

WATER RESOURCES INVENTORY

ZION NATIONAL PARK

by

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INTRODUCTION

Water is obviously a valuable resource -- without it all other resources become meaningless or nonexistent. As a resource, water can be exploited to the point that its quality and quantity become so deteriorated as to limit future use. To maintain desired levels of water quantity and quality it is necessary to have data available that will aid in management decisions. With this in mind, a general inventory of the water resources of the eastern part of Zion National Park was undertaken.

Southwestern Utah is an arid to semi-arid region, where the timing and quantity of available water is very critical. The United States Geological Survey (USGS) provides historical records that have been analyzed and synthesized into graphs and tables describing the timing and quantity of flows.

Through discussions with the Park Superintendent and other concerned members of the Park Service, certain key areas of interest have been identified. There is limited available water and stream flow diversion is increasing. To facilitate water demand decisions, stream flow quantity and regime data become essential. Coal mining within the watershed -- a strong possibility for the future -- requires careful background water chemistry data. Also, flood frequency and flood probability are important in management decisions. This is particularly true in areas of high intensity thunder storms. Lastly, with increased public and private use of the North Fork of the Virgin River (NFVR) watershed, a comprehensive evaluation of the hydrologic characteristics of the watershed is a necessity to long range management.

AREA DESCRIPTION

The NFVR is a 364 mi² (94,276 ha) watershed located in southwestern Utah, with almost one third of the watershed within the boundaries of the Zion National Park. The watershed consists of five perennial contributors: Deep Creek, Kolob Creek, Goose Creek, Orderville Creek, and Pine Creek. Figure 1 shows the watershed boundaries and major tributaries and Table 1 shows the drainage area of each perennial stream. The watershed's complexity includes its ownership, usage, climate and geologic uniqueness.

Ownership: There are 5 principle land holders of the NFVR watershed. Of the total 364 mi², 236 are held by private interests (representing 65%). National resource land, national parks and monuments, state lands, and national forest land make up the remaining 35%. Table 2 gives the percentages of each of the major land holders within the watershed.

Land Use: Land use within the watershed includes recreation, grazing, summer homes, and farming. The watershed also serves as habitat for various wildlife including deer, cougar, and various small mammals and birds.

Recreation within the watershed includes hiking, camping (both day and overnight) and sightseeing. There are public campgrounds, camping facilities, and overnight lodging located within the park below Orderville Creek. Access roads to camping, fishing and private land holdings are located throughout the upper regions of the watershed.

One of the main recreational attractions within the park is a 12-mile stretch on the NFVR, the Zion Narrows. Within the Narrows both overnight camping and day use occur. The Park Service estimates that 2000 people walk the entire 12 miles per visitor season (June 15-September 30).

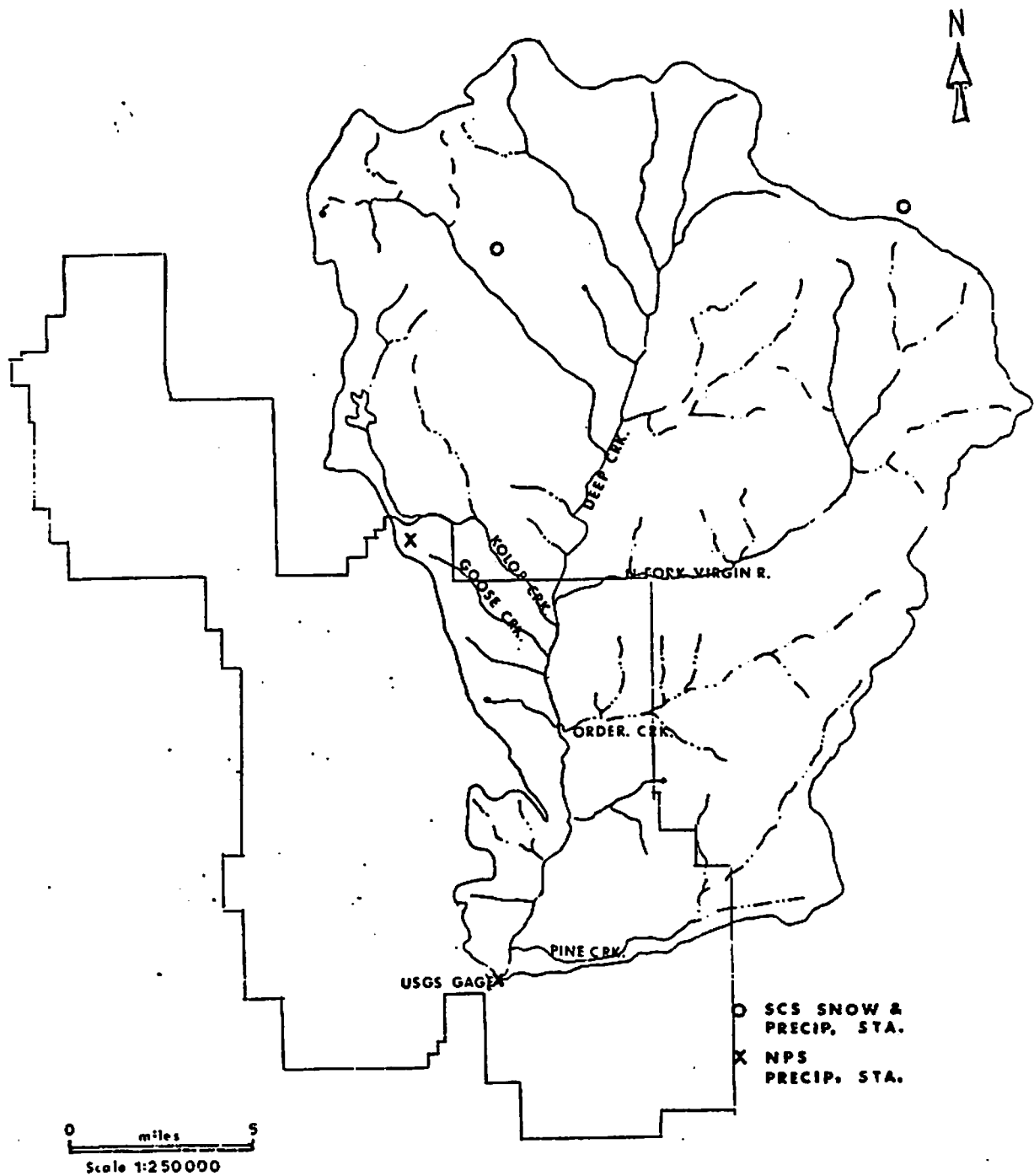


Figure 1. Watershed boundary, North Fork of the Virgin River, near Springdale, Utah.

Table 1. Tributary drainage area, NFVR watershed.

Drainage Basin	Area (mi ²)	% of Total Area
North Fork above confluence with Deep Creek	66	18
Deep Creek	122	34
Kolob Creek	33	9
Orderville Creek	31	9
Pine Creek	30	8
Other tributaries	82	22
TOTAL	364 mi ²	100%

Table 2. Land ownership of the NFVR (BLM Map 1975)

Ownership	% of Total Area	Mi ²
National Resource Land	9%	32
Private Land	65	236
National Parks and Monuments	21	78
State Land	3	10
National Forest	2	8
TOTAL AREA	100%	364 mi ²

Several thousand more visit the lower sections of the Narrows during the same season.

While most of the usage is in the lower parts of the watershed, cattle grazing is an important land use in the higher elevations. Here cattle grazing is interspersed with summer home sites, farming and hunting clubs.

Climate: Climatically the drainage areas receive from 14.33 in. (mean annual precipitation for 1941-1970) at the Park Headquarters, to 31.83 in. at Webster Flat (SCS-Water Supply Outlook for Utah, 1956-75). Snow accumulation is usually confined to the upper reaches of the watershed above 7000 ft. Below that snow does fall and will accumulate but seldom lasts beyond March. Average annual temperatures throughout the watershed vary from 75°F to 47°F, with a maximum of 112°F to a minimum of -15°F. (Climatological Summary, Zion National Park).

Geologic Uniqueness: There is one important factor distinguishing this drainage from other watersheds: the geomorphic uniqueness of the narrow stream channels and the steep channel walls. The NFVR has cut through Navajo sandstone leaving vertical walls of 1000 ft. or greater. With the exception of a few narrow side canyons, the NFVR is accessible only along the river channel itself. When recreationists take the 12 mile walk through the narrows they are confined by the sandstone walls to the active stream channel bottom. Visitors throughout the park are confined by these canyon walls and consequently concentrate themselves, their vehicles and activities to the immediate area surrounding the stream

channel. This concentration enhances the urgency of an inventory of the present conditions of the water resource.

PHYSIOGRAPHIC CHARACTERISTICS

Bifurcation Ratio

Table 3 gives the bifurcation ratio for the NFVR and its major tributaries. The bifurcation ratio is a ratio of stream ordination. For example, if a stream has a bifurcation ratio of 3.5, there are 3 1/2 times as many channel segments of any given order as that of the next higher order. The North Fork at Deep Creek has a ratio of 4.61--meaning there are 4.61 times as many channel segments of the first order as there are of the second order.

Bifurcation ratios characteristically range from 2.0 to 4.5, with a national average of 3.5. The NFVR and its tributaries are within the average except Pine Creek and Kolob Creek which have ratios of 7.59 and 5.5 respectively. High bifurcation ratios can be expected in areas where narrow valleys are confined by steep canyon walls. The higher the ratio, the more elongated the drainage basin; the lower the ratio, the more circular. Pine Creek is the most elongated basin in the NFVR watershed; Deep Creek the most circular.

Stream Channel Slope

The NFVR mean channel slope is 170 feet per mile between Chamberlain's Ranch and the Temple of Sinawava. Tributary slope ranges from 530 feet per mile for Goose Creek to 273 feet per mile for Orderville Creek. Elevations range from 9155 feet to 4048 feet. Table 4 gives the slope and elevational range for the NFVR and its tributaries.

Table 3.. Bifurcation ratio of major tributaries, NFVR.

Contributory Name	Bifurcation Ratio
North Fork above confluence with Deep Creek	4.61
Deep Creek	3.14
Kolob Creek	5.50
Orderville Creek	4.20
Pine Creek	7.59
North Fork at Gage	4.49

Table 4. Tributary stream channel slope, NFVR.

Stream Channel	Slope (feet/mile)	Elevation (feet)
North Fork above Chamberlain's Ranch	280	6000' - 8000'
North Fork below Chamberlain's Ranch to Temple of Sinawava	170	4410' - 6000'
Deep Creek	281	4700' - 9200'
Kolob Creek	331	4850' - 9155'
Goose Creek	530	4650' - 7300'
Orderville Creek	273	4250' - 6980'
Pine Creek	292	4000' - 7800'

HYDROLOGIC DATA

Gaging Station

The study of a water resource is in part a study of the history of the river: its inputs, its regime, and its outflow. The United States Geological Survey (USGS) has been recording stream flow of the NFVR since 1913, with complete annual records since 1924. The USGS station is located in the SW 1/4 NW 1/4 Sec. 22, T.41 S., R.10 W., Washington County, on the right bank of the NFVR in Zion National Park, 1.9 miles (3.1 km) northeast of Springdale. All stream flow analysis contained in this report result from a synthesis and interpretation of the USGS data.

Precipitation

Precipitation is measured by four non-recording rain gages. Two of these gages (Zion Canyon and Lava Point) are maintained by the Park Service, the other two gages are maintained by the Soil Conservation Service (Duck Creek and Webster Flat). Lava Point precipitation is recorded only from July through September, while the other gages record year-round. Three storage gages have been recording data since 1952 and data have been recorded since 1970 at Lava Point.

The Thiessen mean was used to calculate areal precipitation. Tables 5, 6a, 6b, and 7 give the arithmetic mean, Thiessen percent of area, and Thiessen mean precipitation respectively. As can be seen from Table 7, the Thiessen mean annual precipitation is 24.11 inches, with a monthly high of 3.67 inches in March and a low of 0.91 inches in June.

In addition to maintaining storage rain gages, the SCS also maintains snow courses. These courses aid in evaluating the water outlook for the coming year. Water yield predictions are made and published monthly by the Soil Conservation Service (SCS, Water Supply Outlook for Utah, 1956-76).

High intensity summer thunder showers are common in southwestern Utah and individually can be the most significant of climatic events. Table 8 gives the estimated return period for short duration precipitation at the Park Headquarters.

Table 5. Mean monthly precipitation for four rain gages, NFVR watershed. Precipitation is in inches (1970-1975).

Month	Zion Canyon (in)	Lava Point (in)	Webster Flat (in)	Duck Creek (in)
January	1.14	--	2.90	2.15
February	1.10	--	2.78	2.05
March	1.95	--	4.68	3.68
April	0.87	--	3.30	2.04
May	0.87	--	1.40	1.44
June	1.05	0.33	1.23	1.38
July	1.45	1.14	2.05	1.79
August	1.73	1.83	2.05	1.79
September	0.44	0.58	2.05	1.79
October	1.45	--	3.13	2.93
November	1.30	--	3.13	2.93
December	1.17	--	3.13	2.93
TOTAL	14.52 in.	--	21.83 in.	26.90

Table 6(a). Thiessen polygon areas for areal precipitation using three gages within or near NFVR watershed (1970-1975).

Rain gage name	Area (mi ²)	Percent of total area
ZION CANYON	103	28%
WEBSTER	169	47
DUCK	92	25
TOTAL	364 mi ²	100%

Table 6(b). Thiessen polygon areas for areal precipitation using four gages within or near the NFVR watershed (1970-1975).

Rain gage name	Area (mi ²)	Percent total area
ZION CANYON	66	18%
WEBSTER	110	31
DUCK	92	25
LAVA PT.	96	26
TOTAL	364 mi ²	100%

Table 7. Thiessen mean precipitation, combining data from Tables 5, and 6(a) and (b).

Month	Lava Point			Zion Canyon			Webster Flat			Duck Creek			Total Formo.
	% of Area	Mo. Precip.	Weight-ed Precip.	% of Area	Mo. Precip.	Weight-ed Precip.	% of Area	Mo. Precip.	Weight-ed Precip.	% of Area	Mo. Precip.	Weight-ed Precip.	
January*	--	--	--	28	1.14	.32	47	2.90	1.36	25	2.15	.54	2.22
February*	--	--	--	28	1.10	.31	47	2.78	1.31	25	2.05	.51	2.13
March*	--	--	--	28	1.96	.55	47	4.68	2.20	25	3.68	.92	3.67
April*	--	--	--	28	0.87	.24	47	3.30	1.55	25	2.04	.51	2.30
May*	--	--	--	28	0.87	.24	47	1.40	.66	25	1.44	.36	1.26
June	26	0.33	0.08	18	1.05	.19	31	1.23	.38	25	1.38	.34	.91
July	26	1.14	0.30	18	1.45	.26	31	2.05	.64	25	1.79	.45	1.35
August	26	1.83	0.48	18	1.73	.31	31	2.05	.64	25	1.79	.45	1.40
September	26	0.58	0.15	18	0.44	.08	31	2.05	.64	25	1.79	.45	1.17
October*	--	--	--	28	1.45	.41	47	3.13	1.47	25	2.93	.73	2.61
November*	--	--	--	28	1.30	.36	47	3.13	1.47	25	2.93	.73	2.56
December*	--	--	--	28	1.17	.33	47	3.13	1.47	25	2.93	.73	2.53
TOTAL FOR YEAR													24.11 in.

* For these months only three stations are used.

Table 8. Estimated return periods for short duration precipitation.
Zion National Park (Richardson, 1971).

Return Period (years)	Duration									
	5 Min	10 Min	15 Min	30 Min	1 Hr (inches)	2 Hr	3 Hr	6 Hr	12 Hr	24 Hr
1	.22	.34	.43	.60	.76	.83	.90	1.06	1.21	1.36
2	.26	.41	.51	.71	.90	.99	1.08	1.30	1.50	1.70
5	.30	.46	.58	.81	1.02	1.14	1.25	1.54	1.79	2.06
10	.35	.54	.68	.94	1.19	1.33	1.47	1.82	2.13	2.45
25	.42	.65	.83	1.15	1.45	1.62	1.79	2.21	2.58	2.97
50	.47	.73	.93	1.29	1.63	1.83	2.03	2.51	2.94	3.39
100	.53	.82	1.04	1.44	1.82	2.05	2.27	2.81	3.30	3.80

Hydrographs

Figure 2 gives the Thiessen mean monthly precipitation and the arithmetic mean monthly stream flow for 1970 to 1975. As can be seen, there is a large amount of water entering the system as precipitation that does not leave as surface runoff. Mean annual surface runoff, 3.29 in., represents only 13.6 percent of the mean annual precipitation, 24.1 in.

The high variation in surface outflow for any one month is shown in Figure 3. Table 9 gives the coefficient of variation and the standard error of the mean for each of the months of summary. The coefficient of variation ranges from 21 percent to 69 percent, with the greatest variation occurring in the month with the highest mean flow.

Tables 10 and 11 give the percent of total yearly runoff and annual peak flows occurring within any particular month. It is interesting to note that 37 percent of the annual peak flows occur during August and September, the prime recreational use period.

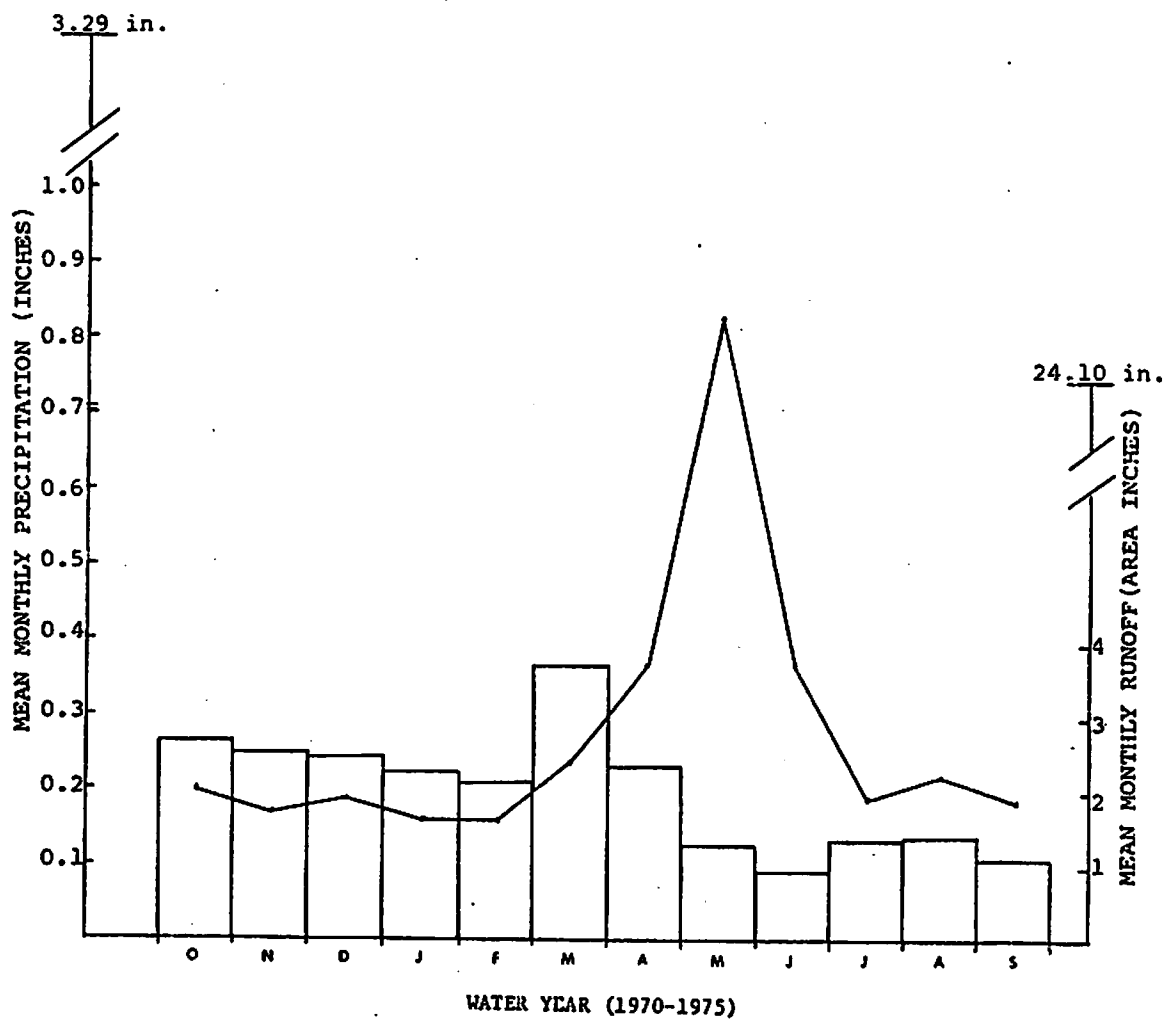


Figure 2 Mean monthly precipitation and stream flow for the North Fork of the Virgin River.

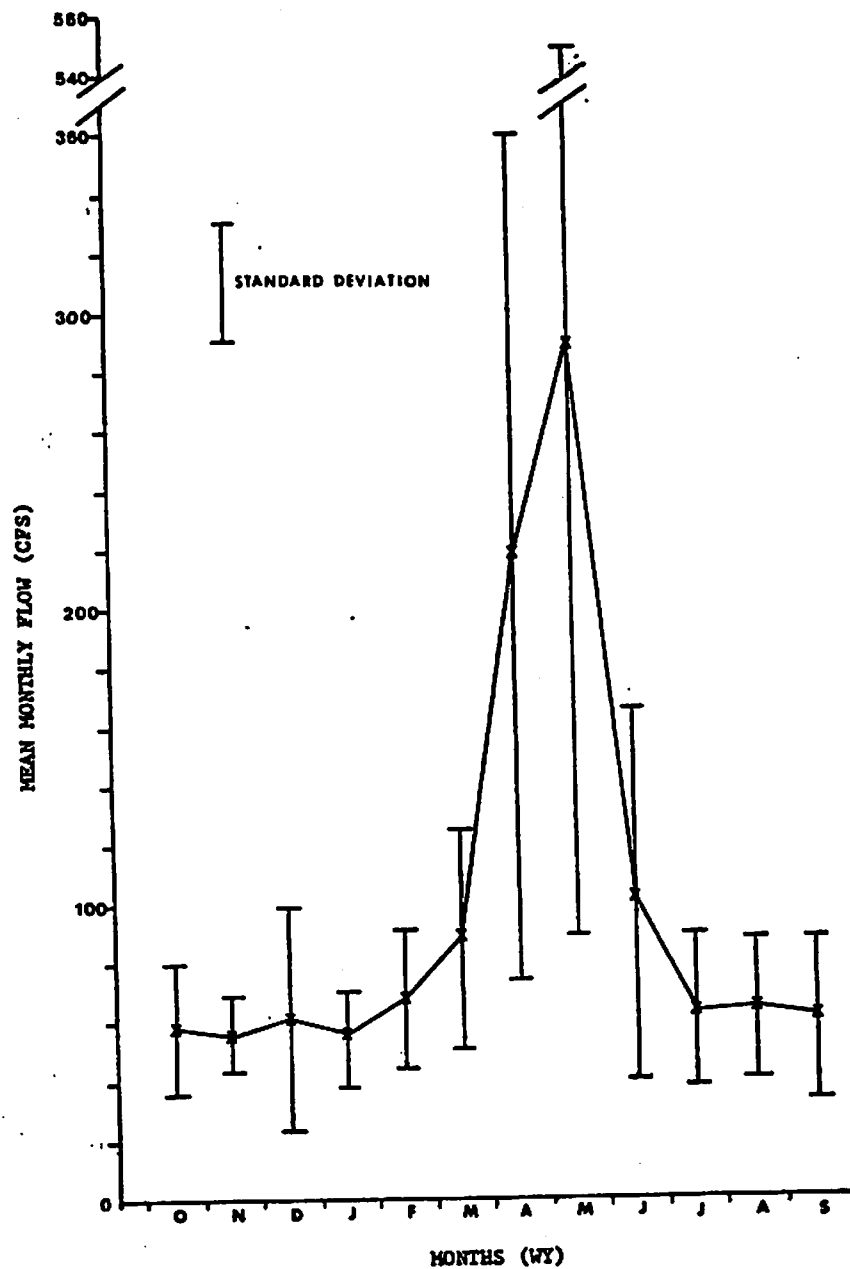


Figure 3 Mean monthly stream flow with standard deviations.

Table 9. Hydrograph statistics North Fork of the Virgin River.
(USGS, 1924-74).

Month (WY)	Mean Flow (cfs)	Standard Deviation (CFS)	Coefficient of Variation (%)	Standard Error of Mean (cfs)
October	59	23	38.98	3.25
November	56	12	21.42	1.69
December	63	37	58.73	5.28
January	57	18	31.58	2.57
February	68	22	32.35	3.11
March	90	38	42.22	5.37
April	220	146	66.36	20.44
May	293	203	69.28	28.42
June	103	63	61.16	8.73
July	65	25	38.46	3.50
August	66	23	34.85	3.19
September	61	27	44.26	3.74

Table 10. Percent of total yearly runoff occurring in any one month. (USGS, 1933-1974).

Month (WY)	Percent of total yearly runoff	Month (WY)	Percent of total yearly runoff
October	5	April	18
November	4	May	26
December	5	June	9
January	5	July	5
February	5	August	5
March	8	September	5

Table 11. Percent of annual peak flows occurring within any one month. (USGS, 1933-1974).

Month	Percent of annual peak flows	Month	Percent of annual peak flows
October	10	April	7
November	5	May	12
December	5	June	5
January	5	July	7
February	0	August	20
March	7	September	17

Flow Duration

Often in water management, the frequency of low and high flows becomes very important. Figures 4 and 5 are flow duration curves and give the percent of time that an indicated flow is equalled or exceeded. As can be seen from Figure 4, the flow in the NFVR has always exceeded 20 cfs. Figure 5 gives the same flow duration curve as in Figure 4 with the flows recorded in acre-feet per day rather than cubic feet per second.

Figure 6 gives a supplemental flow duration curve of the NFVR for the summer months (June 15 to September 30). With the use of the Zion Narrows, it becomes important to know the percent of time the river can be safely waded. If the upper flow limit for safe wading is known, then the percent of time this flow is exceeded can be taken from Figure 6. For example, if the upper safe limit is 60 cfs, then the water is wadable about 60 percent of the time. The 60 percent would represent the percent of time the Narrows could be used for safe hiking in the average summer season.

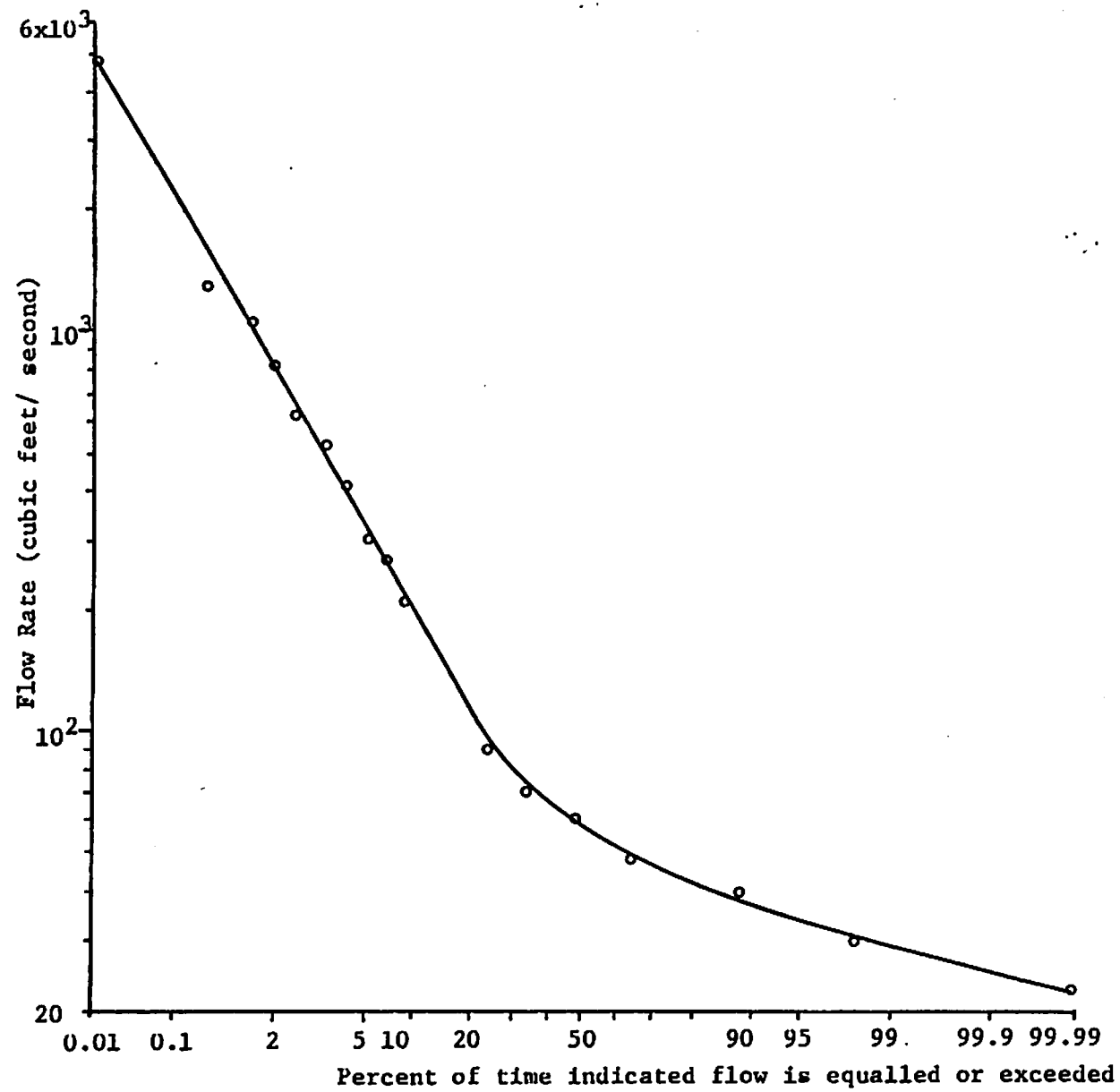


Figure 4. Flow duration curve for the North Fork of the Virgin River, near Springdale, Utah. (USGS, 1923 to 1974).

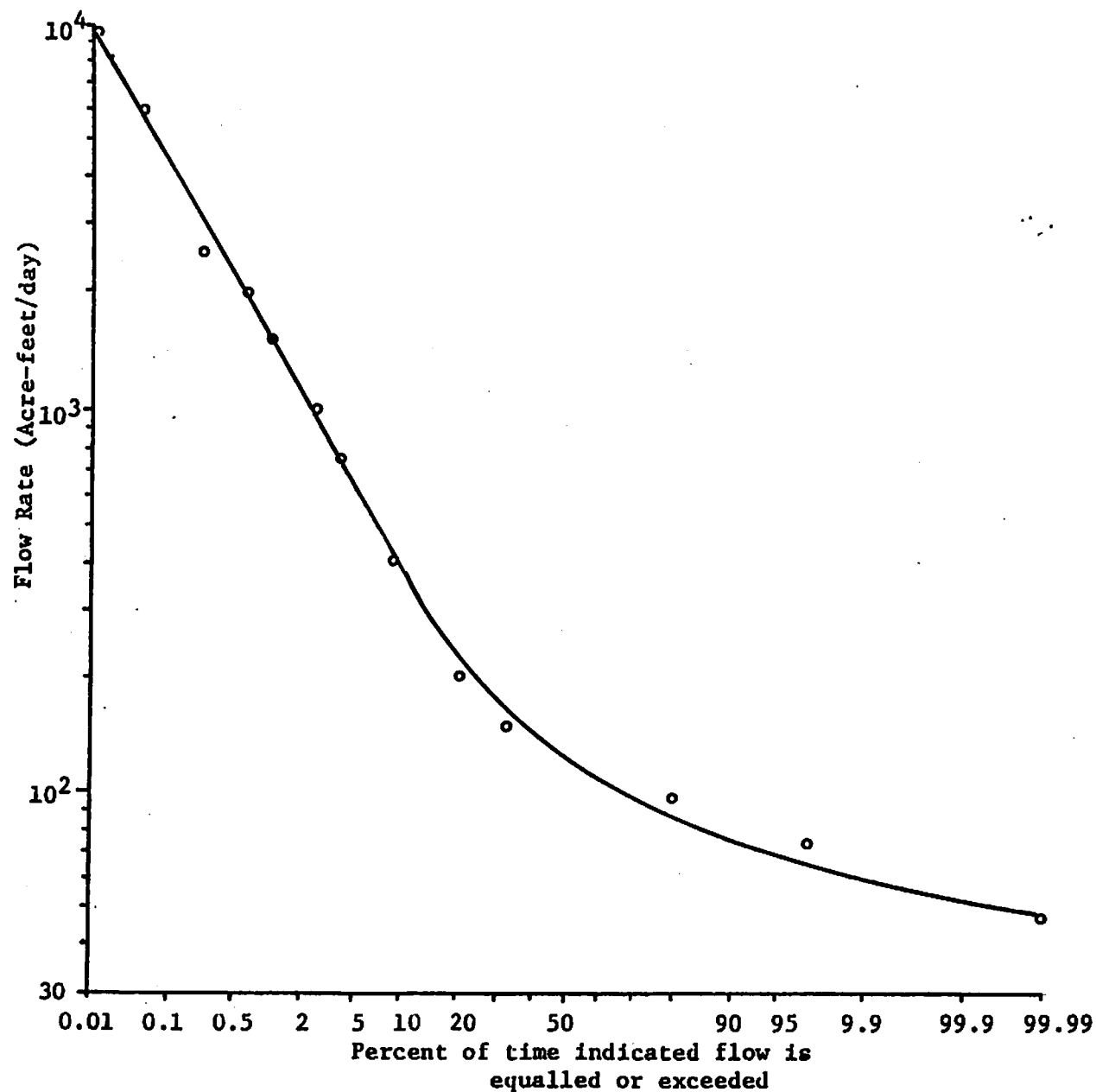


Figure 5. Flow duration curve in acre-feet/day for the North Fork of the Virgin River, near Springdale, Utah (USGS, 1923-1974).

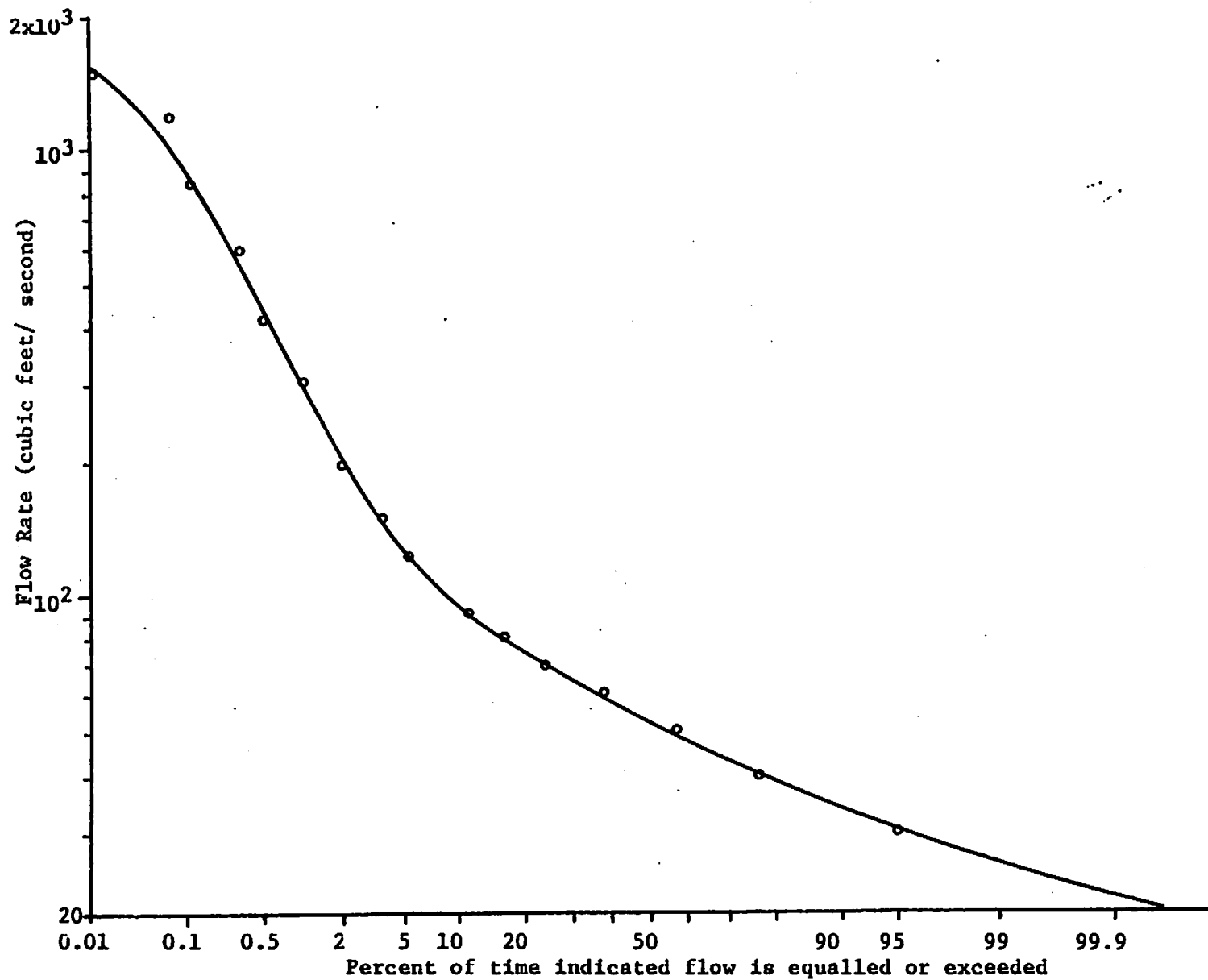


Figure 6. Flow duration curve for June 15 to September 30, of the North Fork of the Virgin River, near Springdale, Utah (USGS, 1923 to 1974).

Flood Frequency

Flood frequency and hydrologic probability become very important watershed management tools. It is with the probability of future hydrologic events that such structures as culverts, roads, bridges and campgrounds may be planned. Figure 7 shows the log-Pearson Type III Distribution giving the flood frequency curve for the NFVR. Frequency is given as recurrence intervals in years. Instantaneous peak flows were used in developing this curve (USGS).

The Zion Park flood of July 29, 1975, had a recorded instantaneous peak flow of 4150 cfs (McCutchen, 1975). Using ^{Figure} Table 7, this peak flow has a recurrence interval of 10 years.

Figure 8 gives the flood frequency for the summer months (June 15 to September 30). Unlike the annual flood frequency curve, the summer curve uses the maximum mean daily flow rather than the yearly instantaneous peak flow. Because of this, caution should be maintained in comparing the two curves which represent different populations. The points given in Figures 7 and 8 are measured flows (U.S.G.S. 1923-74).

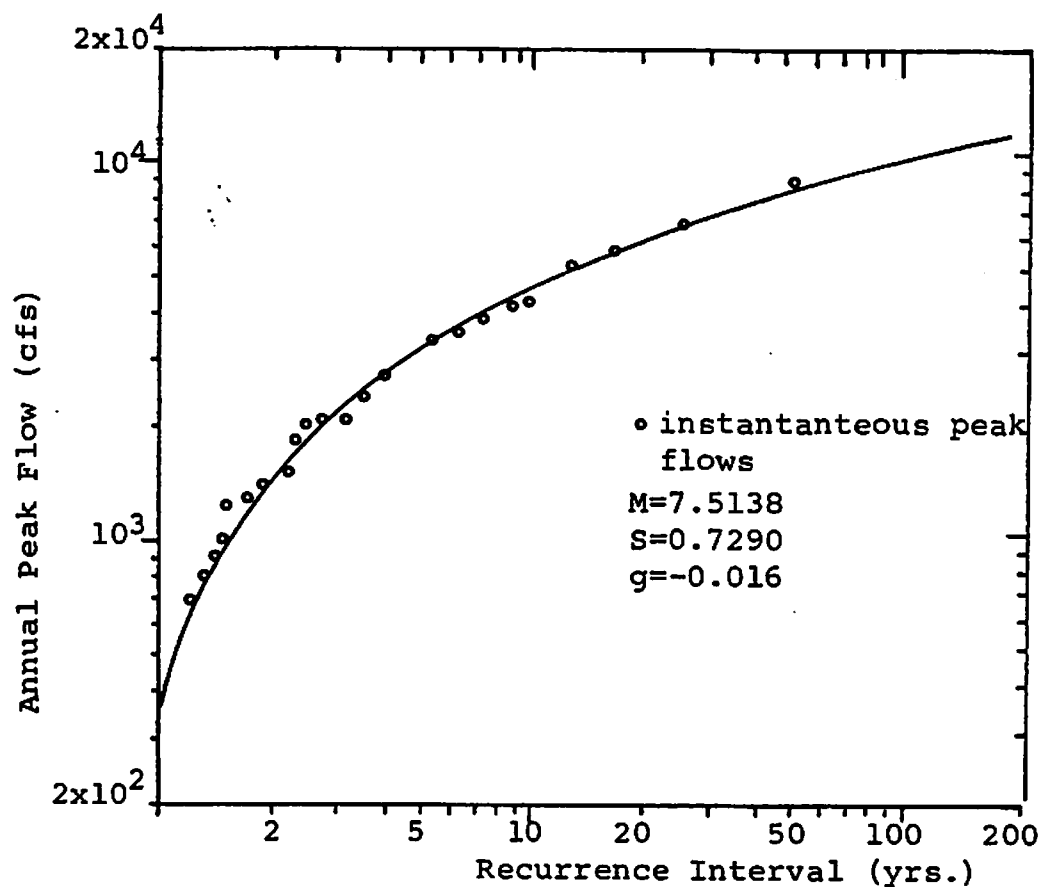


Figure 7. Flood Frequency for the North Fork of the Virgin River, near Springdale, Utah (USGS, 1923-1974). Log-Pearson Type III Distribution.

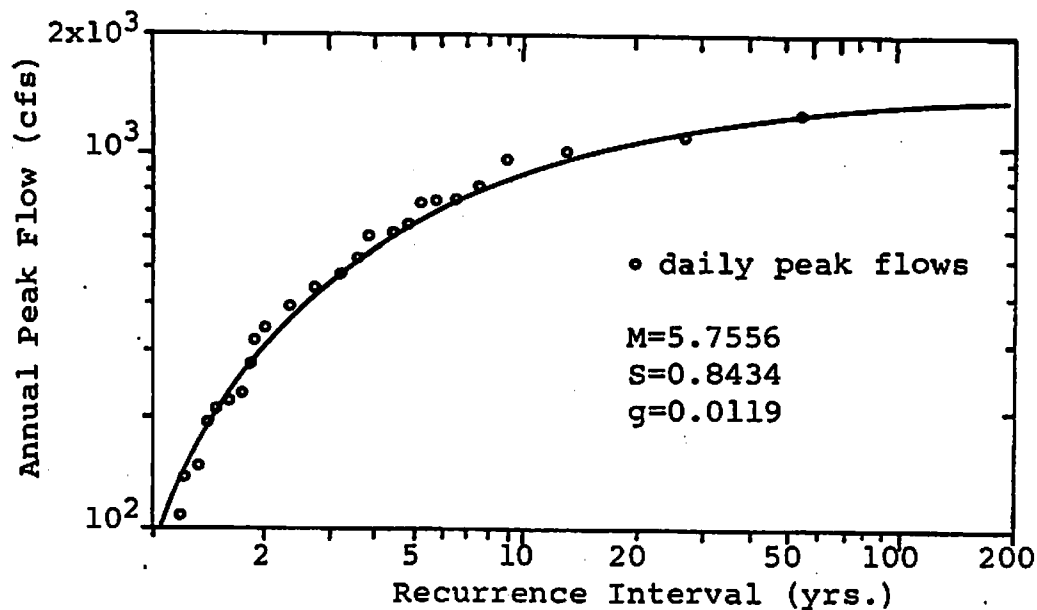


Figure 8. Flood Frequency, June 15 to September 30, for the North Fork of the Virgin River, near Springdale, Utah (USGS, 1923-1974). Log-Pearson Type III Distribution.

Rating Curve

Reference has been made throughout the paper regarding the USGS data. Figure 9 gives the current rating curve for the NFVR gaging station. The gage records the river height, which is then found on the rating curve and translated into a water volume over time. Because of the continual river-bed change, the rating curve must be periodically recalibrated.

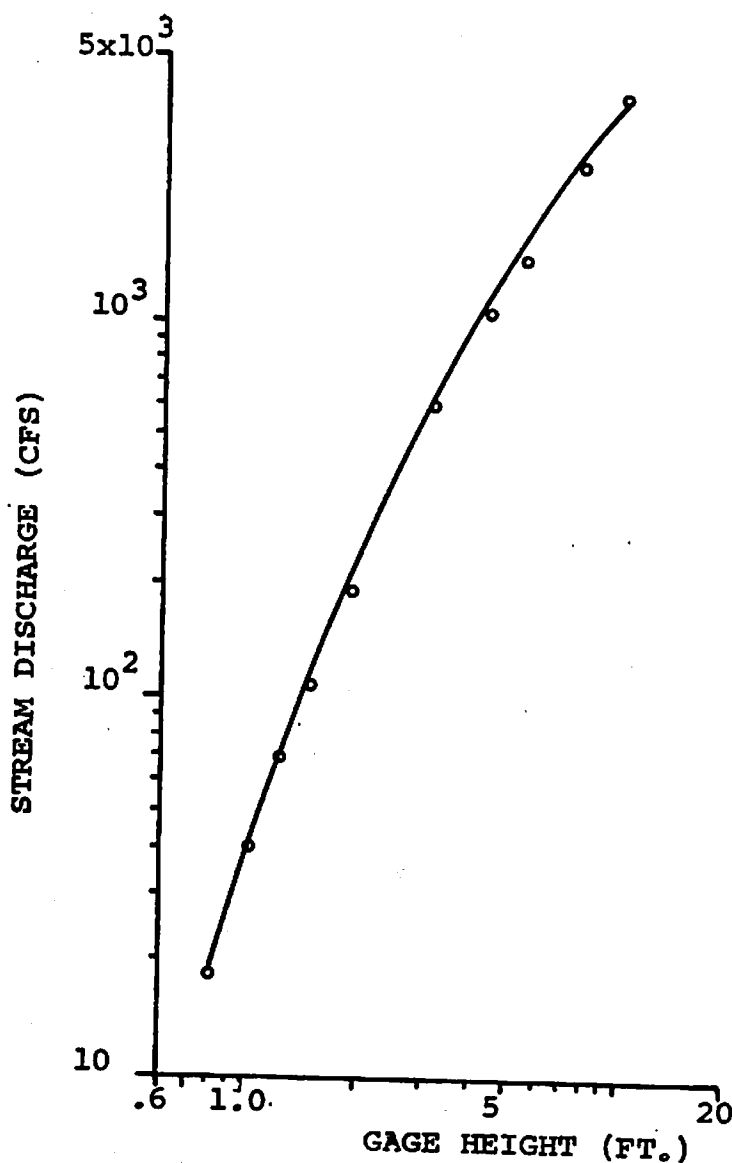


Figure 9. USGS rating curve, North Fork of the Virgin River, near Springdale, Utah (USGS, July 30, 1975).

GEOLOGY

Springs

The major source of springs along the NFVR is the Navajo Formation. Springs have been observed at the contact of the lower Navajo Formation and the Wingate Formation with the upper Kayenta Formation. These springs result from water passing through the permeable Navajo and Wingate sandstone and reappearing along the contact with the impermeable shale of the underlying Kayenta.

Joints and fractures are common in the Navajo Formation and are important to the movement of the ground water. When these joints and fractures appear near the surface of the formation they can serve as areas of recharge, allowing high infiltration rates into the sandstone. Further down into the formation these same joints and fractures may serve as areas of spring discharge. Several examples of springs emanating from joints and fractures exist along the NFVR near Mystery Canyon (DeGraff, 1976).

As the ground water flow is restricted by the Kayenta Formation, it rises to the surface of these joints and fractures in the Navajo Sandstone and appears as a spring or seep. This occurs throughout the NFVR channel with a major seep creating the Hanging Gardens near the Temple of Sinawava.

Location. In several studies done by the Utah Geological and Minerological Survey (WRB 16, 1971), 38 nonthermal springs have been located within the NFVR watershed (Figure 10). Flow rates range from 0.01 cfs to 9.3 cfs, with the majority of the springs having a flow

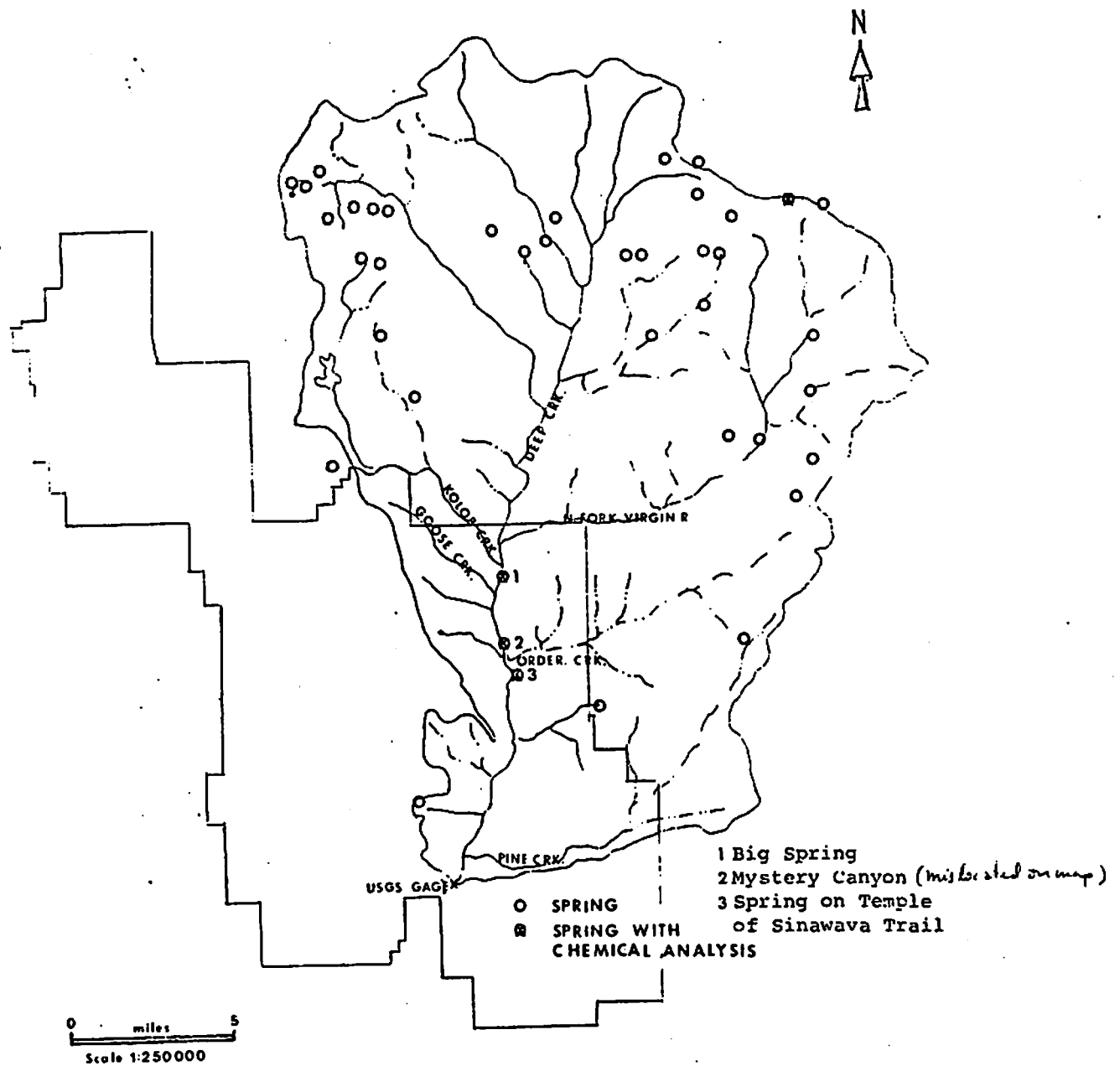


Figure 10. Nonthermal springs within the NFVR watershed as listed by the Utah Geological and Mineralogical Survey (WRB 16, 1971).

less than 0.1 cfs. All the springs listed in Figure 10 lie outside the NFVR channel within the Park. However, there are several springs within the channel itself. The majority of these springs lie between Big Springs and the Temple of Sinawava.

Water chemistry. Table 12 lists the water chemistry analysis for four of the springs within the NFVR watershed. Two of the springs have been studied by the Utah Geological and Mineralogical Survey (WRB 16, 1971). The other two springs were analyzed during the Utah State University 1976 summer study of the NFVR watershed.

Bacteria. Three springs were studied for bacterial concentrations. At all three springs, using three different sampling times, bacterial concentrations were found to be 0 colonies/100ml. Total coliform (TC), fecal coliform (FC) and fecal strep (FS) were measured at Big Springs and at two springs below Mystery Canyon. Samples were taken on July 17, August 10, and August 15 at each of the three sampling points.

Coal and surface water quality

Like much of the southwest, the NFVR watershed has coal deposits. Figure 11 gives the general area of the known coal deposits and Table 13 gives the location of the known coal mines. In the processing of coal, water is both consumed and affected. The actual mining process requires the consumption of water with the results of that processing often causing water quality deterioration.

If coal mining becomes active in the headwater regions of the NFVR, there are certain water quality characteristics requiring special attention. When mine drainage occurs, water often becomes more acidic. The degree of acidity depends primarily upon the sulfur (FeS) content of the coal.

Table 12. Chemical analysis for selected springs within the North Fork of the Virgin River Watershed. Data: (GS) Water Resources Bulletin No. 16, 1971, Utah Geological and Mineralogical Survey "Nonthermal Springs of Utah", pp. 65-6, (WL) Utah Water Research Laboratory, Utah State University, Logan, Utah, (FM) Field Measurements.

	Flow Rate (cfs)	S.C. ¹ μmhos/cm at 25°C	pH	Temp. °C.	SiO ₂	Ca ²	Mg ²	Na	K	HCO ₃ ²	CO ₃ ²	SO ₄	Cl	Fe	NO ₃	B	D.S. ³
(GS) Duck Creek Springs	9.3	203	7.8	7.2	16.0	63	30	5.9	1.5	120	0	5.4	3.0	0.1	1.2	.01	122
(GS) Blue Springs	2.0	143	6.9	-	7.6	88	54	9.7	-	170	-	6.7	10	-	-	-	180
(WL) Mystery Canyon	0.1	600	7.2	-	-	87	36	278	8.6	-	-	-	-	-	0.2	-	-
(WL) Spring on Temple of Sinawava Trail	0.3	1620	7.4	-	-	230	230	190	10	-	-	278	238	-	-	-	-
(FM) Big Springs	1.5	296	6.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-

¹Specific conductance μmhos/cm at 15°C.

²Recorded as mg/liter as CaCO₃.

³Dissolved solids, mg/l.

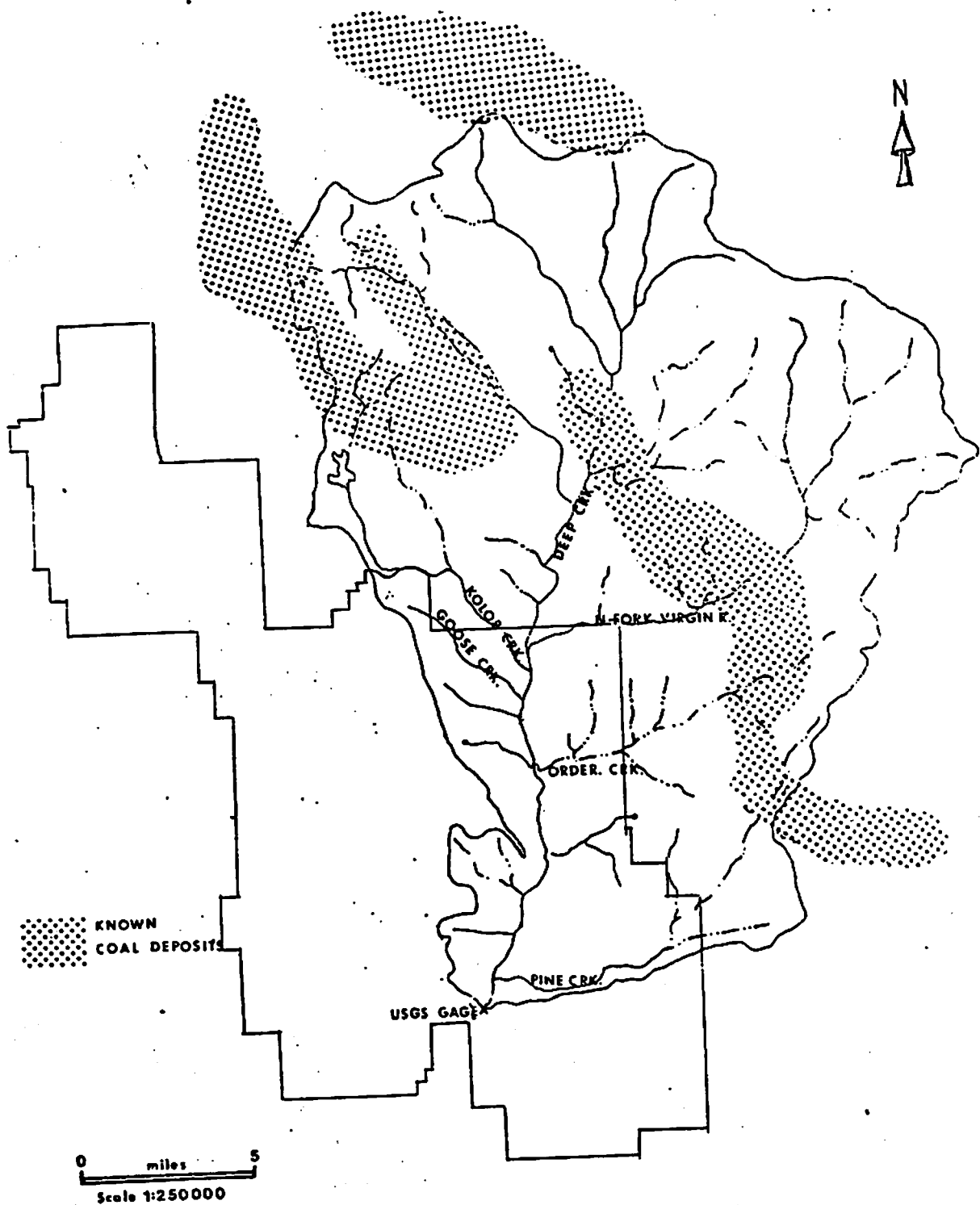


Figure 11. Known coal deposits within or near the North Fork of the Virgin River watershed (Guidebook to Geology of Utah No. 19, 1965).

Table 13. Existing coal mines and their locations within or near the North Fork of the Virgin River watershed (Guidebook to Geology of Utah No. 19, 1965).

Mine Name	Location
Koal Kreek No. 2 mine	NW $\frac{1}{4}$, Sec. 36, T.36S., R.10W
Tucker	NE $\frac{1}{4}$, Sec. 5, T. 37S., R.10W
Webster No. 2	SW $\frac{1}{4}$, Sec. 33, T.36S., R.10W
Cluff	NW $\frac{1}{4}$, Sec. 35, T.36S., R.10W
Corry	NW $\frac{1}{4}$, Sec. 31, T.36S., R.10W
Culver	NW $\frac{1}{4}$, Sec. 24, T.27S., R.11W
Jones-Bullock	SE $\frac{1}{4}$, Sec. 36, T.36S., R.10W
Kanarraville	NW $\frac{1}{4}$, Sec. 33, T.37S., R.11W
Kleen Koal	NW $\frac{1}{4}$, Sec. 28, T.37S., R.11W
Koal Kreek	NW $\frac{1}{4}$, Sec. 36, T.36S., R.10W
Leyson	SW $\frac{1}{4}$, Sec. 33, T.36S., R.10W
Webster	NE $\frac{1}{4}$, Sec. 5, T.37S., R.10W
Wood and Taylor	NW $\frac{1}{4}$, Sec. 4, T.37S., R.10W
Adair	SE $\frac{1}{4}$, Sec. 32, T.40S., R.8W
Cannel King	NE $\frac{1}{4}$, Sec. 26, T.39S., R.9W
Meeks-Carrol	NW $\frac{1}{4}$, Sec. 5, T.41S., R.8W
Zion	SE $\frac{1}{4}$, Sec. 1, T.41S., R.9W

Stream turbidity and sediment loads often increase in runoff from mine tailings and windblown dust from the mining area. This dust may blow from one drainage into another. Because of the chemical nature and dark color of the dust, water chemistry and temperature can be affected if sufficient volumes of dust enter the water.

Without knowing the location, the precautions, or the coal chemistry, it is difficult to predict what specific effects coal mining will have on the water quality. However, acidity and turbidity have become common problems with mining operations (DeGraff, 1976) and may be of concern to the NFVR's future management.

WATER CHEMISTRY

Procedures

Two independent laboratories were used in the water chemistry analysis. They are Ford Laboratory, Salt Lake City, Utah; and Utah Water Research Laboratory, Utah State University, Logan, Utah.

Water samples were collected in 500 ml plastic bottles, refrigerated and delivered to the laboratories within 24 hours of the sampling time. Each of the containers was rinsed with the sample water before the final sample was taken.

Conductivity, temperature and pH were measured in the field. Conductivity and temperature were measured using a Yellow Springs Instrument, Model 33 S-C-T Meter. Conductivity readings were then converted to the standard umhos/cm at 25°C. The pH was measured in the field using "Dual-Tint" pH paper, a product of the J.T. Baker Chemical Company.

Results and Discussion

Table 14 gives the water chemistry of the North Fork of the Virgin River for August 16, 1976. This table gives a comparison between the water chemistry of the major inflows (North Fork at Chamberlain's Ranch, Deep Creek, Kolob Creek, and Orderville Creek) and the primary outflow (USGS gaging station). The inputs are compared to the outputs using a weighted concentration. This is obtained by multiplying the concentration at the sampling point by the estimated flow at that same point, summing the inflows, subtracting the sum from the outflow and dividing by the inflow.

Table 14. Water chemistry concentrations for the North Fork of the Virgin River, including percent variation in weighted concentrations,* (August 16, 1976).

Chemical Parameter	NC @8cfs	DEEP @ 12 cfs	KOLOB @8cfs	ORDER. @2cfs	GAGE @40cfs	% Increase*
Conductivity mhos/cm	570	630	480	2617	820	79%
Total Diss. Solids at 180°C.	370 mg/l	410 mg/l	315 mg/l	--	535 mg/l	106
CaCO ₃	206	138	158	--	234	105
Al	.065	.130	.060	--	.070	9
As	.001	.001	.001	--	.008	--
HCO ₃	251.3	168.4	192.8	--	202.5	45
Ba	.089	.089	.099	--	.144	124
B	.001	.001	.001	--	.001	--
Cd	.001	.002	.001	--	.001	--
Ca	47.2	45.6	50.4	101.4	51.2	34
CO ₃	.01	.01	.01	--	.01	--
Cl	4.0	4.0	4.0	--	90.0	3114
Cr (Hex)	.001	.001	.001	--	.001	--
Cn	.01	.01	.01	--	.01	--
Cu	.005	.005	.011	--	.006	28
F	.30	.27	.30	--	.32	59
Total Hardness as CaCO ₃	208.	180.	190.	--	234.	75
Iron (Total) as Fe	.110	.110	.080	--	.120	69
Iron (Filtered) as Fe	.100	.100	.050	--	.100	67
Lead as Pb	.001	.001	.001	--	.005	--
Mg	21.6	15.84	15.36	45.2	25.4	78
Mn	.025	.038	.030	--	.035	61
Hg	.0002	.0002	.0002	--	.0002	--
NO ₃ -N	.05	.01	.04	.2	.02	-35
PO ₄	.035	.035	.035	--	.065	163
K	1.62	1.58	1.72	7.4	3.32	122
Se	.007	.006	.001	--	.077	2165
Silica as SiO ₂	15.0	0.90	0.40	--	9.9	196
Ag	.001	.001	.001	--	.001	--
SO ₄	34.0	130.0	45.0	--	92.0	68
Sodium as Na	18.7	45.0	10.0	100.7	73.0	207
Zinc as Zn	.012	.008	.003	--	.007	30

*Percent increase refers to GAGE weighted concentrations being greater than the sum of the NC, DEEP, KOLOB, and ORDER. weighted concentrations. The indicated flows do not equal the outflow because of the numerous unmeasured springs within the sampling area.

Increase occurred in all the measured parameters with the exception of $\text{NO}_3\text{-N}$ (nitrate as nitrogen). The largest increase was in Cl (chlorine), which increased over 3000 percent. This increase is primarily due to the water treatment plant located between the Gage and the other sampling points.

Table 15 gives the same type of analysis for the same sampling points as in Table 14. The values in Table 15 are the arithmetic means for two sampling days, June 25 and July 15, 1976. The samples used in Table 15 were analyzed at the Utah Water Research Laboratory, Logan, Utah. The sample analyses presented in Table 14 were processed at Ford Laboratory, Salt Lake City, Utah.

Table 15. Mean chemistry concentrations for the North Fork of the Virgin River, June 24 and July 15, 1976.

Chemical Parameter	NC (@10cfs)	DEEP (@12cfs)	KOLOB (@15cfs)	ORDER (@1cfs)	END (@50cfs)	% Increase
Cond. umhos/cm at 25°C	432	385	332	1240	495	63
pH	6.8	6.5	6.8	6.5	6.5	--
Na mg/l	11.9	6.6	2.8	97.5	29.2	330
K mg/l	2.2	1.6	2.8	7.2	2.7	50
Ca as Ca mg/l	48.5	41.9	43.8	86.3	47.1	36
Mg as Mg mg/l	21.5	14.4	9.3	41.9	18.1	60

Figure 12 gives the ion concentration and water hardness of the major sampling points. The ion concentrations are recorded in milliequivalents per second and total hardness is recorded in mg per liter as CaCO_3 . As can be seen, the ion concentration is much higher at the Gage than at the other sampling points. However, the actual concentrations, (given in Table 16) do not show comparable variations. This difference illustrates the value in using units per second. In this way, dilution factors are accounted for, allowing the actual increases to be determined. For example, total hardness increases in mg/sec although the actual concentrations are similar to the hardness at the other sampling points.

Figure 13 shows the variation in conductivity between the Temple of Sinawava (End) and the Park Headquarters (Gage) sampling points. The conductivity at the End ranged from 450 umhos/cm to 580 umhos/cm at 25°C. The Gage conductivity ranged from 610 umhos/cm to 800 umhos/cm at 25°C.

Table 17 gives the mean temperature, pH, dissolved oxygen and conductivity for the major sampling points. Orderville Creek has the highest conductivity and Deep Creek has the lowest conductivity for these sampling periods.

Water Quality Standards

Table 18 gives the recommended upper limits for the major chemical parameters of natural waters. Both swimming and fisheries standards were selected, as they represent the most common uses of the North Fork of the Virgin River. The upper limit cited in Table 18 represents the lower upper limit of either the swimming or the fisheries criterion. This means that in all but one case the water of the North Fork meets the suggested upper limits for both swimming and fisheries. Sodium (Na) is the only chemical

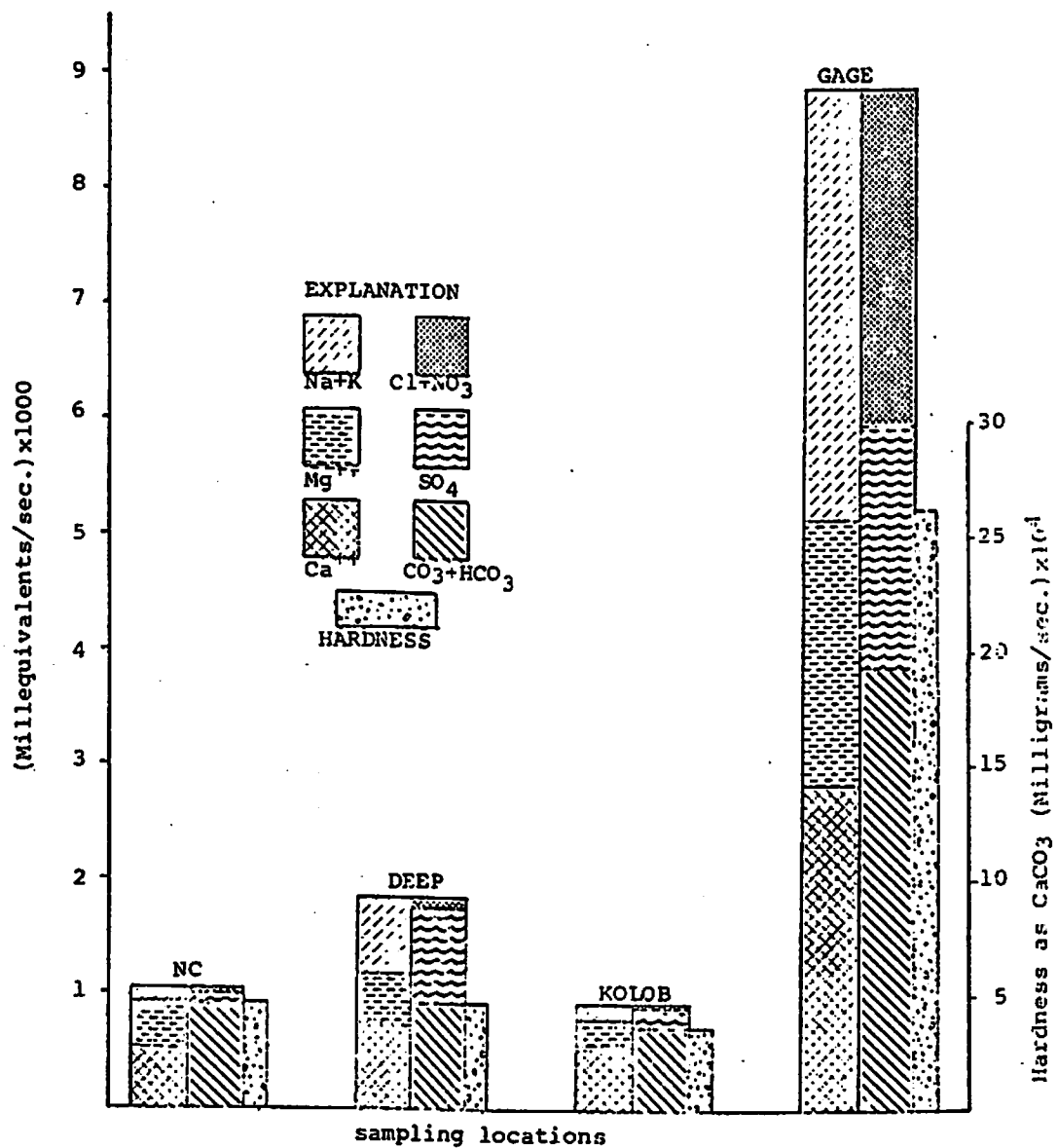


Figure 12. Ion-concentration and water hardness for the major inflows and outflow on the North Fork of the Virgin River.

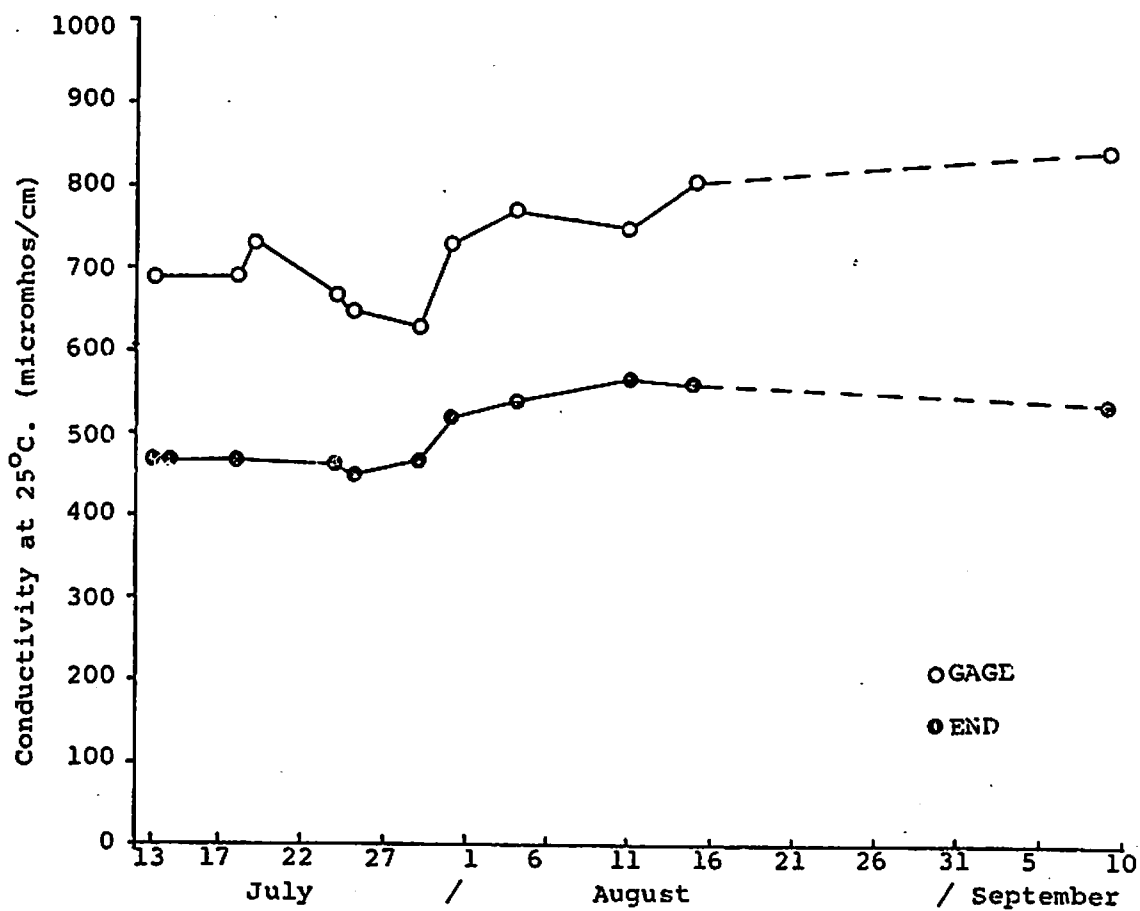


Figure 13. Specific Conductivity variation with respect to time, for the END and GAGE sampling points (July 13 to September 9, 1976).

Table 16. Ion-concentration conversions for four stream sampling locations within the North Fork of the Virgin River Watershed, (August 16, 1976).

Chemical	Mg/l	Meq/l	Meq/sec.	Mg/l	Meq/l	Meq/sec.
NORTH FORK AT CH. (@ 8 cfs)				DEEP CREEK (@ 12 cfs)		
NaK	20.32	0.855	191	46.58	1.998	669
Mg	21.6	1.777	397	15.84	1.303	437
Ca	47.2	2.355	526	45.6	2.275	762
ClNO ₃	4.05	0.114	25	4.01	0.113	38
SO ₄	34.0	0.708	158	130.0	2.707	907
CO ₃ HCO ₃	251.31	4.119	913	168.41	2.760	923
KOLOB CREEK (@ 8 cfs)				NORTH FORK AT GAGING STATION (@ 40 cfs)		
NaK	11.72	0.479	107	76.32	3.260	3642
Mg	15.36	1.264	282	25.4	2.089	2333
Ca	50.4	2.515	562	51.2	2.555	2854
ClNO ₃	4.04	0.113	25	90.02	2.539	2836
SO ₄	45.0	0.937	209	92.0	1.915	2139
CO ₃ HCO ₃	192.81	3.174	717	202.51	3.301	3854

Table 17. Mean flow, temperature, pH, dissolved oxygen and conductivity for five locations on the North Fork of the Virgin River (June to September, 1976).

Site	Est Q (ft ³ /sec)	Temp (°C)	pH	D.O. (mg/l)	Cond. (μmhos/cm) at 25°C
NC	7	20°C	6.8	8	474
DEEP CR.	11	16.8	6.5	9.5	337
KOLOB CR	8	15.7	6.8	10	450
ABS	31	17.7	6.5	9	477
NFOOR.	37	17.4	6.5	9	516
ORDERVILLE CR.	3	17.2	6.5	9	1184
END	44	19.7	6.5	9	513
GAGE	45	21.0	6.7	9	734

Table 18. Recommended upper limits of chemical concentrations for swimming and fishery waters (McKee and Wolfe 1963)*.

Chemical Parameter	GAGE measured (mg/l)	Recommended upper limit* (mg/l)
Al	0.070	0.50
As	0.008	0.10
Ba	0.144	5.00
B	0.001	--
Cd	0.001	--
Ca	51.2	1000.00
Cl	90.0	1500.00
Cr (Hex)	0.001	5.00
Cn	0.01	0.05
Cu	0.006	0.10
F	0.32	5.0
Fe (total)	0.120	0.20
Fe (filtered)	0.100	--
Pb	0.005	0.10
Mg	25.4	100.00
Mn	0.035	40.00
Hg	0.002	0.004
NO ₃ -N	0.02	4.20
PO ₄ -P	0.065	15.00
K	3.32	50.00
Se	0.077	2.0
SiO ₂	9.9	50.0
Ag	0.001	0.033
SO ₄	92.0	500.00
Na	73.0	10.00 ¹
Zn	0.007	0.10
Specific Conductance (umhos/cm at 25°C)	820.00	2000.00

¹ Na (Sodium) exceeds the upper limit for fisheries as suggested by McKee and Wolfe (1963).

parameter that does not meet the criteria. In this instance the sodium exceeds the upper limit for fisheries, but is within the upper limit of the swimming criterion.

Again, the reader is reminded that the values contained in Tables 14 and 18 are not necessarily representative of the yearly or monthly quality of the North Fork. These values represent only a one time measurement of the North Fork, August 16, 1976.

Conclusions

1. With over 60% of watershed under private land ownership, future water management plans will require close cooperation of both public and private land use practices.

2. Using fifty-one years of data as a base, flow duration and flood frequency conclusions are as follows:

- a. Flow rates have always exceeded 24 cubic feet per second at the Park Headquarters.
- b. Floods are not uncommon in this area. A flood equal to the July 29, 1975 flood has a recurrence interval of 10 years.
- c. Summer use of the Narrows may often be restricted because of high flows.

3. There are numerous springs located within the Zion Narrows. Most springs have flows of less than 0.2 cfs and are located between Big Spring and Mystery Canyon.

4. There are extensive coal fields located in the northern section of the watershed. Further development of these coal fields will require intensive water quality monitoring. This monitoring will need to emphasize pH and turbidity.

5. At present, the water chemistry is well within the upper limits of the recommended levels for recreational waters.

Recommendations

1. Additional precipitation data are required to more accurately predict summer storm flood periods. Knowledge of these flood periods is essential to the safety of the recreationists hiking the Zion Narrows. Rain gages need to be located in the higher elevations of the watershed and should be recording gages.

2. Under present conditions sufficient chemistry samples have been taken. However if land use changes significantly (i.e., coal mining, increased grazing, or road construction) additional samples are suggested. These samples should be taken for each of the seasons with emphasis on the spring runoff.

3. High sediment yields undoubtedly exist for the North Fork of the Virgin River. Measurements of these sediment loads may become necessary in the future as increasing aesthetic demands are placed on public water resources.

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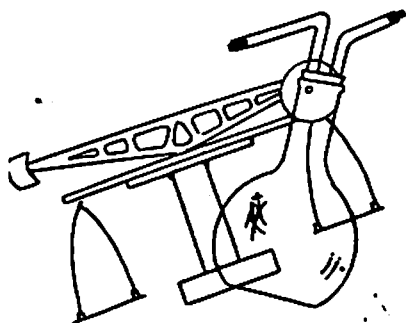
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APPENDIX A

Water chemistry analysis,
Ford Laboratory
Salt Lake City, Utah



Ford Chemical

LABORATORY, INC.
Bacteriological and Chemical Analysis

40 WEST LOUISE AVENUE
SALT LAKE CITY, UTAH 84115
PHONE 485-5761

Date: October 6, 1975

Name Mr. George Hart
Address Forestry & Outdoor Recreation
Utah State University
Logan, UT 84321

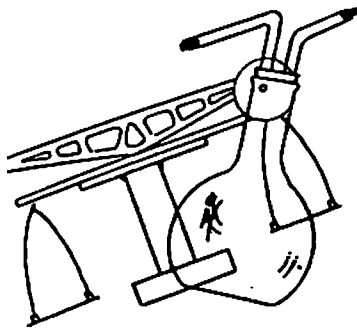
CERTIFICATE OF ANALYSIS

75-4199

Sample Water from North Fork of Virgin River at Highway 89 received
on September 17, 1975.

Turbidity	<u>4.2</u> JTU	Fluoride as F	<u>0.13</u> mg/l
Conductivity	<u>793.0</u> umhos/cm	Total Hardness as CaCO ₃	<u>250.0</u> mg/l
pH	<u>7.14</u>	Iron (Total) as Fe	<u>0.15</u> mg/l
Total Dissolved Solids at 180° C.	<u>516.0</u> mg/l	Iron (Filtered) as Fe	<u>0.02</u> mg/l
Alkalinity as CaCO ₃	<u>158.0</u> mg/l	Lead as Pb	<u><0.01</u> mg/l
Aluminum as Al	<u><0.01</u> mg/l	Magnesium as Mg	<u>26.88</u> mg/l
Arsenic as As	<u><0.01</u> mg/l	Manganese as Mn	<u>0.01</u> mg/l
Bicarbonate as HCO ₃	<u>191.49</u> mg/l	Mercury as Hg	<u><0.001</u> mg/l
Barium as Ba	<u><0.01</u> mg/l	Nitrate as NO ₃ -N	<u>0.04'</u> mg/l
Boron as B	<u><0.01</u> mg/l	Phosphate as PO ₄	<u>0.100</u> mg/l
Cadmium as Cd	<u>0.002</u> mg/l	Potassium as K	<u>3.69</u> mg/l
Calcium as Ca	<u>55.2</u> mg/l	Selenium as Se	<u><0.01</u> mg/l
Carbonate as CO ₃	<u><0.01</u> mg/l	Silica as SiO ₂	<u>4.15</u> mg/l
Chloride as Cl	<u>88.0</u> mg/l	Silver as Ag	<u>0.007</u> mg/l
Chromium as Cr (Hex)	<u><0.01</u> mg/l	Sulfate as SO ₄	<u>95.50</u> mg/l
Cyanide as Cn	<u><0.01</u> mg/l	Sodium as Na	<u>57.00</u> mg/l
Copper as Cu	<u>0.02</u> mg/l	Zinc as Zn	<u>0.01</u> mg/l

Ford Chemical Laboratory, Inc.



Ford Chemical

LABORATORY, INC.

Bacteriological and Chemical Analysis

40 WEST LOUISE AVENUE
SALT LAKE CITY, UTAH 84115
PHONE 485-5761

Date: August 17, 1976

CERTIFICATE OF ANALYSIS

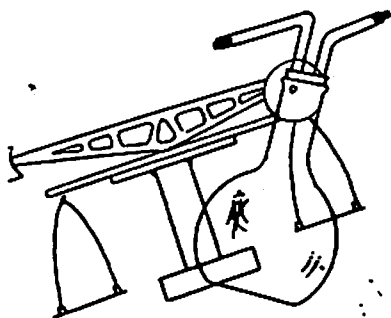
76-5008

me Utah State University
ATTN: George Hart
dress Forestry Science Laboratory
Logan, UT 84321

mples Water at North Fork-Virgin River, Chamberlin Ranch Received on
July 23, 1976 - Zion Park Research:

rbidity	<u>15.0</u> JTU	Fluoride as F	<u>0.30</u> mg/l
nductivity	<u>570.0</u> umhos/cm	Total Hardness as CaCO ₃	<u>208.0</u> mg/l
l	<u>7.60</u>	Iron (Total) as Fe	<u>0.110</u> mg/l
otal Dissolved Solids		Iron (Filtered) as Fe	<u>0.100</u> mg/l
at 180° C.		Lead as Pb	<u>< 0.001</u> mg/l
alkalinity as CaCO ₃	<u>206.0</u> mg/l	Magnesium as Mg	<u>21.6</u> mg/l
luminum as Al	<u>0.065</u> mg/l	Manganese as Mn	<u>0.025</u> mg/l
rsenic as As	<u>< 0.001</u> mg/l	Mercury as Hg	<u>< 0.0002</u> mg/l
icarbonate as HCO ₃	<u>251.3</u> mg/l	Nitrate as NO ₃ -N	<u>0.05</u> mg/l
arium as Ba	<u>0.089</u> mg/l	Phosphate as PO ₄	<u>0.035</u> mg/l
oron as B	<u>< 0.001</u> mg/l	Potassium as K	<u>1.62</u> mg/l
admium as Cd	<u>< 0.001</u> mg/l	Selenium as Se	<u>0.007</u> mg/l
alcium as Ca	<u>47.2</u> mg/l	Silica as SiO ₂	<u>15.0</u> mg/l
arbonate as CO ₃	<u>< 0.01</u> mg/l	Silver as Ag	<u>< 0.001</u> mg/l
hloride as Cl	<u>4.0</u> mg/l	Sulfate as SO ₄	<u>34.0</u> mg/l
hromium as Cr (Hex)	<u>< 0.001</u> mg/l	Sodium as Na	<u>18.7</u> mg/l
yanide as Cn	<u>< 0.01</u> mg/l	Zinc as Zn	<u>0.012</u> mg/l
Copper as Cu	<u>0.005</u> mg/l		

Ford Chemical Laboratory, Inc.



Ford Chemical

LABORATORY, INC.

Bacteriological and Chemical Analysis

40 WEST LOUISE AVENUE
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CERTIFICATE OF ANALYSIS

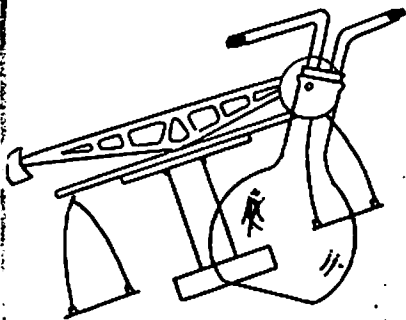
76-5010

Sample Water labeled Deep Creek Received on July 23, 1976, Zion Park

Research: _____

Turbidity	<u>7.5</u> JTU	Fluoride as F	<u>0.27</u> mg/l
Conductivity	<u>630.0</u> umhos/cm	Total Hardness as CaCO ₃	<u>180.0</u> mg/l
pH	<u>7.58</u>	Iron (Total) as Fe	<u>0.110</u> mg/l
Total Dissolved Solids at 180° C.	<u>410.0</u> mg/l	Iron (Filtered) as Fe	<u>0.100</u> mg/l
Alkalinity as CaCO ₃	<u>138.0</u> mg/l	Lead as Pb	<u><0.001</u> mg/l
Aluminum as Al	<u>0.130</u> mg/l	Magnesium as Mg	<u>15.84</u> mg/l
Arsenic as As	<u><0.001</u> mg/l	Manganese as Mn	<u>0.038</u> mg/l
Bicarbonate as HCO ₃	<u>168.4</u> mg/l	Mercury as Hg	<u><0.0002</u> mg/l
Barium as Ba	<u>0.089</u> mg/l	Nitrate as NO ₃ -N	<u><0.01</u> mg/l
Boron as B	<u><0.001</u> mg/l	Phosphate as PO ₄	<u>0.035</u> mg/l
Cadmium as Cd	<u>0.002</u> mg/l	Potassium as K	<u>1.58</u> mg/l
Calcium as Ca	<u>45.6</u> mg/l	Selenium as Se	<u>0.006</u> mg/l
Carbonate as CO ₃	<u><0.01</u> mg/l	Silica as SiO ₂	<u>0.90</u> mg/l
Chloride as Cl	<u>4.0</u> mg/l	Silver as Ag	<u><0.001</u> mg/l
Chromium as Cr (Hex)	<u><0.001</u> mg/l	Sulfate as SO ₄	<u>130.0</u> mg/l
Cyanide as Cn	<u><0.01</u> mg/l	Sodium as Na	<u>45.0</u> mg/l
Copper as Cu	<u>0.005</u> mg/l	Zinc as Zn	<u>0.008</u> mg/l


Ford Chemical Laboratory, Inc.



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Bacteriological and Chemical Analysis

40 WEST LOUISE AVENUE
SALT LAKE CITY, UTAH 84115
PHONE 485-5761

Date: August 17, 1976

Name Utah State University
ATTN: George Hart
Address Forestry Science Laboratory
Logan, UT 84321

CERTIFICATE OF ANALYSIS

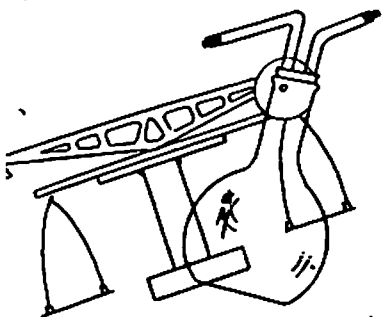
76-5009

Sample Water Labeled Kolob Creek Received on July 23, 1976-Zion Park

Research:

Turbidity	<u>8.0</u> JTU	Fluoride as F	<u>0.30</u> mg/l
Conductivity	<u>480.0</u> umhos/cm	Total Hardness as CaCO ₃	<u>190.0</u> mg/l
pH	<u>7.70</u>	Iron (Total) as Fe	<u>0.080</u> mg/l
Total Dissolved Solids at 180° C.	<u>315.0</u> mg/l	Iron (Filtered) as Fe	<u>0.050</u> mg/l
Alkalinity as CaCO ₃	<u>158.0</u> mg/l	Lead as Pb	<u><0.001</u> mg/l
Aluminum as Al	<u>0.060</u> mg/l	Magnesium as Mg	<u>15.36</u> mg/l
Arsenic as As	<u><0.001</u> mg/l	Manganese as Mn	<u>0.030</u> mg/l
Bicarbonate as HCO ₃	<u>192.8</u> mg/l	Mercury as Hg	<u><0.0002</u> mg/l
Barium as Ba	<u>0.099</u> mg/l	Nitrate as NO ₃ -N	<u>0.04</u> mg/l
Boron as B	<u><0.001</u> mg/l	Phosphate as PO ₄	<u>0.035</u> mg/l
Cadmium as Cd	<u><0.001</u> mg/l	Potassium as K	<u>1.72</u> mg/l
Calcium as Ca	<u>50.4</u> mg/l	Selenium as Se	<u><0.001</u> mg/l
Carbonate as CO ₃	<u><0.01</u> mg/l	Silica as SiO ₂	<u>0.40</u> mg/l
Chloride as Cl	<u>4.0</u> mg/l	Silver as Ag	<u><0.001</u> mg/l
Chromium as Cr (Hex)	<u><0.001</u> mg/l	Sulfate as SO ₄	<u>45.0</u> mg/l
Cyanide as Cn	<u><0.01</u> mg/l	Sodium as Na	<u>10.0</u> mg/l
Copper as Cu	<u>0.011</u> mg/l	Zinc as Zn	<u>0.003</u> mg/l


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Bacteriological and Chemical Analysis

40 WEST LOUISE AVENUE
SALT LAKE CITY, UTAH 84115
PHONE 485-5761

Date: August 17, 1976

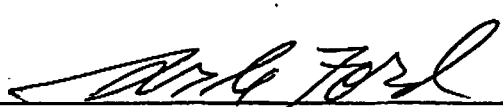
Client Utah State University
ATTN: George Hart
Address Forestry Science Laboratory
Logan, Utah 84321

CERTIFICATE OF ANALYSIS

76-5007

Sample Water Labeled Gage Received on July 23, 1976, Zion Park Research:

Acidity	<u>20.0</u> JTU	Fluoride as F	<u>0.32</u> mg/l
Conductivity	<u>820.0</u> umhos/cm	Total Hardness as CaCO ₃	<u>234.0</u> mg/l
pH	<u>7.56</u>	Iron (Total) as Fe	<u>0.120</u> mg/l
Total Dissolved Solids 180° C.	<u>535.0</u> mg/l	Iron (Filtered) as Fe	<u>0.100</u> mg/l
Alkalinity as CaCO ₃	<u>234.0</u> mg/l	Lead as Pb	<u>0.005</u> mg/l
Aluminum as Al	<u>0.070</u> mg/l	Magnesium as Mg	<u>25.4</u> mg/l
Arsenic as As	<u>0.008</u> mg/l	Manganese as Mn	<u>0.035</u> mg/l
Bicarbonate as HCO ₃	<u>202.5</u> mg/l	Mercury as Hg	<u>< 0.0002</u> mg/l
Barium as Ba	<u>0.144</u> mg/l	Nitrate as NO ₃ -N	<u>0.02</u> mg/l
Boron as B	<u>< 0.001</u> mg/l	Phosphate as PO ₄	<u>0.065</u> mg/l
Cadmium as Cd	<u>< 0.001</u> mg/l	Potassium as K	<u>3.32</u> mg/l
Calcium as Ca	<u>51.2</u> mg/l	Selenium as Se	<u>0.077</u> mg/l
Carbonate as CO ₃	<u>< 0.01</u> mg/l	Silica as SiO ₂	<u>9.9</u> mg/l
Chloride as Cl	<u>90.0</u> mg/l	Silver as Ag	<u>< 0.001</u> mg/l
Chromium as Cr (Hex)	<u>< 0.001</u> mg/l	Sulfate as SO ₄	<u>92.0</u> mg/l
Cyanide as Cn	<u>< 0.01</u> mg/l	Sodium as Na	<u>73.0</u> mg/l
Copper as Cu	<u>0.006</u> mg/l	Zinc as Zn	<u>0.007</u> mg/l


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