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CLINTON CREEK ASBESTOS MINE

WASTE AND TAILINGS PILES
Review Report

PRELIMINARY

Prepared for:

Northern Affairs Program
Water Resources Division
Whitehorse, Y.T.

G044

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1.0 INTRODUCTION

This report summarizes our opinion on the current conditions of the waste and tailings piles of the Cassiar Asbestos Mine (Y.T.). It discusses probable consequences of abandoning the dumps in their present (unstable) state and allowing the natural processes to take their course.

While we were unable to visit the site in 1985, the reports prepared by Klohn Leonoff on behalf of Cassiar Mining and communication with the Water Resources as well as mining company personnel were utilized for this review. The main sources of information and events are listed below:

- Brinco Mining Limited letter of January 9, 1985 outlining the company position regarding the abandonment of piles.
- Klohn Leonoff February 28, 1985 letter report on stability analysis of the north lobe of the tailings pile.
- Klohn Leonoff February 28, 1985 letter report evaluating the Wolverine Creek rock lined channel.
- Klohn Leonoff April 23, 1985 Report on Sediment Transport Analysis.
- Brinco Mining Limited letter of June 28, 1985 summarizing current site conditions.
- Klohn Leonoff September 6, 1985 report on the 1985 site visit.
- Meeting with Cassiar Mine and Klohn Leonoff personnel on January 15, 1986.

Dr. R. Cooper of Northwest Hydraulic Consultants reviewed some of the hydrological aspects of the nteraction between the streams and dumps and the Sediment Transport Analysis.

It should be appreciated that discussions and opinions presented in this report are based on previous performance of the dumps and reflect our experience from similar conditions and natural process developments elsewhere. The conclusions presented in the report are based on engineering judgement rather than analysis.

2.0 BACKGROUND INFORMATION UPDATE

The problems associated with the dumps located in the Clinton Creek and Wolverine Creek valleys is illustrated by aerial photographes, shown on Figures 1 and 2. Photograph 1, taken in 1970, shows original positions of both creeks and initial stages of dumping. Photograph 2, taken in 1976, shows Hudgeon Lake formed by the waste dump blocking the Clinton Creek Valley and a small lake formed in the Wolverine Creek valley because of the failure of the tailings pile North.Lobe.

Schematic cross-sections, illustrating the dumps conditions are presented on Figures 3 and 4.

Stabilization efforts undertaken in 1978 and 1979 which involved recontouring of both waste and tailings piles did not stabilize the embankments. Similarly, existing armouring of lake outfalls did not ensure maintenance free channels and permanent control of affected stream sections.

Results from the monitoring programs (since 1977) suggest that the tailings pile as well as waste dump movements are slightly decreasing. The south lobe of the tailings pile exhibited accelerated movement until 1985. When it reached the valley bottom, displacing the existing lake, the rate of movement decreased. The rate of the Clinton Creek waste dump movement also is decreasing. The Clinton Creek channel downstream from the armoured lake outfall continues to downcut and erode the banks which are oversteepened.

The mining company's opinion regarding the abandonment of the waste and tailings piles has been presented in their January 9, 1985 letter and can be summarized as follows:

- Clinton Creek Dump

  The mining company considers that the waste dump is safe against catastrophic failure involving sudden release of water from Hudgeon Lake. Furthermore, the channel of Clinton Creek is being armoured by large rock fragments, which are being eroded from the waste dump. This gradual, on-going erosion can be expected to occur for a number of years, with more armouring of the creek bed resulting; thus preventing rapid downcutting of the stream bed.

  With the possible exception of removal of the culverts at the outlet of Hudgeon Lake, the Company considers the abandonment plan for Clinton Creek to be completed.

- Wolverine Creek Tailings Pile

  The Company believes that the most practical approach in dealing with the tailings material is to maintain the channel of Wolverine Creek until movement of the tailings pile has stabilized sufficiently so that a permanent channel develops.

  The stability of the north lobe of the tailings pile was reviewed analytically by Klohn Leonoff. The analysis of the present dump configuration and dump regrading steps indicate little benefits from fill redistribution. The risk of sudden failure for the lower segment of the south lobe will decrease when the lobe will begin to buttress itself against the opposite valley wall (Klohn Leonoff letter of February 28/85).

Klohn Leonoff also carried out a sediment transport analysis for Wolverine and Clinton Creeks (report dated April 23, 1985). The study objective was to evaluate how much tailings material may be transported and redeposited downstream of the tailings pile. The impact of sediment from the Clinton Creek dump was not considered. The following general conclusions were presented:

- the existing rock lined channel, lower sections of Wolverine and Clinton Creeks can transport all size of the tailings material;

- the upper reach of Clinton Creek below Wolverine Creek has a limited capacity to transport gravel sized materials;

- 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 sized and finer materials;

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

- 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 Creek segments. 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.

Main aspects of the development of these dumps together with various rehabilitation options previously reviewed (summarized in Hardy/Geo-Engineering report dated March 1985 is referenced in various Brinco and Klohn Leonoff letters and reports) are tabulated on pages 4 and 5. It should be appreciated that the cost estimates are approximate only and that other impacts and benefits could be added to those summarized in the tables.

3.0 DISCUSSION

There has been a significant change in the approach to the abandonment of the suspended mining operation during the past couple of years. Until about 1983 the mining company anticipated that the dumps will achieve (either through regrading or in combination with natural processes) a state of equilibrium which would permit reclamation of the lands. Insofar as the tailings pile is concerned it was expected that the pile will become stable thus allowing the construction of a permanent creek channel.

It has been lately recognized that natural processes affecting the stability of these dumps are of a magnitude which is difficult to control, both from the technical as well as economical standpoint.

The discussion of possible future developments involving Clinton and Wolverine Creeks as they may become influenced by the ongoing instability of both dumps took place in the Cassiar Vancouver office on January 15, 1986. The objective of the meeting (attended by Messrs. C. Jones and T. Miller on behalf of Cassiar, by Mr. P Lighthall representing Klohn Leonoff and Messrs H.F. McAlpine and M. Stepanek on behalf of Northern Affairs) was to clarify the opinions regarding the future behaviour of the dumps and creeks and to review the current abandonment considerations.

The mining company recent opinion regarding the future behaviour of the dumps is briefly summarized below.

- <u>Clinton Creek Waste Dump</u>

  The continuing stream erosion and dump movement is believed to be a dynamically stable process. While some deposition of material in the valley downstream of the dump will occur most of the material is expected to be transported through (as per the sediment transport analysis) with a minimal impact on the Forty Mile River.

CLINTON CREEK WASTE PILE

MAIN EVENTS : 1968 - Start of mining operations
1970 - Initial dump failure
1974 - Dump failure and formation of Hudgeon lake
1918 - Mine shut down
1978 and 1979 - Unsuccessful attempt to stabilize the dump
1980 - Installation of rock -lined outfall channel (weir and apron)
1981 - Rock weir reconstruction
1982 - Rock weir failure
1984 - Rehabilitation of rock - lined channel section

ABANDONMENT OPTIONS

ALTERNATIVE :	COST:	IMPACTS:	BENEFITS:	HAZARDS:
Natural Process Development	?	Destruction of lake outfall. Retrogressive erosion . Deposition of eroded materials downstream.	Restoration of natural equilibrium.	Floods and mudflows Potential loss of life.
Coarse rock drain	>$5 mil.	Questionable durability; possible long term impacts as above.	Stabilization of dumps.	Potential clogging and retrogressive erosion.
Culvert and valley fill	$ 1.0 mil.	Life expectancy 40 years, possible retrogressive erosion in the long term.	Acceleration of natural stabilization process.	Potential clogging of culvert.
Valley fill, spillway and armoured channel	$ 0.5 mil	Uncertain long term performance	Protection of downstr. valley sector. Stabilization of dumps.	Breach of fill and erosion of channel. Flood.
Sedimentation pond below Clinton and Wolverine Creek junction.	<$0.5 mil	Erosion of the dump. Ongoing maintenance.	Protection of area downstream from the pond. One structure for the entire mine area.	Overtopping of sed. pond. Dam failure. Loss of life.

WOLVERINE CREEK TAILINGS PILE

MAIN EVENTS :
1968 - Start of mining operations
1974 - Failure of the South Lobe and formation of a lake
1974 - Start of dumping into North Lobe
1978 - Mine shut down
1978 and 1979 - Unsuccessful attempt to stabilize the piles
1978 - Installation of rock -lined outfall channel (spillway)
1981 - Accelerated movement of North Lobe
1985 - North Lobe encroaching into the valley bottom

ABANDONMENT OPTIONS

ALTERNATIVE :	COST:	IMPACTS:	BENEFITS:	HAZARDS:
Natural Process Development	?	Destruction of rock lined channel. Retrogressive erosion . Deposition of eroded materials downstream.	Restoration of natural equilibrium.	Floods and mudflows Potential loss of life.
Coarse rock drain	>$5 mil.	Questionable durability; possible long term impacts as above.	Stabilization of dumps.	Potential clogging of drain and erosion
Tunnel diversion	>$2.5 mil.	Questionable durability. Long term impacts possibly the same as above.	Natural and undisturbed stabilization of piles.	Tunnel and intake structure deterioration resuting in renewed erosion.
Culvert and valley fill	$ 1.0 mil.	Life expectancy 40 yrs. Potential clogging and induced retrogressive erosion.	Acceleration of natural stabil. process.	Potential obstruction of culvert causing erosion.
Relocation of tailings	~$15 mil.	New waste dump area.	Removal of unstable materials.	
Retaining dam and stabilization berm at South Lobe	$ 0.5 mil	Uncertain long term performance.	Protection of downstr.valley. Stabilization of dumps.	Potential overtopping of dam. Loss of life.
Sedimentation pond downstream from Clinton and Wolverine Creeks confluence	<$0.5 mil	Dump erosion. Ongoing maintenance of pond.	Protection of area downstream from the pond.	Overtopping of sediment. pond. Dam failure. Loss of life.

It is acknowledged that the rock lined section of the outfall channel from the Hudgeon lake is not a maintenance free, permanent structure and that the erosion of the valley sideslope is an ongoing process. However, a significant breach of a valley closure resulting in release of large amounts of water from the lake is not expected.

- Wolverine Creek Tailings Pile

  The existing rock-lined channel may fail or it could be by-passed. This would result in a formation of a new channel. Large quantities of material will be deposited in the area of Clinton and Wolverine Creek confluence and downstreams. It is believed that the Clinton Creek has a sufficient transporting capacity to maintain its present regime.

In summary, it is apparent that the stabilization of both dumps is technically difficult and would be very expensive. Previous attempts to stabilize the dumps were not successful, possibly due to uncertainties relative to the properties of materials and failure mechanism. This experience decreased the confidence level in the possiblity to stabilize the dumps.

The intention to allow the natural process to take it's course requires evaluation of possible impacts. These may range from:

- gradual and slow movement of the mine wastes, generally not exceeding the transportation capacity of the stream, to

- significant erosion of the valley blockage and transportion of large volumes of slide material downstream.

It is expected that transport of wastes, lateral and retrogressive erosion will influence both streams. It is our opinion that some deposition of eroded wastes downstream from the dumps will occur.

4.0 CONSEQUENCES OF NATURAL PROCESSES

The valley blockages are intervening structures distorting the natural stream gradient. The streams will remove these obstacles in order to achieve a smooth or constant gradient. The actual time required for this development is difficult to estimate.

Ranges of horizontal movement (not seasonally adjusted), measured during the 1984-1985 monitoring period, are listed below:

Clinton Creek Waste Dump	0.4 - 0.6 m/yr
Clinton Creek Channel Bank	0.3 - 0.5 m/yr
Wolverine Creek North Lobe	0.1 - 10.4 m/yr
Wolverine Creek South Lobe	17.1 - 22.9 m/yr

Typically, the horizontal rate of movement is about 1.25 times greater during the summer season than in the winter.

Horizontal movements for the toe areas of the waste dump and tailings pile are plotted on diagrams shown on Figures 5 and 6.

Our review of case histories indicates that the majority of slide-formed valley blockages was breached (Hardy/Geo Engineering 1985 Report). Some "landslide dams" were eroded in very short periods of time (i.e. within a few days) while the breach of others occurred after many years.

4.1 Geotechnical Aspects

The movement of both dumps will continue, primarily due to the ongoing destabilizing effect of stream erosion.

Close scrutiny of the Clinton Creek Channel traversing the waste dump shows continuous undercutting of both banks. The north bank (original north valley slope) exhibits localized slides affecting the overburden cover and, to a minor degree, relatively weak, subhorizontally bedded, calcareous, graphitic sandy limestome, sandstone and graphitic argillite or mudstone (G. Abbot, D.I.A.N.D., 1982). The south channel bank, formed by the waste rock, is undergoing a continuous lateral erosion.

The uppermost section of the Wolverine Creek channel is deformed and constricted. It is anticipated that cumulative effects of terrain movements and erosion will eventually result in a failure of this channel.

The significant parameters which determine the impact of continuing sliding and erosion on the eventual destruction of existing landslide dams are:

- rate of flow
- duration of critical flow
- erodibility of slide material
- erodibility of its foundation

The lakes formed by sliding waste and tailings material are relatively small. It is possible that the volume of impounded water is insufficient to trigger a disastrous erosion.

The erosion susceptibility of the waste and tailings materials may be estimate don the basis of the grain size distribution:

Particle size mm	Waste Material Percent Passing (Based on 4 tests)	Tailings Material Percent Passing (Based on 2 tests)
100.0	95 - 100	100
20.0	45 - 100	100
2.0	20 - 75	60
0.2	8 - 30	20
0.06	4 - 16	10
0.02	0 - 12	5

The tailings have a high content of sand particles (about 60 percent) and are considered to be highly erodible. These materials could possibly liquefy and, if oversaturated, flow as viscous fluid. The mine waste has 20 to 80 percent of gravel - sized particles and is less erodible than the tailings. However, the content of large durable rocks in the mine waste is low. Medium gravel and smaller particle sizes are readily eroded from the unstable channel bank and transported downstream into the lower parts of Clinton Creek and, possibly, into the Forty Mile River.

The erodibility of the natural subgrade is of secondary importance. However, it appears that lateral erosion could trigger localized slumps within the valley slope. The bedrock strata are not strong enough to control the stream downcutting (retrogressive erosion) or periodical undermining of valley walls.

It is expected that the combination of the sliding, erosion and depositional processes will gradually modify the existing valley gradient, across the blockages formed by dumps. The resulting slope will likely be greater than the original slope of the valley bottom but less than the current gradient across the valley blockage.

It is anticipated that the dumps will experience changes briefly characterized in the following paragraphs.

- <u>Clinton Creek Waste Dumps</u>

  The continuing retrogressive and lateral erosion will gradually breach the crest of the valley blockage and lower the lake level. Some of the events may be more extensive, causing temporary blockages of the outfall channel. This, in turn, will temporarily increase the lake elevation and accelerate erosion. The outflow from the lake could change its pattern and erode a new gully. This, in turn, may increase the rate of sliding.

  The state of equilibrium will not be achieved until the most of the current valley blockage is redeposited further downstream. The estimated total volume of waste material is in the range of 35 x $10^6 m^3$. It is conceivable that about one third to one half of this volume will be eventually eroded away and redeposited downstream

- <u>Wolverine Creek Tailings Pile</u>

  The rates of movement suggest that both tailings lobes are moving in a "caterpillar-like" manner. As a lower segment fails, toe support for the section above is removed and the failure gradually progresses up the slope. The amount of horizontal movement decreases in the upslope direction. The toe of the dump is rising and gradually spreading in the valley bottom.

  Progressive failure of the north tailings pile lobe (moving presently in the order of 25 m/yr) will likely spread the tailings material across the entire valley bottom. The slide will form a new lake which could be larger than the existing one.

  The blockage would be eventually overflown, forming a new outfall channel likely outside the present rock-lined spillway. The tailings would be eroded progressively down resulting in lowering of the lake level, flooding of the downstream valley section and transportation as well as deposition of large quantities of fine to coarse tailings particles throughout the Wolverine and Clinton Creek valleys. Again, this event may re-occur several times until an equilibrium between the erosion rate and the tailings pile movement is achieved.

It is possible that more than one half of the pile volume which comprises about 10 to 12 x 10^6 tones (about 6 x $10^6 m^3$) of tailings will be eventually displaced.

4.2 Hydrological Aspects

The following paragraphs deal, first, with Clinton Creek and the anticipated morphologic developments of the reach crossing the waste dump; second, with the morphology of the reach of Wolverine Creek crossing the tailings dump; and third, with anticipated sedimentation and morphologic developments that can be anticipated downstream of the two dumps.

- Clinton Creek Waste Dump

  Lake levels and outflows are now controlled by a culvert installation at the outlet. There has been some consideration given to removing these culverts prior to abandonment. Levels and outflows would then be controlled by the geometry and stability of the outlet channel.

  Because the waste dump is still exhibiting horizontal movement into the channel, there is an ongoing process of toe erosion and locallized slope failures which provide the stream with a high sediment load and additional bed paving material.

  The estimated slope of Clinton Creek through the waste dump is 4.5 percent.

With respect to abandonment the key issues would seem to be the future stability of the channel through the waste dump and the rate at which sediment will be supplied to a point downstream of the dump. At present this system is in a state of relatively rapid change. Laterally the channel is confined by natural bedrock on the left and by waste slopes that are still exhibiting horizontal movement on the right. The rate of supply of sediment to the channel through a cycle of toe erosion and localized slope failures in the encroaching dump material is high. This process can be expected to cause localized blockages in the channel which will subsequently erode and be transported downstream. The rate of downcutting has undoubtedely decreased due to the development of a bed paving layer. With time as this paving layer thickens progressively higher flows will be required to disturb the bed paving. In the longer term, as the rate of movement of the dump decreases the channel will tend to widen and migrate laterally into the dump. Downcutting can then proceed as the paved bed will be abandoned.

There are a variety of situations that could cause the failure or abandonment of the rock-lined outfall channel. This is likely to have little impact on the quantities of sediment supplied to the channel along its entire length. Indeed, consideration should be given to allowing the lake outlet to degrade along with the downstream channel.

- Wolverine Creek Tailings Dump

  The main issues of concern with regard to abandonment are uncertainties about conditions that will develop when the north lobe blocks the valley and causes the present impoundment of water to be displaced upstream, and whether or not it will be practically feasible to maintain flow in the rock-lined channel.

In practical terms it may not be feasible to maintain Wolverine Creek flows in a rock-lined crossing of the tailings dump. At a minimum, significant ongoing maintenance costs can be anticipated. Already concerns have been expressed that the capacity of the upper section of the channel has decreased due to encroachment of tailings into the channel. If the rate of encroachment is greater than the capacity of flow in this channel to erode and transport sediment to the steeper section then infilling will ultimately cause the rock-lined channel to be bypassed. When this happens a new channel will rapdily downcut in the highly erodible tailings. Abandonment of the rock-lined channel is also a possibility if not a likelihood when valley bloackage by the north lobe occurs and the lake outlet is displaced upstream.

Consideration should be given to the alternative of allowing the rock-lined channel to be bypassed. If this were to occur a new channel would downcut quite rapidly and develop a graded profile through the dump that would be in rough equilibrium with the rate at which sediment is supplied to the channel. The sediment supply rate would in turn depend on the rate of encroachment by the tailings slope confining the right bank of the channel. A repeating cycle of encroachment, toe erosion, localized slope failure and transport of slumped material downstream could be expected. Periodocal channel blockages could occur due to local slumping. These would be accompanied by ponding, overtopping and rapid downscutting of the slump material. Delivery of sediment donstream would be consistent with the capacity of the high gradient channel to erode and transport the tailings.

As the rate of tailings encroachment decreases with time, further degradation and lateral migration could be expected. Because the tailings do not contain significant quantities of coarse fragments, bed paving woud not be a significant factor in slowing the erosional processes. Ultimately the channel could degrade to near its original profile but the valley would be narrower and contain several levels of terraces comprised of tailings material.

Potentially hazardous conditions would exist on the tailings dump because the channel banks would be continuously oversteepened and subject to local failures. During flood events, mudflow conditions could occur and threaten any development or activity immediately downstream of the dump.

- Downstream Effects

  A 1985 report by Klohn Leonoff analyzes the hydrologic characteristics and sediment transport capacities of Wolverine Creek, Clinton Creek and Forty Mile River into which Clinton Creek discharges. The report presents estimates of the annual sediment transporting capacity of each system. Results of this study have subsequently been used to form conclusions about how sediment that is eroded from the two dumps will be transported through and/or deposited within the downstream drainage systems.

Based on a very preliminary review of the limited information contained in the Klohn Leonoff report I have a concern that the sediment transport model used in the study may have seriously overestimated sediment transport capacities. On Woleverine Creek the estimated annual transport capacity is $2.0 \times 10^6 m^3$. Yet the annual flow volume is $7.9 \times 10^6 m^3$ (based on a reported average annual discharge of $0.25\ m^3/s$). This implies an average total sediment load concentration of 25 percent. On Forty Mile River (estimated annual sediment capacity - $790 \times 10^6 m^3$; annual flow volume - $2870 \times 10^6 m^3$) the average total sediment load concentration would be 28 percent. There would appear to be a need for a thorough review of this analysis and its results.

Both Clinton Creek and Wolverine Creek, if the existing rock-lined channel becomes bypassed, can be expected to discharge high volumes of sediment to the downstream ends of their respective dumps. At the outlet of each dump, channel slope flatten abruptly, velocities decrease and deposition of sediment will occur unless the lower gradient channel has the capacity to aggrade, overtopping of the banks will be more frequent and sediment will be deposited in the overbank areas. Fan like deposits could be expected to build-up and extend downstream of each outlet. Sediment loads in Clinton Creek below the area of deposition should approach the transporting capacity of the natural stream. If the transport capacity of Clinton Creek is eroded from the two dumps, there is a possibility that a large portion of the material that ultimately will be eroded from the dumps will be deposited over a relativley short reach of the Clinton Creek valley floor.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The performance of both the waste dump and tailings pile leads to a conclusion that modest recontouring of the dumps cannot arrest the slope movements.

The stability analysis (undertaken in the past by Hardy and Klohn) indicates that the sloughing may cease when the material is buttressed against the opposite valley wall. The valley fill would require special conveyance of the streams through, over or around the valley fill. However, such stream diversions would deteriorate with time which, in turm, could eventually lead to the failure of the stream diversion structure and renew the erosion process.

Previous works (undertaken by Hardy and Klohn) confirmed that there is a number of unknown factors (such as pore pressures, degradation of shearing resistance of tailings and frost effects) making successful and maintenance free stabilization very difficult.

With respect to this and in view of the costs estimated for individual stabilization or control measures it is prudent to consider the effects of natural developments on the dumps. The approach of allowing the streams to freely redistribute dump materials downstream is worthy of serious consideration as the long-term consequences may well be acceptable.

This approach, in our opinion, requires a thorough evaluation of both short and long-term consequences of material processes on the dumps, valleys and streams involved.

This evaluation should consider:

- probable hazards,
- range of possible impacts on the valley landscape, vegetation and land uses, and
- probable final (relatively stable) terrain configuration.

We have reservations insofar as the applicability and interpretation of the "Sediment Transport Analysis" is concerned. It is our opinion that significant volumes of wastes and tailings will be accummulated downstream of the dumps and below the Clinton and Wolverine Creeks confluence.

It is recommended that the following surveys be undertaken during the 1986 summer season:

1) mapping of the extent of sediments deposited downstream of the Wolverine tailings pile after the 1974 pile failure,

2) survey of the Clinton Creek waste dump channel profile,

3) survey of monitoring points on both dumps,

4) survey of waste dump material characteristics, and

5) acquisition and interpretation of the most recent air photos.

The analysis of sediment transport capacities of the various stream systems should be reviewed thoroughly and revised if necessary. Estimates should be made of the rates at which sediment is likely to be eroded from each dump.

It is futther recommended that all technical data be summarized in a concise report which would also comprise the review of abandonment impacts. These impacts should be outlined on maps (or mosaics) and documented by diagrams.

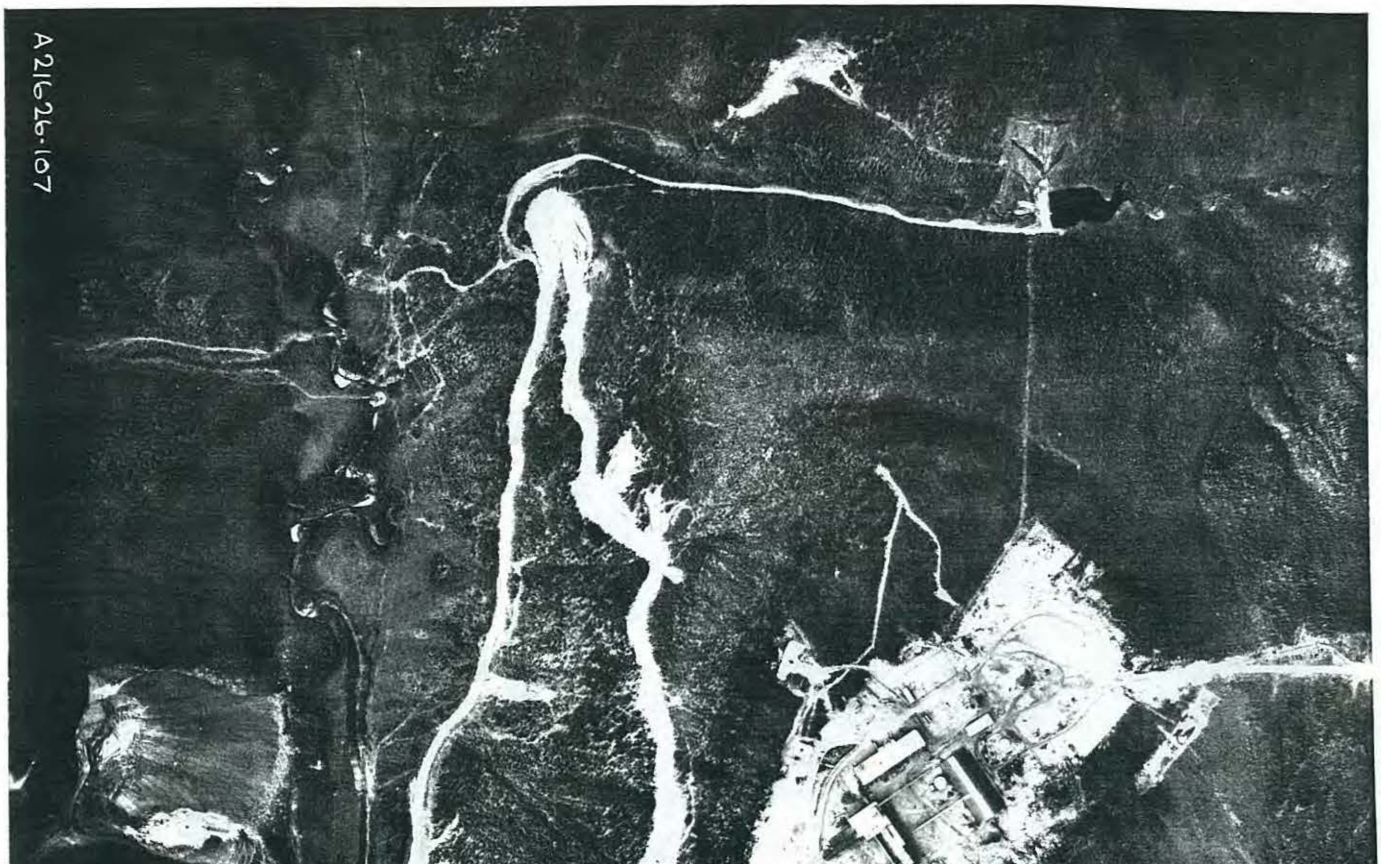
Consideration should be given to future monitoring. Air photos, satelite imagery or combination of both may represent the optimum approach. Digital image analysis (using computer compatible tapes) should make it possible to delineate material drainage patterns, soil-vegetation associations, and vegetation changes in a sufficient detail.

Respectuflly submitted

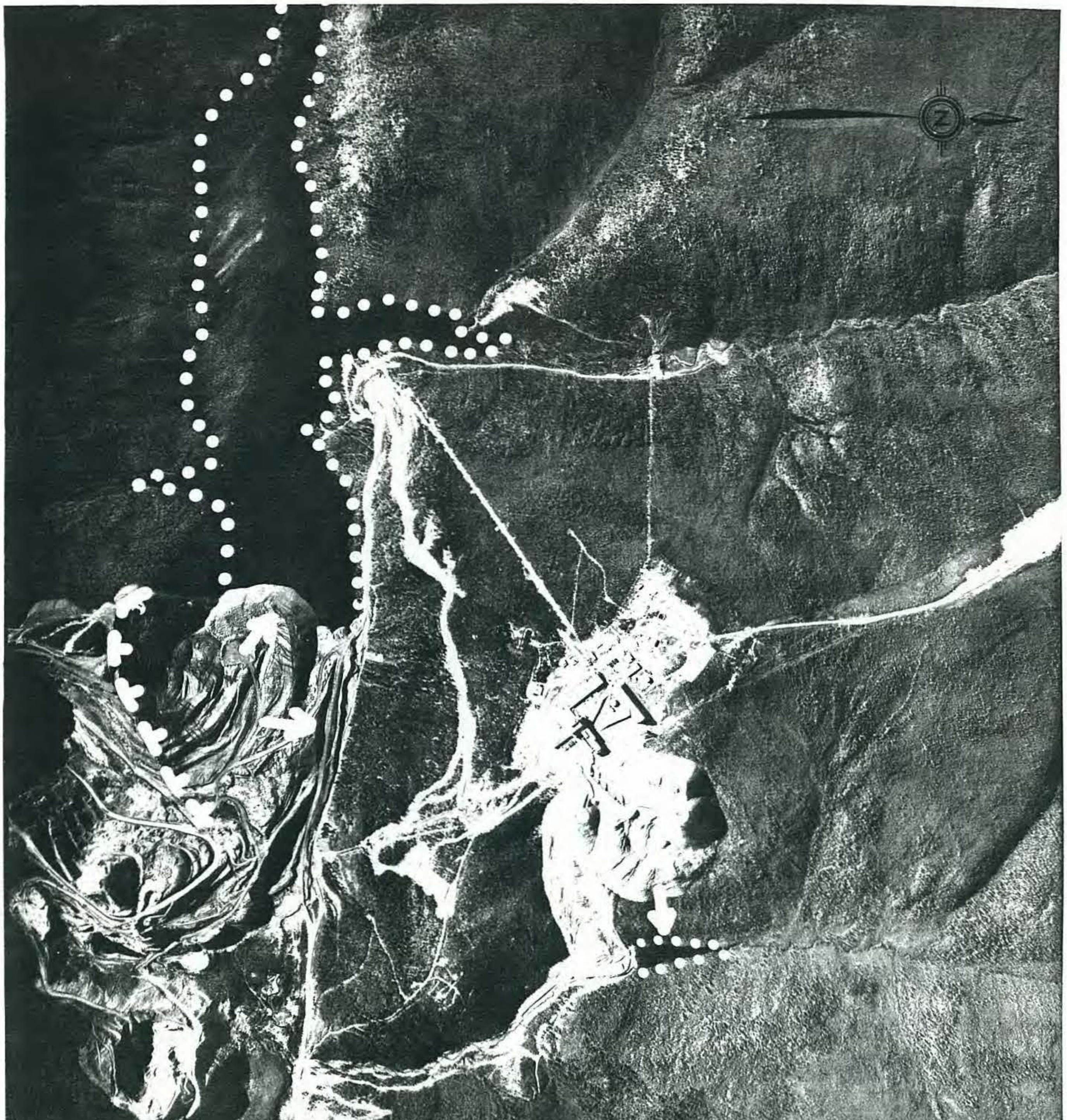
GEO-ENGINEERING (M.S.T.) LTD.

M. Stepanek, M.Sc., P.Eng.

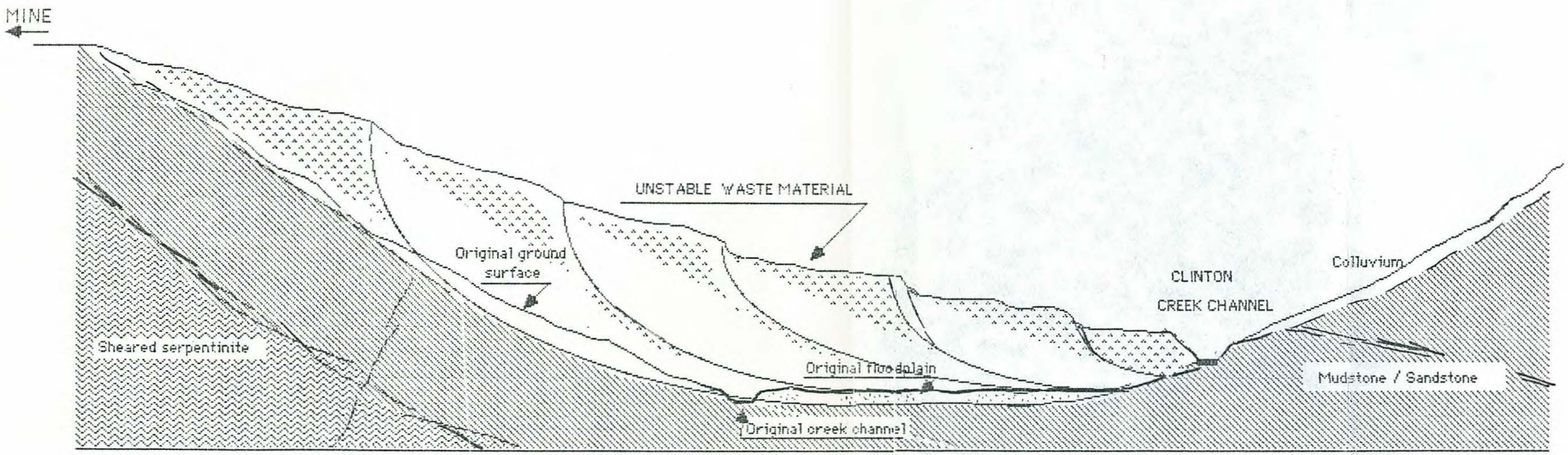
PRELIMINARY



CASSIAR ASBESTOS MINE
1970 AIRPHOTO
FIGURE 1



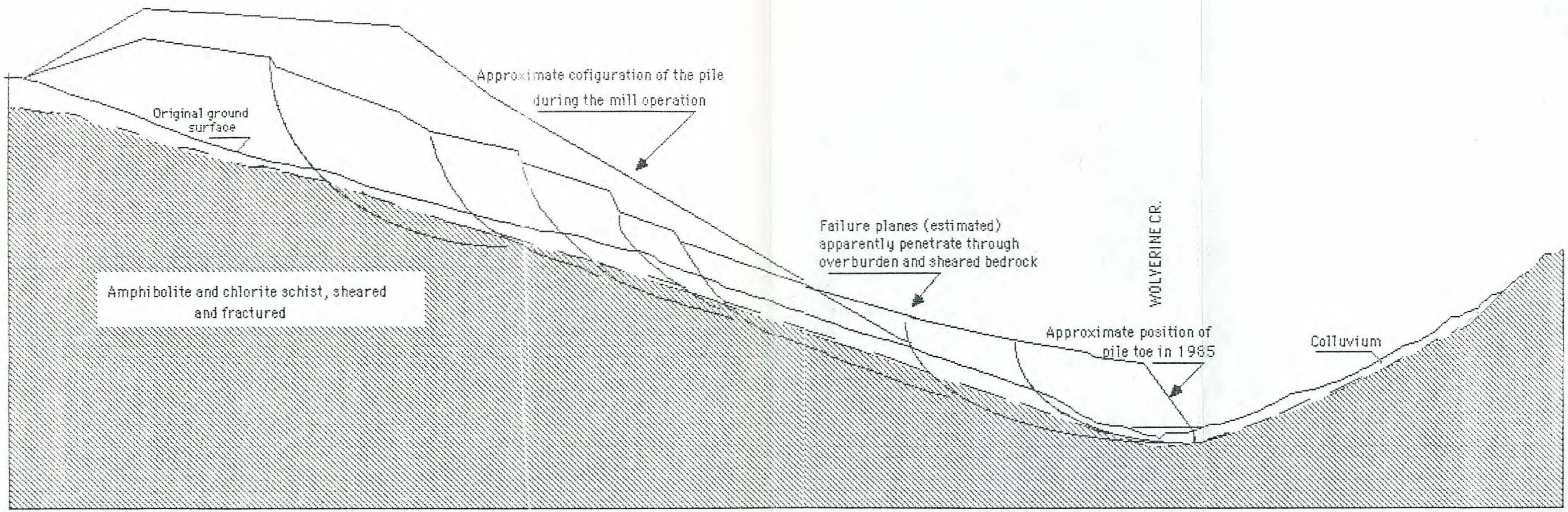
CASSIAR ASBESTOS MINE
1976 AIRPHOTO
FIGURE 2



CLINTON CREEK WASTE DUMP

SCHEMATIC CROSS-SECTION

FIGURE 3.



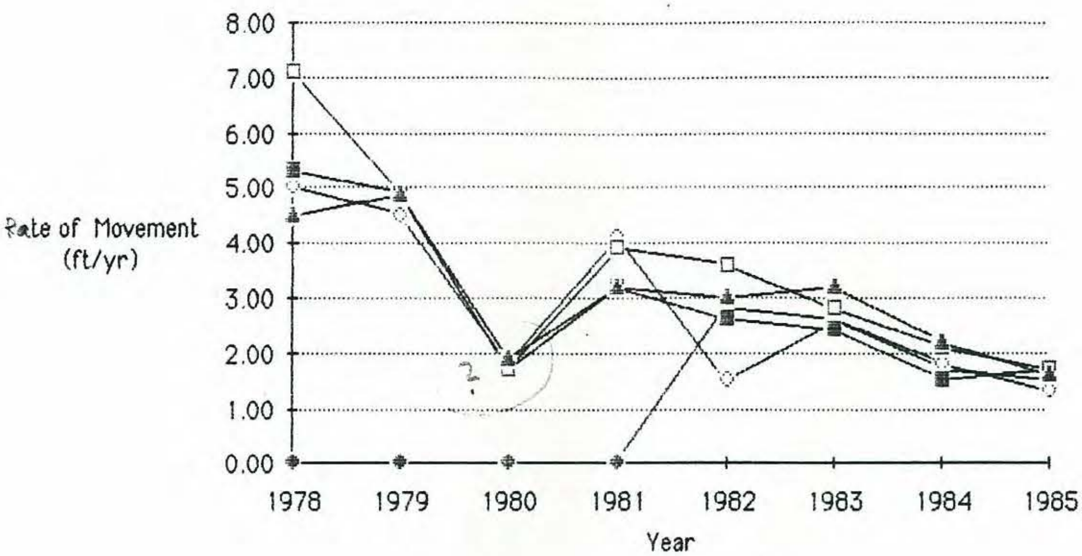
WOLVERINE CREEK TAILINGS PILE

NORTH LOBE

SCHEMATIC CROSS - SECTION

FIGURE 4.

CLINTON CREEK WASTE DUMP



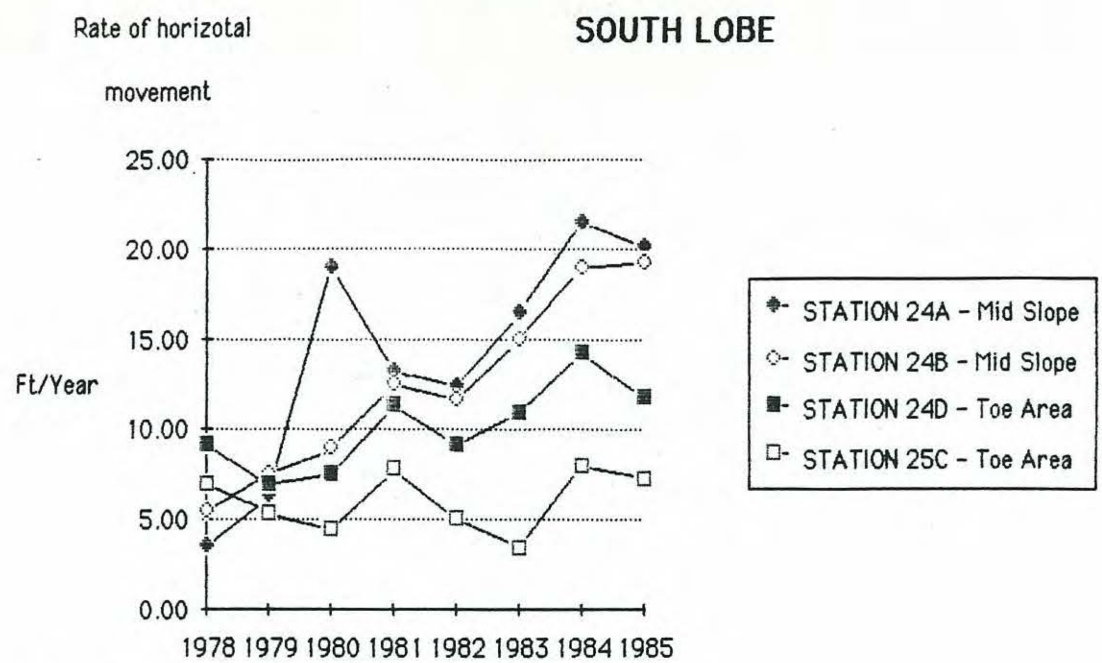
Station 81-2 was installed in 1981.

STATION 81-2
STATION 20
STATION 21 A
STATION 22A
STATION 68

Note : Accuracy of 1980 survey data dubious

FIGURE 5.

WOLVERINE CREEK TAILINGS PILE



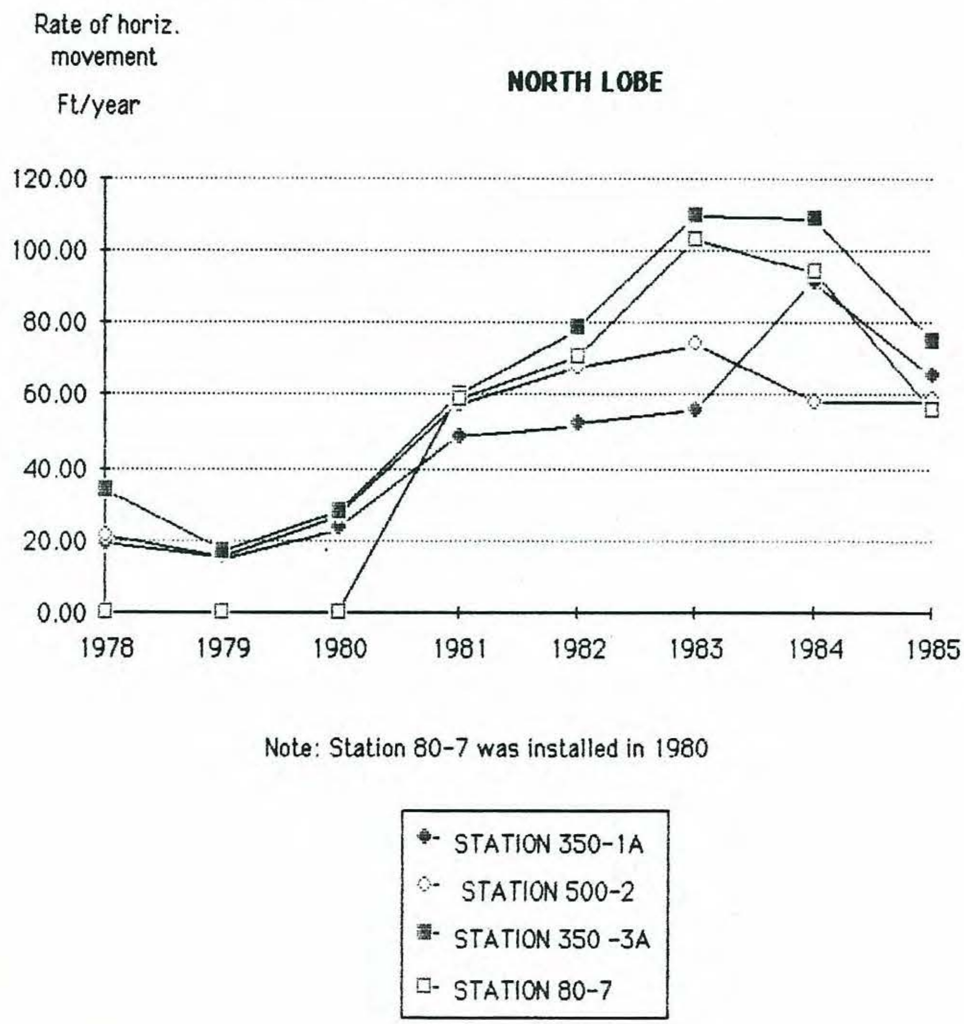


FIGURE 6.