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HAT CREEK PROJECT

MINING FEASIBILITY REPORT

VOLUME V

MINE RECLAMATION
AND
ENVIRONMENTAL PROTECTION

prepared for
British Columbia Hydro and Power Authority

by
Cominco-Monenco Joint Venture

1978

HAT CREEK PROJECT

MINING FEASIBILITY REPORT

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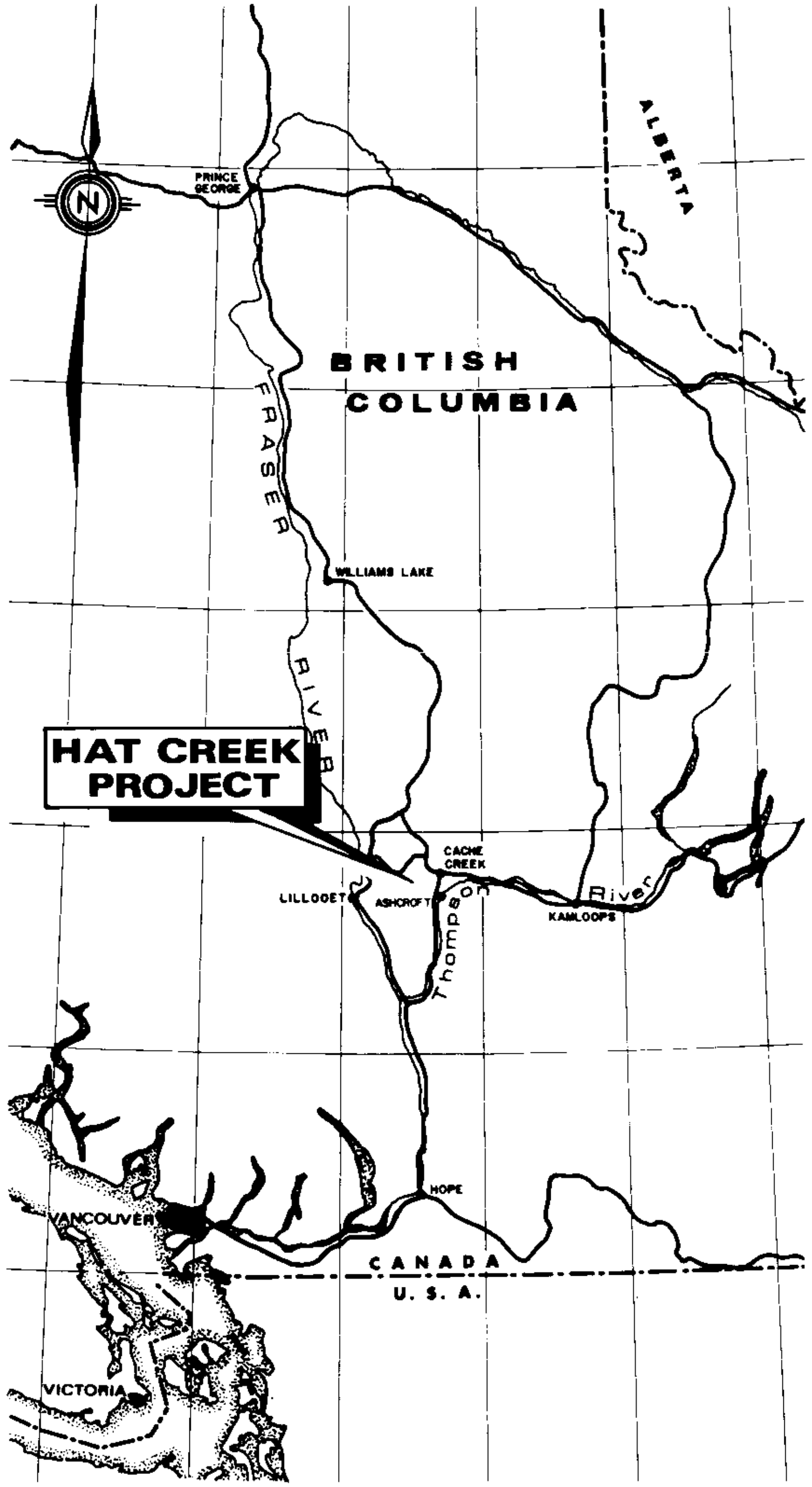

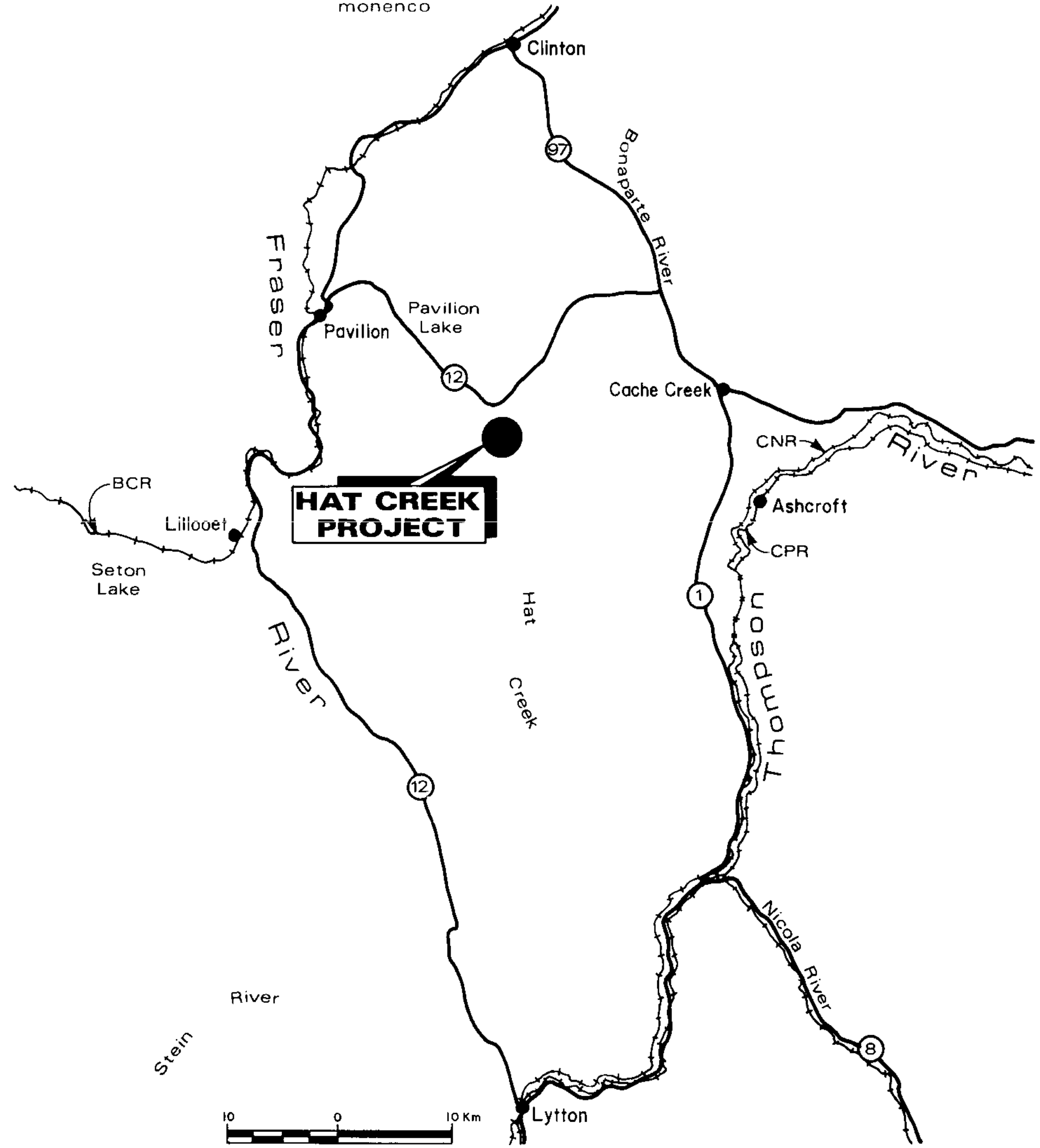

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY
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PREFACE

The Cominco-Monenco Joint Venture (CMJV) was engaged in May, 1977 by British Columbia Hydro and Power Authority to carry out preliminary engineering work for an open pit coal mine in the Upper Hat Creek Valley of south central British Columbia. The mine will supply thermal coal as fuel to a 2000 MW Generating Station located in the immediate vicinity. For convenience of reference the proposed open pit, associated waste dumps, support facilities, stockpiles, and related infrastructure are collectively referred to as the Hat Creek Mine or mine area.

As part of the overall project guidelines incorporated in a Contract for Services, the Joint Venture was requested to: "Incorporate into the planning activities, land reclamation and revegetation schemes to meet the requirements of Section 8 of the Coal Mines Regulation Act as at the date of submission of the Mining Feasibility Report".

A subsequent expansion of this portion of the Project Guidelines issued as "Guidelines for Reclamation and Environmental Matters..." called for the Joint Venture to:

> "prepare a document which could be utilized as a prime submission (with related reports either as a backup or appendices) to regulatory authorities"
>
> "This document will utilize existing reports, new data based on detailed mine planning, and environmental subconsultant reports"

Complete guidelines and scope of work in regard to reclamation and environmental studies by the Joint Venture are contained in Appendix 1 of this report.

The study program was undertaken by the CMJV under the direction of Mr. O.I. Johnson, Project Manager. Mr. D.P. Mahony, Senior Resource Planner, and Mr. J.E. Stathers, Assistant Reclamation Agronomist, were responsible for the required reclamation and environment studies and preparation of the Reclamation Report. Technical assistance was provided by Mr. R.T. Gardiner, Reclamation Agronomist. Mr. E.N. Doyle, P. Eng., Manager, Environmental Control - Cominco Ltd., was assigned to the project team as the environmental advisor.

ACKNOWLEDGMENTS

Preparation of the study report "Mine Reclamation and Environmental Protection" was the result of co-operative effort and assistance from a number of individuals. The authors wish to express their appreciation to all persons who contributed their skills and knowledge, and in particular: D. Ballard, J. Butts, J.P. Christensen, S. Geddes, K. Lunde, D. Taylor, C. Wlasichuk of CMJV, Dr. F.G. Hathorn of BCHPA, D. McQueen, S. Nase, and J. Robertson.

The portions of this document which describe the environment of the mine site and site specific field and laboratory test data were compiled principally from available specialist consultant reports. Consultants and their study areas were:

Physical Habitat and Range Vegetation	Tera Environmental Resource Analyst Limited
Wildlife	Tera Environmental Resource Analyst Limited
Forestry	Reid, Collins and Associates Limited
Agriculture	Canadian Bio Resource Consultants Ltd.
Recreation	Environmental Consultants Ebasco Services Canada Ltd.
Soils	Canadian Bio Resource Consultants Ltd.
Hydrology	Beak Consultants Limited
Water Quality	Beak Consultants Limited
Fisheries	Beak Consultants Limited
Climate	Environmental Research and Technology Inc.
Air Quality	Environmental Research and Technology Inc.

Trace Elements	Environmental Research and Technology Inc.
Waste Characterization	Acres Consulting Ltd.
Heritage Resources	University of British Columbia, Department of Anthropology and Sociology
Geology (Regional and Surficial)	Golder Geotechnical Consultants Ltd.
Groundwater	Golder Geotechnical Consultants Ltd.
Geotechnical	Golder Geotechnical Consultants Ltd.
Sedimentation Analysis	B.C. Research

SUMMARY

The proposed Hat Creek Mine is situated within the Southern Interior Plateau of British Columbia, in an area bounded by the Clear Range (1830 m ASL) to the west, the Marble Range (1830 m ASL) to the north, and the Trachyte Hills (1320 m ASL) to the east. Surficial deposits, generally comprising unconsolidated glacial drift, alluvium, and colluvium, cover the area to depths of up to 150 m. Surface instability is evidenced by slumping, flow slides, and bentonite boils, and results primarily from weak sediments in the bedrock. The principal soils of the area are Chernozemic (grassland) and Luvisolic (forest land); land use is essentially divided between agriculture (rangeland-cattle production), wildland, and forestry. The major types of vegetative cover that have been mapped are Douglas fir-Pinegrass, Douglas fir-Bunchgrass-Pinegrass, and Big Sagebrush-Bluebunch-Wheatgrass associations.

The project area is situated within the Hat Creek drainage basin. Medicine, Finney, Ambusten, and Houth Creeks generally drain northwards into Hat Creek, which also flows north and then east to the Bonaparte River, hence joining the Thompson River system. The water bodies of significance in the general project area are Aleece and Finney Lakes.

The regional climate is classified as continental and is typified by long cold winters and short, warm summers. Semi-arid conditions prevail; mean annual precipitation for the period of record is 317 mm, of which approximately one-half falls as snow. Winds are associated with the mountain/valley topography and are channelled predominantly upslope from the north to the south and southeast during the day and reversed at night.

Environmental disturbance of the Upper Hat Creek Valley during the 35-year mining project will result in the loss to present use of approximately 1930 hectares of land area due to: stockpiles (3%), support facilities (6%), drainage and transportation systems (8%), open pit (31%), and waste dumps (52%).

Consideration was given to creating a lake in the pit void after mining operations are shut down; however, due to instability of the surrounding ground materials and the anticipated poor quality of pit water this option is no longer favoured. The open pit, after a 35-year period of mining, would still

contain a significant coal resource; filling up the pit with water (or alternatively with waste material) could affect the viability of future extraction. Reclamation of the open pit will therefore comprise: regrading and revegetating the upper benches, seeding the remainder of the open pit, maintaining diversion ditches and canals to prevent undue water entry, and fencing the entire pit perimeter including adjoining areas of unstable materials to restrict public access

The limited data available to date indicate that the sodium content of final waste dump surfaces and low-grade coal stockpiles may be elevated. Depending on the nature and extent of sodic conditions, a surface crust could form on mine waste resulting in reduced seedling emergence, a restriction of water infiltration, an increase in surface runoff, and a reduction in available moisture for plant growth. Additionally, upward migration of sodium to non-sodic surface soils and utilization by plants could result in a marked decline in growth.

In order to alleviate potential growth problems, mine planning has allowed for progressive removal and stockpiling of approximately four million bank cubic metres of surface soil and ten million bank cubic metres of non-sodic glacial till and gravels during the 35-year period of mining. Sodic wastes will be buried in order to ensure satisfactory plant growth on revegetated areas. The non-sodic materials will form a buffer zone between sodic waste and replaced surface soil. Depth of non-sodic material required will be determined by site specific research conducted during mining.

Reclamation of disturbed areas will be carried out progressively over the life of the mine; it is expected that between 35% and 40% of disturbed areas could be successfully reclaimed prior to the completion of mining. In total, 69% of disturbed lands will be returned to productive use following reclamation.

Throughout the life of the project, watercourses surrounding the mine area will be protected from runoff and sediment transport through a comprehensive drainage control system established in all disturbed areas. While the topography and native species diversity existing prior to mining cannot be duplicated, reclamation is designed to provide a stable surface of materials which are similar to those on adjacent lands at similar elevations, and which are revegetated with self-sustaining plant communities. With implementation of the proposed reclamation plan, the abandoned mine site will comprise improved grazing land on valley side slopes and waste dump surfaces, selected areas of productive forest and diverse wildlands, and wetland habitat around reservoirs and drainage systems.

SECTION ONE

INTRODUCTION

SECTION ONE

INTRODUCTION

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1.1 PURPOSE OF THE STUDY

The British Columbia Coal Mines Regulation Act stipulates that: "it is the duty of every owner, agent or manager of a mine to institute and carry out a program for the protection and reclamation of the surface of the land and watercourses affected thereby..."

Upon application for a surface work permit, provincial regulations require that a report be submitted by the mine owner or agent which describes the program of protection and reclamation. The report is to include the following:

(a) A map showing the location and extent of the mine and the location of any lakes, streams ...

(b) Particulars of the nature of the mine and extent of the area to be occupied ...

(c) Particulars of the nature and present uses of the land ...

(d) A programme for reclamation and conservation of the land during, and on the discontinuance or abandonment of ...

The British Columbia Guidelines for Coal Development suggest the following key features to be reported regarding mine reclamation:

" - Present programs ...
- Overburden disposal methods ...
- Waste rock disposal proposals ...
- Revegetation proposals ...
- Reclamation program during mining operation ...
- Proposed land use and capability of reclaimed land ...
- Siltation and sedimentation controls ..."

Sections Two and Three of this document describe the proposed mining project and relevant details of the environmental setting within the project area. Site specific data regarding soils and waste characterization, laboratory and field revegetation studies and sedimentation tests, which had a direct bearing on planning mine site reclamation and protection are presented in Section Four. Based on the nature of the project, its physical and biological setting and the data available, a program for the protection and reclamation of the land and water resources has been formulated and is described within Section Five. On-going and future studies, identified during this assignment are summarized in Section Six.

1.2 STUDY AREA

The site of the proposed project development is located approximately 240 km northeast of Vancouver within the Upper Hat Creek Valley of British Columbia. Road access is provided via secondary Highway #12 from the towns of either Lillooet (55 km west) or Cache Creek (30 km east).

1.3 NATURE OF THE PROJECT

The proposed Hat Creek project will consist of an open pit coal mine and mine mouth thermal plant. Reclamation plans have been formulated on the premise that the mine is abandoned following a 35-year period of mine production. Sub-bituminous coal reserves within the deposit proposed to be mined and further south in the upper valley are available in sufficient quantity to continue mining well beyond the 35-year period.

Excavation of the coal measures will be by a combination of truck, shovel, and conveyor system, with waste being placed in adjacent dumps at Houth Meadows and Medicine Creek and coal delivered to a crushing-blending facility immediately north of the open pit. The open pit will extend down to a point approximately 267 metres (using a datum of 900 m) below the valley floor. From the blending facility, an average grade of coal (over the life of the mine) with an estimated calorific value of 17.0 MJ/kg (7327 Btu/lb) on a dry basis will be fed by overland conveyor to the thermal plant. A stockpile equivalent to a 30-day supply of coal will be maintained at either the mine site or the generating station. Maintenance and construction areas, waste water treatment lagoons, administration and ancillary items will be situated adjacent the open pit and crushing-blending facility. Further details of the mine project are provided in Section Two.

SECTION TWO

PROJECT DESCRIPTION

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PROJECT DESCRIPTION

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2.1 GENERAL

The project description is intended to give an overview of the proposed mine with emphasis on those aspects of the project which are significant from an environmental point-of-view. A complete description of engineering details is not provided.

The project description discusses mine construction and development during the pre-production period and mine operations during Years 1 to 35.

211 MINING ALTERNATIVES

Mining of the Hat Creek No. 1 coal deposit was investigated for a number of different alternatives. Amongst those methods considered were: shovel/truck/conveyor, shovel/conveyor, bucket wheel excavator, and combined shovel/truck and bucket wheel excavator. The preferred mining scheme, based on studies to date, is a combined shovel/truck/conveyor system. By this method, access to the open pit would be from a north exit ramp allowing initial waste disposal in the Houth Meadows Valley with provision for routing a portion of the waste material south to Medicine Creek Valley after 15 years, or possibly later.

Mine design considerations studied in developing this mining system included pit access, incremental pit development, slope stability, mining losses and dilution, cut-off grade, blending and stockpiling, an expanded pit to 450 m ASL, and economics.

212 CONSTRAINTS TO MINING

Primary constraints to mining include: geometry of the valley, variable and complex geology, structure of the coal deposit, the requirement for relatively flat pit slope angles (16°-25°) in weak rocks, the presence of slides and faults in or near the pit, major diversions of local streams, and the requirement for consistent quality of coal feed to the thermal power plant. Waste disposal alternatives were limited due to the poor material strengths, thereby necessitating retaining embankments. Final estimates of waste volumes will not be confirmed until swell factors become known during the actual operations.

Because coal reserves in the No. 1 Deposit will not have been exhausted after 35 years of mining (the basis of the feasibility study), and the potential exists for development of adjacent coal reserves, it was not feasible to develop alternatives which would limit the extraction of further coal reserves.

Regulatory acts and guidelines describing measures for pollution control and reclamation were also applied to mine design. Specifications for slope of waste dump surfaces (3°) and foundation criteria (wastes must be limited to areas of stable foundation) were suggested by geotechnical consultants.

2.2 MINE CONSTRUCTION AND DEVELOPMENT

221 CONSTRUCTION SCHEDULE

The following simplified construction schedule (Table 2-1) is provided to illustrate the sequence of activities affecting environmental protection and reclamation during mine site development.

222 DRAINAGE CONTROL

The mine layout at Year 1 illustrates interceptor ditches, water treatment lagoons, diversions, and reservoirs constructed during the pre-production period (Figure 2-1).

The proposed open pit will require diversion of portions of Hat and Finney creeks, around the pit and support facilities back into Hat Creek.

A headworks dam is proposed to divert Hat Creek into a 6.4 kilometre long canal (emergency capacity 27 m^3/s; normal design capacity 18 m^3/s; average annual discharge 0.7 m^3/s) on the east side of the pit at the 975 m contour. A 2 km long buried conduit at the downstream end would return the water downhill to Hat Creek. The canal would be designed with an impermeable liner (in areas of pervious material) to prevent major seepage loss. After about 12 years of mining the Hat Creek diversion canal would require either relocation to a higher elevation or construction of a tunnel to bypass the proposed 35-year pit limits.

A second diversion canal (capacity 5.5 m^3/s; average annual discharge 0.03 m^3/s), about 3.2 km long would intercept and convey Finney Creek along the 985 m contour to the headworks reservoir. The headworks reservoir, behind an earth fill dam, would occupy about 6.1 ha at maximum level; a concrete emergency spillway, with an earth fill fuseplug, would become operational with any flow exceeding the 1000 year design discharge of 27 m^3/s and provide 0.6 m of freeboard for the 100 year flow of 18 m^3/s. Discharge would be to the former streambed of Hat Creek (BCHPA, 1978).

TABLE 2-1

Simplified Construction Schedule
Hat Creek Project Mining Feasibility Report 1978

Year	Quarter	Location	Activity
-5	second	open pit	development drilling
	third	open pit	slope depressurization
		service area	power supply
-4	second	service area	surface drainage systems water, sewer, and fire protection temporary construction facilities
		open pit	lake and surficials dewatering
	third	service area	construction of maintenance and warehouse facilities
-3	first	open pit	completion of Hat and Finney Creek diversion
	second	open pit	soil and overburden removal by scraper water treatment lagoons waste embankment construction
		service area	administration buildings mine dry and miscellaneous facilities
-2	second	open pit	overburden and waste removal by shovel
-1	second	open pit	coal production

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FIGURE 2-1

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY
HAT CREEK PROJECT
MINING FEASIBILITY REPORT

MINE LAYOUT
PRE-PRODUCTION

The pit rim reservoir (refer Figure 2-1) will capture seepage from the headworks reservoir and gather local surface drainage. Maximum storage capacity is estimated at 25.9 hectare metres). A pumphouse and pipeline will return water to the Hat Creek diversion as required. Below the pit rim reservoir a cut-off trench will further reduce seepage to the pit.

Construction and utilization of the headworks and pit rim reservoirs could provide sufficient water for mining purposes and enhance downstream flows in Hat Creek during the period of low summer flow.

223 SUPPORT FACILITIES

The site for support facilities will be prepared northeast of the open pit by cutting, filling, and levelling a gently sloping hillside composed of glacial till and glaciofluvial sands and gravels.

Mine service facilities will include a maintenance building, office and administration buildings, mine changehouse, fuel storage and dispatch area, ancillary maintenance and service facilities, gatehouse and security control, sewage collection and treatment system, fire fighting equipment, and vehicle access and parking.

Roads will be constructed at 5° or less and will be bordered by suitably constructed ditches. Service roads will be surfaced with gravel and average 15 m in width. Haul roads, located mainly in the open pit, will be about 30 m wide and surfaced with burnt zone material (baked detrital rocks and burnt coal residue) or crushed rock. The road and ditch corridor around the pit perimeter will average about 20 m wide and be constructed through glacial till and glaciofluvial gravels.

Potable water is required at the mine dry building, administration building, laboratories, and maintenance buildings for steam cleaning, fire protection, compressor cooling, and hot water. Nonpotable water, required for dust control, will be recycled from waste water holding ponds and pit dewatering flows.

Fire hydrants will be installed in the mine service area, coal stockpile and blending area, and the main pit conveyor incline, with two pumper units available to fight spot fires remote from the permanent water supply system.

Provision has been made for supply of sufficient water to irrigate approximately 2 ha of lawns and landscaped area near support facilities. To the south of the open pit, a reclamation nursery, approximately 10 ha in size, will be supplied with water from the Pit Rim Reservoir.

About 140 m^3/day of sanitary waste water will be discharged from the support facilities. Provision has been made for biological treatment in a package type treatment plant followed by recycling the water for dust control within the area of the open pit. Waste water from the equipment washdown area will be discharged at about 90 m^3/day; this will be channelled to main treatment lagoons. Putrescible refuse will be incinerated, and non-putrescible refuse disposed in suitably approved sanitary landfills.

Scrap equipment will be stored in screened service yards to reduce visual impact.

224 CONVEYOR CORRIDORS

Conveyor beds will be constructed in glacial tills and anchored in concrete where required. About 3 m of the level (10 m) bed surface will support the conveyor, the remaining area will consist of a service road. Conveyor corridors will vary in width up to 40 m depending on cut and fill requirements.

225 PRE-STRIPPING AND WASTE DISPOSAL

Surface soil and overburden removal by scraper will begin in the open pit and Houth Meadows starting in Year -3 after site clearing is completed. Waste removal by shovel will begin in Year -2.

During pre-production approximately .01 million bank cubic metres (BCM) of low-grade coal, .30 million BCM of bedrock waste, .70 million BCM of coal, and 20 million BCM of waste above bedrock will be excavated (refer Table 2-2).

About 10 million BCM of construction material will be required for building the Houth Meadows conveyor causeway and pad, Hat Creek Valley fill, road construction, and Houth Meadows embankments. Houth Meadows will contain about 15 million BCM of disposed waste by the end of pre-production (Table 2-3).

Initially, waste will be removed and hauled by 136 tonne truck to dump areas. As conveyors come on line, waste will be handled by a combination of conveyor and waste spreader.

2.3 MINE OPERATIONS

231 OPEN PIT MINING

231.1 Production Schedule

Volumes and types of materials mined during Years 1 to 15 and Years 16 to 35 are presented in Table 2-2.

About 686 million BCM of material will be mined from the open pit over 35 years.

The current production schedule indicates that low-grade coal, bedrock waste, coal, and waste above bedrock would comprise about 1%, 24%, 34%, and 41%, respectively, of total production by volume.

TABLE 2-2

Simplified Production Schedule (BCM x 10^6)

Material	Pre-Prod.	Yrs. 1-15	Yrs. 15-35	Total
Coal	0.70	102.24	131.38	234.32
Low-grade coal	0.01	4.70	4.26	8.96
Bedrock waste	0.30	40.42	120.43	161.15
Waste above bedrock				
Pervious materials	11.70	102.84	68.46	183.00
Impervious materials	7.43	29.14	29.47	66.04
Hard pan/consolidated till	0.00	7.40	14.60	22.00
Burnt zone	0.58	6.44	2.35	9.37
Surface soil	0.34	0.60	0.50	1.44
Sub-total	20.05	146.42	115.38	281.85
Grand Total	21.06	293.78	371.45	686.28

231.2 Extraction Methods

Coal and waste will occasionally be blasted or dozer ripped (if required) before excavation with 16.8 m^3 shovels and loaded on 109 tonne (coal) or 136 tonne (waste) trucks for transport to one of three conveyor loading stations within the pit. Material will be transported out of the pit by three conveyors to a surface interchange.

231.3 Pit Design

Current mining plans permit experience to be gained with slope stability and allow pit design alterations before the pit becomes too deep. Pit slopes will be excavated at a relatively flat angle as the surface of the pit expands rapidly outward during the initial years of mining. At Year 25 the final surface perimeter is reached and at Year 32 the final depth of 267 m (using a datum of 900 m) is attained.

Flatter pit slopes during the early years of mining reduce shear stress and reduce the possibility of progressive slope failure. Slopes are designed to permit coal removal and will in all probability not remain stable following curtailment of dewatering and depressurization measures.

Recommended pit slope angles for the feasibility study were; 16° for slide debris, 20° for Coldwater rocks (excluding coal), and 25° for surficials and coal, respectively.

232 MATERIALS HANDLING AND WASTE DISPOSAL

232.1 Materials Handling Schedule

Volumes of material delivered to varying locations during pre-production, Years 1 to 15, and Years 16 to 35 are summarized in Table 2-3. Mine layouts for Years 15 and 35 are illustrated on Figures 2-2 and 2-3, respectively. A schematic cross-section and plan view of the Houth Meadows and Medicine Creek waste dumps are presented on Figures 2-4 and 2-5, respectively.

TABLE 2-3

Simplified Materials Handling Schedule
(BCM x 10^6)

Destination	Pre-Production	Years 1-15	Years 16-35	Total
Thermal Plant (coal)	0.70	102.24	131.38	234.32
Low-grade coal stockpile	0.01	4.70	4.26	8.96
Houth Meadows waste dump	15.22	182.08	94.26	291.56
Medicine Creek waste dump	0.00	0.00	139.55	139.55
Other *	5.13	4.76	2.00	11.89
Total	21.06	293.78	371.45	686.28

* includes construction material used for conveyor causeway and pads, road construction, and fill.

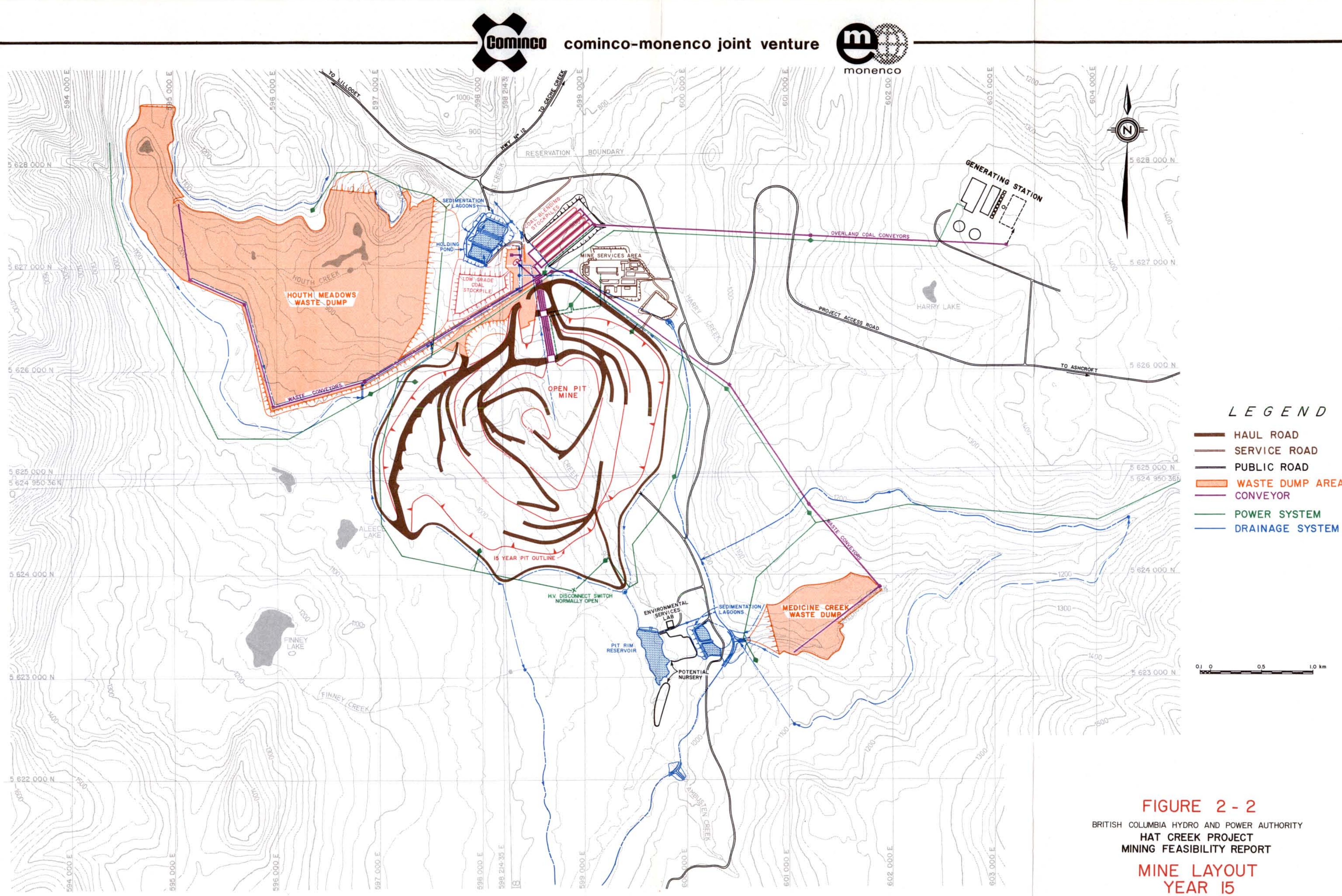

FIGURE 2 - 2

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY
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MINE LAYOUT
YEAR 15

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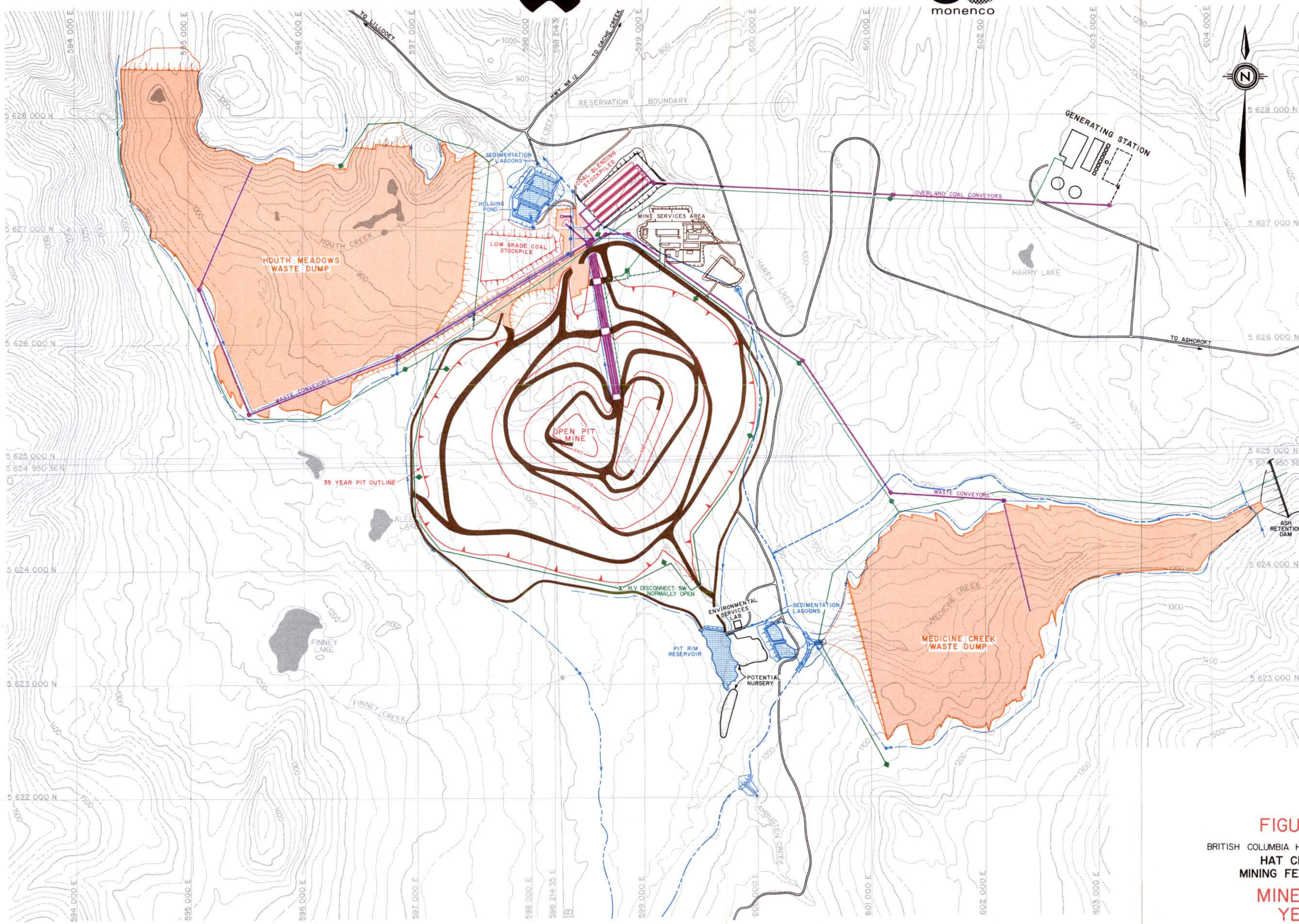

FIGURE 2 - 3

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

HAT CREEK PROJECT

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MINE LAYOUT YEAR 35

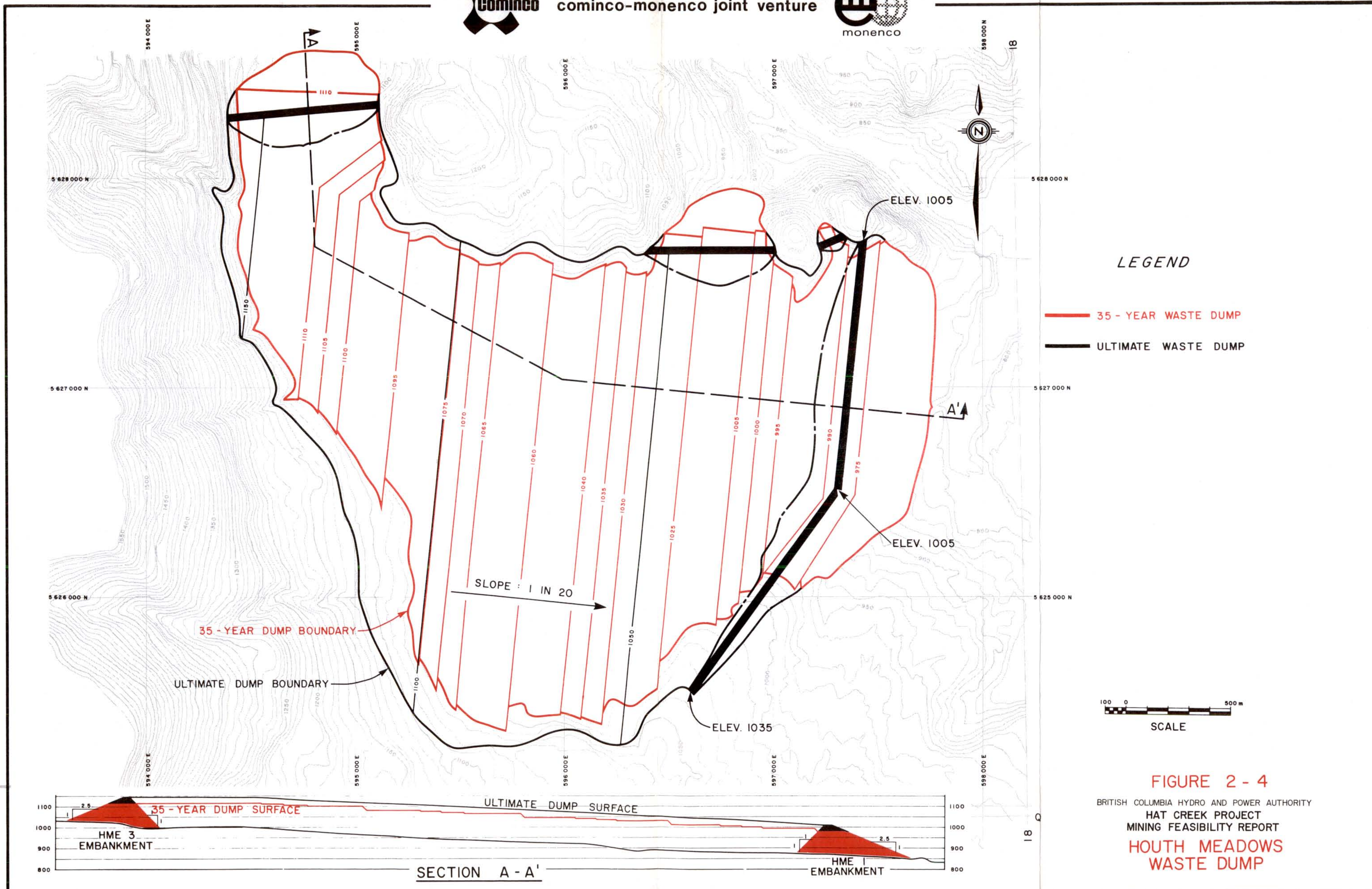

FIGURE 2 - 4

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY
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MINING FEASIBILITY REPORT

HOUTH MEADOWS
WASTE DUMP

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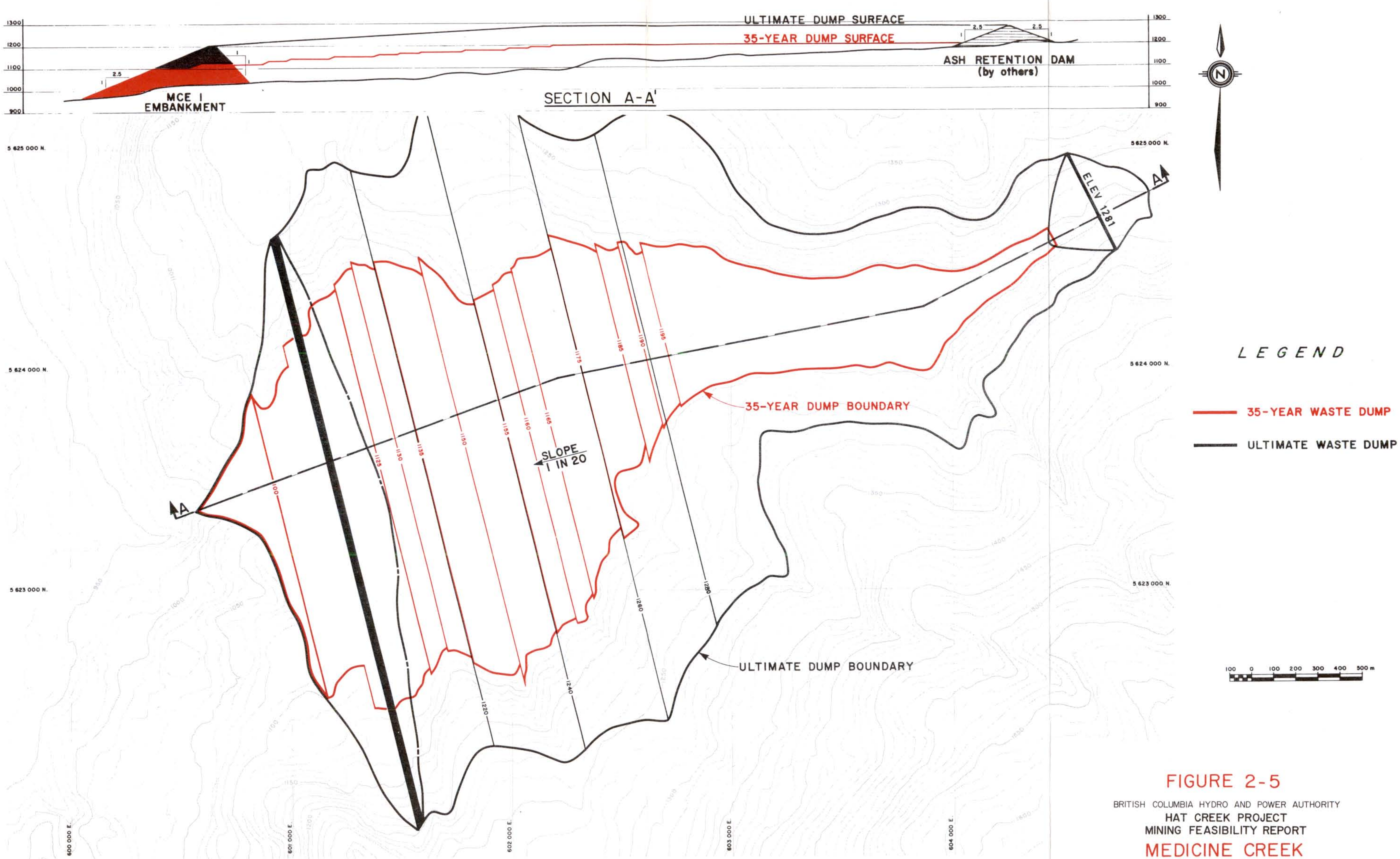

FIGURE 2-5

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

HAT CREEK PROJECT

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MEDICINE CREEK WASTE DUMP

About 65% of the waste will be delivered to Houth Meadows dump, 31% to Medicine Creek, and 2% to the low-grade coal stockpile. The remaining 2%, consisting of construction materials, will be used for conveyor causeways, conveyor pads, road construction, and fill.

232.2 Coal Handling and Storage

Coal will be moved by truck to one of three unloading stations in the pit, where primary crushing will take place, then transported out of the pit by main incline conveyor to a secondary crushing plant; and from there to a coal blending stockpile.

Coal can be stored and blended in four windrow type blending piles during a two week period before transfer to the power plant. Each pile will average about 17 m high, 48 m wide, and 522 m long. Two piles will stand idle while one portion of a pile is being built by slewing stacker and another pile is being reclaimed by a bucket wheel reclaimer. From stockpiles, coal will be blended to meet power plant feed requirements.

Coal will be transported to the power plant by a 4.2 km long overland coal conveyor. The coal conveyor will be hooded throughout its length and enclosed in galleys in areas where snow drifting is a problem. Hydrants will be installed along the route for fire protection. Where the conveyor passes under roads and through cuts it will be constructed in a culvert. A sprinkler system or spray foam will provide additional fire protection within galley areas.

232.3 Waste Handling and Storage

Waste will be transported by truck to one of three conveyor loading stations located in the pit and conveyed up the 1.5 km main incline to a surface interchange. From here, construction material will be routed to embankments and waste will be directed behind embankments on two separate conveyors and spreader systems. The retaining embankments, composed of glaciofluvial sands and gravels, will be constructed to the projected requirements of an open pit expanded to 450 m ASL, thereby making full use of available materials. Stability will also be increased beyond that specified for the 35 year volume of waste. Embankments will be constructed in a series of lifts allowing for permanent reclamation of completed sections. In Year 15, following completion of the principal Houth Meadows embankment, one conveyor will be moved to Medicine Creek for embankment construction, following which waste can be selectively delivered to either dump location as mine operations require. Belt conveyors to Houth Meadows and Medicine Creek do not have protective covers.

Eventually an overland waste conveyor will run 4.7 km along the south side of Houth Meadows to about the 1100 m level and approximately 4.7 km along the north side of Medicine Creek Valley to the 1180 m level. From these conveyors, waste would move on to a shiftable conveyor within the dump area which is moved forward as required by a side boom tractor. Placed on the dump surfaces by a travelling tripper and spreader, waste will eventually be formed into a series of benches 5 m to 20 m in elevation. Overall slope of the final surface will be about 3°. The final dump surface would consist of hummocky terrain left after waste is discharged off the spreader. Microrelief on dump surfaces could range up to 5 m from depression to ridgetop. Semi-circular ridges created by the spreader will be oriented downslope. Surface runoff would be intercepted by depressions and ridges.

A schematic cross-section and plan view of Houth Meadows and Medicine Creek waste dumps at Year 15 and Year 35 is shown in Figures 2-4 and 2-5.

233 DRAINAGE CONTROL

The basic surface drainage plan for initial mine production (Year 1), the approximate mid-point of mining (Year 15), and end of mining (Year 35) is shown on Figures 2-1 to 2-3, respectively. Water volumes and flow rates for the mine are shown in Figure 2-6.

233.1 Surface Water Drainage

Runoff from undisturbed areas to the open pit will be intercepted by the Hat Creek Diversion and the West Perimeter

LEGEND

FIGURE 2-6
MINE DRAINAGE AND WATER SUPPLY SYSTEM FLOWS

HAT CREEK PROJECT MINING FEASIBILITY REPORT 1978

Code (As on flow chart)	Description	Watershed Area Km²	Flow Frequency	Flow Type	Estimated Flow m³/S	Estimated Volume m³ x 10³	Sources of Data	Assumptions and Remarks
DIVERSION DRAINS								
D1	Upper Southwest Perimeter	2.5	100R	P	1.4		1	8mm Runoff
D2	Finney Creek Canal	19.5	1000F	P	4.3		2	
D3	Hat Creek Upstream of Headworks Reservoir	248	1000F	P	27		2	
D4	Ambusten Creek and Southeast Watershed	35	1000F	P	7		2	
D5	South Medicine Creek	6	100R	P	2		1	5mm Runoff
D6	Pit Rim Pump	4.4	-	P	0.12		5	Flow limited to pump capacity
D7	North Medicine Creek	43	1000F	P	8.5		2	Excludes ash pond and reservoir 6 Km²
L1	Canal Leakage	-	DY	M	.01-.025		5	
D8	Hat Creek Downstream of Medicine Creek	360	1000F	P	34		2	Includes Dump Area
D9	East Watershed	2	100R	P	1.2		1	8mm Runoff
D10	West Perimeter	25	1000F	P	5		2	
D11	Hat Creek Downstream of Mine	383	1000F	P	35		2	
D12	North Perimeter	1	100R	P	1		1	5mm Runoff
P1	Lower Southwest Diversion	0.9	100R	P	0.7		1	8mm Runoff
P2	Southeast Diversion	0.5	100R	P	0.5		1	8mm Runoff
P3	Watershed below Canal	3	100R	P	1.5		1	8mm Runoff
MINE SURFACE WATER COLLECTION SYSTEM						24 Hour Volumes		
S1	Disturbed Area Drainage to North Valley Sedimentation Lagoons	3-6 Disturbed +3 Reclaimed	10R 10R	- -	- -	45-90 0-15	1 1	15mm Runoff 5mm Runoff
S2	Mine Service Area Drainage	0.35	10R	-	-	5.3	1	15mm Runoff
S3	Washdown Water		DY	M	-	0.09	1	
S4	Pit Surface Water	1-6	10R	-	-	17	1	Limited to Pump Capacity
S5*	Surficials Groundwater and Seepage		DY DY	M M	.011-.024 .006-.016		6 4	Pumps and Seepage Pumps Only
S6	Disturbed Area Runoff Medicine Creek	2.5 Disturbed +1.3 Reclaimed	10R 10R	- -	- -	0-37.5 0-6.5	1 1	15mm Runoff 5mm Runoff
ZERO DISCHARGE SYSTEM						Annual Volumes		
Z1	Sanitary Effluent	-	DY	M	0.0016	51	7	700 Shifts x 0.2 m³
Z2	Coal Blending Runoff and Seepage	0.2	A	M	-	2-20	7	10-100mm Annual Yield
Z3	Low-Grade Coal Runoff and Seepage	0.33	A	M	-	3-30	7	10-100mm Annual Yield
Z4	Embankment Seepage Mouth Meadows	-	A	M	-	100-550	6	
L2	Seepage lost to Evaporation	-	A	M		2-20	7	1-10 ha x 200mm Loss
Z5	Holding Pond Inflow	-	A	M	-	154-631	7	
Z6	Coal and Bedrock Groundwater	-	A	M	-	5-25	4, 7	5% of Groundwater Flows
Z7	Dust Control Use	-	A	M	-	250-370	7	
L3	Holding Pond Loss	2	A	M	-	4	7	200mm Loss
Z8	Medicine Creek Embankment Seepage	-	A	M	-	55-365	6, 7	
L4	Seepage Lost to Evaporation	-	A	M	-	2-20	7	1-10 ha x 200mm Loss
WATER SUPPLY						Annual Volumes		
H1	Supply to Mine Service Area	-	DY	M	0.0041	101	7	700 Shifts + Garden + Washdown
H2	Supply to Revegetation Nursery	-	A	M	-	75	7	10 Ha.

KEYS TO SYMBOLS IN TABLE:

100R - 100 year recurrence interval rainstorm flood after snowmelt
1000F - 1000 year recurrence interval freshet flood during snowmelt
10R - 10 year recurrence interval rainstorm flood after snowmelt
DY - DAILY
A - ANNUAL
P - PEAK Discharge
M - MEAN Discharge

SOURCES OF DATA:

1 CMJV Rainstorm Nomograph
2 CMJV Freshet Nomograph
3 Hat Creek Flow Records
4 Golder Associates Geotechnical Report 1977
5 B.C. Hydro H.E.D.D. "Diversion of Hat and Finney Creeks" 1978
6 Beak Consultants "Hydrology Drainage and Water Use-Impact Report" 1978
7 CMJV Estimate

NOTE:

These data are based on Preliminary Mine Planning Data, Hydrological and Hydrogeological Studies. Surface water flows from small watersheds and seepage flows are estimates based on several arbitrary assumptions as to runoff infiltration factors and hydraulic conductivities therefore they should be upgraded when further site specific data becomes available.

Where a range of flow is shown this identifies the variability of flow in terms of the assumptions made.

Areas used correspond to the estimated maximum effective area of natural watersheds, disturbed areas or mine facilities to be drained.

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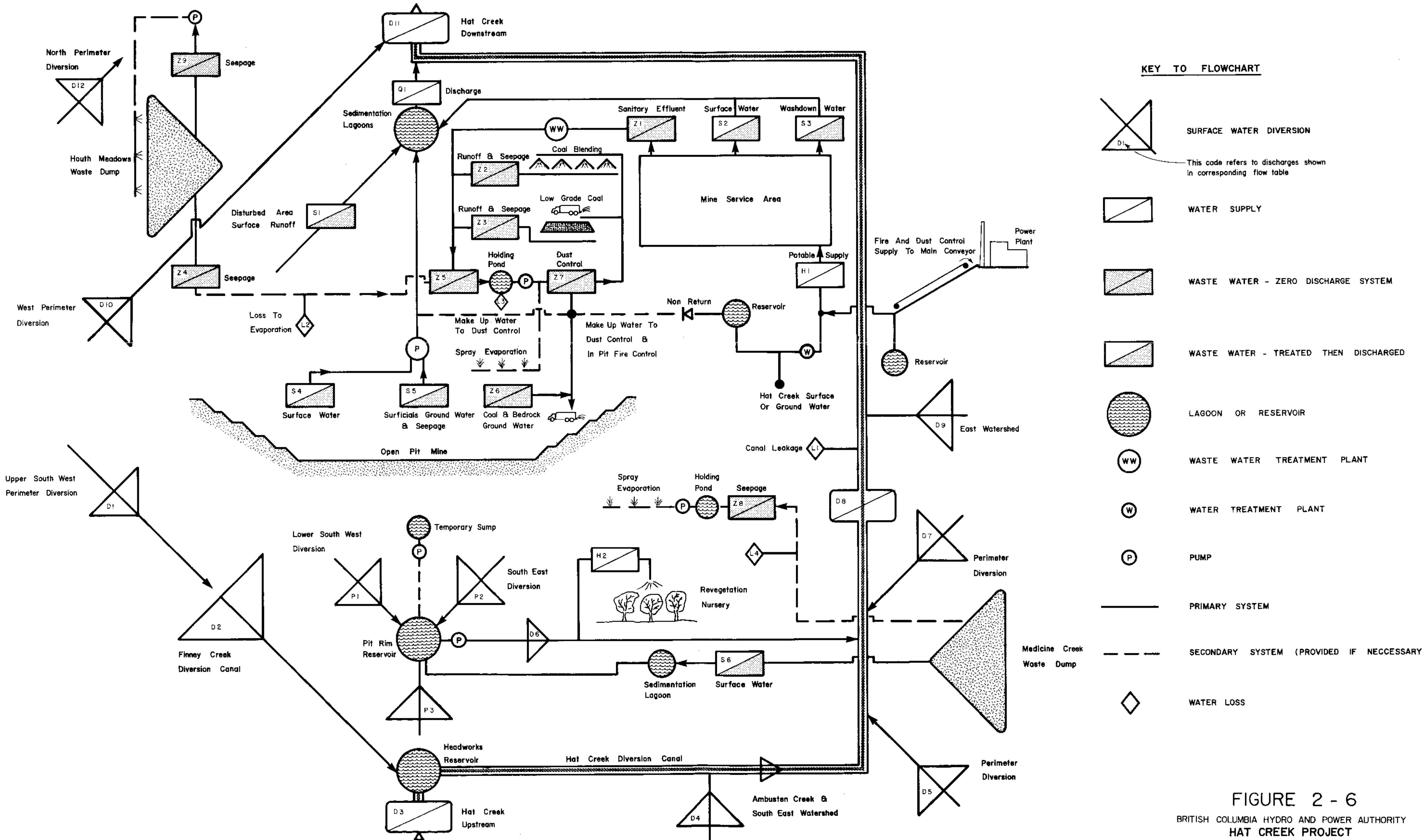

FIGURE 2 - 6

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

HAT CREEK PROJECT

MINING FEASIBILITY REPORT

MINE DRAINAGE FLOW CHART

Diversion. The West Perimeter Diversion will originate at Houth Meadows dump and carry water south and east to Hat Creek. The upper part of this diversion is formed by an open drain near the dump perimeter which enters a buried pipe at the head of the conveyor causeway. This pipe parallels the conveyor to the head of the mine before turning north to discharge to the Hat Creek Diversion. The proposed diversion is about 7.5 km long and is designed to accommodate discharges of 2 m^3/s near its origin and 5 m^3/s near the lower reaches of Hat Creek.

Houth Meadows is also protected by the North Perimeter Diversion. This consists of two sidehill drains designed to divert surface water to the Marble Canyon watershed.

Prior to Year 16, Medicine Creek will drain to Hat Creek Diversion. Diversion canals will be constructed in Year 15 on the north and south slopes of Medicine Creek Valley above the 35-year dump perimeter to convey both Medicine Creek and surface runoff around the dump. Water diverted by sidehill canal will be discharged to the Hat Creek Diversion.

Surface water from the mine services area to the southeast will be intercepted before entering the coal blending pile area by an open drain and piped to the main water treatment lagoon. Design capacity of the blending pile drainage system is based on the estimated peak flow occurring in the 10 year 24 hour rainstorm. Runoff will also be diverted away from the low-grade coal stockpile. Soil stockpiles will similarly be protected by perimeter ditches draining away from the pile. The mine services area will be drained by sloped contour and perimeter drains (design capacity 10 year 24 hour rainstorm) to the main sedimentation lagoons. Surface water will be diverted away from the overland coal conveyor during construction, and slopes revegetated after construction to prevent erosion.

The Houth Meadows conveyor lies within the drainage area serviced by the main water treatment lagoons. The Medicine Creek conveyor, located above Hat Creek Diversion, will use temporary perimeter ditches and straw bale dykes as required to reduce erosion during construction.

Haul roads located north of the pit will drain to the main sedimentation lagoons while those to the south will drain to a temporary surface water collection lagoon located between the pit rim dam and the open pit.

Temporary roads at the Medicine Creek waste dump will drain to Medicine Creek lagoon via buried pipe beneath the Hat Creek diversion.

233.2 Subsurface Water Drainage

It is estimated that discharge from pit dewatering will be 0.006 to 0.016 m^3/s depending on the stage of pit development (Golder, 1977). About 90% is estimated to be derived from surficial aquifers and the remainder from bedrock and coal. Discharge will be conveyed to sumps and then pumped up the main conveyor incline to treatment lagoons.

Seepage flow from the Houth Meadows dump to the water table was estimated to range from 200-600 m^3/day under the north saddle embankments and 10-50 m^3/day under the main embankment (Beak, 1978). Predictions were based on a preliminary waste dump plan (PDNCB, 1977). Wells will be drilled to monitor groundwater quality north of the minor saddle embankments. Dewatering pumps could be used to return flow to the surface for temporary storage and evaporation, if required. Seepage which appears at the toe drain of the east embankment will be collected in a perforated drain and discharged to a collection pond for treatment as required.

Seepage from the Medicine Creek dump embankment will be collected and treated as required. A zero discharge system similar to that described for leachate disposal facilities at the north side of the mine area would be provided, should on-site experience prove leachate quantities to be a problem. Seepage to the groundwater table should drain through deeper surficials to the open pit.

Coal stockpiles will be located on a foundation of compacted glacial till overlain by a layer of sand and gravel. Perforated pipes within this pervious layer will convey leachate flow to a collection pipe and thence to a zero discharge system.

The low-grade coal stockpile will be located on a foundation constructed of compacted impervious material. Drainage will be collected at the north end and pumped into a storage lagoon for use as a dust control agent or disposal by spray evaporation. Minor seepage through the compacted layer should be drawn down with pit dewatering and returned to the main water treatment lagoons (Beak, 1978).

234 WASTEWATER TREATMENT

Potential treatment of wastewater from the Hat Creek Mine has been examined. Specific treatment or facilities would be dependent on actual conditions. The following methods of treatment were considered:

(a) Sedimentation lagoons for the primary treatment of surface runoff containing elevated suspended solids levels. A detailed description of the nature and treatment of potential suspended solids is provided in Section 442.

(b) Storage and evaporation of leachates from coal stockpiles and waste dumps. Since the potential quantity and quality of leachate, as described in Section 441, may be unacceptable for discharge, these flows will be handled within a system designed for zero discharge.

(c) Treatment plant for sanitary effluent from the mine service complex.

234.1 Sedimentation Lagoons

Two main sedimentation lagoons located north of the open pit (refer Figure 2-3) would receive the bulk of surface runoff from disturbed areas. Inflow to the first pond will be routed through a common mixing chamber and chemical feeding point located to the east and at a higher elevation. Coagulant, if required, would be added depending on the rate of inflow and the degree of live storage available. The valley bottom site provides for a substantial amount of dead storage capacity. This could be used for both sediment storage during and after mining and to hold water for recycling within the mine. Grease or oil inflow from the service complex or pit water would be removed by conventional grease traps and an oil absorbent boom and be pumped to waste oil holding tanks.

Two sedimentation lagoons near the confluence of Medicine and Hat Creeks, and temporary lagoons as required would perform similar functions. On the basis of available data, discharge to Hat Creek from sedimentation lagoons is expected to meet present PCB level A objectives. It is likely that discharge will normally take place only during spring freshet conditions or peak summer rainfall events.

234.2 Zero Discharge System

Coal pile runoff and leachate from the coal pile, low-grade stockpile, and Houth Meadows waste dump will be channelled to a holding lagoon located north of the low-grade coal stockpile (refer Figure 2-3). Following primary sedimentation and some evaporation in the pond, the bulk of the effluent could be utilized within mine operations as a dust control agent and would be lost to evaporation. If required, additional spray evaporation facilities on the Houth Meadows dump surface will dispose of excess accumulations of effluent. This system should form a closed loop and require zero discharge under normal operation conditions. A similar system to dispose of leachate from the Medicine Creek embankment will be provided if required (refer Figure 2-6).

234.3 Sanitary Treatment

All sanitary effluent from the mine service complex would be channelled to a treatment system conforming to regulatory requirements and thence to the zero discharge system.

2.4 POST PRODUCTION

Mine planning has to date been based on a program of operation for an arbitrary time span of 35 years production, taking care not to affect the future coal resources within the Upper Hat Creek Valley. A decision on operations past Year 35 would logically be made during the later years of mining. Several alternatives would be evaluated in light of conditions prevailing at that time. Coal reserves would not be exhausted by Year 35 and mining could continue to either a greater depth within No. 1 Deposit, open up No. 2 Deposit further south, or some variation of both. Alternatively, the mine could, for any one of a number of reasons, temporarily shut down or be abandoned. The former would entail maintaining where necessary all equipment, access, diversions, etc.

This document has, for the purposes of reclamation planning, assumed that the mine will be abandoned following a production period of 35 years. However, the reclamation plan is flexible and could be modified to accommodate expansion of waste dumps with a continuation of mining after 35 years. Details of the reclamation procedures, protection measures, and current abandonment plans are described in Section Five.

SECTION THREE

ENVIRONMENTAL SETTING

SECTION THREE

ENVIRONMENTAL SETTING

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3.1 PHYSICAL FEATURES

311 GEOLOGY

311.1 Regional Geology

The project area is located within the Southern Interior Plateau physiographic region of British Columbia and is underlain by a Tertiary sedimentary basin, the eastern half of which is faulted against volcanic rocks of early Tertiary and late Cretaceous age. To the north lie older rocks of Permian age. Regional structural trend is to the northwest. The coal measures of interest lie within the Coldwater Formation of the Kamloops Group. Seams can be seen in an outcrop at the northern end of Upper Hat Creek Valley where they have been exposed by erosion. In most areas, bedrock is overlain by unconsolidated Pleistocene glacial drift and recent alluvium and colluvium (Golder, 1978).

Regional geology and geological succession are illustrated in Figure 3-1.

311.2 Bedrock Geology

Bedrock within the proposed mine area is classified as the Coldwater, Marble Canyon, and Kamloops Volcanics Formations. The coal-bearing Coldwater Formation is overlain by Kamloops Volcanics and underlain by the Marble Canyon Formation. Marble Canyon limestones outcrop north of the proposed mine area and to the east in the Cornwall Hills. The principal rock types of the Coldwater Formation are siltstone, claystone, sandstone, conglomerate, and coal (Golder, 1978). The bedrock stratigraphy of the coal deposit is outlined in Table 3-1.

311.3 Surficial Geology

Surficial deposits of varying origin provide a thick and almost total cover over the Coldwater Formation. Depth to bedrock ranges from less than a metre to 150 metres. The principal

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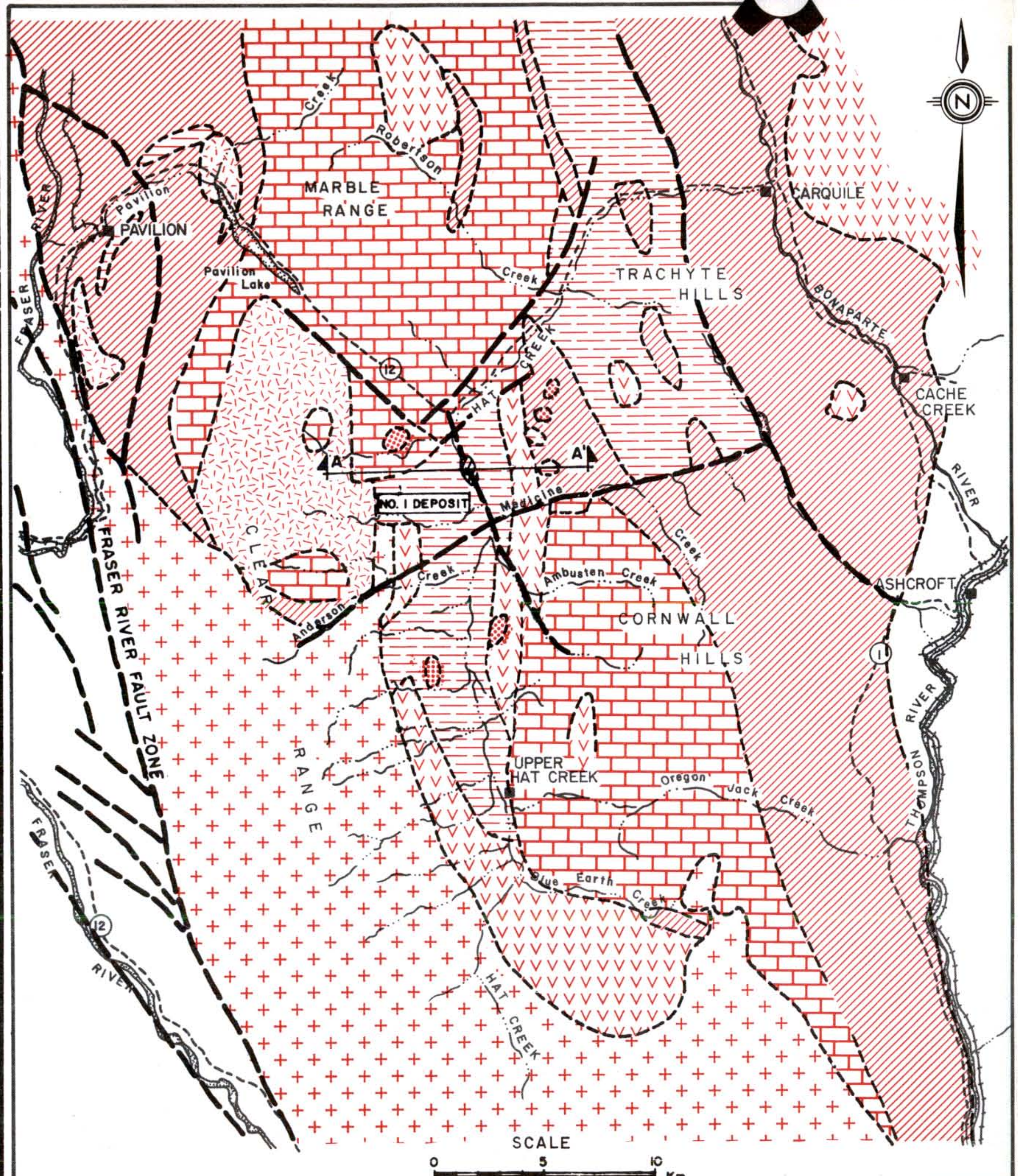

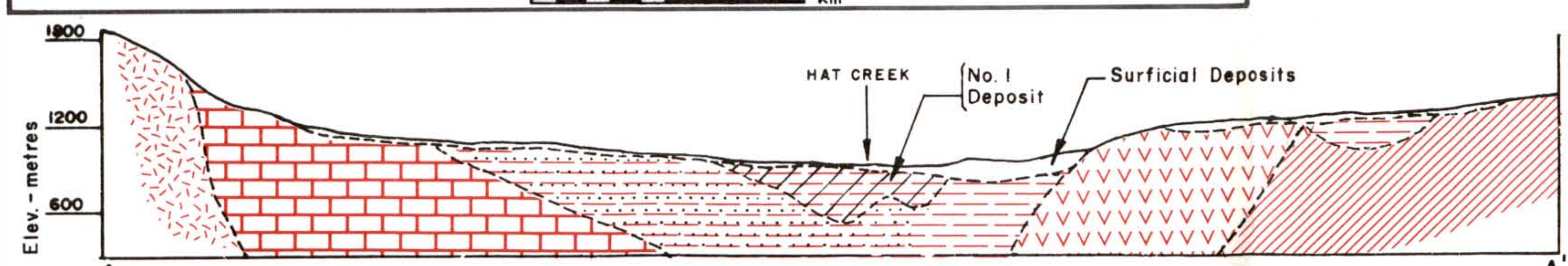

SCHEMATIC GEOLOGICAL SECTION A-A'

NATURAL SCALE
0 500 1000 meters

SOURCE: Golder Associates 1977

GEOLOGICAL SUCCESSION

Cenozoic	Quaternary	Recent	alluvium, colluvium, landslide debris, peat, volcanic ash.
		Pleistocene	glacial till, glacio-lacustrine silt, glacio-fluvial sand and gravel, landslide debris, colluvium, volcanic ash.
	Tertiary		Olivine basalt and lahar (Miocene)
		Kamloops Group	Coldwater Formation; conglomerate, sandstone, siltstone, claystone and coal, often bentonitic or tuffaceous (Eocene)
			Kamloops Volcanics; basalt, andesite, dacite, rhyolite with associated tuffs, agglomerates and breccias (Eocene).
Mesozoic	Early Tertiary to Late Cretaceous	Spences Bridge Group	volcanic and minor sedimentary rocks.
Palaeozoic	Permian	Cache Creek Group	Marble Canyon Formation; limestone.
			Greenstone, chert, argillite, quartzite, limestone and phyllite.
	Intrusive Rocks		
Mesozoic	Early Cretaceous to Late Jurassic	Mount Lytton Batholith (Mount Martley Stock).	granodiorite, quartz diorite and diorite

LEGEND

------ Inferred Geological Contact

—— —— Inferred Fault

REFERENCES:

G.S.C. Ashcroft Sheet - Map 1010A.
H. Trettin - Geology of the Fraser River Valley - B.C. Dept. of Mines - Bull. 44, 1961.
B.N. Church - Geology of the Hat Creek Basin - B.C. Dept. of Mines - Summary of Field Work, 1975.
Dolmage Campbell & Assoc. - Outline Map 1" = 2000', 1976.
Golder Assoc., B.C. Hydro & Power Authority - Field Work, 1976.
B.N. Church - Geology of the Hat Creek Coal Basin - B.C. Dept. of Mines - Geology in British Columbia (1975 work), 1977.

NOTES:

Glacial cover omitted from Plan.
Coldwater Formation subdivided by rock types on section as follows:

Siltstone and claystone (Medicine Creek Fm.)*

Coal (Hat Creek Coal Fm.)*

Sandstone, conglomerate siltstone. (Coldwater Beds)*

* Nomenclature suggested by Church (1977).

FIGURE 3 - 1

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY
HAT CREEK PROJECT
MINING FEASIBILITY REPORT

REGIONAL GEOLOGY

TABLE 3-1

Detailed Stratigraphy of the Coldwater Formation

Hat Creek Project Mining Feasibility Study 1978

Unit (GA)	Unit (B.C. Department of Mines)	Location	Symbol Used on Drawings	Strati-graphic Thickness	Range of Hydraulic Conductivity (m/sec)	Description
Upper claystone/ siltstone	Medicine Creek Formation	Stratigraphically above the coal (Unit Tcu). Subcrops in an arc from NE to SW in final pit slopes.	Tcu	488 m +	10^{-10}	Grey to blue-grey uniform bentonitic clayey siltstone-claystone with thin tuff bands which may be highly altered to bentonite. Becomes sandy and conglomeratic towards east margin (DD-76-815, 816). Very uniform gamma and density logs. Colour soon changes to brown on exposure. Part of sequence significantly stronger possibly with higher quartz content.
A-Zone Coal	Hat Creek Coal Formation	Centre of pit and limited area in SW wall.	Tcc	170 - 205 m		Thick zone showing much variation in coal quality. Divided into four sub-zones separated by three partings. *A waste zone (A_2) separates Zones A and B. High proportion of interbeds which are composed of quartz, montmorillonite, kaolinite, and occasionally siderite. Geotechnical logs highly variable.
B-Zone Coal	"	"	"	50 - 83 m	10^{-5}-10^{-6}	Black dull-bright coal with some interbeds. Divided into two sub-zones varying in quality. Density and gamma logs reasonably uniform becoming more irregular towards west. Correlation good over much of basin but becomes difficult towards the west.
C-Zone Coal	"	"	"	60 - 120 m		Poor quality coal with many interbeds composed of quartz, kaolinite, and siderite. Bentonite partings in western portions. Divided into two sub-zones separated by lenticular waste. A waste zone (C_1) separates Zones B and C. Geophysical logs show much variation although less than Zone A. May be gradational into Zone D. Correlation good-poor.
D-Zone Coal	"	"	"	60 - 120 m		Black, clean bright coal with very few interbeds. Divided into four sub-zones of varying quality. Occasional tuff and ironstone bands, some resin beads. Thickens to east, thins to west, but still recognizable. Very uniform gamma and density logs. Good correlation between holes on overall lithology and on tuff bands.
Lower siltstone/ sandstone/ conglomerate	Coldwater Beds		Tlc	190 m	10^{-11}-10^{-10}	Variable sequence of interbedded green and grey clayey siltstone and sandstone with occasional thin conglomerates, claystone, and coals. Generally highly bentonitic, often tuffaceous. Thick zones of shearing and brecciation, occasionally calcite-cemented. Density and gamma logs highly variable but overall trends give good correlation.
Conglomerate with sandstone and siltstone	"	West and NW pit slopes. Stratigraphically below the coal. Also occurs as interbeds in the conglomerate.	Tcg_1	190 m	10^{-10}	Massive grey-green conglomerate w with sandstone and siltstone interbeds, often tuffaceous. Conglomerate cement variable from calcite through sand and silt to bentonitic clay. Some disaggregated friable zones possibly caused by drilling. Clasts sub-rounded to angular.

TABLE 3-1 - continued

Unit		Location	Symbol Used on Drawings	Strati-graphic Thickness	Range of Hydraulic Conductivity (m/sec)	Description
GA	B.C. Department of Mines					
Interbedded silt-stone and sandstone with thin coals	Coldwater Beds		Tcs	150 m	10^{-10}	Grey-green weak clayey siltstone with occasional sandstones and thin coals overlying tuffaceous silty sandstone and coals.
Conglomerate	"	South abutment of Houth Meadows Embankment. Forms ridge between Houth Meadows and pit.	Tco_2	16 m +	10^{-10}	Grey micaceous, tuffaceous con-glomerate. Clast sub-rounded to angular in siltstone matrix.

* Zonation from BCH Briefing Report to the Review Board (January, 1978).

Source: Golder Associates, 1978.

surficial deposits within the proposed mine area are glacial till and glaciofluvial outwash, while colluvium, alluvium, slide debris, lacustrine deposits, bentonite, and burn zone material comprise smaller areas. The geological processes that produced these materials include subsidence, glaciation, burning, and weathering.

Portions of the coal measures were burned during late Tertiary times producing subsidence zones into which lacustrine sediments were deposited. During the Pleistocene Age, Hat Creek Valley was glaciated by sheet ice moving in a northwest/southeast direction. A till blanket was deposited following ice recession. Later, ice tongues from Marble Canyon re-advanced over the area, leaving moraines and a meltwater channel down the existing valley. Freezing and thawing of the surface materials resulted in flow and creep. Thick mantles of colluvium accumulated on steeper slopes and flow slides developed within weak expansive materials. Subsidence, erosion, and changing groundwater conditions caused re-activation of old slides in some areas. Down-cutting of the Thompson River increased erosion by Hat Creek and resulted in reworking of existing surficial materials (Golder, 1977).

The nature, origin, extent, and distribution of surficial deposits is described in Table 3-2, and illustrated on Figure 3-2.

311.4 Structural Geology

The Coldwater sediments within the Hat Creek Basin are folded into three parallel folds with the eastward and westward dipping limbs of the structures conforming with the valley margins. The basin is truncated by faulting on the east, and possibly on the west as well. The main structure is a north/south trending syncline which plunges at 10 to 35° to the south and closes to the north. A similar trend and plunge is exhibited by a second syncline to the east of the proposed mine. An anticline which separates these two synclines has been dislocated by a fault. All three structures are truncated by a fault zone in the southeast (Golder, 1977).

TABLE 3-2

Description of Surficial Materials in the Mine Area
Hat Creek Project Mining Feasibility Report 1978

Type of Material	Symbol	Description	Thickness	Location	Range of Hydraulic Conductivity (m/sec)	Moisture Content on Dry Weight Basis
Till	Qt	Glacial deposit composed of cobbles and gravels, with occasional boulders up to 1 m dia. maximum but generally much less, in a matrix of sand, silt, and clay. Locally variable, depending on matrix.	40 m-	West side of valley.	10^{-10} - 10^{-8}	15% - 50% Average 26%
Lacustrine Deposits	Ql	Bedded silts with coarse sand and occasional gravel. May be also clayey, laminated, and/or highly disturbed. Overconsolidated. Glacial origin.	100 m-	Locally throughout glacial deposits. Houth Meadows embankment foundations.	10^{-7} - 10^{-6}	18% - 32% Average 25%
Glacio-fluvial Deposits	Qf	Interbedded rounded-subrounded sands and sandy gravels with cobbles and boulders up to 60 cm dia. (approx.). Much variation in grading. Some interbedded tills. Glacial meltwater deposit.	NS	East side of valley.	10^{-7} - 10^{-5}	Depends on drainage.
Colluvium	Qc	Coarse, angular, roughly bedded, perhaps with variable proportion of fines formed on slopes by erosion. May comprise volcanics, limestone, or granodiorite.	NS	Widespread at base of steeper slopes.	10^{-7} - 10^{-4}	11% - 60% Highly dependent on composition. Average 30%.
Slide Debris (stable)	Qg	Composed of variable assortment of till and Coldwater sediments often in a bentonite matrix. Post-glacial.	112 m	West side of valley, especially NW.	not known	11% - 60% Highly dependent on composition. Average 30%.
Slide Debris (active)	Qs	As above, but some softer zones. Currently unstable.	(112 m)	Active slide in NW and minor slides elsewhere in west.	not known	11% - 60% Highly dependent on composition. Average 30%.
Alluvium	Qa	Rounded sands and gravels probably with silt interbeds. Mostly reworked glacials.	NS	Predominantly on Hat Creek Valley bottom.	10^{-6} - 10^{-4}	Depends on drainage.
Burn Zone	Qb	Varies from an irregular mass of red-brown partly-fused claystone and siltstone with some coal to well bedded slightly baked in-situ Coldwater materials.	NS	Dry Lake area. May be obscured by glacial or slide deposits in sub-crop on west side.	highly variable	

NS: not stated

Source: Golder Associates, 1978

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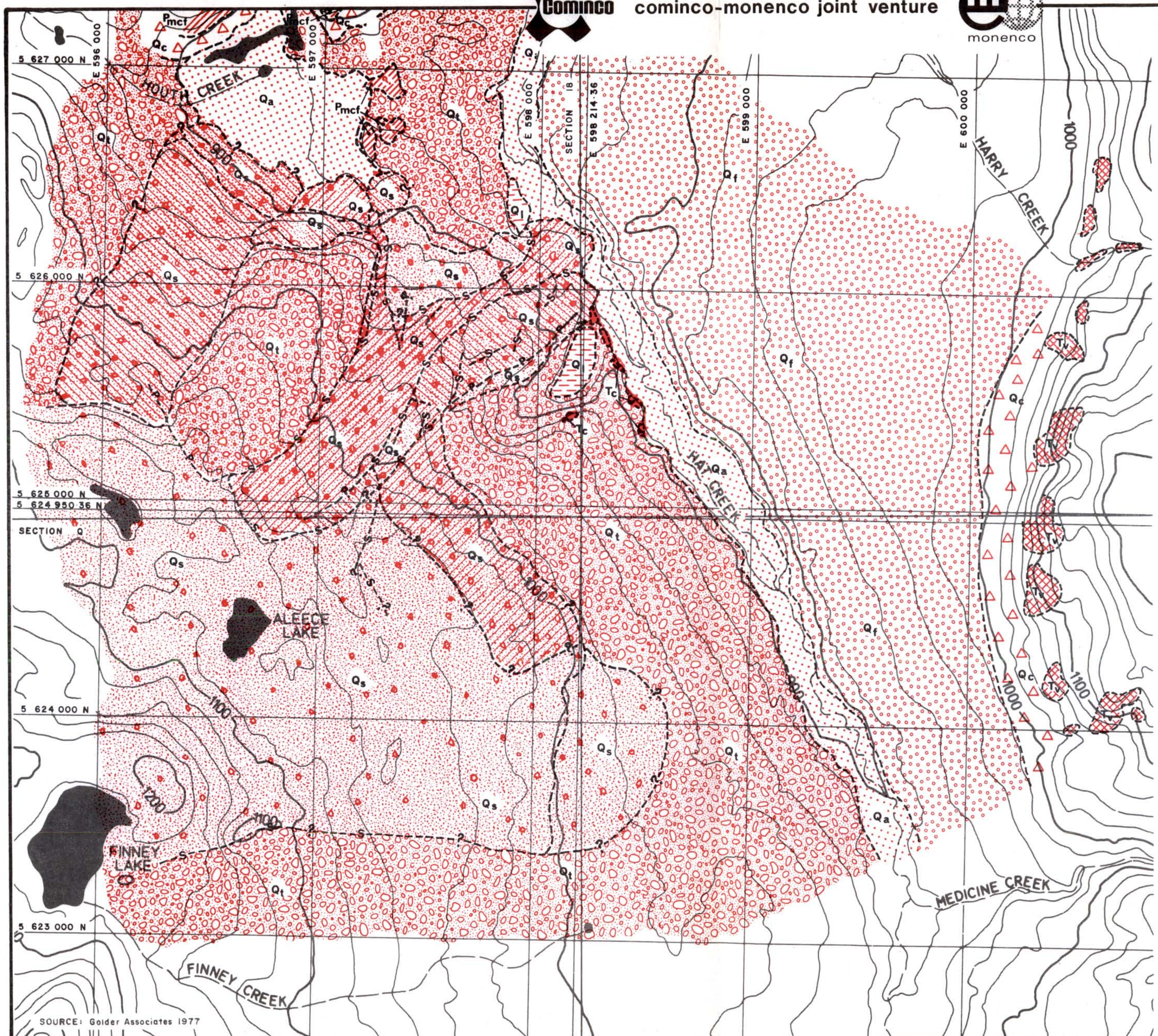

True North
Magnetic North 1976
23°

GEOLOGICAL SUCCESSION

Quaternary	Recent	Alluvium	Q_a
		Colluvium	Q_c
		Lacustrine deposits	Q_l
	Pleistocene – Recent	Slide Deposits: Active zone	Q_s
		Marginally active zone	Q_s
		Stable zone	Q_s
	Pleistocene	Till	Q_t
		Glacio-fluvial sands and gravels with till	Q_f
Tertiary		Kamloops Volcanics	T_v
		Coldwater Formation	T_c
Permian		Marble Canyon Formation	P_{mcf}

LEGEND

- - - - - - - - Geological boundary
- - - -?- - - - Doubtful boundary
- - - -S- - - Active shear plane
- - - -P- - - Photo-lineament

200m 0 200 400 600 800m

FIGURE 3 - 2

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SURFICIAL DEPOSITS

312 SOILS

312.1 Classification

Soils were mapped within the mine area to subgroup level and soil units were determined on the basis of soil depth, surface texture, drainage, and slope (CBRC, 1978). Location and characteristics of soil units are illustrated and summarized on Figure 3-3 and Table 3-3, respectively.

Soils in the proposed mine area have developed mainly on glacial till and glaciofluvial deposits. Soils developed on glaciolacustrine deposits, alluvium, and colluvium occupy a relatively minor area.

Most soils at lower elevations developed on glacial till are classified as Orthic Dark Brown and Calcareous Black Chernozems. At higher elevations soils consist mainly of Orthic Gray Luvisols. Chernozems develop in grasslands and are characterized by a surface horizon enriched with organic matter. Luvisols have developed under forest cover and are characterized by a leached surface with an underlying horizon in which leached materials, particularly silicate clays, have accumulated (Agriculture Canada, 1974).

Soils developed on glaciofluvial materials consist primarily of Orthic and Degraded Eutric Brunisols. Eutric Brunisols have developed under open forest cover and are characterized by an organic horizon over an underlying horizon in which the base saturation (NaCl) is 100% and the pH ($CaCl_2$) is usually 5.5 or higher. In grasslands at lower elevations, chernozemic soils have also developed on glaciofluvial outwash.

Soils in depressions and on hummocky terrain may be more susceptible to mottling at higher elevations, and to accumulation of soluble salts at lower elevations. Under natural, undisturbed conditions, salinity is not excessive for native vegetation.

FIGURE 3-3

Legend - Soils

Map Units	Parent Material	Order	Subgroup	Drainage
1 - 4	glacial till	Chernozemic	Calcareous Black	well
5 - 11			Orthic Dark Brown	well
12 - 17		Brunisolic	Degraded Eutric Brunisol	well
18 - 27		Luvisolic	Orthic Gray Luvisol	well
28	glaciofluvial	Chernozemic	Orthic Dark Brown	well to rapid
29 - 31		Brunisolic	Degraded Eutric Brunisol	well to rapid
32	colluvium	Chernozemic	Orthic Dark Brown	well
33 - 34		Brunisolic	Degraded Eutric Brunisol	well to rapid
35 - 36	alluvium	Chernozemic	Calcareous Black	poor
37		Regosolic	Orthic Regosol	poor
38		Gleysolic	Carbonated Gleysol	poor
39 - 43	slide debris	Regosolic	Orthic Regosol	imperfect to well
		Brunisolic	Orthic Eutric Brunisol	well to rapid

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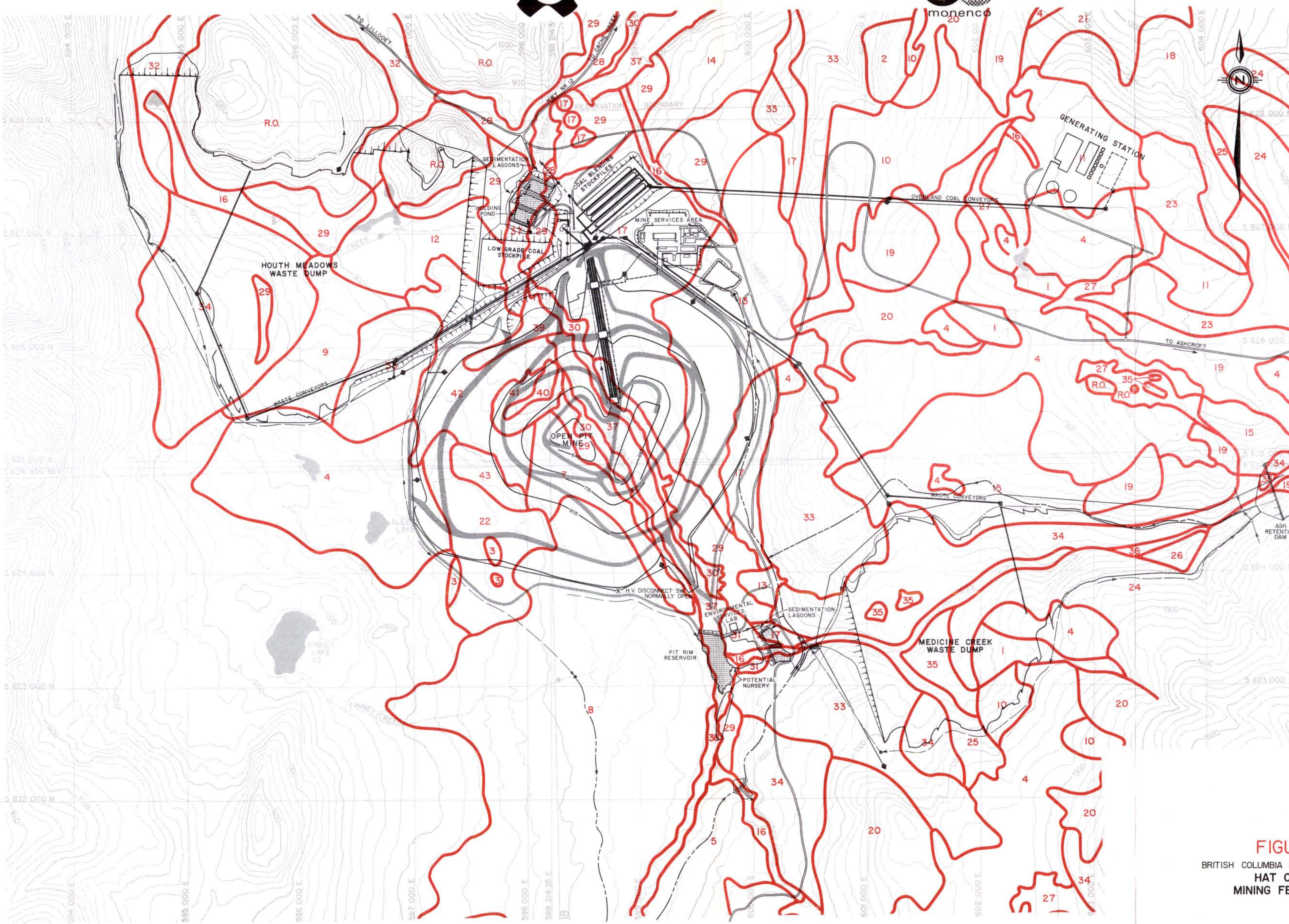

FIGURE 3 - 3

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

HAT CREEK PROJECT

MINING FEASIBILITY REPORT

SOILS

TABLE 3-3

Soil Units Within the Proposed Mine Area
Hat Creek Project Mining Feasibility Report 1978

Unit	Soil Series (E.L.U.C.)*	Soil Subgroup Major	Soil Subgroup Minor	Depth incl. B Horizon (cm)	Surface Texture	Drainage	Slope (%)	Potential Salinity **
Soils Developed on Glacial Till								
1	Medicine	CaBlC	-	10 - 15	l-gl	3	5 - 15	-
2	"	CaBlC	-	61 - 76	l	2	5 - 10	+
3	"	CaBlC	-	46 - 64	l-sl	4	<5	+
4	"	CaBlC	-	5 - 10	l-sil	2	5 - 20	-
5	"	ODBC	SaBlC	20 - 46	l-sl	1 - 4	5 - 15	+
6	"	ODBC	-	46	l-sil	1	5 - 10	-
7	"	ODBC	DEB	25	sil	3	5 - 9	-
8	"	ODBC	DEB	0 - 46	sil-sicl	1 - 5	5 - 10	-
9	"	ODBC	DEB	45	sicl	2 - 4	5 - 15	-
10	"	RDGC	-	5 - 20	gsil-sil	2	5 - 10	-
11	"	LDGC	-	3 - 5	sil-sicl	-	5 - 15	-
12	Maiden	DEB	ODBC	46	l-sil	3 - 4	<5	+
13	"	DEB	-	5 - 20	l-sl	3	2 - 5	-
14	"	DEB	-	30	sil	3	5 - 15	-
15	"	DEB	-	15 - 20	fsl-sil	3	5 - 20	-
16	"	DEB	RBlC	10	l-sil	1	30 - 50	-
17	"	DEB	ODBC	30	sil	1	7 - 15	-
18	McLaren	OGL	-	46 - 51	gsil	1	20 - 40	-
19	"	OGL	-	23 - 35	sil-gsil	3	5 - 20	-
20	"	OGL	DEB	14 - 48	fsl-sil	2 - 4	15 - 30	-
21	"	OGL	DEB	45 - 50	l-sil	1	>30	-
22	"	OGL	DEB	15 - 30	sil	2 - 4	5 - 15	+
23	"	OGL	LGL	8 - 25	sil-gcl	-	>15	-
24	"	LGL	-	15 - 30	sil-gsil	-	20 - 30	-
25	"	OGL	OR	15 - 25	sil-gsl	1	>40	-
26	"	GlOGL	-	15	sil-sicl	4	>30	-
27	"	GlOGL	-	25	sil-gcl	5	-	-
Soils Developed on Glaciofluvial Deposits								
28	Glimpse	ODBC	-	76	sil	2	<5	-
29	Glossey	DEB	ODBC	36 - 46	sil-sicl	2	2 - 10	-
30	"	DEB	ODBC	<25	sil-sicl	1	>20	-
31	"	DEB	-	61 - 91	l-sil	1	5 - 10	-
Soils Developed on Colluvium								
32	Chasm	DEB	-	30 - 38	sil-sicl	2	5 - 12	-
33	Crown	ODBC	-	10 - 15	gsl-gl	-	10 - 40	-
34	"	ODBC	DEB	15 - 20	sil-gsil	1	5 - 20	-
Soils Developed on Alluvium								
35 (53)	Frances	CaBlC		45	sil-l	3 - 4	2 - 25	-
36 (55)	"	CaBlC		25 - 30	l-sil	5	<5	-
37 (4)	"	OR		15 - 76	l-sil	3 - 5	<5	-
38 (3)	"	CaGl	-	15	l	5	<5	+
Soils Developed on Glaciolacustrine/Till Slide Materials								
39	active slide	OR	-	0	c	2	5 - 9	+
40	depression	OR	-	0	c	4	<5	+
41	inactive slide	OEB	-	36 - 46	sicl-cl	1	>15	+
42	" "	OEB	-	10 - 30	sil	2	7 - 10	-
43	" "	OR	OEB	20 - 41	sil	3	7 - 10	-

* Provincial Environment and Land Use Committee
** "+" indicates potential salinity problem

Source: Canadian Bio Resources Consultants, 1978

L E G E N D

Soil Subgroups

ODBC	Orthic Dark Brown Chernozem
CaBlC	Calcareous Black Chernozem
SaBlC	Saline Black Chernozem
LDGC	Lithic Dark Gray Chernozem
RDGC	Rego Dark Gray Chernozem
OEB	Orthic Eutric Brunisol
DEB	Degraded Eutric Brunisol
OGL	Orthic Gray Luvisol
GlOGL	Gleyed Orthic Gray Luvisol
LGL	Lithic Gray Luvisol
CaGl	Carbonated Gleysol
OR	Orthic Regosol

Texture

- g - gravelly
- s - sandy
- fs - fine sandy
- l - loam
- si - silt
- c - clay

Drainage

- 1 - rapid
- 2 - well
- 3 - moderately well
- 4 - imperfect
- 5 - poor

312.2 Chemical and Physical Properties

Samples collected from selected soil profiles within the proposed mine area were analyzed to determine the suitability of soils as plant growth media (Acres, 1978). Analyses included pH, conductivity, organic matter, and available nutrient content. Chemical analyses are summarized in Table 3-4.

Surface soil horizons (0 to 30 cm) developed on glacial till, glaciofluvial materials, and alluvium within the proposed open pit and Medicine Creek areas are non-saline, non-sodic, and moderately calcareous. The soils generally contain high concentrations of available calcium, magnesium, and potassium, and low concentrations of available nitrogen and phosphorous. Soil units located in depressions and developed on slide debris, carbonaceous shale, and glaciolacustrine deposits are slightly to moderately saline.

Soils developed on glacial till are medium- to fine-textured (Table 3-3). Those soils developed on glaciofluvial materials and alluvium are coarse-textured. Tills appear to be more susceptible to surface crust formation, rill erosion, and dusting than coarser textured soils. Fine-textured glacial tills also have improved moisture storage capacity, nutrient retention, and leach more slowly than glaciofluvial outwash and alluvium.

313 VEGETATION

313.1 Existing Vegetation

Vegetation Associations

Vegetation in the Upper Hat Creek Valley was mapped and described using colour aerial photography, forest cover maps, and subjectively located 10 m^2 sample plots (Tera, 1978). Eleven vegetation associations were mapped within the proposed mine area, and those occupying significant areas include Douglas fir-Pinegrass (23%, 416 ha), Douglas fir-Bunchgrass-Pinegrass (24%, 433 ha), Kentucky Bluegrass (13%, 241 ha), and Big Sagebrush-Bluebunch Wheatgrass (29%, 525 ha).

TABLE 3-4

Chemical Analyses of Selected Soil Profiles
Hat Creek Project Mining Feasibility Report 1978

Horizon	Depth (cm)	Conductivity (mmhos/cm)	pH	O.M. (%)	Available Plant Nutrients (pp 2 M) * NO_3-N	P	K	Ca	Mg
1. Slumped Glacial Till									
Ah 1	0-6	< 1	6.5	7.2	7	44	495	7860	>1000
Ah 2	6-11	< 1	7.5	7.6	3	7	205	>10 000	>1000
Ck 1	11-33	< 1	8.4	4.6	2	5	111	>10 000	>1000
Ck 2	33-48	5	8.3	5.3	1	7	154	>10 000	>1000
II C	48-137	8	4.5	>30	0	25	99	>10 000	>1000
III Ck	>137	4	8.3	1.1	6	3	233	7630	>1000
IV C		8	8.3	1.0	7	13	214	>10 000	>1000
2. Glaciolacustrine									
Ah	0-9	1	5.7	5.7	6	58	888	8241	>1000
C 1	9-36	1	7.1	7.1	3	22	>1000	>10 000	>1000
C 2	36-76	2	8.0	4.6	1	20	>1000	>10 000	>1000
II Ck 1	76-91	3	7.8	2.2	1	40	>1000	>10 000	>1000
II Ck 2	91-99	4	7.8	-	1	50	939	>10 000	>1000
3. Loess overlying Carbonaceous Shale									
Ah	0-8	< 1	7.2	>30	49	14	747	>10 000	>1000
Bm 1	8-28	2	7.8	14	60	7	155	>10 000	>1000
Bm 21	28-46	4	5.3	12	150	14	108	>10 000	>1000
Bm 22	46-66	5	4.5	20	320	14	112	>10 000	>1000
C	66-99	6	4.3	5.3	415	23	559	8726	>1000
II C	99>	5	4.4	20	355	29	114	>10 000	>1000
4. Loess overlying Colluvium									
Ah	0-15	< 1	6.2	9.0	5	19	683	9540	>1000
Bm	15-28	< 1	6.9	6.6	4	10	291	>10 000	>1000
Ck 1	28-38	< 1	8.2	5.5	3	8	170	>10 000	>1000
Ck 2	38-76	< 1	8.3	4.7	3	5	186	>10 000	>1000
5. Loess overlying Glaciofluvial Outwash									
Ah	0-20	< 1	7.5	3.6	1	44	>1000	7082	752
Bm	20-41	< 1	7.6	2.5	1	28	626	7873	710
II Ck	41-64	< 1	8.0	2.7	1	58	500	>10 000	801
III Ck	64-81	< 1	8.2	1.5	1	28	672	>10 000	672
IV Ck	81-99	< 1	8.3	1.6	1	7	367	>10 000	>1000
V C	99-127	< 1	8.0	1.1	1	10	426	>10 000	>1000
6. Baked Clay									
red clay	-	5	8.2	0.5	1	56	389	6031	>1000
yellow clay	-	< 1	8.2	0.7	1	17	>1000	>10 000	>1000
7. Alluvium									
Ah	0-23	< 1	7.2	4.7	2	32	>1000	7127	995
Bm	23-38	< 1	8.0	3.5	1	16	944	>10 000	>1000
Ck 1	38-61	< 1	8.5	1.4	1	7	530	> 9081	>1000
Ck 2	61	< 1	8.5	0.9	2	5	380	7927	>1000
8. Glaciofluvial Outwash									
Ah	0-18	< 1	7.7	4.0	4	14	377	8204	>1000
Bm	18-41	< 1	8.1	3.1	1	4	226	>10 000	>1000

* pp 2 M - equivalent to pounds per acre - six inch depth

Source: Acres (1977)

Percent cover, species composition, and frequency were determined for each stratum within the sample plots. A list of vegetation associations, characteristic dominant species, percent cover, and frequency are presented in Table 3-5. Relative importance and resource use of the dominant plant species are summarized in Table 3-6.

Biophysical Classification

Forty-eight biophysical sub-units were mapped and described within the proposed mine area based on detailed soil, landform, vegetation, and land use mapping (Figure 3-4).

No rare or endangered vegetative species or sensitive biophysical units were identified in the proposed mine area (Tera, 1978). Approximately 15% or 289 ha of the proposed mine area would be located on bottom land (0-5° slope). The majority of land to be disturbed (85%) consists of sloping land (6-17° slope) and steeply sloping land (>17° slope).

Potential for alkalinity and/or salinity were identified in 455 ha or 25% of the mine area, soil erosion or mass movement potential in 124 ha or 7%, and flooding in 70 ha or 4% (Tera, 1978).

313.2 Climax Vegetation

The proposed Hat Creek mine is located within the Interior Douglas Fir Biogeoclimatic Zone. Fire, logging, and grazing have altered the successional pattern. Removal of trees has increased the amount of light and encouraged regeneration of drought-tolerant understory vegetation. Palatable plant species were reduced by livestock overgrazing with a concomitant increase in species such as weeds and sagebrush which are not palatable (Tera, 1978).

Successional pattern was inferred from regenerating forest species and from grassland increasers, decreasers, and invaders (Table 3-7). At higher elevations, regenerating forest species

TABLE 3-5

Existing Vegetation Within the Proposed

Mine Area

Hat Creek Project Mining Feasibility Report 1978

Vegetation Association	Area * (ha)	Characteristic Dominant Species	Mean Vegetative Cover (%)	Species Frequency (%)	No. of Plots
Douglas fir-Pinegrass	416	Douglas fir	38	100	9
		Pinegrass	72	100	
		Lichen	36	100	
Douglas fir-Bunchgrass-Pinegrass	433	Douglas fir	13	100	6
		Bluebunch wheatgrass	33	100	
		Pinegrass	13	100	
Kentucky bluegrass	241	Kentucky bluegrass	36	100	5
		Richardson's needlegrass	8	80	
		Yarrow	6	100	
Douglas fir-Bunchgrass	70	Bluebunch wheatgrass	57	100	3
		Ponderosa pine	13	66	
		Douglas fir	7	33	
Sagebrush-Bluebunch wheatgrass	479	Big Sagebrush	65	100	4
		Bluebunch wheatgrass	39	100	
		Rocky Mountain juniper	8	75	
Bunchgrass-Kentucky bluegrass	1	Bluebunch wheatgrass	17	78	9
		Kentucky bluegrass	12	89	
		Pasture sage	7	78	
Saline Depression	2	Baltic rush	37	100	3
		Red top	22	100	
		Saltgrass	22	66	
		Foxtail barley	50	66	
Big Sagebrush-Bunchgrass	46	Big Sagebrush	37	100	6
		Bluebunch wheatgrass	31	100	
Douglas fir-Spirea-Bearberry	91	Douglas fir	18	100	2
		Spirea	5	50	
		Bearberry	25	50	
Riparian	24	Alder	23	66	3
		Willow	20	66	
		Horsetail	25	100	
		Red-osier Dogwood	28	66	
Willow-Sedge Bog	?	Willow	35	75	4
		Sedge	33	50	
		Large-leaved avens	13	75	

* area excludes roads, open water, rock outcrops, and includes biophysical units which are mapped as a complex

TABLE 3-6

Relative Importance and Use of
Dominant Plant Species
Hat Creek Project Mining Feasibility Report 1978

Plant Species	Relative Abundance	Resource Use	Relative Importance	Season of Use	Comments
<u>TREES</u>					
Ponderosa Pine	high	Forestry	low	-	Some local forestry value.
		Deer	medium-high	winter/spring	Forage and cover. Forestry/wildlife conflict.
		Livestock	low	spring/fall	Abortion potential.
Trembling Aspen	high	Deer	low	winter/spring summer/fall	
		Moose	medium	winter/spring	
		Livestock	high	all	New shoots.
		Beaver	high	all	
		Ruffed Grouse	high	all	Buds and leaves constitute 25% of diet.
Black Cottonwood	medium	Moose	medium-low	winter/spring	
Douglas fir	high	Forestry	high	-	<u>General</u> - Used by wildlife for forage as well as cover.
		Deer	medium	winter/spring summer/fall	Forestry/wildlife conflict.
		Gamebirds	high	all	Buds and leaves constitute up to 50% of diet.
Lodgepole Pine	high	Forestry	medium	-	<u>General</u> - Forestry/wildlife conflict.
		Moose	low	winter/spring	
Alder	low	Moose	low	winter/spring	
Englemann Spruce	medium	Forestry	medium	-	<u>General</u> - Forestry/wildlife conflict. Forest fire/wildlife conflict.
		Grouse	low	all	

Source: Tera, 1978

(continued)

TABLE 3-6 continued

Plant Species	Relative Abundance	Resource Use	Relative Importance	Season of Use	Comments
GRASSES					
Kentucky Bluegrass	medium	Livestock	high	spring	
		Waterfowl	medium	-	Food and cover.
Bluebunch Wheatgrass	high	Deer	medium	winter/spring	Important winter forage.
		Livestock	high	spring/summer	Very serious livestock/wildlife competition.
		Gamebirds	low	all	
Red Top	medium	Livestock	high	spring/summer	
		Waterfowl	medium	-	
Pinegrass	high	Livestock	medium	late summer	Livestock/wildlife competition.
Sedge (all *Carex* species)	high	Deer	low	winter/spring	
		Moose	medium medium-low	winter/spring summer/fall	
		Livestock	low	fall	Livestock/wildlife competition.
		Waterfowl	medium	-	Food and cover.
		Blue and Spruce Grouse	low	all	Seeds (less than 5% of diet).
Saltgrass	medium	Livestock	low	spring	
Foxtail Barley	high	Livestock	high	all	
		Waterfowl	high	-	
Baltic Rush	medium	Livestock	low	spring	
		Waterfowl	medium	-	

Source: Tera, 1978

TABLE 3-6 continued

Plant Species	Relative Abundance	Resource Use	Relative Importance	Season of Use	Comments
SHRUBS					
Big Sagebrush	high	Deer	medium	all	Important browse species in Big Sagebrush benchlands at mouth of Upper Hat Creek.
Pasture Sage	high	Livestock	low	late summer/ fall	Important browse species on sheep winter range. Livestock/wildlife competition.
Rabbit brush	high	Deer	medium-low	winter/spring	Widely distributed in Hat Creek area.
Red-osier Dogwood	high	Moose	medium	winter/spring	Important winter browse species.
		Livestock	low-medium	late summer/ fall	Livestock/wildlife competition.
Common Juniper	high	Deer	medium medium-low	winter/spring summer/fall	
		Man	-	fall	
		Gamebirds	low	all	
Rocky Mountain Juniper	high	Gamebirds	low	all	
Bearberry	high	Deer	medium-high	winter/spring	
		Man	-	early fall	
Willow	high	Deer	medium-low	winter/spring	Very important component of winter and summer diet.
		Moose	high	winter/spring summer/fall	
		Livestock	low	summer/fall	Livestock/wildlife competition.
		Gamebirds	medium	all	Young leaves and buds.
Buffaloberry	high	Deer	low	winter/spring	
		Man	-	late summer/fall	
		Gamebirds	low	all	
Spirea	low	Gamebirds	low	all	

Source: Tera, 1978

(continued)

FIGURE 3-4

Legend

Biophysical Land Classification

Map Unit	Vegetation Association	Present Land Use	Parent Material	Slope (%)	Soil Great Group	Limitations
INTERIOR DOUGLAS FIR ZONE						
1	Douglas fir-Pinegrass		glacial till	10 - 30	Black Chernozem	alkalinity, salinity
2		forestry/grazing	glacial till	10 - 30	Dark Grey Chernozem	
3			glacial till	10 - 30	Eutric Brunisol	
4			glacial till	>30	Eutric Brunisol	
5			glacial till	10 - 30	Gray Luvisol	
6			glacial till	>30	Gray Luvisol	
7			colluvium	10 - 30	Eutric Brunisol	
8			colluvium	>30	Eutric Brunisol	
9			colluvium	>30	Eutric Brunisol	mass movement
10			colluvium	>30	Dystric Brunisol	
11			colluvium	>30	Eutric Brunisol	alkalinity, salinity, mass movement
12	Douglas fir-Bunchgrass	forestry/grazing	glacial till	10 - 30	Dark Brown Chernozem	alkalinity, salinity
13			glacial till	10 - 30	Eutric Brunisol	
14			glaciofluvial	0 - 9	Eutric Brunisol	
15	Douglas fir-Bunchgrass-Pinegrass	forestry/grazing	glacial till	10 - 30	Eutric Brunisol	
16			glacial till	>30	Eutric Brunisol	
17			colluvium	10 - 30	Eutric Brunisol	alkalinity, salinity
18			colluvium	>30	Eutric Brunisol	
19			colluvium	>30	Eutric Brunisol	mass movement
20			glaciofluvial	0 - 9	Eutric Brunisol	
21			alluvium	0 - 9	Regosol	flooding
22	Douglas fir-Spirea-Bearberry/ Douglas fir-Bunchgrass Complex	forestry/grazing	colluvium	>30	Dark Gray Chernozem	alkalinity, salinity, mass movement
23			colluvium	>30	Dark Gray Chernozem	alkalinity, salinity, mass movement
24	Douglas fir-Spirea-Bearberry/ Douglas fir-Bunchgrass-Pinegrass Complex	forestry/grazing	colluvium	>30	Eutric Brunisol	mass movement
25			colluvium	>30	Dark Gray Chernozem	alkalinity, salinity
GRASSLAND ASSOCIATIONS						
26	Kentucky bluegrass	grazing	glacial till	10 - 30	Dark Gray Chernozem	
27			glacial till	10 - 30	Black Chernozem	alkalinity, salinity
28			glacial till	>30	Black Chernozem	alkalinity, salinity
29			glacial till	10 - 30	Black Chernozem	mass movement
30			glacial till	>30	Dark Brown Chernozem	
31			colluvium	>30	Dark Gray Chernozem	alkalinity, salinity, mass movement
32			glaciofluvial	0 - 9	Dark Brown Chernozem	
33			glaciofluvial	>30	Dark Brown Chernozem	
34	Bunchgrass-Kentucky bluegrass	grazing	glacial till	10 - 30	Dark Brown Chernozem	alkalinity, salinity
35			glacial till	10 - 30	Eutric Brunisol	
36	Sagebrush-Bluebunch wheatgrass	grazing	glacial till	10 - 30	Eutric Brunisol	
37			glacial till	10 - 30	Dark Brown Chernozem	
38			glacial till	10 - 30	Dark Brown Chernozem	alkalinity, salinity
39			glaciofluvial	0 - 9	Eutric Brunisol	
40	Bunchgrass-Kentucky bluegrass/ Saline Depression Complex	grazing	glacial till	10 - 30	Dark Brown Chernozem	alkalinity, salinity
41			alluvium	10 - 30	Dark Brown Chernozem	
42	Kentucky bluegrass/Riparian Complex	grazing	glaciofluvial	0 - 9	Eutric Brunisol	
43			alluvium	0 - 9	Regosol	alkalinity, salinity, flooding
44	Bunchgrass-Kentucky bluegrass/ Riparian Complex	grazing	alluvium	0 - 9	Gleysol	alkalinity, salinity, flooding
45	Sagebrush-Bunchgrass/ Riparian Complex	grazing	alluvium	0 - 9	Regosol	alkalinity, salinity, flooding
INTRAZONAL						
46	Riparian	grazing	alluvium	0 - 9	Regosol	alkalinity, salinity, flooding
47	Willow-Sedge Bog	wildlife habitat	glacial till (seepage)	0 - 9	Gleysol	flooding
48	Cultivated Fields	agriculture	alluvium	0 - 9	Regosol	alkalinity, salinity, flooding
49			glacial till	10 - 30	Dark Brown Chernozem	alkalinity, salinity
50			colluvium	10 - 30	Eutric Brunisol	

Note: 0-9% equals 0-5°
10-30% equals 6-17°
>30% equals >17°

cominco-monenco joint venture

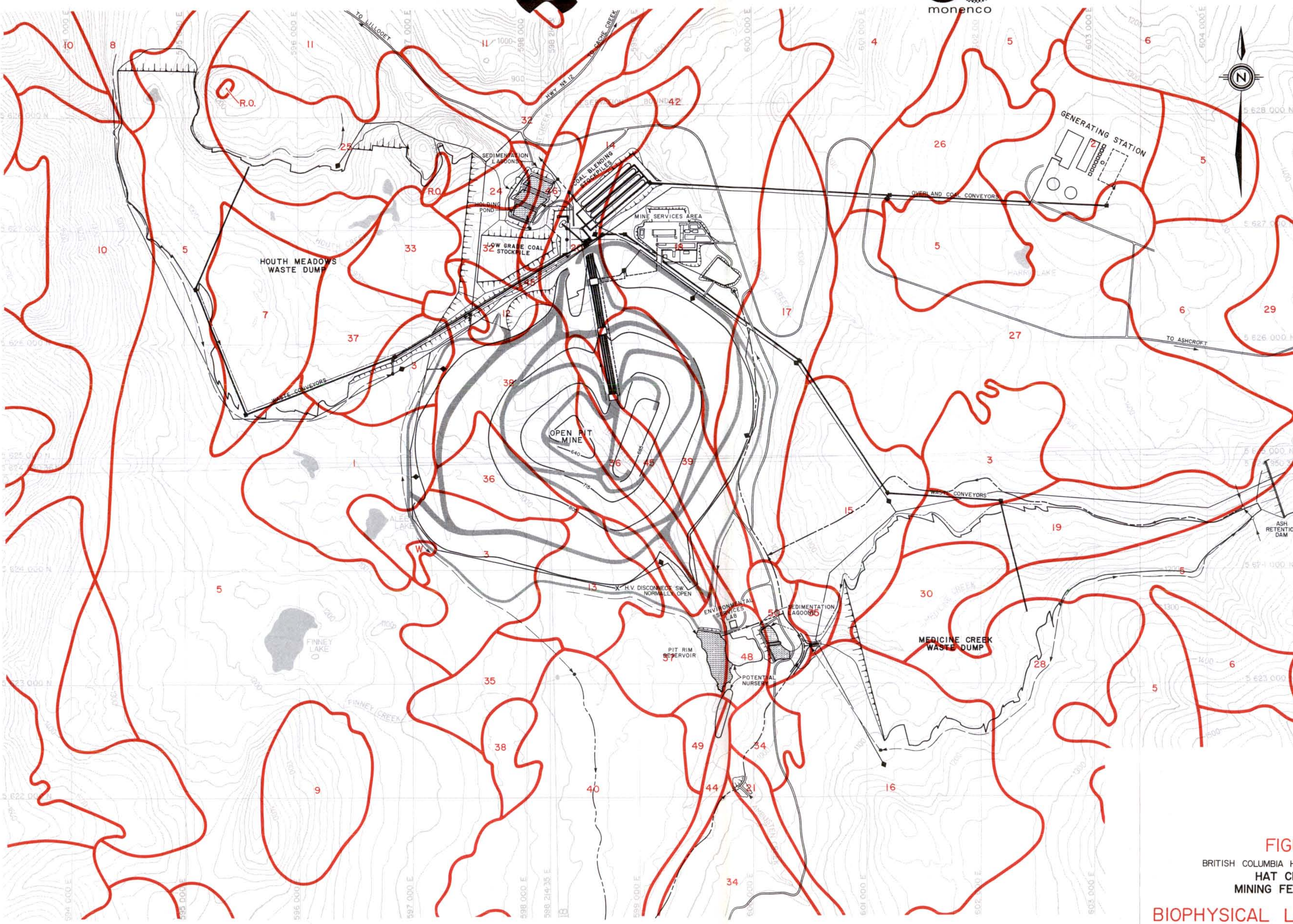

FIGURE 3 - 4

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

HAT CREEK PROJECT

MINING FEASIBILITY REPORT

BIOPHYSICAL LAND CLASSIFICATION

TABLE 3-7

Climax Vegetation and Successional Pattern
in Proposed Mine Area
Hat Creek Project Mining Feasibility Report 1978

	S U C C E S S I O N A L P A T T E R N				
VEGETATION ASSOCIATION	Stage	Rate	Regenerating Species	History	SPECIES DIVERSITY*
Douglas fir-Pinegrass	late seral to climax	normal	Douglas fir	fire, logging	72
Douglas fir-Bunchgrass-Pinegrass	late seral to climax	normal	Douglas fir	fire, logging	60
Kentucky bluegrass	seral	slower than normal	rose, needlegrass, junegrass	grazing, fine soil texture	55
Douglas fir-Bunchgrass	late seral	normal	Douglas fir	fire	40
Sagebrush-Bluebunch wheatgrass	seral	slower than normal	sage, yarrow Douglas fir, Ponderosa Pine	grazing, mudslide	53
Bunchgrass-Kentucky bluegrass	seral	slower than normal	rabbit-brush, pasture sage, foxtail barley, western needlegrass	fire, grazing	49
Saline Depression	edaphic climax	normal	baltic rush, red top, salt-grass, dandelion, Kentucky bluegrass	saline seepage, salinity	20
Big Sagebrush-Bunchgrass	seral	slower than normal	pasture sage, rabbit-brush, Sandberg bluegrass, sand dropseed, downy brome	grazing	35
Douglas fir-Spirea-Bearberry	late seral to climax	slower than normal	Douglas fir	rock slide	36
Riparian	seral	faster than normal	Engelmann spruce, Douglas fir	flooding	58
Willow-Sedge Bog	seral	slower than normal	willows, shrubs	high water table	31
Cultivated field	early seral	slow		cultivation	

* number of species recorded

Source: Tera (1978)

include lodgepole pine, trembling aspen, and Douglas fir. Aspen regenerated in logged areas on glacial till and in depressions between hummocks. Destruction of the tree canopy by fire promoted the invasion of fireweed and willow, and it is estimated that closure of the forest canopy could take 10-20 years.

Grasslands were classified on the basis of existing vegetation rather than climax vegetation, due to alteration of species composition by fire, insect infestation, and overgrazing (Tera, 1978).

Climax grasslands in the area are believed to be Sagebrush-Bluebunch Wheatgrass, Bluebunch Wheatgrass-Bluegrass and Bluebunch Wheatgrass-Rough fescue at low (885-1000 m ASL), medium (1000-1300 m ASL), and high (1300-1600 m ASL) elevations, respectively.

314 CLIMATE

Climatic data for Upper Hat Creek Valley is summarized in Table 3-8 (Acres, 1978).

314.1 Precipitation

Mean annual total precipitation in the mine area is 317 mm. About 44% occurs as rain during the growing season (May through September). Total precipitation varies greatly with elevation. At the top of the proposed waste dumps precipitation would be somewhat greater than indicated from present records. Total annual snowfall at the mine area is estimated to be approximately 133 cm with approximately 80% recorded during the months of November through February. Of primary importance is the soil moisture deficit, which is estimated at 238 mm.

TABLE 3-8

Climatic Data for Hat Creek Area

Hat Creek Project Mining Feasibility Report 1978

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Mean Daily Temperature	-11.0	-5.7	-1.8	3.7	9.1	12.3	15.1	14.2	10.3	4.1	-3.4	-8.3	3.2
Mean Daily Maximum Temperature	-5.1	1.0	4.6	10.6	16.9	20.1	23.9	22.9	18.9	10.7	1.9	-2.9	10.3
Mean Daily Minimum Temperature	-16.9	-12.4	-8.2	-3.2	1.7	4.6	6.1	5.4	2.1	-2.5	-8.7	-13.6	-3.8
Extreme Maximum Temperature	11.7	13.3	17.2	21.1	27.8	33.9	34.4	34.4	31.1	23.3	12.2	10.0	34.4
Extreme Minimum Temperature	-40.6	-25.0	-27.8	-11.1	-7.8	-3.3	-0.6	-2.2	-7.2	-12.2	-30.0	-42.8	-42.8
Mean Rainfall	3	3	5	8	18	35	29	32	20	21	7	4	184
Mean Snowfall	368	157	102	81	38	0	0	0	5	38	231	310	1331
Mean Total Precipitation (M.T.P.)	39	19	15	16	22	35	29	32	21	25	30	35	317
Greatest Rainfall in 24 Hours	10	5	3	8	17	23	39	30	27	18	5	8	39
Greatest Snowfall in 24 Hours	424	84	91	119	94	0	0	0	trace	86	191	221	424
Greatest Precipitation in 24 Hours	42	10	91	16	17	23	39	30	27	18	19	22	42
Potential Evapotranspiration (P.E.)*	0	0	0	35	71	104	125	105	65	28	0	0	532
M.T.P. minus P.E.	39	19	15	-18	-48	-68	-95	-72	-43	-2	30	35	-214
Actual Evapotranspiration (A.E.)*	0	0	0	35	61	65	48	38	23	25	0	0	295
Moisture Deficit (A.E. minus P.E.)	0	0	0	0	10	38	77	67	42	3	0	0	238
Mean Degree Days above 5.0°C	0	0.2	2.1	18.0	124.9	238.5	311.0	306.4	153.1	38.1	0.3	0	1192.6

Notes: All temperature values are in degrees Celsius.
All precipitation values are in millimetres.
Degree-days are in their own units.

* Assumed water-holding capacity is 100 mm.

Source: Acres, 1978 modified from:

1. Climate of British Columbia Tables of Temperature and Precipitation, Climatic Normals 1941 - 1970, Extremes of Record, Publications Branch, B.C.D.A., Victoria, British Columbia

2. Preliminary data from AES Station #1163340, The Atmospheric Environment Service, Environment Canada

314.2 Temperature

The mean annual daily temperature in the area is 3.2°C. January is the coldest month with a mean daily temperature of -11°C, while July is the warmest month with a mean of 15.1°C. Extreme maximum and minimum temperatures of 34.4°C and -42.8°C were recorded in July/August and December, respectively. The mean annual number of degree days above 5° C is calculated to be 1192.

314.3 Humidity

Stations recently established in the Upper Hat Creek Valley provide the only available site-specific information on humidity. Table 3-9 summarizes the diurnal and seasonal ranges within the proposed mine area. Diurnal variations are quite great throughout all seasons.

TABLE 3-9

Mean Relative Humidity
in Proposed
Hat Creek Mine Area (1975)

Hour	Spring	Summer	Fall	Winter
01	69.8	73.0	74.8	76.9
04	73.8	80.0	77.6	76.8
08	65.7	72.3	78.6	74.6
12	35.2	46.0	53.8	55.0
16	27.0	39.0	46.4	48.6
20	51.8	47.9	61.9	71.6
24	67.8	69.6	73.7	77.2

Source: ERT (1978)

314.4 Wind

Recently-established meteorological stations on-site indicated that the maximum frequency of daytime wind occurrence is associated with the mountain/valley topography and direction of the valley floor (i.e., upslope to the southeast). Nighttime winds are generally from the south-southwest. An annual wind rose representative of the mine site is presented in Figure 3-5.

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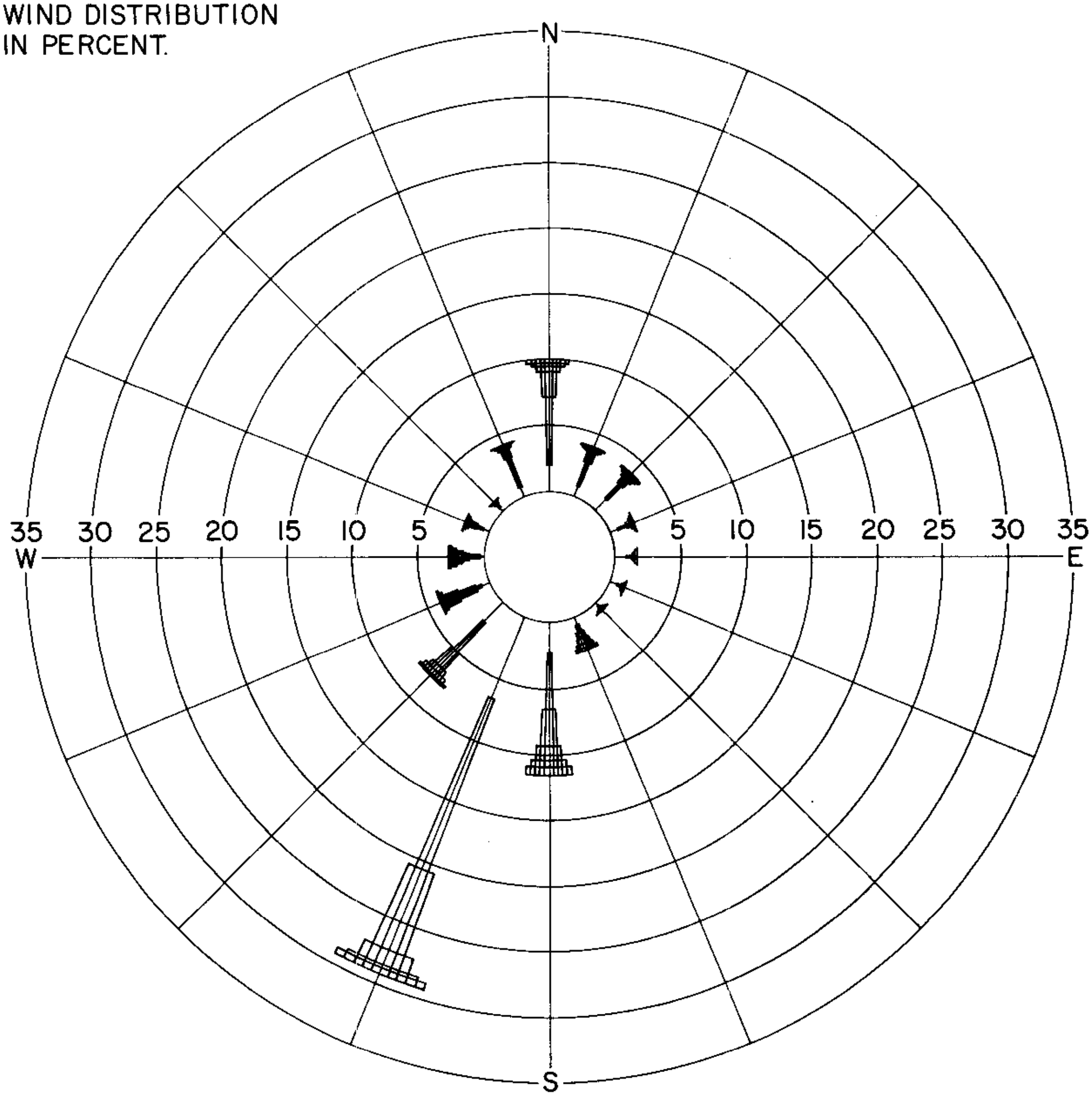
B.C. HYDRO
STATION NO. - H.C. MECHANICAL 5
JANUARY 1975 - DECEMBER 1975

TOTAL OBSERVATIONS
6238 HOURS
ALL CALM 10.3%

*GRID VALUES REPRESENT
WIND DISTRIBUTION
IN PERCENT.



LEGEND

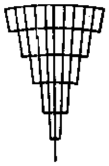


FIGURE 3 - 5

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY
HAT CREEK PROJECT
MINING FEASIBILITY REPORT

WIND ROSE

3.2 WATER

321 SURFACE WATER

321.1 Hydrology

Drainage Systems

Drainage in the proposed mine area is shown in Figure 3-6. Hat Creek, the principal watercourse in the valley, flows northward through the centre of the mine area and empties into the Bonaparte and Thompson river systems. Tributary streams to Hat Creek within the mine area include Houth, Medicine, Finney, and Ambusten creeks. Mine operations would also include portions of the catchment areas of several small unnamed ephemeral streams. Finney Lake (160 ha surface area) and Aleece Lake (15 ha) are located near the proposed mine area. The level of Finney Lake has been raised by installation of a small dam at the outflow point and flow is regulated by a manually controlled sluice gate. Outflow from Aleece Lake is intermittent, depending on precipitation and snowmelt.

Most lakes and ponds in the area are evaporitic, perched, and unaffected by groundwater flow. Groundwater and flowing water is derived from precipitation (Beak, 1978).

Precipitation and Snowmelt Hydrology

The flow regime of Hat Creek, although influenced by periods of heavy rainfall, is generally dominated by snowmelt. Elevation strongly influences total precipitation within the valley, particularly accumulation and melt of snowpack. Site-specific data are not available to date, but based on comparable areas in the surrounding region, it is estimated that approximately 45% of the total precipitation input to the basin is absorbed into the snowpack prior to runoff (Beak, 1978). Estimated maximum snowpack, average snow depth over the total Hat Creek catchment area, and maximum snowpack water equivalent are 22.6, 35.6, and 86.6 cm, respectively (Monenco, 1977).

FIGURE 3-6

Legend

Drainage Basin	Map No.	Plan Area km^2
Houth Meadows	1	5
	2	3
	3	2.5
	4	19
		29.5
Finney Creek	5	13
West Pit	6	8.1
South West Pit	7	5.0
South East Pit	8	1.3
Ambusten Creek	9	35
Medicine Creek	10	12.6
	11	43.1
	12	5.9
		61.6
Harry Creek	13	9.9
East Pit	14	6.5
North West Pit	15	0.4
North East Pit	16	0.8
Marble Canyon (South)	17	10.0
		182
Hat Creek Valley (Upstream)	18	248
Hat Creek Valley (Downstream)	19	236
Total		666 km^2

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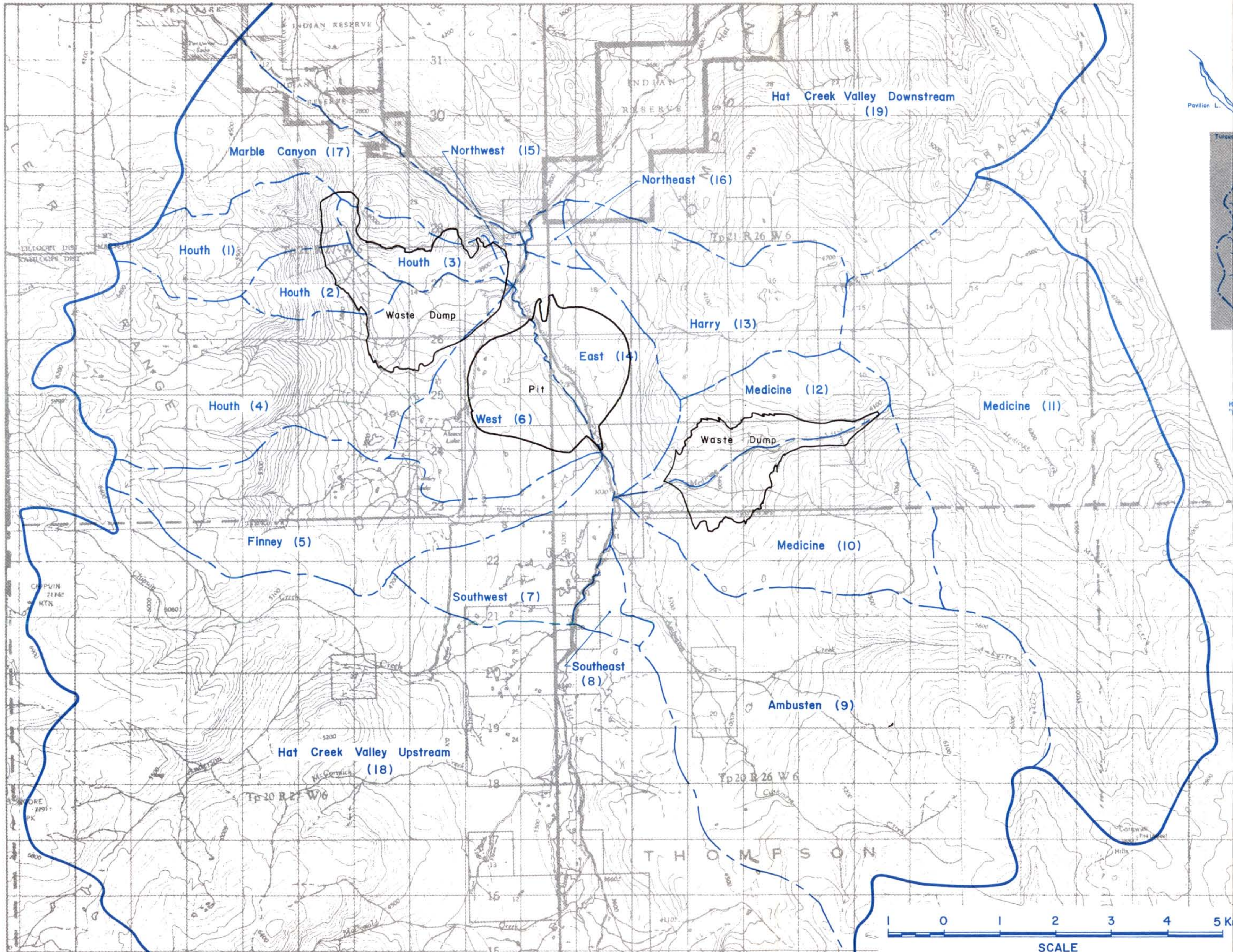

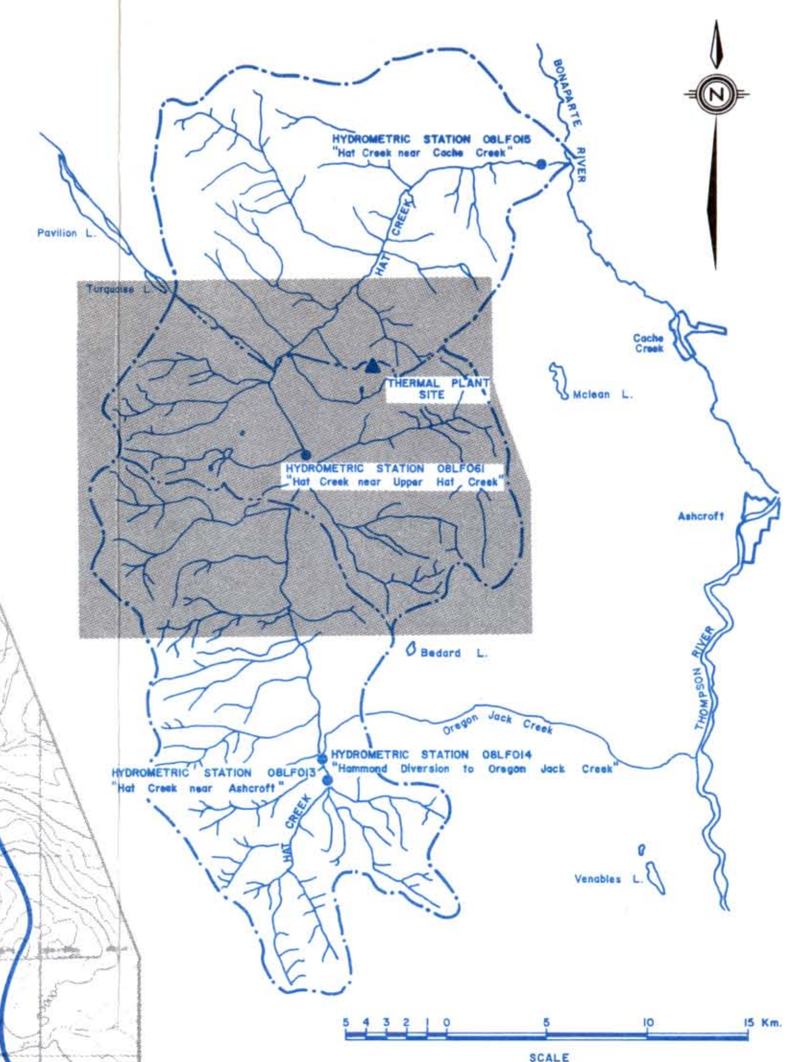

FIGURE 3 - 6

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

HAT CREEK PROJECT

MINING FEASIBILITY REPORT

DRAINAGE BASINS

Maximum precipitation occurs in January and June, whereas March, April, and September are typically dry months.

Snowmelt and Runoff Flow Waters

A runoff hydrograph for Hat Creek below the proposed mine area is presented on Figure 3-7.

Hat Creek flow is characterized by high snowmelt spring freshets with peak flood normally occurring in May or June. Early snowmelt in March-April is uncommon. Based on 15 years of record, the mean annual runoff volume at Hat Creek, as measured at the Upper Hat Creek stream gauge is 2100 ha-m or 62 mm over the 350 m^2 drainage area. Sixty-seven percent of mean annual runoff occurs during May, June, and July. Flow is low during summer, fall, and winter, particularly late August to early September. Summer rainfall peaks in the hydrograph are lower than spring freshet peaks (Beak, 1978).

Evaporation and Water Balance

A water balance was calculated by the Thornthwaite Method (Table 3-10). Using 317 mm as precipitation input, 62 mm runoff as output, and 200 mm as soil moisture storage; annual actual and potential evapotranspiration were computed at 317 and 532 mm, respectively. A 215 mm moisture deficit occurs from April-October. Adjustments for elevation differences, irrigation, and diversion losses were incorporated, resulting in annual precipitation of 394 mm, surface runoff of 75 mm, and a natural evapotranspiration loss of 319 mm (Beak, 1978).

Channel and Floodplain Morphology

The slope of Hat Creek within the mine area is approximately 1°. Streambed material consists of cobble, gravels, and sands. Channel cross-sections (Beak, 1978) within the mine area indicate the following characteristics:

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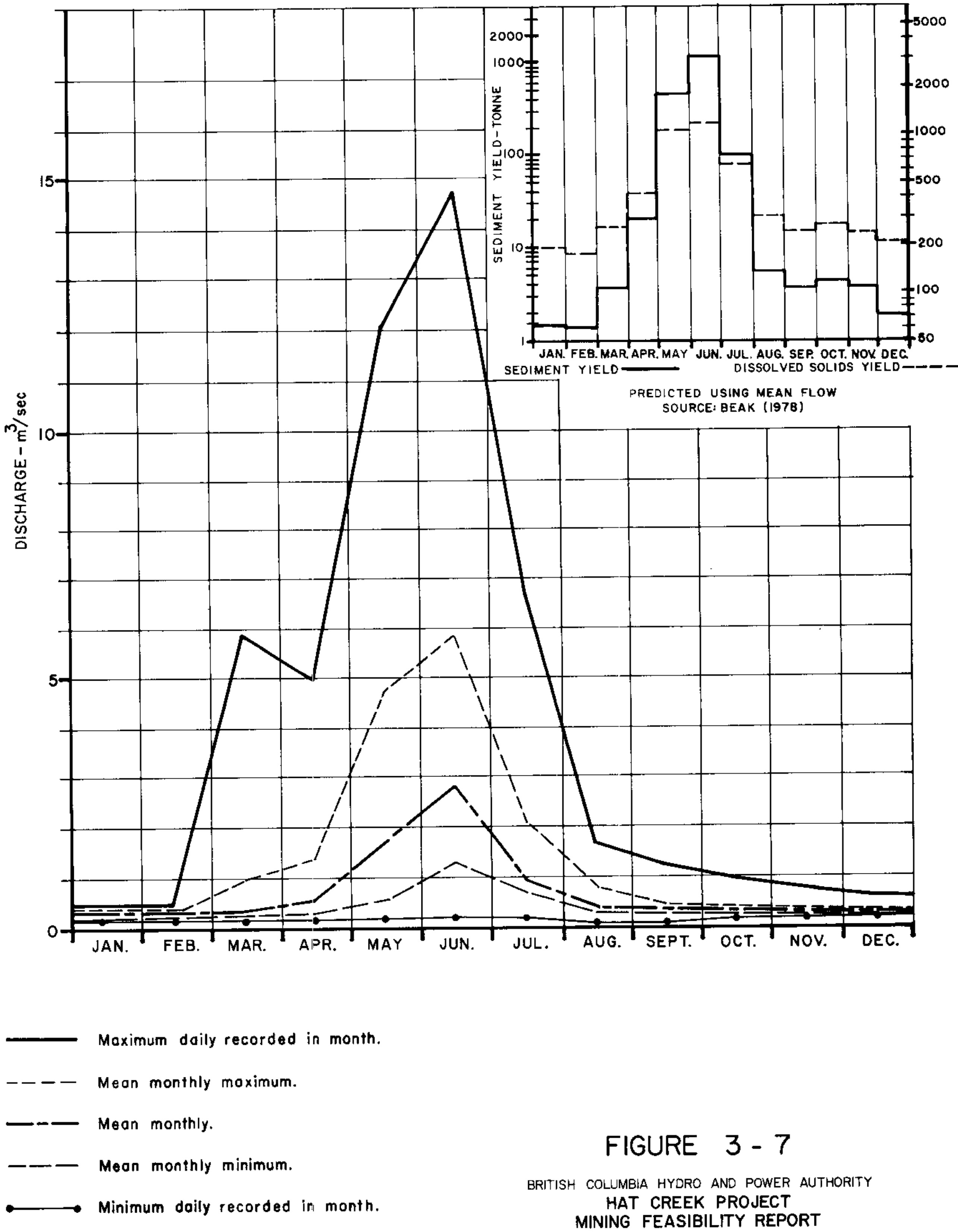

GAUGE STATION 08LF061
HAT CREEK NEAR UPPER HAT CREEK
BASED ON FLOW RECORD 1960-1975
SOURCE: MONENCO (1977)

FIGURE 3 - 7

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY
HAT CREEK PROJECT
MINING FEASIBILITY REPORT

STREAM DISCHARGE
SEDIMENT YIELD
& DISSOLVED SOLIDS YIELD

TABLE 3-10

Thornthwaite Climatic Water Balance
for Hat Creek
Hat Creek Project Mining Feasibility Report 1978

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Mean Daily Temperature (°C)	-11.0	-5.7	-1.8	3.7	9.1	12.3	15.1	14.2	10.5	4.1	-3.4	-8.3	3.2
Potential Evapotranspiration (P.E.)	0	0	0	35	71	104	125	105	65	28	0	0	532
Mean Total Precipitation (M.T.P.)	39	19	15	16	22	35	29	32	21	25	30	35	317
M.T.P. minus P.E.	39	19	15	-18	-48	-68	-95	-72	-43	-2	30	35	-214

ASSUMED WATER-HOLDING CAPACITY: 100 mm

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Storage	106	119	120	100	61	31	12	6	4	4	33	68	
Change in Storage	32	0	0	0	-38	-29	-18	-5	-1	0	30	35	
Actual Evapotranspiration	0	0	0	35	61	65	48	38	23	25	0	0	295
Moisture Deficit	0	0	0	0	10	38	77	67	42	3	0	0	238
Moisture Surplus	0	0	0	1	0	0	0	0	0	0	0	0	1
Surplus Runoff	0	0	0	1	0	0	0	0	0	0	0	0	1
Snowmelt Runoff	1	6	14	0	0	0	0	0	0	0	0	0	21
Total Runoff	1	6	14	1	0	0	0	0	0	0	0	0	22
Snowmelt Runoff Ratio (%)	9	25	41	0	0	0	0	0	0	0	0		

ASSUMED WATER-HOLDING CAPACITY: 200 mm

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Storage	132	151	166	151	118	84	52	36	29	28	58	93	
Change in Storage	39	19	15	-14	-32	-33	-31	-15	-6	0	30	35	
Actual Evapotranspiration	0	0	0	31	55	69	61	48	28	26	0	0	317
Moisture Deficit	0	0	0	4	16	34	64	57	37	2	0	0	215
Moisture Surplus	0	0	0	0	0	0	0	0	0	0	0	0	0
Surplus Runoff	0	0	0	0	0	0	0	0	0	0	0	0	0
Snowmelt Runoff	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Runoff	0	0	0	0	0	0	0	0	0	0	0	0	0
Snowmelt Runoff Ratio (%)	0	0	0	0	0	0	0	0	0	0	0	0	

Notes: * based on climatic normals from 1941 to 1970

All values except temperature and snowmelt runoff ratio are in millimetres.

Source: Beak, 1978, data from AES Station #1163340
50° 45 N, 121° 35 W
899 metres ASL

active channel width .... 1-10 m
assumed bankfull level .... 10-15 m
depth .... 0.25-0.5 m
flow .... 0.286-0.937 m^3/s

Similar data are unavailable for tributaries of Hat Creek within the mine area; most creek beds consist of coarse deposits or bedrock.

From aerial photographs, the Hat Creek floodplain within the mine area was estimated to cover 1.14 km^2. The floodplain consists of wetland meadows, dense willow thickets, beaver ponds, and marshes developed on sand and silt sediments. The lengths of Hat, Medicine, Finney, and Houth Creeks within the area of proposed disturbance have been estimated at 5, 5, 3.2, and 2.5 km, respectively.

321.2 Quality

The surface water quality of streams and lakes in the mine vicinity is summarized on Table 3-11, and sampling locations are shown on Figure 3-8. Mean values are presented for a varying number of samples collected at each site between September 1976 and 1977. Insufficient data are available to accurately describe the temporal variation in base-line water quality in the proposed mine area. Samples were collected primarily in low flow periods during an abnormally dry year, and may not be typical of conditions over the long-term.

Streams

Flowing waters within the proposed mine area are suitable for drinking and irrigation (Beak, 1978). Containing relatively high levels of calcium and magnesium, waters are very hard and are predominantly of the calcium bicarbonate type. Hardness is believed due to groundwater contact.

Chemical oxygen demand (COD), biological oxygen demand (BOD), total organic carbon (TOC), phenol, and temperature were low

TABLE 3-11

Mean Surface Water Quality of Streams and

Lak[illegible]inity of Hat Creek Mine

Hat Creek Project Mining Feasibility Report 1978

WATER QUALITY PARAMETER	HAT CREEK above mine area	HAT CREEK mid-mine area	HAT CREEK below mine area	MEDICINE CREEK	FINNEY LAKE	ALEECE LAKE (outlet)	GOOSE/ FISHHOOK LAKE
Station* #	14	10	7	1	17	5	16
Number of Samples	13	13	13	4	4	1	4
CATIONS - Trace Metals (mg/L)							
Aluminum (Al)	<0.010	<0.010	< 0.010	< 0.010	< 0.010	-	< 0.010
Arsenic (As)	<0.005	<0.005	< 0.005	< 0.005	< 0.005	-	< 0.005
Cadmium (Cd)	<0.005	<0.005	< 0.005	< 0.005	< 0.005	-	< 0.005
Chromium (Cr)	<0.010	<0.010	< 0.010	< 0.010	< 0.010	-	< 0.010
Copper (Cu)	<0.005	<0.005	< 0.005	< 0.005	< 0.005	-	< 0.005
Iron (Fe)	0.048	0.037	< 0.018	0.021	< 0.041	< 0.05	< 0.018
Lead (Pb)	<0.010	<0.010	< 0.010	< 0.010	< 0.010	-	< 0.010
Mercury (Hg)	<0.00027	<0.0012	< 0.00038	0.00050	< 0.00033	-	< 0.00040
Molybdenum (Mo)	<0.020	<0.020	< 0.020	< 0.020	< 0.020	-	0.03
Selenium (Se)	<0.003	<0.003	0.003	< 0.003	< 0.003	-	< 0.003
Vanadium (V)	<0.005	<0.005	< 0.005	< 0.005	< 0.005	-	0.006
Zinc (Zn)	0.007	<0.005	0.008	0.009	< 0.0060	-	< 0.030
CATIONS - Alkali Earths & Metals (mg/L)							
Calcium (Ca)	49	58	58	61	24	33.9	11
Lithium (Li)	<0.0025	<0.0025	< 0.002	0.003	<0.001	-	0.070
Magnesium (Mg)	16	20	17	29	8.3	25.2	99
Potassium (K)	4.9	4.5	4.0	-	2.4	11.5	190
Sodium (Na)	17	24	20	14	15	38.0	1390
Strontium (Sr)	0.28	0.34	0.30	0.44	0.13	-	1.2
ANIONS - General (mg/L)							
Boron (B)	<0.1	<0.1	<0.1	<0.1	<0.1	-	0.3
Chloride (Cl)	0.61	1.0	1.2	0.50	0.53	<0.5	96
Fluoride (F)	0.15	0.18	0.14	0.122	0.22	-	< 0.57
Sulfate (SO_4)	50	57	50	40	5.0	52.2	2140
ANIONS - Nutrients (mg/L)							
Total Kjeldahl Nitrogen (N)	0.19	0.27	0.19	0.26	0.83	-	3.2
Nitrate Nitrogen (NO_3 - N)	0.06	0.04	< 0.06	0.04	<0.02	-	<0.67
Nitrite Nitrogen (NO_2 - N)	<0.0017	<0.001	< 0.0018	<0.0010	<0.0019	-	<0.0016
Total Orthophosphate Phosphorus (P)	0.050	0.065	0.038	0.010	0.025	-	1.5
ORGANIC, NONIONIC & CALCULATED VALUES (mg/L)							
COD	45	10	17	10	72	-	124
TOC	8.5	16	8	27	18	-	164
Phenol	<0.002	<0.002	< 0.002	< 0.002	< 0.002	-	< 0.002
Total Hardness ($CaCO_3$)	189	226	215	272	94.8	188	436
Total Alkalinity ($CaCO_3$)	99	278	212	188	123	217	1520
PHYSICAL DATA							
pH (units)	8.1	8.4	8.4	8.4	8.2	7.6	9.8
Specific Conductance (umhos/cm @ 25°)	450	495	472	550	232	508	6700
True Colour (Pt-Co Units)	12	18	11	10	19	-	50
Turbidity (NTU)	1.6	1.40	2.5	0.30	1.1	-	3.9
Temperature (°C)	4.6	9.8	6.4	7	5.8	-	6.4
PHYSICAL DATA - Residues (mg/L)							
Total Residue	321	356	344	361	179	-	5076
Filterable Residue	312	350	336	359	176	-	5070
Nonfilterable Residue	8	5	8	2	3	-	6
Fixed Total Residue	266	280	274	261	113	-	4706
Fixed Filterable Residue	261	276	269	260	112	-	4703
Fixed Nonfilterable Residue	<8	4	< 5	1	< 1	-	3
BIOCHEMICAL, DISSOLVED GASES & RELATED MEASUREMENTS (mg/L)							
BOD	<1	<1	<1	10.1	1	-	1
DO	11.2	10	11.1	-	9.0	-	9.6

* See Figure 3-8 for station locations. Station numbers 7 and 14 lie outside the area of Figure 3-8.

Source: Beak, 1978

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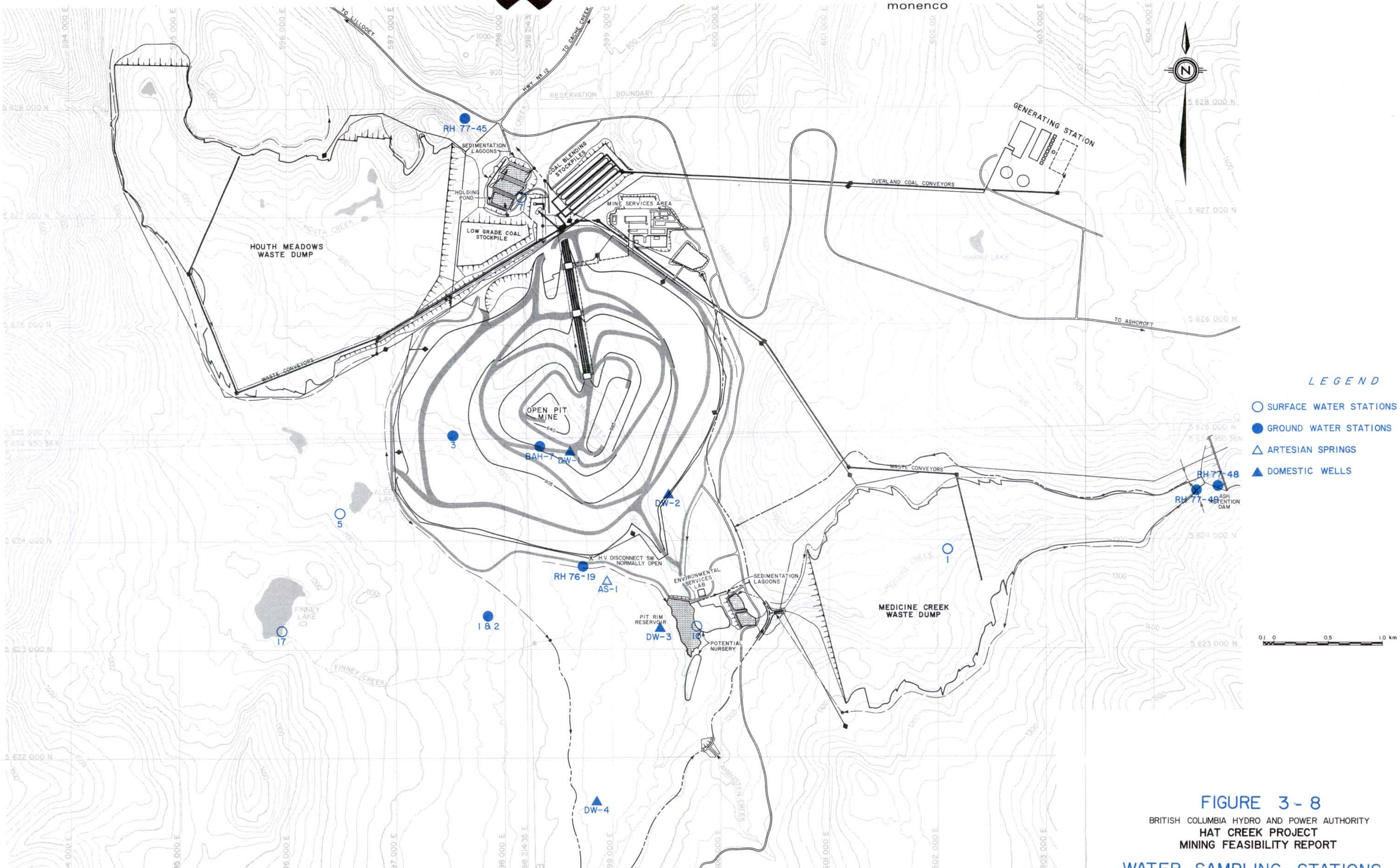


FIGURE 3 - 8

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

HAT CREEK PROJECT

MINING FEASIBILITY REPORT

WATER SAMPLING STATIONS

indicating minor organic loading and satisfactory conditions for fish. The nitrogen:phosphorous ratio was low, possibly indicating the presence of agricultural wastes or fertilizers in runoff upstream of the proposed mine area (Beak, 1978).

Sediment Transport

Sediment yield during spring runoff was predicted by a graphical analysis of 1977 suspended sediment and dissolved solids concentrations versus discharge (Beak, 1978). Data from freshet sample stations located on Hat Creek in the mine area are presented on Table 3-12 (see also Figure 3-7). Further sampling is required to determine runoff typical of long-term conditions, since 1977 was an unusually dry year.

Predicted suspended solids concentration in Hat Creek may average 300 mg/L during freshet (Beak, 1978). Suspended sediment yield in Hat Creek varied from 2 tonnes/month during winter to more than 2400 tonnes/month during freshet. The dissolved solids load in Hat Creek may range from 260-400 tonnes/month in winter to 3000 tonnes/month during freshet. Hat Creek drainage also appears to be very turbid during runoff.

Lakes

The water quality of Aleece Lake (within the mine area) and of Finney and Goose/Fishhook Lakes (outside the mine area) is summarized in Table 3-11. These waterbodies exhibit water quality extremes to be found in the area. Finney Lake is a wilderness oligotrophic lake characterized by low nutrient levels; its water quality similar to nearby streams.

Goose Lake is characteristic of Southern Interior alkali sloughs with high sodium and sulphate levels, filterable residue, and specific conductance. It lies in a depression, collects groundwater seepage, and is evaporitic (Beak, 1978).

Aleece Lake water quality falls within the extremes presented by Finney and Goose lakes.

TABLE 3-12

Freshet 1977 - Daily Collection Data

Hat Creek Project Mining Feasibility Report 1978

Station (Base) and Parameter	19 May	20 May	21 May	22 May	23 May	24 May	25 May	26 May	27 May	28 May	8 June	9 June	10 June
7 Conductivity*	480	470	490	490	480	470	450	440	460	470	340	390	420
Nonfilterable** Residue	3	7	6	9	10	24	10	7	4	3	38	15	8
Turbidity*** (below mine)	0.85	0.95	1.1	1.2	1.0	2.1	2.1	0.75	1.4	1.1	13	4.5	2.4
14 Conductivity	480	510	510	490	500	480	460	450	450	460	290	350	380
Nonfilterable Residue	<1	<1	3	3	4	9	4	3	7	3	25	9	3
Turbidity	0.45	0.45	0.50	0.50	0.55	0.95	0.75	1.0	1.4	0.90	7.8	2.2	1.1
Flow, m^3s^{-1} (above mine)	0.29	0.29	0.35	0.38	0.58	0.60	0.43	0.41	0.35	0.32	0.80	0.52	0.43

* μmhos/cm @ 25^{0}
** mg/L
*** NTU

Source: Beak, 1977

Summary

Sulphate concentrations in some surface water samples are slightly elevated compared to PCB level A objectives. Suspended solids concentrations during freshet may be greater than PCB level A objectives.

322 GROUNDWATERS

322.1 Hydrology

Groundwater in the proposed mine area was studied by field interviews, piezometer head distributions, falling head permeability tests, and pump tests carried out during 1976-1977 (Golder, 1977). The location of groundwater sampling stations, artesian springs, domestic wells, and piezometers within the mine area are shown in Figure 3-8.

Principal Aquifers

Locally significant types of aquifers contributing to groundwater within the proposed mine area include fractured limestone and granodiorite bedrock, glaciofluvial sediments, and alluvium. Bedrock aquifers are concentrated to the north and east of Upper Hat Creek Valley at higher elevations, whereas glaciofluvial and alluvial aquifers are located at lower elevations near the valley bottom (Beak, 1978).

Flow Regime

Groundwater recharge rate and movement depend on the topography and nature of the surficial and bedrock materials at the site. Aquifers in the vicinity of the proposed mine are generally small due to the low hydraulic conductivity of the materials and to the low annual precipitation; resulting recharge to the groundwater table is low. Recharge zones are generally located at higher elevations and flow occurs mainly through surficial deposits. Less than 2% of the recharge is estimated to flow in Coldwater Sediments (Beak, 1978).

Glacial tills on the west side of the proposed mine area have low permeability and are poorly drained compared to glacio-fluvial materials on the east side of the valley. As a result, groundwater in the east passes through alluvium into Hat Creek without surface discharge. Springs and seeps are present below an elevation of 900 m ASL on the west side of the mine area.

Flow Patterns and Rates

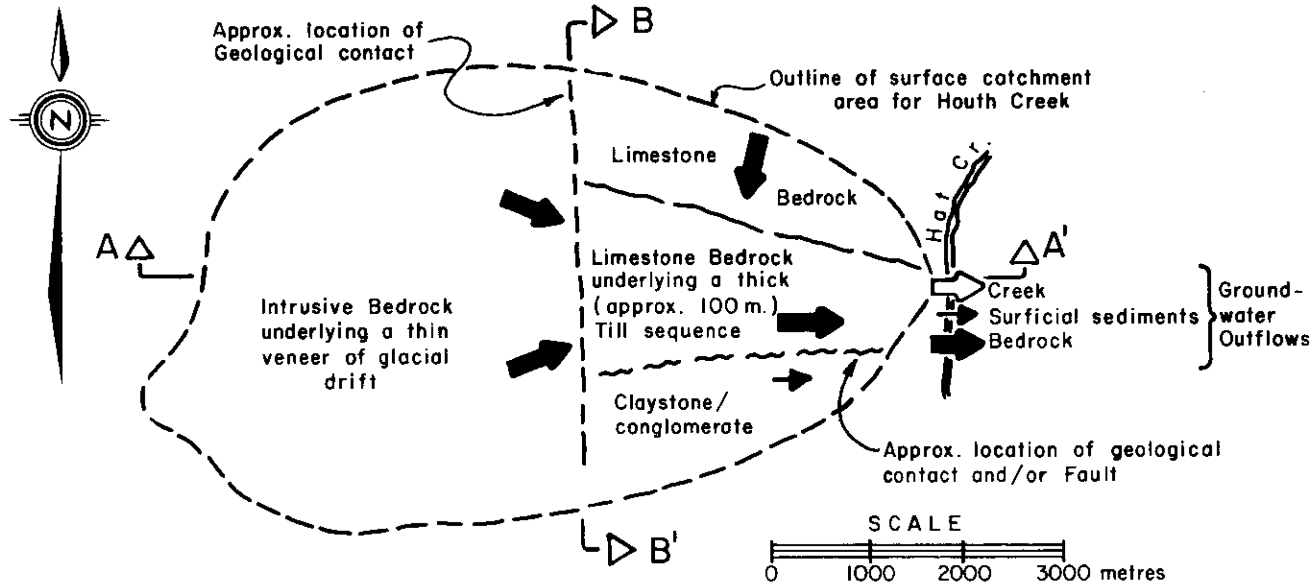
Groundwater flow systems and estimated flow rates for the proposed open pit and waste dump areas are illustrated on Figure 3-9.

Water Wells

Five domestic wells are situated within the proposed mine area with depths ranging from less than 1 to 5 m. Flows are reported to vary from less than 1.5 to 10 m^3 per day. These wells tap aquifers in either shallow springs, impermeable till, or Hat Creek alluvium.

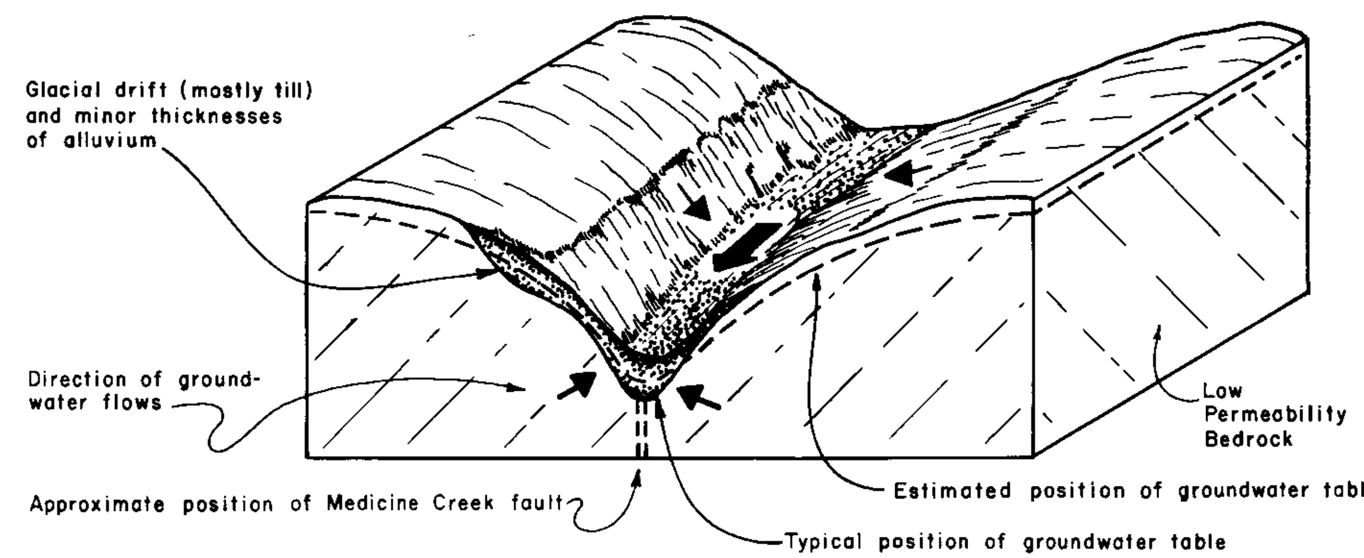
322.2 Water Quality

Saline, sodic, and isotopic characteristics of groundwaters are summarized in Table 3-13. Water quality of shallow groundwater in Hat Creek alluvium, surficial groundwater in the limestones, deep permeable bedrock groundwater, and unique samples is presented in Table 3-14. Variations in groundwater with depth and lithology are listed in Table 3-15.

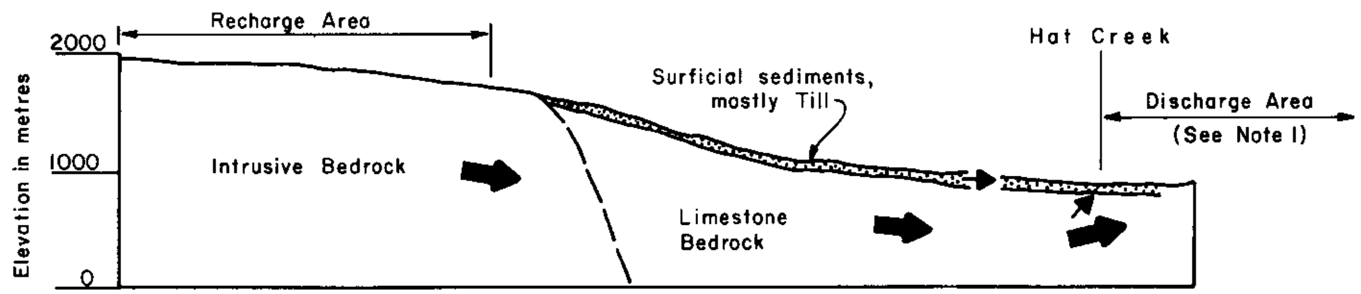


PLAN OF HOUTH CREEK CATCHMENT

NOT TO SCALE



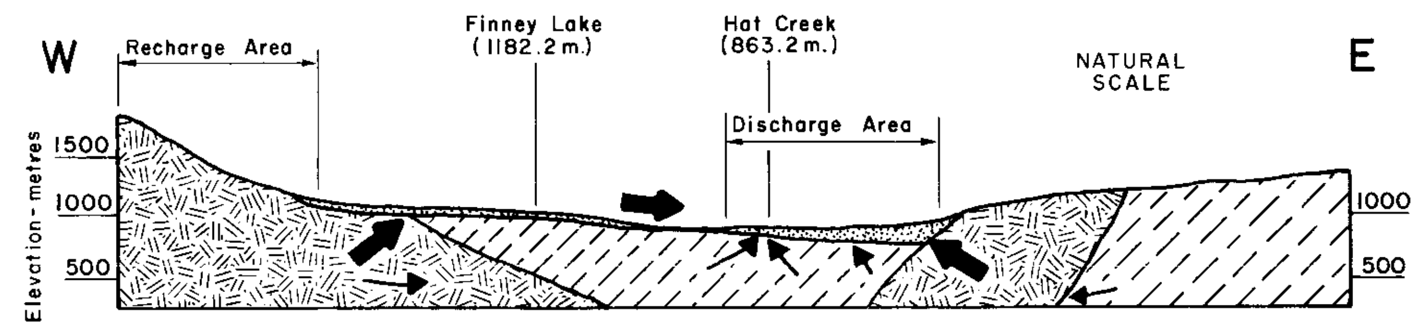
ISOMETRIC SKETCH OF TYPICAL GROUNDWATER FLOW REGIME IN MEDICINE CREEK VALLEY



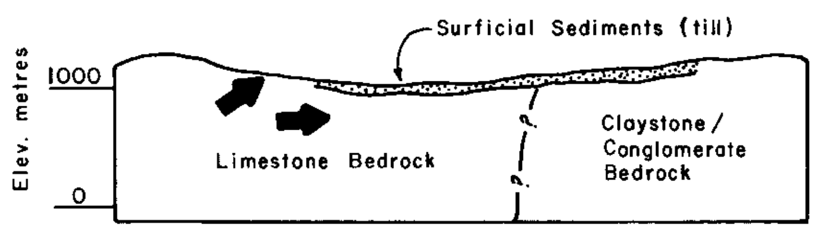
SECTION A-A'

NATURAL SCALE

Notes: 1) Discharge area possibly extends towards the east in the vicinity of the buried glaciofluvial channel.



SECTION THROUGH HAT CREEK VALLEY AT LOCATION OF PROPOSED COAL PIT



NATURAL SCALE

SECTION B-B'

GROUND WATER FLOW SYSTEMS IN HOUTH CREEK BASIN

LEGEND

- Rocks with relatively high hydraulic conductivity (greater than 10^{-4} cm./sec.)
- Rocks with relatively low hydraulic conductivity (less than 10^{-4} cm./sec.)
- Surficial sediments.
- Groundwater flows less than 10 m^3/d.
- Groundwater flows greater than 10 m^3/d.
- Surface groundwater flows (base flow)
- (863.2 m.) Approximate elevation of water surface.

FIGURE 3-9

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY
HAT CREEK PROJECT
MINING FEASIBILITY REPORT

GROUNDWATER FLOW SYSTEMS

SOURCE: Golder Associates 1978.

TABLE 3-13

Saline, Sodic, and Isotopic Characteristics of Groundwaters and Surface Waters
Derived From Groundwater Seepage in the Proposed Mine Area
Hat Creek Project Mining Feasibility Report 1978

Sample No.	Sample Date	Sample Site	Notes	Lithology	Cations (ppm) Na^+	Ca^{+2}	Mg^{+2}	K^+	Anions (ppm) HCO^-_3	SO_4^{-2}	Cl	pH	EC	SAR	Isotopes ^{18}O ($^o/oo$)	D ($^o/oo$)	Tritium (TU)
76-1	9/11/76	Aleece Creek	600 m from lake outlet	-	33.0	44.8	21.7	9.0	-	-	-	7.85	508	1.0	-14.0	-	-
76-2	9/11/76	Spring	On south shore of Aleece Lake	alluvium	-	-	-	-	-	-	-	-	-	--	-14.3	-	
76-3	9/11/76	Aleece Lake	At outlet from 0.6 m depth	-	38.0	33.9	25.2	11.5	265	52.2	<.5	7.6	508	<1	-8.8	-	
76-4	9/11/76	Well RH76-19	During development	claystone	110.0	19.0	9.4	18.0	260	47.7	<.5	7.6	677	5.1	-18.0	-	
76-5	9/11/76	Hat Creek	Near Hole RH 76-20	-	21.3	58.0	17.4	4.0	-	-	-	8.0	462	<1	-18.1	-	
76-6	14/10/76	Well RH76-19	At end of pump test	claystone	330.0	47.7	21.6	34.0	1150	17.3	<.5	7.6	1834	9.9	-20.1	-	
77-20	30/4/77	Houth Lake	At outlet	-									460	-	-14.9	-130.8	
77-21	30/4/77	Houth Creek	At Hat Creek	-									200	-	-17.5	-139.2	
77-22	30/4/77	Hat Creek	At Houth Creek	-	(21)	(59)	(19)	(4)	(289)	(46)	(1.2)	(8.4)	410	<1	-17.5	-138.5	
77-23	30/4/77	Houth Creek	South branch	-									700	-	-14.0	-124.7	
77-24	30/4/77	Aleece Lake	At outlet from 0.6 m depth	-									500	-	-8.5	-102.9	
77-26	30/4/77	Finney Lake	At outlet	-	(12)	(29)	(8.3)	-	(127)	(5.1)	(0.5)	(8.0)	210	<1	-11.2	-112.1	
77-27	30/4/77	Alkaline slough	2000 m east of Finney Lake	-									3800	-	-10.4	-109.3	
77-28	30/4/77	Medicine Creek	At road culvert	-	(14)	(61)	(29)	-	188	(40)	(0.5)	(8.4)	500	<1	-16.9	-134.8	
77-29	28/5/77	Spring	Upper Hat Creek Valley (H-E)	alluvium	(28)	(140)	(66)	-	(439)	(250)	(7.6)	(7.6)	1100	<1	-18.2	-142.4	
77-31	25/8/77	RH 77-45 #1	From piezo. at 90 m depth	limestone	23	64.4	29.3	4.3	325	62.4	5	7.8	626	<1	-18.2	145.1	0.5 ± 8
77-32	25/8/77	RH 77-45 #2	From piezo. at 63 m depth	limestone	43.7	55.2	32.0	4.6	330	91.2	6	8.0	689	<1	-18.4	137.6	-
77-33	25/8/77	RH 77-45 #3	From piezo. at 35 m depth	weathered limestone	57.5	54.3	29.9	4.7	344	96	7	8.1	729	1	-18.5	147.1	-5 ± 9
77-34	25/8/77	RH 77-48 #1	From piezo. at 90 m depth	shale	172.5	20.2	7.4	3.9	407	115.2	4	8.1	936	8.3	-18.3	144.1	20 ± 9
77-35	25/8/77	RH 77-48 #2	From piezo. at 79 m depth	sandstone	203.6	25.1	8.3	4.1	476	139.2	5	8.1	1019	9.0	-18.8	149.4	3 ± 8
77-36	25/8/77	RH 77-48 #3	From piezo. at 58 m depth	shale	170.2	15.2	4.6	3.5	408	81.6	3.5	8.4	879	9.9	-18.3	143.4	19 ± 9
77-37	25/8/77	RH 77-49 #1	From piezo. at 90 m depth	greenstone	32.2	123.4	91.2	4.7	672	196.8	2	8.0	1326	<1	-18.1	144.9	-4 ± 8

Note: ^{18}O is the oxygen isotope concentration given in SMOW
D is the deuterium isotope concentration given in SMOW
EC is electrical conductivity in umhos/cm
SAR is sodium adsorption ratio $SAR = \frac{Na^+}{\sqrt{(Ca^{+2} + Mg^{+2})/2}}$ in meq/L.
Tritium (TU) - if less than 30 groundwater is considered > 16 years old
SMOW - Standard Mean Ocean Water

Source: Beak (1978)

TABLE 3-14

Groundwater Quality in the Vicinity of the Proposed Mine
Hat Creek Project Mining Feasibility Report 1978

WATER QUALITY PARAMETER	SHALLOW GROUNDWATER		SURFICIAL GROUNDWATER	BEDROCK GROUNDWATER				UNIQUE SAMPLE DATA - SHALLOW WATERS		
				Pit		Medicine Creek				
	Hat Creek Alluvium	Domestic Wells	RH 77-45 Limestone	RH 76-19 Claystone	BAH-7 Coal	RH 77-48 Shale	RH 77-49 Greenstone	Well 1, 2 and Trench B	Well 3 (near Dry Lake)	Goose/ Fishhook Lake
Number of Samples	1	4	1	2	1	1	1	8	5	1
CATIONS - Trace Metals (mg/L)										
Aluminum (Al)	<0.010	<0.011	-	0.004	(0.030)	-	-	<0.014	< 0.011	< 0.010
Arsenic (As)	<0.005	<0.005	-	<0.005	(0.012)	-	-	<0.005	< 0.005	< 0.005
Cadmium (Cd)	<0.005	<0.005	< 0.001	<0.001	<0.005	<0.001	< 0.001	-	-	< 0.005
Chromium (Cr)	<0.010	<0.010	-	<0.001	<0.010	-	-	<0.010	< 0.010	< 0.010
Copper (Cu)	<0.005	<0.009	< 0.002	0.007	<0.005	0.004	< 0.001	<0.009	< 0.005	< 0.005
Iron (Fe)	<0.026	<0.284	<0.041	<0.05	0.125	<0.035	0.073	0.323	0.162	< 0.18
Lead (Pb)	<0.010	<0.010	<0.001	<0.002	<0.010	0.002	< 0.001	-	-	< 0.010
Mercury (Hg)	<0.00040	<0.00028	-	-	(0.00039)	-	-	(<0.00012)	(<0.00013)	(<0.0040)
Molybdenum (Mo)	<0.020	<0.020	-	<0.004	-	-	-	-	-	0.03
Selenium (Se)	<0.003	<0.003	-	<0.10	<0.003	-	-	<0.004	< 0.003	< 0.003
Vanadium (V)	<0.005	<0.005	< 0.04	1.97	<0.005	<0.04	< 0.04	<0.005	< 0.005	0.006
Zinc (Zn)	<0.007	0.074	0.008	0.020	0.008	<0.015	< 0.001	<0.016	0.038	< 0.030
CATIONS - Alkali Earths & Metals (mg/L)										
Calcium (Ca)	57	69	58.0	47.7	48	20.2	123.4	66	246	11
Lithium (Li)	0.002	0.004	-	0.05	<0.008	-	-	0.004	0.051	0.070
Magnesium (Mg)	19	21	30.4	21.6	41	6.8	91.2	16	80	99
Potassium (K)	4.0	-	4.6	34.0	27	3.8	4.7	-	-	190
Sodium (Na)	20	15	41.4	330	300	182.1	32.2	20	384	1390
Strontium (Sn)	0.32	0.33	0.50	0.06	0.14	0.34	1.26	0.25	1.26	1.2
ANIONS - General (mg/L)										
Boron (B)	<0.10	<0.10	-	<0.10	<0.10	-	-	<0.10	0.18	0.3
Chloride (Cl)	1.1	<1.4	6.0	<0.5	8.2	4.2	2.0	1.3	7.5	96
Fluoride (F)	0.16	0.35	-	0.067	0.33	-	-	0.120	0.128	0.57
Sulfate (SO_4)	54	50	83.2	17.3	260	112.0	196.8	49	1328	2140
ANIONS - Nutrients (mg/L)										
Total Kjeldahl Nitrogen (N)	0.19	0.16	-	22.2	5.7	-	-	-	-	3.2
Nitrate-Nitrogen (NO_3-N)	<0.05	<0.10	-	<0.10	0.02	-	-	-	-	< 0.067
Nitrite-Nitrogen (NO_2-N)	<0.002	<0.0011	-	<0.001	0.001	-	-	-	-	< 0.0016
Total Orthophosphate Phosphorus (P)	0.043	0.037	-	<0.01	0.037	-	-	0.027	0.040	1.5
ORGANIC, NONIONIC & CALCULATED VALUES (mg/L)										
COD	21	< 37	-	-	-	-	-	-	-	124
TOC	9	19	-	-	21	-	-	38	88	164
Phenol	<0.002	<0.002	-	-	-	-	-	-	-	< 0.002
Total Hardness ($CaCO_3$)	224	247	269	208	289	78	682	231	945	436
Total Alkalinity ($CaCO_3$)	226	246	333	943	791	431	672	233	533	1520
PHYSICAL DATA										
pH (units)	8.4	7.8	8.0	7.6	7.3	8.2	8.0	7.8	7.4	9.8
Specific Conductance (µmhos/cm @ 25°C)	489	519	681	1834	1700	942	1326	530	3010	6700
True Colour (Pt-Co Units)	12	<9	-	-	20	-	-	-	-	50
Turbidity (NTU)	1.5	1.3	-	-	3.3	-	-	-	-	3.9
Temperature (°C)	6.6	-	-	-	10	-	-	-	-	6.4
PHYSICAL DATA - Residues (mg/L)										
Total Residue	348	357	-	-	1244	-	-	379	2858	5076
Filterable Residue	342	353	-	1600	1220	-	-	347	2714	5070
Nonfilterable Residue	6	4	-	-	24	-	-	32	144	6
Fixed Total Residue	281	309	-	-	1088	-	-	-	-	4706
Fixed Filterable Residue	278	308	-	1400	1080	-	-	-	-	4703
Fixed Nonfilterable Residue	4	<3	-	-	8	-	-	-	-	3
BIOCHEMICAL, DISSOLVED GASES, & RELATED MEASUREMENTS (mg/L)										
BOD	<1	-	-	-	7	-	-	-	-	1
D.O.	11.1	-	-	-	0.8	-	-	-	-	9.6
% Saturation	90.2	-	-	-	7.1	-	-	-	-	90.3

Note: - ( ) denotes total concentration
Source: Golder (1977), Beak (1978)

TABLE 3-15

Variation in Groundwater Quality
with Lithology and Depth

Hat Creek Project Mining Feasibility Report 1978

Hole Number	Lithology	Sample Depth (m)	pH	Electrical* Conductivity	Sodium Adsorption Ratio
RH 77-45	gravel	24	6.5	660	-
	weathered	30	7.2	645	-
	limestone	38	7.0	560	<1
	blue limestone	43	7.2	700	-
	" "	49	7.1	650	-
	" "	56	7.3	655	-
	" "	60	7.2	600	<1
	" "	69	7.5	650	-
	" "	74	7.4	625	-
	" "	88	7.4	610	1
RH 78-48	sandstone	24	7.4	500	-
	greenstone	32	7.4	540	-
	sandstone	35	7.4	545	-
	greenstone	38	7.9	560	-
	"	41	7.6	610	-
	grey shale	56	7.6	600	-
	" "	58	8.4	879	9.9
	sandstone	79	8.1	1019	9.0
	shale	90	8.1	936	8.3
RH 77-49	greenstone	75	7.4	950	-
	"	79	7.6	1000	-
	"	90	8.0	1326	<1

*μmhos/cm

Source: Golder (1977)

Shallow Groundwater

Shallow groundwater in the proposed mine area is of the calcium-magnesium bicarbonate type and strongly resembles Hat Creek water with high levels of calcium, magnesium, total hardness, and alkalinity. The calcium to sodium ratio is high, while filterable residue and specific conductance are relatively low. Shallow groundwater is suitable for drinking and irrigation (Beak, 1978).

Surficial Groundwater

Groundwater in the surficial limestone is of the calcium-magnesium bicarbonate type and is similar to Hat Creek water. Surficial limestone water is also suitable for drinking and irrigation. Intermediate calcium:sodium ratio, filterable residue, and specific conductance are slightly elevated compared to that recorded for shallow groundwaters.

Groundwater flow to Hat Creek along the length of the valley is estimated to be approximately 284-568 m^3/day per kilometre. Potential groundwater flows for Houth and Medicine creek basins are estimated at 261 and 350 m^3/day, respectively. Regional flow in the vicinity of the mine is estimated at 2054 m^3/day for Marble Canyon (Beak, 1978). Regional flow within the valley alluvium, and the buried preglacial valley is estimated to be 2592 m^3/day (Golder Associates, 1978). The extent of the buried valley is unknown at present but discharge from it is considered likely to seep through alluvium and enter Hat Creek.

Groundwater Origins

Isotopic composition of groundwaters (deuterium, tritium, and oxygen-18) and hydrogeochemical patterns provide an indication of water origin within the proposed mine area (Table 3-13). Present data indicate that the groundwater is derived from precipitation and that standing surface waters and small streams are evaporitic.

Tritium analysis of groundwaters sampled shows that they are in the range of 16 to 25 years of age (Beak, 1978).

Water Tables

Water table variation in the vicinity of the proposed pit and Medicine Creek area has been recorded monthly since November 1976 in 12 piezometers. Based on present data (recorded during an abnormally dry summer) the maximum annual fluctuation of piezometer heads in recharge zones is estimated at 3-10 m. In the discharge area near Hat Creek, fluctuations are controlled by creek level and maximum variation is reported at 1-2 m (Beak, 1978).

Bedrock Groundwater

Considerable variations in deep bedrock water quality occur with lithology and depth.

Groundwater from greenstones and shales in the Medicine Creek area is of the calcium-magnesium bicarbonate type. High concentrations of calcium, magnesium, and strontium are present. The calcium:sodium ratio is low but specific conductance is high. Below a depth of 58 m, water in contact with shale is sodic and has high specific conductance. Further data are required to determine whether groundwater from shales and greenstones is suitable for drinking and irrigation.

Groundwater contacting claystones and coal is of the sodium bicarbonate type and is characterized by a low calcium:sodium ratio and high filterable residue and specific conductance. Elevated sodium, sulphate, vanadium, specific conductance, and alkalinity are also evident. Water quality from Drill Hole RH-76-19 (claystones) may represent the most probable "worst case" composition for groundwater in the open pit (Beak, 1978) (refer Table 3-14).

Unique Samples

Wells 1, 2, and 3 (Table 3-14, Figure 3-8) were established in the mine area during the summer of 1977 as part of a bulk coal sampling program. Analyses of Wells 1 and 2 indicate that the groundwater is similar to that of nearby alluvial waters and that its origin is most probably Hat Creek. Groundwater from Well 3 is evaporitic and contains high levels of sodium and sulphate. Dry Lake, an evaporitic slough near Well 3, is believed to be similar in ionic composition to Goose/Fishhook Lake (see Table 3-11).

Summary

Surficial groundwater is suitable for drinking and irrigation but suitability of deep bedrock groundwater may vary with lithology and depth. Sulphate concentrations were slightly elevated compared to PCB level A objectives for most groundwater samples.

3.3 AQUATIC RESOURCES

Hat Creek exhibits a variety of characteristics with respect to stream morphology, flow rate, and type of aquatic habitat. The width of the streambed varies from 1.5 m at the headwaters to approximately 9.0 m in the lower reaches; substrata consists of silt and sand in the pools, ranging to boulders in the steeper portions. In periods of average flow, stream depth varies from 25 mm in riffle areas to 1.5 m in the deeper pools. Banks are generally stable and vegetation is primarily deciduous, consisting of grasses, shrubs, and trees.

331 FISHERIES

The habitat and fisheries of Hat Creek comprise two principal units: Lower Hat Creek, in which riffles are more prevalent and currents swifter; and Upper Hat Creek, in which pools, fewer riffles, and slower water predominates (Beak, 1978). Beaver dams between Lower and Upper Hat Creek appear to block the upstream movement of fish resulting in separate, self-sustaining populations. Adequate spawning beds and cover are present throughout the length of Hat Creek. Field observations (Beak, 1976 and 1977) indicate that tributaries to Hat Creek provided only minimal fish habitat by comparison. No fish have been recorded at Goose/Fishhook, Aleece, or Finney lakes.

With the exception of the downstream area near the mouth of Hat Creek, rainbow trout is the only fish species present within the proposed mine area. Population estimates for rainbow trout within Upper and Lower Hat Creek are presented in Table 3-16 (Beak, 1978). The density of rainbow trout within the proposed mine area has been estimated at 1.32 fish/m or 0.38 fish/m^2 (Beak, 1976 and 1977). Spawning occurs between mid-June and late July, when water temperatures reach 10-14°C.

332 STREAM BENTHOS

The benthic resources of Hat Creek appear characteristic of clean water conditions. Principal food organisms for rainbow trout were aquatic insects; small size fish utilized Ephemeroptera nymphs and Diptera larvae particularly, while Trichoptera

TABLE 3-16

Population Estimates by Length Interval (mm) for Rainbow Trout
Hat Creek Project Mining Feasibility Report 1978

Month and Length Interval (mm)	LOWER HAT CREEK			UPPER HAT CREEK			Total
	0 - 8.0	8.0 - 22.4	22.4 - 25.5	25.5 - 30.0	30.0 - 39.0	39.0 - 41.0*	
September 1976							
0-100	3120	3351	319	1788	2983	258	11 819
101-150	-	393	502	1391	5038	228	7552
151-200	-	-	46	401	1602	171	2220
201-250	-	-	-	201	801	142	1144
>250	-	-	-	-	116	-	116
TOTAL	3120	3744	867	3781	10 540	799	22 851
June 1977							
0-100	836	3715	698	499	1370	228	7346
101-150	524	979	512	1893	2165	285	6358
151-200	-	589	185	398	1370	484	3023
201-250	-	192	-	298	225	142	957
>250	-	-	-	98	-	-	98
TOTAL	1360	5472	1395	3286	5130	1139	17 782
August 1977							
0-100	330	1567	465	1883	1498	260	6003
101-150	440	2350	465	2477	2189	-	7921
151-200	110	783	185	1283	1728	-	4089
201-250	-	196	94	297	345	-	932
250	-	-	-	-	-	-	-
TOTAL	880	4896	1209	5940	5760	260	18 945

* Kilometres from Hat Creek - Bonaparte River confluence

Source: Beak, 1978

larvae and Plecoptera nymphs were more important to larger size fish. Drift organisms such as Hymenoptera and Coleoptera were found to be an important food source for larger trout during the months of June and August. Adequate food resources, indicated by the good condition of fish sampled, and the variety of organisms present in stomach contents indicate that the rainbow trout are successfully utilizing foods available to them (Beak, 1978).

The diversity and abundance of benthic organisms provide an indication of an area's ability to sustain a greater fishery resource. Lower Hat Creek appeared to be consistently higher in benthic organisms than either Upper Hat Creek or the Bonaparte River. In addition, variance over time was minimal in Lower Hat Creek, indicating a stable biological community. Up to a threshold level, this portion of the stream would therefore be able to withstand a higher degree of stress than Upper Hat Creek.

3.4 LAND CAPABILITY AND PRESENT USE

341 AGRICULTURE

341.1 Productivity

Production of irrigated hay and livestock on natural rangeland are currently the only agricultural uses of land within the proposed mine area. Irrigated hay land occupies 46.5 ha or 2.4% of the proposed mine area and crops consist primarily of alfalfa, timothy, orchardgrass, and bromegrass, with yields ranging from 4.5-11.2 t/ha (CBRC, 1978).

Native rangeland (land rated as grazing capability classes G-2, G-3, and G-4) occupies 1255 ha or 65% of the proposed mine area. Preferred range species include bluebunch, crested, western, and bearded wheatgrass; Kentucky bluegrass; timothy; red top; white clover; sage; and pea-vine. Productivity ranges from 280-1120 kg/ha (CBRC, 1978).

Crown grazing permits are issued annually based on range area, carrying capacity, livestock numbers, and grazing duration expressed in hectares per animal-unit-month (AUM). The mine area includes portions of four grazing permits.

Highly productive Kentucky bluegrass rangeland, with carrying capacity greater than 0.4 ha/AUM/yr, predominates in the Medicine Creek area. At lower elevations, Bunchgrass-Kentucky bluegrass range supports a carrying capacity of 0.8 ha/AUM/yr, while Douglas fir-Pinegrass at higher elevations supports a reduced carrying capacity of 2-2.9 ha/AUM/yr. Cattle numbers within the mine area vary considerably throughout the year but may approach 1500 to 1800 head in peak periods. These figures reflect cattle "usage" of the overall Upper Hat Creek Valley.

Approximately 1408 ha or 73% of the proposed mine area is located within a provincial Agricultural Land Reserve.

The present agricultural use within the mine area is summarized in Table 3-17.

TABLE 3-17

Present Agricultural Use of Lands
in the Proposed Mine Area*+
Hat Creek Project Mining Feasibility Report 1978

Land Use Parameters	FARM UNIT NUMBER 4	5	6	7	Total
1. Tenure					
Private (ha)	651	4973	2037	199	10 160
Lease (ha)	3811	9267	4955	772	18 805
Total	4462	14 240	6992	971	
2. Use					
Private and Lease Land					
irrigated (ha)	187	603	432	165	1437
rangeland (ha)	4275	13 637	6560	741	27 463
Other Crown Land					
grazing permit (ha)	4049	12 658	25 915	4121	46 743
permit use (AUM/yr)	638	3360	2780	533	7604
3. Livestock					
Cattle on Permit Land					
from permit information	150	980	590	160	1920
from discussions with ranchers	800		800	225	1885

* Data represent total farm units which mine area disturbs or influences. Farm units extend beyond the area of mine operations.

\+ Source: CBRC, 1978

341.2 Capability

Canada Land Inventory (CLI) capability maps for agriculture were used to evaluate potentials and limitations of the soils and climate of the mine area for agricultural use (Figure 3-10). The CLI classification describes the range of possible crops which may be grown without consideration of economic constraints.

High capability agricultural land (Soil Capability for Agriculture Classes 1 to 3) comprises 22% of the proposed mine area. Approximately 428 ha are theoretically capable of producing a fairly wide range of regional crops under good management practices (Soil Capability for Agriculture Classes 3 and 4). Lands suitable only for production of perennial forage crops (Soil Capability for Agriculture Classes 5 and 6) comprise 248 ha of the total mine area.

Class G-2, G-3, and G-4 grazing land comprise approximately 43, 20, and 2% of the proposed mine area and have potential productivity of 560-1120 kg/ha, 280-560 kg/ha, and 140-280 kg/ha, respectively.

342 WILDLIFE

342.1 Wildlife Habitat

Wildlife habitat throughout the region has been classified according to vegetation associations (Tera, 1978). Ten distinct habitats were mapped within the proposed mine area and correlated with vegetation associations (refer to Table 3-18 and Figure 3-11). Although the Douglas-fir/pinegrass habitat occupies the largest area within the mine area, approximately 611 ha, the most productive and diverse habitat for wildlife is generally the riparian habitat which occupies approximately 51 ha.

Wetlands, located primarily to the west of Hat Creek, occupy about 190 ha. Although small in area, they represent a significant resource to the local region, and are rated under the Canada Land Inventory system as having a high capability

FIGURE 3-10

Legend

Capability for Agriculture

SOIL CAPABILITY FOR AGRICULTURE

CLASSES:

1	No significant limitations in use for crops.
2	Moderate limitation that restrict the range of crops or require moderate conservation practices.
3	Moderately severe limitations that restrict the range of crops or require special conservation practices.
4	Severe limitations that restrict the range of crops or require special conservation practices or both.
5	Very severe limitations that restrict capability to produce perennial forage crops. Improvement practices are feasible.
6	Capable only of producing perennial forage crops. Improvement practices are not feasible.

LAND CAPABILITY FOR GRAZING

CLASSES:

G-1	No important limitations.* Productivity is usually over 1120 kg/ha.
G-2	Slight limitations.* Productivity 560 - 1120 kg/ha.
G-3	Moderate limitations.* Productivity 280 - 560 kg/ha.
G-4	Moderately severe limitations.* Productivity 140 - 280 kg/ha.
G-5	Severe limitations.* Productivity 0 - 140 kg/ha.

* ... to the growth of native forage plants.

CLIMATE CAPABILITY FOR AGRICULTURE

CLASSES:

1	Capable of producing the very widest range of vegetables, cereal grains, forages, berry fruits, and numerous specialty crops. Soil and climate are optimum.
2	Capable of producing a wide range of regional crops as above with some differences in variety due to minor restrictions of soils or climate.
3	Capable of producing a fairly wide range of regional crops under good management practices. Soils and climate are somewhat restrictive.
4	Capable of a restricted range of regional crops such as hardy cereal grains, hardy vegetables, and forages. Soils and climate demand special management practices.
5	Capable of producing perennial forage crops only. Soils and climate severely restrict land capability.
6	Natural rangeland. Soils and climate preclude cultivation
7	No agricultural capability.

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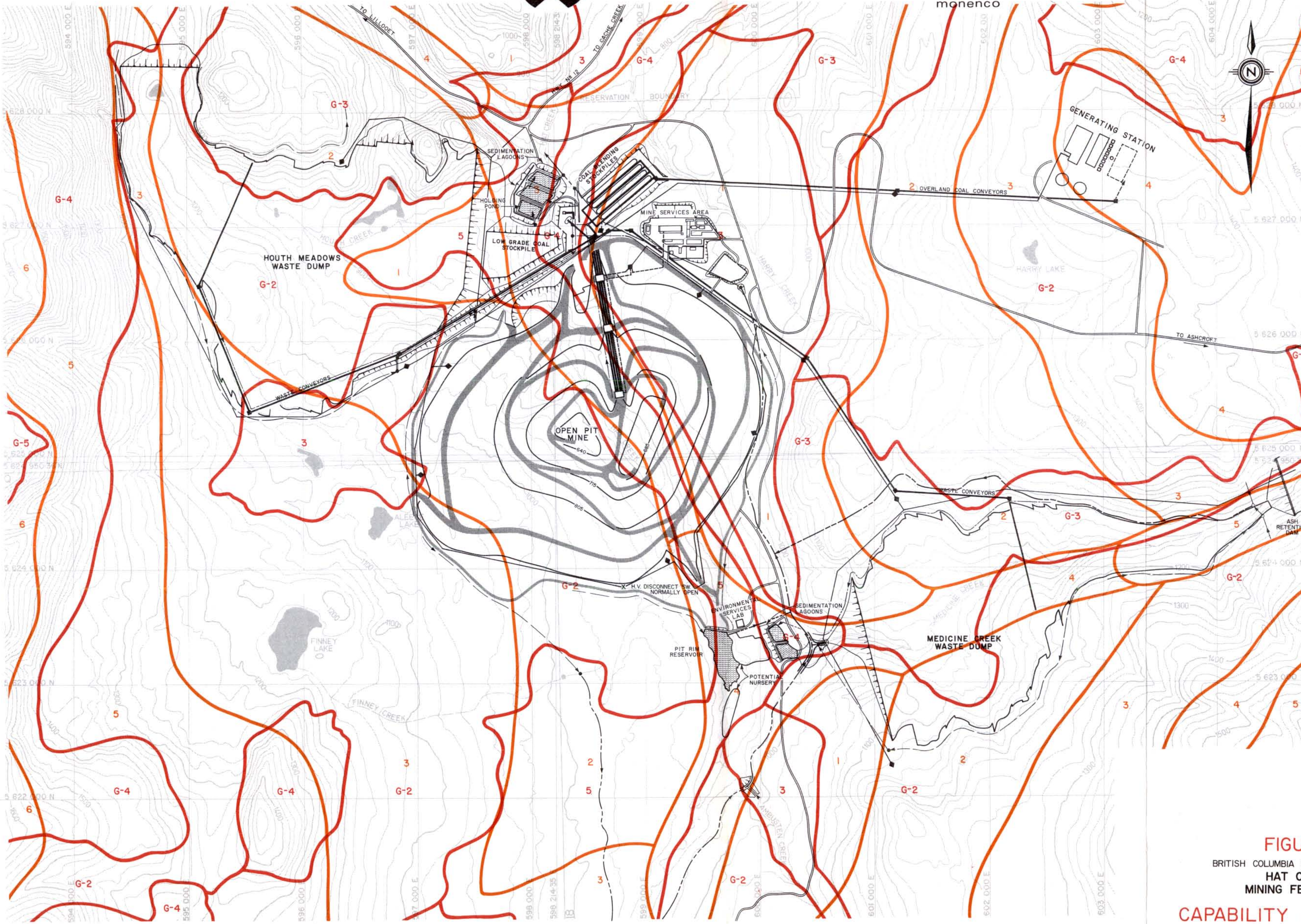

LEGEND

3	CLIMATE CAPABILITY FOR AGRICULTURE
3	SOIL CAPABILITY FOR AGRICULTURE
G-3	GRAZING CAPABILITY FOR AGRICULTURE

0.1 0 0.5 1.0 km

FIGURE 3 - 10

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

HAT CREEK PROJECT

MINING FEASIBILITY REPORT

CAPABILITY FOR AGRICULTURE

TABLE 3-18

Wildlife Habitat

Hat Creek Project Mining Feasibility Report 1978

Habitat	Vegetation Association	Habitat Within the Proposed Mine Area (ha)
Engelmann spruce - lodgepole pine forest	Engelmann spruce - grouseberry . - white rhododendron Engelmann sprucé - grouseberry Engelmann spruce - Subalpine-Fir - grouseberry Engelmann spruce - grouseberry - pinegrass Engelmann spruce - horsetail	None
Douglas-fir/pinegrass	Some seral stages within Engelmann spruce - grouseberry Some seral stages within Engelmann spruce - Subalpine-Fir - grouseberry Some seral stages within Engelmann spruce - grouseberry - pinegrass Douglas-fir - spirea - bearberry Douglas-fir - pinegrass Douglas-fir - bunchgrass - pinegrass Douglas-fir - bunchgrass (a few mature, closed canopy stands)	611
Ponderosa pine - Douglas-fir/ bunchgrass	Some seral stages within Douglas-fir - bunchgrass - pinegrass Most seral stages within Douglas-fir - bunchgrass Ponderosa pine - bunchgrass	505
Aspen	Some forest types within Douglas-fir - pinegrass Some forest types within Douglas-fir - pinegrass - bunchgrass	36
Riparian	Riparian	51
Open Range - Mid elevation grassland	Kentucky bluegrass	111
Open Range - Low elevation grassland	Bunchgrass - Kentucky bluegrass	24
Open Range - Sagebrush	Sagebrush - bluebunch wheatgrass	548
Bog	Willow - Sedge Bog - Engelmann spruce - horsetail	6
Rock Outcrop	-	39
Total Habitat	=	1931 ha

Source: Tera (1978)

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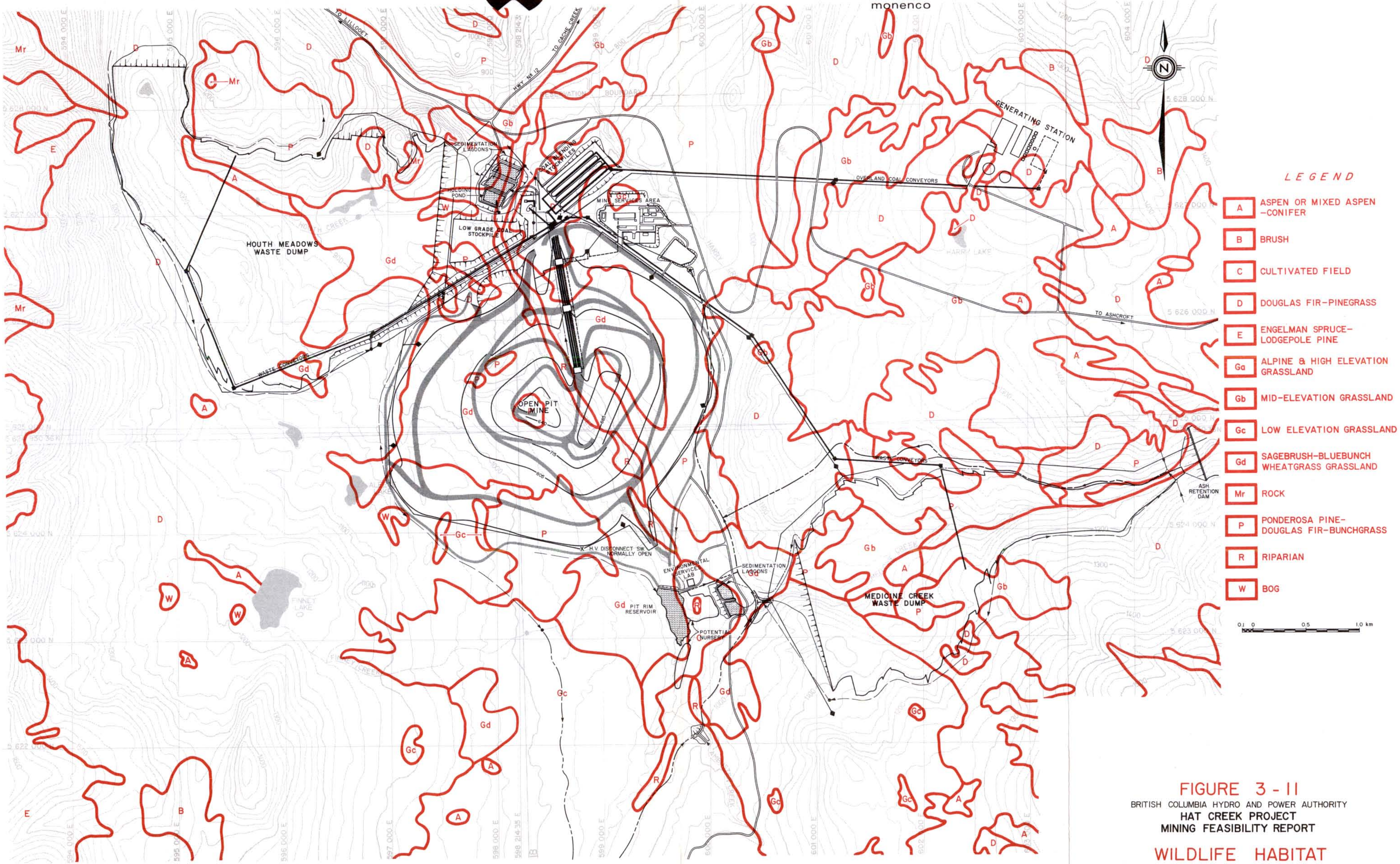

FIGURE 3 - 11
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY
HAT CREEK PROJECT
MINING FEASIBILITY REPORT
WILDLIFE HABITAT

(Class 1, 2, 3, or 3M - special migration area) for waterfowl production. Principal limitations to the development of higher quality wetlands and wetland vegetation appear to be water quality, soil fertility, and overgrazing (Tera, 1978). The distribution of wetlands within the mine area is illustrated on Figure 3-12. Details of those wetlands which would be disturbed by mining are summarized in Table 3-19. Physical characteristics of selected ponds within the proposed open pit are presented in Table 3-20. The wetlands of Upper Hat Creek Valley, and particularly the western portion of the proposed mine area, are considered to have well interspersed nesting and brooding areas, but relatively low production when compared to their estimated potential capability (Tera, 1978).

342.2 Wildlife Resources

No significant concentrations of any rare or endangered wildlife species are known to occur within the mine area (Tera, 1978).

The Upper Hat Creek Valley is considered peripheral to the zone of abundance for reptiles. Only three reptiles (garter, rubber boa, and blue racer snakes) are expected to inhabitat the proposed mine area.

Similarly, few species of amphibians (western toad, long toed salamander, and spotted frog) are present, although their numbers are substantially greater due to favourable habitat.

There are estimated to be approximately 250 breeding pairs of waterfowl utilizing the wetlands of Upper Hat Creek Valley (total including mine area). The area is thought to represent the highest waterfowl production within an 80 km radius. Upland game bird species in the valley are limited to ruffed and blue grouse, mourning dove, and common snipe. Populations are low, with the result that most sport hunting for upland birds takes place outside of the Hat Creek area. With its diverse avifauna, Hat Creek has an excellent potential for bird watching; this is presently under-utilized, however, due to limited access. Riparian and aspen habitats have the greatest numbers of unique species as well as the greatest diversity of avifauna.

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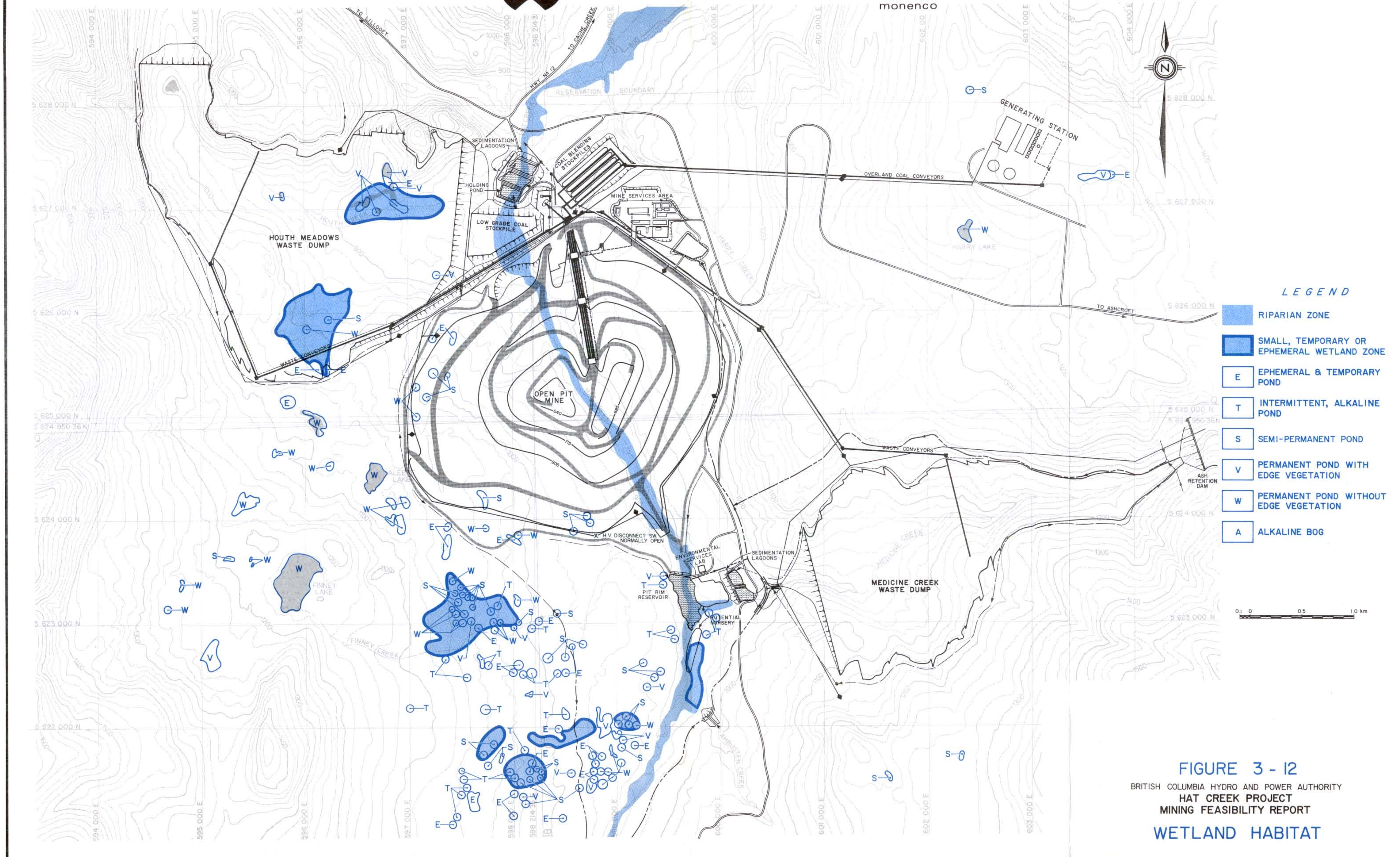

FIGURE 3 - 12

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY
HAT CREEK PROJECT
MINING FEASIBILITY REPORT

WETLAND HABITAT

TABLE 3-19

Summary of Wetlands
Within the Proposed Mine Area
Hat Creek Project Mining Feasibility Report 1978

Wetland Type	Number*
Riparian Zone	N/A +
Ephemeral (wetland zone)	N/A ++
Ephemeral ponds	8
Intermittent ponds	1
Semi Permanent ponds	10
Permanent ponds (edge vegetation)	8
Permanent ponds (no edge vegetation)	5
Alkaline bog	none

* Majority of wetlands occupy less than .2 ha.

\+ Riparian Zone estimated to be 120 ha.

++ Ephemeral wetland zone estimated to be 65 ha.

Source: Tera (1978)

TABLE 3-20

Physical Parameters of Selected Sample Ponds
Within the Proposed Open Pit Area
Hat Creek Project Mining Feasibility Report 1978

Field pH	Lab pH	Conductivity uS/cm at 25°C	Type	Invertebrates *	Vegetation **
7	6.5	430	Permanent	moderate: *B*,*E*,*F*	Border plus emergent patches of *U*, some *W*,*Y*,*Z*
7	7	497	Permanent	lots: *A*,*D*,*F*	Border of *U*,*W* small patch of *X*,*Y*,*Z*
7	7	573	Semi-permanent	nothing	Narrow border of *U*,*V* 80% *W*; some *Y*,*Z*
7	7	1040	Temporary	moderate: *B*,*C*,*E*	50% cover of *T*

* Invertebrates

A freshwater clams
B gastropods
C copepods
D Amphipods
E Dipteran larvae
F Amphibian larvae

** Vegetation

T Baltic rush
U Hood's sedge
V Foxtail barley
W Duckweed
X Cattail
Y Submergents
Z Algae

Source: Tera (1978)

There is a scarcity of small mammals and furbearers in the area, with the largest numbers concentrated in riparian habitat. At present there are no registered traplines within the valley. Ungulate species are limited to mule deer and moose, and populations are relatively low with principal habitat located in the Medicine Creek and Anderson Creek watersheds. The northern end of Upper Hat Creek Valley is believed to provide wintering habitat for mule deer. The Canada Land Inventory Capability for Ungulates has rated most land in the mine area as Class 4 (moderate limitations to production).

343 MINERAL AND PETROLEUM RESOURCES

Mineral resources which may be buried or alienated by the proposed mine include aggregate (sand and gravel) and limestone deposits. The impact of burying 360 million tonnes of limestone under waste dumps is considered minimal due to the large reserves of limestone which are found in the adjacent Marble Canyon Formation (McCullough, 1978). Aggregate excavated during mining may be stockpiled for future use in highway maintenance and construction.

Clay, burned claystone, and coaly waste could also be produced as by-products of the mine. Depending on markets, economics, and properties of the materials, they could be used for high temperature refractory brick, tri-calcium aluminum cement, drilling muds, ceramic products, grog (a component of bricks), cement, and concentrate.

344 FORESTRY

344.1 Resources

The mine area is composed largely of rangeland in the valley bottom. At higher elevations mixed stands of mature, merchantable Douglas-fir and yellow pine occur. Allowing for a buffer zone of 20 metres around principal mine components and assuming that any stands occurring between components would have to be logged, Table 3-21 outlines the merchantable timber volume by species within the proposed mine area.

TABLE 3-21

Site Specific Study Area; Merchantable Volume by Species for Mine and Related Facilities

Species	Merchantable Volume (cubic metres)
Douglas-fir	98 000
Red cedar	150
Hemlock	10
Balsam (Subalpine fir)	400
Spruce	3000
White pine	150
Lodgepole pine	1500
Yellow pine (Ponderosa Pine)	17 000
Deciduous (Aspen, Birch, and Cottonwood)	100
TOTAL	120 310

Source: Reid Collins, 1978

As shown on Figure 3-13, the land within the mine area consists of approximately 1114 ha of productive forest land, 805 ha of non-forest land, and 12 ha of non-productive forest land.

Approximately 430 ha of the mine area has been logged in the past, for the most part by selective logging methods. Of the productive forest land, consisting primarily of mature and immature Douglas-fir - yellow pine, age classes are generally 141-250 years (mature) and 61-80 years (immature). Height classes for mature timber range from 20-29 m and immature timber from 11-20 m. An average diameter breast height (dbh) of 30 to 50 cm, combined with the above age and height classes result in the majority of present forest resources rated as poor quality.

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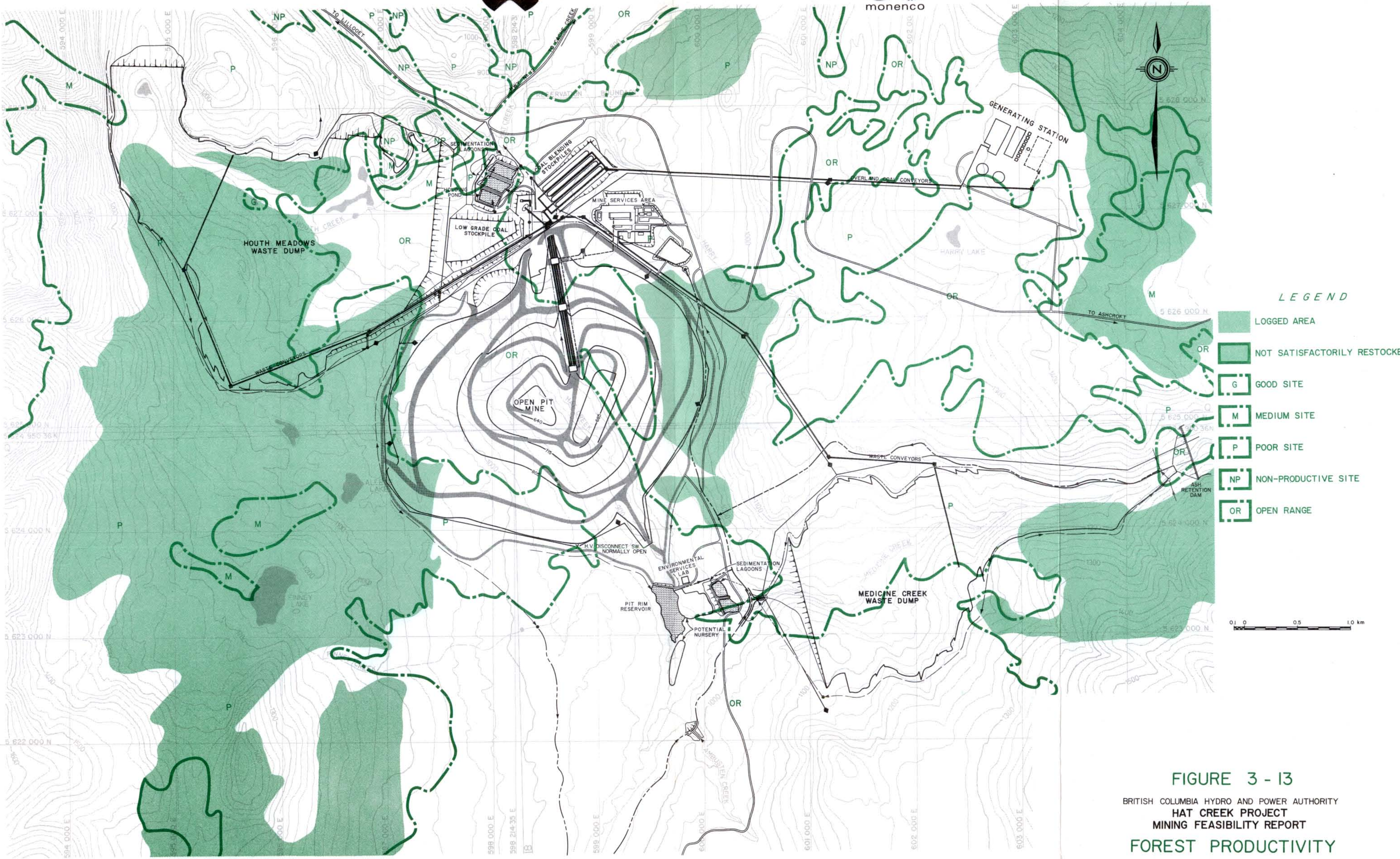

FIGURE 3 - 13

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY
HAT CREEK PROJECT
MINING FEASIBILITY REPORT

FOREST PRODUCTIVITY

344.2 Forest Productivity

Forest productivity was mapped within the mine area on the basis of site quality and rated as good, medium, and poor. Of the land within the mine area classed as forest (1126 ha), over 90% is designated as poor site-class (Reid-Collins, 1978). The area productivity was estimated using pure Douglas-fir (the predominant forest species within the mine area) as the factor for mean annual increment (MAI) within each site-class. Total annual increment (TAI), the theoretical amount of wood that the area could supply, is determined by multiplying the given area of a site-class and the representative mean annual increment. The mine area is estimated to contain a total annual increment of 1137 m^3. Forest productivity of the mine area is summarized below:

Site Class	Area (ha)	MAI (m^3/ha)	TAI (m^3)
Good	2.	3.6	7.2
Medium	26.	1.7	44.2
Poor	1086.	1.0	1086
	1114. ha		1137 m^3

345 RECREATION

345.1 Present Use

Recreational activities within the mine area consist primarily of fishing, hunting, backroad travel, and sightseeing. These activities are estimated to account for approximately 2600 activity days spent annually in the general mine and plant area (ESCLEC, 1978). Angling is estimated to account for 1500 activity days, followed by hunting for 850 activity days.

The Upper Hat Creek Valley contains no recreation reserves nor identifiable plans for construction of facilities. Most recreation is limited by restricted access (private agricultural land). On a regional basis the valley contains no spectacular or above-average recreational resources.

With no permanent facilities or developments present in the mine area, recreation activity depends on the influence of season and climate.

345.2 Capability

The Canada Land Inventory Recreation Capability maps rate the mine area primarily as Class 5 (low capability), with a small pocket of Class 4 (moderate). Potential recreation activities include fishing, hunting, sightseeing, and bird-watching.

3.5 WATER USE

351 GROUNDWATER

Five domestic wells are situated within the proposed mine area and all are located within the boundary of the open pit (refer Figure 3-8 and Table 3-14). Well depths range from less than 1 to 5 m. Well flow rates range from less than 1.5 to 10 m^3/day and are generally developed from shallow springs located in impermeable glacial till or Hat Creek alluvium.

The principal use of water in the area is for residential supplies, although a minor amount is used for irrigation.

352 SURFACE WATERS

352.1 Irrigation

Irrigation water license data for the mine area and Hat Creek downstream of the mine are summarized in Table 3-22.

Of the 1050 ha-m of water licensed for withdrawal from the total Hat Creek watershed, the mine area accounts for 28% (296 ha-m) and downstream areas approximately 18% (188 ha-m).

Theoretical calculations (Beak, 1978) of irrigation water use, based on climate, soil, crop, and irrigation system characteristics indicate that irrigation licenses are presently fully utilized. Details provided in Table 3-23 below illustrate the comparison between analyses of licenses and predicted use.

TABLE 3-22

Irrigation Water License Data
for Hat Creek Area

Location of Diversion	Irrigation License		
	Number of Licenses	Water Quantity (ha-m)	Land Area
Region I (Downstream of Mine Area)			
Hat Creek	2	165 (37)*	
Gallagher Creek	1	11	
Robertson Creek	2	12	
Total	5	188 (37)*	205 (40)*
Region II (Mine Area)			
Hat Creek	4	21	
Lloyd (Houth) Creek	1	11	
Medicine Creek	5	236 (224)*	
Finney Creek	2	24	
Anderson Creek	-	-	
Ambusten Creek**	1	4	
Total	13	296 (224)*	346 (318)

* used outside of Hat Creek watershed
** fully recorded

Source: CBRC (1978)

TABLE 3-23

Comparison of Water Use Estimates

Region	Water License Analysis Water Quantity (ha-m)	Water Use Model Water Quantity (ha-m)
I (Downstream)	151	143
II (Mine Area)	72	81
	Irrigated Land (ha)	Irrigated Land (ha)
I (Downstream)	165	210
II (Mine Area)	128	128

Source: Beak, 1978

An estimate of present irrigation water use within the mine area, using land areas classed by aerial photograph interpretation, is shown in Table 3-24. Upland soils used for pasture and improved by ditch irrigation are the largest consumer of irrigation waters.

352.2 Livestock

Based on the maximum number of cattle within the overall mine area at any one time, i.e., 1880 animals (CBRC, 1978), and assuming a daily rate of water consumption of 0.033 m^3/day, the total daily water consumption by livestock is estimated to be in the order of 62 m^3/day or 2.3×10^4 m^3 annually. This represents less than 1% of the total water presently used for irrigation within the mine area (1050 ha-m). As consumption would vary seasonally, this consumption estimate is undoubtedly high; however, due to limited data, it is considered acceptable for working purposes.

TABLE 3-24

Estimate of Present Irrigation Water Use in Region II

(Proposed Mine Area)

Hat Creek Project Mining Feasibility Report 1978

	IRRIGATION METHOD AND CROP TYPE							
	Sprinkler-Hay		Ditch-Hay		Ditch-Pasture		Total	
Soil Group	Area (ha)	Water Volume (ha-m)	Area (ha)	Water Volume (ha-m)	Area (ha)	Water Volume (ha-m)	Area (ha)	Water Volume (ha-m)
Floodplain Soils	16	7	-	-	-	-	16	7
Upland Soils	18	11	35	23	59	40	112	74
Total	34	18	35	23	59	40	128	81

AVERAGE SEASONAL DISTRIBUTION (ha-m)					
May	June	July	August	September	Total
12	15	25	20	9	81

Source: Beak, 1978

352.3 Domestic and Municipal

Within the mine area a total of 4.5 m^3/day of water is licensed (two licenses) for withdrawal for domestic purposes from Hat Creek and its tributaries. Downstream, between the mine area and the mouth of Hat Creek, a total of 34 m^3/day is licensed (six licenses) for withdrawal.

353 DOWNSTREAM FISHERIES REQUIREMENTS

Minimum flow requirements for fisheries resources downstream of the proposed mine area have been calculated (Beak, 1978) on the basis of habitat requirements. These estimates are outlined below:

Base flow period (October to March)	.21 m^3/s
Base flow period (April to September)	.28 m^3/s
Flushing flows (for two week duration during May-June)	1.42 m^3/s

These flows are believed adequate to preserve present habitat downstream of the mine area in good to excellent condition and thereby support similar numbers of fish.

3.6 COMMUNITY FEATURES

361 HERITAGE RESOURCES

361.1 Prehistoric

The Upper Hat Creek Valley was part of the hunting territory of the Spences Bridge Band of the Upper Thompson Indian population. Their prime activity centred locally on fishing and hunting and their living pattern was semi-nomadic in character. Although use of the area has not yet been researched or documented in great detail, the data indicate that activity in Upper Hat Creek Valley was concentrated in the Early Nesikep Period (5000 to 8000 B.C.).

Field investigations of potential archeological sites place the majority of resources within the grassland areas as opposed to the forested areas (approximately three times as many). Sites uncovered to date are of two principal types: lithic scatter and cultural depression (processing pits). Estimates based on preliminary field results place the potential number of archeological sites within the Upper Hat Creek Valley area at 963. Predicted numbers of sites within the proposed mine area are listed on Table 3-25 (Pokotylo and Beirne, 1978). Houth Meadows appears to have the greatest frequency of sites and also those of larger size.

361.2 Historic

European entrance to the local area was initially transitory in nature, and occurred with the establishment of the fur trading routes around the year 1812. Upper Hat Creek Valley was utilized for grazing land, although no settlements were established until the 1880's. Homesteaders then settled in the valley and set up a sawmill and small coal mine operation. Production of root crops and hay together with resident cattle operations occurred with the establishment of the China Ranch in Upper Hat Creek Valley in the early 1900's. By 1920 all available homestead land was used and land use focussed on mixed farming and ranching; these activities have continued through to present times.

TABLE 3-25

Known and Predicted Cultural Heritage Resources
in the Proposed Development Zones
Hat Creek Project Mining Feasibility Report 1978

Proposed Development Zone	Estimated # of Surficial Sites in Zones	Estimated Total Site Area (m^2)	Other Known Cultural Heritage Resources
Medicine Creek* Waste Dump	18.2	5151	
Medicine Creek Offsite Areas	18.2	800	Source for vitreous basalt (Trachyte Hills - western scarp)
Openpit	158.3	73 556	source for pollen cores (Finney Lake)
Houth Meadows Waste Dump	71.7	88 196	
Hat Creek Diversion Reservoir	12.0	5372	

* These figures may be underestimates since the proposed development area(s) have been expanded since the completion of the 1977 survey.

Source: Pokotylo and Beirne, 1978.

362 SOCIO-ECONOMIC BASE

Cattle ranching is the principal economic activity in the Upper Hat Creek Valley. Within the proposed mine area, portions of Crown range involving four ranch operations are located.

Timber sale harvest licenses include portions of the mine area at higher elevations. Mine operations would not result in a loss of potential timber harvest but would delay restocking.

363 AESTHETICS

Evaluation of the aesthetic or visual quality of an area is based on the parameters of variety, vividness, and unity of the landscape. Within the proposed mine area visual units identified and evaluated (Toby et al, 1978) were the Upper Hat Creek and Medicine Creek valleys. The aesthetic quality of Upper Hat Creek Valley has been classified as outstanding based on the integration of man-made and natural elements into a unified landscape. No special aesthetic features or landscapes were identified within the Upper Hat Creek Valley area. Due to the rolling hills which enclose the valley, it is considered capable of absorbing changes, many of which could be screened or integrated to the surrounding landforms (Toby et al, 1978).

Medicine Creek Valley, classed as having a high aesthetic quality, has similar components to Upper Hat Creek Valley but because it is smaller in scale, its capacity to withstand environmental change is similarly limited from the aesthetic standpoint.

3.7 OTHER

371 TRACE ELEMENTS

Base-line trace element concentrations are presented in Table 3-26 for important receptors sampled near the mine area. Water, stream sediment, rainbow trout, soil, willow, bluebunch/ wheatgrass, lichen, and deer mouse were sampled in October 1976, January 1977, and May 1977. Values presented represent an average of three replicates from the described sample sites.

Potential trace element sources (coal, waste, and waste rock) were analyzed initially for 63 elements. Twenty-one trace elements were considered to be of potential concern at Hat Creek. Arsenic, cadmium, chromium, copper, fluorine, lead, mercury, vanadium, and zinc were considered of greatest concern due to their relatively high natural concentration in source materials and their potential for mobility and accumulation in receptors.

In natural undisturbed soils and stream sediment, arsenic, cadmium, and fluorine concentrations are elevated. Grass samples have elevated fluorine concentrations and small mammals were found to contain elevated arsenic, chromium, lead, and copper concentrations compared to normal reported values. Chromium concentrations in fish and lead values in water are relatively high compared to normal reported values. Natural concentrations of mercury, vanadium, and zinc in sampled receptors are similar to values reported in the literature (ERT, 1977).

372 AMBIENT NOISE

Present ambient noise levels within the proposed mine area are less than 60 decibels. Intermittent levels of 50 to 90 decibels occur as a result of road traffic and agricultural machinery.

TABLE 3-26

Base-Line Trace Element Concentrations in Natural Receptors
Hat Creek Project Mining Feasibility Report 1978

Element	Sampling Date	TRACE ELEMENT CONCENTRATION IN RECEPTOR (ppm) Water	Stream Sediment	Rainbow Trout	Soil	Willow	Bluebunch Wheatgrass	Lichen	Deer Mouse
Arsenic	October 1976	<0.002	10.0	<0.43	8.33	<0.97	<1.83	1.57	<0.73
	January 1977	0.0027	59.0	-	67.0	-	-	2.3	-
	May 1977	<0.05	42.0	2.3	61.0	<7	<7	5.0	<1.5
Cadmium	October 1976	0.0032	<0.37	<0.30	<0.43	<0.33	<0.33	<0.40	<0.33
	January 1977	<0.0013	5.0	-	9.5	-	-	0.4	-
	May 1977	<0.005	5.1	<0.1	5.3	1.1	<0.7	0.4	<0.15
Chromium	October 1976	0.0113	61.67	9.83	154.33	1.67	8.33	9.67	3.0
	January 1977	0.0167	38.0	-	44.0	-	-	8.2	-
	May 1977	<0.002	30.0	2.2	35.0	3.5	4.1	7.6	4.0
Copper	October 1976	0.0028	26.67	4.67	58.33	31.33	13.67	9.67	11.67
	January 1977	0.0057	48.0	-	21.0	-	-	29.0	-
	May 1977	<0.01	28.0	3.6	28.0	7.9	7.8	10.0	7.5
Fluorine	October 1976	-	202.0	74.33	<466.67	110.67	24.0	157.0	153.0
	January 1977	0.070	455.0	-	36.0	-	-	100.0	-
	May 1977	0.15	260.0	14.0	90.0	26.0	1360.0	11.0	24.0
Lead	October 1976	0.00567	<4.33	<2.00	7.67	10.00	<21.67	53.33	<2.50
	January 1977	<0.05	<2	-	<2	-	-	45	-
	May 1977	<0.05	<3	3.6	<3	2.6	4.1	3.6	1.5
Mercury	October 1976	<0.0001	0.16	<0.08	0.07	0.10	0.12	0.25	<0.02
	January 1977	<0.0001	0.1	-	0.1	-	-	0.8	-
	May 1977	<0.001	0.11	0.40	0.09	0.41	0.30	0.59	0.39
Vanadium	October 1976	0.0058	56.33	0.97	277.67	<0.17	1.60	6.00	0.27
	January 1977	0.0020	51.0	-	63.0	-	-	3.9	-
	May 1977	0.007	52.0	0.3	45.0	<0.3	<0.4	3.7	<0.15
Zinc	October 1976	0.0153	42.33	81.67	92.33	156.67	23.33	31.0	165.0
	January 1977	0.0123	45.0	-	119.0	-	-	33.0	-
	May 1977	0.076	54.0	86.0	123.0	160.0	25.0	35.0	0.2

Note: 1) Means of 3 samples

2) The less than symbol (<) indicates that one or more of the replicate measurements were below the analytical detection limit. When such analytical data occurred, means were calculated by using the detection limit as the concentration and then reporting the mean with a < symbol.

3) Only water, stream sediment, soil, and lichen were collected during January 1977.

4) Sampling Site Description

	Aquatic Site (1) Hat Creek near mouth of Anderson Creek		Terrestrial Site (2) Lower Hat Creek	
	Elevation	915 m	Elevation	750 m
	Slope	1°	Slope	<10°
	Aspect	-	Aspect	SW
Stream sediment	pH	7.8	pH	8.0
	CEC (meq/100 g)	28	CEC (meq/100 g)	14
	O.M. (%)	13	O.M. (%)	8
	Texture	sandy loam	Texture	loamy sand
	Source: ERT, 1977			

Source: ERT, 1977

SECTION FOUR

SITE CONDITIONS AFFECTING
RECLAMATION AND ENVIRONMENTAL PLANNING

SECTION FOUR

SITE CONDITIONS AFFECTING

RECLAMATION AND ENVIRONMENTAL PLANNING

CONTENTS

SECTION FOUR - CONTENTS (Continued)

LIST OF TABLES

SECTION FOUR - LIST OF TABLES (Continued)

4.1 INTRODUCTION

Studies to characterize site conditions influencing the development of the reclamation and environmental plan are described in Section Four.

Based on the description of the proposed project in Section Two and of the existing environment in Section Three, three major reclamation and environmental protection priorities were identified. Development of a safe pit abandonment scheme, effective revegetation of waste dumps and disturbed land areas, and drainage control during and after mining.

Before developing the plan, it was necessary to define some of the geotechnical and hydrogeological properties of the open pit, characterize the revegetation potential of various materials which will remain on disturbed land surfaces and in stockpiles, and analyze the chemical and physical properties of mine drainage.

The results of studies undertaken to date are summarized in Section Four and provide the basis for the plan discussed in Section Five. Although site-specific studies were used to define the overall approach to reclamation and environmental control, further studies will be required in many areas to provide detailed planning information.

4.2 OPEN PIT

After 35 years of mining, the open pit will comprise the largest single area of land disturbance within the proposed mine area. There is no practical way to further reduce the area of disturbance or eliminate the open pit from the landscape based on current mining plans. The reclamation and environmental protection plan must therefore be based on long term stability of the pit slopes and the degree to which the pit will fill with water.

Creation of a lake within the abandoned open pit was considered (PD-NCB, 1977). It was assumed that as much water as possible from the mine area would be diverted into the pit and fill it to the 853 m level over a 26-year period.

Subsequent examination of a lake concept suggested that the water quality and limnology may be unsatisfactory (Beak, 1978). It was suggested that the lake would be strongly alkaline and that the pH would probably be high due to the absence of organic matter, the flushing action during filling of the pit, and evaporation and concentration of dissolved constituents. The gradient of a tunnel or diversion would restrict fish migration between the pit lake and Hat Creek.

On abandonment, open pit slopes are expected to fail within local areas over the short term and massive failure could be expected over the long term (Golder, 1978). The nature and extent of pit failure cannot be predicted accurately with present data but is felt to be almost certain in slide areas and weak claystones, siltstones, and shales. Over the long term, failure is expected to retreat to the more stable conglomerates. Faults, seepage, and weaker materials located below surficials on the pit perimeter will cause intermittent creeping and slumping. Surface reclamation work such as resloping 45° berm angles to 26° or revegetation would not discourage failure, nor would flooding the pit to form a lake. Landslides and waves resulting from failure in a flooded pit could make the area unsafe and create serious downstream effects.

Other problems in creating a lake within the open pit included those associated with constructing a tunnel or diversion canal to direct pit lake outflow around the low-grade coal stockpile and the main water treatment area. The potential for spontaneous combustion of coal in an abandoned pit would not be resolved by a lake since flooding would take at least 26 years and would still leave six coal berms (12 ha) exposed. As well, draining a pit lake would add to the cost of coal if further reserves were to be mined.

Limited data were available to develop a pit abandonment scheme. Monitoring slope stability over the long term would provide more information in order to optimize a pit abandonment scheme. Analysis of groundwater seepage into the pit and discharge from dewatering wells during mining should provide additional information in order to assess the lake water quality and feasibility.

Present geotechnical and water quality data suggest that closure of access to the pit area by fencing and minimizing water entry into the pit by maintaining ditches and diversions is a preferred pit abandonment scheme. Reclamation and environmental protection of the open pit, described in Section Five, was based on this approach.

4.3 REVEGETATION OF DISTURBED AREAS

Identification, segregation, and differential placement of soil and waste materials according to suitability as plant growth media are basic to planning an effective revegetation program for disturbed areas. The potential of various soil and waste materials as plant growth media can be assessed by analysis of certain chemical and physical properties which influence plant life. These include growth chamber studies and field investigations. Results of preliminary studies designed to assess the suitability as growth media of soil and waste material exposed during mining at Hat Creek are reported. Recommendations for conservation of soil materials are made on the basis of present information.

431 CHEMICAL AND PHYSICAL PROPERTIES OF SOIL AND WASTE

Soil and waste were analyzed for the chemical and physical properties considered important for placement on waste dumps and disturbed lands and for plant growth on final surfaces. Selection was based on the following properties: pH, electrical conductivity; organic matter content; available plant macronutrient and micronutrient content; particle size, texture, cation exchange capacity, exchangeable cations, exchangeable sodium percentage; sodium adsorption ratio, saturation percentage, water-soluble cations and anions, and trace element content. Selection criteria are outlined in Table 4-1.

Waste from selected drill cores were analyzed to determine variation in pH, electrical conductivity, mineralogy, and pore fluid chemistry with lithology and depth. Polydrill 357, an organic polyelectrolyte, was employed as the drilling fluid.

431.1 Soils

Soils are defined as those surficial materials to the depth of maximum plant root penetration. The surface soils (0-30 cm depth) currently support native vegetation and are considered desirable for conservation as surface reclamation material.

Due to a higher organic matter content, surface soils provide improved nutrient content, moisture retention, and microbiological

TABLE 4-1

Criteria for Selection of Surface Reclamation Materials
Hat Creek Project Mining Feasibility Report 1978

Criteria	Range		Rating	Suitability(*) for Use as a Surface Reclamation Material
1. pH[1]	4.5 - 5.0		very strongly acid	
	5.0 - 5.5		strongly acid	*
	5.5 - 6.0		medium acid	*
	6.0 - 6.5		slightly acid	*
	6.5 - 7.5		neutral	*
	7.5 - 8.0		mildly alkaline	*
	8.0 - 8.5		moderately alkaline	*
	8.5 - 9.0		strongly alkaline	
2. Electrical Conductivity (mmhos/cm)[2]	0 - 2		non to very slightly saline	*
	2 - 4		slightly saline	*
	4 - 8		moderately saline	
	8 - 16		strongly saline	
3. Sodium Adsorption Ratio[2]	0 - 10		low sodium hazard (non-sodic)	*
	10 - 18		medium sodium hazard (moderately sodic)	
	18 - 26		high sodium hazard (highly sodic)	
	>26		very high sodium hazard	
4. Exchangeable Cations (meq/100g)[3]	Ca	Mg		
	< 2.0	< 0.4	very low	*
	2.0 - 5.0	0.4 - 1.0	low	*
	5.0 - 10.0	1.0 - 2.0	medium	*
	10.0 - 20.0	2.0 - 4.0	high	
	>20.0	> 4.0	very high	
	K	Na		
	< 0.1	< 0.3	very low	*
	0.1 - 0.2	0.3 - 0.7	low	*
	0.2 - 0.6	0.7 - 2.0	medium	*
	0.6 - 1.0	2.0 - 6.5	high	
	> 1.0	> 6.5	very high	
5. Texture[4]	sand, loamy sand		very coarse	
	sandy loam		moderately coarse	*
	loam, silt loam, silt		medium	*
	silty and sandy clay loam, clay loam		moderately fine	*
	sandy and silty clay, clay		fine	
	heavy clay (60%)		very fine	
6. Drainage[4]	very coarse		rapidly drained	
	moderately coarse - medium		well drained	*
	medium		moderately well drained	*
	medium - moderately fine		imperfectly drained	
	fine - very fine		poorly drained	

Sources:
1. Collins, D.N. and White, W.C., 1972, The Fertilizer Handbook
2. U.S.D.A., 1954, Diagnosis and Improvement of Saline and Alkali Soils, Handbook #60.
3. Schumacher, A. 1977, Montreal Engineering Company, Keephills Overburden Investigations.
4. Agriculture Canada, 1974, The System of Soil Classification for Canada

properties compared to waste. Surface soils contain low levels of plant available nitrogen and phosphorous (Tables 3-4, 4-2a). Removal of vegetative cover from fine textured materials increases the potential for wind erosion and dusting. However, stabilization by weed growth occurs rapidly as a result of remnant seed and plant parts. In shallow soil units removal of the surface 30 cm mixes surface soil with subsoil materials.

Subsoils, defined as soils occurring within the plant root zone but below a depth of 30 cm are also considered as suitable material for surface reclamation (Table 3-4). They are low in organic matter compared to surface soils. Subsoils of glacial or alluvial gravels are less prone to dusting and rill erosion than surface soils or glacial till due to their coarser textures (Table 4-2b). Tills at lower elevations within those soil units designated as potentially saline, may be unsuitable as a reclamation material.

Potential stripping depths are indicated for specific soil units based on depth of soil development, slope, and texture (Figure 3-3). Shallow soils (A and B horizons less than 15 cm), soils on slopes of 14° or greater, those soils developed on hummocky terrain, bentonitic boils, or bentonitic slide debris and potentially saline-alkali soil units were rejected as reclamation material.

431.2 Waste Above Bedrock

These materials include burn zone material (burnt coal residue, baked detrital rocks), construction material (glaciofluvial-alluvial sands and gravels, granodiorite colluvium), hardpan (clay rich glacial till and colluvium), and other (lacustrine sediments, glaciofluvial deposits, slide debris).

Glaciofluvial and glacial till deposits appear to have a plant growth potential similar to those subsoils located in the plant root zone and defined as suitable for reclamation (Tables 3-4, 4-2a, 4-2b). Most of these wastes may be characterized as moderately alkaline, non saline to very slightly saline, and non-sodic (Table 4-3). Organic matter and available nitrogen and phosphorous content are low for optimum plant growth.

TABLE 4-2a

Selected Chemical and Physical Properties of Soil and Waste

Hat Creek Project Mining Feasibility Report 1978

Subsurface Material	E.C.* mmhos/cm	pH 1:1 H_2O	pH 1:2 $CaCl_2$	O.M. %	Macronutrients (pp2M) NO_3-N	P	K	Ca	Mg	Micronutrients (ppm) S	B**	Cu	Zn	Fe	Al	Mn
Soil																
Topsoil A (till)	<1	7.4	7.1	7.0	15	40	939	>10 000	>1000	>30	0.44	0.42	1.57	7.9	183.3	45.0
Topsoil B (outwash)	<1	7.7	7.3	3.9	36	29	493	9795	>1000	13.4	0.60	0.67	2.75	15.6	373.5	103.5
Waste Above Bedrock																
Alluvium B	<1	8.2	7.5	0.9	4	17	195	5344	655	10.6	0.26	0.66	1.22	10.2	76.3	61.0
Glaciofluvial A	<1	8.0	7.6	1.7	5	11	378	8926	>1000	19.4	0.12	0.10	0.05	<5	15.0	17.9
Medicine Creek glacial till	<1	8.2	7.6	1.2	2	10	346	8221	>1000	>30	0.14	0.31	0.15	10.2	10.2	34.1
Colluvium A	6	8.4	8.4	0.6	31	7	216	9927	>1000	>30	1.91	0.31	0.10	35.6	25.5	9.2
Bedrock Waste																
Bentonitic clay	9	7.4	7.5	0.9	5	10	982	9059	>1000	>30	0.25	4.62	4.78	122.1	90.3	58.4
Baked clay	3	7.7	7.6	0.8	2	32	801	9370	>1000	>30	0.38	0.31	0.63	<5	408.5	30.4
Coaly waste	3	4.8	4.7	>30	16	17	591	4432	>1000	>30	4.01	1.97	16.5	730.3	533.1	95.9
Carbonaceous shale	3	4.2	4.2	>30	96	16	235	5965	>1000	>30	2.57	0.43	3.47	32.6	1248	22.8
Gritstone	3	8.0	7.7	0.5	1	22	542	3593	>1000	>30	0.14	13.4	12.3	34.4	77.0	5.6

* E.C. (Electrical conductivity) - is directly related to the concentration of soluble salts in solution. EC of saturation extracts, expressed as millimhos per centimetre (mmhos/cm) at 25°C is used for appraising the effect of salinity on plant growth.

** Hot-water soluble boron (plant available boron content).

*** pp2M - equivalent to pounds per acre - 6 inch depth

<u>Note</u>: A and B indicate origin of samples from bulk sample trenches.

Source: Acres (1978)

TABLE 4-2b

Selected Chemical and Physical Properties of Soil and Waste

Hat Creek Project Mining Feasibility Report 1978

Subsurface Material	Exchangeable Cations Ca (meq/100 g***)	Mg	K	Na	Cl	C.E.C.*	E.S.P.** (%)	Sand	Silt	Clay	Texture
Soil											
Topsoil A (till)	37.5	13.3	1.9	0.3	0.02	40.8	0.7	32	39	29	clay loam
Topsoil B (outwash)	30.4	7.2	0.8	0.3	0.02	29.2	1.0	42	35	23	loam
Waste Above Bedrock											
Alluvium B	12.3	2.7	0.3	0.2	0.01	11.1	1.8	75	19	6	sandy loam
Glaciofluvial A	25.8	6.2	0.5	0.4	0.02	16.4	0.1	32	61	7	silt loam
Medicine Creek glacial till	20.5	5.0	0.4	0.3	0.02	13.0	0.2	49	29	22	loam
Colluvium A	32.8	13.7	0.3	1.9	0.08	9.4	19.9	48	21	31	sandy clay loam
Bedrock Waste											
Bentonitic clay	28.9	14.5	1.8	12.9	-	45.4	28.5	22	34	44	clay
Baked clay	31.6	14.4	1.8	2.2	0.24	33.6	6.5	50	44	6	sandy loam
Coaly waste	24.7	16.1	1.7	1.0	0.02	60.8	1.6	14	30	56	clay
Carbonaceous shale	26.8	13.7	0.5	0.6	0.01	86.4	0.7	-	-	-	-
Gritstone	9.9	9.2	1.2	3.3	0.01	21.1	15.6	43	33	24	loam

* C.E.C. (cation-exchange capacity) - the total quantity of cations which a soil can adsorb by cation exchange

** E.S.P. (Exchangeable-sodium-percentage) - degree of saturation of the soil exchange complex with sodium, calculated by $ESP = \frac{\text{Exchangeable sodium}}{\text{CEC}} \times 100$

*** meq/100 g - milliequivalent of an ion in 100 grams of solids.

Source: Acres (1979)

TABLE 4-3

Salinity of Waste Determined from a Saturation Extract

Hat Creek Project Mining Feasibility Report 1978

Subsurface Material	SAR*	SP** %	EC mmhos/cm	pH	Cations Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Anions $SO4^{-2}$	Cl^{-}	$HCO3^{-}$	Boron*** ppm
					meq/L							
Waste Above Bedrock												
Slide debris	7.1	52.2	4.2	7.5	13.52	15.13	26.74	0.42	42.89	2.13	0.95	< 0.05
Colluvium A (till)	4.3	19.3	9.2	7.8	2.15	94.57	29.91	0.48	187.38	1.37	1.70	< 0.05
Glacial till (Medicine Creek)	0.7	30.3	0.6	7.9	3.87	1.96	1.25	0.15	1.77	0.33	2.49	0.05
Glacial till (1)	0.9	30.2	0.4	8.1	1.31	1.03	1.03	0.06	< 0.42	0.28	ND	0.02
Glaciofluvial sand and gravel	0.4	20.5	0.5	7.5	2.90	1.39	0.52	0.11	3.75	0.32	0.74	0.02
Alluvial gravel B	0.5	21.3	0.4	8.1	2.80	1.03	0.70	0.10	0.42	0.25	ND	0.12
Glacial gravels	0.8	27.2	0.9	7.7	6.19	3.91	1.71	0.13	9.70	0.34	ND	0.02
Bedrock Waste												
Bentonitic clay	9.8	137.7	2.8	7.9	5.79	3.91	21.52	0.81	33.31	1.38	ND	1.75
Baked clay	2.2	31.6	3.4	7.7	25.24	14.64	9.78	0.57	39.97	3.67	0.57	< 0.05
Coaly waste	1.0	40.9	4.2	7.3	25.54	28.78	5.30	1.48	64.54	0.80	0.31	1.70
Carbonaceous shale	0.5	39.3	3.1	5.0	30.24	16.04	2.26	0.19	37.47	0.32	0.09	0.05
Low grade coal	20.1	44.6	2.2	8.7	1.25	1.03	21.52	0.47	12.91	1.07	ND	< 0.05
Waste (1)	11.9	62.4	0.7	8.3	0.56	0.11	6.91	0.14	1.87	1.20	ND	<0.02
Waste (2)	24.9	49.4	1.9	8.7	0.87	0.29	18.91	0.29	12.22	0.72	ND	0.05
Gritstone	6.1	51.6	2.8	8.1	9.18	7.09	17.39	1.14	30.39	0.25	ND	<0.05
Composite Waste	16.2	48.8	2.2	8.5	2.19	1.13	20.87	0.41	12.08	1.72	ND	<0.05

ND - not determined

* S.A.R. (Sodium-Adsorption-Ratio) - an empirical ratio used to express the relative activity of sodium ions in exchange reactions with soil which is in equilibrium with the soil solution. Ionic concentrations are expressed in meq/L solution

$$SAR = \frac{Na^{+}}{\sqrt{(Ca^{++} + Mg^{++})/2}}$$

** S.P. (Saturation percentage) - the moisture percentage of a saturated soil paste expressed on a dry-weight basis. Values greater than 80 indicate high quantities of adsorbed sodium.

*** Water soluble boron determined in an extract from a saturated paste.

meq/L - milliequivalent of an ion in one litre of solution

Note: (1) Composite sample selected by Golder (1978).
(2) Composite sample selected by Acres (1978).

Source: B.C. Research (1978)

431.3 Low-Grade Coal and Bedrock Waste

The low-grade coal (3000 to 4000 Btu), carbonaceous shale, bentonitic clays, baked clay, and coaly waste (clay rich coals less than 3000 Btu) materials exhibit a wide range of chemical characteristics and plant growth potential. Low-grade coal is highly sodic, slightly saline and strongly alkaline (Table 4-3). Carbonaceous shales and coaly waste in contrast are strongly acidic, slightly saline, and have low sodium content (Table 4-2a).

Boron concentrations of carbonaceous shale and coaly waste are elevated to levels which may affect growth of boron-sensitive plant species.

Low-grade coal, coaly waste, and carbonaceous shale have dark colour which may result in high surface soil temperature seedling dieback (refer Section 453).

Bentonitic clay varies from slightly to strongly saline and is moderately sodic. In contrast, baked clay is slightly saline and non-sodic (Table 4-2b).

These materials are generally deficient in nitrogen and phosphorous (Table 4-2a).

Bedrock waste also includes siltstones, sandstones, claystones, gritstones, shales, and other sedimentary materials lying above coal, between seams, and below coal.

These wastes are moderately to highly sodic, very slightly to slightly saline, moderately to strongly alkaline, and low in organic matter, nitrogen, and phosphorous (Tables 4-2a, 4-2b).

The Coldwater Formation (refer Section 311) contains high levels of montmorillonite clays. Other minerals include feldspar, quartz, and siderite. Sodium is the dominant cation in most montmorillonites tested (Golder, 197/) although sufficient quantities of magnesium, calcium, and iron were also present in some samples to ensure that a predominantly divalent regime exists in the double layer crystal-lattice.

Sodium adsorbed on montmorillonite could disperse clay colloids resulting in structural instability, development of impermeable subsoils, and formation of a surface crust. Impermeable subsoils restrict root and water penetration.

A surface crust could impede seedling emergence and restrict water infiltration increasing surface runoff and reducing plant available moisture supplies.

Sodicity is expected to increase with depth in the coal deposit (Tables 3-15, 4-4, 4-5). The effects of mixing and dilution of sodic bedrock waste with non-sodic waste are not known. Under the semi-arid climatic conditions prevailing at the mine site, there is potential for upward migration of sodium from sodic waste into the non-sodic soil cover.

432 GROWTH CHAMBER STUDIES

In addition to analytical studies, growth chamber studies were carried out to identify plant growth limiting factors and compare plant growth potential of low-grade coal and waste materials. Waste samples were selected from drill cores and bulk samples, and composited to obtain representative growth media. Results are summarized in Sections 432.1 and 432.2.

432.1 Barley Germination and Growth on Hat Creek Waste

Conquest barley was grown for 28 days on 11 samples of waste with and without fertilizer (B.C. Research, 1975). Germination and growth of barley varied with waste material as did growth response to the addition of N, P_2O_5, and K_2O (equivalent of 112 kg/ha each) (refer Table 4-6). With the exception of boulder till, germination was satisfactory on all materials. Fertilizer did not affect germination significantly.

Maximum barley growth without fertilizer occurred on glacial till, boulder till, and coal. Fertilizer increased the dry weight per plant on all materials except sandstone and shale-siltstone. Growth response to fertilizer in excess of 100% occurred on boulder till, glaciofluvial, and glacial till materials.

TABLE 4-4

Variation in pH and Conductivity of Waste with Lithology and Depth

Hat Creek Project Mining Feasibility Report 1978

Hole No.	Lithology	Depth from Surface (m)	pH*	EC** (mmhos/cm)
76-1	silty sands and gravels	0-2.4	8.3	<1
		2.4-6.0	8.8	<1
		6.0-9.3	9.0	<1
		9.3-12.5	8.9	<1
76-13	sandy gravel	0-2.4	8.2	3
	silty sands and gravels	2.4-3.6	8.6	<1
	gravelly clay and silt	3.6-10.4	8.7	<1
	silty sands and gravels	10.4-14.0	8.9	<1
	silty sands and gravels	14.0-17.7	8.4	<1
76-127	coarse sandstone	27-30	8.6	1
76-144	carbonaceous shale	43-46	7.7	2
76-124	tuffaceous sandstone	52-55	8.6	2
76-155	shale	88-91	7.8	2
76-134	conglomerate	88-91	9.0	2
76-135	gritstone	247-250	9.1	2

* a pH exceeding 8.5 at saturation could possibly indicate SAR greater than 10, ESP greater than 15 (USDA handbook #60, 1954).

** EC = electrical conductivity

Source: Golder (1977)

TABLE 4-5

Variation in Mineralogy and Pore Fluid Chemistry
with Lithology and Depth
Hat Creek Project Mining Feasibility Report 1978

Hole No.	Lithology	Depth (m)	MINERALS: Montmorillonite	Feldspar	Quartz	Siderite	pH	Carbonate (%)	Glycol Retention (mg/g)	Salinity (g/L)	Na (g/L)	Ca (g/L)	Mg (g/L)	Cl (g/L)	Fe (g/L)
Above Coal Measures															
803	coal	41	A	A	A	-	8.7	1.7	207	1.9	0.71	0.02	0.04	-	-
815	clayey siltstone	171	A	Mi	Mi	Mi	8.6	9.3	136	3.4	1.15	0.00	0.06	-	-
74-28	siltstone-sandstone	146	A	Mi	Mi	-	8.7	2.0	-	6.46	2.07	0.04	0.03	1.93	0.0
74-28	siltstone-sandstone	164	A	Mo	Mi	-	8.6	2.7	190	3.90	1.24	0.00	0.05	0.96	0.0
Below Coal Measures															
806	sandstone	41	A	Mo	Mi	-	-	2.5	-	-	1.96	-	0.78	0.03	-
808	siltstone	84	A	Mi	-	-	9.3	2.7	185	4.6	2.13	0.00	0.49	0.24	0.74
811	siltstone	54	A	Mi	Mi	-	9.3	2.5	243	4.2	2.10	0.00	0.63	-	0.62
818	bentonitic clay + conglomerate	9	A	Mo	Mi	-	9.1	2.4	264	3.7	1.59	0.00	0.14	-	0.12

Note:
1. A = abundant Mo = moderate Mi = minor
2. pH exceeding 8.5 indicates very strong alkalinity
3. Test results of 1% carbonate may reflect complete absence of carbonate in some samples.
4. Pore fluid chemistry results indicate relative composition of cations and chloride.
5. Glycol retention of pure montmorillonite is estimated at 250 mg/g.

Source: Golder (1977)

TABLE 4-6

Barley Germination and Growth on Hat Creek Waste
Hat Creek Project Mining Feasibility Report 1978

Growth Media	Depth from Surface (m)	Not Fertilized	Fertilized	$\bar{x}$
1. Germination (%)				
2 glacial till	1	100	100	100 a
6 glaciofluvial	21	100	100	100 a
3 boulder till	0	90	100	95 a
5 glaciofluvial	3	90	90	90 a
1 glacial till	0	90	80	85 a
4 glaciofluvial	1-2	90	70	80 a
10 sandstone	261-280	70	90	80 b
9 shale-siltstone	242-255	70	70	70 a
11 coal	261-280	80	60	70 b
7 glaciofluvial	27	60	20	40 c
8 boulder till ("Hoodoos")	0	10	40	25 c
		86	75 N.S.	
2. Average Dry Weight per Plant (mg)				
8 boulder till ("Hoodoos")	0	1	25	13 a
5 glaciofluvial	3	4	16	10 b
3 boulder till	0	7	14	10 b
6 glaciofluvial	21	4	15	9 b
2 glacial till	1	8	10	9 b
11 coal	261-280	7	10	8 b
1 glacial till	0	4	12	8 b
7 glaciofluvial	27	3	10	6 b
4 glaciofluvial	1-2	4	8	6 b
10 sandstone	261-280	5	5	5 c
9 shale-siltstone	242-255	5	2	3 c
		5	12 *	

* significant at 5% level   N.S. - not significant

Note: numbers followed by the same letter are not significantly different

Source: B.C. Research (1975)

432.2 Grass, Legume, and Cereal Germination and Growth on Waste, and Low-Grade Coal Treated with Fertilizer and Surface Soil

Barley, white and red clover, bromegrass, timothy, slender wheatgrass, Kentucky bluegrass, and Canada bluegrass were grown for 6 weeks on potential surface materials covered with 1.25 cm of soil and fertilized soil (Acres, 1977). Germination and growth varied with plant species, growth media, soil coverage, and with addition of (equivalent) 55 kg/ha N, P_2O_5, and K_2O (Tables 4-7 to 4-10).

Germination was satisfactory on waste above bedrock and low-grade coal; but unsatisfactory on bedrock waste (Table 4-7). Covering waste with a 1.25 cm layer of soil improved germination significantly.

Maximum growth without soil or fertilizer occurred on waste above bedrock. Covering waste (above bedrock) with unfertilized and fertilized soil increased the average dry weight by 33% and 100%, respectively (Table 4-8).

Growth on waste and low-grade coal varied significantly with both plant species and soil-fertilizer treatment (Table 4-9). Without a surface layer of unfertilized or fertilized soil on waste, growth was unsatisfactory. With unfertilized and fertilized soil layers the average dry weight was increased by 183% and 350%, respectively. Soil amendments to low-grade coal increased the average dry weight by 120% and 180% for the same treatments.

Growth response to soil and fertilizer was attributed to chemical and physical properties of the growth media (Table 4-10). Bedrock waste and low-grade coal contained elevated sodium levels and were slightly saline. Wastes above bedrock was deficient in organic matter, nitrogen, and phosphorous. In contrast to other growth media, surface soil contained improved organic matter and available phosphorous content.

433 FIELD REVEGETATION STUDIES

The combined effect of prevailing climate and site conditions on plant growth potential of mine waste can best be evaluated by field investigations on sites using materials representative of those requiring revegetation. During the fall of 1977 field studies

TABLE 4-7

Grass, Legume, and Cereal Germination
on Waste and Low-Grade Coal
Hat Creek Project Mining Feasibility Report 1978

	Growth Media	Plant Species	Germination (%) Growth Media	Growth Media + Soil	$\bar{x}$
1.	Waste Above Bedrock	White clover v New Zealand	92	90	91*
		Barley v Hector	92	85	88
		Bromegrass v Manchar	87	87	87
		Red clover v Altaswede	80	87	83
		Slender wheatgrass v Revenue	48	73	60
		Timothy v Climax	67	45	56
		Canada bluegrass	48	58	53
			73	63 N.S.	
2.	Bedrock Waste	Barley	40	93	66*
		Brome	10	77	43
		Red clover	5	52	28
		White clover	0	48	24
		Timothy	7	38	22
		Slender wheatgrass	0	45	22
		Canada bluegrass	0	32	16
			9	55*	
3.	Low Grade Coal	Red clover	68	87	77*
		Brome	67	87	77
		Slender wheatgrass	58	92	75
		Barley	70	77	73
		White clover	53	93	73
		Timothy	38	45	41
		Canada bluegrass	10	48	29
			52	76 N.S.	

* - significant at 5% level   N.S. - not significant $\bar{x}$ - average

Source: Acres (1978)

TABLE 4-8

Grass, Legume, and Cereal Growth
on Waste and Low-Grade Coal
Hat Creek Project Mining Feasibility Report 1978

Growth Media	Plant Species	Average Dry Weight per Plant (mg): Growth Media	Growth Media + Soil	Growth Media + Fertilized Soil	$\bar{x}$
1. Waste Above Bedrock	Barley	42	51	88	60*
	Red clover	16	24	25	22
	Brome	10	13	24	16
	Timothy	12	11	21	15
	Slender wheatgrass	10	13	17	13
	White clover	4	8	14	9
	Canada bluegrass	4	4	8	5
		14	18	28*	
2. Bedrock Waste	Barley	96	118	147	120*
	Brome	13	24	47	28
	Red clover	7	20	33	20
	Slender wheatgrass	11	26	20	19
	Timothy	4	14	25	14
	White clover	0	12	23	12
	Canada bluegrass	0	4	12	5
		19	31	44*	
3. Low Grade Coal	Barley	58	63	98	73*
	Brome	7	21	16	15
	Red clover	8	16	22	15
	Slender wheatgrass	8	7	15	10
	White clover	3	10	12	8
	Timothy	2	8	7	6
	Canada bluegrass	0	3	9	4
		12	18	26*	

* significant at 5% level

Source: Acres (1978)

TABLE 4-9

Effect of Soil and Fertilizer on Germination and Growth of Grasses and Legumes on Waste
Hat Creek Project Mining Feasibility Report 1978

		Growth Media	Growth Media + Soil	Growth Media + Fertilized Soil	$\bar{x}$
1. Percent Germination					
Waste above bedrock		70	73	-	72*
Low grade coal		49	75	-	62
Bedrock waste		4	49	-	26
	$\bar{x}$	41	66*		
2. Average Dry Weight per Plant (mg)					
Bedrock Waste		6	17	27	17*
Waste above bedrock		9	12	18	13
Low grade coal		5	11	14	10
	$\bar{x}$	7	13	20*	

* significant at 5% level

Note: 1) Interaction between species and topsoil and fertilizer treatments are not significant for waste rock, but are significant for waste above bedrock and coal.

2) Interaction among barley, growth media, and treatments are not significant.

Source: Acres (1978)

TABLE 4-10

pH, Conductivity, and Available Nutrient Content of Growth Media

Hat Creek Project Mining Feasibility Report 1978

Growth Media	Conductivity mmhos/cm	pH	Organic Matter %	Available Nutrients (pp2M) NO_3-N	P	K	Ca	Mg	Hot-water soluble B	Extractable Na*
									ppm	
Soil	0.64	8.0	26	<1	50	633	8436	> 1000	0.68	170
Waste Above Bedrock	0.44	8.5	0.4	6	8	324	9679	723	0.20	72
Low grade coal	3.00	8.1	11.0	3	17	728	3918	> 1000	0.48	-
Bedrock Waste	3.45	8.7	1.6	<1	17	615	3817	887	< 0.20	2704

* extracted by neutral 1.0 N ammonium acetate

Source: Acres (1978)

were initiated at Hat Creek on subsurface materials excavated during the bulk coal sample program. Stockpiles, dumps, and slopes created or constructed from excavated materials provided the opportunity to assess revegetation potential under conditions simulating waste disposal alternatives. Experimental sites representative of the Houth Meadows and Medicine Creek waste dump embankments were also constructed (Table 4-11).

Field plots were fertilized and seeded in the fall of 1977 and vegetation establishment was observed in April 1978. Individual field studies and results to date are summarized.

433.1 Embankments

Experimental embankments were constructed near the proposed sites of the Houth Meadows and Medicine Creek waste dumps (Table 4-11). Surface materials, elevations, and slope aspects were similar to those proposed for embankment construction. The Medicine Creek site was constructed with glacial till. The Houth Meadows site was constructed with glaciofluvial material with one-half of the embankment surface covered with 5 cm of surface soil. Embankment slopes were constructed to simulate 16 m lifts at slope angles of 22, 26, and 30°. Resultant slope lengths were 41, 35, 30 m. Twenty-two and 26° slopes simulate designed embankments. A 30° slope angle, if demonstrated to revegetate satisfactorily, could improve economics of waste disposal by reducing amount of embankment construction material required.

A grass-legume mixture composed of crested wheatgrass (39% by seed), Drylander alfalfa (20%), Canada bluegrass (2%) and fall rye (39%) was hydroseeded at 57 kg/ha on the constructed slopes on September 19-21, 1977.

Fertilizer equivalent to 33, 134, and 33-66 kg/ha of N, P_2O_5, and K_2O respectively, was applied as ammonium phosphate, ammonium phosphate-sulphate, and muriate of potash in solution with seed, mulch, and binder. Silvafibre mulch was applied at 2240 kg/ha with 13 kg/ha of Dowell J197 binder.

No rill erosion was evident on embankment slopes during an inspection (April 26, 1978) following spring snowmelt. Seedling emergence, vegetative cover, and species composition appeared similar on slopes of varying angle and length. Species composition con-

TABLE 4-11

Site Characteristics of Embankment
and Waste Revegetation Plots
Hat Creek Project Mining Feasibility Report 1978

1. Houth Meadows Embankments

Elevation:	914 m ASL
Aspect:	SE
Growth Media:	recent gravels end-dumped by truck and covering slopes to 1 m depth
Plot Size:	main plot: 16 m x 40 m
	subplots: 8 m x 40 m

2. Medicine Creek Embankments

Elevation:	1006 m ASL
Aspect:	W
Growth Media:	glacial till stripped of surface soil, ripped to 0.7 m depth, and compacted by bulldozer
Plot Size:	16 m x 40 m

3. Aleece Lake Wastes

Elevation:	1067 m ASL
Aspect:	flat
Growth Media:	7 materials excavated from bulk sample trenches, spread to 1 m depth and rototilled to 15 cm depth (sandstone, coaly waste, carbonaceous shale, baked clay, slide debris, bentonitic clay, glacial gravels)
Plot Size:	main plot: 16 m x 16 m
	subplot: 8 m x 16 m

sisted of fall rye (>50% of total cover), crested wheatgrass (26-50%), Drylander alfalfa (1-5%), and Canada bluegrass (1-5%).

Covering glaciofluvial gravels on the Houth Meadows embankment with 5 cm of surface soil introduced weeds which increased vegetative cover slightly but had no apparent effect on density of seeded species.

433.2 Waste

Revegetation of seven potential waste materials excavated during the bulk coal sample program was initiated during the fall 1977. Wastes included gritstone, coal waste, carbonaceous shale, baked clay, slide debris-colluvium, bentonitic clay, and glacial gravels. Prior to seeding, a 5 cm layer of soil was placed over one-half the surface of each waste material. Three grass-legume mixtures were seeded on each type of waste (Table 4-12). Fertilizer applications were varied according to B.C. Department of Agriculture soil test recommendations. Fertilizer and seed were incorporated by raking following broadcast application on roto-tilled waste.

On inspection on April 26, 1978, seedling emergence was observed to vary with growth medium and seed mixture. Emergence was improved on glaciofluvial overburden relative to waste. Covering waste with surface soil appeared to improve emergence. Seedling density of mixture one (Table 4-12) was greater than density of other mixtures. Some legume seedlings growing in waste exhibited leaf tip chlorosis. Plant tissue analysis would be required to evaluate the cause of chlorosis.

433.3 Drill Sites

Exploration drill sites must be revegetated as soon as possible following completion of drilling. Prior to 1977, drill sites were revegetated by seeding a mixture of crested wheatgrass (45%), Manchar bromegrass (25%), Russian wildrye (10%), Ladak alfalfa (10%), and sweet clover (10%). Drill sites seeded in fall 1977, received a mixture of crested wheatgrass (41%), Canada bluegrass (29%), Drylander alfalfa (26%), and fall rye (4%). All sites were fertilized with 31, 134, and 67 kg/ha of N, P_2O_5, and K_2O, respectively. Nutrient sources included ammonium phosphate and muriate of potash. Drill sites were harrowed before and after broadcast application of seed and fertilizer.

TABLE 4-12

Seed Mixtures and Fertilizer Programs Used
for Revegetation of Hat Creek Bedrock Waste
Hat Creek Project Mining Feasibility Report 1978

Seed Mixtures

Mixture	Plant Species	Seeding Rate kg/ha
1	Crested wheatgrass v Nordan	22.4
	Canada bluegrass	1.0
	Alfalfa v Drylander	11.2
	Fall rye	22.4
		57
2	Russian wildrye v Sawki	22.4
	Slender wheatgrass v Revenue	11.2
	Sainfoin v Melrose	140.0
	Sweet clover	6.7
		180.5
3	Smooth bromegrass v Manchar	14.6
	Streambank wheatgrass v Sodar	22.4
	Canada bluegrass v Reubens	0.5
	Double cut red clover	10.0
		47.5

Fertilizer Programs

Nutrient Rates

Growth Media	N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)
sandstone	33	88	0
coal waste	33	112	0
carbonaceous shale	33	112	56
baked clay	33	66	0
colluvium	33	134	56
bentonitic clay	33	134	0
glacial gravels	33	124	44

Nutrient Sources

N	46-0-0	urea
P_2O_5	0-45-0	treble superphosphate
K_2O	0-0-60	muriate of potash

Source: Acres (1978)

Several drill sites were inspected on April 26, 1978. Vegetation establishment appeared to vary with location, parent material, area, and depth of surface soil removal. At several sites native species invasion was progressing favourably.

433.4 Site Preparation

Disturbed land below embankment plots as well as waste dumps and stockpiles in the vicinity of the bulk sample trenches were revegetated using two methods of seed and fertilizer application. Steeper areas were hydroseeded using silvafibre mulch applied at 1344 kg/ha to retain seed on the slope surface. Flatter areas amenable to use of agricultural equipment were harrowed using a chain-harrow to incorporate fertilizer and seed broadcast using a cyclone spreader.

A grass-legume mixture composed of crested wheatgrass (41% by seed), Canada bluegrass (39%), Drylander alfalfa (26%), and fall rye (4%) was seeded at 57 kg/ha on glacial and alluvial gravels, glacial till, sandstone, baked clay, carbonaceous shale, and coal waste. Fertilizer programs varied according to growth media and soil test recommendations (Table 4-13).

Based on a qualitative examination, seedling emergence and density varied among sites with growth media, and seeding method. Harrowed level surfaces produced greater seedling density than hydroseeded level surfaces. Mulch did not appear to improve emergence. Seedlings established in harrow furrows. Furrows remained intact on coaly waste, carbonaceous shale, and gravels. In contrast furrows in sodic gritstone broke down and a surface crust developed. Seedling emergence appeared satisfactory on gravels, glacial till, and coaly waste. Seedling density on baked clay, carbonaceous shale, and gritstone appeared unsatisfactory.

434 RECOMMENDATIONS FOR RECLAMATION MATERIAL SELECTION

Based on results of studies reported in Section 4.3 and applying selection criteria listed in Table 4-1; soil, bedrock waste, and wastes above bedrock tested to date were arranged in order of preference for use as reclamation material (Table 4-14). Accordingly, the following recommendations were made with respect to selection of suitable reclamation material:

TABLE 4-13

Site Preparation Methods and Fertilizer Programs Used in Areas
Disturbed During the Bulk Sample Program
Hat Creek Project Mining Feasibility Report 1978

Growth Media	Site	Seeding Method	Fertilizer Program (kg/ha) N	P_2O_5	K_2O	Area ha
1. Glaciofluvial gravels	Houth Meadows (below plots)	hydroseeding	33	134	0	0.04
		harrowing	33	112	79	
2. Recent alluvial gravels	Trench B (gravel dump)	hydroseeding	33	134	66	0.05
		harrowing	33	112	79	
3. Glacial till	Medicine Creek (adjacent area)	hydroseeding	33	134	33	
4. Gritstone (950 m)	Trench A (waste dump)	hydroseeding	27	104	0	0.15
		harrowing	33	90	0	
5. Baked clay (957 m)	Trench A (level waste dump)	hydroseeding	27	104	0	
6. Carbonaceous shale (963 m)	Trench A (level waste dump)	hydroseeding	33	134	66	0.29
		harrowing	33	112	57	
7. Coal waste	Trench A (stockpile)	hydroseeding	33	134	0	0.27
		harrowing	33	112	0	0.40

Source: Acres (1978)

TABLE 4-14

Suitability of Soil, and Waste for Reclamation
Hat Creek Project Mining Feasibility Report 1978

Order of Preference	Reclamation Material	Plant Growth Limiting Factors	Susceptibility to Erosion	Susceptibility to Dusting	Susceptibility to Leaching
1	Surface soils	low levels of nitrogen and phosphorous	moderate	high	moderate
2	Glacial till	low levels organic matter, N, and P; depressions may be saline	moderate	moderate	low
3	Glaciofluvial gravels	low levels of O.M., N, P, and possibly K; soil moisture deficiency	low	low	high
4	Alluvial gravels	low levels of O.M., N, P, and possibly K; soil moisture deficiency	low	low	high
5	Baked clay	slightly saline; coarse texture; low O.M., N, and P content	low	low	high
6	Slide debris	moderately saline; elevated B levels; strongly saline; low O.M., N, and P	moderate	moderate	low
7	Bentonitic clay	strongly saline; fine texture; low O.M., N, and P content	high	low	low
8	Coaly waste	low pH, slightly saline; elevated B; low O.M., N, and P content; dark colour resulting in increased surface temperature	high	low	low
9	Carbonaceous shale	low pH, slightly saline; elevated B; low O.M., N, and P content; dark colour resulting in increased surface temperature	high	high	low
10	Low-grade coal	highly sodic; low O.M., N, and P content	moderate	moderate	low
11	Gritstone	slightly sodic; slightly saline; low O.M., N, and P content	moderate	moderate	low
12	Waste rock	highly sodic; low O.M., N, and P content	moderate	moderate	low

Note: Materials 1-4 - suitable.
Materials 8 and 9 require addition of lime for use as surface reclamation materials.
Materials 5, 6, 7, 10, 11, and 12 require addition of chemical and organic amendments and leaching for use as surface reclamation materials.
O.M. - refers to organic matter

Note: Materials were rated for susceptibility to erosion, dusting, and leaching based on texture.
Susceptibility to rill erosion and dusting increases with finer texture.
Susceptibility to leaching increases with coarser texture.
A surface crust tends to form with increased sodium content which reduces dusting and leaching; but increases runoff.

Sources: Acres (1978) and B.C. Research (1975)

(1) Surface soils are the preferred reclamation material and should be used to cover final waste dumps and disturbed lands.

(2) Bedrock waste and slide debris are designated unsuitable for reclamation and should be buried.

(3) Non-sodic glacial till, glaciofluvial and alluvial gravels are acceptable surface reclamation materials and are considered suitable for covering sodic waste. Glacial till is preferred to gravels because of its improved moisture holding capacity.

(4) Non-sodic wastes above bedrock with satisfactory water retention properties should be placed as a buffer material or layer between sodic waste and surface soils.

(5) Low-grade coal and bedrock waste are considered unsuitable and would probably require incorporation of chemical amendments (gypsum, $CaCl_2$) and leaching if used as surface reclamation material.

(6) Coaly waste and carbonaceous shale are strongly acid and would probably require incorporation of lime if used as surface reclamation material.

4.4 DRAINAGE QUALITY

Precipitation that infiltrates or runs off waste dumps and stockpiles could contain trace elements and salts possibly resulting in poor water quality discharge to ground or surface water. In order to determine what form of treatment, if any, should be applied to the various waste streams, studies were undertaken to characterize seepage, leachate, and runoff.

441 LEACHATE

Estimates of leachate quality were obtained from laboratory studies and analyses of field samples (Acres, 1978). Total water-soluble elements were extracted from crushed, wastes, low-grade coal, and coal according to the laboratory procedures of Shannon and Fine (1974) (Table 4-15). Sodium, calcium, magnesium, sulphur, and chloride were the primary water-extractable salts from coal and mine waste.

Leachate water quality was also calculated from a rate of release laboratory test (Table 4-16). Results are presented for the lowest pore volume displacement (i.e., first leach) which, if representative of site conditions, could simulate the "worst case" condition of a prolonged rainstorm. If leachate from the low-grade coal, coal stockpiles, and from waste dumps is similar to the rate of release test results, then the characteristics presented in Table 4-17 would be elevated above present PCB level A objectives and require treatment (Beak, 1978; Acres, 1977).

In April 1978, leachate was also collected from the base of seam waste and low-grade coal stockpiles constructed at Hat Creek in summer 1977. Leachate was collected on a plastic sheet underlying stockpiles which drained by plastic pipe to covered plastic buckets. Field samples collected from the base of a small low-grade coal and a seam waste (coaly waste) stockpile had low pH and elevated dissolved solids and sulphate concentrations compared to present PCB level A objectives (Table 4-16).

442 RUNOFF

Studies were initiated to determine sedimentation behaviour of dominant surface materials, flocculants or coagulants required, and quality of treated waste water (B.C. Research, 1978). Particle

TABLE 4-15

Total Extractable Salts Test Result*
for Waste, Waste Rock, Low-Grade Coal, and Coal
Hat Creek Project Mining Feasibility Report 1978

Parameter		Waste BAH 76-1	Waste BAH 76-13	Waste Rock	Low Grade Coal Waste	B Zone Coal
pH		7.6	7.65	7.85	7.85	7.0
Suspended Solids		72	412	7520	1650	640
Total Filterable Residue		630	1008	2100	5320	2200
Alkalinity as $CaCO_3$		920	1120	1320	3120	1750
Chloride	-Cl	28	16	270	380	200
Fluoride	-F	<0.4	<0.4	2.4	1.5	1.4
Nitrate-Nitrogen	-N	15	18	19	19	21
Nitrite-Nitrogen	-N	<0.4	<0.4	6	9	<0.4
Total Kjeldahl Nitrogen	-N	6	5	2	12	13
Biochemical Oxygen Demand (5-day)		370	340	400	520	1250
Chemical Oxygen Demand		440	440	660	950	1840
Ortho-Phosphate-Phosphorous	-P	2.7	3.5	9.2	5.0	3.0
Sulphur	-S	80	111	250	224	160
Aluminum	-Al	26	13	24	25	20
Arsenic	-As	1.3	0.5	1.0	0.8	0.4
Boron	-B	1.0	1.0	2.0	1.0	1.0
Cadmium	-Cd	<0.08	<0.08	<0.08	<0.08	<0.08
Càlcium, Hard as $CaCO_3$		290	400	480	600	90
Chromium	-Cr	1.0	1.5	<1	<1	<1
Copper	-Cu	2.2	3.4	4.0	6.0	5.0
Iron	-Fe	14	31	76	76	30
Lead	-Pb	<3	<3	<3	<3	<3
Lithium	-Li	<0.3	<0.3	<0.3	0.6	0.3
Magnesium, Hard as $CaCO_3$		358	380	440	540	86
Mercury	-Hg	0.010	0.010	0.006	0.006	0.006
Selenium	-Se	0.2	0.2	0.2	0.9	0.6
Sodium	-Na	178	225	542	1280	975
Strontium	-Sr	<4	<4	<4	<4	<4
Vanadium	-V	<0.2	<0.2	0.2	0.3	0.2
Zinc	-Zn	6.8	10.8	8.8	15.0	7.2

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

Source: Acres (1978) based on laboratory method of Shannon and Fine (1974)

TABLE 4-16

Leachate Characteristics from Laboratory and Field Tests
Hat Creek Project Mining Feasibility Report 1978

Parameters (mg/L)	LABORATORY SAMPLES[1] Waste 76-1	Waste 76-13	Waste Rock	Low-Grade Coal	Coal B	FIELD SAMPLES[2] Bedrock Waste	Low Grade Coal
pH	7.6	7.9	8.3	7.8	7.2	5.6	4.6
Filterable Residue	180	160	2078	1520	2735	8190	5400
BOD_5 **	105	63	395	148	-	-	-
Alkalinity	55	77	180	393	540	56	< 0.5
Chloride	2	1.5	53	40	52	15	0.88
Fluoride	0.05	0.07	0.06	0.08	0.1	-	-
Nitrate-Nitrogen	2.5	6.0	3.7	2.4	5.3	-	-
Ortho-Phosphate-Phosphorous	0.15	0.2	0.4	0.15	0.2	-	-
Sulphur	0.7	6.7	10.0	10.0	21.3	-	-
Arsenic	0.03	0.03	0.1	0.06	0.02	<0.005	<0.005
Boron	0.02	0.02	0.05	0.12	0.3	0.2	0.7
Cadmium	<0.002	< 0.002	-	0.002	< 0.002	-	-
Calcium, Hard as $CaCO_3$	13.2	25	76.2	37.5	24.2	760*	430*
Chromium	0.05	0.05	0.2	0.2	0.075	<0.01	< 0.01
Copper	0.35	1.4	2.1	2.45	3.5	0.034	0.007
Iron	0.3	1.05	1.85	5.7	0.9	0.30	0.01
Lead	<0.02	< 0.02	< 0.02	0.02	< 0.02	-	-
Magnesium, Hard as $CaCO_3$	14.6	29.2	43.7	34.02	18.3	580*	420*
Mercury	0.002	0.002	0.003	0.004	0.005	< 0.00025	<0.00025
Sodium	15.0	40.0	70	267	286	240	150
Vanadium	<0.01	< 0.01	< 0.01	0.01	< 0.01	0.042	0.006
Zinc	0.031	0.031	0.275	0.125	0.125	0.057	0.18

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

Sources: (1) Calculated by Beak (1978) from Acres (1977) Leachate Data (2) Beak (1978)

* Total concentration.

Note: Additional analyses of field samples included:

	Bedrock Waste	Low-Grade Coal
Conductivity (umhos/cm)	7100	4630
Hardness	4290	2800
Nonfilterable residue	22	3
Sulfate	3800	3800
Total Aluminum	2.9	0.70
Total Lithium	0.17	0.36
Total Potassium	30	36
Total Selenium	<0.003	<0.003
Total Strontium	1.8	1.2

TABLE 4-17

Leachate Characteristics Which Could Exceed
Present PCB Level A Objectives
Based on Laboratory Rate of Release Tests

Material	Arsenic	Chromium	Copper	Iron	BOD	Mercury	Dissolved Solids	Suspended Solids
waste	-	-	+	+	-	-	+	+
waste rock	+	+	+	+	-	-	+	+
low grade coal	+	+	+	+	+	-	+	+
coal	-	+	+	+	+	+	+	+

+ exceeds level A objectives

- meets level A objectives

size analyses, settling column tests of treated (coagulant added) and untreated solids, and water quality analysis of supernatant from columns treated with coagulant were carried out using glaciofluvial and glacial till slide debris, two waste rock samples, low-grade coal, and a composite sample. Sample composition and location are outlined on Table 4-18.

Each material was suspended in solution at an initial concentration exceeding 10 000 mg/L. After 24 hours all materials (with exception of glacial gravels and slide debris) had suspended solids exceeding 1000 mg/L.

Based on results presented in Table 4-19, chemical treatment beyond 24 hour retention was considered essential.

Materials were evaluated qualitatively with commercial anionic, cationic, and nonionic polyacrylamide flocculants at dosages up to 50 mg/L. Settling proved unsatisfactory. Alum (aluminum sulphate) provided satisfactory flocculation at high dosages in columns with very high initial suspended solids levels typical of extreme circumstances such as flooding or erosion induced slumping. Column settling test results and alum dosage requirements are summarized in Tables 4-20, 4-21, and 4-22.

The high settling rates and clean settling interfaces indicate that alum treatment, followed by quiescent settling in ponds of adequate size could clarify drainage water containing extremely high suspended solids levels to meet present PCB level A objectives of 50 mg/L.

Salinity of supernatant from column settling tests was analyzed to determine if treated wastewater would be suitable for irrigation (Table 4-23). If supernatant is representative of treated wastewater, all materials would produce a medium-saline, low-sodium water suitable for irrigation assuming satisfactory trace element levels (based on criteria provided by CBRC, 1978).

The pH of supernatant from waste and low-grade coal was low compared to present PCB level A objectives. Sulphate levels for all materials were elevated above present PCB level A objectives; however, this may be due in part to the fact that initial suspended solids levels and corresponding alum dosages employed in the study were very high.

TABLE 4-18

Composition of Sodic Bedrock Waste Samples
Hat Creek Project Mining Feasibility Report 1978

Material	Drill Hole No.	Lithology	Depth (m)	Composition (% by weight)
Low-grade coal(1)	DDH 76-134	coaly shale	191-197	34
	DDH 76-128	coal with siderite and calcite	130-131	17
SAR = 20	DDH 76-125	coal	78-79	9
	DDH 76-122	carbonaceous shale	107-109	22
	DDH 76-120	shale; coaly shale	149-155	13
			17 m	100
Waste (1)	DDH 76-127	sandstone	27-30	14
SAR = 25	DDH 76-124	sandstone, gritstone	52-55	18
	DDH 76-153	gritstone, shale	247-250	24
	DDH 76-134	conglomerate	88-91	22
	DDH 76-155	shale	88-91	13
	DDH 76-144	boulder clay, shale	43-46	9
				100
Waste(2)	DDH 76-841	sandstone	66-68	50
SAR = 12	DDH 76-817	sandstone	149-158	50
				100
Gritstone(1)	Bulk Sample Program			100
SAR = 6	Trench A			
ESP = 16				
Composite waste		glaciofluvial sand/gravel (quarry east of Trench B)		20
SAR = 16		glacial till (road cut from Lehman Ranch to sawmill)		20
		slide debris (road cut beside DDH 76-810)		20
		waste(2)		20
		low-grade coal(1)		20
				100

Note: (1) Composite sample selected by Acres (1978).

(2) Composite sample selected by Golder Associates

TABLE 4-19

Column Settling Tests in 2-1 Graduate Cylinders without Flocculant
Hat Creek Project Mining Feasibility Report 1978

Material	Time (hr)	Suspended Solids (mg/L) 0 cm	11 cm	28.5 cm	Particle Size (%) Clay + Silt (sample)*	Sand	pH
		-------depth	------------				
Glaciofluvial sand/gravel	0.25	188	404	428	2	98	7.4
	4.5	120	132	132			
	24	76	56	60			
Glacial till	0.25	2600	5643	5893	19	81	8.1
	4.5	510	1980	2670			
	24	45	1040	1360			
Slide debris	0.25	5798	10 049	11 218	36	64	8.2
	4.5	560	2760	4130			
	24	60	65	70			
Waste (1)	0.25	10 000	15 000	16 640	2	98	8.5
	4.5	840	9480	10 160			
	24	133	5800	7020			
Waste (2)	0.25	12 500	17 080	19 160	6	94	8.3
	4.5	2410	9400	10 960			
	24	120	5400	6920			
Low-grade coal	0.25	13 280	17 080	19 060	n.a.	n.a.	6.9
	4.5	1680	9860	11 789			
	24	90	6040	8100			
Composite	0.25	7700	10 820	12 260	n.a.	n.a.	8.1
	4.5	2060	5980	7040			
	24	53	3200	4340			

Note: 50 g of original solids (coarse plus fine) per litre distilled water

* B.C. Research (1978)
Golder (1978)

(1) Golder

(2) Acres

TABLE 4-20

Column Settling Tests in 15 cm x 180 cm Cylinders
with Aluminum Sulphate
Hat Creek Project Mining Feasibility Report 1978

Material	Time (hr)	Suspended Solids (mg/L)	Turbidity NTU	Interface Depth (cm)	Sample Depth (cm)
Glacial till	0.3	44	21.0	61	48
	0.6	19	7.5	81	48
Slide debris	0.3	144	48.0	43	20
	0.6	68	29.0	67	36
	1.6	42	21.0	78	65
Waste (1)	0.9	105	32.0	8	6
	2.5	66	23.0	22	20
	5.3	5	3.2	48	37
	6.7	4	2.2	53	52
Waste (2)	0.7	28	11.0	7	5
	4.1	2	2.5	38	20
	4.2	21	7.5	38	36
	21.4	25	8.2	69	52
Low grade coal	0.6	11	7.2	8	5
	1.9	21	8.8	24	20
	4.7	8	5.2	51	36
	6.2	2	2.4	59	51
Composite	0.3	20	16.0	9	7
	0.9	9	6.5	28	22
	1.8	7	4.5	47	37
	3.7	3	4.2	67	53
	5.1	5	2.8	70	66

(1) Golder
(2) Acres

Note: Alum dosages are described in Table 4-21.

Source: B.C. Research (1978)

TABLE 4-21

Column Settling Tests in 15 cm x 180 cm Cylinders
with Aluminum Sulphate
Hat Creek Project Mining Feasibility Report 1978

Material	Alum Dosage mg/L	Free Interface Settling Rate cm/hr	Time to Achieve Suspended Solids < 50 mg/L at 50 cm depth hours	SO_4 mg/L
Glacial till	100	253	< 1	74
Slide debris	120	143	< 2	138
Composite waste	206	30	4	106
Low grade coal	125	12	6	171
Waste (1)	206	9	6	152
Waste (2)	206	9	21	178

(1) Golder
(2) Acres

Source: B.C. Research (1978)

TABLE 4-22

Alum Dosage Requirements for Hat Creek Run-off
at High Initial Suspended Solids Concentrations
(>10 000 mg/L)
Hat Creek Project Mining Feasibility Report 1978

Material	$Al_2(SO_4)3$ (mg/L)
Glaciofluvial sand/gravel	10
Glacial till	60
Slide debris	80
Composite waste	100
Low grade coal	160
Waste (1)	160
Waste (2)	160

(1) Golder
(2) Acres

Source: B.C. Research (1978)

TABLE 4-23

Salinity Analyses of Supernatant from Column Settling Tests
with Aluminum Sulphate
Hat Creek Project Mining Feasibility Report 1978

Material	Sodium Adsorption Ratio (SAR)	Specific Conductance (umhos/cm)	pH	Cations (meq/L) Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Anions (meq /L) SO_4^{-2}	Cl^{-1}	HCO_3^{-}	Boron ppm
Slide debris	1.2	435	7.3	2.09	1.18	1.50	0.06	2.87	0.06	1.26	< 0.02
Glacial till (1)	< 0.1	255	7.3	2.17	0.58	0.06	0.01	1.54	0.01	0.90	< 0.02
Low grade coal	2.3	385	4.9	0.80	0.55	1.91	0.13	3.56	0.03	0.04	< 0.02
Waste (1)	4.5	370	4.8	0.45	0.16	2.48	0.12	3.16	0.07	0.02	< 0.02
Waste (2)	3.3	430	6.2	1.02	0.25	2.57	0.12	3.71	0.02	0.43	< 0.02
Composite waste	1.5	345	7.2	1.07	0.50	1.32	0.08	2.21	0.02	1.07	< 0.02

Note: Supernatant is classified as medium-salinity and low-sodium water. Medium-salinity water can be used for irrigation if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown in most cases without special practices for salinity control. Low-sodium water can be used for irrigation on almost all soils with little chance of development of harmful levels of exchangeable sodium.

(1) Golder
(2) Acres

Source: B.C. Research (1978)

Tests were performed on highly contaminated wastewater to model a worst case and may not be representative of the mixing and dilution which may occur in lagoons.

443 RECOMMENDATIONS

Recommendations for drainage control are based on studies to date with limited number of samples. This may not be representative of the mixture of materials on the surfaces of waste dumps, stockpiles, and disturbed lands. In addition, results from laboratory tests do not represent the effect of evaporation, mixing, and dilution which will occur when the wastewater is collected in lagoons.

The following recommendations were used for reclamation and environmental protection planning:

(1) Leachate and runoff should be segregated from clean water and where possible disposed of by recycling or evaporation.

(2) Runoff may require treatment with coagulants before discharge to reduce suspended solids levels in order to meet regulatory requirements.

(3) The need for water treatment beyond sedimentation lagoons can best be determined by monitoring and on-site experience. Leachate studies to date show discrepancies in analytical results between laboratory and field samples.

4.5 OTHER CONSIDERATIONS

Dust, noise, and spontaneous combustion of carbonaceous materials were monitored during the 1977 bulk sampling program in order to provide data for planning and base-line monitoring.

451 DUST

Two high volume samplers monitored ambient air suspended particulate concentrations in the mine area during the 1977 bulk sample program (Acres, 1978) (Table 4-24).

Dust problems developed in and near Trench A during dry windy weather but were confined mainly to the trench. Carbonaceous shale and surface soil were particularly susceptible to dusting. Dust was controlled on access roads and trenches by water truck. Dust from dormant coal piles did not appear to be a problem. In all cases suspended particulate concentrations were less than either the 24-hour or annual, present PCB level A objectives of 150 and 60 $\mu g/m^3$, respectively (geometric mean value).

452 NOISE

Noise levels resulting from operation of heavy equipment and blasting in Trench A were monitored during the 1977 bulk sample program (Acres, 1978). Three one-half hour long continuous samples (of A-weighted noise level) were recorded. Noise levels were averaged within half hour periods to provide the "equivalent energy level" for each period (Table 4-25).

Noise levels varied with intervening terrain and wind velocity. A site located in view of the trench had higher noise levels than sites which were shielded from the trench by high points of land.

Trench excavation did not significantly affect background noise levels. At the Lehmman Ranch, about 1.2 km from Trench A, background noise was estimated to be 40-44 decibals (dBA). The excavation noise could be heard intermittently above background noise levels. A peak noise level of 96 dBA resulted at Site 3 due to blasting (Table 4-25). At the Hat Creek junction the excavation activity was not audible.

TABLE 4-24

Air Suspended Particulate Concentrations During
Coal Extraction and Transportation from Bulk Sample Trenches
Hat Creek Project Mining Feasibility Report 1978

Date		ACTIVITY		SUSPENDED PARTICULATE MATTER mg/m^3	
		Excavation	Transportation	Hat Creek Junction	B.C. Hydro Camp
May	18	Trench A	-	9	*
	22	"	-	21	13
	25	"	-	11	11
June	8	Trench A + B	-	*	35
	9	"	-	*	78
	12	"	-	57	22
	15	"	+	41	24
	18	"	-	58	19
	21	"	-	*	34
	27	"	-	*	36
	30	"	-	*	26
July	3	"	-	*	8
	9	"	-	13	13
	12	Trench A	-	9	*
	15	"	+	19	*
	18	Trench A + B	+	62	*
	21	Trench B	+	131	*
	24	"	+	36	*
	27	-	+	61	*
	30	-	-	17	*
August	2	-	+	28	*
	5	-	+	43	*
	8	-	+	36	*
	11	-	-	49	*
	14	-	-	18	*
	17	-	-	77	*
	29	-	-	8	*
September	4	-	-	9	*
					*
				range 8-131	1-78

* Test not valid.
Source: Acres (1977)

TABLE 4-25

Base-Line Noise Levels in the Proposed Mine Area With and Without Trench A Excavation Hat Creek Project Mine Feasibility Report 1978

Measurement Particulars	Site 1 (935 m from trench)	Site 2 (762 m from trench)	Site 3 (823 m from trench)
1. Measurements			
Leq (1/2 hour) with excavation	33	39	49
Leq (day) approximate base-line	32	32	30
difference	1	7	19
2. Heavy Equipment (# units operating)			
Cat 621 Scrapers	3	3	3
DJB Trucks (Cat D250)	0	1	2
Cat 966C Loader	0	1	1
Cat D8K Dozer	1	1	1
Cat D7 Dozer	2	1	1
Wabco 660B Grader	1	1	1
Pneumatic Rock Drill	1	0	1
3. Wind Conditions (41 m aboveground)			
Speed (ft/sec)	2.5	4.1	12.7
Direction Rel. to True North	50.3°	27.0°	170.0°
4. Weather Conditions			
Temperature (°C)	5.8	8.8	10.1
Relative Humidity (%)	54	51	61
5. Location	125 m east of DDH 76-138	DDH 76-144	DDH 76-168
6. Day	May 25	May 25	May 26
7. Time	08:15-08:45	10:10-10:45	07:40-08:10

Source: Acres (1977)
Note: Leq - equivalent noise level (decibals)

453 SPONTANEOUS COMBUSTION

Test piles of loose and compacted coal were constructed and monitored with thermometers and thermocouples to determine temperature change with time and potential for fire occurrence (Fawcett, 1977).

Fires began in loose, crushed coal and uncrushed low-grade coal piles after 14-28 days and 50-70 days of exposure, respectively. Fires generally occurred near the base of piles in areas of loose coal usually after the average temperature had risen to 60-70°C. Evidence indicating potential for ignition included steam rising off the pile and the formation of white evaporites on the surface. Rainy, cooler weather generally delayed temperature rise in coal piles. Most fires started in early morning. Compaction of hot or burning coal extinguished all fires and reduced coal temperatures.

454 RECOMMENDATIONS

Dust, noise, and spontaneous combustion were monitored from the bulk sample program and results, although potentially different for a large operating mine, are presented for planning purposes:

(1) Dust from carbonaceous shale and surface soils appears greater than for other materials. Clay materials containing sodium are not expected to pose a dust problem due to formation of a surface crust.

(2) Experimental modelling (ERT, 1978) to date of possible suspended particulate levels, resultant from mining activity, indicates potential problem areas to be: wind erosion, dust generated by haul road vehicles, removal of overburden and stripping of surficial materials. Further work should be conducted, using current mine plans and site specific material data, in order to confirm the problem areas and relative magnitude of dusting potential.

(3) Noise levels may be blocked by intervening terrain.

(4) Spontaneous coal combustion is delayed by compaction and reduced atmospheric exposure time. Monitoring of coal pile temperatures can be used to determine susceptibility to ignition and ensure that adequate precautions are taken.

SECTION FIVE

RECLAMATION AND ENVIRONMENTAL PROTECTION PLAN

SECTION FIVE

RECLAMATION AND ENVIRONMENTAL PROTECTION PLAN

CONTENTS

SECTION FIVE - CONTENTS (Continued) Page

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5.1 INTRODUCTION

The surface areas of land which will be disturbed by mining activity throughout the various stages of the project are:

Disturbance	% of Total Disturbed Area		
	Pre-Production	Year 15	Year 35
Open Pit	20	40	31
Waste Dumps	31	35	52
Materials Storage Areas	6	4	3
Transportation Corridors	7	5	4
Support Facilities	20	9	5
Drainage Control Systems	16	7	5
	100%	100%	100%
Total Area	528 ha	1,257 ha	1,931 ha

These areas involve land presently used for agriculture, forestry wildlife and wetland habitat, and watercourses.

Proposed measures for reclamation, revegetation of drainage control systems, dust control and emergency protection measures are described in this section of the report. Each component of the mine is disucssed on the basis of four periods of time: Pre-Production, Years 1 to 15, Years 16 to 35, and Years 36 to 45.

5.2 OBJECTIVES

The objective of the Reclamation and Environmental Protection Plan, in accordance with the British Columbia Coal Mines Regulation Act, is to protect land, water and air during the construction and operational phases of mining and on completion, to re-establish where practical, land uses of similar type and productivity as existed prior to mining.

During the construction and operation phases of the project, much of the emphasis will be on control of drainage and seepage in order to minimize the impact to the downstream aquatic environment. However, it will also be important to ensure that any practical revegetation of disturbed areas is undertaken on a continuing basis. This will serve to stabilize these areas, reduce seepage and runoff problems, and generally improve the aesthetic appearance. Control of dust and noise will also be important during the mine development and operation.

Over the long term, the objective will be to establish a self-sustaining vegetative cover consistent with the specified land uses when the mining operation is completed. Rangeland, both native and improved, wildlife habitat, and forestry constitute the present major land use in the mine area and are proposed as the end land use following mining. Drainage control sources will be stabilized such that operation of the collection and treatment facilities will no longer be necessary.

The manner by which short and long term objectives will be met is discussed for each component of the development.

5.3 OPEN PIT

Pit development and operating procedures are designed for efficient extraction of the coal and to ensure safe operating conditions in the pit.

During operations water trucks, supplied from pit waste water or treatment lagoons, will be used in the pit as required to control dust. Discharge from pit dewatering wells and pit bottom will be treated within main settling lagoons prior to discharge into Hat Creek. Perimeter interceptor ditches and dewatering wells, discharged to the mine drainage system, will reduce water inflow to the pit.

Pit abandonment and reclamation are planned with the primary objective of protecting human life, livestock, and wildlife from the potential hazards of a large void constructed in weak material. Land use in the excavated pit is dependent on future mining considerations, the extent and cost of reclamation desired, and safety.

531 PRE-PRODUCTION PERIOD

The Hat Creek diversion will be operational at the beginning of Year -3. Temporary ditches will be constructed near working areas to trap runoff and sediment, and will be expanded as required before removal of soil and overburden. The ditches should transport runoff from the pit working area to the main water treatment lagoon which will be constructed with initial excavation materials.

Runoff from construction areas prior to establishment of main treatment lagoons will be channelled as required to temporary settling ponds.

Clearing and overburden removal in the pit area increase potential for surface runoff and reduced groundwater recharge. Groundwater tables are currently near the surface in Hat Creek alluvium but generally deeper than 20 m over most of the proposed pit area. Deep wells will be drilled as required around the pit perimeter beginning in Year -5 to lower groundwater tables in bedrock. Water discharged from dewatering wells will be pumped to the main water treatment lagoon. In Year -4, drainage of surficial groundwater in the working area will be initiated using vertical wells.

Aleece Lake, small ponds, and groundwater present in surficial deposits within the slide area to the southwest of the open pit will be dewatered during Year -5 to reduce potential for slide instability in and above the pit. Lake drainage will be controlled to occur slowly over several months. Small lakes and kettles will be excavated at the natural outlet or drained by pump and siphon.

Before overburden removal, which will commence in Year -2, the area identified for operations in the following year will be cleared and surface soils stripped and transported to stockpiles. Surface soils will not be removed in hummocky terrain where equipment cannot operate efficiently, nor in the active and inactive slide areas where limited data indicate soils to be unacceptable as growth media. Soil scraping will be done progressively just prior to overburden removal to minimize the extent of soil exposed and susceptible to erosion. By the end of pre-production, 72.5 ha will be stripped of surface soil and 258×10^3 BCM conserved.

532 YEARS 1 TO 15

During Years 1 to 15, about 289.6 ha or 736×10^3 BCM of surface soil will be scraped progressively before overburden removal in the open pit.

Temporary revegetation, mulching, water, dust suppression and scheduling of scraping operations, to minimize areas of exposed soil will be carried out as required to reduce wind and water erosion.

Temporary drainage ditches will continue to be constructed around and in pit working areas as required to collect and convey surface water and seepage.

533 YEARS 16 TO 35

The estimated volume of surface soil to be removed from the open pit between Years 16 and 35 is 441×10^3 BCM. Similar wind and water erosion control practices will be used as in Years 1 to 15. No revegetation will be done within the pit-void during mining.

534 YEARS 36 TO 45 (ABANDONMENT)

The final pit abandonment scheme will be based on future mining considerations, continued geotechnical and water quality monitoring, and on-site experience. As previously stated (Section 4), the abandoned open pit is presently envisaged to remain a void. Water entry would be minimized. A cross-section and plan view of the proposed 35-year pit showing berm elevations and geology of exposed surfaces is illustrated in Figures 5-1, 5-2.

At Year 35, the open pit operation will have removed about 606 ha from the present surface, will be about 10.8 km in circumference, and 267 m deep (using a datum elevation of 900 m ASL). Upper pit slopes in glaciofluvial and glacial till overburden will be constructed at an overall slope angle of 25° on the east perimeter of the pit. Upper pit slopes in siltstones, claystones, and slide deposits on the west side of the pit will be constructed at an overall angle of 16°.

About 300 ha of the pit surface exposed after 35 years will consist of materials susceptible to failure once stabilization measures are curtailed. Siltstone and claystone will comprise about 240 ha of the total exposed surface, 60 ha will consist of slide deposits, 180 ha of glaciofluvial and glacial till overburden, and 120 ha of coal.

Similar topography and land use within the proposed open pit cannot be replaced unless the pit is filled with waste, topsoiled, and revegetated. Returning waste to the open pit either during mining or from the 35 year waste dumps is not feasible due to limitations of economics, mine safety and scheduling. Filling the 35 year pit-void with waste or water would severely limit the economics for future coal extraction at greater depth.

With abandonment, exposed carbonaceous material may be susceptible to spontaneous combustion. Coal on the pit floor would be covered with seepage, but about 100 ha on the southwest slope of the pit would remain exposed. Coal would probably be intermittently saturated with seepage and runoff. As slide deposits on upper berms failed and slumped, coal would probably be partially covered with overburden.

The necessity of covering exposed coal will be determined by experience during mining.

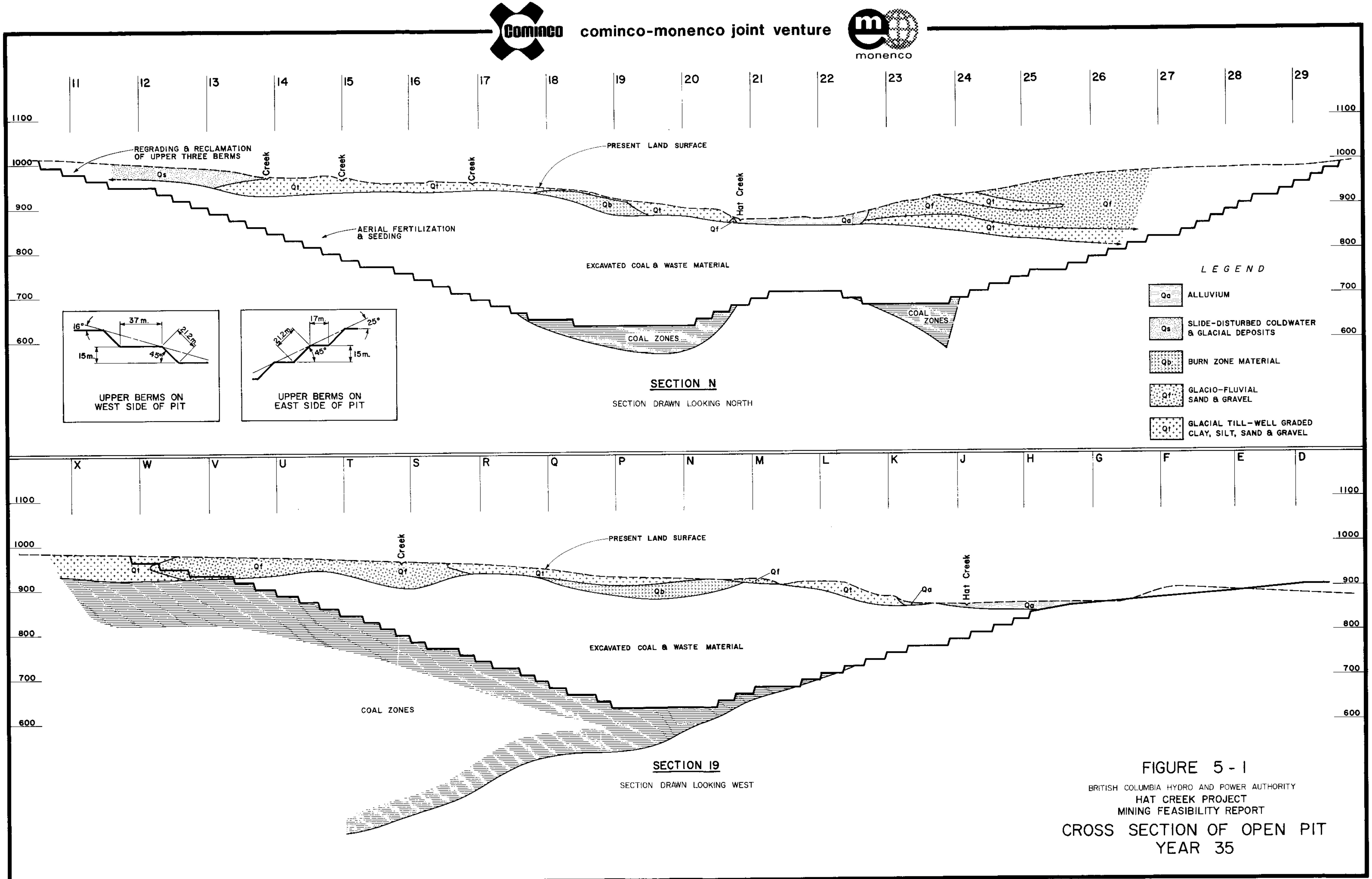
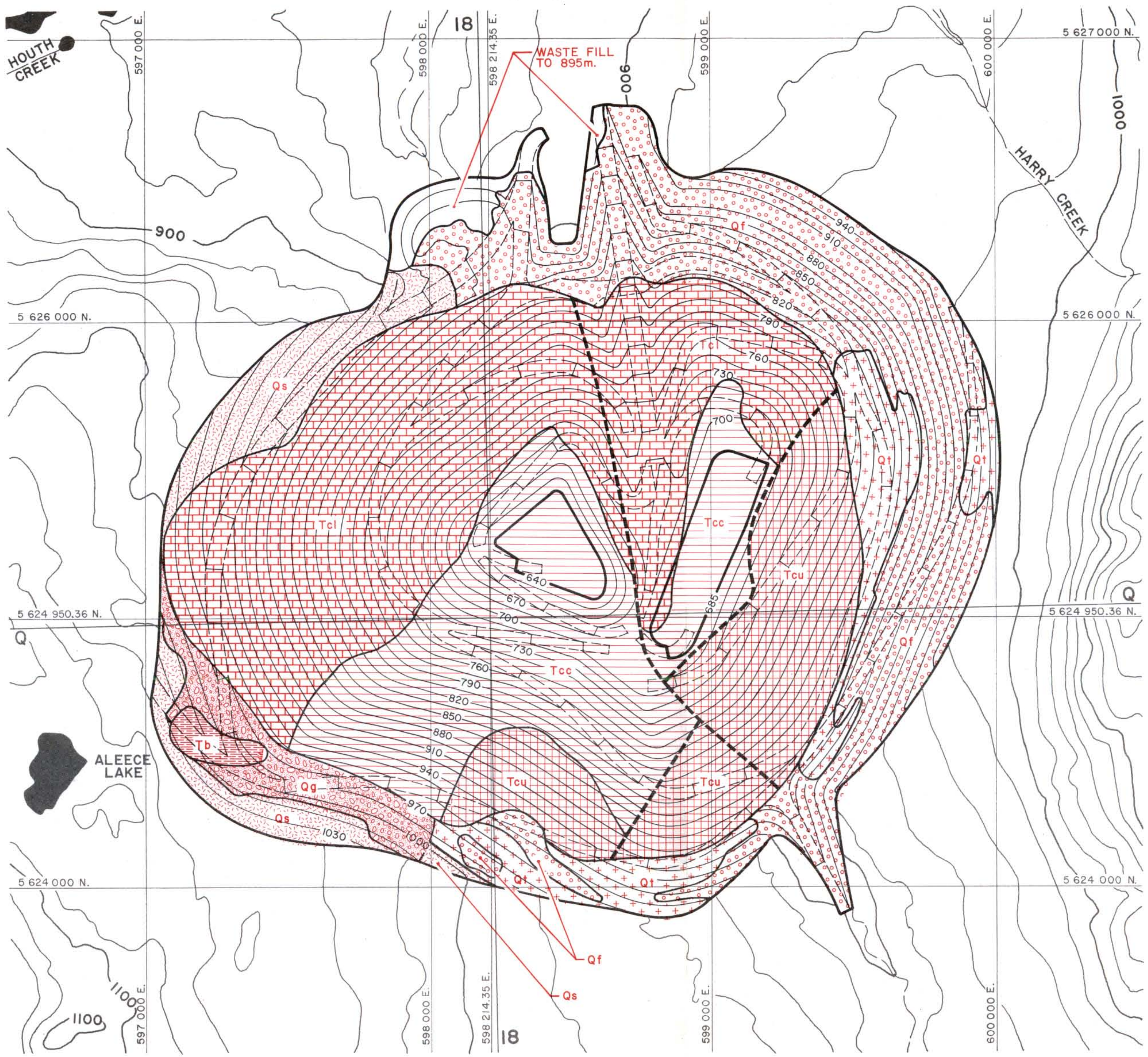


FIGURE 5 - 1

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY
HAT CREEK PROJECT
MINING FEASIBILITY REPORT

CROSS SECTION OF OPEN PIT YEAR 35

cominco-monenco joint venture



LEGEND

QUATERNARY
- Qs — SLIDE-DISTURBED COLDWATER & GLACIAL DEPOSITS
- Qg — GRANODIORITE COLLUVIUM / SLIDE DEPOSIT
- Qf — GLACIO-FLUVIAL SAND & GRAVEL
- Qt — GLACIAL TILL-WELL GRADED CLAY, SILT, SAND & GRAVEL

TERTIARY
- Tb — BASALTIC & ANDESITIC VOLCANICS

COLDWATER FORMATION
- Tcu — CLAYSTONE & SILTONE
- Tcc — COAL (ZONES A, B, C & D)
- Tcl — SILTSTONE WITH SANDSTONE CONGLOMERATE & CARBONACEOUS INTERBEDS

FAULT PLANE

SOURCE: GOLDER ASSOCIATES (1978)

200 100 0 200 m.

FIGURE 5 - 2

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY
HAT CREEK PROJECT
MINING FEASIBILITY REPORT

GEOLOGY OF EXPOSED SURFACES OF OPEN PIT YEAR 35

Pit-void reclamation will be initiated with the long term objective of accelerating natural succession in the upper reaches of the pit to establish grazing and wildlife habitat. Interceptor ditches around the pit, Hat Creek diversion, and Finney Creek diversion will be retained to protect Hat Creek water quality and ensure adequate water flow and water quality downstream. Land use within the pit will depend on the nature and extent of failure and vegetation establishment.

Vegetation will establish on those portions of the upper berms which consist of non-sodic glaciofluvial and glacial till overburden. Vegetation establishment will probably be less satisfactory on saline slide deposits and unsatisfactory on sodic siltstones, claystones, and coal.

The top three benches around the pit perimeter (about 115 ha) will be resloped from 45° to 26° to provide a safer perimeter and lessen the visual impact. No resloping will be done below this level. Following resloping fertilizer and seed will be aerial broadcast on all pit benches. Over the long term revegetated overburden and slide areas are expected to creep and slump into the pit.

Based on an average annual precipitation of 300 mm/year, surface runoff of 50 mm/year, groundwater seepage to the pit of 0.015 m^3/s, and a potential evaporation rate of 532 mm/year, it is estimated that the maximum level of water in the abandoned open pit would be lower than the 895 m elevation (lowest point of possible pit water surface outflow). Further, it is estimated that a period of greater than 1000 years would be required to achieve this maximum level, assuming that diversion canals and ditches are maintained.

The open pit will be fenced to restrict access. Fences will surround the entire pit perimeter and those areas to the southwest which may be susceptible to failure over the long term. In selected areas on the pit perimeter, trees will be planted to screen the pit.

5.4 WASTE EMBANKMENTS AND DUMPS

Mine wastes will be stored behind retaining embankments in Houth Meadows and Medicine Creek Valleys. Construction of Medicine Creek dump will be deferred until Year 15 based on current production schedules (refer Section 2).

Rapid revegetation of embankments and waste dumps will stabilize exposed surfaces against erosion. Temporary reclamation will be carried out on all areas of dump surfaces left inactive for a number of years. Retaining embankments will be constructed in lifts which allow for long term reclamation progressively with construction. Waste dump surfaces will be progressively reclaimed as soon as the final surface elevation is reached.

Surface waters will be channelled during critical periods such as spring snowmelt and high intensity rainstorms by temporary and permanent interceptor ditches which will convey runoff around waste dumps, isolate runoff from working areas, and contain sediment near the source. Runoff and seepage will be trapped, evaporated, diluted, or treated in water treatment lagoons as required. During operations, normal precipitation on waste dumps will be trapped in hummocky terrain on the dump surface and evaporate. Dusting within dumps may be reduced by the formation of a surface crust on sodic waste and by hummocky nature of the terrain.

The Houth Meadows Valley within the proposed waste dump area ranges from 850-1110 m ASL elevation and consists primarily of open range (188 ha) and forest land of poor productivity (382 ha). Medicine Creek Valley, a proposed dump area, ranges from 980-1195 m ASL elevation and consists of open range (125 ha), and 260 ha of forest land.

Waste dumps will be progressively revegetated to an end use comparable with adjacent lands at similar elevation, i.e., open range, wildlife habitat, and forest land. Final dump surfaces will be about 100 m higher than the pre-mining land surface in some portions of the dump.

Topography and native species diversity similar to pre-mining conditions cannot be duplicated but reclamation of waste dumps will be designed to provide a revegetated, self-sustaining stable surface composed of materials similar to or better than those of adjacent lands at similar elevation.

The growing season in the Upper Hat Creek area extends from May through September, but without supplemental irrigation, seeding is restricted to Fall (September to November) and early Spring (April and May) to ensure adequate moisture for seedling establishment. Water from treatment lagoons may be slightly sodic and saline and unsuitable for use in reclamation.

Soil moisture deficits restricts the choice of revegetation species which will become estabished without irrigation. Dryland range grasses, cereals, and local native species will establish with either Fall or Spring seeding. Dryland range legumes (e.g. creeping-rooted alfalfas) will probably require early Spring seeding. Legumes fix atmospheric nitrogen and are considered essential in developing a self-sustaining low maintenance vegetative cover. Reduced nitrogen fertilizer application required for legumes also reduces potential for eutrophication of receiving waters.

Native shrubs and forbs, considered essential in reclamation for wildlife habitat, will require transplanting or nursery propagation.

541 PRE-PRODUCTION PERIOD

Houth Meadows embankment construction will be initiated in Year -2. Before embankment construction and waste disposal begin, temporary perimeter ditches will be constructed as required to isolate surface runoff from working areas.

Surface soils will be progressively removed from the dump area prior to embankment construction and waste disposal. Soils will not be scraped from inactive slide debris composed of saline colluvium or from areas with bentonitic boils at the surface. The estimated volume of soil to be removed from Houth Meadows during pre-production is 520 x 10^3 BCM. Temporary revegetation, mulch, watering, or dust suppressants will be employed to control wind and water erosion from soil scraping and waste disposal operations.

Initially, dumped waste will be loose and any seepage that infiltrates through embankments will be channelled to a holding lagoon (refer Section 2). In later years the dump is expected to seal under its compressive weight. Surface runoff from dumps is expected to be minimal because of hummocky surface terrain. Runoff will be collected in temporary ditches and channelled to the waste water lagoons for treatment as required. No development will take place in the Medicine Creek Valley during pre-production.

The nature and extent of disturbed and reclaimed land at end of pre-production is illustrated on Figure 5-3.

542 YEARS 1 TO 15

About 38 ha of Houth Meadows waste dump is projected to be revegetated by Year 15.

The surface 2 m depth of the dump surface will contain randomly distributed non-seam waste (about 61% by volume), seam waste (22%), and overburden depending on the sequence of extraction and disposal. Suitable surface reclamation material (i.e., non-sodic glacial till and gravel construction material) is available to cover dump surfaces to a depth of about 1 m if required. Construction material will be stockpiled or windrowed during mining at less than 1.5 km from final destination. Soil testing will be done to determine the quality of construction materials before they are stockpiled. Recently dumped waste is expected to behave as a partially saturated soil. Rain and snowmelt is expected to infiltrate recently disposed waste. However, as wastes dry out a surface crust may form on sodic portions resulting in reduced infiltration and local puddling following rainstorms or snowmelt.

Precipitation on dump surfaces will, because of hummocks, form puddles in depressions; the quality of impounded water is expected to be similar to an alkaline slough (e.g., Goose/Fishhook Lake) but should evaporate during the year.

Removal and stockpiling of suitable surface soils will continue progressively until the commencement of waste disposal. The estimated area and volume of surface soil to be scraped from Houth Meadows between Years 1 to 15 are 153 ha and 317 x 10^3 BCM, respectively.

Construction of Medicine Creek waste dump embankments is expected to begin in Year 15. Soils suitable for reclamation will be removed from slopes of 14° or less before embankment construction and waste disposal. By the end of Year 15 about 89 ha of land are projected to be disturbed in embankment construction.

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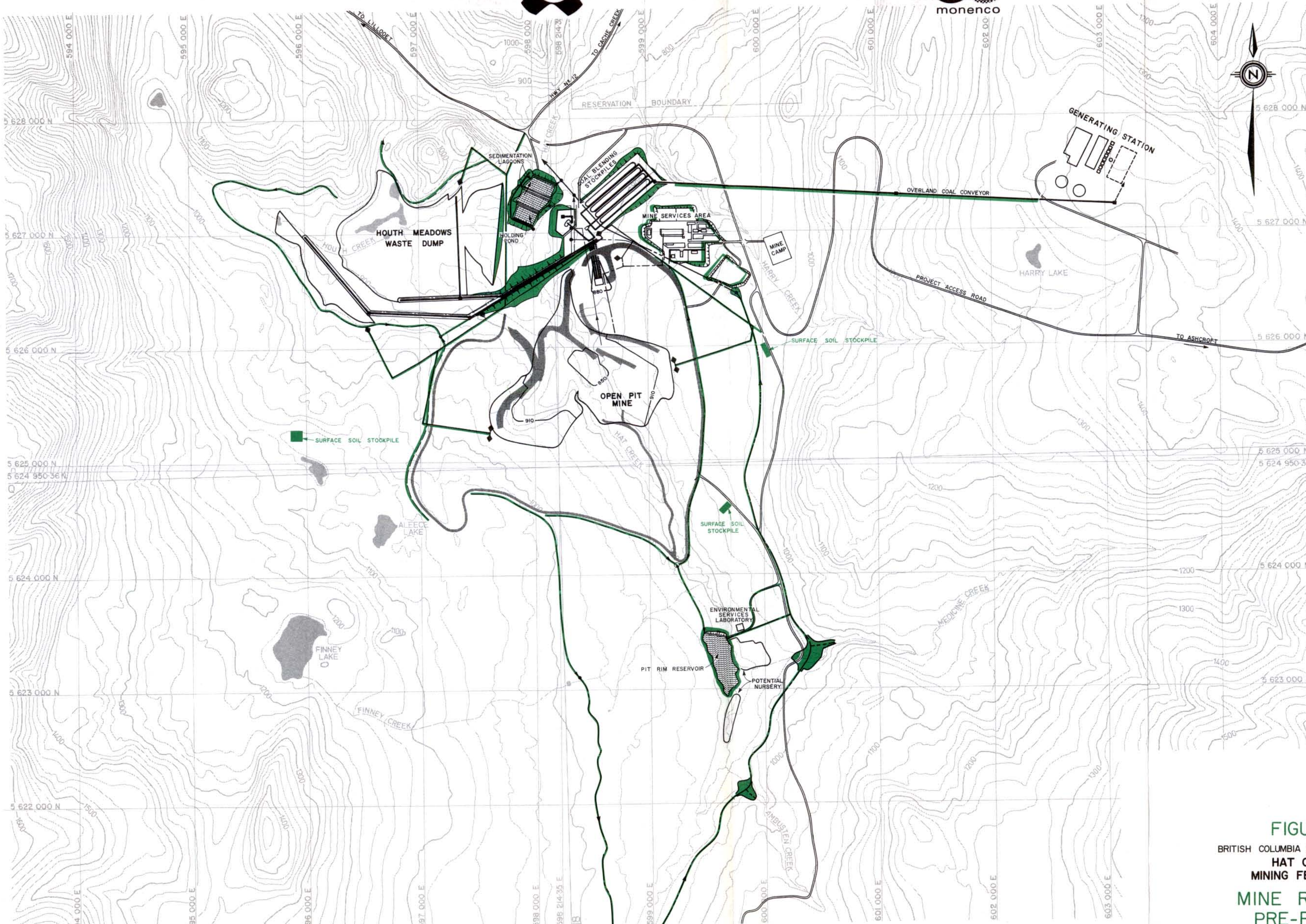

LEGEND

RECLAIMED AREA

FIGURE 5 - 3

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY
HAT CREEK PROJECT
MINING FEASIBILITY REPORT

MINE RECLAMATION
PRE-PRODUCTION

Similar environmental protection measures will be employed at Medicine Creek as at Houth Meadows. Before embankment construction begins perimeter ditches will be constructed to intercept and convey clean surface runoff to Hat Creek diversion, and temporary perimeter ditches will be constructed around working areas as required to isolate runoff and contain sediment. Runoff from Medicine Creek dump will be collected and treated in an adjacent settling lagoon. Leachate will be handled in a zero discharge system similar to that at Houth Meadows. Medicine Creek runoff and leachate are expected to be similar to that at Houth Meadows, assuming that waste dumps contain similar materials.

The extent of disturbed land revegetated land for Year 15 is illustrated on Figure 5-4.

543 YEARS 16 TO 35

The estimated volumes of surface soil to be scraped from Houth Meadows and Medicine Creek between Years 16 to 35 are 358 and 460 x 10^3 BCM, respectively.

As the dump heights increase, waste is expected to compact under its own weight which will tend to reduce seepage. Presence of swelling clays with high cation exchange capacity is expected to adsorb a considerable amount of soluble cations and trace metals.

The nature and extent of disturbed land and revegetated land is illustrated for Year 35 on Figure 5-5.

By Year 35, disturbed land and revegetated land in Houth Meadows is estimated at 610 and 380 ha, respectively. Medicine Creek is projected to include 385 ha of disturbed land and 212 ha of revegetated land by Year 35.

544 YEARS 36 TO 35

Revegetation of waste dumps is expected to be completed within a reasonable time of mine closure, but maintenance applications of fertilizer will be added as required for several years thereafter to ensure adequate vegetation survival. The extent of final reclaimed areas are illustrated in plan view on Figure 5-6.

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FIGURE 5 - 4

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

HAT CREEK PROJECT

MINING FEASIBILITY REPORT

MINE RECLAMATION YEAR 15

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LEGEND

PUBLIC ROAD
WASTE DUMP AREA

LEGEND

RECLAIMED AREA

FIGURE 5 - 5
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY
HAT CREEK PROJECT
MINING FEASIBILITY REPORT

MINE RECLAMATION
YEAR 35

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LEGEND

PUBLIC ROAD

WASTE DUMP AREA

LEGEND

RECLAIMED AREA (MAJOR RECLAMATION)

RECLAIMED AREA (MINOR RECLAMATION)

0.1 0 0.5 1.0 km

FIGURE 5 - 6

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

HAT CREEK PROJECT

MINING FEASIBILITY REPORT

MINE RECLAMATION

YEAR 45

Reclamation of waste dumps will require reshaping of hummocky terrain to provide long term stability and accessibility for placement of buffer material and surface soil. Following reshaping and settling, selected construction materials such as non-sodic glacial till or gravels will be spread over waste surfaces to the depth required based on site-specific research. During reshaping, ridges will be struck off.

Local surface instability, piping, and settling is expected to occur on final dump surfaces following recontouring. In order to prevent flow slides, large hummocks and ponds will not be constructed on the final dump surface, however, varied microrelief will be constructed or retained where possible to provide habitat suitable for range, wildlife, and forestry.

Wildlife habitat on dump surfaces will be provided initially by establishing islands of native vegetation obtained from adjacent areas, allowing for rapid, self-seeding of native plants. Expansion of these islands will be aided by collection of native seeds, propagation at the project nursery (refer Section 5-10) and selective planting on waste dumps. Vegetation type and composition, although not duplicated to present conditions, will be patterned along and correlated to, data recorded in baseline inventory programs for site-specific wildlife habitat and vegetation associations (refer Table 3-6, 3-7). Primary effort will be directed towards the establishment of dryland wildlife habitat since geotechnical concerns preclude creation of small waterbodies on waste dump surfaces, which may induce flow slides. Small intermittent wetlands may form in depressions during years of increased precipitation.

Any surface runoff and drainage from Houth Meadows dump will be directed by ridges southeast into an interceptor ditch, conveyed in a pipe across the waste conveyor causeway and discharged into sedimentation lagoons. Medicine Creek surface drainage will be directed northwest by means of ridges into an interceptor ditch and directed by a pipe to nearby sedimentation lagoons.

Native deciduous and coniferous trees and shrubs will be planted on berms and embankments to screen waste dumps. Prior to final revegetation of embankments, berms will be contoured to present a "rounded-off" edge and where possible (within imposed geotechnical constraints) will be blended with adjacent topography.

5.5 MATERIAL STORAGE AREAS

Storage areas include the coal blending stockpile, the low-grade coal stockpile, surface soil stockpiles, and temporary stockpiles of construction material.

The objectives of reclamation and protection measures in these areas are to conserve soil, to minimize the area of non-vegetated stockpile surface susceptible to erosion, to minimize the overall area of disturbance, and to reduce potential dust, leachate, runoff, and fire hazard.

551 PRE-PRODUCTION PERIOD

The coal blending facility will be constructed during pre-production; temporary perimeter ditches will be in place as required to isolate and contain runoff from the area to be cut and filled. The cut and fill area will be constructed of compacted impervious construction material (glacial till) to minimize seepage. Although coal conveyed to stockpiles will be at field moisture levels, the surface of piles will probably dry out during summer. Water hydrants located throughout the blending facility and fire fighting equipment will be available to respond quickly to any fire or severe dust problems. After blending operations are established, site-specific research will be done to assess the extent of dusting and to develop control measures to meet both air and coal quality standards.

Under normal unsaturated conditions, no leachate or runoff is expected from coal stockpiles. Leachate and runoff resulting from a prolonged rainstorm will be collected and treated as required in the main water treatment lagoon.

The risk of fire from spontaneous combustion of coal will be minimized by compaction and excavation as required. Short coal storage time and temperature monitoring will reduce the potential for coal fires.

Three major surface soil stockpiles and several minor stockpiles will be constructed during pre-production. The estimated area and volume of the stockpiles will cover 4.3 ha and will contain 1283×10^3 BCM of surface soil by the end of pre-production (Table 5-1).

TABLE 5-1

Schedule for Removal, Stockpiling, and Re-Use of Surface Reclamation Materials
Hat Creek Project Mining Feasibility Report 1978

Location	Time	SOIL REMOVAL		VOLUME RE-USED		Total
		Volume	Stockpile Area (# ribbons)	Soil	Buffer Material	
Open Pit	Pre-Production	258	7	0	0	0
	Years 1-15	736	21	0	0	0
	Years 16-35	441	13	0	0	0
	Years 35-45	0	0	0	0	0
	Sub-total	1435	41	0	0	0
Houth Meadows Dump	Pre-Production	520	15	6	0	6
	Years 1-15	317	9	108	130	238
	Years 16-35	358	10	1026	3420	4446
	Years 35-45	0	0	621	2070	2691
	Sub-total	1195	34	1761	5620	7381
Medicine Creek Dump	Pre-Production	0	0	0	0	0
	Years 1-15	191	6	0	0	0
	Years 16-35	460	13	636	1850	2486
	Years 35-45	0	0	519	1730	2249
	Sub-total	651	19	1155	3580	4735
Low Grade Coal Stockpile	Pre-Production	65	2	0	0	0
	Years 1-15	0	0	16	86	102
	Years 16-35	0	0	16	86	102
	Years 35-45	0	0	33	172	205
	Sub-total	65	2	65	344	409
Service Yards (includes coal stockpiles)	Pre-Production	320	9	0	0	0
	Years 1-15	0	0	0	0	0
	Years 16-35	0	0	0	0	0
	* Years 35-45	0	0	320	264	584
	Sub-total	320	9	320	264	584
Conveyor Corridors	Pre-Production	21	0.6	0	0	0
	Years 1-15	9	0.4	0	0	0
	Years 16-35	0	0	0	0	0
	Years 35-45	0	0	30	0	30
	Sub-total	30	1	30	0	30
Roads	Pre-Production	77	2.2	0	0	0
	Years 1-15	50	1.4	0	0	0
	Years 16-35	24	0.7	0	0	0
	Years 35-45	0	0	71	0	71
	Sub-total	151	4.3	71	0	71
Clearwater Reservoirs	Pre-Production	41	1	41	0	41
	Years 1-15	0	0	0	0	0
	Years 16-35	0	0	0	0	0
	Years 35-45	0	0	0	0	0
	Sub-total	41	1	41	0	41
Lagoons	Pre-Production	27	0.8	27	0	27
	Years 1-15	3	0.1	3	0	3
	Years 16-35	0	0	0	0	0
	Years 35-45	0	0	0	0	30
	Sub-total	30	0.9	30	0	30
Hat Creek Diversion	Pre-Production	19	0.5	19	0	19
	Years 1-15	0	0	0	0	0
	Years 16-35	0	0	0	0	0
	Years 35-45	0	0	0	0	0
	Sub-total	19	0.5	19	0	19
Grand Total		3937	113	3492	9808	13300
Pre-Production		1283	36	93	0	93
Years 1-15		1371	40	127	216	343
Years 16-35		1283	37	1678	5356	7034
Years 35-45		0	0	1594	4236	5830

Note: Volume: BCM x 10^3
Stockpile Area: 1 ribbon = 1163 m^2 = 0.12 ha
Stockpile Volume: 1 ribbon = 34 875 m^3 = 35 BCM x 10^3

The proposed method of soil stockpile construction is illustrated on Figure 5-7. Surface soil will be transported from specified development areas (refer Figure 3-3) to stockpiles normally located less than 1.5 km distance from the source.

Thirty metre wide active "ribbons" will be constructed by the scrapers, which will be revegetated as soon as possible after dumping with a rapidly-growing nurse crop for stabilization against erosion. Vegetation grown on soil stockpiles will be maintained by fertilizer as required. Stockpile design and location will be optimized as on site experience is gained. Soil stockpiles will be stabilized as soon as possible during Fall with a ryegrass mixture or the following Spring with a grass-legume mixture. Temporary vegetation, mulch, dust suppressants, and chemical sprays will be used as required to stabilize non-vegetated surfaces. Soil stockpiles will be surrounded by small perimeter ditches to contain runoff sediment. Proposed locations for soil stockpiles during preproduction are illustrated on Figure 5-3)

552 YEARS 1 TO 15

The estimated area and volume of soil stockpiles by Year 15 are 9.1 ha and 2654 x 10^3 m^3, respectively.

Prior to placement of the low-grade coal stockpile, vegetation will be removed and surface soil scraped and transported to stockpiles. The foundation of the low-grade coal stockpile will be constructed of compacted impervious material with the surface of the foundation sloping towards the water treatment lagoons. Two locations for the stockpile were originally considered, one on the mountain between the Medicine Creek dump and the generating station, the other at the toe of the Houth Meadows embankment between the water treatment facility and the conveyor causeway. The latter site was chosen as it was more accessible, gave the stockpile wind protection, was close to established water treatment lagoons, and the area was considered already environmentally disturbed, thus, preventing disturbance of new areas.

Low-grade coal will be spread in 0.5 m layers and compacted. The stockpile would be divided into 4 areas of equal size and low-grade coal would be deposited in one of these areas only, until an elevation of 895 m ASL is reached. At this level, the compacted surface would be reclaimed and deposition of low-grade coal would proceed in the next area.

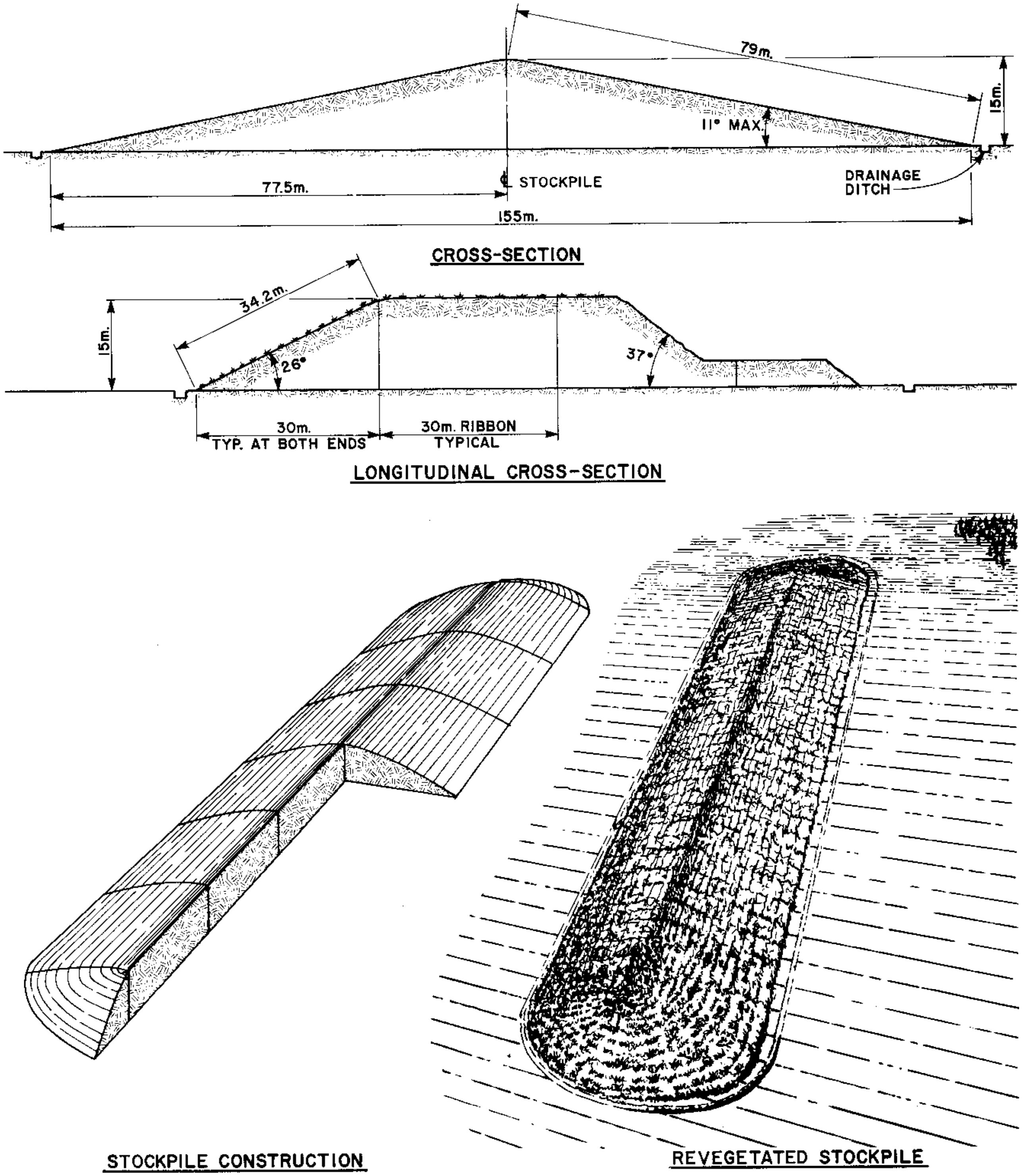

FIGURE 5 - 7

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

HAT CREEK PROJECT

MINING FEASIBILITY REPORT

SURFACE SOIL STOCKPILE
CONSTRUCTION & RECLAMATION

When stockpiling is completed, the low-grade coal will be covered with non-sodic medium-textured overburden (buffer material), followed by 15 to 30 cm depth of surface soil, and revegetated. The depth of buffer material required to cover sodic low-grade coal will be based on site-specific research.

Water and chemical suppressants will be employed as required to reduce dusting. Runoff and leachate from prolonged rainstorms will be trapped by perimeter ditches and by the impervious foundation, and will be conveyed as required to treatment or holding lagoons. Under normal unsaturated conditions, leachate is expected to be negligible

553 YEARS 16 TO 35

The ultimate stockpile capacity (allowing for swell and maching compacting) required to contain the low-grade coal mined is estimated to be 10.75 x 10^6 m^3 and the maximum estimated area of disturbance is 17.2 ha. The final elevation at Year 35 would be 910 m with side slopes of (2.5 to 1) 22°.

During Years 16 to 35, areas and volumes of surface soil stockpiles will vary as soils are used in capping final surfaces just prior to revegetation. Surface soil stockpiles will be stabilized by vegetation until excavated for reclamation use. Where possible, surface soils removed during the later stages of mining operations will be used immediately for reclamation of final surfaces without stockpiling so as to minimize the areal extent of stockpiles and the area susceptible to dusting and erosion.

Reusing surface soils immediately after they are removed, reduces the potential for compaction and deterioration. Freshly excavated and spread soils are expected to have improved microbiological, chemical, and physical properties compared to stockpiled soils. Another advantage is that it contains remnant native plant seeds and parts which will speed up the reclamation process.

554 YEARS 36 TO 45

Revegetation of the coal stockpile and blending area will be achieved within 10 years after mining is completed. Unused coal will be levelled, resloped to blend with adjacent topography, and compacted to prevent spontaneous combustion. Coal will be sealed with a layer of non-sodic medium-textured overburden, surfaced with 15 to 30 cm of soil, and revegetated.

Depth of coverage required to prevent spontaneous combustion and to support vegetation will be based on site-specific research.

Low-grade coal will be covered and revegetated in a manner similar to coal. Native deciduous and coniferous trees and shrubs will be planted where possible to screen stockpiles and perimeter ditches retained to convey potential runoff or seepage to the open pit or lagoons.

Soil stockpiles will decrease progressively both in area and volume following mine shutdown as the material is spread over disturbed lands. When the stockpiles are depleted, the sites will be levelled and resloped to blend with adjacent topography before revegetation is carried out.

5.6 TRANSPORTATION CORRIDORS

Transportation corridors include rights-of-way, overland conveyors, haul roads, service roads, and transmission lines.

Suitable surface soils will, where possible, be removed from corridors before construction and will normally be stockpiled in adjacent areas. Revegetation of inactive portions of transportation corridors should be initiated as soon as possible following construction to minimize potential for dusting and erosion. Cut and fill slopes will, where practical, be resloped to 26° and revegetated. Trees and brush will be removed from rights-of-way to reduce fire hazard.

561 PRE-PRODUCTION PERIOD

Roads will be sprayed with water to control dusting, and in winter, calcium chloride will be applied to improve traction. Where practical, road cuts and fill slopes will be resloped to 26° to permit revegetation of these areas as soon as possible following construction.

Runoff and sediment transport which could result during construction will be intercepted by temporary ditches and straw bale dykes as required. The construction of water treatment lagoons and of the Hat Creek diversion before conveyor construction will reduce runoff entry to Hat Creek. Conveyor corridors will vary in width up to 40 m depending on cut and fill requirements; slopes will be reduced to a stable angle to permit revegetation.

562 YEARS 1 TO 35

The estimated area and amount of soil stripped and conserved from transportation corridors is summarized in Table 5-1. Revegetation of corridors will proceed concurrently with construction.

The hooded coal conveyors will be enclosed in galleys within potential snowdrift areas. The potential for dusting from the coal and waste being transported is considered minimal because these materials are mined and conveyed at field moisture conditions.
A hydrant system will be incorporated along the length of the over-

land conveyor and sprinklers or foam will be available within galley portions to ensure adequate protection against fire.

Based on current production schedules the conveyor and transmission line to Medicine Creek will be constructed in Year 15. Environmental protection and reclamation practices employed for the Medicine Creek conveyor will be similar to those described above.

563 YEARS 36 TO 45

During the years immediately following mine shutdown, conveyors, transmission lines, and culverts will be dismantled and removed, and transportation corridors will, where practical, be resloped to blend with adjacent topography. Roads (except main access roads) and conveyor routes constructed of gravels and glacial till will be ripped to relieve compaction before revegetation. Water bars will be constructed on slopes with a potential for rill erosion.

5.7 SUPPORT FACILITIES

The present land use of the proposed support facilities area is predominantly forest. The site quality has a poor rating and reclamation will be designed to enhance the value of the disturbed land.

571 PRE-PRODUCTION PERIOD

Perimeter ditches will be placed around support facility sites prior to construction in order to prevent runoff entry to either Hat or Harry Creeks. A buffer zone of forest at least 30 m wide should be left on the east side of the support service area in order to help screen the storage complex from main access roads. Following construction, cut and fill embankments will be revegetated as soon as possible with a dryland grass-legume mixture and native trees and shrubs.

Lawns and shade trees will be planted in selected areas near offices and parking lots to improve the overall appearance and to reduce the potential for dusting.

Water hydrants will be located throughout required areas of the service complex to provide fire protection.

572 YEARS 1 TO 35

Based on current mine planning, the size and location of support facilities should not undergo any significant changes subsequent to initial construction. Reclamation activities will be minor and concerned primarily with revegetation in areas of site expansion or relocation and in areas left inactive for a number of years.

573 YEARS 36 TO 45

During the years following mine closure, buildings not retained for alternate uses such as ranch operations will be dismantled, sold, and levelled to their foundations. Any areas littered with scrap metal, broken equipment, etc., will be cleared during mine clean-up operations prior to reclamation. After removal, the majority of the service area will be ripped to relieve compaction, covered with 15 to 30 cm of soil, and revegetated. Where practical, slopes will be regraded to blend with adjacent topography. Where surface materials are unsuitable for plant growth, a suitable depth of overburden will be placed before soil coverage and revegetation.

5.8 REVEGETATION OF DRAINAGE CONTROL SYSTEMS

Watercourses, wetlands, and riparian habitat occupy a relatively small portion of the mine area but are considered of primary importance for wildlife, waterfowl, fisheries, and downstream users. Effort will be made to conserve and rehabilitate as much of this habitat as practical within the constraints imposed in mining the deposit. Lagoons, diversions, ditches, and reservoirs will be revegetated to establish wetland and riparian habitat wherever possible. Drainage control structures, where lined, will be grass seeded; in unlined portions and where reclamation efforts would not affect designed flow capacity or erosion, grasses, shrubs, and trees will be planted.

Diverted clean water will be channelled around development areas and discharged to the natural water drainage system. Wastewater from the mine will undergo treatment to meet regulatory objectives or baseline conditions.

581 PRE-PRODUCTION PERIOD

581.1 Hat Creek Diversion

Due to design constraints, reclamation within the Hat Creek Diversion Canal is limited to revegetation with shallow rooted grass and legumes. This will reduce erosion of the till lining and improve the appearance without obstructing projected flows. Along outer slopes of the canal, trees, shrubs, and grasses will be established. As part of the canal inspection, any woody growth invading the inner canal slopes will be pruned back to prevent disruption of the liner.

581.2 Finney Creek Diversion

Finney Creek diversion will be bordered on one side by a service road. The canal will be at least 2.4 m deep, 15 m wide, and will be lined with 60 cm of till in areas where pervious soils are encountered.

Constructed through an ephemeral wetland zone containing numerous small ponds, the canal and road slopes will be revegetated with a grass-legume mixture as soon as possible. Trees and shrubs considered valuable for riparian habitat will be planted in selected areas outside the canal on the side opposite the road.

581.3 West and North Perimeter Ditches

Interceptor ditches will be revegetated in a similar manner to the Finney Creek diversion. Due to the narrow width of the corridor, rapid invasion of native vegetation is expected. In selected areas where native plant invasion is slow and sufficient moisture is available, native plant species considered valuable for riparian habitat will be planted.

581.4 Reservoirs

During construction fertile alluvial soils will be stripped and conserved adjacent to reservoirs. Areas adjacent to the pit rim dams and reservoirs would be revegetated as soon as possible following construction with a grass-legume mixture to stabilize erodable surfaces and improve the aesthetic appearance. Native plants will be established around the reservoir above the water line to provide a marsh edge for waterfowl habitat. Fencing the reservoir area to prevent cattle entry should help increase standing vegetation important for waterfowl nesting, brooding, and cover.

During operations, experience will be gained with the interplay of water level, fluctuation, nutrient content, water temperature, and hunting restrictions. Water chemistry within these reservoirs (pH and salinity) is projected to be suitable for waterfowl (Beak, 1978).

Trial fish stocking programs will be attempted providing final reservoir design allows for adequate flows and a minimum water depth of 9 m. The volume of live storage within the Pit Rim Reservoir could be maintained by releasing water from the headworks dam to the original Hat Creek stream bed. This would also reduce the effective length of the Hat Creek Diversion Canal and may reduce the projected water temperature rise during low flow periods. With a pump intake on the Pit Rim Reservoir located near the bottom of the pond, cooler water could also be diverted to the canal. Low flows in Hat Creek may be partially augmented by utilizing live storage volumes on the headworks dam and Pit Rim Reservoir.

581.5 Lagoons

During construction fertile alluvial soils will be stripped and conserved. Perimeter slopes would be reduced to a stable angle which permits early revegetation with a grass-legume mixture. Native trees and shrubs would be planted around the lagoon perimeters to provide wind protection and promote quiescent settling conditions. Use of nitrogen-fixing species and minimal phosphate fertilizer applications on the adjacent calcareous soils should reduce the potential for nutrient loading in receiving waters.

Water levels in the sedimentation lagoons will fluctuate significantly throughout the year. Major inflows are expected during the period of spring freshette. During summer, water levels will decline due to evaporation although rainfalls may temporarily increase the levels.

582 YEARS 1 TO 35

Temporary drainage ditches will be constructed in the mine area throughout the project life to isolate surface runoff from working areas. Ditches will be revegetated with a grass-legume mixture to provide a grass waterway as soon as possible following construction. Permanent ditches, such as those established in Medicine Creek Valley will be grassed and wherever possible trees and shrubs will be planted to provide shade and improved habitat. During mining the Hat Creek Diversion may be altered to either a higher elevation open canal or a canal-tunnel. The cut and fill slopes of the new alignment will be revegetated as soon as possible following construction and, where practical within the constraints of engineering design, native trees and shrubs established to provide riparian habitat.

583 YEARS 36 TO 45

Ditches, diversions, lagoons, and reservoirs would be left intact in order to isolate runoff from waste disposal areas and the open pit. During Years 36 to 45 lagoons, ditches, diversions, and reservoirs would be monitored and maintained by reclamation staff, in accordance with the appropriate regulatory agency. Over the long term, diversions, ditches, and reservoirs could be used by local residents to supplement irrigation supplies. They would, however, continue to require maintenance.

5.9 SUPPLEMENTARY PROTECTION MEASURES

591 MONITORING PROGRAMS

591.1 Land

Geotechnical monitoring of pit slopes, waste dumps, and slide areas will continue during mining to ensure operating safety and to develop reliable abandonment procedures. Temperature of carbonaceous materials will be monitored to prevent spontaneous combustion. The quality of soil and buffer materials placed over wastes will be monitored to ensure adequate depth of uncontaminated growth medium. The quantity, quality, regeneration potential, and nutrient and metal content of vegetation grown on disturbed mined-land will be monitored to determine if vegetation is self-sustaining and satisfactory for livestock and wildlife consumption.

591.2 Water

Surface and groundwater quality and quantity will be monitored to ensure compliance with present PCB level A objectives. Potential seepage and leachate flows will be monitored in groundwater wells located near waste dump embankments and the perimeter of the coal and low-grade coal stockpiles. Discharge from all treatment lagoons will be monitored regularly prior to discharge.

The primary objective of water monitoring will be to segregate sediment-laden water, clear water, waste water, and other surface flow. Sources of varying water quality may then be treated as required by regulatory agencies to ensure an acceptable discharge to Hat Creek.

591.3 Air

Suspended particulate and dustfall levels will be monitored at strategic locations in the mine area and on the mine perimeter. Air quality monitoring in the mine area will also include parameters considered important in evaluating the effect of the generating station emissions on water, soils, flora, and fauna of the mine area.

592 MAINTENANCE PROGRAMS

Regular inspection and maintenance of revegetated areas and environmental protection structures by knowledgeable personnel is considered essential. Revegetated areas will be fertilized as required until vegetation is considered self-sustaining.

Small quantities of sediment removed from ditches will be buried or disposed of behind a protective berm or grass filter strip and revegetated. The sediment accumulation from the main treatment lagoons may not have to be removed during the 35-year mine period due to their large storage capacity.

593 EMERGENCY MEASURES

593.1 Spontaneous Combustion

Reducing atmospheric exposure time, compaction, and sealing with clay are all methods which can be used to minimize spontaneous combusion of carbonaceous materials. Should any fires develop in coal or low-grade coal stockpiles, sufficient mobile fire fighting equipment in the form of excavating equipment, pumper trucks, hose or hydrants will be available.

After mine operations are completed, exposed carbonaceous material outside the pit may be buried to a sufficient depth with compacted, fine-textured overburden. The nature and extent of fire control measures adopted within the pit will be based on future mining considerations and on the degree of hazard determined from 35 years of mining experience.

593.2 Flooding

The Hat Creek and Finney Creek diversion canals, and the major diversion ditches at Medicine Creek and on the western valley slopes will be designed to handle all flows up to the 1 in 1000 year rainfall event, while ditches within small watersheds in the mine area are designed to accept a 1 in 100 year rainstorm. Small diversion ditches and treatment lagoons are capable of containing a 1 in 10 year, 24-hour rainstorm with zero discharge, although floods exceeding this latter capacity would not affect mine operations.

593.3 Instability

Both the open pit haul roads and main access roads will accommodate intermittent small slope failure during operations.

The risk of massive pit slope and entrance ramp failure during operations will be minimized by constructing moderate slopes (16-25°).

Waste dump embankments will be engineered and located on Marble Canyon limestones, Mount Lytton intrusives, and Kamloops volcanics foundations, thereby reducing potential for regional failure. Embankments will be constructed of compacted sands and gravels and should thereby prevent any potential liquefaction of either fine-textured lenses or fill in the event of severe seismic shocks. Waste dump surfaces will be constructed at a 3° slope, which is less than the angle of repose of the unstable materials.

Slide instability will be reduced by draining numerous small ponds and lakes on the west side of the pit before mining. Depressurization of groundwater aquifers will also help in stabilizing materials near the open pit.

The probability of earthquakes near Hat Creek was estimated by the Victoria Geophysical Observatory based upon statistical analysis of 1169 earthquakes in the region between 1899 and 1974. The analysis showed that the seismic risk to the mine is not considered to be a serious problem.

594 SPECIAL SALVAGE MEASURES

594.1 Archaeological

A conservation strategy will be adopted to preserve significant heritage resources excavated during surface soil and overburden removal. As scraper work will be carried out progressively during mining, there will be sufficient time to complete an inventory of heritage resources in proposed development areas.

594.2 Equipment

During mining, scrap equipment, metal, tires, etc. will be sold and removed from the property, where practical. When the mine is shutdown, fixed equipment including conveyors, coal, and spoil handling equipment, electrical supply systems, and pipework will be dismantled and sold as will heavy structural steel, electrical copper, and other scrap metal. Unuseable scrap left in the service area will be cleared and disposed of.

594.3 Buildings

Mine buildings should either be dismantled or demolished and levelled to their foundations. Depending on ultimate land use, selected buildings such as workshops, stores, and large-sized concrete pads could be usefully retained as ranch buildings and feed-lots.

595 EDUCATION PROGRAMS

The proposed Hat Creek mine will be constructed primarily in grasslands and open forest located on fine-textured soils. Summer drought in grassland increases the potential for dust and fire. Compared to forests, grasslands also have less capacity to absorb overland water and sediment flow.

Operating personnel will therefore receive basic instruction in preferred work methods to reduce potential for fires, dusting, and increased surface runoff, and will be made aware of sensitive environmental and heritage areas. Indiscriminate disposal of wastewater, garbage, and broken equipment in undesignated areas and unnecessary removal of native vegetation will be discouraged as well as unnecessary use of off-road vehicles in grassland and open forest. The potential for greatest environmental degradation exists during the period of mine development. Contractors and operators will be informed of preferred work methods in order to minimize off-site damage and to prevent unnecessary environmental disturbance.

With permanent reclamation and environmental staff on site to provide instruction, a regular briefing/information period can be set up for operating staff (supervisors and equipment operators).

5.10 RECLAMATION AND ENVIRONMENTAL SERVICES COMPLEX

Reclamation (primarily soils and vegetation aspects) and pollution control (primarily air and water aspects) facilities have been identified. It is proposed that an environmental services complex be constructed on reasonably fertile, level agricultural land to the southeast of the 35-year open pit area (refer Figure 5-3). It would comprise: an office-sample preparation building, two greenhouses (primary, aluminum and glass; secondary, metal or wood quonset structure), a machinery storage shed, bulk fertilizer storage bins, and a nursery. Analytical laboratory testing for air, water, soils, and vegetation parameters is proposed to be conducted within the main administration-service complex north of the open pit. This is located in a common facility with the coal laboratory and can thus utilize common major analytical equipment as well as any special utility function related to power, water, and ventilation. Samples will be obtained by environmental staff, prepared at the environmental services complex, and taken to the main service area for analysis. Sample storage will be maintained within the environmental services building.

The environmental services complex will be constructed during the pre-production period, and any laboratory or office work required previous to this can utilize temporary or mobile facilities on site. Equipment and staff will be built up as necessary through to Year 15 in accordance with the volume of reclamation work. From Years 15 to 40 a full complement of staff and facilities would be on site.

For planning purposes the following numbers and details of staff, facilities, and equipment have been estimated.

A. <u>Analytical Lab</u>

1. Staff - 1 professional
   2 lab technicians
   1 field assistant

2. Facility - laboratory and offices within the central administration-service complex

3. Equipment - analytical equipment to complete all required tests except bioassay and metals analysis.
   - 2 x 4 wheel drive 1/2 ton vehicles

B. Environmental Services Complex

1. Staff
   - 3 professionals (including 1 supervisor for all environmental operations)
   - 2 technicians
   - 4 summer staff workers Years -4 to 5
   - 6 summer staff workers Years 6 to 20
   - 12 summer staff workers Years 21 to 39
   - 1 secretary Years -4 to 45

2. Facility
   - one office/sample preparation building size 10 m x 15 m; concrete slab
   - one primary greenhouse (including special lighting fixtures); concrete slab size 7 x 15 m
   - one secondary greenhouse; concrete slab size 5 m x 10 m
   - two bulk fertilizer storage bins size 2 m x 2 m
   - one machinery storage shed size 15 m x 20 m
   - nursery area approximately 10 ha (final) in size

3. Equipment
   - 3 x 4 wheel drive 1/2 ton trucks
   - 1 mid size conventional farm tractor
   - 1 utility farm tractor
   - seed drill
   - vermeer tree planter
   - sheeps foot roller
   - disc harrow
   - fertilizer applicators
   - sprinkler irrigation system (nursery)
   - miscellaneous hand and small implements

The environmental services complex, including nursery lands, will be fenced (standard range fence) to prevent inadvertent access and grazing by livestock. Helipcopter and hydro-seeding are proposed to be contracted out as required.

Material handling requirements for the reclamation programs will utilize standard mine fleet vehicles as required. Tasks such as removal of surface soils, stockpiling, resloping and spreading were considered to utilize scrapers, and bulldozers.

5.11 SUMMARY

Local surface soils are considered to be the most suitable materials available for reclamation in order to achieve desired end land use and productivity. These soils, varying in depth from 15 cm to 45 cm, will, where practical, be conserved from all disturbed areas and reused in 15 cm to 30 cm layers.

On areas identified as having serious sodic problems such as waste dumps and low-grade coal stockpiles, a sufficient depth of non-sodic overburden will be applied as "buffer material" to form a plant root zone between surface soils and sodic wastes. Based on limited data, a buffer depth of 1 metre has been chosen for planning; on-site research during mining may suggest an increase or decrease in depth of buffer material. Mine planning is presently allowing for excavation and transportation of 10×10^6 BCM of non-sodic glacial till and alluvial sands and gravels, which will be stockpiled on or near waste dumps for later use in reclamation.

In general suitable buffer material should have pH ranging from 5.0 to 8.5, electrical conductivity less than 4 mmhos/cm, sodium adsorption ratio less than 10, and exchangeable sodium percentage less than 15%. Non-sodic medium-textured glacial till with satisfactory moisture retention for plant growth is considered the most desirable "buffer material". Alluvial and glaciofluvial overburden are also suitable but may require greater depth to provide adequate moisture storage for plant growth. Further soil testing will confirm the suitability, depth, and selection of an adequate buffer material.

Productivity of revegetated land is dependent on the quality and depth of surface reclamation material. Increasing depth will improve moisture and nutrient storage for revegetation, however, depth is constrained by scheduling of equipment, availability of suitable material, and cost. Current plans are to cover non-sodic waste and overburden with 15 to 30 cm depth of surface soil.

Commercially available range grasses and legumes will be seeded initially to stabilize non-vegetated areas. Ongoing field research will provide data for the application of field-tested seed mixtures and fertilizer programs during mine construction and initial years of operation. Commercial range grasses and legumes will be fertilized and managed until vegetation is self-sustaining. The determination of whether vegetation is self-sustaining at a given point in time will be based on change in vegetative cover, species composition, biomass, nutrient content, and seed yield and viability. Nutrient cycling and soil development studies would also ensure that established vegetation is self-sustaining.

Nutrient and trace element content in forage and browse will be monitored to ensure satisfactory levels for livestock and wildlife.

Although the diversity of present native vegetation and soils cannot be duplicated exactly, native plant species will eventually invade the perimeter of revegetated areas and over the long term initiate succession similar to that on adjacent lands.

Selected areas for wildlife habitat will be planted with native trees, shrubs, and forbs. On-going studies of the food, cover, nesting, watering, breeding, and migratory habits of local fauna should provide the basis for establishment of wildlife habitat.

Wetlands and riparian habitat cover a relatively small area (190 ha), but are particularly important for waterfowl and wildlife use. Where possible, these areas will be considered.

The perimeters of Hat and Finney Creek diversions, interceptor ditches, reservoirs, and water treatment lagoons will be revegetated as soon as possible following construction. An attempt at rehabilitating and re-establishing riparian habitat will be made based on conservation and re-use of fertile alluvial soils and the propagation and re-planting of dominant, characteristic native plant species.

To prevent overgrazing of revegetated lands and minimize the resultant potential for exposure of materials susceptible to wind and water erosion, fencing is considered essential. When vegetation is considered self-sustaining, grazing or browsing will be controlled and managed to prevent degradation of revegetated lands.

The potential for fire from spontaneous combustion of carbonaceous materials will be reduced on low-grade coal stockpiles by compaction and covering exposed material with a buffer material and surface soil. Coal blending stockpiles will be in place for approximately two weeks prior to conveying to the generating station, thus reducing the potential for combustion. Approximately 20% of the coal present within the blending area will be stockpiled and compacted. Additional protection will be provided from hydrant water supply throughout the storage yards, and equipment capable of excavating any burning coal. Research during the course of mining will determine the need for sealing carbonaceous material exposed in an abandoned open pit.

511.1 Disturbances

Estimates of the land areas disturbed by various mining activities are presented in Table 5-2. Surface area of disturbance at the end of pre-production, Year 15, and Year 35 total 528, 1257, and 1931 hectares, respectively.

511.2 Environmental Losses

The reclamation and environmental plan was based in part on identification of major environmental losses due to the proposed mine plan. Regional losses or land alienated but not disturbed between development areas were not considered. The distribution of major environmental losses among land disturbances and major land uses (agriculture, forestry, wildlife habitat, and wetland habitat) is summarized in Tables 5-3, 5-4, and 5-5, and is described below.

Agriculture

About 1408 hectares of Agricultural Land Reserve will be disturbed by the proposed mine plan. Class 3 agricultural land (428 hectares) will be distrubed primarily by the open pit. Grazing land (about 1255 hectares of Class G-2 and G-3) will be disturbed mainly in areas proposed for waste dumps and the open pit.

Forestry

About 1086 hectares of poor productivity forest land (MAI of 1 m^3/ha) will be disturbed by the proposed mine plan.

TABLE 5-2

Estimated Area of Disturbance (hectares)

(cumulative)

Hat Creek Project Mining Feasibility Report 1978

Disturbance		End of Pre-Production	Year 15	Year 35
Open Pit		105	506	606
Waste Dumps				
Houth Meadows		165	445	610
Medicine Creek		*	*	385
	sub-total	165	445	995
Stockpiles				
Low grade coal		*	17.2	17.2
Coal		26.4	26.4	26.4
Topsoil		4.3	9.1	13.6
	sub-total	30.7	52.7	57.2
Service Yards		107	107	107
Roads				
Pit perimeter		22.5	39.2	47.3
Main access		3.0	3.0	3.0
	sub-total	25.5	42.2	50.3
Conveyor Corridors				
Thermal Plant		14.0	14.0	14.0
Medicine Creek		*	6.0	6.0
	sub-total	14.0	20.0	20.0
Water Treatment Lagoons				
Main		9.0	9.0	9.0
Medicine Creek		*	2.0	2.0
	sub-total	9.0	11.0	11.0
Clearwater Reservoirs				
Headworks (upper)		6.1	6.1	6.1
Pit rim (lower)		8.8	8.8	8.8
	sub-total	14.9	14.9	14.9
Ditches		14.0	15.8	27.0
Stream Diversions				
Hat Creek		33.6	33.6	33.6
Finney Creek		8.9	8.9	8.9
	sub-total	42.5	42.5	42.5
	GRAND TOTAL	528	1257	1931

* not constructed

TABLE 5-3

Estimated Environmental Losses (hectares)
Hat Creek Project Mining Feasibility Report 1978

Losses	Open Pit	WASTE DUMPS Houth Meadows	WASTE DUMPS Medicine Creek	Service Yards	Stock-piles	Roads	CONVEYORS Thermal Plant	CONVEYORS Medicine Creek	DIVERSIONS Hat Creek	DIVERSIONS Finney Creek	Reser-voirs	Lagoons	Ditches	Total
Agriculture														
A.L.R.	590	215	293	107	53	50	7	6	34	9	15	11	18	1408
Class 3	174	61	0	77	50	17	7	2	32	0	6	0	2	428
Class 5	126	93	0	0	0	2	0	0	0	8	9	9	1	248
Class G-2	306	344	134	0	4	30	6	0	0	1	0	0	11	836
Class G-3	0	112	246	0	0	0	1	4	0	0	0	0	10	373
Class G-4	0	0	5	30	3	1	0	0	2	0	0	2	3	46
Total	606	610	385	107	57	50	14	6	34	9	15	11	27	1931
Forestry														
Open Range	423	188	125	0	17	3	4	2	3	9	15	11	5	805
Non-Productive	0	12	0	0	0	0	0	0	0	0	0	0	0	12
Poor	183	382	260	107	40	47	10	4	31	0	0	0	22	1086
Medium	0	26	0	0	0	0	0	0	0	0	0	0	0	26
Good	0	2	0	0	0	0	0	0	0	0	0	0	0	2
Total	606	610	385	107	57	50	14	6	34	9	15	11	27	1931
Wildlife Habitat														
Douglas fir-Pinegrass	60	310	131	14	40	20	4	3	12	0	0	0	17	611
Sagebrush Grass-land	363	157	0	0	10	2	0	0	6	0	4	4	2	548
Ponderosa pine-Douglas fir-Grassland	143	116	133	50	4	27	5	2	16	1	0	2	6	505
Mid-elevation Grassland	0	0	104	0	0	0	5	1	0	0	0	0	1	111
Low-elevation Grassland	2	0	0	6	0	1	0	0	0	8	6	0	1	24
Riparian*	38	0	0	0	3	0	0	0	0	0	5	5	0	51
Aspen	0	19	17	0	0	0	0	0	0	0	0	0	0	36
Bog	0	6	0	0	0	0	0	0	0	0	0	0	0	6
Rock	0	2	0	37	0	0	0	0	0	0	0	0	0	39
Total	606	610	385	107	57	50	14	6	34	9	15	11	27	1931
Heritage Sites														
* Surficial Sites	158	72	36	0	0	0	0	0	12	0	0	0	0	278
Estimated Site Area	7	9	0.6	0	0	0	0	0	0.5	0	0	0	0	17.1
Wetland Habitat														
Riparian Zone	107	0	0	0	3	0	0	0	0	0	5	5	0	120
Ephemeral Wetland Zone	0	65	0	0	0	0	0	0	0	0	0	0	0	65
* Ephemeral Ponds	2	2	0	0	0	0	0	0	0	4	0	0	0	8
* Intermittent Ponds	0	0	0	0	0	0	0	0	0	1	0	0	0	1
* Semi-Permanent Ponds	7	1	0	0	0	0	0	0	0	2	0	0	0	10
* Permanent Pond (Edge Vegetation)	0	7	0	0	0	0	0	0	0	1	0	0	0	8
* Permanent Pond (No Edge Vegetation)	2	1	0	0	0	0	0	0	0	2	0	0	0	5
Watercourses														
** Hat Creek	5	0	0	0										
** Finney Creek	3.2	0	0	0										
** Medicine Creek	0	0	5	0										
** Ephemeral Creeks (Houth)	0	2.5	0	0										
Lakes														
Aleece Lake	15													

* number of sites or ponds
** channel length in kilometres

Sources: Calculated from maps obtained from CBRC (1978) Agriculture, Reid-Collins (1978) Forestry, Tera (1978) Wildland and Wetland Habitat, Pokotylo and Beirne (1978) Heritage Resources

TABLE 5-4

Percentage Summary of Environmental Loss

Hat Creek Project Mining Feasibility Report 1978

		% of Total Disturbance			% of Total Disturbance
Agriculture	ALR	73	Forestry		
	Class G-2	43		Poor	56
	Class 3	22		Open Range	42
	Class G-3	20		Other	4
	Class 5	13			100
	Class G-4	2			
		100			
Wildlife Habitat			Wetland Habitat		
	Douglas fir-Pinegrass	32		Riparian Zone	6
	Sagebrush-Grassland	28		Ephemeral Wetland Zone	3
	Ponderosa pine-Douglas fir-Grassland	26		(Dryland - not applicable -	91)
	Mid-elevation Grassland	6			100
	Riparian	3			
	Rock	2			
	Aspen	2			
	Low-elevation Grassland	1			
		100			

TABLE 5-5

Percentage Distribution of Major Environmental Losses

by Mine Operation

Hat Creek Project Mining Feasibility Report 1978

Environmental Loss		Open Pit	Waste Dumps	Materials Storage Areas	Transportation Corridors	Support Facilities	Other	Total
Agriculture	A.L.R.	42	36	4	4	8	6	100%
	Class G-2	37	57	<1	4	0	2	100%
	Class 3	41	14	10	5	16	14	100%
	Class G-3	0	96	0	1	0	3	100%
Forestry	Poor	17	59	4	6	10	4	100%
	Open Range	53	39	2	1	0	5	100%
Wildlife Habitat								
Douglas fir-Pinegrass		10	72	7	4	2	5	100%
Sagebrush-Grassland		66	29	2	<1	0	3	100%
Ponderosa pine-Douglas fir-Grassland		28	49	<1	7	10	6	100%
Mid-elevation Grassland		0	94	0	6	0	0	100%
Riparian		75	0	6	0	0	19	100%
Wetland Habitat								
Riparian Zone		89	0	2	0	0	9	100%
Ephemeral Wetland Zone		0	100	0	0	0	0	100%

Wildlife Habitat

The major habitats affected by the proposed mine plan include 611 ha of Douglas fir-Pinegrass (waste dumps), 548 ha of Sagebrush-Grassland (open pit), and 505 ha of Ponderosa pine-Douglas fir-Grassland (open pit and waste dumps). Smaller areas of valuable habitat affected include 111 ha of mid-elevation grassland located in Medicine Creek Valley, and 51 ha of riparian habitat.

Watercourses and Wetland Habitat

Mining for 35 years will disrupt about 5 km of Hat Creek, 3.2 km of Finney Creek, 5 km of Medicine Creek, and Aleece Lake (15 ha). About 120 ha of riparian zone will be lost in diverting Hat Creek and approximately 65 ha of ephemeral wetlands west of the pit will be affected by the Houth Meadows dump and Finney Creek diversion.

511.3 Reclamation

Land areas which will be reclaimed throughout the mine area by the end of pre-production, Year 15, Year 35, and Year 45 are summarized in Table 5-6 and illustrated on Figures 5-3 to 5-6, respectively. Reclamation is done progressively during mining and is carried out as soon as any particular activity is completed. Any disturbed areas left inactive for a number of years will be temporarily reclaimed; none of these areas are indicated in tables or figures as their locations may change with minor alterations in mine planning during actual operations.

The area of land to be reclaimed by the end of pre-production, Year 15, Year 35, and Year 45 totals 71, 130, 705, and 1851 hectares, respectively, and is distributed on a percentage basis as follows:

TABLE 5-6

Estimated Area of Reclamation (hectares)
(cumulative)
Hat Creek Project Mining Feasibility Report 1978

Location		End of Pre-production	Years 15	Years 35	Years 45
Open Pit - top 3 berms		0.0	0.0	0.0	115
lower berms					491
					606
Waste Dumps					
Houth Meadows		2.0	38.0	380.0	610
Medicine Creek		*	*	212.0	385
	Sub-total	2.0	38.0	592.0	995
Stockpiles					
Low grade coal		*	8.6	17.2	17.2
Coal		0.0	0.0	0.0	26.4
Topsoil		4.3	9.1	13.6	13.6
	Sub-total	4.3	17.7	30.8	57.2
Service Yards		6.0	6.0	6.0	106.8
Roads					
Pit perimeter		5.0	10.0	15.0	15.0
Main access		1.0	1.0	1.0	1.0
	Sub-total	6.0	11.0	16.0	16.0
Conveyor Corridors					
Thermal Plant		7.0	7.0	7.0	14.0
Medicine Creek		*	3.0	3.0	6.0
	Sub-total	7.0	10.0	10.0	20.0
Water Treatment Lagoons					
Main		2.0	2.0	2.0	2.0
Medicine Creek		*	0.5	0.5	0.5
	Sub-total	2.0	2.5	2.5	2.5
Clearwater Reservoirs					
Headworks (upper)		2.0	2.0	2.0	2.0
Pit rim (lower)		4.0	4.0	4.0	4.0
	Sub-total	6.0	6.0	6.0	6.0
Ditches		3.0	3.5	6.5	6.5
Stream Diversions					
Hat Creek		27.0	27.0	27.0	27.0
Finney Creek		8.0	8.0	8.0	8.0
	Sub-total	35.0	35.0	35.0	35.0
	GRAND TOTAL	71.3	129.7	704.8	1851

* not constructed

Land Reclamation	% of Total Reclaimed Area Pre Production	Year 15	Year 35	Year 45
Open Pit	0	0	0	33
Waste Dumps	3	29	84	54
Materials Storage Areas	6	14	4	3
Transportation Corridors	18	16	4	2
Support Facilities	8	5	1	5
Other (Drainage Control)	65	36	7	3
	100	100	100	100

Attempts will be made to replace about 995 ha of grazing land and wildlife habitat on waste dump surfaces. Reclamation of the open pit could eventually provide wildlife habitat. Reclamation efforts adjacent reservoirs, lagoons, ditches, and diversions will provide about 50 hectares of riparian habitat. Clearwater reservoirs will be retained after mining to aid in regulation of downstream flow, flood control, and provide additional water for agriculture and fisheries. Reclamation of stockpiles, service yards, and transportation corridors (approximately 200 ha), will be devoted to forest land, wildlife habitat, and open range depending on specific location and elevation. Approximately 80 ha of land (refer Tables 5-2 and 5-6) are indicated as unreclaimed. This comprises those portions of roads (34 ha), lagoons (8.5 ha), reservoirs (9 ha), ditches (20.5), and diversion canals (7.5 ha) remaining after mining and on which no reclamation is carried out (i.e., water, active road surfaces, etc.).

SECTION SIX

ONGOING AND FUTURE STUDIES

SECTION SIX

ONGOING AND FUTURE STUDIES

In order to verify proposed methods of reclamation, the following studies are envisaged.

- that an overburden and waste sampling program be conducted during the initial years of mining to determine variation in chemical and physical characteristics with lithology and depth. Specifically the program should examine sodium adsorption ratio; exchangeable sodium percentage; exchangeable cations; pH, electrical conductivity; texture; moisture content; and the effect of mixing and dilution of non-sodic materials with sodic materials.

- that site specific research be initiated on materials representative of final waste during the early years of mining to determine the depth of buffer material and surface soil required to cover sodic waste in order to meet land use and productivity objectives.

- that monitoring of vegetative growth on field trial plots should continue in order to assess reclamation alternatives using site specific data. This program should also include evaluation of revegetation success at drill sites. This program should also include evaluation of sodicity of the growth media and nutrient and trace element content of vegetation grown on waste.

- that variation in quantity (biomass) and quality (nutrient and trace element content) of range and browse vegetation be determined in the proposed mine area. Revegetation objectives should be based on measured productivity.

- that selected chemical and physical properties of mapped soil units be determined to ensure that materials are suitable for use in reclamation. Particular attention should be paid to inactive and active slide areas and depressions at low elevations.

- that site specific research be conducted to determine methods of propagating local native plant species considered valuable for wildlife, and wetland habitat. These studies should be based on the requirements of the local fauna for food, cover, nesting, breeding, migration, etc.

- that site specific research be conducted to develop methods of reducing nitrogen and phosphorous fertilizer requirements for reclamation to reduce potential for eutrophication of receiving waters.

APPENDIX 1

PROJECT GUIDELINES

AND

SCOPE OF WORK

APPENDIX 1

PROJECT GUIDELINES AND SCOPE OF WORK

As part of the overall Scope of Work incorporated in a Contract For Services issued by the British Columbia Hydro and Power Authority (BCHPA), Section B, Subsection (ix) listed below, was applicable to the reclamation and environmental studies carried out. Authorization to proceed was received from BCHPA during June, 1977.

> "Incorporation into the planning activities land reclamation and revegetation schemes for the purposes of Section 8 of the Coal Mines Regulation Act, as at the date of the submission of the Mining Feasibility Report."

Following discussions between the Cominco-Monenco Joint Venture and BCHPA, expanded guidelines for reclamation and environmental matters were issued on 16 May 1978. These are reproduced in full on the following pages.

HAT CREEK PROJECT

Guidelines for Reclamation and Environmental Matters
in Accordance with Section B9(ix) of Appendix B
to Contract of Services dated 16 May 1978

The Cominco-Monenco Joint Venture Environmental Section will:-

1. (a) prepare a reclamation document which could be utilized as a prime submission (with related reports either as backup or appendices) to regulatory authorities.

This document will utilize existing reports, new data based on detailed mine planning, and environmental subconsultant reports.

As per Section 8 of the Coal Mines Regulation Act, the document will consider

(i) - location, nature and extent of the mine,

(ii) - nature and present uses of the land (this is assumed to include water),

(iii) - a program for reclamation and conservation regarding present and potential land use, agriculture, wildlife, watercourses (see e.g. appendix reports A1-6, BH2, C1-4, D1&2, E1&3 of Detailed Environmental Studies).

(b) examine requirements of all regulatory agencies including but not limited to: ELUC, Ministries of Mines and Petroleum Resources, Agriculture, Lands, Forest and Water Resources, Environment, Recreation and Conservation.

(c) assemble and integrate relevant data from detailed environmental subconsultants;

(i) - evaluate applicability of data or conclusions or both in light of mine planning,

(ii) - recommend and update data gap requirements where necessary.

(d) consider the alternatives and preferred method of:

   (i) - waste (liquid and solid) handling, placement and disposal,

   (ii) - topsoiling, contouring and grading,

   (iii) - revegetation,

   (iv) - aspects of the biophysical, social and economic environment related to the mine reclamation,

   (v) - cost of reclamation.

2. (a) assist and contribute to the mine engineering team (B.C. Hydro/CMJV) on matters of:

   (i) - assemble regulatory/environmental criteria for engineering,

   (ii) - detail regulatory permits/licences etc. relative to the environment,

   (iii) - assistance in environmental engineering problems (e.g. dust, water quality, waste, etc.), examination and selection of alternatives,

   (iv) - liaison between mine engineering and environmental subconsultants and environmental coordinator (on environmental matters or questions and mine planning).

(b) perform other such duties as may be determined and agreed upon from time to time.

APPENDIX 2

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REFERENCES

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APPENDIX 3

GLOSSARY

GLOSSARY

A.U.M.	- Animal unit month defined as one cow and calf or one 1120 kg steer grazing for one month.
activity day	- Number of days of the year that a geographic area is used for various types of recreation and used to measure the impact of recreation on the natural environment.
bank cubic metre - BCM	- An in situ volume of 1 m^3 or 1 m x 1 m x 1 m.
bentonite	- Is a clay formed from the decomposition of volcanic ash and is largely composed of the clay minerals montmorillonite and beidellite.
biophysical unit	- A broad geographical unit used for land classification and mapping based on landforms, soils, and vegetation.
B.O.D. 5	- The five-day biochemical oxygen demand used as an index for measuring oxidation of wastes in water.
cation exchange capacity	- The total quantity of cations which a soil can adsorb by cation exchange, usually expressed as milliequivalents per 100 grams. Measured values of cation-exchange-capacity depend somewhat on the method used for the determination.
C.O.D.	- The chemical oxygen demand used for measuring oxidation of wastes in water.

GLOSSARY (Continued)

cultural depression site - A non-natural depression, often with a mounded rim, usually thought to be the remains of occupation or processing/storage structures.

climax - A vegetation association that occupies a habitat indefinitely unless disturbed.

electrical conductivity - (EC) is directly related to the concentration of soluble salts in solution. EC of saturation extracts, expressed as millimhos per centimeter (mmhos/cm) at 25C is used for appraising the effect of salinity on plant growth. EC less than 2 is considered to have negligible effect upon growth of most species, 2 to 4 is considered slightly saline, 4 to 8 is moderate, 8 to 16 is severe, and values over 16 indicate very severe salinity.

eutrophication - Lakes termed eutrophic are those whose waters are relatively rich in plant nutrients, usually have much rapidly decaying organic mud on lake bottom and usually show reduced oxygen tensions in their waters in summer.

exchangeable cations - A cation that is adsorbed on the exchange complex and which is capable of exchange with other cations.

exchangeable sodium percentage - The degree of saturation of the soil exchange complex with sodium. It may be calculated by the formula:

$$ESP = \frac{\text{Exchangeable sodium (meq./100 gm soil)}}{\text{Cation-exchange-capacity (meq./100 gm soil}} \times 100$$

GLOSSARY (Continued)

filterable residue	- Total dissolved solids; portion of effluent which passes through an approved 0.45 micron pore-sized filter.
free interface settling rate	- The depth reached by the settling interface in a fixed time or time required for settlement of a suspension to a selected depth.
hummocky	- Lumpy, or in small uneven knolls.
hydraulic conductivity	- Is a measure of the water conducting capacity of a porous medium (such as soil). Specifically, it is the ratio of flow velocity to the driving force.
isotopic composition	- Content of deuterium, tritium, and oxygen-18 in water used to detect water origins, i.e., effect of precipitation, groundwater, and evaporation.
kaolinite	- A two-layer hydrous aluminum silicate clay mineral.
leachate	- Soluble salts and metals removed by percolating waters.
LEQ	- The "equivalent energy level" or average of noise energy received in several half-hour sampling periods.
lithic scatter site	- An archaeological site which consists of stone tools and debitage strewn on the land surface.

milliequivalent - (meq) refers to one-thousandth of an equivalent. Chemical substances react with each other on the basis of standard equivalent quantities rather than on an equal weight basis. An equivalent quantity of an element is its gram-atomic weight divided by its valence (or oxidation number). As an example, the common table salt, sodium chloride is made up of an equivalent of sodium (Na) which weighs about 23 grams and an equivalent of chloride which weighs about 35 grams.

montmorillonite - A group of clay minerals with deficiencies in charge in the tetrahedral and octahedral positions balanced by the presence of cations, mainly calcium and sodium, subject to ion exchange. They are characterized by swelling in water due to introduction of inter-layer water.

nonfilterable residue - Total suspended solids; portion of effluent discharged which is retained by an approved filter.

receptor - Biotic and abiotic samples collected for assessment of trace element accumulation.

riparian habitat - A wildlife habitat which corresponds to vegetation associations found near streams or oxbow remnants of streams. It is characterized by black cottonwood, willow, and other shrubs.

riparian zone - The alluvial floodplain adjacent a stream and area peripheral to lakes, ponds, and bogs.

GLOSSARY (Continued)

saturation percentage	- Is the amount of water required to saturate the material, expressed as percentage by weight, and is influenced by particle size (texture), organic matter content, and chemical and mineralogical composition. Values greater than 80 may indicate high clay content of montmorillonitic mineralogy, with high quantities of adsorbed sodium.
seral	- An adjective describing a temporary vegetation association or development stage in the sequence of succession.
sodic	- Refers to a soil or soil material that contains excessive amounts of adsorbed or exchangeable sodium.
sodium adsorption ratio	- (SAR) is an empirical relationship to express the relative activity of sodium ions in exchange reactions with soil which is in equilibrium with the soil solution. SAR is calculated by the formula: $SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$ Ionic concentrations are expressed in milliequivalents per litre (meq/l) of solution. SAR of saturation extracts is usually highly correlated with, and approximately equal to, exchangeable sodium percentage, ESP, over the range commonly found in soil materials. Values greater than about 10 to 15 indicate potential management problems.

GLOSSARY (Continued)

specific conductance	- A measure of salinity in water usually expressed in micrommhos/cm.
T.O.C.	- Total amount of organic carbon present in water.