BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

HAT CREEK PROJECT

WATER SUPPLY AND ASH DISPOSAL RESERVOIRS

PRELIMINARY DESIGN REPORT

VOLUME 1

HYDROELECTRIC DESIGN DIVISION

Report No. 916 March 1978

HAT CREEK PROJECT

WATER SUPPLY AND ASH DISPOSAL RESERVOIRS

PRELIMINARY DESIGN REPORT

VOLUME 1

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SYNOPSIS

The British Columbia Hydro and Power Authority is currently proceeding with preliminary engineering design and related cost estimating for a 2000 MW coal-fired thermal generating station at Hat Creek, located about 25 km west of Ashcroft, B.C.

To provide essential storage of the thermal plant's water supply from the Thompson River, a reservoir would be constructed near the thermal plant on the north side of the Medicine Creek valley. As shown on Plate A1, Annex A, two primary embankments would be required to create this reservoir: a main dam 47 m high and 790 m long and a saddle dam at the north end of the reservoir 17 m high and 230 m long. A minor saddle dam on the east side of the reservoir and an emergency overflow outlet on the west side would also be required.

Although alternative ash disposal schemes are still to be studied, a scheme to dispose of both bottom and fly ash in slurry form in upper Medicine Creek has been adopted for this preliminary design study. The facilities required for this ash disposal reservoir comprise a three-stage earthfill dam with an ultimate height and crest length of 83 m and 490 m respectively, and drainage canals surrounding the pond to intercept and convey runoff past the ash pond. Since the absolute security of the ash disposal pond would have to be ensured for perpetuity, these runoff canals would have to be designed with a capacity sufficient for the probable maximum flood. Containment, treatment and release of such extreme runoff volumes in the ash pond would not be practical.

The site investigations and preliminary design studies detailed in this report indicate that construction of the necessary embankments and outlet for the water supply reservoir would pose no special engineering problems. Similarly, design and construction of the ash retention dam for the upper Medicine Creek ash disposal scheme should present no difficulties. However, although every effort has been made to optimize the design of runoff facilities for this scheme, it is still strongly recommended that further studies be conducted to identify, if possible, a disposal scheme that would eliminate uncertainties in the design, construction and operation of the runoff facilities that reflect on the overall security of the upper Medicine Creek ash disposal scheme.

The estimated total capital costs, at September 1977 price levels, of the water supply reservoir and ash disposal reservoir are as follows:

1. Water Supply Reservoir - $11.5 million

2. Ash Disposal Reservoir

   a. Stage 1 including runoff facilities (completed 1985) - $13.4 million

   b. Ash Dam, Stage 2 (completed 1996) - $ 5.3 million

   c. Ash Dam, Stage 3 (completed 2006) - $ 3.2 million

The estimated costs include contingencies, engineering, investigations, supervision and corporate overhead but no allowances have been made for escalation, interest during construction or present worth discounting of future costs.

SECTION 1.0 - INTRODUCTION

1.1 TERMS OF REFERENCE

Under Assignment No. 477-028 dated 6 June 1977, the Hydroelectric Design Division (HEDD) was authorized to provide engineering services as required to conduct preliminary design studies for:

1. The diversion of Hat Creek around the proposed mine pit area.

2. A storage reservoir for the powerplant cooling water supply.

3. A retention structure for the ash disposal area in upper Medicine Creek.

It was arranged to have the geotechnical design of the water supply and ash embankments of Items 2 and 3 above performed by Klohn Leonoff Consultants Ltd., under the direction of the Hydroelectric Design Division. This report deals solely with the water supply and ash disposal reservoirs, including flood control and spillway facilities. A companion report, "Hat Creek Project, Diversion of Hat and Finney Creeks, Preliminary Design Report" describes the work performed by the Hydroelectric Design Division relative to Item 1.

The terms of reference specifically related to the water supply and ash disposal embankments were submitted in a letter dated 8 July 1977 from Mr. F.J. Patterson, Manager, HEDD, authorizing Klohn Leonoff Consultants to carry out the design of the embankments. The terms of reference for their work are reproduced in Appendix I of Annex A. As set out in these terms of reference, the overflow spillway for the water supply reservoir and the runoff handling facilities were the responsibility of the Hydroelectric Design Division.

1.1 TERMS REFERENCE - (Cont'd)

This Summary Report combines into a brief form the results of the studies by Klohn Leonoff Consultants Ltd., presented in Annex A, and those of the Hydroelectric Design Division, presented in Annex B.

1.2 BACKGROUND

The first powerplant feasibility and preliminary environmental impact reports on the Hat Creek coal-fired thermal plant were completed in the summer of 1975. Since that time numerous conceptual design studies and detailed environmental studies have been completed and others are still underway.

In the spring of 1976, B.C. Hydro appointed a joint venture of Intercontinental Engineering Ltd., Vancouver and Ebasco Services of Canada, Toronto to conduct a conceptual design study for the thermal plant. In July 1977 this joint venture, Integ-Ebasco, released the report "Evaluation of Ash Disposal Schemes for Hat Creek Thermal Plant" in which a variety of alternative ash disposal schemes were compared. The upper Medicine Creek ash disposal arrangement, on which this HEDD report is based, was the scheme selected in the Integ-Ebasco report.

During the HEDD studies a number of problems with the upper Medicine Creek scheme were identified and led to a re-evaluation of the upper Medicine Creek and mid-Medicine Creek ash disposal schemes. This re-evaluation showed that, under certain conditions, the mid-Medicine Creek alternative could be more attractive from both economic and environmental viewpoints. However, since the costs of the two alternatives were close and several studies based on the upper Medicine Creek alternative were already well under way, it was decided to proceed with preliminary design on the basis of the upper Medicine Creek scheme. Site investigations, however, were carried out at the alternative ash dam sites.

1.3 AVAILABLE INFORMATION

For details of the existing reports, topography, aerial photography, geology and subsurface investigations, hydrology and meteorology that were available for this preliminary design study, refer to the "List of References" in Annex A and to Section 1.3 of the HEDD report "Hat Creek Project, Diversion of Hat and Finney Creeks, Preliminary Design Report" dated March 1978.

SECTION 2.0 - SUMMARY

2.1 SUMMARY OF INVESTIGATIONS AND STUDIES

During the latter half of 1977 Klohn Leonoff Consultants Ltd., under the direction of the Hydroelectric Design Division, carried out a program of site investigations in Medicine Creek and adjacent areas that included detailed geological reconnaissance mapping, drilling of 21 percussion drill holes and one diamond drill hole and excavation of 60 test pits plus approximately 1500 m of seismic refraction survey. On the basis of these investigations and the subsequent laboratory testing of samples of foundation and embankment construction materials, Klohn Leonoff Consultants Ltd. prepared preliminary designs for the main dam and saddle dam which form the water supply reservoir and for the three-stage embankment required for the ash disposal reservoir. These studies are described in Annex A and the site investigation results are presented in Annex C, Volume 2.

Concurrently, and based solely on the site investigations carried out for the embankment design work by Klohn Leonoff Consultants Ltd., the Hydroelectric Design Division prepared preliminary designs for an emergency overflow facility for the water supply reservoir and flood runoff facilities to safeguard the ash disposal reservoir and its embankment. These studies are described in detail in Annex B.

2.2 WATER SUPPLY RESERVOIR

(a) Main Dam and Saddle Dam

Site investigations at these two damsites indicate no particular foundation problems and the recommended modified homogeneous cross-sections were selected, therefore, on the basis of construction material availability.

2.2 WATER SUPPLY RESERVOIR - (Cont'd)

The main dam would have a maximum height of about 47 m and a crest length of about 790 m. The saddle dam at the north end of the reservoir would have a maximum height of about 17 m and a crest length of approximately 230 m. The total earthfill requirements for the two embankments would be approximately 1.7 million m^3 with over 90 percent of this volume in the main dam.

(b) Overflow Facilities

Due to the remote possibility of control system and communication failure, overflow facilities with a discharge capability equivalent to the maximum Thompson River supply pipeline capacity would be provided.

Although originally intended for the small saddle area on the east side of the reservoir, the overflow facility has now been located in another low saddle area on the west side of the reservoir.

The east saddle would be closed by a small embankment having a maximum height of about 3 m and a crest length of approximately 45 m.

The overflow outlet would comprise simply about 25 m of 1050 mm culvert placed through the access road embankment and a concrete inlet with a crest about 0.4 m above the normal reservoir level.

(c) Cost Summary

A summary cost estimate including contingencies, engineering and corporate overhead in addition to the direct costs

2.2 WATER SUPPLY RESERVOIR - (Cont'd)

shown in Annexes A and B, is presented in Table 2-1. As shown, the overall cost of the water supply reservoir, at September 1977 price levels, is $ 11.5 million.

Cost estimating and scheduling are generally in accordance with the criteria defined in Sub-section 3.3 of the companion HEDD report "Hat Creek Project - Diversion of Hat and Finney Creeks - Preliminary Design Report" dated March 1978. All costs are presented at September 1977 price levels without any allowances for inflation, interest during construction or present worth discounting. The costs of lands and right have also been excluded.

2.3 ASH DISPOSAL RESERVOIR

(a) Ash Retention Dam

On the basis of the site investigations, it was considered desirable to move the ash dam for the upper Medicine Creek ash disposal scheme some 200 m upstream of the original Axis 3 to a new site designated Axis 3B.

As for the water supply dams no significant foundation problems are anticipated and the modified homogeneous dam cross-section was selected again on the basis of construction material availability. Rather than constructing the ash dam in four stages as originally planned, three stages have now been adopted, thus eliminating a comparatively small and costly fourth stage. Data on the three embankment stages are summarized as follows:

2.3 ASH DISPOSAL RESERVOIR - (Cont'd)

	Stage 1	Stage 2	Stage 3
Date completed	1985	1996	2006
Crest elevation (m)	1250	1264	1275.6
Crest length (m)	385	435	490
Maximum height (m)	56	71	83
Cumulative dam volume (million m^3)	2.0	3.5	4.3
Reservoir storage volume (million m^3)	29	60	98

(b) Runoff Handling Facilities

Runoff handling facilities for the ash disposal reservoir would comprise a total of about 11.6 km of canal located immediately above the ultimate ash pond level of El. 1273.5. Because of the perpetual need for these canals, they would be designed with a capacity sufficient for the probable maximum flood.

The north canal would be approximately 5.3 km long, draining an area of 11.7 km^2. The canal's capacity at the downstream end would be approximately 7.8 m^3/s. Discharge from the canal down to Medicine Creek below the ash dam would be accomplished in a reinforced concrete baffled chute about 250 m long.

The south canal would be about 6.3 km long, draining an area of 26.0 km^2. The canal's capacity at its outlet would be about 14.4 m^3/s. Discharge down to Medicine Creek would be via a 220 m long chute excavated into rock and would terminate in a plunge pool.

Small buried culverts have been provided throughout the length of canals to convey the low winter flows which, if left in the canal, could cause serious ice build-up problems.

2.3 ASH DISPOSAL RESERVOIR - (Cont'd)

(c) Cost Summary

A summary cost estimate including contingencies, engineering and corporate overhead is presented in Table 2-2. As shown, the overall cost of Stage 1 of the ash disposal reservoir including runoff facilities is estimated to be \$ 13.4 million at September 1977 price levels.

The costs, also at September 1977 price levels, of Stages 2 and 3 of the ash dam are estimated to be \$ 5.3 million and \$ 3.2 million respectively.

The annual maintenance cost of the runoff facilities for the ash disposal reservoir is estimated to be \$20,000 per year. No indirect costs such as interest, amortization etc. are included.

Cost estimating and scheduling criteria are as described for the water supply reservoir in Sub-section 2.2(c).

As shown on Table 2-2, contingency allowances have been made at rates of 15 percent for Stage 1 of the ash dam and 25 percent for the runoff canals and outlet chutes. The higher rate for the runoff facilities was adopted to reflect the lack of site investigations.

2.4 ENGINEERING AND CONSTRUCTION SCHEDULE

A simplified bar schedule of current and future engineering work and site investigations together with a proposed construction schedule for the water supply and ash disposal reservoirs is shown on Plate 2-1 of this Summary Report. The schedule is based on actual dates

2.4 ENGINEERING AND CONSTRUCTION SCHEDULE - (Cont'd)

of current studies and on the future scheduling criteria presented in Sub-section 3.3 of the HEDD report "Hat Creek Project - Diversion of Hat and Finney Creeks - Preliminary Design Report" dated March 1978.

Ongoing studies during 1978 would include the proposed re-examination of alternative ash disposal schemes in upper and mid-Medicine Creek. Further site investigations and final design are assumed to be carried out primarily during 1981 and 1982 with the award of the construction contract in January of 1983 so that, allowing for mobilization, construction could begin in March 1983.

As defined in the scheduling criteria mentioned above, the water supply reservoir is to be completed by 1 July 1984 and the first stage of the ash retention dam is to be completed by 1 April 1985. The March 1983 start of construction is governed by the construction of the main water supply and ash dams. It has been assumed that the overflow outlet works would be constructed along with the main project access road in 1981.

TABLE 2-1

WATER SUPPLY RESERVOIR
SUMMARY ESTIMATE OF TOTAL CAPITAL COST
(All costs at September 1977 price levels)

		$Thousand
1.	Main dam	7 170
2.	North saddle dam	1 070
3.	East saddle dam and overflow outlet	020
	TOTAL DIRECT COST	8 260
4.	Contingencies (15 percent)	1 240
5.	Engineering, investigations and supervision (15 percent)	1 430
6.	Corporate overhead (5 percent)	550
	TOTAL CAPITAL COST	11 480

Estimated Cash Flow

Fiscal Year	Expenditure $Thousand
1980/81	60
81/82	500
82/83	420
83/84	4 500
84/85	6 000

TABLE 2-2

ASH DISPOSAL RESERVOIR
SUMMARY ESTIMATE OF TOTAL CAPITAL COST
(All costs at September 1977 price levels)

			$Thousand
A.	Stage 1		
	1.	Ash dam, Stage 1	6 520
	2.	Runoff canals and outlet chutes	2 860
		TOTAL DIRECT COST	9 380
	3.	Contingencies (15 percent on (1.) and 25 percent on (2.)	1 690
	4.	Engineering, investigations and supervision (15 percent)	1 660
	5.	Corporate overhead (5 percent)	640
		TOTAL CAPITAL COST	13 370
B.	Ash Dam - Stage 2*		5 330
C.	Ash Dam - Stage 3*		3 170
D.	Annual Maintenance Cost of Runoff Canals		20
E.	Estimated Cash Flow:		

	Fiscal Year	Expenditure $Thousand
1.	Stage 1	
	1980/81	50
	81/82	700
	82/83	420
	83/84	4 200
	84/85	8 000

* Includes contingencies at 15 percent, engineering, investigations and supervision at 15 percent and corporate overhead at 5 percent.

TABLE 2-2 - (Cont'd)

	Fiscal Year	Expenditure $Thousand
2.	Stage 2	
	1993/94	270
	94/95	200
	95/96	4 860
3.	Stage 3	
	2003/04	160
	04/05	110
	05/06	2 900

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

ANNEX A

HAT CREEK PROJECT
WATER SUPPLY AND
ASH RETENTION DAMS
PRELIMINARY DESIGN REPORT

by

KLOHN LEONOFF CONSULTANTS LTD

Our File: VA 2321 March 1978

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ANNEX C

1. INTRODUCTION

The Hat Creek Project as proposed would comprise a 2,000 megawatt coal-fired thermal generating station near Cache Creek, British Columbia. Klohn Leonoff Consultants Ltd were retained to provide a preliminary design and cost estimate for three earth dam structures; two to form a water supply storage reservoir and a third to create a reservoir for the storage of ash slurry.

Authorization to carry out this study was received from Mr. F.J. Patterson, Manager, B.C. Hydro, Hydroelectric Design Division, in a letter dated July 8, 1977. The terms of reference for the work are reproduced in Appendix I.

Foundation conditions at the damsites were investigated using a Becker diesel hammer percussion drill during July and August, 1977. Supplementary investigations, at the damsites and in potential borrow areas, were carried out using backhoe test pits. A seismic refraction survey was also carried out along the alignment of the proposed ash retention dam, in the Medicine/MacLaren Creek divide, and on the alignment of a possible alternate ash retention dam.

The information gathered from this field work, plus a program of laboratory testing and geologic mapping of the area, has been used to determine preliminary designs for the three dams. These designs were then used to establish capital cost estimates for the embankments and foundation treatment, using criteria agreed upon with B.C. Hydro.

In addition to the three damsites discussed in the report, drilling was also carried out on the alignments of two dams forming an alternative ash retention reservoir, the preliminary design of which is outside the scope of this report. Also, three holes, two by percussion drill and one by diamond drill, were drilled in the divide between Medicine Creek and MacLaren Creek, at the east end of the ash storage reservoir.

Additional studies are required before final design and preparation of plans and specifications can proceed. These will include field work to further define foundation conditions and rock permeabilities and the extent of foundation grouting required. Further work should be done to define shear strength and consolidation characteristics of the impervious fill material. If the use of bottom ash as a dam construction material is to be pursued, a laboratory testing program to determine physical characteristics such as shear strength and permeability should be undertaken.

This report is presented in S.I. metric units. For the convenience of the reader not familiar with this system a short list of conversion factors is given in Appendix II.

2. SITE AND PROJECT DESCRIPTION

The project site is in the Hat Creek Valley about 32 km west of Cache Creek, B.C. along highway No. 12. The general layout is shown on Plate A1.

The study described in this report is concerned with the upper Medicine Creek Valley, a tributary of Hat Creek, where two reservoirs are planned, one to store ash from the power plant in slurry form, and the other for water supply. The water supply reservoir, fed by a pipeline from the Thompson River near Ashcroft, would be situated in a small tributary valley on the north side of Medicine Creek, while the ash retention reservoir would be located within Medicine Creek. The ash, both fly ash and bottom ash, totalling 97.5×10^6 cubic metres over the 35 year lifetime of the project, would be deposited in the ash retention reservoir by slurry pipelines from the thermal plant. The ash retention scheme studied in this report is one whereby ash slurry would be stored in the upper Medicine Creek valley behind a single dam on an alignment known as axis No 3B. The locations of these dams and the exploratory drill holes are shown on Plate A2.

There is an alternative proposal for the storage of bottom ash only, in the region of Harry Lake. An appraisal of the geology of this area was made, see Section III.9, but no further engineering studies were requested.

All three dams would be conventional earth embankments. The water supply dam would have a maximum height of 47 m and a length along the crest of 792 m. The water supply saddle dam at the north end of the reservoir to close off a natural divide would be 18 m high with a crest length of 228 m. The ash retention dam would have an ultimate maximum height of 83 m and a crest length of 492 m. This structure is designed to be built in 3 discrete stages over the 35 year projected lifetime of the thermal plant.

The dams would be built out of locally available borrow material. Although some of the overburden stripping materials from the coal pit, scheduled for the lower Medicine Creek disposal area, could be used for construction of the ash retention dam, it will likely prove more expedient to use impervious borrow available immediately adjacent to the dam. Bottom ash could possibly be used for later stages of dam construction as discussed in Section 6.4.4.

3. HYDROLOGY

The hydrology of the Medicine Creek basin is the responsibility of B.C. Hydro, and is outside the terms of reference of this report. Related design parameters such as dam crest elevations and freeboard were supplied by B.C. Hydro. In order to assess stream diversion requirements during construction of the dams, the following preliminary hydrologic data for the site of the ash retention dam was provided by the B.C. Hydro, Hydroelectric Design Division.

Stream diversions during construction of both the water supply and ash retention dam were based on a design flood recurrence interval of 10 years for both snow melt runoff and rainfall produced floods.

Snow Melt Runoff

Flood Return Frequency -yrs-	Peak Discharge $-m^3/s-$	Total Volume $m^3 \times 10^6$
100	4.2	9.5
20	2.8	6.7
10	2.3	5.7
5	1.8	4.6
mean annual	1.2	3.3

Drainage basin area = 4377 ha

The snow melt is assumed to take place over a three month period. Because an actual snow melt hydrograph was not available, estimates of the hydrograph shape, based on hydrographs from neighbouring basins were made as part of this study. As neighbouring basins are larger, the Medicine Creek hydrograph was assumed to rise earlier in the spring and have a sharper peak. The adopted hydrograph is shown on Plate A3.

Rainfall

The peak discharge rate for a rainstorm flood with a frequency of occurrence of 1 in 10 years is estimated by B.C. Hydro to be 7.0 m^3/s. As the duration of this design rainstorm is only approximately 1 hour, the 24 hour rainstorm with a 10 year frequency of occurrence was used to estimate the design rainstorm volume for the pumping alternative. The 10 year rainstorm volume is 110,300 m^3 with a peak discharge of 2.6 m^3/s.

In order to determine preliminary design parameters for flow in the creek at the site of the water supply reservoir, the above figures were reduced in proportion to the catchment area, which for the water supply reservoir is 186 ha. Thus, for a snow melt flood, the design peak discharge and total volume are 0.1 m^3/s and 0.2×10^6 m^3 respectively. For the design rainfall the peak discharge is 0.3 m^3/s, and the 24 hour volume is 4700 m^3.

4. GEOLOGY

The following sections provide a general picture of the geology of the project site, with specific reference to the dam sites and reservoirs. A more detailed discussion of the geology of the area is presented in Appendix III.

4.1 General Geology

The Hat Creek project area lies within the Thompson Plateau Subprovince of the Canadian Cordillera. The rocks and soils of the Hat Creek area can be subdivided into three major groups:

- the basement complex
- the cover formations
- the glacial deposits

4.1.1 Basement Complex

The basement complex includes the oldest rocks known to outcrop in the area. These include metamorphosed sedimentary and volcanic rocks of Pennsylvanian and Permian age (Cache Creek group). The Cache Creek group includes limestone, marble, phyllite, argillite, chert, and altered andesite or basalt ("greenstone").

4.1.2 Cover Formations

The name "cover formations" has been given to a group of sedimentary and volcanic rocks of Tertiary age (Kamloops group) lying unconformably upon the basement complex. These rocks are believed to have been deposited in intermontane basins (grabens) formed by faulting of the basement complex rocks.

The sedimentary members of the Kamloops group include claystone, siltstone, sandstone, conglomerate and the Hat Creek coal seams. The volcanic members include andesite and dacite lava flows, and volcaniclastic materials (tuff, breccia and lahar).

4.1.3 Glacial Deposits

The Hat Creek and Medicine Creek basins are blanketed by glacial and fluvioglacial deposits of the last glaciation (Fraser glaciation). These deposits include basal till blankets, recessional end moraines, eskers, kame ridges and outwask plains.

4.2 Geology of Medicine Creek Basin

A description of the various geologic units in the Hat Creek and Medicine Creek basins is given in the Table of Formations on Plate A4.

The geology of the Upper Medicine Creek Basin is shown on the geologic map on Plate A5. The geologic map was prepared based on a survey of outcrops and from rock hole core data. Location of outcrops and geologic survey traverses are shown on Plate A6. Plate A7 shows a profile up the Medicine Creek Valley and through the divide into the MacLaren Creek.

The Upper Medicine Creek Basin is underlain mainly by Tertiary rocks covered by a mantle of glacial materials. Rocks of the basement complex (limestone and greenstone) are exposed in the Lower Medicine Creek Valley.

The Medicine Creek Valley is believed to follow a fault zone. Other smaller faults are also believed to exist in the basin. The faults are considered to be inactive.

4.3 Geology of Damsites and Reservoirs

4.3.1 Water Supply Reservoir

The water supply dam and reservoir, and the saddle dam closing the back of the water supply reservoir are underlain by conglomerate and siltstone of the Tertiary Kamloops group, except for the extreme right abutment of the water supply dam which is underlain by greenstone and limestone of the Cache Creek group.

The thickness of the till overburden ranges from nil to 15 metres at these sites. Siltstone and claystone are exposed at the saddle dam. Conglomerate is exposed on the left abutment of the water supply dam.

A fault is believed to run along the stream of the water supply reservoir. The fault is considered to be inactive.

Soil and rock foundations at both sites are considered adequate for the structures proposed. The reservoir rim is considered to be essentially impervious, and no significant seepage losses are anticipated.

4.3.2 Ash Storage Reservoir

The ash retention damsite is underlain by greenstone and possibly minor limestone of the Cache Creek group. Two outcrops of Tertiary volcanic rocks (Kamloops group) have been observed on the left abutment, upstream of the dam axis, and may extend into the dam foundation area.

The overburden thickness ranges from nil at the streambed to 45 metres or more on the right abutment. These depths are for the original centreline (dam axis 3), which is in the downstream toe area of the recommended damsite (axis 3B). Overburden is believed to be thicker along axis 3B, but no drillhole information is available from this site.

Most of the ashpond area is underlain by Tertiary sedimentary rocks (claystone, siltstone and conglomerate or breccia), except for the area in the immediate vicinity of the dam, which is underlain by Permian greenstone and small patches of Tertiary volcanics.

The possibility of infiltration of ash leachates from the ashpond into the MacLaren Creek basin to the east has been analyzed carefully (see Appendix III). We have concluded that the possibility of contamination of the MacLaren Creek basin is remote, based on the presence of a substantial thickness of relatively impervious till and siltstone-claystone, and because of a groundwater pressure barrier revealed by artesian conditions in piezometers installed in drill hole DDH77-501.

Some seepage would occur westward along Medicine Creek, but it is not considered significant.

4.4 Seismicity

A statistical analysis of earthquakes recorded since the beginning of the century was recently carried out by the Dominion Observatory, Victoria, B.C. The results of this study have been reported by Golder Associates (1977).[(1)] They show that an earthquake of intensity V has a probability of being felt once every 100 years in the project area. Such an earthquake would impart a firm ground acceleration of 0.02 g, putting the area into Zone 1 of the Seismic Zoning Map of the National Building Code of Canada (1975). For the purposes of stability analysis of the dams, a peak ground acceleration of 0.1 g was assumed.

(1) See end of text for list of references

5. WATER SUPPLY DAMS

5.1 Design and Operating Criteria

The criteria for the water supply reservoir were provided to Klohn Leonoff by B.C. Hydro as follows:

Maximum normal reservoir level	-	El 1372.0
Minimum reservoir level	-	El 1356.0
Drawdown range	-	16.0 m
Live storage	-	6.57×10^6 m^3 *
Maximum drawdown rate		3.15 $m^3/sec \simeq 1.0$ m/day at maximum reservoir level
Maximum reservoir level during emergency spillage	-	El 1373.0
Dam crest	-	El 1374.0

5.2 Geotechnical Considerations

A plan showing the layout of the water supply dam and the locations of boreholes is shown on Plate A8. Similarly, the saddle dam and borehole locations are shown on Plate A9. Graphic drill hole and test pit logs are shown on plates C1 to C16 in Appendix VII. Written bedrock core logs are in Appendix VIII.

The four holes drilled near the centreline of the water supply dam show a surface mantle of glacial drift 5 to 14 m thick overlying bedrock, as shown on the longitudinal profile on Plate A11. The bedrock is mostly sandstone and conglomerate of the coldwater formation, except for some limestone high up on the right abutment. The conglomerate outcrops on the left abutment above El 1370 approximately, and midway up the right abutment.

The down hole permeability test data in the bedrock indicates a wide range of results. See Appendix VI. The packer test results in the conglomerate indicate Lugeon numbers from 1.8 to 24. (1 Lugeon unit is approximately equivalent to a permeability of 10^{-5} m/sec). In the mudstone and siltstone

* Revised to 7.50×10^6 m^3 based on subsequent topography, see Plate A27.

at the saddle dam a Lugeon value of 26 was recorded in one of the tests. The falling head tests in the drill holes and in the standpipe piezometers do not support these higher values obtained by packer tests. The high values are considered to be the result of fractures in the upper weathered zones of the bedrock, and possible leaky packers. The bedrock at depth is expected to be relatively impervious. Additional, more reliable, testing will be required before a final assessment of the rock permeability can be made.

A total grout curtain is not considered necessary since the natural till cover will inhibit seepage over much of the valley. However, a local curtain may be needed on the higher levels of the abutments of the water supply dam where rock is shallow or exposed at the ground surface. Other local areas of the foundations may require some consolidation grouting. Following such treatment we estimate that seepage losses from the reservoir would be in the region of 0.003 m^3/s.

The glacial drift consists principally of a clay rich till, well graded from gravel sizes through to a clay fraction varying from about 10 to 20 percent. It is medium plastic and very stiff to hard. See drill hole logs and Plate C18. Occasional sandy lenses occur throughout, and the surface materials are often friable and more sandy than the unweathered material below.

The three drill holes in the natural saddle at the north end of the reservoir show a thin blanket of the same glacial till (on the right abutment) overlying bedrock. Two different bedrock materials were identified, a sandstone/conglomerate in the right abutment and a claystone/shale in the left abutment. There is little or no soil cover on the left abutment. The upper levels of the claystone/shale are weathered and fractured and moderately permeable, see Appendix VI. Hard clay shale bedrock was also noted in test pit 152 on the west side of the reservoir near the upstream toe of the water supply dam.

In summary, both sites are suitable for construction of the proposed embankments. The bedrock fault believed to run through the reservoir is inactive and of no concern. The foundation materials are strong, posing no stability problems, and a positive cut-off can be obtained either in the bedrock, or in the glacial till that mantles a large part of the dam foundations.

5.3 Construction Materials

A key plan showing the locations of borrow areas explored is shown on Plate A21. In the immediate vicinity of the dams, construction materials are scarce. Except for a relatively small esker-like ridge within the reservoir, the cover of glacial drift is thin. South of the reservoir on the slopes on the north side of Medicine Creek the glacial drift mantle over the rock is also thin, estimated at 1 to 2 m, and is not considered a suitable borrow area.

The two closest sources of large amounts of impervious glacial till borrow material located to date are in the meadows south of Harry Lake, and in the bottom of the Medicine Creek valley on the north side. See Plates A22 and A23. The closest sources of granular material identified to date, with the exception of a relatively small quantity in the ridge noted above, are in upper Medicine Creek meadows, (Plate A24) and on the east side of Hat Creek near Pit No 1 (Plate A25). See Appendix IV for a more detailed discussion of construction materials.

The total fill requirements for the two dams amount to 1.343×10^6 m^3 of impervious material and 0.354×10^6 m^3 granular material, in place.

There is ample impervious material in either of the two till borrow areas. The Harry Lake borrow area is estimated to contain about 3.25×10^6 m^3 and the Medicine Creek borrow area upstream of the ash retention dam is estimated to contain 2.5×10^6 m^3. The natural water content of the till is about 4 percent below the optimum value for compaction as defined by the Standard

Proctor Test (ASTM D-698), so that some water must be added either in the borrow pit or on the embankment prior to compaction. The Hat Creek granular borrow area (Plate A25) is reported by B.C. Hydro (1977), to contain 645 million tonnes of material (approximately 300 x 10^6 m^3), whereas the upper Medicine Creek meadows area, Plate A24, is estimated to contain only 0.4 x 10^6 m^3, although further investigation may prove more. For cost estimating purposes we have assumed the Hat Creek pit to be the source of all granular fill. This material will require screening to produce fill suitable for filter and drainage blankets.

5.4 Embankment Design

5.4.1 General

The scarcity of nearby granular borrow material was a major factor in the choice of a modified homogeneous cross section incorporating a horizontal drainage blanket beneath the downstream zone of the dam, and an internal chimney drain, thereby minimizing the use of granular fill. A typical cross section is illustrated on Plate A10, together with a cross section of the saddle dam.

The purpose of the chimney drain is to control seepage within the dam. The chimney drain is tied to a horizontal drain blanket which then conveys the seepage safely to the downstream toe of the dam. The horizontal drainage blanket will be confined to the bottom of the valley below El 1330, while the filter blanket extends up the abutments to El 1368 as a protection against seepage and piping in the foundation materials.

5.4.2 Foundation Preparation

The dam foundation should be stripped of topsoil and organic material to a nominal depth of 0.5 m. In the area beneath the select impervious zone and drainage blankets the foundations should be stripped down to dense impervious clay till soil, or to sound bedrock in areas of little or no drift cover. The depth of this stripping is assumed to be 1.2 m varying up to 2 m in the stream bed area. The cut-off trench is a nominal 3 m deep. Stripping material can be wasted in the area immediately downstream of the water supply dam. Exposed bedrock should be cleaned and slush grouted as necessary to produce a suitable surface for the core contact.

5.4.3 Embankment Zones

The downstream and upstream random fill zones would consist of fill from the esker ridge in the reservoir, and material from the impervious fill borrow area and any suitable inorganic material from the foundation preparation excavations. The select impervious zone will consist of clay till from either the Harry Lake meadows area or from Medicine Creek borrow pit A_1. The chimney drain and blanket drain will be constructed from processed granular materials from either upper Medicine Creek or from the Hat Creek pit. The Hat Creek source was assumed for cost estimating purposes. It is proposed to construct the chimney drain as a single 4 m wide zone of well graded clean filter material. The foundation drainage blanket in the bottom of the valley will include a layer of coarser drain gravel between two zones of the well graded filter, each 1.5 m thick. Gradation limits for these filter and drain materials are shown on Plate A26.

The upstream slope incorporates a zone of free draining pit run gravel to ensure stability under rapid drawdown conditions. This slope will be protected from wave erosion by a layer of dumped rock riprap resting on a bedding of coarse gravel. The riprap will consist of well graded rock ranging from 0.2 to 0.5 m average dimensions, with a total thickness of 0.75 m. This riprap thickness and grading have been designed using methods developed by the U.S. Army Corps of Engineers (1973), and wind speed data as shown on Table 1 below.

The downstream slope should be seeded to provide a grass cover for surface erosion protection.

TABLE 1

Design Wind Speeds at Thermal Plantsite

Recurrence Interval-Years	Wind Speed* (hourly average) km/hr
50	101
100	108
1000	125
10,000	142

* At 10 m height above ground

5.4.4 Slope Stability

The stability of the embankment slopes and foundations has been analysed for the construction case using total stress parameters. For the long term case under conditions of steady seepage, and on the upstream slope for the case of rapid drawdown, effective stress parameters were used. For the case of long term stability the effect of earthquake loading was studied using a quasi-static analysis with an earthquake coefficient of 0.1 g. The results of the analyses using the method of Janbu (1964), are shown on Plate A12. For comparison, safety factors of selected failure surfaces were computed using the simplified method from Bishop (1954).

Total and effective stress parameters for the impervious fill were obtained from triaxial compression tests on compacted clay till samples, the results of which are presented in Appendix X. Strength parameters chosen for design were:

$$Cu = 79\ \text{kPa};\quad \phi u = 3^{\circ}$$

$$\text{and}\quad c' = 0;\quad \phi' = 27^{\circ}$$

Previously published data, by Golder Associates (1977), indicate that the effective strength parameters for the native undisturbed till foundation material are $c' = 0$, $\phi = 30^{\circ}$. Examination of samples of the foundation materials from the recent drilling and test pit program indicate that the undrained shear strength of the plastic till in place is high. A value of $c_u = 170$ kPa was chosen for design.

The required safety factors are shown in Table 2 below. The actual values calculated for each condition are given on Plate A12.

TABLE 2

Safety Factors for Embankment Stability

Condition	Minimum Safety Factor
Immediate post construction stability of u/s and d/s slopes	1.2
Long term stability of u/s and d/s slopes	1.5
Long term stability of u/s and d/s slopes with earthquake loading of 0.1 g	1.05
Stability of u/s slope with rapid drawdown	1.2

5.4.5 Stream Diversion

The hydrology data discussed in Section 3 indicates that the design 24 hr rainfall discharge for this drainage basin is 4700 m^3, and the design 3 month snow melt runoff is 235000 m^3. The design rainstorm can be controlled during construction by storing the flood behind an upstream cofferdam, and then pumping to the downstream of the construction area. The upstream toe of the dam would be built first to form the cofferdam.

The snow melt runoff in the first construction year is assumed to occur before placement of dam fill. The snow melt runoff in the second construction year can be temporarily stored behind the water supply dam provided that this structure reaches El 1344 during the first season, which should not present any scheduling problem. Pumping capacity of about 0.03 m^3/s for the 3 month snow melt period should be adequate for this purpose.

5.4.6 Instrumentation

A series of piezometers and settlement monuments should be installed to monitor the performance of the water supply dam during construction and operation. Piezometers should be placed in drill holes in the foundations and also in the impervious fill. They should be high air entry value porous stone tips, carefully installed under supervision. Two cross sections of the dam should be instrumented, with piezometer leads carried to terminal houses downstream of the dam. Survey monuments should be established at the upstream edge of the downstream berm and on the downstream side of the dam crest. These should consist of permanent steel survey markers embedded about 3 m into the fill, with a protective sleeve on the upper 1.5 m to prevent movment due to adfreezing. The monuments would be spaced about 30 m apart across the dam, and be surveyed regularly to monitor vertical and horizontal movements.

Suggested locations for the piezometers and survey monuments are shown on Plate A10. A total of 22 piezometers and about 43 survey monuments is proposed.

In addition to the instrumentation to monitor the dam fill we would recommend a weir be installed in the stream channel downstream of the dam to measure the flow from the dam drainage blanket.

6. ASH RETENTION DAM

6.1 Design and Operating Criteria

The parameters for the ash retention reservoir determined by B.C. Hydro are as follows:

Ultimate storage capacity	97.5×10^6 m^3 *
Ultimate maximum reservoir elevation	1273.5
Stage 1 - Dam Crest Elevation	1250.0 - Complete 1985
Stage 2 - Dam Crest Elevation	1264.0 - Complete 1996
Stage 3 - Dam Crest Elevation	1271.6 - Complete 2006
Stage 4 - Dam Crest Elevation	1275.6 - Complete 2016
Crest width	7.5 m minimum

6.2 Geotechnical Considerations

The original dam centreline proposed by B.C. Hydro was called Axis 3. After drilling test holes and conducting preliminary geologic mapping a decision was made to move the dam upstream by about 180 m to provide assurance against reservoir leakage, as discussed in Section III.8.2, Appendix III. This new alignment is designated Axis 3B in this report.

A plan of the proposed dam site at Axis 3B is shown on Plate A13. A longitudinal profile along dam Axis No 3 together with the simplified drill hole profile is shown on Plate A17. The subsoil profile on Axis 3B is expected to be similar to that on Axis No 3.

On Axis No 3 a deposit of glacial till overlies the bedrock. The bedrock encountered in the drill holes is part of the greenstone suite (Plate A4). The glacial till cover is much thinner on the left abutment than on the right abutment (Plate A17). On the left abutment test hole P77-41 indicates 7 m of till over the bedrock, while on the right abutment, at test hole P77-39, a till cover up to 60 m was observed.

* Revised to 105×10^6 m^3 based on subsequent topography, see Plate A28.

The glacial till is the same well graded, medium plastic, clay-rich material encountered in the water supply reservoir. The near surface zones of the deposit are weathered and more granular and pervious than the material at depth. The drill holes encountered occasional sandy lenses within the plastic till. Drill hole permeability tests were mostly carried out in sandy zones and indicate permeability values in the region of 10^{-3} to 10^{-4} cm/sec. The falling head tests in the drill hole are not considered fully reliable, due to possible leakage around the casing and an inability to obtain steady flow conditions. The falling head tests in the standpipe piezometers provide more consistent results. Our interpretation of the data is that with the exception of local sandy lenses, the clay till has an average permeability of about 10^{-6} cm/sec. In the greenstone bedrock drill hole falling head permeability tests indicate a permeability of about 3×10^{-5} cm/sec, (equivalent to about 2 Lugeons). Attempts at packer tests in this material were unsuccessful. Field permeability tests are tabulated in Appendix VI.

In summary, the site is suitable for construction of the proposed 83 m high earthfill dam. The foundations consist of very stiff to hard low permeability till overlying a sound bedrock, so that no unusual stability or seepage problems are expected. A suspected bedrock fault along the valley in this region is inactive and of no concern. A local grout curtain may be needed on the higher levels of the abutments where the till cover over bedrock can be very shallow. Some consolidation grouting is assumed for the core and filter contacts.

6.3 Construction Materials

Impervious fill material can be obtained close by the dam site from the thick glacial till deposit to be found on the lower slopes of the north side of Medicine Creek, borrow areas A_1 and A_2. It is proposed to obtain material for Stage 1 of the dam construction from upstream of the dam site, area A_1.

Impervious fill for subsequent stages would be obtained from a borrow pit downstream of the dam, area A_2. The two borrow areas, together with typical index test data, are shown on Plate A22.

The till is generally several percent dry of the optimum value for compaction as defined by the Standard Proctor test (ASTM D-698), so that some addition of water will be required either in the borrow pit or on the embankment. There will be some boulders in the material, and we anticipate that the till will require ripping in the pit. The near surface materials are likely to be more sandy than at depth, and should be used in the random impervious zone of the dam.

Granular fill for filters and drains for Stage 1 construction is available from the upper Medicine Creek meadows borrow area D, (Plate A24), or from the Hat Creek borrow pit E, (Plate A25). The latter source was assumed for cost estimating. The material will require screening to produce fill of the required gradation for filter and drain zones.

The quantities of impervious fill and granular fill required for the dam are shown in Table 3 below.

TABLE 3

Fill Volume Requirements for Ash Retention Dam

		Impervious fill $\times 10^6 \times m^3$	Granular Fill $\times 10^6 m^3$
Stage 1 to El 1250		1.84	0.17
Stage 2 to El 1264		1.43	0.05
Stage 3 to El 1275.6		0.81	0.02
	TOTAL	4.08	0.24

6.4 Embankment Design

6.4.1 General

Similar to the water supply dam, the availability of borrow materials dictates the adoption of a modified homogenous cross section, making maximum use of impervious fill and minimum use of sand and gravel. The embankment is designed to be built mostly out of clay till, with an internal chimney drain connecting to a horizontal drain blanket beneath the downstream zone of the dam. A typical cross section through the dam is shown on Plate A15.

6.4.2 Staged Construction

The ash retention dam will be built initially to El 1250 and thereafter raised periodically to stay ahead of the rising pond level. The initial B.C. Hydro proposal was to build the dam in four stages as tabulated in Section 6.1. With this scheme, construction of Stages 3 and 4 by adding fill to the downstream side of the structure would involve placing and compacting fill in a zone of restricted horizontal width. For this reason, and because the fill required for Stage 4 would be a relatively small proportion of the total, construction in three stages as shown below is recommended.

Stage 1	-	Dam Crest El 1250	-	completed 1985
Stage 2	-	Dam Crest El 1264	-	completed 1996
Stage 3	-	Dam Crest El 1275.6	-	completed 2006

6.4.3 Foundation Preparation

The dam foundations will be stripped of topsoil and organic materials and any soft stream bed deposits to a nominal depth of 0.5 m. The foundation area beneath the select impervious zone will be stripped to sound unweathered impervious till and a positive cut-off provided. In the core zone stripping depths of 1.2 m with up to 2.0 m in the stream channel are estimated, with the cutoff trench a nominal 3 m deep. On the upper levels of the abutments of Stages 2 and 3, some bedrock may be exposed which will be excavated to sound rock, cleaned off and slush grouted as necessary. Some consolidation grouting may be necessary in the cutoff trench. For purposes of cost estimating we have assumed that the abutments of Stages 2 and 3 would need a single row of grout holes, 15 m deep on a 6 m spacing.

6.4.4 Embankment Fill Materials

Stage 1 of the ash retention dam can be built from clayey till available from borrow areas immediately adjacent to the dam. Alternatively, if the material is suitable, waste from the open pit mine stripping operation, that would otherwise be disposed of in the lower Medicine Creek waste dump, could be used. For cost estimating purposes we have assumed the fill to come from the Medicine Creek borrow areas, A_1 and A_2. Granular materials could be taken from the Hat Creek borrow area or from the upper Medicine Creek meadows borrow area. For cost estimating, the source farthest from the dam, Hat Creek borrow area E, was assumed.

Stages 2 and 3 could be constructed from local till borrow from area A_2 just downstream of the dam, or from suitable pit waste material. Local till borrow has been assumed for the cost estimates given in Section 7. Alternatively, bottom ash could be used to build part of the Stage 2 and 3 embankment as illustrated on Plate A16. The rate of bottom ash production by the thermal plant will be about 890,000 tonnes/year. Assuming a compacted density of 1.6 t/m^3 the amount of ash fill required for Stage 2 of the dam is 1.15×10^6 tonnes, or about 15 months supply, and for Stage 3, 1.39×10^6 tonnes, or about 19 months supply.

The required amount of bottom ash could be stockpiled adjacent to the dam and placed and compacted in one continuous operation. Alternatively, a pipeline system might be designed to allow intermittent hydraulic placement of the fill on the dam followed by spreading and mechanical compaction. During such an operation water would have to be controlled to prevent erosion and flooding of drainage zones in the dam.

Because of the constantly rising pond level and the use of a homogeneous cross section it is not considered necessary to riprap the whole of the upstream slope of the dam. Riprap need only be applied to the upper levels of the upstream slope of Stage 3 if a permanent pond remains. Using the wind speed data from Table 1, Section 5.4.3, and design methods of the Corps of Engineers (1973), a total riprap thickness of 1.2 m has been determined, consisting of well graded rock ranging from 0.3 m to 0.75 m average dimensions. The riprap will be placed on a 0.3 m thick layer of gravel bedding.

The downstream slopes should be seeded to provide a grass cover for surface erosion protection.

6.4.5 Stability Analysis

The Stage 1 dam slopes have been analysed for construction stability using total stress parameters and for long term stability under conditions of steady seepage using effective stress parameters. The long term stability was computed including the effect of earthquake loading, assuming an earthquake coefficient of 0.1 g.

The second and third stages of construction were analysed for construction stability, and the ultimate Stage 3 dam section was also analysed for long term stability. The upstream slope of Stage 1 was analysed for stability under conditions of partial pool levels.

Safety factors were also computed on failure surfaces passing through the foundation soils for the cases of construction stability of Stage 1 and long term stability of the ultimate dam section.

Analysis of the construction stability of the dam immediately after placement of the Stage 2 and 3 fill required an estimate of the pore water pressures in the impervious fill comprising Stage 1. This was done by assuming a pore pressure coefficient $\bar{B}$ = 0.5 and assuming that construction pore pressures in the Stage 1 fill would be 75 percent dissipated over the 10 year period between the completion of Stage 1 and the start of Stage 2 construction.

The fill and foundation material shear strength parameters used in the analysis were the same as those detailed in Section 5.4.4 for the water supply dam.

The minimum acceptable safety factors adopted for design were the same as those presented in Table 2, Section 5.4.4. These analyses were performed using the Janbu (1964) method of noncircular slip surfaces, with the aid of an electronic computer. In addition, some comparisons were made using the simplified method of Bishop (1954) for selected critical failure surfaces. The results of this work are shown on Plates A19 and A20. The relatively low undrained shear strength of the clay till material which would form the bulk of the dam requires reasonably flat slopes for adequate end of construction stability. The most economic dam section for these conditions uses horizontal berms. The berm widths and heights shown for Stage 1 on Plate A19 are needed to ensure adequate stability for Stages 2 and 3, as well as Stage 1.

In final design, a more detailed study of the variation of shear strength of the clay till with placement water content may allow these berm widths to be reduced.

6.4.6 Diversion of Medicine Creek During Construction

Using the hydrologic parameters described in Section 3, two possible creek diversion schemes were studied. One scheme would be to wait for the snow melt runoff to occur at the beginning of the first construction season, and then build the upstream end of the Stage 1 berm very quickly to form a cofferdam for storage of the base flow in the creek and the design rainstorm flood. This water would then be pumped over the Stage 1 embankment. The Stage 1 embankment would be raised during the first construction season to a sufficient height to store the following spring snow melt temporarily while it in turn is pumped over the embankment. A maximum pumping capacity of about 0.71 m^3/s would be required, operating for about 3 months to remove the snow melt water. The berm level required for storage of the design rainstorm flood is El 1209. To store the design snow melt flood the Stage 1 embankment will be required to reach El 1232 at the end of the first construction season.

The second diversion method considered was a diversion culvert installed beneath the dam. The culvert capacity would be adequate to pass the peak flow of 2.3 m^3/s expected during the second season snow melt, in which case no pumping would be required. The culvert would pass through the entire width of the Stage 1 embankment and would be closed, filled with concrete and grouted when no longer required. Even though in service for a relatively short period, the design and installation must ensure that the culvert can withstand the load of the 60 m high dam without distress, and that there is no risk of seepage and piping developing along the embankment/culvert contact. To achieve this, a culvert of heavy gauge corrugated steel pipe, or reinforced concrete pipe, supported on a concrete cradle would be required. Mass concrete would surround the top of the pipe to provide structural strength and a trapezoidal shape against which to place fill and ensure a good seal.

A preliminary comparison of the costs of the "all pumping" and large capacity culvert schemes suggests that they are of the same order of magnitude - approximately $0.25 million. More reliable hydrologic data, if it is available for final design, may indicate a positive cost advantage to one or the other of the schemes, but at the present time we recommend the pumping scheme in preference to building a culvert.

6.4.7 Instrumentation

Piezometers and survey monuments should be installed in the fill and foundation materials to monitor the dam during and after construction. We recommend that three cross sections be instrumented with piezometers, one in the deepest part of the valley and one on each abutment. The foundation piezometers should be installed in drill holes prior to construction, and embankment piezometers carefully placed within the impervious fill during construction. The piezometers should incorporate high entry value porous stone tips, with leads carried to terminal houses downstream of the dam.

Survey monuments should be established in the fill along the upstream sides of the berms for Stage 1 and Stage 2, and along the crest of each of the three stages. The monuments should be installed about 3 m deep, with the upper 1.5 m provided with a protective sleeve to prevent movement due to adfreezing. The monuments would be spaced about 30 m apart, and be surveyed regularly to monitor vertical and horizontal movements.

The survey monument locations and suggested piezometer locations for the central instrumented section are shown on Plate A15. A total of 26 piezometers and about 37 survey monuments is proposed.

We would also recommend that a weir be installed in the stream channel below the dam to measure flow from the drain blanket. If considered necessary, an observation well about 60 m deep could be located just downstream of the dam so that future groundwater quality could be monitored.

7. CAPITAL COST ESTIMATE

The following Tables 7-1 to 7-5 present our estimates of the capital costs of the water supply dam, water supply saddle dam, and the three stages of the ash retention dam. These costs are related to September 1977 price levels, and do not include any allowance for inflation, interest during construction, land acquisition costs, engineering and supervision, or contingencies.

TABLE 7 - 1

COST ESTIMATE SUMMARY FOR - WATER SUPPLY DAM

NO	DESCRIPTION	UNIT	COST/UNIT $	QUANTITY	AMOUNT $	TOTALS $	REMARKS
1	Mobilisation	LS			80 000	80 000	
2	Clearing Reservoir Area	ha	1 980.00	70.0	138 600	138 600	
3	Clearing & Grubbing Dam Foundation Area	ha	2 980.00	13.5	40 230	40 230	
4	Diversion & Water Handling	LS			50 000	50 000	
5	Foundation Excavation						
A	Strip and excavate soil	m^3	2.60	98 900	257 140		
B	Excavate rock	m^3	19.50	50	975	258 115	
6	Drilling & Grouting						
A	Drilling and washing grout holes	m	65.00	1 000	65 000		
B	Supplying, mixing and injecting grout	m^3	175.00	90	15 750	80 750	
7	Pressure Relief Wells						
	Supplying and installing	m	295.00	400	118 000	118 000	
8	Foundation preparation						
A	Prepare rock surface under core and filter blanket	m^2	5.35	4 850	25 947		
B	Supplying and placing shotcrete	m^3	390.00	50	19 500	45 447	
C	Supplying and placing slush grout	bag	60.00	194	11 640	57 087	
						822 782	

TABLE 7 - I (Cont)

COST ESTIMATE SUMMARY FOR - WATER SUPPLY DAM

NO		DESCRIPTION	UNIT	COST/UNIT $	QUANTITY	AMOUNT $	TOTALS $	REMARKS
							822 782	
9		Dam Embankment Fill						
	A	Impervious fill zone I	m^3	2.60	437 000	I 136 210		
	B	Special fill zone IA	m^3	7.80	I 500	II 700		
	C	Random Impervious fill zone 2	m^3	2.34	793 630	I 857 094		
	D	Filter Gravel zone 3	m^3	9.00	156 600	I 409 400		
	E	Drain Gravel zone 4	m^3	9.00	18 000	162 000		
	F	Sand & Gravel zone 5	m^3	6.00	161 500	969 000		
	G	Rip rap bedding zone 6	m^3	9.00	10 100	90 900		
	H	Rip rap zone 7	m^3	20.00	30 150	603 000	6 239 300	
10		Compaction	m^3/pass	0.13	0	0		
11		Instrumentation	LS			55 000	55 000	
12		Permanent access roads	km	150 000.00	0.08	12 000	12 000	
13		Site clean up	LS			40 000	40 000	
						TOTAL	7 170 000	

TABLE 7 - 2

COST ESTIMATE SUMMARY FOR - WATER SUPPLY SADDLE DAM

NO	DESCRIPTION	UNIT	COST/UNIT $	QUANTITY	AMOUNT $	TOTALS $	REMARKS
1	Mobilisation	LS			10 000	10 000	
2	Clearing Reservoir Area	ha		0	0		Included with W/S Dam
3	Clearing & Grubbing Dam Foundation Area	ha	2 980.00	1.5	4 470	4 470	
4	Diversion & Water Handling	LS			0	0	
5	Foundation Excavation						
A	Strip and excavate soil	m^3	2.60	21 100	54 808		
B	Excavate rock	m^3	19.50	0	0	54 860	
6	Drilling & Grouting						
A	Drilling and washing grout holes	m	65.00	400	26 000		
B	Supplying, mixing and injecting grout	m^3	175.00	36	6 300	32 300	
7	Pressure Relief Wells						
	Supplying and installing	m	295.00	255	75 225	75 225	
8	Foundation preparation						
A	Prepare rock surface under core and filter blanket	m^2	5.35	8 120	43 444		
B	Supplying and placing shotcrete	m^3	390.00	200	78 000		
C	Supplying and placing slush grout	bag	60.00	540	32 400	153 844	
						330 699	

TABLE 7 - 2 (Cont)

COST ESTIMATE SUMMARY FOR - WATER SUPPLY SADDLE DAM

NO		DESCRIPTION	UNIT	COST/UNIT $	QUANTITY	AMOUNT $	TOTALS $	REMARKS
							330 699	
9		Dam Embankment Fill						
	A	Impervious fill zone I	m^3	3.28	87 800	287 984		
	B	Special fill zone IA	m^3	7.80	0	0		
	C	Random Impervious fill zone 2	m^3	3.00	23 400	70 200		
	D	Filter Gravel zone 3	m^3	9.00	5 900	53 100		
	E	Drain Gravel zone 4	m^3		0			
	F	Sand & Gravel zone 5	m^3		0			
	G	Rip rap bedding zone 6	m^3	9.00	1 865	16 785		
	H	Rip rap zone 7	m^3	20.00	5 600	112 000	540 069	
10		Compaction	m^3/pass	0.13	0	0		
11		Instrumentation	LS			10 000	10 000	
12		Permanent access roads	km	150 000.00	1.2	180 000	180 000	
13		Site clean up	LS			5 000	5 000	
						TOTAL	1 070 000	

TABLE 7 - 3

COST ESTIMATE SUMMARY FOR - ASH RETENTION DAM STAGE I

NO	DESCRIPTION	UNIT	COST/UNIT $	QUANTITY	AMOUNT $	TOTALS $	REMARKS
1	Mobilisation	LS			65 000	65 000	
2	Clearing Reservoir Area	ha	1 980.00	39.2	77 616	77 616	
3	Clearing & Grubbing Dam Foundation Area	ha	2 980.00	11.3	33 674	33 674	
4	Diversion & Water Handling	LS			250 000	250 000	
5	Foundation Excavation						
A	Strip and excavate soil	m^3	2.60	103 300	268 580		
B	Excavate rock	m^3	19.50	50	975	269 555	
6	Drilling & Grouting						
A	Drilling and washing grout holes	m	65.00	360	23 400		
B	Supplying, mixing and injecting grout	m^3	175.00	33	5 775	29 175	
7	Pressure Relief Wells						
	Supplying and installing	m	295.00	175	51 625	51 625	
8	Foundation preparation						
A	Prepare rock surface under core and filter blanket	m^2	5.35	2 000	10 700		
B	Supplying and placing shotcrete	m^3	390.00	50	19 500		
C	Supplying and placing slush grout	bag	60.00	80	4 800	35 000	
						811 645	

TABLE 7 - 3 (Cont)

COST ESTIMATE SUMMARY FOR - ASH RETENTION DAM STAGE I

NO		DESCRIPTION	UNIT	COST/UNIT $	QUANTITY	AMOUNT $	TOTALS $	REMARKS
							811 645	
9		Dam Embankment Fill						
	A	Impervious fill zone I	m^3	2.34	866 200	2 026 908		
	B	Special fill zone IA	m^3	7.80	100	780		
	C	Random Impervious fill zone 2	m^3	2.08	970 500	2 018 640		
	D	Filter Gravel zone 3	m^3	9.00	129 800	1 168 200		
	E	Drain Gravel zone 4	m^3	9.00	42 600	383 400		
	F	Sand & Gravel zone 5	m^3		0	0		
	G	Rip rap bedding zone 6	m^3		0	0		
	H	Rip rap zone 7	m^3		0	0		
10		Compaction	m^3/pass	0.13	0	0	5 597 928	
11		Instrumentation	LS			45 000	45 000	
12		Permanent access roads	km	15 000.00	2.0	30 000	30 000	
13		Site clean up	LS			35 000	35 000	
						TOTAL	6 520 000	

TABLE 7 - 4

COST ESTIMATE SUMMARY FOR - ASH RETENTION DAM STAGE 2

NO	DESCRIPTION	UNIT	COST/UNIT $	QUANTITY	AMOUNT $	TOTALS $	REMARKS
1	Mobilisation	LS			40 000	40 000	
2	Clearing Reservoir Area	ha	1 980.00	76.5	151 470	151 470	
3	Clearing & Grubbing Dam Foundation Area	ha	2 980.00	2.9	8 642	8 642	
4	Diversion & Water Handling	LS			0	0	
5	Foundation Excavation						
A	Strip and excavate soil	m^3	2.60	22 400	58 240		
B	Excavate rock	m^3	19.50	25	488	58 728	
6	Drilling & Grouting						
A	Drilling and washing grout holes	m	65.00	300	19 500		
B	Supplying, mixing and injecting grout	m^3	175.00	27	4 725	24 225	
7	Pressure Relief Wells						
	Supplying and installing	m	295.00	163	48 085	48 085	
8	Foundation preparation						
A	Prepare rock surface under core and filter blanket	m^2	5.35	1 200	6 420		
B	Supplying and placing shotcrete	m^3	390.00	25	9 750		
C	Supplying and placing slush grout	bag	60.00	80	4 800	20 970	
						352 120	

TABLE 7 - 4 (Cont)

COST ESTIMATE SUMMARY FOR - ASH RETENTION DAM STAGE 2

NO		DESCRIPTION	UNIT	COST/UNIT $	QUANTITY	AMOUNT $	TOTALS $	REMARKS
							352 120	
9		Dam Embankment Fill						
	A	Impervious fill zone 1	m^3	2.34	200 900	470 106		
	B	Special fill zone 1A	m^3	7.80	720	5 616		
	C	Random impervious fill zone 2	m^3	2.08	1 223 872	2 545 654		
	D	Filter Gravel zone 3	m^3	9.00	46 400	417 600		
	E	Drain Gravel zone 4	m^3	9.00	5 400	48 600		
	F	Sand & Gravel zone 5	m^3	-	0	0		
	G	Rip rap bedding zone 6	m^3	-	0	0		
	H	Rip rap zone 7	m^3	-	0	0	3 438 976	
10		Compaction	m^3/pass	0.13	0	0		
11		Instrumentation	LS			32 000	32 000	
12		Permanent access roads	km	-	0	0		
13		Site clean up	LS			20 000	20 000	
						TOTAL	3 840 000	

TABLE 7 - 5

COST ESTIMATE SUMMARY FOR - ASH RETENTION DAM STAGE 3

NO	DESCRIPTION	UNIT	COST/UNIT $	QUANTITY	AMOUNT $	TOTALS $	REMARKS
1	Mobilisation	LS				23 000	
2	Clearing Reservoir Area	ha	1 980.00	64	126 720	126 720	
3	Clearing & Grubbing Dam Foundation Area	ha	2 980.00	1.0	2 980	2 980	
4	Diversion & Water Handling	LS			0		
5	Foundation Excavation						
A	Strip and excavate soil	m^3	2.60	8 100	21 060		
B	Excavate rock	m^3	19.50	40	780	21 840	
6	Drilling & Grouting						
A	Drilling and washing grout holes	m	65.00	225	14 625		
B	Supplying, mixing and injecting grout	m^3	175.00	20	3 500	18 125	
7	Pressure Relief Wells						
	Supplying and installing	m	295.00	170	50 150	50 150	
8	Foundation preparation						
A	Prepare rock surface under core and filter blanket	m^2	5.35	1 500	8 025		
B	Supplying and placing shotcrete	m^3	390.00	25	9 750		
C	Supplying and placing slush grout	bag	60.00	100	6 000	23 775	
						266 590	

TABLE [illegible] - 5 (Cont)

COST ESTIMATE SUMMARY FOR - ASH RETENTION DAM STAGE 3

NO		DESCRIPTION	UNIT	COST/UNIT $	QUANTITY	AMOUNT $	TOTAL $	REMARKS
							266 590	
9		Dam Embankment Fill						
	A	Impervious fill zone 1	m^3	2.34	115 700	270 738		
	B	Special fill zone 1A	m^3	7.80	1 000	7 800		
	C	Random Impervious fill zone 2	m^3	2.08	692 100	1 439 568		
	D	Filter Gravel zone 3	m^3	9.00	22 000	198 000		
	E	Drain Gravel zone 4	m^3	-	0			
	F	Sand & Gravel zone 5	m^3	-	0			
	G	Rip rap bedding zone 6	m^3	9.00	800	7 200		
	H	Rip rap zone 7	m^3	20.00	3 200	64 000	1 987 306	
10		Compaction	m^3/pass	0.13	0			
11		Instrumentation	LS			13 000	13 000	
12		Permanent access roads	km	-	-	0		
13		Site clean up	LS				12 000	
						TOTAL	2 280 000	

8. GEOTECHNICAL INVESTIGATIONS

8.1 Drilling Program

The drilling program was carried out using a Becker diesel hammer drill. This method of drilling uses a double walled steel casing driven into the ground with an 8000 ft-lb diesel pile driving hammer. Compressed air forced down the annular space between the double walls is used to remove cuttings from the hole.

Twenty-one holes were drilled with the Becker drill, 4 along the centreline of the water supply dam, 3 along the centreline of the water supply saddle dam, 3 on ash dam Axis No 1A, 1 on ash dam Axis No 3A, 4 on ash dam Axis No 3 and 4 on ash dam Axis No 4. Two holes were drilled at the divide between Medicine Creek and MacLaren Creek. This divide area was also the site of a diamond drill hole, DDH-501. Plate A2 shows these drill hole locations. All but three of these drill holes were carried down to the bedrock surface, and 15 of them were taken about 5 metres into bedrock using a NQ core barrel.

Sampling in the overburden materials consisted of drive samples, either standard split spoon or heavy walled 2½ inch shelby tubes, and cutting samples taken from the air flush return pipe.

The permeabilities of the overburden materials and the underlying bedrock were determined using falling head tests in the drill casing. At the test depth the drill casing was pulled back about 0.6m, the casing filled with water and the rate of fall in water level recorded. Data from these tests are tabulated in Appendix VI. In several holes single stage packer tests were conducted in the bedrock. These data are also tabulated in Appendix VI. The packer test results cannot be regarded as completely reliable because of the poor quality of the core drilling which may have led to faulty packer sealing in some cases.

8.2 Test Pit Program

A series of 61 test pits were excavated using a tractor mounted backhoe. Most of these pits were in potential borrow areas, with six of them located in the dam foundations. The pits were logged, and disturbed samples were recovered for laboratory testing. The test pit logs are presented on Plates C10 to C16.

8.3 Seismic Refraction Survey

A seismic refraction survey was carried out on each of three alignments; Axis No 3, Axis No 4, and across the Medicine Creek-MacLaren Creek divide. The purpose of the work was to determine the bedrock surface and attempt to locate a suspected bedrock fault and unconformity. The report on this work, by Geotronic Surveys Ltd, is presented in Appendix V. In addition the bedrock profile revealed by the seismic survey on the centreline of Axis 3 is shown plotted on Plate A17.

8.4 Laboratory Testing

All samples from the drilling program and the test pit program were visually examined and classified in the laboratory and their water contents determined. Additional classification tests such as Atterberg limits, and grain size distribution were carried out on selected samples. The resulting water content data are plotted on the test hole logs on plates C1 to C16, Appendix VII. In addition, grain size and plasticity data are presented on plates C18 to C22, Appendix IX.

Two samples of the proposed impervious borrow material were subjected to Standard Proctor Compaction tests according to ASTM D-698. These data are shown on Plates A22 and A23 together with selected grain size curves and Atterberg limit results representative of the two principal impervious borrow areas.

A series of three consolidated undrained triaxial tests with pore pressure measurement were carried out on compacted samples of the impervious borrow material. These samples were formed using the miniature Harvard compaction apparatus, saturated under a back pressure in the triaxial cell, and sheared at a strain rate of 0.033 mm/min. The results of these tests, in the form of stress-strain curves and Mohr circles of stress are shown on Plate C23, Appendix X.

Several unconsolidated undrained triaxial tests were performed on similarly compacted samples to determine total stress parameters of the impervious fill materials. These data are shown on Plate C24, Appendix X.

A falling head permeability test was performed on a compacted sample of impervious borrow material saturated under vacuum. This test indicated a very low permeability of the order of 10^{-10} m/s in the vertical direction. A somewhat higher permeability would be expected in horizontal direction.

To check if the clayey till material is dispersive, three pin hole tests were performed on compacted samples of the clay till. The data from these tests, see Appendix XI, showed the clay to be non-dispersive.

9. RECOMMENDATIONS FOR FINAL DESIGN STUDIES

The work outlined in this report comprises a preliminary design. Before contract drawings and specifications can be prepared there must be a final design phase that should include the following features.

9.1 Field Investigations

To date, test hole drilling in the water supply reservoir has been confined to the centre lines of the two dams. The final design stage should include additional test holes and test pits beneath the upstream and downstream slopes of the water supply dam. For example, test pit 152 near the upstream toe of the cooling water dam shows the absence of till over the bedrock surface. The extent of this feature should be determined at the final design stage.

Similarly additional drilling must be carried out at the site of the ash retention dam 3B, to augment the existing data from Axis No 3.

This work will involve drilling and sampling in both overburden and bedrock materials. It may be necessary to use two different types of drilling equipment, one for overburden and one especially for rock in order that good core recovery can be obtained. It will be essential to carry several holes deep into bedrock at both damsites and carry out good packer tests to assess the grouting requirements in more detail.

In addition to field explorations at the dam sites, additional drilling should be carried out in the upper Medicine Creek granular borrow area and the Medicine Creek impervious borrow areas to confirm the quantities of borrow available.

9.2 Engineering Studies

Additional studies of the engineering characteristics of the embankment fill materials are required. A more detailed study of the shear strength characteristics of the impervious fill, and effect of consolidation time on shear strength may allow some steepening of the design slopes for the two dam structures. Also, before the use of bottom ash can be formally recommended as a dam construction material a testing program to determine its shear strength, compaction, and permeability characteristics is recommended.

KLOHN LEONOFF CONSULTANTS LTD.

BYRON STEWART

ADRIAN WIGHTMAN, P. Eng.

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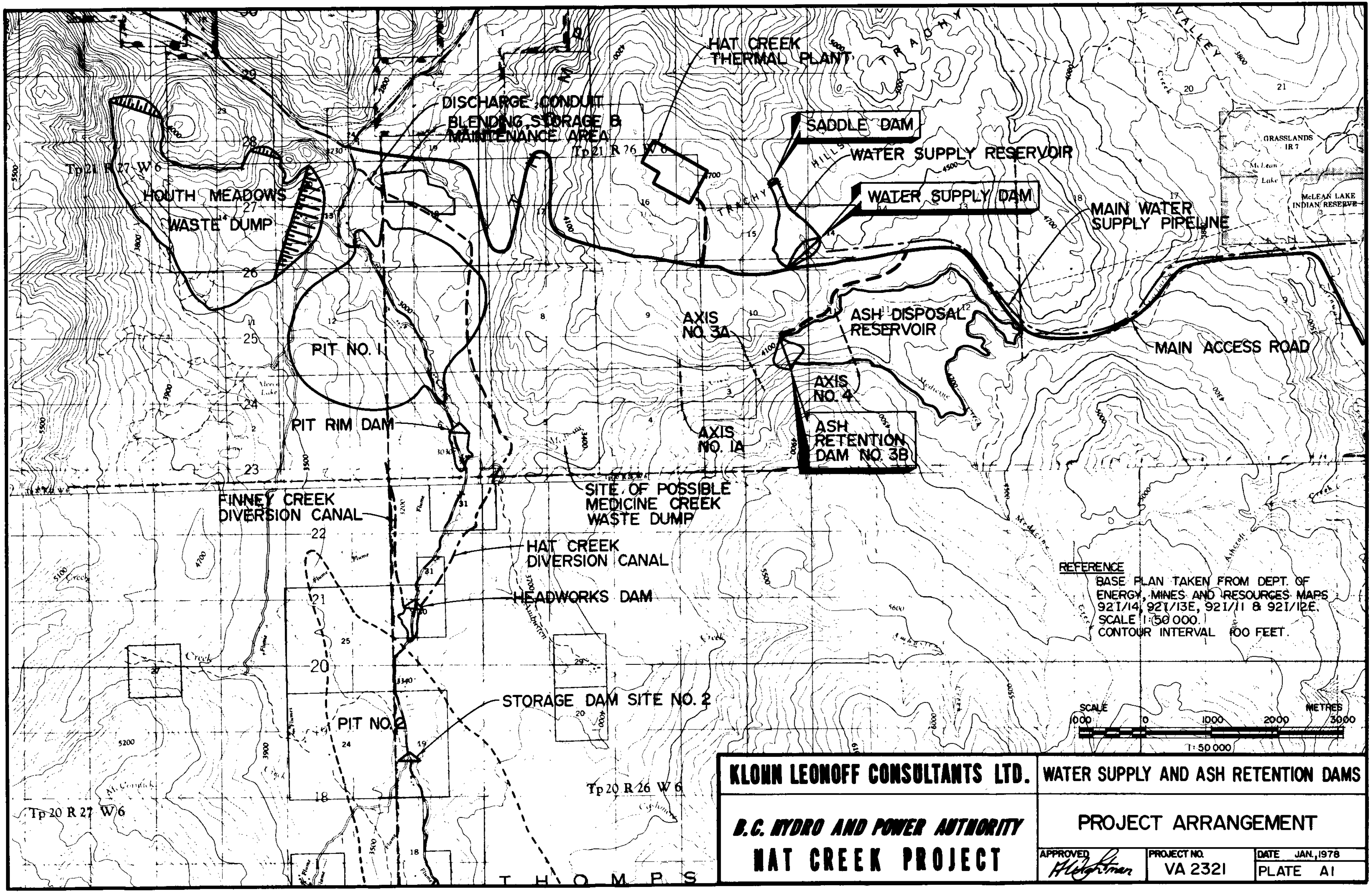
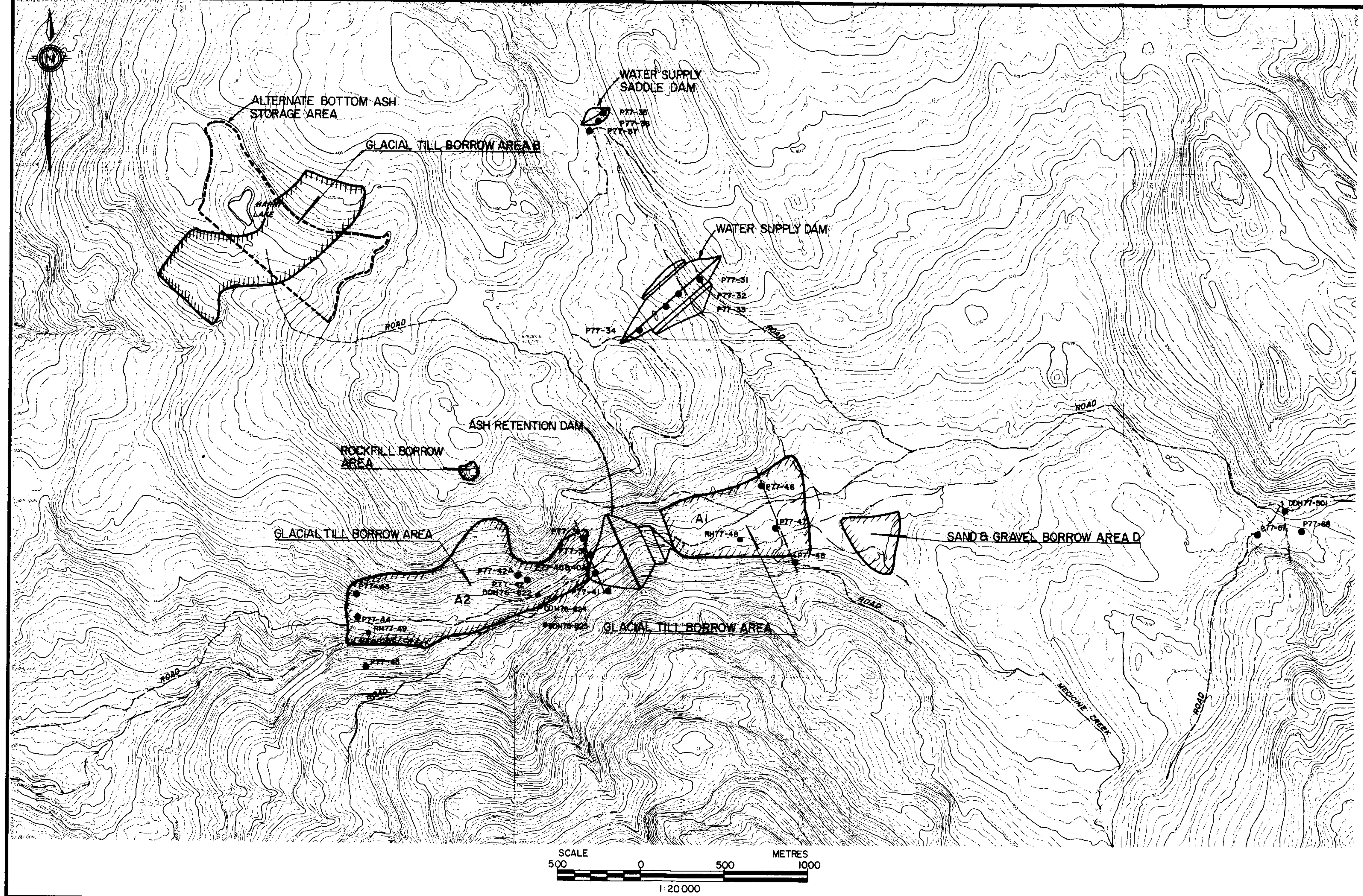
DRAWINGS


HAT CREEK THERMAL PLANT
DISCHARGE CONDUIT
BLENDING, STORAGE & MAINTENANCE AREA
Tp 21 R 26 W 6
Tp 21 R 27 W 6
SADDLE DAM
WATER SUPPLY RESERVOIR
WATER SUPPLY DAM
MAIN WATER SUPPLY PIPELINE
HOUTH MEADOWS WASTE DUMP
TRACHY HILLS
VALLEY
GRASSLANDS IR 7
McLEAN LAKE INDIAN RESERVE
ASH DISPOSAL RESERVOIR
MAIN ACCESS ROAD
AXIS NO. 3A
AXIS NO. 4
AXIS NO. 1A
ASH RETENTION DAM NO. 3B
PIT NO. 1
PIT RIM DAM
SITE OF POSSIBLE MEDICINE CREEK WASTE DUMP
FINNEY CREEK DIVERSION CANAL
HAT CREEK DIVERSION CANAL
HEADWORKS DAM
STORAGE DAM SITE NO. 2
PIT NO. 2
Tp 20 R 26 W 6
Tp 20 R 27 W 6
THOMPS
REFERENCE
BASE PLAN TAKEN FROM DEPT. OF ENERGY, MINES AND RESOURCES MAPS 92I/14, 92I/13E, 92I/11 & 92I/12E. SCALE 1:50 000. CONTOUR INTERVAL 100 FEET.
SCALE
1000 0 1000 2000 3000 METRES
1:50 000
KLOHN LEONOFF CONSULTANTS LTD.
WATER SUPPLY AND ASH RETENTION DAMS
B.C. HYDRO AND POWER AUTHORITY
HAT CREEK PROJECT
PROJECT ARRANGEMENT
APPROVED
PROJECT NO. VA 2321
DATE JAN., 1978
PLATE A1



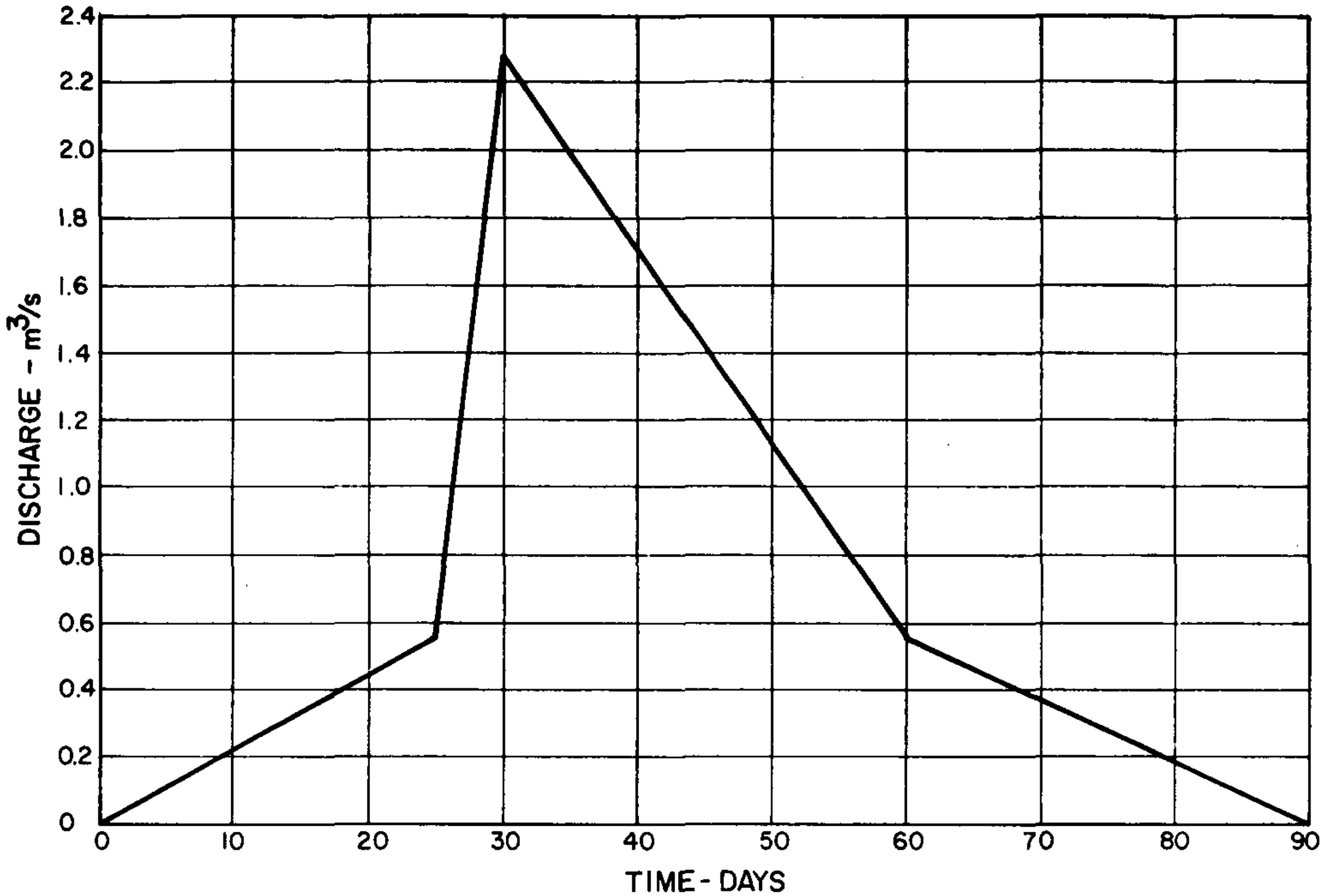
LEGEND

- ● P77-32 — PERCUSSION (BECKER) DRILL HOLES BY KLOHN LEONOFF CONSULTANTS LTD.
- ● DDH77-501 — DIAMOND DRILL HOLES KLOHN LEONOFF CONSULTANTS LTD.
- ● RH77-48 — ROTARY DRILL HOLES BY GOLDER ASSOCIATES LTD.
- ● DDH76-822 — DIAMOND DRILL HOLES EBASCO SERVICES INC.
- — · — · — SEISMIC REFRACTION SURVEY BY GEOTRONICS SURVEYS LTD.

REFERENCE

TOPOGRAPHIC BASE FROM SHEETS 10,11,13,14,16 & 17 OF DIGITAL MODEL TOPOGRAPHY AT 1:5000, SUPPLIED BY B.C. HYDRO.

KLOHN LEONOFF CONSULTANTS LTD.	WATER SUPPLY AND ASH RETENTION DAMS
B.C. HYDRO AND POWER AUTHORITY **HAT CREEK PROJECT**	DRILL HOLE LOCATIONS UPPER MEDICINE CREEK
APPROVED	PROJECT NO. VA 2321 — DATE JAN, 1978 — PLATE A2



ESTIMATED HYDROGRAPH FOR MEDICINE CREEK AT ASH RETENTION DAMSITE FOR SNOW MELT FLOOD WITH 10 YEAR RECURRENCE INTERVAL

NOTES:

1. SNOWMELT VOLUME AND PEAK SUPPLIED BY B.C. HYDRO; HYDROGRAPH SHAPE ESTIMATED BY KLOHN LEONOFF CONSULTANTS LTD.

KLOHN LEONOFF CONSULTANTS LTD.	WATER SUPPLY AND ASH RETENTION DAMS
B.C. HYDRO AND POWER AUTHORITY HAT CREEK PROJECT	HYDROLOGIC DATA
APPROVED	PROJECT NO. VA 2321
DATE JAN, 1978	PLATE A3

TIME-STRATIGRAPHIC UNITS				AGE M.Y.B.P.	ROCK STRATIGRAPHIC UNITS	
ERA	PERIOD	SERIES	STAGE			
CENOZOIC	QUATERNARY	NEOGENE	RECENT			VALLEY ALLUVIUM TALUS, LANDSLIDE.
			PLEISTO-CENE	1.5		GLACIAL DEPOSITS TILL, GLACIOFLUVIAL AND OUTWASH MINOR UNCONFORMITY, - EROSION
	TERTIARY		PLIOCENE	5	KAMLOOPS GROUP	OLIVINE BASALT
			MIOCENE	7 10		MINOR UNCONFORMITY, WARPING, SLIDING, EROSION.
		PALEOGENE	OLIGOCENE	30		FINNEY LAKE BEDS ANDESITE, DACITE, BRECCIA, LAHAR, TUFF.
						MEDICINE CREEK FM. SILTSTONE, CLAYSTONE, SHALE.
			ECOCENE	38		HAT CREEK COAL FM
						COLDWATER BEDS CONGLOMERATE, BRECCIA, SANDSTONE.
MESOZOIC				53	MAJOR UNCONFORMITY- MESOZOIC OROGENIES, REGIONAL METAMORPHISM, FOLDING, FAULTING AND EROSION.	
PALEOZOIC	PENNSYLVANIA AND PERMIAN			230	CACHE CREEK GROUP	MARBLE CANYON LS.
				320		GREENSTONE, CHERT, PHYLLITE, ARGILLITE

AFTER CHURCH, B.N., (1977)

KLOHN LEONOFF CONSULTANTS LTD.

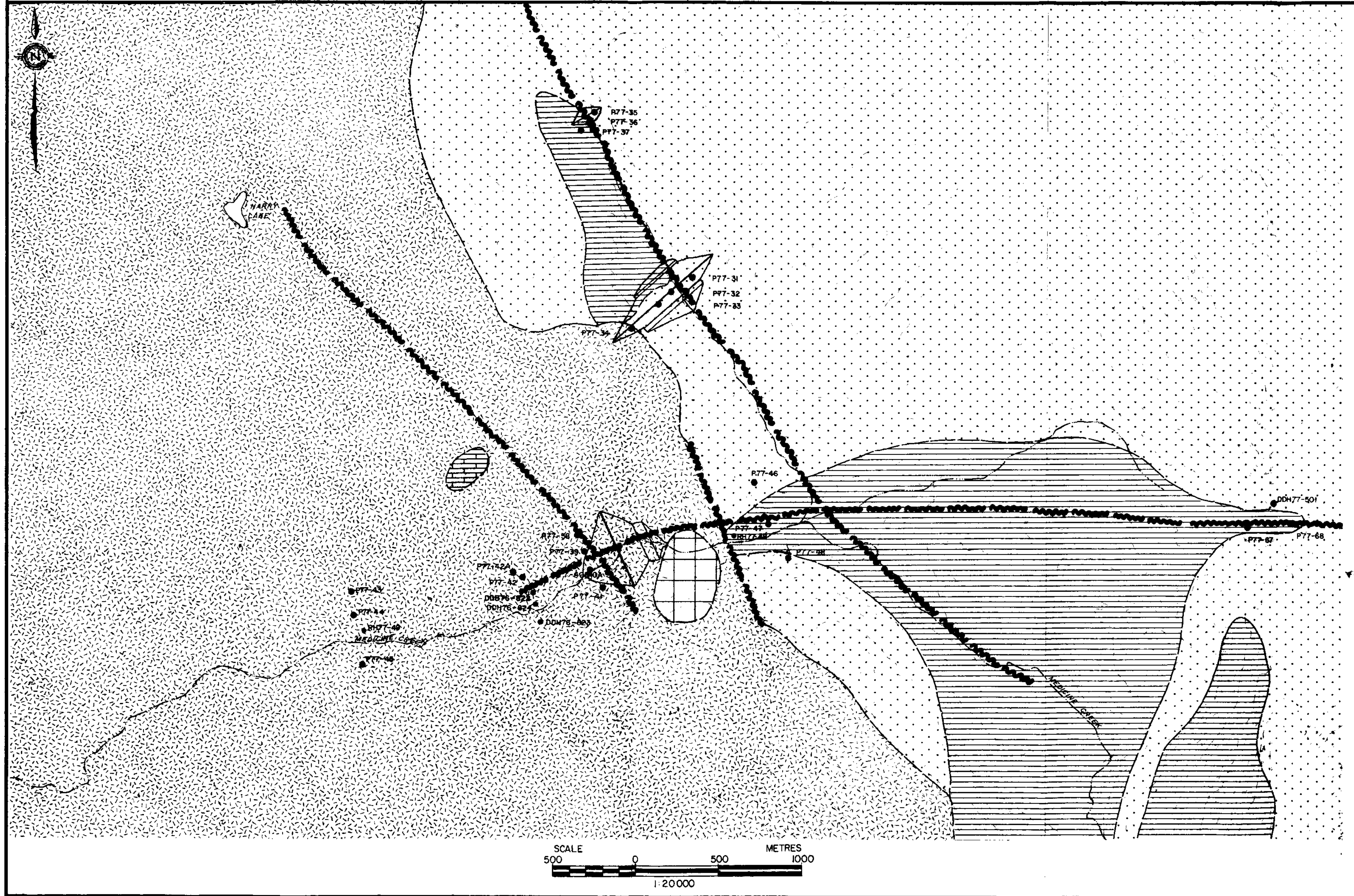
WATER SUPPLY AND ASH RETENTION DAMS

B.C. HYDRO AND POWER AUTHORITY

HAT CREEK PROJECT

TABLE OF GEOLOGIC FORMATIONS

APPROVED	PROJECT NO.	DATE JAN., 1978
[signature]	VA 2321	PLATE A4



LEGEND

KAMLOOPS GROUP
- ANDESITE, TUFF, BRECCIA.
- SILTSTONE - CLAYSTONE
- SANDSTONE & CONGLOMERATE

CACHE CREEK GROUP
- LIMESTONE
- GREENSTONE

GEOLOGICAL BOUNDARY (DEFINED)

GEOLOGICAL BOUNDARY (ASSUMED)

FAULT (DEFINED)

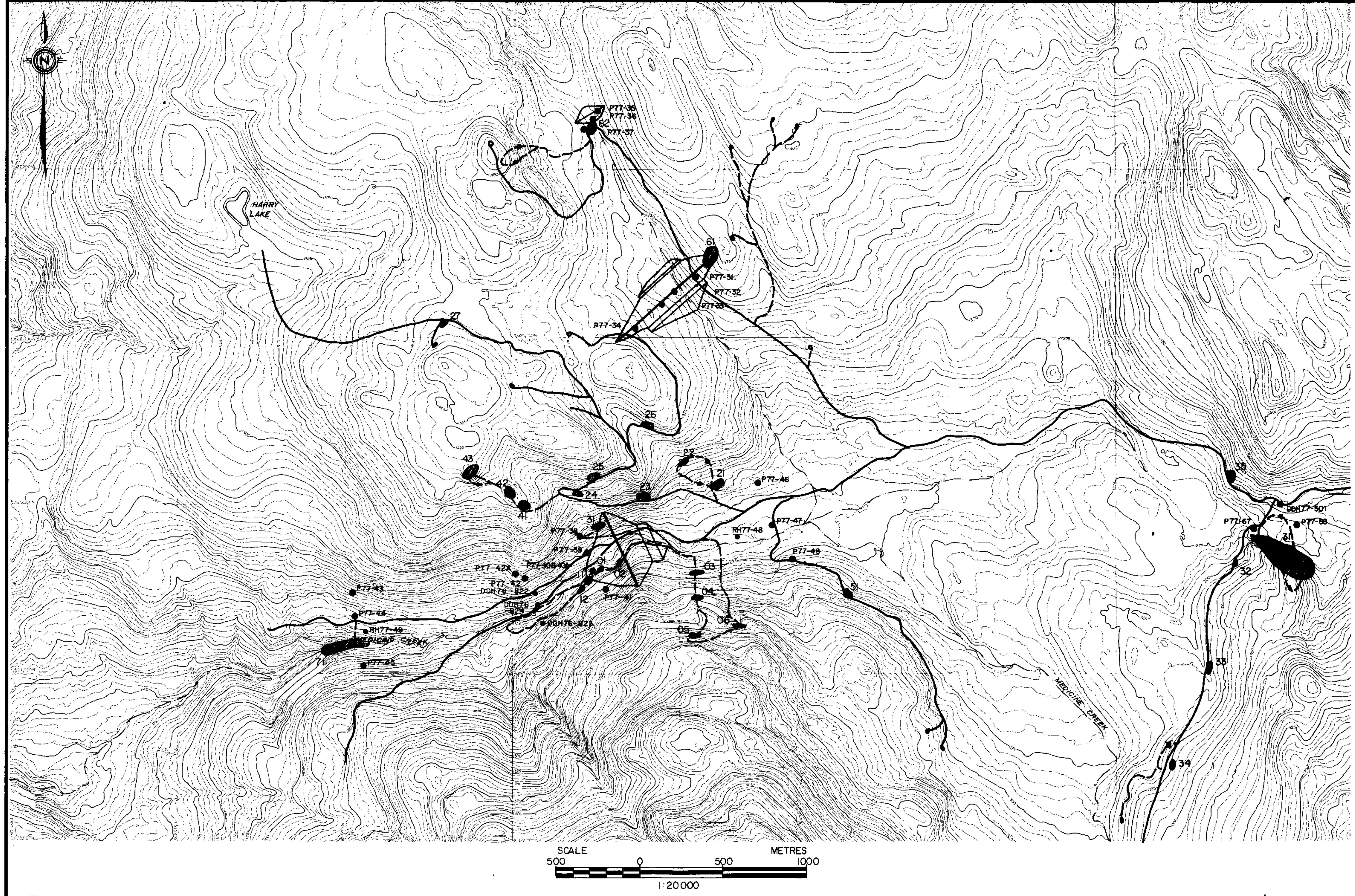
FAULT (ASSUMED)

P77-35 DRILL HOLE

REFERENCE

TOPOGRAPHIC BASE FROM SHEETS 10,11,13,14,16 & 17 OF DIGITAL MODEL TOPOGRAPHY AT 1:5000, SUPPLIED BY B.C. HYDRO.

KLOHN LEONOFF CONSULTANTS LTD.	WATER SUPPLY AND ASH RETENTION DAMS
B.C. HYDRO AND POWER AUTHORITY	GEOLOGIC MAP OF UPPER MEDICINE CREEK
HAT CREEK PROJECT	APPROVED: [signature] / PROJECT NO. VA 2321 / DATE JAN, 1978 / PLATE A5



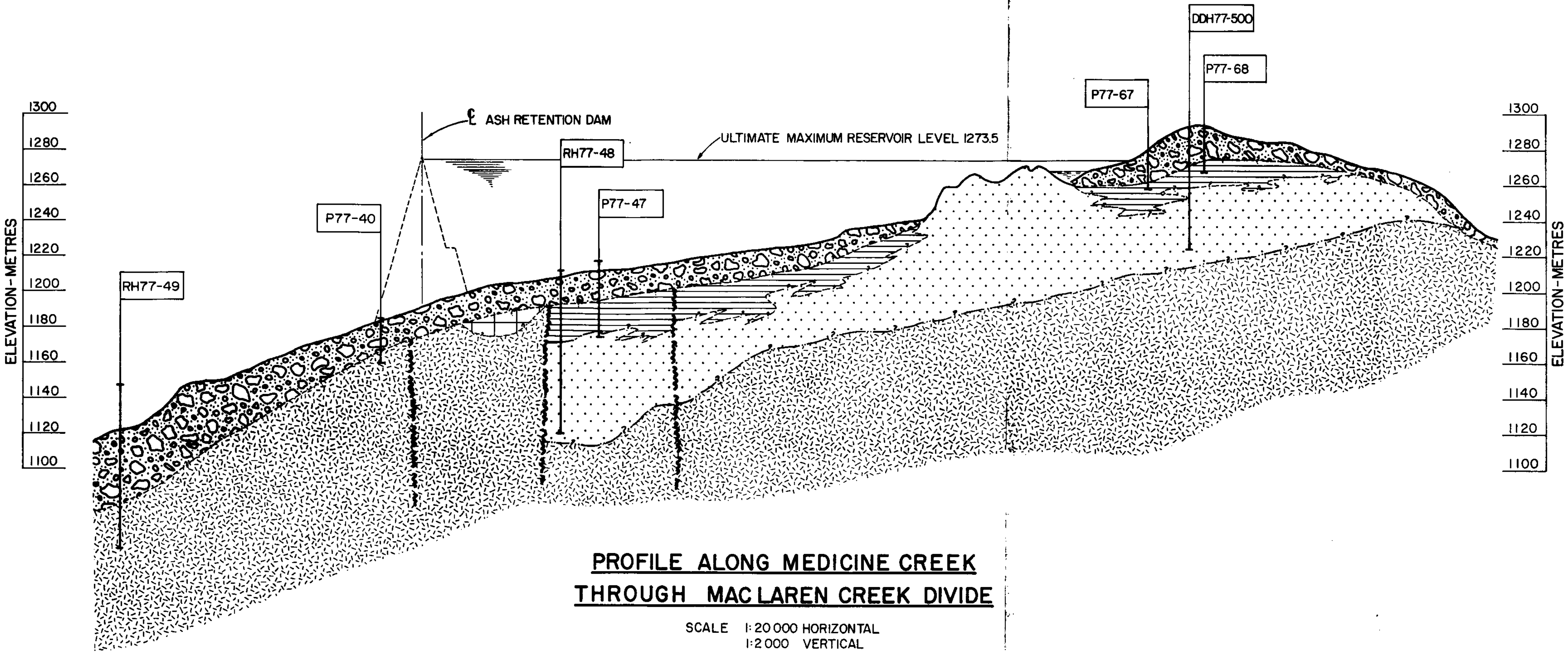
LEGEND

- DRILL HOLE (P77-35)
- ROCK OUTCROP AND REFERENCE NUMBER (SEE APPENDIX IV FOR DESCRIPTION) (23)
- VEHICLE TRAVERSE
- FOOT TRAVERSE

REFERENCE

TOPOGRAPHIC BASE FROM SHEETS 10, 11, 13, 14, 16 & 17 OF DIGITAL MODEL TOPOGRAPHY AT 1:5000, SUPPLIED BY B.C. HYDRO.

KLOHN LEONOFF CONSULTANTS LTD.	WATER SUPPLY AND ASH RETENTION DAMS		
B.C. HYDRO AND POWER AUTHORITY HAT CREEK PROJECT	ROCK OUTCROP LOCATION PLAN UPPER MEDICINE CREEK		
	APPROVED [signature]	PROJECT NO. VA 2321	DATE JAN., 1978 PLATE A6



PROFILE ALONG MEDICINE CREEK THROUGH MAC LAREN CREEK DIVIDE

SCALE 1:20 000 HORIZONTAL
1:2 000 VERTICAL

LEGEND

KAMLOOPS GROUP
- ANDESITE, TUFF, BRECCIA.
- SILTSTONE - CLAYSTONE
- SANDSTONE & CONGLOMERATE

CACHE CREEK GROUP
- GREENSTONE

GLACIAL TILL

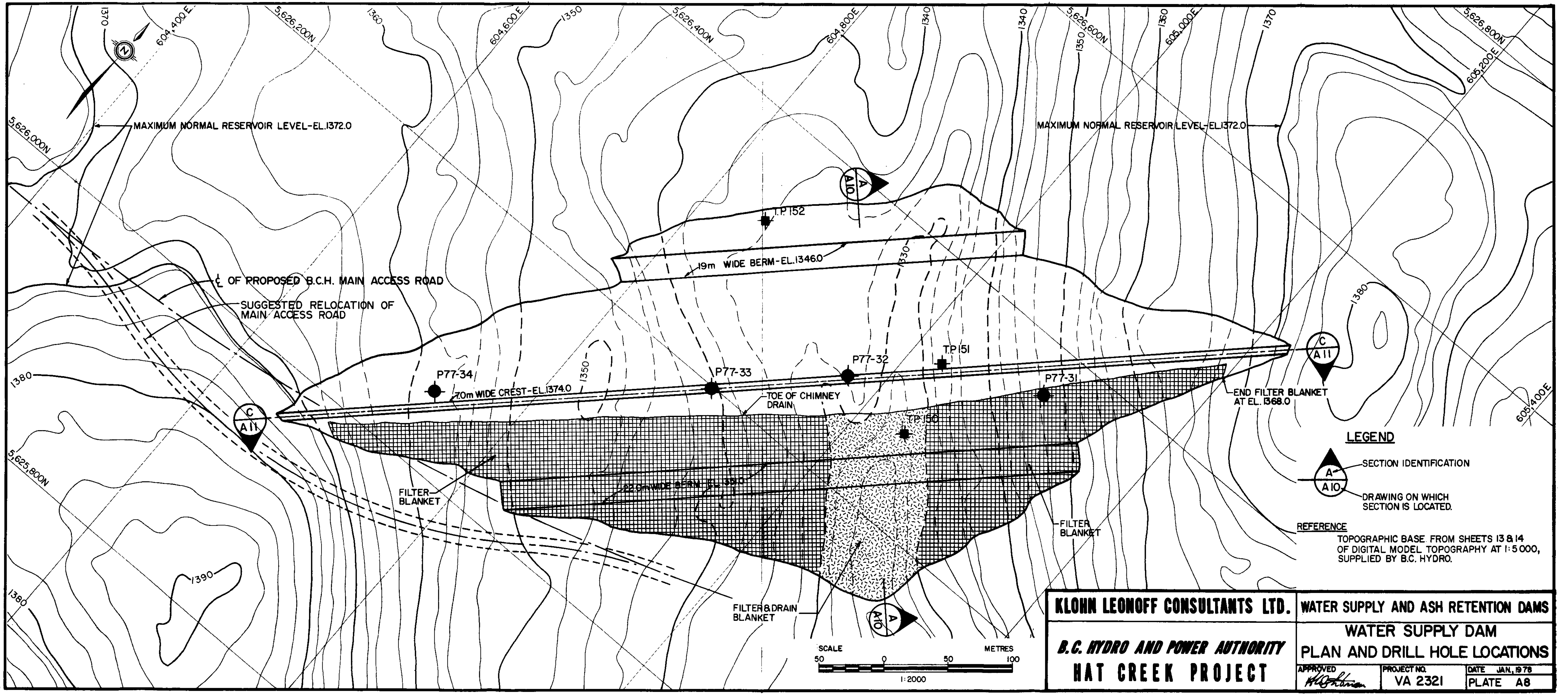
GEOLOGICAL BOUNDARY (DEFINED)

GEOLOGICAL BOUNDARY (ASSUMED)

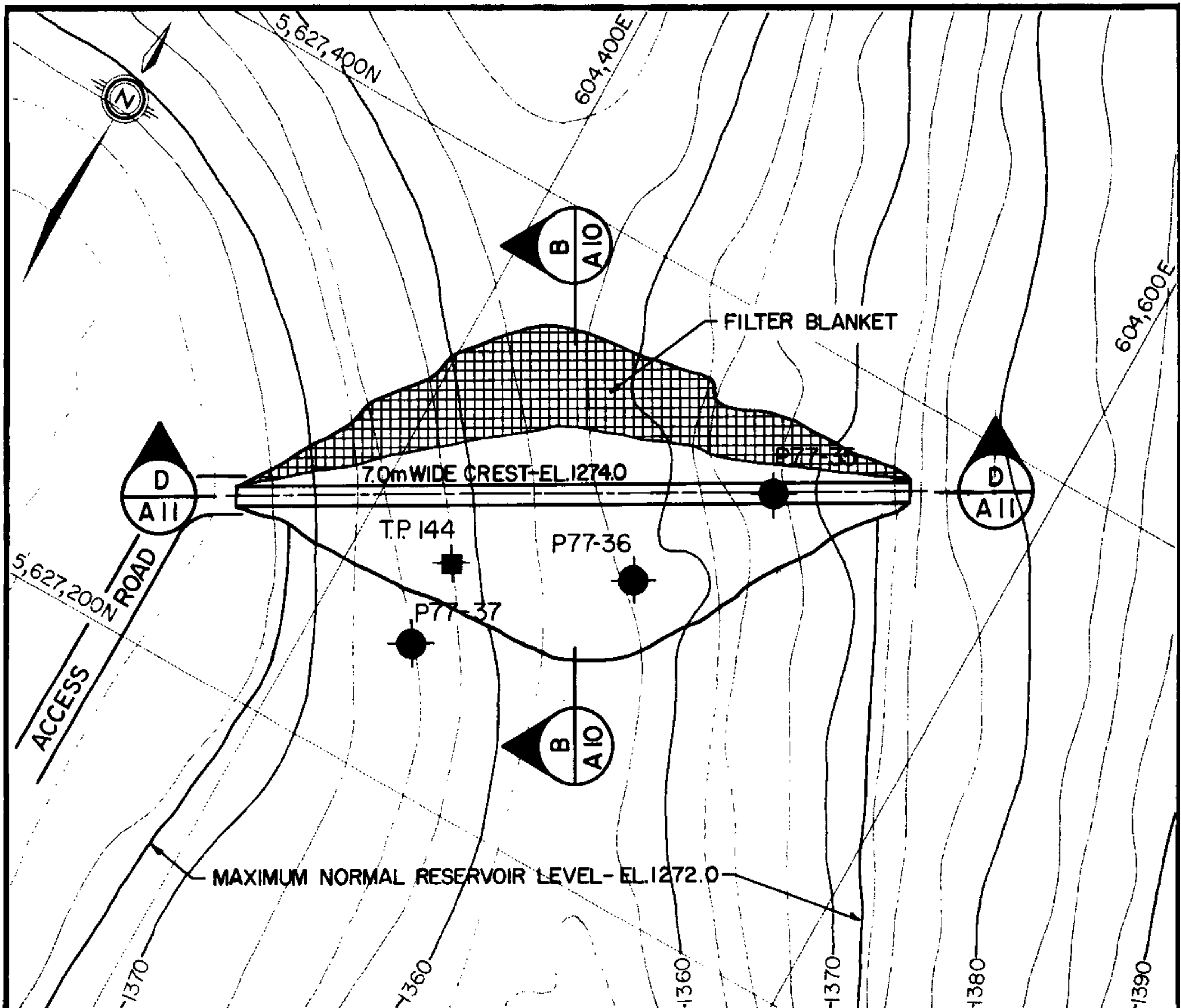
FAULT (ASSUMED)

UNCONFORMITY

KLOHN LEONOFF CONSULTANTS LTD.	WATER SUPPLY AND ASH RETENTION DAMS
B.C. HYDRO AND POWER AUTHORITY HAT CREEK PROJECT	GEOLOGIC PROFILE THROUGH ASH STORAGE RESERVOIR
APPROVED	PROJECT NO. VA 2321
DATE JAN., 1978	PLATE A7



MAXIMUM NORMAL RESERVOIR LEVEL-EL.1372.0
MAXIMUM NORMAL RESERVOIR LEVEL-EL.1372.0
℄ OF PROPOSED B.C.H. MAIN ACCESS ROAD
SUGGESTED RELOCATION OF MAIN ACCESS ROAD
19m WIDE BERM-EL.1346.0
7.0m WIDE CREST-EL.1374.0
22.0m WIDE BERM-EL.1331.0
TOE OF CHIMNEY DRAIN
END FILTER BLANKET AT EL.1368.0
FILTER BLANKET
FILTER BLANKET
FILTER & DRAIN BLANKET
T.P.152
T.P.151
T.P.150
P77-34
P77-33
P77-32
P77-31
5,626,000N
5,626,200N
5,626,400N
5,626,600N
5,626,800N
5,625,800N
604,400E
604,600E
604,800E
605,000E
605,200E
605,400E
LEGEND
SECTION IDENTIFICATION
DRAWING ON WHICH SECTION IS LOCATED.
REFERENCE
TOPOGRAPHIC BASE FROM SHEETS 13 & 14 OF DIGITAL MODEL TOPOGRAPHY AT 1:5000, SUPPLIED BY B.C. HYDRO.
SCALE
METRES
50 0 50 100
1:2000
KLOHN LEONOFF CONSULTANTS LTD.
B.C. HYDRO AND POWER AUTHORITY
HAT CREEK PROJECT
WATER SUPPLY AND ASH RETENTION DAMS
WATER SUPPLY DAM
PLAN AND DRILL HOLE LOCATIONS
APPROVED
PROJECT NO. VA 2321
DATE JAN, 1978
PLATE A8



SCALE METRES
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1:2000

LEGEND

SECTION IDENTIFICATION

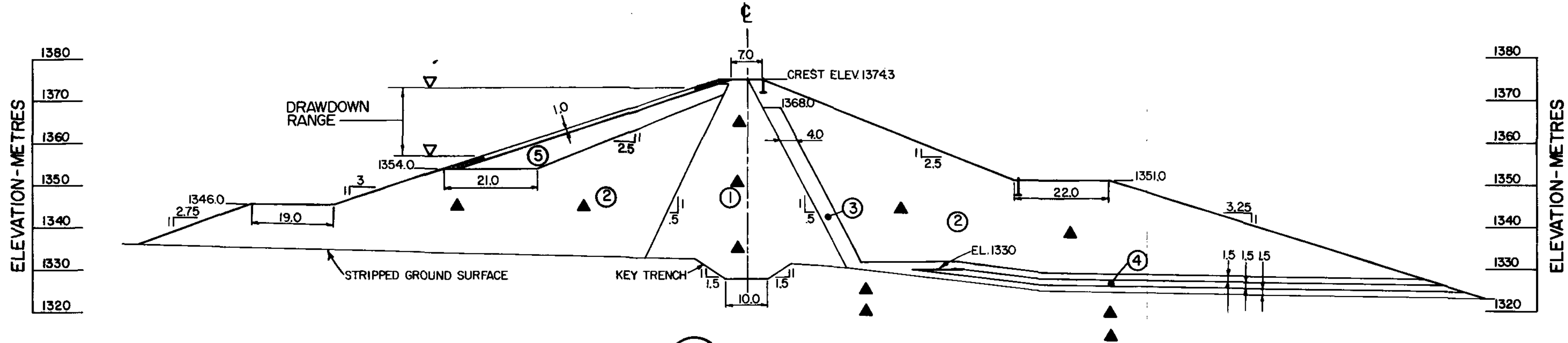
B
A10

DRAWING ON WHICH SECTION IS LOCATED.

REFERENCE

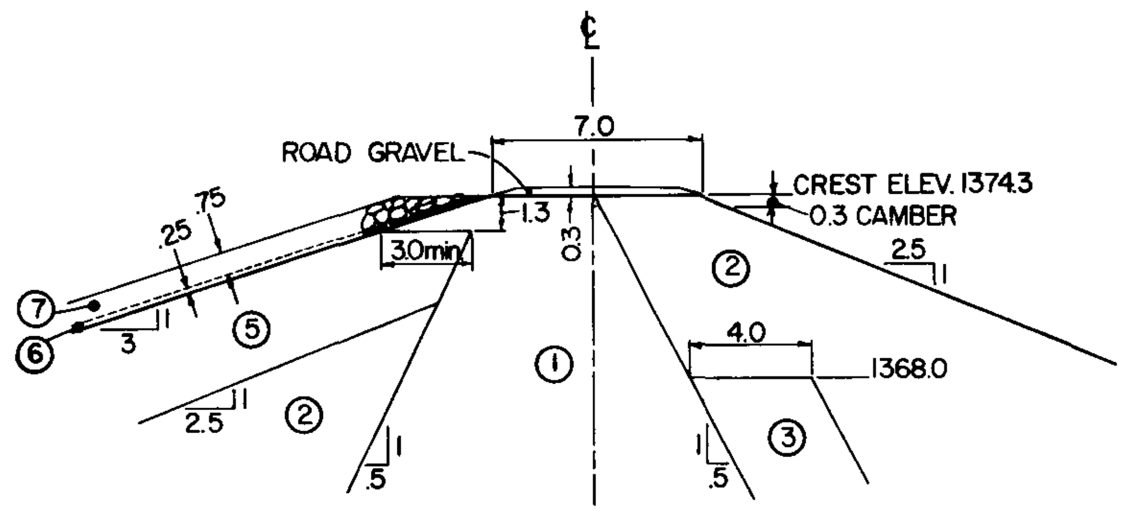
TOPOGRAPHIC BASE FROM SHEET 13 OF DIGITAL MODEL TOPOGRAPHY AT 1:5 000, SUPPLIED BY B.C. HYDRO.

KLOHN LEONOFF CONSULTANTS LTD.	WATER SUPPLY AND ASH RETENTION DAMS		
B.C. HYDRO AND POWER AUTHORITY HAT CREEK PROJECT	WATER SUPPLY SADDLE DAM PLAN AND DRILL HOLE LOCATIONS		
	APPROVED [signature]	PROJECT NO. VA 2321	DATE JAN. 1978 PLATE A9



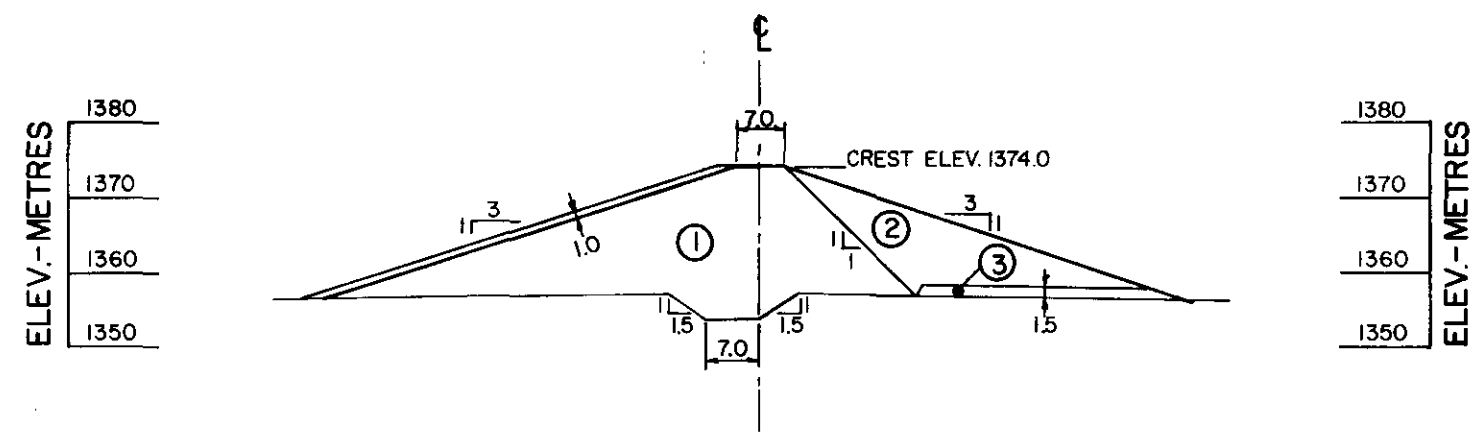
SECTION A/A8 WATER SUPPLY DAM

SCALE 1:1000



CREST DETAIL

SCALE 1:250



SECTION B/A9 SADDLE DAM

SCALE 1:1000

ZONE KEY

1	SELECT IMPERVIOUS FILL
2	RANDOM IMPERVIOUS FILL
3	FILTER GRAVEL
4	DRAIN GRAVEL
5	SAND & GRAVEL
6	RIP RAP BEDDING
7	RIP RAP

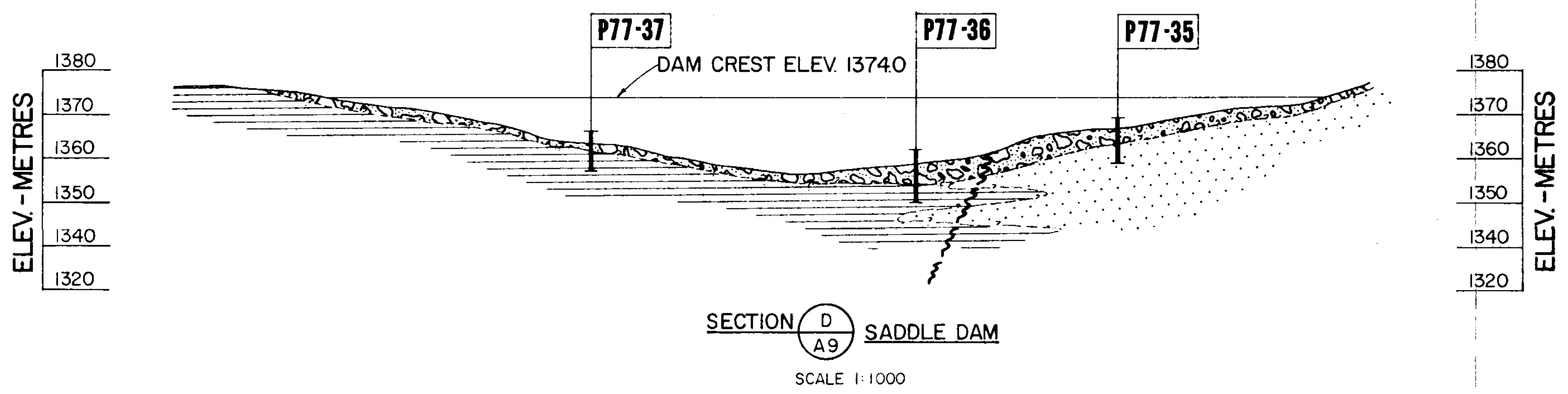
LEGEND

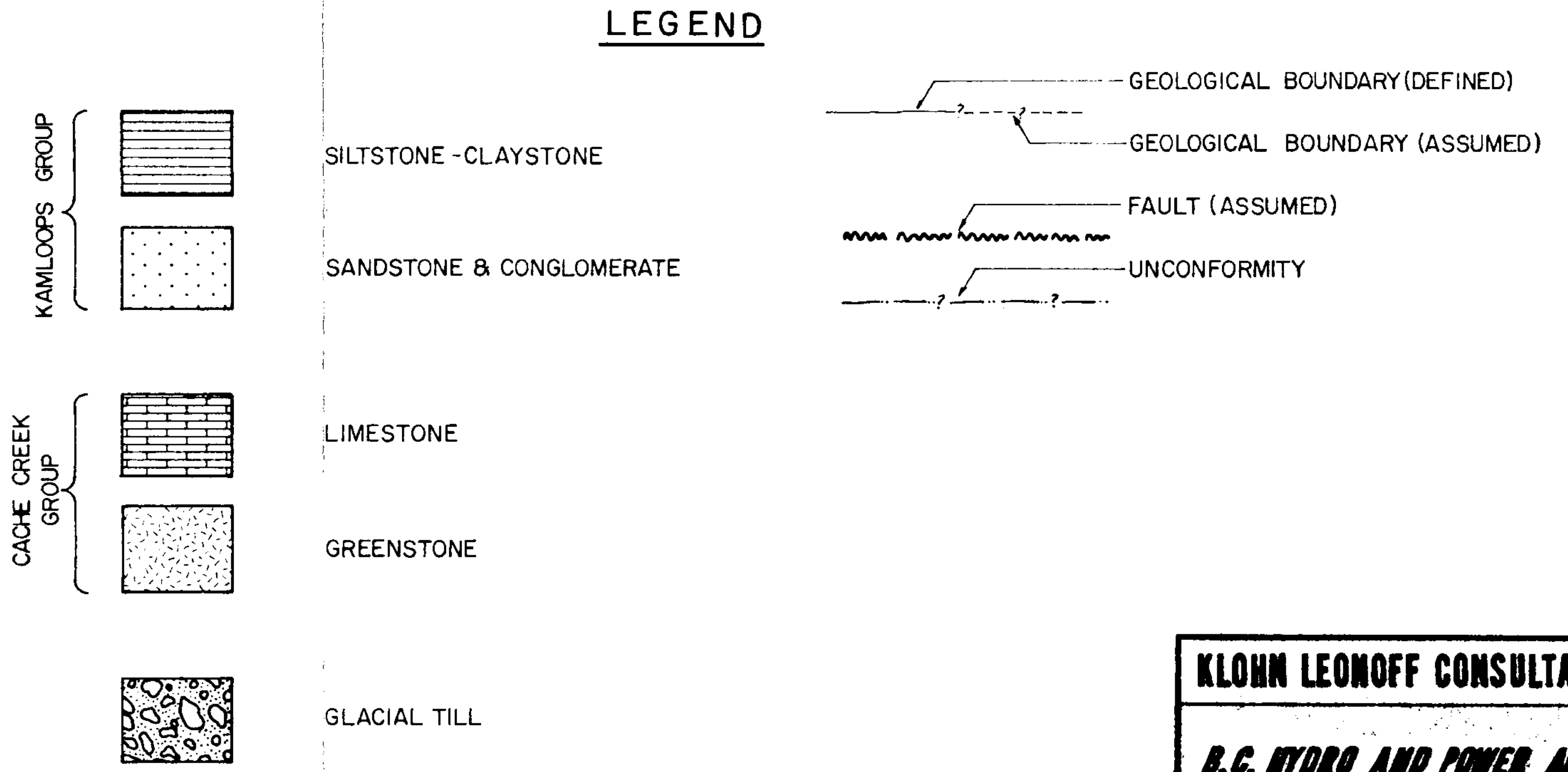
▲ - PIEZOMETER

I - SURVEY MONUMENT

NOTE: ALL DIMENSIONS IN METRES.

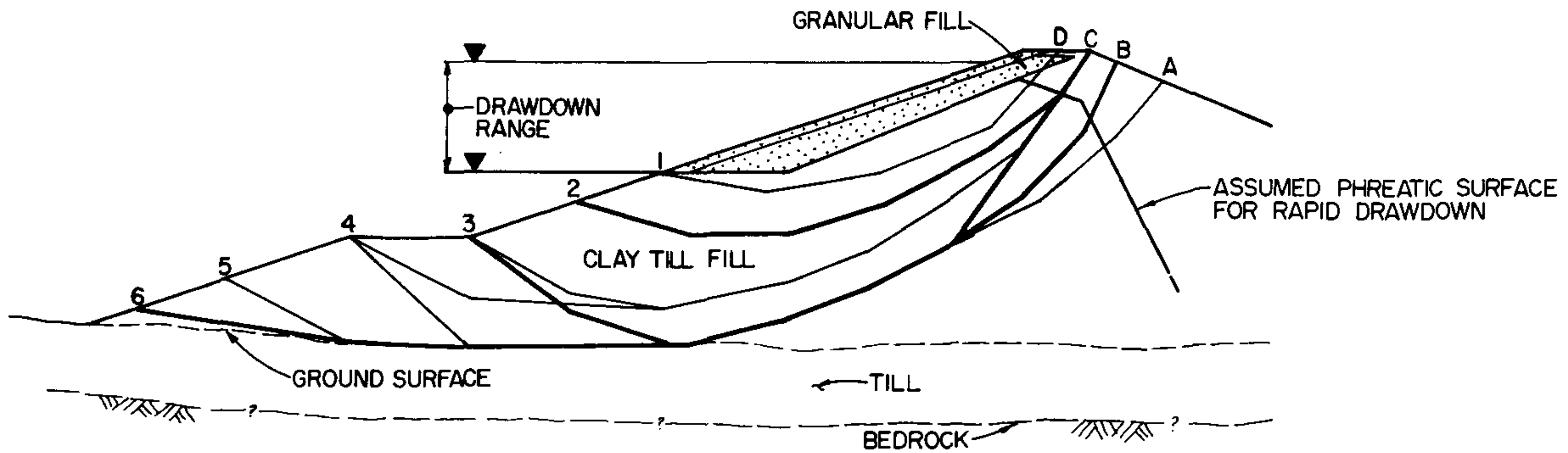
KLOHN LEONOFF CONSULTANTS LTD.	WATER SUPPLY AND ASH RETENTION DAMS
B.C. HYDRO AND POWER AUTHORITY HAT CREEK PROJECT	WATER SUPPLY DAM & SADDLE DAM CROSS SECTIONS
APPROVED	PROJECT NO. VA 2321
DATE JAN., 1978	PLATE A10





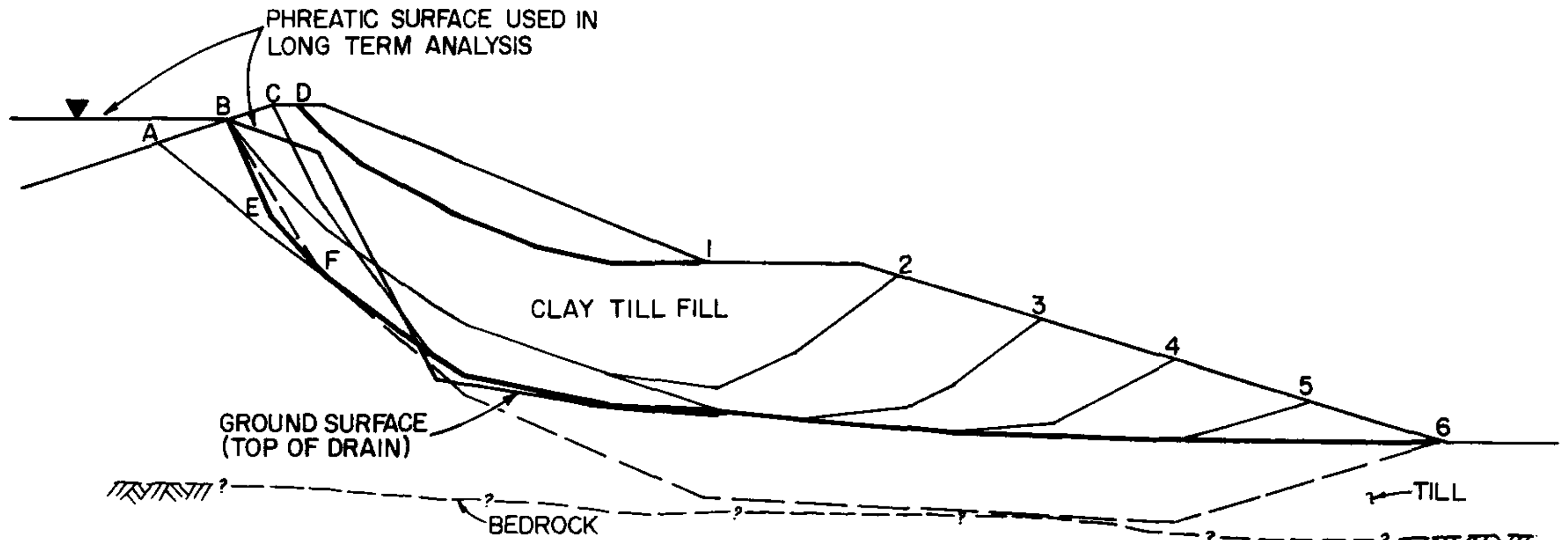
KLOHN LEONOFF CONSULTANTS LTD.	WATER SUPPLY AND ASH RETENTION DAMS
B.C. HYDRO AND POWER AUTHORITY HAT CREEK PROJECT	GEOLOGIC PROFILES WATER SUPPLY DAM & SADDLE DAM
	APPROVED / PROJECT NO. VA 2321 / DATE JAN. 1978 / PLATE A11

UPSTREAM SLOPE



SCALE 1:1000

DOWNSTREAM SLOPE



SCALE 1:1000

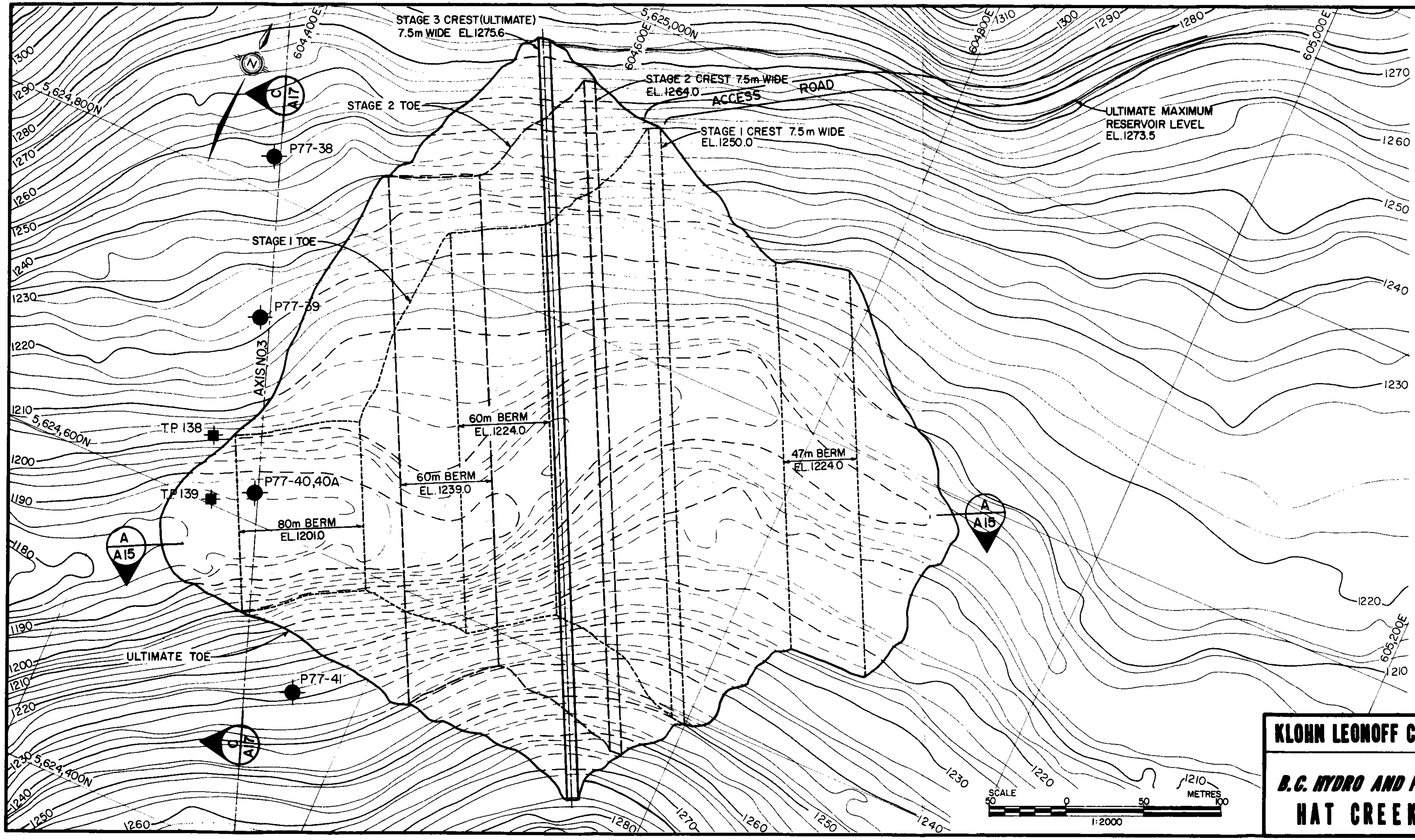
UPSTREAM SLOPE			
END OF CONSTRUCTION		RAPID DRAWDOWN	
FAILURE SURFACE	FACTOR of SAFETY ①	FAILURE SURFACE	FACTOR of SAFETY ①
C4	1.40	C4	1.40
B4	1.29	B4	1.61
B3	1.24 (1.24)②	B3	1.52
B6	1.25	B6	1.56
B5	1.25	B5	1.60
C3	1.33	C3	1.40
C6	1.26 (1.20)②	—	—
A6	1.26	—	—
C2	1.76	C2	1.28 (1.23)②
D1	2.20	D1	1.38

	SOIL PROPERTIES		
	CLAY TILL FILL	GRANULAR FILL	FOUNDATION SOIL
γ moist.	2.08 t/m^3	2.08 t/m^3	2.20
γ sat.	2.15 t/m^3	2.24 t/m^3	2.30 t/m^3
γ dry	1.80 t/m^3	———	———
γ bouyant	———	1.24 t/m^3	1.30 t/m^3
Cu	79 kPa	———	1.70 kPa
ϕu	3°	———	0
C'	0	0	0
ϕ'	27°	35°	30°

DOWNSTREAM SLOPE			
END OF CONSTRUCTION		LONG TERM	
FAILURE SURFACE	FACTOR of SAFETY ①	FAILURE SURFACE	FACTOR of SAFETY ①
B2	1.34	B2	2.10
B6	1.24	B6	2.05
BE6	1.20 (1.27)②	BE6	2.03
C6	1.23	C6	2.11
A6	1.33	A6	2.30
BE5	1.20 (1.28)②	BE5	2.09
BE4	1.22	BE4	2.15
BE3	1.27	BE3	2.28
D1	2.2	D1	1.40 (1.05)③
BFG6	1.34	BFG6	1.85 (1.37)③

NOTES: 1) SAFETY FACTORS FOR ALL FAILUR SURFACES COMPUTED BY JANBU METHOD.
2) COMPARISON SAFETY FACTORS COMPUTED BY SIMPLIFIED BISHOP METHOD.
3) SAFETY FACTOR WITH EARTHQUAKE LOADING OF 0.1g.

KLOHN LEONOFF CONSULTANTS LTD.	WATER SUPPLY AND ASH RETENTION DAMS		
B.C. HYDRO AND POWER AUTHORITY HAT CREEK PROJECT	WATER SUPPLY DAM SLOPE STABILITY ANALYSIS		
	APPROVED	PROJECT NO. VA 2321	DATE JAN. 1978 PLATE A12



KLOHN LEONOFF CONSULTANTS LTD.

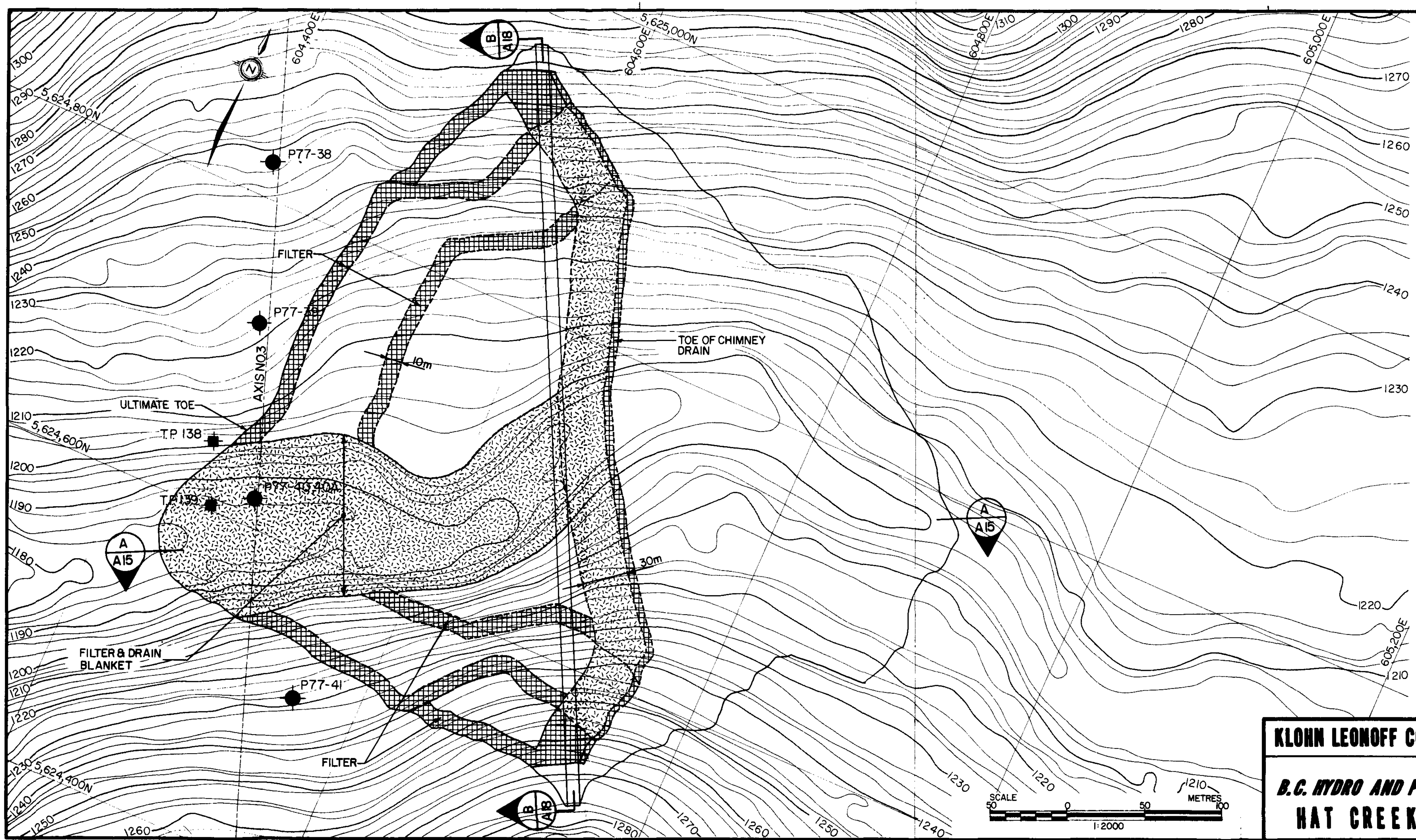
B.C. HYDRO AND POWER AUTHORITY

HAT CREEK PROJECT

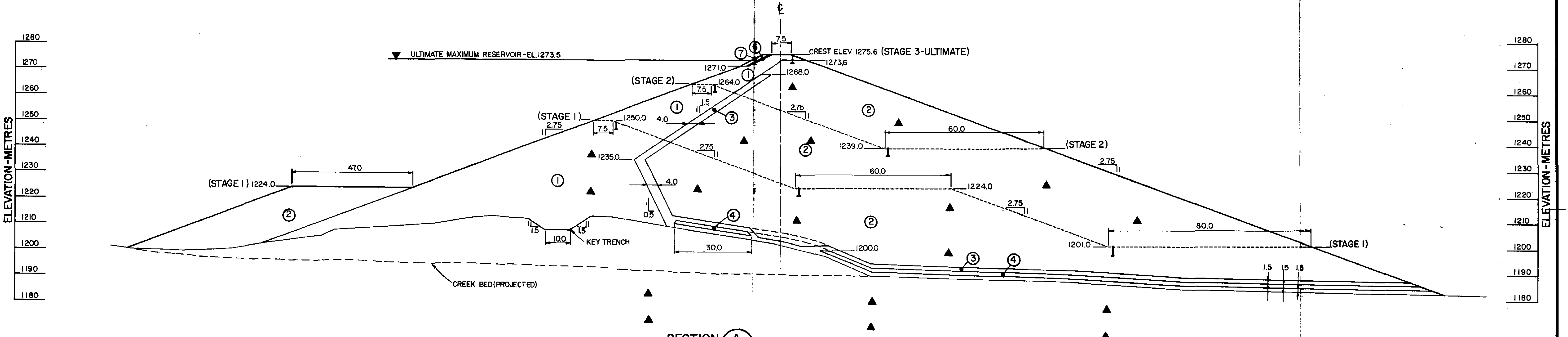
WATER SUPPLY AND ASH RETENTION DAMS

ASH RETENTION DAM - 3B
PLAN SHOWING CONSTRUCTION STAGES

APPROVED	PROJECT NO.	DATE JAN., 1978
	VA 2321	PLATE A13



KLOHN LEONOFF CONSULTANTS LTD.	WATER SUPPLY AND ASH RETENTION DAMS
B.C. HYDRO AND POWER AUTHORITY HAT CREEK PROJECT	ASH RETENTION DAM - 3B PLAN OF DRAINS AND FILTERS
APPROVED	PROJECT NO. VA 2321
DATE JAN., 1978	PLATE A14



SECTION A/A13/A14 ASH RETENTION DAM

SCALE 1:1000

ZONE KEY

1	SELECT IMPERVIOUS FILL
2	RANDOM IMPERVIOUS FILL
3	FILTER GRAVEL
4	DRAIN GRAVEL
6	RIP RAP BEDDING
7	RIP RAP

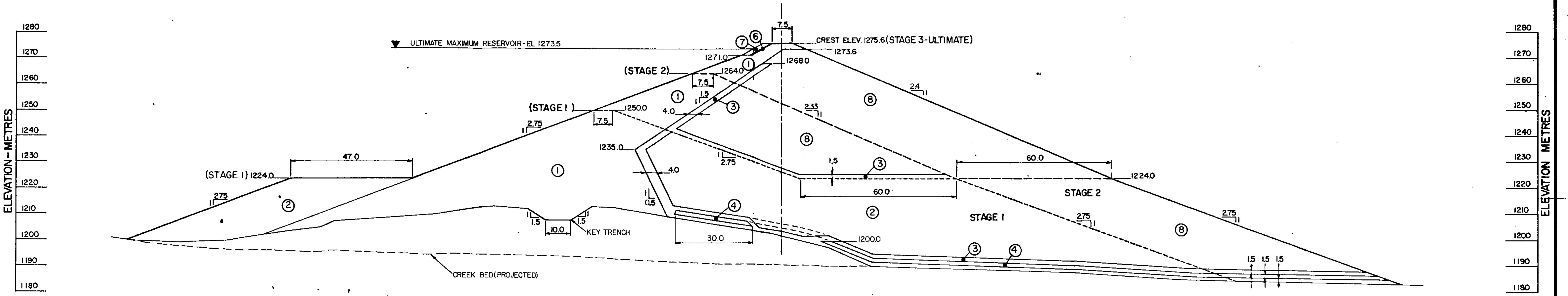
LEGEND

▲ - PIEZOMETER

I - SURVEY MONUMENT

NOTE: ALL DIMENSION IN METRES.

KLOHN LEONOFF CONSULTANTS LTD.	WATER SUPPLY AND ASH RETENTION DAMS
B.C. HYDRO AND POWER AUTHORITY HAT CREEK PROJECT	ASH RETENTION DAM CROSS SECTION WITH LOCAL FILL
APPROVED	PROJECT NO. VA 2321
DATE JAN., 1978	PLATE A15



TYPICAL SECTION-ASH RETENTION DAM

SCALE 1:1000

ZONE KEY

①	SELECT IMPERVIOUS FILL
②	RANDOM IMPERVIOUS FILL
③	FILTER GRAVEL
④	DRAIN GRAVEL
⑥	RIP RAP BEDDING
⑦	RIP RAP
⑧	BOTTOM ASH

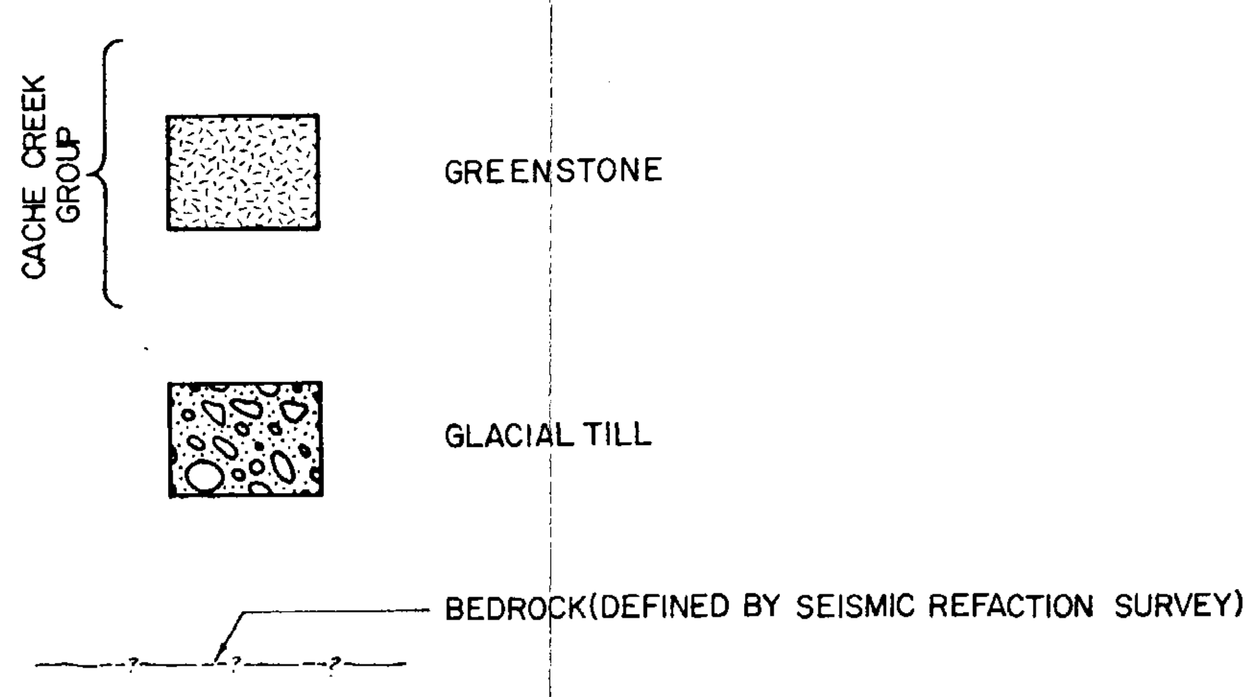
NOTE: ALL DIMENSIONS IN METRES.

KLOHN LEONOFF CONSULTANTS LTD.	WATER SUPPLY AND ASH RETENTION DAMS
B.C. HYDRO AND POWER AUTHORITY HAT CREEK PROJECT	ASH RETENTION DAM CROSS SECTION WITH BOTTOM ASH
APPROVED [signature]	PROJECT NO. VA 2321 — DATE JAN., 1978 — PLATE A16

SECTION C/A13 ASH RETENTION DAM AXIS NO. 3

SCALE 1:1000

LEGEND

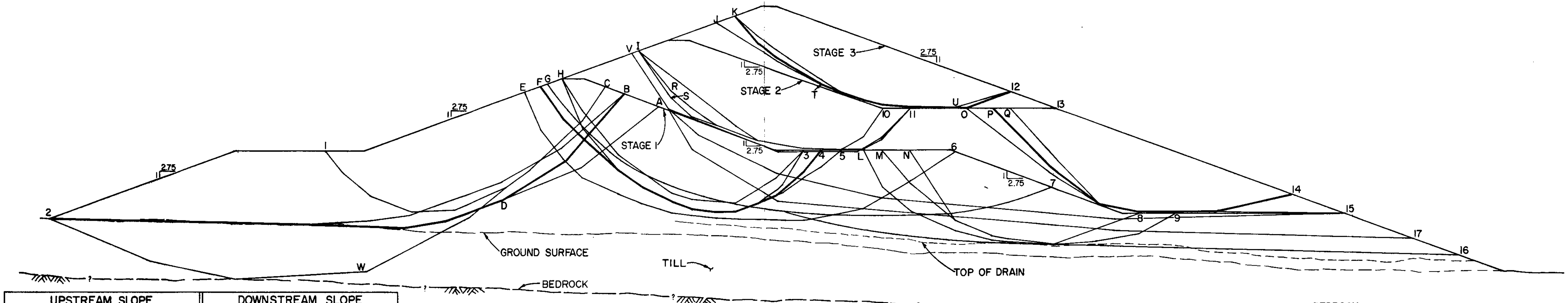


KLOHN LEONOFF CONSULTANTS LTD.	WATER SUPPLY AND ASH RETENTION DAMS		
B.C. HYDRO AND POWER AUTHORITY	ASH RETENTION DAM AXIS 3 GEOLOGIC PROFILE		
HAT CREEK PROJECT	APPROVED	PROJECT NO. VA 2321	DATE JAN. 1978 PLATE A17

SECTION B/A14 ASH RETENTION DAM AXIS NO. 3B

SCALE 1:1000

KLOHN LEONOFF CONSULTANTS LTD.	WATER SUPPLY AND ASH RETENTION DAMS
B.C. HYDRO AND POWER AUTHORITY HAT CREEK PROJECT	ASH RETENTION DAM-3B CENTRELINE PROFILE
APPROVED [signature]	PROJECT NO. VA 2321
DATE JAN. 1978	PLATE A15



UPSTREAM SLOPE		DOWNSTREAM SLOPE	
FAILURE SURFACE	FACTOR OF SAFETY (1)	FAILURE SURFACE	FACTOR OF SAFETY (1)
A2	1.30	H4	1.31
B2	1.30	F5	1.22
BD2	1.20	F4	1.21
C1	1.21	F3	1.22
CW2	1.36	H3	1.30
		E6	1.48
		L9	1.55
		M9	1.45
		M8	1.41
		N8	1.45
		G16	1.54
		G7	1.41

STAGE 1 ONLY

FAILURE SURFACE	FACTOR OF SAFETY (1)
IR11	1.29
I 11	1.29
IS11	1.34
IS 10	1.35
O 15	1.21
P 15	1.20
P 14	1.19 (1.23)(2)
Q 15	1.23

STAGE 2 ONLY

FAILURE SURFACE	FACTOR OF SAFETY
V 11	1.53
V 15	2.26
V 17	1.91

STAGE 1 AND 2

FAILURE SURFACE	FACTOR OF SAFETY (1)
JO 12	1.26
KTU 12	1.24
KTO 12	1.22 (1.21)(2)
KT 13	1.26
K 13	1.26

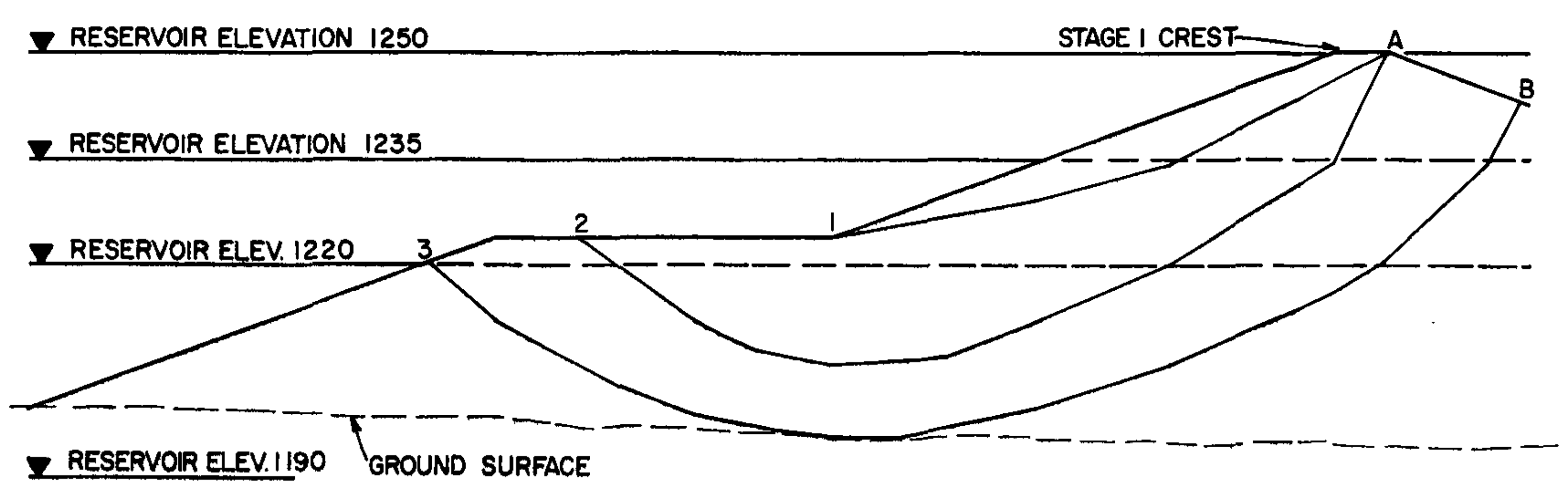
STAGE 3 ONLY

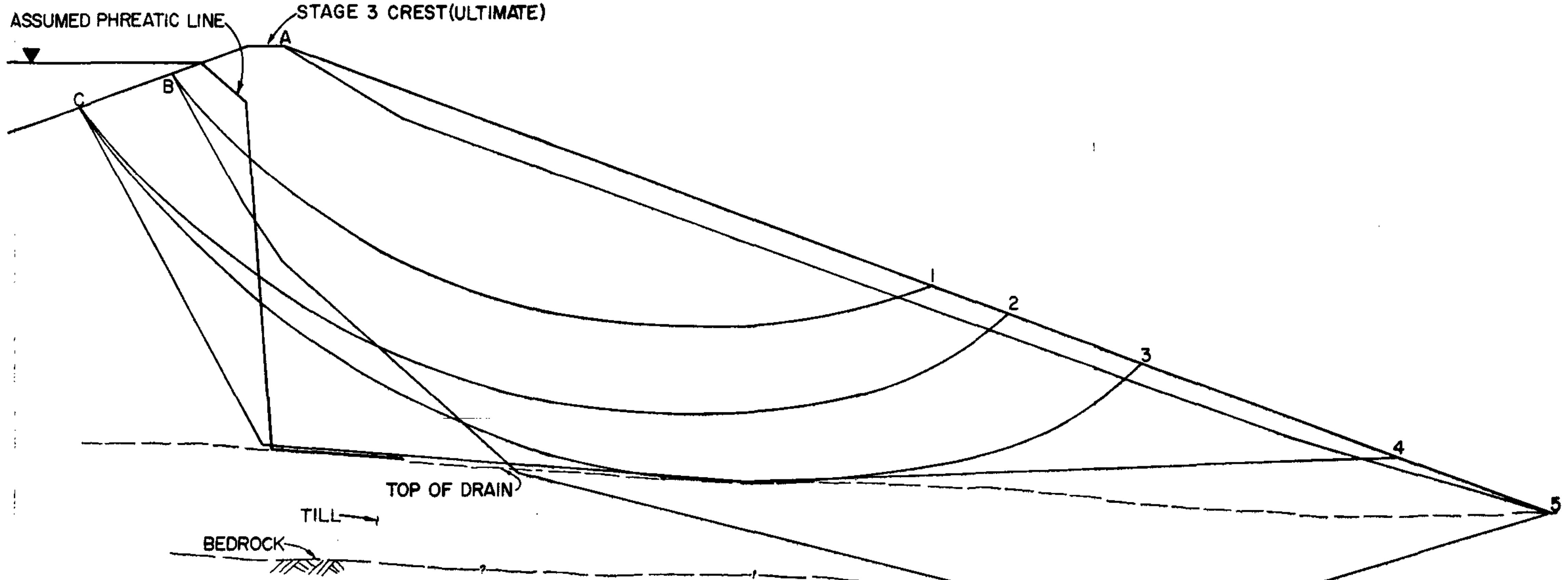
	FILL MATERIAL	FOUNDATION SOIL
γ_{moist}	2.08 t/m^3	2.20 t/m^3
Cu	79 kPa	170 kPa
ϕu	3°	0
$\bar{B}$	0.5	——
$\bar{u}$ after 10yrs	75%	——
C'	0	——
ϕ'	27°	——

SOIL PROPERTIES

NOTES : 1) SAFETY FACTORS FOR ALL FAILURE SURFACES COMPUTED BY JANBU METHOD.
2) COMPARISON SAFETY FACTORS COMPUTED BY SIMPLIFIED BISHOP METHOD.

KLOHN LEONOFF CONSULTANTS LTD.	WATER SUPPLY AND ASH RETENTION DAMS		
B.C. HYDRO AND POWER AUTHORITY HAT CREEK PROJECT	ASH RETENTION DAM CONSTRUCTION STABILITY STAGES 1,2 & 3		
	APPROVED	PROJECT NO. VA 2321	DATE JAN, 1978 PLATE A19





SAFETY FACTORS DURING RISING RESERVOIR

RESERVOIR ELEVATION	FAILURE SURFACE		
	B3	A2	A1
1190	2.85	1.99	1.48
1220	2.14	1.62	1.48
1235	2.33	1.66	1.38
1250	2.85	1.99	1.48

SOIL PROPERTIES

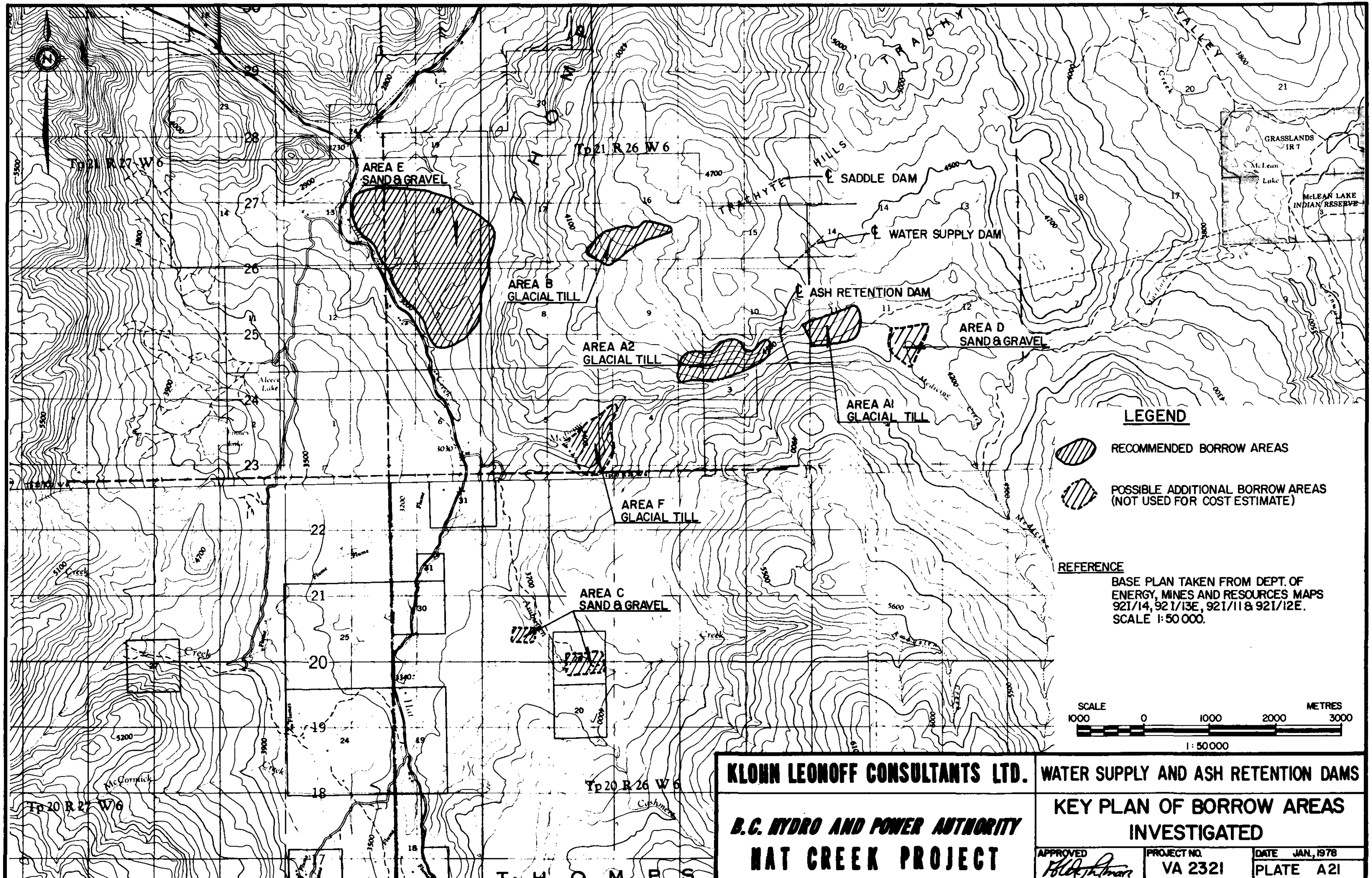
	FILL MATERIAL	FOUNDATION SOIL
γ moist.	2.08 t/m^3	———
γ sat.	2.15 t/m^3	2.30 t/m^3
γ bouyant	1.15 t/m^3	1.30 t/m^3
c'	0	0
ø'	27°	30°

LONG TERM STABILITY - ULTIMATE DAM SECTION

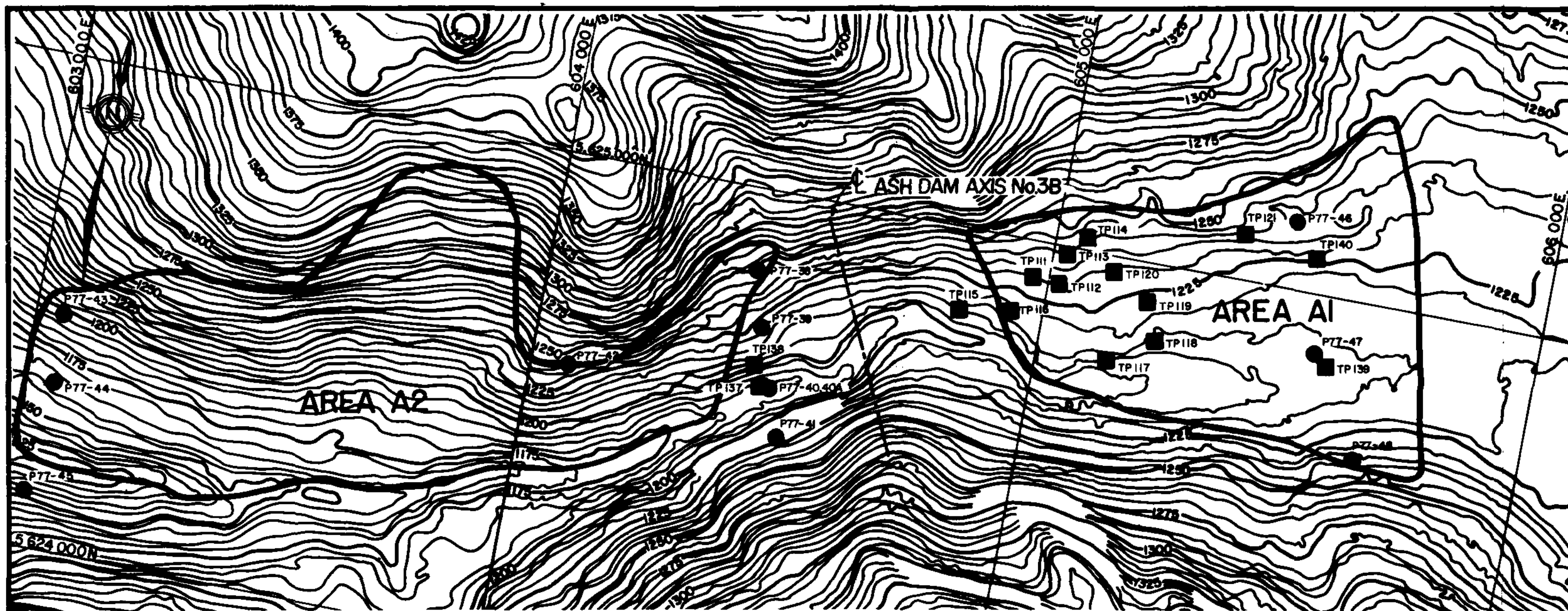
FAILURE SURFACE	FACTOR OF SAFETY
C4	2.09
C3	1.97
C2	2.01
B1	2.23
A5	1.43
A15	1.40(1.06)*
B5	1.80(1.80)*

*- SAFETY FACTOR WITH EARTHQUAKE LOADING ASSUMING GROUND ACCELERATION OF 0.10g.

KLOHN LEONOFF CONSULTANTS LTD.	WATER SUPPLY AND ASH RETENTION DAMS
B.C. HYDRO AND POWER AUTHORITY **HAT CREEK PROJECT**	ASH RETENTION DAM LONG TERM STABILITY
APPROVED [signature]	PROJECT NO. VA 2321
DATE JAN, 1978	PLATE A20



KLOHN LEONOFF CONSULTANTS LTD.	WATER SUPPLY AND ASH RETENTION DAMS
B.C. HYDRO AND POWER AUTHORITY HAT CREEK PROJECT	KEY PLAN OF BORROW AREAS INVESTIGATED
	APPROVED · PROJECT NO. VA 2321 · DATE JAN., 1978 · PLATE A21



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METRES
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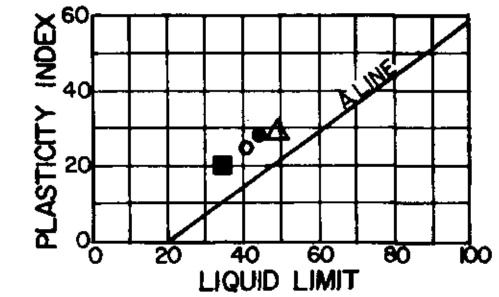
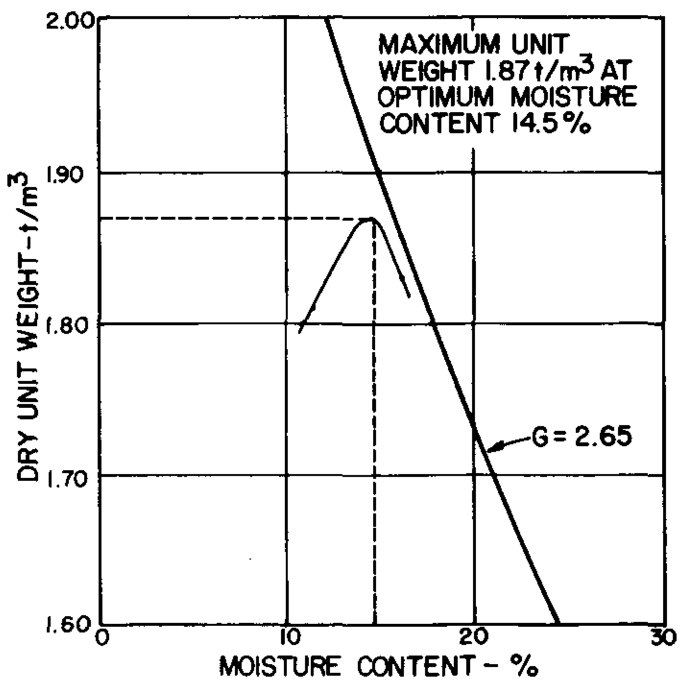
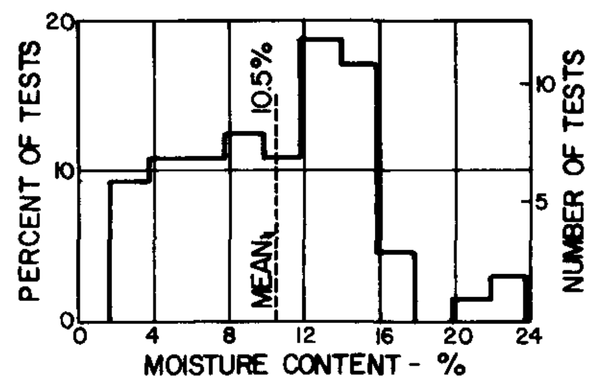


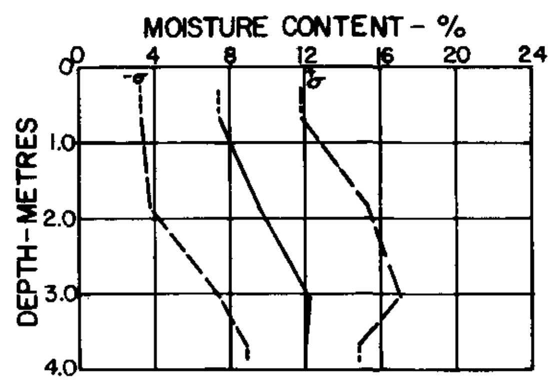
PLASTICITY CHART



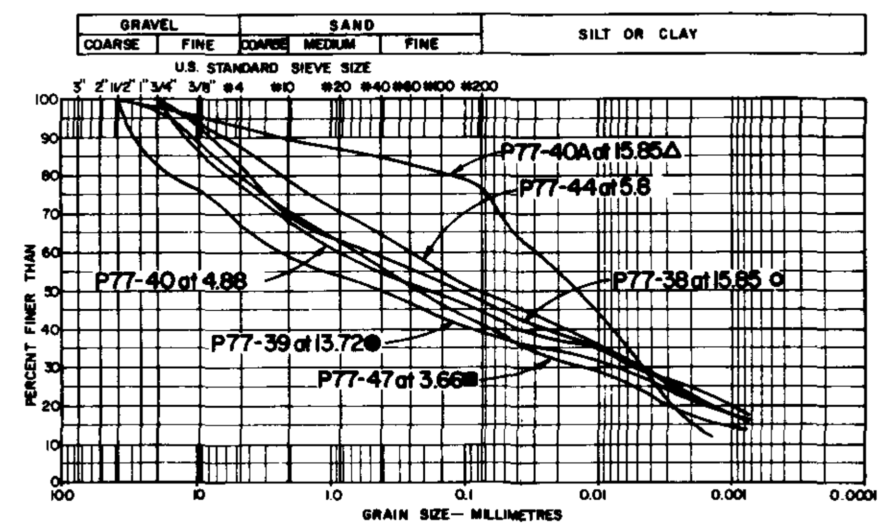
STANDARD PROCTOR ASTM TEST D69 8
METHOD B
COMPOSITE TILL SAMPLE FROM TEST PITS
115,116,117,119 & 120



HISTOGRAM OF MOISTURE CONTENT - %



MOISTURE CONTENT VS DEPTH

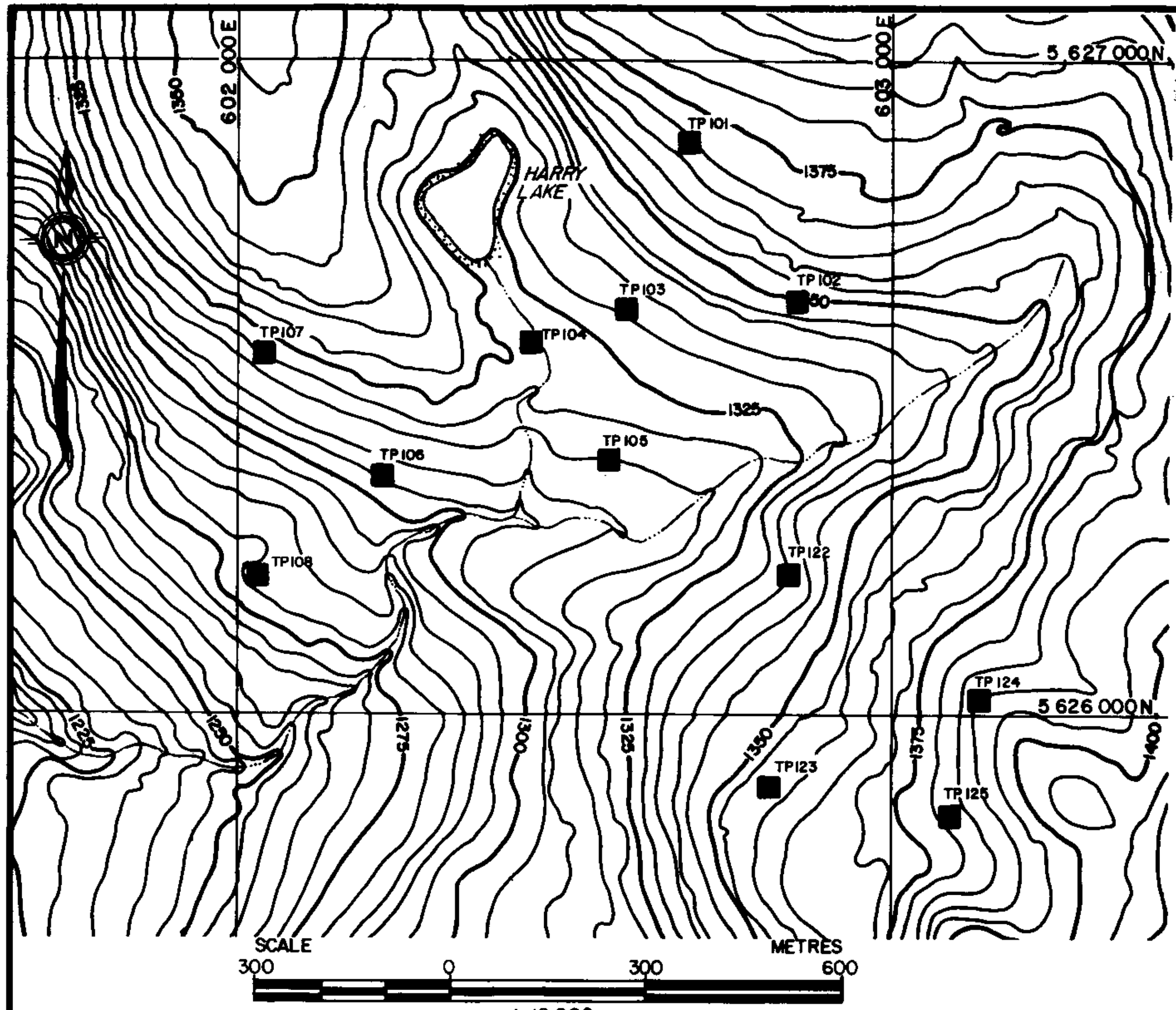


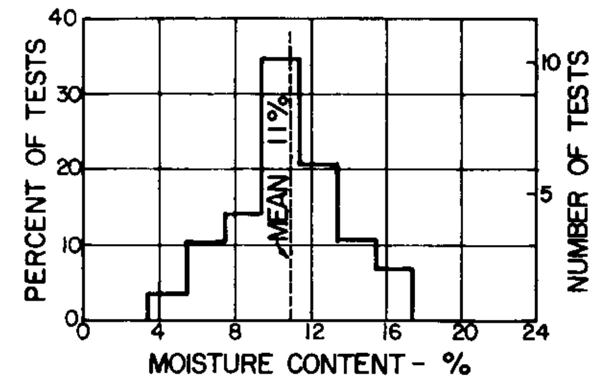
GRAIN SIZE CURVE

REFERENCE

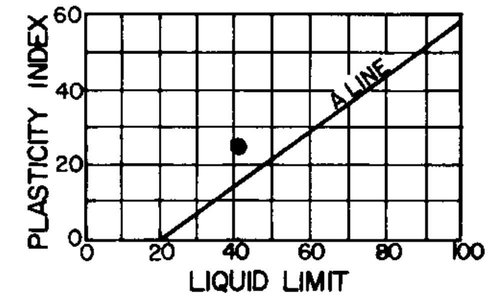
TOPOGRAPHIC BASE FROM SHEETS 11 & 14 OF DIGITAL MODEL TOPOGRAPHY AT 1:5 000, SUPPLIED BY B.C. HYDRO.

KLOHN LEONOFF CONSULTANTS LTD.	WATER SUPPLY AND ASH RETENTION DAMS
B.C. HYDRO AND POWER AUTHORITY HAT CREEK PROJECT	IMPERVIOUS FILL BORROW AREAS A1 & A2 MATERIAL PROPERTIES
APPROVED	PROJECT NO. VA 2321
DATE JAN., 1978	PLATE A22

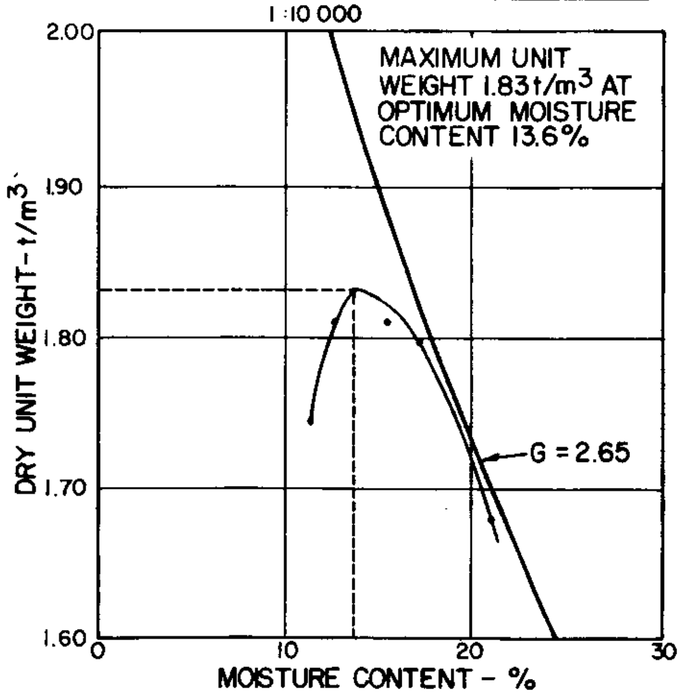




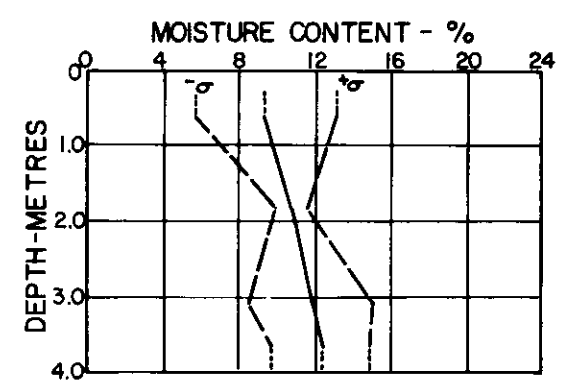
HISTOGRAM OF MOISTURE CONTENT-%



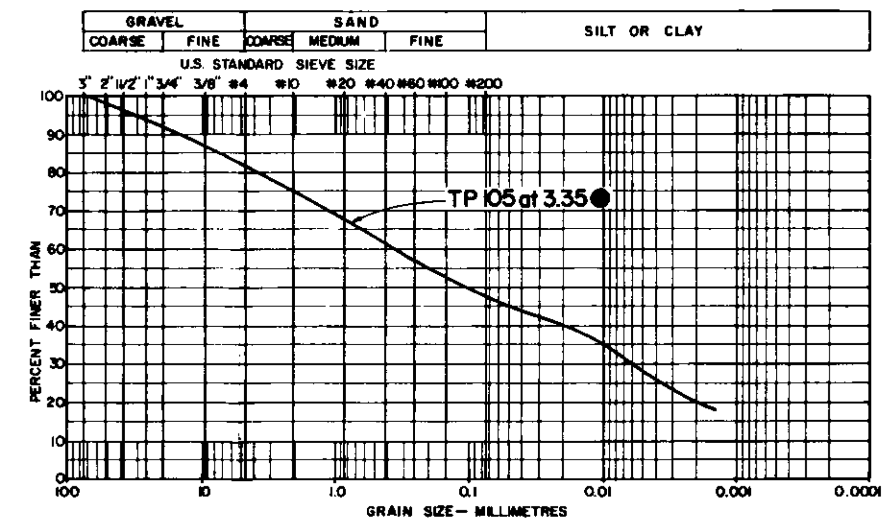
PLASTICITY CHART



STANDARD PROCTOR ASTM TEST D698
METHOD B
TILL SAMPLE FROM TEST PIT 105
AT 3 METRE DEPTH



MOISTURE CONTENT VS DEPTH

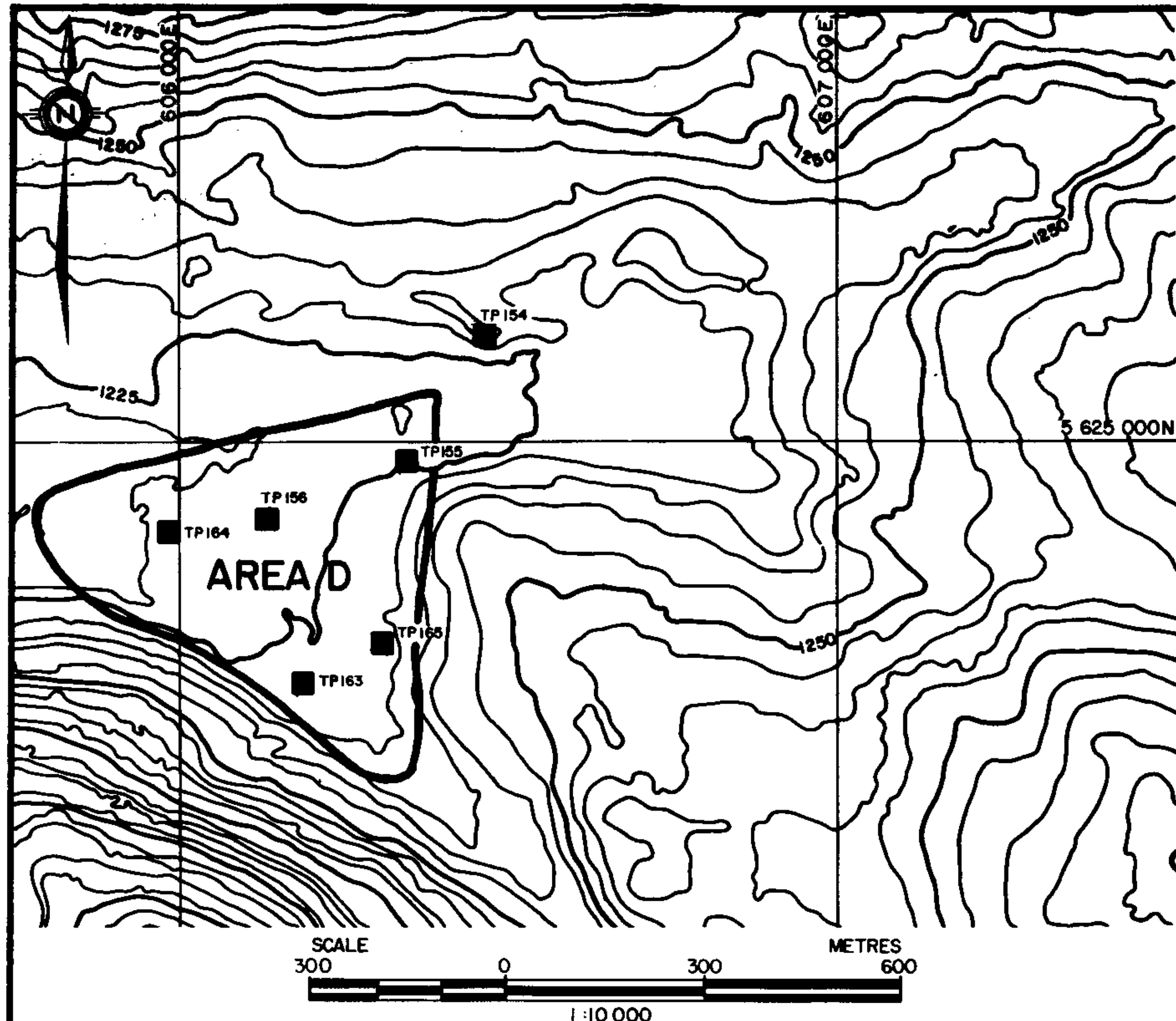


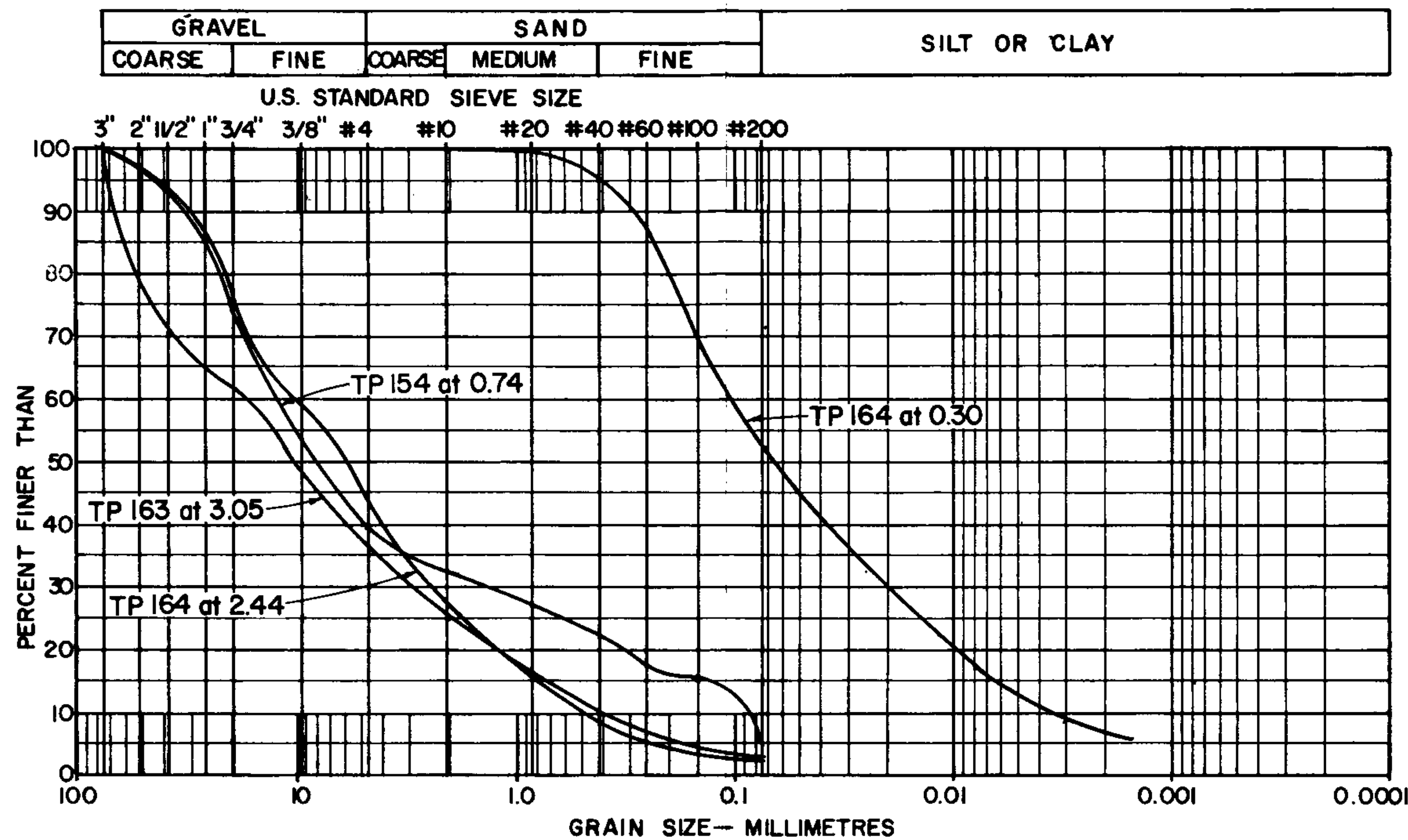
GRAIN SIZE CURVE

REFERENCE

TOPOGRAPHIC BASE FROM SHEETS 10 & 11 OF DIGITAL MODEL® TOPOGRAPHY AT 1: 5 000, SUPPLIED BY B.C. HYDRO.

KLOHN LEONOFF CONSULTANTS LTD.	WATER SUPPLY AND ASH RETENTION DAMS
B.C. HYDRO AND POWER AUTHORITY **HAT CREEK PROJECT**	IMPERVIOUS FILL BORROW AREA B MATERIAL PROPERTIES
	APPROVED [signature] · PROJECT NO. VA 2321 · DATE JAN., 1978 · PLATE A23

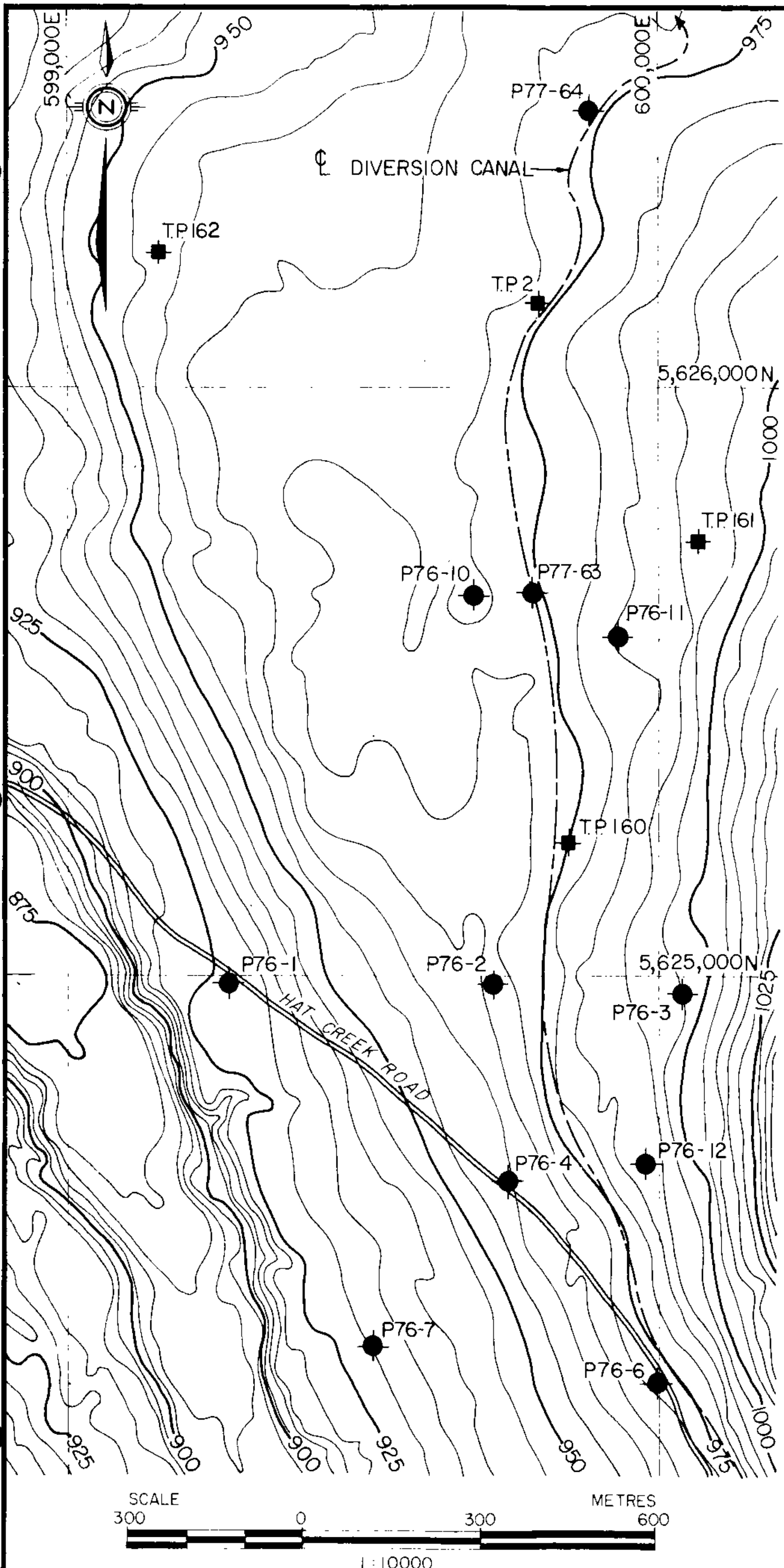


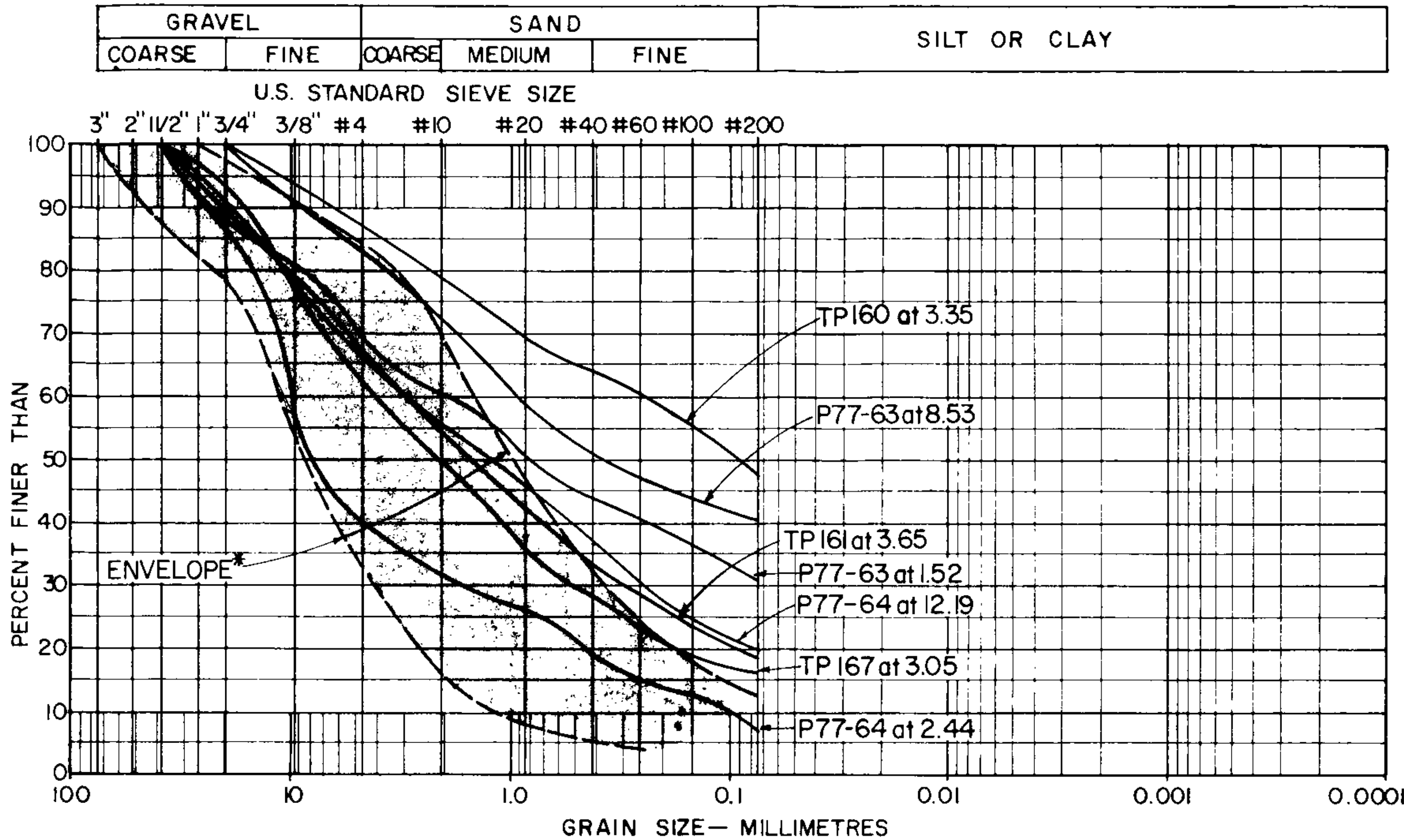


REFERENCE

TOPOGRAPHIC BASE FROM SHEETS 14 & 17 OF DIGITAL MODEL TOPOGRAPHY AT 1:5 000, SUPPLIED BY B.C. HYDRO.

KLOHN LEONOFF CONSULTANTS LTD.	WATER SUPPLY AND ASH RETENTION DAMS
B.C. HYDRO AND POWER AUTHORITY HAT CREEK PROJECT	GRANULAR FILL BORROW AREA D
APPROVED	PROJECT NO. VA 2321
	DATE JAN., 1978 PLATE A 24



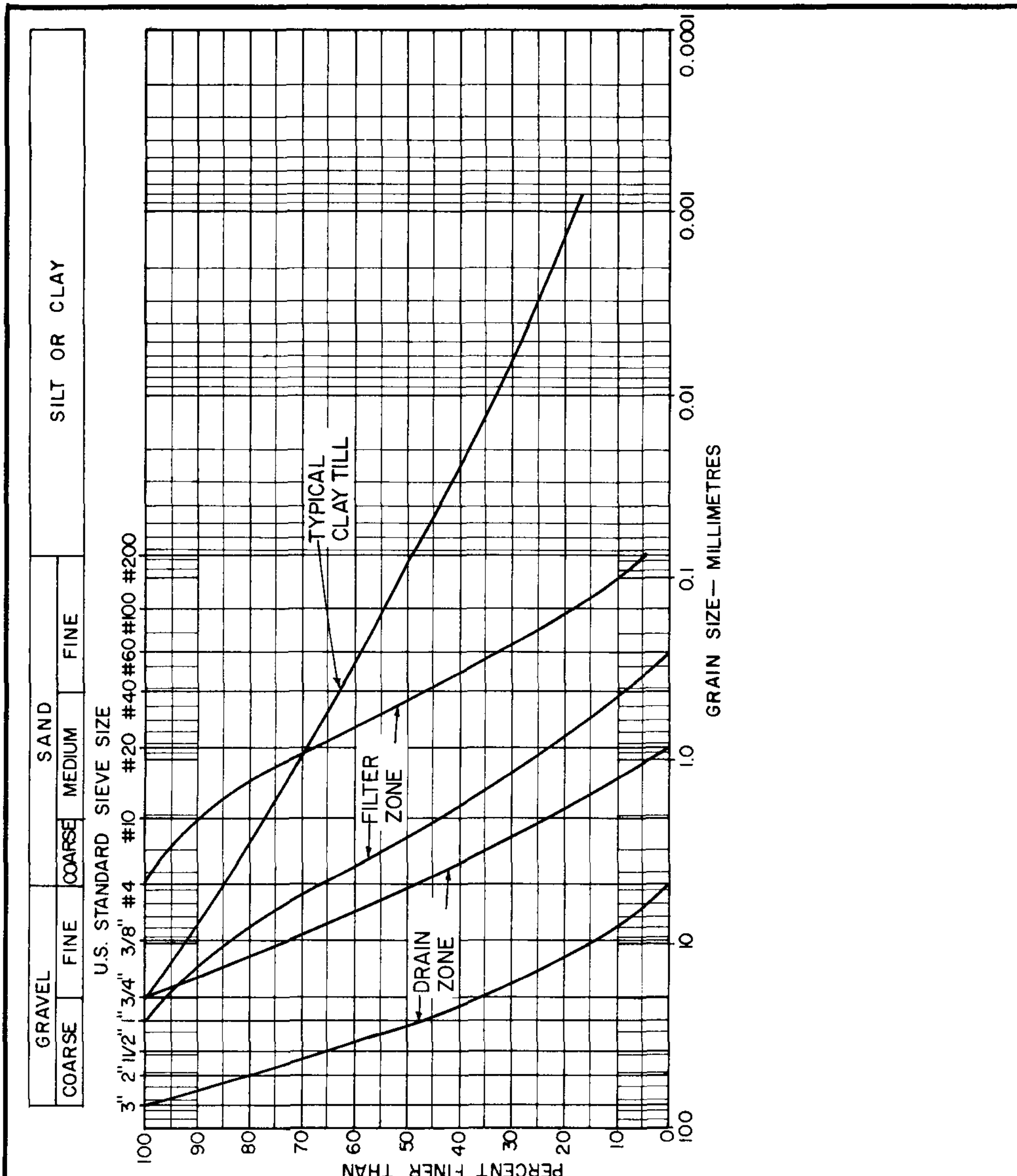


* - GRAIN SIZE ENVELOPE FROM 1976
PERCUSSION HOLES
REF. GOLDER ASSOC. DWG. A7-38

REFERENCE

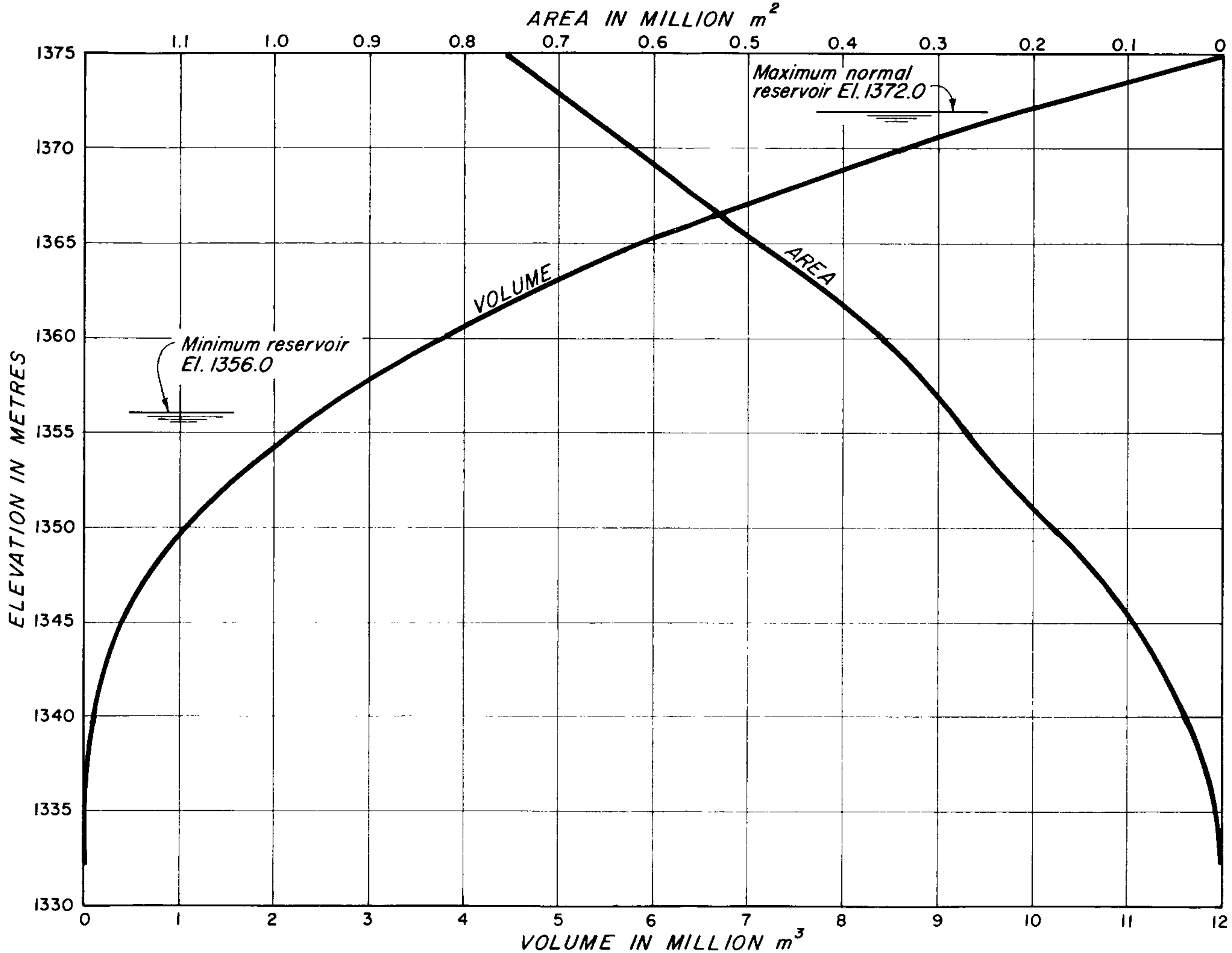
TOPOGRAPHIC BASE FROM SHEETS 7 & 8 OF
DIGITAL MODEL TOPOGRAPHY AT 1:5 000,
SUPPLIED BY B.C. HYDRO.

KLOHN LEONOFF CONSULTANTS LTD.	WATER SUPPLY AND ASH RETENTION DAMS
B.C. HYDRO AND POWER AUTHORITY HAT CREEK PROJECT	GRANULAR FILL BORROW AREA E
APPROVED *[signature]*	PROJECT NO. VA 2321
DATE JAN., 1978	PLATE A25



KLOHN LEONOFF CONSULTANTS LTD.	WATER SUPPLY AND ASH RETENTION DAMS
B.C. HYDRO AND POWER AUTHORITY **HAT CREEK PROJECT**	GRADATION LIMITS FOR FILTER AND DRAIN MATERIAL

APPROVED	PROJECT NO.	DATE JAN., 1978
[signature]	VA 2321	PLATE A26



NOTES:

1. AREAS TAKEN FROM 1:5000 DIGITAL TERRAIN MODEL (D.T.M.) TOPOGRAPHY.
2. CURVES HAVE BEEN ADJUSTED FOR DISPLACEMENT OF DAMS.
3. DAM & RESERVOIR LEVELS WERE BASED ON EARLIER IMPERIAL MAPPING. LOWER GROUND LEVELS INDICATED BY NEW D.T.M. TOPOGRAPHY RESULT IN LIVE STORAGE INCREASE FROM 6.57 TO 7.50 MILLION M^3.

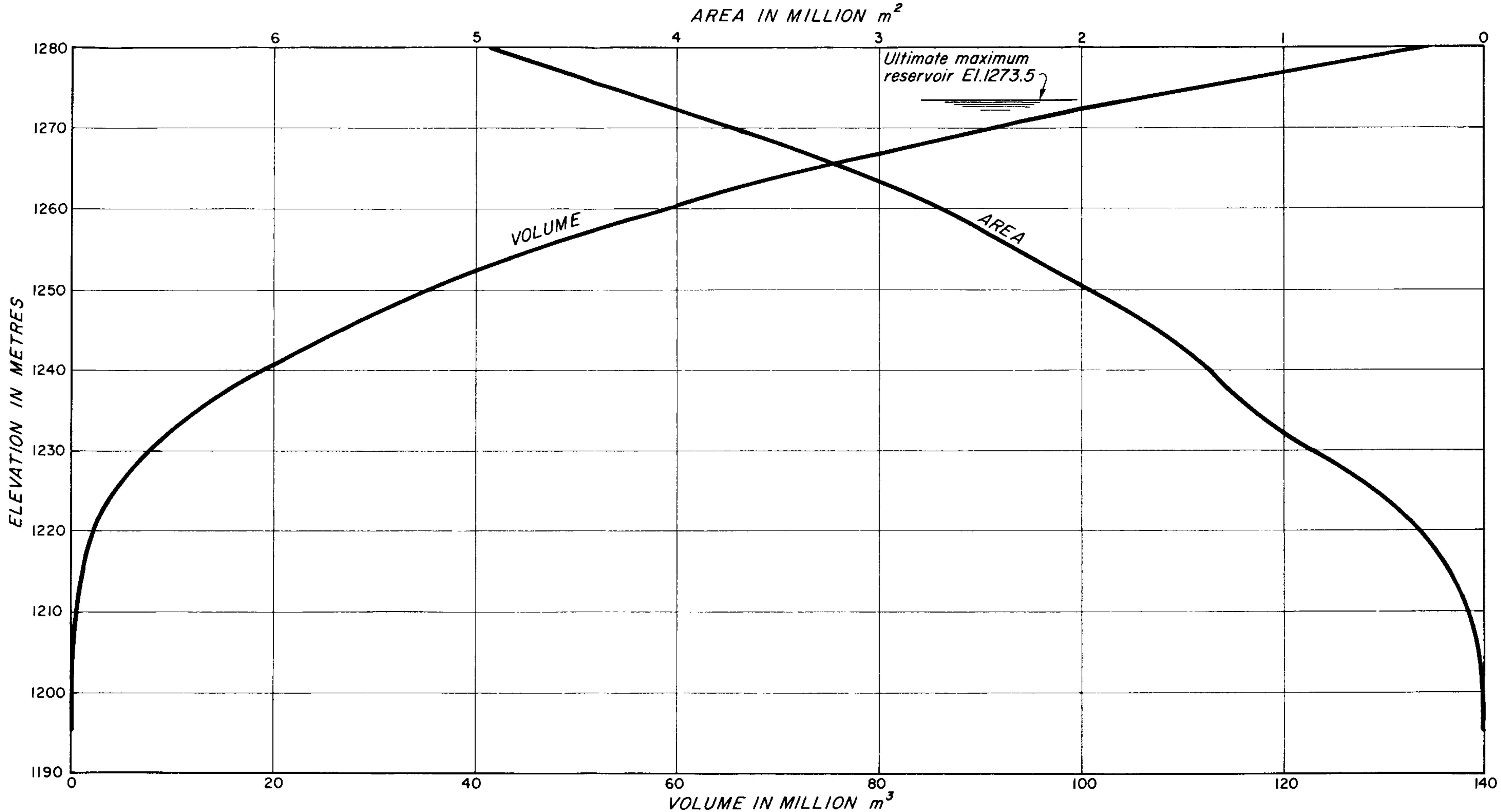
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

HAT CREEK PROJECT

WATER SUPPLY RESERVOIR AREA AND VOLUME CURVES

DATE MAR 1978	PLATE A27	R
DWN GCC	DWG No. 604H-C14-B81	

REPORT No. 916



NOTES:

1. AREAS TAKEN FROM 1:10,000 DIGITAL TERRAIN MODEL TOPOGRAPHY.

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY	
HAT CREEK PROJECT **ASH DISPOSAL RESERVOIR (AXIS 3B)** **AREA AND VOLUME CURVES**	
DATE MAR 1978	PLATE A28 R
DWN GCC	DWG No. 604H-C14-B82

REPORT No. 916

APPENDIX I

Terms of Reference

TERMS OF REFERENCE

PRELIMINARY DESIGN

WATER SUPPLY AND ASH DISPOSAL DAMS

HAT CREEK PROJECT

A. SCOPE

This assignment involves preliminary design (advanced feasibility level) of an embankment to impound the thermal plant cooling water and one or two embankments to impound fly ash delivered in slurry form. The work would include the following:

1. Assistance to B.C. Hydro, as requested, in selection of the general dam site areas.

2. Planning of limited subsurface and construction materials investigations, and interpretation of results.

   A drilling contractor is being selected by B.C. Hydro to perform exploratory drilling for total project preliminary design requirements. The drilling contractor will be supervised by Dolmage Campbell and Associates Limited; however, it will be the responsibility of Klohn Leonoff Consultants Limited (KLC) to establish all drilling, sampling and testing requirements and to provide complete inspection and logging services during the course of drilling at the subject dam sites.

   Seismic refraction surveys, to extend information obtained from the drill holes, would be carried out by a sub-consultant to be selected and directed by KLC. This seismic work would be performed under a separate B.C. Hydro purchase order to be raised following approval of KLC recommendations on sub-consultant, scope of work and estimate of cost.

   Ground surveys to locate drill holes and seismic lines will be performed by others.

3. Preliminary design of the embankments, including control of seepage by cut-offs or blankets if necessary. The watertight integrity of the reservoir at large (principally the upstream end of the reservoir at the divide) is to be assured.

A. SCOPE - (Cont'd)

The general location of the water supply embankment is now established. The exact location and orientation is to be determined based on subsurface and topographic conditions as well as embankment and foundation design requirements. Design of spillway and water inlet and outlet facilities, all independent of the embankment, will be performed by others. The maximum embankment height would be in the order of 140 feet.

The fly ash storage area has not yet been firmly selected. Storage may be obtained upstream of a single embankment at the upper end of Medicine Creek, or it may be obtained between two embankments in a more downstream location on Medicine Creek. Consideration must be given to staged construction of the embankment(s), utilizing suitable spoil from required excavation of Hat Creek No. 1 Pit. Ultimate embankment heights at the axes could vary between 250 and 500 feet. Supernatent water from the ash slurry will be pumped from the ash pond and returned to the powerplant for slurry reuse. Such slurry and water return facilities, as well as any spillway and water interception or bypass facilities, all of which should be independent of the embankment(s), will be the responsibility of others.

4. Preparation of capital cost estimates for the embankments and foundation treatment, using format and criteria to be agreed upon with B.C. Hydro.

5. Preparation of a report setting out in detail the results of the site investigations and laboratory test results, a geological interpretation of subsurface conditions, the basic design criteria adopted, the general arrangements proposed, the estimates of capital costs, and recommendations from further investigations required for detail design purposes. This report will be attached as an appendix to a report to be prepared by B.C. Hydro to cover all aspects of these impoundments. All work is to be presented in terms of metric units.

B. SCHEDULE

Preliminary design and preparation of a relevant design memorandum is to be completed by 1 November 1977. A final draft report is to be submitted for B.C. Hydro review by 15 December 1977.

C. TERMINATION OF WORK

Apart from the normal conditions which could result in work termination, there is some small possibility that dry disposal of the ash may be adopted. If such a decision were taken, all work related to these ash storage embankments is to be terminated immediately upon written notification by B.C. Hydro.

D. AVAILABLE INFORMATION

Such information as maximum and minimum water levels, drawdown rates, ash storage rates varying through the life of the thermal plant, total volume of ash to be stored and ultimate storage levels, will be provided as soon as possible after KLC have been authorized to proceed with this assignment. In addition, the following pertinent information will be made available:

1. Drill hole location drawings and drill logs of any drill holes relating to foundation conditions and construction material availability for the subject embankments.

2. Report by Ebasco Services Incorporated "Harry Lake Site, Preliminary Foundation Investigation, Hat Creek Project" dated February 1977. This report includes material from Golder Associates Ltd. and in particular provides information on three bore holes drilled on an axis across Medicine Creek in a potential ash storage area.

3. Report by Golder Associates Ltd. "Report No. 6, Hat Creek Geotechnical Study, Final Report" dated February 1977. The pertinent aspects of this report cover Hat Creek Pit No. 1 overburden materials and defines the location of the bore holes completed during 1976.

D. AVAILABLE INFORMATION - (Cont'd)

4. Drawing by Dolmage Campbell and Associates Limited (Scale one inch = 2000 feet) showing location of all bore holes in the Hat Creek valley. The prime purpose of these holes was to define the Hat Creek coal deposits, and the description of the surficials is extremely limited.

5. Topographic mapping at a scale of one inch = 400 feet with 10-foot contour intervals.

6. Air photo coverage at a scale of one inch = 2000 feet in black and white and in color.

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APPENDIX II

Metric Equivalents

TABLE II - I

METRIC EQUIVALENTS

MULTIPLY		BY	TO OBTAIN	
S.I. Metric Units	Symbol		Imperial Units	Symbol
centimetres	cm	0.3937	inches	in
centimetres per second	cm/s	3.2808×10^{-2}	feet per second	ft/s
cubic metres	m^3	35.3145	cubic feet	ft^3
cubic metres	m^3	1.30794	cubic yards	yd^3
cubic metres per second	m^3/s	1.58503×10^4	U.S. gallons per minute	gpm
cubic metres per second	m^3/s	35.3145	cubic feet per second	cusec
hectares	ha	2.47104	acres	acre
kilogram	kg	2.205	pounds	lb
kilometres	km	0.62137	miles	mi
kilopascals	kPa	20.8855	pounds per square foot	psf
metres	m	3.28083	feet	ft
millimetres	mm	0.03937	inches	in
square kilometres	km^2	247.104	acres	acre
square metres	m^2	10.7639	square feet	ft^2
tonnes per cubic metre	t/m^3	62.4283	pounds per cubic foot	lb/ft^3

APPENDIX III

Detailed Geology

APPENDIX III

GEOLOGY

APPENDIX III

GEOLOGY

III.1 Location and Physical Characteristics

The Hat Creek project is located approximately 195 km northeast of Vancouver, midway between the towns of Ashcroft and Lillooet.
The project area lies within the Thompson Plateau, subprovince of the Canadian Cordillera, adjacent to the boundary between the Thompson Plateau to the east, and the Clear Range of the Fraser Plateau to the west.

The valley of Hat Creek is a northerly trending topographic depression some 3 to 5 km wide. The depression is bounded by the Clear Range of the Fraser Plateau Province to the west, and by the Trachyte and Cornwall Hills to the east. The boundaries between the Hat Creek depression and the adjoining ranges are well defined, and the hills rise suddenly above the valley floor.

The Hat Creek depression lies parallel to, and approximately halfway between the major valleys of the Thompson River to the east and the Fraser River to the west. Hat Creek flows north and then northeast into the Bonaparte River. The Bonaparte flows southward into the Thompson.

Medicine Creek, the centre of the ash disposal scheme, flows into Hat Creek from the east. Medicine Creek is a small stream that forms the boundary between the Trachyte Hills to the north, and the Cornwall Hills to the south. The Creek drains the western slopes of these ranges (Plate A1).

The basic drainage pattern is influenced by the type, resistance and structural features of the bedrock. Nevertheless, the basic pattern has been much affected by the recent glaciation of the area.

The project area is one of moderate to high relief. The landforms are diverse, and generally reflect the composition and resistance to erosion of the underlying bedrock. Thus, areas underlain by softer sedimentary rocks are generally of low relief and have a smooth, rolling topography with gentle slopes. Areas underlain by harder igneous or metamorphic rocks are generally characterized by sharper landforms with prominent ridges and narrow, steep-walled stream valleys.

The Valley of Hat Creek lies at an average elevation of 900 metres within the project area. The headwaters of Medicine Creek are at approximately 1280 metres elevation. The Clear Ranges rise to near 2300 metres, and the Trachyte and Cornwall hills to about 2050 metres in the region surrounding the project.

III.2 General Geology and Tectonics

The valleys of Hat Creek and Medicine Creek represent the axes of basins that received a thick accumulation of volcanic and clastic sedimentary materials during the Tertiary Period. These basins were formed in a faulted and eroded landscape of Upper Paleozoic rocks. The area was overriden by at least two, and possibly more ice sheets during the Pleistocene Epoch. The ancestral Tertiary landscape was substantially modified by ice sculpturing and deposition of glacial and glacio-fluvial sediments.

The oldest rocks exposed in the region are currently believed to have been formed during the Pennsylvanian and Permian Periods (320 - 230 million years B.P.). These rocks consist of a thick assemblage of cherts, argillites, limestones, quartzites, andesites, tuffs and agglomerates, and their metamorphic derivatives. They were probably formed by combined volcanic and sedimentary processes in a coastal and shallow marine environment. The rocks of the Permian System are collectively defined as the Cache Creek Group.

The rocks of the Cache Creek Group were probably upset by tectonic events that occurred during the Early Triassic Period (Tahltanian stage of the Cordilleran Orogeny). As a consequence of these events, the rocks were folded, faulted and eroded. They were subsequently metamorphosed by regional metamorphism. These events were followed by the intrusion of the Coast Mountains plutonic rocks during the early to middle Jurassic Period, (200 to 140 million years B.P.). Jurassic plutonic rocks occur in areas east and west of the present-day Hat Creek Basin.

The region surrounding the project area remained relatively quiescent during the Mesozoic Era, with some minor tectonic disturbances during the Jurassic (contemporary with the emplacement of the plutons) and Cretaceous Periods. The Hat Creek Valley seems to have been mainly a positive area subject to erosion during this period, while deposition of volcanic and sedimentary rocks was taking place in nearby basins. At the same time, the environment is believed to have been slowly changing from marine to continental, by infilling of basins and slow epeirogenic uplift.

The regional drainage channels (Fraser and Thompson Rivers) are believed to have established themselves in more or less their present form by the end of the Mesozoic Era (65 million years B.P.). By the early Tertiary the area is believed to have been fully continental, and probably resembled a peneplained surface cut by the deep valleys of the ancestral Thompson and Fraser Rivers.

The project area probably underwent a regional uplift and warping during Early Tertiary (Paleocene) times as a result of the Laramide Orogeny that was affecting the Cordilleran region (65 to 53 million years B.P.). This regional warping was accompanied by rupture of the crust along predominantly north-south trending fault lines. As a result of this faulting the region acquired a horst-and-graben topography, characterized by narrow downwarped depressions (grabens) bound by block-faulted pillars (horsts) on either side. This is probably the origin of the present-day Hat Creek Valley depression.

The regional forces responsible for this warping are believed to have acted along predominantly north-south directions. The north-south faults flanking the Hat Creek basin would therefore be tension faults.

The walls of the graben appear to have been offset locally by a system of conjugate, northwest and northeast trending strike-slip faults. A number of conspicuous northwest-southeast striking lineations strongly support this faulting hypothesis. The water supply dam and reservoir are located in a stream believed to have been controlled by these strike-slip faults.

The general relaxation that followed the regional upwarping of the Paleocene Epoch was probably responsible for a younger system of east-west trending gravity faults superimposed upon the older horst-and-graben faults. The valley of Medicine Creek is believed to follow one of these younger fault lines.

The uplift and faulting of the early Tertiary was followed by a period of intense sedimentary and volcanic deposition during the Middle Tertiary (Eocene to Middle Oligocene, or about 53 to 30 million years B.P.).

The low to mid Tertiary deposition of sedimentary and volcanic materials occurred mainly in the basins formed by downwarping and faulting, and along the valleys of major streams, such as the ancestral Thompson and Fraser Rivers.

The Eocene-Oligocene sedimentary rocks are collectively designated as Kamloops Group in the Thompson Plateau region. Within the Hat Creek project area sedimentation of the Kamloops group started with a thick series of coarse grained conglomerates, breccias and interbedded sandstones, known as the Coldwater Beds[1]. These are believed to be fluvial torrential accumulations deposited prior to the main phase of volcanism.

Deposition of the conglomerates was followed by a sedimentation cycle in a lower energy environment which gave rise to the Hat Creek coal beds and associated clastic sediments (Hat Creek Coal formation).

The coal is believed to have been deposited in a continental (non marine) bog and swamp environment. The coal beds are interbedded with, and grade laterally into, clastic sedimentary rocks ranging in grain size from claystone to pebble conglomerate, deposited under lacustrine or fluvial conditions. Deposition of the coal is believed to have terminated suddenly by a regional change from bog and swamp to lacustrine facies.

1. The names used for rock-stratigraphic subdivisions of the Kamloops Group follow the recent nomenclature proposed by Church (1977)

A thick, monotonous sequence of pelitic rocks (mainly claystones and siltstones) was deposited above and adjacent to the coal basins under the new environment. Within the project area, these rocks have been grouped as a single rock-stratigraphic unit known as the Medicine Creek formation.

Various kinds of volcanic rocks are associated with the sedimentary rocks of the Kamloops group. The volcanic rocks are believed to be partly contemporary, but mostly younger than the sedimentary rocks. Within the project area, the volcanic rocks consist mainly of acidic to intermediate lavas and volcaniclastic materials, including tuff, breccia and lahar deposits. The volcaniclastic deposits predominate within the Medicine Creek basin. These rocks are believed to belong to the Finney Lake Beds (Church, 1977).

Volcanic activity probably started at the time of deposition of the Hat Creek and Medicine Creek formations. Shale and claystone beds of tuffaceous origin are found interbedded with these deposits. The climax of volcanic activity was reached after deposition of the Hat Creek and Medicine Creek formations was finished. Volcanic activity is believed to have continued until mid-Oligocene times (about 30 million years B.P.).

The deposition of sedimentary and volcanic rocks of the Kamloops Group was followed by renewed upwarping and faulting. At this time new faults occurred, and the older faults were rejuvenated. Many of the Kamloops Group rocks have been observed to be affected by dislocations. At the same time, frequent landslides probably occurred in steep slopes underlain by weak, tuffaceous deposits.

A renewed volcanic episode occurred between mid Miocene and mid Pliocene times (approximately 10 to 5 million years B.P.). Olivine basalts were spilled through fissures and deposited in some of the valleys and basins of Tertiary sedimentation. These rocks are currently classified as part of the Kamloops Group. They have been largely destroyed as a result of glacial erosion, and only a few remnants have been mapped in the project area.

During the Pleistocene Epoch, all of the project area was covered by continental ice sheets (about 1.5 million to 10 thousand years B.P.). The ice is believed to have reached elevations of up to 2500 metres.

Most of the valleys owe their present forms to glacial action, and were shaped mainly during the valley glacier stages that preceded and followed the period of maximum glaciation. South and southeast-trending valleys are mostly wide, symmetrical and U-shaped. East-trending valleys are commonly asymmetric in cross section, the south walls precipitous and the north walls gently sloping. This effect is, apparently, due to the plucking and steepening action of small glaciers and patches of snow that persist year-round on south walls.

The area is believed to have been overriden by at least two, and possibly three glacial sheets. The greatest influence has been that of the latest ice readvance (Fraser Glaciation, 20 to 10 thousand years B.P.).

The Fraser ice overrode the Hat Creek basin from the Coast Mountains in the west, with the ice moving approximately in an E-SE direction (120 degrees of geographic north). A thick mantle of till was deposited during this stage. The till cover is thicker in areas underlain by softer Tertiary sedimentary rocks, and thinner in areas of harder igneous or metamorphic rocks.

Deglaciation occurred by thinning and stagnation of the continental ice sheet. The higher elevations were free of ice first. During the last stages of deglaciation, isolated ice tongues remained in the lower parts of the valleys, where they were gradually destroyed by downwasting.

Melting of the Fraser ice was accompanied and succeeded by the development of kames and outwash plains. Eskers were formed where meltwater flowed subglacially. In areas where seasonal readvances of the melting ice front took place, small, transverse (cross-valley) moraines were formed. Examples of all these deglaciation-related features can be found in the Hat Creek area.

The thickness of till and outwash deposits varies from 0 to 100 metres. The average thickness is about 50 metres.

III.3 Rock Types in the Medicine Creek Basin

Plate A4 shows a table of geologic units in the Medicine Creek basin. The distribution of the various geologic units is shown on the map on Plate A5, which is derived from the mapping of outcrops shown on Plate A6 and listed at the end of this appendix.

Owing to the thick mantle of glacial deposits in the project area, the contacts between the various geologic units are mainly inferred. The location and extent of faults is also inferred through most of the area.

Following is a brief description of each of the geologic units in the Medicine Creek Basin, from older to younger.

III.3.1 Cache Creek Group (Pennsylvanian and Permian)

The Cache Creek group consists of a thick assemblage of chert, argillite, phyllite, quartzite, limestone, andesite flows, agglomerate and tuff, and their metamorphic derivatives. The massive recrystallized limestones exposed in the Marble Canyon north of Hat Creek are conspicuous amongst these rocks. Since they form a distinct subdivision that can be mapped separately, they have been segregated from the rest in a single unit designated as Marble Canyon Formation. The remainder of the rocks are grouped together and usually referred to as the "Greenstone Suite".

The Marble Canyon limestones are very hard and massive, and they form some of the highest peaks in the project area. There is generally a sharp contrast in topography between areas underlain by limestone, and areas underlain by softer rocks of the greenstone suite.

Limestones occur in thick beds, as well as in small lenses and pods interbedded with other rocks. They are generally fine to medium grained, and coloured bluish white or grey.

Within the Medicine Creek Basin the greenstone suite is represented by green-coloured, low grade metamorphic rocks (slate, phyllite, and metavolcanics, mainly altered andesite or andesite porphyry). Dark grey chert beds are also found in some areas, associated with the limestone and greenstone.

The Cache Creek Group rocks have been so severely distorted by tectonics and regional metamorphism that it is very difficult to establish the internal structural relations among the various constituents. In general, it is believed that sedimentation of the Cache Creek Group started with a thick sequence of limestones. At later stages, limestones were deposited alternating with, or adjacent to, the volcanic and clastic sedimentary rocks that were the source-rocks of the greenstone suite.

The map on Plate A5 shows the Cache Creek rocks to be mainly greenstones. Limestones are shown as small patches, where these rocks have been mapped in outcrops or drillholes. The reason for this interpretation is that greenstones are more frequently encountered than limestones in the Medicine Creek Basin. In reality, given the highly folded and faulted nature of the Cache Creek rocks, it is possible that limestones could have a wider distribution which is not apparent due to the cover of glacial drift.

III.3.2 Kamloops Group (Tertiary)

Deposition of the Upper Paleozoic Cache Creek Group was followed by a long period of alternating tectonism, regional metamorphism and erosion that lasted throughout the Mesozoic Era and into the Lower Tertiary. These events had a significant effect in upsetting and altering the rocks of the Cache Creek Group.

Deposition of the Kamloops Group started in Eocene times. The group has been divided into four separate units in the Medicine Creek Basin (after Church, 1970). These are described from older to younger.

Coldwater Beds (Eocene - Oligecene)

The Coldwater Beds consist of firmly indurated breccia, sandstone and conglomerate. They are believed to represent fluvial accumulations prior to the main phase of volcanism. The clasts in these rocks are probably derived from the Cache Creek Group rocks, and from Cretaceous volcanic rocks present in nearby basins.

The Coldwater Beds occupy most of the ash pond and water supply reservoir basins. In this area, they are found interbedded with siltstones and claystones of the Medicine Creek formation.

Hat Creek Coal Formation (Eocene - Oligocene)

The Hat Creek Coal formation is not present in the Medicine Creek Basin, but it is included here to complete the stratigraphic picture. The coal seams are interbedded with sedimentary rocks ranging in grain size from claystone to conglomerate. The coal is believed to have been formed in continental, intermontane, lagoons.

Medicine Creek Formation (Eocene - Oligocene)

The name Medicine Creek formation is applied to a monotonous claystone-siltstone sequence overlying the coal. These rocks are light to medium brown coloured. Except for a few zones of laminated carbonaceous argillite, the rock is almost massive with only occasional vague expressions of bedding planes.

Petrographically, the rock consists of small angular quartz fragments, shredded mica and clay. These rocks cover part of the ash pond and water supply reservoir areas. They are interbedded with conglomerates of the Coldwater beds, and the contacts shown on Plate A4 should be considered only approximate.

Volcanic Rocks (Eocene - Oligocene)

The volcanic rocks are considered to be partly contemporary, but mainly younger than the sedimentary rocks. The volcanic rocks found in the Medicine Creek Basin are believed to belong mainly to the Finney Lake Beds unit.

This formation consists of andesite and dacite lava flows, and coarsely bedded volcaniclastic deposits. Lahar beds predominate in the volcaniclastic deposits. They consist of rounded to subangular blocks suspended in a mud matrix, the manifestation of chaotic debris flow.

The volcanic rocks are interbedded with sandstones and conglomerates which represent the washed and sorted stream worked derivatives of the original volcanic deposits. The volcanic deposits are represented by a small patch of hard volcanic breccia and agglomerate in the vicinity of the ash retention damsite (dam axis No 3).

Olivine Basalt (Miocene - Pliocene)

This is the youngest formation of the Kamloops Group. This rock has been observed only in a few small outcrops, all of them outside the area of the ash disposal and water supply reservoirs.

III.4 Glacial Deposits

The Medicine Creek Basin is covered by a mantle of glacial till of variable thickness (from 0 to 30 or 40 metres in the areas investigated). A typical profile of overburden includes a thin mantle of boulders and weathered rock overlying bedrock. Above this, there is generally a mantle of dense, clayey lodgement till covered by 1 or 2 metres of gravelly, less dense, ablation till, weathered till and slopewash. Interbeds of clay, silt and fine sand of probable glacio-lacustrine origin are occassionally found within the lodgement till.

Several cross-valley morainal ridges are present within the ash pond area; these probably represent either a stationary front, or minor readvances of the ice front at the time the Medicine Creek ice was receding westwards towards the Hat Creek Valley.

There are no relevant examples of glacio-fluvial or outwash deposits in the basin. The reworking of the glacial materials by the modern stream has given rise to alluvial fans and bars along the streambeds.

III.5 Geologic Structures

Major structures present in the project area include faults and unconformities.

III.5.1 Faults

Three major faults have been observed in drill cores, mapped in outcrops, or otherwise defined within the Medicine Creek Basin.

Two faults striking approximately NW-SE are believed to belong to the set of shear faults caused by compressional upwarping of the area during the Paleocene, prior to the main phase of Middle Tertiary sedimentation and volcanism.

One of these faults is located along the stream valley of the water supply reservoir. This fault trends approximately 160 degrees from geographic north, and appears to continue southeastward along the valley of Upper Medicine Creek.

The second fault is located to the west of the first, approximately in line with ash retention dam No 3. This fault trends approximately 140 degrees, and appears to terminate against the south wall of Medicine Creek Valley.

These faults have been identified mainly from strong lineations in air photographs. The water supply reservoir fault is also suggested by the offset of mudstone beds in the saddle dam area. This evidence is still not conclusive from the field data available.

If the postulated origin of these faults is correct, the displacement along the fault would have been primarily horizontal (strike-slip fault).

A fault coincident with the valley of Medicine Creek has been reported in the literature (Church, 1977). This fault is believed to have originated from the relaxation of the lower Tertiary compressive forces that gave rise to the horst-and-graben topography. According to this theory, the fault would be of the normal (gravity) type, with a predominantly vertical (dip-slip) displacement.

A fault zone was intersected by drillhole DDH-77-500 at the divide between the Medicine Creek basin and MacLaren Creek. A steep cliff of conglomerate on the south wall of the divide is also believed to be a fault scarp (Plate A5). Conglomerate is exposed in outcrops on both sides of the divide, at approximately elevation 1295 m. The same conglomerate was found at elevation 1250 m in drillhole DDH-77-500, underneath 13.5 metres of siltstone and mudstone of the Medicine Creek formation, and 21.5 metres of glacial overburden.

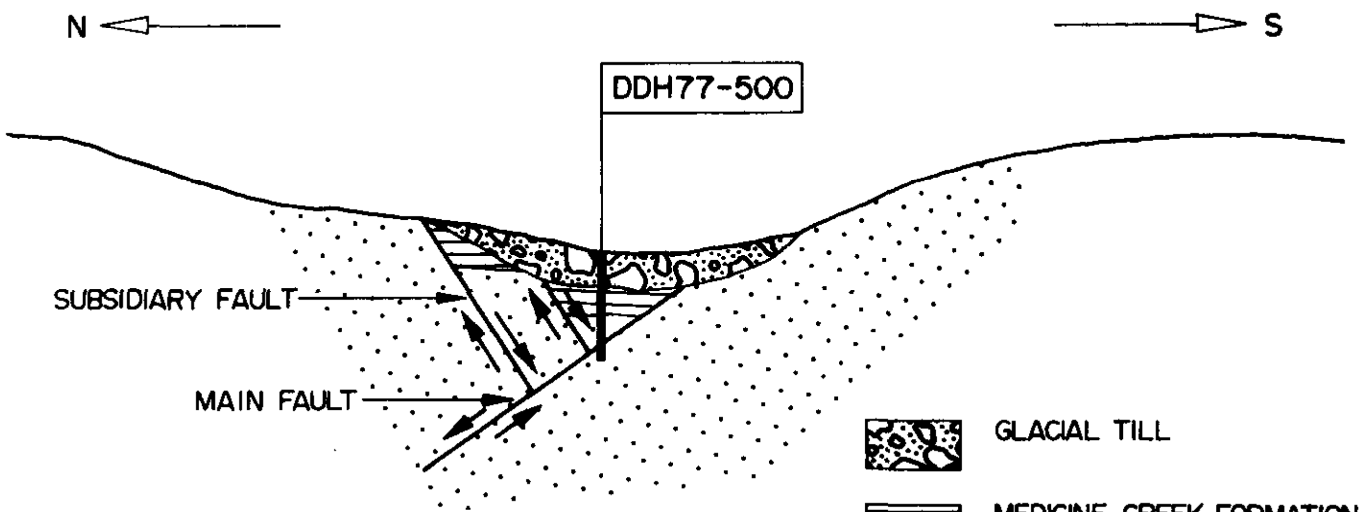

FIGURE I

GEOLOGICAL INTERPRETATION OF FAULTING IN THE DIVIDE BETWEEN MEDICINE CREEK AND MacLAREN CREEK.

If it is assumed that the fault scarp on the south side of the divide, and the fault crossed by the drillhole are both part of a single fracture, a model of the fault may be constructed as shown on Figure 1. This model incorporates a main fault surface, and subsidiary fractures in the downthrown block, forming a graben structure. According to this model, the soft mudstones of the Medicine Creek formation have been eroded from both flanks of the divide, but have been preserved within the graben in the trough of the divide. Since this fault is affecting Coldwater and Medicine Creek formation rocks, it is presumed that the fault is either post-Medicine Creek, or more likely, that it represents a rejuvenated older, pre-Coldwater fault.

There is no reliable evidence of the presence of a fault along Medicine Creek, other than the observations at the divide. Rock outcrops are so scarce, however, that direct evidence would be difficult to obtain. If a fault is indeed present, the trace of the fault surface on the bedrock surface is probably not along the creek but on the abutments. Some evidence of shearing has been noted in drillholes P-77-41 (dam axis No 3) and P-77-47 (dam axis No 4), supporting this hypothesis. On the contrary, there is no evidence of faulting in the outcrop of Cache Creek chert on the Medicine Creek bed at dam axis No 1.

We believe that it is probable that a fault or set of fractures exists along Medicine Creek, from the divide to Hat Creek, and we have included such a fault in our interpretation.

III.5.2 Unconformities

Most of the area of the ash storage reservoir and water supply reservoir is underlain by Tertiary Rocks of the Kamloops Group. A major regional unconformity separates these rocks from the underlying older rocks of the Cache Creek Group (Plate A4). Rocks of the Cache Creek Group outcrop in the Medicine Creek valley in the vicinity of dam axis No 3, and also a short distance east of the divide between the Medicine Creek Basin and the valley of MacLaren Creek, (Plates A6 and A7).

The unconformity is believed to outcrop underneath the till cover in the vicinity of damsite No 3, and also east of the divide. Since an unconformity represents the contact between an ancient, irregular erosion surface and younger sediments, the actual position of this feature cannot be predicted under till covered areas. The boundaries shown on Plate A5 are only approximate.

The major regional unconformity is covered by small patches of late Kamloops Group volcanics in the vicinity of damsite No 3. These rocks consist mainly of hard breccia and agglomerate.

III.5.3 Other Structures

Other structures within the basin include folds, joints and cleavage. The rocks of the Cache Creek Group (limestones and greenstones) are believed to have been folded by repeated orogenies, but the structural patterns are not known owing to the scarcity of outcrops and rapidly changing facies of these rocks.

Some of the outcrops of altered volcanics of the greenstone suite exhibit regular fracture patterns, but these patterns change from outcrop to outcrop. Limestones, where observed, are generally massive with few isolated irregular joints and bedding. There is no visible evidence of solution features in the limestones.

Rock cleavage is present in some of the slate-phyllite members of the greenstone suite, but again the patterns are variable from outcrop to outcrop. Chert outcrops usually exhibit a tabular structure with beds a few centimetres thick. Owing to the low ductility of this rock, good examples of brittle fracture and open bedding planes can be observed where chert beds have been folded.

The Coldwater conglomerate and sandstone have a variable structure, from massive to containing well developed bedding and jointing. When the rock is massive, some master joints are open giving the rock a significant fracture-induced permeability.

The siltstones and claystones of the Medicine Creek formation show alternating sections of massive rock and rock with well developed bedding. Jointing is generally poorly developed. Structures in these materials are difficult to appreciate since the rock softens easily in drill cores, and disintegrates rapidly in surface outcrops.

III.6 Seismicity

A study of seismicity in the Hat Creek project area has been carried out recently by the Dominion Observatory, Victoria. The results of the study have been reported by Golder Associates (1977).

According to the study, an earthquake of intensity V[1] has a probability of being felt once every 100 years in this area. An earthquake of this intensity would cause a ground particle acceleration of 0.02g

1 1931 Mercalli Intensity Scale modified by C.F. Richter (1956)

(2 percent of earth's normal gravity) in firm soils such as the local basal till and bedrock. According to this information, the area corresponds to Zone 1 of the Seismic Zoning Map of the National Building Code of Canada (1975). The seismicity study has been based on statistical analyses of earthquakes recorded since the beginning of the 20th Century.

The faults believed to exist beneath all three damsites are considered inactive since there is no evidence of faulting having affected post Tertiary materials (i.e. materials younger than 1.5 million years B.P.)[2]

III.7 Geology of Water Supply Reservoir

III.7.1 Water Supply Dam

The site of the proposed water supply dam is underlain by conglomerate of the Coldwater beds, except for a small portion near the end of the right abutment, which is underlain by Cache Creek limestone and greenstone. (See Plate A11). The bedrock geology is mainly inferred since drillholes penetrated only a short distance into rock, and core recovery was very poor.

The bedrock is covered by a mantle of lodgement till up to 15 metres thick. Conglomerate is exposed on the upper part of the left abutment.

A fault is indicated along the stream. This fault is inferred from air photo lineations. The location and attitude of the fault shown on Plate A11 are assumed for illustration purposes only.

2 According to recent definitions of the U.S. Atomic Energy Commission an active fault is one that has undergone some movement within the last 500,000 years (Sherard et al, 1974)

III.7.2 Water Supply Saddle Dam

A profile along the saddle dam is shown on Plate A11. The left (west) abutment is underlain by siltstone and claystone of the Medicine Creek formation. The right (east) abutment is underlain by conglomerate of the Coldwater beds.

The same fault noted in the water supply dam is assumed to cross the saddle dam site. The location and attitude of the fault shown on Plate A11 is assumed for illustration purposes only. The fault has not actually been observed either in drillholes or in surface outcrops.

The fault is assumed to be the boundary between the Coldwater beds and the Medicine Creek beds. However, since both formations are known to be interbedded in places, another possible hypothesis is that both units are interfingered at this site. A combination of both hypotheses is illustrated on Plate A11.

III.7.3 Water Supply Reservoir

The water supply reservoir is underlain mainly by Tertiary conglomerate and siltstone-claystone, with a small area underlain by Cache Creek greenstone and limestone. The assumed distribution of the various geologic units is shown on the geologic map on Plate A5.

III.8 Geology of Ash Storage Reservoir

III.8.1 Ash Retention Dam

A geologic section under damsite No 3 is shown on Plate A17. Bedrock at this site is made up mainly of rocks of the greenstone suite (Cache Creek group).

The left abutment has a relatively thin cover of glacial drift (8 to 15 metres). The till cover is thicker on the right (north) abutment and at the valley bottom (20 to 45 metres). The depth to bedrock under damsite No 3 has been measured by drilling and by a seismic refraction survey. The interpreted bedrock surface from the seismic survey is shown on the profile on Plate A17. The complete seismic survey report is presented in Appendix V.

The deepest part of the ancestral bedrock valley is offset approximately 40 metres north of the present valley bottom. The suspected Medicine Creek fault is shown where the bedrock valley is deepest, for illustrative purposes only. No direct evidence of this fault has been found at this site.

III.8.1 Ash Storage Reservoir

The Ashpond area is underlain mainly by Tertiary conglomerates and siltstones-claystones. There is a small patch of Tertiary lavas and breccias on the left abutment of the valley upstream of damsite No 3. The assumed distribution of the various geologic units is shown on the geologic map on Plate A5.

The problem of reservoir leakage was focused mainly on the possibility of contamination of surficial and underground waters in the MacLaren Creek basin by leachates seeping out of the ash storage reservoir through the Medicine Creek Divide.

Some seepage would occur westward along Medicine Creek, but it is not considered to be significant.

The problem of leakage across the Medicine/MacLaren Creek Divide is primarily associated with the major regional unconformity separating the Tertiary rocks of the Kamloops Group from the rocks of the Cache Creek Group. A regional unconformity could potentially be a major aquifer, and this unconformity is believed to connect the valleys of Medicine Creek and MacLaren Creek.

Initial drilling and surface mapping indicated the presence of Cache Creek greenstone on the left (south) abutment of the original ash retention dam centreline (dam axis No 3). Drilling at dam centreline No 4 (approximately 1200 metres east of dam axis No 3) indicated siltstone, claystone and sandstone of the Medicine Creek formation (Tertiary). Several outcrops of igneous rocks at the streambed and on the abutments of dam site No 3 were tentatively identified as Kamloops Group volcanics (Tertiary).

Based on these observations, it was concluded that the contact between Permian and Tertiary rocks must outcrop underneath the till between dam sites No 3 and No 4. It was further postulated that a small patch of Tertiary volcanic rocks exists around dam site No 3, and that this patch may be continuous. Continuity could not be confirmed, however, due to the thick till cover.

Based on the factors described above, it was decided to displace the dam centreline (centreline No 3) approximately 180 metres upstream of the original line to centreline No 3B. Two advantages would be derived from this displacement.

a) Place most of the dam (especially the upstream core zone) on contact with Tertiary volcanics or glacial till to minimize the danger of leachates infiltrating the Permian greenstones and escaping eastward along the unconformity.

b) Effect a small reduction in volume of earthfill.

Detailed petrographic identification of rock specimens at the time the preliminary design was being completed, indicated that some of the rocks identified as Tertiary volcanics are in reality volcanic or hypabissal[1] members of the Permian Cache Creek group. The extent of the patch of Tertiary volcanics was thus reduced from our original interpretation. The true nature of this patch, however, cannot be defined precisely due to the thick till cover. The geologic map on Plate A5 indicates this patch underlying part of the left abutment of the current damsite. The decision to displace the dam axis is still considered appropriate, however, as the depth of till increases upstream of dam centreline No 3.

Our interpretation of the outcrop of the Paleozoic-Tertiary contact is shown on Plate A5. The trace of the contact on the bedrock surface appears to cut sharply across topographic contours. This suggests that the contact may be a fault parallel or subsidiary to the water supply reservoir fault. If this hypothesis is correct, the unconformity would be found at some depth under the Tertiary sediments and cut abruptly by the fault.

The unconformity was not reached by a deep hole drilled some distance upstream of the ash retention dam (hole RH-77-48 by Golder Associates). An attempt to drill the unconformity at the divide proved unsuccessful when hole DDH-77-501 by Klohn Leonoff Consultants had to be abandoned due to breakage and loss of drill rods. Even though the unconformity has not been penetrated, both drillholes have established that

a) the unconformity lies very deep within the ashpond area and
b) it is covered by a thick sequence of till, dense impervious siltstone and mudstone, and massive conglomerate

1 The term hypabissal is applied to igneous rocks that have cooled near the surface in dykes or sills.

The possibility of leakage along the unconformity is considered remote based on the preceding considerations. The possibility of seepage directly from the ashpond across the divide through the glacial and Tertiary cover foundations is also considered remote as a consequence of the impervious nature and substantial combined thickness of the till and the siltstone-claystone formation.

A further protection against seepage through the divide is offered by a natural groundwater barrier at the divide. Groundwater levels were measured continuously during the drilling of hole DDH-77-501 and found to be at or above ground level through the entire depth of the hole (69.76 m).

One piezometer was installed at the overburden/bedrock contact, and two in pervious sections of the Coldwater conglomerate, under the divide. These piezometers were installed in a second rotary hole (RH-77-502) drilled adjacent to DDH-77-501. The two bedrock piezometers were installed on either side of the fault, and sealed from one another.

All piezometers indicated a water level at, or above ground surface. One of the bedrock piezometers was flowing at approximately 0.25 m^3/hour under a head of about 2 m above ground surface. In general, the groundwater pressure barrier rises at least 20 metres above the maximum proposed ashpond elevation.

A few small outcrops of Cache Creek rocks within the ashpond area will require blanketing with impervious material to reduce the danger of leachates seeping into this rock.

III.9 Geology of Alternate Bottom Ash Storage Dam and Reservoir

This site lies on a wide, gentle valley covered by grassland just south of Harry Lake, as shown on Plate A2. Small patches of pine trees grow in some of the protected slopes. Small patches of aspen trees are found at the bottom of the valley indicating a groundwater discharge condition and probably a shallow groundwater level.

Bedrock in the reservoir area is believed to consist of Phyllite, chert and volcanics of the Cache Creek group (Greenstone suite). Bedrock has been investigated by numerous test holes for plantsite foundation studies drilled in the periphery of the reservoir (reports by EBASCO Services Incorporated, and Thurber Consultants Ltd).

There is no indication of bedrock within the damsite and reservoir area. The area appears to be underlain by a moderate thickness of dense, basal glacial till.

The till is exposed in a gulley on the north abutment which drains the overflow of Harry Lake. The gulley is incised from 4 to 6 feet at the dam axis. The material exposed is generally sandy. The walls of the gulley are slumping in places, indicating that there may be significant amounts of seepage during the spring. The till underlying the damsite and reservoir is generally a sandy or clayey gravelly soil. It is probably impervious judging from the presence of Harry Lake.

The gulley at the bottom of the valley is incised only 1 or 2 feet and exposes mainly an organic, silty soil. There are various indications of groundwater discharge, and possibly a shallow groundwater table in this area.

The south abutment is generally steeper than the north abutment and the thickness of till cover may be somewhat less here than in the north abutment. The underlying drift materials are expected to be more bouldery than in the north abutment as there are numerous boulders exposed on the slopes.

KLOHN LEONOFF CONSULTANTS LTD.

R. S. Lopez

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SURFACE GEOLOGIC MAPPING

DESCRIPTION OF OUTCROPS

Outcrop No	Field Descriptions
01*(1)	Greenstone (Cache Creek Group) Medium to dark green, massive. Petrographic Description Phyllite, extensively deformed so it can be classified as a tectonic breccia.
02	Greenstone (Cache Creek Group) Phyllitic structure. Dark green to metallic grey, foliation dips 95/62.(2)
03	Mafic Volcanic (Kamloops Group) Andesite or basalt overlying tuff-breccia. Both are hard and massive. Plunge of contact 130/30. Dip of volcanic flow appears to be 240/43 but is difficult to measure owing to the massive nature of the rock.
04	Tuff Breccia (Kamloops Group) Similar to that at outcrop 03.
05	Greenstone (Cache Creek Group) Two types: a) Massive, porphyroblastic, medium green (altered volcanic) b) Phyllite (metasediment), poorly developed fissility. Numerous boulders of Marble Canyon limestone in overlying till. Petrographic Description Phyllite, nonbedded, dark grey.

(1) Outcrop numbers with an asterisk indicate that a sample has been examined under a petrographic microscope. A summary of the petrographic description follows the field description.

(2) Attitude of planar structures is reported as dip bearing/dip angle.

Outcrop No	Field Description
06*	Greenstone (Cache Creek Group) Altered intermediate or basic volcanic. Petrographic Description Greenstone, microporphyritic, massive, dark green.
11	Greenstone (Cache Creek Group) Altered intermediate or basic volcanic, dark green.
12	Greenstone (Cache Creek Group) Phyllite, fissility dips 110/90 (vertical)
21*	Altered Volcanic (Cache Creek Group) Massive structure with no apparent fracturing, knobby surface.
22	Limestone (Cache Creek Group) Bluish grey, dense, massive
23	Greenstone (Cache Creek Group) Massive, altered intermediate or basic volcanic.
24*	Greenstone (Cache Creek Group) Two types: a) Massive, porphyroblastic, medium green (altered volcanic) b) Phyllitic with poorly developed foliation, numerous calcite veins Numerous boulders of Marble Canyon limestone in overlying till. Petrographic Description Metavolcanic rock, porphyritic, medium to light green.
25	Greenstone (Cache Creek Group) Phyllitic structure, altered to chlorite, minor inclusion of limestone, bluish grey, within the phyllite.
26	Greenstone (Cache Creek Group) Phyllitic structure, altered to chlorite. Two joint sets: 249/86 (well defined) 158/66 (poorly defined)

Outcrop No	Field Description
27	Limestone (Cache Creek Group) White, weathers to yellowish brown, moderately to strongly weathered and fractured.
31	Conglomerate and Breccia (Kamloops Group) Prominent cliff, probably a fault scarp or fault-line scarp.
32	Conglomerate and Claystone (Kamloops Group) Claystone overlying conglomerate or breccia. The claystone may be weathered volcanic ash. Fossil wood within the claystone.
33	Sandstone (Kamloops Group) Brownish red, thin bedded. Beds dip 285/10.
34	Siltstone and Claystone (Kamloops Group) Thin bedded to laminated, medium hard, well indurated, beds dipping at 293/22, greenish or yellowish brown.
35	Gravelly Sandstone (Kamloops Group) Fine to medium grained, beds dipping at 250/25. Two joint sets: 308/85 (dominant, spaced 0.08 - 0.15 m) 216/90 (secondary, spaced 0.10 - 0.25 m)
41*	Altered Volcanic (Cache Creek Group) Massive structure with no apparent fracturing. Knobby surface. Petrographic Description Greenstone, prophyritic, massive, medium to dark green.
42*	Altered Volcanic (Cache Creek Group) Massive structure with no apparent fracturing. Knobby surface. Petrographic Description Greenstone, porphyritic, massive, medium grey-green.

Outcrop No	Field Description
43*	Limestone (Cache Creek Group) Blue grey, overlying chert. Petrographic Description Marble, massive, medium grey, calcite veins.
51	Sandstone and Conglomerate (Kamloops Group) Interbedded. Dip of bedding 29/50. Two joint sets: 316/88 (dominant) 229/60 (secondary)
61	Conglomerate (Kamloops Group) Weathered.
62	Siltstone, Sandstone (Kamloops Group) Exposed in main trail and in bulldozer cut for drillhole P-77-36.
71	Chert (Cache Creek Group) Dark grey to black.

PETROGRAPHY OF DRILL CORES AND HAND SPECIMENS, UPPER HAT CREEK, BRITISH COLUMBIA

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INTRODUCTION

This report is a petrographic investigation of nine specimens from drill core and outcrops. The specimens were supplied by R.S. Lopez of Klohn Leonoff Consultants Ltd. All rocks except those of DDH 500 belong to the Cache Creek Group of late Paleozoic age. These rocks were extensively deformed and regionally metamorphosed during the Triassic (Grette, in prep.; Read and Okulitch, 1977; Read, 1976). The foliated nature of some rocks (Specimens S-01, S-05, P77-41 20-27') and the regionally metamorphic mineralogy of all of the rocks of the Cache Creek Group are evidence of these events. All specimens are grouped in their stratigraphic units and described in order of decreasing age.

CACHE CREEK GROUP

A sequence of grey phyllite, metachert, metagreywacke, marble, and metavolcanic rocks and related hypabyssal intrusions comprises the Cache Creek Group of Pennsylvanian and Permian age. Specimens S-01 and S-05 are typical of the extensively deformed, siliceous grey phyllite, and S-43 is typical of the limestone lenses found in the Cache Creek Group. Specimens S-06, S-41, P77-41 20-27', and S-24 are basic greenstones of which S-24 is a porphyritic (pyroxene) meta-basalt and S-06 and S-41 are fine-grained pyroxene meta-diorite or meta-gabbro which may be the feeders to the metavolcanic rocks.

(a) Metasedimentary Rocks:

Specimen S-01:

Dark grey siliceous phyllite which has been so extensively deformed that it is now a tectonic breccia.

A thin section examination shows:

1. Quartz (75%):

Xenoblastic grains forming (a) veins: grains to 0.2mm dia. forming contorted veins less than 0.5mm thick and (b) matrix: grains to 0.01 mm dia. and a few circular areas up to 0.1mm dia. which are probably recrystallized radiolaria.

2. Muscovite (15%):

Very fine flakes less than 0.01 mm long with a preferred orientation which defines bedding

3. Chlorite (5%):

Very fine flakes less than 0.01mm long with a preferred orientation which defines bedding.

4. Calcite (2%):

Xenoblastic grains to 0.5mm dia. scattered throughout the rock.

5. Opaque Minerals (3%):

Very fine dusting throughout the rock.

Specimen S-05:

Nonbedded, dark grey phyllite

A thin section examination shows:

1. Muscovite (50%):

Fine (less than 0.01mm long) flakes with a preferred orientation which defines the foliation of the rock.

2. Chlorite (5%):

Colourless, fine (less than 0.01mm long) flakes with a preferred orientation that defines the foliation of the rock.

3. Opaque Minerals (11%):

(a) Sulphides(?) (1%): Anhedral grains up to 0.2mm dia. in quartz-rich areas.

(b) Carbonaceous Material (10%): Dusting throughout the rock which imposes a dark grey colour to hand specimen and thin section.

4. Quartz (34%):

Very fine grains (less than 0.01mm) present as small lenses up to 3mm long and circular quartz-rich areas which may represent completely recrystallized radiolaria.

Specimen S-43:

Light grey weathering, medium grey fresh, massive marble cut by an anastomosing network of thin (less than 1mm thick), white calcite veinlets.

A thin section examination shows:

1. Calcite (100%):

(a) very fine-grained, xenoblastic grains (less than 0.01mm dia) representing the micrite component of the rock.

(b) recrystallized oolites or microfossils represented by circular areas about 0.2mm in diameter.

(c) veins composed of xenoblastic grains up to 1mm dia. which are extensively twinned.

(b) Metavolcanic Rocks:

Specimen S-24:

Light to medium green porphyritic, with augite phenocrysts up to 5mm long (15%) greenstone cut by thin (1mm) calcite veins.

A thin section examination shows:

1. Chlorite (50%):

Pale green chlorite with berline blue interference tints which forms pseudomorphs of euhedral pyroxenes.

2. Calcite (25%):

Untwinned, xenoblastic grains to 0.2mm partly forming the pyroxene pseudomorphs.

3. Talc (25%):

Colourless flakes to 0.1mm long forming some of the pyroxene pseudomorphs.

Matrix (65% of the rock):

Appears to be a very fine-grained mixture of chlorite, oxychlorite, carbonate, talc, and sphene.

Specimen P-77-41 20-27':

Medium-green chlorite-rich, foliated greenstone cut by white veinlets (less than 2mm wide) of calcite.

A thin section examination shows:

1. Calcite (52%):

Untwinned, xenoblastic grains of a rhombohedral carbonate

2. Plagioclase (5%):

Xenoblastic, fine (0.1mm dia.) twinned grains of composition An_0.

3. Quartz (3%):

Xenoblastic grains about 0.1mm dia. which are uniaxial positive.

4. Chlorite (35%):

Colourless flakes with a birefringence less than 0.008 suggestive of a magnesian-rich chlorite. The buff colour of the thin section is caused by weathering of the rock to produce an oxychlorite of golden-brown colour and slightly increased birefringence. The preferred orientation of the chlorite defines the foliation of the rock.

Alteration of the rock consists of extensive development of carbonate in the rock which has obliterated most of the original textures of the rock.

(c) Hypabyssal, basic intrusions:

Specimen S-06:

Dark green microporphyritic (1mm) plagioclase and a mafic mineral, massive greenstone.

A thin section examination shows:

1. Plagioclase (42%):

Fine, interlocking grains to 1.0 mm dia. which exhibit a relict igneous texture. Composition An_6 or less.

2. Augite (30%):

Relict igneous grains which are unaltered and retain a subophitic texture of grains 0.2 to 1.0mm dia.

3. Chlorite (20%):

Mainly colourless, fine-grained felted masses present as vein-filling and as an alteration product within plagioclase.

4. Pumpellyite (3%):

Mixed length-fast and length-slow fibers to 0.3mm long in colourless radiating sheaves. The mineral is probably an Fe^{+3}-poor variety.

5. "Leucoxene" (5%):

Forms cloudy white clots up to 1.0mm dia.

Specimen S-41:

Medium to dark green porphyritic (1 - 2mm) mafic minerals and plagioclase, massive greenstone.

A thin section examination shows:

1. Augite (30%):

Relict igneous grains 0.5 to 1.0mm long which has a subophitic relationship with plagioclase.

2. Plagioclase (70%):

Subhedral, interlocking laths up to 1.5mm long which are clouded with alteration products. Composition An_6 or less.

Veins (approximately 2% of rock):

1. Albite (95%):

Clear, xenoblastic grains to 0.2mm dia. of composition An_7 or less.

2. Chlorite (5%):

Felted clots to 1mm dia. within veins and throughout rock.

Specimen S-42:

Medium grey-green porphyritic (pyroxene) (10%), massive greenstone.

A thin section examination shows:

Phenocrysts comprise 25% of the rock.

1. Augite (15%):

Euhedral phenocrysts up to 1.0mm long.

2. Plagioclase (10%):

Euhedral phenocrysts up to 1.5mm long, dusted with alteration products (chlorite, sericite, calcite) so highly that a composition cannot be determined.

Matrix constitutes about 75% of the rock and consists of very fine-grained laths of plagioclase up to 0.1mm long, euhedral augite and a mixture of chlorite, sericite, calcite and opaque minerals.

Vein (2% of thin section):

3. Calcite (85%):

Elongate grains up to 0.6mm long with length oriented perpendicular to length of vein.

4. Chlorite (15%):

A sporadic layer 0 to 0.6mm wide along edge of the vein. Flakes within the felted layer are oriented across the width of the vein.

The mineralogy of this rock corresponds to that of specimens S-06 and S-41, but the texture is porphyritic with a very fine-grained matrix which is more typical of a flow than a hypabyssal intrusion.

COLDWATER BEDS

In the vicinity of Upper Hat Creek, the basal Tertiary section consists of 1350 m of indurated, brown sandstones and conglomerates (Church, 1977). Specimen DDH500-230' is typical of the Coldwater Beds, but Specimen DDH500-154' is extremely well indurated and may belong to a sedimentary lense in the Spences Bridge Group.

Specimen DDH500-230':

Poorly lithified, crumbly, medium buff-brown pebbly mudstone.

A thin section examination shows:

Framework (approximately 40% of the rock):

1. Quartz (30% of framework):

   Angluar grains up to 0.5mm dia. (largers grains have been preferentially plucked out during thin section production).

2. Metachert (60% of framework):

   Rounded fragments up to 0.5mm dia. probably derived from the nearby Cache Creek Group which has metachert as a common component.

3. Plagioclase (10% of framework):

   Untwinned angular grains up to 0.5mm dia.

Matrix (approximately 60% of rock):

Low birefringent material (0.005 to 0.015) of slightly negative to moderate positive relief. Although these minerals are not identified with certainty, they are probably clay minerals

Vein-filling:

Vein-filling:

Calcite and dolomite form a brownish weather vein-filling which replaces pre-existing matrix and to a minor extent some of the framework. The replacement affects areas up to 10mm in width.

Specimen DDH500-154':

A well-lithified, sedimentary breccia consisting of angular clasts of medium to dark grey siliceous phyllite (30%), medium buff-green greenstone (65%), and quartz (5%). The fragments are subangular and range in size from 2mm to 30 mm with an average of 15mm.

A thin section examination shows:

Framework (clasts):

1. Quartz:

Strained (exhibits undulatory extinction), fractured quartz grains 0.5 to 2.5mm dia. forming angular, polycrystalline clasts.

2. Siliceous phyllite:

Subrounded fragments composed of very fine-grained quartz, muscovite, and chlorite. The micas show a preferred orientation.

3. Greenstone:

Present as subhedral grains 0.2 to 1.0mm long which are sericitized. Composition An_2. Some of the fragments have very fine-grained euhedral microphenocrysts which could indicate these fragments are metavolcanic clasts whereas those without the microphenocrysts and fine-grained matrix may be clasts from hypabyssal intrusions.

Fracture-filling:

4. Calcite and dolomite:

Interlayered clear and golden brown grains with long-axis oriented across the vein. The texture indicates open-space filling.

Fragments of siliceous phyllite and greenstone are probably derived from nearby exposures of the Cache Creek Group. Fragments of strained quartz were derived from a terrain of rocks in which the quartz was strained prior to the development of the clasts. The absence of deformed clasts in the hand specimen indicates the clasts were deformed and metamorphosed prior to their deposition as clasts. After deposition, clasts and matrix were fractured and carbonates were deposited in the open-space fillings. The carbonates are unstrained.

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APPENDIX IV

Construction Materials

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CONSTRUCTION MATERIALS

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CONSTRUCTION MATERIALS

IV.1 GENERAL

The following construction materials are required for the project:

1) Impervious fill
2) Sand and Gravel materials for embankment filter and drain zones
3) Rock for embankment riprap zones
4) Concrete aggregate
5) General road and grading fill

The occurrence and availability of each material is discussed below.

IV.2 IMPERVIOUS FILL

The approximate quantities of this material required for the select impervious and random impervious zones of the dams are:

	Volume - $m^3 \times 10^6$
Water supply dam	1.23
Water supply saddle dam	0.11
Ash retention dam - Stage 1	4.05
Ash retention dam - Stage 2	1.43
Ash retention dam - Stage 3	0.81
TOTAL	7.80

Impervious fill can be obtained from deposits of clayey lodgement till. Three major deposits have been identified in the project area.

- Upper Medicine Creek - area A
- Harry Lake meadows - area B
- Hat Creek valley (area of proposed No 1 pit)

IV.2.1 Medicine Creek - Areas A_1 & A_2

Two borrow areas have been defined on either side of the ash retention damsite No 3.

As shown on Plate A22, the borrow areas comprise about 78 ha on the lower slopes of the north side of Medicine Creek both upstream and downstream of the ash retention dam. It is inferred from the available drillholes and test pits shown on the plan on Plate A22, and the seismic data and observance of rock outcrops in the area, that these two areas together contain about 10.8 million cubic metres (2.5 in A_1 and 8.3 in A_2) of clayey till material above the level of the stream bed. Additional material could be recovered by excavating below the present stream bed on its north side. We estimate that stripping to 0.3 m depth, (236,000 m^3) will be sufficient to remove the organic materials from the surface. The subsequent 1 to 2 m of material may consist of more sandy weathered till and slopewash more suitable for the random impervious zones of the dams than the select impervious core. Relatively minor amounts of sand and gravel will come from surficial ridges in area A_1. The centre of each area is about 1 km from the centre of the ash retention dam. Area A_1 is 2.2 km from the water supply dam and 3.2 km from the water supply saddle dam. Typical physical properties of the materials in these two borrow areas are shown on Plate A22.

When developing the borrow areas, the upstream area, A_1, will be first. The pit limits should be confined to a safe distance from the ash retention dam, and a blanket of till should be left in place over the bedrock surface as a seepage barrier.

IV.2.2 Harry Lake Meadows - Area B

The borrow area covers approximately 53 ha. The borrow material consists mainly of dense sandy and gravelly clay till (lodgement till).

Investigations in this area were limited to 12 backhoe test pits with a maximum depth of 4.8 m, but examination of stream bank exposures suggests that the depth to bedrock beneath the till may be about 9 m.

Assuming an average thickness of 6 m, 3.25 million cubic metres of till are available from the area after stripping about 0.3 m of surface organic materials (160,000 m^3).

The centre of the borrow area is 4.8 km from the centre of the ash retention dam, 3.1 km from the water supply dam and 2.6 km from the water supply saddle dam.

Typical grain size curves and physical properties are shown on Plate A22.

IV.2.3 Hat Creek Valley (Area of Proposed No 1 Pit)

Impervious fill of similar quality to that from areas described above can be obtained from the stripping of the No 1 open pit. This area was not investigated directly by Klohn Leonoff Consultants Ltd. Golder Associates Ltd, Report No 6 indicates that large quantities of low permeability till will be stripped from the No 1 pit area on the west side of the valley.

Borrow material from the Hat Creek Valley is economically competetive if the incremental cost of hauling to the sites from the proposed disposal areas compares favourably with the cost of borrowing from nearby pits.

Consideration of the use of impervious fill from Hat Creek also requires that production of pit stripping materials coincide in time and quantity with the fill requirements in the dams. B.C. Hydro will give consideration to the use of impervious fill from the Hat Creek valley if the conditions indicated above are satisfied.

IV.3 GRANULAR FILL

Deposits of natural clean sand and gravel are scarce within short haul distance of the project area. The following possible sources of sand and gravel were defined and investigated by Klohn Leonoff Consultants Ltd. See key plan on Plate A21.

- Morainal ridges and glaciofluvial deposits in Upper Hat Creek and Ambusten Creek - Area C
- Morainal ridges and recent fans in Upper Medicine Creek - Area D
- Glaciofluvial terraces in Middle Hat Creek (area of the proposed No 1 pit) - Area E

The approximate quantities of clean sand and gravel fill required for construction of filters and drains and pervious zones in the dams are:

		volume $m^3 \times 10^3$
Water supply dam		346.1
Water supply saddle dam		7.7
Ash retention dam - Stage 1		172.4
Ash retention dam - Stage 2		46.4
Ash retention dam - Stage 3		22.8
	TOTAL	595.4

IV.3.1 Upper Hat Creek & Ambusten Creek - Area C

The valleys of Upper Hat Creek and Ambusten Creek are characterized by glacial and glaciofluvial deposits that include cross-valley morainal ridges, eskers, kames and outwash plains.

Numerous cross-valley morainal ridges in Upper Hat Creek valley are believed to have been formed by periodic readvances of a melting ice front during the last deglaciation [Alysworth, (1975), Ryder, (1976)]. Retreat of the ice was from south to north. Eskers and kames formed by subglacial and periglacial flow of meltwater are associated with these moraines.

Meltwater from the retreating ice front is believed to have flowed southeastward along Upper Hat Creek and Ambusten Creek, and on into Oregon Jack Creek. Oregon Jack Creek is believed to have been the principal glacial spillway of this area into the Thompson-Fraser Rivers system. Outwash deposits occur in the valley of Ambusten Creek and between it and Oregon Jack Creek.

The morainal ridges, eskers and outwash deposits were investigated with backhoe test pits 126 to 136, as possible sources of sand and gravel. In general, the morainal ridges contain clay rich soil which does not meet the required gradation limits. The outwash deposits are predominantely fine grained silty sand, not suitable for use as free draining material. Soils in esker ridges have a high content of fines which makes them unsuitable for use as free draining materials unless they are washed. Suitable material was located in an alluvial fan in Ambusten Creek. Three test pits in the area, TP's 134, 135 and 136 encountered sand and gravel over 4 m deep. This Ambusten Creek fan could probably yield 0.5 million m^3 of relatively clean sand and gravel.

These deposits are only considered as reserve, to be used in case other sources of cleaner materials turn out to be insufficient. The centre of these deposits is 6 km from the centre of damsite No 3 on a straight line. The estimated haul distance is 9 km by road.

IV.3.2 Upper Medicine Creek - Area D

Several cross-valley morainal ridges in Upper Medicine Creek were investigated with backhoe test pits as possible sources of sand and gravel. The ridges are believed to have been formed by similar processes to those of Upper Hat Creek, at the time the front of the last valley glacier was retreating westward towards the Hat Creek Valley. Soils in these ridges were found to have an unacceptably high content of fines for use as free draining material.

A deposit of clean sand and gravel was found in the Medicine creek Valley upstream of dam axis No 4, (Plate A24). This deposit is believed to be a recent alluvial fan formed by erosion of the Coldwater conglomerate and overlying till deposits after the final retreat of the ice. The deposit is covered by 1 to 2 metres of silt and clayey silt.

The total extent of this deposit is not known since the investigation was limited to six backhoe test pits about 4½ m deep. Two of these pits also encountered groundwater perched in the gravels at about 4 m depth, which may make some of the material uneconomical to recover.

The quantity of sand and gravel is estimated to be 0.4 million m^3 from above the water table. The maximum depth of dry excavation is estimated to be 4.3 m. The average depth of stripping required to expose the sand and gravel will be about 1.5 m^3. Most of this material could be used as random impervious fill in the dams. Before this area can be considered as the main source for all the sand and gravel required for the three dams, additional exploration work will be needed to confirm a larger quantity of material.

The centre of the borrow area is about 1.6 km from the ash retention dam, 2.1 km from the water supply damsite, and 3.0 km from the water supply saddle dam.

Typical grain size curves of the pit materials are shown on Plate A24.

IV.3.3 Hat Creek Valley - Area E

The valley of Hat Creek, in the area of the proposed No 1 pit, is flanked by dissected outwash terraces formed after the final retreat of the Fraser ice. The soils consist of stratified layers of fine uniform silty sand alternating with beds of clean, well-graded sand and gravel. Although the sequence is dominated by the finer-grained soils, some of the coarse sand and gravel layers are of substantially large size and constitute good potential sources of clean free-draining material.

In 1976 nine percussion drillholes were put down in the general area (see Golder Associates Report No 6). An additional 2 percussion holes were drilled in 1977 together with 1 backhoe test pit, as part of the Hat Creek diversion canal investigation. Three backhoe test pits were also excavated as part of the present study. These test locations and representative grain size data are shown on Plate A25. We have not attempted to estimate the quantity of sand and gravel in this area. A report by Dr. P.T. McCullough of B.C. Hydro indicates that 645 million tonnes of sand and gravel are available in this terrace. Development of this pit will be complicated by the fact that it lies within the projected area of the coal pit No 1, and also straddles the proposed alignment for the Hat Creek diversion canal. Stockpiling, and a relocation of the diversion canal further east toward the base of the adjacent hillside, may be required in order to make full use of the aggregate source.

IV.3.4 Lower Medicine Creek Fan - Area F

The terrain inventory map by Ryder (1976) indicates an alluvial fan on the south side of Medicine Creek. See Plate A21. No drilling or test pit work was carried out in this area, but a surficial inspection of the area indicated that granular materials are confined to localized shallow surface deposits overlying low permeability till-like soil. This area is therefore not considered to be a source of any significant amount of granular material.

IV.4 ROCK

Limestone of the Cache Creek group is considered to be the only source of rock of acceptable quality for rockfill and riprap within economic distance from the dams.

Some sections of altered volcanic rocks of the Cache Creek group may also be of acceptable quality but these rocks are generally intermixed with phyllitic and slaty members which are not acceptable and would require excessive wasting of quarried rock.

Coldwater conglomerates, although generally massive, are considered to be more vulnerable to rapid degradation by physical and chemical weathering than the limestone, and are not recommended fur use as a source of construction rock.

A large outcrop of limestone exists north of ash retention damsite No 3. See Plate A21. An estimated gross volume of 50,000 m^3 can be obtained from here, with no stripping of soil or weathered rock required since fresh rock is exposed at the surface.

The required riprap sizes can be obtained by controlled blasting and selection at the source.

The proposed quarry site is located 0.7 km from the ash retention damsite and 1.5 km from the water supply damsite.

Limestone has been found under the till by one drillhole in the right abutment of the water supply dam. The quality and extent of this limestone is not known. Exploratory drilling would be required to determine whether this rock may or may not be used as a source of rockfill.

IV.5 CONCRETE AGGREGATE

Concrete aggregate can be obtained from:

a) natural deposits of sand and gravel
b) crushed and screened limestone

Sources of these materials have been described in previous sections. Local sand and gravel as well as limestone are inert aggregates, and no special additives or precautions are required for normal concrete manufacturing.

IV.6 GENERAL ROAD AND GRADING FILL

Potential sources of material for road and grading fill are:

- stripping of dam foundations and impervious fill borrow area
- stripping of sand and gravel borrow areas
- esker and morainal ridges in Upper Hat Creek

All these sources have been described in previous sections.

APPENDIX V

Seismic Refraction Survey

SEISMIC REFRACTION
STUDY
of
ASH DAM LOCATIONS
HAT CREEK COAL PROJECT
CACHE CREEK AREA, B.C.

October, 1977

for

KLOHN LEONOFF CONSULTANTS LTD.,

VANCOUVER, B.C.

and

B.C. HYDRO & POWER AUTHORITY

ENGINEERING GROUP

VANCOUVER, B.C.

by

GEOTRONICS SURVEYS LTD.,

#420-890 West Pender Street
Vancouver, B.C.

TABLE OF CONTENTS

MAP & PROFILES

INTRODUCTION

This report discusses the results of a seismic refraction programme carried out for Klohn Leonoff Consultants Ltd., who are geotechnical consultants to B.C. Hydro & Power Authority, Engineering Group. The project site was the potential ash reservoir on Medicine Creek of the Hat Creek Coal Project, near Cache Creek, British Columbia.

The field work was carried out from October 13th to 18th, 1977. The scope of the survey consisted of three lines totalling 1.46 kilometers, or 4,800 feet.

Authorization for the study was received from Scott Dunbar, Ph.D,, of Klohn Leonoff Consultants Ltd.

The seismic survey was carried out along ash dam axis 3, ash dam axis 4, and the saddle (see sheet 1). The object of the survey was to obtain information of the bedrock and overburden, including the depth of overburden to the bedrock.

The geophysical information presented in this report is based upon our best interpretation of the field data which were collected according to generally accepted field procedures.

These results are interpretive in nature and are considered to be a reasonably accurate presentation of the existing conditions within the limits of the method employed.

SUMMARY

The seismic depth profiles are shown on Sheets 2 through to 4.

Basically, a three-layer case was encountered on all profiles.

The overburden velocities vary from 250 to 300 meters/second for unconsolidated surface material, and from 1,600 to 2,040 meters/second for water saturated more consolidated material, probably glacial till.

The bedrock velocities were found to vary from 3,350 meters/second to 5,080 meters/second. In correlating with the drill hole information and in the writer's experience, this range of velocities is typical of that of volcanic rocks. Also, the lower end of this velocity range is typical of sedimentary rocks.

The depth to bedrock varies from about 1 meter to 48 meters on axis 3; from 11 meters to 47 meters on axis 4; and from 9 meters to 41 meters on the saddle.

On axes 3 and 4, drill holes encountered a boulder train which may have formed a false seismic-interpretted bedrock surface over part of the profile.

VELOCITY CLASSIFICATION

The following is a suggested velocity classification for the area as determined only from the immediate survey results and the correlating drill hole information.

VELOCITY (meters/second)	SUGGESTED CLASSIFICATION
250 to 300	Loose unconsolidated surface material (1 - 3 meters depth)
1,600 to 2,040	Water-saturated, compact glacial till
3,350 to 5,080*	sandstone and various volcanic-type rocks, possibly boulder trains

*5,080 meters/second could well be the velocity of an intrusive.

PERSONNEL

The field work was carried out with a crew of three men. These were the writer, geophysicist and supervisor, R.R. Fassler, geophysical technician and D.L. Roberts, helper.

LOCATION AND ACCESS

The center of the Hat Creek Coal Project site is about 20 air kilometers S80W (260°) of the town of Cache Creek, B.C. The ash reservoir site on Medicine Creek (a tributary of Hat Creek) on which the seismic survey was done, is about 13.7 air kilometers S70W (250°) of Cache Creek.

The access was excellent since each seismic profile was crossed in two or three places by a logging access road.

AVAILABLE INFORMATION

Though the complete logs of the diamond and percussion-drilled holes along each profile were not available, the depth of the hole, or the depth to the bedrock was. The type of bedrock encountered was also available.

GEOLOGY

The geology is taken from the Geological Survey of Canada's geological map of the area ("Ashcroft", Map 1010A).

Most, and perhaps all, of the survey area appears to be underlain by the Cache Creek Group of Permian and (?) Earlier Age. It is composed of greenstone; chert, argillite, minor limestone and quartzite; chlorite and quartz-mica schist.

Limestone of the Marble Canyon Formation, and about the same age, occurs in the lower part of Medicine Creek, probably just west of axis 3.

To the immediate north of the saddle profile are the Coldwater Beds of the Kamloops Group which are composed of sandstone, shale, conglomerate, and coal. These are of Miocene or Earlier Age.

In the same area, however, the writer noticed outcroppings of breccia. These may belong to the volcanic member of the Kamloops Group.

FIELD PROCEDURE AND EQUIPMENT

This investigation was carried out using an SIE 12-channel refraction/reflection seismograph amplifier system with a photo-recording oscillograph and 8-cycle per second geophones.

The 'two-way, in-line shot' seismic refraction method was used for all traverses. The technique consisted of laying out 12 geophones in a straight line and recording arrival times from shots fired at either end of the spread. The arrival times from an additional shot point approximately half-way of the spread were also recorded. This provided the overburden depth and velocity variations along the spread. Finally, for each spread, two additional off-end shots were fired. Since the off-end shots were fired fairly far from the nearest geophone (about one half the spread length), most or all of the first arrivals were from the bedrock interface. This was felt necessary so that one could correlate the refractions received from other shot points and assign them the correct layer number.

Three spreads of length 168 meters (550 feet) each and a geophone separation of 15.2 meters (50 feet) were used on axis 3. Two spreads of 335 meters (1,100 feet) each and a geophone separation of 30.5 meters (100 feet) were used on axis 4. The seismic profile on the saddle was carried out with one 335 meter spread. (geophone separation 30.5 meters).

In addition to the above, axis 4 was resurveyed with a large spread of length 838 meters (2,750 feet), and a geophone separation of 76 meters in an attempt to obtain the depth to a second bedrock layer.

The offend shots were fired at 75 to 85 meters from the nearest geophone for the 168-meter spreads, 140 to 150 meters for the 335-meter spreads, and 400 meters for the 838-meter spread.

The shots were placed in holes 0.3 to 1.0 meters deep. Depending upon the conditions, the shot size ranged from 0.3 kgs to 10 kgs.

Velocity spreads were carried out on an average of one per main spread in order to obtain more velocity information. The geophone separation for these spreads varied from 1½ meters to 3 meters on each spread, and only 2 shots were fired, one at each end.

The quality of the records was excellent. Whenever the first arrivals were lost due to cross-feed or inadequate shot size, which was minimal, the data were retaken by varying the size of the shot.

The seismic noise background was found to be unusually low, and as a result, very little explosives was found to be needed.

The elevation and horizontal location of each station on each line was provided by Dolmage Campbell & Associates Ltd. The surveying seemed to be accurate except for the north part of axis 3. Some of the stations seem to be closer together than they should be, especially stations 2 and 3, and stations 10 and 11.

COMPUTING METHOD

All seismic data were analyzed using an intercept-delay time technique. Implementation of this method requires reverse refraction profiles with bedrock refractions emanating from a common point for at least two detectors. This rock overlap is necessary in order to obtain a true refractor velocity and travel time in the overburden independent of bedrock dip and/or surface irregularities. The off-end shot times are used to extrapolate the rock refractions from either end back to their respective shot locations. With this information and related overburden velocities, it is possible to compute the depth to rock not only below each shot point but also below each detector. However, the computed depths below shot points should be considered slightly more accurate than those below detectors.

The procedure is as follows:

1. Pick the first arrivals from the field records and draw time-distance graphs for each spread;

2. With the help of a 'Russian' determine which points are bedrock and which are overburden, and how many layers occur in the overburden;

3. Draw a delay line for each end shot and from this determine the delay time for each geophone;

4. Proportion the delay time for each geophone into the various times spent in the various layers. Multiply each layer time by the corresponding layer velocity to obtain the layer thickness. Adding the layer thickness together will give the total overburden depth.

RESULTS AND INTERPRETATION

The location of the seismic lines are shown on sheet 1 at a scale of 1:10,000 or 1 cm = 100 meters. The seismic profiles are drawn on sheets 2 to 4 at a scale of 1:10,000 or 1 cm = 10 meters, showing the drill holes as well.

The data along all profiles has been interpreted as a three-layer case. The three layers are felt to be dry, unconsolidated surface material; water-saturated glacial till and bedrock.

The dry, unconsolidated surface material is probably glacial till as well, and the velocity boundary between this layer and the next layer may simply be a reflection of the water table.

Generally, the degree of error in the depth calculations can be considered to be 10 to 15% with the shot points having the greater accuracy than the stations between the shot points.

AXIS 3

The top layer, unconsolidated surface material, has a velocity of 250 meters/second, and ranges in thickness from a fraction of a meter in the creek area to 2.5 meters on the valley sides.

The second layer, water-saturated (assumed) glacial till, varies in velocity from 1,800 to 2,000 meters/second. Its thickness varies from zero or close to zero meters to 46 meters below stations 17 and 18.

The bedrock velocities vary from 3,810 to 5,080 meters/second. This is a typical range for volcanic-type rocks and is verified by drill holes P77-40 and P77-41 which encountered an altered volcanic. However, the velocity of 5,080 meters/second which is found from stations 1 to 4 and is somewhat high for a volcanic, represents either a hard, unaltered type of volcanic rock or, possibly, an intrusive.

As can be seen on the profile on sheet No. 2, the depth to bedrock is much greater on the north side of the creek than it is on the south side. On the south side, the depth varies from zero meters just north of Station 26, where the writer noticed an outcropping of altered volcanic, to 13 meters below Station 33. On the north side the depth varies from 22 meters below Station 4 to 48 meters below Station 18.

The seismic-interpretted depths to bedrock agree fairly closely with drill holes P77-40 and P77-41. Drill hole P77-38, drilled to a depth of 20 meters, did not encounter bedrock, and, in fact, the seismic interpretation shows the depth to bedrock to be about 30 meters.

Drill Hole P77-39, drilled to a depth of 58.5 meters, apparently did not encounter bedrock either, but did encounter boulders at a depth of 46.9 meters. The seismic interpretation shows the bedrock depth at this drill hole to be 45 meters. Therefore, either the boulders are actually the bedrock surface, or they have created some type of false bedrock surface, If the latter is the case, then it could well be that the velocity interface between layers 2 and 3 from stations 5 to 23 actually reflects a boulder train.

The bedrock surface between stations 25 and 26 is somewhat difficult to interpret because of its apparent cliff type of feature. The writer feels the one drawn should be a close approximation.

AXIS 4

Here, the surface material has a somewhat higher velocity of 300 meters/second than that of axis 3. Its thickness varies from about 1 to 2.5 meters.

The second overburden layer, water-saturated glacial till, varies in velocity from 1,600 meters/second on the south side of the profile, to 2,040 meters/second on the north side. The variance in velocity is probably simply a reflection of the density of the material.

The bedrock velocity varies from 3,370 meters/second on the south side to 3,750 meters/second on the north side. Drill Hole P77-48 on the south side apparently encountered sandstone for which a velocity of 3,370 meters/second is not unusual. However, this velocity, as well as that of 3,750 meters/second, is quite typical of volcanics.

The depth to bedrock is greatest in the valley, especially below stations 11 and 12 where it is about 47 meters.

Like axis 3, the bedrock depth is greater on the north side than it is on the south side. On the north side, it varies from 19 meters below stations 1 and 3 to 28 meters below station 7. On the south side, it varies only about one meter from an average of 12 meters.

Drill Hole P77-47 was drilled to a depth of 44.2 meters and apparently encountered bedrock at a depth of 40.8 meters. However, the seismic interpretation indicates bedrock at a depth of 27 meters. According to Adrian Whiteman, P.Eng., of Klohn Leonoff, the drill encountered a boulder train at about the 32-meter depth. Therefore, as in axis 3, the layer 2/layer 3 interface may be reflecting a boulder train below the valley floor.

The depths to bedrock in Drill Holes P77-46 and P77-48 agree closely with the seismic interpretation.

On this profile, a much larger spread with a length of 838 meters was used in an attempt to obtain depths to a bedrock layer that may occur below the top bedrock layer. The second bedrock layer would have to have a higher velocity in order to be detected. However, not even the off-end shots encountered any bedrock layer with a higher velocity than that of the top bedrock layer. Theoretically, the off-end shots were 'looking' to a depth of 300 to 400 meters. Therefore, either the 2nd bedrock layer has a velocity similar to or less than that of the first bedrock layer (or the boulder train), or, the second layer is at a depth greater than 300 to 400 meters.

SADDLE

On this profile, the surface layer has a velocity of 300 meters/second and a thickness of about one meter. The second overburden layer has a velocity of 1,950 meters/second.

The third layer, which is bedrock, has a velocity of 3,350 meters/second. Drill hole DDH.77-500 shows this bedrock to be a volcanic breccia.

The depth to bedrock varies from nine meters below Station 17 to 41 meters below Station 5. The drill hole encountered bedrock at a depth of 21.6 meters which is similar to the seismic-interpretted depth. Again, the bedrock depth is greater on the north side than it is on the south side.

Respectfully submitted,
GEOTRONICS SURVEYS LTD.,

David G. Mark
Geophysicist

December 17, 1977

LEGEND

CREEK

ROAD

SEISMIC LINE SHOWING STATIONS AT EACH END

Note: Grid is in Imperial units, not metric.

SCALE

Meters 200 100 0 200 400 600 Meters

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KLOHN LEONOFF CONSULTANTS LTD.

B.C. HYDRO & POWER AUTHORITY

ASH DAM STUDY

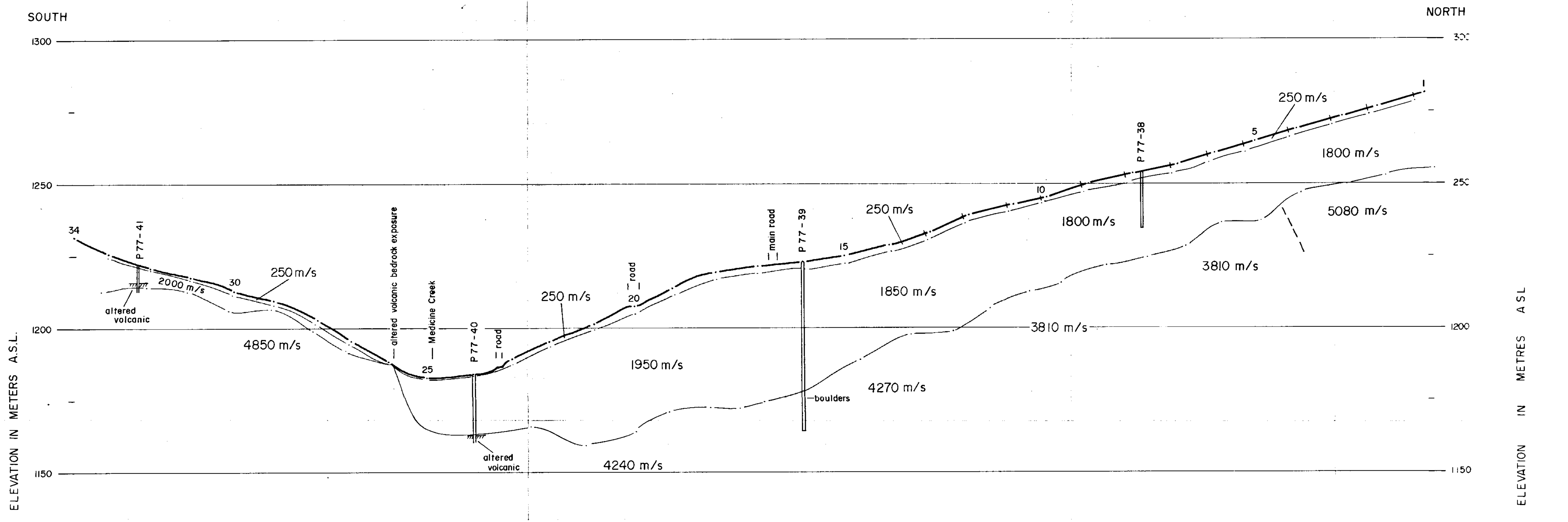
HAT CREEK COAL PROJECT

CACHE CREEK AREA, B.C.

SEISMIC REFRACTION STUDY PLAN

DRAWN BY:	SCALE:	DATE:	JOB No:	SHEET No.
D.G.M.	1 : 10,000	NOV., 1977	77 - 39	1

altair drafting



LEGEND

Station with cross showing Geophone Location if located away from station

Computed depth point on inferred layer boundary.

2040 m/s — Average velocity in meters per second

Drill hole showing bedrock (if encountered.)

NOTE The elevations above sea level as shown are estimated only.

SCALE

Meters 0 20 40 60 Meters

Direction of line – N 20° W (340°)

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HAT CREEK COAL PROJECT
CACHE CREEK AREA, B.C.

SEISMIC REFRACTION STUDY AXIS 3 PROFILE

DRAWN BY	SCALE	DATE	JOB No.	SHEET No.
D.G.M.	1:1000	NOV., 1977	77-39	2

altair drafting

LEGEND

5 — Station with cross showing Geophone Location if located away from station.

Computed depth point on inferred layer boundary.

2040 m/s — Average velocity in meters per second.

Drill hole showing bedrock. (if encountered.)

NOTE : The elevations above sea level as shown are estimated only.

SCALE

Meters 20 10 0 20 40 60 Meters

Direction of line – N 20° W (340°)

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SEISMIC REFRACTION STUDY
AXIS 4 PROFILE

DRAWN BY:	SCALE:	DATE:	JOB No:	SHEET No.
D.G.M.	1 : 1000	NOV., 1977	77 - 39	3

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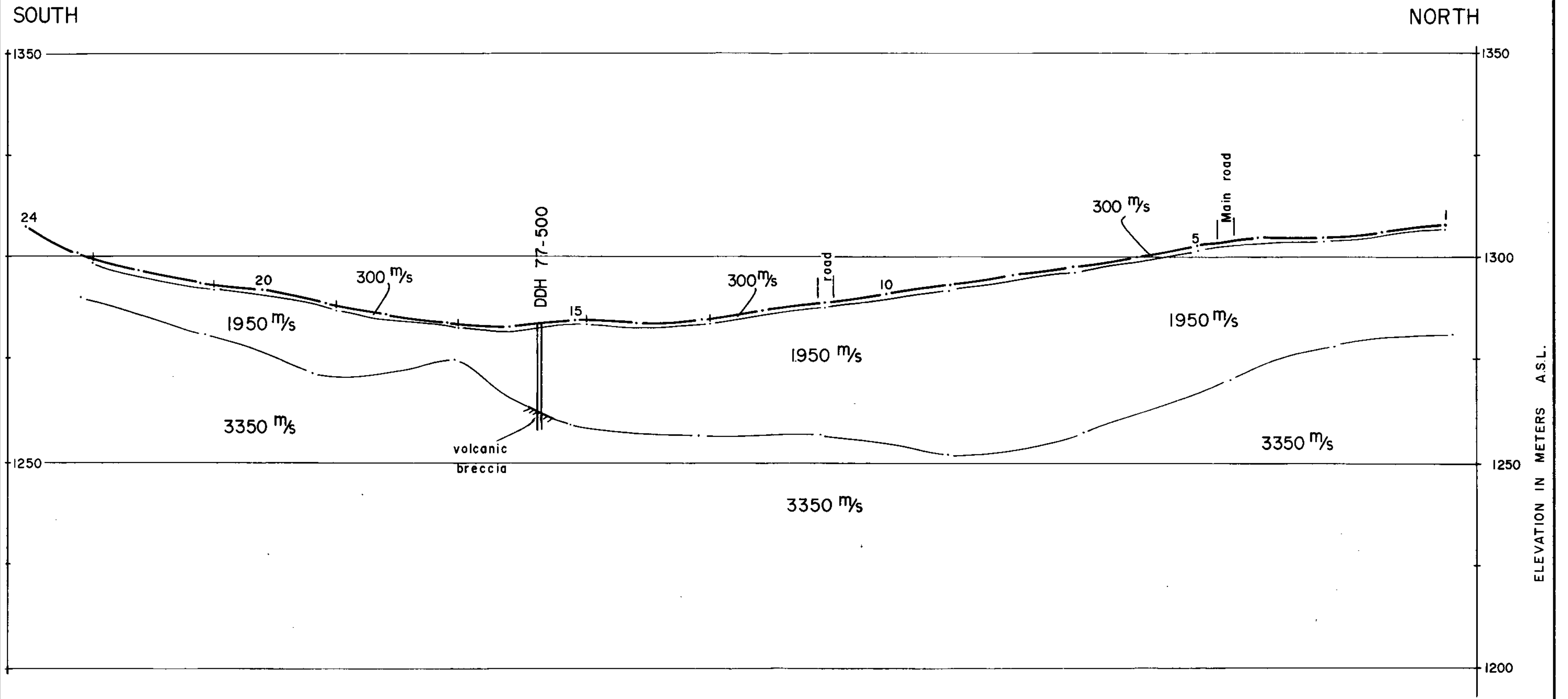

LEGEND

Station with cross showing Geophone Location if located away from station.

Computed depth point on inferred layer boundary.

2040 m/s — Average velocity in meters per second.

Drill hole showing bedrock. (if encountered.)

NOTE: The elevations above sea level as shown are estimated only.

SCALE

Meters 20 10 0 20 40 60 Meters

Direction of line — True South

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ASH DAM STUDY
HAT CREEK COAL PROJECT
CACHE CREEK AREA, B.C.

SEISMIC REFRACTION STUDY
SADDLE PROFILE

DRAWN BY:	SCALE:	DATE:	JOB No:	SHEET No.
D.G.M.	1 : 1000	NOV., 1977	77 - 39	4

altair drafting

APPENDIX VI

Summary of In Situ Permeability Tests

INSITU PERMEABILITY TESTS

Falling head permeability tests were performed through the Becker drill casing. The casing was flushed out with air and then retracted about 60 cm. After filling the casing with water the drop in water level in the casing was timed for a period of about 20 to 30 minutes. These tests were performed at various levels in the overburden and the bedrock. These data were evaluated using methods described by Zangar (1953).

Packer tests were carried out in the bedrock in some of the drill holes. The tests were carried out using a single packer assembly, generally at one test pressure of 25 to 30 p.s.i. These data were then extrapolated to obtain an approximate Lugeon number.

After completion of the drilling program, falling head tests were performed in the standpipe piezometers. The piezometers consist of a 1.5 m length of 1.5 inch PVC schedule 40 pipe with 2 rows of 0.02 in. slots, attached to a line of 3/4 inch PVC riser pipe. The tests were conducted by noting the initial water level in the standpipe, filling the pipe with water, and timing the water level as it fell to its original elevation. These tests were evaluated using methods of the U.S. Navy, Bureau of Yards and Docks, as quoted in Cedergren (1967).

The results of these insitu permeability tests are presented on Table VI-I.

TABLE VI-I

INSITU PERMEABILITY TEST RESULTS

Drill Hole No.	Datum Elev.	Piezo Tip Depth -m-	Depth to Water Level -m-	Test Interval -m-	Rock/Soil[1] Type	Test[2] Type	Permeability[3] cm/sec
P77-31	1352.7	-	-	8.53-11.58	Cgte	P	1.3×10^{-5} (1.8)
P77-31	1352.7	-	-	6.09-11.58	Cgte	FHDH	2.2×10^{-5}
P77-32	1336.5	-	-	12.19-12.80	Cte?	FHDH	1.5×10^{-5}
P77-32	1336.5	13.12	5.44	11.60-14.33	Wx/cgte	FHSP	1.8×10^{-4}
P77-33	1341.1	-	-	5.48-6.09	Wx/cgte	FHDH	8.6×10^{-6}
P77-33	1341.1	-	-	8.84-9.45	Cgte	P	1.8×10^{-4} (24)
P77-34	1362.6	5.18	3.10	3.60-6.60	Wx/Lmst	FHSP	3×10^{-5}
P77-34	1362.6	-	-	5.94-6.55	Lmst	P	6.4×10^{-5} (9.2)
P77-35	1369.3	9.45	9.00	7.30-10.36	Cgte	FHSP	1×10^{-6}
P77-35	1369.3	-	-	9.75-10.36	Cgte	P	2×10^{-5} (2.7)
P77-36	1362.0	-	-	7.92	Shale	FHDH	5.5×10^{-4}
P77-36	1362.0	9.15	4.28	6.70-10.36	Shale/mdst	FHSP	5×10^{-5}
P77-36	1362.0	-	-	7.92-10.97	Shale/mdst	FHDH	4.0×10^{-5}
P77-37	1366.1	-	-	5.49-8.53	Siltst	P	3×10^{-4} (26)
P77-37	1366.1	8.23	6.30	4.87-8.53	Siltst	FHSP	1×10^{-5}
P77-38	1249.4	-	-	18.28-18.90	Till	FHDH	9×10^{-4}
P77-39	1223.2	5.49	-	4.0 - 6.7	Till	FHSP	1.4×10^{-6}
P77-39	1223.2	-	-	5.79- 6.40	Till-sy	FHDH	5.5×10^{-4}
P77-39	1223.2	-	-	11.88-12.50	Till-sy	FHDH	1.8×10^{-4}
P77-39	1223.2	-	-	32.91-33.83	Sand	FHDH	1.4×10^{-3}
P77-39	1223.2	-	-	51.51-56.08	-	FHDH	2.1×10^{-5}
P77-40	1185.5	6.10	5.0	3.0 - 7.0	Till	FHSP	2×10^{-6}
P77-40	1185.5	23.79	23.69 (dry)	18.3 -24.7	Gnstne	FHSP	4×10^{-6}
P77-40	1185.5	-	-	17.98-24.69	Till/gnstne	FHDH	3.4×10^{-5}
P77-41	1229.5	-	-	3.96-5.49	Till	FHDH	6.4×10^{-4}
P77-41	1229.5	-	-	5.63-10.66	Gnstne	FHDH	3.7×10^{-5}
P77-42	1239.6	-	-	5.18- 9.75	Gnstne	FHDH	7.6×10^{-5}
P77-42A	1249.4	-	-	2.13- 5.18	Gnstne/Wx	FHDH	1.7×10^{-4}
P77-43	-	-	-	7.01- 9.15	Basalt	P	7.4×10^{-5} (7)
P77-44	1161.6	28.43	Dry	26.97-29.0	Till	FHSP	2×10^{-6}
P77-44	1161.6	-	-	29.56-30.78	Gnstne	FHDH	4.8×10^{-4}
P77-45	1168.6	-	-	3.05- 5.49	Gnstne	P	2.1×10^{-5} (1.9)
P77-45	1168.6	-	-	1.83- 6.40	Gnstne	FHDH	2.7×10^{-5}
P77-45	1168.6	7.32	4.83	3.65- 8.38	Gnstne	FHSP	1.9×10^{-6}
P77-46	1238.1	22.27	18.5	20.5-23.16	SS/Wx	FHSP	1×10^{-5}

TABLE VI-1

INSITU PERMEABILITY TEST RESULTS - Page-2-

Drill Hole No.	Datum Elev.	Piezo Tip Depth -m-	Depth to Water Level -m-	Test Interval -m-	Rock/Soil[1] Type	Test[2] Type	Permeability[3] cm/sec
P77-47	1214.3	-	-	23.77-24.39	Till	FHDH	4.8×10^{-4}
P77-47	1214.3	-	-	35.5	Sand	RHDH	4.7×10^{-4}
P77-47	1214.3	-	-	40.8 -44.5	SS	RHDH	3.4×10^{-5}
P77-47	1214.3	35.58	5.95	32.4?-38.1	Till	FHSP	8×10^{-6}
P77-48	1234.5	-	-	4.45- 5.64	Sand/Wx?	FHDH	9×10^{-5}
P77-48	1234.5	-	-	8.22- 9.75	Sand/Wx?	FHDH	9×10^{-5}
P77-68	1290.8	-	-	18.28-18.89	Till/Wx	FHDH	5.7×10^{-4}

(1) Cgte = Conglomerate
Lmst = Limestone
Mdst = Mudstone
Gnstne = Greenstone
Wx = Weathered rock

(2) P = Packer Test
FHDH = Falling head test in drill hole
FHSP = Falling head test in standpipe piezometer

(3) Figures in brackets are Lugeon numbers

ANNEX B

WATER SUPPLY AND ASH DISPOSAL RESERVOIRS
OVERFLOW AND RUNOFF HANDLING FACILITIES

By

Hydroelectric Design Division

ANNEX B

WATER SUPPLY AND ASH DISPOSAL RESERVOIRS

OVERFLOW AND RUNOFF HANDLING FACILITIES

CONTENTS

TABLES

PLATES

SECTION B1 - WATER SUPPLY RESERVOIR - OVERFLOW FACILITIES

B1.1 GENERAL DESCRIPTION

The water supply reservoir, shown on Plate A1 of Annex A, would normally be kept at or very near its maximum normal reservoir level of El. 1372 to ensure an ample supply of water for the thermal plant. With a reservoir surface area, at El. 1372, of 61 ha and a total drainage area of only 186 ha any snowmelt or rainstorm runoff would be totally insignificant in terms of overtopping the earthfill embankments.

However, the Thompson River water supply pipeline which serves the reservoir has a maximum capacity of 1.58 m^3/s which, with no reservoir withdrawals, could raise the reservoir level at the rate of about 0.22 m/day. Therefore, overflow facilities with a discharge capability equal to the pipeline capacity would have to be provided to ensure that the reservoir's earthfill embankments would not be overtopped in the unlikely event of failure within the reservoir/pipeline control system.

Until the final month or two of studies, all work was carried out using imperial mapping at a scale of 1 inch = 400 feet (1:4800) with a contour interval of 10 feet. This mapping was subsequently replaced by metric mapping at a scale of 1:5000 with 2.5 m contours prepared by B.C. Hydro's Computer Sciences Division using digital modelling techniques.

On the basis of the earlier imperial mapping, and recognizing the possibility of alternative ash disposal arrangements, it was considered that the most suitable location for an overflow spillway structure was in the vicinity of the east saddle dam, shown on Plate B1. According to the imperial mapping, the low point in this saddle area

B1.1 GENERAL DESCRIPTION - (Cont'd)

was at El. 1375, higher than the dam crest, and an excavated spillway channel would therefore have been required. A test pit, TP 143, was dug in this area to determine the nature of the foundation materials for the channel. As shown on the log in Annex C, Volume 2, the pit indicates clay till to a depth of at least 4.6 m.

The subsequent metric mapping indicates levels throughout the water supply reservoir area to be about 3 m lower than shown on the imperial topography. Because the new mapping has been prepared with more control than the earlier topography, the metric topography has been assumed to be correct and, on this basis, two small saddle dams are required - one on either side of the reservoir. During the final design phase, however, some modification to the adopted reservoir levels may be desirable.

With the ash disposal scheme adopted for this preliminary design report, it was decided that the west saddle dam area would be a better location for the emergency overflow works because it would involve a shorter flow path down to the north runoff canal and outlet chute.

B1.2 PROPOSED FACILITIES

The proposed facilities, shown on Plates B1 and B2, comprise a low earthfill embankment at the east saddle location and a culvert through the embankment of the main project access road that closes off the west saddle.

(a) East Saddle Dam

With a crest level of El. 1374, the same as the main water supply dam embankments, the east saddle dam would have a maximum height of about 3 m and a crest length of about 45 m. The embankment would be constructed of homogeneous impervious fill placed after stripping of the topsoil. The overall fill requirements for this saddle dam, including riprap protection of the upstream slope, are very small, totalling only about 1200 m^3.

(b) West Saddle Dam and Overflow Outlet

The west saddle dam would be provided by the embankment necessary for the main access road between Ashcroft and the Hat Creek project. The currently proposed road grade in the saddle area is several metres higher than the crest level of the main embankments and, therefore, only those items directly related to the outlet works (approach channel, culvert, etc.) would have to be added.

Since the maximum normal reservoir level would be below the base of the embankment and would be rarely exceeded, no special fill materials should be necessary. Riprap slope protection, however, would be provided on the upstream face and around the culvert outlet. Although no foundation investigations were carried out in this area, it is believed that some depth of till, typical of the area generally, would also be present in the west saddle area. Seepage below the embankment level, therefore, should not be a concern.

The outlet works would comprise a short length of approach channel, a reinforced concrete culvert inlet, some 25 m of 1050 mm corrugated metal culvert, and a riprap lined discharge pool at the culvert outlet. A short length of outlet channel would then lead to the marsh at the head of the creek leading down to the north runoff canal.

B1.2 PROPOSED FACILITIES - (Cont'd)

The 2 m wide crest of the concrete inlet would be set at El. 1372.4, 0.4 m higher than the maximum normal reservoir level, to avoid wastage of the valuable Thompson River water with expected minor reservoir level fluctuation.

B1.3 COST ESTIMATE

The estimated total direct cost, at September 1977 price levels, of the east saddle dam and the overflow outlet works in the west saddle area is $20,000. No indirect costs such as contingencies, engineering, corporate overhead, or interest during construction are included.

SECTION B2 - ASH DISPOSAL RESERVOIR-RUNOFF HANDLING FACILITIES

B2.1 GENERAL REQUIREMENTS

The ash disposal scheme adopted for this project has been designed to have no discharge of effluent. Therefore, the size of the ash disposal reservoir is based on a water balance analysis that considers the amount of water deposited with the ash slurry, the amount of water evaporated from the pond and the natural inflow of water as a result of precipitation within the ultimate ash pond perimeter. On this basis, the ultimate ash pond, after 35 years of thermal plant operation, would contain about 98 million m^3 of slurry having a surface area of 408 ha at El. 1273.5. To ensure the absolute security of the embankment and ash pond and minimize the pond size, canals designed for extreme runoff are required around the entire pond perimeter to prevent inflow of runoff from the areas beyond the eventual pond limits. The overall drainage basin area above the ash dam is 4380 ha, almost 11 times the ultimate 35-year ash pond size.

During the preliminary design studies conducted for this report it was recognized that, because of areas of difficult terrain, possible icing problems during winter and because of the need to design for an extremely large runoff capacity, the costs of the canals would undoubtedly be quite significant. A brief analysis was therefore made to update earlier comparisons of alternate ash disposal schemes. It was concluded that a scheme involving disposal of ash in mid-Medicine Creek rather than in upper Medicine Creek could possibly be less costly and environmentally more acceptable. However, because the work of several consultants was already well advanced, HEDD was instructed to complete all studies on the basis of the upper Medicine Creek scheme. Re-examination of alternative ash disposal schemes would be made during subsequent ongoing studies.

B2.1 GENERAL REQUIREMENTS - (Cont'd)

General design criteria adopted for preliminary design of the runoff canals for the upper Medicine Creek ash disposal scheme in this report are as follows:

1. Since the runoff canals would have to function for perpetuity rather than just for the 35-year plant life, their design capacity would be based on the probable maximum flood (PMF) runoff.

2. Because of the high cost of the canals and uncertainties regarding the possible waste dump for mine surficials in lower Medicine Creek it was assumed that the canals could discharge into Medicine Creek immediately below the Axis 3B ash dam. Should the lower Medicine Creek area be used for a waste dump, the design of runoff handling facilities through that area would be the responsibility of the mining consultant.

The hydrologic studies completed to determine the PMF capacities for the canals are described in the report "Hat Creek Project - Diversion of Hat and Finney Creeks - Preliminary Design Report" dated March 1978, by the Hydroelectric Design Division.

B2.2 SITE DESCRIPTION

The general and detailed geology of the upper Medicine Creek area is described in Sub-section 4.2 and Appendix III, both in Annex A. Basically, the upper Medicine Creek basin is underlain by Tertiary rocks covered by glacial materials varying greatly in depth. Near the ash dam site till cover is shallow and numerous rock outcrops occur. Further upstream, however, rock outcrops are sparse.

No site investigations specifically for the canal routes were undertaken. However, some of the geological information and subsurface

B2.2 SITE DESCRIPTION - (Cont'd)

investigations carried out at ash dam Axes 3, 3A and 4 are pertinent. This information is described in Section 8 of Annex A.

Precipitation and runoff in upper Medicine Creek are generally considered to be much higher than the average of the Hat Creek basin but, unfortunately, no records within Medicine Creek currently exist. Two gauges were installed in the basin in 1977 but as yet no meaningful records have been obtained.

An irrigation diversion canal has been in operation in the upper part of the basin for many years and is licensed to divert up to 224 ha-m annually into MacLaren Creek to the east. Because of its relatively small size, however, it would have no effect on the design capacities for the runoff canals around the ash pond.

B2.3 PROPOSED FACILITIES

As shown on Plates B1 and B2, the proposed canals are located immediately above the ultimate ash pond level of El. 1273.5 and comprise a north canal 5.3 km long and a south canal about 6.3 km long, both draining west from the MacLaren Creek divide area.

To prevent ice build-up during winter months when flows would be extremely low, both canals are provided with buried culverts to carry the low winter discharges. Considerable research has shown this scheme to be the only arrangement developed for canals that must be operated through extremely cold winters with low discharges. However, it appears that this arrangement has been used only recently and no literature could be found describing the scheme's long-term performance.

B2.3 PROPOSED FACILITIES - (Cont'd)

Because of uncertainties in the effectiveness of the buried culverts to prevent ice build-up and uncertainties in the nature of foundation materials that would be encountered along the two canal routes, it is strongly recommended that, if an alternative ash disposal scheme without canals is not adopted following the re-examination discussed in Sub-section B2.1, further research be conducted in relation to the culvert arrangement and the icing problem generally.

Both the north and south canals terminate in discharge chutes designed to convey the PMF runoff safely down to Medicine Creek below the toe of the ash dam.

Typical canal sections in rock and in overburden and details of the chutes are shown on Plate B2.

(a) North Canal

From its start near MacLaren Creek to the outlet chute below the ash dam, the north canal would cover a length of 5.3 km serving a total drainage area of 11.7 km^2. The canal's capacity at its lower end would be 7.8 m^3/s. From El. 1287 at its upper end to about El. 1273 at the outlet chute, the canal would have an average slope of about 0.26 percent. Velocities in overburden would be limited to about 1.1 m/s.

An embankment on the downhill side would be constructed with a top width of 3.6 m and would be surfaced with sand and gravel to provide permanent access for canal maintenance. A corrugated metal culvert, smooth-lined with asphalt, with a diameter ranging from 200 to 300 mm would be buried in this embankment, draining the winter flows from the canal in 200 mm diameter pipes spaced along the canal. Flow into these pipes would be through short lengths of perforated pipe buried under gravel in the side of the canals.

The canal embankment would be constructed to form small sedimentation ponds at the confluences of all tributary streams.

Most of the north canal would be located in overburden materials with rock assumed to occur intermittently over the last 1000 m of the route. A 300 m length of reinforced concrete box culvert has been allowed for in the estimates recognizing the very steep area in the vicinity of Sta 4+600. From aerial photographs it appears that active rock slides may be present in this area.

Because of the considerable overburden depth on the north bank near the outlet, the discharge chute would consist of a reinforced concrete baffled chute about 250 m long dropping through a vertical height of about 95 m.

(b) South Canal

The south canal would have an overall length of about 6.3 km draining a total basin area of 26.0 km^2. Its discharge capacity at the downstream end would be about 14.4 m^3/s. Between El. 1280 at the upper end and El. 1272 at the outlet, the canal would have an average gradient of about 0.13 percent, considerably flatter than the north canal slope. The flatter average gradient of the south canal is due to the higher capacity throughout most of its length which results in a significantly greater flow cross-section, particularly depth. With less frictional resistance the slope must be flattened to limit the flow velocity. The main upper stem of Medicine Creek would discharge into the south canal at about Sta 2+800, where the accumulated drainage area already totals some 21.6 km^2, almost twice that of the entire north canal.

Cross-sections for the south canal, although larger, would be generally the same as those for the north canal. Based

B2.3 PROPOSED FACILITIES - (Cont'd)

primarily on airphoto examination it is expected that about 5500 m of the south canal would be in overburden with the remaining 800 m at the downstream end located mostly in rock.

The buried culvert for winter flows in the south canal would range in size from 250 to 450 mm.

The outlet chute for the south canal would be simply a channel excavated into rock since the overburden depth here is expected to be generally shallow. The south chute would have an overall length of 220 m and, like the north chute, would drop through a vertical height of about 95 m. A plunge pool would be required at creek level to complete energy dissipation.

B2.4 OPERATION AND MAINTENANCE

Because of the steep terrain and numerous small tributaries it is expected that considerable annual maintenance would be required, particularly during the early years of use, to remove accumulated sediment and debris from the canals. Also, despite the provision of the culverts to handle low winter flows, it is possible that in severe winters some ice blockages could occur, requiring some additional maintenance.

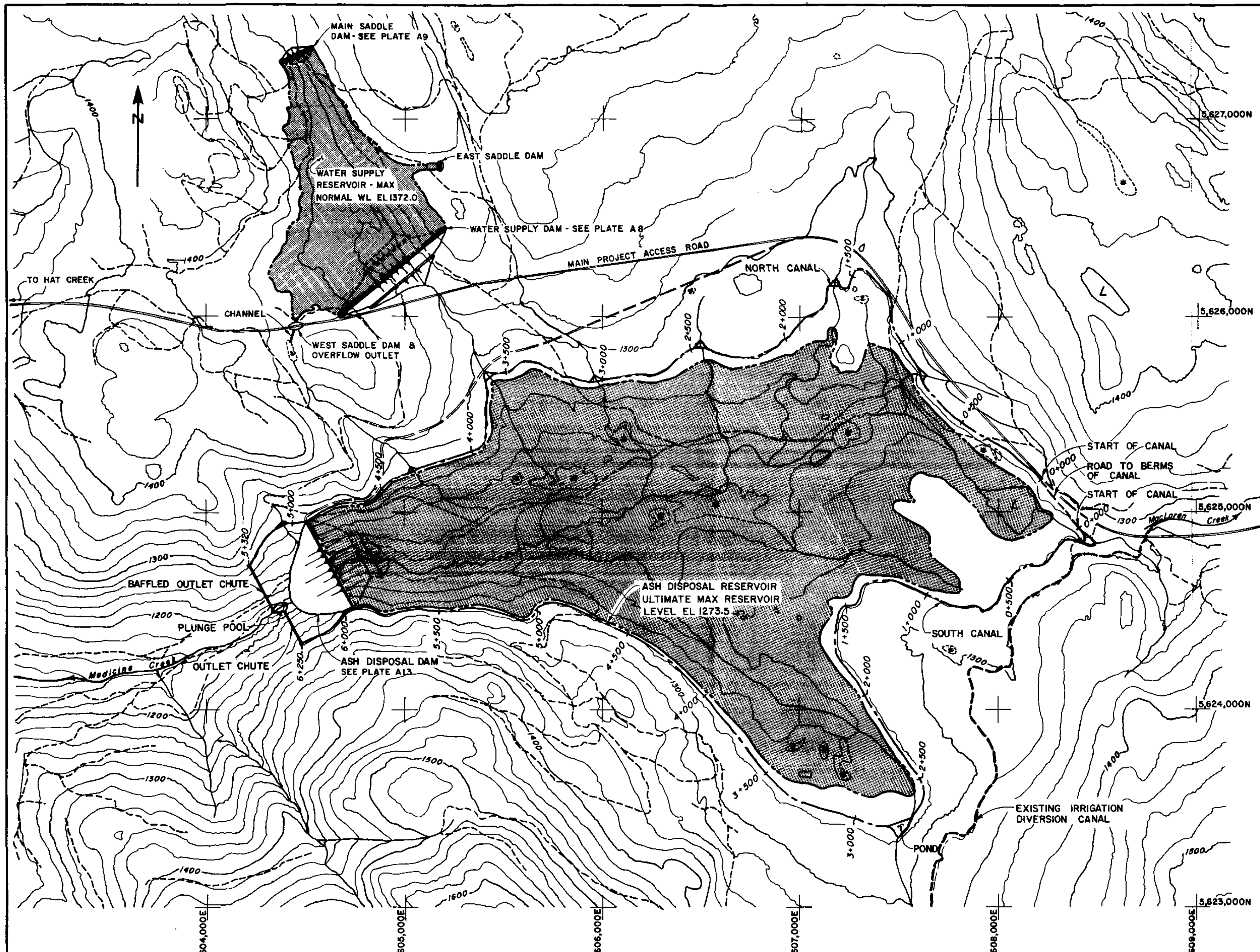
B2.5 COST ESTIMATE

The estimated total direct costs, at September 1977 price levels, of the north and south runoff canals and associated outlet works are summarized in Table B2-1. No indirect costs such as contingencies, engineering and site investigations, corporate overhead or interest during construction are included.

TABLE B2-1

ASH DISPOSAL RESERVOIR
RUNOFF HANDLING FACILITIES
SUMMARY ESTIMATE OF DIRECT COSTS
(Costs at September 1977 price dollars)

		$Thousand
1.	North Canal	
	a. Clearing	90
	b. Earthwork	480
	c. Concrete and reinforcing	630
	d. Culverts and piping	180
	SUBTOTAL	1380
2.	Outlet Chute for North Canal	
	a. Excavation and backfill	30
	b. Concrete and reinforcing	150
	SUBTOTAL	180
	TOTAL NORTH CANAL	1560
3.	South Canal	
	a. Clearing	90
	b. Earthwork	750
	c. Concrete and reinforcing	140
	d. Culverts and piping	270
	SUBTOTAL	1250
4.	Outlet Chute for South Canal	
	a. Excavation and backfill	40
	b. Concrete and reinforcing	10
	SUBTOTAL	50
	TOTAL SOUTH CANAL	1300
	TOTAL DIRECT COST OF NORTH AND SOUTH CANALS	2860



NOTE :

1. For general location map see Plate A1, Annex A

Scale: 200 0 200 400 600 800 Metres

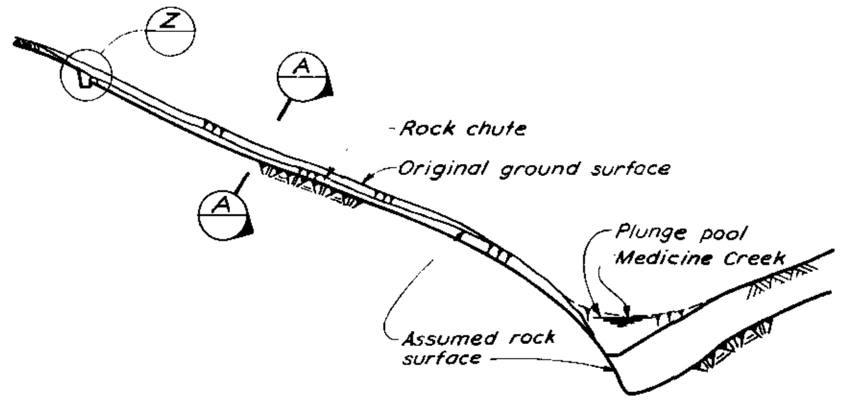
Elevations are in metres

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

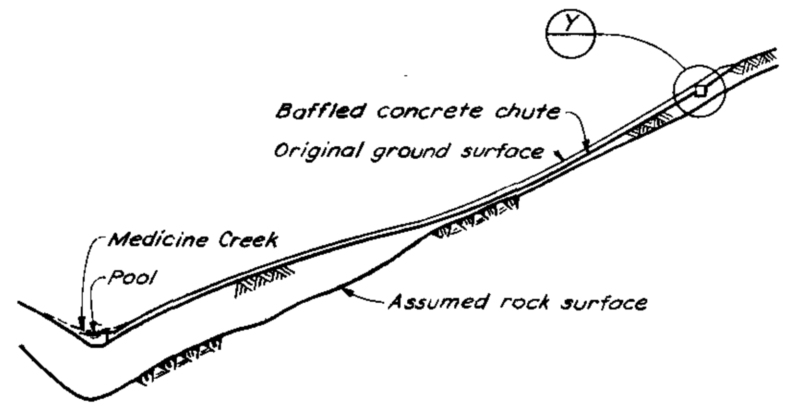
HAT CREEK PROJECT

WATER SUPPLY & ASH DISPOSAL RESERVOIRS RUNOFF HANDLING FACILITIES ARRANGEMENT

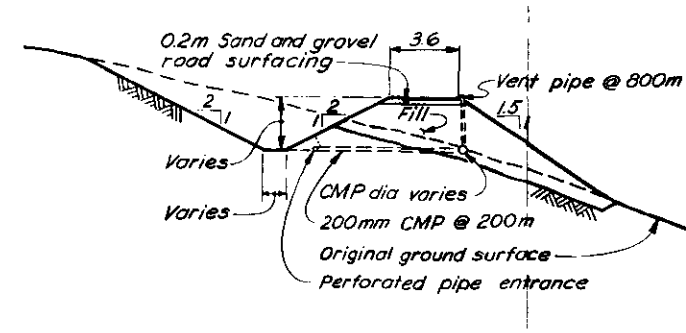
DATE MAR 1978	PLATE B1	R
DWN A.Y.	DWG No. 604H-C14-D64	



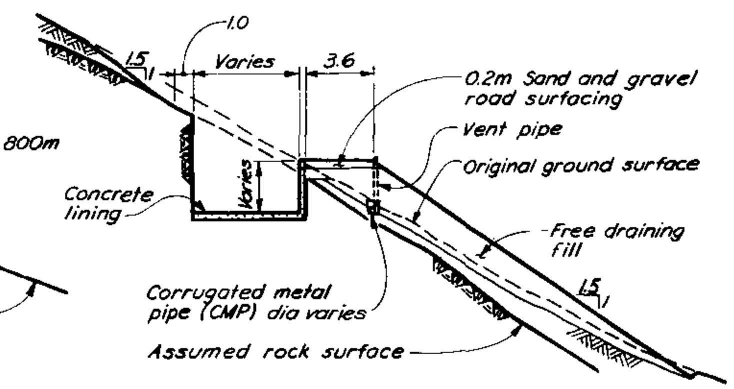
SECTION ALONG SOUTH CANAL OUTLET CHUTE
Scale: A



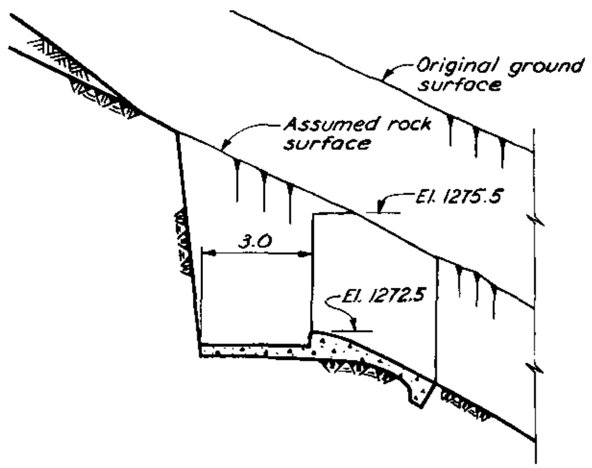
SECTION ALONG NORTH CANAL OUTLET CHUTE
Scale: A



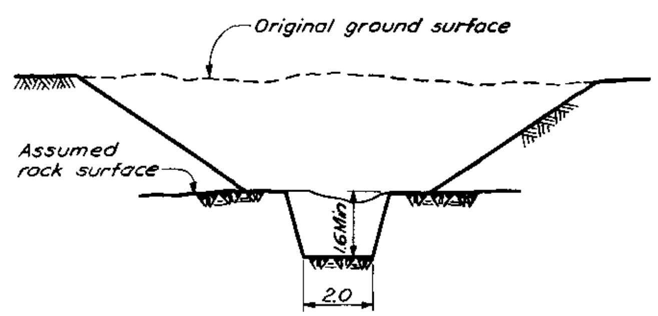
TYPICAL CANAL SECTION IN OVERBURDEN
Scale: B



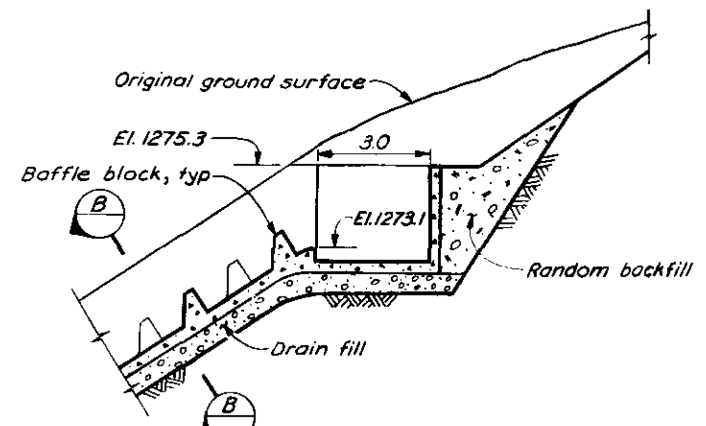
TYPICAL CANAL SECTION IN ROCK
Scale: B



DETAIL Z
Scale: C



SECTION A
Scale: C



DETAIL Y
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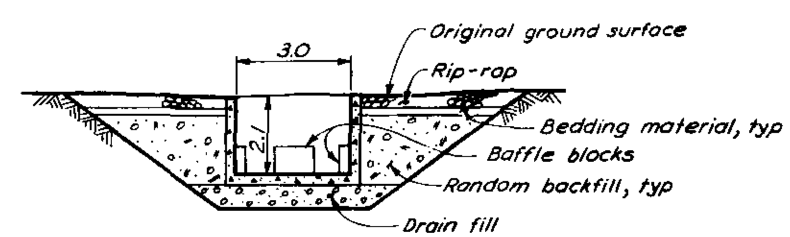

SECTION B
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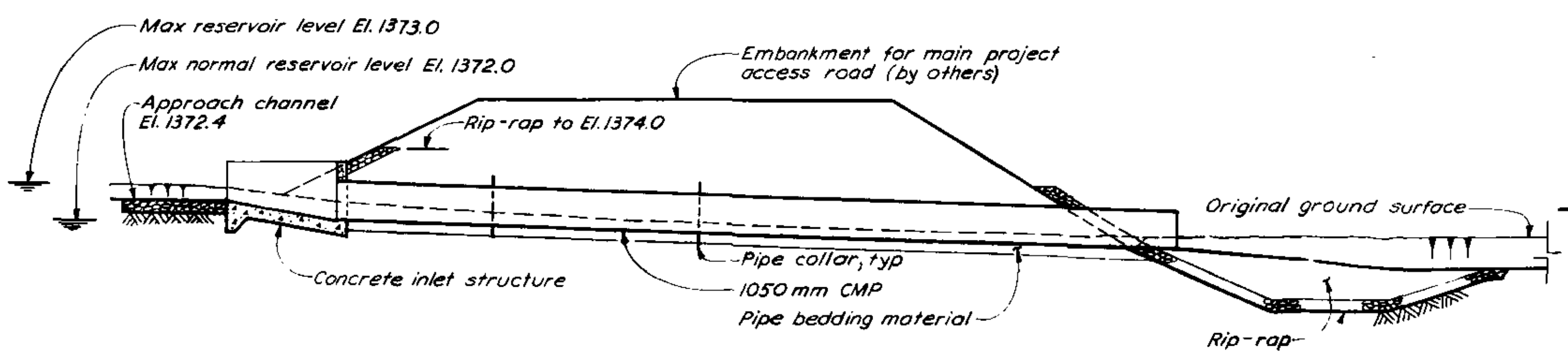
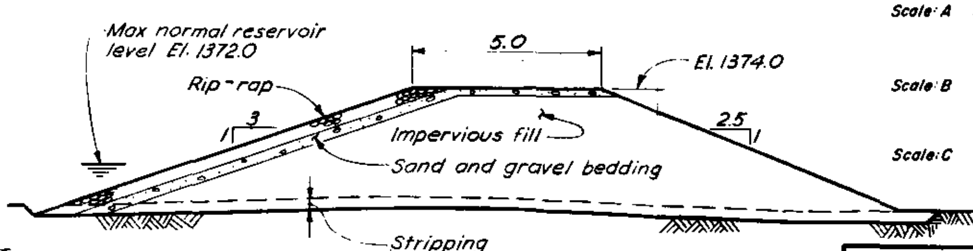


WEST SADDLE DAM AND OVERFLOW OUTLET FOR WATER SUPPLY RESERVOIR
Scale: C



EAST SADDLE DAM FOR SUPPLY RESERVOIR
Scale: C

Scale: A 50 0 50 100 Metres

Scale: B 5 0 5 10 15 Metres

Scale: C 2 0 2 4 6 8 Metres

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

HAT CREEK PROJECT

WATER SUPPLY & ASH DISPOSAL RESERVOIRS
RUNOFF HANDLING FACILITIES
SECTIONS & DETAILS

DATE MAR 1978	PLATE B2	R
DWN K.L.	DWG No. 604H-C14-D65	