B.C. HYDRO

A REVIEW OF SURFACE AND SUBSURFACE HYDROLOGY
OF THE HAT CREEK VALLEY
NO. 1 DEPOSIT

MINING DEPARTMENT

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SECTION 1.0 - INTRODUCTION

Hat Creek Valley has a highly developed drainage system comprised of creeks, lakes, ponds and groundwater flow. The principle creeks flowing through the deposit which may influence coal mining are Hat Creek, Medicine Creek, Houth Creek and Finney Creek. There are about 80 small lakes and ponds associated with slide debris and till to the west side of the Hat Creek Valley. To the east of the valley where gravels predominate, there are relatively fewer lakes and ponds. The study of groundwater movement in the Hat Creek Valley particularly in the No. 1 Deposit, and its effect on slope stability of the proposed 2000 MW pit and of the waste dumps was initiated by Golder Associates in 1976.

These studies continued during 1977, 1978 and 1979 programs, with more detailed pumping tests to characterize the drainability of various stratigraphic horizons and materials encountered in the course of pit development.

In order to study the pattern of groundwater flow through various stratigraphical units, piezometers were installed in boreholes drilled for exploration, geotechnical or hydrological studies.

The piezometers were extended to various depths to monitor the flow through one or more stratigraphical horizons.

Pump tests in specially drilled holes were monitored by observation wells to determine the drainability of the material and provide information on dewatering and depressurization for geotechnical stabiltiy in the pits.

This report summarizes the surface and subsurface hydrology of Hat Creek Valley based on B.C. Hydro's Consultants reports and reassesses its impact on the mine drainage system.

SECTION 2.0 - HYDROGEOLOGY OF THE HAT CREEK VALLEY

2.1 METHOD OF STUDY

Under the geohydrology program the following short and long term hydrological testing and monitoring plans were laid out:

1. Installation of piezometers in the hydrological, geotechnical and exploration holes drilled under 3A, 3B and 3C programs, and monitoring the water levels over next few years until stabilization occured. This provided the pattern of groundwater flow in the Hat Creek Valley.

2. Falling head tests in the piezometers to assess the permeability of representative materials.

3. Pumping test execution to assess the drainability of the material in the proposed pit vis a vis dewatering and depressurization for embankment stabilty.

(a) Piezometer Installations

Since 1976, over 227 piezometers of pneumatic and standpipe type were installed in 137 boreholes uniformly distributed throughout the deposit. As a measure of in situ permeability, 'falling head' tests were conducted in some of the piezometers. All piezometric levels have been monitored continuously over the last five years.

Based on these studies the following broad conclusions are drawn (Golder Assoc. 1979):

1. The hydraulic conductivities of the various lithologic units differ three orders of magnitude and are related to facie changes within formations and possibly to structural features such as faults and joints.

2. The piezometric heights reflect the seasonal variation of water tables during the Fall and Spring depending on the permeability of the rocks.

3. Such piezometric responses are common to more permeable surficial materials as well as to the much less permeable bedrock.

(b) Pump Test

To date, a total of 13 pumping tests have been carried out (Fig. 1). Seven of these were to determine the hydraulic conductivity (a measure of permeability) and co-efficient of consolidation (a measure of depressurizability) of various bedrock lithologic units. The remaining six pump tests were carried out in 1981 in conjunction with "The Hat Creek Construction Water Supply" study. A brief summary of the results in each lithologic unit tested follows and the data for all pump tests is summarized in Table 1.

(i) Hat Creek Coal Formation

A. A Zone Coal

Pump test W78-2 located in RH 78-75 at the centre of the deposit southeast of Trench A was utilized to test the permeability of A zone coal. The initial pumping rate of

TABLE 1
SUMMARY OF RESULTS OF HYDROGEOLOGIC FIELD TESTS ON LITHOLOGIC UNITS

		HYDRAULIC CONDUCTIVITY RESULTS FROM FALLING HEAD TESTS (m/s)				PUMPING TEST RESULTS	
		NUMBER OF TESTS	RANGE		MEDIUM VALUE	HYDRAULIC CONDUCTIVITY m/s	COEFFICIENT OF CONSOLIDATION (c_v) (m^2/yr)
FORMATION	LITHOLOGIC UNIT		FROM	TO			
Medicine Creek Formation	Upper Siltstone Claystone (Tcu)	13	1×10^{-12}	3×10^{-8}	1×10^{-10}	1×10^{-10} (W76-1) 4×10^{-11} (W77-4)	<10 (W77-4) 400* (W77-3)
Hat Creek Coal Formation	A zone siltstone and coal (Tcc)	6	1×10^{-11}	3×10^{-10}	4×10^{-11}	9×10^{-9} (W78-2)	-
	B zone coal (Tcc)	3	2×10^{-7}	5×10^{-7}	4×10^{-7}	-	-
	C zone siltstone and coal (Tcc)	13	3×10^{-11}	3×10^{-8}	1.4×10^{-10}	-	-
	D zone coal (Tcc)	12	6×10^{-9}	1×10^{-6}	5×10^{-7}	6×10^{-11} (W77-1)	<45 (W77-1)
Coldwater Formation	Lower Siltstone - Sandstone-Conglomerate (Tcl)	15	2×10^{-11}	5×10^{-9}	8×10^{-11}	5×10^{-12} (W77-2)	500* (W77-2)
	Conglomerate (Tco_1)	4	9.5×10^{-11}	2.9×10^{-9}	1.3×10^{-10}	-	-
Marble	Limestone	7	1.2×10^{-9}	1×10^{-4}	3×10^{-8}	-	-
Unnamed	Basalt	5	2.3×10^{-11}	1.8×10^{-4}	7×10^{-9}	-	-
Canyon Formation	Greenstone	5	4×10^{-10}	5×10^{-7}	1.8×10^{-7}	-	-
	Surficials overlying Marble Canyon Formation					3.7×10^{-6} OW1+ 2.4×10^{-5} OW2+ 5.1×10^{-5} OW3+ 2.16×10^{-5} PW2+	

*These values were calculated using some assumptions and may be rather high.
+Average of Theis and Jacob method
Note: No values available for PW1, OW4, OW5, and W78-1.

0.1 ℓ/s had to be reduced to 0.03 ℓ/s before stabilization occurred. The estimated average hydraulic conductivity is 3×10^{-9} m/s.

B. D Zone Coal

Pump test W77-1 was carried out in RH 78-67 located southwest of Trench A. Low yields from constant pumping resulted in a bailing method being adopted. A very low hydraulic conductivity of 6×10^{-11} m/s was recorded.

Piezometers indicate a piezometric surface to be approximately 50 m below ground surface. Vertical hydraulic gradients indicate that water flows towards the lower half of D zone (D_3 - D_4) from the Upper D zone (D_1 - D_2) and from the Coldwater Formation, underlying the D zone coal.

(ii) Medicine Creek Formation

The siltstone-claystone unit overlying the Hat Creek Coal Formation was pump tested in two locations. Pump test W76-1 in RH 76-19 located in the south part of the pit, showed very low permeability. An initial pumping rate of 1 gpm had to be reduced to 0.10 gpm after the first day. A second pump test W77-4 in RH 78-70 located to the east of the Finney fault also verified low permeability with the average hydraulic conductivity of 4×10^{-11} m/s.

(iii) Coldwater Formation

Pump test W77-2 was conducted in hole RH 77-59. Two previous attempts to drill pump wells for this test had to be abandonned due to caving and squeezing of the holes.

Extremely low flows were apparent and consequently a bailing method was adopted. An average hydraulic conductivity value of 5×10^{-12} m/s was calculated for this unit. A second pump test W78-1 in RH 78-77 yielded similar results.

(iv) Surficials

Pump test W77-3 was carried out in RH 77-58 close to the location of W76-1. To confirm a 10 m thick semi-confined aquifer, a 33-day test using a submersible pump at a pumping rate of 1.9 ℓ/s was carried out. This yielded a hydraulic conductivity of 4×10^{-6} m/s for the sediments.

It is evident from these low hydraulic conductivities in the various geological formations that water flow through them will be restricted and very limited.

2.2 GROUNDWATER FLOW PATTERNS IN HAT CREEK VALLEY

The groundwater regime in the upper Hat Creek Valley is characterized by recharge in the uplands, generally above El. 1300 m and discharge in the valley bottom. The recharge zones is assumed to extend approximately 2 km towards Hat Creek from a groundwater divide in the upland areas on both sides of the valley. Between 7 and 13 percent of the mean annual precipitation on the upland areas infiltrates through thin surficial sediments to the groundwater table in volcanic, granodiorite or limestone bedrock. Most of the groundwater flow occurs through surficial deposits, while less than 2 percent of the total groundwater flows through bedrock and clastic sediments.

In the vicinity of the pit, flow towards the valley occurs in an east-west direction, generally following the dip of topography (Fig. 2).

(a) Bedrock Flows

Flow systems in the low permeability bedrock are extremely complex and the quantity of flow and piezometric head distribution are controlled by the hydraulic conductivities of the rocks and tectonic features. Fig. 3 shows piezometric contours in relation to the tectonic features.

The flow pattern through these rocks in the north and south sector of the pit are illustrated in Fig. 3 and 4, respectively.

Section A-A, in the northeast sector (Fig. 4) shows the groundwater flowing almost vertically upwards into the surficials, where the flow becomes horizontal. Only a small component of the flow is directed towards Hat Creek.

Section B-B (Fig. 4) shows the flow of groundwater in the Houth Meadows area, northwest of the pit. Here the groundwater flows from the valley sides towards discharge zones in the centre of the valley. The groundwater table approaches the ground surface in the central eastern part of the valley (Fig. 3). The discharge of groundwater is either to Houth Creek or eastwards through limestone bedrock and low permeability surficial sediments.

The presence of white powdery evaporite salt seen along the southern side of the Houth Meadows and around Houth Lake indicates the groundwater discharge zone. The seepage rates are estimated to be approximately 10^{-6} m^3/s per metre along the length of the valley.

The seepage rates are considerably lower (about 10^{-9} m^3/s per metre) in the southern side of the meadows, consequently the rate of deposition of salt is higher in these areas.

In the southern section of the pit (Fig. 5), the flow of groundwater shows a very different pattern. In this section groundwater flows up from the Coldwater Formation through the Hat Creek Coal Formation and horizontally through the Medicine Creek Formation to the centre of the valley. Where intersected by faults the groundwater flows up to the surficials and then horizontally to the lower gradient. The flow patterns have indicated a downward piezometric gradient in the centre of the valley diverting the groundwater away from the Hat Creek and down the valley.

In the general vicinity of Houth Meadows recharge of groundwater occurs via a limestone unit (Marble Canyon Formation). A groundwater divide is located north of Houth Meadows. South of this divide groundwater flows eastward through cracks, fissures and solution cavities in the competent limestone and low permeability surficial sediments discharging into Houth Creek or in the form of seeps creating swampy areas.

High seepage rates in the limestone to the north of Houth Meadows 10^{-6} m^3/s create the swampy areas which persist year round and contribute to the base level flow of Houth Creek.

Low seepage rates in southern Houth Meadows allow water to be evaporated, leaving only the concentrated salt deposits. Consequently the southern arm of Houth Creek dries up every year.

North of the divide, groundwater flows through the limestone unit and is intercepted by the surficial sediment aquifer system of the valley bottom. This system conveys the groundwater to the east and eventually to Hat Creek.

Except for the northeast corner of the pit and the valley bottom, average vertical hydraulic gradients (a measure of vertical conductivity) for the bedrock units are low, less than 0.10, and the vertical piezometric levels are close to hydrostatic level at that point. This indicates that there is very little vertical flow of groundwater within the area.

(b) Flow Patterns in Surficials

Although surficial deposits in general account for roughly 98 percent of the total groundwater flow (5×10^{-6} m^3/s per metre along length of valley) in the Hat Creek Valley, inconsistencies and local patterns are controlled by the variation in the material of the surficials.

The pre-mining water table follows the topography and is at or near the surface in the Hat Creek Valley bottom. However, due to the varying thicknesses and permeabilities of surficial materials the water table in places is above ground level in the western sector and below (up to 100 m) in the eastern sector.

Surficial material thickens eastward and varies from slide debris, till and glacial fluvial material in the western sector to gravels and fine sands in the eastern areas.

The thicker surficials to the east have a moderately high hydraulic conductivity and are consequently better drained. The groundwater discharges through the surficials into Hat Creek. In the western sector, the groundwater flow through the glaciofluvial sediments are interrupted due to the presence of thin interlayered till. The resulting poor drainage finds surface expression in springs an seeps. The presence of the till also tends to develop a confined aquifer building up high pressure and large volume of groundwater. In the southwestern sector, RH 76-16 and RH 76-18 at a depth of 24.5 m encountered up to 50 gpm water during drilling. High pressures and unusually large volumes of groundwater flow suggest that this anomally is highly localized and is confined either by faulting or/and impervious till interbeds.

(i) Aquifers

Three main acquifer systems exist in Hat Creek Valley. A discontinuous alluvial Hat Creek Valley acquifer exists along Hat Creek, while the second, Deep Valley aquifer system exists in the northeastern area of the pit. The third, Marble Canyon Valley acquifer system is confined to the surficials overlying the Marble Canyon Formation in the northern sector of the valley.

A. Hat Creek Valley Aquifer

This aquifer underlies the present Hat Creek. Due to the downward piezometric gradient in the upper section of Hat Creek, the alluvial aquifer is recharged by Hat Creek.

Progressing northwards along Hat Creek, the piezometric gradient reverses and in areas where the alluvium is absent groundwater discharges into Hat Creek. However, where alluvium exists the system is somewhat more complex. In general, water discharges through the alluvium aquifer into Hat Creek with some localized areas where the creek recharges the aquifer.

Various local flow patterns and independent catchment basins exist in the Hat Creek Valley bottom. Small lakes and ponds with impervious basements and high concentrations of the salts resulting from the evaporation of surface and groundwater suggest individual catchment basins.

In areas with more impervious basements, the surface outlets are evidence of discharge regions. Houth Meadows is a good example with its salt deposits and swampy areas.

B. Deep Valley Aquifer

A second aquifer system exists in the northeastern area of the pit. Perhaps formed by a pre-glacial channel this northward dipping deep "valley aquifer" system extends north south with its centerline on the 99500 (approxi-matley) east co-ordinate and reaches maximum width of approximately 600 m (Fig. 1). The aquifer consists of alluvium from a pre-glacial stream or glacial meltwater channel and has a maximum thickness of 250 m at the northern perimeter of the pit. The average thickness of the aquifer below the 834 m elevation of the water table is 100 m. The water table in hole RH 78-870 and the recent hydrologic hole 82-102 remained unchanged, at 110 m depth or 855.4 m elevation. The thickness of the aquifer appears to be 182.0 m. While drilling hole RH 102 a flow of cold gas was detected. Field tests indicated the presence of CO_2 in the gas. Further investigations regarding the composition, temperature ranges and gas flow rates are being conducted.

The hydraulic gradient of this aquifer in the north indicates that the groundwater discharge occurs through the alluvium into Hat Creek (Fig. 1). Suggestions that Hat Creek recharges this "valley aquifer" are not supported by hydrologic projections.

Groundwater flowing down from the eastern slopes and seepage losses from Harry Creek, which drains the eastern uplands, recharge this deep "valley aquifer". Due to the water losses to the valley aquifer system, the lower portions of Harry Creek dry up during the summer months. Although the vertical hydraulic gradient in the bedrock underlying th alluvium reaches values of 0.6, the low vertical hydraulic conductivity (10^{-12} m/s) renders the bedrock a relatively insignificant source of recharge.

Two drillholes in the center of the deep valley, DH 78-284 and RH 78-879 show the average hydraulic conductivity for the saturated zone of this aquifer to be 10^{-7} m/s with corresponding groundwater flow of 6×10^{-3} m/s across the valley. This aquifer system may provide a subterranean conduit for substantial flows.

C. Marble Canyon Valley Aquifer

A third aquifer, "Marble Canyon Valley" was recognized while drilling for potable and concrete batching water supply under the Hydrological Investigation Program of 1981.

Three potential aquifers were encountered during drilling beyond the northern limits of the 2240 MW 35-year pit, at the eastern limit of Marble Canyon. Three holes OW1, OW2 and OW3 (Fig. 1) penetrated the shallow upper aquifer between 20 and 26 m depth. The same aquifer was intersected at a shallower depth in OW5 (Fig. 1), east of Hat Creek. A second, deeper, gravelly coarse sand zone was intersected at a depth of 30 to 32.6 m by OW2 only. The third potential aquifer was intersected at a depth of 50 to 55 m by OW1.

Observation well, OW4 (Fig. 1), at the junction of Houth Creek and Hat Creek, penetrated a thick sequence of silty clays overlying an artesian sand and gravel aquifer between 67.4 and 110.4 m depth. The high rate of flow, 237 U.S. gpm, and the hydraulic head of 3 to 4 m, appeared to be capable of meeting the required water supply, however, stabilization did not occur during pumping, indicating slow recovery.

Hydrological Investigation 1982 was planned to determine whether this aquifer system was related to Hat Creek aquifer or to Marble Canyon system. Indications are more in favour of the latter. This investigation was cancelled due to budgetry constraints.

(ii) Artesian Zones

In course of drilling programs and by surface observations, four highly localized artesian areas (Fig. 1) were found to exist in Hat Creek.

In DDH 78-246 located at the southern periphery of 2240 MW pit, the piezometric water level is higher than the ground elevation of 994.1 m. Over the last four years, the water table has been constantly decreasing and current observations of 1982 show the water table to be at 990.25 m, which is below the ground elevation. This may indicate very slow permeability. The indicated artesian condition may have been a temporary phenomenon.

Borehole 78-846, to the east of the proposed pit, did indicate artesian conditions, but obervation over the number of years have indicated constant lowering of water table.

A third artesian zone was indicated in the vicinity of RH 78-859, in the lower Medicine Creek Valley.

The fourth and the most pronounced artesian condition is indicated around RH 77-52 and RH 77-61A in Dry Lake Area. The flow of artesian water is continuous. This region is topographically low surrounded by bedrock of low hydraulic conductivity and overlain by about 55 m of highly permeable unconsolidated burn zone sediments. The base of this burn zone material is 50 m below the level of Hat Creek. The groundwater is extremely saline suggesting very little flow below the level of Hat Creek. However, equal potential lines around the area indicate that there is substantial flow beyond the capacity of evaporation, and, therefore, a goundwater channel must exist just below the water table.

In hole DDH 76-150 drilled earlier in the vicinity of Dry Lake, the piezometric level showed an extremely low hydraulic head of 797 m (793.5 m in 1982) which is consistent with subsequent observations in RH 77-61A and follows the same general trend. The shape of the piezometric surface is indicative of a highly localized groundwater sink where water flows downwards into a more permeable zone, only to flow out again via an underground channel.

2.3 MODEL OF THE COAL BASIN

As a result of all the work done by Golders, three hydrogeologic units have been identified in the vicinity of the pit:

1. The surficials.
2. Coal.
3. Clastic sediments above and below the coal.

The surficials represent the major water bearing unit with an average hydraulic conductivity of 10^{-6} m/s. The coal unit has highly variable hydraulic conductivities appearing to be dependent on the ash content, cracks and fissures, rank and texture. Falling head tests indicate the coal in the low ash B and D zones is up to four times more permeable than A and C zones.

There is little difference between the hydraulic conductivities of the Medicine Creek Formation and the Coldwater Formation, the clastic sediments which lie above and below the coal. The average hydraulic conductivity for the virtually impermeable claystones, sandstones, siltstones and conglomerates of these formations is 5×10^{-11} m/s.

Recharging of the more permeable coal beds is hindered by the overlying and underlying impervious beds as well as the interlayered bentonitic bands. The synclinal structure of the Hat Creek basin with Coldwater Formation abutting against the Marble Canyon limestone to the north (Fig. 6) reduces the hazard of large water flows into the coal.

SECTION 3.0 - MINE DRAINAGE SYSTEM

To principal sources of water effecting the proposed mine development are:

1. Direct precipitation and runoff.

2. Creeks flowing through the mine site.

3. Surface water in lakes and ponds.

4. Groundwater flow through the bedrocks, joints, faults, cracks and fissures, and the surficials.

5. Mine Waste Water - runoff and leachate from coal handling areas, waste dumps etc., and runoff and seepage from coal and bedrock strata within the open pit.

Since detailed discussion of these factors has been presented in Cominco-Monenco's Report on Mine Drainage, only a brief reference will be made here.

3.1 DIRECT PRECIPITATION AND RUNOFF

Hat Creek lies in a semi arid zone with an average rainfall of 317 mm/y, of which about 174 mm (55 percent of total) is received in form of rain and the rest in snow. Of this, about 16 percent is recorded as stream flow in Hat Creek at the Mine Site, the rest is lost to evapotranspiration and to subsurface runoff.

Such meager quantities of water flowing through Hat Creek can be easily controlled or diverted for practical mining operation.

3.2 CREEKS

Of the several creeks flowing through the Hat Creek Valley, the principals ones are Hat Creek, Medicine Creek, Houth Creek and Finney Creek. There location and watersheds are shown in Fig. 7.

Hat Creek flowing through the proposed mine is likely to have pronounced influence over the development of the pit. The mean flow at the lower level, in the proposed pit, is 0.72 m^3/s and in the summer months a flow as high as 14.64 m^3/s has been recorded. This flow is related to the spring thaw and the more constant flow during the winter months stems from ground water.

In the Upper Hat Creek Valley. Hat Creek discharges water into the groundwater system due to the groundwater level being below the Creek level. Downstream, near the pit areas, water from the surrounding surficials flows into the Creek - recharging it.

Finney Creek, a tributary of Hat Creek has its origin up in Mt. Martley and passes through Finney Lake, lying in the western section of the pit. It has an average annual discharge of approximately 0.03 m^3/s which is about 4.3 percent of Hat Creek discharge.

The other creeks related to the general hydrological system, and having influence over the proposed pit are Anderson Creek, Ambusten Creek and Medicine Creek.

They are discussed in detail in the Monenco Consultants Pacific Ltd.'s "Report on Hat Creek Diversion Study 1977", B.C. Hydro's Report "Diversion of Hat and Finney Creeks" March 1978 and in "Report on 1981

Site Investigation for Hat and Finney Creek - Diversion and Access Road" March 1982.

3.3 SURFACE WATER IN LAKES AND PONDS

Due to the low permeability of the overburden, consisting mainly of slide debris and till, there is an abundance of lakes and ponds on the west side of Hat Creek Valley as compared to the east side.

These water masses, appear to be responsible for the development of active and inactive slides. The bentonitic clays when saturated lose their strength resulting in failures.

As a stabilization measure, Aleece Lake and 61 other lakes and ponds will be drained to reduce recharge of water to the slide area groundwater system. Finney Lake and 15 other small ponds located in a more stable area will be monitored by piezometers for any change in groundwater condition during mining.

3.4 GROUNDWATER

Groundwater movement depends on the hydraulic characteristics of the various lithologic units, the elements of tectonics like joints, cracks, fissues and faults.

The specific nature of coal, its rank, ash content, thickness, nature and type of interlayered wastebands, lateral gradation into carbonaceous shale, etc. have significant influence over groundwater movement. Individual conductivities through various litho-units has been discussed in Section 2.0.

Fig. 8 showing northwest-southeast and northeast-southwest cross-sections of the pit indicate the possibility of groundwater flow into the ultimate 35-year pit and the critical effect on the waste dumps.

3.5 MINE WASTE WATER

Runoff from coal handling areas, waste dumps of sorted materials of various leachate character, mine service area waste, etc. characterize mine waste water.

Seepage and runoff from coal and waste horizons within the pit is expected to be similar to the stockpile and dump effluents.

SECTION 4.0 - DRAINAGE OF THE MINE DEVELOPMENT

For safe operation in the pit and for pit slope stability which is directly related to the surface and groundwater movement pattern, a series of measures are proposed. (Cominco-Monenco Report Vol. IV, Mine Drainage). These measures continue from pre production stage to the final stage.

4.1 DIVERSION OF HAT CREEK AND FINNEY CREEK

These creeks located in the upper valley must be diverted to prevent flooding of the excavation. Extensive studies on various alternatives have been conducted by Monenco 1977, BCH-HEDD 1978 and 1982. It comprises a headworks dam with a Canal intake and an emergency spillway located immediately downstream of Anderson Creek; a diversion canal on the east side of the Hat Creek Valley; a buried conduit with intake and outlet works to convey the flows back to Hat Creek. All seepage and local inflow immediately upstream of the pit will be intercepted by a pit-rim dam, spillway, pumphouse and pipeline between the headworks dam and pit.

The proposed Finney Creek Canal will divert Finney Creek flows south along the west side of the Hat Creek Valley and discharge to the Hat Creek Diversion headworks pond.

Further work on various alternatives of Hat Creek Diversion is being currently undertaken by Golder Associates.

4.2 PERIMETER DRAINAGE

A network of open perimeter drainage ditches is envisaged to intercept small amounts of local surface runoff.

4.3 IN-PIT SURFACE AND GROUNDWATER DRAINAGE

(a) Surface Water and Seepage Drainage

Two levels of flow are anticipated in the open pit:

1. Runoff and seepage from surficial material above the mine mouth (El. 895 m) which is uncontaminated.

2. Runoff and seepage from bedrock (and coal).

Runoff from above the mine mouth will flow by gravity to the north end of the pit where it will be collected and discharged to sedimentation lagoons to the north of the pit.

Runoffs from surficials below the mine mouth will be collected by bench drains and routed to small pump sumps. Once pumped to main sump they will be directed into a leachate lagoon.

Runoffs and seepage from coal and bedrock strata in the base of the pit will drain by bench drains to sumps located near the main pit access.

(b) Groundwater Drainage

A groundwater withdrawal program is planned to control the groundwater entering into the pit. This program comprises two stages of water well drilling.

1. Starting in year 5, two systems of wells should be drilled; 25 wells at 50 m depths within the ultimate pit perimeter, and 10 to 15 extra perimeter wells averaging 300 m depth.

   All wells to be drilled 150 mm diameter and cased.

2. From year 10 through 15, 75 pairs of wells, one shallow at 50 m and one deep at 300 m will be drilled beyond the projected perimeter of 35-year pit.

   These wells are expected to yield an average of 0.017 m^3/s or 1470 m^3/d. Most of this well water will be coming from surficials and should be of suitable chemical quality for discharge into Hat Creek.

   Where the water is pumped from coal or clastic sedimentary rock, it may not be suitable for direct discharge into Hat Creek, and may have to be treated before being discharged.

4.4 WASTE DUMP DRAINAGE

The development of the two waste dumps: Houth Meadows and Medicine Creek has been discussed in detail in Cominco-Monenco Report Vol. IV Section 3A.

SECTION 5.0 - SLIDE AREAS VIS A VIS GROUNDWATER

Stablization of slide areas to a large measure, depends on preventing the surface water from recharging the slide groundwater system and dewatering the groundwater.

As mentioned earlier, it is proposed to drain approximately 62 small lakes and ponds in the western side of the valley in the years prior to coal production.

The dewatering of the groundwater will be effected by open drain system running along the perimeter of the possible slide zone.

Provision has been made for installation of a 20 well system and piping the water to appropriate water channels.

A detailed description and layout this drainage system is described in Cominco-Monenco Report Vol. IV, Section 3A.

SECTION 6.0 - CONCLUSION

A review of the various reports by consultants conducting Hydrological Studies and Hat Creek - Finney Creek Diversion Studies suggest that neither surface water flow through the Creeks, ponds and lakes, nor the groundwater flow through the subsurface beds is likely to cause any serious problem in pit development. However small flows from entrapped pockets of water within coal beds should be expected.

The general hydrology of Upper Hat Creek indicates that the Coldwater Formation and the Medicine Creek Formation have relatively low permeabilities as compared to coal in the Hat Creek Coal Formation and the Kamloops Volcanics. Although the glacio fluvial sands and gravels are permeable, their continuity over any significant distance has been uncertain in spite of the intensive drilling undertaken during exploration and geotechnical programs.

Thus, the hydrological characteristics of these major rock units comprising the Hat Creek Basin are not likely to cause any major water seepage into the proposed pit.

The boundary fault system which brings the semi-permeable Marble Canyon Formation of Permian Period in juxtaposition with the impervious Coldwater Formation of Tertiary Period forms a natural impervious buffer. Any flows from the north, therefore, is highly improbable.

Within the Hat Creek Basin itself the horst-graben fault system brings the overlying impervious Medicine Creek in contact with the less impervious Hat Creek Coal Formation obstructing the flow of groundwater. However, it is possible that in a few areas trapped water acquifers may provide outbursts of waterflows, gradually diminishing to dry condition.

Extensive drilling and piezometric studies within the Hat Creek Basin have not indicated any major water flow problems in the proposed pit.

However, during the course of excavation of Trench D in 1982 pockets of entrapped water with varying pH values were encountered. The flow of these waters diminished gradually, none the less, they hindered the movement and operation of rubber-tired equipment. In planning the haul roads within the pit, it is critical that the clay sections be either covered with suitable material or avoided if possible.

Studies are being continued in 1982 Hydrological program to establish and relate the various acquifer systems present in the Basin.

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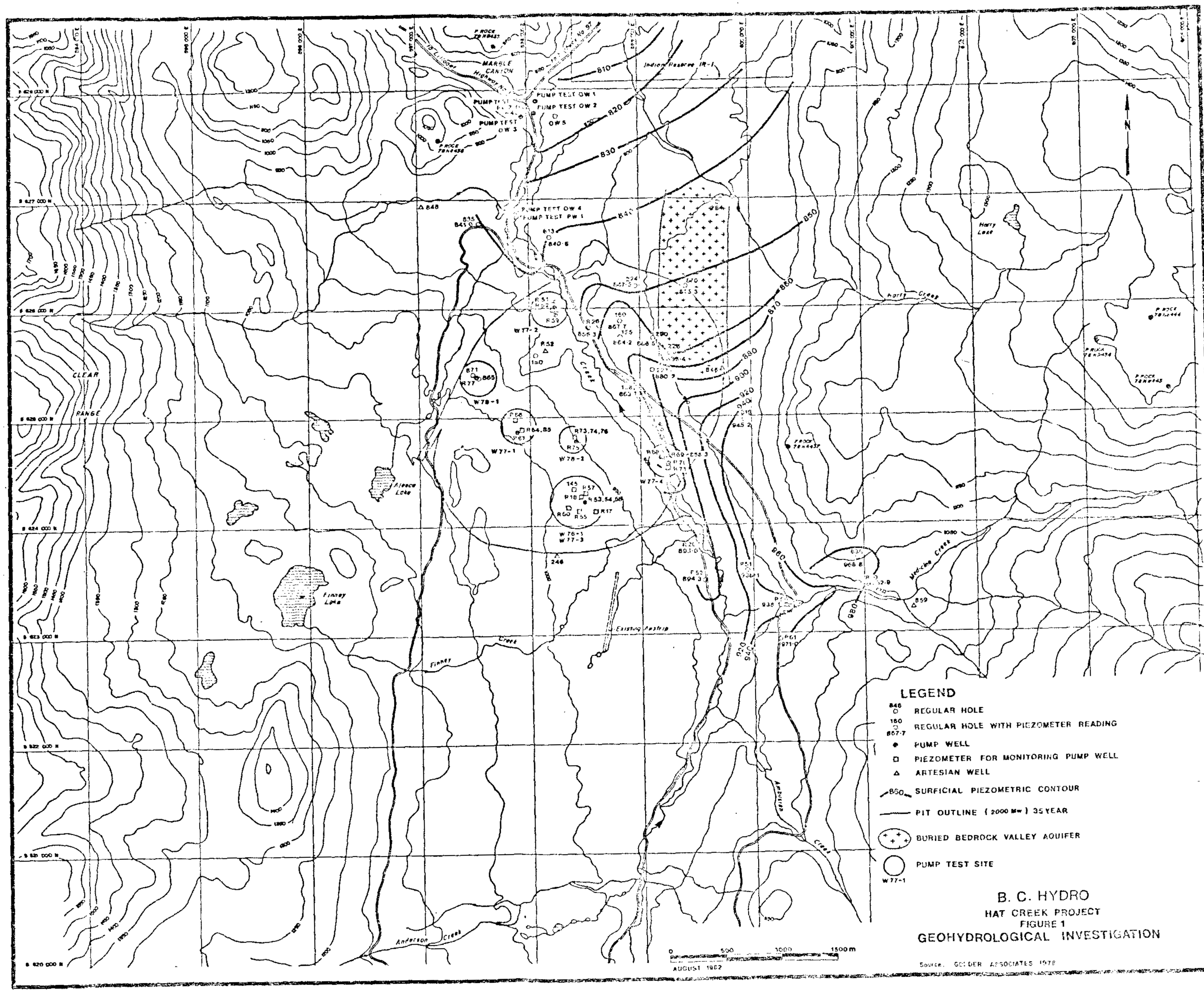
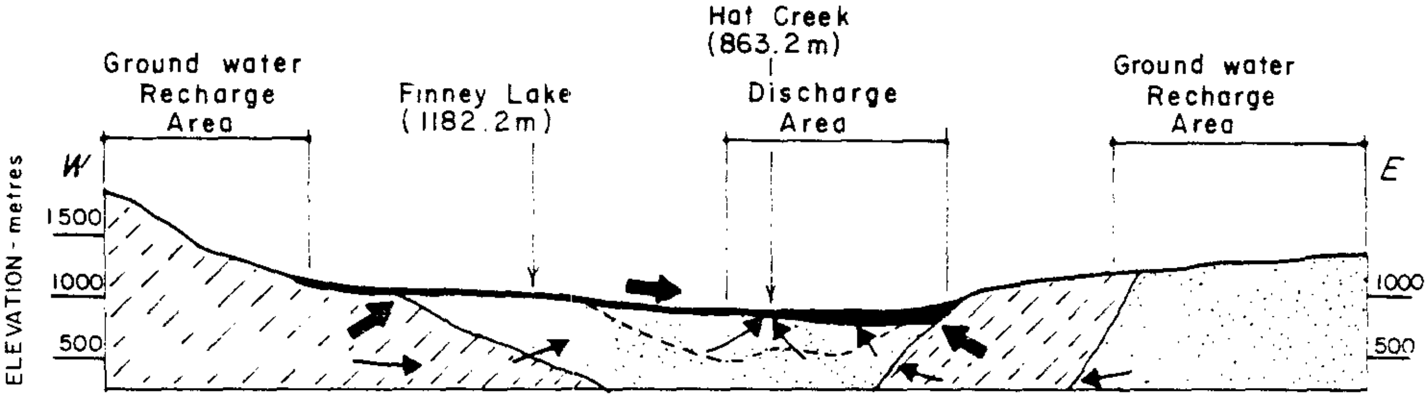


LEGEND
REGULAR HOLE
REGULAR HOLE WITH PIEZOMETER READING
PUMP WELL
PIEZOMETER FOR MONITORING PUMP WELL
ARTESIAN WELL
SURFICIAL PIEZOMETRIC CONTOUR
PIT OUTLINE (2000 Mw) 35 YEAR
BURIED BEDROCK VALLEY AQUIFER
PUMP TEST SITE
B. C. HYDRO
HAT CREEK PROJECT
FIGURE 1
GEOHYDROLOGICAL INVESTIGATION
AUGUST 1982
CLEAR RANGE
MARBLE CANYON
Indian Reserve IR-1
Harry Lake
Harry Creek
Medicine Creek
Finney Lake
Finney Creek
Aleece Lake
Anderson Creek
Ambusten Creek
Existing Airstrip
PUMP TEST OW 1
PUMP TEST OW 2
PUMP TEST OW 3
PUMP TEST OW 4
PUMP TEST PW 1



NATURAL SCALE

LEGEND:

Rocks with relatively high hydraulic conductivity (greater than 10^{-7} m/s.)

Rocks with relatively low hydraulic conductivity (less than 10^{-7} m/s.)

Surficial sediments

Low rate of groundwater flow

Higher rate of groundwater flow

(863.2m) Approx. elevation of water surface

Outline of proposed pit

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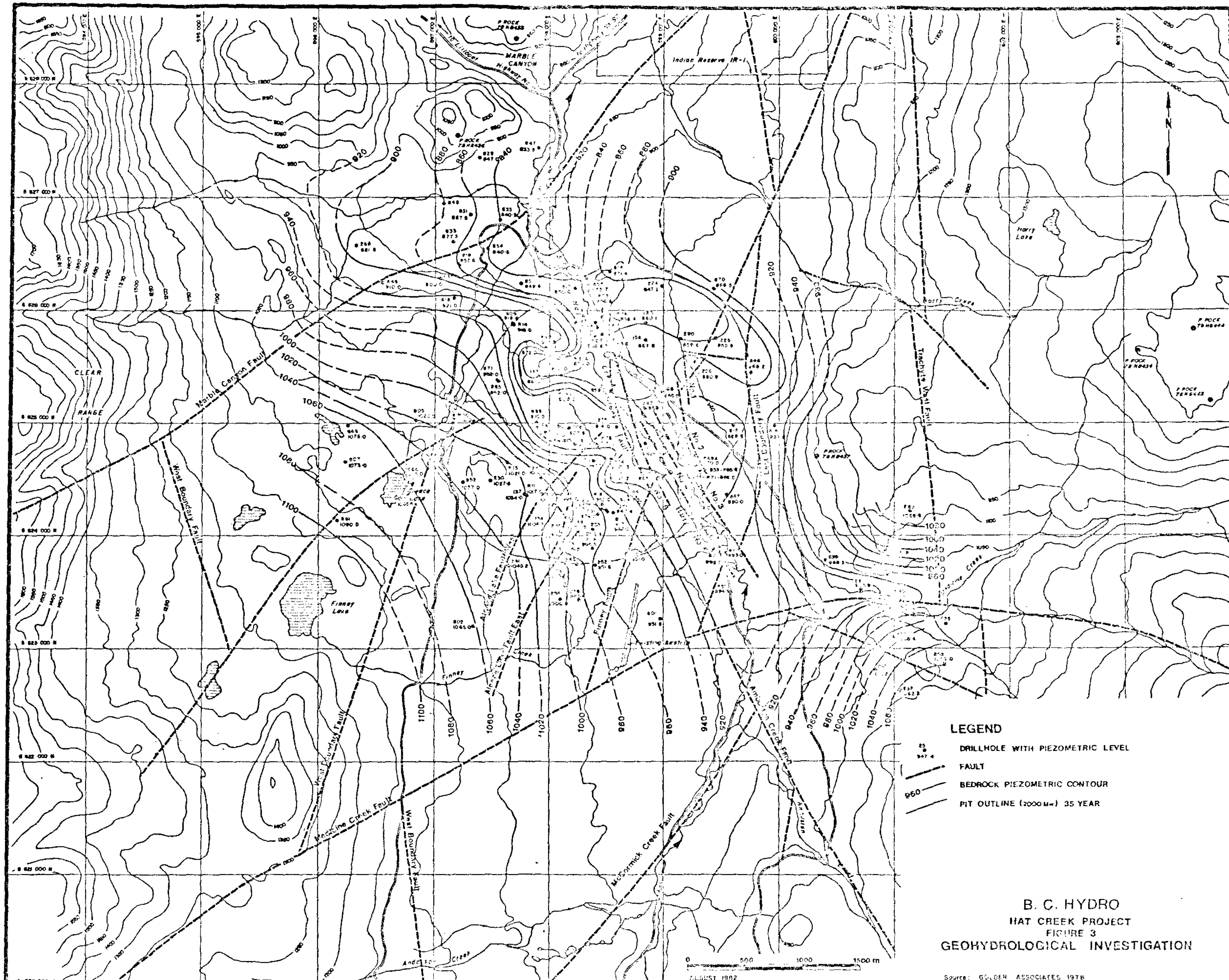
HAT CREEK PROJECT

FIGURE 2

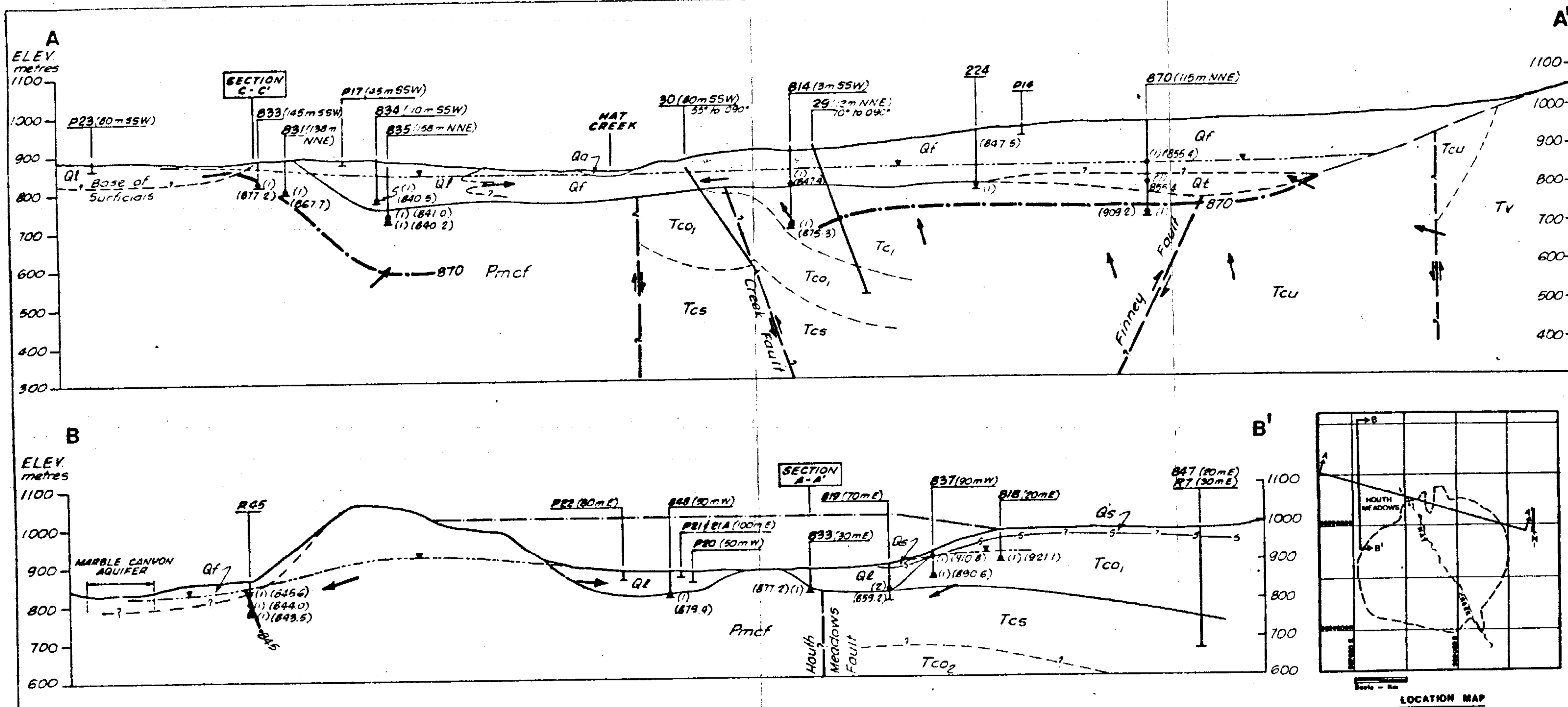
SECTION THROUGH VALLEY AT PROPOSED PIT

August 1982

Source: GOLDER ASSOCIATES 1978



MARBLE CANYON
Indian Reserve IR-1
Harry Lake
Harry Creek
CLEAR RANGE
Marble Canyon Fault
West Boundary Fault
Trachyte Hill Fault
Finney Lake
Medicine Creek Fault
McCormick Creek Fault
Anderson Creek
LEGEND
DRILLHOLE WITH PIEZOMETRIC LEVEL
FAULT
BEDROCK PIEZOMETRIC CONTOUR
PIT OUTLINE (2000 MW) 35 YEAR
0 500 1000 1500 m
AUGUST 1982
B. C. HYDRO
HAT CREEK PROJECT
FIGURE 3
GEOHYDROLOGICAL INVESTIGATION
Source: GOLDER ASSOCIATES 1978



LEGEND:

Qa	Alluvium
Qt	Glacial till - well graded clay, silt, sand and gravel
Qℓ	Mostly lacustrine deposits; glacial lake silts and sands Some occasional till deposits.
Qf	Glacic fluvial sand and gravel
Qs	Slide disturbed coldwater and glacial deposits
Tcu	Upper claystone and siltstone
Tcl	Lower siltstone with sandstone conglomerate and carbonaceous interbeds.
Tco_1	Massive conglomerate with siltstone and sandstone
Tco_2	Conglomerate
Tcs	Interbedded siltstone and sandstone with thin coals
Pmcf	Marble Canyon formation (limestone)
Tv	Kamloops Volcanics
● (1)	Tip of standpipe piezometer. Perforated 3/4" ø p.v.c. pipe.
● (2)	Tip of Thor pneumatic piezometer
(906.7)	Piezometric elevation (metres asl)
—S—	Base of slide area
	Location of piezometric surface in upper part of bedrock and also approximate elevation of water table.
870	Equipotential line (approximate)
	Out line of maximum elevation of proposed waste dump
	Ground water flow direction
—?—	Fault
	Geological contact.
—?—	Inferred geological contact.

NOTE: Piezometric elevations for hole 870 are from October 1978 data, all others are from March 1978 data.

NATURAL SCALE

200 100 0 200 400 METRES

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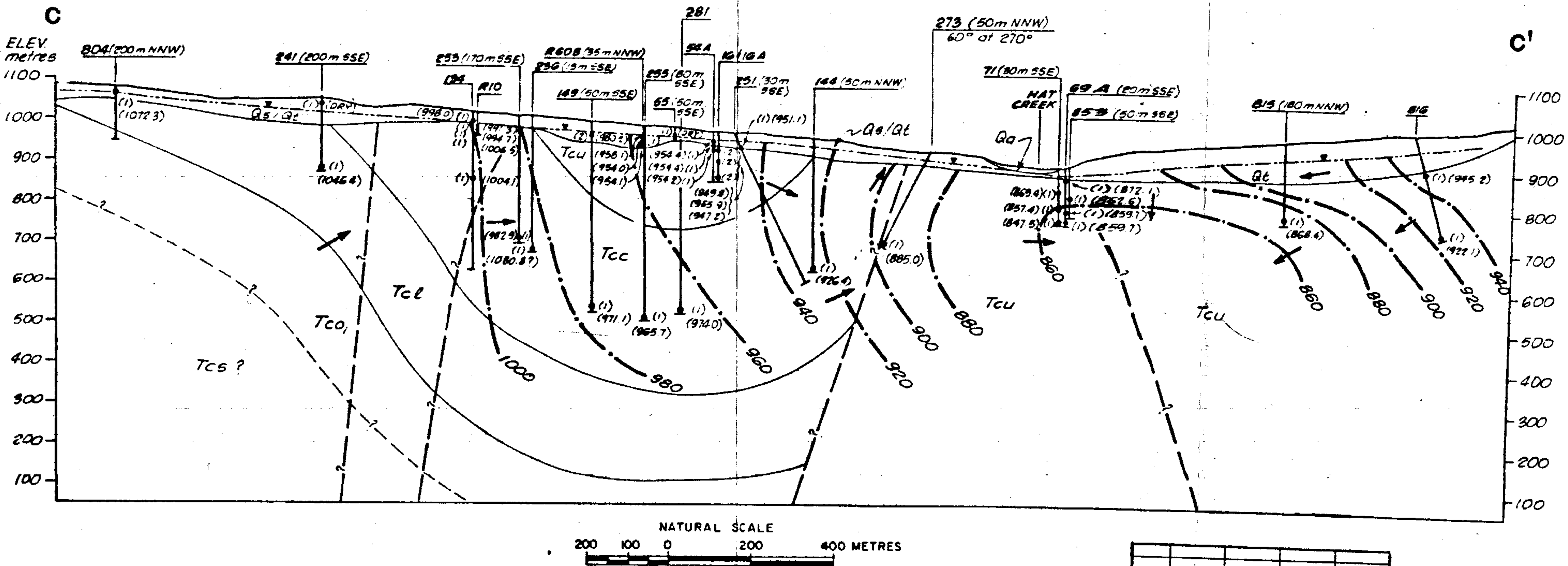
HAT CREEK PROJECT

FIGURE 4 M114.

GEOHYDROLOGIC SECTION A-A' & B-B'

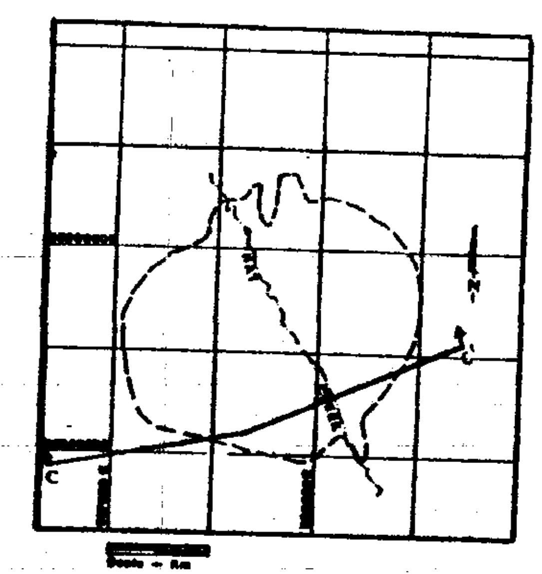
AUGUST 1982 SOURCE: GOLDER ASSOCIATES 1978



LEGEND:

Qt	Glacial till - well graded clay, silt, sand and gravel occasional glacio fluvial pockets.
Qs/Qt	Slide disturbed till, in place till and occasional glacio fluvial pockets.
Qa	Alluvium
Tcu	Upper claystone/siltstone
Tcc	A, B, C, D zone coal
Tcl	Lower siltstone/sandstone/conglomerate
Tco1	Conglomerate with sandstone and siltstone

●(1)	Tip of standpipe piezometer. Perforated 3/4" Ø p.v.c. pipe.
●(2)	Tip of Thor pneumatic piezometer
(965.7)	Piezometric elevation (metres asl)
—●—	Equipotential line (approximate)
→	Ground water flow direction
— ▼ —	Approximate location of water table
—?—	Fault



LOCATION MAP

NOTE: Piezometric elevations for holes 273 and 281 are from October 1978 data, all others are from March 1978 data.

AUGUST 1982 SOURCE: GOLDER ASSOCIATES 1978

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HAT CREEK PROJECT

FIGURE 5

GEOHYDROLOGIC SECTION C-C'

M114

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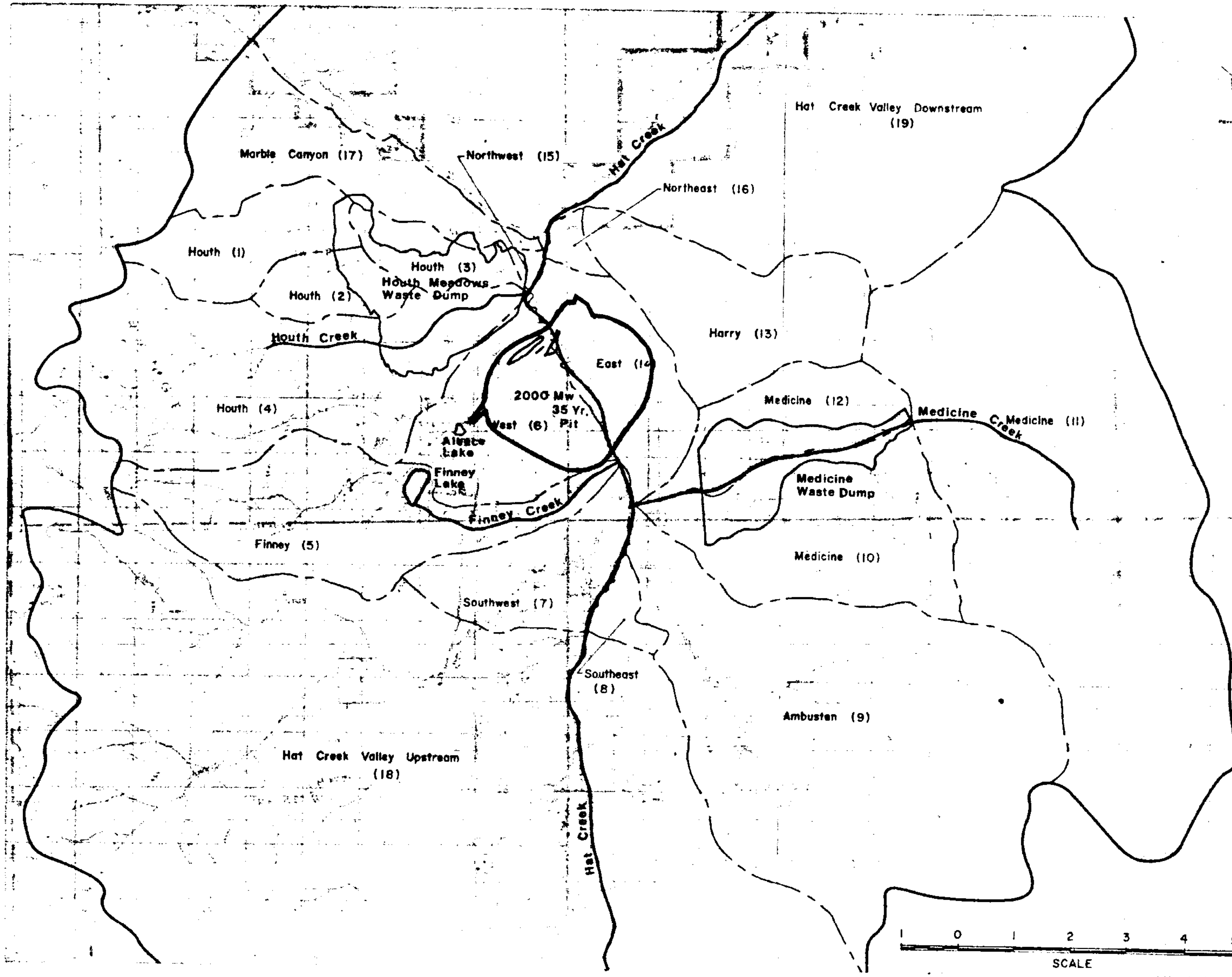
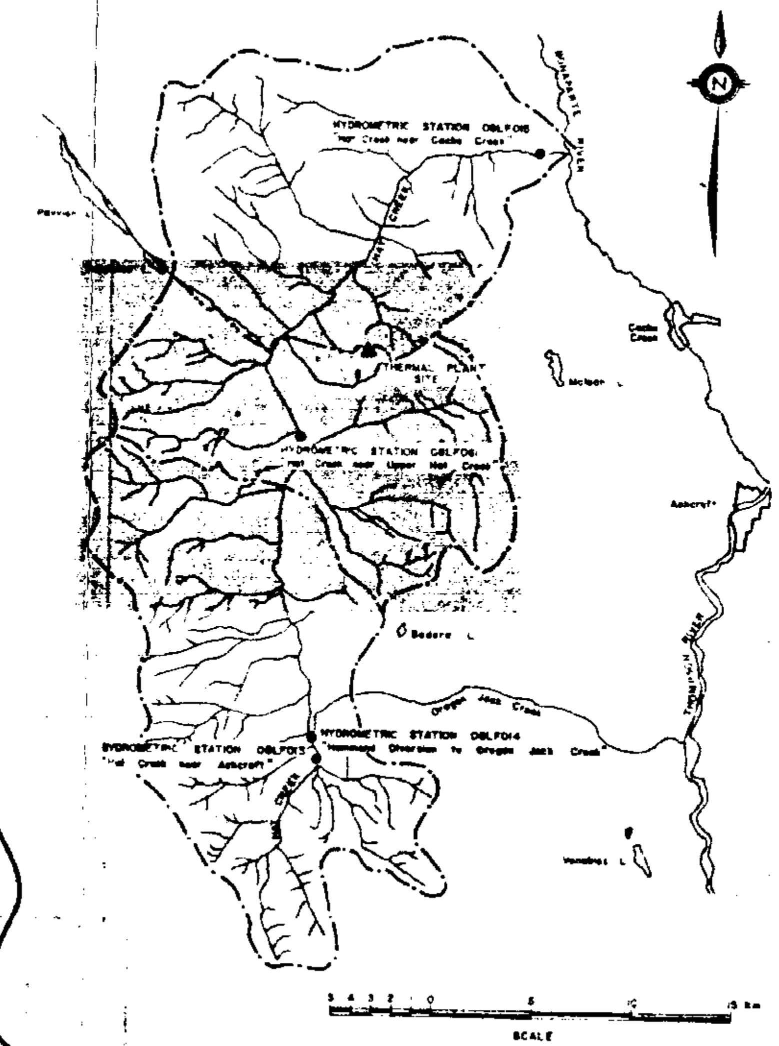
HAT CREEK PROJECT
FIGURE 6
Regional Bedrock Geology
Hat Creek Valley

Source: B.C. Hydro & Power Authority

REV. June 1981





M114.

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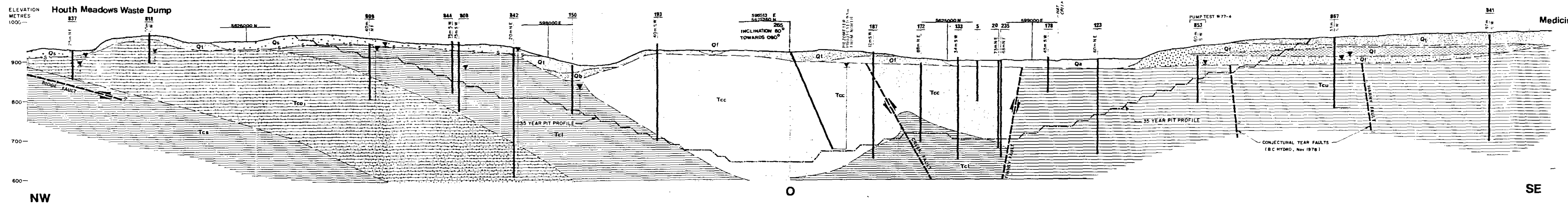
HAT CREEK PROJECT

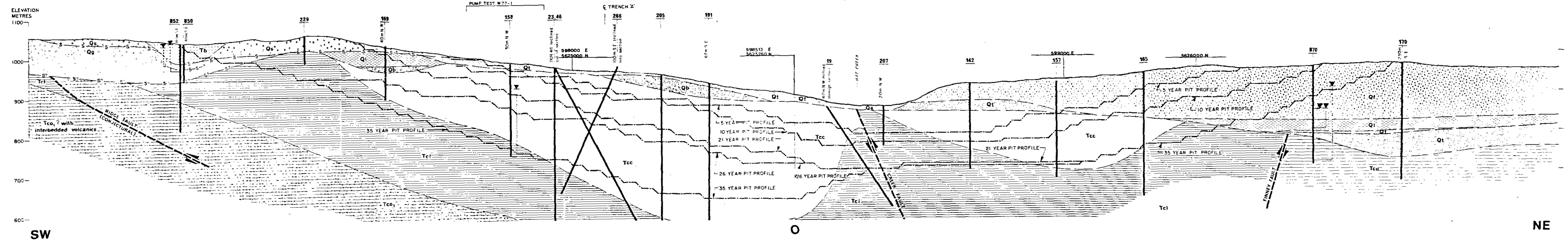
FIGURE 7

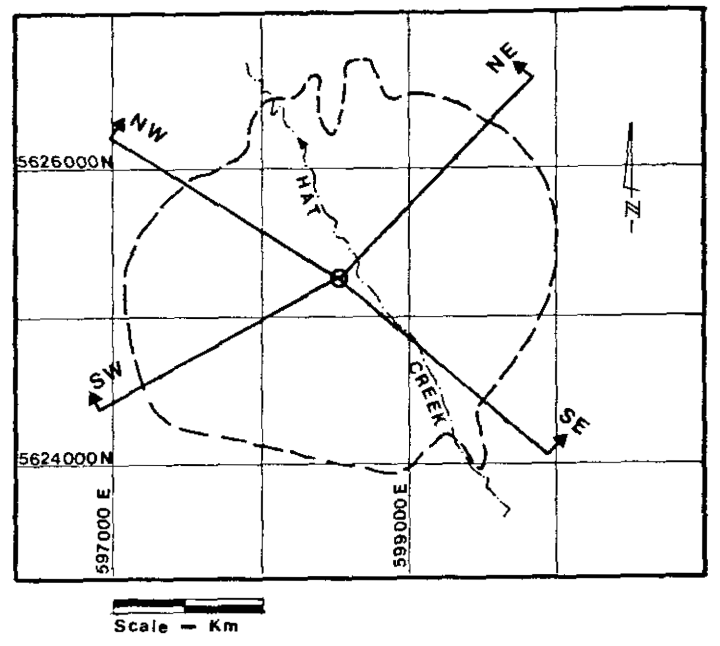
HAT CREEK WATERSHED

AUGUST 1982

Source: COMINCO—MONENCO JOINT VENTURE







LOCATION MAP

LEGEND:

Quaternary
- Alluvium — Qa
- Colluvium — Qc
- Slide-disturbed Coldwater and glacial deposits — Qs
- Granodiorite colluvium / slide deposit — Qg
- Burn zone material — Qb
- Glacio-fluvial sand and gravel — Qf
- Glacial till - well graded clay, silt, sand and gravel — Qt
- Lacustrine deposits - glacial lake silts and glacio-fluvial silts — Ql

Tertiary
- Basaltic and andesitic volcanics — Tb
- Coldwater Formation
  - Claystone and siltstone — Tcu
  - Coal (Zones A, B, C and D) — Tcc
  - Siltstone with sandstone, conglomerate and carbonaceous interbeds — Tcl
  - Conglomerate with siltstone and sandstone — Tco
  - Siltstone and sandstone with coals — Tc3

Permian
- Marble Canyon Formation — Pmcf

- Geological boundary
- Shear zone or base of slide — S—S
- Fault
- CMJV Truck / Shovel Pit Profile

- **843** Drillhole number
- 35 m N. Distance hole is projected normally on to section
- Piezometric elevation October 1978
- Piezometer location in drillhole

Note:
- Pit is shown as projected in 1978.
- Coldwater Formation has subsequently been subdivided into Coldwater Formation, Hat Creek Coal Formation and Medicine Creek Formation.

NATURAL SCALE
100 50 0 100 200 METRES

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HAT CREEK PROJECT

FIGURE 8

SW - NE AND NW - SE CROSS SECTIONS

AUGUST 1982

SOURCE: Golder Associates 1978