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KLOHN LEONOFF
CONSULTING ENGINEERS

Our File: PB 3169 0101

September 12, 1986

Cassiar Mining Corporation
2000 - 1055 West Hastings Street
Vancouver, British Columbia
V6E 3V3

Mr. Peter C. Jones
Executive Vice-President

Clinton Creek Asbestos Mine
Abandonment Plan

Dear Mr. Jones:

We are pleased to provide you with ten (10) copies of an Abandonment Plan for the Clinton Creek Asbestos Mine.

Yours very truly,

KLOHN LEONOFF LTD.

for Peter C. Lighthall, P.Eng.
Project Manager

Encl.

PCL/ld

ABANDONMENT PLAN

PROJECT: CLINTON CREEK ASBESTOS MINE

LOCATION: CLINTON CREEK, YUKON TERRITORY

CLIENT: CASSIAR MINING CORPORATION

OUR FILE: PB 3169 0101 SEPTEMBER 12, 1986

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APPENDICES

DRAWINGS

1. SUMMARY

The Clinton Creek asbestos mine was operated by Cassiar Asbestos Ltd. (presently Cassiar Mining Corporation) from 1968 to 1978. Cassiar operated the mine under the terms of a water license administered by the Yukon Territory Water Board. This water license, which presently has an expiry date of September 30, 1987, requires that a rehabilitation and abandonment plan be submitted to the Board for approval.

Cassiar considers that work required for abandonment of the mine is essentially complete. The following work has been carried out up to the present time:

(a) Removal of all structures and final cleanup of the Clinton Creek townsite;

(b) Burning, dismantling and burial of the concentrator facilities, except for some mass concrete structures (Brinco Mining Limited, 1985);

(c) Removal of all mobile and fixed mining equipment, with the exception of the primary crusher, one shovel and one drill;

(d) Construction of rock-lined channels to convey Clinton Creek and Wolverine Creek over the waste dump and tailings piles, respectively, including repair of a failure which occurred following initial channel construction over the waste dump;

(e) Survey monitoring since 1977 to show the rates of movement of the waste dump and tailings piles;

(f) Hydro seeding of the waste dump, tailings piles and specific areas of the townsite was performed in 1979, although with limited success on the waste dump or the tailings pile.

(g) Environmental and engineering studies and water monitoring to predict and measure the impacts on lower reaches of Clinton Creek, Forty Mile River and the Yukon River of streamflow over the waste dumps and tailings piles.

Minor work to complete abandonment remains for 1986. These items include:

(a) Removal of culverts at the road crossing Clinton Creek at the upper end of the waste dump channel; and

(b) Removal of miscellaneous equipment as described in Brinco Mining Limited (1985).

The Clinton Creek waste dump and tailings piles are considered to be in suitable condition for final abandonment. The performance of both the waste dump and tailings piles has been as expected over recent years. The waste dump channel repairs completed in 1984 have performed satisfactorily, while the ongoing processes of dump movement, slight down-cutting and channel armouring are continuing on downstream sections of the channel. The south tailings lobe continues to move at a moderate rate and movements of the north lobe appear to be slowing down. The toe of the north lobe has reached a relatively flat configuration such that occurrence of a large, rapid failure would not be anticipated. There do not appear to be any reasonable stabalizing measures possible prior to final abandonment, with the exception that the culverts should be removed from the waste dump channel inlet prior to abandonment. Removal is recommended in order to prevent problems resulting from possible future plugging of the culverts. The expected ongoing erosion following abandonment of the site will result in some limited deposition of coarse material in Clinton Creek downstream of the confluence with Wolverine Creek. The lower reaches of Clinton Creek are expected to be essentially unaffected. It is recommended that the site be finally abandoned in 1986.

2. INTRODUCTION

2.1 GENERAL

This report presents a plan for abandonment of the minesite, waste dumps and tailings piles at the Clinton Creek asbestos mine, located 97 km northwest of Dawson City, Yukon Territory. The mine is adjacent to Clinton Creek which drains into the Forty Mile River, 4.8 km upstream from its confluence with the Yukon River. The open pit mine operated from 1968 to 1978, at which time economic ore reserves were exhausted.

The open pit was located on a hilltop on the south side of Clinton Creek, and ore was transported by a cable tramway across the Clinton Creek valley to the concentrator located on a flat-topped ridge to the north of Clinton Creek, Drawing No. A-1012. Waste rock was placed in an area adjacent to the open pit by dumping over the slope which forms the south valley wall of Clinton Creek. Tailings from the concentrator were deposited over the western slope of Wolverine Creek, a small tributary to Clinton Creek. The waste dump and tailings piles are shown in Photos 1 through 4 in Appendix I.

This abandonment plan is submitted to support an application from Cassiar Mining Corporation to the Yukon Territory Water Board to abandon the Clinton Creek mine property, terminate the water license and have Cassiar's water license security bond released. A water license was granted to Cassiar Mining Corporation, effective October 1, 1977, under the terms of the Northern Inland Waters Act and Regulations. The license originally had an expiry date of September 30, 1982. On September 21, 1982, the Yukon Territory Water Board extended the water license to September 30, 1987. It should be noted that Cassiar Mining Corporation did not apply for this license extension.

The proposed abandonment plan for the Clinton Creek mine focuses on the removal of minesite facilities, and assessment of the long-term stability and corresponding impact of the waste dump and tailings piles on the Clinton Creek watershed. Abandonment of minesite facilities is discussed in Section 3; abandonment of the waste dump and tailings piles is discussed separately in Sections 4 and 5, respectively; and assessment of the environmental impact of the proposed plan is presented in Section 6.

Klohn Leonoff Ltd. has served as Consultant on the stability aspects of the waste dump and tailings deposit at the Clinton Creek mine since January, 1983. In this capacity, Klohn Leonoff has made annual site visits in June 1983, June, 1984, June, 1985 and July, 1986; prepared designs and supervised site work for repair of the Clinton Creek waste dump channel; reviewed monitoring data; considered alternative measures for erosion protection and stabilization of the waste dump and tailings piles; and carried out hydrology and sediment transport studies to predict the long-term impacts of abandonment.

2.2 AVAILABLE REPORTS

Information and analyses presented as part of the abandonment plan were extracted from engineering and environmental reports prepared for the Clinton Creek mine since shutdown in 1978. A chronological summary of those reports which are in Cassiar's and Klohn Leonoff's files is given below:

2.2.1 Engineering Analysis

Golder Associates (1978), Clinton Creek Operations, Mine Waste Dump and Tailings Pile. Report for Cassiar Asbestos Corporation Limited.

Klohn Leonoff Ltd. (1983a), Report on Mine Waste Dumps, Clinton Creek Asbestos Mine. Prepared for Brinco Mining Limited.

Klohn Leonoff Ltd. (1983b), Report on 1983 Remedial Works, Mine Waste Dumps, Clinton Creek Asbestos Mine. Prepared for Brinco Mining Limited.

Klohn Leonoff Ltd. (1984a), Report on Wolverine Creek Tailings Piles, Clinton Creek Asbestos Mine. Prepared for Brinco Mining Limited.

Klohn Leonoff Ltd. (1984b), Report on 1984 Site Visit, Clinton Creek Mine Waste Dump and Tailings Piles. Prepared for Brinco Mining Limited.

Hardy Associates Ltd. (1984a), Report on Clinton Creek Asbestos Mine, Waste Dump Area, Review of Rehabilitation Measures. Prepared for Indian and Northern Affairs, Yukon Water Board.

Hardy Associates Ltd. (1984b), Report on Wolverine Creek Tailings Piles, Clinton Creek Asbestos Mine, Review of Rehabilitation Measures. Prepared for Indian and Northern Affairs, Yukon Water Board.

Klohn Leonoff Ltd. (1984c), Letter report, October 22, 1984, on Clinton Creek Abandonment, Cost Estimates of Schemes Proposed by Hardy Associates. Prepared for Brinco Mining Limited.

Klohn Leonoff Ltd. (1984d), Letter report, December 7, 1984, Clinton Creek Asbestos Mine, Waste Dump Abandonment. Prepared for Brinco Mining Limited.

Klohn Leonoff Ltd. (1985a), Letter report, February 28, 1985. Clinton Creek Asbestos Mine, Wolverine Creek Tailings Piles - North Lobe, Stability Analysis for Toe Flattening. Prepared for Brinco Mining Limited.

Klohn Leonoff Ltd. (1985b), Letter report, February 28, 1985. Clinton Creek Mine, Wolverine Creek Tailings Piles, Assessment of Rock Lined Channel. Prepared for Brinco Mining Limited.

Klohn Leonoff Ltd. (1985c), Report on 1985 Site Visit, Clinton Creek Asbestos Mine Waste Dump and Tailings Piles. Prepared for Brinco Mining Limited.

Brinco Mining Limited (1985), Construction Summary, 19 August 1985 to 2 September 1985 on Clinton Creek Abandonment, 1985 Cleanup and Reclamation, Clinton Creek, Yukon.

Klohn Leonoff Ltd. (1986), Report on 1986 Site Visit, Clinton Creek Asbestos Mine Waste Dump and Tailings Piles. Prepared for Cassiar Mining Corporation.

2.2.2 Environmental Assessment

Environmental Protection Service (1978), An Environmental Assessment of the Effects of Cassiar Asbestos Corporation on Clinton Creek, Yukon Territory. Regional Program Report No. 79-13.

EVS Consultants Ltd. (1981), Assessment of the Effects of the Clinton Creek Mine Waste Dump and Tailings, Yukon Territory. Prepared for Cassiar Resources Limited, Vancouver, British Columbia.

Klohn Leonoff Ltd. (1985d), Report on Sediment Transport Analysis, Clinton Creek Asbestos Mine, Wolverine Creek Tailings Piles. Prepared for Brinco Mining Limited.

Norecol Environmental Consultants (1985), Letter report on Clinton Creek Asbestos Mine Aquatic Impact Assessment. Included as Appendix I of Klohn Leonoff (1985d).

2.2.3 Seismicity

Stevens, A.E. and Milne, W.G. (1973), "Seismic Risk in the Northern Yukon and Adjacent Areas". Report prepared by Division of Seismology, Earth Physics Branch, Department of Energy, Mines and Resources for the Environmental-Social Program, Northern Pipelines. Information Canada Cat. No. R72-10973.

2.3 SEISMICITY

Clinton Creek is located in an area of low seismicity. Stevens (1973) produced maps showing contours of acceleration levels for various return period. The map for a 100-year return preiod shows an expected acceleration equal to 6% of the acceleration due to gravity (g) at Clinton Creek. This is a relatively low level of earthquake shaking. The nearest recorded earthquakes have been at least 300 km from Clinton Creek. From this data, it is concluded that the probability is very low that earthquakes will have significant impact on the stability of the waste dump or tailings piles.

3. ABANDONMENT OF MINESITE FACILITIES

Cassiar Mining Corporation considers that work required for abandonment of minesite facilities is essentially complete. The following tasks have been completed through July, 1986:

(a) removal of all structures and final cleanup of the Clinton Creek townsite;

(b) burning, dismantling and burial of the concentrator facilities, except for some concrete structures (Brinco Mining Limited, 1985);

(c) removal of all mobile and fixed mining equipment with the exception of the primary crusher, one shovel and one drill.

Removal of the remainder of the minesite facilities and equipment is scheduled for 1986.

4. CLINTON CREEK WASTE DUMP

4.1 DESCRIPTION

Waste rock from the open pit was disposed of by dumping over the slope which forms the valley wall on the south side of Clinton Creek, Drawing No. A-1012 and Photographs 1 and 2. Originally, the valley floor was flat-bottomed with a width of about 800 ft, and Clinton Creek meandered along the valley bottom. As the toe of the dump reached the valley floor, it began to spread on the low shear strength, presumably ice-rich alluvial soils on the valley floor. As more waste material, primarily argillite, was placed on the dump, spreading of the dump continued until it filled the entire valley bottom.

The total quantity of waste rock in the dump is estimated at about 70 million tons. The gradation of the dump material is primarily sand and gravel sized particles, but occasional cobbles and large boulders of relatively durable rock are found throughout the waste dump.

In its final configuration, when waste dumping stopped in 1977, the waste rock impounded a body of water now known as Hudgeon Lake. The depth of water in Hudgeon Lake is about 85 ft and its surface area is about 180 acres. Outflow from the lake currently passes through four 5 ft diameter culverts into the Clinton Creek channel which flows across the waste dump. Clinton Creek occupies the north side of the valley, where the creek has incised a channel bounded by waste dump material on the right and the valley wall on the left (directions relative to observer facing downstream). The channel has an overall gradient across the dump of about 4.5%.

15300 acre ft
$19 \times 10^6 m^3$

4.2 MONITORING SINCE SHUTDOWN

A monitoring program for the waste dump has been implemented since completion of active dumping in 1977. The purpose of the monitoring program is to provide data with which the long-term stability of the waste dump can be assessed and abandonment options considered. Results of monitoring show that since the completion of dumping, movements of the waste dump have continued as a slow creep from horizontal spreading of the dump on its foundation.

Seven monuments on the dump surface were surveyed annually for vertical and horizontal location and, in addition, six cross-channel reference lines were surveyed for horizontal movement. The locations of the monitoring points and cross-channel reference lines are shown on Drawing No. D-1006A. From the monitoring records, the average annual movements in a horizontal direction toward the north valley wall are as shown in Table 1.

TABLE 1

*AVERAGE ANNUAL HORIZONTAL MOVEMENTS OF WASTE DUMP (ft/year)

	Cross-Channel Reference Lines	**Monitoring Points
1976-77	-	3.2
1977-78	4.0	4.2
1978-79	-	-
1979-80	3.0	-
1980-81	2.4	3.6
1981-82	2.2	2.5
1982-83	1.7	2.6
1983-84	1.5	1.8
1984-85	1.3	1.6
1985-86	1.0	1.2

* The averages shown do not include all of the same sections for each year, but are a reasonable indication of the annual trends.

** Includes points 20A, 21A and 22A.

The data in Table 1 show clearly that movements of the dump have decreased since waste dumping was halted in 1977. All individual horizontal movement rates for the year 1985-86, are less than 1.5 ft/year.

Longitudinal survey profiles of the Clinton Creek channel across the waste dump were obtained in 1983, 1984 and 1986, Drawing No. D-1006B. No measurable downcutting was evident from these three years of survey. Examination of photographs taken over a number of years confirms that general downcutting of the Clinton Creek channel is not occurring at a fast rate. Some local bed erosion of the channel is apparent from comparison of the three profiles. However, resistance to widespread downcutting and bed erosion of the channel across the dump is provided both by the bedrock exposed on the left bank and the presence of large boulders in the dump material, which form a self-armouring bed layer, as does occur in a natural stream.

4.3 REMEDIAL WORKS SINCE SHUTDOWN

Because of the ongoing movement of the waste dump there is a continual squeezing of the stream channel along the north side of the dump and erosion by the stream at the toe of the dump. Remedial works have been undertaken on two occasions since shutdown to stabilize Clinton Creek across the dump, and to minimize erosion by Clinton Creek. One design recommendation for Clinton Creek was proposed by Golder Associates in 1978 and it was constructed in 1981. A second stabilization plan was prepared by Klohn Leonoff in 1983 and it was constructed in the fall of 1983 and summer of 1984.

The recommendation by Golder Associates (1978) was to construct a rock lined section, incorporating energy-dissipating weirs, near the upstream end of the channel to act as a barrier against progressive downcutting. This section of rock weirs was constructed in 1981. During spring runoff in 1982, Clinton Creek escaped the channel formed by the rock lined section and eroded a large scarp in native soil on the left bank (relative to an observer facing downstream). Klohn Leonoff (1983a) prepared a design for repair and modification of this rock-lined section. The design included backfilling of the eroded channel, which was then bypassing the weir section, and placing geotextile filter and riprap along the left bank of the channel to protect the erodible zone. Also, the revised design of the riprapped channel section provided for heavy riprap and geotextile filter along the left bank, a riprap apron at the outlet culverts from Hudgeon Lake and riprap lining without filter on the right bank. A sketch of the site prior to these remedial works, and design recommendations for the channel prepared by Klohn Leonoff are shown on Drawing No. D-1002A. Photographs of the site before and after the 1983 stabilization measures were implemented on Clinton Creek are shown in Appendix I, Photographs 5 and 6.

This section of the Clinton Creek channel across the waste dump has been stable since 1983 and has withstood a relatively high spring runoff flow in 1985.

4.4 ABANDONMENT STRATEGY

Development of an abandonment plan for the waste dump requires that its long-term stability be assessed. The primary consideration is whether or not waste dump movement will continue to occur and impinge upon the Clinton Creek channel. If additional movement of the waste dump does not occur, then the existing riprapped channel provides long-term stability for Clinton Creek across the dump. If waste dump movement continues, two questions must be addressed:

(a) What is the effect of dump movement on the stability of the Clinton Creek channel; and

(b) What is the effect of dump movement on downstream conditions in the Clinton Creek watershed.

These concerns are addressed based on engineering analyses and monitoring undertaken since mine shutdown.

As shown in Table 1 in Section 4.2, monitoring of the waste dump indicates movement has occurred since mine shutdown. Movement of about 4 ft was measured initially for 1977-78, while measurements in recent years are much less, averaging about 1.4 ft for 1984-85.

Golder Associates in their report of July, 1978 considered various strategies for treatment of the Clinton dump. Among these strategies was a scheme referred to as the "Cadillac" treatment, which would increase the Factor of Safety of the dump against base sliding to 1.25. The scheme involved backfilling of the Clinton Creek channel and constructing a raised, riprap-lined channel atop the present channel. This proposal included placement of 460,000 yd^3 of waste dump fill and 21,000 yd^3 of riprap as well as other miscellaneous works. The cost, in 1978 dollars, was estimated at $590,000. This would probably equate to about twice that amount, or over $1 million, in 1986 costs. Golder did not recommend implementation of this scheme because they considered the cost excessive. Instead, Golder recommended the less costly scheme of providing a rock-lined section at the head of Clinton Creek channel to prevent rapid downcutting. This scheme, discussed previously in Section 4.3, was implemented and subsequently modified under the direction of Klohn Leonoff.

Hardy Associates (1984a) prepared a proposal for permanent stabilization measures for the Clinton Creek channel and waste dump area in a report to the Yukon Territory Water Board. An overview of Hardy's scheme is presented below together with an assessment by Klohn Leonoff (1984c, 1984d) of the proposed plan.

Hardy recommended that the dump be stabilized by placing a toe support fill in the present Clinton Creek channel and constructing a new riprap-lined channel over the top of the fill. It was estimated that a suitable toe support fill would require raising the elevation of the channel across the waste dump by about 15 m above its current level. This increase in elevation of the channel would cause a corresponding rise in the water level of Hudgeon Lake located immediately upstream.

It is Klohn Leonoff's opinion that the measures proposed by Hardy Associates may increase the hazard of erosion of the waste dump and also would be very expensive. The proposed channel would be constructed in a new location on top of erodible fill material so that any escapement of flow from the channel would probably result in rapid downcutting, leading to complete failure of the channel and massive erosion. The proposed toe support fill might be successful in stabilizing the dump against movements in the cross-valley direction, but the dump may continue spreading laterally. Such spreading movements of the dump could create weaknesses in the relocated channel, leading to escapement of the flow. The flow could also escape the channel by overtopping caused by ice conditions.

Even though Klohn Leonoff is not in agreement with the design concepts proposed by Hardy Associates, Brinco Mining Limited requested that Klohn Leonoff undertake quantity and cost estimations of the proposed scheme. Results of the preliminary calculations were presented in a letter report (Klohn Leonoff, 1984c) and are reproduced in Table 2.

TABLE 2

COST ESTIMATE (1984 DOLLARS) OF WASTE DUMP REHABILITATION MEASURES PROPOSED BY HARDY

Item	Unit	Quantity	Unit Cost	Total Cost
Mob and Demob	l.s.	-	-	30,000
Channel				
Excavation	m^3	40,000	\$ 2.00	80,000
Riprap Filter	m^3	3,000	\$10.00	30,000
Riprap	m^3	10,000	\$50.00	500,000
General Fill-Borrow and Place	m^3	300,000	\$ 1.75	525,000
Engineering				
Topographic Survey	l.s.	-	-	5,000
Investigation for Riprap Source	l.s.	-	-	5,000
Analysis and Design	l.s.	-	-	30,000
Construction Inspection and Survey	l.s.	-	-	50,000
ESTIMATED TOTAL (1984 DOLLARS)				\$ 1,255,000
		SAY		\$ 1,300,000

Klohn Leonoff's cost estimate of \$1.3 million for the proposed stabilization scheme is more than 2.5 times the amount estimated initially by Hardy Associates. Most of the difference in cost can be attributed to:

(a) the estimated volume of required fill is double the fill requirement considered by Hardy Associates;

(b) the excavation required for the permanent channel would be an extra cost, since this material would be stockpiled until completion of the channel and then re-handled to fill the existing channel.

Because of the high cost of the stabilization scheme proposed by Hardy Associates, and because the plan may actually increase the potential over the long-term for channel erosion across the waste dump, Klohn Leonoff does not support the proposed stabilization scheme. Alternatively, an abandonment plan is proposed which allows for some movement of the waste dump towards the Clinton Creek channel and for the subsequent erosion of this material.

The primary reasons for Klohn Leonoff's recommendation of such an abandonment plan are as follows:

(a) Remedial works undertaken in 1983 and 1984 on the Clinton Creek channel have produced a stable channel across the waste dump. Long-term stability is provided by exposed bedrock on the left bank, and the presence of large boulders in the dump material along the right bank, which allows the formation of a self-armouring layer, as occurs in a natural stream.

(b) Even if waste dump movement continues at about its current 1.5 ft per year, the volume of material which could encroach upon Clinton Creek over the 2,300 ft dump length is less than 3,000 yd^3 per year. This volume of material, even if it is all eroded, will not create an adverse environmental impact on downstream watercourses. Details of the sediment transport dynamics of Clinton Creek, and discussion of the environmental impact of the proposed abandonment scheme, are presented in Section 6.

In summary, the Clinton Creek waste dump is considered to be in an acceptable condition for abandonment. No further remedial works or monitoring are recommended. The culverts at the outlet of Hudgeon Lake which pass flow into the Clinton Creek channel should be removed as the final stage of abandonment. Culvert removal is recommended to prevent problems resulting from possible future plugging.

5 WOLVERINE CREEK TAILINGS PILES

5.1 DESCRIPTION

Tailings piles were formed by depositing, with a stacker conveyor, approximately 10 to 12 million tonnes of dry asbestos tailings from the concentrator over the western slope of Wolverine Creek, a small tributary to Clinton Creek (Drawing No. A-1012 and Photographs 3 and 4). The tailings material consists of well-graded, crushed serpentine rock containing some asbestos fibre not recovered in the milling process. Particle sizes range from about 1 inch to approximately 10% passing the #200 sieve size. The angle of internal friction of the tailings (Golder, 1978) ranges from over 40° at low confining stresses to 33° at higher stresses. The deposited tailings form a crust so that dust from the tailings piles does not occur.

From the millsite (elevation 1,950 ft), the valley side slopes northward at an average slope angle of about 16° to 17° to the valley bottom at elevation 1,300 ft. According to Golder (1978), the foundations of the tailings pile consist of a surface organic layer overlying a deposit of silty sandy gravel, followed by weathered argillite bedrock. The depth of silty sandy gravel soils decreases with elevation, from about 40 ft near the top of the slope to being virtually absent near the bottom. The foundation soils are frozen, except where placement of the tailings pile has altered the temperature regime.

The tailings have been stacked in two piles, referred to as the north and south lobes. The south lobe was deposited from startup until 1974, when a failure of the tailings pile occurred and a segment of the pile moved downslope and blocked Wolverine Creek at the valley bottom. Following the failure, the stacker was relocated northward and tailings were placed on the north lobe until the mine shutdown in 1978.

dam break May 13/7 8:30 → 10:30pm

5.2 MONITORING SINCE SHUTDOWN

A program for monitoring the movement of the tailings piles has been in operation since 1976, although none of the existing reference points provide continuous records since that time. Results of monitoring showed that the north tailings lobe was moving rapidly downslope (eg. 77 ft in 1978) and the south tailings lobe, which failed previously in 1974, was still continuing to move slowly downslope. A plan of the tailings piles is shown on Drawing D-1004C, and sections through the piles from 1978 and 1983 are compared on Drawing D-1005A. Monitoring records from the tailings piles are included in reports by Golder (1978) and Klohn Leonoff (1984a, 1984b, 1985c, 1986).

The north tailings lobe has been sliding down the valley slope at a considerable rate. The surface is highly distorted, with a continuous series of scarps from top to bottom. The toe has moved over 400 ft from its position as plotted in 1978, and the tailings have now reached the valley bottom. Movements of monitoring points on the north lobe have reached maximum horizontal rates of over 100 ft/yr on the lower part of the lobe. Movements appear to have reached a peak in 1983 and have slowed to a maximum observed rate of 62 ft/yr in July, 1986. Monitoring points near the top indicated much lower movements of less than 2 ft/yr. The monitor locations and rates of horizontal movement observed in July, 1986 are shown on Drawing D-1004C. Prior to the 1985 site visit, a high steep face existed at the toe of the north lobe. In June, 1985 this face slumped and flattened considerably, so that the potential for rapid movement of the north lobe is reduced.

Movements of the south tailings lobe are considerably lower than the north lobe, but are still significant as the maximum movement rate observed in July, 1986 was 21.5 ft/yr on monitor point 24A. The highest rates are in the lower part of the south lobe. Movements have been increasing slightly over recent years, with the highest rates recorded in 1986. The channel conveying the stream past the toe of the south lobe is being squeezed against the east valley wall by the advancing tailings pile.

5.3 REMEDIAL WORKS SINCE SHUTDOWN

In a report by Golder (1978), the following remedial works for the tailings piles were recommended:

a) Construct a rock-lined channel to convey Wolverine Creek over the tailings deposited in the creek bottom at the 1974 failure;

b) Unload the slope of both the north and south tailings lobes to improve stability of the tailings piles.

The rock-lined channel was constructed in 1978 and inspection by Klohn Leonoff during annual site visits from 1983 to 1985 show the channel has been stable to date. The channel location is shown in plan on Drawing D-1004C and Photograph 4 shows the channel in operation.

The areas selected by Golder (1978) for excavation of tailings from the north and south lobes are shown on Drawing D-1004C and D-1005A. The program of excavation of tailings from the toe areas was unsuccessful in arresting movement of the tailings piles. As demonstrated by results of the monitoring program, the downslope movement of the tailings piles has continued.

5.4 ABANDONMENT STRATEGY

An abandonment plan for the north and south lobes of the tailings pile must assess their long-term stability. In general, the abandonment strategy must consider whether the tailings piles are stable in their present state or, if not, can additional remedial measures be undertaken to make the piles stable permanently. If long-term stability cannot be ensured, then the consequences of further downslope movement of the tailings piles must be assessed.

Results of monitoring the tailings piles show that downslope movement is still occurring, and that self-stabilization of the piles will not occur in the near future. One proposal for undertaking additional remedial works to stabilize the tailings piles was prepared by Hardy Associates (1984b) for the Yukon Territory Water Board. An overview of the scheme, and an assessment by Klohn Leonoff (1984c) of the proposed plan, is included below.

For the Wolverine Creek tailings piles, Hardy was postulating a catastrophic failure of the north tailings lobe into the Wolverine Creek valley. The environmental impact of this postulated catastrophic failure being a sudden rush of water across the south tailings lobe, resulting in heavy downstream sedimentation similar to or worse than that caused by the initial failure of the south tailings lobe. To guard against such a failure, Hardy proposed the construction of a dam built with tailings material at the location of the south tailings lobe. The purpose of the dam being: to stabilize the south lobe by providing additional toe support, and to contain the sudden release of water. The proposed dam would have a crest elevation of 1,425 ft (about 90 ft above the existing Wolverine Creek channel at the toe of the south lobe), a crest width of 20 ft, and 4 horizontal to 1 vertical side slopes. Two 900 mm diameter culverts would be installed in the dam and a rock-lined spillway would be constructed. In addition to the dam, Hardy stated that additional stabilizing fill would be required on portions of the south lobe where the dam is low.

Klohn Leonoff has not undertaken a detailed technical review of the proposal, however, we are concerned with the concept of the stabilization structures' ability to perform maintenance free following mine abandonment. In particular, we feel such key structures as culverts and spillways, especially in an environment where slides may occur upstream, would require a regular monitoring program to ensure they are operating properly. Such a program would be in conflict with acceptable abandonment strategy to leave the site in a state which is maintenance free over the long term.

While Klohn Leonoff was not necessarily in agreement with the design concepts proposed by Hardy Associates, Brinco Mining Limited requested that Klohn Leonoff undertake quantity and cost estimates for the proposed scheme. Results of the preliminary calculations were presented in a letter report (Klohn Leonoff, 1984c) and are reproduced in Table 3.

TABLE 3

COST ESTIMATE (1984 dollars) FOR CONSTRUCTION OF STABILIZING DAM AT TOE OF SOUTH TAILINGS LOBE

Item	Unit	Quantity	Unit Cost	Total Cost
Mob and Demob	l.s.	-	-	30,000
Foundation Preparation	l.s.	-	-	5,000
Drainage Blanket (mill overs)	m^3	8,000	$ 6.00	48,000
Compacted Fill	m^3	260,000	$ 2.25	585,000
Stabilizing Fill	m^3	50,000	$ 1.75	87,500
Spillway				
Excavation	m^3	3,500	$ 2.00	7,000
Riprap	m^3	2,000	$ 50.00	100,000
Riprap Filter	m^3	700	$ 10.00	7,000
Culvert Pipes	m	3380	$ 75.00	28,500
Engineering				
Site Investigation	l.s.	-	-	15,000
Design	l.s.	-	-	25,000
Construction Inspection and Survey	l.s.	-	-	50,000
ESTIMATED TOTAL (1984 dollars)				$ 988,000
			SAY	$1,000,000

Our preliminary cost estimate of $1,000,000 for the proposed stabilization scheme is over three times the figure estimated by Hardy Associates. Most of the difference in cost is due to:

a) our estimate of compacted fill required for the dam is more than twice the volume considered by Hardy;

b) placing a drainage blanket for the dam and riprap for the spillway; and

c) our estimate of the length of culvert required to pass through the dam is nearly double the length estimated initially.

Klohn Leonoff does not support the proposed stabilization scheme for the tailings piles because long-term, maintenance-free operation, which is a requirement for abandonment, cannot be provided. Alternatively, we support an abandonment plan which allows movement of the tailings piles downslope towards Wolverine Creek, yet does not create an unacceptably adverse environmental impact on downstream watercourses.

Furthermore, the monitored movement of the north tailings lobe to date indicates that such a catastrophic failure is unlikely.

The toe of the north lobe reached the valley bottom in 1985 and, as further movement occurs, it will begin to be buttressed against the opposite valley wall. This buttressing is expected to slow the rate of movement in future. However, even this self-stabilizing tendency resulting from future movement will not eliminate erosion of the tailings piles by Wolverine Creek. Accordingly, Klohn Leonoff (1985d) undertook an analysis of sediment transport capacity through Wolverine Creek and downstream reaches of Clinton Creek. Results of this analysis, discussed in the following section on Environmental Impact of the proposed Abandonment Plan, show that any gravel in the tailings piles would be deposited locally in Wolverine and upper Clinton Creeks, but that sand and finer sizes can be transported through the Clinton Creek system.

Based on our concerns for any stabilization measures, which require monitoring following abandonment, and because our analysis shows that material eroded from the tailings piles will not create unacceptable adverse environmental impacts, Klohn Leonoff supports an abandonment plan which allows downslope movement of the tailings piles. We feel that the tailings piles are in an acceptable condition for abandonment without any additional remedial works or monitoring.

6. ENVIRONMENTAL ASSESSMENT

6.1 SEDIMENT TRANSPORT

The abandonment schemes proposed by Klohn Leonoff for both the waste dump along Clinton Creek and the tailings piles along Wolverine Creek provide for some movement of material which is then susceptible to erosion. To examine further whether these proposed schemes would be acceptable with regard to environmental impact, Klohn Leonoff (1985d) conducted a sediment transport analysis for Clinton and Wolverine Creeks. An overview of the study results are included below, and the complete text is reproduced in Appendix II.

In general, analyses concluded that eroded material coarser than gravel would be deposited locally, just downstream from either the waste dump or tailings piles, while estimated transport capacities of lower Clinton Creek and the Forty Mile River are sufficient to transport all finer material. Gravel material from the waste dump would be deposited and form a fan immediately downstream where the stream gradient flattens from about 6% to 1%. Similarly, any gravel from the tailings piles would deposit in the lower reach of Wolverine Creek and at the confluence with Clinton Creek.

Local sand deposition in Clinton Creek may occur periodically, however on an annual basis, transport capacity should be sufficient to maintain the present regime of the creek. Sands and silts reaching the Forty Mile River will, based on the relative potential transport capacities, be carried away by flows in the Forty Mile River.

6.2 FISHERIES IMPACT

Studies of the impact on fisheries of the Clinton Creek waste dump and tailings pile have been carried out by the Environment Protection Service (1978) and EVS Consultants Ltd. (1981). A review of these studies in relation to sediment transport analysis by Klohn Leonoff (1985d) was carried out by Norecol Environmental Consultants Ltd. (1985). The Norecol summary report is included for reference in Appendix II. The conclusions of Norecols report are as follows:

"The review of information has indicated that lower Clinton Creek (below Wolverine Creek) contains several species of fish and is of low to moderate productivity. The effect of tailings pile failure on the fisheries capability of this drainage depends on the speed of the failure. A slow failure will eventually sediment the stream bottom for 2 km immediately downstream of Wolverine Creek and may also affect a portion of the creek further downstream. The effect on the fish populations within the area that may be affected by slow tailing failure is uncertain. It may or may not be significant considering that fisheries resources have been enhanced as a result of Hudgeon Lake and because the rate of sediment accumulation or flushing is uncertain. A rapid failure of the tailings pile will significantly affect all of Clinton Creek downstream of Wolverine Creek making it of limited fisheries value and significantly affecting fish populations below Wolverine Creek. Flushing of the tailing material may occur during subsequent freshet periods offering the potential for some recovery of the stream".

The above conclusions regarding fisheries impact address two scenarios of movement of the tailings piles. The first scenario of "slow-failure" is the case which is expected to occur; that is, the tailings piles will continue to move gradually downslope to fill Wolverine Creek valley bottom and minor ongoing erosion will occur. This will result in sediment accumulations for a 2 km stretch of Clinton Creek downstream of the confluence of Wolverine Creek. This is the area which has already been impacted by the mining operations, so that little further impact on fisheries is expected as a result of slow failure of the tailings piles.

The second scenario addressed by Norecol is that of a rapid failure of the tailings piles. This scenario was considered possible in early 1985 at the time the fisheries impact summary was prepared, when a high, steep face existed at the toe of the north tailings lobe. Since that time, the toe of the pile has moved into a much flatter configuration and the rapid failure scenario does not seem possible. Therefore, the potential does not exist for the much greater impact on fisheries which would be brought about by a rapid failure.

Norecol's summary report on fisheries impacts also discusses the aspect of asbestos levels, although this is not mentioned in the conclusions quoted above. Their review of monitoring data on asbestos levels indicates that "water sampling programs were conducted by EPS and EVS Consultants but could find no evidence of elevated asbestos concentrations in the Forty Mile or Yukon Rivers attributed to Clinton Creek".

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 MINE FACILITIES

Removal and cleanup of the Clinton Creek townsite, mine facilities and equipment are essentially complete. No further work is required in this area.

7.2 CLINTON CREEK WASTE DUMP

The Clinton Creek waste dump is in a state of stable equilibrium and is suitable for abandonment. Movements of the waste dump have slowed to less than 1.5 ft/yr. The waste dump channel is protected by in situ bedrock on its left bank and by large boulders in the channel bottom. The armouring at the upstream end of the waste dump channel was repaired in 1984 and has performed satisfactorily to date. No practical alternative solution has been identified which will afford a higher degree of protection than the present configuration.

It is recommended that the waste dump be abandoned in its present configuration, with the exception that the culverts should be removed from the road crossing at the upstream end of the channel of Clinton Creek across the waste dump. Culvert removal is recommended to prevent problems resulting from possible future plugging.

7.3 WOLVERINE CREEK TAILINGS PILES

The two tailings piles on the south slope of Wolverine Creek valley will continue to move downslope for a number of years, until a significant amount of the material reaches a more stable configuration in the valley bottom. The configuration of the tailings piles is such that large, catastrophic movements would not be expected to occur. Ongoing erosion of the tailings piles will occur, but at the limited transport capacity of Wolverine Creek.

Alternative solutions have been considered for reclamation of the tailings piles; however, no solutions have been identified which can be implemented at reasonable cost and provide a safe, maintenance-free scheme suitable for abandonment. It is recommended that the tailings piles be abandoned in their present configuration.

7.4 SEISMICITY

Clinton Creek is located in an area of relatively low seismic activity, with an expected 100-year return period acceleration in the order of 6% g. This level of earthquake shaking would not be expected to have significant impact on the stability of the waste dump or tailings piles.

7.5 ENVIRONMENTAL IMPACTS

Sediment generated from ongoing erosion of the waste dumps and tailings piles is expected to have small impact on Clinton Creek. The coarse fraction (gravel sizes and above) are expected to settle in Clinton Creek in the low gradient reach extending about 2 km downstream of the confluence of Wolverine Creek. The fine fraction of sediments is expected to be carried through Clinton Creek into the Forty Mile and Yukon Rivers, where the small quantities will have negligible impact.

Fisheries have been adversely impacted by the sediment deposited in the 2 km reach downstream of the waste dump. However, Hudgeon Lake which was formed by the waste dump is seen as an enhancement to fish rearing, and the waste dump channel provides good habitat. The overall impact on fisheries is uncertain. However, future impacts on fisheries are expected to be minor.

Monitoring of asbestos levels has shown no elevation of fibre levels in Forty Mile on Yukon Rivers. *

KLOHN LEONOFF LTD.

Steve Rice

Steve Rice, P.Eng.
Project Engineer

Tom Bruce

for Peter C. Lighthall, P.Eng.
Project Manager

APPENDIX I

PHOTOGRAPHS

Photo 1: Forty Mile River showing confluence with Yukon River in background. Clinton Creek enters Forty Mile River just upstream of bridge. June 1985.

Photo 2: Clinton Creek waste dump, showing Hudgeon Lake at bottom of photo and channel of Clinton Creek over waste dump on left. June 1985.

Photo 3: Clinton Creek waste dump, looking upstream toward Hudgeon Lake. Open pit is at left, crusher in foreground, and concentrator site on plateau at upper right. July 1986.

Photo 4: Rock lined section at upper end of Clinton Creek channel over waste dump. Access road culverts at upper left. July 1986.

Photo 5: Access road culverts at upper end of waste dump channel. June 1985.

Photo 6: Waste dump channel looking downstream. Note left bank is protected by bedrock and stream bottom is armoured by large boulders from waste dump. June 1985.

Photo 7: Wolverine Creek tailings piles looking upstream (north). July 1986.

Photo 8: Wolverine Creek tailings piles looking northwest. July 1986.

Photo 9: Toe of north tailings lobe. July 1986.

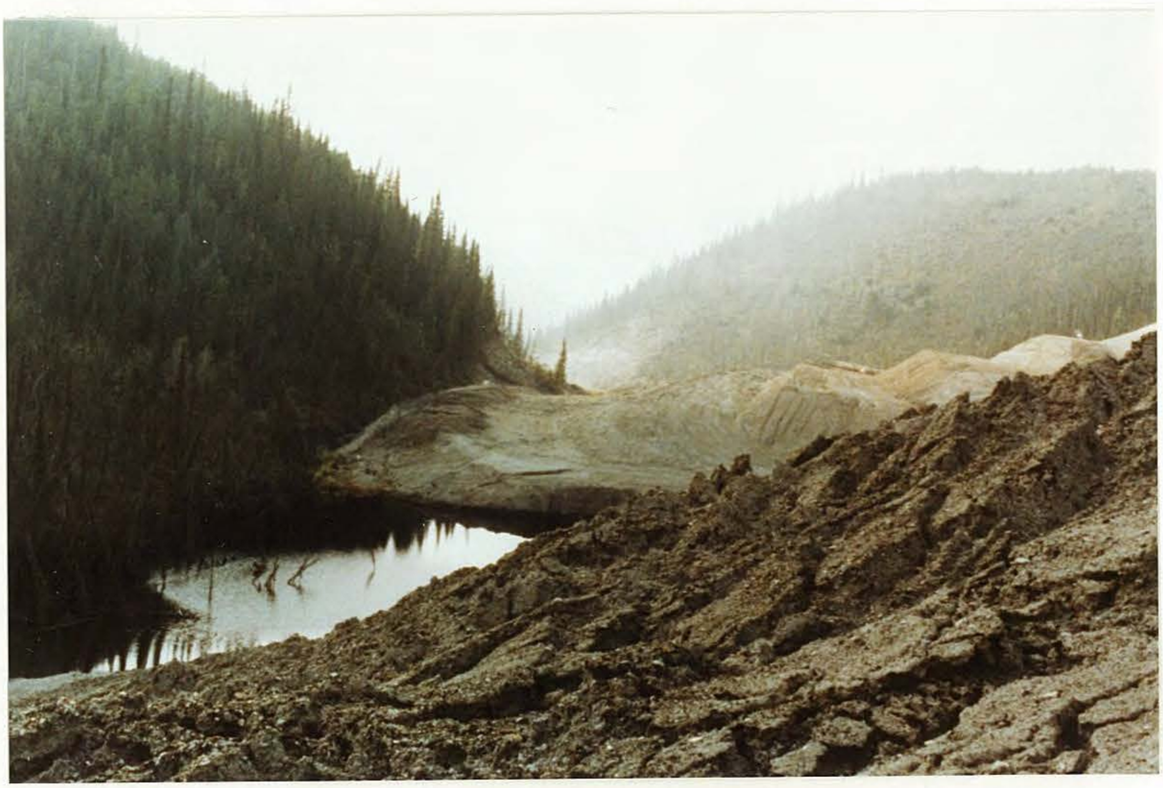

Photo 10: Toe of south tailings lobe. July 1986.

APPENDIX II

KLOHN LEONOFF LTD., SEDIMENT TRANSPORT ANALYSIS FOR CLINTON AND WOLVERINE CREEKS, APRIL 23, 1985

NORECOL ENVIRONMENTAL CONSULTANTS LTD., CLINTON CREEK ASBESTOS MINE AQUATIC IMPACT ASSESSMENT, APRIL 11, 1985

REPORT ON SEDIMENT TRANSPORT ANALYSIS

PROJECT: CLINTON CREEK ASBESTOS MINE
WOLVERINE CREEK TAILINGS PILES

LOCATION: YUKON TERRITORY

CLIENT: BRINCO MINING LTD.

OUR FILE: PB 3169 0301 APRIL 23, 1985

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APPENDICES

DRAWINGS

1. INTRODUCTION

This report presents the results of sediment transport analyses carried out by Klohn Leonoff Ltd. on Wolverine and Clinton Creeks downstream of the Wolverine Creek tailings piles. The work, as proposed in Klohn Leonoff's letter of December 11, 1984, was carried out to assist in further development of a rehabilitation and abandonment strategy for the Wolverine Creek tailings piles at the former Clinton Creek asbestos mine, northwest of Dawson City, Yukon Territory.

The scope of work covered in this report is as follows:

a) a hydrological review of the Wolverine Creek and Clinton Creek catchment areas based on available regional data to estimate extreme peak streamflows and annual flow-duration characteristics for the creeks;

b) an evaluation of the potential sediment carrying capacities of Wolverine and Clinton Creeks to assess how much tailings material may be transported downstream of the tailings piles and to identify areas where re-deposition of this sediment may occur.

Separate letter reports by Klohn Leonoff present the results of the other two work items described in Klohn Leonoff's December 11, 1984 letter, namely an assessment of the existing rock lined channel, and a stability analysis of the tailings pile.

The location of the tailings pile and the downstream reaches of the creeks studied in this report are shown on Drawing No. A-1009.

2. HYDROLOGICAL REVIEW

The catchment area of Wolverine Creek upstream of the tailings piles is estimated to be about 21.6 km^2. Clinton Creek downstream of the confluence with Wolverine Creek has a catchment area of about 140 km^2, increasing to about 200 km^2 at the confluence with the Forty Mile River. Water Survey of Canada streamflow data in the general mine region which were used in this study are summarized below:

TABLE 1

Available Streamflow Data

Station Name	Catchment Area (km^2)	Period of Record
Clinton Creek above Wolverine Creek	106	1964-65 (summers only)
North Klondike near the Mouth	1100	1974-83
Klondike River above Bonanza Creek	7800	1965-83
Forty Mile River near the Mouth	16600	1982-83

With the exception of the two partial years of record for Clinton Creek, there are no flow records available for small catchment area streams near the mine site.

For the purposes of this study, estimates of peak streamflows for the Wolverine Creek/Clinton Creek catchments were prepared based on the North Klondike and Klondike River records. For these rivers, unit flows in L/s/km^2 for average annual discharge and various return period flood events were plotted against catchment area. Flows for the upper Wolverine Creek catchment area of 21.6 km^2 were estimated by extrapolation and are listed in Table 2. The average annual flow was estimated to be 0.25 m^3/s, based on an estimated average annual runoff of 350 mm. The average or 2 year return period flood flow will probably result from snowmelt only and may have a duration of several days. More extreme events will probably result from rain-on-snow events and entail short durations of perhaps a few hours.

TABLE 2

Estimates of Flood Flows for
Upper Wolverine Creek Catchment Area

Flow Event	Unit Flow ($L/s/km^2$)	Flow (m^3/s)
2 Year Flood	220	4.75
50 Year Flood	570	12.3
100 Year Flood	650	14.0
200 Year Flood	740	16.0

Extreme flows for other locations in the Clinton Creek catchment were estimated in a similar fashion.

For relatively small catchment areas such as Wolverine and Clinton Creeks a wide variation in flow magnitudes may be expected during the year, ranging from very high magnitude but short duration flows, resulting from rainfall events,to low (or zero) flows during the coldest months of the winter. The Forty Mile River, with a catchment area of 16 600 km^2, has exhibited flows varying from zero to 1300 m^3/s with an average annual discharge of about 91 m^3/s in 1982 and 1983. Since its drainage area includes Clinton Creek, the Forty Mile River flow duration characteristics were used for the study. A unit flow duration curve was prepared and is shown on Drawing No. A-1010 which plots the ratio of (daily flow to mean annual flow) versus % time flow exceeded.

3. SEDIMENT TRANSPORT ANALYSIS

3.1 GENERAL

Klohn Leonoff have carried out a sediment transport analysis of Wolverine Creek, Clinton Creek and the Forty Mile River to assess the sediment carrying capacity of each. The purpose of the analysis was to estimate how much tailings material may be transported downstream of the tailings piles, and to identify areas where re-deposition of this sediment may occur.

3.2 SEDIMENT TRANSPORT MODEL

An interactive computer program known as MPMPC (developed by Simons, Li and Associates Inc.) was used to estimate potential sediment carrying capacities. MPMPC develops an applicable sediment transport capacity regression equation for a range of hydraulic conditions expected within a channel. The transport capacities are computed using a combination of the Meyer-Peter-Muller formula for bed load transport and Einstein's solution for suspended sediment transport. Required data inputs include the channel slope and hydraulic roughness, flow discharge intensity (discharge per unit width of channel), and a representative grain size distribution for the sediment. The potential annual sediment transport capacity of a stream channel at a particular location may be estimated using the results of the MPMPC program in conjunction with the annual flow duration curve applicable to the stream.

3.3 DATA UTILIZED

The MPMPC program was applied to representative channel sections in the existing rock lined channel across the tailings, lower Wolverine Creek, Clinton Creek below Wolverine Creek, and the Forty Mile River at the Clinton Creek confluence.

Channel gradients were estimated from available topographic maps and drawings, including the 1:50,000 NTS Map Sheet No. 116C/7. A profile along the entire channel length studied is shown on Drawing No. X-1011. Channel gradients range from 0.08 (8%) in the rock-lined section across the tailings pile to less than 0.001 (0.1%) for the Forty Mile River. Lower Wolverine Creek gradients are between 0.02 and 0.03 (2-3%). The initial 2 km of Clinton Creek below Wolverine Creek appears to have a slope of about 0.003 (0.3%) increasing to between 0.009 and 0.014 (0.9 to 1.4%) in the lower reaches.

Channel widths and roughness were estimated from available photographs, mapping, and data contained in previous reports[1], and observations made by Klohn Leonoff personnel during previous site visits. The representative grain size distribution for the tailings was taken from Figure B-3 contained in the 1978 Golder Associates Report and is summarized as follows:

TABLE 3

Tailings Grain Size Distribution

Particle Diameter (mm)	% Finer by Weight
20	100
2.0	60
0.2	20
0.06	10
0.02	5

The grain size curve indicates that 40% of the tailings material would be classified as fine to medium gravel, 50% as sand, and 10% as fine grained silt to clay sizes.

Channel discharge intensities were estimated to vary from less than 1 cfs/ft width (0.1 $m^3/s/m$) to about 30 cfs/ft (2.8 $m^3/s/m$) for Wolverine/Clinton Creeks, and up to about 90 cfs/ft (8.4 $m^3/s/m$) for the Forty Mile River.

3.4 RESULTS OF ANALYSIS

The MPMPC model indicates that, during an average flow year, all tailings material finer than coarse sand (60% of the total) that enters the upper lined channel section will eventually be transported to the Forty Mile River and beyond. The lined channel and the lower reaches of Wolverine Creek appear to have sufficient sediment transporting capacity

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1 Reports included: E.V.S. Consultants Ltd. (June 1981), Golder Associates Ltd. (July 1978).

to carry most of the gravel-sized tailings to the upper reaches of Clinton Creek. Downstream of the Wolverine Creek/Clinton Creek confluence, however, Clinton Creek does not appear to have sufficient capacity to transport medium gravels and only has limited capacity to transport fine gravel-sized material. The Forty Mile River cannot transport any gravel-sized material.

The table below summarizes estimated potential annual tailings transport capacities, and the percent of that total that would be sand sizes or finer, for various reaches of stream between the tailings piles and the Forty Mile River. Drawing No. A-1009 shows the locations of the different reaches. The annual capacities have been estimated by integrating the results of the sediment transport model and the flow-duration characteristics applicable to each reach.

TABLE 4

Potential Tailings Transport Capacities

Reach Number	Description	Potential Annual Capacity ($m^3 \times 10^6$)	Sand Volume* / Annual Volume
1	Rock-lined channel across tailings	0.85	92%
2	Lower Wolverine Creek	2.0	96%
3	Upper Clinton Creek	2.0	99.8%
4	Lower Clinton Creek	13.0	98%
5	Forty Mile River at Clinton Creek	790	100%

(* all material finer than coarse sand)

3.5 LIMITATIONS OF ANALYSIS

The results of the sediment transport analysis described above are discussed further in Section 4. The available data has necessitated making a number of assumptions which apply certain limitations to the results as discussed following:

a) the hydrological characteristics of the Clinton Creek watershed have been estimated from available regional data and are not based on site-specific measurements or data;

How about data from Clinton Creek at bridge?

b) sediment transport capacities determined in the MPMPC model are strongly dependent on channel discharge intensities and hydraulic roughness. Channel widths and roughness have been estimated from site photographs and descriptions without benefit of field measurements carried out at the specific reaches of interest. There are no sediment transport data available in the area with which to calibrate the model;

c) the 1"=200' mapping for Wolverine Creek and 1:50,000 scale NTS map for the area indicate a discrepancy in elevations and slopes of the Wolverine/Clinton Creek channels. The 1"=200' mapping indicates the confluence of the two creeks to be at about elevation 1190 ft, however the 1:50,000 scale topographic maps indicate the confluence elevation to be at about elevation 1270 ft. The 1"=200' scale mapping has been used to determine slopes for Wolverine Creek. Slopes for Clinton Creek downstream have been estimated based on the general trends indicated by the NTS maps and observations contained in earlier reports.

d) transport capacities listed in Section 3.4 are the total quantities of tailings that could be potentially carried by the streams assuming no other sediment is being transported. An unknown proportion of the annual capacities will be taken up transporting natural sediment. Actual rates of natural sediment transport in the streams, including wash load, suspended load and bed load, are probably much less than the potential capacities. The capacities should, however, give an indication of the relative order of magnitude of the annual rates at which natural sediment is being transported by the streams. Seasonal rates will vary widely depending on rates of streamflow.

e) the actual quantity per year of tailings that will be either transported through, or deposited, at different locations within the system depends on the rate at which tailings enter the Wolverine Creek valley from the tailings piles. It is estimated that the potential capacity of the lower rock lined channel is significantly greater than the probable rate of supply, unless there is a sudden slide failure of the tailings lobes into the valley bottom or if the stream should escape the rock lined channel.

The analyses carried out, although limited by available data, nonetheless allow a general appreciation of existing and possible future sediment transport processes at different locations within the Clinton Creek valley. The results are discussed further in the following section.

4. DISCUSSION

Based on the above limitations it is possible to anticipate the general nature of changes that may occur downstream of the Wolverine Creek tailings piles. The anticipated changes, however, depend on the probable short and long term behaviour and stability of the tailings piles which comprise the major source of additional potential sediment loading to the downstream creeks and rivers. The discussion in Sections 4.1 and 4.2 following describes possible downstream changes for two potential modes of behaviour of the tailings:

1) gradual downslope movement of the tailings continuing at a relatively slow or uniform rate;

2) the tailings pile undergoing one or more sudden and rapid slide failures into the valley bottom.

4.1 GRADUAL TAILINGS PILE MOVEMENT

Assuming that the rate of tailings encroachment into the valley either remains relatively slow and uniform or decreases with time, and assuming that the existing rock-lined channel does not fail, the following changes to the existing Wolverine Creek and Clinton Creek channels are anticipated:

a) tailings material will continue to accumulate in the area of the small lake upstream of the south tailings lobe. If the rock lined channel continues to operate as it has over the past six years it will serve to control the elevation and limit the slope of the upstream channel. As the lake fills with tailings, especially gravel/coarse sand sizes, it will be moved progressively further north. Across the east side of the valley a new gravel lined channel, perhaps braided in appearance, may form with a relatively flat slope of perhaps 0.003 to 0.005.

b) some gravel-sized tailings may accumulate in the lower lined channel (Reach No. 1) within the voids between the riprap lining. Over time, the net result may be a gradual decrease in the hydraulic roughness of the channel, thereby increasing the potential flow and sediment carrying capacity of the channel without any significant adjustments to the longitudinal slope;

c) lower Wolverine Creek (Reach No. 2) may experience some local deposition of gravel sizes during periods of decreasing streamflows following snowmelt or rainfall-induced high flow events. No significant long-term aggradation of the streambed is expected in this reach;

d) gravel-sized material entering upper Clinton Creek (Reach No. 3) from Wolverine Creek will probably deposit downstream of the confluence, resulting in a general raising or aggradation of the streambed as happened after the 1974 failure. Due to the lower longitudinal slope, this reach has only a limited capacity to transport gravels, and the rate of bed aggradation will depend on the supply rate of gravel from the tailings piles. Over the long term, some bed aggradation may utimately extend as much as 2 km downstream of the confluence, to the point where the natural channel gradient increases to about 1% (end of Reach No. 3);

e) tailings material transported through Reach No. 3 will probably also be transported through Reach No. 4 (lower Clinton Creek) to the Forty Mile River. Some minor deposition of coarser material may occur in local backwater areas, local scour holes, or areas subject to debris blockage and local ponding as streamflows recede. On average over the long term no major changes to the channel regime is anticipated in this reach;

f) at the confluence with the Forty Mile River, Clinton Creek has formed a natural fan of gravel and cobble-sized material, confirming that the Forty Mile River has little or no capacity to transport coarser material. Any gravel-sized tailings reaching the confluence will probably deposit on or near the fan. Based on the potential sediment transporting capacity of the Forty Mile River (Table 4), it appears that all silt sizes and most sand-sized tailings reaching the confluence will, on an annual basis, be transported downstream by the Forty Mile River to the Yukon River.

4.2 RAPID TAILINGS PILE MOVEMENT

The stability analysis study of the tailings pile carried out by Klohn Leonoff and described in a separate report dated February 28, 1985 indicates that there is a possiblity of the tailings pile undergoing a sudden and rapid slide failure downslope into the Wolverine Creek valley bottom.

Such an occurrence would probably block the inlet to the lower rock lined channel and could raise the level of the present tailings deposit in the valley bottom by up to 20 m (70 ft) over a length of about 150 m (500 ft). The existing small lake would be displaced to the north and may, in time, fill with natural runoff from upper Wolverine Creek to a level and volume significantly greater than is contained at present. When the water level reaches the top level of the failed tailings, the lake will overflow and Wolverine Creek will begin to form a new channel across the tailings without the benefit of the grade control presently provided by the lower rock lined channel. A failure of the rock-lined channel regardless of rates of movement of the tailings piles could also result in a new unlined channel being formed across the tailings. The new channel would progressively erode down through the tailings. Initial rates of erosion and downcutting in the new unlined channel will be rapid but may decrease with time as the channel becomes armoured with the larger tailings gravels. During high flow periods the rates of transport of all sizes of tailings away from the tailings pile will be much higher than would occur under the gradual tailings pile movement scenario discussed previously since the sediment supply would be essentially unlimited in the upper reaches. Depending on the degree of armouring, the developing channel will probably attempt to attain a new stable overall slope of 2-3%, similar to the natural slope of lower Wolverine Creek.

Large quantities of gravel would be transported to upper Clinton Creek where, as a consequence of this reach's limited gravel carrying capacity, gravel deposits will form across the valley bottom in the area of the Wolverine Creek confluence and downstream. Based on the geometry of the overall channel profile these gravel deposits could accumulate, in the long term, to as much as 10 m deep in the area of the confluence and may extend downstream over a length of about 2 km.

Local sand deposition in lower Clinton Creek (Reach No. 4) may be more pronounced on a seasonal basis, however on an annual basis this reach should have sufficient transporting capacity to maintain the present regime of the creek. Sands and silts reaching the Forty Mile River should, based on the relative potential transport capacities, be carried away by the Forty Mile to the Yukon.

5. CONCLUSIONS

Based on the hydrologic, hydraulic, and sediment transport analyses described in this report, the following general conclusions may be drawn:

1) the existing rock lined channel, lower Wolverine Creek and lower Clinton Creek (Reach No.s 1, 2 and 4) can transport all sizes of the tailings material;

2) the upper reach of Clinton Creek below Wolverine Creek (Reach No. 3) has a limited capacity to transport gravel sizes;

3) the Forty Mile River cannot transport sediment larger than coarse sand but has a potential annual sediment transporting capacity significantly higher than Clinton Creek for sand sizes and finer;

4) continued gradual downslope movement of the tailings pile will probable result in some aggradation of gravel in upper Clinton Creek but only minor local depositions of tailings in other reaches;

5) a sudden or rapid slide failure of the tailings piles into Wolverine Creek could eventually result in significant bed aggradation in lower Wolverine

and upper Clinton Creeks. Over the long term no significant accumulation of sediment is anticipated in lower Clinton Creek or the Forty Mile River over and above existing natural processes.

KLOHN LEONOFF LTD.

Peter S. McCreath, P.Eng.
Project Engineer

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April 11, 1985
File: 30-47-2A

Klohn Leonoff Consulting Engineers
10180 Shellbridge Way
Richmond, B.C.
V6X 2W7

Attention: Mr. Peter Lighthall, P.Eng.

Dear Mr. Lighthall,

RE: CLINTON CREEK ASBESTOS MINE AQUATIC IMPACT ASSESSMENT

In accordance with instructions from Brinco Mining, Norecol Environmental Consultants Ltd. has reviewed existing information regarding the tailings pile failure at the Clinton Creek asbestos mine and made an assessment of the potential impacts on the fisheries resource in Clinton Creek. The following report provides background information, identification of the fisheries resources and a preliminary assessment of the impacts on the aquatic environment.

BACKGROUND

The Clinton Creek asbestos mine is located in the northwest corner of the Yukon Territory, 97 km northwest of Dawson City. The mine is situated on Clinton Creek which drains into the Fortymile River, 4.8 km from its confluence with the Yukon River. The open pit mine operated from 1968 to 1978, when economic ore reserves were exhausted. Waste rock overburden, consisting mainly of argillite, was dumped on the south slope of the Clinton Creek valley across Clinton Creek forming a small lake (Hudgeon Lake). Dry tailings, consisting mainly of serpentine material, was dumped on the west side of Wolverine Creek, a tributary of Clinton Creek downstream of Hudgeon Lake. In the spring of 1974 the south lobe of the tailings dump failed, blocking Wolverine Creek. As a result a small lake was impounded in Wolverine Creek (Wolverine Lake) upstream of the toe of the slide. After the failure of the south lobe of the tailings dump a north lobe was established. The north lobe is also moving downslope and encroaching on Wolverine Lake.

Continued . . .

Subsequent to the failure of the tailings piles, concerns were expressed regarding the effects on the aquatic environment in Clinton and Wolverine creeks, and the potential hazard of increased asbestos on downstream domestic water supplies. In response to these concerns environmental studies were conducted by the Environmental Protection Service (1978) in 1974 and 1975, and by EVS Consultants Ltd. (1981) in 1980. In addition, Klohn Leonoff Consulting Engineers conducted stability studies on the tailings piles and waste dump (Klohn Leonoff, 1984a, 1984b) and conducted sediment transport analyses on Wolverine and Clinton creeks to develop a rehabilitation and abandonment strategy (Klohn Leonoff, 1985). In the sediment transport study, Klohn Leonoff discuss two potential scenarios for behaviour of the tailings: 1) gradual downslope movement at a slow, uniform rate; 2) one or more rapid slide failures into the valley bottom. Our analysis also assumed that Hudgeon Lake will remain in its present state.

FISHERIES RESOURCES IN CLINTON CREEK

Clinton Creek is utilized by Arctic grayling (*Thymallus arcticus*), juvenile chinook salmon (*Oncorhynchus tshawytscha*), longnose sucker (*Catastomus catastomus*), lake whitefish (*Coregonus clupeaformis*), round whitefish (*Prosopium cylindraceum*) and sculpins (EPS, 1978; EVS Consultants, 1981). Arctic grayling appear to inhabit Clinton Creek year-round for rearing, adult maturation and spawning. Grayling are known to inhabit Hudgeon Lake and are able to migrate up through the lake outflow culverts during high flow. Juvenile chinook rear in lower Clinton Creek, but probably originate from the Fortymile River, since larger water courses are preferred by chinook for spawning. Other species indigenous to the Yukon River system also appear to use Clinton Creek on a seasonal basis.

Previous physical alteration of the stream channels has apparently been relatively localized. Small lakes have been formed in both Clinton Creek, by the waste rock dump, and Wolverine Creek, by the failing tailing piles. In Clinton Creek physical alteration of the stream channel extends for approximately 2.8 km downstream from the waste rock dump. The upper 0.5 km of this section is channelized for erosion control across the toe of the waste dump and is dominated by a narrow, steep canyon strewn with boulders and bedrock. Downstream of this are braided, unstable channels through washed rock. The area is generally devoid of riparian vegetation due to bank erosion. The remainder of Clinton Creek is relatively undisturbed. In Wolverine Creek a rock-lined channel, devoid of vegetation, carries the stream over the failed south tailings lobe. Downstream, the streambed consists of washed tailings.

Clinton Creek was found to support the greatest abundance of grayling and juvenile chinook in the small canyon below Hudgeon Lake (EVS Consultants, 1981). It appears that this unique lake habitat has enhanced the fish habitat capability. The lake is an abundant source of Daphnia, which was found to be important to the diet of grayling captured just below the lake. The lake also provides extensive overwintering potential for grayling. Another reason for the abundance of fish in the canyon is the extensive instream boulder cover which provides greater habitat diversity than elsewhere in the stream. Since the EVS study the channel has been further modified to prevent erosion and downcutting. These changes may have altered the fish habitat and population characteristics.

It is not clear whether the apparent absence of fish in Wolverine Creek is a result of fish habitat loss due to the failure of the tailings dump or the presence of culverts at the mouth.

FISHERIES IMPACT OF TAILINGS PILE FAILURE

The impact of tailings pile failure on Clinton Creek and downstream waters was made considering the two failure scenarios described by Klohn Leonoff (1985). The first is a gradual downslope movement into Wolverine Creek resulting in continuous erosion and downstream transport of the tailing material. Klohn Leonoff (1985) predicted that at the present rate of encroachment of the tailings dump into Wolverine Creek coarse sediment will be deposited in Clinton Creek causing bed aggradation as much as 2 km downstream. The rate of bed aggradation will depend on the supply rate of material from the tailings piles. It is presumed that of the movement, subsequent erosion and associated high suspended solids concentrations would likely occur during spring high flow periods with reduced erosion and concentrations occurring in lower flow periods. The second scenario was a rapid failure with most of the tailings material entering the creek in a relatively short time period.

Klohn Leonoff (1985) predicted that a rapid slide failure of the tailings dump could cause coarse sediment to be deposited as much as 10 m deep over a 2 km section of Clinton Creek. A rapid failure of the tailings would cause prolonged elevated levels of suspended solids, which would be deposited over the length of Clinton Creek during low flows. Klohn Leonoff state that material finer than coarse sand would eventually be transported to the Fortymile River.

General Water Quality

EPS found elevated levels of calcium, magnesium, iron, manganese, potassium and hardness in Clinton Creek, but the levels were not elevated to the point that would be harmful to aquatic organisms. This is expected to remain the case, having no impact on aquatic resources.

Suspended Solids and Asbestos

Clinton Creek experiences asbestos fibre loading from the waste dump and the tailings piles in Wolverine Creek. The Environmental Protection Service (1978) conducted a series of bioassays using juvenile coho salmon to determine the possible effects of waterborne asbestos fibres in water from Clinton Creek. The samples were found to be non-toxic at 100% concentration over 96 hours, 8 days and 16 days. Subsequent histological analysis indicated some gill tissue damage had occurred in the experimental fish, but the significance of the finding was unknown.

Fish are known to accumulate asbestos fibres in the kidney, liver and pancreas. Metsker (per. comm.) studied various species of fish in the Yukon River for asbestos fibre accumulation and found that while some cellular changes (mechanical damage) were evident, no carcinogenic effects were observed. He indicated that there are no definitive studies which link asbestos in fish tissues to fish disease. Therefore, the effects on fish exposed to asbestos fibres would be similar to fish exposed to other water borne particles or suspended solids such as those from placer mining (McLeay et. al., 1983). The slow failure scenario would not be expected to affect fish other than causing slight gill damage as described by EPS (1978) and McLeay et al. (1984) and found to occur in the fish exposed to Clinton Creek water (EPS, 1978). However, a rapid failure of tailings would cause extreme levels of suspended solids in Clinton Creek and would be expected to cause significant fish deaths by the clogging of gills and suffocation of fish.

Habitat Alteration From Sedimentation

Studies carried out by EVS Consultants (1981) indicated some degradation of habitat had occurred downstream of the tailings piles in Clinton Creek. The piles have continued the process of slow failure since the earlier study and as a result are a constant source of materials for downstream transport and deposition in Clinton Creek. The effect of this downstream transport and deposition since 1980 is not known but may have alienated some additional portion of Clinton Creek from productive fish habitat. Klohn Leonoff (1985) predict that as much as 2 km of the Clinton Creek streambed will eventually be aggraded (sedimented) in this process. It seems likely that some gradient of effect may also occur downstream of the 2 km section of streambed that would be covered with tailings material.

Sediment deposition is known to cause reduction in fish food organisms which would be of particular concern since food availability may be the limiting factor for fish in Clinton Creek during late summer (EVS Consultant, 1981). This would be of more concern in areas removed from Hudgeon Lake where food supplies are not substantially augmented by zooplankton from the lake.

Sediment deposition also reduces rearing and spawning habitat for fish and will reduce survival of fish eggs deposited in or on the gravel. The levels of substrate sediment required to cause such effects may be relatively small (i.e. survival of salmonid eggs has been reduced by sediment levels of less than 10% in the substrate).

The second scenario of rapid tailing pile failure would cause the deposition of sediment throughout Clinton Creek below Wolverine Creek. This would significantly impact the fisheries capability of the stream by severely reducing fish habitat and fish food organisms until the natural transport processes were able to remove the accumulated sediments.

The sudden failure of the tailing piles would change the use of lower Clinton Creek, downstream of Wolverine Creek, from a rearing, migratory, spawning habitat to more restricted use making it primarily suitable for migratory purposes only. The effect of a sudden failure would likely be felt for more than one year but would probably be flushed from the system in succeeding freshet periods. The particle sizes found in the tailing material would indicate that they may be subject to flushing from the system in high flow periods during subsequent years. Although the time period is not known, there is potential for recovery of the stream.

ASBESTOS LEVELS IN DRINKING WATER

Asbestos fibre concentrations in the Clinton Creek drainage was found to be relatively high after the tailings pile failure. However, fibre concentrations in downstream waters subsquent to the failure were of the same magnitude as other Yukon Territory and British Columbia watersheds with comparative geology. Fibre concentrations in Clinton Creek have decreased downstream of the mine since the initial failure probably as a result of stabilization and erosion control measures carried out by the company. Water sampling programs were conducted by EPS and EVS Consultants but could find no evidence of elevated asbestos concentrations in the Fortymile or Yukon rivers attributable to Clinton Creek. These rivers were found to carry naturally high concentrations of asbestos fibre. It is probable that only the most severe asbestos loading in Clinton Creek would be detectable in the Fortymile River, due to the relative size of the water courses.

Domestic water use of the lower Fortymile River is not known but is thought to be minimal since the town of Forty Mile is abandoned and the town of Clinton Creek was closed with the mine. In any case, no studies have linked asbestos ingestion to illness in humans (Shapiro, pers. comm.).

CONCLUSION

The review of information has indicated that lower Clinton Creek (below Wolverine Creek) contains several species of fish and is of low to moderate productivity. The effect of tailings pile failure on the fisheries capability of this drainage depends on the speed of the failure. A slow failure will eventually sediment the stream bottom for 2 km immediately downstream of Wolverine Creek and may also affect a portion of the creek further downstream. The effect on the fish populations within the area that maybe affected by slow tailing failure is uncertain. It may or may not be significant considering that fisheries resources have been enhanced as a result of Hudgeon Lake and because the rate of sediment accumulation or flushing is uncertain. A rapid failure of the tailings pile will significantly affect all of Clinton Creek downstream of Wolverine Creek making it of limited fisheries value and significantly affecting fish populations below Wolverine Creek. Flushing of the tailing material may occur during subsequent freshet periods offering the potential for some recovery of the stream.

If you would like clarification of any of the impacts I have identified or want any further explanation of my interpretations, I would be pleased to discuss them with you. I have also attached a list of the references and personal communications used in the presentation.

Yours truly,
Norecol Environmental Consultants Ltd.

J. G. Malick

J. G. Malick, Ph.D.
Head, Aquatic Sciences

JGM:rm

Attachment

cc: Brinco Mining

REFERENCES

Environmental Protection Service. 1978. An environmental assessment of the effects of Cassiar Asbestos Corporation on Clinton Creek, Yukon Territory. Regional Program Report No. 79-13. 36 p.

EVS Consultants Ltd. 1981. Assessment of the effects of the Clinton Creek Mine waste dump and tailings, Yukon Territory. Prepared for Cassiar Resources Ltd. Vancouver, B.C. 97 p.

Klohn Leonoff Consulting Engineers. 1984a. Report on Wolverine Creek tailings piles - Clinton Creek Asbestos Mine. Prepared for Brinco Mining Ltd., Cassiar Division.

Klohn Leonoff Consulting Engineers. 1984b. Report on 1984 site visit - Clinton Creek Mine waste dump and tailings piles. Prepared for Brinco Mining Ltd., Cassiar Division.

Klohn Leonoff Consulting Engineers. 1985. Draft report on sediment transport - Clinton Creek Asbestos Mine Wolverine Creek tailings pile. Prepared for Brinco Mining Ltd.

McLeay, D.J., A.J. Knox, J.G. Malick, I.K. Birtwell, G. Hartman and G.L. Ennis. 1983. Effects on Arctic grayling (Thymallus arcticus) of short-term exposure to Yukon placer mining sediments: laboratory and field studies. Can. Tech. Rep. Fish. Aquatic Sci. 1171: xvii + 134 p.

Metsker, H. Personal Communication. U.S. Department of Interior, Fish and Wildlife Service, Alaska. Telephone conversation. March 26, 1985.

Shapiro, R. Personal Communication. National Institute of Environmental Health Studies, Research Triangle Park, North Carolina. Telephone conversation. March 27, 1985.

APPENDIX III

MONITORING DATA:

1986 MOVEMENTS OF WASTE DUMP AND TAILINGS PILES

1985 ASBESTOS FIBRE DATA (CASSIAR MINING COPRORATION LETTER OF NOVEMBER 7, 1985)

WOLVERINE TAILINGS PILE

NORTH LOBE

STATION	COORDINATES & ELEV. JULY '86	HORIZONTAL JUN.'84	HORIZONTAL JUN.'85	HORIZONTAL JUL.'86	VERTICAL JUN.'84	VERTICAL JUN.'85	VERTICAL JUL.'86
		RATES OF MOVEMENT (ft/yr)					
26	N 114490.87 E 108226.26 1891.24	0.27	1.55	0.20	- 0.67	+ 0.31	- 0.37
80.2	N 114320.91 E 108441.53 1818.47	0.40	1.41	0.05	- 0.17	- 0.06	- 0.24
26A	N 114482.69 E 108413.54 1835.92	0.17	0.84	0.41	- 1.42	- 0.09	- 0.41
80-1	N 114707.93 E 108419.85 1831.28	0.69	0.84	0.20	- 0.63	- 0.15	- 1.10
80-4	N 114020.46 E 108856.88 1665.42	1.05	0.36	1.26	- 0.54	- 0.39	- 0.90
80-5	N 114175.11 E 108953.25 1598.26	8.35	5.84	8.15	- 9.39	- 6.25	- 4.42
500-1	N 114499.71 E 108956.04 1582.09	33.33	34.06	41.75	-15.39	- 7.72	-18.57
650-1	N 114708.11 E 108894.21 1619.02	18.63	14.10	17.13	- 5.69	- 3.78	- 5.55
350-1A	N 114348.50 E 109225.64 1551.99	91.48	65.27	54.90	-34.05	-24.72	+18.41
500-2	N 114494.88 E 109307.70 1479.83	58.47	58.60	62.09	-29.31	-25.86	-23.14
650-2 (80.6)	N 114692.41 E 109249.50 1483.03	---	68.86	22.90	---	-31.48	-14.62
80-7	N 114501.57 E 109460.25 1425.92	59.88	55.95	50.55	-24.75	-23.01	-17.02
350-3A	N 114399.17 E 109501.38 1408.17	108.69	75.12	54.02	-29.03	-32.53	-21.66

WASTE DUMP CHANNEL CLOSURES

STATION	RATE OF HORIZONTAL CLOSURE (ft/yr)					RATE OF VERTICAL MOVEMENT (ft/yr)				
	JUN'82	JUN'83	JUN'84	JUN'85	JUL'86	JUN'82	JUN'83	JUN'84	JUN'85	JUL'86
A	2.15	1.99	1.63	1.10	0.72	-0.08	0.00	-0.66	+0.15	-0.07
B	1.54	1.56	0.91	DESTROYED	--	-0.07	-0.31	-0.14	DESTROYED	---
E	1.14	0.92	DESTROYED	----------		+0.06	+0.29	DESTROYED	-----------	
F	1.99	1.89	1.21	1.17	0.91	-0.16	-0.09	-0.32	+0.02	+0.03
G	2.53	2.27	1.64	1.55	1.37	+0.01	+0.30	+0.12	-0.12	+2.30
J	--	--	1.17	1.01	0.92	--	--	+0.23	-0.36	-0.45
K	--	--	1.99	1.37	N.R.	--	--	+0.14	-0.05	N.R.
L	--	--	1.76	1.41	1.17	--	--	-0.10	+0.09	+3.15

MINE WASTE DUMPS

STATION	COORDINATES & ELEV. JUL'86	RATES OF MOVEMENT (ft/yr) HORIZONTAL JUN'83	JUN'84	JUN'85	JUL'86	VERTICAL JUN'83	JUN'84	JUN'85	JUL'86
20A	N 110775.69 E 106809.62 1470.07	2.61	1.78	1.28	1.45	-0.66	-1.43	-0.07	-0.52
21A	N 110843.70 E 106346.38 1474.25	2.36	1.53	1.70	1.20	-0.92	-1.40	-0.30	-0.60
22A	N 110830.34 E 106106.76 1471.30	2.82	2.09	1.72	1.40	-1.28	-2.04	-1.09	-0.37
68	N 110951.97 E 107089.60 1434.58	2.69	N.R.	1.58	1.31	-1.25	-0.72	-0.07	-1.64
81-1	N 110208.65 E 106549.84 1500.70	2.15	1.29	1.79	1.09	-0.78	-1.68	-0.31	-0.42
81.2	N 110768.77 E 106661.46 1462.88	2.57	1.72	1.54	1.08	-0.47	-0.26	-0.21	-0.69
19	N 110492.77 E 107817.78 1420.69	----	N.R.	1.19	0.83	---	-0.76	-0.31	-1.33

WOLVERINE CREEK TAILINGS PILE

SOUTH LOBE

STATION	COORDINATES & ELEV. JULY '86	RATES OF MOVEMENT (ft/yr) HORIZONTAL JUN.'84	HORIZONTAL JUN.'85	HORIZONTAL JUL.'86	VERTICAL JUN.'84	VERTICAL JUN.'85	VERTICAL JUL.'86
24A	N 113455.19 E 109022.77 1583.73	19.18	20.09	21.48	- 6.83	- 7.44	- 8.12
24B	N 113479.04 E 109213.07 1520.26	17.92	19.31	20.95	- 6.01	- 6.92	- 6.85
24D	N 113558.23 E 109538.87 1413.08	---	11.76	15.98	---	- 3.84	- 5.16
25C	N 113756.11 E 109826.77 1359.82	6.72	7.25	8.61	+ 2.69	+ 3.15	+ 2.54
80-9	NO REFLECTION	3.43	3.02	---	+ 1.41	+ 1.45	---

file PD 3164

bcc: P. Lighthall

CASSIAR MINING CORPORATION

2000 - 1055 WEST HASTINGS STREET, VANCOUVER, B.C., CANADA V6E 3V3

TELEPHONE: (604) 688-2511
TELEX: 04-508664
TELECOPIER: (604) 688-4769

November 7, 1985

Mr. H.F. (Bud) McAlpine
Water Resources Division
Department of Indian &
Northern Affairs
200 Range Road
Whitehorse, Y.T.
Y1A 3V1

Dear Bud,

Re: Asbestos Fibres in Water - Clinton, Wolverine, Forty Mile and Yukon River.

Please find attached copies of the data on water samples taken at points on the above mentioned water courses in the summer of 1985.

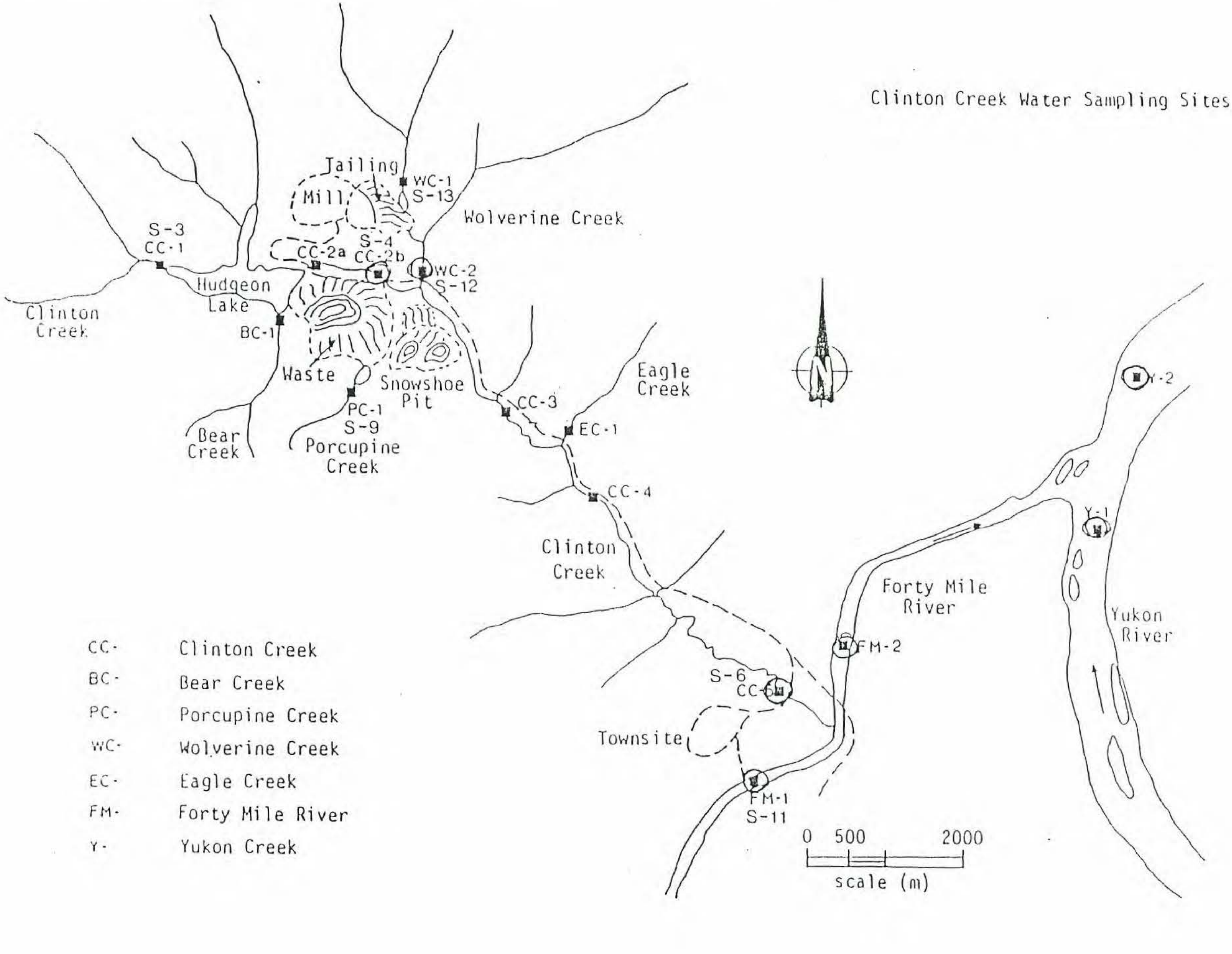
With the exception of a higher count on Wolverine Creek above its confluence with Clinton Creek, all values are low and in line with naturally occurring counts. It is interesting to note that the fibre count in the Yukon River, above its confluence with the Forty Mile River is higher than that below the confluence. We look forward to hearing from you later this month with regard to setting a date for discussion of the abandonment of the Clinton Creek site.

Yours sincerely,

Peter C. Jones
Executive Vice President

Encls.

cc: Mrs. Diane Granger
Chairman, Yukon Territory Water Board
Suite 200, 4114 Fourth Avenue
Whitehorse, Yukon
Y1A 4N7



Clinton Creek Water Sampling Sites.

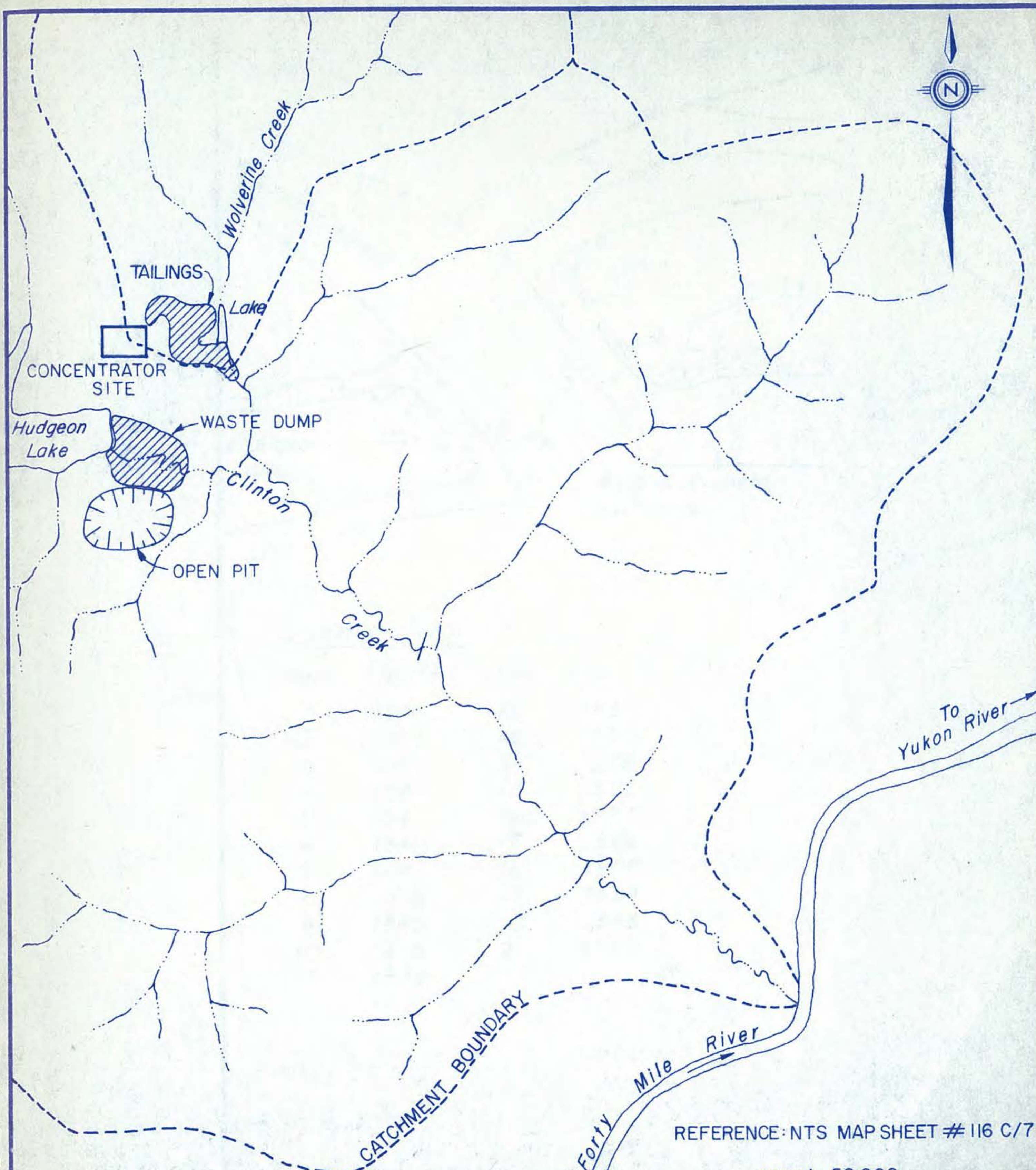
November 5, 1985

ASBESTOS IN WATER RESULTS - CLINTON CREEK (all results X 10^6)

Date	S3 CC1	CC2A	S4 CC2B	CC3	CC4	S6 CC5	S11 FM-1	FM-2	Y-1	Y-2	S13 WC-1	S12 WC-2	EC-1	S9 PC-1	BC1
Aug. 1985	1.6	8.2	7.1	37.1	82.9	6.5	2.2	4.9	114.5	38.2	10.4	1,430.4	2.7	<0.5	5.4
July 1984	74.2	219.2	176.7	1,450.4	1,329.4	1,511.5	3.3	9.8	6.0	3.3	98.7	1,370.8	542.6	4,202.2	211.6
June 1983	0	8.7	4.4	3.3	18.5	8.7	3.8	1.6	16.5	16.5	79.1	3.8		3.3	2.2
Aug. 1982	27.3		26.1			16.4	6.0	1.6			3.3	51.8			
Sept.1981		21.8	13.1			42.5	2.7	4.4			19.6	125.8			
June 1981		68.7	65.4			57.8	3.3	7.6			137.4	114.5			
Nov. 1980	N.D.		12.5			41.4	N.D.		7.1	0.5	3.3	208.3			
Sept.1980	2.7	2.7	4.9	154.3	67.6	166.9	14.7	2.7	14.7	6	N.D.	188.7	0.5	6.4	
July 1980	N.D.		267.2			665.2	43.6		327.2	N.D.	16.4	395.3	10.9		
Oct. 1979	N.D.		398			3,094					20.7	54.5		3.3	
Aug. 1979	14.2		1,505			3,108					5.5	1,908.5		N.D.	
July 1979 (U.A.M.A)			517.9			36,690					101.4	1,381		5,442	
July 1979	1.6		396			14,449					5.5	143		33	
June 1979	6.6		1,292			36,024					38.5	401		55	
May 1979			9,760									45,580		137	
Feb. 1979												12			
Oct. 1978	5.5		396									1,040		11	
Sept.1978	3.3		1,091									53,546		140.7	
Aug. 1978	1.6		1,700									18,299		30.2	
July 1978	N.D.		67,451									58,344		N.D.	
June 1978	N.D.		1,205									730,676		16.4	
May 1978	5.5	141.8	7,917				114.5	330.8				173,399		27.5	
May 1978												127,596			

DRAWINGS

A-1012	-	SITE LOCATION PLAN
D-1006B	-	WASTE DUMP PLAN AND PROFILE ALONG CLINTON CREEK
D-1002A	-	PLAN AND SECTIONS OF CHANNEL RIPRAP PROTECTION
D-1004C	-	PLAN OF TAILINGS PILES
D-1005A	-	SECTIONS THROUGH TAILINGS PILES



KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

PROJECT: CLINTON CREEK ASBESTOS MINE

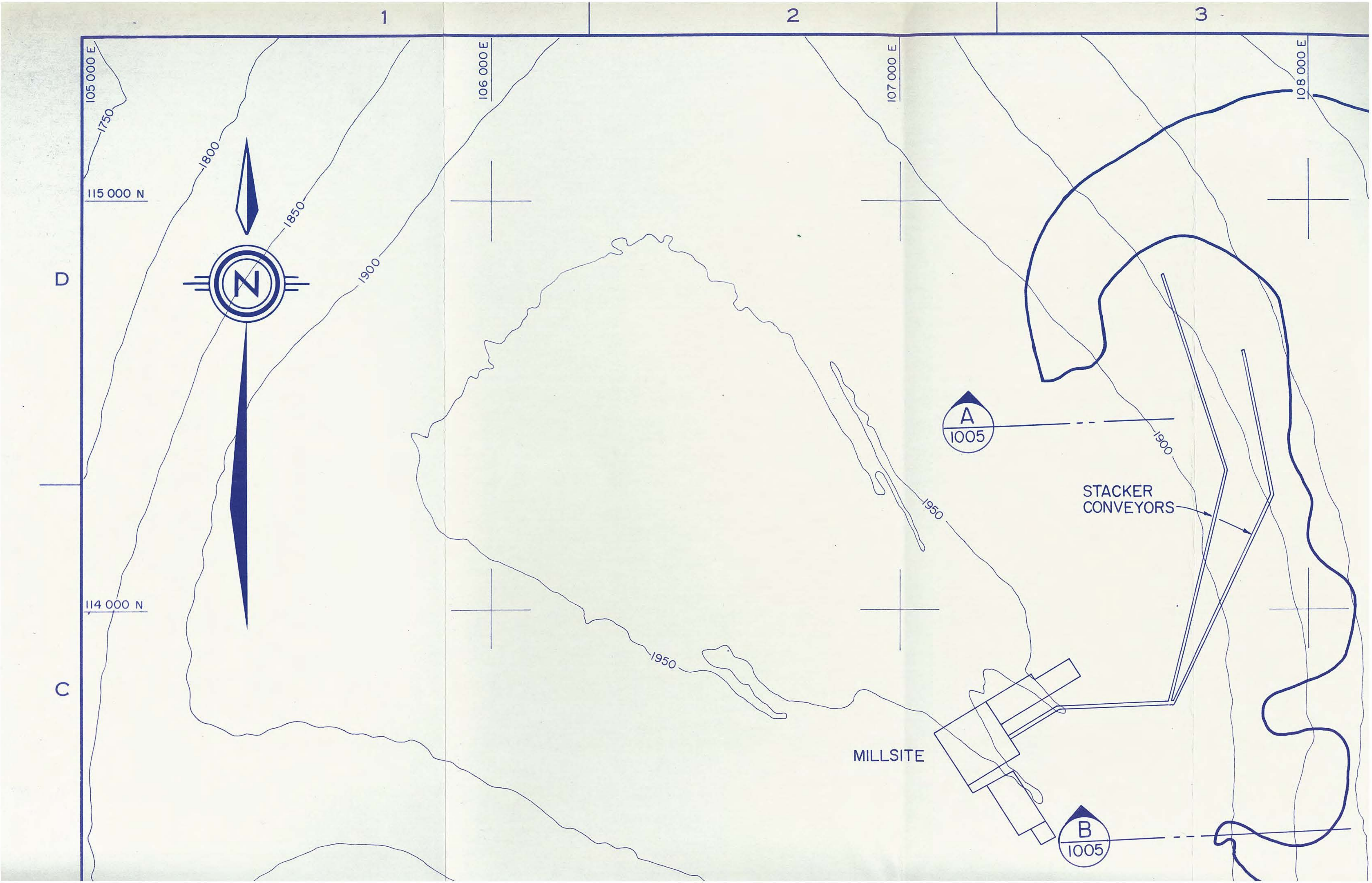
TITLE: LOCATION PLAN

CLIENT: BRINCO MINING LIMITED
CASSIAR DIVISION

DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
SEPT. 12, 1986	PB3169-03	A-1012	

APPROVED

NCI-455-KL


1
2
3
D
C
105 000 E
106 000 E
107 000 E
108 000 E
115 000 N
114 000 N
1750
1800
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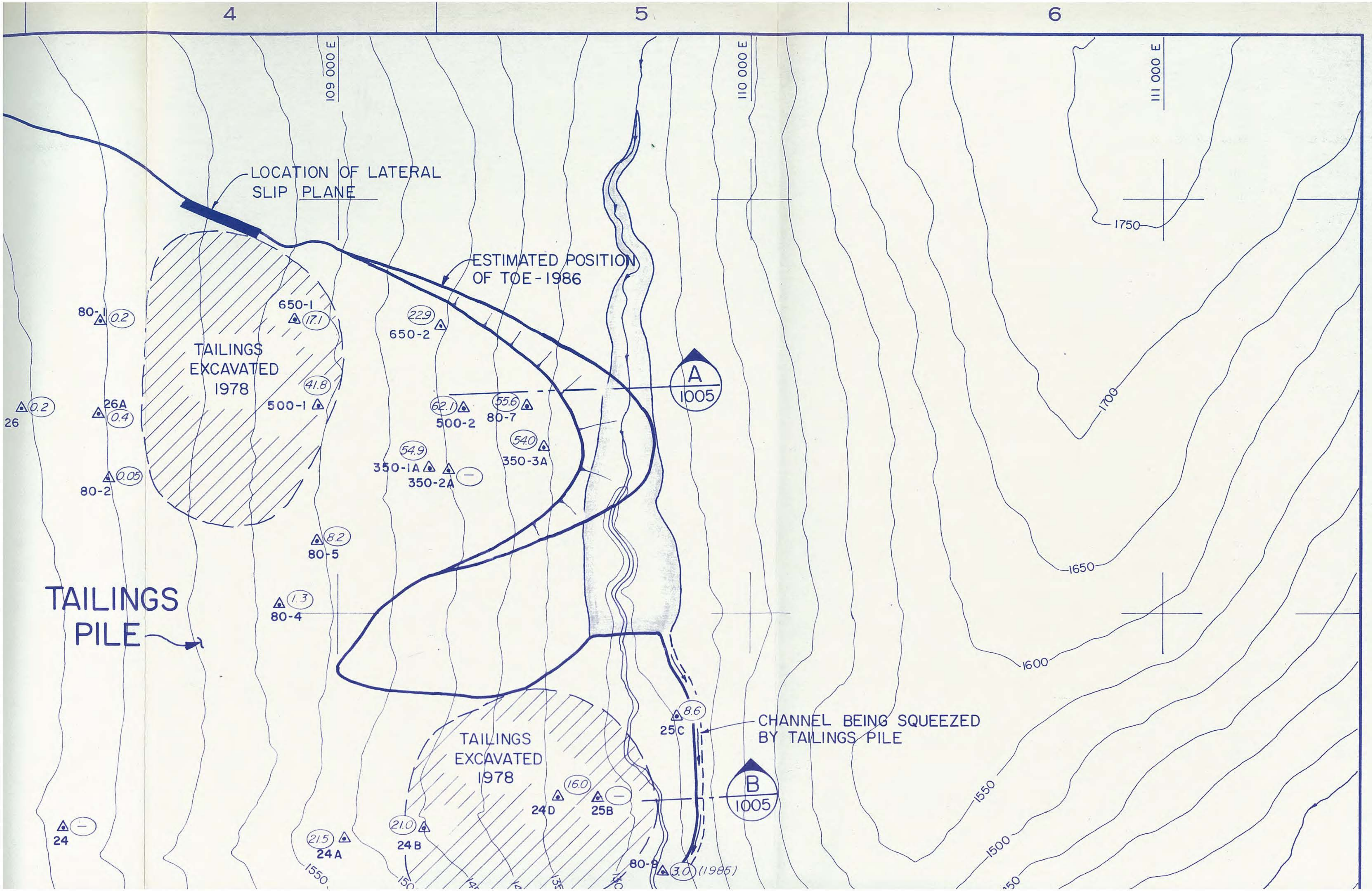
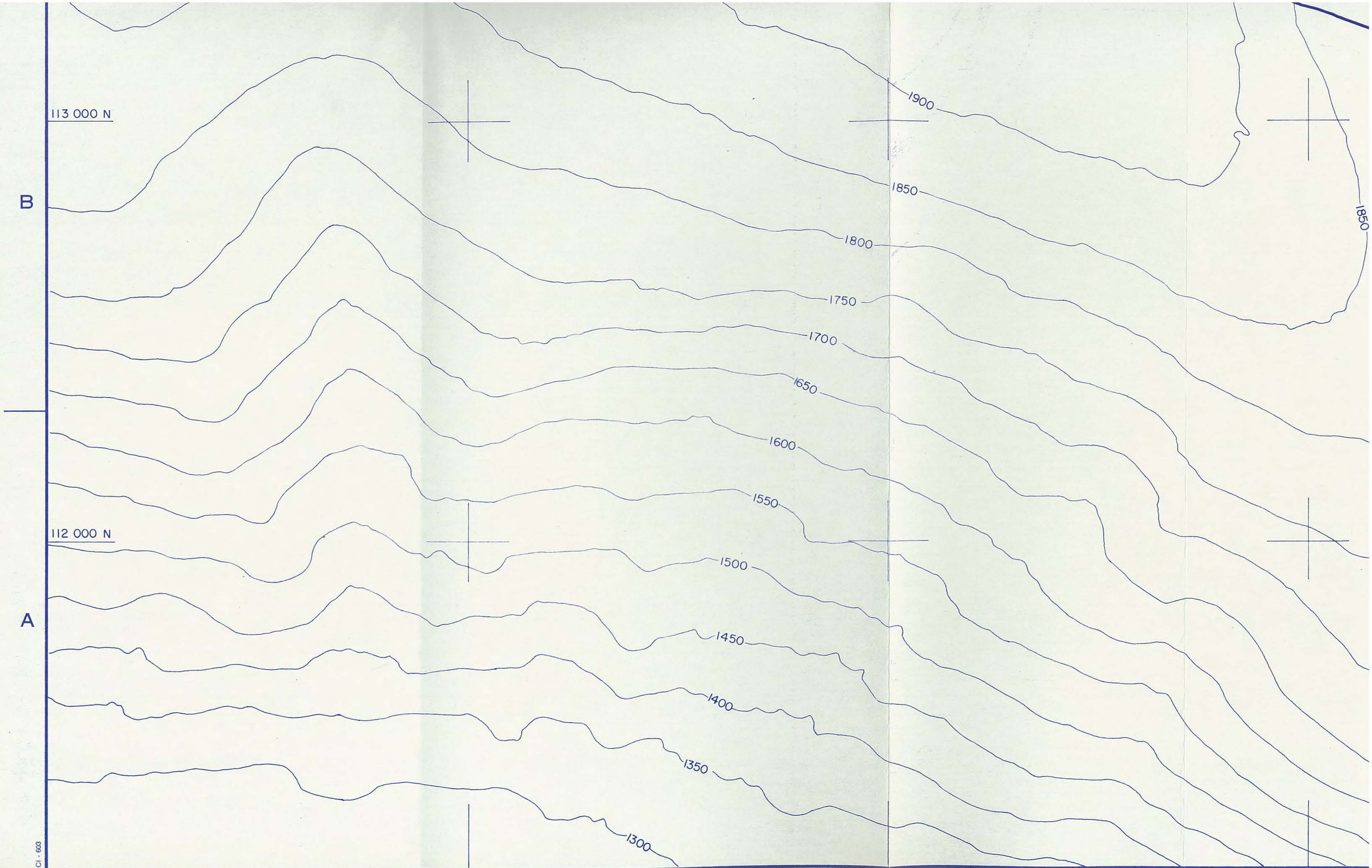
1005
B
1005
STACKER
CONVEYORS
MILLSITE



4
5
6
109 000 E
110 000 E
111 000 E
LOCATION OF LATERAL SLIP PLANE
ESTIMATED POSITION OF TOE - 1986
TAILINGS EXCAVATED 1978
TAILINGS EXCAVATED 1978
TAILINGS PILE
CHANNEL BEING SQUEEZED BY TAILINGS PILE
A
1005
B
1005
1750
1700
1650
1600
1550
1500
80-1
0.2
650-1
17.1
22.9
650-2
41.8
500-1
26
0.2
26A
0.4
62.1
500-2
55.6
80-7
54.0
350-3A
54.9
350-1A
350-2A
80-2
0.05
8.2
80-5
1.3
80-4
8.6
25C
16.0
24D
25B
24
21.5
24A
21.0
24B
80-9
3.0
(1985)



113 000 N
112 000 N
B
A
1900
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1600
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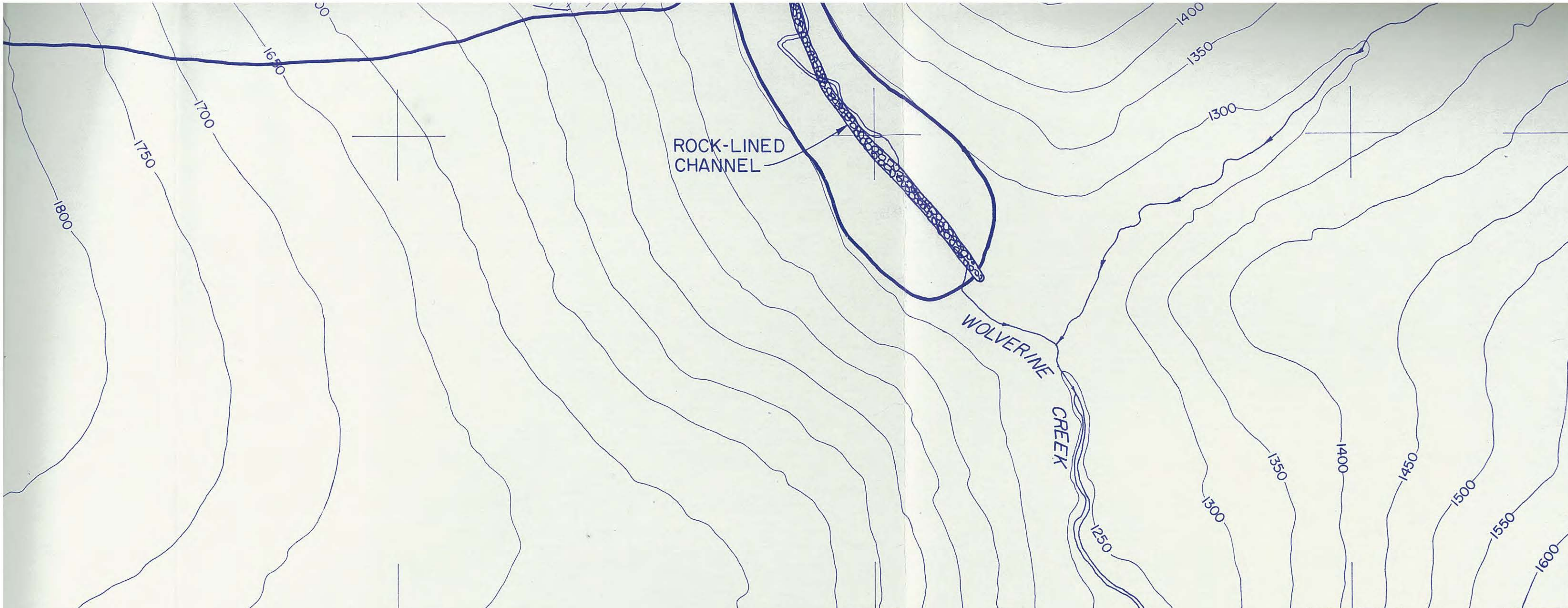
1350
1300
NCI - 603



LEGEND

△(1.9) Monitoring Point (Rate of horizontal movement - ft/yr June 1985 to June 1986)
24

NOTE

TOPOGRAPHY TRACED FROM CASSIAR ASBESTOS CORPORATION LIMITED SHEET No. 223, COMPILED IN 1965 BY McELHANNEY AIR SURVEYS LTD.

REV.	DATE	REVISION DETAILS
C	Aug 86	Monitor points plotted to 1986 coordinates. Movement rates revised. Position of toe revised.
B	Aug 85	Monitor points plotted to 1985 coordinates. Movement rates revised. Position of toe revised.
A	July 84	Monitor points plotted to 1984 coordinates. Movement rates revised. Position of toe revised.

TO BE READ WITH KLOHN LEONOFF REPORT DATED SEPT. 12, 1986

SCALE: 200 0 200 400 ft.

DESIGN	DRAWN	DATE	SCALES
P.C.L.	F.C.	DEC. 1983	1" = 200'

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

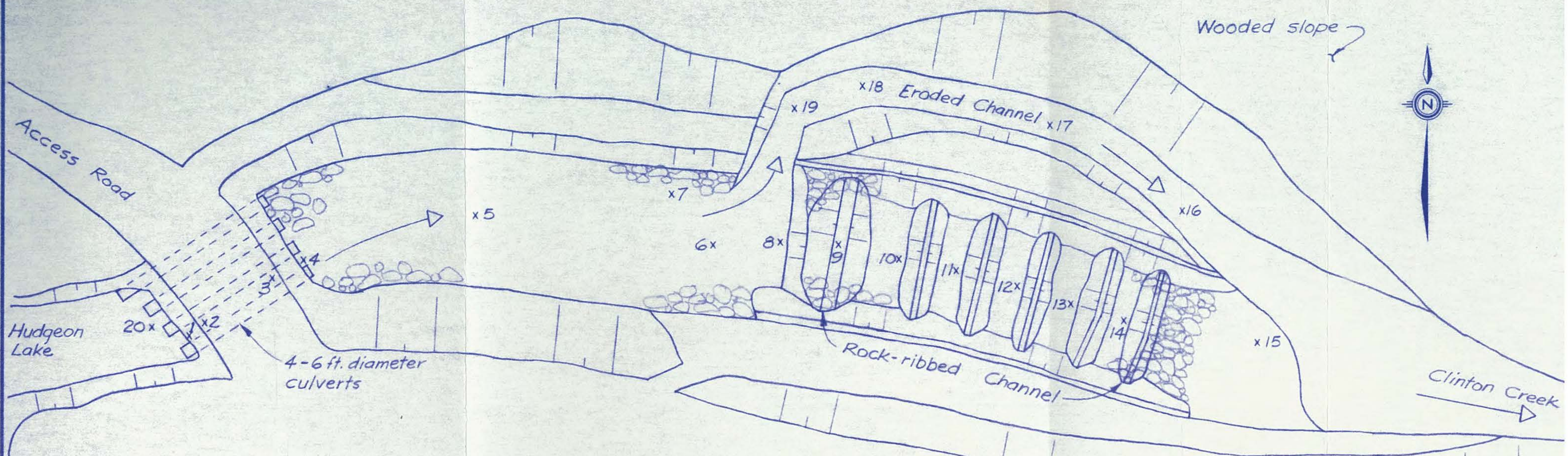
PROJECT: CLINTON CREEK MINE RECLAMATION

TITLE: PLAN OF WOLVERINE CREEK TAILINGS PILES

CLIENT: BRINCO MINING LIMITED CASSIAR DIVISION

DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
JAN. 26, 1984	PB 3169-01	D-1004	C

APPROVED: [signature]

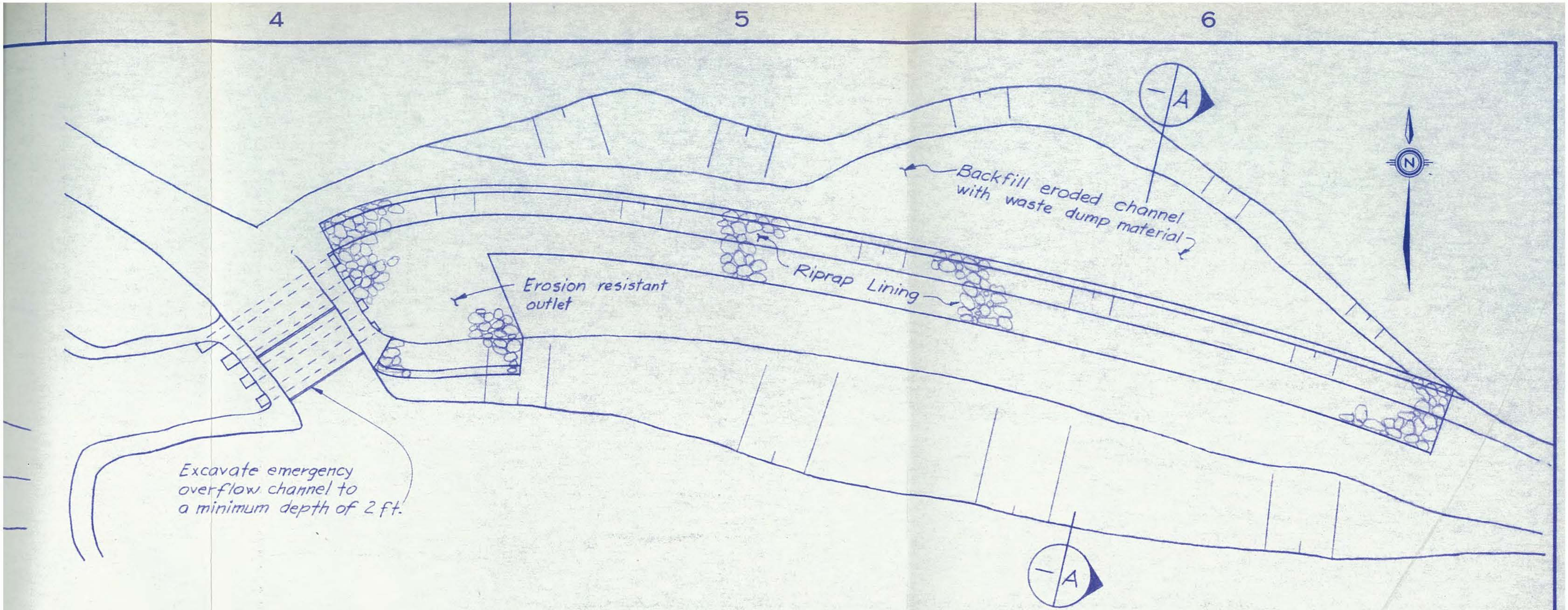


SURVEY DATA

Point	Elev. (ft)	Point	Elev. (ft)
1	1344	12	1332
2	1353	13	1330
3	1354	14	1328
4	1340	15	1322
5	1341	16	1322
6	1340	17	1326
7	1337	18	1325
8	1338	19	1329
9	1343	20	1343
10	1336	21	1355
11	1334		

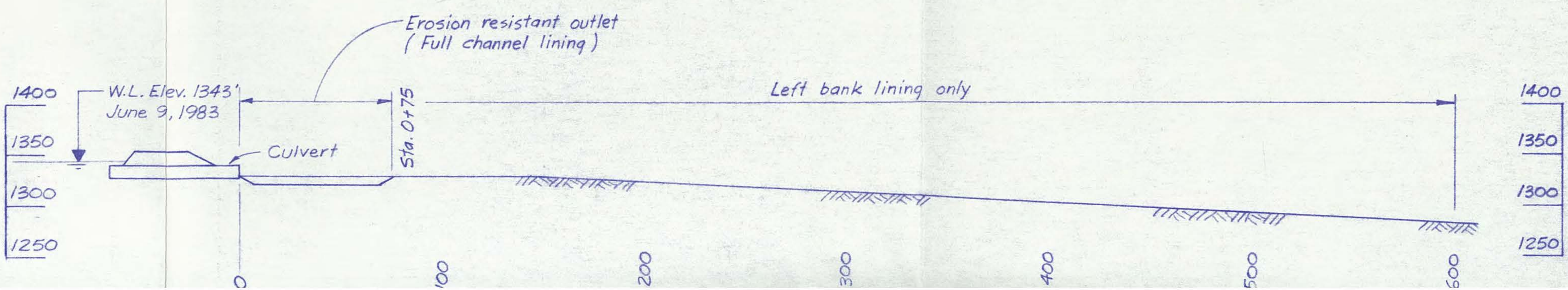
SKETCH OF SITE PLAN FOR EXISTING CHANNEL

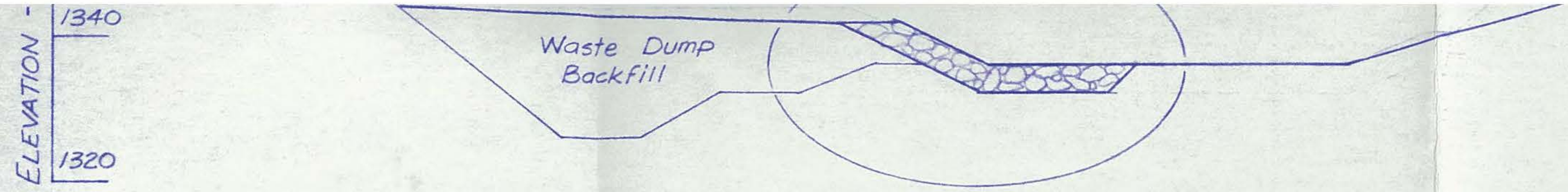
Approx. scale : 1" = 50'



SITE PLAN SHOWING CHANNEL LINING

Approx. scale : 1" = 50'



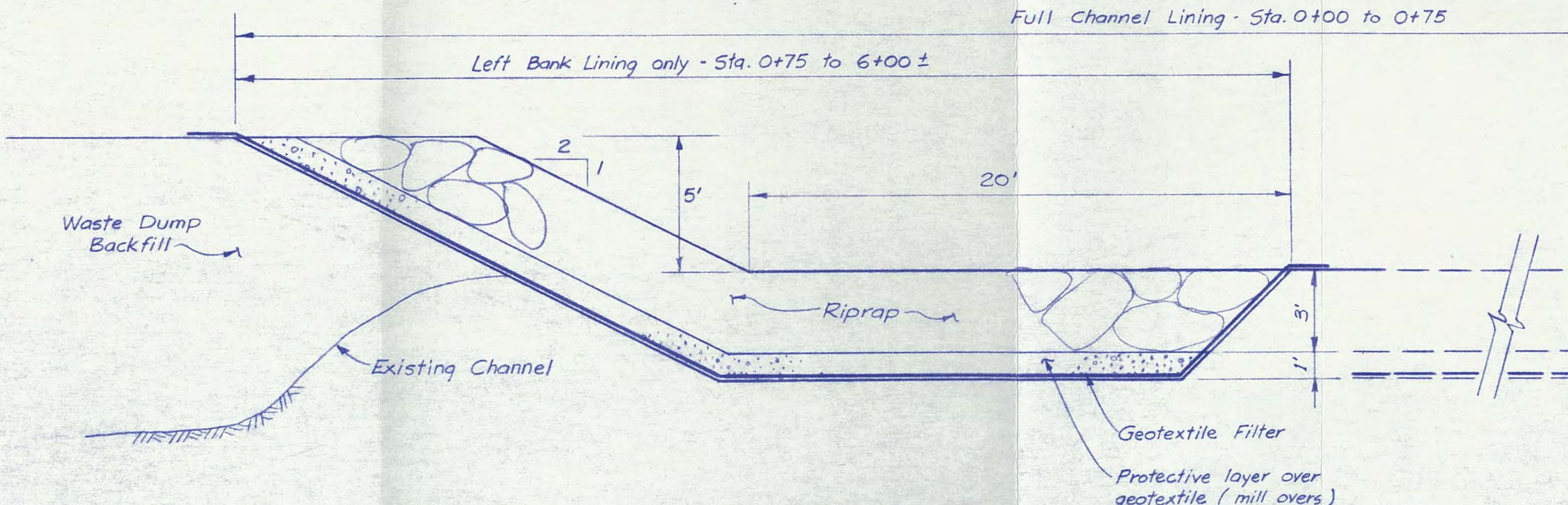


SECTION (A/—)

TYPICAL SECTION OF CHANNEL - STA. 0+75 TO 6+00

Scale : 1" = 20'

B



A

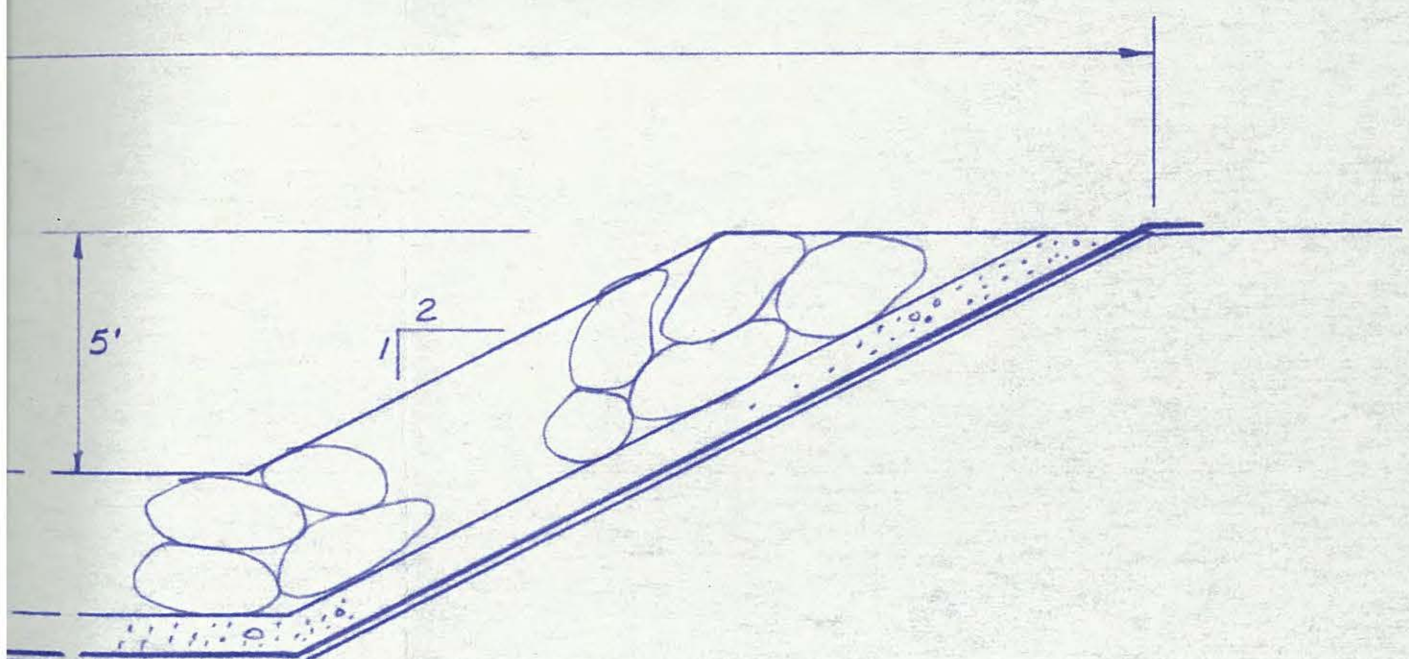
DETAILS OF CHANNEL LINING

Scale 1" = 4'

NCI - 603

PROFILE ALONG CHANNEL ℄

Scale 1" = 50'



NOTES

1. Plans, profile and sections are approximate, based on limited survey data, sketches of site prepared during site inspection by Klohn Leonoff and photographs of the area.

2. Backfill in existing channel should be placed in maximum 1 ft. lifts and compacted by bulldozer travel.

3. Geotextile filter to consist of high strength woven polymer such as Mirafi P600X or equivalent. Where two sheets are joined provide minimum 1 metre overlap.

4. Riprap gradation:

% finer by wt.	rock size
100	3.0 ft.
50	1.5 ft
10	0.5 ft

5. Final alignment of riprap lining and extent of riprap placement to be approved by the Engineer on site.

TO BE READ WITH KLOHN LEONOFF REPORT DATED SEPT. 12, 1986

REV.	DATE	REVISION DETAILS
A	Sept 2 83	Added erosion resistant outlet. Reduced side channel lining from 6' to 5'

SCALE:

DESIGN A.M. / P.L. | DRAWN F.C. | DATE JULY 1983 | SCALES AS SHOWN

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

PROJECT: CLINTON CREEK MINE WASTE DUMP

TITLE: PLAN AND SECTIONS OF CHANNEL RIPRAP PROTECTION

CLIENT: BRINCO MINING LIMITED CASSIAR DIVISION

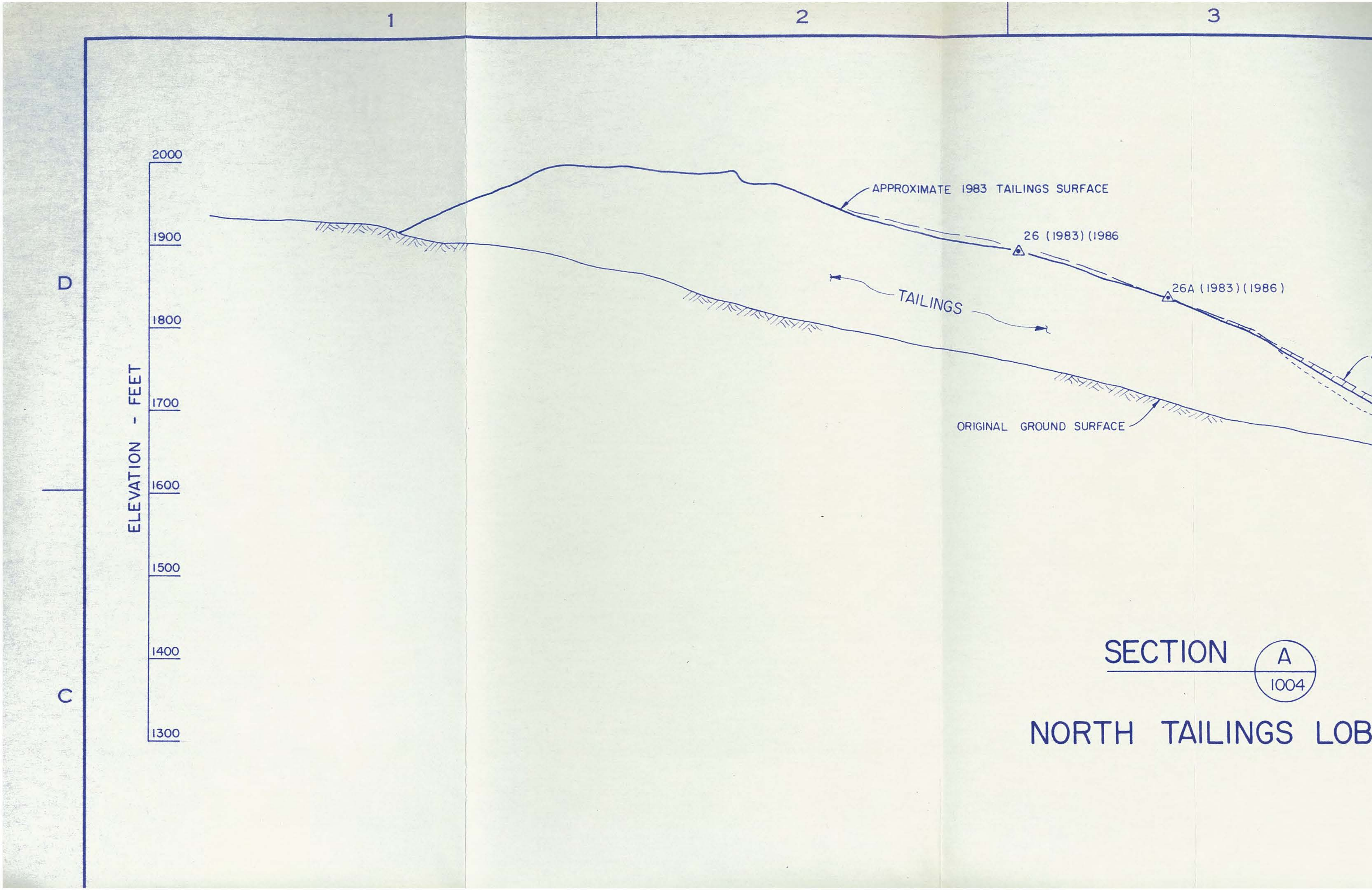
DATE OF ISSUE: AUG. 16, 1983

APPROVED: [signature]

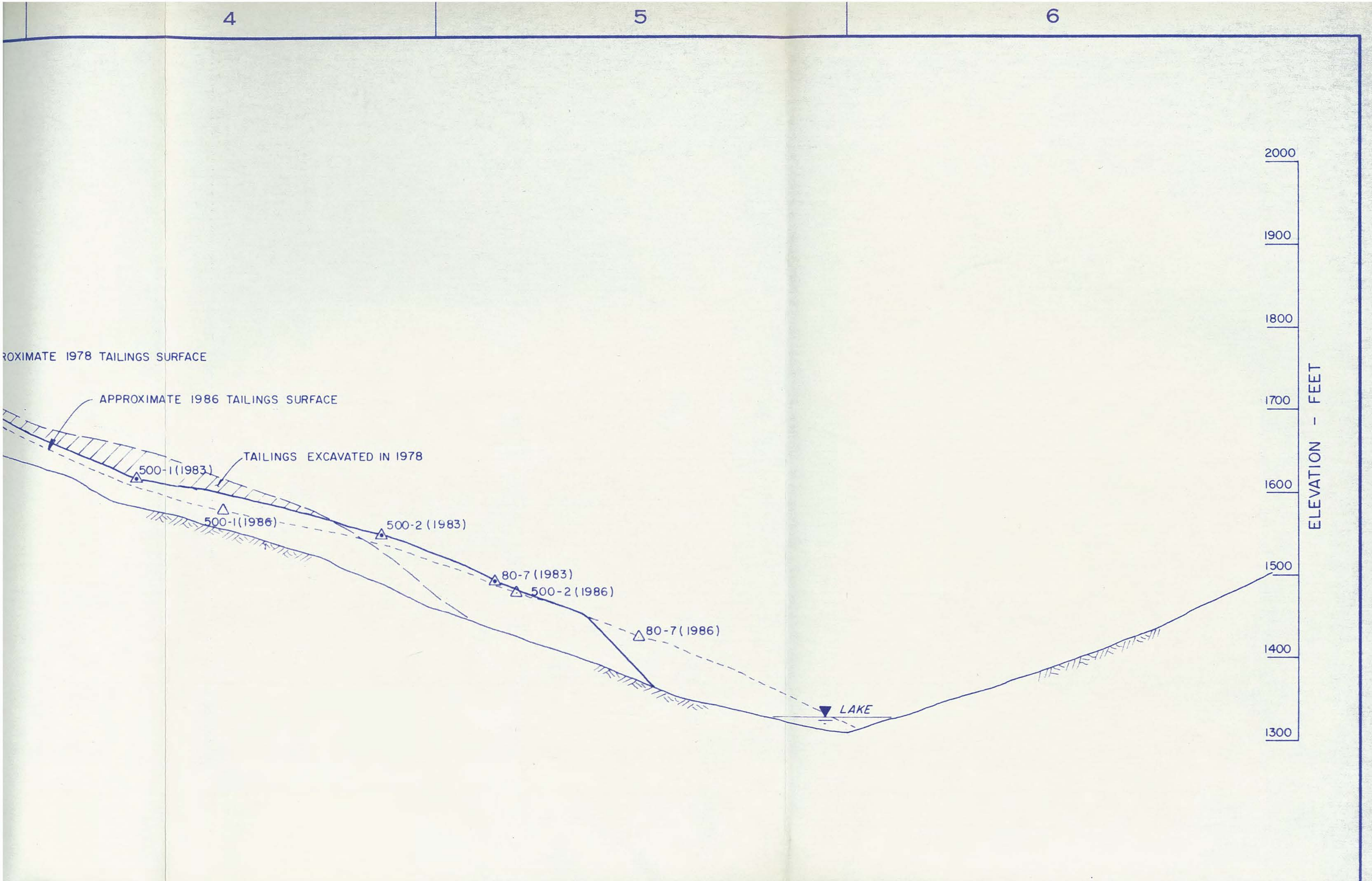
PROJECT No.: PB 3169 01

DWG. No.: D-1002

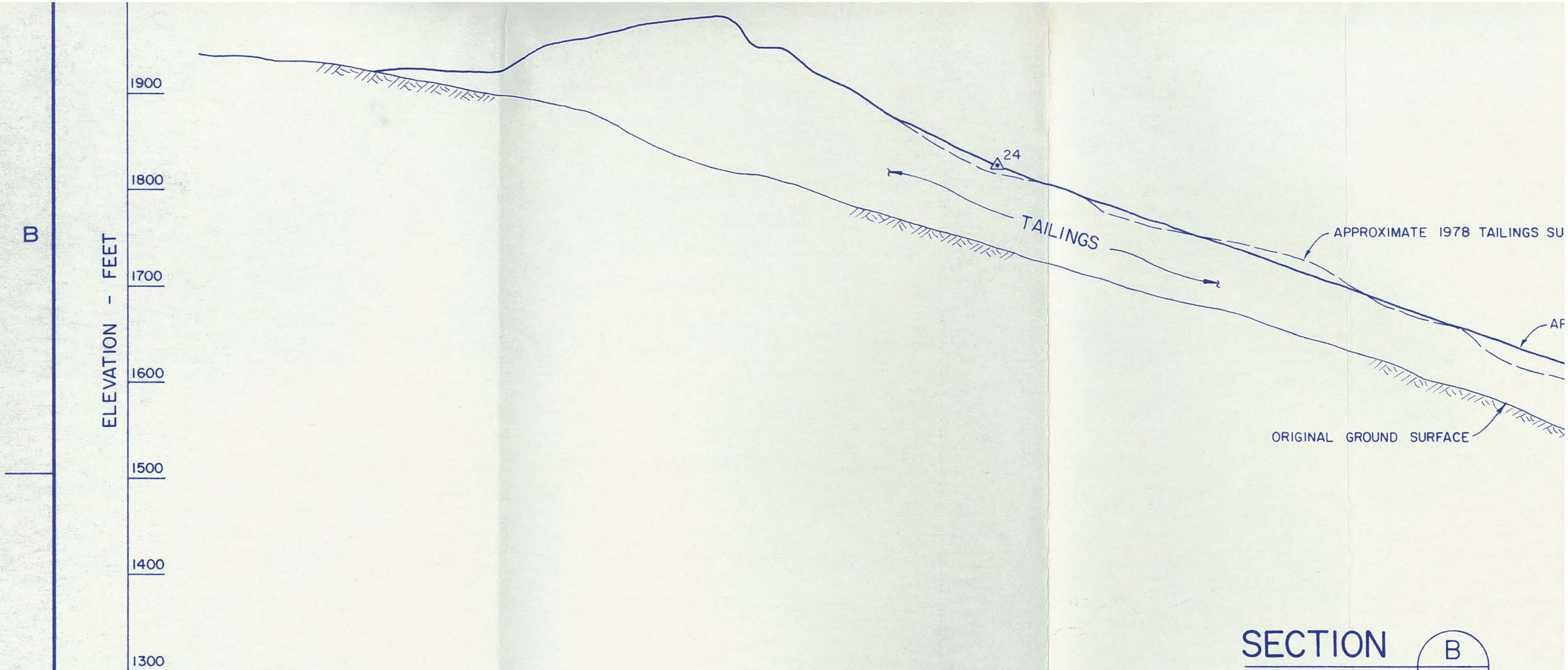
REV.: A



1
2
3
D
C
ELEVATION - FEET
2000
1900
1800
1700
1600
1500
1400
1300
APPROXIMATE 1983 TAILINGS SURFACE
26 (1983) (1986
26A (1983) (1986)
TAILINGS
ORIGINAL GROUND SURFACE
SECTION A 1004
NORTH TAILINGS LOBE



4
5
6
ROXIMATE 1978 TAILINGS SURFACE
APPROXIMATE 1986 TAILINGS SURFACE
TAILINGS EXCAVATED IN 1978
500-1 (1983)
500-1 (1986)
500-2 (1983)
80-7 (1983)
500-2 (1986)
80-7 (1986)
LAKE
2000
1900
1800
1700
1600
1500
1400
1300
ELEVATION - FEET



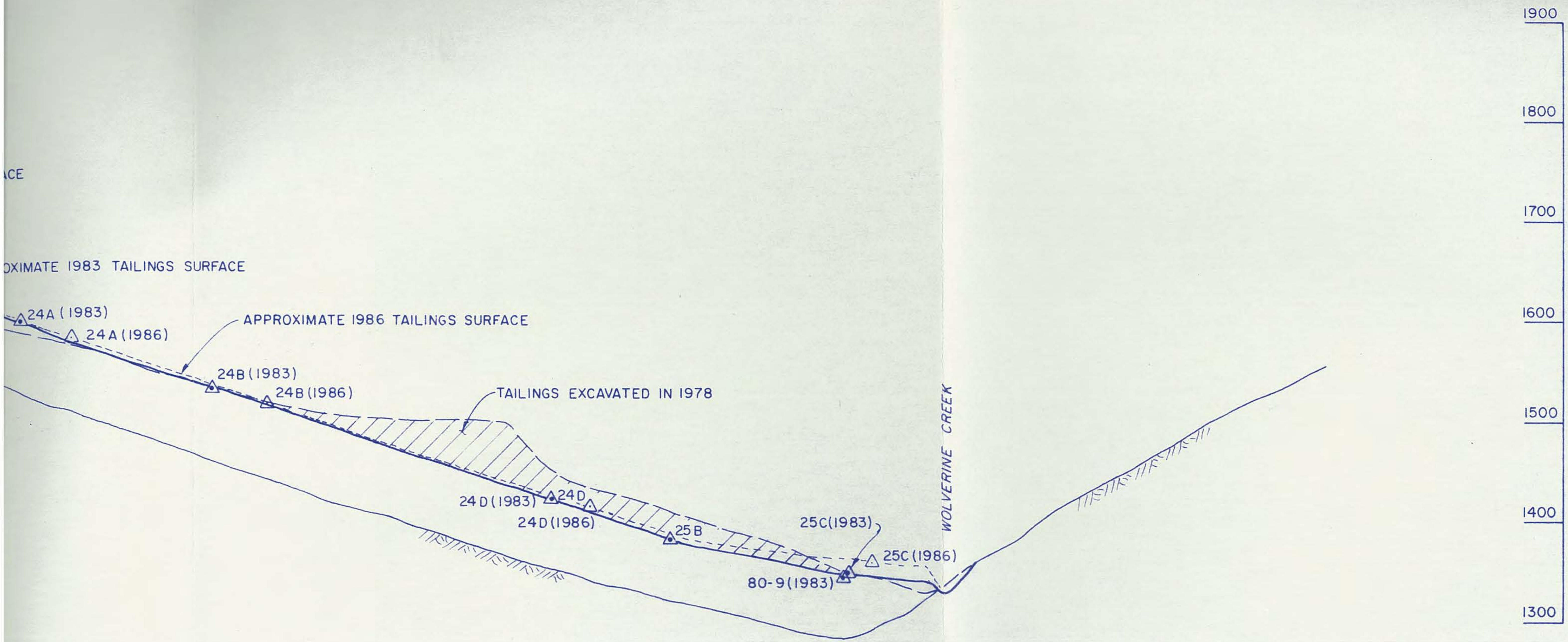
SECTION B/1004

SOUTH TAILINGS LOBE

LEGEND

26A Monitoring Point

NCI-603



TO BE READ WITH KLOHN LEONOFF REPORT DATED SEPT. 12, 1986

SCALE: 100 0 100 200 ft

REV.	DATE	REVISION DETAILS
A		1986 TAILINGS SURFACE ADDED.

DESIGN	DRAWN	DATE	SCALES
P.C.L.	F.C.	DEC. 1983	1" = 100'

AS A MUTUAL PROTECTION TO OUR CLIENT, THE PUBLIC AND OURSELVES, ALL REPORTS AND DRAWINGS ARE SUBMITTED FOR THE CONFIDENTIAL INFORMATION OF OUR CLIENT FOR A SPECIFIC PROJECT AND AUTHORIZATION FOR USE AND/OR PUBLICATION OF DATA, STATEMENTS, CONCLUSIONS OR ABSTRACTS FROM OR REGARDING OUR REPORTS AND DRAWINGS IS RESERVED PENDING OUR WRITTEN APPROVAL.

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

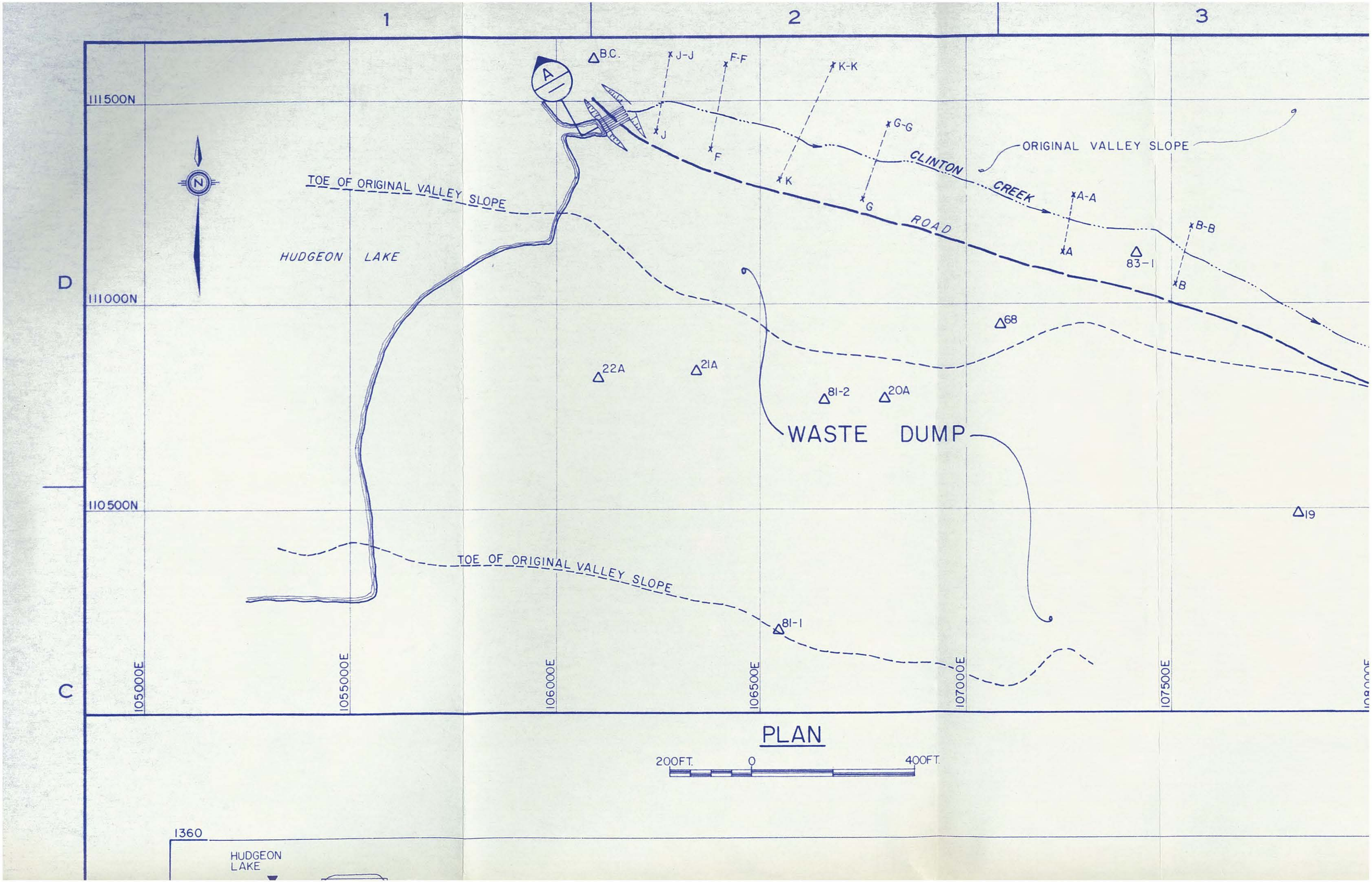
PROJECT: CLINTON CREEK MINE RECLAMATION

TITLE: WOLVERINE CREEK TAILINGS PILES SECTIONS 'A' AND 'B'

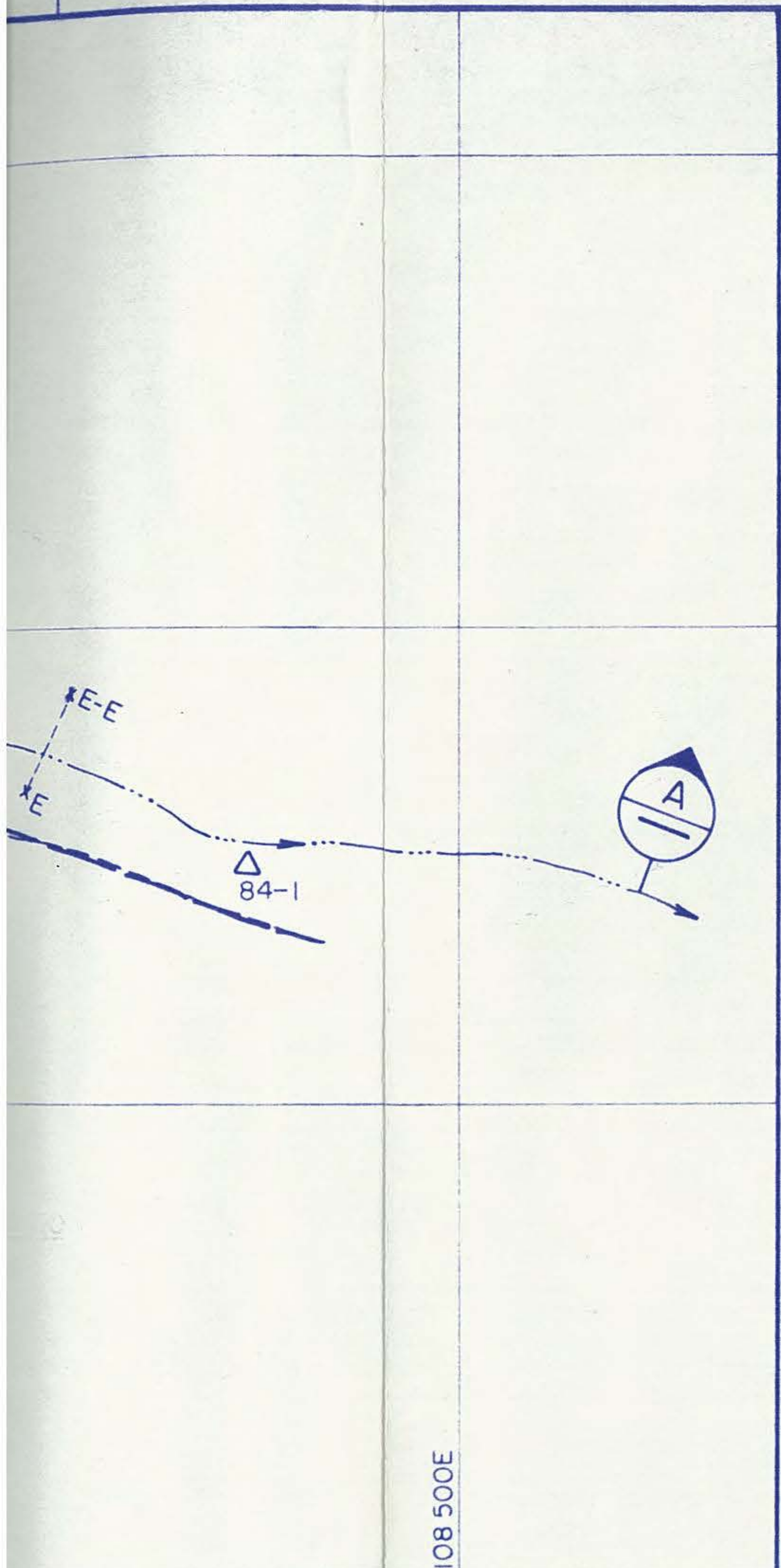
CLIENT: BRINCO MINING LIMITED CASSIAR DIVISION

DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
JAN. 26, 1984	PB 3169-01	D-1005	A

APPROVED: [signature]


1
2
3
D
C
111500N
111000N
110500N
105000E
105500E
106000E
106500E
107000E
107500E
B.C.
J-J
J
F-F
F
K-K
K
G-G
G
A-A
A
B-B
B
A
N
TOE OF ORIGINAL VALLEY SLOPE
HUDGEON LAKE
CLINTON CREEK
ROAD
ORIGINAL VALLEY SLOPE
83-1
68
22A
21A
81-2
20A
WASTE DUMP
19
81-1
PLAN
200FT.
0
400FT.
1360
HUDGEON LAKE

4 5 6



LEGEND

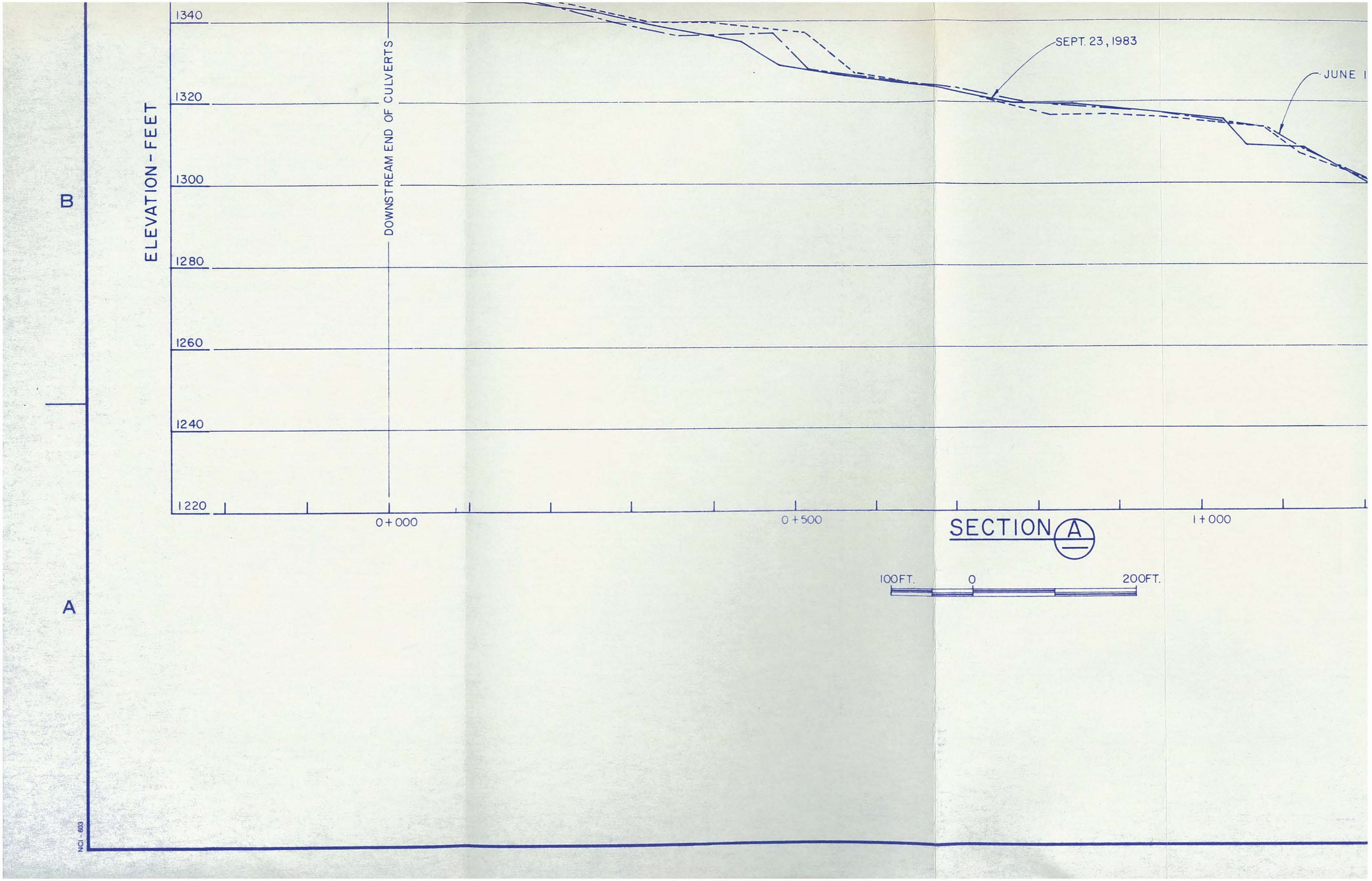
△ 20A SURVEY MONUMENT

x- - - - -x CROSS-CHANNEL REFERENCE LINE
A A-A

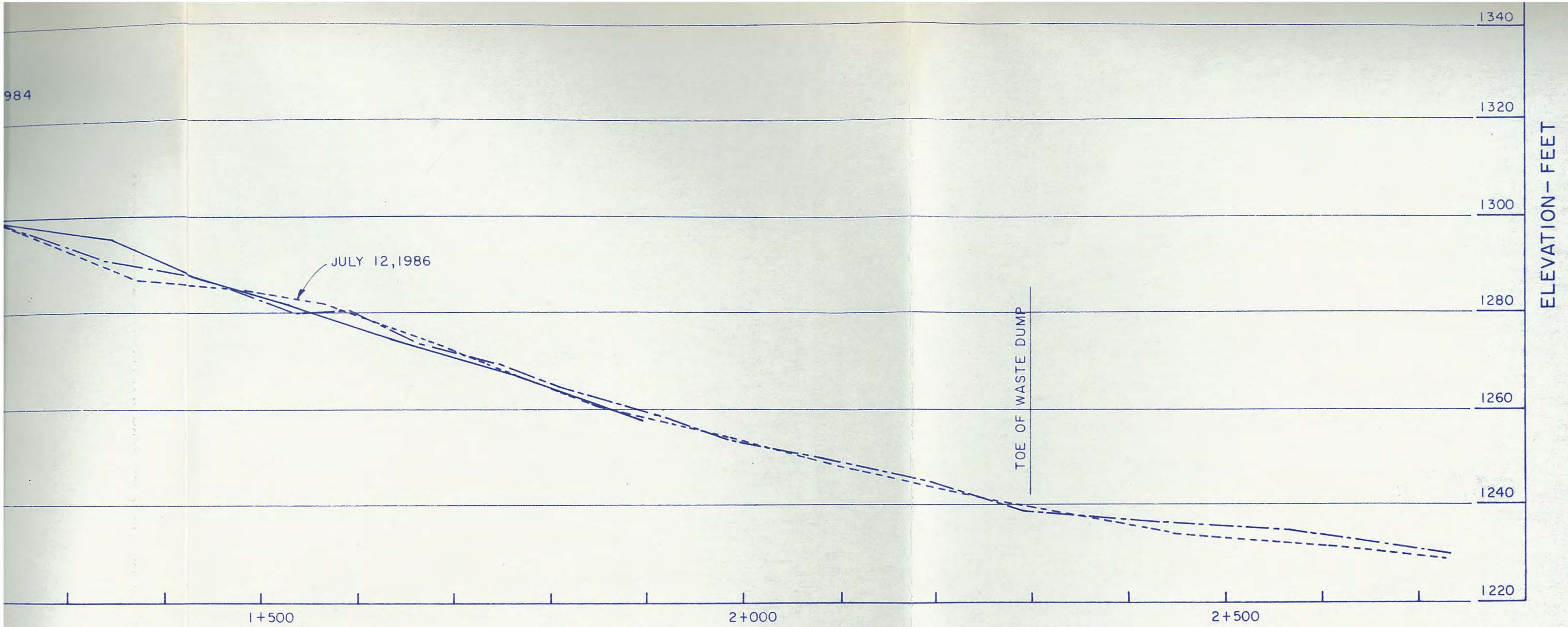
NOTES

1. PROFILE IS PLOTTED WITH 5 TIMES VERTICAL EXAGGERATION.

1360



ELEVATION - FEET
1340
1320
1300
1280
1260
1240
1220
DOWNSTREAM END OF CULVERTS
SEPT. 23, 1983
JUNE I
0+000
0+500
1+000
SECTION A
100FT.
0
200FT.
B
A
NCI - 603



REV.	DATE	REVISION DETAILS
B	Aug 86	ADDED JULY 12, 1986 PROFILE
A	AUG. 1984	ADDED STATIONS TO PROFILE, REVISED CLINTON CREEK PLAN LOCATION ADDED JUNE 15, 1984 PROFILE

TO BE READ WITH KLOHN LEONOFF REPOPT DATED SEPT. 12, 1986

SCALE:

DESIGN	DRAWN	DATE	SCALES
P.C.L.	E.D.P.	FEB., 1984	AS SHOWN

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

PROJECT: CLINTON CREEK MINE WASTE DUMP

TITLE: PLAN AND LONGITUDINAL PROFILE OF WASTE DUMP CHANNEL

CLIENT: BRINCO MINING LIMITED CASSIAR DIVISION

DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
APPROVED [signature]	PB 3169-01	D-1006	B