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

Mogollon Creek near Cliff, New Mexico (09430600)

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.

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Site Characteristics and Land Use

The Mogollon Creek HBN Basin is in the Mexican Highland Section of the Basin and Range physiographic province (Fenneman, 1946) in southwestern New Mexico (Figure 13. *Map showing study area in Mogollon Creek Basin and photograph of a mountain peak in the basin*). The HBN station is about 23 km north of the town of Cliff, N. Mex., at a latitude of 33×10'00" and a longitude of 108×38'57". Mogollon Creek

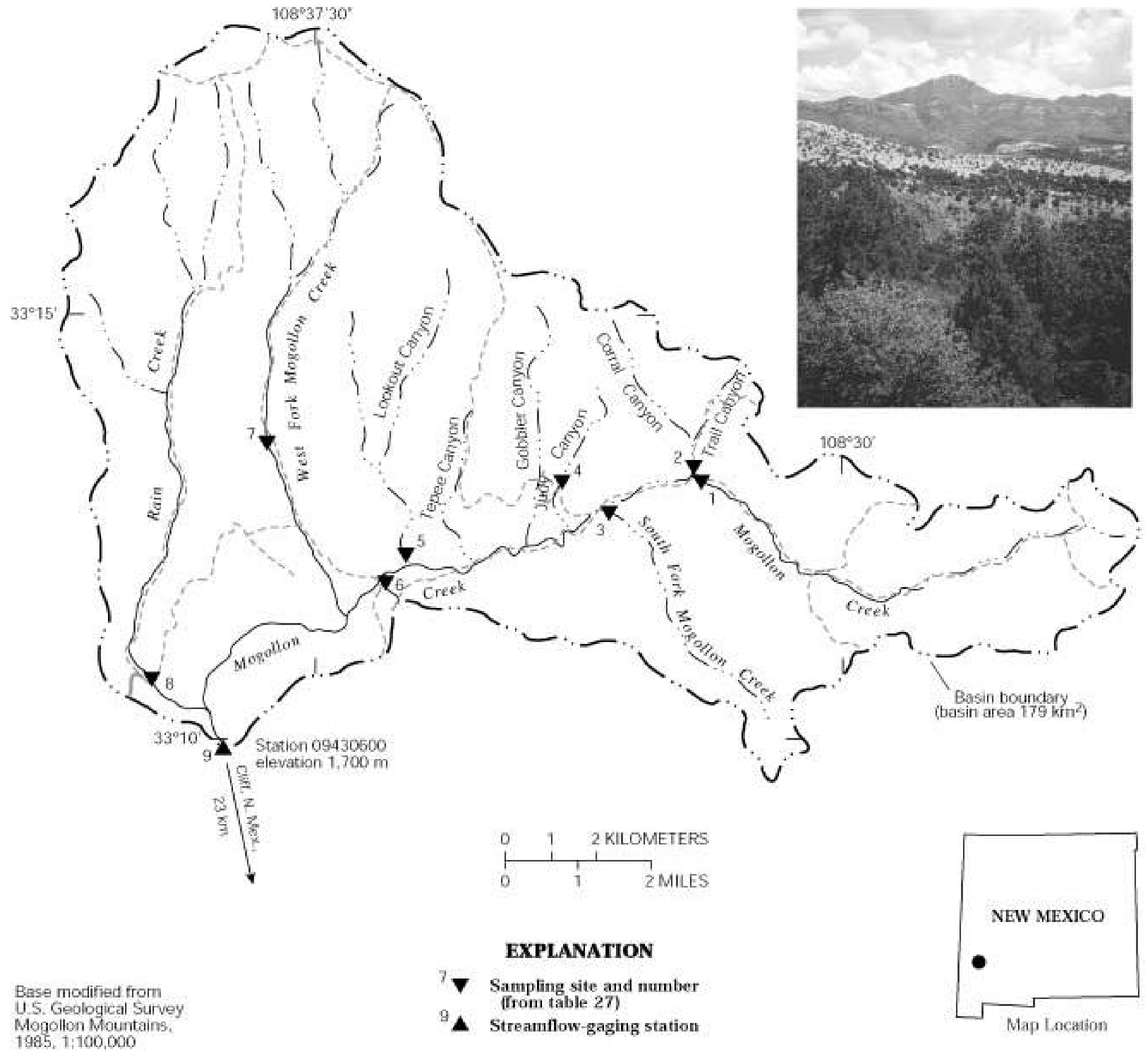

Figure 13. *Map showing study area in Mogollon Creek Basin and photograph of a mountain peak in the basin*

drains about 179 km^2 of rugged, mountainous terrain of the Mogollon Mountains. Basin elevations range from 1,700 to 3,300 m. The slope of the stream is highly variable and ranges from about 190 m/km upstream from the streamflow-gaging station to less than 1 m/km at the station (Cobb and Biesecker, 1971). The ecoregion of the basin is classified as the Arizona-New Mexico Mountains Semi-Desert–Open Woodland–Coniferous Forest–Alpine Meadow Province (Bailey, 1995). Vegetative cover and density change with elevation in the basin. Pine and spruce are the predominant tree types at higher elevations, whereas juniper, cottonwood, and willow grow at lower elevations (Cobb and Biesecker, 1971). The cover is moderately dense at higher elevations and decreases with decreasing elevation. The upper part of the basin also contains ferns, moss, and damp meadows. Mogollon Creek is tributary to the Gila River.

Mogollon Creek is an intermittent stream that typically goes dry in the summer months. Discharge is dependent upon rainfall. Mean monthly discharge ranges from 0.10 m^3/s in June to 2.1 m^3/s in March (Ortiz and Lange, 1996). Average annual precipitation received at the Cliff weather station, about 15 km southeast of the site, is about 37 cm. About 10 percent of the precipitation falls as snow (Cobb and Biesecker, 1971). Average annual runoff is about 17 cm (Ortiz and Lange, 1996). Mean monthly temperatures ranged from 3.6×C in December to 24.4×C in July during the period 1948–95 (National Climatic Data Center, 1996).

The surficial geology of the basin is composed of a series of Tertiary-age extrusive or shallow intrusive volcanic units (Ratte´ and Gaskill, 1975). The area near the HBN station is underlain by a quartz latite of Oligocene age. The unit is described as compositionally zoned ash-flow tuff at least 600 m thick. Parts of the middle basin are underlain by latitic and andesitic lava flows. Other parts of the middle basin are underlain by rhyolite, which includes porphyritic lava flows with quartz and feldspar phenocrysts. In the upper basin of the Rain Creek and West Fork Mogollon Creek drainages (fig. 13) is a densely welded ash-flow tuff of Miocene or Oligocene age with quartz, sanidine, plagioclase, and biotite phenocrysts. In the eastern upper basin, the underlying rocks are banded rhyolite flows and domes of Miocene age. The Bursum Caldera is a prominent structural feature in the area. Some mineralization is associated with resurgent doming of the caldera, with faulting, or both. Fluorite deposits occur in the Rain Creek drainage, which is tributary to Mogollon Creek (Ratte´ and others, 1979).

The Mogollon Creek HBN station is in Grant County. The Mogollon Creek HBN Basin lies almost entirely within the Gila National Forest except for some private land near the station. Most of the National Forest land within the basin is within the Gila Wilderness Area, which was the first wilderness area designated in the United States (Ratte´ and Gaskill, 1975). A private, unimproved dirt road provides access to the HBN station. Pack trails access several tributaries in the drainage; wilderness area access is limited to foot trails and horseback. Recreational activity is limited, as access is limited by private holdings. Several prospect pits or open cuts from historical mining are in the Rain Creek drainage. Some cattle grazing occurs in the basin.

Historical Water-Quality Data and Time-Series Trends

The data set analyzed for the Mogollon Creek HBN station includes 158 water-quality samples that were collected from February 1967 to September 1995. Sampling frequency is described on the basis of water year, which begins on October 1 and ends on September 30. Sampling frequency was highest during the early part of the record; 11 samples per year were collected during water years 1968–70. Sampling frequency decreased to three to six samples per year from 1972 through 1995. Samples were analyzed at the USGS New Mexico District water-quality laboratory until early 1970. From early 1970 through 1973, samples were analyzed at the USGS water-quality laboratory in Salt Lake City, Utah. After 1973, with the creation of the USGS Central Laboratory System, all samples were analyzed at the water- quality laboratory (now called NWQL) in Arvada, Colo. The period of record for discharge is from water year 1967 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 14a and 14b. *Temporal variation of discharge, field pH, major dissolved constituents, and ion balance at Mogollon Creek, New Mexico*. More than 95 percent of the samples had ion balances within the ±10 percent range, indicating that the major-ion analytical results generally were of good quality and that unmeasured constituents, such as organic anions, nutrients, and trace metals, do not contribute substantially to the ion composition of the stream water. Time-series plots of ion concentrations were inspected for evidence of influences that are related to analytical method changes (fig. 14). The decrease in scatter of sulfate concentrations after 1982 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). When changes in methods 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 change rather than an environmental change. Field pH values increased sharply from 1967 to about 1972 and then began to level off.

The median and range of major-ion concentrations in the stream water collected at the Mogollon Creek HBN station and VWM concentrations in wet precipitation measured at the Gila Cliff Dwellings National Monument NADP station are presented in table 24. The NADP station is about 46 km northeast of the HBN station. Precipitation chemistry at the NADP station is dilute and acidic with VWM pH of 4.8 during the period of record, 1985–95. This was the lowest VWM pH for the NADP stations used in this report. The dominant cation in precipitation was hydrogen, which contributed 44 percent of the total cation concentration; calcium contributed 22 percent and ammonium contributed 16 percent. The dominant anion in precipitation was sulfate, which contributed 58 percent of the total anion concentration; nitrate contributed 31 percent.

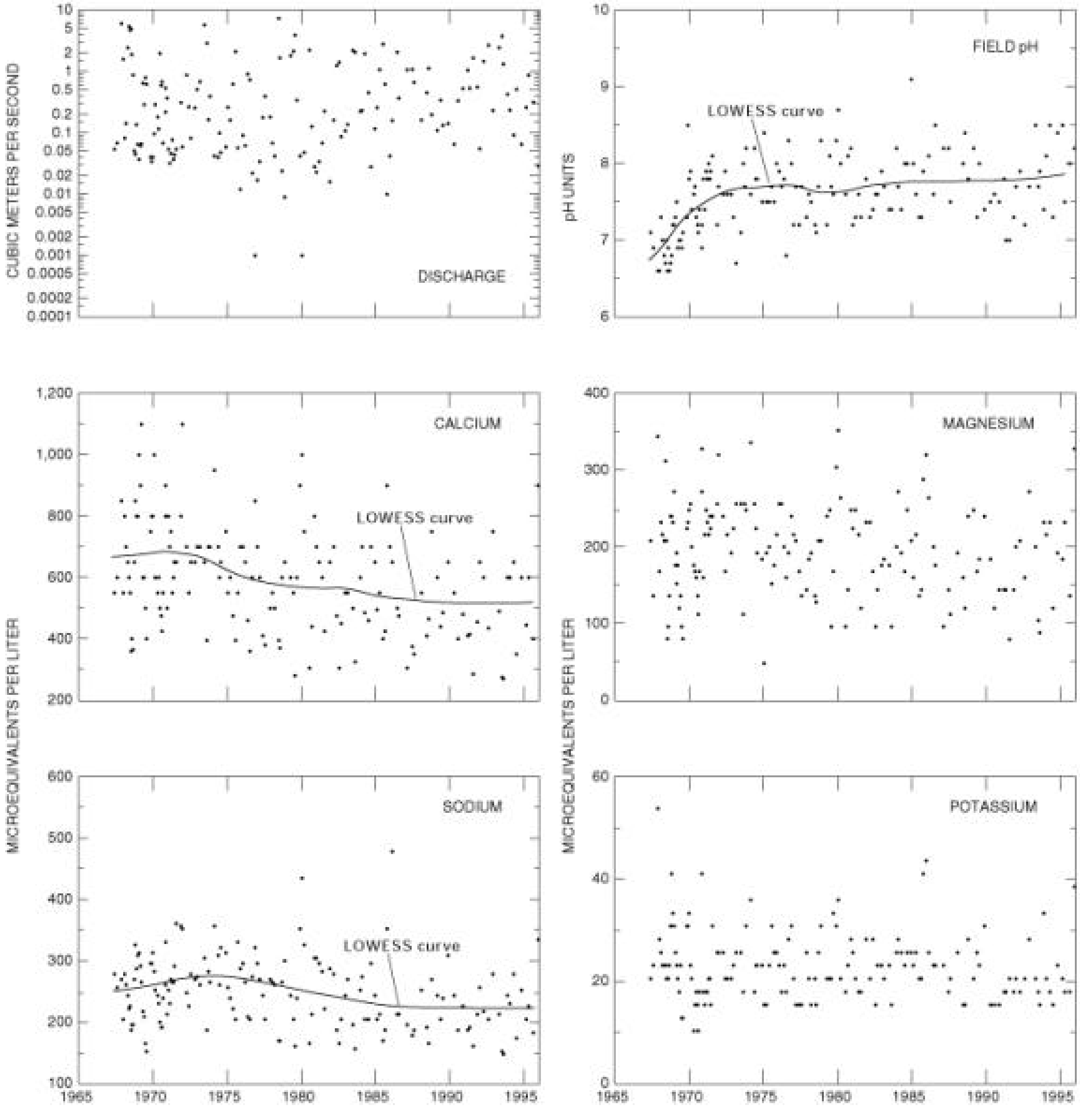

Figure 14a. *Temporal variation of discharge, field pH, major dissolved constituents, and ion balance at Mogollon Creek, New Mexico*

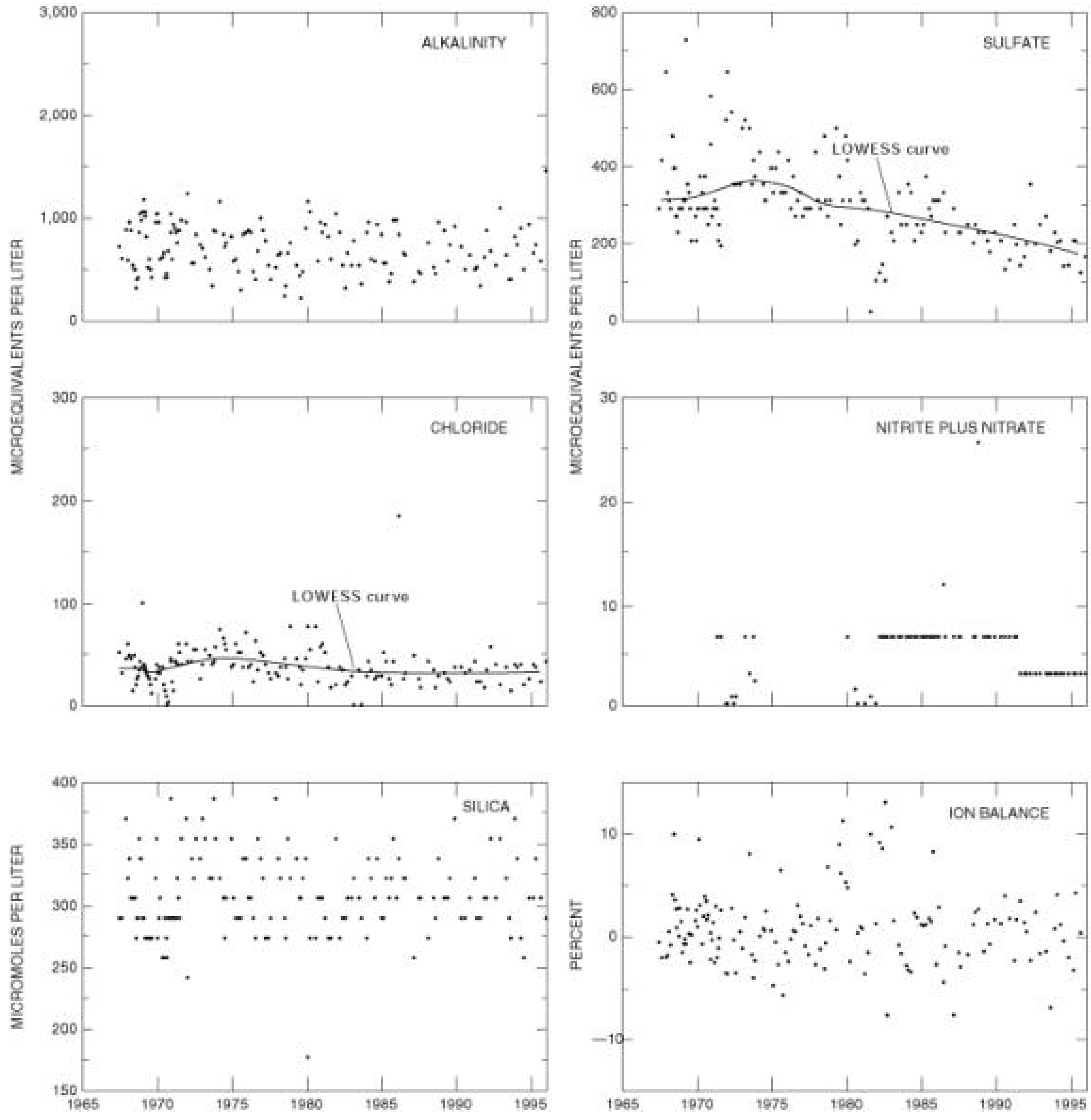

Figure 14b. *Temporal variation of discharge, field pH, major dissolved constituents, and ion balance at Mogollon Creek, New Mexico*

Table 24. Minimum, first quartile, median, third quartile, and maximum values of physical properties and major ions measured in water-quality samples from Mogollon Creek, New Mexico, 1967—95, and volume-weighted mean concentrations in wet precipitation collected at the Gila Cliff Dwellings Station, New Mexico, 1985—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	<0.01	0.06	0.22	0.88	7.4	158	--
Spec. cond., field	47	82	108	122	176	158	--
pH, field	6.6	7.3	7.6	7.9	9.1	157	4.8[a]
Calcium	270	460	600	700	1,100	158	8.0
Magnesium	48	150	200	240	350	158	1.8
Sodium	150	200	250	280	480	157	3.8
Potassium	10	18	23	26	54	157	0.8
Ammonium	<.7	.7	1.4	4.3	11	64	5.8
Alkalinity, laboratory	220	520	680	880	1,500	158	--
Sulfate	23	230	290	350	730	157	21
Chloride	<2.8	28	39	48	190	157	3.9
Nitrite plus nitrate	<.7	<3.6	<7.1	7.1	26	83	11[b]
Silica	180	290	310	320	390	158	--

[a] Laboratory pH.

[b] Nitrate only.

Stream water in Mogollon Creek is a mildly alkaline, calcium bicarbonate type. The sum of ion concentrations ranged from about 1,000 to about 3,700 meq/L. Alkalinity ranged from 220 to 1,500 meq/L, and bicarbonate was the primary contributor to alkalinity at this station. The predominant cation in the stream water was calcium, which contributes 56 percent of the median cation concentration. Sodium was the second most abundant cation in the stream water. These constituents, plus high silica concentrations, typically are weathered from rocks of volcanic origin. The major anion, bicarbonate, contributed about 67 percent of median anion concentration. Annual precipitation and runoff data indicate that evapotranspiration can account for about a twofold increase in stream-water concentrations compared to precipitation. Sulfate and chloride also are input from materials within the basin as precipitation and can only account for about 14 and 20 percent, respectively, of the median concentrations of these constituents in stream water. Median concentrations of ammonium and nitrate were lower in the stream water than in the precipitation, indicating that nitrogen generally is retained by the biomass in the basin.

Correlations among dissolved constituents and discharge were determined for Mogollon Creek (table 25). The base cations and anions showed inverse relations with discharge. These results are consistent with a hydrologic system where base-flow chemistry that is dominated by ground water is diluted from precipitation runoff 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. Sulfate was poorly correlated (rho value = -0.047) with discharge, indicating that another process may be contributing to sulfate concentrations. Accumulations of sulfate salts in soils and subsequently flushing during precipitation may weaken the discharge-dilution relationship. Strong correlations existed among the base cations calcium, magnesium, and sodium. Rho values were 0.954 (calcium and magnesium), 0.933 (calcium and sodium), and 0.904 (magnesium and sodium). These cations also were strongly correlated with alkalinity, with rho values that ranged from 0.922 for magnesium and 0.938 for sodium.

Table 25. Spearman rank correlation coefficients (rho values) showing the relation among discharge, pH, and major ions, Mogollon Creek, New Mexico, 1980 through 1995

[Q, discharge; Ca, calcium; Mg, magnesium; Na, sodium; K, potassium; Alk, alkalinity; SO_4, sulfate; Cl, chloride; SiO_2, silica; --, not applicable]

	Q	pH	Ca	Mg	Na	K	Alk	SO_4	Cl
pH	-0.313	--	--	--	--	--	--	--	--
Ca	-.736	0.272	--	--	--	--	--	--	--
Mg	-.665	.286	0.954	--	--	--	--	--	--
Na	-.822	.251	.933	0.904	--	--	--	--	--
K	-.460	.182	.647	.665	0.601	--	--	--	--
Alk	-.798	.310	.937	.922	.938	0.611	--	--	--
SO_4	-.047	.146	.358	.396	.248	.372	0.191	--	--
Cl	-.247	.207	.487	.542	.478	.327	.447	0.430	--
SiO_2	-.014	.009	.290	.370	.237	.367	.247	.232	-0.001

Results of the seasonal Kendall test for trends in discharge and major dissolved constituents for Mogollon Creek during the period of record, 1967–95, are presented in table 26. Statistically significant downward trends (a = 0.01) were observed for unadjusted concentrations of calcium, sodium, sulfate, and chloride. Downward trends remained after adjusting concentrations of calcium and sulfate for discharge variations. A statistically significant upward trend was observed for pH. No trend was observed for alkalinity. A downward trend in alkalinity was observed at this station by Smith and Alexander (1983) for the period from late 1960's to 1981. The downward trend for sulfate may be attributed to decreasing atmospheric sulfur dioxide concentrations following compliance with more stringent air-quality regulations and decreased production in nearby copper smelters (U.S. Geological Survey, 1993). Sulfur-dioxide emissions decreased by 33 percent in New Mexico during the period 1975–84 (Lins, 1987). The sulfate concentrations decreased around 1982 and 1990, however, when the analytical method changes for sulfate also occurred. Insufficient data existed for nitrate to calculate a trend. The scatter in the time-series plot for nitrate concentrations is a function of a change in the minimum reporting level for the laboratory method about 1991, rather than an environmental change.

Table 26. Results of the seasonal Kendall test for trends in discharge and unadjusted and flow-adjusted pH and major-ion concentrations, Mogollon Creek, New Mexico, 1967 through 1995

[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	0.1	0.115	--	--
pH	.01	.006	0.02	0.005
Calcium	-6	<.001	-3	.006
Magnesium	-.9	.08	-.1	.836
Sodium	-2	.001	-.9	.016
Potassium	<.01	.056	-.04	.590
Alkalinity	<.01	.922	2	.138
Sulfate	-7	<.001	-7	<.001
Chloride	-.5	.003	-.4	.024
Nitrite plus nitrate	([a])	--	--	--
Silica	<.01	.472	([b])	--

[a] Insufficient data to calculate trend.

[b] Concentration-flow model not significant at a = 0.10.

Synoptic Water-Quality Data

Results of a surface-water synoptic sampling conducted August 27–30, 1991, in the Mogollon Creek Basin are presented in table 27, and locations of the sampling sites are shown in figure 13. Discharge at the HBN station (site 9) was 0.48 m^3/s compared to the mean monthly discharge of 0.44 m^3/s for the month of August (Ortiz and Lange, 1996). The water type in the basin is mixed. Percent contributions of the major cations—calcium, magnesium, and sodium—change within the basin. Calcium was the predominant cation at each site, but the percent contribution ranged from 41 percent (site 1) to 62 percent (site 8). The water type in the upper basin (sites 1 and 2) and on the West Fork Mogollon Creek tributary (site 7) was a calcium-sodium-magnesium bicarbonate. The percent magnesium was higher at sites 3, 4, and 6; the water type was a calcium-magnesium-sodium bicarbonate. The higher magnesium at these sites is coupled with higher bicarbonate concentrations. The water type at sites 5, 8, and 9 was calcium bicarbonate.

Table 27. Physical properties and major-ion concentrations in surface-water samples collected at sites in the Mogollon Creek Basin, August 27—30, 1991

[Site locations shown in fig. 13; 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; SO_4, sulfate; Cl, chloride; NO_3, nitrate; SiO_2, silica; concentrations in microequivalents per liter, except silica is in micromoles per liter; --, not measured; <, less than; criteria used in selection of sampling sites: BG = bedrock geology, TRIB = major tributary, LU = land use]

Site	Identification number	Q	SC	pH	Ca	Mg	Na	K	Alk	SO_4	Cl	NO_3	SiO_2	Criteria
1	331304108320700	--	54	7.4	220	96	180	38	260	160	28	<3.6	370	BG
2	331305108320800	--	66	7.4	260	96	240	28	400	150	34	<3.6	400	BG
3	331240108332500	<0.001	115	7.1	600	330	250	24	890	230	23	<.7	500	BG
4	331259108340000	<.002	211	7.4	900	690	380	21	1,600	330	37	<.7	550	BG
5	331203108361200	--	65	7.8	350	80	180	18	400	140	20	<3.6	300	BG
6	331153108363100	<.001	114	7.0	550	350	290	9.5	870	200	23	<.7	480	BG
7	331329108381100	--	101	7.3	550	220	230	20	760	160	25	<3.6	380	TRIB
8	331039108395200	--	77	7.7	470	100	170	12	550	140	16	<3.6	250	TRIB, LU
9	09430600	.48	80	8.0	490	140	240	18	620	140	23	<3.6	320	--

The total ions ranged from about 980 (site 1) to about 4,000 meq/L (site 4); the concentration at the HBN station (site 9) was 1,700 meq/L. In general, concentrations of dissolved constituents of tributaries generally were within the range of dissolved constituents at the HBN station for the period of record, 1967–95 (table 24), except for the unnamed tributary in Judy Canyon (site 4). The unnamed tributary in Judy Canyon contained higher concentrations of magnesium, alkalinity, and silica. The sample collected at the HBN station contained dissolved- constituent concentrations that were generally less than the median value for the period 1967–95 (table 24). Four of the tributary sites (sites 2, 3, 4, and 6) contained silica at a concentration greater than the maximum concentration detected at the HBN station during 1967–95 (table 24). The changes in stream chemistry reflect the different weathering rates of the different volcanic units; however, because of the heterogeneous geology in each drainage, it is difficult to isolate which lithologic units are controlling ion concentrations. All sites had silica concentrations that were high owing to the quartz-rich volcanic rocks in the basin. Concentrations of the major cation, calcium, and the major anion, bicarbonate, increased by twofold in Mogollon Creek between the upper sampling site (site 1) and the HBN station (site 9). The percent difference of cations and anions ranged from 0.1 to 7.8 percent, indicating that unmeasured ions did not substantially contribute to the ionic composition of the water. Nitrate concentrations were low in all basins and were characteristic of undeveloped areas (Mueller and others, 1995).

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Appendix A. List of Map References

a. U.S. Geological Survey topographic maps:

- Diablo Range, New Mexico (1:24,000), 1965
- Grouse Mountain, New Mexico (1:24,000), 1965
- Mogollon Baldy Peak, New Mexico (1:24,000), 1965
- Mogollon Mountains, New Mexico (1:100,000), 1985
- Rice Ranch, New Mexico (1:24,000), 1965, streamflow-gaging station
- Shelley Peak, New Mexico (1:24,000), 1965

b. Geologic maps:

- Ratte´, J.C., and Gaskill, D.L, 1975, Reconnaissance geologic map of the Gila Wilderness Study Area, Southwest New Mexico: U.S. Geological Survey Miscellaneous Investigation Series Map I–886, 2 pl., scale 1:62,500.
- Ratte´, J.C., Gaskill, D.L., Eaton, G.P., Peterson, D.L., Stotelmeyer, R.B., and Meeves, H.C., 1979, Mineral resources of the Gila Primitive Area and Gila Wilderness, New Mexico: U.S. Geological Survey Bulletin 1451, 229 p.

c. Soil surveys: No soil survey available.

d. Other maps:

- Mogollon Mountains, New Mexico, 30' x 60' quadrangle, Bureau of Land Management, 1985, scale 1:100,000.
- Gila National Forest Map, 1996, Southwestern Region, U.S. Department of Agriculture.

Appendix B. NWIS Site-Identification Numbers

Site	Identification Number	Site Name
1	331304108320700	MOGOLLON CREEK ABOVE TRAIL CANYON
2	331305108320800	UNNAMED TRIBUTARY IN TRAIL CANYON
3	331240108332500	SOUTH FORK MOGOLLON CREEK
4	331259108340000	UNNAMED TRIBUTARY IN JUDY CANYON
5	331203108361200	UNNAMED TRIBUTARY IN LOOKOUT CANYON
6	331153108363100	UNNAMED TRIBUTARY BELOW LOOKOUT CANYON
7	331329108381100	WEST FORK MOGOLLON CREEK
8	331039108395200	RAIN CREEK
9	09430600	MOGOLLON CREEK NEAR CLIFF, NEW MEXICO