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PHASE II

WATER QUALITY IN THE ELK AND FLATHEAD RIVER BASINS

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SUMMARY

This report finalizes the study of water quality in the Elk and Flathead River basins. Data collected in 1975 and 1976 confirm the main conclusions reached in the Phase I study, and give rise to some specific recommendations to preserve water quality in the area.

Certain tributaries of the Elk River were affected, at specific locations, by the coal mining industry, and to a lesser extent by logging. Due to its dilution capacity the Elk River itself has not been unduly influenced by industry. The Flathead River is generally in its natural state, as little development has taken place in the basin.

The main water quality problem arising from coal mining, and associated coal processing plants, is suspended solids and turbidity. The problem is seasonal, occurring mostly in the spring during the snowmelt period, and is caused by erosion and sediment runoff from disturbed land. At certain locations in the Fording River and Michel Creek the benthic invertebrates were affected by coal processing effluents and runoff.

None of the localized water quality problems have reached critical proportions. We have made a number of recommendations for specific sites. For example, at Fording Coal Ltd., on the Fording River, we recommended the stabilization of clean water diversions, the limiting of pre-mining clearing, and reclamation of spoil piles and riverbanks to control erosion. At Kaiser Resources Ltd., on Michel Creek, we recommended upgrading of the coke plant effluent to at least level B of the Provincial objectives to control toxicants, reclamation of certain refuse piles to prevent erosion and implementation of sediment and erosion control for several areas. These matters are being acted on by agencies from the Ministry of Environment and the Ministry of Mines and Petroleum Resources.

Water availability in the Elk River basin has not been a problem to date. However, future expansion and development could shift water use to sources which are larger than those used now, but of poorer quality.

Past monitoring has produced a good inventory of data, and the effects of effluents discharged are now generally known. We have recommended a routine monitoring program in which the emphasis is on measuring fewer parameters at more sites, and at a frequency which varies with season. We estimate that this program will save about $25,000 a year compared to 1974 monitoring costs. We also recommend that monitoring be reviewed and reported once a year so that the information can be used efficiently and the program continued at least cost.

Data collected during the Phase II study, and documented in this report, constitute a case study of the effects of coal mining on mountain streams. The results can be used to plan protection of water quality in coal mining areas. They can be applied to developments which will take place in the east Kootenays as well as elsewhere in the Province.

The following paragraphs summarize our main findings, organized according to river basin.

The Fording River Basin

The water quality of the Fording River, above the minesite of Fording Coal Ltd. was good. Sediments from mining, and to some extent logging, caused high turbidity and suspended solids in the river, at the minesite and for some distance downstream especially during spring snowmelt. There were also high nitrate concentrations immediately downstream from the mine, due to the use of ammonium nitrate explosives. Sedimentation altered benthic invertebrate communities, resulting in unstable populations.

At some distance below the mine, near the junction of the Fording and Elk rivers, these effects were less pronounced. Many sediment control measures have already been implemented at the mine and we have made recommendations concerning clean water diversions, land clearing, settling ponds and land reclamation. Action on these will correct many of the water quality problems caused by mining operations.

The Upper Elk River Basin

This stretch of river was relatively undisturbed and its water quality was good. During spring freshet the yield of suspended sediment, although due to natural causes, often exceeded the yield from developed basins in the study area.

Treated sewage from Elkford had only a minor effect on the river, near the discharge point.

The Michel Creek Basin

This mountain stream was affected near its headwaters by the mining operation of Byron Creek Collieries Ltd., and near the junction with the Elk River by Kaiser Resources Ltd. These operations were main sources of sediment, especially during spring snowmelt. As a result, the water was seasonally impaired for recreation and water supply. The effects on benthic invertebrates were similar to those found in the Fording River.

In addition, Kaiser's coke plant was a source of phenol contamination which could affect the taste and odor of water and fish. Action is presently underway to improve control of sediment discharges and to upgrade effluent quality.

The Lower Elk River Basin

The river received sediments discharged directly from the operations of Kaiser Resources Ltd., and sediments contributed by Michel Creek. The input from Michel Creek had some measurable effect on the river. However, it was not always possible to separate the effects of natural river erosion and runoff from man-made effects. Sedimentation occurring naturally and from mining resulted in unstable benthic invertebrate populations at the mouth of the Elk River.

Fecal contamination downstream from Fernie was created by sewage from the City. A program to eliminate raw sewage bypasses to the river and hydraulic overloading of the sewage treatment plant is underway.

The Flathead River Basin

The basin was undeveloped and the water quality was generally good. Coal mining may take place sometime in the future and recommendations for monitoring and maintaining water quality have been made.

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1. INTRODUCTION

1.1 Background

This report describes the water quality of the Elk and Flathead River basins for 1975 and 1976. The Elk and Flathead Rivers are located in the south east corner of British Columbia, as shown in Figure 1.

A detailed evaluation of water quality data, collected in these regions before 1975, was presented in two Phase I reports.[1,2] The Phase I study found that suspended sediments from coal mining was the major influence on water quality. There was no evidence of acid mine drainage or of discharges of toxic materials in significant amounts. The effects on the aquatic biota appeared minor according to the limited information available.

In this report we have set out to confirm these results and to provide more detail on the source of suspended solids and on the state of aquatic biology. We have also examined problems of water availability caused by the shortage of water or deterioration in its quality.

1.2 Organization

The region under study contains the Elk River, which flows south into the Kootenay River; the Fording River, a tributary of the Elk in its upper reaches; Michel Creek, a tributary of the Elk in its mid-reach, and the Flathead River which flows south into Montana.

For data presentation the river system was divided into five sub-basins: the Fording River Basin, which contains the coal mines of Fording Coal Ltd.; the Upper Elk Basin, which has little development; the Michel Creek Basin which contains operations of Kaiser Resources Ltd. and Byron Creek Collieries Ltd.; the Lower Elk River Basin, which also contains part of Kaiser Resources Ltd.; and the Flathead River Basin which has little development. The locations of these sub-basins are shown in Figure 2.

For each sub-basin we present information on the major discharges, water quality, bottom sediments and aquatic biology. We have suggested corrective action where necessary and recommended basic monitoring programs.

1.3 Guidelines for Coal Development

A procedure for assessing the impact of new coal developments has been outlined by the Province of British Columbia in its guidelines for Coal Development[(3)]. The procedure is shown in flowsheet form in Figure 3. It allows for the study of environmental, social and economic impacts of future coal developments.

The guidelines require companies to obtain information on benthic fauna, fisheries, water quality etc. Development can then be planned in a way which will minimize environmental effects. All companies proposing developments in the region are participating in these impact assessments. We expect that this procedure will minimize problems that have occurred, some of which are documented in this report.

2. THE FORDING RIVER BASIN

The coal mining operation of Fording Coal Ltd., located on the upper section of the Fording River, was the major influence on river water quality. Logging in the vicinity of the coal mines was a secondary influence. A large coal mine is proposed by Crows Nest Industries Ltd. on Line Creek, which is a tributary of the Fording River near its mouth. Locations of existing and proposed operations are shown in Figure 4.

2.1 Description of Fording Coal Ltd.'s Operations and Discharges

2.1.1 Description of Operations

Fording Coal Ltd. straddles the Fording River between Kilmarnock and Henretta Creeks as shown in Figure 4. It is primarily a surface coal mining operation, and covered an area of 490 ha at the beginning of 1976[4]. There are two open pits (Clode and Turnbull pits) and an underground hydraulic mine on the east side of the Fording River. On the west side there is one open pit named the Greenhills Pit. The coal is washed in a preparation plant located on the east side of the river. Tailing from the wash plant is deposited in the North Tailing Pond on the west side of the river. Fording Coal shipped 2.9 million tonnes of clean metallurgical coal in 1975 and 1.9 million tonnes in 1976[5]. A map of the Fording Coal operation is shown in Figure 5.

2.1.2 Description of Discharges

Table 1 summarizes the amended Pollution Control Permit PE-424, issued on September 8, 1977. The amended permit covers all the effluent discharges at Fording Coal, with each discharge authorized by a separate appendix of the permit.

Tailing from the coal preparation plant plus surface runoff from the West Clode haul road and breaker plant areas are discharged to the North Tailing Pond. The tailing pond supernatant is recycled to the preparation plant. Overflow from the tailing pond is not allowed, but there is seepage from the pond to the Fording River. Construction has started on a South Tailing Pond to replace the North Tailing Pond, which will be full in 1978. Surface runoff, accumulating in the Greenhills Pit, may be discharged to the tailing pond for recycle, used for irrigation of reclaimed areas, or exfiltrated to ground. Discharge of the pit water to the Fording River is not allowed, except as directed by the Pollution Control Branch.

Surface runoff from other disturbed areas at Fording Coal is (or will be) conveyed by ditches to eight settling ponds, which overflow to the Fording River, Kilmarnock Creek, or the North Tailing Pond. The exception is the rail loop settling ponds which exfiltrate to ground. Discharges from the settling ponds are to have a suspended solids concentration of less than 50 mg/L. Treated domestic sewage from the Fording operation is discharged to the North Rail Loop settling pond which exfiltrates to ground.

2.1.3 Reclamation

Fording Coal has two reclamation permits (Numbers 3 and 102) under the Mines Regulation Act and Coal Mine Regulation Act. Permit No. 3 covers the minesite and Permit No. 102 covers exploration areas[1]. Reclamation was not extensive prior to 1977 because the operation was expanding and most of the mine areas were active. The first reclamation work was done in 1974, and 40 ha were revegetated by the end of 1975. The reclamation effort has now been increased, and the revegetation of 260 ha is planned between 1977 and 1979[4].

Areas to be revegetated include 149 ha of spoil from the Greenhills and K-4 pits, 32 ha of river bank and yard areas adjacent to the preparation plant, 28 ha along the Lower Clode and Taylor Pit haul roads, and 42 ha along the mine access road. Development of a tree nursery at the minesite was started in 1977[4]. An objective of the reclamation plan is to establish a floodplain reserve area along the Fording River, Henretta Creek and Kilmarnock Creek which is not to be disturbed[7].

2.1.4 Future Developments

Future mining development at Fording Coal will expand the area of the operation from 490 ha (1976) to 920 ha by 1980. These developments include: expansion of the Greenhills Pit to the west; expansion of the Turnbull Pit to the north and east; development of the Taylor Pit to the east and south of the existing Clode Pit; development of the K-4 Pit in the Kilmarnock Creek drainage; and development of the hydraulic underground mine and dewatering plant east of the Clode Pit[4].

2.2 Effluent Sampling Data for Fording Coal Ltd.

The effluents at Fording Coal Ltd. were sampled by the B.C. Ministry of the Environment and the company during 1975-76. These data are summarized in Tables 2,3,4,5,7 and 8. The locations of the effluent discharges are shown in Figure 5. The effluent parameters most frequently measured were suspended solids, turbidity and flow.

2.2.1 North Tailing Pond

The tailing pond supernatant was monitored 12 times by government agencies and five times by Fording Coal during 1975-76. These data are summarized in Table 2. The data collected by Fording Coal and the government were quite similar. The supernatant was of good quality, meeting Level A of the Mining Objectives[8]. The exception were sulphate, which was between Levels A and B, and ammonia, manganese and suspended solids which have slightly exceeded Level A on occasion.

There has been no positive discharge of supernatant since 1973, apart from two raw tailing spills to the Fording River on September 26 and December 9, 1975, due to breaks in the tailing pipeline[6]. Much of the supernatant was recycled to the preparation plant, but there were seepage losses from the tailing pond to the Fording River. It has not been possible to measure the quantity or quality of the seepage. Groundwater monitoring below Kaiser Resources Ltd.'s Elkview tailing ponds (Section 5.1.2) indicated that the tailing pond seepage was high in dissolved iron and manganese. The seepage may also be high in nitrite + nitrate nitrogen, since the supernatant has a nitrite + nitrate content of 2 - 3 mg/L as N. Also, nitrate moves readily through soils with the groundwater.

2.2.2 Typical Mine Drainage

The Eagle settling pond was sampled three times during 1975 by the Water Investigations Branch to assess the composition of typical clarified mine drainage. Table 3 shows that the effluent was alkaline (total alkalinity of 95 - 166 mg/L as $CaCO_3$, pH of 8.3 - 8.6), and low in heavy metals and toxic substances. The effluent met Level A of the Mining Objectives[8] for all parameters, except suspended solids. Alkalinity, dissolved solids, hardness (calcium plus magnesium), and nitrite + nitrate concentrations increased as surface runoff decreased from June to August. This was probably due to the increasing proportion of mineralized groundwater seepage from the Clode Pit and spoil pile in the settling pond effluent.

The elevated nitrite + nitrate levels (0.4 - 2.5 mg/L as N) were probably due to the leaching of residual ammonium nitrate explosives from the Clode Pit and spoil pile. Elevated nitrogen levels (i.e. nitrite, nitrate and ammonia) in mine drainage from the Decker Coal Company Mine, in Montana, have been attributed to the use of ammonium nitrate explosives[9]. Fording Coal Ltd. used 4600 - 6700 tonnes/year of ammonium nitrate explosives during the years 1972, 1973 and 1974[10].

Similar or higher nitrite + nitrate concentrations were measured in the Clode settling pond effluent (1.2 mg/L as N), the Greenhills pit water (1.5 - 18. mg/L as N), and the North Tailing Pond supernatant (2.1 - 3.3 mg/L as N). Nitrite + nitrate concentrations in the Fording River at the minesite have reached the maximum permissible limit for drinking water (8.3 - 10.8 mg/L as N) during low flow (see Section 2.5.1).

2.2.3 Suspended Sediment Sources

Suspended solids or sediment was identified as the major contaminant from the Fording Coal Ltd. operation in our Phase I report[1]. Consequently, a sampling program was conducted by the Water Investigations Branch during April to June 1976, and to a lesser extent during 1975. The purpose was to identify and characterize the major sources of suspended sediment in the Fording River basin. Suspended solids, turbidity and flow of the sediment sources were monitored. A summary of the data for the sediment sources at Fording Coal Ltd. is presented in Table 4. The detailed data for all of the sediment sources in the Fording basin are presented in Table 5.

Table 4 and 5 show that the largest sources of sediment during the 1976 freshet were the Harold Creek and South Greenhills Diversions. These diversions were designed to divert clean water around the Greenhills Pit, preventing water from entering the pit and becoming contaminated. The sediment carried by these diversions came from two sources. First, the diversions were new and unstable, and were eroded as they attempted to establish their channels. Second, the area to the west of the Greenhills Pit had been cleared (by Crows Nest Industries Ltd. for Fording Coal Ltd.) to accommodate the westward expansion of the Greenhills Pit. Suspended sediment, eroded from this cleared area, entered the clean water diversions.

The pit water pumped from the Greenhills Pit was another major source of sediment at Fording Coal. This discharge had the highest suspended solids loading measured (104 tonnes/day), but because pumping was intermittent, the total amount of sediment from this source was probably not as great as that from the clean water diversions. Direct discharge of pit water to the Fording River should be avoided.

Tables 4 and 5 show that the Clode and Eagle settling ponds were generally not major sources of suspended sediment during 1975-76. Only one sampling occasion (April 7, 1976) showed the Clode Pond contributing significantly to the suspended sediment load in the Fording River. The ponds exceeded the Provincial objective of 50 mg/L on four of the 12 occasions when they were sampled during the April - June runoff period.

The April - June runoff to these ponds was probably below average, since the April - June flow in the Fording River at the minesite was estimated to be about 20 percent below average in both 1975 and 1976[11]. Thus, it appears that the ponds are not capable of meeting the 50 mg/L objective, even under below average runoff conditions.

Theoretically, the ponds have sufficient surface area to remove sediment particles down to a diameter of 0.006 mm (Clode Pond) and 0.003 mm (Eagle Pond), from the maximum runoff flows recorded in 1975-76. Settling rate calculations are given in Table 6. The suspended solids, remaining in the pond overflow, are probably due to finer particles which cannot be removed by settling, unless their particle size is increased by use of a coagulant[12]. Table 7 shows that the removal efficiency of the Clode Pond ranged from 73 - 90 percent for suspended solids and from 0 - 77 percent for turbidity.

Sporadic sources of suspended sediment (Tables 4 and 5) included runoff from the maintenance area, tailing spills, an unnamed creek from Eagle Mountain (just north of Kilmarnock Creek) and Kilmarnock Creek. The tailing spills were discussed in Section 2.2.1. The cause of the sediment in the unnamed creek and Kilmarnock Creek are not known, but they drain areas of Eagle Mountain that have been logged and contain coal exploration roads[13]. Undisturbed streams in the vicinity of Fording Coal Ltd. did not carry any significant amount of sediment during the 1975-76 study period. These streams were clear and sediment-free whenever they were observed.

The maintenance area runoff was only observed once (August 20, 1975). However, the erosion pattern and black sediment on the river bank adjacent to the maintenance area, indicated that this runoff had flowed to the river several times. The cause of the runoff on August 20, 1975 was vehicle washing in the maintenance garage. Table 8 shows that the runoff contained extremely high concentrations of suspended solids, oil and grease, and total organic carbon (due to the high coal content of the runoff). Iron, phosphorus and zinc levels were also very high, but were present mainly in the particulate matter rather than in the dissolved form. In spite of the small quantity of runoff, it caused the Fording River to become turbid for at least 3 km downstream from the discharge. Maintenance area runoff is now collected and treated in a settling pond prior to discharge to the Fording River. The river bank areas adjacent to the maintenance area are due to be revegetated during 1977 to 1979.

2.2.4 Recommendations

The following recommendations concern various aspects of Fording Coal's operations.

a) Clean Water Diversions

Clean water diversions should be designed, constructed and maintained so that they are stable and will not erode. If necessary, settling ponds should be used to control the discharge of suspended sediment.

b) Cleared Land

When land must be cleared for mining, it should be cleared as close to the time when mining starts as possible. For example, the area west of the Greenhills Pit was cleared several years in advance of the mining operation causing high sediment loads to the river. Sediment control works for future disturbed areas should be constructed first so that they are ready to control sediment when clearing begins. The area cleared should be limited to the smallest practical area.

c) Tailing Lines

The tailing pipelines to the North and South Tailing Ponds should be examined to identify potential spill points. Spill containment measures (e.g. ditches, berms, ponds, etc.) should be planned to prevent spills from entering the Fording River.

d) Reclamation

The reclamation program proposed by Fording Coal Ltd. for 1977-79 should be carried out to control erosion and sediment production at the minesite. Future developments at the minesite should follow the proposals for water quality protection described in Chapter 9.

e) Settling Ponds

Chemical coagulation may be necessary for the settling ponds at Fording Coal to meet the effluent quality objective of 50 mg/L suspended solids. However, more data are needed to confirm this conclusion. The settling ponds should be monitored daily during periods of spring runoff and heavy rains to assess their effectiveness. Suspended solids and flow should be measured. The design of settling ponds is discussed in Section 5.1.1.

Further monitoring for nitrite, nitrate and ammonia should be conducted during low flows to identify the sources of these parameters.

f) Tailing Ponds

Monitoring of the tailing ponds should be substantially reduced. There is no direct discharge of supernatant, and four years of monitoring (1973-76, 28 samples) have shown it to be of relatively good quality. Monitoring should include pH and sufficient flow data to approximate the seepage losses from the tailing pond to the Fording River. The low flow periods are the critical times for assessing seepage, and sampling of the Fording River upstream and downstream from the tailing ponds should be carried out during low flows. The recommended water quality monitoring is outlined in Section 2.5.3 and summarized in Table 89.

g) Sediment Sources

The flow and suspended solids content of all the sediment sources at the minesite should be monitored at least weekly, during spring snowmelt runoff. Surveillance of the early stages of snowmelt, prior to the freshet (March 15 - May 1), is particularly important since streamflow is low and sediment discharge from low elevation sources may be substantial. This monitoring should be closely correlated with the suspended solids and turbidity measurements in the Fording River and Kilmarnock Creek, recommended in Section 2.5.3. The monitoring program should remain flexible, adding, deleting or moving sites as the sediment sources change with development.

Sampling frequency should be stepped up, to a daily basis if possible, during peak runoff periods and after heavy rainstorms occurring at other times of the year. Sampling in the snowmelt period should be done during the afternoon. Sediment levels are usually low in the morning and increase to a maximum in the late afternoon and evening as snowmelt runoff increases during the day.

2.3 Sampling Data for Logging Operations

2.3.1 Presentation and Discussion of Data

The sampling program, conducted from April to June 1976, discovered several sources of sediment related to active or recent logging operations. Suspended sediment derived from logging on the Fording Coal Ltd. property, to accommodate future mining operations, was mentioned in Section 2.2.3. Logging by Crows Nest Industries on the west side of the Fording River, south of Fording Coal Ltd., resulted in 0.04 m^3/s of runoff containing 6686 mg/L of suspended solids (turbidity of 3400 J.T.U.). This discharge entered the Fording River on May 25, 1976 (Table 5). The duration of the discharge prior to May 25 is not known, but the runoff was clear by June 3, 1976.

Grace Creek was a considerable source of sediment to the Fording River in early May 1976 (Table 5). On May 5, 1976, the flow of Grace Creek was about 1.4 - 2.1 m^3/s, and contained 800 mg/L of suspended solids (turbidity of 170 J.T.U.). Again, the duration of the sediment discharge prior to May 5, 1976 is unknown, but the creek was clear by May 19, 1976. The cause of the sediment discharge was not determined, but there was a fire in the basin in 1967 and the basin was logged during 1968-74. Minor timber salvage has taken place since 1974[14].

These data are of a preliminary nature, but they do indicate that excessive sediment discharges may be occurring in the Fording basin due to logging practices.

2.3.2 Recommendations

We recommend that the runoff from logging operations be monitored to identify operations and practices which are causing excessive sediment discharge. This work could be done in conjunction with sediment monitoring for the coal mining operations. If certain logging operations and practices are identified as significant sediment sources, then efforts should be made to improve the management practices of the logging companies involved.

2.4 Proposed Line Creek Coal Project

Crows Nest Industries Ltd. plans to develop an open pit mine and coal preparation plant to produce one million tonnes of clean metallurgical coal per year[1]. The open pit mine would be located on Line Creek Ridge, and the mine spoil would be deposited in the valley of West Line Creek (Figure 4). West Line Creek would be diverted around the spoil pile. Drainage from the mining operation would be directed to settling ponds located adjacent to Line Creek. The raw coal would be trucked to a preparation plant located near the confluence of Line Creek, the Fording River and the Elk River. Waste from the coal preparation plant would be deposited adjacent to the Elk and Fording Rivers[15].

The Line Creek Coal Project is currently proceeding through the four-stage coal development assessment procedure required under the Government's Guidelines for Coal Development (Section 1.3). A prospectus prepared by Crows Nest Industries Ltd.[16], and a Stage I - Preliminary Environmental Study prepared by B.C. Research[15] have been submitted in accordance with the guidelines.

The major potential water quality impact of the proposed project would be increased suspended solids, turbidity and sedimentation and accompanying loss of aquatic habitat in Line Creek, downstream from the minesite. The extent to which this will occur depends on the effectiveness of the erosion and sediment control program to be implemented by the mining company. A discussion of proposals for water quality protection in coal mining is given in Chapter 9.

Crows Nest Industries Ltd. constructed a settling pond adjacent to Line Creek to treat drainage from a test pit on Line Creek Ridge. The effluent from this pond was sampled on three occasions in the spring and summer of 1975. These data are presented in Table 9. The effluent was very low in suspended solids and turbidity, and all parameters measured were better than Level A of the Mining Objectives[8]. The test pit had been reclaimed and did not appear to be a source of suspended sediment.

2.5 Water Quality

The waters of the Fording River basin were sampled by the Pollution Control Branch, the Water Investigations Branch and the

Water Survey of Canada at 20 sites during 1975-76. The locations of the sampling sites are shown in Figures 4 and 5. These sites are described in detail in Table 10.

Provincial Government data are summarized in Table 11 to 15. Table 5 is a compilation of suspended solids (suspended sediment) and turbidity profiles taken on the Fording River during 1975-76. The data for these profiles were obtained mainly by the Water Investigations Branch but applicable Pollution Control and Water Survey of Canada data have been included. Water Survey of Canada suspended sediment loading measurements have been summarized in Table 16, and appropriate flow and sediment data have been cited in the discussion.

2.5.1 Fording River Results

The water quality of the Fording River, upstream from Fording Coal Ltd. (site 0200110, Tables 5, 11 and 12), was unaffected by the activities of man and was typical of natural runoff in the Elk River basin. The water was alkaline, moderately hard[17] and low in color, suspended solids, turbidity, nutrients and heavy metals. During 1975-76, suspended solids (0 -21 mg/L) and turbidity (0.06 - 2.3 J.T.U.) were very low (Tables 5, 11 and Water Survey of Canada[18]).

The water quality of the Fording River at the minesite (site 0200040), and immediately downstream from the minesite (sites 0200201 and 1190008), has been affected by coal mining and logging activity. The parameters that were most dramatically affected were suspended solids and turbidty. Suspended solids concentrations of up to 732 mg/L and turbidity levels of up to 240 J.T.U. were measured immediately downstream from the minesite in 1975 and 1976 (Table 5). The objectives for receiving water for the mining industry specify that turbidity should not increase by more than five units from upstream to downstream from a mining operation[8].

Suspended solids and turbidity levels were greatest during the spring runoff period and normally decreased to background levels during the remainder of the year. The sources of the suspended sediment to the Fording River are listed in Table 4 and 5 and are discussed in Section 2.1.

Suspended solids and turbidity levels tended to decrease with distance downstream from Fording Coal Ltd. At 11 to 16 km downstream from Fording Coal Ltd. , the maximum measured suspended solids and turbidity levels were 136 mg/L and 23 J.T.U. respectively (Table 5). These decreases were probably caused by dilution and by sedimentation in low-gradient reaches of the Fording River located between 5 and 8 km downstream from Fording Coal Ltd. Suspended solids measurements at the mouth of the Fording River ranged from 0 - 218 mg/L (Water Survey of Canada[19]) and 4 - 262 mg/L (Water Investigations Branch) during 1975-76, but the extent to which these levels were caused by mining and logging as opposed to natural sediment sources is not known. The eight suspended solids and turbidity profiles conducted in May to June, 1976, showed little or no change between 11 to 16 km downstream from Fording Coal Ltd. and the mouth (Table 5).

The suspended sediment yield, expressed in tonnes/km^2 or tonnes/(m^3.s), of the Fording River at the mouth (Table 16) was greater than that of its sub-basins, the Fording River upstream from Fording Coal Ltd. and Line Creek, which are relatively undisturbed watersheds. However, the yield was less than that of the larger, although relatively undisturbed upper Elk River basin and less than that of the similarly-sized Michel Creek basin, which contains several coal mining operations.

The increased suspended solids and turbidity levels in the Fording River, downstream from Fording Coal Ltd., may limit the usefulness of the stream. The desirability of the water for public or industrial water supply is reduced, because it would either be necessary to remove the suspended solids or to remove more suspended solids than usual prior to use. There is one water license (domestic) on the Fording River downstream from Fording Coal Ltd.[20], but the water is not being used at the present time. The recreational and aesthetic appeal of the river is reduced by the presence of high suspended solids and turbidity, particularly by the presence of black sediment derived from coal.

The possible effects of suspended solids and turbidity on aquatic life were reviewed in the Phase I report[1]. There were effects on benthic invertebrates which were studied during 1975. These results are presented in Section 2.7.

Nitrate, nitrite and ammonia nitrogen tended to increase from upstream to downstream from Fording Coal. Upstream from Fording Coal (site 0200110), the maximum levels of nitrate nitrogen (0.05 mg/L), nitrite nitrogen (<0.005 mg/L) and ammonia nitrogen (0.01 mg/L) were very low. At the minesite (site 0200040), and immediately downstream (site 0200201), levels ranged up to 8.3 - 10.8 mg/L for nitrate nitrogen, 0.04 - 0.05 mg/L for nitrite nitrogen and 0.12 mg/L for ammonia nitrogen. The highest concentrations occurred during low flows in the Fording River. The nitrogen compounds are believed to have come from the leaching of residual ammonium nitrate explosives from the pits, spoil piles and the North Tailing Pond (Section 2.2.2).

Seven of twelve samples at the downstream site 0200201, exceeded a nitrate nitrogen level of 0.3 mg/L. This is the level which may contribute to nuisance levels of aquatic plant growth (provided sufficient concentrations of other essential nutrients are present[21,22]). Excessive aquatic plant growth has not been observed in the Fording River, although heavy growths of attached algae were observed on the rocks in the Fording River in front of the North Tailing Pond (see Sections 2.7.2 and 2.7.3).

The highest nitrate nitrogen levels were at the maximum permissible limit for drinking water (10 mg/L as N)[23]. This limit is based on the susceptibility of infants, under three months of age, to methemoglobinemia, following ingestion of water containing over 10 mg/L nitrate nitrogen[23,24]. Two domestic water licenses have been issued on the Fording River: one for the Fording Coal operation, and one for B.J. Volpatti on Lot 6637[20] (near site 0200201). The nitrate levels are not a cause for concern at the present time since the Volpatti license is not being used, and the Fording Coal intake is upstream from the minesite. The next downstream domestic water users are located on the Elk River, at which point the nitrate is diluted to harmless levels.

The ammonia nitrogen levels were within the acceptable limit for drinking water (0.5 mg/L)[23] and levels recommended for aquatic life (i.e. <0.02 mg/L un-ionized ammonia)[24]. At the pH and water temperature of the Fording River only five percent of the ammonia present would be un-ionized. Nitrite nitrogen was well below harmful levels for drinking water (1 mg/L), and slightly below the level considered safe for salmonid fishes (0.06 mg/L)[24].

Other changes detected in the water quality of the Fording River, due to Fording Coal, were of relatively minor significance. Total iron levels increased during the spring freshet, but dissolved iron remained very low (<100 μg/L) (Table 12). The total iron concentrations are of little significance since they were caused by the iron content of the inert suspended sediment derived from mining operations[25].

There were small increases in total alkalinity, dissolved solids, sulphate, dissolved manganese, dissolved nickel and dissolved copper (Tables 11 and 12), during low flow conditions, but the resulting levels were not harmful. These increases may be related to groundwater seepage from the pits, spoil piles, tailing pond, settling ponds, and to other land disturbances at the Fording Coal minesite.

2.5.2 Line Creek Results

Water quality data were collected at three sites on Line Creek (Table 15, sites 1190010, 1190011 and 0200044) during 1975. They show that the water was alkaline, moderately hard[17], low in nutrients, heavy metals (copper, iron, lead, manganese, nickel and zinc), arsenic, suspended solids and turbidity. The water was typical of natural runoff in the Elk basin. There were no significant changes in water quality from upstream to downstream in Line Creek. These results indicate that Crows Nest Industries Ltd. coal exploration activities were not affecting water quality in the spring and summer of 1975. Water quality data for Line Creek and its tributaries collected by B.C. Research during 1975-76 for the Proposed Line Creek Project[15], were similar to those collected at sites 1190010, 1190011 and 0200044.

The Water Survey of Canada has monitored suspended sediment and flow at site 08NK022 (near site 0200044), near the mouth of Line Creek, from 1971 through 1976. The ranges of suspended sediment concentrations measured during these years is as follows:

1971	1 - 101 mg/L	1974	0 - 625 mg/L
1972	0 - 224 mg/L	1975	0 - 55 mg/L
1973	0 - 52 mg/L	1976	1 - 38 mg/L

These ranges indicate that suspended sediment levels in Line Creek were usually quite low, although in years of high runoff (1972 and 1974), high concentrations occurred during peak runoff conditions. These suspended sediment levels may not be completely indicative of natural conditions because developments such as road access, coal exploration and logging (South Line and Tornado Creeks) have already occurred in the Line Creek basin. However, suspended sediment yield from the Line Creek basin during 1971-74 was among the lowest in the Elk River basin (Table 16).

The water quality of Line Creek and its tributaries is currently being monitored by B.C. Research for Crows Nest Industries Ltd. This project is part of the environmental impact assessment, required by the government[3], for the proposed Line Creek Coal Project.

2.5.3 Recommendations

Erosion and sediment control measures for Fording Coal Ltd. were recommended in Section 2.2.4. The water quality results emphasize the need for these measures. The Fording River at Fording Coal Ltd. is fairly sensitive to effluent discharges. It is close to the headwaters, and thus flows and natural levels of contaminants are low. Consequently, the effects of mining on water quality has been greater than for mines located on larger streams.

We recommend the following water quality monitoring program in the Fording River basin.

a) Suspended Solids

Suspended solids and turbidity should be monitored weekly during spring snowmelt runoff. Monitoring should be at sites in the Fording River and Kilmarnock Creek upstream and downstream from the mining related sediment sources. This monitoring should be closely correlated (i.e. all samples collected within a period of a few hours) with the sediment source monitoring recommended in Section 2.2.4.

b) Nitrogen

Nitrite, nitrate and ammonia nitrogen should be monitored three times during winter low flows at sites in the Fording River upstream, immediately downstream and several kilometres downstream from the minesite. Monitoring should be closely correlated with the nitrite, nitrate and ammonia source monitoring recommended in Section 2.2.4. (pH and water temperature should be measured in the field).

c) Other Parameters

We also recommend an occasional sampling (three times) during low flows at sites in the Fording River, above and below the minesite, for the following parameters:

- pH
- dissolved copper
- dissolved iron
- dissolved manganese
- temperature

These parameters are related to groundwater seepage from settling ponds, tailing ponds and disturbed land surfaces.

We do not recommend further monitoring of Line Creek by government agencies, until development of the Line Creek Coal Project begins.

2.6 Bottom Sediments

The bottom sediments of the Fording River were sampled by the Water Investigations Branch in three ways: with a freeze-core sediment sampler, with sediment traps and by grab samples.

2.6.1 Procedure

a) Freeze-Core Sampler

The freeze-core sediment samples were taken in July 1976 (after the spring freshet) at sites upstream from Fording Coal Ltd. (0200110), immediately downstream (0200201) and 11 km downstream. The purpose was to determine if sediments were being clogged by fines from the mining operation. The equipment was loaned by Fisheries and Marine Service, Environment Canada, Vancouver. Freeze-core sampling consisted in driving a probe, 5 cm diameter, 45 cm long, into the bottom sediments; freezing a core of sediment, 20 cm diameter, 45 cm long, to the probe by circulating acetone cooled with dry ice through the probe; and then removing the frozen sediment core from the streambed. Two freeze-core samples were taken at each site. The upper 30 cm of the sediment cores was analyzed for particle-size distribution. The results of these analyses are presented in Table 17.

b) Sediment Traps

The sediment traps were placed in the Fording River in April 1976, before the spring freshet, and removed three months later in July 1976, after the freshet. The aim was to measure the fines settling out in the river. Sediment traps were located at sites upstream from Fording Coal Ltd. (0200110), and 11 km downstream. It was not possible to install sediment traps immediately downstream from Fording Coal Ltd. since the streambed was covered with a layer of ice in April 1976. The sediment traps were plastic pails, 20 cm diameter, 22 cm deep, filled with clean (washed), fine gravel (2.38 mm to 4.76 mm). The sediment traps were dug into the streambed so that the top of the traps were flush with the streambed. The lids on the traps were then removed to expose the fine gravel. After three months of exposure, the lids were replaced and the traps were removed from the water. Three traps were used at each site. The fine sediment (finer than 2.38 mm) was weighed (dry weight) and analyzed for particle-size distribution. The results of the analyses are presented in Table 18.

c) Grab Samples

The sediment grab samples were collected at the same time as the invertebrate samples (Section 2.7.1), and analyzed for particle-size distribution and chemical composition. We wanted to compare particle-size distribution and the invertebrate communities, check the presence of toxic substances, and determine whether the visual presence of coal fines was reflected by total carbon content. Samples were scooped into three 3300 mL acid washed containers at sites 0200110, 1190007, 0200201 and 0200093. The analyses were performed on the pooled samples. The results are summarized in Table 19.

2.6.2 Discussion of Results

The freeze-core and sediment trap results are not conclusive because too few samples (three or less per site) were taken to account for the natural variability of the bottom sediments. The sediment trap data (Table 18) indicate that twice as much fine sediment (finer than 2.38 mm) was collected downstream from Fording Coal Ltd. than upstream, but this difference is only significant for the 50 percent confidence interval. This means that 50 percent of the time, the variation between samples at the same site was similar to variations between samples at upstream and downstream sites. Similarly, the freeze-core data (Table 17) show that there was more fine sediment (e.g. finer than 0.59 mm) in the bottom sediments downstream from Fording Coal than upstream, but again, the differences are only significant for the 50 percent confidence intervals. With the exception of sample A, taken 11 km downstream from Fording Coal, the percentage of fine material (i.e. finer than 0.59 mm) was relatively low (<8.2 percent).

Future bottom sediment sampling will require more sampling effort to define the sample means within acceptable limits. Other investigators have suggested that 10-15 freeze-cores may adequately define the mean for homogeneous sediments, but that many more samples (100 or more) would be required for non-homogeneous sediments[28]. The variability of the sediment trap data suggests that many samples would be required to define the mean sedimentation rate at a site, and therefore we do not recommend this sampling method.

Freeze-core sediment sampling shows some promise in monitoring the clogging of bottom sediments by fine sediments derived from land disturbances. The method may be useful in the study of fish spawning areas subjected to increased sedimentation. However, freeze-core sampling is limited to small, wadable streams, with a maximum depth of about 0.6 metres, and a maximum sediment size of about 10 cm in diameter. There is also a need to develop a standard method for freeze-core sampling, since different equipment and techniques yield different results[28].

The particle-size distributions of the grab sediment samples (Table 19) suggest that there was more very fine sediment (i.e. <0.297 mm) downstream from Fording Coal (site 0200201) than at (site 1190007) or upstream from Fording Coal (site 0200110). The sample at site 0200093, 16 km downstream from Fording Coal, contained much finer sediment than the other sites because it was taken in a low velocity reach (see Section 2.7.3). Particle-size distribution of the grab sediment samples was determined to complement the benthic invertebrate studies. As outlined in Section 2.7.3, sediment is an important factor which often determines the distribution and structure of invertebrate populations. However, the particle-size distribution of the fine sediment is only a small portion of the total substrate information needed to assess impacts on benthic populations. There was no apparent relationship between the particle size-distribution and the benthic populations.

The chemical analysis of the bottom sediments (Table 19) did not indicate where coal sediments were accumulating, even on the basis of carbon analysis. The chemical composition data show that the levels of nutrient and metals were low, and that there was relatively little variation from upstream to downstream from Fording Coal Ltd. This suggests that the mining activities were not affecting the general chemistry of the river bottom sediments.

2.6.3 Recommendations

Future substrate studies, done in association with benthic invertebrate surveys, should include:

a) a good qualitative description of the substrate sampled, supplemented by photographs.
b) an estimate of the cobble factor: the percentage of the sampled area covered by rocks, plus the particle-size distribution of the rocks.
c) an estimate of cobble embeddedness: the degree to which the cobbles are embedded in the surrounding sediments (expressed as a percentage).
d) the percentage of fine sediment cover (i.e. particles less than about 1 cm in diameter) in the sampling area.
e) the particle-size distribution and chemical composition of the fine sediment (as done for the grab samples). Chemical analysis of the sediment does not appear to be necessary in future studies related to coal mining in the Elk basin.

The above is a modification of a procedure outlined in the literature[29].

2.7 AQUATIC BIOLOGY

The Phase I report[1] indicated that the Fording Coal mining activities produced a significant increase in suspended solids and turbidity in the Fording River. The effects on biota were discussed generally, but there was no knowledge of the status of the Fording River biological community. A detailed survey of certain biota, particularly of invertebrates and periphyton, was therefore carried out.

Invertebrates play an important role in food webs of rivers and streams[30,31]. As primary and secondary consumers[32,33] they obtain energy from primary producers, algae and other plants, and transport it to higher trophic levels including fish[31]. Aquatic invertebrates, particularly bottom-dwelling (benthic) forms, are also often studied as environmental indicator organisms[34,35,36]. The benthic invertebrates tend to remain in a small area for periods of time, but leave these areas during disruption. Many factors affect the composition of invertebrate communities[31]. The factors include water flow and temperature, water chemistry, especially the presence of toxic parameters, food availability and substrate conditions. Although suspended solids and turbidity were suggested to be problem parameters, the other factors must be considered in the analysis of the data from the invertebrate survey. Attached algae, referred to here as periphyton, were studied to gain a better understanding of food availability.

2.7.1 Data Collection and Analysis

Benthic invertebrates were collected in August, 1975 and periphyton in September, 1975 at the following water quality sites (Table 10):

Site 0200110, upstream from Fording minesite.
Site 1190007, downstream from Eagle Setting Pond.

Site 0200201, just downstream from all the major mining activities of Fording Coal Limited

Site 0200093, 16 km downstream from the operation.

Invertebrates in samples (or subsamples where appropriate) were sorted to systematic level of order or family. Individuals of the orders Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddis flies) were sorted to the genus level and identified. The identifications were then confirmed[37]. Sampling and laboratory procedures are described in a separate report[38]. Periphyton samples were heated to 550° C to attain their ash free dryweights, and dominant genera were determined microscopically.

The invertebrate data were examined both qualitatively and quantitatively. Qualitative analyses of benthic invertebrates involved comparisons of the kinds and numbers of individuals at the different sites relative to their known life habitats. Quantitative analyses were used to reduce the data to a more interpretable form by simultaneously comparing all of the taxonomic groups at all of the stations. For the quantitative analyses, the samples at each site were considered as communities and three different community analyses were performed. These were mutual information analysis[39], indirect gradient polar ordination[40], and diversity and redundancy indices[41].

Mutual information analysis is a classificatory method of community analysis by which the communities, or sites which are most similiar, are grouped together. The basis of comparison of the communities is the relative proportions of the representative taxa, and this is defined by the mutual information statistic (2I). The results are presented in a dendrogram or tree-diagram, which shows the joining of the most similiar stations.

Indirect gradient polar ordination is an ordination method of community analysis in which gradual changes and similarities in communities are apparent. The results are presented as the co-ordinates of points in two axes. The X co-ordinate represents linearized values of the percent difference in representative taxa between all pairs of sites. The Y co-ordinate is the error involved in linearizing the X co-ordinates.

The diversity index is a measure of both the number of taxonomic groups present, and the relative abundance (evenness) of the groups. Redundancy is a measure of the unevenness of the taxonomic groups, with high redundancy suggesting the dominance of one or two taxa. The diversity and redundancy indices are calculated independently for each site, and the kinds of individuals present are not considered. Thus, only the relative values of the indices can be compared.

All of the calculations were based on the total number of individuals per taxa from the three replicate samples per site. Totals rather than means were used to avoid rounding off the fractions which occur for means of less common taxa.

Ash free dryweights of periphyton samples from the sites were compared to gain a relative understanding of abundance of algae.

2.7.2 Presentation of Data

The results of the invertebrate counts of the representative taxa are given in Table 20. Histograms showing the number of genera of Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddis flies), at the four river sites, are presented In Figures 6 and 7. The mutual information dendrogram and the ordination plot are shown in Figure 8 and the diversity and redundancy indices are tabulated in Table 21. Physical characteristics of each of the sampling sites are described in Table 22. The periphyton data, including the dominant forms present and the ash free weight, are given in Table 23.

There were qualitative differences in the invertebrate taxa from the four river sites (Table 20 and Figures 6 and 7), and these differences were reflected in the quantitative community analyses.

Mutual information analysis (Figure 8) showed the invertebrate communities at site 0200201, just downstream from the mining activities and site 1190007, downstream from Eagle Settling Pond as most similar. Communities at these two sites differed most with the community at the control site, 0200110.

Similar results were shown in the ordination plot (Figure 8). It showed that the invertebrate community at site 0200201, just downstream from the mine, was more different than at any other site. The population at site 0200201 showed more similarity to site 1190007, near the Eagle Settling Pond, than to the control site 0200110 or to site 0200093, located 16 km downstream from the mining operation.

The diversity and redundancy indices at the mine site 0200201, and the control site 0200110 showed the greatest difference in values (Table 21), indicating that the greatest difference was between the communities at these two sites. Mutual information analysis and polar ordination showed the invertebrate population at site 0200093, 16 km downstream from the mine as being different from the populations at the control site and the two sites associated with the mine (Figure 8). The community at site 0200093, was, however, more similar to the control site, and had a relatively high diversity index (Table 21).

2.7.3 Discussion of Results

Differences in invertebrate populations at the four sites, shown by the community analyses, may be due to a number of factors. These include river flow (velocity and amount of water), water temperature, water chemistry, food availability and the characteristics of the substrate. These factors are discussed below.

The Fording River is in general a continuously, fast flowing mountain river. The site observations (Table 22) suggest that at site 0200093, 16 km downstream from the minesite, the slope of the river decreased and the velocity of the water was slower than at the other sites. Invertebrates, including the mayflies Ephemerella and Pseudocloeon, (Figure 6) which are morphologically and physiologically adapted to slower waters[42,43,44], were more abundant or were unique at site 0200093. The community analyses showed that although the community was diverse, it was different from the control site and the sites at the mining operation.

Water temperature measurements suggested that at the same time of day the water temperature at all sites was similar. Vegetative cover was similar along the stretch of river sampled, and the range in altitude was only 160 m. Temperature was probably not responsible for the apparent changes in the invertebrate populations down the river[31,45,46].

The quality of the water of the Fording River was generally good. The water was slightly alkaline and low in dissolved metals and other possible toxicants. Levels of nitrite + nitrate nitrogen and ammonia were on occasion high at sites 119007 and 0200201, but never reached levels harmful to fish and presumably not to invertebrates. Suspended solids and turbidity were found to be very high at times at sites 1190007 and 0200201 (Section 2.5.1), confirming the observations of the Phase I report. Suspended solids can affect food availability and substrate characteristics and hence invertebrate distribution.

The sources of suspended solids are discussed in Sections 2.1 to 2.3. Fording Coal Ltd. was a major source and the logging operations of Crowsnest Industries were a secondary source. The suspended solids reached a level of 730 mg/L and dropped to 135 mg/L at site 0200093 (Section 2.2).

Periphyton was examined as a means of determining food availability because many benthic invertebrates are known to be non-selective feeders, eating any available algal or plant material[30,43,46 to 53]. High suspended solids can inhibit algal growth[31]. However, periphyton was much more abundant (Table 23) at the site where suspended solids was the highest (0200201), than at the upstream control site (0200110). The high levels of nitrates and ammonia, originating from explosives used in the mine, may have promoted algal growth at this site. Since suspended solids did not inhibit growth of periphyton, food availability did not cause the observed differences in the invertebrate populations.

The substrate is the final factor known to control invertebrate distributions. Suspended solids were very high at sites 1190007 and 0200201. High levels of suspended solids in the water column may cause invertebrates to leave the affected area and drift, decreasing the population size[54]. A more important effect in the Fording River is the settling of sediments which changes the structure of the cobble bottom of riffle reaches. Observations of the sample sites listed in Table 22 suggest this occurred to some extent at site 1190007, downstream from Eagle Settling Pond, and to a greater extent at site 0200201, immediately downstream from all the major sources of suspended solids. Black sediment was evident in crevices between and under rocks, and covering some upper surfaces. Measurements on bottom sediments (Section 2.6) also suggested there was a greater percentage of very fine sediment at these two sites. Silt was also present at site 0200093. However, it appeared to be natural substrate, related to the decreased slope and velocity of the river at this point. No black material was evident.

Substrates composed of rocks and cobbles are the optimum substrate for benthic invertebrates[32,54,55]. Addition of sediment to the substrate will change the habitat and eliminate many invertebrates by filling crevices and niches between and under rocks. Populations may decrease in number[54]. Alternately, they may become less diverse and unstable, being composed of a few dominant forms which can inhabit fine sediment[31,56].

The ordination plot indicated that the invertebrate population at site 0200201 was unique and most different from those at the other sites. Two very dominant groups were found there: the mayfly Baetis and chironomid larvae (Table 20, Figure 6). There were low numbers of other invertebrates. Baetis and chironomids of the subfamily orthocladiinae have proven to be suited to a substrate with a high sediment component and high oxygen saturation in the water[43,56,57]. The dominance of two taxa at site 0200201 is also shown by the low diversity index and the high redundancy index. The invertebrate population at site 1190007 showed a similar trend to that at site 0200201. The same two taxa were dominant (Table 20 and Figure 6) and the diversity index was only slightly higher. However, the total number of taxa was greater at site 1190007 (Table 20 and Figure 7). These results suggest the populations were unstable at these two sites. The other community analyses support this conclusion by showing that the populations at sites 1190007 and 0200201 were most similar.

There were more taxa and no overtly dominant forms at the control site 0200110, and the site 16 km downstream, 0200093. The higher diversity indicies at these two sites indicate more stable populations, probably because there was no disruption of the natural substrate. The difference at site 0200093, shown in the mutual information dendrogram and the ordination plot, reflects the natural differences in river flow and substrate type.

The presence and absence of certain other invertebrates was also caused by sediment altering the original substrate. There were fewer genera of Trichoptera and Plecoptera at sites 0200201 and 1190007, than at the other two sites (Figure 7). These orders usually decrease in number where a rocky riffle bottom is disturbed[30]. Generally this was true at sites 0200201 and 1190007, although Nemoura (Plecoptera) was common at site 0200201 (Figure 7). It is adapted to a bottom covered with fine sediment[48,49]. The free-living caddis fly Rhyacophila was also noted at these two sites. It can survive where the substrate is not covered with sediment, because it is not dependent on the debris usually found there for case-building materials. Case-building forms were found at sites 0200110 (Ecclisomyia) and 0200093 (Oligophlebodes).

Mayflies Cinygmula and Iron, which cling to or under rocks[31,42], were abundant at the control site 0200110, but few in number at sites 1190007 and 0200201. Their niches were presumably filled by sediment at the latter two sites.

We can conclude from this study that the increased sediment on the cobble bottom disrupted the invertebrate populations to some extent downstream from Eagle Settling Pond, at site 1190007, and to a greater extent immediately downstream from the entire coal mining operation at site 0200201. The populations of invertebrates at these sites were unstable and not "resistant" to further environmental stresses. Most of the sediment and associated fauna (e.g. Chironomidae, Baetis and Rhyacophila) will be washed out during freshet. The fish population of the Fording River is dependent on benthic invertebrates such as mayflies, stoneflies, caddis flies and chironomids for food[58]. During freshet, and until the bottom is recolonized, these portions of the river will probably not support a fishery, In addition, there were fewer kinds of invertebrates at the sites where black, fine sediment had accumulated. This may reduce the fishery if certain fishes show dietary preferences for taxa excluded from these areas.

2.7.4 Recommendations

The results from sampling aquatic biology support the recommendations to control the discharge of suspended solids from the mining operations, as outlined in Section 2.2.4. If the discharge of suspended sediment is not significantly reduced, the work done on invertebrate populations should be repeated, and the effects on the fish populations should be assessed.

For new mining areas, we recommend that baseline information on populations of invertebrates be collected from an unaltered stretch of river after freshet and during mid-summer. Permanent transects should be established across the river, using stakes or some other demarcating device, at each chosen site. At least one upstream control and one downstream site should be included. A minimum of four, but preferably more, samples should be taken along the transects using a Mundie or similar bottom sampler. After mining has been underway for two to five years, the established transects should be re-sampled for benthic invertebrates. These samples should be taken at the same time of year as the baseline samples, namely after freshet and during mid-summer. We also recommend that additional samples be taken in the fall and winter, if possible.

When the benthic invertebrates are sampled, comprehensive information on the substrate, as outlined in Section 2.6.3, should be collected to aid in the interpretation of the data.

Work in the field of stream ecology has shown that benthic invertebrates leave the substrate and drift when the carrying capacity is exceeded, and there is heavy competition for food and space[59]. We would expect the number of invertebrates in the drift to be higher below a disturbed stretch of river than below an unaltered stretch. Drift samples, as an indicator of river disturbances, should be collected in conjunction with the bottom samples.

3. THE UPPER ELK RIVER BASIN

The upper Elk River basin is the portion of the Elk basin lying upstream from the Fording River confluence. There is relatively little human activity in the upper Elk at the present time.

The Village of Elkford, at the confluence of Boivin Creek and the Elk River, discharges treated domestic sewage to the ground near to the Elk River. There are access roads to the upper Elk basin on both the east and west sides of the Elk River. Elco Mining Ltd. has conducted extensive and exploration activities in the vicinity of Weary Creek, and has proposed a major coal mining development in this area. These existing and proposed developments are shown in Figure 9.

3.1 Description of Discharges

3.1.1 Village of Elkford

The sewage treatment facilities at Elkford were described in the Phase I report(1), and there have been no changes. Effluent from the aerated lagoon system continued to exfiltrate to the ground adjacent to the Elk River. Additional effluent data have been collected since our last report, but these are not discussed here since there was no positive discharge from the lagoons. Monitoring of the Elk River upstream and downstream from the lagoons, reported below in Section 3.2, indicated that the discharge had no effect on the Elk River.

If the effluent begins to discharge directly to the Elk River, then the routine effluent monitoring, now carried out, should be reviewed. Recommended monitoring for the Elk River with regard to this discharge is outlined in Section 3.2.

3.1.2 Proposed Elk River Coal Project

Elco Mining Ltd. has proposed a major metallurgical coal mining development for the upper Elk basin[60,61]. The project would consist of an open pit mine on the east side of the Elk River, stretching from Cadorna Creek to slightly downstream of Weary Creek. Diversion of Weary Creek and 3.3 km of the Elk River would be necessary to accommodate the open pit.

A coal preparation plant capable of producing 3.6 million tonnes of clean coal per year, tailing ponds, coal blending facilities, and a water reservoir would be located on the west side of the Elk River, between Cadorna and Bleasdell Creeks. Preparation plant tailing would be discharged to the tailing ponds and the supernatant would be recycled back to the plant. Settling ponds would be used to remove suspended sediment from mine drainage.

Mine employees and their families would be housed at Elkford, or at a new townsite at the confluence of Forsyth Creek and the Elk River. An extension of the C.P. railway to the minesite from the existing line in the Fording or Elk valleys would be necessary[60].

Elco Mining Ltd. has prepared a prospectus[61] and a Stage I report[60] in accordance with Provincial requirements[3]. The review process required by Provincial guidelines, as outlined in Section 1.3, is being applied to Elco Mining's proposed development.

One major potential impact of the proposed development will be increased sediment discharge to the Elk River, caused by erosion of disturbed land surfaces. This will increase suspended solids, turbidity and sedimentation in the Elk River downstream from the minesite. The extent to which this occurs will depend upon the effectiveness of the erosion and sediment control program implemented by Elco Mining Ltd. Some guidelines for water quality protection in coal mining are given in Section 9.

3.2 Water Quality

3.2.1 Presentation of Data

The waters of the upper Elk basin were sampled by government agencies and consultants to Elco Mining Ltd.[60] during 1975-76. Data collected by the Pollution Control Branch and the Water Investigations Branch are summarized in Tables 24 to 28. Data from Elco Mining Ltd. have not been included but will be discussed. Suspended sediment yield data for the upper Elk River, calculated from Water Survey of Canada data, are contained in Table 16. The locations of government sampling sites are shown in Figure 9 and are described in Table 10.

3.2.2 Discussion of Results

Tables 24, 25 and 26 show that the water quality at all of the stations in the upper Elk basin was quite similar. Differences that did appear are not particularily significant, and are attributed mainly to variations in sampling time and number of samples.

The waters of the upper Elk were alkaline, moderately hard[17] (fair to good quality for domestic purposes[23]), low in colour, nutrients (nitrogen and phosphorus), arsenic, and heavy metals, such as chromium, copper, iron, lead, manganese, nickel and zinc. This is typical of the water quality of undisturbed streams in the Elk basin.

Tables 24 to 28 show that suspended solids and turbidity were generally low during 1975-76. This is probably due in part to the below average runoff during 1975 and 1976[11,62]. Suspended solids and turbidity were lowest in the Elk River at sites upstream from Aldridge Creek (2 - 22 mg/L suspended solids, 0.2 - 5.6 J.T.U. turbidity). Aldridge and Weary Creeks were very low in suspended solids and turbidity. The highest values (166 mg/L suspended solids, 35 J.T.U. turbidity) were measured in the Elk River at Elkford (Site 0200202) and upstream from Weigert Creek, near the Fording River confluence (Table 27). The profiles in Table 28 show a tendency for suspended solids and turbidity to increase from upstream to downstream in the Elk River.

Two unnamed creeks in the vicinity of Mt. Veits and Round Prairie (Table 28) were identified as sources of suspended sediment to the Elk River during the 1976 freshet, but were too small to account for increases in the suspended sediment in the Elk River. The cause of suspended sediment in the unnamed creeks appeared to be natural rather than man-made. All of the other tributaries to the upper Elk River were clear and sediment-free during the 1976 freshet on the sampling dates shown in Table 28. The suspended sediment in the upper Elk River may be partly due to natural channel erosion downstream from Aldridge Creek.

The suspended sediment yield (tonnes/km^2 or tonnes/(m^3.s)) from the upper Elk basin (Table 16) exceeded that from the Fording basin from 1970-74. The yield was about double in years of higher flow (1971, 1972 and 1974). The yield from the upper Elk was exceeded by that from Michel Creek in all years except 1974, a year of very high flow. During peak flows of the 1974 freshet, suspended sediment concentrations in the order of 1700 - 2600 mg/L (June 17-21) have been calculated for the Elk River, upstream from the Fording River. These concentrations are equal or higher than any recorded in the Elk River basin to-date. These data show that the sediment yield from the relatively undisturbed upper Elk basin can equal or exceed that from basins disturbed by surface mining and logging.

Table 26 shows that the water quality upstream from the Elkford sewage lagoons (sites 0200202 and 0200218) was virtually identical to that downstream from the lagoons (site 0200039).

The Elco Mining Ltd. water quality data[60] are rather preliminary, with only one or two samples taken in 1976. The data are similar to those collected by the Ministry of the Environment for many parameters. There are some differences in parameters, such as arsenic, ammonia, nitrate and a number of heavy metals, which are mostly due to differences in analytical and reporting techniques. Elco's consultants continued to collect pre-development water quality data in the vicinity of the proposed minesite during 1977.

3.2.3 Recommendations

We recommend that the monitoring program for the Elk River above and below the Elkford sewage lagoons be reduced, since the lagoons have not had a measurable effect on Elk River water quality. Monitoring can be limited to fecal coliforms to indicate fecal contamination of the river. Several replicate samples should be taken on each sampling occasion since coliform test results can be extremely variable. Sampling should be conducted during low flows, especially when there may be recreational use of the river. This program should be reviewed if the Elkford lagoons begin to discharge directly to the Elk River, or if there is a substantial increase in the population of Elkford.

As a second priority, pre-operational data on suspended solids and turbidity should be collected in the vicinity of the proposed Elco Mining Ltd. coal project.

3.3 Aquatic Biology

Benthic invertebrates were sampled at one site (0200042) in the upper Elk basin. These data are presented and discussed in Chapter 5, on the lower Elk basin.

4. THE MICHEL CREEK BASIN

The water quality of the Michel Creek basin was influenced mainly by the coal mining and processing operations of Kaiser Resources Ltd., Byron Creek Collieries Ltd. and Coleman Collieries Ltd. The approximate locations of these operations are shown in Figure 10.

4.1 Byron Creek Collieries Limited

4.1.1 Description of Operations

Byron Creek Collieries Limited operates a surface coal mine on Coal Mountain, at the confluence of Michel and Corbin Creeks, as shown in Figure 10. The operation consists of two open pits on Coal Mountain and a dry coal preparation plant adjacent to Corbin Creek. To date, coal has been hauled by truck to the rail head at McGillivray. Thermal coal production was 315,000 tonnes in 1975 and 388,000 tonnes in 1976[5]. Byron Creek is in the process of expanding production to 887,000 tonnes by mid 1978[63].

This expansion entails the construction of a new coal preparation plant at the minesite, a 19 km extension of the railroad from McGillivray with a rail loop at Corbin, overland coal conveyors, coal product stockpiles, and unit coal train loading facilities. The preparation plant will have total wastewater recycle. No fine coal tailing will be produced, and coarse coal refuse will be dumped with the surface mine spoil. Spills or intentional discharges from the plant will flow to an emergency pond and will be pumped back to the plant. Domestic sewage (less than 25 m^3/day) will be disposed of under Ministry of Health regulations, probably by septic tank and tile field system. Byron Creek has applied to the Pollution Control Branch for air, effluent and refuse permits for the proposed development[64].

4.1.2 Description of Discharges

The discharges from Byron Creek Collieries during the 1975-76 study period were sediment-laden surface runoff from spoil piles, haul roads and plant yard areas. Open Cut Creek, draining spoil piles on the west side of Coal Mountain into Michel Creek, was the major sediment source from the minesite. There were no sediment control measures during 1975-76 to prevent sediment from reaching Michel and Corbin Creeks.

Byron Creek Collieries has prepared a drainage control plan for the minesite. Construction of the control works has started, and will be completed in 1978. The first step in the plan was to stabilize the spoil piles on the west side of Coal Mountain by resloping the spoil and diverting water away from the spoil via a drainage system along the main haul road.

An interceptor ditch along the west flank of Coal Mountain will convey Open Cut Creek and drainage from the west side of the spoil piles to a settling pond. The pond will overflow to Corbin Creek, about 1000 m upstream from its confluence with Michel Creek. An interceptor ditch on the north flank of Coal Mountain, leading to the settling pond, will receive drainage from the mine haul road and plant yard areas.

The mine haul road drainage system has been completed and a berm along Corbin Creek will be constructed to divert plant yard drainage to the north interceptor. Drainage from the new coal stockpile and rail load out facilities will be collected by a berm around the edge of the coal stockpile and conveyed to a settling pond for treatment. Clean water from above the coal stockpile will be diverted away from the stockpile by small ditches[7,63].

The mine drainage control works have been authorized by the Ministry of Mines and Petroleum Resources and by the Water Rights Branch.

4.1.3 Effluent Sampling Data from Byron Creek Collieries Ltd.

Open Cut Creek was the major mine drainage stream from Coal Mountain in 1975-76, and it was sampled by the Pollution Control Branch and the Water Investigations Branch. These data are summarized in Tables 29 and 30. The data show that the mine drainage was very high in suspended solids (up to 12,000 mg/L) and turbidity (up to 5200 J.T.U.) during spring snowmelt. Suspended solids loadings of up to 330 tonnes/day were calculated from the flow and suspended solids concentrations. Heavy rains in early August 1976 caused a mud slide from a spoil pile on Coal Mountain, to enter Michel Creek[111].

The mine drainage was alkaline and low in dissolved iron, dissolved lead, and total vanadium. Total iron levels were high (up to 61 mg/L), but were not significant because they were due to the iron content of the inert suspended sediment, rather than to the precipitation of dissolved iron. Similarly, total copper levels were higher than normal (up to 0.12 mg/L), but it is believed that this was also due to the copper content of the suspended sediment. We expect that dissolved copper levels were low.

Total phosphorus levels in the mine drainage were high at times (up to 3 mg/L), but dissolved phosphorus remained low (<0.02 mg/L). Total organic carbon levels were high (up to 470 mg/L), due to the coal content of the mine drainage. The dissolved manganese concentrations (0.03 - 0.18 mg/L) slightly exceeded Level A of the Mining Objectives (0.05 mg/L)[8], and the acceptable limit for drinking water (0.05 mg/L, based on aesthetic considerations)[23].

Open Cut Creek will be intercepted by the west interceptor ditch and conveyed to a settling pond. The effluent from the settling pond should meet Level A of the Mining Objectives[8], with perhaps the exception of suspended solids during high runoff conditions and dissolved manganese. The settling pond effluent may also contain elevated levels of nitrite, nitrate and ammonia nitrogen, because of the leaching of residual ammonium nitrate explosives which are used at the mine. Elevated nitrate levels in mine drainage at Fording Coal (Section 2.2) and Kaiser Resources (Section 5.1.2) are believed to be due to leaching of residual explosives. Nitrate plus nitrite levels will probably not exceed Level A[8] or the maximum permissable limit in drinking water (10 mg/L as N)[23], but could easily reach levels which might contribute to nuisance growth of aquatic plants (provided that sufficient concentrations of other essential nutrients were present).

Other sources of suspended sediment from the Byron Creek Collieries operation were not measured during 1975-76. There was evidence of other sources from aerial photographs, monitoring data for Corbin Creek and site inspections. Aerial photographs of the Byron Creek minesite, taken on July 4, 1975[65], show that the plant yard area and coal haul road extend right to the bank of Corbin Creek in places. A site inspection on July 3, 1975, confirmed the absence of vegetation between Corbin Creek and mine disturbances, and it was evident that machinery had been driven across the creek bed. Two small settling ponds were constructed in the plant yard area during the winter of 1975-76 to control sediment, but the effectiveness of these ponds has not been determined. A site inspection in April, 1976, identified two mine drainage streams from the northern flank of Coal Mountain[111]. These streams will be intercepted by the north interceptor ditch and conveyed to the settling pond.

Water quality data for Corbin Creek (Section 4.5) showed high concentrations of suspended solids (430 to 1472 mg/L) on two sampling occasions during 1975-76. These high values were caused by the mining disturbances described in the previous paragraphs.

In future developments at Byron Creek Collieries, the guidelines for water quality protection in Chapter 9 should be followed.

4.1.4 Recommendations

We recommend that effluent objectives be set for discharges from the proposed settling ponds. These objectives should be met for a range of flood conditions, but could be exceeded for specific unusual flood occurrences. This concept is discussed in more detail in Sections 5.1.1 and 5.1.3. An effluent objective for suspended solids of 50 mg/L is recommended, because water quality monitoring indicates that natural levels in adjacent streams are low.

The settling pond effluent should be monitored for suspended solids and flow daily, if possible, during spring snowmelt runoff and heavy rains. During snowmelt, samples should be taken in the afternoon since snowmelt runoff is typically low in the morning and reaches a peak in late afternoon or evening. This effluent monitoring should be closely correlated with the water quality monitoring recommended for Corbin and Michel Creeks in Section 4.5.6. The nitrite, nitrate, ammonia and dissolved manganese levels in the effluent should be measured several times during the year, especially during low flows for the nitrogens.

4.2 Coleman Collieries Limited

4.2.1 Description of Discharges

Coleman Collieries Ltd. operates a surface coal mine in Alberta, adjacent to the provincial boundary, as shown in Figure 10. Spoil from the Number 2 and 3 pits is dumped over the ridge of Tent Mountain, on the provincial boundary, into British Columbia. Drainage from the waste dump flows to Michel Creek via an unnamed creek. Coleman Collieries has constructed a settling pond to remove suspended sediment from the mine drainage[66].

Pollution Control Permit PE-3986 was issued on June 9, 1976, authorizing the discharge from the settling pond. The permit specifies that suspended solids in the effluent must not exceed 50 mg/L. The rate of effluent discharge is not specified, since it depends on the natural surface runoff from the waste dump area. The discharge rate is not expected to exceed 0.53 m^3/s. The Company is required to monitor, weekly, the suspended solids of the settling pond influent and the suspended solids and flow of the settling pond effluent[66].

Coleman Collieries Ltd. recently abandoned plans to expand its coal mining operation on the British Columbia side of Tent Mountain. (Figure 10). The expansion would have consisted of an open pit mine and spoil pile, extending from the B.C. - Alberta border to the Corbin Road adjacent to Michel Creek. Twenty million tonnes of raw coal would have been mined in B.C. and 135 million cubic metres of spoil would have been disposed of in B.C. during the life of the mine[67].

4.2.2 Effluent Sampling Data

The Water Investigations Branch monitored the unnamed creek draining the spoil pile during 1975-76. During 1975, the drainage was monitored for a wide range of parameters to assess its composition. These data are summarized in Table 31. Suspended solids and turbidity were monitored during 1975-76 and these data are contained in Table 32.

Table 31 shows that the drainage was alkaline and low in heavy metals and nutrients. Table 32 indicates that the suspended solids and turbidity of the drainage were relatively low during 1975-76, with maximums of 68 mg/L suspended solids and 38 J.T.U. turbidity. These low values for suspended solids and turbidity may be due, in part, to the below average runoff which occurred during 1975-76. In comparison, an undisturbed creek near Tent Mountain, called Andy Good Creek, was completely free of turbidity on all the dates when the Coleman drainage was sampled (Table 32). The drainage from the spoil pile met Level A of the Mining Objectives[8] for all parameters except suspended solids, which was exceeded on one sampling occasion.

4.2.3 Recommendations

We recommend that the discharge from the settling pond be monitored for suspended solids and flow. If possible, monitoring should be performed daily during spring snowmelt runoff, and during and immediately after heavy rains. Weekly monitoring throughout the year, as now carried out, is not appropriate for a runoff-related discharge. Typically, more than 90 percent of the annual sediment discharge occurs during the spring snowmelt period. Sediment discharges are normally very low during the rest of the year, with the exception of occasional heavy rainstorms. Consequently, monitoring should be keyed to these heavy runoff periods. Weekly monitoring during heavy runoff periods is too infrequent to detect peak runoff and sediment concentrations. During the snowmelt period, samples should be taken in the afternoon since snowmelt runoff (and suspended sediment) is low in the morning, and reaches a maximum in late afternoon and evening.

The monitoring should be correlated with monitoring in Michel Creek, upstream and downstream from the discharge (see Section 4.5.6). The nitrite, nitrate, ammonia and dissolved manganese levels in the effluent should be checked occasionally during low flow.

The dumping of spoil on Tent Mountain began at least three years before the start of construction of the sediment control works.

In future developments, sediment control works should be constructed first so that they are ready to control sediment when land disturbance begins. General guidelines for water quality protection in surface coal mining are given in Chapter 9.

4.3 Kaiser Resources Limited

4.3.1 Description of Discharges

This section discusses the discharges from Kaiser Resources Ltd. to Michel Creek. The discharges from Kaiser Resources to the Elk River are discussed in Chapter 5.

The operations of Kaiser Resources Ltd. were described in the Phase I report[1]. They include several open pit mines, a coal preparation plant, a hydraulic mine and a coke plant. The location of these operations is shown in Figure 11.

The major discharges to Michel Creek are from mine drainage, coal refuse piles and the coke plant in Michel. Mine drainage enters Michel Creek via Qualtieri Creek north of the hydraulic mine, Baldy Creek north of the coke plant, and Erickson Creek east of the coke plant. There are coal refuse piles alongside Michel Creek: one labelled R4, near the hydraulic mine, and one labelled R2, opposite the coke plant (Figure 11).

a) The Michel Coke Plant

The plant was described in some detail in the Phase I report[1]. The plant is old and obsolete and creates discharges to air and water which would not occur in a modern plant. Under order from the Pollution Control Branch to upgrade or shutdown the plant, the Company has decided to improve the operation. It has applied for a pollution control permit which should result in an effluent that meets at least Level B of the Mining Objectives[8], within a year or two.

b) The Erickson Creek Settling Pond

This pond was mentioned only briefly in the Phase I report[1]. Its design is described here because it is typical of settling ponds needed to treat drainage from coal mines.

The location of the pond is shown in Figure 11. It was constructed after the spring freshet, in 1972, to remove suspended sediment from Kaiser's surface mines on Natal Ridge. The settling pond was authorized by the Water Rights Branch (Conditional Water Licence 40954)[68]. The design factors are summarized in Table 33. The pond was designed to provide a minumum of two hours water retention time at the design flow, plus 15 years of sediment storage. The design flow was derived by assuming an average precipitation of 760 mm/year, a runoff/precipitation ratio of 0.50, and a ratio of maximum flow to average flow of 10[68].

Most of the water entering the Erickson settling pond percolates into the ground and the spillway has only overflowed on one occasion[69]. Thus, in this case, the design factors were not important. Ideally, the design of settling ponds should be based on the pond surface area, and on the particle-size distribution and concentration of the suspended sediment which the pond must remove, as outlined in Section 5.1.1.

Flow records collected in the adjacent Grave Creek watershed (site 08NK019), and the Elk River (sites 08NK005 and 08NK016)[11,62], indicate that the design flow of the Erickson pond is roughly equal to the one in ten year maximum daily flow in Erickson Creek. This meets the U.S. Environmental Protection Agency specification of handling the one in ten year, 24 hour precipitation event[12].

4.3.2 Effluent Sampling Data

Effluent sampling was carried out by the Ministry of the Environment during 1975-76. It centered on the two problem areas identified in the Phase I report[1]: the Michel coke plant settling pond effluent, and sources of suspended sediment to Michel Creek. The effluent sampling data for the coke plant are summarized in Tables 34 and 35. Data on suspended sediment sources are contained in Tables 32, 35 and 36.

a) Michel Coke Plant

Tables 34 and 35 show that the coke plant settling pond effluent was of poor quality, frequently exceeding Mining Objective Levels A and B for suspended solids and Levels A, B and C for ammonia and phenols[8]. Sulphate exceeded Level A on occasion. Effluent flow rates ranged from 0.2 m^3/s during spring runoff, to 0.006 m^3/s during the winter. The concentrations of contaminants in the effluent were highest during the winter and lowest during spring, when runoff from plant yard areas diluted the coke plant effluent.

b) Suspended Sediment Sources

The largest source of suspended sediment to Michel Creek during 1976 was Baldy Creek (Tables 32 and 36). Suspended solids and turbidity reached values of 4426 mg/L and 1400 J.T.U., respectively, during the spring snowmelt period. Suspended solids loadings to Michel Creek of up to 270 tonnes/day were calculated from suspended solids and flow data. The creek was black with coal dust during the spring snowmelt period. We do not know the exact sources of suspended sediment in Baldy Creek, but the creek drains mine yard areas adjacent to Michel Creek and areas disturbed by surface mining and mine roads. Kaiser Resources is preparing an erosion and sediment control program for Baldy Creek[70].

The Michel coke plant settling pond, described previously, was a source of sediment and turbidity to Michel Creek during the spring freshet. Suspended solids levels of up to 1338 mg/L, and turbidities of up to 960 J.T.U. were measured (Table 35). Peak suspended solids loadings of six to nine tonnes/day were calculated from the flow and suspended solids measurements. These results indicate that the settling pond was a much smaller sediment source than Baldy Creek.

A site inspection on March 8, 1976, found that black, sediment-laden surface runoff from the yard areas, around Kaiser's Michel operations, was entering Michel Creek at several locations[71]. Another source of suspended sediment from Kaiser's Michel operations was the coal refuse piles, located adjacent to Michel Creek. These piles were described in the Phase I report[1], and were inspected during 1975-76 to determine if erosion had been effectively controlled.

The refuse pile just south of the hydraulic mine (denoted as R4 in Figure 11) was found to have a fairly good vegetative cover. On the creek side of the pile, there had been some erosion of the coal into the creek by snowmelt or rain, and the creek had eroded the bottom of the refuse pile at the southern end.

The refuse pile located just north of the coke plant (denoted as R2 in Figure 11) had been eroded by snowmelt or rain along a 700 metre front on Michel Creek. The slope of the refuse pile is very steep and extends right to the bank of Michel Creek. There was virtually no vegetation on the creek side of the pile.

Qualtieri Creek was also found to contain considerable amounts of black suspended sediment (232 - 986 mg/L suspended solids, 100 - 280 J.T.U. turbidity) in early May, 1976. However, the creek deposited most of its sediment load on flat pastureland, adjacent to Michel Creek.

The Erickson Creek settling pond which receives mine drainage from Kaiser's surface mines did not appear to be a source of sediment during 1975-76. There was no overflow from the pond when it was visited in May-June, 1976.

The creeks draining the southern flank of Natal Ridge to Michel Creek, between site 0200046 near the coke plant and the mouth of Erickson Creek, are suspected of being sources of suspended sediment (Figure 11). These creeks drain an area which had been mined and reclaimed. Observations made during July, 1976, from the road between the Michel Coke plant and the Erickson Creek settling pond, indicated that substantial erosion was occurring.

A coal slurry spill occurred at Kaiser's hydraulic mine on December 20, 1976, and a small amount of coal slurry entered Michel Creek. Kaiser Resources Ltd. is preparing spill prevention plans for the hydraulic mine[(70)].

4.3.3 Recommendations

Erosion and sediment control measures are required for the Baldy Creek drainage and are being planned by the Company. All surface runoff from the yard areas at the Michel operations should be collected and treated in settling ponds (or suitable alternative) prior to discharge to Michel Creek. Settling ponds should be designed to discharge, for example, no more than 50 mg/L suspended solids for flows up to the one in ten year flood.

Coal refuse piles R2 and R4 should be reclaimed to prevent further erosion of the coal refuse into Michel Creek. The siting of coal refuse piles on the floodplain should be avoided. The piles should be designed to remain stable indefinitely against floods and the changing course of streams within the floodplain.

The creeks draining Natal Ridge, between site 0200046 and Erickson Creek, should be investigated to determine if erosion and sediment control measures are necessary. The hydraulic mine should be inspected to ensure that future Company proposals for spill prevention and containment are suitable.

We recommend that the coke plant effluents be upgraded to at least Level B of the Mining Objectives[8]. Upgrading the coke plant settling pond effluent to Level B would reduce the quantity of phenol and ammonia discharged by one to two orders of magnitude, and should restore acceptable water quality downstream from the coke plant.

We recommend that the suspended sediment sources at Kaiser's Michel operations be monitored daily, during the spring snowmelt period and heavy rains, for suspended solids and flow. This monitoring should be closely correlated with the water quality monitoring recommended for Michel Creek in Section 4.5.6.

After the coke plant effluent is upgraded, it should be monitored for pH, phenols, ammonia, cyanide, sulphide, suspended solids and flow. The monitoring should be done in conjunction with monitoring of Michel Creek during low flow, since water quality detrioration is only likely to occur during low flow.

4.4 Miscellaneous Sources of Suspended Sediment

During 1975-76, two creeks, discharging to Michel Creek, were found to be important sources of suspended sediment.

One source was an unnamed creek which flows from Tent Mountain Pass into Michel Creek (Figure 10). The sampling data for this creek are summarized in Table 37. Suspended solids (up to 4203 mg/L) and turbidity (up to 1120 J.T.U.) were high. Total iron (11 mg/L) was also high, but was probably part of the suspended solids, and thus not important to water quality. The dissolved iron concentration of similar sediment-laden runoff in the Michel basin was very low (Section 4.1.3). The sediment in this creek was caused by the creek leaving its channel and eroding a new channel, 2.5 to 3.5 m deep, in the middle of an old road, adjacent to the creek.

The second sediment source was Fir Creek, discharging to Michel Creek (Figure 10). On June 2, 1976, this creek carried much more sediment (suspended solids of 190 mg/L and turbidity of 130 J.T.U.) than other creeks in the Michel basin (Table 32). The sediment was caused, at least in part, by the erosion of the logging road in the Fir Creek basin. The basin was logged in the past[72], but there did not appear to be any recent logging activity.

These sediment sources show the importance of proper design and maintenance to prevent erosion when building roads.

We recommend surveillance of these sediment sources, and other similar sources, during the snowmelt period. Chronic sediment sources should be documented to determine what action could be taken to control the sediment discharge.

4.5 Water Quality

The waters of the Michel Creek basin were sampled by the Pollution Control Branch, the Water Investigations Branch and the Water Survey of Canada during 1975-76. The locations of the sampling sites are shown in Figures 10 and 11 and are described in Table 10.

Provincial Government data on suspended solids and turbidity are given in Table 32. The table provides a turbidity profile for Michel Creek, showing how the turbidity changes along the creek.

Other water quality data for Michel Creek and its tributaries are summarized in Tables 38 to 43.

Suspended solids data collected in Michel Creek above and below Kaiser Resources Ltd. are plotted in Figure 12 for 1975 and Figure 13 for 1976.

4.5.1 Suspended Solids and Turbidity

The lowest suspended solids and turbidity levels in Michel Creek were at the headwaters, upstream from Byron Creek Collieries Ltd. (site 0200184). Suspended solids ranged from 2 - 122 mg/L, and turbidity ranged from 0.4 - 27 J.T.U. These values were somewhat higher than observed for other headwater streams in the Elk basin, and may be due to natural channel erosion.

Suspended solids (2 - 346 mg/L) and turbidity (1.6 - 136 J.T.U.) increased at sites 0200208 and 1190001, downstream from Open Cut Creek, because Open Cut Creek added runoff from Byron Creek Collieries Ltd. These increases show that Open Cut Creek tripled the suspended sediment load in Michel Creek, since the flows at sites 0200184 and 0200208 are similar.

Corbin Creek (site 0200209) occasionally had high suspended solids (up to 1472 mg/L) and turbidity levels (up to 440 J.T.U.). These values are extremely high compared to adjacent undisturbed headwater streams, such as Michel Creek at site 0200184 and Andy Good Creek which was clear. The high values in Corbin Creek were probably due to runoff from Byron Creek Collieries Ltd. (Section 4.1.3). There is one domestic water license (C.L. 38216, 2.3 m^3/d)[73] on Corbin Creek to supply water for a vacation cottage. High suspended solids and turbidity levels could ruin this water supply.

Michel Creek, downstream from Corbin Creek, at sites 1190031 and 0200185, also had increased suspended solids (2 - 754 mg/L) and turbidity levels (0.5 - 440 J.T.U.), due to the sediment discharge from Byron Creek Collieries Ltd. Suspended solids at 1190031 and 0200185 were usually lower than those at 0200208 (1190001), immediately downstream from Open Cut Creek. This result may be due to dilution from Corbin and Andy Good Creeks and to sedimentation in Michel Creek (see Section 4.6.2).

The highest values at site 0200185 (754 mg/L, 440 J.T.U.) were measured in the late afternoon on a hot spring day (April 8, 1976, 1730 hours). Earlier the same day (1230 hours), suspended solids and turbidity were only 64 mg/L and 22 J.T.U., respectively. These results show that extreme diurnal fluctuations can occur in small streams during snowmelt.

Site 0200186, downstream from Coleman Collieries Ltd., had suspended solids and turbidity levels similar to site 0200185, upstream from Coleman Collieries. The Coleman Collieries mine runoff did not appear to have any effect on suspended sediment in Michel Creek during 1975-76.

Sediment-laden runoff in an unnamed creek from Tent Mountain Pass (Section 4.4) increased suspended solids in Michel Creek from 134 to 222 mg/L and turbidity from 46 to 62 J.T.U. on May 4, 1976 (Table 32).

On the other hand, suspended solids (6 - 50 mg/L) and turbidity (2.6 - 18 J.T.U.) in Leach Creek, an undisturbed tributary of Michel Creek (approximately equal in size to Michel Creek at their confluence) were consistently lower than those in Michel Creek (12 - 222 mg/L, 4.2 - 62. J.T.U.).

The suspended solids concentration and turbidity in Michel Creek during 1975-76 (Table 32) were usually similar from site 0200186, downstream from Coleman Collieries, to site 0200046, upstream from Kaiser Resources Ltd. These results imply that suspended sediment loading was increasing, since streamflow was increasing from site 0200186 to site 0200046. The increase in suspended sediment loading may have been due to erosion in the channel of Michel Creek.

Suspended solids in Michel Creek generally increased from upstream to downstream of Kaiser Resources Ltd. (Figures 12 and 13).

For example, there were 11 increases during 1975-76 from site 0200046 to site 0200025 (Figure 10 and Table 32). However, results were variable. On two occasions, suspended solids were higher at the upstream site than at the downstream site.

There were also variations in sediment input. On three occasions (April 8, May 9 and May 12, 1976), when both sediment sources and stream loadings were measured, the discharges from Baldy Creek and the coke plant represented 74, 7 and 0.7 percent of the suspended solids load in Michel Creek, downstream from Kaiser Resources Ltd. at site 0200025 (Table 32).

Figures 12 and 13 illustrate some of the very large day to day and diurnal fluctuations which can occur in suspended sediment concentrations. For example, on April 6, 1976, the concentration downstream from Kaiser was 150 mg/L at 1230 h and 852 mg/L at 1630 h. Consequently, to obtain comparable upstream and downstream data, samples should be taken on the same day at approximately the same time. The higher concentrations at the upstream site (0200046) indicate that concentrations varied rapidly with time and within the cross-section of the creek.

The additional suspended solids and turbidity in the Michel basin would need to be removed prior to domestic or industrial use. The aesthetic and recreational value of the water is reduced, particularly by black or brown-black sediment derived from coal[74]. Increased suspended solids, turbidity and sedimentation can affect aquatic life as outlined in the Phase I report[1]. The effects on benthic invertebrates were studied during Phase II and the results are presented in Section 4.7.

4.5.2 Phenols

Phenol concentrations in Michel Creek were higher downstream from Kaiser's coke plant than upstream. Concentrations upstream (site 0200046) ranged from <0.002 to 0.007 mg/L, while concentrations downstream (sites 0200025 and 1190041) ranged from <0.002 to 0.064 mg/L. The highest phenol concentrations occurred during low flow periods in Michel Creek and were similar to those reported in Phase I[1]. The downstream concentrations frequently exceeded the acceptable limit for drinking water (0.002 mg/L)[23] and levels which can affect the taste of fish[24,75]. The highest values measured approached the recommended limit for the protection of fish (0.1 mg/L)[75].

There have been complaints, during February 1976, about the tainted flesh of fish caught in the Elk River, downstream from Michel Creek. Surveys indicated that the only apparent sources of tainting substances were the coke plant settling pond discharge and yard drainage containing fuel and lubricating oils from Kaiser's Michel operations[71, 112].

4.5.3 Ammonia

Ammonia concentrations in Michel Creek were higher downstream from Kaiser's coke plant than upstream. Concentrations upstream (site 0200046) ranged from <0.005 to 0.027 mg/L as N, while concentrations downstream (sites 0200025 and 1190041) ranged from 0.06 to 0.26 mg/L. The highest concentrations occurred during low flow periods, and were similar to those reported in Phase I[1].

The toxicity of aqueous solutions of ammonia is due to the un-ionized ammonia content. A limit of 0.02 mg/L un-ionized ammonia has been recommended to protect freshwater aquatic life[24,75]. The un-ionized ammonia content will be only about five percent of the ammonia concentration, at the pH and temperature levels of Michel Creek water[75,76]. On this basis, it is unlikely that un-ionized ammonia exceeded the toxic level of 0.02 mg/L in the creek. Total ammonia exceeded the drinking water objective of 0.01 mg/L but not the acceptable limit of 0.5 mg/L[23].

4.5.4 Surfactants

The concentration of surfactants (methylene blue active substances) ranged from 0.18 to 0.29 mg/L at sites 0200186, 0200046 and 0200025, during June 2-4, 1975. Surfactant concentrations were normally <0.03 mg/L in Michel Creek. The usual source of surfactants in water is linear alkylate sulfonate (LAS), a surface-active agent used in synthetic detergents. However, several organic and inorganic compounds can react with methylene blue in the test to cause high readings[77].

The surfactant concentrations in Michel Creek were within the acceptable limit for drinking water (0.5 mg/L)[23], but equalled the level of LAS recommended for the protection of aquatic life (0.2 mg/L)[75]. The surfactant readings in Michel Creek were probably due to interferences with the test by organic and inorganic compounds, since there are no apparent sources of LAS at sites 0200186 and 0200046.

4.5.5 Other Parameters

Several other parameters increased because of the effluent discharges to Michel Creek and its tributaries, but were of limited significance to water quality. Coal mine drainage to Michel Creek (sites 0200208, 1190001, 0200185) and Corbin Creek (site 0200209) caused higher levels of total organic carbon, organic nitrogen, total phosphorus, total iron, total zinc and total copper. The increased levels were due to the presence of these compounds in the suspended sediment from the coal mining areas (Section 4.1.3).

The treated sewage discharged from Kaiser's coke plant increased fecal coliform densities at site 0200025 in Michel Creek, but the densities were less than 94 per 100 mL. This level met the acceptable limit for raw drinking water (i.e. prior to treatment)[23], the recommended criterion for bathing waters[24] and the general criterion recommended by the Municipal Objectives[78].

4.5.6 Recommendations

Measures to control the discharge of suspended sediments have been recommended in Sections 4.1.4, 4.2.3 and 4.3.3.

We recommend weekly monitoring of suspended solids and turbidity, upstream and downstream from each coal mining operation, during the spring snowmelt period. The upstream and downstream sites should be sampled at approximately the same time, and should be closely correlated with the sediment source monitoring recommended in previous sections.

The snowmelt period in the Michel basin started between March 15 and May 1 during 1970-76, and lasted until June 1 to July 1. Suspended sediment levels were high for 1.5 - 3 months/year (average of 2 months/year) during the snowmelt period. Suspended sediment increases, due to mining sources, were particularily large during the first part of the snowmelt period.

Suspended sediment levels can also be high during heavy rains, in the summer and fall, and should be monitored at these times if possible. Rainfall events, being unpredictable, are not amenable to routine monitoring. If sediment control measures operate satisfactorily during the snowmelt period, they will probably operate satisfactorily during most rainfall events.

A list of sites which should be monitored in the Michel Creek basin is contained in Table 89. The program should be flexible, adding, deleting or moving sites as sediment sources change with development.

It may be necessary to monitor nitrite, nitrate, ammonia and dissolved manganese in Corbin and Michel Creeks if the effluents from mine drainage settling ponds contain high concentrations of these parameters. Fecal coliform densities should be monitored at sites 0200046 and 0200025, particularily during low flows when there is recreational use of lower Michel Creek, and the Elk River downstream from Michel Creek.

The effect of the coke plant effluent on Michel Creek has been documented and further monitoring is not needed until the effluent is upgraded. When this occurs, sites 0200046 and 0200025 should be monitored for pH, phenols, ammonia, cyanide, sulphide, suspended solids, turbidity and water temperature. The monitoring should be closely correlated with effluent monitoring (Section 4.3.3) and conducted once a month during low flow periods. Deterioration of water quality is likely to occur only during low flows.

4.6 Bottom Sediment

4.6.1 Presentation of Data

Freeze-core and sediment trap samples were taken in Michel Creek, by the Water Investigations Branch, during April to July 1976. The procedures are outlined in Section 2.6.

Three sediment traps were installed in April 1976, in the vicinity of each of the following sites: 0200184, 1190031, 0200185, 0200186, 0200098 and 0200025 (Figure 10). In July 1976, the traps at sites 0200184, 0200185, 0200186 and two of the traps at site 0200025 were recovered. The data from the analysis of these samples are summarized in Table 44. One trap at 0200025, and the traps at sites 1190031 and 0200098 could not be found in July 1976.

Freeze-core sediment samples were taken in July 1976, in the vicinity of sites 0200184, 1190001 (or 0200208) and 0200185. The data from the analysis of these cores are presented in Table 45. Samples could not be taken at sites 0200186, 0200098 and 0200025, and only one core was taken at site 0200185 because the large substrate sizes at these sites made it impossible to drive the freeze-core probe into the sediment.

Sediment grab samples were taken at the same time as invertebrate samples were collected. The method is outlined in

Section 2.6. Samples from sites 0200184, 1190031, 1190029, 0200203 and 0200025 were analyzed for particle-size distribution and chemical composition (Table 46). The analysis was more extensive for samples from sites 0200203 and 0200025 because they were upstream and downstream from Kaiser's coke plant.

4.6.2 Discussion of Results

The sediment data obtained by sediment trap and freeze-core sampling will be discussed qualitatively since too few samples were taken at each site to account for the inherent variability in results.

The particle-size analyses of the freeze-core samples (Table 45) show that the particle-size distribution, in the upper 30 cm of bottom sediment, was similar upstream (site 0200184) and downstream from Byron Creek Collieries Ltd. (sites 0200208 and 0200185). This suggests that fine-grained sediment, derived from the coal mining disturbances, was not being deposited in Michel Creek downstream from the minesite.

The particle-size analyses of the sediment trap samples (Table 44) suggest that more fine sediment (finer than 2.38 mm) was collected at sites downstream from Byron Creek Collieries, Coleman Collieries and Kaiser Resources (0200185, 0200186 and 0200025), than at the site upstream from all mining disturbances (0200184). This tendency is consistent with the fact that much higher suspended sediment levels were measured at the downstream sites than at the upstream site. Deposition of suspended sediment in bottom gravels occurs when stream velocity decreases. It also occurs through turbulent entrainment when velocities are too high to permit deposition on the gravel surface[79].

There was an apparent conflict between the freeze-core and sediment trap results. This may be due to the fact that with the exception of one freeze-core sample at 0200185, the downstream freeze-core and sediment trap sampling sites were different. Also, the sediment traps may be more efficient in trapping fine sediment than are the bottom gravels, although at site 0200184, the percentage of sediment finer than 2.38 mm was similar in the freeze-core and sediment trap samples.

The grab sediment samples (Table 46) showed that sediment from sites 1190031 and 1190029, downstream from minesites, was finer (i.e. more particles less than 0.297 mm in diameter) than sediment from other sites in Michel Creek.

There was a high total and organic carbon content in sediment from site 1190031, downstream from Byron Creek Collieries. The carbon was deposited by Open Cut Creek, which empties into Michel Creek just upstream from site 1190031 (Figure 10). Carbon from coal was associated with fine particles and this could explain the high carbon values at this site, but not at site 0200025, downstream from Kaiser Resources. At this site, coal was evident on the bottom; however, sediment particles were generally larger.

Nitrogen was also associated with fine particles. This would explain the high nitrogen in sediment from sites 1190031 and 1190029 where there was more fine sediment. Levels of heavy metals in the sediment, at sites 0200203 and 0200025, upstream and downstream from Kaiser's coke plant, were very similar. This result suggests that the coke plant did not contribute heavy metals to the sediments.

4.6.3 Recommendations

Future benthic invertebrate studies should include substrate analyses of the kind recommended in Section 2.6.3. A discussion regarding the future use of freeze-core and sediment trap sampling is presented in Section 2.6.2.

4.7 AQUATIC BIOLOGY

The Phase I study[1] suggested that suspended solids from mining operations and contaminants from the coke plant could affect aquatic life. A survey of benthic invertebrates and attached algae or periphyton was therefore carried out in Michel Creek during the summer of 1975.

As explained in Section 2.7, we studied benthic invertebrates because of their importance to aquatic foodwebs and their usefulness as environmental indicators[30 to 36]. A range of factors, including water flow and temperature, water chemistry, food availability, and substrate characteristics are known to control the nature of invertebrate populations[31]. These factors were considered together with suspended solids and toxic contaminants in assessing changes in the populations of invertebrates.

Periphyton is an important food for many benthic invertebrates[43, 46 to 53]. It was studied in Michel Creek because it could limit invertebrate distribution through food availability.

4.7.1 Data Collection and Analysis

Benthic invertebrates were collected in August, 1975, and periphyton in early September, 1975, at five of the water quality sites in Michel Creek. These sites were:

- Site 0200184: upstream from Corbin Creek and from mining activity.
- Site 1190031: downstream from Corbin Creek and Byron Creek Collieries Ltd.
- Site 1190029: downstream from Andy Good Creek and Coleman Collieries Ltd.

Site 0200203: upstream from Kaiser Resources Ltd.

Site 0200025: downstream from Kaiser Resources Ltd.

Site locations are shown in Figure 10. The collection method and laboratory procedures are described in a separate report[38].

Invertebrate samples, or sub samples, were sorted to the systematic levels of order or family. Generic identifications of specimens of the orders Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddis flies) were made, the identifications were confirmed[37], and the invertebrates of each taxon were counted. Periphyton samples were dried at 550° C to obtain their ash-free dry weights.

Periphyton data were interpreted by comparing the relative abundance (based on the ash-free dry weights) of periphyton present at all sites. Invertebrate data were analyzed both qualitatively and quantitatively as explained in section 2.7.1. Qualitatively we compared the numbers and kinds of representative taxa at the various sites, relative to their known life habitats.

Quantitatively the invertebrates were examined using three different community indices. These were: mutual information analysis[39], indirect polar ordination [40], and diversity and redundancy indices[41]. Calculations were based on pooled counts of triplicate samples from each site.

4.7.2 Presentation of Data

General observations made of the riverbed, while sampling, are listed in Table 47. Counts of invertebrate taxa are shown in Table 48, and the relative abundance of genera of mayflies, stoneflies and caddis flies are shown by histograms in Figures 14 and 15.

Visual interpretations of the results of the community analyses are given in Figure 16. The diversity and redundancy indices are given in Table 49. Ash-free dry weights for periphyton samples and dominant genera from samples are listed in Table 47.

In general, more invertebrates were found at sites in Michel Creek than at sites in the Fording River. Mayflies were the most numerous group at all sites, except for site 0200025, downstream from Kaiser Resources. Chironomids were dominant here.

The mutual information analysis (Figure 16) shows that the invertebrate communities at sites 1190031, downstream from Byron Creek Collieries, and 1190029, downstream from Coleman Collieries, were the most similar. It also shows that the populations, at sites 0200184, the upstream control site and site 0200203, upstream from Kaiser Resources were similar, and that the community at site 0200025, downstream from Kaiser Resources, was the most different.

The ordination plot (Figure 16) indicated that the communities of sites 1190031 and 1190029 were comparable, but that the other three communities showed a change down the river from site 0200184 and 0200025.

The diversity indices (Table 49) were all quite high and the redundancy indices were low, with the exception of site 0200025 where this trend was reversed. Periphyton appeared to be more abundant at site 0200184, the control site and site 1190029, downstream from Coleman Collieries (Table 47). Dominant genera did not appear to be related to water quality.

4.7.3 Discussion of Results

A number of factors are responsible for the invertebrate distributions in Michel Creek. These include river flow (velocity and quantity of water), water temperature, water chemistry, food availability and characteristics of the substrate[31].

Water flow in Michel Creek fluctuates seasonally, but is continuous. The velocity decreases somewhat down the creek. In general, however, most of the benthos collected were fastwater forms. Pseudocloeon and Ephemerella, both inhabitants of slower waters[42,43,44], were found in large numbers at site 1190029, downstream from Coleman Collieries. The mainstream current at this site was so strong, that samples were taken from the river sides, where the velocity was much less. This procedure introduced differences in the community collected.

Water temperature increased five degrees from the site furthest upstream, 0200184, to the site furthest downstream, 0200025. This increment was detected over a time period of ten hours. We suspect that the temperature change would have been less, had all measurements been taken simultaneously. The altitude change from site 0200184 to 0200025 was 330 m, and greater than that observed in the Fording River. Because vegetative cover was similar along the creek, we assumed that temperature did not strongly influence the nature of the invertebrate populations in Michel Creek.

Water chemistry, discussed in Section 4.5, can also influence the distribution of stream invertebrates. The quality of Michel Creek was generally good, but levels of ammonia and phenols detected at site 0200025 were sometimes higher than the drinking water standards. It was unlikely that ammonia was in the chemical state known to be detrimental to aquatic life (Section 4.5.3). High numbers of invertebrates were collected at site 0200025, suggesting that phenols were not producing acute effects. Other parameters, including dissolved metals, were within recommended limits. Metals in the sediments at sites upstream from Kaiser Resources were low, and similar to the site downstream (Section 4.6.2). The Phase I report[1] found that mining operations created high suspended solids and turbidity in Michel Creek. This was verified in this study at sites 1190031, 1190029 and 0200025, downstream from each of the mining operations.

Suspended solids produce turbid waters and settle out on the substrate, thus influencing algal growth, or food availability and substrate characteristics. Byron Creek Collieries, Coleman Collieries and Kaiser Resources Ltd. were the major sources of suspended solids to Michel Creek, as described in Sections 4.1, 4.2 and 4.3. The effect on water quality was described in Section 4.5.1.

Periphyton is a food source for many benthic invertebrates[43, 46-53]. The ash-free dry weights of each sample can therefore be considered an indication of food availability. Algae were not abundant at sites 1190031, downstream from the mouth of Corbin Creek and 0200203, upstream from Kaiser Resources. The high turbidity at site 1190031 probably limited algal growth, which in turn limited the invertebrate population there which was small. On the other hand, the invertebrate population at site 0200203, upstream from Kaiser, was large, but periphyton did not appear to be abundant, nor was turbidity high. Heavy grazing on the algae by the benthic invertebrates could account for this result. Periphyton was abundant at the other three sites including 0200025, downstream from Kaiser Resources, where turbidity apparently did not limit growth.

The substrate was not completely similar at all sites, although an attempt was made to sample rocky cobble reaches. Black sediment was evident between rocks at sites 1190031, downstream from Corbin Creek and 0200025, downstream from Kaiser Resources (Table 47). High levels of suspended solids were detected in discharges upstream from both of these sites (Sections 4.1 and 4.3). More small-sized particles were found in the sediments at sites 1190031, 1190029 and 0200025 upstream from mining operations, than at downstream sites 0200184 and 0200203.

As noted in Section 2.7, a riffle reach, having a rocky cobble bottom, supports stable and diverse benthic communities[32,54,55].

Suspended solids, in settling out, can destroy habitat for many invertebrates by filling spaces between and under rocks. Mutual information analysis showed that the populations of sites 1190031, downstream from Byron Creek Collieries and 1190029, downstream from Coleman Collieries, were similar. However, at site 1190031 there were high suspended solids and sedimentation, whereas at Site 1190029, suspended solids were not a problem when measured. We conclude that suspended solids had no acute effect on invertebrates at these sites.

Mutual information analysis also indicated that invertebrate communities at the upstream control site 0200184 and site 0200203, upstream from Kaiser Resources were comparable, and the invertebrate population at site 0200025, downstream from Kaiser Resources, was different from all the others. Suspended solids and sedimentation were not severe at sites 0200184 or 0200203, but were notable at site 0200025. We conclude that suspended solids had a negative effect on invertebrates at site 0200025, downstream from Kaiser. Polar ordination also showed site 0200025 to be different to the others, but suggested a gradual downstream change from site 0200184 to 0200025.

Ephemeroptera were clearly dominant at sites 0200184, the upstream control, site 1190031, downstream from Byron Creek Collieries, and site 0200203, upstream from Kaiser Resources. Dominance of this group suggests a non-stressed community[80]. Mayflies were comparable, in number, to chironomids at site 1190029, but at site 0200025, chironomids were definitely dominant. Of the mayflies present at site 0200025, Baetis was notably dominant. As indicated in Section 2.7, Baetis and chironomids of the subfamily orthocladiinae can survive well on a substrate with a high sediment component in oxygen saturated waters[43,56,57]. These results confirm the negative effect of suspended solids, discharged by the mining operations, on the composition of invertebrate communities in the downstream vicinity of the mines.

The lowest diversity index and the highest redundancy index results from the dominance of a small number of invertebrate groups. Such indices were obtained at site 0200025, downstream from Kaiser Resources. This result implies that the population at this site was unstable[48] due to the suspended load. Diversity indices were higher at sites 1190031 and 0200203. They were very high at sites 0200184 and 1190029, indicating that there were no environmental disruptions at these sites.

The trends shown by the community analyses result from the presence or absence of certain genera at the sites. Mayflies which cling under or between rocks such as Rhithrogena, Cinygmula and Iron[31], were relatively small in number at site 1190031, and almost absent from site 0200025. Plecoptera are not usually abundant where their environment has been disturbed[30]. They were small in number at sites 1190031 and 0200025, where black sediment was noted on the substrate. Likewise, Trichoptera, also sensitive to disruption[30] were small in number at site 0200025, downstream from Kaiser Resources. Beetle larvae of the family Elmidae are rarely found in waters having a heavy sediment load[81]. They were abundant at the upstream site 0200184, decreased in number at sites 1190031 and 1190029, and were absent further downstream where suspended solids were higher.

The same environmental problem was present in Michel Creek, as was found in the Fording River. High suspended solids, introduced to the creek from the coal mining operations, settled out increasing the amount of fine, black sediment in the cobble bottom. This sedimentation occurred to some extent at site 1190031, downstream from Byron Creek Collieries, and very evidently at site 0200025, downstream from Kaiser Resources Ltd. The population at the latter site was composed mainly of chironomid larvae and the mayfly Baetis. Such a population is unstable and unable to withstand further environmental stress. If mining expands upstream in Michel Creek, with poor control measures, the populations there could also reach an unstable state.

As suggested in Section 2.7, the types of invertebrates dominant at site 0200025 are likely to be washed out with the sediment during freshet. Until recolonization occurs, these areas would not support a fishery dependent on benthic invertebrates for food[58]. The selection pressure in reaches covered with fine black sediment reduces the diversity of the benthos. This in turn can have a negative effect on fish because of the reduced selection of food species.

4.7.4 Recommendations

Recommendations to control suspended sediment discharges to Michel Creek (Sections 4.1, 4.2 and 4.3) should prevent further alteration of some of the benthic invertebrate populations in this system.

If mining operations expand to new portions of the Michel basin, we recommend that invertebrate studies be made in the new areas, as outlined in Section 2.7.4.

5. THE LOWER ELK RIVER BASIN

The lower Elk River basin is downstream from the Fording River confluence and excludes the Michel Creek basin, as shown in Figure 17. It drains the upper Elk, Fording and Michel basins, which were discussed in Chapters 2, 3 and 4.

Activities that influence water quality are the Kaiser Resources Ltd. surface coal mining and coal preparation complex at Sparwood, and discharges of treated domestic sewage from the towns of Sparwood and Fernie. Kaiser Resources is planning to develop an underground hydraulic coal mine and a preparation plant near Hosmer. The locations of these existing and proposed developments are shown in Figures 11 and 17.

5.1 Kaiser Resources Limited

5.1.1 Description of Discharges

Surface coal mines and the Elkview coal preparation plant at Sparwood were described in the Phase I report(1). Kaiser's Michel Creek operations were discussed in Section 4.3.1. Further details on the pollution control facilities at Kaiser's Elk River operations are outlined below.

Coal production by Kaiser Resources during 1975-76, in millions of metric tons shipped, was as follows(5):

	1975	1976
Metallurgical coal	5.7	4.6
Thermal coal	0.45	0.36

Decreased production during 1976 was due to a lengthy strike.

a) Elkview Preparation Plant

The Phase I study[1] reported that an average of 4100 m^3/d of preparation plant effluent was discharged to tailing pond D, adjacent to the Elk River. We also thought that the supernatant from the tailing pond was recycled to the preparation plant. The quantity of seepage from the tailing pond was not known, but was assumed to be a small fraction of the inflow to the tailing pond.

Investigation after the Phase I study has shown that there has been no recycle of supernatant from tailing pond D, and that most of the liquid exfiltrates to the ground. There are reported to be numerous springs along the dike of pond D, which enter Otto Creek, which then flows to the Elk River. Also, there has been seepage to Otto Creek via an abandoned culvert in the dike of pond D.

More accurate flow measurements showed that about three times as much effluent (13,000 m^3/d) was being discharged to pond D than authorized by Kaiser's Pollution Control Permit, No. PE-425. Kaiser has since applied to amend Permit PE-425, to allow the discharge of 13,000 m^3/d to the tailing pond[70].

b) Harmer Creek Settling Pond

The Harmer Creek settling pond is located on Harmer Creek, just upstream from Grave Creek, as shown in Figure 11. The pond was built to control suspended sediment from Kaiser's surface coal mines on Harmer Ridge, and was completed in November, 1971. The settling pond was authorized by the Water Rights Branch (Conditional Licence 40628)[82]. The design factors for the Harmer Creek settling pond are summarized in Table 33. The pond was designed to provide at least two hours water retention time at the design flow, plus 15 years of sediment storage. The design flow was based on an average precipitation of 760 mm/year, a ratio of runoff to precipitation of 0.50, and a ratio of maximum flow to average flow of ten[82].

The design flow for the settling pond was crudely derived, but flow records collected for Grave Creek at the mouth (site 08NK019), and the Elk River (sites 08NK005 and 08NK016)[11,62], indicate that the design flow is roughly equal to the maximum daily flow occurring in Harmer Creek once every ten years. The Pollution Control Board objective for suspended solids in effluent from settling ponds is 50 mg/L at Level A and 150 mg/L at Level B[8]. The objectives do not specifty the range of flood sizes which apply to these concentrations.

The U.S. Environmental Protection Agency has specified that coal mine settling ponds should be designed to meet suspended solids objectives (70 mg/L daily maximum, 35 mg/L monthly average) for the runoff from the maximum 24 hour precipitation event occurring once in ten years. Runoff events in excess of the one in ten year storm are exempt from the effluent objectives, because it is impractical to design settling ponds for all runoff events[12,83].

The Harmer pond design was based on retention time (i.e. retention time = pond volume ÷ design flow). However, it is the surface area of the settling pond and the overflow rate which govern the removal of suspended sediment in a settling pond (overflow rate = design flow ÷ surface area). For a given design flow, the surface area of the pond determines the overflow rate or settling velocity in the pond. The settling velocity in turn determines the size of the smallest particle which can settle out. The concentration and particle-size distribution of the suspended sediment in the inflow thus determine the concentration of suspended sediment in the pond overflow.

5.1.2 Effluent Sampling Data

Sampling was carried out in 1975 and 1976 to identify sources of sediment, and to assess the effect of seepage and runoff from the tailing ponds and coarse refuse piles.

a) Elkview Preparation Plant

The Company and the Pollution Control Branch monitored the tailing pond supernatant. They also sampled seepage and groundwater near the tailing ponds and the coal refuse piles. Results of the analyses are summarized in Tables 50 to 54.

Table 50 shows that the supernatant in tailing pond D was alkaline and low in metals. The supernatant met Level A of the Mining Objectives[8] for all parameters, except suspended solids. This is not of concern since the supernatant evaporates or exfiltrates from the pond, and does not overflow unless there is an accidental spill. Such spills are rare.

Tables 51 and 52 show that the groundwater below tailing ponds C and D was alkaline (pH >6.9), total alkalinity >205 mg/L). The acidity (at pH 8.3) was up to 140 mg/L, although acidity values reported by Kaiser were substantially higher than those measured by the Pollution Control Branch. The groundwater was low in metals with the exception of dissolved iron (up to 7.6 mg/L) and dissolved manganese (up to 2.5 mg/L). These metals frequently exceeded the acceptable limits for drinking water of 0.3 mg/L for iron and 0.05 mg/L for manganese. The acceptable limits are based on aesthetic considerations rather than on toxicity to humans[23].

Manganese in the groundwater frequently exceeded Levels A and B of the Mining Objectives[8], and occasionally exceeded Level C. Iron frequently exceeded Level A, and occasionally exceeded Levels B and C. The high values for dissolved iron and manganese were probably due to the reduction of insoluble ferric and manganese compounds to soluble ferrous and manganous forms, under anaerobic conditions in or beneath the tailing ponds[84]. The iron and manganese levels in the tailing pond supernatant (Table 50) were low.

The concentrations of toxic materials such as arsenic, copper, lead and zinc were very low in the groundwater. Even the maximum concentrations of these contaminants were below values which would be harmful to aquatic life.

The water quality of Otto Creek is shown by data in Table 53. The creek receives seepage from tailing pond D, and drains a portion of the preparation plant area. It was alkaline and low in metals with the exception of dissolved manganese (0.11 - 0.24 mg/L), which exceeded the acceptable limit for drinking water (0.05 mg/L)[23]. Dissolved iron (0.02 - 0.3 mg/L) was within the acceptable limit for drinking water (0.3 mg/L)[23], and the recommended criteria for freshwater aquatic life (1.0 mg/L)[24]. One total iron value of 5.9 mg/L was measured. It was probably due to the iron content of suspended sediment, which was high in Otto Creek (turbidity 108 J.T.U.), rather than to the precipitation of dissolved iron. Arsenic, copper and lead levels were occasionally higher than those normally found in surface water in the Elk basin. However, concentrations were well below values which would be harmful to aquatic life.

The unnamed creek (site 0200118, Table 53), upstream from tailing pond D, was alkaline and contained low concentrations of all metals (dissolved manganese <0.02 mg/L). The creek sometimes received substantial amounts of suspended sediment (turbidity of up to 580 J.T.U.). The source of the sediment may have been mine roads or workings on the western flank of Baldy Mountain (Figure 11).

Surface water and groundwater drainage from the coarse coal refuse pile at the Elkview plant (Table 54), was alkaline and low in metals, with the exception of manganese and zinc. Manganese (0.35 mg/L) exceeded the acceptable limit for drinking water (0.05 mg/L)[23] and one zinc measurement (0.63 mg/L), gave a value which may be harmful to aquatic life[24]. The manganese and zinc concentrations were between Levels A and B of the Mining Objectives[8].

Water quality monitoring in the Elk River, upstream and downstream from the Elkview preparation plant (Section 5.6) indicates that seepage and runoff from the plant area had no effect on Elk River water quality. We attribute this result to the substantial dilution available in the Elk River, at the Elkview plant.

b) Harmer Creek Settling Pond

The effluent from the Harmer Creek settling pond was sampled five times during May - August 1975. The results in Table 55 show the composition of surface coal mine drainage.

The effluent was alkaline and met the Level A objectives[8] for all parameters, except suspended solids. (The discharge of suspended solids is discussed in the next section, 5.1.2 c, on sediment sources). The effluent was low in heavy metals (copper, lead, zinc) and phenol.

The nitrite + nitrate nitrogen levels in the pond effluent were higher than those normally found in surface water in the Elk basin. This may be due to the leaching of residual ammonium nitrate explosives from the mining areas in the Harmer Creek basin. Kaiser Resources used 12,000 - 16,000 tonnes/year of ammonium nitrate based explosives in its surface mining operations, from 1971 to 1974[10]. Elevated nitrogen levels have also been observed in mine drainage at Fording Coal (Section 2.2.2) and at Decker Coal in Montana[9]. The nitrite + nitrate levels were well within the Level A objective[8], and the maximum permissible limit for drinking water (10 mg/L as N)[23]. However, at these levels, nitrogen could contribute to the nuisance growth of aquatic plants, if sufficient concentrations of other essential nutrients were available[21,22].

c) Sources of Suspended Sediment

The sources of suspended sediment from Kaiser's Elk River operations, during 1975-76, included Six Mile Creek, Goddard Creek, Otto Creek, the Harmer Creek settling pond, and an unnamed creek from Sparwood Ridge. The locations of these sediment sources are shown in Figure 11.

Six Mile Creek was the largest source of suspended sediment measured during 1976 (Table 56). Suspended solids loadings of up to 260 tonnes/day were measured. The suspended solids and turbidity levels were up to 6058 mg/L and 1950 J.T.U., respectively. During May, 1976, the suspended solids loadings in Six Mile Creek were from 3 to 18 percent of the suspended solids loading in the Elk River, at site 0200027, just upstream from the mining operations.

Six Mile Creek has a drainage area of 2.8 km^2, and drains the north end of Harmer Ridge (Harmer Knob) where a Kaiser Resources Ltd. spoil pile is located. In the past, spoil from the pile had slid partway down Six Mile Creek[85]. In early August, 1976, heavy rainfall caused a mud slide which carried sediment into the Elk River[70].

Otto and Goddard Creeks drain the area around the Elkview preparation plant. They were observed to have high levels of suspended sediment on occasion during 1975-76. Otto Creek had turbidities of up to 460 J.T.U. (Table 53). There were tailing spills to Otto Creek on April 18 and 19, 1976, due to breaks in the tailing line to pond D. Kaiser Resources has constructed spill collection and diversion ditches to prevent future spills from entering Otto Creek and the Elk River. Settling ponds are being built to control suspended sediment discharge to Otto Creek from the preparation plant area[70].

Goddard Creek drains part of the Elkview plant area, and the coarse coal refuse pile, to the Elk River via a swampy area near the coarse refuse pile. It was observed to be carrying high concentrations of suspended solids into the Elk river during April, 1976. Kaiser Resources has constructed a settling pond on

Goddard Creek, between the coarse refuse pile and the rail loop, to control the sediment discharge[70].

The unnamed creek from Sparwood Ridge crosses Highway 3 at the southern limit of the Sparwood District Municipality, and drains an area containing coal exploration roads and workings (Balmer 10-7). Suspended solids loadings of up to 28 tonnes/day were measured from May to June 1976 (Table 56). Suspended solids and turbidity levels were up to 290 mg/L and 1250 J.T.U., respectively. There were actually several small creeks carrying sediment to the Elk River from Sparwood Ridge, but only the largest creek was monitored.

The Harmer Creek settling pond was the second largest source of suspended sediment from Kaiser's Elk River operations, in 1975-76. The suspended solids loadings were up to 49 tonnes/day (Table 57). However, these loadings were due to the comparatively large flow through the settling pond (up to 3.4 m^3/s), rather than to high levels of suspended solids. The maximum suspended solids and turbidity levels, measured in the pond effluent, during 1975-76, were 168 mg/L and 80 J.T.U., respectively (Tables 57 and 58).

The suspended solids in the effluent exceeded Level A (50 mg/L)[8] on five sampling occasions (58 - 168 mg/L) and Level B (150 mg/L) on one sampling occasion (168 mg/L) during snowmelt runoff in 1975-76. Peak runoff flows were average in 1976 and below average in 1975[11,62]. These flows peaked at roughly 70 percent of the design flow (4.9 m^3/s) for the Harmer pond. These results show that the Harmer pond does not meet the Level A objectives under average runoff conditions. A further example shows that, during the 1972 freshet, the Harmer pond effluent contained up to 690 mg/L suspended solids, and values were in excess of the Level A and B objectives for about a one month period (Table 59). 1972 peak flows were approximately equal to the design flow for the Harmer pond[11].

Stoke's Law predicts that the smallest particle that can settle out in the Harmer pond, at the design flow, is in the order of 0.02 mm (medium silt)[86] (Table 33). For particles that have a low specific gravity, such as coal particles (S.G ≃1.3), or that do not have a spherical shape, such as clay particles, the smallest particle that can settle out is larger[12,83]. The suspended solids in the overflow from the Harmer pond probably contained a high percentage of particles of less than 0.02 mm. Studies at coal mines in the eastern U.S.A. have shown that up to 45 percent of the suspended solids in mine drainage can be less than 0.02 mm[12].

These data suggest that chemical coagulation would probably be necessary for the Harmer pond to meet the effluent objective of 50 mg/L. Enlarging the pond may not be practical, since the surface area required increases rapidly as the particle diameter to be removed decreases ($A \propto \frac{1}{D^2}$). Erosion control measures employed upstream from the Harmer pond, to prevent fine-grained sediment from becoming suspended in water, would also improve the pond effluent quality.

Tables 57, 58 and 59 show that suspended solids in Grave Creek, upstream from its confluence with Harmer Creek, were often greater than in the Harmer pond effluent, during the 1972, 1975 and 1976 freshets. Grave Creek, upstream from Harmer Creek, has not been affected by coal mining, but has been logged. Thus, it was not representative of natural suspended solids levels. There has also been logging in the Harmer basin, upstream from the settling pond. This means that some portion of the suspended solids entering the pond was probably due to logging.

The Level A effluent objectives for suspended solids ($\leq$ 50 mg/L) is a reasonable goal for most settling pond effluents in the Elk basin. Most small natural streams in the Elk basin carry less than 50 mg/L suspended solids, except under extreme runoff events. However, the upgrading of the Harmer pond may not be justifiable. Some portion of the suspended sediment entering the pond is due to logging. Also, the levels in the receiving stream (Grave Creek) are higher than those normally found in small streams in the Elk basin because of logging. Data on suspended and bottom sediment (Sections 5.6 and 5.7) suggest that the Harmer pond discharge was not unduly affecting Grave Creek and the Elk River. The benthic invertebrate data for Harmer Creek showed that the population was somewhat unstable (Section 5.8.3).

5.1.3 Recommendations

Effluent objectives should specify not only the maximum con-cencentration of suspended solids in settling pond effluent, but also the flood size (for example a one in ten year flood) above which the effluent will be exempt from the objectives.

The design of settling ponds should be based on the following factors: the effluent suspended solids objective, the design flow (i.e. the flood above which exemption is allowed), and the influent suspended solids concentration and particle-size distribution. These factors set the overflow rate and surface area of the pond necessary to meet the effluent objective at the design flow. Influents containing high percentages of clay and fine silt (less than 0.01 mm) will require chemical coagulation or filtration, since it is impractical to remove these fine sediments by plain sedimentation.

We recommend that erosion and sediment control programs be established for Six Mile Creek and the unnamed creek from Sparwood Ridge. The sediment control structures for these creeks, and the existing settling ponds on Harmer, Goddard and Otto Creeks should be operated to meet effluent objectives for flows up to certain flood conditions.

The level of suspended solids in the Harmer Creek settling pond effluent should not exceed present values if stream deterioration is to be avoided. Suspended solids levels in Grave Creek and the Harmer pond effluent should continue to be monitored. If suspended solids from the Harmer pond cause levels to increase in Grave Creek, then further abatement measures may be required.

The situation in the Grave Creek basin illustrates the difference in approach in the handling of sediment discharges from surface mining and logging. Efforts should be made to control sediment discharges from logging through improved management practices, and the building of settling basins if required.

Seepage from Kaiser Resources Ltd.'s tailing ponds has rendered the groundwater and adjacent surface water (Otto Creek) unsuitable for domestic and many industrial purposes. We recommend that tailing ponds be designed to minimize seepage where groundwaters, or small surface streams, may be used for water supply purposes.

The suspended solids and flow of the various suspended sediment sources at Kaiser's Elk River operations should be monitored. Daily sampling is recommended during the spring snowmelt period and during, or immediately after, heavy rains. During the snowmelt period, samples should be taken in the afternoon since snowmelt runoff and suspended sediment are typically low in the morning and reach a maximum in the late afternoon or evening.

Monitoring of sources should be correlated with the receiving water monitoring program, recommended in Section 5.6.6. Nitrite, nitrate, ammonia and dissolved manganese levels in the settling pond overflows should be checked occasionally during low flow.

Past monitoring programs at the Elkview preparation plant have largely defined the effects of the tailing ponds and coarse refuse pile on water quality. We therefore recommend that the monitoring effort be reduced. Monitoring of the six groundwater wells below tailing ponds C and D, and the unnamed stream upstream from tailing pond D (Site 0200118) can be discontinued. Otto Creek

(Site 0200117), which receives seepage from the tailing ponds, should be monitored four times per year during low flow periods to indicate any change in the quality of seepage from the tailing ponds.

Similarly, sites 0200235 and 0200236, near the coarse coal refuse pile (Figure 11), should be monitored four times per year during low flows. This will indicate changes in the quality of seepage from the pile. Parameters that should be monitored are: pH, flow, temperature, nitrite, nitrate, ammonia and dissolved iron, manganese and zinc. Monitoring of these parameters in the Elk River is not necessary unless there is a substantial change in the streams or groundwater receiving seepage. Monitoring in the Elk River showed that the seepage has had no effect on water quality (Section 5.6).

The tailing pond monitoring can be reduced to influent flow, pH, water levels and tailing levels. Nitrite, nitrate and ammonia levels should be measured a few times during low river flow to check if the supernatant is a source of nitrogen to Otto Creek and the Elk River.

5.2 Proposed Hosmer-Wheeler Coal Project

5.2.1 Description of the Proposed Project

Kaiser Resources Ltd. has proposed an underground hydraulic coal mine and coal preparation plant near Hosmer. The development would produce 2 million tonnes of clean metallurgical coal per year. The location of the proposed development is shown in Figure 17.

All coal will be mined underground using high pressure jets of water. The coal-water slurry will be flumed by gravity to the preparation plant, located on the surface in the valley bottom. The coal will be removed from the coal-water slurry in clarfiers, and the water will be recycled to the underground mine. The raw coal will be cleaned and dried in the preparation plant. The fine and coarse coal waste from the plant will be pumped to a tailing pond.

The wastewater in the tailing pond, that does not exfiltrate or evaporate, will be recycled to the preparation plant. There will be an emergency dump pond for the mine water circuits. Surface runoff from disturbed areas will be conveyed by ditches to a settling pond and then pumped to the tailing pond. Sanitary sewage from the project will be treated and discharged to the tailing pond or to ground[87].

5.2.2 Possible Impacts on Water Quality

The project may increase suspended solids, turbidity and sedimentation in No-name Creek and its tributaries. Also, contamination of groundwater, No-name Creek, and possibly Transmission Line Creek, may occur by seepage from the tailing pond. The impact of the project on Elk River water quality should be negligible. The impacts on water quality will be similar to those of Kaiser Resources Elkview preparation plant, discussed in Section 5.1.2.

Kaiser Resources has submitted Stage I and II[87,88] environmental assessment reports, in accordance with the Guidelines for Coal Development[3]. To proceed with the project, Kaiser must now obtain the necessary permits and licences from provincial resources agencies (Stage III).

The Company, and its consultants, continue to gather pre-operational water quality data in the area.

5.2.3 Monitoring Data

We monitored suspended solids and turbidity in No-name Creek, upstream from Hosmer Creek, and in Hosmer Creek, upstream from No-name Creek (Figure 17), during the spring freshet of May-June, 1976. Suspended solids (4 - 14 mg/L) and turbidity (1.8 - 12 J.T.U.) were found to be very low at this time (Table 60). More data on suspended solids and turbidity should be collected from No-name and Transmission Line, Creeks, during spring runoff.

5.3 City of Fernie

5.3.1 Description of Discharges

The Fernie sewage treatment plant was described in the Phase I report[1], and there were few changes during 1975-76. The Fernie sanitary sewer system suffers from excessive storm water infiltration. This produced hydraulic overloads at the treatment plant in 1974, as well as raw sewage bypasses to the Elk River, and the flooding of basements and streets with sewage[1,89]. The City has embarked on a program to reduce storm water inflow to the sanitary sewer system[89].

The raw sewage bypasses to the Elk River during 1974 were due to cross-connections between the sanitary sewer system, the storm sewer system and the old septic tank system[89]. Water quality monitoring during February and March, 1976 (Section 5.6) indicated that there were still raw sewage bypasses in the City of Fernie, upstream from the sewage treatment plant.

5.3.2 Effluent Sampling Data

Monitoring results for the Fernie sewage treatment plant effluent are summarized in Tables 61 and 62. The effluent limits, specified in the City of Fernie's Pollution Control (Permit PE-390), and Level AA of the Pollution Control Objectives for Municipal Type Waste Discharges in B.C.[78], are also included in Table 61.

The BOD_5 and suspended solids in the effluent were low, meeting the permit levels and the more stringent Level AA objectives. Chlorine residuals (Table 62) ranged from 0 - 1.5 mg/L (total) and 0 - 0.4 mg/L (free), with no chlorine residual occurring on two sampling occasions. The minimum dilution of the effluent in the Elk River is roughly 200:1. Thus, the resulting total chlorine residual in the Elk River could be up to about 0.005 - 0.0075 mg/L after complete mixing. Acute toxicity, or sublethal toxic conditions for fish, are likely when total chlorine residuals exceed 0.02 mg/L, [90] and water quality criteria of 0.002 mg/L (salmonid fish) and 0.01 mg/L (other freshwater organisms) have been recommended[24]. It does not appear that toxic levels of chlorine are likely to occur in the Elk River. The total chlorine residual in the effluent should be carefully regulated between the 0.5 - 1.0 mg/L limits specified by the Municipal Objectives[78]. This will ensure adequate disinfection of the effluent, and non-toxic chlorine levels in the Elk River.

Fecal coliform densities in the effluent have often been high (92,000 to 240,000/100 mL). This result may be due to inadequate chlorine residual and contact time. At minimum dilution of effluent in the river (200:1), fecal coliform densities of up to 460 to 1200/100 mL could occur in the Elk River. Fecal coliform densities of over 2400/100 mL have been measured in the Elk River, downstream from the sewage treatment plant, but were due, in part, to raw sewage bypasses in Fernie (section 5.6). The Municipal Objectives [78] specify that fecal coliform levels in receiving water should generally not exceed a median of 200/100 mL.

Ammonia levels in the effluent were high (4.6 - 10.5 mg/L as N). However, dilution was such that the levels in the river would be safe for aquatic life, even at minimum flow.

5.3.3 Recommendations

The program to reduce storm water inflow to the sanitary sewer system should continue, and raw sewage bypasses to the Elk River should be eliminated. The effluent should be monitored for BOD_5, suspended solids, total chlorine residual, fecal coliforms and flow. Although nutrient discharges in the Elk basin are not a problem at the present time (section 5.6.6) total phosphorus and total nitrogen should be occasionally measured in the effluent, to establish nutrient loadings.

Total chlorine residuals in the effluent should be carefully regulated, to between 0.5 and 1.0 mg/L, and past and future flow data should be entered into the Provincial Government computer storage system.

5.4 District of Sparwood

5.4.1 Description of Discharges

Sparwood's sewage treatment plant was described in the Phase I report[1], and there were no material changes during 1975-76. The Phase I report identified inadequate chlorination of the effluent as the main problem at the plant.

5.4.2 Effluent Sampling Data

Monitoring results for the effluent, obtained in 1975-76 are summarized in Table 61. The effluent limits specified by the District of Sparwood's Pollution Control Permit (PE-253), and Level AA of the Pollution Control Objectives for Municipal Type Waste Discharges in B.C.[78], are also included in Table 61.

The BOD_5 and suspended solids in the effluent were generally low. Only one suspended solids value and two BOD_5 values slightly exceeded permit limits, and Level AA. Chlorination at the plant was still poor. Five of six measurements showed no chlorine residual, and one measurement showed a high residual of 1.7 mg/L. Minimum dilution of the effluent in the Elk River is in the order of 300:1, and thus toxic chlorine levels in the Elk River are unlikely (section 5.3.2).

Fecal coliform densities in the effluent were moderate (up to 79,000/100 mL), and could be reduced by proper chlorination. With 300:1 minimum dilution, the resulting fecal coliform levels in the Elk River would be less than the 200/100 mL median level specified by the Municipal

Objectives[78]. Water quality monitoring in the Elk River, downstream from the sewage treatment plant, recorded a maximum fecal coliform level of 540/100 mL during 1975-76, but levels were normally less than 80/100 mL (see section 5.6.2).

5.4.3 Recommendations

The total chlorine residual in the sewage treatment plant effluent should be carefully regulated, between the 0.5 - 1.0 mg/L limits specified by the Municipal Objectives[78]. This will ensure adequate disinfection, and non-toxic chlorine levels in the Elk River. Monitoring of the sewage treatment plant effluent should continue. Important parameters to monitor are BOD_5, suspended solids, total chlorine residual, fecal coliforms and flow (daily and peak hourly flows). In the interest of long-term waste management, it would be useful to measure total phosphorus and nitrogen, on occasion, to establish nutrient loadings.

5.5 Miscellaneous Sources of Suspended Sediment

Our monitoring program in the lower Elk basin, during the 1976 spring freshet, discovered two sediment sources in addition to those discussed in section 5.1. These were Hartley Creek downstream from Hosmer, and Lizard Creek downstream from Fernie (Figure 17). Table 60 shows that during May, 1976, Hartley Creek had suspended solids of up to 1110 mg/L and turbidity of up to 290 J.T.U. The suspended solids loading in Hartley Creek was calculated to be 110 tonnes/day. Lizard Creek had suspended solids of up to 300 mg/L and turbidities of up to 112 J.T.U.

The cause of the fairly high suspended sediment levels in these creeks was not investigated. They are relatively undisturbed basins. There are no mining or logging activities, although each basin has a road through it. Thus, the suspended sediment may have been due to road erosion. Natual erosion from the steep southern slopes of Mount Hosmer may also have contributed to the high levels in Hartley Creek.

5.6 Water Quality

The waters of the lower Elk Basin were sampled by the Pollution Control Branch, the Water Investigations Branch, and the Water Survey of Canada, during 1975-76. The locations of the sampling sites are shown in Figures 11 and 17, and are described in Table 10.

Provincial Government data are summarized in Table 60 and Tables 63 to 70. Water Survey of Canada suspended sediment data are summarized in Tables 16, 60 and 69.

The data are discussed by parameter in the following sub-sections. Parameters not specifically mentioned were not significant to water quality.

5.6.1 Suspended Solids and Turbidity

Suspended solids and turbidity in the lower Elk Basin during 1975-76, were generally lowest just downstream from the Fording River (site 0200027), and highest at Fernie (sites 08NK002, 1190004 and 0200113), or at the mouth of the Elk River (site 0200016) (Tables 60 and 69).

Suspended solids and turbidity at site 0200027 ranged from 1 to 212 mg/L, and 0.1 to 52 J.T.U. respectively (Table 63 and 69). These levels were due to the inputs from the upper Elk River (2-166 mg/L, 2.1-35 J.T.U., 1976 data only) and the Fording River (0-262 mg/L, 1.3-62 J.T.U.), which are discussed in sections 3.2 and 2.5.

Grave Creek enters the Elk River just downstream from site 0200027, and drains surface mining and logging areas, as shown in Figures 11 and 17. Suspended solids (0-214 mg/L) and turbidity (0.4-68 J.T.U.) in Grave Creek at the mouth (sites 0200026 and 08NK019, Tables 63 and 69) were normally less than or equal to values in the

Elk River at site 0200027. The exception was June 30, 1976, when an isolated high value of 1720 mg/L was measured. These results show that Grave Creek did not generally increase the concentrations of suspended solids and turbidity in the Elk River during 1975-76.

Suspended sediment loadings, measured by the Water Survey of Canada (Table 16), indicate that during 1970, 1971 and 1972, the Grave Creek basin had the highest suspended sediment yield in the Elk River basin. However, in 1973 and 1974 the suspended sediment yield was among the lowest. This reduction in suspended sediment yield was mainly due to the completion of the Harmer Creek settling pond, in November 1971. The high suspended sediment yield in 1972, after the completion of the Harmer settling pond, was due partly, to erosion downstream from the pond spillway during the 1972 freshet[68], and partly to the discharge of suspended solids from the pond in May-June, 1972 (section 5.1.2).

The data for sites 1190012 and 0200111 (Tables 60 and 63) indicate that Kaiser Resources Ltd.'s Elk River operations had little effect on suspended solids and turbidity in the Elk River, during 1975-76. The levels at site 1190012 (4-116 mg/L, 0.8-48 J.T.U.) were always less than or equal to those at the upstream site 0200027. The levels at site 0200111, further downstream (2-204 mg/L, 0.4 - 54 J.T.U.), ranged from slightly above to slightly below those at site 0200027. These results were probably due to dilution and sedimentation in the Elk River of suspended solids discharged by Kaiser Resources.

Michel Creek had the highest levels of suspended solids (1-958 mg/L) and turbidity (0.1-216 J.T.U.) in the Elk basin during 1975-76 (section 4.5.1 and Table 69). Input from Michel Creek caused increases in these parameters in the Elk River, downstream from Michel Creek. Site 0200103, just downstream from Michel Creek, was affected the most, with suspended solids of 1-592 mg/L and turbidities of 0.4 -

135 J.T.U. (Tables 60 and 65). Incomplete mixing between the Elk River and Michel Creek probably caused the levels to be higher at site 0200103 than if mixing were complete (Site 0200103 was sampled from the shore on the Michel Creek side). Further downstream, at sites 0200102 and 0200024, where mixing was complete, suspended solids (2-246 mg/L) and turbidity (0.7 - 52 J.T.U.) (Tables 60 and 65) were lower than at site 0200103, but still slightly higher than at site 0200111, upstream from Michel Creek.

The suspended sediment discharge in the Unnamed Creek at the Sparwood Municipal Limit, which drains Kaiser Resources workings on Sparwood Ridge (section 5.1.2), was not detected in the Elk River. This result was probably due to dilution and sedimentation of the discharge in the Elk River.

The highest levels of suspended solids and turbidity in the lower Elk River, during 1975-76, generally occurred at Fernie (sites 1190004, 08NK002 and 0200113: 0-540 mg/L, 0.5-118 J.T.U.), or at the mouth (site 0200016: 2-608 mg/L, 0.8 - 176 J.T.U.) (Tables 60,67 and 69). The cause of these high levels was not always clear. On a few occasions, the high levels at Fernie were correlated with high levels in Michel Creek. On several other occasions, when high values occurred at Fernie or at the mouth, the values upstream were relatively low. The known sources of suspended sediment downstream from Hosmer (Hartley and Lizard Creeks, section 5.5) were too small to account for the high values in the Elk River. A possible source of suspended sediment could be channel erosion in the Elk River. The river has been excavating a channel in the valley bottom since the end of valley glaciation[91]. Also, other streams such as the Wigwam River, which were not measured during 1975-76, may be contributing suspended solids.

The increase in suspended sediment between Hosmer and Fernie is confirmed by measurements of the Water Survey of Canada in the Elk Basin, from 1970-74 (Table 16).

The Fording River, the upper Elk River, Grave Creek and Michel Creek have a drainage area of 2600 square kilometres, or 83 percent of the drainage area of the Elk River at Fernie (3100 km^2). During 1970-74, these basins accounted for 76 to 83 percent of the flow in the Elk River at Fernie, but contributed only 41 to 66 percent of the suspended sediment in the Elk River at Fernie. Either there was an unknown source of suspended sediment to the Elk River, between these basins and Fernie, or the monitoring program was not intensive enough to give an accurate account of suspended sediment movement in the Elk Basin[92].

The significance of increased suspended solids, turbidity and subsequent sedimentation, are discussed generally in sections 2.5 and 4.5. Effects on the benthic invertebrates of the lower Elk and its tributaries were studied, and are presented in section 5.8.

5.6.2 Fecal Coliforms

Fecal coliform densities in the Elk River, upstream from Michel Creek (sites 0200027 and 0200111, Table 63), were very low (< 22/100 mL). Densities increased slightly between Michel Creek and Fernie, but were normally still low (< 80/100 mL) (sites 0200103, 0200102, 0200024 and 1190004, Table 65). A few higher values up to 540/100 mL, were recorded. The increases were probably due to the sewage treatment plant discharges from Sparwood and from the coke plant on Michel Creek.

Large increases in fecal coliforms occurred in the Elk River, at Fernie, due to raw sewage bypasses and the discharge from Fernie's sewage treatment plant. Table 70 shows that the raw sewage bypasses caused densities of over 2400/100 mL, 0.3 km upstream from the Fernie sewage treatment plant. These densities were probably high due to incomplete mixing. Downstream from the Fernie sewage treatment plant (site 0200113), densities ranged from 2 to above 2400/100 mL, with a median of 790/100 mL. Densities at the mouth of the Elk River (site 0200016) were substantially lower (<280/100 mL), but the sampling times did not usually coincide with the times of high densities at site 0200113.

Fecal coliform levels in receiving waters in British Columbia should generally not exceed a median of 200/100 mL.[78] The recommended criterion for recreational waters is in the 200 - 400/100 mL range[24]. The acceptable and maximum permissable limits for fecal coliforms in drinking water, before treatment, are 100 and 1000/100 mL, respectively.[23]

The lower Elk River normally meets the above criteria, except at Fernie and points downstream, where these criteria were often exceeded. Other than fecal coliforms, the sewage treatment plant discharges to the lower Elk River have had no measurable effect on water quality.

5.6.3 Ammonia and Phenol

Increased ammonia and phenol levels were measured in the Elk River during low flow, just downstream from Michel Creek (site 0200103). These contaminants were discharged from Kaiser's coke plant on Michel Creek (Section 4.3.1). Maximum measured levels were 0.12 mg/L ammonia (as N), and 0.043 mg/L phenol. These high levels may have been caused by incomplete mixing between Michel Creek and the Elk River. As described in Section 4.5, the ammonia levels are unlikely to affect aquatic life, but the high phenol levels exceed the acceptable limit for drinking water, and could affect the taste of fish.

5.6.4 Metals and Toxic Substances

The levels of metals and toxic substances in the lower Elk River were very low, normally below the detectable limits for these parameters (Tables 64, 66 and 68). Higher than normal values for copper and lead were occasionally measured at sites 0200111 and 0200103, downstream from Kaiser Resources. However, values were always below levels which would be toxic to aquatic life. Some high readings may have been due to analytical procedures. For example at site 0200111, the highest levels of copper and lead were reported by Kaiser Resources Ltd., although samples taken on the same day by the Pollution Control Branch showed normal copper and lead levels. There are no known sources of copper and lead in the Elk Basin, other than those occurring naturally in soils and rock.

Total iron values of up to 8.2 mg/L were measured in the Elk River, but dissolved iron levels were very low, less than 0.1 mg/L. The total iron values were probably due to the iron content of the inert suspended sediment in the water, and consequently are not significant[25].

5.6.5 Other parameters

Parameters such as total organic carbon, total phosphorus, organic nitrogen, and total iron have increased at times because they are present in the suspended sediment discharged to the Elk and its tributaries. A reduction in suspended sediment will reduce these parameters.

Nitrogen levels in the lower Elk basin were low. The threshold level for nuisance growths of aquatic plants, taken as 0.3 mg/L nitrate nitrogen[22], was never exceeded, except in Grave Creek. The high values here were due to the discharge from the Harmer Creek settling pond. The threshold level for total Kjeldahl nitrogen, taken as 0.6 mg/L[22], was only exceeded on one occasion at site 0200103, when suspended sediment levels were high.

Assigning definite criteria for phosphorus in water is difficult. Guideline levels for total phosphorus of 0.10 mg/L in flowing waters, and 0.05 mg/L in flowing waters discharging into lakes and reservoirs, have been suggested[24]. The average total phosphorus levels in the lower Elk basin (0.02 - 0.05 mg/L) met these guidelines. The peak levels, during freshet (0.1 - 0.4 mg/L), exceeded these guidelines due to the phosphorus content of the suspended sediment. Dissolved phosphorus levels were low, averaging 0.003 - 0.006 mg/L, with peak levels of 0.01-0.02 mg/L during freshet.

The Elk River contributed about 10 percent of the dissolved phosphorus and 13 percent of the total phosphorus to the Libby Reservoir (Lake Koocanusa). The river also contributed 27 percent of the inflow to the reservoir. Phosphorus input from the Elk appears low in comparison to that from the St. Mary River[94,113].

5.6.6 Recommendations

Measures that would reduce the discharge of suspended sediment, phenol and fecal coliforms are recommended in the sections of Chapters 2, 4 and 5, which deal with effluents.

Suspended solids and turbidity should be monitored weekly, during spring snowmelt runoff, at the following sites: Grave Creek upstream and downstream from Harmer Creek, in the Elk River upstream from Kaiser Resources Ltd. (0200027), downstream from Kaiser Resources (0200111), downstream from Michel Creek (0200102) and at Hosmer (0200024). This monitoring should be closely correlated with the suspended sediment source monitoring recommended in Section 5.1. It should also be correlated with other monitoring in the basin, at Michel Creek (site 0200025), the Fording River (site 0200028) and the Elk River upstream from the Fording River (site 0200039 or a new site closer to the confluence with the Fording River). Guidance should be sought from the Water Survey of Canada on the use of suspended sediment samplers to obtain representative samples, especially in the larger streams.

Fecal coliform densities should be monitored upstream and downstream from the Sparwood sewage treatment plant discharge (sites 0200103 and 0200102), and the Fernie sewage treatment plant discharge (sites 1190004, 0200113 and a new site at Morrissey Provincial Park). Monitoring should be done monthly during lower flows, particularily when there is recreational use of the Elk River. Several replicate samples should be taken on each sampling occasion since coliform test results can be extremely variable. Monitoring should be correlated with the sewage treatment plant effluent sampling recommended in sections 5.3.3 and 5.4.3, and if possible, with coliform sampling on Michel Creek (section 4.5.6), and the upper Elk River at Elkford (section 3.2.2).

Monitoring should continue in the Elk River at the mouth (site 0200016), so as to document the contribution of the river to the Libby Reservoir. The parameters to monitor are solids, nutrients (nitrogen and phosphorus), and the field measurements (pH, total alkalinity and temperature). Details are given in Table 89, which summarizes all monitoring recommended for the region. High reservoir water levels influence site 0200016. The site should be located further upstream, at least during the times when the reservoir is influencing site 0200016.

5.7 Bottom Sediments

5.7.1 Presentation of Data

Sediment trap samples were taken in Harmer and Grave Creeks during April to July 1976. The purpose and sampling methods were outlined in section 2.6.1. Freeze-core sediment samples could not be taken in Harmer and Grave Creeks due to the coarse size of the bottom sediments.

Three sediment traps were installed in Harmer Creek, just downstream from the Harmer settling pond (site 1190005). Two traps were installed in Grave Creek, upstream from Harmer Creek. The traps were installed in early April, before the spring freshet, and removed in early July, after the spring freshet. One of the traps in Grave Creek could not be found in July. The contents of the sediment traps were analysed for particle-size distribution, and the results are summarized in Table 71.

Grab sediment samples were taken, as described in section 2.6.1, from sites 0200027, 1190012, 0200111 and 0200016 on the Elk River, site 1190005 on Harmer Creek, and from site 0200026 on Grave Creek. These samples were analysed for particle size distribution (in the range of 1.19 mm. to 0.037 mm) and chemical compositon (carbon, nitrogen and phosphorus). The results are shown in table 72.

5.7.2 Discussion of Results

The sediment trap data for Harmer and Grave Creeks (Table 71) are not conclusive. Not enough samples (1 to 3) were taken to account for the variability amongst samples. The data for Harmer Creek show large variations in the quantity and particle-size distribution of fine sediment collected at the same site. The characteristics of the fines may be governed mostly by water flow in the immediate vicinity of the sediment trap. This would make it difficult to detect differences in the sediment trap samples caused by changes in suspended sediment concentrations in the stream.

The sediment trap in Grave Creek collected more fine sediment than the traps in Harmer Creek, but the particle-size distribution was slightly coarser (Table 71). The suspended sediment levels in Grave and Harmer Creeks were similar during the period when the samples were taken (April-July 1976). We would therefore expect the bottom sediments to be similar.

The quantity of fine sediment collected by the sediment traps in Harmer Creek was similar to that collected by traps in undisturbed streams (i.e. Fording River upstream from Fording Coal (site 0200110, section 2.6) and Michel Creek upstream from Byron Creek Collieries (site 0200110, section 4.6)). However, the sediment collected in Harmer Creek contained substantially more of the very fine fraction (<0.149 mm) than sediment from undisturbed streams. This result suggests that surface coal mining and logging produce finer sediments than natural erosion.

Data from grab sediment samples indicate that there was a slow change in particle size down the lower Elk River, from the sediment containing very fine particles (<0.149 mm.) to sediment containing coarser (>0.149 mm) material. Sediment from sites on Harmer and Grave Creeks had particle size distributions similar to that of site 0200016, at the mouth of the Elk River.

The chemical composition of the sediments from the Elk River, Harmer Creek and Grave Creek sites appeared alike, with the possible exception of site 0200016 (Table 72). Levels were all lower in the sediment from this site. There does not appear to be a relationship between the particle-size distribution and chemical compositon of the sediment.

5.7.3 Recommendations

We do not recommend further sediment trap sampling because there is too much variability in the samples taken at the same site. The use of freeze-core sediment sampling in fish spawning areas, subjected to increased sedimentation, is discussed in Section 2.6.3. Future benthic invertebrate studies should include substrate analyses of the kind also recommended in section 2.6.3.

5.8 Aquatic Biology

Previous chapters show that the Fording River and Michel Creek are sources of suspended solids to the Elk River. Kaiser Resources operates an open pit mine on Harmer Ridge. A settling pond receives effluent from the mine, and pond drainage enters Harmer Creek, which flows into Grave Creek, a tributary of the Elk River. Kaiser Resources also operates surface coal mines and a preparation plant south of Harmer Ridge. Drainage from this area enters the Elk River. The towns of Elkford, Sparwood and Fernie discharge treated municipal effluent to the river.

Invertebrates and periphyton were surveyed in Harmer and Grave Creek and the Elk River, as recommended in the Phase I report[1]. The purpose was to measure the effect of mining activities on aquatic life. Aquatic invertebrates were monitored because they are used to indicate environmental quality[34,35,36], and they are important to aquatic food webs[30,31]. Several factors determine the distribution of invertebrates, including food availability[31]. Periphyton was sampled to indicate whether an invertebrate food source had been affected by mining activities, and whether this in turn affected invertebrate populations.

5.8.1 Data collection and analysis

Benthic invertebrates were collected in August, 1975, at one water quality site in Harmer Creek, one in Grave Creek and seven in the Elk River. These sites were:

site 1190005: Harmer Creek downstream from the pond
site 0200026: Grave Creek downstream from Harmer Creek
site 0200042: Elk River headwaters
site 0200027: Elk River downstream from Fording River
site 1190012: Elk River downstream from Grave Creek
site 0200111: Elk River downstream from Otto Creek
site 0200103: Elk River downstream from Michel Creek
site 0200102: Elk River downstream from Sparwood
site 0200016: Elk River at the mouth.

Periphyton was collected in September, 1975, at the following sites in the Elk River:

site 0200043: Elk River upstream from Elkford
site 0200034: Elk River downstream from Elkford

and sites 0200027, 1190012, 0200103 and 0200016, as indicated above.

Site locations are shown in Figures 9 and 17, and are described in more detail in Table 10. The collection method and laboratory procedures are described in a separate report[38].

Invertebrate and periphyton samples were treated as described in Sections 2.7 and 4.7. Dominant periphyton taxa at the sites were noted and the ash-free weight of each sample determined. Invertebrate data were analysed qualitatively by comparing relative numbers, and the dominance of different groups of invertebrates amongst sites. The data were also analysed quantitatively, using three community analyses. These are: mutual information analysis[39], indirect polar ordination[40], and diversity and redundancy indices[41]. The analyses are described in Section 2.7.1.

5.8.2 Presentation of Data

General observations of the invertebrate sample sites are listed in Table 73. The number of invertebrate taxa collected at each site are shown in Tables 74 for the Elk River, and 75 for Harmer and Grave Creeks. The relative abundance of genera of mayflies, stoneflies, and caddis flies, are illustrated by histograms in Figures 18 to 22. The mutual information dendrogram is shown in Figure 23 and the polar ordination plot in Figure 24. The diversity and redundancy indices are listed in Table 76. Dominant genera of periphyton, and the ash free dry weights of the periphyton samples are given in Table 77.

There were many more invertebrates in the Harmer Creek (site 1190005) and Grave Creek (site 0200026) samples, than found elsewhere in the Elk River. Chironomids were clearly the dominant group at these sites. The mutual information analysis supported this observation. The dendrogram paired these two sites and separated them from the other sites in the Elk River (Figure 23). The ordination technique (Figure 24) also showed that sites 1190005 and 0200026 were different, and separated from the Elk River sites. The dominance of few groups of organisms was shown in Harmer Creek (site 1190005), and to a lesser extent in Grave Creek (site 0200026), by a low diversity index (1.49 and 2.00 respectively) and a high redundancy index (0.71 and 0.61 respectively). Periphyton was not collected from these sites for ashing. However, algae, particularly green, was abundant at both sites.

There were no large differences among groups of invertebrates from sites on the Elk River. Invertebrates were most numerous at sites 0200103 and 0200102, upstream and downstream from the Sparwood STP. Chironomids were the dominant group at site 0200027, downstream from the mouth of the Fording River and at site 0200016 near the mouth of the Elk River. Mayflies were as abundant as chironomids at site 1190012, downstream from the mouth of Grave Creek. At the other sites, mayflies were the dominant insect (Table 74).

Quantitative analyses showed similar results. The ordination technique grouped all the Elk River sites closely, indicating similarity among the invertebrate communities. The mutual information analysis grouped sites 0200027, 0200016 and 1190012, sites 0200042 and 0200111, and showed that sites 0200103 and 0200102 were somewhat different from the others. Diversity indices were high and redundancy indices low for all sites on the Elk River except 0200016, near the mouth of the river. Periphyton was abundant at most sites, with the possible exceptions of 1190039 and 0200027.

5.8.3 Discussion of Results

a) Harmer and Grave Creeks

The communities of invertebrates at the sites on Harmer and Grave Creeks were distinct from those of the Elk River. Several factors could account for the abundance of invertebrates and other characteristics of the communities. These factors include water flow and temperature, water chemistry, food availability and substrate characteristics[31].

The flow was very fast at both sites, but the rate would vary with season. There was little vegetative cover at the sampling sites and, since the creeks were small, temperatures could rise to values not reached elsewhere. These probable differences in flow and temperature could account for the presence of certain genera found at sites 1190005 and 020005 and 0200026, but not found elsewhere in the Elk River (i.e. Paraleuctra, Parapsyche elsis, and Oligophlebodes ruthae).

Although the water quality of Harmer and Grave Creek was usually good (Section 5.6), levels of nitrite + nitrate nitrogen and suspended solids were sometimes noteworthy at site 1190005, on Harmer Creek. High soluble nitrogen may have stimulated algal growth, accounting for the high productivity noted at the site. Turbidity resulting from suspended matter apparently did not interfere with plant growth. The large amounts of food may have been partially responsible for the sizable invertebrate communities at sites 1190005 and 0200026.

Examination of the streambed showed that sediment was accumulating at sites 1190005 and 0200026, altering the cobble substrate. Chironomids were dominant and extremely abundant at both sites, due to the fine sediment[57]. There was a small variety of stonefly genera and one mayfly genus was dominant at site 1190005. These community trends resulted in a relatively low diversity index and high redundancy index (Table 76). Dominance of a few groups was less pronounced at Grave Creek, site 0200026, but there is reason to believe that these communities, particularly at Harmer Creek, might be unstable[48]. The instability was probably produced by increased bottom sediment originating from open pit mines on Harmer Ridge. Invertebrates suited to sediment increased in number, while those occupying habitat destroyed by sediment decreased. Nemoura, a stonefly suggested to be opportunistic[95], was abundant at site 1190005. Young hydropsychids (caddis flies) also were abundant here. As free living caddis flies, they may be able to live on the surface of the substrate, provided there is something to cling to such as algae.

In summary, water flow and temperature, water chemistry, food availability and substrate characteristics influenced the invertebrate communities of Harmer and Grave Creeks. The resulting communities were extremely large and possibly unstable.

b) The Elk River

The invertebrate communities of the Elk River are also controlled by the same factors as in Harmer and Grave Creeks. Differences amongst the populations along the Elk River were small suggesting these factors were similar at all the sites.

Water flow was continuous in the Elk River and, despite local variations, generally fast, except near the mouth at site 0200016. The invertebrate fauna were mostly fast water forms and showed little generic variation along the river.

This consistency of genera along the river indicated that water temperature was relatively constant from site to site. An increase in temperature tends to exclude certain insects and to replace them with others more tolerant of the higher temperature[45,46].

The quality of the water of the Elk River was good (Sections 3.2 and 5.6). Levels of ammonia and phenol, originating from the coke plant on Michel Creek, were occasionally high at site 0200103, downstream from the mouth of Michel Creek. These contaminants did not affect aquatic life, as indicated by the large, diverse invertebrate community observed at the site. Metals and other toxic substances were present in very low amounts and the chemical composition of the sediments was similar to the composition of sediment elsewhere in the basin (Section 5.7).

Sparwood's sewage treatment plant discharges between sites 0200103 and 0200102. If a sewage effluent causes organic enrichment, or produces high levels of bacteria, then chironomids and oligochaetes increase noticeably in number(34, 96). The effluent did not have this effect. In fact, oligochaetes were more numerous upstream from the discharge (site 0200103), and there was a similar number of chironomids at both the upstream (0200103) and downstream (0200102) sites.

Food availability was not a critical factor for the invertebrate communities of the Elk River. There was a fairly large invertebrate community at site 0200027, downstream from the mouth of the Fording, although periphyton was not abundant at this site. Periphyton was more abundant downstream from the Elkford Sewage Treatment Plant (020039) than upstream (0200043), suggesting that the sewage effluent enriched the water at site 0200039.

High levels of suspended solids were not detected in the Elk River above Fernie. Some fine sediment was found on the bottom at site 0200027 downstream from Fording River, site 1190012 downstream from Grave Creek, and to a greater extent at site 0200016, at the mouth. The Fording River may have contributed sediment to site 0200027. Heavy machinery had been working at the edge of the river, upstream from site 1190012 for sometime. Channel erosion and decreased river gradient have been suggested as the source of silt at site 0200016, near the mouth of the Elk River. Chironomids were the dominant group at sites 0200027 and 0200016, and the second largest group at site 1190012. This is consistent with the observation of fine sediment at these sites[57]. Also, the mutual information analysis (Figure 23) found the invertebrate communities at sites 0200016 and 0200027 to be similar to each other and to site 1190012.

The mutual information analysis also found the invertebrate populations at site 0200111, downstream from the mouth of Otto Creek, and site 0200042, the upstream control site, to be similar. This result indicates that the Elkview preparation plant, drained by Otto Creek, was not disrupting the biota of the Elk River. Sediment was not evident on the substrate at these sites (Table 73). Stoneflies and mayflies were particularly abundant at sites 0200103 and 0200102, upstream and downstream from Sparwood.

Communities at these sites were stable, and showed no environmental stress[30].

High diversity indices (and low redunancy indices) were found at Elk River sites, except site 0200016 (Table 76). Such a result is normal for an undisturbed river receiving a large number of tributaries[97]. The high diversity indices at sites 0200027 and 1190012 suggest that fine sediment was not a large enough component of the substrate to stress the invertebrate community, although it influenced the composition of the community. Certain mayflies were scarce at site 0200016 (Rhithrogena, Cinygmula, Iron). Stoneflies and caddis flies were scarce at most Elk River sites indicating that silt on the substrate was generally a disruptive factor[31]. The ordination analysis reflects the similarity of invertebrate communities of the Elk River by grouping all sites closely together (Figure 24).

Of the invertebrate communities studied in the lower Elk basin, those at site 1190005 (Harmer Creek) and site 0200016 (near the mouth of the Elk River) were found to be unstable. The instability was related to sediment accumulation on the substrate. In Harmer Creek the sediment came from mining activities and at the mouth of the Elk River it came mainly from natural erosion and decreased river gradient. The situation could be controlled at site 1190005, but probably not at site 0200016. If Harmer Creek supports a fishery, it would be affected during freshet when the sediment and associated invertebrate fauna are washed out. Little food would be available to the fish at this time.

5.8.4 Recommendations

Suspended solids in the Harmer Creek settling pond effluent should not exceed present levels, as recommended in Section 5.1.3. A study of the fishery potential of Harmer and Grave Creeks will help decide if improvements in effluent quality are necessary. If these creeks support a fishery then further sampling of benthic invertebrates should be done, immediately after freshet, and again in mid-summer (August).

The population of benthic invertebrates at site 0200016, near the mouth of the river, was found to be unstable, partly because natural sediment accumulated at this site. Future monitoring of benthic invertebrates, from this portion of the Elk River should be carried out further upstream.

As mining expands along the Elk River, particularly in the upper part of the basin, invertebrate monitoring will be required. We recommend monitoring be conducted, as outlined in section 2.7.4. It should include pre-operational sampling and sampling after two or three years of operation.

6. THE FLATHEAD RIVER BASIN

Coal exploration and logging are the only industrial activities in the Flathead basin. Rio Tinto Canadian Exploration Ltd., a subsidiary of Rio Algom Ltd., has proposed a major metallurgical coal development on Cabin Creek.

6.1 Proposed Sage Creek Coal Project

Rio Algom Ltd. proposed a metallurgical coal project straddling Cabin Creek, that would produce 2.7 million tonnes of clean coal per year. The salient features of this development are described in the Phase I report for the Flathead River Basin[2]. Rio Algom Ltd. submitted a Stage I impact assessment report[98] for the project, in accordance with the Guidelines for Coad Development[3]. Poor market conditions have since halted the project and Stage II environmental studies [99] for an indefinite period.

Rio Algom is preparing a Stage I impact assessment report for a smaller version (1.3 million clean tonnes/year) of the original project. There are no definite plans to proceed with the smaller project at this time. The smaller project is similar to the original proposal, but features a different mining sequence for the South and North Hill pits. Coal would be trucked from the minesite to the railhead at Morrissey. There would be a townsite located 24 km north of Cabin Creek instead of one located close to the minesite[99].

The project would increase suspended solids, turbidity and sedimentation in streams downstream from the minesite. The extent to which this occurs will depend upon the erosion and sediment control measures used. Chapter 9 gives guidelines for water quality protection during coal mining.

6.2 Water Quality

6.2.1 Presentation of Data

In 1975-1976 the waters of the Flathead River basin were sampled by the Pollution Control Branch, Environment Canada, the U.S. Geological Survey, and the consultants of Rio Algom Limited. The waters of the Upper Flathead basin, in the United States, were studied by the State of Montana[100].

Water quality data, collected at 5 sites by the Pollution Control Branch, are summarized in Tables 78 to 81. The locations of the sampling sites are shown in Figure 25, and are described in detail in Table 10.

Environment Canada collected data during 1975-1976 to document the water quality before development occurred[101]. Water quality data were collected at ten stations (08NP0001 to 08NP0010) shown in Figure 25, and described in detail in Table 10. These data are summarized in Tables 81 to 87. Attached algae, macroinvertebrates, fish and sediments were also studied. Environment Canada is preparing a detailed report on this study.

The U.S. Geological Survey sampled the Flathead River at the International Boundary during 1975-76(site 12355000, Figure 25). About 54 water quality parameters were monitored, as well as algae, flow, and the discharge of suspended sediment. The water quality data are similar to those collected by Environment Canada and the Pollution Control Branch. They have not been reproduced in this report, but are discussed in the following section.

The State of Montana published a study of the Upper Flathead River Basin in January, 1977[100]. This study evaluated the broad impacts of the Sage Creek Coal Project on the upper Flathead basin in Montana. The main impacts on water quality were judged to be: increased suspended and dissolved solids from land disturbances, the possibility of increased levels of toxic metals and phosphorus from land disturbances, sewage pollution from the new town, and the adverse effects of increased sedimentation on fish spawning areas and benthic insects. The water quality data obtained in this study concurs with data presented in Tables 78 to 87, and thus has not been included.

Data collected by the consultants of Rio Algom Ltd. were not available at the time of writing.

6.2.2 Discussion of Results

The data in Tables 78 to 87 show that the waters of the Flathead basin were alkaline (pH of 7.1 - 8.6) and slightly to moderately hard[17], or of good to fair quality for domestic purposes[23]. The waters were normally very low in metals and toxic substances (usually below the detectable limits).

Barium levels in the Flathead River (1.6 mg/L) and Howell Creek (1.5 mg/L) exceeded the maximum permissable limit for drinking water (1.0 mg/L)[23] once, during the winter low flow period (February 1976). There are barite (barium sulphate) deposits in the Flathead basin, and the barium levels may be due to naturally high concentrations in the groundwater[102]. The barium concentrations in surface water (during low flows) and groundwater should be monitored before the water is used for drinking.

Cadmium levels were below the detectable limits (<0.2 and <0.5 µg/L) except for 3 values. These were measured in the Flathead River (4 and 5 µg/L) and in Howell Creek (10 µg/L), during winter low flows (December 1975) and the spring freshet (April 1976). The maximum permissable cadmium level in drinking water is 10 µg/L [23], and recommended criteria for aquatic life in hard water are 1-12 µg/L,[24] and 3-30 µg/L [75]. Higher than normal metal concentrations are not uncommon in streams in the Kootenays, during the spring freshet, due to increased suspended sediment levels. Elevated cadmium levels during winter low flows may be due to naturally high levels in groundwater. The cadmium concentrations in surface water, during low flows, and in groundwater should be monitored before the water is used for drinking.

The levels of the major nutrients, nitrogen and phosphorus, were usually low. The threshold levels for nuisance growths of aquatic plants are 0.3 mg/L nitrate nitrogen and 0.6 mg/L total Kjeldahl nitrogen[22] (i.e. organic plus ammonia nitrogen). These levels were never exceeded. Assigning definite criteria for phosphorus in water is difficult. Guideline levels for total phosphorus are 0.10 mg/L in flowing waters and 0.05 mg/L in flowing waters, discharging into lakes and reservoirs[24,93].

These guidelines were slightly exceeded during the spring freshet (0.1 to 0.2 mg/L), largely due to the phosphorus content of the suspended sediment. On one occasion high levels (0.76 mg/L, average) occurred during winter low flows, possibly due to the entrainment of suspended sediment in slush ice[102]. Dissolved phosphorus levels were low ($\leq$0.015 mg/L).

Suspended sediment levels in the Flathead basin were low during most of the year, but reached relatively high levels during the spring snowmelt-freshet period. Environment Canada and the Pollution Control Branch measured suspended solids of <1 - 150 mg/L and 2 - 334 mg/L (turbidities of <1 - 68 J.T.U.) respectively, in the Flathead River at the border. The peak levels measured at other sites in the Flathead basin were lower. The U.S. Geological Survey measured suspended sediment and turbidity daily in the Flathead River at the border from early April to the end of September in 1975. Results ranged from 1 to 1310 mg/L suspended solids and 0 to 240 J.T.U. turbidity.

The sanitary quality of the Flathead River was good, since U.S. Geological Survey measurements showed that fecal coliform densities ranged from 0 to 24/100 mL.

The water quality of the Flathead River basin has not been greatly affected by the activities of man. Coal exploration, logging and road building may have contributed some suspended sediment to the streams, but this contribution was probably small compared to naturally occurring levels.

6.2.3 Recommendations

We do not recommend further water quality monitoring in the Flathead River basin by Provincial agencies until definite development proposals are made. Cadmium and barium levels, in groundwater and in surface water (during low flows), should be monitored before the water is used for drinking.

7. WATER AVAILABILITY

This chapter documents the problems of water availability in the Elk and Flathead River basins. Water availability problems may be caused by an actual water shortage, where there is insufficient water to meet water supply meeds, or by poor water quality, where the water is unfit or undesirable for the intended use. Water supplies can be available, but unusable in practice because of the costs of pipelines, pumps, storage, drilling, treatment, etc.

7.1 Flathead River Basin

The Flathead basin is virtually uninhabited and largely undeveloped. There are thus no water availability problems in the basin at the present time. Only one water licence (2.3 m^3/d on Cabin Creek) has been issued in the basin[(2)].

7.2 Elk River Basin

There have been few water availability problems in the Elk basin to date, since the population is fairly small (≈12,000), and there has not been extensive development (i.e. agriculture, mining, forestry). The smaller, good quality, gravity-flow water sources have usually been adequate to meet water demands. The larger streams, such as the Elk River, the Fording River, and Michel Creek, in which water quality was affected by development, have not been heavily used for water supply. There may be water availability problems in the future, because increased development from coal mining will increase the demand for water. Development may make it necessary to use the larger, poorer quality sources, and may cause a deterioration in the quality of some water sources.

7.2.1 Water Quantity

Water sources in the Elk basin which have had, or may have, water shortages, are shown in Figures 26 and 27 and are listed in Table 88. Baldrey, Bean, Labelle, Mott and Nordstrum Creeks are small tributaries of the Elk River which are fully committed, or nearly so, due to irrigation of agricultural land in the Elk valley. MacKenzie Spring is fully committed for water supply for the District of Sparwood. Fairy and Boivin Creeks are committed to water supply for Fernie, and Elkford, respectively, but there is no shortage of water from these sources.

The Elk River, upstream from the Elko Dam, is fully committed. B.C. Hydro is licenced to use 25 m^3/s for power generation but the flow often drops below 25 m^3/s during the winter months. Thus, any consumptive use of water, upstream from the dam, reduces the amount of power that can be generated. However, water licences for relatively small quantities have been issued upstream from the dam. The Elk River downstream from the dam is not fully committed. Since power generation is not a consumptive use, there is no water shortage downstream.

The unlicenced water in the Fording River, Line Creek and Grave Lake was reserved by Order-in-Council No. 79 on January 28, 1926, to provide a water supply for a power project. Interim water licences could be issued with the approval of the Minister of the Environment. The Minister has approved water licences on these sources, and there are no plans for a power project in this area at the present time.

The availability of water on fully committed sources, or sources with a possible water shortage, often changes with time. Cancellation or abandonment of water rights, more efficient use of water, and more accurate flow records often result in water becoming available for further licencing. Consequently, persons interested in obtaining water rights on the water sources mentioned in this section should contact the Water Rights Branch for the latest information on these sources.

7.2.2 Water Quality

The water quality of the Elk basin is discussed in chapters 2,3,4 and 5, but we will highlight the water sources which have been rendered unfit, or undesirable for water supply, due to water quality deterioration.

The major cause of water quality deterioration in the Elk basin is suspended solids and turbidity produced by coal mining and logging. Suspended solids and turbidity levels are normally high during the spring freshet period, but may also be high during heavy rainstorms. Increased suspended solids makes treatment necessary for most water uses, or increases the load on a treatment system. The major streams in which suspended solids and turbidity levels increased, are shown in Figure 28.

Figure 28 also shows the streams in which fecal coliforms, phenols and nitrate rendered the water unfit or undesirable for certain uses. There was fecal contamination in the Elk River downstream from Fernie, phenols in lower Michel Creek and in the Elk River immediately downstream from Michel Creek, and nitrate plus nitrite in the Fording River immediately downstream from the mine.

8. RECEIVING WATER AND EFFLUENT MONITORING

8.1 Recommended Monitoring

This chapter presents the receiving water and effluent monitoring program that the provincial government should conduct in the Elk and Flathead River basins. The monitoring program specifies sites, parameters and frequencies for routine monitoring of water quality and major effluents. Monitoring for minor effluents, that did not have an effect on water quality, has not been specified. The detailed recommendations for monitoring can be found at the end of each section on effluent and water quality.

The recommended program is summarized in Table 89. This program represents the initial monitoring effort required for the existing operations in the Elk and Flathead basins, but with experience the monitoring effort can probably be reduced. The development of new operations will require an increase in monitoring.

The recommended program represents a significant departure from the type of monitoring conducted before the Kootenay Study. Past monitoring was characterized by a relatively small number of samples, taken at regular intervals throughout the year, and analysed for a large number of parameters. For example, in 1974, the year before the Kootenay Study, approximately 200 samples were taken at 40 sites. About 4000 laboratory analyses and 1000 field analyses were conducted on these samples. Initial monitoring for a large number of parameters was useful, because little water quality and effluent data had been collected before the early 1970's. It was thus necessary to monitor a wide range of parameters to establish levels and to determine the effects of various discharges. There is now however, a substantial inventory of water quality data, and the effects of the various effluents have largely been determined. The number of parameters can now be substantially reduced, and we should focus on those parameters that are known to be important.

The recommended program involves more sites (65) and samples (600), but these samples are analysed for far fewer parameters. About 1400 laboratory analyses and 1000 field analyses will be required. Compared to 1974 monitoring, the total number of analyses will be reduced by one-half and the number of laboratory analyses will be reduced by two-thirds. The saving in analytical costs will be slightly offset by the additional field costs required to collect the greater number of samples. We estimate that the recommended program will take 80 man-days per year to conduct compared to 60 man-days in 1974. The increase in field costs is estimated to be in the order of 10 percent of the saving in analytical costs. Assuming the average cost of a laboratory test is $10, the overall saving will be about $25,000 per year.

We recommend that the frequency of monitoring should increase when water quality deterioration is most likely to occur. That is, monitoring should be conducted mainly during critical conditions. For example, when dilution of effluents is a problem, monitoring should be most frequent during low river flows. For suspended sediment discharges, monitoring should be conducted mainly during spring snowmelt, when most of these discharges occur. Large suspended sediment discharges can also occur during heavy rains or winter thaws, and these events should be monitored if the opportunity arises. Since these events are not predictable, they are not amenable to routine monitoring. We believe however, that if erosion and sediment control measures are in place, and work satisfactorily during spring snowmelt, then they should be able to control sediment from other runoff events. Effluent and water quality monitoring should be closely correlated. Samples should be taken on the same day, at approximately the same time, in cases where discharges directly affect water quality.

The main goals of the recommended program are to check compliance with effluent objectives, to assess the effectiveness of pollution abatement works, and to monitor the effect of discharges on receiving water quality. Minor goals are the aquisition of baseline data in areas of proposed development, and continued input to the post-impoundment study of the Libby reservoir.

The results of the program should be assessed regularly during the year, and the findings published in report form once a year. This will allow for review and revision of the monitoring program, so that monitoring can be continued at least cost. Yearly bulletins on water quality will also be useful to those planning development in the region, and to managers of the water resource.

8.2 Future Developments

The development of the coal resources of the Elk and Flathead basins could cause rapid growth in mining activity and populations[103]. The potential developments through 1995 are summarized in Table 90. The 1976 populations of the Elk and Flathead basins were 12,000 and 0, respectively. If all the proposed coal developments proceed, the 1985 populations could be 24,000 in the Elk basin and 2,000 in the Flathead basin. Population growth will probably be somewhat slower, because not all proposed developments are likely to proceed by 1990[103].

The proposed developments could increase levels of suspended sediment, produce sedimentation in streams, and cause loss of aquatic habitat through land disturbances. Fecal contamination from domestic sewage, and localized impairment of water for domestic use by mine drainage could also occur.

In view of the high growth potential of the Elk basin, it may be necessary to conduct another synoptic river-quality study of the basin in the future. The need for another study will be determined, in part, by results of the continuing routine effluent and water quality monitoring.

8.3 Water Quality Modelling

We reviewed water quality modelling[104,105,106] and the potential for applying modelling techniques to the Elk and Flathead basins. The techniques available are generally not applicable to the types of water quality problems that exist or that are likely to occur in these basins in the foreseeable future.

The main water quality problems in the Elk and Flathead basins are increased suspended sediment levels and sedimentation due to land disturbances at coal mining operations. The erosion-transport-deposition process however, is one of the most difficult processes to model quantitatively. The process is so variable in time and space that it cannot presently be adequately studied and quantified for river-basin sized watersheds[104]. There is one sediment transport model now available but the data requirements are high and the model has not yet had wide application[105].

Water quality models are well suited to analyse complex water quality problems, where many management alternatives must be examined[105]. The existing water quality problems in the Elk basin, with the exception of suspended sediment (i.e., phenols, nitrates, fecal contamination), are simple, single-source problems, for which the cause - effect relationships and the solutions required are already known. Proposed developments in the Elk and Flathead basins are similar to those existing in the Elk basin. The effects that the developments will have on water quality, and the actions necessary to counter these effects, are largely known.

9. PROPOSALS FOR WATER QUALITY PROTECTION IN COAL MINING

These proposals represent some of the principles and measures that should be adopted to protect water quality affected by the coal mining industry. Specific recommendations for the abatement of water pollution at existing coal mining operations in the Elk basin have been made in sections 2.2.4, 4.1.4, 4.2.3, 4.3.3, and 5.1.3. The proposals are based on the findings of this study and on the recommendations of other investigators[3,12,74,107,108]. More comprehensive guidelines for environmental protection in coal and mineral exploration[109] have been issued by the Ministry of Mines and Petroleum Resources, and guidelines for environmental protection in coal and mineral development will be issued[7].

9.1 Planning

Careful planning is an essential prerequisite for the protection of water quality in coal mining. Many of the water quality problems in the Elk basin have occurred because of poor planning with regard to erosion and sediment control. Water quality protection should be an integral part of mine planning, rather than an end-of-process mitigation precedure.

9.2 Source Control

Erosion and sediment production should be controlled at the source, as the first step in limiting downstream sedimentation. Sediment control works (e.g. settling ponds) should be used as the second line of defence in preventing downstream sedimentation[12].

To achieve source control the following measures should be adopted:

- minimize the area disturbed by spoil disposal by backfilling pits with spoil to the maximum extent possible.
- construct spoil piles and coal refuse piles so that they are stable both physically and biologically (i.e., slopes not exceeding 26 degrees[3,74]), and can be progressively reclaimed as they are constructed.

- expose the smallest possible area of land for the shortest possible time
  - clear land to be mined as close to the time when mining begins as possible
  - conduct reclamation concurrently with mining
- leave buffer strips of vegetation between all land disturbances and watercourses to trap sediment (an exception are roads in steep valleys, where the best place for the road is adjacent to the stream, to avoid large cuts and fills on steep slopes)
- divert clean water around land disturbances as much as possible
- design diversion channels so that they are stable and will not erode (settling ponds may be necessary in some areas)
- use proper practices in the design, construction and maintenance of mine roads[107,108].

9.3 Sediment Control

Sediment-laden drainage from disturbed areas (e.g. plant yard areas spoil piles, coal refuse piles, open pits, haul roads etc.) should be treated in sediment control works (e.g. settling ponds) prior to discharge to surface water. Sediment control works should be constructed first so that they are ready to control sediment when land disturbances begin.

9.4 Pond Design

Settling pond effluents should meet effluent quality objectives for up to a specified design flow return period. Established design principles should be employed in the design of settling ponds. Chemical coagulation or filtration will be required to meet effluent quality objectives where appreciable quantities of fine-grained suspended sediments are produced. (See section 5.1 for a discussion of settling pond design). Regular maintenance of settling ponds should be carried out to achieve good quality effluent.

9.5 Pond Removal

Settling ponds should be removed from the drainage system once reclamation is complete. If this is not done an extreme runoff event will eventually wash the settling pond dam, and the accumulated sediment, into the watercourses they were designed to protect(12).

9.6 Pipelines

Spill containment facilities (e.g. ditches, berms, settling ponds, etc.) should be provided where necessary along the entire length of tailing and coal slurry pipelines. The crossing of streams by pipelines should be avoided.

9.7 Recycling

Pit water and settling pond effluents should be recycled as much as possible (e.g. for coal preparation plant make-up water, irrigation, hydraulic mine make-up water), instead of discharging to surface water.

9.8 Floods

Locating tailing ponds, coal refuse piles, spoil piles and settling ponds on the floodplain should be avoided. Temporary structures should be able to withstand the largest flood probable during the life of the structure. Permanent structures should be designed to remain stable indefinitely against floods, and the changing course of the stream within the floodplain.

9.9 Seepage

Seepage from coal tailing ponds into groundwater or small surface streams should be minimized. This is important when the water is used, or likely to be used, for water supply purposes.

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FIGURE I
KOOTENAY REGION SHOWING THE ELK AND FLATHEAD RIVER BASINS

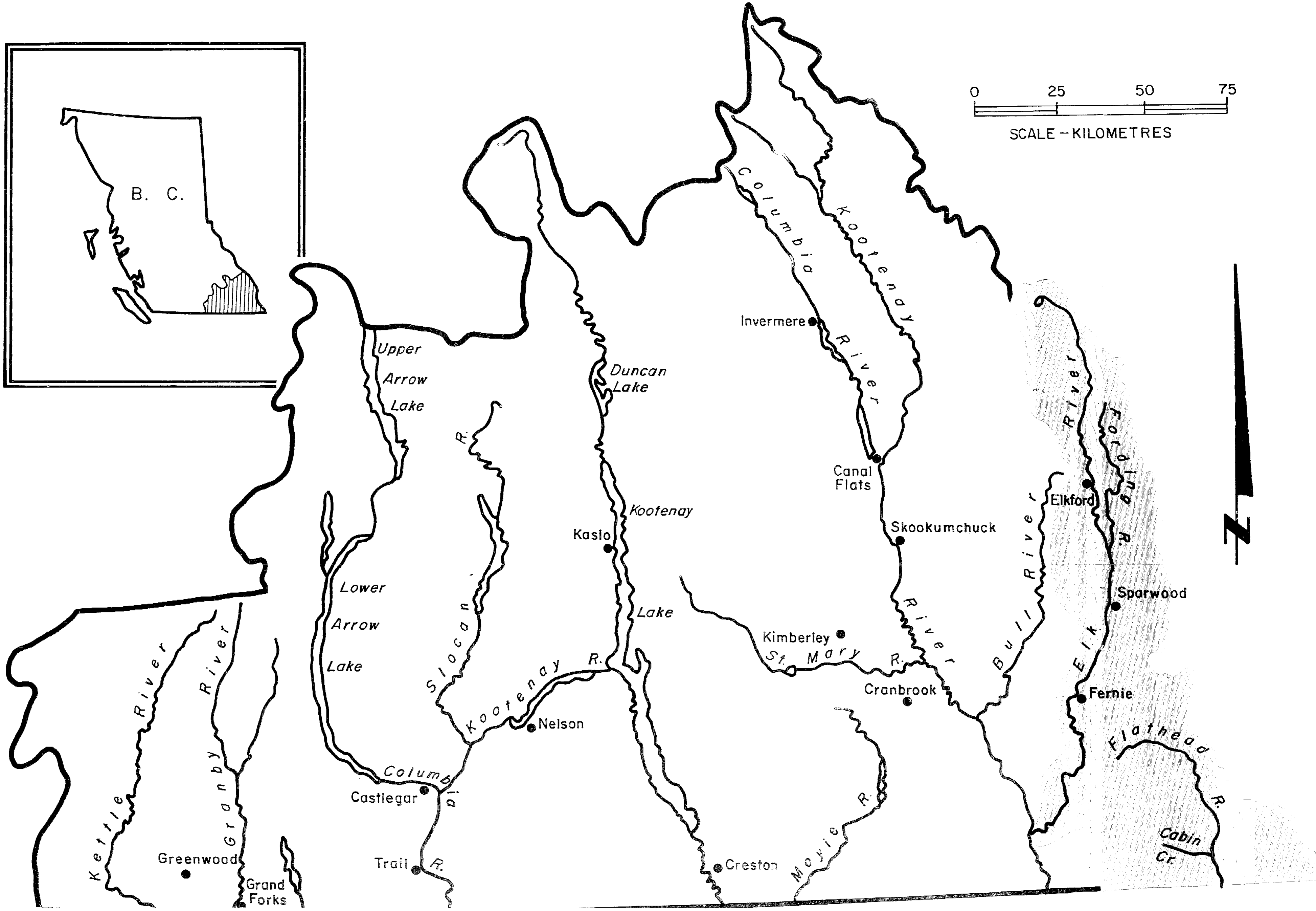


FIGURE 2
ELK AND FLATHEAD RIVER BASINS EXISTING AND PROPOSED COAL DEVELOPMENTS

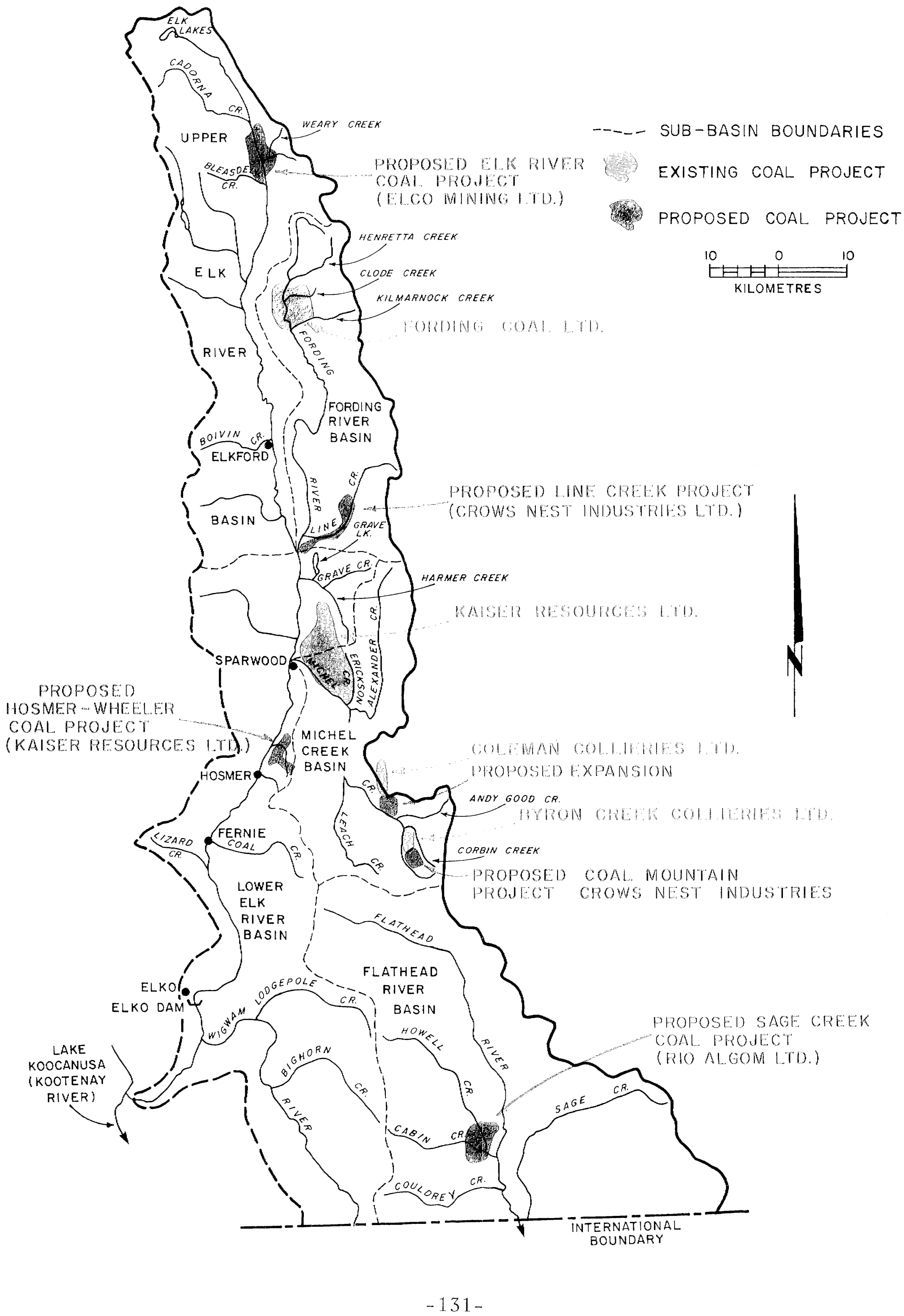


FIGURE 3
COAL DEVELOPMENT ASSESSMENT PROCEDURE (3)

PROSPECTUS

Initial outline of coal reserves and exploration, minesite, and offsite development proposals, including
- the mining properties
- the reserves (location, type, amount, recoverable, developed, etc.)
- forecast production by phase
- estimated labour force by phase
- exploration and mining programs and areas influenced.

→

STAGE I: PRELIMINARY ASSESSMENT

1. Preliminary outline of development program impacts related to
   - exploration
   - mine development
   - mine reclamation
   - coal processing
   - power development
   - transportation
   - community development
   - regional economy.
2. Analysis of existing data to identify data gaps related to existing environment and the community.
3. Design and implementation of environmental monitoring programs to fill data gaps. This to be done by contact with appropriate agencies.
4. Preliminary identification of problems warranting assessment and alternative solutions to be explored.

→ Review Process →

STAGE II: DETAILED ASSESSMENT

1. Detailed outline of development program related to
   - exploration
   - mine development
   - mine reclamation
   - coal processing
   - power development
   - transportation
   - community development.
2. Site specific impact assessments for all elements of the development program on natural environment
   - terrestrial resources, including land capability
   - water and aquatic resources
   - air resources, including noise levels.
3. Alternative proposals for managing identified environmental impacts and meeting identified community and social development requirements.
4. A statement of alternatives preferred by developer with supporting reasons.

→ Review Process →

STAGE III: OPERATIONAL PLANS AND APPROVAL APPLICATIONS

1. Preparation of detailed plans of action for
   - managing identified environmental impacts
   - meeting community and social development requirements of selected alternatives.
2. Application for necessary permits:
   - Mines and Petroleum Resources
   - Pollution Control Branch
   - Water Rights
   - Lands Service
   - Municipal Affairs
   - Highways
   - Forest Service.
3. Design of monitoring programs for construction and operation.

→ Approval by Cabinet →

STAGE IV

Implementation of continuing monitoring programs.

FIGURE 4

FORDING RIVER BASIN
LOCATION OF DEVELOPMENTS AND SAMPLING SITES

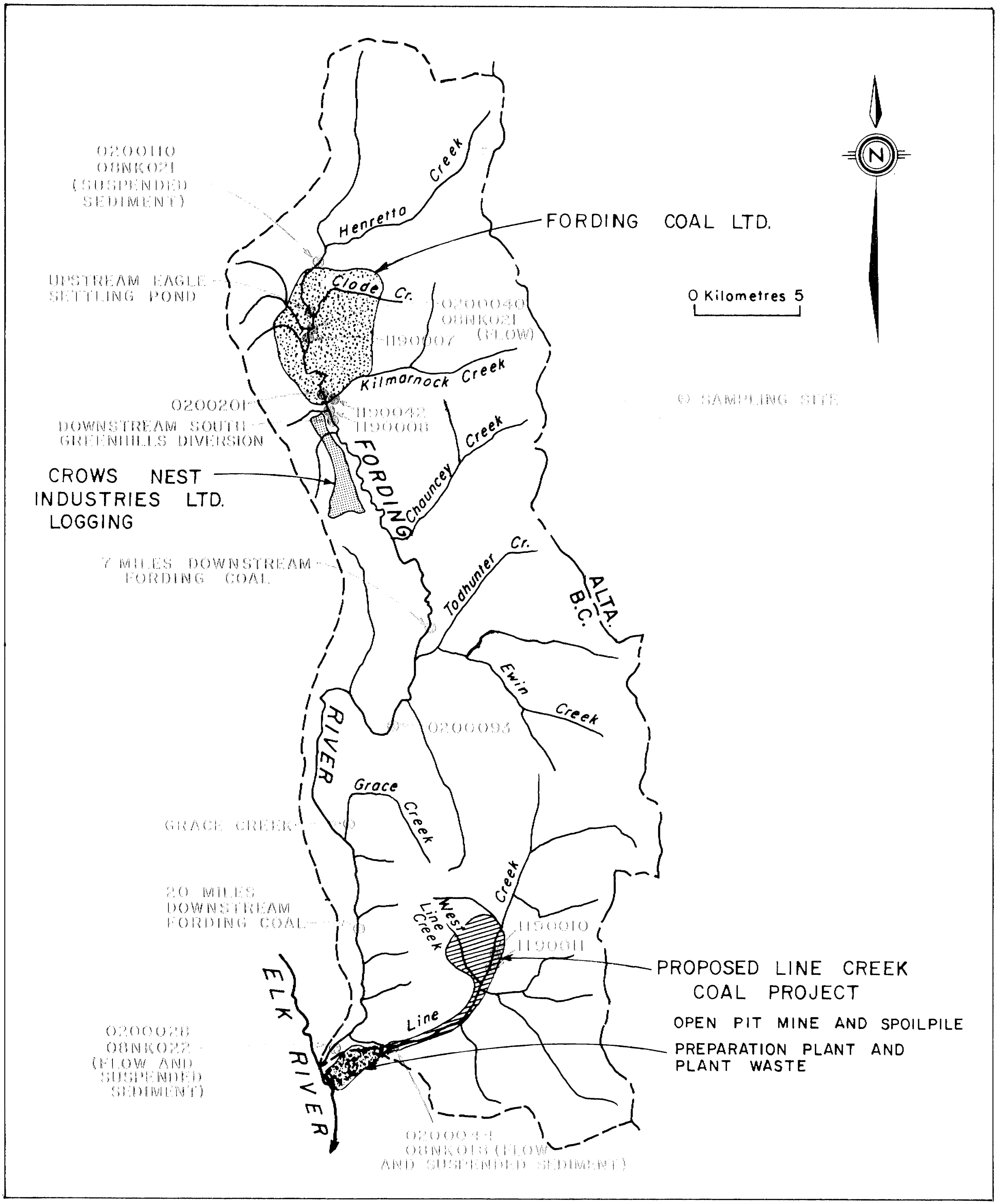


FIGURE 5
FORDING COAL LTD.

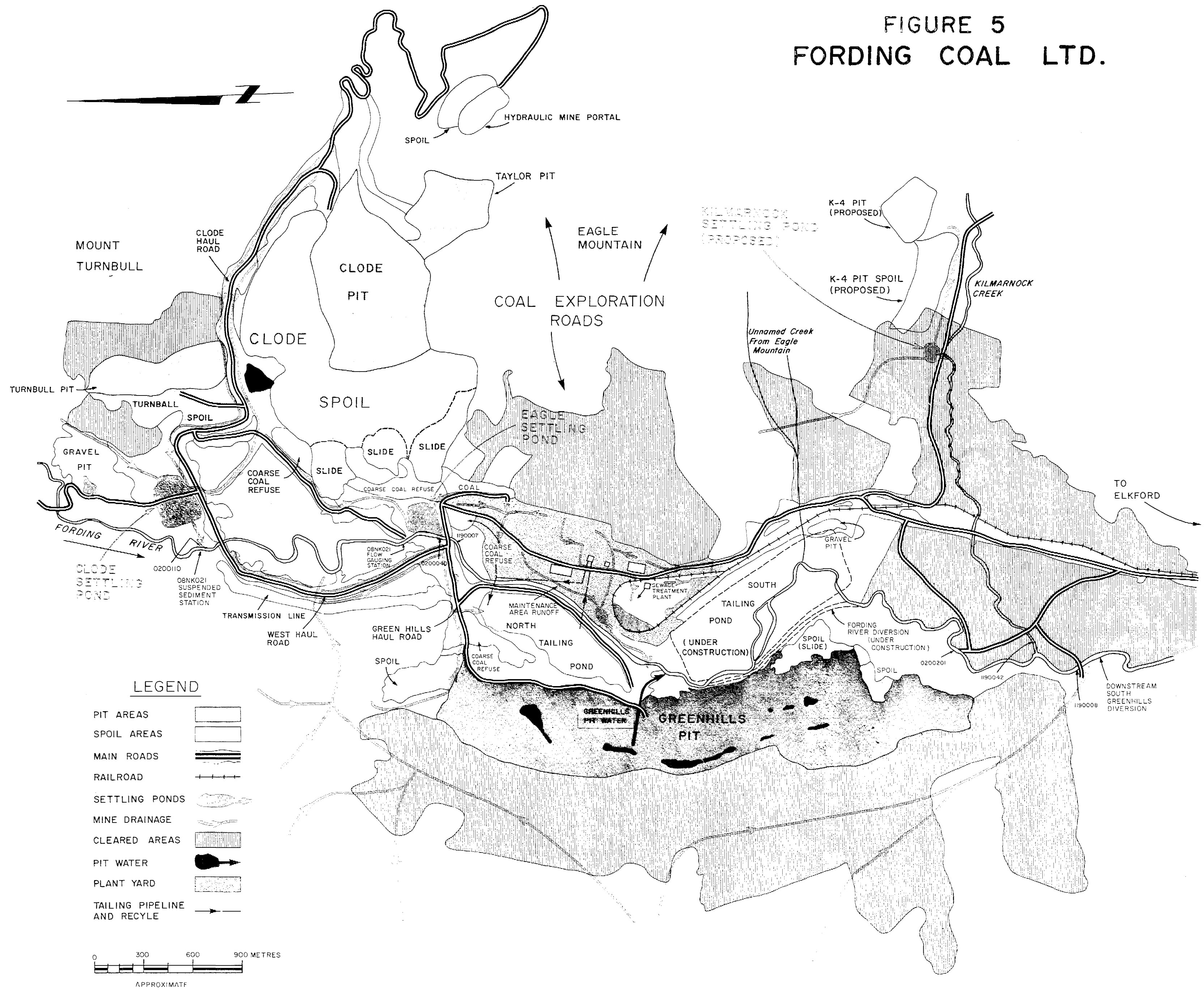


FIGURE 6

GENERA OF EPHEMEROPTERA OBTAINED FROM THE FORDING RIVER IN AUGUST, 1975.

(Pooled Counts from Triplicate Mundie Samples)

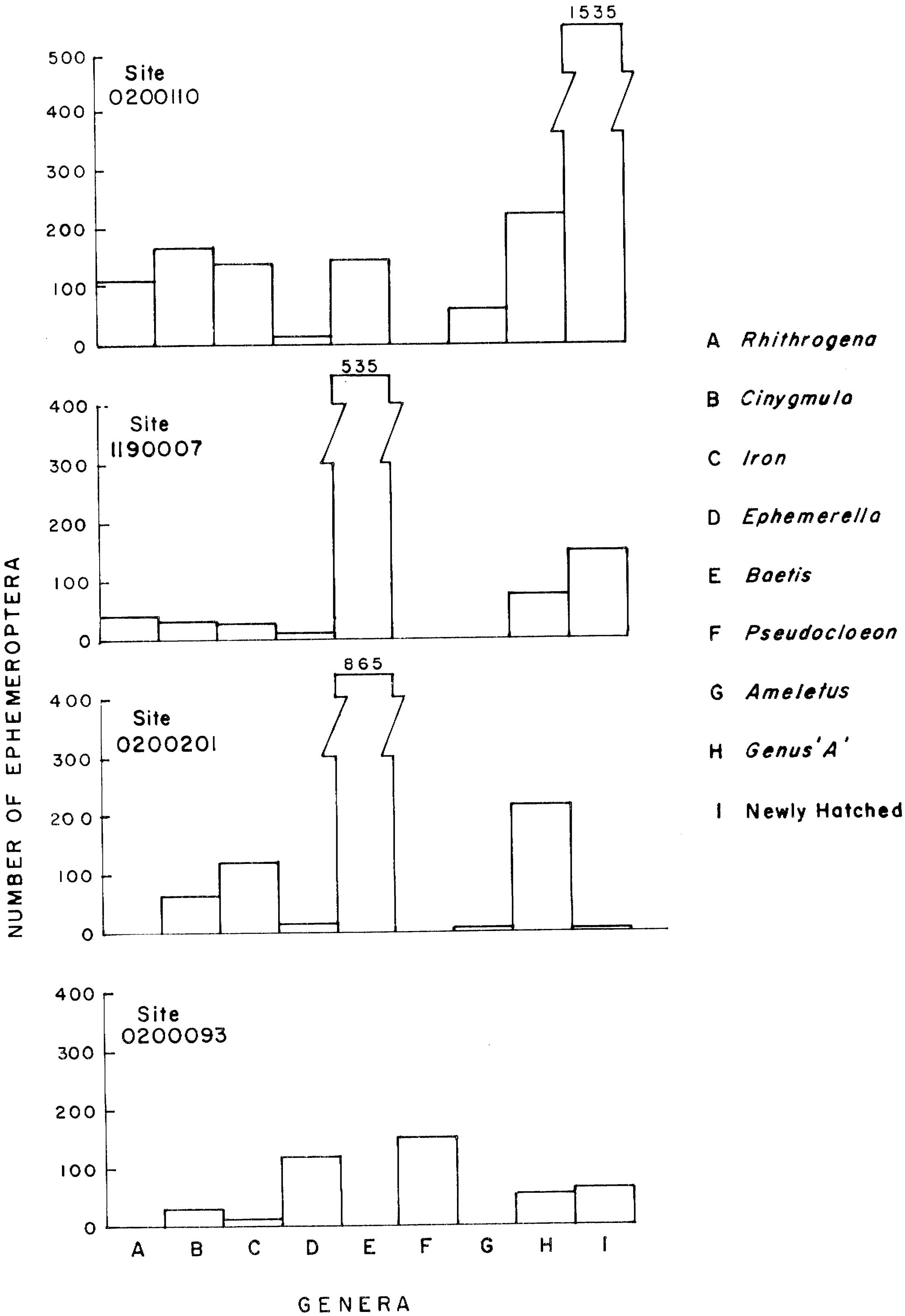


FIGURE 7

GENERA OF PLECOPTERA AND TRICHOPTERA OBTAINED FROM THE FORDING RIVER IN AUGUST, 1975.

(Pooled counts from triplicate Mundie Samples)

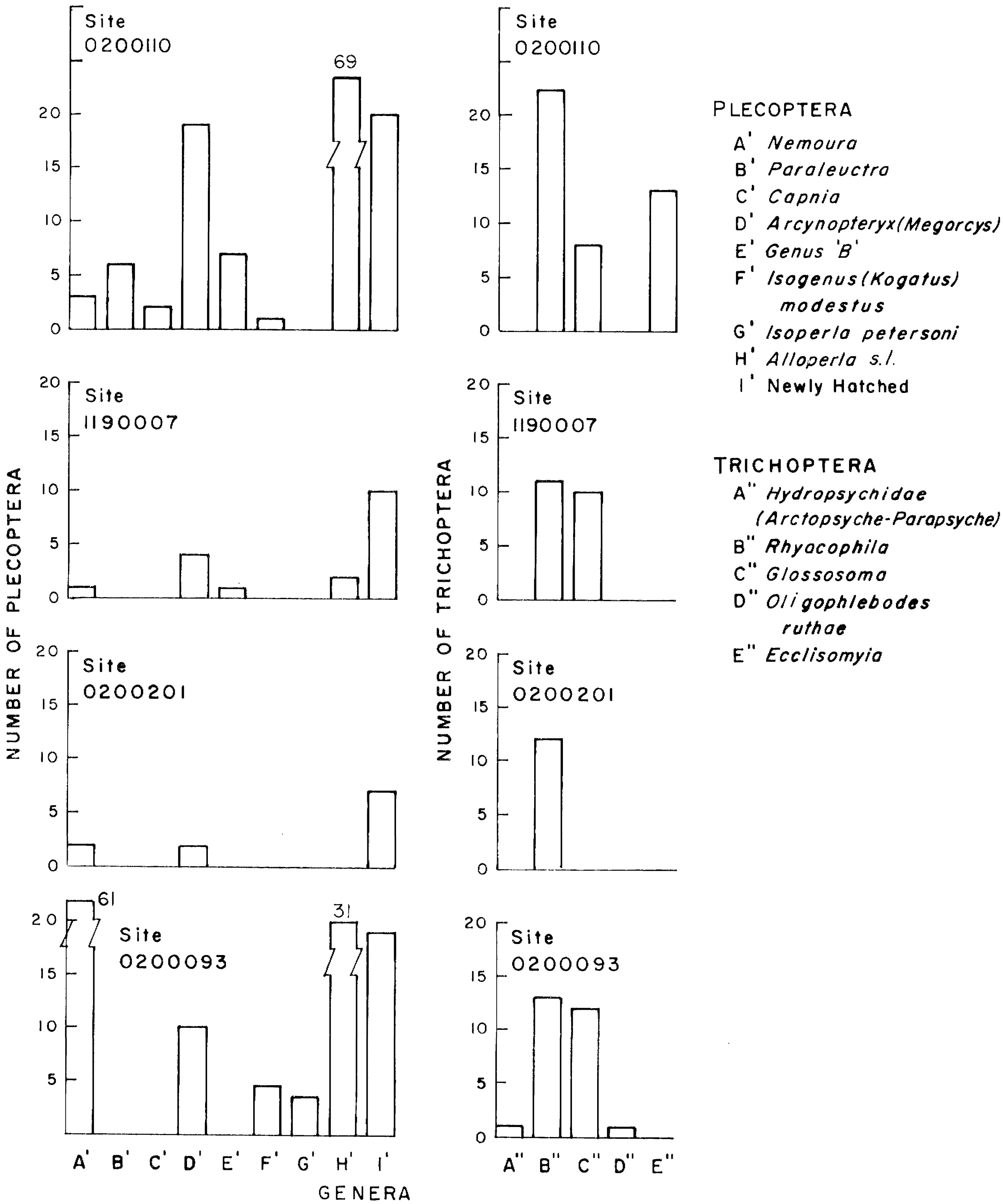
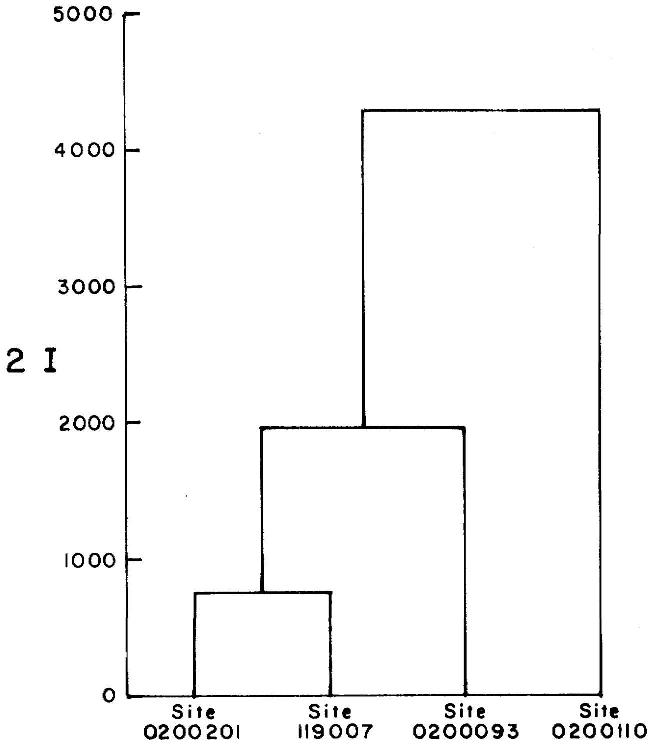


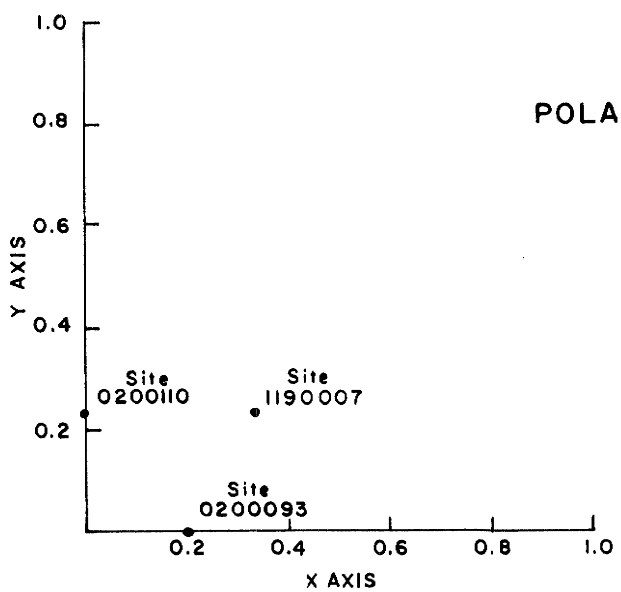
FIGURE 8

QUANTITATIVE ANALYSIS OF BENTHIC INVERTEBRATE DATA OBTAINED FROM THE FORDING RIVER IN AUGUST, 1975



A

MUTUAL INFORMATION DENDROGRAM

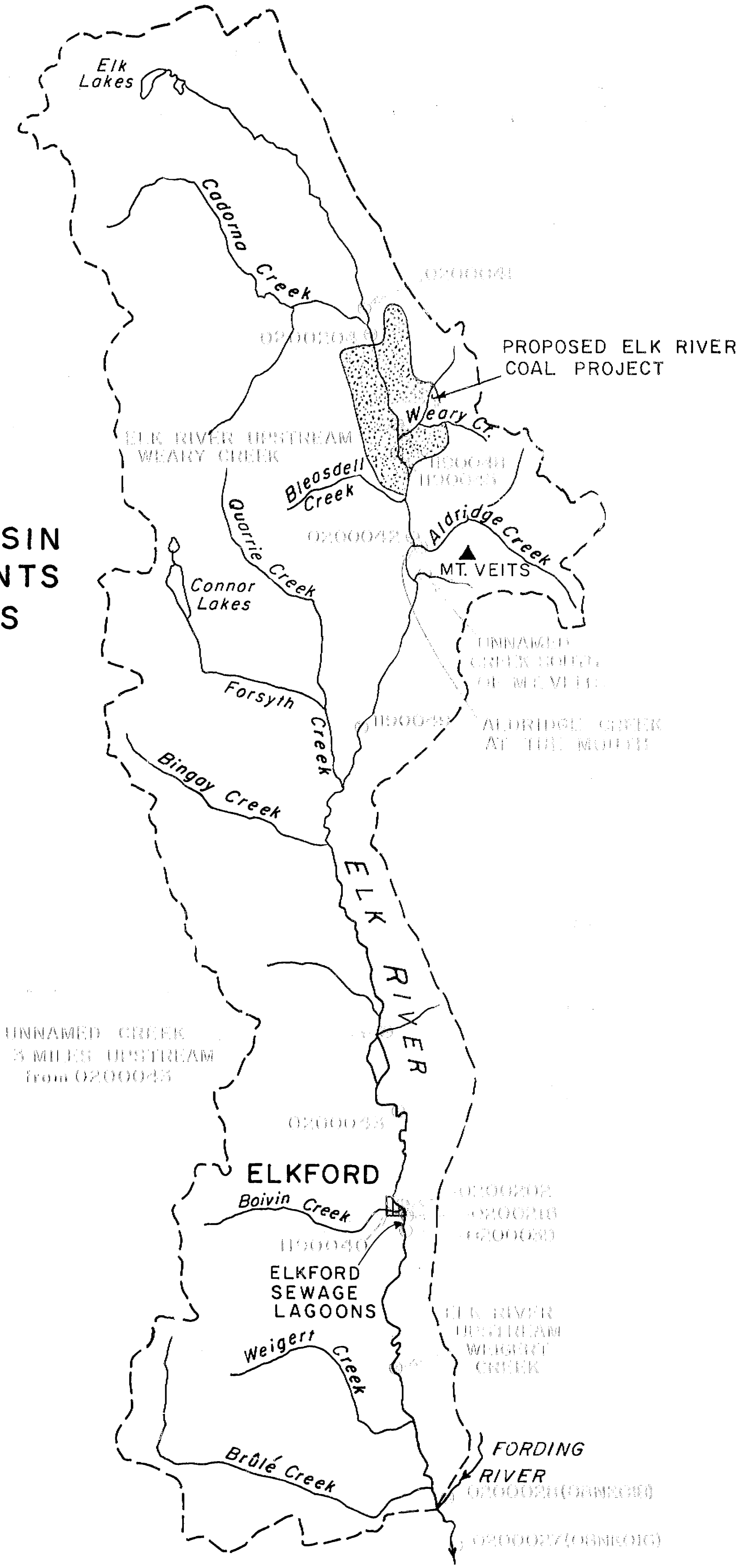


B

POLAR ORDINATION PLOT

FIGURE 9

UPPER ELK RIVER BASIN LOCATION OF EFFLUENTS AND SAMPLING SITES



○ SAMPLING SITE

0 5 10
SCALE in KILOMETRES

FIGURE 10

MICHEL CREEK BASIN
LOCATION OF EFFLUENTS AND SAMPLING SITES

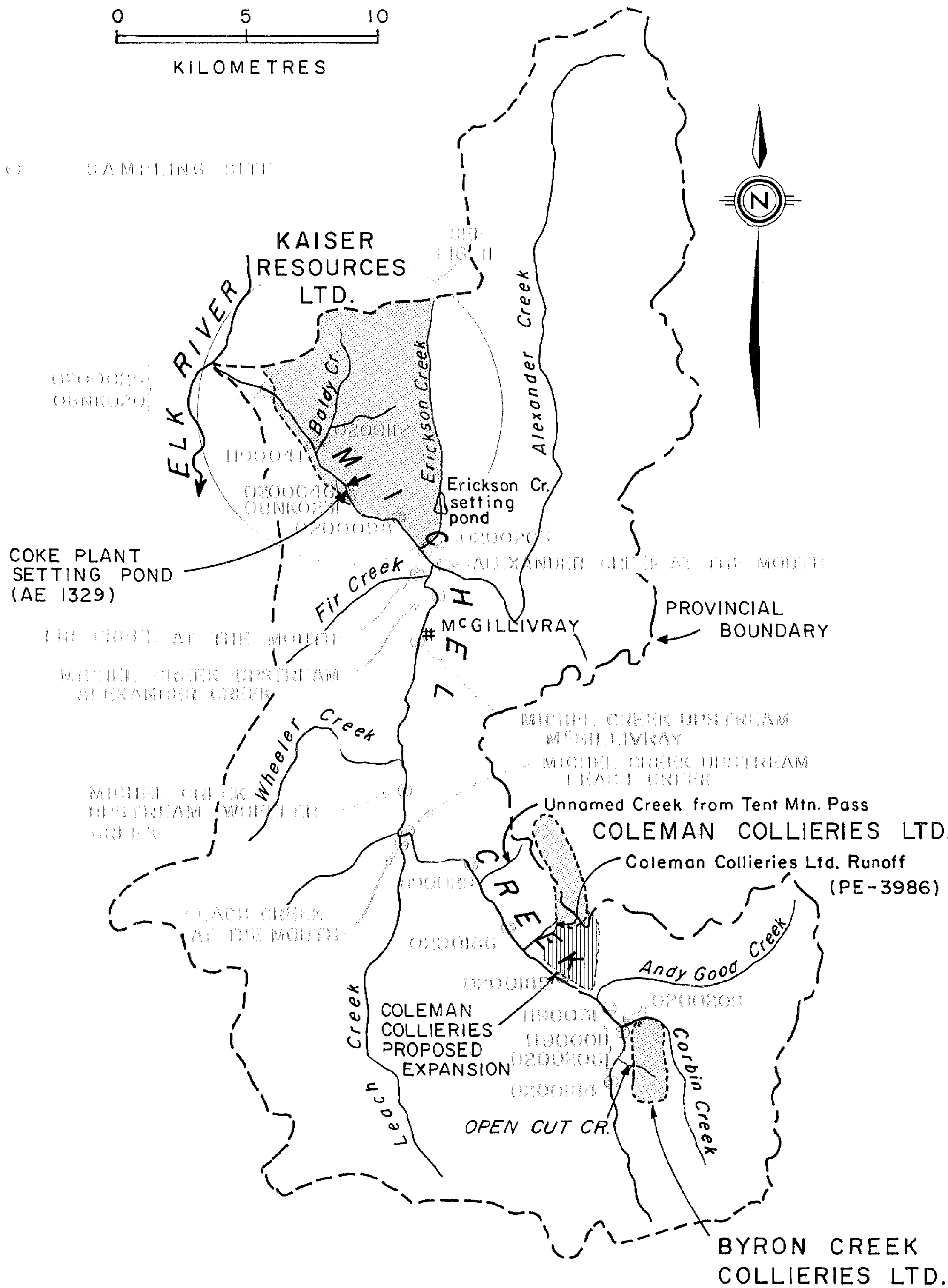


FIGURE 11

KAISER RESOURCES LTD. LOCATION OF MAJOR OPERATIONS, DISCHARGES AND SAMPLING SITES

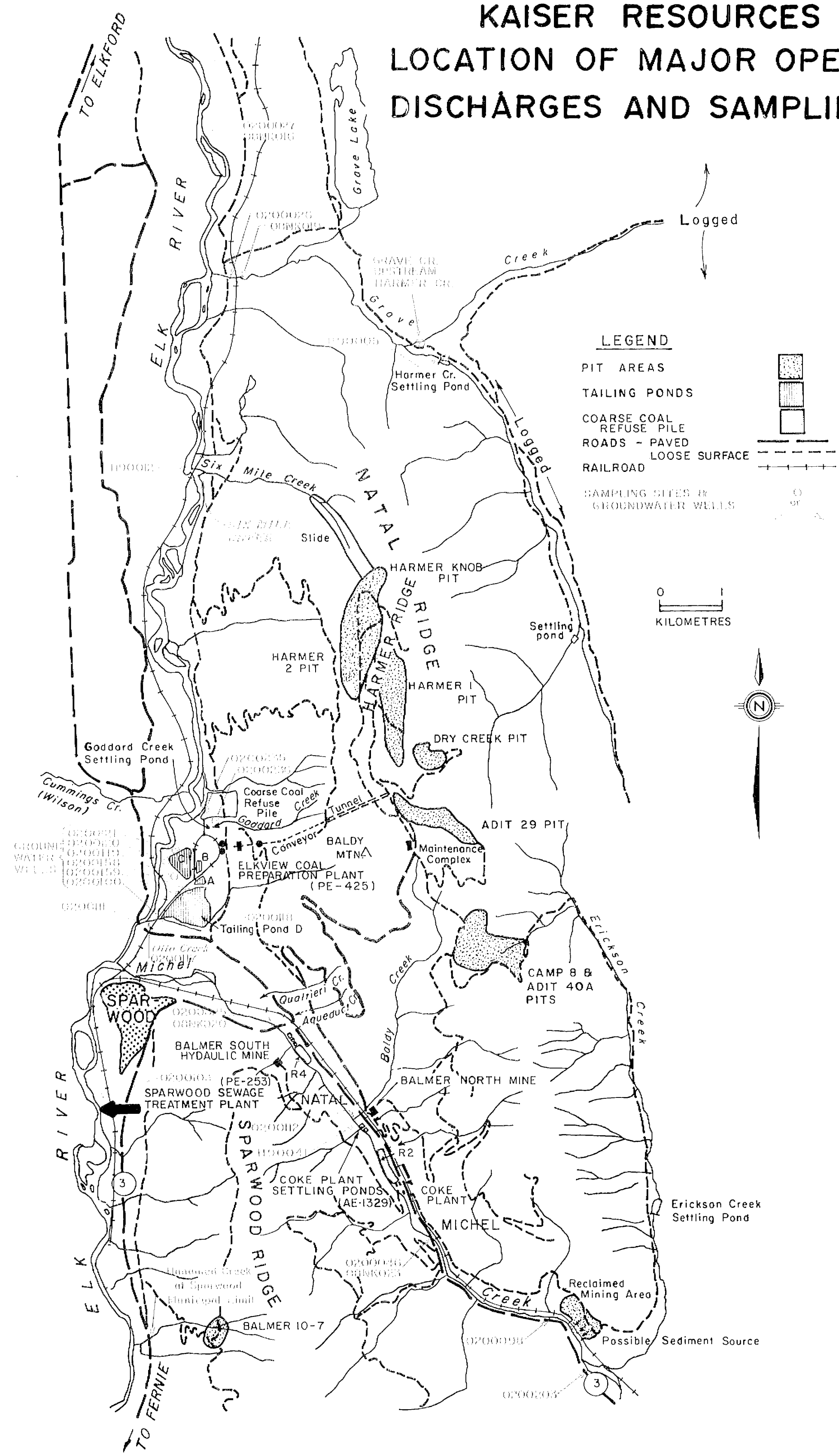


FIGURE 12

SUSPENDED SEDIMENT CONCENTRATIONS FROM LOWER MICHEL CREEK IN 1975.

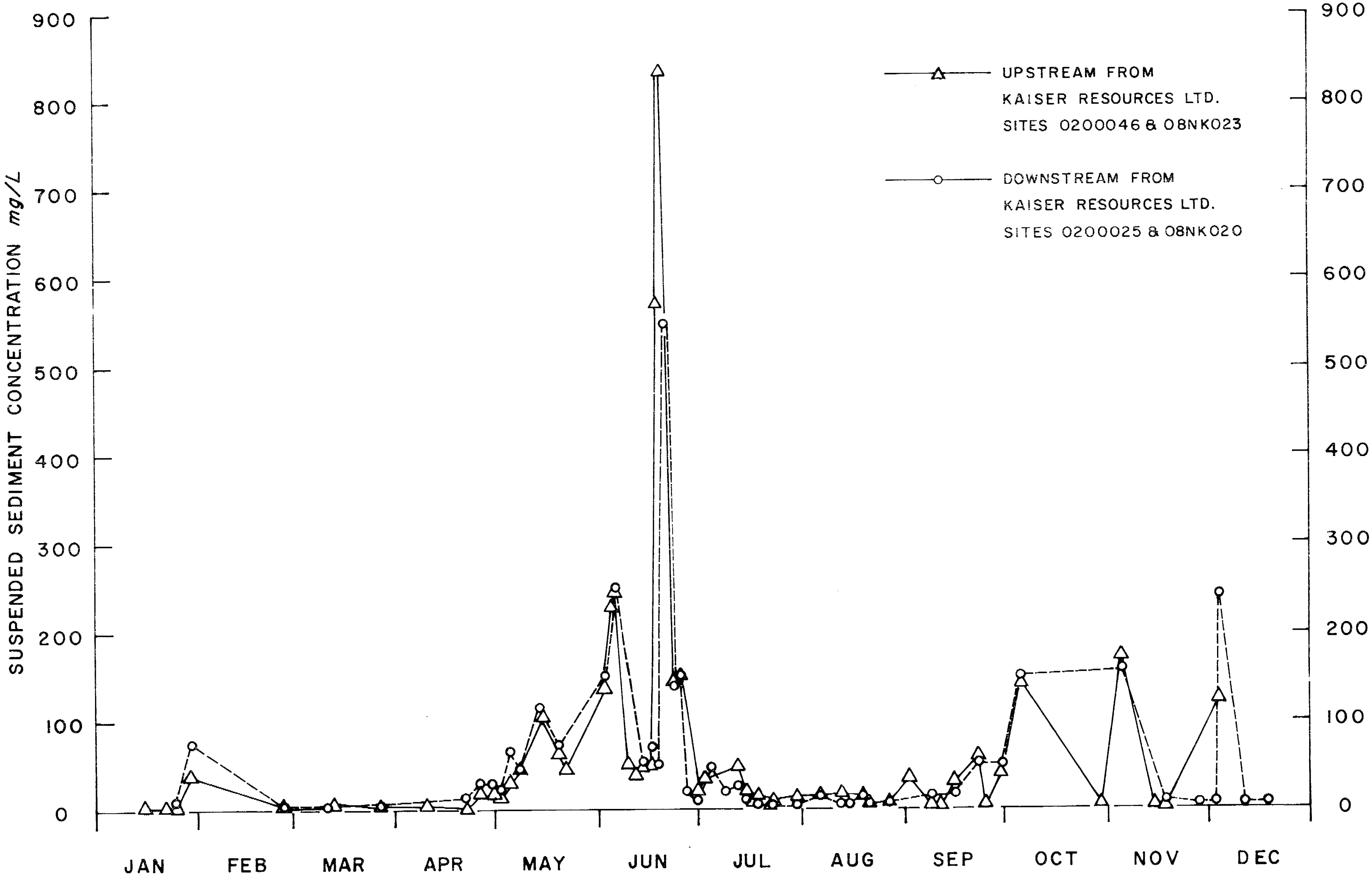


FIGURE 13

SUSPENDED SEDIMENT CONCENTRATIONS FROM LOWER MICHEL CREEK IN 1976.

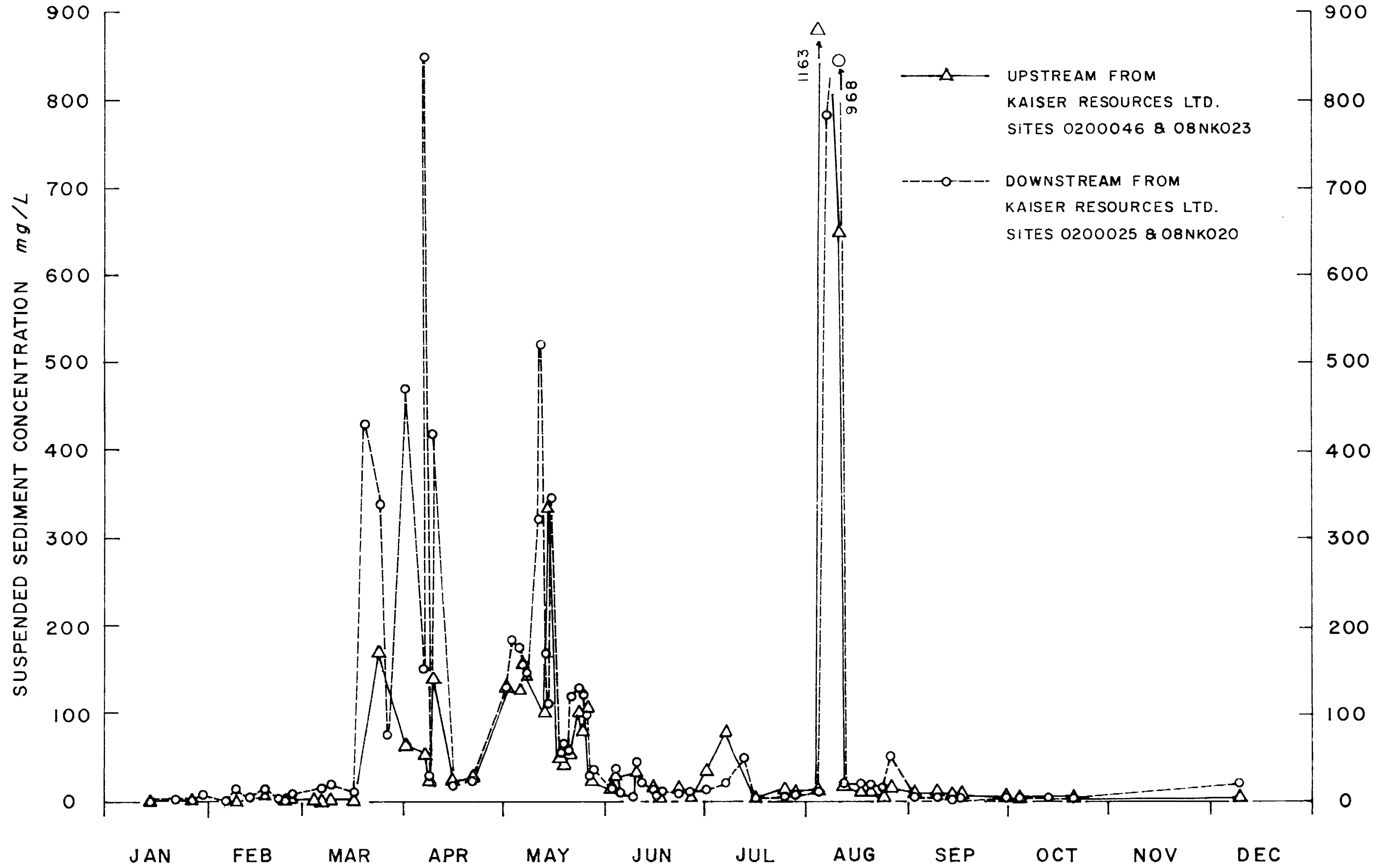


FIGURE 14

GENERA OF EPHEMEROPTERA OBTAINED FROM MICHEL CREEK IN AUGUST,1975.

(Pooled Counts from Triplicate Mundie Samples)

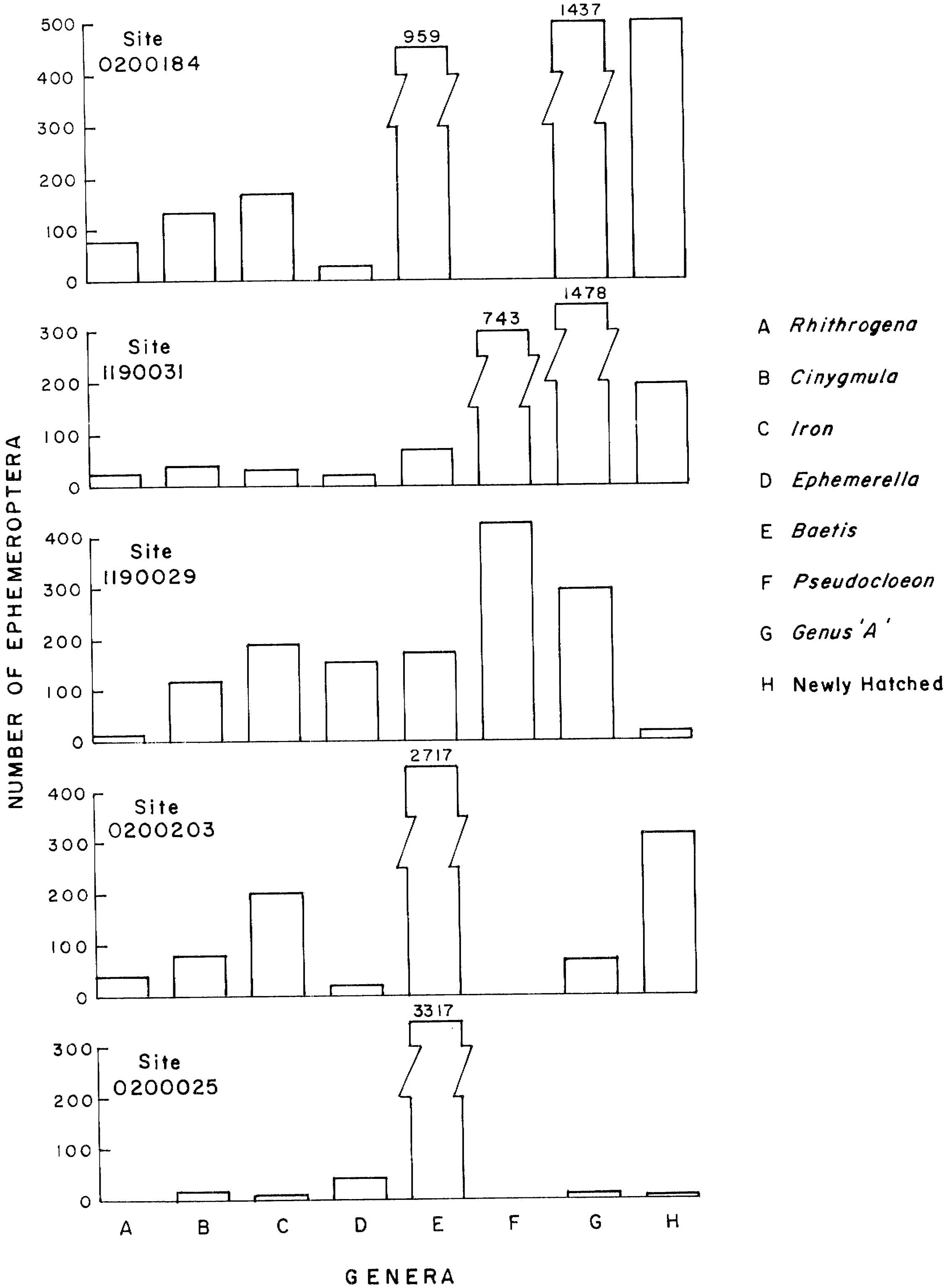


FIGURE 15

GENERA OF PLECOPTERA AND TRICOPTERA OBTAINED FROM MICHEL CREEK IN AUGUST, 1975.
(Pooled Counts from Triplicate Mundie Samples)

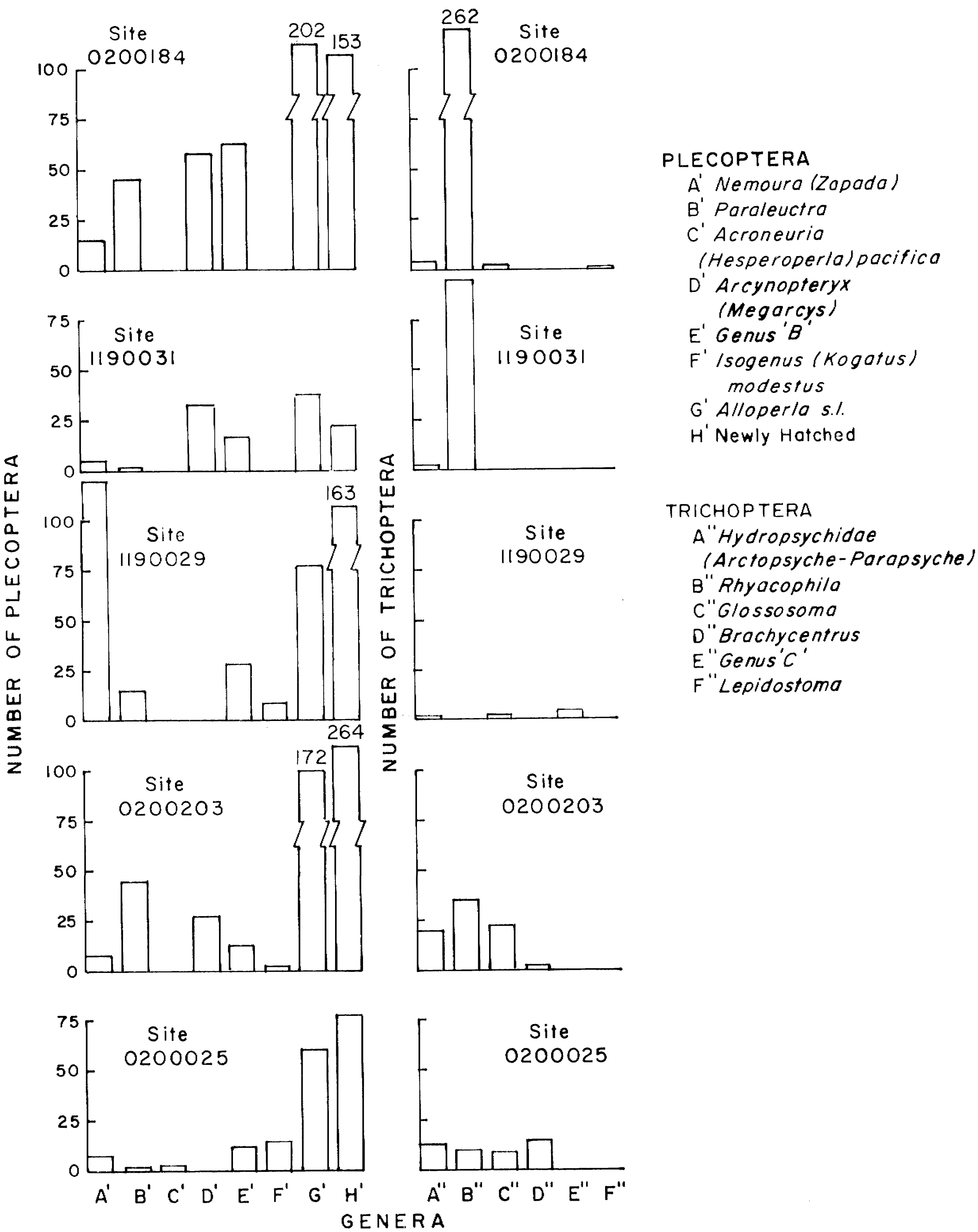
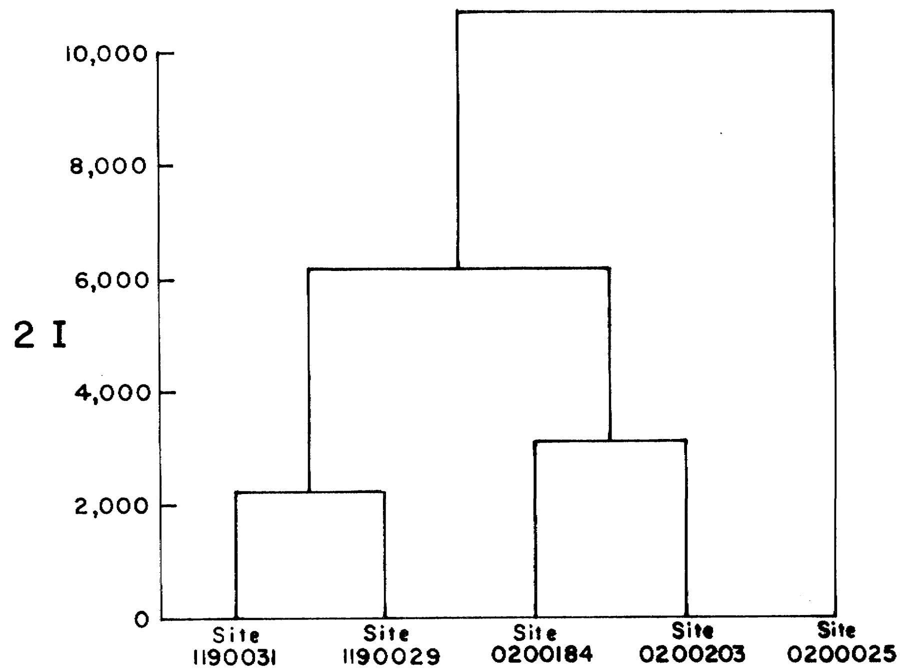


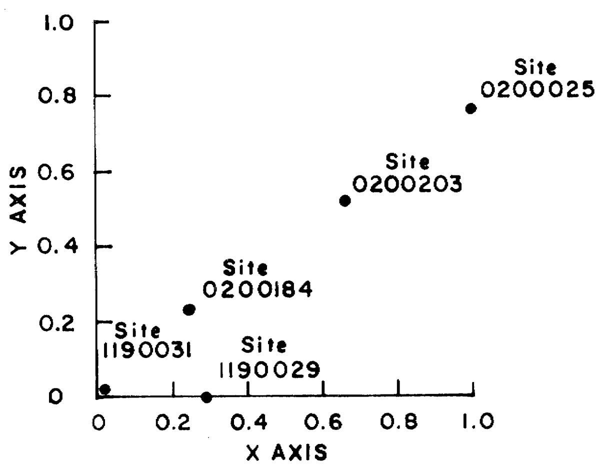
FIGURE 16

QUANTITATIVE ANALYSIS OF BENTHIC INVERTEBRATE DATA OBTAINED FROM MICHEL CREEK IN AUGUST, 1975.



A

MUTUAL INFORMATION DENDROGRAM



B

POLAR ORDINATION PLOT

FIGURE 17

LOWER ELK RIVER BASIN, LOCATION OF MAJOR OPERATIONS, EFFLUENTS AND SAMPLING SITES

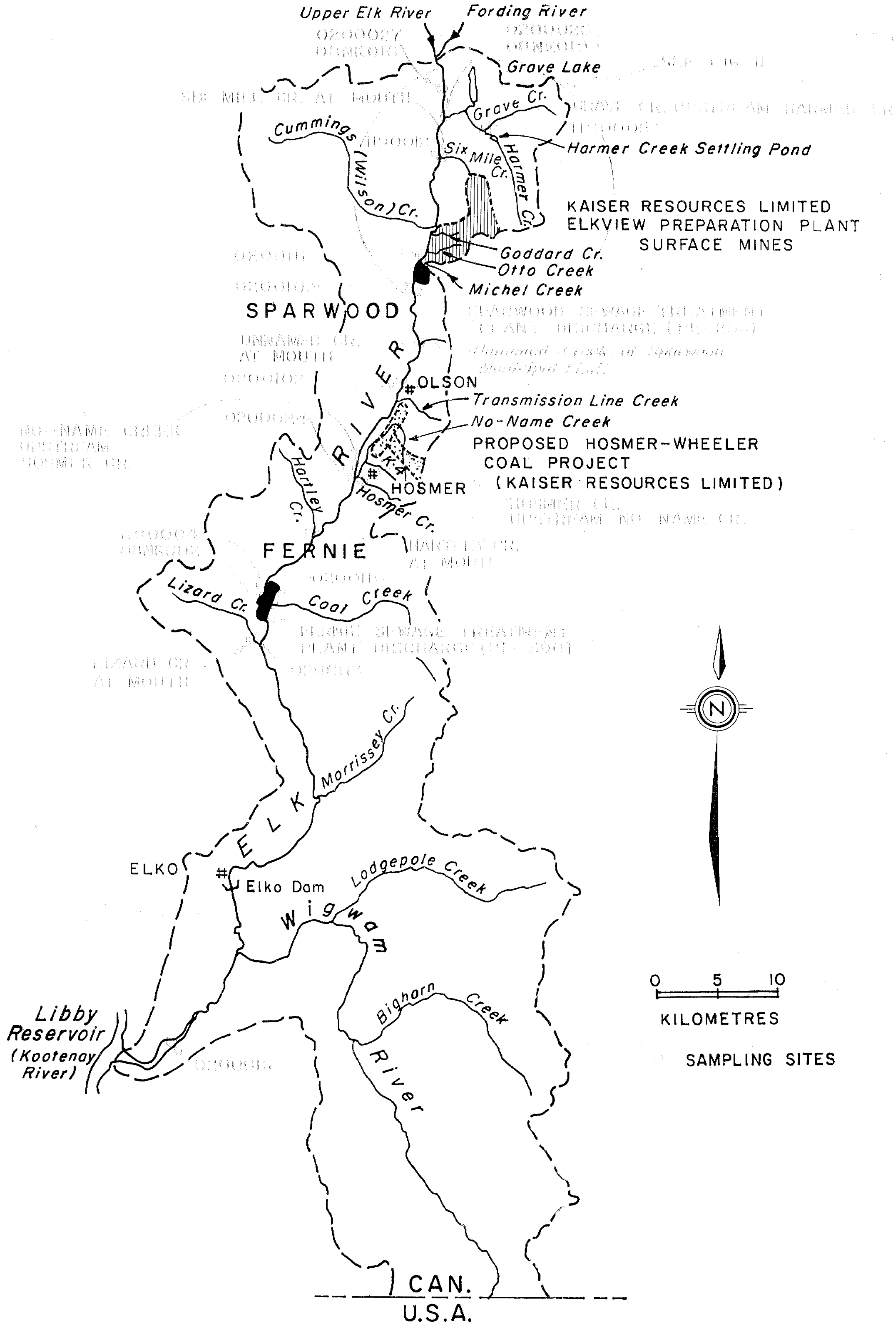


FIGURE 18

GENERA OF EPHEMEROPTERA OBTAINED FROM THE ELK RIVER IN AUGUST, 1975.

(Pooled Counts from Triplicate Mundie Samples)

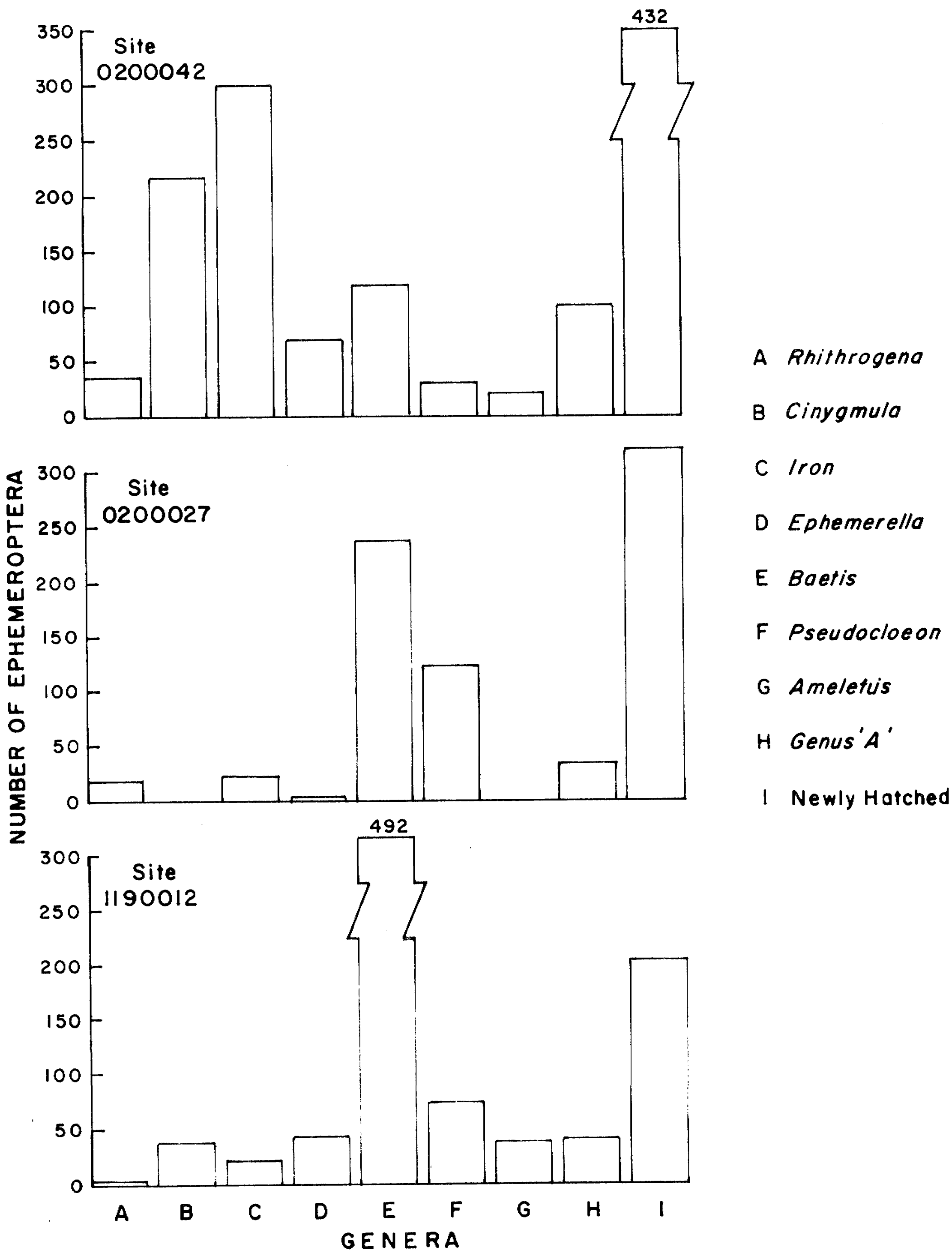


FIGURE 19

GENERA OF EPHEMEROPTERA OBTAINED FROM THE ELK RIVER IN AUGUST, 1975.

(Pooled counts from Triplicate Mundie Samples)

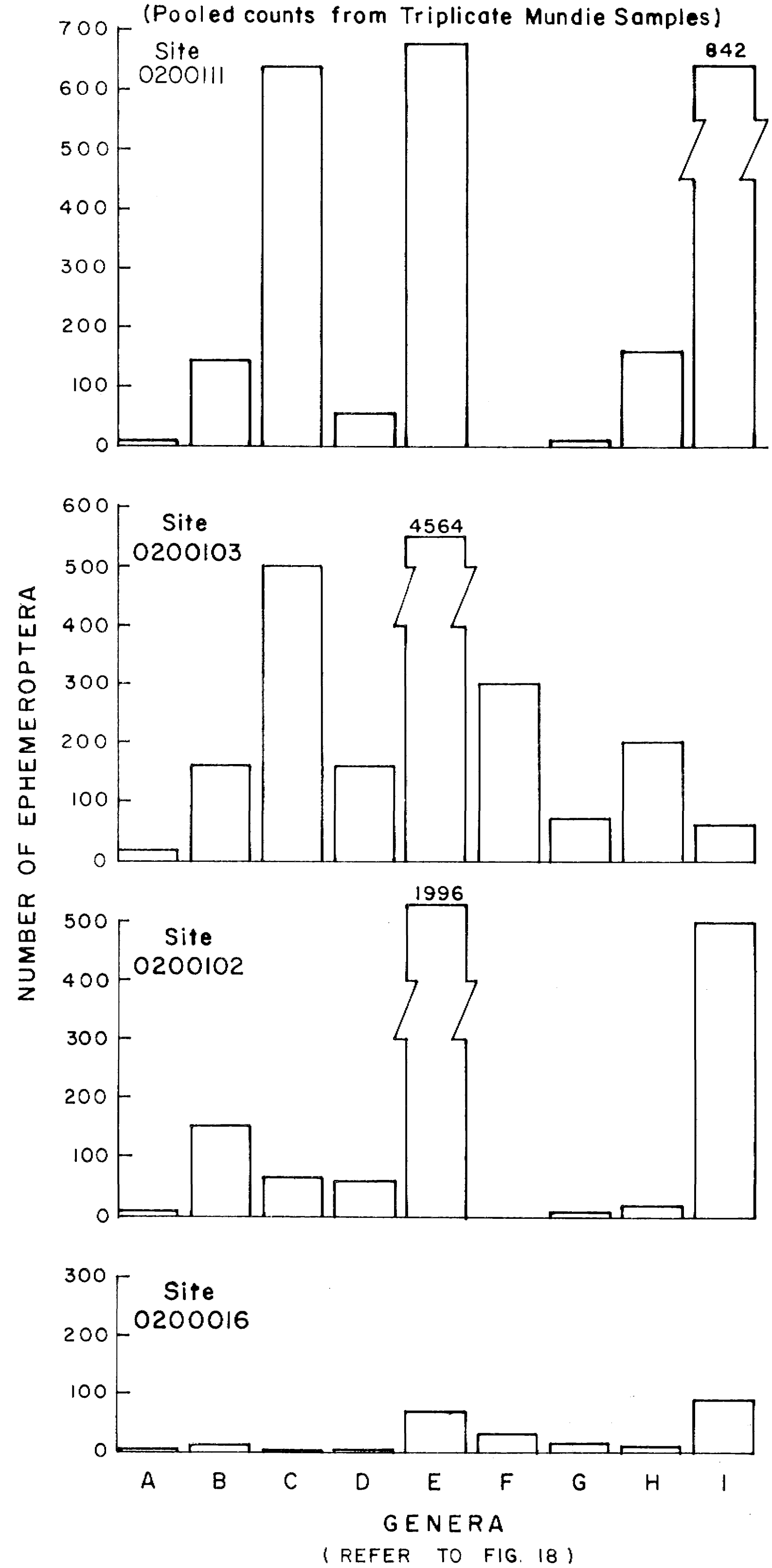


FIGURE 20

GENERA OF PLECOPTERA AND TRICHOPTERA OBTAINED FROM THE ELK RIVER IN AUGUST,1975.

(Pooled Counts from Triplicate Mundie Samples)

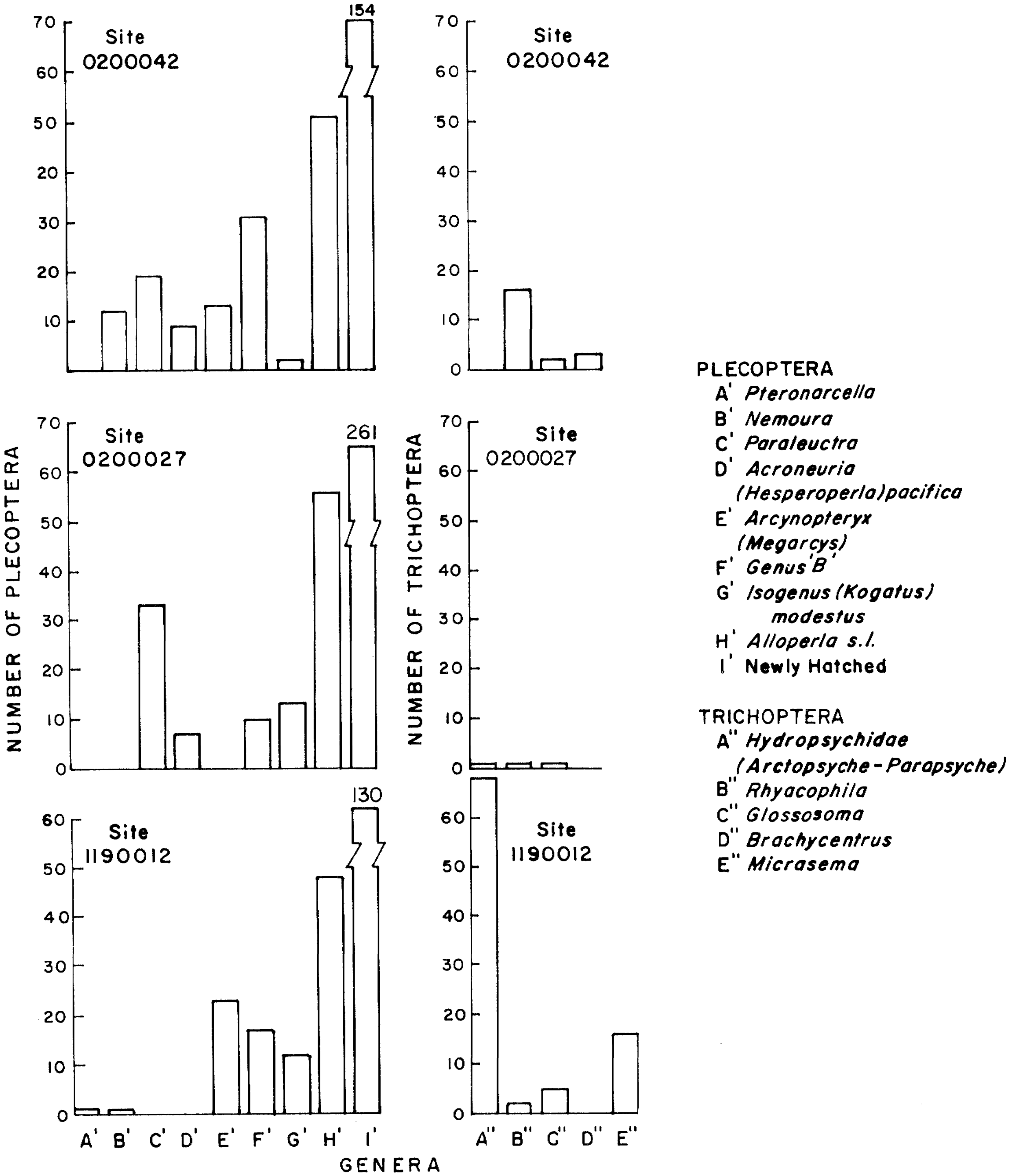


FIGURE 21

GENERA OF PLECOPTERA AND TRICOPTERA OBTAINED FROM THE ELK RIVER IN AUGUST, 1975.

(Pooled Counts from Triplicate Mundie Samples)

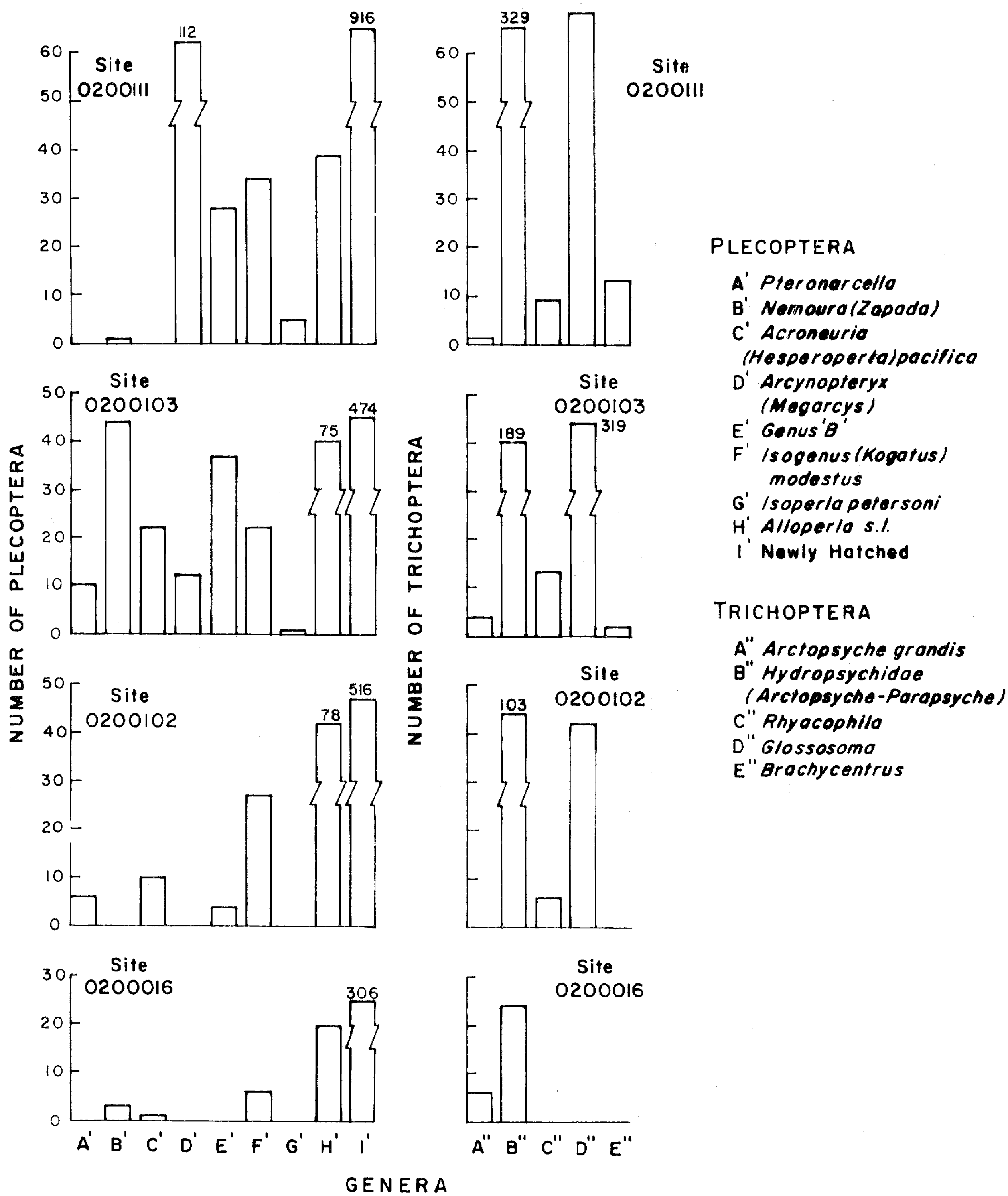
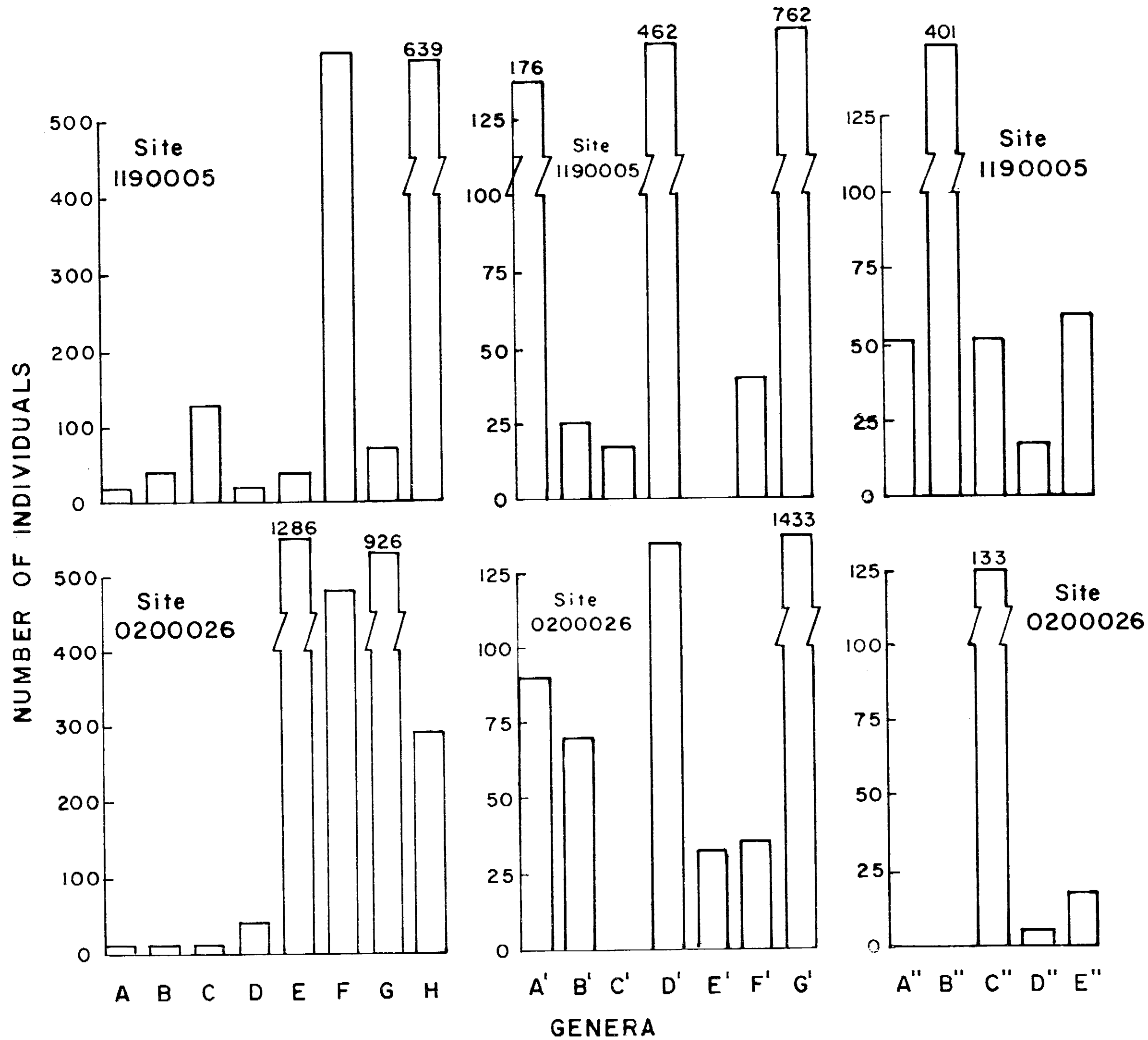


FIGURE 22

GENERA OF EPHEMEROPTERA, PLECOPTERA AND TRICHOPTERA OBTAINED FROM HARMER AND GRAVE CREEKS IN AUGUST, 1975.

(Pooled Counts from Triplicate Mundie Samples)



EPHEMEROPTERA
- A *Rhithrogena*
- B *Cinygmula*
- C *Iron*
- D *Ephemerella*
- E *Baetis*
- F *Pseudocloeon*
- G *Genus 'A'*
- H Newly Hatched

PLECOPTERA
- A' *Nemoura*
- B' *Paraleuctra ?*
- C' *Acrcynopteryx (Megarcys)*
- D' *Genus 'B'*
- E' *Isogenus (Kogatus) modestus*
- F' *Alloperla s.l.*
- G' Newly Hatched

TRICHOPTERA
- A" *Parapsyche elsis*
- B" *Hydropsychidae (Arctopsyche–Parapsyche)*
- C" *Rhyacophila*
- D" *Glossosoma*
- E" *Oligophlebodes ruthae*

FIGURE 23

MUTUAL INFORMATION DENDROGRAM BASED ON INVERTEBRATE DATA FROM LOWER ELK RIVER BASIN

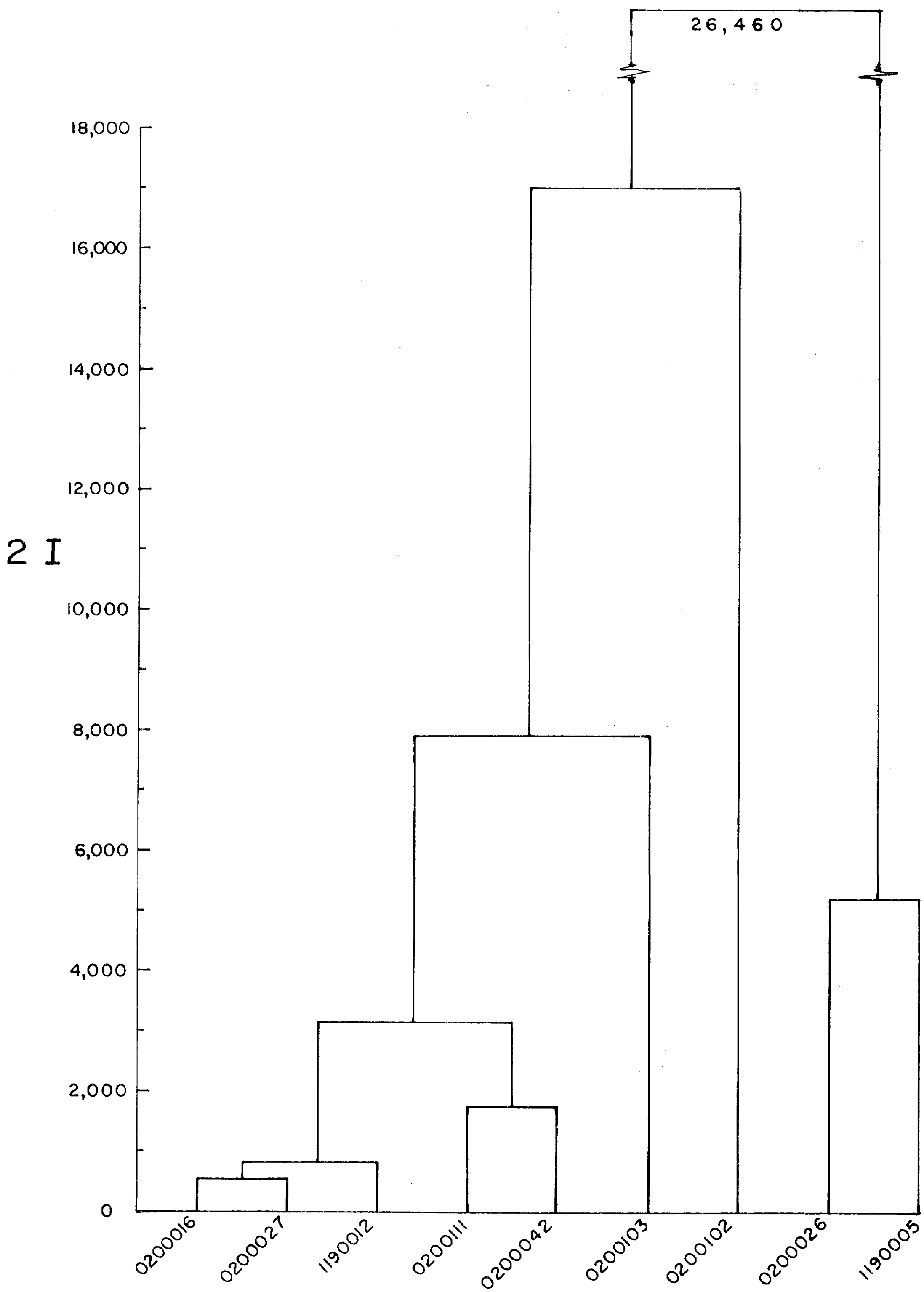


FIGURE 24

POLAR ORDINATION PLOT BASED ON INVERTEBRATE DATA FROM THE LOWER ELK RIVER BASIN

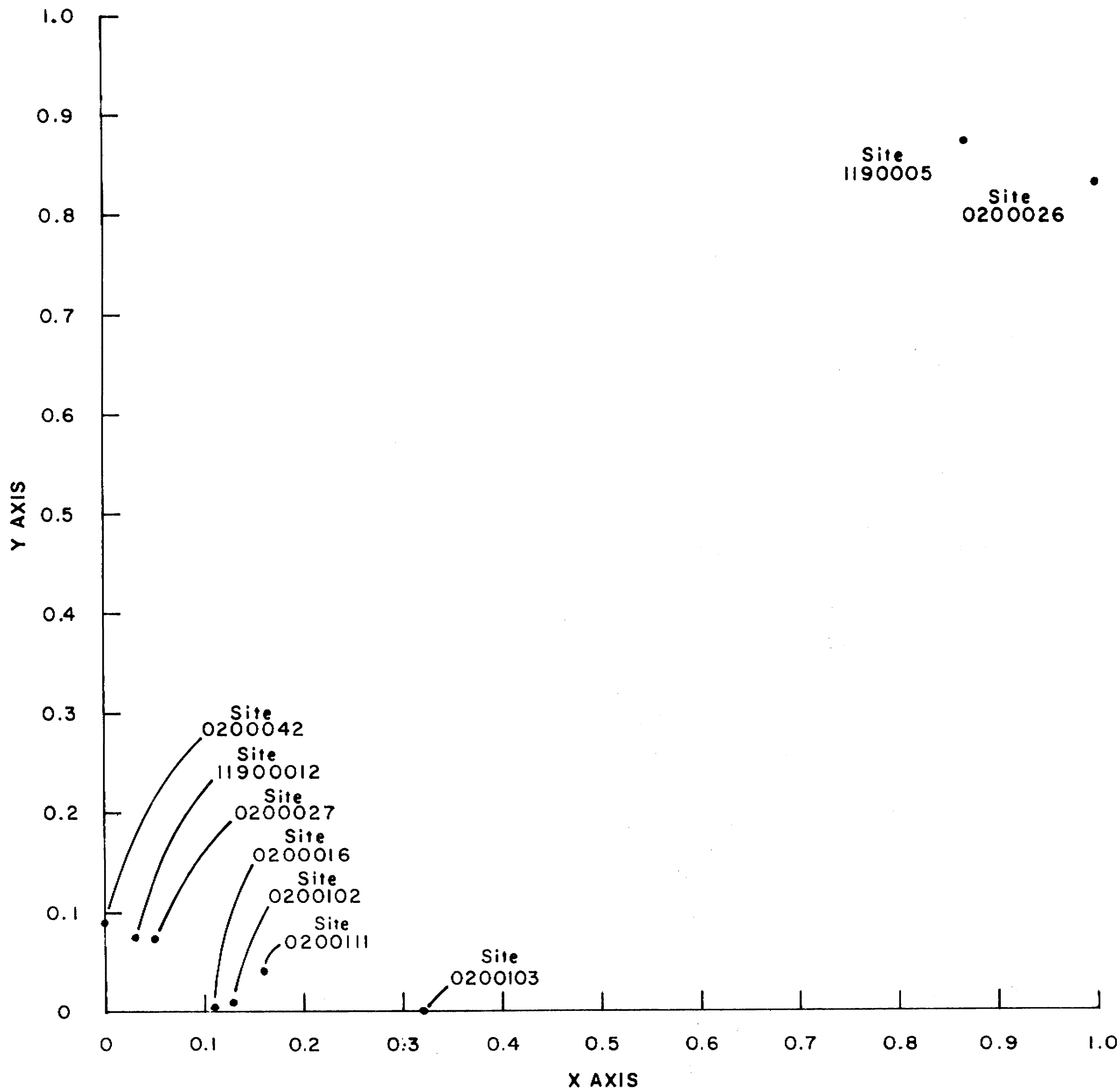


FIGURE 25

FLATHEAD RIVER BASIN LOCATION OF PROPOSED SAGE CREEK COAL PROJECT AND SAMPLING SITES

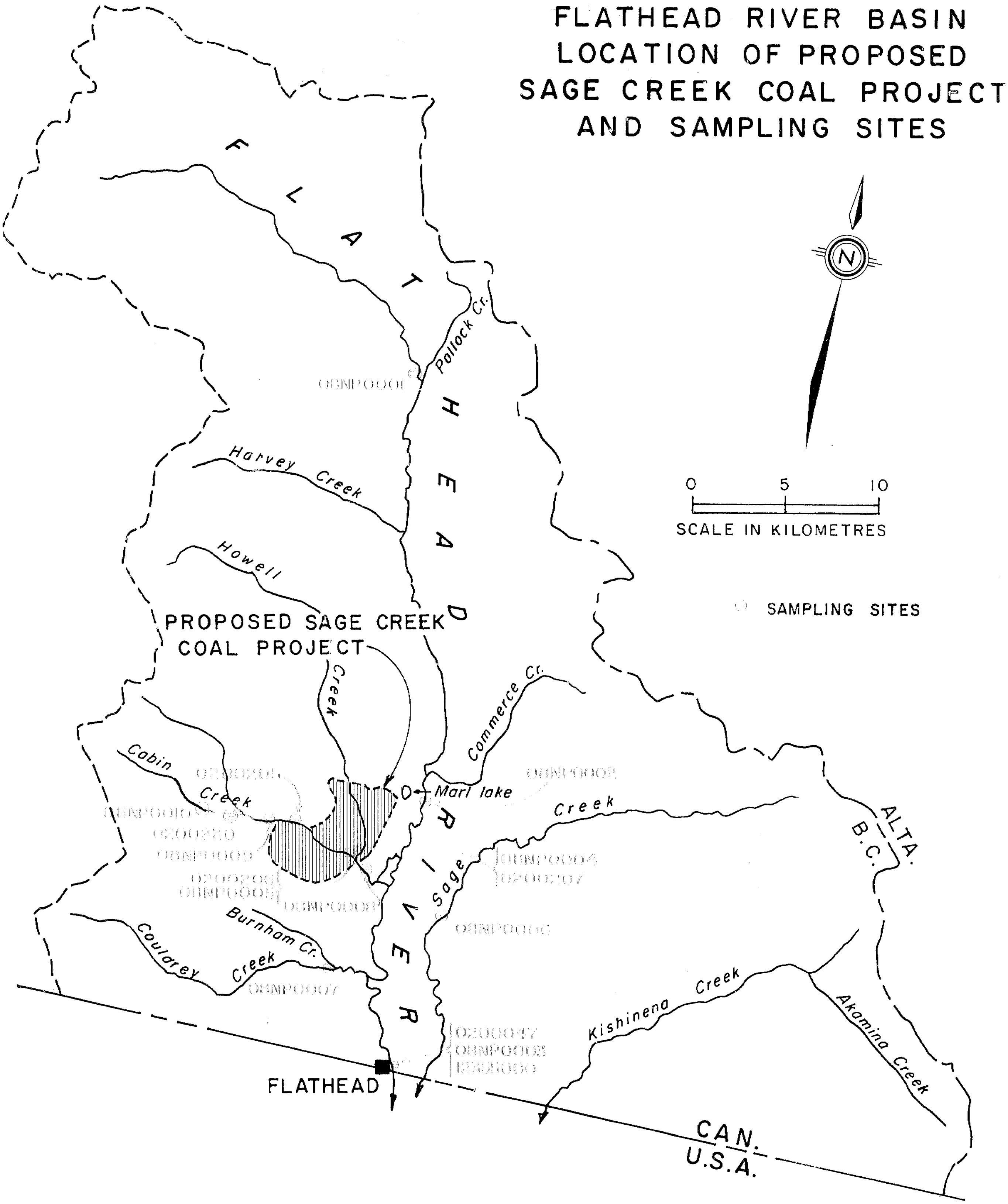


FIGURE 26

WATER SOURCES WITH LIMITED WATER AVAILABILITY IN THE ELK RIVER BASIN (SOUTH SECTION)

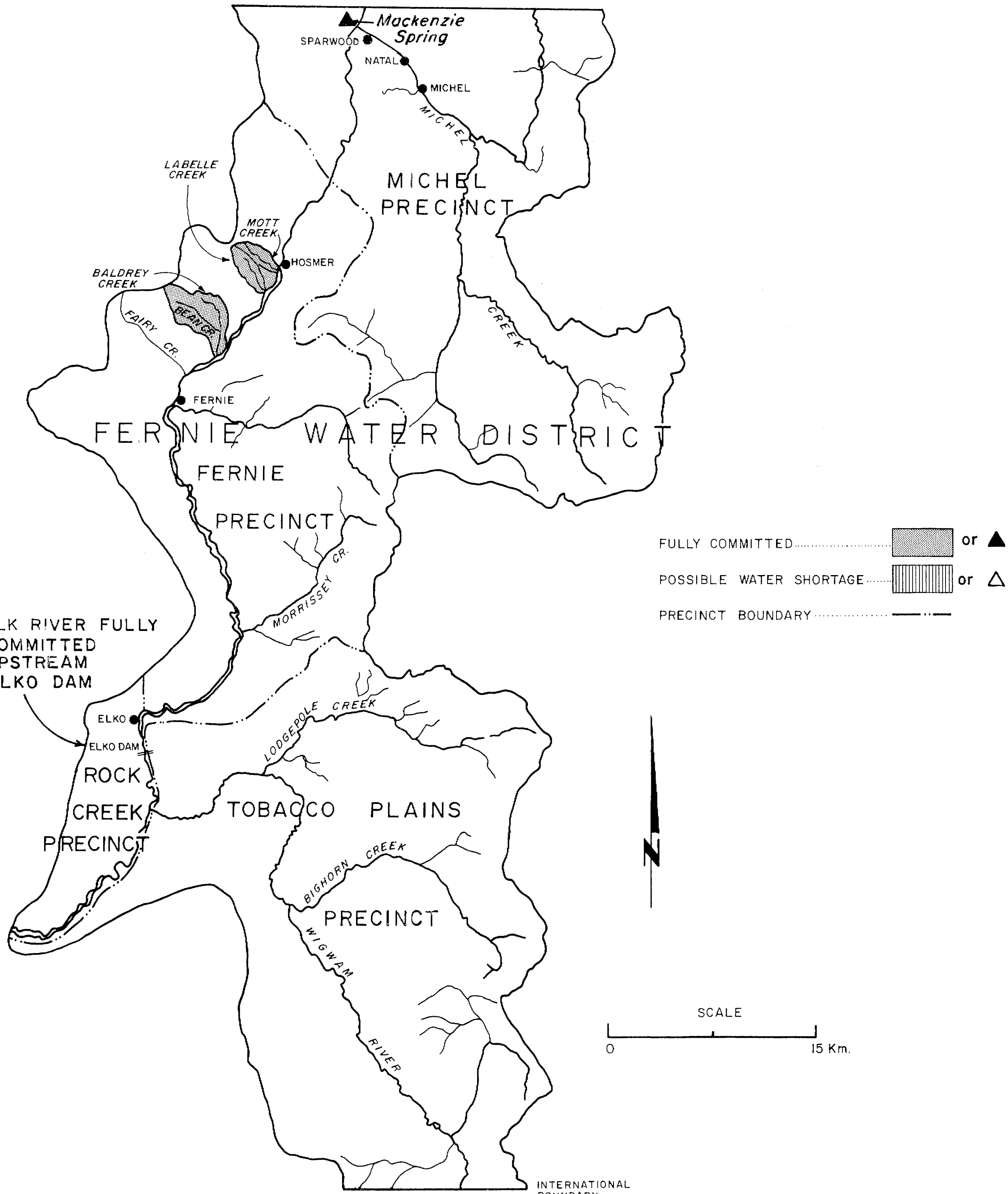


FIGURE 27
WATER SOURCES WITH LIMITED WATER AVAILABILITY IN THE ELK RIVER BASIN (NORTH SECTION)

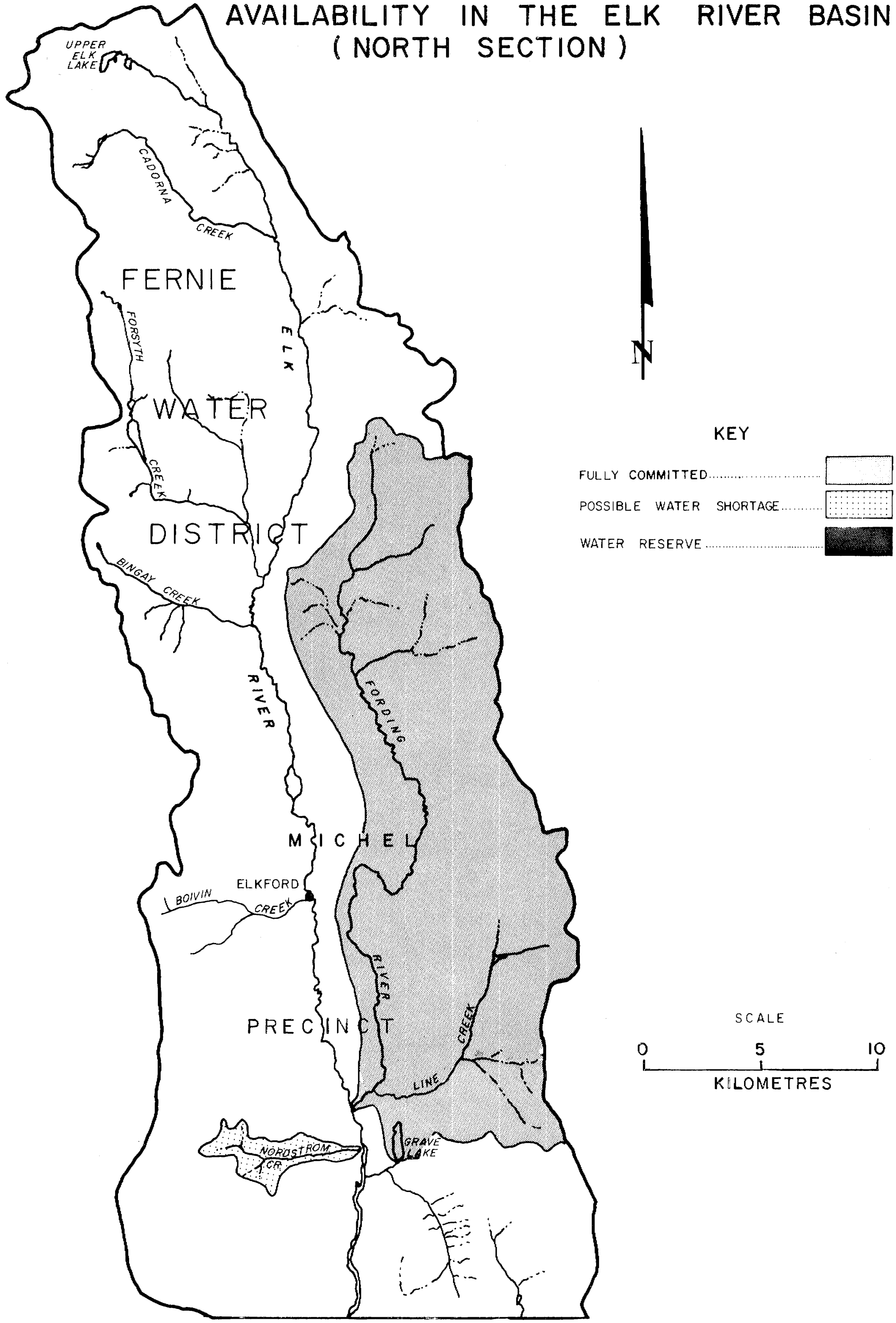


FIGURE 28

STREAMS WITH WATER QUALITY DETERIORATION DUE TO EFFLUENTS AND NON-POINT SOURCES

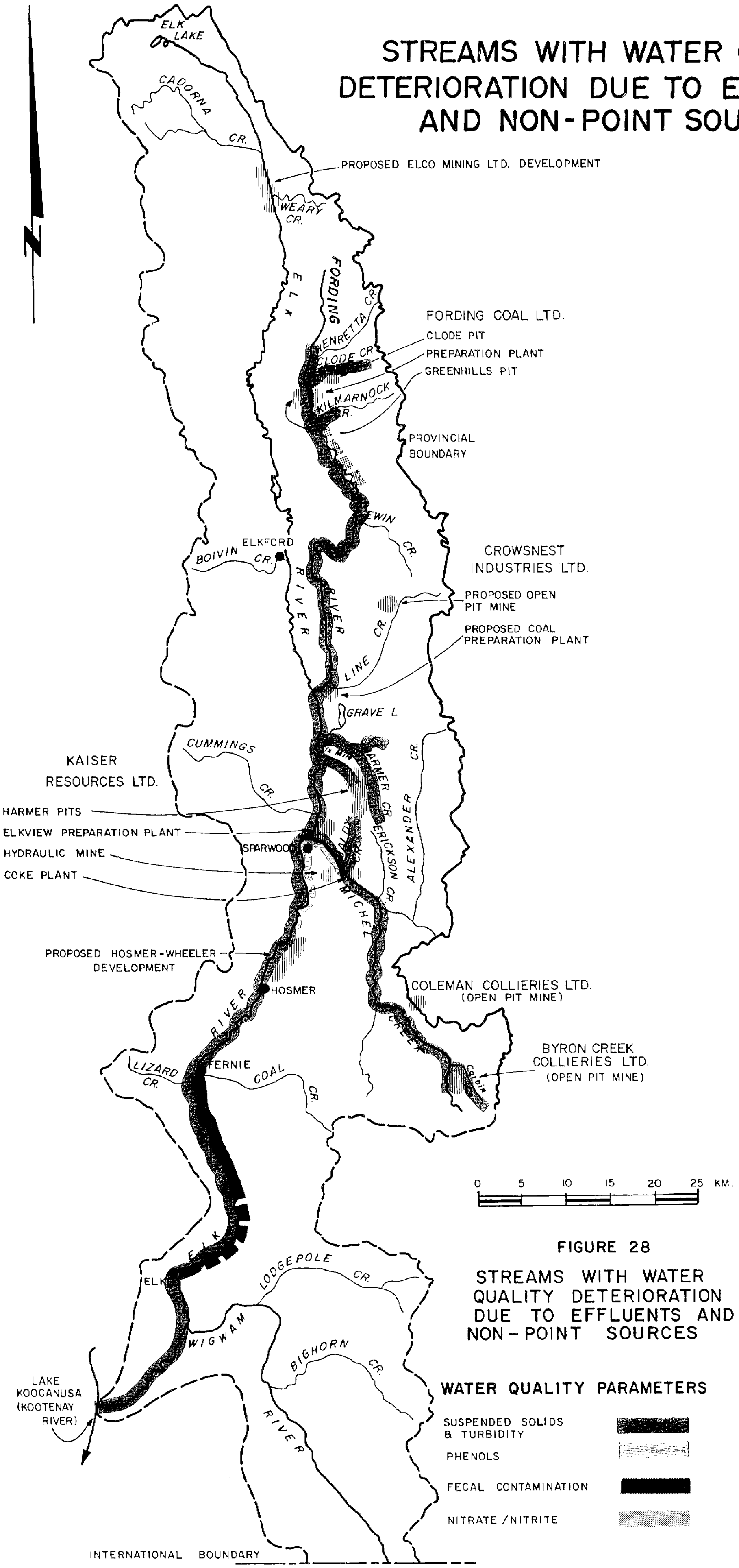


TABLE 1

FORDING COAL LTD.

SUMMARY OF POLLUTION CONTROL PERMIT NO. PE-424, AMENDED SEPTEMBER 8, 1977

Effluent Description \ Permit Appendix No.	01	02	03	04
Source	Coal Preparation Plant	Coal Preparation Plant, Drier, Maintenance Complex and Product Storage Areas	Area East of Cathedral Coal Product Storage Building	Wash Plant and Maintenance Complex Yard Areas
Type	Tailing Slurry	Washdown and Surface Runoff	Surface Runoff	Surface Runoff
Treatment	North or South Tailing Ponds, Water Reclaim	North Loop Settling Pond (2.6 ha in Rail Loop)	South Loop Settling Pond (in Rail Loop)	Settling Pond (0.5 ha)
Discharge Point	Recycled	Ground or Fording River	Ground or South Tailing Pond	Fording River
Quantity m^3/d	55,000 (max.)	3,200 (max.)	410 (max.)	820 (max.)
Quality	Typical Coal Preparation Plant Tailings	SS<50mg/L, Oil and Grease <15mg/L	Typical Surface Runoff From a Coal Processing Plant	SS<50mg/L, Oil and Grease <15mg/L
Comments	Recycled to Coal Preparation Plant. Plant is currently Being Modified and Expanded	Effluent Exfiltrates to Ground, No Positive Discharge to Fording River. Settling Pond also Receives Treated Domestic Sewage (Appendix 11)	Effluent Exfiltrates To Ground	

Note: SS = Suspended Solids
BOD5 = 5-day, Biochemical Oxygen Demand

TABLE 1 continued

FORDING COAL LTD.

SUMMARY OF POLLUTION CONTROL PERMIT NO. PE-424, AMENDED SEPTEMBER 8, 1977

Effluent Description \ Permit Appendix No.	05	06	07	08
Source	Breaker Plant Area	Eagle Drainage Area	Clode Drainage Area	Kilmarnock Drainage Area
Type	Surface Runoff	Surface Runoff	Surface Runoff	Surface Runoff
Treatment	North or South Tailing Ponds, Water Reclaim	Eagle Settling Pond (2.7 or 4.2 ha)	Clode Settling Pond (6.1 ha)	Kilmarnock Settling Pond (0.8 ha)
Discharge Point	Recycled	Fording River	Fording River	Kilmarnock Creek
Quantity m^3/d	3,300 (max.)	Unknown, to be Determined by Permittee Monitoring	66,000 (max.)	Unknown, to be Determined by Permittee Monitoring
Quality	Typical Surface Runoff From Coal Preparation Plant	SS<50mg/L	SS<50mg/L	SS<50mg/L
Comments	Recycled to Coal Preparation Plant	Receives Drainage From Clode Spoil Areas	Constructed In Early 1976. Receives Drainage From Clode and Turnbull Pit and Spoil Areas	To Be Constructed in Early 1977. Estimated Life of Kilmarnock Pit is Two Years

Note: SS = Suspended Solids
BOD_5 + 5-day, Biochemical Oxygen Demand

TABLE 1 continued

FORDING COAL LTD.

SUMMARY OF POLLUTION CONTROL PERMIT NO. PE-424, AMENDED SEPTEMBER 8, 1977

Effluent Description / Permit Appendix No.	09	10	11
Source	West Clode Haul Road Area	North, Central and South Greenhills Pits	Sewage Treatment Plant
Type	Surface Runoff	Surface Runoff Accumulated in Pits	Treated Domestic Sewage
Treatment	Two Settling Ponds (0.2 and 0.4 ha), North Tailing Pond, Water Reclaim	Pumped to North or South Tailing Ponds, Water Reclaim, or as Directed by PCB	Oxidation Ditch, Clarifier, Sludge Drying Facilities and Settling Ponds
Discharge Point	Recycled	Recycled	Ground
Quantity m^3/d	130 (max.)	9,800 (max.)	110 (max.)
Quality	Typical Surface Run-off From Coal Mining Haul Road	Typical Water Accumulated in Coal Pits	SS <130mg/L BOD_5 <130mg/L
Comments	Recycled to Coal Preparation Plant	Discharge to Fording River Not Allowed, May Be Used For Irrigation of Reclaimed Areas or Exfiltration to Ground	Discharged to North Rail Loop Settling Pond (Appendix 02). Effluent Exfiltrates To Ground, No Positive Discharge to Fording River Formerly PE-309-P.

Note: SS = Suspended Solids
BOD_5 = 5-day, Biochemical Oxygen Demand

TABLE 2

FORDING COAL LTD.

ANALYSIS OF NORTH TAILING POND SUPERNATANT,

CARRIED OUT BY THE COMPANY AND THE PROVINCE IN 1975 AND 1976

Parameter \ Type of Value	Max.	Min.	Mean	No. of Values	Level A Mining Objectives
Alkalinity, Total mg/L	123	70	101	14	
Aluminum, Dissolved mg/L	0.2	<0.01	0.06	6	0.5
Total mg/L	0.2	<0.1	0.1	3	
Arsenic, Dissolved mg/L	<0.005	<0.005	<0.005	3	0.05
Total mg/L	0.02	<0.005	0.01	3	
Carbon, Total Organic mg/L	14	14	14	1	
Chromium, Dissolved mg/L	<0.005	<0.005	<0.005	3	0.05
Total mg/L	<0.005	<0.005	<0.005	3	
Copper, Dissolved mg/L	0.005	<0.001	0.003	12	0.05
Total mg/L	0.005	<0.005	0.005	5	
Iron, Dissolved mg/L	0.1	<0.05	0.1	12	0.3
Total mg/L	0.1	<0.05	0.1	5	
Lead, Dissolved mg/L	0.01	<0.001	0.005	12	0.05
Total mg/L	0.01	<0.01	0.01	5	
Manganese, Dissolved mg/L	0.09	<0.05	0.06	8	0.05
Total mg/L	0.05	<0.05	0.05	3	
Mercury, Dissolved µg/L	<0.05	<0.05	<0.05	4	
Total µg/L	0.08	<0.05	0.06	6	1.0
Nickel, Dissolved mg/L	<0.01	<0.01	<0.01	3	0.3
Total mg/L	<0.01	<0.01	<0.01	3	
Nitrogen, Ammonia mg/L	0.85	0.27	0.58	3	0.5
Nitrite+Nitrate mg/L	3.3	2.1	2.8	3	10
Organic mg/L	0.85	0.34	0.60	2	
Total mg/L	4.19	3.22	3.71	2	
Oil and Grease mg/L	5	<0.5	3.17	9	15
pH	8.4	6.9	7.7	26	6.5-8.5
Phosphorus, Total mg/L	0.042	0.023	0.032	4	2
Total Dissolved mg/L	0.005	<0.003	0.004	4	
Solids, Dissolved mg/L	364	160	284	12	2500
Suspended mg/L	60	2	31	12	50
Total mg/L	418	302	357	7	
Sulphate, Dissolved mg/L	114	72	91	9	50
Turbidity J.T.U.	33	1	17	12	
Zinc, Dissolved mg/L	0.03	<0.005	0.011	8	0.5

TABLE 3

FORDING COAL LTD.

ANALYSIS OF EAGLE SETTLING POND DISCHARGE
CARRIED OUT BY THE PROVINCE

Parameter \ Date		June 11 1975	July 10 1975	August 7 1975	Level A Mining Objectives
Alkalinity, Total	mg/L	95	129	166	
Arsenic, Total	mg/L	<0.005	0.006	<0.005	0.05 (dissolved)
Calcium, Dissolved	mg/L	27.9	40.7	65.0	
Carbon, Total Organic	mg/L	17	10	3	
Copper, Total	mg/L	0.006	0.003	0.001	0.05 (dissolved)
Hardness, Total	mg/L	117	169	268	
Iron, Total	mg/L	3.0	1.7	0.4	
Dissolved	mg/L			<0.1	0.3
Lead, Dissolved	mg/L	<0.001	<0.001	<0.001	0.05
Magnesium, Dissolved	mg/L	11.6	16.3	25.8	150
Maganese, Dissolved	mg/L	0.02	0.03	0.04	0.05
Nickel, Dissolved	mg/L	<0.01	<0.01	<0.01	0.3
Nitrogen, Ammonia	mg/L	0.013	0.042	0.021	0.5
Nitrite + Nitrate	mg/L	0.39	1.08	2.53	10
Organic	mg/L	0.42	0.38	0.30	
Total	mg/L	0.82	1.50	2.85	
pH		8.6	8.3	8.4	6.5-8.5
Phosphorus, Total	mg/L	0.18	0.089	0.03	2.0
Total Dissolved	mg/L	0.024	0.018	0.003	
Solids, Dissolved	mg/L	156	240	372	2,500
Suspended	mg/L	136	32	44	50
Turbidity	J.T.U.		42	11	
Vanadium, Total	mg/L			<0.001	
Zinc, Total	mg/L	0.05	0.03	0.015	0.5 (dissolved)

TABLE 4

SUMMARY OF SEDIMENT SOURCES AT FORDING COAL LTD.

Sediment Source	Suspended Solids mg/L	Turbidity J.T.U.	Flow m^3/s	Suspended Solids t/d
Clode Settling Pond	4-300	2.3-256	0.22-0.62	0.1-11
Eagle Settling Pond	14-136	11-64	0.06-0.25	0.09-0.9
Greenhills Pit Water	40-8,207	37-4,610	0.07-0.15	0.4-104
Harold Creek Diversion	4-298	2.1-88	1.4-2.1**	36-54**
South Greenhills Diversion	32-720	8.3-240	0.7-1.7	10-44
*Maintenance Area Runoff	80,700		0.0015	11
*Unnamed Creek From Eagle Mountain	170	52	0.11	1.6
*Kilmarnock Creek	545	21		

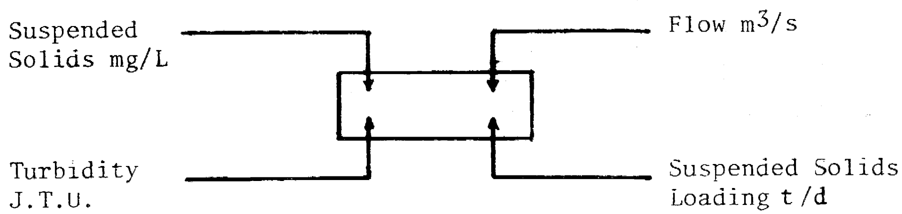
* Only one sample was taken for these sources.

** Only one flow measurement made for this source.

TABLE 5

SUSPENDED SOLIDS AND TURBIDITY MEASUREMENTS ALONG THE FORDING RIVER

Site \ Date	May 22 1975	June 10 1975	July 7-9 1975	July 30 1975	August 6-7 1975	October 8 1975
Upstream Fording Coal (0200110) (08NK021)	2 0.3	16 1.6	6 2.3	4 0.5	4 0.2	0.2
→ Upper Settling Pond						
→ Clode Settling Pond						
→ Harold Creek Diversion						
Upstream Eagle Settling Pond						
→ Eagle Settling Pond		136	32 0.25 42 0.7		44 11	
Downstream Eagle Settling Pond (0200040)	12 9.6	22 5.2	8 4.1	4 2.6	4 0.8	
→ Greenhills Pit Water						
Downstream Fording Coal (0200201)	26 13	14 4.8	18 7.4	26 8	6 4.6	1.5
→ Kilmarnock Creek (1190042)	4 0.7	4 0.7	2 0.5		4 2.5	
Downstream Kilmarnock Creek (1190008)	14 7.8	12 4.1	12 4.8		8 3.2	
→ South Greenhills Diversion						
Downstream South Greenhills Diversion						
→ Logging Runoff						
11 km Downstream Fording Coal						
16 km Downstream Fording Coal (0200093)	6 5.2			14 1.8	2 0.6	



→ Discharge or Tributary to Fording River

TABLE 5 continued

SUSPENDED SOLIDS AND TURBIDITY MEASUREMENTS ALONG THE FORDING RIVER

Site / Date	January 14 1976	April 7 1976	May 5 1976	May 12 1976	May 19 1976	May 25 1976
Upstream Fording Coal (0200110) (08NK021)	2 <0.1	2 0.1	4 1.1	2 1.1	2 0.6	4 0.9
→ Upper Settling Pond			22 0.45 18 0.9			Clear
→ Clode Settling Pond		300 0.42 256 11	42 0.62 42 2.2	48 0.42 54 1.7	18 0.51 11 0.8	18 0.40 10 0.6
→ Harold Creek Diversion			298 14-21 88 36-54	54 15	60 28	66 19
Upstream Eagle Settling Pond			44 17			
→ Eagle Settling Pond		88 0.12 64 0.9	14 0.06 0.07	70 0.11 24 0.6		
Downstream Eagle Settling Pond (0200040)	2 0.7	142 104			16 16.8	14 6
→ Greenhills Pit Water						
Downstream Fording Coal (0200201)	4 1.2	308 148	108 27	54 16	30 9.6	14 7.1
→ Kilmarnock Creek (1190042)		545 216	Clear	Clear		
Downstream Kilmarnock Creek (1190008)		732 240	60 15		12 4.3	8 3.8
→ South Greenhills Diversion			444 1.1 170 43	66 1.7 14 9.6	42 14	720 240
Downstream South Greenhils Diversion						56 19
→ Logging Runoff						6686 0.04 3400 24
11 km Downstream Fording Coal		136 20	4 1.8		2 0.5	22 10
16 km Downstream Fording Coal (0200093)			86 23	36 13	14 5.2	14 8.7
→ Grace Creek			800 14-21 170 96-144	100 0.57 19 4.9	Clear	Clear
32 km Downstream Fording Coal (CNI Bridge)			104 26	40 12	28 6.4	32 10
→ Line Creek (0200044) (08NK022)		4			10	
Mouth (0200028) (08NK018)			110 18		12 4.6	10 9.2

TABLE 5 continued

SUSPENDED SOLIDS AND TURBIDITY MEASUREMENTS ALONG THE FORDING RIVER

Site / Date	June 3 1976	June 8 1976	June 10 1976	June 15 1976	June 23 1976
Upstream Fording Coal (0200110) (08NK021)	2 0.3	2 0.5	2 0.6	2 0.3	2 0.3
→ Upper Settling Pond					
→ Clode Settling Pond	6 0.28 3.3 0.1	6 0.27 2.4 0.14		4 0.22 2.3 0.07	
→ Harold Creek Diversion	4 2.7	6 2.1	12 4.2	6 2.5	6 2.3
Upstream Eagle Settling Pond	2 1.2	2 0.8	6 1.8	2 1.1	
→ Eagle Settling Pond					
Downstream Eagle Settling Pond (0200040)					4 0.9
→ Greenhills Pit Water	308 0.12 144 3.1	82 0.07 80 0.5	8207 0.15 4610 104	54 0.10 51 0.5	40 3.5 37 0.3
Downstream Fording Coal (0200201)	10 3.5	6 2.4	56 28	6 3	4 2.2
→ Kilmarnock Creek (1190042) Downstream Kilmarnock Creek (1190008)					
→ South Greenhills Diversion	46 9.7	48 10	168 0.74 40 11	32 8.3	
Downstream South Greenhills Diversion	6 3		34 19		
→ Logging Runoff	CLEAR				
11 km Downstream Fording Coal	8 3	2 1.4	10 4.7	4 1.6	
16 km Downstream Fording Coal (0200093)		2 1.3		4 1.8	
→ Grace Creek	CLEAR				
32 km Downstream Fording Coal (CNI Bridge)	4 1.9	2 2.0		4 1.8	
→ Line Creek (0200044) (08NK022)	4 1.2				
Mouth (0200028) (08NK018)	4 1.7	4 1.3	6 3.3	4 1.9	

TABLE 6

CALCULATION OF PARTICLE SIZE THAT CAN
BE SETTLED IN CLODE AND EAGLE SETTLING POND

	Clode Pond	Eagle Pond
A = surface area of pond (m^2)	60,700	26,700
Q_{max} = maximum discharge recorded m^3/s	0.76	0.12
V_s = settling velocity = $\frac{Q_{max}}{A} \times 100$ cm/s	12.6×10^{-4}	4.66×10^{-4}
$V_s \times 1.2$ (safety factor)* cm/s	15.1×10^{-4}	5.60×10^{-4}
D = diameter of particle that can be settled ** cm	0.0005	0.0003
mm	0.005	0.003

* To account for non-ideal settling.

** Calculated from Stoke's Law: $V_s = \frac{g}{18\mu} (S-1) D^2$

g = acceleration of gravity = 981 cm/s^2
μ = kinematic viscosity of water = 1.7923×10^{-2} cm^2/s at 0^oC
S = specific gravity of particle = 2.65 (assumed)

TABLE 7

FORDING COAL LTD.

EFFICIENCY OF CLODE SETTLING POND, MEASURED IN 1976

Date	Influent			Effluent			Efficiency, %	
	Flow m^3/s	Suspended Solids mg/L	Turbidity J.T.U.	Flow m^3/s	Suspended Solids mg/L	Turbidity J.T.U.	Suspended Solids	Turbidity
April 7				0.42	300	256		
May 5	0.76	360	185	0.62	42	42	88	77
May 12	0.51	202	44	0.42	48	54	76	0
May 19	0.51	176	38	0.51	18	11	90	71
May 25	0.59	78	16	0.40	18	10	77	38
June 3	0.40	30	6	0.28	6	3.3	80	45
June 8	0.22	22	6.6	0.27	6	2.4	73	64
June 15	0.28	28	5.4	0.22	4	2.3	86	57

TABLE 8

FORDING COAL LTD.

ANALYSIS OF RUNOFF FROM MAINTENANCE AREA

Parameter \ Date		August 20 1975
Carbon, Total Organic	mg/L	27,000
Flow Rate	m^3/s	1.5×10^{-3}
Iron, Dissolved	mg/L	1.1
Total	mg/L	642
Oil and Grease	mg/L	998
pH		7.5
Phosphorus, Dissolved Orthophosphate	mg/L	0.268
Total	mg/L	74.9
Total Dissolved	mg/L	0.712
Solids, Dissolved	mg/L	900
Suspended	mg/L	80,700
Total	mg/L	81,600
Zinc, Dissolved	mg/L	0.5
Total	mg/L	6.4

TABLE 9

CROWS NEST INDUSTRIES LTD.

ANALYSIS OF SETTLING POND EFFLUENT (Site 1190009)

Parameter \ Date		June 5 1975	July 2 1975	July 23 1975
Alkalinity, Total	mg/L	118	157	171
Arsenic, Total	mg/L	<0.005	<0.005	<0.005
Calcium, Dissolved	mg/L	30.1	38.3	44.7
Carbon, Total organic	mg/L	13	<1	1
Copper, Total	mg/L	<0.001	<0.001	<0.001
Flow Rate	m^3/s	0.042	0.028	0.021
Hardness, Total	mg/L	131	165	190
Iron, Total	mg/L	0.2	<0.1	0.2
Lead, Dissolved	mg/L	<0.001	<0.001	<0.001
Magnesium, Dissolved	mg/L	13.5	16.9	19.0
Manganese, Dissolved	mg/L	<0.02	<0.02	<0.02
Nickel, Dissolved	mg/L	<0.01	<0.01	<0.01
Nitrogen, Ammonia	mg/L	0.023	0.008	0.011
pH		8.5	8.4	8.1
Phosphorus, Total	mg/L	0.039	0.026	0.022
Total Dissolved	mg/L	0.032	0.018	0.019
Solids, Dissolved	mg/L	148	182	202
Suspended	mg/L	4	2	2
Total	mg/L	152	184	204
Turbidity	J.T.U.	3.1	1.2	0.2
Vanadium, Total	mg/L			<0.001
Zinc, Total	mg/L	0.02	<0.005	0.009

TABLE 10

DESCRIPTION OF SAMPLING SITES

Site No.	Fording River Basin
	Pollution Control Branch (PCB) Sites
0200028	Fording River at mouth (same as WSC 08NK018)
0200040	Fording River downstream from Eagle settling pond at haul road river crossing
0200044	Line Creek at the mouth (same as WSC 08NK022)
0200093	Fording River 16 km from Fording Coal at highway crossing due east of Elkford
0200110	Fording River upstream from Fording Coal, downstream from Henretta Creek
0200201	Fording River downstream from Fording Coal, upstream from Kilmarnock Creek
	Water Investigations Branch (WIB) Sites
1190007	Fording River downstream from Eagle settling pond, upstream from north tailing pond
1190008	Fording River downstream from Kilmarnock Creek, upstream from South Greenhills Diversion at logging bridge downstream from Fording Coal
1190010	Line Creek upstream from Crows Nest Industries settling pond for coal exploration test pit
1190011	Line Creek downstream from Crows Nest Industries settling pond
1190042	Kilmarnock Creek at the mouth
sites sampled only for suspended solids and turbidity	Fording River upstream from Eagle settling pond at WSC gauging station 8NK021
	Fording River downstream from South Greenhills Diversion
	Fording River 11 km downstream from Fording Coal, upstream from Ewin Creek (where the river first touches the highway downstream from Fording Coal)

TABLE 10 continued

DESCRIPTION OF SAMPLING SITES

Site No.	Fording River Basin
	Water Investigations Branch (WIB) Sites
sites sampled only for suspended solids and turbidity	Grace Creek at the mouth
	Fording River 32 km downstream from Fording Coal Ltd. at Crows Nest Industries bridge
	Water Survey of Canada (WSC) Sites (sampled for flow and suspended sediment only)
08NK018	Fording River at the mouth (same as PCB 0200028)
08NK021	Fording River at Fording Coal minesite. Flow measured upstream from Eagle settling pond, suspended sediment measured at PCB site 0200110
08NK022	Line Creek at the mouth (same as PCB 0200044)
	Upper Elk River Basin
	Pollution Control Branch Sites
0200039	Elk River downstream from the Elkford sewage lagoons
0200041	Elk River upstream from Cadorna Creek in District Lot 8470
0200042	Elk River upstream from Aldridge Creek at the former bridge crossing in District Lot 6826
0200043	Elk River at the bridge over the river at Round Prairie
0200202	Elk River just upstream from Boivin Creek at Elkford
0200204	Elk River about 0.4 km downstream from Cadorna Creek in District Lot 1999
0200218	Elk River immediately upstream from the Elkford sewage lagoons
	Water Investigations Branch Sites
1190040	Boivin Creek at the mouth (at Elkford)
1190045	Elk River downstream from Weary Creek in District Lot 1934

TABLE 10 continued

DESCRIPTION OF SAMPLING SITES

Site No.	Upper Elk River Basin
	Water Investigations Branch Sites
1190048	Weary Creek at Forestry Road
1190049	Elk River upstream from Britt Creek in District Lot 6848
	Michel Creek Basin
	Pollution Control Branch Sites
0200025	Michel Creek downstream from Kaiser Resources coke plant at highway bridge
0200046	Michel Creek upstream from Kaiser Resources coke plant at highway bridge
0200098	Michel Creek downstream from Erickson Creek
0200184	Michel Creek upstream from Open Cut Creek
0200185	Michel Creek upstream from Andy Good Creek and from Coleman Collieries runoff
0200186	Michel Creek downstream from Coleman Collieries runoff
0200203	Michel Creek upstream from Erickson Creek
0200208	Michel Creek downstream from Open Cut Creek, just upstream from Corbin Creek
0200209	Corbin Creek at the mouth
	Water Investigations Branch Sites
1190001	Same as PCB site 0200208
1190029	Michel Creek downstream from an unnamed creek from Tent Mountain Pass
190031	Michel Creek downstream from Corbin Creek and upstream from Andy Good Creek

TABLE 10 continued

DESCRIPTION OF SAMPLING SITES

Site No.	Michel Creek Basin
	Water Investigations Branch Sites
1900041	Michel Creek downstream from Kaiser Resources coke plant discharge, upstream from Baldy Creek
sites sampled only for suspended solids and turbidity	Michel Creek just upstream from Leach Creek
	Leach Creek at the mouth
	Michel Creek downstream from Leach Creek and upstream from Wheeler Creek
	Michel Creek downstream from Wheeler Creek and upstream from McGillivray
	Michel Creek downstream from McGillivray and upstream from Alexander Creek
	Alexander Creek at the mouth
	Fir Creek at the mouth
	Water Survey of Canada Sites (sampled for flow and suspended sediments only)
08NK020	Same as PCB site 0200025
08NK023	Same as PCB site 0200046
	Lower Elk River Basin
	Pollution Control Branch Sites
0200016	Elk River at the mouth, at highway 93 bridge crossing
0200024	Elk River at Hosmer, at highway 3 bridge
0200026	Grave Creek at the mouth, between CPR bridge and Crows Nest Industries road bridge
0200027	Elk River downstream from Fording River and upstream from Grave Creek
0200102	Elk River downstream from the Sparwood treatment plant outfall, at McGauley Ready Mix Concrete Co.
0200103	Elk River downstream from Michel Creek and just upstream from the Sparwood treatment plant outfall

TABLE 10 continued

DESCRIPTION OF SAMPLING SITES

Site No.	Lower Elk River Basin
	Pollution Control Branch Sites
0200111	Elk River downstream from Kaiser Resources and upstream from Michel Creek at the highway bridge
0200113	Elk River downstream from the Fernie treatment plant and just upstream from Lizard Creek
0200116	Coal Creek at the mouth
	Water Investigations Branch Sites
1190004	Elk River upstream from Fernie, at highway 3 bridge at northern end of Fernie
1190012	Elk River downstream from Grave Creek and upstream from Six Mile Creek at the CPR bridge
sites sampled for suspended solids and turbidity or fecal coliform	No-name Creek upstream from Hosmer Creek
	Hosmer Creek upstream from No-name Creek
	Hartley Creek at the mouth, at highway 3
	Elk River, 0.3 km upstream from the Fernie treatment plant
	Lizard Creek at the mouth, at highway 3
	Water Survey of Canada Sites (sampled for flow and suspended sediments only)
08NK002	Elk River at Fernie, at highway 3 bridge at southern end of Fernie
08NK016	Same as PCB site 0200027
08NK019	Same as PCB site 0200026
	Flathead River Basin
	Pollution Control Branch Sites
0200047	Flathead River at the International Boundary
0200205	Cabin Creek about 4 km upstream from Howell Creek
0200206	Cabin Creek just upstream from Howell Creek

TABLE 10 continued

DESCRIPTION OF SAMPLING SITES

Site No.	Flathead River Basin
	Pollution Control Branch Sites
0200207	Howell Creek just upstream from Cabin Creek
0200220	Cabin Creek about 7 km upstream from Howell Creek
	Environment Canada Sites
08NP0001	Flathead River, above Pollock Creek at the road bridge
08NP0002	Flathead River, 1.3 km east of Marl Lake
08NP0003	Same as PCB site 0200047
08NP0004	Same as PCB site 0200207
08NP0005	Same as PCB site 0200206
08NP0006	Sage Creek, 0.8 km north of Proctor Lake at the road bridge
08NP0007	Couldrey Creek at the road bridge 200 m above the confluence with Burnham Creek
08NP0008	Howell Creek at the road bridge 750 m above the confluence with the Flathead River
08NP0009	Cabin Creek, 4.5 km above the confluence with Howell Creek
08NP0010	Cabin Creek, 9 km above the confluence with Howell Creek

TABLE 11

WATER QUALITY DATA COLLECTED FROM THE FORDING RIVER AND KILMARNOCK CREEK BY THE PROVINCE IN 1975-76

GENERAL PARAMETERS

Site / Parameter	0200110 Max.	Min.	Mean	No. Of Values	0200040 Max.	Min.	Mean	No. Of Values
Alkalinity, Total mg/L	129	96	114	14	167	106	127	9
Carbon, Total Organic mg/L	2	<1	1.2	9	3	<1	2	8
Coliform, Fecal MPN/100 mL	17	<2	5	5	2	<2	2	4
Colour, True	5	<5	5	6	5	<5	5	9
Hardness, Total mg/L	132	99	116	4	133	108	120	2
Nitrogen, Ammonia mg/L	0.01	<0.005	0.006	9	0.125	<0.005	0.02	9
Nitrate mg/L	0.05	<0.02	0.03	11	10.8	0.02	1.48	9
Nitrite mg/L	<0.005	<0.005	<0.005	6	0.036	<0.005	0.009	8
Organic mg/L	0.23	<0.01	0.07	9	0.18	<0.01	0.06	9
Total mg/L	0.27	<0.02	0.09	9	11.0	0.16	1.56	9
Oil and Grease mg/L					5.3	5.3	5.3	1
pH	8.5	8.0	8.2	28	8.6	7.9	8.2	18
Phosphorus, Dissolved Orthophosphate mg/L	0.004	<0.003	0.003	6	0.005	<0.003	0.003	6
Total mg/L	0.029	0.004	0.013	8	0.029	0.006	0.015	7
Total Dissolved mg/L	0.005	0.003	0.004	4	0.008	0.007	0.0075	2
Solids, Dissolved mg/L	197	112	153	14	341	120	201	10
Suspended mg/L	16	<1	3	14	132	2	21	10
Total mg/L	198	118	157	15	408	142	222	10
Sulphate, Dissolved mg/L	44	12	28	9	69	14	34	8
Turbidity J.T.U.	2.3	0.06	0.4	15	54	0.5	10.1	9

TABLE 11 continued

WATER QUALITY DATA COLLECTED FROM THE FORDING RIVER AND KILMARNOCK CREEK BY THE PROVINCE IN 1975-76

GENERAL PARAMETERS

Parameter \ Site	0200201 Max.	Min.	Mean	No. Of Values	1190042 Max.	Min.	Mean	No. Of Values
Alkalinity, Total mg/L	185	101	124	11	125	102	113	4
Carbon, Total Organic mg/L	7	<1	3	9	2	<1	1.3	3
Coliform, Fecal MPN/100 mL	21	<2	5	6				
Colour, True	5	<5	5	3				
Hardness, Total mg/L	146	107	126	4	142	104	124	4
Nitrogen, Ammonia mg/L	0.119	0.01	0.04	10	0.01	0.006	0.009	3
Nitrate mg/L	8.3	0.18	1.1	12	0.22	0.02	0.10	3
Nitrite mg/L	0.048	<0.005	0.013	6				
Organic mg/L	0.25	0.06	0.14	10	0.09	0.03	0.06	3
Total mg/L	8.55	0.32	1.4	10	0.32	0.09	0.17	3
Oil and Grease mg/L	2.8	<1	1.6	4				
pH	9.0	8.0	8.4	23	8.6	8.3	8.4	4
Phosphorus, Dissolved Orthophosphate mg/L	0.007	<0.003	0.004	6				
Total mg/L	0.056	0.008	0.029	11	0.011	0.008	0.01	4
Total Dissolved mg/L	0.01	<0.003	0.007	4	0.008	0.003	0.006	4
Solids, Dissolved mg/L	384	118	182	12	158	116	140	4
Suspended mg/L	36	3	14	12	4	2	4	4
Total mg/L	392	136	197	13	162	118	137	4
Sulphate, Dissolved mg/L	91	11	33	7				
Turbidity J.T.U.	23	1.2	6.6	13	2.5	0.5	1.1	4

TABLE 12

WATER QUALITY DATA COLLECTED FROM THE FORDING RIVER AND KILMARNOCK CREEK BY THE PROVINCE IN 1975-76

METALS AND TOXIC ELEMENTS IN μg/L

Site / Parameter	0200110				0200040			
	Max.	Min.	Mean	No. Of Values	Max.	Min.	Mean	No. Of Values
Aluminum, Dissolved	<10	<10	<10	8	20	<10	12	6
Arsenic, Dissolved	<5	<5	<5	3				
Total	<5	<5	<5	7	<5	<5	<5	2
Chromium, Dissolved	<5	<5	<5	2				
Total	<5	<5	<5	1				
Copper, Dissolved	2	<1	1	9	5	<1	1	8
Total	<1	<1	<1	5	<1	<1	<1	2
Iron, Dissolved	<100	<100	<100	9	<100	<100	<100	8
Total	100	<100	100	5	400	300	350	2
Lead, Dissolved	2	<1	1	12	<1	<1	<1	9
Total	<1	<1	<1	1				
Manganese, Dissolved	<20	<20	<20	12	30	<20	21	9
Total	<20	<20	<20	1				
Mercury, Dissolved	<0.05	<0.05	<0.05	1	<0.05	<0.05	<0.05	1
Total	<0.05	<0.05	<0.05	7	<0.05	<0.05	<0.05	6
Nickel, Dissolved	<10	<10	<10	7	<10	<10	<10	2
Total	<10	<10	<10	1				
Vanadium, Total	<1	<1	<1	1				
Zinc, Dissolved	20	<5	7	9	20	<5	7	8
Total	<5	<5	<5	4	20	<5	12	2

TABLE 12 continued

WATER QUALITY DATA COLLECTED FROM THE FORDING RIVER AND KILMARNOCK CREEK BY THE PROVINCE IN 1975-76

METALS AND TOXIC ELEMENTS IN µg/L

Parameter \ Site	0200201				1190042			
	Max.	Min.	Mean	No. Of Values	Max.	Min	Mean	No. Of Values
Aluminum, Dissolved	20	<10	11	7				
Arsenic, Dissolved	<5	<5	<5	4				
Total	<5	<5	<5	8	<5	<5	<5	4
Chromium, Dissolved	<5	<5	<5	3				
Total	<5	<5	<5	4				
Copper, Dissolved	2	<1	1	7				
Total	10	<1	2	8	<1	<1	<1	4
Iron, Dissolved	<100	<100	<100	7				
Total	800	<100	388	8	200	<100	100	4
Lead, Dissolved	<1	<1	<1	10	<1	<1	<1	4
Total	3	<1	2	4				
Manganese, Dissolved	30	<20	22	10	<20	<20	<20	3
Total	50	<20	32	4				
Mercury, Dissolved								
Total	<0.05	<0.05	<0.05	4				
Nickel, Dissolved	10	<10	10	8	<10	<10	<10	4
Total	10	<10	10	4				
Vanadium, Total	<1	<1	<1	1				
Zinc, Dissolved	20	<5	7	7				
Total	20	<5	8	8	20	<5	9	4

TABLE 13

WATER QUALITY DATA COLLECTED FROM THE FORDING RIVER BY THE PROVINCE IN 1975-76

GENERAL PARAMETERS

Site / Parameter		1190008				0200093			
		Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values
Alkalinity, Total	mg/L	124	97	111	4	159	129	138	4
Carbon, Total Organic	mg/L	3	<1	2	3	2	<1	1	4
Coliforms, Fecal	M.P.N./ 100 mL					17	<2	7	3
Color, True						5	<5	5	3
Hardness, Total	mg/L	145	107	126	4	155	155	155	1
Nitrogen, Ammonia	mg/L	0.018	0.013	0.015	3	0.009	<0.005	0.007	4
Nitrite + Nitrate	mg/L	0.33	0.14	0.23	3	0.18	<0.02	0.14	4
Organic	mg/L	0.13	0.04	0.08	3	0.13	0.04	0.09	4
Total	mg/L	0.41	0.19	0.32	3	0.32	0.13	0.24	4
Oil and Grease	mg/L								
pH		8.7	8.2	8.4	4	8.7	8.0	8.3	8
Phosphorus, Dissolved Orthophosphate	mg/L					0.005	<0.003	0.004	3
Total	mg/L	0.026	0.015	0.022	4	0.028	0.004	0.013	4
Total Dissolved	mg/L	0.007	<0.003	0.006	4	0.003	0.003	0.003	1
Solids, Dissolved	mg/L	164	118	142	4	200	162	178	4
Suspended	mg/L	14	8	11	4	14	2	6	4
Total	mg/L	174	130	154	4	204	176	185	4
Sulphate, Dissolved	mg/L					28	16	21	3
Turbidity	J.T.U.	7.8	3.2	5.0	4	5.2	0.2	2.0	4

TABLE 14

WATER QUALITY DATA COLLECTED FROM THE FORDING RIVER BY THE PROVINCE IN 1975-76

METALS AND TOXIC MATERIALS IN μg/L

Site / Parameter	1190008				0200093			
	Max.	Min.	Mean	No. Of Values	Max.	Min.	Mean	No. Of Values
Aluminum, Dissolved					<10	<10	<10	3
Arsenic, Dissolved								
Total	<5	<5	<5	4	<5	<5	<5	1
Chromium, Dissolved								
Total								
Copper, Dissolved					<1	<1	<1	3
Total	2	<1	1	4	<1	<1	<1	1
Iron, Dissolved					<100	<100	<100	3
Total	400	100	300	4	<100	<100	<100	1
Lead, Dissolved	1	<1	1	4	<1	<1	<1	4
Total								
Manganese, Dissolved	<20	<20	<20	3	<20	<20	<20	4
Total								
Mercury, Dissolved					<0.05	<0.05	<0.05	1
Total					<0.05	<0.05	<0.05	2
Nickel, Dissolved	<10	<10	<10	4	<10	<10	<10	1
Total								
Vanadium, Total								
Zinc, Dissolved					<5	<5	<5	3
Total	20	<5	9	4	<5	<5	<5	1

TABLE 15

WATER QUALITY DATA COLLECTED FROM LINE CREEK BY THE PROVINCE IN 1975

Site / Parameter	1190010				1190011				0200044			
	Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values
Alkalinity, Total mg/L	113	101	106	3	114	105	110	2	123	103	114	4
Arsenic, Total mg/L	<0.005	<0.005	<0.005	3	0.007	<0.005	0.006	2	0.006	<0.005	0.005	4
Carbon, Total Organic mg/L	2	<1	2	3	2	<1	1.5	2	4	<1	2	4
Copper, Total mg/L	0.01	<0.001	0.004	3	<0.001	<0.001	<0.001	2	<0.001	<0.001	<0.001	4
Hardness, Total mg/L	131	112	119	3	134	114	124	2	141	115	128	4
Iron, Total mg/L	0.5	<0.10	0.3	3	0.2	<0.10	0.15	2	0.4	<0.1	0.2	4
Lead, Dissolved mg/L	<0.001	<0.001	<0.001	3	<0.001	<0.001	<0.001	2	<0.001	<0.001	<0.001	4
Manganese, Dissolved mg/L	<0.02	<0.02	<0.02	3	<0.02	<0.02	<0.02	2	<0.02	<0.02	<0.02	3
Nickel, Dissolved mg/L	<0.01	<0.01	<0.01	3	<0.01	<0.01	<0.01	2	<0.01	<0.01	<0.01	4
Nitrogen, Ammonia mg/L	0.01	<0.005	0.007	3	0.005	0.005	0.005	2	0.006	0.005	0.006	4
pH	8.6	8.0	8.3	6	8.6	8.1	8.3	4	8.6	8.2	8.3	8
Phosphorus, Total mg/L	0.044	0.007	0.02	3	0.007	0.006	0.006	2	0.039	0.007	0.018	4
Total Dissolved mg/L	0.009	0.004	0.006	3	0.006	0.005	0.006	2	0.009	0.006	0.008	4
Solids, Dissolved mg/L	140	126	131	3	142	134	138	2	160	128	144	4
Suspended mg/L	28	2	11	3	6	2	4	2	36	2	12	4
Total mg/L	156	128	142	3	148	136	142	2	166	136	156	4
Turbidity J.T.U.	9.6	0.2	3.4	3	0.4	0.2	0.3	2	6.4	0.2	2.8	4
Zinc, Total mg/L	0.006	<0.005	0.005	3	<0.005	<0.005	<0.005	2	<0.005	<0.005	<0.005	4

TABLE 16

SUMMARY OF SUSPENDED SEDIMENT LOADS IN THE ELK RIVER BASIN, FROM 1970 TO 1974, DERIVED FROM WATER SURVEY OF CANADA DATA

Site / Year	1970			1971			1972		
	$\frac{t}{Year}$	$\frac{t}{km^2}$	$\frac{t}{m^3/s}$	$\frac{t}{Year}$	$\frac{t}{km^2}$	$\frac{t}{m^3/s}$	$\frac{t}{Year}$	$\frac{t}{km^2}$	$\frac{t}{m^3/s}$
Fording River, Upstream Fording Coal Ltd. (08NK021) 106 km^2							>3,600	>34	>1,300
Fording River at the Mouth (08NK018) 619 km^2	7,400	12	1,100	10,900	18	1,200	>36,400	>59	>2,700
Upper Elk River, Upstream of Fording River* 1253 km^2	20,200	16	1,400	54,600	44	2,600	<140,300	<112	<5,800
Line Creek at the Mouth (08NK022) 148 km^2				>1,380	>9		>2,700	>18	>770
Grave Creek at the Mouth (08NK019) 84 km^2	3,300	39	4,200	14,900	177	10,100	>13,500	>161	>9,700
Michel Creek at the Mouth (08NK020) 637 km^2	17,100	27	1,900	>37,000	>58	>2,600	>121,790	>191	>7,300
Elk River at Fernie (08NK002) 3134 km^2	72,600	23	2,000	288,000	92	4,900	540,800	173	7,600

* Difference Between Loading in the Elk at Natal (08NK016) and Loading in the Fording at the Mouth (08NK018)
<> Used for Years in Which Records Incomplete.
m^3/s=Mean Annual Flow for the Year.

TABLE 16 continued

SUMMARY OF SUSPENDED SEDIMENT LOADS IN THE ELK RIVER BASIN, FROM 1970 TO 1974, DERIVED FROM WATER SURVEY OF CANADA DATA

Site \ Year	1973			1974		
	$\frac{t}{Year}$	$\frac{t}{km^2}$	$\frac{t}{m^3/s}$	$\frac{t}{Year}$	$\frac{t}{km^2}$	$\frac{t}{m^3/s}$
Fording River, Upstream Fording Coal Ltd. (08NK021) 106 km^2	750	7	450	3,600	34	1,400
Fording River at the Mouth (08NK018) 619 km^2	6,500	10	960	58,000	94	5,200
Upper Elk River, Upstream of Fording River* 1253 km^2	22,500	18	1,400	273,200	218	10,900
Line Creek at the Mouth (08NK022) 148 km^2	430	3	260	12,100	82	3,900
Grave Creek at the Mouth (08NK019) 84 km^2	760	9	770	6,200	74	3,600
Michel Creek at the Mouth (08NK020) 637 km^2	18,000	28	2,100	132,000	207	7,000
Elk River at Fernie (08NK002) 3134 km^2	84,800	27	2,000	955,300	305	12,800

* Difference Between Loading in the Elk at Natal (08NK016) and Loading in the Fording at the Mouth (08NK018).
<> Used for Years in Which Records Incomplete.
m^3/s=Mean Annual Flow for the Year.

TABLE 17

RESULTS OF FREEZE-CORE SEDIMENT SAMPLING IN THE FORDING RIVER, JULY, 1976

Site / Parameter	0200110			0200201			11 km Downstream Fording Coal Ltd.		
	A	B	Average	A	B	Average	A	B	Average
Dry Sample Weight, g	24,144	13,597		22,680	20,045		13,170	13,410	
Percentage Finer than:									
50.8 mm	70.9	64.1	67.5	80.0	70.8	75.4	91.2	61.3	76.2
12.7 mm	36.2	20.8	28.5	36.9	27.9	32.4	52.1	23.3	37.7
4.76 mm	23.9	11.1	17.5	23.3	17.4	20.4	37.4	15.2	26.3
2.38 mm	17.7	6.2	12.0	17.3	12.7	15.0	31.1	12.1	21.6
0.59 mm	6.7	1.8	4.2	8.2	7.7	8.0	22.3	7.4	14.8
0.297 mm	3.6	1.0	2.3	4.4	3.6	4.0	16.6	4.2	10.4
0.149 mm	2.4	0.6	1.5	2.4	1.7	2.0	6.4	2.1	4.2
0.074 mm	1.6	0.3	1.0	1.3	0.9	1.1	1.3	0.8	1.0

TABLE 18

RESULTS OF SEDIMENT TRAP SAMPLING IN THE FORDING RIVER, APRIL-JULY, 1976

Site / Parameter	0200110				11 km Downstream Fording Coal Ltd.			
	A	B	C	Average	A	B	C	Average
Total Dry Weight, g	7079	4733	6993	6268	5161	4516	4720	4799
Weight Finer than 2.38 mm, g	158	1173	777	703	1316	776	2518	1537
Percentage of Total Weight Finer than 2.38 mm	2.2	24.8	11.1	12.7	25.5	17.2	53.4	32.0
Percentage finer than:*								
2.38 mm	100	100	100	100	100	100	100	100
0.59 mm	25.3	42.5	35.0	34.3	48.5	56.4	37.6	47.5
0.297 mm	21.5	14.4	16.0	17.3	23.9	35.6	12.5	24.0
0.149 mm	15.8	7.1	9.7	10.9	12.2	25.4	6.4	14.7
0.074 mm	9.5	3.4	5.5	6.1	5.5	13.5	2.9	7.3

* Particle-size analysis of portion of sample finer than 2.38 mm

TABLE 19

PARTICLE SIZE DISTRIBUTION AND CHEMICAL COMPOSITION OF SEDIMENT GRAB SAMPLES FROM THE FORDING RIVER, AUGUST, 1975

	Percentage Finer Than							
Sieve Number	16	30	50	100	140	200	270	400
Site / Size (mm)	1.19	0.59	0.297	0.149	0.105	0.074	0.053	0.037
0200110	66.2	35.0	6.4	1.4	1.0	0.3	0.2	0.1
1190007	72.1	32.0	5.1	1.2	1.0	0.4	0.3	0.1
0200201	67.2	39.6	13.6	4.5	3.5	2.0	1.5	1.0
0200093	83.9	59.3	35.6	24.3	21.8	14.2	10.8	6.4

Site / Parameter	Carbon Total mg/g	Carbon Organic mg/g	Nitrogen Kjeldahl mg/g	Phosphorus Total mg/g	Arsenic µg/g	Cadmium µg/g	Chromium µg/g	Iron µg/g	Lead µg/g	Mercury µg/g	Molybdenum µg/g	Zinc µg/g
0200110	26	14.6	0.73	1.48	3	1	16	38.3	20	0.05	<5	130
1190007	34	5.8	0.62	1.33								
0200201	34	27.9	0.87	1.55	2	1	12.5	27.7	20	0.06	<5	120
0200093	36	20.1										

TABLE 20

BENTHIC INVERTEBRATE COUNTS IN THE FORDING RIVER

(EACH NUMBER IS THE TOTAL OF 3 REPLICATE SAMPLES)

Class, Order or Family \ Site	0200110 Control, Upstream Mining Activities	1190007 Downstream Eagle Settling Pond	0200201 Just Downstream Mining Activities	0200093 16 Km Downstream Mining Activities
Turbellaria	51	2		2
Nematoda	6	1	19	11
Oligochaeta	19		124	21
Crustacea				
Ostracoda	4	1		6
Copepoda	3	17	9	3
Arachnida				
Acarina	17	10	39	50
Insecta				
Collembola				1
Lepidoptera	2			
Hymenoptera		2	2	
Coleoptera			1	1
Ephemeroptera*	2397	918	1286	430
Plecoptera*	128	18	11	128
Trichoptera*	43	21	12	28
Diptera				
Tipulidae	3		4	7
Simuliidae	10	1		
Heleidae	37	19	6	31
Rhagionidae			2	
Dolichopodidae	3	0	2	1
Empididae	5	7	31	46
Adult Diptera	4	0	3	1
Chironomidae	1177	1053	2928	1183

*Numbers of individuals in the various genera of these orders are shown in Figures 6 and 7.

TABLE 21

DIVERSITY AND REDUNDANCY INDICES FOR BENTHIC INVERTEBRATES COLLECTED IN THE FORDING RIVER

Site No.	Diversity Index	Redundancy Index
0200110	2.72	0.47
1190007	2.14	0.55
0200201	1.73	0.63
0200093	2.46	0.51

TABLE 22

GENERAL OBSERVATIONS OF THE INVERTEBRATE SAMPLING SITES

IN THE FORDING RIVER, AUGUST, 1975

Site No.	Flow and Velocity	Bottom Type
0200110	Fast 1 m/s	Riffle Stretch Large Cobble Bottom, Clean Stones.
1190007	Fast	Riffle Stretch Cobble Bottom, Crevices Between Rocks Somewhat Filled with Black Sediment.
0200201	Fast 1.2 m/s	Riffle Stretch Cobble Bottom, Crevices Between and Under Rocks Obviously Filled with Black Sediment.
0200093	Slow	Back-Eddy Area Large Cobble Bottom with Silt on Rock Surfaces and in Crevices.

TABLE 23

RESULTS FROM SAMPLING PERIPHYTON IN THE FORDING RIVER, SEPTEMBER, 1975

Site	Field Observations	Dominant Algae	Ash Free Dry Wt. mg
0200110	Little Periphyton, Pristine; Diatoms Evident.	Diatoms	8.0
1190007	Coal Dust Around Rocks; *Enteromorpha* Present.	*Enteromorpha*	5.0
0200201	Coal Dust Around Rocks; *Nostoc* Present	*Nostoc*	30.0
0200093	High Productivity	*Enteromorpha*	29.0

TABLE 24

WATER QUALITY DATA COLLECTED FROM THE UPPER ELK RIVER AND WEARY CREEK BY THE PROVINCE IN 1975-76

Parameter \ Site		0200041				0200204			
		Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values
Alkalinity, Total	mg/L	125	96	110	2	112	97	106	3
Arsenic, Total	mg/L					<0.005	<0.005	<0.005	3
Carbon, Total Organic	mg/L					4	1	2.7	3
Copper, Total	mg/L					0.002	<0.001	0.001	3
Hardness, Total	mg/L	134	97	115	2	117	98	105	3
Iron, Total	mg/L	<0.1	<0.1	<0.1	1	0.3	0.1	0.2	3
Lead, Dissolved	mg/L	<0.001	<0.001	<0.001	1	<0.001	<0.001	<0.001	3
Manganese, Dissolved	mg/L	<0.02	<0.02	<0.02	1	<0.02	<0.02	<0.02	3
Nickel, Dissolved	mg/L	<0.01	<0.01	<0.01	1	<0.01	<0.01	<0.01	3
Nitrogen, Ammonia	mg/L					0.01	<0.005	0.007	3
pH		8.4	8.1	8.3	4	8.6	8.0	8.2	5
Phosphorus, Total	mg/L					0.025	0.009	0.017	2
Total Dissolved	mg/L					0.003	<0.003	0.003	2
Solids, Dissolved	mg/L	156	108	132	2	136	102	117	3
Suspended	mg/L	2	2	2	2	4	2	3	3
Turbidity	J.T.U.	1.3	0.6	1.0	2	5.4	0.5	2.4	3
Zinc, Total	mg/L	<0.005	<0.005	<0.005	1	<0.005	<0.005	<0.005	3

TABLE 24 continued

WATER QUALITY DATA COLLECTED FROM THE UPPER ELK RIVER AND WEARY CREEK BY THE PROVINCE IN 1975-76

Parameter (Site)		1190048				1190045			
		Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values
Alkalinity, Total	mg/L	107	95	100	3	108	95	100	3
Arsenic, Total	mg/L	<0.005	<0.005	<0.005	3	<0.005	<0.005	<0.005	3
Carbon, Total Organic	mg/L	3	<1	1.7	3	3	1	2.3	3
Copper, Total	mg/L	<0.001	<0.001	<0.001	3	<0.001	<0.001	<0.001	3
Hardness, Total	mg/L	125	99	110	3	116	101	107	3
Iron, Total	mg/L	0.1	<0.1	0.1	3	0.4	<0.1	0.2	3
Lead, Dissolved	mg/L	0.002	<0.001	0.001	3	0.001	<0.001	0.001	3
Manganese, Dissolved	mg/L	<0.02	<0.02	<0.02	3	<0.02	<0.02	<0.02	3
Nickel, Dissolved	mg/L	<0.01	<0.01	<0.01	3	<0.01	<0.01	<0.01	3
Nitrogen, Ammonia	mg/L	0.005	<0.005	0.005	3	0.005	<0.005	0.005	3
pH		8.4	8.0	8.3	3	8.6	8.0	8.2	3
Phosphorus, Total	mg/L	0.01	0.006	0.008	3	0.027	0.006	0.014	3
Total Dissolved	mg/L	0.005	0.003	0.004	3	0.004	<0.003	0.003	3
Solids, Dissolved	mg/L	138	112	122	3	130	112	119	3
Suspended	mg/L	2	2	2	3	18	2	8	3
Turbidity	J.T.U.	0.7	0.2	0.4	3	5.6	0.6	2.3	3
Zinc, Total	mg/L	<0.005	<0.005	<0.005	3	0.1	<0.005	0.007	3

TABLE 25

WATER QUALITY DATA COLLECTED FROM THE UPPER ELK RIVER BY THE PROVINCE IN 1975-76

Site / Parameter	0200042				1190049				0200043			
	Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values
Alkalinity, Total mg/L	99	98	98	2			110	1	146	145	146	2
Aluminum, Dissolved mg/L			<0.01	1								
Arsenic, Total mg/L			0.007	1			<0.005	1				
Carbon, Total Organic mg/L			1	1			4	1	<1	<1	<1	2
Coliforms, Fecal MPN/100mL									2	<2	2	2
Colour, True									5	<5	5	5
Copper, Total mg/L			<0.001	1			0.003	1				
Hardness, Total mg/L	105	97	101	2			108	1	164	162	163	2
Iron, Total mg/L	0.1	<0.1	0.1	2			1.3	1				
Lead, Dissolved mg/L			<0.001	1			<0.001	1				
Total mg/L			<0.001	1								
Manganese, Dissolved mg/L			<0.02	1			<0.02	1				
Total mg/L			<0.02	1								
Nickel, Dissolved mg/L			<0.01	1			<0.01	1				
Total mg/L			<0.01	1								
Nitrogen, Ammonia mg/L			<0.005	1			<0.005	1	<0.005	<0.005	<0.005	2
Nitrite+Nitrate mg/L			<0.02	1					0.08	0.07	0.08	2
Organic mg/L			0.05	1					0.03	0.01	0.02	2
Total mg/L			0.05	1					0.10	0.09	0.10	2

TABLE 25 continued

WATER QUALITY DATA COLLECTED FROM THE UPPER ELK RIVER BY THE PROVINCE IN 1975-76

Site / Parameter	0200042				1190049				0200043			
	Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values
pH	8.5	8.4	8.4	2			8.2	1	8.6	8.4	8.5	2
Phosphorus, Dissolved Orthophosphate mg/L									<0.003	<0.003	<0.003	2
Total mg/L			0.007	1			0.10	1	0.003	<0.003	0.003	2
Total Dissolved mg/L			<0.003	1			0.005	1				
Solids, Dissolved mg/L	120	110	115	2			128	1	182	180	181	2
Suspended mg/L	2	2	2	2			72	1	2	2	2	2
Sulphate, Dissolved mg/L			6.2	1					20.1	19.6	19.8	2
Turbidity J.T.U.	1.7	1.0	1.4	2			25	1	0.4	0.2	0.3	2
Zinc, Total mg/L	<0.005	<0.005	<0.005	2			0.02	1				

TABLE 26

WATER QUALITY DATA COLLECTED FROM THE UPPER ELK RIVER AND BOIVIN CREEK BY THE PROVINCE IN 1975-76

Parameter \ Site		0200202				1190040			
		Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values
Alkalinity, Total	mg/L	140	111	132	7	123	109	117	4
Carbon, Total Organic	mg/L	2	<1	1.3	6	2	<1	1.2	4
Chromium, Total	mg/L	<0.005	<0.005	<0.005	4	<0.005	<0.005	<0.005	4
Coliforms, Fecal	MPN/ 100mL	50	<2	11	9				
Colour, True		5	5	5	3				
Hardness, Total	mg/L	154	124	140	6	167	140	146	4
Nitrogen, Ammonia	mg/L	0.007	<0.005	0.006	6	0.008	<0.005	0.006	4
Nitrite+Nitrate	mg/L	0.07	0.02	0.04	6	0.09	0.04	0.07	4
Organic	mg/L	0.22	<0.01	0.09	6	0.33	<0.01	0.10	4
Total	mg/L	0.27	0.02	0.13	6	0.41	0.06	0.17	4
pH		8.6	8.0	8.3	15	8.8	8.5	8.6	4
Phosphorus, Dissolved Orthophosphate	mg/L	<0.003	<0.003	<0.003	3				
Total	mg/L	0.06	0.004	0.03	5	0.054	0.006	0.02	4
Total Dissolved	mg/L	0.004	<0.003	0.004	4	0.005	<0.003	0.004	4
Solids, Dissolved	mg/L	186	134	159	7	192	144	173	4
Suspended	mg/L	32	2	14	7	32	2	10	4
Sulphate, Dissolved	mg/L	14.8	11.6	12.8	3				
Turbidity	J.T.U.	11	0.2	3.8	8	15	0.5	4.4	4

TABLE 26 continued

WATER QUALITY DATA COLLECTED FROM THE UPPER ELK RIVER AND BOIVIN CREEK BY THE PROVINCE IN 1975-76

Site / Parameter		0200218				0200039			
		Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values
Alkalinity, Total	mg/L					148	108	132	16
Carbon, Total Organic	mg/L	2	<1	1.4	5	4	<1	1.6	14
Chromium, Total	mg/L					0.01	<0.005	0.006	5
Coliforms, Fecal	MPN/100mL					50	<2	10	18
Colour, True		5	<5	5	6	10	<5	5.4	12
Hardness, Total	mg/L	173	131	156	6	171	124	150	15
Nitrogen, Ammonia	mg/L	0.009	<0.005	0.006	6	0.018	<0.005	0.006	15
Nitrite+Nitrate	mg/L	0.08	0.03	0.06	6	0.08	<0.02	0.05	15
Organic	mg/L	0.17	0.01	0.06	6	0.21	<0.01	0.08	15
Total	mg/L	0.26	0.05	0.12	6	0.28	0.06	0.14	15
pH		8.4	8.0	8.2	12	8.5	8.0	8.3	33
Phosphorus, Dissolved Orthophosphate	mg/L	<0.003	<0.003	<0.003	6	<0.003	<0.003	<0.003	12
Total	mg/L	0.013	<0.003	0.005	6	0.063	<0.003	0.016	15
Total Dissolved	mg/L					0.007	0.003	0.005	3
Solids, Dissolved	mg/L	200	144	180	6	192	138	172	15
Suspended	mg/L	6	2	3	6	44	2	9	16
Sulphate, Dissolved	mg/L	31.3	14.9	25.7	6	29	12.8	20.3	12
Turbidity	J.T.U.	2.5	0.2	0.7	6	13	0.1	2.6	16

TABLE 27

SUSPENDED SOLIDS AND TURBIDITY MEASURED IN THE UPPER ELK RIVER

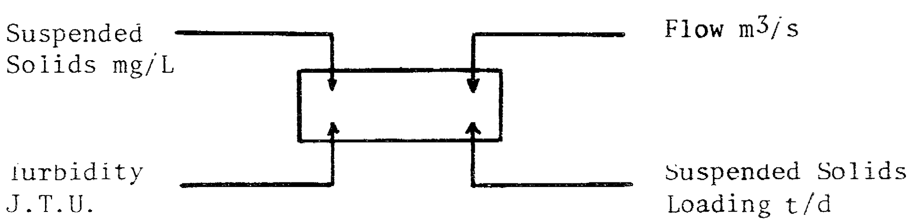
BY THE PROVINCE APRIL-JUNE, 1976

Site	Elk River Upstream From Elkford (0200202)		Elk River Upstream From Weigert Creek	
Parameter / Date	Suspended Solids mg/L	Turbidity J.T.U.	Suspended Solids mg/L	Turdidity J.T.U.
April 7	2	5.1		
May 5	100	27	74	23
May 10	152	35		
May 12			166	34
May 13	46	15	66	17
May 19			28	9.7
May 20	40	8.2	37	12
May 25			32	9.4
May 26	16	5.9	26	8.3
June 3			14	4.7
June 4	8	2.9		
June 6			12	3.2
June 8	6	2.1	10	3.3
June 10	34	7.2	30	6.8
June 15	6	2.5	8	2.8

TABLE 28

SUSPENDED SOLIDS AND TURBIDITY MEASUREMENTS ALONG THE UPPPER ELK RIVER

Site \ Date	May 21 1975	June 9 1975	June 12 1975	June 19 1975	July 7 1975	July 8 1975
Downstream Cadorna Creek (0200204)	2 0.6		2 1.2			4 5.4
Upstream Weary Creek (Bridge)						
→ Weary Creek (1190048)			2 0.3			2 0.7
Downstream Weary Creek (1190045)			2 0.6			18 5.6
Upstream Aldridge Creek (0200042) → Aldridge Creek → Unnamed Creek South of Mt. Veits						
Upstream Forsyth Creek (1190049)						72 25
→ Unnamed Creek 5 km Upstream 0200043 At Round Prairie (0200043)						
Upstream Elkford (0200202)	12 3.9	32 9.3		20 4.5	28 11	
→ Boivin Creek (1190040)	2 0.6	2 1.4			32 15	
Downstream Elkford (0200039)		44 9.4		14 4.7	38 13	
Upstream Weigert Creek						



→ Tributary to Elk River

TABLE 28 continued

SUSPENDED SOLIDS AND TURBIDITY MEASUREMENTS ALONG THE UPPER ELK RIVER

Site \ Date	August 5 1975	August 6 1975	May 5-6 1976	May 20 1976	June 3-4 1976	June 18 1976
Downstream Cadorna Creek (0200204)		2 0.5	12 3	4 1.5	2 0.7	2 0.8
Upstream Weary Creek (Bridge)			4 2.6	4 1.2		2 0.7
→ Weary Creek (1190048)		2 0.2	Clear	2 0.7	2 0.5	2 0.5
Downstream Weary Creek (1190045)		4 0.7				
Upstream Aldridge Creek (0200042)		2 1.0	18 10	22 8.2		2 1.1
→ Aldridge Creek			Clear	6 2.3	8 2.1	4 1.2
→ Unnamed Creek South of Mt. Veits			262 0.21 56 4.7	208 0.51 72 0.9	Clear	90 0.10 38 0.8
Upstream Forsyth Creek (1190049)			60 11	10 5.2	4 1.8	4 1.7
→ Unnamed Creek 5 km Upstream 0200043			90 0.28 14 2.2	36 0.24 7.1 0.7	Clear	Clear
At Round Prairie (0200043)			56 20	32 8.4	4 1.9	6 2.3
Upstream Elkford (0200202	4 0.6		100 27	40 8.2	8 2.9	
→ Boivin Creek (1190040)	4 0.5					
Downstream Elkford (0200039)	4 0.6					
Upstream Weigert Creek			74 23	37 12	14 4.7	

TABLE 29

WATER QUALITY OF OPEN CUT CREEK MEASURED BY THE PROVINCE

Parameter / Date	May 13 1975	June 3 1975	July 1 1975	July 3 1975	July 22 1975	August 14 1975	May 27 1976	June 2 1976	Level A Mining Objectives
Alkalinity, Total mg/L	64	37	65		75	90			
Carbon, Total Organic mg/L	114	129	31	470	7	1			
Copper, Total mg/L	0.07	0.08	0.02	0.12	0.003	0.004			0.05 (Dissolved)
Flow Rate m^3/s				0.06	0.03		0.07	0.31	
Iron, Dissolved mg/L						<0.1	<0.1	<0.1	0.3
Total mg/L	48.9	50.5	9.5	61.0	2.3	1.0	6.3	8.5	
Lead, Dissolved mg/L	<0.001	<0.001	<0.001	0.001	<0.001				0.05
Manganese, Dissolved mg/L	0.03	0.18	0.14		0.17	0.14			0.05
Nitrogen, Ammonia mg/L							0.035	0.04	0.5
Nitrite+Nitrate mg/L	0.05	0.05	0.04	0.05	0.02	<0.02	0.05	0.04	10
Organic mg/L							0.22	0.43	
Total mg/L							0.31	0.51	
Oil and Grease mg/L	1.7	<1.0			<1.0				15
pH	8.6	6.9	8.3	7.3	8.2	8.3	7.9	7.9	6.5-8.5
Phosphorus, Dissolved Orthophosphate mg/L		0.009	0.02	0.06	0.008		0.006	0.008	
Total mg/L	1.79	3.08	0.41	1.59	0.08	0.04	0.26	0.17	2
Total Dissolved mg/L						0.007			

TABLE 29 continued

WATER QUALITY OF OPEN CUT CREEK MEASURED BY THE PROVINCE

Parameter / Date	May 13 1975	June 3 1975	July 1 1975	July 3 1975	July 22 1975	August 14 1975	May 27 1976	June 2 1976	Level A Mining Objectives
Solids, Dissolved mg/L	112	234	156	160	194	200	244	240	2,500
Suspended mg/L	1,846	4,188	572	3,838	68	32	282	233	50
Turbidity J.T.U.	1,400	1,350	272	1,020	44	24	128	110	
Vanadium, Total mg/L					0.006	0.003			
Zinc, Dissolved mg/L						0.006	0.009	0.01	0.5
Total mg/L	0.25	0.34	0.12	0.54	0.04	0.02	0.06	0.11	

TABLE 30

SUSPENDED SOLIDS AND TURBIDITY IN OPEN CUT CREEK IN

1975-76

Date	Turbidity J.T.U.	Suspended Solids mg/L	Flow m^3/s	Suspended* Solids Loading t/d
May 13, 1975	1,400	1,846		
June 3, 1975	1,350	4,188		
July 1, 1975	272	572		
July 3, 1975	1,020	3,838	0.06	21
July 22, 1975	44	68	0.03	0.18
August 14, 1975	24	32		
April 9, 1976	1,000	2,786	0.06	14
May 4, 1976**	3,000	6,362	0.11	67
	608	1,008	0.06	
May 11, 1976**			0.31	331
	850	1,662	0.06	
May 18, 1976	156	424	0.11	4.2
May 27, 1976	128	282	0.07	1.7
June 2, 1976	110	233	0.31	6.3
June 9, 1976	104	228	0.05	1.0
June 16, 1976	68	158	0.06	0.8

* Suspended Solids Loading = mg/L x m^3/s x 0.086 t/d

**Open Cut Creek split into two or more channels

TABLE 31

COLEMAN COLLIERIES LTD.

ANALYSIS OF RUNOFF FROM SPOIL PILE ON TENT MOUNTAIN, 1975

Parameter \ Date		May 14	June 3	July 1	July 22	Aug. 19	Level A*
Alkalinity, Total	mg/L	132	81	86	105	127	
Carbon, Total Organic	mg/L		5	1	7	2	
Copper, Dissolved	mg/L	<0.001					0.05
Total	mg/L		0.003	<0.001	0.003	<0.001	
Flow Rate m^3/s					0.03		
Iron, Dissolved	mg/L	<0.10				<0.1	0.3
Total	mg/L		0.2	0.2	0.6	0.1	
Lead, Dissolved	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	0.05
Manganese, Dissolved	mg/L	<0.02	<0.02	0.03	<0.02	<0.02	0.05
Nitrogen, Nitrite + Nitrate	mg/L	<0.02	<0.02	<0.02	0.27	0.13	10
Oil and Grease	mg/L		<1.0		<1.0	<1.0	15
pH		7.9	8.2	8.5	8.4	8.5	6.5-8.5
Phenol	mg/L	0.003					0.2**
Phosphorus, Total	mg/L	0.068	0.032	0.032	0.045	0.026	2
Total Dissolved	mg/L		0.022	0.022		0.017	
Solids, Dissolved	mg/L	156	140	126	218	244	2500
Suspended	mg/L	42	6	10	24	4	50
Turbidity J.T.U.		5.8	3.2	5.0	9.1	3.0	
Vanadium, Total	mg/L				0.003	<0.001	
Zinc, Dissolved	mg/L	<0.005	<0.005			<0.005	0.5
Total	mg/L			<0.005	0.03	<0.005	

* Pollution Control Objectives for Mining, Mine-milling, and Smelting Industries of British Columbia, December 1973.

** Pollution Control Objectives for the Chemical and Petroleum Industries of British Columbia, March 1974.

TABLE 32

SUSPENDED SOLIDS AND TURBIDITY MEASUREMENTS IN MICHEL CREEK

Site \ Date	May 13-14 1975	June 3 1975	July 1 1975	July 22 1975	August 14 1975
Upstream Open Cut Cr. (0200184)	42 17	68 20	6 2.2	2 0.7	2 0.6
→ Open Cut Cr. (AE-3957)	1846 1400	4188 1350	572 272	68 0.04 44 0.2	32 24
→ Unnamed Cr. Adjacent to Open Cut Cr.					
Downstream Open Cut Cr. (1190001)	138 76	196 52	12 6.3		
→ Corbin Creek (0200209)					6 0.6
Downstream Corbin Creek (1190031)				4 0.9	4 1.0
Upstream Coleman Collieries (0200185)	62 13	76 22	12 4	2 0.5	
→ Coleman Collieries Runoff (AE-3986)	42 5.8	6 3.2	10 5	24 9.1 1.0	
Downstream Coleman Collieries (0200186)	52 18	98 28	10 5.3	2 0.5	2 0.5
→ Unnamed Creek From Tent Mtn. Pass	394 160				
Upstream Leach Creek → Leach Creek Downstream Leach Cr. Upstream Wheeler Cr. Downstream Wheeler Cr. Upstream McGillivray Downstream McGillivray Upstream Alexander Cr. → Alexander Creek → Fir Creek					
Upstream Erickson Creek (0200203)					2 0.8
→ Erickson Creek			Clear		
Upstream Michel (0200046)	104 35				
→ Coke Lagoon Discharge → Baldy Creek					
Downstream Kaiser Resources (0200025)	118 34				4 1.1

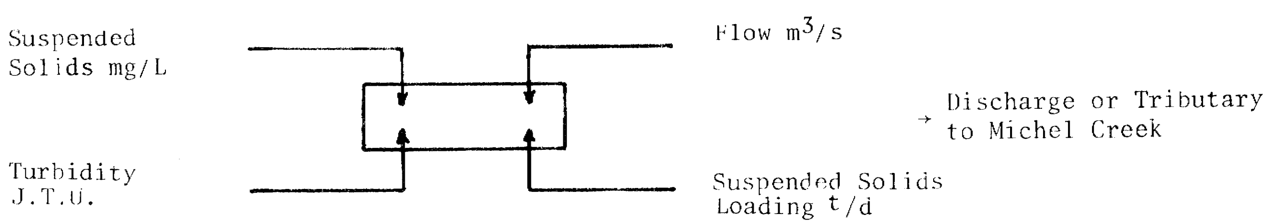


TABLE 32 continued

SUSPENDED SOLIDS AND TURBIDITY MEASUREMENTS IN MICHEL CREEK

Date / Site	April 8-9 1976		May 4 1976		May 11 1976		May 12 1976	
Upstream Open Cut Cr. (0200184)	12 4.8		34 12		122 27			
→ Open Cut Cr. (AE-3957)	2786 1000	0.06 14	6362 3000	0.11 62	12000 5200	0.312 322		
→ Unnamed Cr. Adjacent to Open Cut Cr.			1008 608	0.06 52	1662 850	0.07 9.1		
Downstream Open Cut Cr. (1190001)	190 42		346 136					
→ Corbin Creek (0200209)	30 51		34 13		36 10			
Downstream Corbin Creek (1190031)	132 38		182 72		230 54			
Upstream Coleman Collieries (0200185)	64-754 22-440		134 46		150 56			
→ Coleman Collieries Runoff (AE-3986)			68 38	0.14 0.8	Clear		Clear	
Downstream Coleman Collieries (0200186)	88 33		134 46		220 74			
→ Unnamed Creek From Tent Mtn. Pass			4203 1120	0.40 143			204 74	0.54 9.1
Upstream Leach Creek	100 40		222 62				112 32	
→ Leach Creek	24 5.9		40 11				50 18	
Downstream Leach Cr. Upstream Wheeler Cr.	108 32		100 36				78 26	
Downstream Wheeler Cr. Upstream McGillivray			128 40				92 33	
Downstream McGillivray Upstream Alexander Creek	296 116							
→ Alexander Creek							94 22	
→ Fir Creek								
Upstream Erickson Creek (0200203)	232 116							
Erickson Creek							34 10	
Upstream Michel (0200046)	142 62	9.51 117	128 42	49.4 547			98 36	76.1 645
→ Coke Lagoon Discharge	948 700	0.11 9.2	134	0.11 1.3			132	0.2 2.3
→ Baldy Creek	4426 1400	0.71 270	732 260	0.85 53			96 32	0.85 7.0
Downstream Kaiser Resources (0200025)	422 124	10.3 377	174 42	50.4 758	522 120		164 42	77.0 1090

TABLE 32 continued

SUSPENDED SOLIDS AND TURBIDITY MEASUREMENTS IN MICHEL CREEK

Site \ Date	May 18 1976		May 27 1976		June 2 1976		June 9 1976		June 16 1976	
Upstream Open Cut Cr. (0200184)	28 8.2		10 6.6		6 3.9		8 6.9		6 3.1	
→ Open Cut Cr. (AE-3957)	424 156	0.11 4.2	282 128	0.08 1.7	233 110	0.31 6.2	228 104	0.05 1.0	158 68	0.07 0.8
→ Unnamed Cr. Adjacent to Open Cut Cr.										
Downstream Open Cut Cr. (1190001)	62 16		94 29		26 10		38 12		36 13	
→ Corbin Creek (0200209)	 12		4 1.5		4 1.5		4 1.2		4 1.6	
Downstream Corbin Creek (1190031)	60 13		54 20		8 4.2		16 7.2		10 6.3	
Upstream Coleman Collieries (0200185)	32 10		26 11		14 6.6		16 6.3		8 4.4	
→ Coleman Collieries Runoff (AE-3986)	28 11	0.05 0.09	Clear		Clear		Clear		Clear	
Downstream Coleman Collieries (0200186)			36 12		16 6.9		32 8.6		10 5.2	
→ Unnamed Creek From Tent Mtn. Pass	68 21	0.31 1.8	142 40	0.21 2.6	14 6.4	0.14 0.2	10 3.9	0.13 0.09		
Upstream Leach Creek	50 13		44 16		14 6		52 10		12 4.2	
→ Leach Creek	14 7.7		8 4		12 4.1		14 6.8		6 2.6	
Downstream Leach Cr. Upstream Wheeler Cr.	24 9.6		22 10		8 5.5		20 9.5		 3.4	
Downstream Wheeler Cr. Upstream McGillivray	36 10		40 14		14 6.4		28 10		8 4.8	
Downstream McGillivray Upstream Alexander Cr.										
→ Alexander Creek	26 8.3									
→ Fir Creek					190 130	1.36 23	28 11	0.79 1.9	Clear	
Upstream Erickson Cr. (0200203)					20 10					
→ Erickson Creek	Clear									
Upstream Michel (0200046)	42 13		22 10		14 6.6		34 10		8 4.6	
→ Coke Lagoon Discharge	32 21	0.14 0.3	12 11	0.08 0.09	24 15.4	0.08 0.2	8 6.3	0.08 0.09	22 17	0.08 0.2
→ Baldy Creek	60 17	0.34 1.7	26 10	0.24 0.3	10 6.6	0.18 0.2	10 4.1	0.13 0.19	14 4.6	0.1 0.2
Downstream Kaiser Resources (0200025)	66		30 10		12 6.6		30 13		10 5	

TABLE 33

DESIGN FACTORS FOR ERICKSON AND HARMER CREEK SETTLING PONDS[68]

			Erickson	Harmer
Drainage Area	km^2		25.9	40.1
Design Flow	m^3/s		3.14	4.87
Surface Area	m^2		49,300	19,400
Volume	m^3	design	92.9×10^3	88.9×10^3
		1974		83.8×10^3
		1975		59.4×10^3
		1976		58.0×10^3
		1977		55.7×10^3
Mean Depth (Volume/Surface Area), m		design	1.8	4.6
		1974		4.3
		1975		3.0
		1976		3.0
		1977		2.7
Retention Time (Volume/Design Flow), h		design	8.2	5.1
		1974		4.8
		1975		3.4
		1976		3.3
		1977		3.2
Overflow Rate (Design Flow/Surface Area), cm/s			64×10^{-4}	251×10^{-4}
Smallest Particle Removed at Design Flow (From Stoke's Law, Assuming Specific Gravity = 2.65, Water Temperature = 0^oC)	mm		0.01	0.02

TABLE 34

ANALYSIS OF MICHEL COKE PLANT SETTLING POND EFFLUENT, CARRIED OUT BY THE PROVINCE IN 1975-76

Parameter \ Type of Value		Max.	Min.	Mean	No. of Values	Effluent Quality Objectives* A	B	C
Alkalinity, Total	mg/L	286	183	230	8			
BOD_5	mg/L	<30	<10	20	4	20	45	130
Carbon, Total Organic	mg/L	710	8	165	7			
COD	mg/L	1740	26	374	8			
Colour, True		100	10	42	4			
Conductance, Specific	µmhos/cm	991	286	604	20			
Cyanide, Total	mg/L	0.03	<0.01	0.01	20	0.1	0.5	2.0
Flow Rate	m^3/s	0.08	0.01	0.03	12			
Nitrogen, Ammonia	mg/L	58.5	0.39	16.2	19	0.5	1.0	10.0
Oil and Grease	mg/L	1.7	<1	1.4	4	15	15	15
pH		8.7	7.3	8.0	31	6.5-8.5	6.5-9.5	6-10
Phenol, Total	mg/L	34.4	0.03	7.5	19	0.2	0.3	1.0
Solids, Dissolved	mg/L	431	186	310	4	<2500	<3500	<5000
Suspended	mg/L	1338	40	271	15	50	150	
Sulphate, Dissolved	mg/L	73	27	54	4	50	250	1000
Sulphide, Total	mg/L	<0.5	<0.5	<0.5	14	0.1	0.1	1.0
Temperature	°C	15	0		15			
Turbidity	J.T.U.	960	13	122	13			
Vanadium, Total	mg/L	<0.001	<0.001	<0.001	1			

*Pollution Control objectives for the mining, mine-milling, and smelting industries of British Columbia, December 1973 and Pollution Control objectives for the chemical and petroleum industries of British Columbia, March 1974.

TABLE 35

SUSPENDED SOLIDS AND TURBIDITY MEASURED IN THE
MICHEL COKE PLANT SETTLING POND EFFLUENT
BY THE PROVINCE IN 1975-76

DATE	TURBIDITY J.T.U.	SUSPENDED SOLIDS mg/L	FLOW m^3/s	SUSPENDED* SOLIDS LOADING t/d
Nov. 17, 1975	110	86	0.01	0.05
Nov. 27, 1975	29	52	0.01	0.03
Dec. 11, 1975	66	97	0.01	0.09
Dec. 18, 1975	13	47	0.01	0.05
Jan. 13, 1976	15	40	0.01	0.02
Jan. 21, 1976	21	76	0.01	0.05
Jan. 29, 1976	32	121	0.01	0.18
Feb. 5, 1976	32	65	0.01	0.03
Feb. 12, 1976	18	142	0.01	0.07
March 18, 1976	960	1338	0.05	6.3
March 25, 1976	80	105	0.02	0.18
April 8, 1976	700	948	0.11	9
May 4, 1976		134	0.11	1.3
May 12, 1976		132	0.20	2.3
May 18, 1976	21	32	0.14	0.36
May 24, 1976	26	28	0.14	0.36
May 27, 1976	11	12	0.08	0.09
June 2, 1976	15.5	24	0.08	0.18
June 9, 1976	6.3	8	0.08	0.05
June 16, 1976	17	22	0.08	0.18

*Suspended Solids Loading = mg/L x m^3/s x 0.086 t/d

TABLE 36

WATER QUALITY OF BALDY CREEK (SITE 0200112)
MEASURED BY THE PROVINCE IN 1975-76

Parameter / Date	Turbidity J.T.U.	Suspended Solids mg/L	Flow m^3/s	Suspended* Solids Loading t/d
Oct. 16, 1975	8.7	18		
Jan. 26, 1976	5.2	24		
April 7, 1976		1,431		
April 8, 1976	1,400	4,426	0.71	270
May 4, 1976	260	732	0.85	53
May 12, 1976	32	96	0.85	7.0
May 18, 1976	17	60	0.34	1.7
May 24, 1976	17	46	0.24	0.90
May 27, 1976	10	26	0.17	0.36
June 2, 1976	6.6	10	0.18	0.18
June 9, 1976	4.1	10	0.13	0.09
June 16, 1976	4.6	14	0.11	0.18
July 26, 1976	2.1	6		
Dec. 7, 1976	2.2	6		

*Suspended Solids Loading = mg/L x m^3/s x 0.086 t/d

Parameter / Type of Value	Max.	Min.	Mean	No. Of Values
Alkalinity, Total mg/L	132	75	103	3
Carbon, Total Organic mg/L	197	3	42	5
Coliforms, Fecal MPN/100 mL	<200	<2		3
Nitrogen, Nitrite+Nitrate mg/L	0.56	<0.02	0.18	5
pH	8.7	7.9	8.3	8
Solids, Dissolved mg/L	330	268	296	5

TABLE 37

WATER QUALITY OF UNNAMED CREEK FROM TENT MOUNTAIN PASS, MEASURED BY THE PROVINCE IN 1975-76

Date	Turbidity J.T.U.	Suspended Solids mg/L	Flow m^3/s	Suspended* Solids Loading t/d
May 13, 1975	160	394		
May 4, 1976	1,120	4,203	0.40	143
May 12, 1976	74	204	0.54	9.1
May 18, 1976	21	68	0.31	1.8
May 27, 1976	40	142	0.22	2.6
June 2, 1976	6.4	14	0.14	0.18
June 9, 1976	3.9	10	0.13	0.09

*Suspended Solids Loading = mg/L x m^3/s x 0.086 t/d

Parameter	Date	May 13, 1975
Alkalinity, Total	mg/L	77
Carbon, Total Organic	mg/L	10
Copper, Total	mg/L	0.01
Iron, Total	mg/L	11.0
Lead, Dissolved	mg/L	<0.001
Manganese, Dissolved	mg/L	<0.02
Nitrogen, Nitrite+Nitrate	mg/L	0.04
Oil and Grease	mg/L	1.4
pH		8.6
Phosphorus, Total	mg/L	0.62
Solids, Dissolved	mg/L	108
Suspended	mg/L	394
Turbidity	J.T.U.	160
Zinc, Total	mg/L	0.05

TABLE 38

WATER QUALITY DATA COLLECTED FROM MICHEL CREEK AND CORBIN CREEK BY THE PROVINCE IN 1975-76

GENERAL PARAMETERS

Parameter (Site)		0200184 Max.	Min.	Mean	No. of Values	0200208 & 119001 Max.	Min.	Mean	No. of Values
Alkalinity, Total	mg/L	139	69	106	10	133	70	101	9
Carbon, Total Organic	mg/L	3	<1	1.7	13	17	<1	5.8	13
Colour, True		20	<5	7.5	12	40	<5	13.3	9
Nitrogen, Ammonia	mg/L	0.012	<0.005	0.007	12	0.019	<0.005	0.008	10
Nitrite+Nitrate	mg/L	0.04	<0.02	0.02	13	0.07	<0.02	0.03	12
Organic	mg/L	0.22	<0.01	0.07	12	0.39	0.02	0.14	9
Total	mg/L	0.23	<0.02	0.09	12	0.48	0.02	0.16	9
Oil and Grease	mg/L	1.2	<1	1.0	6			<1	1
pH		8.8	7.9	8.2	23	8.6	7.9	8.2	8
Phosphorus, Dissolved Orthophosphate	mg/L	0.009	0.003	0.006	12	0.013	0.005	0.007	9
Total	mg/L	0.11	0.007	0.03	13	0.19	0.011	0.06	13
Total Dissolved	mg/L	0.01	0.007	0.008	4	0.011	0.008	0.009	3
Solids, Dissolved	mg/L	160	86	122	13	160	92	127	13
Suspended	mg/L	68	2	15	13	208	2	58	13
Sulphate, Dissolved	mg/L	12.6	<5	8	12	14.8	5.9	10.6	9
Turbidity	J.T.U.	20	0.4	5.0	13	76	1.6	21.3	13

TABLE 38 continued

WATER QUALITY DATA COLLECTED FROM MICHEL CREEK AND CORBIN CREEK BY THE PROVINCE IN 1975-76

GENERAL PARAMETERS

Parameter / Site		0200209 Max.	0200209 Min.	0200209 Mean	0200209 No. of Values	1190031 Max.	1190031 Min.	1190031 Mean	1190031 No. of Values
Alkalinity, Total	mg/L	190	154	175	8	143	128	136	2
Carbon, Total Organic	mg/L	240	<1	28	11	2	<1	1.5	2
Colour, True		20	<5	7.5	10				
Nitrogen, Ammonia	mg/L	0.052	<0.005	0.012	10				
Nitrite+Nitrate	mg/L	0.07	<0.02	0.04	11	<0.02	<0.02	<0.02	2
Organic	mg/L	6.95	<0.01	0.76	10				
Total	mg/L	7.0	<0.02	0.81	10				
Oil and Grease	mg/L	<1	<1	<1	3				
pH		8.6	8.0	8.3	18	8.3	8.1	8.2	2
Phosphorus, Dissolved Orthophosphate	mg/L	0.008	0.003	0.005	10				
Total	mg/L	1.44	0.006	0.19	11	0.015	0.009	0.012	2
Total Dissolved	mg/L	0.029	0.006	0.018	2	0.008	0.007	0.008	2
Solids, Dissolved	mg/L	230	162	200	11	4	4	4	2
Suspended	mg/L	1472	2	183	11	170	152	161	2
Sulphate, Dissolved	mg/L	12.9	7.5	10.6	10				
Turbidity	J.T.U.	440	0.3	70	11	1.0	0.9	1.0	2

TABLE 39

WATER QUALITY DATA COLLECTED FROM MICHEL CREEK AND CORBIN CREEK BY THE PROVINCE IN 1975-76

METALS AND TOXIC MATERIALS IN μg/L

Parameter \ Site	0200184				0200208 & 1190001			
	Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values
Arsenic, Total					<5	<5	<5	1
Copper, Total	2	<1	1	5	10	<1	4	4
Iron, Total	1,600	<100	653	5	4,400	200	2,175	4
Lead, Dissolved	<1	<1	<1	5	<1	<1	<1	4
Manganese, Dissolved	<20	<20	<20	4	<20	<20	<20	4
Nickel, Dissolved					<10	<10	<10	1
Phenol, Total	<2	<2	<2	6			<2	1
Surfactant, Dissolved	<30	<30	<30	1				
Total	<30	<30	<30	4				
Zinc, Total	5	<5	5	5	30	<5	17.5	4

TABLE 39 continued

WATER QUALITY DATA COLLECTED FROM MICHEL CREEK AND CORBIN CREEK BY THE PROVINCE IN 1975-76

METALS AND TOXIC MATERIALS IN μg/L

Site / Parameter	0200209				1190031			
	Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values
Arsenic, Total					<1	<1	<1	1
Copper, Total	18	<1	10	2	<1	<1	<1	2
Iron, Total	13,800	<100	6,950	2	200	<100	150	2
Lead, Dissolved	<1	<1	<1	2	<1	<1	<1	2
Manganese, Dissolved	<20	<20	<20	2	<20	<20	<20	2
Phenol, Total	<2	<2	<2	2				
Surfactant, Dissolved								
Total	<30	<30	<30	1				
Zinc, Total	90	<5	48	2	20	<5	12	2

TABLE 40

WATER QUALITY DATA COLLECTED FROM MICHEL CREEK BY THE PROVINCE IN 1975-76

GENERAL PARAMETERS

Site / Parameter		0200185				0200186			
		Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values
Alkalinity, Total	mg/L	154	92	118	10	154	92	127	12
Carbon, Total Organic	mg/L	33	<1	4.6	14	16	<1	3.5	14
Colour, True		20	<5	8.1	13	20	<5	8.6	14
Nitrogen, Ammonia	mg/L	0.02	<0.005	0.008	13	0.018	<0.005	0.007	15
Nitrite+Nitrate	mg/L	0.08	<0.02	0.05	13	0.08	<0.02	0.05	15
Organic	mg/L	0.47	<0.01	0.12	13	0.38	<0.01	0.12	15
Total	mg/L	0.52	0.02	0.18	13	0.44	<0.02	0.17	15
Oil and Grease	mg/L	1.8	<1	1.1	6	1.3	<1	1.1	6
pH		8.7	7.9	8.2	24	8.7	8.0	8.2	26
Phosphorus, Dissolved Orthophosphate	mg/L	0.009	0.003	0.005	13	0.009	0.003	0.005	15
Total	mg/L	0.12	0.005	0.04	14	0.12	0.006	0.04	15
Total Dissolved	mg/L	0.008	0.005	0.007	4	0.008	0.007	0.008	2
Solids, Dissolved	mg/L	178	106	139	14	182	110	145	15
Suspended	mg/L	130	2	35	14	156	2	38	15
Sulphate, Dissolved	mg/L	14.5	<5	9.2	12	14.5	<5	9.4	15
Turbidity	J.T.U.	42	0.5	12.1	14	44	0.4	13.1	15

TABLE 40 continued

WATER QUALITY DATA COLLECTED FROM MICHEL CREEK BY THE PROVINCE IN 1975-76

GENERAL PARAMETERS

Site / Parameter		0200203 Max.	0200203 Min.	0200203 Mean	0200203 No. of Values	0200098 Max.	0200098 Min.	0200098 Mean	0200098 No. of Values
Alkalinity, Total	mg/L	129	104	112	3	160	66	118	6
Carbon, Total Organic	mg/L	2	<1	1.5	2	7	4	5.7	3
Colour, True						30	<5	12	6
Nitrogen, Ammonia	mg/L	0.006	<0.005	0.006	2	0.012	<0.005	0.008	2
Nitrite+Nitrate	mg/L	<0.02	<0.02	<0.02	2	0.09	0.04	0.06	3
Organic	mg/L								
Total	mg/L								
Oil and Grease	mg/L								
pH		8.4	8.1	8.2	4	9.1	7.8	8.4	12
Phosphorus, Dissolved Orthophosphate	mg/L								
Total		0.016	0.012	0.014	2	0.23	0.03	0.14	3
Total Dissolved	mg/L	0.012	0.009	0.01	2	0.027	0.016	0.022	2
Solids, Dissolved	mg/L	154	118	136	2	188	84	141	6
Suspended	mg/L	4	2	3	2	102	2	29	5
Sulphate, Dissolved	mg/L								
Turbidity	J.T.U.	0.8	0.8	0.8	2	42	0.2	14.7	6

TABLE 41

WATER QUALITY DATA COLLECTED FROM MICHEL CREEK BY THE PROVINCE IN 1975-76

METALS AND TOXIC MATERIALS IN μg/L

Site / Parameter	0200185				0200186			
	Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values
Arsenic, Dissolved					<5	<5	<5	1
Cadmium, Total					<0.5	<0.5	<0.5	1
Copper, Total	<1	<1	<1	5	1	<1	1	4
Cyanide, Dissolved								
Iron, Total	1500	<100	680	5	1800	<100	950	4
Lead, Dissolved	<1	<1	<1	5	<1	<1	<1	3
Total					<1	<1	<1	1
Manganese, Dissolved	<20	<20	<20	5	<20	<20	<20	3
Phenol, Total	3	<2	2	6	12	<2	3	7
Surfactant, Dissolved					250	250	250	1
Total	<30	<30	<30	5	<30	<30	<30	5
Vanadium, Total								
Zinc, Total	30	<5	10	5	6	<5	5	4

TABLE 41 continued

WATER QUALITY DATA COLLECTED FROM MICHEL CREEK BY THE PROVINCE IN 1975-76

METALS AND TOXIC MATERIALS IN μg/L

Site / Parameter	0200203				0200098			
	Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values
Arsenic, Dissolved								
Cadmium, Total								
Copper, Total								
Cyanide, Dissolved	<10	<10	<10	2	<10	<10	<10	3
Iron, Total								
Lead, Dissolved								
Total								
Manganese, Dissolved								
Phenol, Total	<2	<2	<2	2	3	<2	2	3
Surfactant, Dissolved					70	70	70	1
Total					<30	<30	<30	5
Vanadium, Total	<1	<1	<1	1				
Zinc, Total	<5	<5	<5	2	30	9	20	3

TABLE 42

WATER QUALITY DATA COLLECTED FROM MICHEL CREEK BY THE PROVINCE IN 1975-76

GENERAL PARAMETERS

Parameter \ Site	0200046				1190041				0200025			
	Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values
Alkalinity, Total mg/L	159	70	125	27	115	71	93	4	176	75	136	28
Carbon, Total Organic mg/L	24	<1	3.8	22	10	<1	5.7	3	36	<1	7.0	23
Coliforms, Fecal MPN/100mL	<20	<2		5					94	2	29	16
Colour, True	40	<5	9.3	23					50	<5	11.3	26
Nitrogen, Ammonia mg/L	0.027	<0.005	0.01	27	0.06	0.027	0.04	3	0.26	0.012	0.06	37
Nitrite+Nitrate mg/L	0.19	0.02	0.09	24	0.13	0.02	0.07	4	0.28	0.02	0.14	26
Organic mg/L	0.56	<0.01	0.13	22					1.0	0.01	0.2	25
Total mg/L	0.65	0.02	0.23	22					1.3	0.07	0.39	25
Oil and Grease mg/L	3.9	<1	1.3	20					3.9	<1	1.4	22
pH	9.0	8.0	8.3	52	8.7	8.3	8.5	4	8.6	7.9	8.2	67
Phosphorus, Dissolved Orthophosphate mg/L	0.021	0.003	0.01	24					0.021	<0.003	0.01	26
Total mg/L	0.25	0.007	0.05	24	0.21	0.011	0.10	4	0.23	0.004	0.06	26
Total Dissolved mg/L	0.024	0.008	0.016	3	0.023	0.007	0.016	3	0.022	0.004	0.012	4
Solids, Dissolved mg/L	198	88	148	25	130	90	114	4	220	98	158	26
Suspended mg/L	172	<1	29	25	164	2	66	4	429	1	47	37
Sulphate, Dissolved mg/L	19.6	5.4	13.2	23					21.6	5.6	14.4	24
Turbidity J.T.U.	108	0.2	13.2	27	46	0.6	20.5	4	216	0.1	17.7	37

TABLE 43

WATER QUALITY DATA COLLECTED FROM MICHEL CREEK BY THE PROVINCE IN 1975-76

METALS AND TOXIC MATERIALS IN µg/L

Site / Parameter	0200046				1190041				0200025			
	Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values
Cyanide, Dissolved	<10	<10	<10	4	40	<10	18	4	<10	<10	<10	6
Total	<10	<10	<10	5					<10	<10	<10	18
Iron, Total	3330	3330	3330	1	300	<100	200	2	2700	<100	1120	5
Phenol, Total	7	<2	2	24	29	5	15	4	64	<2	15	35
Sulphate, Total	<500	<500	<500	3					<500	<500	<500	12
Surfactant, Dissolved	180	180	180	1					290	290	290	1
Total	<30	<30	<30	8					<300	<30		10
Vanadium, Total									<1	<1	<1	1
Zinc, Total	9	<5	7	3								

TABLE 44

RESULTS OF SEDIMENT TRAP SAMPLING IN MICHEL CREEK, APRIL-JULY 1976

Parameter \ Site	0200184				0200185				0200186				0200025		
	A	B	C	Mean	A	B	C	Mean	A	B	C	Mean	A	B	Mean
Total Dry Weight, g	8222	8846	8968	8679	8524	4998	6624	6715	5534	6954	3683	5390	9006	5149	7078
Weight Finer than 2.38 mm, g	1297	1340	1032	1223	1499	1134	1578	1404	1702	2169	1211	1694	2466	2024	2245
Percentage of Total Weight Finer than 2.38 mm	15.8	15.1	11.5	14.1	17.6	22.7	23.8	21.4	30.8	31.2	32.9	31.6	27.4	39.3	33.4
Percentage Finer than*:															
2.38 mm	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
0.59 mm	63.4	51.3	45.7	53.5	73.4	75.7	71.9	73.7	62.0	50.7	53.3	55.3	42.4	35.6	39.0
0.297 mm	43.8	30.6	30.0	34.8	53.6	47.3	53.5	51.5	31.9	28.8	27.9	29.5	24.6	17.8	21.2
0.149 mm	23.4	14.9	17.9	18.7	30.2	22.9	32.2	28.4	14.3	15.6	10.9	13.6	15.7	10.4	13.0
0.074 mm	9.8	6.8	9.1	8.6	13.9	9.7	13.0	12.2	5.8	5.7	2.8	4.8	6.7	5.1	5.9

*Particle-size analysis of portion of sample finer than 2.38 mm.

TABLE 45

RESULTS OF FREEZE-CORE SEDIMENT SAMPLING IN MICHEL CREEK, JULY 1976

Site / Parameter	0200184				0200208			0200185	0200208 and 0200185
	A	B	C	Mean	A	B	Mean	A	Mean
Total Dry Weight, kg	16.433	19.074	14.221	16.576	19.711	16.865	18.288	17.598	18.058
Percentage finer than:									
50.8 mm	59.8	54.7	75.8	63.4	54.9	73.0	64.0	50.0	59.3
12.7 mm	30.0	29.8	43.2	34.3	27.8	38.1	33.0	18.9	28.3
4.76 mm	23.2	18.3	28.9	23.5	17.6	26.0	21.8	12.8	18.8
2.38 mm	18.8	11.3	20.0	16.7	11.6	18.9	15.2	9.8	13.4
0.59 mm	5.6	5.9	8.0	6.5	5.1	7.2	6.2	5.2	5.8
0.297 mm	3.1	4.0	5.1	4.1	3.1	4.4	3.8	3.8	3.8
0.149 mm	2.1	2.4	3.1	2.5	2.0	2.9	2.4	3.0	2.6
0.074 mm	1.4	1.0	1.5	1.3	1.1	1.8	1.4	1.8	1.6

TABLE 46

PARTICLE SIZE DISTRIBUTION AND CHEMICAL COMPOSITION OF SEDIMENT GRAB SAMPLES

FROM MICHEL CREEK, AUGUST, 1975

	Percentage Finer Than							
Sieve Number	16	30	50	100	140	200	270	400
Size (mm) / Site	1.19	0.59	0.297	0.149	0.105	0.074	0.053	0.037
0200184	58.9	19.4	3.6	2.0	1.8	1.2	0.8	0.2
1190031	86.9	74.2	59.2	42.3	38.9	26.5	20.1	12.7
1190029	94.5	88.3	76.6	50.6	43.6	21.7	14.7	8.5
0200203	78.5	38.5	16.3	7.2	6.0	2.7	1.8	1.0
0200025	96.7	70.5	22.6	7.6	6.1	2.6	1.8	1.0

Parameter / Site	Carbon Total mg/g	Carbon Organic mg/g	Nitrogen Kjeldahl mg/g	Phosphorus Total mg/g	Arsenic μg/g	Cadmium μg/g	Chromium μg/g	Iron μg/g	Lead μg/g	Mercury μg/g	Zinc μg/g
0200184	10.0	1.6	0.81	1.49							
1190031	287.0	134.0	5.12	0.74							
1190029	54.0	36.2	5.13	1.31							
0200203	21.0	12.9	0.45	1.52	0.003	1.0	13.5	24.5	20.0	0.08	87.0
0200025	41.0	28.5	0.75	1.17	0.002	0.8	13.0	18.1	20.0	0.07	75.6

TABLE 47

GENERAL OBSERVATIONS OF THE INVERTERATE SAMPLING SITES IN MICHEL CREEK, AND RESULTS FROM SAMPLING PERIPHYTON IN THE CREEK, AUGUST, 1975

Site	Flow and Velocity	Bottom	Field Observations	Dominant Algae	Ash Free Dry Wt. mg
0200184	Fast 0.9 m/s	Small cobbles	Clean rocks	Nostoc	14.0
1190031	Medium 0.3 m/s	Small cobbles, some isolated pockets of black sediment (coal dust).	Coal dust pockets, Nostoc present	Nostoc	2.0
1190029	Fast 0.5 m/s	Large cobbles, tightly packed, algae on rocks.	Some rocks covered with moss - Fontinalis, Prasiola and Nostoc present	Prasiola ?	13.0
0200203	Medium 0.4 m/s	Large cobbles, algae on rocks.	Old diatoms and new Nostoc present	Nostoc and Diatoms.	6.0
0200025	Medium 0.3 m/s	Large cobbles, much black sediment on bottom, water very turbid (black).	Lots of coal dust, little algae.	Unidentified green colony.	10.0

TABLE 48

BENTHIC INVERTEBRATE COUNTS IN MICHEL CREEK

(EACH NUMBER IS THE TOTAL OF 3 REPLICATE SAMPLES)

Class, Order or Family \ Site	0200184 Control Upstream of Mining Operations	1190031 Downstream from Byron Creek Collieries	1190029 Downstream from Coleman Collieries	0200203 Upstream from Kaiser Resources	0200025 Downstream from Kaiser Resources
Turbellaria	1	20	21	22	21
Nematoda	7	4	32	9	38
Oligochaeta	5	2	4	16	82
Crustacea					
Ostracoda	6		3	3	
Copepoda					5
Arachnida					
Acarina	46	29	110	37	72
Insecta					
Collembola		1	1		
Hymenoptera			2		
Coleoptera	199	57	96	10	5
Ephemeroptera*	3334	2624	1186	3441	3381
Plecoptera*	534	113	411	527	180
Trichoptera*	271	96	117	84	45
Diptera					
Tipulidae	12	2	4	3	3
Tanyderidae			2		
Simuliidae	3	2	1	32	4
Heleidae	12	3	58	14	14
Dolichopodidae	2				
Empididae	4		24	6	101
Adult Diptera	3	1	2	3	5
Chironomidae	339	218	851	448	4393

*Numbers of individuals of the genera in these orders shown in Figures 14 and 15.

TABLE 49

DIVERSITY AND REDUNDANCY INDICES FOR BENTHIC INVERTEBRATES COLLECTED IN MICHEL CREEK

Site Number	Diversity Index	Redundancy Index
0200184	3.26	0.34
1190031	2.56	0.48
1190029	3.58	0.30
0200203	2.47	0.51
0200025	1.60	0.68

TABLE 50

ANALYSIS OF ELKVIEW PREPARATION PLANT, TAILING POND D SUPERNATANT, CARRIED OUT BY THE COMPANY AND THE PROVINCE IN 1975-76

Site Number		0225021				Level A Mining Objectives
Parameter \ Type of Value		Maximum	Minimum	Average	No. of Values	
Acidity (at pH 8.3)	mg/L	15	<0.5	3.2	11	
Alkalinity, Phenolphthalein	mg/L	15	<1	6	5	
Alkalinity, Total	mg/L	140	95	118	11	
Aluminum, Dissolved	mg/L	<0.5	<0.01	0.13	4	0.5
Total	mg/L	1.3	<0.01	0.27	5	
Arsenic, Dissolved	mg/L	<0.005	<0.005	<0.005	4	0.05
Total	mg/L	<0.005	<0.005	<0.005	5	
Carbon, Total Organic	mg/L	192	<1	55	6	
Chromium, Dissolved	mg/L	0.008	0.002	0.004	6	0.05
Copper, Dissolved	mg/L	0.017	<0.001	0.004	10	0.05
Total	mg/L	0.02	<0.001	0.006	5	
Iron, Dissolved	mg/L	<0.1	0.035		10	0.3
Total	mg/L	0.8	<0.1	0.3	5	
Lead, Dissolved	mg/L	0.01	<0.001	0.003	10	0.05
Total	mg/L	0.003	<0.001	0.001	5	
Manganese, Dissolved	mg/L	0.02	<0.02	0.02	5	0.05
Total	mg/L	0.02	<0.02	0.02	5	
Mercury, Dissolved	μg/L			<0.05	1	
Total	μg/L	<0.2	<0.05		10	1
pH		8.7	7.7	8.2	17	6.5 - 8.5
Solids, Dissolved	mg/L	402	173	239	11	<2500
Suspended	mg/L	394	12	111	11	50
Sulphate, Dissolved	mg/L	49	31	36	7	50
Zinc, Dissolved	mg/L	<0.005	<0.005	<0.005	5	0.5
Total	mg/L	0.04	<0.005	0.02	5	

TABLE 51

ANALYSIS OF GROUNDWATER BELOW THE ELKVIEW PREPARATION PLANT TAILING POND C, CARRIED OUT BY THE COMPANY AND THE PROVINCE IN 1975-76

Parameter \ Site	0200119 (EP-7)				0200120 (EP-8)				0200121 (EP-9)			
	Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values
Acidity: ph 8.3 mg/L	140	6	34	10	120	5	50	11	119	7	49	9
Alkalinity, Total mg/L	319	205	270	11	537	252	337	9	>600	247	349	8
Arsenic, Dissolved mg/L	0.012	<0.005	0.006	6	0.005	<0.005	0.005	6	<0.005	<0.005	<0.005	3
Carbon, Total Organic mg/L	29.2	9.0	14.8	5	55	22	39	5	116	22	59	5
Copper, Dissolved mg/L	0.011	<0.001	0.003	11	0.008	<0.001	0.002	10	0.015	<0.001	0.004	8
Iron, Dissolved mg/L	1.3	0.01	0.29	11	1.0	0.04	0.32	10	0.6	0.03	0.24	8
Lead, Dissolved mg/L	0.02	<0.001	0.003	11	0.02	<0.001	0.003	10	0.02	<0.001	0.004	8
Manganese, Dissolved mg/L	1.37	<0.02	0.64	6	2.5	1.0	1.5	5	2.0	0.25	1.0	3
Mercury, Dissolved µg/L	<0.05	<0.05	<0.05	2								
Total µg/L			<0.05	1			0.07	1			<0.05	1
pH	8.3	7.2	7.6	20	8.4	6.9	7.4	19	7.9	7.0	7.4	14
Solids, Dissolved mg/L	828	328	473	6	942	347	512	6	1,225	404	587	6
Suspended mg/L	215	82	130	5	1,090	93	756	5	693	223	441	5
Sulphate, Dissolved mg/L	134	32	65	7	68	38	56	7	272	52	116	6
Turbidity J.T.U.	40	14	27	2	187	14	99	3	102	66	84	2
Zinc, Dissolved mg/L	0.02	<0.005	0.008	7	0.02	<0.005	0.008	6	0.02	<0.005	0.009	4

TABLE 52

ANALYSIS OF GROUNDWATER BELOW THE ELKVIEW PREPARATION PLANT TAILING POND D, CARRIED OUT BY THE COMPANY AND THE PROVINCE IN 1975-76

Site / Parameter	0200158 (EP-16)				0200159 (EP-17)				0200160 (EP-18)			
	Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values
Acidity: ph 8.3 mg/L	100	<1	29	9	100	<0.5	28	10	120	<1	49	9
Alkalinity, Total mg/L	380	252	312	8	398	211	274	9	422	359	392	7
Arsenic, Dissolved mg/L	<0.005	<0.005	<0.005	5	<0.005	<0.005	<0.005	6	0.006	<0.005	0.005	5
Carbon, Total Organic mg/L	55	5	22	5	262	7	74	5	210	20	95	5
Copper, Dissolved mg/L	0.008	<0.001	0.002	9	0.011	<0.001	0.003	10	0.01	<0.001	0.003	9
Iron, Dissolved mg/L	2.1	0.04	0.74	9	0.6	0.04	0.2	10	7.6	0.03	2.9	9
Lead, Dissolved mg/L	0.024	<0.001	0.008	9	0.015	<0.001	0.004	10	0.026	<0.001	0.006	9
Manganese, Dissolved mg/L	1.62	0.58	1.0	4	1.43	0.56	0.82	5	0.76	0.46	0.58	4
Mercury, Dissolved µg/L			<0.05	1	<0.05	<0.05	<0.05	2			<0.05	1
Total µg/L			0.11	1			<0.05	1			<0.05	1
pH	8.0	7.2	7.5	16	8.4	7.1	7.7	18	7.7	7.0	7.3	16
Solids, Dissolved mg/L	866	253	468	6	554	381	452	6	1,075	512	713	6
Suspended mg/L	1,820	54	435	5	2,511	57	1,011	5	2,989	243	1,594	5
Sulphate, Dissolved mg/L	227	30	114	6	70	24	47	6	419	112	200	6
Turbidity J.T.U.	183	14	91	3	254	133	178	3	660	105	391	3
Zinc, Dissolved mg/L	<0.005	<0.005	<0.005	6	<0.005	<0.005	<0.005	6	0.02	<0.005	0.008	5

TABLE 53

ANALYSIS OF SURFACE WATER ABOVE AND BELOW THE ELKVIEW PREPARATION PLANT TAILING PONDS, CARRIED OUT BY THE COMPANY AND THE PROVINCE IN 1975-76

Site Number		0200118 (EP-10)				0200117 (EP-13)			
Site Description		Unnamed Stream, Upstream From Tailing Pond D				Otto Creek, Downstream From Ponds C and D			
Parameter	Type of Value	Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values
Acidity: ph 8.3	mg/L	1.1	<0.5	0.6	3	11	<0.5	3.6	8
Alkalinity, Total	mg/L	450	214	304	7	>250	213	232	11
Aluminum, Dissolved	mg/L					0.01	<0.01	0.01	5
Arsenic, Dissolved	mg/L	0.009	<0.005	0.006	5	0.01	<0.005	0.006	5
Total	mg/L					0.032	<0.005	0.018	2
Carbon, Total Organic	mg/L			8	1	65.6	1.4	17.6	5
Copper, Dissolved	mg/L	0.001	<0.001	0.001	5	0.006	<0.001	0.002	10
Total						0.007	<0.001	0.004	2
Iron, Dissolved	mg/L	<0.1	<0.1	<0.1	5	0.3	0.02	0.1	10
Total	mg/L					5.9	0.3	3.1	2
Lead, Dissolved	mg/L	0.001	<0.001	0.001	6	0.01	<0.001	0.003	10
Total	mg/L					0.004	<0.001	0.002	2
Manganese, Dissolved	mg/L	<0.02	<0.02	<0.02	5	0.24	0.11	0.15	5
Mercury, Dissolved	µg/L			<0.05	1			<0.05	1
Total	µg/L			<0.05	1			<0.05	1
pH		8.6	8.0	8.3	12	8.6	7.7	8.0	18
Solids, Dissolved	mg/L			525	1	782	264	385	6
Suspended	mg/L			47	1	100	3	43	6
Sulphate, Dissolved	mg/L	53	34	43	6	71	40	53	8
Turbidity	J.T.U.	580	4.1	199	3	460	3	73	11
Zinc, Dissolved	mg/L	<0.005	<0.005	<0.005	4	0.009	<0.005	0.006	6
Total	mg/L					0.017	<0.005	0.011	2

TABLE 54

ANALYSIS OF WATER FROM THE ELKVIEW PREPARATION PLANT COARSE REFUSE PILE, CARRIED OUT BY THE COMPANY AND THE PROVINCE IN 1975-76

Site Number	0200235 (EP-12)				0200236 (EP-14)				0200144 (EP-15)			
Site Description	Groundwater Seepage From Coarse Refuse Pile				Surface Water Swamp Below Coarse Refuse Pile				Groundwater Seepage From Coarse Refuse Pile			
Parameter	Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values
Acidity: ph 8.3 mg/L	20	<1	10	3	14	<1	5	3	<1	<0.5		5
Alkalinity, Total mg/L	224	128	188	3	254	236	243	3	360	332	343	4
Arsenic, Dissolved mg/L									<0.005	<0.005	<0.005	3
Carbon, Total Organic mg/L	5.2	1.2	2.7	3	11.6	4.8	7.2	3	64	2	22	4
Chromium, Dissolved mg/L									0.008	<0.005	0.006	5
Copper, Dissolved mg/L	0.005	<0.001	0.003	3	0.006	0.004	0.005	3	0.006	<0.001	0.004	4
Iron, Dissolved mg/L	0.06	<0.01	0.03	3	0.18	0.05	0.1	3	0.14	0.03	0.08	4
Lead, Dissolved mg/L	0.02	<0.002	0.008	3	0.006	<0.002	0.004	3	0.012	<0.001	0.006	4
Manganese, Dissolved mg/L											0.35	1
Mercury, Dissolved μg/L									<0.2	<0.05		4
pH	9.0	7.9	8.4	3	8.0	8.0	8.0	3	8.3	8.1	8.2	5
Solids, Dissolved mg/L	653	318	443	3	528	293	383	3	815	638	713	4
Suspended mg/L	20	13	17	3	167	29	75	3	393	4	199	4
Sulphate, Dissolved mg/L									276	181	228	2
Turbidity J.T.U.	34	2	18	2	146	31	76	3	11	2	7	4
Zinc, Dissolved mg/L											0.63	1
Total mg/L									0.66	0.45	0.56	2

TABLE 55

ANALYSIS OF HARMER CREEK SETTLING POND DISCHARGE (SITE 1190005)

CARRIED OUT BY THE PROVINCE IN 1975

Parameter / Date	May 15	June 4	July 2	July 23	August 13	Level A(8,110)
Alkalinity, Total mg/L	136	118	145	145	153	
Carbon, Total Organic mg/L	10	6	2	2	2	
Copper, Dissolved mg/L		0.002				0.05
Total mg/L			<0.001	<0.001	<0.001	
Cyanide, Total mg/L	<0.01	<0.01	<0.01		<0.01	0.1
Flow Rate m^3/s			0.85	0.57	0.42	
Lead, Dissolved mg/L		<0.001	<0.001	<0.001	<0.001	0.05
Nitrogen, Ammonia mg/L	0.012	0.009	0.012	0.015	0.014	0.5
Nitrite+Nitrate mg/L	1.13	0.75	1.09	1.17	1.13	10
pH	8.5	8.4	8.4	8.2	8.4	6.5-8.5
Phenol, Total mg/L		<0.002	<0.002	0.003	<0.002	0.2
Phosphorus, Total Dissolved mg/L	0.021	0.014	0.008	0.011	0.009	2
Solids, Dissolved mg/L	206	198	220	250	282	<2,500
Suspended mg/L	90	58	6	2	4	50
Turbidity J.T.U.	50	23	2.3	0.5	3.9	
Zinc, Dissolved mg/L		<0.005	<0.005	<0.005		0.5
Total mg/L	0.03				<0.005	

TABLE 56

ANALYSIS OF MISCELLANEOUS SEDIMENT SOURCES FROM KAISER RESOURCES LTD. TO THE ELK RIVER, CARRIED OUT BY THE PROVINCE IN MAY-JUNE, 1976

Date	Turbidity J.T.U.	Suspended Solids mg/L	Flow m^3/s	Suspended Solids Loading t /d
Six Mile Creek				
May 4	608	2,341	0.14	28
May 11	1,950	6,058	0.49	258
May 19	460	2,947	0.16	399
May 24	28	46	0.06	0.2
May 26	74	252	0.17	3.6
June 3	23	58	0.11	0.5
June 7	18	46	0.20	0.8
June 16	15	38	0.06	0.2
Unnamed Creek at Sparwood Municipal Limit				
May 3	1,250	2,901	0.11	28
May 10	400	1,304	0.14	16
May 17	27	130	0.06	0.6
May 20	60	118	0.08	0.9
May 24	28	46	0.06	0.2
June 3	23	58	0.11	0.5
June 7	Clear			
June 14	Clear			

TABLE 57

SUSPENDED SOLIDS AND TURBIDITY IN THE HARMER CREEK SETTLING POND AND GRAVE CREEK, MEASURED BY THE PROVINCE

Date	Harmer Creek Settling Pond						
	Flow* m^3/s	Influent Turbidity J.T.U.	Effluent Turbidity J.T.U.	Influent Suspended Solids mg/L	Effluent Suspended Solids mg/L	Percent Removal of Suspended Solids	Effluent Suspended Solids Loading t/d
May 15, 1975	1.98		50		90		15
June 4	2.69		23		58		14
July 2	0.85		2.3		6		0.4
July 23	0.57		0.5		2		0.1
August 13	0.42		3.9		4		0.2
April 7, 1976		93	48	386	86	78	
May 4	3.25	27	46	120	92	23	24
May 11	3.40	72	80	302	168	44	49
May 19	3.11	15	11	66	16	76	4.5
May 26	2.69	10	10	22	18	18	4.5
June 3	1.84	5.3	5.3	19	10	47	1.8
June 7	1.70	4.3	4.1	12	12	0	1.8
June 10	1.70	9	11	52	18	65	2.7
June 16	0.85	5.4	6.2	14	16	0	0.9

*May 15/75, June 4/75 and April 7/76 flows assumed to be 0.48 of flow in Grave Creek at the mouth (site 08NK019); all other flows measured at Harmer Creek settling pond spillway.

TABLE 57 continued

SUSPENDED SOLIDS AND TURBIDITY IN THE HARMER CREEK SETTLING POND AND GRAVE CREEK, MEASURED BY THE PROVINCE

Date	Grave Creek			
	Upstream Harmer Creek		Downstream Harmer Creek	
	Turbidity J.T.U.	Suspended Solids mg/L	Turbidity J.T.U.	Suspended Solids mg/L
May 15, 1975				88
June 4				
July 2			2.3	6
July 23			0.5	2
August 13				
April 7, 1976	10	18		
May 4	20	82	38	80
May 11	46	214	68	214
May 19	11	40	10	20 & 27
May 26	11	36	11	28
June 3	7.1	20	5.9	7 & 16
June 7	5.8	14	4.2	10
June 10	19	52	13	28
June 16	6.8	16	4.5	14

TABLE 58

SUSPENDED SOLIDS IN HARMER CREEK SETTLING POND AND GRAVE CREEK, MEASURED BY KAISER RESOURCES LTD. IN 1975

Date	Harmer Creek Settling Pond			Grave Creek	
	Flow* m^3/s	Influent Suspended Solids mg/L	Effluent Suspended Solids mg/L	Upstream Harmer Creek Suspended Solids, mg/L	Downstream Harmer Creek Suspended Solids, mg/L
Jan. 8	0.17	5	4	2	2
Mar. 21	0.17	5	5	1	4
May 29	1.58	26	19	24	20
June 11	1.78	28	29	20	35
June 26	1.73	26	20	41	34
July 9	1.33	18	14	17	14
July 23	0.65	7	5	6	8
Aug. 6	0.48	7	5	3	4
Aug. 20	0.45	5	7	4	5
Sept. 3	0.42	7	3	2	7
Sept. 17	0.37	8	4	4	9
Sept. 29	0.31	10	5	3	4
Oct. 22	0.28	5	4	4	4
Nov. 20	0.31	3	3	2	4

*Flows assumed to be 0.48 of flow in Grave Creek at the mouth (site 08NK019)

TABLE 59

SUSPENDED SOLIDS IN HARMER CREEK SETTLING POND AND GRAVE CREEK, MEASURED BY KAISER RESOURCES LTD. IN 1972[68]

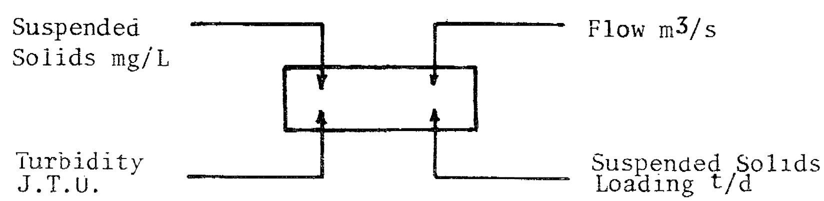
Date	Harmer Creek Settling Pond				Grave Creek Upstream Harmer Creek Suspended Solids mg/L
	Flow* m^3/s	Influent Suspended Solids mg/L	Effluent Suspended Solids mg/L	Percent Removal of Suspended Solids	
May 16	3.82	863	690	20	
29	2.97	477	481	0	
30	2.83	582	227	61	
31	2.69	643	243	62	
June 1	3.82	509	289	43	466
2	5.09	386	177	54	351
3	5.09	1528	487	68	95
4	4.53	1479	433	71	185
5	4.53	893	354	60	379
6	4.53	432	225	48	121
7	4.53	193	144	25	205
8	4.10	177	118	33	152
9	3.82	298	278	7	268
11	3.96	426	240	44	369
12	3.40	208	106	49	229
13	2.83	106	56	47	112
14	2.55	73	40	45	72

*May 16-June 2 flows assumed to be 0.48 of flow in Grave Creek at the mouth (site 08NK019)
June 3-June 14 flows measured at the Harmer Creek settling pond.

TABLE 60

SUSPENDED SOLIDS AND TURBIDITY MEASUREMENTS IN THE LOWER ELK RIVER

Site \ Date	May 15 1975	May 21 1975	June 2 1975	June 5 1975	June 30 1975	July 2 1975
Upstream Fording River		12 3.9				
→ Fording River			218	104		
Upstream Grave Creek (08NK016) (0200027)	80 24		186	174 37		2.8
→ Grave Creek (0200026)	88		123	74 28		6 2.3
Downstream Grave Creek (1190012)				94 32		6 2.7
→ Six Mile Creek						
Upstream Michel Creek (0200111)	112 37					
→ Michel Creek (0200025)			158 36		10 4.3	
Upstream Sparwood Sewage Treatment Plant (0200103)			154 38		14 4.0	
→ Unnamed Creek at Sparwood Municipal Limit						
Downstream Sparwood Sewage Treatment Plant (0200102)		30 16	164 36		10 4.2	
At Hosmer (0200024)		14 12	116 26		14 2.6	
Upstream Fernie (08NK002) (1190004)			140 44		36 7.1	
→ Coal Creek (0200116)		6 4.3				
Downstream Fernie (0200113)		50 118				
Near Mouth (0200016)				486 45		



→ Discharge or Tributary to Elk River

TABLE 60 continued

SUSPENDED SOLIDS AND TURBIDITY MEASUREMENTS IN THE LOWER ELK RIVER

Site \ Date	July 3 1975	July 23 1975	April 7 1976	May 3 1976	May 4 1976	May 5 1976
Upstream Fording River			2 5.1			74 23
→ Fording River			29		114 27	110 18
Upstream Grave Creek (08NK016) (0200027)		4 1.3	8-92 10.6 58 45		94-152 47.0 22-31 498	
→ Grave Creek (0200026)		2 0.5	13		80 38	
Downstream Grave Creek (1190012)		14 1.3			106 24	
→ Six Mile Creek					2,341 0.14 608 28	
Upstream Michel Creek (0200111)	10 4.4	4 1.2		48 14		64 24
→ Michel Creek (0200025)			30	184 49.5 42 785	174 50.4 42 755	
Upstream Sparwood Sewage Treatment Plant (0200103)		2 1.3		124 36		
→ Unnamed Creek at Sparwood Municipal Limit				2,901 0.11 1,250 26		
Downstream Sparwood Sewage Treatment Plant (0200102)		4 1.5				
At Hosmer (0200024)		2 0.9		98 29		
→ No-Name Creek → Hosmer Creek → Hartley Creek Upstream Fernie (08NK002) (1190004)						
→ Coal Creek (0200116)	16 1.7					
Downstream Fernie (0200113)				116 38		
→ Lizard Creek				266 112		
Near Mouth (0200016)	45 14.5			108 38		

TABLE 60 continued

SUSPENDED SOLIDS AND TURBIDITY MEASUREMENTS IN THE LOWER FRASER RIVER

Site \ Date	May 10 1976	May 11 1976	May 13 1976	May 17 1976	May 18 1976	May 19 1976
Upstream Fording River	152 35		66 17			28 9.7
→ Fording River		262 54.1 62 1220	26 10	28 6.4		12 4.6
Upstream Grave Creek (08NK016) (0200027)		212 112 52 2050	44 16	31-38 10	28 6.9	31 84.6 226
→ Grave Creek (0200026)		214 68		31		27-20 10
Downstream Grave Creek (1190012)		116 48				20 7.7
→ Six Mile Creek		6058 0.49 1950 258				2947 0.16 460 40
Upstream Michel Creek (0200111)	192 52	204 54	80 19		38 10	38 10
→ Michel Creek (0200025)	331 103 85 2930	522 113 120 5090	106 27	57	66	57 52.6 258
Upstream Sparwood Sewage Treatment Plant (0200103)	386 72	592 135	56 24	46 20	33 12	
→ Unnamed Creek at Sparwood Municipal Limit	1304 0.14 400 16			130 0.05 27 0.6		
Downstream Sparwood Sewage Treatment Plant (0200102)						
At Hosmer (0200024)	246 52			40 14		
→ No-Name Creek				8 6.4		
→ Hosmer Creek				10 5.5		
→ Hartley Creek	1110 1.13 290 108					
Upstream Fernie (08NK002) (1190004)	298				57	
Coal Creek (0200116)	42 13					
Downstream Fernie (0200113)	540 108		98 35			
→ Lizard Creek						
Near Mouth (0200016)	608 176		244 84	176 48		

TABLE 60 continued

SUSPENDED SOLIDS AND TURBIDITY MEASUREMENTS IN THE LOWER ELK RIVER

Site \ Date	May 20 1976	May 24 1976	May 25 1976	May 26 976	June 1 1976	June 2 1976
Upstream Fording River	37 12		32 9.4	26 8.3		
→ Fording River		23	10 9.2	18 8.5		
Upstream Grave Creek (08NK016) (0200027)		32	22 9.7	18 88.3 7.4 137		
→ Grave Creek (0200026)				28 11		
Downstream Grave Creek (1190012)				14 7.8		
→ Six Mile Creek				252 0.16 74 3.5		
Upstream Michel Creek (0200111)	42 10	24 9.1		24 8.1		8 4.6
→ Michel Creek (0200025)	120 32	121-102 29		28 59.7 10 144		12 6.6
Upstream Sparwood Sewage Treatment Plant (0200103)	86 29	72 22		30 10		20 6.2
→ Unnamed Creek at Sparwood Municipal Limit	118 0.09 60 0.9	46 0.05 28 0.2				Clear
Downstream Sparwood Sewage Treatment Plant (0200102)						
At Hosmer (0200024)	40 17	50 18		32 11		14 5.3
→ No-Name Creek	10 7.4	12 10		12 6.3		4 2.9
→ Hosmer Creek	10 6	14 6.8		6 3.9		4 2.3
→ Hartley Creek	156 52	134 50		74 26		22 17
Upstream Fernie (08NK002) (1190004)		92		58	23	
→ Coal Creek (0200116)	22 10	20 10			4 3.9	
Downstream Fernie (0200113)	62 24	60 26		32 13	20 8.1	
→ Lizard Creek	300 104	220 105		88 38	38 18	
Near Mouth (0200016)		174 54			48 14	

TABLE 60 continued

SUSPENDED SOLIDS AND TURBIDITY MEASUREMENTS IN THE LOWER ELK RIVER

Site \ Date	June 3 1976	June 4 1976	June 6 1976	June 7 1976	June 8 1976	June 9 1976
Upstream Fording River	14 4.7	8 2.9	12 3.2		10 3.3	
→ Fording River	8-4 1.7		4 1.8		4 1.3	
Upstream Grave Creek (08NK016) (0200027)	17-10 3.7		8 3	6 2.8	4 2.4	
→ Grave Creek (0200026)	7-16 5.9			10 4.2		
Downstream Grave Creek (1190012)	6 2.6			4 2.3		
→ Six Mile Creek	58 0.11 23 0.5			46 0.20 18 0.8		
Upstream Michel Creek (0200111)		32 4.1		4 2.7		14 5
→ Michel Creek (0200025)	35	10 4.1		4 3.8		30 13
Upstream Sparwood Sewage Treatment Plant (0200103)		10 3.8		8 3.8		30 10
→ Unnamed Creek at Sparwood Municipal Limit Downstream Sparwood Sewage Treatment Plant (0200102)						
At Hosmer (0200024)				4 3.2		
→ No-Name Creek				4 2.3		
→ Hosmer Creek				4 1.8		
→ Hartley Creek						
Upstream Fernie (08NK002) (1190004)	18			6		27
→ Coal Creek (0200116)				6 2.7		
Downstream Fernie (0200113)				10 4.1		
→ Lizard Creek						
Near Mouth (0200016)				18 9		

TABLE 60 continued

SUSPENDED SOLIDS AND TURBIDITY MEASUREMENTS IN THE LOWER ELK RIVER

Site / Date	June 10 1976	June 14 1976	June 15 1976	June 16 1976
Upstream Fording River	30 6.8		8 2.8	
→ Fording River	6 3.3	4-5 1.7	4 1.9	
Upstream Grave Creek (08NK016) (0200027)	24 6.5	8-15 3.3	4 2.3	
→ Grave Creek (0200026)	28 13	12-11 7.2		14 4.5
Downstream Grave Creek (1190012				4 2
→ Six Mile Creek				38 0.06 15 0.2
Upstream Michel Creek (020011	14 5.4	6 2.9		6 2.5
→ Michel Creek (0200025)	22 12	10-15 5.3		10 5
Upstream Sparwood Sewage Treatment Plant (0200103)	22 10	14 4.7		6 3.8
→ Unnamed Creek at Sparwood Municipal Limit Downstream Sparwood Sewage Treatment Plant (0200102)				
At Hosmer (020024)	40 9.4	6 3.7		
→ No-Name Creek	14 12	8 5		
→ Hosmer Creek	6 4.6	4 2.2		
→ Hartley Creek	22 17			
Upstream Fernie (08NK002) (1190004)			12	
→ Coal Creek (0200116)		8 3.2		
Downstream Fernie (0200113)	24 12	12 5.8		
Near Mouth (0200016)	64 24	52 22		

TABLE 61

ANALYSIS OF EFFLUENT FROM THE CITY OF FERNIE AND DISTRICT OF SPARWOOD SEWAGE TREATMENT PLANTS, CARRIED OUT BY THE PROVINCE IN 1975-76

Site / Parameter	City of Fernie (PE0039001)					District of Sparwood (PE0025301)					Municipal Objectives Level AA (78)
	Max.	Min.	Mean	No. of Values	Permit Limit	Max.	Min.	Mean	No. of Values	Permit Limit	
BOD_5 mg/L	32	<10	22	12	50	57	<10	20	11	45	30 or 45
Carbon, Total Organic mg/L	36	12	24	12		54	5	17	11		
Chlorine, Residual	See Table 62					1.7	0	0.3	6	0.1-1.0	<0.05 or 0.5-1.0
Coliforms, Fecal M.P.N./100 mL	>240,000	2,000		9		79,000	1,300	25,400	10		
Flow Rate m^3/d					2,270					1,730	
Nitrogen, Ammonia mg/L	10.5	4.6	8.5	4							
Nitrite+Nitrate mg/L	0.37	0.04	0.19	4							
Organic mg/L	4.4	3.2	3.7	4							
Total mg/L	14.0	9.4	12.4	4							
pH	7.9	7.2	7.6	23		7.8	7.3	7.5	19		
Phosphorus, Total mg/L								5.6	1		1.5
Solids, Suspended mg/L	43	9	23	12	57	54	4	21	11	45	40 or 60

TABLE 62

MEASUREMENTS OF CHLORINE RESIDUAL IN THE CITY OF FERNIE SEWAGE TREATMENT PLANT EFFLUENT, MADE BY THE PROVINCE IN 1975-76

Date	Total Chlorine Residual (Amperometric Titration)** mg/L	Total Chlorine Residual (Hach Kit) mg/L	Free Chlorine Residual (Hach Kit) mg/L
Jan. 28, 1975			0.35
Mar. 11			0.2
May 21			0.1
July 16			0.2
Sept. 2			0.3
Jan. 13, 1976	<0.01-0.5		
Jan. 20	<0.01-0.25*		0
Jan. 29			0.3-0.4
Feb. 5		1.1	0.4
Feb. 12	0.5-1.5, 0.75 Average	0.8-0.9	0.3
March 18			0.5
March 25			0.4
May 17			0.4
July 27			0.1
Sept. 28			0
Dec. 20			0.3

*Chlorine addition adjusted to increase concentration from 0 to 0.25 mg/L.

**Level AA of the Municipal Objectives specify total chlorine residuals (based on amperometric procedures) of 0.5-1.0 mg/L for dilutions of 200:1 to 2000:1, and <0.05 mg/L for dilutions of 20:1 to 200:1.

TABLE 63

WATER QUALITY DATA COLLECTED FROM THE ELK RIVER AND GRAVE CREEK BY THE PROVINCE IN 1975-76

GENERAL PARAMETERS

Site / Parameter		0200027 Max.	0200027 Min.	0200027 Mean	0200027 No. of Values	0200026 Max.	0200026 Min.	0200026 Mean	0200026 No. of Values
Alkalinity, Total	mg/L	170	118	142	51	172	115	154	21
Carbon, Total Organic	mg/L	5	<1	2.3	9	11	2	5.2	5
Coliforms, Fecal	MPN/ 100mL	22	<2	6	6				
Colour, True		10	<5	5.2	25	15	<5	6.1	22
Hardness, Total	mg/L	193	136	166	25	201	137	169	5
Nitrogen, Ammonia	mg/L	0.015	<0.005	0.006	25	0.015	0.009	0.01	5
Nitrite+Nitrate	mg/L	0.18	0.05	0.11	25	0.74	0.45	0.63	5
Organic	mg/L	0.38	<0.01	0.08	25				
Total	mg/L	0.54	0.07	0.19	25				
pH		9.0	7.4	8.3	53	9.0	8.0	8.5	43
Phosphorus, Dissolved Orthophosphate	mg/L	0.005	<0.003	0.003	25				
Total	mg/L	0.24	<0.003	0.02	25	0.12	0.01	0.05	5
Total Dissolved	mg/L	0.007	0.003	0.004	4	0.011	0.006	0.008	4
Solids, Dissolved	mg/L	214	150	187	26	312	160	257	22
Suspended	mg/L	174	2	14	25	88	2	14	22
Turbidity	J.T.U.	37	0.1	3.2	26	28	0.4	3.8	19

TABLE 63 continued

WATER QUALITY DATA COLLECTED FROM THE ELK RIVER AND GRAVE CREEK BY THE PROVINCE IN 1975-76

GENERAL PARAMETERS

Parameter / Site		1190012 Max.	1190012 Min.	1190012 Mean	1190012 No. of Values	0200111 Max.	0200111 Min.	0200111 Mean	0200111 No. of Values
Alkalinity, Total	mg/L	140	126	132	5	162	122	144	53
Carbon, Total Organic	mg/L	4	<1	2	5	8.8	0.2	2.3	13
Coliforms, Fecal	MPN/ 100mL					17	<2	6	8
Colour, True						10	<5	5.4	26
Hardness, Total	mg/L	160	137	150	5	196	134	168	26
Nitrogen, Ammonia	mg/L	0.011	<0.005	0.006	5	0.026	<0.005	0.008	26
Nitrite+Nitrate	mg/L	0.15	0.06	0.09	5	0.22	0.05	0.13	26
Organic	mg/L					0.41	0.01	0.08	26
Total	mg/L					0.61	0.05	0.21	26
pH		8.5	8.1	8.4	5	9.1	8.0	8.3	58
Phosphorus, Dissolved Orthophosphate	mg/L					0.013	<0.003	0.004	26
Total	mg/L	0.13	0.005	0.04	5	0.19	<0.003	0.02	26
Total Dissolved	mg/L	0.007	<0.003	0.004	5	0.008	<0.003	0.004	4
Solids, Dissolved	mg/L	180	154	164	5	473	150	202	31
Suspended	mg/L	94	4	26	5	172	2	10	31
Turbidity	J.T.U.	32	0.8	9.1	5	37	0.4	3.2	27

TABLE 64

WATER QUALITY DATA COLLECTED FROM THE ELK RIVER AND GRAVE CREEK BY THE PROVINCE IN 1975-76

METALS AND TOXIC MATERIALS IN μg/L

Site / Parameter	0200027				0200026			
	Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values
Aluminum, Dissolved	10	<10	10	12				
Total	10	<10	10	5				
Arsenic, Dissolved	9	<5	5	13				
Total	<5	<5	<5	17	<5	<5	<5	5
Copper, Dissolved	1	<1	1	12				
Total	4	<1	1	18	3	<1	2	5
Iron, Dissolved	<100	<100	<100	11				
Total	2000	<100	300	18	2500	<100	900	5
Lead, Dissolved	1	<1	1	12	1	<1	1	4
Total	3	<1	1	13			<1	1
Manganese, Dissolved	<20	<20	<20	12	<20	<20	<20	5
Total	20	<20	20	13				
Mercury, Dissolved	<0.05	<0.05	<0.05	8				
Nickel, Dissolved	<10	<10	<10	5	<10	<10	<10	5
Phenol, Total	4	<2	2	25				
Zinc, Dissolved	<5	<5	<5	12				
Total	8	<5	5	18	9	<5	6	5

TABLE 64 continued

WATER QUALITY DATA COLLECTED FROM THE ELK RIVER AND GRAVE CREEK BY THE PROVINCE IN 1975-76

METALS AND TOXIC MATERIALS IN μg/L

Parameter \ Site	1190012				0200111			
	Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values
Aluminum, Dissolved								
Total					10	<10	10	3
Arsenic, Dissolved					7	<5	5	14
Total	<5	<5	<5	5	8	<5	5	16
Copper, Dissolved					16	<1	3	15
Total	5	<1	2	5	2	<1	1	18
Iron, Dissolved					<100	40	89	15
Total	1600	<100	500	5	2500	<100	400	18
Lead, Dissolved	<1	<1	<1	5	14	<1	3	15
Total					3	<1	1	13
Manganese, Dissolved	<20	<20	<20	4	<20	<20	<20	12
Total					<20	<20	<20	13
Mercury, Dissolved					<0.05	<0.05	<0.05	9
Nickel, Dissolved	<10	<10	<10	5	<10	<10	<10	5
Phenol, Total					2	<2	2	26
Zinc, Dissolved					<5	<5	<5	12
Total	9	<5	6	5	6	<5	5	17

TABLE 65

WATER QUALITY DATA COLLECTED FROM THE LOWER ELK RIVER BY THE PROVINCE IN 1975-76

GENERAL PARAMETERS

Parameter \ Site		0200103				0200102			
		Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values
Alkalinity, Total	mg/L	165	90	137	35	168	111	140	16
Carbon, Total Organic	mg/L	6	<1	2.1	10	8	<1	3	7
Coliforms, Fecal	MPN/ 100mL	80	<2	12	17	80	<2	19	15
Colour, True		20	<5	7.7	22	20	<5	6.5	13
Hardness, Total	mg/L	192	90	154	22	188	127	161	13
Nitrogen, Ammonia	mg/L	0.12	0.008	0.02	22	0.024	<0.005	0.01	15
Nitrite+Nitrate	mg/L	0.21	0.03	0.11	22	0.22	0.04	0.05	15
Organic	mg/L	1.88	0.02	0.2	22	0.35	0.01	0.1	13
Total	mg/L	2.11	0.06	0.33	22	0.41	0.05	0.24	13
pH		9.0	7.9	8.3	45	8.9	8.1	8.3	31
Phosphorus, Dissolved Orthophosphate	mg/L	0.017	<0.003	0.006	22	0.012	<0.003	0.005	13
Total	mg/L	0.24	0.003	0.04	22	0.22	0.005	0.04	15
Total Dissolved	mg/L	0.019	<0.003	0.008	4	0.045	<0.003	0.014	5
Solids, Dissolved	mg/L	220	114	178	22	222	134	181	15
Suspended	mg/L	260	1	30	23	186	2	29	15
Turbidity	J.T.U.	84	0.4	11.2	22	52	0.5	8.6	15

TABLE 65 continued

WATER QUALITY COLLECTED FROM THE LOWER ELK RIVER BY THE PROVINCE IN 1975-76

GENERAL PARAMETERS

Parameter / Site		0200024 Max.	0200024 Min.	0200024 Mean	0200024 No. of Values	1190004 Max.	1190004 Min.	1190004 Mean	1190004 No. of Values
Alkalinity, Total	mg/L	175	103	140	26	134	111	121	4
Carbon, Total Organic	mg/L	10	<1	2.8	9	6	<1	2.8	4
Coliforms, Fecal	MPN/ 100mL	540	<2	68	13	540	<2	88	9
Colour, True		15	<5	6.2	13				
Hardness, Total	mg/L	214	132	165	13				
Nitrogen, Ammonia	mg/L	0.034	<0.005	0.01	13				
Nitrite+Nitrate	mg/L	0.2	0.03	0.09	15	0.14	0.05	0.09	4
Organic	mg/L	0.2	0.04	0.1	13				
Total	mg/1	0.32	0.12	0.21	13				
pH		8.7	7.8	8.3	29	8.5	8.1	8.3	8
Phosphorus, Dissolved Orthophosphate	mg/L	0.021	<0.003	0.006	13				
Total	mg/L	0.14	0.005	0.025	15	0.18	0.007	0.08	4
Total Dissolved	mg/L	0.036	0.004	0.018	4	0.01	0.003	0.007	3
Solids, Dissolved	mg/L	236	124	179	15	152	138	144	4
Suspended	mg/L	116	2	16	15	140	2	58	4
Turbidity	J.T.U.	26	0.7	5.3	14	44	0.5	18.9	4

TABLE 66

WATER QUALITY DATA COLLECTED FROM THE LOWER ELK RIVER BY THE PROVINCE IN 1975-76

METALS AND TOXIC MATERIALS IN μg/L

Site / Parameter	0200103				0200102				0200024			
	Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values
Arsenic, Dissolved	7	<5	6	3								
Total	5	<5	5	11								
Copper, Dissolved	70	<1	2	11								
Total	2	<1	1	2								
Cyanide, Dissolved	<10	<10	<10	5	<10	<10	<10	5				
Iron, Dissolved	100	100	100	11								
Total	200	100	150	2								
Lead, Dissolved	<1	<1	<1	11								
Total	<1	<1	<1	2								
Manganese, Dissolved	20	<20	20	11								
Total	<20	<20	<20	2								
Mercury, Dissolved	<0.05	<0.05	<0.05	4								
Total	<0.05	<0.05	<0.05	5								
Phenol, Total	43	<2	3	14	2	<2	2	3	3	<2	2	7
Zinc, Dissolved	6	<5	5	11								
Total	<5	<5	<5	2								

TABLE 67

WATER QUALITY DATA COLLECTED FROM THE ELK RIVER AND COAL CREEK BY THE PROVINCE IN 1975-76

GENERAL PARAMETERS

Parameter \ Site	0200116				0200113				0200016			
	Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values
Alkalinity, Total mg/L	61	24	39	4	181	112	146	23	163	42	126	26
Carbon, Total Organic mg/L	8	2	4.2	8	7	<1	1.9	11	8	<1	2.5	23
Coliforms, Fecal MPN/100 mL	70	<2	18	9	>2400	2	992	18	280	5	101	14
Colour, True			20	1	10	<5	5.4	11	20	<5	6.8	22
Fluoride, Dissolved mg/L									0.2	0.12	0.16	22
Hardness, Total mg/L					213	125	168	12	190	99	144	22
Nitrogen, Ammonia mg/L			0.013	1	0.03	<0.005	0.014	12	0.021	0.005	0.01	24
Nitrite+Nitrate mg/L	0.17	<0.02	0.05	10	0.18	0.02	0.11	12	0.18	<0.02	0.1	22
Organic mg/L	0.17	<0.02	0.07	9	0.32	0.03	0.10	12	0.39	<0.01	0.1	24
Total mg/L	0.41	0.05	0.19	9	0.42	0.08	0.23	12	0.54	0.07	0.2	24
pH	8.5	7.4	7.9	20	8.8	7.9	8.3	27	9.0	7.8	8.3	50
Phosphorus, Dissolved Orthophosphate mg/L					0.012	<0.003	0.006	12	0.013	<0.003	0.005	24
Total mg/L	0.046	0.011	0.02	10	0.075	0.005	0.02	12	0.42	0.005	0.05	24
Total Dissolved mg/L	0.022	0.013	0.018	4					0.016	<0.003	0.007	17
Solids, Dissolved mg/L	76	36	56	4	234	140	189	12	216	114	166	23
Suspended mg/L	20	2	8	4	58	2	12	13	486	2	50	24
Turbidity J.T.U.	7.2	0.3	2.8	5	118	0.8	12.8	13	140	0.8	22.5	22

TABLE 68

WATER QUALITY DATA FROM THE ELK RIVER AND COAL CREEK
COLLECTED BY THE PROVINCE IN 1975-76
METALS AND TOXIC MATERIALS IN µg/L

Parameter \ Site	0200116				0200016			
	Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values
Arsenic, Dissolved					<5	<5	<5	22
Copper, Dissolved	<1	<1	<1	6	4	<1	1	22
Total	<1	<1	<1	3				
Iron, Dissolved					<100	<100	<100	22
Total			300	1	8200	<100	1000	22
Lead, Dissolved	<1	<1	<1	6	4	<1	1	22
Total	<1	<1	<1	3				
Manganese, Dissolved					<20	<20	<20	21
Phenol, Total					4	<2	2	22
Zinc, Dissolved	<5	<5	<5	6	5	<5	5	22
Total	<5	<5	<5	3				

TABLE 69

RANGE OF SUSPENDED SEDIMENT DATA
FOR THE LOWER ELK RIVER AND ITS MAJOR TRIBUTARIES
VALUES IN mg/L

Site \ Data Source	Water Survey of Canada 1975	Water Survey of Canada 1976	Province 1975	Province 1976
Elk River Upstream Fording River				2-166
Fording River at the Mouth (08NK018, 0200028)	0-218	2-119		4-262
Elk River Downstream Fording River, Upstream Grave Creek (08NK016, 0200027)	4-186	1-89	4-174	2-212
Grave Creek at the Mouth (08NK019, 0200026)	0-161	4-1720*	2-123	7-214
Michel Creek at the Mouth (08NK020, 0200025)	3-548	1-958	2-242	1-850
Elk River at Fernie (08NK002, 1190004, 0200113)	0-501	2-492	2-140	6-540
Elk River at the Mouth (0200016)			2-486	2-608

*1720 mg/L on June 30, next highest value was 189 mg/L

TABLE 70

FECAL COLIFORM MEASUREMENTS IN THE ELK RIVER OBTAINED BY THE PROVINCE

VALUES IN MPN/100 mL

Site / Date	1190004	0.3 km Upstream Fernie Sewage Treatment Plant	0200113	0200016
Jan. 28/75			5	
March 11/75			>2400	
May 21/75			240	
June 5/75				10
July 3/75				140
July 16/75			350	
Aug. 12/75				79
Sept. 2/75			1600	
Oct. 7/75	34		920	130
Oct. 9/75	2		700	110
Nov. 17/75			170	
Jan. 7/75				280
Jan. 12/76	<2		540	
Jan. 20/76			>2400	
Jan. 21/76	5		1100	
Jan. 29/76	540		790	
Feb. 5/76	130	>2400	1300	
Feb. 12/76	70	2400	330	
March 3/76				5
March 18/76	8	>2400	2200	
March 25/76	4	3500	920-2400	
April 29/76				94
May 5/76				110
May 17/76			2	
May 25/76				49
June 3/76				79
June 22/76				70
July 20/76				240
Sept. 28/76			<20	
Nov. 29/76				5

TABLE 71

RESULTS OF SEDIMENT TRAP SAMPLING IN GRAVE AND HARMER CREEKS, APRIL - JULY, 1976

Site / Parameter	Harmer Creek Downstream Harmer Settling Pond				Grave Creek Upstream Harmer Creek
	A	B	C	Mean	B
Total Dry Weight, g	6715	7763	9021	7833	9614
Weight Finer Than 2.38 mm,g	1139	580	453	724	2219
Percentage of Total Weight Finer Than 2.38 mm	17.0	7.5	5.0	9.8	23.1
Percentage Finer Than:*					
2.38 mm	100	100	100	100	100
0.59 mm	38.7	63.1	48.8	50.2	40.3
0.297 mm	26.2	44.7	37.3	36.1	25.1
0.149 mm	20.9	35.5	26.9	27.8	16.0
0.074 mm	8.2	26.4	18.3	17.6	8.1

*Particle-size analysis of portion of sample finer than 2.38 mm

TABLE 72

PARTICLE-SIZE DISTRIBUTION AND CHEMICAL COMPOSITION OF SEDIMENT GRAB SAMPLES FROM THE ELK RIVER, HARMER CREEK AND GRAVE CREEK, AUGUST, 1975

Sieve No.		Percentage Finer Than 16	30	50	100	140	200	270	400
Site	Size-mm	1.19	0.59	0.297	0.149	0.105	0.074	0.053	0.037
Elk River	0200027	99.2	94.8	90.9	74.8	67.2	38.5	26.7	16.1
	1190012	98.2	92.5	81.1	48.4	40.4	18.1	11.8	6.9
	0200111	99.3	97.6	86.6	48.9	40.7	17.3	10.9	6.1
	0200016	88.4	63.6	28.7	15.1	12.7	8.5	6.5	4.6
Harmer Creek	1190005	74.5	53.9	36.6	24.8	22.5	15.6	12.0	7.8
Grave Creek	0200026	76.0	49.1	20.3	9.3	7.6	4.2	3.0	2.1

Site	Parameter	Carbon Total mg/g	Carbon Organic mg/g	Nitrogen Kjeldahl mg/g	Phosphorus Total mg/g
Elk River	0200027	43.0	19.9	1.4	1.17
	1190012	42.0	15.7	1.03	1.16
	0200111	47.0	18.3	0.95	1.25
	0200016	28.0	3.1	0.35	0.68
Harmer Creek	1190005	49.0	21.7	0.93	1.54
Grave Creek	0200026	36.0	11.8	0.93	1.55

TABLE 73

GENERAL OBSERVATIONS OF THE INVERTEBRATE SAMPLING SITES IN THE ELK RIVER AND TRIBUTARIES, AUGUST, 1975

Site		Flow and Velocity	Bottom Type
Elk River	0200042	Fast	Medium Sized Cobbles, No Spaces Between the Rocks; Fine Silt Under Rocks
	0200027	Fast 0.7 m/s	Large Cobbles, Scattered; Very Silty Between Rocks
	1190012	Fast	Small and Medium Cobbles; Some Silt Under and Between the Rocks
	0200111	Medium 0.5 m/s	Large Deep Pools, Bottom Bedrock; Sampled Cobble Bottom Before Pools
	0200103	Medium 0.4 m/s	Medium Sized Cobbles, Loosely Arranged; A Small Amount of Sediment Between Rocks
	0200102	Medium 0.3 m/s	Medium Sized Cobbles; Loosely Arranged; A Small Amount of Sediment Between Rocks
	0200016	Medium 0.4 m/s	Very Large Scattered Rocks; Silt Very Evident
Harmer Creek	1190005	Fast 1 m/s	Medium to Small Cobbles, Loosely Arranged; Some Sediment
Grave Creek	0200026	Fast	Medium to Large Cobbles, Close Pack; Loose Silt, When Rocks Disturbed

TABLE 74

BENTHIC INVERTEBRATE COUNTS IN THE ELK RIVER

(EACH NUMBER IS THE TOTAL OF THREE REPLICATE SAMPLES)

Class, Order or Family / Site	0200042 Control, Upstream From Tributaries and Mining	0200027	1190012	0200011	0200103 Upstream From Sparwood's S.T.P.	0200102 Downstream From Sparwood's S.T.P.	0200016 Near the Mouth of Elk River
Turbellaria	5	1	6	20		4	
Nematoda	16	7	4	10	31	18	12
Oligochaeta	15	3	5	2	984	10	6
Gastropoda				4			
Crustacea							
Ostracoda	2	4	2	1	3	1	3
Copepoda		1	1				
Arachnida							
Acarina	44	37	55	33	160	70	14
Araneae				1			
Insecta							
Odonata	6						
Hemiptera	2						
Neuroptera				1			
Hymenoptera					1	1	
Coleoptera	4	1	0	1	8		1

TABLE 74 continued

BENTHIC INVERTEBRATE COUNTS IN THE ELK RIVER

(EACH NUMBER IS THE TOTAL OF THREE REPLICATE SAMPLES)

Class, Order or Family \ Site	0200042 Control, Upstream From Tributaries and Mining	0200027	1190012	0200011	0200103 Upstream From Sparwood's S.T.P.	0200102 Downstream From Sparwood's S.T.P.	0200016 Near the Mouth of Elk River
Insecta							
Ephemeroptera*	1,326	775	967	2,844	5,988	2,794	236
Plecoptera*	292	380	235	1,135	695	641	336
Trichoptera*	21	3	94	425	528	151	32
Diptera							
Tipulidae	3	2	14	1	4	3	1
Tanyderidae				3			
Blephariceridae				2			
Simuliidae	3	1	1	28	15	4	2
Heleidae	39	14	2	16		3	5
Dolichopodidae						3	
Empididae	14	25	46	22	90	21	1
Adult Diptera			2	9	14		
Chironomidae	1,459	1,076	1,000	1,209	1,870	1,436	1,340

* Numbers of individuals of the genera in these orders are shown in Figures 18 to 22.

TABLE 75

BENTHIC INVERTEBRATE COUNTS IN HARMER AND GRAVE CREEKS
(EACH NUMBER IS THE TOTAL OF 3 REPLICATE SAMPLES)

Class, Order or Family \ Site	1190005, Downstream From Harmer Settling Pond on Harmer Creek	0200026, Downstream From Confluence with Harmer Creek on Grave Creek
Turbellaria	17	418
Nematoda	128	304
Oligochaeta	5	5
Crustacea		
Ostracoda	18	232
Copepoda		4
Arachnida		
Acarina	147	373
Insecta		
Collembola	2	
Hemiptera		2
Hymenoptera	4	2
Coleoptera	1	3
Ephemeroptera*	1,562	3,056
Plecoptera*	1,474	2,058
Trichoptera*	585	175
Diptera		
Tipulidae	5	21
Simuliidae	48	7
Heleidae	2	157
Dolichopodidae	2	3
Empididae	11	261
Adult Diptera	18	1
Chironomidae	15,514	15,456

*Numbers of individuals in the various genera of these orders are shown in Figures 18 to 22.

TABLE 76

DIVERSITY AND REDUNDANCY INDICES FOR BENTHIC INVERTEBRATES COLLECTED IN THE ELK RIVER AND TRIBUTARIES

Site	Number	Diversity Index	Redundancy Index
Harmer Creek	1190005	1.49	0.71
Grave Creek	0200026	2.00	0.61
Elk River	0200042	3.62	0.29
	0200027	2.66	0.46
	1190012	3.00	0.42
	0200111	3.25	0.39
	0200102	2.61	0.47
	0200103	2.39	0.44
	0200016	1.84	0.63

TABLE 77

RESULTS FROM SAMPLING PERIPHYTON IN THE ELK RIVER, SEPTEMBER, 1975

Site	Field Observations	Dominant Algae	Ash Free Dry Wt. mg.
0200043	Little Obvious Periphyton, "Clean"	Green Branched Filament, Stigeoclonium?	8.0
0200039		Small Oscillatoria	32.0
0200027	Some Erosional Sediment (Fine), Enteromorpha and Nostoc Obvious	Nostoc and Diatoms	6.0
1190012	Productive	Enteromorpha	23.0
0200103		Ulothrix	34.0
0200016	Very Productive, Diatoms Present	Diatoma and Synedra	36.0

TABLE 78

WATER QUALITY DATA FROM THE FLATHEAD RIVER COLLECTED BY THE PROVINCE IN 1975-76 AT SITE 0200047

Parameter \ Type of Value	Max.	Min.	Mean	No. of Values
Alkalinity, Total mg/L	138	109	125	10
Carbon, Total Organic mg/L	6	2	4	2
Colour, True	15	<5	6.4	7
Hardness, Total mg/L	141	120	130	5
Nitrogen, Ammonia mg/L	0.01	<0.005	0.006	7
Nitrite+Nitrate mg/L	0.06	<0.02	0.03	8
Organic mg/L	0.2	0.02	0.12	5
Total mg/L	0.36	0.02	0.15	7
pH	8.6	8.0	8.2	13
Phosphorus, Dissolved Orthophosphate mg/L	<0.003	<0.003	<0.003	5
Total mg/L	0.23	0.003	0.04	7
Total Dissolved mg/L	0.006	0.004	0.005	2
Solids, Dissolved mg/L	152	124	139	5
Suspended mg/L	334	2	50	7
Tannin and Lignin mg/L	0.6	<0.1	0.35	2
Turbidity J.T.U.	68	0.4	10.6	7

Parameter \ Type of Value	Max.	Min.	Mean	No. of Values
Arsenic, Total µg/L	<5	<5	<5	2
Cadmium, Dissolved µg/L	<0.5	<0.5	<0.5	4
Total µg/L	<0.5	<0.5	<0.5	2
Copper, Dissolved µg/L	3	<1	1	5
Total µg/L	2	<1	1	2
Cyanide, Total µg/L			<10	1
Iron, Dissolved µg/L	<100	<100	<100	5
Total µg/L	2,700	200	1,450	2
Lead, Dissolved µg/L	<1	<1	<1	5
Total µg/L	<1	<1	<1	2
Manganese, Dissolved µg/L	<20	<20	<20	5
Total µg/L	60	<20	40	2
Mercury, Total µg/L	<0.05	<0.05	<0.05	2
Phenol, Total µg/L	2	<2	2	2
Selenium, Dissolved µg/L	<5	<5	<5	2
Zinc, Dissolved µg/L	<5	<5	<5	5
Total µg/L	<5	<5	<5	2

TABLE 79

WATER QUALITY DATA FROM CABIN CREEK AND HOWELL CREEK COLLECTED BY THE PROVINCE IN 1975-76

GENERAL PARAMETERS

Site / Parameter		Cabin Creek 0200220				Cabin Creek 0200205			
		Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values
Alkalinity, Total	mg/L	143	88	111	3	133	112	122	2
Carbon, Total Organic	mg/L	6	<1	3.3	3			4	1
Colour, True		40	5	17	3			20	1
Nitrogen, Ammonia	mg/L	0.011	<0.005	0.008	3			0.01	1
Nitrite+Nitrate	mg/L	0.15	<0.02	0.07	3	0.09	0.09	0.09	2
Organic	mg/L	0.14	0.04	0.08	3			0.09	1
Total	mg/L	0.3	0.05	0.15	3	0.27	0.19	0.23	2
pH		8.4	7.9	8.2	5	8.6	8.0	8.2	4
Phosphorus, Dissolved Orthophosphate	mg/L							0.008	1
Total	mg/L	0.051	0.013	0.027	3	0.039	0.018	0.028	2
Total Dissolved	mg/L	0.015	0.012	0.013	3			0.01	1
Solids, Dissolved	mg/L			168	1			152	1
Suspended	mg/L	25	2	10	3	25	4	15	2
Tannin and Lignin	mg/L	0.5	<0.1	0.3	3			0.4	1
Turbidity	J.T.U.	12	0.3	4.6	3	10	1.6	5.8	2

TABLE 79 continued

WATER QUALITY DATA FROM CABIN CREEK AND HOWELL CREEK COLLECTED BY THE PROVINCE IN 1975-76

GENERAL PARAMETERS

Site / Parameter		Howell Creek 0200207				Cabin Creek 0200206			
		Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values
Alkalinity, Total	mg/L	141	122	131	4	134	96	118	4
Carbon, Total Organic	mg/L	2	<1	1.7	3	5	<1	1.6	3
Colour, True		10	<5	7	3	30	5	13	3
Nitrogen, Ammonia	mg/L	0.011	<0.005	0.007	3	0.011	0.005	0.007	3
Nitrite+Nitrate	mg/L	0.05	<0.02	0.03	4	0.15	<0.02	0.06	3
Organic	mg/L	0.12	<0.01	0.06	3	0.26	0.06	0.13	3
Total	mg/L	0.18	<0.02	0.08	4	0.42	0.07	0.17	4
pH		8.5	8.1	8.3	7	8.7	8.0	8.3	7
Phosphorus, Dissolved Orthophosphate	mg/L			<0.003	1			0.008	1
Total	mg/L	0.026	0.005	0.012	4	0.054	0.013	0.026	4
Total Dissolved	mg/L	0.008	0.004	0.006	3	0.015	0.012	0.013	3
Solids, Dissolved	mg/L	154	148	151	2	156	150	153	2
Suspended	mg/L	17	2	6	4	35	2	11	4
Tannin and Lignin	mg/L	0.2	<0.1	0.13	3	0.5	<0.1	0.3	3
Turbidity	J.T.U.	5.9	0.4	1.9	4	14	0.4	4.4	4

TABLE 80

WATER QUALITY DATA FROM CABIN CREEK AND HOWELL CREEK
COLLECTED BY THE PROVINCE IN 1975-76
METALS AND TOXIC MATERIALS IN μg/L

Site / Parameter	Cabin Creek 0200220				Cabin Creek 0200205			
	Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values
Arsenic, Total	<5	<5	<5	3			<5	1
Cadmium, Total	<0.5	<0.5	<0.5	3			<0.5	1
Copper, Total	2	2	2	3			<1	1
Iron, Dissolved							<100	1
Total	900	<100	400	3	800	300	600	2
Lead, Total	5	<1	2	3			<1	1
Manganese, Total	20	<20	<20	3			<20	1
Mercury, Total	<0.05	<0.05	<0.05	3			<0.05	1
Phenol, Total	2	<2	2	3			3	1
Selenium, Dissolved	<5	<5	<5	2			<5	1
Zinc, Total	<5	<5	<5	3			<5	1

TABLE 80 continued

WATER QUALITY DATA FROM CABIN CREEK AND HOWELL CREEK
COLLECTED BY THE PROVINCE IN 1975-76
METALS AND TOXIC MATERIALS IN μg/L

Site / Parameter	Howell Creek 0200207				Cabin Creek 0200206			
	Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values
Arsenic, Total	<5	<5	<5	3	<5	<5	<5	3
Cadmium, Total	<0.5	<0.5	<0.5	3	<0.5	<0.5	<0.5	3
Copper, Total	7	<1	3	3	1	<1	1	3
Iron, Dissolved			<100	1			<100	1
Total	500	<100	250	4	1000	<100	375	4
Lead, Total	<1	<1	<1	3	<1	<1	<1	3
Manganese, Total	<20	<20	<20	3	20	<20	20	3
Mercury, Total	<0.05	<0.05	<0.05	3	<0.05	<0.05	<0.05	3
Phenol, Total	<2	<2	<2	3	<2	<2	<2	3
Selenium, Dissolved	<5	<5	<5	2	<5	<5	<5	2
Zinc, Total	<5	<5	<5	3	<5	<5	<5	3

TABLE 81

RANGE OF MISCELLANEOUS PARAMETERS MEASURED IN THE FLATHEAD RIVER AND TRIBUTARIES BY THE PROVINCE AND ENVIRONMENT CANADA IN 1975-76

Parameter	Range mg/L
Calcium, Dissolved	11-47
Chloride, Dissolved	<0.2-0.7
Carbon, Total Inorganic	8-36
Fluoride, Dissolved	0.04-0.29
Magnesium, Dissolved	7.6-9.0
Potassium, Dissolved	0.2-0.6
Silica, Reactive	3.5-5.8
Sodium, Dissolved	0.5-1.5
Sulphate, Dissolved	2.3-11.0

TABLE 82

WATER QUALITY DATA FROM THE FLATHEAD RIVER COLLECTED BY ENVIRONMENT CANADA IN 1975-76

GENERAL PARAMETERS

Parameter / Site	08NP0001				08NP0002				08NP0003			
	Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values
Alkalinity, Phenolphthalein mg/L	1.7	0	0.3	6	4.2	0	0.4	12	3.4	0	0.3	17
Total mg/L	110	46	79	6	130	74	106	12	140	80	101	17
Carbon, Total Organic mg/L	5	<1		6	6.5	<1		12	8.2	<1		17
Colour, Apparent	5	<5		6	7	<5		12	15	<5		17
Hardness, Total mg/L	110	49	81	6	130	78	108	12	160	84	111	17
Nitrogen, Ammonia mg/L	0.084	0.004	0.02	6	0.091	0.003	0.014	12	0.118	0.003	0.016	17
Nitrite+Nitrate mg/L	0.067	0.006	0.02	6	0.060	0.005	0.02	12	0.063	0.002	0.02	17
Dissolved mg/L	0.23	0.05	0.11	6	0.28	0.04	0.08	12	0.24	0.04	0.08	17
pH	8.2	7.6	7.8	5	8.3	7.8	8.1	10	8.3	7.5	8.1	14
Phosphate, Total mg/L	0.051	0.006	0.02	6	0.196	0.005	0.04	12	0.76	0.005	0.09	15
Solids, Dissolved mg/L	168	60	109	5	179	105	138	11	216	62	142	16
Suspended mg/L	22	0.4	8	5	100	<0.2	20	11	150	0.8	37	16

TABLE 83

WATER QUALITY DATA FROM THE FLATHEAD RIVER COLLECTED BY ENVIRONMENT CANADA IN 1975-76

METALS AND TOXIC MATERIALS IN μg/L

Site / Parameter	08NP0001				08NP0002				08NP0003			
	Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values
Arsenic, Extractable	0.3	0.1	0.2	6	0.5	0.2	0.3	12	1	0.2	0.4	16
Barium, Extractable	220	80	130	5	290	90	170	10	1,600	110	280	16
Cadmium, Extractable	<0.2	<0.2	<0.2	6	<0.2	<0.2	<0.2	11	5	<0.2		17
Cobalt, Extractable	<1	<1	<1	5	1	<1		10	1	<1		16
Copper, Extractable	1	<1		6	1	<1		11	4	<1		17
Iron, Extractable	180	11	66	6	260	6	75	11	630	6	180	17
Lead, Extractable	3	<1		6	1	<1		11	2	<1		17
Manganese, Extractable	20	<10		6	40	<10		11	50	<10		17
Mercury, Extractable	0.05	<0.05		6	<0.05	<0.05	<0.05	10	0.08	<0.05		16
Nickel, Extractable	1	<1		5	<1	<1	<1	10	2	<1		16
Phenolic Material			<2	1			4	1			3	1
Selenium, Extractable	0.2	0.1	0.2	6	0.1	<0.1		12	0.2	<0.1		16
Zinc, Extractable	1	<1		6	3	<1		11	50	<1		17

TABLE 84

WATER QUALITY DATA FROM SAGE, COULDREY AND HOWELL CREEKS, COLLECTED BY ENVIRONMENT CANADA IN 1975-76

GENERAL PARAMETERS

Site / Parameter		08NP0004				08NP0006			
		Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values
Alkalinity, Phenolphthalein	mg/L	3.5	0	0.8	6	0	0	0	6
Total	mg/L	130	110	122	6	5.8	32	47	6
Carbon, Total Organic	mg/L	4.8	<1		6	2.9	<1		6
Colour, Apparent		5	<5		6	10	<5		6
Hardness, Total	mg/L	140	120	128	6	67	36	53	6
Nitrogen, Ammonia	mg/L	0.075	0.003	0.018	6	0.088	0.003	0.022	6
Nitrite+Nitrate	mg/L	0.053	0.005	0.02	6	0.13	0.016	0.05	6
Dissolved	mg/L	0.26	0.04	0.10	6	0.22	0.07	0.13	6
pH		8.4	7.2	8.0	5	8.1	7.1	7.4	5
Phosphate, Total	mg/L	0.044	0.004	0.015	6	0.031	<0.002	0.014	6
Solids, Dissolved	mg/L	258	144	193	5	104	56	81	5
Suspended	mg/L	20	0.3	7	5	25	<0.2	10	5

TABLE 84 continued

WATER QUALITY DATA FROM SAGE, COULDREY AND HOWELL CREEKS, COLLECTED BY ENVIRONMENT CANADA IN 1975-76

GENERAL PARAMETERS

Parameter \ Site		08NP0007				08NP0008			
		Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values
Alkalinity, Phenolphthalein	mg/L	0	0	0	4	1.5	0	0.1	13
Total	mg/L	82	55	68	4	140	92	115	13
Carbon, Total Organic	mg/L	4	<1		4	7	<1		13
Colour, Apparent		7	<5		4	10	<5		13
Hardness, Total	mg/L	86	58	71	4	160	98	123	13
Nitrogen, Ammonia	mg/L	0.013	0.002	0.007	4	0.012	0.004	0.009	13
Nitrite+Nitrate	mg/L	0.016	0.006	0.01	4	0.082	0.003	0.03	13
Dissolved	mg/L	0.05	0.03	0.04	4	0.15	0.04	0.08	13
pH		8.0	7.6	7.8	3	8.4	7.1	8.2	10
Phosphate, Total	mg/L	0.036	0.007	0.016	4	0.062	0.009	0.021	13
Solids, Dissolved	mg/L	140	88	105	4	223	122	162	13
Suspended	mg/L	21	0.8	6	4	28	1.2	9	13

TABLE 85

WATER QUALITY DATA FROM SAGE, COULDREY AND HOWELL CREEKS, COLLECTED BY ENVIRONMENT CANADA IN 1975-76

METALS AND TOXIC SUBSTANCES IN μg/L

Site / Parameter	08NP0004				08NP0006			
	Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values
Arsenic, Extractable	1	0.3	0.6	6	0.6	0.3	0.4	6
Barium, Extractable	330	120	180	5	250	140	200	5
Cadmium, Extractable	<0.2	<0.2	<0.2	6	<0.2	<0.2	<0.2	6
Cobalt, Extractable	<1	<1	<1	5	<1	<1	<1	5
Copper, Extractable	4	<1		6	2	<1		6
Iron, Extractable	170	13	50	6	120	8	38	6
Lead, Extractable	1	<1		6	1	<1		6
Manganese, Extractable	20	<10		6	20	<10		6
Mercury, Extractable	<0.05	<0.05	<0.05	6	0.07	<0.05		6
Molybdenum, Extractable								
Nickel, Extractable	<1	<1	<1	5	1	<1		5
Phenolic Material			<2	1			4	1
Selenium, Extractable	0.3	0.1	0.2	6	0.1	<0.1		6
Zinc, Extractable	5	<1		6	<1	<1	<1	6

TABLE 85 continued

WATER QUALITY DATA FROM SAGE, COULDREY AND HOWELL CREEKS,
COLLECTED BY ENVIRONMENT CANADA IN 1975-76
METALS AND TOXIC SUBSTANCES IN μg/L

Parameter \ Site	08NP0007				08NP0008			
	Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values
Arsenic, Extractable	0.5	0.3	0.4	4	1	0.3	0.5	12
Barium, Extractable	210	160	180	4	1,500	120	300	11
Cadmium, Extractable	<0.2	<0.2	<0.2	4	10	<0.2		11
Cobalt, Extractable	1	<1		4	<1	<1	<1	11
Copper, Extractable	1	<1		4	1	<1		11
Iron, Extractable	180	6	56	4	200	9	62	11
Lead, Extractable	2	<1		4	1	<1		11
Manganese, Extractable	<10	<10	<10	4	20	<10		11
Mercury, Extractable	<0.05	<0.05	<0.05	4	<0.05	<0.05	<0.05	9
Molybdenum, Extractable							0.5	1
Nickel, Extractable	<1	<1	<1	4	1	<1		11
Phenolic Material								
Selenium, Extractable	0.1	<0.1		4	0.3	0.1	0.2	12
Zinc, Extractable	<1	<1	<1	4	1	<1		11

TABLE 86

WATER QUALITY DATA FROM CABIN CREEK, COLLECTED BY ENVIRONMENT CANADA IN 1975-76

GENERAL PARAMETERS

Parameter / Site	08NP0009				08NP0010				08NP0005			
	Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values
Alkalinity, Phenolphthalein mg/L	1.5	0	0.5	3			0	1			3.4	1
Total mg/L	130	92	111	3			79	1			120	1
Carbon, Total Organic mg/L	5.9	1.3	3.8	3			5	1			1.5	1
Colour, Apparent	25	5	12	3			25	1			5	1
Hardness, Total mg/L	130	99	116	3			85	1			130	1
Nitrogen, Ammonia mg/L	0.014	0.008	0.011	3			0.01	1			0.107	1
Nitrite+Nitrate mg/L	0.131	0.024	0.069	3			0.233	1			0.013	1
Dissolved mg/L	0.23	0.08	0.14	3			0.35	1			0.23	1
pH	8.4	8.0	8.2	2			8.2	1			8.0	1
Phosphate, Total mg/L	0.090	0.012	0.04	3			0.215	1			0.036	1
Solids, Dissolved mg/L	220	116	169	3			100	1				
Suspended mg/L	36	1.5	13	3			120	1				

TABLE 87

WATER QUALITY DATA FROM CABIN CREEK COLLECTED BY ENVIRONMENT CANADA IN 1975-76

METALS AND TOXIC MATERIALS IN μg/L

Site Parameter	08NP0009				08NP0010				08NP0005			
	Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values	Max.	Min.	Mean	No. of Values
Arsenic, Extractable	0.5	0.2	0.3	3			1.2	1			0.7	1
Barium, Extractable	260	130	200	3			290	1				
Cadmium, Extractable	<0.2	<0.2	<0.2	3			<0.2	1			<0.2	1
Cobalt, Extractable	<1	<1	<1	3			<1	1				
Copper, Extractable	<1	<1	<1	3			1	1			2	1
Iron, Extractable	290	16	110	3			460	1			120	1
Lead, Extractable	<1	<1	<1	3			1	1			<1	1
Manganese, Extractable	50	<10		3			60	1			<10	1
Mercury, Extractable	<0.05	<0.05	<0.05	3			<0.05	1			<0.05	1
Nickel, Extractable	<1	<1	<1	3			<1	1				
Phenolic Material											<2	1
Selenium, Extractable	0.2	0.2	0.2	3			0.2	1			0.3	1
Zinc, Extractable	<1	<1	<1	3			4	1			1	1

TABLE 88

WATER SOURCES WITH LIMITED WATER AVAILABILITY IN THE ELK RIVER BASIN

(FERNIE WATER DISTRICT)

Locality	Water Source	Number of Licences	Quantity & Purpose	Comments
Elko	Elk River	7	25 m^3/s Power 0.038 m^3/s Industrial 4.5 m^3/d Irrigation	The Elk River Upstream From Elko Dam is Fully Committed Because B.C. Hydro is Entitled to Use 25 m^3/s for Power Generation at the Dam, But the Flow in the Elk River is Often Less Than 25 m^3/s.
Fernie	Baldrey Creek	3	37 dam^3/a Irrigation 36 m^3/d Industrial	Fully Committed, One Refusal of Water in June 1970.
	Bean Creek	1	74 dam^3/a Irrigation 4.5 m^3/d Domestic	Fully Committed, One Refusal of Water (34 m^3/d) in Sept. 1940.
Hosmer	Labelle Creek	2	87 dam^3/a Irrigation 4.5 m^3/d Domestic	Fully Committed
	Mott Creek	1	74 dam^3/a Irrigation 4.5 m^3/d Domestic	Fully Committed, One Refusal of Water (9 m^3/d Domestic) in July, 1936.
Sparwood	MacKenzie Spring	1	455 m^3/d Waterworks	Fully Committed, District of Sparwood Water Supply
	Nordstrum Creek	2	185 dam^3/a Irrigation 14 m^3/d Domestic	Possible Water Shortage
Fording River Grave Creek Line Creek	Fording River Grave Creek Line Creek			The Waters of These Streams are Reserved by Order-in-Council No. 79 (Jan. 28, 1926) for a Power Project. Water May be Obtained Under Interim Licences with Consent of the Minister of the Environment.

TABLE 89

RECOMMENDED WATER QUALITY AND EFFLUENT MONITORING FOR THE ELK AND FLATHEAD RIVER BASINS

Sites \ Parameters	BOD_5	Chlorine, Tot. Res.	Coliforms, Fecal	Copper, Diss.	Cyanide	Flow	Iron, Diss.	Manganese, Diss.	N. Ammonia	N. Nitrate	N. Nitrite	N. Total	pH	Phenols	Phosphorus, Diss.	Phosphorus, Tot.	Solids, Sus.	Sulphide	Temperature	Turbidity	Zinc, Diss.	Frequency	Period	Comments
Fording River Basin																								
Fording River u/s and d/s Fording Coal (0200252 and New Site)													✓				✓		✓	✓		Weekly	Spring Snowmelt	See Section 2.5.1
				✓			✓	✓	✓	✓	✓		✓						✓			3 Times/Year	Winter Low Flows	Re Seepage From Tailing Ponds, Pits, Spoil Piles, etc.
Fording River 16 km d/s Fording Coal (0200093)									✓	✓	✓		✓						✓			3 Times/Year	Winter Low Flows	
Kilmarnock Creek u/s and d/s Fording Coal (New Site and 0200252)													✓				✓		✓	✓		Weekly	Spring Snowmelt	
Line Creek	No Further Monitoring Until Development of Line Creek Coal Project Begins																							
Suspended Sediment Sources (Fording Coal, Logging)						✓											✓					Weekly	Spring Snowmelt	Fording Coal Should Monitor Daily During Spring Snowmelt and Heavy Rains See Sections 2.2 and 2.3
Nitrogen Sources at Fording Coal						✓			✓	✓	✓		✓						✓			3 Times/Year	Winter Low Flows	See Section 2.2

TABLE 89 continued

RECOMMENDED WATER QUALITY AND EFFLUENT MONITORING FOR THE ELK AND FLATHEAD RIVER BASINS

Sites \ Parameters	BOD_5	Chlorine, Tot. Res.	Coliforms, Fecal	Copper, Diss.	Cyanide	Flow	Iron, Diss.	Manganese, Diss.	N. Ammonia	N. Nitrate	N. Nitrite	N. Total	pH	Phenols	Phosphorus, Diss.	Phosphorus, Tot.	Solids, Sus.	Sulphide	Temperature	Turbidity	Zinc, Diss.	Frequency	Period	Comments
Upper Elk River Basin																								
Elk river u/s and d/s Elco Mining (Sites 0200204 and 0200042)													✓				✓		✓	✓		Weekly if Possible	Spring Snowmelt	Lower priority, Baseline for Elco Mining
Elk River u/s and d/s Elkford Sewage Treatment Plant (Sites 0200218 and 0200039)			✓																			4 Times/Year	Low Flow	Especially When there is Recreational Use of River
Michel Creek Basin																								
Michel Creek u/s and d/s Byron Creek Collieries (Sites 0200184 and 0200242)													✓				✓		✓	✓		Weekly	Spring Snowmelt	
Corbin Creek u/s and d/s Byron Creek Collieries (New Site and 0200209)													✓				✓		✓	✓		Weekly	Spring Snowmelt	
Andy Good Creek Near Mouth (Site 0200243)													✓				✓		✓	✓		Weekly	Spring Snowmelt	Baseline for Coleman Collieries Expansion
Michel Creek u/s and d/s Coleman Collieries (Sites 0200185 and 0200186)													✓				✓		✓	✓		Weekly	Spring Snowmelt	
Michel Creek u/s and d/s Kaiser Resources (Sites 0200203 and 0200025)													✓				✓		✓	✓		Weekly	Spring Snowmelt	

TABLE 89 continued

RECOMMENDED WATER QUALITY AND EFFLUENT MONITORING FOR THE ELD AND FLATHEAD RIVER BASINS

Sites \ Parameters	BOD_5	Chlorine, Tot. Res.	Coliforms, Fecal	Copper, Diss.	Cyanide	Flow	Iron, Diss.	Mangancse, Diss.	N. Ammonia	N. Nitrate	N. Nitrite	N. Total	pH	Phenols	Phosphorus, Diss.	Phosphorus, Tot.	Solids, Sus.	Sulphide	Temperature	Turbidity	Zinc, Diss.	Frequency	Period	Comments
Michel Creek u/s and d/s Kaiser Resources coke plant (Sites 0200046 and 0200025)			✓		✓				✓				✓	✓			✓	✓	✓	✓		Monthly	Low Flow	Only if Coke Plant Effluent Upgraded (Section 4.3.3)
Suspended Sediment Sources at Byron Creek Collieries, Coleman Collieries, Kaiser Resources and Miscellaneous Sources						✓											✓					Weekly	Spring Snowmelt	See Chapter 4 Companies Should Monitor Daily During Spring Snowmelt and Heavy Rains
Kaiser Resources Coke Plant Effluent (AE 0132901)					✓	✓			✓				✓	✓			✓	✓				Monthly	Low Flow	Only if Coke Plant Effluent Upgraded (Section 4.3.3)
Byron Creek Collieries and Coleman Collieries Settling Ponds						✓		✓	✓	✓	✓		✓						✓			3-4 Times/Year	Especially at Low Flows for Nitrogens	To Establish Levels During Initial Operation of Ponds
Lower Elk River Basin																								
Elk River u/s and D/s Kaiser Resources (Sites 0200027 and 0200111)													✓				✓		✓	✓		Weekly	Spring Snowmelt	
Grave Creek u/s and d/s Harmer Creek (Sites 0200255 and 0200026)													✓				✓		✓	✓		Weekly	Spring Snowmelt	

TABLE 89 continued

RECOMMENDED WATER QUALITY AND EFFLUENT MONITORING FOR THE ELK AND FLATHEAD RIVER BASINS

Sites \ Parameters	BOD_5	Chlorine, Tot. Res.	Coliforms, Fecal	Copper, Diss.	Cyanide	Flow	Iron, Diss.	Manganese, Diss.	N. Ammonia	N. Nitrate	N. Nitrite	N. Total	pH	Phenols	Phosphorus, Diss.	Phosphorus, Tot.	Solids, Sus.	Sulphide	Temperature	Turbidity	Zinc, Diss.	Frequency	Period	Comments
Suspended Sediment Sources at Kaiser Resources, (and other sources)						✓											✓					Weekly	Spring Snowmelt	See Section 5.1 Kaiser Resources Should Monitor Daily During Spring Snowmelt and Heavy Rains
						✓		✓	✓	✓	✓		✓						✓			3-4 Times/Year	Especially at Low Flows For Nitrogens	Kaiser Sources Only to Establish Levels
Kaiser Resources Tailing Pond and Refuse Pile Otto Creek d/s Tailing Pond (0200117), Seepage From Refuse Pile (0200235) and Surface Water Below Refuse Pile (0200236)						✓	✓	✓	✓	✓	✓		✓						✓		✓	4 Times/Year	Low Flow	Re Tailing Pond and Refuse Pile Seepage
Tailing Pond Supernatant (0225021)									✓	✓	✓											3-4 Times/Year	Low Flow	To Establish Levels
Elk River u/s Sparwood Sewage Treatment Plant (0200103)			✓																			Monthly	Low Flows	
Elk River d/s Sparwood Sewage Treatment Plant (0200102)			✓																			Monthly	Low Flows	
													✓				✓		✓	✓		Weekly	Spring Snowmelt	

TABLE 89 continued

RECOMMENDED WATER QUALITY AND EFFLUENT MONITORING FOR THE ELK AND FLATHEAD RIVER BASINS

Sites / Parameters	BOD5	Chlorine, Tot. Res.	Coliforms, Fecal	Copper, Diss.	Cyanide	Flow	Iron, Diss.	Manganese, Diss.	N. Ammonia	N. Nitrate	N. Nitrite	N. Total	pH	Phenols	Phosphorus, Diss.	Phosphorus, Tot.	Solids, Sus.	Sulphide	Temperature	Turbidity	Zinc, Diss.	Frequency	Period	Comments
Elk River at Hosmer (0200024)													✓				✓		✓	✓		Weekly	Spring Snowmelt	
No Name and Transmission Line Creeks													✓				✓		✓	✓		Weekly	Spring Snowmelt	Lower Priority, Baseline for Hosmer-Wheeler Project
Elk River u/s Fernie (1190004)																						Monthly or as Necessary During Hydraulic Overloading or Raw Sewage Bypasses at Fernie	Low Flow	Especially When There is Recreational Use of River
Elk River d/s Fernie (0200113)			✓																					
Elk River at Morrissey Provincial Park																								
Sparwood and Fernie Sewage Treatment Plant Effluent	✓	✓	✓			✓											✓					Monthly	Low Flow	
(PE0025301 and PE0039001)						✓						✓				✓						3-4 Times/Year		To Establish Loadings
Elk River at the Mouth (0200016 or New Site Above Influence of Libby Reservoir)									✓	✓	✓	✓	✓		✓	✓	✓		✓	✓		Weekly	Spring Snowmelt	Re. Contribution of Elk River
									✓	✓	✓	✓	✓		✓	✓	✓		✓	✓		Monthly	Remainder of Year	To Libby Reservoir
Flathead River Basin	No Further Monitoring Until Definite Development Proposals Received																							

TABLE 90

POTENTIAL COAL DEVELOPMENTS IN THE ELK AND FLATHEAD BASINS FROM 1975 TO 1995[103]

Event	Output Million Tonnes/Year	Community Affected	Timing	Employment Operations	Employment Construction	Comments
Kaiser Resources Hosmer-Wheeler Coal Project	1.4-1.8	Sparwood & Fernie	1977-81	600-800	300	Coking Coal Underground Hydraulic Mine (See Section 5.2)
Byron Creek Collieries Expansion	0.5-0.9	Corbin or Sparwood	1976-79	150-200	100	Surface Mine, Thermal Coal (See Section 4.1)
Coleman Collieries[67] Expansion in B.C.	20 Million Tonnes of Raw Coal From B.C. Over Life of Mine	Coleman (Alberta)	1978-			Coking Coal Surface Mine in B.C., Processing Plant in Alberta (See Section 4.2)
Crows Nest Industries Line Creek Coal Project	0.9-1.4	Elkford & Sparwood	1977-80	350	300-	Surface Mine, Coking Coal (See Section 2.4)
Elco Mining Elk River Coal Project	3.6	Elkford or New Townsite	1978-83	1,000-1,100	600-800	Surface Mine, Coking Coal (See Section 3.1.2)
Rio Algom Mines Sage Creek Coal Project (Flathead Basin)	1.4-2.7	New Townsite or Possibly Fernie	1978-83	900	600-800	Surface Mine, Coking Coal (See Section 6.1)

TABLE 90 continued

POTENTIAL COAL DEVELOPMENTS IN THE ELK AND FLATHEAD BASINS FROM 1975 TO 1995[103]

Event	Output Million Tonnes/Year	Community Affected	Timing	Employment Operations	Employment Construction	Comments
B.C. Hydro Thermal Electric Power	5.4-7.2	Kootenay Valley	1985-90	75-100	500-1,100	Using Middlings and Thermal Coal From Various Mines, Assumes 1,500 - 2,000 MW at 2.0 Million Tonnes Per Year Per 500 MW
Dominion Coal Block	2.7	Fernie Area	1985-90	900	500-700	Underground Mine, Coking Coal
Coke Production	1.8-2.7	Kootenay Valley	1985-90	800-1,000	500-1,000 Over 3 Yrs.	