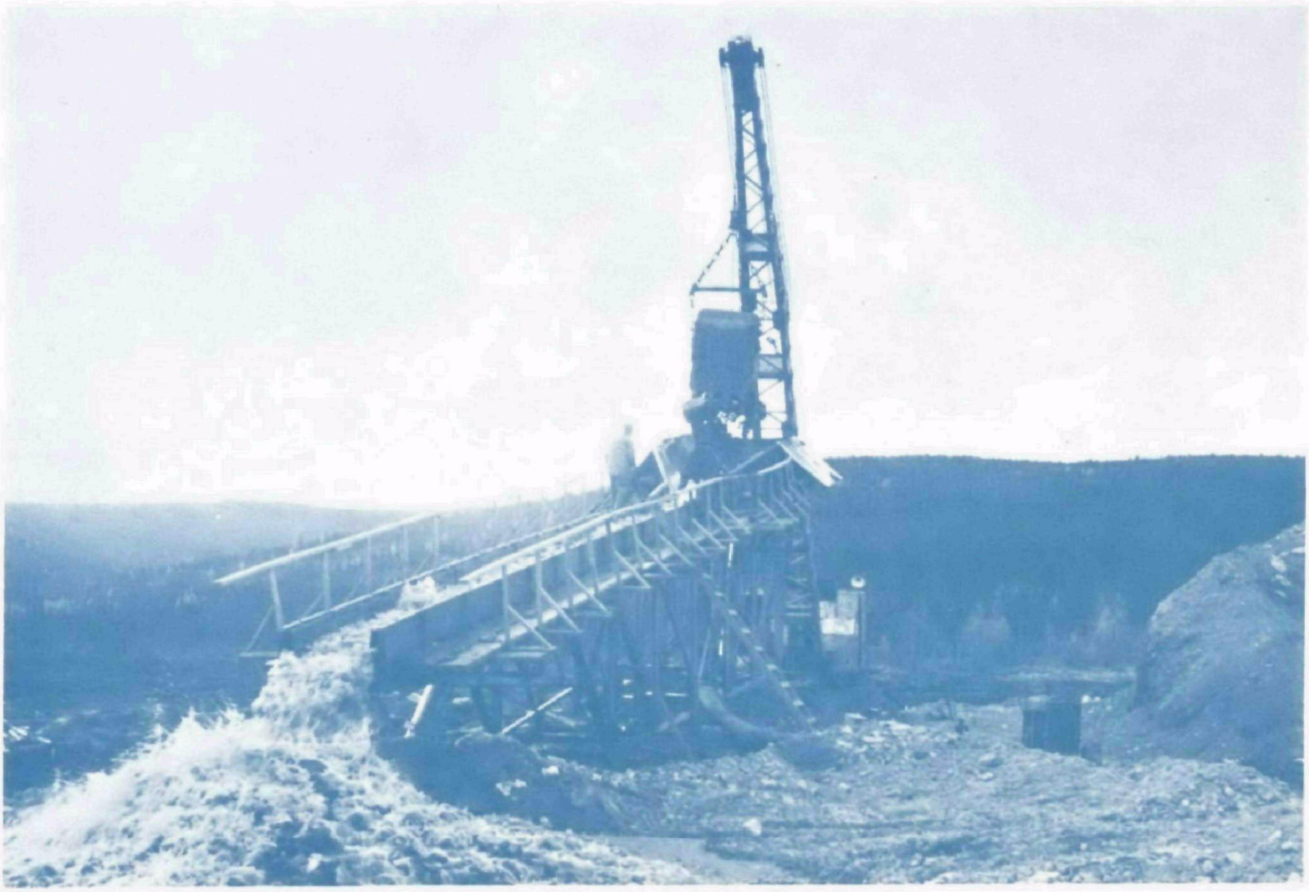
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
NORTHWEST REGION, ALASKA WATER LABORATORY

EFFECTS OF PLACER MINING ON WATER QUALITY IN ALASKA



February 1969

EFFECTS OF PLACER MINING
ON WATER QUALITY IN ALASKA

U. S. Department of the Interior
Federal Water Pollution Control Administration
Northwest Region
Alaska Water Laboratory
College, Alaska

February 1969

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INTRODUCTION

Problem

In 1965, Congress passed the Water Quality Act creating the Federal Water Pollution Control Administration (FWPCA) and requiring the establishment of water quality standards for interstate waters. Each state was given the task of adopting their own standard which, in turn, had to be acceptable to the Secretary of the Interior.

In the adoption of the Alaskan water quality standards, the following definition of pollution provided under state statute (Section 46.05.230.5) was used:

> "'Pollution' means the contamination or altering of waters of the state in a manner which creates a nuisance or makes waters unclean, or noxious, or impure, or unfit so that they are actually or potentially harmful or detrimental or injurious to public health, safety or welfare, to domestic, commercial, industrial, or recreational use, or to livestock, wild animals, bird, fish, or other aquatic life; the results of activities connected with gravel-washing plants and placer mining operations are not pollution;"

The Alaskan standards were presented to the Secretary for approval in 1967. They were accepted with three provisos, one of which was that the section of the Alaska State Statutes excluding placer and gravel mining as polluting activities be rescinded. The State was given a year to make this deletion.

In June of 1968, the Commissioner of FWPCA requested by memorandum that the Northwest Region undertake a technical study of placer mining operations in Alaska as they relate to water pollution control programs.

Objectives and Scope

The objectives of the study undertaken were to find answers to the following questions:

1. What is the nature and extent of placer mining activities in Alaska?

2. What effects do placer mining operations exert on water quality and water use?

3. What treatment and control methods are presently being used, or could be used, for the control of placer mining wastes?

The scope of this study was confined to the State of Alaska. In view of the great variation in geology, hydrology and mining techniques within the state, six representative districts were selected for study. These districts are shown on Figure 1 and are listed below:

1. Fairbanks District
2. Tolovana District
3. Iditarod District
4. Seward Peninsula District
5. Koyukuk District
6. Wiseman District

Acknowledgments

Special thanks are extended to the following agencies and institutions for their assistance in this study:

College of Earth Sciences and Mineral Industry, Univ. of Alaska
Institute of Water Resources Research, University of Alaska
Department of Mines and Geology, State of Alaska
Department of Fish and Game, State of Alaska

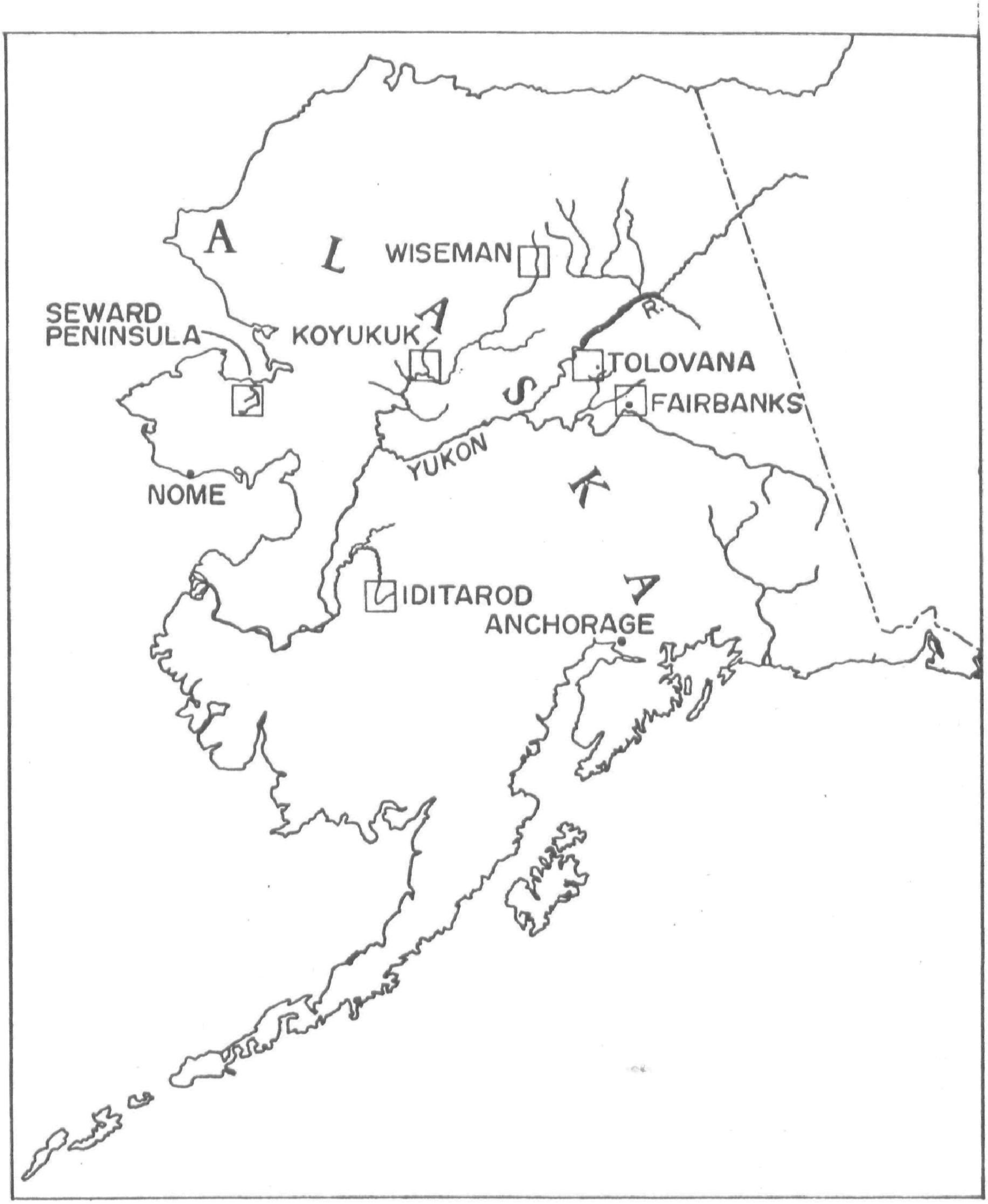


Figure 1. Index Map Showing Mining Districts Examined

SUMMARY

General Findings

1. Clear, clean and biologically productive water of excellent quality was found in most streams above the influence of mining operations and in streams where there were no mining operations.

2. Significant populations of fish and/or fish-food organisms were found associated with the clean water above mining operations, but were absent or found in significantly reduced numbers in the highly turbid and silt-laden stream below mining operations.

3. Mines and mining operations can produce physical and water quality barriers that prevent the upstream migration of fish.

4. The sediment load from one mine can interfere with the utility of the water supply for downstream mining.

5. Hydraulic stripping operations greatly increase the loading of suspended material as measured by turbidity, and can reduce the oxygen level in a stream to zero.

6. When the overburden is mechanically stripped and stockpiled, less water quality degradation results than from hydraulic stripping operations.

7. The number of mines and total gold production in Alaska has been declining for many years, and in 1967, the income from gold mining in Alaska accounted for less than one percent of the value of total mineral products, and less than 0.3 percent of the value of total natural resource products.

8. A substantial rise in the price of gold would increase the number of placer mines in Alaska.

9. Few, if any, mines provide treatment for the wastes generated from their stripping and sluicing operations.

10. Settling ponds can be effective in improving water quality by reducing turbidity.

11. The distribution of sluice box effluent over old placer mine workings via numerous small streams reduces the turbidity of the waste through the processes of sedimentation and filtration.

12. Changes in stream gradients resulting from mining operations have in some cases caused erosion to exist for many years.

Conclusions

1. Placer mining operations degrade downstream water quality as evidenced by an increase in turbidity, a reduction in dissolved oxygen (D.O.), and a resulting significant reduction of fish and fish-food organisms.

2. The major impact on water quality from placer mining comes from the hydraulic stripping operation.

3. The termination of mining operations does not necessarily eliminate water quality degradation.

4. Techniques for the control of sediments from mining operations are available but are generally not being employed at the present time.

GENERAL BACKGROUND OF PLACER MINING IN ALASKA

Description of Geology and Extent of Operations

A placer mine is an operation that extracts a valuable mineral from an alluvial or glacial deposit. In Alaska, most gold placer mines are in alluvial gravels. These gravels may rest directly on bedrock or upon an older alluvial deposit. The gold bearing gravels may in turn be overlain by more recent deposits of alluvium, loess, or products of mass wasting. In Alaska, this overlying material ranges in thickness from zero to a hundred or more feet and is commonly referred to as overburden or "muck". This overburden is usually frozen and must be thawed before it can be removed.

Gold is found in all districts of Alaska. Heiner and Wolff 1/ have compiled a list of all known mines or prospects for that portion of Alaska north of the 65th parallel. Most of these are placer, and gold is listed as a mineral found in at least 575 locations. Assuming a similar number for that portion south of 65^{O}N latitude, which roughly divides the State in half, it is estimated that there are about 1,000 locations where gold is known to occur. Although many of these are unlikely to produce much gold profitably at the present price, their widespread occurrence indicates the possible magnitude of activity should gold prices rise enough to permit mine operators to make a profit.

Development of Placer Mining Methods

Early placer mining was largely a hand operation, involving underground workings. The miners usually thawed the frozen ground with wood fires, then drift-mined to remove the paydirt during winter, and stockpiled it on the surface. During the summer, the stockpiled gravel was sluiced to remove the gold. Because of the small quantities of material being handled, the mining debris was insignificant. Later, with the development and use of equipment capable of handling large volumes of earth material, such as bulldozers, draglines, dredges, and hydraulic giants, placer mining waste material increased in volume. Figure 2 shows a sluicing operation with an elevated sluice box being fed by a dragline. A placer mining dredge working at the Hog Mine is shown in Figure 3A. Figure 3B shows a hydraulic giant which is used to strip overburden. This process produces large quantities of mining debris which degrade the water quality of the streams draining the mining area.

Figure 2. Elevated Sluice Box

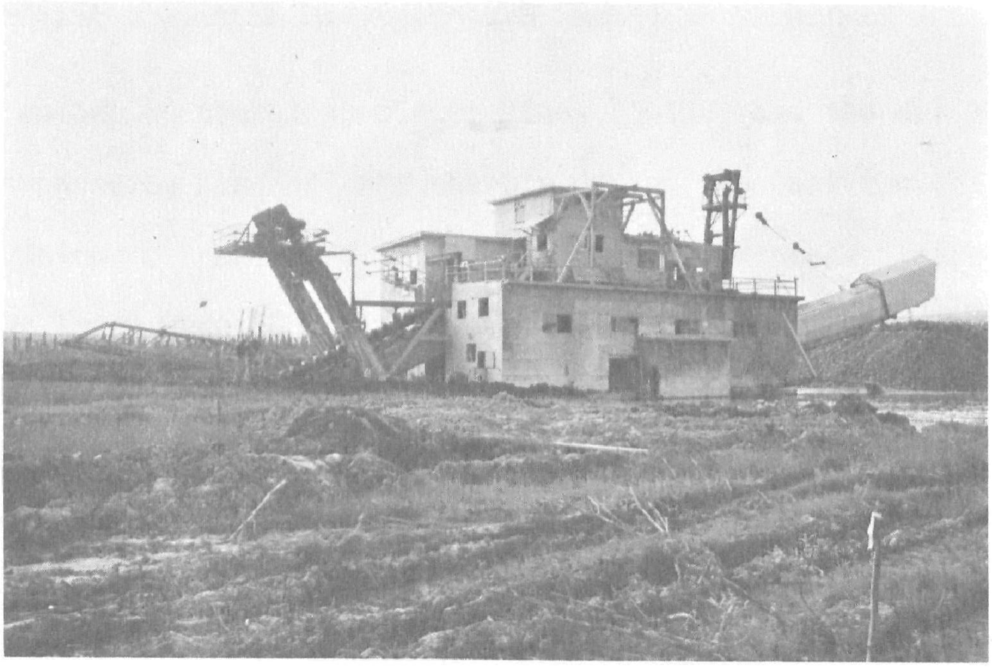


Figure 3A. Placer Mining Dredge

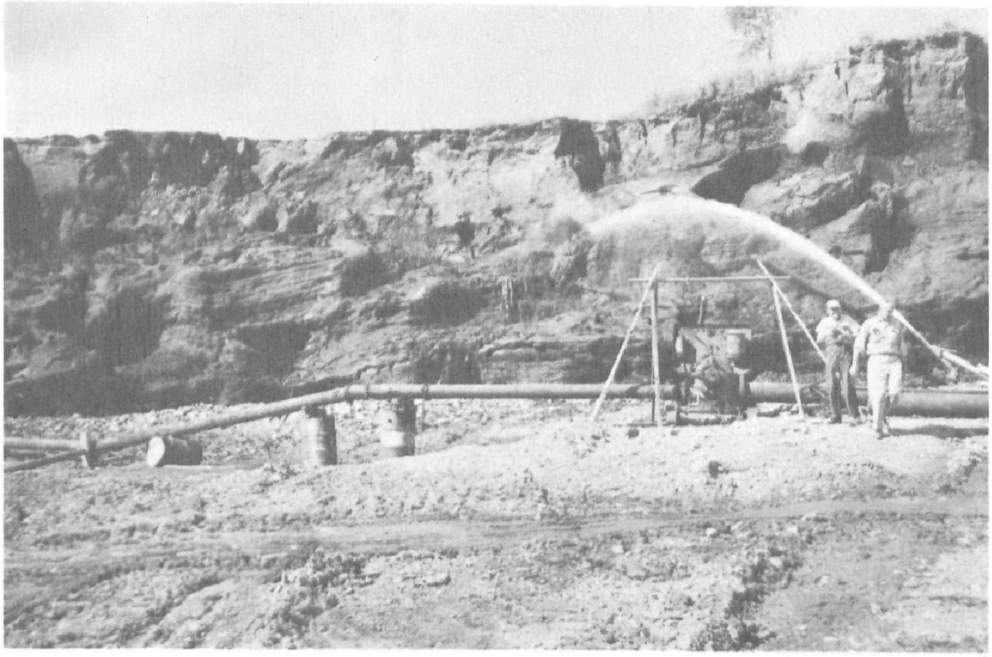


Figure 3B. Hydraulic Stripping of Overburden

Impact of Placer Mining on the Economics of Alaska

The number of operating placer mines, output and the dollar value of gold production has declined sharply during the past ten years. Table 1, which is from the U. S. Bureau of Mines Minerals Yearbook, shows that there were 50 active placer mines in 1967, with a production of 22,948 troy ounces valued at $803,180. This can be contrasted with the 1957-61 average of 93 active mines, and a production of 171,975 troy ounces valued at $6,019,132.

TABLE 1

PLACER GOLD PRODUCTION IN ALASKA [a/]

Year	Number of Mines	Gold Recovered	
		Troy Ounces	Value
1957-61 Average	93	171,975	$6,019,132
1962	66	164,966	5,773,810
1963	72	98,362	3,442,670
1964	87	56,284	1,969,940
1965	69	38,686	1,354,010
1966	55	26,532	928,620
1967	50	22,948	803,180

a/ Minerals Yearbook 1966 and 1967, U. S. Bureau of Mines, Vol. 3

The decline in gold production can, in large part, be attributed to the increasing cost of gold mining and the near uniform price of gold received by the mine owners. This decline in placer gold production has also reduced the impact of placer mining operations on water quality. This condition could change almost overnight, however, as any substantial increase in the price of gold would bring many of the existing mines and new mines into production. Without control of the effects of this industry on water quality, any major revival of placer mining would result in serious water degradation throughout many parts of Alaska.

Gold mining currently accounts for less than one percent of the value of mineral production in Alaska. Figure 4 shows the relation of gold to other mineral products and the relation of mineral products to other resource industries. It is apparent that the income and economic benefit of gold mining to the economy of Alaska is very small in comparison with these other sources of income.

The income from tourism, whose potential for development is almost unlimited [2/], is not shown in Figure 4. This rapidly growing industry will probably contribute an important part of Alaska's income in the not too distant future. The continued success of tourism and recreation will in large part depend upon the wise management of the State's water and wildlife resources.

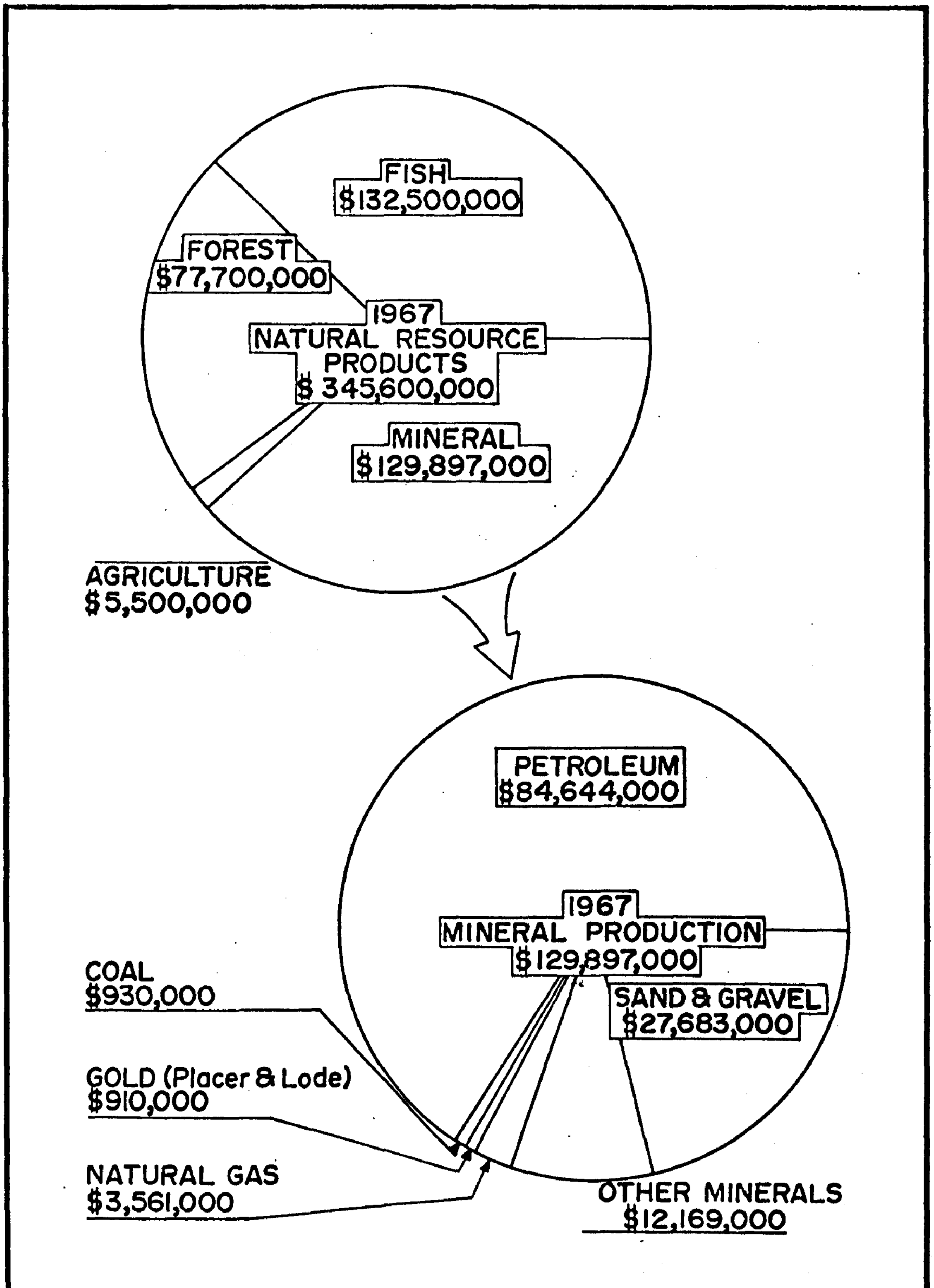


Figure 4. The 1967 Production of Gold in Relation to Alaska's Other Natural Resource Products

EFFECTS OF PLACER MINING ON WATER QUALITY AND USES

General Study Methods

Six mining districts were selected for the study. These districts are listed below and a map showing their location is shown in Figure 1.

1. Fairbanks District
2. Tolovana District
3. Iditarod District
4. Seward Peninsula District
5. Koyukuk District
6. Wiseman District

To determine the impact of mining operations on water quality, representative mining operations within each district were selected and water quality monitoring stations established above and below each mine. These stations were visited periodically and basic physical, chemical and biological characteristics were determined for comparative purposes. These characteristics are as follows:

1. Physical

    Streamflow

    Temperature

    Geological character of the streambed and bank

    Turbidity

2. Chemical

    Dissolved Oxygen (D.O.)

3. Biological

Fish

Benthos

Streamflow for the smaller streams was calculated from velocity measurements made with a Price current meter. Flow of the larger streams was obtained from the U. S. Geological Survey, or estimated. Temperatures were measured with a standard mercury column thermometer. The character of the stream bed and bank were determined by visual observations. Turbidities which gave a relative measure of suspended solids were determined in the laboratory using a Hellige [a/] Turbidimeter. The dissolved oxygen (D.O.) and pH were determined in the field by use of a galvanic cell D.O. probe and a pH meter, respectively.

The presence of fish was determined by visual observation. The benthos and bottom sediments were collected with the use of a Surber (square foot frame and net) Sampler or an Ekman (.25 $ft.^2$) Dredge. The benthic organisms were separated from the fine sediments with the use of a fine mesh (60 meshes/inch) screen, grossly identified as to kind and stage of development (form), and counted in the laboratory with a Stereo Zoom microscope. Detailed biological data for the stations can be found in Appendix A.

a/ Use of product and company names is for identification only and does not constitute endorsement by the U.S. Department of the Interior or the Federal Water Pollution Control Administration.

Mining Districts Study

Fairbanks District

The Fairbanks District is the most accessible because of the number of highways and roads; therefore, most of the study effort was concentrated in this district. Two separate areas within the district were examined. These are the Cripple Creek Area, which contains the Ready Bullion and the Eva Mines, and the Fish Creek Area which contains the Fish Creek Mine.

Cripple Creek Area

This area is located approximately 8 miles west of Fairbanks. It has a drainage basin of about 20 square miles and is bounded by low rolling forested hills. In the mining area, a layer of gold-bearing gravel overlies bedrock. This layer generally ranges from 10 to 20 feet in thickness and is overlain by a permafrost layer of silt and organic material. This overburden ranges up to 100 or more feet in thickness. Approximately 4 square miles of the Cripple Creek Area were mined by a dredge prior to 1962.

The Ready Bullion and the Eva mines are the only active mines and are located in the headwaters area. The location of these mines, the streams, and the water quality monitoring stations are shown in Figure 5.

READY BULLION MINE: This mine, located on Ready Bullion Creek, utilizes two hydraulic nozzles to strip the overburden, which ranges in thickness from 40 to 80 feet. The gold-bearing gravel layer

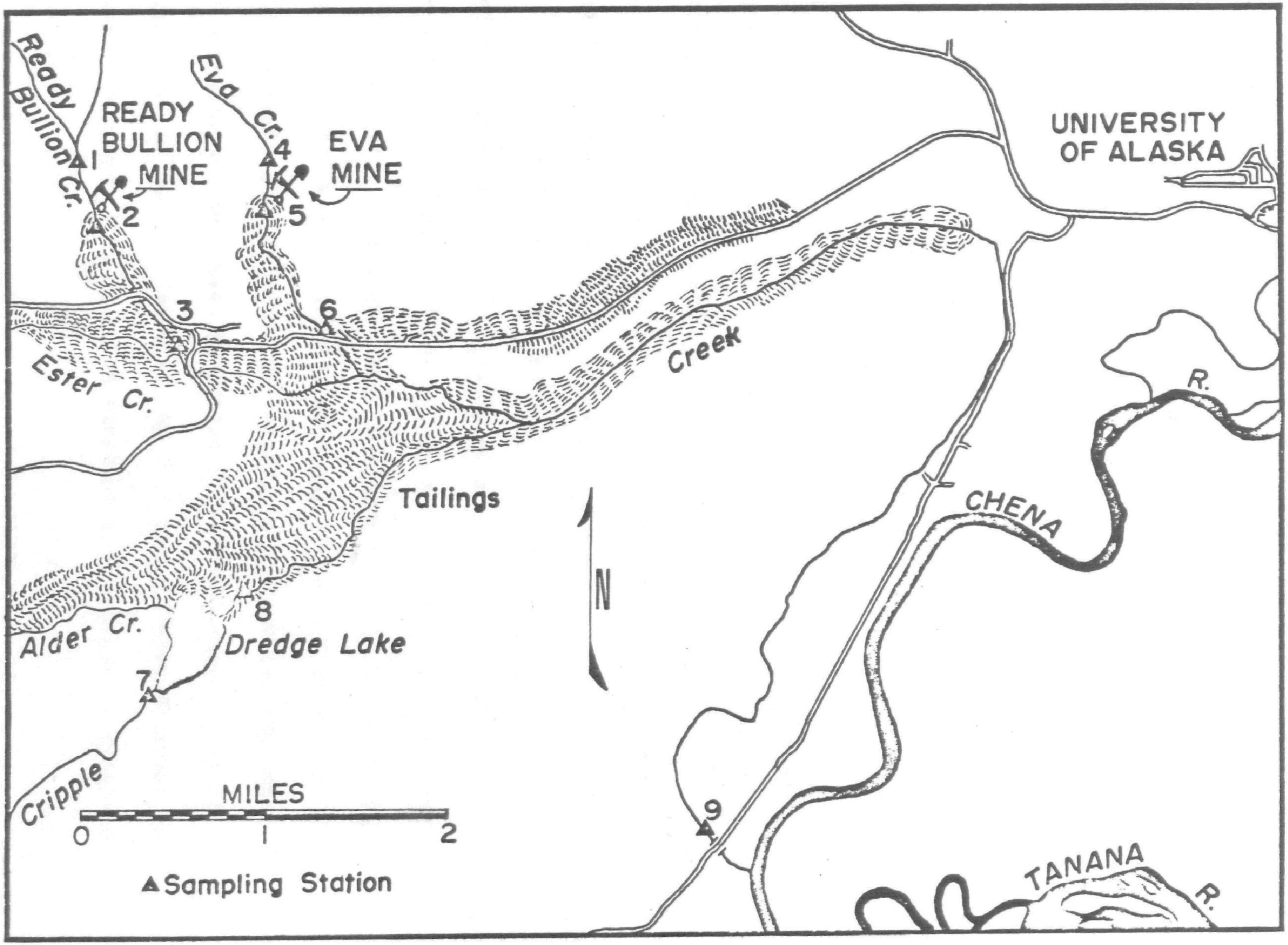


Figure 5. Cripple Creek Area

ranges in thickness from 12 to 20 feet. After stripping,the gravel is moved to a sluice box at the lower end of the operation by draglines and bulldozers. The tailings are dozed aside and piled on each side of the stream course. There are no settling ponds or waste treatment facilities, thus the fines, muck and detritus from both the stripping and sluicing operations are flushed downstream. This mine is normally operated from May to October by a crew of two.

Ready Bullion Creek, a secondary tributary of Cripple Creek, was sampled on July 25, August 1, and October 3, 1968. The physiochemical and biological characteristics were measured at three points. Station 1 was located above the Ready Bullion Mine, Station 2 was located just below the influence of the mine, and Station 3 was located approximately one-half mile downstream of Station 2. Data pertaining to these stations are summarized in Table 2.

Ready Bullion Creek above the mine at Station 1 was comprised of mostly riffles and runs, with an occasional small pool. The creek bottom was composed primarily of small rocks, gravel and coarse sand in the riffle areas, and sand and silts over gravel in the pool areas. Filamentous algae growths were most prevalent on the rocks. All of the rocks and gravel supported diatom populations and most rocks and some of the gravel supported significant populations of various forms of aquatic insects. No fish species were observed in the area; however, this is to be expected as migration is prevented

TABLE 2

READY BULLION CREEK AREA
PHYSIOCHEMICAL AND BIOLOGICAL DATA

							Organisms/sq. ft.			
Station	Date (1968)	Temp. C°	pH	D.O. mg/l	Turbidity J.T.U.	Flow cfs.	No. Kinds	No. Forms	Number	Remarks
1	7-25	18.0	8.2	9.2	1.4	0.7	7	7	42	
	8-1	9.6	7.3	11.2	1.4	1.3	7	7	360	
	10-3	2.8	7.8	11.5	4.8					
2	7-25	18.0	7.8	3.8	7,600		0	0	0	Very turbid, stripping
	8-1	12.0	7.0	0.9	22,500	3.4	0	0	0	Stripping
		12.0	7.0	0.0	40,700	3.4	-	-	-	Stripping
	10-3	2.9	7.4	10.6	77	-	-	-	-	Not operatin
3	7-25	20.0	7.6	2.4	15,800	2.7	0	0	0	Very turbid
	8-1	12.2	7.4	0.4	30,000	5.3	0	0	0	Very turbid
	10-3	3.6	7.7	10.1	110	-	-	-	-	Not operatin muddy, botto scouring

both by the vertical drop of 80 feet at the mine face and by the severely degraded water quality below the mine. From Table 2, it can be seen that the D.O. values at Station 1 were quite high, ranging from 9.2 to 11.5. It is also seen that the turbidities are extremely low. All analyses indicate that the water at Station 1 is of excellent quality.

At Station 2, a tremendous change in water quality was observed. No biological organisms were found at Station 2 nor were any fish observed. A significant decrease in D.O. concentration can be seen when comparing Stations 1 and 2. This decrease was most probably caused by a high organic content in the overburden being stripped off. The data for Station 2 shows an increase in turbidity from less than 10 to 40,000 JTU. Two measurements on August 1 show that large changes in turbidity can occur in a very short period of time. These changes are caused by variations in the number of nozzles in operation and the efficiency of stripping. From a mining standpoint, the efficiency is computed by comparing the volume of material stripped to the volume of water used. The more efficient the stripping,the greater the concentration of solids in the effluent, and the greater the effects on water quality. Figure 6A and 6B show the contrast between Ready Bullion Creek above and below the Ready Bullion Mine.

The data at Station 3 further confirms the degradation of water quality observed at Station 2. As at Station 2, no biological organisms were noted nor were any fish observed. The turbidities at

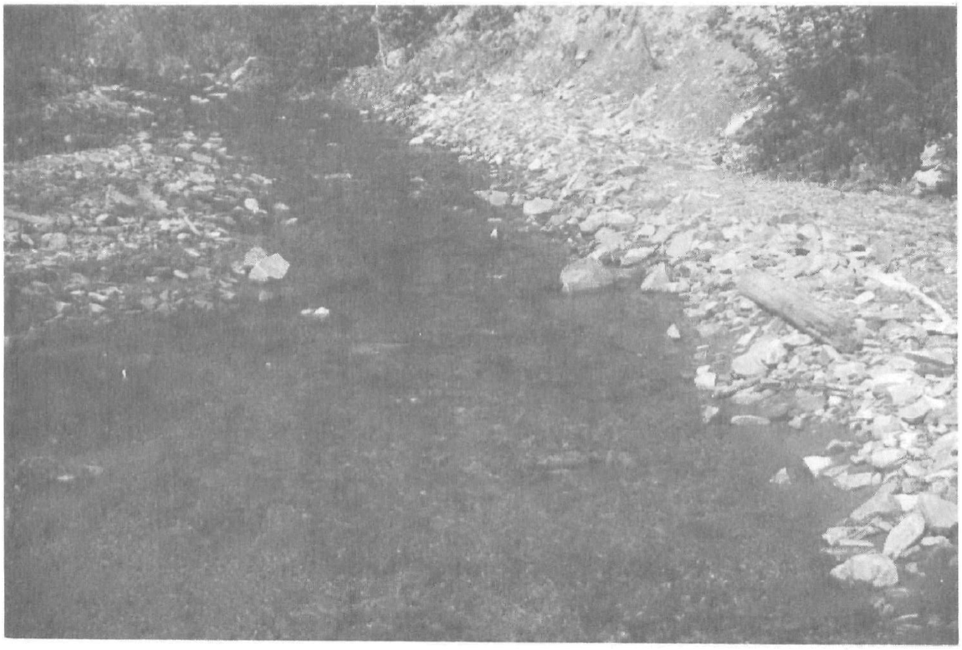
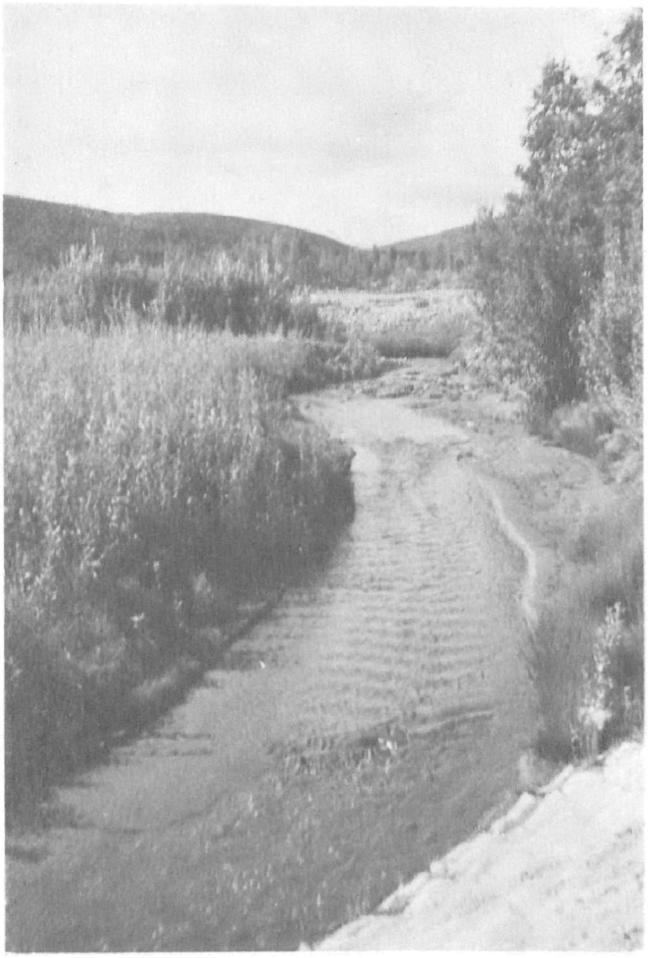


Figure 6A. Ready Bullion Creek Upstream from the Ready Bullion Mine.

Figure 6B.
Ready Bullion Creek Downstream from the Ready Bullion Mine.



Station 3 were much the same as at Station 2; however, the D.O. concentrations were slightly lower at Station 3 than those measured at Station 2.

EVA MINE: This mine is located on another small secondary tributary to Cripple Creek. The gold-bearing gravels and overburden at the Eva Mine are similar to those at the Ready Bullion Mine, the gravels being approximately 10 to 15 feet thick and the overburden from 90 to 110 feet thick.

The overburden is stripped by an "Intelligiant" [a/] type hydraulic giant. The gravel is then processed in an elevated sluice box fed by a dragline and a bulldozer. The tailings are stacked in rowed piles that parallel the stream course. Stripping operations over a period of five years, from May to October, have been required to expose about an acre of gravel. The stripping operation requires the part-time service of one man and the sluicing requires the services of two men. There is no settling or waste treatment, and the fines, muck, detritus and other debris from the stripping and sluicing operations are flushed down Eva Creek. Sluicing operations commenced in September 1968.

Three sampling stations were established on Eva Creek to evaluate the impact of the Eva Creek Mine on water quality. The location of these stations is shown in Figure 5. Station 4 was located

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on Eva Creek just above the mine. Station 5 was located directly below the mine, and Station 6 was approximately one mile downstream of Station 5. Physiochemical and biological data pertaining to these stations are tabulated in Table 3.

Eva Creek, at Station 4 above the mine flows on a gentle gradient over a soft silty bottom. The banks are covered with low overhanging brush. Referring to Table 3, it is seen that no biological organisms were found at Station 4. It is also noted that on two occasions, the turbidity at Station 4 was in the order of 200 JTU imparting a milky appearance to the creek. Even though no biological life could be found at Station 4, the D.O. concentration was 9.8 mg/l or higher on all three occasions that it was measured.

Data for Station 5, located just below the mine, shows a tremendous increase in turbidity and a total depletion of dissolved oxygen. It should also be noted that no biological organisms could be found at Station 5.

The water quality at Station 6 is very similar to that at Station 5. Here, the stream bed is composed of old gravel tailings and a layer of silt, detritus and other debris. These sediments are continually scoured by fluctuations of streamflow. Only a few rooted emergent aquatic plants were noted and no fish species or other forms of aquatic life were observed.

Dredge mining has occurred along Cripple Creek, both above and below the confluence of Ester Creek which carries the runoff of both Ready Bullion and Eva Creeks. A short distance up Cripple Creek

TABLE 3

EVA CREEK
PHYSIOCHEMICAL AND BIOLOGICAL DATA

Station	Date (1968)	Temp. C°	pH	D.O. mg/l	Turbidity J.T.U.	Flow cfs	Organisms/sq.ft. No. Kinds	No. Forms	Number	Remarks
4	7-24	15.0	8.5	9.8	29	0.3	0	0	0	Clear, Silty bottom
	8-1	9.0	7.9	10.6	230	0.4	0	0	0	Milky
							0	0	0	
	10-3	0.3	7.9	11.2	200	-	0	0	0	Milky
5	7-25	18.5	7.3	0.0	24,700	0.3	0	0	0	Very turbid, Stripping
	8-1	9.6	7.2	0.0	111,000	2.6	0	0	0	Very turbid, Stripping
6	7-24	20.0	7.3	4.0	29,000	0.4	0	0	0	Very turbid, Stripping
	8-1	10.4	7.2	0.0	97,500	2.9	0	0	0	Very turbid, Stripping

from this confluence is Dredge Lake. This impoundment on Cripple Creek has a surface area of around 425 acres. Monitoring stations were established on Cripple Creek in order to see what impact Dredge Lake has on water quality.

Station 7 was located on Cripple Creek before it enters Dredge Lake and Station 8 was located just below the lake outlet. A third station, Station 9, was located about seven miles further downstream just above the confluence of Cripple Creek and the Chena River. Figure 5 shows the location of Dredge Lake and the three sampling points. A summary of the data for these stations is given in Table 4.

No mining operations have existed above Station 7; however, due to upsets in the normal stream gradient caused by past mining operations, the creek is still eroding and depositing materials in an attempt to establish a more uniform gradient. The data shows that the turbidity of Cripple Creek above Dredge Lake, at Station 7, was relatively high with a reading of 950 JTU. The turbidity measured at Station 8 at the outfall of the lake was 6 JTU indicating a major reduction across the lake. The presence of biological organisms at Station 8 as compared to Station 7, where none were found, indicates an improvement in water quality.

The high turbidity and absence of biological life at Station 9 shows that the water quality at the mouth of Cripple Creek is greatly affected by the upstream mining operations on Ready Bullion and Eva Creeks.

TABLE 4

CRIPPLE CREEK
PHYSIOCHEMICAL AND BIOLOGICAL DATA

Station	Date (1968)	Temp. C°	pH	D.O. mg/l	Turbidity J.T.U.	Flow cfs	Organisms/sq.ft. No. Kinds	No. Forms	Number	Remarks
7	8-1	9.6	7.9	11.0	950	2.2	0	0	0	Turbid, Silt. Cutting new
							0	0	0	bed, above
8	8-1	17.8	7.8	10.8	6.0	2.5	7	9	966	Clear,Red/ Brown. Diatoms
							5	5	684	pm rpcls
9	7-25	21.0	7.8	7.2	6,050	5.5	0	0	0	Turbid, Silt, Fine sand,
	8-1	13.4	7.5	5.0	22,500	9.6	0	0	0	detritus and debris
							0	0	0	
	10-3	2.5	8.1	10.5	390	-	-	-	-	Muddy, bottom eroding

Fish Creek Area

The Fish Creek Area is located about 20 miles northeast of Fairbanks. It is in an area of low hills similar to that of Cripple Creek. The upper valley is about one-half mile wide and about three miles long, and is forested with black spruce and some deciduous species. Gold occurs in a 10 to 15 foot thick layer of gravel that overlies bedrock. This gravel layer is generally overlain by 8 to 10 feet layer of permafrost.

The Fish creek Area has been dredge-mined except for the last few claims at the head of the watershed. The only active placer mine in the watershed is at the head of Fish Creek on a small tributary stream. The location of this mine, the streams, and the water quality monitoring stations are shown in Figure 7.

FISH CREEK MINE: Stripping at this mine is accomplished by two hydraulic giants. After the overburden has been stripped off, bulldozers move the gravel to a dragline where it is lifted to an elevated sluice. Tailings are piled along the stream bank below the sluice. The mine is generally operated from May through October with a crew of eight men.

Six water quality monitoring stations were located on Fish Creek and the Little Chena River to assess the impact of the Fish Creek Mine on water quality. Station 1 was established immediately upstream from the mine, Station 2 approximately three miles below the mine, Station 3 further downstream below the confluence of Fairbanks Creek, Station 4 just above the confluence with the Little Chena River, Station 5 on the Little Chena River just upstream

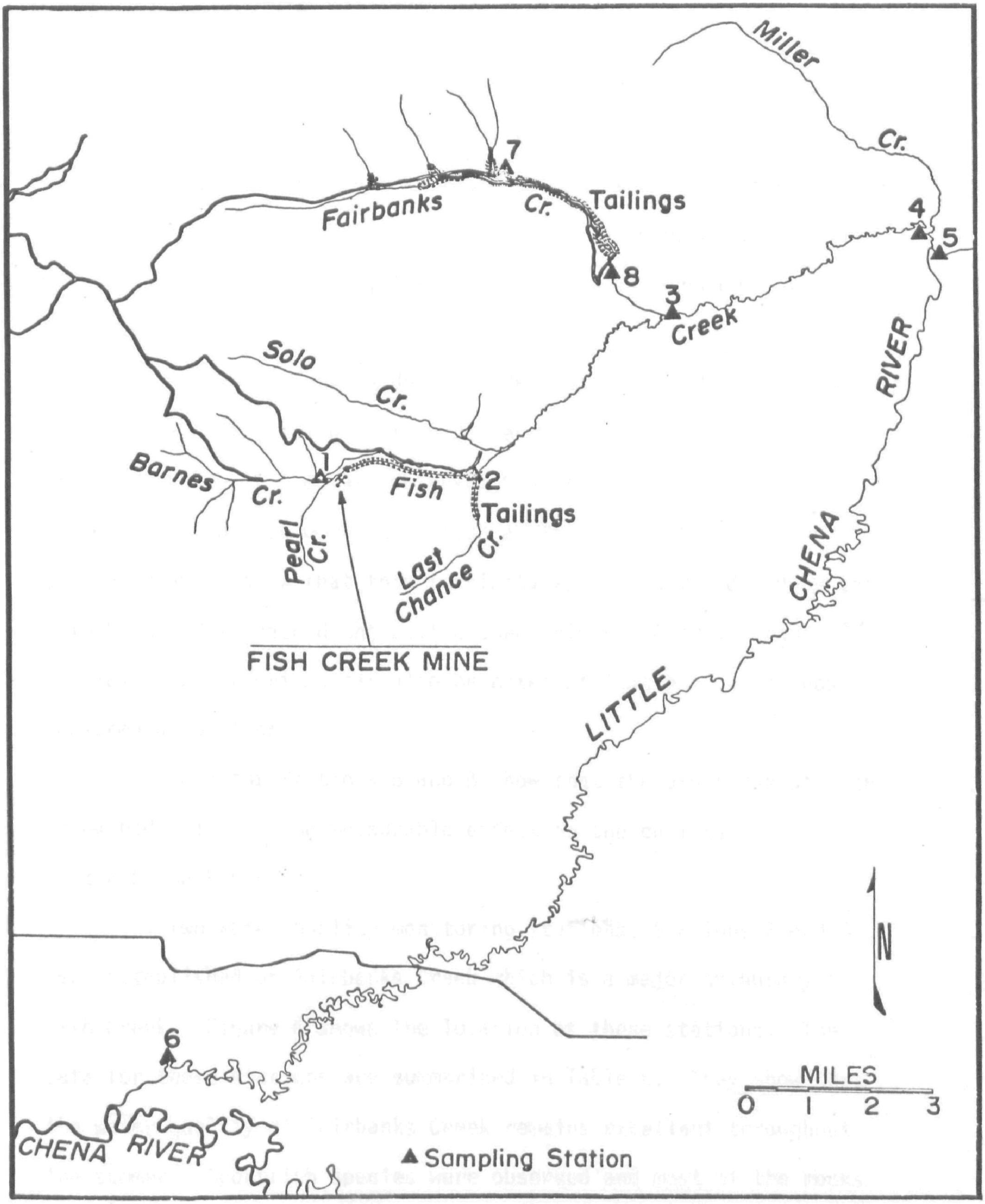

Figure 7. Fish Creek Area

from the mouth of Fish Creek, and Station 6 approximately 32 miles downstream. The data for these stations are summarized in Table 5.

The data contained in Table 5 shows that the water quality of Fish Creek at Station 1, above the mine, was generally excellent with high dissolved oxygen, low turbidity and an abundance of biological organisms.

Below the mine, a definite degradation of the water quality can be seen. At Station 2, turbidities ran as high as 6,000 and a slight decrease in D.O. was observed over that measured at Station 1. Although turbidities were quite high at Station 2, the data from Station 3 and 4 show that this turbidity was greatly reduced by the time Fish Creek reached the Little Chena River. A great reduction in biological organisms can also be noted at Station 2 over those measured at Station 1.

Data for Stations 5 and 6 show that the discharge of Fish Creek had little or no measurable effect on the quality of the Little Chena River.

Two water quality monitoring stations, Stations 7 and 8, were established on Fairbanks Creek which is a major tributary of Fish Creek. Figure 6 shows the location of these stations. The data for these stations are summarized in Table 6. They show that the water quality of Fairbanks Creek remains excellent throughout the summer. Sportfish species were observed and most of the rocks and exposed gravel supported diatom or green algae populations in addition to aquatic insects.

TABLE 5

FISH CREEK AREA
PHYSIOCHEMICAL AND BIOLOGICAL DATA

Station	Date (1968)	Temp. C°	pH	D.O. mg/l	Turbidity J.T.U.	Flow cfs	Organisms/sq.ft. No. Kinds	No. Forms	Number	Remarks
1	7-26	15.0	7.7	10.0	3.8	3.7	7	7	15	Clear, Amber color
	8-2	9.5	7.2	11.0	14	3.7	4	4	13	Slightly milky
							4	4	124	
	8-28	6.5	7.4	12.5	3.5	0.7	15	15	238	Clear
	9-20	1.5	7.6	13.8	3.5	-	-	-	-	Clear, Icy
2	7-26	15.6	7.9	9.7	103	5.8	1	1	1	Turbid and milky colored
	8-2	11.0	6.8	10.2	1,010	8.1	2	2	7	Turbid, Stripping
							2	2	16	
	8-28	10.0	6.7	10.8	6,000	9.2	0	0	0	Very turbid, Stripping
							0	0	0	

Continued on next page

TABLE 5 (CONT.)

FISH CREEK AREA
PHYSIOCHEMICAL AND BIOLOGICAL DATA

							Organisms/sq.ft.			
Station	Date (1968)	Temp. C°	pH	D.O. mg/l	Turbidity J.T.U.	Flow cfs	No. Kinds	No. Forms	Number	Remarks
3	8-2	9.5	7.0	11.2	152	32.7	1	1	36	Turbid, Mine stripping
							8	10	112	
4	8-2	9.0	6.9	10.7	73	43.4	3	3	1,144	Very milky
							3	4	101	
5	8-2	8.0	6.9	11.0	0.6	109	4	5	40	Clear. Too deep. Sample not representative of Benthos
6	8-2	11.0	6.8	10.4	6.0	-	Too deep to sample properly. Milky			

TABLE 6

FISH CREEK (FAIRBANKS CREEK) AREA
PHYSIOCHEMICAL AND BIOLOGICAL DATA

Station	Date (1968)	Temp. C°	pH	D.O. mg/l	Turbidity J.T.U.	Flow cfs	Organisms/sq.ft. No. Kinds	No. Forms	Number	Remarks
7	7-26	14.3	8.3	10.0	3.8	6.0	9	9	117	Clear, Algae Diatoms, Fish
	8-28	8.8	7.3	11.6	3.0	5.1	11	11	172	Clear, Diatoms, Fish
	9-20	3.2	7.9	12.4	-	-	-	-	-	
8	8-2	13.5	8.0	10.5	3.3	6.6	5	5	20	Clear, Fish
							5	5	29	

Summary of Findings for Fairbanks District

The investigations of the placer mining operations in the Cripple Creek and Fish Creek areas show the following:

1. Clear, clean, biologically productive water of excellent quality was consistently found above the mining operations in streams examined.

2. Hydraulic stripping at the three mines examined increased the loading of suspended material, as measured by turbidity, and reduced the oxygen level in two cases to zero.

3. Significant populations of fish and/or fish-food organisms were found associated with the clear water, but were absent or found in significantly reduced numbers in the highly turbid and silt-laden streams below mining operations.

4. Mines and mining operations can produce physical and water quality barriers that prevent the upstream migration of fish.

5. Mines or mining operations on Cripple Creek have changed the stream gradient to such a degree that water quality degradation from erosion has existed for many years after the mining operations were terminated.

6. The lower ten miles of Cripple Creek and its tributaries, and at least seven miles of Fish Creek, are seriously degraded from present mining operations.

7. A settling pond, such as Dredge Lake on Cripple Creek, can be effective in improving water quality by reducing turbidity.

Tolovana District

The Tolovana District is located approximately 50 miles northwest of Fairbanks. The investigation was concentrated in the Livengood Creek Area which contains the Amy and Livengood Mines. The area was selected because these mines operate almost in tandem on the same stream.

Livengood Creek Area

Livengood Creek is a tributary to the Tolovana River. The creek valley is about a mile wide, ten miles long, and is bounded by low hills that are forested with black spruce.

Gold occurs in a gravel layer that overlies bedrock. This layer, which ranges from about 4 to 20 feet in thickness, is mantled by up to 100 feet of overburden. The location of the mines, streams and water quality monitoring stations are shown in Figure 8 and the water quality data are summarized in Table 7.

AMY MINE: This mine is located on Amy Creek just above its confluence with Livengood Creek. The gold-bearing gravel layer is less than 100 feet wide and extends down the center of the valley. The gravel ranges from 10 to 20 feet thick and is covered with 80 to 100 feet of overburden.

The mine equipment consists of a hydraulic giant used to thaw and strip the overburden, and a bulldozer and dragline used to stockpile the gravel and feed the sluice box. The mine employs three men from May to October.

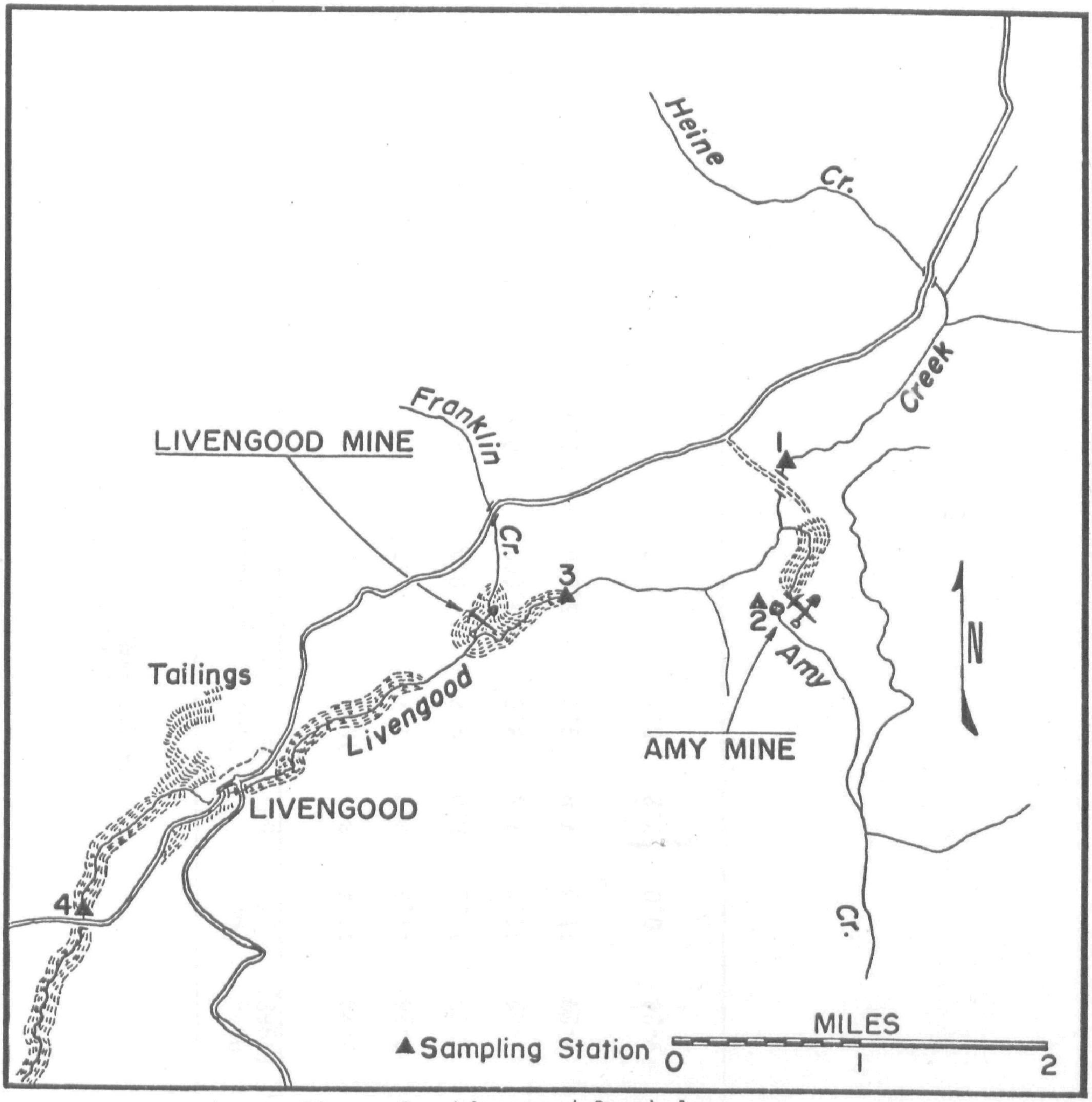

Figure 8. Livengood Creek Area

TABLE 7

LIVENGOOD CREEK AREA
PHYSIOCHEMICAL AND BIOLOGICAL DATA

Station	Date (1968)	Temp. C°	pH	D.O. mg/l	Turbidity J.T.U.	Flow cfs	Organisms/sq.ft. No. Kinds	No. Forms	Number	Remarks
1	7-29	11.4	8.1	10.8	32	0.2	9	9	197	Milky colored. Cat. work.
	9-24	-1.2	7.5	7.1	42	-	-	-	-	Rock bottom gravel
2	7-29	17.2	8.0	9.2	8.4	Pond	-	-	-	Clear
3	7-29	13.0	7.5	8.5	35,000	0.8	1	1	10	Yellow mud
4	7-29	11.0	7.8	9.0	5,620	2.9	6	6	10	Yellow clay, bottom-silty
	9-24	0.0	7.2	8.1	39	-	-	-	-	80% ice-covered

The flow of Amy Creek is so low that its flow is impounded in a small reservoir at the mine in order to accumulate sufficient water to operate. In 1968, the flow was so low that the hydraulic giant could be operated for only 40 minutes each 24 hours. The silt, muck and other debris from the stripping operation is flushed down Amy Creek into Livengood Creek. The tailings from the sluice box are piled along the stream.

Water quality monitoring Station 1 was established on Livengood Creek just above the mouth of Amy Creek and Station 2 was established at the supply reservoir at the Amy Mine. The data for these two stations represent the natural water quality that occurs upstream from mining operations. Turbidities at these two stations were quite low and dissolved oxygen was high. The rocks at Station 1 supported limited populations of diatoms and green algae. Station 3 is on Livengood Creek approximately one and one-half miles below the mouth of Amy Creek and represents water quality below the Amy Mine. Turbidities at Station 3 measured 35,000 JTU and a slight decrease in dissolved oxygen over values at Stations 1 and 2 can be seen.

LIVENGOOD MINE: This mine is located on Livengood Creek just below Station 3. The gold-bearing gravel at this mine ranges from about 4 to 6 feet in thickness and is covered by up to 8 feet of overburden. As the valley is relatively wide in this area, the gravel layer extends over a wide area. This mine generally employs a crew of four from May to October.

The overburden is stripped by bulldozers afterwhich the gravel is pushed by a bulldozer to a sluice box installed in the creek bottom. The mine operators have constructed a small reservoir to regulate the flow to the sluice box. This reservoir was almost full of silt that had been washed down from the Amy Mine.

At time of sampling, the Livengood Mine did not operate because of the low water supply and the large load of suspended solids in the water. It was reported that the water supply at the Livengood Mine has carried suspended solids that have ranged up to 12 percent by volume.

Station 4 is located on Livengood Creek some four miles below the Livengood Mine. The data for this station show that the reservoir at the Livengood Mine and the dilution from tributary streams substantially reduces the turbidity. The turbidity at Station 4, however, still exceeds 5,000 JTU and no biota or fish were observed.

Summary of Findings for Tolovana District

The investigation of the placer mining operations in the Livengood Creek area shows the following:

1. Clear, clean biologically productive water was found upstream from the influences of mining operations.

2. Hydraulic stripping on Amy Creek contributed a suspended load to Livengood Creek that resulted in turbidities in excess of 5,000 JTU at a distance of about six miles downstream.

3. Water quality degradation from stripping operations at the Amy Mine has reduced the population and diversity of fish-food organisms in Livengood Creek for more than six miles downstream.

4. The sediment load from the Amy Mine interfered with the utility of the water supply for mining downstream at the Livengood Mine.

Iditarod District

The Iditarod District is located approximately 380 miles southwest of Fairbanks in the Yukon Drainage Basin. The Otter Creek Area was selected as being representative of this mining district.

Otter Creek Area

The Otter Creek Area consists of a long, narrow, west-trending valley that is bounded by mountains that rise 2,000 feet or more above the valley floor. Slate Creek is a major tributary stream that enters Otter Creek from the south. The hills and mountains are forested with spruce and the valley floor is a muskeg.

Placer mining activity has been intense in past years; however, only the Slate and the Willow mines are still active. The gold is found in a thin gravel layer that is covered with up to ten feet of overburden.

SLATE MINE: This mine is on Slate Creek approximately one quarter mile above its confluence with Otter Creek. The overburden is stripped with a bulldozer and the gravel is fed to the sluice box with a large backhoe. The total flow of Slate Creek is passed through the sluice box. The tailings are dispersed with the bulldozer. The effluent from the sluice box flows to Otter Creek through numerous small distributaries that flow over the previous workings. This mine is generally operated by two men from May through October.

Water quality monitoring Station 1 was located on Slate Creek just upstream from the mine; Station 2 was on Otter Creek just upstream from the confluence of Slate Creek; Station 3 was on one of the distributaries of Slate Creek just before it discharges into Otter Creek; and Station 4 was on Otter Creek approximately three miles downstream . The location of the mine, the streams, and the water quality stations are shown in Figure 9, and the data for the stations are summarized in Table 8.

The bottom of Slate Creek at Station 1, above the mine was comprised of alluvial silt and sand deposits as the result of upstream mining operations in the past. Very sparse growths of algae were noted and no fish species were observed. The turbidity at Station 1 was quite low and the D.O. was high.

At Station 2, the bottom of Otter Creek was clean and covered with small rock and coarse gravel. This substrata supported appreciable populations of diatoms and moderate populations of green algae. A small benthic dwelling fish (<u>Cottus</u> sp.) was also collected.

Data for Station 3 shows the great change in water quality resulting from the mining operation. The turbidity at Station 3 measured 3,600 JTU and a decrease in dissolved oxygen over Stations 1 and 2 can be noted. While the turbidity values measured at Station 3 were high, they were significantly less than those measured below similar operations. Visual observation indicates

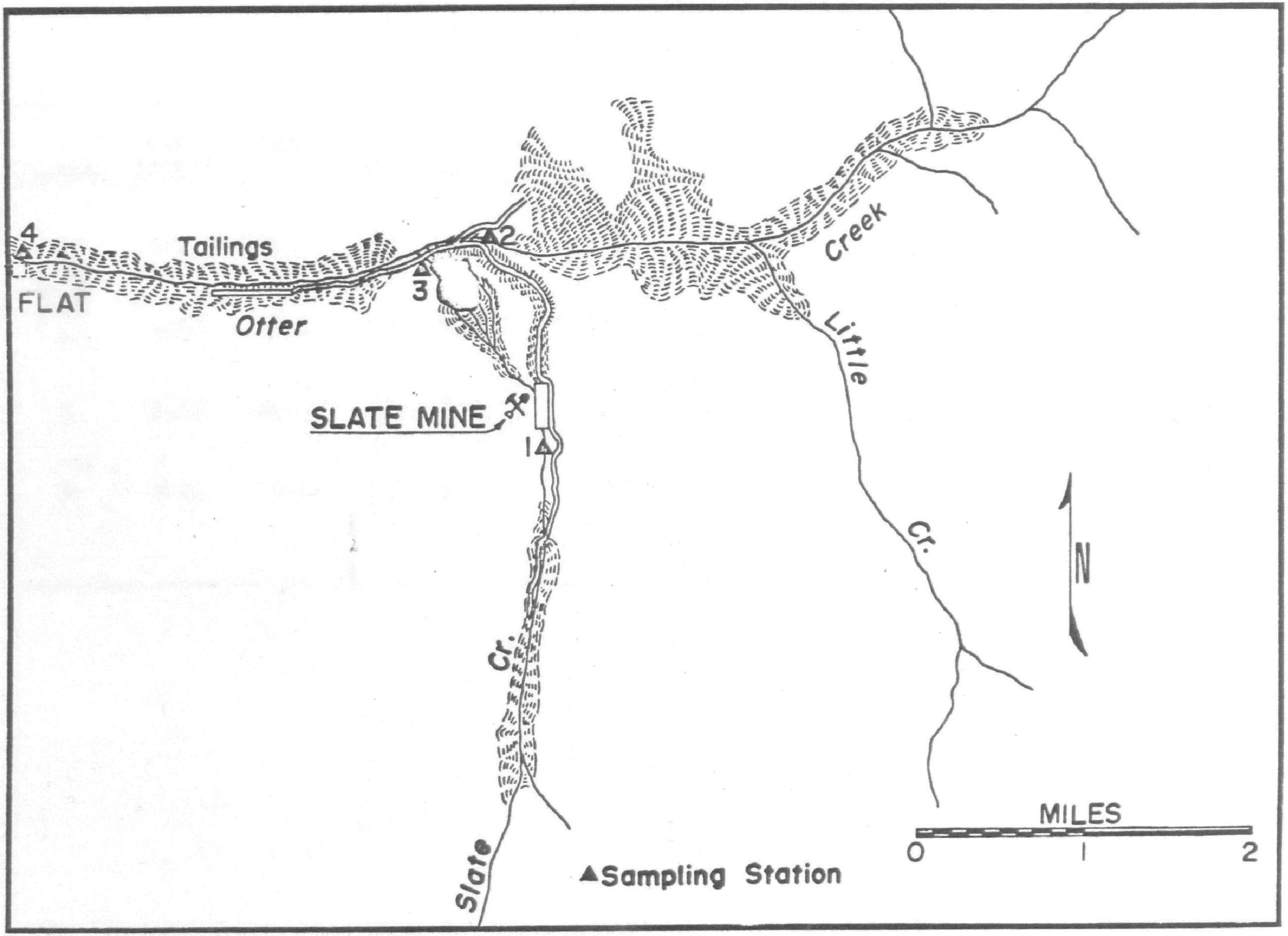

Figure 9. Otter Creek Area

TABLE 8

OTTER CREEK
PHYSIOCHEMICAL AND BIOLOGICAL DATA

Station	Date (1968)	Temp. C°	pH	D.O. mg/l	Turbidity J.T.U.	Flow cfs	Organisms/sq.ft. No. Kinds	No. Forms	Number	Remarks
1	8-12	19.0	7.9	9.9	3.5	5.8	2	2	48	Bottom silty, Very soft
2	8-12	17.0	7.6	9.7	5.0	-	8	8	99	Clear-bottom Clean, 1 fish
3	8-12	20.0	7.0	7.4	3,600	-	-	-	-	Very fine sediment
4	8-12	18.0	7.2	9.2	250	-	8	8	83	Bottom light silt cover

this reduction was accomplished by distributing the wastes generated over the old mine workings.

Station 4 data show a great reduction in turbidity over that measured at Station 3. This reduction was due to further sedimentation, filtration, and dilution of the mining waste water over and through the tailings. Station 4 also had a number of diatoms growing on silt-covered rocks.

WILLOW MINE: The Willow Mine is on Willow Creek which is a tributary of the Iditarod River. Gold occurs in a thin layer of gravel that is mantled with 4 to 8 feet of overburden. Bulldozers are used to remove the overburden and move the gravel to a dragline which feeds an elevated sluice box. Bulldozers are also used to remove and pile the tailings.

As the flow of Willow Creek is very low, the mine operators have constructed a small catch basin and recycle the water for their sluicing operation. The turbidity of the water being pumped from the catch basin to the sluice box had a turbidity of 77,000 JTU and the effluent from the sluice box was 100,000 JTU. Mercury was used to increase the efficiency of gold recovery in the sluice box. As gold was still collected in the last riffle of the sluice box, it is concluded that a high sediment load in a mine water supply reduces the efficiency of gold removal.

Summary of Findings for Iditarod District

1. Clear, clean, biologically productive water of high quality was found above the mining operations on Otter and Slate Creeks.

2. The distribution of sluice box effluent over old placer mine workings via numerous small streams below the Slate Mine reduced turbidities by providing sedimentation and filtration.

3. The efficiency of gold recovery at the Willow Mine was reduced by high turbidities and suspended material in the process water.

Seward Peninsula District

The Seward Peninsula is the large peninsula that extends westward towards Siberia, approximately 500 miles west of Fairbanks. This is an old mining district made famous by the gold production at Nome, which is located along the south shore of the peninsula.

Inmachuk River Area

The only mine examined on the Seward Peninsula was the Inmachuk Mine located in the Inmachuk River Basin. This stream, which extends about 25 miles inland, flows north and discharges into Kotzebue Sound at Deering. The area is one of low relief with rounded ridges. Tundra and muskeg cover most of the area along with some scrub willow growing adjacent to the river. The valley is narrow and the stream gradient is low, being less than 50 feet in five miles.

Gold occurs in a thin layer of gravel that is mantled with silt and muskeg. Several idle dredges and several miles of extensive tailing piles in the river and along the watercourse can be observed and bear mute testimony to the extensive mining operations in the past.

INMACHUK MINE: This mine is located on the west bank of the river about 16 miles south of Deering.

In mining, the thin layer of overburden is removed by a bulldozer and piled at the edge of the valley floor. The gravel is then fed to an off-channel sluice box supplied with water pumped from the river. The tailings are also pushed to the edge of the valley floor. One man full time and four men part time are generally employed at this mine from May to October.

The effluent from the sluice box flows through a series of six small settling ponds prior to its return to the Inmachuk River. These ponds provide a retention time of about six hours. Water quality monitoring Station 1 was established on the river upstream from the mine; Station 2 was at the discharge from the sluice box; Station 3 was at the outfall from the last settling pond; and Station 4 was on the Inmachuk River about one mile below the mine. Figure 10 shows the location of the stream, the Inmachuk Mine and the water quality monitoring stations.

The data from the stations sampled are presented in Table 9. At the time of sampling the sluicing had only been underway for a few hours. As a result, equilibrium in the ponds had not been achieved and the pond effluent at Station 3 is not representative of the discharge that would occur after a sustained period of mine operation. Conditions at Station 4 are also not representative of conditions during operation, but instead are similar to those when the mine does not run.

The bottom of the Inmachuk River at both Stations 1 and 4 was composed of loose gravel. The water was clear and colorless and there was a complete lack of diatoms and filamentous algae at these sites. Multiple sampling failed to show any fish-food organisms in the river. This lack of organisms is attributed to a shifting

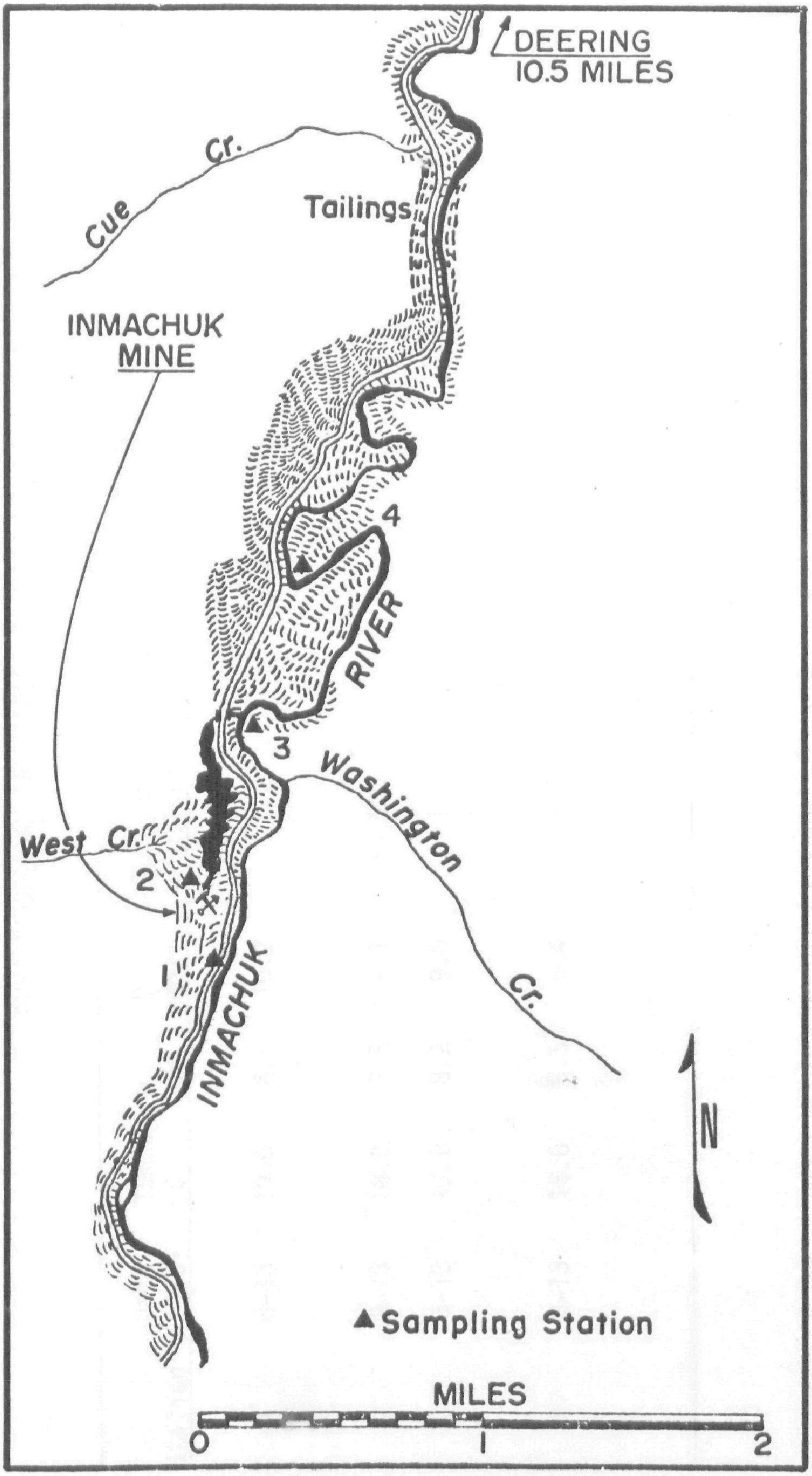

Figure 10. Inmachuk River Area

TABLE 9

INMACHUK RIVER
PHYSIOCHEMICAL AND BIOLOGICAL DATA

Station	Date (1968)	Temp. C°	pH	D.O. mg/l	Turbidity J.T.U.	Flow cfs	Organisms/sq.ft. No. Kinds	No. Forms	Number	Remarks
1	8-13	19.0	8.5	10.2	0.2	670	0	0	0	Clear, Bottom Loose, clean Fish
2	8-13	18.0	7.5	9.1	16,500	6.7	-	-	-	
3	8-13	19.0	8.2	9.0	1.5	8.0	-	-	-	Bottom thinly silted Fish
4	8-13	18.0	8.5	9.4	0.6	1,340	0	0	0	Like at Station 1 Fish

and moving action of the bottom gravels. Several sportfish and other fish species were observed in the river, and it was reported that chinook and chum salmon utilize the river for spawning. Data from Table 9 show the turbidities at both of these stations to be very low, while dissolved oxygen is very high.

A comparison of the data for Stations 1 and 2 show the impact of sluicing on water quality. The measured turbidity increase of 16,500 JTU is quite significant but still less than the values of 40,000 JTU found below mines where hydraulic stripping is employed.

Summary of Findings for Seward Peninsula District

The investigation in the Seward Peninsula District shows the following:

1. Clear, clean water was observed in the Inmachuk River above and below the Inmachuk Mine.

2. The gravel bottom above and below the mine was barren of diatoms and filamentous algae and fish-food organisms were absent.

3. An increase in turbidity of 16,500 JTU was measured across the sluice box at the Inmachuk Mine.

4. The sluice box effluent from the Inmachuk Mine receives some treatment in a series of settling ponds. The efficiency of these ponds in removing solids under sustained loading is not known.

5. Stripping wastes are stockpiled and there is no water quality degradation from the stripping operation.

Koyukuk District

The Koyukuk District is located some 250 miles northwest of Fairbanks. The only active mining operation is that done by a placer dredge operating in the Bear/Ida Creeks Area near the Hogatza River. This dredge is operated by the American Smelting Refining and Mining Company on a 2,000-acre claim that is known as the Hog Mine. The location of the streams, Hog Mine and the water quality monitoring stations are shown in Figure 11.

Bear/Ida Creeks Area

The Bear/Ida Creeks Area is a broad basin of low relief that is surrounded by forested hills and mountains. Caribou Mountain, which lies to the west, rises to an elevation of 3,000 feet and forms the headwaters area for Bear and Ida Creeks. The basin contains great expanses of swampy muskeg and numerous oxbow lakes. These lakes were formed by the Hogatza River as the channel shifted back and forth across the floodplain.

HOG MINE: This mine lies between Caribou Mountain and the Hogatza River at the man-made confluence of Bear, Ida, Dry and Moraine Creeks. Most of the overburden in the mining area was stripped during the late '30's and '40's. The remaining overburden consists of a blue clay layer that ranges from 4 to 10 feet thick. This clay and the underlying gravels are mined and processed by a large floating dredge which is shown in Figure 12A.

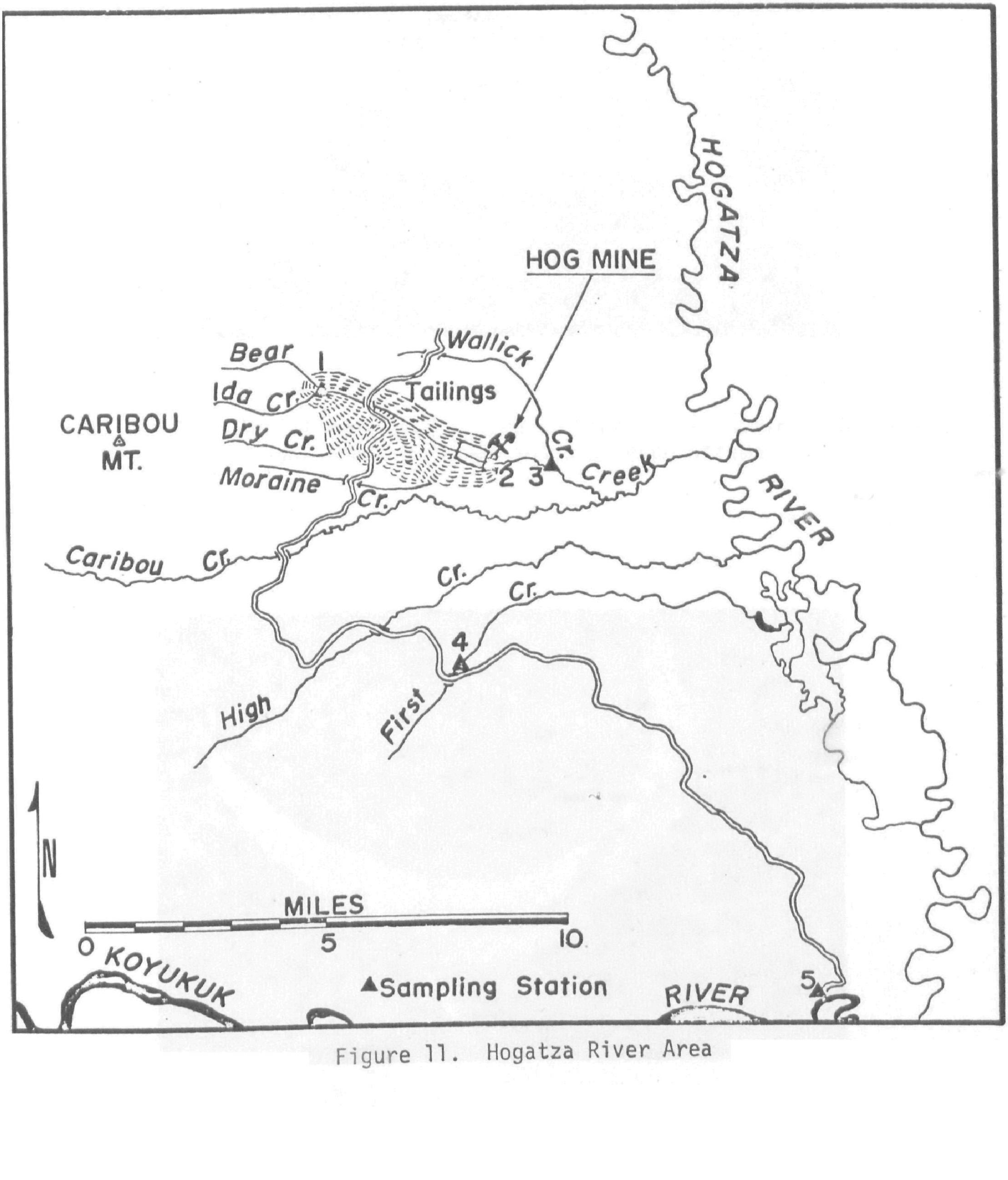

Figure 11. Hogatza River Area

Figure 12A. Aerial view of Hog Mine on Bear Creek showing the dredge, dredge pond, tailings and discharge stream.

Figure 12B. Aerial view of Bear Creek at its confluence with the Hogatza River showing turbidity produced by the dredging at the Hog Mine.

The dredge-pond water supply comes from the combined flow of Bear and Ida Creeks that is introduced at the head of the mining operation. The dredge works in a downstream direction and the discharge from the pond flows back to the Bear Creek channel through a man-made ditch. A crew of 23 men are employed at this mine which is normally operated from May to October.

Five sampling stations were established in the vicinity of the Hog Mine in order to assess the impact of this mining operation on water quality. Figure 11 shows the location of these stations. Station 1 was established on the combined Bear/Ida Creeks just upstream from the mine. Station 2 was located at the head of the dredge-pond effluent ditch. Station 3 was located on the effluent ditch 1,500 feet downstream from Station 2. Station 4 was established on the nearby First Creek to provide water quality information on a stream not affected by mining operations. Station 5 was located on the Hogatza River near its mouth, about 27 road miles downstream from the Hog Mine. The data for these stations are summarized in Table 10.

The bottom of the Bear/Ida Creek channel at Station 1 was clear, clean and covered by rock, gravel of various sizes, and sand. The rock and gravel supported moderate populations of diatoms and algae. The gravel riffle areas produced the greatest populations of aquatic insects. Fish were not observed at this station; however, grayling and other sportfish were observed and collected with sport gear in both Bear and Ida Creeks about one-fourth mile above the

TABLE 10

BEAR/IDA CREEK (HOGATZA RIVER)
PHYSIOCHEMICAL AND BIOLOGICAL DATA

							Organisms/sq.ft.			
Station	Date (1968)	Temp. C°	pH	D.O. mg/l	Turbidity J.T.U.	Flow cfs	No. Kinds	No. Forms	Number	Remarks
1	8-9	17.0	7.6	10.7	3.8	8.5	9	9	67	Clear, rock gravel and sand.
							4	4	20	Algae and diatoms on rocks.
2	8-9	-	-	-	24,000	11.0	-	-	-	Very turbid Firm bottom
3	8-9	15.5	6.5	9.0	20,000	11.9	0	0	0	Very turbid Firm
							0	0	0	Silt and gravel bottom
4	8-9	9.5	7.2	12.2	0.7	10.6	10	11	187	Clear, clean rock-gravel bottom
5	8-9	19.5	7.3	9.2	156	5500 est.	3	3	12	Soft, silty sand bottom

station. Data from Table 10 shows the turbidity at Station 1 to be low (3.8 JTU) and the dissolved oxygen to be high (10.7 mg/l).

At Stations 2 and 3, the water was extremely turbid and the bottom was very firm and covered by partially exposed rock and gravel which were firmly embedded in the substrata. The very high concentration of suspended solids could be felt by hand. Some of the eddies were completely filled with very fine silt. Algae, diatoms, and fish-food organisms were not found at Stations 2 and 3. This degradation of the biological life is coupled with very high turbidities (20,000 and 24,000 JTU) measured at these two stations.

Station 4 was established on First Creek, but High Creek was also visually examined. The water was very clear, and the bottom was clean and clear of silt and fines. The bottom of First Creek was covered with rock and gravel which provided good productive habitats for fish-food organisms. Grayling up to about 14-inches long were observed. Data for Station 4 shows a great abundance of biological life, a very low turbidity (0.7 JTU) and high D.O. (12.2 mg/l).

Data from Station 5 shows the Hogatza River to still be turbid (156 JTU) about 27 miles downstream from the mining operation. Figure 12B shows the highly turbid water of Bear Creek entering the Hogatza River.

Summary of Findings for Koyukuk District

The results of the study in this district are:

1. Clear, clean, biologically productive water of high quality was found above the Hog Mine and in undisturbed streams.

2. Very turbid, biologically unproductive water was discharged from the dredging operation at the Hog Mine.

3. Clay overburden processed with the gravel was the chief source of the very high turbidity, extremely high suspended solids concentration, and amount of mud and silt in the dredge pond effluent from the Hog Mine.

4. Sport and/or commercial fish species utilize the habitable portions of the watershed.

5. Turbidity from the Hog Mine was detected some 27 miles below the mine on the Hogatza River.

Wiseman District

The Wiseman District is located about 200 miles north of Fairbanks. It is a mountainous area criss-crossed by broad valleys. There are numerous mines in the district; however, only the Porcupine Creek Area was examined.

Porcupine Creek Area

Porcupine Creek is a short stream that is tributary to the Middle Fork of the Koyukuk River about 14 miles downstream from Wiseman. It drains a small, mountainous area and flows in a narrow V-shaped valley.

Gold occurs in a thin layer of gravel alluvium that is mantled with a thin cover of slopewash and talus. The location of Porcupine Creek, Porcupine Mine and the water quality monitoring stations are shown in Figure 13.

PORCUPINE MINE: This mine is located on the narrow valley floor of Porcupine Creek approximately two miles above its junction with the Koyukuk River. The thin overburden at the mine is stripped with a hydraulic nozzle. The gravel is fed to an off-channel sluice box by a bulldozer and the tailings are piled along the stream below the mine. The overburden and the sluice box effluent are flushed down the creek. The mine is generally operated from May to October by one man.

Sampling Station 1 was established above the mine. Station 2 was established 50 feet below the sluice effluent outfall. Station 3 was at the mouth of Porcupine Creek. The Middle Fork of the Koyukuk

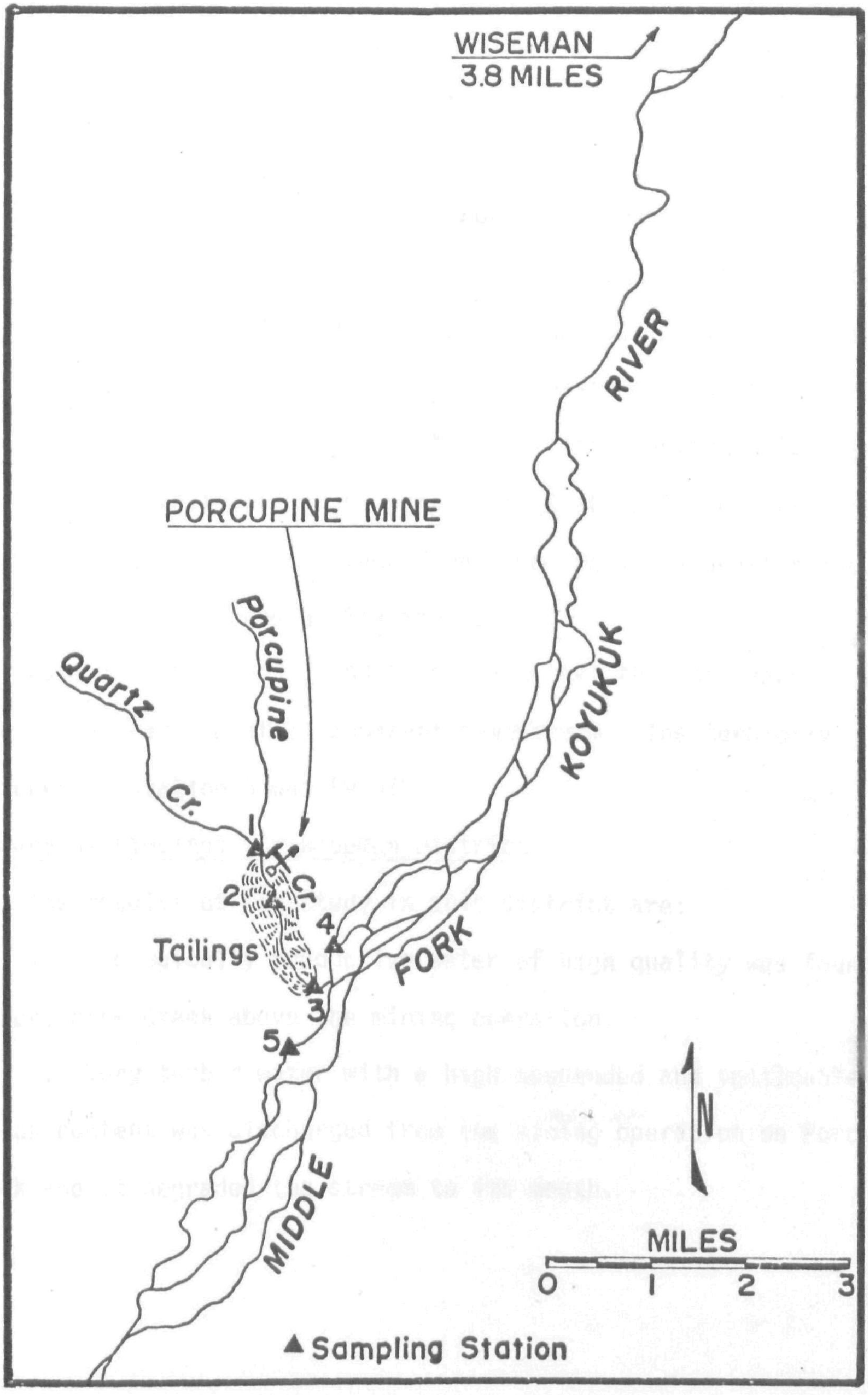

Figure 13. Porcupine Creek Area

River was sampled just upstream from the mouth of Porcupine Creek at Station 4 and below the mouth at Station 5. The data for these stations are summarized in Table 11.

The water in Porcupine Creek above the mine at Station 1 was clear and very productive of fish-food organisms. The turbidity here was very low (0.6 JTU) and the D.O. was quite high (11.8 mg/l).

At Station 2 just below the mine, a distinct change in the water quality was noted. Here, the turbidity measured 6,500 JTU. Biological organisms were not sampled at Station 2; however, measurements made at Station 3 further downstream showed a great reduction over the number measured at Station 1.

Data from Stations 3 and 5 indicate that the influence of the mine is reduced but still apparent downstream. The turbidity measured at Station 5 was 59 JTU.

Summary of Findings for Wiseman District

The results of the study in this district are:

1. Biologically productive water of high quality was found in Porcupine Creek above the mining operation.

2. Very turbid water with a high suspended and settleable solids content was discharged from the mining operation on Porcupine Creek and it degraded the stream to its mouth.

TABLE 11

PORCUPINE CREEK
PHYSIOCHEMICAL AND BIOLOGICAL DATA

Station	Date (1968)	Temp. C°	pH	D.O. mg/l	Turbidity J.T.U.	Flow cfs	Organisms/sq.ft. No. Kinds	No. Forms	Number	Remarks
1	8-22	7.5	7.3	11.8	0.6	17	11	12	156	Clear, clean gravel,rock
							6	6	22	bottom
2	8-22	7.5	6.8	11.0	6,500	-	-	-	-	Very turbid
3	8-22	12.8	7.3	10.4	350	17	1	2	2	Very murky colored
4	8-22	12.4	7.5	11.2	2.2	-	1	1	1	Sample not representative
5	8-22	12.5	7.5	11.0	59	-	4	4	5	Sample not representative
							1	1	3	River milky colored

TREATMENT AND CONTROL OF PLACER MINE WASTE

Treatment Methods in Use

Wastes from placer mines are from three types of operations: stripping, sluicing, and dredging. The dredging operation may be a combination stripping--sluicing operation or may just involve the sluicing process.

The wastes generated from the stripping process differ from sluicing wastes in being composed of finer sized particles and in containing various amounts of organic material.

In general, there is little or no treatment of wastes at operating placer mines. Of the mines examined, two systems were observed. One was a settling pond at the Inmachuk Mine and the other was at the Slate Mine where the waste was distributed across the old mine workings. Both systems provide some treatment, but data is not available to evaluate their efficiencies.

Potential Methods

There are certain techniques and practices that would provide some treatment of mine wastes improving water quality in receiving streams. These would include the following:

Stripping Operations

1. Where the overburden is shallow, the material could be stripped and stockpiled by mechanical means.

2. Where hydraulic stripping is the only feasible method of removing the overburden, the effluent could be discharged into settling ponds or diverted onto abandoned tailing dumps. Where it is not feasible to pond or spread the waste, consideration should be given to restrict stripping to periods of time when the impact of turbidity would be at a minimum. At some operations it may be desirable to reduce the efficiency of hydraulic stripping so as to reduce the amount of suspended solids and turbidity in the mine effluent.

Sluicing Operations

1. The effluent from sluicing operations could be diverted into settling ponds or spread onto abandoned tailing dumps.

2. The use of an off-channel sluice box and the reuse of water from the settling ponds would reduce the loading to the stream system.

3. Where ponding and spreading of sluice box effluent is not feasible, it may be desirable to restrict sluicing operations to particular periods of time to reduce the impact of the mine waste on the receiving stream.

Dredging Operations

1. Dredge ponds could be off-channel or the stream could be bypassed around the pond through a ditch or canal. Water diversions to the pond could be controlled so that there is no surface discharge from the pond.

2. Where possible, dredging could proceed in an upstream direction so that the subsurface outflow or leakage from the dredge pond would be filtered through the tailings prior to its return to the stream system.

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APPENDIX A

BIOLOGICAL DATA

TABLE 1A

CRIPPLE CREEK BIOLOGICAL DATA

Station	Date (1968)	Sampler	Organisms: Common Name	Family	State	Number	Remarks
1	7-25	Surber	Stoneflies	Perlodidae	Nymph	11	Moderate amounts of filamentous algae and diatoms on rock and gravel. Water clear. Bottom clean.
			Mayflies	Baetidae	Nymph	1	
			Caddisflies	Limnephilidae	Pupae	2	
			True Flies	Tendipedidae	Larvae	19	
				Simuliidae	Larvae	4	
			Miscellaneous				
			Spongue	Unknown	Unknown	3	
			Nematoda	Unknown	Unknown	2	
	8-1	Surber	Stoneflies	Perlodidae	Nymph	8	Moderage amounts of filamentous algae, diatoms, and other green algae. Water clear. Bottom clean. Raining this date.
			Mayflies	Baetidae	Nymph	1	
			Caddisflies	Limnephilidae	Pupae	1	
			True Flies	Tendipedidae	Larvae	337	
				Simuliidae	Larvae	4	
			Miscellaneous				
			Spongue	Unknown	Unknown	7	
			Nematoda	Unknown	Unknown	2	
		Ekman	True Flies	Tendipedidae	Larvae	9	Fragments of green algae.
					Pupae	1	
				Simuliidae	Larvae	3	
			Caddisflies	Limnephilidae	Pupae	1	
			Miscellaneous				
			Nematoda	Unknown	Unknown	7	

TABLE 1A (CONT.)

CRIPPLE CREEK BIOLOGICAL DATA

Station	Date (1968)	Sampler	Organisms: Common Name	Family	State	Number	Remarks
2	7-25	Ekman	-	-	-	0	Silt and detritus.
	8-1	Ekman	-	-	-	0	Silt and detritus.
	8-1	Ekman	-	-	-	0	Silt and detritus.
3	7-25	Ekman	-	-	-	0	Lots of silt and detritus.
	8-1	Ekman	-	-	-	0	Lots of silt and detritus.
4	7-24	Ekman	-	-	-	0	Soft bottom
	8-1	Ekman	-	-	-	0	composed of silt
	8-1	Ekman	-	-	-	0	and some detritus.
5	7-25	Ekman	-	-	-	0	Sand, soft silt
	8-1	Ekman	-	-	-	0	and lots of detritus.
6	7-24	Ekman	-	-	-	0	Soft "rock" bottom -
	8-1	Ekman	-	-	-	0	pools and eddys filled with silt and detritus.
7	8-1	Ekman	-	-	-	0	Detritus, rootlets. Sand and lots of silt.
		Surber	-	-	-	0	Detritus and rootlets.

TABLE 1A (CONT.)

CRIPPLE CREEK BIOLOGICAL DATA

Station	Date (1968)	Sampler	Organisms: Common Name	Family	State	Number	Remarks
8	8-1	Surber	Mayflies	Baetidae	Nymph	14	Filamentous greet
			True Flies	Ceratopogonidae	Larvae	1	algae and diatoms
					Pupae	14	on rocks and gravel.
				Tendipedidae	Larvae	83	Bottom sediments had
				Simuliidae	Larvae	455	some sand and fine,
					Pupae	365	soft silt.
			Miscellaneous				
			Nematoda	Unknown	Unknown	31	
			Coelenterata	Unknown	Unknown	2	
			Oligochaeta	Unknown	Unknown	1	
	8-1	Ekman	Caddisflies	Limnephilidae	Pupae	5	Diatoms.
			True Flies	Tendipedidae	Larvae	29	Bottom sediments
							of small gravel.
				Simuliidae	Larvae	112	Sand and fine soft
			Miscellaneous				silt.
			Nematoda	Unknown	Unknown	22	
9	7-25	Ekman	-	-	-	0	Very silty. Fine
	8-1	Ekman	-	-	-	0	sand and detritus.
	8-1	Ekman	-	-	-	0	

TABLE 2A

FISH CREEK BIOLOGICAL DATA

Station	Date (1968)	Sampler	Organisms: Common Name	Family	State	Number	Remarks
1	7-26	Surber	Mayflies	Baetidae	Nymph	3	
			Caddisflies	Limnephilidae	Larvae	1	
			True Flies	Tendipedidae	Larvae	4	
				Simuliidae	Larvae	2	
					Pupae	3	
				Empididae	Pupae	1	
			Miscellaneous				
			Flatworm	Unknown	Unknown	1	
	8-2	Surber	Stoneflies	Nemouridae	Nymph	1	
			True Flies	Tendipedidae	Larvae	7	
				Simuliidae	Pupae	1	
			Miscellaneous				
			Nematoda	Unknown	Unknown	4	
		Ekman	True Flies	Empididae	Larvae	2	
				Tendipedidae	Larvae	24	
			Miscellaneous				
			Nematoda	Unknown	Unknown	4	
			Water Bears	Unknown	Unknown	1	
	8-28	Surber	Stoneflies	Perlodidae	Nymph	23	
				Nemouridae	Nymph	10	
			Mayflies	Heptageniidae	Nymph	2	

TABLE 2A (CONT.)

FISH CREEK BIOLOGICAL DATA

Station	Date (1968)	Sampler	Organisms: Common Name	Family	State	Number	Remarks
			Mayflies	Baetidae	Nymph	9	
1	8-28		Caddisflies	Limnephilidae	Larvae	2	
				Lepidostomatidae	Larvae	1	
			True Flies	Tendipedidae	Larvae	139	
				Empididae	Larvae	23	
				Ceratopogonidae	Larvae	2	
				Psychodidae	Larvae	4	
				Tipulidae	Larvae	3	
			Miscellaneous				
			Oligochaeta	Unknown	Unknown	16	
			Mites	Unknown	Unknown	2	
			Nematoda	Unknown	Unknown	1	
			Flatworm	Unknown	Unknown	1	
2	7-26	Surber	True Flies	Tendipedidae	Larvae	1	
	8-2	Surber	True Flies	Tendipedidae	Larvae	6	
				Ceratopogonidae	Larvae	1	
		Ekman	True Flies	Tendipedidae	Larvae	3	
			Miscellaneous				
			Oligochaeta	Unknown	Unknown	1	
	8-28	Dipnet	-	-	-	0	
		Surber	-	-	-	0	

TABLE 2A (CONT.)

FISH CREEK BIOLOGICAL DATA

Station	Date (1968)	Sampler	Organisms: Common Name	Family	Stage	Number	Remarks
3	8-2	Ekman	True Flies	Tendipedidae	Larvae	9	
		Surber	Stoneflies	Nemouridae	Nymph	1	
			Caddisflies	Limnephilidae	Nymph	1	
			True Flies	Tendipedidae	Larvae	86	
					Pupae	8	
				Empididae	Unknown	2	
				Tipulidae	Pupae	1	
				Dolichopodidae	Unknown	1	
			Miscellaneous				
			Oligochaeta	Unknown	Unknown	2	
			Nematoda	Unknown	Unknown	1	
4	8-2	Ekman	True Flies	Tendipedidae	Larvae	275	
				Tipulidae	Larvae	8	
			Miscellaneous				
			Nematoda	Unknown	Unknown	3	
		Surber	True Flies	Tendipedidae	Larvae	89	
					Pupae	10	
				Empididae	Unknown	1	
			Mayflies	Heptageniidae	Nymph	1	
5	8-2	Surber	Mayflies	Heptageniidae	Nymph	19	Not representative of benthos
			True Flies	Tendipedidae	Larvae	17	
					Pupae	1	
				Empididae	Unknown	1	

TABLE 2A (CONT.)

FISH CREEK BIOLOGICAL DATA

Station	Date (1968)	Sampler	Organisms: Common Name	Family	Stage	Number	Remarks
			Miscellaneous Oligochaeta	Unknown	Unknown	2	
6	8-2	Ekman	True Flies	Tendipedidae	Larvae	2	Benthos not representative
			Miscellaneous Nematoda	Unknown	Unknown	1	
7	7-26	Surber	Stoneflies	Nemouridae	Nymph	9	
				Perlodidae	Nymph	2	
			Mayflies	Baetidae	Nymph	8	
				Heptageniidae	Nymph	46	
			True Flies	Tendipedidae	Larvae	5	
					Pupae	1	
				Simuliidae	Larvae	44	
					Pupae	1	
			Miscellaneous Oligochaeta	Unknown	Unknown	1	
	8-28	Dip Net	Stoneflies	Nemouridae	Nymph	30	
				Perlodidae	Nymph	1	
			Mayflies	Baetidae	Nymph	30	
				Heptageniidae	Nymph	1	
			Caddisflies	Limnephilidae	Pupae	7	
			True Flies	Tendipedidae	Larvae	90	
					Pupae	1	

TABLE 2A (CONT.)

FISH CREEK BIOLOGICAL DATA

Station	Date (1968)	Sampler	Organisms: Common Name	Family	Stage	Number	Remarks
				Tipulidae	Larvae	1	
				Empididae	Larvae	2	
				Psychodidae	Larvae	1	
			Miscellaneous				
			Oligochaeta	Unknown	Unknown	8	
8	8-2	Ekman	True Flies	Tendipedidae	Larvae	1	
				Simuliidae	Pupae	1	
				Empididae	Unknown	1	
			Miscellaneous				
			Nematoda	Unknown	Unknown	1	
			Mite	Unknown	Unknown	1	
		Surber	True Flies	Tendipedidae	Larvae	22	
				Simuliidae	Pupae	1	
				Empididae	Unknown	3	
			Stoneflies	Nemouridae	Nymph	1	
			Miscellaneous				
			Nematoda	Unknown	Unknown	2	

TABLE 3A

LIVENGOOD CREEK BIOLOGICAL DATA

Station	Date (1968)	Sampler	Organisms: Common Name	Family	Stage	Number	Remarks
1	7-29	Surber	Stoneflies	Nemouridae	Nymph	7	
			Mayflies	Baetidae	Nymph	35	
			Caddisflies	Limnephilidae	Larvae	1	
			True Flies	Tendipedidae	Larvae	25	
				Simuliidae	Larvae	78	
					Pupae	21	
				Tipulidae	Pupae	1	
			Miscellaneous				
			Oligochaeta	Unknown	Unknown	27	
3	7-29	Surber	True Flies	Tendipedidae	Larvae	10	
4	7-29	Surber	Mayflies	Baetidae	Nymph	1	
			True Flies	Tendipedidae	Larvae	3	
				Simuliidae	Larvae	2	
			Miscellaneous				
			Oligochaeta	Unknown	Unknown	1	
			Mite	Unknown	Unknown	1	

TABLE 4A

OTTER CREEK BIOLOGICAL DATA

Station	Date (1968)	Sampler	Organisms: Common Name	Family	State	Number	Remarks
1	8-12	Ekman	True Flies	Tendipedidae	Larvae	27	
			Miscellaneous Oligochaeta	Unknown	Unknown	2	
2	8-12	Surber	Stoneflies	Perlodidae	Nymph	5	
			Mayflies	Baetidae	Nymph	26	
				Heptageniidae	Nymph	37	
			Caddisflies	Limnephilidae	Larvae	12	
			True Flies	Simuliidae	Larvae	3	
				Tipulidae	Larvae	3	
			Miscellaneous Fish	Cottidae	Unknown	1	
4	8-12	Surber	Stoneflies	Perlodidae	Nymph	4	
			Mayflies	Heptageniidae	Nymph	23	
				Baetidae	Nymph	5	
			Caddisflies	Limnephilidae	Larvae	26	
				Lepidostomatidae	Larvae	13	
			True Flies	Tendipedidae	Larvae	11	
			Beetle	Unknown	Pupae	1	

TABLE 5 A

INMACHUK RIVER BIOLOGICAL DATA

Station	Date (1968)	Sampler	Organisms: Common Name	Organisms: Family	Organisms: Stage	Organisms: Number	Remarks
1	8-13	Ekman	-	-	-	0	
		Surber	-	-	-	0	
		Surber	-	-	-	0	
4	8-13	Ekman	-	-	-	0	
		Surber	-	-	-	0	
		Surber	-	-	-	0	

TABLE 6A

HOGATZA RIVER BIOLOGICAL DATA

	Date		Organisms				
Station	(1968)	Sampler	Common Name	Family	State	Number	Remarks
1	8-9	Surber	Stoneflies	Nemouridae	Nymph	1	
			Mayflies	Heptageniidae	Nymph	12	
				Baetidae	Nymph	4	
			Caddisflies	Limnephilidae	Larvae	1	
			True Flies	Tendipedidae	Larvae	42	
				Simuliidae	Larvae	4	
				Ceratopogonidae	Larvae	1	
			Miscellaneous				
			Nematoda	Unknown	Unknown	1	
		Ekman	Mayflies	Heptageniidae	Nymph	1	
			True Flies	Tendipedidae	Larvae	1	
				Tipulidae	Larvae	1	
				Ceratopogonidae	Larvae	1	
3	8-9	Ekman	-	-	-	0	
		Ekman	-	-	-	0	
4	8-9	Surber	Stoneflies	Nemouridae	Nymph	13	
		Ekman	Mayflies	Baetidae	Nymph	25	
				Heptageniidae	Nymph	48	
			True Flies	Tendipedidae	Larvae	81	
					Pupae	2	
				Simuliidae	Larvae	1	
				Empididae	Larvae	1	

TABLE 6A (CONT.)

HOGATZA RIVER BIOLOGICAL DATA

Station	Date (1968)	Sampler	Organisms: Common Name	Family	State	Number	Remarks
			Miscellaneous				
			Mite	Unknown	Unknown	1	
			Nematoda	Unknown	Unknown	1	
			Oligochaeta	Unknown	Unknown	13	
			Scuds	Talitridae	Adult	1	
5	8-9	Ekman	True Flies	Tendipedidae	Larvae	1	Sample not representative i.e. river too big.
				Ceratopogonidae	Larvae	1	
			Miscellaneous				
			Nematoda	Unknown	Unknown	1	

TABLE 7A

PORCUPINE CREEK BIOLOGICAL DATA

			Organisms				
Station	Date (1968)	Sampler	Common Name	Family	Stage	Number	Remarks
1	8-21	Surber	Stoneflies	Nemouridae	Nymph	5	Clean bottom
			Mayflies	Baetidae	Nymph	6	
			True Flies	Tendipedidae	Larvae	2	
				Empididae	Pupae	3	
			Miscellaneous				
			Flatworms	Unknown	Unknown	3	
			Watermites	Unknown	Unknown	2	
		Dipnet	Stoneflies	Nemouridae	Nymph	20	
				Perlodidae	Nymph	3	
				Chloroperlidae	Nymph	4	
			Mayflies	Baetidae	Nymph	23	
				Heptageniidae	Nymph	4	
			Caddisflies	Limnephilidae	Larvae	2	
			True Flies	Tendipedidae	Larvae	71	
					Pupae	1	
				Simuliidae	Larvae	1	
				Empididae	Pupae	18	
			Miscellaneous				
			Nematoda	Unknown	Unknown	4	
			Watermites	Unknown	Unknown	5	
3	8-21	Surber	Springtails	Unknown	Unknown	2	Water turbid Mine Sluicing
4	8-21	Surber	Mayflies	Heptageniidae	Nymph	1	Sample not representative

TABLE 7A (CONT.)

PORCUPINE CREEK BIOLOGICAL DATA

Station	Date (1968)	Sampler	Organisms				Remarks
			Common Name	Family	Stage	Number	
5	8-21	Surber	True Flies	Tendipedidae	Larvae	3	Samples not representative
		Dipnet	Mayflies	Heptageniidae	Nymph	1	
			Caddisflies	Lepidostomatidae	Nymph		Stream too large
			True Flies	Tendipididae	Larvae	2	
				Empididae	Larvae	1	

APPENDIX B

DEFINITION OF TERMS

DEFINITION OF TERMS

Alluvium . . . . Stream deposits of comparatively recent time.

Benthos . . . . Bottom dwelling organisms.

Dissolved Oxygen . . . The amount of oxygen dissolved in water. It is generally referred to as D.O. and is expressed in milligrams per liter (mg/l).

Hydraulic Giant . . . The large nozzle or water cannon used in hydraulic stripping and mining.

Hydraulic Stripping . The removal of the earth material that overlies an ore zone by a powerful jet of water.

Loess . . . . A homogeneous, non-stratified deposit of wind-blown material consisting predominantly of silt.

Sluicing . . . . The washing of gold-bearing materials through long boxes or troughs which are provided with riffles for arresting the gold.

Turbidity . . . . . . The cloudiness of water caused by the presence of suspended matter. These particles cause light to be scattered and absorbed rather than transmitted in straight lines. It is measured in Jackson Turbidity Units (JTU).