PREPARED IN COOPERATION WITH
THE MONTANA BUREAU OF MINES AND GEOLOGY

GROUND WATER

WATER RESOURCES

GROUND WATER

The largest quantity of good quality ground water in the study area is found in the unconsolidated deposits. Wells drilled into the Cretaceous rocks yield only small quantities of poor quality water, except for the Judith River Formation and the Eagle Sandstone, which yield small quantities of water of fair quality.

The unconsolidated deposits are about 50 feet thick in the central part of the valley floor and increase to about 120 feet thick along the north border. The thickness of these deposits at any point can be estimated by subtracting the altitude of the base of the alluvium as shown on the hydrologic map from the altitude of land surface.

The depth to water in the unconsolidated deposits can be estimated by subtracting the altitude of the water-table contours shown on the hydrologic map from the altitude of the land surface. The contours are representative of a period of high water levels; the water table is lower during winter and spring. The water table fluctuates according to the season and fluctuations are greatest near irrigation canals as is shown by the well hydrographs.

Ground water moves down the hydraulic gradient. Water-table contours show that ground water in the unconsolidated deposits moves toward the Yellowstone River and contributes to the flow of the river. Some of the ground water discharges into streams, springs, and drainage ditches and is carried to the Yellowstone River as surface flow.

In some areas the water table coincides with the land surface forming marshes or waterlogged land. Where waterlogging interferes with farming, a system of drainage ditches are dug to lower the water table. Waterlogged areas or areas of high water table are common along the Yellowstone River especially along the north edge of terrace 2 between Park City and Billings and from 2 to 5 miles west of Billings along Grand Avenue. Drainage-ditch systems are used extensively in these areas. The drainage system and those areas where waterlogging is a problem are shown on the hydrologic map.

Storage

The quantity of water stored in the unconsolidated deposits during August 1968 was estimated to be about 180,000 acre-feet. This estimate was made by calculating the volume of saturated alluvium and multiplying by assumed specific yields of 0.12 for gravel, 0.08 for sand, and 0.05 for silt. Annual fluctuations of the water table are estimated to cause a change in storage of about 30,000 acre-feet.

Well Yield From Unconsolidated Deposits

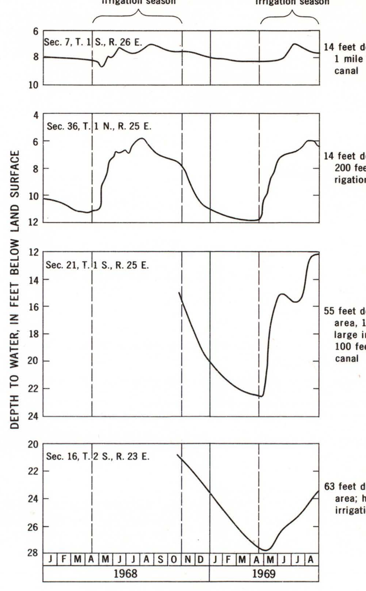
The amount of water that can be pumped from the unconsolidated deposits is determined largely by the type and thickness of saturated material tapped by the well. Gravel yields water to wells at a faster rate than sand, and sand yields water to wells at a much faster rate than does silt or silty clay. Results of pumping tests made during the study are summarized in tabular form.

Quality

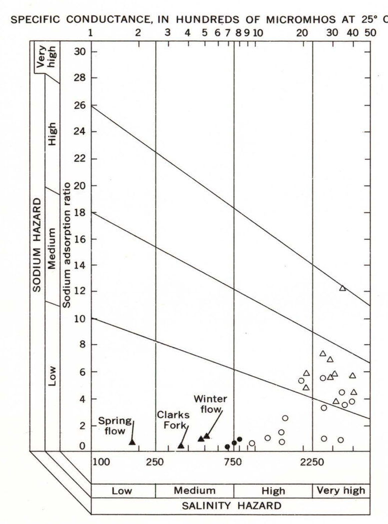
The chemical quality governs the utility of the water. Except in small areas, ground water is too highly mineralized to be suitable for human consumption, but the water can be used for livestock. The areal variation of water quality is shown on the hydrologic map by the conductivity data. The majority of residents outside service areas of the municipal water systems of Billings and Laurel haul city water for domestic purposes. Ground water that contains less than 1,500 mg/l (milligrams per liter) dissolved solids generally is satisfactory for domestic uses; the best ground-water supply in the area contains 300 to 800 mg/l dissolved solids. Water having concentrations above 1,500 mg/l is used by some residents, but water that has a dissolved-solids concentration greater than 2,500 mg/l is seldom used by area residents.

The ground water of the study area is characterized by very high concentrations of sulfate and sodium (see ground water-quality table).

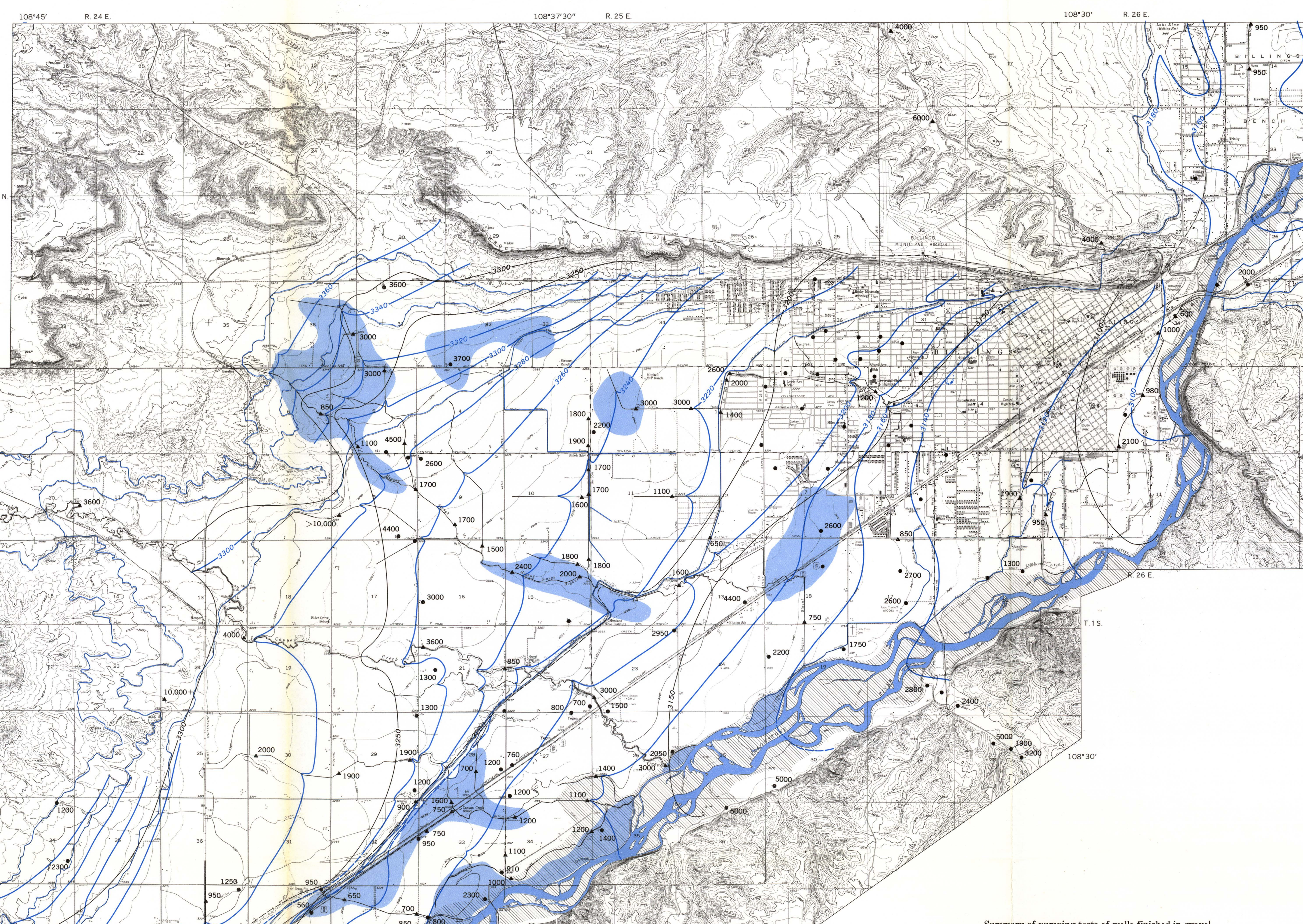
The suitability of water for irrigation according to its specific conductance and sodium adsorption ratio is shown on the diagram classifying water for irrigation use. Most ground water from wells near the river could be used for irrigation. Water from the deposits beneath the second and third terraces contains abundant sodium and dissolved solids and is marginal for irrigation use. However, it is not expected that ground water would be used for irrigation because of the large supply available from the Yellowstone River.

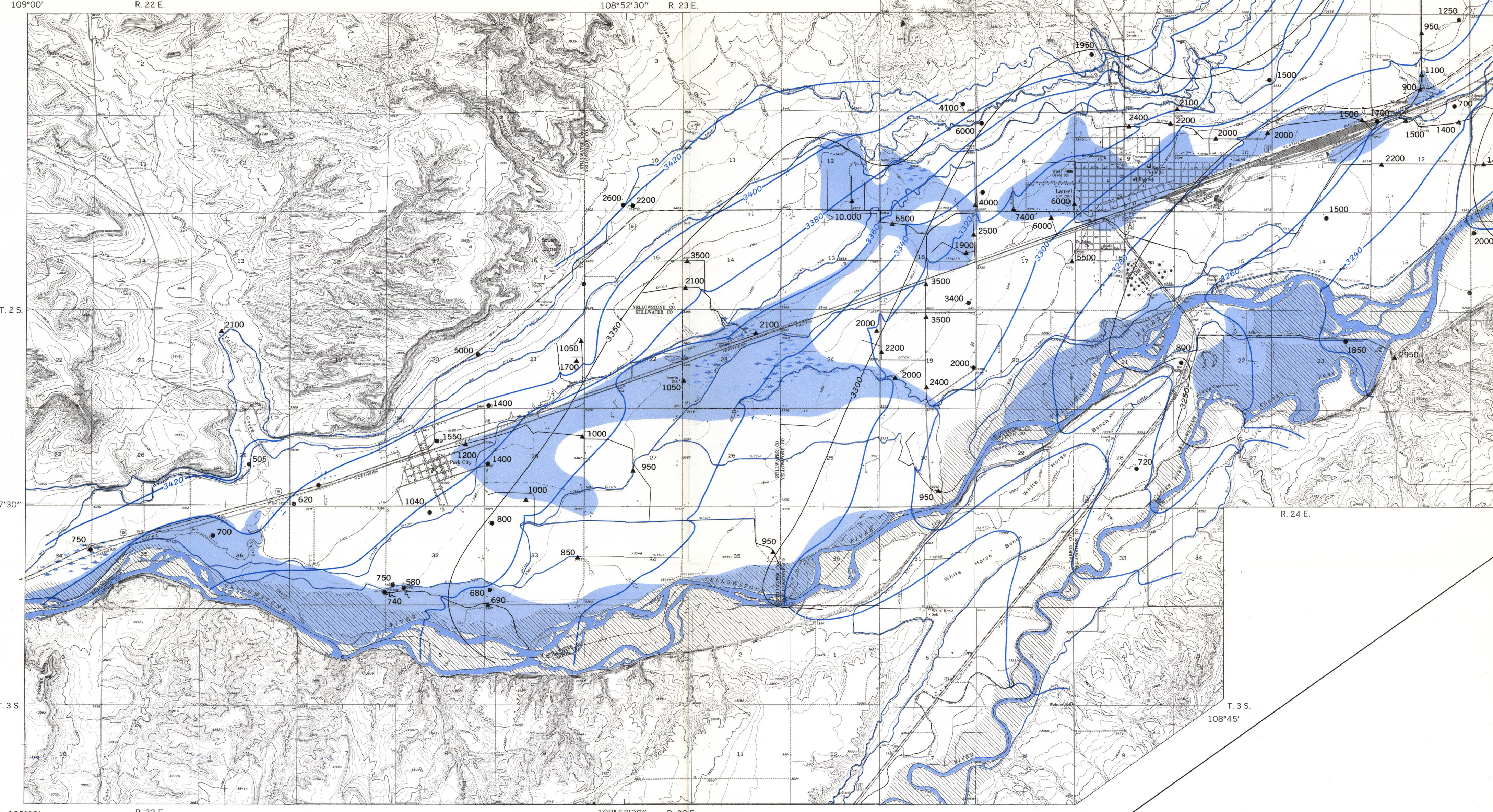


HYDROGRAPHS OF SELECTED WELLS IN UNCONSOLIDATED DEPOSITS



CLASSIFICATION OF WATER FOR IRRIGATION USE





Base from U.S. Geological Survey Billings East, 1956; Billings West, 1957; Laurel, 1956; Montaqua, 1956; Mossmain, 1956; Park City, 1956; Rimrock, 1956; Silesia, 1956; Two Pine School, 1956; and Yegan 1956

SCALE 1:48 000

CONTOUR INTERVAL 20 FEET
DASHED LINES REPRESENT 10-FOOT CONTOURS
DATUM IS MEAN SEA LEVEL

APPROXIMATE MEAN DECLINATION, 1973

HYDROLOGIC MAP

EXPLANATION

Water-table contour (3300)
Shows altitude of water table for August 1968; dashed where approximately located. Contour interval 20 feet. Datum is mean sea level

Generalized bedrock contour (3250)
Shows altitude of bedrock surface; dashed where approximately located. Contour interval 50 feet. Datum is mean sea level

Line of ground-water discharge
Drainage ditch, natural drain, irrigation return flow ditch, or storm sewer.

Irrigation canal

Water conductivity (2050, 1100)
Conductivity of ground water in micromhos at 25° C. Circle, well; triangle, point of natural discharge, such as drainage ditch or gaining stream

Well

Spring

Marsh area

Area of potential flood hazard
Based on projected stage of 50-year flood, about 72,000 cubic feet per second for Yellowstone River at Billings and about 12,000 (cfs) for Clarks Fork near mouth. (Compiled by M. V. Johnson and R. J. Omang)

Waterlogged areas
Area where the water table rises to land surface or to within 5 feet of land surface each year during the irrigation season

Summary of pumping tests of wells finished in gravel

Well location	Owner or location	Pumping rate (gpm)	Pumping rate (cfs)	Draw-down (feet)	Time (minutes)	Transmissivity[1] (square feet per day)
NE¼NW¼ sec. 5, T. 1 S., R. 26 E.	Lewis and Clark Junior High School	264	0.589	1.59	200	3,600
SE¼SW¼ sec. 6, T. 1 S., R. 26 E.	Billings West High School	122	.272	1.36	100	3,200
NE¼SE¼ sec. 6, T. 1 S., R. 26 E.	Miles Avenue School	52	.116	.71	200	2,500
NW¼NW¼ sec. 7, T. 1 S., R. 26 E.	Central Heights School	161	.359	None	100	-------

[1]All wells have open-end finish; therefore, these transmissivity values are considerably less than those for a well obtaining water from the entire saturated thickness.

Summary of analyses of ground water from wells in alluvium

[Analyses by Montana State Board of Health]

	Concentrations in milligrams per liter									
	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids[2]	Total hardness ($CaCO_3$)
Average for 20 samples	190	117	209	354	1,020	30	1.2	19	1,900	857
NW¼NW¼ sec. 8, T. 2 S., R. 24 E. high dissolved solids	465	300	630	435	3,230	30	1.2	1.4	5,330	2,400
NW¼SE¼ sec. 25, T. 2 S., R. 22 E. low dissolved solids	56	26	26	238	78	16	1.0	1.0	298	245
Recommended limit for drinking water[1]	-----	-----	-----	-----	500	250	[3]1.3	45	500	------

[1]U.S. Public Health Service drinking water standards, 1962.
[2]Calculated.
[3]Recommended upper limit for an annual average maximum air temperature of 58.4–63.8°F.

WATER USE

WATER REQUIREMENTS

The annual water requirement of water users in the study area ranges from 200,000 to almost 400,000 acre-feet per year. Agricultural consumption is 180,000 to 360,000 acre-feet per year, municipal consumption is about 20,000 acre-feet per year, and industrial and commercial consumption is about 5,000 acre-feet per year. The Yellowstone River supplies about 98 percent of water used; the remaining 2 percent is supplied from ground water.

IRRIGATION USE

The greatest use of water in the study area is for irrigation. Water to irrigate 61,000 acres is diverted from the Yellowstone River and the Clarks Fork of the Yellowstone within the study area. However, only 46,000 acres of the irrigated land lie within the boundaries of the study.

Five large irrigation companies and 12 small irrigation companies distribute water within the study area. The main canals of these companies can deliver 2,000 cfs from the Yellowstone River; however, only about 1,500 cfs is delivered during the peak irrigation season in an average year. About one-third of this water is used to irrigate land downstream, east of the study area.

The irrigation companies normally begin diversion in late April and end diversion about November 1. The requirement for irrigation varies from year to year, depending on the amount and distribution of rainfall and the air temperature during the growing season. The largest quantity of irrigation water is usually diverted in July and August. Rainfall in June is usually sufficient to sustain crops. Diversions during May, September, and October are about one-third of the peak requirement. Diversions in the study area range from 180,000 to 360,000 acre-feet per year. If 70 percent of the diversion is consumed, streamflow would be reduced by 130,000 to 250,000 acre-feet annually.

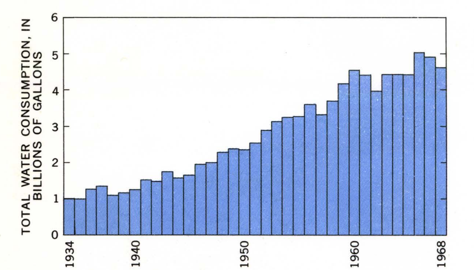
There is a trend toward reducing the total irrigated acreage as less profitable farmland is abandoned and as urban expansion infringes upon cultivated fields. As all irrigable land within the study area has been under cultivation at one time or another, it is not expected that the irrigation water requirement will be increased above the present level.

MUNICIPAL WATER CONSUMPTION

There are three water-treatment facilities in the study area. Billings and Laurel are supplied by water pumped from the river for treatment. The Lockwood suburban area east of Billings pumps water for municipal supply from three wells adjacent to the river. The Billings Bench area, the suburban expansion north and east of Billings, was supplied by individual wells until recently when the area was connected to the Billings water system. The residents of Park City are supplied from individual wells. Most of the farm residents in the valley use cisterns and haul water.

Municipal water supplied to Billings annually has increased from 1.1 billion gallons in 1934 to 4.6 billion gallons (14,100 acre-feet) in 1968 (see graph showing water consumption). The Billings municipal water system treats about 4 million gallons of water per day (6 cfs) during the winter and spring. It operates at capacity, 29 million gallons per day (44 cfs), during the lawn-watering season. This is a small part of the total flow of the Yellowstone River. Total municipal consumption is only about 10 percent of agricultural use. Residential consumption accounts for about 65 percent, industrial about 20 percent, and commercial about 15 percent of the municipal supply.

Billings is growing steadily and the population may exceed 100,000 in the 1980's. The water requirement of the city is not expected to rise above 30,000 acre-feet per year in the foreseeable future. Per capita water consumption in Billings was 40,000 gallons per year in 1949 and increased to about 45,000 gallons per year in 1968.



TOTAL WATER CONSUMPTION FOR BILLINGS, MONT., 1934–68
DATA FROM BILLINGS WATER TREATMENT PLANT

SURFACE WATER

SURFACE WATER

The Yellowstone River at Billings drains 11,795 square miles. The U.S. Geological Survey maintains one streamflow station in the study area at Billings. The average annual discharge at Billings was 4,840,000 acre-feet per year for 1929–68 (see annual-discharge hydrograph).

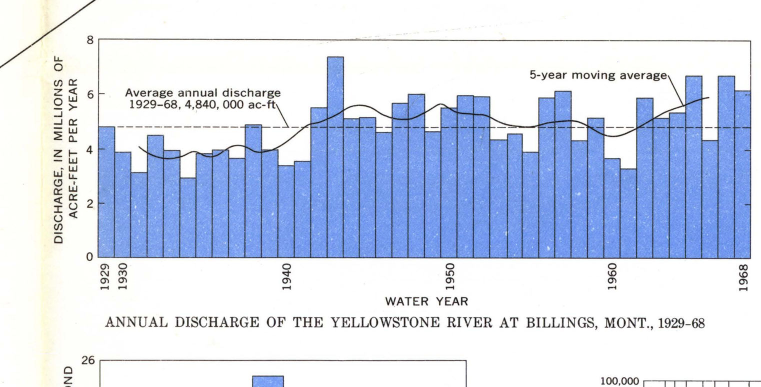
The principal tributary to the Yellowstone River in the study area is the Clarks Fork of the Yellowstone. Its basin comprises about 24 percent of the drainage area of the Yellowstone River at Billings. The Clarks Fork was gaged from 1921–69 at Edgar, 27 miles from the mouth. The stream is now (1970) gaged at Silesia, 22 miles from the mouth. The Clarks Fork contributes about 18 percent of the total annual flow, 21 percent of total low flow, and 18 percent of total high flow of the Yellowstone River.

Six small perennial streams join the Yellowstone River in the study area. These streams are not gaged, therefore, no stream-flow data are available.

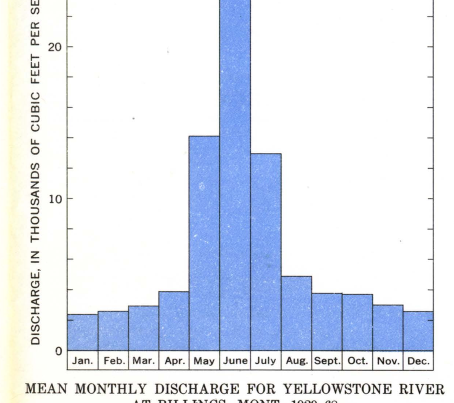
The major contribution to the flow of the Yellowstone River from August through April is ground-water inflow along the entire length of the river. From May through July, the flow at Billings is 10 times greater than low flow (see mean-monthly discharge graph). The high flow is the result of runoff from rain and from snowmelt at higher altitudes in the Yellowstone Park area.

Flood frequency analysis for the Yellowstone River at Billings shows that the peak flow of record, 66,100 cfs on June 16, 1967, was a 25-year high-water event. Recurrence intervals for floods of varying discharges are shown on the flood-frequency curve.

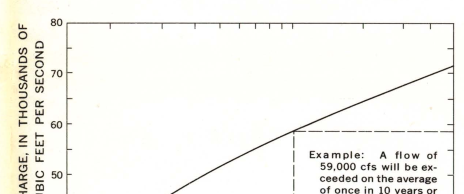
The flow-duration curve for the Yellowstone River at Billings shows the distribution of different magnitudes of daily flow during the period of record. The flow at Billings has exceeded 500 cfs 99.99 percent of the days. An analysis of the annual 1-day, 7-day, and 30-day periods of minimum flow is shown by the low-flow frequency curves. Low-flow periods occur in winter, usually in January or February, when subzero temperatures cause freezing of the river.



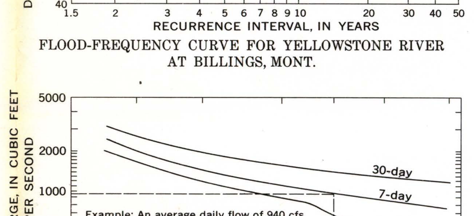
ANNUAL DISCHARGE OF THE YELLOWSTONE RIVER AT BILLINGS, MONT., 1929–68



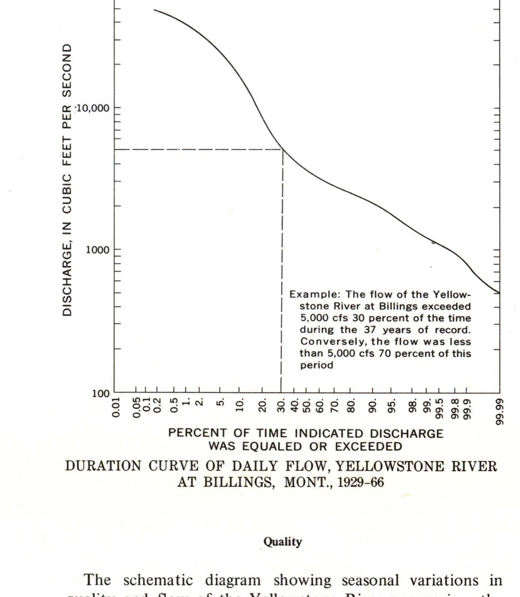
MEAN MONTHLY DISCHARGE FOR YELLOWSTONE RIVER AT BILLINGS, MONT., 1929–68



FLOOD-FREQUENCY CURVE FOR YELLOWSTONE RIVER AT BILLINGS, MONT.



LOW-FLOW FREQUENCY CURVES OF ANNUAL MINIMUM 1-DAY, 7-DAY, AND 30-DAY MEANS FOR YELLOWSTONE RIVER AT BILLINGS, MONT., 1930–66



DURATION CURVE OF DAILY FLOW, YELLOWSTONE RIVER AT BILLINGS, MONT., 1929–66

Summary of water quality of the Yellowstone River at Billings — summary of daily sampling for the periods 1951-58 and 1964-67

[Data from published records of the U.S. Geological Survey]

	Concentrations in milligrams per liter											
	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Total hardness ($CaCO_3$)
Record high[1]	26	107	55	62	6.2	322	383	25	1.9	3.4	868	316
Record low[1]	6	14	1	6	1.1	50	12	.0	.0	.0	87	52
Normal annual range	12–20	17–45	4–18	6–38	1.5–4.5	70–210	20–160	2–12	.1–.7	.2–3.0	95–380	60–210
Average	14	27	7.7	17	2.5	110	45	4	.3	1.0	180	104

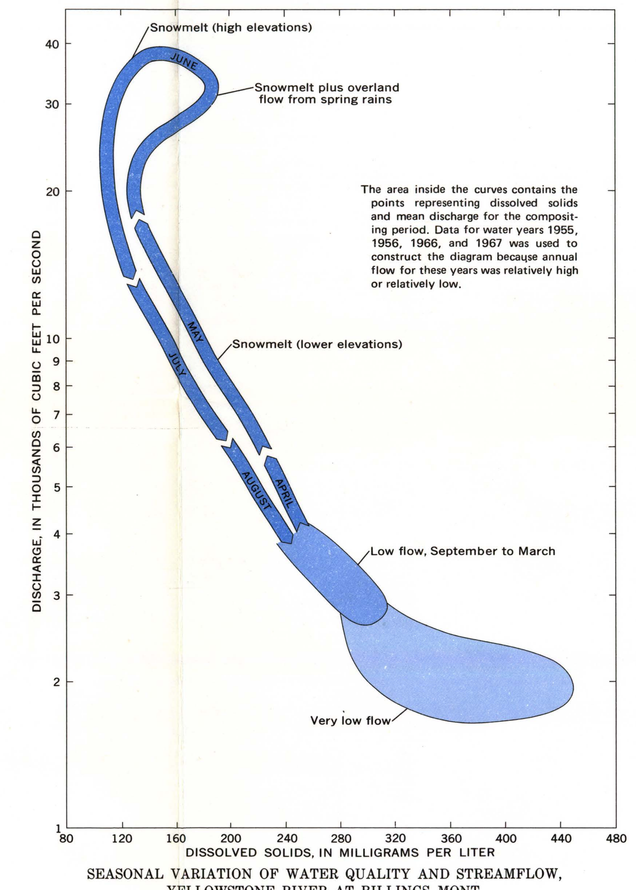
[1]Highest and lowest values for individual constituents during the period of record.

Quality

The schematic diagram showing seasonal variations in quality and flow of the Yellowstone River summarizes the results of chemical analyses of daily samples composited for periods of discharge. Dissolved solids normally decrease as flow increases, averaging 130 mg/l during high flow and 270 mg/l during low flow.

The water quality of the Yellowstone River is summarized in the table. The quality of the river water even during very low-flow periods is better than most of the ground water in the valley. The water is a calcium bicarbonate sodium sulfate type.

A 34-year record of daily water temperature (Aagaard, 1969) shows that the mean monthly water temperature varies from 0°C (32°F) in winter up to 19.5°C (67°F) in summer. The highest recorded water temperature at Billings is 24.5°C (76°F). The water temperature data indicate the suitability of the Yellowstone River water for use in cooling in industrial processes and the ability of the river to support trout or other game fish.



SEASONAL VARIATION OF WATER QUALITY AND STREAMFLOW, YELLOWSTONE RIVER AT BILLINGS, MONT.

CONCLUSIONS

The Yellowstone River valley is abundantly supplied by water from the Yellowstone River. The ground-water resources of the study area are adequate for domestic and stock supplies; however, in many areas the quality of ground water is marginal for these uses. The Yellowstone River is capable of supplying anticipated municipal and industrial requirements.

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WATER RESOURCES OF THE YELLOWSTONE RIVER VALLEY, BILLINGS TO PARK CITY, MONTANA

By
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1973