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BULLETIN NO. 33

GEOHYDROLOGY AND GROUND WATER POTENTIAL OF ST. JOSEPH COUNTY, INDIANA

Prepared by the

GEOLOGICAL SURVEY

UNITED STATES DEPARTMENT OF THE INTERIOR

in cooperation with the

DIVISION OF WATER

DEPARTMENT OF NATURAL RESOURCES

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STATE OF INDIANA

Edgar D. Whitcomb, Governor

DEPARTMENT OF NATURAL RESOURCES

Perley H. Provost, Jr., Director

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Robert F. Jackson, Chief

GEOHYDROLOGY AND GROUND-WATER POTENTIAL OF ST. JOSEPH COUNTY, INDIANA

BY

J. D. Hunn and J. S. Rosenshein

Geologists, U. S. GEOLOGICAL SURVEY

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CONTENTS

ILLUSTRATIONS

(Plates in pocket)

TABLES

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By J. D. Hunn and J. S. Rosenshein

ABSTRACT

The principal sources of ground water in St. Joseph County are the unconsolidated rocks of Quaternary age. These rocks form a single but complex hydrologic system that is locally more than 450 feet thick and consists of three units. These units were previously recognized in Lake, Porter and La Porte Counties, where they were designated as units 2, 3 and 4, in descending order. Unit 1 is missing in St. Joseph County. The ground-water potential of the county is estimated to be 400 mgd (million gallons per day) of which about 54 mgd is being pumped.

Unit 4 consists of clay till containing discontinuous zones of sand and gravel, which are potential sources of moderate to large supplies of water. Sand and gravel within unit 4 is the principal aquifer in the South Bend-Mishawaka area, yielding as much as 3,000 gpm (gallons per minute) to individual wells.

Unit 3, a sand and gravel, is the principal aquifer of the county. This unit is partly artesian and partly water-table. Recharge is derived chiefly from local precipitation. Recharge to the artesian part and to about 70 square miles of the water-table part of the aquifer must percolate through the overlying till (unit 2). This recharge is estimated to average 200,000 gpd (gallons per day) per square mile, or about 40 mgd. Recharge to that part of the aquifer which is exposed at the surface is estimated to average 1.2 mgd per square mile. The potential yield from natural recharge of this part of the aquifer is estimated to be 350 mgd. Possible yields to individual wells range from about 25 to more than 3,000 gpm. Pumpage from the unit is about 32 mgd, or about 69 percent of the ground water pumped in the county.

Unit 2, a silt till, is the confining layer for the artesian part of the principal aquifer. The unit may have as much as 2 million acre-feet of water in storage. Production from the unit is limited to relatively thin, discontinuous sand and gravel zones and is not a significant part of the ground water pumped in the county.

INTRODUCTION

Purpose and Scope

A ground-water investigation is currently being conducted in northwestern Indiana by the U. S. Geological Survey, in cooperation with the Division of Water, Indiana Department of Natural Resources, as part of the statewide investigation of ground-water resources in Indiana. The purpose of this report is to describe the geologic and hydrologic characteristics of the aquifers, to estimate their current and potential yields, and to identify the problems relating to their development. This is the third and last of a series of interpretive reports scheduled for the area. It presents an evaluation of the ground-water resources of St. Joseph County (fig. 1) and provides information to guide the development and management of these resources.

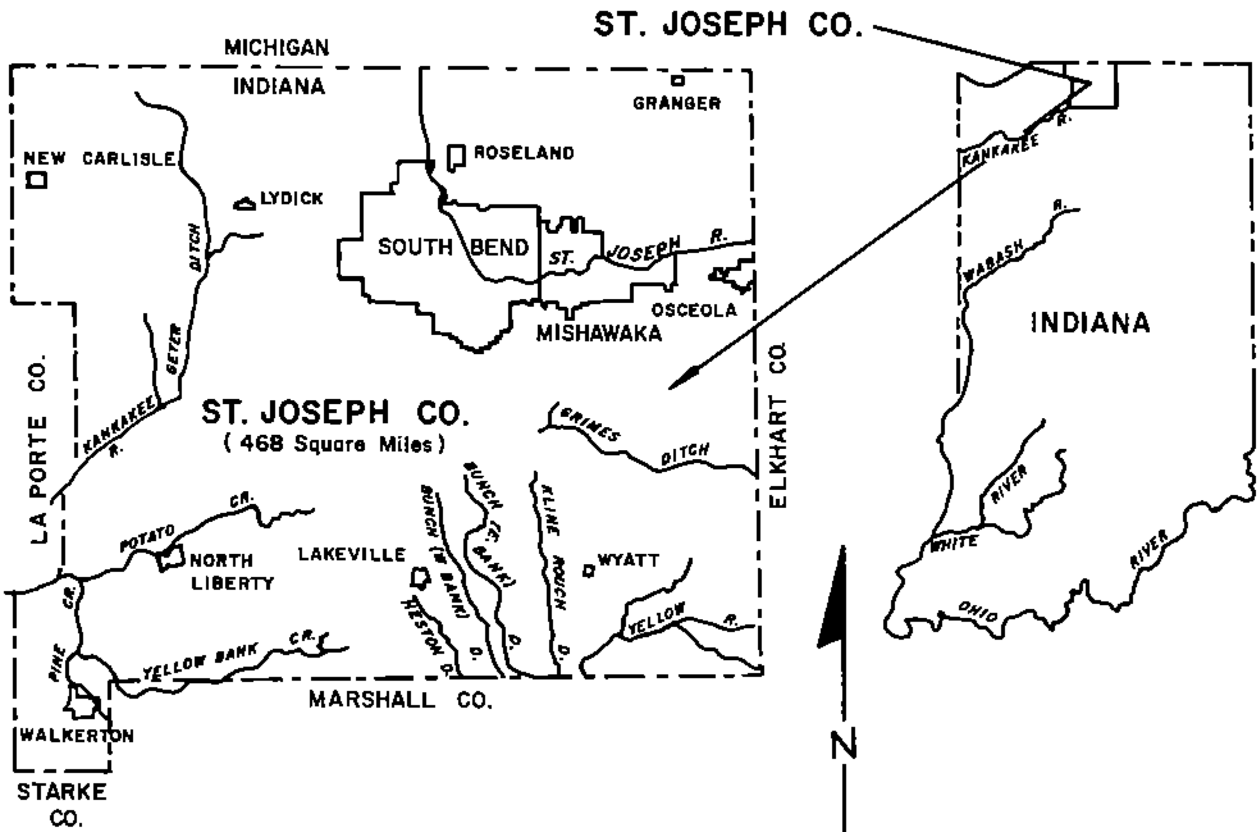

FIGURE 1.--Map of Indiana showing area covered by this report.

The demand for water will increase during the next few decades, as a result of the economic development of the Great Lakes region, and the available ground water in the county will be a source of supply of increasing importance.

Although the available ground water should be more than adequate to satisfy the needs of the county for several decades, the increased demands will produce hydrologic problems such as those of contamination and well spacing which are common to highly urbanized areas. Therefore, in order to tap a major part of the potential yield, sound practices of development and responsible management of water resources will be required.

Previous Investigations

A detailed evaluation of the ground-water resources of St. Joseph County has not previously been published; however, Klaer and Stallman (1948) prepared a quantitative evaluation of the ground-water resources of the South Bend area. The water-bearing sand and gravel described by them is separated into two units (3 and 4) in the present report. A preliminary evaluation of the ground-water resources of the county is published in a report by Rosenshein and Hunn (1963a). Other publications referring to St. Joseph County are listed in the "Selected References," at the end of this report.

Acknowledgments

The authors thank all persons who contributed time, information, and assistance during the preparation of this report. The investigation was under the immediate supervision of C. M. Roberts, district geologist of the Ground Water Branch, U. S. Geological Survey. R. J. Vig, formerly of the U. S. Geological Survey, assisted in the geologic reconnaissance and data processing. Well drillers supplied logs and other information. A. F. Schneider, of the Geological Survey, Indiana Department of Natural Resources, permitted use of his interpretation of a soil map of St. Joseph County (Ulrich and others, 1950).

The following government agencies provided information: the Geological Survey, the Division of Oil and Gas, and the Division of Water, all in the Indiana Department of Natural Resources; the Indiana State Highway Department; the Indiana Toll Road Commission; and the Indiana State Board of Health.

CLIMATE AND GEOGRAPHY

The average annual precipitation at South Bend, the county seat, is about 37 inches, and the average annual air temperature is about 49° F.

The Maxinkuckee moraine, extending from South Bend southward into Marshall County, is the chief topographic feature of the area. A drainage divide extends from northwest to southeast across the county and separates the St. Lawrence River basin from the Mississippi River basin.

The maps in this report show the pattern of the principal streams and ditches. Points of highest elevation are on the Maxinkuckee moraine, and the lowest elevation in the county is the surface of the St. Joseph River where it enters Michigan; maximum relief is about 260 feet.

GEOHYDROLOGY OF THE PRINCIPAL WATER-BEARING UNITS

General Aspects

The principal sources of ground water in St. Joseph County are the unconsolidated rocks, which locally are more than 450 feet thick and were deposited chiefly as a result of glaciation during Pleistocene time. These rocks form a single but complex hydrologic system from which about 54 mgd (million gallons a day) of water is currently being withdrawn.

Rosenshein (1962) subdivided the rocks into the lithologic units used in this report. The units are discussed in ascending order. Their stratigraphy, character and distribution, and geohydrologic properties are summarized in table 1. The areal extent of those units that are exposed at the surface is shown on plate 1.

The underlying dolomite, dolomitic limestone, and shale of Devonian age are potential sources of water of uncertain quality and quantity, but are not presently used.

Unit 4

Water-Bearing Characteristics

Unit 4 is a clay till that contains zones of sand and gravel which are generally discontinuous and small in areal extent. The unit underlies about 90 percent of the county and is as much as 350 feet thick in buried valleys. It is not exposed at the surface. The vertical permeability (see p. 17) of the till is probably similar to that estimated by Rosenshein (1963) for the part of the same unit underlying Lake County--0.003 gpd (gallons per day) per square foot. The porosity (p. 18) of the till may be as much as 30 to 40 percent (Rosenshein and Hunn, 1968a, p.21) and the unit may have as much as 6 million acre-feet of water in storage.

Quality of Water

Water in unit 4 is chemically similar to water in the overlying aquifer, unit 3 (p. 7). However, the water in unit 4 is more uniform in quality, and may represent a mixing of recharge water from unit 3 containing wider ranges of dissolved constituents. The quality of water in unit 4 is summarized in table 2, and the significance of the dissolved constituents is shown in table 3.

Table 1.--Stratigraphic section and summary of water-bearing properties of rocks of Quaternary age, St. Joseph County, Indiana

System	Series	Strati-graphic unit	Thickness (feet) Range	Average	Character and distribution	Geohydrologic properties and significance	Remarks
Quaternary	Recent and Pleistocene	Unit 2	0-140	50	Till, silt, sandy and somewhat clayey, moderately calcareous, pebbly and cobbly; generally yellowish-gray to brown; contains discontinuous lenses of sand and gravel of small areal extent; underlies about 183 square miles of the county.	Discontinuous sand and gravel lenses utilized locally as a source of water for some domestic and farm supplies; mantles artesian and water-table parts of unit 3; contributes to base flow of streams.	Forms dissected ground and terminal moraines.
		Unit 3	10-250	120	Sand, generally medium to coarse, somewhat pebbly, silty and clayey, calcareous, and sand and gravel; grains subrounded to rounded; composed of fragments of shale, quartz, dolomite, limestone, and igneous and metamorphic rocks; locally contains thick clays of small areal extent; underlies the entire county.	Principal aquifer; potential source of water supplies of less than 50 to more than 3,000 gpm; contributed to base flow of streams. Estimated average permeability, 900 gpd per square foot. Estimated average coefficient of storage, 0.003 for artesian part, 0.12 for water-table part.	
		Unit 4	0-300+	60	Till, clay, silty, sandy, pebbly, slightly to moderately calcareous, locally hard and compact, olive-gray to greenish gray; contains discontinuous sand and gravel zones; underlies about 420 square miles of the county.	Sand and gravel zones utilized locally as source of water for some municipal and industrial supplies, and occasionally for domestic and farm supplies. Yields as much as 1,000 to more than 3,000 gpm to individual wells in the South Bend area.	

Development and Potential

The sand and gravel zones within unit 4 are used locally throughout the county as a source of water for municipal and industrial supplies and occasionally for domestic and farm use. These zones are tapped either in a search for large supplies of water or to obtain supplies free of contamination. In most of St. Joseph County larger yields are possible in unit 3, the sand and gravel aquifer overlying unit 4. Wells tapping unit 4 discharge an estimated 22 mgd, or about 41 percent of the ground water used in the county. Of this amount about 14.8 mgd is pumped for municipal use by South Bend, Mishawaka, New Carlisle, and Walkerton, and about 7 mgd for industrial and commercial use.

Table 2.--Summary of water quality in unit 4.

Constituent or property	Minimum (ppm)	Maximum (ppm)	Mode (most common value) (ppm)	Average	Number of samples
Iron (Fe)	< 0.1	2.5	0.14	1.04	47
Bicarbonate (HCO_3)	151	549	295	312	48
Sulfate (SO_4)	< 5	260	----------	75	18
Chloride (Cl)	< 4	108	14	16	47
Hardness as $CaCO_3$	128	508	279	300	48
Total dissolved solids	267	649	----------	397	16

Sand and gravel within unit 4 is the principal aquifer in the South Bend-Mishawaka area. Klaer and Stallman (1948, pls. 4 and 5) refer to this aquifer as the "deeper sands and gravels." The transmissibility (p. 17) of this aquifer ranges from less than 10,000 to more than 300,000 gpd per foot. The permeability ranges from less than 200 to more than 6,000 gpd per square foot. The average coefficient of storage was calculated by Klaer and Stallman (1948) to be 3×10^{-4}. Figure 2 shows estimated transmissibilities and relates these to specific capacities (p. 18) and possible yields obtainable from properly constructed wells. The specific capacities are those to be expected for a 12-inch well after pumping for 1 day. The yield for a specified drawdown will be greater for a large-diameter well than for a small-diameter well. Owing to these and other factors, such as well efficiency, figure 2 gives only an approximation of the capability of the aquifer as a source of water.

Much of this aquifer is a possible source of water for users requiring 1,000 gpm or more. However, actual yields from improperly constructed wells may be considerably less than those indicated on figure 2. Proper construction requires careful choice of well diameter, screen diameter and length, and slot size of screen openings. Guidelines to aid in proper selection of the above factors are given by Walton (1962, p. 28-30). Wells tapping unit 4 require development to remove the clay, silt, and very fine sand from the immediate vicinity of the screen.

The depth to the water-bearing zone can be estimated from figure 3. This information may then be used in conjunction with information on figure 2 to estimate the depth to which a well must be drilled in order to develop a water supply. For maximum yield, the full thickness of the aquifer should be screened.

Klaer and Stallman (1948, p. 43) reported that water levels in the South Bend-Mishawaka area declined at an average rate of 0.5 foot per year for the period 1895-1945. This rate of decline includes both unit 4 and unit 3 (p. 7). Available observation-well records indicate that water levels in both units have declined at an average rate not greater than 0.2 foot per year from 1946 to the present time. The long-term decline of water levels does not indicate a present or a future water shortage. The hydrograph of well St. Joseph 17 on figure 4 illustrates the maximum recorded long-term decline of water levels in unit 4 since 1946. This hydrograph also shows the effects of seasonal variations of recharge and discharge, and of pumping of nearby wells.

Transmissibilities of sand and gravel zones outside the South Bend area range from about 1,000 to about 10,000 gpd per foot. The permeability ranges from less than 100 to about 800 gpd per square foot. The potential of most of these zones for development is limited by their small areal extent and by the small vertical permeability of the enclosing till, which largely determines the rate of recharge. Recharge is derived chiefly from local precipitation percolating downward through the overlying units.

Unit 3

Water-Bearing Characteristics

Unit 3 consists chiefly of sand and gravel that locally contains thick zones of clay. This unit underlies the entire county and is the principal aquifer. It is overlain by till (unit 2, p. 16) in the southeastern part and in a small area in the northwest corner of the county (pl. 1). The aquifer is water-table, except in about half the area overlain by unit 2 in the southeastern part of the county.

The permeability of unit 3 ranges from less than 100 to more than 5,000 gpd per square foot. The coefficient of transmissibility ranges

Table 3.--Significance of selected dissolved mineral constituents and properties of ground water[a/]

Constituent or property	Significance
Iron (Fe)	Oxidizes to reddish-brown sediment upon exposure to air. More than about 0.3 ppm stains laundry and utensils reddish-brown. More than 0.5 to 1.0 ppm imparts objectionable taste to water. Larger quantities favor growth of iron bacteria. Objectionable for food processing, textile processing, beverages, ice manufacturing, brewing, and other purposes.
Calcium (Ca) and Magnesium (Mg)	Cause most of the hardness and scale-forming properties of water; soap consuming. See hardness. Waters low in calcium and magnesium desired in electroplating, tanning, dyeing, and in textile manufacturing.
Sodium (Na) and Potassium (K)	Large amounts, in combination with chloride, give a salty taste. Moderate quantities have little effect on the usefulness of water for most purposes. Sodium salts may cause foaming in steam boilers and a high sodium ratio may limit the use of water for irrigation.
Bicarbonate (HCO_3)	Bicarbonate in conjunction with carbonate (CO_3) produces alkalinity. Bicarbonate of calcium and magnesium decomposes in steam boilers and hot water facilities to form scale and release corrosive carbon-dioxide gas.
Sulfate (SO_4)	Sulfate in water containing calcium forms hard scale in steam boilers. In large amounts sulfate in combination with other ions gives bitter taste to water. Some calcium sulfate is considered beneficial in the brewing process. Public Health Service drinking-water standards[b/] recommend that the sulfate content should not exceed 250 ppm.
Chloride (Cl)	Gives salty taste to drinking water when present in large amounts in combination with sodium. Increases the corrosiveness of water when present in large amounts. Public Health Service drinking-water standards[b/] recommend that the chloride content should not exceed 250 ppm.
Dissolved solids	Public Health Service drinking-water standards[b/] recommend that the dissolved solids should not exceed 500 ppm. Waters containing more than 1,000 ppm of dissolved solids are unsuitable for many purposes.
Hardness as $CaCO_3$ (Calcium and magnesium)	Hard water increases amount of soap needed to make lather. Forms scale in boilers, water heaters, and pipes. Leaves curdy film on bathtubs and other fixtures and on materials washed in the water.

a/ Adapted in part from Palmquist and Hall (1961), p. 34-38.

b/ U. S. Public Health Service (1962)

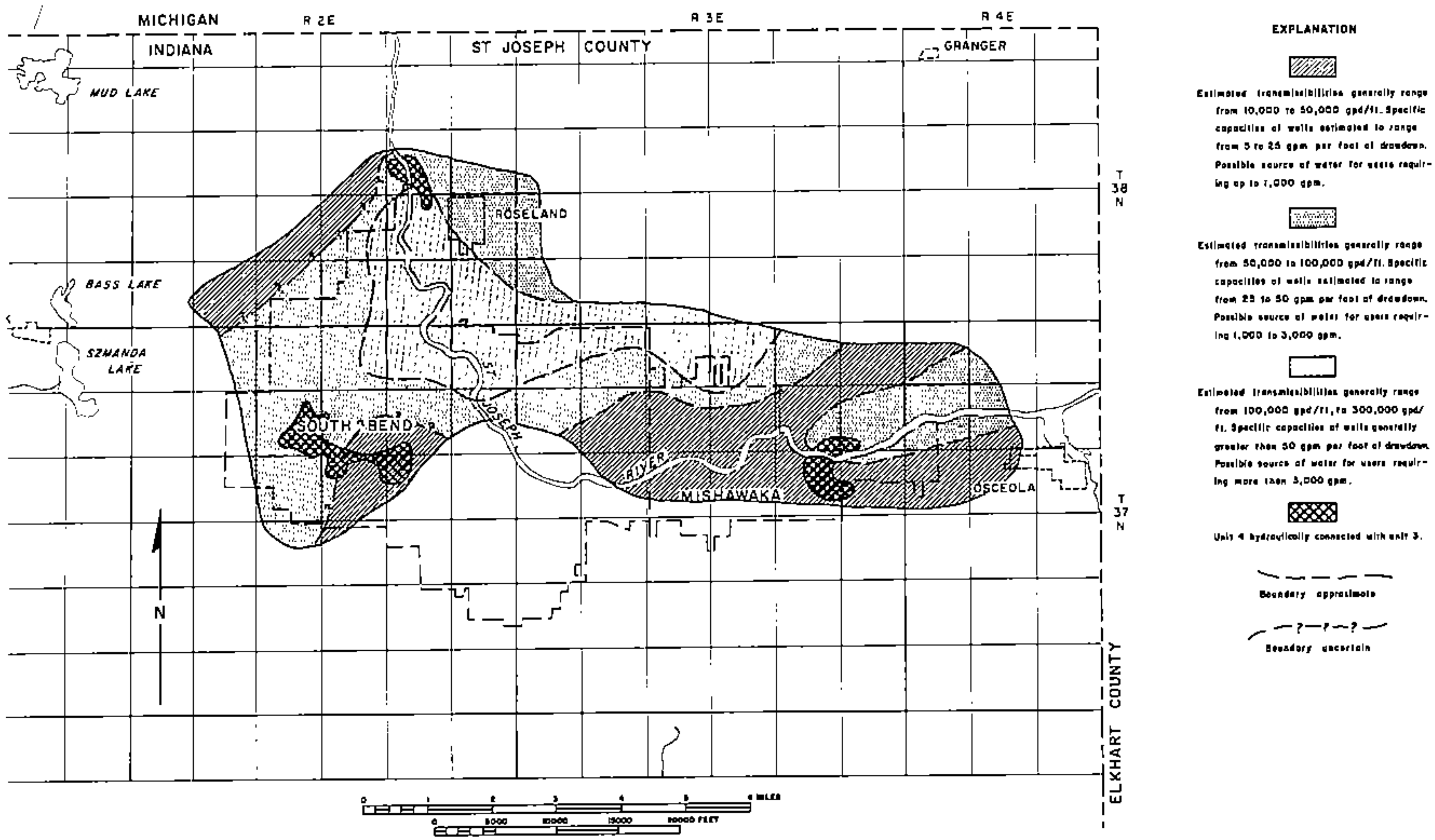

FIGURE 2.--Map of the South Bend - Mishawaka area, showing capability of unit 4 as a source of water.

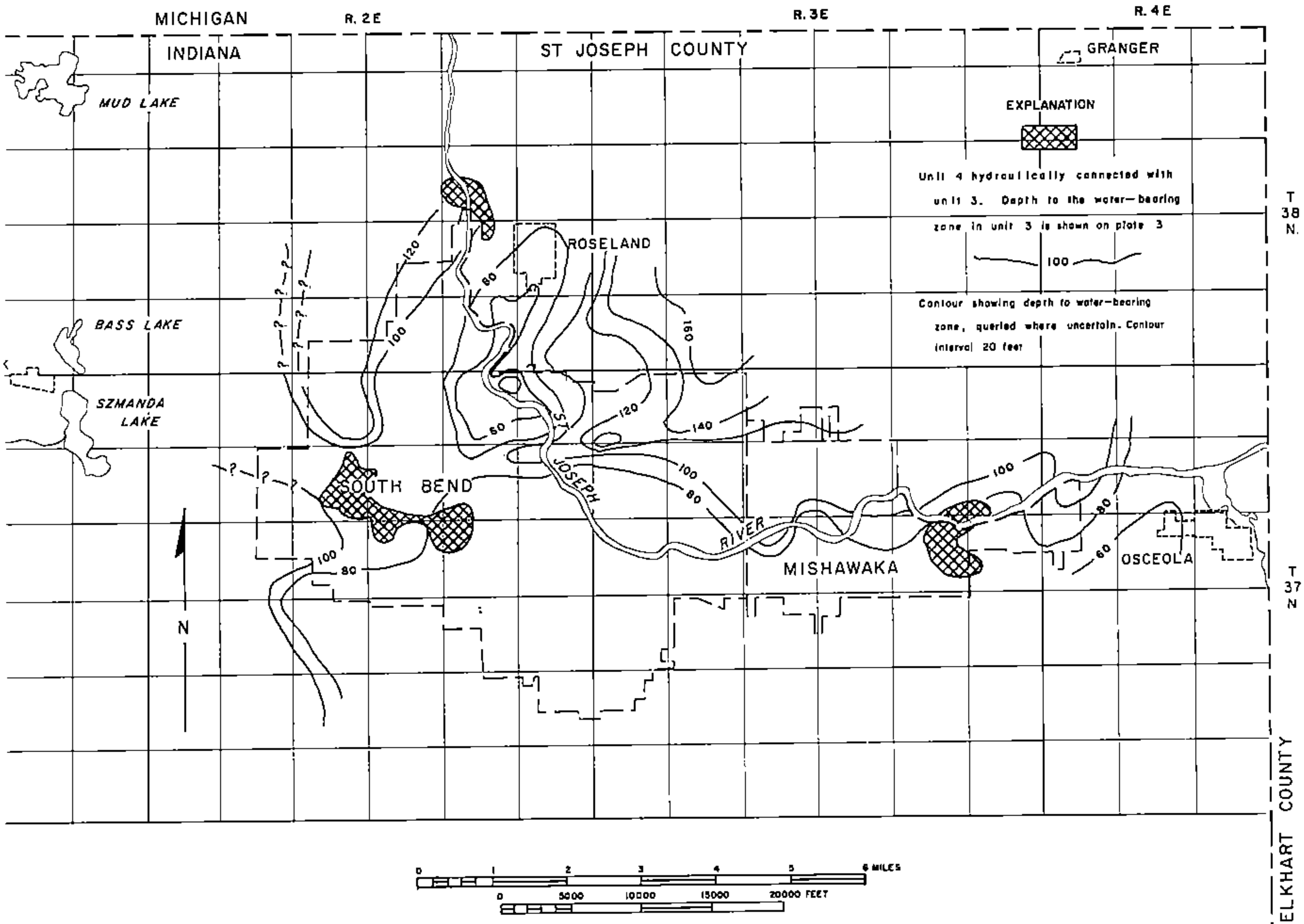

FIGURE 3.— Map of the South Bend—Mishawaka area, showing depth to the water—bearing zone in unit 4.

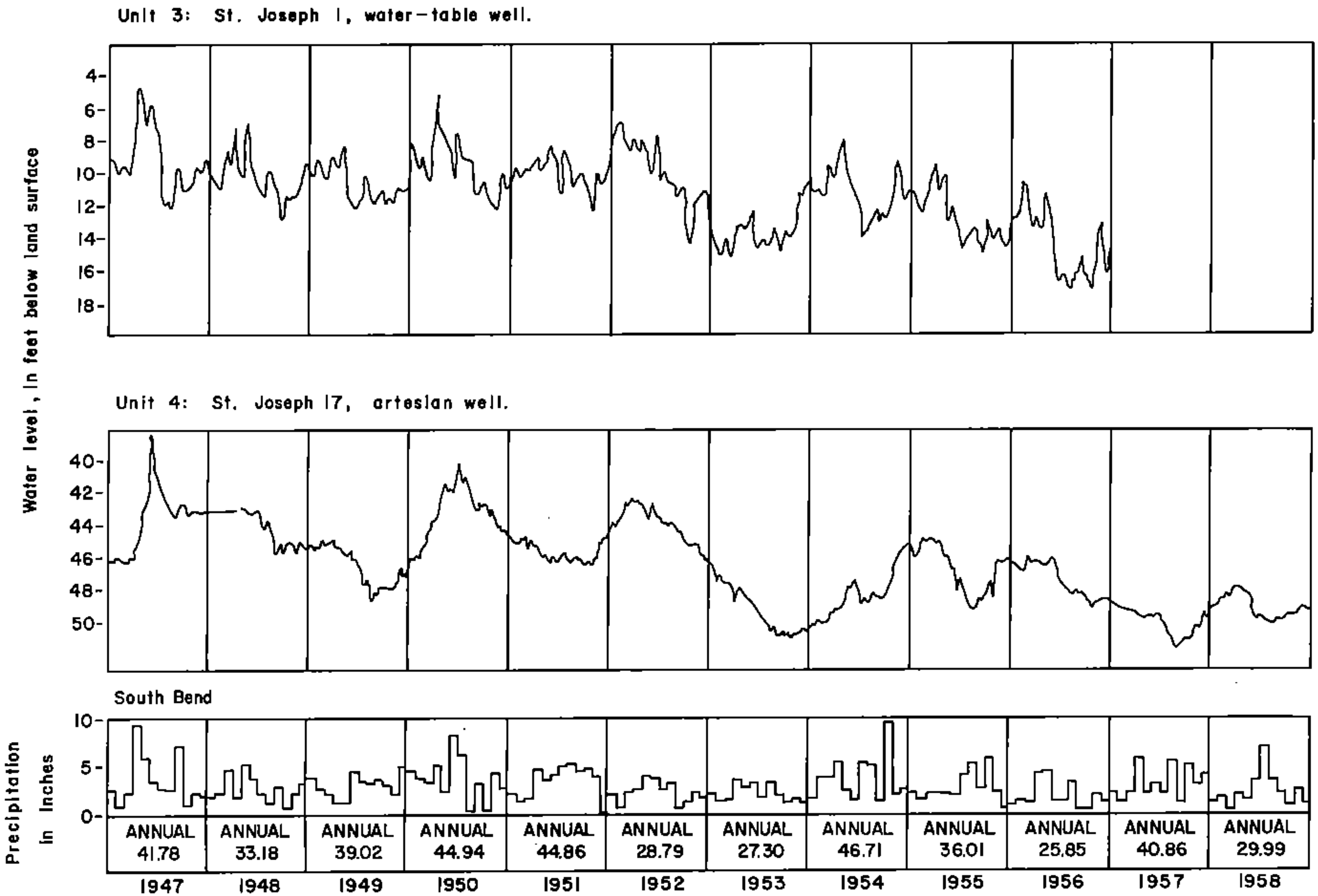

FIGURE 4.--Fluctuations of water levels in observation wells and monthly precipitation in St. Joseph County.

from less than 10,000 up to 500,000 gpd per foot. The unit has an estimated regional transmissibility of 70,000 gpd per foot.

Rosenshein and Hunn (1968a, p. 21) have estimated that in Lake County the coefficient of storage for the artesian part of the aquifer averages 0.003 and for the water-table part 0.12. These estimates should be sufficiently accurate to evaluate regional characteristics of the aquifer in St. Joseph County.

Recharge and Discharge

Fluctuations of the water level in the aquifer due to seasonal variations of recharge and discharge and to pumping of nearby wells are shown on figure 4. This hydrograph also shows the maximum recorded decline of water levels in unit 3 in the South Bend area since 1946.

Recharge to the unit is derived chiefly from precipitation within the county. Some ground water enters the county by underflow from nearby areas in Michigan and in La Porte County, Indiana. During periods of heavy pumping in South Bend, some infiltration is induced from the St. Joseph River.

Recharge to the artesian part of the aquifer, and to much of the water-table part, must take place by slow percolation through the overlying till (unit 2, p. 16). This recharge is estimated to average 200,000 gpd per square mile.

That part of the unit which is exposed at the surface (pl. 1) is recharged mainly by direct percolation of precipitation through the upper part of the unit. This recharge is estimated to average 1.2 mgd per square mile.

Natural discharge from the water-table part occurs chiefly as effluent seepage (p. 17) to the ditches and streans that penetrate the unit and as direct evapotranspiration. Effluent seepage constitutes most of the discharge in the nongrowing season and only a small part in the growing season. The importance of the streams and ditches as a means of discharge from the unit is indicated by their effects upon the configuration of the piezometric surface (fig. 5). This discharge produces most of the streamflow from July through September.

Discharge by evapotranspiration from the water-table part in the growing season occurs chiefly where the water-bearing zone is less than 20 feet below the land surface (pl. 3). Although no detailed evaluation of this discharge has been made, it should be similar per square mile to that estimated for the water-table part of this unit in Lake County (Rosenshein and Hunn, 1968a, p. 24). This discharge in St. Joseph County was probably about 20,000 million gallons or about 130 mgd during the 1960 growing season.

Natural discharge from the artesian part of unit 3 occurs as upward leakage through the overlying till. Some discharge by evapotranspiration takes place locally where the confining layer is less than 20 feet thick; however, the quantity discharged must be relatively small. Some discharge from both the artesian and the water-table parts occurs also as downward movement to the underlying rock units.

Wells tapping unit 3 discharge an estimated 32 mgd. This discharge accounts for about 59 percent of the ground water used in the county. Of this amount, about 17 mgd is pumped for domestic and farm use, about 11.6 mgd for municipal use by South Bend, Mishawaka, Lakeville, North Liberty, Walkerton and Wedgewood Park, and about 3.7 mgd for industrial and commercial use.

Quality of Water

The principal constituents of the water are bicarbonate, calcium, and magnesium. Locally, sulfate is a major constituent. Concentrations of the dissolved constituents are summarized in table 4. The significance of these constituents is shown in table 3. Maps showing distribution of hardness and iron concentrations in St. Joseph County have been published in a preliminary report (Rosenshein and Hunn, 1963a).

Bicarbonate concentrations in unit 3 are often relatively high where the unit is overlain by unit 2, a calcareous silt till (p. 16). This relationship is not as pronounced in St. Joseph County as in Lake and Porter Counties (Rosenshein and Hunn, 1968a and 1968b), where the till is finer grained, and exposes more surface area per unit volume to percolating ground water.

Table 4.--Summary of water quality in unit 3.

Constituent or property	Minimum (ppm)	Maximum (ppm)	Mode (most common value) (ppm)	Average	Number of samples
Iron (Fe)	< 0.1	7.5	0.12	0.72	368
Bicarbonate (HCO_3)	24	512	312	306	373
Sulfate (SO_4)	< 5	430	37	44	210
Chloride (Cl)	< 4	164	12	15	370
Hardness as $CaCO_3$	96	816	276	287	372
Total dissolved solids	70	1,010	340	343	206

Development and Potential

Plate 2 shows estimated transmissibilities and relates these to specific capacities and possible yields obtainable from properly constructed wells. The specific capacities are those to be expected for a 12-inch well after pumping for 1 day. The yield for a specified drawdown will be greater for a large-diameter well than for a small-diameter well, and will decrease with time of pumping. Possible yields for the water-table part of the aquifer are estimated from the specific capacities, by using a drawdown limited to one-half the saturated thickness of the unit. Owing to these and other factors, such as well efficiency, plate 2 gives only an approximation of the capability of the aquifer as a source of water. Much of the unit is a possible source of water for users requiring 500 gpm or more. However, without proper construction (see p. 7), actual yields of wells may be considerably less than those indicated on plate 2.

The depth to the water-bearing zone in unit 3 can be estimated from plate 3. This information can then be used in conjunction with plate 2 to estimate the depth to which a well must be drilled to develop an adequate water supply. For maximum yields from the artesian part, the full thickness of the aquifer should be penetrated and screened. For domestic or farm supplies only the upper 10 to 15 feet need be penetrated and a short, small-diameter screen used.

The quantity of water potentially available for development from unit 3 depends on its rate of recharge. In part of the area this rate is controlled to a large extend by the geohydrologic properties of the overlying till, unit 2. Recharge to this part of the aquifer is currently estimated to be 40 mgd. Rosenshein (1963, p. 17) has shown that the rate of recharge to the artesian part will increase as it is extensively developed. This increase could raise the potential of this part of the unit to about 80 mgd.

The potential yield of the water-table part that is exposed at the surface is estimated to be 300 mgd. Development of water supplies in this part is complicated by several factors. The saturated thickness varies seasonally by about 2 to 5 feet. Because pumping from the water-table part results in an actual dewatering of the unit, the transmissibility decreases as water is withdrawn. Estimates of the specific capacities and possible yields of this part of the aquifer (pl. 2) have been adjusted for these factors.

The current pumpage is only about 8 percent of the water potentially available for use from the aquifer.

Land-use practices and the susceptibility of shallow aquifers to contamination also complicate possible development. The land in much of the area is used chiefly for farming. As a result, it is continually being ditched--a practice that decreases the average saturated thickness, thereby permanently dewatering a part of the aquifer and decreasing its potential for development. Because the aquifer is readily susceptible to contamination, the user should guard against waste-disposal methods that permit downward leakage of undesirable waste products.

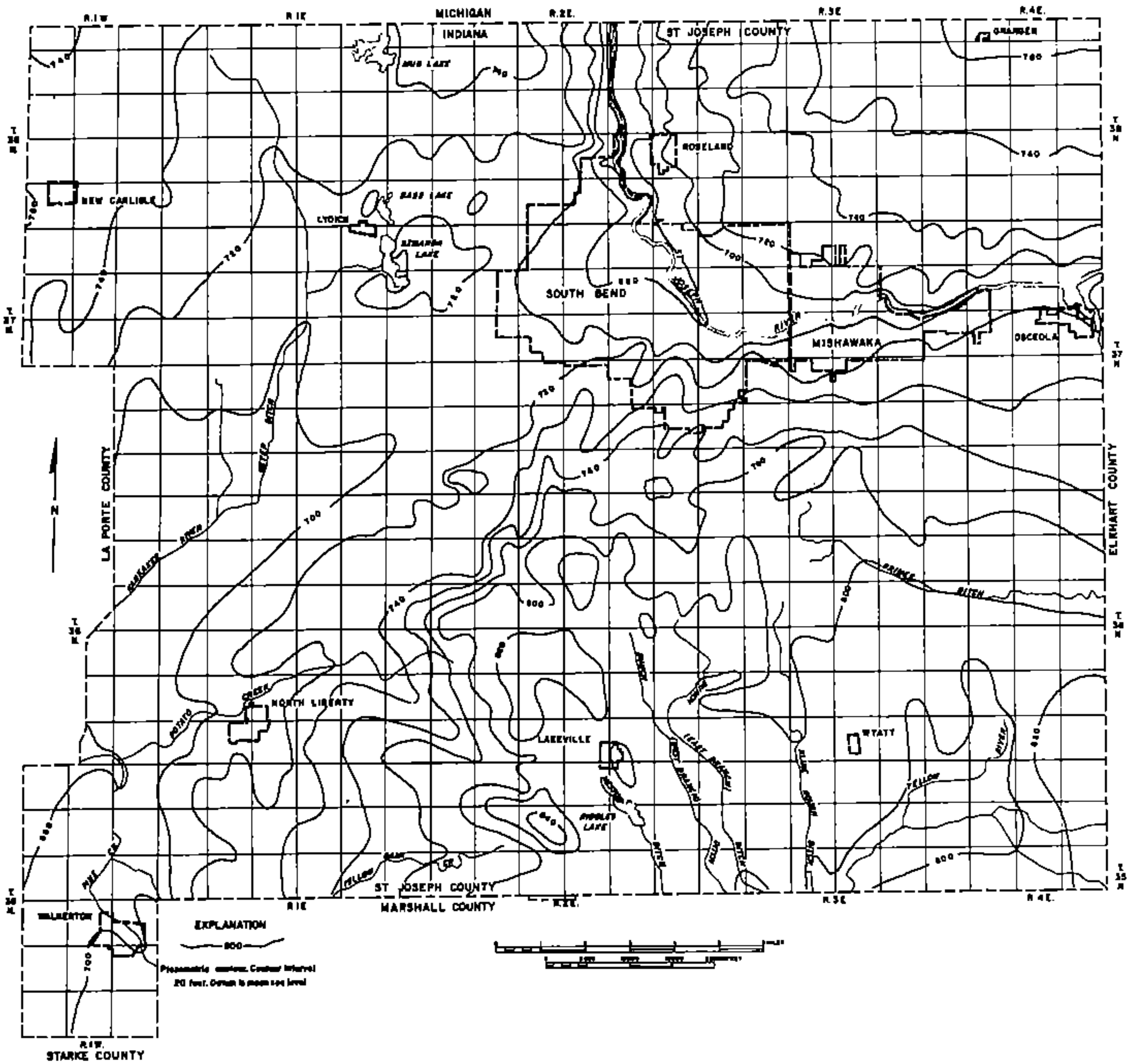

FIGURE 5 — MAP SHOWING CONFIGURATION OF THE PIEZOMETRIC SURFACE OF UNIT 3, ST. JOSEPH COUNTY, JANUARY 1960

Unit 2

Water-Bearing Characteristics

Unit 2 consists chiefly of silt till, which mantles much of unit 3. The rate of recharge to the underlying aquifer depends in part on the vertical permeability of unit 2. Rosenshein (1963, p. 16) estimated that the vertical permeability of the unit averages 0.007 gpd per square foot in Lake County. Although no calculations have been made for St. Joseph County, the till in this area is much coarser grained and the vertical permeability is probably 1.5 to 3 times that of unit 2 in Lake County.

The porosity of the unit may be about 40 percent and its saturated thickness may average 20 feet. On the basis of these estimates, the unit may have as much as 2 million acre-feet of water in storage. However, because of its small permeability, direct production from the unit is limited to relatively thin, discontinuous sand and gravel zones which are used only for domestic and farm supplies.

Hydrologic Aspects

Unit 2 is the second most extensive unit exposed at the surface in St. Joseph County. The flow of many streams and ditches is determined to a significant extent by its ground-water discharge and runoff characteristics. Although this discharge has not been calculated, it is considerably less than that estimated by Rosenshein and Hunn (1968a, p. 29) for the unit in Lake County (110 mgd), where the unit covers three-fourths of the land surface.

SUMMARY

The principal sources of ground water in St. Joseph County are the unconsolidated rocks of Quaternary age. The underlying bedrock is not used; however, it is a potential source of water of uncertain quality and quantity. The unconsolidated rocks form a single but complex hydrologic system composed of three units. This system has a potential yield from natural recharge of about 400 mgd (million gallons per day), of which about 54 mgd or about 13 percent is currently being withdrawn.

Geohydrology of rock units.--Unit 4, a clay till, contains discontinuous zones of sand and gravel that are used locally for industrial and municipal supplies. The permeability of these zones ranges from less than 100 to about 800 gpd per square foot. Vertical permeability of the unit is probably about 0.003 gpd per square foot. The unit may have as much as 6 million acre-feet of water in storage.

Sand and gravel within unit 4 is the principal aquifer of the South Bend-Mishawaka area. The transmissibility of this zone ranges from less than 10,000 to more than 300,000 gpd per foot. The permeability ranges from less than 200 to more than 6,000 gpd per square foot. The coefficient of storage is about 0.0003.

Unit 3, a sand and gravel, is the principal aquifer underlying the county. Its coefficient of transmissibility ranges from less than 10,000 up to 500,000 gpd per foot. The unit has an estimated regional transmissibility of 70,000 gpd per foot. The regional values of the coefficient of storage are probably about 0.003 for the artesian part and 0.12 for the water-table part. Recharge to the artesian part and to much of the water-table part must percolate through the overlying till (unit 2). This recharge is about 40 mgd. Extensive development of the artesian part will increase its potential to about 80 mgd. Direct recharge to the water-table part is about 1.2 mgd per square mile, and the estimated potential yield is 300 mgd.

The principal dissolved constituents in the water from unit 3 are calcium, magnesium, and bicarbonate. The concentration of dissolved solids averages about 340 ppm.

Unit 2, a silt till, is the confining layer for the artesian part of the principal aquifer. Its vertical permeability is probably greater than 0.007 gpd per square foot. The unit may have as much as 2 million acre-feet of water in storage. Discontinuous sand and gravel zones within the unit are used occasionally for domestic and farm supplies. It is the second most extensive unit exposed at the surface in the county. The flow of many streams and ditches is influenced by the ground-water discharge and runoff characteristics of the unit.

GLOSSARY

Hydraulic Coefficients (after Ferris and others, 1962)

Permeability.--Measure of a material's capacity to transmit water; expressed as rate of flow of water in gallons per day through a cross-sectional area of 1 square foot under a hydraulic gradient of 1 foot per foot at prevailing water temperature.

Storage.--Volume of water released from or taken into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface.

Transmissibility.--Rate of flow of water, at the prevailing water temperature, in gallons per day, through a vertical strip of the aquifer 1 foot wide extending the full saturated height of the aquifer under a hydraulic gradient of 1 foot per foot.

Miscellaneous Terms

Effluent seepage.--Discharge of ground water to surface bodies of water.

Porosity.--Volume of pore space expressed as a percentage of the total volume of the rock.

Specific capacity.--Yield of a well in gallons per minute per foot of drawdown.

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DEPARTMENT OF NATURAL RESOURCES
DIVISION OF WATER

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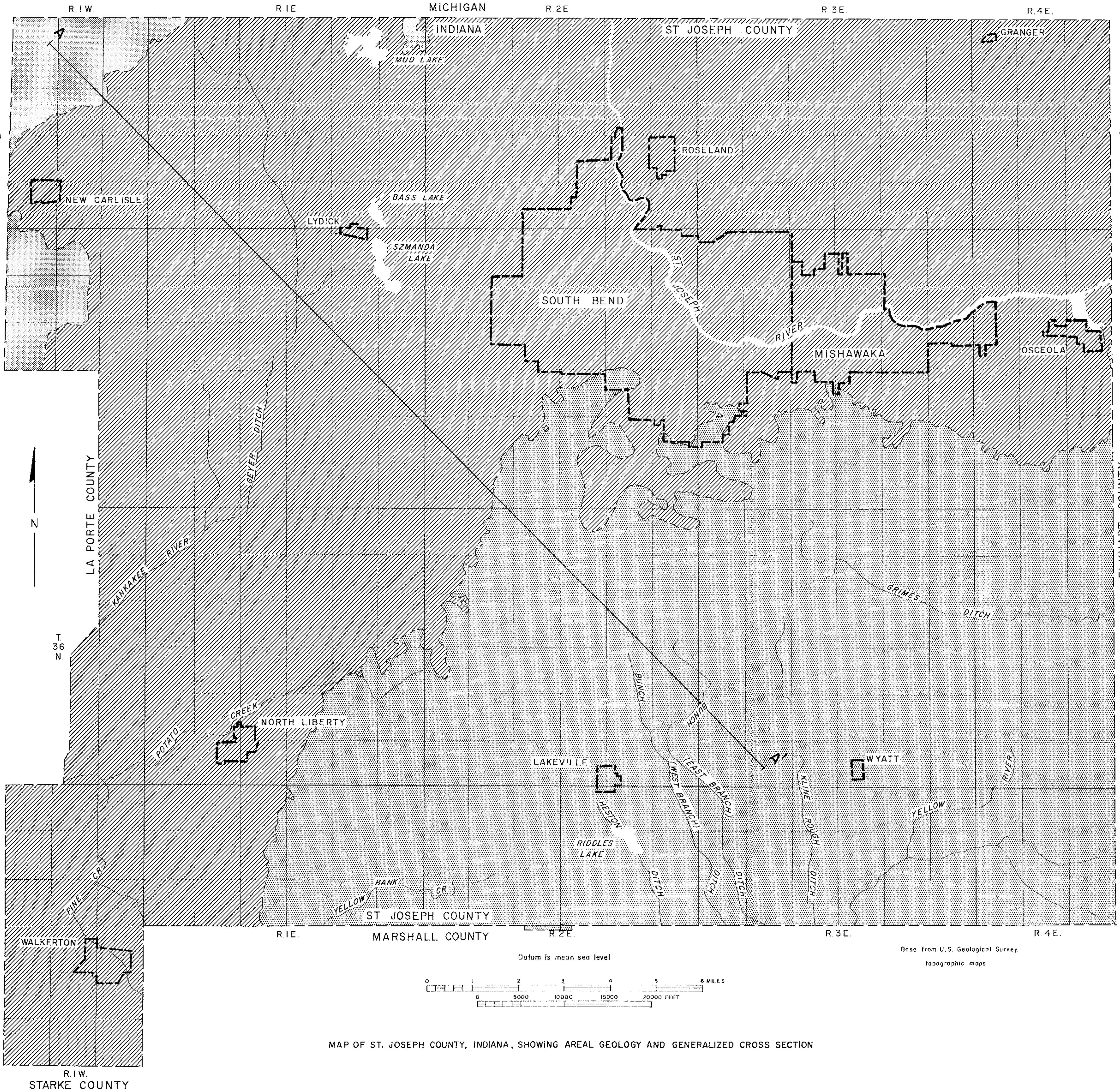
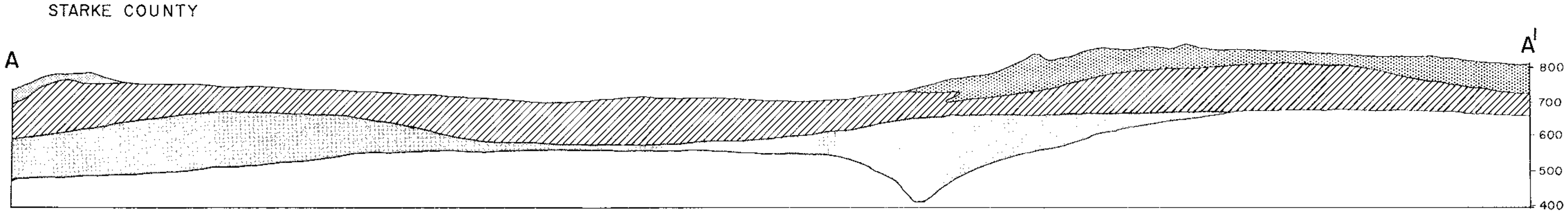


MAP OF ST. JOSEPH COUNTY, INDIANA, SHOWING AREAL GEOLOGY AND GENERALIZED CROSS SECTION



EXPLANATION

QUATERNARY — PLEISTOCENE TO RECENT

UNIT 2
TILL

Silt, clayey and sandy, pebbly and cobbly, generally buff to tan or reddish-brown in outcrop. Forms dissected ground and terminal moraines

Silt, clayey and sandy, pebbly and cobbly, generally tan to brown in outcrop. Forms Maxinkuckee Moraine and associated ground moraine

UNIT 3
CHIEFLY GLACIOFLUVIAL

Sand, medium to course, somewhat pebbly, silty, and clayey, and sand and gravel. Locally interbedded with layers of organically rich silt and clay of relatively small areal extent. Contains some wind-blown sand

UNIT 4
TILL

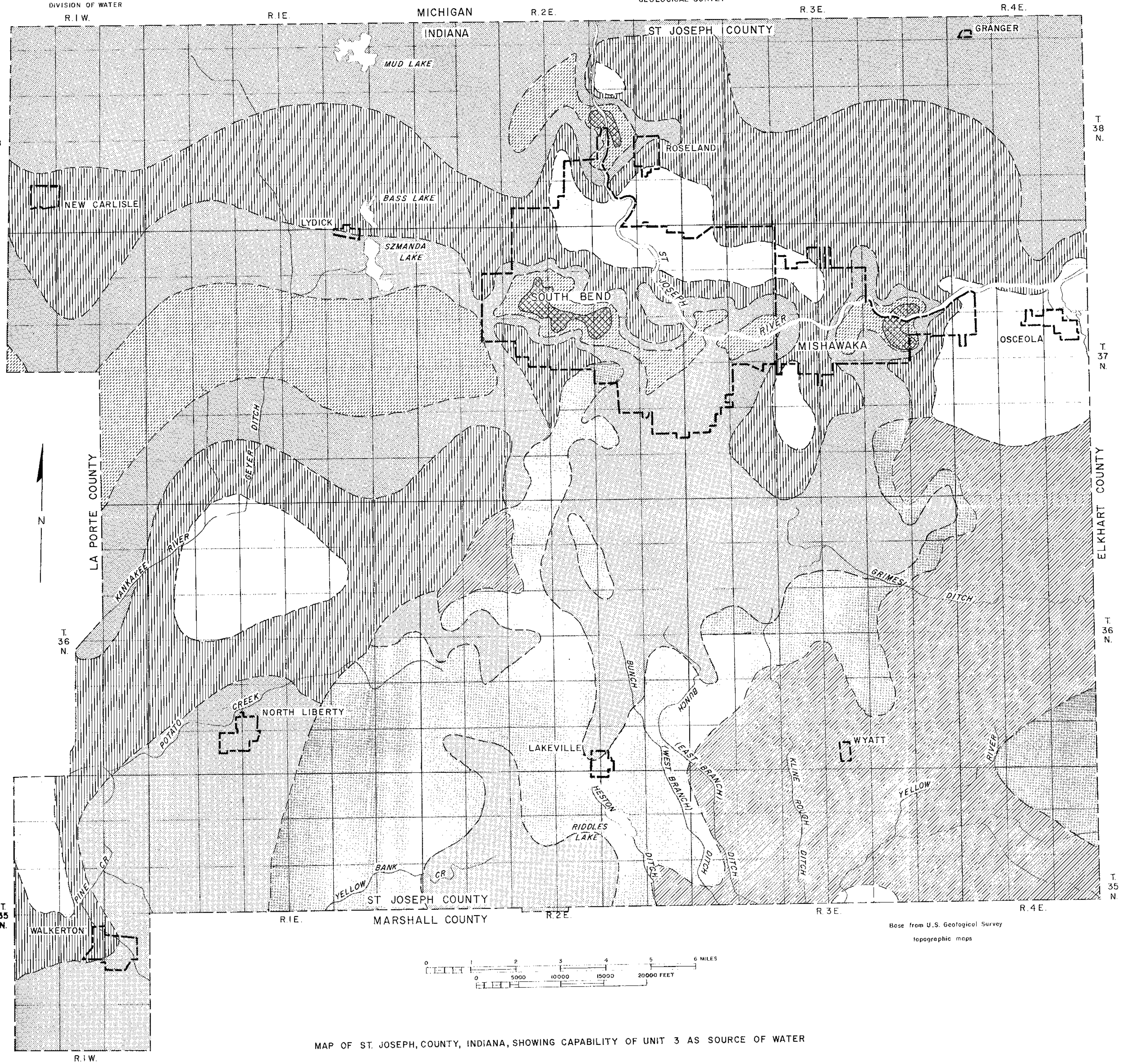
Clay, locally hard and compact, gray. Contains some layers of sand and gravel. (Shown on cross section only)

UNDIFFERENTIATED — PRE-PLEISTOCENE

BEDROCK

Chiefly shale and limestone. (Shown on cross section only)

Boundaries of unit 2 generalized in part from an interpretation of a U.S. Department of Agriculture soils map (Ulrich and others, 1950) by A.F. Schneider, Indiana Geological Survey



MAP OF ST. JOSEPH, COUNTY, INDIANA, SHOWING CAPABILITY OF UNIT 3 AS SOURCE OF WATER

EXPLANATION

WATER-TABLE PART

Estimated transmissibilities generally range from 10,000 to 25,000 gpd/ft. Specific capacities of wells estimated to range from 5 to 10 gpm per foot of drawdown. Possible source of water for users requiring 25 to 180 gpm.

Estimated transmissibilities generally range from 25,000 to 50,000 gpd/ft. Specific capacities of wells estimated to range from 10 to 20 gpm per foot of drawdown. Possible source of water for users requiring 180 to 800 gpm.

Estimated transmissibilities generally range from 50,000 to 100,000 gpd/ft. Specific capacities of wells estimated to range from 20 to 40 gpm per foot of drawdown. Possible source of water for users requiring 800 to 3,000 gpm.

Estimated transmissibilities generally range from 100,000 to 500,000 gpd/ft. Specific capacities of wells estimated to be more than 40 gpm per foot of drawdown. Possible source of water for users requiring more than 3,000 gpm.

ARTESIAN PART

Estimated transmissibilities generally range from 10,000 to 25,000 gpd/ft. Specific capacities of wells estimated to range from 7 to 15 gpm per foot of drawdown. Possible source of water for users requiring 120 to 300 gpm.

Estimated transmissibilities generally range from 25,000 to 50,000 gpd/ft. Specific capacities of wells estimated to range from 15 to 25 gpm per foot of drawdown. Possible source of water for users requiring 300 to more than 1,000 gpm.

APPROXIMATE BOUNDARY

Unit 3 hydraulically connected with unit 4.

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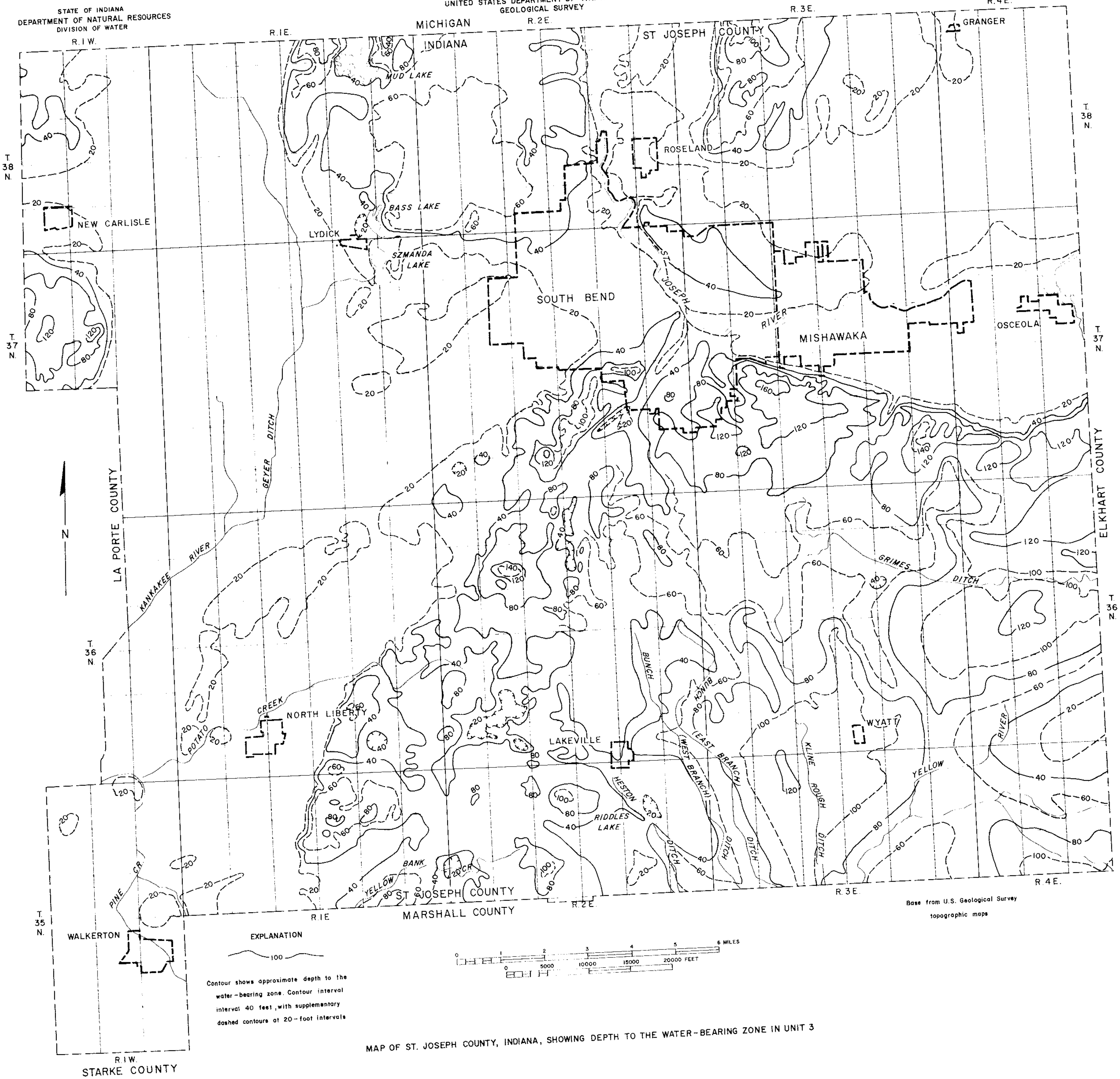

MAP OF ST. JOSEPH COUNTY, INDIANA, SHOWING DEPTH TO THE WATER-BEARING ZONE IN UNIT 3