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GEOLOGICAL SURVEY

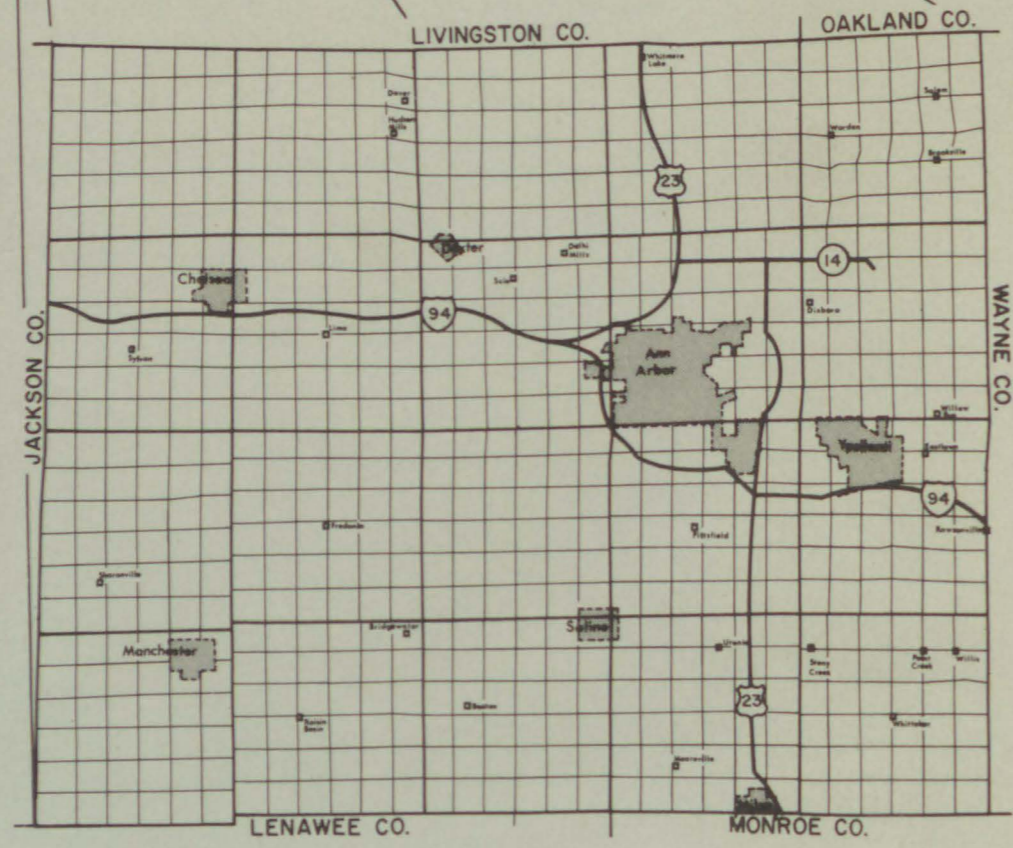
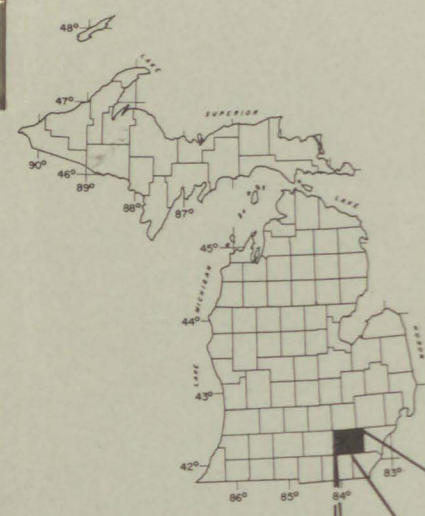
GEOLOGY AND HYDROLOGY FOR  
ENVIRONMENTAL PLANNING IN  
WASHTENAW COUNTY, MICHIGAN

U.S. GEOLOGICAL SURVEY  
Open-File Report

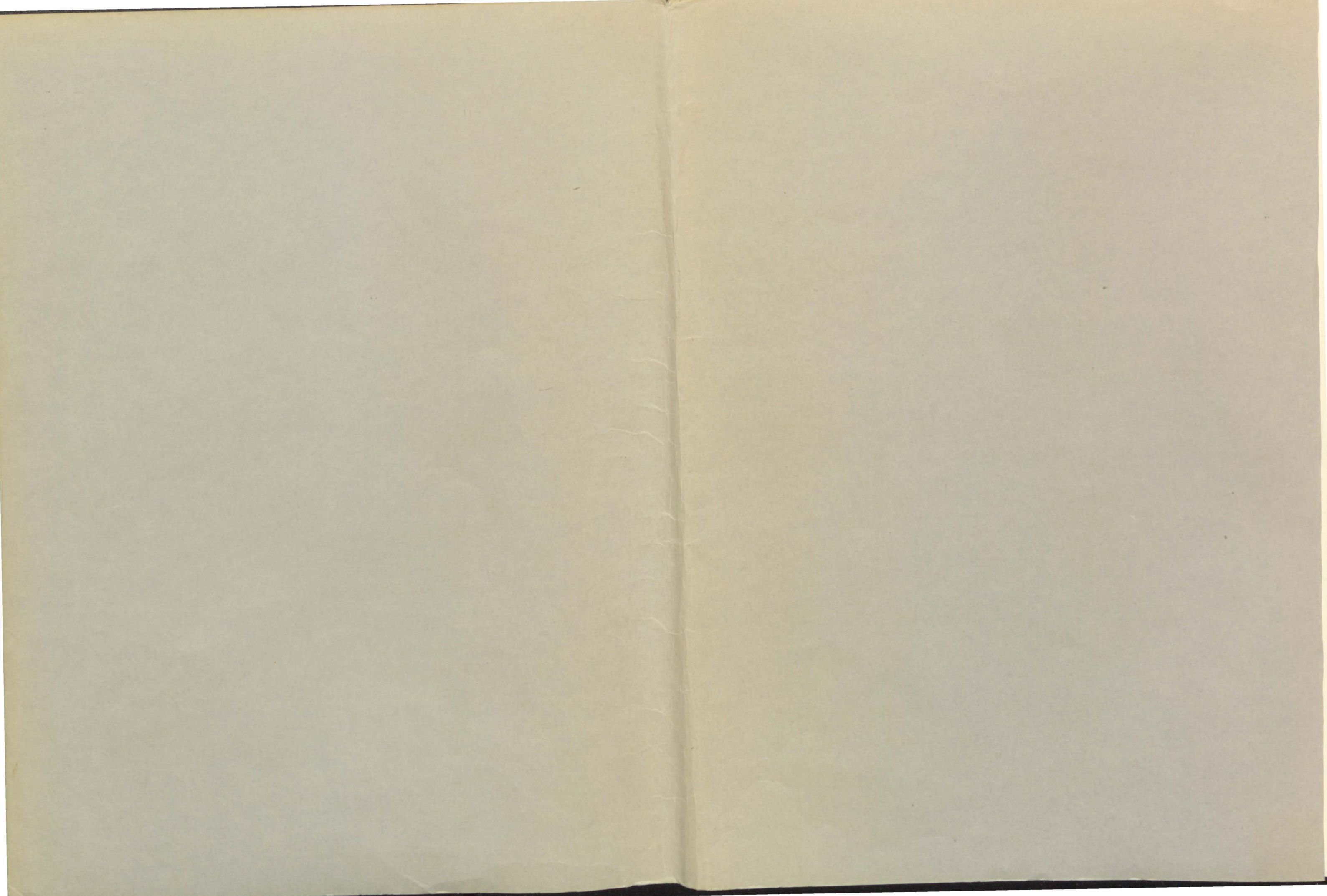
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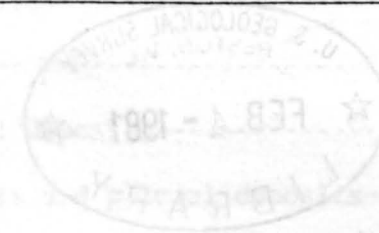
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GEOLOGY AND HYDROLOGY FOR  
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WASHTENAW COUNTY, MICHIGAN  
By William B. Fleck

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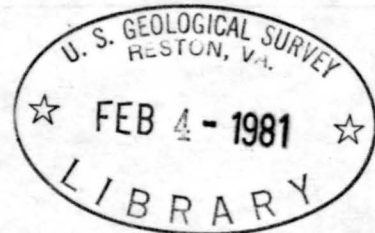
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UNITED STATES DEPARTMENT OF THE INTERIOR

CECIL D. ANDRUS, Secretary

GEOLOGICAL SURVEY

H. William Menard, Director



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CONVERSION FACTORS

The inch-pound units used in this report can be converted to the metric system of units as follows:

<u>Multiply inch-pound unit</u>	<u>By</u>	<u>To obtain metric unit</u>
inches (in)	2.54	centimeters (cm)
feet (ft)	0.3048	meters (m)
miles (mi)	1.609	kilometers (km)
square miles (mi <sup>2</sup> )	2.590	square kilometers (km <sup>2</sup> )
inches per hour (in/hr)	2.54	centimeters per hour (cm/hr)
feet per mile (ft/mi)	0.1894	meters per kilometer (m/km)
gallons per minute (gpm)	0.06309	liters per second (L/s)
gallons per minute per foot of drawdown (gpm/ft)	0.207	liters per second per meter of drawdown (L/s/m)
	0.207x10 <sup>-3</sup>	square meters per second (m <sup>2</sup> /s)
degrees Fahrenheit (°F)	( <sup>1</sup> )	degrees Celsius (°C)

<sup>1</sup> Temperature °C = (temperature °F - 32)/1.8.

GEOLOGY AND HYDROLOGY FOR ENVIRONMENTAL  
PLANNING IN WASHTENAW COUNTY, MICHIGAN

by

William B. Fleck

ABSTRACT

Washtenaw County is underlain by glacial deposits that range in thickness from about 50 feet to about 450 feet. Underlying the glacial deposits are sedimentary rocks of Mississippian and Devonian age. The youngest of these rocks are the sandstones of the Marshall Formation in the western part of the county; the oldest are the limestones of the Detroit River Group in the southeast corner.

Sand and gravel deposits in some places in the county may yield more than 500 gallons per minute of water. Approximately 50 percent of the wells tapping the Marshall Formation, the most reliable bedrock aquifer, can yield as much as 60 gallons per minute.

Washtenaw County has sand and gravel deposits that are more than 50 feet thick. The deposits are mined in several areas and are of economic importance. In addition, there may be potential for peat production in the western part of the county and for clay production in the eastern part.

INTRODUCTION

Washtenaw County, an area of 723 square miles, is in the southeastern part of Michigan's Southern Peninsula, adjacent to Detroit. Rapid urban and industrial growth in the county has made land-use and water-use planning essential if geologic and hydrologic resources are to be developed wisely. Available land for such activities as sanitary-landfill operations, municipal water supplies and waste-water treatment, sand and gravel development, and recreation is diminishing. Prospects for increased oil and gas production and development of peat and clay resources may complicate land-use practices. An understanding of the geologic and hydrologic characteristics and their relation to the development of the county's resources is thus necessary.

Purpose and Scope

The purpose of this study is to provide geologic and hydrologic data for environmental land-use planning in Washtenaw County. Drillers' well records and results of other investigations, including a 1976 investigation by the U.S. Geological Survey (Twenter, F. R., Knutilla, R. L., and Nowlin, J. O., 1976), were the principal sources of data for this study. These data were used to define the thickness and permeability of surficial deposits, location and types of bedrock deposits, altitude of bedrock surface, and location of selected mineral resources. The data were also used to define ground-water levels, availability of water from surficial and bedrock deposits, and the thickness of relatively impermeable deposits. Maps showing each of these geologic and hydrologic characteristics are included in the report; maps showing surface-water bodies and oil and gas pipe lines are also included because of their significance in land-use planning.

ILLUSTRATIONS

Population

Most residents of Washtenaw County live in Ann Arbor and Ypsilanti, and the smaller communities of Chelsea, Manchester, and Saline. More than 60 percent of the 234,000 people (1970 census) live on only 5 percent of the land. Population trends projected by the National Sanitation Foundation (1964) indicate that the population of Washtenaw County will more than double during the next 40 years (fig. 1). Many townships that were rural in 1972 will be urbanized (figs. 2 and 3). Coincident with the probable population increase, it is likely that industry will spread outward from Detroit, which lies just to the east of Washtenaw County. Projected changes in population, population distribution, and industrial activity indicate a need for good land-management practices.

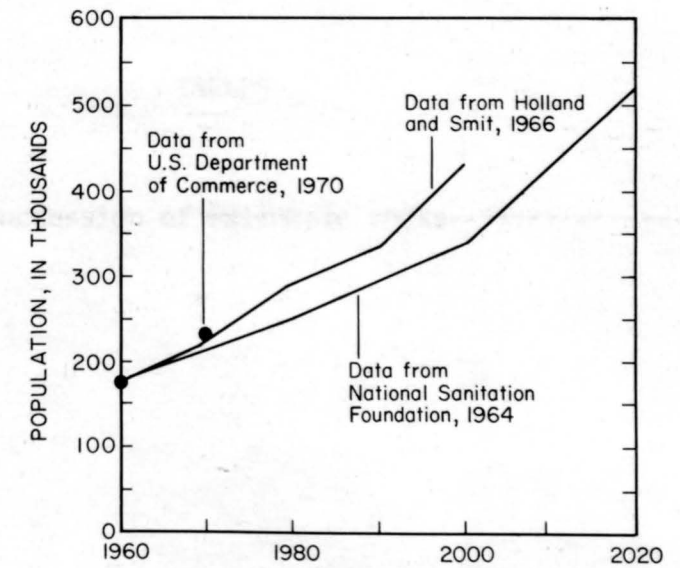


Figure 1.--Population trends.

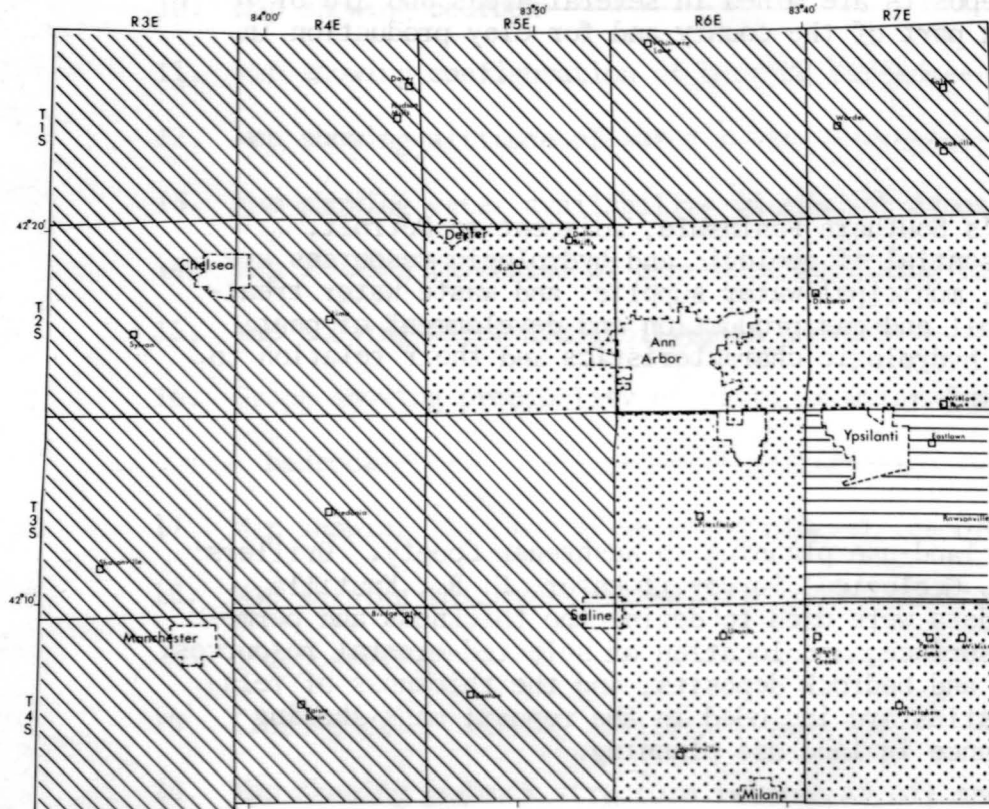
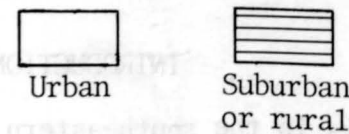


Figure 2.--Population distribution, 1970 (Data from U.S. Department of Commerce, 1970).

EXPLANATION



Population more than 1,000 per square mile.

Population from 100 to 999 per square mile.

Population less than 100 per square mile.

0 1 2 3 4 5 MILES

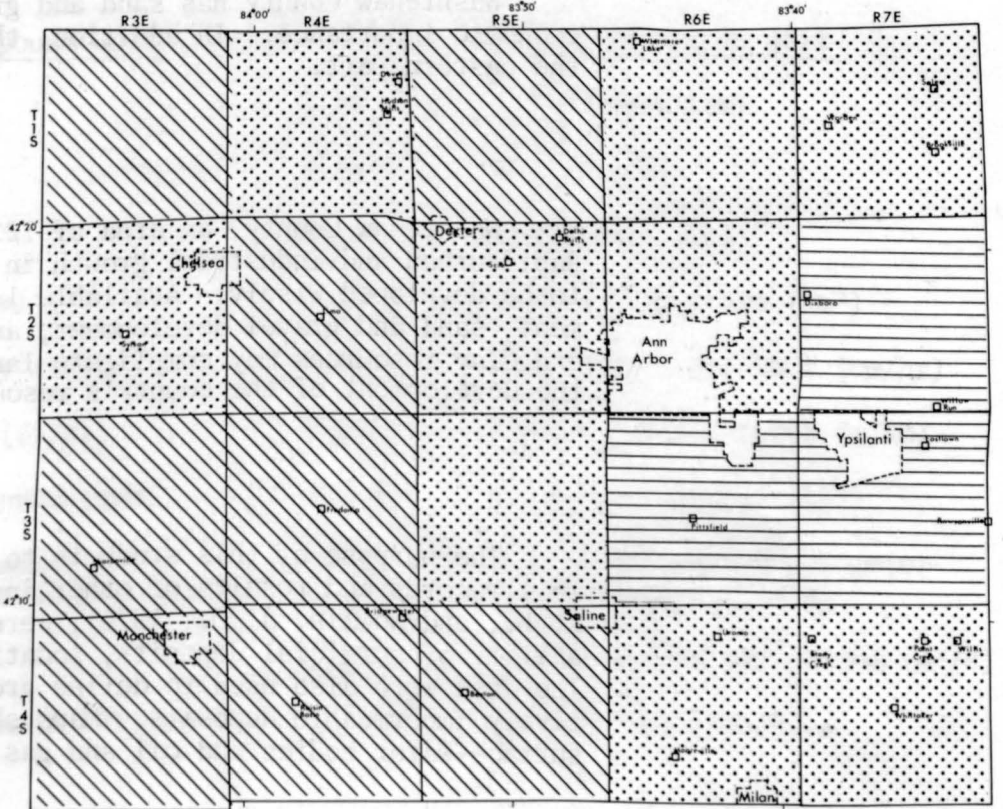
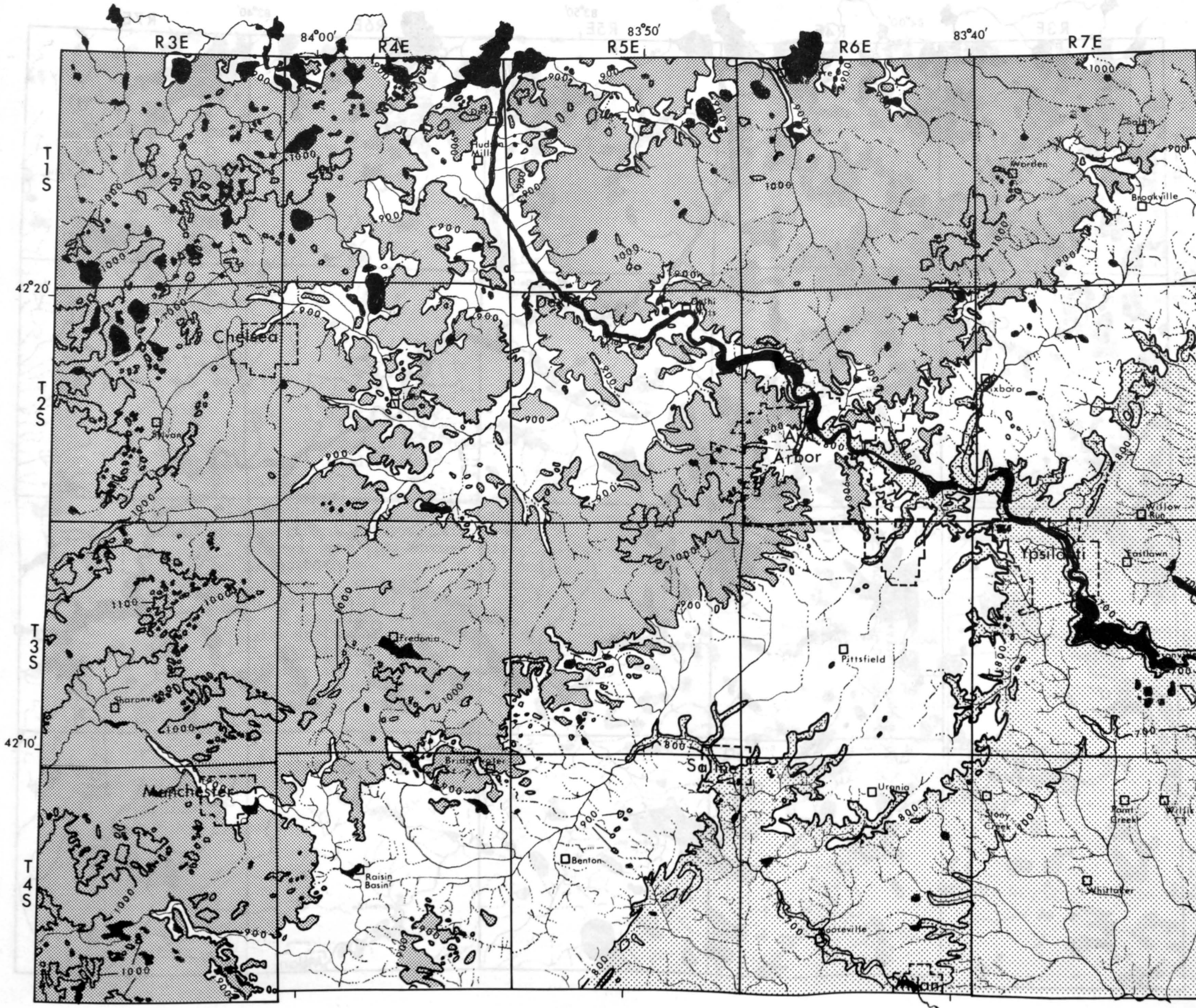


Figure 3.--Projected population distribution for the year 2020 (Data from National Sanitation Foundation, 1964).




PHYSICAL SETTING

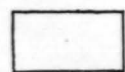
Altitude of Land Surface


Altitude of land surface ranges from about 1,100 feet above mean sea level in the western part of Washtenaw County, to about 650 feet in the southeastern part. The northwestern part is hilly and has numerous lakes and wetlands. Southeast of Ann Arbor, the altitude of the land surface decreases as the undulating moraines terminate and lakebed area begins. Between these two topographically different areas, local steepening of the land surface marks the shoreline of former glacial lakes.

EXPLANATION

—900—  
 Line of equal altitude of land surface above mean sea level; interval 100 feet.

 Altitude more than 900 feet.

 Altitude 800 to 900 feet.

 Altitude less than 800 feet.

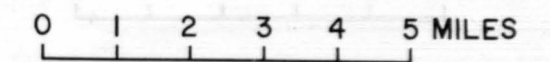


Figure 4.--Altitude of land surface.

PHYSICAL SETTING  
 Altitude of land surface  
 Ranges of land surface ranges  
 from about 100 feet above mean sea  
 level in the western part of Wash-  
 ington County to about 650 feet in  
 the southeastern part. The north-  
 western part is mostly level and  
 the southeastern part is mostly  
 hilly. The land surface is  
 generally level between these  
 two regions. The land surface  
 is generally level between these  
 two regions. The land surface  
 is generally level between these  
 two regions.

EXPLANATION

Streams  
 (intermittent where broken)

Lakes and ponds

Wet Lands

0 1 2 3 4 5 MILES

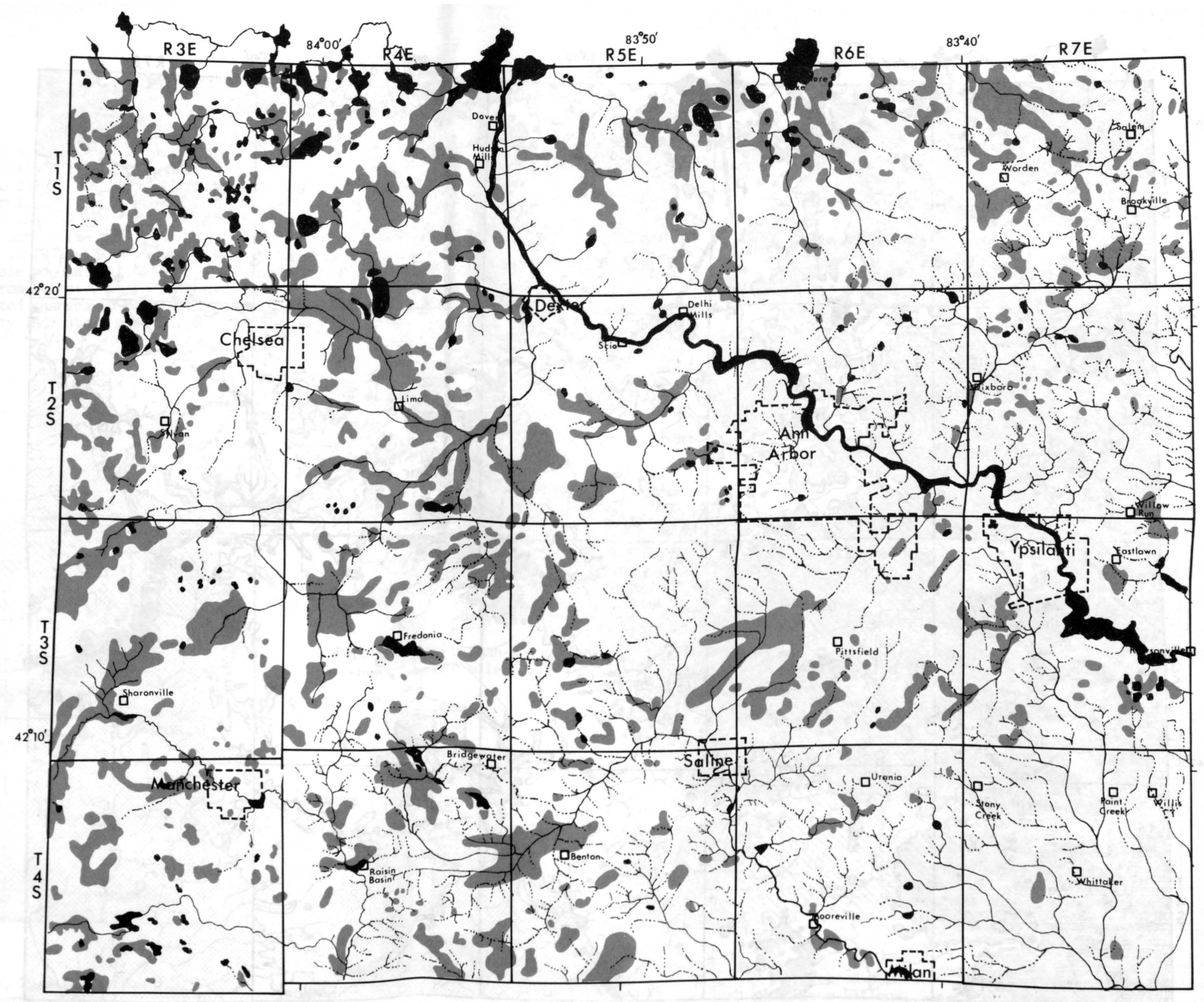
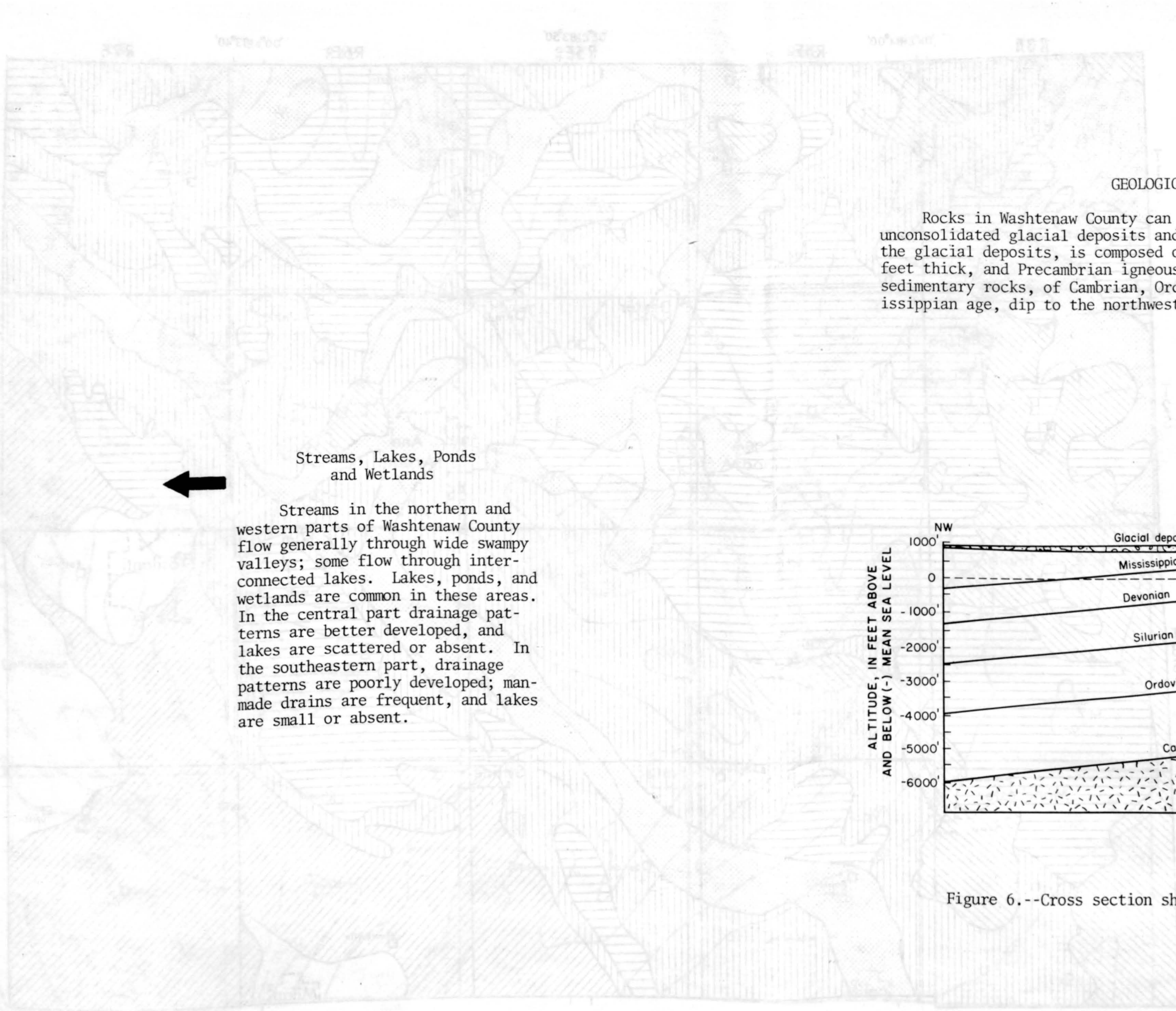


Figure 5.--Streams, lakes, ponds, and wetlands.



Streams, Lakes, Ponds  
and Wetlands



Streams in the northern and western parts of Washtenaw County flow generally through wide swampy valleys; some flow through inter-connected lakes. Lakes, ponds, and wetlands are common in these areas. In the central part drainage patterns are better developed, and lakes are scattered or absent. In the southeastern part, drainage patterns are poorly developed; man-made drains are frequent, and lakes are small or absent.

GEOLOGIC SETTING

Rocks in Washtenaw County can be separated into two major categories: unconsolidated glacial deposits and bedrock. The bedrock, which underlies the glacial deposits, is composed of sedimentary rocks, 4,000 to 7,000 feet thick, and Precambrian igneous and metamorphic rocks (fig. 6). The sedimentary rocks, of Cambrian, Ordovician, Silurian, Devonian, and Mississippian age, dip to the northwest at about 50 feet per mile.

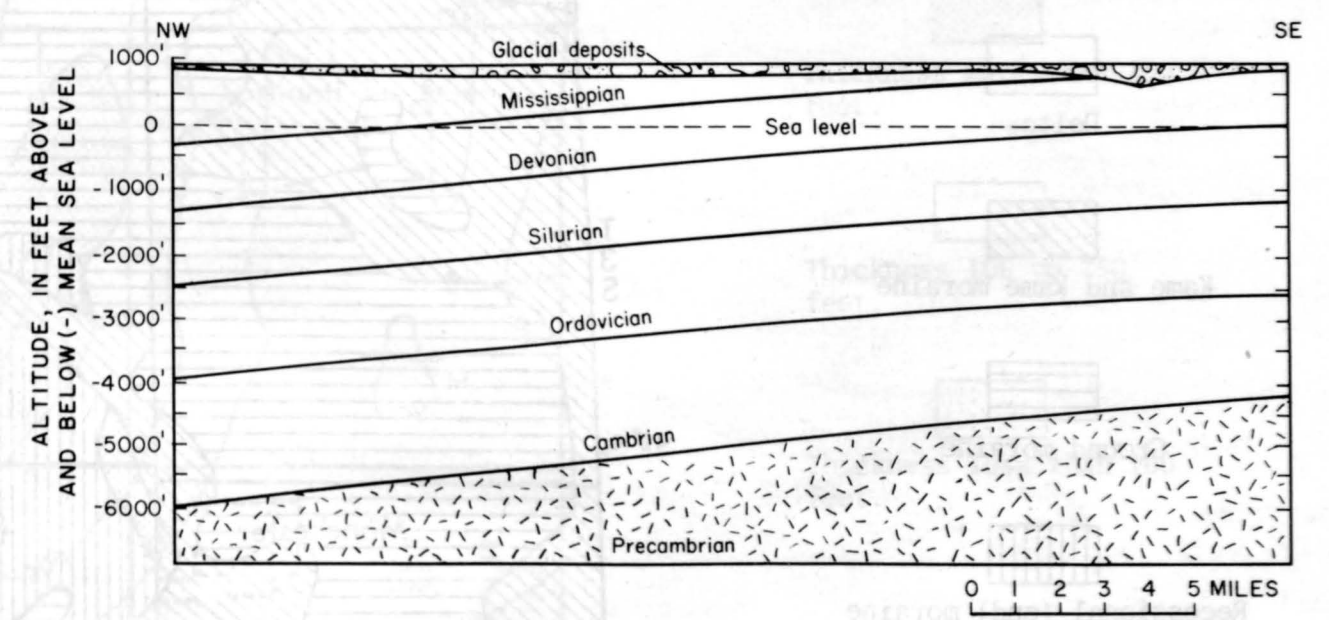
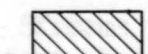


Figure 6.--Cross section showing relation of geologic units.

Glacial Deposits

Glacial deposits consist of lakebeds, outwash, deltas, and moraines. Lakebeds, composed primarily of clay and silt that is overlain by a thin layer of sand, predominate in the southeastern part of the county. Elsewhere in the county, moraines and outwash predominate. Moraines are composed of clay, silt, sand, and gravel mixtures. Outwash is principally sand and gravel.

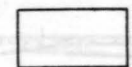
EXPLANATION



Lakebeds



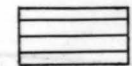
Outwash



Deltas



Kame and kame moraine



Ground moraine



Recessional (end) moraine

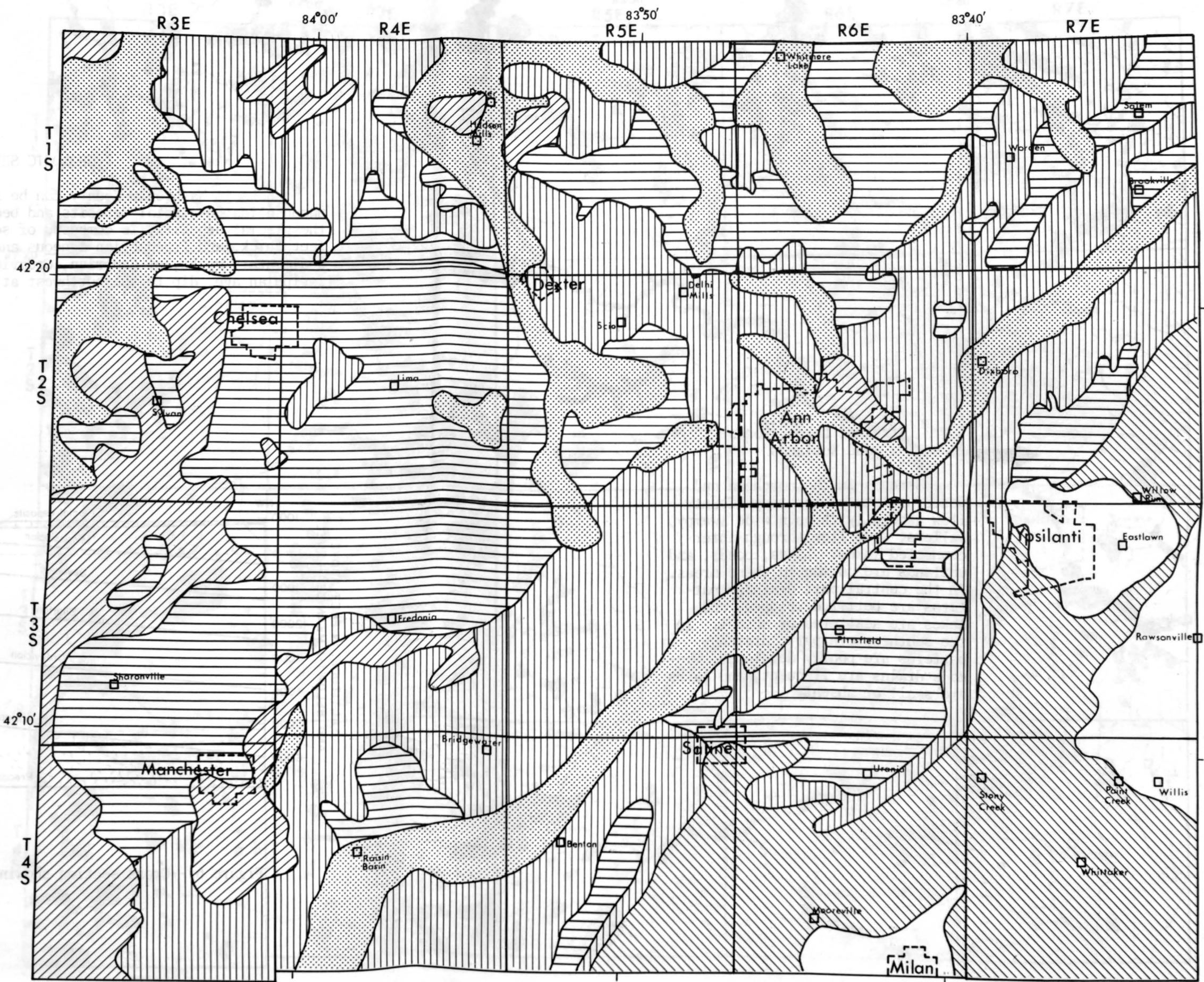
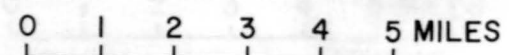
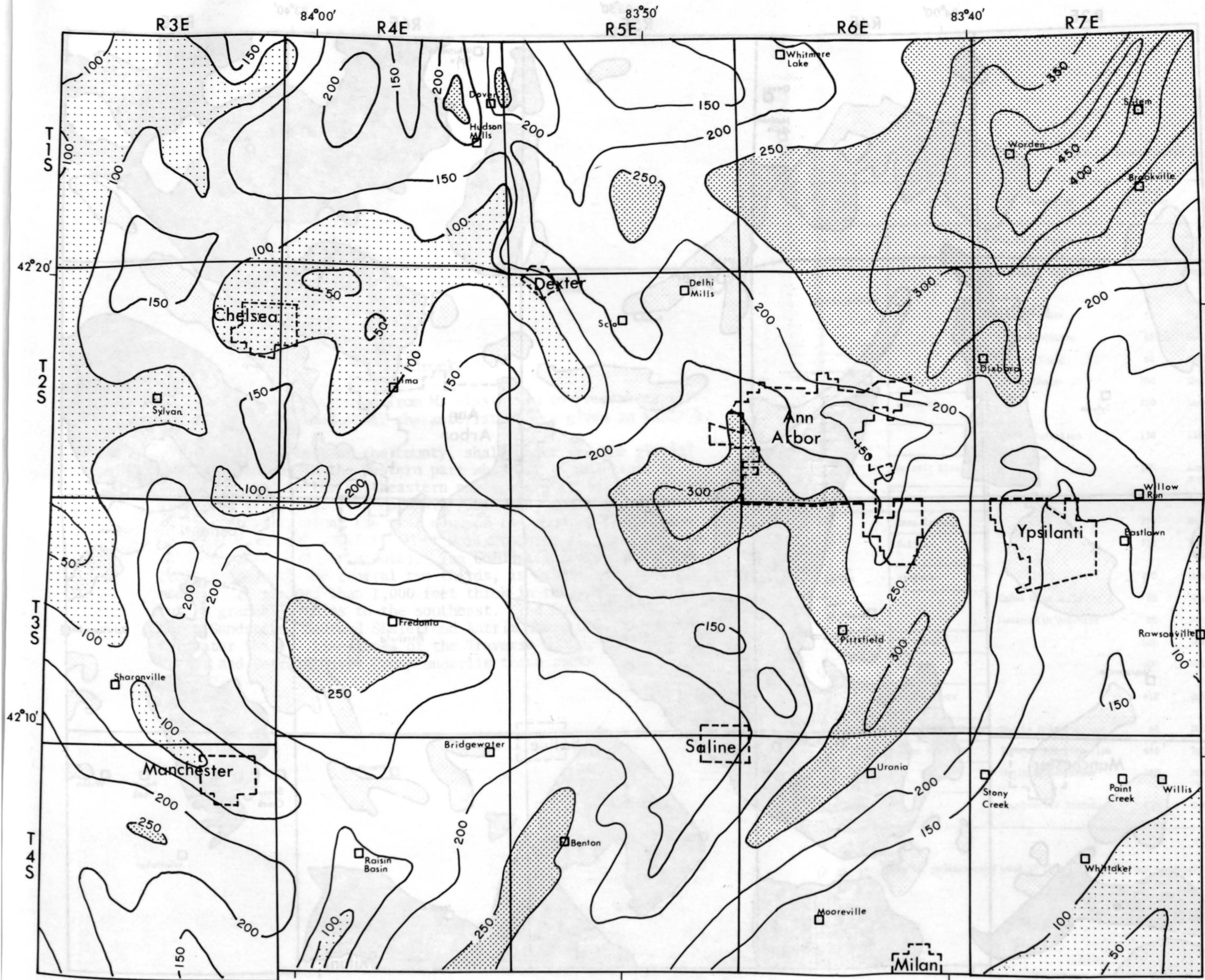



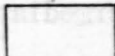
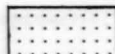
Figure 7.--Glacial deposits (from Kunkle, 1960).



Thickness of Glacial Deposits

The thickness of glacial deposits ranges from 50 feet to 450 feet. In the central and northeastern parts of the county, the deposits are more than 250 feet thick; in the northwestern part and in small areas to the southeast they are generally less than 100 feet thick.

EXPLANATION

- 100—  
Line of equal thickness of surficial deposits; interval 50 feet.
-  Thickness more than 250 feet.
-  Thickness 100 to 250 feet.
-  Thickness less than 100 feet.

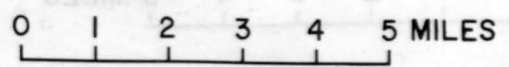
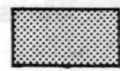


Figure 8.--Thickness of glacial deposits.

Permeability of Soils and Glacial Deposits

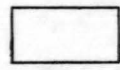
Soils and glacial deposits having a relatively high permeability lie in a northeast-southwest belt through the central and southeastern parts of the county. At other locations, soils and glacial deposits generally have a low to intermediate permeability. Permeabilities shown are based on a soils map (Veatch and others, 1930) and on unpublished data from the files of the U.S. Geological Survey.

EXPLANATION



Permeability low

Infiltration rates generally less than 0.8 inches per hour.



Permeability intermediate

Infiltration rates generally from 0.8 to 2.5 inches per hour.



Permeability high

Infiltration rates generally more than 2.5 inches per hour.

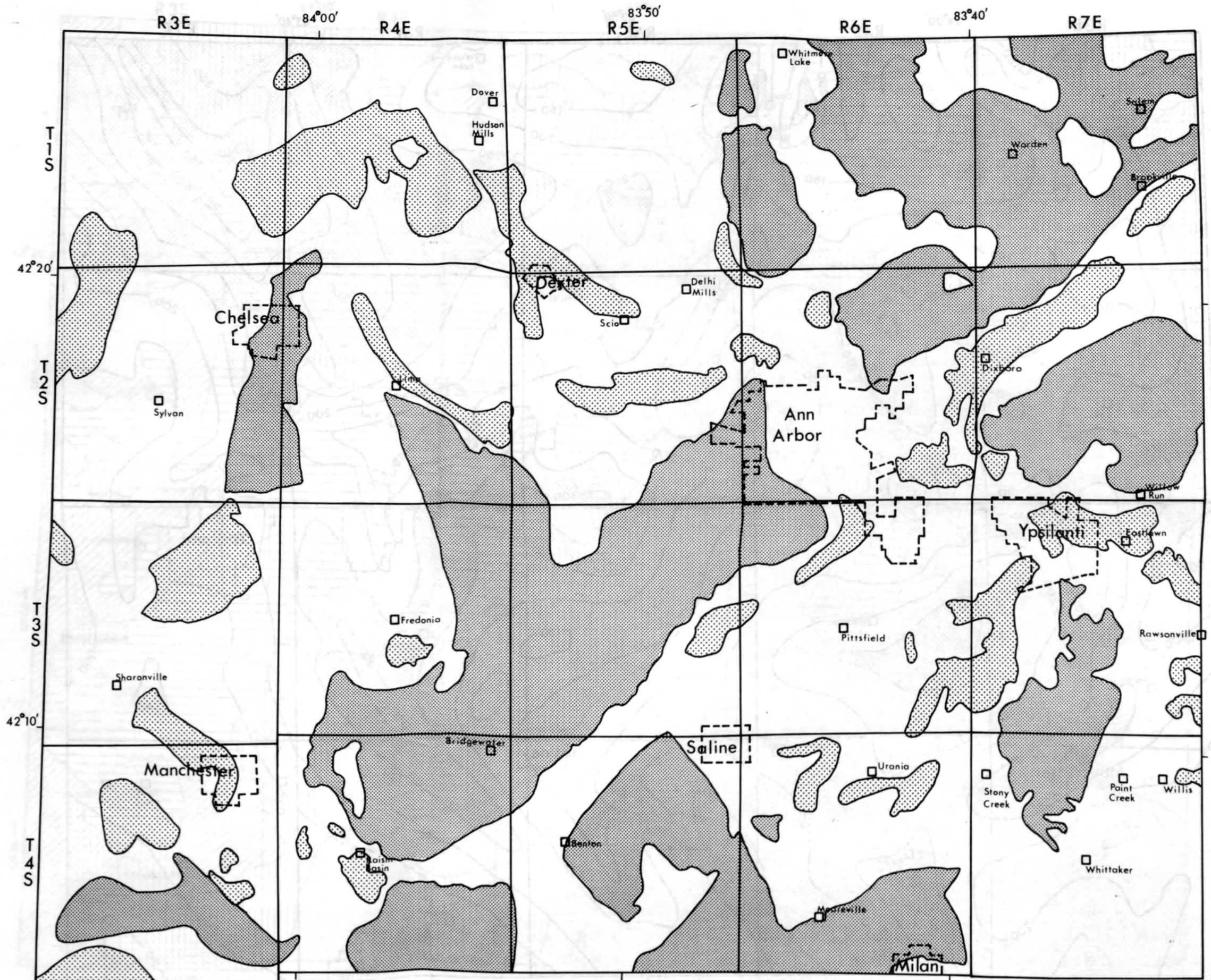
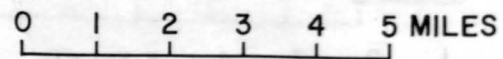
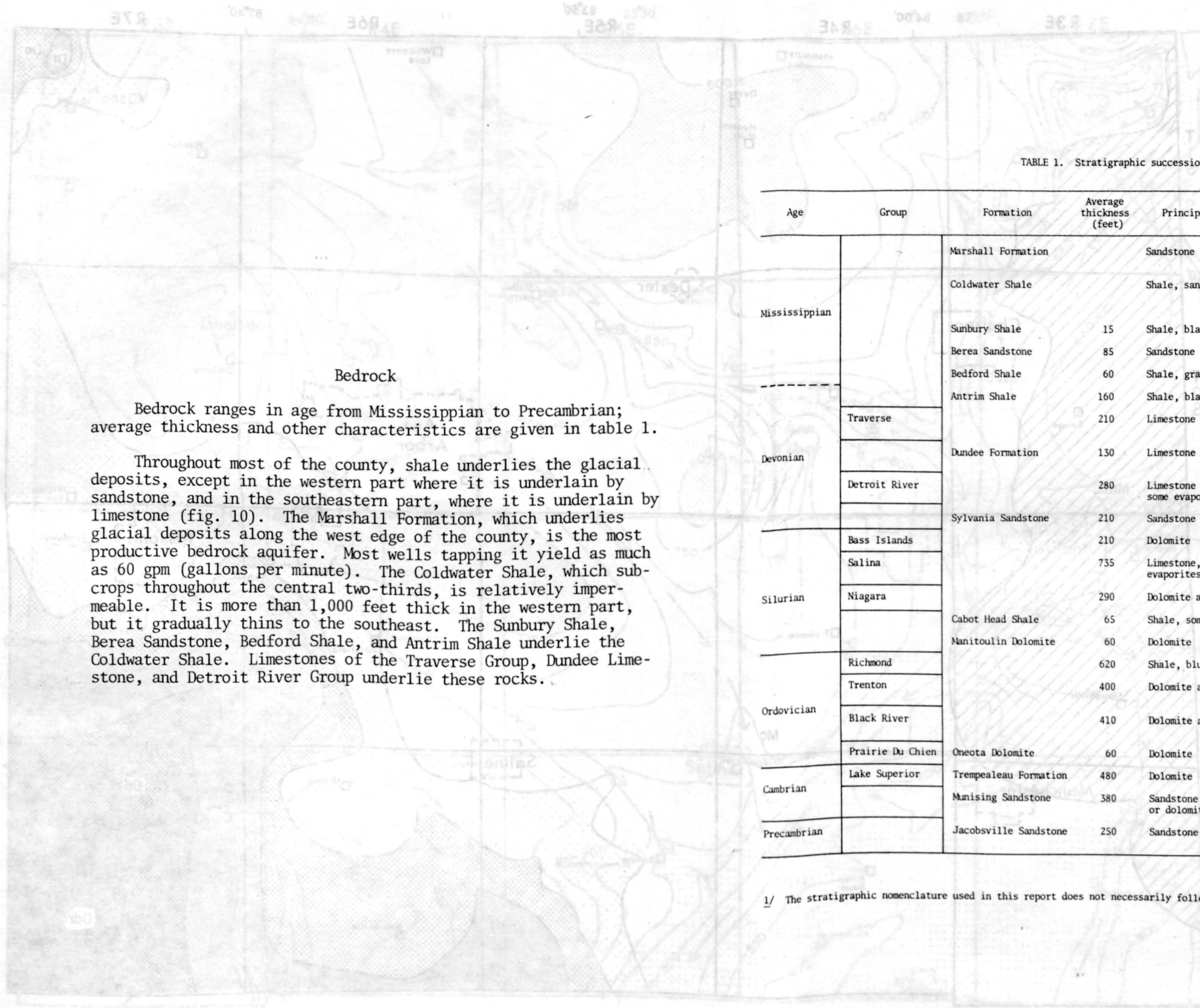


Figure 9.--Permeability of soils and glacial deposits (to a depth of 30 feet).



Configuration of Bedrock Surface

The configuration of the bedrock surface indicates the general drainage pattern before glaciation. The surface of the bedrock is in general a gentle slope from the west to the east. In the eastern part of the county, the bedrock surface is in the form of a series of low hills and valleys.

TABLE 1. Stratigraphic succession of Paleozoic rocks<sup>1/</sup>

Age	Group	Formation	Average thickness (feet)	Principal rock type	Remarks
Mississippian		Marshall Formation		Sandstone	Productive aquifer, but occurs only in western part of county.
		Coldwater Shale		Shale, sandy, gray	As much as 1,000 feet thick in the western part of county. Relatively impermeable, source for some domestic water supplies.
		Sunbury Shale	15	Shale, black	Impermeable, except in sandy lenses.
		Berea Sandstone	85	Sandstone	Aquifer, source for some domestic water supplies.
		Bedford Shale	60	Shale, gray	Impermeable, except in sandy lenses.
Devonian		Antrim Shale	160	Shale, black	Impermeable, except in sandy lenses.
	Traverse		210	Limestone and shale, gray	Gas (Lyndon field); oil (Clinton field); source for some domestic water supplies.
		Dundee Formation	130	Limestone and dolomite	Gas (Northville field); source for some domestic water supplies.
		Detroit River	280	Limestone and dolomite some evaporites	Gas (Lyndon field); source for some domestic water supplies.
Silurian		Sylvania Sandstone	210	Sandstone	Saline water.
		Bass Islands	210	Dolomite	Impermeable.
		Salina	735	Limestone, dolomite, and evaporites	Salt beds up to 400 feet thick in northern part of county.
		Niagara	290	Dolomite and limestone	Oil (Northville field); gas (Northville field).
		Cabot Head Shale	65	Shale, some limestone	Impermeable.
		Manitoulin Dolomite	60	Dolomite	Impermeable.
Ordovician		Richmond	620	Shale, bluish or greenish	Impermeable.
		Trenton	400	Dolomite and limestone	Generally impermeable; oil (Freedom and Northville field); gas (Northville field).
		Black River	410	Dolomite and limestone	Generally impermeable; oil and gas (Northville field).
		Prairie Du Chien	60	Dolomite	Impermeable.
Cambrian		Lake Superior	480	Dolomite	Impermeable.
		Munising Sandstone	380	Sandstone and limestone or dolomite	Saline water.
Precambrian		Jacobsville Sandstone	250	Sandstone	Saline water.

Bedrock ranges in age from Mississippian to Precambrian; average thickness and other characteristics are given in table 1.

Throughout most of the county, shale underlies the glacial deposits, except in the western part where it is underlain by sandstone, and in the southeastern part, where it is underlain by limestone (fig. 10). The Marshall Formation, which underlies glacial deposits along the west edge of the county, is the most productive bedrock aquifer. Most wells tapping it yield as much as 60 gpm (gallons per minute). The Coldwater Shale, which sub-crops throughout the central two-thirds, is relatively impermeable. It is more than 1,000 feet thick in the western part, but it gradually thins to the southeast. The Sunbury Shale, Berea Sandstone, Bedford Shale, and Antrim Shale underlie the Coldwater Shale. Limestones of the Traverse Group, Dundee Limestone, and Detroit River Group underlie these rocks.

<sup>1/</sup> The stratigraphic nomenclature used in this report does not necessarily follow the usage of the U.S. Geological Survey.

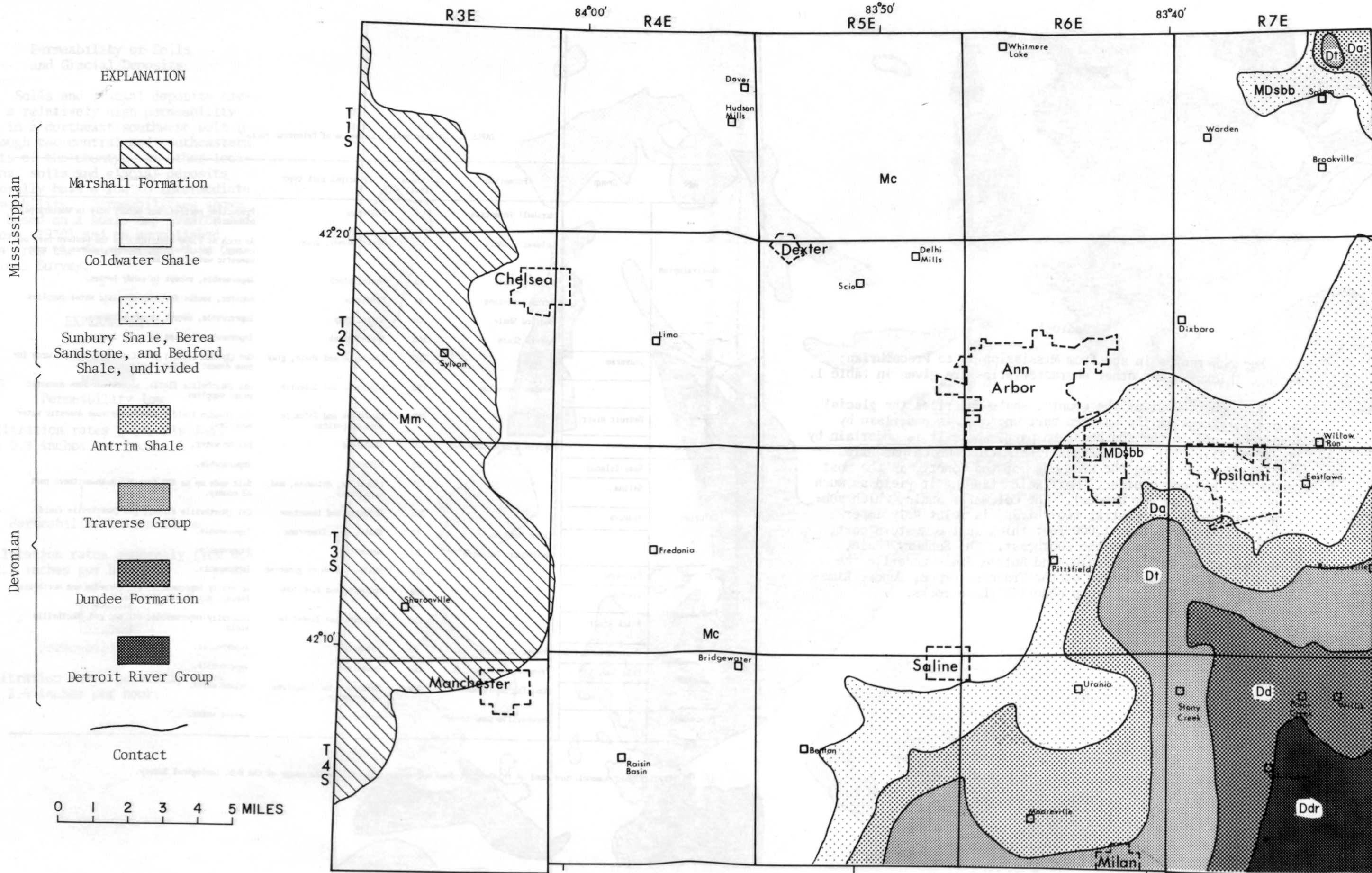
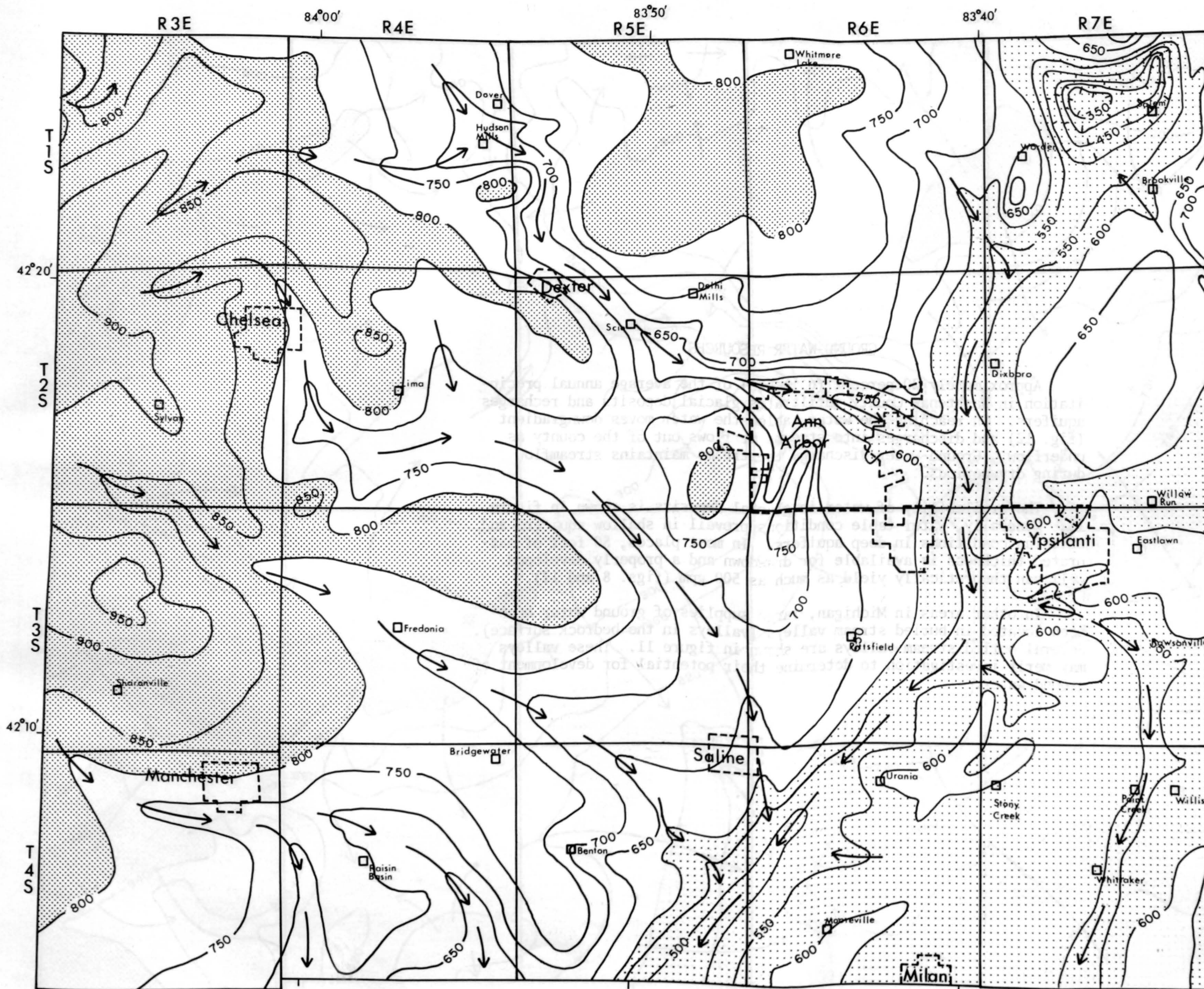



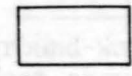
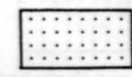

Figure 10.--Bedrock.



Configuration of Bedrock Surface

The configuration of the bedrock surface indicates the general drainage pattern before glaciation. The altitude of the bedrock surface in Washtenaw County ranges from 900 feet above mean sea level in the western part to about 600 feet in the eastern part; it is less than 350 feet in the northeastern part. The bedrock surface was generally drained southeastward, and the major drains were in the south and southeastern parts.

EXPLANATION

- 800—  
Line of equal altitude of bedrock surface above mean sea level; interval 50 feet.
-  Altitude of bedrock surface more than 800 feet above mean sea level.
-  Altitude of bedrock surface 600 to 800 feet above mean sea level.
-  Altitude of bedrock surface less than 600 feet above mean sea level.
-  Direction of pre-glacial drainage.

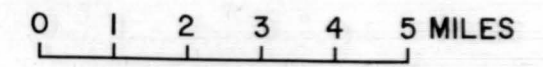
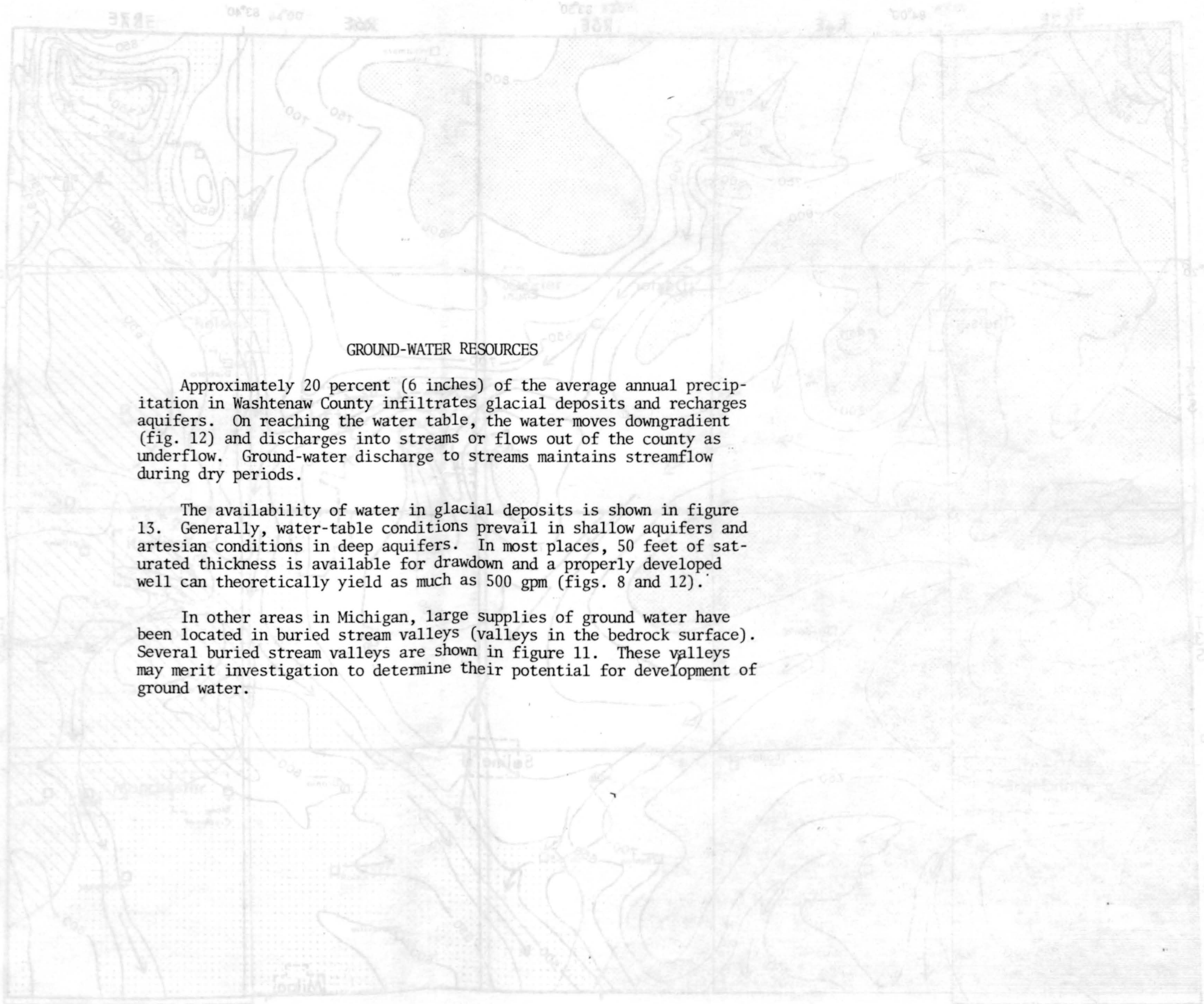


Figure 11.--Configuration of bedrock surface.



**GROUND-WATER RESOURCES**

Approximately 20 percent (6 inches) of the average annual precipitation in Washtenaw County infiltrates glacial deposits and recharges aquifers. On reaching the water table, the water moves downgradient (fig. 12) and discharges into streams or flows out of the county as underflow. Ground-water discharge to streams maintains streamflow during dry periods.

The availability of water in glacial deposits is shown in figure 13. Generally, water-table conditions prevail in shallow aquifers and artesian conditions in deep aquifers. In most places, 50 feet of saturated thickness is available for drawdown and a properly developed well can theoretically yield as much as 500 gpm (figs. 8 and 12).

In other areas in Michigan, large supplies of ground water have been located in buried stream valleys (valleys in the bedrock surface). Several buried stream valleys are shown in figure 11. These valleys may merit investigation to determine their potential for development of ground water.

Configuration of bedrock surface  
 The configuration of the bedrock surface indicates the general drainage pattern before glaciation. The altitude of the bedrock surface in Washtenaw County ranges from 900 feet above mean sea level in the western part to about 600 feet in the eastern part; it is less than 500 feet in the northeastern part. The bedrock surface was generally divided southeastward, and the major drainage was in the south and southeastern parts.

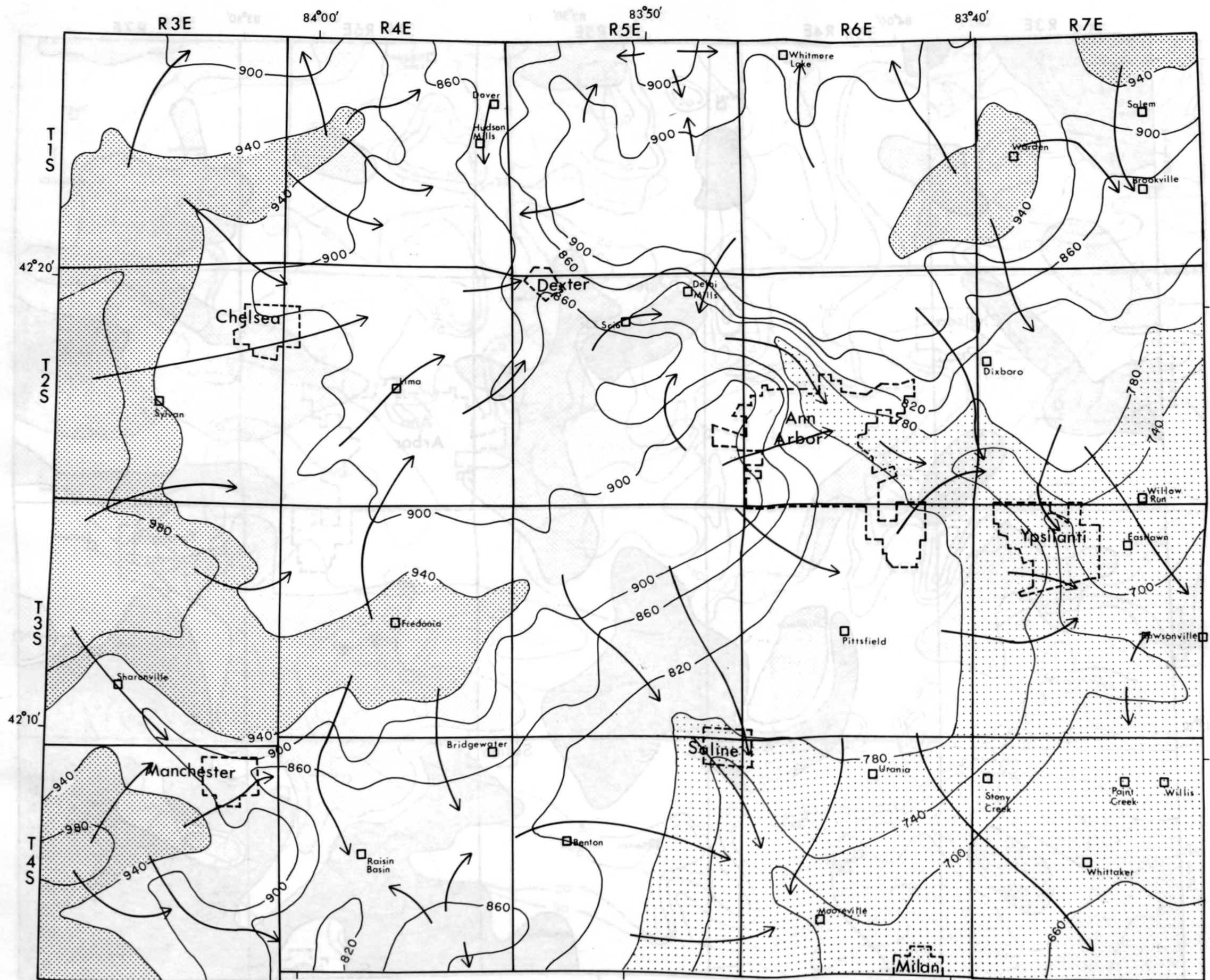
Direction of glacial discharge  
 Line of equal altitudes of bedrock surface above mean sea level; interval 50 feet.

Altitude of bedrock surface more than 500 feet above mean sea level.

Altitude of bedrock surface less than 500 feet above mean sea level.

Direction of glacial discharge






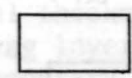
Water Table

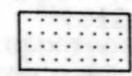
The water table is the surface of the saturated zone. In Washtenaw County, the altitude of the water table is generally highest in the western and northern parts, and lowest in the southeastern part. Locally, water in the saturated zone moves toward major streams; overall movement is south and southeast.

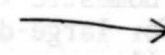
EXPLANATION

—820—  
 Line of equal altitude of water table above mean sea level; interval 40 feet.

 Altitude of ground-water table more than 940 feet above mean sea level.

 Altitude of ground-water table 780 feet to 940 feet above mean sea level.

 Altitude of ground-water table less than 780 feet above mean sea level.

 Direction of ground-water movement.

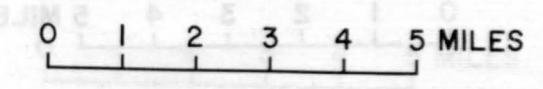


Figure 12.--Altitude of water table.

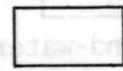
Water Availability  
in  
Glacial Deposits

Favorable areas for development of large supplies of ground water occur throughout the county. The most favorable areas are near Ann Arbor and Ypsilanti and southwest of Manchester. Much of the south-eastern part of the county and small isolated areas elsewhere are not favorable for development of large supplies; in places yields may be inadequate even for a domestic supply. Water in the glacial deposits occurs under both artesian and water-table conditions.

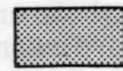
EXPLANATION



Areas favorable for 2- or 4-inch diameter domestic wells and large-diameter high-capacity wells with yields up to 500 gpm, or more.



Areas generally adequate for 2- or 4-inch diameter domestic wells but less favorable for large-diameter high-capacity wells.



Areas adequate to poor for 2- or 4-inch diameter domestic wells and unsatisfactory for large-diameter high-capacity wells.

0 1 2 3 4 5 MILES

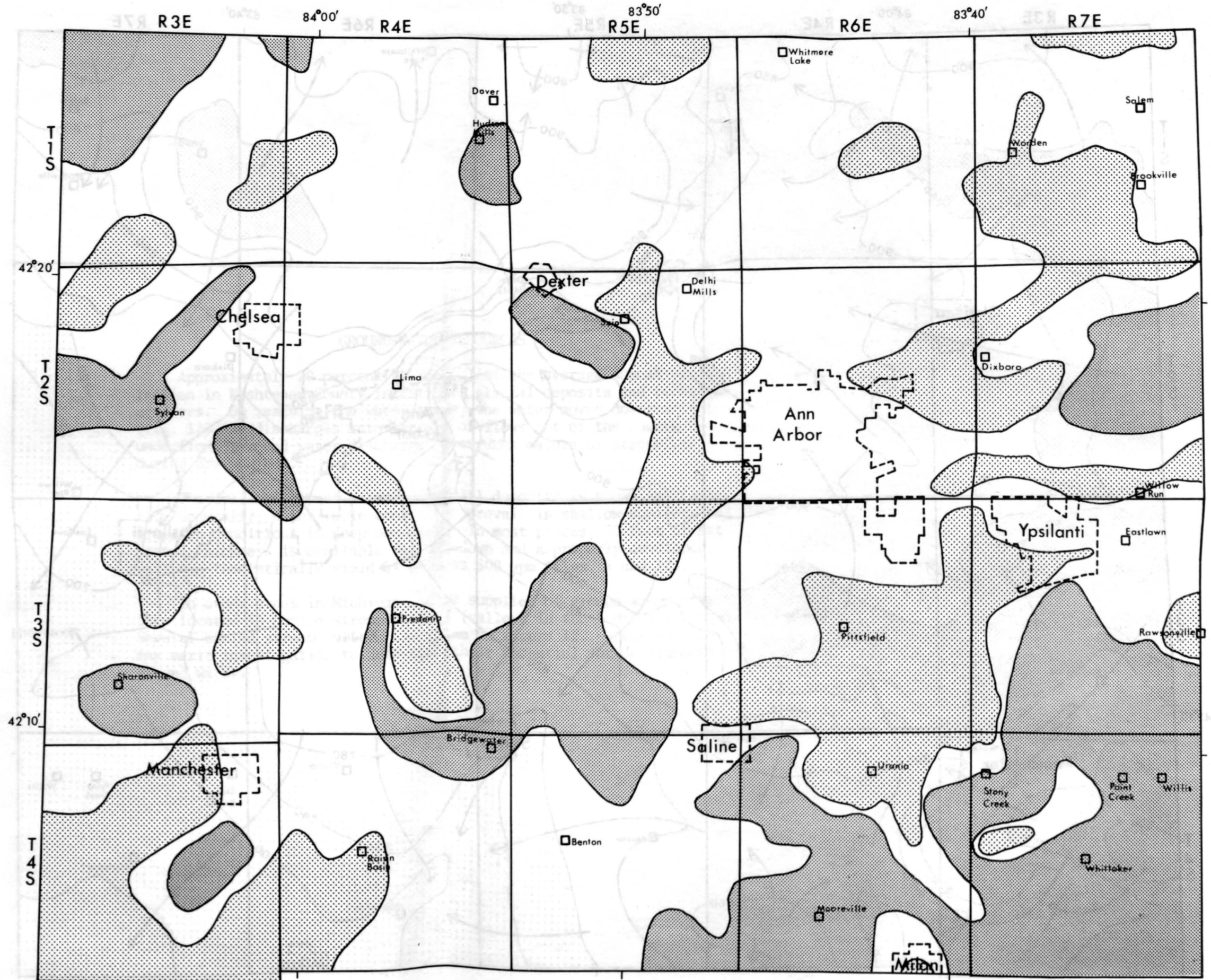
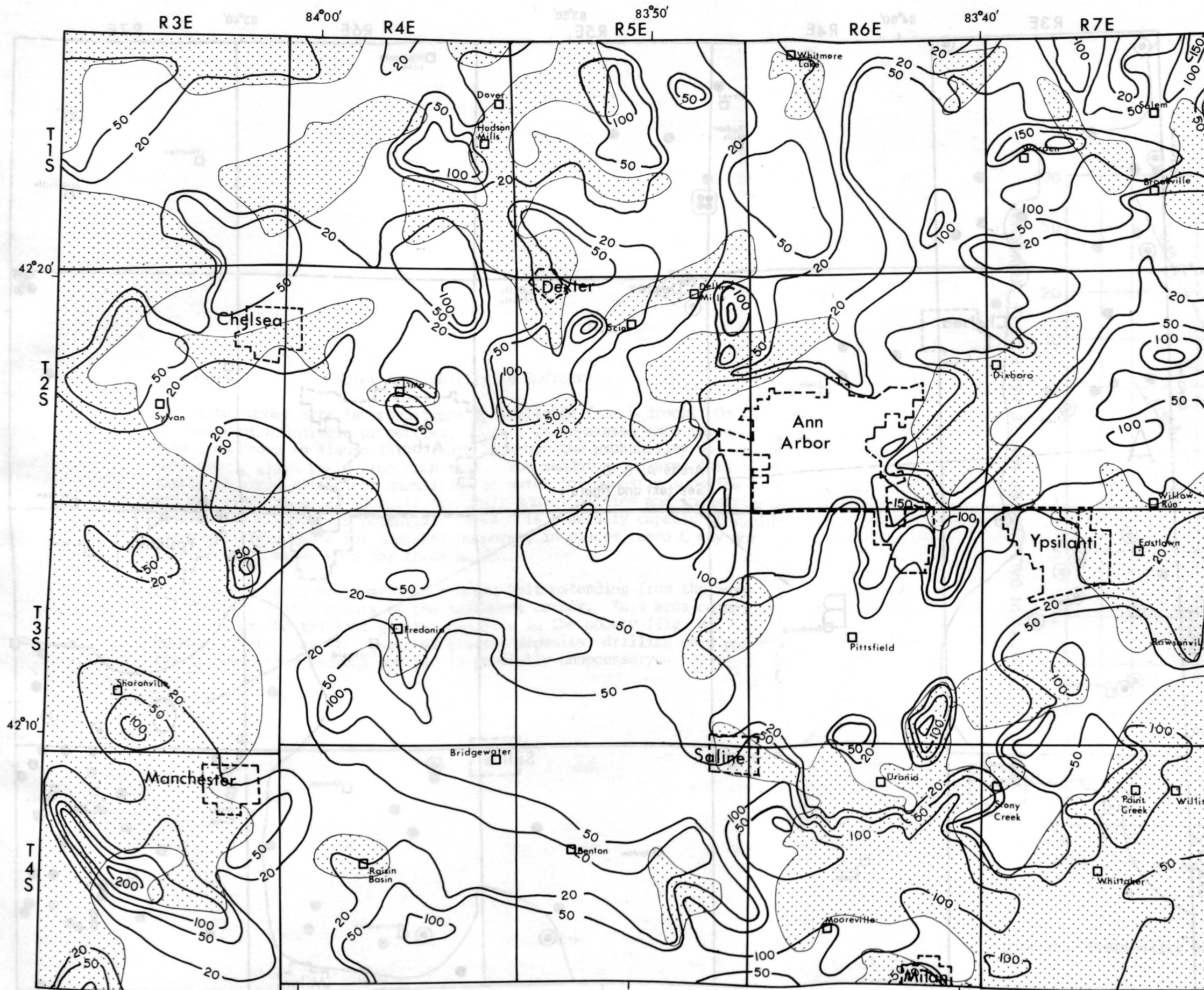


Figure 13.--Water availability in glacial deposits.



**Confining Beds**

In many areas, aquifers may be overlain by confining beds of relatively impermeable clay or till. Except in scattered areas, confining beds in most of the central part of the county are at land surface. In the western part and in the south-eastern corner, confining beds are below land surface.

Confining beds may be as thick as 200 feet; average thickness is 50 to 100 feet. Beds in most of the county are at least 20 feet thick.

**EXPLANATION**

—100—

Line of equal thickness of uppermost confining layer; interval 50 feet, supplementary line at 20-foot thickness.



Areas where uppermost confining layer is below land surface.

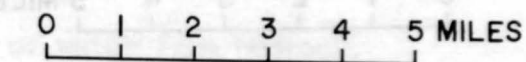


Figure 14.--Thickness of uppermost confining layer.

Water availability in bedrock deposits.

Favorable areas for development of large aquifers are located throughout the county. The water-bearing beds of the lower part of the Silurian system are particularly favorable. The thickness of these beds is generally 50 to 100 feet, and the water-bearing beds are of considerable thickness. The water-bearing beds are of considerable thickness. The water-bearing beds are of considerable thickness.

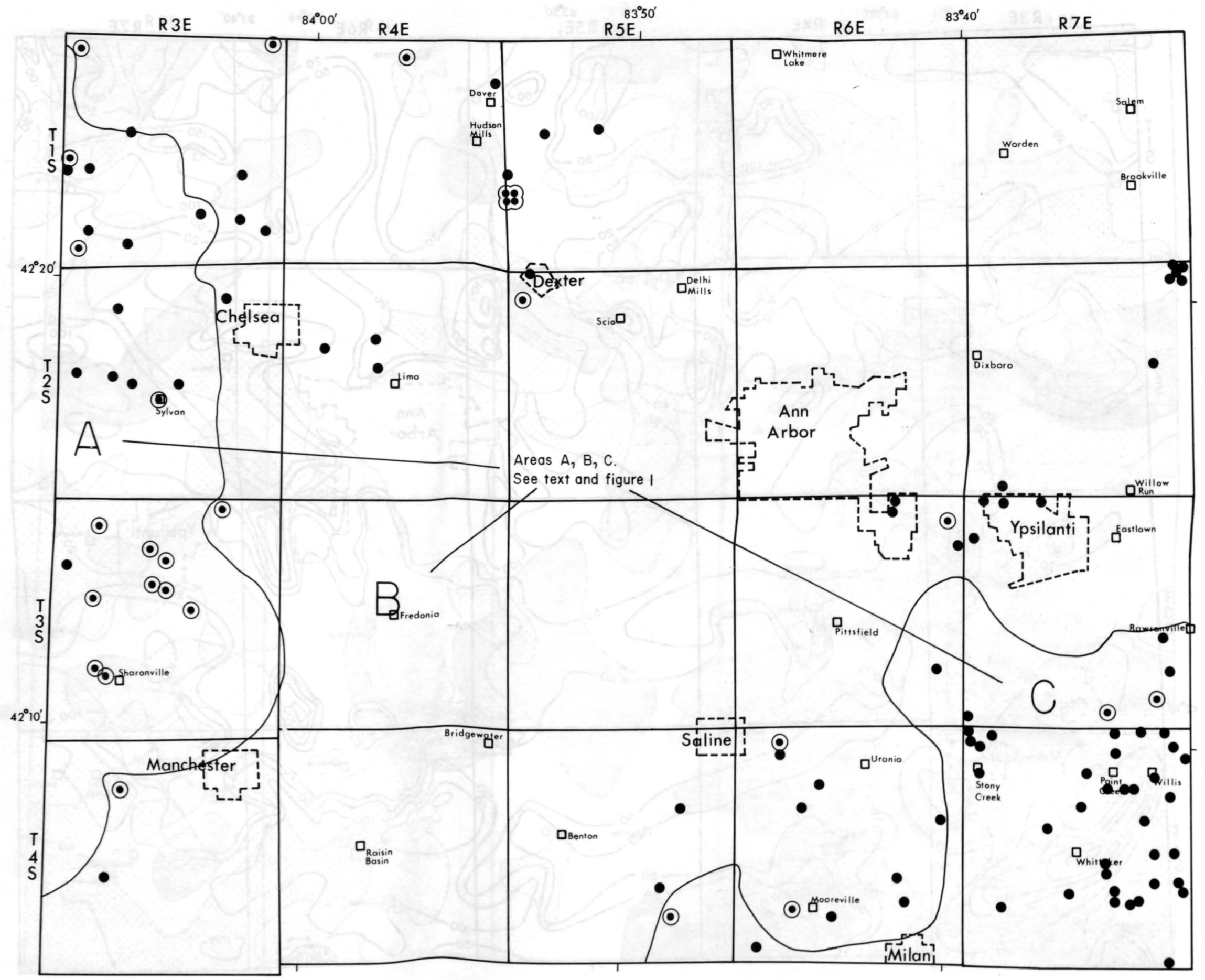
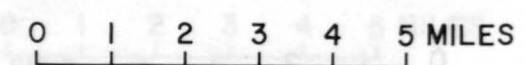
EXPLANATION

● Bedrock well.

⊙

Bedrock well having specific capacity greater than one gallon per minute per foot of drawdown.

~ Contact between areas having hydrologically different properties.



Areas A, B, C.  
See text and figure 1

Figure 15.--Water availability in bedrock.

### Water Availability in Bedrock

Water under artesian conditions is available from bedrock. On the basis of hydrologic properties, bedrock is separated into three areas, as shown in figure 15. Figure 16 shows the probability of obtaining a given yield from each area. The sandstone in area A is likely to yield sufficient quantities of water for domestic supplies and may yield supplies adequate for small municipalities and industries. Areas B and C have less potential. Area B is generally capable of yielding supplies adequate for domestic purposes; in places, area C may not supply enough water even for these needs.

Bedrock wells are sparse in a broad belt extending from the north-eastern part of the county to the southwest corner. This area coincides with some of the thickest glacial deposits in the county (fig. 8). Because of the great thickness of glacial deposits, drilling to a potentially productive bedrock aquifer is generally unnecessary.

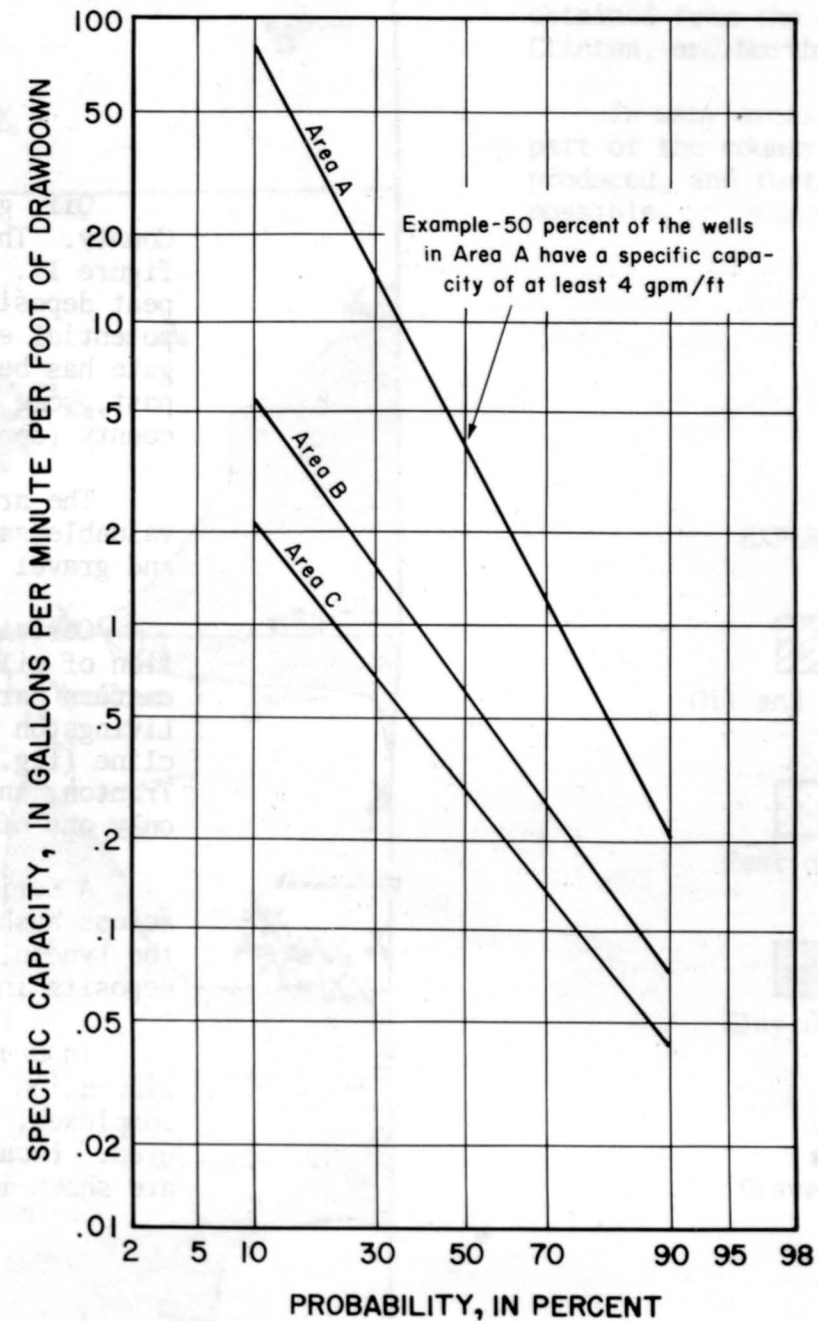


Figure 16.--Probability of yield of water from bedrock.

## OIL, GAS, AND MINERAL RESOURCES

Oil, gas, and sand and gravel are economically important in Washtenaw County. The location of oil and gas fields and gravel pits are shown on figure 17. Also, shown on this figure are the locations of clay and peat deposits. At present, clay and peat are not mined, although the potential exists. Clay for pottery, brick, tile, and light-weight aggregate has been mined in neighboring Wayne and Monroe Counties. In the past, some peat was mined near Salem in the northeastern part of the county (deposits are small and not shown on figure 17).

The areal distribution and approximate thickness of potentially valuable sand and gravel deposits are shown on figure 18. Other sand and gravel deposits may lie at shallow depths in other places.

Certain types of geologic structures are required for the accumulation of oil and gas. A typical structure is an anticline in the northeastern part of Washtenaw County and in adjacent Wayne, Oakland, and Livingston counties; the Northville oil and gas field is on this anticline (fig. 20). Production is from the Dundee Formation and Niagara, Trenton, and Black River Groups (table 1). The Northville field is only one of many fields associated with this anticlinal structure.

A series of parallel anticlines is oriented northwest to southeast across Washtenaw County (fig. 20). Associated with these anticlines are the Lyndon, Freedom, and Clinton oil and gas fields. Known oil and gas deposits in these fields occur in rocks older than the Traverse Group.

In developing land for mineral resources or waste disposal, consideration is generally given to power lines, pipe lines, and housing complexes. Pipe lines, because they are buried, are not always considered. Locations of the larger oil and gas pipe lines in Washtenaw County are shown in figure 21.

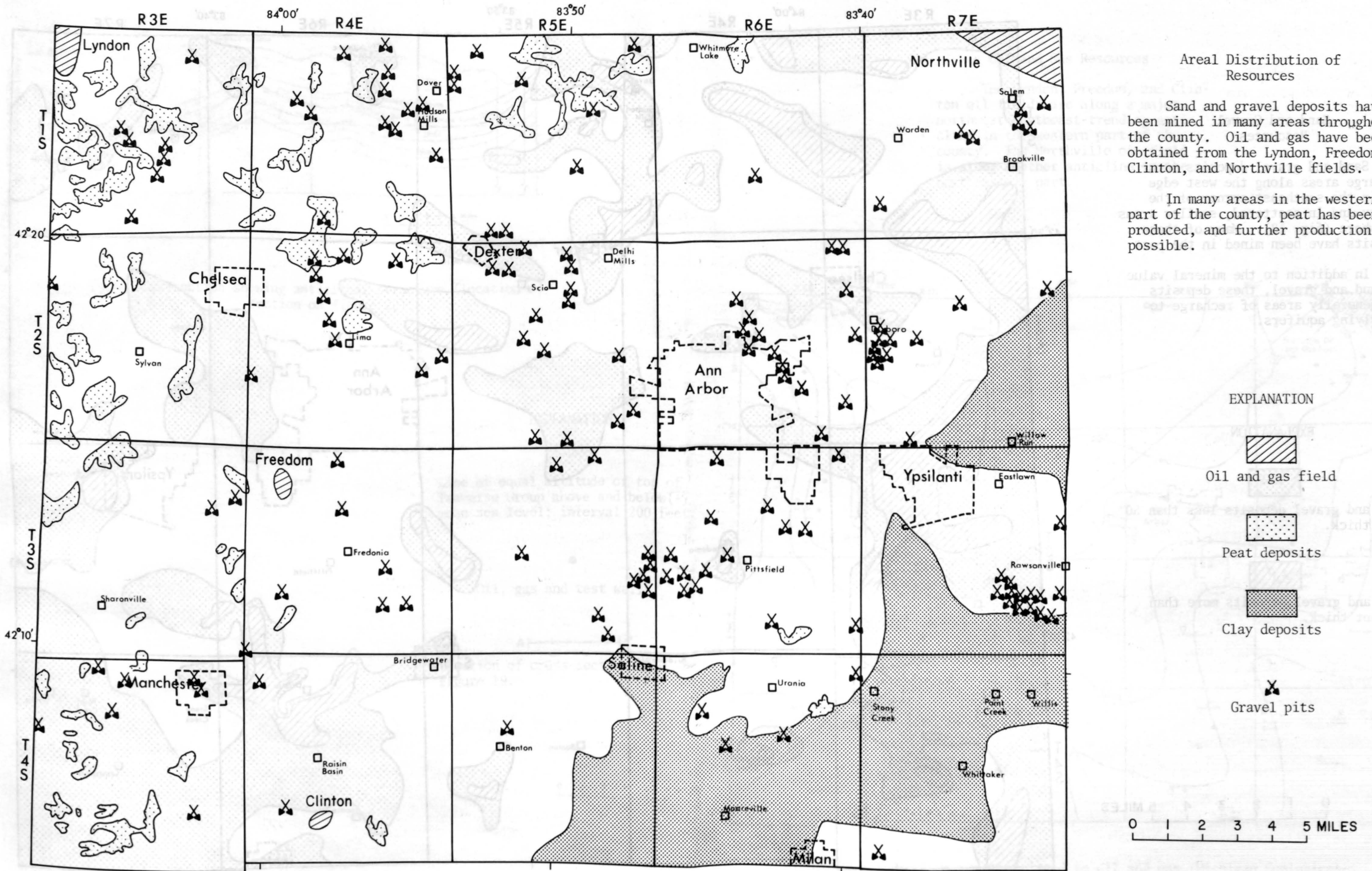


Figure 17.--Location of selected mineral resources (Michigan State Highway Department, 1959; Segall, 1972).

**Sand and Gravel Resources**

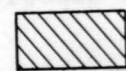
Sand and gravel deposits occur in large areas along the west edge and in the southeast corner of the county and in scattered, smaller areas elsewhere (fig. 18). Many of these deposits have been mined in the past.

In addition to the mineral value of sand and gravel, these deposits are generally areas of recharge to underlying aquifers.

**EXPLANATION**



Sand and gravel deposits less than 50 feet thick.



Sand and gravel deposits more than 50 feet thick.

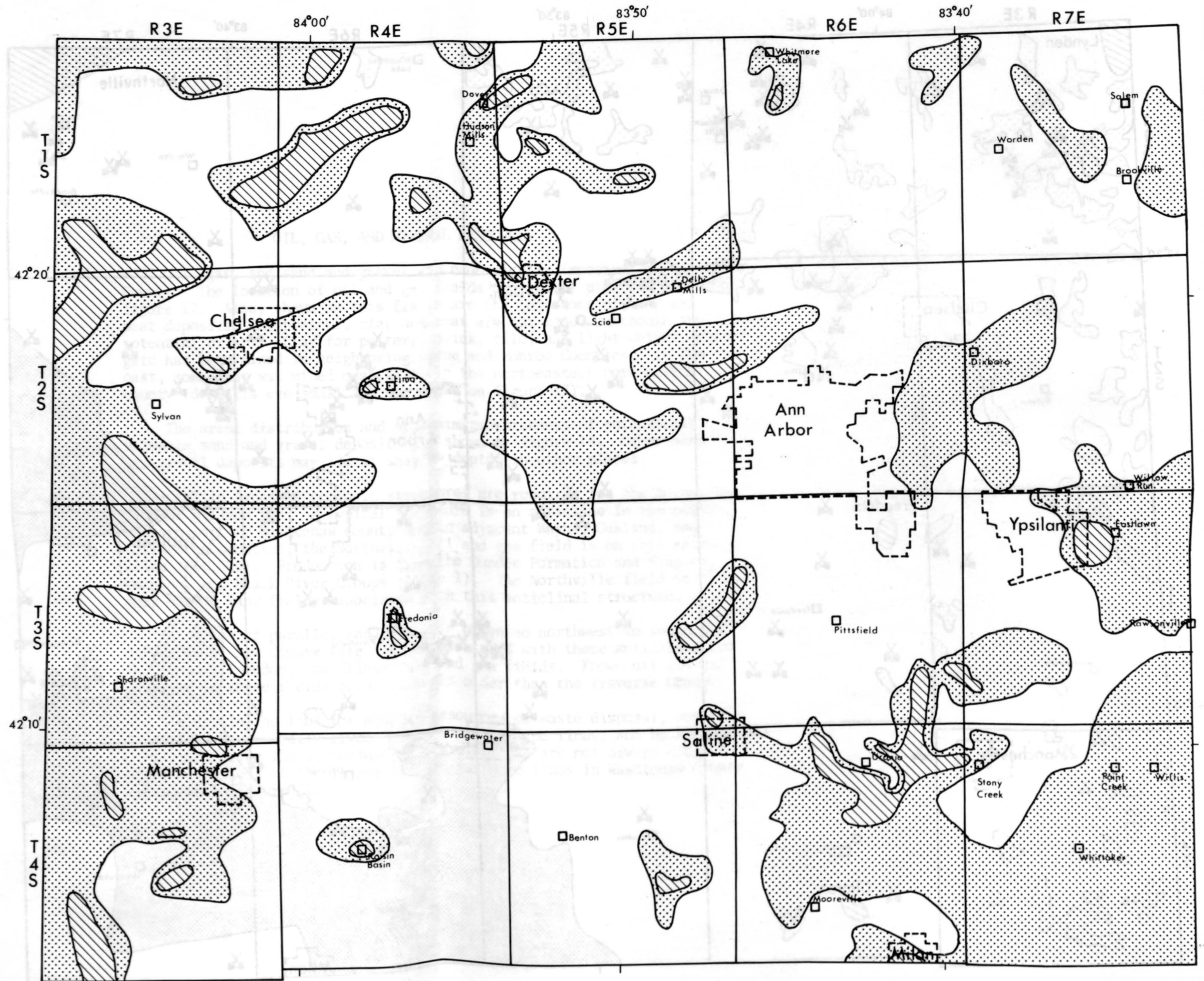
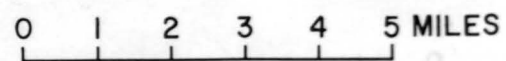


Figure 18.--Thickness of sand and gravel surface deposits.

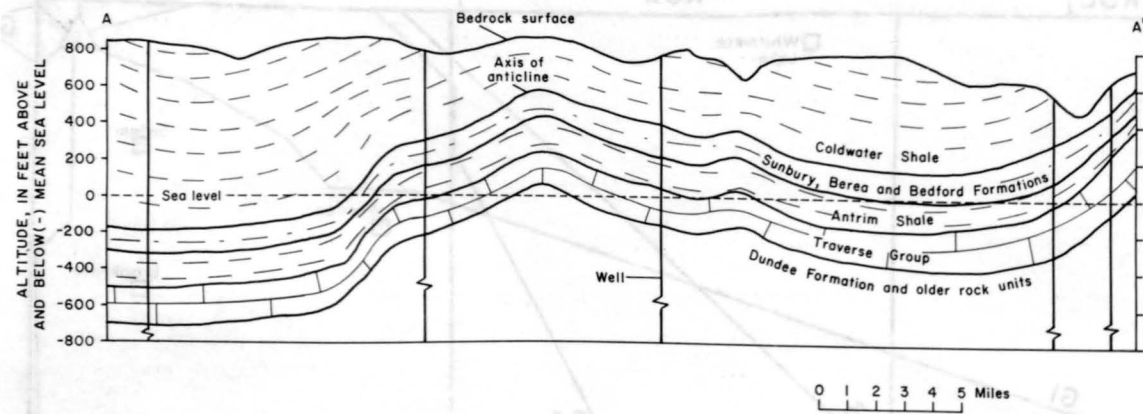


Figure 19.--Cross-section showing anticlinal structure (location of section on figure 20).

EXPLANATION

—500—  
Line of equal altitude of top of Traverse Group above and below(-) mean sea level; interval 200 feet.

●  
Oil, gas and test wells.

A — A'  
Location of cross-section shown on figure 19.

0 1 2 3 4 5 MILES

Oil and Gas Resources

The Lyndon, Freedom, and Clinton oil fields are along a major northwest-southeast-trending anticline in the western part of the county. The Northville oil field is along another anticline in the northeastern part.

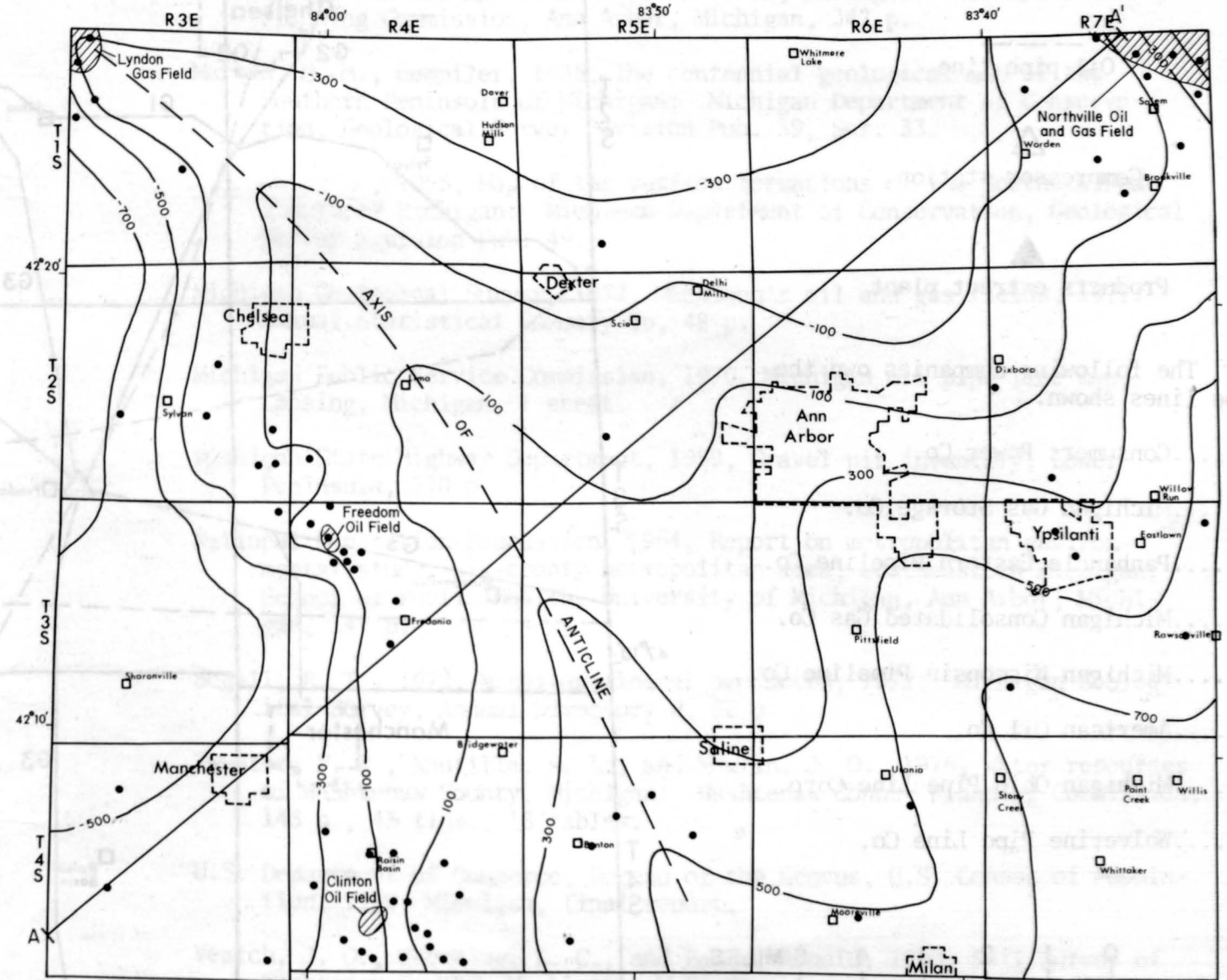


Figure 20.--Bedrock structure related to oil and gas (Michigan Geological Survey, 1972).

Buried Oil and Gas Pipe Lines

Buried gas pipe lines radiate from two compressor stations, and crisscross the county. Three buried oil pipe lines cross the county.

EXPLANATION

Gas pipe line

Oil pipe line

Compressor station

Products extract plant

The following companies own the pipe lines shown.

- G1.....Consumers Power Co.
- G2.....Michigan Gas Storage Co.
- G3.....Panhandle Eastern Pipeline Co.
- G4.....Michigan Consolidated Gas Co.
- G5.....Michigan Wisconsin Pipeline Co.
- O1.....American Oil Co.
- O2.....Michigan Ohio Pipe Line Corp.
- O3.....Wolverine Pipe Line Co.

0 1 2 3 4 5 MILES

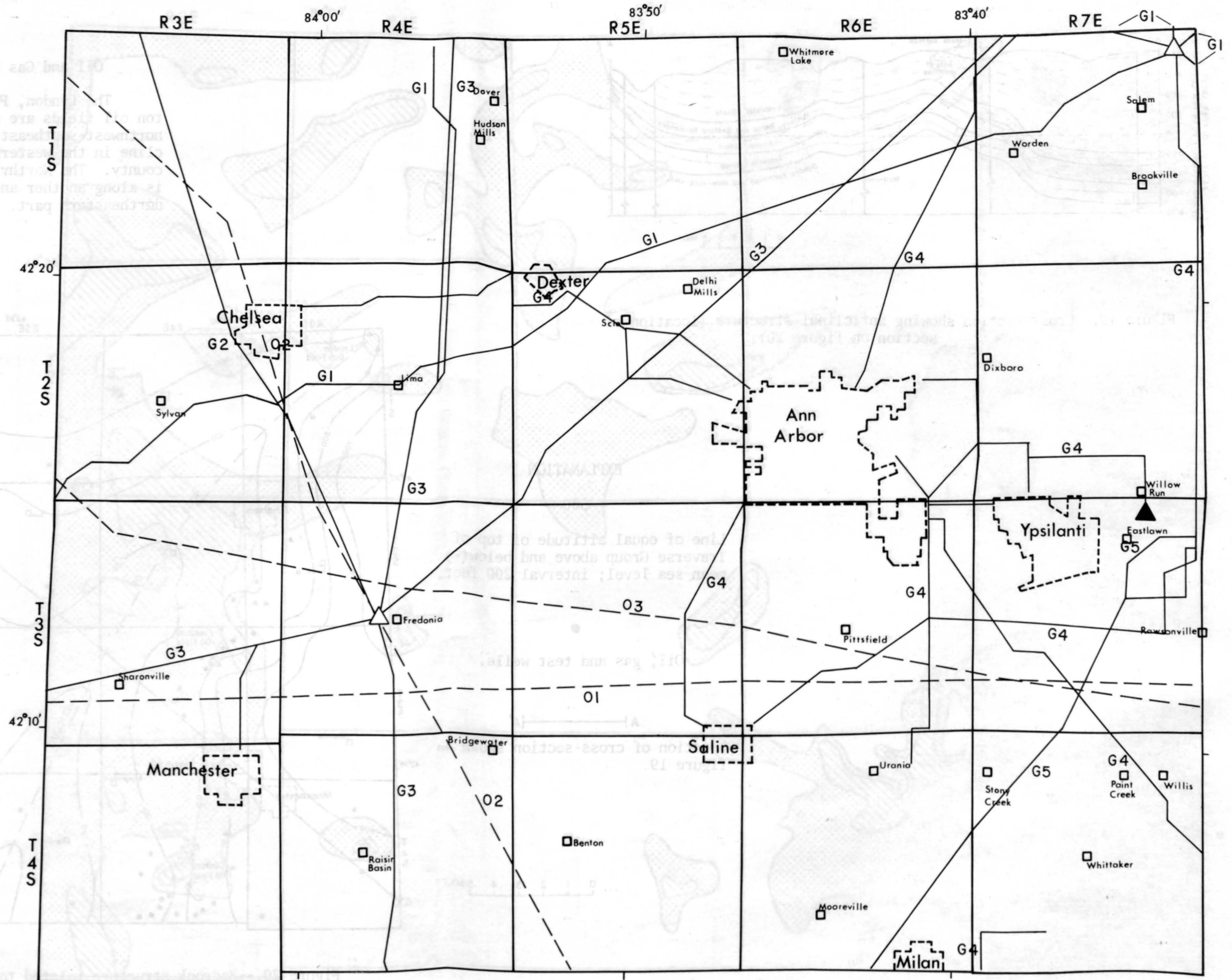


Figure 21.--Location of oil and gas pipe lines (Michigan Public Service Commission, 1970; Consumers Power Company, 1971).

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