BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

HAT CREEK PROJECT

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HAT CREEK PROJECT
DETAILED ENVIRONMENTAL STUDIES
WATER RESOURCES SUBGROUP
HYDROLOGY, DRAINAGE, WATER QUALITY AND USE

VOLUME 3
IMPACT ASSESSMENT

A Report for:

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY
Vancouver, B.C.

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A MEMBER OF THE SANDWELL GROUP

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6.0 IMPACTS OF THE PROJECT

6.1 HYDROLOGY

(a) Ground Water

The following assessment of impacts is based on the site development plans described in four unpublished reports[1,2,3,4]. These reports together with approximately 60 additional tables and figures were provided for this assessment.

In making the following assessment of potential impacts on hydrogeology, the following considerations were examined for each area and phase of development:-

Changes in Ground Water Level:

Higher ground water tables were generally considered as a beneficial impact. However, this did not include areas where the high water table could cause either water logging of the plant root zone or soil slope instability.

Changes in Ground Water Flow:

Increased ground water flows were considered to be beneficial impacts provided that no side effects would develop. These side effects could include; deterioration of water quality and/or adverse effects caused by an accompanying rise of the ground water table. Water quality aspects are addressed in Section 6.2(a).

(i) Preliminary Site Development

A. Mine, Plant, and Offsites

Mine Trailer Camp

The existing exploration trailer camp has been set up near Hat Creek in the vicinity of the proposed coal pit (see location Figure 6-1). The water supply to this camp comes from a shallow dug well approximately 5 m deep. Most of the estimated 10 m^3/d flow of ground water reaching the well will have infiltrated almost directly from Hat Creek. Details of this well (DW-1) are presented in Appendix A2.0. This rate of abstraction is only 0.24 percent of the 1:20 year flow in Hat Creek and hence represents only a minor impact on the low water flow in the creek.

The sewage treatment and disposal from this camp is by means of a septic tank and drain field. The drain field is located near the camp and seepage water flows down from the drain field to the water table in the alluvial aquifer approximately 2.0 m below ground. The average down valley flow in this aquifer was estimated to be 2,300 m^3/d (Section 4.1 (a) (ii) A) and hence an estimated discharge of 8 m^3/d to the aquifer represents only 0.35 percent of the total aquifer flow. The alluvium has a high hydraulic conductivity and hence, little or no rise in the water table can be expected.

The existing camp water supply and sewage disposal system induces an increased flow of infiltrated water from Hat Creek and after use in the camp returns the water to the alluvial aquifer with only a minor water loss. This water exchange is illustrated in Table 6-1. A similar type of water transfer has been observed to occur naturally at various reaches along the creek bed, and hence the net impact on the physical aspects of the ground water resource would be very minor. The estimated water loss is 2 m^3/d and represents about 0.1 percent of ground water flow.

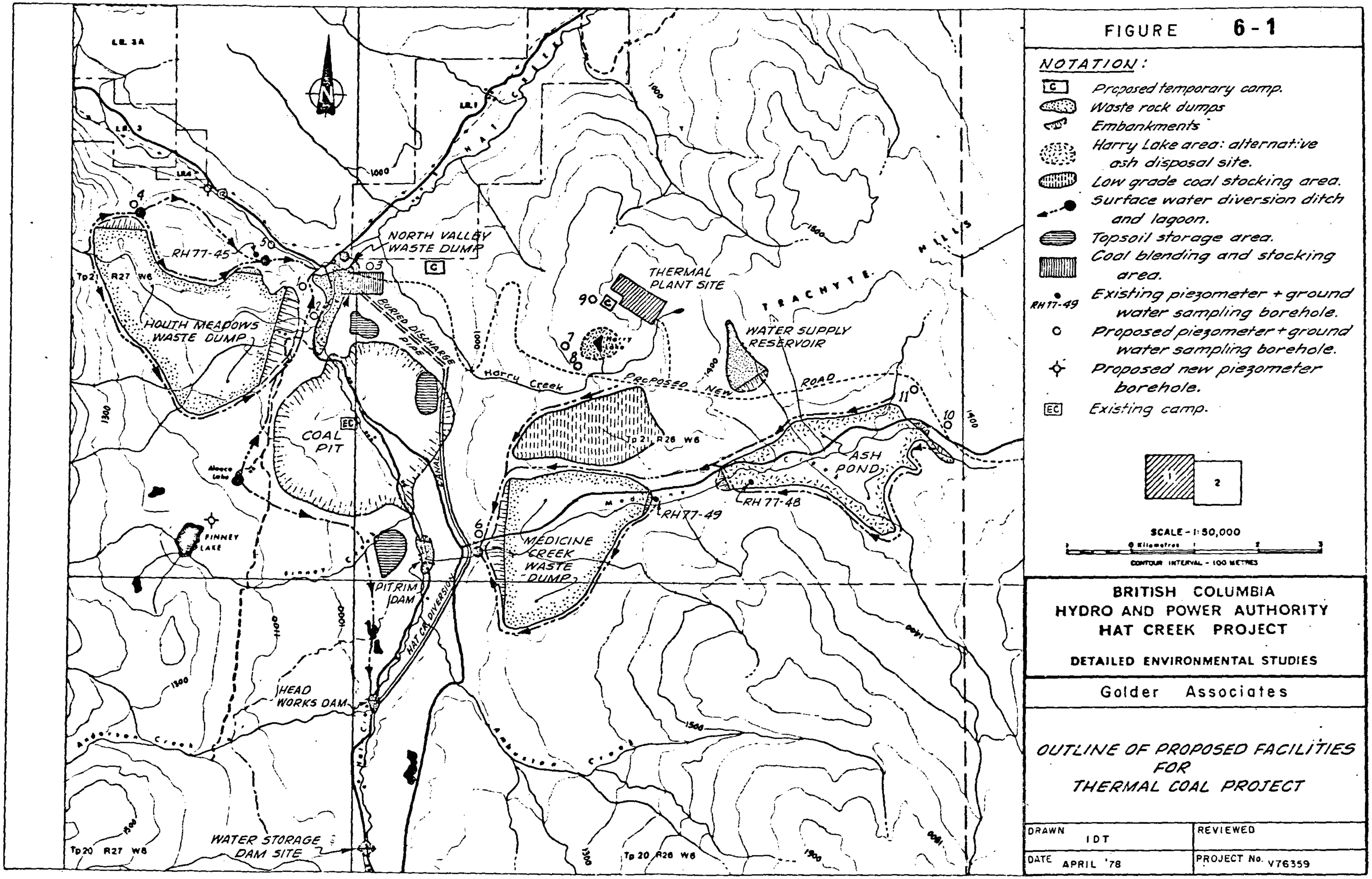
FIGURE 6-1
NOTATION:
Proposed temporary camp.
Waste rock dumps
Embankments
Harry Lake area: alternative ash disposal site.
Low grade coal stocking area.
Surface water diversion ditch and lagoon.
Topsoil storage area.
Coal blending and stocking area.
RH77-49 Existing piezometer + ground water sampling borehole.
Proposed piezometer + ground water sampling borehole.
Proposed new piezometer borehole.
Existing camp.
SCALE - 1:50,000
Kilometres
CONTOUR INTERVAL - 100 METRES
BRITISH COLUMBIA
HYDRO AND POWER AUTHORITY
HAT CREEK PROJECT
DETAILED ENVIRONMENTAL STUDIES
Golder Associates
OUTLINE OF PROPOSED FACILITIES FOR THERMAL COAL PROJECT
DRAWN IDT
REVIEWED
DATE APRIL '78
PROJECT No. V76359
NORTH VALLEY WASTE DUMP
THERMAL PLANT SITE
HOUTH MEADOWS WASTE DUMP
RH77-45
BURIED DISCHARGE PIPE
WATER SUPPLY RESERVOIR
TRACHYTE HILLS
Harry Creek
PROPOSED NEW ROAD
COAL PIT
ASH POND
RH77-48
RH77-49
MEDICINE CREEK WASTE DUMP
FINNEY LAKE
PITRIM DAM
HAT CR. DIVERSION
HEAD WORKS DAM
WATER STORAGE DAM SITE
Tp 21 R27 W6
Tp 21 R26 W6
Tp 20 R27 W6
Tp 20 R26 W6

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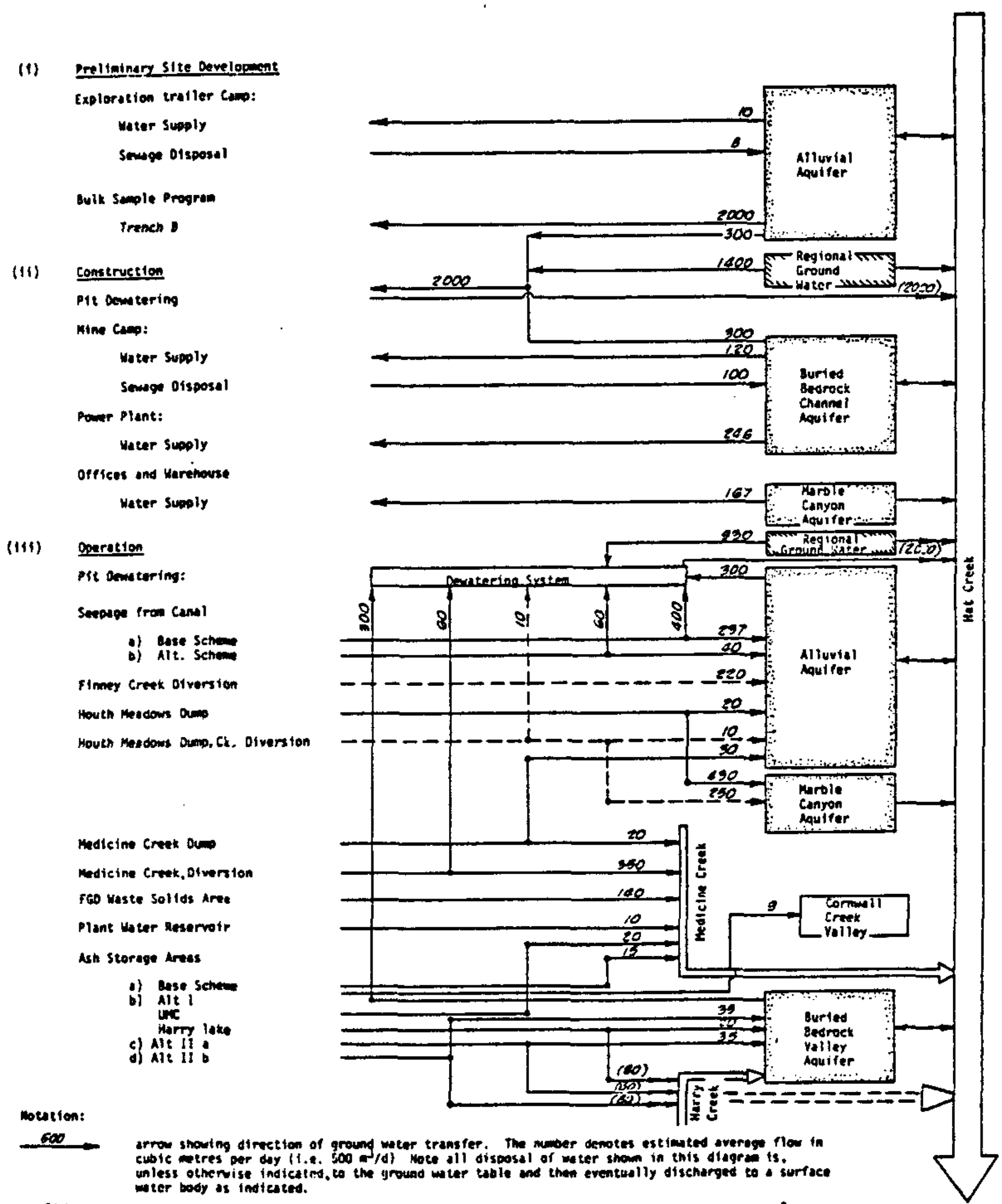
TABLE 6-1

Summary of Approximate Quantities of Transfered Ground Water Resulting from Proposed Coal Project

(for explanation of notation see below)



Notation:

600 — arrow showing direction of ground water transfer. The number denotes estimated average flow in cubic metres per day (i.e. 500 m^3/d) Note all disposal of water shown in this diagram is, unless otherwise indicated, to the ground water table and then eventually discharged to a surface water body as indicated.

500 — arrow showing direction of seasonal ground water transfers. The number denotes (ie 500 m^3/d) estimated peak seasonal flow in cubic metres per day.

(500) — double arrowhead and bracketed number denote an above ground discharge.

major ground water aquifer

Perennial surface water flow.

Ephemeral surface water flow.

Exploratory Drilling

The exploratory drilling program includes several boreholes which were drilled and developed as water wells. These wells have been pump tested so that soil and rock hydraulic conductivities can be determined. A total of seven wells have either been tested or are planned for the period up to August 1978. The predicted yields from wells that have been screened off in the bedrock formations are expected to be low (less than 6 m^3/d total). However, the total yield from wells completed in surficial sediments is expected to be much greater. One well, located on the western side of the coal pit, is expected to yield about 300 m^3/d. The estimated ground water flow towards Hat Creek and the alluvial aquifer in the vicinity of the proposed coal pit, is estimated to be about 1,000 m^3/d. This estimate is based on data presented in Section 4.1 (a) (ii) A, and assumes an effective pit width of 3 km. Thus, the discharge from this well represents about 20 percent of the natural ground water flow in the area and 9 percent of the flow in the alluvial aquifer.

In all cases, about 90 percent of the pumped ground water would be returned to the ground water table at a location greater than 200 m from the well. The only water losses would result from evapotranspiration on the soil surface. The periods of pumping, or in some cases bailing, would not exceed 40 days.

The impacts on local ground water aquifers caused by the exploratory drilling program would be minor in relation to the overall ground water resource. No impacts would be observed outside the area of the proposed coal pit.

Bulk Sample Program

Excavations were made at three locations in the northwest sector of the proposed coal pit for sampling purposes. Two of these excavations, referred to as Trench A and the Clay-Cut, were not excavated down to the water table. Trench B, located in the Hat Creek Valley bottom, was excavated to a depth of 9 m below the ground water table. The estimated seepage pumped from this trench was 2,000 m^3/d. This seepage had infiltrated from the surrounding alluvial aquifer, which in turn had exfiltrated from Hat Creek.

While the dewatering of Trench B represented a temporary major impact on the ground water flow in the alluvial aquifer, the pumping was restricted to a period of only two months. During this period the pumped water was discharged to a pond in the Dry Lake area west of Trench B. Seepage losses from this pond were very low and most of the water losses were due to evaporation from the pond surface. The pond is still in existence as a feature in April 1978.

The other activities of the Bulk Sample Program have resulted in very minor impacts on ground water resources in the area. A more detailed description of these impacts is presented in British Columbia Hydro and Power Authority Report, 1977 [5] .

The bulk sampling program has had only a minor negative impact on the ground water flows in the alluvial aquifer and most of the impacts were of short duration.

Summary of all Activities

The preliminary site development activities have been spread over a number of years. Significant drilling activity did not start until 1964 and will probably continue intermittently until construction starts possibly some time in the early 1980's. The overall impact of the site development activities on the ground water resources of the area have been and probably will continue to be very minor.

(ii) Construction

The basis for evaluation of the impact on ground water resources and the development plan are the same as outlined in Section 6.1 (a) (i) A. Construction activities can be subdivided into three main categories: mine (including the pit, waste dumps and infrastructure); power plant (including ash disposal areas, water reservoir and construction camp); and offsites (including creek diversions, water supply and access roads).

A. Mine

Clearing and Stripping in Pit Area

The ground water table is generally deeper than 20 m over most of the pit, and the only exception occurs in the valley bottom where the ground water table is close to the ground surface. The clearing and stripping operations proposed would remove top soil, surficial sediments and claystone bedrock from part of the upland recharge areas. This removal would reduce ground water recharge and increase surface water run-off in these areas. The result would be a minor negative impact on recharge to the alluvial aquifer.

Drainage Ditching in Pit Area

A system of surface ditching is proposed for the pit perimeter. Most of this ditching would be constructed on the west side of the pit where surface water run-off is more significant. Most of the surficial sediments in the vicinity of the coal pit are classified as glacial till and hydraulic conductivities are expected to be low.

The ditching system would probably consist of a major ditch located beyond the 35 year pit perimeter, together with a system of temporary ditches located closer to the working pit. These diversion ditches would collect surface run-off from the areas around Finney and Aleece Lakes and would convey the run-off away from the pit area. In the general pit area these ditches may have to be lined in order to minimize seepage losses to the ground water table. In areas outside the cone of depression in the ground water table caused by the coal pit dewatering, these ditches need not be lined. Some minor recharge to the water table can be expected in these areas. The net impact of the ditching system would be a reduction of ground water recharge near the pit and some increased ground water recharge in areas beyond the pit. These impacts are both relatively minor in terms of the ground water resource and are respectively negative and positive impacts, with the result that overall impact is ambivalent.

Lake Dewatering

The proposed development plan includes the dewatering of both Aleece and Finney Lakes (see locations on Figures 6-1). When water levels are high, these lakes could contribute significant quantities of seepage water to the local ground water table. However, based on an evaluation of natural isotopes in the lake water (see Section 4.1 (a) (iii) B) these lakes were found to lose most water by evaporation from the lake surface. Only a small portion of the lake water is lost as seepage through the lake bottom and most of this seepage would be through the upper 1 m around the wetted perimeter of the lake. Thus, the complete dewatering of the lakes would have little or no impact on the ground water resources of the area. For this reason consideration could be given to lowering the outlet from Finney Lake, but not completely dewatering the lake.

Pit Area Dewatering

The dewatering of the coal pit would be achieved by means of vertical wells drilled in the pit around the working area and around the pit perimeter. A proposed schedule of well installation was given in Table 5G (see Reference

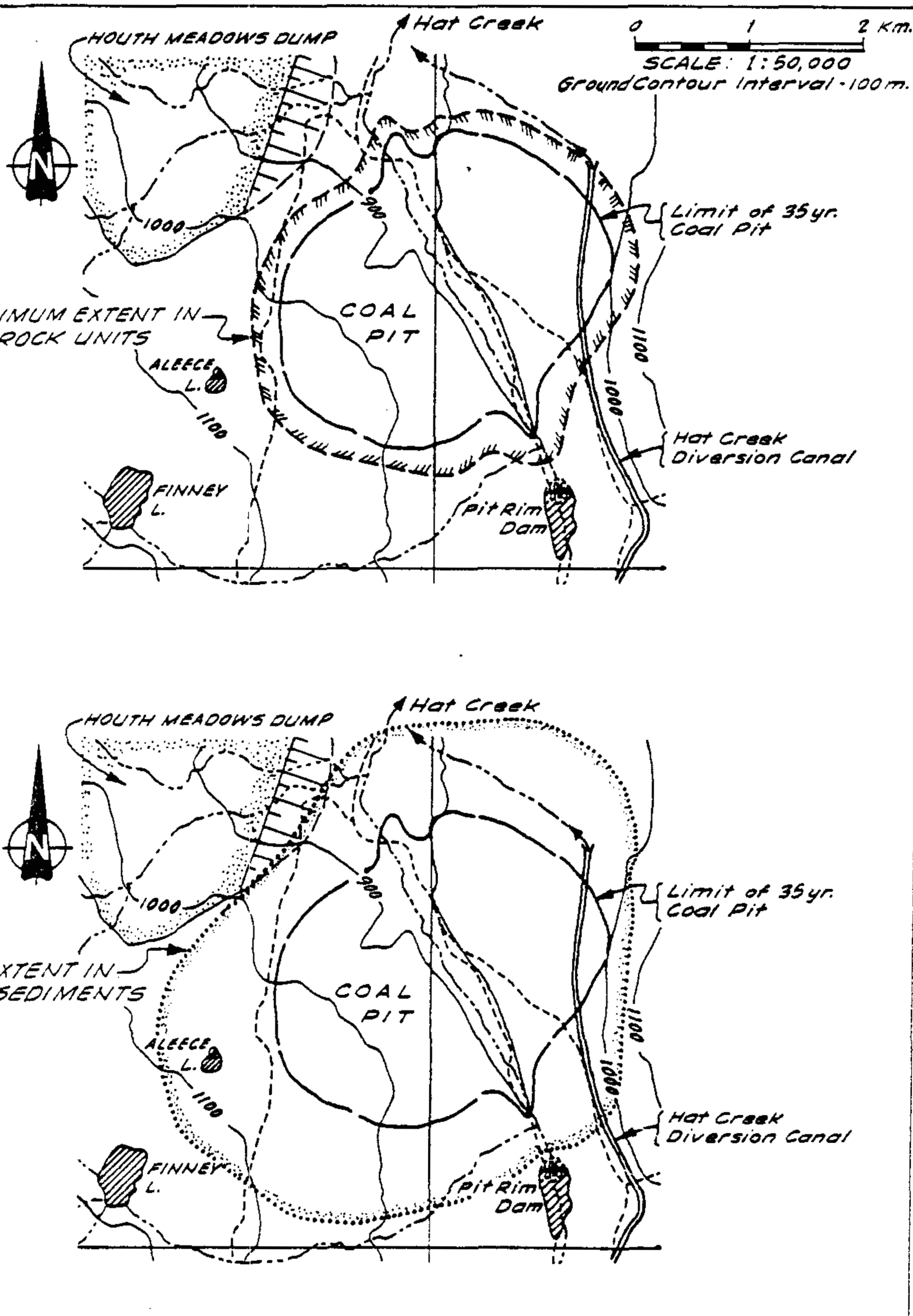
No. 1). This table shows that at least 22 wells would be installed one year prior to the start of mine operations. The initial total discharge of ground water from the coal pit has been estimated to be 700 m^3/d. By the time the thermal plant gets into operation the number of wells would have increased to 266 and the ground water discharge increased to a maximum of 1,600 m^3/d. Further work will enable these predictions to be verified.

The coal deposits are encapsulated within low permeability claystone and siltstone units. Hydraulic conductivities of these massive claystone units are around 10^{-10} m/sec. (see Section 4.1 (a) (i) B) and hence the *radius of influence of the dewatered bedrock around the coal pit will be* restricted to distances less than 100 m beyond the pit face at any stage. As the final radius of the proposed coal pit is approximately 1.5 km, the maximum distance to the edge of the zone of ground water influenced in bedrock would be about 1.6 km (see Figure 6-2).

The surficial sediments around the pit perimeter generally consist of glacial and glacio-fluvial sediments and slide debris. These sediments have higher hydraulic conductivities than the underlying claystones, however, saturated thicknesses are not very great. Estimated average hydraulic conductivities for the surficial sediments range between 10^{-8} to 10^{-5} m/sec. and saturated thicknesses along the western side of the pit average 20 m. Assuming maximum hydraulic conductivities, the calculated maximum radius of influence caused by pit dewatering could extend about 1 km beyond the pit perimeter (i.e. extending to a maximum radius of 2.5 km from the center of the final pit) (see Figure 6-2). However, if average hydraulic conductivities were lower than 10^{-6} m/sec. the radius of influence would be in the order of a few hundred meters beyond the pit perimeter at any stage.

AREAL EXTENT OF GROUNDWATER DRAWDOWN CONE IN HAT CREEK COAL PIT.

Figure 6-2



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The hydrogeology of the eastern side of the pit is more complex, due to the presence of a buried bedrock valley. As described earlier (Section 4.1 (a) (ii) A) this buried valley extends along the northeastern side of the pit and is filled with glacio-fluvial sediments. The volcanic bedrock exposed along the eastern side of the Hat Creek Valley (Figure 4-1) limits the extent of these surficial sediments and the drawdown cone imposed on the ground water table.

The impacts caused by the pit dewatering will be threefold.

1) A cone of depression in the ground water table in the surficial sediments around the pit could extend to as much as 1 km from the pit rim.
2) A ground water discharge which would gradually increase to about 1,600 m^3/d would be pumped and discharged back into Hat Creek.
3) The shallow alluvial valley aquifer would be cut in two by the pit and blocked at the pit rim dam (see Figure 6-2). The alluvial aquifer is fed both from the creek and the surficial sediments along the valley. Thus, dissection of this aquifer by the pit would affect only that part of the aquifer that is within the influence of the pit dewatering, and downstream of the pit to the diversion discharge pipe. The estimated length of this alluvial aquifer is 18 km and the length affected by the pit is 5 km. Thus, 28 percent of the alluvial aquifer would be affected and similarly 40 percent of the buried channel would be affected.

These impacts, while significant in the vicinity of the pit, would be restricted to the area close to the pit and hence would not cause a major regional impact. Hat Creek flows downstream of the pit would be very slightly reduced as a result of water losses due to evaporation in the pit.

Clearing and Stripping in Dump Areas

The clearing and stripping operations in the Houth Meadows Creek dumps would result in a minor lowering of the ground water table in the valley floor. In the Medicine Creek Valley where the water table is well below the valley floor, no impacts would occur. The result would be a minor negative impact.

Creek Diversions Around Dumps

As the ground water table is well below ground surface along the alignment of the proposed creek diversions, there would be no impact on ground water during construction.

Embankments and Spoil Dumping

The placing of the spoil and embankment materials in the valley floors of both dump areas would have no significant impact on the local ground water regime.

Stock Piles

The topsoil, coal and low grade waste stock pile areas would all retain moisture and under saturated conditions this water would seep down to the bottom of the pile. These areas are all located in areas where the surficial sediments are mostly glacial tills with low hydraulic conductivity. The estimated depth to ground water table varies from 10 - 80 m below ground surface.

While the hydraulic conductivity of the till in the vicinity of the proposed stockpiles is not known a reasonable range, based on data obtained on till in the vicinity of the coal pit, is between 10^{-7} and 10^{-9} m/s. By assuming an average hydraulic conductivity of 10^{-8} m/s, the estimated seepage loss through till is between 1×10^{-5} and 5×10^{-4}

$m^3/d/m^2$ of storage area. This seepage range will depend on the geometry and type of surface drainage facilities. On this basis the seepage losses to the ground water table beneath the fully developed coal blending and stocking area would be between 26 and 130 m^3/d. The lower range would be applicable if the surficial area beneath the pile was properly drained.

The seepage from these three areas would be only slightly greater than the present rate of precipitation seeping to the ground water table. Construction and stocking of these storage areas would therefore result in an increased ground water recharge and hence on the basis of hydrology alone, is considered to be a minor beneficial impact.

Mine Camp Water Supply

The offsites description proposes that two wells should be drilled and developed near Hat Creek in the vicinity of the proposed pit. These wells would supply water at approximately 346 m^3/d to both the mine and power plant camps and would operate until the Hat Creek diversion canal is in operation. About 100 m^3/d would be required for the mine camp.

If wells were drilled and developed in the area close to Hat Creek, the ground water abstracted from these wells would come from an alluvial aquifer which is hydraulically connected to Hat Creek. As most of the water would come indirectly from Hat Creek there would be little or no impact on the ground water flow in this aquifer.

A minor negative impact on the ground water table in the area could be expected. However, this impact would be accompanied by a net withdrawal of about 346 m^3/d from the flow in Hat Creek.

Mine Camp Sewage Disposal

The sewage effluent from the aerobic sewage treatment plant would be discharged into either drainfields, exfiltration ponds, deep wells or spray irrigated on the ground. No detailed soil testing has been carried out, however preliminary data indicate that these methods could be feasible in the area.

The ground water table is estimated to be 100 m below ground surface and the underlying glacio-fluvial sediments have estimated hydraulic conductivities ranging between 10^{-8} and 10^{-5} m/s (8.6 x 10^{-4} and 8.6 x 10^{-1} m/d). A potential aquifer in the glacio-fluvial sediments extends beneath the camp, however the infiltrating sewage would have only a minor impact on this aquifer. The estimated sewage discharge would be a maximum of 100 m^3/d and if a conventional drainfield were built to meet Pollution Control Board requirements, the sewage would require an area of about 1,000 square meters. Thus, the average infiltration rate over the entire disposal area would be 10 mm/d (10^{-2} m/d). For the on ground disposal options and depending on the nature of the sediments beneath the disposal area, the effluent would either flow laterally through more permeable sediment layers or would flow vertically downward through unsaturated sediments. The former flow path could reach Hat Creek without recharging the buried channel aquifer, however, the latter flow path is more likely to occur. This would result in recharge to the buried channel aquifer and a minor beneficial impact would result.

Office and Warehouses Water Supply

The project description indicates that the water supply for the shops and warehouses would be between 23 and 167 m^3/d. This water could come from a water well near the offices or perhaps be linked to the camp water supply. A well in the vicinity of the offices could be located either in the Marble Canyon or Alluvial aquifers. The projected water requirements are small in comparison to the aquifer flows of 2,000 and 2,300 m^3/d respectively. Hence, there would be a minor negative impact.

B. Plant

Ash Disposal Facilities

The project description[3] describes one proposed scheme (the base scheme) and three alternative schemes (Schemes I, IIa and IIb) for ash disposal. These schemes are summarized in Table 6-2 and show that disposal areas are located either in the upper part of Medicine Creek or in the Harry Lake area (see locations Figure 6-1).

Embankment Construction:

No details of the embankment construction are available. However there appears to be adequate fill and other granular material available to make a relatively impervious dam. These construction activities are not likely to affect the local ground water flows at either site.

Creek Diversions:

Both Medicine and Harry Creeks would have to be diverted around the ponds or dumps. As with the waste dump diversion ditches some positive benefit could be expected from increased infiltration from the bottom of the ditches. The seepage rates are likely to be low, 60 - 150 m^3/d per km, and these seepage rates would only apply during the few months of the year when there is water in the ditches.

There would be a very small net positive impact resulting from a slightly increased seepage from the diverted creeks over the present seepage losses from natural creek channels.

Table 6-2

Summary of Proposed Ash Transport and Storage Schemes

Scheme	Notes	Ash Type	Transport Mode	Storage Mode	Location of(1) Storage Area
Base	(1)	Bottom	wet sluice	wet pond	UMC
		Fly	wet sluice	wet pond	UMC
Alternative I	(2)	Bottom	wet sluice	wet pond(6)	HC
	(5)	Fly	wet sluice	wet pond	UMC
Alternative II(a)	(3)	Bottom	wet sluice	dry dump	HL
	(3)	Fly	dry	dry dump	HL
Alternative II(b)	(4)	Bottom	dry	dry dump	HL
	(4)	Fly	dry	dry dump	HL

Notes:
(1) UMC = Upper Medicine Creek Area (see location Figure 6-1)
HL = Harry Lake Area (see location Figure 6-1)
(2) Bottom ash pond is shown in Figure 6-5
(3) Ash dumps are shown in Figure 6-6
(4) Ash dumps are shown in Figure 6-7
(5) No details of this pond are available and it is assumed that it would be a smaller version of the combined ash pond
(6) The pond would be self-draining and approach a dry state.

Other Activities

Construction activities including: transport systems, base preparation, drainage ditching and lagoons would all be done above the water table and would not involve any major water transfer. Hence, there would be no impact on the ground water.

Clearing and Stripping for Reservoir

The removal of vegetation and loose topsoil on upland areas would cause increased run off and decreased infiltration to the water table. This would cause a minor negative impact on ground water table and flow regime.

Activities at Power Plant Site

The same comments given for clearing and stripping the reservoir site apply. Only a minor negative impact would result.

Summary of Activities

Most construction activities would be done above the water table and only minor impacts would result from clearing and stripping operations and where perennial streams are diverted.

C. Offsites

Clearing and Stripping for Hat Creek Diversion

The removal of vegetation and loose topsoil on upland areas would cause increased run-off and decreased infiltration to the water table resulting in a lowering of water tables. A minor negative impact would result.

Reservoir Construction for Diversion Scheme

The construction of cut off trenches and/or grouting of permeable sediments beneath the embankment structures for the Head Works and Pit Rim Dams would partially cut off the ground water flow in the alluvial aquifer adjacent to Hat Creek. The estimated down valley flow in this aquifer is 2,300 m^3/d (Section 4.1 (a) (ii) A). The reduced ground water flow in this aquifer immediately downstream of the two embankments would be in the order of 300 m^3/d. Most of this ground water would be collected in dewatering wells around the pit perimeter. As it is the intent of these works to reduce ground water seepage, the net result would be a major negative impact on the alluvial aquifer.

Main Access Road

The limited hydrogeologic data available along the access road suggests that there would be no impacts on ground water resources.

Water Supply

The limited hydrogeologic data available suggests that there would be no impacts.

(iii) Operation

A. Mine

Overburden Removal in Pit Area

The comments given for construction clearing and stripping in pit area during construction would apply.

Pit Area Dewatering (including: pit dewatering, mine dewatering and slope stabilization)

The impacts discussed in the construction phase apply. The total ground water abstraction is estimated to reach a peak of about 2000 m^3/d about 8 years after construction starts. This includes an estimated 400 m^3/d which would seep from the diversion canal. This pumpage rate would gradually decline to a rate of about 1000 m^3/d at the end of 35 years of mining operations. The maximum zone of influence due to pit dewatering is shown in Figure 6-2 and there would be no impact on local aquifers beyond this zone.

Drainage Control in Pit Area

Comments given in the drainage ditching section of construction phase apply. In addition some additional in-mine drainage would be required to collect surface water and some ground water seepage at the bottom of the pit. As in the construction phase the overall impact would be ambivalent.

Finney Creek Diversion

Very little data is available on the soils along the diversion canal route. The surficial soils consist of tills and outwash deposits typical of respectively hummocky moraine and ice contact deposits. Data from field observations in the area suggest that the route crosses through a significant ground water discharge zone (see Figure 3-4). This zone appears to be discharging water from a series of shallow ground water flow systems that are possibly related to past earth slide activity in the area.

The hydraulic conductivity of the ground moraine is likely to be relatively variable, ranging from 10^{-5} to 10^{-8} m/s. Estimated seepage losses from a lined ditch are in the order of 50 to 150 m^3/d per km length of canal. Hence the diversion canal would collect ground water seepage flows around the Finney Creek area and distribute this seepage toward the south. Presently much of the seepage that does appear on the ground surface around Finney Creek will re-infiltrate into the ground and eventually reach Hat Creek through surficial sediments.

The diversion will redistribute ground water seepage flows toward the south. Based on the limited data the resulting impact is likely to be ambivalent.

Houth Meadows Dump

The hydrogeology of the existing dump area is described in Section 4.1 (a) (ii) B. When dumping commences in this area some major changes in ground water flow patterns are likely to occur particularly in the limestone bedrock at the north of the dump. The placement of waste rock in the ground water discharge areas in the northern part of the valley will cause a progressive restriction of these ground water flows from the limestone and consequently the water table in the limestone will start to rise.

Hydraulic conductivities are estimated to be between 10^{-5} and 10^{-3} m/s for loose dumped waste rock and these values would be reduced to about 10^{-11} m/s as the waste rock consolidated under its own weight at the bottom of the dump. Data on hydraulic conductivities of Hat Creek waste rock materials are very limited. The lower range values assumed above are based on laboratory tests of Hat Creek samples and some field data from other coal mine areas (see Table 6-3). The upper range values are estimated hydraulic conductivities and are assumed to apply to the upper 30 m

Table 6-3

Summary of Some Ash and Coal Waste Properties

Waste Type		Optimum Water Content %	Dry Unit Weight kg/m^3	Effective Size D_{10} (mm)	Coeff. of Uniformity	Hydraulic Conductivity m/s	Information Source Ref. No.
Bottom Ash	Coals from US Northeast	13 → 26	1140 → 1600			$5.0x10^{-5}$ $9.4x10^{-4}$	6
Bottom Ash	Hat Creek	-		10^{-2}	48	$10^{-6(2)}$	
Fly Ash	Coals from US Northeast	23	1378		-	$5x10^{-9}$ $5x10^{-7}$	6
Fly Ash	U.K.	19.5 → 32	1188 → 1486	$2x10^{-3}$ $4x10^{-3}$	- -	$5x10^{-9}$ $8x10^{-7}$	9
Fly Ash	Hat Creek	-	-	$2x10^{-3}$	30	$4x10^{-8(2)}$	11
Claystone Waste Rock	Hat Creek		-			$1x10^{-10(3)}$	
Siltstone & Shale Rock	NE; USA Siltstone & Shale	12.5	-			$2x10^{-9}$ $1.2x10^{-8}$	8
Coarse Coal Refuse	Western, USA		1301 → 1568	0.21 0.44	23.4 31.4	$1.2x10^{-8}$ $5.9x10^{-4}$	10
Fine Coal Refuse	Western, USA	9 → 51.9	752 → 1650	$1.2x10^{-3}$ 0.1	5.6 40.5	$<10^{-8(1)}$ $6.8x10^{-5}$	10
Flue Gas Desulphurization Sludge		-	-	-	-	10^{-5} 10^{-7}	12

Notes: (1) Vertical hydraulic conductivities.
(2) Calculated hydraulic conductivities from size grading. These values are very approximate.
(3) Based on laboratory testing of remoulded waste rock samples.

of the waste dump only. Due to the wide range of expected hydraulic conductivities, predictions on seepage losses to the ground water table are difficult to make as much would depend on dump operation techniques used. However the following summarizes some of the probable impacts:

- initially when the waste rock is dumped it would be loose and seepage water would easily pass through.
- as the dump height increases the material in the bottom of the dump would become more compact and would tend to seal off the seepage flow through the base of the dump.
- the water table in the limestone bedrock would rise at about the same rate that the dump surface rises.
- ground water seepage and surface runoff from the limestone bedrock would flow toward the dump until the water table in the dump became higher than the ground water divide in the bedrock. At this point seepage from the dump would flow into the bedrock (see illustrations in Figure 6-3a).
- the major seepage losses to the ground water table would occur in the northeastern corner, around the saddle embankments and beneath the east embankment (see illustration in Figure 6-3a). Estimated seepages from the dump through the limestone bedrock have been made assuming a hydraulic conductivity of bedrock equal to 10^{-7} m/s. These estimates are:-

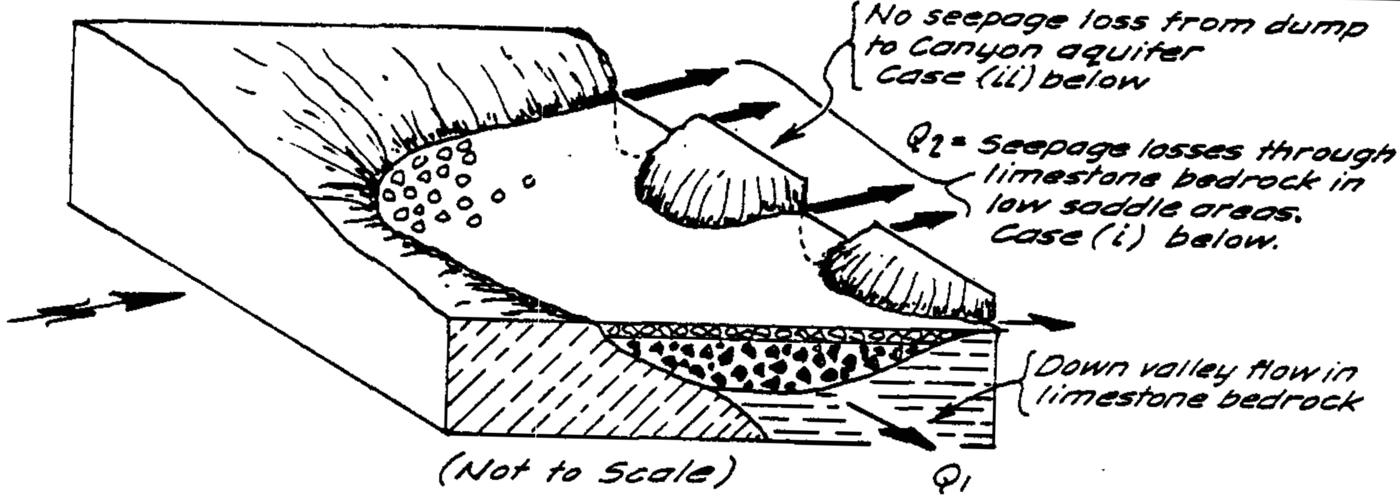
  Q1 under the east embankment 10 - 50 m^3/d (see Figure 6-3a). This is only 20 percent of the estimated natural ground water seepage, see Section 4.1 (a) (ii) B. As shown on Table 6-1, approximately 30 percent of this seepage could be intercepted by the coal pit dewatering system.

  Q2 northward around the saddle embankments 200 - 600 m^3/d (see illustration in Figure 6-3a) (note: these figures do not include seepages through the embankments themselves as this seepage does not reach the ground water table).

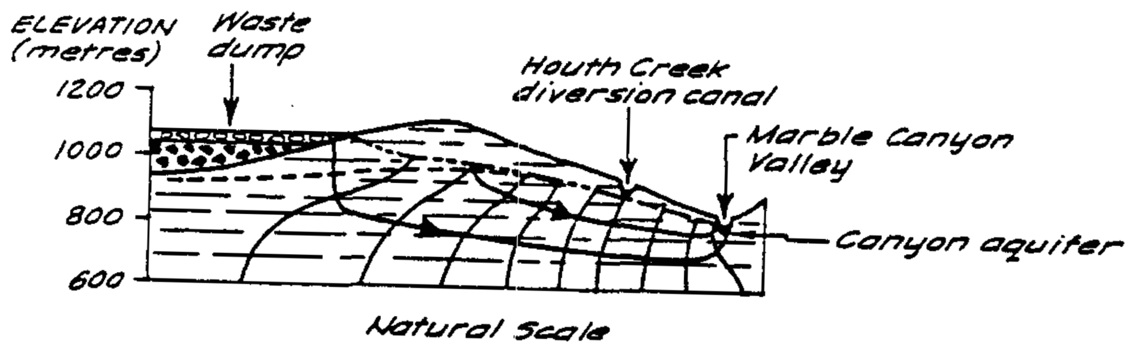
The dump would have a significant impact on ground water tables and flow directions in the limestone bedrock north of the Houth Meadows. This would

MAJOR GROUNDWATER FLOWS FROM AND INTO BEDROCK AROUND THE HOUTH MEADOWS WASTE DUMP AT FULL HEIGHT.

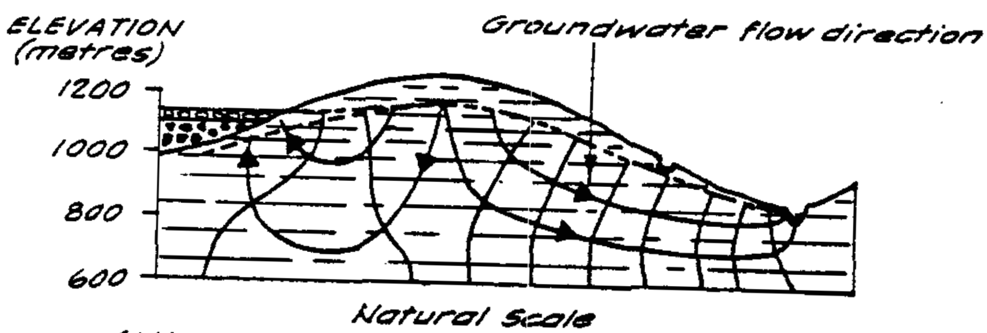
Figure 6-3a



ISOMETRIC VIEW OF WASTE DUMP



CASE (i) SEEPAGE FROM WASTE DUMP ENTERS LIMESTONE BEDROCK.



CASE (ii) GROUNDWATER FLOWS FROM LIMESTONE BEDROCK TOWARDS WASTE DUMP AND CANYON AQUIFER.

LEGEND:

- Compacted waste rock.
- Uncompacted waste rock.
- Existing groundwater table.
- New water table after dump is in operation.
- Limestone bedrock.
- Claystone bedrock.
- Minor groundwater seepage from dump.
- Significant groundwater seepage from dump.

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Golder Associates

result in a diversion of an estimated additional water flow of 400 m^3/d toward the surficial aquifer in Marble Canyon. This represents about a 50 percent increase in ground water flow in the limestone bedrock on the south side of the canyon. The ground water level in the canyon aquifer, which flows eastwards, would rise by a few metres but would not reach the ground surface. The result would be a major beneficial impact on the Canyon aquifer. This assumes that the seepage water quality would be satisfactory.

The estimation of seepage flows through the embankment structures, while not strictly ground water flows, have been estimated to be between 300 and 1,500 m^3/d. This seepage would depend on embankment and dump construction procedures used, and on the hydraulic conductivity of the loose upper materials in the dump.

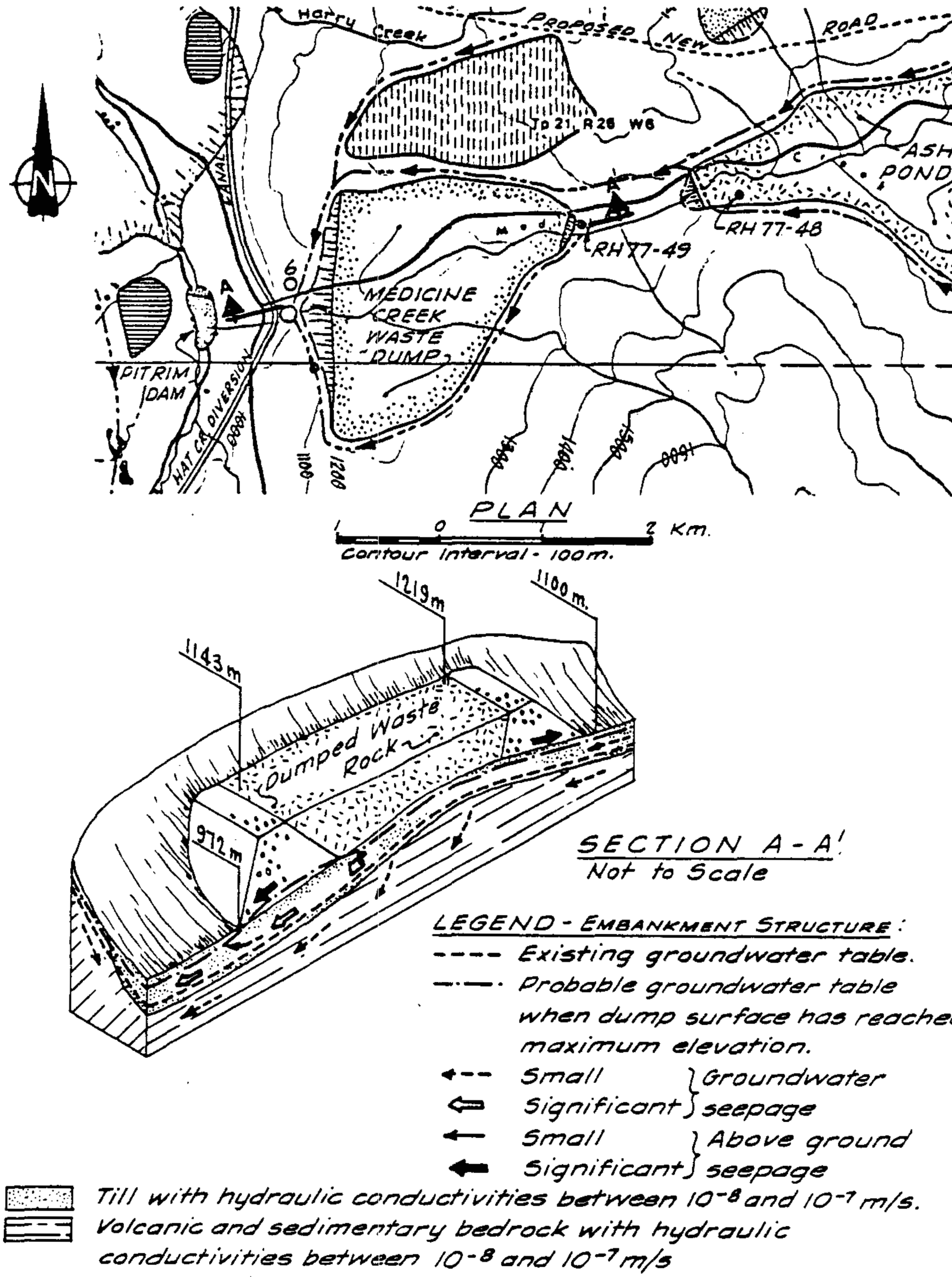
Medicine Creek Dump

The depth to ground water table below the base of the dump is about 30 m below ground surface and hydraulic conductivities of underlying bedrock and surficial sediments are low (10^{-8} to 10^{-7} m/s). When the waste rock dumping commences there will be some seepage down to the water table and laterally into the side walls. This would result in a rise of the water table by 10 to 30 m and possibly to the ground surface. Eventually the steeper hydraulic gradient toward the Hat Creek Valley would dominate and ground water seepage would become greatest in this direction (see Figure 6-3b).

The waste rock to be dumped in this area would be coarser than that placed in the Houth Meadows. Initially this material could be "free-draining" for a period of a few months after placement. However, the effects of weathering and consolidation would reduce hydraulic conductivities to values similar to those given for the Houth Meadows dump. Recharge to the dump

SKETCH OF PROBABLE GROUNDWATER SEEPAGE AROUND AND THROUGH MEDICINE CREEK WASTE DUMP.

Figure 6-3b



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would come from; precipitation on the loose surface materials (assumed to be relatively coarse), leakage from diversion canals around the dump and from seepage from the small pond behind the embankment at the eastern end of the dump.

Some minor seepage losses from this dump to the ground water, in the order of about 10 - 50 m^3/d, could be expected and a minor beneficial impact would result. The estimated maximum short term seepage through the embankment would be between 300 and 2,000 m^3/d. However, this seepage would not reach the ground water table. The fate of these seepage flows are summarized in Table 6-1.

North Valley Dump

This dump would store approximately 9.2×10^6 cu. m-of surficial materials. The estimated dump area is 0.5 sq. km and the average hydraulic conductivity of the material could be about 10^{-6} m/s.

The dump straddles the alluvial aquifer and cuts across the eastern end of the marble canyon aquifer. Estimated depths to the ground water table suggest that the ground water would be no closer than 7 m from the base of the waste dump. Precipitation on the top surface of the dump would either run-off or seep down through the dump. By assuming a maximum of 10 percent of the annual precipitation would seep through the dump, the calculated maximum seepage out of the base of the dump would be 50 m^3/d. This would be an unsaturated seepage flow and most of the discharge would flow down to the alluvial aquifer below.

The resultant would be a minor beneficial impact on the local ground water resource.

Creek Diversions Around Dump Areas

The diversion of the creeks would result in some ground water recharge at a higher elevation as a result of leakage from the diversion canals. The hydraulic conductivity of the natural soils around the proposed dumps would be relatively low (less than 10^{-7} m/s) in most areas. By assuming a typical cross-section of channel and an estimated wetted perimeter of about 5 m the estimated seepage from the unlined diversion ditches would be between 50 to 150 m^3/d per km length of channel.

The ground water table in the Medicine Creek area is in the order of 30 m below ground surface in the valley bottom and is estimated to be less than 30 m in the bedrock on the valley walls. The leakage from the ditches would cause the ground water table to rise by a few tens of metres. However the exact amount of rise cannot be estimated at this stage.

The proposed Houth Creek diversions are to go around the dump perimeter and along the southern side of the Marble Canyon Valley. Most of the surface soils would be glacial till, however the ditches would have to be cut through solid limestone bedrock in some sections, and in other sections colluvial deposits would be encountered. Hydraulic conductivities in these areas would be high and sealing of the bottom of the ditches would be required.

The diversion of the two creeks through ditches around the two dumps would result in increased ground water recharge in the valley sides. In the Houth dump area, there would be a transfer of water to the Marble Canyon. This increased ground water recharge would be a minor beneficial impact particularly in the Marble Canyon area where there is a significant aquifer.

Dump Area Drainage Ditching and Lagoons

These ditches would help to control ground water tables in the valley bottom, but would have no major impact on the overall ground water resource. The result would be a minor impact on water tables and the ground water flow regime.

B. Plant

Water Reservoir

The surficial sediments in the area are made up primarily of clay with glacial drift. Based on limited borehole information in other parts of the Medicine Creek Valley and on the bedrock geology map (Figure 4-1) the underlying bedrock is likely to be a sedimentary rock with hydraulic conductivities of about 10^{-7} m/s. The depth to ground water table is not known but is likely to be in the order of 2-10 m below ground. Estimated seepage losses from the reservoir to the ground water table would be between 3 and 10 m^3/d.

The seepage from the reservoir could raise the local water table by an order of a few metres. This is considered a minor beneficial impact.

Ash Disposal Facilities

The project description[3] describes one preferred scheme (base scheme) and three alternative schemes (Schemes I, IIa and IIb) for ash disposal from the power plant. These schemes are summarized in Table 6-2.

The quantities of recirculation water and water lost with the ash for various types of Hat Creek coal are given in the water management study Integ-Ebasco[38]. This report shows that the estimated water discharge to the wet ash ponds is 91.2 l/s (7880 m^3/d). All of this water would be stored in the pond, some would eventually be lost as evaporation from the pond surface and some would seep through the retaining structures or through the local surficial materials. No detailed testing results on the engineering properties of Hat Creek fly and bottom ashes are available. A summary of selected ash properties reported in the literature, together with some data on Hat Creek ash are included in Table 6-3. These preliminary data suggest hydraulic conductivities in the range 10^{-6} - 10^{-4} m/s for Hat Creek bottom ash and 5 x 10^{-9} - 10^{-6} m/s for Hat Creek fly ash.

The following is a brief discussion of hydrogeological conditions and estimated seepage flows from the proposed ash disposal dumps and three alternate schemes. The estimated flows are approximate ($\pm$ 50 percent) and are intended to represent maximum steady state seepage flows. The fate of the ground water seepage for each scheme is summarized in Table 6-1.

Base Scheme

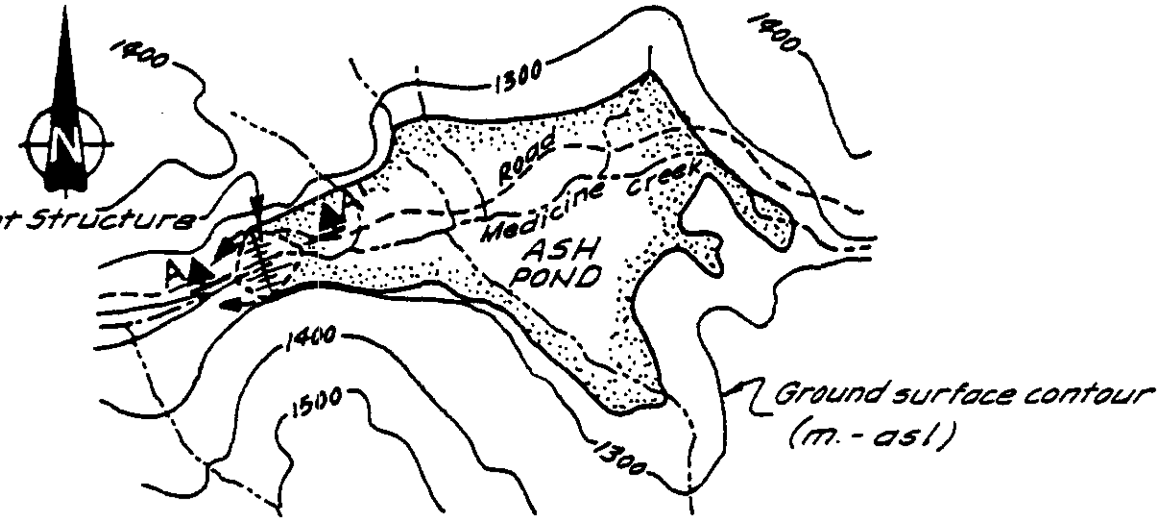
A till blanket covers most of the sandstone - shale - greenstone bedrock in the proposed ash pond area. Boreholes RH77-48 and RH77-49 are located in the vicinity of the western embankment (see logs in Appendix A3.0). Field tests of the hydraulic conductivity of these bedrock sediments in the boreholes gave values of about 10^{-7} m/s. The depth to ground water table in the bottom of the valley is about 20 m.

The upper Medicine Creek Valley forms a natural containment bowl for retention of the wet ash. However a major fault passes beneath the pond (see Figure 4-1) and the possibility of seepage along this fault was considered. However, tests in Boreholes RH77-48 and 77-49 do not indicate significant hydraulic conductivity differences between fractured and unfractured rock in this valley. If the hydraulic conductivity values obtained from the two boreholes are representative of the bedrock over the entire site, then the seepage from this pond is not likely to be very high.

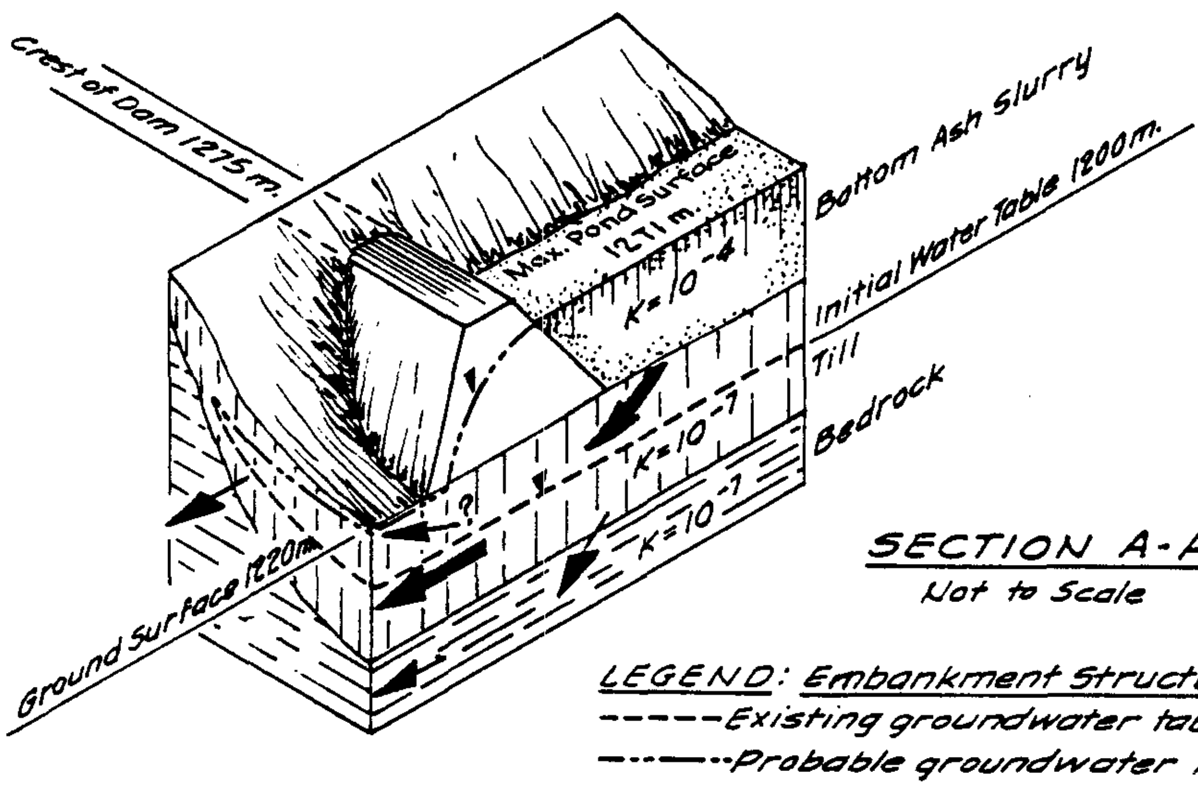
By assuming the conditions shown in Figure 6-4, the estimate of seepage loss to the ground water table underneath the western dam embankment, when

SKETCH OF PROBABLE GROUNDWATER SEEPAGE FLOWS AROUND EARTH FILL EMBANKMENT AT WESTERN END OF UPPER MEDICINE CR. ASH POND.

Figure 6·4



PLAN
SCALE - 1:50,000
0 1 2 Kilometres
Contour Interval - 100 m.



SECTION A-A'
Not to Scale

LEGEND: Embankment Structure:
- - - - - Existing groundwater table.
-·-·-·- Probable groundwater table when pond surface has reached maximum elevation.

Groundwater Flows:
← Minor
⬅ Major

NOTE: K values given are typical hydraulic conductivities (m/s)

Project No V76359 Drawn ... Checked ... Apr '77 at full construction height, is 20 m^3/d. Little data is available on the geology at the eastern side of the pond (in topographic divide). However the estimated seepage to the ground water table beneath the pond and flowing eastwards through the topographic divide is 10 m^3/d. Depending on the type of embankment construction at the western end of the pond, the seepage through this structure could be between 20 and 100 m^3/d.

The seepage losses to the ground water table are from physical considerations only, considered to be a minor beneficial impact.

Alternative Scheme I:

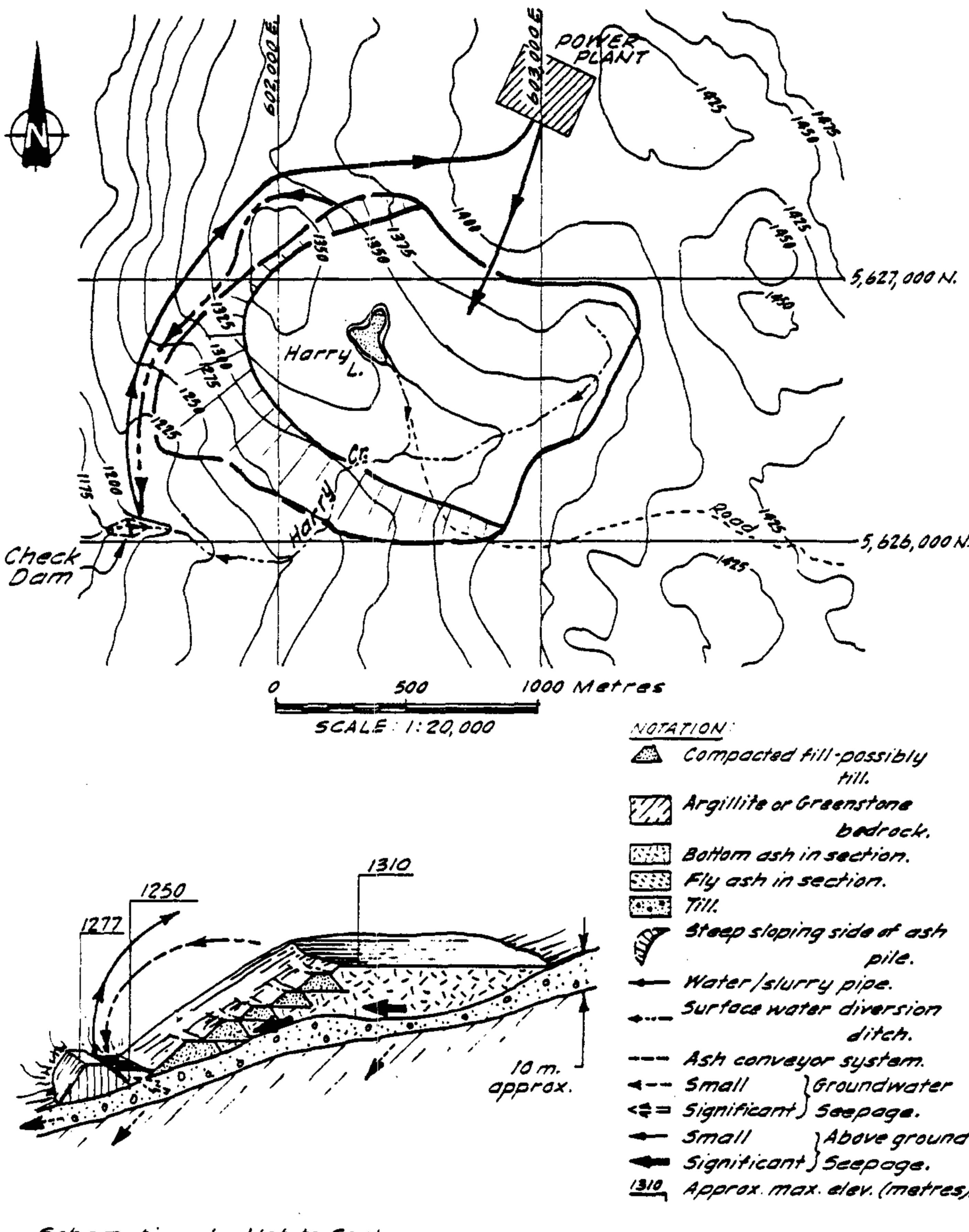
Little geologic data is available for the evaluation of the Harry Lake area. No boreholes have been drilled in the proposed bottom ash disposal area. However, some holes drilled southeast of the site (see DDH-827, see Figure 3-4) indicate that bedrock is about 10 m below ground surface and that the surface till deposits are extensive. The ground water table is about 3 m below ground.

In a wet ash disposal scheme at the Harry Lake site a considerable amount of seepage could flow both out of the toe of the ash spoil slope and as ground water seepage under the dump itself (see Figure 6-5). Most of the ground water seepage would reappear in the channel of Harry Creek and would be collected in the catch basin. However the estimated recharge added to the local deep ground water flow system resulting from the ash storage would be about 20 m^3/d (see Figure 6-5). This ground water flow system discharges into the glacio-fluvial aquifer in the buried bedrock valley (see location Figure 3-4). In addition, during the drier months, much of the flow in Harry Creek appears to seep down to this aquifer.

While not strictly ground water seepage the maximum annual above ground seepage (i.e. in the ash or retaining embankment) would be between 20 and 100 m^3/d. The seepage from the pond would have a minor beneficial impact on the local ground water flows. This seepage, plus seepage losses

ASH DISPOSAL ALTERNATIVE No. I
WET DISPOSAL OF BOTTOM ASH AT HARRY LAKE.

Figure 6-5



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from Harry Creek would indirectly recharge the buried channel aquifer in the Hat Creek Valley.

The disposal of fly ash in the Upper Medicine Creek Valley would have similar impacts to the base scheme with a lower magnitude. Annual peak seepage flows through the embankment would be between 20 and 80 m^3/d.

Alternative Scheme IIa:

Most of the water losses would be as direct seepage out of the toe of the bottom ash storage area. However, some seepage to the ground water table would occur. The total seepage losses to the ground water table from the bottom ash storage area, wet pond and fly ash storage area combined is estimated to be 35 m^3/d (see Figure 6-6). Depending on the depth to natural ground water table and thickness and hydraulic conductivity of the underlying till, some ground water seepage could surface in Harry Creek. Peak annual above ground seepage would range between 20 and 120 m^3/d.

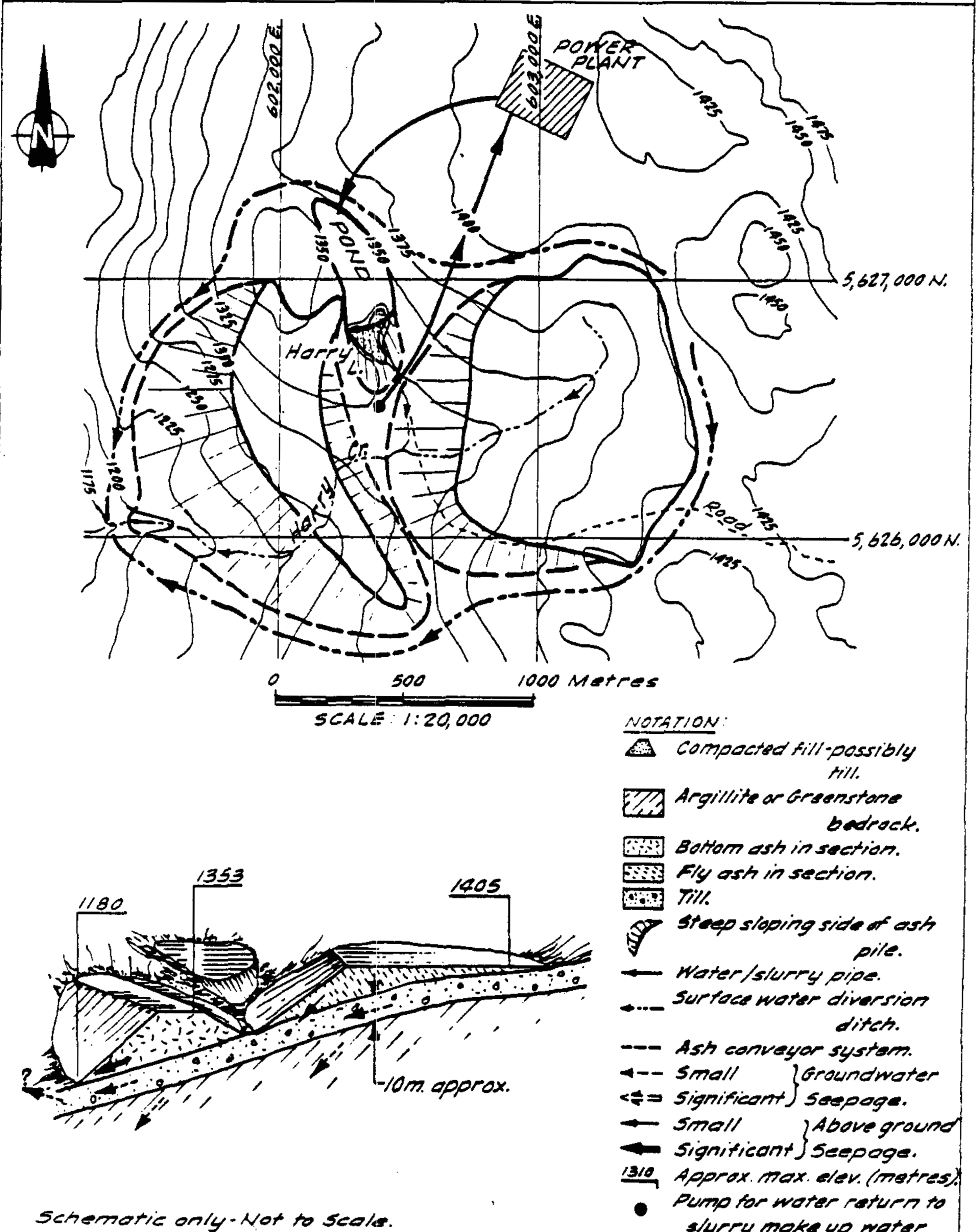
As with Alternative Scheme I, the seepage from the ash storage area would indirectly recharge the buried channel aquifer, both as seepage from beneath the storage piles and as seepage losses resulting from increased flows in Harry Creek. The ash storage would result in a minor beneficial impact on ground water resources.

Alternative IIb:

Precipitation and some residual moisture retained in the ash would seep down through the ash piles and enter and eventually saturate the surficial sediments and bedrock below (see Figure 6-7). The total seepage losses to the ground water table would be about 35 m^3/d. The above ground seepages surfacing at the toe of the bottom ash pile would be between 20 and 120 m^3/d. These seepage losses would indirectly recharge the buried channel aquifer.

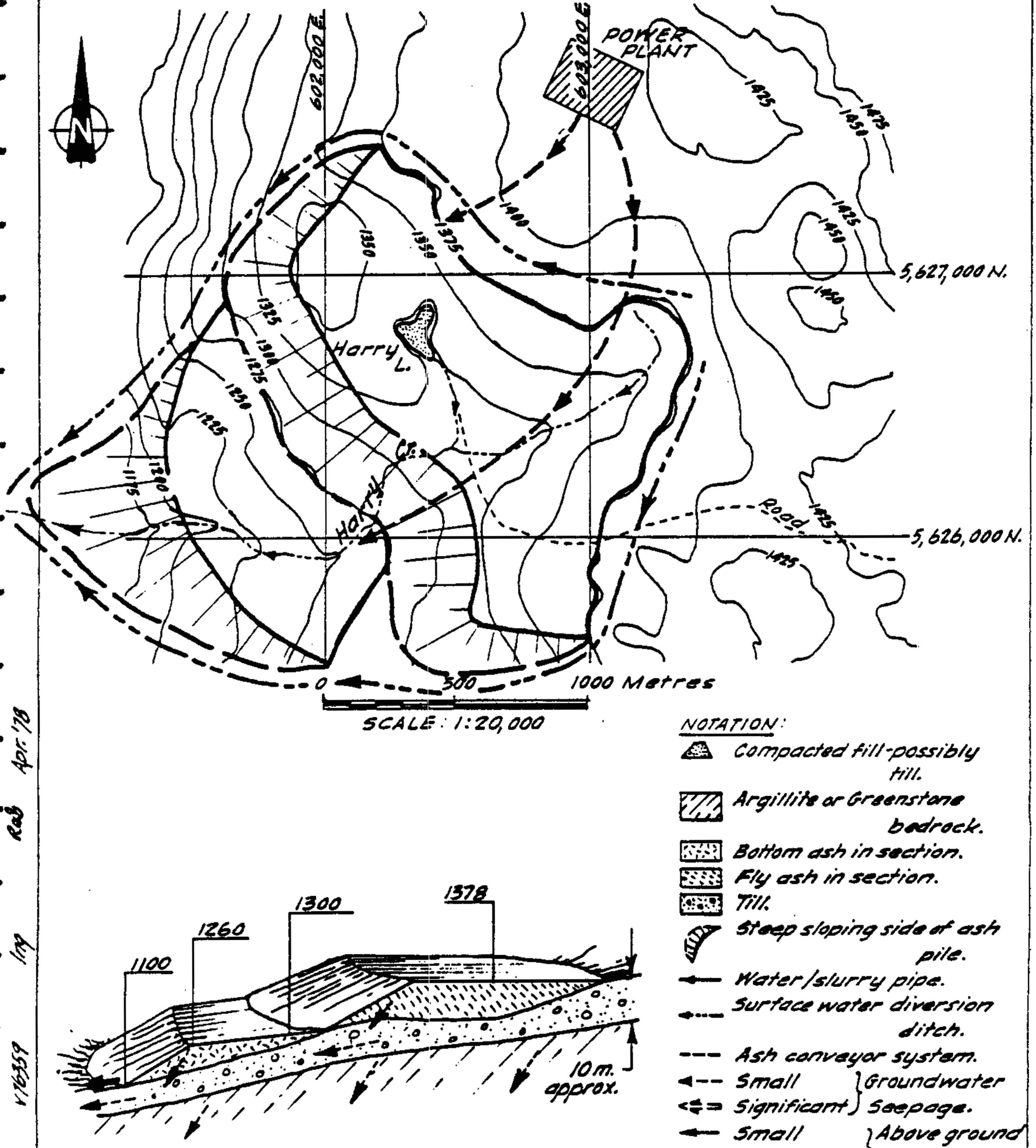
ASH DISPOSAL ALTERNATIVE No. II (a)
WET-DRY BOTTOM ASH DISPOSAL AND DRY FLY ASH DISPOSAL AT HARRY LAKE SITE.

Figure 6-6



ASH DISPOSAL ALTERNATIVE No. II (b)
DRY-DISPOSAL OF BOTH BOTTOM AND FLY ASH AT HARRY LAKE SITE.

Figure 6-7



NOTATION:

- Compacted fill-possibly till.
- Argillite or Greenstone bedrock.
- Bottom ash in section.
- Fly ash in section.
- Till.
- Steep sloping side of ash pile.
- Water/slurry pipe.
- Surface water diversion ditch.
- Ash conveyor system.
- Small / Significant } Groundwater Seepage.
- Small / Significant } Above ground Seepage.
- 1310 Approx. max. elev. (metres).

Schematic only - Not to Scale.

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Flue Gas Desulphurization Waste Solids Area

No detailed information is available on the subsoil conditions at the proposed pond site. However, assuming a 10 m thickness of till and/or a compacted clay liner with an average hydraulic conductivity of 10^{-8} m/s, the estimated seepage loss from this pond would be 140 m^3/d. This represents a minor beneficial impact on the ground water resource. However, water quality considerations might negate this benefit.

Ash Sluice Water Sludge Area

Little data is available on the construction details and soil conditions at the sites of these facilities. However, the seepage losses to ground water are likely to be low due to the presence of till at or near the ground surface. This activity would result in a minor beneficial impact.

Creek Diversions

The same comments given in the construction phase will apply.

C. Offsites

Hat Creek Diversion

Canal (Base Scheme):

The surficial sediments along the canal route are likely to be very varied ranging from relatively clean sands and gravels to dense till. The estimated hydraulic conductivity of these sediments could range from

10^{-8} to 10^{-4} m/s. The depth to ground water table along most of the canal route would generally be greater than 100 m. If we assume that the highly pervious zones are lined with a low permeability material and that the average hydraulic conductivity of the material at the canal base is 10^{-6} m/s, then the estimated seepage loss per kilometer would be 100 m^3/d. Thus, the total seepage over the entire 6.37 km canal would be 637 m^3/d.

Minor ground movements due to pit excavation could cause some damage to the liner material in the canal invert. However, this damage would be repaired as part of the on-going maintenance of the canal system.

The canal follows the same direction of the buried channel aquifer and most of the seepage would infiltrate down through the unsaturated sediments to this aquifer. However, the canal is located near the pit rim and most of the recharge is within the zone of influence of the pit dewatering. Consequently, most of the seepage would be collected in the pit dewatering wells. Some seepage beneath the northern end of the canal would flow northwards, resulting in a minor beneficial impact on the buried channel aquifer.

Canal (Alternative):

In this alternative, some of the Hat Creek flow would be pumped in a pipe to the power plant and a smaller flow diverted around the pit in a small canal. The seepage losses from the pipe would be negligible, however a minor seepage loss of about 100 m^3/d from the canal can be anticipated. There would be a minor beneficial impact on the local ground water flows.

Reservoir (Base Scheme):

The surficial sediments at the proposed reservoir dam site are likely to be made up of alluvium close to the creek and dense till deposits beneath the alluvium and flanking the valley walls. Average hydraulic conductivities in the order of 10^{-5} m/s for the alluvium and 10^{-7} m/s for the till can be expected. The estimated seepage losses through and underneath the dam would depend on construction details. However, seepage losses of about 1,000 m^3/d could be expected even if a seepage blanket was installed.

The estimated ground water flow down valley in the alluvium is 2,300 m^3/d (see Section 4.1 (a) ii) A). Thus, the reservoir dam would lower the ground water table in this aquifer downstream of the dam. Thus, the natural ground water flow in this aquifer would be reduced by 43 percent.

There would be a rise of between 20 and 35 m in the ground water tables along each side of the valley south of the embankment. However, the overall impact on the alluvial aquifer would be ambivalent.

Reservoir (Alternate):

This alternative proposes that a large reservoir be retained behind a 30 m high dam. The reservoir would be much larger than proposed in the base scheme (15 m). Estimated seepage losses under the dam would be at least twice as great as the base case. The resultant impact would be ambivalent.

Drainage Control Along Main Access Road

There would be a minor ambivalent impact due to increased ground water recharge in some areas and reduced ground water tables in others.

iv) Decommissioning

A. Mine

Reclamation of Dumps

Some ground water could be used to irrigate the revegetated dump areas. The recharge to ground water table would be negligible and considerably less than during the operating stages. The overall impact on ground water would be ambivalent.

Reclamation of Pit

The ground water table would return to its present elevation. Based on geotechnical data obtained in the evaluation of the stability of the pit side slopes, a moderate rise in the ground water table would make the wall unstable. Thus, as the anticipated rise of the water table during the filling of the pit would be very large, there would be significant slope instability. This would cause very severe downhill slope movement. The resulting downhill slope movement would make the task of maintaining the diversion canal very difficlt and extremely expensive.

Ground water recharge to the alluvial and buried bedrock valley aquifers would be restored to slightly more than pre-construction flows. However, the overall impact of the decommissioning of the pit would be a major negative impact resulting from the rising ground water table.

Maintain Creek Diversions Around the Pit

The canal would continue to recharge ground water to local aquifers resulting in a minor beneficial impact on ground water resources.

Maintain Drainage Diversions

As outlined in the construction phase the impact from stream diversion would be ambivalent.

B. Plant

Reclamation of Ash Disposal Areas

The cessation of circulation water discharge and the planting of vegetation on dump surfaces would reduce ground water recharge. However, the rate of recharge would still be slightly greater than the pre-construction rates and the net result would be a minor beneficial impact.

Maintain Ditching Lagoons and Creek Diversions

As with construction phase, the impact would be ambivalent.

C. Offsite

There would be no impacts caused by offsite facilities during the decommissioning phase.

v) Overall Impact Assessment

The impacts of the proposed development on the ground water resource are summarized qualitatively in a matrix given in Appendix E. Quantitative values of the more easily assessed impacts are summarized in Appendix F. This quantitative matrix relates impacts to the three major aquifers in the area.

The total ground water resource in the area would not be seriously affected by the proposed Hat Creek Project. However, most of the mitigating beneficial impacts are contingent on satisfactory water quality at the point of recharge. Most of the ground water abstractions apply to the construction period only and would not apply when Thompson River water is made available.

The pit dewatering system would pump up to 3,000 m^3/d of ground water at peak periods. This dewatering and the pit excavation would cut the alluvial aquifer in half and significantly reduce ground water flow in the northern end of this aquifer. However, even this peak flow represents only 32 percent of the total ground water available for development in the northern part of the valley. Most of this water would be returned to Hat Creek and only a small percentage (less than 20 percent) would be lost in evaporation from the pit walls. The steady state ground water pumpage from the pit would be about one half the peak flow and only 16 percent of the total ground water resource.

The upper parts of the waste dumps would act as large sponges that would retain precipitation and surface water run-off during wet periods and would release this water, along with soil moisture expelled with soil water resulting from consolidation, gradually during the remainder of the year. As the bottom of the dumps would be well sealed, most of the seepage would be directed into the valley walls and to surface water channels. The total seepages from these dumps, both directly to these channels and to ground water, could be significant if the rock does not compact under its own weight. However, the combined maximum discharges to the ground water table from the three waste dumps represents only 7 percent of the total resource.

As with the waste dump, the seepage from the ash dumps and ponds would largely affect the surface water flows and have only a minor impact on ground water. Most diversion canals and ditches would redistribute the surface water and slightly increase recharge to the ground water aquifers. However, seepage from the Hat Creek diversion canal would cause some slope instability and during the decommissioning stage would seriously affect the operation of the canal.

All impacts on the ground water resources would be restricted to an area with a radius of about 7 km from the center of the coal pit. Within the area of influence there would be many minor negative impacts, however, these would be mitigated by an equal number of beneficial impacts and the net impact would be ambivalent.

(b) Surface Water

A major surface coal mine and thermal power plant can affect surface waters in many ways. Before discussing the detailed impacts of the various project activities, a discussion of the processes which generate impacts may be in order. They are generally well understood, although some cannot be quantified with the type of data available for the Hat Creek area. The predominant processes by which the Hat Creek development will affect surface water hydrology in the Hat Creek area are: 1) modification of the local water balance by changing the nature of the ground surface, and 2) re-arrangement of the drainage system.

The project will eventually involve some surface disturbance over an area of approximately 35 km^2, 97 percent of which lies in the Hat Creek drainage. Most of the remaining area lies in the Cornwall Creek drainage. The effects of surface disturbance can vary widely, depending on the details of the activity.

Simple clearing of the relatively sparse forest cover in the Hat Creek area has the following three principle effects:

1. Interception losses are almost eliminated, thereby making more precipitation available for storage in the snowpack, for infiltration, and for runoff. The magnitude of this effect is difficult to estimate but, based on various studies cited by Chow[13], the increase in precipitation reaching the ground could be of the order of 5 to 10 percent, or 15 to 30 mm. New growth of grasses or shrubs on cleared areas could quickly eliminate most of this effect.
2. The depth of soil available for active soil water storage is reduced. Comparison of the two parts of Table B1-2, for 200 mm and 100 mm of soil storage respectively, gives an estimate of the magnitude of this effect. Runoff is seen to increase from zero to 22 mm.

3. The forest canopy tends to prolong and delay snowmelt by several weeks, thereby reducing peak runoff rates during spring freshet.

Secondary effects due to clearing include decreased infiltration capacity, decreased surface storage and hydraulically smoother surface. All these factors work in the same direction as the main effects, namely towards earlier and larger flows during spring freshet and during rain floods.

These conclusions are well supported by extensive studies on the effects of logging on streamflow regimes[14]. In the case of coal mines there are fewer studies and the conclusions are not nearly as clear cut. Collier et al[15], and Curtis[16,17] find that mined drainage basins do produce larger floods but the converse has also been noted (Cederstrom[18]; Curtis[19]). This is not surprising since clearing is only one of several activities in coal mining that can have major effects on the surface flow regime. Runoff storage in pump sumps and in sedimentation basins, or increased ground water storage in deep, permeable coal or waste piles are other mining activities that tend to delay and regulate runoff.

Another important secondary effect of clearing is increased erosion and sediment yield. Clearing exposes soil to erosive action of rain, sheet flow and concentrated flow. The effect of logging on sediment yield has been studied extensively but the findings depend strongly on local climate, soils and terrain slopes and are therefore not readily transferable. Assuming that clear-cut logging corresponds to clearing, the sediment yield from small areas could increase by a factor of 2000 to 4000[14].

Collier et al[15] list some comparative sediment yields for various surfaces in the surface-mined Beaver Creek drainage basin of Kentucky, indicating that spoil banks produce 1000 and 2000 times more sediment than equal areas of undisturbed land. Sedimentation problems will be discussed in Section 6.2 (b) but it should be noted here that, if sediment is not properly controlled, it could be redeposited in the stream channel downstream of the mine, where it might obstruct the flow and cause flooding and erosion damage.

Grading changes surface slopes, generally in the sense of making them more uniform and hydraulically smoother. The effect on surface runoff is unpredictable because the average surface slope and surface storage might be increased or decreased. The effects will likely be much smaller than those due to clearing, and therefore not recognizable.

The project will also change the ground surface composition over extensive areas. Forest and rangeland with rough and relatively permeable soil surfaces will be replaced by extensive impervious surfaces (e.g. spoil dumps, buildings, paved areas, open pit mine), standing water (e.g. Medicine Creek ash dump, make-up water reservoir), and smoothly graded surfaces with low infiltration capacity (e.g. gravel roads, storage areas, camps, etc). These areas will provide considerably increased runoff rates. More important than this increased annual average water yield, is the much increased runoff rates during periods of intense rainfall or snowmelt. Impervious surfaces can easily produce runoff rates that may be ten times as high as the corresponding rate from an undisturbed, natural surface[20]. Under wet conditions, fast storm runoff from all disturbed areas combined might reach over 50 percent of precipitation, almost twice the highest observed value for Hat Creek of approximately 28 percent (Table 4-6).

The second major cause of project impacts on surface water results from the extensive rearrangement of the drainage system in the general area of the mine and plant. The mine, the two spoil dumps, the ash dump and the make-up water reservoir will occupy valleys and displace the existing streams. Extensive diversion channels and runoff intercepting ditches will have to be constructed to prevent flooding of the mine and of the dump areas. Natural streams and flood plains are being replaced by a system of small dams, canals, ditches, chutes, sedimentation ponds and pump stations.

While the natural channels can, and frequently do, overtop their banks, the diversion canals cannot be allowed to do so, since they generally follow hillsides where overtopping could have serious consequences. The canals therefore have been designed for much larger flows than the capacity of the natural channels they replace and they will generally operate far below design capacity.

They will give the appearance of large, almost dry channels during most of the year. This gives rise to problems with water temperature as discussed in Section 6.2(b)(iii)C.

The system of drainage ditches will tend to speed up runoff during periods of major rainfall or snowmelt and this in turn will tend to increase peak flows. By itself this effect would be negligible but in combination with the extensive surface disturbances discussed earlier, the effect could be noticeable, although not necessarily significant.

The tendency towards faster and somewhat increased runoff is counteracted by the provision of storage in the head ponds of diversion canals, in sedimentation basins and in pump sumps. The mine in particular will drain internally to a sump, which will be pumped out to a sedimentation basin at a much slower rate than the peak inflows from a major rainstorm.

Downstream of the project area, the modified runoff regime of Hat Creek could cause changes in stream morphology. It is, however, well established[21] that stream channel dimensions are relatively insensitive to changes in the flow regime. Channel width tends to be proportional to $Q^{0.5}$, while depth is normally found to vary in the range of $Q^{0.3}$ to $Q^{0.4}$. In practical terms this means that a 20 percent change in the channel-forming discharge would eventually result in a 10 percent change in channel width and a 6 to 8 percent change in channel depth. According to Section 4.1 (b) (ii) D the channel-forming discharge of Hat Creek is ill-defined because the channel itself is ill-defined. It appears to be of the order 10 to 25 $m^3 \cdot s^{-1}$ with a return period somewhere between 4 and 30 years. These values would need to be altered considerably before any downstream changes in channel morphology could become noticeable. Only the alternate diversion scheme with significant storage in the Hat Creek valley and decommissioning by conversion of the mine pit into a lake have the potential of doing so. Diversion of the entire Upper Medicine Creek into

MacLaren Creek and Cornwall Creek offers a similar potential for changing (increased) channel dimensions there.

As part of the general rearrangement of the natural drainage system in Hat Creek, Finney Lake (16 ha) and Aleece Lake (4 ha) will be drained. This replaces 20 ha of open water with a corresponding area of lake sediments, probably fine grained and quite impermeable. The effect will be a tendency for earlier, higher peak flow rates during snowmelt or rainfall events and increased average runoff due to the elimination of evaporation from perennial open water surfaces. Re-forestation of the dry lake basin could diminish both of these effects to a considerable degree.

The proposed project involves many other activities affecting surface water hydrology, besides the ones discussed so far in a general context (e.g. culverts, a water intake on a major river, drainage of a water pipeline etc.), but all the main impacts are associated with the activities discussed here. Other, minor impacts will be discussed in the course of the succeeding detailed discussion of the project activities.

(i) Preliminary Site Development

The preliminary site development activities will have only minor impacts. The surface disturbance caused by such activities as access road construction, installation of trailer camps, exploratory drilling, etc., are too small to cause noticeable changes in runoff regime, but there will be a certain amount of erosion, generating sediment.

The airport would result in a paved area of approximately 50,000 m^2 at an elevation of 500 m in the Ashcroft-Cache Creek area. No drainage system appears to be planned, runoff from the pavement would infiltrate on adjoining areas. This approach is probably acceptable since the water balance of that area shows a large water deficit. Whether the soils surrounding the paved area are sufficiently permeable to permit infiltration remains to be investigated.

The Bulk Sampling Program is now completed and a preliminary description is available[5]. The environmental assessment of May 1977, prior to construction, pointed out two potential concerns with Trench B. It appeared that runoff from the waste pile could drain into Hat Creek and that the pile was exposed to erosion by floods on Hat Creek.[22] From the "as built" report it now appears that some minor design changes have been made to ameliorate at least one of these problems. The exposed toe of the waste pile was built out of the coarsest gravel available from the excavation. The overburden (waste) pile still drains into Hat Creek. However, since most of the material was below the Hat Creek water table and therefore "well washed", this was not expected to create any water quality problems. This would appear to have been borne out (see Section 6.2(b)(i)A).

(ii) Construction

A. Mine

Construction of the mine and associated dumps and infrastructure involves extensive clearing, grading and earth moving. According to the mine description[1] up to 3400 ha of terrain will be disturbed during the course of mining. Detailed estimates of how much of this will be disturbed during construction are not available but it is likely to be of order 1000 ha, or 3 percent of the drainage area of Hat Creek in the vicinity of the mine area. Besides being only a small percentage of the total Hat Creek drainage area, the disturbed areas are also relatively low-lying, where surface runoff tends to be negligible according to Figure 4-39.

Erosion and sedimentation problems will depend greatly on the details of construction planning. If the various diversions and drainage ditches with sedimentation ponds are built prior to clearing and earthmoving, impacts should be relatively minor but if extensive earth work is undertaken near or in the existing stream channels prior to diversion, sedimentation problems would likely develop in the downstream channel.

The Hat Creek and Medicine Creek diversions replace 9 km and 11.5 km of natural stream habitat, with comparable lengths of canals and ditches. Some other smaller and mostly intermittent water courses such as Finney Creek, Harry Creek and Houth Creek, will also be partially eliminated or replaced by ditches.

Draining of Finney and Aleece Lakes should not damage the stream environment if it is done slowly and carefully as proposed in the mine description. Draining lakes is a difficult operation that can easily get out of hand because any erosion of the drainage channel tends to increase the channel capacity and thereby leads to further erosion. Field supervision of the drainage work by a hydraulic engineer is recommended.

B. Plant

As in the case of the mine, power plant construction also involves extensive clearing and grading, but the affected areas are generally located 200 to 400 m higher in elevation, in a zone where there is significant runoff (see Figure 4-39). To what degree the ash pond is to be cleared during the initial construction phase is not known at this stage. By assuming that only one third of its final area will be disturbed initially, it appears that a total of 300 ha will be disturbed during the initial construction phase (prior to operation of the first unit), but 13 percent of this area is contained within the make-up water reservoir dikes, and a further 49 percent within the ash pond dikes. The impacts on surfacé waters will be essentially as described in the introduction to Section 6.1 (b). As in the case of the mine waste dumps, the magnitude of the impacts will depend greatly on the details of the construction schedule. Impacts can be reduced considerably if the make-up water reservoir and ash storage areas are cleared only after the stream diversions, drainage ditches and sedimentation ponds have been installed.

The plant construction site has an area of approximately 1 km^2 of which roughly 15 percent will be impervious. Under conditions of a 2 hour-2 year storm, storm drainage flows could amount to 0.2 $m^3 \cdot s^{-1}$, and this drainage will probably be released into Harry Creek after passage through a sedimentation basin. The rate of release will depend on the size of that basin and on the detailed design of its outlet works. Care will have to be exercised to assure that the releases to Harry Creek combined with natural flows do not exceed its natural capacity, otherwise gullying and erosion damage might occur. According to Figure 4-34, the natural capacity of the channel is probably of order 100 $l \cdot s^{-1}$, which corresponds to the estimated 5-year flood flow.

Although the project description[3] provides no details on the proposed source of the construction water supply, the most likely source would be from wells in the buried bedrock valley aquifer. A flow of approximately 18 $l \cdot s^{1}$ or 600,000 $m^3 \cdot yr^{-1}$ will be required. Any surface water source in the valley might be significantly affected by such a withdrawal but the construction period of a few years is too short to cause significant alterations in channel morphology or other long-term surface water hydrology impacts.

The location of the construction waste water discharge is also not stated in the plant description. Section 6.2 (b)(ii) 8 recommends against discharge into Harry Creek from a water quality point of view. From a morphological point of view, Harry Creek could be used as long as the rate of release is kept well below the natural capacity of the stream channel, as discussed above.

C. Offsites

From a hydrological point of view, the most important activities during construction of off-site facilities will be clearing, grading, installation of culverts, stream diversions and construction of a major river water intake.

The clearing and grading activities are mainly associated with the construction of the access road, the water supply pipeline, the transmission lines, the diversions of Hat, Medicine and Finney Creeks and the ash retaining embankments.

A total of approximately 200 ha of terrain will be disturbed, 48 percent of which lies in the Hat Creek drainage and 52 percent in Cornwall Creek[23]. In both cases, the disturbed area is a small percentage of the total drainage area. While relatively small in areal extent, these disturbances are, however, dispersed over much wider areas. This makes careful erosion control and treatment of runoff in sedimentation ponds much more difficult than in the case of the more concentrated disturbances associated with mine and plant construction. Surface water hydrology impacts due to such activities as clearing and grading will depend greatly on the details of day-by-day operations. While road and pipeline construction have often been observed to cause extensive damage to surface water resources, mainly due to erosion and sedimentation, most damage is avoidable with careful construction procedures[24] and the proponent is committed to their adoption. The basic principle is to minimize the exposed area and time of exposure of unprotected soil surfaces.

Temporary stream diversions, culvert installation and construction of the make-up water intake on the Thompson River all have the potential for damaging stream environments and fish resources. Virtually all damage is avoidable by proper scheduling, careful execution, and adequate design of any temporary culverts to meet fisheries guidelines.

(iii) Operation

A. Mine

In the course of mining, large areas that produce practically no surface runoff in their natural state will be converted to relatively impervious runoff-producing areas. The mine description lists the main areas of concern. Both at the mid-point and at the completion of mining, the bulk of the disturbed area (roughly three quarters) consists of the pit excavation and the two main waste dumps, in roughly three equal parts. The remainder is distributed on many dispersed facilities (e.g. Hat Creek diversion, roads, etc.) and on the stockpiles for low-grade coal, for coal blending and for topsoil. Surface runoff from these artificial, relatively smooth surfaces will be rapid and the proposed extensive system of drainage ditches will contribute further to this unnaturally rapid response. The proposed two major lagoons and the large sump capacity in the mine will, however, act in the opposite sense by permitting regulation of outflows. The details of this regulating process are not known at this stage but some rough estimates can be made.

A ten-year, 24 hour rainstorm would deliver roughly 150,000 m^3 of runoff to the mine sump, assuming 60 percent runoff. This would be removed from the mine at a rate of 100 $l \cdot s^{-1}$, taking 17 days. Storage in Lagoon No. 1 would not significantly alter this rate of outflow and one can assume that the mine might contribute 0.1 $m^3 \cdot s^{-1}$ to Hat Creek for 17 days following such a major storm. Note that the above 60 percent is not a runoff coefficient but simply the percentage of total rainfall over the pit that is assumed to find its way to the pit sump within 17 days of the storm. The assumption is based on engineering judgement and is not intended to be particularly conservative.

The Houth Meadows Dump, with an area of 6.15 km^2 could produce approximately 130,000 m^3 of fast storm runoff (again based on 60 percent runoff), requiring 11 m of storage in a 1.2 ha lagoon. Storage space for the water pumped from the mine is to be added to this volume, indicating that the proposed lagoon area of 1.2 ha may be somewhat small. Runoff from the Medicine Creek dump is less critical with the material to be deposited there being more permeable. This dump will have its own lagoon.

Assuming a 20-day discharge period, releases from Lagoon No. 1 would take place at a maximum rate of 175 $l \cdot s^{-1}$, consisting of 100 $l \cdot s^{-1}$ pumped from the pit sump and 75 $l \cdot s^{-1}$ from the retained Houth Meadow Dump runoff. Releases from the other lagoons are more difficult to estimate, but doubling the above rate to 350 $l \cdot s^{-1}$ should lead to a conservative (large) estimate.

In order to estimate the impact of such a rate of release, it can be compared with Figure 4-31, which summarizes natural flows recorded by the gauge "Hat Creek near Upper Hat Creek". It is reasonable to assume that natural Hat

Creek flows would be at least at the median level during the 20 days following a major rainstorm. On that basis, the added contribution of the lagoon releases to prevailing natural flows in Hat Creek could range from 10 percent during freshet to 100 percent in August and September. Being based on a 10-year storm, it is exceedingly unlikely that releases of this magnitude would occur more than 10 times during the life of the mine. In Hat Creek, the channel-forming discharge and the discharge at which the lowest parts of the flood plain become innundated are of order 10 to 25 $m^3 \cdot s^{-1}$ (see Section 4.1 (b) (ii) D). Since lagoon releases only amount to 3.5 percent of 10 $m^3 \cdot s^{-1}$, no significant changes in the frequency of flooding or in channel morphology are likely.

Surface runoff will occur infrequently at the mine site. Except during snowmelt, which will not normally last for more than a month (Figure 4-28) there will be very few runoff-producing rainstorms. During the remaining time the effect of the mining operation will mainly consist in releasing some treated effluent and flow from the dewatering wells into Hat Creek. The potable water supply from the Thompson River (via the Plant Site) has a capacity of 1.6 $l \cdot s^{-1}$, which constitutes an insignificant addition to Hat Creek except under exceedingly dry conditions (see Figure 4-36). The expected flow from dewatering wells, at 16 $l \cdot s^{-1}$ and seepage into the mine, also at 16 $l \cdot s^{-1}$ could occasionally constitute a more significant addition. According to Figure 4-36 it could amount to 50 percent of Hat Creek flows in late summer once in 30 years. However, this flow is not really an addition to Hat Creek. Practically all the flow that will be intercepted by dewatering wells and by the mine pit is now entering Hat Creek as ground water seepage. By depressing the ground water table, wells and mine seepage will probably be more uniform than the natural ground water seepage and the above 16 $l \cdot s^{-1}$ may constitute an addition to Hat Creek under exceedingly dry conditions. The resulting changes in natural flows are far too small to have noticeable effects on channel morphology, but increased dry weather flows are a beneficial impact.

During winter, dust from the mine will settle on the snowpack of the surrounding area and increase its albedo. Based on experience with snowmelt in urban areas one can assume that this will have the effect of increasing the rate of snowmelt under clear sky, sunny conditions. Dusted areas will produce snowmelt on some clear mid-winter days when there would otherwise not be any melt. In general, snowmelt will occur earlier and more frequently, the duration of snowmelt will be extended, snow accumulation will be reduced and snowmelt flows will normally be reduced but could, under some circumstances, also increase.

Reclamation of embankments and waste dump surfaces will create surfaces with similar hydrological properties as the original natural surface. The volume of runoff from reclaimed surfaces will therefore return to approximately its natural value but the time distribution of runoff will remain affected by the project since terrain slopes will be changed permanently and the system of ditches and lagoons is to remain in place. The exact effect will depend largely on the operation and maintenance of the lagoons. Lagoons can only continue to regulate flows if sediment accumulations are removed regularly.

B. Plant

According to the Air Quality and Climatic Effects Report[25], the local and regional effects of the proposed power plant on climate will be so minor that noticeable secondary effects on surface water hydrology appear highly improbable.

The main effects of the power plant will be due to the isolation of significant areas from the natural drainage system and due to the discharge of runoff from impervious or disturbed areas to Hat Creek. Both effects are considered minor.

The Medicine Creek ash disposal area of 408 ha, the make-up water reservoir of 62 ha and the plant area of 100 ha will drain internally and will reduce the total drainage area of Medicine Creek by somewhat over 10 percent. Compared to the major impact on Medicine Creek discussed earlier (diversion into ditches and loss of the natural channel) this small change in runoff will be insignificant.

From a surface water hydrology point of view there is only a minor difference between the impact of the various ash disposal alternatives, but the dry ash disposal schemes are preferable. All schemes involve the isolation of considerable areas from the Medicine Creek drainage area. The dry ash disposal schemes would avoid the infilling of the Upper Medicine Creek Valley and the associated loss of 5 km of natural Medicine Creek channel. In view of the fact that Lower Medicine Creek will have to be diverted around a large spoil dump and the fact that economic considerations will probably dictate the use of most of Medicine Creek flows in the plant, this is not a major benefit although it is significant.

Whether the Upper Medicine Creek drainage is to be diverted to MacLaren Creek appears to be uncertain. A diversion of limited capacity from Medicine Creek to MacLaren Creek is presently operating and could be enlarged to handle all possible flows. Environmental effects on MacLaren Creek might be only minor as the stream may already be adjusted to handling most possible flows. The MacLaren Creek channel morphology has, however, not been investigated so far and, depending on prevailing bed and bank materials and on the magnitude of diverted flows, the potential for significant detrimental impacts through erosion and gullying does exist.

Since the plant water supply system can only raise the make-up water reservoir by 22 cm per day and since there is practically no surface runoff into that reservoir, it appears most improbable that the spillway of that reservoir will ever operate. If it did, there could be some erosion and gullying downstream.

C. Offsites

The offsite facilities associated with the Hat Creek project are of a rather diverse nature, so that their impact on surface water hydrology cannot be discussed in a general way. The following item-by-item discussion is arranged according to severity of impacts.

Stream Diversions

From a surface water hydrology point of view, the diversion of Hat Creek undoubtedly represents the most severe impact of the entire project operation. Approximately 9 km of the natural Hat Creek channel is to be replaced by 500 m of reservoir, 6.4 km of open canal and 1.9 km of buried conduit. The headworks reservoir has a maximum area of only 7 ha, with an operating range of 3 m and an active storage volume of 154,000 m^3. This is too small to modify Hat Creek discharges significantly.

According to Section 4.2 (b)(vii), the mean annual suspended sediment load of Hat Creek is approximately 3,000 tonnes, with well over 90 percent being carried during the period May to July. This estimate does not include bed load (materials rolling, sliding and saltating along the streambed) but in a degrading gravel-bed stream such as Hat Creek, bedload is generally small, certainly not more than 10 percent of the suspended load. No data on the grain size distribution of the suspended load are available, but a certain percentage, probably around 20 to 50 percent, is likely to consist of clay and would pass through the head pond. With 3,000 $t \cdot yr^{-1}$ of sediment load deposited, approximately 2,000 $m^3 \cdot yr^{-1}$ of reservoir volume may be lost initially, but as the reservoir volume becomes smaller, an increasing percentage of the sediment load will pass through the reservoir into the diversion canal. It will take between 50 and 100 years for the head pond to fill with sediment. While this process will convert the 7 ha lake to an equivalent area of flood plain, it will not impare the functioning of the diversion.

Downstream of the diversion, Hat Creek will be lacking its natural sediment load and this will lead to some morphological adjustments. They will be minor because Hat Creek is a degrading stream in its natural state, with the bed becoming active only during infrequent major floods. The stream will gradually develop the appearance of a lake-outlet channel with a better defined channel than at present. The change will probably not be noticeable except through careful before-and-after surveys and it should not extend more than 1 to 2 km beyond the diversion. Water levels and the extent of flooding will decline slightly but this also will be too small and too slow a change to be noticeable.

Some questions concerning winter operation of the diversion canal and the conduit have not yet been investigated. Considerable quantities of frazil ice could be generated in the conduit. In the canals, the formation of icings (ice accumulations formed by surficial accretion) can be suppressed by providing buried, insulated, or heated conduits, or by increasing the depth of flow in the canals to permit the formation of a thick ice cover. The last solution is presently favored but since sudden large flows are possible in March (Figure 4-31B) the ice cover might become an obstruction.

An alternate Hat Creek diversion scheme, involving significant upstream storage and consequently lower capacity diversion works, has been suggested. Its downstream effects would be much more noticeable and would extend to the Bonaparte River as this scheme would effectively regulate Hat Creek. Over a period of a few years, Hat Creek would develop a smaller and better defined channel downstream of the diversion and most of the flood plain would not be flooded again except under most unusual conditions approaching the assumptions made for the maximum probable flood. Being smaller and more regulated, Hat Creek could become more attractive to beavers and this would tend to counteract the above tendencies. Major parts of the present flood plain could readily be converted to marshland by beaver dams.

The natural channel of Hat Creek is lined by dense phreatic vegetation which must withdraw significant quantities of water from ground water seepage flowing towards (or out of) Hat Creek. The vegetation also shades Hat Creek. In the diversion canal, on the other hand, no trees or bush can be allowed to become established in order to maintain its carrying capacity and the flow will consequently be fully exposed to the sun. The combined effect on evaporation is probably a slight reduction in losses. Assuming a 20 m vegetation band and maximum evaporation rates (Figure 4-38) the diversion canal could possibly reduce losses by 5 to 10 $l \cdot s^{-1}$ under extreme conditions.

Seepage losses from the canal are estimated at 7.5 $l \cdot s^{-1}$ in Section 6.1 (a) (iii) B and these losses would naturally occur at all times. Some of the seepage flow will be returned to Hat Creek via the mine dewatering system. Whether the overall effect of changed evaporation, seepage out of the diversion canal, and discharge of mine dewatering flows will be positive or negative is impossible to say but any changes in flow will certainly be small, probably too small to be detectable.

Make-up Cooling Water Supply

Even under extreme conditions, the make-up water system depletes the Thompson River by little more than one percent, so that there will be no significant hydrologic effects on the Thompson River.

Operation of the pipeline should not cause any major impacts. The most significant impact is likely to result from minor failures of drainage and erosion-control measures during the first few years of operation, before revegetation of the pipeline right-of-way has taken hold everywhere. Such minor failures are almost unavoidable. They can cause some erosion damage, which will have to be repaired. A major pipeline rupture is highly unlikely to occur. It would release a large flow of short duration, which could cause significant damage, depending on the location of the rupture. The capacity of the pipeline drain to the Bonaparte River is too small to introduce significant flows into that stream.

Project Access Road

The main project access road will be a 31 km long, paved, two-lane highway. Its main impacts on water resources will be threefold:

(i) possible damage to water courses and particularly to their fish resources due to culverts,

(ii) sedimentation due to gullying of road ditches and erosion of embankment slopes and,

(iii) increased surface runoff from the paved surface.

Only item (iii) is relevant to this section.

The quantity of storm runoff can be estimated conservatively as follows: Assuming a ten year-one hour rainfall of 15 $mm \cdot hour^{-1}$ falls onto the 25 ha of paved surface, with 80 percent running off, storm runoff of 0.8 $m^3 \cdot s^{-1}$ would be generated. Since 7 km of the road parallels Cornwall Creek, 0.2 $m^3 \cdot s^{-1}$ might find its way into Cornwall Creek where it could temporarily constitute a significant addition to normal summer flows (20 - 100 $l \cdot s^{-1}$). The 4 km road segment along MacLaren Creek could similarly contribute to that stream. Morphologically the road runoff is insignificant in both cases but impacts on water quality are possible. Significant effects on McLean Lake are precluded due to the size of that lake.

Other Facilities

The other off-site facilities, such as the 60 kV transmission system, the airstrip, the off-loading facilities and other minor facilities will have insignificant effects on surface water hydrology due to their small areal extent and dispersed locations. All these facilities involve a certain amount of clearing and grading, and the creation of minor amounts of impervious paved and roofed areas.

(iv) Decommissioning

Being over 40 years in the future, the details of the project abandonment process are not well-defined at this stage. The bulk of the cleared and graded areas, such as waste dumps, embankments, plant site, coal storage sites, etc., will be revegetated and should therefore return to reasonably natural water balances. The main permanent impacts on surface water hydrology result from filling of the mine pit and its conversion to a lake and from the permanent disturbance of the drainage system caused by drainage ditches and by the permanent diversion of Medicine Creek around the ash pond.

Conversion of the mine pit to a 225 ha lake will create far more extensive changes to the surface water hydrology of the Hat Creek area than any of the project impacts. Downstream of the lake, Hat Creek would be significantly depleted during the 26 year filling period and then highly regulated. As in the case of the alternate diversion scheme, it would eventually develop a much smaller but better defined stream channel. The entire present flood plain would be converted to low terraces. Extensive beaver activity could, however, change this and could result in extensive flooding. A simple, gated control structure at the lake outlet could give almost complete control over flows in Lower Hat Creek. Depending on developments in the Lower Hat Creek Valley at that time, regulation could constitute a very beneficial impact. The relatively deep lake might not freeze during winter or it might only freeze late in winter. The large open water surface will have some climatic effects, particularly during cold spells, when open water tends to generate fog.

Major problems concerning the period of pit filling remain to be answered. In accordance with normal mining practice, the pit slopes will be as steep as possible and probably only marginally stable in the long term. It is unlikely that such slopes could remain stable during filling of the pit, yet the continued operation of the Hat Creek diversion during pit filling will probably depend on stable pit slopes.

The proposed permanent diversion of Medicine Creek around the ash pond also gives rise to concern. A side-hill canal requires continuing maintenance, since any blockage (e.g. due to debris jams, beaver dams, ice or slides) could lead to overtopping of the banks, followed by diversion of the flow straight down the slope (in the present case, to the ash pond). It would be desirable to direct Medicine Creek around the edge of the full ash pond at a level below the pond level by excavating into the side hill.

(v) Overall Impact Assessment

The overall impact of the Hat Creek power development on surface water hydrology, excluding sedimentation, is significant. The most severe impacts are the draining of two natural lakes and the loss of 9 km of Hat Creek channel and of most of Medicine Creek. With the prime diversion scheme there will be only minor impacts on the quantity and time-distribution of runoff but decommissioning with conversion of the mine to a lake could result in almost complete regulation of Hat Creek.

Due to the relatively short life of the mine it would be unreasonable to design the minor engineering works associated with the drainage system (ditches, culverts, sedimentation ponds, etc.) for the worst possible condition, which, in this case, would be the probable maximum flows. One has to accept, therefore, that some failures will occur during the life of the project and they are likely to result in erosion damage and possibly some sedimentation in Hat Creek, downstream. The erosion damage can easily be repaired but downstream sedimentation is not easily remedied. Its detrimental effects should not last more than one or possibly two seasons.

The surface hydrology impacts on the Bonaparte and Thompson Rivers are not significant.

6.2 WATER QUALITY

(a) Ground water

(i) Preliminary Site Development

A. Mine

Bulk Sample Program

The Bulk Sample Program[5,26] involved excavation and removal of coal from two trenches for burning tests. During this program three ground water stations, in the vicinity of the trench near Hat Creek (Trench B), were monitored by B.C. Hydro. Data collected at these stations are included in Appendix C, Tables C1-19 to C1-21. Based on this data, the Bulk Sample Program did not alter ground water quality significantly. The only noteworthy changes were at Ground Water Station Number 3, where concentrations of some metal ions increased between June and August 1977; iron, zinc and strontium increased by factors of about 2 to 5 while sodium increased by about 20 percent. Since the activities of the Bulk Sample Program are unknown to Beak Consultants, it is not possible to determine whether these increases are due to project activities or natural causes. A separate report on the Bulk Sample Program has been written by B.C. Hydro.

Other Activities

Other activities associated with preliminary site development (eg. exploratory drilling, environmental sampling and surveying) have not affected ground water quality.

B. Plant and Offsites

None of the activities associated with Preliminary Site Development for the power plant and offsite facilities could have affected ground water quality.

(ii) Construction

A. Mine

Camp Sewage Disposal

The project description proposes that the construction camp system involve biological treatment in an earthen basin with ultimate disposal of the treated effluent by subsurface injection or alternatively by surface irrigation. The quantity of treated sewage from a construction camp accommodating 440 workers would be about 83 $m^3 \cdot d^{-1}$ (22,000 USGPD), as indicated in the project description. Seepage from the earthen basin should not be a problem, providing dykes and the bottom are constructed of high impermeable materials. Disposal by deep well injection, if feasible, should not significantly alter ground water quality, providing there is sufficient subsurface travel through a suitable soil type before emergence of the effluent as ground water seepage in Harry Creek.

Disposal by irrigation would have little impact, provided there is no direct surface runoff to Harry Creek and provincial pollution guidelines and objectives are followed during design and operation.[27,28]

A permit from the Pollution Control Branch would be required for construction and operation of the sewage disposal system.[29]

Office and Warehouses Sewage Disposal

The project description indicates that sewage from the shops and warehouses would be treated in a "package-type extended aeration system" with ultimate disposal from a storage lagoon by using the treated wastewater for dust control. The effluent quantity was estimated by B.C. Hydro to vary from 20 to 136 $m^3 \cdot d^{-1}$ (5,000 to 36,000 USGPD). It is unlikely that this disposal system will have any impact on ground water quality. A permit will likely be required from the Pollution Control Branch for construction and operation of the system.[29]

Refuse Disposal

Land disposal has been proposed for refuse from the mine construction camp, the shops and warehouses. Provided the selected landfill sites are a safe distance above the water table, with suitable soil base and cover materials, the impact of leachates on the ground water should be minimal. Ministry of the Environment Guidelines on Refuse Disposal dictate landfill design and operation.[30] Further, a permit would be required from the Pollution Control Branch.[29] Considering that the proposed facilities would be operated for several decades, it would be advisable to select a suitable disposal site for all refuse rather than using a temporary site for the mine construction camp.

Coal Stockpile

It is proposed that 1,000,000 tonnes (1.1×10^6 tons) of uncrushed coal be stored near the mouth of the mine prior to commissioning the power plant. The estimated area of the coal pile is approximately 8 ha (20 acres). The proposed drainage control would consist of collection of runoff by ditching and diverting the runoff to the closest lagoon.

Assuming the coal pile storage area base is properly prepared with relatively impermeable compacted material, it is anticipated that there would be no significant pollution of ground water by leachates. Most leachate would leave the coal pile along the base and become surface water. An assessment of the quality of the runoff and its impact on surface water (including leachates) is discussed in more detail in Section 6.2 (b) (ii) A.

Low Grade Waste Stockpile

The low grade waste dump would begin to be developed during the construction phase of the project. Assuming proportional production on a yearly basis, this dump could contain 5 x 10^6 tonnes or more prior to power plant startup. Thus, the areal size of the dump could be about 12 ha (30 acres). A proposed design has not been developed for the dump; however, it is assumed that a relatively impermeable base would be used to minimize percolation of leachate into the ground water. If this were the case, any leachates would appear in the surface drainage from the dump. This aspect is considered in more detail in Section 6.2 (b) (ii) A.

Area Dewatering

Both pit dewatering and area dewatering would be required during the construction phase. This would be done with pumps in the mine and dewatering wells on the pit periphery. The estimates of initial quantities of pumped water are about 6 $l \cdot s^{-1}$ (100 USGPM) from the dewatering wells and about 6 $l \cdot s^{-1}$ (100 USGPM) from dewatering of the pit proper. Additional water will be pumped from the mine as a result of precipitation; this is estimated in the mine description to be, at the most, 9 $l \cdot s^{-1}$ (150 USGPM), during the early years of the mine. Extraction of ground water from the dewatering activities should not effect the quality of the remaining ground water. The impact of the mine water on surface water quality is discussed in Section 6.2 (b) (ii) A.

Overburden Dump Construction

During the initial stages of the mining operation, three principal areas will be developed for disposal of overburden: the Houth Meadows region for clays and structurally weak, low permeable materials, the Medicine Creek area for disposal of more stable higher permeable overburden, and the North Valley zone for other surficial materials. Both the Houth Meadows and Medicine Creek dumps will be contained by embankments made from selected gravel and till materials. Initially, the overburden materials will be removed and taken to the respective areas by scrapers; however,, at a later date, when distance becomes uneconomical for direct dumping, conveyors will be used. Each of the main dumps would be constructed with blanket or strip "underdrains" at the lower end of the valley to provide drainage of the embankment and dumped materials. Surface streams in the dump area will be diverted away from and around the dumps. Control of infiltration and percolation of precipitation into the dumps will be minimized by maintaining relatively level working surfaces and preventing ponding. Water which percolates into the dump or drains from saturated sections of dumped materials will be collected by dump underdrains.

The material to be placed in the Houth Meadows dump is highly impermeable and seepage either into or out of the bottom of this dump is expected to be minimal. The material proposed for disposal in the Medicine Creek dump is considerably more "free draining" and seepage and leachate production will be greater. Consequently, consideration should be given to sealing each layer with impermeable material at certain periods of the year to minimize the infiltration of snowmelt and early summer rains. Temporary reclamation, by grassing over idle areas of the dump to reduce infiltration, has been mentioned as a partial solution to the problem. The estimated quantity of seepage from each dump is given in Section 6.1 (a) (iii) A. Since these seepages become surface water at the discharge of the dump underdrains, the quality of this water is discussed under Section 6.2 (b) (iii) A.

Other Activities

Activities during construction phase of the mine (eg. construction of the coal preparation plant, access roads, power line, substation, conveyors and topsoil stockpiles) are not expected to affect ground water quality.

B. Plant

Construction Camp Sewage Disposal

The project description indicates that the Power Plant construction camp sewage disposal system would consist of biological treatment in an earthen basin with discharge of treated effluent to Harry Lake which would be impounded (presumably by dyking to prevent positive overflow) and the wastewater eventually disposed by natural evaporation. The proposal would require the containment of all natural surface runoff in the Harry Creek watershed above the impoundment as well as the treated sewage.

This concept of sewage disposal would have little effect on ground water quality, provided the earthen basin is constructed of suitable impermeable soils and seepage losses from the Harry Lake impoundment and embankment are negligible. If these conditions were met, there would be no danger of polluting the remainder of the Harry Creek surface or subsurface flows. A permit under the Pollution Control Act will be required for this system.[29]

Shops and Warehouses Sewage Disposal

The project description indicates that a sanitary sewage disposal system will be installed to service the office, shop, warehouses and Concrete Batch Plant during power plant construction. There is no indication, however, of the proposed disposal method. The quantity of sewage for disposal, based on projected potable water requirements listed in the description, would be about 500 $m^3 \cdot d^{-1}$ (130,000 USGPD). Water supply would probably be via a well near Hat Creek. Since the proposed disposal technique is unknown, it is not possible to comment on the impact on ground water quality. It is recommended, however, that the design comply with relevant guidelines protecting ground water, if subsurface disposal is used.

Refuse Disposal

Information on the disposal of refuse from the camp and office, shops and warehouse operations during the construction phase has not been provided in the project descriptions. It is anticipated, however, that selection of a site meeting all criteria for a Level A landfill[30] should not be difficult, thus negating any potential for ground water pollution from this source. Toxic wastes should not be disposed to this landfill.

Concrete Batch Plant

It is proposed to locate a batch plant near the power plant site to supply the concrete during construction. The plant would have a capacity of about 153 m^3 (200 cu. yd.) per hour, an area for stockpile of sand and gravel, a washdown area and sedimentation pond to trap suspended solids in the plant wastewaters. The stated rate of supply of water to the plant is 6.9 $l \cdot s^{-1}$ (100 USGPM). It is estimated that 95 percent of this water would be consumed in production of the concrete mix while the remainder would be used for washrooms and washdown. No threat to ground water quality is expected, provided the pond is constructed of impermeable material.

Ash Disposal Facilities Construction

The project description indicates that several alternate sites are being considered for disposal of ash generated at the power plant. However, bottom ash and fly ash are to be disposed separate from mine waste materials due to the possible future value of the ash as a recoverable resource. The disposal method proposed as the "base case" is to sluice both the bottom ash and fly ash from the power plant to an ash pond in Upper Medicine Creek Valley. This will necessitate construction of an engineered embankment at the lower end of the proposed pond to retain the ash and provide a column of water above the ash. Ash pond supernatant would be returned to the plant for reuse in the ash slurry system. Construction operations would include base preparation, embankment construction, creek diversions, and construction of a cutoff wall for ground water in the embankment area to prevent ash pond leachate from entering the ground water once the system is functional. These activities should not affect ground water quality.

Two alternate ash disposal systems are under consideration:

Alternative I — Bottom ash sluiced to an area in the region of Harry Lake. Flyash sluiced to a pond in Upper Medicine Creek.

This alternative would be considered if segregation of fly ash and bottom ash is established as desirable to facilitate future recovery.

Alternative II — Bottom ash disposal, either by dry methods or by sluicing, to a Harry Lake site. Fly ash disposal by conveyor to a site near Harry Lake.

This alternative would be evaluated if disposal in Medicine Creek Valley is impractical, and/or uneconomical.

Activities related to these alternatives would include: base preparation, embankment and berm construction, runoff ditching and stream diversion, possible cutoff wall construction, construction of the recirculation water pump station and the treatment plant, slurry pipeline construction and conveyor construction. These activities should not affect ground water quality.

Water Supply Reservoir Construction

Construction of the main cooling water supply reservoir (8.3×10^6 m^3) will involve area clearing, embankment construction (49 meter dam), and construction of the makeup water pumphouse and the spillway. These activities should not affect ground water quality.

Power Plant Construction

Construction of the power plant will involve building of offices, warehouses, services, turbine hall, boiler house, cooling towers, switchyard, construction laydown area, conveyors, stack construction, site drainage facilities, roads and parking areas. These activities should not affect ground water quality. Construction of the power plant and auxiliary systems will take several years as proposed plans indicate a time-span of one year between start of the construction of each unit (one unit is 500 MW).

C. Offsites

Hat Creek Diversion Construction

The proposed Hat Creek diversion around the open pit coal mine would consist of a headworks reservoir, a pit rim reservoir and pump station, a 7.1 km (23,000 ft) open earthen canal, a 2.2 km (7,000 ft) steel discharge conduit and a plunge pool at the end of the diversion. The alternative scheme would involve the addition of a larger reservoir upstream and possibly a smaller diversion canal. Construction of these facilities should not affect ground water quality.

Main Access Road Construction

Construction of the proposed two lane, paved highway will involve activities such as clearing, grade preparation and surface preparation. No activities are apparent in the information concerning this activity that would affect ground water quality.

Plant Cooling Water Supply System Construction

The proposed cooling water supply system consists of a 23 km (14 mile) pipeline, originating at a pier-mounted river intake in the Thompson River, near Ashcroft. There would be two (2) booster stations along the pipeline and a water treatment plant, consisting of a gravity clarifier (30 m), situated near the intake. Construction of the system would involve activities such as clearing, trenching, excavation for structures, and construction of a cofferdam. None of the activities should affect ground water quality.

Other Activities

The other main offsite construction activities involve an airport, an unloading facility and 60 kV transmission line systems. These activities should not affect ground water quality.

(iii) Operation

A. Mine

Blasting

One of the activities that will occur to a presently unknown degree is mine blasting. Project information [1,31,32] varies on this aspect from projections that blasting will not likely be necessary to the use of considerable blasting materials (0.12 to 0.17 kg/tonne of coal and overburden). Blasting materials would probably consist of ANFO (Ammonium nitrate/diesel fuel mixture) where possible due to its economy. Blasting can cause fracturing and cracks in the surrounding bedrock which would allow mine water seepage to enter the ground water regime. The potential for this is considered to be negligible in the case of Hat Creek. Mine water quality aspects derived from blasting are discussed in Section 6.2 (b) (iii) A.

Mine Area and Pit Dewatering

Once the mine is in full production, mine area dewatering requirements increase considerably over the rate during construction phase, principally because of the pit size. Thus the quantity of seepage into the pit, direct precipitation and runoff increases. The quantities of mine water involved have been estimated in the mine description to be about 30 $l \cdot s^{-1}$ (500 USGPM) from dewatering wells and from mine seepage and depending on time of year and weather, about 9 - 125 $l \cdot s^{-1}$ (150 to 2080 USGPM) from direct precipitation into the pit proper. According to project descriptions, these waters are all to be pumped into a lagoon treatment system near the Houth Meadows area (designated in project descriptions as Lagoon No. 1) and discharged into Hat Creek. Extraction of ground water for pit stability control and removal of mine waters is not expected to pose any significant hazard to the quality of the remaining ground water resources in the valley. The assessment of the disposal of this water is discussed in Section 6.2 (b) (iii) A. Figure 6-8 shows the layout of the proposed pit and overburden dumps.

Overburden Dumps

As indicated in the project descriptions and in Section 6.2 (a) (ii) A. Overburden Dump Construction, these dumps would be designed specifically for the type of surficial or claystone overburden to be placed in the disposal sites. The two main dumps, Houth Meadows and Medicine Creek dumps, would be developed with underdrain systems which will collect seepage. The volume of waste material and area of each dump has been estimated as follows:

Dump Location	Mid Point of Mining	End of Mining	
	Area-ha (acres)	Area-ha (acres)	Volume $10^6 m^3$
Houth Meadows Dump	400 (1006)	608 (1520)	467
Medicine Creek Dump	232 (580)	482 (1204)	289
North Valley Dump	50 (124)	50 (124)	9.2

The maximum volume of seepage expected to emanate from the respective dumps to the ground water table as previously stated in Section 6.1 (a) (iii) A. is relatively low, totaling about 400 $m^3 \cdot d^{-1}$ (106,000 USGPD) from the proposed Houth Meadows dump and 40 $m^3 \cdot d^{-1}$ (10,500 USGPD) from the Medicine Creek dump. However, the estimated maximum seepage through the embankments is much higher, and is estimated to be between 300 and 1500 $m^3 \cdot d^{-1}$ for the Houth Meadows dump and between 300 and 2000 $m^3 \cdot d^{-1}$ for the Medicine Creek dump. These flows become surface water which would be directed to treatment lagoons near each dump. The quality of the seepages has been estimated from leachates test data done by others[33] as shown in Tables 6-4 to 6-8. The overburden material would be similar to that proposed for disposal to the Medicine Creek dump whereas the waste rock would be similar to the claystone material proposed for disposal in the Houth Creek dump. The chemical quality of effluent

PROPOSED MINE AND WASTE DUMP LAYOUT

Figure 6-8

TABLE 6-4

TOTAL EXTRACTABLE SALTS TEST RESULTS*
OVERBURDEN BAH 76-1 AND BAH 76-13

Parameter		Overburden BAH 76-1	Overburden BAH 76-13
pH		7.6	7.65
Suspended Solids		72	412
Total Filterable Residue		1900	2000
Alkalinity as $CaCO_3$		920	1120
Chloride	-Cl	28	16
Fluoride	-F	< 0.4	< 0.4
Nitrate-Nitrogen	-N	15	18
Nitrite-Nitrogen	-N	< 0.4	< 0.4
Total Kjeldahl Nitrogen	-N	6	5
Biochemical Oxygen Demand (5-day)		370	340
Chemical Oxygen Demand		440	440
Ortho-Phosphate - Phosphorus	-P	2.7	3.5
Sulphur	-S	80	111
Aluminum	-Al	26	13
Arsenic	-As	1.3	0.5
Boron	-B	1.0	1.0
Cadmium	-Cd	< 0.08	< 0.08
Calcium, Hard as $CaCO_3$		290	400
Chromium	-Cr	1.0	1.5
Copper	-Cu	2.2	3.4
Iron	-Fe	14	31
Lead	-Pb	< 3	< 3
Lithium	-Li	< 0.3	< 0.3
Magnesium, Hard as $CaCO_3$		358	380
Mercury	-Hg	0.010	0.010
Selenium	-Se	0.2	0.2
Sodium	-Na	178	225
Strontium	-Sr	< 4	< 4
Vanadium	-V	< 0.2	< 0.2
Zinc	-Zn	6.8	10.8

Data from Acres Consulting Services Ltd.

* Except for pH, all units are mg/kg, indicating milligrams extracted per kilogram of dry solids.

TABLE 6-5

TOTAL EXTRACTABLE SALTS TEST RESULTS*
WASTE ROCK

Parameter	Waste Rock
pH	7.85
Suspended Solids	7520
Total Filterable Residue	3400
Alkalinity as $CaCO_3$	1320
Chloride -Cl	270
Fluoride -F	2.4
Nitrate-Nitrogen -N	19
Nitrite-Nitrogen -N	6
Total Kjeldahl Nitrogen -N	2
Biochemical Oxygen Demand (5-day)	400
Chemical Oxygen Demand	660
Ortho-Phosphate - Phosphorus -P	9.2
Sulphur -S	250
Aluminum -Al	24
Arsenic -As	1.0
Boron -B	2.0
Cadmium -Cd	< 0.08
Calcium, Hard as $CaCO_3$	480
Chromium -Cr	< 1
Copper -Cu	4.0
Iron -Fe	76
Lead -Pb	< 3
Lithium -Li	< 0.3
Magnesium, Hard as $CaCO_3$	440
Mercury -Hg	0.006
Selenium -Se	0.2
Sodium -Na	542
Strontium -Sr	< 4
Vanadium -V	0.2
Zinc -Zn	8.8

Data from Acres Consulting Services Ltd.

* Except for pH, all units are mg/kg, indicating milligrams extracted per kilogram of dry solids.

TABLE 6-6

RATE OF RELEASE TEST RESULTS*
OVERBURDEN BAH 76-1

Parameter		Individual Extract					Cumulative Extract				
		Day 1	Day 2	Day 3	Day 4	Day 5	Day 1	Day 2	Day 3	Day 4	Day 5
Volume of Extract	- ml	186	121	83	100	150	186	307	390	490	640
pH		7.6	8.05	8.0	7.8	8.0					
Suspended Solids	- mg/l	21	52	22	10	8	21	33	31	27	22
Total Filterable Residue	- mg/l	180	129	109	120	88	180	160	149	143	130
Specific Conductance	- µmho/cm	80	110	101	110	82					
Alkalinity as $CaCO_3$	- mg/kg	102	54	39	45	60	102	156	195	240	300
Chloride	- mg/kg	4	3	2	2	2	4	7	9	11	13
Fluoride	- mg/kg	0.09	-	-	-	-	0.09	-	-	-	-
Nitrate-Nitrogen	- mg/kg	7.4	3.0	1.7	1.0	0.5	7.4	10.4	12.1	13.1	13.6
Ortho-Phosphate - Phosphorus	- mg/kg	0.28	0.12	0.25	0.25	0.38	0.28	0.40	0.65	0.80	1.18
Sulphur	- mg/kg	1.3	4.8	3.7	3.9	3.2	1.3	6.1	9.8	13.7	16.9
Arsenic	- mg/kg	0.1	-	-	-	-	0.1	-	-	-	-
Boron	- mg/kg	0.04	-	-	-	-	0.04	-	-	-	-
Cadmium	- mg/kg	< 0.004	-	-	-	-	< 0.004	-	-	-	-
Calcium, Hard as $CaCO_3$	- mg/kg	24.6	20.4	20.9	23.0	24.3	24.6	53.0	73.9	96.9	121.2
Chromium	- mg/kg	0.09	0.07	0.05	0.04	0.05	0.09	0.16	0.21	0.25	0.30
Copper	- mg/kg	0.65	0.03	0.03	0.02	0.02	0.65	0.68	0.71	0.73	0.75
Iron	- mg/kg	0.6	1.5	0.3	0.1	0.2	0.6	2.1	2.4	2.5	2.6
Lead	- mg/kg	< 0.04	-	-	-	-	< 0.04	-	-	-	-
Magnesium, Hard as $CaCO_3$	- mg/kg	27.2	28.7	19.7	25.4	26.9	27.2	55.9	75.6	101.0	127.9
Mercury	- mg/kg	0.037	-	-	-	-	0.037	-	-	-	-
Sodium	- mg/kg	27	13	7	5	6	27	40	47	52	58
Vanadium	- mg/kg	< 0.02	-	-	-	-	< 0.02	-	-	-	-
Zinc	- mg/kg	0.06	0.04	0.03	0.02	0.01	0.06	0.10	0.13	0.15	0.16

Additional Data:

		Individual Extract		
		Day 6	Day 7	Day 8
Volume of Extract	- ml	250	200	200
pH		8.3	8.4	8.5
Suspended Solids	- mg/l	9	10	10
Specific Conductance	- µmho/cm	65	58	54

Weight of Sample:	100 g
Particle Size:	2 mm x 0.6 mm
Packed Column Length:	10 cm
Water Required for Saturation:	25 ml
Average Temperature:	22° C

Data from Acres Consulting Services Ltd.

* Except where noted, results are expressed in units of mg/kg, indicating milligrams extracted per kilogram of dry solids. Individual results are shown for extracts collected after successive 24-hour periods and cumulative figures are calculated from individual results. A dash (-) indicates that the parameter was not analysed.

TABLE 6-7

RATE OF RELEASE TEST RESULTS*
OVERBURDEN DAH 76-13

Parameter		Individual Extract					Cumulative Extract				
		Day 1	Day 2	Day 3	Day 4	Day 5	Day 1	Day 2	Day 3	Day 4	Day 5
Volume of Extract	- ml	117	267	75	125	100	117	384	459	564	684
pH		7.9	8.0	7.5	7.5	7.6					
Suspended Solids	- mg/l	25	41	54	21	20	25	36	39	35	33
Total Filterable Residue	- mg/l	160	57	66	66	36	160	88	85	81	74
Specific Conductance	- µmho/cm	290	54	60	68	55					
Alkalinity as $CaCO_3$	- mg/kg	90	93	25	40	28	90	183	208	248	276
Chloride	- mg/kg	2	8	1	1	1	2	10	11	12	13
Fluoride	- mg/kg	0.08	-	-	-	-	0.08	-	-	-	-
Nitrate-Nitrogen	- mg/kg	7.0	4.0	1.1	1.3	1.0	7.0	11.0	12.1	13.4	14.4
Ortho-Phosphate - Phosphorus	- mg/kg	0.23	0.67	0.11	0.19	0.10	0.23	0.90	1.01	1.20	1.30
Sulphur	- mg/kg	7.8	6.1	1.2	1.9	1.3	7.8	13.9	15.1	17.0	18.3
Arsenic	- mg/kg	0.04	-	-	-	-	0.04	-	-	-	-
Boron	- mg/kg	0.02	-	-	-	-	0.02	-	-	-	-
Cadmium	- mg/kg	< 0.003	-	-	-	-	< 0.003	-	-	-	-
Calcium, Hard as $CaCO_3$	- mg/kg	29.3	29.4	6.0	14.0	10.0	29.3	58.7	64.7	78.7	88.7
Chromium	- mg/kg	0.06	0.08	0.03	0.04	0.03	0.06	0.14	0.17	0.21	0.24
Copper	- mg/kg	1.64	0.03	0.08	0.03	0.03	1.64	1.67	1.75	1.78	1.81
Iron	- mg/kg	1.2	0.6	0.2	0.5	0.7	1.2	1.8	2.0	2.5	3.2
Lead	- mg/kg	< 0.03	-	-	-	-	≤ 0.03	-	-	-	-
Magnesium, Hard as $CaCO_3$	- mg/kg	34.2	19.0	3.5	7.8	5.8	34.2	53.2	56.7	64.5	70.3
Mercury	- mg/kg	0.002	-	-	-	-	0.002	-	-	-	-
Sodium	- mg/kg	47	27	8	8	5	47	74	82	90	95
Vanadium	- mg/kg	< 0.02	-	-	-	-	≤ 0.02	-	-	-	-
Zinc	- mg/kg	0.04	0.03	0.02	0.04	0.03	0.04	0.07	0.09	0.13	0.16

Additional Data:

		Individual Extract		
		Day 6	Day 7	Day 8
Volume of Extract	- ml	100	175	150
pH		7.5	8.55	8.7
Suspended Solids	- mg/l	16	17	17
Specific Conductance	- µmho/cm	43	40	40

Weight of Sample:	100 g
Particle Size:	2 mm x 0.6 mm
Packed Column Length:	10 cm
Water Required for Saturation:	25 ml
Average Temperature:	22° C

Data from Acres Consulting Services Ltd.

* Except where noted, results are expressed in units of mg/kg, indicating milligrams extracted per kilogram of dry solids. Individual results are shown for extracts collected after successive 24-hour periods and cumulative figures are calculated from individual results. A dash (-) indicates that the parameter was not analysed.

TABLE 6-8

RATE OF RELEASE TEST RESULTS*
WASTE ROCK

Parameter		Individual Extract					Cumulative Extract				
		Day 1	Day 2	Day 3	Day 4	Day 5	Day 1	Day 2	Day 3	Day 4	Day 5
Volume of Extract	- ml	100	129	118	155	230	100	229	347	502	732
pH		8.3	8.7	7.7	8.5	8.4					
Suspended Solids	- mg/l	1210	950	620	210	120	1210	1064	913	696	515
Total Filterable Residue	- mg/l	2078	700	465	210	190	2078	1347	1047	789	600
Specific Conductance	- µmho/cm	670	270	180	95	70					
Alkalinity as $CaCO_3$	- mg/kg	180	129	84	47	71	180	309	393	440	511
Chloride	- mg/kg	53	14	11	8	3	53	67	78	86	89
Fluoride	- mg/kg	0.06	-	-	-	-	0.06	-	-	-	-
Nitrate-Nitrogen	- mg/kg	3.7	1.3	0.5	0.3	0.2	3.7	4.0	4.5	4.8	5.0
Ortho-Phosphate - Phosphorus	- mg/kg	0.40	0.34	0.12	0.16	0.23	0.40	0.74	0.86	1.02	1.25
Sulphur	- mg/kg	10.0	3.5	2.1	2.5	2.5	10.0	13.5	15.6	18.1	20.6
Arsenic	- mg/kg	0.1	-	-	-	-	0.1	-	-	-	-
Boron	- mg/kg	0.05	-	-	-	-	0.05	-	-	-	-
Cadmium	- mg/kg	< 0.002	-	-	-	-	< 0.002	-	-	-	-
Calcium, Hard as $CaCO_3$	- mg/kg	76.2	51.0	31.9	41.9	28.8	76.2	127.2	159.1	201.0	229.8
Chromium	- mg/kg	0.20	0.09	0.05	0.08	0.12	0.20	0.29	0.34	0.42	0.54
Copper	- mg/kg	2.10	0.08	0.06	0.06	0.23	2.10	2.18	2.24	2.30	2.53
Iron	- mg/kg	1.9	3.9	2.2	1.6	2.3	1.9	5.8	8.0	9.6	11.9
Lead	- mg/kg	< 0.02	-	-	-	-	< 0.02	-	-	-	-
Magnesium, Hard as $CaCO_3$	- mg/kg	43.7	12.9	17.6	12.9	19.1	43.7	56.6	74.2	87.1	106.2
Mercury	- mg/kg	0.003	-	-	-	-	0.003	-	-	-	-
Sodium	- mg/kg	70	57	30	3	16	70	127	157	160	176
Vanadium	- mg/kg	< 0.01	-	-	-	-	< 0.01	-	-	-	-
Zinc	- mg/kg	0.28	0.19	0.20	0.20	2.76	0.28	0.47	0.67	0.87	3.63

Additional Data:

		Individual Extract Day 6	Day 7	Day 8
Volume of Extract	- ml	150	200	140
pH		7.7	7.9	8.3
Suspended Solids	- mg/l	90	80	80
Specific Conductance	- µmho/cm	70	93	115

Weight of Sample:	100 g
Particle Size:	2 mm x 0.6 mm
Packed Column Length:	11 cm
Water Required for Saturation:	65 ml
Average Temperature:	22° C

Data from Acres Consulting Services Ltd.

* Except where noted, results are expressed in units of mg/kg, indicating milligrams extracted per kilogram of dry solids. Individual results are shown for extracts collected after successive 24-hour periods and cumulative figures are calculated from individual results. A dash (-) indicates that the parameter was not analysed.

seepages emanating from the dump under drains is projected as being similar to that indicated in Table 6-9 which gives the quality of the leachate derived at the first test (the lowest pore volume displacement) in the column rate of release leachate experiments conducted by others[33].

Seepage from the Medicine Creek dump could be expected to have elevated levels of iron and copper whereas seepage from the Houth Meadows dump would be expected to have elevated levels of arsenic, chromium, copper, iron and dissolved solids (Filterable Residue). Both seepages would contain unpredictable levels of suspended solids. The Houth Meadows seepage could be expected to contain upwards of several hundred milligrams per liter due to the fact that the material being disposed in that location would consist of fine clay materials (bentonite etc.) which produces difficult to remove colloidal solids.

It is not possible to estimate the acid generation potential of these overburden materials because the pyrite sulfur content of these materials has not been determined. Given the water soluble neutralizing potential of the materials from the leachate tests, the pyrite sulphur percent above which acid drainage might be possible can be estimated. In the case of the overburden tested the critical pyritic sulphur level is about 0.03 percent while the critical pyritic sulphur level in the waste rock would be about 0.04 percent. This does not, however, take into account any solid phase neutralizing capacity which may be available. Refer to Section 6.2 (b) (ii) A for method.

<u>Coal Stockpile</u>

The discussion in Section 6.2 (a) (ii) A. <u>Coal Stockpile</u> regarding projected effects on ground water quality applies to the mine mouth coal storage during the Operation phase of the development and will not be repeated. The only significant difference will be that, during operation, the coal storage area including the coal preparation area, will be about 32 ha (80 acres) of which about 20 ha (70 acres) will be coal storage, assuming continued existence of the uncrushed coal pile.

TABLE 6-9

PROJECTED OVERBURDEN AND WASTE ROCK LEACHATE CHARACTERISTICS

Sample:	Overburden 76-1	Overburden 76-13	Waste Rock
Parameters (mg/l)			
pH (units)	7.6	7.9	8.3
Filterable Residue Dried at 105 degrees C	180	160	2078
BOD_5**	35	27	244
Alkalinity (as $CaCO_3$)	55	77	180
Chloride	2	1.5	53
Fluoride	0.05	0.07	0.06
Nitrate (as N)	4.0	6.0	3.7
O-phos. (as P)	0.15	0.2	0.4
Sulphur	0.7	6.7	10.0
Arsenic	0.03	0.03	0.1
Boron	0.02	0.02	0.05
Cadmium	0.002	0.002	<0.002
Calcium (as $CaCO_3$)	13.2	25	76.2
Chromium	0.05	0.05	0.2
Copper	0.35	1.4	2.1
Iron	0.3	1.05	1.85
Lead	0.02	0.02	0.02
Magnesium (as $CaCO_3$)	14.6	29.2	43.7
Mercury	0.002	0.002	0.003
Sodium	15.0	40.0	70
Vanadium	0.01	0.01	0.01
Zinc	0.031	0.031	0.275

Data from Acres Consulting Services Limited

**Estimated by BEAK utilizing BOD_5 from Total Extractable Tests and multiplying by ratio of filterable residue extracted in 24 hours to Total Extractable Filterable Residue.

*At low pore volume displacement (see example calculation)

Leachate Characteristic in mg/l =

$$\frac{(\text{Extractable Component at Day 1 in mg}\cdot\text{kg}^{-1})\times(\text{Weight of Sample in kg})}{(\text{Volume of Extract at Day 1 in liters})}$$

Low Grade Waste Dump

The discussion presented in Section 6.2 (a) (ii) regarding impact on the ground water quality applies to the Operation phase of the Low Grade Waste Dump. There is not expected to be any significant percolation of leachates to the ground water providing the base construction utilizes well compacted impermeable material. The only significant difference is that the waste dump could expand to an estimated 128 ha (317 acres) containing 46 x 10^6 tons of low grade waste coal over the Operation phase of the development. The extent of utilization of low grade coal in the plant in the latter stages of the plant life is not predictable according to the project description. Runoff and leachates emanating as surface water are discussed in Section 6.3 (b) (ii) and 6.3 (b) (iii).

Reclamation

During the operating phase of the mine, reclamation would proceed where possible on completed zones of the waste dumps and retaining embankments. The project description indicates that by midpoint of mining the outer face of the retaining embankments (designated No. 1 and 2) of the Houth Meadows Dump (Total Area Reclaimed - 125 ha (312 acres)) and No. 4 of the Medicine Creek Dump (Total Area Reclaimed - 44 ha (110 acres)) would be fully reclaimed and revegetated. At the end of mining the entire dumps will have been reclaimed (Houth Meadows Dump - 608 ha (1520 acres) and Medicine Creek Dump - 482 ha (1204 acres).

Revegetation studies are currently being conducted by others[33]. It is known however, that fertilization will be required and that irrigation may be utilized to enhance the reclamation process. Fertilization rates applied are not well defined at this point, however, based on experiences elsewhere[34] and recommendations by the B.C. Department of Mines[35] 17 - 34 kg$\cdot$ $ha^{-1}\cdot yr^{-1}$ (100-200 lb $\cdot$ $acre^{-1}\cdot yr^{-1}$) would probably be applied. Estimates of the loss of nitrogen and phosphorous to the ground water were found to be

17 percent and 2 percent of the amount applied in lysimeter studies conducted in the Okanagan[36]. Although these nutrient losses would enter the ground water within the dump faces, these flows would surface at the seepage drains and enter the surface water system. The impact of this aspect of reclamation is discussed further in Section 6.2 (b) (iii) A.

Sewage and Refuse Disposal

Supply of the potable water requirements to the mine office and warehouses will be by pipelines from the power plant. Sewage handling in the amount of 140 $m^3 \cdot d^{-1}$ (37,000 USGPD) will be by means of a package biological treatment system, disinfection by chlorination, storage in a pond and ultimate disposal by utilizing the treated effluent for mine fugitive dust control. Considering the quantity involved and proposed treatment and disposal methods, impact on ground water is projected as insignificant.

Refuse disposal would cause insignificant impairment to the ground water quality of the valley provided the landfill is well situated, designed and operated and precipitation infiltration is minimized.

Other Activities

The other operations associated with the mine, waste dumps and infrastructure are not expected to present any impact on ground water quality. The disposal of tailings from a wet beneficiation process has not been addressed in this report. No conceptual design has been done on which to base an assessment. Due to the large size of the tailings pond requirements from a wet beneficiation process, it would be necessary to conduct a specific environmental assessment if this alternate is considered further.

B. Plant

Ash Disposal

As indicated in Section 6.2 (a) (ii) B, a number of alternate schemes are being considered besides the "base case" of wet disposal. Estimates of seepage quantities in the wet disposal system and the alternates have been made as indicated in Section 6.1 (a)(iii) B. These have been summarized as follows:

	Method	Seepage to Ground Water ($m^3 \cdot d^{-1}$)	Seepage to Surface Water ($m^3 \cdot d^{-1}$)
Base Case	Combined Ash Pond	20	20 - 100
Alternate 1	Harry Lake - Bottom Ash Pond	20	20 - 100
	Medicine Creek - Fly Ash Pond	15	20 - 80
Alternate 2	Harry Lake - Bottom Ash Dump Harry Lake - Fly Ash Dump	} 35	20 - 120

The quantity of ash produced as indicated in the descriptions, is about 6000 tonnes per day (6600 tons/day). The quantity of recycled ash pond supernatant presently estimated for the base case would be about 13.4 $m^3 \cdot min^{-1}$ (3500 USGPM). The seepage loss thus amounts to about 0.6 percent of sluice water input to the Upper Medicine Creek pond. On another basis, the seepage amounts to about 14 $l \cdot min^{-1}$ per 1000 tonnes per day (4 USGPM per 1000 tons per day) of ash production. Existing base metal mine tailings operations in British Columbia experience seepages at 40 to 115 $l \cdot min^{-1}$ per 1000 tonnes per day (10 to 30 GPM per 1000 tons per day)[37].

Although rate of release leachate tests were not run on fly ash or bottom ash, total extraction leachate tests were conducted by others[33], and are shown in Table 6-10. These have been reviewed in comparison to other materials tested to project the probable quality of leachates from ash disposal areas.

TABLE 6-10

TOTAL EXTRACTABLE SALTS TEST RESULTS*
FLY ASH AND BOTTOM ASH

Parameter		Fly Ash	Bottom Ash
pH		9.4	8.8
Suspended Solids		35	80
Total Filterable Residue		9450	4770
Alkalinity as $CaCO_3$		2600	1110
Chloride	-Cl	110	110
Fluoride	-F	55.2	6.8
Nitrate-Nitrogen	-N	5	3
Nitrite-Nitrogen	-N	< 0.4	< 0.4
Total Kjeldahl Nitrogen	-N	9	4
Biochemical Oxygen Demand (5-day)		200	200
Chemical Oxygen Demand		360	700
Ortho-Phosphate - Phosphorus	-P	1.3	2.2
Sulphur	-S	2000	1000
Aluminum	-Al	10	7
Arsenic	-As	4.3	3.1
Boron	-B	6.3	0.7
Cadmium	-Cd	0.02	0.06
Calcium, Hard as $CaCO_3$		3240	1320
Chromium	-Cr	< 1	< 1
Copper	-Cu	0.2	0.2
Iron	-Fe	1	1
Lead	-Pb	< 3	< 3
Lithium	-Li	0.3	0.3
Magnesium, Hard as $CaCO_3$		190	190
Mercury	-Hg	< 0.002	< 0.001
Selenium	-Se	< 0.02	< 0.01
Sodium	-Na	100	110
Strontium	-Sr	< 4	< 4
Vanadium	-V	1.4	3.8
Zinc	-Zn	40	80

Data from Acres Consulting Services Ltd.

* Except for pH, all units are mg/kg, indicating milligrams extracted per kilogram of dry solids.

The literature and rate of release tests on other waste materials indicate pore volume displacements of 5 to 15 will be necessary before leachate quality levels off. The time required to reach this point depends on the permeability of the material as well as on the quantity of water applied or infiltrated in excess of the material water storage capacity.

Due to the probable permeability of the ash, it is estimated that it will take many years to displace 5 to 15 pore volumes. Thus the quality projections have been based on concentrations which are likely to occur during the initial pore volume displacements.

Leachate from waste disposal areas are generally of similar quality to the input liquor plus any extracted components. In this case the input liquor, excluding any precipitation, will be power plant wastewaters such as reverse osmosis wastewater, water treatment regenerant wastewater and general plant wastewater used for the ash sluicing, dewatering and wetting.

By ratio of total extractables in ash materials to total extractables in other materials tested, times concentration in leachate at low pore volume displacements, an estimate of the range of major parameters in the ash leachate due solely to extractables in the ash has been made as indicated in Table 6-11. Contribution to each major parameter concentration level due to input liquor from plant wastewaters can be estimated from information on quality of this liquor as calculated from the project descriptions[38] and as shown in Table 6-12, under Combined Wastewaters.

Assuming that the return sluice water treatment system offsets any concentration effect due to reuse, an estimate of the leachate quality likely to emanate based on the additive contribution from ash extractables and plant wastewaters is as shown in Table 6-13. Plant wastewater parameters not shown in Table 6-12 were calculated from Thompson River values assuming: the cooling tower blowdown is Thompson River water concentrated 20 times, the combined treatment waste is the Thompson River concentrated 11 times, the treated floor drains

TABLE 6-11

PROJECTED LEACHATE QUALITY CONTRIBUTION FROM ASH EXTRACTABLES*

Parameter (mg/l)	Fly Ash Range	Bottom Ash Range
pH (units)	9 - 10	8.5 - 9.5
Filterable Residue (105°C)	3000 - 8000	1500 - 4000
BOD_5**	15 - 175	15 - 175
Alkalinity (as $CaCO_3$)	400 - 500	200 - 400
Chloride	10 - 25	10 - 25
Fluoride	1.5 - 4.0	0.2 - 0.5
Nitrate (as N)	0.7 - 1.8	0.3 - 0.7
Ortho-phosphate (as P)	0.04 - 0.13	0.07 - 0.22
Sulfate	80 - 160	40 - 80
Arsenic	0.5 - 2.5	0.4 - 2.0
Boron	1.5 - 2.5	0.2 - 0.3
Cadmium	< 0.002	< 0.002
Calcium (as $CaCO_3$)	400 - 500	150 - 200
Chromium	0.02 - 0.14	0.009 - 0.03
Copper	0.1 - 0.2	0.1 - 0.2
Iron	0.1 - 0.2	0.1 - 0.2
Lead	< 0.02	< 0.02
Magnesium (as $CaCO_3$)	20 - 30	20 - 30
Mercury	< 0.0004 - 0.0017	< 0.0002 - 0.0008
Sodium	20 - 30	20 - 30
Vanadium	0.05 - 0.07	0.13 - 0.19
Zinc	0.3 - 1.5	0.6 - 3.0

* At low pore volume displacement

**Estimated by BEAK by comparison of total extractable BOD_5 to projections of BOD_5 in other waste materials tested.

Developed from Leachate Data provided by Acres Consulting Services Limited

TABLE 6-12

ESTIMATED WATER QUALITY OF PRIMARY WATER USE SYSTEMS BLOWDOWN

PARAMETER*	COOLING TOWER BLOWDOWN**	COMBINED REGENERANT WASTES	TREATED SANITARY WASTEWATER	HVAC	TREATED FLOOR DRAINAGE	COMBINED WASTEWATERS***
TDS	1625	6119	300	150	100	1890
Calcium	295	147	15	30	15	235
Magnesium	52	26	3	6	3	40
Sodium	64	1710	3	6	3	240
Chloride	63	748	56	6	3	130
Sulphate	1060	3263	10	20	10	1140
pH	8.0	5.0	8.0	8.0	8.5	8.0
Flow (l/s)	32.7	5.0	0.6	0.2	6.3	44.8

* All parameter concentrations in mg/l except for pH which is in units and flow as specified.

** Cooling tower blowdown water quality is based on twenty cycles of concentration.

*** Calculated by Beak Consultants Limited.

(After Integ-Ebasco, February 1978. Water Management Study for Hat Creek Power Plant. Report to B.C. Hydro)

TABLE 6-13

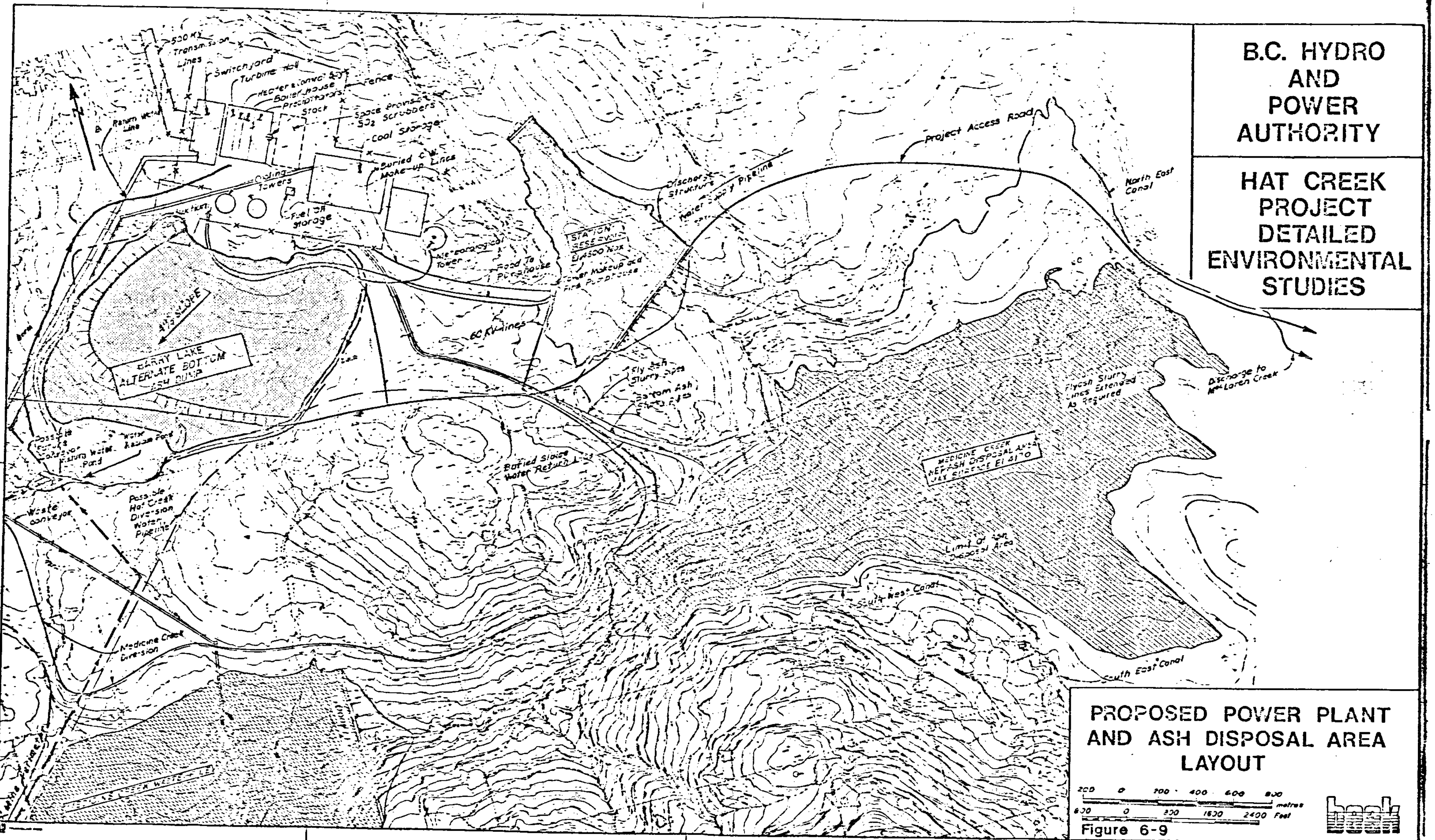
PROJECTED ASH LEACHATE QUALITY

Parameter (mg/l)	Fly Ash Range	Bottom Ash Range
pH (units)	8.5 - 9.5	8.0 - 9.0
Filterable Residue (105°C)	4900 - 9900	3400 - 5900
BOD_5	< 30 - 190	< 30 - 190
Alkalinity (as $CaCO_3$)	1030 - 1130	830 - 1030
Chloride	140 - 155	140 - 155
Fluoride	3.3 - 5.8	2.0 - 2.3
Nitrate (as N)	2.2 - 3.3	1.8 - 2.2
Ortho-phosphate (as P)	0.15 - 0.24	0.18 - 0.33
Sulphate	220 - 300	1180 - 1220
Arsenic	< 0.6 - 2.6	< 0.5 - 2.1
Boron	< 3.1 - 4.1	< 1.8 - 1.9
Cadmium	< 0.08	< 0.08
Calcium (as $CaCO_3$)	990 - 1090	740 - 790
Chromium	< 0.1 - 0.22	< 0.089 - 0.11
Copper	< 0.2 - 0.3	< 0.1 - 0.3
Iron	< 1.6 - 1.7	< 1.6 - 1.7
Lead	< 0.04	< 0.04
Magnesium (as $CaCO_3$)	190 - 200	190 - 200
Mercury	< 0.0012 - 0.0023	< 0.001 - 0.0016
Sodium	260 - 270	260 - 270
Vanadium	< 0.13 - 0.15	< 0.21 - 0.27
Zinc	0.6 - 1.8	0.9 - 3.3

are the same as the Thompson River, and the treated sanitary wastewater and HVAC are insignificant. Figure 6-9 shows the proposed layout of the power plant and ash disposal areas for the base case and Alternate I. For the layout of Alternate II, see Reference 3.

The literature contains many references to studies on leachate characteristics from ash disposal. Brown, J. et al[39] conducted laboratory and field investigations on pulverized ash and found the quality of leachate is dependent upon the condition of the ash. Leachates from ash conditioned to 15 percent water by weight contained approximately 1.9 times the dissolved solids content of leachates from lagooned ash (7900 mg/l versus 4100 mg/l) at low bed volume detentions. The study also found that the levels of some elements in leachates may be reduced in passing through substrata before reaching the ground water regime or surfacing.

Chu, T.J. et al[40] characterized ash pond effluents in recirculation systems. It was found that concentrations of calcium, sulfate and total alkalinity leveled off after about the eighth cycle in alkaline recycled ash sluice water. Further, alkaline fly ash in repeated contact with water did not release cadmium, iron, lead, manganese and mercury because of low solubilities of these trace metals. Boron, barium, arsenic, chromium, copper, nickel, selenium and zinc did leach into the sluice water, but concentrations quickly leveled off after about three to four cycles. Sodium and potassium continued to increase in concentration after 20 cycles (Figures 6-10 and 6-11). The composition of the ash utilized is compared to that of the ash expected from Hat Creek in Table 6-14.



B.C. HYDRO AND POWER AUTHORITY

HAT CREEK PROJECT DETAILED ENVIRONMENTAL STUDIES

PROPOSED POWER PLANT AND ASH DISPOSAL AREA LAYOUT

Figure 6-9

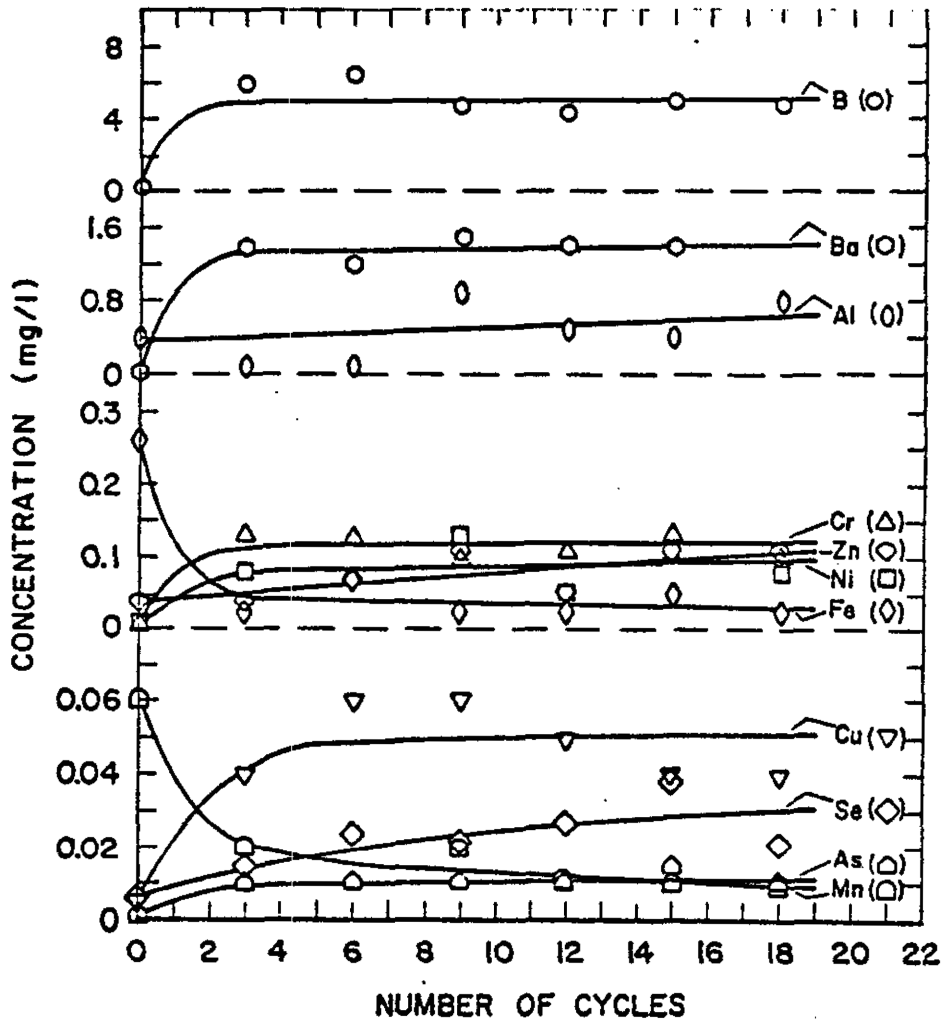


Figure 6-10 Leaching of trace metals after repeated cycles of contact with fresh fly ash from plant E.

(Chu, T.J. et al. October, 1976)

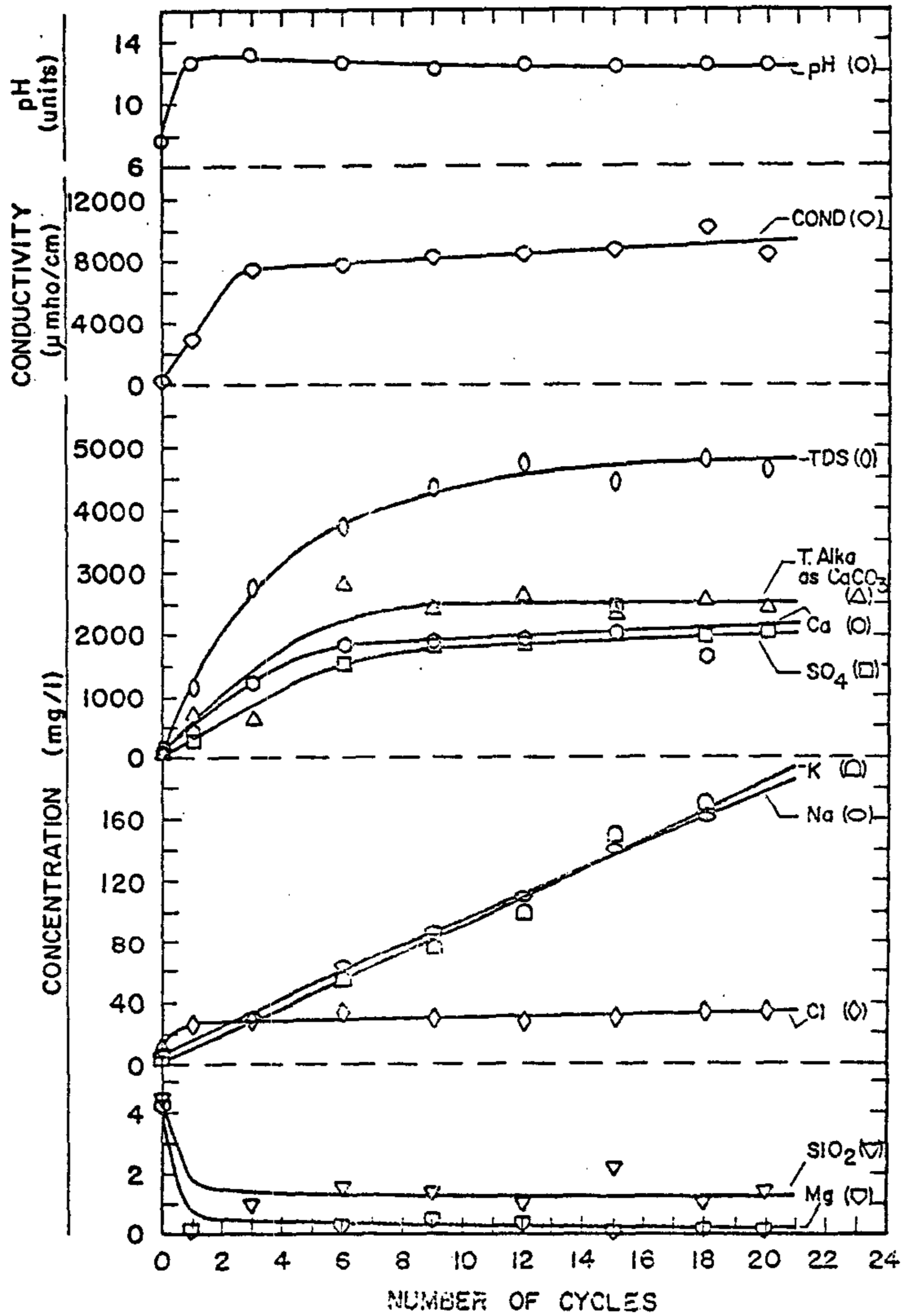


Figure 6-11 Major leaching components after repeated cycles of contact with fresh fly ash from plant E. (Chu, T.J. et al. October, 1976)

TABLE 6 - 14

CHEMICAL COMPOSITION OF DRY ASHES

Constituent (%)	Hat Creek (Ash) *	Plant E (Fly Ash) **
Alumina (Al_2O_3)	22 - 38	18.52
Calcium Oxide (CaO)	1.4 - 8.5	5.74
Iron Oxide (Fe_2O_3)	2.4 - 28	20.79
Magnesium Oxide (MgO)	0.7 - 3.3	1.23
Potassium Oxide (K_2O)	0.2 - 0.8	3.37
Silica (SiO_2)	32 - 56	46.28
Sodium Oxide (Na_2O)	0.4 - 2.6	0.66
Sulfur Trioxide (SO_3)	0.4 - 3.7	1.55
Titanium Oxide (TiO_2)	0.4 - 1.3	1.07

Constituent (μg/g)	Hat Creek Bottom Ash ***	Hat Creek Fly Ash ***	Plant E **
Arsenic	12	111	55
Boron	10	47	1800
Cadmium	0.3	0.5	6
Chromium	86	280	90
Copper	166	119	78
Lead	10	32	75
Mercury	0.03	1.48	0.1
Selenium	5.0	4	6
Zinc	61	180	540

* From Integ-Ebasco. January 1977 Power Plant Conceptual Design Report.
** From Chu, T.J. et al. October 1976.
*** From Acres Consultants Limited, January 1977, Leachate And Vegetation Report.

Theis, T.L. et al[41,42] studied the movement of trace metals in ground water near an ash disposal facility and also investigated the sorptive characteristics in ash-soil environments. Their studies found that the sorptive capacity of soil increases with pH and also that of the soils tested, the ranking for sorptive capacity of metals was organic peat > bentonite > calcite sand > silica sand. The quantity of metal ions adsorbed was found to be concentration dependent following Freundlich isotherms. The studies indicate that a control strategy to reduce movement of metals in leachates from ash ponds is to line the pond with a highly adsorptive soil material such as bentonite. In other studies by Theis, T.L. et al[43], it was found that the relative amount of calcium and amorphous iron oxides on the surface of the ash defines whether the ash in solution will be acidic or basic in solution. No such extractions have been performed on Hat Creek coal fly ash or bottom ash, however, this should be considered to confirm that the ash waters will be alkaline as the present water extract leachate test data indicate. Theis, T.L. et al[43] also found that, excepting arsenic and cadmium, metals in aqueous fly ash solution follow a predictable pattern of decreasing release with increasing pH. In the study by Theis, T.L. et al[41] on a fly ash disposal site, it was found that trace metals were released to the ground water at generally low levels. Metals were found to accumulate in the soils beneath and around the pond. Precipitates of insoluble phases and adsorption of metals onto higher levels of hydrous iron and manganese oxides were thought to be responsible. Nickel was found to migrate without forming any precipitate or being adsorbed. The soil surrounding the ash disposal site was a fine sand, having a permeability of about 0.1 $cm \cdot s^{-1}$.

The strategies for controlling leachate percolation from the ash disposal site are not dealt with in the project descriptions. Further, disposal of seepage surfacing at the retaining embankments is not addressed. As indicated in Section 4.1 (a) (ii) D, the existing information suggests that the Medicine Creek Valley is overlain with low permeable till (hydraulic conductivity of 10^{-8} $m \cdot s^{-1}$) of variable thickness. The bedrock below the till is highly impermeable (hydraulic conductivity of 10^{-10} $m \cdot s^{-1}$) mixture of limestone, altered sedimentary rocks, volcanic rocks and sedimentary rocks. The present ground water flow, of which 90 percent is estimated to flow through the till, amounts to about 35 $m^3 \cdot d^{-1}$ per kilometer along the creek. Alluvium is almost absent in the creek bed.

The proposed ash disposal pond in Upper Medicine Creek would be about 3 km in length and the projected seepage from the pond is 20 $m^3 \cdot d^{-1}$ compared to the existing ground water flow of 175 $m^3 \cdot d^{-1}$ from the total reach above the ash pond embankment. This indicates a moderate dilution potential exists for any contaminated percolation from the ash pond. There are no known ground water users in the Upper Medicine Creek Valley. It would thus seem unnecessary from a ground water quality viewpoint to require lining of the proposed ash pond to further reduce seepage and percolation. It would, however, be prudent to install a cutoff wall at the lower embankment such that contaminated seepages are intercepted before reaching aquifers in the Hat Creek Valley. Also, as is common practice in the mining industry, it is assumed that a surface and sub-surface seepage recovery system below the retaining embankments would be installed with collected seepage returned to the ash system eliminating all discharges to the environment outside the immediate ash disposal areas. Provided this is done, the ground water quality of the remaining ground waters of the valley should not be affected by the ash disposal operations in the Upper Medicine Creek Valley.

Ash disposal to the Harry Lake region in the alternate schemes (Alternate I - bottom ash sluiced to Harry Lake, fly ash sluiced to Upper Medicine Creek: Alternate II - bottom ash and fly ash to dry disposal in Harry Lake site dumps) will also generate leachates. Bottom ash is quite permeable (hydraulic conductivity 10^{-5} $m \cdot s^{-1}$) would drain quite rapidly and exist after disposal in an unsaturated state. Fly ash having extremely low permeability (hydraulic conductivity 10^{-6} $m \cdot s^{-1}$) will effectively become a saturated dump after compaction. The geological nature of the Harry Lake area is not well defined at this stage as test holes have not been sunk in the alternate ash site of the Harry Lake region.

Disposal design strategies similar to those required in Upper Medicine Creek will be necessary to prevent contamination of ground waters (suitable base preparation, cutoff walls if necessary and seepage collection and return to the ash water circuit).

Ash Sluice Water Treatment Sludge

Several of the alternates for ash disposal require treatment of the recycled ash pond supernatant to avoid scaling of the sluicing system pipelines. This treatment would generate a calcium carbonate, magnesium hydroxide and calcium sulphate type sludge which would be dewatered by mechanical means to 10 - 25 per cent solids by weight.[38] The sludge, calculated to be 45 - 68 tonnes per day (50 - 75 tons per day) based on a sludge flow of 1.6 - 2.3 $l \cdot s^{-1}$ at 3.5 percent solids, would be disposed to a sludge storage pond.

The size of the disposal area required over the life span of the power plant is estimated at 2 - 4 ha and will contain 600,000 tonnes of dewatered sludge. Leachate data is not available for this material, however, assuming adequate pond lining with impermeable materials and siting the disposal pond suitably above local ground water, the operation should not impact on the ground water quality. The nature of the sludge, being highly alkaline, would prevent dissolution of most metal constituents in the sludge.

It is noted from the project descriptions that power plant boiler cleaning wastes are also proposed for disposal into the ash sluice water treatment system. These discharges are first neutralized in a holding pond prior to discharge to the ash sluice water treatment system. These discharges although infrequent (every 3 to 5 years - 1135 m^3 per 500 MW unit) usually contain high levels of ammonia, iron and copper ranging from 80 - 300 mg/l, 30 - 4000 mg/l and 0 - 131 mg/l respectively.[44,45] The metals should precipitate in the sluice water treatment process and be disposed with the sludge from this process.

FGD Sludge Disposal

The alternative to a Meteorological Control System (MCS) for controlling sulphur dioxide levels is a Flue Gas Desulphurization (FGD) system whereby a portion of the flue gas is treated in absorbers utilizing a lime or limestone process. The sludge produced in the process results from chemical reaction between the reagent and SO_2 in the flue gas. The sludge would be converted to a solid waste material and transported to a storage area. The quantities of sludge involved are about 9 tonnes per hour per 500 MW unit or about 7.2 x 10^6 tonnes over the plant life from all units, if all were so equipped. Other than the sludge for disposal, all unit process wastewaters would be recycled thus eliminating any positive discharge. The sludge would be mixed with dry fly ash and additional lime to condition the material prior to disposal. The material reportedly can attain considerable strength after a week of curing in the disposal site. If disposed of in a dedicated landfill situation, an area of about 80 ha (200 acres) could eventually be required. No specific site has been studied or identified in the project descriptions for evaluation in this environmental assessment. If FGD is chosen, a separate environmental study would be required in the site selection phase to examine impact on ground water and surface waters. Leachates from this material can contain extremely elevated levels of calcium, sulfates, chlorides, and total dissolved solids.[46] The quantity of leachates is dependant on the permeability of the sludge. Raw sludge permeabilities have been reported by Rossoff, J. et al.[47] to be 1 x 10^{-3} $cm \cdot s^{-1}$ to 1 x 10^{-5} $cm \cdot s^{-1}$, whereas chemically fixed sludges are reportedly less permeable by one order of magnitude. Rossoff also reported no evidence of altered ground water quality near test FGD disposal sites where base soils had permeabilities of 10^{-8} $cm \cdot s^{-1}$. Schafish, R.J. et al[48] reviewed the factors to be considered in selecting a FGD sludge disposal site. Environmental factors outlined relate mainly to: avoidance of ground water interactions; control of surface run-off; bearing strength of sludge such that the site can eventually be reclaimed, and dust control.

A brief review of FGD waste reuse has been conducted by others.[33]

Plant Wastewaters

As indicated in the project descriptions the power plant would be designed and operated in a "no liquid discharge" mode utilizing a "cascading" water use philosophy whereby wastewaters are reused where requirements on quality allow recycle without disrupting the process thereby minimizing overall water use. There appears to be no plant wastewaters other than those discussed in this section that would interact with ground water in the area.

The potential for contamination of the environment due to accidental release of P.C.B.'s from the plants effluent system is considered negligible. Regulations proposed under the Environmental Contaminants Act will ban the purchase of new equipment filled with P.C.B.'s as of 18 October 1978.

Other Activities

Sanitary wastewater would be treated in a package extended aeration treatment plant. Treated wastewater would then be reused in the ash handling system. Waste sludge from the treatment plant would be disposed of with sludge from the ash recirculation water treatment plant. No impacts on ground water quality are foreseen due to the relatively small quantities involved.

An alternate to total coal storage at the mine mouth storage area is to provide a coal stockpile near the power plant of 7 to 30 days supply on a 10 ha (25 acre) site. Assuming base preparation of an impermeable material, percolation of leachates to the substrata would be minimal. Leachates would surface as seepage into the coal pile drainage system becoming part of surface water runoff. The system of collecting surface runoff and conveying to a basin prior to treatment with the ash recirculation water would avoid any interaction with uncontaminated surface or ground waters in the plant site area. The quality of coal pile seepage would be as discussed in Section 6.2 (b) (ii) A and 6.2 (b) (iii) A.

C. Offsites

Main Access Road

Winter maintenance of the main access road could involve using salting compounds for ice control. This activity has some potential for ground water contamination via percolation of contaminated snowmelt.[49] Wherever shallow ground waters are encountered during construction and within a reasonable distance from surface creeks or streams, use of deicing compounds should be avoided.

Cooling Water Supply System

Operation of the cooling water supply pipeline and pump stations should not cause any significant impact on ground water resources and its quality. Provisions should be provided at each pump station for safe disposal of used lubricating liquids, other waste materials and sanitary waste waters. Provided proven and environmentally acceptable methods are utilized, there would be no significant interaction with ground water, thus no impact on ground water quality.

Other Activities

The other activities include operation of the Hat Creek diversion, 60 kV transmission lines, airport and off-loading facility (note: off-loading may only be a "construction phase" activity). Significant interactions with the ground water regime are not projected from these activities. There would of course be some seepage loss from the diversion canal and reservoir into the ground. In general, however, Hat Creek water is a higher quality water than ground waters of the area and thus the impact from seepage could be rated beneficial although insignificant.

(iv) Decommissioning

A. Mine

Reclamation of The Mine And Dumps

Following completion of mining, reclamation of the remaining disturbed areas would commence. As indicated by the project descriptions, this would include:

mine pit; North Valley fill area after removal of infrastructure; stockpiles (low grade coal; blending stockpile; and topsoil); and the intervening areas. According to project descriptions, the Houth Creek and Medicine Creek dumps will have been reclaimed by the end of the mine operation phase.

In the case of the pit, reclamation would include recontouring pit slopes, top dressing, covering of exposed coaly materials, revegetation and flooding of the pit (over several years). The total reclaimed area as given in the descriptions would be 570 ha (1426 acres).

The stockpile areas 340 ha (854 acres) would be reclaimed if necessary, by top covering with soil. It cannot be predicted at this time whether any of the coal or low grade coal stockpiles will remain after completion of mining. All infrastructure would be dismantled and removed (conveyors, buildings, etc.) and the 50 ha (124 acres) North Valley fill area reclaimed. Lagoons and drainage control ditches will be maintained and not decommissioned. The intervening area of 1050 ha (2615 acres) will also be reclaimed as will the 25 ha (51 acres) of roads and conveyor right of ways.

The exact strategy of revegetation has not been developed at this time. It is likely, however, that fertilization will be necessary and in addition irrigation may be required to expedite the process.

The total area to be reclaimed in the decommissioning phase is 2035 ha (5090 acres) related to the mining project. The reclamation will have a beneficial impact on ground water quality in that any leaching by precipitation of soluble constituents from the waste material, pit slopes, dumps and stockpiles will be lessened. Cover material will also prevent further oxidation and weathering of waste materials. The application of fertilizers during revegetation will increase the nutrient level in the surficial ground water. As discussed in Section 6.2 (b) (iv), the major interaction will ultimately be with surface water since the surficial ground waters eventually appear as seepage to the surface water regime in the valley bottom.

Flooding of the pit is not expected to cause any significant ground water quality impairment because ground waters will be emanating into the pit lake over the majority of the pit rather than out from the lake as dictated by the water table governed ground water flow patterns that will still prevail in the area after mining ceases. There will be a recharge into the valley alluvium and buried bedrock channel aquifers of 500-700 $m^3 \cdot d^{-1}$. The quality of the water in the channel aquifer is presently unknown and the quality of the lake water requires further study. The impact of this recharge is thus indeterminant at this stage.

B. Plant

Reclamation of the Disposal Areas

Project descriptions available provide little detail on reclamation plans for the plant site, ash disposal areas or waste sludge disposal areas. In the case of the ash disposal pond in Upper Medicine Creek (434 ha; 1085 acres), reclamation would not be able to proceed until the area had dried out and attained sufficient bearing capacity to allow machines to operate. Based on net evaporation (300 mm per year) and the volume of water above the ash (6.8×10^6 m^3) this interval could last about five years or more. Descriptions indicate a top cover of 300 mm (1 ft) of topsoil would be placed followed by revegetation. It is not known whether this quantity of topsoil is available (50,000 m^3 or 1.75×10^6 cu yd). As in the case of mine reclamation, it is possible that any suitable "soil-forming" materials may be required to be used which would tend to prolong the reclamation duration.

Reclamation will have a beneficial impact on ground water quality in that the quantity of precipitation percolating through the ash pond will be reduced in the long term. Because of the permeability of fly ash, however, many years would pass before leachates and seepages will cease to emanate from the ash pond even after reclamation. Fertilization and possibly irrigation would be activities of the revegetation program in order to expedite the process. As indicated in other sections of the report, some residual nutrients inevitably migrate into the surficial ground water system and then eventually into the surface water regime. The impact of this activity is discussed more fully in Section 6.2 (b).

Reclamation of the alternative dry ash disposal system dumps would proceed throughout the "operation" phase and would be almost fully completed by the plant decommissioning stage. The fly ash dump would continue to produce seepage after reclamation however, because the permeability of the ash dictates a very slow desaturation process. Bottom ash on the other hand would become an unsaturated dump in relatively short periods of time and once topped and revegetated should effectively become "inactive" relative to inner drainage.

The effect on ground water of a future resource recovery operation (ash utilization) from the reclaimed ash disposal areas is not addressed in this report. Decommissioning of the power plant and related infrastructure (conveyors, buildings, cooling towers, switchyard, etc.) would not be expected to cause any significant impact on ground water quality. It is presumed, although not stated in the project descriptions that the main water supply reservoir would remain intact. Its potential value for water supply purposes is discussed in Section 6.3.

C. Offsites

There are no significant ground water quality impacts visualized from decommissioning of the Hat Creek diversion, power plant water supply system, or 60 kV transmission lines. It is assumed that the main access road and airport would remain intact.

(v) Overall Impact Assessment

A. Preliminary Site Development

Activities undertaken in the preliminary site development stage such as the Bulk Sample Program, exploratory drilling, and environmental sampling and surveying have not had, nor is it anticipated that they will have, any significant effect on the ground water quality of the area.

B. Construction

Activities occurring during the construction phase of the project should not produce any significant environmental impact on the ground water provided that proposed and recommended procedures and design methods are followed. This is particularly critical for sewage treatment and impermeable storage lagoon facilities.

C. Operation

Mine water removed from the pit during operation will be pumped into a treatment lagoon and will not have any effect on ground water quality. In the overburden dumps, because of the provision of drain systems, the majority of leachates from these dumps will not reach the ground water system and, thus, will have minor effects on ground water quality. In the coal stockpile and low grade waste dump, given that the bases of these are made from well compacted impermeable material and that drainage systems in the form of ditching are provided, then insignificant amounts of the runoff or leachates produced will reach the ground water; hence there will be no impact on the ground water from these areas. Reclamation work undertaken during the operating period of the mine will require the use of fertilizers. It is anticipated, however, that any nutrient losses that enter the ground water system will surface at seepage drains and enter the surface water system. Sewage and refuse disposal for the mine is projected as having an insignificant impact on the ground water. Other activities associated with the mine are not expected to present any impact on ground water quality.

In the operation of the plant, the only possible source of impact on the ground water system would be leachate from the ash disposal site. The amount and extent of the impact will be dependent upon the particular option selected for fly ash disposal; but in any case, the impact should be minimal provided that suitable control actions are taken (suitable base preparation, cutoff walls, and seepage collection and return). Because the plant is designed and will be operated in a "no liquid discharge" mode there will be no other plant wastewater to have an effect on the ground water. Sanitary wastewater will be treated by extended aeration with the treated wastewater being used in the ash handling system and the sludge being disposed of with sludge from the ash recirculation water treatment plant. Thus there will be no impact on the ground water from this source. If a coal stockpile is located near the plant, proper preparation of the base will ensure that leachates do not enter the ground water system.

During the operation of the project, the only offsite activity which could have an impact on the ground water would be the use of salts for ice control during winter maintenance of the main access road. To minimize this effect, wherever surficial aquifers are encountered during construction and within a reasonable distance from creeks or streams, deicing compounds should not be used.

D. Decommissioning

During the decommissioning phase of the project, the main activities that will be taking place will be reclamation of the mine and plant sites. The only impact this will have on the ground water will be the small, and beneficial one, of reducing any slight input of leachates to the ground water of the valley, which may have been occurring during the operating phase. Flooding of the pit will cause a recharge to the valley alluvium and buried bedrock channel aquifer on the north end of the pit. Since the water quality of the buried aquifer is unknown and the eventual lake water requires further study, the impact of this activity on ground water quality is indeterminant at this stage. The decommissioning of the offsite facilities will not have any impact on the ground water regime in the valley.

(b) Surface Water

(i) Preliminary Site Development

A. Mine

The only activities which had potential for interacting with the quality of surface water in this phase of the proposed development were the Bulk Sample Program, exploratory drilling, and access road construction. Surface water quality was monitored by BEAK and B.C. Hydro throughout this phase as indicated in the Inventory Sections 4.2. The surface disturbance from the Bulk Sample Program consisted of two trench areas comprising an estimated total area of 4 ha (10 acres). A further 8 ha (20 acres) was utilized for overburden disposal and coal stockpiles and reclamation test plots in various areas of the valley. Monitoring of the events by B.C. Hydro[5] indicated no project related alterations to Hat Creek water quality to date. Dusting was apparently only a local operational problem and no leachates have been observed from the storage piles. Further monitoring is proposed during the revegetation trials of the waste piles. Ground water entering Trench B near Hat Creek was pumped to Dry Lake area without influencing Hat Creek water quality.

Review of the water quality data available to BEAK indicates elevated levels of total organic carbon (20 mg/l at Bulk Sample Station 3) in comparison with annual mean values (8 mg/l at BEAK Station 7) for this parameter. This was the case for stations above and below the trench areas which would indicate a natural phenomenon that occurs during a low spring run-off year and is not detected in the annual means based on other available analytical data.

Construction of access roads to the trench areas, drill camp and information trailer for example, causes surface disturbance subject to future erosion by precipitation and spring run-off. Exploratory drilling likewise causes very localized small area disturbances to the existing vegetation cover which then becomes subject to erosion. The probable sediment yield increases in Hat Creek due to preliminary site development activities are not predictable quantitatively and are not detectable in inventory monitoring water quality data. However, the period of monitoring has been during a relatively dry period and may be non-reflective of conditions during a normal or above normal precipitation and run-off year. Considering the small size of the disturbances created in the preliminary site development, should the project not proceed, reclamation would be quite straight forward and no long-term impacts are visualized. All sewage from the drill camp has been contained by utilizing septic tanks with no discharge to any surface water course.

B. Plant and Offsites

There are no activities associated with Preliminary Site Development of the power plant and offsites that have caused long-term impacts on surface water quality. Exploratory drilling undertaken to establish foundation conditions at the proposed locations for power plant facilities, ash disposal, reservoir embankments and for subsoil data along the proposed Hat Creek diversion route have caused only minor localized disturbances which could be reclaimed should the project not proceed. No long-term impacts on surface water quality are projected. Dusting from added traffic on Hat Creek Valley roads and upper trails probably caused a certain amount of fine sediment to enter the creeks directly and through precipitation washout. The impact to this stage is considered minor to insignificant.

(ii) Construction

A. Mine

Pit and Dump Area Activities

The primary activities which will cause interactions with surface water during the construction phase of the mine, will be operations which disturb the landscape by removing or destroying existing vegetation cover and exposing areas which then become subject to erosion by the elements. Similarly materials removed and stock piled create additional disturbed areas. These operations include clearing and stripping, excavation, construction of drainage ditching, embankment construction, surficials and claystone removal, hauling and disposal.

Sediment yield from construction activities is difficult to estimate and governed by many variables. These include character of the material, slope, climate, amount and intensity of precipitation. Sediment yield to surface runoff is also increased via fugitive dust fallout and eventual washout by precipitation and spring snowmelt.[36] Since the areal disturbance in the Hat Creek Valley during the construction phase is only a small fraction of that which will exist throughout the mine life, predictions on sediment yield are made in Section 6.2 (b) (v) based on the juncture of maximum disturbance subject to runoff erosion.

Other pit area activities which have potential for impact on water quality include blasting and dewatering. The potential for causing increases in the nutrient (nitrogen) level of Hat Creek via blasting residuals contained in the mine water is discussed in more detail in Section 6.2 (b) (iii) A.

According to the project descriptions considerable dewatering will occur in the construction phase. The quantity involved, as estimated in the mine description, is 12 $l \cdot s^{-1}$ (200 USGPM) from the dewatering wells and pit proper plus 9 $l \cdot s^{-1}$ (150 USGPM) at times from precipitation falling within the pit. Disposal would be by pumping to a treatment lagoon (designated Lagoon #1) and ultimate discharge to Hat Creek. The quality of the water is difficult to estimate as only a few analyses have been conducted of ground waters in the pit area. These analyses are for Well RH 76-19 and Bucket Auger Hole #7 (Tables C1-16 and C1-17 of Appendix C). It is considered the best available estimate of the probable quality of the water to be disposed from the pit area dewatering activities. The suspended sediment (Nonfiltrable Residue) could be high and the chemical characteristics would likely be diluted whenever precipitation water made up a significant portion of the total.

This water, after passing through a settling pond, should be of acceptable quality for discharge to Hat Creek although it would be quite saline (TDS 1200 - 1600 mg/l) and contain some color (20 Pt-Co units). This water may also contain some biodegradable materials (BOD_5 of Coal Seam Water was 7 mg/l); however, Hat Creek should provide a satisfactory dilution (5-10:1) even at low flow. This source would add about 10 kg per day (25 lb per day) of BOD_5 which would be about 10 percent of the total future assimilative capacity of Hat Creek at low flow. This water may also contain elevated levels of ammonia from blasting residuals. Comparison of Coal Seam ground water indicates all parameters to be within regulatory guidelines for discharge excepting sulphate (260 mg/l versus guideline for Level A of 50 mg/l).

Lake dewatering proposed includes draining Finney and Aleece Lakes. The impact of this activity regarding water quality could result from highly enriched water drained from the bottom of these lakes into Hat Creek. Timing of these dewaterings would appear to be the critical factor. Draining during a period such as spring would allow considerable dilution potential in Hat Creek. Otherwise, it may be desirable to allow evaporation of the last portions of water from the lakes. It is not possible to predict the exact quality to be expected based on existing data. It is known only that the dissolved oxygen level in Finney Lake near the bottom (1.0 mg/l: Figure 4-47) is indicative of an enriched environment at this level.

Coal Stockpile

The proposed coal stockpile near the mine mouth is estimated to contain approximately 1.0×10^6 tonnes (1.1×10^6 tons) of coarse uncrushed coal on a site covering approximately 8 ha (20 acres). The quantity of runoff and leachates (which eventually become surface drainage from coal piles located on impermeable base material) depends on the amount of precipitation which falls onto the pile. This precipitation is then divided into runoff and infiltration into the pile. The literature indicates that the runoff and leachate collection and treatment systems are commonly designed on the basis of a certain storm precipitation ranging from the ten year 1 hour rainfall to the twenty-five year 15 day rainfall.[50,51,52] In the case of Hat Creek if a reasonable design storm basis of ten year 24 hour storm (35 mm) is utilized and assuming 80 percent direct runoff, the quantity of wastewater to be handled from a 8 ha (20 acre) coal pile would be 2300 m^3 (600,000 USG). If this quantity is equalized and distributed over a one day period, the discharge flow would be 0.03 $m^3 \cdot s^{-1}$ (420 USGPM).

Under normal conditions, however, it is likely that runoff and leachates would be non-existent as the average short duration rainfall would likely be totally infiltrated into the coal pile and would subsequently evaporate. It is however, necessary that the treatment system be designed to handle extreme cases such as indicated above. The runoff from the coal pile will be collected in ditches and directed to the "nearest lagoon" according to the project description.

In order to assess the impact of the discharged wastewater, the quality of the effluent must be examined. Leachates tests conducted by others were examined as well as evidence presented in the available literature; leachates are considered the worst case for runoff water qualities.

The coal to be stockpiled during the construction phase will be from Zone A primarily. According to information given in the various project documentation this coal would contain approximately 0.60 percent Total Sulphur on a dry basis. Assuming approximately 30 percent of the sulphur is present as pyrite[53], the total pyrite sulphur available for potential acid production is 0.18 percent. Based on the following equation[52]; the acid potential can be predicted in terms of acidity expressed as $CaCO_3$:

$$FeS_2 + 3.75O_2 + 3.5H_2O = Fe(OH)_3 + 2H_2SO_4$$

The calculated value of potential acidity is 5600 mg/kg of coal expressed as $CaCO_3$. The leachate tests conducted by others,[34] as shown in Tables 6-15,16,17,18 indicates a total extractable alkalinity (as $CaCO_3$) of 1850 mg/kg. The Rate of Release leachate tests conducted on the Coal A indicate a cumulative extracted alkalinity of 1263 mg/kg. This comparison indicates a fairly high potential for acid generation in the coal pile and the possibility of high levels of heavy metal and undesirable dissolved ions. Other evidence exists which indicates further detailed study is necessary on this subject. The leachate tests conducted to date were not designed to assess acid generation potential in that they were tests on unweathered material and of too short a duration to allow acid producing bacteria to develop. Work on Hat Creek coal by others[54] indicated surface coal samples reduced the pH of distilled water to values of 3.7 - 4.5 while core samples of Hat Creek coal did not change the pH to acidic conditions.

There are basically four types of pyrite occurring in coal strata; these are in turn related to the paleo environment of the host strata.[55] Fine grained pyrite ($<$ 10 microns) occurs either as crystals where pyramid like forms can be discerned or as spherical clusters of 0.5 micron particles called framboidal pyrite. The former, although averaging about 2 microns or less, is stable whereas the latter, the framboidal type is extremely reactive, readily oxidized, and accounts for the high degree of acidity found in mine drainages. Coarse grained pyrite ($>$50 microns) occurs as joint coatings, plant tissue replacements and layers, within sections. These types of pyrites are relatively stable, i.e., they do not readily oxidize, and the slight amount of acidity they produce can be readily neutralized by the alkalinity available in the ground water regime. The presence of trace amounts of titanium may act as a negative catalyst while trace amounts of silver may act as a positive catalyst.

Western coals are not normally known for acid problems because of low sulphur and that drainage is usually alkaline.[52,56,57] However, this depends on the neutraliza-

TABLE 6-15

TOTAL EXTRACTABLE SALTS TEST RESULTS*
COALS A, B & C (LOW, MEDIUM AND HIGH HEATING VALUE)

Parameter		Coal A (Low HV)	Coal B (Medium HV)	Coal C (High HV)
pH		7.1	7.0	7.4
Suspended Solids		2010	640	1000
Total Filterable Residue		2940	3500	3700
Alkalinity as $CaCO_3$		1850	1750	1080
Chloride	-Cl	220	200	80
Fluoride	-F	1.2	1.4	< 0.4
Nitrate-Nitrogen	-N	24	21	2
Nitrite-Nitrogen	-N	6	< 0.4	< 0.4
Total Kjeldahl Nitrogen	-N	9	13	21
Biochemical Oxygen Demand (5-day)		1400	1250	1520
Chemical Oxygen Demand		1840	1840	2940
Ortho-Phosphate - Phosphorus	-P	3.0	3.0	3.6
Sulphur	-S	96	160	420
Aluminum	-Al	10	20	12
Arsenic	-As	0.6	0.4	0.8
Boron	-B	1.0	1.0	1.0
Cadmium	-Cd	< 0.08	< 0.08	< 0.08
Calcium, Hard as $CaCO_3$		80	90	60
Chromium	-Cr	1.0	< 1	< 1
Copper	-Cu	7.0	5.0	6.5
Iron	-Fe	40	30	32
Lead	-Pb	< 3	< 3	< 3
Lithium	-Li	0.3	0.3	0.6
Magnesium, Hard as $CaCO_3$		80	86	100
Mercury	-Hg	0.004	0.006	0.008
Selenium	-Se	0.6	0.6	0.6
Sodium	-Na	980	975	920
Strontium	-Sr	< 4	< 4	< 4
Vanadium	-V	0.2	0.2	0.2
Zinc	-Zn	8.4	7.2	15.0

Data from Acres Consulting Services Ltd.

* Except for pH, all units are mg/kg, indicating milligrams extracted per kilogram of dry solids.

TABLE 6-16

RATE OF RELEASE TEST RESULTS*
COAL A (LOW BTU)

Parameter		Individual Extract					Cumulative Extract				
		Day 1	Day 2	Day 3	Day 4	Day 5	Day 1	Day 2	Day 3	Day 4	Day 5
Volume of Extract	- ml	128	275	92	200	300	128	403	495	695	995
pH		6.95	7.5	7.65	7.35	7.45					
Suspended Solids	- mg/l	289	84	74	55	58	209	149	135	112	96
Total Filterable Residue	- mg/l	2560	570	310	190	150	2560	1202	1036	793	593
Specific Conductance	- μmho/cm	1900	410	215	156	115					
Alkalinity as $CaCO_3$	- mg/kg	606	367	63	107	120	606	973	1036	1143	1263
Chloride	- mg/kg	63	55	6	7	2	63	118	124	131	133
Fluoride	- mg/kg	0.04	-	-	-	-	0.04	-	-	-	-
Nitrate-Nitrogen	- mg/kg	6.0	7.3	1.2	2.7	1.0	6.0	13.3	14.5	17.2	18.2
Ortho-Phosphate - Phosphorus	- mg/kg	0.26	0.55	0.12	0.27	0.40	0.26	0.81	0.93	1.20	1.60
Sulphur	- mg/kg	12.5	20.7	3.9	3.6	4.0	12.5	33.2	37.1	40.7	44.7
Arsenic	- mg/kg	0.03	-	-	-	-	0.03	-	-	-	-
Boron	- mg/kg	0.26	-	-	-	-	0.26	-	-	-	-
Cadmium	- mg/kg	< 0.002	-	-	-	-	• 0.002	-	-	-	-
Calcium, Hard as $CaCO_3$	- mg/kg	9.1	15.9	0.8	1.3	3.0	9.1	25.0	25.8	27.1	30.1
Chromium	- mg/kg	0.21	0.00	0.03	0.05	0.06	0.21	0.29	0.32	0.37	0.43
Copper	- mg/kg	2.05	0.27	0.15	0.17	0.26	2.05	2.32	2.47	2.64	2.90
Iron	- mg/kg	2.8	2.5	0.8	1.2	1.5	2.8	5.3	6.1	7.3	8.8
Lead	- mg/kg	0.02	-	-	-	-	0.02	-	-	-	-
Magnesium, Hard as $CaCO_3$	- mg/kg	14.5	16.8	3.8	5.6	10.8	14.5	31.3	35.1	40.7	51.5
Mercury	- mg/kg	0.002	-	-	-	-	0.002	-	-	-	-
Sodium	- mg/kg	314	213	36	48	50	314	527	563	611	661
Vanadium	- mg/kg	< 0.01	-	-	-	-	< 0.01	-	-	-	-
Zinc	- mg/kg	0.18	0.01	0.01	0.01	0.01	0.18	0.19	0.20	0.21	0.22

Additional Data:

		Individual Extract		
		Day 6	Day 7	Day 8
Volume of Extract	- ml	200	230	298
pH		7.0	7.3	7.2
Suspended Solids	- mg/l	43	49	39
Specific Conductance	- μmho/cm	73	75	76

Weight of Sample:	150 g
Particle Size:	2 mm x 0.6 mm
Packed Column Length:	20 cm
Water Required for Saturation:	60 ml
Average Temperature:	22° C

Data from Acres Consulting Services Ltd.

* Except where noted, results are expressed in units of mg/kg, indicating milligrams extracted per kilogram of dry solids. Individual results are shown for extracts collected after successive 24-hour periods and cumulative figures are calculated from individual results. A dash (-) indicates that the parameter was not analysed.

TABLE 6-17

RATE OF RELEASE TEST RESULTS*
COAL B (MEDIUM BTU)

Parameter	Unit	Individual Extract Day 1	Individual Extract Day 2	Individual Extract Day 3	Individual Extract Day 4	Individual Extract Day 5	Cumulative Extract Day 1	Cumulative Extract Day 2	Cumulative Extract Day 3	Cumulative Extract Day 4	Cumulative Extract Day 5
Volume of Extract	- ml	94	137	300	410	254	94	231	531	941	1195
pH		7.2	7.95	7.45	7.0	7.05					
Suspended Solids	- mg/l	187	261	18	5	6	187	231	111	65	52
Total Filterable Residue	- mg/l	2735	1025	512	297	287	2735	1721	1038	715	624
Specific Conductance	- µmho/cm	1925	850	350	175	135					
Alkalinity as $CaCO_3$	- mg/kg	338	320	420	246	119	338	658	1078	1324	1443
Chloride	- mg/kg	33	9	16	6	3	33	42	58	64	67
Fluoride	- mg/kg	0.06	-	-	-	-	0.06	-	-	-	-
Nitrate-Nitrogen	- mg/kg	3.5	3.7	3.0	2.7	0.8	3.5	7.2	10.2	12.9	13.7
Ortho-Phosphate - Phosphorus	- mg/kg	0.13	0.14	0.40	0.55	0.34	0.13	0.27	0.67	1.22	1.56
Sulphur	- mg/kg	13.3	11.1	13.4	6.3	4.4	13.3	24.4	37.8	44.1	48.5
Arsenic	- mg/kg	0.01	-	-	-	-	0.01	-	-	-	-
Boron	- mg/kg	0.19	-	-	-	-	0.19	-	-	-	-
Cadmium	- mg/kg	< 0.02	-	-	-	-	< 0.02	-	-	-	-
Calcium, Hard as $CaCO_3$	- mg/kg	15.2	10.5	12.4	7.4	6.3	15.2	25.7	38.1	45.5	51.8
Chromium	- mg/kg	0.05	0.21	0.05	0.08	0.05	0.05	0.26	0.31	0.39	0.44
Copper	- mg/kg	2.19	0.01	0.02	0.02	0.01	2.19	2.20	2.22	2.24	2.25
Iron	- mg/kg	0.6	0.4	0.8	0.7	0.3	0.6	1.0	1.8	2.5	2.8
Lead	- mg/kg	< 0.02	-	-	-	-	< 0.02	-	-	-	-
Magnesium, Hard as $CaCO_3$	- mg/kg	11.5	19.7	10.0	8.7	3.6	11.5	31.2	41.2	49.9	53.5
Mercury	- mg/kg	0.003	-	-	-	-	0.003	-	-	-	-
Sodium	- mg/kg	179	174	202	112	49	179	353	555	667	716
Vanadium	- mg/kg	< 0.01	-	-	-	-	< 0.01	-	-	-	-
Zinc	- mg/kg	0.08	0.02	0.02	0.03	0.01	0.08	0.10	0.12	0.15	0.16

Additional Data:

Parameter	Unit	Individual Extract Day 6	Individual Extract Day 7	Individual Extract Day 8
Volume of Extract	- ml	197	175	160
pH		7.05	7.0	7.2
Suspended Solids	- mg/l	8.3	0.0	0.0
Specific Conductance	- µmho/cm	135	105	75

Weight of Sample:	150 g
Particle Size:	2 mm x 0.6 mm
Packed Column Length:	20 cm
Water Required for Saturation:	80 ml
Average Temperature:	22° C

Data from Acres Consulting Services Ltd.

* Except where noted, results are expressed in units of mg/kg, indicating milligrams extracted per kilogram of dry solids. Individual results are shown for extracts collected after successive 24-hour periods and cumulative figures are calculated from individual results. A dash (-) indicates that the parameter was not analysed.

TABLE 6-18

RATE OF RELEASE TEST RESULTS*
COAL C (HIGH BTU)

Parameter		Individual Extract Day 1	Day 2	Day 3	Day 4	Day 5	Cumulative Extract Day 1	Day 2	Day 3	Day 4	Day 5
Volume of Extract	- ml	165	218	305	500	500	165	383	688	1188	1688
pH		5.0	6.25	6.8	6.35	6.7					
Suspended Solids	- mg/l	253	36	12	2	1	253	129	77	46	32
Total Filterable Residue	- mg/l	1658	853	287	92	80	1658	1200	795	499	375
Specific Conductance	- µmho/cm	1310	590	180	74	48					
Alkalinity as $CaCO_3$	- mg/kg	297	320	189	100	67	297	617	806	906	973
Chloride	- mg/kg	44	9	8	7	7	44	53	61	68	75
Fluoride	- mg/kg	0.22	-	-	-	-	0.22	-	-	-	-
Nitrate-Nitrogen	- mg/kg	0.3	0.3	0.2	0.3	0.3	0.3	0.6	0.8	1.1	1.4
Ortho-Phosphate - Phosphorus	- mg/kg	0.11	0.15	0.21	0.33	0.33	0.11	0.26	0.47	0.80	1.13
Sulphur	- mg/kg	46.9	19.2	10.5	13.3	13.3	46.9	66.1	76.6	89.9	103.2
Arsenic	- mg/kg	0.04	-	-	-	-	0.04	-	-	-	-
Boron	- mg/kg	0.11	-	-	-	-	0.11	-	-	-	-
Cadmium	- mg/kg	< 0.0022	-	-	-	-	< 0.0022	-	-	-	-
Calcium, Hard as $CaCO_3$	- mg/kg	15.1	7.3	5.3	15.0	12.3	15.1	22.4	27.7	42.7	55.0
Chromium	- mg/kg	0.06	0.03	0.03	0.05	0.04	0.06	0.09	0.12	0.17	0.21
Copper	- mg/kg	2.09	0.04	0.03	0.03	0.03	2.09	2.13	2.16	2.19	2.22
Iron	- mg/kg	1.1	1.4	0.9	0.7	0.3	1.1	2.5	3.4	4.1	4.4
Lead	- mg/kg	< 0.022	-	-	-	-	< 0.022	-	-	-	-
Magnesium, Hard as $CaCO_3$	- mg/kg	18.9	19.2	21.2	17.3	10.3	18.9	38.1	59.3	76.6	86.9
Mercury	- mg/kg	0.002	-	-	-	-	0.002	-	-	-	-
Sodium	- mg/kg	191	148	86	53	27	191	339	425	478	505
Vanadium	- mg/kg	< 0.011	-	-	-	-	< 0.011	-	-	-	-
Zinc	- mg/kg	0.01	0.03	0.09	0.07	0.07	0.01	0.04	0.13	0.20	0.27

Additional Data:

		Individual Extract Day 6	Day 7	Day 8
Volume of Extract	- ml	195	500	255
pH		6.7	6.95	6.95
Suspended Solids	- mg/l	0.0	0.0	0.0
Specific Conductance	- µmho/cm	51	64	66

Weight of Sample:	150 g
Particle Size:	2 mm x 0.6 mm
Packed Column Length:	20 cm
Water Required for Saturation:	80 ml
Average Temperature:	22° C

Data from Acres Consulting Services Ltd.

* Except where noted, results are expressed in units of mg/kg, indicating milligrams extracted per kilogram of dry solids. Individual results are shown for extracts collected after successive 24-hour periods and cumulative figures are calculated from individual results. A dash (-) indicates that the parameter was not analysed.

tion potential, the length of storage, and potential establishment of acid producing bacteria.

Given the previous information, it is not possible to state with any certainty whether drainage from the coal pile will be acidic or alkaline in nature except to say that evidence appears to support the possibility that weathered coal does have potential for acid generation. Table 6-19 lists the probable range of raw wastewater quality for both alkaline and acid drainage from surface coal mining operations. Estimates of the leachate quality from the Rate of Release Tests at the lowest pore volume detention time tested, simulating the probable worst wastewater quality from the coal pile during the "flush phenomena" effect of a quite prolonged rainstorm, assuming acid conditions do not develop, are shown in Table 6-20.

Comparison of the coal pile drainage quality figures with Ministry of the Environment Guidelines[58] Table 6-21, considering the proposed treatment of discharging through a lagoon, indicate the following:

1. If the wastewater is similar to that projected from the Rate of Release tests, the following components of the effluent would be above levels allowed for fresh-water discharges -

   Chromium
   Copper
   Iron
   Mercury*

2. If the wastewater is comparable to the average from alkaline mine operations in the USA (Table 6-19), the following constituents would be above acceptable levels.

   Iron
   Manganese
   Ammonia
   Sulfate*

3. If the wastewater is comparable to average acidic type drainage, the effluent would not meet any of the required objectives and will require extensive treatment.

The suspended solids level in the raw coal pile drainage could range from 0-700 mg/l and would be substantially reduced by plain sedimentation in a lagoon. It is unlikely, however that the required level of 50 mg/l would be met at all

*Guidelines are subject to review. See Table 6-21.

TABLE 6-19

RAW MINE DRAINAGE CHARACTERISTICS - SURFACE MINES

ALKALINE

Parameter	Minimum (mg/l)	Maximum (mg/l)	Mean (mg/l)	Std. Dev.
pH (units)	6.2	8.2	7.7	
Alkalinity	30	860	313	183
Total Iron	0.02	6.70	0.78	1.87
Dissolved Iron	0.01	2.7	0.15	0.52
Manganese	0.01	6.8	0.61	1.40
Aluminum	0.10	0.85	0.20	0.22
Zinc	0.01	0.59	0.14	0.16
Nickel	0.01	0.18	0.02	0.04
TDS	152	8,358	2,867	2,057
TSS	1	684	96	215
Hardness	76	2,900	1,290	857
Sulphate	42	3,700	1,297	1,136
Ammonia	0.04	36	4.19	6.88

RAW MINE DRAINAGE CHARACTERISTICS - SURFACE MINES

ACID OR FERRUGINOUS

Parameter	Minimum	Maximum	Mean	Std. Dev.
pH (units)	2.6	7.7	3.6	
Alkalinity	0	184	5	32
Total Iron	0.08	440	52.01	101
Dissolved Iron	0.01	440	50.1	102.4
Manganese	0.29	127	45.11	42.28
Aluminum	0.10	271	71.2	79.34
Zinc	0.06	7.7	1.71	1.71
Nickel	0.01	5	0.71	1.05
TDS	120	8,870	4,060	3,060
TSS	4	15,878	549	2,713
Hardness	24	5,400	1,944	1,380
Sulphate	22	3,860	1,842	1,290
Ammonia	0.53	22	6.48	4.70

From EPA, May, 1976. Development Document For Interim Final Effluent Limitations Guidelines And New Source Performance Standards For Coal Mining.

TABLE 6-20

COAL LEACHATE CHARACTERISTICS*

Sample:	COAL A	COAL B	COAL C
Parameters (mg/l)			
pH (units)	6.95	7.2	5.0
Filterable Residue (105°C)	2560	2735	1658
BOD_5**	1219	977	681
Alkalinity (as $CaCO_3$)	710	540	270
Chloride	74	52	40
Fluoride	0.05	0.1	0.2
Nitrate - N	7.0	5.3	0.3
O-phos. - P	0.3	0.2	0.1
Sulphur	14.65	21.3	42.6
Arsenic	0.03	0.02	0.04
Boron	0.3	0.3	0.1
Cadmium	<0.002	<0.002	<0.002
Calcium (as $CaCO_3$)	10.7	24.2	13.7
Chromium	0.25	0.075	0.05
Copper	2.4	3.5	1.9
Iron	3.3	0.9	1.0
Lead	<0.02	<0.02	<0.02
Magnesium (as $CaCO_3$)	17.0	18.3	17.2
Mercury	0.002	0.005	0.002
Sodium	368.2	286	174
Vanadium	<0.01	<0.01	<0.01
Zinc	0.213	0.125	0.125

*At low pore volume displacement (See Table 6-9 for example calculation).

**Estimated by BEAK utilizing BOD of Total Extractable Tests and multiplying by ratio of Filterable Residue extracted in 24 hours to Total Extractable Filterable Residue.

From Acres Consulting Services Limited. March 1977. Leachate Data.

TABLE 6-21

Objectives for Effluent Discharges

Characteristics	Description	Unit of Measurement	Fresh-water Discharge		
			Level A	Level B	Level C
Total suspended solids (non-filterable residue)	That portion of the effluent, as discharged which is retained by an approved filter	mg/l	50[1]	150[1]	([2])
Total dissolved solids (filterable residue)	That portion of the effluent as discharged which passes through an approved 0.45-micron pore-sized filter	mg/l	<2,500	<3,500	<5,000
Colour[3]	Colour of the effluent, at the point of discharge	Approved units	....	....	....
pH[3]	The pH of the effluent at the point of discharge	pH units	6.5–8.5[4]	6.5–9.5	6.0–10
Specific elements and compounds[1]	Material contained in the effluent, at the point of discharge, which passes an approved 0.45-micron pore-sized filter (except where total values are required)	....	....	———	———
Aluminum (Al)	Dissolved in the effluent	mg/l	0.50	1.00	10.00
Ammonia (as N)	Dissolved in the effluent	mg/l	0.50[4]	1.00	10.00
Antimony (Sb)	Dissolved in the effluent	mg/l	0.05	0.25	1.00
Arsenic (As)	Dissolved in the effluent	mg/l	0.05	0.25	1.00
Cadmium (Cd)[5]	Dissolved in the effluent	mg/l	0.005	0.01	0.02
Chromium (Cr)	Dissolved in the effluent	mg/l	0.05	0.30	0.50
Cobalt (Co)	Dissolved in the effluent	mg/l	0.10	0.50	1.00
Copper (Cu)	Dissolved in the effluent	mg/l	0.05	0.30	1.00
Cyanide (CN)	Total cyanide in the effluent	mg/l	0.10	0.50	2.00
Fluoride (F)	Dissolved in the effluent	mg/l	2.50	5.00	15.00
Iron (Fe)	Dissolved in the effluent	mg/l	0.30	1.00	5.00
Lead (Pb)	Dissolved in the effluent	mg/l	0.05	0.10	0.50
Manganese (Mn)	Dissolved in the effluent	mg/l	0.05	0.50	1.50
Magnesium (Mg)	Dissolved in the effluent	mg/l	150	300	500
Mercury (Hg)	Total in the effluent	mg/l	0.001[4]	0.003	0.01
Molybdenum (Mo)	Dissolved in the effluent	mg/l	0.50[4]	1.00	10.00
Nickel (Ni)	Dissolved in the effluent	mg/l	0.30	0.50	1.00
Nitrates/Nitrites (as N)	Dissolved in the effluent	mg/l	10.00	25.00	50.00
Phosphate (as P)	Total in the effluent	mg/l	2.00	5.00	10.00
Selenium (Se)	Dissolved in the effluent	mg/l	0.05	0.10	1.00
Silver (Ag)	Dissolved in the effluent	mg/l	0.10	0.50	1.00
Sulphate (SO_4)	Dissolved in the effluent	mg/l	50[4]	250	1,000
Uranyl (UO_2)	Dissolved in the effluent	mg/l	2.00	5.00	10.00
Zinc (Zn)	Dissolved in the effluent	mg/l	0.50	5.00	10.00
Oil and Grease	Total in the effluent	mg/l	15.00	15.00	15.00

NOTE—Acceptable concentrations for characteristics not appearing in this list are to be determined as required. When all liquids are totally recycled, the applicability of the above objectives will be assessed.

[1] Initially, semiquarterly sampling on effluents and at control and test stations in receiving-waters; quarterly sampling on effluent discharged to closed systems.
[2] Daily sampling.
[3] To be reviewed.
[4] Tentative, subject to review.
[5] Subject to review where applied to smelters.

times. Metry, A.A. et al[52] indicate gravity settling of Western coal storage runoff did not meet EPA's effluent discharge criteria of 15 mg/l suspended solids and that chemically-aided settling of coal fines could be effective using a combination of lime and polymer. Further, sludge from the clarification system cannot be thickened by gravity but must be chemically assisted. Coal pile drainage also contains biodegradable organics as indicated by the leachate test data. (Extractable BOD_5 = 1400 mg/kg). Assuming BOD_5 is extracted at the same rate as dissolved solids, the BOD_5 concentration of coal pile leachate could be as high as 1200 mg/l. Discharge of this quality of effluent would not be possible. This aspect is discussed in more detail in Section 6.2 (b) (iii) A.

Low Grade Waste Stockpile

The low grade waste stockpile would begin to be developed in the construction phase. The size during this phase could reach 12 ha (30 acres). It is assumed that this material would be placed in a side hill non-impounding embankment since the project descriptions do not indicate a retaining structure. It could be expected that this stockpile would exist in an unsaturated condition and be unlikely to produce any continuous leachate seepage. The only leachates expected would be during spring snowmelt runoff and during rainstorms.

The leachate test data produced by others[33] is shown in Tables 6-22 and 6-23.. Table 6-24 indicates the leachate quality at low pore volume displacement, which is considered to represent the worst case, assuming the low grade waste does not develop acid drainage characteristics in the long term. There are some indicators that point to possible acid drainage. Analysis of low grade waste for others[33] by the B.C. Department of Agriculture indicated a low pH (pH 5.0) of the wastewater solution. The neutralizing capacity of the extractable alkalinity in the low grade waste (3120 mg/kg) is such that it could theoretically offset the acid potential of the waste only if it contains less than 0.10 percent pyritic sulphur The actual pyritic sulphur is not presented in the project information available for this assessment. The quantity of runoff water from the pile for design pur-

TABLE 6-22

TOTAL EXTRACTABLE SALTS TEST RESULTS* LOW GRADE COAL WASTE

Parameter		Low Grade Coal Waste
pH		7.85
Suspended Solids		1650
Total Filterable Residue		5320
Alkalinity as $CaCO_3$		3120
Chloride	-Cl	380
Fluoride	-F	1.5
Nitrate-Nitrogen	-N	19
Nitrite-Nitrogen	-N	9
Total Kjeldahl Nitrogen	-N	12
Biochemical Oxygen Demand (5-day)		520
Chemical Oxygen Demand		950
Ortho-Phosphate - Phosphorus	-P	5.0
Sulphur	-S	224
Aluminum	-Al	25
Arsenic	-As	0.8
Boron	-B	1.0
Cadmium	-Cd	< 0.08
Calcium, Hard as $CaCO_3$		600
Chromium	-Cr	< 1
Copper	-Cu	6.0
Iron	-Fe	76
Lead	-Pb	< 3
Lithium	-Li	0.6
Magnesium, Hard as $CaCO_3$		540
Mercury	-Hg	0.006
Selenium	-Se	0.9
Sodium	-Na	1280
Strontium	-Sr	< 4
Vanadium	-V	0.3
Zinc	-Zn	15.0

Data from Acres Consulting Services Ltd.

* Except for pH, all units are mg/kg, indicating milligrams extracted per kilogram of dry solids.

TABLE 6-23

RATE OF RELEASE TEST RESULTS*
LOW GRADE COAL WASTE

Parameter		Individual Extract					Cumulative Extract				
		Day 1	Day 2	Day 3	Day 4	Day 5	Day 1	Day 2	Day 3	Day 4	Day 5
Volume of Extract	- ml	222	59	101	125	175	222	281	382	507	682
pH		7.8	8.5	8.9	8.65	7.6					
Suspended Solids	- mg/l	81	225	154	90	28	81	111	123	115	92
Total Filterable Residue	- mg/l	1520	690	958	72	70	1520	1346	1243	954	728
Specific Conductance	- µmho/cm	865	460	650	72	50					
Alkalinity as $CaCO_3$	- mg/kg	872	197	214	24	50	872	1069	1283	1307	1357
Chloride	- mg/kg	89	10	15	4	9	89	107	122	126	135
Fluoride	- mg/kg	0.18	-	-	-	-	0.18	-	-	-	-
Nitrate-Nitrogen	- mg/kg	5.3	1.1	0.4	0.1	0.2	5.3	6.4	6.8	6.9	7.1
Ortho-Phosphate - Phosphorus	- mg/kg	0.33	0.12	0.20	0.19	0.18	0.33	0.45	0.65	0.84	1.02
Sulphur	- mg/kg	22.2	3.0	2.4	3.0	3.0	22.2	25.2	27.6	30.6	33.6
Arsenic	- mg/kg	0.1	-	-	-	-	0.1	-	-	-	-
Boron	- mg/kg	0.27	-	-	-	-	0.27	-	-	-	-
Cadmium	- mg/kg	< 0.005	-	-	-	-	< 0.005	-	-	-	-
Calcium, Hard as $CaCO_3$	- mg/kg	83.3	23.0	43.4	17.1	21.9	83.3	106.3	149.7	166.8	188.7
Chromium	- mg/kg	0.44	0.05	0.05	0.04	0.12	0.44	0.49	0.54	0.58	0.70
Copper	- mg/kg	5.44	0.06	0.02	0.16	0.04	5.44	5.50	5.52	5.68	5.72
Iron	- mg/kg	12.7	2.2	1.1	0.3	1.2	12.7	14.9	16.0	16.3	17.5
Lead	- mg/kg	< 0.05	-	-	-	-	< 0.05	-	-	-	-
Magnesium, Hard as $CaCO_3$	- mg/kg	75.9	10.6	18.9	31.1	7.2	75.9	86.5	105.4	136.5	143.7
Mercury	- mg/kg	0.004	-	-	-	-	0.004	-	-	-	-
Sodium	- mg/kg	593	81	11	4	19	593	674	685	689	708
Vanadium	- mg/kg	< 0.022	-	-	-	-	< 0.022	-	-	-	-
Zinc	- mg/kg	0.28	0.03	0.04	0.04	0.05	0.28	0.33	0.37	0.41	0.46

Additional Data:

		Individual Extract		
		Day 6	Day 7	Day 8
Volume of Extract	- ml	250	275	175
pH		7.25	7.2	7.4
Suspended Solids	- mg/l	31	40	37
Specific Conductance	- µmho/cm	46	43	21

Weight of Sample:	100 g
Particle Size:	2 mm x 0.6 mm
Packed Column Length:	11 cm
Water Required for Saturation:	30 ml
Average Temperature:	22° C

Data from Acres Consulting Services Ltd.

* Except where noted, results are expressed in units of mg/kg, indicating milligrams extracted per kilogram of dry solids. Individual results are shown for extracts collected after successive 24-hour periods and cumulative figures are calculated from individual results. A dash (-) indicates that the parameter was not analysed.

TABLE 6-24

PROJECTED LOW GRADE LEACHATE CHARACTERISTICS

Parameters (mg/l)	
pH (units)	7.8
Filterable Residue Dried at 105 degrees C	1520
BOD_5**	148
Alkalinity (as $CaCO_3$)	393
Chloride	40
Fluoride	0.08
Nitrate - N	2.4
O-phos. - P	0.15
Sulphur	10.0
Arsenic	0.06
Boron	0.12
Cadmium	0.002
Calcium (as $CaCO_3$)	37.5
Chromium	0.2
Copper	2.45
Iron	5.7
Lead	0.02
Magnesium (as $CaCO_3$)	34.02
Mercury	0.002
Sodium	267
Vanadium	0.01
Zinc	0.125

*At low pore volume displacement (See Table 6-9 for example calculation)

**Estimated by BEAK utilizing BOD of Total Extractable Tests and multiplying by ratio of Filterable Residue extracted in 24 hours to Total Extractable Filterable Residue.

From Acres Consulting Services Limited. March 1977. Leachate Data.

poses based on a ten year 24 hour storm (35 mm) and assuming an 80 percent direct runoff would be 3400 m^3 (1,400,000 USG) or 0.04 $m^3 \cdot s^{-1}$ (980 USGPM). Project descriptions indicate runoff would be directed through lagoons (No. 5 and then No. 4) prior to discharge to Hat Creek in the diversion channels. If the quality of the effluent is as listed in Table 6-24, the following chemical parameters would be above Level A requirements considering the physical treatment proposed:

Arsenic
Chromium
Copper
Iron
Mercury*

It should be noted that as the runoff quality is considered to be the same as the leachate quality, the estimates for dissolved parameter levels is probably conservatively high. The level of suspended solids in the untreated runoff would be several hundred milligrams per liter, however, this would be reduced through treatment in the settling lagoons. The chemical constituents in the runoff from the low grade waste are, excepting arsenic, the same parameters that could be present in elevated levels from the coal pile runoff (see Section 6.2 (b) (ii) A).

The level of biodegradable organics could be substantial in the runoff and based on the flow from the storm utilized and projected BOD_5, could add about 800 kg (1700 lb) of BOD to Hat Creek. Color of the runoff would also be expected to be elevated due to the fact that the low grade waste is, in effect, low grade coal. It would appear from the predictions that the proposed physical treatment will be inadequate and either more extensive treatment is required or other means of disposal such as total containment and evaporation or reuse by irrigation may be required.

*Guideline is subject to review. See Table 6-21.

Other Activities

Construction of the mine substation, roads and conveyors could be expected to alter some surface area, thus increasing the disturbed area subject to erosion and sediment loss to runoff.

Dust control is considered a major beneficial activity as it will minimize dust fallout and subsequent washout due to precipitation. The literature indicates the potential for fugitive dust generation from a coal mining operation from drilling, blasting, hauling, loading, unloading and crushing operations at about 3.3 kg per tonne of coal produced.[36]

Estimates specific to the Hat Creek project by others,[25] also indicates the extent of dust problems to be expected with a projection at 0.24 kg per tonne of coal (2400 tonnes of particulates during the year of peak activity) presumably with dust control measures. While the quantity of this material which may end up in the surface water runoff is not predictable, the majority will undoubtedly fall within drainage areas from which runoff is to be treated in sedimentation ponds.

B. Plant

Ash Disposal

The main activities which would cause interactions with the surface water quality are clearing and stripping, embankment and creek diversion construction, base preparation and construction of drainage ditching and sedimentation ponds. It is not possible to predict the level of sediment which will reach the main surface watercourses (Medicine Creek and Hat Creek). If the wet ash pond in Medicine Creek is selected as the disposal method, it will likely be necessary to avoid construction activities during spring runoff. Provided all construction area runoff is treated via settling lagoons to the prescribed levels (50 mg/l in the pond effluent and maximum change in receiving stream turbidity of 5 APHA units), the impact would be acceptable from a water quality viewpoint. It is not possible to assess the design of runoff control and treatment systems due to the lack of conceptual design information on these items in the project descriptions.

Water Supply Reservoir

Clearing, stripping, embankment construction and base preparation activities will generate dust and surface areas subject to erosion and sediment loss. Construction sediment control systems will be necessary to protect Medicine Creek water quality.

Other Activities

At the plant site considerable grading, clearing, stripping, excavation and fill, drainage ditching, lagoon and road construction activity will occur. These activities through disturbances of ground cover and dust generation have the potential to cause impact on the physical quality of Harry Creek and Medicine Creek surface water via erosion and sediment loss. Sediment control facilities will be necessary to protect these tributaries of Hat Creek.

The disposal method for sewage from the shops, office and construction warehouses has not been established. The quantity could be about 500 $m^3 \cdot d^{-1}$ (130,000 USGPD). Considering the size of the creeks near the plant site, having extremely limited dilution and assimilative capacity, it would not be advisable to discharge treated sewage. Total containment in an aerobic lagoon with ultimate disposal by evaporation or possibly coupled with irrigation would appear to be the most desirable methods to avoid impact on surface water quality of area watercourses.

The concrete batch plant will be provided with a closed circuit water system utilizing a sedimentation pond. Thus there would be no interaction or impact on surface water quality from this activity.

C. Offsites

Hat Creek Diversion

Construction of the Hat Creek diversion will entail clearing, stripping, excavation, fill, embankment and access road construction. The total disturbed area including reservoirs (base case) is about 46 ha (115 acres) assuming the reservoir bases are stripped of topsoil. These activities expose barren soils to the process of erosion. In addition the construction activities cause fugitive dust subject to precipitation washout. Little detail is provided in the project descriptions on the strategies to be used to minimize these interactions with surface water quality. It will be necessary, however, that all runoff from construction areas be controlled, collected and treated to appropriate levels (50 mg/l of suspended solids and maximum change in receiving water turbidity of + 5 APHA units) to avoid serious impact on Hat Creek water quality. Construction of the reservoirs and discharge conduit plunge pool within the existing creek bed would likely be done during summer low flow period. However, at low flow the creek is least able to cope with sediment due to its then low carrying capacity. Sediment will tend to settle out in the first few kilometers having potential of silting up trout spawning areas and smothering creek benthos. Low flow periods will require extremely good erosion control to protect downstream creek values.

Main Access Road

Construction of the main access road will entail such activities as clearing, stripping, excavation, fill, borrow areas, culvert installation and drainage ditching, disturbing a total of 100 - 120 ha (250 - 300 acres) between Ashcroft and the plant and mine site. The road crosses surface streams and creeks nine (9) times. It will be necessary to control erosion related sediment loss and fugitive dust, particularly at crossing of Cornwall Creek because of existing domestic water uses. Normal road construction sediment control measures will be necessary to protect surface water quality.

Cooling Water Supply System

Construction of the 23 km (14 miles) of pipeline, pump stations, access road and Thompson River intake will disturb about 38 ha (97 acres) of terrain. Activities such as clearing, stripping, trench excavation, blasting and spoil disposal have potential to cause erosion and fugitive dust related sediment loss to surface drainages. Extra precautions to avoid impact from sediment entering the creek will be necessary at the Cornwall Creek and Bonaparte River crossings. Attention to construction timing will be necessary at the Thompson River intake construction site and at the Bonaparte River pipeline crossing due to anadromous fish migration and spawning.

Provided precautions are taken, impact on water quality should be of short duration. The level of physical water quality impairment due to construction is not predictable. Provided regulatory levels are met for discharge of suspended solids and allowable increases in receiving water turbidity, the impacts would be minor.

Airport and Offloading Facilities

The activities of clearing, stripping, base preparation and construction of drainage control will expose areas to possible erosion and a certain amount of fugitive dust will occur. The areas involved are 24 ha (60 acres) at the airport site and about 3 ha (7.5 acres) at the offloading site. These sites have not been studied in the inventory program. Impact on water quality due to sediment loss would likely be minor providing normal construction sediment loss procedures are utilized. The sites for the airport (A and C) being considered appear to be away from significant developed surface runoff systems, thus sediment loss should not be difficult to control.

(iii) Operation

A. Mine

Blasting

The explosive ANFO will probably be used where practical and where moisture conditions will allow. This explosive consists of ammonium nitrate pellets which are coated with diesel fuel. When these pellets get wet, they tend to deform into a sludge that will not explode on detonation. When the moisture content of the pellets exceeds about 8 percent by weight, explosion will not occur.

Since ammonium nitrate is highly soluble in water, use of ANFO may result in nutrient discharge in mine waters and subsequent increased algal and weed growth in Hat Creek. The main potential for contamination of water courses would be from ANFO spillage during handling, blast-hole loading and from misfired charges during the blast. Some contamination would also result from the common practice of flushing away partially used explosives instead of returning them to explosive storage.[59] Normal safety practice requires that all misfired charges be completely washed from the blast-hole[59]; such practices would increase the likelihood of ammonium nitrate discharges.

Pollution of mine water by ammonium nitrate from ANFO can be minimized by the following measures:

(a) strong packaging of ANFO
(b) careful handling and loading of material
(c) total return of unused explosives to the storeroom
(d) use of plastic liners in bore holes to minimize exposure of ANFO to moisture
(e) use of less soluble water gel type explosives in wet sections of the mine

Little information is available to predict the seriousness of mine water pollution from ammonium nitrate type explosives. However, ammonia nitrogen (includes ammonium) concentrations of about 5 mg/l have been observed in mine waters at one site.[60]

Ammonium nitrate is toxic to fish at about 1000 ppm.[61]

Dewatering

The degree of dewatering increases substantially in the operation phase to about 30 $l \cdot s^{-1}$ (500 USGPM) from dewatering wells and from mine seepage. A further 9 - 125 $l \cdot s^{-1}$ (150 to 2080 USGPM) will require pumping from the pit at times due to direct precipitation into the pit area. Project descriptions indicate these waters will be pumped to a lagoon (Lagoon #1) for treatment prior to discharge to Hat Creek downstream of the mine. As indicated in Section 6.2 (b) (ii), the best estimate of probable quality of this water is that it will contain high levels of dissolved solids (1200 - 1600 mg/l), some color (20 Pt-Co units) and some biodegradable organics (BOD_5) similar to the water quality of Inventory pit area wells sampled (Well RH 76-19 and Bucket Auger Hole #7: Tables C1-16 and C1-17 of Appendix C). The suspended solids level in the raw mine water could be high and the chemical constituents would be diluted wherever precipitation waters made up a significant portion of the total. After passing through a settling basin the level of suspended solids would be reduced. However, color, BOD_5 and ammonia (latter from blasting residuals) will not change appreciably by sedimentation treatment alone. Assuming a dilution in Hat Creek at low flow (about 3:1), the color addition could cause a minor aesthetic impact while the BOD_5 addition of about 20 kg per day (50 lb per day) could reduce the dissolved oxygen level in future Hat Creek to less than 5 mg/l. The ammonia level could also be substantially above regulatory levels (0.50 mg/l). Sulfates may also be considerably above current regulatory levels (50 mg/l). Table 6-25 lists the projected quality of this water based on limited inventory information.

TABLE 6-25

PROJECTED MINE WATER QUALITY*

Parameter (mg/l)	Value
pH (units)	7.5
Filterable Residue	1400
BOD_5	3.5
Alkalinity	870
Chloride	4
Fluoride	0.2
Nitrate (as N)**	< 0.06
Kjeldahl Nitrogen (as N)**	14.0
Ortho Phosphate (as P)	< 0.03
Sulfate	140
Arsenic	< 0.009
Boron	< 0.05
Cadmium	< 0.005
Calcium (as $CaCO_3$)	120
Chromium	< 0.010
Copper	< 0.006
Iron	< 0.08
Lead	< 0.015
Magnesium (as $CaCO_3$)	128
Mercury	< 0.0003
Sodium	315
Vanadium	< 0.05
Zinc	1.0

*Based on the average of Well RH76-19 and Bucket Auger Hole #7 as given in Tables C1-16 and C1-17 of Appendix C.

**Not including any contribution from blasting residuals.

Overburden Dumps

The overburden dumps excepting the North Valley dump, are of retaining embankment type. Excepting the faces of the retaining embankments, overburden will not be subject to significant reclamation and revegetation until completion of mining. Thus the entire dump surfaces (excluding embankments) will be subject to precipitation runoff and sediment loss. Due to the short contact time of precipitation runoff, the major water quality parameter of concern during storm periods will be suspended solids. The level of suspended solids in the runoff is not predictable as there are many variables. Mean values ranging from about 0 - 1300 mg/l during baseline conditions to values ranging from 250 - 3900 mg/l during rain events have been observed by others in studies of sedimentation ponds at surface mining operations.[62] Under normal circumstances of low precipitation in the Hat Creek Valley, there will be insignificant runoff from the dumps. Under these conditions the only waters to contend with are seepage from the toe drains of the dumps. The quality of these flows, as predicted in Table 6-9 of Section 6.2 (a) (iii) A, could contain elevated dissolved solids and metals such as arsenic, chromium, copper, and iron. Treatment by sedimentation alone would not be expected to reduce levels of dissolved metals. Without additional treatment, considering the dilution provided by Hat Creek (3:1) at low flow, the impact on water quality of the creek would be high. It appears that treatment to reduce heavy metals to regulatory levels will be necessary.

During a storm event the quantity of surface runoff to be treated will be of considerable magnitude. Assuming a ten year 24 hour rainstorm as the design basis, (Note: Environmental Protection Agency of the USA require no treatment limitations for runoff in excess of that produced by a ten year 24 hour precipitation event) a runoff coefficient of 0.6 and rainfall of 35 mm, the quantity of runoff from the two main dumps would be as follows:

	Area-ha	Runoff m^3
Houth Meadows Dump	608	128,000
Medicine Creek Dump	482	101,000

As presently laid out the lagoons servicing the Houth Meadows (3 lagoons) and the Medicine Creek dumps (1 lagoon) will also intercept surface runoff from undisturbed areas as well as from the dump areas. This arrangement does not provide the best approach to erosion sediment loss control as the lagoons are in effect "in-stream" facilities. Lagoons of a "dedicated" nature are considered by industry and regulatory authorities to function better and of course can be smaller in size. Further discussion of the design criteria and efficiency to be expected is included in this Section under Drainage Control And Lagoons.

Coal Stockpile

The volume of coal to be stored at the mine mouth facility will be 0.9×10^6 tonnes (1.0×10^6 tons) of crushed blended coal and the uncrushed coal pile developed during construction phase will gradually be reclaimed. The area of the coal piles at maximum will be about 28 ha (70 acres). Since the coal will be crushed to 3 cm size and compacted it will be somewhat more resistant to precipitation infiltration. The average sulphur content of the pile will probably be about 0.45 percent (wet basis). Similar calculations to those presented in Section 6.2 (b) (ii) A on acid potential based on pyrite content indicate an equivalent acidity of 5015 mg/kg of coal as $CaCO_3$. The average neutralizing capacity of the extractable alkalinity based on leachate tests by others is 1560 mg/kg. The coal usage rate of the plant is about 420 $kg \cdot s^{-1}$ (1660 tons/hour) which translates to a possible coal stockpile turnover rate of about 14 days. It is not known if this storage time is within the time frame required for weathering and acclimation of acid producing bacteria resulting in possible acid drainage during "flushing" by a prolonged rainfall. The following subsection discusses sulphide oxidation in some detail in an attempt to assess the probability of acid drainage production.

Sulphide and reduced sulphur compounds can be either chemically or biologically oxidized to sulphuric acid. The biological mechanism is generally believed to be predominant.[63,64] The major sulphur oxidizing bacterium is Thiobacillus ferroxidans which is capable of directly oxidizing dissolved and undissolved reduced sulphur compounds and ferrous iron. For example, the complete biological oxidation of pyrite results in the formation of two moles of sulphuric acid per mole of pyrite:

$$4FeS_2 + 15O_2 + 14H_2O \rightarrow 4Fe(OH)_3 + 8H_2SO_4$$

The amount of acid formed will vary with the nature of the sulphide mineral. With regard to the dissolved components, acid may result from the chemical or biological oxidation of ferrous iron or reduced sulphur compounds. In the oxidation of ferrous iron, there is a net gain of two moles of hydrogen ion per mole of ferrous iron:

$$2Fe^{2+} + \tfrac{1}{2}O_2 + 2H^+ \rightarrow 2Fe^{3+} + H_2O$$

$$2Fe^{3+} + 6H_2O \rightarrow 2Fe(OH)_3 + 6H^+$$

With reduced sulphur compounds, the amount of acid released would depend on the species present and the mode of oxidation:

$$S_2O_3^{2-} + 2O_2 + H_2O \rightarrow 2SO_4^{2-} + 2H^+$$

$$S_4O_2^{2-} + 3\tfrac{1}{2}O_2 + 3H_2O \rightarrow 4SO_4^{2-} + 6H^+$$

For the sulphur oxidizing bacteria to thrive they require an acidic medium, the presence of dissolved oxygen, nutrients and favourable temperature. As a rule, sulphur oxidation occurs only to a slight degree in polar areas.[65] If sulphur oxidation does occur, the eventual pH is dependent on the acid consuming ability of the effluent which is due to the alkalinity and the precipitated carbonate species.

Rivett and Oko[66] also found that the factors influencing the formation of sulphuric acid were determined to be sunlight, temperature, pH and the presence of sulphur for oxidizing bacteria.

Kuznetsov et al[65] discuss factors affecting the oxidation of sulphide ores. They state that the susceptibility to bacterial or chemical oxidation is dependent on the type of sulphide present. Apparently, the oxidation is also influenced by the solubility of the resulting sulphate.

Singer and Stumm[67] investigated the chemical oxidation of iron pyrite (FeS_2). They concluded that ferric ion is required in this oxidation according to the following sequence:

$$Fe^{3+} + FeS_2 + 4O_2 \longrightarrow Fe^{2+} + 2SO_4^{2-}$$

The oxidation of Fe^{2+} is the rate limiting step. The chemical oxidation of Fe^{2+} is very slow and bacteria are needed to accelerate this rate.

Chen and Morris[64] found that the kinetics of the chemical oxidation of dissolved sulphide is complicated. There is a complex dependence on the sulphide to oxygen ratio and this ratio combined with pH can be critical with regard to the product formed. Catalysts (eg. heavy metal ions) also play an important role.

The pH of natural waters is largely regulated by its alkalinity. Carbon dioxide and the three forms of alkalinity (CO_3^{2-}, HCO_3^-, OH^-) are all part of one system that exists in equilibrium according to the following equations:

$$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons HCO_3^- + H^+$$

$$M(HCO_3)_2 \rightleftharpoons M^{2+} + 2HCO_3^-$$

$$HCO_3^- \rightleftharpoons CO_3^{2-} + H^+$$

$$CO_3^{2-} + H_2O \rightleftharpoons HCO_3^- + OH^-$$

A change in the concentration of any one species will cause a shift in the equilibrium and result in a change in pH. Conversely, a change in pH will shift the equilibrium. If, for example, a quantity of acid is discharged into a water system containing solid calcium carbonate, this will lead to dissolution of the calcium carbonate which will neutralize the acid and establish a new position of equilibrium. The restraint to an alkaline pH is the large reservoir of carbon dioxide in the atmosphere. Stumm and Morgan[68] discuss this equilibrium quite extensively.

Considering the short period of storage of the crushed blended coal pile (assuming a turnover time of 14 days), it is unlikely that significant weathering of the coal or development of acid producing bacteria would occur. On this basis, the quality of drainage is projected as being alkaline and of a nature and quality as previously listed in Table 6-19 (Alkaline Drainage) and Table 6-15(Coal A, B and C) of Section 6.2 (b) (ii) A. As stated in that Section, problems are projected in meeting all current regulating guideline levels with treatment proposed in the project description documents. Total containment or additional treatment appears necessary.

As estimated earlier, the BOD_5 of the coal pile runoff could range as high as 1200 mg/l, if contact time was 24 hours. Based on a nomograph solution for time of concentration in the commonly used Rational Method for estimating runoff, the contact time, assuming the majority of precipitation remains as surface flow over the pile, would be in the order of 10 to 15 minutes[69] for the proposed coal pile. Some of the precipitation will percolate into the pile and flush out materials previously dissolved in the moisture within the coal pile.

The quantity of runoff and leachate from the crushed coal pile could probably be about 8000 m^3 (2.1×10^6 USG) during a ten year 24 hour storm or about 0.09 $m^3 \cdot s^{-1}$ (1500 USGPM). This quantity may seem high, however it was noted during a visit to the Centralia Steam-Electric Plant at Centralia, Washington that runoff from a 32 ha (80 acres) coal storage area has reached peaks of 0.25 $m^3 . s^{-1}$ (4000 USGPM) which is then directed to treatment.[34] Anderson, W.C. et al[50] studied a coal pile and found about 12 litres of water per tonne of coal was required for a complete flushing of the pile.

It is thus difficult to predict the BOD_5 level to be expected in the effluent. Assuming 80 percent surface runoff and 20 percent percolation and contact for upwards of 12 hours and a straight line time proportional BOD extraction rate, the combined effluent would contain in the order of 130 mg/l. If the effluent from such a storm runoff were discharged to Hat Creek, the potential BOD_5 load would be in the order of 1500 kg.

Data reported herein with respect to the inventory of current water quality indicate that the waters of Hat Creek are usually almost saturated with dissolved oxygen. If conditions suitable for the continued well-being of rainbow trout are an objective for Hat Creek, the dissolved oxygen concentration must be maintained at 5 mg/l or greater.[61,70]

Methods used for predicting the effect of discharged biochemical oxygen demand (BOD) on the dissolved concentrations in receiving waters are approximate and have some deficiencies. Nonetheless, the Streeter/Phelps equation[70] was used to calculate the quantities of BOD that could be discharged to Hat Creek, while maintaining the concentration of dissolved oxygen at 5 mg/l or greater. This equation involves the use of two important coefficients, the value of which had to be assumed, based on related experience elsewhere.

Temperature predictions associated with the diversion of Hat Creek indicate that at the two-year-return minimum flow of 0.12 $m^3.s^{-1}$, the temperatures in lower Hat Creek could be as high as 40^oC, under extreme weather conditions. With a flow of 0.12 $m^3.s^{-1}$ and a temperature of 40^oC, the maximum allowable discharge of BOD_5 would be about 20 $kg{\cdot}day^{-1}$, for maintenance of 5 mg/l dissolved oxygen.

For a BOD_5 discharge of 80 $kg{\cdot}day^{-1}$ or higher, the creek would be septic, with no dissolved oxygen; foul odours would result.

If the temperature of the water from the diversion channel was 25^oC, rather than 40°C, the maximum allowable discharge of BOD_5 would be approximately 100 $kg \cdot day^{-1}$, based on a flow of 0.12 $m^3 \cdot sec^{-1}$, and a minimum allowable dissolved oxygen concentration of 5 mg/l.

During the freshet in June, the flow in Hat Creek could be about 2.8 $m^3 \cdot sec^{-1}$ with a temperature of approximately 8°C. Under these conditions, about 17,500 $kg \cdot day^{-1}$ of BOD_5 could be discharged, while maintaining a minimum dissolved oxygen concentration of 5 mg/l in Hat Creek. The discharge of 17,500 $kg \cdot day^{-1}$ of BOD_5 into Hat Creek during June would lower the dissolved oxygen levels in the Bonaparte River by about 1 mg/l. This estimate is based on a June flow in the Bonaparte River of 14 $m^3 \cdot sec^{-1}$, a temperature of about 11°C, normal BOD_5 concentrations less than 1 mg/l, up-stream dissolved oxygen levels at saturation and a travel time of 12 hours in the Bonaparte River. The effect of the BOD on the Thompson River would be insignificant, because of extensive dilution. If discharges of BOD_5 to Hat Creek were restricted to maintain a minimum concentration of dissolved oxygen of 5 mg/l in Hat Creek, the impact of the discharged BOD_5 on the Bonaparte River would be insignificant.

As indicated by the foregoing discussion, discharge of 1500 kg of BOD_5 from the coal pile drainage would not be possible during normal summer flows in Hat Creek without severe impact on the water quality. Containment or additional treatment thus appears necessary for this runoff source.

Low Grade Waste Stockpile

The area of the low grade waste stockpile at maximum size is projected at 127 ha (317 acres). It is assumed to be a side hill non-impounding embankment. The quantity of runoff from the pile based on a ten year 24 hour rainstorm (35 mm) and an 80 percent runoff coefficient would be about 36000 m^3. Runoff from the stockpile is scheduled to be routed through two lagoons (No. 5 and No. 4) prior to discharge to Hat Creek. As indicated in Section 6.2 (b) (ii) the quality of this runoff after removal of settleable solids in the basins could contain elevated levels of arsenic, chromium, copper iron, organics (BOD_5) and color based on the leachate data on this material.

It is thus concluded that further treatment beyond sedimentation will be necessary for any runoff from this stockpile otherwise positive discharge should not be considered in order to avoid impacting water quality in Hat Creek.

Drainage Control And Lagoons

Surface mining operations have the potential to generate large volumes of sediment. As long as the sediment generated is contained on the mine site, it does not present a problem. However, if it washes into watercourses, the sediment can have several detrimental effects; some of the effects are listed in a report by the U.S. Environmental Protection Agency.[20] The first step in controlling the discharge of sediment is to use mining practices which minimize erosion; the EPA report discusses these practices. The second step is to use sedimentation basins to remove settleable particles from surface waters, as close as possible to the sediment source. The basins should intercept drainage ways before they meet the main stream; off-stream sedimentation ponds are more effective than on-stream ponds, which keep streams turbid for long periods following a storm.[71] The U.S. Soil Conservation Service suggests that sedimentation basins have a volume of at least 380 m^3 per hectare of disturbed area in the drainage basin.[20] However, a study of nine basins designed by this criteria revealed that during a storm, the suspended solids removal efficiency could drop from a normal level of about 90 percent to a value as low as 35 - 50 percent.

The approach that best ensures that the performance of a sedimentation basin will be adequate to meet water quality criteria is based on consideration of the overflow velocity and the critical settling velocity of the smallest particles that are to be removed. Settling conditions should be as ideal as possible; turbulence should be minimized and the entrance and exit effects should be minor. The EPA report[20] discusses several measures which can be used to improve pond efficiency. For example, short circuiting is minimized with a length-to-width ratio of about five. Also, two or more ponds in series, instead of one larger basin covering the same area, increase overall removal efficiency.

If the inflow of a settling basin has a high proportion of fine-grained sediments (silt and clay), there may not be enough land area available to construct a settling basin of the size required to obtain the desired water quality. In such a situation, it may be necessary to add coagulants to increase sedimentation efficiency. Coagulants which have been demonstrated to be effective for clarification of mine waters include lime and high-molecular-weight polyelectrolytes.[62] If coagulant addition is contemplated, consideration should be given to the possible effects of the coagulant on downstream water quality in Hat Creek and the Bonaparte River.

The most important maintenance problem associated with sedimentation basins is the removal of accumulated sediment. Accumulation of sediment in the basin reduces the retention time for runoff thereby reducing particle removal efficiency. The highest sediment loads are often observed during the first six months after mining begins.[20] Basins are usually cleaned out when half of the basin volume is occupied by sediment, or six months after the mining operation was started, whichever comes first. The sediment removed from the basin must be disposed in such a manner that it will not re-enter the surface drainage system during successive storms.

Reclamation

Throughout the life of the mine considerable reclamation will occur, mainly on the outer faces of retaining embankments in the early years followed by gradual reclamation of the top surfaces after mid point of mining. The total area of the Houth Meadows dump (608 ha: 1520 acres) and of the Medicine Creek dump (408 ha: 1204 acres) will have been reclaimed by the end of mining. Reclamation of the pit will not be possible until after cessation of mining.

Once the results of this activity begin to have an effect, the rates of soil erosion, chemical leaching and wind caused dust from previously disturbed areas will diminish to the benefit of both surface and subsurface water quality. In the case of the Hat Creek Project, due to the arid climate and the general lack of topsoils to utilize in top surfacing of spoil dumps, it will be necessary to utilize artificial fertilization and likely irrigation to expedite the revegetation process. This aspect of the reclamation activity is considered a potential negative impact on water quality. Loss of nutrients will raise the level of biological parameters (nitrogen and phosphorous) to levels which could foster algae and slime growth in Hat Creek. This impact is discussed further in Section 6.2 (b) (iv).

Infrastructure

Operation of the mine infrastructure includes only a few activities which are considered to pose potential minor negative impacts on surface water quality. These activities are operation of the coal crushing and blending plant, coal conveyors and coal haul roads. Operation of coal crushing and blending plant, including loading, unloading and crushing, could produce about 1.2 kg of fugitive dust and emissions per tonne of coal processed. An undeterminable portion of this dust will eventually settle on the area vegetation in summer and in the snow blanket in winter where it is subject to transport via rain runoff and snowmelt runoff. Provided surface drainage in the vicinity of this coal crushing and blending plant is routed through sedimentation basins the impact from this source will be minimized. Some fugitive dust emissions will also occur at coal transfer points (conveyors, stacker, reclaimer etc.) which, although controlled by emission control devices and other measures cannot be totally avoided. Runoff to Harry Creek which is near to the coal crushing and blending area may be subject to impact from coal fines. Consideration should be given to placing a settling basin on this creek to protect Hat Creek water quality.

B. Plant

Ash Disposal

The base case ash disposal system under consideration is a combined fly ash and bottom ash pond in Upper Medicine Creek. This pond would be retained behind an engineered embankment. The approximate size of the pond at maximum capacity would be about 440 ha (1,100 acres). Uncontaminated surface runoff from contributing drainage areas above the pond would be diverted around the pond.

The ash pond would be designed to have no discharge of effluent. Considering this factor, there is no direct interaction with surface water quality by the ash disposal scheme as precipitation falling onto the ash pond will be contained in the pond. Contaminated seepage through the retaining embankment, as discussed in Section 6.2 (a) (iii) B, should be collected and returned to the pond. Dusting around the edge of the ash pond is considered to pose a potential minor negative impact on water quality of Medicine Creek and MacLaren Creek. Diversion of intercepted runoff around the ash pond could cause additional sediment levels in creeks receiving the diverted waters. The project description indicates the diversion of some of these waters eastward into Cornwall Creek via MacLaren Creek. This could cause interaction with domestic water users in this watershed.

All waters collected below the existing Upper Medicine Creek diversion presumably would be conveyed westward to eventually be discharged into the Hat Creek main diversion canal. It is not certain whether it is intended to direct this runoff through the sedimentation lagoon at the base of the Lower Medicine Creek overburden dump. Should this turn out to be the case, the sedimentation basin would have to be sized accordingly and equipped such that flood flows could be bypassed to avoid flushing of collected sediment into Hat Creek.

The first alternate (Alternate I) ash disposal plan is placing fly ash in a 300 ha (750 acre) Upper Medicine Creek ash pond and bottom ash in a 152 ha (380 acre) Harry Lake dump. The water quality interactions for the fly ash pond in this alternate are the same as for the base case combined pond discussed previously. The bottom ash disposal dump would be constructed by slurrying bottom ash onto sloping ground and allowing natural separation. A system of berms and ditches and a basin would collect the drained waters for return to the plant for reuse in the ash system. This system of bottom ash disposal would preclude any reclamation of this dump during operation phase. The return water system would have to be designed to handle all precipitation and snowmelt runoff from the dump and contributing drainage area around the dump. Seepage through the collection dam would also have to be collected to avoid contamination of lower Harry Creek water quality. Assuming these actions are taken in the design and operation of the dump, there would effectively be no interaction with the surface waters outside the immediate area of the ash dump. Dusting should not be a problem from bottom ash as it is a considerably coarser material than fly ash.

Disposal of ash in dry dumps at Harry Lake area (Alternate II) would consist of disposal of wetted fly ash to a 190 ha (470 acre) dump while bottom ash would be dewatered either in-plant or in a small dewatering pond (3 month capacity) and then conveyed in a dewatered state to a 90 ha (230 acre) dump. The precipitation runoff from these dumps is dependent upon many factors including duration, runoff coefficient, size of disposal area, and slope.

As planned these dumps would be developed in sections such that as each section is completed it could be covered with topsoil and revegetated. The process will minimize the disturbed area subject to runoff,likewise the amount of contaminated runoff to be handled. Assuming the maximum disturbed area subject to direct precipitation runoff from a ten year - 24 hour rainstorm (35 mm) to be one half the eventual dump sizes and a runoff coefficient of 0.36, the quantity of runoff could be 12,100 m^3 from the fly ash dump and 5,700 m^3 from the bottom ash dump.

The quality of this water would be similar to that listed in Table 6-11 of Section 6.2 (a) (iii) B during dry periods when the seepage water constitutes the major portion. The quality during a rainstorm will be dependent on individual storm intensity and runoff volume. The shorter more intense rainstorm will cause the runoff to contain high levels of suspended solids and only moderate levels of dissolved solids. Longer duration low intensity rainfall will cause moderate levels of suspended solids and dissolved solids. The quality of ash pile runoff will most likely be of similar makeup as ash pile leachates excepting that levels of each parameter will be less on a concentration basis due to low contact time of runoff waters and the dilution effect. Fly ash suspended solids are very small in size and have poor settling characteristics. Bottom ash suspended solids are less soluble than fly ash, are larger and settle more rapidly.

The strategy to be used for disposal of runoff and leachates from the ash dumps in this alternate are not stated in the project descriptions. A water management study by others [38] however indicates a runoff holding pond would be included in the scheme with reuse of waters collected for ash dust control and presumably no positive discharge. This course of action would be necessary, given the extremely poor quality water to be expected from the ash dump, in order to protect uncontaminated natural runoff in both Medicine Creek and Harry Creek. The holding pond should be constructed with impervious material to minimize seepage.

<u>Coal Pile Storage</u>

Runoff and leachate from the coal pile (an Alternate) at the plant site, according to project descriptions, would be collected, routed to a holding basin and subsequently reused in the ash handling system. The quality of this water would be poor as discussed in Section 6.2 (b) (ii) A and 6.2 (b) (iii) A. Since there will be no positive discharge, there will be no interaction with uncontaminated surface waters in the plant site area.

Ash Sluice Water Treatment Sludge Disposal

The site for disposal of sludge from the ash pond recirculation water treatment plant has not been established. It is not possible to assess the possible impact of surface water quality without some basic information on the type of disposal method. If a pond storage system for disposal is utilized it will be necessary to insure isolation from interaction with uncontaminated surface runoff by means of dyking and diversion ditches. Disposal of this dewatered sludge in the alternate ash disposal scheme, as indicated in the water management study,[38] would be to bury with the fly ash in the dry fly ash dump. Leachates and runoff from this sludge would be highly alkaline, and be unlikely to contain significant dissolved metals. Provided runoff from the dump is contained and returned to the ash system, there should be no interaction or contamination of area surface waters.

FGD Sludge Disposal

Flue gas desulphurization is an alternate to a Meteorological Control System (MCS) for controlling ambient air sulphur dioxide levels. Sludge disposal from the process would require a fairly large site. If FGD is chosen, a separate environmental study would be conducted to examine all aspects, including assessment of interactions with surface water quality.

Plant Operation

The proposed "no liquid discharge" mode of operation and minimization of wastewater production by recycling of effluents for reuse will reduce the conflict and interactions of the development with the water resource and environment in general. Since there will be no direct discharge of plant wastewaters to the creeks and streams of the Hat Creek Valley, there will be no direct impact on water quality of these resources from this source. Experience elsewhere[34] indicates that "no liquid discharge" is difficult to meet in practise when all factors including contaminated precipitation runoff, seepages and leachates, are considered.

All sources such as these must eventually be carefully considered by the designers in the water balance of the power plant, otherwise an excess of water results. Disposal methods such as evaporator trains[72,73] or direct discharge to the surface water environment may then be necessary.

Particulate and sulphur dioxide emissions from the power plant have been estimated by others[25] to be 79×10^3 tonnes and 9.7×10^3 tonnes per year, respectively. The impact of particulate fallout in the Hat Creek watershed and of any sulphur dioxide acid rain potential is not addressed in this assessment. There will undoubtedly be an increase in the dustfall level in the valley from particulate emitted by the plant. Some of this will fall directly on water bodies and a portion of the remainder will be subject to washout by precipitation and snowmelt.

Other Activities

Operation of creek diversions around the ash disposal site can be expected to contribute some sediment loss to the runoff during spring freshet. The levels of sediment are not predictable and are flow and velocity dependent. It will be important to ensure sediment losses are low during nonfreshet conditions as it is during this period that Hat Creek will be most susceptible and have the least sediment carrying capacity.

Reclamation during the operation phase of the power plant would be carried out on the retaining embankment faces and dry ash dumps (should this alternate be selected). This activity will produce a positive impact on water quality by reducing disturbed areas. Addition of fertilizers however, can be expected to contribute some nutrient loss to the watershed. Nutrient loss during reclamation is discussed in more detail in Section 6.2 (b) (iv).

C. Offsites

Hat Creek Diversion
Canal and Reservoir Temperature Predictions

Information available on normal water temperatures in Hat Creek is restricted to a limited number of spot checks at two stations[74]. In mid-summer, the water temperature at Station 08LF061, near the proposed mine, is usually between 10°C and 15°C. The highest observed water temperature at this sampling station is 18°C, with a corresponding flow of 0.11 $m^3 \cdot s^{-1}$. Further downstream at Station 08LF015, near the Bonaparte River, mid-summer temperatures in Hat Creek are usually between 15°C and 20°C, the highest observed temperature being 24°C.

The diversion of Hat Creek would raise water temperatures because the surface area exposed to solar radiation would increase significantly. Methods available for predicting temperature changes in running and standing waters are approximate and have many deficiencies. Nonetheless, estimates were made of the maximum water temperatures expected at the downstream end of the diversion canal on a clear, hot, humid, still, mid-summer day, for two situations. The first situation, referred to as the base case, involves a 7.3 ha reservoir with a maximum storage of about 220,000 m^3 and no flow regulation. Downstream of the reservoir is a 7,000 m diversion canal, followed by a 2100 m discharge conduit. The canal considered was that proposed in the September 1977 Hat Creek Project Description: a trapezoidal canal with a 3.7 m base. The second situation, referred to as the water supply alternate, involves addition of a 120 ha reservoir upstream from the 7.3 ha reservoir. This large reservoir would have a sufficient storage to maintain a minimum flow of 0.23 $m^3 \cdot s^{-1}$ in the diversion canal and provide an average flow of 0.45 $m^3 \cdot s^{-1}$ for water supply.

Predictions of water temperature were based on a method outlined by Velz and Gannon[75] with appropriate modifications. The calculations considered solar insolation, radiation from the water to the atmosphere, convective heat transfer between the water and the air, and evaporation from the water surface. In absence of required information, it was necessary to make several assumptions, some of which are important to the results of the calculations:

1. Water could take six hours to travel the length of the diversion channel (7000 m).

2. No conductive heat transfer between the water and the channel bed. In reality, heat would be transferred from the water to the channel bed during the warmer part of the day, and in the opposite direction at other times.[76]

3. No shading of the diversion channel by trees or topography between 9 a.m. and 3 p.m. solar time.

4. 90 percent of incident solar radiation absorbed by the water, the balance being reflected at the water surface. At a flow of about 0.1 $m^3 \cdot s^{-1}$, the water depth in the diversion canal would be about 10 cm. This shallow water depth may result in a reduced level of solar energy absorption because some of the radiation would be reflected off the channel bottom.[77]

5. Harry, Finney, Lloyd and Ambusten Creeks would be dry and the flow in Medicine Creek would be 0.003 $m^3 \cdot s^{-1}$, at 14°C. Flow from the pit rim reservoir would be insignificant.

6. Meteorological conditions:

   (a) Solar radiation incident on a horizontal surface varying from 3.27 $MJ \cdot hr^{-1} \cdot m^{-2}$ at noon to 2.55 $MJ \cdot hr^{-1} \cdot m^{-2}$ three hours before and after noon.

   (b) Air temperature varying from 15°C at 9 a.m. to 35°C at 3 p.m.

   (c) Absolute humidity (partial pressure of water vapour) 13.5 mm Hg from 9 a.m. to 3 p.m.

(d) Wind speed varying from 6.4 $km \cdot hr^{-1}$ at 9 a.m. to 1.6 $km \cdot hr^{-1}$ at 3 p.m.

These conditions are considered extremes for the area.

For the base case, a flow of 0.12 $m^3 \cdot s^{-1}$ was used for temperature calculations in the diversion channel. This flow is the two-year-return flow at Station 08LF061 on Hat Creek. At this flow, the water temperature at the end of the diversion channel was calculated as about 40°C, almost independent of the water temperature at the beginning of the channel. At 40°C, the water in the channel would be close to thermal equilibrium with the prevailing environmental conditions.

For the water supply alternative, the water temperature at the end of the diversion channel could be as high as 35°C, based on a flow of 0.23 $m^3 \cdot s^{-1}$ and a temperature of 20°C at the beginning of the channel.

Since the calculated increases in water temperature in the diversion channel were considerable, no effort was made to estimate the effects of the impoundments on water temperature. However, surface water temperatures in lakes, creeks and canals in the interior of British Columbia seldom exceed 25°C.[74] Therefore, 25°C would likely be the maximum temperature expected for water leaving either of the two proposed reservoirs. If the diversion design was altered to reduce water temperature increases to minimum levels, a more serious examination of the effect of any impoundments on water temperature would be warranted.

Mid-summer water temperatures in an evaporation pan at Summerland[78] have been in the range of 32° - 35°C on several occasions and the maximum observed temperature in recent years is 37°C. Although the water in the pan is stagnant, the information indicates that the calculated temperatures of 40°C and 35°C, at the end of the diversion channel, are realistic as potential maximums.

Temperatures in Hat Creek below the diversions would likely be less than the temperature in the diversion channel, for several reasons:

(a) There would be some evaporative cooling in the plunge pool at the bottom of the discharge conduit.

(b) Tributaries to Hat Creek would bring some cooler water to be mixed with upstream water.

(c) Evaporative cooling and back radiation would be more significant relative to solar insolation than was the case in the diversion channel.

It is difficult to quantify these effects so it must be assumed, as a worse case, that water temperatures of 40°C or 35°C could persist in Hat Creek down to the confluence with the Bonaparte River.

The ten-year-return flow in the Bonaparte River is about 5.5 $m^3 \cdot s^{-1}$ and the mid-summer water temperature at the confluence with Hat Creek could be as high as 20°C. Even if the temperature of water from Hat Creek were increased to 40°C, the temperature in the Bonaparte River would increase by only 0.5°F, at low flow.

The preferable water temperature for rainbow trout is 13°C and temperatures of about 25°C are lethal.[61] For common white suckers, the lethal temperature is about 31°C. Therefore, it is possible that diversion of Hat Creek through the proposed channel could make mid-summer water temperatures in the lower part of Hat Creek unsuitable for fish life. Furthermore, mid-summer water temperatures would be well in excess of the 15°C maximum temperature recommended for drinking water supplies.[79] While the calculations were approximate, it appears that the diversion of Hat Creek, as planned, would significantly raise the summer water temperatures in the lower part of Hat Creek. The high temperatures in Hat Creek would have minimal impact on the temperature of the Bonaparte River. Further study would be warranted to improve the reliability of the temperature predictions and to investigate methods to minimize water temperature increases in lower Hat Creek.

Hat Creek Diversion
Supersaturation of Nitrogen Gas in Lower Hat Creek

The diversion scheme proposed in the September 1977 Hat Creek Project Descriptions could result in supersaturation of nitrogen gas in the downstream waters of Hat Creek. Such supersaturation would represent a threat to fish.

Nitrogen supersaturation could result from both temperature increases in the diversion canal and the discharge of diverted waters from the conduit into a plunge pool.

Mid-summer increases in water temperature in the diversion canal would decrease the saturation concentration for nitrogen. Supersaturation of nitrogen would result and if the supersaturated gas did not transfer out of the water fast enough, the extent of nitrogen supersaturation in downstream Hat Creek waters could be significant. For example, if water saturated with nitrogen at 15°C was heated to 40°C, with no release of nitrogen gas, nitrogen concentrations of 140 percent of saturation would result.

When water is discharged into a plunge pool, there is considerable turbulence. As a result, air is entrained in the water and taken to various depths, where the increased pressure forces more nitrogen into solution than would be the case at the water surface. When the water returns to a point closer to the surface, the nitrogen concentrations in the water could be as much as 140 percent of those corresponding to saturation at the water surface. If the water were discharged, instead, into a stilling basin the potential for causing nitrogen supersaturation would be reduced but it would still exist, especially if water in the basin was reasonably deep and there was considerable turbulence.

The simplified examples illustrate that a more extensive examination of the problem appears warranted.

To avoid nitrogen supersaturation from the discharge of the diverted water, a long rock-covered slope resembling a steep creek bed is suggested. The system would be designed such that the kinetic energy of the diversion water could be dissipated on the rocks, with no pools or significant depth. The system would provide turbulent contact of the water with the surrounding atmosphere. As a result, any nitrogen supersaturation from the temperature increases in the channel would tend to be reduced by the enhancement of the transfer of nitrogen from the water to the air. Also, evaporative cooling would be enhanced, thereby reducing water temperature. The system would have to be designed to avoid erosion and to minimize problems associated with icing in the winter.

Main Access Road

The only water quality concerns relating to operation of the access road would be minor sediment loss from runoff concentration in ditches channeled into Cornwall Creek and possible excessive use of deicing products near creek crossings. Neither of these interactions are quantifiable but are considered minor negative potential impacts.

Cooling Water Supply System

Discharge of water treatment clarification plant sludge blowdown to the Thompson River will cause minor localized turbidity. The discharge point should be selected with care to avoid interaction with other intakes downstream and also to ensure acceptability by regulatory agencies concerned with fish spawning and rearing areas especially if in the future coagulants are found necessary at certain times of the year.

Discharge of pipeline drainage to Cornwall Creek and the Bonaparte River are proposed during line maintenance procedures. For discharge into Cornwall Creek it will be necessary to establish a controlled drainage rate below which turbidity levels do not disturb downstream domestic water users. Discharge to the Bonaparte River at too large a rate during salmon migration may cause fish disorientation problems. The project description indicates some chlorination for control of bacterial growth in the pipeline may be necessary. It is unlikely that the level of chlorine would be very high, however discharge of any chlorinated water may be objectionable from a fisheries viewpoint. Fisheries regulatory agencies should be consulted on both of these issues.

Offloading Facility And Airport

Operation of the offloading facility (not yet located) and the proposed airstrip should not cause any affect on surface water quality providing environmentally conscious decisions are made during design for disposal of sewage and refuse, control of runoff, and spill control if hazardous materials or liquids are to be used or handled.

(iv) Decommissioning

A. Mine

Reclamation of Disturbed Areas

In the reclamation of the land area during and following mining, the application of fertilizers will be required.[33] The fertilizer recommended for use[35] in this application is a composite fertilizer of the formulation 20-24-15 applied at a rate of 225 $kg \cdot ha^{-1}$. The loss of fertilizer due to ground water runoff can be approximately 17 percent for nitrogen and 2 percent for phosphorous.[80] Based on topography of the mine area, it may be anticipated that the majority of this runoff will eventually enter Hat Creek. The two possible extremes that may occur in the reclamation program are:

(1) A single application of fertilizer at the time of the first seeding.

(2) Annual application of fertilizer over all reclaimed land. Experience elsewhere[81] indicates that annual fertilization may be required for an indefinite period.

Based on these two cases and using the proposed reclamation plans provided in the project description,the average annual fertilizer application for the various stages of reclamation were calculated to be:

	Single Fertilization	Annual Fertilization
From startup to midpoint of mining	2,400 kg	20,300 kg
From midpoint to end of mine	13,100 kg	149,400 kg
From end of mine to 10 years after	54,900 kg	549,700 kg

The average flow rate of Hat Creek at the mouth based on existing flow data[82] is about 80,000 $m^3 \cdot d^{-1}$. Using this data the contribution from fertilizer to the nitrogen and phosphorous levels in Hat Creek may then be calculated and the percentage increase in these nutrients at various stages in the reclamation program determined. The results of calculations of fertilizer application for the two cases are shown in Table 6-26, and the potential addition of nutrients to Hat Creek for these two cases is as shown in Table 6-27.

From this data it may be seen that fertilization could cause a significant increase in the nutrient loading to Hat Creek even in the minimal case of a single application of fertilizer, particularly in the last stage of reclamation. This increase in nutrient loading will probably have the effect of markedly increasing plant life in the creek to its eventual detriment.

With respect to the Bonaparte River, if a dilution effect of 6:1 is assumed,[82] and using the base value of 0.27 mg/l for nitrogen and 0.039 mg/l for phosphorous, the percentage increase on the base value for single fertilizer addition during the period from end of mine to 10 years after would be 3.9 percent for nitrogen and 1.7 percent for phosphorous. It is not considered that this increase would exert any noticeable effect on the Bonaparte River. In the case of annual addition,

TABLE 6-26

CALCULATIONS OF FERTILIZER APPLICATIONS

Year	Area(ha)		Application (kg)	
	Average Per Year	Total	Average Per Year	Total
SINGLE FERTILIZATION APPLICATION				
1. Startup To Midpoint 1 - 16	10.7	170	2,400	38,400
2. Midpoint To End 17 - 32	58	932	13,100	209,300
3. End To 10 Years Later 33 - 42	245	2,446	54,900	549,400
ANNUAL FERTILIZATION APPLICATION				
1. Startup To Midpoint 1 - 16	90	170	20,300	325,900
2. Midpoint To End 17 - 32	745	1,102	149,400	2,392,400
3. End To 10 Years Later 33 - 42	2,448	3,549	549,700	5,497,900

TABLE 6-27

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ESTIMATED NUTRIENT ADDITION TO HAT CREEK FROM RECLAMATION FERTILIZATION

Period	Base Value	Fertilizer Addition	Total	% Increase on Base Value
1. From startup to midpoint of mining:				
Single Addition				
Nitrogen (N),mg/l	0.19	0.003	0.193	1.5
Phosphorous (P),mg/l	0.043	0.0002	0.043	0.4
Annual Addition				
Nitrogen (N),mg/l	0.19	0.023	0.213	12.3
Phosphorous (P), mg/l	0.043	0.001	0.044	3.4
2. From midpoint to end of mine:				
Single Addition				
Nitrogen (N),mg/l	0.19	0.015	0.205	7.9
Phosphorous (P),mg/l	0.043	0.001	0.044	2.2
Annual Addition				
Nitrogen (N),mg/l	0.19	0.172	0.362	90
Phosphorus (P),mg/l	0.043	0.011	0.054	25
3. From end of mine to 10 years after				
Single Addition				
Nitrogen (N),mg/l	0.19	0.063	0.253	33
Phosphorous (P),mg/l	0.043	0.004	0.048	9
Annual Addition				
Nitrogen (N),mg/l	0.19	0.063	0.822	333
Phosphorous (P),mg/l	0.043	0.039	0.082	91

however, the percentage increase on the base value would be 39 percent for nitrogen and 17 percent for phosphorous for the period from end of mine to 10 years after. This amount of increase could be detrimental to the Bonaparte River and if this pattern of fertilization was required, preventative measures would have to be implemented.

With respect to the Thompson River, if a further dilution effect of 175:1 is assumed,[82] and using the base value of 0.08 mg/l for nitrogen and 0.020 mg/l for phosphorous, the percentage increase on the base value for annual fertilizer addition during the period from end of mine to 10 years after would be 0.8 percent for nitrogen and 0.2 percent for phosphorous. It is not considered that this increase would exert any noticeable effect on the Thompson River.

Reclamation of the Pit

Reclamation of the pit would include recontouring of the pit slopes which will improve stability, drainage and aesthetics in addition to providing a suitable profile for a top dressing prior to revegetation activities. Exposed coal would be covered with sterile material to prevent spontaneous combustion. Subsequent to these preparations, the proposed strategy is to begin flooding of the pit with excess Hat Creek water over a period which could last as long as 26 years. Once the pit is filled to a predetermined level, all of Hat Creek would be redirected through the newly formed lake with the overflow channelled back to its original course downstream of the lake.

Creation of the lake is expected to have a positive effect on the physical water quality in that the lake would cause Upper Hat Creek to deposit its entire sediment load at all times of the year. This has other consequences on downstream Hat Creek stream morphology as discussed in Section 6.1 (b). This impoundment would increase water temperatures above normal temperatures in Hat Creek. Calculations were not made, but based on measurements of relevant surface water temperatures,[74] the temperature of water leaving the flooded pit could be as high as $25^{o}C$. The impact on physical water quality is thus considered ambivalent overall.

The effect of creating a lake on the chemical water quality is difficult to predict and it is recommended this aspect be studied further when more details are known of the probable top dressing materials. Water column studies should be undertaken to help predict the dissolved solids leaching rates from the proposed lake bottom sediments. Since the lake would be of substantial size and depth (335 ha. and 120 meters deep), it may be subject to thermal stratification and semi-annual turnover.[83]

The lake has the potential to be a "meromictic" lake, where a layer of water at the bottom is stabilized by dissolved solids or even suspended matter causing a permanent increase in density. This would be caused by leaching of dissolved material from the bottom sediments and from highly saline ground waters entering the bottom of the lake. Lake Mahony, near Okanagan Falls, is an example of a highly meromictic lake. The available leachate data on Hat Creek surficial and waste rock is not directly applicable to making predictions in a lake situation. If the lake were to be meromictic, this would be beneficial to water quality in the upper levels as turnovers would not mix the high-density highly-saline bottom waters with the remainder of the water column. Previous experience of flooding a similar large open pit coal mine was not found in the literature. In the Estevan area of Saskatchewan, water bodies of about 36 ha and 6 meters deep have been created within reclaimed coal mine spoil areas[84] and subsequently stocked with rainbow trout with apparent success. Data was not reported on water quality changes after flooding.

Runoff of nutrients from reclamation as indicated in the previous subsection will raise the nitrogen and phosphorous levels depending on the degree of fertilization. The project concentrations were 0.19 - 0.8 mg/l for nitrogen and 0.043 - 0.082 mg/l for phosphorous. These levels, even at the lowest values (existing Hat Creek water quality), are in the range generally accepted as being able to stimulate algae growth in lake waters (nitrogen above 0.1 mg/l and phosphorous above 0.01 mg/l).[85]

In summary, from a water quality viewpoint, the impacts of the proposed pit reclamation plans are considered to be mainly negative. The proposal should be examined in a thorough limnological assessment which is considered beyond the scope of this study.

Drainage Control

The plan to maintain creek diversions, drainage ditches and lagoons after phase out of the mine, is considered beneficial. These facilities will contain runoff and erosion, and minimize sediment losses.

Other Activities

Removal of mine infrastructure (buildings, conveyors, etc.) will undoubtedly cause some short-term area disturbances which would be subject to erosion. The impact of this decommissioning activity is considered minor negative.

B. Plant

Reclamation of Disposal Areas

The impacts of reclamation of disposal areas associated with the power plant would be the same as those discussed in Section 6.2 (b) (iv) A for reclamation of mine waste disposal areas.

Drainage Control

Continued existence of drainage facilities is considered a beneficial impact as these facilities will protect the integrity of waste dumps and control runoff erosion.

Other Activities

Minor impacts relating to sediment loss from short term area disturbances during removal of plant infrastructure (buildings, cooling towers, switchyard conveyors, etc.) can be expected to occur. It is assumed that the water supply reservoir would be left intact after phase out of the power plant. No interactions are visualized if this is done. Because the drainage area above the reservoir is minimal, this reservoir will eventually become dry through evaporation losses.

C. Offsites

Hat Creek Diversion

Decommissioning of Hat Creek diversion in association with creation of a lake in the pit is considered to offer both beneficial and negative impacts. Physical water quality in terms of temperature should improve somewhat over that which is projected to occur in the diversion canal at low flow. In addition, the newly created lake will reduce sediment load formerly carried in the canal from tributary streams (such as Medicine Creek and Houth Meadows area drainage). The chemical water quality impacts associated with decommissioning of the diversion are considered negative. This is due to the potential degradation of Hat Creek chemical water quality in passing through the lake as discussed previously. Continued existence of the reservoirs associated with the diversion (in Upper Hat Creek) is considered an ambivalent impact (both positive and negative effects). The reservoirs will reduce sediment levels in Hat Creek which is considered beneficial, while they will continue to cause water temperatures in the summer at higher levels than occur in the natural creek.

Cooling Water Supply System

Decommissioning of the water supply system is considered to have minor beneficial implications on water quality. Phase out will mean no further discharges of water treatment plant sludge to the Thompson River. In addition, the need of emergency drainages from the pipeline to both the Cornwall Creek and Bonaparte River will cease to exist. It is assumed that the pipeline itself would be left in place.

Other Activities

Significant impacts on water quality from decommissioning of 60 kV transmission lines and the offloading facilities are not visualized. The access road and airport are assumed to remain intact.

(v) Overall Impact Assessment

A. Preliminary Site Development

The activities during this stage of the project which could have affected surface water quality were the Bulk Sample Program, exploratory drilling, and access road construction. Surface water quality monitoring during this period has indicated a minimal effect on water quality. Should the project not proceed, reclamation would be implemented and thus no long-term impacts are foreseen. Thus, the impact on surface water quality at this stage is insignificant.

B. Construction

The main impacts to the surface water quality during construction of the mine will be:

1. An increase in the levels of non-filtrable residue and turbidity due to increased erosion caused by removing or destroying existing vegetative and soil cover.

2. An increase in the levels of filtrable residue, nutrients and colour due to pit dewatering activities.

The main source of possible impact to the surface water during construction of the plant and the offsite facilities will be increased non-filtrable residue and turbidity caused by erosion and precipitation washout of fugitive dust as a result of the clearing, stripping, etc., associated with construction activity. The effect of this will be controlled by collection of runoff and treatment in settling basins. The other source of possible impact during construction of the plant would be sewage from the shops, office and construction warehouses. This should be treated by total containment in an aerobic lagoon with ultimate disposal by evaporation, possibly coupled with irrigation. Provided regulatory levels for point source discharges and receiving streams are met, the impact on water quality would be minor.

C. Operation

The main impacts to surface water during operation of the mine and plant will be from:

1. Disposal of mine water from pit area dewatering.

2. Seepage and runoff from the Houth Meadows and Medicine Creek waste disposal areas.

3. Increased temperature in Hat Creek within the diversion canal during summer periods of low flow.

4. Sediment loss from intervening disturbed areas and fugitive dust precipitation washout.

5. Nutrient loss from fertilization activities during reclamation.

6. Dissolved solids loss to runoff via surface leaching of disturbed areas.

It is assumed that due to the probable low quality leachate and runoff from the coal pile, low grade waste dump and leachate from the ash disposal areas, these sources of contamination will not be discharged to the Hat Creek surface water streams.

In order to project a probable maximum change in quality of Hat Creek water after the development is in place and operating, a water quality balance was made of the main discharges to Hat Creek. A period of summer low flow has been assumed when the dilution effect is minimum; surface runoff is negligible; mine water from dewatering and waste dump surface seepages are at a maximum. Minor ground water subsurface flows from waste dump areas which eventually reach Hat Creek, as discussed in Section 6.1 (a), are not considered in the water quality balance. The discharges considered in this case were as follows:

Q_1	Mine Water	$0.030\ m^3 \cdot s^{-1}$
Q_2	Houth Meadows Dump Seepage	$0.017\ m^3 \cdot s^{-1}$
Q_3	Medicine Creek Dump Seepage	$0.023\ m^3 \cdot s^{-1}$
Q_4	Hat Creek Discharge	$0.12\ m^3 \cdot s^{-1}$
Q_T	Total Discharge	$0.19\ m^3 \cdot s^{-1}$

In order to derive the resultant concentration of any water quality parameter in the final combined flow downstream of all discharges, the following water quality balance formula was utilized:

$$C = \frac{Q_1 C_1 + Q_2 C_2 + Q_3 C_3 + Q_4 C_4}{Q_1 + Q_2 + Q_3 + Q_4}$$

where $C_1 - C_4$ = levels of the parameters in component discharges

C = level in the combined discharge.

In the case of the foregoing scenario, this formula can be transposed into the following:

$$C = \frac{(0.158\ Q_T)C_1 + (0.089\ Q_T)C_2 \div (0.121\ Q_T)C_3 + (0.632\ Q_T)C_4}{Q_T}$$

The quality of various component project related discharges utilized were those projected previously in Tables 6-9 and 6-25 adjusted as follows:

1. Those parameters, excepting sulphate, which exceeded the current regulatory Level 'A' Objectives were reduced to the Objective level to simulate the result of treatment prior to discharge. Based on available data, the level of sulphate to be expected from the ground water within the coal seam could be about 260 mg/l. It can thus be expected that whenever the proportion of ground water from dewatering wells within the coal seam is greater than about 15 percent of the total water from dewatering activities, the sulphate level in this discharge will exceed the Level 'A' Objective of 50 mg/l. Since there is not a cost effective technology available for removing sulphate plus the fact that this objective is under review (see Table 6-21), the sulphate levels in the relevant discharge to Hat Creek were not assumed to be altered by any treatment. It is assumed that cost effective treatment is available to meet Level 'A' Objectives for all other parameters. This may or may not be the case however, and treatability studies will be necessary as recommended in Section 8.2 (b).

2. The quality of the discharge was averaged where necessary. For instance, the quality of the Medicine Creek seepage is assumed to be the average of that produced by Overburden 76-1 and 76-13 of Table 6-9. Likewise, the quality of the mine water is assumed to be the average of Well RH 76-19 (Surficials) and Bucket Auger Hole #7 (Coal Seam) of Tables C1-16 and C1-17. This latter assumption would represent the worst case because on average the quantity of coal seam water would be considerably less than the amount of water removed from the surficials.

3. The level of suspended solids after treatment is assumed to be less than or equal to Level 'A' requirement of 50 mg/l.

4. The maximum temperature is that value projected to occur in the diversion canal.

5. The nutrient levels are those values projected to result from reclamation fertilization on an annual basis, plus contributions from seepage and mine waters to be discharged to Hat Creek. It does not include any contribution from blasting residuals.

The water quality of Hat Creek utilized was that established in the Inventory as the mean as shown in Table 4-16. The resulting water quality derived from this balance is given in Table 6-28 for pertinent parameters.

The results indicate a substantial increase can be expected in the salinity of Hat Creek water (90 percent increase in dissolved solids level). The sum of inorganic ions does not balance with the projected filterable residue because the filterable residue includes the volatile fraction from the leachate data utilized. Increases are also projected in the alkalinity, sodium and chloride levels. The increase in levels of dissolved trace metals varies from nil to about a sixteen-fold increase in zinc. With the exception of dissolved solids, temperature, arsenic, chromium, copper, iron, and lead, all other parameters remain within the Objective Level of Recommended Limits for Drinking Water as listed in Table 4-12.

The increase in dissolved solids by more than one-third of the natural value may present problems to aquatic life[95]. The level of arsenic projected exceeds the acceptable levels of 0.01 mg/l but would still be considerably lower than the maximum permissible level of 0.05 mg/l. The projected levels of chromium, copper, iron, and lead, however, would remain below the acceptable limits. Temperature of the water will pose a severe problem to existing fisheries resources and would also be above the level deemed maximum acceptable for drinking water purposes (15^{o}C). The projected level of suspended solids is such that the corresponding turbidity (from Figure 4-44) will be about 7 NTU which is somewhat above the acceptable level of 5 NTU. This factor indicates treatment for turbidity removal may be required at times by any downstream Hat Creek domestic water users.

Predictions have not been made for BOD_5 or dissolved oxygen levels because BOD_5 load projections from component discharges based on existing data are not considered reliable. If further testing indicates that the BOD_5 load is above about 50 kg $\cdot$ day^{-1}, biological treatment may be required to maintain adequate D.O. levels in Lower Hat Creek.

TABLE 6-28

COMPARISON OF PROJECTED WATER QUALITY AND EXISTING WATER QUALITY IN HAT CREEK

Parameters (mg/l)	Projected	Existing
pH (units)	8.2	8.4
Temperature (^{o}C)	40	24
Suspended Solids	≤ 22	6
Filterable Residue	642	342
Total Hardness (as $CaCO_3$)	197	224
Alkalinity (as $CaCO_3$)	305	226
Chloride	6.2	1.1
Fluoride	0.15	0.16
Total Nitrogen - N	3.61	0.19
Phosphorus - P	< 0.096	0.043
Sulphate	60	54
Arsenic	< 0.013	< 0.005
Boron	< 0.10	< 0.10
Cadmium	< 0.005	< 0.005
Calcium (as $CaCO_3$)	118	143
Chromium	< 0.018	< 0.010
Copper	< 0.015	< 0.005
Iron	< 0.092	< 0.026
Lead	< 0.013	< 0.010
Magnesium (as $CaCO_3$)	75	77
Mercury	< 0.0005	< 0.0004
Sodium	72	20
Vanadium	< 0.013	< 0.005
Zinc	< 0.111	< 0.007

The projected levels of the nutrients nitrogen and phosphorus indicate a significant increase can be expected. The mine water and waste dump seepages contribute a major portion of the projected increases. The projected levels are considerably in excess of those generally accepted as being able to stimulate algae growth[85].

With the exception of the periods where the available dilution in the Bonaparte River is low, the impact of changes in the Hat Creek water quality will have an insignificant effect on the Bonaparte River. During low flow the level of dissolved solids may increase by 10 to 20 percent. The nutrient levels may also increase significantly during this period. Total nitrogen levels may increase from about 0.3 mg/l to upwards of 0.8 to 0.9 mg/l whereas phosphorus levels could increase to 0.048 mg/l from the existing mean of 0.039 mg/l. As with Hat Creek these nutrient additions may foster some increased algae growth.

Studies by others on water quality effects of surface mining operations offer some information for comparative purposes for parameters such as dissolved solids and sediment yields.

McWhorter, D.B. et al[86] found that the equivalent dissolved solids from disturbed areas of a Colorado coal mining operation was 6.5 times as great as from undisturbed areas, and that about 99 percent of the annual pickup was attributable to ground water runoffs (mine and dump seepages etc.). As indicated in Section 4.2 (b), the existing dissolved solids yield on average in Hat Creek ranges from 12-14 $t \cdot km^{-2} \cdot yr^{-1}$. If the yield from disturbed areas of the project (about 35 km^2) were 6.5 times higher or about 85 $t \cdot km^{-2} \cdot yr^{-1}$, the projected yield of dissolved solids from the total Hat Creek Valley would be about 16.8 $t \cdot km^{-2} \cdot yr^{-1}$, or an increase of about 30 percent on an average annual basis.

The literature contains information on the sediment yield that can be expected from surface mining operations. A document developed by the U.S. Environmental Protection Agency[20], states that 17,000 $t \cdot km^{-2} \cdot yr^{-1}$ is representative of the rate of erosion from active surface mines in eastern United States. Further, the document lists rates of erosion from spoil banks and haul roads at 9,600 $t \cdot km^{-2} \cdot yr^{-1}$ and 20,400 $t \cdot km^{-2} \cdot yr^{-1}$ based on experience in the eastern U.S. Appalachia area. These values are stated as rates of erosion approximately 970 to 2,070 times that from unmined-undisturbed areas. Steele[87] reported on the projections of sediment loss made in environmental assessments of coal developments in Colorado. The assessment estimated about 20 percent of the sediment load generated by the development would be discharged to stream systems. Over a 15 year period the residual sediment loss was projected at about 30 $t \cdot km^{-2} \cdot yr^{-1}$ or about three times the pre-development level on a 100 km^2 development. James et al[88] states the generation of water-borne sediment from surface Colorado coal mining operations without reclamation and sediment control facilities, would be about 30,000 $t \cdot yr^{-1}$ per million tonnes of coal mined.

Information on the rates of residual sediment and dissolved solids yield from surface mining in B.C. is very sparse. The Ministry of the Environment[89], has not studied the surface mining operations in the Highland Valley or the Kootenays with a view to providing data amenable to predictive assessments for new mines.

In the case of the Hat Creek development, about 35 km^2 will be disturbed and the annual coal production will be about 11 x 10^6 $t \cdot yr^{-1}$. As indicated in the Inventory Section 4.2 (b), the existing mean annual sediment yield in Hat Creek is about 5.6 $t \cdot km^{-2} \cdot yr^{-1}$. Utilizing a projected residual sediment yield from the disturbed area of three times the existing mean annual or 17 $t \cdot km^{-2} \cdot yr^{-1}$ on 35 km^2, the development could be expected to cause a total residual sediment of 390 $t \cdot yr^{-1}$ to enter the water course. This would represent a sediment yield increase from the total Hat Creek drainage basin (660 km^2) of about 0.6 $t \cdot km^{-2} \cdot yr^{-1}$ or an increase of 11 percent on an annual basis. This increase is considered to be a minor negative effect.

The projected increase in dissolved solids and sediment loss from Hat Creek (2,500 $t \cdot yr^{-1}$ and 390 $t \cdot yr^{-1}$ respectively) would cause increases in the mean annual dissolved solids and sediment yield in the Bonaparte River of about 6 percent. This increase is considered a minor negative effect unlikely to cause any impact on stream values. Considering the dilution potential available in the Thompson River, water quality changes in the Thompson River will be insignificant.

The Hat Creek development would result in a substantial increase in the population of the village of Cache Creek and Ashcroft. Providing treatment facilities were expanded, the impact of the additional sewage on the Bonaparte and Thompson Rivers would likely be minimal.

D. Decommissioning

The potential significant impacts projected during the decommissioning phase are as follows:

1. Nutrient loss to Hat Creek and to the proposed pit lake, resulting in possible fostering of algae and eutrophication effects.

2. Potential degradation of Hat Creek water quality upon passing through the pit lake. In addition, Hat Creek would have a considerably reduced flow for an extended period of time during filling of the pit. This flow reduction reduces the capacity of Lower Hat Creek to assimilate runoff residuals.

3. Reclamation of remaining disturbed areas will be a major positive impact in reducing water-borne sediment and dissolved solids leachates residuals reaching the surface water systems.

6.3 WATER USE

(a) Ground Water

(i) Preliminary Site Development

A. Mine

The exploration camp well would be the only new ground water source. This would be classified as a minor municipal impact on ground water use.

B. Plant

No wells would be drilled and there are no existing ground water users in the vicinity of the plant. Hence, there would be no impact on ground water use.

C. Offsites

No wells would be drilled and existing ground water users would not be disturbed. Hence, there would be no impact on ground water use.

(ii) Construction

A. Mine

All existing domestic wells and developed springs within the pit perimeter would be abandoned. These would include DW-1, DW-2, DW-3, DW-4 and DW-14, (see locations in Figure 3-4). The estimated total pumpage from these five ground water sources is 16 m^3/d. The proposed water wells supplying the offices and warehouses, and the mine and plant construction camps would be the only new wells in the area. The estimated maximum water requirement for the mine camp is 100 m^3/d and mine offices and warehouses is between 20 to 136 m^3/d. These flows are all small in comparison to aquifer flows and hence minor negative impacts would result.

B. Plant

As discussed earlier the water supply to the plant construction camp would use about 228 m^3/d from a well. An additional 1,096 m^3/d would be required for a concrete batch plant, workshops and warehouses. The total requirement of 1,324 m^3/d would probably have to be obtained from a well or wells located at the buried bedrock valley aquifer. This water requirement represents 26 percent of the flow in this aquifer. The ground water use would increase from no usage at the present to 1324 m^3/d. This represents a major impact on ground water use.

C. Offsites

The offsite activities do not require the use of ground water. There are no wells which are presently located close to the diversion canal and dam that would have to be abandoned. Hence there would be no impact on ground water usage.

iii) Operation

Some ground water may be used to supply water for irrigation of revegetated areas in waste dumps. Some of this water could be supplied from the pit area dewatering wells. However, some additional wells could be developed as required and would cause an impact ranging from minor to significant.

iv) Decommissioning

The same comments as given in operation (see previous Section iii) would apply.

v) Overall Impact Assessment

Domestic:

The current domestic water consumption of about 30 m^3/d would be reduced by about half. The proposed development will have no impact on the quantities of ground water presently being used by residents either upstream or downstream of the study area.

Municipal:

The construction camps would use a maximum of about 328 m^3/d of ground water for about five years only.

Industrial:

The present ground water use is about 125 m^3/d which is used as wash water at a limestone quarry. With water required for concrete batch plants, warehouses, workshops and other facilities, the total industrial usage could increase to about 1,357 m^3/d.

Irrigation:

Ground water is not presently being used for irrigation in the valley. Many of the pit area dewatering wells plus some additional wells could be used to irrigate vegetated waste dump areas.

The total ground water use would increase during the construction period from the present estimated 155 m^3/d to about 2,500 m^3/d. The maximum figure would depend on the amount of irrigation water that would be supplied from water wells. Some of the irrigation water could possibly be supplied from the dewatering wells around the pit perimeter. However, the maximum ground water usage without irrigation would be about 1,700 m^3/d and represents a moderate impact on the total ground water available. The three major aquifers (Marble Canyon, Buried Bedrock Channel and Alluvial) have a combined potential ground water yield of about 4,700 m^3/d. This assumes that half the combined aquifer flows can be intercepted by water wells.

Thus, the proposed ground water usage required for the project at the end of the construction period and excluding irrigation requirements would be about 36 percent of the available ground water. This is a moderate impact on water usage.

(b) Surface Water

(i) Preliminary Site Development

A. Mine, Plant and Offsites

The preliminary site development will have no significant affect on surface water usage.

(ii) Construction

A. Mine, Plant and Offsites

Irrigation

The quantities of irrigation water use affected by alienation of irrigable land by the construction of the mine, plant, and offsite facilities are tabulated in Table 6-29. Activities of the base project scheme would alienate a total of 273 ha (675 ac) of lands projected as being irrigated in the future (probable use) without the project. The quantity of irrigation water associated with these lands is 156.5 ha-m (1268 ac-ft). The large majority of this water use, 147 ha-m (1190 ac-ft) is located in Subregion II of the Hat Creek drainage basin (Figure 4-48) and represents about 53 percent of the total probable water use projected for this subregion (Table 5-5). The remaining alienation of irrigation water use occurs in the Cornwall drainage study area - 7 ha-m (57 ac-ft), and the lower Bonaparte drainage study area - 3 ha-m (24 ac-ft). Included in water use alienation is 45 ha (111 ac) of land that is presently

TABLE 6-29

IRRIGATION WATER USE IMPACTS
DUE TO PROJECT CONSTRUCTION

Impact of Land Alienation

Water Use Category	Project Activity	Area (ha)	Water Quantity, (ha-m-yr^{-1})
	Base Project Scheme:		
Presently Irrigated Land	Mine	12.5	8.3
	Plant	16.2	10.7
	Offsites	16.6	13.8
	Sub Total	45.3	32.8
Projected Irrigated Corn	Mine	113.0	74.6
	Plant	-	-
	Offsites	61.5	40.6
	Sub Total	174.5	115.2
Projected Irrigated Spring Pasture	Mine	47.7	7.6
	Plant	-	-
	Offsites	5.7	0.9
	Sub Total	53.4	8.5
Total Projected Use	Mine	173.2	90.5
	Plant	16.2	10.7
	Offsites	83.8	55.3
	Total	273.2	156.5
	Alternate Schemes:		
Presently Irrigated Land	Offsites	105.0	78.0

Other Impacts

Water Use Category	Project Activity	Water Quantity (ha-m-yr^{-1})
Loss of Present Storage	Finney Lake Dewatering	12
Conveyance Disruption	Finney Creek Diversion	12*
	Hat Creek Diversion	23
Total		47

* excludes 12 ha-m-yr^{-1} of use lost due to Finney Lake dewatering.

All sources such as these must eventually be carefully considered by the designers in the water balance of the power plant, otherwise an excess of water results. Disposal methods such as evaporator trains[72,73] or direct discharge to the surface water environment may then be necessary.

Particulate and sulphur dioxide emissions from the power plant have been estimated by others[25] to be 79 x 10^3 tonnes and 9.7 x 10^3 tonnes per year, respectively. The impact of particulate fallout in the Hat Creek watershed and of any sulphur dioxide acid rain potential is not addressed in this assessment. There will undoubtedly be an increase in the dustfall level in the valley from particulate emitted by the plant. Some of this will fall directly on water bodies and a portion of the remainder will be subject to washout by precipitation and snowmelt.

Other Activities

Operation of creek diversions around the ash disposal site can be expected to contribute some sediment loss to the runoff during spring freshet. The levels of sediment are not predictable and are flow and velocity dependent. It will be important to ensure sediment losses are low during nonfreshet conditions as it is during this period that Hat Creek will be most susceptible and have the least sediment carrying capacity.

Reclamation during the operation phase of the power plant would be carried out on the retaining embankment faces and dry ash dumps (should this alternate be selected). This activity will produce a positive impact on water quality by reducing disturbed areas. Addition of fertilizers however, can be expected to contribute some nutrient loss to the watershed. Nutrient loss during reclamation is discussed in more detail in Section 6.2 (b) (iv).

C. Offsites

Hat Creek Diversion
Canal and Reservoir Temperature Predictions

Information available on normal water temperatures in Hat Creek is restricted to a limited number of spot checks at two stations[74]. In mid-summer, the water temperature at Station 08LF061, near the proposed mine, is usually between 10°C and 15°C. The highest observed water temperature at this sampling station is 18°C, with a corresponding flow of 0.11 $m^3 \cdot s^{-1}$. Further downstream at Station 08LF015, near the Bonaparte River, mid-summer temperatures in Hat Creek are usually between 15°C and 20°C, the highest observed temperature being 24°C.

The diversion of Hat Creek would raise water temperatures because the surface area exposed to solar radiation would increase significantly. Methods available for predicting temperature changes in running and standing waters are approximate and have many deficiencies. Nonetheless, estimates were made of the maximum water temperatures expected at the downstream end of the diversion canal on a clear, hot, humid, still, mid-summer day, for two situations. The first situation, referred to as the base case, involves a 7.3 ha reservoir with a maximum storage of about 220,000 m^3 and no flow regulation. Downstream of the reservoir is a 7,000 m diversion canal, followed by a 2100 m discharge conduit. The canal considered was that proposed in the September 1977 Hat Creek Project Description: a trapezoidal canal with a 3.7 m base. The second situation, referred to as the water supply alternate, involves addition of a 120 ha reservoir upstream from the 7.3 ha reservoir. This large reservoir would have a sufficient storage to maintain a minimum flow of 0.23 $m^3 \cdot s^{-1}$ in the diversion canal and provide an average flow of 0.45 $m^3 \cdot s^{-1}$ for water supply.

Predictions of water temperature were based on a method outlined by Velz and Gannon[75] with appropriate modifications. The calculations considered solar insolation, radiation from the water to the atmosphere, convective heat transfer between the water and the air, and evaporation from the water surface. In absence of required information, it was necessary to make several assumptions, some of which are important to the results of the calculations:

1. Water could take six hours to travel the length of the diversion channel (7000 m).

2. No conductive heat transfer between the water and the channel bed. In reality, heat would be transferred from the water to the channel bed during the warmer part of the day, and in the opposite direction at other times.[76]

3. No shading of the diversion channel by trees or topography between 9 a.m. and 3 p.m. solar time.

4. 90 percent of incident solar radiation absorbed by the water, the balance being reflected at the water surface. At a flow of about 0.1 $m^3 \cdot s^{-1}$, the water depth in the diversion canal would be about 10 cm. This shallow water depth may result in a reduced level of solar energy absorption because some of the radiation would be reflected off the channel bottom.[77]

5. Harry, Finney, Lloyd and Ambusten Creeks would be dry and the flow in Medicine Creek would be 0.003 $m^3 \cdot s^{-1}$, at 14°C. Flow from the pit rim reservoir would be insignificant.

6. Meteorological conditions:

   (a) Solar radiation incident on a horizontal surface varying from 3.27 $MJ \cdot hr^{-1} \cdot m^{-2}$ at noon to 2.55 $MJ \cdot hr^{-1} \cdot m^{-2}$ three hours before and after noon.

   (b) Air temperature varying from 15°C at 9 a.m. to 35°C at 3 p.m.

   (c) Absolute humidity (partial pressure of water vapour) 13.5 mm Hg from 9 a.m. to 3 p.m.

(d) Wind speed varying from 6.4 $km \cdot hr^{-1}$ at 9 a.m. to 1.6 $km \cdot hr^{-1}$ at 3 p.m.

These conditions are considered extremes for the area.

For the base case, a flow of 0.12 $m^3 \cdot s^{-1}$ was used for temperature calculations in the diversion channel. This flow is the two-year-return flow at Station 08LF061 on Hat Creek. At this flow, the water temperature at the end of the diversion channel was calculated as about 40°C, almost independent of the water temperature at the beginning of the channel. At 40°C, the water in the channel would be close to thermal equilibrium with the prevailing environmental conditions.

For the water supply alternative, the water temperature at the end of the diversion channel could be as high as 35°C, based on a flow of 0.23 $m^3 \cdot s^{-1}$ and a temperature of 20°C at the beginning of the channel.

Since the calculated increases in water temperature in the diversion channel were considerable, no effort was made to estimate the effects of the impoundments on water temperature. However, surface water temperatures in lakes, creeks and canals in the interior of British Columbia seldom exceed 25°C.[74] Therefore, 25°C would likely be the maximum temperature expected for water leaving either of the two proposed reservoirs. If the diversion design was altered to reduce water temperature increases to minimum levels, a more serious examination of the effect of any impoundments on water temperature would be warranted.

Mid-summer water temperatures in an evaporation pan at Summerland[78] have been in the range of 32° - 35°C on several occasions and the maximum observed temperature in recent years is 37°C. Although the water in the pan is stagnant, the information indicates that the calculated temperatures of 40°C and 35°C, at the end of the diversion channel, are realistic as potential maximums.

Temperatures in Hat Creek below the diversions would likely be less than the temperature in the diversion channel, for several reasons:

(a) There would be some evaporative cooling in the plunge pool at the bottom of the discharge conduit.

(b) Tributaries to Hat Creek would bring some cooler water to be mixed with upstream water.

(c) Evaporative cooling and back radiation would be more significant relative to solar insolation than was the case in the diversion channel.

It is difficult to quantify these effects so it must be assumed, as a worse case, that water temperatures of 40°C or 35°C could persist in Hat Creek down to the confluence with the Bonaparte River.

The ten-year-return flow in the Bonaparte River is about 5.5 $m^3 \cdot s^{-1}$ and the mid-summer water temperature at the confluence with Hat Creek could be as high as 20°C. Even if the temperature of water from Hat Creek were increased to 40°C, the temperature in the Bonaparte River would increase by only 0.5°F, at low flow.

The preferable water temperature for rainbow trout is 13°C and temperatures of about 25°C are lethal.[61] For common white suckers, the lethal temperature is about 31°C. Therefore, it is possible that diversion of Hat Creek through the proposed channel could make mid-summer water temperatures in the lower part of Hat Creek unsuitable for fish life. Furthermore, mid-summer water temperatures would be well in excess of the 15°C maximum temperature recommended for drinking water supplies.[79] While the calculations were approximate, it appears that the diversion of Hat Creek, as planned, would significantly raise the summer water temperatures in the lower part of Hat Creek. The high temperatures in Hat Creek would have minimal impact on the temperature of the Bonaparte River. Further study would be warranted to improve the reliability of the temperature predictions and to investigate methods to minimize water temperature increases in lower Hat Creek.

Hat Creek Diversion
Supersaturation of Nitrogen Gas in Lower Hat Creek

The diversion scheme proposed in the September 1977 Hat Creek Project Descriptions could result in supersaturation of nitrogen gas in the downstream waters of Hat Creek. Such supersaturation would represent a threat to fish.

Nitrogen supersaturation could result from both temperature increases in the diversion canal and the discharge of diverted waters from the conduit into a plunge pool.

Mid-summer increases in water temperature in the diversion canal would decrease the saturation concentration for nitrogen. Supersaturation of nitrogen would result and if the supersaturated gas did not transfer out of the water fast enough, the extent of nitrogen supersaturation in downstream Hat Creek waters could be significant. For example, if water saturated with nitrogen at 15°C was heated to 40°C, with no release of nitrogen gas, nitrogen concentrations of 140 percent of saturation would result.

When water is discharged into a plunge pool, there is considerable turbulence. As a result, air is entrained in the water and taken to various depths, where the increased pressure forces more nitrogen into solution than would be the case at the water surface. When the water returns to a point closer to the surface, the nitrogen concentrations in the water could be as much as 140 percent of those corresponding to saturation at the water surface. If the water were discharged, instead, into a stilling basin the potential for causing nitrogen supersaturation would be reduced but it would still exist, especially if water in the basin was reasonably deep and there was considerable turbulence.

The simplified examples illustrate that a more extensive examination of the problem appears warranted.

To avoid nitrogen supersaturation from the discharge of the diverted water, a long rock-covered slope resembling a steep creek bed is suggested. The system would be designed such that the kinetic energy of the diversion water could be dissipated on the rocks, with no pools or significant depth. The system would provide turbulent contact of the water with the surrounding atmosphere. As a result, any nitrogen supersaturation from the temperature increases in the channel would tend to be reduced by the enhancement of the transfer of nitrogen from the water to the air. Also, evaporative cooling would be enhanced, thereby reducing water temperature. The system would have to be designed to avoid erosion and to minimize problems associated with icing in the winter.

Main Access Road

The only water quality concerns relating to operation of the access road would be minor sediment loss from runoff concentration in ditches channeled into Cornwall Creek and possible excessive use of deicing products near creek crossings. Neither of these interactions are quantifiable but are considered minor negative potential impacts.

Cooling Water Supply System

Discharge of water treatment clarification plant sludge blowdown to the Thompson River will cause minor localized turbidity. The discharge point should be selected with care to avoid interaction with other intakes downstream and also to ensure acceptability by regulatory agencies concerned with fish spawning and rearing areas especially if in the future coagulants are found necessary at certain times of the year.

Discharge of pipeline drainage to Cornwall Creek and the Bonaparte River are proposed during line maintenance procedures. For discharge into Cornwall Creek it will be necessary to establish a controlled drainage rate below which turbidity levels do not disturb downstream domestic water users. Discharge to the Bonaparte River at too large a rate during salmon migration may cause fish disorientation problems. The project description indicates some chlorination for control of bacterial growth in the pipeline may be necessary. It is unlikely that the level of chlorine would be very high, however discharge of any chlorinated water may be objectionable from a fisheries viewpoint. Fisheries regulatory agencies should be consulted on both of these issues.

Offloading Facility And Airport

Operation of the offloading facility (not yet located) and the proposed airstrip should not cause any affect on surface water quality providing environmentally conscious decisions are made during design for disposal of sewage and refuse, control of runoff, and spill control if hazardous materials or liquids are to be used or handled.

(iv) Decommissioning

A. Mine

Reclamation of Disturbed Areas

In the reclamation of the land area during and following mining, the application of fertilizers will be required.[33] The fertilizer recommended for use[35] in this application is a composite fertilizer of the formulation 20-24-15 applied at a rate of 225 $kg \cdot ha^{-1}$. The loss of fertilizer due to ground water runoff can be approximately 17 percent for nitrogen and 2 percent for phosphorous.[80] Based on topography of the mine area, it may be anticipated that the majority of this runoff will eventually enter Hat Creek. The two possible extremes that may occur in the reclamation program are:

(1) A single application of fertilizer at the time of the first seeding.

(2) Annual application of fertilizer over all reclaimed land. Experience elsewhere[81] indicates that annual fertilization may be required for an indefinite period.

Based on these two cases and using the proposed reclamation plans provided in the project description,the average annual fertilizer application for the various stages of reclamation were calculated to be:

	Single Fertilization	Annual Fertilization
From startup to midpoint of mining	2,400 kg	20,300 kg
From midpoint to end of mine	13,100 kg	149,400 kg
From end of mine to 10 years after	54,900 kg	549,700 kg

The average flow rate of Hat Creek at the mouth based on existing flow data[82] is about 80,000 $m^3 \cdot d^{-1}$. Using this data the contribution from fertilizer to the nitrogen and phosphorous levels in Hat Creek may then be calculated and the percentage increase in these nutrients at various stages in the reclamation program determined. The results of calculations of fertilizer application for the two cases are shown in Table 6-26, and the potential addition of nutrients to Hat Creek for these two cases is as shown in Table 6-27.

From this data it may be seen that fertilization could cause a significant increase in the nutrient loading to Hat Creek even in the minimal case of a single application of fertilizer, particularly in the last stage of reclamation. This increase in nutrient loading will probably have the effect of markedly increasing plant life in the creek to its eventual detriment.

With respect to the Bonaparte River, if a dilution effect of 6:1 is assumed,[82] and using the base value of 0.27 mg/l for nitrogen and 0.039 mg/l for phosphorous, the percentage increase on the base value for single fertilizer addition during the period from end of mine to 10 years after would be 3.9 percent for nitrogen and 1.7 percent for phosphorous. It is not considered that this increase would exert any noticeable effect on the Bonaparte River. In the case of annual addition,

TABLE 6-26

CALCULATIONS OF FERTILIZER APPLICATIONS

Year	Area(ha) Average Per Year	Area(ha) Total	Application (kg) Average Per Year	Application (kg) Total
SINGLE FERTILIZATION APPLICATION				
1. Startup To Midpoint 1 - 16	10.7	170	2,400	38,400
2. Midpoint To End 17 - 32	58	932	13,100	209,300
3. End To 10 Years Later 33 - 42	245	2,446	54,900	549,400
ANNUAL FERTILIZATION APPLICATION				
1. Startup To Midpoint 1 - 16	90	170	20,300	325,900
2. Midpoint To End 17 - 32	745	1,102	149,400	2,392,400
3. End To 10 Years Later 33 - 42	2,448	3,549	549,700	5,497,900

TABLE 6-27

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ESTIMATED NUTRIENT ADDITION TO HAT CREEK FROM RECLAMATION FERTILIZATION

Period	Base Value	Fertilizer Addition	Total	% Increase on Base Value
1. From startup to midpoint of mining:				
Single Addition				
Nitrogen (N),mg/l	0.19	0.003	0.193	1.5
Phosphorous (P),mg/l	0.043	0.0002	0.043	0.4
Annual Addition				
Nitrogen (N),mg/l	0.19	0.023	0.213	12.3
Phosphorous (P), mg/l	0.043	0.001	0.044	3.4
2. From midpoint to end of mine:				
Single Addition				
Nitrogen (N),mg/l	0.19	0.015	0.205	7.9
Phosphorous (P),mg/l	0.043	0.001	0.044	2.2
Annual Addition				
Nitrogen (N),mg/l	0.19	0.172	0.362	90
Phosphorus (P),mg/l	0.043	0.011	0.054	25
3. From end of mine to 10 years after				
Single Addition				
Nitrogen (N),mg/l	0.19	0.063	0.253	33
Phosphorous (P),mg/l	0.043	0.004	0.048	9
Annual Addition				
Nitrogen (N),mg/l	0.19	0.063	0.822	333
Phosphorous (P),mg/l	0.043	0.039	0.082	91

however, the percentage increase on the base value would be 39 percent for nitrogen and 17 percent for phosphorous for the period from end of mine to 10 years after. This amount of increase could be detrimental to the Bonaparte River and if this pattern of fertilization was required, preventative measures would have to be implemented.

With respect to the Thompson River, if a further dilution effect of 175:1 is assumed,[82] and using the base value of 0.08 mg/1 for nitrogen and 0.020 mg/1 for phosphorous, the percentage increase on the base value for annual fertilizer addition during the period from end of mine to 10 years after would be 0.8 percent for nitrogen and 0.2 percent for phosphorous. It is not considered that this increase would exert any noticeable effect on the Thompson River.

Reclamation of the Pit

Reclamation of the pit would include recontouring of the pit slopes which will improve stability, drainage and aesthetics in addition to providing a suitable profile for a top dressing prior to revegetation activities. Exposed coal would be covered with sterile material to prevent spontaneous combustion. Subsequent to these preparations, the proposed strategy is to begin flooding of the pit with excess Hat Creek water over a period which could last as long as 26 years. Once the pit is filled to a predetermined level, all of Hat Creek would be redirected through the newly formed lake with the overflow channelled back to its original course downstream of the lake.

Creation of the lake is expected to have a positive effect on the physical water quality in that the lake would cause Upper Hat Creek to deposit its entire sediment load at all times of the year. This has other consequences on downstream Hat Creek stream morphology as discussed in Section 6.1 (b). This impoundment would increase water temperatures above normal temperatures in Hat Creek. Calculations were not made, but based on measurements of relevant surface water temperatures,[74] the temperature of water leaving the flooded pit could be as high as 25°C. The impact on physical water quality is thus considered ambivalent overall.

The effect of creating a lake on the chemical water quality is difficult to predict and it is recommended this aspect be studied further when more details are known of the probable top dressing materials. Water column studies should be undertaken to help predict the dissolved solids leaching rates from the proposed lake bottom sediments. Since the lake would be of substantial size and depth (335 ha. and 120 meters deep), it may be subject to thermal stratification and semi-annual turnover.[83]

The lake has the potential to be a "meromictic" lake, where a layer of water at the bottom is stabilized by dissolved solids or even suspended matter causing a permanent increase in density. This would be caused by leaching of dissolved material from the bottom sediments and from highly saline ground waters entering the bottom of the lake. Lake Mahony, near Okanagan Falls, is an example of a highly meromictic lake. The available leachate data on Hat Creek surficial and waste rock is not directly applicable to making predictions in a lake situation. If the lake were to be meromictic, this would be beneficial to water quality in the upper levels as turnovers would not mix the high-density highly-saline bottom waters with the remainder of the water column. Previous experience of flooding a similar large open pit coal mine was not found in the literature. In the Estevan area of Saskatchewan, water bodies of about 36 ha and 6 meters deep have been created within reclaimed coal mine spoil areas[84] and subsequently stocked with rainbow trout with apparent success. Data was not reported on water quality changes after flooding.

Runoff of nutrients from reclamation as indicated in the previous subsection will raise the nitrogen and phosphorous levels depending on the degree of fertilization. The project concentrations were 0.19 - 0.8 mg/l for nitrogen and 0.043 - 0.082 mg/l for phosphorous. These levels, even at the lowest values (existing Hat Creek water quality), are in the range generally accepted as being able to stimulate algae growth in lake waters (nitrogen above 0.1 mg/l and phosphorous above 0.01 mg/l).[85]

In summary, from a water quality viewpoint, the impacts of the proposed pit reclamation plans are considered to be mainly negative. The proposal should be examined in a thorough limnological assessment which is considered beyond the scope of this study.

Drainage Control

The plan to maintain creek diversions, drainage ditches and lagoons after phase out of the mine, is considered beneficial. These facilities will contain runoff and erosion, and minimize sediment losses.

Other Activities

Removal of mine infrastructure (buildings, conveyors, etc.) will undoubtedly cause some short-term area disturbances which would be subject to erosion. The impact of this decommissioning activity is considered minor negative.

B. Plant

Reclamation of Disposal Areas

The impacts of reclamation of disposal areas associated with the power plant would be the same as those discussed in Section 6.2 (b) (iv) A for reclamation of mine waste disposal areas.

Drainage Control

Continued existence of drainage facilities is considered a beneficial impact as these facilities will protect the integrity of waste dumps and control runoff erosion.

Other Activities

Minor impacts relating to sediment loss from short term area disturbances during removal of plant infrastructure (buildings, cooling towers, switchyard conveyors, etc.) can be expected to occur. It is assumed that the water supply reservoir would be left intact after phase out of the power plant. No interactions are visualized if this is done. Because the drainage area above the reservoir is minimal, this reservoir will eventually become dry through evaporation losses.

C. Offsites

Hat Creek Diversion

Decommissioning of Hat Creek diversion in association with creation of a lake in the pit is considered to offer both beneficial and negative impacts. Physical water quality in terms of temperature should improve somewhat over that which is projected to occur in the diversion canal at low flow. In addition, the newly created lake will reduce sediment load formerly carried in the canal from tributary streams (such as Medicine Creek and Houth Meadows area drainage). The chemical water quality impacts associated with decommissioning of the diversion are considered negative. This is due to the potential degradation of Hat Creek chemical water quality in passing through the lake as discussed previously. Continued existence of the reservoirs associated with the diversion (in Upper Hat Creek) is considered an ambivalent impact (both positive and negative effects). The reservoirs will reduce sediment levels in Hat Creek which is considered beneficial, while they will continue to cause water temperatures in the summer at higher levels than occur in the natural creek.

Cooling Water Supply System

Decommissioning of the water supply system is considered to have minor beneficial implications on water quality. Phase out will mean no further discharges of water treatment plant sludge to the Thompson River. In addition, the need of emergency drainages from the pipeline to both the Cornwall Creek and Bonaparte River will cease to exist. It is assumed that the pipeline itself would be left in place.

Other Activities

Significant impacts on water quality from decommissioning of 60 kV transmission lines and the offloading facilities are not visualized. The access road and airport are assumed to remain intact.

(v) Overall Impact Assessment

A. Preliminary Site Development

The activities during this stage of the project which could have affected surface water quality were the Bulk Sample Program, exploratory drilling, and access road construction. Surface water quality monitoring during this period has indicated a minimal effect on water quality. Should the project not proceed, reclamation would be implemented and thus no long-term impacts are foreseen. Thus, the impact on surface water quality at this stage is insignificant.

B. Construction

The main impacts to the surface water quality during construction of the mine will be:

1. An increase in the levels of non-filtrable residue and turbidity due to increased erosion caused by removing or destroying existing vegetative and soil cover.

2. An increase in the levels of filtrable residue, nutrients and colour due to pit dewatering activities.

The main source of possible impact to the surface water during construction of the plant and the offsite facilities will be increased non-filtrable residue and turbidity caused by erosion and precipitation washout of fugitive dust as a result of the clearing, stripping, etc., associated with construction activity. The effect of this will be controlled by collection of runoff and treatment in settling basins. The other source of possible impact during construction of the plant would be sewage from the shops, office and construction warehouses. This should be treated by total containment in an aerobic lagoon with ultimate disposal by evaporation, possibly coupled with irrigation. Provided regulatory levels for point source discharges and receiving streams are met, the impact on water quality would be minor.

C. Operation

The main impacts to surface water during operation of the mine and plant will be from:

1. Disposal of mine water from pit area dewatering.

2. Seepage and runoff from the Houth Meadows and Medicine Creek waste disposal areas.

3. Increased temperature in Hat Creek within the diversion canal during summer periods of low flow.

4. Sediment loss from intervening disturbed areas and fugitive dust precipitation washout.

5. Nutrient loss from fertilization activities during reclamation.

6. Dissolved solids loss to runoff via surface leaching of disturbed areas.

It is assumed that due to the probable low quality leachate and runoff from the coal pile, low grade waste dump and leachate from the ash disposal areas, these sources of contamination will not be discharged to the Hat Creek surface water streams.

In order to project a probable maximum change in quality of Hat Creek water after the development is in place and operating, a water quality balance was made of the main discharges to Hat Creek. A period of summer low flow has been assumed when the dilution effect is minimum; surface runoff is negligible; mine water from dewatering and waste dump surface seepages are at a maximum. Minor ground water subsurface flows from waste dump areas which eventually reach Hat Creek, as discussed in Section 6.1 (a), are not considered in the water quality balance. The discharges considered in this case were as follows:

Q_1	Mine Water	$0.030\ m^3 \cdot s^{-1}$
Q_2	Houth Meadows Dump Seepage	$0.017\ m^3 \cdot s^{-1}$
Q_3	Medicine Creek Dump Seepage	$0.023\ m^3 \cdot s^{-1}$
Q_4	Hat Creek Discharge	$0.12\ m^3 \cdot s^{-1}$
Q_T	Total Discharge	$0.19\ m^3 \cdot s^{-1}$

In order to derive the resultant concentration of any water quality parameter in the final combined flow downstream of all discharges, the following water quality balance formula was utilized:

$$C = \frac{Q_1 C_1 + Q_2 C_2 + Q_3 C_3 + Q_4 C_4}{Q_1 + Q_2 + Q_3 + Q_4}$$

where $C_1 - C_4$ = levels of the parameters in component discharges

C = level in the combined discharge.

In the case of the foregoing scenario, this formula can be transposed into the following:

$$C = \frac{(0.158\ Q_T)C_1 + (0.089\ Q_T)C_2 + (0.121\ Q_T)C_3 + (0.632\ Q_T)C_4}{Q_T}$$

The quality of various component project related discharges utilized were those projected previously in Tables 6-9 and 6-25 adjusted as follows:

1. Those parameters, excepting sulphate, which exceeded the current regulatory Level 'A' Objectives were reduced to the Objective level to simulate the result of treatment prior to discharge. Based on available data, the level of sulphate to be expected from the ground water within the coal seam could be about 260 mg/l. It can thus be expected that whenever the proportion of ground water from dewatering wells within the coal seam is greater than about 15 percent of the total water from dewatering activities, the sulphate level in this discharge will exceed the Level 'A' Objective of 50 mg/l. Since there is not a cost effective technology available for removing sulphate plus the fact that this objective is under review (see Table 6-21), the sulphate levels in the relevant discharge to Hat Creek were not assumed to be altered by any treatment. It is assumed that cost effective treatment is available to meet Level 'A' Objectives for all other parameters. This may or may not be the case however, and treatability studies will be necessary as recommended in Section 8.2 (b).

2. The quality of the discharge was averaged where necessary. For instance, the quality of the Medicine Creek seepage is assumed to be the average of that produced by Overburden 76-1 and 76-13 of Table 6-9. Likewise, the quality of the mine water is assumed to be the average of Well RH 76-19 (Surficials) and Bucket Auger Hole #7 (Coal Seam) of Tables C1-16 and C1-17. This latter assumption would represent the worst case because on average the quantity of coal seam water would be considerably less than the amount of water removed from the surficials.

3. The level of suspended solids after treatment is assumed to be less than or equal to Level 'A' requirement of 50 mg/l.

4. The maximum temperature is that value projected to occur in the diversion canal.

5. The nutrient levels are those values projected to result from reclamation fertilization on an annual basis, plus contributions from seepage and mine waters to be discharged to Hat Creek. It does not include any contribution from blasting residuals.

The water quality of Hat Creek utilized was that established in the Inventory as the mean as shown in Table 4-16. The resulting water quality derived from this balance is given in Table 6-28 for pertinent parameters.

The results indicate a substantial increase can be expected in the salinity of Hat Creek water (90 percent increase in dissolved solids level). The sum of inorganic ions does not balance with the projected filterable residue because the filterable residue includes the volatile fraction from the leachate data utilized. Increases are also projected in the alkalinity, sodium and chloride levels. The increase in levels of dissolved trace metals varies from nil to about a sixteen-fold increase in zinc. With the exception of dissolved solids, temperature, arsenic, chromium, copper, iron, and lead, all other parameters remain within the Objective Level of Recommended Limits for Drinking Water as listed in Table 4-12.

The increase in dissolved solids by more than one-third of the natural value may present problems to aquatic life[95]. The level of arsenic projected exceeds the acceptable levels of 0.01 mg/l but would still be considerably lower than the maximum permissible level of 0.05 mg/l. The projected levels of chromium, copper, iron, and lead, however, would remain below the acceptable limits. Temperature of the water will pose a severe problem to existing fisheries resources and would also be above the level deemed maximum acceptable for drinking water purposes (15^{o}C). The projected level of suspended solids is such that the corresponding turbidity (from Figure 4-44) will be about 7 NTU which is somewhat above the acceptable level of 5 NTU. This factor indicates treatment for turbidity removal may be required at times by any downstream Hat Creek domestic water users.

Predictions have not been made for BOD_5 or dissolved oxygen levels because BOD_5 load projections from component discharges based on existing data are not considered reliable. If further testing indicates that the BOD_5 load is above about 50 kg $\cdot$ day^{-1}, biological treatment may be required to maintain adequate D.O. levels in Lower Hat Creek.

TABLE 6-28
COMPARISON OF PROJECTED WATER QUALITY AND
EXISTING WATER QUALITY IN HAT CREEK

Parameters (mg/l)	Projected	Existing
pH (units)	8.2	8.4
Temperature (^{o}C)	40	24
Suspended Solids	≤ 22	6
Filterable Residue	642	342
Total Hardness (as $CaCO_3$)	197	224
Alkalinity (as $CaCO_3$)	305	226
Chloride	6.2	1.1
Fluoride	0.15	0.16
Total Nitrogen - N	3.61	0.19
Phosphorus - P	< 0.096	0.043
Sulphate	60	54
Arsenic	< 0.013	< 0.005
Boron	< 0.10	< 0.10
Cadmium	< 0.005	< 0.005
Calcium (as $CaCO_3$)	118	143
Chromium	< 0.018	< 0.010
Copper	< 0.015	< 0.005
Iron	< 0.092	< 0.026
Lead	< 0.013	< 0.010
Magnesium (as $CaCO_3$)	75	77
Mercury	< 0.0005	< 0.0004
Sodium	72	20
Vanadium	< 0.013	< 0.005
Zinc	< 0.111	< 0.007

The projected levels of the nutrients nitrogen and phosphorus indicate a significant increase can be expected. The mine water and waste dump seepages contribute a major portion of the projected increases. The projected levels are considerably in excess of those generally accepted as being able to stimulate algae growth[85].

With the exception of the periods where the available dilution in the Bonaparte River is low, the impact of changes in the Hat Creek water quality will have an insignificant effect on the Bonaparte River. During low flow the level of dissolved solids may increase by 10 to 20 percent. The nutrient levels may also increase significantly during this period. Total nitrogen levels may increase from about 0.3 mg/l to upwards of 0.8 to 0.9 mg/l whereas phosphorus levels could increase to 0.048 mg/l from the existing mean of 0.039 mg/l. As with Hat Creek these nutrient additions may foster some increased algae growth.

Studies by others on water quality effects of surface mining operations offer some information for comparative purposes for parameters such as dissolved solids and sediment yields.

McWhorter, D.B. et al[86] found that the equivalent dissolved solids from disturbed areas of a Colorado coal mining operation was 6.5 times as great as from undisturbed areas, and that about 99 percent of the annual pickup was attributable to ground water runoffs (mine and dump seepages etc.). As indicated in Section 4.2 (b), the existing dissolved solids yield on average in Hat Creek ranges from 12-14 $t \cdot km^{-2} \cdot yr^{-1}$. If the yield from disturbed areas of the project (about 35 km^2) were 6.5 times higher or about 85 $t \cdot km^{-2} \cdot yr^{-1}$, the projected yield of dissolved solids from the total Hat Creek Valley would be about 16.8 $t \cdot km^{-2} \cdot yr^{-1}$, or an increase of about 30 percent on an average annual basis.

The literature contains information on the sediment yield that can be expected from surface mining operations. A document developed by the U.S. Environmental Protection Agency[20], states that 17,000 $t \cdot km^{-2} \cdot yr^{-1}$ is representative of the rate of erosion from active surface mines in eastern United States. Further, the document lists rates of erosion from spoil banks and haul roads at 9,600 $t \cdot km^{-2} \cdot yr^{-1}$ and 20,400 $t \cdot km^{-2} \cdot yr^{-1}$ based on experience in the eastern U.S. Appalachia area. These values are stated as rates of erosion approximately 970 to 2,070 times that from unmined-undisturbed areas. Steele[87] reported on the projections of sediment loss made in environmental assessments of coal developments in Colorado. The assessment estimated about 20 percent of the sediment load generated by the development would be discharged to stream systems. Over a 15 year period the residual sediment loss was projected at about 30 $t \cdot km^{-2} \cdot yr^{-1}$ or about three times the pre-development level on a 100 km^2 development. James et al[88] states the generation of water-borne sediment from surface Colorado coal mining operations without reclamation and sediment control facilities, would be about 30,000 $t \cdot yr^{-1}$ per million tonnes of coal mined.

Information on the rates of residual sediment and dissolved solids yield from surface mining in B.C. is very sparse. The Ministry of the Environment[89], has not studied the surface mining operations in the Highland Valley or the Kootenays with a view to providing data amenable to predictive assessments for new mines.

In the case of the Hat Creek development, about 35 km^2 will be disturbed and the annual coal production will be about 11 x 10^6 $t \cdot yr^{-1}$. As indicated in the Inventory Section 4.2 (b), the existing mean annual sediment yield in Hat Creek is about 5.6 $t \cdot km^{-2} \cdot yr^{-1}$. Utilizing a projected residual sediment yield from the disturbed area of three times the existing mean annual or 17 $t \cdot km^{-2} \cdot yr^{-1}$ on 35 km^2, the development could be expected to cause a total residual sediment of 390 $t \cdot yr^{-1}$ to enter the water course. This would represent a sediment yield increase from the total Hat Creek drainage basin (660 km^2) of about 0.6 $t \cdot km^{-2} \cdot yr^{-1}$ or an increase of 11 percent on an annual basis. This increase is considered to be a minor negative effect.

The projected increase in dissolved solids and sediment loss from Hat Creek (2,500 $t \cdot yr^{-1}$ and 390 $t \cdot yr^{-1}$ respectively) would cause increases in the mean annual dissolved solids and sediment yield in the Bonaparte River of about 6 percent. This increase is considered a minor negative effect unlikely to cause any impact on stream values. Considering the dilution potential available in the Thompson River, water quality changes in the Thompson River will be insignificant.

The Hat Creek development would result in a substantial increase in the population of the village of Cache Creek and Ashcroft. Providing treatment facilities were expanded, the impact of the additional sewage on the Bonaparte and Thompson Rivers would likely be minimal.

D. Decommissioning

The potential significant impacts projected during the decommissioning phase are as follows:

1. Nutrient loss to Hat Creek and to the proposed pit lake, resulting in possible fostering of algae and eutrophication effects.

2. Potential degradation of Hat Creek water quality upon passing through the pit lake. In addition, Hat Creek would have a considerably reduced flow for an extended period of time during filling of the pit. This flow reduction reduces the capacity of Lower Hat Creek to assimilate runoff residuals.

3. Reclamation of remaining disturbed areas will be a major positive impact in reducing water-borne sediment and dissolved solids leachates residuals reaching the surface water systems.

6.3 WATER USE

(a) Ground Water

(i) Preliminary Site Development

A. Mine

The exploration camp well would be the only new ground water source. This would be classified as a minor municipal impact on ground water use.

B. Plant

No wells would be drilled and there are no existing ground water users in the vicinity of the plant. Hence, there would be no impact on ground water use.

C. Offsites

No wells would be drilled and existing ground water users would not be disturbed. Hence, there would be no impact on ground water use.

(ii) Construction

A. Mine

All existing domestic wells and developed springs within the pit perimeter would be abandoned. These would include DW-1, DW-2, DW-3, DW-4 and DW-14, (see locations in Figure 3-4). The estimated total pumpage from these five ground water sources is 16 m^3/d. The proposed water wells supplying the offices and warehouses, and the mine and plant construction camps would be the only new wells in the area. The estimated maximum water requirement for the mine camp is 100 m^3/d and mine offices and warehouses is between 20 to 136 m^3/d. These flows are all small in comparison to aquifer flows and hence minor negative impacts would result.

B. Plant

As discussed earlier the water supply to the plant construction camp would use about 228 m^3/d from a well. An additional 1,096 m^3/d would be required for a concrete batch plant, workshops and warehouses. The total requirement of 1,324 m^3/d would probably have to be obtained from a well or wells located at the buried bedrock valley aquifer. This water requirement represents 26 percent of the flow in this aquifer. The ground water use would increase from no usage at the present to 1324 m^3/d. This represents a major impact on ground water use.

C. Offsites

The offsite activities do not require the use of ground water. There are no wells which are presently located close to the diversion canal and dam that would have to be abandoned. Hence there would be no impact on ground water usage.

iii) Operation

Some ground water may be used to supply water for irrigation of revegetated areas in waste dumps. Some of this water could be supplied from the pit area dewatering wells. However, some additional wells could be developed as required and would cause an impact ranging from minor to significant.

iv) Decommissioning

The same comments as given in operation (see previous Section iii) would apply.

v) Overall Impact Assessment

Domestic:

The current domestic water consumption of about 30 m^3/d would be reduced by about half. The proposed development will have no impact on the quantities of ground water presently being used by residents either upstream or downstream of the study area.

Municipal:

The construction camps would use a maximum of about 328 m^3/d of ground water for about five years only.

Industrial:

The present ground water use is about 125 m^3/d which is used as wash water at a limestone quarry. With water required for concrete batch plants, warehouses, workshops and other facilities, the total industrial usage could increase to about 1,357 m^3/d.

Irrigation:

Ground water is not presently being used for irrigation in the valley. Many of the pit area dewatering wells plus some additional wells could be used to irrigate vegetated waste dump areas.

The total ground water use would increase during the construction period from the present estimated 155 m^3/d to about 2,500 m^3/d. The maximum figure would depend on the amount of irrigation water that would be supplied from water wells. Some of the irrigation water could possibly be supplied from the dewatering wells around the pit perimeter. However, the maximum ground water usage without irrigation would be about 1,700 m^3/d and represents a moderate impact on the total ground water available. The three major aquifers (Marble Canyon, Buried Bedrock Channel and Alluvial) have a combined potential ground water yield of about 4,700 m^3/d. This assumes that half the combined aquifer flows can be intercepted by water wells.

Thus, the proposed ground water usage required for the project at the end of the construction period and excluding irrigation requirements would be about 36 percent of the available ground water. This is a moderate impact on water usage.

(b) Surface Water

(i) Preliminary Site Development

A. Mine, Plant and Offsites

The preliminary site development will have no significant affect on surface water usage.

(ii) Construction

A. Mine, Plant and Offsites

Irrigation

The quantities of irrigation water use affected by alienation of irrigable land by the construction of the mine, plant, and offsite facilities are tabulated in Table 6-29. Activities of the base project scheme would alienate a total of 273 ha (675 ac) of lands projected as being irrigated in the future (probable use) without the project. The quantity of irrigation water associated with these lands is 156.5 ha-m (1268 ac-ft). The large majority of this water use, 147 ha-m (1190 ac-ft) is located in Subregion II of the Hat Creek drainage basin (Figure 4-48) and represents about 53 percent of the total probable water use projected for this subregion (Table 5-5). The remaining alienation of irrigation water use occurs in the Cornwall drainage study area - 7 ha-m (57 ac-ft), and the lower Bonaparte drainage study area - 3 ha-m (24 ac-ft). Included in water use alienation is 45 ha (111 ac) of land that is presently

TABLE 6-29

IRRIGATION WATER USE IMPACTS
DUE TO PROJECT CONSTRUCTION

Impact of Land Alienation

Water Use Category	Project Activity	Area (ha)	Water Quantity, $(ha\text{-}m\text{-}yr^{-1})$
	Base Project Scheme:		
Presently Irrigated Land	Mine	12.5	8.3
	Plant	16.2	10.7
	Offsites	16.6	13.8
	Sub Total	45.3	32.8
Projected Irrigated Corn	Mine	113.0	74.6
	Plant	-	-
	Offsites	61.5	40.6
	Sub Total	174.5	115.2
Projected Irrigated Spring Pasture	Mine	47.7	7.6
	Plant	-	-
	Offsites	5.7	0.9
	Sub Total	53.4	8.5
Total Projected Use	Mine	173.2	90.5
	Plant	16.2	10.7
	Offsites	83.8	55.3
	Total	273.2	156.5
	Alternate Schemes:		
Presently Irrigated Land	Offsites	105.0	78.0

Other Impacts

Water Use Category	Project Activity	Water Quantity $(ha\text{-}m\text{-}yr^{-1})$
Loss of Present Storage	Finney Lake Dewatering	12
Conveyance Disruption	Finney Creek Diversion	12*
	Hat Creek Diversion	23
Total		47

* excludes 12 $ha\text{-}m\text{-}yr^{-1}$ of use lost due to Finney Lake dewatering.

under irrigation with an associated water use quantity of 33 ha-m (243 ac-ft). Of the total 156.5 ha-m of irrigation water use directly alienated by base project scheme activities, 90.5 ha-m or 58 percent are alienated by mine activities, 10.7 ha-m or 7 percent by plant activities, and 55.3 ha-m or 35 percent by offsite activities. The alienation of irrigable lands and associated water use quantity may not represent a total loss of the use of this water for irrigation. As long as the project does not affect the availability of this water, then irrigation of other lands may result. However, the practicality of transferring water use to other irrigable lands has not been assessed in this study.

Two alternate project activities, the Hat Creek water supply reservoir and the airport (Site C) would alienate additional irrigated lands. In the case of the Hat Creek reservoir, 69 ha (170 ac) and water quantity of 45 ha-m (365 ac-ft) would be affected. This impact lies within Subregion III of the Hat Creek drainage basin and represents about 12 percent of the probable irrigation water use quantity projected for this subregion. In the case of the Site C airport location, 36 ha (89 ac) and water quantity of 33 ha-m (267 ac-ft) would be affected. This impact lies east of the Bonaparte drainage area defined in this study (Figure 4-48)

Aside from the direct alienation of irrigation water uses, the draining of Finney Lake would result in the loss of irrigation storage presently licenced in the amount of 12 ha-m per year (Table 6-29). A relatively small quantity in itself, it represents about 30 percent of the total storage presently licenced within the Hat Creek drainage basin.

The construction of certain project facilities would restrict the use of present irrigation water conveyance systems (ditches) by blocking their present routes. The Finney Creek diversion channel would cut across two irrigation ditches affecting the use of 12 ha-m (9.7 ac-ft) of water. This channel would also have affected the conveyancing of the 12 ha-m of water lost from use by the dewatering of Finney Lake. The Hat Creek diversion canal would cut off irrigation water supply associated with five present diversion points, the associated water use totalling about 23 ha-m (186 ac-ft). One of these points of diversion on Medicine Creek would also be alienated by the Medicine Creek mine waste dump. Some of these affected uses may be effectively compensated by the provision of an alternate water conveyance route or alternate source of water.

Livestock Use

The impacts on livestock water use due to the construction of mine, plant, and offsite facilities are associated primarily with the alienation of rangeland. The *Agriculture* report[90] states that about 3400 ha (8400 ac) of rangeland will be alienated (lost to grazing use) by the B.C. Hydro project and thus eliminate, as well, the use of watering sites within the alienated areas.

In addition to the loss of watering sites due to land alienation, the draining of Finney and Aleece Lakes to the west of the mine pit will eliminate them as cattle watering sites. The effect this will have on water use is not clear as there are other small lakes and creeks in the vicinity of these two lakes which may provide adequate watering for the future use of this range area.

TABLE 6-30

POPULATION AND SURFACE WATER USAGE* PROJECTIONS

	ASHCROFT				CACHE CREEK			
	Without Project		With Project		Without Project		With Project	
Year	Population	Usage	Population	Usage	Population	Usage	Population	Usage
1976	2030	1847	-	-	1050	956	-	-
1980	2455	2234	3071	2795	1205	1097	1509	1373
1986	2685	2443	4665	4245	1355	1233	2330	2120
1990	3035	2762	5242	4770	1595	1451	2683	2442

*Water usage figures are $m^3 \cdot d^{-1}$.

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Domestic, Municipal, and Industrial

All water requirements for the mine and plant including construction camp and infrastructure, are from ground water sources and are discussed in Section 6.3 (a).

Domestic surface water requirements are based on population projections for the towns of Cache Creek and Ashcroft, and the rural areas. This discussion encompasses the operation phase of the project as well.

Population projections for Ashcroft and Cache Creek as determined by Strong Hall & Associates[91] are presented in Table 6-30. Total water usages have been calculated based on a per capita usage of 0.91 $m^3 \cdot d^{-1}$ (240 USGPD)[92]. Strong Hall & Associates provided population projections for Ashcroft and Cache Creek combined.

Due to the proximity and accessibility of Ashcroft to the project site BEAK has assumed that two-thirds of this population increase would occur in Ashcroft and one-third in Cache Creek. Ashcroft obtains its water from the Thompson River and Cache Creek from the Bonaparte River.

As Table 6-30 shows, the maximum domestic water requirement by Ashcroft from the Thompson River would be about 5,000 $m^3 \cdot d^{-1}$, an insignificant volume when compared to the two year mean minimum flow of about 18 x 10^6 $m^3 \cdot d^{-1}$ (Figure 4-16). Cache Creek's maximum domestic water requirements would be about 2,500 $m^3 \cdot d^{-1}$, which is approximately 0.2 percent of the mean summer Bonaparte River discharge of 1.2 x 10^6 $m^3 \cdot d^{-1}$; again an insignificant amount and producing no significant impact.[93]

Strong Hall & Associates projected that the maximum increase in rural population during the construction and operation phases would be 200. This compares to an existing rural population of about 500 as outlined in Section 4.3 (b) (iii).

This population is not expected to significantly increase without the project and therefore the total estimated rural population during construction and operation is 700. At 0.91 $m^3 \cdot d^{-1}$ per capita (this is the same as the estimated domestic consumption for Ashcroft[92], and approximately the present domestic consumpton in Hat Creek from both ground water and licenced surface water sources as discussed in Section 4.3 (a) and 4.3 (b) (iii), respectively) the total usage would be 637 $m^3 \cdot d^{-1}$, some of which would be ground water. Because this water usage is distributed over a large area, the overall impact on the surface water is deemed insignificant.

(iii) Operation

A. Mine, Plant, and Offsites

Irrigation

The impact of the operation of the project on irrigation water use is summarized in Table 6-31. These items all deal with impacts that limit or reduce the availability of irrigation water. In addition to the tabulated impacts, a very small amount of irrigated land, 9 ha (22.2 ac), was identified in the Agriculture report[90] as possibly being removed from production because of the loss of productivity due to injury caused by plant stack emissions. This projected impact occurs in the south end of Hat Creek Valley (Subregion IV) with an associated water quantity of approximately 5 ha-m.

TABLE 6-31

IMPACT ON IRRIGATION WATER USE
DUE TO PROJECT OPERATION

Project Activity	Impact
Base Scheme:	
Mine Dust Control	- Evaporation of 10 ha-m during irrigation season; intended source of water unspecified.
Pit Rim Reservoir	- Evaporation of approximately 3 ha-m from reservoir surface during irrigation season.
Headworks Reservoir	- Evaporation of approximately 3 ha-m from reservoir surface during irrigation season.
Mine Pit Seepage	- Evaporation of up to 21 ha-m of seepage during irrigation season.
	- Potentially unsuitable water quality.
Pit Rim Dewatering	- Collection of up to 21 ha-m of ground and surface water in vicinity of mine; diversion to Hat Creek canal during irrigation season.
Coal Stockpiles	- Potentially unsuitable leachate quality.
Alternate Activity:	
Medicine Creek Diversion to MacLaren Creek	- Diversion of unknown quantity of of water from Hat Creek drainage to Cornwall Creek drainage.
Medicine Creek Water Supply	- Storage and use of unknown quantity of Medicine Creek Water.
Hat Creek Water Supply Reservoir	- Storage and use of Hat Creek flow.

The base project scheme includes four activities in which loss of water from the Hat Creek flow regime would occur due to evaporation and one other activity which would divert water from its present situation, while making it available for use elsewhere.

Water consumption used for the control of dust around the mine is estimated to be about 10 ha-m (81 ac-ft) during the irrigation season. Although the source of this water has not been given, surface water use would require appropriate licencing, and due to the lack of available water in Hat Creek during part of June, August, and September (see Table 5-3) this use would conflict with irrigation water use unless storage of freshet flows or an alternate water source is developed.

The pit rim and headworks reservoirs could each lose about 3 ha-m to evaporation during the period of irrigation - May through September. These estimates were based on potential evaportranspiration rates shown in Table 4-24 and the assumption that each has a surface area of about 7 hectares.

Mine seepage water could account for the largest evaporation loss, up to 21 ha-m-yr^{-1}. This represents a worst case, though, as it is based on the highest mine water seepage rate given in project description and assumes that seepage is completely evaporated during the irrigation season. The origin of this water might not totally be from the surface water regime and therefore the effect or conflict with irrigation water use could be less than the total amount of water lost. The potential water quality of mine seepage water with respect to total dissolved solids (Table 6-25) indicates levels that would be unacceptable for irrigation use.

The interception of surface and ground water by the pit rim dewatering system would divert up to 21 ha-m of water during the irrigation season to the Hat Creek canal. This amount was calculated using the highest pumping rate in the project description for the pit rim dewatering activity. While localized lowering of the water table and decrease in the availability of water would be apparent in close proximity to the dewatering wells, there does not appear to be a major conflict with irrigation water use.

The coal stockpiles may produce leachate of a quality unsuitable for irrigation use due to potentially high values of total dissolved solids (Table 6-20).

The alternate proposal for diversion of upper Medicine Creek water to MacLaren Creek would decrease the amount of water flowing to Hat Creek and thus have a negative impact on use of irrigation water in Hat Creek Valley but be of benefit to the irrigation water use in the Cornwall Creek drainage area. The impact on Hat Creek use would be greater since not only would the water be made unavailable but present irrigation licences and facilities would be affected. The quantity of water that would be involved in this diversion scheme is unknown.

Two other alternative project activities would also have effects on irrigation use of water. The alternate proposal which uses Hat Creek water as the source of power plant make up water is not clearly defined as to the amount of water that would be used for this purpose. If the storage and use of freshet flows only are considered, then the present irrigation use in the valley could coexist with this use. Two or three users, however, immediately downstream of the reservoir may be affected since the proposed base flow release to Hat Creek just satisfies the fisheries base flow requirement. If utilization of Hat Creek water as plant make up is in excess of freshet flows, then conflict with other water uses would be apparent, the major one being irrigation.

The other alternate project activity that would affect irrigation water use is the proposal for using Medicine Creek water for the power plant. As details of this alternative are not known, the potential effects could not be fully quantified. Water users in both Hat Creek Valley and the Thompson River area could be affected. The total water collected and used during the irrigation season, May through September, could be considered, in large measure, as displacing current licenced water use. In addition, up to 216 $ha\text{-}m\text{-}yr^{-1}$ of freshet water normally diverted and stored in Mclean Lake could also be affected. Both of the above alternate water supply schemes could negatively affect the feasibility of developing irrigation storage for the future irrigation of the corn land located in Subregion II of the Hat Creek drainage.

Use of project reservoirs and impoundments during the operation phase for irrigation storage use does not appear feasible due to constraints of the operating mode of these facilities.

Livestock Use

Leachate from the coal stockpiles and perhaps seepage from the mine could exhibit (Table 6-20 & 6-25) levels of copper that would exceed the upper limit of 0.5 mg/l recommended[94] for livestock waters and therefore present a hazard to livestock should they gain access to these undiluted waste waters.

It appears that only limited use of livestock could be made of water facilities created by the project. None of the small sedimentation ponds are located in areas where cattle would have ready access to them. The reservoirs created on Hat Creek itself could perhaps provide some benefit to cattle use during the winter months in the case of a herd being wintered close by. The main plant water supply reservoir could provide a source of water to spring and summer grazing value limiting the number of animals that would be in the area.

No other major impacts on livestock animals or on their utilization of the range have been projected by the *Agriculture* study. Thus the effect of project operation on the quantity of livestock water use in Hat Creek Valley is not considered to be significant.

Domestic, Municipal, and Industrial

Infrastructure (office, warehouse, and shops) water requirements for the mine during operation will be supplied by the power plant from the Thompson River and is estimated at 140 $m^3 \cdot d^{-1}$ (1.6 $l \cdot s^{-1}$) assuming a labour force of 918 as indicated in the project descriptions.[1]

All power plant water requirements including cooling, demineralizer, sootblowers, and domestic will be supplied via pipeline from the Thompson River.

The total make-up water requirement from the Thompson River during power plant operation can range from about 662 to 1395 $l \cdot s^{-1}$ (10,500 - 22,100 USGPM) depending on the ash disposal system selected and the plant capacity factor[38]. As the minimum average daily discharge of the Thompson River is about 200 $m^3 \cdot s^{-1}$ (Figure 4-16), the impact of this water requirement is not significant.

Water usage increases due to area population changes has been discussed under Section 6.3 (b) (ii).

(iv) Decommissioning

A. Mine, Plant, and Offsites

Irrigation

The impacts of decommissioning are all perceived to be beneficial. This assumes that any irrigation use of water developed during and as a result of the project and depending on it will be protected (e.g., maintenance of flow in the canal or maintenance of creek diversions to provide water required of irrigation uses developed with the project). Table 6-32 summarizes the project activities, causes, and water quantities associated with benefits of decommissioning. The economic feasibility of potential benefits identified has not been addressed in this study.

A large potential benefit occurring at decommissioning is that of irrigation water being made available through storage provided by project reservoirs. As shown in Table 5-4, almost 1600 ha-m (12,970 ac-ft) of water are potentially available for storage in the Hat Creek drainage basin. Subtracting 84 ha-m (680 ac-ft) of additional probable use (see Section 5.3, Probable Use) of stream flow for spring pasture irrigation leaves almost 1516 ha-m (12,285 ac-ft) available for storage in Pit Lake and other project reservoirs. Assuming an eventual surface area of about 1000 ha (2471 ac) for all reservoirs and a potential evaporation rate of 0.48 ha-m-yr^{-1}(Table 4-24) evaporation loss would be about 480 ha-m-yr^{-1}. This leaves 1036 ha-m (8395 ac-ft) of storage water that could be used for irrigation. The Pit Rim reservoir and proposed Pit Lake would have far more than adequate capacity to store this quantity for irrigation use. In Table 6-32, 22 ha-m (180 ac-ft) of storage are allocated to the Pit Rim reservoir as its maximum effective capacity. This accounts for about 3 ha-m (24 ac-ft) of annual evaporation. The remainder 1014 ha-m (8217 ac-ft) of storage is allocated to Pit Lake.

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TABLE 6-32

BENEFICIAL IMPACTS ON IRRIGATION WATER USE DUE TO PROJECT DECOMMISSIONING

Project Activity	Cause of Benefit	Water Quantity ($ha\text{-}m\text{-}yr^{-1}$)
Base Scheme:		
Pit Rim Reservoir	- Storage becomes available	22
	- Pump becomes available	-
	- Evaporation of Summer flow stops	3
Pit Lake	- Storage becomes available	1014
	- Seepage evaporation stops	21
Dust Control	- Project use stops	10
Pit Rim Dewatering	- Diversion stops	21
Make Up Reservoir	- Storage becomes available	830
Supply Pipeline	- Capacity (25,000 USGPM)	650
Alternate Activity:		
Medicine Creek Water Supply	- Project use stops and storage becomes available	?
Hat Creek Water Supply Reservoir	- Project use stops and storage becomes available	213

Assuming 0.76 m to 0.91 m (2.5 to 3 ft) irrigation requirement, between 1349 ha (3333 ac) and 1126 ha (2782 ac) could be irrigated with this stored water. Since this quantity of undeveloped irrigable land is not available in the near vicinity of the proposed Pit Lake and Pit Rim reservoir a water district would probably need to be set up to make use of this water. The extent and feasibility of a water district of this nature was not determined in this study.

Other decommissioning impacts of the mine are comparatively minor. A number of operation impacts causing reduced summer flow would cease. These include the effect of Pit Rim reservoir evaporation on summer flow, Mine Pit seepage evaporation and water used for dust control. Also, the diversion of water due to Pit Rim dewatering would cease. A total of about 55 ha-m-yr^{-1} are involved.

Another of the major potential benefits of decommissioning would be the availability of up to 830 ha-m (6730 ac-ft) of storage in the plant make-up reservoir. Subtracting evaporation losses leaves about 800 ha-m (6483 ac-ft). Assuming application rates between 0.61 m - 0.91 m (2 - 3 ft) from 879 - 1311 ha (2172 - 3239 ac) could be irrigated with this water.

The water supply pipeline from the Thompson River with a capacity of 25,000 USGPM could supply irrigation water for 700 - 1100 ha (1730 - 2720 ac) assuming a daily peak demand double the July peak demand shown in Table 4-24. These quantities of land are available in the study area but no attempt was made to assess specific irrigation feasibility. On a seasonal basis, about 650 ha-m could be supplied by the Thompson River pipeline for irrigation use.

With the alternate water supply schemes, the two water supply reservoirs would make further storage capacities available. The volume of the Medicine Creek water supply reservoir was not known. The Hat Creek water supply reservoir with a capacity of about 271 ha-m (2200 ac-ft) and evaporation losses of about 58 ha-m-yr^{-1} could supply 213 ha-m (1939 ac-ft) of water which could irrigate about 323 ha (797 ac).

Livestock Use

Use of water by livestock during and after decommissioning depends on the agricultural use of lands at that time. Projections of this use are not available.

Domestic, Municipal, and Industrial

Mine and plant water requirements for process use will return to zero. Domestic surface water usage will reduce as people move away from the surrounding area. However, some water demand in excess of the "without project" usage will remain as a percentage of the people who worked on the project will stay to retire or until other work is available. The fraction of the incremental area population that will remain after the project is difficult to predict. However, any reduction in population will reduce the usage of surface water.

(v) Overall Impact Assessment

Irrigation

Construction of project facilities would alienate use of 157 ha-m-yr^{-1} (1268 ac-ft-yr^{-1}) of irrigation water on those lands projected as likely being irrigated in the future. Part of this water may be available, however, for the irrigation of other lands and thus the net impact on water use would be reduced accordingly. There is a loss of a small amount of licenced storage, 12 ha-m-yr^{-1}, which would result from the dewatering of Finney Lake. The impact of the Hat Creek and Finney Creek diversions on the use of present irrigation conveyance ditches, associated with the supply of 35 ha-m (284 ac-ft) of water, probably could be appropriately mitigated should the use of these waters be practical with the project.

Project operation (base scheme) could affect the availability of up to 60 ha-m-yr^{-1} (486 acftyr^{1}) of water for irrigation use. Partially composed of non-consumptive uses that would only change the location of water availability, the net impact on irrigation water use would more than likely be less than the above quantity.

Decommissioning of the project would be associated with major potential benefits to irrigation through the use of project reservoirs for water storage. Over 1000 ha-m (8105 ac-ft) of water of the Hat Creek drainage basin could be made available for irrigation in this way. This is roughly one and one-half times the current use of water for irrigation in the Hat Creek Valley.

Livestock Use

The losses or benefits from the project on livestock water use would appear to be minor in nature, especially in view of the fact that the magnitude of this use is small in comparison to other water uses.

Domestic, Municipal, and Industrial

Although the surface water usage for the towns of Ashcroft and Cache Creek during the construction phase will almost double with the project, compared to without, the usages are insignificant relative to the surface water resources and produce insignificant impact. Increased surface water usage in rural areas will also be insignificant.

During operation all water will be supplied from the Thompson River and the quantity is determined to be insignificant.

7.0 OPPORTUNITIES FOR MITIGATION, COMPENSATION AND ENHANCEMENT

7.1 HYDROLOGY

a) Ground Water Hydrology Impacts

i) Lake Dewatering

Finney Lake may have some aesthetic and recreational value and consideration should be given to maintaining this lake. Based on natural isotope data on lake water (see Section 4.1 (a) (iii) B) this lake does not appear to contribute significantly to the ground water recharge in the area. Most of the present seepage would exit around the upper 1 m of the wetted perimeter of the lake. Thus, we judge that if the existing discharge control structure at the lake outlet were lowered to a level 1 m below the present average summer levels the natural seepage would be negligible and significant portions of the lake would remain.

ii) Seepage from Waste Rock Dumps

If seepage through and around the waste dump embankments in the Houth Meadows area became significant, this water could be collected by installing shallow wells. This water could be either returned to a temporary storage pond within the dump and used for dust control, or for irrigation of revegetated areas as suggested in Section 7.3(b).

The hydraulic conductivity of the loose waste rock on the dump surface is likely to be high (10^{-5} to 10^{-3} m/s) but when compacted would be substantially reduced (between 10^{-11} and 10^{-9} m/s). Thus, consideration should also be given to ensuring that the waste rock immediately upstream of the embankments and adjacent bedrock abutment areas, is adequately compacted.

iii) Seepage from Harry Lake Ash Ponds

Most of the seepage from the proposed ponds would be in the surficial sediments and in the vicinity of the channel of Harry Creek. If subsurface seepage were significant, a well or series of wells could be installed along the toe of the waste embankments to collect the seepage and pump the water to the sluice water pond.

iv) Location of Hat Creek Diversion Canal

The diversion canal alignment is within the area of the proposed pit and ground movements on the mine slopes could damage the natural and artificial lining materials. These materials would be placed beneath the canal invert and any damage could result in greater seepage losses. These seepage losses would in turn cause more slope instability and further increase seepage losses from the canal.

Due to a time dependency effect in the rock slopes, the slope movements during the operating phase of the mine might not be severe. In addition, the dewatering wells would also help to control slope instability. However, when the mining activity is completed and the pit is filling with water, the ground water pressures within the slopes would increase with time and slope instability would be likely to develop. Thus, the canal would be difficult and very expensive to maintain.

Consideration should be given to driving a low level tunnel further to the east of the pit. This diversion tunnel could be driven either at the start of the project or to replace a temporary diversion canal some time before the end of the mining activity.

(b) Surface Water Hydrology Impacts

The impacts described in Section 6.1 (b) are almost all unavoidable, since the ore body happens to be located immediately below the valley of Hat Creek. The valley of Medicine Creek could conceivably be saved by placing the ash and waste dumps elsewhere but wherever these dumps happen to be placed they will certainly destroy some resources, and locations other than Medicine Creek would be prohibitively expensive. Procedures and techniques for minimizing hydrological impacts of large mining projects such as Hat Creek are well known and the proponent is committed to their adoption. Particularly during construction, the impacts on surface water hydrology depend greatly on the detailed scheduling of the various tasks. No significant terrain disturbances should be undertaken before the relevant drainage and erosion control measures are in place. The exposed area of unprotected or unvegetated soil should always be kept as small as possible. The design of many standard mitigating measures such as lagoons, is still at a very early stage and there are indications that some mitigating measures will need to be altered. Besides designing sedimentation basins for adequate residence times, the basins should also be large enough to assure that the outflow does not damage the downstream channel. This is particularly relevant in the case of Harry Creek. If draining of Finney Lake could be avoided, a major impact would disappear.

The fact that the water balance of the Hat Creek region is highly negative, with potential evaporation exceeding precipitation by 200 to 300 mm depending on elevation (Figure 4-39), might be used to alleviate certain water quality impacts. The drainage flows from some areas such as waste dumps could be eliminated by providing surface storage for evaporation.

7.2 WATER QUALITY

(a) Ground Water Quality Impacts

This sub-section describes those items identified in this assessment that should be examined for feasibility in the detail design and operation phase in order to ameliorate the potential significant impacts.

1. All ponds or lagoons receiving effluents, seepages or runoff should be constructed to minimize loss of contaminated water to the ground water regime.
2. The areas to be utilized for storage of coal and low grade waste should be prepared in a manner to minimize percolation of leachates to the ground water table.
3. Reclamation should proceed as soon as possible on all disturbed areas, especially on those areas known to have high levels of leachable constituents (ash, low grade waste and claystone waste overburden). This would include short-term reclamation measures on areas temporarily inactive.
4. Overburden and stock piled materials should not be placed over thick snow in order to maintain minimum leachate drainage generation from the materials.
5. Lining the ash pond areas with a material having both a low permeability and a high sorptive capacity for trace metals such as bentonic clay should be considered.
6. A separate environmental assessment will be necessary to study areas proposed for disposal of FGD sludge, should flue gas desulphurization be selected as the sulphur dioxide control method.

(b) Surface Water Quality Impacts

Opportunities identified in the assessment as having possibilities to further mitigate the potential significant impacts of the development on surface water quality are outlined.

1. Vegetation filter strips should be utilized where possible between all disturbed areas and surface drainage ditches, creeks and streams to control and minimize residual sediment reaching the surface water systems.
2. Stripping of vegetation and topsoil from a site designated for a development related facility should be limited to only that area immediately needed for the construction.
3. In addition to the proposed main sediment control lagoons, temporary drainage ditches and settling basins should be constructed as required within the activity area to confine sediment losses to a minimum.
4. On terraced embankments, reverse slopes should be utilized to minimize runoff concentration.
5. Fertilization during reclamation should be minimized.
6. Construction of the Houth Meadows and Medicine Creek waste disposal retaining embankments to minimize seepage through these structures should be considered in order to reduce the quantity of contaminated water to be treated and discharged to Hat Creek.
7. Seepage through the ash disposal retaining embankment should be collected and returned to the ash pond. Since the permeability of fly ash is considerably lower than for bottom ash, the advantages of placing the fly ash in the westerly end of the pond should be considered as a means of reducing seepage through the embankment.
8. Surface runoff and leachate runoff from the coal pile and low grade waste storage areas should be contained and not discharged to Hat Creek unless further studies establish that treatment for organics, color and trace metals can be achieved to acceptable levels.

9. The feasibility of other canal cross-sections should be examined for the Hat Creek diversion in order to provide lower surface area and reduced temperature increases during summer low flows. Other mitigative measures such as artificial cooling or use of a rock lined creek bed rather than the proposed steel discharge conduit may be necessary to overcome impacts of temperature increases in Hat Creek water. The use of trees along the canal route to provide shade should also be considered. The design of facilities for energy dissipation of diverted Hat Creek should avoid nitrogen supersaturation.

10. Consideration should be given where possible to utilizing "dedicated" sedimentation lagoons which minimize the inclusion of runoff from undisturbed areas.

11. Consideration should be given to placing a settling basin on lower Harry Creek to control sediment loss originating from fugitive dust from the coal stockpile, coal blending and coal preparation operations.

12. The draining of Finney and Aleece Lakes should be conducted during high flow in Hat Creek. In addition, the quality of the bottom water should be assessed in detail prior to draining to allow better prediction of any impact on Hat Creek water quality.

13. If further studies on the quality of seepages from the waste dumps indicate a significant biological oxygen demand exists in these waters, consideration of biological treatment may be necessary. Alternatively, other means of disposal or reuse such as irrigation may require further investigation.

7.3 WATER USE

(a) Ground Water Use Impacts

As most abstractions of ground water would cease at the start of the pumping of Thompson River water, there would be no significant permanent ground water use impacts in the area.

(b) Surface Water Use Impacts

Irrigation

Opportunities for mitigation and compensation as discussed herein are based on the assumption that presently irrigated or potentially irrigable lands not directly alienated by project construction would be available for agricultural use. In some cases, however, the viability of agricultural operation may in fact be impractical and the appropriateness of the mitigating or compensation procedures would need to be considered in this light.

The possible relocation of four project activities has been identified in the *Agriculture* assessment[1] as helping to mitigate impacts on irrigable lands and thus impacts on the associated water use. These mitigation measures include: relocation of project drainage ditches near the southwest extremity of the mine pit so as to avoid splitting a presently irrigated field into two pieces; relocation of the mine construction camp so as to avoid alienation of high agricultural capability land (corn potential); and relocation of the main access road and conveyors to minimize the partition of the potential corn land located northeast of the mine pit.

The perceived blockage of present irrigation conveyance systems by the Finney Creek and Hat Creek diversion channels could be mitigated by constructing water control outlets on these channels that would allow continued use of the present ditch systems. Alternatively, new conveyance routes or water supply systems could compensate for the impact on present conveyance systems.

Compensation for the loss of irrigation water use due to land alienation could be possible in part, or perhaps in full, by providing water for the irrigation of alternate agricultural lands. In Subregion II of the Hat Creek Valley where 147 ha-m of water is affected (out of project alienation total of 157 ha-m), there would appear to be enough potentially irrigable land (total potential given in Table 5-1/3) to which the transfer of water use could be made. This aspect, however, has not been confirmed quantitatively nor has the desirability of such water use transfer been assessed.

Since consumptive use of surface waters due to the project operation is perceived as conflicting with other uses, the largest of which is irrigation, appropriate mitigation and/or compensation measures would be required. If the probable (without project) irrigation water use is to coexist with project water use, the supply of water from other than that of the present summer flows of Hat Creek would be necessary to account for the additional consumptive use of water during the summer. This supply could be made available by constructing larger project reservoirs to provide for the storage of freshet flows or by making use of the proposed water supply from the Thompson River.

In the case of the alternate schemes for supplying plant water from Hat Creek and/or Medicine Creek, measures should be implemented so that adequate base flows would be ensured so as to maintain current irrigation licences, especially those located immediately downstream of the respective project reservoirs.

It is advised that adequate treatment or dilution of mine water, waste dump seepages and coal stockpile drainage waters be afforded prior to the possible use for irrigation because of the potentially unsuitable quality of these waters with respect to the level of total dissolved solids. The concentration of total dissolved solids desired for irrigation water is below 1400 mg/l (Table 5-3).

Livestock Use

Since, in general, the effect of project construction on livestock water use is thought to be minimal, mitigation and compensation measures would appear to be unnecessary. However, because the impact on livestock water use due to the draining of Finney and Aleece Lakes is not clear, further evaluation of this aspect may deem that mitigation or compensation for this situation is, indeed, warranted.

Access by livestock to coal stockpile drainage waters and perhaps mine seepage should be prevented because of the potentially unsuitable quality of these waters as a livestock drinking supply.

Domestic, Municipal, and Industrial

As there are no impacts on surface water during preliminary site development, mitigation measures are not applicable.

The impacts of surface water usage for domestic purposes during construction as discussed in Section 6.3 (b), have been determined insignificant and therefore mitigation is not required.

Although the impact of surface water use on the resource (Thompson River) during operation has been determined as insignificant, water usage should be followed relative to Thompson River flow in order to minimize the percent usage and to identify high percent usages if the site requirements increase or the Thompson River experiences abnormally low flows.

The impact during decommissioning is beneficial and therefore mitigation is not required.

8.0 RESEARCH AND MONITORING PROGRAM RECOMMENDATIONS

8.1 HYDROLOGY

a) Ground Water

i) Hydraulic Conductivity of Waste Materials

Laboratory and field tests should be carried out to obtain more data on hydraulic conductivity values for dumped materials. These materials should include: waste rock (both loose and weathered and compacted), low grade wastes coal, FGD wastes, and ash (both bottom and fly). The laboratory tests would only require small sample quantities, however, a minimum of 0.5 m^3 of material would be required for field tests. Where possible both types of tests should be combined with a further evaluation of the chemical leaching properties of the materials.

ii) Installation of Piezometers and Water Sampling Stations

Combination water sampling and ground water level monitoring piezometers should be installed in boreholes located around the ash and rock waste dump areas. These piezometers would supplement the three operating monitoring piezometer stations in the valley. The locations of the three existing and eleven proposed boreholes are shown in Figure 6-1. At least three piezometers should be installed at different depths in each borehole. Where appropriate, suction lysimeters should also be installed to sample water from the unsaturated zones (see typical details in Figure A3-1).

All three existing piezometer boreholes, RH77-45, 77-48 and 77-49 should be preserved. Special provisions would have to be made to protect these installations particularly RH-48 which is inside the ash pond.

The water levels in existing piezometers are being read once a month. When the new piezometers are installed the monitoring program should be extended to include these piezometers. Samples of water should be taken for chemical analysis from these piezometers once a year for three years prior to the commencement of mining and dumping activities. A more regular monitoring program could be instituted when mining activities commence.

Numerous piezometers have already been installed in the vicinity of the coal pit and water levels in these piezometers are being monitored once a month. In addition, one borehole with a minimum of three piezometers should be installed and monitored adjacent to Finney Lake and alongside Highway No. 12 just west of Indian Reserve No. 4 in the Marble Canyon. These two stations would monitor respectively the effects of lake discharge and recharge and/or withdrawals from the Marble Canyon aquifer (see locations Figure 6-1).

iii) Subsurface Exploration at Harry Lake

Should the Harry Lake area be chosen for ash disposal, a drilling and testing program should be carried out to determine ground water and lithologic conditions within and adjacent to the proposed dumps. This would involve approximately 350 m of drilling and the installation of 20 piezometers over and above the monitoring piezometers proposed in Section ii) above. Falling head tests should be run in all completed standpipe piezometers so that hydraulic conductivities of rock materials can be determined.

(b) Surface Water

The design of the drainage and erosion control facilities is seriously impeded by lack of reliable small-plot runoff observations. Unless such data becomes available,most facilities will probably be substantially over-designed in order to be conservative. An experimental study of runoff conditions from the various types of surfaces to be created by the project under climatic conditions of the Hat

Creek area is desirable both from economic and environmental points of view. The study would involve a series of runoff plots built to simulate surfaces such as the Houth Meadow dump, Medicine Creek dump, dump embankments, yard areas, topsoil storage etc., with the more important areas simulated for two or more slope conditions. The same installations could also be used to investigate the effect of dust on snowmelt. Detailed precipitation and snowmelt data would naturally be required for all runoff plots.

The stream gauging stations presently established on Hat Creek and its tributaries should be monitored carefully until such time as they have to be abandoned because of the proposed project developments. The gauging station on Upper Hat Creek should be replaced further upstream and a new station established just below the development. The two gauging stations on Medicine Creek should be reviewed for possible relocation once the design of development in this area is firmly established. Consideration should be given to gauging Cornwall Creek if diversions are proposed to this stream in the final design. The value of streamflow records from small drainage basins is greatly increased by good concurrent climatic data. Consideration should be given to installing several additional rain gauges (preferably tipping bucket gauges) at various elevations to define precipitation over the newly gauged basins. Discharge from the sedimentation lagoons should be gauged. Sediment accumulation in the Hat Creek diversion headworks reservoir should be monitored.

Another area where lack of precedent could lead to inadequate and/or unnecessarily expensive designs is the handling of winter flows in the Medicine Creek and Hat Creek diversions. Field tests may be called for.

The functioning of the chute part of the Hat Creek diversion is similarly open to some questions. Unless a closely relevant precedent can be found, some aspects such as winter operation and the formation of roll or slug waves will need to be investigated.

If Medicine Creek is to be diverted to MacLaren Creek, that stream will need to be studied in considerable detail to assess its capacity.

The present abandonment scheme, which involves gradual filling of the mine pit over 25 years, during which the Hat Creek diversion is to be kept in operation gives rise to some concern related to pit slope stability. Failure of some pit slopes might divert the entire flow of Hat Creek into the pit, leaving the lower reaches of Hat Creek dry for a prolonged period.

8.2 WATER QUALITY

(a) Ground Water

(i) Research Recommendations

The following additional information should be obtained to fill present data gaps regarding possible interactions of project activities on ground water quality:

1. Further data should be collected on the quality of ground waters in the proposed pit area, both from the surficials, claystone overburden and coal zones. Data should also be collected on the water quality of the buried bedrock channel aquifer.
2. The geologic nature and ground water regime needs to be defined in the Harry Lake ash disposal areas.
3. Site specific detail geology and ground water regime should be established at all proposed disposal sites, impoundments, lagoons, stockpiles and storage areas to allow engineering designs that minimize negative interactions on ground water quality.

(ii) Monitoring Program Recommendations

At the present time a number of wells in the Hat Creek Valley provide water for domestic use. A selected number of these wells should continue to be monitored for the parameters performed in the baseline study (Section 3.2). Manganese and nickel should be added to the list of Cations - Trace Metals. If after a reasonable number of years (approximately 10), there has been no significant change from the baseline values established, then the program likely could be reduced and some of the less important parameters (i.e. sulphate hardness, alkalinity, etc.) could then be dropped.

At each dump and storage pile established, test wells should be drilled and sampled routinely. This program would establish whether or not there was, in fact any problems arising from leachates entering the ground water system. The parameters which should be analyzed at these test wells should be selected on an individual basis depending upon the nature of the dump or pile being monitored. Monitoring may well be required many years after decommissioning at some of the waste disposal sites.

Seepage waters should be monitored for flow, suspended solids and water chemistry for selected parameters. The latter allows comparison with samples from the ground water wells while suspended solids monitoring can help identify any piping action within embankments.

(b) Surface Water

(i) Research Recommendations

The following areas have been identified as requiring additional study to allow a more complete understanding of the potential impacts of the proposed project activities on surface water quality.

1. Further study and testing appears necessary to establish whether drainage from the coal piles and low grade waste will be alkaline or acidic in nature.
2. More data should be obtained on the probable mine water and dewatering well discharge quality.
3. Additional data on the biological oxygen demand (BOD) of all proposed discharges to Hat Creek is required.
4. Consideration should be given to conducting amorphous oxide extractions on ash samples to confirm the projected alkaline character of ash seepages.

5. Further study is necessary on designs of the Hat Creek diversion that will mitigate the projected temperature impact on Hat Creek water quality.
6. Treatability studies should be conducted on simulated runoff and seepages for removal of colloidal solids and trace metals. This should include assessment of the need and effectiveness of any flocculants or polyelectrolytes for suspended solids removal and of physical-chemical treatment for trace metal reduction.
7. Further study is recommended from a water quality viewpoint on the proposal to transform the mine pit into a lake.

(ii) Monitoring Program Recommendations

Semi-annual monitoring should be carried out at pertinent test stations established in the baseline study for Hat Creek and the Bonaparte River that will remain intact (See Section 3.2). Particular attention should be given to temperature, dissolved oxygen, nutrient levels, suspended and dissolved solids and trace metals, as it is considered that these are the parameters most likely to be affected by the project. In particular, detailed temperature monitoring should be carried out at Hat Creek in the diversion and at mouth until the thermal effects of the project are known. In addition to the other parameters already selected for the baseline study, manganese and nickel should be added to the list of Cations - Trace Metals. Manganese has been detected in drainages at other coal mines in the province and nickel has been observed in association with ash disposal drainages.

In the case of the Thompson River, annual monitoring at the two sites established in the baseline study is considered adequate. Examination of worst case conditions indicates that even under these conditions the effect on the Thompson River would be negligible due to the large dilution factor of the Hat Creek water (approximately 1000:1).

In addition to existing stations, it is recommended that a monitoring site be established on MacLaren Creek and another site be established on Cornwall Creek to monitor any effects from the ash pond and the access road. At least initially, all parameters monitored at other surface water sample points should be included at these sites as well.

The implementation of these recommended monitoring programs will provide the necessary data to determine the effect on surface water quality of the Hat Creek Project. Monitoring of all point source discharges to receiving waters will also likely be required under terms of permits issued by the Ministry of the Environment.

8.3 WATER USE

(a) Ground Water

(i) Potable Water Supply from Wells

A drilling and testing program should be carried out to confirm proposed ground water supplies. This should include the drilling of wells into the Marble Canyon and Buried Bedrock Valley aquifers in areas close to the administration and camp buildings. However, consideration should also be given to locating the wells away from potential sources of pollution.

In some areas, economic considerations may suggest that ground water sources are desirable for the irrigation of revegetated slopes. A drilling and testing program should be carried out to prove these water sources.

(b) Surface Water

(i) Irrigation

The discharge to natural waters of potentially unsuitable project waste waters should be routinely monitored and strictly controlled to ensure acceptable water quality for irrigation use. The two waste waters identified in this study that might be potentially unsuitable are the mine seepage water and the coal stockpile drainage water.

Surface waters should be monitored throughout the project and evaluated relative to irrigation use.

(ii) Livestock Use

A user survey should be carried out to ascertain the effect that dewatering of Finney and Aleece Lakes will have on the livestock watering capability of the range area west of the mine pit.

Surface waters should be monitored throughout the project and evaluated relative to livestock use.

(iii) Domestic, Municipal and Industrial

Surface water uses for these purposes should be monitored throughout the project and their impacts evaluated relative to current projected uses and also any changes in the surface water resources.

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SECTION 7

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