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**Golder Associates**
CONSULTING GEOTECHNICAL ENGINEERS

# REPORT TO CASSIAR ASBESTOS CORPORATION LIMITED ON STABILIZATION MEASURES FOR MINE CLOSURE

CLINTON MINE YUKON TERRITORY

Distribution:

3 copies - Cassiar Asbestos Corporation Ltd.,
Clinton Mine,
Clinton Creek, Yukon Territory

3 copies - Golder Brawner & Associates Ltd.,
Vancouver, British Columbia

Originally submitted in draft: May 1976
Final submission, without revision: April 1977 V76083

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## 1. INTRODUCTION

Mining production at Clinton Mine, an asbestos mine owned and operated by Cassiar Asbestos Corporation Ltd., at Clinton Creek, Yukon Territory, is expected to cease in the spring of 1978, when the ore reserves will have been depleted. Cassiar Asbestos intend to develop a program for stabilizing, where necessary, the various slopes and creek channels that have been affected by the mining operations, so that the mine and mill sites will be left in a condition which is environmentally acceptable to regulatory agencies. Of primary concern is Clinton Dump (and the new channel for Clinton Creek which flows at the toe of the dump), the tailings pile, and the walls of the Porcupine Pit.

At the request of G. R. Vincent, Mine Manager, D. B. Campbell and G. R. Tomlin of Golder, Brawner & Associates Ltd. visited the mine between May 3 and 6, 1976. During this time, discussions were held with G. R. Vincent and N. W. Kelly, Production Superintendent on the slope movements and creek channel erosion that have occurred to date. Inspections were made of the various dumps, pits, tailings pile, and creek channels in the company of N. W. Kelly and other mine staff. This report summarizes the observations made during the on-site inspections, and makes recommendations concerning further monitoring of slope movement, and prevention of creek channel erosion.

## 2. CONCLUSIONS AND RECOMMENDATIONS

1. Large-scale creep-type movements are continuing in Clinton Dump, but the rate of creep is decreasing progressively with time. In the toe region of the dump (below El. 1400), there is evidence to suggest that the major component of movement is parallel to the valley direction, i.e., the valley confinement may itself be preventing further large across-valley movement.

2. Further monitoring locations should be established on the toe region of Clinton Dump, at least 200 ft. back from the crests of local slopes. Readings on existing monitors, which are at the crests of local slopes, may include the effect of localized surface movements on these slopes. The existing program of displacement measurements should be expanded to include the new monitors, as well as the existing ones.

3. The toe of Clinton Dump is extremely stable with regard to forces due to water seeping from Hudgeon Lake through the dump.

4. When it has been confirmed from monitor readings that dump movement towards Clinton Creek channel has virtually ceased, a construction program should be carried out on the channel where it passes the dump, to prevent large-scale channel creek erosion. The program should consist of principally:

(a) flattening certain local slopes in the dump material, adjacent to the channel of Clinton Creek,

(b) constructing energy dissipators in the channel.

5. Although movements in the upper part of Porcupine Dump might still be continuing, these do not affect the discharge in Porcupine Creek.

6. To monitor possible continuing creep movements within the toe region of that portion of the tailings pile that slid in 1974, a program should be set up to measure, at regular intervals, the distance between surface markers installed in the toe region, and a reference point(s) on stable ground on the east side of Wolverine Creek.

7. Large-scale erosion of tailings by Wolverine Creek, such as occurred in 1974, is not expected to recur. To prevent small-scale erosion as the creek downcuts the tailings on a continuing basis, the channel could

be lined with rockfill. Alternatively a culvert could be installed in the tailings to carry flood flows.

8. The surface of the tailings pile is virtually dust-free. The predominant particle size on the surface is about 1/4-inch. Wind action on the pile is not expected to raise dust after the fines on the surface at time of placement have been blown off.

9. No stability problems are foreseen with the more northerly portion of the tailings pile. This portion has been placed since 1974.

10. Numerous relatively small wedge failures and ravelling have occurred on the inter-bench slopes of the west wall of Porcupine Pit.

11. Material which has sloughed on to the benches on Porcupine Pit walls should be removed as practicable, to restore the bench catchments.

12. Movements of the west wall of Porcupine Pit should be monitored, as a check on overall stability and small-scale movement.

13. It is suggested that electronic distance measuring equipment (Geodimeter) be used for the distance measurements in the monitoring programs on Clinton Dump, the tailings pile, and at the Porcupine Pit.

## 3. MINE AND MILLSITE LAYOUT

The layout of the principal features at the Clinton Mine is shown in Figure 1.

The mine is located in hilly, unglaciated terrain. Two of the open pits (Porcupine and Snowshoe) are located on hills on the south side of Clinton Creek, and the third (Creek Pit) is on the original alignment of Porcupine Creek. The largest of the three pits is Porcupine. This pit will be mined to a maximum depth of about 800 ft. below original ground surface, (i.e. to El. 1110). At present, the pit floor is approximately at El. 1230.

Snowshoe and Creek pits are located to the east of Porcupine pit, and are considerably smaller than Porcupine. At present Snowshoe pit is mined to about 200 ft. below the original ground surface (to El. 1400). Mining in Creek Pit was abandoned at El. 1270, due to wet conditions.

The Porcupine ore (serpentine) strikes NE and dips to the NW at approximately 45 degrees. The serpentine is a grey-green material with a greasy lustre. The waste rock overburden in the hanging wall consists of black, graphitic argillite which fractures easily.

The waste rock overburden from the pits (mainly argillite) has been dumped in two main areas: Clinton Dump and Porcupine Dump. Clinton Dump is located to the northwest of Porcupine Pit, and south of Clinton Creek, and contains several tens of millions of tons of waste rock. Porcupine Dump is located southeast of the Porcupine Pit, towards Porcupine Creek. From cursory inspection, this dump appears to contain less than 5 million tons of waste. The Clinton and Porcupine dumps extend across the original channels of Clinton and Porcupine Creeks respectively.

The mill is located on a plateau on the north side of Clinton Creek, some 500 ft. higher than the mine area. The ore from the mine is transported across the Clinton Valley on an overhead tramway. Tailings generated during the milling operations are deposited in a pile at the top of, and extending down, a slope on the east side of the mill. The tailings, in an almost dry condition, are deposited by means of ejection from a high-speed conveyor.

## 4. CLINTON DUMP AND CLINTON CREEK CHANNEL

### 4.1 Dump - Observations

The top of Clinton Dump is at about El. 1800. The dump extends across the original Clinton Creek channel at El. 1200. The toe of the dump is at about El. 1340 on the north side of the valley. A view of the dump is shown in Photograph 1.

The original channel of Clinton Creek was blocked as a result of waste material gradually creeping downslope. During the initial stages of dumping, material was dumped at or near the top of the slope, and it crept downslope with relatively little bulldozing. We understand that, as creep was taking place, there were no sudden or deep-seated movements of material. After the channel was blocked, a lake was formed upstream of the toe of the dump, (Hudgeon Lake). This lake can be seen on the right of Photograph 1.

Recent dumping of material has been at about the El. 1400 level, in a "plateau" area of the dump, near the crest of a bench above Hudgeon Lake. We understand that dumping in this area is almost complete and that waste rock disposal will commence shortly at a new dump to be located on the valley flat northwest of Snowshoe Pit.

Cracks having widths of up to 3 ft. and depths up to 10 ft. were observed in the surface of the Clinton Dump, (see photographs 2 and 3). The cracks in the upper part of the dump are orientated roughly east-west, i.e. parallel to the contours of both the dump surface and original ground surface. These cracks appear to be scarps caused by vertical shear as the dump material has gradually crept downslope. In the lower part of the dump, most of the cracks are aligned approximately north-south, i.e., in the across-valley direction, and there is evidence of graben development (downward movement of a block of material, relative to the blocks either side). Some of the north-south cracks extend almost to the creek, i.e., across the main access road from the townsite. In some areas near the crest of local slopes in the lower part of dump, cracks have developed parallel to the crests of the local slopes.

Since June 1975, measurements of vertical and horizontal displacements have been made at 8 locations (dump movement monitors) within the toe region of the dump. The maximum measured displacement is 26 ft. horizontally, and 15 ft. settlement, at monitor No. 8. The direction of movement has generally been radial, relative to a point roughly in the centre of the toe region, as shown on Figure 1. However, all of the monitors are positioned at crests of local slopes within the toe region, and a large part of the north-south component of the measured displacements may reflect localized surface creep near the crest of benches on the surface of the dump, rather than the north-south components of movement within the main body of the dump.

## 4.2 Creek Channel - Observations

It was reported to the writers that spillage from Hudgeon Lake around the toe of the dump has not resulted in any deep-seated sudden failures in the toe of the dump, or at the toe of the natural slope on the north side of the channel.

At the time of the May 3 to 6 inspection, Clinton Creek was flowing in a channel at the toe of the Clinton Dump. At some locations both sides of the channel consisted of dump material. At other locations in situ bedrock was exposed on the north side of the channel.

The channel had undercut its north bank in several areas. For example, opposite dump monitor 3, the channel was completely hidden at the time of inspection, as flows were undercutting a 200 cu.yd. block of waste material on the north bank (photograph 4). Bedrock (argillite) is exposed on the north bank opposite monitors 1 and 2. This had been eroded to a depth of about 5 ft. below the original bedrock surface.

Along the south side of the channel, the local slope (within dump material) is at its maximum height and inclination between dump monitors 1 and 2. Vertical shear cracking at the top of the slope indicated that this part of the slope was about to slump into the channel (photograph 5).

## 4.3 Clinton Dump and Channel - Discussion

The major problem in the Clinton Dump/Clinton Creek Channel area is erosion at the toe of the dump, and at the base of the natural slope on the north side of channel. Based on the elevations at the two locations where the main access road crosses the channel, the average channel grade is about 5 per cent, (the grade of the original valley floodplain surface was about 1.5 per cent, but the channel meandered considerably so that the original hydraulic gradient was probably less than 1 per cent). A maximum discharge of 13,400 cfs has been recorded in Clinton Creek (see Table I). Channel erosion could be expected each spring, unless energy dissipators, such as weirs, were installed in the channel. Before construction of the weirs proceeds, the channel bed should be widened, and work should be carried out on the channel to flatten the side-slopes (as noted below).

The toe of the dump is acting as a dam with about 120 ft. head of water (Hudgeon Lake) acting on its upstream slope. The dump infills about 2400 ft. length of valley. With a head to seepage path ratio of 1 in 20, the toe of the dump is extremely stable with regard to any seepage from the lake through the dump material.

The rock fragments in the dump are composed of argillite. This material breaks down relatively easily (mainly by slaking). The tendency to break down is probably increased by point-to-point contact between adjacent fragments in the dump. As the fragments become degraded, further dump movement occurs. Since the process of fragment degradation is time-dependent, it is not possible, from the data available to date, to estimate

## 5. PORCUPINE DUMP

Porcupine Dump has a much smaller volume than Clinton Dump, and the pond that has been formed upstream of the toe of the dump is much smaller and shallower than Hudgeon Lake. The surface of the dump is very hummocky, and has an estimated average slope of 3 horizontal to 1 vertical, (see photograph 6). There are many cracks in the dump surface, mostly parallel to the overall surface contours, and there are some cracks indicating graben-like features. The majority of the waste material in this dump is argillite rock fragments.

The cracking and hummocky features on the surface of the dump indicate that creep movements have occurred, and may still be occurring. No measurements have been made of movement on the surface of this dump, but the writers were shown a pile of broken lumber, which was once at the crest and has now moved to a point 200 ft. down the slope from the crest and about 60 ft. vertically below the crest.

At the upstream end of the toe of the dump, in situ surface soils, trees, and debris have been heaved and displaced laterally towards the opposite side of the valley (i.e., against the toe of the east valley wall). Most of the discharge from the upstream pond flows in a small channel across the displaced soils, and then enters the toe of the dump. The rock fragments in the toe area only, consist of serpentine and are up to 4-ft. size. This material is durable (relative to argillite) and permits water to flow through the rockfill easily. This water can be seen emerging on the downstream side of Porcupine Dump. Only a small portion of the pond discharge flows in the channel formed by the toe of the dump and the east valley wall.

Although movements in the upper part of the dump might still be continuing, these do not affect the discharge in Porcupine Creek. Some minor ravelling may occur occasionally on the face of the dump where the Porcupine discharge emerges, but no large-scale failures are foreseen.

## 6. TAILINGS PILE

In the spring of 1974, a large section of the tailings pile moved downslope, and blocked Wolverine Creek (photograph 7). The crest of the pile is approximately 700 ft. above the toe of the slide. A small pond formed upstream of the toe of the slide. Considerable tailings erosion occurred when the pond level rose sufficiently for water to spill over the toe of the slide. Flood waters in Wolverine and Clinton Creek channels downstream of the slide rose to several feet above the banks of the creeks, and white mineral fibre can still be seen clinging to the bottom 2 ft. or so of the trees in the valley bottoms. After the slide occurred, a channel for flood flows in Wolverine Creek was bulldozed across the toe region of the slide.

We were advised that, soon after the slide occurred, the tailings conveyors were moved, and the tailings pile was advanced in a more northerly direction.

The creek has now cut below the level of the bulldozed flood channel and is flowing on bedrock (argillite) that outcrops at the toe of the slope on the east side of Wolverine Creek (see photograph 8). The erosion below the flood channel has also exposed organic soil mixed in with the tailings. This would suggest that the seat of movement within the toe region of the 1974 slide was in unfrozen soil close to the original ground surface. Inspection of the topographic contours of the area (made prior to tailings disposal) indicates that the portion of the tailings pile that failed was located above a shallow draw in the hillside. The presence of the draw could have contributed to the slide, in that the surface soil in the draw could have been locally wetter.

The surface of the toe of the slide is marked by 2 to 3 ft. deep cracks which are orientated radially, as shown on Figure 1. These cracks extend to the extreme toe. Surface cracking and slumping is evident in the upper region of the tailings pile.

The pattern of cracking suggests that movements in the toe region are radial outwards (i.e., towards the toe extremity). Movement in the toe region may still be continuing, but, based on presently available information, this cannot be confirmed. There is no evidence of any sudden movements (since the 1974 slide). If the 1974 slide occurred by sliding in in situ soil underlying the pile, it is expected that the toe material would now be in a stable condition with regard to any sudden movement.

To check on possible creep movements within the slide, surface markers (monitors) should be installed in the toe region, and reference points established on stable ground on the east side of Wolverine Creek. The monitors on the tailings pile should be located at least 200 ft. back from the crests of locally steeper slopes within the toe region. Periodic measurements should be made of the distance between the reference points and the monitors.

No cracks were observed in the more recently placed tailings to the north of the slide material. The slope of this portion of the pile is at the angle of repose of the material, and the base of the slope is supported on a flatter part of the original ground slope surface. The topographic contours indicate that this part of the pile does not cover any draw or areas which might be locally wetter. The more recently placed portion of the tailings pile appears to be relatively stable. No stability problems are foreseen if tailings disposal is continued in a more northerly direction.

The predominant particle size on the surface of the tailings pile is about 1/4-inch. However the tailings as a whole contain many fines and fibres. This suggests that after the tailings have been placed for some time, the surface fines are removed by wind or surface run-off, and that subsequent wind action would not raise dust from the pile surface.

## 7. PORCUPINE PIT

### 7.1 Observations

At the time of the May 3 to 6 inspection, Porcupine Pit had been mined to El. 1230, a maximum depth of about 650 ft. below original ground surface. Benches in the pit walls are spaced at 90 ft. difference in elevation. The design width of the benches is 58 ft. Originally, the overall pit slope was set at 50 degrees, but due to ravelling and surface failures which were experienced in the argillite rock exposed in the west portion of the pit, the wall on this side of the pit has been cut at an overall slope of 45 degrees.

Ravelling and numerous small wedge failures have occurred on the inter-bench slopes of the west wall, as evidenced by accumulations of broken rock debris on the benches. Cracks were observed at a maximum distance of 10 ft. behind the crest of the west wall, as shown in photographs 9 and 10. At the time of inspection, the pit walls above El. 1380 were final, and the El. 1380 bench on the west wall had been left approximately 150 ft. wide. The mining company propose to cut this back eventally to 58 ft. width.

The south and east walls of the pit have been cut at an overall slope of 50 degrees, and, from surficial inspection, appear to be relatively stable, with only a minor amount of inter-bench ravelling.

Water is now ponded in the bottom of the pit at El. 1231, and we understand that this is the first level at which subsurface water has been encountered in the pit. At the time of inspection, the bottom of the pit had been drilled and pumping tests had been conducted, during which the subsurface water was drawn down to El. 1200 (approximately) by pumping at a rate of 30 to 40 gallons per minute.

## 7.2 Interpretation

Instability of the pit walls to date has been confined to the inter-bench slopes of the west wall. Material from surface ravelling is accumulating on the benches. This material should be removed as practicable in order to restore the bench catchment.

During the May 3 to 6 inspection, no evidence of potential deep-seated slides or overall pit-wall movement could be seen. However, the possibility of a deep-seated slide on the west wall cannot be ruled out.

Surface markers should be set up on the west wall of the pit to monitor small scale movements, and to provide adequate advance warning of potential deep-seated slides. The locations of the markers should be selected so that surface movements can be differentiated from deep-seated movements. The distance between the markers and fixed reference points established on the east side of the pit should be measured on a regular basis, to monitor movements on the west wall of the pit.

Yours very truly,

GOLDER BRAWNER & ASSOCIATES LTD.

Per: D. B. Campbell, P. Eng.

G. R. Tomlin, P. Eng.

GRT/jh
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TABLE I

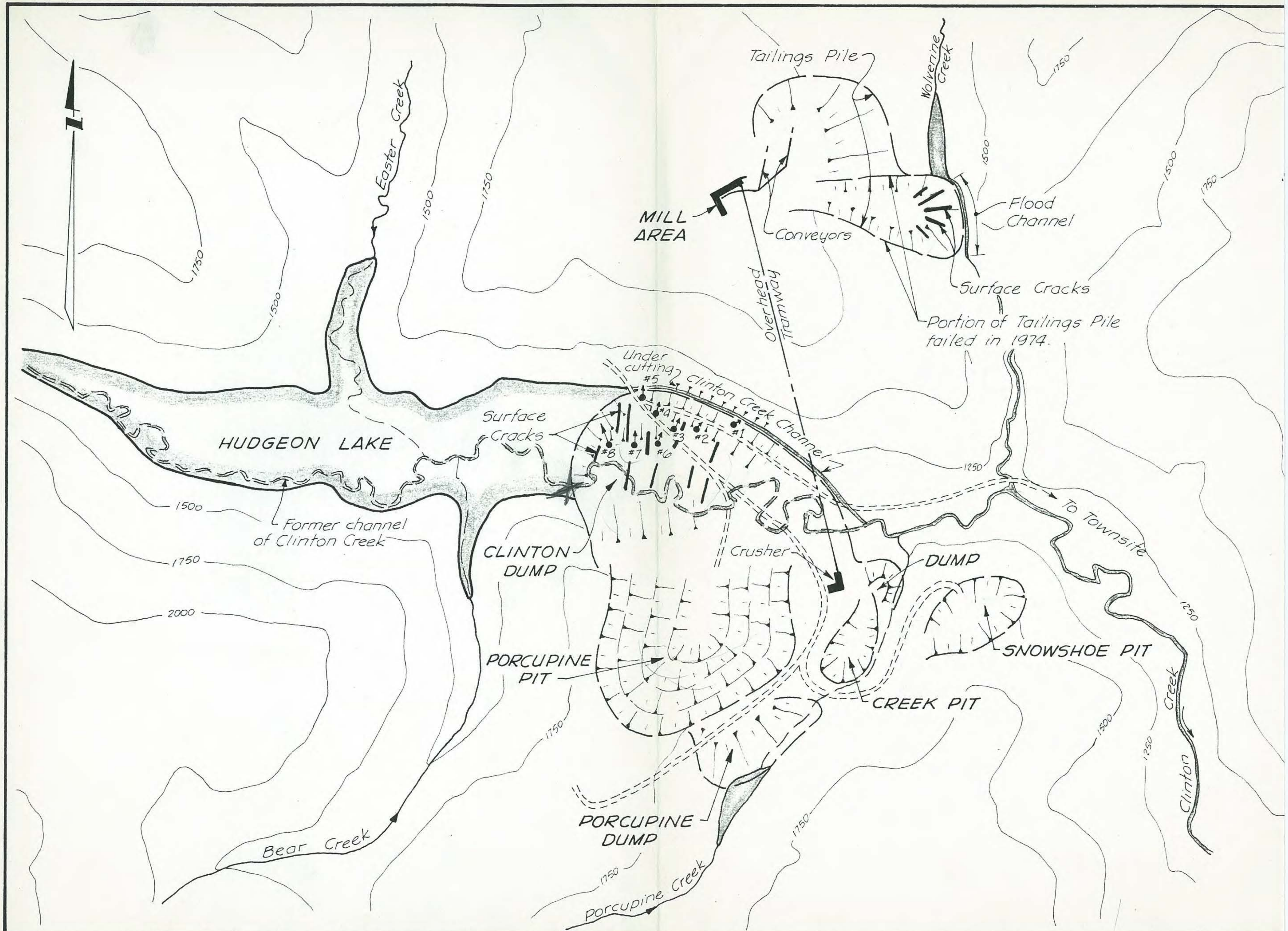
Recorded and computed maximum discharge in Clinton Creek above Wolverine Creek.

| Year | Discharge (c.f.s.) |
|---|---|
| 1964 (May)* | 13,400 |
| 1965 (July)* | 4,780 |
| 1975 (Spring)** | 5,000 |

* Recorded at Gauge Station 9EC-1. (Lat: 64° 26' 54"N; Long: 140° 42' 24"W) Information published by Inland Waters Directorate, Water Survey of Canada (Note: 1964 and 1965 are the only years for which records are available).

** Computed discharge, based on the following verbal information from G. R. Vincent:

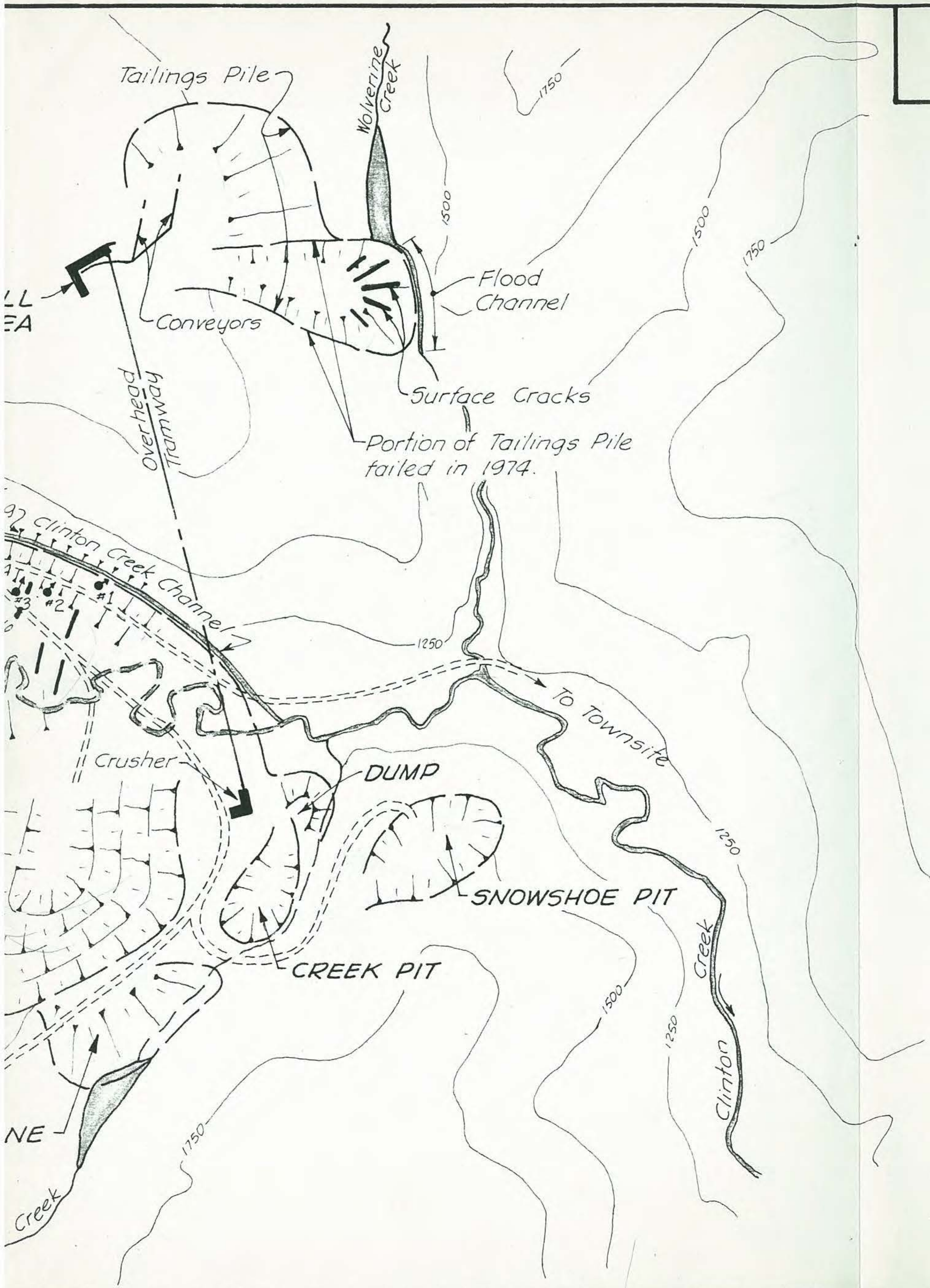
Spring 1975, outlet from Hudgeon Lake: The discharge flowed through two culverts under the main access road. The culverts were each 6 ft. diameter. At the time of the peak discharge, there was 7 ft. head at the upstream end of the culverts. For computing discharge it was assumed that the length of each of the culverts was 60 ft.



Tailings Pile
Wolverine Creek
1750
1500
1750
Flood Channel
MILL AREA
Conveyors
Surface Cracks
Portion of Tailings Pile failed in 1974.
Overhead Tramway
Easter Creek
1500
1750
1750
1500
Under cutting
Clinton Creek Channel
#5
#4
#3
#2
#1
#8
#7
#6
Surface Cracks
HUDGEON LAKE
1250
To Townsite
1500
Former channel of Clinton Creek
CLINTON DUMP
Crusher
DUMP
1750
2000
SNOWSHOE PIT
PORCUPINE PIT
CREEK PIT
1250
1750
1500
1250
Creek
Clinton
PORCUPINE DUMP
1750
Bear Creek
1750
Porcupine Creek

# CLINTON MINE, PLAN OF MINESITE AND MILLSITE AREAS

FIGURE 1




LEGEND:

| | |
|---|---|
| | Road |
| | Slope direction within pits and on dumps (general indication only) |
| #1 | Dump monitor No. 1 (Arrow indicates direction of movement from June 16, 1975 to April 12, 1976. Length of arrow represents amount of movement at a scale of 1 inch to 100 feet. |

NOTES:

1) Outline of pits, dumps and tailings pile is approximate, and is based on Cassiar Asbestos Corporation Ltd. Dwgs "Topography Porcupine, Snowshoe and Creek Pits, Jan. 1, 1976 100 scale" and "Sheet No. 46" (marked up.)

2) Topography based on 1965 Survey by Mc Elhanney Surveys Ltd., sheet No. 1001.

Scale: 1 inch to 1000 feet, except movement of dump monitors (see Legend).

Golder Associates

Drawn JH
App'd. GRP
Date May '76

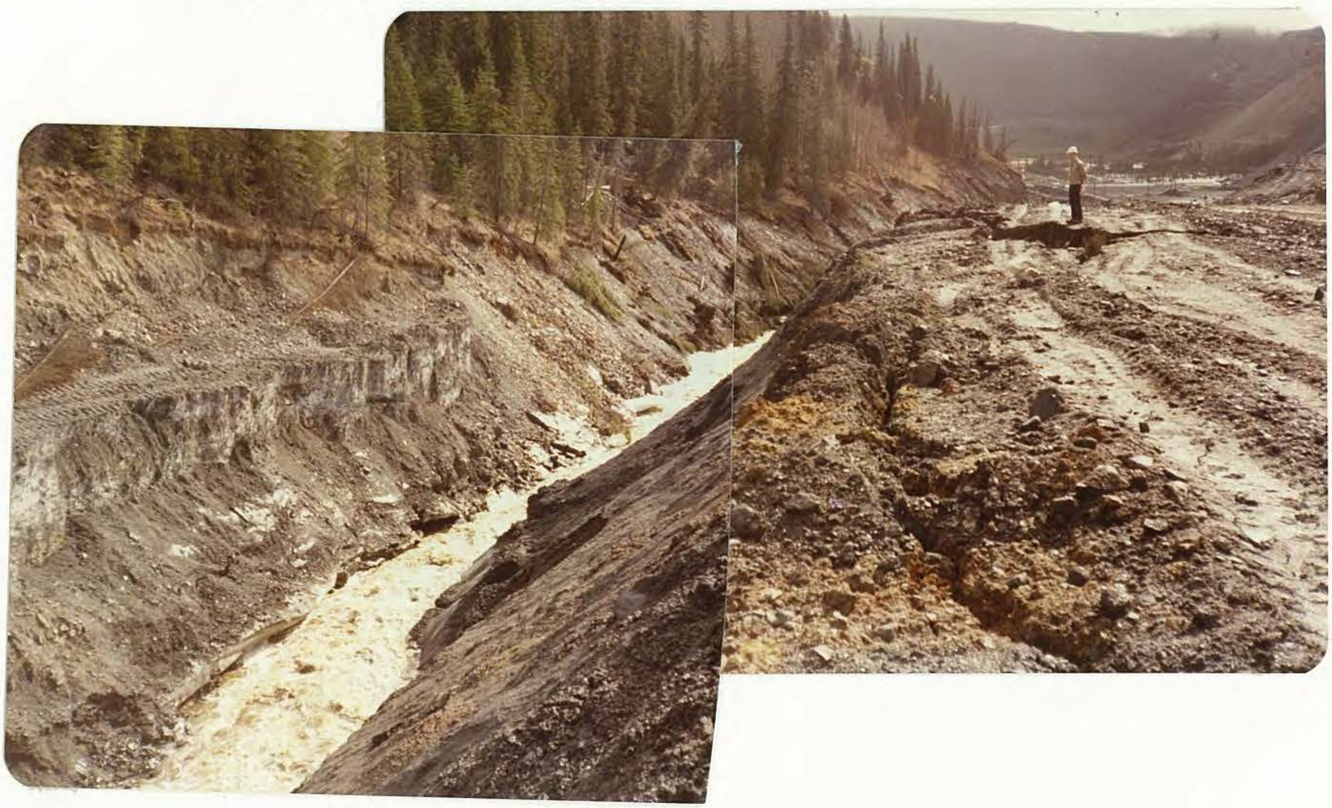
V-76083

1. Clinton Waste Dump - looking across valley from North Side. Note cracks in lower part of dump in across-valley direction.

2. View looking North showing cracks in Clinton Waste Dump. Dump monitor No. 7 on right.

3. Looking North over Clinton Waste Dump, from upper crest.

4. Clinton Creek discharge, May 5, 1976, looking downstream at a location opposite dump monitor No. 3. Note undercutting of in situ material on left bank.



5. Clinton Creek discharge looking downstream, between dump monitors Nos. 1 and 2. Note cracking at top of oversteepened right bank.

6. Porcupine Creek dump, looking East from crest. Note extremely broken surface in foreground, indicating large vertical and horizontal movement, and graben-like development. Note also debris and trees pushed up against the valley wall at the base of the dump.

7. Tailings Pile, looking upstream from East side of Wolverine Creek. Portion of pile which moved downslope in 1974 is in foreground.

8. Base of tailings pile, looking upstream. Wolverine Creek has cut below the level of the 1974 flood channel. It now appears to be flowing on bedrock (argillite) that is visible in foreground.

9. West wall of Porcupine Pit. Note cracking at rim of pit, and numerous cases of ravelling on the inter-bench slopes.

10. West wall of Porcupine Pit. Pit wall above El. 1380 bench (i.e. the bench above that on which loader is working) is final. Further excavation is planned below El. 1380, leaving a 58-ft. wide bench at El. 1380.