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George F. Weisel
University of Montana, Missoula

Robert L. Newell
University of Montana, Missoula

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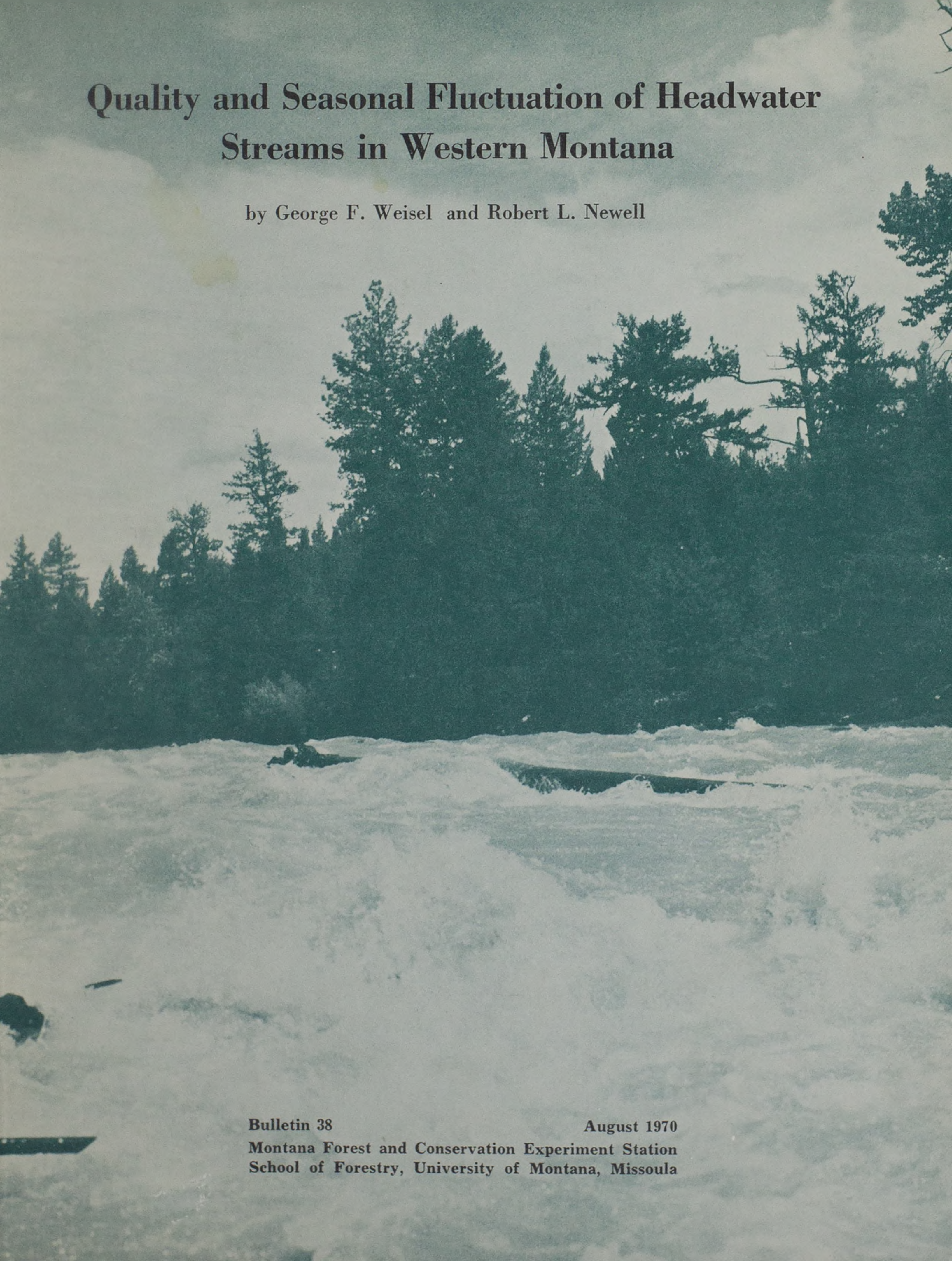

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Quality and Seasonal Fluctuation of Headwater Streams in Western Montana

by George F. Weisel[1] and Robert L. Newell[2]

Acknowledgments

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Introduction

There have been few investigations of waters unaltered by man's activities. Data on such streams should be accumulated to serve as a base for evaluating man-caused changes. The spread of industry, mining, logging, recreational use, and roading in the Northwest is rapidly changing the physical and biological character of the waters. Small feeder streams are especially susceptible to alteration because their flow is slight, and the land surrounding them is frequently steep and fragile. These streams must be protected for their quality determines the purity of larger bodies of water and sensitive cold-water organisms and spawning salmonids depend on the type of habitat they provide.

A massive amount of data on large rivers, including some in Montana, has been accumulated (U.S. Dept. of the Interior, 1964; 1965; 1966; 1967); but headwater streams have, so far, been neglected. When the water of a particular stream reaches a larger river, the identity of its various physical and chemical components is obscured by mixing with the components of other headwater streams. Consequently, definitive knowledge of these components can only be gained by studying the headwaters themselves (Neel, 1951).

Recent efforts to set water quality standards and to establish water use classifications at both the federal and state level have made it apparent that little is known of the present quality of the Northwestern streams and that information about seasonal fluctuation is particularly lacking. It is clear that pertinent data on existing quality must be gathered before realistic standards of quality can be established.

Methods

Field analyses for temperature, turbidity, dissolved oxygen, carbon dioxide, pH, and alkalinity were made with a Model Dr-El Hach kit and a Delta Model 85 oxygen meter. Extra burettes, glass ware, and distilled water containers were added to the kit for more rapid and accurate measurements. pH was measured photoelectrically with the Hach kit in which we used narrow-range indicators. To insure accuracy we spot-checked our readings with an electrometric meter and found a variation between the two methods of ± .2 on the pH scale.

In addition, water samples from all of the streams except those in the Blackfoot River system were analyzed in the laboratory with the Hach kit and a Delta Model 260 water analyzer. In addition to our field analyses of the Blackfoot, samples of its water were analyzed according to standard procedures by the Helena laboratory of the Montana State Board of Health.

We took samples during all four seasons of the year. The stations on the Blackfoot River and on Morrell and Deer Creeks were sampled monthly. The 22 Blackfoot tributaries were sampled every three months. We investigated Pattee Creek over a 19-month period taking water samples on five consecutive days each month. Although collecting dates and the numbers of samples taken were not identical for each stream, we feel that, because the streams were sampled during every extreme

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[1] Professor of Zoology, University of Montana, Missoula.

[2] Graduate student, zoology, University of Montana, Missoula.

of water condition, our data provide a valid basis for comparison of quality.

A special study was made of the residues and settleable solids in Pattee Creek. Total residue was determined by evaporating a 250 ml water sample over a steam bath. The remainder was oven-dried at 103 to 105°C for one hour, cooled in a disiccator, and weighed on a Mettler balance. Fixed and volatile residues were then isolated by burning the total residue in a muffle furnace at 600°C for an hour and weighing the resultant ash.

The procedure for measuring residues outlined in *Standard Methods* (Amer. Public Health Assoc., 1965) was inappropriate for our use because many of the water samples contained so little filterable material that it was necessary to pass one or more liters of the sample through the membrane to get a weighable amount of residue. A method of centrifugation based on Klein (1959, p. 14) proved satisfactory. Under this method we divided 500 ml samples into two equal portions and centrifuged each portion in 250 ml buckets at 2,500 rpm for 10 minutes. The separated water was decanted and tested for turbidity. By comparing the results of this test with turbidity data gathered in the field, we were able to calculate the relationship between settleable solids and turbidity. The suspended matter at the bottom of the buckets was washed with distilled water into two 50 ml tubes and recentrifuged at 2,500 rpm for 10 minutes. After decanting the water, we washed the suspended matter with jets of distilled water into two previously weighed crucibles. The liquid in the crucibles was evaporated in an oven at 103 to 105°C. After evaporation was complete, the crucibles were further oven-dried for one hour, cooled in a desiccator, and weighed. The weights of settleable solids obtained from the two 250 ml portions of a single sample were invariably within 0.005 mg of each other.

To ascertain the proportions of the total settleable solids which were fixed and those which were volatile, we placed the crucibles in the muffle furnace for an hour at 600°C, cooled them in a desiccator, and weighed them.

Using the above procedures, we determined the following:

1. the total residue and the percents of volatile and non-volatile material in the total residue,
2. the total settleable solids and the percents of volatile and non-volatile materials in the total settleable solids,
3. the percent of total residue attributable to settleable solids, and
4. the percent of turbidity attributable to settleable solids.

We gauged the volume of stream flow with a Gurley current meter using the method outlined by Robins and Crawford (1954). Admittedly, our estimates of stream flow are rough, but they do reflect the relative sizes of the streams. We made a more accurate accounting of runoff in Pattee Creek using a measured culvert.

The altitudes above sea level of the sampling stations, rounded off to the nearest 10 feet, were taken from U. S. Geological Survey maps.

In our results and discussion we have described, when appropriate, some tributaries and other streams which we did not examine as thoroughly as we did those listed immediately below.

Physical Description of the Rivers and Streams

The Blackfoot System

The six sampling sites on the Blackfoot River proper range in elevation from 5,050 feet at Pop's Place to 3,400 feet at Rainbow Bend (Figure 1). At the Geological Survey station a few miles below Rainbow Bend the flow of the river ranged during the sampling year from 5,960 cubic feet per second (cfs) on June 4, 1968, to 300 cfs on December 31, 1969.

A glacier undoubtedly occupied the upper valley of the Blackfoot River as far west as the Lincoln Canyon. Glacial ice probably invaded the Lincoln Valley through gorges extending to the Continental Divide along Alice Creek, Landers Fork, and Stonewall and Beaver Creeks. This ice deposited both extensive outwashes of gravel and morainal drifts. To the south, glacial drift from the gravelly flats near Helmville extended northwestward along the Blackfoot River and up Cottonwood Creek. Branches of the Piedmont glacier occupied gorges of Cottonwood and Monture Creeks and the North Fork of the Blackfoot. Considerable glaciation also occurred in the Clearwater Valley and extended southward to the Blackfoot (Alden, 1953).

Precipitation and streamflow vary in the northern Rockies. The average total annual precipitation in the Missoula Valley is close to 14 inches. Precipitation in the mountains ranges from 20 to 60 inches annually with snow constituting as much as 65 percent of the total. As a result, the spring snow-melt accounts for most of the water in the region's peak runoff. The months of July and August are usually very dry; and, during these months, water flow is largely dependent on

LOCATION OF SAMPLING STATIONS ON THE BLACKFOOT DRAINAGE

KEY TO MAP:

Blackfoot R.

1. Pop's Place
2. Flesher Pass Rd.
3. Hogum Pass Rd.
4. Dalton Mt. Rd.
5. Arrastra Camp
6. Rainbow Bend

Blackfoot R. Tributaries

7. Pass Cr.
8. Alice Cr.
9. Landers Fk.
10. Poorman Cr.
11. Spring Cr.
12. Spring Cr. Overflow
13. Keep Cool Cr.
14. Beaver Cr.
15. Willow Cr.
16. Arrastra Cr.
17. North Fk.
18. Noname Spr.
19. Warren Cr.
20. Monture Cr.
21. Cottonwood Cr.
22. Clearwater R.
23. Elk Cr.
24. Belmont Cr.
25. Gold Cr.
26. Union Cr.
27. E. Twin Cr.
28. W. Twin Cr.

Clearwater Tributaries

29. Morrell Cr.
30. Deer Cr.

FIGURE 1. Collection sites in the Blackfoot-Clearwater drainage.

snow water originating in the high mountains.

During low water in the summer and winter, stretches of many streams and rivers are dry or nearly so. In these segments water percolates beneath the surface through loose gravel and boulder fills. The percolation probably filters suspended matter from the water and introduces dissolved materials to it from soluble rocks. The intermittancy of surface flow also probably reduces the stream's biota. In the summer months fish congregate in a few pools and are easy prey to predators.

The human population is sparse in the Blackfoot Valley. The valley's economy is primarily based on raising livestock, growing hay, and logging the surrounding slopes. The amount of water taken from the river for irrigation is negligible. Except for a small barite processing plant, which has not operated since 1967, there are no industries or dams on the river above Bonner, a sawmill town near the confluence of the Blackfoot and Clark Fork Rivers. For a period beginning just before the turn of the century, many tributaries of the upper Blackfoot were extensively placer mined. The greatest mining activity was in the Heddleston district (Mike Horse Mine) close to the Continental Divide.

The substratum of the Blackfoot is stable, consisting almost entirely of large boulders and rubble. Nevada Creek, a sizeable tributary from the south, flows through meadow land in the Helmville district. This creek flows slowly over alluvium, sand, and gravel.

Tributaries of the Blackfoot River

The tributaries of the Blackfoot are listed here in the order, upstream to downstream, in which they enter the river. Each stream's estimated flow during medium runoff and its altitude at the collection site are placed in parentheses following the name of the stream. Geological information presented here was derived from Ross (1950), Alden (1953), and Ross et al. (1955).

Pass Creek (0.4 cfs, 5,280 ft) originates in Helena limestone and Spokane shale near the Continental Divide south of Rogers Pass. One of its tributaries, Mike Horse Creek, drains the Heddleston mining district; and there is, undoubtedly, considerable leaching from old mine tailings. Although this area is not now being mined, its suitability as a site for a large-scale mining operation is under study.

Alice Creek (10 cfs but with greater flow upstream, 4,940 ft) originates in geological formations similar to those giving rise to Pass Creek and enters the Blackfoot from the north. Unlike Pass Creek, however, much of Alice Creek flows through beaver dams in a valley with deep soil. There is considerable grazing in the area.

Landers Fork (15 cfs, 4,590 ft) also comes from the north. It receives water from Helena limestone and flows through a valley floor consisting of glacial drift. This drainage has never been mined. Thirty to 35 years ago, however, it was heavily grazed by sheep; and, to improve the range, ranchers burned away much of its forest. During high water the creek carries a heavy silt load attributable largely to erosion of its unstable banks.

Poorman Creek (4 cfs, 4,580 ft) and its tributaries were extensively placer and hardrock mined for gold in the late 1800's. Some of its water disappears under the old dredgings and tailings, but it has apparently recovered from the mining and abounds with small trout. The creek arises in Newland and Helena limestone, flows northward along the Stemple Pass road through valley fill, and joins the Blackfoot near Lincoln.

Spring Creek and **Spring Creek Overflow** (18 cfs, 4,570 ft) are both fed by springs close to Lincoln. The water in these springs probably originates in the mountains north of Lincoln and flows under extensive glacial gravel deposits to the spring sites.

Keep Cool Creek (11 cfs, 4,650 ft), also coming from the north, is fed by two small lakes and flows in rock predominately of the Spokane group. Although there has been some limited gold mining along the creek, the greatest alteration of its waters has resulted from recent, extensive clearcut logging. Fortunately the slopes of the drainage are gentle and the soil fairly stable. During the dry summer months, water in some of the lower portions of Keep Cool Creek flows beneath the glacial and valley fill. It surfaces again on the flat valley plain where it is used for irrigation before entering the Blackfoot River.

Beaver Creek (8 cfs, 4,560 ft) lies over the ridge to the west of Keep Cool Creek. The slopes of this creek have been extensively roaded and logged. Beaver Creek has a steeper gradient than does Keep Cool Creek; and, because of the disturbance of the land, it carries a considerable silt load. Like Keep Cool Creek, it is used for irrigation at its lower end.

Willow Creek (6 cfs, 4,480 ft) flows from the south into the Blackfoot. It was mined during the turn of the century, but not extensively. Some of its slopes have been recently logged.

Arrastra Creek (7 cfs, 4,340 ft) flows in valley fill and over Spokane shale interspersed with quartzite. There are remnants of old mining operations along the creek which, in the past few years, has been heavily logged. Sections of the creek go underground, and, presumably, the resulting percolation through the gravel filters much of the silt from the creek before it surfaces in its lower reaches.

The North Fork of the Blackfoot (26 cfs, 4,909 ft) flows out of a relatively untouched watershed where the surface rocks consist of a complex of Piegan and Missoula formations and Helena limestone. Its lower end flows over glacial drift and onto a valley floor of gravel and boulder alluvium. Some of its water is diverted for irrigation of the valley. Much of the water in the lower end of the North Fork is subsurface during the summer. This phenomenon occurs most strikingly on the Dry Fork. The steep mountains bordering the North Fork and its tributaries are plastered with a loose glacial till, some of which sloughs into the river during spring breakup and heavy rains causing short-term turbidity. Usually, however, the river is crystal clear.

Kleinschmidt Spring (22 cfs, 4,090 ft) rises to form a pond close to where Highway 200 bridges the North Fork at the west end of Kleinschmidt Flats, a gravelly plain formed by glacial outwash. The spring enters the North Fork about 50 feet below the highway bridge.

Warren Creek (6 cfs, 4,060 ft) is a small, short tributary from the north. Much of it flows through open grazing land and meadows. During the summer little of its water reaches the Blackfoot.

Monture Creek (62 cfs, 4,030 ft) is a beautiful stream which originates on the divide between the Flathead and Blackfoot Rivers in geologic formations primarily of the Missoula group and partly of the Piegan group. There has been recent logging where the creek emerges from its canyon, and a small amount of the creek's water is used for irrigation. Little of this water returns to the creek. The lower end of the creek flows over valley fill consisting of boulders.

Cottonwood Creek (20 cfs, 3,920 ft) is a few miles west of Monture Creek. It is used for irrigation and flows through some swampy hay land and beaver impoundments in the valley.

The Clearwater River Complex (125 cfs, 3,740 ft) flows through gravel and boulder valley fill and broadens into seven sizeable eutrophic lakes. Its western tributaries arise in Missoula group formations and glacial drift, and its eastern tributaries originate in the Piegan group formations of the Swan Range.

Elk Creek (6 cfs, 3,720 ft) comes from the southeast. Its upper tributaries flow from the Boulder batholith (mainly quartz monzonite), its middle portion through formations of the Missoula group, and its lower reaches through undifferentiated sedimentary material and alluvium. In the Greenough Valley water from Elk Creek is used extensively for irrigation. There has been considerable placer mining on this stream.

Belmont Creek (20 cfs, 3,530 ft) enters the Blackfoot from the north. It flows through geologic formations primarily of the Missoula group. The drainage of this creek is heavily logged.

Gold Creek (35 cfs, 3,420 ft) originates in the Missoula group and its lower reaches flow through glacial drift. Its drainage has also been recently logged.

Union Creek (30 cfs, 3,500 ft) is mostly confined to the Potomac Valley, the soils of which are undifferentiated tertiary sediments of poorly consolidated gravel, sand, silt, and clay. It joins the east side of the Blackfoot at McNamara's Landing after receiving a great deal of runoff from hay lands.

East and West Twin Creeks (30 and 35 cfs, 3,400 ft) come from the north through Missoula group formations and join the Blackfoot within one-third of a mile of each other. They are in a logged area, and there is some housing near their confluence with the river.

Tributaries of the Clearwater River

Deer Creek (8 cfs, 4,010 ft) originates on the east slope of the Mission Range and its foothills and empties into Seeley Lake. Geologically, the mountains are of the Missoula group. The lower portions of Deer Creek flow in valley fill similar to that underlying Morrell Creek (see below), and the slopes draining into it have been logged and roaded during the past 20 years.

Morrell Creek (15 cfs, 4,200-4,500 ft) flows through a narrow valley consisting of boulder and gravel fill. Most of its water emanates from the Swan Range, which is essentially a Piegan formation. Carbonate rocks predominate in most of the Morrell Creek drainage. Three sampling stations were established on this creek: one in a pristine section above any roads or logging sites, one at a clearcut area, which is also an intermittent flow section, and a third downstream from the clearcut. During the summer and fall months, long sections of Morrell Creek have only subsurface water.

Pattee Creek

Pattee Creek (1 cfs, 3,350 ft) originates in the low mountains south of Missoula. Geologically the mountains belong to the Missoula group. The creek water sinks into the gravelly valley floor before reaching the Bitterroot River. Most of the creek's substrate is gravel and small rock well-sealed with clay.

This small stream flows through an area that has been logged, roaded, and partly developed for real estate. It also flows through several small enclosures where horses are kept periodically. The sampling site on Pattee Creek was just above the Missoula city limits and above any extensive residential development.

Results and Discussion

Turbidity, Settleable Solids, and Residues

Pattee Creek was the only waterway we tested for settleable solids and residues. The turbidity of this stream, which ranged from 9 to 130 JTU (Jackson Turbidity Units), is directly affected by the volume of stream flow (Figure 2). In 1967 its greatest turbidity occurred during the initial high runoff in May and June; whereas in 1968 both high runoff and greatest turbidity occurred in February and March. The flushing effect of the first high water, which dislodges accumulated debris and silt from quiet backwaters and ice crevices, usually results in greater turbidity than do even heavier stream flows occurring soon thereafter.

Turbidity of the creek fluctuates widely during periods of rain and thaw. In fact, samples taken during the winter of 1967 (Figure 3) revealed one instance in which turbidity increased tenfold within a three-hour period. Turbidity of the creek also corresponds roughly to the volume of water flow (Figure 2).

It is evident that little of the turbidity of Pattee Creek can be traced to sediment accumulated on the stream bed and banks. Instead, runoff following heavy rains or snow melts carries a heavy silt load from neighbor-

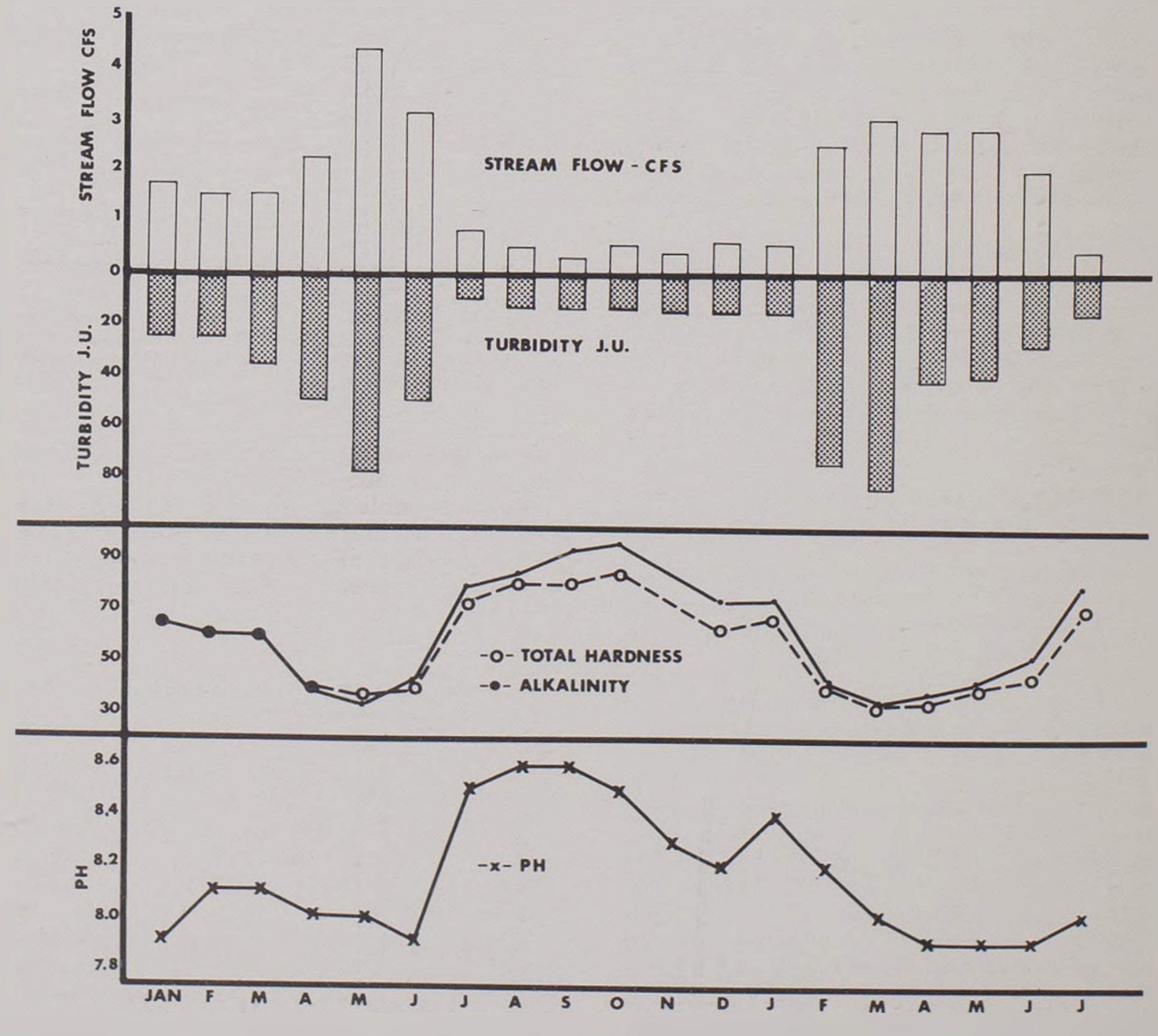

FIGURE 2. Correlation between the stream flow of Pattee Creek and its turbidity, alkalinity, total hardness, and pH for the period from January 1967 to July 1968.

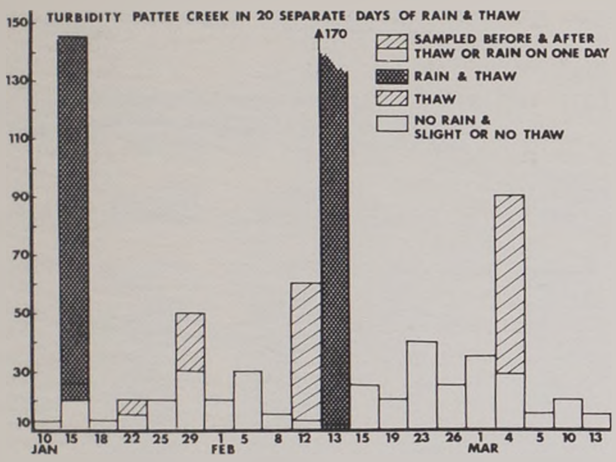

FIGURE 3. Fluctuations in turbidity in Pattee Creek during periods of rain, thaw, and freeze. The measurements are given in Jackson Turbidity Units.

ing road banks and man-made earth cuts to the stream. The turbidity of this runoff water is frequently in excess of 500 JTU.

In general, the percent of turbidity attributable to settleable solids is greatest during periods of high runoff and consequent high turbidity (Figure 4) apparently because the great turbulence of the water keeps more solids suspended. This seeming relationship was not born out, however, by the high percent of settleable solids we recorded in March 1967 and in May and July 1968.

Total residues ranged from 71 to 248 milligrams per liter (mg/l). We began the sampling in months of high water and continued it until the water receded (Figure 5). Five day samples were taken twice in May 1967 and in March 1968, periods in which the water levels differed markedly within a single month. As might be expected, the total residues were always greatest during high water. Similarly, during high water the percent of settleable solids in the total residue increased because the swifter the current the more settleable material is suspended.

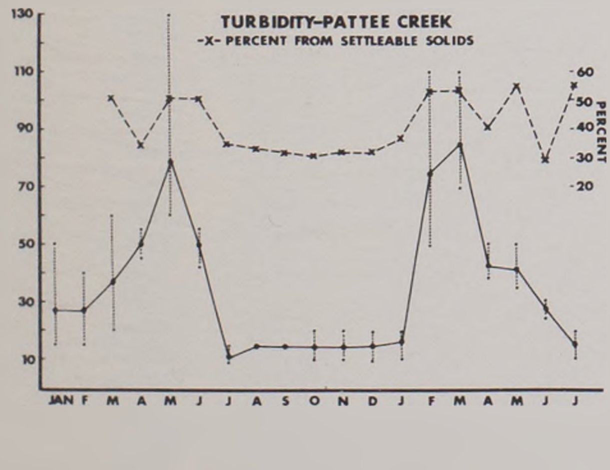

FIGURE 4. Turbidity and percent of turbidity caused by settleable solids in Pattee Creek over a 19-month period. The readings, in Jackson Turbidity Units, were taken on five successive days in the middle of each month. The extremes in each month are indicated by the vertical lines. High water occurred in May and June in 1967, whereas there was an early thaw and rain in February and March of 1968.

The percent of fixed material in the total residue varied, but it tended to decrease as the total residue increased. This is apparently because high water, which causes increased residue, carries more volatile material (mostly organic detritus flushed from the creek banks) than does low water.

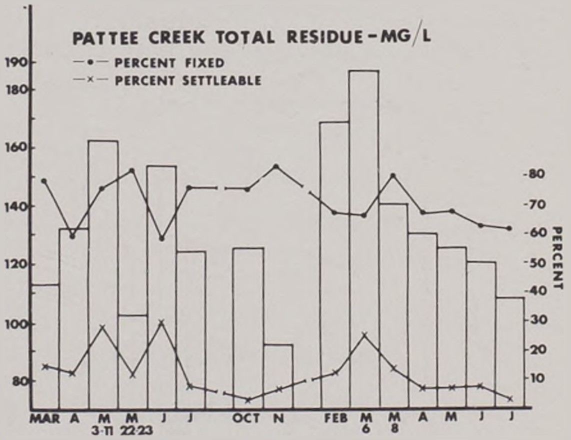

FIGURE 5. Total residue and percent of fixed materials and settleable solids in the total residue in Pattee Creek water. Refer to Figure 2 for months of high and low runoff.

The settleable solids in Pattee Creek ranged from 3 to 94 mg/l and were greatest at peak flows (Figure 6). Unlike the case of total residues, the percent of settleable solids com-

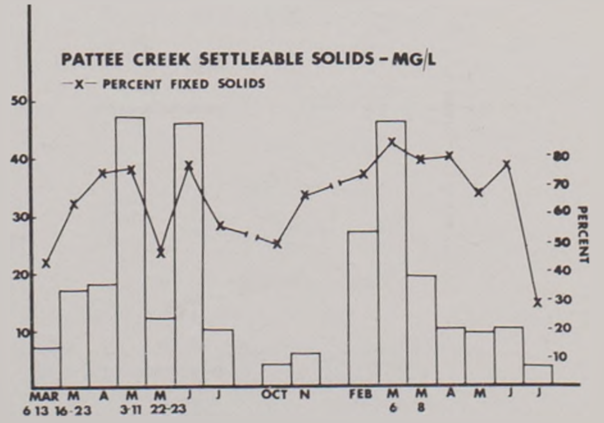

FIGURE 6. Settleable solids and percent of fixed solids in total settleable solids in Pattee Creek water. Refer to Figure 2 for months of high and low runoff.

TABLE 1. SUMMARY OF WATER ANALYSIS DA

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In cases where the range represents three or more is expressed in Jackson Turbidity Units. Except f See footnote for analyses not included in the table.

Sampling Station	Turbidity	Total Dissolved Solids	pH	Total Hardness	Calcium Hardness	Alkalinity	Calcium
Blackfoot River							
Pop's Place	0-3 (0)	80-186 (127)	6.8-8.0 (7.5)	45-110 (87)	25-65 (49)	35-60 (50)	10-29 (19)
Flesher Pass Road	0-3 (0)	100-132 (118)	7.5-8.0 (7.9)	70-100 (91)	45-60 (53)	55-80 (67)	13-28 (21)
Hogum Pass Road	0-6 (1)	100-134 (124)	7.8-8.2 (8.0)	70-120 (102)	45-75 (65)	60-115 (99)	16-33 (28)
Dalton Mountain Road	0-9 (2)	88-186 (158)	7.8-8.2 (8.1)	110-170 (153)	60-120 (102)	115-180 (157)	20-48 (37)
Arrastra Camp	0-10 (3)	130-186 (165)	7.9-8.3 (8.1)	110-165 (149)	60-120 (102)	110-170 (154)	27-50 (40)
Rainbow Bend	0-8 (3)	60-146 (130)	7.8-8.4 (8.1)	80-135 (116)	50-120 (79)	90-145 (122)	17-46 (31)
Tributaries							
Pass Creek	0-2 (0)	68-100 (84)	7.2-7.9 (7.6)	45-75 (63)	25-40 (36)	45-75 (65)	16-26 (21)
Alice Creek	0-3 (1)	90-132 (116)	7.8-8.1 (8.0)	85-115 (108)	60-75 (70)	90-120 (111)	16-44 (30)
Landers Fork	0-4 (1)	128-162 (142)	8.0-8.2 (8.1)	110-140 (131)	75-90 (85)	110-145 (135)	22-42 (34)
Poorman Creek	0-5 (2)	100-160 (134)	7.9-8.2 (8.1)	105-130 (121)	75-90 (85)	95-130 (118)	28-40 (33)
Spring Creek	0-3 (1)	166-180 (174)	8.1-8.2 (8.1)	170-175 (171)	105-120 (112)	160-180 (173)	38-46 (42)
Spring Creek Overflow	0-1 (0)	180-190 (184)	7.9-8.1 (8.0)	165-170 (169)	105-120 (112)	170-180 (176)	38-56 (42)
Keep Cool Creek	0-4 (2)	142-180 (163)	7.8-8.2 (8.1)	140-145 (144)	90-105 (100)	145-160 (153)	34-50 (41)
Beaver Creek	0-4 (2)	110-158 (140)	7.8-8.3 (8.1)	80-145 (121)	65-120 (98)	80-155 (126)	25-48 (39)
Willow Creek	4-15 (8)	100-114 (106)	7.2-7.8 (7.7)	55-75 (69)	40-55 (49)	55-90 (78)	14-28 (23)
Arrastra Creek	0-6 (3)	72-136 (110)	8.0-8.2 (8.1)	60-100 (89)	30-65 (54)	60-105 (91)	19-28 (24)
North Fork	0-6 (2)	136-150 (143)	7.9-8.3 (8.1)	130-140 (135)	80 (80)	140-145 (142)	28-44 (37)
Kleinschmidt Spring	0-4 (1)	140-160 (149)	8.2-8.4 (8.3)	135-150 (144)	90-95 (91)	145-165 (154)	28-51 (36)
Warren Creek	8-30 (15)	122-140 (131)	7.8-8.2 (8.0)	85-105 (93)	60-65 (63)	90-110 (98)	24-33 (28)
Monture Creek	0-4 (3)	46-126 (88)	7.7-8.1 (7.9)	30-115 (75)	20-75 (46)	40-110 (78)	12-32 (21)
Cottonwood Creek	0-7 (2)	150-176 (160)	8.1-8.3 (8.2)	145-150 (148)	100 (100)	145-160 (153)	28-46 (36)
Clearwater Creek	0-6 (4)	60-90 (80)	7.6-8.0 (7.9)	50-70 (64)	35-50 (44)	60-80 (71)	14-20 (17)
Elk Creek	4-65 (29)	168-186 (178)	8.1 (8.1)	125-140 (132)	90-110 (102)	125-150 (137)	38-44 (41)
Belmont Creek	0-75 (2)	110-160 (141)	8.1-8.3 (8.2)	90-145 (125)	70-120 (100)	75-150 (123)	24-68 (45)
Gold Creek	0-7 (2)	100-110 (103)	8.0-8.3 (8.2)	75-95 (88)	50-65 (60)	80-100 (93)	20-32 (27)
Union Creek	9-44 (22)	190-242 (220)	7.6-8.3 (8.0)	120-200 (171)	70-120 (103)	120-210 (180)	24-62 (45)
East Twin Creek	0-11 (6)	24-50 (39)	6.9-7.9 (7.3)	10-15 (12)	5 (5)	10-15 (13)	2-8 (5)
West Twin Creek	0-7 (3)	10-30 (21)	6.6-7.5 (7.0)	2-10 (6)	2-5 (3)	2-10 (6)	2-4 (3)

Oxygen values ranged from 7 mg/l in Pass Creek to a high reading of 14 mg/l in Kleinschmidt Spring. The stream averages for dissolved oxygen were nearly all 10 or 11 mg/l. All analyses indicated only a trace of **carbon dioxide** amounting to less than 2 mg/l. As might be expected, nearly all analyses for carbonates were negative. The exceptions were single instances in the Blackfoot at Dalton, Arrastra Camp, and Rainbow Bend with values of 6 to 12 mg/l. One sample from Poorman Creek measured 24 mg/l; Spring and Elk and Union Creek **lead** was detected at any of the st in February and March 1969, February samples from Arrastra Blackfoot River, above Arrastr and the Blackfoot at Rainbow

R THE BLACKFOOT RIVER AND ITS TRIBUTARIES

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s, average values are shown in parentheses. Turbidity
, all other items are expressed in milligrams per liter.

agnesium	Sodium and Potassium	Bicarbonate	Sulfate	Chloride	Nitrate	Fluoride	Iron	Zinc	Copper
2-36 (12)	0-26 (6)	43-73 (60)	10-79 (41)	1-9 (3)	0-0.2 (0.1)	0-0.50 (0.15)	0-0.20 (0.08)	0.07-0.44 (0.25)	0
2-15 (8)	0-18 (6)	67-152 (92)	13-43 (27)	1-6 (4)	0-0.4 (0.1)	0-0.28 (0.10)	0-0.50 (0.08)	0.02-0.12 (0.07)	0
2-18 (9)	0-13 (7)	79-152 (125)	0-20 (11)	1-6 (3)	0-0.5 (0.1)	0-0.30 (0.10)	0-0.60 (0.09)	0-0.03 (0)	0
1-18 (13)	0-30 (10)	140-210 (189)	0-9 (3)	1-6 (4)	0-0.3 (0)	0-0.28 (0.09)	0-0.10 (0.04)	0-0.02 (0)	0
1-22 (12)	0-28 (9)	122-201 (182)	0-14 (4)	1-5 (3)	0-0.4 (0.1)	0-0.38 (0.09)	0-0.60 (0.10)	0-0.02 (0)	0-0.03 (0)
1-17 (10)	0-13 (5)	98-171 (145)	0-9 (5)	1-8 (4)	0-0.6 (0.1)	0-0.44 (0.16)	0-0.50 (0.10)	0-0.06 (0)	0-0.02 (0)
5-10 (8)	0	61-110 (88)	0-5 (2)	1-5 (3)	0-0.2 (0)	0.10-0.28 (0.18)	0	0-0.17 (0.05)	0
10-24 (12)	0-5 (2)	104-153 (137)	0-7 (3)	1-5 (3)	0-0.2 (0)	0-0.10 (0.03)	0	0	0
9-15 (12)	0-12 (5)	122-180 (162)	0-6 (3)	1-5 (3)	0-0.1 (0)	0-0.28 (0.13)	0	0	0
5-15 (9)	0-19 (7)	121-154 (140)	4-12 (8)	1-4 (3)	0-0.1 (0)	0-0.20 (0.07)	0	0	0
12-17 (14)	2-17 (9)	201-220 (212)	0-4 (1)	1-5 (3)	0-0.3 (0.1)	0-0.52 (0.20)	0	0	0
8-17 (13)	0-22 (11)	204-235 (215)	0-10 (4)	1-6 (3)	0-0.5 (0.2)	0-0.10 (0.05)	0	0	0
8-20 (13)	0-18 (9)	177-201 (186)	0-7 (3)	1-6 (3)	0-0.1 (0)	0-0.34 (0.15)	0-0.30 (0.13)	0	0
2-10 (6)	0-16 (8)	104-186 (160)	0-8 (3)	1-5 (3)	0-0.1 (0)	0-0.10 (0.03)	0	0	0
1-12 (6)	0-9 (6)	88-116 (104)	6-11 (9)	2-7 (4)	0-0.5 (0.2)	0.14-0.38	0.10-0.12 (0.11)	0	0
1-10 (8)	0-12 (7)	79-140 (117)	3-6 (4)	1-5 (3)	0-0.3 (0.1)	0-0.38	0-0.12 (0.03)	0	0-0.03 (0)
2-15 (9)	0-17 (9)	158-183 (172)	0-2 (1)	2-7 (4)	0-0.7 (0.3)	0.02-0.06	0-0.50 (0.17)	0-0.01 (0)	0
0-20 (12)	6-22 (14)	182-201 (189)	5-6 (6)	2-4 (3)	0-0.6 (0.3)	0-0.10	0	0	0-0.02 (0)
4-24 (15)	0-16 (5)	115-144 (129)	0-3 (2)	3-5 (4)	0-0.5 (0.3)	0-0.06	0.10-0.30 (0.20)	0	0
1-10 (7)	1-9 (6)	43-147 (103)	0-7 (4)	1-6 (3)	0-0.6 (0.3)	0-0.14	0-0.14 (0.03)	0	0
14-18 (16)	0-20 (7)	127-187 (165)	2-20 (8)	3-6 (4)	0-0.5 (0.3)	0	0	0-0.02	0
0-10 (7)	3-10 (7)	73-110 (95)	0-4 (2)	3-4 (3)	0-0.9 (0.4)	0-0.04	0-0.10 (0.03)	0-0.02	0-0.03 (0)
2-12 (6)	10-22 (16)	165-174 (170)	12-14 (13)	2-5 (3)	0-0.6 (0.2)	0.28	0-0.62 (0.22)	0	0
5-20 (12)	0-10 (3)	116-175 (155)	0	3-5 (4)	0	0	0-0.40 (0.15)	0	0
11-12 (11)	0	104-122 (115)	0-4 (1)	2-5 (4)	0	0	0-0.40 (0.13)	0	0
2-24 (15)	1-20 (11)	155-256 (220)	8-11 (10)	2-6 (5)	0-0.6 (0.2)	0.10-0.24	0.10-0.45 (0.28)	0	0-0.02 (0)
0-1 (0)	5-12 (9)	24-36 (29)	0-8 (4)	2-3 (2)	0-0.3 (0.1)	0.10-0.44	0-0.18 (0.08)	0-0.01	0-0.12
0-8 (3)	0-5 (2)	6-34 (20)	0-4 (1)	2 (2)	0	0.04-0.34	0-0.08 (0.04)	0	0

sample each from Kleinschmidt
sured 6 mg/l. Neither **arsenic** nor
s. Except for some positive results
ts for **copper** were negative. In
k, the Clearwater River, and the
mp contained 0.03 mg/l copper;
Kleinschmidt Spring, and Union Creek contained 0.02 mg/l. In March one sample from East Twin Creek contained 0.12 mg/l copper which may have been introduced to the water by pollution from the Anaconda logging camp or from a private fish pond. Water temperatures at the time of sampling ranged from 0 to 18°C. They were highest in streams used for irrigation.

posed of fixed material was greater during the initial runoff. This is because a large part of the volatile matter suspended during high water is non-settleable.

Turbidity was recorded for all other streams studied; and, as in the case of Pattee Creek, it was always greatest during initial spring runoff. In comparing the various streams, a correlation between the amount of turbidity and soil disturbance is evident. In undisturbed Morrell Creek the turbidity never exceded 5 JTU; whereas in Deer Creek, flowing through a logged area of the same drainage, turbidity definitely increased during peak flows—attaining a value of 70 JTU in one sample (Figure 7). Warren, Elk, and Union Creeks in the Blackfoot drainage are used extensively for irrigation; and these also have high turbidity during high water (Table 1). Terrain and soil type also play a role in turbidity. The North Fork of the Blackfoot, for instance, becomes markedly turbid for a few days in the spring undoubtedly because of sloughing of the unstable soil from the surrounding steep slopes.

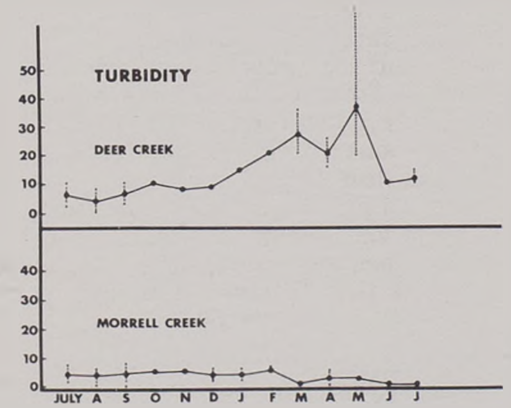

FIGURE 7. Turbidity, in Jackson Turbidity Units, of water in Deer and Morrell Creeks over a 13-month period. The creeks were sampled weekly for most of the study period. The extremes in each month are indicated by the vertical lines.

Of all the characteristics analyzed, turbidity is the most variable and should be seriously considered in planning further road building, logging, and other development in the watersheds of delicate streams. There is no doubt that siltation is injurious to aquatic biota (Moffett, 1936; Wallen, 1951; Bartsch, 1959; Condone and Kelley, 1961; Chapman, 1962; etc.).

Oxygen

In all of the streams tested the level of dissolved oxygen remains close to the saturation point throughout the year. This level falls almost invariably between 8 and 11 mg/l. The lowest value we recorded was 5 mg/l on a sample taken from Deer Creek on a summer's day. The highest reading, 14 mg/l, was shared by Kleinschmidt Spring, which has an abundance of aquatic vegetation, and by Deer Creek.

Our most intensive analysis of oxygen concentration was made on Pattee Creek, which, as regards changes in the oxygen level, is similar to the other waters studied with the exception of Kleinschmidt Spring.

The lowest percent of saturation (92%) occurred in Pattee Creek in March 1968 during a period of high runoff. The highest (112%) occurred during low water in August 1967. The water became slightly supersaturated in the summer months, indicating some photosynthetic addition of oxygen. The oxygen concentration by weight ranged from 8.5 to 13 mg/l. This level is primarily dependent on water temperature, being consistently higher during the winter months (Figure 8).

There is no apparent nocturnal oxygen sag. The water is physically mixed by turbulence, and there is paltry plant growth. Oxygen levels recorded on clear summer days every four hours over 24-hour periods show that the oxygen concentration in the creek inversely responds, with a slight lag, to changes in water temperature. Consequently, the concentration is highest in the morning and lowest in the evening. Apparently photosynthesis and nocturnal respiration by algae play only a minor part in the addition or removal of oxygen.

Carbon Dioxide

Free cardon dioxide was either zero or less than 2 mg/l in all the streams. The waters are

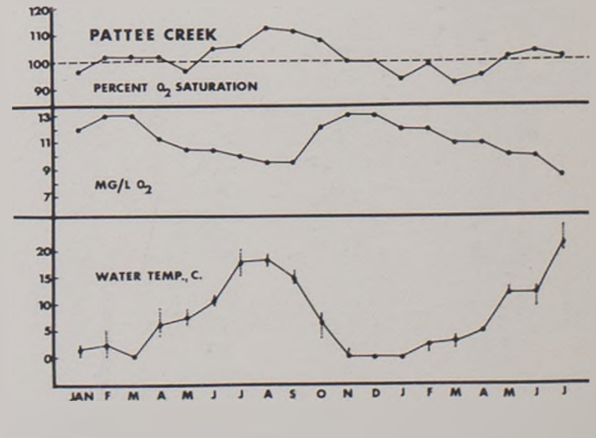

FIGURE 8. Dissolved oxygen, percent of oxygen saturation, and water temperature in Pattee Creek over a 19-month period. Five samples were taken at about the middle of each month. The vertical lines on the temperature graph represent the extremes recorded each month.

fairly high in bicarbonates, and there is little organic decay.

Hydrogen Ion

With rare exceptions, the pH value was basic (7.4 to 8.6) in all streams examined. At Pop's Place on the Blackfoot, near where the river receives seepage from old mine tailings, the pH was 6.8 on one occasion; and in one instance the two Twin Creeks had values of 6.6 and 6.9 (Tables 1 and 2).

TABLE 2. SUMMARY OF WATER ANALYSIS DATA FROM PATTEE CREEK,[1] MORRELL CREEK, AND DEER CREEK

JULY 1967-JULY 1968

Average values, in parentheses, are shown below the ranges. Turbidity is expressed in Jackson Turbidity Units, the bottom four items in milligrams per liter.

	Pattee Creek	Morrell Creek	Deer Creek
Stream Temperature in °C	0-21 (9)	0-10 (5)	0-20 (9)
Turbidity	10-110 (31)	0-10 (3)	0-70 (15)
pH	7.5-8.6 (8.3)	7.9-8.6 (8.2)	7.6-8.6 (8.1)
Oxygen	8-13 (10)	7-13 (9)	5-14 (8)
Alkalinity[2]	30-100 (65)	50-80 (65)	20-70 (45)
Total Hardness	30-90 (58)	45-90 (65)	25-70 (45)
Calcium Hardness	20-50 (34)	35-70 (53)	10-55 (32)

[1] In order to make a valid comparison of these creeks, this table reflects only data gathered from the creeks during the same 12-month period. When presented elsewhere in this bulletin, information concerning Pattee Creek includes data collected from January 1967 to July 1968.

[2] Phenolphthalein alkalinity was zero at all stations. The level of carbon dioxide was usually zero at all stations and never exceeded 2 mg/l.

Our study revealed definite seasonal trends in the hydrogen ion concentrations. The streams become more basic during summer months when their primary water sources are springs and ground seepage. At the time of high water this basicity is somewhat neutralized by the snow and rain runoff. The seasonal pattern of pH values in Pattee Creek is typical (Figure 2).

Total Hardness, Calcium Hardness, and Alkalinity

The levels of total hardness, calcium hardness, and alkalinity vary inversely with the volume of stream flow, which dilutes, to a greater or lesser degree, the cations responsible for those levels. It follows from this that fewer hardness-producing cations are received from surface runoff than from water flowing from springs or seepages. As regards hardness and alkalinity, all of the streams in this study responded to changes in flow volume as did Pattee Creek (Figure 2).

The total hardness ranged from 200 mg/l in Union Creek to 2 mg/l in West Twin Creek. Calcium hardness ranged from 120 mg/l in a number of tributaries of the Blackfoot River to 3 mg/l in West Twin Creek. Alkalinity ranged from 210 mg/l in Union Creek to 2 mg/l in West Twin Creek. The highest levels recorded for three warm springs which feed the Clark Fork River were 475 mg/l total hardness, 340 mg/l calcium hardness, and 190 mg/l alkalinity (see Table 6).

With the exception of the upper Blackfoot River and Poorman and Belmont Creeks, all of the streams and rivers tested had total alkalinity equal to or greater than their total hardness (Tables 1 and 2). Excluding the exceptions, this indicates that none of the hardness is noncarbonate hardness. The upper Blackfoot and Poorman Creek receive material leached from mine tailings which may explain their noncarbonate hardness. Hardness in Belmont Creek is only slightly greater than its alkalinity.

Because all phenolphthalein alkalinity tests were negative, we concluded that calcium carbonate does not contribute to the total alkalinity of the streams. Although carbon-

TABLE 3. SUMMARY OF CHEMICAL COMPONENTS IN PATTEE CREEK, MORRELL CREEK, AND DEER CREEK

JULY 1967-JULY 1968

Average values, in parentheses, are shown below the ranges. All analyses are expressed in milligrams per liter.

	Pattee Creek	Morrell Creek	Deer Creek
Iron	0-0.01 (0.01)	0-0.10 (0.04)	0.04-0.30 (0.12)
Copper	<0.05	<0.05	<0.05
Manganese	- -	0.01-0.75 (0.30)	0.03-0.50 (0.29)
Silica	16-25 (19)	2-5 (4)	3-7 (5)
Chromate	- -	0.03-0.07 (0.05)	0.04-0.10 (0.06)
Fluoride	0.05 (0.05)	0-0.30 (0.10)	0-0.25 (0.10)
Sulfate	4-15 (10)	5-12 (7)	4-11 (7)
Chloride	2.5-7.5 (3.0)	0-2.5 (2.5)	0-2.5 (2.5)
Phosphate	0.30-0.60 (0.43)	0.08-0.20 (0.12)	0.05-0.30 (0.15)
Nitrate	0.02-0.60 (0.20)	0.03-0.12 (0.07)	0.01-0.24 (0.08)
Nitrite	<0.005	<0.005	<0.005

Tests for chlorine and hydrogen sulfide were negative at all stations. Tanin-lignin-like substances were not present in quantities above 1 mg/l at any station.

ates were occasionally detected (footnote, Table 1), the usually high alkalinity precluded their presence.

Inasmuch as the total hardness of the water was always higher than the calcium hardness, it follows that a considerable amount of the total hardness probably results from the presence of other alkaline earth metals, especially magnesium.

Chemical Components

The chemicals found in Pattee Creek and

TABLE 4. ANALYSES, IN MILLIGRAMS PER LITER, OF WATER FROM THE BLACKFOOT RIVER AND ITS TRIBUTARIES COMPARING CONDITIONS AT HIGH (H) AND LOW (L) DISCHARGE.

Sampling Station		Total Dissolved Solids	Calcium	Magnesium	Sodium and Potassium	Carbonate	Bicarbonate	Sulfate	Chloride	Nitrate
Blackfoot River										
Pop's Place	H.	100	22	2	6	0	61	13	1.5	0.1
	L.	146	29	10	0	0	64	45	4.0	0
Flesher Pass Road	H.	100	26	4	1	0	85	13	3.5	0.1
	L.	130	28	10	0	0	91	25	4.0	0
Hogum Pass Road	H.	106	27	2	10	0	98	14	2.5	0.3
	L.	132	33	12	2	0	143	11	4.0	0
Dalton Mtn. Road	H.	88	40	1	10	0	140	6	4.0	0.1
	L.	168	43	14	6	0	207	0	5.0	0
Arrastra Camp	H.	130	38	1	16	0	140	14	2.0	0.3
	L.	184	44	16	0	0	195	5	4.0	0
Rainbow Bend	H.	60	31	1	9	0	110	6	3.0	0.4
	L.	150	46	10	0	0	171	9	4.0	0
Tributaries										
Pass Creek	H.	70	19	5	-	0	61	5	1.0	0.1
	L.	98	26	6	0	0	95	2	4.0	0
Alice Creek	H.	90	16	10	5	0	104	7	1.0	0.2
	L.	132	37	14	0	0	149	4	4.0	0
Landers Fork	H.	130	22	10	6	0	122	6	1.0	0.1
	L.	162	42	12	0	0	174	3	3.0	0
Poorman Creek	H.	100	28	6	9	0	121	12	1.0	0.1
	L.	160	40	10	0	24	134	5	4.0	0
Spring Creek	H.	180‡	38	12	13	0	201	4	1.0	0.2
	L.	170	46	14	5	0	214	0	4.0	0
Keep Cool Creek	H.	180‡	35	8	16	0	177	7	1.0	0.1
	L.	142	50	11	0	0	177	5	3.0	0
Beaver Creek	H.	110	25	12	12	0	104	8	1.0	0.1
	L.	158	48	14	0	0	180	2	4.0	0
Willow Creek†	H.	100	27	1	9	0	98	6	2.0	0.5
	L.	104	28	7	-	0	116	8	7.0	0
Arrastra Creek	H.	72	19	1	8‡	0	79	4	3.5	0.2
	L.	128	28	10	9	0	140	6	5.0	0
North Fork†	H.	150‡	28	15‡	10‡	0	183‡	0	2.0	0.3
	L.	136	39	12	17	0	158	2	7.0	0
Kleinschmidt Spring	H.	140	51‡	0	15	0	183	6	3.0	0.5
	L.	140	28	20	12	6	189	6	4.0	0.2
Warren Creek†	H.	140‡	24	4	16	0	128‡	0	3.0	0.5
	L.	122	33	24	0	0	115	3	5.0	0
Monture Creek	H.	46	12	1	1‡	0	43	0	1.0	0.5
	L.	90	20	10	8	0	113	7	6.0	0
Cottonwood Creek	H.	150	28	14	20	0	127	20	3.0	0.5
	L.	176	46	16	0	0	187	2	6.0	0
Clearwater River	H.	60	19	0	8	0	73	0	3.0	0.5
	L.	90	20	7	6	0	110	4	3.0	0
Elk Creek†	H.	186‡	44‡	2	17	0	165	12	3.0	0.6
	L.	168	40	12	10	6	171	13	5.0	0
Belmont Creek	H.	110	24	5	10	0	116	0	3.0	0
	L.	160	68	10	0	0	173	0	5.0	0
Gold Creek	H.	100	20	11	-	0	104	0	2.0	0
	L.	110	32	11	0	0	122	4	5.0	0
Union Creek†	H.	242	62‡	2	19	0	232	8	2.0	0.6
	L.	242	48	22	1	6	256	11	6.0	0
East Twin Creek	H.	24	2	1‡	5‡	0	24	0	2.0	0.2
	L.	50	8	0	9	0	36	5	3.0	0
Average										
High Water		114	29	5	11	-	118	6	2.2	0.3
Low Water		140	37	12	3	-	149	7	4.4	0

†A tributary which receives irrigation water runoff.

‡This response to high discharge is contrary to the relationships prevailing in most of the tributaries studied.

their concentrations are similar to the relatively untouched Morrell and Deer Creeks and other waters in the Northwest (Tables 3 and 5). The nitrate and phosphate levels in Pattee Creek are higher than those in Morrell and Deer Creeks, indicating that the horse corrals and septic tanks along Pattee Creek are a source of these materials. The nitrates and phosphates were at their highest concentrations during ground runoff. The concentration of silica also is higher in Pattee Creek than in the other two streams. A deep bed of siliceous clay underlies the lower part of the creek, and much of the silt in the creek comes from road embankments composed of this clay soil. Most of the silica is undoubtedly colloidal inasmuch as the water is quite alkaline.

There was no apparent difference in the water quality at the three sampling stations on Morrell Creek. From an ecological standpoint the logging practices used on this stream's drainage have been exemplary. Except for one small clearcut on a piece of flat land (at one of our sampling stations), timber close to the stream has not been cut. The Morrell Valley also is wider and has more gentle slopes than is typical of watersheds in western Montana.

Although the total dissolved solids and the chemicals present in the Blackfoot and its tributaries vary considerably, our analyses indicate that the streams are generally pure (Table 1). The relatively high concentrations of sulfates and zinc at Pop's Place on the Blackfoot River undoubtedly result from seepage and runoff from old mine tailings.[1] Of the river's tributaries Union Creek has the highest level of total dissolved solids and West Twin Creek the lowest. Union Creek, which flows slowly through an alluvial valley, is used heavily for irrigation. West Twin Creek, on the other hand, flows precipitously over boulder fill. In general, the spring-fed streams and the streams used extensively for irrigation contain the greatest amounts of dissolved materials.

The concentrations of most of the dissolved materials vary depending on the amount of runoff (Table 4). With the few exceptions noted in Table 4, total dissolved solids, calcium, magnesium, bicarbonates, and chlorides are at their highest levels during low water. Sodium-potassium and nitrate concentrations are highest during high water. The materials which are highest during low water are derived mostly from water percolated through the soil, whereas the sodium-potassium and nitrate compounds are introduced mostly by surface runoff. The sulfates do not follow any pattern.

Information concerning the geological environment of the streams studied is too meager to be correlated accurately with their water chemistry. It is obvious, however, that the chemical composition of the streams is largely dependent on the type of rock and soil of the watershed. Kootenai Creek, for instance, is fed by water flowing over the relatively insoluble quartz monzonite of the Idaho batholith. Where the creek disgorges from its narrow canyon, its water is nearly neutral

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[1] The United States Geological Survey has established a sampling station at Pop's Place. The Survey's preliminary analyses from September 1968 to April 1969, shown here as ranges in mg/l, are: iron, 0.02-0.28; manganese, 0.15-0.45; magnesium, 7.8-11.3; sulfate, 4.3(?)-70.2; zinc, 0.45-0.55; copper, 0.007-0.009; fluoride, 0-0.2; and boron, 0-0.07.

TABLE 5. A COMPARISON OF SOME CONSTITUENTS IN WATERS OF THE UPPER COLUMBIA RIVER

Weighted averages in milligrams per liter.

	Silica	Sulfate	Chloride	Nitrate	Iron
Pattee Creek	19	10	3.0	0.20	0.01
Morrell Creek	4	7	2.5	0.12	0.04
Deer Creek	5	7	2.5	0.08	0.12
*Spokane River (Spokane, Wash.)	8	9	0.6	0.23	0.02
*Snake River (Weiser, Ida.)	26	35	17.0	0.60	0.04
†Thompson River (Kamloops, B.C.)	6	6	5.5	0.44	0.03
†Flathead River (Columbia Falls, Mont.)	6	5	0.8	0.40	0.04
†Columbia River (Golden, B.C.)	4	18	1.5	0.10	0.07
‡Flathead River (Columbia Falls, Mont.)	6	4	0.6	0.10	—
‡Wolf Creek (Libby, Mont.)	14	9	1.4	0.07	0.04
‡Fisher River (Libby, Mont.)	11	2	0.8	0.17	0.03

*Clarke, 1924 (based on a year's sampling).

†Livingston, 1963 (based on single samples taken from the Thompson and Columbia Rivers in July and on a year's sampling of the Flathead River).

‡U.S.G.S. Water Resource Data for Montana, 1967 (based on three samples taken during periods of high, medium, and low discharge).

and remarkably pure (Table 6). Lolo and Miller Creeks are neighboring streams in the same Bitterroot watershed but are more basic and contain higher concentrations of dissolved substances than does Kootenai Creek. Lolo Creek lies in Ravalli and Wallace formations (siliceous shale, argillaceous limestone, limy quartzite, etc.); and Miller Creek flows through formations of the Missoula group (argillite, impure quartzite, limestone, etc.). Streams in the Blackfoot drainage with headwaters in limestone formations, such as the North Fork and Landers Fork, and streams used extensively for irrigation, such as Cottonwood and Union Creeks, have the hardest water.

TABLE 6. WATER ANALYSES FROM MISCELLANEOUS WATERS OF WESTERN MONTANA

All analyses are shown in milligrams per liter except pH and turbidity.
Turbidity is given in Jackson Turbidity Units.

Part 1

Place	Date	Temperature °C	Oxygen	Carbon Dioxide	pH	Alkalinity	Total Hardness	Calcium Hardness	Nitrate
Clark Fork Valley									
Shandy Warm Spring	5/6/68	16.5	5	30	8.2	190	330	215	0.11
Bearmouth Warm Spring	5/6/68	19.0	6	32	8.3	165	460	340	0.06
Nimrod Warm Spring	5/6/68	20.0	4	40	7.6	170	475	330	0.09
Bitterroot Valley									
Kootenai Creek	8/8/68	13.0	10	0	7.2	10	5	5	0
	11/15/68	1.0	12	0	6.8	10	5	5	0.10
Lolo Creek	8/8/68	18.0	9	0	8.7	50	50	40	0.44
	11/15/68	2.0	13	0	7.8	40	35	20	0.10
Miller Creek	8/8/68	17.0	10	0	8.7	140	145	110	0.44
	11/15/68	2.0	13	0	8.2	145	140	95	0.10
Pattee Creek Spring	7/14/68	12.0	6	-	8.3	50	50	20	0.17
Swan Valley									
Lost Creek	7/31/68	13.0	6	2	8.2	40	90	65	-
	8/7/68	-	-	-	-	-	140	100	-
Goat Creek	7/31/68	11.0	7	2	8.0	130	135	100	-
	8/7/68	-	-	-	-	-	135	100	-
Lion Creek	7/31/68	10.0	7	2	8.1	90	130	110	-
	8/7/68	-	-	-	-	-	90	80	-
Buck Creek	7/31/68	17.0	6	2	8.0	145	155	125	-
	8/7/68	-	-	-	-	-	150	110	-

Part 2

Place	Date	Orthophosphate	Silica	Sulfate	Chloride	Copper	Iron	Fluoride	Turbidity
Clark Fork Valley									
Shandy Warm Spring	5/6/68	0.20	13	140	4.0	0.35	0.02	0.75	5
Bearmouth Warm Spring	5/6/68	0.20	10	350	4.0	0.40	0.02	1.30	5
Nimrod Warm Spring	5/6/68	0.18	12	340	4.0	0.35	0.02	1.10	0
Bitterroot Valley									
Kootenai Creek	8/8/68	0.05	4	-	0.3	0	0	0.19	0
	11/15/68	0.08	11	-	0.3	0	0	-	0
Lolo Creek	8/8/68	1.05	12	-	0.2	0.01	0	0.19	0
	11/15/68	0.10	24	-	0.2	0.01	0	-	0
Miller Creek	8/8/68	1.25	10	-	0.3	0.05	0	0.21	5
	11/15/68	0.10	22	-	0.3	0.04	0	-	0
Pattee Creek Spring	7/14/68	0.84	19	3	2.0	0.25	0.40	0	5
Swan Valley									
Lost Creek	7/31/68	0.10	2	6	2.5	-	-	-	0
	8/7/68	0.10	4	7	2.5	0.10	0	0.10	-
Goat Creek	7/31/68	0.05	4	8	2.5	0.10	0.05	0	-
	8/7/68	0.10	4	7	2.5	-	-	-	0
Lion Creek	7/31/68	0.10	3	7	2.5	-	-	-	0
	8/7/68	0.05	3	7	2.5	0.08	0	0	-
Buck Creek	7/31/68	0.15	33	7	2.5	-	-	-	0
	8/7/68	0.10	5	8	2.5	0.10	0.10	0.10	-

Summary

1. The water quality of 25 headwater streams and the Blackfoot River, all tributaries of the Clark Fork River in the Columbia River system, was investigated. In comparison with other waters in the United States these streams are relatively unaltered by man's activities; several of them are pristine. With the exception of the lower Blackfoot River, the streams are all small streams; and, compared to most watersheds, are of remarkable purity.

2. Most of the qualities analyzed exhibit definite seasonal trends. Turbidity is one of the most variable features. It is greatest during the initial high runoff and fluctuates widely and rapidly during periods of thaw and rain. The streams with the greatest turbidity and fluctuation are those used for irrigation or those whose drainages have been roaded and logged. Total residue and the percent of residue from settleable solids increase, and the percent of fixed material in total residue decreases, during high water.

3. The streams maintain a high level of dissolved oxygen—seldom less than 8 mg/l. Photosynthesis and nocturnal respiration by algae do not detectably affect the amount of dissolved oxygen in these mountain streams. Temperature is the major factor controlling oxygen concentrations.

4. Carbon dioxide is present only in amounts less than 2 mg/l.

5. The pH values generally range from 7.4 to 8.6. Only rarely is the water acidic. In the case of one stream this acidity results from seepage from old mine tailings. The water is most basic during summer months and becomes less so during snow and rain runoff.

6. The levels of total hardness, calcium hardness, and alkalinity decrease with increased runoff. With rare exceptions, alkalinity is equal to or greater than the total hardness, indicating an absence of noncarbonate hardness. Calcium carbonate does not contribute to alkalinity. Because total hardness is always greater than calcium hardness, it follows that alkaline earth metals other than calcium contribute to total hardness.

7. Total dissolved solids, calcium, magnesium, bicarbonates, and chlorides are at highest levels during low water. They are derived mostly from water percolated through the soil. Sodium-potassium and nitrates are most concentrated during high water with surface runoff. Sulfate levels do not seem to follow any pattern. In general, the spring fed streams and streams used for irrigation contain the greatest amounts of dissolved materials.

8. During summer months sections of many of the stream beds become dry. In those sections where the bedrock is close to the surface, there is surface flow; but where the bedrock is covered with gravel and boulder glacial fill, the flow is underground. One may presume that the intermittancy of surface flow reduces the biota of the streams and that the consequent subsurface percolation filters suspended matter from the water.

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