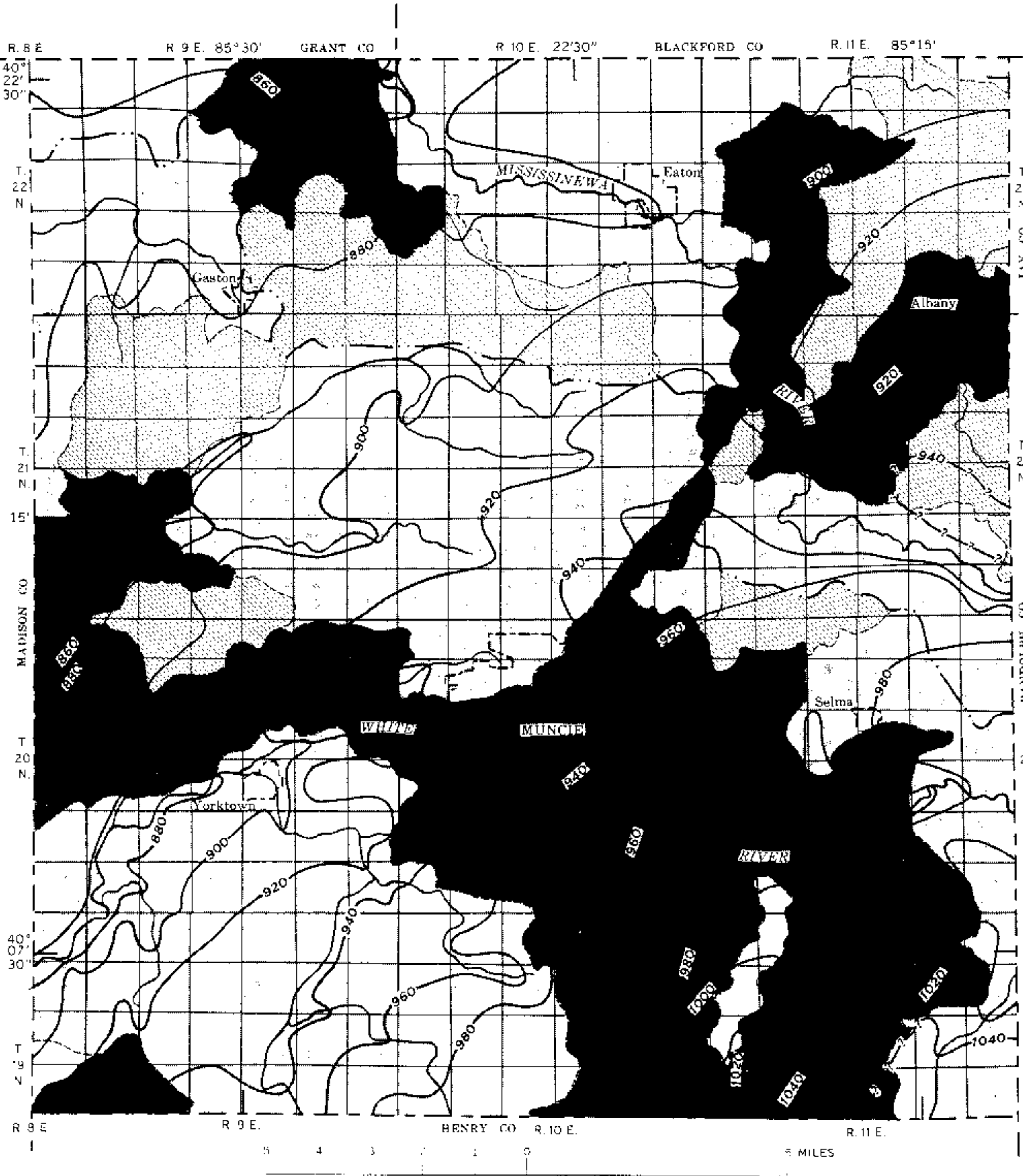
Inflow from deeper sand and gravel aquifers and from the Silurian Dolomite occurs principally as upward flow toward the larger streams. This inflow occurs in areas where contours on the piezometric surface of the Silurian Dolomite (fig. 13, p. 37) are approximately parallel to the streams.

The estimates of recharge from precipitation to the principal Pleistocene aquifer shown on figure 7 were obtained from parts of the piezometric surface and the hydraulic characteristics of the aquifer, using Darcy's Law. These estimates are only approximations because of limited knowledge of the hydraulic properties of the aquifer and should not be used to extrapolate into other apparently similar areas. They are adequate, however, to show the relative importance of direct recharge and underflow in the hydrologic cycle in Delaware County. The estimates of underflow may be misleading unless compared with the configuration of the piezometric surface. Ground-water flow along the county boundaries is nearly parallel to the boundaries in many places. Only a small amount of ground water flows across the boundaries. The eastern and southern boundaries together are about 40 miles long. The quantity of water flowing through an aquifer of similar hydraulic properties directly across a line 40 miles long would be about 14 mgd, assuming a hydraulic gradient of about 10 feet per mile. Even this hypothetical figure is small compared with the amount of recharge from precipitation within the county.

Ground water is discharged to the streams in the county through the surficial confining layer. This discharge constitutes most of the base flow of the streams. Figure 8 shows the stream runoff per square mile at near 90 percent flow duration for small drainage basins within the county, and contours on the piezometric surface of the principal Pleistocene aquifer, drawn from water-well data. Ground water flows approximately at right angles to the contour lines and down the hydraulic gradient. Where the contour lines are approximately parallel to the streams, ground water is being discharged into the streams. The figure shows a general correlation between gain in base flow of the streams and direction of ground-water flow. The principal Pleistocene aquifer supplies most of the base flow; however, some ground water is discharged to streams from the bedrock, from the sand and gravel unit overlying the principal Pleistocene aquifer (fig. 6), and from the surficial confining layer each of which has its own piezometric surface. Although there is usually some difference in head between these surfaces at any particular place their configurations are similar to the configuration of the piezometric surface of the principal Pleistocene aquifer.



EXPLANATION

Base flow (cfsm)

0 to 0.009	0.01 to 0.099	0.10 and above	Not measured

——900—?—
Generalized contour
Drawn on the piezometric surface of the principal Pleistocene aquifer, 1963. Contour interval 20 feet. Datum is mean sea level Dashed and queried where less accurate

Divide between White and Mississinewa River basins

Surface drainage divide

Figure 3.—Ground water supplies most of the base flow of streams of Delaware County. Streamflow was measured at near 90 percent flow duration, when nearly all of the flow of the streams was base flow.

Development and Potential

Principal Pleistocene Aquifer. This aquifer is capable of yielding as much as 500 gpm to individual wells in the south-central and southeastern parts of the county (fig. 9). These areas probably will not be extensively developed in the foreseeable future. Figure 9 shows expected one-day specific capacities and possible yields of 12-inch wells screened the full thickness of the aquifer. Screen diameter, length, and slot size must be chosen carefully in order to obtain the yields indicated on figure 9. Wells require development to remove the clay, silt, and very fine sand from the immediate vicinity of the screen. For domestic and farm supplies, screens are generally not used in Delaware County, and the possible yields shown are not applicable.

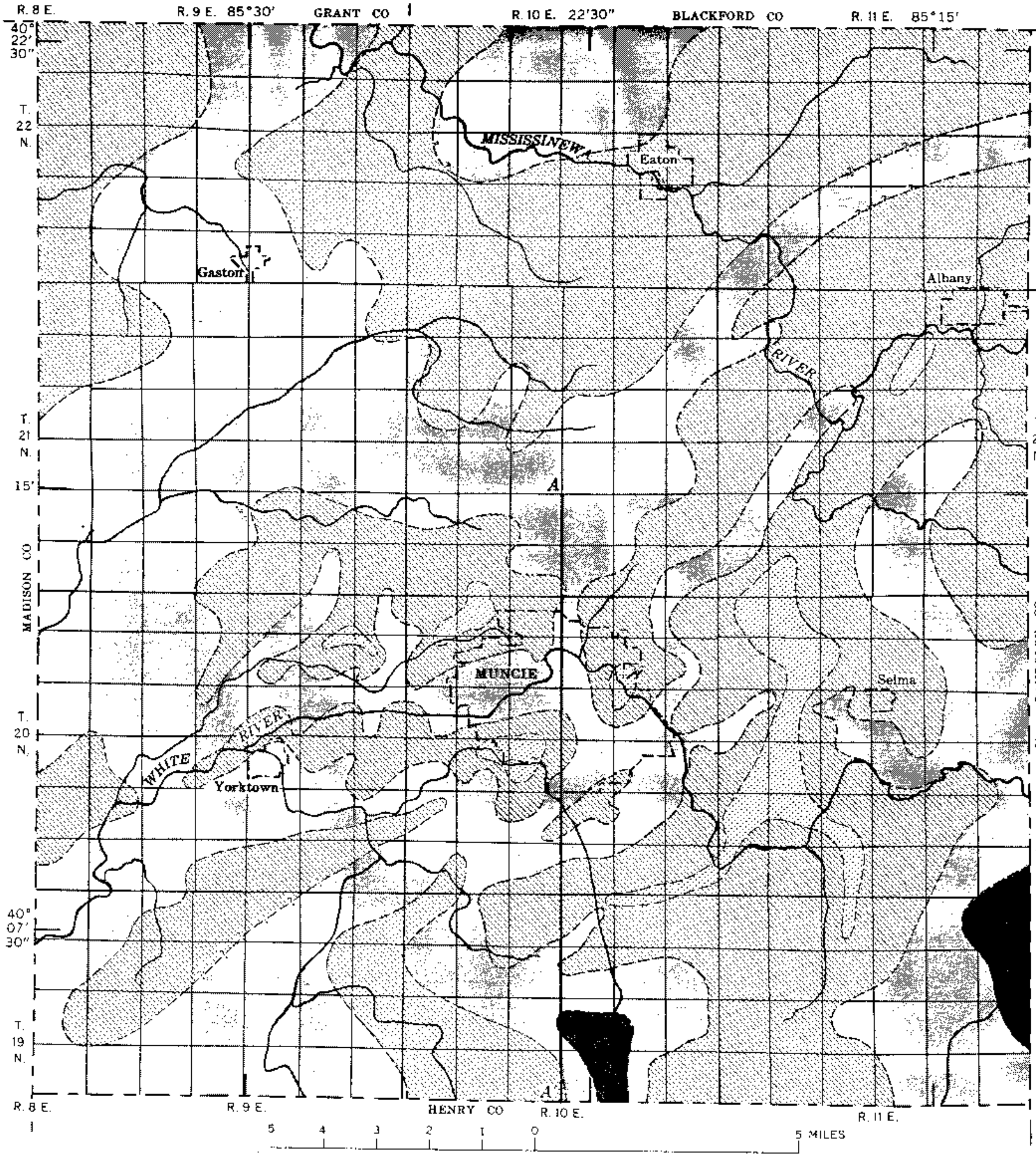
The yield of a well for a specified drawdown will decrease with time of pumping, and will be greater for a larger diameter well. Because of these limitations, and because of the lack of carefully controlled pumping data, the map shows only an approximation of the capability of the aquifer, and will probably need refining in the future.

The depth to the top of this aquifer can be estimated from figure 10. This depth, used along with figure 9, can be used to estimate the well depth necessary to develop a water supply in the aquifer.

The potential of the principal Pleistocene aquifer for future development depends to a large extent upon its rate of recharge, which is determined partly by the difference between the hydraulic head in the aquifer and the head in the surficial confining layer. If the head in the aquifer is lowered by pumping, recharge to the aquifer will increase until the water level is lowered to the top of the aquifer.

Deeper sand and gravel aquifers. Figure 11 shows the known areal extent of these aquifers and gives selected data on depth to the water-bearing zone, thickness penetrated, and pumping data where available. Saturated thickness and areal extent of these aquifers are not well known; however, the potential yield of these aquifers is much less than the potential of the principal Pleistocene aquifer.

Total potential of glacial deposits. For maximum yields, the entire thickness of the glacial deposits should be penetrated, and all major aquifers should be screened. By this method, yields of as much as 600 to 700 gpm might be obtained where the principal Pleistocene aquifers are most productive (fig. 9).



EXPLANATION

Anticipated range of maximum yields and anticipated one-day specific capacities of 12-inch wells that penetrate and screen the full thickness of the aquifer

Maximum yields 300 to 500 gpm (gallons per minute). Specific capacities 25 to 40 gpm/ft. (gallons per minute per foot of drawdown). Aquifer usually consists of 40 to 80 feet of sand and gravel

Maximum yields 150 to 300 gpm. Specific capacities 12 to 25 gpm/ft. Aquifer usually consists of 20 to 70 feet of sand and gravel

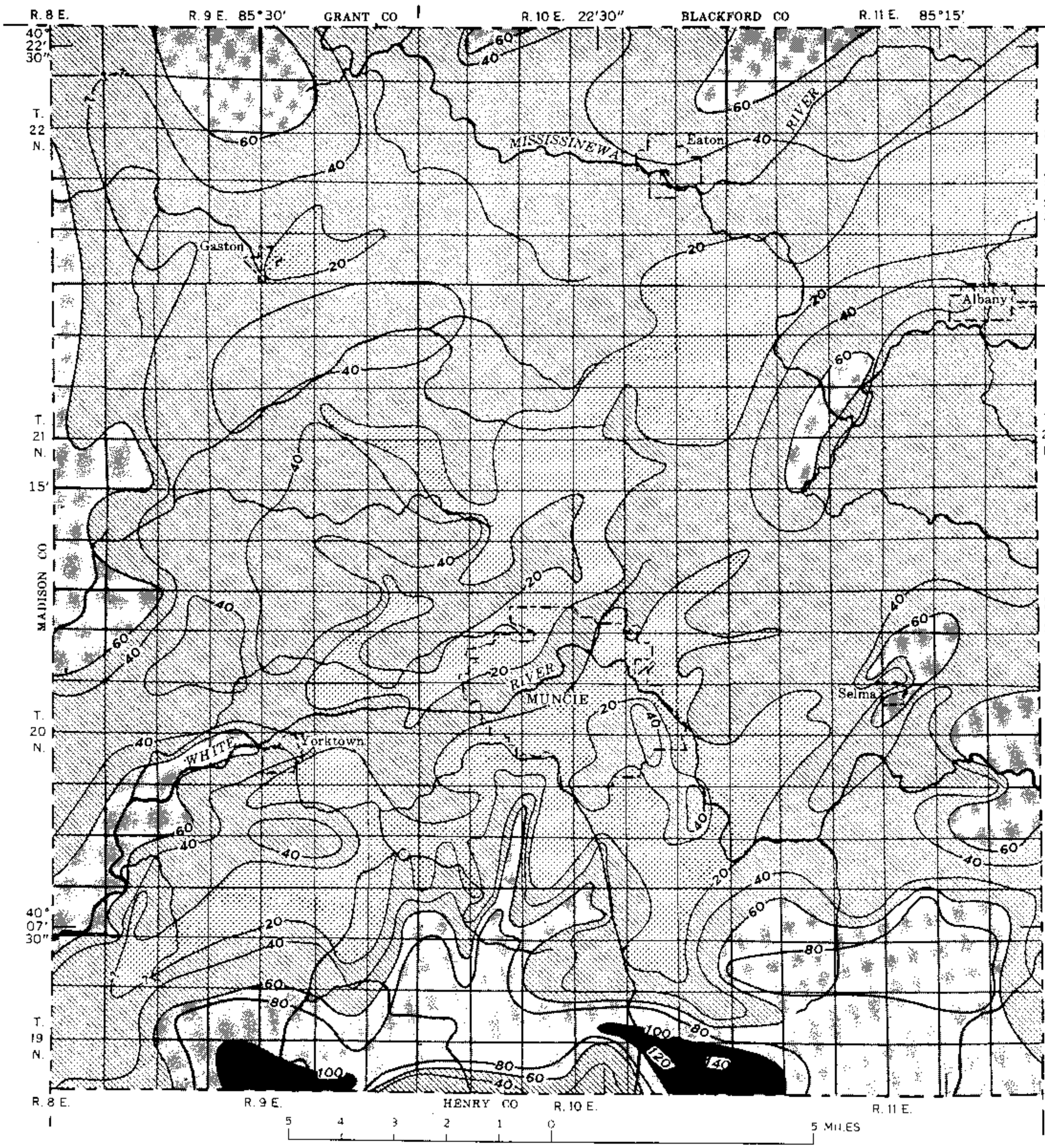
Maximum yields 150 gpm or less. Specific capacities 1.5 to 12 gpm/ft. Aquifer usually consists of sand up to 50 feet thick, or sand and gravel up to 15 feet thick

Aquifer very thin or missing. Deeper aquifers are usually better sources of water

A ——— A′
Line of cross section (fig. 6)

— — — - -?- -?- - -
Approximate boundary
Queried where less accurate

Figure 9.—The principal Pleistocene aquifer is capable of supplying as much as 500 gpm to individual wells.



EXPLANATION

Approximate depth to top of aquifer below land surface (feet)

Less than 20

20 to 60

60 to 100

More than 100

—20—
Contour

Showing approximate depth to top of aquifer. Contour interval 20 feet

Figure 10.—The principal Pleistocene aquifer lies at depths of less than 20 to more than 140 feet below land surface.

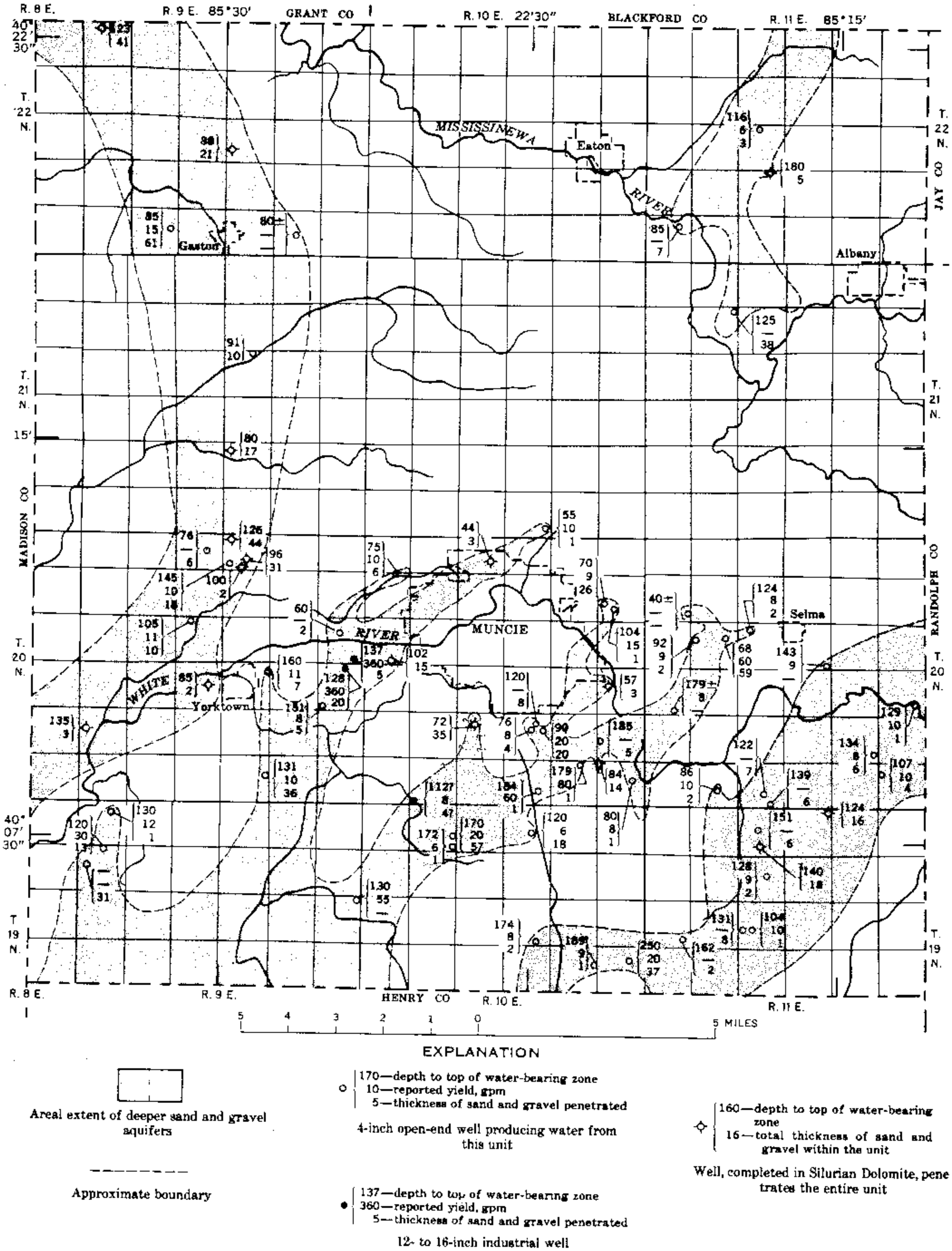


Figure 11.—Sand and gravel below the principal Pleistocene aquifer usually occurs in bedrock valleys. Saturated thickness and potential of the unit are not well known.

Bedrock Formations

The principal bedrock aquifer of Delaware County is dolomite of Silurian age. It underlies the entire county at depths of 0 to about 300 feet. Drillers report some shale and occasionally sandstone, but these reports are too widely distributed to permit adequate mapping at the present time. The Trenton limestone of Ordovician age is a potential source of saline water. The Trenton is reached at depths of 900 to 1,000 feet below the land surface in Delaware County. The quantity of water available is uncertain.

Additional sources of saline water probably occur below the Trenton limestone in the Chazyan Series of Ordovician age, the Knox dolomite of Cambrian and Ordovician age and possibly the Mt. Simon sandstone of Cambrian age. Little is known about these sources and the quality or quantity of the water.

Silurian Dolomite

Water-bearing characteristics. The natural porosity and permeability of the dolomite are relatively small and most ground water occurs chiefly in the joints, fractures, and solution openings in the rock. Most of these openings were produced by chemical and physical weathering during pre-Pleistocene time, when the bedrock was exposed at the surface.

The permeability of the dolomite decreases rapidly with depth. Most of the water produced from the dolomite is obtained from the upper 50 feet; however, drillers occasionally report water-bearing zones after penetrating as much as 100 feet. These deeper zones yield generally less than 15 gpm to individual wells.

In other parts of the state, areas of high permeability in the Silurian dolomite have been found to coincide with bedrock uplands and upper parts of buried valley walls (Watkins and Rosenshein, 1963; Watkins and Ward, 1962; Rosenshein and Hunn, 1964). This relationship is probably valid in Delaware County; however, it cannot be fully substantiated with data presently available.

Recharge and discharge. Most of the inflow to the dolomite is precipitation that percolates through the overlying glacial deposits. Some water enters the county by underground flow, mostly along the eastern and southern boundaries. Average inflow and outflow in the dolomite and the deeper sand and gravel aquifers is symbolized by figure 12. The rate of recharge to the deeper sand and gravel aquifers must be about the same as the rate of recharge to the dolomite, because of the similarity of the overburden.

Very little or no inflow to the dolomite from underlying rocks is believed to occur in Delaware County. No saline water contamination has been reported, except as surface contamination in the vicinity of some pumping oil wells. Fresh ground water flows from some abandoned oil or gas wells during periods of high water levels. Locations of some of

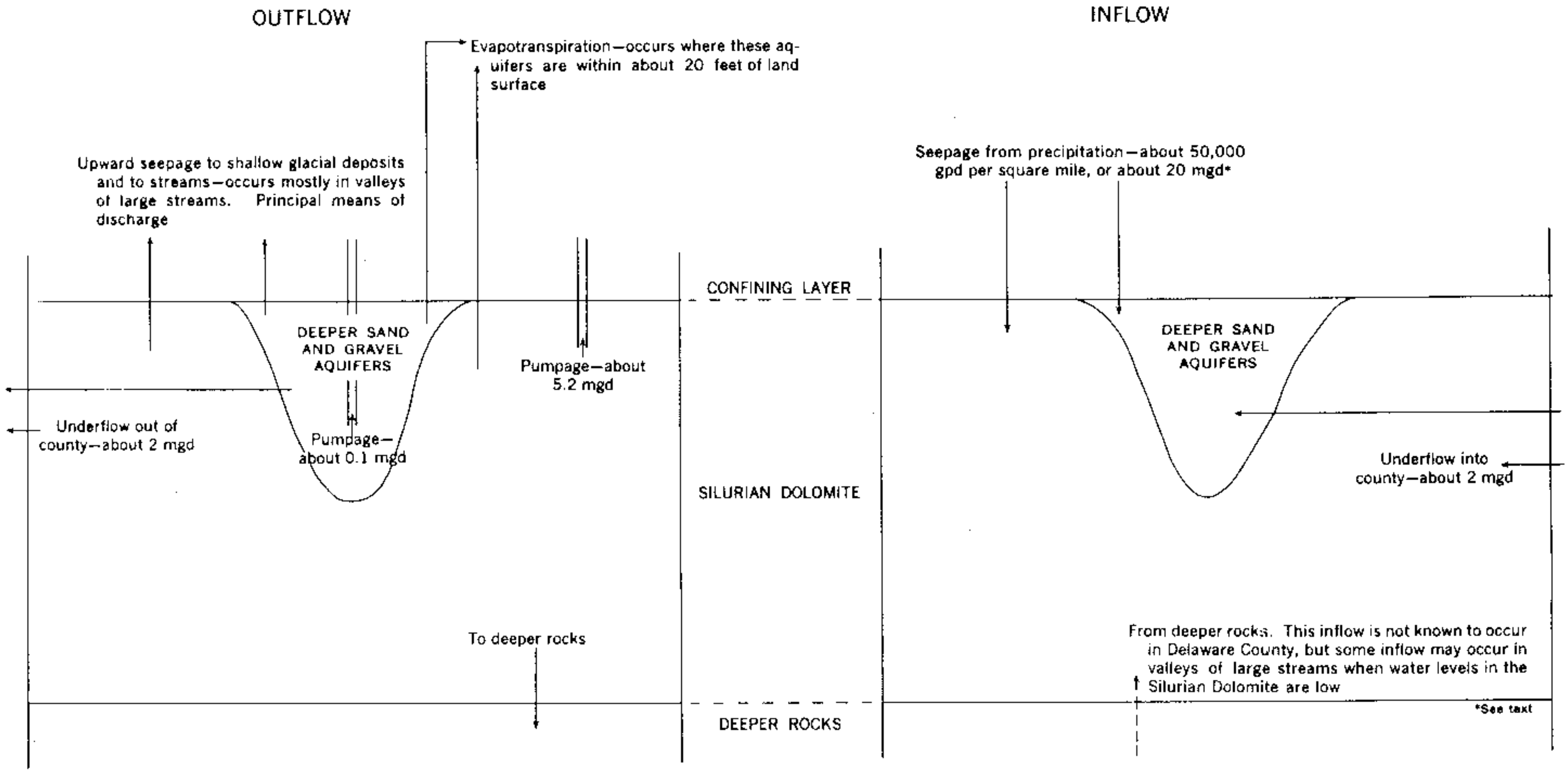


Figure 12.—Average recharge and discharge of the Silurian dolomite and the deeper sand and gravel aquifers.

these wells and field-chemical analyses of the water are shown in the quality of water section (p. 39).

The principal means of discharge from the dolomite and from the deeper sand and gravel aquifers is seepage to the overlying glacial drift in the valleys of the larger streams. Areas where this seepage occurs can be inferred from the piezometric surface of the dolomite (fig. 13). Discharge by evapotranspiration can occur in areas where the dolomite is within about 20 feet of the surface (fig. 14, p. 38).

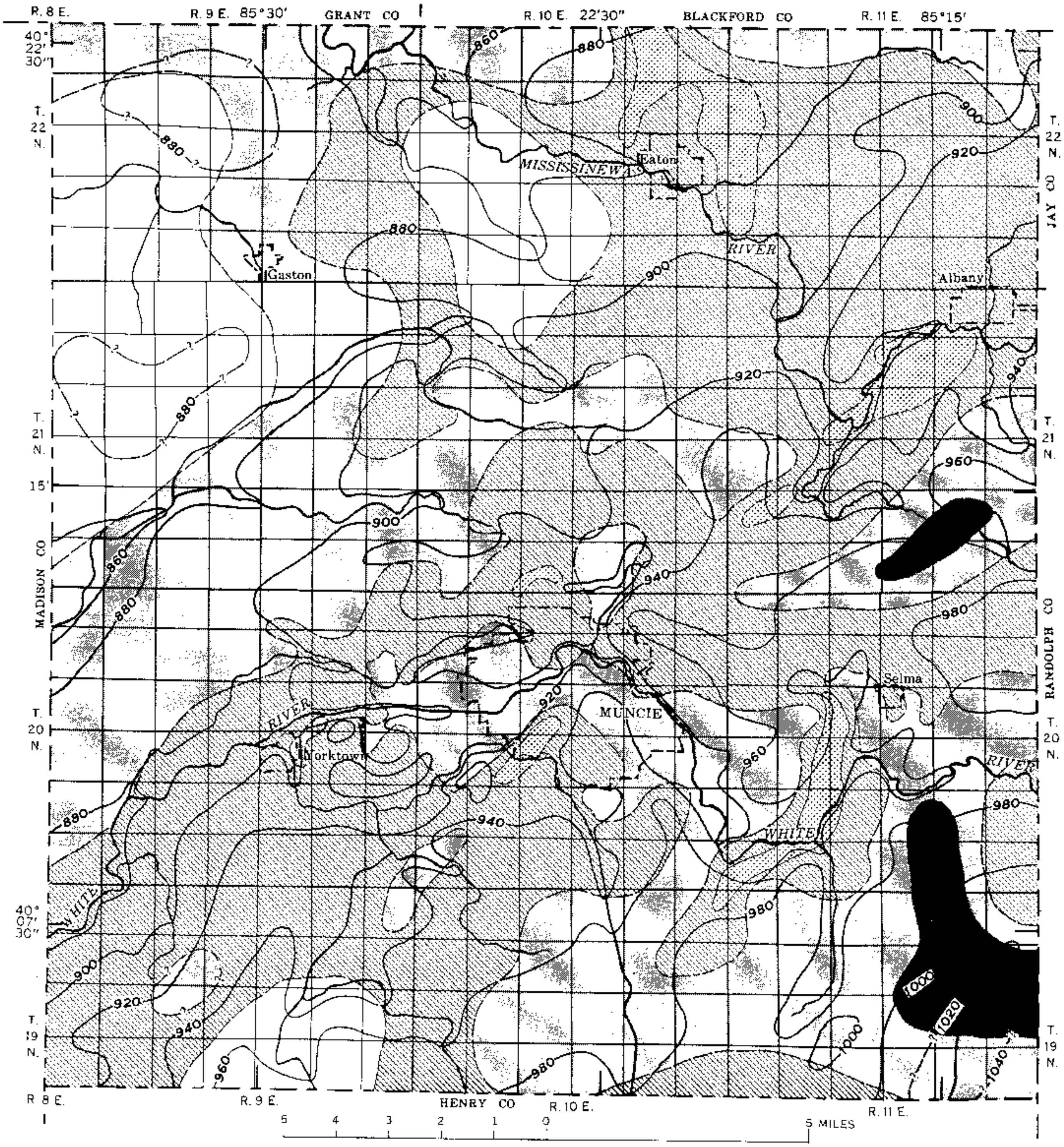
The estimates of recharge from precipitation and underflow in and out of the dolomite were obtained by the same methods used for the principal Pleistocene aquifer, and the same limitations are applicable.

The rate of recharge of the dolomite and of the deeper sand and gravel aquifers determines to a large extent their potential for future development. Recharge to the aquifers will increase as the hydraulic head of the aquifer is lowered by pumping, until the water level reaches the top of the aquifer.

Development and potential. This aquifer is capable of yielding as much as 500 gpm to individual wells in the southeastern part of the county. Figure 13 shows expected one-day specific capacities and possible yields of 12-inch wells that penetrate the upper 100 feet of dolomite. Wells may require surging and chemical treatment to develop their maximum yields.

The pumping level of a well should not be continuously lowered below the top of the aquifer, where the more permeable zones occur. Lowering of the water level below these zones could cause precipitation of dissolved solids in openings in the rock, resulting in decreased well yields. In some areas this condition is unavoidable if the aquifer is to be developed at all. These areas are included within the areas of lowest potential on figure 13. Chemical treatment may improve the performance of wells whose yields have decreased for the above reason. Csallany and Walton (1963, p. 20, 21) report successful results of hydrochloric acid treatment for developing new wells in dolomite and for rehabilitating old wells.

The depth to the top of the aquifer can be estimated from figure 14. This depth, along with figure 13, can be used to estimate the well depth necessary to develop a water supply in the dolomite. The map and the associated data are subject to the same limitations as those applied to the capability map of the principal Pleistocene aquifer.



EXPLANATION

Anticipated range of maximum yields and anticipated one-day specific capacities of 12-inch wells that penetrate the upper 100 feet of dolomite

Maximum yields 300 to 500 gpm (gallons per minute). Specific capacities 4.0 to 10.0 gpm/ft (gallons per minute per foot of drawdown)

Maximum yields 100 to 300 gpm. Specific capacities 2.0 to 4.0 gpm/ft

Maximum yields 15 to 100 gpm. Specific capacities 0.3 to 2.0 gpm/ft

Maximum yields 15 gpm or less. Specific capacities 0.3 gpm/ft or less

Data not sufficient to show capability of aquifer

— — — —?—
Approximate boundary
Queried where less accurate

—980— —?—
Generalized contour
Drawn on the piezometric surface, 1963. Contour interval 20 feet. Datum is mean sea level. Dashed and queried where less accurate

Figure 13.—Dolomite of Silurian age is capable of supplying as much as 500 gpm to individual wells.

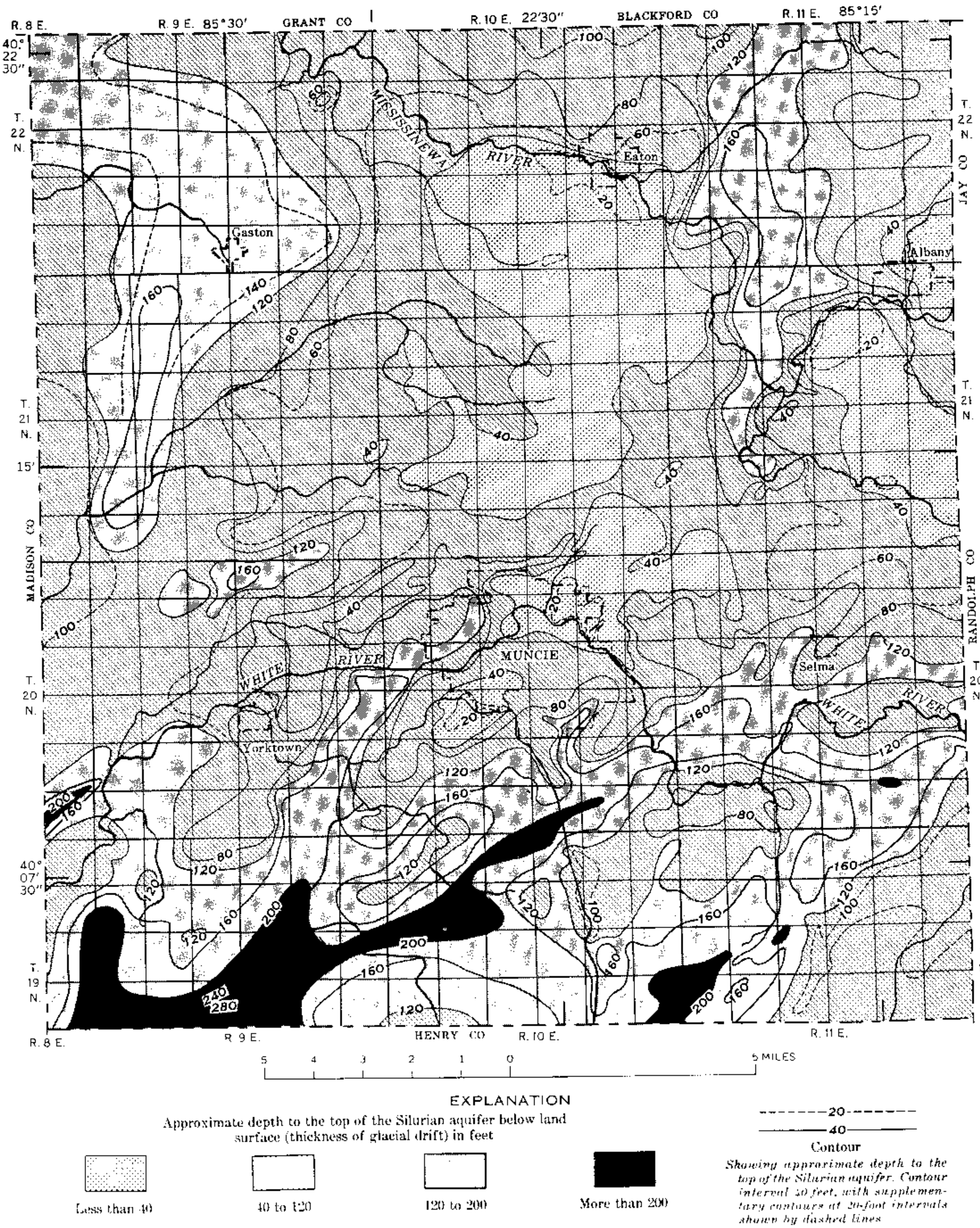


Figure 14.—The Silurian aquifer underlies the entire county at depths of 0 to about 300 feet below land surface. The top of the aquifer is the bedrock surface.

QUALITY OF THE WATER SUPPLY

The quality of the water in the aquifers and in the streams during low flow in Delaware County is generally acceptable for most uses. The concentration of dissolved chemical constituents are generally within the limits recommended by the U. S. Public Health Service (1962, p. 7) for drinking water. Iron content in the ground water, and hardness in both ground and surface water are generally present in undesirable quantities.

The ideal quality of water requirements for industrial use vary widely for the many purposes to which water is put. In fact, within any given industrial plant, water may have several functions for which the quality requirements vary considerably. To illustrate some of the quality standards necessary to meet those generally acceptable for drinking water and for certain industries, bar graphs are shown in figure 15 giving the acceptable, marginal, and undesirable ranges.

Chemical and Physical Quality of the Surface Water

The chemical quality of the surface water in Delaware County at about 90 percent flow duration is generally acceptable for most uses. Most of the water is hard and will require softening.

Water samples were collected for chemical analysis at the 7 stream-gaging stations, 4 partial-record stations and nearly every site where base-flow measurements were made, during the week of November 11, 1963. Generalized maps showing concentration of chloride, sulfate, and total dissolved solids are presented as figures 16, 17, and 18. The figures illustrate the variation of concentrations of these three chemical constituents at about 90 percent flow duration. The abrupt changes in concentration are due to the activities of man, mainly by the introduction of sewage effluents.

The surface waters are generally too hard for most industrial uses and would need to be softened. Hardness concentrations range from 258 ppm to 716 ppm, with most of the analyses ranging between 300 and 400 ppm. Water in Prairie Creek, below the Reservoir, contains less hardness (214 ppm) than other surface waters in the area. This better quality is due principally to the fact that the reservoir is filled during periods of high-water flow when the water has less dissolved solids than the mineralized ground waters that sustain dry-weather streamflows.

The bicarbonate concentration varied from 200 to 435 ppm with most of the waters ranging between 300 and 400 ppm, during the week of November 11, 1963, when the streams were at 90 percent flow duration.

When base-flow conditions end because of precipitation entering the stream by overland runoff, the chemical quality changes. The surface runoff dilutes most chemical constituents, and adds certain dissolved minerals and suspended sediments from the ground surface over which the water flows. The effect of increasing flow from combined underground and

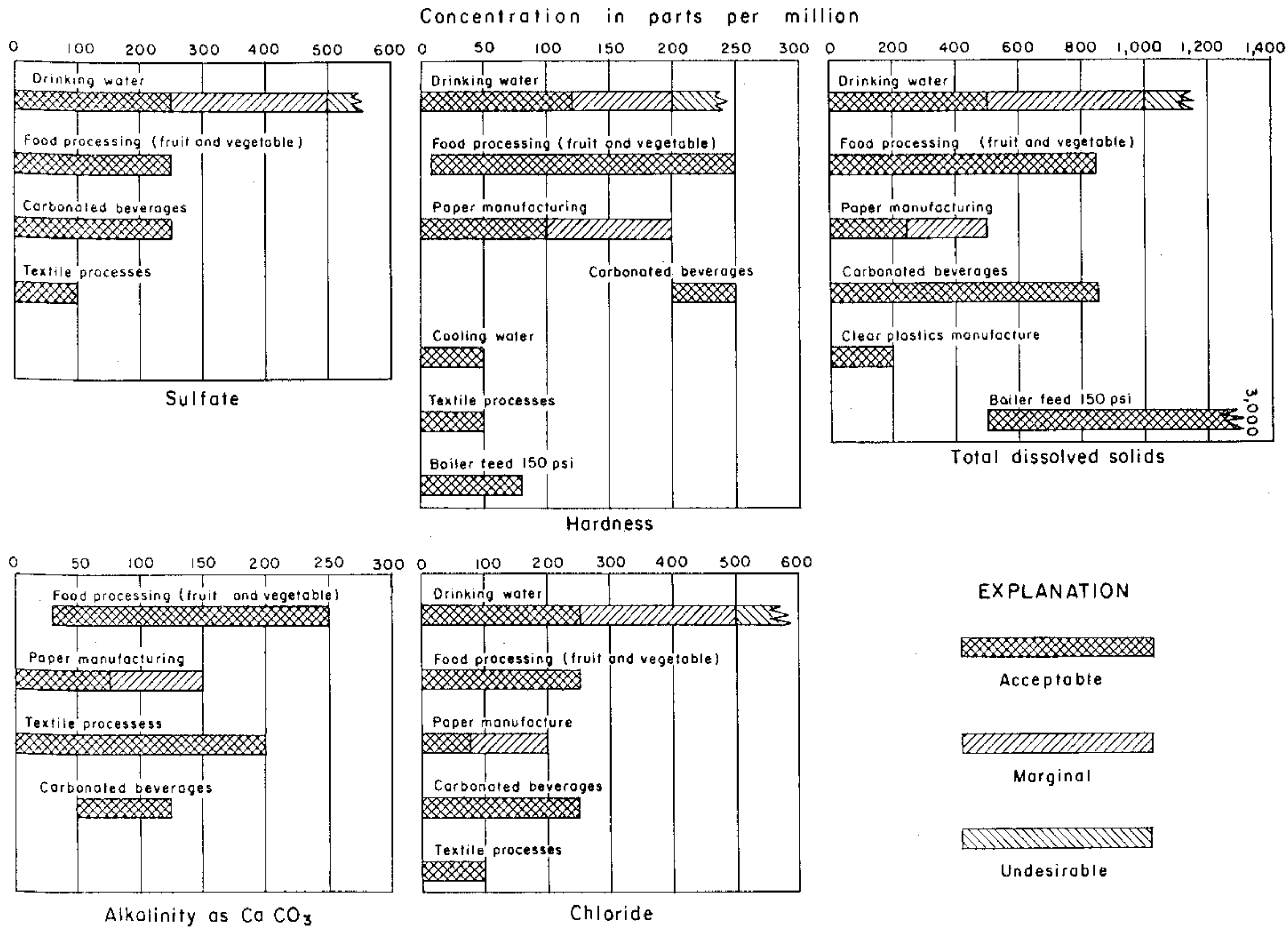


Figure 15. -- General raw water criteria for significant chemical constituents for drinking water and several industrial uses.

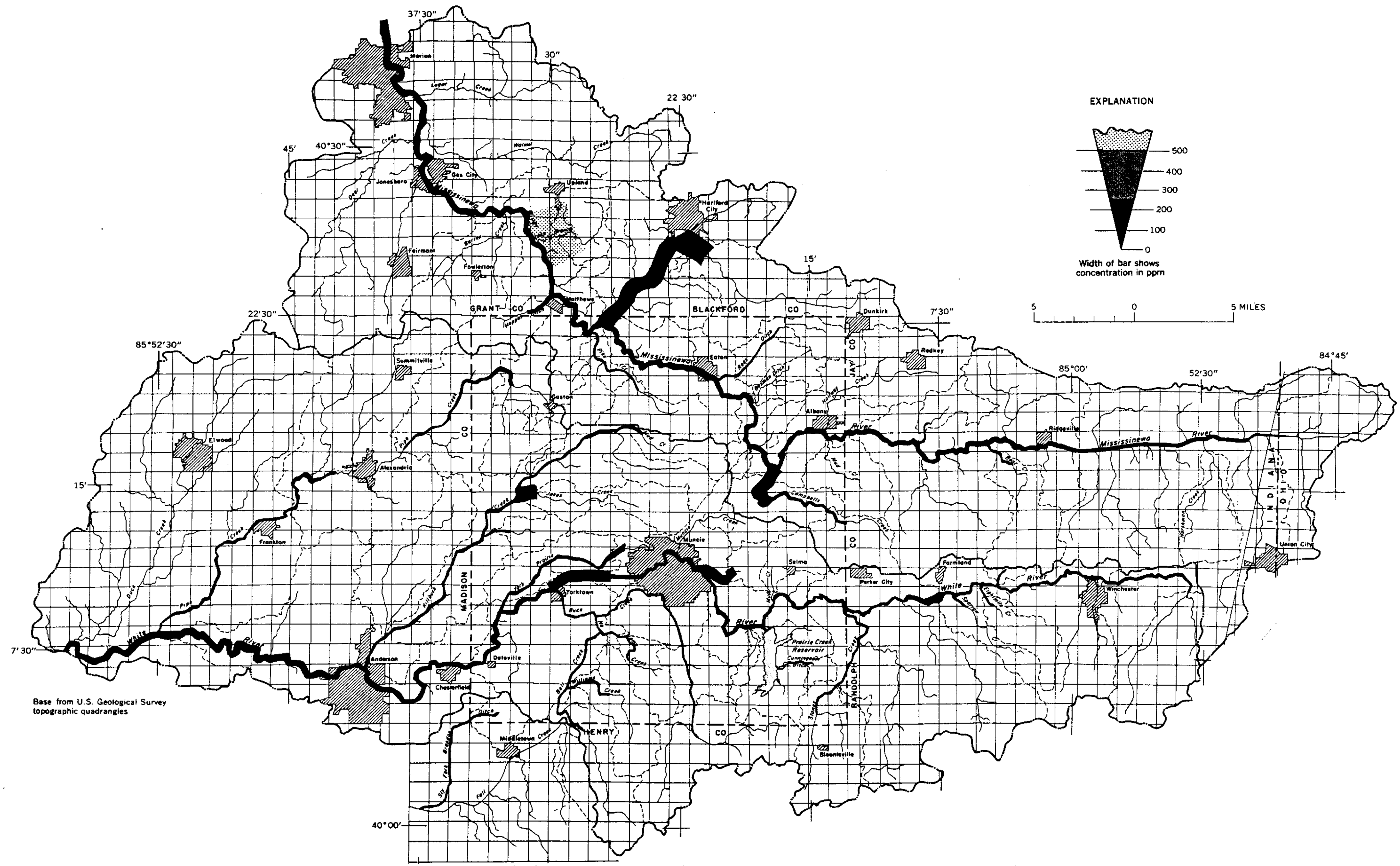


Figure 16.—Concentration of chloride in the streams of Delaware County at about 90 percent flow duration (week of Nov. 11, 1963) was generally less than 10 ppm excepting downstream from points of man-made effects.

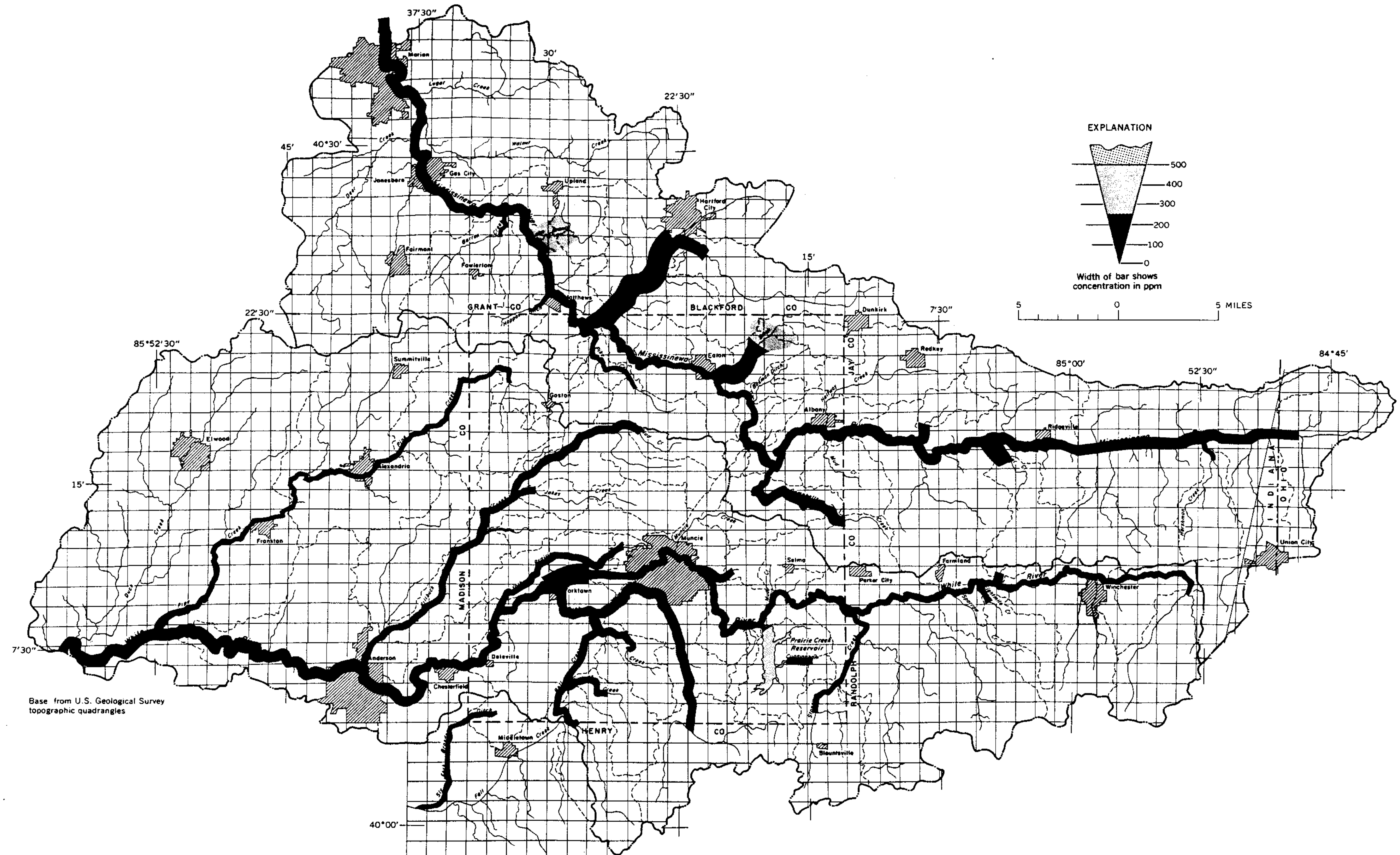


Figure 17.—Concentration of sulfates in the streams of Delaware County at about 90 percent flow duration (week of Nov. 11, 1963) was generally less than 100 ppm excepting downstream from points of man-made effects.

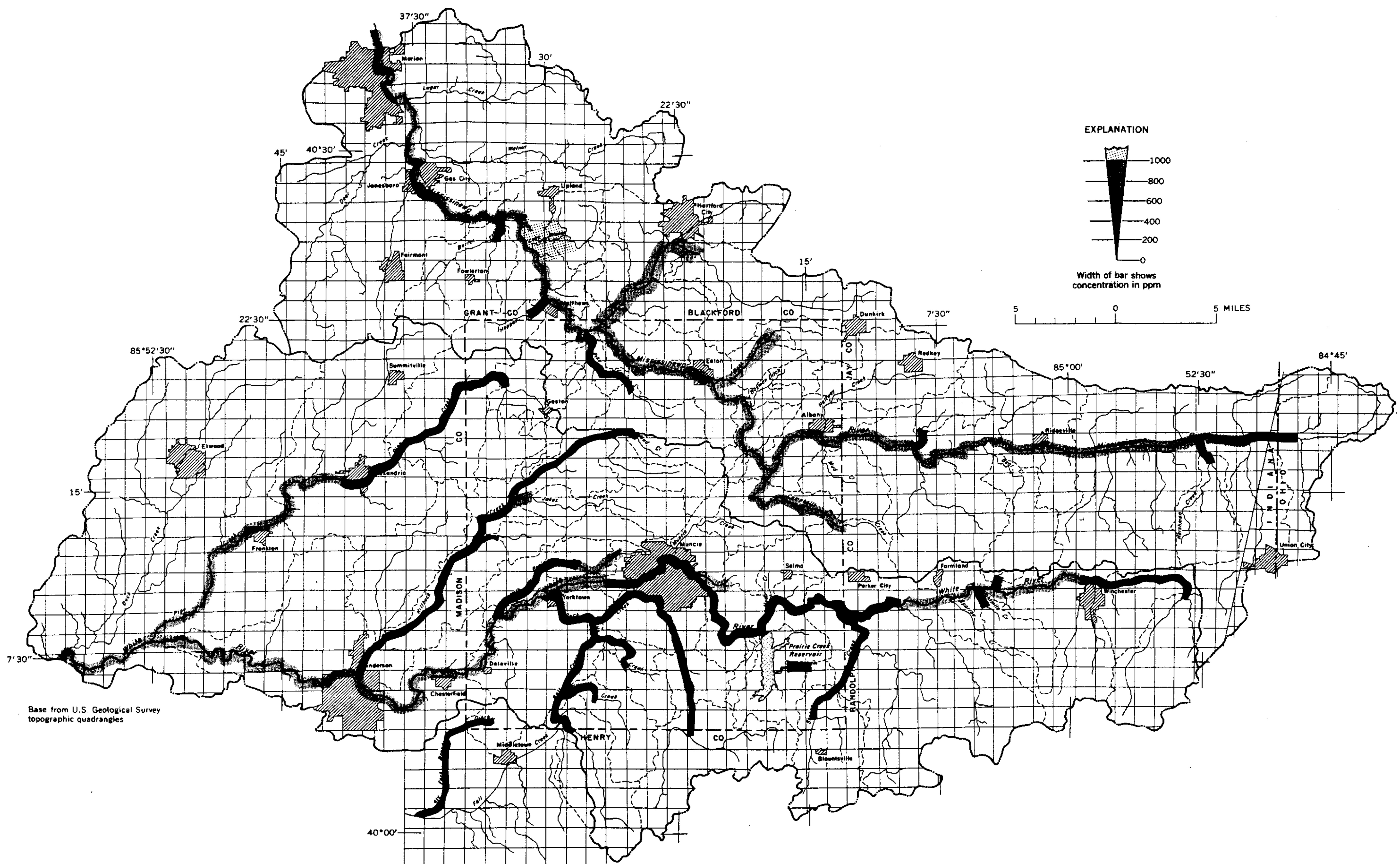


Figure 18.—Concentration of total dissolved solids in the streams of Delaware County at about 90 percent flow duration (week of Nov. 11, 1963) was generally less than 500 ppm excepting downstream from points of man-made effects.

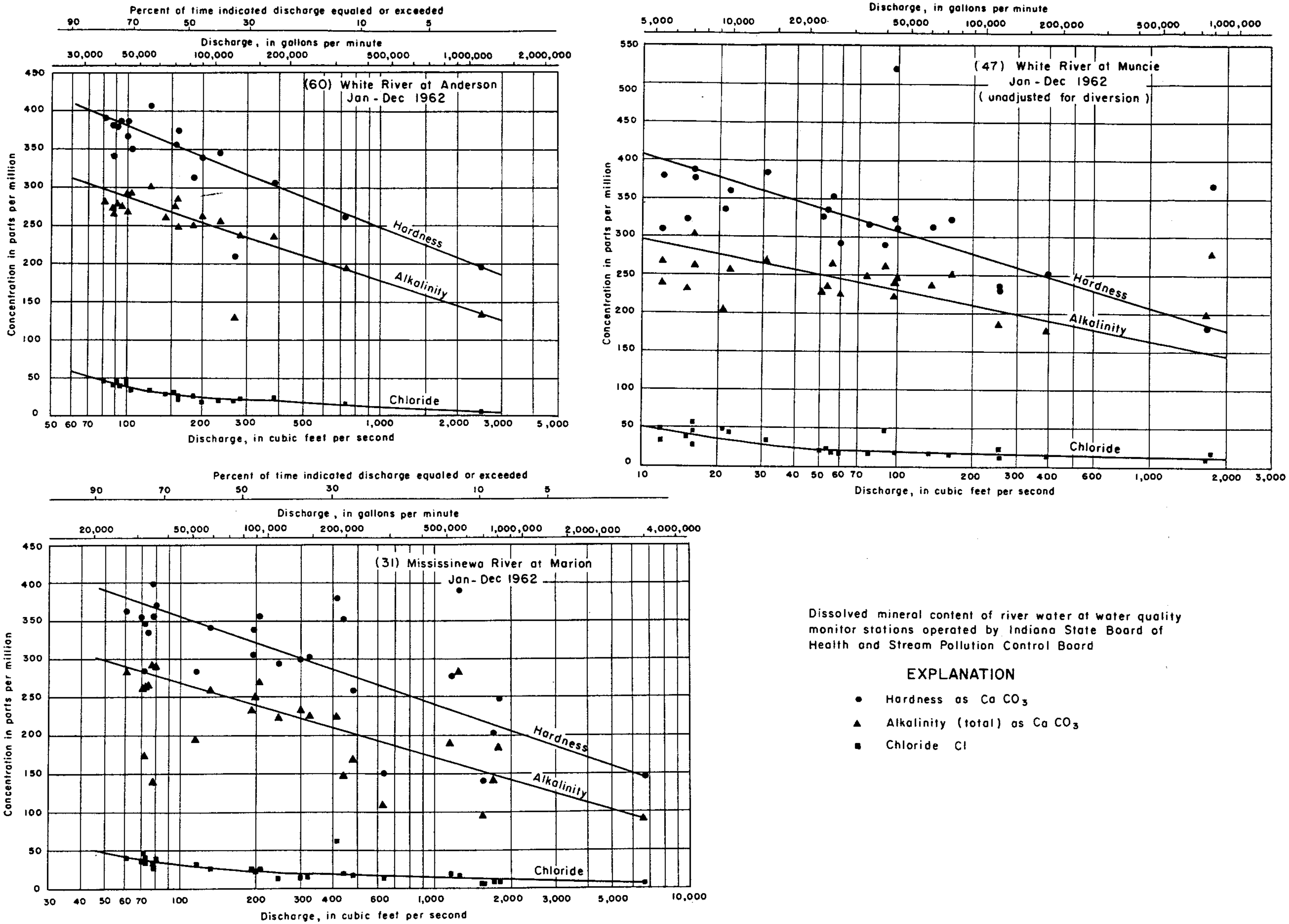


Figure 19 . -- Relation of mineral concentration to river discharge showing how quality of water varies with changing discharge.

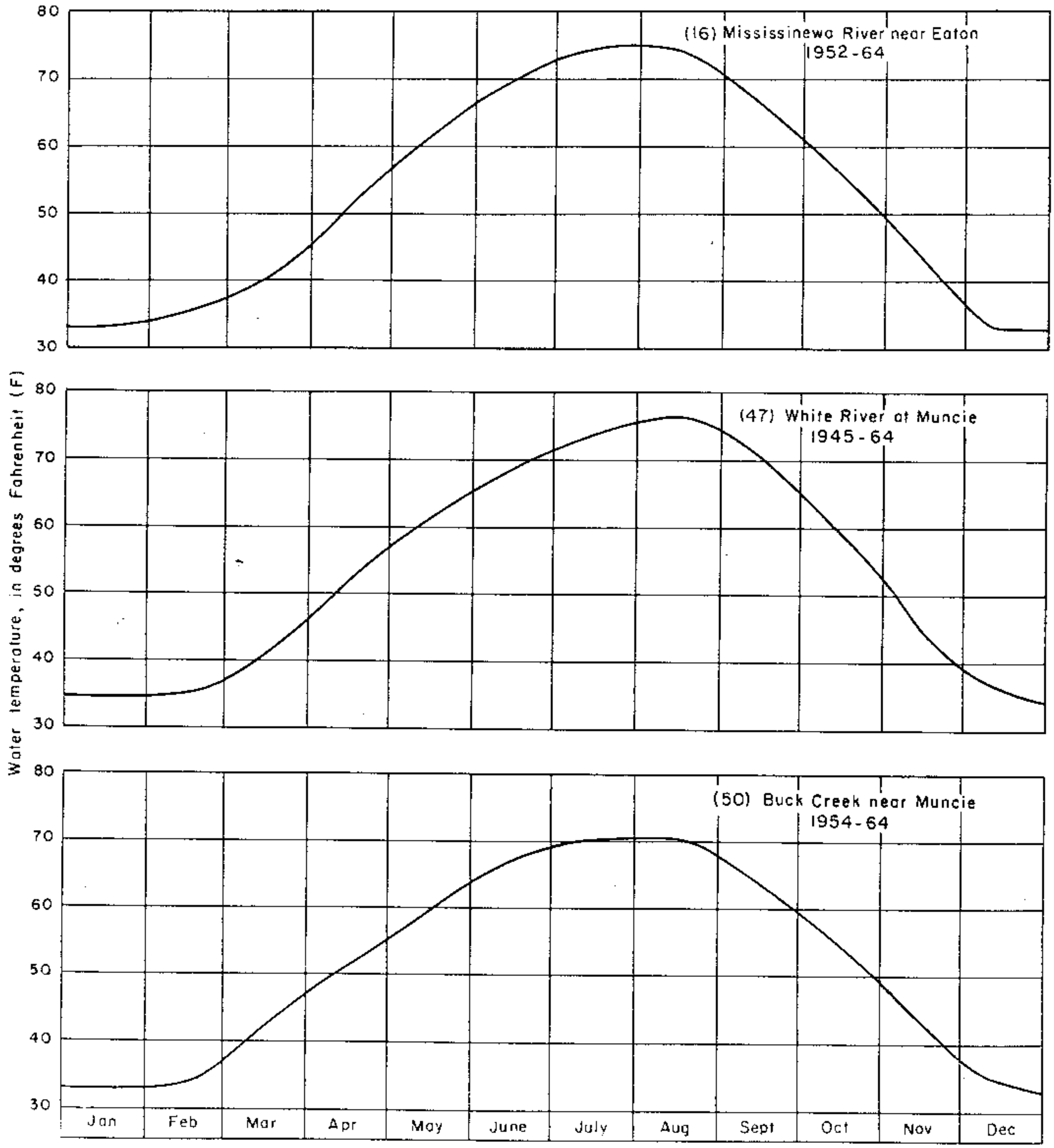


Figure 20.--Variation in approximate average water temperature during year for the Mississinewa River near Eaton, White River at Muncie, and Buck Creek near Muncie.

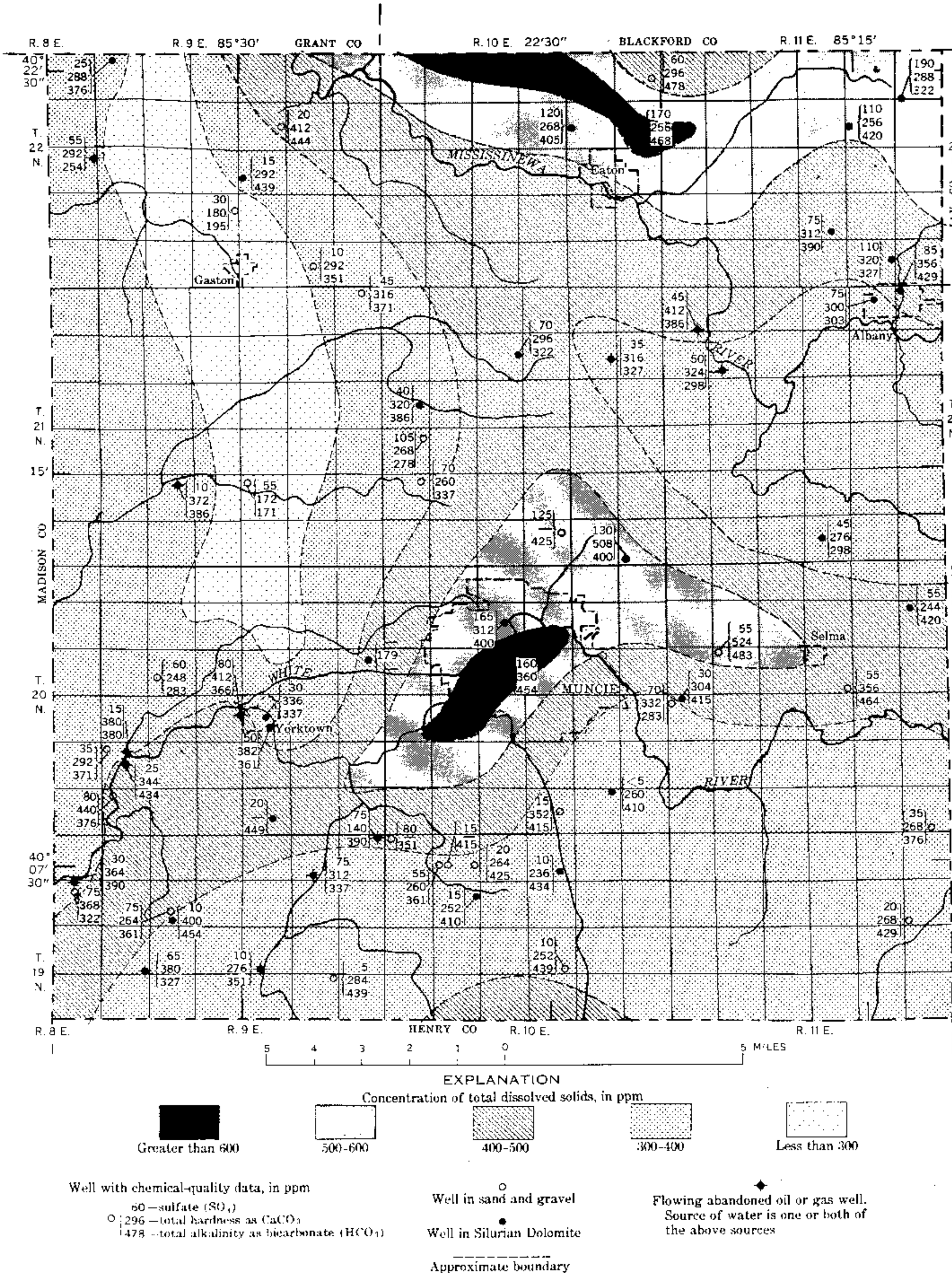


Figure 21.—Quality of ground water in Delaware County is similar in all important aquifers.

Table 8. Summary of water quality in Delaware County. Concentrations in ppm.

	Number of samples		Iron (Fe)	Total Alkalinity As Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Total Dissolved Solids [b]	Hardness As $CaCO_3$
Streams [a]	29	range	---	200-435	22-455	5-162	298-922	258-716
		mode	---	367	74	9	386	362
Principal Pleistocene Aquifer	27	range	0.1-5.0	171-483	5-195	<4-48	205-724	172-524
		mode	0.9	388	66	4	379	288
Silurian Dolomite	28	range	0.1-7.5	303-468	<5-190	<4-32	302-653	179-508
		mode	1.6	425	17	3	407	288
Flowing Wells	14	range	0.8-2.5	254-434	5-80	4-28	302-449	276-440
		mode	2.1	370	30	9	350	333

[a] Sampled at approximately 90 percent flow duration (Week of Nov. 11, 1963).

[b] Total dissolved solids for ground-water samples estimated (Collins, 1927).

surface sources on hardness and alkalinity of the water and its chloride content is shown on figure 19. This figure is based on data collected by the State of Indiana at 3 gaging stations in the area.

As an example of the use of figure 19, let as assume that the industry investigating a location at Eaton in the hypothetical case desires water for a manufacturing process that will not exceed a hardness concentration of 250 ppm. From the curve for the Mississinewa River at Marion it is estimated that the hardness may be less than 250 ppm about 15 percent of the time, or 85 percent of the time the water would not meet the standards of the industry unless softened. Therefore, during the periods of objectionable quality, it would be necessary to set up a treatment process, or seek out a ground-water supply that would meet the criteria in quality. If a ground-water supply is considered there is a good possibility that the hardness of the water will be greater than 250 ppm (fig. 21, p.47), and treatment will be necessary.

An important physical characteristic of any surface water is its temperature. The use to which a water of sufficient quantity and acceptable quality may be put can be limited by too high a temperature. Figure 20 illustrates the approximate average variation of water temperature at the 3 stream-gaging stations in Delaware County. These curves are based on determinations of the temperature, usually once a month, for the period of record shown on the graphs. The variation at these 3 stations is similar. The White River at Muncie reached a high of approximately 77° F. during August whereas the Mississinewa River near Eaton and Buck Creek near Muncie reached a high of approximately 75° and 70° F., respectively. The lower average temperature on Buck Creek is due to the larger yield from ground water. None of the curves indicate heavy thermal loading by man immediately above the stream-gaging stations.

If a more even temperature is needed throughout the year (e. g. cooling, etc.), a prospective user should consider a ground-water source.

Chemical Quality of the Ground Water

The principal dissolved constituents are bicarbonate, calcium, and magnesium. In some areas, sulfate is a major constituent. Areal distribution of total dissolved solids, and sulfate, hardness, and alkalinity at selected wells is shown on figure 21. The range of concentration and mode (most common value) is shown on table 8.

Concentration of the chemical constituents are similar in range and distribution in all important aquifers. This similarity is a result of the recharge characteristics of the area. Most of the recharge to all aquifers must percolate through the surface till (fig. 6). Only a minor amount of water enters the county by underground flow. After percolating through the surface till, the water has dissolved soluble minerals and consequently has lost much of its ability to dissolve additional minerals. The water-soluble minerals in the till are principally dolomite and limestone.

Although the water in the dolomite is similar in quality to the water in the principal Pleistocene aquifer, the range in concentration of each constituent except iron is slightly smaller in the dolomite. This apparently greater uniformity of chemical character of the water in the dolomite indicates that some mixing of recharge water of differing chemical composition has taken place.

The chemical quality of the water in the streams, during the week of November 11, 1963, in a period of approximately 90% flow duration is similar to the quality of water shown on table 8 for ground-water aquifers. This is to be expected as much of the runoff during periods of low flow is derived from ground-water discharge. The extremes found in the dissolved chemical constituents at both high and low flows are not natural and may be attributed to the works of man.

Effects of Man's Activities on Water Quality

The effect of man's activity on water quality in Delaware County is generally not so adverse as to render the chemical quality of surface and ground waters undesirable.

His effect on surface water quality with respect to chloride, sulfate, and total dissolved solids may partially be seen in figures 16, 17, and 18. The larger concentrations and abrupt changes in concentration may be attributed to the works of man. These figures represent perhaps the worst conditions because of the low flow in the streams during the sampling period.

A further look at the surface water quality is shown by figures 22 and 23 in which concentrations of alkyl benzene sulfonate (ABS) and dissolved oxygen are shown by color lines along the sampled streams at 90 percent flow duration. The largest amounts of the synthetic detergents and the smallest amounts of dissolved oxygen were downstream from the larger towns. The White River below Muncie is the most adversely affected; however, the quality improves considerably before leaving the county, owing to the dilution effect of the waters from Buck and York Prairie Creeks.

The temperature of the water in White River downstream from Muncie is increased for a few river miles by the addition of sewage effluent. During the week of November 11, 1963, heat loss had taken place over the distance between Muncie and the county line and the water temperature was nearly the same at the county line as in other streams in the area. This cooling was due not only to the distance traveled but also to the addition of discharge from Buck and York Prairie Creeks.

Contamination of the surface waters by waste from oil wells has happened in the past. This is not a major problem at the present owing to the small activity in this field.

Man's effects on the surface water are not always adverse. The quality may be improved by impounding during high runoff periods and releasing during low runoff or base-flow periods. This is evidenced in Prairie Creek where hardness has been decreased by the release of impounded reservoir water.

The chemical quality of ground water has not been measurably affected by man. The relatively impermeable surficial confining layer prevents direct contamination of aquifers throughout most of the county. Contamination of fresh-water aquifers by upward movement of saline water from deep aquifers is a remote possibility if the hydraulic head in the Silurian dolomite is drastically lowered for a long period of time.

PLANNING WATER DEVELOPMENT

The planning of a water development entails a large amount of engineering and management know-how. Before the first shovel of dirt is moved for a new reservoir or a driller sets up his rig to drill a well for a large water supply, someone has had to make decisions as to the quantity and quality of the water needed and possibilities of getting this water through the new development.

Problems to Consider

Many problems must be considered by those concerned with the development and use of water when seeking a new supply. The first problem is that of deciding between a surface-water or ground-water supply.

If a surface-water supply is being considered some of the problems are: (1) Is there a dependable flow in the stream sufficient to meet future demands without reservoir construction? (2) If not, is there enough natural flow available in the stream to make the construction of a reservoir feasible? (3) Does the topography lend itself to a reservoir site? (4) What will be the losses in the reservoir, if constructed, owing to leakage and evaporation? (5) Will the losses be of sufficient magnitude to nullify the advantage of storage? (6) What is the quality of the water and treatment necessary? (7) If municipal and industrial wastes are emptied into the stream, will streamflow be adequate to dilute present and future volumes of waste effluent?

If a ground-water supply is being considered some of the problems are: (1) Can enough water be obtained to supply anticipated needs? (2) If so, will treatment be necessary to overcome water quality problems? (3) What will heavy pumping in the new area do to existing water levels?

Interrelated and similar problems will occur when either of the above sources are considered. The most significant of these problems are: (1) How will the proposed reservoir or pumped well affect downstream or nearby users of water? (2) Which source of supply of possibly several alternates will produce the desired quantity and quality for the least expenditure of funds? (3) Will well supplies located near stream courses be affected by

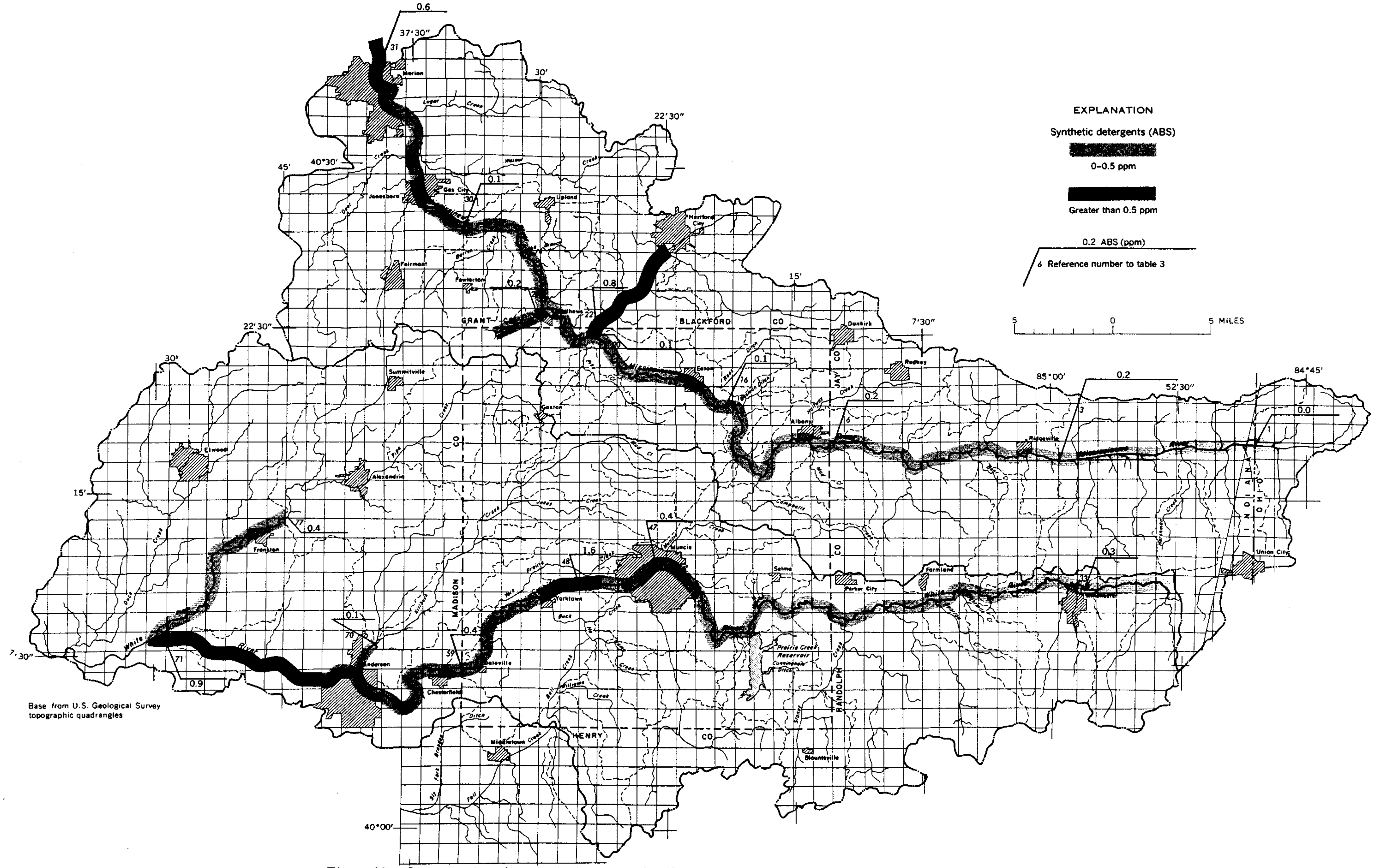


Figure 22.—Concentration of synthetic detergents (ABS) in the Mississinewa and White Rivers in Delaware County at about 90 percent flow duration (week of Nov. 11, 1963) was less than about 0.1 ppm for the Mississinewa River and 0.4 ppm for the White River excepting on the White River below Muncie.

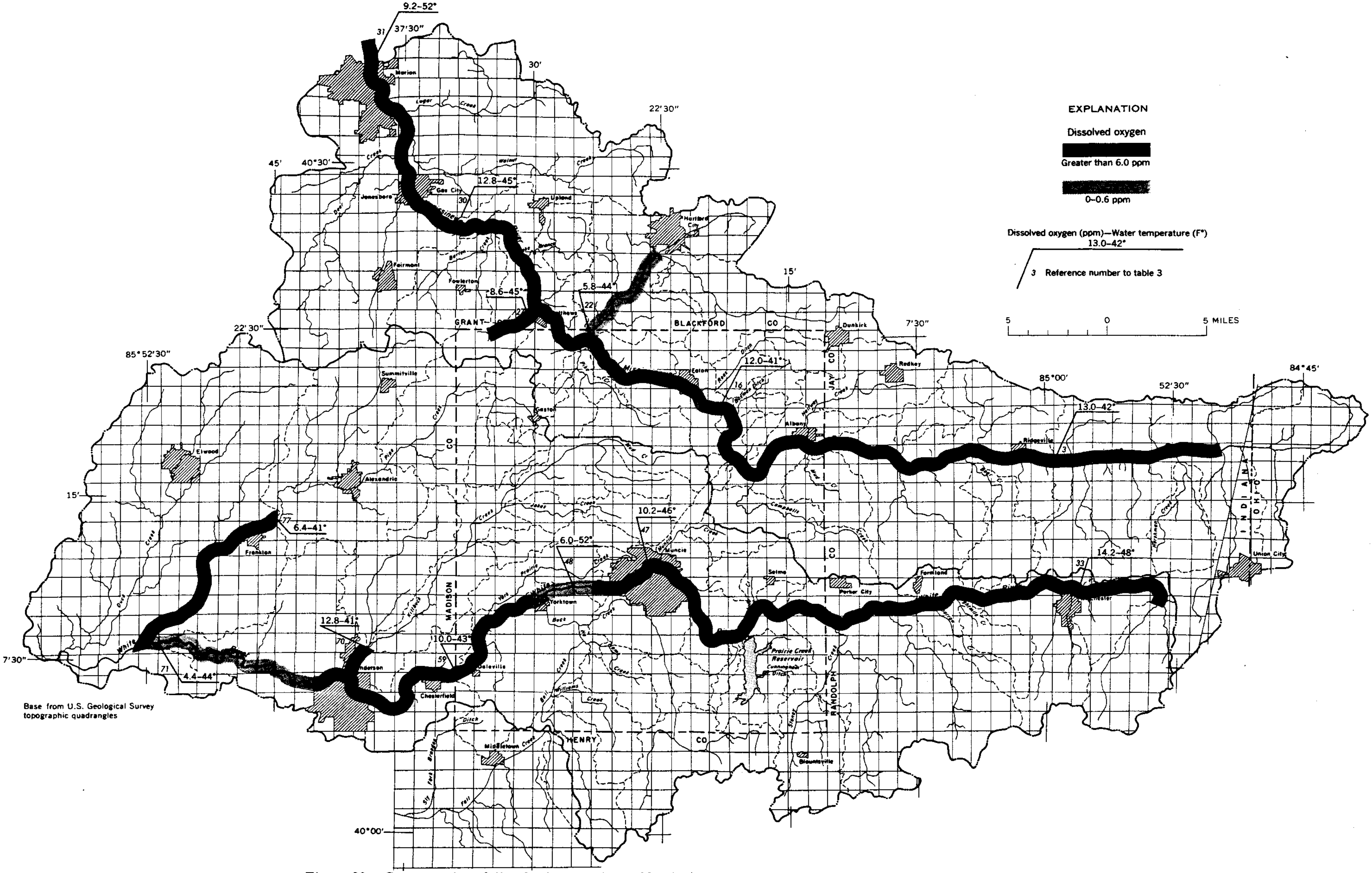


Figure 23.—Concentration of dissolved oxygen in the Mississinewa and White Rivers in Delaware County at about 90 percent flow duration (week of Nov. 11, 1963) was generally greater than 10 ppm excepting in the White River below Muncie.

chemical or bacterial pollutants from surface sources? (4) Will heavy pumping of wells in the vicinities of streams during low flows affect the ground-water discharge sifnificantly, thus decreasing the amount of base flow available to streams to dilute waste effluents?

A problem is presented in Delaware County by gas wells which were drilled during the period of the old "Trenton Field Boom". These wells, many of which are improperly plugged or abandoned, constitute a potential problem to water supplies. They serve as points of weakness for conveying water to or from deeper horizons where mineralized water exists.

There is no end to the problems that the decision makers must confront, and their decisions will affect the economy, the environment, and thus the lives of future generations.

CONCLUSIONS

The availability of water in the streams, glacial deposits, and upper bedrock formations in Delaware County is generally adequate for most foreseeable development and use. The chemical and physical quality of water in the streams and in the aquifers is acceptable for most uses.

Conclusions reached by this study are:

1. Most streams in the northern half of the county having less than 10 square miles of drainage area, including the headwaters of larger streams, go dry frequently.

2. Most streams in the southern half of the county, regardless of size, yield more than 9 gpm (0.013 mgd) per square mile 90 percent of the time.

3. A large user of water in the county requiring 25 mgd or more, more than 90 percent of the time, will have to depend on surface-water impoundment.

4. The limit of surface-water potential in cfs on any streams in the county is approximately the product of the drainage area, in square miles, times 1 cfsm. This would necessitate an impoundment and the ability to release at a uniform rate the total water that flows from the area above the reservoir.

5. The principal sources of ground water occur within 400 feet of the surface. The rocks below this depth are potential sources of uncertain but probably small quantities of saline water.

6. The ground-water reservoir has a recharge rate of about 80 mgd, of which 6.8 mgd is currently being pumped.

7. The best sources of ground and surface water are located in the southern and southeastern parts of the county. Wells in this area could yield as much as 1,000 gpm by using all of the aquifers. The upper part of Buck Creek yields as much as 120 gpm per square mile 90 percent of the time.

8. There is adequate ground water available throughout the county for rural domestic and livestock use.

9. Occasionally the hardness may be more than 500 ppm in the ground water and 700 ppm in the surface water. The total dissolved solids may be more than 700 ppm in the ground water and 900 ppm in the surface water.

10. Iron content in the ground is generally greater than 1.0 ppm.

11. The available surface and ground water sources with proper development should be adequate to supply the needs of the county in the foreseeable future.

DEFINITIONS

Base flow (ground-water runoff). That part of runoff which has passed into the ground, has become ground water, and has been discharged into a stream channel as spring or seepage water.

cfs. Abbreviation of cubic feet per second. One cfs equals 448.83 gpm or 0.646317 mgd.

Coefficient of 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 hydraulic gradient of 1 foot per foot at prevailing temperature. (After Ferris and others, 1962).

Flow-duration curve. A cumulative frequency curve that shows the percentage of time that specified discharges are equaled or exceeded.

gpm. Abbreviation of gallons per minute. One hundred gpm equals 0.22280 cfs or 0.144 mgd.

Low-flow frequency curve. A graph showing the magnitude and frequency of minimum flows for a period of a given length. Frequency is usually expressed as the average interval, in years, between recurrences of an annual minimum flow equal to or less than that shown by the magnitude scale.

mgd. Abbreviation of million gallons per day. One mgd equals 1.5472 cfs or 694.44 gpm.

Mode. The value which occurs most frequently.

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

Recurrence interval. The average interval of time within which the given low flow will be less than or equaled once. A recurrence interval of two years is equivalent to a 50 percent chance of the event occurring in any one year and a recurrence interval of 20 years is equivalent to a 5 percent chance of the event occurring in any one year.

Specific capacity. Yield of well in gallons per minute per foot of drawdown. Usually stated for a definite period of pumping.

Storage-required frequency curve. A graph showing the frequency with which storage equal to or greater than selected amounts will be required to maintain selected rates of regulated flow.

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Plate 1.—Map of upper Mississinewa and White River basins embracing Delaware County showing stream runoff for the week of November 11, 1963, at about 90 percent flow duration.