MINISTRY OF ENVIRONMENT AND PARKS
PROVINCE OF BRITISH COLUMBIA

PEACE RIVER AREA

BULLMOOSE CREEK SUB-BASIN WATER QUALITY ASSESSMENT AND OBJECTIVES

TECHNICAL APPENDIX

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INTRODUCTION

Bullmoose Creek is an important tributary within the Murray River Sub-basin relative to northeast coal development. The Murray River sub-basin is one of seven priority sub-basins in the Peace River Planning Unit for which water quality assessments are being conducted as a part of the initial strategic plan for the Unit. The location of the Peace River Planning Unit is shown in Figure 1, and Figure 2 shows the Unit and its seven priority sub-basins.

Bullmoose Creek is a tributary of the Wolverine River which in turn flows into the Murray River (Figure 3). The Murray River then flows north into the Pine River at East Pine, approximately 40 km downstream from the Village of Chetwynd.

Bullmoose Creek flows easterly from its origin in the Rocky Mountain Foothills to its junction with the Wolverine River. West Bullmoose Creek and South Bullmoose Creek[(1)] join at the headwaters to form Bullmoose Creek at the site of the Teck Bullmoose coal mine.

Over its entire 50 km length, Bullmoose Creek lies within the coal-bearing Rocky Mountain Foothills physiographic region (Holland, 1964). This region is characterized by a series of subparallel ridges and valleys situated between the Rocky Mountains and the Alberta Plateau benchlands to the east. The elevation of Bullmoose Creek at its origin is approximately 1 520 m, whereas the elevation of its confluence with the Wolverine River is approximately 700 m.

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[1] "South Bullmoose Creek" is the name given to that portion of the main Bullmoose Creek upstream from the confluence with West Bullmoose Creek. These stream names were used in the Teck Bullmoose Coal Inc. (1982) Stage II Report to differentiate the southern branch of the mainstem upstream from the minesite.

The Bullmoose Coal Project is the most significant economic activity affecting the future of the Bullmoose Valley. In the past, there was extensive logging of the valley bottom and natural gas exploration. Agricultural potential is low and, except for some grazing, is presently not utilized.

The Teck Bullmoose open-pit coal mine located south of the confluence of South and West Bullmoose Creeks has a production capability of about 2.3 million tonnes over a lifetime of 26 years beginning in late 1983. The coal is processed at the preparation plant located near the mine site and trucked approximately 34 km down the Bullmoose Creek Valley to the coal loadout terminal. The coal is then transferred from storage silos to rail cars for transport to Ridley Island near Prince Rupert. There are no townsites in the Bullmoose Valley at present and none for the foreseeable future. Most mine employees live in the town of Tumbler Ridge. The main contaminants of concern are suspended sediments from logging and mining disturbance, and nutrient input from explosives residues, pit water, and domestic sewage.

2. HYDROLOGY

Continuous streamflow data for West Bullmoose Creek and South Bullmoose Creek were recorded during 1981 (Tables 1, 2; Teck Bullmoose Coal Inc., 1982). This was the first year of streamflow measurements for Bullmoose Creek.

In 1981, ice break-up in Bullmoose Creek occurred at the end of April. The spring snowmelt flood period occurred from early May to the beginning of June. South Bullmoose Creek had a maximum daily discharge of 10 286 L/s on May 22 and West Bullmoose Creek had a maximum daily discharge of 8 353 L/s on May 26. No significant rainstorms occurred during either the snowmelt period or the summer. Flows in South Bullmoose Creek dropped to a minimum daily discharge of 61 L/s on September 18. West Bullmoose Creek had considerably lower flows during the period July-September with a minimum daily discharge of 48 L/s on September 19.

Precipitation during October and November again increased the streamflow. This precipitation fell mainly as snow, which quickly melted at lower elevations. Streamflow increases ended with freeze-up, which occurred on November 12 in 1980 and on November 15 in 1981. No under-ice flows were recorded during the winter. However, it is expected that Bullmoose Creek would experience annual minimum flows during the winter period, November-April, similar to other drainages on the east slopes of the Rocky Mountains as studied by Miles (1981). According to Klohn Leonoff Ltd. (1982), winter flows in Bullmoose Creek are fed primarily by groundwater.

Low flow estimates for Bullmoose Creek were taken from the regionalized low flow plots by Obedkoff (1983). West Bullmoose Creek, with a drainage area of 50.3 km^2, is predicted to have a mean seven-day average low flow for the October-April period of 22 L/s. The 1-in-10 year seven-day average low flow for this same period is estimated to be 11 L/s. The late summer low flow is substantially higher: the mean seven day average in August is estimated to be 160 L/s, and the 1-in-10 year seven-day average low flow is estimated to be 110 L/s.

South Bullmoose Creek (drainage area of 53.1 km^2) is predicted to have a mean seven-day average low flow of 24 L/s for the October-April period. The 1-in-10 year seven-day average low flow for the same period is estimated to be 13 L/s. The mean seven-day average low flow in August is estimated to be 170 L/s, and the 1-in-10 year seven-day average low flow in August is estimated to be 120 L/s.

It must be noted that the above low flow values predicted for Bullmoose Creek may be imprecise as a result of the regionalization procedure in defining a curve through a scatter of points. Obedkoff (1983) urges caution in the use of these potentially unreliable small-stream low-flow estimates.

Peak daily discharge estimates were also taken from regionalized plots by Obedkoff. West Bullmoose Creek (at the mouth) is expected to have a mean peak daily discharge of 27 m^3/s and a peak daily discharge for a 10-year return period of 35 m^3/s. At the mouth of South Bullmoose Creek, the peak daily discharge is expected to be 28 m^3/s (mean) and 37 m^3/s (10-year return). Downstream from the confluence of South and West Bullmoose Creeks, the peak daily discharge is estimated to be 48 m^3/s (mean) and 62 m^3/s (10-year return).

WATER USES

There are no existing water withdrawals from Bullmoose Creek either upstream or downstream from the minesite, and no known proposals for future withdrawal which would be affected by minesite discharges.

The two water licences for the Bullmoose Creek watershed relate to the Teck Bullmoose coal project. One is for a withdrawal of 75.7 L/s from wells near Bullmoose Creek. This water is used for domestic purposes, fire-fighting, dust suppression, and as preparation plant make-up water. The other is for the diversion of natural drainage to settling ponds and is related to 3.08 km of land improvement. Neither water withdrawal directly affects the natural flow of South Bullmoose Creek or West Bullmoose Creek.

The fish population in the Bullmoose drainage has been rated within a regional context as of 'medium-to-low' density by the Regional Fisheries Biologist (Kumka, 1982). Dolly Varden char are the most abundant and wide-spread species in the Bullmoose drainage (Teck Bullmoose Coal Inc., 1982). Other species are present in the system, but appear to be restricted to the lower reaches by a 2 m waterfall, 8 km upstream from the confluence with the Wolverine River. These species include Arctic grayling, Rocky Mountain whitefish, burbot, longnose sucker, and sculpins. High abundance of Dolly Varden fry (age 0+) in the lower reaches of South and West Bullmoose Creeks and in the mainstem downstream from the minesite is indicative of optimal spawning/rearing habitat conditions. Based on this information, it has been concluded that this area, in the immediate vicinity of the minesite, is most critical for Dolly Varden char production (Teck Bullmoose Coal Inc., 1982).

Recreational resource values of the Bullmoose Valley are considered to be of 'moderate' significance (Teck Bullmoose Coal Inc., 1982). Existing uses of the aquatic environment include canoeing and fishing. Swimming is not presently known to occur in Bullmoose Creek, but may assume some importance as the growing population of Tumbler Ridge seeks summer recreation.

WASTE DISCHARGES

The Bullmoose coal mine is a large project involving up-slope clearing and excavation, blasting, extensive coal preparation and washing, and domestic sewage disposal. Wastewaters generated from these activities have the potential to degrade the water quality of Bullmoose Creek. Significant increases in suspended solids levels from surface runoff could have a detrimental effect on the aquatic life of Bullmoose Creek: reduced light penetration could result in lower primary and benthic production; and increased silt deposition could cause shifts in the benthic invertebrate community, and reduce the spawning/rearing capabilities of Dolly Varden spawning redds. (Silt deposited after freshet would remain in the creek and impair substrate quality for fall spawning Dolly Varden). Increased nitrogen and phosphorus concentrations from explosives residues and domestic sewage could contribute to toxic ammonia and nitrate levels, and to excessive algal growth in Bullmoose Creek. There is also the potential for water from the waste dump and mine drainages to be acidic.

An extensive water management system has been designed by the proponent to prevent these potential changes to Bullmoose Creek water quality. A series of ditches collects sediment-laden runoff from prestripping, mining, waste dumps, and the preparation plant, and channels it into three sedimentation ponds, where particulate material is removed prior to discharge. Additionally, fine tailings from the preparation plant and treated domestic sewage effluent from two treatment plants are directed to an exfiltrating tailings pond. The only direct discharge to Bullmoose Creek is decant from the settling ponds; however, there will be continual seepage from the settling ponds and the tailings pond. A summary of the waste discharges from the mine is presented in Table 3.

4.1 SEDIMENTATION PONDS

Three sedimentation ponds collect maintenance shop effluent, pit water, and surface runoff and seepage from the plant site area, waste dumps, and the mine area (Table 3 and Figure 4; Waste Management Branch permits PE 6865, PE 6667, and PE 6696). During the four month free-flowing period (May-September), inflows can be expected to exceed estimated seepage and the ponds may overflow to Bullmoose Creek. As a result of routing storm runoff through the sedimentation ponds, there will be a slight damping of peak flows in Bullmoose Creek. When overflow is occurring, the sedimentation pond discharge will be diluted by higher flow rates in Bullmoose Creek.

During low flow periods, water will exit from the sedimentation ponds only by evaporation and exfiltration. The seepage from the ponds (at least in the early years of operation) is estimated to be:

Pond 1 and 2 (combined) = 25 L/s

Pond 3 = 25 L/s

A significant (but unknown) portion of this seepage is expected to reach the bed of Bullmoose Creek within a short distance of the sedimentation ponds rather than contribute to the groundwater resource. Groundwater in the valley aquifer is not expected to be significantly affected by sedimentation pond seepage (Klohn Leonoff Ltd., 1982). If all of the seepage reached West Bullmoose and South Bullmoose Creeks, the ratio of receiving water to seepage would be 1:2 during the 7-day average winter low flow (10-year return period) and 1:1 during the mean 7-day average winter low flow. During the August low flow, the dilution ratio would be 5:1 (10-year return) to 7:1 (mean low flow).

(a) FLOW

No actual records of effluent flow from the sedimentation ponds were available at the time of writing. Pond discharge is expected to commence during the 1984 open-water season. The permitted peak daily discharge rates are: Pond 1 - 1.5 m^3/s

Pond 2 - 0.7 m^3/s

Pond 3 - 2.16 m^3/s

Total - 4.36 m^3/s

Given that the 1-in-10-year peak daily discharge for Bullmoose Creek downstream from the confluence of South and West Bullmoose Creeks is 62 m^3/s (Section 2), the dilution ratio would be approximately 14:1. For the mean peak daily discharge (48 m^3/s), the dilution ratio would be 11:1. The dilution of discharge from the sedimentation ponds in West Bullmoose Creek would be less, i.e., 8:1 during the 1-in-10-year peak daily discharge and 6:1 during the mean peak daily discharge.

(b) SUSPENDED SOLIDS

Records of suspended solids concentrations from sedimentation pond discharges were not available at the time of writing. The performance of the ponds in clarifying runoff to permitted levels can be evaluated only after such data are collected.

Suspended solids loading is allowed by permit to vary according to suspended solids concentrations in the receiving waters. When ambient (background) concentrations are high (i.e., >50 mg/L), for example during spring-melt, sedimentation pond effluent can be discharged at a concentration equivalent to that of the receiving waters plus 10 mg/L. Given close tracking of effluent concentrations to receiving water concentrations, it seems reasonable to predict little effect from this additional 10 mg/L on Bullmoose Creek during periods of high flow which will occur due to spring melt or rainstorm events. The dilution available in West Bullmoose Creek (6:1) and Bullmoose Creek downstream from the confluence (11:1) will act to provide additional reduction in suspended solids concentrations outside the mixing zone.

When receiving water suspended solids concentrations are low (i.e., <50 mg/L), effluent from the sedimentation ponds may be discharged with a suspended solids concentration equivalent to 50 mg/L. Since effluent flows will tend to be proportional to stream flows, it is reasonable to assume that the effluent dilution ratios (6:1, 11:1) calculated for mean peak discharges should approximate those for low flow periods. Given this worst case assumption, projected increases in receiving water suspended solids downstream from each sedimentation pond have been calculated (Table 4) as follows: pond 3, 4 mg/L; pond 1, 2.8 mg/L; and pond 2, 1.25 mg/L. Under conditions of minimum background suspended solids concentration* (0.5 mg/L), the suspended solids concentration in Bullmoose Creek downstream from the confluence of South and West Bullmoose Creeks would be less than 4 mg/L. Although such a concentration may be up to eight times greater than the minimum background value recorded, this level would not constitute impairment of the Bullmoose Creek water quality. Downstream Dolly Varden spawning habitat would not be seriously affected by this level of suspended solids loading. EIFAC (1965) reported that there should be no harmful effects on fisheries in waters having less than 25 mg/L suspended solids; however, salmonid spawning substrates should be kept as free as possible from siltation.

(c) NITROGEN

The most significant potential impact of mining on Bullmoose Creek water quality is the release of nitrates and ammonia from blasting. The explosives used at the Bullmoose mine are based on water soluble ammonium-nitrate. Thus, residual nitrogenous compounds from misfires, blasting

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*Suspended solids at water quality station 0410076 (nearest the sedimentation ponds) ranged from 0.5 mg/L to 6.0 mg/L for the months of July and August (1978-1981) (Teck Bullmoose Coal Inc., 1982).

residues, and spillage will be carried by the pit water and waste rock water to the sedimentation ponds. Such fugitive loss of nitrogen to coal mine wastewaters may range up to 6 percent of explosives used under wet blasting conditions in British Columbia (Pommen, 1982).

Klohn Leonoff Ltd. (1982) approximated the total fugitive loss of nitrogenous compounds from the Teck Bullmoose mine to be 2 percent or 21 900 kg/yr (60 kg/d) for each of ammonia-N and nitrate-N. The partitioning of these loadings among the sedimentation ponds is shown in Table 5. By considering the sedimentation pond retention times and nitrification of ammonia to nitrate, Klohn Leonoff Ltd. derived anticipated concentrations of ammonia-N and nitrate-N in each of the sedimentation ponds (Table 5). These concentrations were calculated from annual flow estimates based on average precipitation (the use of average flows does not predict the highest N concentrations that may occur).

Maximum ammonia-N concentrations are expected to vary from 1.8 mg/L in pond 2 to 3.4 mg/L in pond 3. Maximum nitrate-N concentrations are expected to vary from 4.5 mg/L in pond 2 to 6.5 mg/L in pond 1. These concentrations will increase after 1987 when explosives consumption increases by 25 percent. Assuming that ammonia and nitrate concentrations increase proportionally, it is projected (Table 5) that: maximum ammonia-N concentrations will range from 2.3 mg/L in Pond 2 to 4.3 mg/L in pond 3; and maximum nitrate-N concentrations will range from 5.6 mg/L in Pond 2 to 8.1 mg/L in pond 1.

The predicted maximum increases in receiving water concentrations of ammonia-N and nitrate-N are presented in Table 6. These were calculated for the predicted August and winter low flows when the highest N concentrations would occur. The effluent loading values used in these calculation were calculated assuming that the total fugitive N loss equals 2 percent of maximum explosives use.

Actual concentrations may be greater than shown since fugitive loss of nitrogenous compounds could exceed 2 percent and since explosives consumption increases after 1987.

Receiving water ammonia-N concentrations

The most important process governing the fate of fugitive nitrogen from explosives use is nitrification. Under aerobic conditions ammonia (NH_4^+, NH_3) is oxidized by bacteria to nitrite (NO_2^-) and nitrate (NO_3^-). Work by Pommen (1983) at Fording Coal demonstrated that 95 percent nitrification was typical in effluent from spoil piles and settling ponds over an entire year. This rate of nitrification was used to predict the level of ammonia-N in Bullmoose Creek (Table 6).

Under conditions of the predicted winter low flow, the ammonia-N concentration in West Bullmoose Creek downstream from the three sedimentation ponds could increase by 0.8-1.7 mg/L (mean annual and 10 year return low flow, respectively) over a maximum background level of 0.2 mg/L. As a result of an equally low flow in South Bullmoose Creek during the winter, there would not be substantial dilution of these concentrations downstream from the confluence of South and West Bullmoose Creeks. At this point in main Bullmoose Creek, the maximum increase in the concentration of ammonia-N is expected to be 0.4-0.8 mg/L.

For the worst case, namely winter conditions with a pH of 8.5 and a temperature of 5°C, criteria developed by Nordin and Pommen (1986) are a maximum ammonia-N of 1.99 mg/L and a 30-day average of 0.384 mg/L to protect aquatic life. The maximum predicted increases in West Bullmoose and Bullmoose Creeks would not exceed the maximum criterion. However, if these maximums persisted for any length of time they could exceed the 30-day average criterion.

The August low flow provides more dilution for the sedimentation pond effluent. The maximum increase in ammonia-N concentration in West Bullmoose Creek is expected to be 0.11-0.17 mg/L. Downstream from the confluence of West and south Bullmoose Creeks, the ammonia-N level is expected to increase by 0.05-0.08 mg/L. Assuming that pH=8.5, T=16°C, the criteria to protect aquatic life are a maximum of 1.9 mg/L and a 30-day average of 0.341 mg/L total ammonia-N (Nordin and Pommen, 1986). The predicted increases in summer levels of ammonia-N should therefore not affect downstream aquatic life, although any increase would need to be carefully monitored.

Thus, under worst-case conditions projected above, the high capability Dolly Varden spawning/rearing and overwintering habitat in the lower reach of West Bullmoose Creek and in main Bullmoose Creek downstream from the confluence could be subject to levels of un-ionized ammonia-N approaching toxic levels during the severe winter low flow period. To protect the downstream Dolly Varden char population, higher effluent quality may be necessary.

Receiving water nitrate-N concentrations

During worst-case conditions of a winter low flow, nitrate-N levels in West Bullmoose Creek downstream from the sedimentation ponds could increase from a maximum background level of 0.3 mg/L by 32-63 mg/L.

The input of flow from South Bullmoose Creek would reduce the increase in concentration to 15-29 mg/L downstream from the confluence of West and South Bullmoose Creeks. These winter increases of nitrate-N exceed the criterion for public water supply protection (10 mg/L), and warrant concern for future potential downstream users. However, it should be emphasized that raw water consumption by recreationists will be generally limited to the summer months.

With greater dilution available during the summer low flow, the predicted increases in nitrate-N levels would be much lower: 4.3-6.3 mg/L in West Bullmoose Creek, and 2.1-3 mg/L downstream from the confluence of South and West Bullmoose Creeks. These predicted August low flow increases are within the acceptable drinking water level (10 mg/L), but exceed the 1.0 mg/L criterion recommended by EPA (1973) to prevent nuisance algal growth in streams. Although this latter criterion is crude and does not consider many site specific factors, a potential problem with nutrification is suggested. This matter is considered further in Section 5.5.

Nitrogen removal

If the above worst-case projections for receiving water ammonia-N concentrations are correct, Bullmoose Creek may experience toxic levels of un-ionized ammonia-N during mean and 10-year return low-flow periods. There are presently no proven and cost-effective methods for the removal of nitrogen from the large volumes of wastewater resulting from explosives use (Pommen, 1983). It may be possible to increase the rate of nitrification through increased pond-retention times and the installation of mechanical aeration. However, the latter would be of less advantage during the winter low flow periods when cold temperatures reduce the rate of biological nitrification.

Actual receiving water monitoring data are required before various nitrogen removal and treatment options can be considered more fully. The theoretical receiving water ammonia-N concentrations may greatly exceed actual levels since there may be significant ammonia-N adsorption at the cation exchange sites in the soil particles as the wastewaters exfilter from the sedimentation pond to the creek.

(d) PHOSPHORUS

Phosphorus is predicted to enter the sedimentation ponds via runoff from fertilized reclamation areas and from land disturbance related to mining activity. Revegetation will require an unknown quantity of fertilizer, some of which would be lost to drainage water. No assessment of this diffuse discharge has been completed by Teck Bullmoose Coal Inc., and no accurate predictions of its effect on receiving waters are possible at this time. The results of a nutrient study at another coal mine in British Columbia may be pertinent to this situation. Nordin (1982) investigated the effects of increased nitrate concentrations from the Fording Coal Ltd. mine on periphytic algal growth in the Fording River. Nitrate concentrations increased from less than 0.1 mg/L above the minesite to 10 mg/L within the minesite; however, increases in algal biomass were small in proportion to the increase in nitrate concentration. This system was strongly phosphorus limited and the minesite did not contribute sufficient phosphorus to cause large increases in algal growth. There is a potential for heavy algal growth in the event of higher phosphorus loading.

(e) ACID GENERATION

One of the five coal seams was found to be a weak acid (sulphuric acid) producer. However, pit drainage-water is not expected to be acidified because of the low sulfide content of the coal and because of the high buffering capacity of the surrounding geologic materials. The high bicarbonate content of the effluent in the sedimentation ponds (150-192 mg/L) should completely neutralize any excess acid production. The pH of the sedimentation pond discharge is projected to be 7.2 for pond 1 and 7.3- 7.5 for ponds 2 and 3. The sulphate content of the sedimentation ponds is expected to be 22 mg/L for pond 1, 15 mg/L for pond 2, and 17 mg/L for pond 3. Waste rock was not proven to be a net acid producer (Klohn Leonoff Ltd., 1982).

4.2 TAILINGS POND

The Teck Bullmoose tailings pond collects fine refuse and water from the coal washing plant, sewage effluent from the two package treatment plants, and surface runoff (Waste Management Branch permit PE 6757). Seepage from the pond is expected to be sufficient to allow complete exfiltration at least in the early years of operation. Klohn Leonoff Ltd. (1982) estimated that the average annual seepage will be approximately 8.3 L/s and the peak annual seepage approximately 16.6 L/s. Tailings pond seepage will act as a recharge to the valley aquifer, and according to Klohn Leonoff Ltd. it will only enter Bullmoose Creek several kilometers downstream from the minesite. There is no direct discharge to surface receiving waters.

Tailings pond seepage is a potential source of chemical change to the groundwater with consequent effects on Bullmoose Creek. Predicting these changes is difficult since the chemistry of the seepage is dependent on water quality and flow from the sewage treatment plants and the coal preparation plants, as well as the amount of dilution available in the groundwater. However, significant attenuation of the chemical constituents in the seepage is expected as it is diluted and travels a considerable distance with groundwater in the valley aquifer before emerging in Bullmoose Creek downstream from the mine.

The tailings pond water quality is expected to be similar to that of the sedimentation ponds. Nitrate-N concentrations are expected to be 3-10 mg/L and ammonia-N, 0.1-0.5 mg/L. The slight increase in ammonia load, as the result of sewage input, will be negated by nitrification of the ammonia to nitrate. The long retention time in the tailings pond will favor the nitrification process. Production of excess acid is not expected to occur in the tailings pond, and pH is expected to be 7.1-7.4 (Klohn and Leonoff Ltd., 1982). Phosphates from the sewage can be expected to adsorb to the soil and coal particles and be largely retained in the pond, while the more mobile nitrate could eventually reach Bullmoose Creek. Infiltration and percolation through tailings materials may:

- remove ammonia and phosphorus by adsorption
- convert ammonia and nitrite to nitrate by nitrification
- dilute the effluent with groundwater
- smooth out the peaks in nitrogen concentration

By the time the effluent reaches Bullmoose Creek, it will contain mostly nitrate and very little ammonia and nitrite (Pommen, 1982). No estimate of nitrate-N loading to Bullmoose Creek from tailings pond seepage has been promulgated by Teck Bullmoose.

4.3 DIFFUSE AND UNPERMITTED WASTE DISCHARGES

Logging activity and oil and gas exploration prior to the coal mine development have disturbed significant portions of the Bullmoose Creek watershed, with presumed effects on the flow and suspended solids regime of Bullmoose Creek (Girard, 1982). The extent of these non-point source discharges has not been documented with specific water quality data. Thus, it is impossible to calculate loadings or to determine true background water quality. Any future logging and petroleum exploration activities with the potential to impact Bullmoose Creek water quality should be monitored.

5. WATER QUALITY

There are 14 water quality sites on Bullmoose Creek. The locations of these are shown in Figures 3 and 4, and site descriptions are given in Tables 7-11 along with summaries of the water quality data. B.C. Ministry of Environment sampled Bullmoose Creek in 1976, 1977, 1978, and 1982. These data are presented in Table 7. Water quality data collected by the consultants to Teck Bullmoose Coal Inc., are shown in Tables 8, 9, 10 and 11. All these data constitute pre-development background conditions. Water quality data showing any effects of the development will not be available until after 1984, when the minesite becomes fully operational.

5.1 DILUTION

Natural flow in Bullmoose Creek affords little to negligible dilution for sedimentation pond effluent seepage under conditions of the winter minimum flow. As previously stated in Section 4.1, the ratio of receiving water to seepage is predicted to be 1:1 during the mean 7-day, 10-year return winter low flow. During the August low flow, the dilution is predicted to be 5:1 (10 year return) and 7:1 (mean low flow).

5.2 pH, ALKALINITY, AND HARDNESS

The waters of Bullmoose Creek are alkaline and of variable hardness. The pH is similar to other streams in the Murray River sub-basin, ranging from 6.9 to 8.5. Bicarbonate represents the major form of alkalinity at this pH and alkalinity ranges from 40 to 195 mg/L of $CaCO_3$. Hardness levels range from 35 to 155 mg/L, which classifies this water as varying from soft to hard (McNeeley et al., 1979).

None of these characteristics is predicted to be lowered significantly by sedimentation pond discharge or general minesite development. However, there is the potential that levels of alkalinity, hardness, and pH could increase slightly due to the increased weathering of exposed rock formations.

5.3 COLOR, TEMPERATURE, AND DISSOLVED OXYGEN

The color of Bullmoose Creek water is highly variable with a range of <5 to 50 true color units. Natural color levels frequently exceed the maximum acceptable level of 15 color units for public water supplies (B.C. Ministry of Health). However, these data are from one site 18 km downstream from the mine, and the high color values may reflect inflow from downstream bog waters.

Eamer (1979) described the color as being slightly green to very brown, and due to organic acids in soil and decaying vegetation. Temperature varies widely, from 0 to 17° C. Dissolved oxygen measurements range from 7.8 to 14.5 mg/L during the open-water season, although oxygen depletions may occur under winter ice-cover.

Neither the color nor the dissolved oxygen of Bullmoose Creek surface waters are predicted to be altered by sedimentation pond discharge. The temperature of Bullmoose Creek may undergo a slight increase immediately downstream from the sedimentation ponds, when warmer surface pond water is decanted into the creek. The extent and effects of such warming are not known, but would be expected to be negligible.

5.4 TURBIDITY AND SUSPENDED SOLIDS

Turbidity data for Bullmoose Creek range from 0.2 to 410 NTU. Suspended solids levels vary from 0.5 to 651 mg/L. The major source of the suspended material is soil and bank erosion. Both characteristics follow the seasonal and short-term event patterns, characteristic of drainages in northeast B.C.: high concentrations during spring freshet and summer rainstorms, and low concentrations during low flow periods, late summer to winter.

Seasonal changes in suspended solids in the Teck Bullmoose Coal Project area are shown in Figure 5. Elevated levels of suspended solids (>5 mg/L) generally occurred during the snowmelt (May, June) or rainstorm events, and low levels (<5 mg/L) occurred during the summer and winter low flows (Teck Bullmoose Coal Inc., 1982). Suspended solids levels in Bullmoose Creek were generally higher for higher flow rates, although there was no well-defined relationship.

Eamer (1979) recorded significant increases in these characteristics in Bullmoose Creek over two days associated with increased snowmelt runoff (16 to 62 NTU turbidity and 28 to 148 mg/L suspended solids). She also recorded high values following heavy precipitation in July (34 NTU turbidity and 96 mg/L suspended solids). Both characteristics dropped to very low levels as flows declined in August and September.

It is questionable whether the turbidity and suspended solids values shown in Tables 7-11 and Figure 5 can be described as natural background levels. Land disturbance associated with coal mining exploration, gas pipeline construction, logging, and road construction occurred prior to and during the water quality sampling in 1976-1982. These activities have likely contributed to the periodically high values recorded.

Suspended solids loadings from the Teck Bullmoose sedimentation ponds during low flow periods are not predicted to impair the water quality of Bullmoose Creek. The increase in receiving water suspended solids concentration downstream from the confluence of South and West Bullmoose Creeks is predicted to be ≤4 mg/L (see Section 4.1 b). Sedimentation pond discharge during spring freshet would have no significant effect if permit conditions are met: discharge would occur during a period of high natural concentrations (>50 mg/L) and at a level equivalent to ambient (i.e., background) plus 10 mg/L (Section 4.1 b).

5.5 NUTRIENTS

Nutrient levels in Bullmoose Creek were very low and were similar to levels determined for other undisturbed watersheds in northeast British Columbia.

Nitrate levels, as measured by the Province at three different sampling sites in Bullmoose Creek during the period September-October, 1982, were below the detection limit (0.02 mg/L as N; Table 7). Nitrate measurements made by the consultants (Tables 8, 9, 10, 11) fluctuated widely (0.002-0.4 mg/L as N) with no evident seasonal trend. Nitrite levels were at or below the detection limit (0.005 mg/L as N). Ammonia levels have generally been non-detectable (<0.005 mg/L as N), although the Province has recorded concentrations of up to 0.026 mg/L as N (station 1177708 downstream from the minesite, Table 7).

Pre-development dissolved phosphorus levels were also low in Bullmoose Creek, but at the level (0.003-0.004 mg/L as P) that was associated with maximum periphyton growth in the lower Thompson River by Bothwell (1985). The Province recorded dissolved levels ranging from <0.003 to 0.006 mg/L as P at site 1177708 in Main Bullmoose Creek over the period 1976-1982 (Table 7). Provincial sampling at three different sites on Bullmoose Creek during the period September-October, 1982, indicated that dissolved orthophosphorus levels averaged 0.005 mg/L as P, and ranged from 0.003 to 0.017 mg/L as P. The highest value (0.017 mg/L as P) was recorded at site 0410062, downstream from the confluence of West and South Bullmoose Creeks. The detection limit (0.010 mg/L as P) for dissolved phosphorus used by the consultants was too high for meaningful interpretation.

Estimated N:P ratios using mean nutrient concentrations recorded by the Province for Bullmoose Creek sites are presented in Table 12. The average N:P ratio for the four sites on Bullmoose Creek is estimated to be 8:1. This indicates that Bullmoose Creek was neither nitrogen nor phosphorus limited. According to Nordin (1982), concentrations of biologically available nitrogen and phosphorus in the ratio of approximately 8-10:1 indicates nutrient co-limitation. Ratios of less than 5 or 6:1 indicate nitrogen limitation and greater than 12:1 indicate phosphorus limitation. Phosphorus levels were very low, suggesting that input of nitrogen from mine wastewaters would drive the N:P ratio to a phosphorus limited situation before excessive plant growth would occur. The exception to this trend appears to be site 0410062, downstream from the confluence of South and West Bullmoose Creeks, and just downstream from the minesite. Using mean nutrient concentrations, the N:P ratio for this site is estimated to be 4.3:1. Using the maximum orthophosphorus value (0.017 mg/L as P) recorded September 9, 1982, the N:P ratio becomes <2:1. Under these conditions, with a high level of biologically available phosphorus, nitrogen input from mine wastewaters at levels predicted in Section 4.1 would result in excessive growth of attached algae (assuming appropriate levels of temperature, light, turbidity, and trace nutrients for plant growth). Thus, it is possible that the high capability Dolly Varden spawning/rearing habitat downstream from the minesite could be degraded by excessive algal growth. An algal-growth covered substrate would decrease available fish habitat, and algal respiration and decomposition could lower dissolved oxygen to levels harmful to aquatic life. However, phosphorus levels have been generally too low for prolonged algal growth. Since the mine effluent is not expected to contribute phosphorus to the receiving waters, nuisance algal growth is not deemed likely. This prediction is reinforced by the findings of Nordin at the Fording River coal mine: although receiving water nitrate levels increased 100-fold at the minesite, there was insufficient phosphorus loading to initiate problem algal growth.

5.6 METALS

Natural background concentrations of some trace metals in Bullmoose Creek were elevated relative to the Provincial preliminary working water quality criteria. Of 28 metals measured by Teck Bullmoose Coal Inc. during the period 1977 to 1981, 14 exceeded criteria for aquatic life, wildlife, and public water supplies (Tables 8 to 11 and Table 13). These include: aluminum, antimony, arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, silver, titanium, and zinc. Only aluminum, cadmium, copper, and silver consistently (>45 percent of values) exceeded their respective working criteria for aquatic life. The remaining trace metals only occasionally (1-32 percent of values) exceeded the preliminary criteria.

Five trace metals infrequently (<15 percent of values) exceeded water quality criteria for public water supplies: total iron, total manganese, total titanium, and total and dissolved nickel. With the exception of dissolved nickel, these metals are tied up in the suspended solids and should not be of concern since suspended solids would be removed prior to public consumption of the water.

Provincial data for trace metals in Bullmoose Creek indicate that only five metals out of a total of 25 infrequently exceeded the respective criteria for aquatic life and public water supply. These include total manganese, total aluminum, total copper, total cadmium, and total and dissolved iron. The total concentrations are high due to suspended sediment and thus are not important. There was only one dissolved iron value (out of 12) which equalled the public water supply criterion of 0.3 mg/L.

The apparent discrepancy between the provincial metals data and the Teck Bullmoose metals data may be a result of the limited scope of provincial sampling. Provincial sites 0410076, 0410079, and 0410062 were sampled only during September and October 1982. Provincial site 1177708 was sampled more frequently but was located 18 km downstream from the minesite. In contrast, the Teck Bullmoose metals data were recorded on a more frequent basis between 1977 and 1981 in the vicinity of the minesite.

The potential impact of minesite development on trace metals concentrations in Bullmoose Creek is unknown. The Stage II report for the Bullmoose Mine made no predictions of future trends in trace metals levels. Considering the exposure to runoff of large areas of disturbed land surfaces, higher metal concentrations might be expected. Given the existing high natural levels for some trace metals, any further additions could have significant biological effects. However, according to Pommen (personal communication), experience in the south-east B.C. coal area has shown that metal contamination in pit drainage waters is not a problem in the absence of acid mine drainage.

6. WATER QUALITY OBJECTIVES

Water quality objectives are recommended for the Bullmoose Creek drainage (including South and West Bullmoose Creeks) downstream from the Teck mine development with regard to fecal coliform bacteria, suspended solids, un-ionized ammonia-N, pH, periphytic algal growth, turbidity, dissolved oxygen, nitrite plus nitrate-N, and nitrite-N. It is proposed that the designated water uses to be protected should be public water supplies, recreation, wildlife, and aquatic life. Although there is no present use of this reach for drinking/public water supply, such future use is possible and protection should be provided. Increased water-based recreation (i.e., canoeing, swimming, angling, and associated camping) is likely, given the improved accessibility and the proximity to the town of Tumbler Ridge. Those reaches of the Bullmoose Creek drainage downstream from the minesite which are critical for Dolly Varden char production also require protection. Nutrient input could cause excess algal growth, which in turn could degrade the fish rearing capability of downstream habitat. Excessive suspended solids input could cause siltation of spawning gravels. Additionally, the fish population must be protected from depressed pH and toxic levels of un-ionized ammonia-N and nitrite-N.

There are no present or potential uses of the following type between the minesite and the confluence with the Wolverine River: livestock watering, irrigation, or industrial consumption. However, protection of these uses is assured by the objectives set for public water supplies, aquatic life, and recreation. Fecal coliform contamination is unlikely since there is no direct discharge of minesite sewage to Bullmoose Creek, only treated seepage from the tailings pond. However, objectives for fecal coliform bacteria levels are set to protect future potential use.

The objectives are based on approved and working criteria for water quality, on available data for ambient water quality, water uses, and river flows, and on projected worst-case waste loadings. According to these worst-case projections, the proposed objectives would be met for turbidity, suspended solids, pH, dissolved oxygen, substrate sedimentation, fecal coliforms, and periphyton standing crop. However, the projections suggest that there may be problems with meeting the objectives for ammonia-N, nitrite-N, and nitrate-N.

The objectives will remain provisional until receiving water monitoring programs provide adequate data, and the Ministry has established approved water quality criteria for the characteristics of concern.

Water quality objectives have no legal standing and would not be directly enforced. The objectives can be considered as policy guidelines for resource managers to protect water uses in the specified water bodies. They will guide the evaluation of water quality, the issuing of permits, licences, and orders, and the management of the fisheries and of the Province's land base. They will also provide a reference against which the state of water quality in a particular water body can be checked, and serve to make decisions on whether to initiate basin-wide water quality studies.

Depending on the circumstances, water quality objectives may already be met in a water body, or may describe water quality conditions which can be met in the future. To limit the scope of the work, objectives are only being prepared for waterbodies and for water quality characteristics which may be affected by man's activity, now and in the foreseeable future.

The recommended provisional water quality objectives are as follows:

Periphyton Standing Crop

For the protection of aquatic life in the reaches downstream from Teck Bullmoose sedimentation ponds and tailings pond #3, a maximum standing crop biomass of 50 mg/m^2 chlorophyll a is recommended (Nordin, 1985). The average of at least ten samples collected at random from the streambed on one day should be below this maximum.

This objective applies outside the initial dilution zones and applies on a year-round basis to prevent aesthetic degradation. Since this objective is based upon the more stringent criterion to protect recreational use (Nordin, 1985), it would also act to prevent summer dissolved oxygen depletions and prevent the reduction of available fish habitat (Dolly Varden char) for spawning/rearing/feeding.

Nitrogen or phosphorus values above which nuisance algal growth would occur cannot be specified. A study of algal growth in Bullmoose Creek and its multivariate correlation with temperature, light, flow, trace nutrients etc., would be necessary before absolute objectives could be set for nitrogen or phosphorus.

Total ammonia-N

- total ammonia-N not to exceed the average 30-day concentrations given in the following table (Nordin and Pommen, 1986).

This objective applies everywhere in Bullmoose Creek except initial dilution zones, on a year-round basis to protect aquatic life (especially the resident salmonids).

pH

- minimum 6.5 as measured in any surface sample of stream water (McNeeley *et al*., 1979).

This objective is set to prevent sub-lethal and lethal conditions for aquatic life arising from acid generation, and to prevent the potential mobilization of toxic metals.

AVERAGE 30-DAY CONCENTRATION OF TOTAL AMMONIA NITROGEN FOR PROTECTION OF AQUATIC LIFE.
(mg/L NH_3-N)

pH	Temp. 0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
6.5	2.079	2.046	2.016	1.992	1.965	1.940	1.919	1.896	1.878	1.857	1.841
6.6	2.076	2.049	2.021	1.991	1.965	1.940	1.917	1.896	1.878	1.859	1.842
6.7	2.077	2.048	2.019	1.992	1.968	1.943	1.919	1.897	1.877	1.860	1.841
6.8	2.078	2.049	2.018	1.991	1.955	1.943	1.918	1.898	1.877	1.859	1.842
6.9	2.081	2.048	2.020	1.992	1.968	1.943	1.920	1.899	1.878	1.859	1.842
7.0	2.079	2.050	2.021	1.993	1.967	1.943	1.921	1.899	1.879	1.861	1.843
7.1	2.079	2.050	2.020	1.994	1.968	1.944	1.921	1.900	1.880	1.861	1.844
7.2	2.080	2.049	2.021	1.994	1.959	1.945	1.921	1.900	1.881	1.863	1.845
7.3	2.081	2.051	2.022	1.994	1.969	1.945	1.923	1.902	1.882	1.864	1.846
7.4	2.082	2.052	2.023	1.996	1.971	1.947	1.924	1.903	1.884	1.865	1.848
7.5	2.083	2.053	2.024	1.997	1.973	1.949	1.926	1.905	1.884	1.867	1.850
7.6	2.085	2.054	2.026	1.999	1.974	1.950	1.928	1.907	1.888	1.870	1.853
7.7	2.085	2.054	2.026	2.000	1.975	1.952	1.929	1.908	1.890	1.872	1.855
7.8	1.780	1.754	1.730	1.708	1.687	1.667	1.648	1.631	1.615	1.600	1.586
7.9	1.504	1.482	1.462	1.443	1.426	1.409	1.394	1.379	1.360	1.354	1.342
8.0	1.260	1.242	1.225	1.210	1.195	1.182	1.169	1.157	1.146	1.136	1.127
8.1	1.003	0.989	0.976	0.963	0.952	0.942	0.932	0.922	0.914	0.906	0.899
8.2	0.799	0.788	0.777	0.768	0.759	0.751	0.743	0.736	0.730	0.724	0.718
8.3	0.636	0.628	0.620	0.613	0.606	0.599	0.594	0.588	0.583	0.579	0.575
8.4	0.508	0.501	0.495	0.489	0.484	0.479	0.475	0.471	0.467	0.464	0.461
8.5	0.405	0.400	0.396	0.381	0.387	0.384	0.380	0.377	0.375	0.372	0.370
8.6	0.324	0.320	0.317	0.313	0.310	0.308	0.305	0.303	0.301	0.300	0.293
8.7	0.260	0.257	0.254	0.251	0.249	0.247	0.246	0.244	0.243	0.242	0.241
8.8	0.208	0.206	0.204	0.202	0.201	0.200	0.198	0.197	0.197	0.196	0.196
8.9	0.168	0.166	0.165	0.163	0.162	0.161	0.161	0.160	0.160	0.160	0.160
9.0	0.135	0.134	0.133	0.132	0.132	0.131	0.131	0.131	0.131	0.131	0.131

pH	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0
6.5	1.664	1.809	1.795	1.781	1.770	1.641	1.523	1.413	1.312	1.220
6.6	1.663	1.809	1.795	1.782	1.769	1.641	1.523	1.414	1.313	1.221
6.7	1.663	1.809	1.795	1.782	1.770	1.642	1.523	1.414	1.313	1.221
6.8	1.665	1.810	1.796	1.783	1.771	1.642	1.524	1.415	1.315	1.221
6.9	1.665	1.811	1.797	1.783	1.772	1.643	1.525	1.416	1.315	1.222
7.0	1.666	1.811	1.798	1.785	1.773	1.644	1.526	1.416	1.315	1.222
7.1	1.667	1.812	1.799	1.786	1.774	1.646	1.526	1.417	1.316	1.224
7.2	1.669	1.814	1.800	1.788	1.776	1.646	1.527	1.418	1.318	1.225
7.3	1.670	1.815	1.802	1.789	1.776	1.647	1.529	1.420	1.319	1.226
7.4	1.672	1.818	1.804	1.792	1.778	1.649	1.531	1.422	1.321	1.228
7.5	1.674	1.820	1.807	1.795	1.780	1.651	1.533	1.424	1.323	1.231
7.6	1.677	1.823	1.810	1.798	1.783	1.655	1.536	1.427	1.327	1.234
7.7	1.680	1.826	1.813	1.802	1.787	1.659	1.540	1.431	1.331	1.238
7.8	1.437	1.562	1.551	1.542	1.791	1.662	1.544	1.435	1.335	1.242
7.9	1.216	1.322	1.314	1.306	1.533	1.423	1.322	1.229	1.144	1.065
8.0	1.022	1.111	1.104	1.098	1.299	1.206	1.121	1.043	0.970	0.904
8.1	0.816	0.887	0.882	0.878	1.092	1.015	0.944	0.878	0.818	0.762
8.2	0.653	0.709	0.706	0.703	0.874	0.812	0.756	0.704	0.655	0.611
8.3	0.523	0.568	0.566	0.564	0.700	0.651	0.606	0.565	0.527	0.491
8.4	0.420	0.456	0.455	0.453	0.562	0.523	0.487	0.455	0.424	0.396
8.5	0.338	0.367	0.366	0.366	0.452	0.421	0.393	0.367	0.343	0.321
8.6	0.273	0.297	0.296	0.296	0.365	0.341	0.318	0.298	0.278	0.261
8.7	0.222	0.240	0.240	0.241	0.296	0.277	0.259	0.242	0.227	0.213
8.8	0.181	0.196	0.196	0.197	0.241	0.226	0.212	0.198	0.186	0.175
8.9	0.148	0.161	0.161	0.162	0.198	0.185	0.174	0.164	0.154	0.145
9.0	0.122	0.132	0.133	0.134	0.163	0.153	0.144	0.136	0.128	0.121

- the average of the measured values must be less than the average of the correspondin- individual values in the above table.
- each measured value is compared to the corresponding individual values in the table. No more than one in five of the measured values can be greater than one-and-a-half times the corresponding criteria values in the table.

Suspended solids

- induced suspended solids (nonfilterable residue) not to exceed 10 mg/L when background suspended solids is less than 100 mg/L and not to be more than 10 percent of background when background is greater than 100 mg/L (Singleton, 1983).

This objective applies year-round to prevent siltation of critical Dolly Varden char spawning beds downstream from sedimentation pond discharges, and to protect other aquatic life and aquatic habitat.

Turbidity

- induced turbidity not to exceed 5 NTU when background turbidity is less than 50 NTU and not to be more than 10 percent of background when background is greater than 50 NTU (Singleton, 1983).

This objective applies year-round to protect aquatic life and aquatic habitat. Background turbidity and suspended solids are defined as the values measured upstream from a waste discharge at the time when downstream values are measured.

Dissolved Oxygen

- 7.75 mg/L minimum (Davis, 1975).

This value corresponds to the Davis level A of protection and assures a high degree of protection for the important salmonid sports fish species in Bullmoose Creek.

This objective applies year-round to protect all life history stages of the Dolly Varden char population and other aquatic life.

Nitrite-N

- nitrite-N concentrations not to exceed an average of 20 μg/L measured over 30 days (using a minimum of 5 weekly samples) and not to exceed a maximum of 60 μg/L at any time (Pommen, 1983).

This objective applies on a year-round basis to protect the Dolly Varden char population and other aquatic life.

Nitrite-N plus nitrate-N

- nitrite-N plus nitrate-N not to exceed a maximum of 10 mg/L at any time (B.C. Ministry of Health, 1982).

This objective is set to protect future drinking water use, including occasional use by transient users (e.g., campers, fishermen).

Substrate Sedimentation

- the benthic accumulation of particulate matter less than 3 mm in diameter should not be significantly* increased (by weight) over natural background levels (Singleton, 1983).

This objective applies on a year-round basis to protect Dolly Varden char spawning beds.

Fecal Contamination

- the fecal coliform content shall not exceed 10 MPN/100 mL in 90 percent of river water samples taken in any consecutive 30-day period (B.C. Ministry of Health, 1982).

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*The level of significance is defined as the 95% confidence level applied to a comparison of average sediment compositions (to be measured by the use of sediment traps or a freeze-core sampler) at the background (or control) and downstream (or affected) sites.

This objective applies on a year-round basis to protect downstream drinking water use by recreationists. It is assumed that transient recreational users would treat (disinfect) their drinking water before use. This objective applies throughout Bullmoose Creek. Water-contact recreation would also be protected by this objective.

7. CONCLUSIONS

The Teck Bullmoose Coal Inc. open-pit mine is the most significant activity in the Bullmoose Creek watershed with the potential to degrade water quality. The main effluent characteristics of concern are suspended solids from land disturbance and nitrogen input from explosives residues. There are no existing or proposed water withdrawals from Bullmoose Creek either upstream or downstream from the minesite which would be affected by minesite discharges. However, water-contact recreation is deemed an important water use. Fish habitat in the immediate vicinity of the minesite is most critical for Dolly Varden char production.

The water management plan for the mine involves a series of ditches which channel sediment-laden run-off into three sedimentation ponds. The only direct discharge to Bullmoose Creek is decant from these ponds for up to a four-month period during spring discharge. For the remainder of the year, the sedimentation ponds exfiltrate to West Bullmoose Creek. The tailings pond does not directly discharge to the creek, but rather exfiltrates to recharge the valley aquifer, and from there may enter Bullmoose Creek several kilometers downstream from the minesite.

No effluent discharge data were available at the time this assessment was written, and waste loadings were projected from permitted and expected effluent quality. The results of worst-case projections indicate that:

- natural streamflow in Bullmoose Creek cannot provide 20:1 dilution for sedimentation pond effluent under conditions of either direct discharge during the 1-in-10 year peak flow or exfiltrating seepage during the summer and winter low flows.

- suspended solids concentrations in Bullmoose Creek downstream from the confluence of South and West Bullmoose Creeks are not expected to impair water quality, i.e., during low flows (when background suspended solids is <50 mg/L) suspended solids are not expected to exceed 3 mg/L.

- un-ionized ammonia-N concentrations in Bullmoose Creek could reach levels toxic to aquatic life during severe winter low flow periods.

- receiving water nitrate-N concentrations could increase 100-200 times during extreme low flow conditions. Future water licences for domestic use downstream from the mine should only be issued contingent upon nitrate-N levels of less than 10 mg/L. Phosphorus levels in Bullmoose Creek are naturally low and the minesite is not expected to contribute sufficient phosphorus loading to allow the excess nitrate input to form nuisance algal growth.

- general water quality variables such as pH, alkalinity, hardness, color, dissolved oxygen, and temperature are not expected to be altered significantly by sedimentation pond discharge or minesite development.

- the potential effects of the minesite on trace metals concentrations in Bullmoose Creek are unknown; however, based on experience at other B.C. coal mines, metal contamination in pit drainage waters should not be a problem.

Provisional water quality objectives are recommended for the Bullmoose Creek drainage with regard to: suspended solids, ammonia-N, nitrite/nitrate-N, nitrite-N, pH, turbidity, dissolved oxygen, substrate sedimentation, fecal coliforms, and periphyton standing crop. The designated water uses to be protected should be drinking water supplies, aquatic life, wildlife, and recreation.

8. MONITORING RECOMMENDATIONS AND PERMIT AMENDMENTS

Table 14 summarizes the present effluent sampling program required of the permittee for permits PE 6696, PE 6667, and PE 6865. The existing sampling program incorporates those variables expected to reflect the major contaminants in the mine drainage water, e.g., suspended solids, nutrients, and dissolved metals. No additions to the variable list is necessary at this time. The frequency of monitoring is also deemed appropriate.

It is recommended that effluent sampling coincide with effluent flow measurements so that accurate waste loadings can be calculated. Effluent sampling and receiving water monitoring should also coincide so that the effects of known waste loadings on the receiving environment can be observed directly. All monitoring data collected by the permittee and the Ministry should meet Ministry data standards and be placed in the Ministry computer data bank.

A systematic water quality sampling program is recommmended in Table 15. It should be recognized that these monitoring recommendations are made from a technical perspective and the extent to which monitoring is conducted will depend on the overall priorities and monitoring resources available for the Province.

The water quality program entails sampling weekly during the spring (April 1-June 23) and monthly for the remainder of the year at nine sites on Bullmoose Creek. One of the objectives of the receiving water monitoring is to define the extent of the effluent dilution zone. Field personnel responsible for the actual sampling should be aware of this purpose so that sampling sites can be deleted or added as necessary. Sampling should be conducted on the same day at all sites and receiving water sampling should coincide with discharge from the sedimentation ponds during spring freshet and summer low flow. The variables to be measured are shown in Table 15. Sampling may need to be increased to check the actual water quality relative to the objectives, depending on circumstances. Sampling may be decreased if monitoring provides sufficient water quality information or if objectives are being met on a consistent basis.

The above recommended receiving water monitoring program is the "minimum" program. The "optimum" program would involve increasing the frequency of sampling as well as adding sites to evaluate diffuse loading of suspended solids from present and future logging and petroleum exploration.

These activities have impacted the water quality of Bullmoose Creek in the past (Girard, 1982). The significance of such diffuse suspended solids loadings is unknown at present. Monitoring resources surplus to the achievement of the "minimum" program should be directed toward the "optimum" program.

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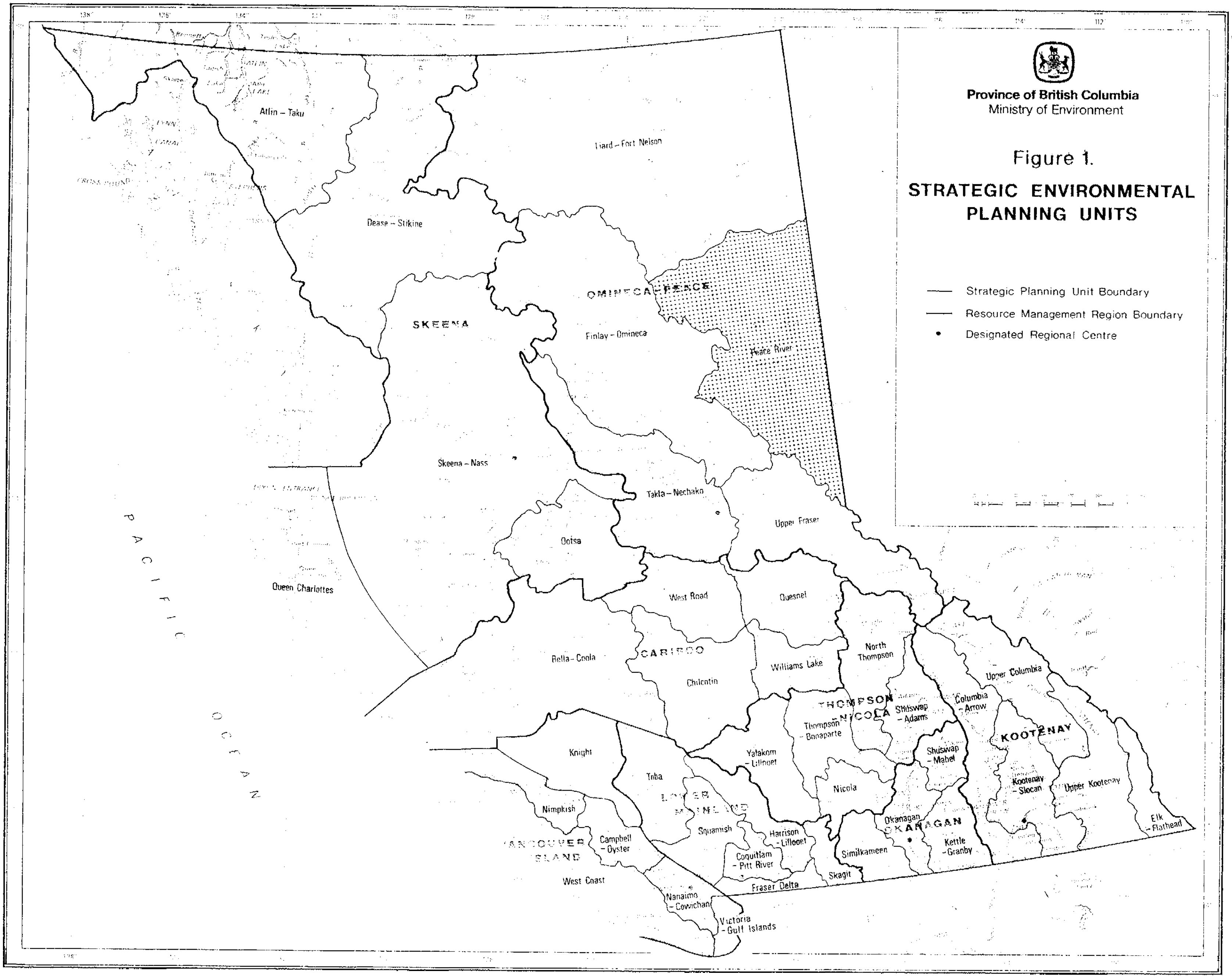

Province of British Columbia
Ministry of Environment
Figure 1.
STRATEGIC ENVIRONMENTAL PLANNING UNITS
Strategic Planning Unit Boundary
Resource Management Region Boundary
Designated Regional Centre
Atlin – Taku
Liard – Fort Nelson
Dease – Stikine
SKEENA
Skeena – Nass
Finlay – Omineca
Peace River
Takla – Nechako
Upper Fraser
Ootsa
Queen Charlottes
West Road
Quesnel
Bella – Coola
Chilcotin
Williams Lake
North Thompson
THOMPSON
NICOLA
Thompson – Bonaparte
Shuswap – Adams
Upper Columbia
Columbia – Arrow
KOOTENAY
Kootenay – Slocan
Upper Kootenay
Elk – Flathead
Shuswap – Mabel
Nicola
Yalakom – Lillooet
Knight
Toba
Nimpkish
Campbell – Oyster
West Coast
Squamish
Harrison – Lillooet
Coquitlam – Pitt River
Fraser Delta
Skagit
Similkameen
Okanagan
OKANAGAN
Kettle – Granby
Nanaimo – Cowichan
Victoria – Gulf Islands
PACIFIC OCEAN

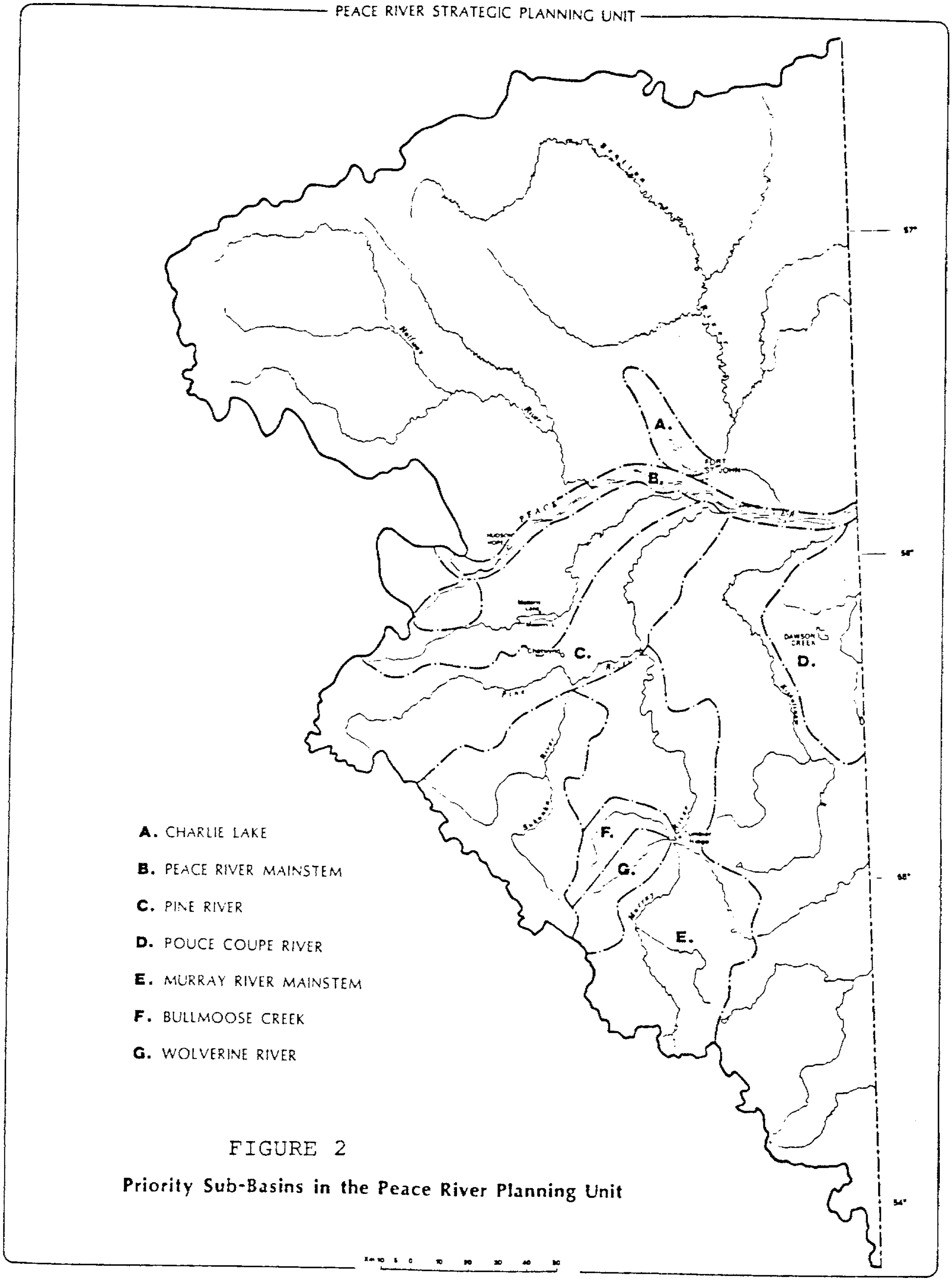


FIGURE 2

Priority Sub-Basins in the Peace River Planning Unit

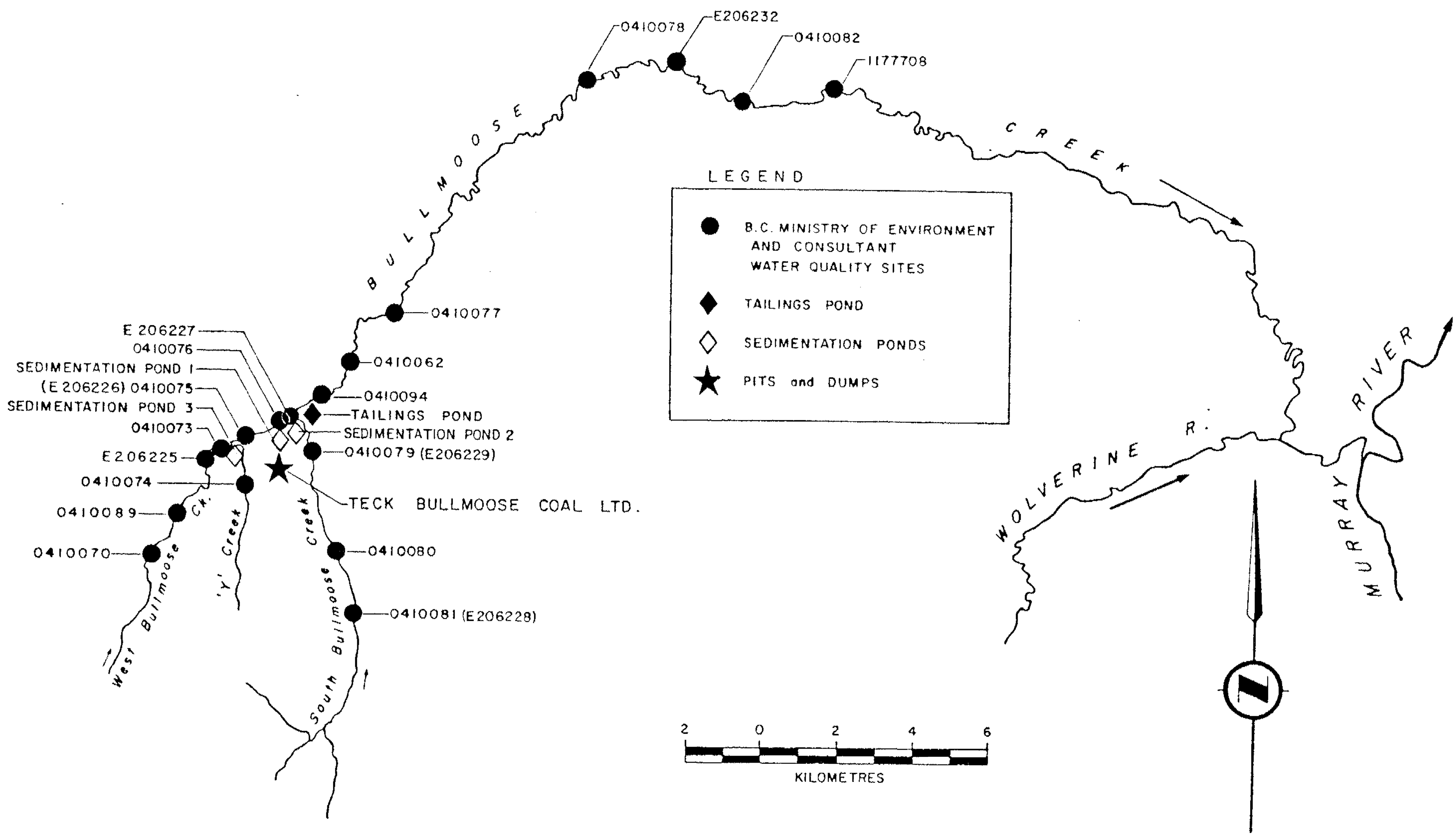


FIGURE 3 MAP OF BULLMOOSE CREEK SHOWING TECK BULLMOOSE COAL INC. MINESITE AND WATER QUALITY SITES.

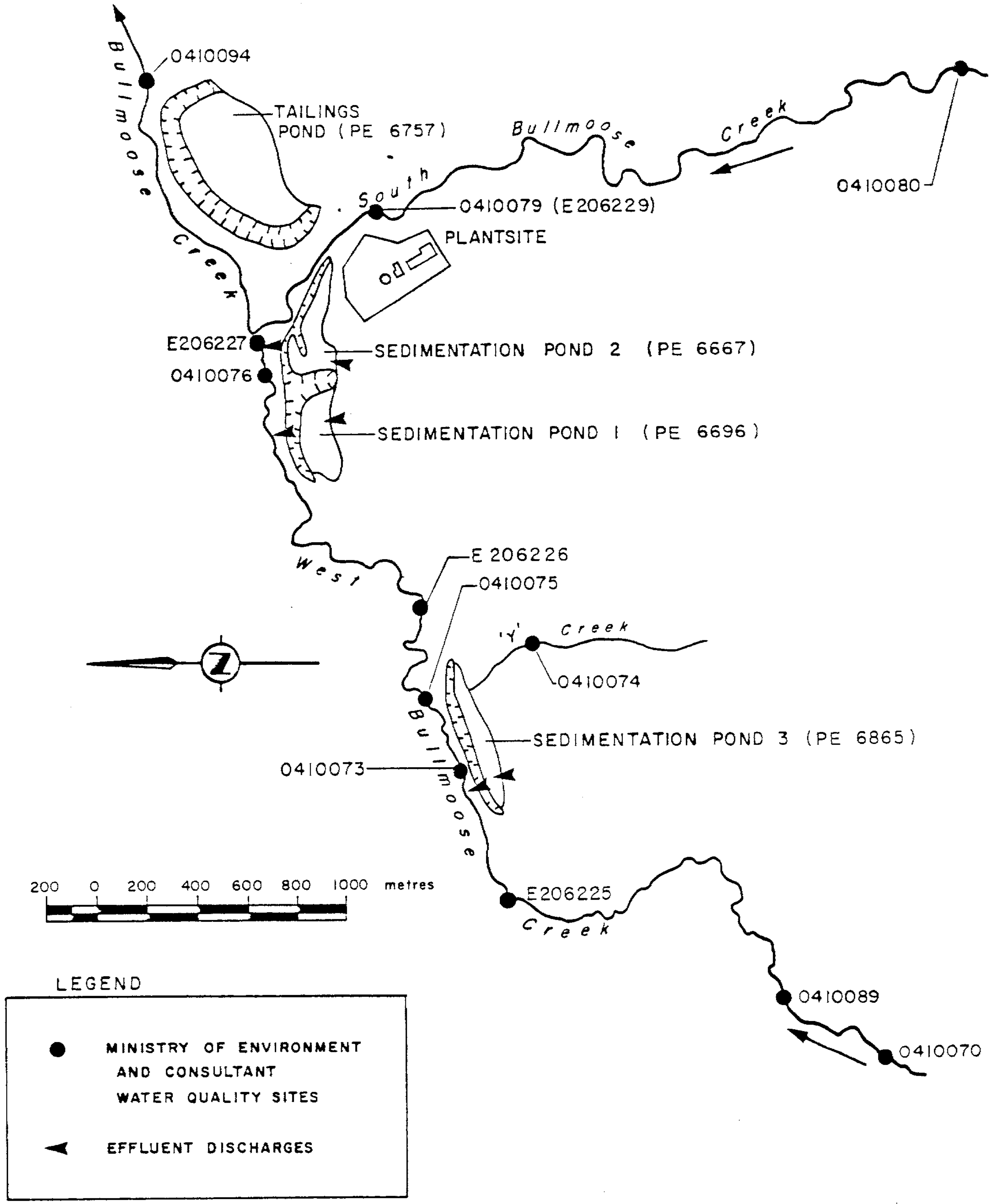
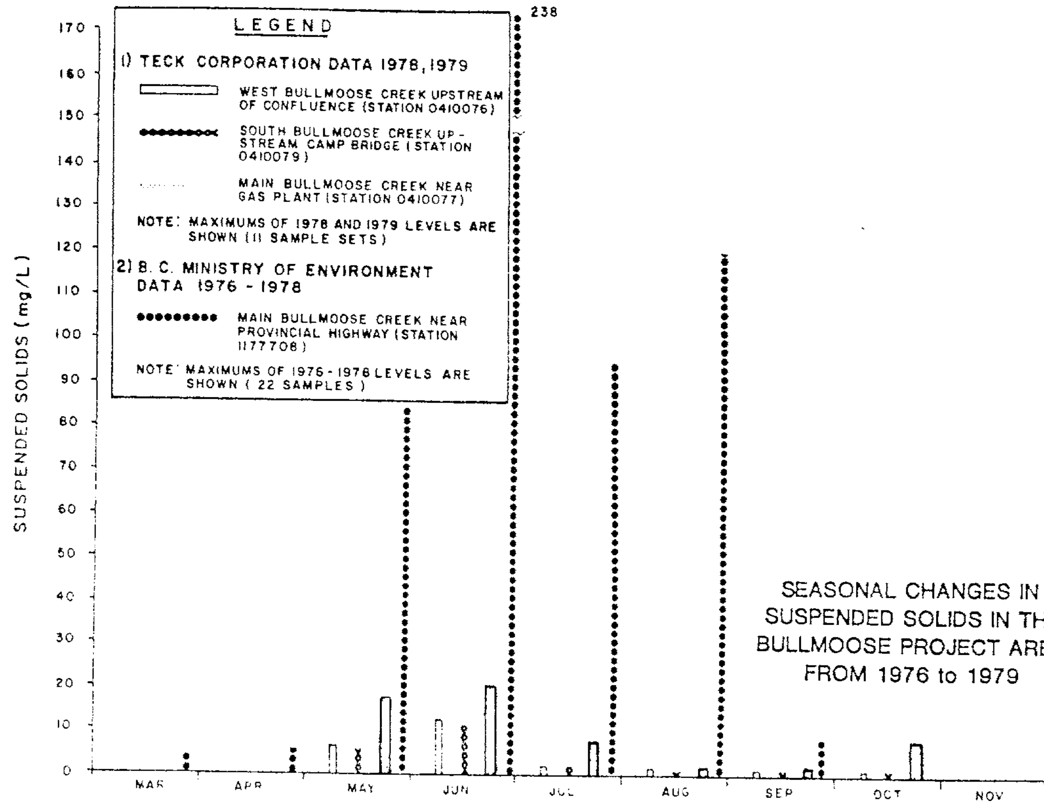


FIGURE 4 MAP OF THE TECK BULLMOOSE COAL INC. MINESITE SHOWING BULLMOOSE CREEK AND THE LOCATIONS OF THE SEDIMENTATION PONDS, TAILINGS POND, AND WATER QUALITY SITES.

A.


LEGEND
1) TECK CORPORATION DATA 1978, 1979
WEST BULLMOOSE CREEK UPSTREAM OF CONFLUENCE (STATION 0410076)
SOUTH BULLMOOSE CREEK UP-STREAM CAMP BRIDGE (STATION 0410079)
MAIN BULLMOOSE CREEK NEAR GAS PLANT (STATION 0410077)
NOTE: MAXIMUMS OF 1978 AND 1979 LEVELS ARE SHOWN (11 SAMPLE SETS)
2) B. C. MINISTRY OF ENVIRONMENT DATA 1976 - 1978
MAIN BULLMOOSE CREEK NEAR PROVINCIAL HIGHWAY (STATION 1177708)
NOTE: MAXIMUMS OF 1976 - 1978 LEVELS ARE SHOWN (22 SAMPLES)
238
SUSPENDED SOLIDS (mg/L)
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
SEASONAL CHANGES IN SUSPENDED SOLIDS IN THE BULLMOOSE PROJECT AREA FROM 1976 to 1979

B.

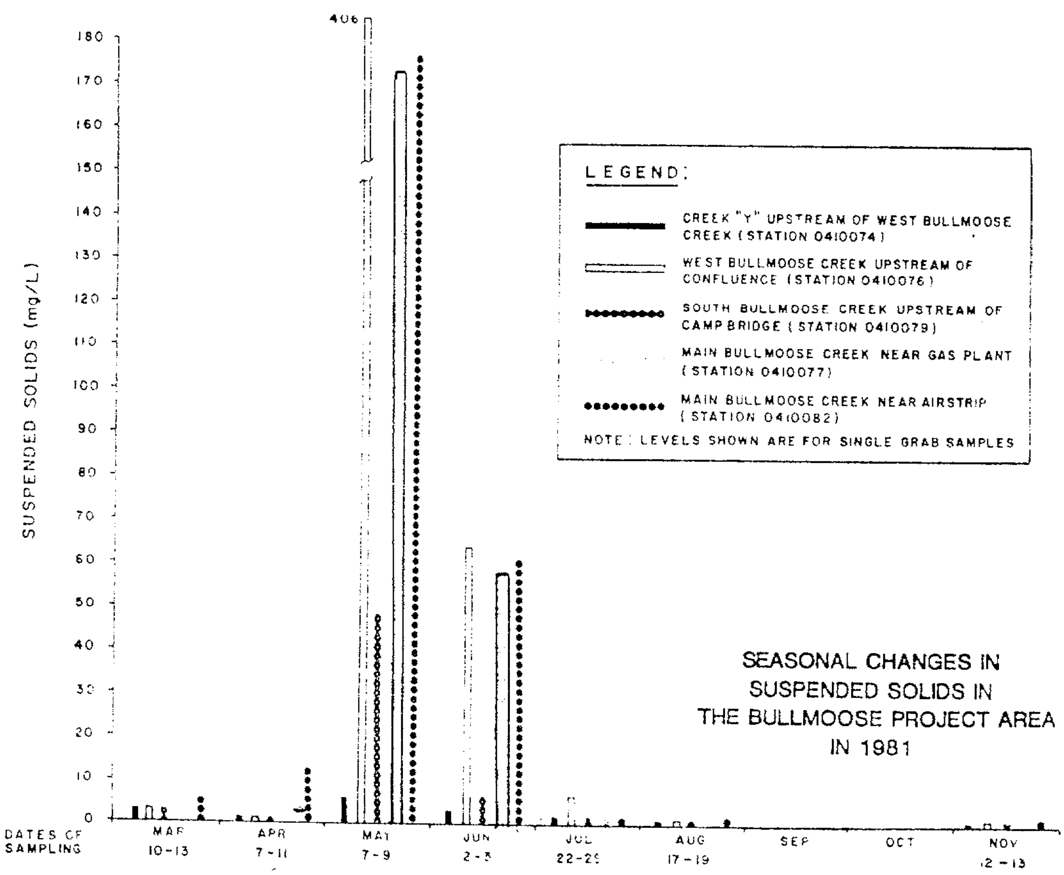

406
SUSPENDED SOLIDS (mg/L)
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
LEGEND:
CREEK "Y" UPSTREAM OF WEST BULLMOOSE CREEK (STATION 0410074)
WEST BULLMOOSE CREEK UPSTREAM OF CONFLUENCE (STATION 0410076)
SOUTH BULLMOOSE CREEK UPSTREAM OF CAMP BRIDGE (STATION 0410079)
MAIN BULLMOOSE CREEK NEAR GAS PLANT (STATION 0410077)
MAIN BULLMOOSE CREEK NEAR AIRSTRIP (STATION 0410082)
NOTE: LEVELS SHOWN ARE FOR SINGLE GRAB SAMPLES
SEASONAL CHANGES IN SUSPENDED SOLIDS IN THE BULLMOOSE PROJECT AREA IN 1981
DATES OF SAMPLING
MAR 10-13
APR 7-11
MAY 7-9
JUN 2-3
AUG 17-19
SEP
OCT
NOV 12-13

FIGURE 5

Table 1: Streamflow data for West Bullmoose Creek recorded in 1981 by consultants to Teck Bullmoose Coal Inc.

STATION NAME: WEST BULLMOOSE CREEK
LOCATION: WEST BULLMOOSE CREEK U/S OF CONFLUENCE WITH SOUTH BULLMOOSE CREEK
STATION NO: 0410074

DAILY DISCHARGE IN LITERS PER SECOND FOR 1981

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DAY
1	--	--	--	--	--	7563 E	938	483	91	236	245	--	1
2	--	--	--	--	--	7238 E	892	443	105	186	228	--	2
3	--	--	--	--	--	6837 E	879	415	96	151	237	--	3
4	--	--	--	--	--	6435 E	780	399	94	144	249	--	4
5	--	--	--	--	--	6034 E	694	363	91	140	253	--	5
6	--	--	--	--	--	5632 E	652	332	86	132	275	--	6
7	--	--	--	--	--	5231 E	600	304	77	140	262	--	7
8	--	--	--	--	1630 A	4829 E	558	276	71	143	219	--	8
9	--	--	--	59 AB	3339	4428 E	513	254	65	136	268	--	9
10	--	--	--	--	3265	4026 E	471	233	62	129	291	--	10
11	--	--	88 AB	--	2874	3625 E	432	227	67	122	342	--	11
12	--	--	--	--	3146	3224 E	421	207	68	112	457	--	12
13	--	--	--	--	3811	2822	573	194	73	105	--	--	13
14	--	--	--	--	4354	2752	655	100	70	104	--	--	14
15	--	--	--	--	4574	2656	558	158	64	128	--	--	15
16	--	--	--	--	4449	2813	453	143	58	186	--	--	16
17	--	--	--	--	4753	2380	365	127	53	176	--	--	17
18	--	--	--	--	5128	2080	323	116	50	184	--	--	18
19	--	--	--	--	5405	2003	328	112	48	218	--	--	19
20	--	--	--	--	5182	1863	397	113	49	180	--	--	20
21	--	--	--	--	5923 E	1732	453	105	50	148	--	--	21
22	--	--	--	--	7456 E	1608	482	96	53	144	--	--	22
23	--	--	--	--	7034 E	1569	734	89	53	144	--	--	23
24	--	--	--	--	7083 E	1443	642	85	62	144	--	--	24
25	--	--	--	--	7599 E	1349	531	81	68	163	--	--	25
26	--	--	--	--	8353 E	1255	465	78	71	182	--	--	26
27	--	--	--	--	7448 E	1154	424	84	69	175	--	--	27
28	--	--	--	--	6862 E	1111	424	92	71	175	--	--	28
29	--	--	--	--	6813 E	1137	761	92	90	175	--	--	29
30	--	--	--	--	7010 E	1063	571	88	90	172	--	--	30
31	--	--	--	--	7518 E	--	523	77	--	233	--	--	31
TOT	0.0	0.0	88.0	59.0	131314.0	97892.0	17492.0	6046.0	2115.0	4909.0	3526.0	0.0	TOT
MEAN	0.0	0.0	88.0	59.0	5471.4	3263.1	564.3	195.0	70.5	158.4	293.8	0.0	MEAN
MAX	0.0	0.0	88.0	59.0	8353.0	7563.0	938.0	483.0	105.0	236.0	457.0	0.0	MAX
MIN	0.0	0.0	88.0	59.0	1630.0	1063.0	323.0	77.0	48.0	104.0	219.0	0.0	MIN

SUMMARY FOR THE YEAR 1981

MEAN DISCHARGE, 1379.3 L/S
MAXIMUM DAILY DISCHARGE, 8353.0 L/S ON MAY 26
MINIMUM DAILY DISCHARGE, 48.0 L/S ON SEP 19

MAXIMUM INSTANTANEOUS DISCHARGE:
9,318 L/S AT 23100 PST ON MAY 25

TYPE OF GAUGE - RECORDING
LOCATION LAT 55 08 10 N
LONG 121 29 19 W

A-MANUAL GAUGE
B-ICE CONDITIONS
E-ESTIMATED VALUE

NATURAL FLOW

Table 2: Streamflow data for South Bullmoose Creek recorded in 1981 by consultants to Teck Bullmoose Coal Inc.

STATION NAME: SOUTH BULLMOOSE CREEK
LOCATION: SOUTH BULLMOOSE CREEK U/S CAMP BRIDGE
STATION NO: 0410079

DAILY DISCHARGE IN LITERS PER SECOND FOR 1981

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DAY
1	--	--	--	--	--	7314	1718	903	162	424	374	--	1
2	--	--	--	--	--	6129	1775	826	182	295	344	--	2
3	--	--	--	--	--	5656	1883	760	165	189	304	--	3
4	--	--	--	--	--	5081	1591	721	149	161	317	--	4
5	--	--	--	--	--	4363	1359	646	131	149	291	--	5
6	--	--	--	--	--	4175	1306	600	116	137	294	--	6
7	--	--	--	--	--	3747	1148	543	108	142	291	--	7
8	--	--	--	--	2850 A	3359	1036	498	97	138	293	--	8
9	--	--	--	--	3583	3128	949	448	93	132	283	--	9
10	--	--	--	78 AB	3285	3001	885	408	95	124	303	--	10
11	--	--	--	--	2885	2861	855	384	113	122	314	--	11
12	--	--	129 AB	--	3075	3916	909	355	101	109	507	--	12
13	--	--	--	--	3876	3924	1342	330	91	102	--	--	13
14	--	--	--	--	4573	3878	1222	300	84	107	--	--	14
15	--	--	--	--	4580	3795	1055	276	74	179	--	--	15
16	--	--	--	--	5081	3647	944	256	68	348	--	--	16
17	--	--	--	--	5522	3119	886	230	64	271	--	--	17
18	--	--	--	--	6129	2871	872	212	61	245	--	--	18
19	--	--	--	--	7017	2731	848	195	62	245	--	--	19
20	--	--	--	--	7288	2489	883	187	62	200	--	--	20
21	--	--	--	--	8282	2304	853	166	64	168	--	--	21
22	--	--	--	--	10286	2218	782	159	81	176	--	--	22
23	--	--	--	--	8349	2235	1131	166	75	171	--	--	23
24	--	--	--	--	7862	2224	1046	181	90	180	--	--	24
25	--	--	--	--	9191	2124	890	144	111	228	--	--	25
26	--	--	--	--	9341	2012	821	148	97	240	--	--	26
27	--	--	--	--	6733	1905	761	159	88	201	--	--	27
28	--	--	--	--	5754	1883	789	179	93	196	--	--	28
29	--	--	--	--	5741	2052	1438	160	109	184	--	--	29
30	--	--	--	--	6284	1901	1171	148	94	170	--	--	30
31	--	--	--	--	8691	--	1028	132	--	439	--	--	31
TOT	0.0	0.0	129.0	78.0	146258.0	100042.0	34174.0	10820.0	2980.0	4172.0	3915.0	0.0	TOT.
MEAN	0.0	0.0	129.0	78.0	6094.1	3334.7	1102.5	349.0	99.3	199.1	326.2	0.0	MEAN
MAX	0.0	0.0	129.0	78.0	10284.0	7314.0	1883.0	703.0	182.0	439.0	507.0	0.0	MAX
MIN	0.0	0.0	129.0	78.0	2850.0	1883.0	761.0	132.0	41.0	102.0	283.0	0.0	MIN

SUMMARY FOR THE YEAR 1981

MEAN DISCHARGE, 1594.6 L/S
MAXIMUM DAILY DISCHARGE, 10284.0 L/S ON MAY 22
MINIMUM DAILY DISCHARGE, 41.0 L/S ON SEP 18

MAXIMUM INSTANTANEOUS DISCHARGE:
11.639 L/S AT 00:30 PST ON MAY 22

TYPE OF GAUGE - RECORDING
LOCATION LAT 55 07 57 N
LONG 121 28 41 W
DRAINAGE AREA: 53.1 KM2

A-MANUAL GAUGE
B-ICE CONDITIONS
E-ESTIMATED VALUE

NATURAL FLOW

TABLE 3

SUMMARY OF WASTE MANAGEMENT APPLICATIONS AND PERMITS FOR EFFLUENT DISCHARGE IN THE BULLMOOSE RIVER VALLEY

PERMIT OR APPLICATION	PERMIT HOLDER APPLICANT	DISCHARGE TO	DISCHARGE FLOW	TYPE OF DISCHARGE	CHARACTERISTICS OF EFFLUENT
PE-6667	Teck Bullmoose Coal Inc.	Bullmoose Cr.	0.7 m^3/s peak daily flow (10 yr. return)	maintenance shop effluent, pit water, and surface runoff from waste rock dump and prep. plant into sedimentation pond #2	Suspended solids-50 mg/L or background +10 mg/L, whichever is greater
PE-6696	Teck Bullmoose Coal Inc.	Bullmoose Cr.	1.5 m^3/s peak daily flow (10 yr. return)	settled surface runoff and pit water from sedimentation pond No. 1 (mine operations)	Suspended solids-50 mg/L or background +10 mg/L, whichever is greater
PE-6422	Teck Bullmoose Coal Inc.	the ground via exfiltration basins	191 m^3/d	domestic camp sewage	BOD_5 - 130 mg/L TSS - 130 mg/L
PE-6865	Teck Bullmoose Coal Inc.	West Bullmoose Cr.	2.16 m^3/s peak daily flow (10 yr. return)	settled surface runoff and pitt water from sedimentation pond No. 3 (Y Creek)	Suspended solids-50 mg/L or background +10 mg/L, whichever is greater
PE-6757	Teck Bullmoose Coal Inc.	tailings pond and infiltration to ground	3,000 m^3/d tailings slurry 170 m^3/d domestic sewage effluent	tailings slurry from coal preparation plant and domestic sewage from two packaged treatment plants with no pond overflow	BOD_5 - 130 mg/L TSS - 130 mg/L

TABLE 4

PROJECTED SUSPENDED SOLIDS CONTRIBUTIONS TO WEST BULLMOOSE CREEK FROM THE SEDIMENTATION PONDS

DOWNSTREAM FROM	EFFLUENT CONDITIONS	SUSPENDED SOLIDS CONTRIBUTION ATTRIBUTABLE TO DISCHARGE mg/L
Pond 3	Dilution = 12.5:1[1] Suspended solids - assume 50 mg/L	$\frac{50}{12.5}$ mg/L = 4
Pond 1	Dilution = 18:1[2] Suspended solids - assume 50 mg/L	$\frac{50}{18}$ mg/L = 2.8
Pond 2	Dilution = 40:1[3] Suspended solids - assume 50 mg/L	$\frac{50}{40}$ mg/L = 1.25

Assumption:

- effluent dilution ratio at peak daily discharge equals that for low flow periods

[1]dilution ratio calculated by dividing the mean peak daily streamflow for West Bullmoose Creek (27 m^3/s) by peak pond discharge rate (2.16 m^3/s)

[2]dilution ratio calculated by dividing the mean peak daily streamflow for West Bullmoose Creek (27 m^3/s) by peak pond discharge rate (1.5 m^3/s)

[3]dilution ratio calculated by dividing the mean peak daily streamflow for South Bullmoose Creek (28 m^3/s) by peak pond discharge rate (0.7 m^3/s)

TABLE 5

EXPECTED HYDRAULIC CHARACTERISTICS AND NITROGEN CONCENTRATIONS AND LOADING OF THE TECK BULLMOOSE SEDIMENTATION PONDS (FROM KLOHN LEONOFF LTD., 1982)

EXPECTED HYDRAULIC AND WATER QUALITY CHARACTERISTICS		SEDIMENTATION PONDS #1	#2	#3	TOTALS
Flow[1] from Mine Pit	L/s	11.6	0	12.5	24
Flow[1] from Waste Rock	L/s	<46.4	13	62.5	122
Flow[1] from Other Areas	L/s	37	19	22	78
Total Inflow	L/s	95	32	97	224
Pond Retention Time	days	26	38.5	20.0	
Ammonia-N Loading[2]	kg/d	23.7	5.3	30.7	60
Nitrate-N Loading[2]	kg/d	23.7	5.3	30.7	60
To 1987					
Ammonia-N Concentration[3]	mg/L	0.8-3.1	0.1-1.8	1.1-3.4	
Nitrate-N Concentration[3]	mg/L	4.2-6.5	2.8-4.5	3.9-6.2	
After 1987					
Ammonia-N Concentration[4]	mg/L	1-3.9	0.13-2.3	1.4-4.3	
Nitrate-N Concentration[4]	mg/L	5.3-8.1	3.5-5.6	4.9-7.8	

[1] based on average precipitation

[2] loading calculation assumes 2% fugitive loss of nitrogenous compounds from total explosives used

[3] retention times, loadings, and rates of nitrification were used to estimate the concentrations (both summer and winter)

[4] explosives consumption increases by 25% after 1987. It is assumed that sedimentation pond concentrations will show a corresponding increase

TABLE 6

PREDICTED WORST-CASE INCREASES IN NITROGEN CONCENTRATIONS DOWNSTREAM FROM THE BULLMOOSE SEDIMENTATION PONDS

SITE	LOW FLOW PERIOD	PREDICTED DAILY MINIMUM FLOWS Mean Annual m^3/s	10-year return m^3/s	FUGITIVE N LOSS[1] kg/d	MAXIMUM NITRATE-N CONCENTRATION[2] mg/L	MAXIMUM AMMONIA-N CONCENTRATION[3] mg/L	MAXIMUM UN-IONIZED AMMONIA CONCENTRATION[4] µg/L
WEST BULLMOOSE CR. (upstream from confluence with South Bullmoose Cr.)	Winter	0.022	0.011	60	32-63	0.8-1.7	30-64
	August	0.16	0.11	60	4.3-6.3	0.11-0.17	9-14
BULLMOOSE CR. (immediately downstream from confluence of West and South Bullmoose Creeks)	Winter	0.046	0.024	60	15-29	0.4-0.8	15-30
	August	0.33	0.23	60	2.1-3	0.05-0.08	4-7

[1]assumption : - total fugitive N loss equals 2% of maximum annual explosives use

[2]range denotes concentrations for mean annual and 10-year return minimum flows, respectively

[3]assuming that 50% of N loss is ammonia and 95% nitrification

[4]assumptions: - August, pH = 8.5, T = 16°C (i.e. 8.52% of total ammonia is un-ionized ammonia) (Trussell, 1972)

- Winter, pH = 8.5, T = 5°C (i.e. 3.77% of total ammonia is un-ionized ammonia) (Trussell, 1972)

TABLE 7

WATER QUALITY OF BULLMOOSE CREEK AS MEASURED BY THE PROVINCE, 1976-1982

CHARACTERISTICS		0410075 WEST BULLMOOSE CREEK (SEPTEMBER-OCTOBER 1982)			0410079 SOUTH BULLMOOSE CREEK (SEPTEMBER-OCTOBER 1982)			0410062 BULLMOOSE CREEK DOWNSTREAM FROM CONFLUENCE (SEPTEMBER-OCTOBER 1982)			1177708 BULLMOOSE CREEK 18 KM DOWNSTREAM FROM MINE (1976, 1977, 1978)			CRITERIA
		Mean	Range of Values	No. of Values	Mean	Range of Values	No. of Values	Mean	Range of Values	No. of Values	Mean	Range of Values	No. of Values	
Alkalinity, Total	mg/L										101	72-145	14	
, Phenolphthalein	mg/L										-	1.7	1	
Aluminum, Total	mg/L										0.4*	<0.1-2*	5	A,R 0.05-0.1
Arsenic, Total	mg/L										<0.005	<0.005	5	
Biomass, Total	mg	18	1.7-45	12	5.4	<1-11.3	14	28	3.7-78.9	16				
Cadmium, Total	µg/L										0.55*	<0.5-0.7*	4	A 0.2-4
, Dissolved	µg/L										-	<0.5	1	
Calcium, dissolved	mg/L										28.4	20-41	12	
Carbon, Organic	mg/L							1.7	<1-3	3	3.5	1-6	6	
Chloride	mg/L										0.55	<0.5-0.6	2	
Chlorophyll a	mg/m²	4.3	<0.3-15.1	10	0.9	<0.3-2	10	0.76	<0.3-2.3	13				
Chromium, Total	µg/L										5.3	<5-6	4	
Coliform, Fecal	MPN/100 mL										-	2	1	
, Total	MPN/100 mL										-	7	1	
Color											19*	<5-50*	21	P, R 15
Copper, Total	µg/L										3*	<1-8*	4	A 2
, Dissolved	µg/L										<1	<1	5	
Fluoride	mg/L										<0.1	<0.1	4	
Hardness	mg/L										103	73-149	12	
Iron, Total	mg/L										1.3*	0.2-4.8*	14	A, P 0.3-1
, Dissolved	mg/L										0.12	<0.1-0.3*	12	A, P 0.3-1
Lead, Total	µg/L										2.5	<1-4	4	
, Dissolved	µg/L										<1	<1	5	
Magnesium, Dissolved	mg/L										7.9	5.7-11.2	12	
Manganese, Total	mg/L										0.03	<0.002-0.1*	14	A, 0.1,P0.05
, Dissolved	mg/L										<0.02	<0.02	1	
Mercury, Total	µg/L										<0.05	<0.05	5	
Molybdenum, Total	µg/L										0.53	<0.5-0.6	4	
, Dissolved	µg/L										<0.5	<0.5	1	
Nickel, Total	mg/L										<0.01	<0.01	4	
, Dissolved	mg/L										<0.01	<0.01	1	
Nitrogen, Ammonia	mg/L	-	<0.005	1	<0.005	<0.005	2	<0.00	<0.005	2	0.008	0.005-0.026	17	
, Kjeldahl	mg/L	-	0.13	1	0.07	0.06-0.08	2	0.23	0.17-0.28	2	0.2	<0.01-0.7	10	
, Nitrate Total	mg/L	-	<0.02	1	<0.02	<0.02	2	<0.02	<0.02	2				
, Nitrite Dissolved	mg/L	-	<0.005	1	<0.005	<0.005	2	<0.00	<0.005	2				
, Nitrite/nitrate	mg/L	-	<0.02	1	<0.02	<0.02	2	<0.02	<0.02	2	0.03	<0.02-0.05	20	

TABLE 7

WATER QUALITY OF BULLMOOSE CREEK AS MEASURED BY THE PROVINCE, 1976-1982 (Continued)

CHARACTERISTICS		0410075 WEST BULLMOOSE CREEK (SEPTEMBER-OCTOBER 1982)			0410079 SOUTH BULLMOOSE CREEK (SEPTEMBER-OCTOBER 1982)			0410062 BULLMOOSE CREEK DOWNSTREAM FROM CONFLUENCE (SEPTEMBER-OCTOBER 1982)			1177708 BULLMOOSE CREEK 18 KM DOWNSTREAM FROM MINE (1976, 1977, 1978)			CRITERIA
		Mean	Range of Values	No. of Values	Mean	Range of Values	No. of Values	Mean	Range of Values	No. of Values	Mean	Range of Values	No. of Values	
, Organic	mg/L	-	0.13	1	<0.07	0.06-0.08	2	0.23	0.17-0.28	2	0.14	<0.01-0.3	5	
, Total	mg/L	-	0.13	1	0.07	0.06-0.08	2	0.23	0.17-0.28	2	0.3	0.08-0.8	6	
Oxygen, Dissolved	mg/L										11.5	7.8-14.5	15	
pH		8.15	8.1-8.2	6	8.2	8.1-8.3	7	8.27	8.2-8.3	6	8.1	7.8-8.4	23	
Phaeophytin a	mg/m²							-	<0.3	1				
Phenol	µg/L										<2	<2	5	
Phosphorus, Total	mg/L	-	0.008	1	-	0.01	1	0.04	0.008-0.071	4	0.09	0.004-0.4*	10	P, R 0.1
, Dissolved		-	3	1	3.5	3-4	2	7	<3-17	4	4	<3-6	7	
(Orthophosphorus)	µg/L											-0.006		
Potassium, Dissolved	mg/L										0.5	0.5	2	
Salinity	mg/L										100	0-1000	12	
Sodium, Dissolved	mg/L										2.3	2.2-2.4	2	
Solids, Total	mg/L										171	128-334	21	
, Dissolved	mg/L										124	94-164	21	
, Suspended	mg/L	6.1	2-21	6	4.3	2-14	7	16.5	2-60	6	-	33	1	
Specific Conductance	µs/cm	179	170-192	6	190	168-202	7	192	178-202	6	203	143-285	22	
Sulphate	mg/L										7.3	<5-9.3	14	
Tannin and Lignin	mg/L										0.3	0.1-0.7*	5	P 0.4
Temperature	°C										6.3	2.4-10.5	20	
Turbidity	NTU	3.4	1.4-12	6	1.7	0.6-6.8	7	13	1-40*	6	17.6	0.8-62*	21	R 25
Vanadium, Total	µg/L										2.7	<1-4	3	
, Dissolved	µg/L										-	<1	1	
Zinc, Total	µg/L										10	<5-23	14	
, Dissolved	µg/L										<5	<5	5	

A - working water quality criteria for aquatic life
P - working water quality criteria for public water supplies
R - working water quality criteria for recreation and aesthetics
* - in excess of working water quality criteria

TABLE 8

WATER QUALITY OF MAIN BULLMOOSE CREEK AS MEASURED BY CONSULTANTS TO TECK BULLMOOSE COAL INC., (1977-1981).

CHARACTERISTICS		0410077 MAIN BULLMOOSE CR. NEAR GAS PLANT			0410078 MAIN BULLMOOSE CR. 11 KM DOWNSTREAM FROM SOUTH BULLMOOSE CR.			0410082 MAIN BULLMOOSE CR. NEAR AIRSTRIP			CRITERIA
		Mean	Range of Values	No. of Values	Mean	Range of Values	No. of Values	Mean	Range of Values	No. of Values	
Alkalinity, Total	mg/L	106	63-184	13	98	63-124	7	144	82-195	8	
Aluminum, Total	µg/L	148*	5-530*	12	115*	7-170*	9	208*	50*-230*	6	A 50-100
, Dissolved	µg/L	60*	10-270*	8	13	10-25	6	92*	15-160*	6	A 50-100
Antimony, Total	µg/L	<1	<1	2	-	-	-	26.5	<1-150*	6	A 50
, Dissolved	µg/L	<1	<1	2	-	-	-	26.5	<1-150*	6	A 50
Arsenic, Total	µg/L	4	1-5	9	5	5	6	51*	1-300*	6	A 40
, Dissolved	µg/L	1	1	2	-	-	-	51*	1-300*	6	A 40
Barium, Total	mg/L	0.11	0.09-0.13	2	-	-	-	0.17	0.1-0.2	6	
, Dissolved	mg/L	0.10	0.08-0.12	2	-	-	-	0.16	0.1-0.2	6	
Bismuth, Total	mg/L	<0.5	<0.5	2	-	-	-	<0.5	<0.5	6	
, Dissolved	mg/L	<0.5	<0.5	2	-	-	-	<0.5	<0.5	6	
Boron, Total	mg/L	0.04	0.02-0.06	2	-	-	-	0.02	0.01-0.02	4	
, Dissolved	mg/L	<0.01	<0.01	2	-	-	-	0.012	<0.01-0.017	4	
Cadmium, Total	µg/L	<1	<1	9	<1	<1	6	6.5*	1*-25*	6	A 0.2-4
, Dissolved	µg/L	<1	<1	8	<1	<1	7	6.5*	1*-25*	6	A 0.2-4
Calcium, Total	mg/L	21.8	18.3-25.3	2	-	-	-	38	24-44	6	
, Dissolved	mg/L	26	16.6-36.3	15	27	20-30	10	34	20-44	9	
Carbon, Total Organic	mg/L	2.7	2.0-5.0	14	3.7	2-17	10	10.7	3-28	6	
Chloride	mg/L	<0.5	<0.5	2	-	-	-	0.8	<0.5-1.3	4	
Chromium, Total	µg/L	5.4	1-18	9	3.8	1-5	6	14	6-30*	6	A 20-40
, Dissolved	µg/L	4.4	1-8	7	4.4	2-5	5	10	6-30*	6	A 20-40
Cobalt, Total	µg/L	<5	<5	2	-	-	-	7.5	<5-20	6	
, Dissolved	µg/L	<5	<5	2	-	-	-	7.5	<5-20	6	
Conductivity	µS/cm	202	106-278	14	254	145-318	10	237	145-330	6	
Copper, Total	µg/L	9.3*	1-54*	12	14.4*	2*-58*	9	6*	2*-15*	6	A 2
, Dissolved	µg/L	3.6*	1-8*	12	4.9*	1-10*	10	6*	1-15*	6	A 2
Flow	L/s	-	-	-	-	-	-	3350	729-9294	4	
Fluoride	mg/L	0.07	0.04-0.15	9	0.06	0.04-0.07	6	0.07	0.05-0.09	5	
Hardness, $CaCO_3$	mg/L	96.6	60.3-135	15	101	62-133	10	124	72-155	9	
Iron, Total	mg/L	0.23	0.02-0.54*	13	0.20	0.01-0.38*	10	0.2	0.05-0.5*	6	P, A 0.3
, Dissolved	mg/L	0.02	0.004-0.054	12	0.02	0.002-0.03	10	0.035	0.03-0.05	6	
Lead, Total	µg/L	4.5	1-17*	12	4.2	1-10*	9	23*	1-33*	5	A² 5
, Dissolved	µg/L	1.5	1-5*	13	1.6	1-4	10	17*	1-80*	5	A² 5
Magnesium, Total	mg/L	6.2	5.1-7.3	2	-	-	-	9.9	6.4-11.6	5	
, Dissolved	mg/L	7.6	4.5-11.3	15	8.2	4.9-11	10	9.0	5.4-11.2	9	
Manganese, Total	µg/L	5.9	1-12	13	5.9	1-13	10	18	6-33	6	
, Dissolved	µg/L	2.3	1-5	7	1.4	1-2	5	11	3-19	6	
Mercury, Total	µg/L	<0.05	<0.05	13	<0.05	<0.05	10	0.07	<0.05-0.1*	5	A 0.1

TABLE 8

WATER QUALITY OF MAIN BULLMOOSE CREEK AS MEASURED BY CONSULTANTS TO TECK BULLMOOSE COAL INC., (1977-1981), (Continued)

CHARACTERISTICS		0410077 MAIN BULLMOOSE CR. NEAR GAS PLANT			0410078 MAIN BULLMOOSE CR. 11 KM DOWNSTREAM FROM SOUTH BULLMOOSE CR.			0410082 MAIN BULLMOOSE CR. NEAR AIRSTRIP			CRITERIA
		Mean	Range of Values	No. of Values	Mean	Range of Values	No. of Values	Mean	Range of Values	No. of Values	
Molybdenum, Total	µg/L	2	1-5	8	<1	<1	6	11	5-40	6	
, Dissolved	µg/L	2.6	1-5	5	<1	<1	3	11	5-40	6	
Nickel, Total	µg/L	1.8	1-5	12	1.3	1-2	9	8.3	5-25*	6	P 13, A 25
, Dissolved	µg/L	1.8	1-5	10	1.4	1-3	9	8.3	5-25*	6	P 13, A 25
Nitrogen, Ammonia	mg/L	0.10	0.05-0.21	4	-	-	-	0.05	0.01-0.08	5	
, Kjeldahl	mg/L	0.26	0.05-0.36	4	-	-	-	0.13	0.02-0.25	5	
, Nitrate	mg/L	0.08	0.002-0.42	6	-	-	-	0.03	0.002-0.07	8	
, Nitrite	mg/L	<0.001	<0.001	4	-	-	-	0.002	<0.001-0.005	6	
Oxygen, Dissolved	mg/L	10.4	8.5-11.8	13	10.5	9.0-11.6	9	11.5	9-12.8	5	
pH (Lab.)		8.1	8.0-8.3	16	8.2	8.0-8.3	10	8.1	7.75-8.5	8	
Phenol, Total	µg/L	7.9*	1-63*	12	3.1*	1-10*	10	8.2*	1*-16*	5	A[1] 1
Phosphorus, Total	mg/L	0.24*	0.02-0.58*	4	-	-	-	0.14*	0.05-0.4*	6	P, R[3] 0.1
, Dissolved	mg/L	0.03	0.02-0.03	3	-	-	-	0.024	0.012-0.03	6	
Potassium, Total	mg/L	0.6	0.56-0.61	2	-	-	-	0.51	0.45-0.58	6	
, Dissolved	mg/L	0.8	0.31-4.6	12	0.5	0.4-0.6	10	0.46	0.36-0.34	6	
Silica, Total	mg/L	3.2	1-5.6	6	3.1	2.8-3.4	4	4.3	3.8-4.8	6	
, Dissolved	mg/L	3.1	2.8-3.6	8	3.1	2.9-3.5	6	3.9	3.3-4.1	6	
Silver, Total	µg/L	<1.0*	<1.0*	2	-	-	-	11*	1*-30*	6	A 0.1
, Dissolved	µg/L	<1.0*	<1.0*	2	-	-	-	11*	1*-30*	6	A 0.1 .
Sodium, Total	mg/L	2.1	1.5-2.7	2	-	-	-	2.5	1.6-2.8	6	
, Dissolved	mg/L	2.3	0.8-5.5	12	2.4	0.7-5.3	10	2.4	1.4-2.8	6	
Solids, Total	mg/L	142	76-248	14	141.2	92-210	10	225	150-272	5	
, Dissolved	mg/L	136	70-247	14	132	84-180	10	218	132-259	5	
, Suspended	mg/L	20	0.5-173	16	8.8	1-30	10	34	0.5-177	9	
Strontium, Total	mg/L	0.06	0.05-0.07	2	-	-	-	0.09	0.05-0.1	6	
, Dissolved	mg/L	0.06	0.05-0.07	2	-	-	-	0.09	0.05-0.1	6	
Sulphate, Dissolved	mg/L	7.6	4.4-21.0	14	8.8	2.6-21	10	6.9	5-10	5	
Temperature	°C	8.7	0.5-16	15	8.9	0.5-16.0	10	4.8	5-15	6	
Tin, Total	mg/L	<0.03	<0.03	2	-	-	-	<0.03	<0.03	6	
, Dissolved	mg/L	<0.03	<0.03	2	-	-	-	<0.03	<0.03	6	
Titanium, Total	µg/L	7	6-8	2	-	-	-	6	6	6	
, Dissolved	µg/L	6	6	2	-	-	-	6	6	6	
Turbidity (Lab.)	NTU	13.4	0.4-125*	16	5.9	1.2-20	10	30*	0.8-175*	8	R 25
Vanadium, Total	µg/L	6.3	1-18	6	4	2-5	3	7	5-12	6	
, Dissolved	µg/L	8.3	2-18	3	<2	-	1	7	5-12	6	
Zinc, Total	µg/L	4.4	1-14	7	3	1-6	5	18	10-33	6	
, Dissolved	µg/L	4.2	1-12	11	2	1-6	9	17	10-32	6	

TABLE 8 (Continued)

* - in excess of working water quality criteria
[1] - natural phenol levels are often in excess of this criterion. Phenol is a non-specific analysis and may include substances that do not contribute to effects on which criteria are based
[2] - toxicity depends upon hardness and species present
[3] - phosphorus criteria for algal growth are very crude and do not consider many site specific factors
A - working water quality criteria for aquatic life
P - working water quality criteria for public water supplies
R - working water quality criteria for recreation and aesthetics

TABLE 9

WATER QUALITY OF SOUTH BULLMOOSE CREEK AND Y CREEK AS MEASURED BY CONSULTANTS TO TECK BULLMOOSE COAL INC., (1977-1981).

CHARACTERISTICS		0410081 SOUTH BULLMOOSE CR. 4.5 KM UPSTREAM FROM MAIN BULLMOOSE CR.			0410080 SOUTH BULLMOOSE CR. 1.4 KM UPSTREAM FROM CONFLUENCE WITH WEST BULLMOOSE CR.			0410079 SOUTH BULLMOOSE CR.			0410074 Y CREEK UPSTREAM FROM WEST BULLMOOSE CR.			CRITERIA
		Mean	Range of Values	No. of Values	Mean	Range of Values	No. of Values	Mean	Range of Values	No. of Values	Mean	Range of Values	No. of Values	
Alkalinity, Total	mg/L	99	93.9-109	3	95.4	-	1	107	53-157	20	101	40-171	8	
Aluminum, Total	µg/L	25	18-32	2	20	-	1	194*	5-950*	16	320*	50*-830*	6	A 50-100
, Dissolved	µg/L	-	-	-	-	-	-	76	10-350*	13	193*	50*-500*	6	A 50-100
Antimony, Total	µg/L	-	-	-	-	-	-	44	<1-150*	7	26	1-50*	6	A 50
, Dissolved	µg/L	-	-	-	-	-	-	44	<1-150*	7	26	1-150*	6	A 50
Arsenic, Total	µg/L	5	5	2	-	-	-	46*	1-300*	14	50*	1-30	6	A 40
, Dissolved	µg/L	-	-	-	-	-	-	86*	1-300*	7	50*	1-30	6	A 40
Barium, Total	mg/L	-	-	-	-	-	-	0.12	0.08-0.15	7	0.17	0.08-0.21	6	
, Dissolved	mg/L	-	-	-	-	-	-	0.11	0.07-0.04	7	0.17	0.08-0.2	6	
Bismuth, Total	mg/L	-	-	-	-	-	-	<0.05	<0.5	7	<0.5	<0.5	6	
, Dissolved	mg/L	-	-	-	-	-	-	<0.05	<0.5	7	<0.5	<0.5	6	
Boron, Total	mg/L	-	-	-	-	-	-	0.03	<0.1-0.08	5	0.14	<0.01-0.02	4	
, Dissolved	mg/L	-	-	-	-	-	-	0.02	<0.01-0.03	5	0.013	<0.01-0.02	4	
Cadmium, Total	µg/L	<1	<1	2	<1	-	1	11*	<1-110*	14	6.3*	<1-25*	6	A 0.2-4
, Dissolved	µg/L	<1	<1	2	<1	-	1	5*	<1-25*	14	6.3*	<1-25*	6	A 0.2-4
Calcium, Total	mg/L	-	-	-	-	-	-	29	17-37	7	23	11.7-31.3	6	
, Dissolved	mg/L	26	25.4-26.4	3	26.5	-	1	26	15-36	22	21	9.6-30	8	
Carbon, Total Organic	mg/L	5	3-7	2	-	-	-	5.2	2-22	19	8.5	2-18	6	
Chloride	mg/L	-	-	-	-	-	-	0.64	0.5-1.8	6	0.7	0.5-1.1	4	
Chromium, Total	µg/L	<1	<1	2	<1	-	1	9.9	<1-30*	14	16.8	3-39*	6	A 20-40
, Dissolved	µg/L	-	-	-	-	-	-	8.9	2-30*	12	9.3	2-30*	6	A 20-40
Cobalt, Total	µg/L	-	-	-	-	-	-	9	<5-20	7	7.5	5-20	6	
, Dissolved	µg/L	-	-	-	-	-	-	9	<5-20	7	7.5	5-20	6	
Conductivity	µS/cm	185	185	2	183	-	9	199	121-266	18	167	60-284	6	
Copper, Total	µg/L	1	1	2	2*	-	1	9*	2-40*	17	9*	5*-25*	6	A 2
, Dissolved	µg/L	1	1	2	2*	-	1	4.8*	1-15*	18	6.5*	2-15*	6	A 2
Flow	L/s	-	-	-	-	-	-	1262	78-3863	7	79	2.5-204	5	
Fluoride	mg/L	-	-	-	-	-	-	0.06	0.03-0.13	12	0.07	0.05-0.1	5	
Hardness, $CaCO_3$	mg/L	94.3	92-95.6	3	96.2	-	1	95	53-132	22	80	35-118	8	
Iron, Total	mg/L	0.11	0.09-0.12	2	0.09	-	1	0.10	0.01-0.45*	18	0.03	0.03-0.04	6	P, A 0.3
, Dissolved	mg/L	0.013	0.007-0.018	2	0.01	-	1	0.02	0.001-0.03	18	0.02	0.001-0.08	6	
Lead, Total	µg/L	2	1-3	2	3	-	1	7*	1-80*	16	15.7*	1-80*	6	A^2 5
Dissolved	µg/L	2	1-3	2	3	-	1	6*	1-80*	17	3.8	1-80*	6	A^2 5
Magnesium, Total	mg/L	-	-	-	-	-	-	8.2	5.3-10.5	7	7.7	3.6-11	6	
, Dissolved	mg/L	7.1	6.9-7.3	3	7.3	-	1	7.3	3.9-10.2	22	6.8	2.9-10.5	8	

TABLE 9

WATER QUALITY OF SOUTH BULLMOOSE CREEK AND Y CREEK AS MEASURED BY CONSULTANTS TO TECK BULLMOOSE COAL INC., (1977-1981), (Continued).

CHARACTERISTICS		0410081 SOUTH BULLMOOSE CR. 4.5 KM UPSTREAM FROM MAIN BULLMOOSE CR.			0410080 SOUTH BULLMOOSE CR. 1.4 KM UPSTREAM FROM CONFLUENCE WITH WEST BULLMOOSE CR.			0410079 SOUTH BULLMOOSE CR.			0410074 Y CREEK UPSTREAM FROM WEST BULLMOOSE CR.			CRITERIA
		Mean	Range of Values	No. of Values	Mean	Range of Values	No. of Values	Mean	Range of Values	No. of Values	Mean	Range of Values	No. of Values	
Manganese, Total	µg/L	1.5	1-2	2	1	-	1	3.5	1-11	18	3.8	3.7	6	
, Dissolved	µg/L	-	-	-	-	-	-	2.4	1-3	12	3.0	3.0	6	
Mercury, Total	µg/L	<0.05	<0.05	2	<0.05	-	1	0.12*	<0.05-1.0*	16	0.08	<0.05-0.1*	5	A 0.1
Molybdenum, Total	µg/L	1	1	2	1	-	1	5.6	1-40	13	11	5-40	6	
, Dissolved	µg/L	-	-	-	-	-	-	7.6	1-40	9	11	5-40	6	
Nickel, Total	µg/L	1.5	1-2	2	2	-	1	5.4	1-25*	17	8.3	5-25*	6	P13; A 25
, Dissolved	µg/L	-	-	-	-	-	-	5.4	1-25*	16	8.3	5-25*	6	P13; A 25
Nitrogen, Ammonia	mg/L	0.1	0.1	2	0.1	-	1	0.07	0.01-0.18	8	0.13	0.01-0.2	5	
, Kjeldahl	mg/L	0.2	0.2	2	0.2	-	1	0.17	0.02-0.4	8	0.27	0.02-0.4	5	
, Nitrate	mg/L	0.12	0.01-0.23	3	0.15	-	1	0.03	0.002-0.16	13	0.01	0.002-0.07	8	
, Nitrite	mg/L	<0.001	0.001	3	<0.001	-	1	<0.001	<0.001-0.002	9	<0.001	<0.001-0.002	6	
Oxygen, Dissolved	mg/L	10.5	10.3-10.7	2	10.6	-	1	11	9-12.6	17	11.8	10.1-12.6	5	
pH (Lab.)		8.1	7.6-8.4	3	-	-	-	8.2	7.3-8.4	23	7.9	7.6-8.4	8	
Phenol, Total	µg/L	-	-	-	-	-	-	2.7*	1-7*	16	8.8*	1*-14*	5	A[1] 1
Phosphorus, Total	mg/L	0.06	-	1	-	-	-	0.1*	0.02-0.21*	8	0.07	0.03-0.1*	6	P, R[3] 0.1
, Dissolved	mg/L	-	-	-	-	-	-	0.02	0.006-0.03	8	0.03	0.030-0.031	5	
Potassium, Total	mg/L	-	-	-	-	-	-	0.4	0.3-0.6	7	0.35	0.22-0.48	6	
, Dissolved	mg/L	-	-	-	-	-	-	0.4	0.3-0.6	17	0.34	0.22-0.45	6	
Silica, Total	mg/L	-	-	-	-	-	-	3	1-5.5	11	3.0	2.5-3.3	6	
, Dissolved	mg/L	-	-	-	-	-	-	2.8	2.3-3.2	13	2.9	2.5-3.2	6	
Silver, Total	µg/L	-	-	-	-	-	-	13*	1*-30*	7	10.5*	0.4-30*	6	A 0.1
, Dissolved	µg/L	-	-	-	-	-	-	13*	1*-30*	7	10.5*	0.1-30*	6	A 0.1
Sodium, Total	mg/L	-	-	-	-	-	-	3.2	1.9-5.4	7	6.3	0.7-14.5	6	
, Dissolved	mg/L	-	-	-	-	-	-	2.1	0.4-4.3	17	6.1	0.7-14.1	6	
Solids, Total	mg/L	112	112	2	112	-	1	132	21-214	19	152	68-221	5	
, Dissolved	mg/L	111	111	2	111	-	1	136	75-213	18	151	68-218	5	
, Suspended	mg/L	0.8	0.5-1.0	3	1	-	1	5.8	0.5-48	22	1.9	0.5-6.0	8	
Strontium, Total	mg/L	-	-	-	-	-	-	0.07	0.04-0.09	7	0.08	0.03-0.12	6	
, Dissolved	mg/L	-	-	-	-	-	-	0.07	0.04-0.09	7	0.08	0.03-0.12	6	
Sulphate, Dissolved	mg/L	5.5	5-6	2	6	-	1	6.0	5.0-10.0	18	6.5	5-7.5	5	
Temperature	°C	6.0	6.0	2	7	-	1	6.5	1-16	19	2.8	0-40	6	
Tin, Total	mg/L	-	-	-	-	-	-	<0.03	<0.03	7	<0.03	<0.03	6	
, Dissolved	mg/L	-	-	-	-	-	-	<0.03	<0.03	7	<0.03	<0.03	6	
Titanium, Total	µg/L	-	-	-	-	-	-	8	6-21	7	<6	<6	6	
, Dissolved	µg/L	-	-	-	-	-	-	6	6	7	<6	<6	6	

TABLE 9

WATER QUALITY OF SOUTH BULLMOOSE CREEK AND Y CREEK AS MEASURED BY CONSULTANTS TO TECK BULLMOOSE COAL INC., (1977-1981), (Continued).

CHARACTERISTICS		0410081 SOUTH BULLMOOSE CR. 4.5 KM UPSTREAM FROM MAIN BULLMOOSE CR.			0410080 SOUTH BULLMOOSE CR. 1.4 KM UPSTREAM FROM CONFLUENCE WITH WEST BULLMOOSE CR.			0410079 SOUTH BULLMOOSE CR.			0410074 Y CREEK UPSTREAWM FROM WEST BULLMOOSE CR.			CRITERIA
		Mean	Range of Values	No. of Values	Mean	Range of Values	No. of Values	Mean	Range of Values	No. of Values	Mean	Range of Values	No. of Values	
Turbidity (Lab.)	NTU	0.48	0.4-0.65	3	0.5	-	1	5.6	0.3-39*	23	0.94	0.34-2.0	8	R 25
Vanadium, Total	µg/L	1	1	2	1	-	1	6	1-13	11	6.7	5-10	6	
, Dissolved	µg/L	-	-	-	-	-	-	7	2-13	8	6.7	5-10	6	
Zinc, Total	µg/L	-	-	-	-	-	-	24	1-180*	12	13.3	10-28	6	A² 50-300
, Dissolved	µg/L	15	7-23	2	10	-	1	7	1-31	17	13.8	10-28	6	

A - working water quality criteria for aquatic life
P - working water quality criteria for public water supplies
R - working water quality criteria for recreation and aesthetics
¹ - natural phenol levels are often in excess of this criterion. Phenol is a non-specific analysis and may include substances that do not contribute to effects on which criteria are based
² - depending on hardness and species present
³ - phosphorus criteria for algal growth are very crude and do not consider many site specific factors
* - in excess of working water quality criteria

TABLE 10

WATER QUALITY OF WEST BULLMOOSE CREEK AT SITES 0410070 AND 0410089 AS MEASURED BY CONSULTANTS TO TECK BULLMOOSE COAL INC. (1977-1981)

CHARACTERISTICS		0410070 WEST BULLMOOSE CR. UPSTREAM FROM LONESOME LAKE			0410089 WEST BULLMOOSE CR. 2.0 KM UPSTREAM FROM LONESOME L. OUTLET			CRITERIA
		Mean	Range of Values	No. of Values	Mean	Range of Values	No. of Values	
Alkalinity, Total	mg/L	107	57-142	10	107	63-156	7	
Aluminum, Total	µg/L	75*	5-150*	12	-	-	-	A 50-100
, Dissolved	µg/L	87*	10-150*	7	-	-	-	A 50-100
Antimony, Total	µg/L	51*	<1-150*	3	91.2*	1-150*	5	A 50
, Dissolved	µg/L	51*	<1-150*	3	91.2*	1-150*	5	A 50
Arsenic, Total	µg/L	40*	1-300*	8	180*	1-300*	5	A 40
, Dissolved	µg/L	100*	1-300*	3	180*	1-300*	5	A 40
Barium, Total	mg/L	0.14	0.13-0.15	3	0.14	0.08-0.17	5	
, Dissolved	mg/L	0.13	0.12-0.15	3	0.12	0.08-0.16	5	
Bismuth, Total	mg/L	<0.5	<0.5	3	<0.5	<0.5	5	
, Dissolved	mg/L	<0.5	<0.5	3	<0.5	<0.5	5	
Boron, Total	mg/L	<0.01	<0.01	3	0.013	0.01-0.016	4	
, Dissolved	mg/L	<0.01	<0.01	3	<0.01	<0.01	4	
Cadmium, Total	µg/L	4*	1*-25*	8	15.6*	1*-25*	5	A 0.2-4
, Dissolved	µg/L	4*	1*-25*	8	15.6*	1*-25*	5	A 0.2-4
Calcium, Total	mg/L	29	25-32	3	30	20-35	5	
, Dissolved	mg/L	25	15-32	12	25	15-350	7	
Carbon, Total Organic	mg/L	4.1	2-19	12	11.8	4-15	5	
Chloride	mg/L	0.8	<0.5-1.1	2	<0.5	-	1	
Chromium, Total	µg/L	30*	3-170*	9	18.5	4-30*	4	A 20-40
, Dissolved	µg/L	7.4	2-30*	7	18	2-30*	5	A 20-40
Cobalt, Total	µg/L	10	<5-20	3	15.6	<5-20	5	
, Dissolved	µg/L	10	<5-20	3	14.0	<5-20	5	
Conductivity	µS/cm	208	137-300	11	178.3	92-270	3	
Copper, Total	mg/L	8.5*	1-29*	12	10.8*	3*-16*	5	A 2
, Dissolved	µg/L	4.6*	1-15*	12	11.2*	2*-15*	5	A 2
Flow	L/s	-	-	-	-	-	-	
Fluoride	mg/L	0.05	0.04-0.07	6	0.048	0.046-0.05	2	
Hardness, $CaCO_3$	mg/L	94.3	57-120	12	88	54-128	7	
Iron, Total	mg/L	0.007	0.030-0.15	12	0.66*	0.13-2.2*	5	P,A 0.3
, Dissolved	mg/L	0.014	0.003-0.03	12	0.03	0.03	5	
Lead, Total	µg/L	12*	2-80*	11	49*	1-80*	5	A^2 5
, Dissolved	µg/L	8*	2-80*	12	49*	1-80*	5	A^2 5
Magnesium, Total	mg/L	8.3	7.4-9.1	3	8.9	4.9-10	5	
, Dissolved	mg/L	7.4	4.5-9.4	12	6.5	4.9-10	7	
Manganese, Total	µg/L	2.6	1-5	12	52*	3-110*	5	P50,A100
, Dissolved	µg/L	1.9	1-3	7	12	3-17	5	
Mercury, Total	µg/L	<0.05	<0.05	11	0.13*	0.06-0.20*	2	A 0.1
Molybdenum, Total	µg/L	6.9	1-40	8	26	5-40	5	
, Dissolved	µg/L	12.8	1-40	4	26	5-40	5	

TABLE 10 (Continued)

CHARACTERISTICS		0410070 WEST BULLMOOSE CR. UPSTREAM FROM LONESOME LAKE			0410089 WEST BULLMOOSE CR. 2.0 KM UPSTREAM FROM LONESOME L. OUTLET			CRITERIA
		Mean	Range of Values	No. of Values	Mean	Range of Values	No. of Values	
Nickel, Total	μg/L	4	1-25*	11	15*	5-25*	5	P13, A25
, Dissolved	μg/L	3.9	1-25	11	15*	5-25*	5	P13, A25
Nitrogen, Ammonia	mg/L	0.10	0.01-0.18	3	0.055	0.05-0.06	2	
, Kjeldahl	mg/L	0.34	0.05-0.76	3	0.14	0.13-0.14	2	
, Nitrate	mg/L	0.04	0.002-0.16	4	0.004	0.002-0.012	7	
, Nitrite	mg/L	<0.001	<0.001-0.002	4	<0.001	<0.001	6	
Oxygen, Dissolved	mg/L	10.6	9.4-12	10	11.1	10.8-11.4	2	
pH (lab.)		8.3	7.9-8.5	12	8.2	7.8-8.5	7	
Phenol, Total	μg/L	6.7*	1*-40*	10	4.5*	1*-8*	2	A[1] 1
Phosphorus, Total	mg/L	0.049	0.03-0.07	2	0.34*	0.11*-0.45*	7	P R[3] 0.1
, Dissolved	mg/L	0.026	0.018-0.03	3	0.03	0.03	5	
Potassium, Total	mg/L	0.35	0.28-0.43	3	0.7	0.4-1.6	5	
, Dissolved	mg/L	0.35	0.3-0.4	11	0.4	0.2-0.5	5	
Silica, Total	mg/L	2.9	2.2-3.5	7	22	2.5-11.2	5	
, Dissolved	mg/L	2.9	2.3-3.3	7	3.1	2.5-3.4	5	
Silver, Total	μg/L	10*	0.1*-30*	3	22.8*	1*-30*	5	A 0.1
, Dissolved	μg/L	10*	0.1*-30*	3	22.8*	1*-30*	5	A 0.1
Sodium, Total	mg/L	3.6	3.0-3.8	3	3.8	0.9-7.7	5	
, Dissolved	mg/L	2.4	0.9-3.9	11	3.3	0.9-7.7	5	
Solids, Total	mg/L	121	80-194	11	164	104-224	2	
, Dissolved	mg/L	110	71-183	11	160	103-216	2	
, Suspended	mg/L	2.1	0.5-9.0	12	219	0.5-651	9	
Strontium, Total	mg/L	0.07	0.06-0.08	3	0.06	0.04-0.09	5	
, Dissolved	mg/L	0.07	0.06-0.08	3	0.06	0.04-0.09	5	
Sulphate, Dissolved	mg/L	4.0	2.6-6.3	11	5	5	2	
Temperature	°C	7.7	0.5-16.0	11	2.3	0.2-4.7	3	
Tin, Total	mg/L	<0.03	<0.03	3	0.03	0.03	5	
Dissolved	mg/L	<0.03	<0.03	3	0.03	0.03	5	
Titanium, Total	μg/L	<6	<6	3	10	6-21	5	
, Dissolved	μg/L	<6	<6	3	6	6	5	
Turbidity (Lab.)	N.T.U.	1.0	0.3-3.3	11	236*	1-410*	9	R 25
Vanadium, Total	μg/L	5.6	1-11	6	7.5	5-10	5	
, Dissolved	μg/L	7	2-11	4	7.5	5-10	5	
Zinc, Total	μg/L	10.5	1-29	7	67*	10-180*	5	A[2] 50
Dissolved	μg/L	8.0	1-29	10	13	10-15	5	

* - in excess of working water quality criteria

[1] - natural phenol levels are often in excess of this criterion. Phenol is a non-specific analysis and may include substances that do not contribute to effects on which criteria are based

[2] - toxicity depends upon hardness and species present

[3] - phosphorus criteria for algal growth are very crude and do not consider many site-specific factors

A - working water quality criteria for aquatic life

P - working water quality criteria for public water supplies

R - working water quality criteria for recreation and aesthetics

TABLE 11

WATER QUALITY OF WEST BULLMOOSE CREEK AT SITES 0410073, 04100975, AND 0410076, AS MEASURED BY CONSULTANTS TO TECK BULLMOOSE COAL INC., (1977-1981).

CHARACTERISTICS		0410073 WEST BULLMOOSE CR. 0.5 KM DOWNSTREAM FROM LONESOME LAKE OUTLET			0410075 WEST BULLMOOSE CR. AT W. BRIDGE			0410076 WEST BULLMOSE CR. UPSTREAM FROM CONFLUENCE WITH SOUTH BULLMOOSE CR.			CRITERIA
		Mean	Range of Values	No. of Values	Mean	Range of Values	No. of Values	Mean	Range of Values	No. of Values	
Alkalinity, Total	mg/L	96	79-113	2	110	72-150	8	105	45-140	18	
Aluminum, Total	µg/L	98*	17-178*	2	540*	150*-1640*	6	334*	20-3150*	17	A 50-100
, Dissolved	µg/L	-	-	-	194*	150*-360*	5	82*	10-310*	13	A 50-100
Antimony, Total	µg/L	-	-	-	61*	<1-150*	5	40	<1-150*	7	A 50
, Dissolved	µg/L	-	-	-	61*	<1-150*	5	40	<1-150*	7	A 50
Arsenic, Total	µg/L	-	-	-	101*	1-300*	6	45*	1-300*	14	A 40
, Dissolved	µg/L	-	-	-	121*	1-300*	5	86*	1-300*	7	A 40
Barium, Total	mg/L	-	-	-	0.14	0.1-0.15	5	0.15	0.12-0.16	7	
, Dissolved	mg/L	-	-	-	0.12	0.08-0.14	5	0.14	0.08-0.16	7	
Bismuth, Total	mg/L	-	-	-	<0.5	<0.5	5	<0.5	<0.5	7	
, Dissolved	mg/L	-	-	-	<0.5	<0.5	5	<0.5	<0.5	7	
Boron, Total	mg/L	-	-	-	0.03	0.02-0.09	5	0.04	<0.01-0.08	5	
, Dissolved	mg/L	-	-	-	0.016	<0.01-0.02	5	0.08	<0.01-0.4	6	
Cadmium, Total	µg/L	1*	1*	2	23*	1*-110*	6	71*	1*-950*	14	A 0.2-4
, Dissolved	µg/L	1*	1*	2	9*	1*-25*	6	5*	1*-25*	14	A 0.2-4
Calcium, Total	mg/L	-	-	-	27	16.2-32	5	29	18-34	7	
, Dissolved	mg/L	28.6	24.8-32.3	2	25	14.6-32	8	25	15-22	22	
Carbon, Total Organic	mg/L	5.5	5-6	2	0.01	0.005-0.02	5	5.8	2-24	18	
Chloride	mg/L	-	-	-	<0.5	<0.5	3	0.66	<0.5-1.2	5	
Chromium, Total	µg/L	1	1	2	14.5	1-30*	6	10	1-30*	14	A 20-40
, Dissolved	µg/L	-	-	-	14.8	2-30*	5	9	1-30*	12	A 20-40
Cobalt, Total	µg/L	-	-	-	11	<5-20	5	9	<5-20	7	
, Dissolved	µg/L	-	-	-	11	<5-20	5	9	<5-20	7	
Conductivity	µS/cm	194	175-213	2	173	92-222	6	199	127-246	18	
Copper, Total	mg/L	1.5	1-2*	2	6.8*	1-15*	6	11.4*	1-20*	17	A 2
, Dissolved	µg/L	1.5	1-2*	2	6.7*	1-15*	6	7*	1-20*	18	A 2
Flow	L/s	-	-	-	311	-	1	1068	57-3543	7	
Fluoride	mg/L	-	-	-	0.08	0.06-0.1	3	0.07	0.05-0.1	11	
Hardness, $CaCO_3$	mg/L	104	91-117	2	90	52-117	8	93	55-122	22	
Iron, Total	mg/L	0.24	0.23-0.25	2	0.5*	0.22-1.1*	6	0.18	0.080-0.5*	18	P,A 0.3
, Dissolved	mg/L	0.7*	0.6*-0.8*	2	0.04	0.03-0.06	6	0.03	0.001-0.1	18	P,A 0.3
Lead, Total	µg/L	4	3-5*	2	17*	1-80*	5	7.6*	1-80*	16	A[2] 5
, Dissolved	µg/L	3.5	2-5*	2	17*	1-80*	5	5.9*	1-80*	17	A[2] 5

TABLE 11 (Continued)

CHARACTERISTICS		0410073 WEST BULLMOOSE CR. 0.5 KM DOWNSTREAM FROM LONESOME LAKE OUTLET			0410075 WEST BULLMOOSE CR. AT W. BRIDGE			0410076 WEST BULLMOOSE CR. UPSTREAM FROM CONFLUENCE WITH SOUTH BULLMOOSE CR.			CRITERIA[1]
		Mean	Range of Values	No. of Values	Mean	Range of Values	No. of Values	Mean	Range of Values	No. of Values	
Magnesium, Total	mg/L	-	-	-	7.9	4.6-9.8	5	8.4	5.3-9.5	7	
, Dissolved	mg/L	7.95	6.0-8.9	2	7.0	4.6-9.3	8	7.4	4.1-9.5	22	
Manganese, Total	µg/L	-	-	-	31	4-56*	6	8.4	1-35	18	P 50
, Dissolved	µg/L	-	-	-	18	3-47	5	5	1-22	12	
Mercury, Total	g/L	<0.05	<0.05	2	0.06	0.05-0.1*	4	0.06	0.06	16	A 0.1
Molybdenum, Total	g/L	1	1	2	11	1-40	5	5.5	1-40	13	
, Dissolved	g/L	-	-	-	14	5-40	4	7.6	1-40	9	
Nickel, Total	g/L	2.5	2-3	2	11	2-25*	6	5	1-25*	17	P 13; A 25
, Dissolved	g/L	-	-	-	13*	5-25*	5	5	1-25*	16	P 13; A 25
Nitrogen, Ammonia	mg/L	0.1	0.1	2	0.07	0.01-0.13	5	0.07	0.01-0.2	7	
, Kjeldahl	mg/L	0.2	0.2	2	0.26	0.08-0.45	5	0.26	0.02-0.5	5	
, Nitrate	mg/L	0.26	0.1-0.4	2	0.04	0.02-0.26	8	0.04	0.002-0.27	11	
, Nitrite	mg/L	<0.001	<0.001	2	0.002	<0.001-0.005	6	0.002	<0.001-0.005	8	
Oxygen, Dissolved	mg/L	10.45	10.4-10.5	2	11.1	9.9-12.1	4	11	9.3-12.7	16	
pH (lab.)		8.38	8.3-8.4	2	8.1	7.9-8.5	8	8.1	6.9-8.4	21	
Phenol, Total	g/L	-	-	-	9*	1*-28*	4	3.3*	1*-15*	15	A[1] 1
Phosphorus, Total	mg/L	-	-	-	0.13*	0.06-0.18*	5	0.14*	0.06-0.31*	7	P, R[3] 0.1
, Dissolved	mg/L	-	-	-	0.03	0.03	4	0.03	0.01-0.04	7	
Potassium, Total	mg/L	-	-	-	0.74	0.5-1.4	5	0.6	0.4-1.2	6	
, Dissolved	mg/L	-	-	-	0.42	0.32-0.5	5	0.4	0.3-0.5	17	
Silica, Total	mg/L	-	-	-	5.3	3.7-10.2	5	4.7	1-20	11	
, Dissolved	mg/L	-	-	-	3.2	2.9-3.6	5	22.1	2.6-250	13	
Silver, Total	g/L	-	-	-	12*	0.1*-30*	5	13.3*	1*-30*	7	A 0.1
, Dissolved	g/L	-	-	-	12*	0.1*-30*	5	13.3*	1*-30*	7	A 0.1
Sodium, Total	mg/L	-	-	-	3.5	1.7-4.8	5	3.5	1.9-4.5	7	
, Dissolved	mg/L	-	-	-	3.4	1.4-4.4	5	2.8	0.8-4.4	17	
Solids, Total	mg/L	120	112-128	2	163	120-196	5	140	80-200	17	
, Dissolved	mg/L	118	109-127	2	152	98-185	5	134	68-197	17	
, Suspended	mg/L	2.0	1-3	2	81	0.5-568	8	42.5	0.5-406	22	
Strontium, Total	mg/L	-	-	-	72	43-86	5	0.08	0.05-0.09	7	
, Dissolved	mg/L	-	-	-	70	43-82	5	0.07	0.05-0.09	7	
Sulphate, Dissolved	mg/L	8.5	4-13	2	6.8	5-9	5	6.7	4.4-10	17	
Temperature	°C	7.05	7.0-7.1	2	5.3	0.5-12.5	6	6.4	1-16	18	
Tin, Total	mg/L	-	-	-	0.03	0.03	5	<0.03	<0.03	7	
, Dissolved	mg/L	-	-	-	0.03	0.03	5	<0.03	<0.03	7	
Titanium, Total	g/L	-	-	-	7	6-10	4	21	<6-110	7	
, Dissolved	g/L	-	-	-	6	6	5	<6	<6	7	

TABLE 11 (Continued)

CHARACTERISTICS	0410073 WEST BULLMOOSE CR. 0.5 KM DOWNSTREAM FROM LONESOME LAKE OUTLET			0410075 WEST BULLMOOSE CR. AT W. BRIDGE			0410076 WEST BULLMOOSE CR. UPSTREAM FROM CONFLUENCE WITH SOUTH BULLMOOSE CR.			CRITERIA[1]
	Mean	Range of Values	No. of Values	Mean	Range of Values	No. of Values	Mean	Range of Values	No. of Values	
Turbidity, (Lab.) N.T.U.	2.75	1.3-4.2	2	49.3*	2.2-240*	8	31.4*	0.2-280*	21	R 25
Vanadium, Total g/L	1	1	2	10	1-24	6	7	1-15	11	
, Dissolved g/L	-	-	-	8	5-12	5	7	2-15	8	A[3] 50
Zinc, total g/L	-	-	-	23	10-40	3	28	1-200*	12	A[3] 50
, Dissolved g/L	12	4-20	2	14	1-31	6	13	1-59*	14	A[3] 50

* - in excess of working water quality criteria

[1] - natural phenol levels are often in excess of this criterion. Phenol is a non-specific analysis and may include substances that do not contribute to effects on which criteria are based

[2] - toxicity depends upon hardness and species present

[3] - phosphorus criteria for algal growth are very crude and do not consider many specific factors

A - working water quality criteria for aquatic life

P - working water quality criteria for public water supplies

R - working water quality criteria for recreation and aesthetics

TABLE 12

MEAN NUTRIENT CONCENTRATION AND ESTIMATED N:P RATIOS FOR BULLMOOSE CREEK USING PROVINCIAL DATA

Site	No. of Samples $NO_3/NO_2/NH_3/P$	Nitrate NO_3 mg/L as N	Nitrite NO_2 mg/L as N	Ammonia NH_3 mg/L as N	Total Nitrogen mg/L as N	Dissolved Ortho-Phosphorus mg/L as N	N:P Total Nitrogen / Diss. ortho-P
West Bullmoose Cr. 0410075 (1982)	1/1/1/1	<0.02	<0.005	<0.005	0.03	0.003	10:1
South Bullmoose Cr. 0410079 (1982)	2/2/2/2	<0.02	<0.005	<0.005	0.03	0.004	7.5:1
Main Bullmoose Cr. 0410062 (1982)	2/2/2/4	<0.02	<0.005	<0.005	0.03	0.007	4.3:1
Main Bullmoose Cr. 117708 (1975-1978)	20/17/17	0.03 (Nitrate + Nitrite)		0.008	0.038	0.004	9.5:1
Average N:P							8:1

TABLE 13

SUMMARY OF BACKGROUND METALS CONCENTRATION SAMPLED BY TECK BULLMOOSE COAL INC., EXCEEDING THE PRELIMINARY WORKING PROVINCIAL WATER QUALITY CRITERIA

Characteristic		Criteria	Exceeding Criteria		Use Criteria Exceeded	Comments
			No.	%		
Aluminum,	Total	50 µg/L	60/89	67	A	toxicity depends on pH and hardness
,	Diss.	50 µg/L	30/64	47	A	toxicity depends on pH and hardness
Antimony,	Total	50 µg/L	11/41	27	A	
,	Diss.	50 µg/L	11/42	26	A	
Arsenic,	Total	40 µg/L	11/72	15	A	
,	Diss.	40 µg/L	11/42	26	A	
Cadmium,	Total	0.2 µg/L	79/79	100	A	synergism with Pb, Cu, Zn
,	Diss.	0.2 µg/L	79/79	100	A	synergism with Pb, Cu, Zn
Chromium,	Total	20 µg/L	14/79	18	A	
,	Diss.	20 µg/L	11/67	16	A	
Copper,	Total	2 µg/L	82/94	87	A	synergism with Cd, Pb, Zn
,	Diss.	2 µg/L	73.97	75	A	synergism with Cd, Pb, Zn
Iron,	Total	0.3 mg/L	14/99	14	A,P	likely due to suspended sediment load
,	Diss.	0.3 mg/L	0/98	0	-	important form of Fe
Lead,	Total	5 µg/L	29/90	32	A	synergism with Cd, Cu, Zn
,	Diss.	5 µg/L	12/95	13	A	synergism with Cd, Cu, Zn
Manganese,	Total	50 µg/L	1/99	1	A,P	likely due to suspended sediment load
,	Diss.	50 µg/L	0/59	0	-	most important form of Mn
Mercury,	Total	0.1 µg/L	13/87	15	A	
Nickel,	Total	13 µg/L	11/94	12	A,P,W	
,	Diss.	13 µg/L	11/84	13	A,P,W	
Silver,	Total	0.1 µg/L	40/40	100	A	
,	Diss.	0.1 µg/L	40/40	100	A	
Titanium,	Total	100 µg/L	1/39	3	A,P	
,	Diss.	100 µg/L	0/39	0	-	
Zinc,	Total	50 µg/L	3/64	5	A	synergism with Cd, Cu, Pb
,	Diss.	50 µg/L	1/88	1	A	

A - aquatic life
P - public water supply
W - wildlife

TABLE 14

SUMMARY OF THE EXISTING EFFLUENT SAMPLING AND MINIMUM RECOMMENDED RECEIVING WATER MONITORING PROGRAM FOR THE BULLMOOSE COAL MINE

TYPE AND LOCATION OF MONITORING	RESPONSIBLE AGENCY	PERIOD OF SAMPLING	FREQUENCY	CHARACTERISTICS*
Permit PE 6696 (Pond #1)	Permittee	Mar. 15-June 30	weekly	Physical Variables 1,2,3
		all year	monthly	all of above plus Nutrients 1,2,3,4 Physical Variables 4,5
		all year	quarterly	Anions 1,2 Dissolved metals 1,3,5,7,9,10,11,13,15 16,18
Permit PE 6667 (Pond #2)	Permittee	as for PE 6696	as for PE 6696	as above plus monthly sampling of oil and grease
Permit PE 6865 (Pond #3)	Permittee	as for PE 6696	as for PE 6696	as for PE 6696
PIT WATER Permits PE 6696, PE 6667, PE 6865				
Pit sump	Permittee	all year	weekly	Nutrients 1,2,3 Flow
Bullmoose Creek	Permittee	all year	weekly and monthly	Nutrients 1,2,3,4 Physical Variables 1,2,3,4,5 Anions 3
GROUNDWATER Groundwater monitoring wells	Permittee	all year	quarterly	Nutrients 1,2,3,4 Physical Variables 4,5 Anions 1 Dissolved Metals 1,3,4,5,7,10,11,13,14,18 Pollutant Tests 2,3,4 Total Metals 1

TABLE 14 (Continued)

TYPE AND LOCATION OF MONITORING	RESPONSIBLE AGENCY	PERIOD OF SAMPLING	FREQUENCY	CHARACTERISTICS*
Bullmoose Creek	Waste Management Branch	April 1-June 23	weekly	Physical Variables 1,2,3,4,5,6,7
		remainder of year	monthly	Nutrients 1,2,3,4,5 Anions 1,2 Pollutant Tests 1,2,4,5 Dissolved Metals 1,2,3,4,5,6,7,8,9,10,11,12,13,15,16,17,18 Total Metals 1

*Key to characteristics numbers (minimum detection limits follow in brackets).

Physical variables

1. S.S. (1.0 mg/L)
2. Turbidity
3. Flow
4. pH
5. Temperature
6. Hardness (0.02 mg/L)
7. Dissolved Oxygen

Dissolved metals

1. Aluminum (10 µg/L)
2. Arsenic (5 µ/L)
3. Barium (100 µg/L)
4. Boron (0.1 mg/L)
5. Cadmium (0.5 µg/L)
6. Calcium (0.01 mg/L)
7. Chromium (5 µg/L)
8. Cobalt (5 µg/L)
9. Copper (1 µg/L)
10. Iron (10 µg/L)
11. Lead (1 µg/L)
12. Magnesium (0.02 mg/L)
13. Manganese (20 µg/L)
14. Molybdenum (0.5 µg/L)
15. Nickel (10 µg/L)
16. Silver (5 µg/L)
17. Vanadium (1 µg/L)
18. Zinc (5 µg/L)

Nutrients

1. Nitrate⁻N (20 µg/L)
2. Nitrite⁻N (5 µg/L)
3. Ammonia⁻N (10 µg/L)
4. Dissolved Phosphorus (3 µg/L)
5. Total Phosphorus (3 µg/L)

Total Metals

1. Mercury (0.05 µg/L)

Anions

1. Alkalinity (0.5 mg/L)
2. Dissolved Sulphate (2.0 mg/L)
3. Dissolved Chloride

Pollutant Tests

1. Oil and grease (1 mg/L)
2. COD (10 mg/L)
3. TOC (1.0 mg/L)
4. Total Phenol (2 µg/L)

TABLE 15

SUGGESTED RECEIVING WATER MONITORING PROGRAM FOR TECK BULLMOOSE COAL INC. DISCHARGES TO BULLMOOSE CREEK

1. SITES - E206225, E206226, E206227, E206228, E206229, 0410094, E206232.

2. FREQUENCY - weekly during spring freshet (April 1-June 23) to coincide with the peak effluent discharge.
   - monthly for the remainder of the year to coincide with low flows.

3. ANALYSIS - obtain analysis of the samples as follows:

Alkalinity, Total	(mg/L)	Metals, Total and Dissolved (µg/L)	
Flow	(L/s)		
Hardness, ($CaCO_3$)	(mg/L)	Aluminum	Iron
Nitrogen, Ammonia-N	(mg/L)	Arsenic	Lead
, Nitrate-N	(mg/L)	Barium	Magnesium
, Nitrite-N	(mg/L)	Boron	Manganese
Oxygen, Dissolved	(mg/L)	Cadmium	Nickel
Oil and Grease	(mg/L)	Calcium	Vanadium
pH		Chromium	Zinc
Phenol, Total	(mg/L)	Cobalt	Silver
Phosphorus, Total	(mg/L)	Copper	
, Dissolved	(mg/L)		
Solids, Suspended	(mg/L)		
Sulphate, Dissolved	(mg/L)		
Temperature	(°C)	Mercury, Total	(µg/L)
Turbidity	(NTU)		
Fecal Coliforms	(MPN/100 mL)		

- Analyses are to be carried out in accordance with procedures described in the second edition (February, 1976) of "A Laboratory Manual for the Chemical Analyses of Waters, Wastewaters, Sediments, and Biological Materials", or by suitable alternative procedures as approved by the Director or Regional Manager.