Golder Associates
CONSULTING GEOTECHNICAL AND MINING ENGINEERS

REPORT TO
MINISTRY OF ENERGY, MINES & PETROLEUM RESOURCES
FOR
GEOTECHNICAL AND HYDROLOGICAL ASSESSMENT
OF
HAT CREEK NO. 2 DEPOSIT

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March 1981

802-1585

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ABSTRACT

A desk study of the geotechnical considerations of open pit mining the Hat Creek Coal No. 2 Deposit is presented. The coal is part of the same sequence of Tertiary sediments that surround the No. 1 Deposit to the north. Very weak claystones, siltstones and sandstones are present, although there is some indication that a somewhat stronger sequence of volcanic, volcaniclastic and tuffaceous rocks would form the east pit walls. However, major slope instability is evident in this area, and detailed investigation by drilling and testing would be needed in order to address feasibility. Provisionally, therefore, the slope angles arrived at for the No. 1 Pit are recommended. Waste dump sites have been identified at Anderson Creek, Ambusten Creek and the head of Medicine Creek: haul distances could be long, but a total waste dump volume of 2.6 Gm^3 is available. Hydrogeological problems would be comparable to those in the No. 1 Pit on the west side, but because of the proximity of the limestones east of the No. 2 Deposit ground water pressures in the east slopes of the pit could be more severe: rocks of higher permeability may be interbedded with very low permeability rocks similar to those tested further north and may consequently create a complex ground water situation. Recommendations and estimated costs for feasibility and detailed design investigations are given.

HAT CREEK NO. 2 DEPOSIT

GEOTECHNICAL & HYDROLOGICAL ASSESSMENT, PRE-FEASIBILITY STUDY

1.0 INTRODUCTION

1.1 Terms of Reference

The Terms of Reference for the present study are contained in the Request for Proposal letter sent by B.C. Hydro & Power Authority (BCH) to Golder Associates (GA) and dated September 25th, 1980. The details are as follows:

Purpose

Provide an assessment of the geotechnics and hydrology to establish preliminary design criteria for an open pit mine in the Hat Creek No. 2 Deposit. Existing data will be used. No additional drilling is planned for this stage.

Scope of Work

(1) Assess existing data and develop pit slope design criteria for No. 2 Deposit.

(2) Assess the extent of active-inactive slides in the No. 2 Deposit area.

(3) Evaluate possible additional waste areas.

(4) Establish preliminary design criteria for selected waste areas including maximum dump capacity and recognizing overall dump-pit slope stability.

(5) Assess any potential ground water problems.

(6) Prepare a short assessment report.

(7) Prepare recommended evaluation programs, including cost estimates, to provide adequate information for:

(a) Feasibility study purposes;

(b) Final Design.

1.2 Previous Work

A recent report by BCH (June 1980) summarized the current knowledge on the geological and mining aspects of the No. 2 Deposit. The various phases of investigation undertaken, including the geophysical surveys, are described.

Those parts of the previous work which have proved to be useful in this study include the following:

(a) PD-NCB/Wright Engineers/Golder Associates joint report dated 1976 in which the feasibility of mining the No. 2 Deposit was examined. The 1975-76 drilling program was complete at the stage of writing and Dolmage Campbell & Associates (DCA) had interpreted the basic geology from those results. The PD-NCB report incorporated the DCA interpretations. A small amount of geotechnical strength testing was undertaken by Golder Associates for that report.

(b) An outcrop map of the Upper Hat Creek valley in the vicinity of both coal deposits at a scale of 1:20,000 produced by Dr. T. MacCullough in 1977. This map of the solid geology, was an interpretation of the structural geology from the rock exposures and drilling results.

(c) A draft updated version of the 1977 map at the same scale with considerable reinterpretation of the results by Mr. H. Kim of BCH in October 1980. The present report recommends modification of that map.

(d) The same series of published topographic maps and aerial photographs that were available for work on the No. 1 Deposit studies, were also available for the current study. In addition, topographic maps were available at a scale of 1:10,000 for the whole of the project area.

1.3 Methodology

In order to make the geotechnical and hydrological assessment of the mining feasibility of the No. 2 Deposit, the geotechnical reports produced previously by Golder Associates for the No. 1 Deposit were re-evaluated. Conclusions were drawn on the similarities and differences between the two geological sequences and further photo-interpretation was undertaken to verify those aspects. Topographic maps were studied.

A field visit was made in mid-October 1980, for reconnaissance of the project area particularly to investigate the geology, existing slope stability and suitability of various sites for waste dumps. A map at a scale of 1:10,000 was produced to summarize the features of significance (reproduced as Figure 1 at a scale of 1:20,000). A second field visit was made in early November 1980, to explore the hydrogeological aspects of the area.

After the field visits further photo-interpretation was carried out, some rock index testing was done and the geotechnical and ground water aspects of the proposed open pit mine were considered.

The initial conclusions on the geology, slope designs, ground water and waste dump location and designs were presented to BCH on October 31st, 1980. The final conclusions of the study are contained in this report; recommendations are also made on the further work necessary to evaluate the deposit for geotechnical feasibility and final design purposes.

2.0 GEOLOGY

2.1 Stratigraphy

2.1.1 General

Table I shows the regional stratigraphic succession in the area as defined by BCH. The succession local to the proposed No. 2 Pit is shown on Table II.

Most of the No. 2 Coal Deposit and surrounding rocks are covered by surficial deposits; outcrop is sparse. Most of the geological knowledge of the area has, therefore, come from the drilling results. It is immediately apparent from the drill logs, from examination of the rock core and from the few exposures that the rock sequence has much in common with that in the No. 1 Deposit and is, therefore, Tertiary in age.

2.1.2 Tertiary Rocks

The three main formations, the Coldwater Formation (GA Unit Tcl), the Hat Creek Coal Formation (GA Unit Tcc) and the overlying Medicine Creek Formation (GA Unit Tcu) have been recognized in holes drilled in the center and west of the valley. The rocks drilled on the east of the coal deposit have lithological similarities with those drilled at the Medicine Creek waste dump embankment site and beyond the eastern limit of the proposed No. 1 Pit. Unfortunately no hole has encountered the complete rock sequence in the No. 2 Deposit area, and although it is possible to verify the relationship between the coal and overlying claystone (Medicine Creek Formation), it is not possible to determine unequivocally the relationships between the rocks encountered on the east and west flanks and those in the center of the valley.

A typical E-W section through the deposit is shown on Figure 2. The coal body is apparently anticlinal and is bounded by postulated faults to the east and west. The base of the coal has not as yet been penetrated. Rocks west of the fault cutting off the coal on the west side termed here the McCormick Fault, have been intersected by drill holes DDH 76-66 and DDH 76-67; they comprise green-grey sandstones and conglomerates with siltstones and minor flow rocks such as basalts. They are similar to the sequence drilled in the southwest of the No. 1 Pit, e.g. DDH 75-47, 76-802. They are considered to be an upthrown fault block to the west of the coal.

A thickness of some 450 m of coal has been proved to date, and it is apparently conformable with the overlying claystones, although some rocks may have slid over incomplete coal sequences. To date, it has not been possible to recognize the coal zones identified in the coal sequence to the north, although, correlations are being attempted by BCH. The Medicine Creek Formation claystones are extremely uniform grey or brown weak blocky rocks which are sheared or highly fractured at some horizons. They may be distinguished from the lithologies of the other formations by their homogeneous composition. It is believed that they represent lacustrine deposition in a low-energy environment. Although no further mineralogical work has been carried out, similar rocks above the No. 1 Deposit were high in montmorillonite. It is likely that these sediments were formed by the reworking of highly tuffaceous volcaniclastic deposits similar to those seen on the eastern side of the upper Hat Creek Valley.

The coal is apparently truncated to the east by a fault which runs approximately parallel to the escarpment on the east side of the valley (see Figures 1 and 2); for the purposes of this report it has been termed

TABLE 1

REGIONAL STRATIGRAPHY - HAT CREEK COAL BASIN

Period	Epoch	Million Years	Formation or Group	Thickness (m)	Rock Types
Quaternary	Recent			Not Determined	Alluvium, Colluvium, fluvial sands and gravels, slide debris, lacustrine sediments.
	Pleistocene	1.5 - 2			Glacial till, glacio-lacustrine silt, glacio-fluvial sands and gravels, land slides.
Unconformity					
Tertiary	Miocene	7 - 26	Plateau Basalts	Not Determined	Basalt, olivine basalt (13.2 m.y.), andesite, vesicular basalt.
	Unconformity (?)				
	Miocene or Middle Eocene ?		Kamloops Group: Finney Lake Formation	Not Determined	Lahar, sandstone, conglomerate.
			Unconformity		
	Late Eocene		Kamloops Group: Medicine Creek Formation	600+	Bentonitic claystone and siltstone.
			Paraconformity		
	Late Eocene to Middle Eocene	* 36 - 42	Kamloops Group: Hat Creek Coal Formation	550	Mainly coal with intercalated siltstone, claystone, sandstone and conglomerate.
			Kamloops Group: Coldwater Formation	375	Siltstone, claystone, sandstone, conglomerate, minor coal.
			Fault Contact or Nonconformity		
	Middle Eocene	43.6-49.9	Kamloops Group	Not Determined	Rhyolite, dacite, andesite, basalt and equivalent pyroclastics.
Unconformity (McKay 1925; Duffell & McTaggart 1952)					
Cretaceous or Later	Coniacian to Aptian **	88.3±3 m.y.	Spences Bridge Group	Not Determined	Andesite, dacite, basalt, rhyolite; tuff breccias, agglomerate.
	Erosional Unconformity (Duffell & McTaggart 1952)				
		98	Mount Martley Stock	Not Determined	Granodiorite, tonallite.
Intrusive Contact (Duffell & McTaggart 1952)					
Pennsylvanian to Permian or earlier		250-330	Cache Creek Group: Marble Canyon Formation	Not Determined	Marble, limestone, argillite
			Cache Creek Group: Greenstone	Not Determined	Greenstone, chert, argillite; minor limestone and quartzite, chlorite schist, quartz-mica, schist.

* Based on palynology by Rouse 1977

** Based on plant fossils by Duffell & McTaggart 1952.

the Boundary Fault. The rocks which are faulted against the coal comprise a very mixed sequence of volcaniclastic and tuffaceous sedimentary rocks with some flow rocks such as dacites and andesites which may be concordant with the sediments. Little is known about these rocks and much further investigation is necessary. The outcrops seen are of dacite, andesitic breccia and agglomerate, bentonitic siltstone and brown sandstone. Field relationships suggest that these rocks are probably the oldest in the sequence (see Table II), but they could also be the lateral equivalent of the Coldwater Formation. Their composition, particularly the high content of volcanic debris, indicates a nearby volcanic source.

Massive deposits of lahar are seen in outcrop near the Ambusten Creek/Hat Creek junction and in the northeast of the proposed pit area. The materials are massive, crudely interbedded with tuffaceous sediments and andesitic breccias. They are highly variable in grain size, composed predominantly of angular or sub-angular volcanic debris set in a fine grained volcanic ground mass.

2.1.3 Pre-Tertiary Rocks

It is suspected that older rocks, possibly of the Spences Bridge Group, form the western slopes beyond the limits of the pit. The natural slopes are steeper and a major photo-lineament is apparent defining the change of slope. There are as yet no drilling results in this area to verify this supposition. The higher ground to the east of the proposed pit is formed by rocks of the Permian Cache Creek Group. They are well exposed in the new forestry road shown on Figure 1. The rocks comprise limestones, phyllites, greenstones, chert and argillite.

2.1.4 Surficial Materials

A wide range of surficial materials may be encountered in the No. 2 Pit; they are of Pleistocene (glacial) to Recent in age.

Recent alluvium is present along the course of the present day Hat Creek. The deposit is sinuous and may be locally overlain by slide debris or lacustrine sediments where the valley has been dammed by slide activity from the east. The steeper slopes, which have been formed due to the presence of stronger volcanic rocks, produce coarse colluvial debris; the shallower slopes show more mixed, usually cohesive, colluvium formed from the glacial tills and Tertiary sedimentary rocks. Undisturbed tills are common and burn zone debris may be found locally. Fluvioglacial sands and gravels are also present at and beyond the east limit of the proposed pit.

Slide debris is also widespread (see Figure 1); it is highly variable in composition being very dependent on the local source rocks.

A large alluvial fan is present in the central part of the pit resulting from deep erosion in dispersive(?) Tertiary rocks to the east. A similar feature is present on the north side of White Rock Creek.

Within the slide area in which Fish Hook Lake has been developed, deposits of calcareous tuffa and dense travertine are seen along the stream courses. The deposits appear as a capping to the colluvium soils as slide debris and have resulted from precipitation out of Ca-bearing waters emerging as a spring in that vicinity.

2.2 Geological Structure

The limited data that has been obtained to date shows that the coal body has been folded into a tight anticline which plunges both to the north and to the south. The marker horizon that has been used to identify the structure is the junction between the coal and the overlying Medicine Creek Formation. The coal is found within a down faulted block flanked by the older Coldwater Formation to the west and the supposedly older "undifferentiated volcanics and volcaniclastics" to the east (see Figure 2). The geological picture is undoubtedly more complicated but the current level of investigation does not permit any better understanding of the overall structure. Major boundary faults bringing the Tertiary rocks against older deposits are considered to be present close to the western boundary of the pit and at the limit of the limestone outcrop to the west of the pit.

Dips within the coal are variable (see DCA sections in PD-NCB 1976 Report) and average 35 degrees on the flanks of the anticline as shown on Figure 2. To the east of the Boundary Fault both strikes and dips are uncertain, but the regional map of B.C. Hydro (1980) indicates a regional strike with a NW-SE trend.

2.3 Slide Activity

Figure 1 shows the slides which have been mapped at the surface as recognized from the air photos in the vicinity of the pit and the potential waste dump sites. A further large slide on the west side of the valley opposite White Rock Creek has not been included in this map because it has no engineering significance for the planned No. 2 Pit. The slides show well-defined land forms; their topographic expression and their influence on the ground water pattern assist in their identification.

The slides have been separated into three categories; stable, marginally stable and active. These relate to present conditions and do not necessarily have any connotation for their susceptibility under changed topographic or ground water conditions. Stable slides show no evidence of obvious movement within the recent geological past. Marginally stable slides show well defined features indicating movement but no tension cracks, seeps etc., which show that movement is currently occurring. Only one definitely active slide was found but others could possibly be present locally. Small lobate structures were examined on the west side of the pit and they are believed to be bentonite boils, but probably stable under existing ground water conditions. Similar structures elsewhere around the pit are more equivocal and could be glacial in origin.

The three slide areas depicted on Figure 1 are considered to relate to instability within the undifferentiated volcaniclastic and tuffaceous rocks forming the higher ground on the east side of the pit. In the southern area, investigations in the area of the head scarp showed the presence of bentonitic sediments. In view of the experience at the No. 1 Deposit it must be considered highly likely that weak tuffacious and bentonitic materials are present wherever slides have developed. It is also possible that the volcanic rocks within that sequence prevent such sliding developing, and only where those stronger materials have been removed by erosion or glacial action, has sliding been able to occur.

TABLE 2

LOCAL STRATIGRAPHY, HAT CREEK NO. 2 COAL DEPOSIT

Quaternary	Pleistocene to Recent	Colluvium alluvial sands and gravels, calcareous tuffa/travertine, till, outwash sands and gravels, lacustrine deposits, slide debris, burn zone material.
	Miocene	Finney Lake Formation - Lahar deposit, olivene basalt, sandstone, tuffs, agglomerate.
		U N C O N F O R M I T Y
Tertiary	Late Eocene	Medicine Creek Formation - bentonitic claystone and siltstone.
	Late - Middle Eocene	Hat Creek Coal Formation - coal with interbeds of siltstone, sandstone and conglomerate.
	Late - Middle Eocene	Coldwater Formation - green siltstone, sandstone, pebble conglomerates, basalt.
		F A U L T E D B O U N D A R Y
	Middle Eocene?	Undifferentiated tuffaceous and volcaniclastic rocks, dacite, andesite breccias and agglomerates.

3.0 GROUND WATER

3.1 Regional Perspective

Ground water behaviour at the No. 2 Pit is expected to be generally similar to the behaviour noted at the No. 1 Pit. The topography of Hat Creek Valley should permit recharge conditions in the higher ground on the valley walls and ground water discharge conditions near the valley bottom. The western side of the proposed pit would occupy low ground in the valley bottom and might, therefore, encounter the increasing hydraulic heads with depth which are characteristic of ground water discharge areas. The steeper topography underlying the eastern side of the proposed pit coupled with the topographic divide between Ambusten Creek and Hat Creek in this region are likely to provide somewhat more complex ground water behaviour.

3.2 Surficial Materials

The glacio-fluvial and alluvial deposits accumulated in the Hat Creek valley bottom are anticipated to provide the greatest dewatering requirement in the proposed excavations. Existing boreholes indicate a considerable thickness of surficial materials, however, there is no information on their hydraulic properties. It would be necessary to measure representative hydraulic properties and estimate ground water in storage in these materials at an early stage in the feasibility assessment. Surficial materials in the Ambusten - Cashmere Creek basin may provide limited ground water storage. These materials may receive recharge from Ambusten Creek or Cashmere Creek or by percolation through the Cache Creek carbonate rocks to the east. Ground water in storage within the alluvial fan in Ambusten Creek or the small terraced features in Cashmere Creek valley could act to enhance recharge to bedrock units beneath the eastern half of the No. 2 Pit and could contribute to stability problems in potential waste dump development in the Ambusten - Cashmere Creek basin.

3.3 Bedrock Materials

There is no direct evidence from the existing boreholes of the hydraulic properties in the bedrock materials. It is likely, however, that the Coldwater, Hat Creek Coal and Medicine Creek Formations will have similarly low permeabilities in the No. 2 Pit as were evident in the No. 1 Pit. The sequence of volcaniclastics, tuffaceous sediments and flow rocks which underly the eastern side of the No. 2 Pit will likely have variable hydraulic properties and will require particular attention in feasibility investigation.

Investigation at No. 1 Pit indicated that the Cache Creek Group carbonates exhibit greater permeability than the Tertiary rocks in the region. Such carbonate rocks underly much of the eastern catchment area of the Hat Creek Valley. These rocks may influence ground water recharge rates and volumes to the Ambusten Creek basin and indirectly contribute to ground water behaviour under the east side of the No. 2 Pit excavation. The carbonates will also, of course, represent a consideration in the stability of waste materials stored in the Ambusten - Cashmere basin.

3.4 Natural Ground Water Discharges

The unstable areas noted in the region of No. 2 Pit are likely to have low permeabilities; this is supported by the frequency of local small ground water discharge seepages associated with these deposits. Ground water behaviour along the failure surfaces of the slides would need to be investigated.

A significant natural discharge is noted near the head of the slide zone above Fishook Lake on the escarpment at the east side of the No. 2 Pit. The spring issues from an area characterized by secondary carbonate deposition. The carbonates range from an apparent dense travertine to light, porous calc-tuffa deposits. The calcareous materials were apparently derived by evaporation of mineralized ground water. The location of the spring suggests that this ground water discharge has been a major contributory mechanism for the slope failure. In late October of this year, the discharge from this spring was estimated at approximately 0.1 lps. In view of the very limited catchment available to the discharge point it is reasoned that the source of the ground water is external to the escarpment on which it occurs. The presence of this spring demands careful hydrogeological investigation; it may indicate possible proximity of Cache Creek Group carbonates or possible high artesian flowing heads.

4.0 GEOTECHNICS

4.1 Lithologies

In general, the geotechnical properties of the materials likely to be encountered in No. 2 Deposit would be similar to those studied for No. 1 Deposit. The descriptions of the No. 1 Deposit surficial and rock materials, together with their average geotechnical properties, are reproduced in Tables 3 and 4. The departures from, and modification of, those properties for the No. 2 Deposit are described in the following text.

No new drilling was carried out for this study, therefore, fresh material for testing was not available. The existing cores were only suitable for index tests to confirm that the materials were in fact similar to those tested previously. Seven Atterberg limit tests were run on air dried core samples, the material being "blenderized" in the laboratory as in the earlier tests. The results are shown on Figure 3 superimposed on the results of the tests on the No. 1 Deposit materials. As before, there is indication that the Medicine Creek Formation (GA Upper Claystone/Siltstone Unit Tcu), which in the No. 2 Deposit appears east of the McCormick Fault (see Figures 1 and 2) has significantly lower liquid limits that the Coldwater Formation (GA Lower Siltstone/Sandstone Unit Tcl), which appears west of this fault. As stated in the GA earlier reports, this is probably a reflection of differences in mineralogy between the two sequences.

4.2 Strength of In Situ Materials

No uniaxial compression strength testing was carried out on No. 2 Deposit materials, but the average properties can be assumed to be as indicated in Table 4 for rock types comparable to the No. 1 Deposit; the exception to this could be the volcanic rocks of the sequence to the east of the

Boundary Fault. However, insufficient data is available to comment meaningfully on them. It is possible that the weaker members of this sequence are comparable to the rocks tested.

Similarly, no shear strength testing was carried out, but, based on visual examination of the rock core samples drilled in the No. 2 Area, it is recommended that, for the purposes of this study, the shear strength parameters derived for the No. 1 Deposit materials should be adopted. These can be summarized as follows for all the Tertiary rocks, except the coal, there being no significant differences between them within the range of stresses operative in the pit slopes:

	Effective Angle of Internal Friction (degrees)	Cohesion, kPa (psi)
Average strength	20	395 (57)
Normally consolidated strength	20	0
Residual strength	7-1/2 to 12	0

The average strength is the mean of a very wide range of results. Individual results depend very much on the intensity of the fissure patterns within each specimen. Mohr Envelopes of Effective Stress for the Tertiary Claystone/Siltstone sediments are shown on Figure 4. These envelopes are derived from a statistical regression analysis of drained triaxial compression test results on samples from both the 1976 and 1977 investigations of the No. 1 Deposit. The statistical parameter r^2 shown on Figure 4 is the coefficient of correlation. The closer this value of r^2 is to 1.0 the better the fit of that envelope to the data. For all these tests the fit is poor, reflecting the large spread in the individual Mohr circles.

TABLE 3

DESCRIPTION OF SURFICIAL MATERIALS - NO.1 DEPOSIT

TYPE	DESCRIPTION	LOCATION	RANGE OF HYDRAULIC CONDUCTIVITY m/sec	GEOTECHNICAL COMMENTS	MOISTURE CONTENT ON DRY WEIGHT BASIS	UNIAXIAL STRENGTH	ATTERBERG LIMITS
Till	Glacial deposit composed of cobbles and gravels with occasional boulders up to 1 m dia. maximum but generally much less, in a matrix of sand, silt and clay. Locally variable, depending on matrix. Seen in base of Clay-Cut.	West and southeast sides of valley	10^{-10}-10^{-8}	Generally dense or compact, boulder size may locally inhibit digging although usually will be able to be dug by hydraulic excavator. Where gravelly, may make water.	15% - 50% Average 26%	0 - 300 kPa	LL = 86 PL = 42 (avg. from a small number of tests)
Lacustrine Deposits	Bedded silts, silty sand with coarse sand and occasional gravel may be also clayey, laminated and/or highly disturbed. Overconsolidated. Glacial origin.	Locally through-out glacial deposits. Houth Meadows embankment foundations.	10^{-7}-10^{-6}	Unusually dense. Where laminated, easy to dig but uniform heavily overconsolidated silts of Houth Meadows could give difficulties. Surface materials in Dry Lake and Houth Meadows are soft.	18% - 32% Average 25%	200 - 500 kPa	LL = 48 PL = 26 (avg. from a small number of tests)
Glacio-fluvial Deposits	Interbedded rounded-subrounded sands and sandy gravels with cobbles and boulders up to 0.7 m dia. (approx.). Much variation in grading. Some interbedded tills. Glacial meltwater deposit.	East side of valley, locally on west also.	10^{-7}-10^{-5}	Dense, possibly slightly cemented, free draining. Will not generally present digging problems. Boulder size smaller than till. Rounded materials. Some ironpans present.	Depends on drainage	non-cohesive	Non-plastic
Colluvium	Coarse, angular, roughly bedded perhaps with variable proportion of fines formed on slopes by erosion. May comprise volcanics, limestone or granodiorite.	Widespread at base of steeper slopes.	10^{-7}-10^{-4}	Variable depending on local rock type. Angular, abrasive, maximum rock size large although generally gravel to cobble sizes. Free draining, locally unstable during digging.	11% - 60% Highly dependent on composition average 30%	100 - 500 kPa, depending on composition	Varies over full range because of composition variability.
Slide Debris (Stable)	Composed of variable assortment of glacial and glacio-fluvial materials Coldwater sediments and granodioritic material often in a bentonite matrix. Seen in upper part of Trench A and Clay-Cut. Mostly post glacial.	West side of valley especially NW.	not known	Variable. Generally moderately dense. Handling characteristics similar to Clay-Cut material.	11% - 60% Highly dependent on composition average 30%	100 - 500 kPa, depending on composition.	Varies over full range because of composition variability.
Slide Debris (Active)	As above, but some softer zones. Currently unstable.	Active slide in NW and minor slides elsewhere in W.	not known	Broken locally softened and weak rock probably sticky. Some seepages. Contains some proportion of gravel. Could give some handling and trafficking problems. Occasional boils.	11% - 60% Highly dependent on composition average 30%	100 - 500 kPa, depending on composition.	Varies over full range because of composition variability.
Alluvium	Rounded sands and gravels probably with silt interbeds as seen in Trench B. Mostly reworked glacials.	Predominantly in Hat Creek Valley bottom.	10^{-6}-10^{-4}	Generally loose and free draining. Maximum size say 0.4 m. Gravel subsidiary to sand.	Depends on drainage	Usually not cohesive	Usually non-plastic but could go up to about LL = 40, PL = 15 (no test results).
Burn Zone	Varies from an irregular mass of red-brown partly-fused claystone and siltstone with some coal to well bedded slightly baked in situ Coldwater mate-	Dry Lake area. May be obscured by glacial or slide deposits in subcrop on W. side.	highly variable	Hard abrasive generally breaking up into gravel sized fragments, easy to dig. Difficult or impossible to dig where completely fused (as in part of Trench A). Some blasting locally necessary.	Insufficient data for characterization; properties highly variable.		

TABLE 4

DESCRIPTION OF ROCK MATERIALS - NO.1 DEPOSIT

TYPE	DESCRIPTION	LOCATION	RANGE OF HYDRAULIC CONDUCTIVITY m/sec	GEOTECHNICAL COMMENTS	MOISTURE CONTENT ON DRY WEIGHT BASIS	UNIAXIAL STRENGTH	ATTERBERG LIMITS
Claystone/ Siltstone	Very weak to moderately weak clayrich rocks in which bedding often hard to discern. Rock breaks along joints. Where softened or reworked, material highly plastic and tenacious. Zones of shearing and brecciation. Possibly tuffaceous near margins of basin. Generally dark grey or dark brown colour. Distinct tuff bands present.	Stratigraphically above the coal (Unit Tcu). Subcrops in an arc from NE to SW in final pit slopes.	10^{-12}-10^{-10}	Should be considered as a hard clay rather than a rock for excavation purposes. Easily dug where joints are present. Very uniform beds may be troublesome to hydraulic excavator. Handling and trafficking problems will occur in wet conditions due to presence of montmorillonite. Only slakes where sheared or brecciated.	13% - 32% Average 24% May tend to decrease with depth from 29% at subcrop to 18%, 150 m deeper.	400 - 12,000 kPa Average 3,700 kPa May tend to increase from 1,000 kPa to 8,000 kPa after 150 m.	LL = 95 PL = 35 (average)
Siltstone/ Sandstone	Interbedded siltstone and sandstone with subsidiary conglomerate, claystone and coals. Generally light grey in colour, highly anisotropic but bedding planes often difficult to find. Much facies variation.	W and NW pit slopes. Stratigraphically below the coal. Also occurs as interbeds in the conglomerate.	10^{-11}-10^{-10}	Should be considered as a stiff clay rather than a rock for excavation purposes. Easily dug where joints are present. Handling and trafficability problems will occur in wet conditions due to presence of montmorillonite. Dispersive, highly erodible, will form gullies, and sub-surface cavities. Slakes readily.	23% - 70% Average 31%	600 - 3,500 kPa As interbeds in conglomerate, 3,500 - 7,000 kPa	LL = 143 PL = 34 (average)
Sandstone	Varies from weak silty sandstone through to moderately strong fine grained conglomerate. Matrix usually composed of silt/clay and granular material may be tuffaceous and weak. Locally cemented especially immediately below the coal. Generally greenish.	W and NW Pit slopes. Stratigraphically below the coal. Forms interbeds in Lower siltstone/sandstone (Unit Tcl) and in conglomerate (Unit Tco_1).	10^{-10}-10^{-9}	Generally weak rock whose excavation characteristics may differ little from the siltstones. Some trafficking problems as material breaks down. Often highly bentonitic. Characterized by west face of Trench A.	19% - 32% Average 25%	Some tendancy to increase from 1,000 kPa at surface to 10,000 kPa at 300 m depth. Interbeds in conglomerate range from 3,500 kPa to 10,000 kPa and vary similarly with depth.	LL = 80 PL = 30 (based on only a few results)
Conglomerate	Highly variable in character depending on relative proportions of granular material and matrix. Coarse gravel fragments rounded to subrounded but also angular where tuffaceous. Matrix may be bentonitic. Often clacite cemented. Not yet seen in outcrop or excavation. Contains interbeds of siltstone and sandstone.	S abutment of Mouth Meadows Embankment. Forms ridge between Mouth Meadows and pit (Unit Tco_1). Also occurs as interbeds in Lower siltstone/sandstone (Unit Tcl) and at base of whole sequence (Unit Tco_2).	10^{-10}	Harder and more abrasive to dig. Where weathered could be disaggregated and behave as gravel. Will break down with much rehandling except where cemented. Calcite cemented conglomerate could not be dug without blasting.	Average 15%, based on few test results. Note that interbeds will raise overall average.	Depends on cementation; up to 43,600 kPa has been measured locally. Some zones almost uncemented.	LL = 60 PL = 27 (based on very few results)
Coal	Thinly bedded moderately strong but highly fractured. Interbedded with siltstone partings and beds, often highly sheared. Some cleating. Much variation from clean to dirty coal except in D-Zone. Some zones of complete fragmentation.	Centre of pit and limited area in SW wall.	10^{-11}-10^{-6}	Easily dug due to multitude of weak joints and partings. Bench failures common especially where bedding unfavourably oriented. Seepages from face, generally no sizable water inflows.	See DCA report	1,000 - 17,000 kPa	See DCA report
Coal Interbeds	Generally thinly bedded claystone/siltstone of moderate plasticity. Some bentonitic material in A-Zone and near margins of basin. May be highly sheared or brecciated.	Centre of pit and limited area in SW wall.	10^{-12}-10^{-10}	Easily dug and similar to coal in some respect although will not break up as much. Impermeable locally softened. Thinner beds may be difficult to separate from coal.	12% - 36% Average 23%	No data	LL = 59 PL = 33 (average)
Volcanics	Includes an assortment of basalts, dacites, rhyolites, agglomerates, breccias and tuffs. Closely jointed.	E and W of pit.	10^{-11}-10^{-6}	May require blasting or ripping. Generally hard and abrasive. Permeable. Generally drained.	No data	Up to 23,000 kPa has been measured. Strength may often be much greater.	N/A
Limestone	Massive or brecciated limestone with phyllite interbeds.	Underlying Mouth Meadows.	10^{-9}-10^{-4}	Will require blasting. Generally strong phyllite bands weaker. Dry.	No data	No data	N/A

The few tests that were carried out on the volcaniclastic rocks at the Medicine Creek waste dump embankment site, suggest that these materials may be stronger than the Coldwater Formation (GA Lower, Siltstone/Sandstone, Unit Tcl) and the Medicine Creek Formation (GA Upper Claystone/Siltstone Unit Tcu). However, some very weak brecciated claystones are present in the sequence and pending further investigation of the rocks east of No. 2 Deposit, we would assign the same strength to these materials as for the Coldwater Formation.

While the range of strength values for the Medicine Creek and Coldwater Formations is similar, within the operative range of normal stresses likely to be encountered in pit slopes, mean values for samples truly representative of the materials may differ considerably. On first appearances, the more brittle, cleanly fractured Medicine Creek material appears stronger than the Coldwater material. However, drilling in No. 1 Deposit revealed that many highly fractured zones do occur in the Medicine Creek material. Clearly, where such zones are unfavourably orientated with respect to pit slopes, failures could occur with equal opportunity in either material.

The lower bound of the range of strengths is close to the normally consolidated strength. It is also close to the strength of the heavily fissured materials. This is the value which has been judged to be the operative strength for use in pit slope design (see GA Report, 1978), and it is further recommended as the basis for design in the proposed No. 2 Pit.

Because of the fundamental importance of the choice of shear strength on the pit design, it is considered useful to reiterate some of the points made in connection with the No. 1 Deposit.

It might be argued that the operative strength for pit slope design purposes ought to be the average strength. However, because of the influence of fissures on the measured strength parameters and the method by which the data is analyzed using the Mohr-Coulomb approach, the average strength is not the logical choice for the operative strength. The average strength is unconservative, and a discussion of this argument was given in the GA Report (1978), Volume 4, Appendix 9, pp. 6-8.

Comparing the average and the normally consolidated strength, it is seen that the only difference is that cohesion is absent in the latter. Thus the operative strength parameter for pit slope design, $\phi = 20°$, $c = 0$, assumes that over the duration of time during which the pit would be operative, a cohesive strength component cannot be relied upon. There is considerable evidence for this engineering judgement, see Skempton (1970 and 1977) and the analysis of the Panama Canal experience with clay shale slopes, Banks (1978). Skempton argued that the limiting strength of stiff fissured clay that has fully softened on fissures following lateral stress release in an excavation is numerically equal to the normally consolidated strength. He identified this fully softened strength parameter as the lower limit for first-time slides, at least in London Clay and probably many others, the residual value only being reached after slippage has occurred.

It is possible of course that in highly overconsolidated clays, such as those at Hat Creek, stress release and subsequent strain could be sufficient to mobilize residual values, or else the residual had already been mobilized by tectonic shearing along bedding planes. However, the latest analyses of the Panama Canal failures indicate that such first-time slides do occur in accordance with Skempton's concept. The term "first-time slide" is used to distinguish slides in previously unsheared material from those due to reactivation of movement along a pre-existing shear surface.

The aspect of the selection of shear strength parameters is dealt with at some length because it is crucial to the determination of pit slope angles (and hence economic feasibility), which is discussed in Section 5.

With regards to the surficial soils, it can be assumed for preliminary purposes that the sands and gravels, and the glacial till would have the following properties:

Material (Sample Location)	Effective Angle of Internal Friction (degrees)	Cohesion, kPa (psi)
Alluvial Sands and Gravels (Hat Creek, No. 1 Deposit)	42	0
Glacial Till (Medicine Creek Waste Dump Embankment Site)	30	14 (2)

All the above information should be used as a guide only, and further testing would be needed on samples of material taken from around the No. 2 Deposit.

4.3 Strength of Waste Aggregate

Laboratory testing of materials and experience from the performance of small trial waste piles of material excavated from around the No. 1 Deposit, indicate that the mean moisture content of the low strength claystone and siltstone waste materials is about 31 per cent at a dry density of 9 kN/m^3. Because of the low permeability of the waste, consolidation in dumps would take many years. Therefore, to assess the strength, tests under unconsolidated undrained conditions measuring total stresses are appropriate. The results for material excavated from the No. 1 Deposit trial pits are shown on Figure 5. In general the material has a shear strength of about 200 kN/m^2 (30 psi) at the stress levels operative in the waste dumps.

5.0 PIT SLOPES

Considerations of both the geology and the geotechnics indicate that provisionally the materials in the pit slopes around No. 2 Deposit should be treated similar to those around No. 1 Deposit.

It has been our opinion that because of the low strength of the claystones and siltstones, structure such as bedding would not be a controlling factor in overall slope stability. In high slopes the materials would behave essentially as engineering soils, and the mode of failure would be generally a circular arc slip. Therefore, the analysis of the stability of high slopes in both the No. 1 and No. 2 Deposits are provisionally the same, and the recommended pit slope angles for mine planning purposes are as follows:

Surficial deposits (other than slide debris)	25°
Slide debris	16°
Coal	25°
Coldwater Formation, Medicine Creek Formation and undifferentiated volcanics, volcaniclastic and tuffaceous and tuffaceous rocks	20°

However, some structurally controlled failures are likely where strong beds are dominant in the sequence or in lower slopes where the structure is unfavourably oriented. In the No. 2 Deposit, the coal being folded anticlinally is generally favourably oriented. The structure of the volcanic/volcaniclastic and tuffaceous rocks east of the Boundary Fault is unknown.

Differences such as physical appearance are apparent in the Tertiary Claystone/Siltstone sequences. The Medicine Creek Formation (GA Unit Tcu) appears to have a lower mean natural moisture content, lower mean liquid limit, to be less dispersive and to slake less on soaking in water than the Coldwater Formation (GA unit Tcl). In terms of effective strength parameters, however, the testing so far has not revealed significant differences. There seems little rational basis, therefore, for recommending any difference in pit slope angles between these materials, at least for mine planning purposes. Zones of silty sandstone in the Coldwater sequence may not be extensive enough to significantly improve pit slope stability, and such improvement could be offset by extensive brecciation in the claystone. Moreover, some of the tests have indicated that the bentonitic sandstone is little stronger than the siltstone. Provisionally, therefore, the pit slope angle of 20 degrees is recommended throughout.

The previous assumptions on pit slope angles apply as follows:

(a) that pit slopes would only be stable if some means (natural or artificial) is available to depressurize the slopes;

(b) that pit slope depressurization by negative pore pressure generation through stress relief on excavation would be moderately successful; with more rapid excavation it might be better in the No. 2 Deposit than in the No. 1 Deposit;

(c) that slopes would be excavated to flat angles during the initial process of mining, both to minimize shearing stresses that could lead to progressive slope failures and in order to promote slope depressurization;

(d) that interim bench failures would be acceptable, that considerable road maintenance would be necessary and that wide benches would be needed locally;

(e) that slope heights are generally not dependent on slope angles because the design is based on the lower limiting strength of the pit slope materials;

(f) that slopes are designed to be stable only for the duration of mining.

The key assumptions are (a), (b) and (c). It is assumed that full slope depressurizations would be achieved either by dewatering where the ground permeability permitted, or more probably by excavating to flat interim pit slope angles during the initial stages of mining, reducing the pore water pressures by release of overburden stress. Flat slopes during the early stages of mining would minimize the disturbing shear stresses and delay the onset of failure.

It is also assumed that any mine plan adopted must be flexible to cater for changes in pit slope designs, and changing ground conditions as they are revealed. This approach should achieve the steepest final pit slopes, but at the expense of excavating much material during the early phases of mining, the final volume however being minimized.

Should the pit be expanded to include the Cache Creek Formation or the Spences Bridge Formation rocks, it could be assumed for preliminary mine planning purposes that the overall pit slope angle in those materials would be 45 degrees.

With regards to interim bench slopes, much depends on the method of mining, and recommendations cannot be given at this stage. However, because the potential failures are small scale they are likely to be structurally controlled. As stated above, in the No. 2 Deposit the predominant anticlinal structure is less adverse with respect to bench failure than in the No. 1 Deposit.

Currently no consideration has been given to the reactivation of the mudslides on the east side of the valley during mining, but it would clearly be necessary to do so in a feasibility study. Subsurface drainage and diversion of surface run-off are likely to be necessary precautionary measures to control the slide during mining operations. Alternatively since the major portion of the slide would appear to fall within the outline of the pit, removal of the entire slide prior to, or during, mining might be feasible. It is important to be able to ascertain the reason for, and the mechanism of, the sliding in order to guard against further instabiity of the same nature.

6.0 WASTE DUMPS

Potential waste dump sites have been identified in Anderson Creek, Ambusten Creek and at the head of Medicine Creek valleys. The layouts of the various alternatives with preliminary estimates of maximum dump volumes in million cubic meters are shown on Figures 6 to 8. Potential dump sites to the south of No. 2 Deposit were not studied, since the haul distances would become excessive for access at the north end of No. 2 Pit. Even for the two major dumps at Anderson Creek and Medicine Creek the haul distances and rises become large with increasing dump volumes, see Figure 9.

The allowable slope of the surface of the waste depends upon the strength of the waste, see Figure 5, and its thickness in the dump. In general, 5 per cent is the allowable slope, but for the dump of shallow thickness at Ambusten Creek the slope could be increased to 10 per cent.

A possible dumping site was considered in the basin at the back of White Rock Creek to the east of No. 2 Deposit. Since this is a major landslide area, however, it would not be feasible to dump waste there, unless very carefully engineered waste retaining embankments were constructed where White Rock Creek exits to the main Hat Creek Valley. For retaining embankment stability, it would be necessary to excavate the slide material from beneath the foundations.

Interaction of the waste dump and the pit slope would need to be investigated for the smaller dump at Ambusten Creek.

The largest dumping area is at the head of Medicine Creek, where about one billion cubic meters of material could be placed, in addition to the waste dumped from No. 1 Pit, if Alternative A water supply reservoirs for Hat Creek Thermal Generating Plant were adopted, see Figure 8; it would also involve disposing of ash from the power plant in the Medicine Creek waste pile.

The total volume of waste that could be disposed of at the three sites proposed, would be about 2.6 billion cubic meters including about 700 million cubic meters of No. 1 Pit waste. Waste retaining embankment sites for the Anderson Creek and Ambusten Creek dumps would need to be investigated by drilling. It has been assumed that adequate quantities of materials suitable for the construction of retaining embankments would become available from the mining of No. 2 Deposit. These materials would probably be glacial sands and gravels, and possibly coarse volcanic rocks from the east of the No. 2 Deposit. It might be necessary to supplement these materials with sand and gravel, excavated from the east side of No. 1 Pit; the question of material supply should be addressed in a feasibility study.

7.0 CONCLUSIONS

From the foregoing sections, it is apparent that there are wide gaps in the knowledge of the basic geology, ground water and material properties of the Hat Creek No. 2 Deposit. Until these are filled the geotechnical conclusions must be of necessity provisional. The recommendations for work that needs to be carried out for geotechnical feasibility and design studies are presented in Section 8.

It may be concluded from the work carried out in this study that:

(a) the geological sequence of Tertiary - age rocks is similar to that investigated in the No. 1 Pit, except that the suite of volcanic, volcaniclastic and tuffaceous rocks believed to be present in the eastern slopes of the proposed No. 2 Pit was not present within the confines of the No. 1 Pit;

(b) the rocks within the sequence in the No. 2 Deposit are of low strengths comparable to those in the No. 1 Deposit. However, the steep natural slopes in the east indicate that some stronger materials may be present within the sequence; these could be interbedded intrusive volcanic rocks but could alternatively be cappings of later extrusive basalts or lahar deposits;

(c) the coal being steeply anticlinal and faulted on either flank, would be present largely in the pit bottom and slopes would be cut predominantly in Tertiary sediments other than coal;

(d) extensive instability has occurred in the geological past from the escarpment on the east side of the proposed pit. Some of the slide debris has been highly mobile and evidence of bentonitic materials has been obtained from near the backscarp of the slide at the head of White Rock Creek area;

(e) there is no justification for assuming higher rock shear strengths than were previously measured for the No. 1 Deposit rocks. For pit planning purposes the operative shear strengths for the various materials recommended in Golder Associates 1978 Report should be used. The volcanic, volcaniclastic tuffaceous deposits should be treated as for the Coldwater Formation and slopes of 20 degrees are recommended until the distribution of the stronger elements can be ascertained;

(f) the ground water regime is dominated by recharge on the higher slopes with discharge on the lower slopes near the creek. A major exception is the discharge area within the slide zone above Fish Hook Lake. The highly calcareous spring deposits in this area suggest the possible proximity of limestones at depth along the conjectural Boundary Fault;

(g) in the Medicine Creek and Coldwater Formations, it is likely that significant ground water pressures could be present but that they might be relieved on excavation by stress relief. Ground water pressures in the volcanic, volcaniclastic tuffaceous deposits are likely to be complex due to the presence of interbeds of higher permeability. The effects of excavation on these pressures cannot be assessed at this stage, but local depressurization by dewatering might be possible;

(h) areas suitable for dumping waste exist in Anderson Creek, Ambusten Creek but not in White Rock Creek where extensive past instability is an inhibiting factor. In addition, if the Alternative A water supply reservoirs were adopted, the No. 1 Pit waste dump in Medicine Creek could be extended uphill without the construction of further retaining embankments. The interaction between the Ambusten Creek dump and the proposed pit would need to be carefully investigated;

(i) a major program of site investigation would be needed to study the basic geology of the scheme, the hydrogeological aspects of both pit and dumps, to obtain samples for testing, to carry out in situ strength tests and to obtain hydraulic parameters of the materials and to produce an inventory of construction materials.

8.0 RECOMMENDED EVALUATION PROGRAM

8.1 General

The work which would be needed to determine the geotechnical and hydrogeological feasibility of mining the coal of the No. 2 Deposit is itemized below. It is anticipated that this program would identify those geotechnical factors which would be of significance in the economics of pit development. It would not recommend engineering design solutions although a range of alternatives would be identified.

A subsequent program for final design would be directed towards solving the particular geotechnical design problems. Obviously at present, whilst the geotechnical factors have not as yet been identified, the costing of a design program must be imprecise.

Any geotechnical evaluation program must be based on a mine plan that will have enough flexibility to permit ongoing investigation and redesign as new information on the pit becomes available. Holes drilled for the No. 2 Pit would on average be deeper than for the No. 1 Pit. This is a result of the presence of the high escarpment on the east side of the pit area.

8.2 Feasibility Investigation

8.2.1 Geotechnical

It is recommended that the following geotechnical work be carried out:

Open Pit

(a) Investigation of the interim and final slopes of the proposed pit along radial sections. The locations of the suggested holes are shown on Figure 10.

(b) Investigation with "infill" holes of those areas of the pit where, geology is inadequately known.

(c) Investigation of the interaction between a waste dump in Ambusten Creek and the eastern slopes of the proposed pit.

(d) Investigation of the steeper slopes beyond the west side of the pit.

(e) Search for construction materials within the pit.

(f) Log and obtain samples from representative coal exploration holes.

Waste Dumps

(g) Investigation of the proposed embankment at Ambusten Creek.

(h) Examination of the glacial deposits which would underlie the Ambusten Creek dump, also part of the hydrogeological program (see Figure 7).

(i) Investigation of the proposed embankment at Anderson Creek (see Figure 6).

(j) Investigation of the geology in the watershed at the eastern end of the Medicine Creek waste dump (see Figure 8).

Laboratory Testing

(k) A continuing program of strength testing of the materials sampled from the No. 2 Pit would be needed.

8.2.2 Hydrogeological

The program for the ground water investigation necessary to establish feasibility of the No. 2 Deposit would be as follows:

(a) Field investigations to monitor flow measurements at active discharge locations, obtain samples for water chemistry and monitor stream flows where applicable to determine ground water storage possibilities.

(b) Install piezometers in representative parts of the formations to measure ground water pressures, permeabilities and to investigate flow systems.

(c) Carry out pumping tests in screened developed wells in the surficial materials in the valley bottom at the perimeter of the proposed pit to assess potential inflow to the mine.

(d) Carry out pumping tests in screened developed wells in representative bedrock materials to determine hydraulic characteristics for dewatering and depressurization considerations, especially on the east side of the pit.

(e) Install piezometers and carry out permeability tests in coal exploration holes.

Much data will become available from the mining of the No. 1 Deposit. If the No. 2 Deposit geotechnical and ground water investigation take place after the onset of mining, the thrust of the work might take a somewhat different direction. Also the degree to which it can be shown that the geology of the deposits is similar, will affect the number of assumptions that can be made about the No. 2 Deposit geotechnics. For example, it might not be necessary to test pump the west side of the No. 2 Pit if the materials can be shown to be of equally low permeability to those further north. Because of the high cost of the proposed ground water investigations and the limitations on their effectiveness in low permeability formations further thought should be put into the design of the program, especially item (d) above, before its implementation. Some field research and development might yield useful results.

8.3 Design Stage Investigation

It is anticipated that the design stage investigations would comprise further definitive geotechnical drilling for the purposes of geology and obtaining samples, further instrument installation and pump testing, laboratory strength testing and other more particular studies for mine design purposes that cannot be defined at this stage.

8.4 Cost of Further Evaluation Program

8.4.1 Geotechnical (Feasibility Stage)

The following are the costs of the recommended contracting and consulting engineering works for the further program. They are based on current drilling rates for similar work in B.C. and are in 1980 dollars.

		$
(a)	Core Drilling	
	Pit slope investigation - 4400 m in 19 holes @ $150/m	660,000
	Ambusten Creek Waste Dump - 700 m in 5 holes @ $150/m	105,000
	Anderson Creek Waste Dump - 400 m in 9 holes @ $150/m	60,000
	Medicine Creek Waste Dump - 100 m in 2 holes @ $150/m	15,000
(b)	Rotary Soils Drilling	
	Ambusten Creek Waste Dump - 420 m in 14 holes @ $ 20/m	8,400
(c)	Laboratory Testing	
	Estimated lump sum	50,000
(d)	Geotechnical Engineering - Planning, Supervision, Analysis Reporting	510,000
	Total estimated costs - Feasibility Stage - Geotechnical Investigation	1,408,400

8.4.2 Hydrogeological (Feasiblity Stage)

(a)	Piezometer Installation	
	Assume an average of 2 piezometers in each of 35 geotechnical holes	70,000

(b) Pump Testing

Surficial deposits - 2 installations comprising one pump well and 2 observation wells	44,000
2 pumping tests	12,000
Rock - 3 installations of one pump well and 3 observation wells	270,000
3 pumping tests	18,000
Hydrogeological engineering - planning supervision, analysis and reporting	115,000
Total estimated costs feasibilty stage hydrogeological investigation	$ 529,000

(It is possible that some of this work could prove to be more appropriately done at the design stage).

8.4.3 Geotechnical and Hydrogeological (Design Stage)

For the reasons given above, an accurate figure cannot be given at present for design stage contracting and engineering costs. However, using the No. 1 Deposit as an analogy, it would be prudent to allow a minimum budget figure of $750,000 for this work. Consultants' costs would need to be added to this figure in a similar proportion to that for the feasibility stage.

We thank you for the opportunity of carrying out this interesting study. We should be pleased to discuss any parts of this work which might need expansion.

Yours very truly,

GOLDER ASSOCIATES

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GER/NAS/bn

802-1585

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LEGEND:

Formations encountered below surficials in drillholes

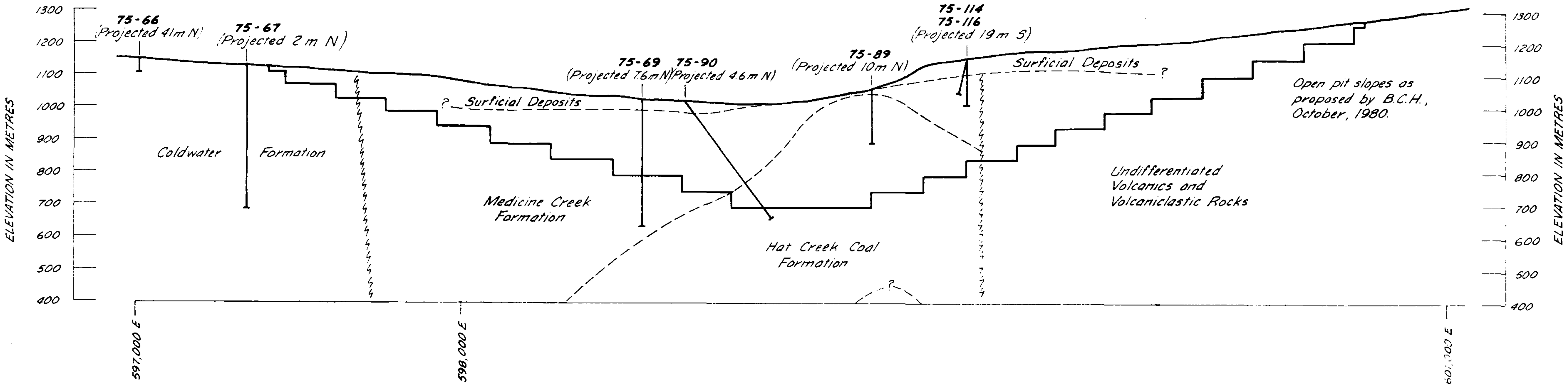
- Medicine Creek Formation (Tcu)
- Hat Creek Coal Formation (Tcc)
- Coldwater Formation (Tcl)
- Undifferentiated Volcanics or Volcaniclastics
- Kamloops Volcanics ? - Dacite
- Slide Debris - Stable
- Slide Debris - Marginally Stable
- Slide Debris - Active
- Fault Traces (Hypothesized) within pit vicinity
- 60 Drillhole location & number

SCALE: 1:20,000

Golder Associates		
B.C. HYDRO & POWER AUTHORITY		
HAT CREEK GEOTECHNICAL STUDY		
No. 2 DEPOSIT LOCATION OF SLIDE ZONES AND FAULTS IN PROPOSED PIT		
Drawn: B.A.D.	Checked:	Reviewed:
Date: DEC. 1980	Scale: As shown	Figure: 1

HAT CREEK PROJECT
DIAGRAMMATIC GEOLOGICAL SECTION
THROUGH NO. 2 COAL DEPOSIT

Figure 2



SECTION ALONG 5,617,870 N

Scale 1:5000 Natural

LEGEND:

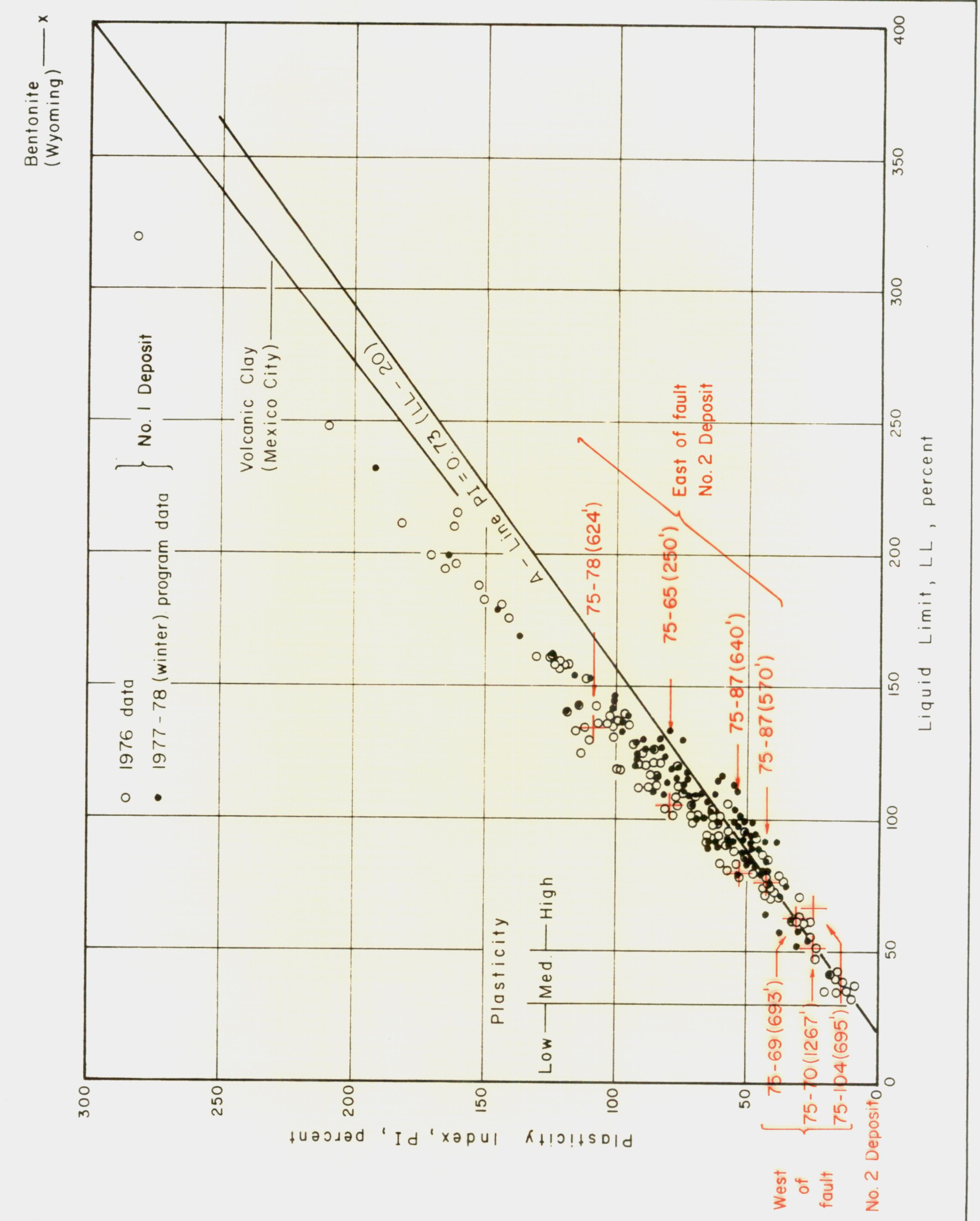
Fault

Geological boundary

Drawn: BAD
Reviewed:
Date: Dec. '80

PLASTICITY CHART
TERTIARY SEDIMENTS

Figure 3

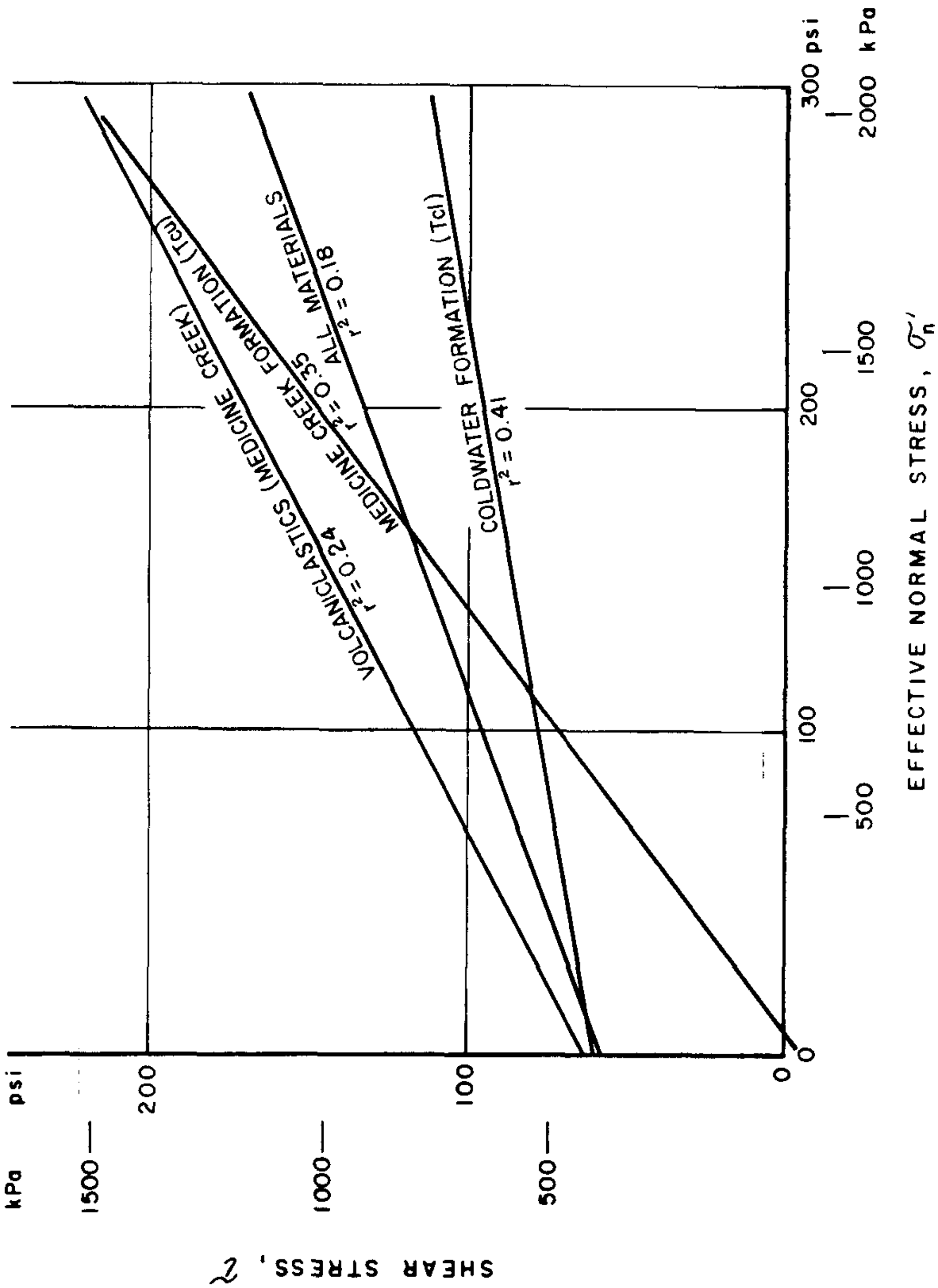


Project No. 802-1585 Drawn BAD Reviewed SR Date Dec '80

Golder Associates

MOHR ENVELOPES OF EFFECTIVE STRESS TERTIARY CLAYSTONE / SILTSTONE SEDIMENTS

Figure 4



Project No 802-1585 Drawn BAD Reviewed Date DEC. '80

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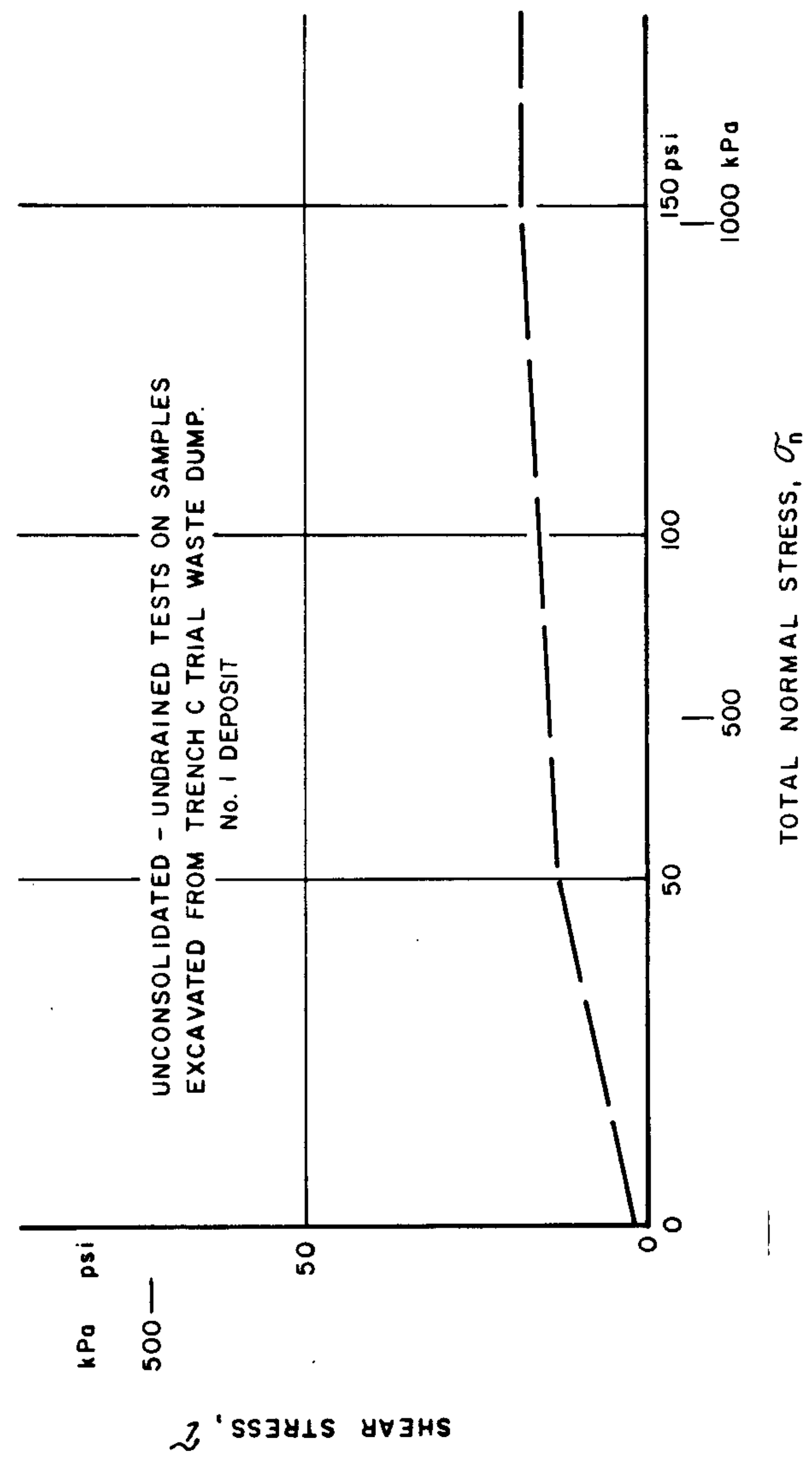
MOHR ENVELOPE OF TOTAL STRESS
CLAY - CUT WASTE DUMP MATERIAL (REMOULDED)

Figure 5



Project No. 802-1585 Drawn BAD Reviewed Date DEC. '80

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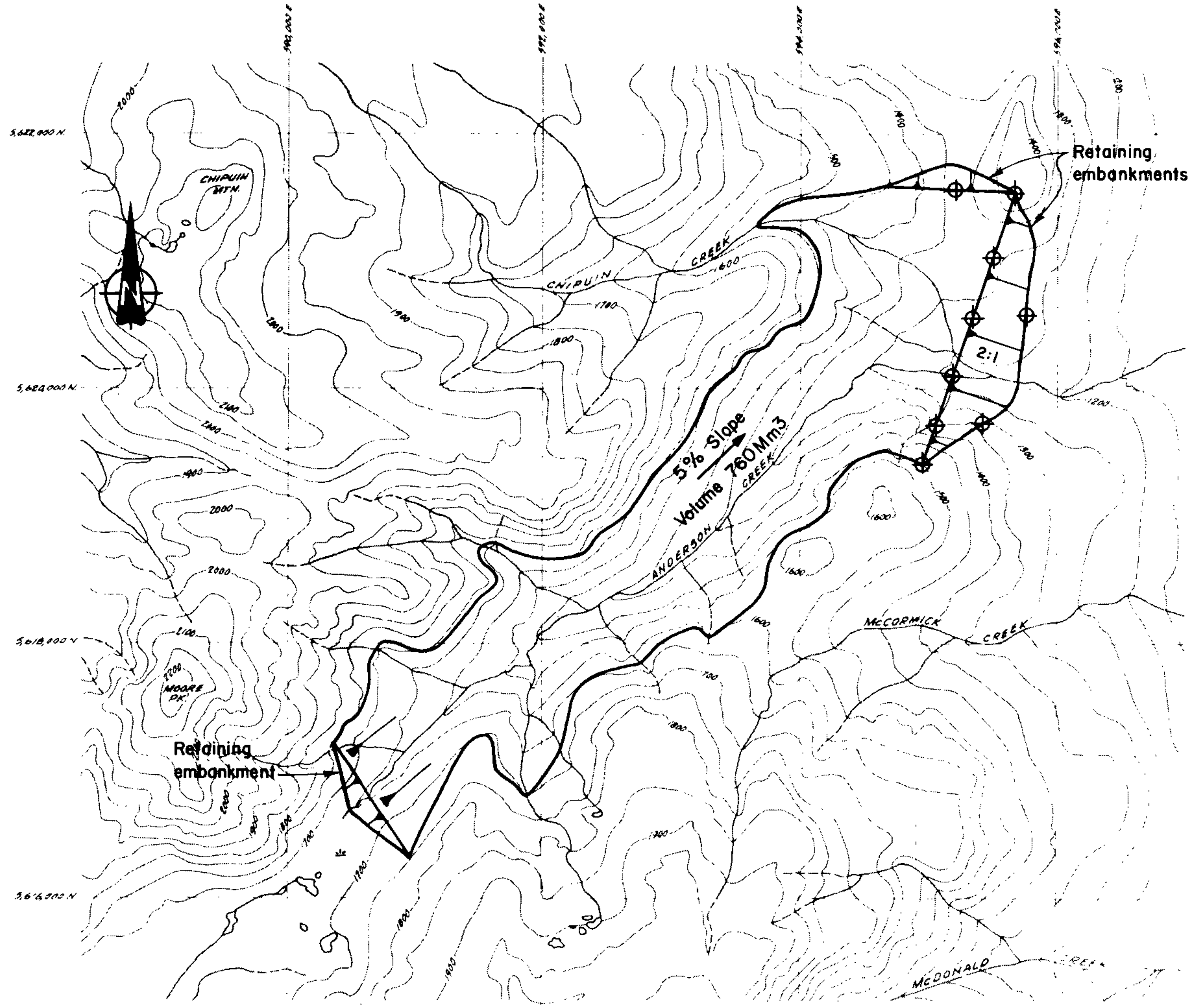

LEGEND

⊕ Proposed holes for geotechnical investigation.

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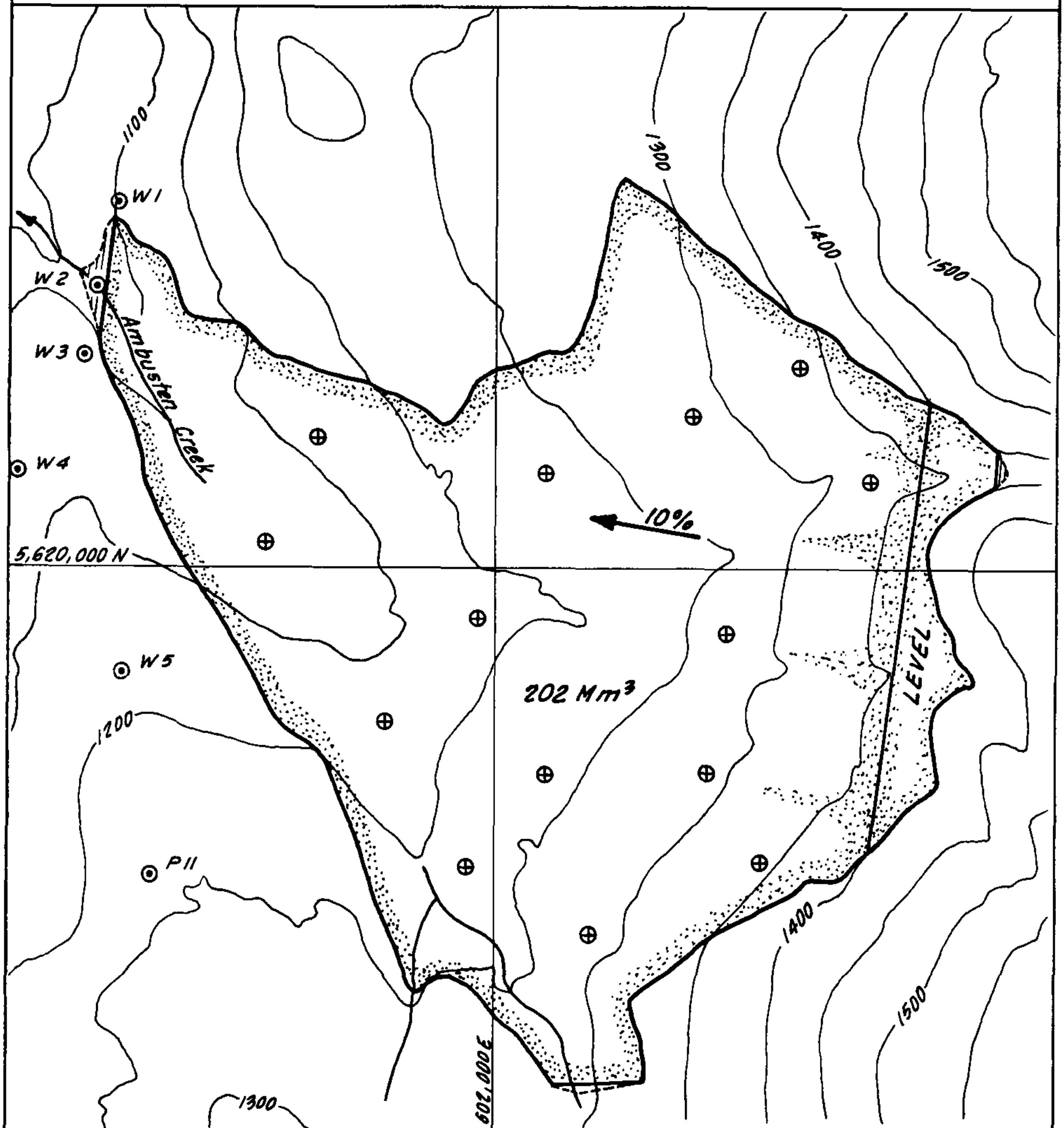
B.C. HYDRO & POWER AUTHORITY

HAT CREEK GEOTECHNICAL STUDY

NO. 2 DEPOSIT
PROPOSED ANDERSON CREEK
WASTE DUMP

Drawn	R.D.	Checked	N.A.S.	Reviewed	
Date	Mar. '81	Scale	1 : 40,000	Figure	6

PROPOSED AMBUSTEN CREEK WASTE DUMP **Figure 7**



PROPOSED INVESTIGATIONS

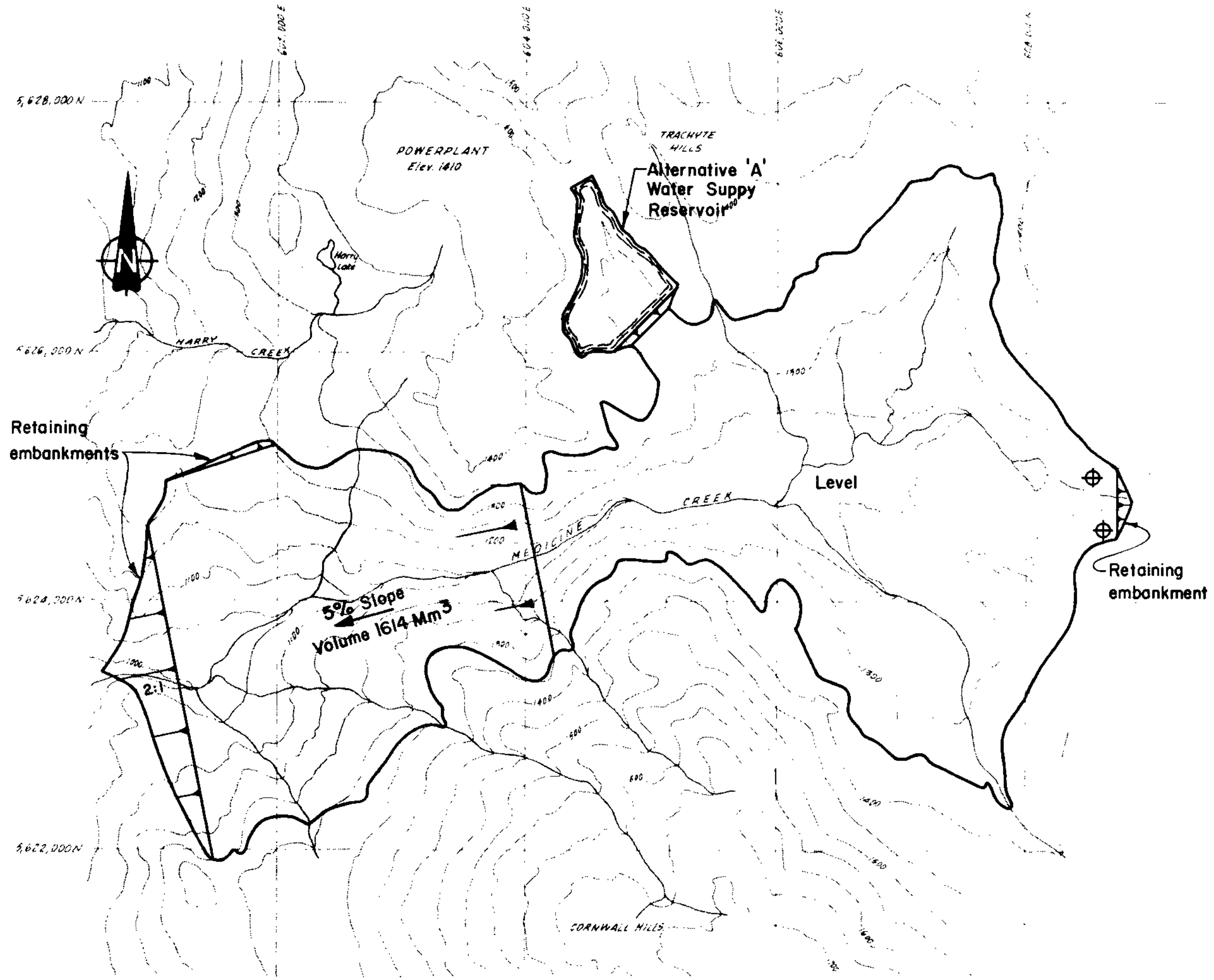
Scale 1:20,000

⊕ Holes to investigate surficial deposits.

⊙W4 Waste dump cored holes.

⊙P11 Pit slope cored holes.

Project No. .... Drawn .... Reviewed NAS Date ....



LEGEND

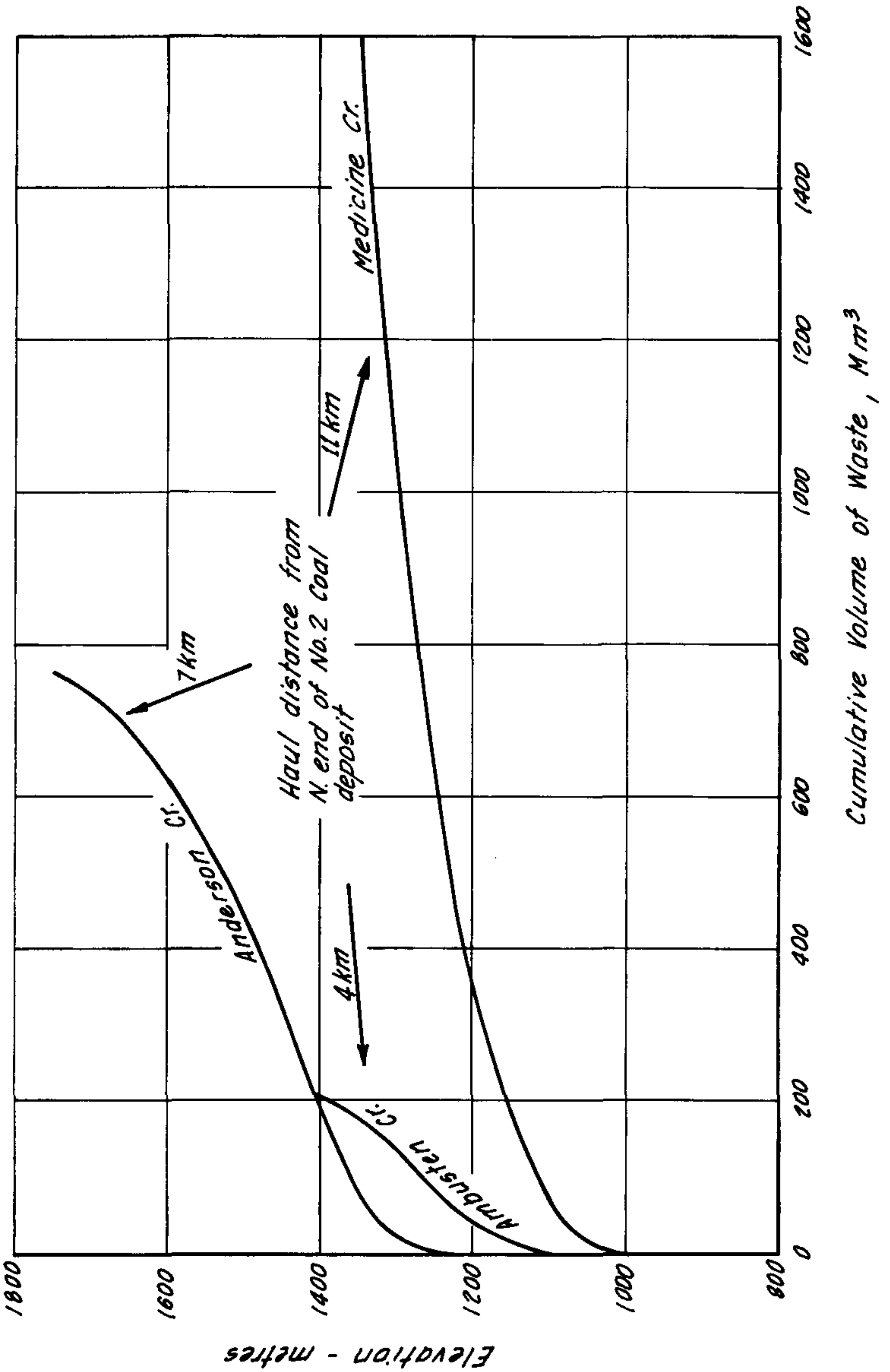
⊕ Proposed holes for geotechnical investigation.

NOTE

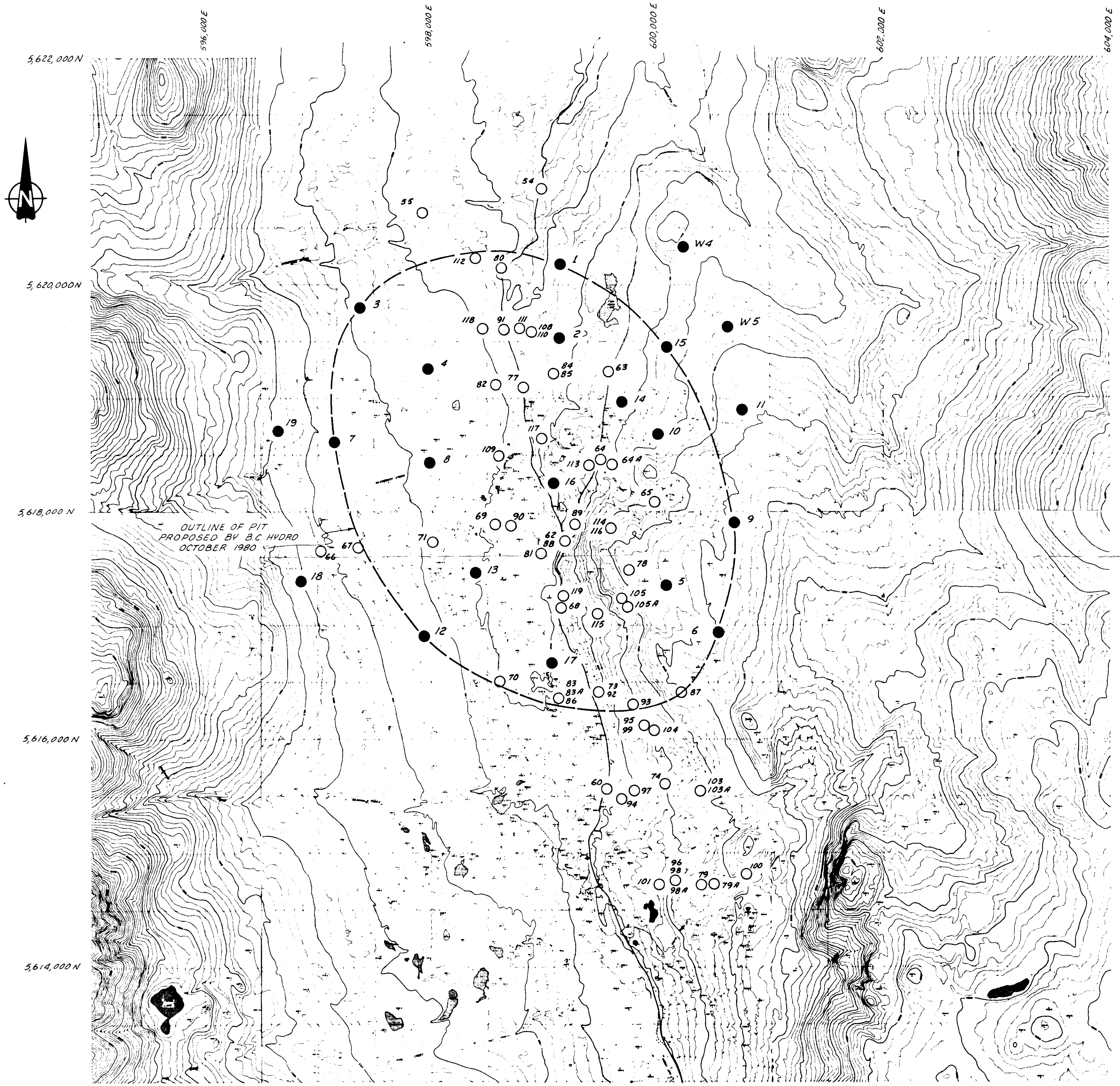
Volume shown is total volume including 770 Mm^3 of waste from No.1 Pit.

Golder Associates		
B.C. HYDRO & POWER AUTHORITY		
HAT CREEK GEOTECHNICAL STUDY		
NO. 2 DEPOSIT PROPOSED EXTENDED MEDICINE CREEK WASTE DUMP		
Drawn R. D.	Checked N.A.S.	Reviewed
Date Mar. '81	Scale 1:40,000	Figure 8

VOLUMES OF WASTE DUMPS **Figure 9**



Project No. 802-1585 Drawn ___ Reviewed ___ Date Oct.'80



SCALE: 1:20,000

LEGEND:

- ● 5 Drillholes proposed for geotechnical investigation.
- ○ 77 Existing drillholes
- ● W4 Drillholes for Ambusten Creek Waste Dump interaction investigation.

Golder Associates		
B.C. HYDRO & POWER AUTHORITY		
HAT CREEK GEOTECHNICAL STUDY		
LOCATION OF PROPOSED DRILLHOLES FOR GEOTECHNICAL INVESTIGATION		
Drawn: B.A.D.	Checked:	Reviewed: [signature]
Date: DEC. 1980	Scale: As shown	Figure: 10