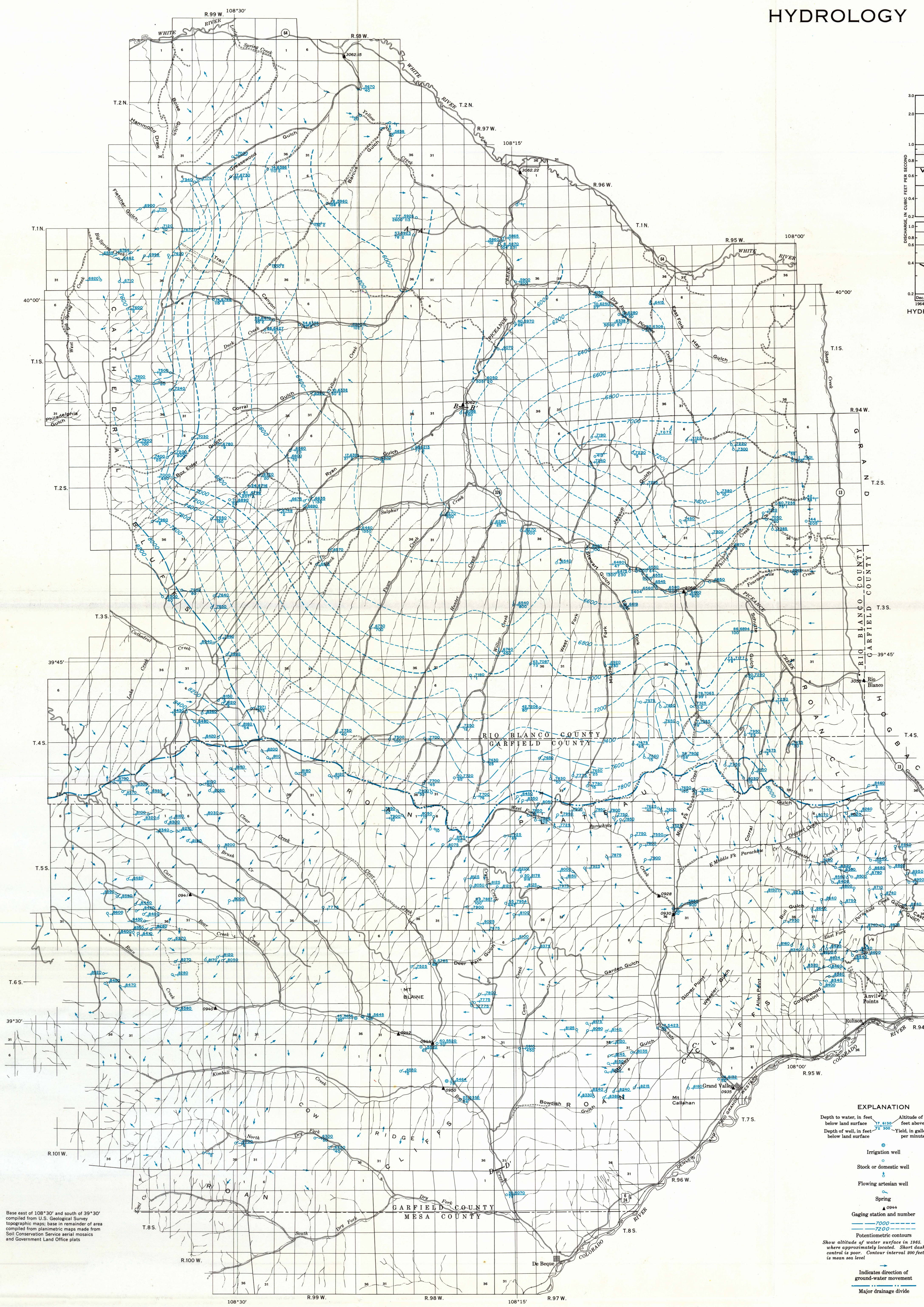
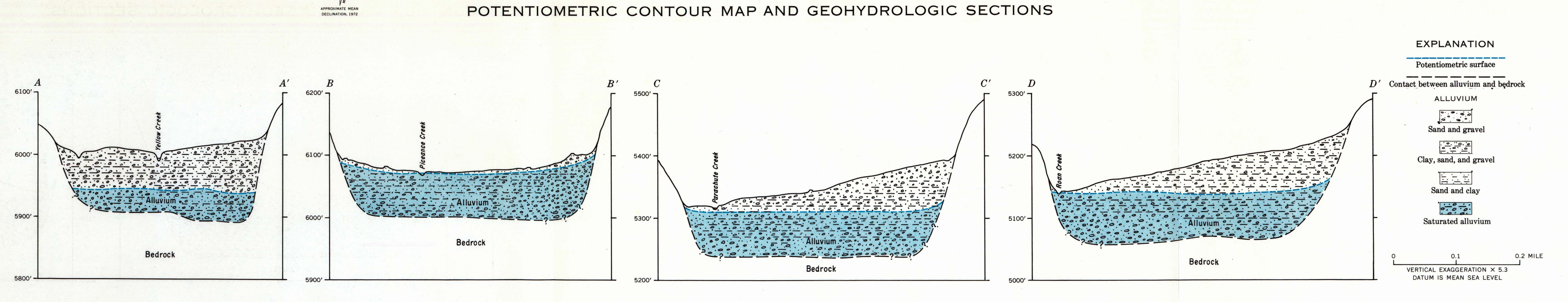
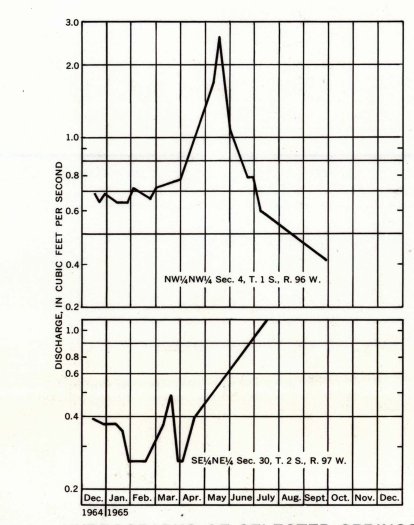
HYDROLOGY

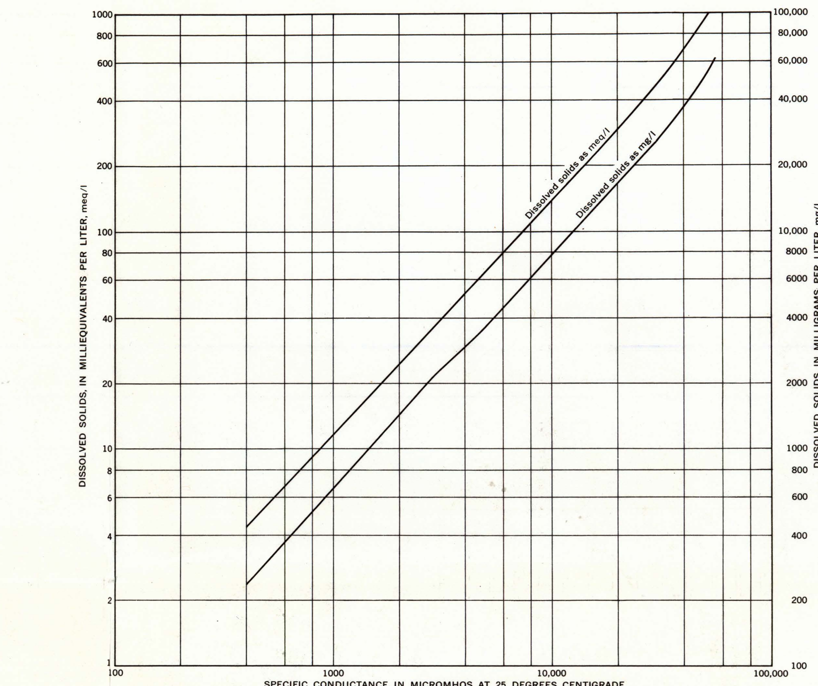


POTENTIOMETRIC CONTOUR MAP AND GEOHYDROLOGIC SECTIONS

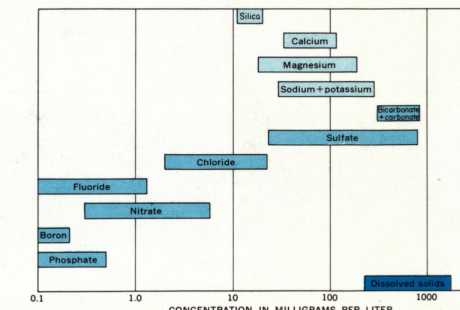




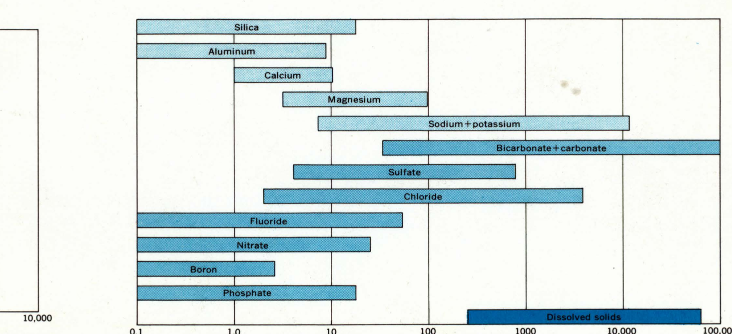
HYDROGRAPHS OF SELECTED SPRINGS



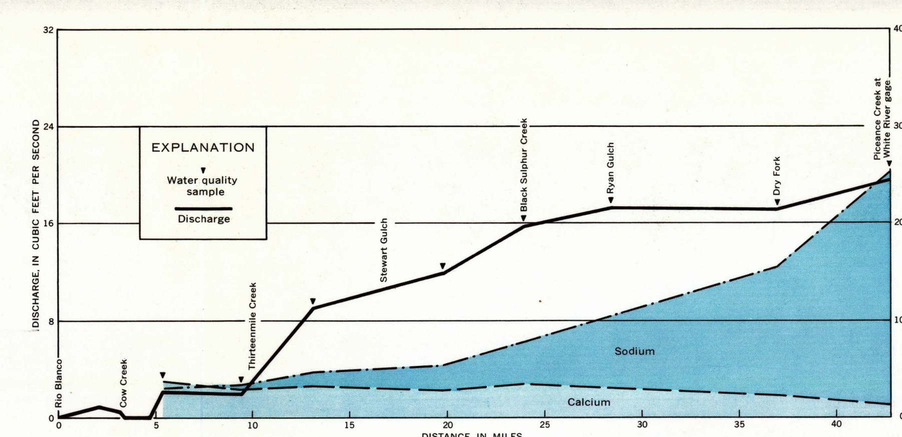
GRAPH RELATING SPECIFIC CONDUCTANCE AND DISSOLVED SOLIDS



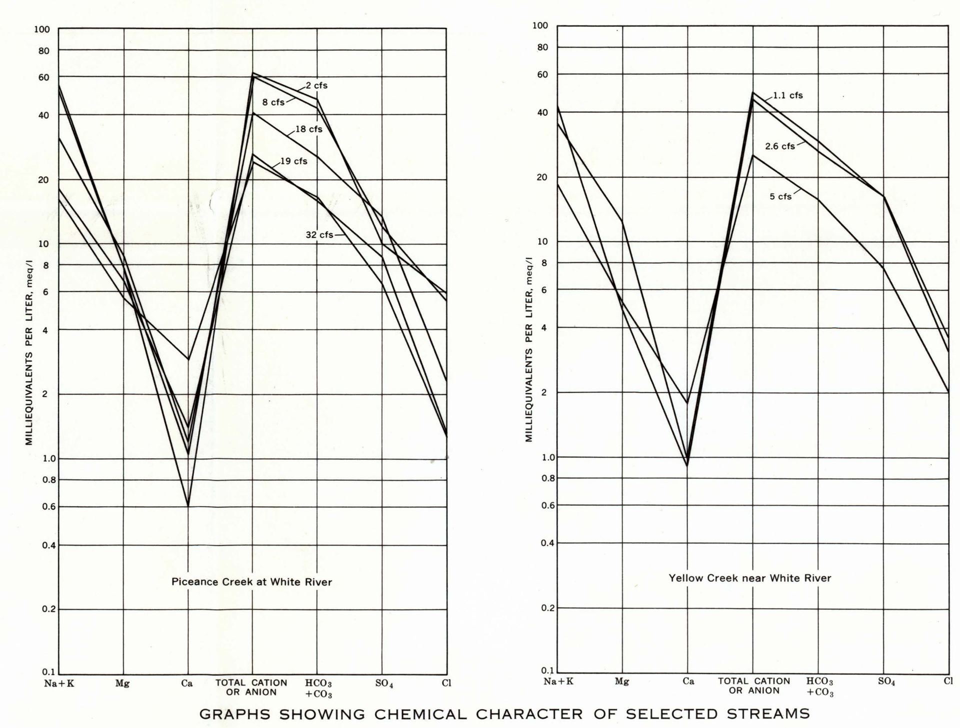
BAR GRAPH SHOWING RANGE OF WATER QUALITY IN THE EVACUATION CREEK MEMBER



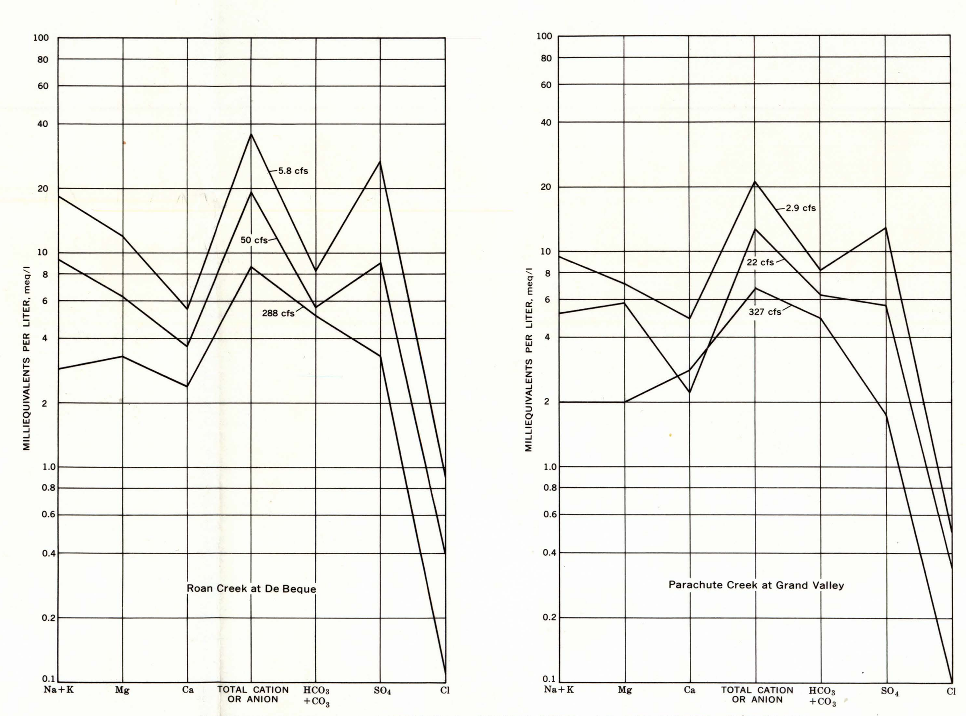
BAR GRAPH SHOWING RANGE OF WATER QUALITY IN THE PARACHUTE CREEK MEMBER



GRAPH SHOWING DISCHARGE AT VARIOUS PLACES ALONG PICEANCE CREEK AND CHANGES IN QUALITY OF WATER, OCTOBER 6, 1965



GRAPHS SHOWING CHEMICAL CHARACTER OF SELECTED STREAMS



GRAPHS SHOWING CHEMICAL CHARACTER OF SELECTED STREAMS

SUMMARY OF STREAMFLOW RECORDS

[Station numbers are those used in publication of surface-water records, except prefix 9 is omitted]

Station No.	Streamflow station	Period of record	Drainage area (sq mi)	Average discharge (cfs)	Extremes of discharge (cfs)	
					Maximum	Minimum daily
0928	West Fork Parachute Creek near Grand Valley	Oct. 1957–Sept. 1962	48.1	4.37	147	0
0930	Parachute Creek near Grand Valley	Oct. 1948–Sept. 1954 Oct. 1964–Sept. 1967	144	17.7	738	0
0935	Parachute Creek at Grand Valley	Apr. 1921–Sept. 1927 Oct. 1948–Sept. 1954	200	30.3	912	0
0940	Roan Creek at Simmons Ranch	June 1935–Sept. 1935 Apr. 1936–Oct. 1936 Mar. 1937–Sept. 1937	79	----	142	0
0941	Carr Creek at Altenbern Ranch	June 1935–Nov. 1936 Mar. 1937–Sept. 1937	17	2.85	143	0
0942	Roan Creek above Clear Creek	Oct. 1962–Sept. 1967	151	14.8	800	1.0
0944	Clear Creek near DeBeque	July 1966–Sept. 1967	111	----	1,540	0
0950	Roan Creek near DeBeque	Apr. 1921–Sept. 1926 Oct. 1962–Sept. 1967	321	40.0	1,220	3.2
3055	Piceance Creek at Rio Blanco	Oct. 1952–Sept. 1957	9	1.40	23	.1
3060	Piceance Creek near Rio Blanco	Oct. 1940–Sept. 1943	153	20.3	430	.1
3062	Piceance Creek below Ryan Gulch	Oct. 1964–Sept. 1967	485	12.5	400	.80
3062.22	Piceance Creek at White River [1]	Oct. 1964–Sept. 1966	629	17.0	550	.9
3062.55	Yellow Creek near White River [1]	Oct. 1964–Sept. 1966	258	1.37	1,060	0

[1] Unpublished record.

PRECIPITATION

Distribution of precipitation in the Piceance Creek structural basin is markedly affected by altitude (Iorns and others, 1965, p. 184–185). Areas where the altitude is greater than 8,000 feet, such as along the major divide and Cathedral Bluffs, receive as much as 26 inches of precipitation per year, mostly as snow in the winter months. Areas between altitudes of about 5,500 and 8,000 feet generally receive from 12 to 20 inches of precipitation annually. Streamflow generally is greatest during spring snowmelt. Some of the springs in the basin show a similar response to snowmelt as shown by the hydrographs of selected springs.

Samples of water having a dissolved-solids content ranging from 250 to 63,000 mg/l (milligrams per liter) have been collected in the basin. The best quality of water is found in streams and aquifers in the higher altitudes in the basin. The worst quality of water is found in the high resistivity zone of the Parachute Creek Member.

GROUND WATER IN THE GREEN RIVER FORMATION

The Green River Formation is the best potential source of ground water in the northern part of the Piceance Creek basin. The leached zones of the Parachute Creek Member and the Evacuation Creek Member are aquifers and contain water under artesian pressure in most of the area. There are many flowing wells and the maximum depth to water is about 200 feet. The Garden Gulch Member and the high resistivity zone of the Parachute Creek Member have very low permeability and confine water in underlying aquifers. The Mahogany zone of the Parachute Creek Member also confines water except where it is cut by vertical fractures. These fractures permit water to move between aquifers (see diagrammatic section on Sheet 1). The leached zone contains water in fractures and solution openings and is considered the principal bedrock aquifer in the northern part of the Piceance Creek basin because it has the greatest areal extent, permeability, and storage capacity. It contains 2.5 million acre-feet or more of water in storage. The transmissivity distribution in the leached zone was estimated from the thickness map of the zone (Sheet 1) and from six aquifer tests (Coffin and others, 1968). The transmissivity of the zone ranges from less than 3,000 gpd per ft (gallons per day per foot) in the margins of the basin to 20,000 gpd per ft in the center of the basin. Tests indicate that the potential yield of a well tapping the leached zone may be as much as 1,000 gpm (gallons per minute). The artesian storage coefficient of the leached zone is estimated to be about 10^{-4}, but when not confined, the storage coefficient would be about 10^{-1}. Thus, pumping very large quantities of water would cause water levels to decline several hundred feet to the top of the leached zone in a short time (< 1 yr), but after water levels reached the leached zone the decline would be much slower. The Evacuation Creek Member contains water mainly in fractures. Its permeability is much less than the leached zone. Test wells penetrating the Evacuation Creek Member in the north-central part of the basin yield 100 gpm or less.

The major ground-water divide in the basin is approximately the same as the topographic divide between the White River and the Colorado River. Ground-water movement in the Green River Formation (northern part of the Piceance Creek basin) is toward the two major drainages of the basin, Piceance and Yellow Creeks. Movement is normal to the contours shown on the potentiometric contour map. The Green River Formation is bounded on the west by Cathedral Bluffs. On the north, the divide is near the main stem of the White River. Recharge on the margins of the basin moves downward through the Evacuation Creek Member and Mahogany zone into the leached zone of the Parachute Creek Member. Data from a few wells indicate that the potentiometric head in the leached zone near the edges of the basin is lower than the head in the overlying zones. Other data indicate that near the center of the basin the head in the leached zone is higher than the head in the upper zone. These head relations indicate that the direction of flow is downward in the margins of the basin, laterally toward the center and northern edge of the basin, and upward in the lower reaches of Piceance and Yellow Creeks and in the White River valley (see diagrammatic section on Sheet 1). In the center and northern edge of the basin water moves upward and discharges into Piceance Creek, Yellow Creek, the White River, or is evaporated. Smaller amounts of ground water are discharged to springs and flowing wells. The potentiometric contours indicate that about half of the northern part of the basin contributes ground water to Piceance Creek. South of the major divide, water is discharged by springs that issue from fractures near the top of the Mahogany zone. In the lower part of the stream valleys, the Mahogany forms part of a cliff as high as 2,000 feet above the stream. Spring discharge from the top of the zone in these areas can be seen as a dark band along the upper part of the cliff. However, most of this water evaporates before reaching a stream.

Pumping large quantities of ground water from the Green River Formation would change the points of discharge. Continuous pumping of large amounts of ground water for a number of years could dry up springs over a large part of the basin and stop much of the seepage to the creeks. Many of the water holes used by wildlife would disappear and the base flow of Piceance and Yellow Creeks would be appreciably diminished to the detriment of present appropriators.

The dissolved-solids concentration of water in the Green River Formation ranges from 250 to 63,000 mg/l. Water near the edges of the basin contains less than 2,000 mg/l dissolved solids and the dominant ions are calcium, magnesium, and bicarbonate. About halfway between the edges of the basin and the center, dissolved-solids are about the same as at the edges, but the dominant ions are sodium and bicarbonate. Near the center of the basin, the water has dissolved considerable amounts of saline minerals and the dissolved solids average 25,000 mg/l and the principal constituents are sodium and bicarbonate. Chloride concentration ranges between 500 and 2,500 mg/l. The graph relating dissolved solids of water in the basin to specific conductance can be used to approximate dissolved-solids concentrations from field conductivity measurements. Water in the Parachute Creek and Evacuation Creek Members are chemically similar in the higher parts of the basin (Coffin and others, 1968). However, in the lower parts of the basin, water in the Parachute Creek Member becomes highly mineralized from contact with the saline minerals. For example, water in an abandoned oil test well near Piceance Creek about 1.5 miles below Ryan Gulch contained 17,400 mg/l dissolved solids, principally sodium and bicarbonate. The water in the well contained 542 mg/l chloride and is unsuitable for most uses. Water in the Evacuation Creek Member is a mixed chemical type with no dominant cation or anion. The principal constituents are sodium, magnesium, and sulfate. Analyses of water samples from the Evacuation Creek Member are summarized in a bar graph at the left. The dissolved-solids concentration ranges from 250 to 1,800 mg/l. Water in the Parachute Creek Member has sodium and bicarbonate as the principal ions, however, when the dissolved-solids are less than 500 mg/l, the principal ions are calcium and bicarbonate. A summary of analyses of water samples from the Parachute Creek Member is given in a bar graph at the left. The dissolved solids concentration ranges from 250 to 63,000 mg/l. The average dissolved solids concentration of 6 water samples obtained during a pumping test of the high resistivity zone was 63,000 mg/l.

GROUND WATER IN THE ALLUVIUM

Alluvium is a source of ground water along Piceance, Yellow, Roan, and Parachute Creeks. The alluvial aquifer is capable of storing and transmitting more water per unit volume than any other aquifer in the basin. However, the areal extent of the deposits is small compared to that of the bedrock aquifers. The alluvium is confined to belts less than 1 mile wide along the creeks. Along the major drainages, the alluvium ranges from 0 to 140 feet thick and the saturated thickness may be as much as 100 feet in a few places (Coffin and others, 1968). Water in the alluvium occurs under both water-table and artesian conditions. The permeability of the clay is much less than that of the sand and gravel, and where it confines water in underlying sand and gravel under enough pressure, water flows at the land surface when tapped by a well. Typical occurrences of alluvium in the major stream drainages are shown by the sections below the potentiometric contour map.

An aquifer test in the alluvium of Piceance Creek showed that after pumping a few hours, the hydrologic boundaries of the alluvium will affect drawdowns and well yields (Coffin and others, 1968). The storage coefficient probably averages about 0.20. In places where the alluvium contains clay beds, the transmissivity may be as low as 20,000 gpd per ft. Thus, well yields vary widely from place to place according to variations in lithology of the alluvium at the well and proximity of the well to the hydrologic boundaries. Initial yields from properly located, developed, and constructed wells are estimated to be as much as 2,000 gpm. An irrigation well in Roan Creek was reported to yield 1,500 gpm.

The alluvial aquifer is recharged by precipitation, by applied surface water, by streams, and by infiltration from the Green River Formation. The aquifer discharges to streams, springs, wells, and to the atmosphere by evapotranspiration.

The dissolved-solids concentration of water in the alluvium ranges from 250 to 25,000 mg/l. Water in alluvium in the upper reaches of the major drainages contains less than 700 mg/l dissolved-solids. In general, the principal ions in the alluvial water are calcium, magnesium, and bicarbonate. Ions in the water in the alluvium of Piceance Creek are predominantly calcium, magnesium, sodium, and bicarbonate; the dissolved-solids concentration increases downstream. The dissolved-solids concentration is about 700 mg/l at Cow Creek and 2,500 mg/l at Dry Fork. Below Dry Fork the concentration increases to 8,300 mg/l and sodium becomes the dominant cation. These changes occur by solution and ion exchange and reflect the change in nature of the bedrock underlying the alluvium. Above Dry Fork the alluvium is underlain by the Evacuation Creek Member and below by the Parachute Creek Member. Abandoned flowing wells below Dry Fork tapping the Parachute Creek Member contribute locally to the increase in dissolved solids. Water in the alluvium in Yellow Creek appears to be within the range in composition and concentration of the water in the alluvium of Piceance Creek. Dominant ions in the water in the alluvium of Roan and Parachute Creeks are calcium, magnesium, sodium, bicarbonate, and sulfate. The dissolved-solids concentration of the water is as much as 7,200 mg/l. The alluvium of Roan and Parachute Creeks contains some gypsum which was derived from the Wasatch Formation. Water in contact with the gypsum becomes increasingly concentrated with sulfate. The sulfate concentration of a water sample obtained near the mouth of Roan Creek was 4,200 mg/l.

SURFACE WATER

There are no long-term records of streamflow in the Piceance Creek structural basin between the Colorado and White Rivers. Gaging stations on seven streams have been operated at various times. The records of these stations are summarized in the table and the station locations are shown on the potentiometric contour map. Except for two unpublished records, these data are published in Water-Supply Papers of the U.S. Geological Survey and in the annual series, Surface Water Records for Colorado, Part 1.

Commonly, all streams in the basin reach a peak during the snowmelt runoff and decrease in flow beginning in June or July, and reach low flow in September or October. Low flow continues through the winter. Parachute Creek is often dry, or almost dry, from December until April. The flow of Piceance Creek is more uniform than that of Parachute or Roan Creeks because the flow is sustained by ground-water discharge from the Green River Formation. However, in 1965 and 1966 the flow of Piceance Creek below Ryan Gulch dropped below its average of 12.5 cfs (cubic feet per second) to as little as 0.8 cfs during April or May due to diversions for irrigation before the snowmelt runoff.

On October 6, 1965, discharge was measured at 13 sites and 8 samples for chemical analysis were collected from Piceance Creek from Rio Blanco to the White River gage. The results of this study are shown on the discharge-quality graph at the left. Little water was being diverted for irrigation and there had been no precipitation for several weeks. The gain in flow downstream from Rio Blanco was caused by a thinning of the alluvium, forcing the ground water to the surface. The streamflow disappeared into the alluvium where it thickens at Cow Creek, but 2 miles downstream the alluvium was saturated and surface flow resumed. The potentiometric contour map indicates that the reach between Thirteenmile Creek and Black Sulphur Creek is fed by ground water. The 14 cfs gain in this reach, as determined by the October 6, 1965 study, supports this conclusion.

The effect of ground-water discharge from the Green River Formation on the chemical quality of water in Piceance Creek is illustrated on the discharge-quality graph. Above Thirteenmile Creek, the bedrock is the Evacuation Creek Member and ions in the water in Piceance Creek are predominantly calcium, magnesium, and bicarbonate; below Thirteenmile Creek, water contributed from the Parachute Creek Member caused a gradual increase in sodium, which became the dominant cation in the reach below Ryan Gulch. The dissolved-solids concentration ranged from 600 mg/l at Cow Creek to 2,000 mg/l at the White River gage.

Samples of water for chemical analysis at various discharges were collected on Piceance, Yellow, Roan, and Parachute Creeks. The results of the analyses are shown on the graphs showing chemical character for the various streams. Water in the alluvium is generally the same chemical character as the water in the stream, but has a higher dissolved-solids concentration. In general, the quality of the water is best at high discharges but the chemical character remains about the same. The observed range in dissolved-solids concentration in the four streams was as follows: Piceance Creek, 440 to 5,700 mg/l; Yellow Creek, 1,400 to 3,000 mg/l; Roan Creek, 430 to 2,300 mg/l; and Parachute Creek, 360 to 1,280 mg/l.

CONCLUSIONS

1. Surface-water supplies in the basin are small and are completely developed.
2. Additional ground-water supplies could be developed from the Green River Formation or from the alluvium. Wells in the Green River Formation might yield as much as 1,000 gpm. Wells in the alluvium might yield as much as 2,000 gpm.
3. Pumping large quantities of ground water from either the alluvium or from the leached zone of the Green River Formation would have adverse effects on present surface supplies.
4. The water stored in the leached zone represents a potential source of industrial supply that might last many years. The zone contains 2.5 million acre-feet of ground water in storage. Pumping large quantities of water from the Green River Formation would cause levels to decline several hundred feet in a short period of time (< 1 yr).
5. Water pumped from the leached zone would contain dissolved solids ranging from less than 2,000 mg/l near the edges of the basin to more than 60,000 mg/l in the center of the northern half of the basin. The 60,000 mg/l water might have a chloride concentration of 1,000 mg/l or more. Water with a chloride concentration this high is unsuitable for most uses. Ions in the water near the edges of the basin are predominantly calcium, magnesium, and bicarbonate; the ions near the center of the basin are predominantly sodium and bicarbonate.
6. Oil shale mining operations may be hampered by ground water. Flooding by ground water would be most serious in mines which are excavated in or below the leached zone. For example, near the center of the basin, an open-pit mine with a radius of half a mile might require a pumping rate of as much as 60 cfs to keep the mine dewatered.
7. Disposal of mine effluent in surface streams would increase the salt load in the White and Colorado Rivers, which would pose a serious pollution problem.

SELECTED REFERENCES

Coffin, D. L., and Bredehoeft, J. D., 1969, Digital computer modeling for estimating mine-drainage problems, Piceance Creek basin, northwestern Colorado: U.S. Geol. Survey open-file report, 20 p.
Coffin, D. L., Welder, F. A., Glanzman, R. K., and Dutton, X. W., 1968, Geohydrologic data from Piceance Creek basin between the White and Colorado Rivers, northwestern Colorado: Colorado Water Conserv. Board Circ. 12, 38 p.
Donnell, J. R., 1961, Tertiary geology and oil-shale resources of the Piceance Creek basin between the Colorado and White Rivers, northwestern Colorado: U.S. Geol. Survey Bull. 1082–L, 891 p.
Gale, H. S., 1910, Coal fields of northwestern Colorado and northeastern Utah: U.S. Geol. Survey Bull. 415, 265 p.
Iorns, W. V., Hembree, C. H., Phoenix, D. A., and Oakland, G. L., 1964, Water resources of the Upper Colorado River Basin—basic data: U.S. Geol. Survey Prof. Paper 442, 1036 p.
Iorns, W. V., Hembree, C. H., and Oakland, G. L., 1965, Water resources of the Upper Colorado River Basin—technical report: U.S. Geol. Survey Prof. Paper 441, 370 p.
Milton, Charles, and Eugster, H. P., 1959, Mineral assemblages of the Green River formation, Colorado-Utah-Wyoming, in Abelson, P. H., ed., Researches in geochemistry: New York, John Wiley and Sons, Inc., p. 118–150.
Peale, A. C., 1876, Report on valleys of Eagle, Grand, and Gunnison Rivers, Colorado: U.S. Geol. Geog. Survey Terr. (Hayden) Ann. Rept. for 1874, p. 148, 156, 159–161.

GEOHYDROLOGY OF THE PICEANCE CREEK STRUCTURAL BASIN BETWEEN THE WHITE AND COLORADO RIVERS, NORTHWESTERN COLORADO

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1971