QUALITY OF GROUND WATER IN MONITOR AND WILLIAMS TOWNSHIPS, BAY COUNTY, MICHIGAN

By F. R. Twenter and T. R. Cummings

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WILLIAMS TOWNSHIP, BAY COUNTY

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CONVERSION FACTORS AND ABBREVIATIONS

For the convenience of readers who may prefer to use metric (International System) units rather than the inch-pound units used in this report, values may be converted by using the following factors:

Multiply inch-pound unit	By	To obtain metric unit
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	259.0	hectare (ha)
	Volume	
gallon (gal)	3.785	liter (L)
	Flow	
gallon per minute (gal/min)	0.06308	liter per second (L/s)
	Mass	
pound, avoirdupois (lb)	453.6	gram (g)
	Temperature	
degree Fahrenheit (°F)	°C = 5/9 (°F -32)	degree Celsius (°C)

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ABSTRACT

Migration of mineralized water from abandoned subsurface coal mines in Monitor and Williams Townships was thought by many residents to have affected the quality of domestic ground-water supplies in the area. To investigate the possibility, wells were installed to obtain geologic data and water samples for chemical analysis; analysis also was made of concurrent related data collected by other agencies.

The principal rock units are glacial deposits and the Saginaw Formation. Glacial deposits, 75 to 175 feet thick, are primarily clay underlain in places by sand and gravel. This sand and gravel is the primary source of ground water. Underlying the glacial deposits is the Saginaw Formation--a unit that is mostly shale and silty shale containing beds of siltstone, sandstone, and coal.

Specific conductance of water from wells indicate that dissolved-solids concentration increases with depth. About 50 percent of specific conductance values of water from wells more than 100 feet deep were equal to or greater than 5,000 microsiemens, whereas only 13 percent of the values of water from wells less than 100 feet deep were equal to or greater than 5,000 microsiemens.

Results of chemical analyses indicate no apparent correlation between concentration and source for most constituents. Plots of chloride/sulfate ratios versus specific conductances indicate that water from the Saginaw Formation is as likely to influence the quality of water in glacial deposits as is water from abandoned mines.

INTRODUCTION

Availability of ground water in Bay County, Michigan, has been of concern for many years. At some locations well yield has been barely adequate to meet the need; at other locations the high mineralization of the water has made it unsuitable for domestic use. Alternative supplies are not readily available. Past coal-mining activity has been thought by many residents to be responsible for the poor quality of water in the glacial deposits which are the source of many domestic supplies. However, abandoned coal mines and bedrock contain highly mineralized water; movement of this water during the past 100 years because of pumping from water-supply wells and mines could have increased mineralization of water in glacial deposits. Other potential pathways for migration of highly mineralized water are the numerous exploratory holes drilled for brine, oil, and coal. The affect of these holes on the movement of mineralized water into glacial deposits is not known and probably cannot be easily determined. Because numerous flowing wells are present throughout the area, potential for upward movement of salty water is great.

Purpose and Scope of Study

This report describes the results of a study to (1) determine the chemical and physical characteristics of ground water in Monitor and Williams Townships, (2) relate these characteristics to the source of water, and (3) evaluate the effect, if any, of water from abandoned coal mines on chemical characteristics of domestic ground-water supplies.

Methods of Investigation

In the initial stages of the investigation, geologic and hydrologic data in the files of the Geological Survey Division of the Department of Natural Resources and the U.S. Geological Survey were compiled and analyzed. Previous reports, including those describing past coal-mining activity, were reviewed and pertinent information extracted. Four-inch diameter observation wells were installed at 20 sites to measure the chemical and physical characteristics of water in glacial deposits, abandoned coal mines, coal deposits, and Saginaw Formation. Once the wells were installed, water samples were collected and analyzed for a wide range of constituents, including common dissolved substances, trace metals, and gases. The Geological Survey Division made field measurements of specific conductance, pH, and temperature of water from 116 wells. They also studied records of coal-mining activity, and provided geologic sections based on an analysis of bore-hole data. In addition, the State of Michigan's water-quality laboratory analyzed 69 water samples for calcium, magnesium, sodium, potassium, chloride, sulfate, bicarbonate, and carbonate, and measured pH.

Description of Study Area

The study area, about 60 mi^2, is in Bay County in the east-central part of Michigan's Lower Peninsula (fig. 1). The principal areas of investigation were in Monitor and Williams Townships; supporting data were obtained in the townships of Beaver, Bangor, Frankenlust, Kawkawlin, and Merritt. Altitude of land surface ranges from 585 ft along the east part of Frankenlust Township

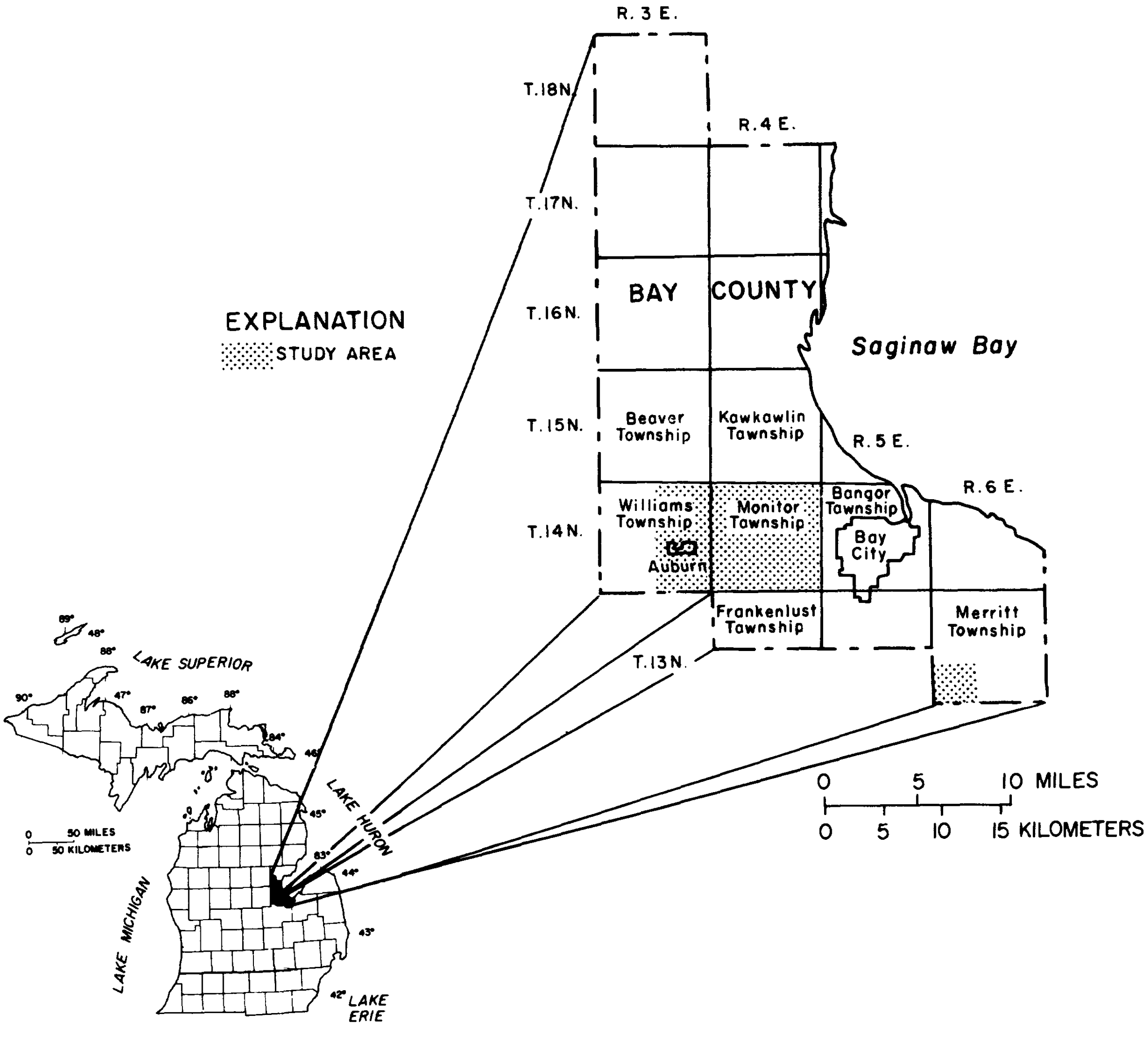

Figure 1.--Location of Bay County and study area.

and the southwest part of Merritt Township to 640 ft southwest of Auburn; in most of the area, however, the altitude is between 595 and 610 ft. Monitor and Williams Townships are drained by the Kawkawlin River; southwest Merritt Township is drained by Cheboyganing Creek (a north-flowing stream about 2 mi west of the township). The Kawkawlin River flows to Lake Huron about 3 mi east of Monitor Township. Auburn, the only community within the study area, has a population of 1,921 (U.S. Department of Commerce, 1982).

The study area is in the northeastern part of the Michigan coal basin, an area of 12,000 mi^2 (fig. 2). Known coal reserves underlie Monitor and Williams Townships. Coal was discovered in Monitor Township in 1893 and mining of coal began in 1895 (Cooper, 1906). Coal beds generally range in thickness from 2 in. to 4 ft and are lenticular. At some places, two to four beds occur in the vertical sequence. Table 1 shows that coal beds in the vicinity of abandoned mines (fig. 3) generally lie at depths ranging from 100 to 160 ft. Abandoned mines underlie about 5 mi^2 in the study area. The water table throughout much of the area is 5 to 25 ft below land surface. Most domestic wells are 50 to 150 ft deep and are completed in the glacial deposits and Saginaw Formation.

Table 1.--Depths to coal beds at and near mines

Mine	Depth to coal beds (ft)
Bay City Nos. 1 and 2	130-160
Beaver	100-190
Monitor and New Monitor	100-160
Pittsburg	190-210
Robert Gage Nos. 5, 6, and 7	100-160
What Cheer	160-170
Wolverine Nos. 2 and 3	120-160
Zagelmeyer	115-125

Description of Observation Wells

Pertinent data for the 20 observation wells installed by the U.S. Geological Survey to sample water from the glacial deposits, abandoned coal mines, coal deposits, and Saginaw Formation are summarized in table 2.

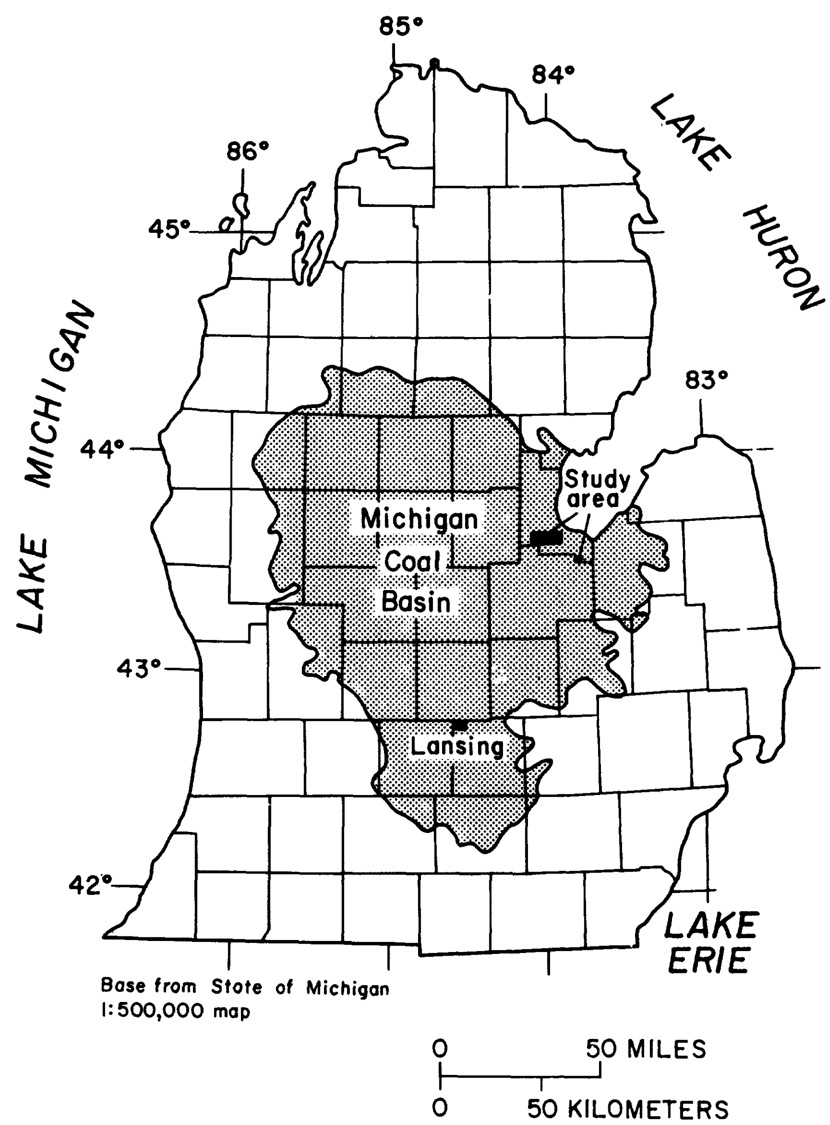

Figure 2.--Location of study area in Michigan coal basin.

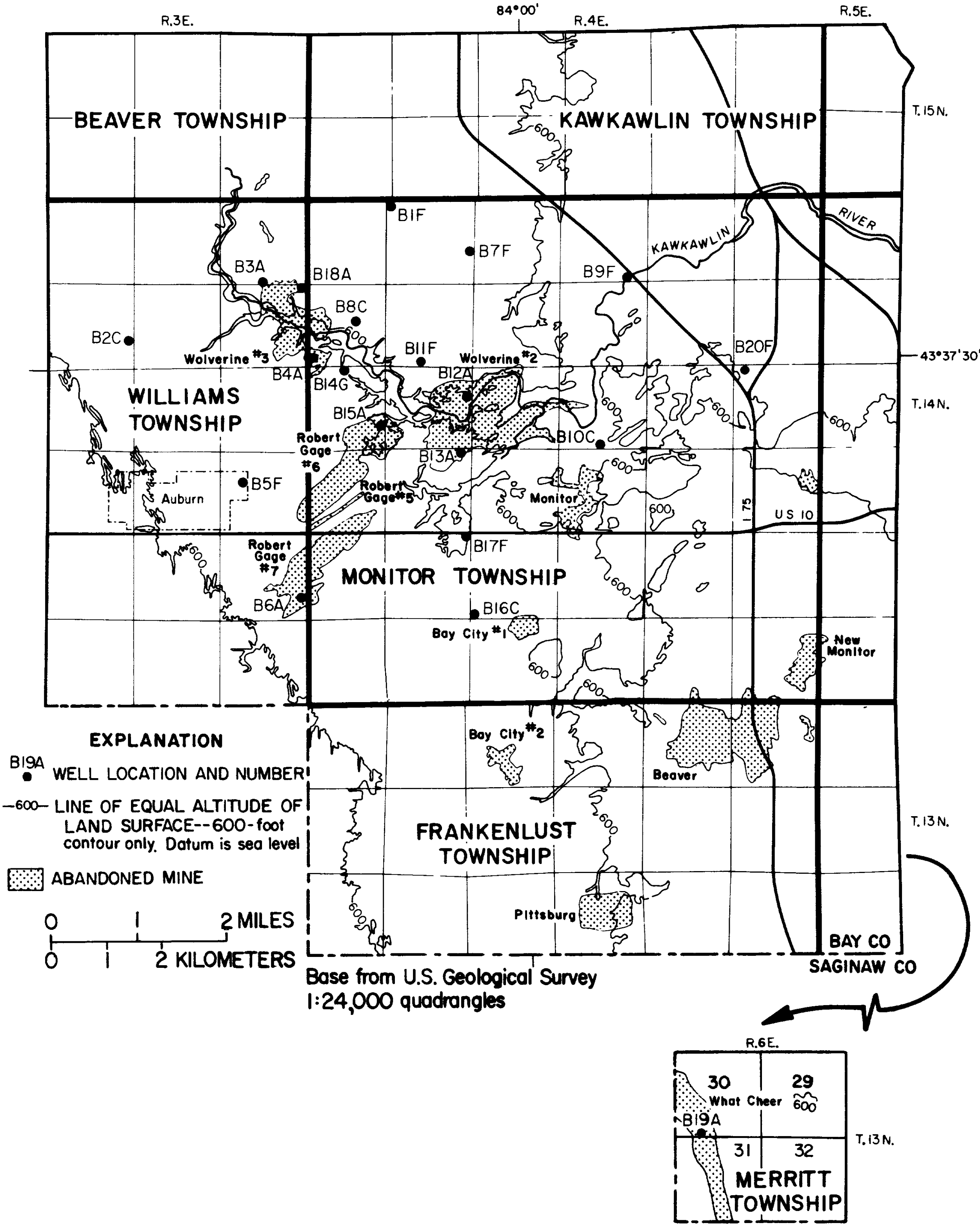

Figure 3.--Topography, location of abandoned coal mines, and location of wells installed by U.S. Geological Survey.

Table 2.--Information for wells installed by U.S. Geological Survey

Well[a] no.	Altitude of land surface (ft)	Depth of well below land surface (ft)	Depth to bottom of casing below land surface (ft)	Depth to water below land surface (ft)
B1F	607	150	102	7
B2C	614	212	126	21
B3A	607	202	105	15
B4A	603	182	125	13
B5F	614	230	189	21
B6A	618	202	142	37
B7F	605	207	105	20
B8C	605	147	135	13
B9F	583	142	105	10
B10C	597	190	147	16
B11F	602	187	160	13
B12A	592	141	112	4
B13A	605	162	126	14
B14G	602	76	72	10
B15A	602	182	105	11
B16C	608	160	126	27
B17F	605	204	147	29
B18A	615	182	105	17
B19A	590	210	105	2
B20F	598	165	147	4

[a]Letter following number in well number indicates source of water: A, abandoned mine; C, beds containing coal; F, Saginaw Formation; G, glaical deposits.

Cooperation and Acknowledgments

The investigation was a cooperative effort between the U.S. Geological Survey, Monitor Township, Williams Township, and the Geological Survey Division of the Michigan Department of Natural Resources, each of which provided funds for the work. In addition, the Geological Survey Division assisted in the collection of field data and in assembling files and old records.

Acknowledgments are made to the many citizens and township officials in Monitor and Williams Townships, as well as those in surrounding townships, who took an active interest in the study and provided data.

HYDROGEOLOGIC SETTING

Glacial Deposits

Glacial deposits underlie all the study area. The deposits range in thickness from 75 to 175 ft; they are thickest in buried valleys that cut diagonally northeastward across Frankenlust, Monitor, and Williams Townships and northwestward across Merritt Township (fig. 4). In the upper 50 to 150 ft, the glacial deposits consist of clay (fig. 5) that may contain thin layers of silt or very fine-grained sand. In some places, the clay extends from land surface to the bedrock surface; at other places, sand and gravel beds ranging in thickness from a few feet to 60 ft occur in the lower part of the glacial deposits.

The clay yields only scant amounts of water, mostly to crock wells. Sand and gravel beds, which are most widespread in the northeastern and western parts of Monitor Township and in the northeastern and southeastern part of Williams Township (fig. 6), yield water to some wells in sufficient quantities to supply domestic needs. Many wells that tap sand and gravel beds yield potable water.

In the late 1800's and early 1900's, many wells completed in glacial deposits in northwestern Monitor Township and northeastern Williams Township flowed (Cooper, 1906). Most wells were 50 to 100 ft deep. Water from the flowing wells was often reported to be "salty".

Saginaw Formation

The Saginaw Formation of Pennsylvanian age is the uppermost bedrock unit in the study area and the only bedrock unit investigated for this report. The formation, which immediately underlies glacial deposits throughout the study area, is several hundred feet thick and is primarily shale and silty shale. It contains beds of siltstone and fine-grained sandstone and thin (2 in. to 4 ft thick) beds of coal (fig. 5). A limestone bed was found during installation of one well (B11F). It is difficult and, in most areas, impossible to trace specific beds for any great distance. For example, in the lithologic columns in figure 5, some beds are found in only one well. Few beds can be traced beyond two or three adjacent wells. Because there is no evidence of significant geologic structure (although small displacements of a few tens of feet would not be easily discernable), it is believed that the discontinuity of beds is due to depositional variation.

Sandstone and siltstone beds in the Saginaw Formation yield water to many wells but quantities are scant and the water is sometimes highly mineralized. Because of the discontinuity of beds, water in the lenticular sandstone, siltstone, and coal beds, under natural conditions, is usually confined by the relatively impermeable shale or silty shale surrounding it. Conditions are similar at abandoned mines, except water can flow more freely in open, man-made shafts. The general relation of rock units to each other and to ground-water flow is shown in figure 7.

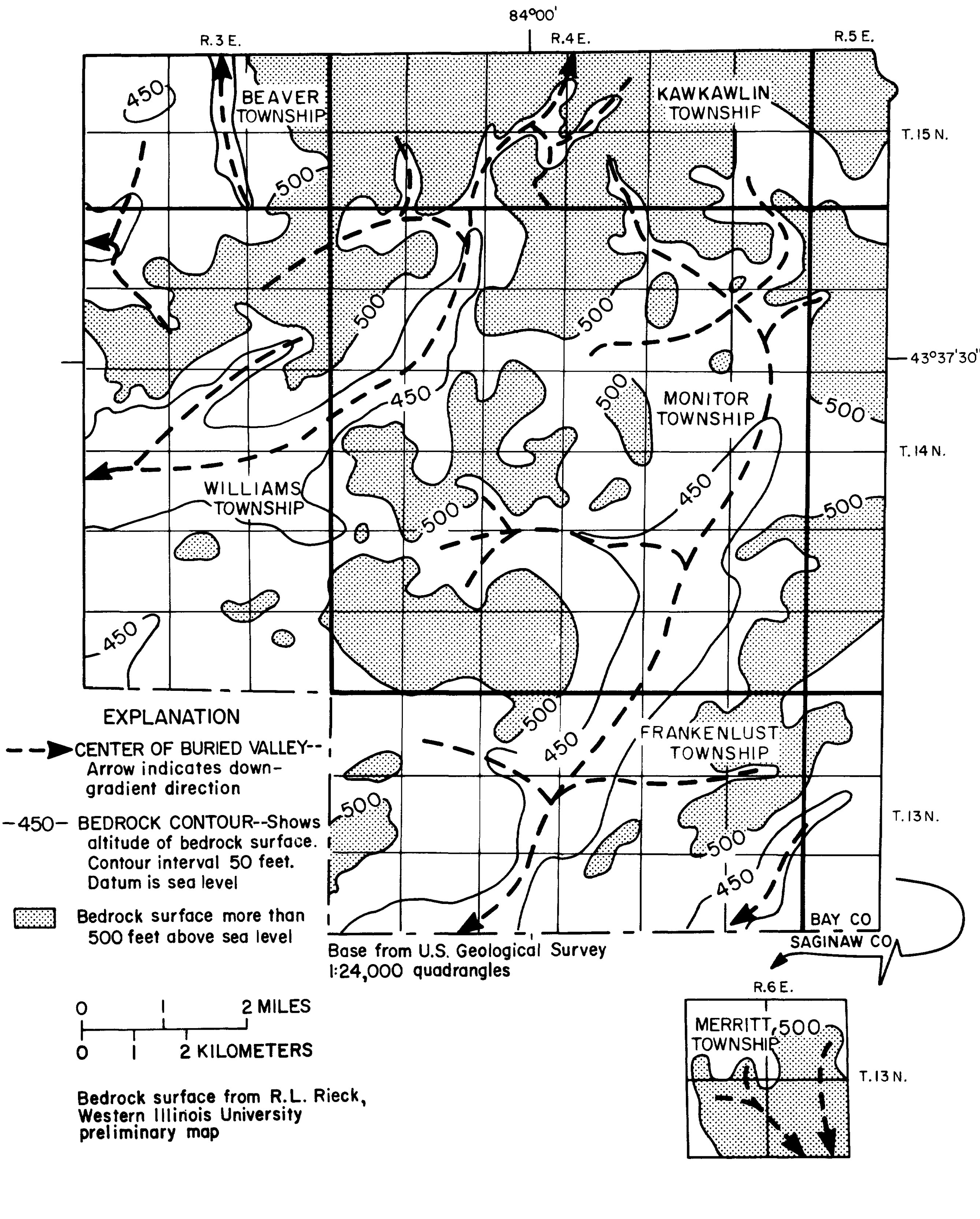

Figure 4.--Location of buried valleys.

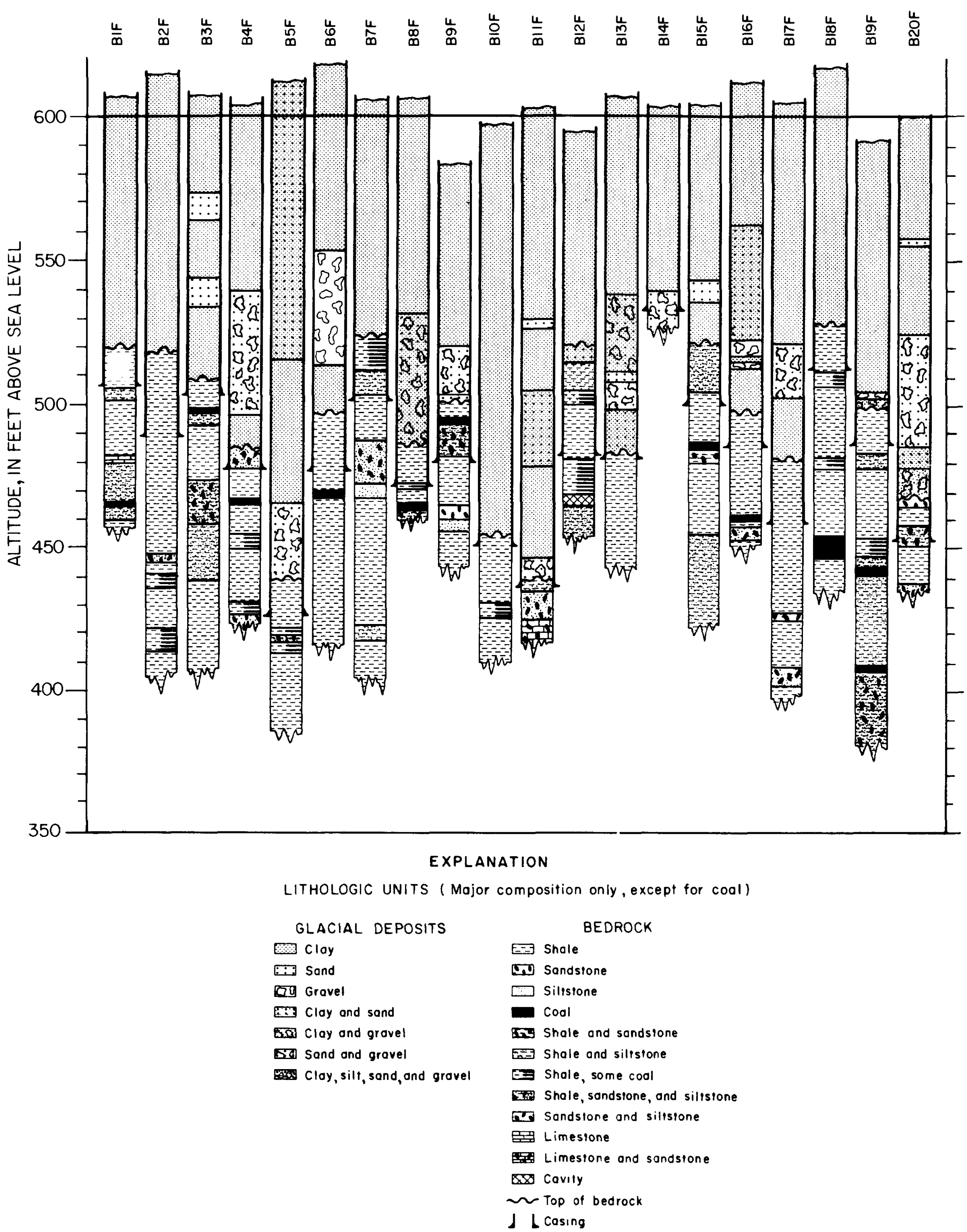

Figure 5.--Lithologic columns of materials in wells installed by U.S. Geological Survey.

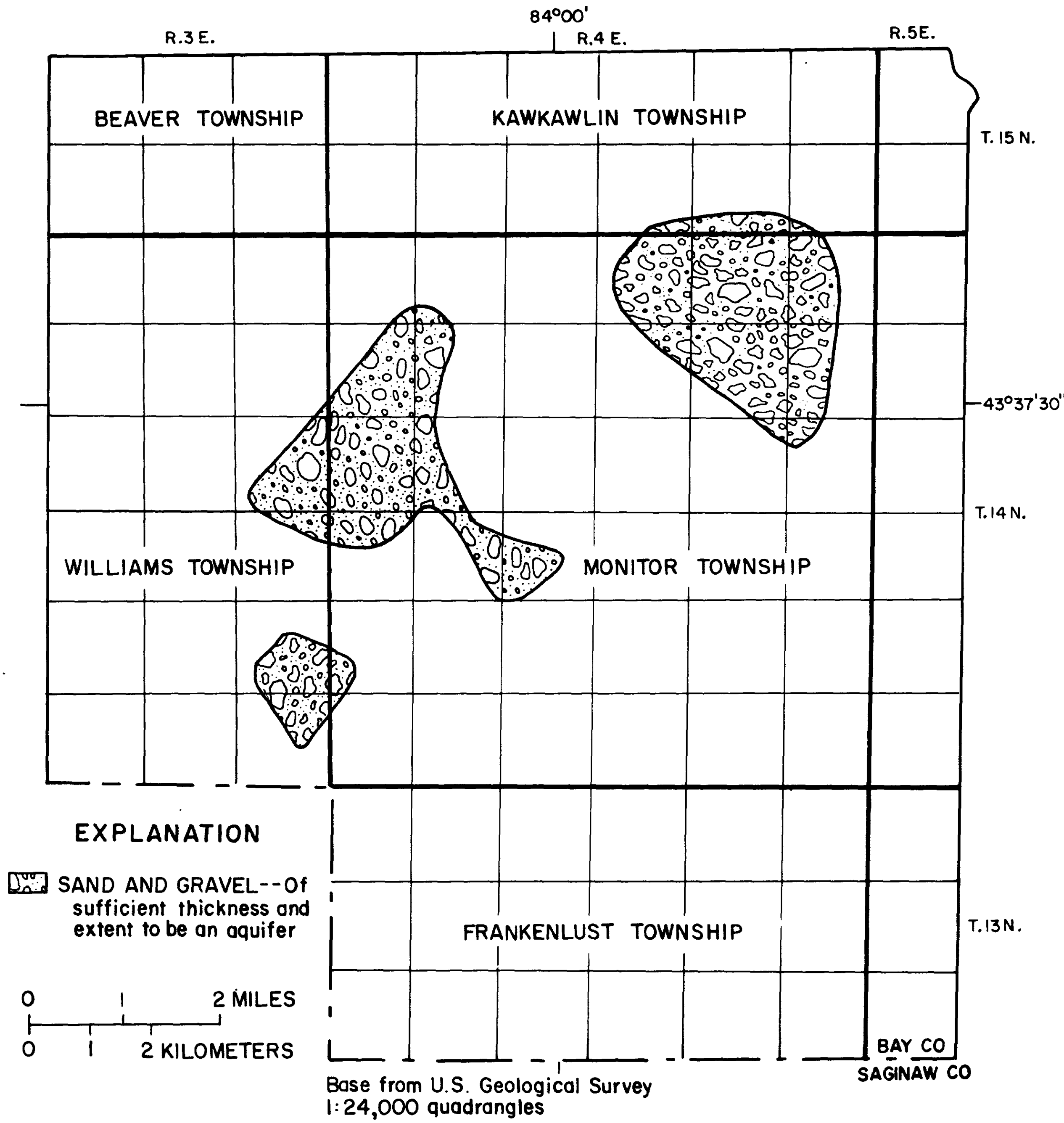

Figure 6.--Areas in Monitor and Williams Townships where glacial deposits contain sand and gravel of sufficient thickness and areal extent to be an aquifer.

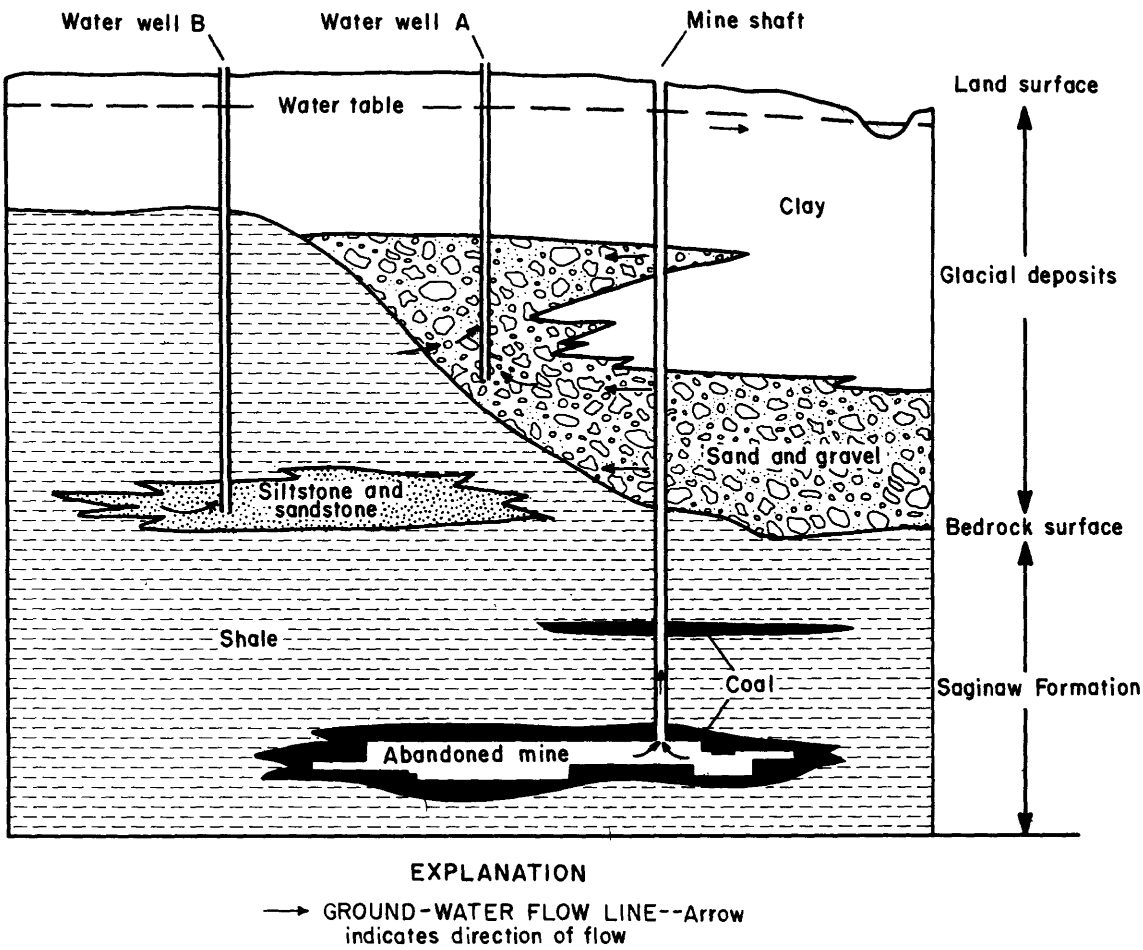

Figure 7.--Generalized hydrogeologic section showing direction of ground-water flow.

At most places, water in the Saginaw Formation moves very slowly--probably no more than a few feet per year. However, in areas where the formation is in contact with sand and gravel in glacial deposits and under pumping conditions similar to that shown by well A in figure 7, water flows more rapidly and moves from the formation to the sand and gravel. A domestic well so situated would collect water from both bedrock and glacial deposits. Under such conditions, water from the well would perhaps initially be potable, but in time would become unsuitable for use because more highly mineralized water would flow to the well from the bedrock. Wells in siltstone and sandstone beds in the Saginaw Formation, such as well B in figure 7, yield water, but commonly in only small quantities; at most places the water is highly mineralized.

CHEMICAL AND PHYSICAL CHARACTERISTICS OF GROUND WATER

The occurrence of highly mineralized ground water in Bay County has been reported for many years. A report by Cooper (1906) on the geology of the county provided data on water quality and contains descriptive comments by drillers and owners on the nature of the ground water. About a third of the comments term water as "trifle salty", "mineral", "brackish", or "very salty". Wells included in Cooper's tabulation ranged from 6 to 251 ft deep; the median depth was 60 ft. The report suggests that highly mineralized water has not been uncommon in the past even at shallow depths. At one location, water and depth to bedrock was described as "quite brackish; within 2 feet of surface; 60 feet to rock". A report by Owen (1902) indicates that waters from several wells installed in Monitor and Williams Townships prior to 1900, and thus prior to significant coal-mining activity in these townships, had dissolved-solids concentrations ranging from about 5,000 to about 11,000 mg/L.

The Saginaw Formation, which underlies glacial deposits and is the source of water for many wells, is known to yield water having a comparatively high dissolved-solids concentration at many locations in the eastern part of Michigan's Lower Peninsula. Statewide, Cummings (1980) found the mean dissolved-solids concentration of water from the Saginaw Formation to be 1,629 mg/L (milligrams per liter); whereas, 90 percent of all samples of other Michigan ground waters contained less than 630 mg/L. In the same survey, water from glacial deposits in Michigan had a mean dissolved-solids concentration of 241 mg/L. The mean pH of water from the Saginaw Formation was 7.6; the mean pH of water from glacial deposits ranged from 7.7 to 8.1, depending on the glacial unit tapped.

Field Measurements of Specific Conductance and pH

Specific conductance, an easily measured electrical property of water, was used in this investigation to estimate the dissolved-solids concentration of some water samples. The relation between dissolved-solids concentration and specific conductance, based on laboratory analyses given in table 3, is shown in figure 8. For observed dissolved-solids and specific-conductance values the relation may be expressed as:

$$\text{Dissolved solids, sum (mg/L)} = [0.5941 \times \text{Specific conductance } (\mu S)] - 160$$

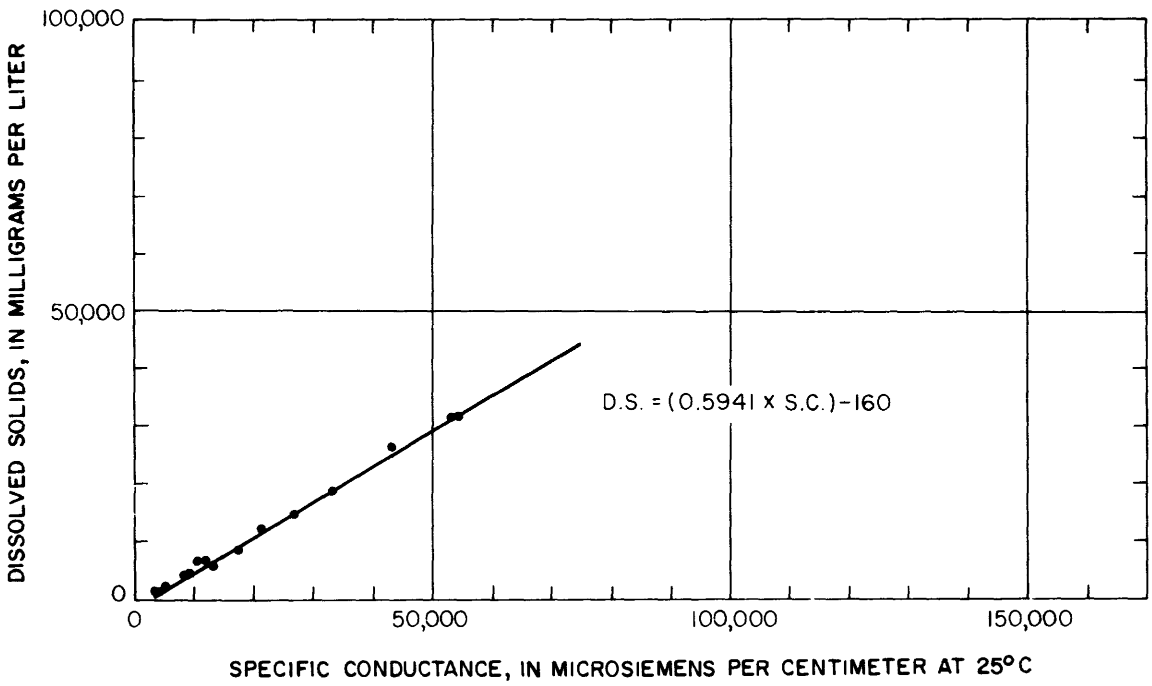

Figure 8.--Relation of dissolved-solids concentration to specific conductance.

The equation, which has a correlation coefficient of 0.99, was based on specific conductance values of more than 3,000 μS and less than 55,000 μS; thus, it may be less accurate at lower or higher values. The maximum specific conductance measured during this investigation (158,000 μS) was not used in formulation of the equation.

Measurements of specific conductance and pH of ground water are given in table 4. These data have been analyzed to determine variations in water quality related to location, source, and depth. Table 5 shows the range and median values of specific conductance and pH for each township independent of geologic source or depth.

Table 5.--Specific conductance and pH of water by township

Township	Specific conductance (μS)			pH (units)		
	Number	Range	Median	Number	Range	Median
Bangor	2	4,000-8,500	--	2	7.6-7.8	--
Beaver	3	1,400-3,500	1,600	0	--	--
Frankenlust	25	800-6,500	2,000	25	6.9-8.0	7.5
Kawkawlin	6	1,000-4,000	[a]1,800	5	7.8-8.2	8.0
Merritt	10	1,400-43,400	[a]3,875	10	6.4-8.3	[a]7.7
Monitor	44	400-158,000	3,750	44	5.6-9.4	7.6
Williams	26	250-53,070	4,000	26	6.2-9.0	7.8

[a]Estimated

Data for Monitor, Williams, and Merritt Townships indicate that characteristics of water in these areas do not differ appreciably. Data for Frankenlust Township suggest that mineralization of water may be lower. Data for Beaver, Kawkawlin, and Bangor Townships, because of the lesser number of measurements, may not accurately reflect existing conditions.

Frequency distributions of specific conductance and pH based on data from all seven townships are shown in figures 9 and 10. Fifty percent of the specific conductance values are equal to or greater than 2,750 μS; 25 percent are equal to or greater than 4,800 μS. Using the dissolved solids-specific conductance relationship previously discussed, values of 2,750 and 4,800 μS indicate dissolved-solids concentrations of about 1,480 mg/L and 2,690 mg/L, respectively. This further suggests that the dissolved-solids concentration of ground water in the study area is higher than commonly found in many other parts of the State. With respect to pH, 50 percent of the values were 7.6 or greater; 95 percent are 6.5 or greater. In general, more acidic water, once thought to be common, was not found.

Relation of Specific Conductance and pH to Source of Water

Analyses shown in table 4 were grouped by source of water to determine variation in specific conductance and pH; table 6 shows the range and median found.

Table 4.--Well locations and field measurements of specific conductance and pH of water
[Analyses by the State of Michigan, except as indicated; a dash indicates not known or not determined]

Well location	Land location	Source of water[a]	Depth below land surface (ft)	Land surface altitude (ft)	Bedrock surface altitude (ft)	Specific conductance, field (µS)	pH, field (units)
Bangor Township (T14N,R5E)							
5143 Two Mile Road	14N5E 30BCBB	G	85	597	495	4,000	7.8
5165 S. Two Mile Road	30BCBC	--	--	597	495	8,500	7.6
Beaver Township (T15N,R3E)							
2149 S. Nine Mile Road	15N3E 25BCBB	G	97	611	500	1,400	--
2161 S. Nine Mile Road	25BCBC	I	108	609	500	1,600	--
2258 S. Nine Mile Road	26DAAD	G	100	610	465	3,500	--
Frankenlust Township (T13N,R4E)							
1183 Delta Road	13N4E 4CDCD	G	81	611	450	1,600	7.8
934 Hotchkiss Road	5AAAB	--	--	612	490	1,450	8.0
6259 Seven Mile Road	5CBBB	--	--	620	485	6,500	7.4
511 Delta Road	5CCCC	F	142	625	500	800	7.8
6331 Eight Mile Road	6CBCA	F	145	625	490	3,500	7.8
1380 Delta Road	9ABAA	--	--	603	450	1,600	7.3
1417 Weiss Road	9ADCD	F	143	608	470	1,800	7.8
1131 Weiss Road	9BDCC1	G	85	614	460	1,200	7.7
1133 Weiss Road	9BDCC2	--	--	614	460	1,400	6.9
1201 Weiss Road	9BDDC	G	75	614	460	1,400	7.0
2323 E. Amlethe Road	11DCDC1	F	120	597	505	3,000	7.6
2323 E. Amlethe Road	11DCDC2	F	130	597	505	2,500	7.6
2901 E. Schwab Road	12ADCD	F	197	584	502	3,500	7.5
6815 Three Mile Road	12CBCB	F	130	592	516	2,000	7.5
2905 E. Amlethe Road	12DDCD	F	212	585	458	5,000	7.5
2916 Englehart Road	13DABA	F	170	584	502	3,000	7.4
2412 E. Amlethe Road	14AABA	F	133	596	498	3,250	7.6
7115 Bentwood Road	14ABCD1	F	130	597	485	2,000	7.5
7116 Bentwood Road	14ABCD2	F	137	597	485	2,700	7.5
1968 Kloha Road	15ADAB	--	--	601	505	2,000	7.5
1692 Kloha Road	15BDBA	--	--	601	500	2,000	7.5
7130 Mackinaw Road	16ADAA	G	125	608	470	2,500	7.8
1084 Amlethe Road	16BBAC	F	159	616	480	2,500	7.5
7115 Fraser Road	16BCBB	I	168	617	450	1,500	7.4
7135 Fraser Road	16BCBC	I	172	617	450	2,000	7.3
Kawkawlin Township (T15N,R4E)							
670 Wetter Road	15N4E 17CABA	G	160	612	510	1,000	8.0
367 River Road	18DDCC	F	200	603	460	1,500	8.1
1987 Eight Mile Road	19CCCC	F	130	632	520	1,600	7.8
1578 Fraser Road	20AADA	F	195	602	505	2,000	8.2
2055 Seven Mile Road	29BBBC	F	160	616	505	4,000	8.0
2076 Mosher Road	30ABCB	F	101	617	520	3,750	--
Merritt Township (T13N,R6E)							
769 W. Brown Road	13N6E 30BAAB	F	106	592	510	3,000	7.8
885 W. Brown Road	30BBAA	--	--	591	510	4,000	7.7
2107 S. Jones Road	30BBCC	--	--	591	510	1,400	7.6
B19A[b]	30CDCC	A	210	590	398	43,400	6.4
824 Kinney Road	30CDCD	--	--	589	500	3,000	7.6
707 Kinney Road	31ABBA	G	70	592	490	1,950	7.7
733 Kinney Road	31ABBB	F	130	592	490	3,750	8.3
811 Merkel Road	31CAAB	G	78	587	490	6,000	7.7
2782 S. Knight Road	31DAAD	--	--	588	475	10,000	8.0
2594 Burns Road	32BADA	--	--	602	490	8,500	7.8

[a]Letter in column indicates source of water as follows:
- A - from area of abandoned mine
- C - from beds containing coal
- F - from siltstone and sandstone beds in the Saginaw Formation
- G - from glacial deposits
- I - from interface of glacial deposits and Saginaw Formation

[b]Analyses by U.S. Geological Survey

Table 4.--Well locations and field measurements of specific conductance and pH of water--Continued

Well location	Land location	Source of water	Depth below land surface (ft)	Land surface altitude (ft)	Bedrock surface altitude (ft)	Specific conduct-ance, field (μS)	pH, field (units)
			Monitor Township (T14N,R4E)				
B9F[a]	14N4E 3DDCC	F	142	583	510	33,080	7.3
1300 E. Chip Road	4DBBA	F	100	602	520	3,750	7.5
B1F[a]	5BBBB	F	150	607	510	24,440	7.8
B7F[a]	5DAAD	F	207	605	520	11,730	9.4
863 Wheeler Road	5DCDD	--	--	604	510	3,000	7.7
3446 Fraser Road	5DDDD	G	78	604	530	4,000	7.9
53 Wheeler Road	6CCDC	I	82	610	530	1,600	7.2
451 Wheeler Road	6DDDC	G	105	610	480	2,000	7.5
B8C[a]	7ACDC	C	147	605	475	16,920	8.6
439 Ott Road	7ADCC	G	116	607	460	2,500	8.1
3517 Eight Mile Road	7BBBB	G	72	615	530	600	7.6
171 Ott Road	7BDDC	--	--	605	495	5,000	7.9
3863 Eight Mile Road	7CBCD	G	84	602	440	6,000	7.5
B4A[a]	7CCCA	A	182	603	500	11,750	7.0
253 E. Wilder Road	7CDDD	G	82	602	470	4,000	7.7
360 Ott Road	7DBAA	--	--	607	470	400	7.8
295 E. Wilder Road	7DCCA	G	90	602	460	3,000	7.6
265 E. Wilder Road	7DCCB	G	92	602	465	3,500	7.9
315 E. Wilder Road	7DCDB	G	98	601	460	3,000	7.8
329 E. Wilder Road	7DCDC	G	105	601	455	2,500	7.8
B11F[a]	8CDDC	F	187	602	430	4,170	9.0
1200 E. Wheeler Road	9BAAA	F	104	602	515	2,500	7.9
3939 Fraser Road	9CCCB	F	188	614	481	6,000	7.2
B20F[a]	13BBAB	F	165	598	445	4,750	7.9
2181 N. Union Road	14CDCD	G	70	602	480	1,100	6.6
B10C[a]	15CDDD	C	190	597	450	52,540	8.4
1256 E. Wilder Road	16ABBB	G	76	602	490	1,000	7.4
4133 Fraser Road	16BBCC	I	106	597	490	5,500	7.5
1281 N. Union Road	16DCCD	G	62	597	495	1,600	7.3
B12A[a]	17ADAD	A	141	592	510	9,660	5.6
450 E. Wilder Road	18AAAC	--	--	600	420	3,750	7.5
B14G[a]	18ABBB	G	76	602	445	5,000	7.6
4317 Eight Mile Road	18CBBD	G	65	608	410	3,500	7.8
B15A[a]	18DADD	A	182	602	505	[b]3,440	6.6
B13A[a]	20AAAA	A	162	605	500	2,990	7.7
1866 N. Union Road	22ABAA	G	58	602	485	2,000	6.8
5183 Four Mile Road	26BCBC	G	113	598	430	1,100	6.8
B16C[a]	28CCCC	C	160	608	495	[b]52,300	8.6
B17F[a]	29AAAA	F	204	603	475	[b]158,000	7.1
5864 Seven Mile Road	31DADD	F	184	616	520	406	7.9
5904 Seven Mile Road	31DDAD	F	111	614	510	4,000	7.4
1377 Hotchkiss Road	33DCCD	I	90	602	510	1,800	6.9
1427 Hotchkiss Road	33DDCD	--	--	602	515	4,500	6.5
1467 Hotchkiss Road	33DDDC	F	140	602	515	4,000	6.4
			Williams Township (T14N,R3E)				
446 W. Chip Road	14N3E 1BCDB	G	70	616	500	250	8.0
450 W. Chip Road	1BCDC	G	36	616	500	250	7.8
390 W. Chip Road	1BCDD	G	60	608	500	550	7.9
394 W. Chip Road	1BCDD	G	50	616	500	300	7.8
376 W. Chip Road	1BDCC	G	84	612	510	4,250	7.6
257 W. Chip Road	1CAAA	G	75	615	520	900	7.5
379 W. Chip Road	1CABB	--	--	612	505	2,200	7.8
426 Wheeler Road	1CCDC	G	87	607	510	6,250	7.8
B3A[a]	1DCCC	A	202	607	520	[b]8,960	8.7
3101 Garfield Road	2BBCC	I	144	613	469	2,000	7.5
778 Wilder Road	2CDDD	G	98	612	495	5,000	7.4
730 Wheeler Road	2DCCC	--	--	604	520	1,000	7.6
B2C[a]	10DADA	C	212	614	510	27,120	9.0
609 Wheeler Road	11AABB	G	86	607	515	6,000	7.6
B18A[a]	12AAAA	A	182	615	525	19,740	6.2
47 Wheeler Road	12AAAB	--	--	610	525	2,000	8.7
3558 Eight Mile Road	12AAAD	G	71	609	525	2,500	8.2
363 W. Wheeler Road	12BABB	G	77	610	530	4,000	7.6
407 Wheeler Road	12BBAB	G	72	607	515	4,000	8.5
3751 S. Nine Mile Road	12CBBB	--	--	608	475	7,000	7.5
312 Wilder Road	12CDDC	G	93	607	475	5,750	7.7
B5F[a]	24BCDA	F	230	614	455	8,480	8.4
B6A[a]	25DADD	A	202	618	505	53,070	8.4
5434 Eight Mile Road	25DDDA	--	--	617	505	3,000	7.9
5450 Nine Mile Road	26DDDA	--	--	626	500	1,050	8.0
5994 Nine Mile Road	35DDDD	--	--	635	490	5,000	7.9

[a]Analyses by U.S. Geological Survey
[b]Laboratory measurement

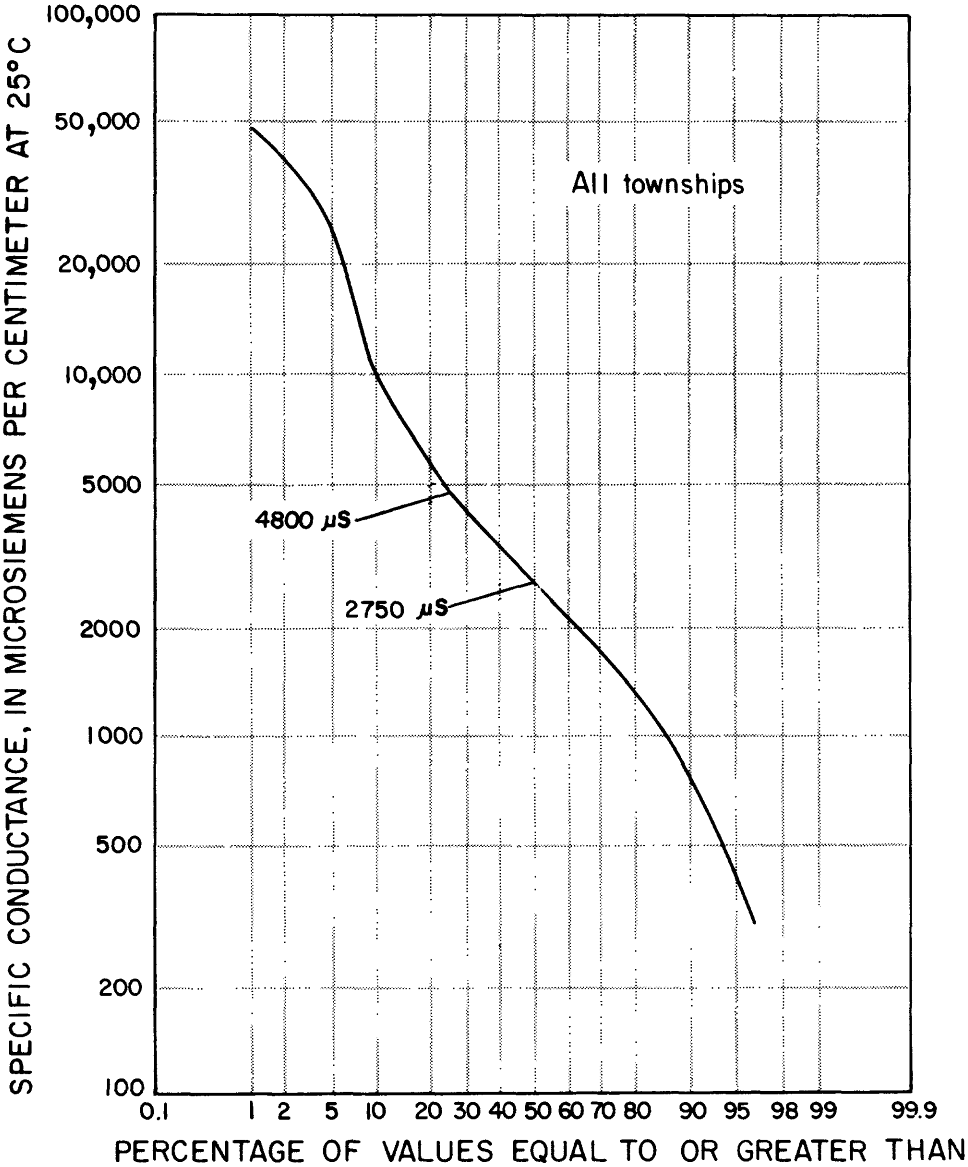

Figure 9.--Frequency distribution of specific conductance values.

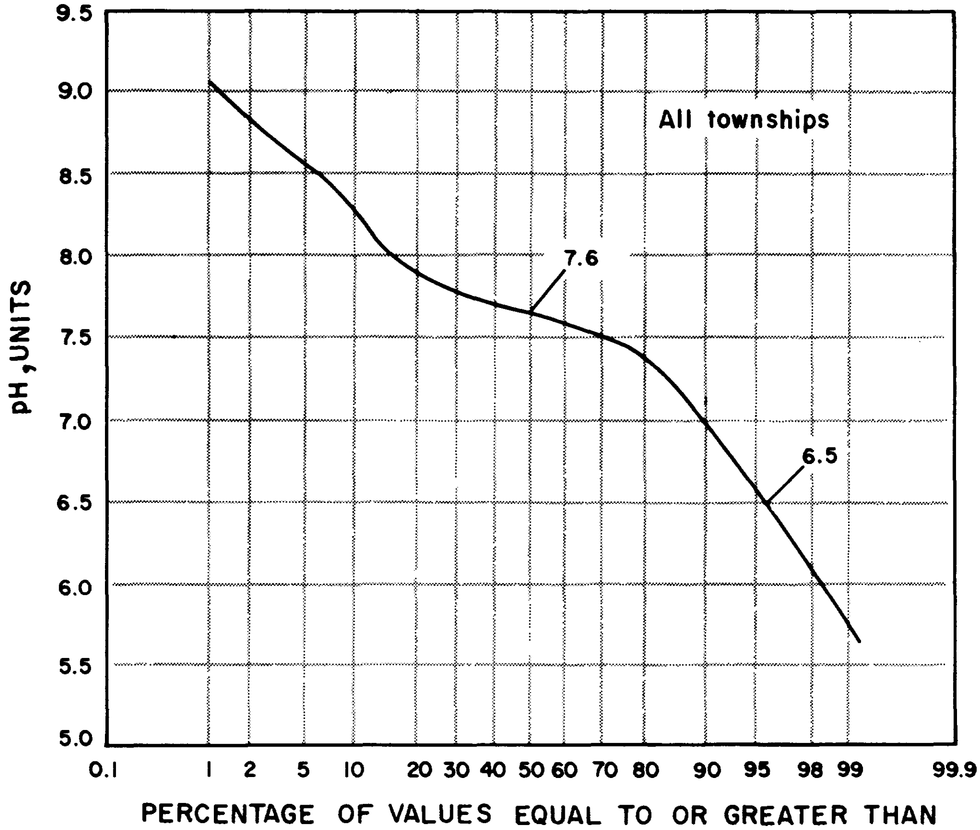

Figure 10.--Frequency distribution of pH values.

Table 6.--Specific conductance and pH of water by source, all townships

Source	Specific conductance (µS)			pH (units)		
	Number	Range	Median	Number	Range	Median
Abandoned mines	8	2,990-54,070	[b]10,700	8	5.6-8.7	[b]6.8
Coal	4	16,920-52,540	[b]39,700	4	8.4-9.0	8.6
Saginaw Formation	33	406-158,000	3,500	32	6.4-9.4	7.6
Glacial deposits	40	250-6,250	2,500	38	6.6-8.5	7.7
Interface[a]	7	1,500-5,500	1,800	6	6.9-7.5	[b]7.4

[a]Exact source cannot be determined. Water withdrawn from near the glacial deposit-Saginaw Formation contact.
[b]Estimated.

Data indicate that water in abandoned mines and coal deposits has the highest mineralization, and that water from the glacial deposits, the lowest. The highest single dissolved-solids concentration of water, however, was detected in a well in the Saginaw Formation.

Data for abandoned mines and coal are similar to those found by Handy (1982) in an investigation of the water quality of coal deposits and abandoned mines near St. Charles in Saginaw County adjacent to Bay County on the south. However, Handy found that the pH of samples from undisturbed coal beds decreased significantly in some instances after water was collected. For example, the field pH of one sample was 6.8; a subsequent laboratory measurement was 4.7. In another instance, the field pH was 6.8 and the laboratory pH was 4.3. The pH of water from abandoned mines, however, increased only slightly when allowed to stand. Changes in pH were not noted during the study in Bay County.

A comparison of data in table 7 with that in table 6 suggests that water

Table 7.--Specific conductance and pH of water by source, Monitor and Williams Townships

Source	Specific conductance (µS)			pH (units)		
	Number	Range	Median	Number	Range	Median
Abandoned mines	7	2,990-53,070	9,660	7	5.6-8.7	[b]7.0
Coal	4	16,920-52,540	[b]39,700	4	8.4-9.0	8.6
Saginaw Formation	13	406-158,000	4,750	13	6.4-9.4	7.8
Glacial deposits	30	250-6,250	[b]2,750	30	6.6-8.5	7.6
Interface[a]	4	1,600-5,500	[b]1,900	3	6.9-7.5	7.5

[a]Exact source cannot be determined. Water withdrawn from near the glacial deposit-Saginaw Formation contact.
[b]Estimated.

from the Saginaw Formation in Monitor and Williams Townships may be slightly more mineralized than water in the seven townships as a whole. Other results are inconclusive because most analyses of water from abandoned mines, coal, and at the interface were of water obtained in Monitor and Williams Townships.

Relation of Specific Conductance of Water to Depth of Well

Figure 11 is a plot of specific conductance values versus well depth for all data given in table 4. The plot suggests that ground water tends to become more highly mineralized as depth of well increases. A similar plot of data for Monitor and Williams Townships did not differ appreciably from that shown in figure 11.

Increased mineralization as depth increases is also illustrated in figure 12, which shows frequency distributions of specific conductance of water from wells 100 ft or less in depth, and from wells greater than 100 ft deep, in Monitor and Williams Townships only. About 50 percent of specific-conductance values of water from the deeper wells were equal to or greater than 5,000 μS; whereas, only 13 percent of the values of water from shallower wells was 5,000 μS or greater.

Because the Saginaw Formation may be encountered at comparatively shallow depths, specific conductance of water from only the Saginaw Formation in the seven townships was compared to depth of wells. Half of the wells were less than 143 ft deep. The median specific conductance of water from wells greater than 143 ft deep was 4,500 μS; the median value for wells less than 143 ft deep was 3,000 μS.

The similarity of water from the Saginaw Formation to water from abandoned mines in a given depth range can be illustrated by comparing the specific conductance values of water from each source. The depths of the major abandoned mines in Monitor and Williams Townships ranged from 140 to 210 ft; the median specific conductance of water from these mines was 9,660 μS. The median specific conductance of water from wells in the Saginaw Formation, in the same depth range in the same townships, was 8,860 μS. This comparison suggests that the characteristics of water from these two sources do not differ appreciably in a given depth range.

Mine Shafts and the Quality of Water in Glacial Deposits

To investigate the possibility of movement of highly mineralized water from abandoned mines into glacial deposits, an area encompassing the abandoned mines--Wolverine no. 2, Wolverine no. 3, and Robert Gage no. 6--was selected for closer examination (fig. 13). The area includes sections 1 and 12 of Williams Township, and sections 5, 6, 7, 8, 9, 16, 17, 18, 19, 20, and 21 of Monitor Township. The locations of 10 former mine shafts have been identified in the three abandoned-mine areas. The specific conductance of water from all glacial-deposit wells within a radius of 2,900 ft of each shaft was tabulated. The median value was 2,500 μS, identical to the value previously determined for the seven townships as a group (table 6). Although this comparison does not demonstrate that movement of highly mineralized water upward through old mine shafts affects the quality of water in glacial deposits, it does suggest that such an affect, if it occurs, must be localized rather than pervasive throughout the mined area.

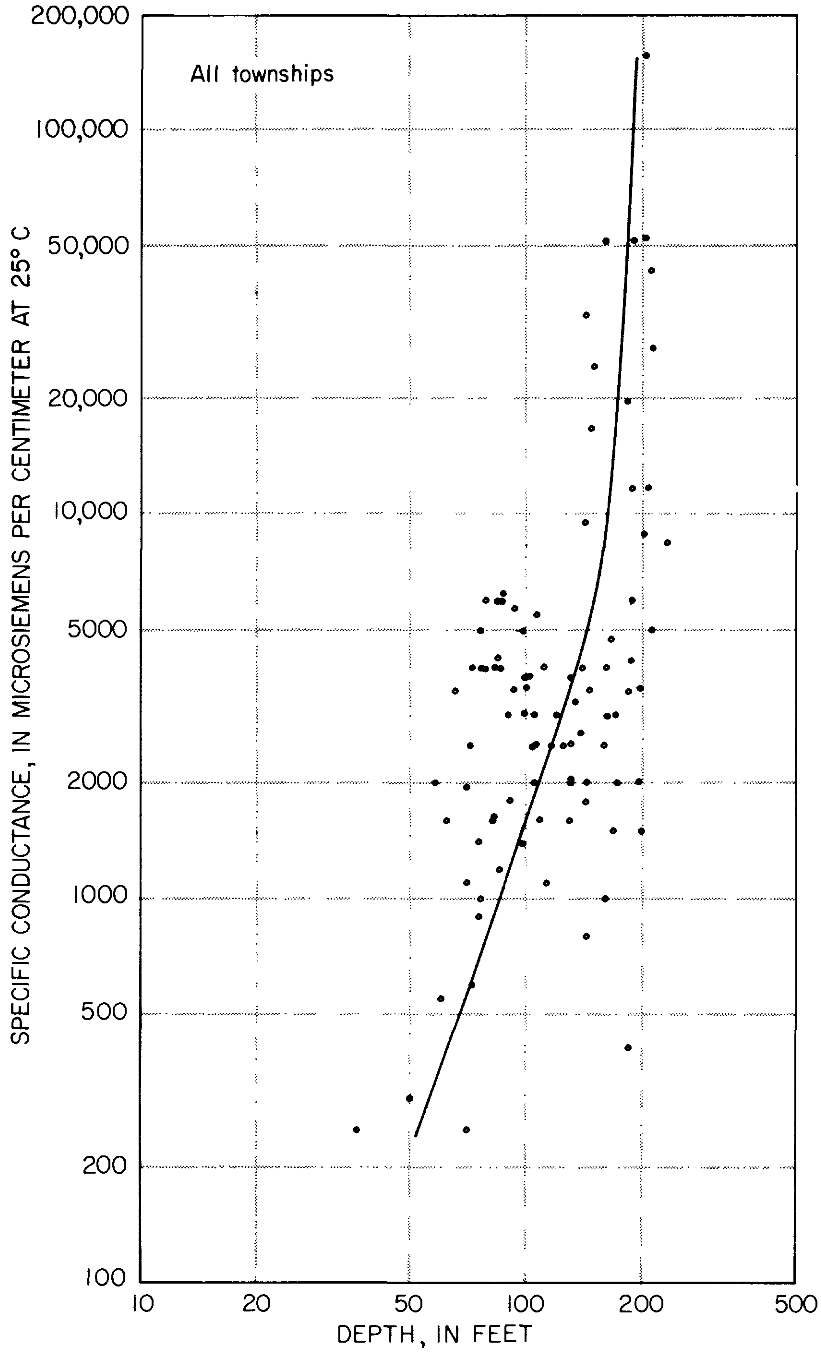

Figure 11.--Relation of specific conductance to depth of well.

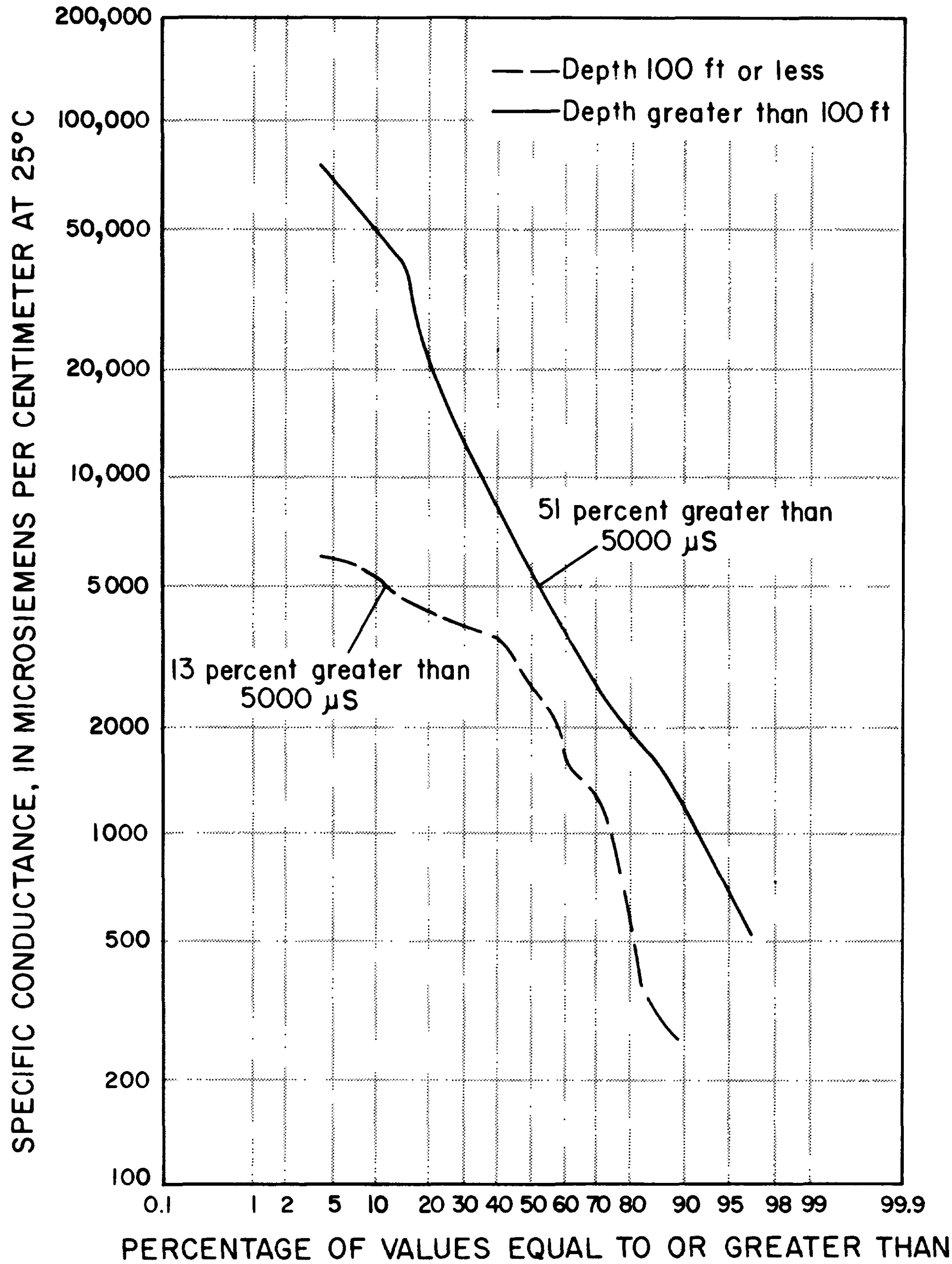

Figure 12.--Frequency distribution of specific conductance values, Monitor and Williams Townships.

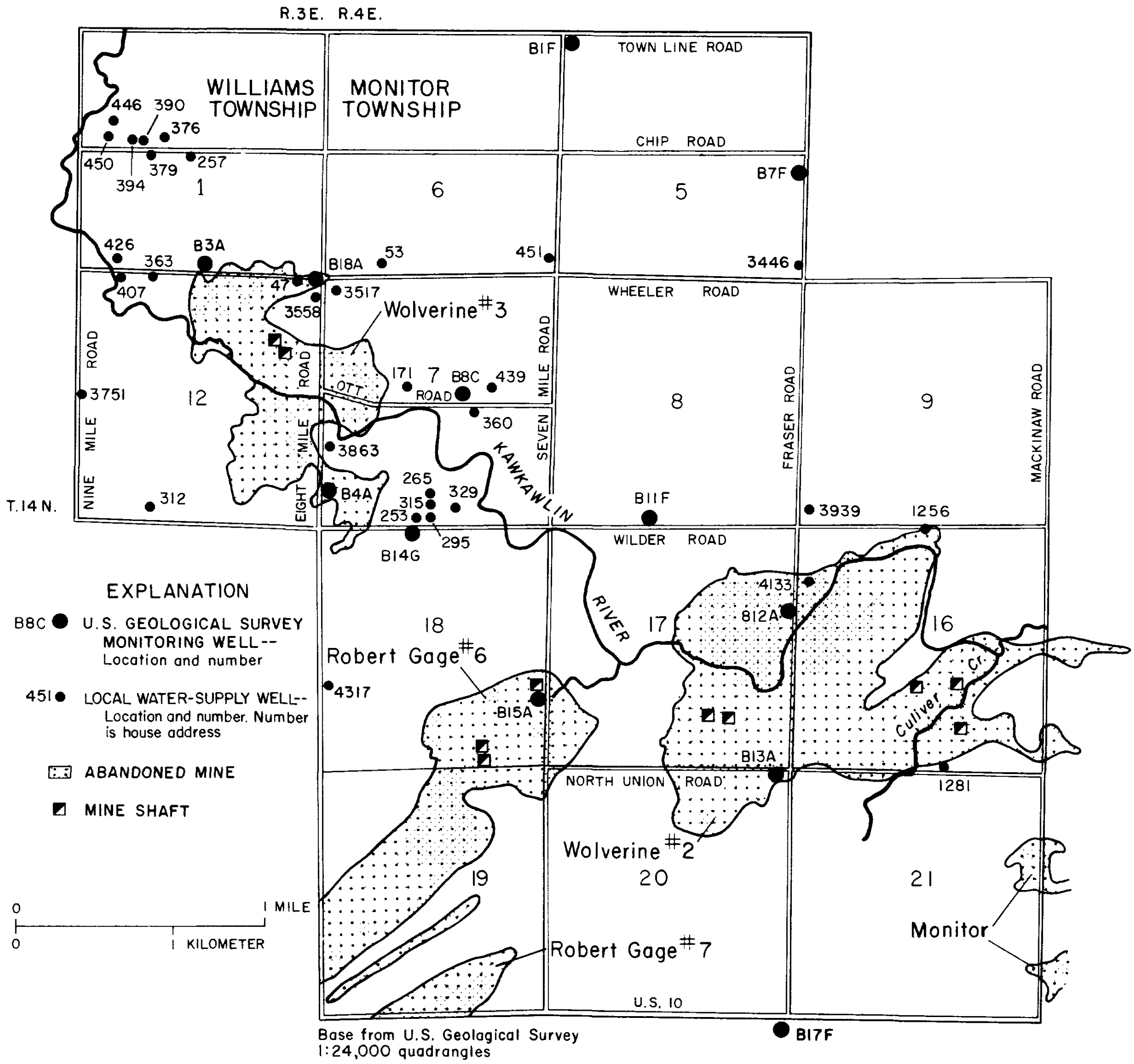

Figure 13.--Abandoned mines, mine shafts, and well locations, Monitor and Williams Townships.

Common Dissolved Substances, Trace Metals, and Gases

Detailed chemical analyses were made on water from 20 wells installed by the U.S. Geological Survey (table 3) and on water collected from 69 wells by the Geological Survey Division of the Michigan Department of Natural Resources (table 8, at back of report) in an effort to determine the specific characteristics of water from each source. It was hoped that such analyses would provide an indication of the movement of water, and allow a determination as to whether water from abandoned mines was modifying the characteristics of water in the glacial deposits. Study of the data, however, failed to yield significant results.

Semiquantitative analyses[1] of selected trace metals (table 9), including

Table 9.--Semiquantitative analyses of trace metals
[Analyses by U.S. Geological Survey, Results in milligrams per liter.]

Well	Antimony	Gallium	Germanium	Tin	Titanium	Vanadium
B2C	0.3	0.5	0.7	>10	0.01	0.07
B3A	.3	.5	.3	7	.01	.05
B4A	.7	.3	.7	>10	.01	.07
B5F	.3	.3	.3	7	<.005	.03
B6A	.5	.7	1	>10	.03	.1
B7F	.3	1	.3	5	.01	.05
B8C	.3	.5	.5	>10	.007	.05
B9F	.3	.5	.5	>10	.01	.05
B10C	.5	3	1	>10	.01	.07
B12A	.7	.7	.7	>10	.007	.1
B13A	.1	.1	.1	5	<.005	.01
B14G	.1	<.03	.3	10	<.005	.03
B15A	.3	.5	.3	3	.01	.03
B18A	.3	.5	.5	>10	.007	.05
B19A	.5	.5	1	>10	.01	.07

germanium, which is known to be high in Michigan coals, were made of water from wells installed by the U.S. Geological Survey. These semiquantitative analyses also included antimony, gallium, tin, titanium, and vanadium. Because of the high mineralization of most samples, spectral interferences probably made results of the analyses for trace metals unreliable. There was no apparent correlation between concentration and source.

[1]Analyses were made by using an Inductively Coupled Plasma-jet spectrophotometer (ICP).

Analyses of hydrocarbon gases and hydrogen sulfide also were made (table 10). Hydrocarbon gases other than methane were not detected. Because

Table 10.--Analyses of gases in water from selected wells
[Analyses of methane by Rocky Mountain Analytical Laboratory, Arvada, Colorado; analyses of hydrogen sulfide by Environmental Research Group, Inc., Ann Arbor, Michigan. ND indicates "not detected".]

Well	Methane ($\mu g/L$ as CH_4)	Hydrogen sulfide (mg/L as H_2S)
B8C	15	<0.1
B9F	.3	<.1
B10C	.6	<.1
B11F	ND	<.1
B12F	ND	<.1
B13A	ND	<.1
B14G	.1	<.1
B15A	.5	<.1
B16C	16	ND
B17F	.2	ND

only traces of methane and hydrogen sulfide were detected, the above data suggest that neither are suitable for tracing water movement. Concentrations of methane in water from coal seem to be higher as expected. Well B13A, which tapped an abandoned mine, vigorously discharged gas around the casing at land surface. The gas may have been carbon dioxide, although laboratory analyses and field pH measurements offer no evidence to confirm this.

Chloride/Sulfate Relationships

Chloride and sulfate concentrations seem to indicate water source. Figure 14 shows a plot of the chloride/sulfate ratios versus specific conductances for glacial deposits and coal. Not only is the specific conductance of water from coal higher, but the relative proportions of chloride and sulfate are different. Figure 15 shows a similar plot for glacial deposits and abandoned mines[2]. Overlap of the two areas delineated suggests some possible mixing of more highly-mineralized, abandoned-mine water with less-mineralized water in glacial deposits. Figure 16 shows a plot for glacial deposits and the Saginaw Formation. Characteristics of water from the Saginaw Formation are so variable, and the mineralization range so great, that it seems probable that water of the Formation is as likely to influence the water-quality characteristics of glacial deposits as does water from abandoned mines. Water having the highest specific conductance (158,000 μS, table 3) was from a well in silty beds in the Saginaw Formation, about 1 mi

[2]Chloride/sulfate ratios of water collected by Handy (1982) from coal deposits and abandoned mines plot within the appropriate areas delineated on figures 14 and 15.

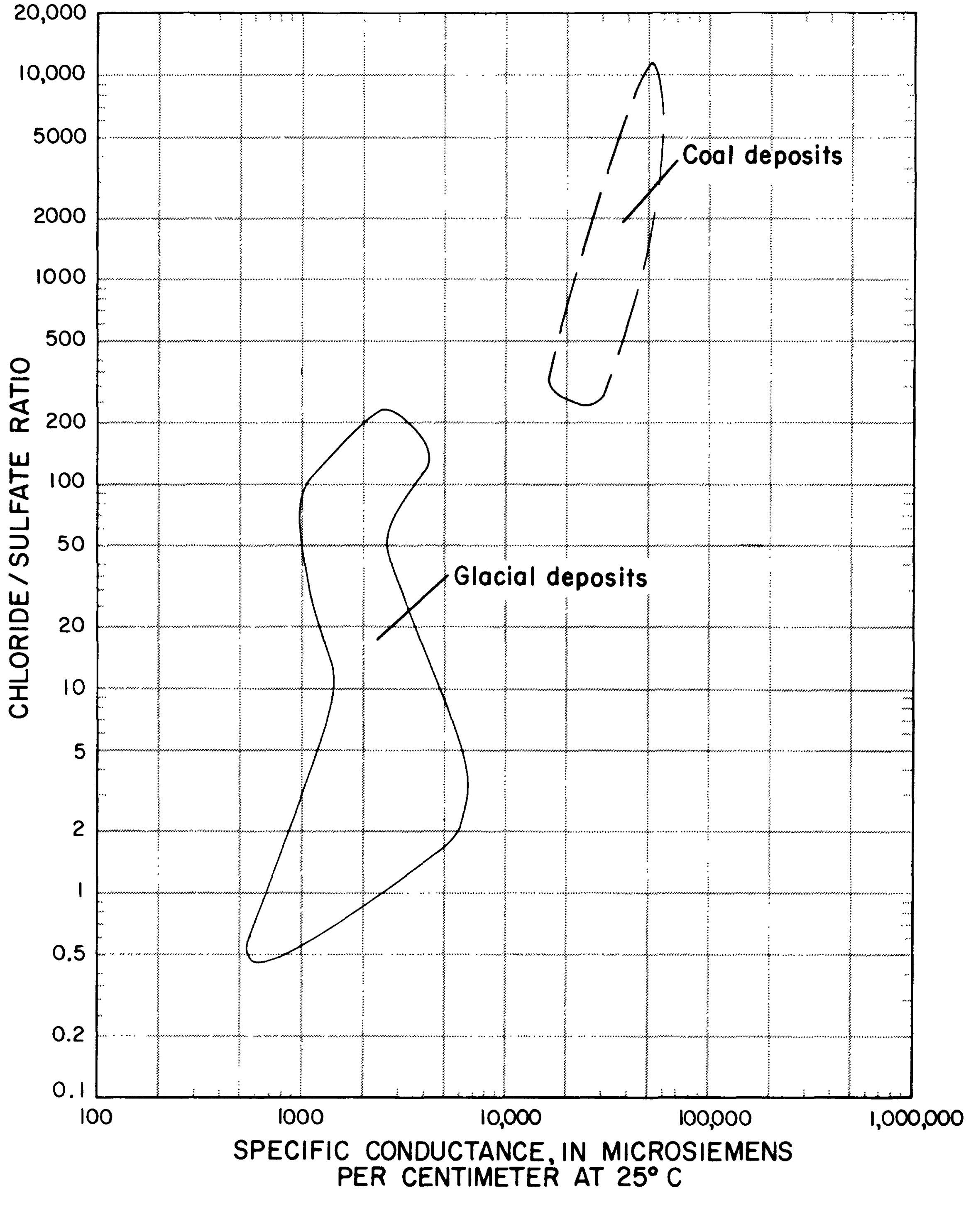

Figure 14.--Relation of specific conductance to chloride/sulfate ratios of water from glacial deposits and coal.

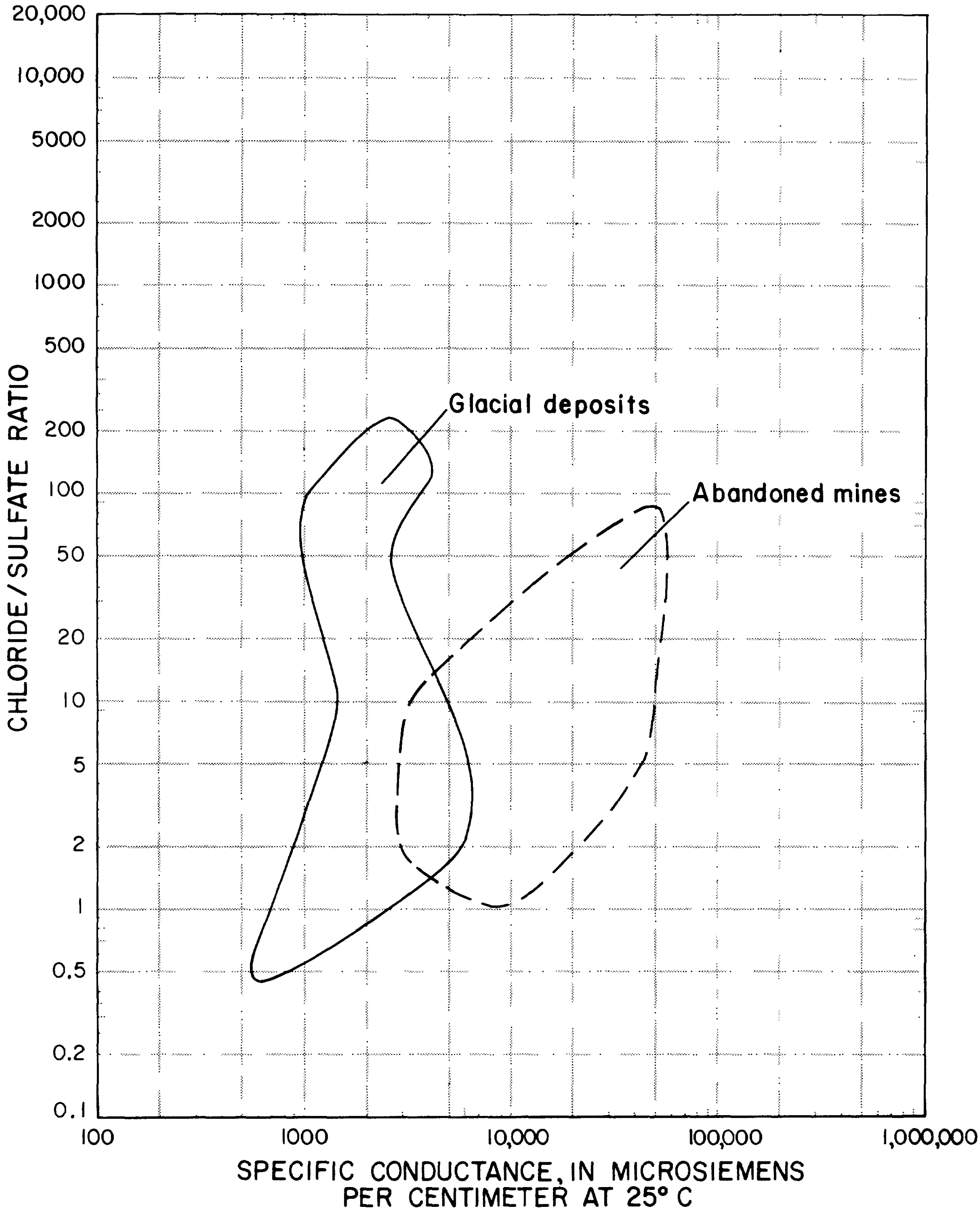

Figure 15.--Relation of specific conductance to chloride/sulfate ratios of water from glacial deposits and abandoned mines.

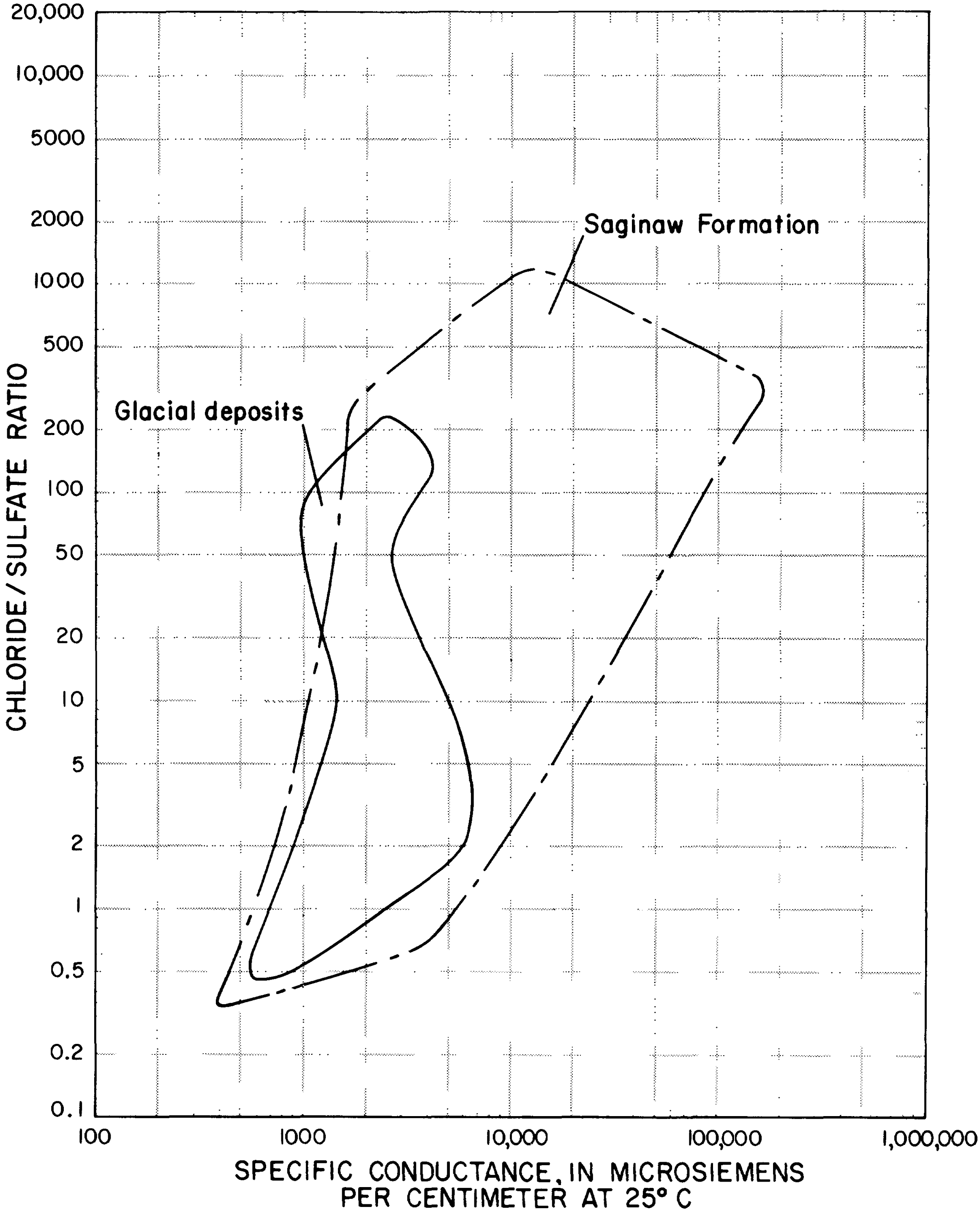

Figure 16.--Relation of specific conductance to chloride/sulfate ratios of water from glacial deposits and the Saginaw Formation.

from any significant coal beds or former mining activity. Although water from abandoned mines undoubtedly moves into glacial deposits, water from the Saginaw Formation does also. Because characteristics of abandoned-mine water and Saginaw Formation water are sometimes similar, determining which of the two waters may have mixed with glacial deposits water is felt to be impossible based on data obtained during this study.

SUMMARY AND CONCLUSIONS

Monitor and Williams Townships are in the east-central part of Michigan's Lower Peninsula. The townships are underlain by glacial deposits and the Saginaw Formation. Coal was mined from deposits in the Saginaw Formation during the early part of this century. Past coal-mining activity has been thought by some to affect the quality of domestic ground-water supplies in the area. Twenty observation wells were installed and many water samples analyzed to determine the quality of ground water in the townships.

Glacial deposits, 75 to 175 ft thick, are primarily clay underlain in places by sand and gravel. The clay yields little or no water to wells, whereas, the sand and gravel yields sufficient water to some wells for domestic needs.

The Saginaw Formation, which is several hundred feet thick, is primarily shale and silty shale containing beds of siltstone, fine-grained sandstone, and coal. Coal beds generally range in thickness from a few inches to 4 ft and are lenticular. The Saginaw Formation is a poor source of water supplies. Although small quantities of water can be withdrawn from sandstone and siltstone beds, the water generally is highly mineralized.

The specific conductance of water from wells in the study area indicates that dissolved-solids concentrations are higher than commonly found in other parts of the State. Water having the highest specific conductance (158,000 μS) was from a well in silty beds in the Saginaw Formation, about 1 mi from any significant coal beds or former mining activity.

The specific conductance of ground water indicates that dissolved-solids concentration increases as depth increases. About 50 percent of specific conductance values of water from wells more than 100 ft deep were equal to or greater than 5,000 μS; whereas only 13 percent of the values of water from wells less than 100 ft deep were 5,000 μS or greater. The lowest specific conductance values were commonly found in water from glacial deposits.

Detailed chemical analyses, including semiquantitative analyses for several trace metals, showed no apparent correlation of concentration with source for most constituents. Analyses for hydrocarbon gases showed only traces of methane in some samples.

Plots of chloride/sulfate ratios versus specific conductance suggest that water of the Saginaw Formation is as likely to influence the water-quality characteristics of water in the glacial deposits as is water from abandoned mines. Although water from abandoned mines could modify the quality of water in glacial deposits in some places, identification of such situations seems impossible, because waters from both abandoned mines and the Saginaw Formation may move to the glacial deposits in the vicinity of a pumped well; water withdrawn from a well in glacial deposits is likely to be a mixture of waters from other sources.

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DEFINITION OF TERMS

Altitude. Vertical distance of a point or line above or below sea level.

Aquifer. A formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs. It is also called a ground-water reservoir.

Bedrock. Designates consolidated rocks underlying glacial deposits.

Concentration. The weight of dissolved solids or sediment per unit volume of water expressed in milligrams per liter (mg/L) or micrograms per liter (μg/L).

Contour. An imaginary line connecting points of equal value, whether the points are on the land surface, on the clay surface, or on a potentiometric or water-table surface.

Ground water. Water that is in the saturated zone from which wells, springs, and ground-water runoff are supplied.

Ground-water divide. A line on a potentiometric or water-table surface on each side of which the potentiometric surface slopes downward away from the line.

Specific conductance. A measure of the ability of water to conduct an electric current, expressed in microsiemens (μS) per centimeter at 25°C. Because the specific conductance is related to amount and type of dissolved material, it is used for approximating the dissolved-solids concentration of water. For most natural waters the ratio of dissolved-solids concentration (in milligrams per liter) to specific conductance (in microsiemens) is in the range 0.5 to 0.8.

Water table. That surface in an unconfined water body at which the pressure is atmospheric. It is defined by levels at which water stands in wells.

 (p. 35 follows)

TABLES OF DATA

Table 3.--Chemical and physical characteristics of water in wells installed by U.S. Geological Survey

[Analyses by U.S. Geological Survey; a dash indicates not determined]

Well number[a]	Date of sample	Time	Depth of well, total (ft)	Temper-ature (deg C)	Tur-bid-ity (NTU)	Color (plat-inum-cobalt units)	Specific conduct-ance (µS)	Carbon dioxide, dis-solved (mg/L as CO_2)	pH (stand-ard units)	Silica, dis-solved (mg/L as SiO_2)	Calcium, dis-solved (mg/L as Ca)	Magne-sium, dis-solved (mg/L as Mg)	Sodium, dis-solved (mg/L as Na)	Potas-sium, dis-solved (mg/L as K)
B1F	May 16, 1984	1330	150	12.0	100	10	24,400	--	7.8	2.9	300	130	5,100	50
B2C	September 21, 1983	1715	212	10.0	11	1	27,000	0.1	8.2	.3	500	170	5,600	45
B3A	September 22, 1983	0930	202	11.0	55	1	8,960	.3	7.8	6.0	160	56	1,600	30
B4A	September 22, 1983	1450	182	13.0	140	2	12,000	46	6.8	7.4	470	200	1,800	34
B5F	September 21, 1983	1515	230	11.0	6.0	1	8,380	.8	8.6	1.8	130	51	1,700	16
B6A	September 22, 1983	1610	202	12.5	20	1	53,200	.4	7.0	1.5	990	330	13,000	96
B7F	September 22, 1983	1315	207	10.0	32	2	12,800	.1	8.1	.9	60	39	2,400	19
B8C	September 22, 1983	1100	147	10.5	40	1	17,400	.7	8.5	2.5	160	100	3,200	38
B9F	September 22, 1983	1430	142	11.0	6.5	1	33,600	19	7.2	5.9	240	100	7,500	40
B10C	September 22, 1983	1600	190	11.0	37	2	54,000	.5	8.2	1.8	410	230	11,000	77
B11F	October 6, 1983	1100	187	10.5	200	2	4,500	4.2	7.9	4.3	150	50	670	6.8
B12A	September 22, 1983	1155	141	11.0	100	2	10,000	--	5.6	37	280	120	1,600	31
B13A	September 22, 1983	0915	162	10.0	1.3	1	3,060	13	7.4	9.4	130	45	600	9.4
B14G	September 21, 1983	1640	76	10.0	35	2	5,360	18	7.1	13	250	82	700	5.8
B15A	September 22, 1983	1025	182	10.0	200	1	3,440	85	7.0	6.9	130	39	550	8.8
B16C	October 6, 1983	1330	160	13.0	10	1	[b]37,900	24	7.8	6.2	240	120	9,100	48
B17F	October 6, 1983	1500	204	11.0	50	1	158,000	29	7.6	5.5	1,300	510	28,000	120
B18A	September 22, 1983	1345	182	10.5	45	1	21,000	106	6.3	16	530	120	4,000	62
B19A	September 21, 1983	1145	210	11.5	28	1	43,400	560	6.4	8.8	730	360	8,500	72
B20F	May 16, 1984	1130	165	11.0	<1.0	10	4,750	--	7.9	9.6	50	18	870	8.5

[a]Letter following number in well number indicates source of water as follows:
A - from area of abandoned mine
C - from beds containing coal
F - from siltstone and sandstone beds in the Saginaw Formation
G - from glacial deposits

[b]Field measurement.

Table 3.--Chemical and physical characteristics of water in wells installed by U.S. Geological Survey--Continued

Well number	Sulfate, dis-solved (mg/L as SO_4)	Chlo-ride, dis-solved (mg/L as Cl)	Flou-ride, dis-solved (mg/L as F)	Nitro-gen, ammonia, total (mg/L as N)	Nitro-gen, nitrite, total (mg/L as N)	Nitrogen, nitrate + nitrite, total (mg/L as N)	Nitro-gen, organic, total (mg/L as N)	Phos-phorus, ortho, total (mg/L as P)	Phos-phorus, total (mg/L as P)	Carbon, organic, dis-solved (mg/L as C)	Cyanide, total (mg/L as CN)	Phenols, total (μg/L)	Alka-linity, lab (mg/L as $CaCO_3$)	Hardness (mg/L as $CaCO_3$)
B1F	18	9,400	0.5	4.7	0.01	<0.10	3.0	<0.01	0.01	--	<0.01	250	166	1,300
B2C	39	9,800	.30	5.3	<.01	<.10	1.0	<.01	.02	1.0	<.01	<1	28	1,950
B3A	180	2,800	.60	2.0	<.01	<.10	.20	<.01	.02	4.6	<.01	41	70	630
B4A	1,600	3,100	.40	2.7	.02	<.10	.40	<.01	.06	2.8	<.01	21	237	2,000
B5F	19	2,700	.40	1.8	.08	<.10	.50	<.01	.02	3.2	<.01	3	100	535
B6A	270	22,000	.20	6.6	.07	<.10	.00	<.01	.10	1.6	<.01	32	59	3,830
B7F	3.5	4,000	.50	2.1	<.01	<.10	.90	<.01	.04	1.5	<.01	35	105	310
B8C	19	5,800	.50	3.1	<.01	<.10	.50	<.01	.04	6.8	<.01	73	141	811
B9F	500	11,000	.20	5.2	.08	<.10	.40	<.01	.03	.5	<.01	2	195	1,010
B10C	6.1	20,000	.20	9.1	<.01	<.10	.00	<.01	.05	4.4	<.01	<1	82	1,970
B11F	130	1,200	<.10	<.01	<.01	.20	--	<.01	--	4.5	<.01	21	136	580
B12A	2,500	2,700	.10	4.1	<.01	<.10	.10	.01	.04	1.1	<.01	2	<1.0	1,190
B13A	370	710	.30	3.1	.08	<.10	.30	<.01	.03	2.3	<.01	49	333	510
B14G	410	1,300	.30	2.2	<.01	<.10	.90	<.01	.07	2.2	<.01	32	372	962
B15A	100	1,000	.40	1.7	<.01	<.10	2.0	<.01	.02	1.5	<.01	<1	175	485
B16C	1.2	14,000	<.10	3.2	<.01	<.10	--	<.01	--	.1	<.01	<1	244	1,080
B17F	160	50,000	.20	7.5	<.01	<.10	--	<.01	--	<.1	<.01	<1	148	5,300
B18A	720	6,700	.10	3.4	.07	<.10	.10	<.01	.08	.9	<.01	<1	87	1,820
B19A	2,600	14,000	<.10	5.9	<.01	<.10	.20	<.01	.02	1.6	<.01	1	485	3,300
B20F	5.4	1,400	.5	3.7	.02	.10	1.2	.11	.07	--	<.01	20	266	200

Table 3.--Chemical and physical characteristics of water in wells installed by U.S. Geological Survey--Continued

Well number	Hard-ness, noncar-bonate (mg/L as $CaCO_3$)	Acidity (mg/L as H)	Acidity (mg/L as $CaCO_3$)	Solids, sum of consti-tuents, dis-solved (mg/L)	Solids, redisue at 180 deg. C, dis-solved (mg/L)	Alum-inum, total recov-erable (µg/L as Al)	Arsenic, total (µg/L as As)	Barium, total recov-erable (µg/L as Ba)	Beryl-lium, total recov-erable (µg/L as Be)	Boron, total recov-erable (µg/L as B)	Cadmium, total recov-erable (µg/L as Cd)	Chro-mium, total recov-erable (µg/L as Cr)	Cobalt, total recov-erable (µg/L as Co)	Copper, total recov-erable (µg/L as Cu)
B1F	1,100	--	--	15,100	15,500	850	1	4,100	<10	1,600	<1	20	3	16
B2C	1,920	--	--	15,500	17,000	70	3	400	<10	1,600	<1	10	3	32
B3A	561	--	--	4,880	5,450	550	3	<100	<10	1,200	<1	20	7	31
B4A	1,760	<0.1	--	7,370	8,120	100	3	<100	<10	1,300	<1	20	16	180
B5F	435	--	--	4,680	4,610	130	3	--	<10	390	1	<10	4	20
B6A	3,780	--	--	31,400	36,700	600	2	<100	<10	1,600	<1	70	8	1,000
B7F	206	--	--	6,590	7,030	600	2	500	<10	1,300	<1	20	5	49
B8C	671	--	--	9,400	10,200	400	2	300	<10	1,100	<1	<10	5	66
B9F	817	--	--	19,500	19,700	70	2	<100	<10	2,800	<1	20	6	36
B10C	1,890	--	--	31,800	35,900	300	2	1,000	10	1,500	<1	50	6	81
B11F	445	--	--	2,290	2,540	6,300	3	<100	<10	260	4	40	22	70
B12A	1,190	11	546	--	7,490	<100	10	<100	<10	1,300	<1	20	8	20
B13A	178	--	--	2,070	1,840	40	2	<100	<10	370	<1	10	4	13
B14G	591	--	--	2,900	3,080	<100	3	200	<10	230	<1	30	11	190
B15A	311	--	--	1,940	2,070	1,000	3	<100	<10	690	<1	40	31	49
B16C	851	--	--	--	26,300	400	2	300	10	1,800	1	60	6	<10
B17F	5,200	--	--	80,200	76,000	700	2	--	20	1,300	1	80	8	180
B18A	1,730	.4	20	12,200	12,900	<10	4	200	10	1,800	1	20	11	40
B19A	2,850	.9	45	26,600	29,200	<100	6	300	<10	2,600	1	40	18	54
B20F	0	--	--	2,520	2,570	20	<1	600	<10	460	<1	10	2	8

Table 3.--Chemical and physical characteristics of water in wells installed by U.S. Geological Survey--Continued

Well number	Iron, total recov-erable (µg/L as Fe)	Iron, dis-solved (µg/L as Fe)	Lead, total recov-erable (µg/L as Pb)	Lithium, total recov-erable (µg/L as Li)	Manga-nese, total recov-erable (µg/L as Mn)	Manga-nese, dis-solved (µg/L as Mn)	Mercury, total recov-erable (µg/L as Hg)	Molyb-denum, total recov-erable (µg/L as Mo)	Nickel, total recov-erable (µg/L as Ni)	Sele-nium, total (µg/L as Se)	Silver, total recov-erable (µg/L as Ag)	Stron-tium, total recov-erable (µg/L as Sr)	Uranium, natural, dis-solved (µg/L as U)	Zinc, total recov-erable (µg/L as Zn)
B1F	2,300	60	500	110	200	130	1.2	3	7	1	<1	5,200	--	27,000
B2C	420	260	26	140	100	70	--	2	<1	<1	<1	9,900	<1.1	11,000
B3A	690	300	11	60	100	90	--	2	2	<1	<1	3,100	<.5	1,200
B4A	21,000	12,000	48	140	1,200	1,000	--	1	3	<1	<1	3,200	<4.0	68,000
B5F	440	40	21	30	20	20	<.1	1	2	<1	<1	2,600	<.5	6,000
B6A	1,500	590	900	140	220	170	.4	3	5	<1	<1	27,000	<1.5	26,000
B7F	1,500	90	300	50	70	<10	--	3	1	<1	<1	1,700	<.5	47,000
B8C	1,400	130	74	100	140	20	--	2	1	<1	<1	4,400	<.5	22,000
B9F	1,000	900	8	290	110	110	<.1	2	<1	<1	<1	6,000	<1.1	300
B10C	1,600	550	83	180	140	70	--	2	2	<1	<1	10,000	<1.1	15,000
B11F	19,000	270	33	40	500	30	<.1	7	26	<1	<1	1,900	<.4	6,900
B12A	--	410,000	300	120	8,000	7,100	<.1	<1	1	<1	<1	1,800	<.5	1,100
B13A	70	50	9	49	--	210	<.1	2	<1	<1	<1	1,500	<.5	4,000
B14G	3,000	3,000	10	30	320	300	--	4	1	<1	<1	3,600	<.5	850
B15A	45,000	3,400	24	110	1,600	350	<.1	2	110	1	<1	1,500	2.0	1,800
B16C	2,800	900	7	220	210	170	--	2	8	<1	<1	4,700	<1.1	1,300
B17F	6,400	3,900	8	210	700	600	.7	2	10	<1	<1	17,000	<1.4	1,200
B18A	12,000	12,000	13	110	--	1,800	--	2	3	<1	<1	3,900	<1.0	1,200
B19A	13,000	13,000	17	310	1,600	1,100	<.1	2	7	<1	<1	7,400	6.3	1,600
B20F	290	20	7	40	20	--	.4	1	3	<1	<1	1,100	--	900

Table 8.--Chemical analyses of major ions and pH of ground water in Bay County
[Analyses by the State of Michigan]

Well location	Land location	Source of water[a]	Calcium, dis-solved (mg/L as Ca)	Magne-sium, dis-solved (mg/L as Mg)	Sodium, dis-solved (mg/L as Na)	Potas-sium, dis-solved (mg/L as K)	Chlo-ride, dis-solved (mg/L as Cl)	Sulfate, dis-solved (mg/L as SO_4)	Bicar-bonate (mg/L as HCO_3)	Car-bonate (mg/L as CO_3)	pH, lab (units)
					Bangor Township (T14N,R5E)						
5143 Two Mile Road	14N5E 30BCBB	G	100	40	720	6.8	1,300	10	171	0	8.0
5165 S. Two Mile Road	30BCBC	--	150	68	2,200	23	3,600	18	290	0	7.8
					Beaver Township (T15N,R3E)						
2149 S. Nine Mile Road	15N3E 25BCBB	G	62	22	270	3.1	390	180	183	0	7.9
2161 S. Nine Mile Road	25BCBC	I	82	29	340	3.4	520	200	177	0	7.9
2258 S. Nine Mile Road	26DAAD	G	110	38	910	5.1	1,500	310	170	0	7.8
					Frankenlust Township (T13N,R4E)						
1183 Delta Road	13N4E 4CDCD	G	47	16	290	3.2	430	7.8	280	0	8.2
934 Hotchkiss Road	5AAAB	--	1.2	--	360	0.9	330	3.5	405	0	8.3
6259 Seven Mile Road	5CBBB	--	80	20	1,700	17	2,600	120	410	0	7.9
511 Delta Road	5CCCC	F	20	8.2	130	3.2	96	41	260	0	8.4
6331 Eight Mile Road	6CBCA	F	160	61	650	4.1	1,100	640	90	0	8.0
1380 Delta Road	9ABAA	--	150	59	23	.8	230	52	355	0	7.7
1417 Weiss Road	9ADCD	F	47	17	370	5.0	540	2.1	345	0	8.2
1131 Weiss Road	9BDCC1	G	43	15	230	2.8	320	12	310	0	8.2
1133 Weiss Road	9BDCC2	--	50	18	210	3.0	200	3.6	460	0	7.5
1201 Weiss Road	9BDDC	G	55	22	170	2.7	240	96	192	0	8.1
2323 E. Amlethe Road	11DCDC1	F	90	31	500	4.4	920	6.3	220	0	8.1
2323 E. Amlethe Road	11DCDC2	F	86	30	420	4.1	800	22	193	0	8.1
2901 E. Schwab Road	12ADCD	F	38	12	670	10	990	86	255	0	8.2
6815 Three Mile Road	12CBCB	F	24	13	370	4.9	490	13	300	6	8.6
2905 E. Amlethe Road	12DDCD	F	8.2	6.9	1,000	7.1	1,700	20	102	40	9.4
2916 Englehart Road	13DABA	F	63	28	530	3.3	410	4.0	360	0	8.0
2412 E. Amlethe Road	14AABA	F	75	25	510	7.6	860	26	205	0	8.2
7115 Bentwood Road	14ABCD1	F	62	23	400	8.0	600	61	205	0	8.2
7116 Bentwood Road	14ABCD2	F	70	24	430	9.3	690	60	195	0	8.2
1968 Kloha Road	15ADAB	--	65	23	420	4.8	680	2.5	255	0	8.2
1692 Kloha Road	15BDBA	--	53	23	390	6.9	580	1.4	305	0	8.2
7130 Mackinaw Road	16ADAA	G	48	20	600	6.7	870	3.9	315	0	8.3
1084 Amlethe Road	16BBAC	F	90	33	540	6.0	930	2.1	265	0	8.1
7115 Fraser Road	16BCBB	I	80	34	230	3.4	320	1.1	500	0	7.8
7135 Fraser Road	16BCBC	I	64	21	410	6.2	480	4.0	645	0	7.8
					Kawkawlin Township (T15N,R4E)						
670 Wetter Road	15N4E 17CABA	G	23	7	270	3.1	280	130	210	0	8.1
367 River Road	18DDCC	F	4	1	300	2.5	260	130	210	5	8.5
1987 Eight Mile Road	19CCCC	F	97	28	300	4.5	430	300	137	0	7.9
1578 Fraser Road	20AADA	F	83	22	520	6.7	750	190	181	0	7.9
2055 Seven Mile Road	29BBBC	F	190	50	1,300	10	2,300	300	156	0	7.7
2076 Mosher Road	30ABCB	F	140	41	790	5.9	1,300	300	144	0	7.7
					Merritt Township (T13N,R6E)						
769 W. Brown Road	13N6E 30BAAB	F	25	7	640	9.2	690	280	215	0	8.2
885 W. Brown Road	30BBAA	--	100	26	670	12	930	240	215	0	7.9
2107 S. Jones Road	30BBCC	--	130	50	17	1.5	27	120	470	0	7.8
824 Kinney Road	30CDCD	--	200	50	220	4.5	200	550	410	0	7.8
811 Merkel Road	31CAAB	G	180	73	830	14	1,400	340	335	0	7.5
2548 Burns Road	32BAAD	--	320	100	16,000	16	2,700	430	88	0	7.7
2711 Knight Road	32BCCB	--	270	87	1,500	12	2,500	680	145	0	7.9
E. Kinney Road	35BBBA	--	1,000	200	13,000	45	19,000	3,800	76	0	7.5

[a]Letter in column indicates source of water as follows:
F - from siltstone and sandstone beds in the Saginaw Formation
G - from glacial deposits
I - from interface of glacial deposits and Saginaw Formation

Table 8.--Chemical analyses of major ions and pH of ground water in Bay County--Continued

Well location	Land location	Source of water	Calcium, dis-solved (mg/L as Ca)	Magne-sium, dis-solved (mg/L as Mg)	Sodium, dis-solved (mg/L as Na)	Potas-sium, dis-solved (mg/L as K)	Chlo-ride, dis-solved (mg/L as Cl)	Sulfate, dis-solved (mg/L as SO_4)	Bicar-bonate (mg/L as HCO_3)	Car-bonate (mg/L as CO_3)	**pH, lab (units)**
Monitor Township (T14N,R4E)											
1300 E. Chip Road	14N4E 4DBBA	F	82	26	620	7.8	1,000	62	290	0	8.1
3446 Fraser Road	5DDDD	G	140	49	640	8.0	1,300	100	199	0	7.5
53 Wheeler Road	6CCDC	I	210	89	56	2.9	270	220	620	0	7.2
451 Wheeler Road	6DDDC	G	96	38	330	3.9	600	100	185	0	8.0
3517 Eight Mile Road	7BBBB	G	48	13	13	2.9	18	37	154	0	8.0
3863 Eight Mile Road	7CBCD	G	450	160	1,300	9.3	2,500	1,100	460	0	7.2
253 E. Wilder Road	7CDDD	G	230	76	720	6.0	1,400	380	385	0	7.3
295 E. Wilder Road	7DCCA	G	150	51	440	4.2	1,000	66	189	0	7.9
265 E. Wilder Road	7DCCB	G	170	57	460	4.0	1,300	81	168	0	7.8
315 E. Wilder Road	7DCDB	G	140	46	450	4.4	960	64	215	0	8.0
329 E. Wilder Road	7DCDC	G	110	40	400	3.8	830	19	260	0	8.1
3939 Fraser Road	9CCCB	F	79	24	2,100	12	2,800	100	193	0	8.1
2181 N. Union Road	14CDCD	G	7.7	2.8	260	.6	120	89	390	0	7.5
1256 E. Wilder Road	16ABBB	G	120	55	37	2.0	140	96	355	0	7.9
4133 Fraser Road	16BBCC	I	410	130	1,000	9.7	1,000	820	380	0	7.3
1281 N. Union Road	16DCCD	G	200	75	75	5.0	310	31	345	0	7.4
450 E. Wilder Road	18AAAC	--	140	49	560	4.8	1,100	140	199	0	8.0
1866 N. Union Road	22ABAA	G	97	43	320	4.4	590	44	270	0	7.9
5183 Four Mile Road	26BCBC	G	44	19	170	1.9	260	2.7	280	0	7.7
5864 Seven Mile Road	31DADD	F	52	20	10	1.8	15	42	182	0	8.0
5904 Seven Mile Road	31DDAD	F	310	54	610	8.5	870	1,200	162	0	7.5
1377 Hotchkiss Road	33DCCD	I	44	30	340	4.8	450	170	275	0	8.1
1427 Hotchkiss Road	33DDCD	--	89	40	990	12	--	22	330	0	7.8
1467 Hotchkiss Road	33DDDC	F	97	50	860	12	1,500	7.5	245	0	7.9
Williams Township (T14N,R3E)											
1355 N. Union Road	14N3E 16DCDD	--	400	140	880	24	1,200	2,400	39	0	6.0
2718 Salzburg Road	36BAAA	--	270	99	43	.7	380	290	415	0	7.7

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