



Hydrologic Benchmark Network Stations in the West-Central U.S. 1963-95 (USGS Circular 1173-C)

Abstract and Map Index	List of all HBN Stations	Introduction to Circular	Analytical Methods
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Rock Creek below Horse Creek near International Boundary, Montana (06169500)

This report details one of the approximately 50 stations in the Hydrologic Benchmark Network (HBN) described in the four-volume U.S. Geological Survey Circular 1173. The suggested citation for the information on this page is:

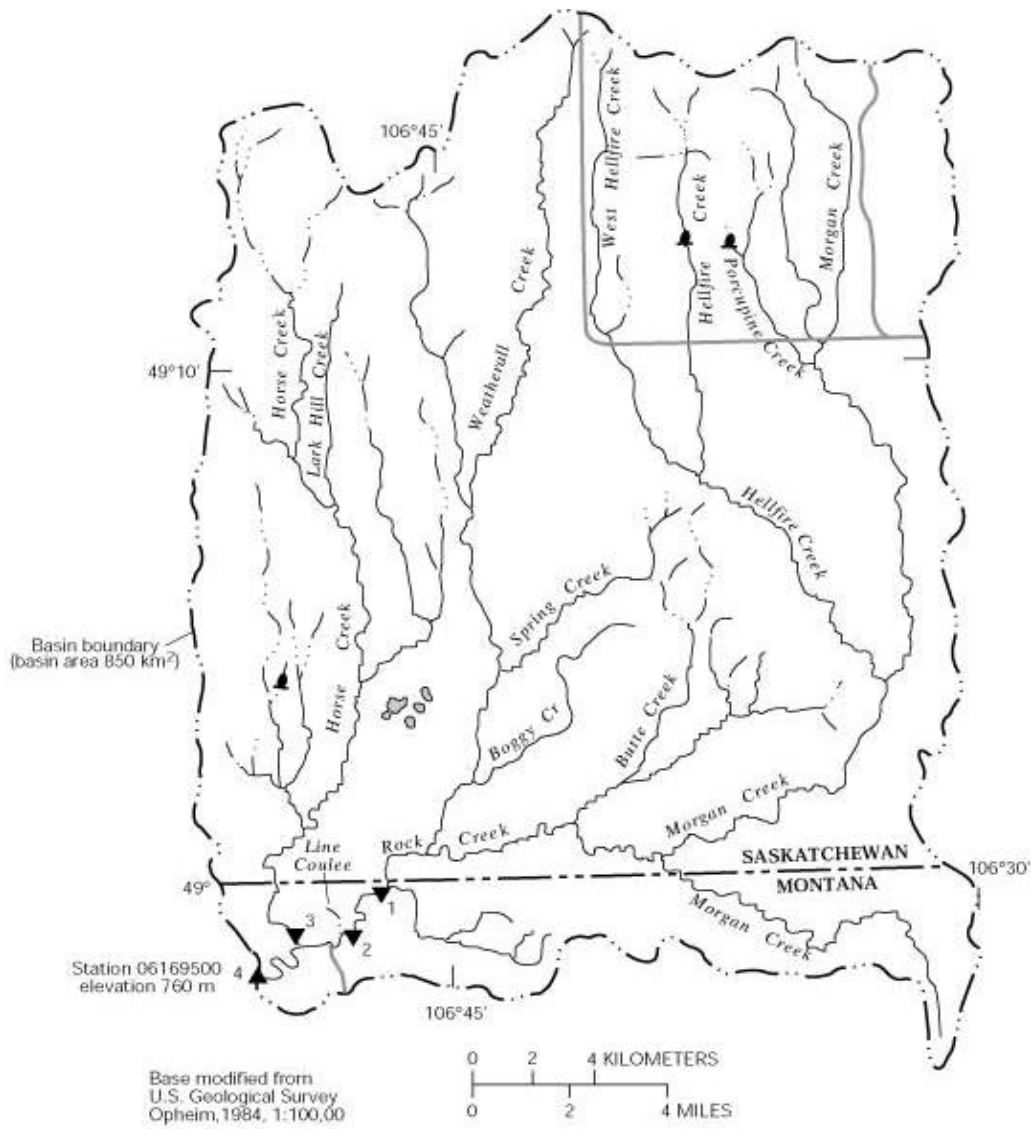
Mast, M.A., and Turk, J.T., 1999, Environmental characteristics and water quality of Hydrologic Benchmark Network stations in the West-Central United States, 1963–95: U.S. Geological Survey Circular 1173–C, 105 p.

All of the tables and figures are numbered as they appear in each circular. Use the navigation bar above to view the abstract, introduction and methods for the entire circular, as well as a map and list of all of the HBN sites. Use the table of contents below to view the information on this particular station.

Table of Contents
1. Site Characteristics and Land Use
2. Historical Water Quality Data and Time-Series Trends
3. Synoptic Water Quality Data
4. References and Appendices

Site Characteristics and Land Use

The Rock Creek HBN Basin is a sparsely populated basin in the Great Plains physiographic province (Fenneman, 1946) in northeastern Montana and southern Saskatchewan ([Figure 8](#). Map showing study area in Rock Creek Basin and photograph



- EXPLANATION**
- 3 ▼ Sampling site and number (from table 17)
 - 4 ▲ Streamflow-gaging station
 - ▲ Dam and reservoir



Figure 8. Map showing study area in Rock Creek Basin and photograph of Rock Creek

of Rock Creek). The Rock Creek HBN station is about 3 km south of the Canadian boundary at latitude of 48°58'10" and a longitude of 106°50'20". At the station, Rock Creek drains 850 km² of gently rolling grasslands, flat valleys, and moderately defined drainage systems. The basin has little relief, with elevations that range from 760 to 980 m. The ecoregion of the basin is classified as the Great Plains-Palouse Dry Steppe Province (Bailey, 1995). Vegetative cover in the basin is predominantly prairie grass and scattered sagebrush; cottonwood trees and shrubs grow in some riparian areas. Rock Creek is tributary to the Milk River.

Streams in the Rock Creek Basin mostly are ephemeral or intermittent, including Rock Creek. Rock Creek typically goes dry at times in the late summer and early fall and may not flow during the winter owing to freezing conditions. Snowmelt produces runoff each year during the spring, and thunderstorms produce runoff in most streams during the summer. Thunderstorm activity typically causes increased discharge within a couple days (M.R. Johnson, U.S. Geological Survey, oral commun., 1997). The mean monthly discharges range from 0.01 m³/s in January to 2.5 m³/s in April (Shields and others, 1996). Average annual precipitation at the Opheim 10N weather station (about 34 km southeast of the site) is 29 cm. June is the wettest month, and February is the driest (Parrett and Hull, 1989, p. 2). Average annual runoff is less than 2 cm (Shields and others, 1996). The climate of the basin is typically continental where winters are cold and dry, and summers are hot and moderately dry. Mean monthly temperatures ranged from -13.5°C in January to 18.8°C in July during the period of record, 1959–95 (National Climatic Data Center, 1996).

The basin is underlain by gently dipping sedimentary rocks of Mesozoic age and unconsolidated deposits of Cenozoic age (Whitaker and Pearson, 1972, pl. 1). The rocks of Mesozoic age include undifferentiated Cretaceous formations: Frenchman, Whitemud, and Eastend Formations and the Bearpaw Shale (Whitaker and Pearson, 1972, pl. 1). The Frenchman, Whitemud, and Eastend Formations are generally interbedded sands, silts, and clay with locally carbonaceous zones (Whitaker and Pearson, 1972, pl. 1). The Bearpaw Shale of Late Cretaceous age is a noncalcareous, silty marine shale containing numerous bentonite beds and concretionary zones (Colton and others, 1989). Two formations of Tertiary age, Wood Mountain Formation and Ravenscrag Formation (Whitaker and Pearson, 1972), are in the northern part of the basin. The Wood Mountain Formation is composed of alluvial sand and gravel deposits locally conglomerated with carbonaceous cement and is preserved as an erosional remnant capping uplands (Whitaker and Pearson, 1972, pl. 1). The Ravenscrag Formation is a lignite-bearing, alluvial plain sediment. The area later was covered by continental glaciation from the Keewatin ice sheet. Most surficial deposits are of Quaternary age, either Pleistocene till, Holocene alluvium and colluvium, or Holocene alluvium. The soils in the area are deep, nearly level to strongly sloping soils formed in glacial till on uplands (U.S. Department of Agriculture, 1984b). Soils along the alluvial valleys are level to gently sloping with variable soil characteristics. Generally, they are moderately to well drained, but they are subject to flooding. The soil type is stratified loam to clay; soils high in clay tend to be alkaline.

The HBN station lies within Valley County, Mont.; however, most of the basin is within the Canadian Province of Saskatchewan. The Canadian part of the basin is designated as the

Provincial Grasslands Park. Some of the land in the U.S. part of the basin is privately owned and some is administered by the Bureau of Land Management. Access is by way of a few light-duty roads and several unimproved roads. Access may be restricted across private holdings. Land use in the basin primarily is cattle grazing, with some hay and small grain production. Recreational use is limited to hunting in the fall. There are several minor diversions on Rock Creek and the tributary streams for irrigation and stock ponds.

Historical Water-Quality Data and Time-Series Trends

The data set analyzed for the Rock Creek HBN station includes 91 water-quality samples that were collected from March 1977 to August 1995. Sampling frequency is described on the basis of water year, which begins on October 1 and ends on September 30. Sampling frequency was at its peak during 1979–82 when an average of 10 samples were collected per year. The typical sampling frequency for this site, with the exception of the 1979–82 period, was about three samples per year. Samples were analyzed at the USGS NWQL in Arvada, Colo. The period of record for discharge is from water year 1916 to 1926, and from 1956 to current year (2000).

Data quality was checked using ion balances and time-series plots. Calculated ion balances for samples with complete major-ion analyses are shown in [Figures 9a](#) and [9b](#). *Temporal variation of discharge, field pH, major dissolved constituents, and ion balance at Rock Creek, Montana.* All but two of the samples had an ionic balance within ± 5 percent, indicating that the major-ion analytical results were of good quality and that unmeasured constituents, such as organic anions, nutrients, and trace metals, do not contribute substantially to the ionic composition of Rock Creek. Time-series plots of ion concentrations were inspected for evidence of influences that are related to analytical method or sampling changes (fig. 9). The influence of analytical method changes should be less at this site because of the higher concentrations of dissolved constituents in samples collected from Rock Creek. Higher scatter exists in data for several of the constituents around the period of 1979–82. The constituents include calcium, magnesium, silica, and chloride. The increased scatter is the likely result of the higher sampling frequency of 10 samples per year compared to the lower sampling frequency of three samples in later years. A higher sampling frequency results in samples that are representative of a wider range of environmental conditions, and thus, a wider range in chemical concentrations.

The reason for the higher scatter of nitrate data up to about 1985 could not be isolated. The step-pattern observed in the nitrate data around 1992 reflects a change to a lower minimum laboratory reporting level. Changes were made in meters and electrodes used for field pH determinations during the study period. When changes in methods or instrumentation result in improved precision or elimination of measurement bias, time-series data can exhibit less scatter or a directional shift, respectively. The time-series data, therefore, may reflect the method or instrument change rather than an environmental change.

The median and range of major-ion concentrations in stream water collected at the Rock Creek HBN station and VWM concentrations in wet precipitation measured at the Give Out Morgan NADP station are presented in table 14. The NADP station is 190 km southeast of the HBN station. Precipitation chemistry at the NADP station was dilute and slightly acidic with a VWM pH of 5.3 from 1982 to 1995. The dominant cations in precipitation were ammonium, 34 percent, and calcium, 32 percent. The dominant anions in precipitation were sulfate, 55 percent, and nitrate, 37 percent. A high proportion of nitrate in precipitation in some western areas has been attributed to exhaust from cars and other vehicles in urban areas and agricultural activity in the Great Plains States (National Atmospheric Deposition Program/ National Trends Network, 1997).

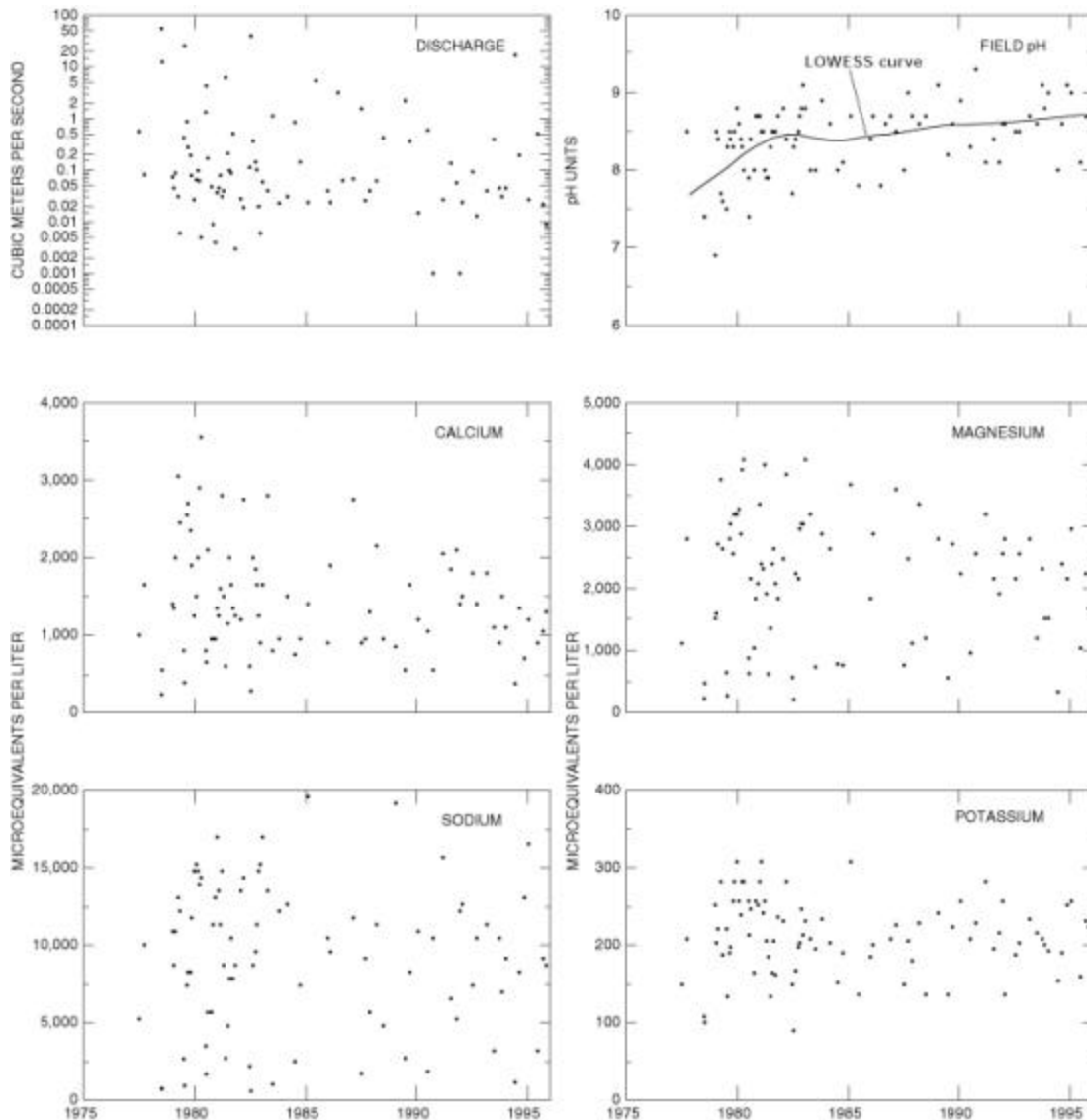


Figure 9a. Temporal variation of discharge, field pH, major dissolved constituents, and ion balance at Rock Creek, Montana

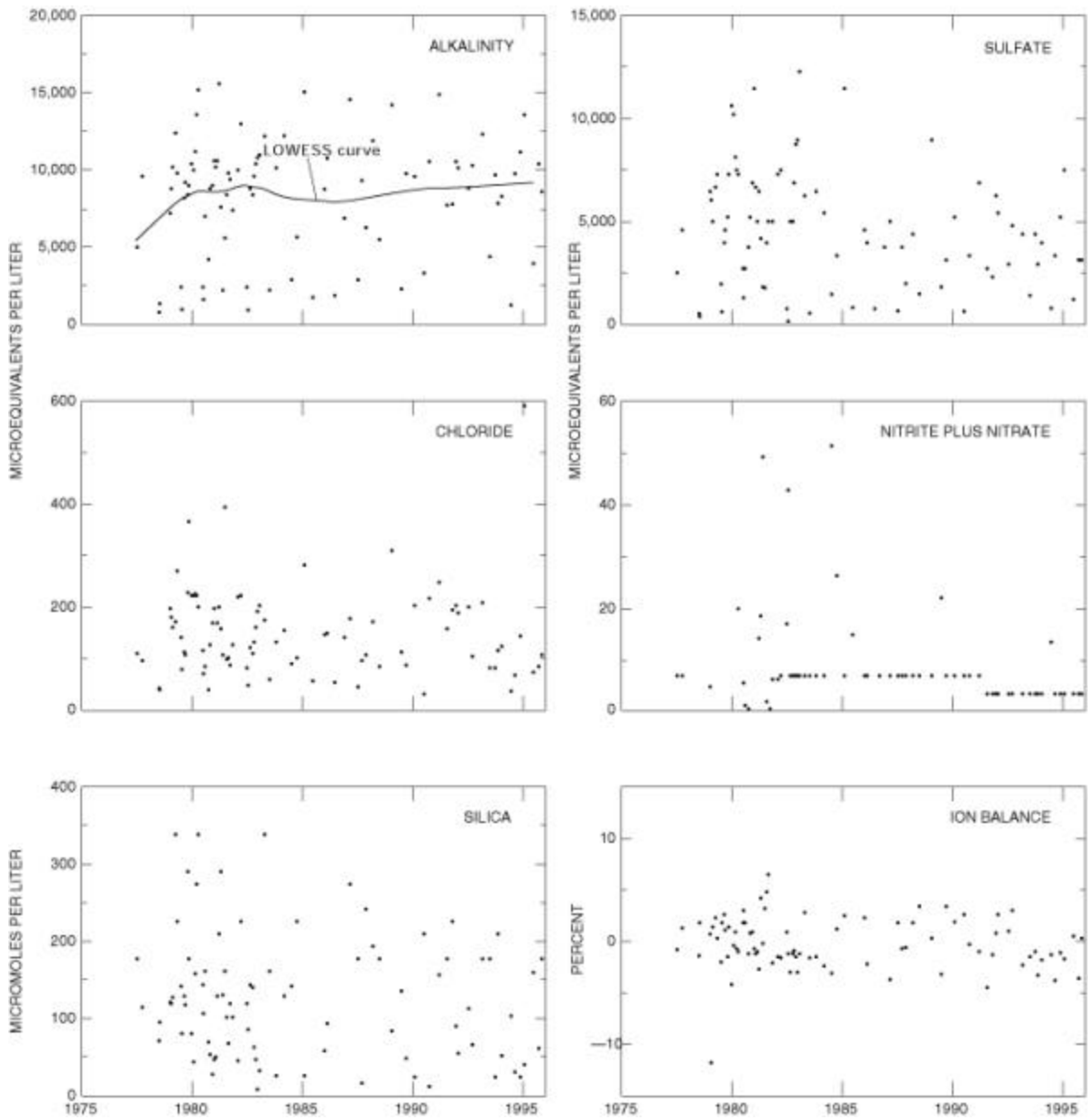


Figure 9b. Temporal variation of discharge, field pH, major dissolved constituents, and ion balance at Rock Creek, Montana – Continued30

Table 14. Minimum, first quartile, median, third quartile, and maximum values of physical properties and major ions measured in water-quality samples from Rock Creek, Montana, 1977—95, and volume-weighted mean concentrations in wet precipitation collected at the Give Out Morgan Station, Montana, 1982—95

[Parameters in units of microequivalents per liter, except for discharge in cubic meters per second, specific conductance in microsiemens per centimeter at 25 degrees Celsius, pH in standard units, and silica in micromoles per liter; n, number of stream samples; VWM, volume-weighted mean; spec. cond., specific conductance; --, not reported; <, less than]

Parameter	Stream Water						Precipitation VWM
	Minimum	First quartile	Median	Third quartile	Maximum	n	
Discharge	<0.001	0.03	0.06	0.37	56	91	--
Spec. cond., field	90	750	1,220	1,560	2,380	91	--
pH, field	6.9	8.1	8.5	8.7	9.3	90	5.3 ^a
Calcium	240	950	1,400	1,800	3,600	87	15
Magnesium	210	1,200	2,300	2,900	4,100	87	5.7
Sodium	570	5,700	10,000	13,000	20,000	87	4.0
Potassium	90	190	210	250	310	89	1.5
Ammonium	<.7	1.4	4.3	7.9	36	60	16
Alkalinity, laboratory	780	5,600	9,000	11,000	16,000	90	--
Sulfate	140	2,500	4,400	6,500	12,000	89	21
Chloride	31	90	130	200	590	89	3.1
Nitrite plus nitrate	<.7	<.7	<7.1	7.1	51	72	14 ^b
Silica	8.2	58	120	180	340	87	--

^a Laboratory pH.

^b Nitrate only.

The stream water at the Rock Creek HBN station is a sodium bicarbonate type. The sum of ion concentrations ranged from about 2,300 to about 49,000 meq/L. Alkalinity ranged from 780 to 16,000 meq/L. Bicarbonate was the primary contributor to alkalinity at this station and accounted for 66 percent of the median anion concentration. Sodium accounted for 72 percent of median cation concentration in stream water. Wide ranges of sodium can occur in natural waters because high concentrations of dissolved sodium can be reached before any precipitate is formed (Hem, 1992, p. 101). Potassium concentrations were high, which probably reflects the weathering of the clay materials in the basin (Deer and others, 1966). Ion concentrations, with the exception of ammonia and nitrite plus nitrate, are much greater in the stream water than in the precipitation, indicating that the input of most ions into the streams is from sources within the basin. In arid regions, when precipitation and runoff are insufficient to redissolve salts, salt residues accumulate in the soil or on exposed streambeds. Streams in basins with low average annual runoff and geologic settings that contain fine-grained sediments generally are characterized by high dissolved-solids concentrations (Biesecker and Leifeste, 1975). Specific conductance (median = 1,220 mS/cm) is an indicator of the high dissolved solids at this station. Annual precipitation and runoff data indicate that evapotranspiration can account for about a twentyfold increase in stream-water concentrations compared to precipitation. The median sodium concentration is 2,500 times greater in the stream than in the precipitation chemistry. This indicates that sodium is widely abundant in the soils and geologic materials in the basin. In contrast, median concentrations of ammonium and nitrate are lower in Rock Creek than in the precipitation and indicate that some nitrogen is retained by the biomass in the basin.

Correlations among dissolved constituents and stream discharge were determined for Rock Creek (table 15). Base cations and anions were inversely correlated with discharge. These results are consistent with a hydrologic system where base-flow chemistry that is dominated by ground water is diluted during periods of increased discharge. Ion concentrations in ground water tend to be greater than in surficial sources because the contact time with rocks and minerals is longer. The correlations with discharge, however, were not always strong. Some increases in discharge may be associated with temporary increases in dissolved-solids concentrations because salts that have accumulated in the soil are flushed out during the initial phases of melting of snow, thawing of frozen ground, or rainfall events. The strongest correlation among cations was between magnesium and sodium (rho value = 0.881). The strongest solute correlation was between sodium and sulfate (rho value = 0.969). Strong correlations also were found between sodium and alkalinity (rho value = 0.906), magnesium and alkalinity (rho value = 0.927), magnesium and sulfate (rho value = 0.835), and sodium and chloride (rho value = 0.777). These data reflect an abundance of various mineral salts in the basin.

Table 15. Spearman rank correlation coefficients (rho values) showing the relation among discharge, pH, and major ions, Rock Creek, Montana, 1980 through 1995

[Q, discharge; Ca, calcium; Mg, magnesium; Na, sodium; K, potassium; Alk, alkalinity; SO₄, sulfate; Cl, chloride; SiO₂, silica; --, not applicable]

	Q	pH	Ca	Mg	Na	K	Alk	SO ₄	Cl
pH	-0.639	--	--	--	--	--	--	--	--
Ca	-.173	-0.048	--	--	--	--	--	--	--
Mg	-.540	.379	0.668	--	--	--	--	--	--
Na	-.702	.485	.435	0.881	--	--	--	--	--
K	-.570	.316	.331	.620	0.714	--	--	--	--
Alk	-.649	.455	.569	.927	.906	0.664	--	--	--
SO ₄	-.652	.473	.431	.835	.969	.689	0.832	--	--
Cl	-.577	.343	.449	.691	.777	.602	.739	0.754	--
SiO ₂	.346	-.624	.394	-.173	-.329	-.164	-.162	-.350	-0.064

Results of the seasonal Kendall test for trends in discharge and major dissolved constituents for Rock Creek during the period of 1978 through 1995 are presented in table 16. Statistically significant upward trends ($\alpha = 0.01$) were detected in pH and alkalinity for unadjusted concentrations. The alkalinity trend was no longer detected once the concentrations were adjusted for discharge, indicating that the trend was likely a function of streamflow conditions rather than changing water-quality conditions in the basin. The upward trend in pH remained after flow adjustment. A significant downward trend in sulfate concentrations also was detected in the flow-adjusted data. These trends in stream-water chemistry correspond with trends detected by Lynch and others (1995) for precipitation chemistry at an NADP station in western Montana during the period 1980–92. Lins (1987) reported that monthly sulfur-dioxide emissions in Montana decreased by 47 percent between 1975 and 1984. After accounting for evapotranspiration, stream-water sulfate concentrations were about 10 times greater than precipitation sulfate contributions, making it difficult to attribute stream-water trends only to changes in precipitation chemistry. The sulfate concentrations may have been slightly affected by sulfate method changes in 1982, which corresponds with the change from a methylthymol blue procedure to a turbidimetric titration method (U.S. Geological Survey Office of Water Quality Technical Memorandum No. 83.07, 1983), and 1990, which corresponds with the change from turbidimetric titration to an ion-exchange chromatography analytical method (U.S. Geological Survey Office of Water Quality Technical Memorandum No. 90.04, 1989; U.S. Geological Survey Office of Water Quality Technical Memorandum No. 90.13, 1990). The method changes, however, were more likely to have a higher impact on water with low sulfate concentrations.

Table 16. Results of the seasonal Kendall test for trends in discharge and unadjusted and flow-adjusted pH and major-ion concentrations, Rock Creek, Montana, 1978—95

[Trends in units of microequivalents per liter per year, except for discharge in cubic meters per second per year, pH in standard units per year, and silica in micromoles per liter per year; p-value, attained significance level; --, not calculated; <, less than]

Parameter	Unadjusted		Flow adjusted	
	Trend	p-value	Trend	p-value
Discharge	-0.09	0.088	--	--
pH	.04	<.001	0.02	0.001
Calcium	<.01	.748	-4	.671
Magnesium	20	.365	-8	.339
Sodium	30	.471	-100	.151
Potassium	<.01	.840	-.4	.688
Alkalinity	100	.003	40	.369
Sulfate	-40	.130	-100	.005
Chloride	-.8	.662	-2	.234
Nitrite plus nitrate	.1 ^a	.565	--	--
Silica	<.01	.999	(^b)	--

^a Trend test for highly censored data was used.

^b Concentration-flow model not significant at $\alpha = 0.10$.

Synoptic Water-Quality Data

Results of a surface-water synoptic sampling conducted June 9 and 10, 1993, in the Rock Creek Basin are shown in table 17, and locations of the sampling sites are shown in figure 8. All sampling sites are south of the international border, in the southwestern part of the basin, and may not be representative of waters in the upper basin. Discharge at the HBN station (site 4) was 0.020 m³/s, which is less than the historical mean monthly discharge of 0.34 m³/s for the month of June (Shields and others, 1996). The discharge measured is more typical of streamflow conditions that occur in winter than in June.

Table 17. Physical properties and major-ion concentrations in surface-water samples collected at sites in the Rock Creek Basin, June 9 and 10, 1993

[Site locations shown in fig. 8; Q, discharge in cubic meters per second; SC, specific conductance in microsiemens per centimeter at 25 degrees Celsius; pH in standard units; Ca, calcium; Mg, magnesium; Na, sodium; K, potassium; Alk, alkalinity; SO₄, sulfate; Cl, chloride; NO₃, nitrate; SiO₂, silica; concentrations in microequivalents per liter, except silica is in micromoles per liter; --, not measured; <, less than; criteria used in selection of sampling sites: TRIB = major tributary]

Site	Identification number	Q	SC	pH	Ca	Mg	Na	K	Alk	SO ₄	Cl	NO ₃	SiO ₂	Criteria
1	485949106463900	0.022	1,260	8.9	1,100	2,500	10,000	200	10,000	3,800	76	<0.4	8.5	TRIB
2	485858106473500	.020	1,330	9.0	950	2,700	11,000	230	11,000	4,200	79	<.4	13	TRIB
3	485856106492600	.020	713	8.5	1,400	1,200	4,300	280	4,400	3,100	60	.5	9.3	TRIB
4	06169500	.020	1,430	8.9	1,100	2,600	11,000	240	12,000	4,400	120	2.1	28	--

The water type of the main-stem sites (sites 1, 2, and 4) and Horse Creek tributary (site 3) was sodium bicarbonate. Concentrations of dissolved constituents for the three main-stem sites (sites 1, 2, and 4) and one tributary (site 3) generally were within the range of historical values recorded at the HBN station for the period 1977–95 (table 14). The sum of ions ranged from about 15,000 meq/L on Horse Creek (site 3) to about 31,000 meq/L at the HBN station (site 4). Sodium carbonate salts contribute less to the ion composition of the water of Horse Creek than Rock Creek, as indicated by the percentages of contributions from major ions. Sodium constituted about 60 percent of cation concentration in the Horse Creek sample compared to about 73 percent in the Rock Creek samples. Bicarbonate constituted about 58 percent of the anion concentration in the Horse Creek sample compared to about 73 percent in the samples from Rock Creek. After adjusting for the effects of evapotranspiration, precipitation only contributes part of the salt-forming anions. Sulfate contributions from precipitation ranged from about 10 percent (site 4) to about 13 percent (site 3). This indicates that sources for sulfate occur in both Horse Creek and Rock Creek drainages. Chloride contributions from precipitation range from about 53 percent (site 4) to nearly 100 percent (site 3). Discharge and lower ion concentrations in Horse Creek did not appear to have any dilution effects on Rock Creek as ion concentrations increased between sites 2 and 4. Precipitation chemistry probably can account for nitrate concentrations at all four synoptic sites.

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Appendix A. List of Map References

a. U.S. Geological Survey topographic maps:

- Coal Mine Creek East, Montana-Saskatchewan (1:24,000), 1976
- Coal Mine Creek West, Montana-Saskatchewan (1:24,000), 1984
- Lighthouse Hill, Montana-Saskatchewan (1:24,000), 1984, streamflow-gaging station

b. Geologic maps:

- Colton, R.B., Whitaker, S.T., and Ehler, W.C., 1989, Geologic map of the Opheim 1× $\frac{1}{2}$ 30' quadrangle, Valley and Daniels Counties, Montana: U.S. Geological Survey Open-File Report 89–319.
- Whitaker, S.H., and Pearson, D.E., 1972, Geological map of Saskatchewan: Province of Saskatchewan Department of Mineral Resources and Saskatchewan Research Council, 1 pl.

c. Soil surveys:

- U.S. Department of Agriculture, 1984, Soil survey of Valley County, Montana: U.S. Department of Agriculture, Soil Conservation Service, 102 p.

d. Other maps:

- Opheim, Montana, 30' x 60' quadrangle, Bureau of Land Management, 1984, scale 1:100,000.
- Horse Creek topographic map, Surveys and Mapping Branch, Department of Energy, Mines, and Resources, 1974, scale 1:50,000.
- McCord topographic map, Surveys and Mapping Branch, Department of Energy, Mines, and Resources, 1975, scale 1:50,000.

Appendix B. NWIS Site-Identification Numbers

Table B-1. NWIS site-identification numbers and site names for water-quality sampling sites.

Site	Identification Number	Site Name
1	485949106463900	ROCK CREEK BELOW INTERNATIONAL BOUNDARY
2	485858106473500	ROCK CREEK ABOVE LINE COULEE
3	485856106492600	HORSE CREEK ABOVE CONFLUENCE WITH ROCK CREEK
4	06169500	ROCK CREEK BELOW HORSE CREEK NEAR INTERNATIONAL BOUNDARY, MONTANA