Settings

7Ac	Glacial Till Over Limestone
7Af	Sand and Gravel Interbedded in Glacial Till
7D	Buried Valley
7Ec	Alluvium Over Sedimentary Rocks (Limestone)
7F	Glacial Lake Deposits
7Gb	Thin Till Over Limestone
7H	Beaches, Beach Ridges, Deltas and Dunes
7I	Swamps/Marshes

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 Sandusky County", GWPP Report No. 19, Ohio Department of Natural Resources, Division of Water.

Pesticide Pollution Potential Index Range

Higher to Lower

- 200+
- 180 - 199
- 160 - 179
- 140 - 159
- 120 - 139
- 100 - 119

Description of Map Symbols

Hydrogeologic Region — Hydrogeologic Setting
7Ad 6
98 — Relative Pollution Potential

Gravel Pit / Quarry

Observation Well Site**

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

1 0 1 2 Miles

1 0 1 2 Kilometers

CONTOUR INTERVAL 5 FEET

County Line

Township Line

Incorporated City Limit

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