HARDY ASSOCIATES (1978) LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

WOLVERINE CREEK TAILINGS PILES
CLINTON CREEK ASBESTOS MINE

REVIEW OF REHABILITATION MEASURES

Prepared For:
INDIAN AND NORTHERN AFFAIRS
YUKON WATER BOARD

By:
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Calgary, Alberta

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1.0 INTRODUCTION

Hardy Associates (1978) Ltd. were commissioned by Indian and Northern Affairs to review slope monitoring data from the Cassiar Asbestos Mine tailings piles and to evaluate possible methods for rehabilitation of the site.

The work undertaken has involved a review of the available monitoring data on movements of both the north and south tailings piles adjacent to Wolverine Creek. Reclamation alternatives presented by Klohn Leonoff, 1980, have been reviewed and further rehabilitation measures have been considered and evaluated.

2.0 BACKGROUND INFORMATION

The Cassiar Asbestos Mine is located approximately 100 km northwest of Dawson City, Yukon. Mining operations commenced in 1968 with tailings being stockpiled in the south lobe. Tailing were dumped on the south lobe until 1974 at which time a major failure occurred. Wolverine Creek channel was moved eastward by the sliding mass and partially blocked. A rock-lined channel was installed in 1978 to convey Wolverine Creek over the extreme southern portion of the tailings pile in the valley bottom.

From 1974 to 1978, tailings were deposited on the north lobe. The mine discontinued operations in 1978. An unsuccessful attempt to stabilize the dump (by partial regrading) was made in 1978 and 1979.

3.0 SLOPE MOVEMENTS

Movements in both the north and south lobe have been monitored since 1978. A total of 14 monitoring points are operational within the north lobe and another 7 points are located within the southern tailings pile. Locations of these monitoring points are shown on Drawing D-1004, Klohn Leonoff 1984.

3.1 NORTH LOBE

Table 1 presents a summary of the horizontal rates of movement measured at the various monitoring points within the north lobe. Readings have been catagorized into either summer, extending from May 15 to December 31, or winter, extending from January 1 to May 15. Typically, the horizontal rate of slope movement recorded in summer is about 1.5 to 1.75 times greater than that recorded in the winter season. Figures 1 to 3 show the cumulative horizontal movements for representative points near the slope crest, at mid slope and at the slope toe of the north lobe.

Figure 1 shows the results from Survey Point 26-A, on the upper slope. The rate of horizontal movement fluctuates considerably from year to year and is relatively small (0.3 to 1.5 m per year).

Average horizontal movements at mid slope (Survey Points 500-1 and 650-1) over the monitoring period are plotted on Figure 2. A general increase in the average yearly rate of movement can be noted with the present average rate in the order of 10 m per year (33 ft/year).

TABLE 1

SUMMARY OF SLOPE MOVEMENT - NORTH LOBE

Location	Approximate Co-ords.	Horizontal Rates of Movement (ft/year)									Position On Slope
		Summer Monitoring			Aug	June	June	Sept	Winter		
		1978	1979	1980	1981	1982	1983	1983	1978-79	1980	
26	N114, 490 E108, 220				4.6	0.10	3.61	11.91			upper
80-2	N114, 320 E108, 440				4.4	0.1	6.50	0.45			upper
26-A	N114, 480 E108, 410	5.7	1.1	1.6	4.9	0.3	0.62	0.93	1.6	1.0	upper
80-1	N114, 710 E108, 420				5.4	0.6	0.77	0.76			upper
80-4	N114, 020 E108, 850				-	0.9	1.96	1.14			mid
80-5	N114, 170 E108, 930				-	-	32.64	12.43			mid
500-1	N114, 510 E108, 840	28.6	17.3	27.0	48.9	55.4	57.14	50.20	11.6	16.5	mid
650-1	N114, 710 E108, 840	31.6	15.5	26.5	49.1	52.7	50.26	32.57	12.2	14.0	mid
350-1A	N114, 360 E109, 040	18.9	14.8	23.5	48.8	-	55.9	79.47	11.5	15.0	mid
500-2	N114, 500 E109, 120	21.6	15.4	27.0	57.6	-	74.37	93.73	11.0	17.0	toe
650-2	N114, 710 E109, 140	21.6	16.4	29.0	61.7	72.2	88.62	66.66	10.4	16.0	toe
350-2A	N114, 340 E109, 190	23.1	16.6	27.5	57.3	65.9	91.95	95.14	11.6	17.5	toe
350-3A	N114, 500 E109, 280	33.7	17.3	28.3	60.6	78.4	109.93	95.04	13.3	18.0	toe
80-7	N114, 390 E109, 290				58.9	71.0	103.27	94.49			toe

FIGURE 1 Upper Slope, NORTH LOBE - Survey Point 26-A

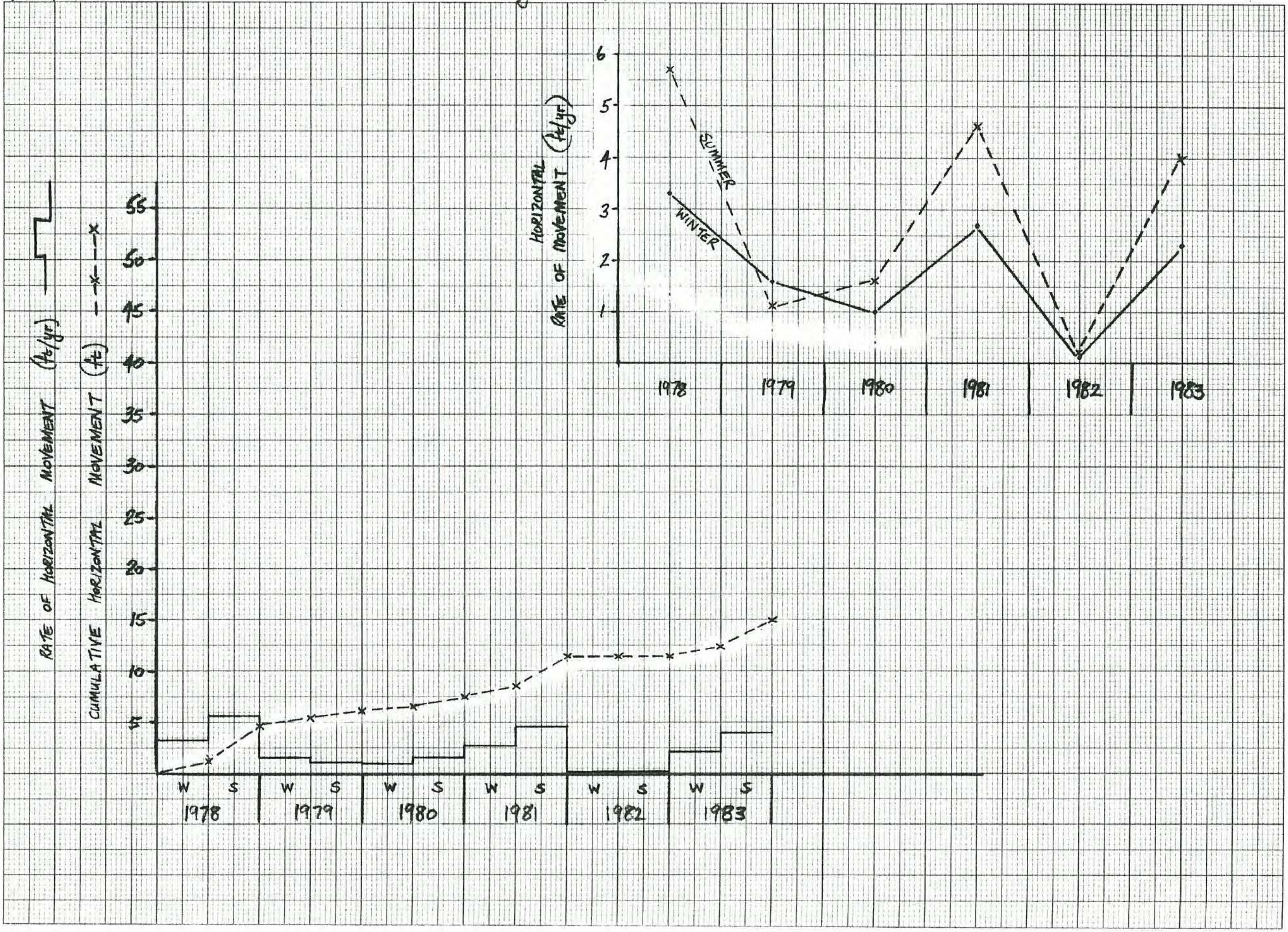
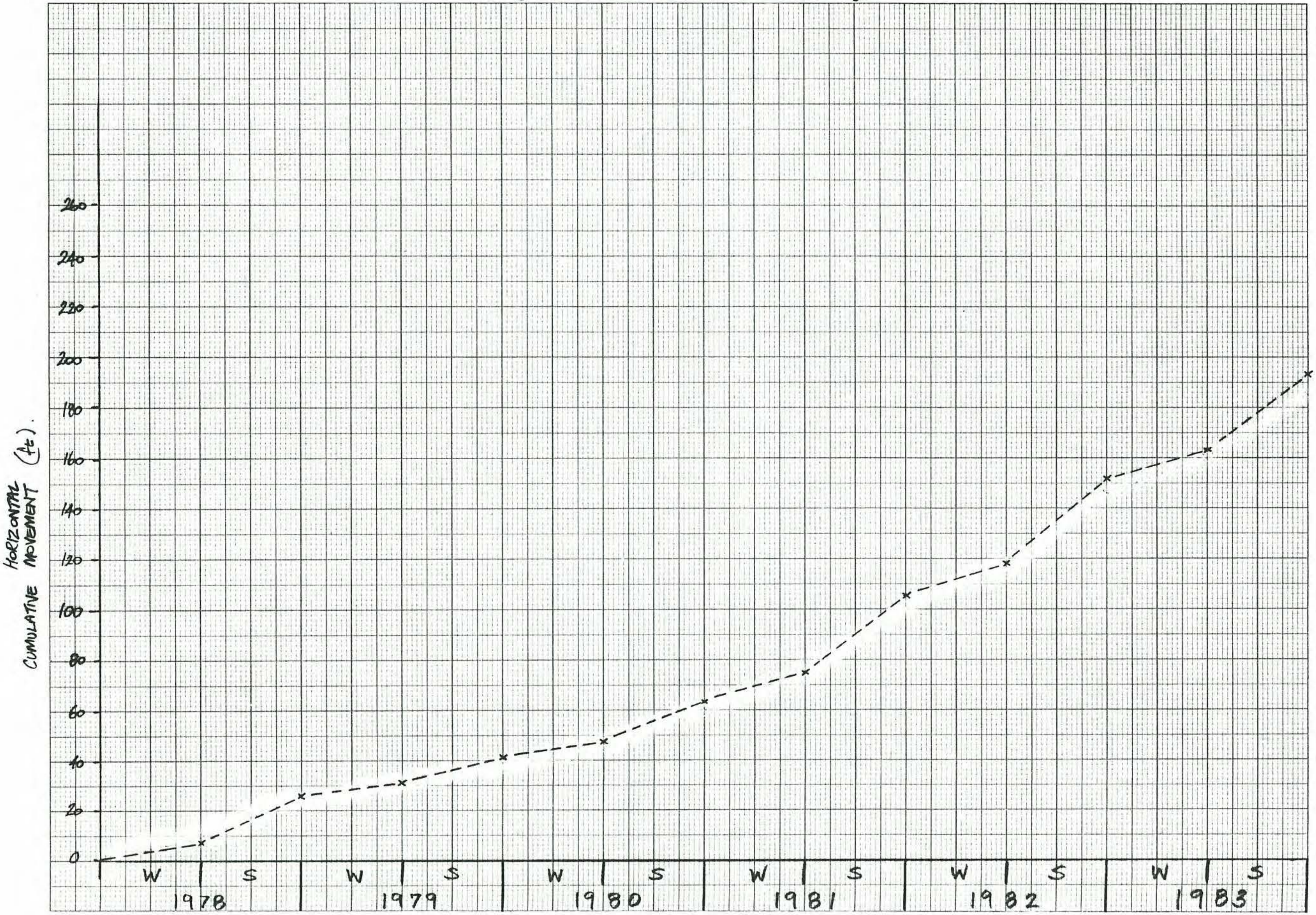


FIGURE 2 Mid Slope NORTH LOBE - Survey Points 500-1 and 650-1 averaged.



Cumulative horizontal movements at the toe of the north lobe are shown on Figure 3. Movements have accelerated over the past few years and are presently in the order of 30 m per year (100 ft/year). Based on the previous trends, the cumulative horizontal movement curve (Figure 3) has been extrapolated to predict future movements. If the present trends continue, it is predicted that a major failure of the north lobe would occur within the next couple of years (1986).

The movement rates recorded suggest that the tailings lobe is moving in a "caterpiller-like" manner. As a lower segment fails, toe support for the section above it is removed and the failure gradually progresses up the slope with the amount of horizontal movement decreasing in the upslope direction.

3.2 SOUTH LOBE

Table 2 presents a summary of the horizontal rates of movement measured at the various monitoring points within the south lobe. The movements range from a couple to 21.5 feet per year during the summer season. The ratio of the rate of horizontal movement in summer to that in winter varies from 1.6 at the toe of the slope to 1.9 in the upper slope.

Figures 4 through 6 show cumulative horizontal movements recorded on the upper, middle and lower slope of the south lobe. Rates of movements have been more or less constant over the past few years. It is believed that these downslope movements will continue unless more toe support than presently in existence is provided.

FIGURE 3 TOE SLOPE - NORTH LOBE SURVEY POINTS 350-2A and 350-3A averaged

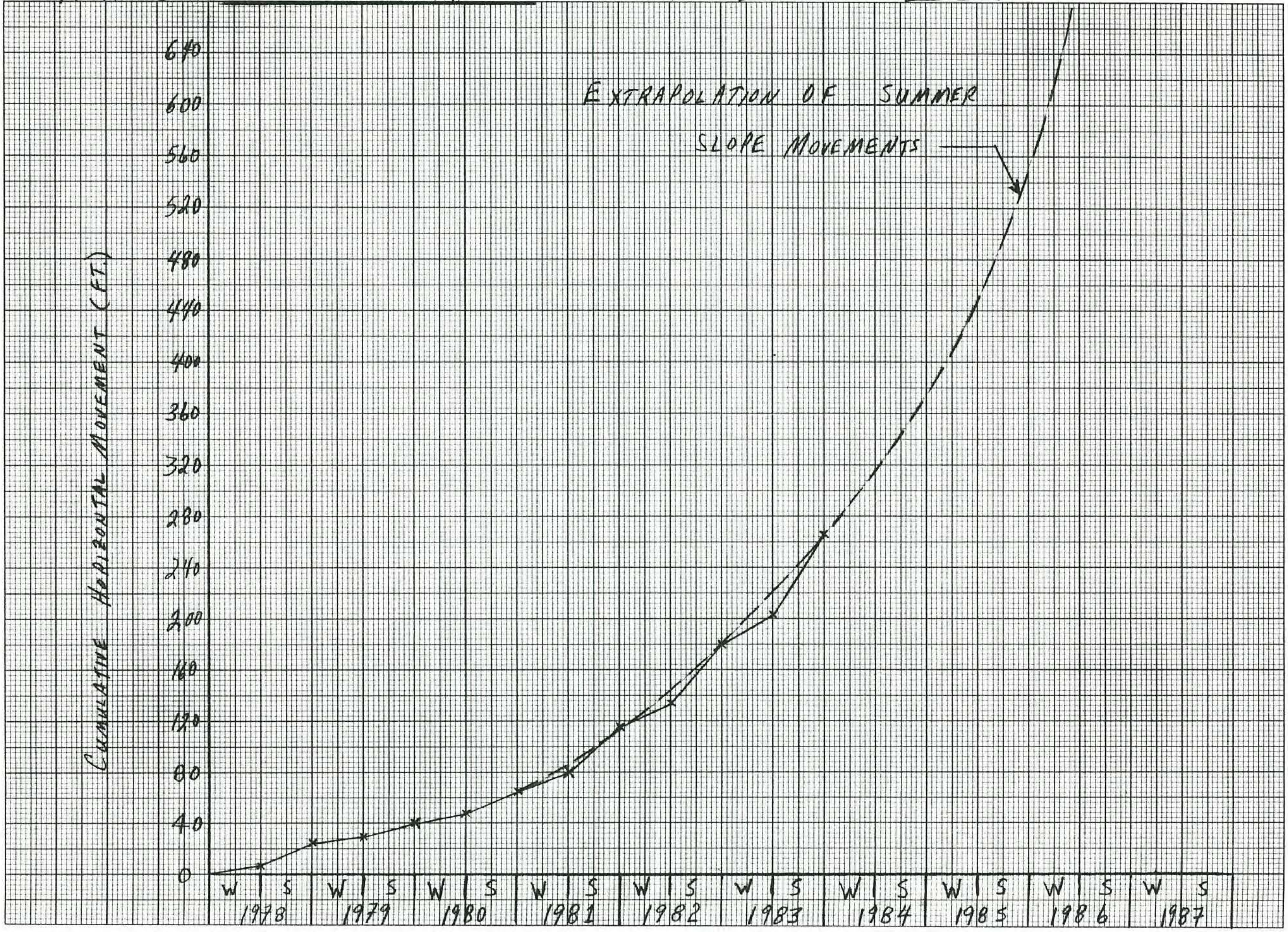


FIGURE 4 ~~Upper Slope~~ SOUTH LOBE – Survey Point 24

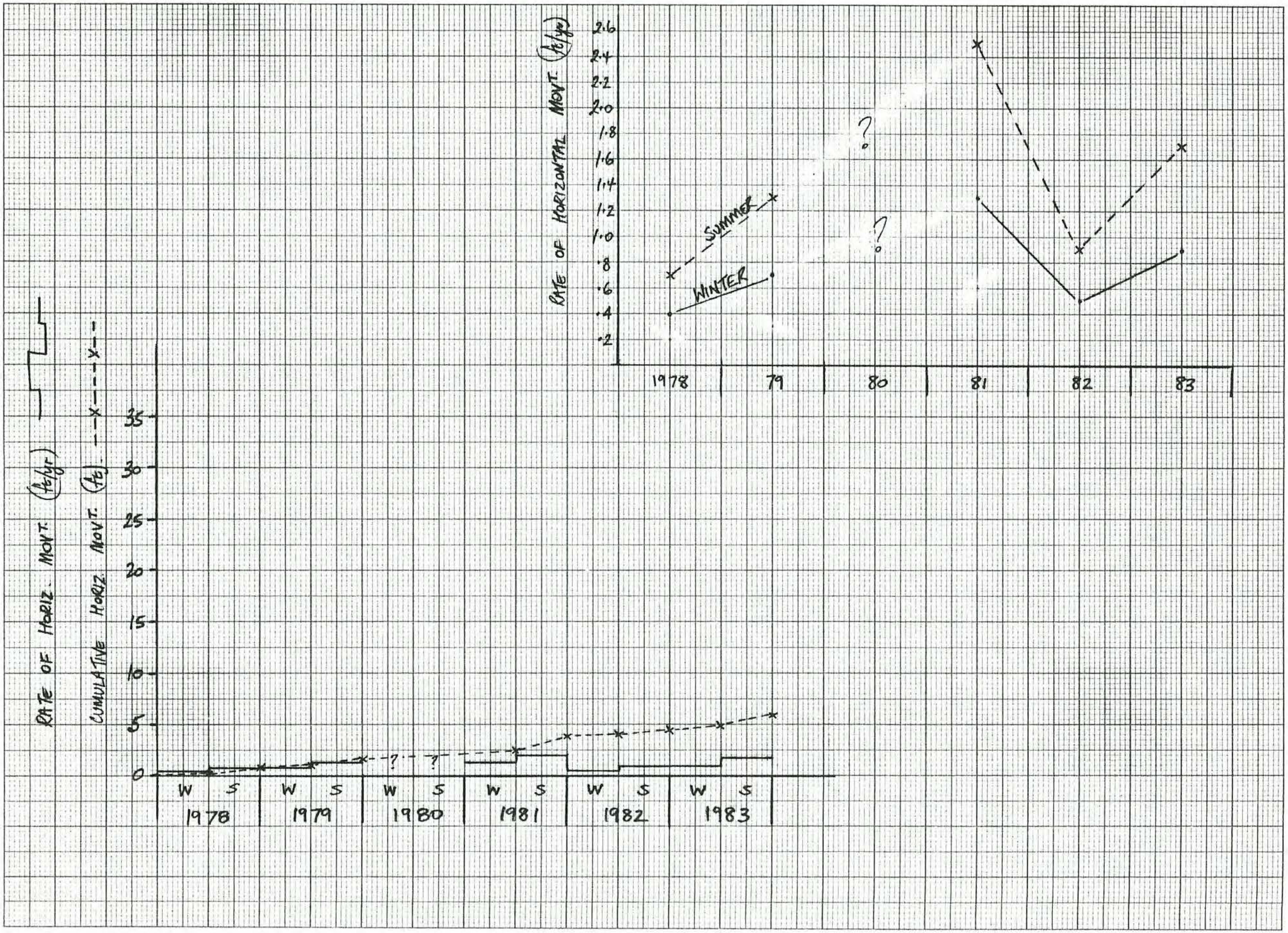


FIGURE 5 ~~Mid Slope +~~ SOUTH LOBE – Survey Points $\boxed{24\text{-}A}$ & $\boxed{24\text{-}B}$

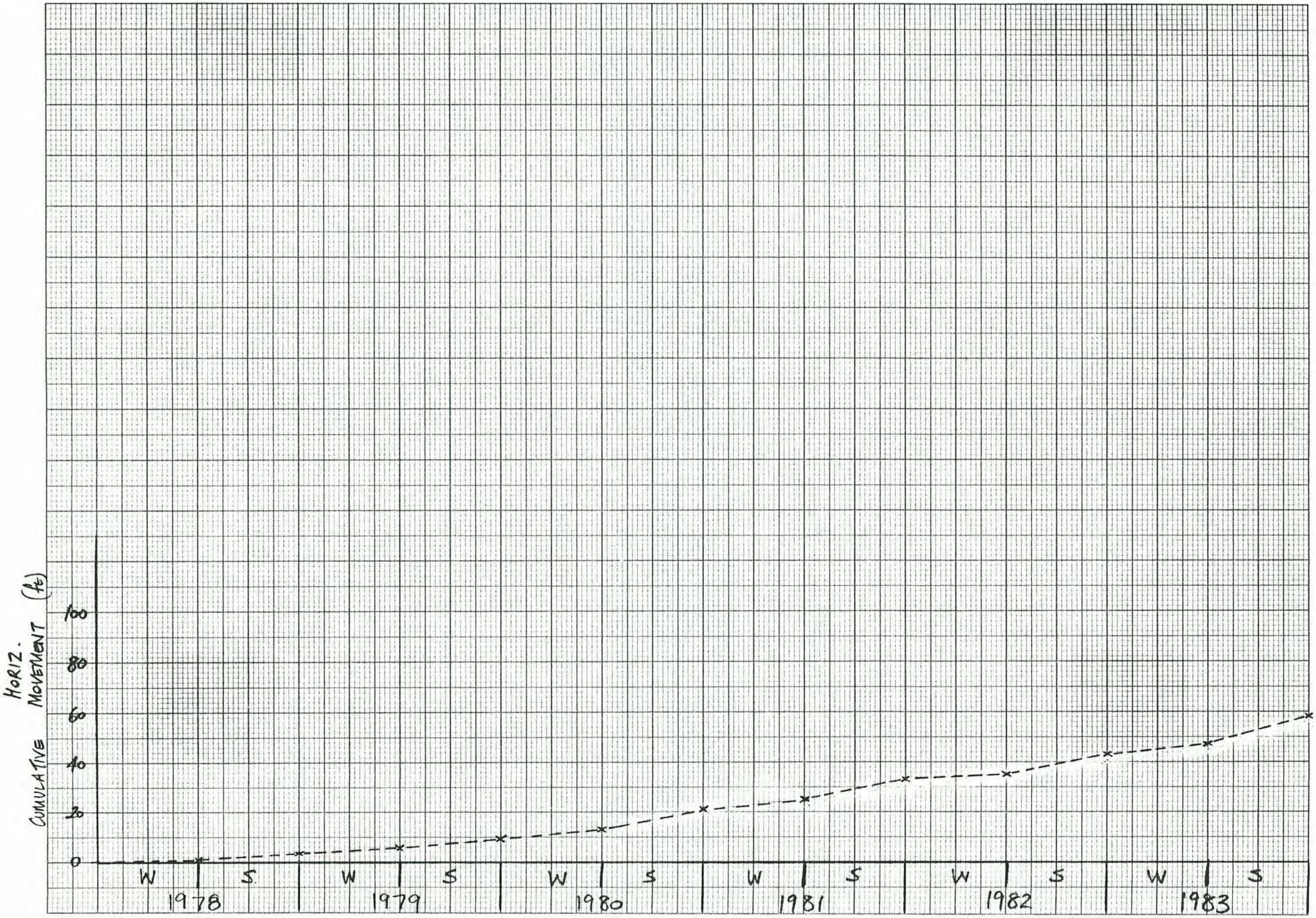


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FIGURE 6 Toe Slope - SOUTH LOBE - Survey Points 24-D, 25-B and 25-C

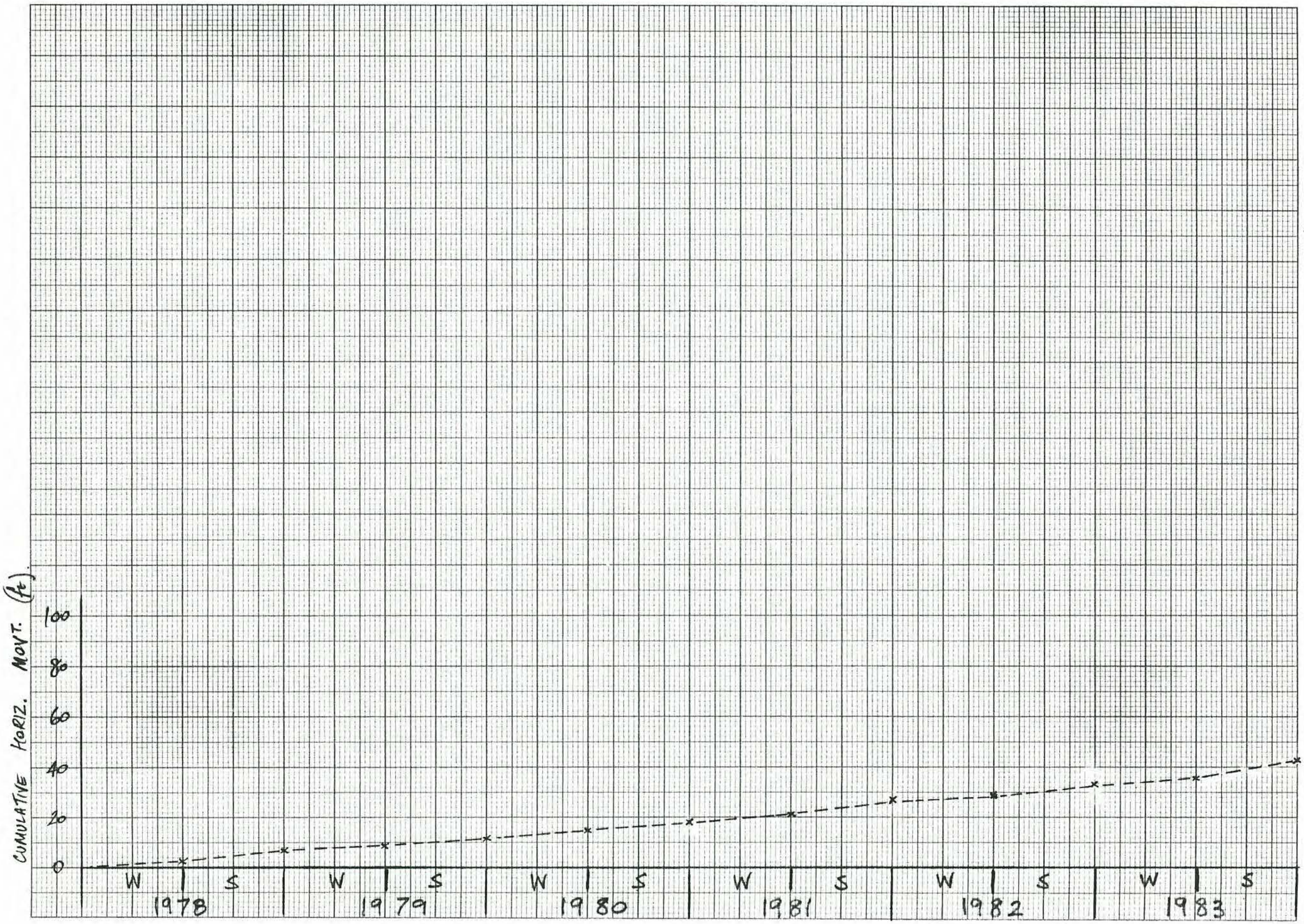

TABLE 2

SUMMARY OF SLOPE MOVEMENT - SOUTH LOBE

Location	Approximate Co-ords.	Horizontal Rates of Movement (ft/year): Summer Monitoring 1978	Summer Monitoring 1979	Summer Monitoring 1980	Aug 1981	June 1982	June 1983	Sept 1983	Winter 1978-79	Winter 1980	Position On Slope
24	N113, 480 E108, 330	0.7	1.3	0+	2.5	0.9	-	1.73	0.7	0+	upper
24A	N113, 440 E108, 960	3.6	6.3	19.0	13.3	12.4	16.39	21.52	5.1	7.5	mid
24B	N113, 470 E109, 150	5.5	7.6	9.0	12.5	11.6	15.02	19.04	4.1	7.5	mid
24D	N113, 550 E109, 500	9.1	6.9	7.5	11.3	9.1	10.87	14.29	3.8	6.5	toe
25B	N113, 550 E109, 630	7.3	6.5	7.3	11.2	8.9	10.44	14.12	3.7	3.5	toe
25C	N113, 750 E109, 800	6.9	5.4	4.5	7.8	5.0	3.43	7.99	2.6	7.5	toe
80-9	N113, 370 E109, 790				4.3	2.1	2.72	3.68			toe

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4.0 REHABILITATION ALTERNATIVES

Monitoring data suggests that downslope movements of the north and south tailings piles adjacent to Wolverine Creek will continue for some time. The north lobe is moving downslope at a very high rate and soon will begin displacing the lake at the bottom of the valley. The tailings piles will continue to move until they have reached a stable state in the valley bottom.

It is desirable to leave the site in a condition which will minimize the detrimental environmental impact and be acceptable to the Yukon Territory Water Board. Five alternate reclamation schemes have been considered during the present study. Details of each scheme are outlined in the following sections.

4.1 COARSE ROCK DRAIN

The concept of using a coarse rock drain to channel water flow through spoil dumps has been employed with success at the Fording River Coal Mine (Lane and Berdusco) and McIntyre Mine in Grande Cache. The design is based on a given return period flood and the hydraulic gradient (change in elevation head with distance) of the channel. It is important that the drain be constructed of durable rock to minimize weathering of the rock and subsequent creation of fines which may cause localized plugging of the drain. Separation of drain from surrounding material (by means of a filter) is required to prevent plugging.

The 100 year return period flood for the Wolverine Creek has been estimated at 20 m^3/sec (Klohn Leonoff, 1984). Based on a contour map of the area (Drawing D-1004, Klohn Leonoff 1984), the hydraulic gradient over the section of interest appears to be in the order of 2.5 percent. Based on this hydraulic gradient, a rock drain constructed of durable boulders with a diameter of 0.6 to 1.0 m would require an area of about 500 m^2 to handle the 100 year return period flow of 20 m^3/sec.

The rock drain would be required to extend over a length of some 450 m making the rock volume requirements in excess of 200,000 m^3. Furthermore, durable rock would have to be quarried. Although no price quote was obtained, previous experience indicates that the cost of constructing the drain would be considerably in excess of 5 million dollars.

There is a large degree of uncertainty associated with the 100 year return period flow of 20 m^3/sec. The required area of the rock drain is directly proportional to the flow volume it must accommodate. Thus, a 40 percent reduction in the design flow (to 12 m^3/sec) would result in a 40 percent decrease in the required rock drain area. Similarly, a 40 percent cost reduction would be realized.

In addition to construction of the rock drain, it would be necessary to place some fill (tailings) over the drain to minimize the possibility of failure planes penetrating through the drain.

Along with the inherent risk of clogging of the drain, the cost of implementing such as system makes this alternative unattractive for the site conditions encountered at Wolverine Creek.

4.2 CONVEYANCE OF WOLVERINE CREEK AROUND THE TAILINGS

A second alternative would be to constuct a tunnel to convey Wolverine Creek around the tailings piles. A hydraulic tunnel with a minimum dimension of 1.80 m would be required for this purpose. It would be advisable to construct two intakes (at different elevations) to accomodate flow in the event that the lower intake becomes blocked by ice during the winter season.

The creek diversion would allow for natural development to take place. The tailings will eventually come to rest in the valley bottom achieving a certain degree of consolidation. The creek may then be rerouted into a prepared channel traversing stable valley infill.

A similar alternative was reviewed by Klohn Leonoff (1984) who indicated a cost of approximately $1000 per foot ($3280 per m) for such a tunnel and, a total cost in the order of $2.5 million. We are in agreement with this figure as a rough cost estimate for this alternative.

Some maintenance requirements would be involved to prevent blockage. However, this alternative would provide a very long term solution to the problem. Again, the relatively large capital outlay make this alternative unattractive.

4.3 CONVEYANCE OF WOLVERINE CREEK THROUGH THE TAILINGS

It would be possible to place one or more corrugated steel pipes in the vicinity of the existing channel and allow the creek to flow through this pipe to the existing spillway located to the south of the tailings piles.

The concept involves placing the pipe (possibly in a shallow trench) and subsequently placing a considerable height of fill (say 10 m) over the pipe to minimize the potential for failures developing below the pipe elevation.

To accomodate the anticipated 100 year return flow of 20 m^3/sec would require; 3-1500 mm diameter pipes; 2-1800 mm diameter pipes; or 1-2400 mm diameter pipe. Alternatively, an expanded intake leading into a smaller diameter pipe acting as a syphon may be a possibility. However, further studies would be required to verify the feasibility of such a system.

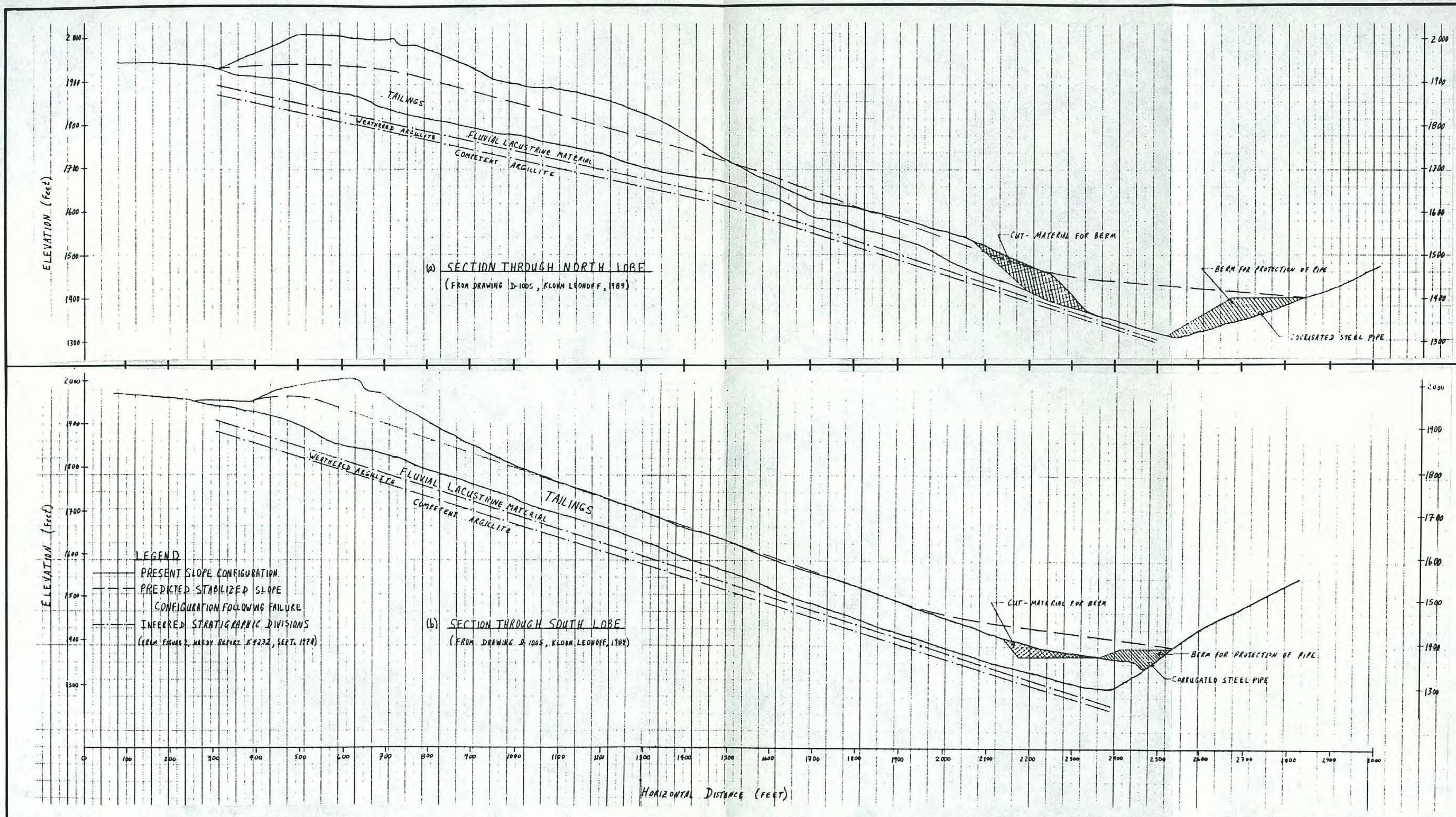
The pipe must extend over a length of approximately 450 m. Transport costs begin to dominate for the smaller diameter pipes (1500 mm and 1800 mm) when they are shipped in circular sections. The 2400 mm diameter pipe could be transported in non-circular segments and assembled on site. However, the smaller diameter pipes have greater strength and their performance is not as dependent on the installation workmanship.

For cost estimating purposes, the most economical alternative would be one 2400 mm pipe. The estimated cost, including transporting and assembling the pipe, is about $400,000 for this case. The smaller diameter pipe alternative would be considerably more expensive (1.5 to 2 times the cost).

For a smaller 100 year return period flow of 12 m^3/sec, the pipe requirements could be decreased to one 2100 mm diameter pipe. The estimated cost reduction associated with this decrease in pipe size is not anticipated to be large (i.e. in the order of 15 percent).

Only very shallow trenches would be required for the installations and the cost involved is expected to be in the order of $50,000. It would be necessary to place a "berm" over the pipes so that material moving downslope would not destroy the pipes (see Figure 7). The berms could be constructed of tailings or native material. It would be necessary to conduct a detailed study to determine the amount of material cover required to ensure the safety of the pipe. A conceptual illustration of the proposed scheme is shown on Figure 7. The construction costs for the berms is estimated to be in the order of $300,000, based on a fill volume of about 280,000 yd^3.

Material volumes required for construction of the berms have been estimated based on the cross sections shown on Figure 7. Actual fill volumes may vary considerably. For example, the section of pipe over the length between the two tailings piles may not require as much fill for adequate protection. Similarly, fill requirements near the outer limits of the two tailings piles may be reduced. On the other hand, the berms illustrated on Figure 7 may not provide adequate protection for the pipe and additional fill may be required.



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CASSIAR ASBESTOS MINE-WOLVERINE CREEK
CONCEPTUAL ILLUSTRATION OF CORRUGATED PIPE ALTERNATIVE

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FIGURE 7

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The total cost for the pipe, its installation and protection, is estimated to be about $750,000.

Material for construction of the berms could be taken from the toe area of the tailings piles. This would accelerate movement of the tailing piles. Failure of the north lobe would still be anticipated. Figure 7 shows a prediction of the final location of the tailings piles following stabilization of movement.

The corrugated steel pipe is expected to have a life in excess of 40 years. It is anticipated that stabilization of the tailings piles will have occurred prior to this time. Following stabilization of the tailings piles, a permanent channel could be cut through the debris to carry the creek water over the tailings.

Additional monitoring points would have to be installed in the fill and monitoring of existing points should be continued.

This approach appears to be economically viable and it is recommended that it be given further consideration as a feasible reclamation alternative.

4.4 MONITORING AND MAINTENANCE PROGRAM

A fourth alternative, recommended by Klohn Leonoff (1984) as the most practical approach, would be to continue the monitoring and maintenance program which has been ongoing for the past several years. An erosion resistant channel would have to be maintained over the tailings and the monitoring program continued.

However, if, as predicted, a major failure of the north lobe does occur within the next couple of years, a major blockage of the valley bottom will develop. This will likely be followed by a breach and uncontrolled erosion of relatively fine tailings. It is conceivable that newly formed channel may not fit the existing armoured canal. Indeed, the worst scenario includes undercutting of the armoured channel and its destruction during the surging overflow event. Consequently, major contamination of the creek and the downstream river system water may occur.

This would create a situation similar to the one caused by failure of the south lobe. However, it would not be possible to construct a permanent channel over the tailings immediately following failure due to ongoing movements of the material.

4.5 DAM AT TOE OF SOUTH LOBE

The fifth alternative involves construction of a dam at the toe of the south lobe for the purpose of:

a) stabilizing the south lobe by providing additional toe support, and

b) controlling the path of water flow to ensure connection with the existing rock-lined channel.

In order to accomplish this, it would be necessary to construct a dam with a crest elevation higher than the elevation of the failed north lobe toe material. It would be prudent to construct the dam with a spillway, capable of handling the design return period flow, and one or two corrugated steel pipes extending through the dam to the armoured channel (Figure 8). Alternatively, a "flow through" segment can be designed to convey the creek flow into the armoured channel. The dam could be constructed from tailings material.

Preliminary studies indicate that a crest elevation of about 1425 feet (434.3 m) would be required. The corrugated steel pipes would require a diameter of 900 mm and could be placed at staggered elevations of about 1410 feet (429.8 m) and 1413 feet (430.7 m) as shown on Figure 9. The pipes should be equipped with valves to allow all the flow to be channeled through the spillway if required.

The dam crest and pipe elevations have been estimated based on the predicted stabilized slope configurations shown on Figure 7. The dam height may have to be adjusted to be compatible with the actual final tailings pile location.

No detailed design has been undertaken at this time, but it would be prudent to provide relatively shallow upstream and downstream slopes on the dam, in the order of 4:1 (horizontal to vertical). These slopes could accommodate an increase in dam height (if necessary) and to withstand cyclic loading conditions associated with possible earthquakes.

The dam would have to extend over the entire length of the south lobe. In order to achieve stability of the south lobe, it may be necessary to add extra fill in areas where the dam height is low.

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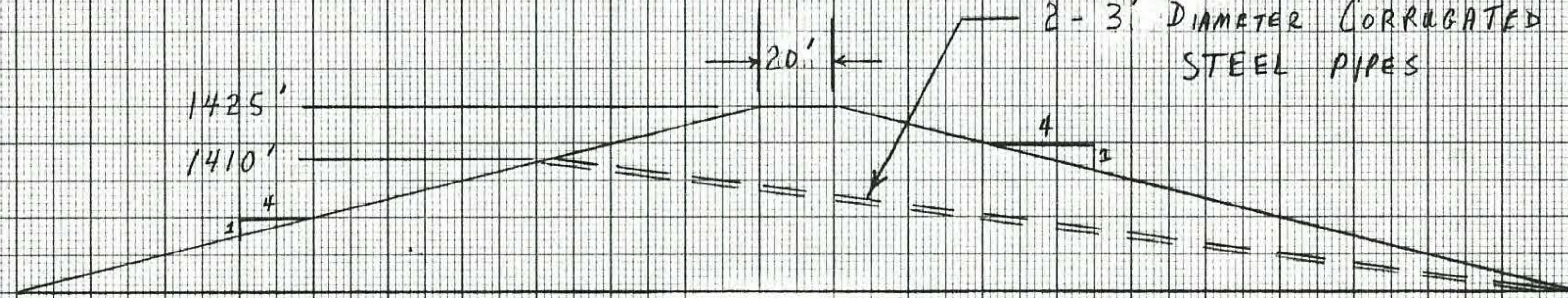

CASSIAR ASBESTOS MINE

TYPICAL DAM CROSS SECTION

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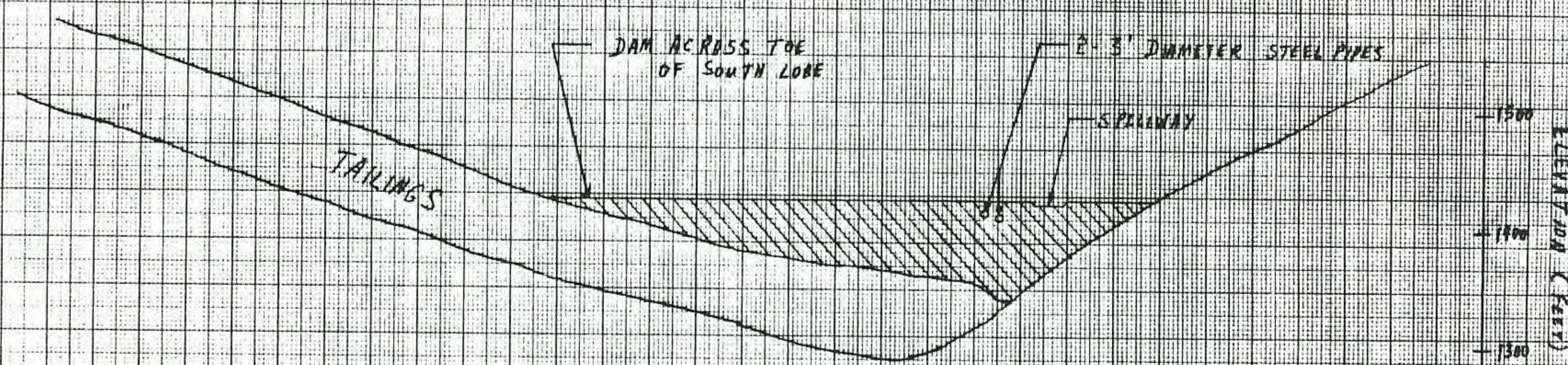
FIGURE 8



CASSIAR ASBESTOS MINE

CONCEPTUAL ILLUSTRATION OF DAM ACROSS SOUTH LOBE TOE

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FIGURE 9

It is estimated that approximately 150,000 yd^3 (115,000 m^3) of material would be required to construct the dam. The total length of 900 mm diameter corrugated steel pipe required is about 200 m. The estimated cost of implementing this scheme would be in the order of $300,000.

Construction could be undertaken prior to or following failure of the north lobe. Undertaking construction prior to the failure would allow for monitoring and modifying the design to ensure the stability of the south lobe. Following failure, the dam crest elevation could be more readily determined. However, equipment would have to be on emergency standby to cut a channel through the tailings soon after failure.

Due to the short distance from the north lobe toe to the valley bottom (about 100 m), it is not believed that wave action caused by the failure will pose a significant threat to the safety of the dam. However, this possibility cannot be completely disregarded. There is a high degree of uncertainty associated with the prediction of the elevation of the dam crest and there exists a possibility that the dam height may have to be increased following the failure.

Despite these drawbacks, we believe that this alternative can provide a practical and economical solution to the problem. Ongoing monitoring along with installation of new monitoring points would be essential.

5.0 SUMMARY AND CONCLUSIONS

A review of the slope monitoring data that has been collected since 1978 has been undertaken. The south lobe appears to be in a creep stage moving at rates in the order of 1.5 m per year horizontally. On the other hand, the north lobe, which appears to be moving in a "caterpillar like" manner, exhibits accelerating movements, suggesting that a major failure may occur in the near future. If the present trend continues, it is predicted that a failure would occur in 1986.

We do not consider the current program of inspection and unspecified maintenance to represent the most practical strategy for controlling erosion of tailings. This approach could lead to a situation similar of the Clinton Creek, i.e. long channel, experiencing retrogressive erosion cut through unstable and highly erodible material.

Several alternate reclamation schemes have been presented and reviewed. The most practical and economical solution appears to be construction of a dam at the toe of the south lobe (as discussed in Section 4.5).

Further studies and analysis would be required to verify the required crest elevation and the fill volumes necessary to stabilize the south lobe.

It is considered to be prudent to undertake the construction prior to failure of the north lobe. Any stabilization work is complex and a time consuming process. While the implementation of rehabilition measures could be delayed until a better picture regarding the probable vertical extent of the valley blockage is obtained, the planning should proceed. It is our opinion that a fairly accurate plan for the abandonment should be available. Its absence will result in delays which, in turn, could adversely affect the pile stability and produce environmental damages.

Respectfully submitted,

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