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A bacteriological investigation of the Haskell Creek drainage

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A BACTERIOLOGICAL INVESTIGATION OF THE HASKELL CREEK DRAINAGE

By

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The controversy over human access to a watershed supplying public drinking water initiated this bacterial study. Fecal coliform, total coliform and fecal streptococcus were used to determine the point source. Then, the fecal coliform, fecal streptococcus ratio was used to determine the origin of bacterial contamination. The variation between a ski area (open watershed) and an area of little human use (closed watershed) showed only a slight difference in bacterial counts due to higher amounts of run-off from the ski area. The impact of the ski area's sewage lagoon was negligible and was not detectable at the intake to the public water supply.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

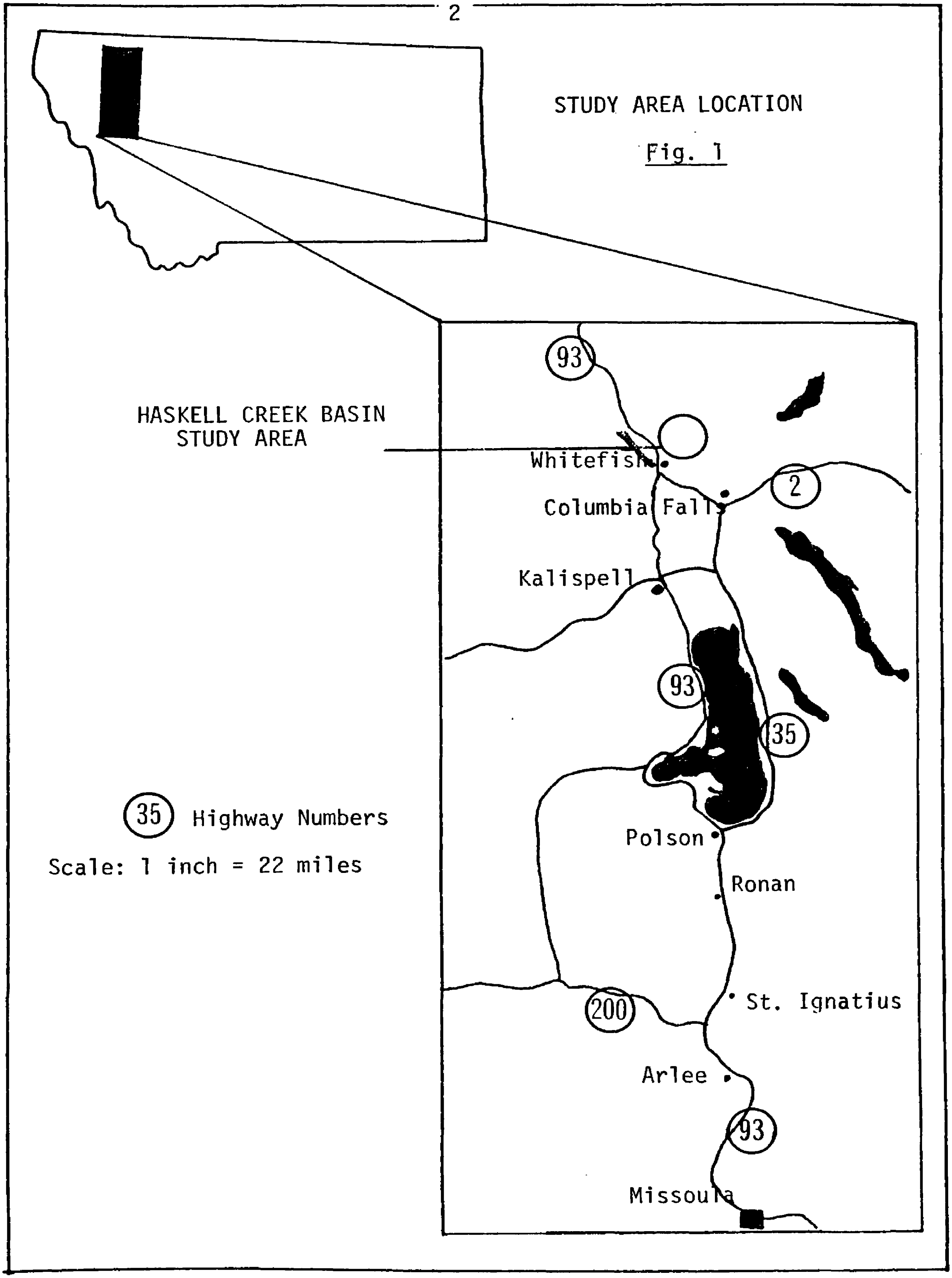
CHAPTER I

INTRODUCTION

Water has occupied a primary position in man's life since earliest written history and probably since time began. Its hieroglyphic symbol is one of the twenty-four consonants of the ancient Egyptian alphabet (Ceram, 1954) and, even in recent historic times, it has been endowed with the "divine" qualities which make life possible (Ingalls, 1890). In more practical terms, access to water has led to disputes ranging from individual confrontation to international wars; its control has been the subject of single agreements and multi-national treaties. In a survey of Montana towns for which data is available, sixty-four per cent were found to have incorporated in order to obtain a municipal water supply (Nash, 1969).

City of Whitefish Water Supply

Whitefish, situated in the northwest region of the state, incorporated in 1905. Almost from the moment its water system was established in the fall of 1907, the town was plagued by contamination of water supplied by the Whitefish River. In 1918, therefore, it was proposed that the city seek a mountain supply "free from human contamination" (Trippet, 1918). The watershed selected was Haskell Creek Basin, located approximately three and one-half miles north of the city (see Fig. 1). After official survey for danger of contamination, the Montana State Board of Health gave final approval to this source on


STUDY AREA LOCATION
Fig. 1
HASKELL CREEK BASIN
STUDY AREA
93
Whitefish
2
Columbia Falls
Kalispell
93
35
Polson
Ronan
St. Ignatius
200
Arlee
93
Missoula
35
Highway Numbers
Scale: 1 inch = 22 miles

February 19, 1919.

In less than five years, the problem of bacterial contamination erupted again. The history of the Whitefish water supply since that time (see Appendix A) chronicles repeated efforts to pinpoint and eliminate the probable sources.

Since 1965, it has been suggested that contamination has been increased by the development of the Big Mountain Ski Resort and associated housing within the watershed. Several modifications of the resort's sewage system have been made upon recommendation of the State Board of Health. The present plan consists of a gravity flow through two aerated lagoons to a third lagoon which is used for storage. Formal and informal complaints have blamed contamination of the Whitefish water supply on leakage and state-approved dumping from the third lagoon.

Research Objectives

Haskell Creek consists of two drainages: First Creek, an "open" drainage with human access from the Big Mountain Ski Resort; and Second Creek, a "closed" drainage with very limited access.

St dies have already been made of the water quality of mountain watersheds and the bacteriological impact of human access (Snow, 1972; F.W.P.C.A., 1969; E.P.A., 1973). Other studies have demonstrated deterioration of water quality of watersheds without human access but with access from native animal populations (Bissonette, 1971; Stuart, 1971; Ehlke and Soltero, 1969; Bissonette, et al., 1970). But study of the Haskell Creek watershed made possible the comparison of an open drainage with a closed drainage immediately adjacent.

Therefore, the combined research objectives of this study were to:

1. Determine the bacteriological quality of the surface water in First and Second Creeks. This would include finding all point sources of contamination and analyzing their impact upon the watershed;

2. Determine whether differences in bacteriological water quality existed between the open drainage, First Creek, and the closed drainage, Second Creek; and

3. Assess the effect of leakage and occasional dumping from the Big Mountain Ski Resort's sewage system on the water quality of First Creek and, possibly, the Whitefish water supply.

Literature Review

Bacteriological content has been used as a gauge of water contamination since 1885 when *Bacillus coli* was isolated from feces by Escherich (Scarpino, 1971). From that time on, most investigations dealing with coliforms and water quality made reference to fecal contamination. The majority of early studies dealt with biochemical analysis (MacConkey, 1905, 1909) and taxonomic differentiation (Bergey and Deehan, 1908; Smirnow, 1916).

These works laid the broad groundwork for more recent quantitative studies to pinpoint the specific origin and significance of fecal coliforms (Parr, 1939; Kabler and Clark, 1960). Studies to determine origin by relating fecal coliform counts to fecal streptococcus counts were initiated by Kenner and associates (1960). This technique was perfected as the Fecal Coliform/Fecal Streptococcus Ratio by Geldreich

(1966); its use is discussed in more detail in the Methods section of this study.

Geldreich (1966) stated that since the presence of fecal coliforms was evidence of recent fecal pollution, it was necessary to consider all fecal coliforms as indicators of dangerous contamination. Therefore, differentiation of fecal from non-fecal coliforms in total coliform counts is important to the evaluation of water quality.

The results of the following investigations into the origins of fecal and non-fecal organisms are pertinent to this study.

Coliforms and Fecal Streptococci in Fish

Both coliforms and fecal streptococci have been found in the intestinal tracts of various species of freshwater fish caught in India (Venkataraman and Sreenivasan, 1953); in Canada (Amyot, 1901; Margolis, 1935; Evelyn and McDermott, 1961; Potter and Baker, 1961); and in the United States (Johnson, 1904; Havens and Dehler, 1923; Glantz and Krantz, 1965. However, Margolis (1935) and Potter and Baker (1961) reported that the coliforms found in the intestinal tracts of fish resulted from the contamination of the fishes' food and water and not from their natural intestinal conditions. After numerous investigations, Geldreich and Clark (1966) confirmed that:

> . . . there is no permanent coliform or streptococcal flora in the intestinal tract of fish. The composition of the intestinal flora is related in varying degrees to the level of contamination of water and food in the environment. . . . Fish may also be carriers of pollution from warm-blooded animals for periods up to approximately seven days, and could in this manner transfer potential pathogens to clean water areas.

Coliforms and Fecal Streptococci in Vegetation

The possibility that coliforms and fecal streptococci may enter surface water from nearby vegetation has also been investigated. Wilson, et al., (1935) found that the coliform counts on grass, hay, and straw were relatively low except in samples which had been contaminated by soil. Thomas and McQuillin (1952) reported that coliforms were abundant in grass from both ungrazed and intensively grazed pastures. After examination of the foliage of a wide variety of garden plants, trees, shrubs, and field plants, Fraser, Reid and Malcolm (1956) reported that coliform bacteria were seldom found. They also suggested that exceptions were the result of contamination by insects, animals, and/or dust. On the other hand, Sherman (1937) reported that fecal streptococci were rather common on plants. Mundt, Johnson and Khatchikian (1958) examined the leaves, flowers, and shoots of plants grown in uninhabited areas and isolated coliform bacteria in 58.5% and fecal streptococci in 67.0% of their samples.

The presence of coliforms and fecal streptococci on vegetation may stem partly from insect contact. Steinhaus (1941) isolated eleven strains of coliforms from the alimentary tracts of species of Orthoptera, Hemiptera, Coleoptera, and Lepidoptera. Fecal streptococci were also found in five species of Orthoptera, Hemiptera, Homoptera, and Lepidoptera. Fecal streptococci were reported by West (1951) and Eaves and Mundt (1960) in twenty-six insect species.

The possibility of insect contamination of vegetation was also investigated by Geldreich, Kenner and Kabler (1964) who reported that:

> . . . the numbers of coliforms, fecal coliforms, and fecal streptococci on plants and in insects are very low. They [Geldreich's analyses] also show that the ratio of fecal coliforms to coliforms is quite small . . . . These findings support the current interpretation that fecal coliforms in surface waters are largely, if not completely, derived from fecal pollution of animal origin.

Soil and Water Run-off

Soil and storm water run-off have been shown to be short term sources of fecal coliforms. Parr (1938) hypothesized that all coliforms found in soil were of fecal origin. Griffin and Stuart (1940) stated that only Escherichia coli were derived from feces. Taylor (1951) found insufficient evidence to conclude that any of the coliform group were normally soil inhabitants. The eleventh edition of Standard Methods for the Examination of Water and Waste Water (A.P.H.A., 1960) suggests that none of the coliform bacteria normally inhabits soil.

These conflicting observations may result from variation in soil types and surrounding environments. Randall (1956) stated that the number of coliforms and fecal coliforms was an indicator of the degree of pollution of the soil. Bordner, et al., (1962) found that fecal coliforms were absent, or nearly so, in undisturbed soil but noted marked increases in disturbed areas. Van Donsel, et al., (1967) reported that both coliforms and streptococci were isolated from storm-water run-off and that isolations were more frequent during prolonged rain than they were during short rain storms. It was reported by Geldreich, et al., (1968) that the survival of coliforms and fecal streptococci in storm-water run-off indicated that these organisms persisted at higher levels during the winter (at 10° C.) than they did during the summer (at 20° C.). He concluded that storm-water "can be a major source of intermittent pollution to water supply reservoirs" and suggested that such reservoirs should not be opened to public recreational use.

CHAPTER II

METHODS

Study Parameters

The study area encompassed the entire Haskell Creek Basin, an area of 2,995 acres drained by First and Second Creeks. Since the whole region was formed during the post-Cretaceous period and underwent the same changes, the two drainages have the same geological history (see Appendix B).

A complementary study undertaken jointly with the Soil Conservation Service and fellow graduate student, Douglas Kikkert, revealed that soil composition of the two drainages was also similar except that clearing of trees and shrubs for the ski resort had resulted in a "slightly higher filtering capacity and run-off potential" (see Appendix C).

There was no appreciable difference in weather and precipitation in the two areas during the period of the study (see Appendices D and E). Data were obtained directly from the U.S. Weather Bureau at Glacier International Airport and the Flathead Forest Service.

A second complementary study of streamflow was undertaken with the assistance of United States Forest Service hydrologist, Mr. Robert Delk. This study compared First and Second Creeks and confirmed that the larger volume of streamflow of Second Creek was proportionate to the larger area drained--1,727 acres to First Creek's 1,268 acres (see Appendix F).

Location of Collection Sites

Water was sampled intermittently during the period September 27, 1973 to May 14, 1974 at the following collection sites (see Fig. 2 and Table 1):

First Creek and Tributaries

F-1 - One-fourth mile north of the ski lodge, where First Creek enters "fire insurance" pond.

F-2 - One-half mile east of ski lodge, on a small tributary of First Creek.

F-3 - One-fourth mile east of F-2, on a second tributary of First Creek.

F-4 - At the base of chairlift #2, where First Creek enters a small trout pond.

F-5 - One-half mile downstream from the ski resort sewage lagoons.

F-6 - At the confluence of First Creek and its two tributaries.

F-7 - One and one-half miles downstream from the sewage lagoons and one-half mile above the intake for the Whitefish water supply.

Second Creek and Tributary

S-1 - On Second Creek, approximately one mile from city water intake.

S-2 - On a tributary, six-tenths of a mile from confluence with Second Creek.

S-3 - On Second Creek, one-tenth of a mile from confluence with its tributary.

S-4 - At the Whitefish city water intake on Second Creek.

Fourth Creek

Z-1 - On Fourth Creek, one-tenth of a mile north of Haskell Creek Road.

Since seepage from the ski resort's sewage lagoons had been

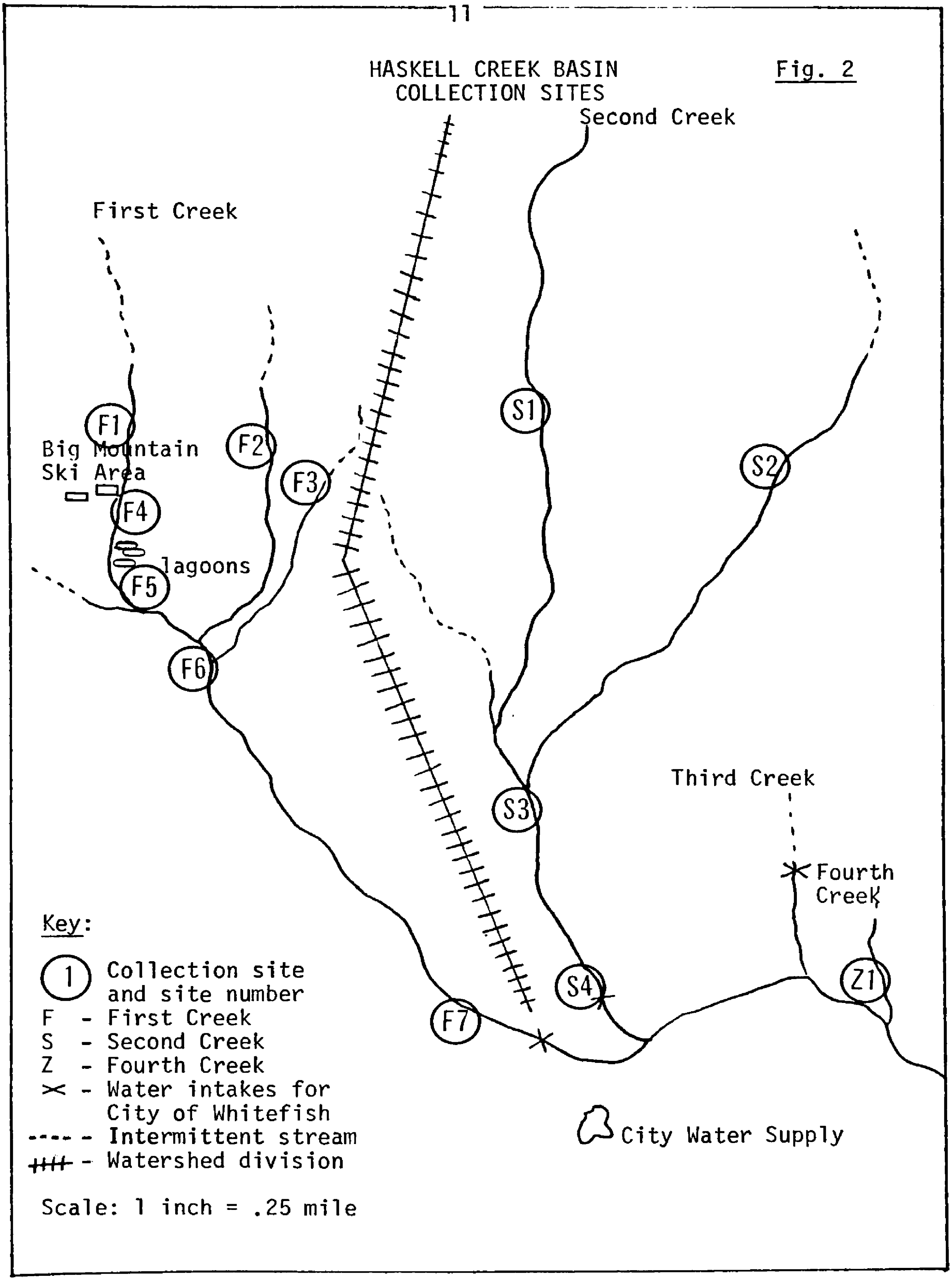

HASKELL CREEK BASIN
COLLECTION SITES
Fig. 2
Second Creek
First Creek
S1
F1
F2
Big Mountain
Ski Area
F3
S2
F4
lagoons
F5
F6
Third Creek
S3
Fourth
Creek
Key:
1 Collection site
and site number
F - First Creek
S - Second Creek
Z - Fourth Creek
- Water intakes for
City of Whitefish
- Intermittent stream
- Watershed division
S4
Z1
F7
City Water Supply
Scale: 1 inch = .25 mile

TABLE 1

COLLECTION SITES

Site Number	Location							Elevation (ft.)
F-1	T32N	R22W	Sec. 35	S.E.1/4	S.E.1/4	S.E.1/4		5,000
F-2	T32N	R22W	Sec. 36	S.W.1/4	S.E.1/4	S.W.1/4		5,040
F-3	T31N	R22W	Sec. 36	S.W.1/4	S.E.1/4	S.E.1/4		5,120
F-4	T31N	R22W	Sec. 2	N.E.1/4	N.E.1/4	N.E.1/4		4,780
F-5	T31N	R22W	Sec. 2	N.E.1/4	S.E.1/4	N.E.1/4		4,520
F-6	T31N	R22W	Sec. 1	N.W.1/4	S.W.1/4	N.W.1/4		4,500
F-7	T31N	R22W	Sec. 12	N.E.1/4	S.W.1/4	N.W.1/4		3,980
S-1	T31N	R22W	Sec. 1	N.E.1/4	S.W.1/4	N.E.1/4		4,400
S-2	T31N	R21W	Sec. 5	S.W.1/4	N.W.1/4	N.E.1/4		4,540
S-3	T31N	R22W	Sec. 1	S.E.1/4	S.E.1/4	S.E.1/4		4,080
S-4	T31N	R22W	Sec. 12	N.E.1/4	S.E.1/4	N.E.1/4		3,960
Z-1	T31N	R21W	Sec. 8	N.E.1/4	S.E.1/4	S.W.1/4		3,840

F - First Creek
S - Second Creek
Z - Fourth Creek

suspected as a possible source of contamination, a special evaluation of this source was undertaken during part of the study. Sampling bracketed the period when spring melt and resort usage necessitated controlled and state-approved dumping from the third lagoon.

Beginning April 9 and continuing through April 23, 1974, effluent was pumped and siphoned over the retaining dike of the third lagoon. Dates and volumes of effluent released are shown in Table 3. Distance from the discharge area to First Creek was approximately ten yards.

Collections were made at Sites F-4, F-5 and F-7 and at additional sites established for this special study, as follows:

F-4a - Approximately 100 yards below the ski lodge parking lot, above the lagoons;

F-5a - Two hundred yards east of F-5, below the lagoons; and

F-7a - Three quarters of a mile below the confluence of First Creek and its two tributaries.

The distance from the dumping area to the nearest sampling site on First Creek itself was approximately 100 yards.

Collections were made once on April 8, prior to dumping; three times on April 11, by which time the effluent had reached First Creek; and once on April 24, the day after dumping was discontinued.

Collection and Analysis of Water Samples

The procedures followed for the collection and analysis of water samples were taken from Standard Methods for the Examination of Water and Wastewater (A.P.H.A., 1967) and Millipore's Biological Analysis of Water and Wastewater (1973). To insure accuracy, three samples were

TABLE 2

RECORD OF DUMPING FROM THIRD LAGOON
BIG MOUNTAIN SKI RESORT

Date		Gallons of Effluent
April 9		21,000
April 10		33,000
April 11		24,000
April 12		18,000
April 16		90,000
April 17		120,000
April 18		120,000
April 19		72,000
April 20		72,000
April 21		72,000
April 22		72,000
April 23		72,000
	Total	786,000

collected on each occasion. Sterilized one-liter Nalgene bottles were used for collection of samples and, wherever possible, were submerged six to twelve inches to avoid surface debris.

Counts were made using the culture media and ranges recommended by the Environmental Protection Agency (see Table 3). Since small numbers of bacteria were found at certain sites, large volumes of water were collected and filtered in order to fall within the guidelines shown. Samples were kept cool and, in every case, analyses were performed within six hours of collection.

Samples were subjected to two separate tests for each of the three test organisms. Duplicate counts from each collection were then compared. If there were differences of more than five total coliform colonies, or three fecal coliform colonies, or three fecal streptococcus colonies, the samples were recounted and/or the site was sampled again to try to pinpoint the inconsistency. This procedure insured the accuracy of the counts and the various types of test.

Standards

The criteria for measuring bacterial contamination of water samples were those published by the State of Montana and approved by the Environmental Protection Agency (1972):

Class A - Public water supply after disinfection: Average total coliforms less than 50 per 100 milliliters.

Class A - Public water supply after disinfection and removal of natural impurities: Average total coliforms less than 50 per 100 milliliters as a result of domestic sewage.

TABLE 3

RECOMMENDED COLONY COUNT RANGES FOR SIGNIFICANT QUANTITATIVE DETERMINATIONS WITH MEMBRANE FILTER TESTS*

Test	No. of Colonies per Plate		Medium	Remarks
	Minimum	Maximum		
Total coliform	20	80	M-Endo Broth MF, LES Endo Medium	Not more than 200 colonies of all types
Fecal coliform	20	60	M FC Broth	
Fecal streptococci	20	100	M-Enterococcus Agar, KF Agar	

* Millipore Corporation. 1973. Biological Analysis of Water and Wastewater. Application Manual AM 302. Millipore Corporation, Bedford, MA.

Class B - Public water supply after treatment: Average total coliforms less than 1,000 per 100 milliliters where demonstrated to be the result of domestic sewage; not more than 20% to exceed this value.

All other classifications: Same as B.

This same source incorporates the National Technical Advisory Committee's recommendations for public water supplies:

200/100 ml fecal coliforms - permissible

10,000/100 ml total coliforms - permissible

20/100 ml fecal coliforms - desirable

100/100 ml total coliforms - desirable

Identification of Test Organisms

Analysis for coliform bacteria can be accomplished either by the multi-tube Most Probable Number (MPN) procedure or through use of the membrane filter system. The latter was used throughout this study, specifically in the total coliform, fecal coliform and fecal streptococcus tests.

Total Coliform Test

Coliforms are rod-shaped and measure approximately 2 to 4 microns by 0.5 microns. Some of the sixteen types are flagellated and fimbriated. Coliforms do not form spores. They are Gram stain negative and ferment lactose to produce gas and acid.

The membrane filtering procedure adopted for this study utilized the metabolic steps leading to acid production. This produced an indicator reaction which developed color within the colony. Cultures were incubated for 24 hours at 35° $\pm$ 0.5° C. on M-Endo MF Broth. One coliform organism on the surface of the filter paper was considered to have produced one visible colony (Millipore, 1973). Colony size varied and the texture ranged from smooth to rough. The color of the colony also varied from pink to dark red with a golden metallic sheen which often had a greenish tint. This green metallic sheen sometimes covered the entire colony, sometimes concentrated in its center.

Fecal Coliform Test

To isolate fecal from non-fecal coliforms, filtered organisms were incubated at 44.5° $\pm$ 0.5° C. on a M-FC Broth for 24 hours. Fecal coliforms were identified by their ability to ferment lactose with associated production of gas and acid. After the 24-hour incubation period, fecal coliform colonies appeared blue to gray in color.

Fecal Streptococcus Test

Fecal streptococci are spherical or oval in shape, approximately one micron in diameter, and are arranged in pairs or chains of various lengths. They are non-motile and non-spore-forming. Some are capsulated. Fecal streptococci are Gram stain positive. They are aerobic and exhibit marked resistance to heat, alkalinity and strong saline concentrations. They grow in 40% bile solution at 45° C. and produce acid, but no gas, in mannitol and lactose.

Two media were used in sequence during this study. A pre-enrichment of PC Enrichment Broth was required to produce the best enumeration of the organisms. This was followed by M-Enterococcus Agar to inhibit further growth of non-fecal coliforms.

Resulting fecal streptococcal colonies were light, flat and smooth. They ranged in color from pink to dark red with pink margins.

In accordance with Millipore's prescribed procedure, each colony was counted as one fecal streptococcus organism, although they normally occur in pairs or chains. Thus, the quantitative results of this test are of questionable value unless related to the fecal coliform count by means of the mathematical ratio developed by Geldreich and his associates in 1966.

Fecal Coliform/Fecal Streptococcus Ratio

As pointed out by Kenner and associates (1961), it is difficult to differentiate between fecal coliforms from humans and those which originate in other warm-blooded species. However, subsequent investigations (Geldreich, et al., 1962; Geldreich, 1966) have led to the development of a significant analytical tool, the Fecal Coliform/Fecal Streptococcus Ratio, used as follows:

$$\frac{\text{Fecal Coliform}}{\text{Fecal Streptococcus}} = \text{FC/FS Ratio.}$$

This ratio has proved to be a reliable indicator of the probable origin of fecal contamination (see Table 4). When the FC/FS ratio is significantly greater than two, the water contains wastes of human origin; when the FC/FS ratio is significantly less than one, the water contains wastes of animal origin, particularly livestock. More specifically, the ratio indicates the following.

When the ratio is greater than or equal to 4.0, it may be taken as strong evidence that pollution derives from human wastes.

When the ratio lies between 2.0 and 4.0, it suggests a

TABLE 4

ESTIMATED PER CAPITA CONTRIBUTION OF INDICATOR MICROORGANISMS FROM SOME ANIMALS*

		Average indicator density per gram of feces.		Average contribution per capita per 24 hr.		
Animals	Avg wt of Feces/24 hr. wet wt, g.	Fecal coliform, millions	Fecal streptococci, millions	Fecal coliform, millions	Fecal streptococci millions	Ratio FC/FS
Man	150 (sic)	13.0	3.0	2,000	450	4.4
Duck	336	33.0	54.0	11,000	18,000	0.6
Sheep	1,130	16.0	38.0	18,000	43,000	0.4
Chicken	182	1.3	3.4	240	620	0.4
Cow	23,600	0.23	1.3	5,400	31,000	0.2
Turkey	448	0.29	2.8	130	1,300	0.1
Pig	2,700	3.3	84.0	8,900	230,000	0.04

*Source: Geldreich, E.E., C.B. Huff, R.H. Bordner, P.W. Kabler, and H.F. Clark. 1962. Type distribution of coliform bacteria in the feces of warm-blooded animals. J. Water Poll. Con. Fed. 34: 295.

predominance of human wastes in mixed pollution.

When the ratio is between 0.7 and 1.0, it suggests a predominance of livestock and poultry wastes in mixed pollution.

When the ratio is less than or equal to 0.7, it may be taken as strong evidence that pollution derives predominantly or entirely from livestock or poultry wastes.

If the FC/FS ratio falls between 1.0 and 2.0, it is considered a "gray" area of uncertain interpretation. In such cases, it is suggested that samples be taken again, nearer to the source of pollution.

Two precautions were taken to insure the reliability of this technique. To overcome the problem of bacterial mortality, the fecal coliform and fecal streptococcus counts were made from samples which were gathered at the same collection sites not more than 24 hours downstream from the source of pollution. Secondly, since bacterial survival is also affected by very high or very low pH, care was taken to insure that the pH of the sampled water lay between 4.0 and 9.0.

Mathematical Interpretations

The mathematical interpretations used were means, standard deviation, variance, and T-test. These were calculated by the procedures outlined in Elementary Statistics by R.R. Johnson (1973).

The T-test was used specifically to analyze variances between paired collection sites on each creek and between the two creeks. T-test analysis of the differences virtually eliminated the effect of all outside factors such as weather, streamflow and population size.

CHAPTER III

RESULTS

A total of 125 collections were made at the 14 sampling sites on First, Second, and Fourth Creeks during the period September 27, 1973 to May 14, 1974. Three samples were taken at each collection. Each sample was then tested at random for two of the three test organisms. Of the 750 samples analyzed, 10 were abandoned because of test malfunctions. Results are shown in Table 5. Data are expressed as the number of organisms per hundred milliliters (100 ml = standard volume). The figures were calculated by multiplying the number of organisms counted by the standard volume and then dividing them by the volume sampled.

Accuracy of Colony Count

As mentioned in the Methods section, accuracy was assured by running duplicate analyses for each organism used in the study. These duplicate analyses of data revealed percentage accuracy as follows: 95.9% for total coliforms, 94.3% for fecal coliforms, and 96.3% for fecal streptococci (see Table 6).

Lagoon Dumping Study

Results of the special study of dumping from the third sewage lagoon of the Big Mountain Ski Resort are shown separately as Table 7.

Data from these collections show a slight elevation in total coliform, fecal coliform and fecal streptococcus counts at Sites F-5

TABLE 5

RAW DATA SUMMARY

(No. of Organisms per 100 ml water)

Site	Sept. 27			Oct. 13			Nov. 23			Dec. 17			Dec. 29			Jan. 20			Feb. 16			Apr. 4		
	TC[a]	FC[b]	FS[c]	TC	FC	FS	TC	FC	FS	TC	FC	FS	TC	FC	FS	TC	FC	FS	TC	FC	FS	TC	FC	FS
F1	8	0	4	13	0	6	23	1	8	13	0	2	8	0	2	7	0	0	5	0	0	4	0	0
F2	2	0	0	2	0	0	4	0	0				2	0	0									
F3	3	0	0	3	0	0	6	0	0				3	0	0									
F4	10	0	4	16	1	8	23	1	10	21	0	4	11	0	2	10	0	0	8	0	0	7	0	0
F4b										23	0	5												
F5				27	2	5	33	3	4	34	2	5	25	0	5	21	0	4	17	0	1	15	2	4
F5a																						21	3	4
F6	5	0	0	9	0	1	12	0	2				5	0	0	11	0	0	13	0	0	23	1	5
F7	26	5	7	33	5	10	35	4	8				20	0	2	17	0	1	21	2	7	12	1	6
S1							13	0	3				7	0	0	9			7	0	1	6	0	0
S2																			0	0	0	0	1	0
S3	11	0	2	15	0	6	31	2	4				7	0	0	9	0	1	10	0	0	4	1	5
S4	19	2	5	25	3	7	39	3	6				12	0	2	10	0	2	8	2	5	7	2	4
Z1	0	0	1	0	0	0	0	0	0															

a TC = Total Coliform
b FC = Fecal Coliform
c FS = Fecal Streptococci

TABLE 5 (CONTD)

RAW DATA SUMMARY

(No. of Organisms per 100 ml water)

Site	April 8			April 11 10:00 a.m.			April 11 noon			April 11 4:00 p.m.			April 24			May 7			May 14		
	TC	FC	FS	TC	FC	FS	TC	FC	FS	TC	FC	FS	TC	FC	FS	TC	FC	FS	TC	FC	FS
F1	9	0	4										19	1	3	5	1	5	43	3	10
F2	28	0	5																		
F3																					
F4	2	0	7				1	0	4				3	2	5	16	2	7	158	5	14
F4b				7	0	6				11	0	6	5	2	6						
F5	25	3	6	38	3	5	28	4	7	24	3	6	25	4	7	16	2	7	177	10	58
F5a	14	1	6	5	2	3	5	3	2	3	4	4	1	0	1						
F6																8	1	7	35	2	7
F7	6	3	7	7	3	8	5	3	8	13	3	6	13	3	6	13	2	6	206	13	42
F7a							15	5	7	20	3	7	15	4	5						
S1																12	0	0	53	1	4
S2																0	0	0	36	2	7
S3																11	0	4	69	4	15
S4																7	1	6	71	7	22

TABLE 6

ACCURACY OF COLONY COUNTS

Organism	Number of Analyses Checked	Percentage Accuracy*
Total Coliforms	251	95.9
Fecal Coliforms	249	94.3
Fecal Streptococci	240	96.3

* Differences in duplicate counts were rendered as percentages; percentages were then totalled and divided by the number of analyses checked.

TABLE 7

DATA FROM COLLECTIONS MADE DURING DUMPING FROM THIRD LAGOON

(No. of Organisms per 100 Milliliters)

Site	April 8			April 11 10:00 A.M.			April 11 Noon			April 11 4:00 P.M.			April 24		
	Total	FC	FS	Total	FC	FS	Total	FC	FS	Total	FC	FS	Total	FC	FS
Site 4	2	0	7				1	0	4				3	2	5
Site 4				7	0	6				11	0	6	5	2	6
Site 5	25	3	6	38	3	5	28	4	7	24	3	6	25	4	7
Site 5a	14	1	6	5	2	3	5	3	2	3	4	4	1	0	1
Site 7	6	3	7	7	3	8	5	3	6	13	3	6	13	3	6
Site 7a							15	5	7	20	3	7	15	4	5

and F-5a, immediately below the third sewage lagoon. All total coliform counts at these sites were below levels permitted for drinking water, but the ratio of fecal coliforms to fecal streptococci increased.

At Site F-7, results fall within the range of normal fluctuations and show no impact of the dumping upstream.

All data from the lagoon dumping study are included in the raw data summary.

Violation of State Standards

Included separately as Table 8 are readings taken on May 14, 1974, the only day during the study when average total coliform counts violated the state's standards for drinking water.

Total coliform counts showed violations at six collection sites on First and Second Creeks. Furthermore, the three collection sites on First Creek (F-4, F-5 and F-7) showed counts which were triple those at the three collection sites on Second Creek (S-1, S-3 and S-4) on the date indicated.

These data are also included in the raw data summary.

Statistical Analysis of Data

Statistical analyses of data for total coliform, fecal coliform and fecal streptococcus counts are shown in Tables 9, 10 and 11, respectively.

T-Test for Total Coliforms

T-tests were used to determine possible variances between

TABLE 8

VIOLATIONS OF STATE STANDARDS FOR TOTAL COLIFORMS IN DRINKING WATER

May 14, 1974

Sites	No. of Coliforms/ 100 ml.
F-4	158
F-5	177
F-7	206
S-1	53
S-3	69
S-4	74

TABLE 9

STATISTICAL ANALYSIS OF DATA - TOTAL COLIFORM COUNT

(No. of Organisms per 100 Milliliters)

Site	Number of Analyses	Minimum Number of Organisms	Maximum Number of Organisms	Mean	Variance	Standard Deviation
F1	30	4	43	12.7333	101.375	10.069
F2	14	2	28	6.0714	84.071	9.169
F3	12	3	6	3.6667	3.697	1.923
F4	31	1	158	20.7792	1396.38	37.368
F5	32	15	177	34.8438	1320.33	36.336
F6	22	5	36	12.4545	82.45	9.080
F7	32	5	206	29.9375	2228.64	47.209
S1	16	6	53	14.50	228.8	15.126
S2	8	0	36	9.00	278.0	16.675
S3	23	4	69	18.0455	332.141	18.225
S4	22	7	71	22.6364	373.671	19.331
E1	9	0	0	.222	.194	.441

TABLE 10

STATISTICAL ANALYSIS OF DATA - FECAL COLIFORM COUNT

(No. of Organisms per 100 Milliliters)

Site	Number of Analyses	Minimum Number of Organisms	Maximum Number of Organisms	Mean	Variance	Standard Deviation
F1	29	0	3	.3793	.6724	.820
F2	14	0	0	.0000	.0000	.000
F3	12	0	0	.000	.0000	.000
F4	32	0	5	.75	1.6774	1.295
F5	32	0	10	2.625	5.4677	2.338
F6	22	0	2	.3182	.4177	.646
F7	32	0	13	3.3125	8.8024	2.967
S1	16	0	1	.125	.1167	.342
S2	8	0	2	.625	.8393	.916
S3	22	0	4	.8182	1.5844	1.259
S4	22	0	7	.2	3.2381	1.799
Z1	8	0	0			

TABLE 11

STATISTICAL ANALYSIS OF DATA - FECAL STREPTOCOCCUS COUNT

(No. of Organisms per 100 Milliliters)

Site	Number of Analyses	Minimum Number of Organisms	Maximum Number of Organisms	Mean	Variance	Standard Deviation
F1	30	0	10	3.7	9.252	3.042
F2	14	0	5	.7143	3.297	1.816
F3	12	0	0	.000	.000	.000
F4	32	0	14	4.8125	15.061	3.881
F5	32	4	58	8.25	172.903	13.149
F6	22	0	7	2.50	9.595	3.098
F7	32	1	42	8.4375	81.480	9.027
S1	14	0	4	1.2857	2.681	1.637
S2	8	0	7	1.75	10.500	3.240
S3	22	1	15	3.8636	17.171	4.144
S4	22	2	22	6.1364	29.552	5.436

specific, paired collection sites within each drainage and between the two drainages. Results are shown in Table 12.

FC/FS Ratios: First and Second Creeks

The fecal coliform/fecal streptococcus ratios derived from the First Creek raw data are shown in Table 13. It should be noted that the ratios increased significantly during the lagoon discharge period. The FC/FS ratios for Second Creek are shown in Table 14.

TABLE 12

MEAN DIFFERENCE T-TESTS FOR TOTAL COLIFORMS

Comparison of Paired Sites
First Creek and Second Creek Drainages

Paired Sites	Number of Pairs (N)	Mean Difference (d)	Standard Deviation (S_d)	T-Test Value (T)	Probability of Similarity (<p)
F-1 & F-4	10	14.90	35.275	1.33	-*
F-4 & F-5	8	11.875	3.48	9.65	.01
F-5 & F-7	8	3.25	8.86	1.04	-
S-1 & S-4	7	6.714	11.086	1.60	-
S-3 & S-4	9	2.667	5.745	1.39	-
F-1 & S-1	7	1.714	6.343	.72	-
F-7 & S-4	9	23.00	33.010	1.69	.1

* Probability of similarity is not within the accepted values of 0.1.

TABLE 13

FC/FS RATIOS - FIRST CREEK

Date Site	1	2	3	4	4a	5	5a	6	7	7a
9/27	.0	.0	.0	.0				.0	.63	
10/13	.0	.0	.0	.13		.4		.0	.5	
11/23	.13	.0	.0	.1		.75		.0	.5	
12/17	.0			.0	.2	.4				
12/29	.0	.0	.0	.0		.0		.0	.0	
1/20	.0			.0		.0		.0	.0	
2/16	.0			.0		.0		.0	.29	
4/4	.0			.0		.5	.75	.2	.18	
4/8	.0	.0		.0		.45	.17		.43	
Discharge Period										
4/11 (10 a.m.)					.0	.67	.66		.40	
4/11 (12 p.m.)				.0		.61	1.50		.40	.69
4/11 (4 p.m.)					.0	.5	1.14		.50	.46
4/24	.33			.44	.33	.62	.0		.50	.80
5/7	.2			.23		.28		.14	.33	
5/14	.3			.36		.17		.28	.31	

TABLE 14

FC/FS RATIOS - SECOND CREEK

Date	Site	1	2	3	4	Z1
9/27				.20	.4	.0
10/13				.17	.43	.0
11/23		.0		.46	.50	.0
12/17						
12/29		.0		.00	.50	
1/20				.00	.00	
2/16		.0	.0	.00	.30	
4/4		.0	.0	.20	.57	
4/8						
4/24						
5/7		.0	.0	.0	.17	
5/14		.25	.28	.27	.30	

CHAPTER IV

DISCUSSION

Physical Parameters

For the purpose of the study, most physical parameters of the First and Second Creek drainages were so similar that they are considered as constants as far as their impact upon water quality is concerned.

Geological history, soil type, weather, precipitation, wildlife and vegetation were practically identical. Small areas of both drainages were logged in 1940. The altitude of comparable sites within the two drainages differed by not more than 380 feet. Streamflow of Second Creek was larger in volume but was proportionate to the larger area drained (1,727 acres to First Creek's 1,268 acres).

The major difference between the two drainages is that Second Creek is a closed drainage with relatively little human access, whereas First Creek is an open drainage with access from the Big Mountain Ski Resort. But, more important, the study by the Soil Conservation Service found that clearing for ski runs has resulted in a greater water run-off potential in the resort area.

Intakes for the Whitefish water supply are located on both First and Second Creeks above the point where they flow together to form Haskell Creek.

Raw Data

Analysis of raw data showed that, with one exception, bacterial levels of both First and Second Creeks were below those permitted by state standards for drinking water for the entire period of the study. The single exception occurred on May 14, 1974 when coliform counts at six collection sites violated those standards. Furthermore, the collections from the three sites on First Creek (F-4, F-5 and F-7) yielded counts that were triple those of collections from the three sites on Second Creek (S-1, S-3 and S-4) on that date. The significance of those counts will be discussed later in this section.

Application of T-test

The T-test was applied to raw data in order to determine variances in collection data within and between the two drainages (see Table 12).

Using total coliform data, all sites were paired. It was found that there were no variances in the mean difference between any of the paired sites located on Second Creek.

On First Creek, there were no variances in the mean difference between Site F-1 and F-4 collection data. However, inferences drawn from variances in the mean difference between sites F-4 and F-5 show definite impact of the ski area in the form of elevated total coliform counts. These variances will be compared later with FC/FS ratios derived from collection data from these sites to determine whether the elevated counts resulted from lagoon seepage or from contamination by some other source.

A comparison of collections from sites F-5 and F-7 shows no variance in the mean difference--from which it is inferred that the total coliform counts remained elevated farther downstream. But it should be emphasized that, even when elevated, the total coliform counts of ninety-three per cent of the F-5 and F-7 collections were below permissible levels for the entire study period.

A comparison of variances in the mean difference between sites S-1 and F-1 and between sites S-4 and F-7 confirmed the deterioration of water quality below the ski resort area on First Creek.

Sources of Contamination

At first glance, disparity in coliform counts between the collection sites on First and Second Creeks, and deterioration of water quality of First Creek below the ski resort, might logically be attributed to the presence of the ski resort lagoons. However, this is disputed by data derived from the special study of the effects of lagoon effluent conducted during the dumping period.

Lagoon Dumping Study

Dumping of chlorinated effluent from the resort's third lagoon was approved by the State Board of Health for the period April 9 to 23, 1974. Collections were made at sites F-1, F-4, F-4a, F-5, F-5a, F-7, and F-7a from April 8 to 24, 1974.

Data derived from these collections revealed a slight elevation in total coliform, fecal coliform and fecal streptococcus counts. However, even immediately below the lagoon (sites F-5 and F-5a) total coliform levels never exceeded the state standards and had dropped to normal (upstream) levels before reaching the intake for the Whitefish water supply, site F-7.

The proportion of fecal coliforms to fecal streptococci increased. At site F-5a, for example, the FC/FS ratio increased from 0.17 on April 8 to a high of 1.5 at noon on April 11, but had dropped to 1.14 by 4 p.m. The ratio for this site was zero on April 24.

Further downstream, at collection site F-7, neither raw data nor FC/FS ratios reveal any impact from the controlled dumping. It is concluded, therefore, that even when lagoon effluent is released directly into First Creek, it is dispersed long before it reaches the intake and has no effect on the Whitefish water supply.

Sources Indicated by FC/FS Ratios

As shown in the Methods section, the source of contamination may be indicated by the fecal coliform/fecal streptococcus ratio. The ratios derived from analyses of May 14 collections made at the six sites indicated were all below 0.36. The FC/FS ratio indicating any percentage of human wastes is 2.0 or higher. Therefore, using the ratio as an indicator, the highest levels on May 14--which were, in fact, relatively low--reveal little possibility of contamination by human wastes.

A fecal coliform/fecal streptococcus ratio below 0.7 indicates that pollution derives predominantly or entirely from livestock or poultry wastes. As far as can be ascertained, domestic livestock and poultry have not been kept in the study area for over forty years. However, the Department of Fish and Game (personal interview,

R. Shumaucher, May 23, 1974) confirmed observations that the area is frequented by bears, elk, deer, coyotes, white-tailed ptarmigan and various grouse. The sole study (McFeters, et al., 1974) yielding FC/FS ratios for wildlife gives a range of 0.1 to 0.3 for contamination by elk. Other studies of fish and insects cited earlier have eliminated both as possible sources of contamination.

Therefore, based upon the FC/FS ratios from creek collections, and lacking evidence of any other source, it is concluded that indigenous wildlife is responsible for contamination in the study area.

Streamflow and Spring Run-off

In considering data from the six collections which violated state standards for drinking water on May 14, 1974, it is necessary to examine other data which reflected marked changes at that time. It will be seen that there was a significant increase in the volume of streamflow of both First and Second Creeks (see Appendix F) which correlates directly with the high total coliform counts on the same date.

Related data record the onset of seasonal changes. Spring melt had begun by April 11, when measurement of snow depth (Appendix D) at the Big Mountain Ski Resort recorded a reduction from 61 to 57 inches. The period beginning April 23 had been marked by high daytime temperatures and night-time low temperatures that were above freezing. Rain had fallen intermittently from May 7 on.

In studying bacterial content of water, Geldreich (1968) found that stormwater and spring run-off can be major factors in fluctuations in raw data. Van Donsel, et al., (1967) also reported that both coliform and fecal streptococcal isolations were more frequent during prolonged rain storms. In the absence of any other change in the physical parameters of the study, it is concluded that the high coliform levels recorded on May 14, 1974 resulted from high levels of run-off during that period.

The remaining question to be considered is the great disparity between raw data from the three sites on First Creek and the three sites on Second Creek on May 14, 1974. As has been shown above, the presence of the sewage lagoons at the Big Mountain Ski Resort did not result in unusually high coliform levels at sites immediately below the third lagoon. Indeed, the effect of direct dumping was not apparent downstream at collection sites above the First Creek intake for the Whitefish water supply.

This brings to attention again the main physical difference between the two drainages. Large areas of First Creek were cleared of trees, small shrubs, and debris in order to develop ski runs. According to recent studies (Bateridge, 1974; Likens, et al., 1970; Lantz, 1971; Teller, 1963) such clearing causes premature and accelerated melting of snowpack. It was found by Bateridge and Likens and his associates that the resulting run-off can be increased in volume by as much as 400% above run-off from similar, but untouched, forest areas. These studies support the findings of the study of First and Second Creek soils conducted by J.B. Seago of the Soil Conservation Service, Flathead Conservation District.

It is concluded, therefore, that clearing and accelerated melting of snowpack causes unusually high levels of surface run-off. The increased volume and velocity of this run-off removes from the soil and debris of adjacent areas greater numbers of coliforms, fecal streptococci, and other bacteria. This, in turn, results in bacterial levels in the water of First Creek which are much higher than those in the water of Second Creek during the same period.

CHAPTER V

SUMMARY AND RECOMMENDATION

It is believed that melting snowpack during the spring and normal run-off during the remainder of the year carry contamination by indigenous wildlife into the surface waters of the Haskell Creek Basin. It is concluded, further, that accelerated melting and higher volume of spring run-off in the Big Mountain Ski Resort area are responsible for the disparity in bacterial levels between First and Second Creeks. Since this is a natural phenomenon, it is expected that these problems will recur during similar seasonal changes in future years.

With respect to the specific research objectives of the study, it was found that:

1. Surface waters of both First and Second Creeks are suitable for drinking water. Violations of state standards for bacterial quality occurred only rarely during the period of spring run-off.

2. The difference in water quality which exists between First Creek, the open drainage, and Second Creek, the closed drainage, stems from larger volume of run-off rather than seepage from the Big Mountain Ski Resort lagoons.

3. The effect of seepage and occasional dumping from the third lagoon into First Creek is negligible and is not detectable at the intake for the Whitefish water supply.

Finally, in response to the Environmental Quality Council's request for recommendations, it is suggested that the City of Whitefish consider Fourth Creek (Site Z-1, Fig. 2 and Tables 1 and 5) as an alternative to First Creek for the establishment of a new water supply.

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APPENDIX A

HISTORY OF THE STUDY AREA

The original inhabitants of the Whitefish area were Flathead Indians. In 1891, Chief Charlo and members of the tribe left the area and were replaced within a year by several dozen squatters. Rapid development and access by railroad led to formal incorporation of the City of Whitefish on April 11, 1905.

During this early period, water was either fetched from the river or lake or bought from a delivery man who filled barrels and carted them by wagon to his customers. The usual price ran from fifteen to fifty cents per barrel; the water at that time being described as "usually clear and cold".

In 1905, the City Council instructed the water commissioner to design and develop a water system. This system was surveyed and presented on October 2, 1905, financed by passage of a bond in April, 1906 and finally implemented in the fall of 1907. It consisted of a pumping plant on the lake, leading to a water storage tank. In January, 1908, wooden mains were buried within the city proper and some are still in use today (Schafer and Engetter, 1973).

For ten years this system proved satisfactory but, in 1918, W.K. Trippet, city water commissioner, applied for a change in the supply. It was planned to "go to a mountain supply, free from human contamination" and the drainage ultimately selected was the Haskell Creek Basin. In reply to the State Board of Health's query about humans in the area, the City of Whitefish stated on July 11, 1918:

> Our honest belief is that it will be many years before there are even temporary inhabitants for logging purposes, and probably never will people live in such a snow infested region.

Four days later, the city received a statement from A.T. Lees, M.D., confirming that there was no human habitation in the area but including the warning:

> Whether there is any probability that there will be any human habitation in the future, is an extremely important matter to be considered in approving the plan.

Within a month, the city was notified of contamination within its original system. By December 19, 1918 the new water supply was tentatively approved, pending a study of possible contamination. This was completed early in the following year and final approval given by the Montana State Board of Health on February 19, 1919.

From the inception of the new system, occasional samples were analyzed. Then, on August 15, 1923, _The Whitefish Pilot_ headline read: "State Board of Health Has Found Contamination in City Water Supply." The state had issued a notice of contamination, stating that the city's water was unsafe. Further samples were taken and found not entirely satisfactory. The statement of the Board of Health on August 28, 1923 recommended policing of the drainage area.

Bacterial contamination was found in samplings analyzed by city health official, A.T. Lees, in 1929 but no conclusions were drawn from the investigation which followed. Similar reports were issued after sampling on April 25, October 14 and November 1, 1929; and again on June 26, 1930; August 7, 1933; and July 6, 1935.

State studies carried out on water quality during this period classified the Whitefish supply as "fair" and "good" on January 21, 1927 and March 15, 1932, respectively. Early in 1927, a chlorinating device had been installed on the main water system. A further step to protect the watershed was taken in 1931 when the City of Whitefish applied for a permit for the six sections above the water intake. It was hoped to keep people out and prevent pasturing of sheep. This application was endorsed by the State Board of Health.

During 1933, the city faced the problem of too many fish and algae (Anaboena) in the city reservoir but the algal problem solved itself within a year and the question of the fish was left alone.

As a result of contamination evident on January 16, 1936, the state recommended a special investigation of the area. In its reply on January 21 the city expressed surprise about the bad samples but "an old man told them that every Saturday or Sunday from six to eight people go up toward the reservoir on snow-shoe hikes." The subsequent discovery of fecal coliforms in the excreta of a coyote on June 29, 1936 led to the belief that the origin was animal contamination. It was decided to try to keep animals away from the area.

On January 13, 1937 it was proposed to replace the transport ditches with wooden mains. (This was finally accomplished as a WPA project begun in mid-1941.) Satisfactory samples were obtained on January 19, 1937 and May 19, 1938 but a year later water samples tested unsatisfactorily again. When the Stolz Lumber Company began logging operations within the area on July 25, 1940, the State Board of Health advised the use of a better chlorination system.

The years between 1945 and 1965 saw several changes within the watershed. On January 17, 1947, "black bugs and white worms" were found in the water system and the addition of DDT to the reservoir was considered--but the problem rectified itself and DDT was not used. On June 19, 1947, the large reservoir dam broke filling it with mud and silt, and necessitating the replacement of the main reservoir. On November 19, 1949 the State Board of Health was notified that work was being done on the ski run within the First Creek drainage area. It was proposed on Februaru 20, 1952 that the water be fluoridated but this was turned down by the people of the area. Wooden mains were replaced by cast iron ones in May 1961.

During this period, only four unsatisfactory reports were issued by the Montana State Board of Health (August 5, 1951; April 24, 1954; May 9, 1958 and June 18, 1963). These were issued with the recommendation that Whitefish take some steps to safeguard and improve the quality of its water system.

In reviewing the history of the Whitefish water supply, attention must be drawn to the concurrent development of the Big Mountain Ski Resort.

The Hell-Roaring and Big Mountain area was first used by small ski parties in 1935. At that time a small cabin was built which held eight skiers and was heated by a small barrel wood stove. This was followed by the construction of a second cabin and the organizing of the Whitefish High School ski team in 1937. Two years later, the area was the site of the first high school ski tournament. By 1939, the United States Forest Service had constructed a parking lot and road to the ski area, which had been enlarged by the clearing of trees. Until that time, access had been limited to walking, snowshoeing or skiing. World War II saw little change in the area and only slight use of the ski slopes.

In 1947, however, the organizing of Winter Sports, Inc., was followed by further development of the ski resort on Big Mountain within the boundaries of the Haskell Creek drainage. Officially opened on December 14, 1947 construction continued with new slopes, more trails, and a new lodge. The sewage facilities consisted of a septic tank located in a heavy clay formation. In 1948, the State Board of Health recommended that drain tile be laid to carry sewage to a more suitable gravel bed. The Board stated further, on November 14, 1949 that the development of the ski resort in the First Creek drainage should be "watched carefully" in order to avoid contamination of the First Creek drainage.

The construction of a new chalet in 1949 enabled the resort to remain open during the summer. A radio station tower and other extensive facilities were added in 1957 and again in 1960.

The first controversy arose in October, 1965 when the City of Whitefish asserted that the Big Mountain development was endangering the water supply. An investigation the following year resulted in the issuing of a statement by the Flathead County Health Department on August 10, 1966 to the effect that there was no problem (Flathead County Health Department, 1968).

The first quantitative test on First Creek showed 15 coliforms per 100 ml on January 4, 1966. As a result, the State Board of Health issued a statement on January 28, 1966 confirming that " . . . the results of the test showed 8.3% of samples had 3 or more portions positive for coliform" in the previous year's samples.

By that time, the Big Mountain Ski Resort's sewage facilities consisted of three separate systems: a cesspool, a septic tank and drain field, and a second septic tank connected to a large cesspool, 24 feet in diameter. On January 6, 1966 the staff of the State Board of Health inspected these facilities, found no major problems, but asked for a review of the design with a view to some changes. At that time, the Board stated that:

> . . . the drinking water supply for the city of Whitefish must be protected at all costs and if your [Big Mountain] operation is to continue, every effort must be made to prevent the waste water from affecting the quality of the drinking water . . . (Montana State Board of Health, 1966)

On March 7, 1967 the city filed another complaint about bacterial contamination of the water supply. The State Board of Health dealt with this complaint at a meeting held April 26, 1967 by stating that " . . . to this point in time Big Mountain has not contaminated the city water supply, but the problem does exist, and it is the state's responsibility to insure a good water supply."

The report of a field investigation conducted by the State

Board of Health on July 12, 1967 revealed problems with both the resort and the city:

> From the past year's inspections at Whitefish, two things are apparent:
> 1. The resort needs better sewage disposal facilities.
> 2. The city needs better water supply facilities.
>
> Both need correction at an early date. (Montana State Board of Health, 1967)

Modification of the resort's sewage facilities in mid-1968 resulted in a two lagoon and aeration system. On December 6, 1968 the State Board of Health noticed that MPN's on First Creek were quite high but this was attributed to construction activity on the mountain (Montana State Board of Health, 1968).

Further controversy concerning water quality led to the addition of a third lagoon to the resort's system. This was troubled by leakage and more complaints arose about dumping during spring run-off. Another formal complaint was made to the State Board of Health on September 28, 1973 but subsequent testing failed to show high levels of total and fecal coliforms.

A list of all recorded bacterial analyses of water from the Haskell Creek area follows.

WATER ANALYSES BY MONTANA STATE BOARD OF HEALTH HASKELL CREEK AREA*

Aug. 9, 1918 - Contamination.

Aug. 15, 1923 - Water unsafe.

Aug. 28, 1923 - Not entirely satisfactory.

Apr. 10, 1925 - Not satisfactory.

Apr. 25, 1929 - Coliform found in 3 of 4 samples.

Oct. 14, 1929 - Unsatisfactory report on 2 of 4 samples.

Nov. 1, 1929 - Contamination of water.

Jun. 26, 1930 - All samples contaminated.

Sep. 24, 1930 - All samples good.

Aug. 7, 1933 - Unsatisfactory.

Jul. 6, 1935 - Problem shown in 2 of 4 samples.

Jan. 16, 1936 - Unsatisfactory.

Jan. 19, 1937 - Satisfactory.

May 19, 1938 - Satisfactory.

May 3, 1939 - Unsatisfactory.

Aug. 5, 1951 - Contaminated.

Apr. 24, 1954 - Contamination of water.

May 9, 1958 - Unsatisfactory.

Jan. 4, 1966 - Above First Creek intake 15 coliform/100 ml.

Jan. 28, 1966 - 8.3% of samples had 3 or more portions positive for coliform [in the previous year's samples].

*Water analysis data taken from Montana State Board of Health, File No. Box 26, 5-19-11, 5-19-12.

WATER ANALYSES BY MONTANA STATE BOARD OF HEALTH
HASKELL CREEK AREA (CONTD)

Date	First Creek (above intake)	First Creek Intake	Second Creek Intake	Third Creek Intake
May 27, 1971	430[a]	43	93	1
Jun. 28, 1971	-	-	4	1
Jul. 12, 1971	-	-	43	23
Jul. 26, 1971	430	230	93	75
Aug. 16, 1971	230	430	150	230
Sep. 27, 1971	1100	>1100	240	1100 (surface runoff)
Oct. 19, 1971	930	1500	430	460
Nov. 22, 1971	150	210	23	23
Jan. 4, 1972	4 samples (one sample had one portion positive)[b]			
Feb. 1, 1972	4 samples (all good)			
Feb. 29, 1972	4 samples (all good)			
Apr. 3, 1972	3 samples (all good)			
May 2, 1972	4 samples (all good)			
May 3, 1972	1 sample (all portions positive)			
Jun. 13, 1972	4 samples (one sample had two portions positive)			
Jun. 27, 1972	4 samples (all good)			
Jul. 31, 1972	4 samples (all good)			
Aug. 22, 1972	3 samples (one sample had three portions positive; one sample had five portions positive)			
Sep. 26, 1972	2 samples (all good)			
Oct. 30, 1972	4 samples (all good)			
Dec. 4, 1972	4 samples (all good)			
Jan. 22, 1973	43	93	23	0
Apr. 9, 1973	-	130	31	5
May 14, 1973	-	33	17	2
Jun. 25, 1973	-	49	33	2
Jul. 30, 1973	70	-	49	110
Sep. 4, 1973	-	920	34	49
Sep. 24, 1973	130	-	17	79
Dec. 30, 1973	-	23	110	23
Jan. 7, 1974	-	-	(combined - 46)	
Mar. 19, 1974	-	-	(combined - 23)	
Sep. 28, 1973	64 total 5 fecal	[membrane sample]		

a No. of coliforms (MPN) per 100 ml water.
b Samples were not identified separately.
- Indicates sample not taken on that date.

APPENDIX B

GEOLOGY OF THE HASKELL CREEK BASIN

The Whitefish range of mountains, where the Haskell Creek Basin is located, was formed by uplifting during the post-Cretaceous period about sixty to one hundred million years ago (Alt and Hyndman, 1972). Faulting subsequently formed individual mountain ranges. The stratigraphic displacement of the Swan-Whitefish fault, which lies to the west of the Swan and Whitefish ranges, is believed to have created those ranges (Smith, 1963). Subsequent glaciation ten thousand years ago left exposed bedrock on over-riding peaks and areas of till in the valleys.

The major rock type of the Whitefish range is that of the Belt rock series (Barnes, 1963; Bentzin, 1960) which underlies the glacial till in lower areas and is exposed at upper elevations. The rock itself was deposited in the form of sand, silt, clay and carbonates. Metamorphosis changed these sediments to argillite; the carbonates were altered to an impure form of limestone.

The surface of the Haskell Creek drainage is covered by a thick bed of glacial till which extends up the slope to about six thousand two hundred feet. It is composed of random-sized silt, clay, gravel and one to six-inch stones (Sweeney, 1955).

No serious mining has taken place in the area. The Micho mine on Second Creek was developed approximately thirty years ago, but work done there on copper-stained quartzite is believed to have been merely exploratory (Winter Sports, Inc., 1974).

APPENDIX C

REPORT ON SOIL SURVEY OF HASKELL CREEK DRAINAGES

The following is the report on the complementary study of soil in the Haskell Creek Basin. The survey was conducted jointly by:

J.B. Seago, Soil Conservation Service

John Cloninger, Soil Conservation Service

Douglas Kikkert, Graduate Student, University of Montana

Gary Gagermeier, Graduate Student, University of Montana

It should be noted that the name "Haskell" has been rendered incorrectly as "Haskill" in this Appendix and in Appendix F.

UNITED STATES DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE

P.O. Box 766
Polson, Montana 59860

August 12, 1974

Douglas Kikkert
Dept. pf Botamy
EVST
University of Montana
Missoula, Montana 59801

Doug:

Enclosed is a brief write-up of the soil's in the Haskill Creek Study Area.

Surprisingly the two drainages have very similar soils. First Creek through the ski resort developement has a slightly higher water run-off potential. But also has a slightly higher potential for filtering waters that move through the soil profile than those of Secound Creek.

Hope this information is of benefit to your study. Let us know the results of your study.

Sincerely,

J.B. Seago
Soil Conservation Services
Polson, Montana

ss

Soils of Haskell Creek Study Area

Area 1. This area consists of approximately 90 percent moderately deep soil and 10 percent rock outcrop. The soil has a yellowish brown gravelly (45% rock fragments) silt loam surface layer, that is moderately acid, high in organic matter, low in base saturation and about 15 inches thick. The subsoil is a brown very gravelly (70% rock fragments) loam, that is slightly acid, low in organic matter, moderate to high in base saturation and about 9 inches thick. This rests on fractured Precambrian argillite rock. This soil is well drained, and moderately permeable (0.6 to 2.0 in./hr). It has formed in material weathered from the bedrock. Slopes range from 30 to 70 percent.

Area 2. This area consists of approximately 80 percent deep soils and 20 percent shallow soils. The deep soils have a yellowish brown gravelly (25% rock fragments) silt loam surface layer that is moderately acid,moderate in organic matter content, low in base saturation and about 10 inches thick. The subsoil is pale brown gravelly (50% rock fragments) loam, that is slightly acid; low in organic matter; high in base saturation; has had a small amount of iron, clay, and silt leached downward; and extends to below the 60 inch depth. This soil is well drained and moderately slow to moderate in permeability (0.2 to 2.0 in./hr.). It is formed in glacial till containing mainly noncalcarious argillites but there are occasional calcarious argillites or limestone rock fragments. A mechanical analysis of the 18 to 24 inch depth of a representative profile of this soil, indicated that the fines were composed of about 47% sand, 29% silt, and 24% clay.

The shallow soils have a yellowish brown gravelly (35% rock fragments) silt loam surface layer that is moderately acid, moderate in organic matter content, low in base saturation and about 10 inches thick. The subsoil is a pale brown very gravelly (60% rock fragment) loam that is slightly acid, low in organic matter, high in base saturation and about 8 inches thick. This rests on fractured Precambrain argillites bedrock. This soil is well drained and moderate in permeability (0.6 to 2.0 in./hr.). It is formed in a thin smear of glacial till and residium from the bedrock.

Slopes for this area range from 10 to 30 percent.

Area 3. This area consists of a deep soil. It has a yellowish brown gravelly (35% rock fragments) silt loam surface layer that is moderately acid, moderate in organic matter content, low in base saturation and about 8 inches thick. The subsoil is a pale brown very gravelly (60% rock fragments) loam or very gravelly clay loam that is slightly acid; low in organic matter; high in base saturation; has had a small amount of iron, clay and silt leached downward; and extends to below the 60 inch depth. This soil is well drained and moderately slow to moderate in permeability, (0.2 to 2.0 in./hr.). It has formed in glacial till and colluvium. Rock fragments are dominantly noncalcareous argillites. Slopes range from 30 to 60 percent.

Area 4. This area also consists of a deep soil. It has a yellowish brown gravelly (20% rock fragments) silt loam surface layer that is moderately acid, moderate in organic matter content, low in base saturation, and about 10 inches thick. The subsoil is pale brown to light gray gravelly (40% rock fragments) clay loam or very gravelly loam that is slightly acid; low in organic matter; high in base saturation; has had some iron,clay, and silt leached downward; and extends to below the 60 inch depth. A mechanical analysis of the 18 to 24 inch depth of a representative profile from this soil was composed of 35% sand, 34% silt, and 30% clay. This soil is formed in glacial till containing mainly noncalcareous argillite rock fragments. However, a few rock fragments of calcareous argillite or limestone occur randomly throughout the material. It is well drained and moderately slow to moderate in permeability. Slopes range from 5 to 25 percent.

Area 5. This area also consists of a deep soil. It has a yellowish brown gravelly (40% rock fragment) silt loam surface layer that is moderately acid, moderate in organic matter, low in base saturation and about 15 inches in thickness. This rests on light gray very gravelly (70% rock fragments) loamy sand that is slightly acid and very low in total base elements. This soil is formed on a thin mantle over glacial stream out-wash. It is well drained and rapid in permeability. Slopes range from 0 to 10 percent slopes.

Key to Terminology Criteria

Acidity
- Slight - pH 6.1 to 6.6
- Moderate - pH 5.65 to 6.1

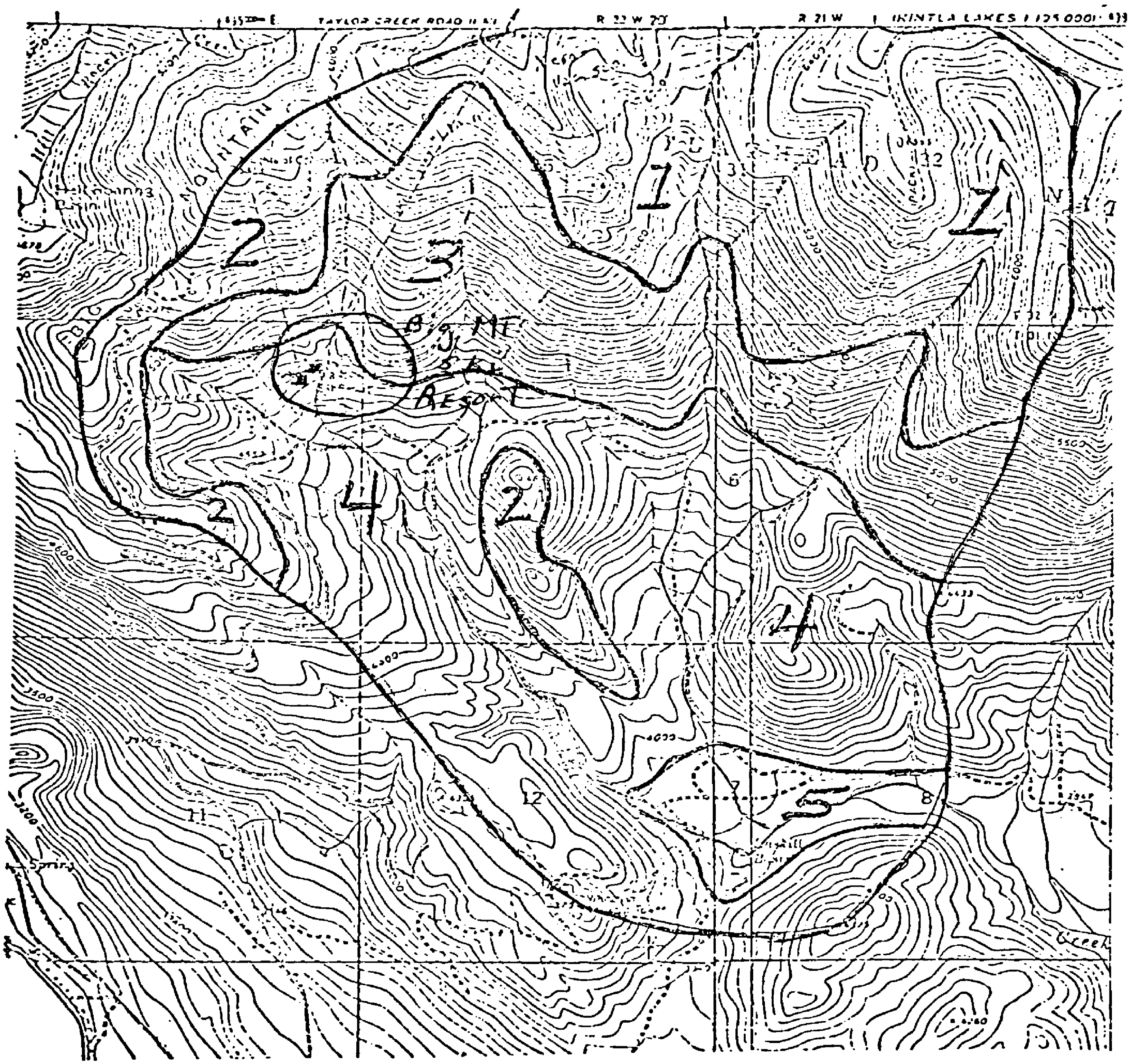
Organic Matter Content
- High $>$ 5%
- Moderate 2-5%
- Low 0-2%

Base Sateration (of clay fraction)
- High $>$ 85%
- Moderate 50-85%
- Low $<$ 50%

Permeability
- Rapid $>$ 6.0 inches per hour
- Moderate 0.6 to 2.0 inches per hour
- Moderately slow 0.2 to 0.6 inches per hour

Soil Particles

Rock Fragments - pieces of rocks more than 2 millimeters in size
- Sand 0.05 to 2 MM.
- Silt 0.002 to 0.05 MM.
- Clay less than 0.002 MM.


TAYLOR CREEK ROAD
R 22 W
R 21 W
KINTLA LAKES
BIG MT
SKI
RESORT
1
2
3
4
5
12
11
Spring
Creek

APPENDIX D

WEATHER DATA:* BIG MOUNTAIN

Date	Precipitation (in.)		Temperature				Snow Depth (in.)	
			Maximum		Minimum			
	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
1973								
Nov. 23	4	5	24	31	16	19	52	20
Dec. 17	11	0	29	37	27	34	95	28
Dec. 29	1	Trace	13	26	5	12	108	37
1974								
Jan. 20	4	3	30	35	10	22	125	38
Feb. 16	2 1/2	1 1/2	25	32	20	29	150	60
Apr. 4	2	1	35	47	12	29	181	64
Apr. 8	Trace	Trace	32	43	15	22	180	61
Apr. 11	Trace	0	40	54	24	34	177	57

Source: U.S. Weather Bureau, Glacier International Airport, Kalispell, Montana.

WEATHER DATA
GLACIER INTERNATIONAL AIRPORT

Date	Weather	Cloud Cover (%) Day	Cloud Cover (%) Night	Temperature (°F) Max.	Temperature (°F) Min.	Precipitation (in.)
1973						
Sep. 25	--	80	70	59	35	Trace
Sep. 26	--	90	60	59	29	-
Sep. 27	Ground fog	-	-	70	30	-
Oct. 11	Rain shower	100	100	49	35	.04
Oct. 12	--	100	90	54	41	Trace
Oct. 13	Rain	100	100	56	44	Trace
Nov. 21	Snow	100	100	33	20	.06
Nov. 22	Snow	100	100	34	18	.03
Nov. 23	Snow	60	80	27	9	.01
Dec. 15	Rain	100	100	38	30	.07
Dec. 16	Rain	100	100	45	34	.43
Dec. 17	Rain	100	100	46	34	.04
Dec. 27	Snow	80	90	30	21	.04
Dec. 28	Snow	100	100	25	13	.08
Dec. 29	Snow	90	90	22	7	Trace
1974						
Jan. 18	Snow, rain	100	90	36	25	.09
Jan. 19	Snow, rain	100	100	40	32	Trace
Jan. 20	--	100	90	34	26	Trace
Feb. 14	--	80	80	45	30	-
Feb. 15	--	100	90	40	26	Trace
Feb. 16	Snow, rain	100	100	37	31	.22
Apr. 2	Drizzle	100	100	43	34	.09
Apr. 3	Rain	100	90	45	33	.01
Apr. 4	Rain	100	100	48	31	Trace
Apr. 6	Rain	100	100	48	38	-
Apr. 7	Snow	90	80	52	34	Trace
Apr. 8	--	70	60	57	25	-
Apr. 9	Rain	100	100	56	39	-
Apr. 10	Rain	90	90	57	40	-
Apr. 11	Rain	100	100	47	38	-
Apr. 22	Rain	100	80	56	29	Trace
Apr. 23	--	50	50	73	40	Trace
Apr. 24	--	30	20	75	54	-
May 5	--	20	40	72	32	-
May 6	--	90	90	69	47	-
May 7	Rain	100	90	60	40	Trace
May 12	Rain	100	100	48	36	.24
May 13	Rain	100	100	45	37	Trace
May 14	--	100	100	50	34	.03

APPENDIX E

SNOW MEASUREMENT*

TALLY LAKE DISTRICT
FLATHEAD NATIONAL FOREST

Year	Jan 1	Feb 1	Mar 1	Apr 1	Apr 15	May 1	May 15	Jun 1
1942	-	-	-	63	-	35	-	-
1943	-	-	-	90	-	49	-	-
1944	-	-	-	60	-	39	-	-
1945	-	-	-	70	-	83	-	-
1946	-	-	-	89	-	70	-	-
1947	-	-	-	89	-	69	-	-
1948	-	-	-	87	-	73	-	-
1949	-	-	-	93	80	57	19	-
1950	-	-	-	111	-	91	-	-
1951	-	-	82	85	-	55	-	-
1952	-	-	83	92	-	52	-	-
1953	-	-	79	77	-	70	-	-
1954	-	-	88	102	-	88	-	-
1955	-	-	63	74	-	73	-	-
1956	-	-	92	94	-	68	-	-
1957	-	-	84	81	-	75	-	-
1958	-	-	81	78	-	82	-	-
1959	-	-	93	98	-	88	-	-
1960	-	-	88	88	-	81	-	-
1961	-	-	87	85	-	83	-	-
1962	-	-	77	82	-	62	-	-
1963	-	-	69	67	-	60	-	-
1964	38	68	70	98	-	88	89	53
1965	78	83	94	95	-	77	58	38
1966	36	66	76	68	-	57	36	-
1967	62	92	94	110	-	95	85	41
1968	41	60	66	76	-	60	47	23
1969	63	92	86	78	-	60	18	6
1970	28	77	83	79	-	-	35	-
1971	64	-	86	-	-	71	42	14
1972	68	95	-	-	99	-	-	-
1973	-	62	-	-	-	60	-	-
1974	68	-	113	116	-	102	91	80

* Depth, in inches, on or about the dates indicated.

APPENDIX F

STREAMFLOW STUDY
HASKELL CREEK BASIN

The following is the report of the complementary study of streamflow in the Haskell Creek Basin. The survey was conducted jointly by:

Robert Delk, Hydrologist, Flathead National Forest

Gary Gagermeier, Graduate Student, University of Montana

Douglas Kikkert, Graduate Student, University of Montana

It should be noted, again, that the name "Haskell" has been rendered incorrectly as "Haskill" in this Appendix.

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
FLATHEAD NATIONAL FOREST
Kalispell, Montana 59901

REPLY TO: 2500 May 31, 1974

SUBJECT: Water quality study in Haskill Basin

TO: Gary Cagermeier, Botany Department
University of Montana
Missoula, Montana 59801

The current water quality study in the Haskill Basin area includes streamflow as one of the parameters considered. Discharge at the time of sampling can be accomplished with a current meter. Continuous records are not available for the two streams in the study; thus, extrapolation is required in order to compute mean monthly flows.

Mean annual precipitation and runoff can be calculated using methodology discussed by Farnes (1972). Mean annual precipitation lines are illustrated on the map (Figure 1). Mean annual runoff is then obtained from Figure 2 (Farnes 1972). The results are presented in Table 1.

TABLE 1 - Mean Annual Precipitation (MAP) and Runoff (MAR) on 1st Creek and 2nd Creek.

1ST CREEK

(1) ZONE	(2) MAP (ins.)	(3) MAR (feet)	(4) ACRES	(5)=(3)X(4) ACRE FEET
X	55	2.5	361	903
Y	45	1.75	557	975
Z	35	1.08	350	379
TOTAL			1268	2257

2ND CREEK

(1)	(2)	(3)	(4)	(5)
A	65	3.17	96	304
B	55	2.5	736	1840
C	45	1.75	553	968
D	35	1.08	342	369
TOTAL			1727	3481

The next step is to determine mean monthly flows for 1st and 2nd Creeks based on the mean annual runoff calculated in Table 1. This is accomplished by taking records of similar streams that have been gaged and determining what percent of the annual flow each month contributes. Al Martinson, Soil Scientist, Flathead National Forest has divided the forest into several major physiographic units. These units have many similarities among them is timing of flow. Haskill Basin is located in the area delineated as westerly aspect scarp faces. This unit includes the west side of the Swan, Missions, Flathead and Whitefish Mountain Ranges. Streams with continuous records in this unit include Twin, Lower Twin and Spotted Bear River. Those values are presented in Table 2.

TABLE 2 - Percent of Annual Runoff by Months for Three Similar Streams.

Size	Lower Twin 22.4 mi^2	Twin 47 mi^2	Spotted Bear 184 mi^2	Average
OCT	3	2	2	2
NOV	3	3	2	3
DEC	3	3	2	3
JAN	2	2	1	2
FEB	2	2	1	2
MAR	2	2	1	2
APR	13	14	9	12
MAY	35	38	35	36
JUN	26	25	32	27
JUL	8	6	10	8
AUG	2	2	3	2
SEP	1	1	2	1

The average monthly percent for this unit is then used to make monthly flow estimations for 1st and 2nd Creeks. These data are presented in Table 3.

TABLE 3 - Monthly Flow from 1st and 2nd Creeks (Acre Feet)

% of MAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
	2	3	3	2	2	2	12	36	27	8	2	1	
1st Creek	45	68	68	45	45	45	271	812	609	181	45	23	2257
2nd Creek	70	104	104	70	70	70	418	1252	940	278	70	35	3481

These data can also be illustrated in graphical form such as Figure 3. The values are in acre feet and represent the total flow from the watershed for a given month. If other units are desired, conversion factors will have to be applied

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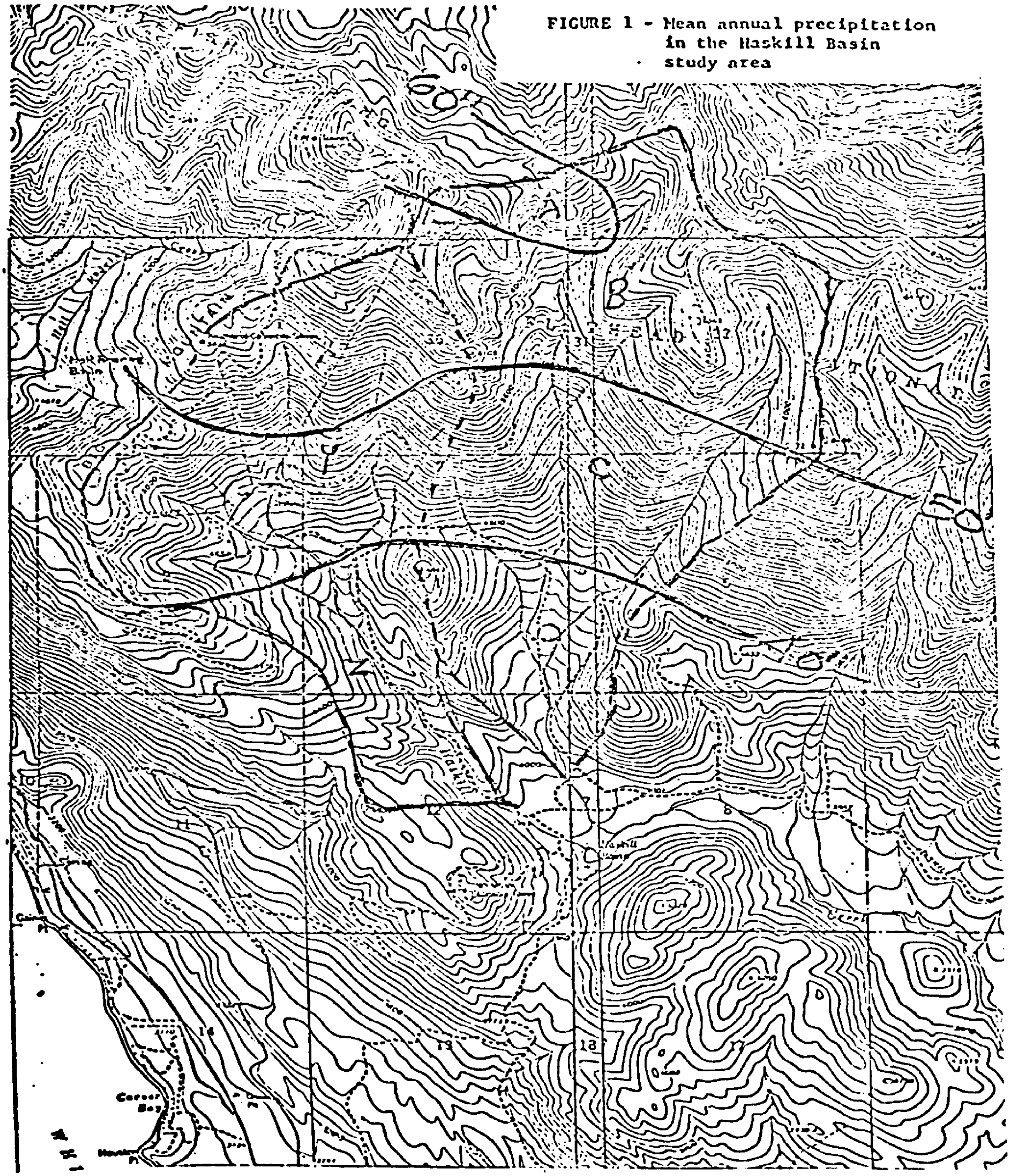

FIGURE 1 - Mean annual precipitation in the Haskill Basin study area

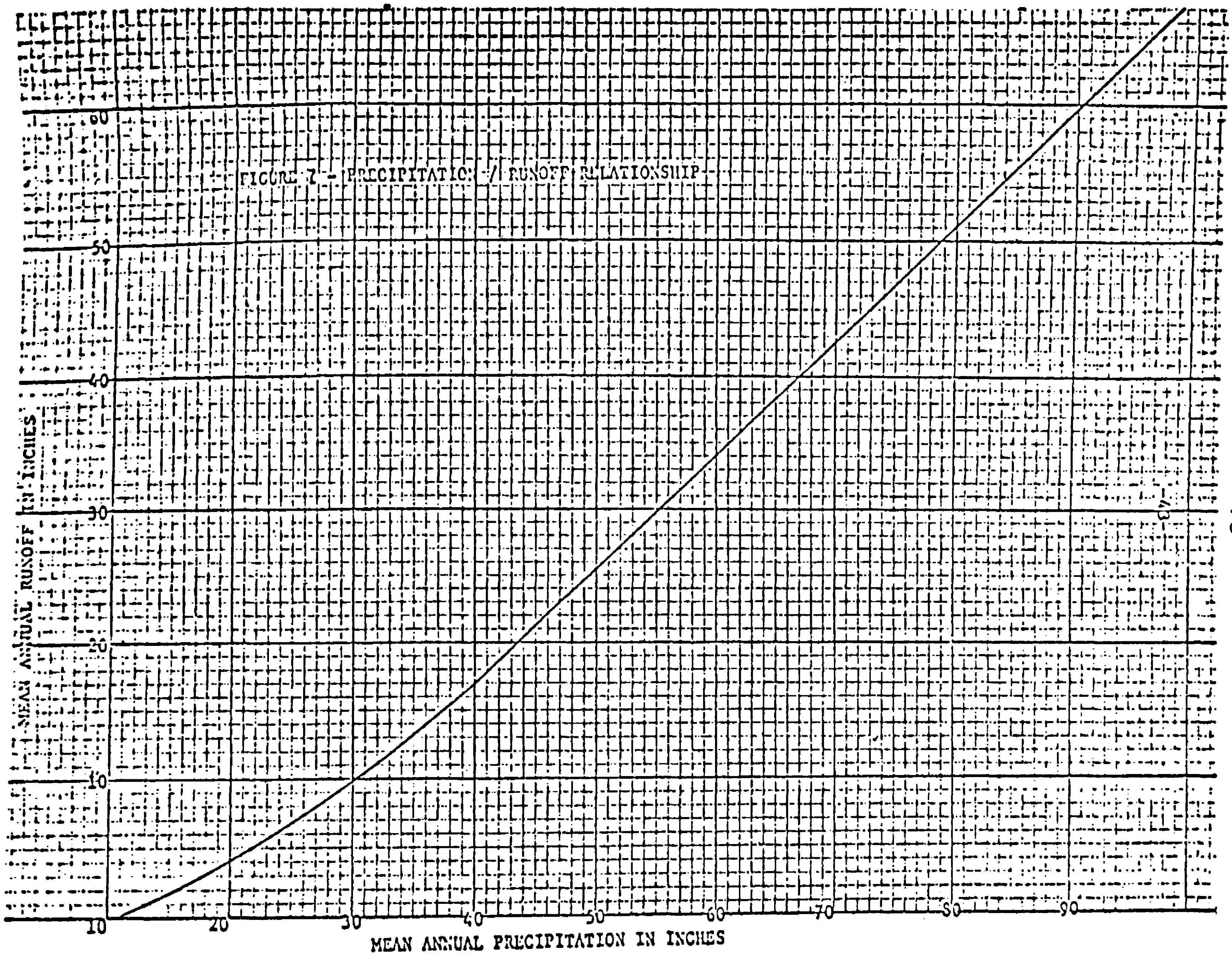

FIGURE 7 - PRECIPITATION / RUNOFF RELATIONSHIP

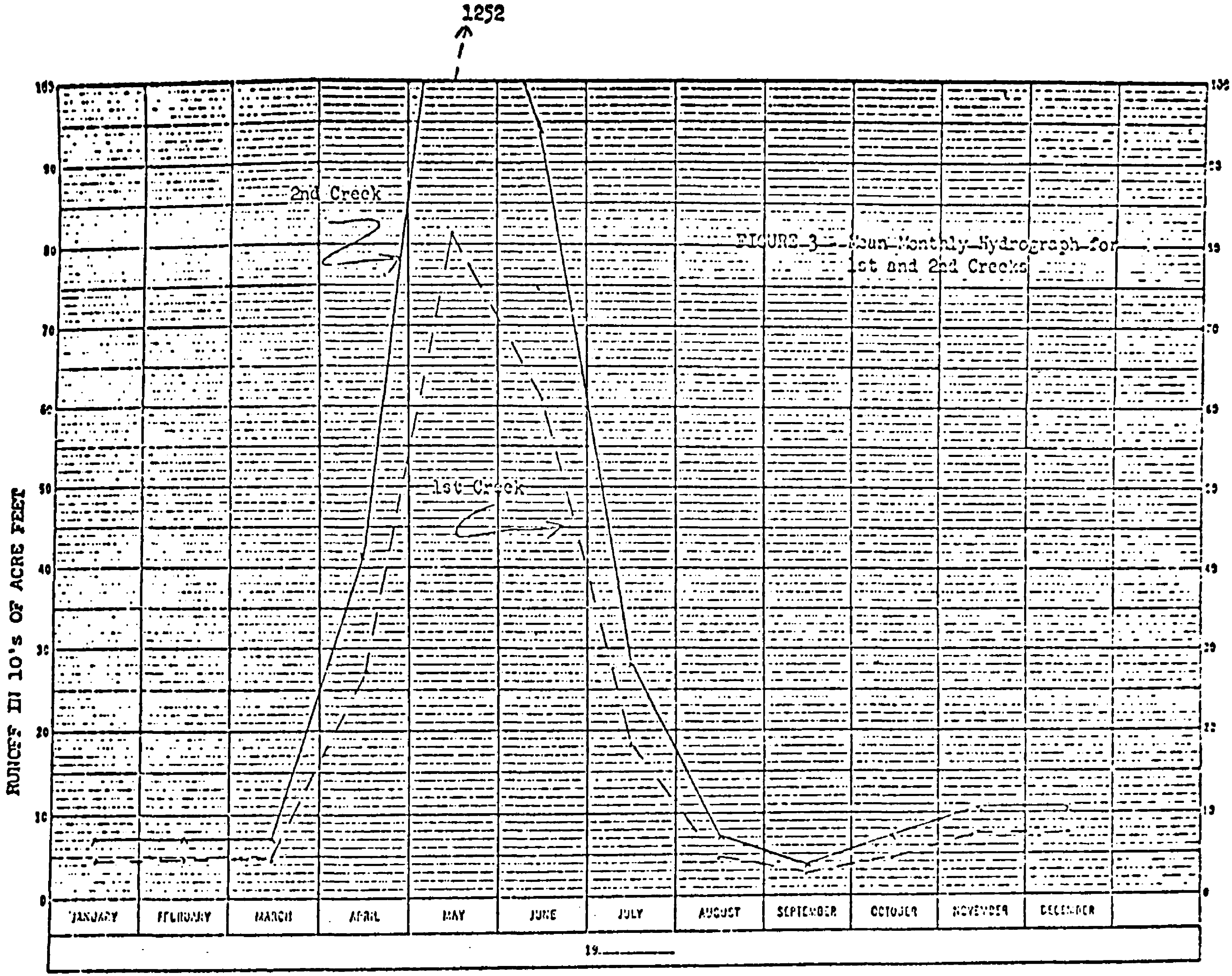

FIGURE 3 — Mean Monthly Hydrograph for 1st and 2nd Creeks