Water Quality in the Mad River Basin, Humboldt and Trinity Counties, California

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CONVERSION FACTORS

Factors for converting English units to metric units are given below to four significant figures. However, in the text the metric equivalents are shown only to the number of significant figures consistent with the values for the English units.

English	*Multiply by*	*Metric*
acres	4.047×10^{-1}	ha (hectares)
acre-ft (acre-feet)	1.233×10^{-3}	hm^3 (cubic hectometres)
°F (degrees Fahrenheit)	5/9 (F - 32)	°C (degrees Celsius)
ft (feet)	3.048×10^{-1}	m (metres)
ft^3/s (cubic feet per second)	2.832×10^{-2}	m^3/s (cubic metres per second)
in (inches)	2.540×10^{1}	mm (millimetres)
mi (miles)	1.609	km (kilometres)
mi^2 (square miles)	2.590	km^2 (square kilometres)

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ABSTRACT

The Mad River of north-coastal California has been the proposed site of the Butler Valley Dam and Blue Lake Project. This report presents the results of a study of surface- and ground-water quality in the Mad River basin from 1970 through 1974. The general chemical quality of both ground and surface water was found to be acceptable for domestic and industrial uses after limited treatment to remove dissolved iron from the water. Nitrogen, phosphorus, and carbon nutrients were found in the river in quantities sufficient to promote algal growth. These nutrients, when combined with water temperatures reaching 25°C in the summer, could result in algal blooms in the proposed reservoir. No measurable concentrations of pesticides were found in the river sediment or water, and concentrations of trace metals were very low. Diel studies showed a slight dissolved-oxygen sag at night, near river bottom, which is attributed to consumption of oxygen by algae.

Biologically the river is of high quality with a diverse macroinvertebrate population. Periphyton in the river was predominantly *Cladophora sp.* Diatoms composed most of the phytoplankton population. Fecal coliform counts were less than 20 colonies per 100 millilitres, indicating no significant source of fecal pollution in the reaches of the river studied.

INTRODUCTION

The Mad River of north-coastal California has been the proposed site of the Butler Valley Dam and Blue Lake Project. Since 1956 the U.S. Army Corps of Engineers has been considering the construction of Butler Valley Dam to create a multipurpose reservoir (Blue Lake) on the Mad River. Blue Lake would provide flood control and a supplemental water supply. This supply, when combined with the existing water-supply sources, would be sufficient to meet the needs of the Mad River basin and an estimated two million visitors per year (U.S. Army Corps of Engineers, 1968). In addition, the lake would provide a large area for boating, fishing, and other outdoor recreation.

The U.S. Geological Survey, in cooperation with the U.S. Army Engineer District, San Francisco, Corps of Engineers, has made preimpoundment studies of the quality of ground and surface water, streamflow, sediment discharge, and turbidity in the Mad River basin. This report presents the results of the study of ground- and surface-water quality in the Mad River basin made from 1970 through 1974. Another report (Brown, 1975) presents the results of a companion study which evaluated the sediment discharge and turbidity of the river and the possible effects of the proposed dam on sediment transport and channel configuration.

Purpose and Scope

The purpose of the study was to obtain basic data to determine the chemical and biological conditions in the Mad River basin which could serve as a basis of comparison for future studies of the effects of the Butler Valley Dam and Blue Lake Project on water quality in the lower Mad River drainage basin.

Nine wells in the Mad River basin were sampled quarterly to determine ground-water quality in the alluvium along the river. Five U.S. Geological Survey gaging stations were chosen for sampling the chemical and biological condition of the river. These stations included Mad River above Ruth Reservoir, near Forest Glen, Mad River below Ruth Reservoir, near Forest Glen, Mad River near Forest Glen, Mad River near Kneeland, and Mad River near Blue Lake. Sampling and analyses of river water for major cations and anions was done 10 times during the study at Mad River near Kneeland and once at Mad River near Blue Lake. These analyses were used to indicate water-quality conditions in the proposed reservoir. Nitrogen, phosphorus, and carbon nutrients were sampled 10 to 25 times at all stations. Metals and pesticides in river-bottom sediments and in water were sampled two to four times at Mad River below Ruth Reservoir, near Forest Glen, and at Mad River near Forest Glen and four to six times at Mad River near Kneeland.

Diel (24-hour) studies were made nine times at Mad River near Kneeland and twice at Mad River near Blue Lake to determine daily changes in temperature, dissolved oxygen, pH, specific conductance, and alkalinity.

Biological parameters studied included coliform bacteria, benthic macroinvertebrates, periphyton biomass, and phytoplankton identification. Coliform bacteria were studied in six diel periods at Mad River near Kneeland. Coliform bacteria were also sampled once at Mad River near Forest Glen and three times at the station below Ruth Reservoir. Macroinvertebrates were collected using artificial substrates at all five stations during the summers 1972 and 1973. Periphyton biomass was determined from a limited number of samples at all stations except Mad River near Forest Glen. Phytoplankton samples were taken in August 1973 at Mad River near Blue Lake, Mad River near Kneeland, and Mad River near Forest Glen.

Location and Description

The Mad River is in north-coastal California (fig. 1). The river begins in southern Trinity County and then flows northwestward through Humboldt County, entering the Pacific Ocean about 10 mi (16 km) north of Eureka. The drainage area of the river is 497 mi^2 (1,290 km^2), and its length is about 100 mi (160 km). The average basin width is about 5 mi (8 km). The basin is characterized by rugged mountains generally covered with dense conifer forests of coastal redwoods (*Sequoia sempervirens*) and Douglas-fir (*Pseudotsuga menziesii*). In addition, large areas are covered with tan oak (*Quercus densiflora*).

Tributary streams entering the river form a subtrellis drainage pattern. The dominant topographic features within the basin are series of large parallel ridges deeply cut by V-shaped canyons. The basin rises from its sea-level mouth to more than 6,000 ft (1,830 m) at the headwaters.

The dominant geologic unit is the Franciscan assemblage of Jurassic and Cretaceous age. Other major units included in the basin are the Tertiary Falor Formation of Manning and Ogle (1950, p. 22), nonmarine Pleistocene sedimentary rocks, and Quaternary alluvium (Strand, 1962).

The major form of erosion in the basin is landslides. These are especially common in the Franciscan assemblage which is, in many areas, severely folded, fractured, and faulted (Brown, 1973). These landslides contribute heavily to the great sediment load of the river.

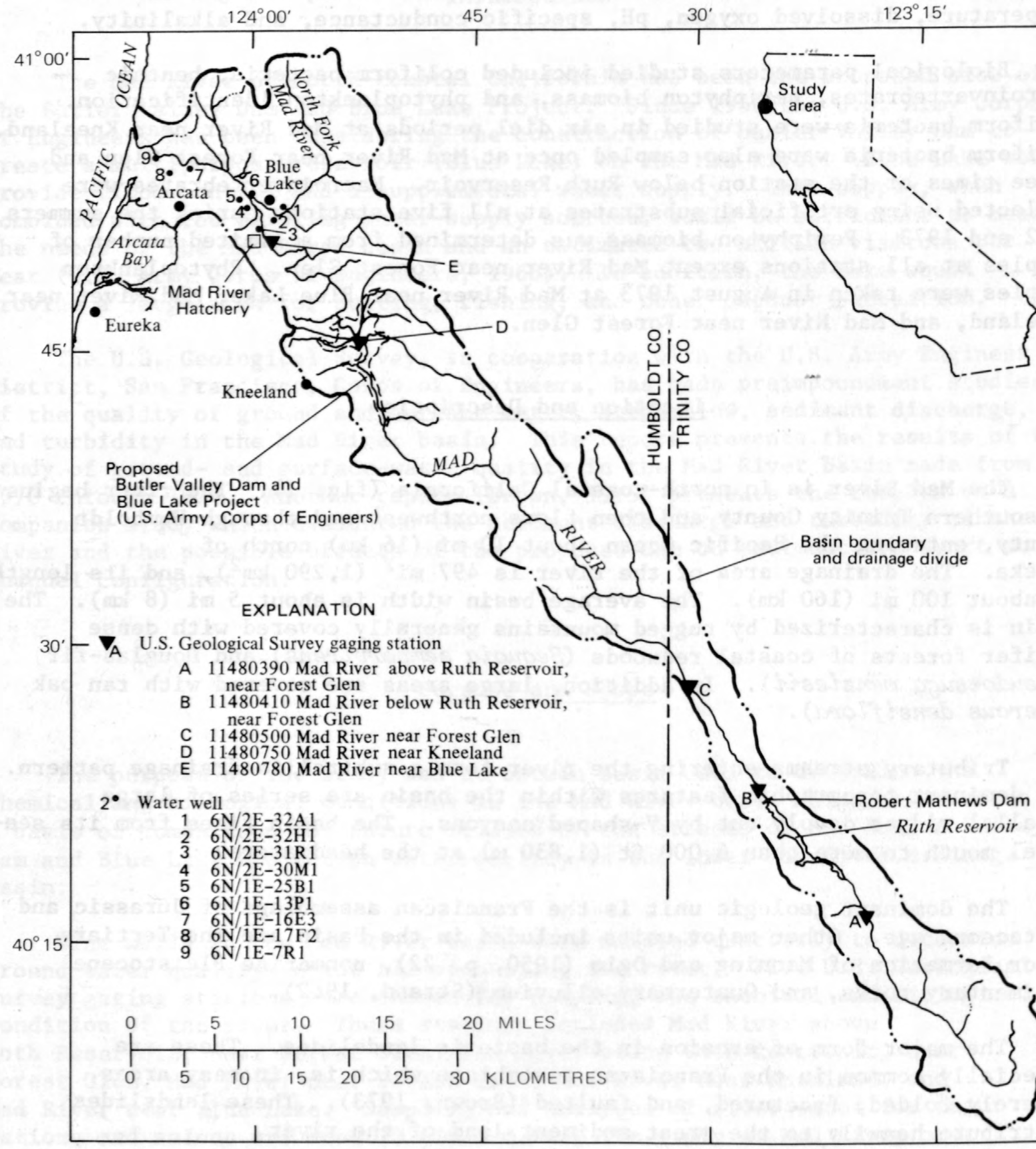

FIGURE 1.--Index map of the Mad River area.

The climate is characterized by cool winters and moderate summers. Fog is prevalent in the lower, coastal part of the basin, and snow seldom falls at elevations below 3,000 ft (910 m). Annual precipitation is approximately 40 in (1,000 mm) along the coastal plain and 70 in (1,800 mm) in the central part of the basin. The estimated average annual precipitation for the basin is 63 in (1,600 mm) (U.S. Army Corps of Engineers, 1968). Seventy-five percent of the annual precipitation occurs from November through March. The coastal region of the basin has a climate comparable to Eureka. Yearly high temperatures are about 79°F (26°C), and lows are about 25°F (-4°C). The monthly mean high temperature is 57°F (14°C), and the mean low is 46°F (8°C). The central and upper basin is less temperate with highs up to 109°F (43°C). The mean monthly high temperature at Forest Glen is 68°F (20°C), and the mean monthly low is 36°F (2°C).

SAMPLING STATIONS AND METHODS

Ground-Water Sampling Stations

Nine wells in the Mad River basin (fig. 1) were sampled to estimate the chemical quality of the ground water and to provide background data which will serve as a basis for comparison with future conditions.

Wells 6N/2E-32A1 and 6N/2E-32H1 were sampled to determine the effect of the North Fork Mad River on ground-water quality. Wells 6N/2E-31R1, 6N/2E-30M1, 6N/1E-25B1, 6N/1E-13P1, 6N/1E-16E3, 6N/1E-17F2, and 6N/1E-7R1 (downstream order) were sampled to estimate the quality of ground water in the alluvium adjacent to the Mad River proper (wells are numbered according to the system used by the U.S. Geological Survey for California described by Bader, 1969).

River-Sampling Stations

Five stations on the Mad River were sampled periodically. They were located in, above, and below the proposed reservoir area (fig. 1).

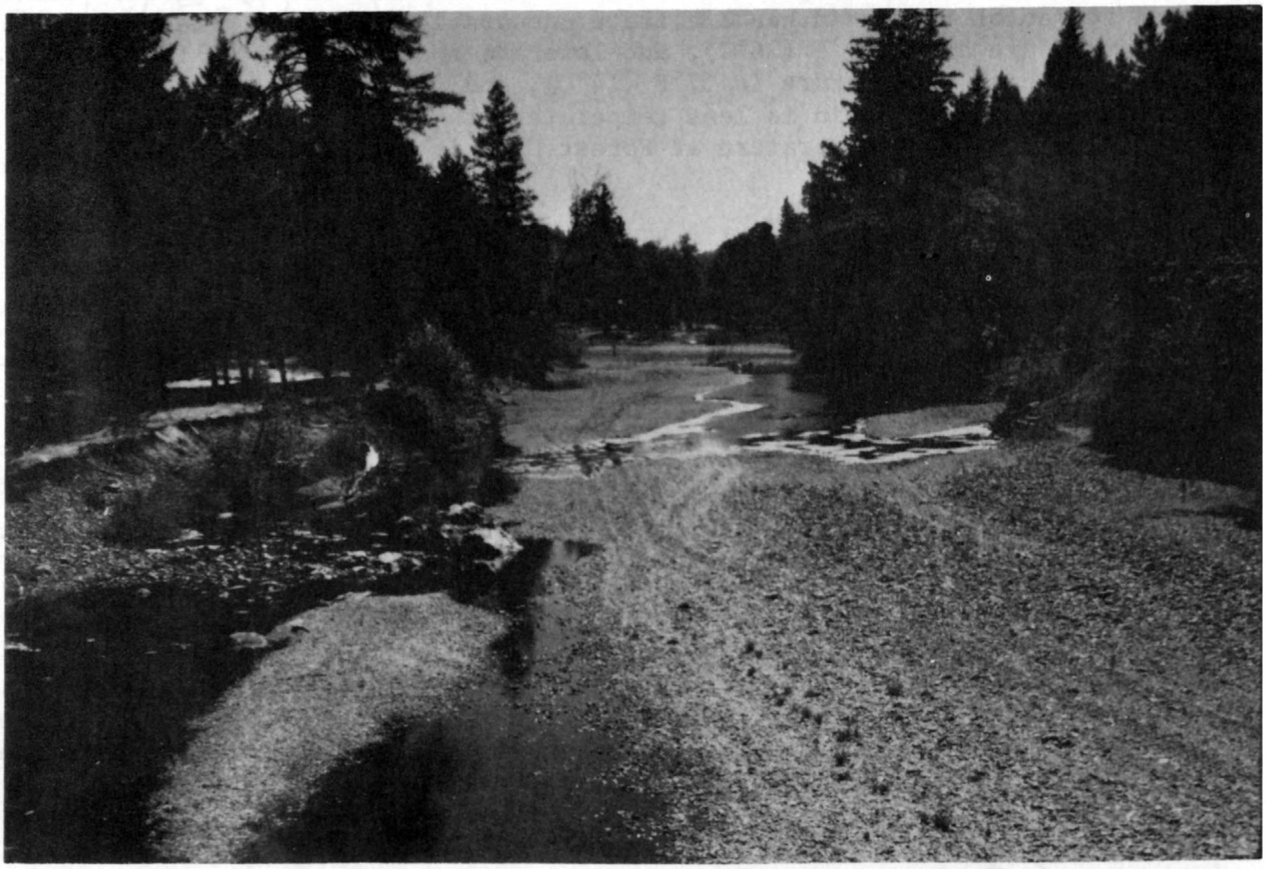

FIGURE 2.--Mad River above Ruth Reservoir, near Forest Glen. U.S. Geological Survey gaging station 11480390, river mile 79.

Mad River above Ruth Reservoir, near Forest Glen (U.S. Geological Survey gaging station 11480390, river mile 79)[1].--This station is above Ruth Reservoir (fig. 2) and was the farthest upstream station. The river was shallow and slow flowing during the summer months. The drainage area above the station is 103 mi^2 (267 km^2). Water temperature in the summer rises above 22°C. In late summer and early autumn algal mats are common in the river.

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[1]Station locations are identified by river mile designations which refer to the distance upstream from U.S. Geological Survey gage at Arcata.

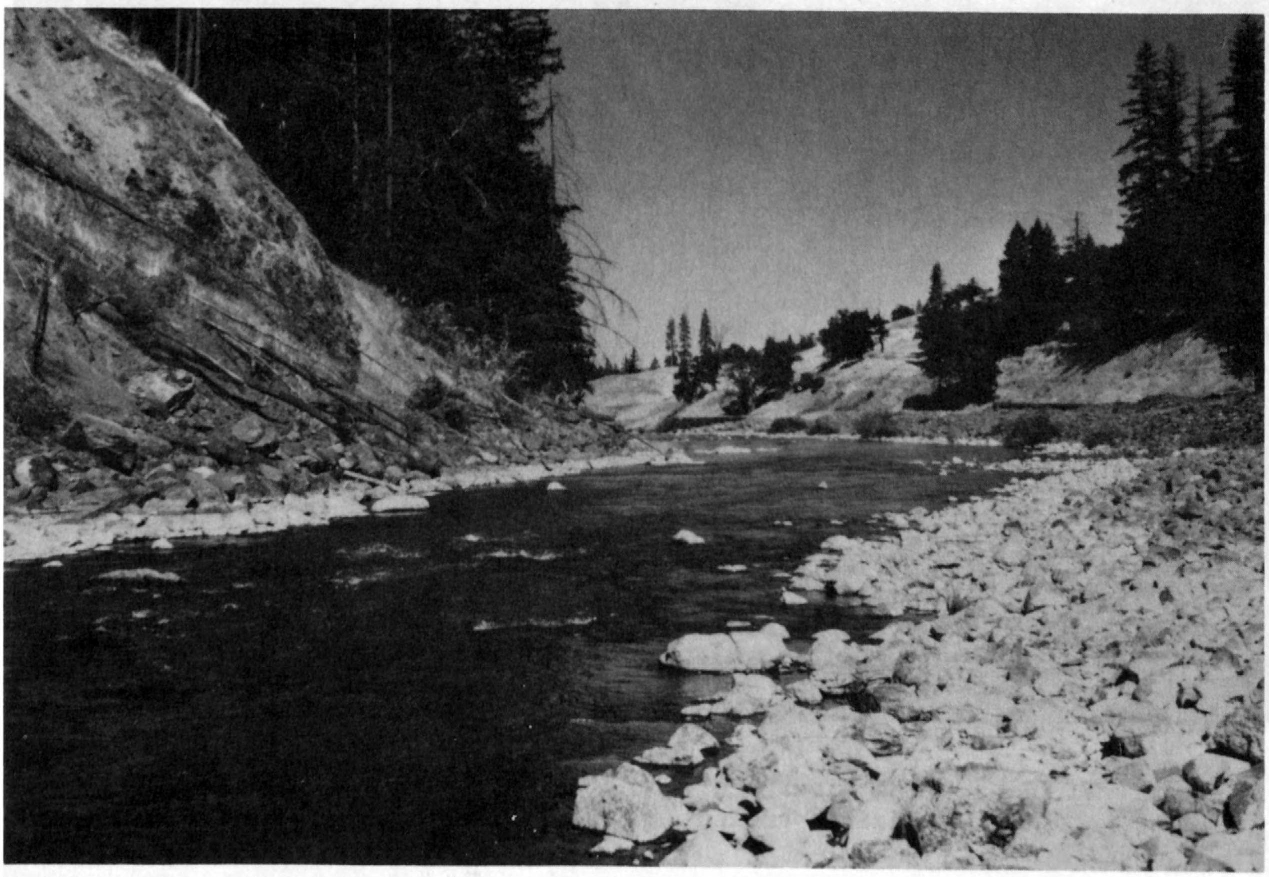


FIGURE 3.--Mad River below Ruth Reservoir, near Forest Glen U.S. Geological Survey gaging station 11480410, river mile 69.

Mad River below Ruth Reservoir, near Forest Glen (U.S. Geological Survey gaging station 11480410, river mile 69).--This station is 1,200 ft (370 m) downstream from Robert Matthews Dam, which forms Ruth Reservoir. The river at this station had a substrate of cobbles and boulders (fig. 3). Discharge is a function of dam releases. Flows in summer were usually 60 to 90 ft^3/s (2.0 to 3.0 m^3/s). The drainage area of the river at this station is 119 mi^2 (308 km^2).

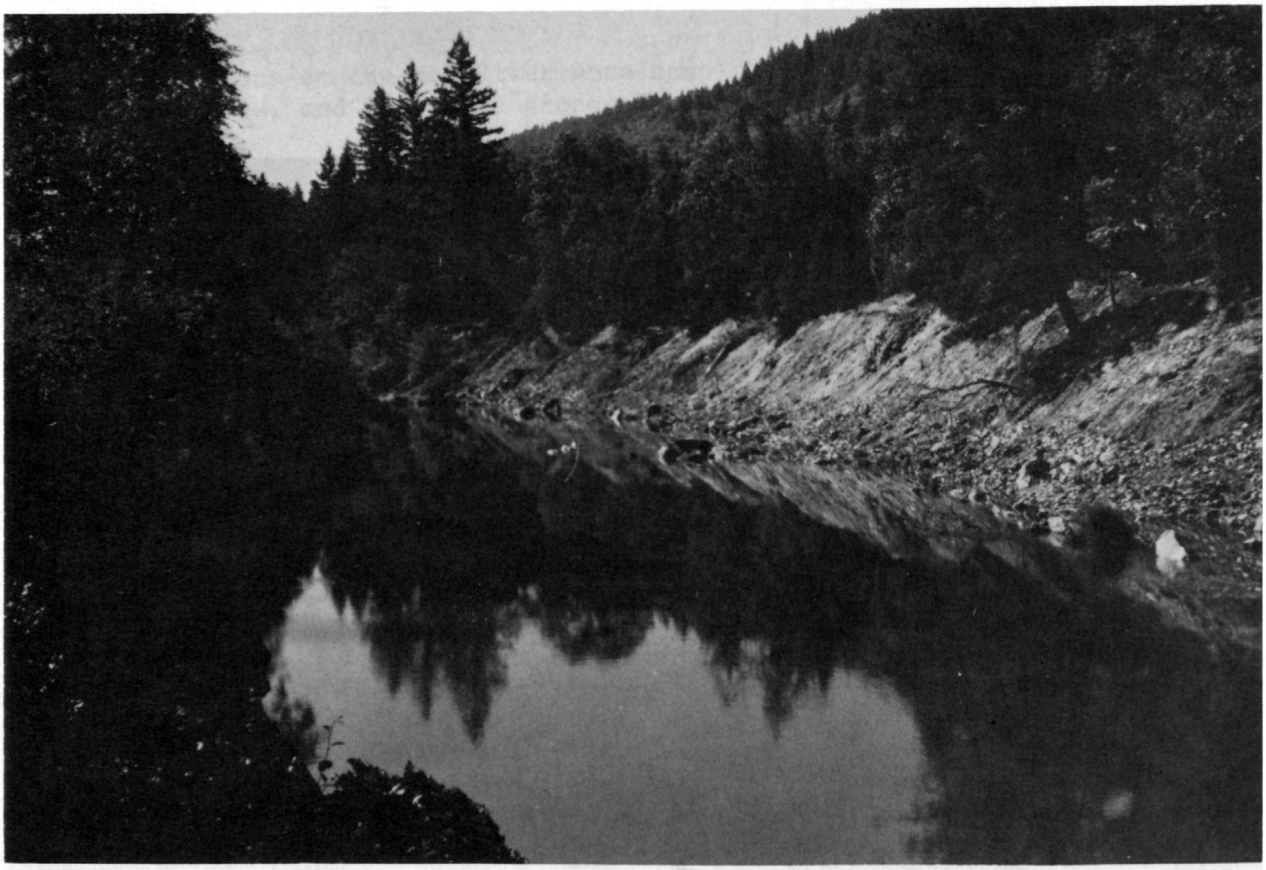


FIGURE 4.--Mad River near Forest Glen. U.S. Geological Survey gaging station 11480500, river mile 60.

Mad River near Forest Glen (U.S. Geological Survey gaging station 11480500, river mile 60).--This station is 9 mi (15 km) below Robert Mathews Dam on a wide and calm stretch of the river (fig. 4). Flows in summer are about 0.5 ft^3/s (0.2 m^3/s). The river has a drainage area of 143 mi^2 (370 km^2) above this station.

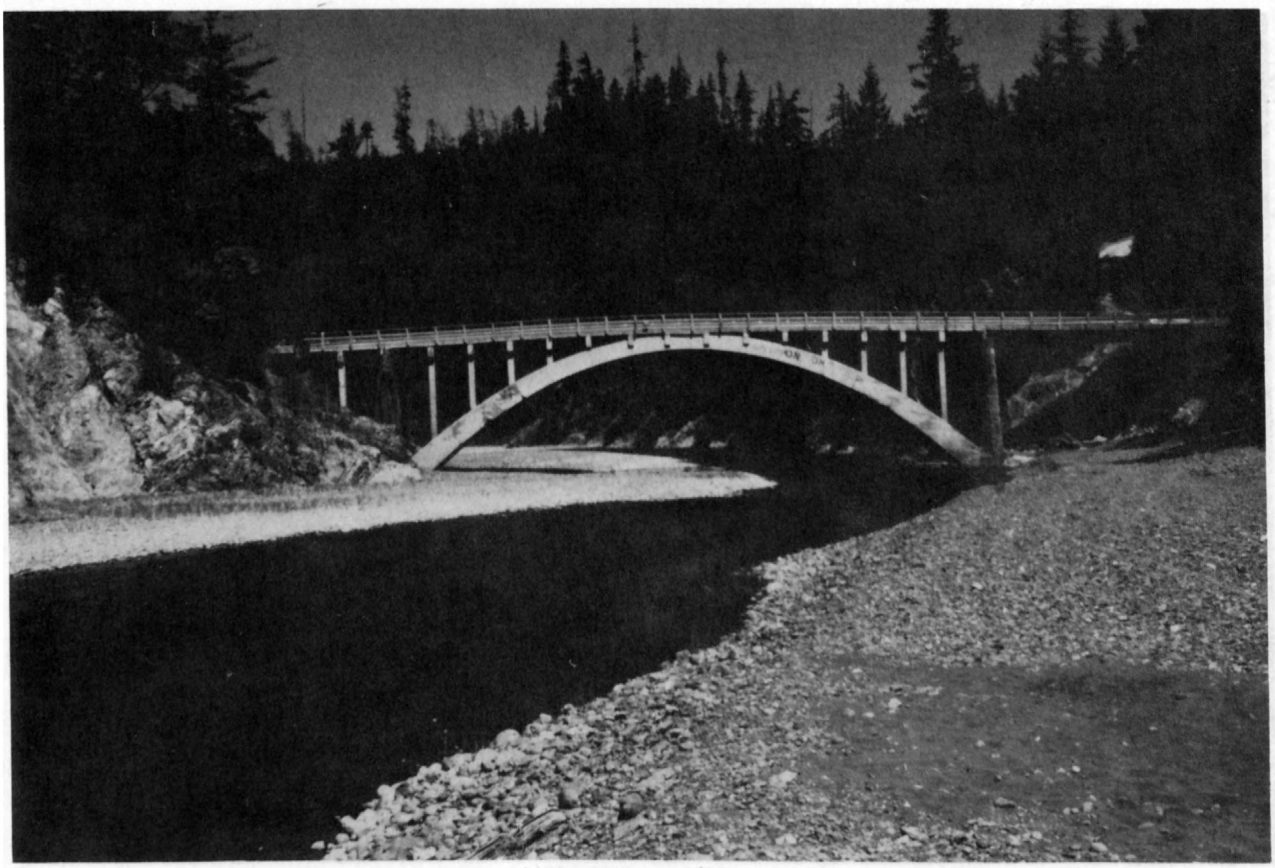


FIGURE 5.--Mad River near Kneeland. U.S. Geological Survey gaging station 11480750, river mile 22.

Mad River near Kneeland (U.S. Geological Survey gaging station 11480750, river mile 22).--This station is 38 mi (61 km) downstream from the Forest Glen station along a large gravel bar and would be inundated by Blue Lake (fig. 5). This station was sampled extensively because water passing it would be characteristic of the water that would fill Blue Lake. The drainage area of the river above this station is 352 mi^2 (912 km^2).

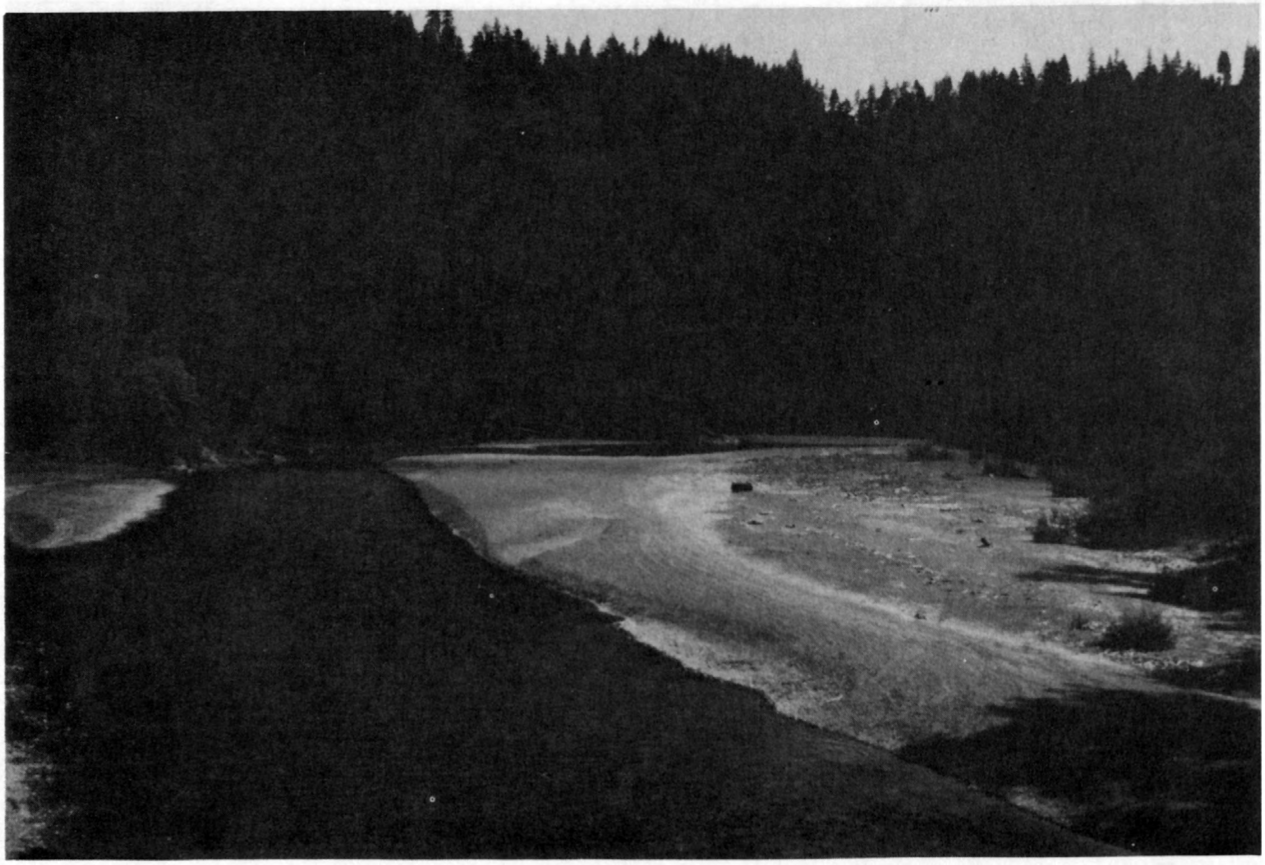


FIGURE 6.--Mad River near Blue Lake. U.S. Geological Survey gaging station 11480780, river mile 8.

Mad River near Blue Lake (U.S. Geological Survey gaging station 11480780, river mile 8).--This is the farthest downstream station, 9 mi (15 km) downstream of the proposed Butler Valley Dam. The station is between a high bluff and a large gravel bar (fig. 6). The river above this station has a drainage area of 393 mi^2 (1,020 km^2).

Sampling Methods and Variables Analyzed

Ground-water samples taken from nine wells were analyzed for major cations and anions. Water samples collected at five stations on the Mad River were analyzed for major cations and anions, nitrogen, phosphorus, carbon, trace metals, and pesticides.

The analyses of surface- and ground-water samples for cations and anions, including nitrogen, phosphorus, carbon, and trace metals, were made by the U.S. Geological Survey Central Water Quality Laboratory, Salt Lake City, Utah, using the methods described by Brown and others (1970). Samples of river water were analyzed for pesticides at the U.S. Geological Survey Laboratory, Austin, Texas.

Field measurements included alkalinity, specific conductance, pH, temperature, and dissolved oxygen. Alkalinity measurements were made using the electrometric titration method (Brown and others, 1970, p. 42-44). Specific conductance was measured using the wheatstone bridge method with temperature adjustment to 25°C (Brown and others, 1970, p. 148-150). Field measurements of pH were made with a portable pH meter using a glass electrode (American Public Health Association and others, 1971, p. 276-281). Temperature measurements were made with a thermister (American Public Health Assocation and others, 1971, p. 348-349). The dissolved-oxygen concentration in the water was determined using the Alsterberg azide modification of the Winkler method (Brown and others, 1970, p. 126-127). Sediment samples were analyzed for pesticides and trace metals using the methods of Goerlitz and Brown (1972).

Biological measurements included coliform bacteria, macroinvertebrates, periphyton, and phytoplankton. River water was sampled for coliform bacteria to determine the possibility of fecal pollution of the river. The membrane-filter test for total coliform bacteria, using M-Endo medium, was used during the early part of the study from 1970 to mid-1971. Fecal coliform bacteria analyses were made using the membrane-filter technique with M-FC medium incubated at 44.5°C (American Public Health Association and others, 1971; Slack and others, 1973) during the rest of the study. Macroinvertebrates were collected using multiplate substrates (Hester and Dendy, 1962) and basket artificial substrates (American Public Health Assocaition and others, 1971; Slack and others, 1973). Organisms were removed from the substrates, preserved in 40-percent isopropyl alcohol, and later identified and counted in the laboratory. Periphyton samples were collected on plastic substrates and air dried in the field. Substrates were generally given 6 to 10 weeks for colonization. Analysis for biomass was done in the laboratory using methods in Slack and others (1973). Water samples collected for phytoplankton were preserved in Lugol's solution and identified and counted in the laboratory using the method in Slack and others (1973).

RESULTS AND DISCUSSION

Ground Water

Chemical analyses of water from the nine wells sampled are shown in table 1. These analyses indicate that concentrations of all measured dissolved constituents except iron are acceptable for domestic and industrial use. The high iron content affects water color and causes staining. Both problems can often be eliminated by oxygenation of the water. Oxygenation causes the precipitation of ferric hydroxide, $Fe(OH)_3$, which removes the iron from the water. Concentrations of dissolved solids ranged from 72 to 306 mg/l (milligrams per litre). Concentrations of chloride were generally low; the highest reported value was 28 mg/l. Water quality in the two wells along the North Fork Mad River was about the same as for the other wells along the Mad River proper.

Values for iron in a number of wells have a large range with differences in the orders of magnitude. The wide range of values for a given well may be due to the effect of corrosion of well casings which adds iron to the water in the well casing. If all the water in the casing is not pumped out before the sample is collected, anomalously high concentrations of iron may be found in the sample. Consistently high values for a given well may be due to contact with rocks of the iron-rich Franciscan assemblage. The values of zero for iron at wells sampled October 15, 1970, are thought to be analytical errors.

In well 6N/1E-25B1 three samples taken in 1970 and 1971 gave values for potassium which exceed the values for sodium. This is unusual for water in this area of the country. Samples taken from the same well in 1972 and 1973 do not show this anomaly. High values for boron at well 6N/2E-32A1 on June 21, 1971, and at well 6N/1E-13P1 on January 24, 1974, and the low value at well 6N/1E-13P1 on October 15, 1970, cannot be explained but may be due to analytical errors.

Plots of chemical analyses of wells 2N/1E-13P1 and 6N/2E-30M1 using trilinear diagrams (Piper, 1944) are shown in figure 7. Points were plotted as milliequivalents per litre. Only analyses in which the cations and anions balanced to within 5 percent were used. These plots indicate that chemical analyses for a given well show little variation over a 4-year period of time. Changes in water quality could be determined by comparing future analyses of water from the Mad River wells that have been sampled with the analyses given in table 1.

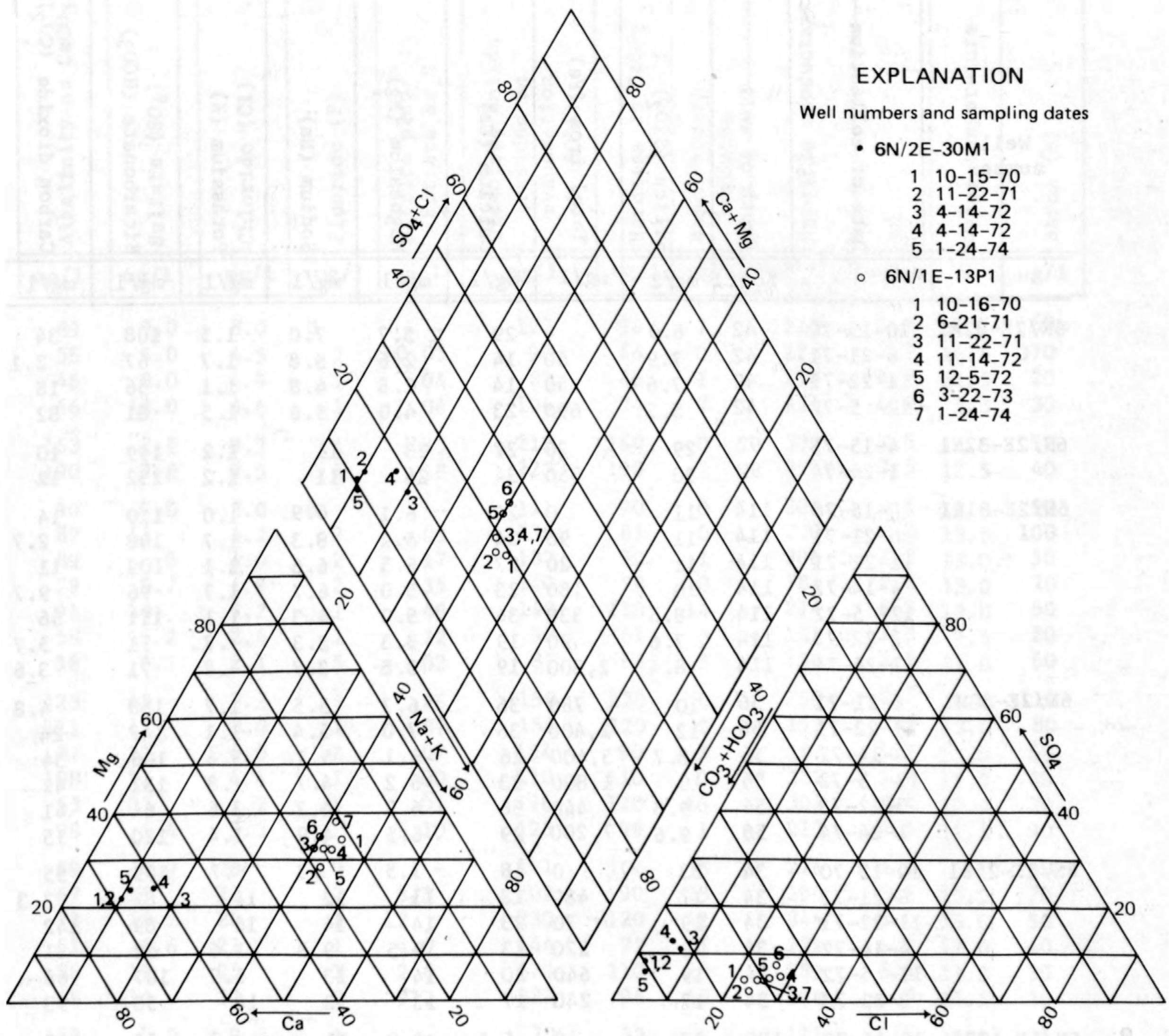


FIGURE 7.--Trilinear diagram showing chemical constituents for wells 6N/1E-13P1 and 6N/2E-30M1, October 1970-January 1974.

TABLE 1.--*Chemical analyses of water from*

Well number	Date of collection	Depth of well (feet)	Silica (SiO_2) (mg/l)	Total iron (Fe) (µg/l)	Calcium (Ca) (mg/l)	Magnesium (Mg) (mg/l)	Sodium (Na) (mg/l)	Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Carbon dioxide (CO_2) (mg/l)
6N/2E-32A1	10-15-70	42	8.0	-	29	5.7	7.0	1.5	108	34
	6-21-71	42	7.9	60	14	2.6	5.8	1.7	67	2.1
	11-22-71	42	7.6	40	14	2.8	4.8	1.1	56	18
	12- 5-72	42	5.5	690	23	4.0	5.6	1.5	81	82
6N/2E-32H1	4-15-73	92	29	30	27	23	11	1.2	199	10
	1-24-74	92	30	350	34	26	11	1.2	232	12
6N/2E-31R1	10-15-70	114	11	0	26	6.1	6.9	1.0	110	14
	6-21-71	114	11	90	24	5.2	8.3	1.7	108	2.7
	11-22-71	114	11	20	27	5.5	6.6	1.1	109	11
	4-14-72	114	10	180	23	5.0	6.7	1.7	96	9.7
	12- 5-72	114	8.6	330	34	5.0	4.3	1.1	111	56
	3-22-73	114	7.6	90	19	3.3	3.3	.7	71	5.7
	1-24-74	114	8.4	2,300	19	3.8	3.7	.8	71	3.6
6N/2E-30M1	6-21-71	56	10	760	36	6.7	5.5	1.7	150	4.8
	11-22-71	56	12	2,400	36	7.0	5.4	1.1	147	24
	4-14-72	56	8.7	3,400	26	6.1	5.1	3.4	106	34
	12- 5-72	56	10	1,800	33	6.2	4.7	.8	132	42
	3-22-73	56	9.8	440	36	6.9	4.2	3.6	64	41
	1-24-74	56	9.6	7,200	29	6.5	4.9	1.4	120	15
6N/1E-25B1	10-15-70	34	23	0	18	1.5	.3	.7	109	55
	6-21-71	34	17	480	18	11	12	14	82	3.3
	11-22-71	34	19	70	23	14	14	16	89	142
	4-14-72	34	12	220	13	9.5	9.8	1.6	62	31
	12- 5-72	34	19	640	20	14	13	6.9	107	68
	3-22-73	34	17	240	17	13	12	14	58	93
6N/1E-13P1	10-15-70	120	27	0	5.1	4.8	11	.7	52	42
	6-21-71	120	29	250	7.5	4.7	12	2.3	58	1.9
	11-22-71	120	30	160	6.6	4.9	11	1.2	55	22
	4-14-72	120	29	310	6.4	4.9	11	1.1	51	129
	12- 5-72	120	29	660	7.0	4.9	11	.9	50	40
	3-22-73	120	26	50	6.6	5.2	11	.9	51	41
	1-24-74	120	23	230	6.2	6.6	13	.8	56	71
6N/1E-16E3	4-14-72	14	15	410	57	12	7.6	1.8	230	23
	12- 5-72	14	15	1,300	65	11	7.4	1.1	235	75
	3-22-73	14	14	470	58	12	7.4	1.2	230	15
	1-24-74	14	14	620	65	12	7.8	1.2	247	16
6N/1E-17F2	4-14-72	70	32	8,400	55	21	8.2	1.3	257	82
	12- 5-72	70	32	9,100	53	20	7.7	1.0	258	104
	3-22-73	70	30	13,000	56	21	8.0	1.2	264	42
	1-24-74	70	33	9,000	59	20	8.2	1.1	256	52
6N/1E-7R1	4-14-72	150	19	450	41	27	11	1.6	265	53
	12- 5-72	150	19	700	40	26	9.8	1.5	272	109
	3-22-73	150	19	110	40	27	11	1.4	264	27

nine wells, October 1970-January 1974

Alkalinity as $CaCO_3$	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrite plus Nitrate as N	Dissolved solids (residue on evaporation at 180°C)	Hardness as $CaCO_3$	Noncarbonate hardness	Specific conductance	pH	Water temperature	Boron (B)
mg/1	mg/1	mg/1	μg/1	mg/1	mg/1	mg/1	mg/1	micromhos at 25°C	units	°C	μg/1
89	9.0	8.0	0	–	127	96	7	219	6.7	19.0	60
55	6.0	4.5	.2	0.05	90	46	0	124	7.7	16.5	370
46	8.0	4.9	.1	.04	82	46	1	118	6.7	11.5	20
66	14.0	6.6	.1	.04	104	74	7	173	6.2	5.5	30
163	7.6	9.7	.1	.15	212	160	0	332	7.5	14.5	50
190	7.8	9.5	.4	.18	223	190	2	399	7.5	12.5	40
90	9.0	3.0	0	–	111	90	0	205	7.1	15.0	90
89	11	4.2	.2	.08	136	81	0	200	7.8	13.5	100
89	.0	4.0	.2	.17	132	90	1	206	7.2	13.0	50
79	9.7	4.9	.2	.35	140	78	0	184	7.2	13.0	70
91	14	5.2	.1	.46	148	110	14	214	6.5	12.0	60
58	8.2	2.4	.1	.12	90	61	3	138	7.3	9.5	20
58	6.7	2.1	.5	.02	81	63	5	136	7.5	11.0	60
123	13	3.2	.1	.26	158	120	0	250	7.7	16.0	110
121	11	3.0	.1	.07	154	120	0	252	7.0	13.0	80
87	12	4.0	.2	.07	154	90	3	197	6.7	12.0	60
108	12	4.4	.1	.00	150	110	0	232	6.7	12.0	80
53	85	2.7	.5	.01	196	120	66	307	6.4	10.0	30
98	6.4	2.3	.1	1.10	125	99	1	213	7.1	11.5	90
89	6.0	28	.0	–	161	104	15	276	6.5	–	40
67	15	22	.2	8.5	202	90	23	290	7.6	15.0	70
73	13	28	.1	12	230	120	42	344	6.0	13.0	50
51	8.6	21	.1	4.0	144	72	21	222	6.5	11.0	40
88	11	25	.1	2.6	170	110	20	282	6.4	11.5	30
48	14	22	.0	9.7	222	96	48	304	6.0	10.5	30
43	2.0	9.3	.1	–	72	32	0	121	6.3	14.5	5
48	1.5	11	.2	.94	102	38	0	128	7.7	15.5	80
45	3.0	11	.1	.94	98	37	0	127	6.6	14.0	30
42	1.8	11	.1	.85	108	36	0	124	5.8	12.0	60
41	2.9	12	.1	.92	108	38	0	129	6.3	12.5	40
42	3.9	12	.1	.96	104	38	0	127	6.3	9.0	60
46	2.0	12	.2	1.50	89	43	0	146	6.1	11.5	290
189	6.3	11	.1	.03	242	190	3	392	7.2	–	70
193	6.4	12	.1	.02	236	210	15	393	6.7	5.5	70
194	7.4	11	.0	.02	246	190	1	409	7.4	13.5	60
203	5.3	11	.5	.03	235	210	9	426	7.4	11.5	90
211	26	8.0	.2	.02	290	220	13	455	6.7	14.0	120
212	23	9.2	.2	.00	306	210	3	444	6.6	12.0	120
217	22	7.7	.3	.03	302	230	10	466	7.0	11.5	110
210	24	7.4	1.5	.05	272	230	20	460	6.9	12.5	140
217	4.9	7.9	.2	.02	242	210	0	422	6.9	14.5	80
223	5.3	9.3	.2	.20	246	210	0	423	6.6	14.5	70
217	5.0	7.6	.2	.21	266	210	0	426	7.2	10.0	60

Surface Water

The samples collected at Mad River near Kneeland were used to determine the character of the river with respect to major chemical constituents because water at this station should represent the water that would be impounded in Blue Lake. Table 2 shows mean, maximum, and minimum values for major chemical constituents and the standard deviations from the mean. With the exception of high concentrations of iron, the concentrations of constituents measured in this study were relatively low, and the water meets the quality criteria for domestic and industrial use (Environmental Protection Agency, 1972). These values indicate that the concentrations of major constituents should not cause water-quality problems in the proposed Blue Lake.

TABLE 2.--*Concentrations of major chemical constituents at Mad River near Kneeland*

[Concentrations of iron and boron reported in micrograms per litre; specific conductance reported in micromhos at 25°C; pH reported in units; all other constituents reported in milligrams per litre]

Constituent	Number of samples	Mean	Standard deviation	Maximum	Minimum
Silica	10	6.7	0.631	7.9	5.6
Iron	10	685	829	2,100	20
Calcium	10	20	4.45	24	12
Magnesium	10	3.3	.604	4.2	2.1
Sodium	10	3.5	.508	4.2	2.4
Potassium	10	.8	.173	1.2	.6
Bicarbonate	10	70	14.7	88	50
Sulfate	10	11.6	5.31	25	5.2
Chloride	10	1.9	.971	3.7	.6
Fluoride	10	.13	.068	.2	0
Dissolved solids	6	87.2	26.9	124	52
Hardness as $CaCO_3$	10	64	17.9	76	39
Specific conductance	119	151	53.1	420	90
pH	119			8.8	6.2
Boron	10	47	24.1	70	0

Nitrogen, Phosphorus, and Carbon Nutrients

Nitrogen, phosphorus, and carbon are nutrients important to algal growth. If large concentrations of these nutrients were to accumulate in Blue Lake, algal blooms could result. Various minimum nutrient levels have been suggested below which algal growth will be inhibited. Studies have suggested nitrogen concentrations necessary for algal blooms range from trace concentrations to 5.3 mg/l; for phosphorus the necessary concentrations range from 0.002 to 0.09 mg/l (Greeson, 1971). Carbon is generally always present in sufficient quantities for algal growth (Meyer and others, 1964).

Figures 8 through 14 show the mean, the range, and the standard deviation about the mean for concentrations of total nitrogen, organic nitrogen plus ammonium, nitrite plus nitrate, ammonium, total phosphorus, dissolved orthophosphate, and total organic carbon at the five sampling stations. The five sampling stations (A through E) correspond to the five gaging stations shown in figure 1 and pictured in figures 2 to 6.

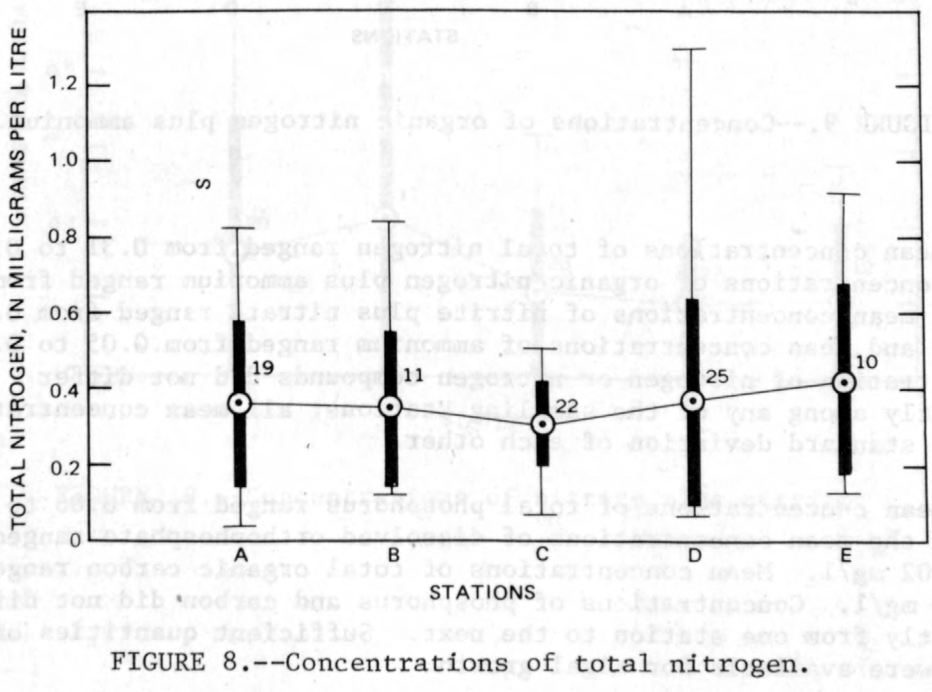
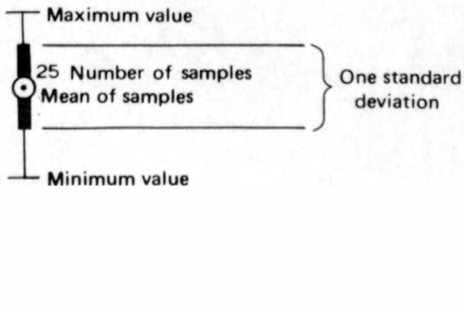


FIGURE 8.--Concentrations of total nitrogen.



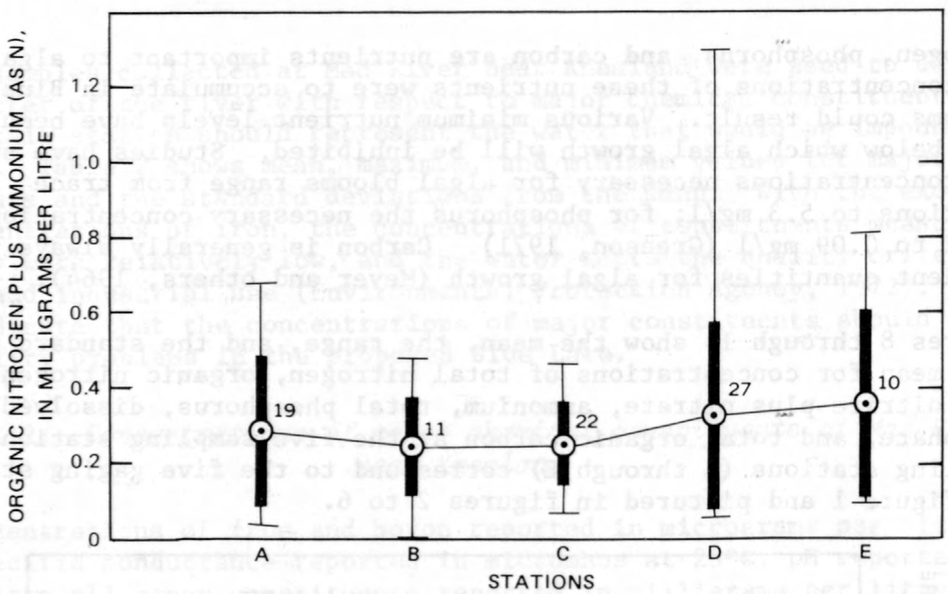


FIGURE 9.--Concentrations of organic nitrogen plus ammonium.

The mean concentrations of total nitrogen ranged from 0.31 to 0.43 mg/l. The mean concentrations of organic nitrogen plus ammonium ranged from 0.25 to 0.36 mg/l; mean concentrations of nitrite plus nitrate ranged from 0.05 to 0.10 mg/l; and mean concentrations of ammonium ranged from 0.05 to 0.14 mg/l. The concentration of nitrogen or nitrogen compounds did not differ significantly among any of the sampling stations; all mean concentrations were within one standard deviation of each other.

The mean concentrations of total phosphorus ranged from 0.06 to 0.27 mg/l; the mean concentrations of dissolved orthophosphate ranged from 0.01 to 0.02 mg/l. Mean concentrations of total organic carbon ranged from 1.4 to 3.9 mg/l. Concentrations of phosphorus and carbon did not differ significantly from one station to the next. Sufficient quantities of these nutrients were available for algal growth.

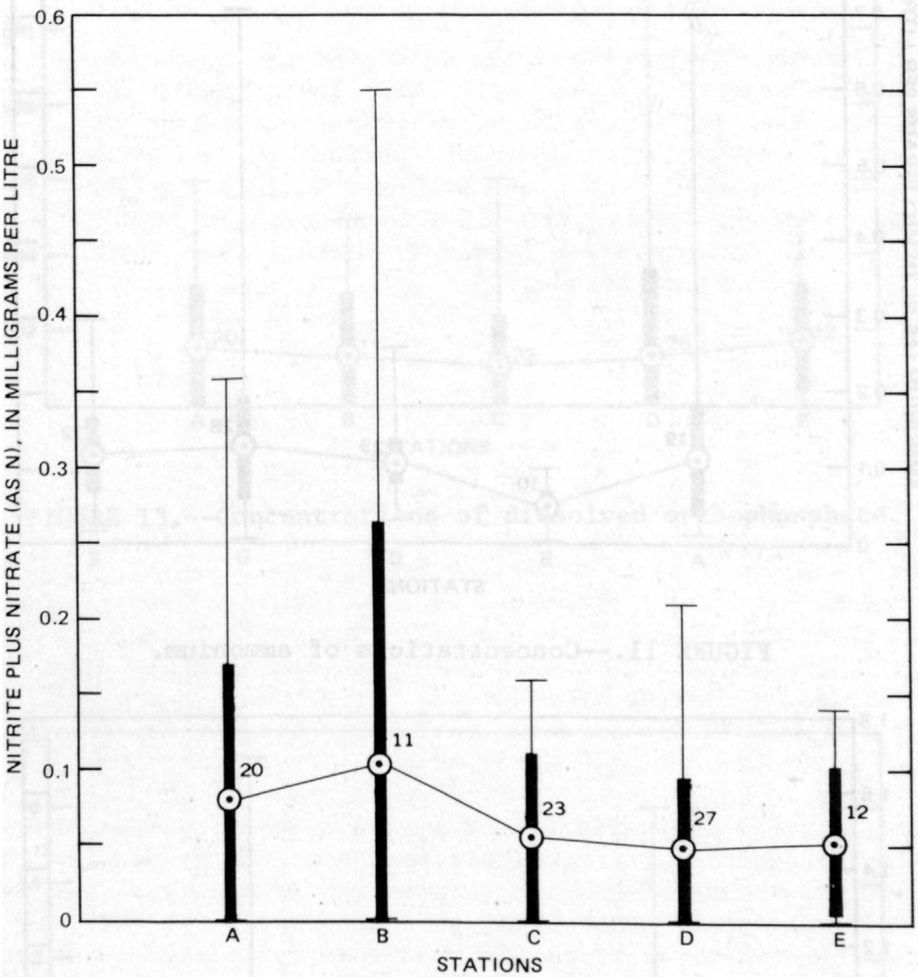


FIGURE 10.--Concentrations of nitrite plus nitrate.

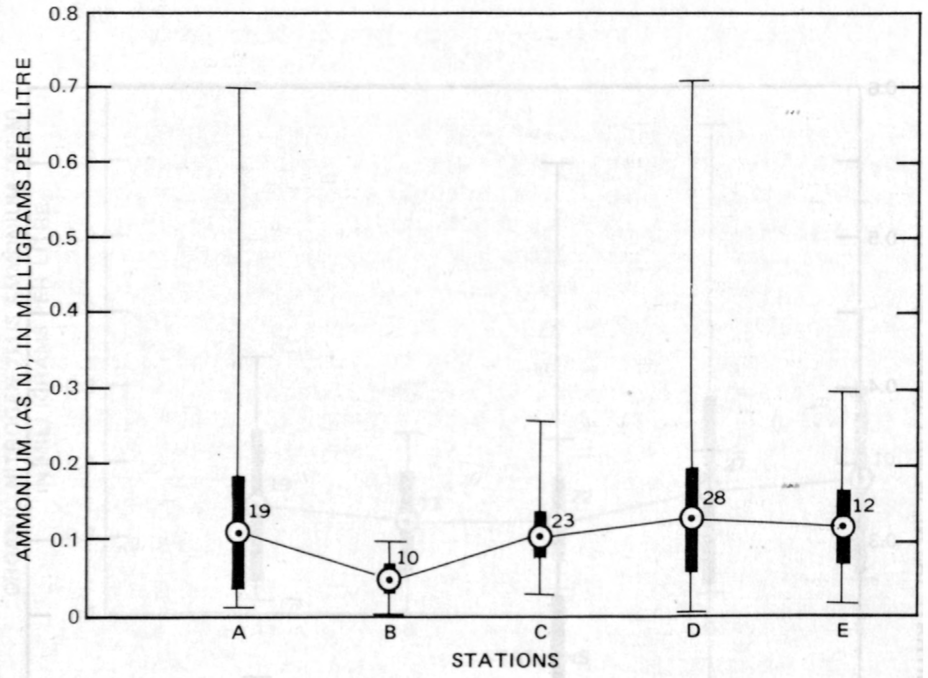


FIGURE 11.--Concentrations of ammonium.

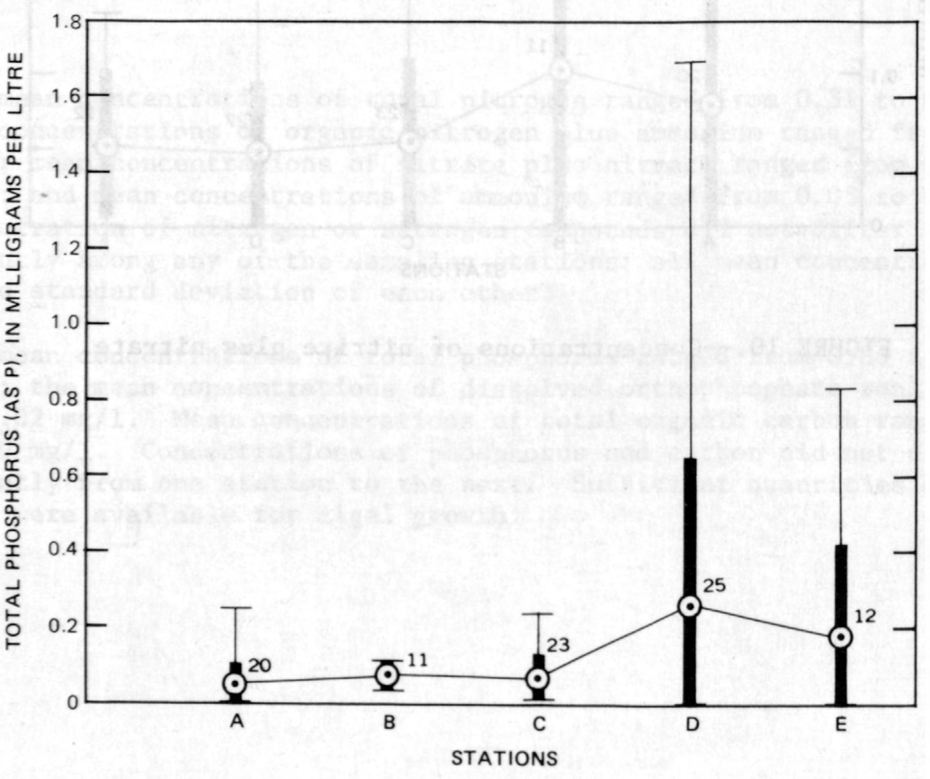


FIGURE 12.--Concentrations of total phosphorus.

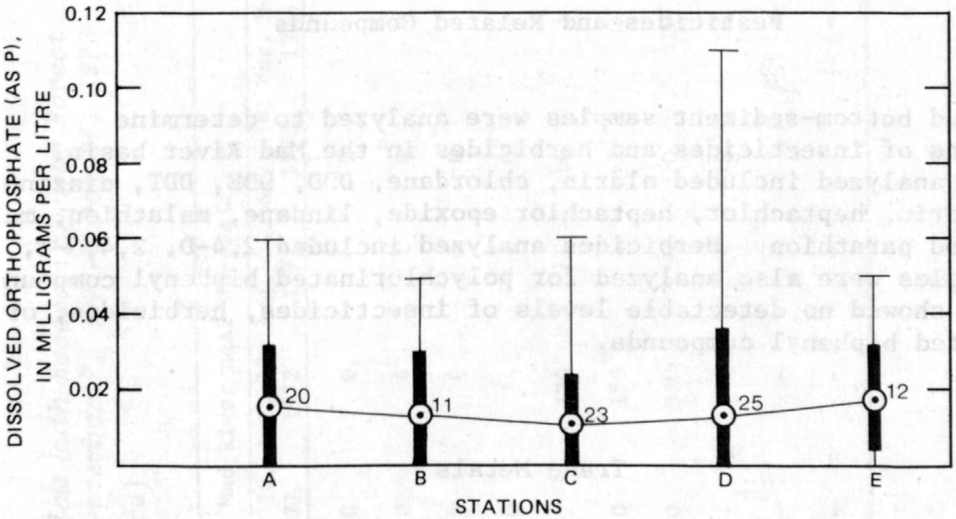


FIGURE 13.--Concentrations of dissolved orthophosphate.

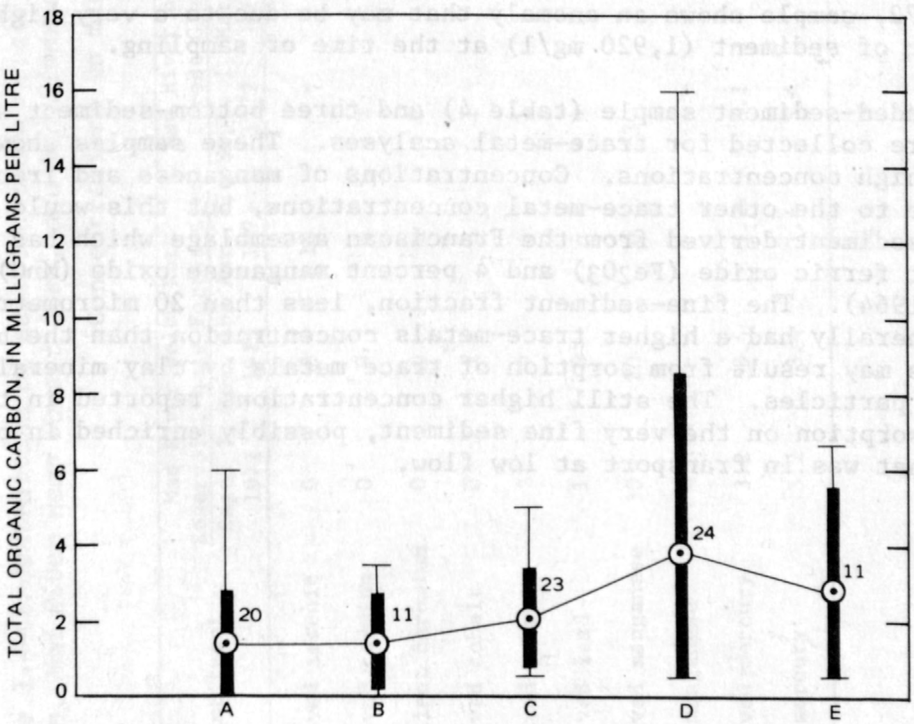


FIGURE 14.--Concentrations of total organic carbon.

Pesticides and Related Compounds

Water and bottom-sediment samples were analyzed to determine concentrations of insecticides and herbicides in the Mad River basin. Insecticides analyzed included aldrin, chlordane, DDD, DDE, DDT, diazinon, dieldrin, endrin, heptachlor, heptachlor epoxide, lindane, malathion, methyl parathion, and parathion. Herbicides analyzed included 2,4-D, 2,4,5-T, and silvex. Samples were also analyzed for polychlorinated biphenyl compounds. The analyses showed no detectable levels of insecticides, herbicides, or polychlorinated biphenyl compounds.

Trace Metals

Samples of water collected at Mad River below Ruth Reservoir, near Forest Glen, Mad River near Forest Glen, and Mad River near Kneeland were analyzed to determine the concentration of dissolved trace metals. Analyses were made for arsenic, cadmium, hexavalent chromium, cobalt, copper, lead, manganese, mercury, and zinc (table 3). With the exception of the sample collected April 12, 1972, concentrations of dissolved trace metals were low, as would be expected in an area receiving no industrial or domestic waste discharges. The April 12, 1972, sample shows an anomaly that may be due to a very high concentration of sediment (1,920 mg/l) at the time of sampling.

A suspended-sediment sample (table 4) and three bottom-sediment samples (table 5) were collected for trace-metal analyses. These samples showed no anomalously high concentrations. Concentrations of manganese and iron were high relative to the other trace-metal concentrations, but this would be expected of sediment derived from the Franciscan assemblage which has as much as 15 percent ferric oxide (Fe_2O_3) and 4 percent manganese oxide (MnO) (Bailey and others, 1964). The fine-sediment fraction, less than 20 micrometres in diameter, generally had a higher trace-metals concentration than the bulk sample. This may result from sorption of trace metals by clay minerals and fine organic particles. The still higher concentrations reported in table 4 may reflect sorption on the very fine sediment, possibly enriched in organic particles, that was in transport at low flow.

Table 3.--*Concentrations of selected trace metals at Mad River below Ruth Reservoir, near Forest Glen, Mad River near Forest Glen, and Mad River near Kneeland, September 7, 1971-March 27, 1973*

[Concentrations in micrograms per litre]

Constituent	Mad River below Ruth Reservoir, near Forest Glen			Mad River near Forest Glen		Mad River near Kneeland					
	Sept. 7, 1971	Nov. 16, 1971	Apr. 12, 1972	Sept. 1, 1972	Mar. 27, 1973	Sept. 8, 1971	Nov. 18, 1971	Apr. 12, 1972	Aug. 30, 1972	Nov. 16, 1972	Mar. 26, 1973
Dissolved arsenic	0	0	10	-	1	8	0	0	-	0	-
Dissolved cadmium	0	0	1	1	0	0	0	4	1	0	0
Hexavalent chromium	0	0	0	0	0	0	0	0	0	0	0
Dissolved cobalt	0	1	3	1	0	0	0	14	1	0	0
Dissolved copper	3	9	4	1	-	6	7	130	1	16	3
Dissolved lead	1	0	4	4	2	1	0	150	4	2	3
Dissolved manganese	30	20	0	30	0	20	10	320	110	0	10
Total manganese	-	-	-	-	-	-	-	-	-	10	-
Dissolved mercury	3.2	3.4	1.2	3.1	.1	2.3	-	-	-	3.0	-
Total mercury	3.2	3.4	1.4	3.4	.2	3.9	-	-	-	-	-

TABLE 4.--*Concentrations of selected trace metals in suspended sediment at Mad River near Kneeland, November 16, 1972*

[Concentrations in milligrams per kilogram]

Constituent	Concentration
Iron	47,000
Cadmium	49
Copper	120
Lead	74
Mercury	2.4

During periods of high flow in the Mad River, however, concentrations of suspended sediment are commonly as high as 3,000 to 4,000 mg/l. This large amount of suspended sediment, and the concentrations of trace metals shown in tables 4 and 5, constitutes a large sink of trace metals. Though the dissolved trace-metals content of the water is far below all recommended water-quality criteria, the seasonally high concentrations of suspended sediment and the associated trace metals constitute total concentrations of trace metals that may at times exceed the criteria for public water supplies and aquatic life (Environmental Protection Agency, 1972). The suspended sediment, if accumulated in a reservoir, could act as a large sink for trace metals.

TABLE 5.--*Concentrations of selected trace metals in bottom sediments at Mad River near Forest Glen, Mad River near Kneeland, and Mad River near Blue Lake, August 29, 1972*

[Concentrations in milligrams per kilogram]

Sampling station	Constituent	Less than 20 micrometres fraction	Bulk sample
Mad River near Forest Glen	Arsenic	10	3.1
	Cadmium	0	1
	Chromium	0	0
	Cobalt	8.7	9
	Copper	13	3
	Lead	11	10
	Manganese	1,200	580
	Mercury	.23	.022
Mad River near Kneeland	Arsenic	6.9	2.6
	Cadmium	4.1	1
	Chromium	0	0
	Cobalt	25	11
	Copper	14	4
	Lead	43	11
	Manganese	1,200	580
	Mercury	1.4	.029
Mad River near Blue Lake	Arsenic	4.2	2.7
	Cadmium	0	2
	Chromium	0	0
	Cobalt	6.2	9
	Copper	5.8	4
	Lead	6.2	11
	Manganese	670	570
	Mercury	-	.053

Diel Studies

Diel studies (studies during a 24-hour period) were made in November 1970, July, August, and September 1971, April, August, and November 1972, and March and August 1973 at Mad River near Kneeland. Two diel studies were also made in August 1972 and 1973 at Mad River near Blue Lake. The purpose of these studies was to determine the daily variations in alkalinity, specific conductance, pH, water temperature, and dissolved oxygen. Changes in some of these parameters during different periods of the day may indicate biological activity in the river ecosystem.

Typical diel changes in alkalinity, specific conductance, pH, and water temperature are shown in figures 15 through 18. The alkalinity, specific conductance, and pH were generally constant during diel periods. In a few instances, such as is shown in figures 15 through 17, these values increased during periods of high air temperature, light, and biological activity. Water temperature was generally the warmest at about 1500 hours and then dropped steadily until about 0700 or 0900 hours. The water temperature changes during a 24-hour period ranged from 7°C in July to 2°C in November.

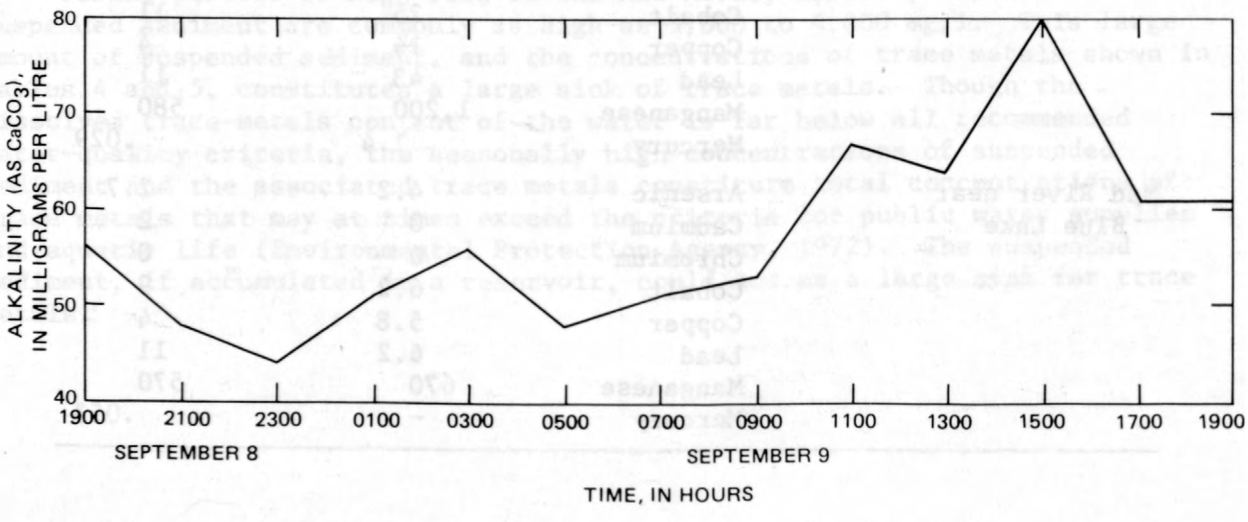


FIGURE 15.--Diel changes in alkalinity at Mad River near Kneeland, September 8-9, 1971.

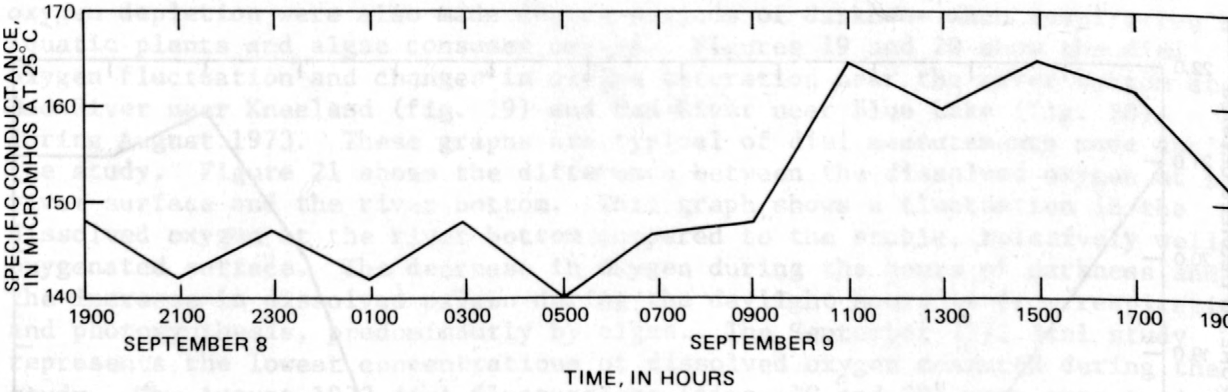


FIGURE 16.--Diel changes in specific conductance at Mad River near Kneeland, September 8-9, 1971.

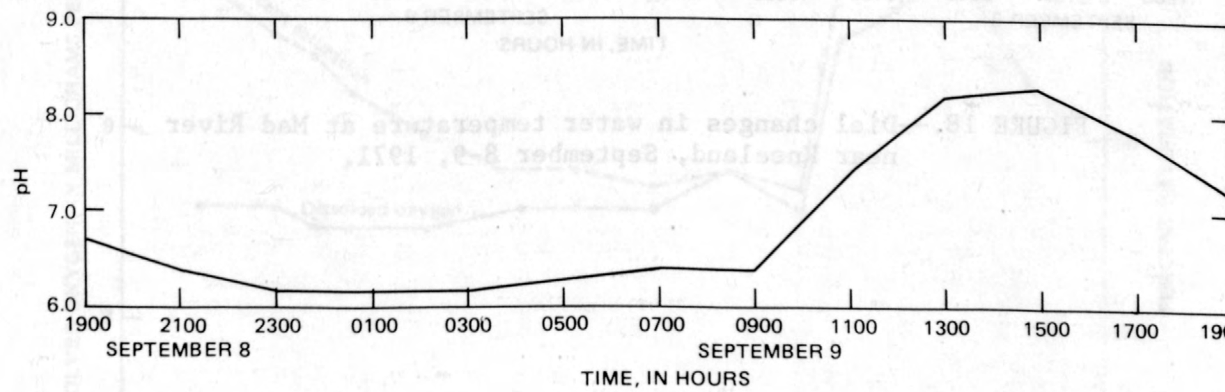


FIGURE 17.--Diel changes in pH at Mad River near Kneeland, September 8-9, 1971.

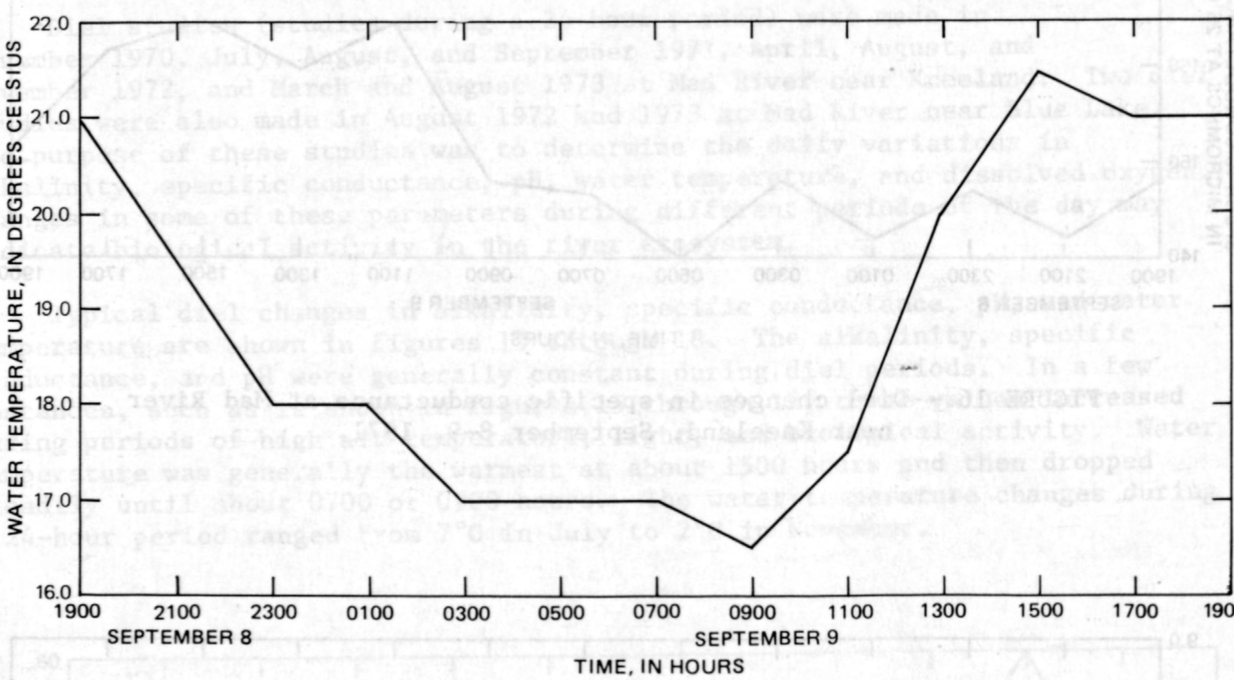


FIGURE 18.--Diel changes in water temperature at Mad River near Kneeland, September 8-9, 1971.

Dissolved oxygen in the river was measured to determine if significant quantities of dissolved oxygen were produced by rooted aquatic plants and algae during daylight hours as a result of photosynthesis. Measurements of oxygen depletion were also made during periods of darkness when respiration by aquatic plants and algae consumes oxygen. Figures 19 and 20 show the diel oxygen fluctuation and changes in oxygen saturation near the river bottom at Mad River near Kneeland (fig. 19) and Mad River near Blue Lake (fig. 20) during August 1973. These graphs are typical of diel measurements made during the study. Figure 21 shows the difference between the dissolved oxygen at the river surface and the river bottom. This graph shows a fluctuation in the dissolved oxygen at the river bottom compared to the stable, relatively well-oxygenated surface. The decrease in oxygen during the hours of darkness and the increase in dissolved oxygen during the daylight hours is from respiration and photosynthesis, predominantly by algae. The September 1971 diel study represents the lowest concentrations of dissolved oxygen measured during the study. The August 1973 diel fluctuations (figs. 19 and 20) were more typical of dissolved oxygen changes during the study.

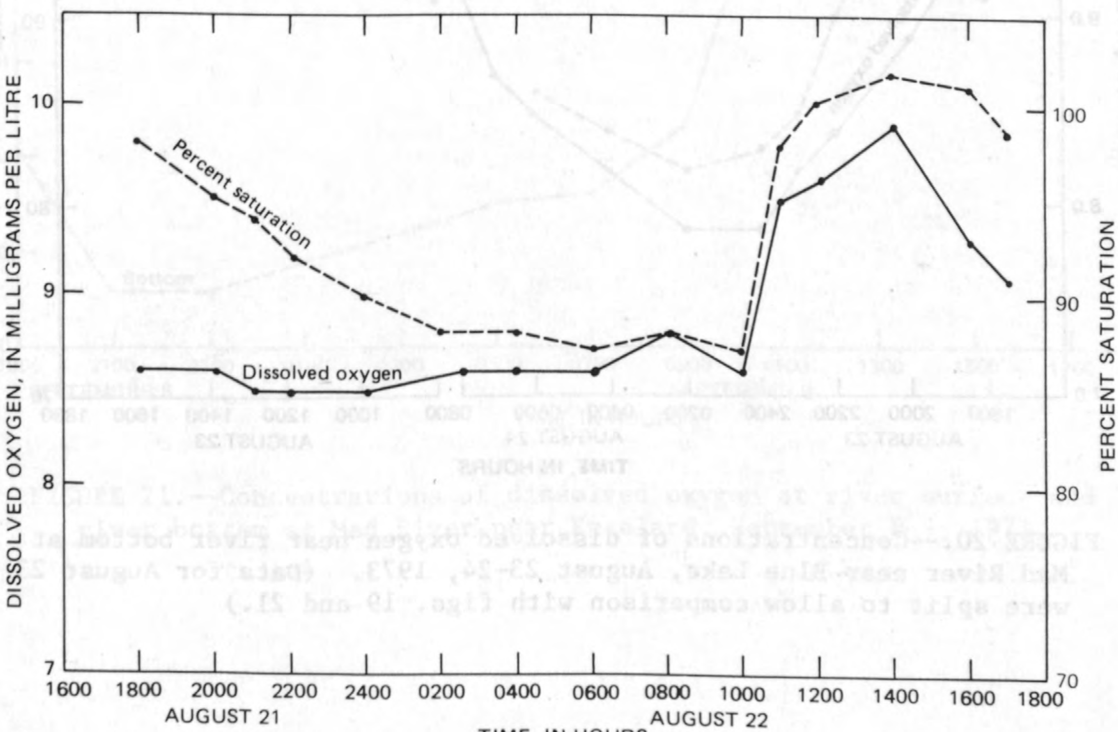


FIGURE 19.--Concentrations of dissolved oxygen near river bottom at Mad River near Kneeland, August 21-22, 1973.

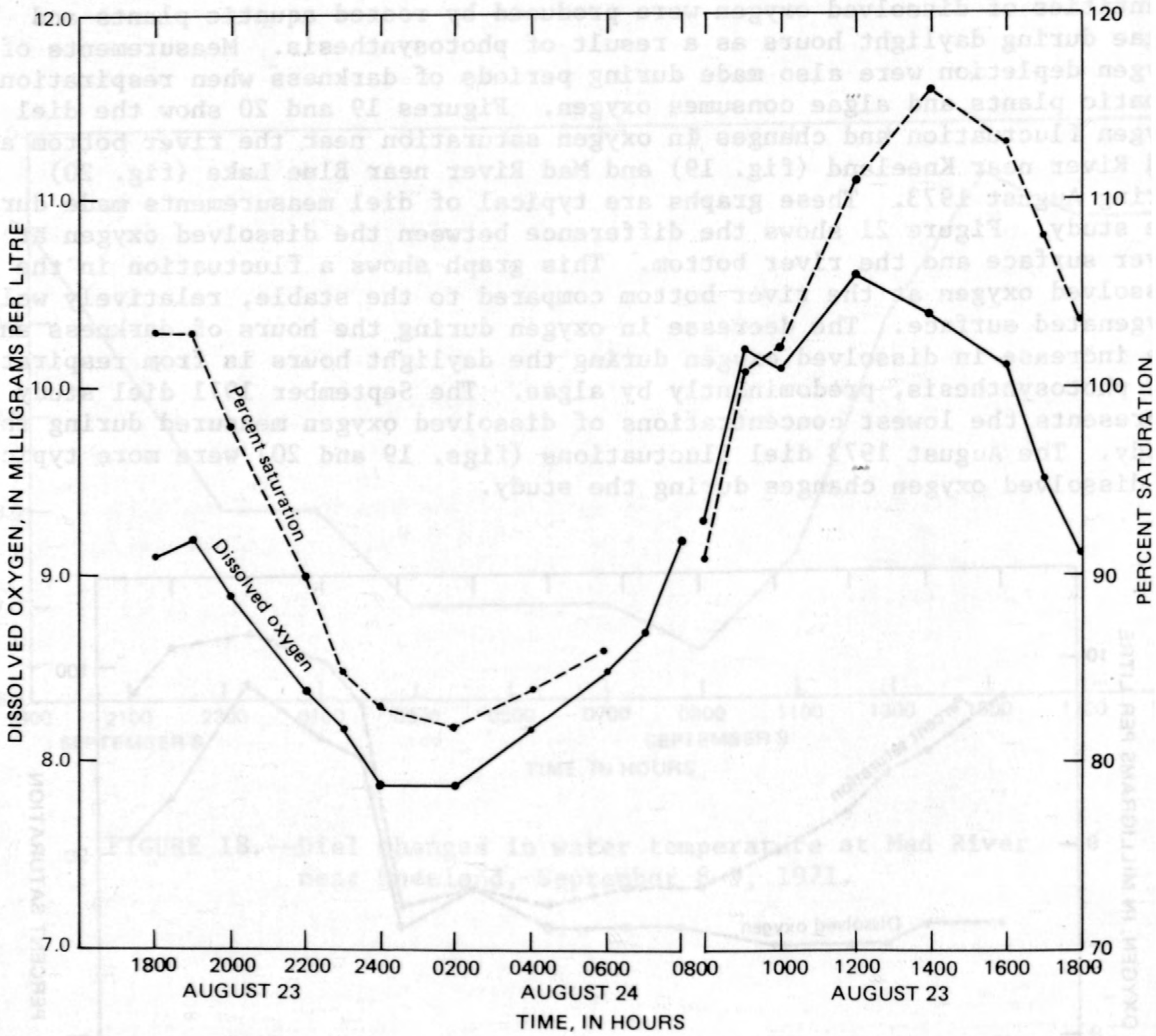


FIGURE 20.--Concentrations of dissolved oxygen near river bottom at Mad River near Blue Lake, August 23-24, 1973. (Data for August 23 were split to allow comparison with figs. 19 and 21.)

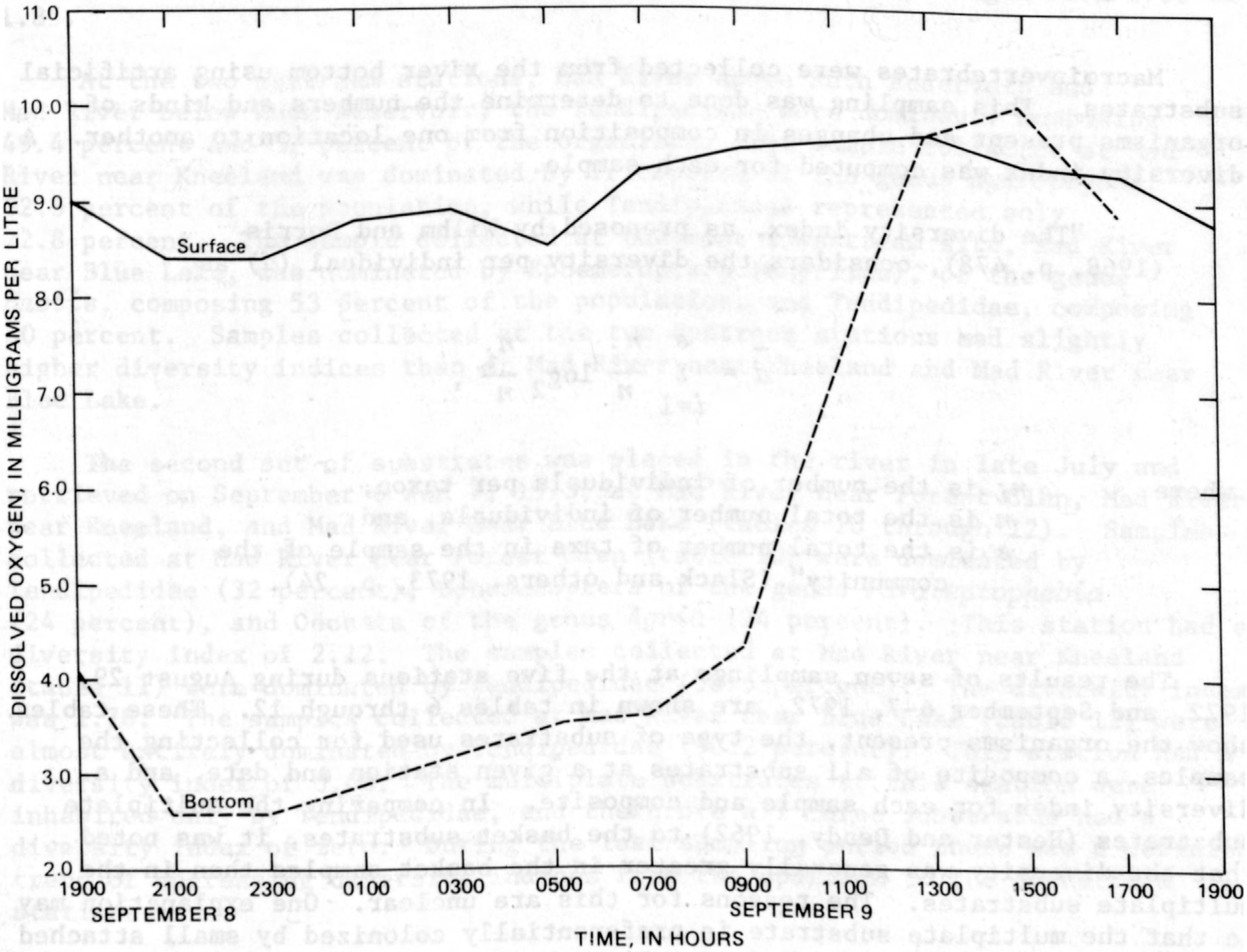


FIGURE 21.--Concentrations of dissolved oxygen at river surface and river bottom at Mad River near Kneeland, September 8-9, 1971.

Macroinvertebrates

Macroinvertebrates were collected from the river bottom using artificial substrates. This sampling was done to determine the numbers and kinds of organisms present and changes in composition from one location to another. A diversity index was computed for each sample.

"The diversity index, as proposed by Wilhm and Dorris (1968, p. 478), considers the diversity per individual ($\bar{d}$) as

$$\bar{d} = \sum_{i=1}^{s} \frac{n_i}{n} \log_2 \frac{n_i}{n} ,$$

where n_i is the number of individuals per taxon,
n is the total number of individuals, and
s is the total number of taxa in the sample of the community" (Slack and others, 1973, p. 24).

The results of seven samplings at the five stations during August 29, 1972, and September 6-7, 1972, are shown in tables 6 through 12. These tables show the organisms present, the type of substrates used for collecting the samples, a composite of all substrates at a given station and date, and a diversity index for each sample and composite. In comparing the multiplate substrates (Hester and Dendy, 1962) to the basket substrates, it was noted that the diversity was generally greater in the basket samples than in the multiplate substrates. The reasons for this are unclear. One explanation may be that the multiplate substrate is preferentially colonized by small attached organisms such as Tendipedidae (midge larvae) of the genus *Rheotanytansus* and is not as readily inhabited by the more mobile, larger organisms such as Tricoptera (caddisflies). The multiplate and basket substrate counts were therefore combined to form a composite sample which may be more representative of the macroinvertebrate community at each sampling station.

The first set of substrates were placed in the river in mid-July and retrieved August 29, 1972 (tables 6 through 9). Diversity ranged from 2.66 to 1.85.

At the two upstream stations, Mad River above Ruth Reservoir and Mad River below Ruth Reservoir, the Tendipedidae were dominant, composing 49.4 percent and 37 percent of the organisms. The sample collected at Mad River near Kneeland was dominated by Tricoptera of the genus *Hydropsyche*, 52.3 percent of the population, while Tendipedidae represented only 22.8 percent. The sample collected at the most downstream site, Mad River near Blue Lake, was dominated by Ephemeroptera (mayflies), of the genus *Baetis*, composing 53 percent of the population, and Tendipedidae, composing 30 percent. Samples collected at the two upstream stations had slightly higher diversity indices than at Mad River near Kneeland and Mad River near Blue Lake.

The second set of substrates was placed in the river in late July and retrieved on September 6 and 7, 1973, at Mad River near Forest Glen, Mad River near Kneeland, and Mad River near Blue Lake (tables 10 through 12). Samples collected at Mad River near Forest Glen (table 10) were dominated by Tendipedidae (32 percent), Ephemeroptera of the genus *Paraleptophebia* (24 percent), and Odonata of the genus *Agria* (24 percent). This station had a diversity index of 2.12. The samples collected at Mad River near Kneeland (table 11) were dominated by Tendipedidae (58.5 percent). The diversity index was 1.78. The samples collected at Mad River near Blue Lake (table 12) were almost entirely dominated by Tendipedidae (90.2 percent). This station had a diversity index of 0.68. The multiplate substrates at this station were inhabited only by Tendipedidae, and therefore all three substrates had a diversity index of zero. During the last sampling period there was a definite trend of decreasing diversity indices from the upstream to the downstream stations.

TABLE 6.--*Summary of macroinvertebrate data collected at*

Taxonomy	Meta-morphic stage	Multiplate substrate 1 Organism count	Percentage of total
Coleoptera (beetles)			
Dytiscidae; Hydroporinae			
Elmidae	Larva	1	4.5
Psephenidae; *Psephenus sp.*			
Diptera (two-winged flies)			
Tendipedidae	Larva	12	54.6
Ephemeroptera (mayflies)			
Baetidae	Nymph	2	9.1
Baetidae; Baetinae: *Baetis sp.*			
Baetidae; Leptophlebiinae			
Baetidae; Siphlonurinae: *Ameletus sp.*	Nymph	2	9.1
Ephemeridae	Nymph		
Hemiptera (water boatmen and creeping water bugs)			
Corixidae			
Naucoridae; *Ambrysus sp.*	Adult	1	4.5
Megoloptera (alderflies)			
Sialidae			
Odonota (dragonflies and damselflies)			
Anisoptera; Aeshindae			
Zygoptera; Coenagrionidae	Nymph	4	18.2
Totals		22	100
Diversity index		1.96	

Mad River above Ruth Reservoir, near Forest Glen, August 29, 1972

Multiplate substrate 2		Multiplate substrate 3		Basket substrate		Composite of all substrates	
Organism count	Percentage of total	Organism count	Percentage of total	Organism count	Percentage of total	Organism count	Percentage of total
		4	12.9			4	4.9
		2	6.5			3	3.7
				1	5.6	1	1.2
7	70	21	67.6			40	49.6
						2	2.5
				1	5.6	1	1.2
				2	11.1	2	2.5
		2	6.5			4	4.9
1	10					1	1.2
1	10					1	1.2
		2	6.5	1	5.6	4	4.9
				1	5.6	1	1.2
				3	16.5	3	3.7
1	10			9	50	14	17.3
10	100	31	100	18	100	81	100
	1.36		1.53		2.21		2.59

TABLE 7.--*Summary of macroinvertebrate data collected at*

Taxonomy	Metamorphic stage	Multiplate substrate 1	
		Organism count	Percentage of total
Coleoptera (beetles)			
Elmidae			
Diptera (two-winged flies)			
Muscidae	Larva		
Muscidae; *Limnophora sp.*	Larva	2	10
Simulidae	Larva	2	10
Tendipedidae	Larva	14	70
Ephemeroptera (mayflies)			
Baetidae; Baetinae; *Baetis sp.*	Nymph		
Baetidae; Ephemerellinae: *Ephemerella sp.*	Nymph		
Baetidae; Leptophlebiinae	Nymph		
Heptageniidae; *Heptagenia sp.*	Nymph		
Plecoptera (stoneflies)			
Nemouridae	Nymph	1	5
Perlodidae	Nymph		
Tricoptera (caddisflies)			
Hydroptilidae	Larva	1	5
Hydropsychidae; *Hydropsyche sp.*	Larva		
Totals		20	100
Diversity index		1.46	

Mad River below Ruth Reservoir, near Forest Glen, August 29, 1972

Multiplate substrate 2		Multiplate substrate 3		Basket substrate		Composite of all substrates	
Organism count	Percentage of total	Organism count	Percentage of total	Organism count	Percentage of total	Organism count	Percentage of total
		3	21.5			3	1.8
				9	9.9	9	5.5
1	2.6	3	21.5			6	3.7
				1	1.1	3	1.8
23	60.6	5	35.7	19	20.9	61	37.5
				26	28.5	26	16.0
		1	7.1	2	2.2	3	1.8
6	15.8			1	1.1	7	4.3
4	10.5			2	2.2	6	3.7
						1	.6
		1	7.1			1	.6
4	10.5	1	7.1	30	33.0	36	22.1
				1	1.1	1	.6
38	100	14	100	91	100	163	100
1.68		2.30		2.30		2.66	

TABLE 8.--*Summary of macroinvertebrate data*

Taxonomy	Metamorphic stage	Multiplate substrate 1 Organism count	Multiplate substrate 1 Percentage of total
Diptera (two-winged flies)			
Rhagionidae; *Atherix variegata*	Larva	2	2.4
Simulidae	Larva	6	7.3
Tendipedidae	Larva	30	36.7
Ephemeroptera (mayflies)			
Baetidae; Baetinae: *Baetis sp.*	Nymph	13	15.9
Baetidae; Siphlonurinae: *Isonychia velma*	Nymph		
Plecoptera (stoneflies)			
Chloroperlidae; *Chloroperla sp.*	Nymph	1	1.2
Perlidae; *Acroneuria sp.*	Nymph		
Tricoptera (caddisflies)			
Hydropsychidae; *Hydropsyche sp.*	Larva	28	34.1
Hydroptilidae	Larva		
Psychomyiidae	Larva	2	2.4
Totals		82	100
Diversity index		2.10	

collected at Mad River near Kneeland, August 29, 1972

Multiplate substrate 2		Multiplate substrate 3		Basket substrate		Composite of all substrates	
Organism count	Percentage of total	Organism count	Percentage of total	Organism count	Percentage of total	Organism count	Percentage of total
1	0.6	3	3.4			6	1.1
17	9.7	2	2.3	8	3.8	33	6.0
64	36.7	30	34.6	2	1.0	126	22.8
32	18.3	18	20.7	4	1.9	67	12.1
				3	1.4	3	.5
						1	.2
				15	7.2	15	2.7
53	30.3	31	35.6	177	84.7	289	52.2
		1	1.1			1	.2
8	4.6	2	2.3			12	2.2
175	100	87	100	209	100	553	100
2.07		2.02		0.92		1.99	

TABLE 9.--*Summary of macroinvertebrate data*

Taxonomy	Metamorphic stage	Multiplate substrate 1 Organism count	Multiplate substrate 1 Percentage of total
Coleoptera (beetles)			
Elmidae	Larva		
Diptera (two-winged flies)			
Tendipedidae	Larva	20	38.5
Ephemeroptera (mayflies)			
Baetidae; Baetinae: *Baetis sp.*	Nymph	1	1.9
Baetidae; Caeninae: *Tricorythodes fallax*	Nymph	19	
Baetidae; Siphlonurinae	Nymph	1	36.6
Baetidae; Siphlourinae: *Ameletus sp.*	Nymph	1	1.9
Baetidae; Siphlonurinae: *Parameletus sp.*	Nymph		1.9
Heptageniidae; *Heptagenia sp.*	Nymph		
Unidentified genus	Nymph	10	19.2
Plecoptera (stoneflies)			
Chloroperlidae; *Alloperla sp.*	Nymph		
Tricoptera (caddisflies)			
Hydropsychidae; *Hydropsyche sp.*	Larva		
Leptoceridae	Larva		
Totals		52	100
Diversity index		1.85	

collected at Mad River near Blue Lake, August 29, 1972

Multiplate substrate 2		Multiplate substrate 3		Basket substrate		Composite of all substrates	
Organism count	Percentage of total	Organism count	Percentage of total	Organism count	Percentage of total	Organism count	Percentage of total
		1	1.4			1	0.5
27	35.5	19	27.6			66	30
		9	13.0	5	21.8	15	6.8
49	64.5	38	55.2	11	47.9	117	53
						1	.5
						1	.5
				1	4.3	1	.5
		1	1.4	2	8.7	3	1.3
						10	4.5
				1	4.3	1	.5
		1	1.4	2	8.7	3	1.3
				1	4.3	1	.5
76	100	69	100	23	100	220	100
0.94		1.64		2.19		1.85	

TABLE 10.--*Summary of macroinvertebrate data*

Taxonomy	Metamorphic stage	Multiplate substrate 1	
		Organism count	Percentage of total
Diptera (two-winged flies)			
Tendipedidae	Larva	1	33.3
Ephemeroptera (mayflies)			
Baetidae; Lepthophlebiinae: *Paraleptophlebia sp.*	Nymph		
Megaloptera (alderflies)			
Sialidae; *Sialis sp.*			
Odonota (damselflies and dragonflies)			
Zygoptera; Coenagrionidae; *Agria sp.*	Nymph	2	66.7
Amphipoda; *Hyalella azteca* (scuds)			
Totals		3	100
Diversity index		0.92	

collected at Mad River near Forest Glen, September 7, 1973

Multiplate substrate 2		Multiplate substrate 3		Basket substrate		Composite of all substrates	
Organism count	Percentage of total	Organism count	Percentage of total	Organism count	Percentage of total	Organism count	Percentage of total
		2	100	5	29.4	8	32
						6	24
				6	35.3		
1	33.3					1	4
2	66.7			2	11.8	6	24
				4	23.5	4	16
3	100	2	100	17	100	25	100
0.92		0		1.90		2.12	

TABLE 11.--*Summary of macroinvertebrate data*

Taxonomy	Metamorphic stage	Multiplate substrate 1 Organism count	Multiplate substrate 1 Percentage of total
Coleoptera (beetles)			
Elmidae	Larva		
Diptera (two-winged flies)			
Simulidae	Larva		
Tendipedidae	Larva	174	85.7
Tipulidae; *Antocha sp.*	Larva	2	1.0
Ephemeroptera (mayflies)			
Baetidae; Baetinae: *Baetis sp.*	Nymph	7	3.4
Baetidae; Sipholonurinae: *Isonychia velma*	Nymph		
Heptageniidae		2	1.0
Odonota (dragonflies and damselflies)			
Zygoptera; Agrionidae: *Hetaerina sp.*	Naiad		
Plecoptera (stoneflies)			
Perlidae; *Acroneuria sp.*	Nymph	2	1.0
Tricoptera (caddisflies)			
Hydropsychidae; *Hydropsyche sp.*	Larva	16	7.9
Totals		203	100
Diversity index		0.84	

collected at Mad River near Kneeland, September 6, 1973

Multiplate substrate 2		Basket substrate		Composite of all substrates	
Organism count	Percentage of total	Organism count	Percentage of total	Organism count	Percentage of total
2	2.4	1	0.3	3	0.4
		65	17.0	65	9.7
78	94.0	139	36.3	391	58.6
				2	.3
		71	18.6	78	11.7
		1	.3	1	.1
				2	.3
1	1.2			1	.1
		8	2.1	10	1.5
2	2.4	97	25.4	115	17.3
83	100	382	100	668	100
0.42		2.08		1.78	

TABLE 12.--*Summary of macroinvertebrate data*

Taxonomy	Metamorphic stage	Multiplate substrate 1	
		Organism count	Percentage of total
Coleoptera (beetles)			
Elmidae	Larva		
Diptera (two-winged flies)			
Tendipedidae	Larva	18	100
Ephemeroptera (mayflies)			
Baetidae; Caeninae: *Tricorythodes fallax*	Nymph		
Ephermeridae; *Hexagenia linbata californica*	Nymph		
Plecoptera (stoneflies)			
Chloroperlidae; *Alloperla sp.*	Nymph		
Pteronacidae; *Pteronarcys sp.*	Nymph		
Tricoptera (caddisflies)			
Limnephilidae; *Psychoronia sp.*	Larva		
Totals		18	100
Diversity index		0	

collected at Mad River near Blue Lake, September 6, 1973

Multiplate substrate 2		Multiplate substrate 3		Basket substrate		Composite of all substrates	
Organism count	Percentage of total	Organism count	Percentage of total	Organism count	Percentage of total	Organism count	Percentage of total
				1	1.9	1	1.0
18	100	12	100	44	81.5	92	90.2
				1	1.9	1	1.0
				5	9.3	5	4.9
				1	1.9	1	1.0
				1	1.9	1	1.0
				1	1.9	1	1.0
18	100	12	100	54	100.3	102	100.1
0		0		1.09		0.68	

Algae

Periphyton were collected at four stations during August 1972 and September 1973 to determine biomass. The analyses of five samples are shown in table 13. *Cladophora glomerata* was the dominant alga.

Mean values of biomass for four periphyton samples ranged from 3.84 to 5.21 g/m^2 (grams per square metre). The fifth sample, taken at Mad River below Ruth Reservoir, near Forest Glen, had a mean value of 14.7 g/m^2. This anomalously high value may be attributed to discharge from near the bottom of Ruth Reservoir, just 1,200 ft (370 m) upstream of this station, that was high in algae and algal nutrients.

Phytoplankton (free-floating algae) were sampled at three stations to determine species composition and concentrations. The results of a typical sample are shown in table 14. Diatoms were the dominant phytoplankton group of algae.

Coliform Bacteria

Samples of Mad River water were analyzed for total and fecal coliform bacteria. The coliform group of bacteria have long been used as indicators of wastewater pollution (Slack and others, 1973). This group does, however, inhabit diverse natural sources such as soil, water, and vegetation, as well as feces. The first part of the study was restricted to analyses of total coliform bacteria with counts of up to 8,000 col/100 ml (colonies per 100 millilitres of water) and a mean value of 2,300 col/100 ml (table 15).

From August 1972 through the summer 1973, analyses were restricted to fecal coliform bacteria. This fraction of the coliform group is present only in the gut and feces of warmblooded animals. These organisms are therefore a much better indicator of possible pollution from wastewater. Analyses of water for fecal coliform bacteria showed few present. Cell counts ranged from 2 to less than 20 col/100 ml (table 15). This indicates that the initial total coliform bacteria analyses reflected large populations of nonfecal coliforms and that no significant fecal material occurred in the area of the river studied.

TABLE 13.--*Summary of periphyton biomass data collected in the Mad River, August 1972 and September 1973*

Sampling station	Date of collection	Periphyton biomass (g/m^2)	Mean values (g/m^2)
Mad River above Ruth Reservoir, near Forest Glen	August 1972	0.80	
		6.92	
		7.92	
Total		15.64	5.21
Mad River below Ruth Reservoir, near Forest Glen	August 1972	14.1	
		3.4	
		26.5	
Total		44.0	14.7
Mad River near Blue Lake	August 1972	3.36	
		4.00	
		.20	
		3.96	
Total		11.52	3.84
Mad River near Kneeland	September 1973	5.64	
		2.64	
		3.88	
		4.44	
		4.44	
		4.84	
		5.68	
		4.80	
		4.68	
Total		41.04	4.56
Mad River near Blue Lake	September 1973	7.48	
		1.56	
		3.16	
		4.76	
		2.80	
		3.28	
		7.64	
		6.84	
		6.96	
		3.32	
Total		47.80	4.78

TABLE 14.--*Summary of phytoplankton data collected in the Mad River, August 2-3, 1973*

Sampling station	Date of collection	Species	Cells per millilitre
Mad River near Kneeland	August 2, 1973	*Epithemia sorex*	21
		Cocconeis placentula	12
		Gomphonema sp.	9
		Synedra ulna	7
		Nitzschia sp.	6
		Navicula sp.	3
		Scenedesmus bijuga	2 colonies
		Scenedesmus sp.	2 colonies
		Nitzschia acicularis	1
		Flagellates	1
		Diatoma vulgare	1
		Denticula sp.	1
			66
Mad River near Blue Lake	August 2, 1973	*Cocconeis placentula*	39
		Epithemia sorex	28
		Nitzschia sp.	7
		Gomphonema sp.	5
		Synedra ulna	3
		Pinnularia sp.	3
		Nitzschia acicularis	3
		Melosira varians	2
		Diatoma vulgare	2
		Cymatopleura sorlea	1
		Rhopalodia gibba	1
			94
Mad River near Forest Glen	August 3, 1973	*Fragilaria crotonensis*	46
		Diatoma vulgare	9
		Asterionella formosa	3
		Melosira sp.	4
		Cymbella ventricosa	1
		Hannaea arcus	1
		Nitzschia acicularis	1
		Nitzschia sp.	1
		Gomphonema sp.	1
		Cocconeis placentula	1
		Epithemia sorex	1
			69

TABLE 15.--*Summary of coliform bacteria data collected in the Mad River, November 10, 1970-August 22, 1973*

Date of collection		Time of collection	Total coliform (col/ml)	Fecal coliform (col/ml)
Mad River below Ruth Reservoir, near Forest Glen				
September	7, 1971		350	
November	15, 1971		2,700	
April	11, 1972		320	
Mad River near Forest Glen				
September	1, 1972			<20
Mad River near Kneeland				
November	10, 1970	1100	60	
November	10, 1970	2100	130	
July	13, 1971	2100	[1]1,700	
September	8, 1971	1900	800	
September	9, 1971	0100	[1]1,500	
September	9, 1971	0700	4,100	
September	9, 1971	1300	625	
November	17, 1971	2200	2,200	
November	17, 1971	2000	2,000	
November	18, 1971	2000	2,000	
November	18, 1971	1550	1,550	
April	11, 1972	1900	3,000	
April	12, 1972	0400	2,500	
April	12, 1972	0900	8,000	
April	12, 1972	1500	<8,000	
August	29, 1972	2100		<20
August	30, 1972	0300		<20
August	30, 1972	0900		<20
August	30, 1972	1500		<20
March	26, 1973	1900		7
March	27, 1973	0100		3
March	27, 1973	0700		3
March	27, 1973	1300		7
March	27, 1973	1900		9
August	21, 1973	1800		3
August	21, 1973	2400		2
August	22, 1973	0600		9
August	22, 1973	1200		2

[1]Estimated value from nonideal counts.

CONCLUSIONS

Water in the Mad River basin was generally acceptable for domestic and industrial uses according to standards by the Environmental Protection Agency (1972). Ground water was low in dissolved solids. A possible problem related to ground-water quality is the high concentration of iron. This may be attributed to contact with rocks of the iron-rich Franciscan assemblage or to iron from corroded well casings. This iron can be removed from water before use by aeration and by filtering to remove the resulting precipitate of insoluble ferric hydroxide, $Fe(OH)_3$. Analyses of major dissolved constituents in surface water in the basin also showed no other dissolved constituents in quantities deleterious to domestic or industrial uses.

Although the concentrations of dissolved trace metals in Mad River water are generally low, the total trace-metal concentration may often exceed the recommended drinking water standards (Environmental Protection Agency, 1972). This is due to metals concentrations of suspended sediment. Although concentrations of trace metals in the sediment correspond to concentrations in the source of the sediment, the Franciscan assemblage, suspended-sediment concentrations during periods of high runoff are often as high as 3,000 to 4,000 mg/l. This high sediment concentration, if allowed to accumulate in a reservoir, may act as a large sink for trace metals.

Plant nutrients including nitrogen, phosphorus, and carbon were found in the river in sufficient quantities to provide adequate nutrients for algal growth. These nutrients in a system that has summer temperatures of 25°C at the Mad River near Kneeland station could result in large algal blooms in the proposed Blue Lake during the summer months. These bloom conditions could result in the degradation of water quality making the water unfit for domestic purposes because of undesirable taste and odor. These blooms could also discourage recreational use of Blue Lake. Algal blooms might also cause a deficiency of dissolved oxygen owing to bacterial oxidation of organic matter and result in fishkills in the reservoir. Although similar conditions occur in Ruth Reservoir, upstream from the proposed reservoir, no major problems with algal blooms have occurred.

A water-quality monitoring program should be maintained, if the Butler Valley Dam and Blue Lake Project is constructed. This is needed to evaluate conditions such as algal growth and to initiate measures to control algae such as the treatment of the lake with an algicide, possibly copper sulfate.

Pesticides in the river basin were not detected in either sediment or water and therefore pose no present threat of contamination.

Diel (24-hour) studies at Mad River near Kneeland and Mad River near Blue Lake showed that an oxygen gradient developed during hours of darkness, resulting in an oxygen deficiency along the river bottom. This may be due to the use of oxygen by algae and rooted aquatic plants. However, the oxygen-deficient zone was reoxygenated by midafternoon by the addition of oxygen to the system as a product of photosynthesis. The greatest concentration of dissolved oxygen was generally found in the water between 1300 and 1700 hours. This coincided with periods of greatest light intensity and warmest temperatures. The alkalinity, specific conductance, and pH of the system were generally constant except for some slight increases in the concentrations during daylight hours. This slight increase may be attributed to the response of the system to biological activity, predominantly photosynthesis.

Study of the biota in the river indicated a diverse population of benthic invertebrates. Maximum diversity was found in the upstream stations whereas a generally decreased diversity occurred in the downstream stations.

Periphyton in the river was dominated by *Cladophora glomerata*, a green alga. Biomass measurements mostly ranged from 3.84 to 5.21 g/m^2. The highest mean value, 14.7 g/m^2, was recorded at Mad River below Ruth Reservoir, near Forest Glen. This is attributed to nutrient flow from the reservoir. Phytoplankton samples were almost entirely diatoms. Cell counts ranged from 48 to 2,231 cells/100 ml.

Fecal coliform bacteria were present in the water only in small numbers. This indicates that no significant source of fecal material, such as in wastewater, enters the river in the area studied.

The findings of this study provide baseline information which may serve as a basis for evaluating future changes in the chemical and biological conditions.

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