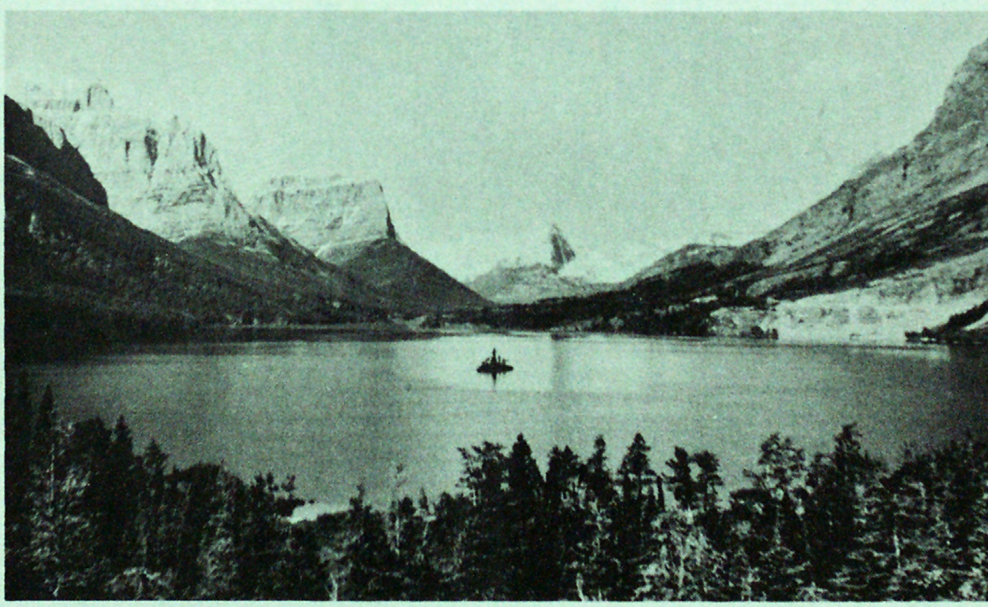
APPRAISAL OF GROUND-WATER QUALITY NEAR WASTEWATER-TREATMENT FACILITIES, GLACIER NATIONAL PARK, MONTANA

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 82-4



Prepared in cooperation with the
NATIONAL PARK SERVICE

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Water-level and water-quality data were collected from monitoring wells at wastewater-treatment facilities in Glacier National Park. Five additional shallow observation wells were installed at the Glacier Park Headquarters facility to monitor water quality in the shallow ground-water system.

Water-level, water-quality, and geologic information indicate that some of the initial monitoring wells are not ideally located to sample ground water most likely to be affected by waste disposal at the sites. Small differences in chemical characteristics between samples from monitor wells indicate that effluent may be affecting ground-water quality but that impacts are not significant.

Future monitoring of ground-water quality could be limited to selected wells most likely to be impacted by percolating effluent. Laboratory analyses for common ions could detect future impacts.

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Front cover: Photograph showing Wild Goose Island in Saint Mary Lake, about 6 miles southwest of Saint Mary. View is southwest from Going to the Sun Highway.

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Helena, Montana
June 1982

UNITED STATES DEPARTMENT OF THE INTERIOR

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CONTENTS

ILLUSTRATIONS

TABLES

METRIC CONVERSION TABLE

The following factors can be used to convert inch-pound units in this report to the International System (SI) of metric units.

Multiply inch-pound unit	By	To obtain metric unit
foot	0.3048	meter
gallon per day (gal/d)	3.785	liter per day
gallon per minute (gal/min)	0.06309	liter per second
inch	0.02540	meter
micromho	1.000	microsiemens
mile	1.609	kilometer

National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "mean sea level." NGVD of 1929 is referred to as sea level in this report.

APPRAISAL OF GROUND-WATER QUALITY NEAR WASTEWATER-TREATMENT FACILITIES, GLACIER NATIONAL PARK, MONTANA

by Joe A. Moreland and Wayne A. Wood

ABSTRACT

Water-level and water-quality data were collected from monitoring wells at wastewater-treatment facilities in Glacier National Park. Five additional shallow observation wells were installed at the Glacier Park Headquarters facility to monitor water quality in the shallow ground-water system.

Water-level, water-quality, and geologic information indicate that some of the initial monitoring wells are not ideally located to sample ground water most likely to be affected by waste disposal at the sites. Small differences in chemical characteristics between samples from monitor wells indicate that effluent may be affecting ground-water quality but that impacts are not significant.

Future monitoring of ground-water quality could be limited to selected wells most likely to be impacted by percolating effluent. Laboratory analyses for common ions could detect future impacts.

INTRODUCTION

Glacier National Park (fig. 1) in northwestern Montana is visited by about 1.8 million persons during the primary tourist season, which extends from about mid-May to late September each year. Wastewater-treatment facilities have been constructed at Glacier Park Headquarters (herein called Headquarters) and Many Glacier and a third facility at Saint Mary began operation in the spring of 1981 to treat and dispose of wastewater generated by visitors and park employees.

The National Park Service requested that the U.S. Geological Survey investigate ground-water quality at the three facilities to determine if it had been affected by wastewater treatment and disposal practices. The National Park Service also requested that a program be developed to monitor any future impacts.

Purpose and scope

The purposes of this report are to describe the ground-water quality and to present a monitoring program designed to detect any ground-water-quality changes resulting from the park's wastewater-treatment programs.

Three facilities were inspected to determine the general hydrologic conditions. Water samples were collected from existing observation wells to document ground-water quality. Effluent samples were collected from the Headquarters and Many

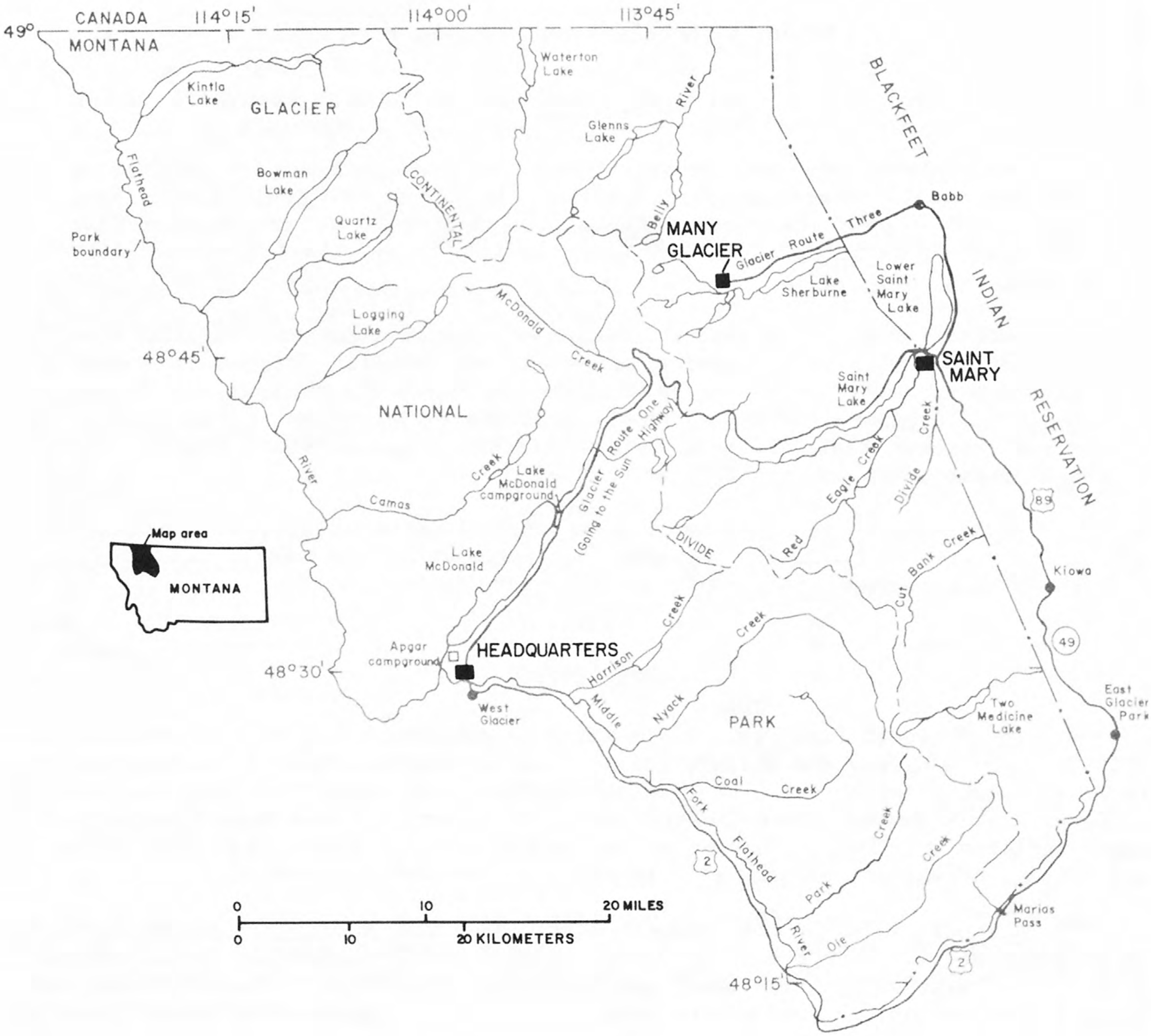

Figure 1.--Areas of study at Headquarters, Many Glacier, and Saint Mary.

Glacier facilities to determine the quality of the wastewaters. Five shallow observation wells were installed in the Headquarters spray field to supplement existing monitoring wells. National Park Service personnel were given instruction and provided with equipment and forms to monitor water-level fluctuations in observation wells.

Sampling procedures and sample processing

Samples collected during this study were submitted to the Analytical Division, Montana Bureau of Mines and Geology, for determination of common ions and selected trace elements. Water temperature, specific conductance, and pH were measured onsite at the time of collection. Samples were filtered, acidified, chilled, or otherwise preserved in accordance with standard methods of collection and preservation of water samples (Frank Abercrombie, Montana Bureau of Mines and Geology, written commun., 1980).

Before a sample was collected, the observation wells were pumped at a rate of about 11 gal/min using a portable submersible pump. Sufficient water was removed to ensure collection of representative aquifer water rather than water stored in the well casing. The shallow, small-diameter wells were sampled using a vacuum pump.

HEADQUARTERS

Description of facilities

The Headquarters wastewater-treatment facility receives sewage from the lodge areas near Apgar and Lake McDonald campgrounds and the Headquarters complex. The facility is designed to process 250,000 gal/d. Wastewater is piped to an aerated lagoon system where aerobic digestion is used to treat the sewage. Effluent from the lagoons is piped to a spray field located in a corral area on an alluvial flood plain between McDonald Creek and the Middle Fork Flathead River. Plants use part of the effluent through evapotranspiration and the remaining effluent infiltrates into the soil and enters the underlying aquifer system.

Four 6-inch-diameter observation wells were installed by the National Park Service in the spray field during 1975 to monitor ground-water quality (fig. 2). The wells range in depth from 30 to 52 feet and are perforated from 10 feet below land surface to the bottom of the well (table 1). Wells H-1 and H-2 are adjacent to McDonald Creek on the west side of the spray field. Well H-3 is located on a terrace northeast of the spray field. Well H-4 is adjacent to the Middle Fork Flathead River on the south side of the spray field. Five shallow observation wells were installed by the Geological Survey during this study near the center of the spray field in a northwest-trending line. The 1¼-inch-diameter wells range in depth from 7.7 to 11.4 feet. Each well has a 2.5-foot well screen at the bottom. The shallow wells are identified as H-A, H-B, H-C, H-D, and H-E in figure 2.

Geohydrologic setting

The spray field is underlain by unconsolidated alluvial deposits composed of clay, silt, sand, and gravel. Drillers' logs of the observation wells (table 2)

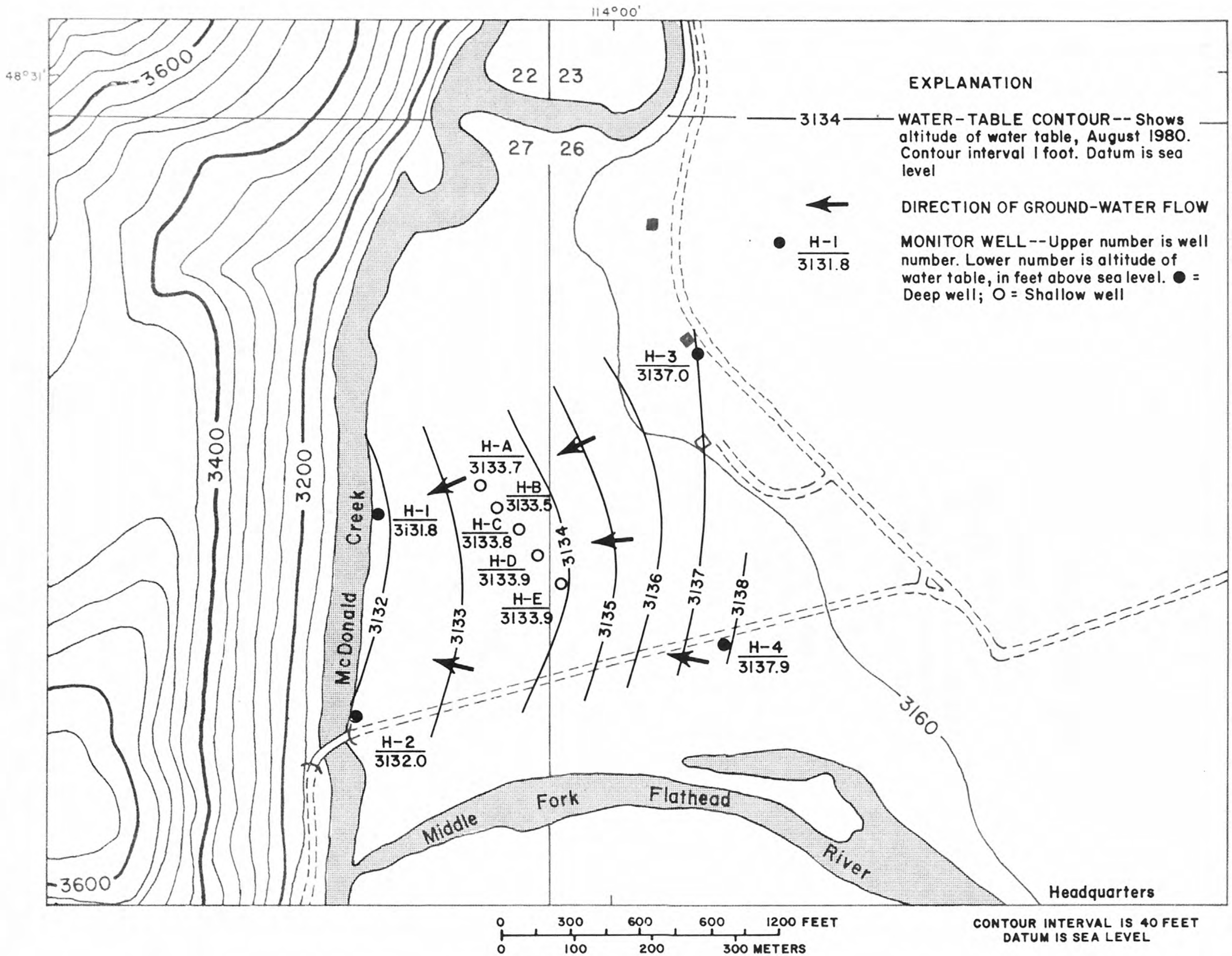

Figure 2.--Altitude of water table, direction of ground-water flow, and location of wells at Headquarters wastewater-treatment facility.

denote that the upper few feet of the unconsolidated deposits is predominately fine-grained material. Beneath the fine-grained material are layers of sand and gravel. Because the sand and gravel layers are more permeable than the finer grained material, water moves preferentially through them. The 6-inch-diameter wells, which are perforated in both the finer-grained material and the coarser sand and gravel layers, yield water primarily from the deeper, more permeable layers.

The direction of ground-water flow is generally to the west toward McDonald Creek (fig. 2). Ground water enters the spray field from the north and east and flows through the unconsolidated material under a gradient of about 1 foot per 200 feet. Water from the Middle Fork Flathead River probably recharges the ground-water system along the southern edge of the spray field. Based on the direction of flow, it is apparent that observation wells H-2, H-3, and H-4 are not down-gradient from the spray field.

The water table fluctuates in response to changes in stage of the Middle Fork Flathead River and McDonald Creek. Water levels from the observation wells (table 3) indicate that the water table is highest during the spring when the river and creek are high. The water table recedes about 1 to 5 feet during the year to the seasonal low during late summer.

Wastewater sprayed over the field would tend to remain in the upper part of the aquifer because of the layering of sediments. However, the fluctuations in the water table would cause mixing and would allow wastewater to percolate downward toward the permeable sand and gravel layers. Once the wastewater reaches the saturated zone, its predominant direction of movement is downgradient toward McDonald Creek.

Ground-water chemistry

Ground water at the Headquarters facility is dominated by calcium and bicarbonate with small concentrations of magnesium, sodium, chloride, and sulfate. The effluent from the wastewater treatment facility conversely is a sodium bicarbonate type water with significant concentrations of calcium and chloride.

As plotted on a trilinear water-quality diagram (fig. 3), the ground-water samples cluster in one region of the diagram. The effluent sample plots in a distinctly different location. Based strictly on the proportions of dissolved ions, there appears to be little or no mixing of effluent with the ground water. If significant mixing were occurring, affected ground-water samples would plot along a line trending toward the effluent sample.

However, if individual constituents in samples from each well are examined, subtle differences can be identified that indicate some mixing of effluent with ground water beneath the spray field. For example, chloride and potassium concentrations are larger in samples from wells H-1 and H-3 than in samples from wells H-2 and H-4 (table 4). Because concentrations of these two constituents are substantially larger in the effluent water than concentrations in the ground water, one might infer that mixing has occurred. Well H-3 is upgradient from the spray field, however, and would not be subject to contamination from that source. If effluent has mixed with ground water at well H-3, its source was the lagoon system rather than the spray field.

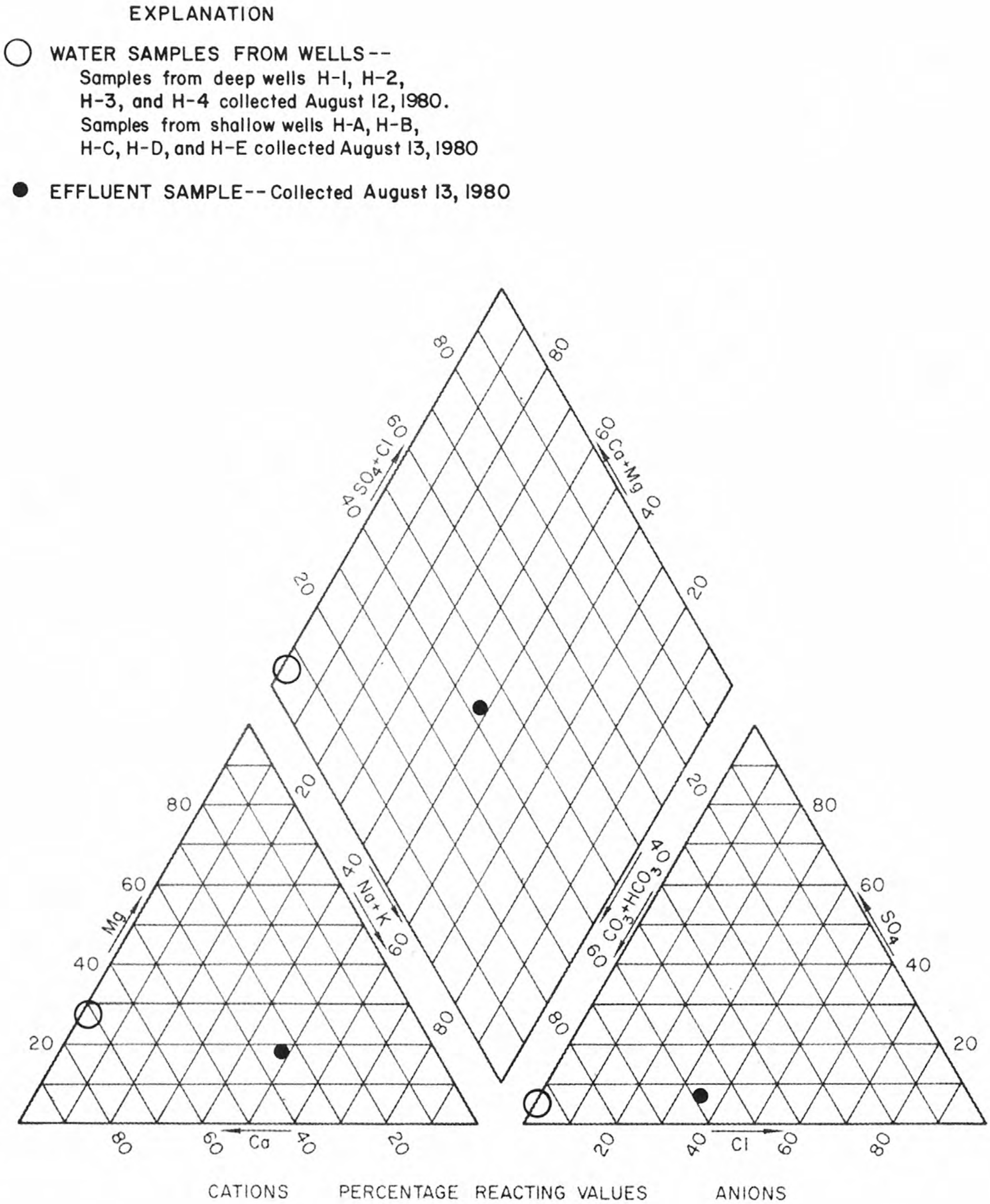

Figure 3.--Ground-water and effluent-water quality at Headquarters wastewater-treatment facility.

The concentrations of dissolved constituents in samples from well H-4 are significantly smaller than in the other ground-water samples. Samples from well H-2 are also more dilute than other samples, but much less so than those from well H-4. The smaller concentrations in samples from wells H-2 and H-4 may be the result of recharge from the Middle Fork Flathead River. This information substantiates the earlier statement that wells H-2 and H-4 are not downgradient from the spray field and, therefore, would not be affected by the effluent. The water samples from shallow wells H-A, H-B, H-C, H-D, and H-E generally contained slightly larger concentrations of sodium, sulfate, and chloride than the samples from wells H-2 and H-4.

Nitrate concentrations commonly are used to detect contamination of ground water by sewage effluent. The ground-water samples from the Headquarters facility contained nitrate (as nitrogen) in concentrations ranging from 0.02 to 0.56 mg/L (milligram per liter). None of the samples consistently contained nitrate concentrations larger than about 0.2 mg/L. These concentrations are considerably less than the 10 mg/L maximum contaminant level established by the U.S. Environmental Protection Agency (1977) for public drinking-water supplies.

The sample of effluent (table 5) contained detectable concentrations of aluminum, boron, cadmium, copper, iron, strontium, and zinc. Copper, aluminum, and strontium appear to be widespread in the system and, therefore, are not particularly useful in tracing the movement of effluent. Concentrations of the other trace metals were less than, or only slightly more than, the detectable limits in samples from the four deep observation wells. The only exception was a zinc concentration of 27 µg/L (micrograms per liter) in the sample from well H-1 collected on August 12, 1980.

Most of the samples from the shallow wells installed within the spray field contained detectable concentrations of boron, cadmium, iron, and zinc. This condition strongly implies that effluent has mixed slightly with the shallower ground water beneath the spray field.

Future monitoring

The data collected during this study can serve as baseline information for future studies of ground-water quality. Unless significant increases in constituent concentrations are determined, continued sampling of wells H-2 and H-4 seem unnecessary.

Samples collected during the early spring and late summer from the shallow observation wells and from wells H-1 and H-3 would provide ample evidence of any significant increases in constituent concentrations associated with operation of the spray field and lagoon system. Chemical analysis for common ions would be sufficient to detect future impacts. Specifically, the samples could be analyzed for sodium, potassium, magnesium, calcium, bicarbonate, sulfate, chloride, and nitrate. Minor constituents including iron, manganese, phosphates, and trace metals could be included if concentrations of common ions increase significantly.

When samples are collected, onsite determinations of water temperature, specific conductance, and pH would provide a check for significant increases in constituent concentrations. Effluent samples collected during the summer would be useful

in identifying potential contaminants. Chemical analysis for the common ions listed previously probably would be sufficient for this purpose unless significant increases in constituent concentrations occur.

MANY GLACIER

Description of facilities

Wastewater from the Many Glacier tourist facility is treated in an aerated lagoon system. Four percolation ponds located on Appekunny Flat near the northern end of Lake Sherburne are used for effluent disposal. The facility is designed to process 140,000 gal/d. Part of the effluent evaporates from the ponds but most infiltrates through the bottoms and sides of the ponds and recharges the underlying ground-water system.

Four 6-inch-diameter observation wells were installed by the National Park Service around the ponds during 1975 (fig. 4). The wells range in depth from 30 to 40 feet and are perforated from 10 feet below land surface to the well bottom (table 1). Well MG-1 is located on an alluvial fan north of the ponds. Wells MG-2, MG-3, and MG-4 are located near a marshy area east and south of the ponds.

Geohydrologic setting

The ponds at the Many Glacier facility are underlain by unconsolidated clay, sand, and gravel. The drillers' logs for the observation wells (table 2) denote that the upper material is predominately clay with a few thin layers of sand or gravel. A sand and gravel aquifer underlies the clay deposits.

Ground water flows southwest toward Lake Sherburne under a gradient of about 1 foot per 10 feet. A swampy area south and west of the ponds attests to the fact that ground water discharges through springs and seeps immediately downgradient from the ponds.

The water levels for well MG-1, upgradient from the ponds, decline about 6 feet between May and August (table 3). However, the water levels in the observation wells downgradient from the ponds fluctuate less than 3 feet from the spring high to the summer low. Evidently, the proximity of the discharge area stabilizes water-level fluctuations in the downgradient wells.

Although the observation wells are perforated from 10 feet below land surface to the well bottom, the character of the sediments indicates that the wells would obtain most of their yield from the lower sand and gravel layer. Shallower and thinner layers of sand and gravel are probably discontinuous and areally limited. During May 1980, the static water level in well MG-4 was above land surface, indicating that the lower sand and gravel aquifer is confined by the overlying clay layers, at least when water levels are high.

This evidence implies a limited hydraulic connection between the upper material directly beneath the ponds and the lower sand and gravel layer that yields most of the water to the observation wells. The probable relationship between the ponds, the swampy area, and the lower sand and gravel layer is illustrated in figure 5.

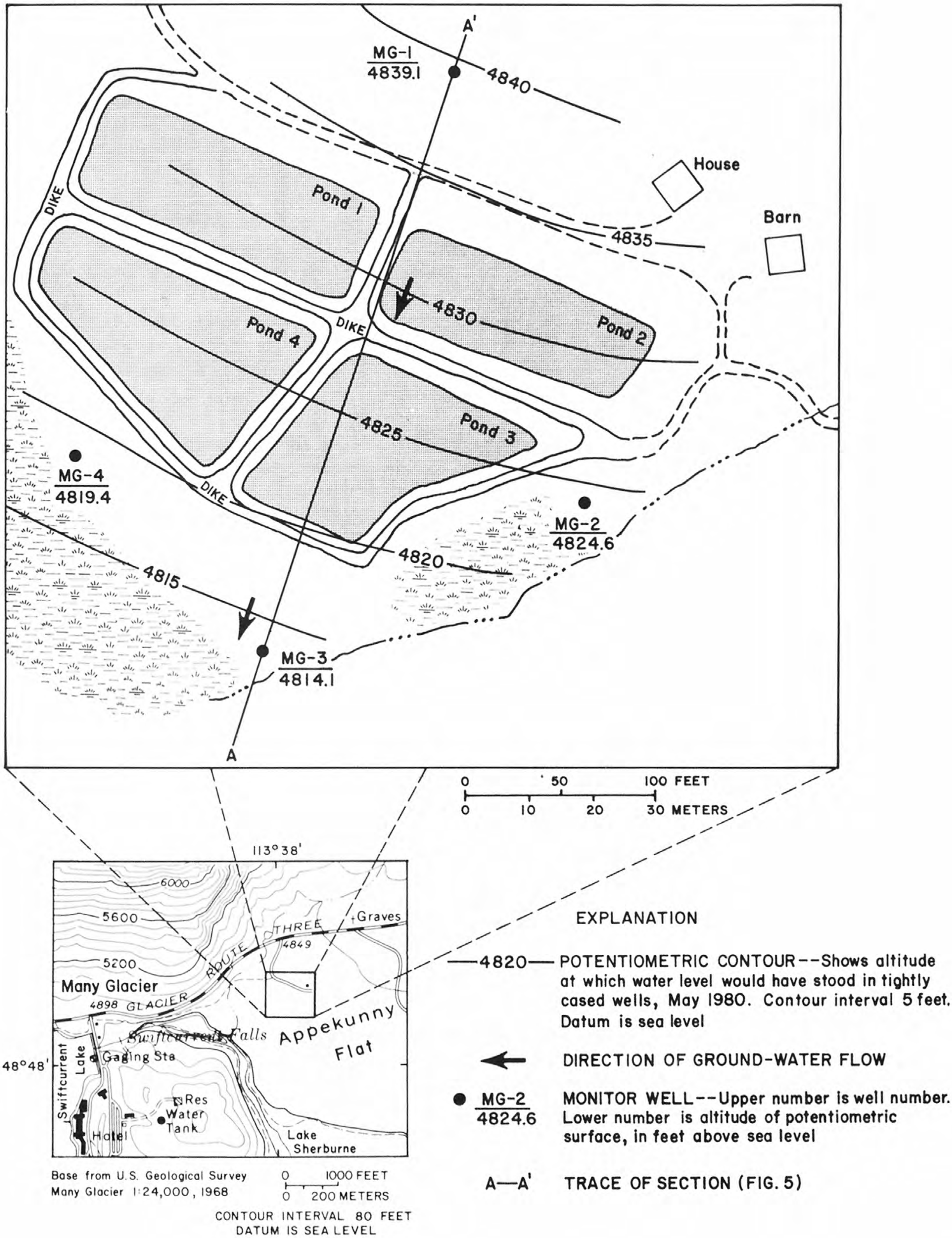

Figure 4.--Altitude of potentiometric surface, direction of ground-water flow, and location of wells at Many Glacier wastewater-treatment facility.

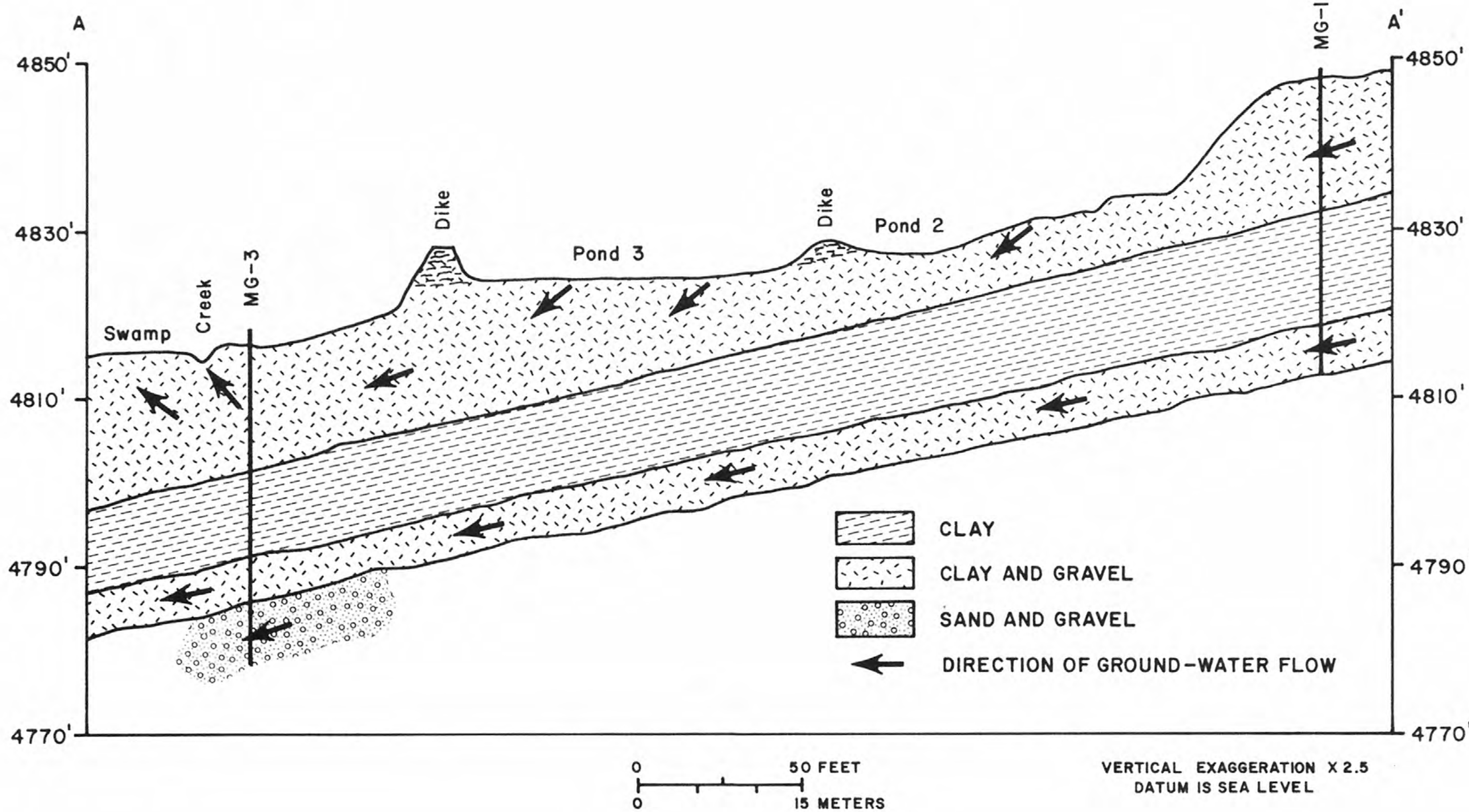

Figure 5.--Geohydrologic section of ground-water flow at Many Glacier wastewater-treatment facility. Trace of section is shown on figure 4.

Ground-water chemistry

Ground water at the Many Glacier facility contains principally calcium, magnesium, and bicarbonate ions with small concentrations of sodium, chloride, and sulfate (table 4). Effluent from the facility is a sodium bicarbonate type water with significant concentrations of calcium and chloride.

As plotted on a trilinear water-quality diagram (fig. 6), three of the ground-water samples cluster in one region of the diagram. The effluent sample plots in a distinctly different location. On the cation part of the diagram, the sample from well MG-3 plots along an imaginary line trending from the other ground-water samples to the effluent sample. This alinement of points suggests that water from well MG-3 contains a mixture of ground water and effluent. However, no similar pattern is apparent for anions, which may indicate that other factors are affecting the chemical character of water from well MG-3. Natural softening or ion exchange may be the cause of the increase in sodium concentration.

The concentrations of dissolved ions in samples from well MG-1, upgradient from the percolation ponds, and well MG-4, downgradient from the lagoons, are remarkably similar. This condition indicates that water from well MG-4 is probably not affected by effluent from the ponds as hypothesized from the geologic conditions at the site. Water samples from wells MG-2 and MG-3 contain larger concentrations of most constituents--notably sodium, potassium, and chloride--which implies that these wells may yield some water from the upper sand and gravel layers.

Nitrate concentrations in samples from wells MG-1 and MG-4 ranged from 0.01 to 0.21 mg/L. Nitrate concentrations in samples from wells MG-2 and MG-3, however, ranged from about 0.01 to 1.1 mg/L.

Effluent contained detectable concentrations of aluminum, boron, cadmium, chromium, copper, iron, lithium, manganese, strontium, titanium, and zinc (table 5). Aluminum, chromium, copper, iron, lithium, and strontium were detected in water from all the wells, and titanium was found in water from all wells except well MG-3. Boron was found in detectable concentrations in water from wells MG-2, MG-3, and MG-4. Zinc was detected in one of the three samples from well MG-1, and in samples from wells MG-2 and MG-3 but not well MG-4. The occurrence of trace elements in samples from wells MG-2 and MG-3 provides further evidence that effluent affects those wells.

Future monitoring

Water-quality data collected during this study can serve as baseline information for future studies of ground-water quality. However, additional water samples from springs and seeps downgradient from the ponds would be useful in monitoring movement of effluent through the shallow ground-water system.

Samples collected from observation wells during the early spring and late summer could be analyzed for common ions including calcium, magnesium, sodium, bicarbonate, sulfate, chloride, and nitrate to monitor future conditions. Onsite determinations of water temperature, specific conductance, and pH would indicate the need, if any, for more detailed analyses.

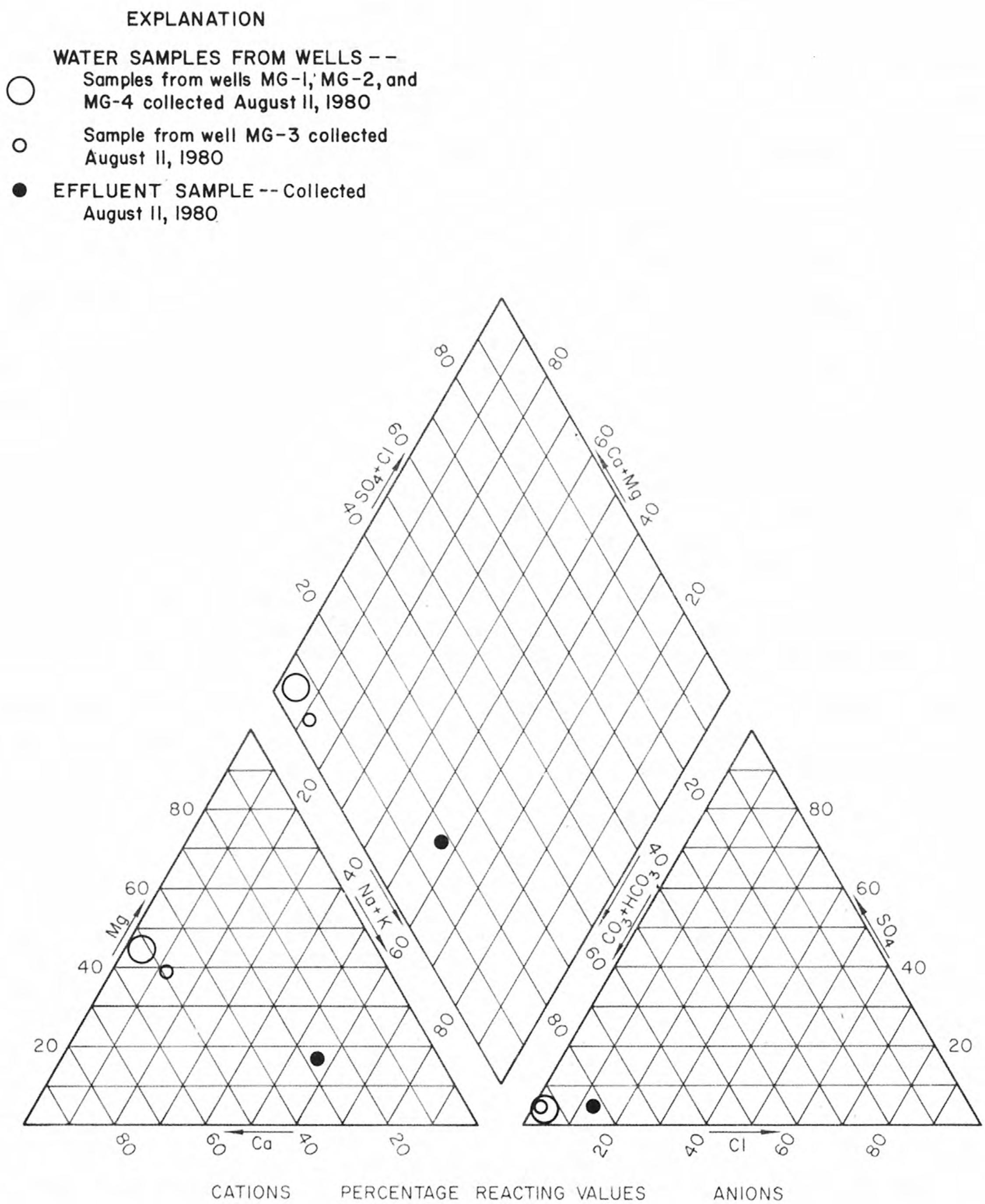

Figure 6.--Ground-water and effluent-water quality at Many Glacier wastewater-treatment facility.

Effluent samples collected during the summer would be useful in identifying potential contaminants. Chemical analysis for the common ions listed previously probably would be sufficient for this purpose unless significant increases in constituent concentrations occur.

SAINT MARY

Description of facilities

The Saint Mary wastewater treatment facility was under construction during this study. When completed, the facility will receive sewage wastes from the park facilities at Saint Mary and nearby camp areas. Wastewater will be treated in an activated sludge plant having a design capacity of 107,000 gal/d. Effluent disposal will be in percolation-evaporation ponds located between Divide Creek and Saint Mary Lake. Part of the effluent will evaporate from the ponds but most will percolate to the underlying ground-water system.

Four 6-inch-diameter observation wells were installed by the National Park Service around the percolation ponds during 1979. The wells range in depth from 44 to 80 feet with perforated-casing intervals ranging from 10 to 60 feet below land surface and extending to the bottom of each well (table 1). Well SM-1 is located southeast of the ponds and between the ponds and Divide Creek. Well SM-2 is located west of the ponds. Wells SM-3 and SM-4 are north of the ponds.

Geohydrologic setting

The Saint Mary facility is underlain by coarse sand, gravel, and boulders deposited as an alluvial fan by Divide Creek. The drillers' logs (table 2) for the observation wells denote no fine-grained material that would retard downward movement of effluent from the ponds.

Water in Divide Creek infiltrates rapidly into the coarse sand and gravel deposits and flows westerly toward Saint Mary Lake (fig. 7). The water-table gradient is difficult to determine, because the ground-water body is mounded beneath Divide Creek and is virtually flat near Saint Mary Lake.

The direction of ground-water flow as shown on figure 7 indicates that well SM-1 is upgradient from the percolation ponds. Wells SM-3 and SM-4 appear to be outside the ground-water flow path from the ponds. Well SM-2 is located downgradient from the ponds and within the path of ground-water flow from them.

The water table fluctuates about 10 feet from the high during late spring to the low during late summer (table 3). The range of fluctuations attests to the fact that recharge from Divide Creek is significant during spring runoff. After spring recharge, the water table recedes rapidly to about the level of Saint Mary Lake.

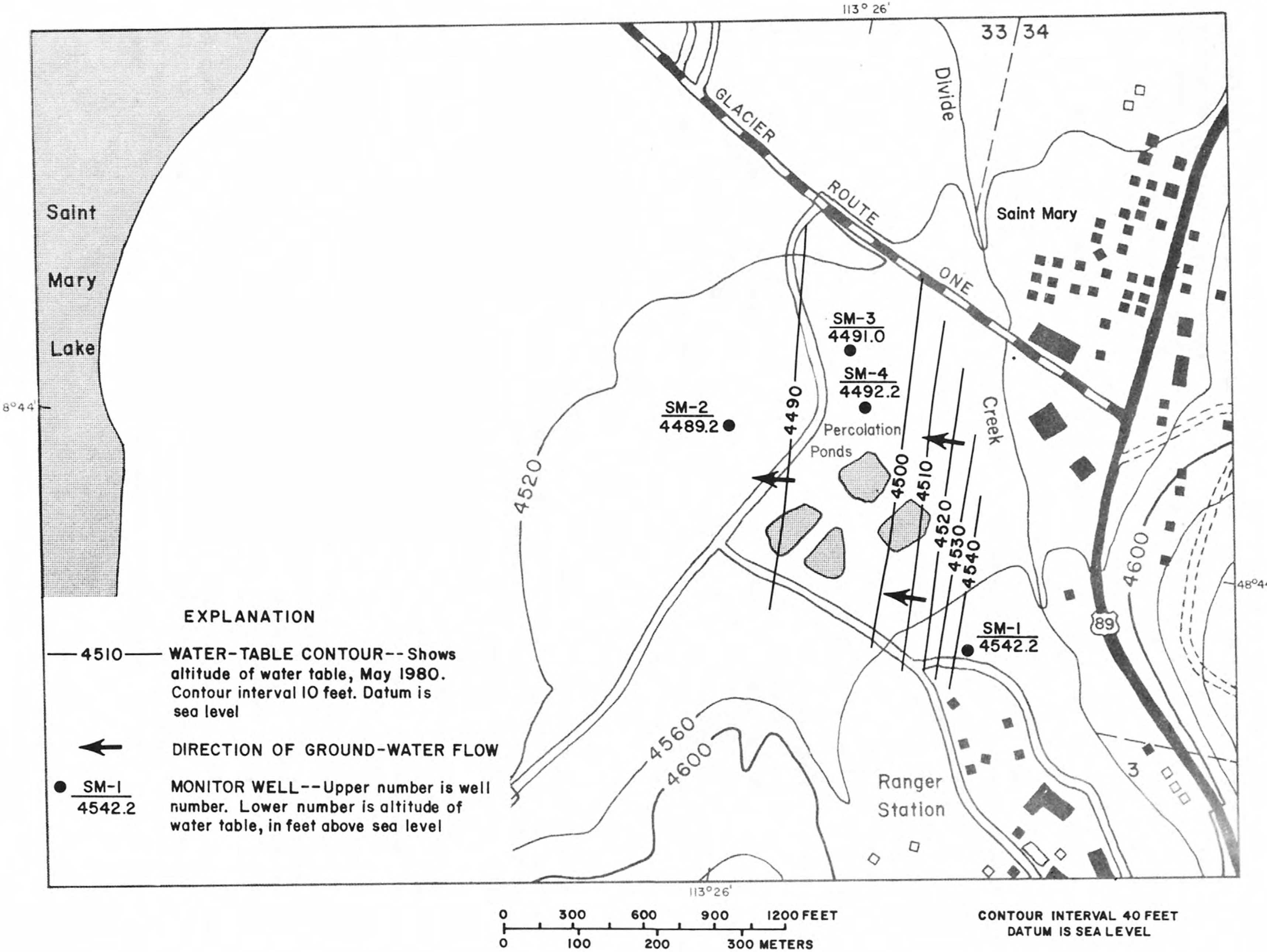

Figure 7.--Altitude of water table, direction of ground-water flow, and location of wells at Saint Mary wastewater-treatment facility.

Ground-water chemistry

Only one set of water samples was collected at the Saint Mary facility because the system was under construction during the study. The samples indicate that the ground water contains principally calcium, magnesium, and bicarbonate with small concentrations of sodium and chloride (table 4).

As plotted on a trilinear water-quality diagram (fig. 8), the samples cluster at one location. However, the concentrations of calcium, magnesium, bicarbonate, chloride, sulfate, and nitrate are slightly larger in samples from wells SM-1 and SM-2. This slight variation in quality between wells SM-1 and SM-2 and wells SM-3 and SM-4 may be related to the location of the wells. The two southerly wells (SM-1 and SM-2) are located downgradient from the park complex and may be affected by effluent from septic tanks.

The samples from all four wells contain detectable concentrations of aluminum, chromium, copper, lithium, molybdenum, strontium, titanium, and vanadium (table 5). Samples from wells SM-2, SM-3, and SM-4 contained silver. Samples from wells SM-2 and SM-3 contained lead.

Future monitoring

Water-quality data collected during this study can serve as baseline information for future studies of ground-water quality. After the facility begins operation, samples could be collected during the early spring and late summer from wells SM-1 and SM-2 to monitor ground-water quality.

Samples could be analyzed for common ions including calcium, magnesium, sodium, bicarbonate, sulfate, chloride, and nitrate. Onsite determination of water temperature, specific conductance, and pH would indicate the need for more detailed analyses.

Unless significant lateral movement of ground water occurs perpendicular to the primary direction of flow, no changes in water quality are likely to occur at wells SM-3 and SM-4. Future sample collection from these wells could be limited to one sample per year unless significant increases in constituent concentrations occur.

Effluent samples collected during the summer would be useful in identifying potential contaminants. Chemical analysis for the common ions listed previously probably would be sufficient for this purpose unless significant increases in constituent concentrations occur.

CONCLUSIONS

Water-quality samples collected from monitoring wells at three wastewater-treatment facilities provide a comprehensive base of information on dissolved constituents and trace elements contained in ground water at the sites. Although many of the existing wells are not downgradient from the facilities or are not completed in the aquifers most likely to be impacted by effluent, the data are useful in describing the present (1980) ground-water-quality conditions.

EXPLANATION

O WATER SAMPLES FROM WELLS--
Samples from wells SM-1, SM-2, SM-3, and SM-4. Collected May 29, 1980

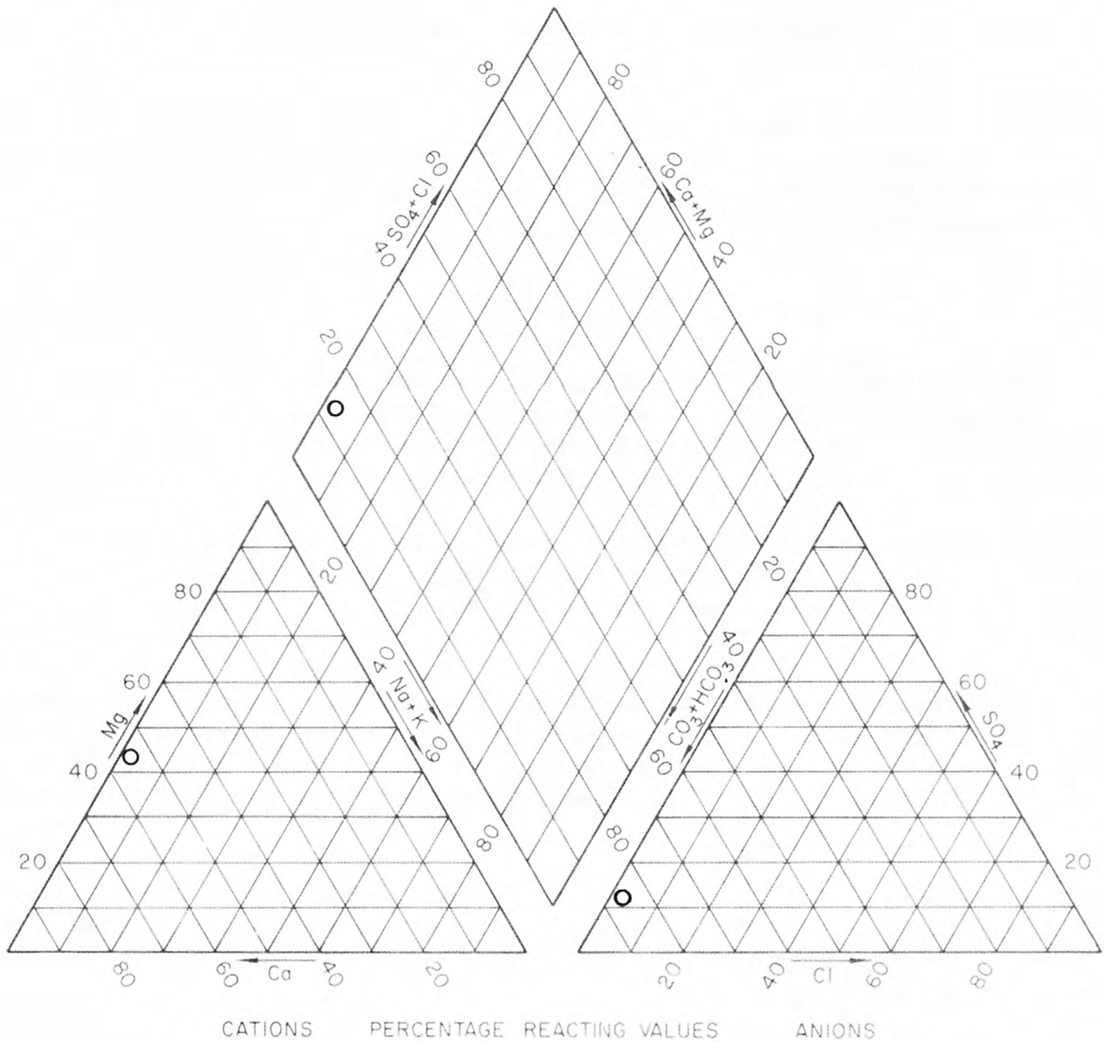

Figure 8.--Ground-water quality at Saint Mary wastewater-treatment facility.

Water-quality differences between samples from wells and effluent indicate that subtle variations might be related to percolating effluent. However, no significant impacts were noted.

At the Headquarters facility, five shallow wells installed in the spray field yielded water containing larger concentrations of sodium, sulfate, and chloride than those in wells H-2 and H-4. Wells H-1 and H-3 yielded water containing slightly larger concentrations of chloride than wells H-2 and H-4. This information implies that sewage effluent is percolating to the ground-water system but significant impacts were not observed.

At Many Glacier, wells MG-2 and MG-3 yielded water containing larger concentrations of most dissolved constituents than water from wells MG-1 and MG-4, which provides evidence that effluent may be slightly affecting ground-water quality. Water from well MG-4 appears to be from a deeper aquifer not affected by effluent from the percolation ponds.

The Saint Mary facility was not operational during this study. Data collected from the four monitoring wells provide information for future reference. Water-level information collected from the wells indicates that wells SM-1, SM-3, and SM-4 are either upgradient from the percolation ponds, or outside the ground-water flow path.

Future monitoring at the sites could be limited to onsite measurements of water temperature, specific conductance, and pH and laboratory analysis of water samples for calcium, magnesium, sodium, bicarbonate, sulfate, chloride, and nitrate concentrations. Samples collected during early spring and late summer from the shallow wells and deep wells H-1 and H-3 would be useful in monitoring the effects of waste-disposal practices at the Headquarters facility. Samples collected during early spring and late summer from springs and seeps downgradient from the percolation ponds and from wells at the Many Glacier facility would document the movement of effluent through the shallow ground-water system. Samples collected during early spring and late summer from wells SM-1 and SM-2 at the Saint Mary facility would be useful in monitoring the movement of effluent through the ground-water system. Chemical analyses for major ions in effluent samples from each facility are needed to identify potential contaminants.

REFERENCE CITED

U.S. Environmental Protection Agency, 1977, National interim drinking water regulations: EPA 570/9-76-003, 159 p.

Table 1.--*Records of wells*

Number	Well depth (feet)	Perforated interval (feet)	Casing diameter (inches)	Date completed (month-day-year)	Approximate altitude of land surface (feet above sea level)
H-1	35	10-35	6	09-11-75	3,150
H-2	35	10-33	6	08-27-75	3,150
H-3	52	10-52	6	09-10-75	3,165
H-4	30	10-30	6	09-02-75	3,145
H-A	11.4	8.9-11.4	1.25	06-30-80	3,150
H-B	7.7	5.2-7.7	1.25	06-30-80	3,150
H-C	10.4	7.9-10.4	1.25	07-01-80	3,150
H-D	10.4	7.9-10.4	1.25	07-01-80	3,150
H-E	10.2	7.7-10.2	1.25	07-01-80	3,150
MG-1	35	10-35	6	08-05-75	4,850
MG-2	40	10-40	6	08-07-75	4,825
MG-3	38	10-38	6	08-12-75	4,815
MG-4	30	10-30	6	08-15-75	4,820
SM-1	44	10-44	6	09-27-79	4,560
SM-2	75	55-75	6	09-27-79	4,530
SM-3	80	60-80	6	09-28-79	4,530
SM-4	80	60-80	6	10-01-79	4,535

Table 2.--*Drillers' logs of wells*

Lithology	Thickness (feet)	Depth (feet)
	H-1	
Clay, brown	11	11
Sand and gravel	1	12
Clay, tan	13	25
Sand and gravel	10	35
	H-2	
Clay, brown; sand and gravel	4	4
Clay, brown; and boulders	6	10
Clay, tan; sand and gravel	2	12
Clay, tan; and gravel	8	20
Sand and gravel	15	35
	H-3	
Clay, tan; and gravel	10	10
Clay, tan	22	32
Sand and gravel	16	48
Silt	4	52
	H-4	
Sand and clay, tan	11	11
Sand and gravel	1	12
Clay, tan; sand and gravel	10	22
Silt	8	30
	MG-1	
Clay, tan; and boulders	12	12
Clay, tan; and gravel	3	15
Clay, tan	14	29
Clay, red; and gravel	6	35
	MG-2	
Soil	2	2
Clay, red; sand and gravel	7	9
Sand and gravel	18	27
Clay, red; and gravel	12	39
Sand and gravel	1	40

Lithology	Thickness (feet)	Depth (feet)
	MG-3	
Soil	3	3
Clay, brown; and gravel	12	15
Clay, tan	10	25
Clay, tan; and gravel	5	30
Sand and gravel	8	38
	MG-4	
Soil	2	2
Clay, dark-brown; and gravel	9	11
Clay, tan; and gravel	17	28
Sand and gravel	1	29
Sand	1	30
	SM-1	
Gravel	44	44
	SM-2	
Gravel	75	75
	SM-3	
Gravel and sand	80	80
	SM-4	
Gravel	80	80

Table 3.--*Water levels in wells, 1980*

Well number	Date measured (month-day)	Water level (feet below land surface)	Well number	Date measured (month-day)	Water level (feet below land surface)
H-1	05-28	2.89	H-A	07-25	7.50
	07-11	6.90		08-08	8.10
	07-25	7.70		08-13	8.16
	08-08	8.30		08-22	8.10
	08-12	8.35		09-05	8.00
	08-22	8.20		09-19	8.20
	09-05	8.00		09-25	7.41
	09-19	8.20			
	09-24	7.37	H-B	07-02	3.49
				07-03	4.62
H-2	07-11	7.60		07-11	5.40
	07-25	8.50		07-25	6.20
	08-08	9.10		08-08	6.80
	08-12	9.22		08-13	6.82
	08-22	8.90		08-22	6.80
	09-05	8.80		09-05	6.70
	09-19	9.00		09-19	6.90
	09-24	8.14		09-25	6.22
H-3	05-28	25.49	H-C	07-02	5.56
	07-11	26.60		07-03	5.67
	07-25	27.40		07-11	6.50
	08-08	27.90		07-25	7.20
	08-12	28.00		08-08	7.80
	08-22	28.55		08-13	7.88
	09-05	28.80		08-22	7.90
	09-19	28.90		09-05	7.80
	09-24	28.76		09-19	8.00
				09-25	7.28
H-4	07-11	5.20			
	07-25	5.90	H-D	07-02	6.03
	08-08	6.40		07-03	6.13
	08-12	6.44		07-11	7.00
	08-22	6.40		07-25	7.70
	09-05	6.45		08-08	8.20
	09-19	6.60		08-13	8.31
	09-24	6.16		08-22	8.20
				09-05	8.20
H-A	07-02	5.80		09-19	8.40
	07-03	5.93		09-25	7.74
	07-11	6.70			

Well number	Date measured (month-day)	Water level (feet below land surface)	Well number	Date measured (month-day)	Water level (feet below land surface)
H-E	07-02	6.24	MG-3	05-29	2.45
	07-03	6.42		06-29	1.75
	07-11	7.10		07-06	1.85
	07-25	7.80		07-14	1.95
	08-08	8.40		07-21	2.09
	08-13	8.55		07-29	2.21
	08-22	8.40		08-05	2.37
	09-05	8.40		08-10	2.33
	09-19	8.60		08-11	2.32
	09-25	7.95		08-18	2.32
				08-25	2.20
MG-1	05-29	8.56		08-31	2.28
	06-29	11.05		09-09	2.34
	07-06	11.22		09-16	2.29
	07-14	11.96		09-23	2.06
	07-21	12.64			
	07-29	13.26	MG-4	05-29	-0.20
	08-05	13.63		06-29	.30
	08-10	14.32		07-06	.45
	08-11	14.33		07-14	.71
	08-18	14.66		07-21	.91
	08-25	13.08		07-29	1.12
	08-31	13.65		08-05	1.40
	09-09	14.24		08-10	1.45
	09-16	13.61		08-11	1.48
	09-23	11.25		08-18	1.56
				08-25	1.23
MG-2	05-29	1.52		08-31	1.36
	06-29	2.50		09-09	1.52
	07-06	2.51		09-16	1.32
	07-14	2.85		09-23	.78
	07-21	3.04			
	07-29	3.25	SM-1	05-29	19.89
	08-05	3.57		07-16	25.93
	08-10	3.80		08-01	26.93
	08-11	3.90		08-12	26.19
	08-18	4.17		08-19	27.89
	08-25	3.54		09-15	27.89
	08-31	3.58		09-24	29.58
	09-09	3.97			
	09-16	3.70	SM-2	05-29	39.89
	09-23	2.88		07-16	44.60

Table 3.--*Water levels in wells, in 1980*--Continued

Well number	Date measured (month-day)	Water level (feet below land surface)	Well number	Date measured (month-day)	Water level (feet below land surface)
SM-2	08-01	46.94	SM-3	09-15	48.16
	08-12	48.42		09-24	47.88
	08-19	48.83			
	09-15	49.90	SM-4	05-29	42.41
	09-24	49.44		07-16	49.11
				08-01	50.69
SM-3	05-29	37.89		08-12	51.26
	07-16	44.10		08-19	52.01
	08-01	45.60		09-15	53.56
	08-12	46.28		09-24	53.18
	08-19	46.85			

Table 4.--*Common constituents in water samples*

[Constituents are dissolved and constituent values are reported in milligrams per liter. Analyses by Montana Bureau of Mines and Geology. Abbreviations and symbols: micromhos, micromhos per centimeter at 25 degrees Celsius; °C, degrees Celsius; <, less than]

Sample site	Date of collection (month-day-year)	Depth of well (feet)	Laboratory specific conductance (micromhos)	Onsite pH (units)	Onsite water temperature (°C)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)
								Headquarters facility				
H-1	05-28-80	35	360	7.6	5.5	60	12	1.2	0.9	220	0	7.8
	08-12-80		360	7.1	8.0	59	12	1.6	.5	220	0	6.3
	09-24-80		330	7.4	8.0	54	10	1.4	.7	210	0	6.4
H-2	08-12-80	35	300	7.9	7.0	47	9.8	1.2	.6	180	0	5.1
	09-24-80		270	7.5	8.0	44	9.2	1.0	.6	170	0	6.2
H-3	05-28-80	52	330	7.7	6.0	53	10	1.2	1	210	0	3.9
	08-12-80		410	7.4	6.5	67	13	1.8	.7	260	0	4.6
	09-24-80		220	7.2	6.5	68	14	1.7	1	180	0	4.5
H-4	08-12-80	30	190	7.5	15.0	29	6.8	.9	.5	110	0	6.0
	09-24-80		180	8.2	11.0	26	6.3	.7	.5	110	0	6.0
H-A	07-02-80	11.4	360	7.5	7.5	56	11	2.1	.7	220	0	4.8
	08-13-80		360	7.5	9.0	56	11	1.8	.4	230	0	6.5
	09-25-80		340	7.2	9.0	55	11	1.7	.5	210	0	3.3
H-B	07-02-80	7.7	380	7.6	10.5	59	12	2.2	.6	230	0	6.8
	08-13-80		350	7.4	9.0	55	11	1.6	.6	220	0	6.4
	09-25-80		350	7.2	10.0	57	11	2.0	.9	220	0	6.5
H-C	07-02-80	10.4	340	7.6	6.5	54	11	1.7	.6	210	0	12
	08-13-80		310	7.4	9.5	49	9.8	1.4	.6	190	0	5.5
	09-25-80		310	7.4	11.0	49	9.5	1.3	.4	190	0	6.2
H-D	07-02-80	10.4	310	7.6	6.0	48	9.7	1.3	.2	190	0	6.2
	08-13-80		260	7.7	10.5	40	8.5	1.2	.4	150	0	5.7
	09-25-80		--	7.8	12.0	41	8.5	1.1	.5	160	0	5.7
H-E	07-02-80	10.2	380	7.7	9.0	60	12	1.4	.6	240	0	7.4
	08-13-80		310	7.6	15.0	48	9.2	1.2	.5	190	0	6.1
	09-25-80		300	7.9	15.0	48	9.0	1.0	.7	180	0	6.6
Effluent	08-13-80	--	390	10.1	28.0	21	7.0	28	11	110	0	11
								Many Glacier facility				
MG-1	05-29-80	35	120	--	5.0	13	6.6	.5	.5	69	0	3.6
	08-11-80		110	--	6.0	12	6.2	.9	<.1	66	0	3.7
	09-23-80		120	7.5	6.5	14	7.0	.9	.3	73	0	4.3
MG-2	05-29-80	40	200	--	6.5	22	11	.9	3.2	120	0	5.0
	08-11-80		220	7.3	9.0	23	12	1.3	2.2	130	0	1.9
	09-23-80		220	6.9	8.0	24	12	1.1	2.0	130	0	6.1
MG-3	08-11-80	38	220	7.0	9.5	21	11	5.2	1.1	120	0	3.7
	09-23-80		180	7.2	8.0	18	8.9	4.6	.9	97	0	4.4
MG-4	05-29-80	30	130	--	5.5	15	7.5	.6	.5	78	0	4.3
	08-11-80		120	7.3	6.0	13	6.4	1.0	.2	69	0	4.3
	09-23-80		110	8.1	5.0	13	6.3	.9	.2	68	0	4.0
Effluent	08-11-80	--	410	8.9	16.0	16	5.6	35	8	190	0	9.0
								Saint Mary facility				
SM-1	05-29-80	44	410	7.7	3.0	51	24	1.3	.9	230	0	28
SM-2	05-29-80	75	400	--	6.0	49	23	1.5	.9	230	0	27
SM-3	05-29-80	80	340	--	6.5	41	19	1.5	.8	190	0	20
SM-4	05-29-80	80	340	--	6.5	42	20	1.5	.9	200	0	23

Chloride (Cl)	Fluoride (F)	Silica (SiO_2)	Dissolved solids, sum of constituents	Nitrate, as N	Phosphorus (P)
3.0	0.1	7.5	316	0.42	0.032
1.2	<.1	7.5	311	.10	.028
.9	<.1	7.6	290	.14	.026
.2	<.1	5.8	252	.06	.003
.7	<.1	6.0	237	.06	.011
2.4	.1	18	296	.40	.100
1.0	<.1	20	370	.44	.114
.9	.1	27	295	.03	.360
.4	<.1	5.5	161	.56	.013
.9	.2	4.8	154	.08	.125
.4	.1	6.9	303	.30	.031
1.9	<.1	6.9	312	.23	.019
1.1	<.1	7.3	289	.15	.029
2.2	.2	6.9	316	.30	.032
1.7	<.1	6.9	300	.23	.016
1.3	.2	7.1	306	.15	.018
2.8	.2	7.0	298	.20	.034
.6	<.1	7.4	269	.14	.028
.9	<.1	7.2	265	.15	.022
1.4	.1	6.3	262	.20	.027
.5	<.1	7.0	216	.13	--
.6	<.1	6.8	219	.09	.018
2.6	<.1	6.5	326	.02	.057
1.0	<.1	6.0	259	.06	.058
.6	<.1	6.4	253	.08	.018
38	<.1	6.1	230	.01	2.53
.2	.1	3.8	97	.15	.010
.5	<.1	3.8	93	.21	--
.6	<.1	4.2	104	.01	.012
2.7	.1	4.4	167	.66	.070
.3	<.1	5.0	175	.03	.034
2.0	<.1	4.9	182	.34	.011
.3	<.1	4.5	166	<.01	.034
1.4	<.1	4.3	140	1.1	.018
<.1	<.1	4.2	110	.13	.019
.5	<.1	3.8	98	.12	.016
.6	<.1	3.9	97	.05	.014
19	<.1	3.1	284	.09	2.79
2.1	.1	5.1	346	.71	.016
2.1	.1	5.9	336	.24	.025
2.0	.1	5.7	284	.20	.049
.6	.1	5.6	289	.19	.025

Table 5.--*Trace elements in water samples*

[Constituents are dissolved and constituent values are reported in micrograms per liter. Dashes indicate constituent concentration was less than the detection limit. Analyses are by Montana Bureau of Mines and Geology]

Sample site	Date of collection (month-day-year)	Aluminum (Al)	Boron (B)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Iron (Fe)	Lead (Pb)	Lithium (Li)	Manganese (Mn)	Molybdenum (Mo)	Nickel (Ni)	Silver (Ag)	Strontium (Sr)	Titanium (Ti)	Vanadium (V)	Zinc (Zn)	Zirconium (Zr)
Detection limit		30	20	2	2	2	10	40	2	10	20	10	2	1	1	1	4	4
Headquarters facility																		
H-1	05-28-80	60	--	--	10	7	10	--	8	--	30	--	--	71	22	20	--	--
	08-12-80	--	--	--	--	6	120	290	2	--	--	--	--	--	--	--	27	4
	09-24-80	140	--	--	2	9	130	--	3	--	--	--	5	66	11	2	--	--
H-2	08-12-80	50	--	--	--	4	40	--	--	10	--	--	--	67	12	--	--	--
	09-24-80	150	--	3	--	12	90	--	5	10	--	--	9	62	12	6	--	5
H-3	05-28-80	70	--	--	10	7	740	--	8	80	30	--	--	45	--	22	--	--
	08-12-80	--	--	--	--	--	950	--	--	70	--	--	--	56	17	--	--	--
	09-24-80	160	20	3	--	14	1,900	--	4	220	--	--	9	65	15	80	--	--
H-4	08-12-80	--	--	--	--	4	10	--	--	--	--	--	--	53	9	--	--	--
	09-24-80	140	--	--	--	7	20	--	--	--	--	--	6	47	9	1	--	--
H-A	07-02-80	--	--	5	4	7	20	--	--	--	40	30	--	70	15	--	61	--
	08-13-80	--	--	--	2	5	30	--	--	--	--	--	3	65	6	--	66	5
	09-25-80	--	100	2	4	--	110	--	--	--	--	--	--	65	--	--	54	--
H-B	07-02-80	80	--	9	8	9	80	--	--	10	30	20	--	70	17	3	145	--
	08-13-80	--	--	--	--	3	40	--	--	--	20	--	--	64	5	--	71	--
	09-25-80	--	70	2	--	--	100	--	--	--	--	--	--	65	--	--	79	--
H-C	07-02-80	70	--	5	--	10	20	--	--	--	30	10	--	71	19	--	30	--
	08-13-80	--	30	2	2	4	40	40	2	--	--	20	--	65	2	--	53	--
	09-25-80	--	40	2	--	--	120	--	--	--	--	--	--	62	2	--	36	--
H-D	07-02-80	50	--	3	--	7	20	--	--	--	40	20	--	69	20	--	13	--
	08-13-80	--	--	--	--	--	60	--	--	--	--	--	--	59	11	--	27	--
	09-25-80	70	20	--	--	7	--	--	--	--	--	--	--	59	5	2	--	--
H-E	07-02-80	60	20	6	4	7	80	--	--	20	30	30	--	80	17	--	130	--
	08-13-80	30	--	--	--	5	30	60	--	20	20	20	3	62	5	--	430	--
	09-25-80	80	20	--	--	9	150	--	--	--	--	--	6	62	9	1	540	7
Effluent	08-13-80	30	220	7	--	7	40	--	--	--	--	--	--	31	--	--	19	--
Many Glacier facility																		
MG-1	05-29-80	100	--	--	12	6	--	--	9	--	--	--	3	39	--	21	--	33
	08-11-80	--	--	4	--	--	--	120	--	--	--	--	--	38	3	--	7	--
	09-23-80	90	--	--	--	3	10	--	6	--	--	--	4	42	3	--	--	--
MG-2	05-29-80	50	--	--	13	7	--	--	8	--	40	--	7	58	4	22	--	--
	08-11-80	--	40	--	2	3	20	50	--	--	20	--	--	61	--	--	10	--
	09-23-80	70	30	--	--	3	20	--	3	--	--	--	--	65	4	--	--	--
MG-3	08-11-80	--	30	--	3	4	60	--	3	20	--	20	--	61	--	--	11	--
	09-23-80	50	--	--	--	3	20	--	2	--	--	--	--	52	--	--	--	--
MG-4	05-29-80	40	--	--	9	4	--	--	9	--	--	--	--	50	2	20	--	--
	08-11-80	30	--	--	2	2	--	40	--	--	--	--	--	43	--	--	--	--
	09-23-80	70	20	--	--	--	--	--	--	--	--	--	--	43	--	--	--	--
Effluent	08-11-80	30	80	2	4	9	100	--	3	20	--	--	--	46	2	--	49	--
Saint Mary facility																		
SM-1	05-29-80	80	--	--	10	2	--	--	9	--	20	--	--	68	5	22	--	--
SM-2	05-29-80	70	30	--	15	7	--	130	12	--	30	--	5	66	4	22	--	--
SM-3	05-29-80	120	--	--	17	11	--	60	11	--	20	--	7	58	4	28	--	--
SM-4	05-29-80	130	--	2	17	10	--	--	12	--	20	--	7	58	4	24	--	--