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Golder Associates
CONSULTING GEOTECHNICAL ENGINEERS

REPORT TO CASSIAR ASBESTOS CORPORATION LTD. ON GEOTECHNICAL ASPECTS OF MINE CLOSURE

CLINTON CREEK MINE YUKON TERRITORY

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Clinton Creek, Yukon Territory

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1.0 INTRODUCTION

Cassiar Asbestos Corporation Ltd. are planning to cease mining operations at Clinton Creek during the summer of 1978. On abandonment of the property, Cassiar Asbestos wish to leave the Clinton Creek operation in a condition which will be acceptable to the Yukon Territories Water Board, the government agency responsible for environmental protection within the Yukon Territory. The principal problems associated with abandonment of the property are associated with continuing movements of both the overburden waste pile and the tailing pile.

2.0 FIELD AND LABORATORY WORK

To date several field inspections have been made by Golder Brawner & Associates engineers. Geotechnical investigations are currently being carried out under the supervision of Golder Brawner. The field program includes drilling and sampling of materials in and under the Clinton waste dump and the tailing disposal areas, installation of thermistors to determine whether permafrost is aggrading or degrading in these areas, and installation of piezometers in the Clinton dump to determine the ground water conditions in that area. Also, a number of additional survey reference points to monitor the rates of horizontal and vertical movements on the waste rock and tailing pile are being installed by Cassiar during this program. Data from these additional stations, as well as the previously existing survey installations, will be gathered by Cassiar personnel and forwarded to Golder Brawner for assessment. Monitoring of the thermistor and piezometer installations is to be done by Cassiar Asbestos personnel in accordance with instructions concerning frequency and accuracy of the required readings as provided by Golder Brawner.

3.0 CLINTON DUMP

3.1 Site Conditions

Overburden materials excavated in the course of mining operations consisted predominantly of argillite. Development of the Clinton waste dump began on the sloping hillside on the south side of Clinton Creek. At a relatively early stage of development slumping of the dump face began to occur. With continued consignment of material to the dump, the toe region of the waste pile advanced northward across the original Clinton Creek channel resulting in damming of the drainage course. As a result, Hudgeon Lake, which now has a maximum depth of about 85 ft., has been impounded on the upstream side of the dump, and the channel of Clinton Creek has been displaced laterally toward the north, and vertically upward. The Clinton Creek channel is now located at the northern limit of the dump along the line of contact where the toe of the dump abuts the toe of the slope below the plantsite. This segment of the channel drops approximately 120 ft. over a distance of approximately 2,900 ft.

What is slope of Clinton Creek

3.2 Horizontal Movements

Observations on reference points located on the surface of the Clinton waste dump show that surface movements continue to occur. The horizontal movement vectors are aligned radially outward toward the perimeter of the dump. Plots of the horizontal displacement versus time for the reference points on the surface of the dump do not show any significant trend of decreasing rate of movement with increasing time.

The data so far gathered indicate that movements are primarily the result of horizontal spreading as opposed to rotational shear failure.

Prior to April 1978, horizontal movements on the surface of the waste dump were being monitored at five locations, as shown on Figure 1. As at March 1978, the observations at references points, Nos. 19 and 23, cover a period of approximately 475 days. The period of observation on the remaining waste dump reference points is somewhat shorter. The data show that each of the reference points is moving at a virtually uniform rate, which varies between 0.025 ft. per day to 0.012 ft. per day (9 ft. - 4.4 ft. per year). The movement records show that the waste dump is continuing to creep and to crowd the segment of the channel located along the junction between the northern limit of the dump and the toe of the north valley wall. Creep movements of the dump in the direction toward Hudgeon Lake are also continuing, as evidenced by a pressure ridge that formed on the ice surface of Hudgeon Lake during the winter of 1977-78. This pressure ridge is located a short distance out from the face of the dump and parallel to the shoreline where the face of the dump plunges into Hudgeon Lake.

As a result of the continuing creep movements, the northern limit of the waste dump encroachs on the segment of the creek channel that borders the northern limit of the dump. However, the channel is maintained by stream erosion of both waste dump material and in situ bedrock on the northern slope of the valley.

3.3 Clinton Dump as a Water Retention Structure

The overburden dump must continue to serve as a dam to effectively retain the waters impounded in Hudgeon Lake. If failure of the waste rock dam were to occur, it could result in rapid release of the impounded waters with serious flooding downstream.

In the course of the geotechnical investigations currently in progress, representative samples of the Clinton dump materials will be subjected to laboratory shear strength tests to determine the basic shear strength parameters for the materials comprising the overburden dump. These shear strength parameters, together with piezometric data from the piezometer installations will be used in stability analyses to assess the ability of the dump to continue to function as a permanent dam. It is expected that the results of these analyses will indicate that there is no danger of failure and that the overburden dump will continue to function as a permanent dam.

3.4 Clinton Channel

As noted in Section 3.1, the overburden dump continues to creep toward the creek channel. The creek maintains its grade and channel cross-section by erosion of both in situ bedrock along the toe of the hillside on the north valley wall, and overburden materials that encroach on the channel as a result of the creep movements.

It might be possible to halt the creep movements in the waste dump by redistribution of materials such that the stresses within the toe region of the dump are changed to a state of equilibrium. However, the amount of material that would have to be moved is probably so great as to make this solution economically impracticable.

In our opinion, the continuation of movements in the waste dump should be accepted, and provision should be made to maintain the level of the outlet from Hudgeon Lake and to guard against excessive downcutting of the channel. We recommend that a series of rock groynes be constructed transverse to the channel, and extending approximately 200 ft. south of the channel (see Figure 2). As the creep movements at the toe of the dump continue, the rock will be shifted gradually into the channel. A 200 ft. long groyne would accommodate movements at the present rate for a period of 20 to 30 years. We expect that the creep movements will have ceased by that time.

So what does this do. - erosion still occurs between the groins.

Observations of the Clinton Creek channel over the past year indicate that scattered rock fragments of various sizes are disbursed through the dump material in the creek channel. Continued erosion of that portion of the waste dump which encroaches in the channel results in removal of soil and fine rock fragments. The larger rock fragments remain as lags which form a rock pavement on the bottom of the channel. Examples of lags from the waste dump in the bottom of the channel are shown in Photograph No. 9, of GBA report V77016 to Cassiar Asbestos Corporation dated November 1977. These observations indicate that the channel is developing its own natural rock pavement.

3.5 Schemes Considered and Rejected

The suggestion has been made that a diversion channel could be constructed to conduct water from Hudgeon Lake into the Porcupine Pit from which the flows would be discharged into the original drainage course downstream of the existing waste dump. This solution would, to some extent, alleviate siltation problems since the pit would act as a settling pond for silt-bearing water running between Hudgeon Lake and the Porcupine

Pit. However, excavation and maintenance of a permanent and competent channel in the waste rock for such a purpose would be extremely difficult. Since movements in the dump are occurring in the vertical as well as in the horizontal directions, downward vertical movements toward the south end of the dump could result in the stream leaving any constructed channel, no matter how well constructed, and moving into the waste rock in an uncontrolled manner. In the event of a flood, an occurrence of this nature could result in the removal of large amounts of waste from the dump area. On the basis of the information so far available, this alternative does not appear to lend itself to a safe and reliable solution to the Clinton Creek drainage problem.

We have considered a buried culvert to conduct the flows from Hudgeon Lake to the eastern limit of the dump. A culvert could be subject to deformation and potential collapse as a result of horizontal earth pressures developed within the advancing toe of the waste pile. Also, any culvert or closed conduit would be subject to icing during the winter. The supply of heat to guard against icing is considered to be impracticable over the long term.

why not consider putting it in. L-H Bea

The use of concrete, or other rigid-type drop structures or energy dissipators has been considered. With continued creep movements rigid structures would be displaced, resulting in loss of soil contact, and in erosion around or beneath the structures. For this reason, rigid and semi-rigid control structures or energy dissipators are not suitable.

Rock lining of the channel would provide a temporary solution. However, with continued creep movements the rock lining would be shifted laterally and upward toward the east. Eventually the stream would begin to

-if made "erosion proof" would not the channel slowly rise in elevation to the level of the stabilized dam (augers etc).

erode along the southern edge of the channel lining and the stream would again flow in waste dump material on the right hand side of the rock lining material.

4.0 TAILING DISPOSAL AREA

4.1 Introduction

The separation of asbestos fibre at the Clinton Creek operation is a dry process. Tails are transported from the mill by conveyor, and have been deposited in the form of a large pile located to the east of the mill, and on a gently sloping hillside above the west bank of Wolverine Creek.

In 1974, a segment of the tailing pile, near its southern extremity, moved downslope and blocked Wolverine Creek. In the spring of 1974 run-off water ponded behind this obstruction to a level which resulted in overtopping of the toe of the slide debris. When this occurred, the flows resulted in rapid erosion and down cutting within the toe region of the failure lobe. The impounded water rushed through the erosion gap resulting in flooding of Clinton Creek to which Wolverine Creek is tributary.

4.2 Creep Movements on Tailing Pile

Reference points have been established on the surface of the tailing pile to monitor the rates of movement at various locations. Prior to April 1978, 4 references points had been installed, 2 on the 1974 failure lobe, and 2 on the northern segment of the waste pile. The approximate locations of the reference points on the tailing pile are shown on Figure 3. Additional reference points have recently been installed on the surface of the pile.

Reference point No. 25 located at the toe of the 1974 failure lobe indicates that the movements within this region of the tailing pile are continuing at a rate of approximately 1/4 inch per day. There is no indication that this rate of movement is diminishing significantly with time. Reference point No. 24, located at or near the upper limit of the 1974 failure lobe, indicates that movements within this region of the tailing pile have virtually ceased.

R.M. Hardy report. – All monitors a rate of movement which could be considered failure
309 day – Δ = 1.28 ft Δ elev = 0.52 ft.

Monitor No. 29, located within the toe region of the actively moving northern segment of the waste pile, is moving at a steady rate of
up from ≈ 5 in/day
about 0.5 ft. per day. Field observations indicate that the toe segment to the east of monitor No. 29 is creeping downslope at a rate slightly greater than 0.5 ft. per day. The toe of the tailing pile, when inspected on March 8, 1978, was estimated to be approximately 300 ft. from Wolverine Creek. During field inspections on April 4 and 5, 1975, it was noted that a segment of material from the toe region of the tailing pile in this area had moved downslope since the inspection of March 8. The nature of these movements suggests that the downslope creep movements will continue, and that the northern segment of the tails will eventually reach Wolverine Creek.

< 2 yrs. to creek

4.2 Assessment of Site Conditions

The tails contain a significant amount of asbestos fibre and the principal concern of the Yukon Territories Water Board is the possible entry of asbestos fibre into Wolverine Creek as a result of stream erosion of the tails at such time as the toe of the tailing pile reaches the creek.

Initial shear strength tests have been conducted on a representative sample of tails from the Clinton Creek operation. The results of these tests indicate that the material has an effective angle of internal friction in the range of 35 to 40 degrees. The tailing pile is currently moving on a slope which is inclined at approximately 14 degrees. Examinations in the field indicate that the base of the tailing pile contains segregated coarse rock. The permeability of this coarse material, together with low annual precipitation at the site, precludes the possibility that the movements are associated with the build-up of pore water pressures within the lower regions of the tailing pile itself.

R.M. Hardy $\phi = 46^{\circ}$ peak $= 30^{\circ}$ resid.

Examinations in the field show conclusively that the downslope creep movements of the tailing pile are accompanied by displacements of significant amounts of in situ foundation materials on which the pile has been deposited. The dominant material which has been displaced by the downslope movements of the tailing pile is weathered argillite bedrock. The field observations also show that the displaced material which is bulldozed ahead of the tailing pile as it moves downslope varies in thickness from a few feet up to thicknesses of the order of 15 to 20 ft. At one soil exposure within the toe region of the tailing pile, the displaced materials consisted of weathered inorganic soils with a total accumulated thickness of between 35 and 40 ft.

why did G.B. not inform Cassiar of the inherent instability of this ground in 1974 & advised an alternate system of tailing disposal

Shear strength tests have not yet been completed on representative samples of the weathered argillite bedrock that underlie the surface organic mantle in the region of the tailing pile. However, it is reasonable to assume that the effective friction angle of these soils is considerably greater than 14 degrees. Hence, the downslope creep movements of the tailing pile cannot be explained by a low friction angle for the weathered soils that evidently are being displaced ahead of the advancing toe of the tailing pile.

Ore that enters the mill is heated to approximately 20 degrees C during the milling process. Thus, the tails exiting the mill also have a temperature of approximately 20 degrees C, suggesting that a considerable amount of latent heat may be contained within the tailing pile. Examination of aerial photographs taken prior to construction of the tailing pile, together with onsite examinations of the character of the ground surface within the area immediately surrounding the perimeter of the pile, indicate that the hillside is underlain by permafrost. This was corroborated by a field inspection on April 4 and 5, 1978, during which a bulldozer was used to penetrate the frozen weathered material downslope of the toe of the tailing pile. The in situ frozen material was observed to contain a high percentage of water in the form of ice crystals and ice lenses. Several ice lenses observed during the inspection were greater than 1 inch thick. On the basis of these observations it is considered possible that the creep movements within the tailing pile may be associated with thawing of permafrost with an accompanying build-up in pore water pressures within the weathered inorganic soils beneath the pile itself.

4.4 Solutions to the Problem

In order to prevent entry of asbestos fibre into Wolverine Creek it will be necessary to maintain stream flows in the creek free of contact with the tails.

A number of alternative solutions to the problem of contact between run-off water in Wolverine Creek and the tails from the milling operation have been considered and are presented in the following paragraphs.

4.4.1 Open Sidehill Channel

The information available suggests that the best solution to the problem of continued movement of the tailng pile toward the Wolverine Creek Valley is to construct an open channel along the base of the slope on the east side of Wolverine Creek. The cross-section and grade of the open channel will be designed so that it will be capable of carrying the maximum anticipated flows.

The construction of a sidehill channel in the Wolverine Creek Valley will involve the removal of weathered rock and surface soil from the area in which the channel is to be made. Following this, a berm consisting of tails would be constructed on the downslope side of the channel itself. A schematic section of the channel is shown on Figure 4. The construction of the berm should prevent the possibility of stream flows breaking out of the downhill (western) side of the channel. Depending upon the design elevation of the channel, it may be necessary to construct a dam across Wolverine Creek upstream of the tails, to divert Wolverine Creek into the new channel. There are potential problems of rapid erosion at the outlet end of the constructed sidehill channel and measures will have to be taken to ensure that excessively rapid erosion of either weathered or unweathered rock in the east wall of the Wolverine Creek Valley does not occur. These measures could include the installation of coarse rock energy dissipators in the form of drop structures or, paving of the bottom of the outlet end of the channel with suitable coarse rock.

4.4.2 Schemes Considered and Rejected

Alternative solutions which have been considered, but rejected, include the construction of a retaining embankment between Wolverine Creek and the present toe of the tailing pile, installation of a culvert in the bottom of the stream channel and a downstream dam to reduce stream flow velocities past the tails. These alternatives are discussed briefly in the following paragraphs.

A retaining embankment within the region between the advancing toe of the tailing pile and Wolverine Creek could be constructed. Such a construction would involve the removal of all organic and weathered rock material down to the level of competent bedrock. In view of the fact that the rock is frozen to an undetermined depth in this area a guarantee would have to be made that the tails placed on the rock to construct the embankment were below freezing temperatures and could be maintained at those temperatures. If this was not the case it could be expected that thawing would take place in the rock and that there would again be a potential for the build-up of excess pore pressures near the base of the tailing pile with subsequent movement of the tails and the embankment into the Wolverine Creek drainage course. This scheme would involve the removal of possibly as much as 20 ft. of organic material and weathered bedrock over a width of 200 - 250 ft. along the west valley wall of Wolverine Creek over a length of as much as 2,500 ft. This would require the removal of about 450,000 cu. yds. of overburden and the placement of between 800,000 and 1 million cu. yds. of tails into that region for embankment construction. The lack of certainty of the success of this solution, together with the amounts of materials that would have to be moved for construction makes it unlikely that this alternative would be either economically or practicably feasible.

The installation of a closed metal or concrete culvert in the bottom of the stream valley of a size sufficient to conduct Wolverine Creek stream flows through it would preclude contact of any stream flows with the tailing pile and thereby guard against erosion of the tails. In this case the culvert could be installed and the tailing pile would be allowed to continue creeping downslope to eventually over-run the culvert or, alternatively, tails of a predetermined thickness could be used to cover the pipe to a sufficient depth to preclude against the culvert being moved or crushed by downslope creep of the tails. Aside from the high cost of installation the principal problems associated with this proposal are the possible lateral deformations and collapse of the culvert pipe as a result of lateral loads imposed by the advancing toe of the tailing pile and the likelihood that the culvert would fill with ice due to the presence of permafrost in the bottom of the valley. In order to prevent permanent icing-up of such an installation, some method of heating of the culvert would have to be installed.

The construction of a dam downstream of the tailing pile in the Wolverine Creek Valley would have the effect of creating a settling pond in the vicinity of contact between water in Wolverine Creek and the tails. However, the particle size of the asbestos fibres in the pile are so small that significant quantities of them would probably remain in suspension and travel through the Wolverine/Clinton Creek system and eventually into the Yukon River. It is considered unlikely that this proposal would meet with the approval of the Yukon Territories Water Board.

that's for — sure

Yours very truly

GOLDER BRAWNER & ASSOCIATES LTD.

Per: David B. Campbell, P. Eng.

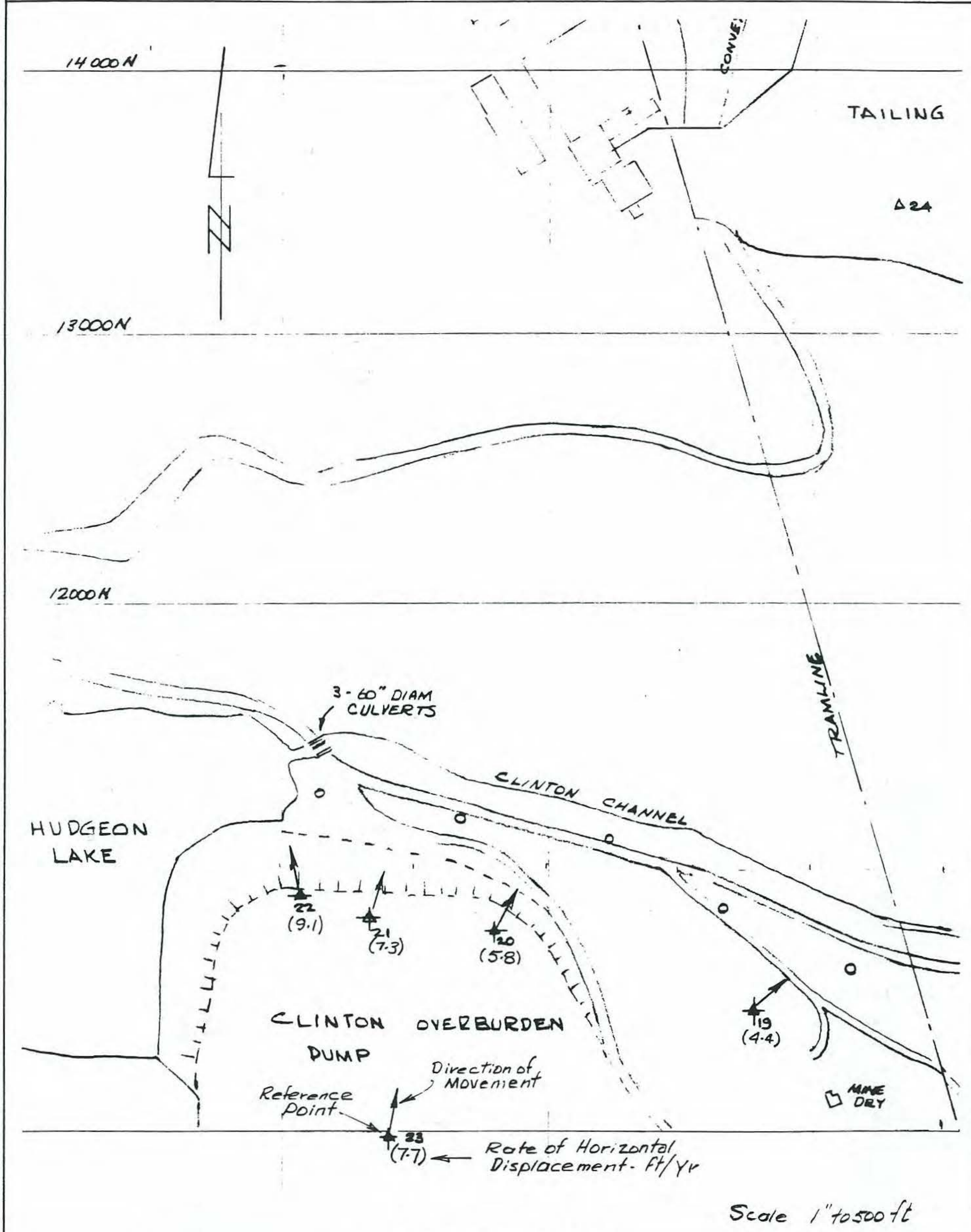
E.B. Fletcher, P. Eng.

DBC/EBF:rme

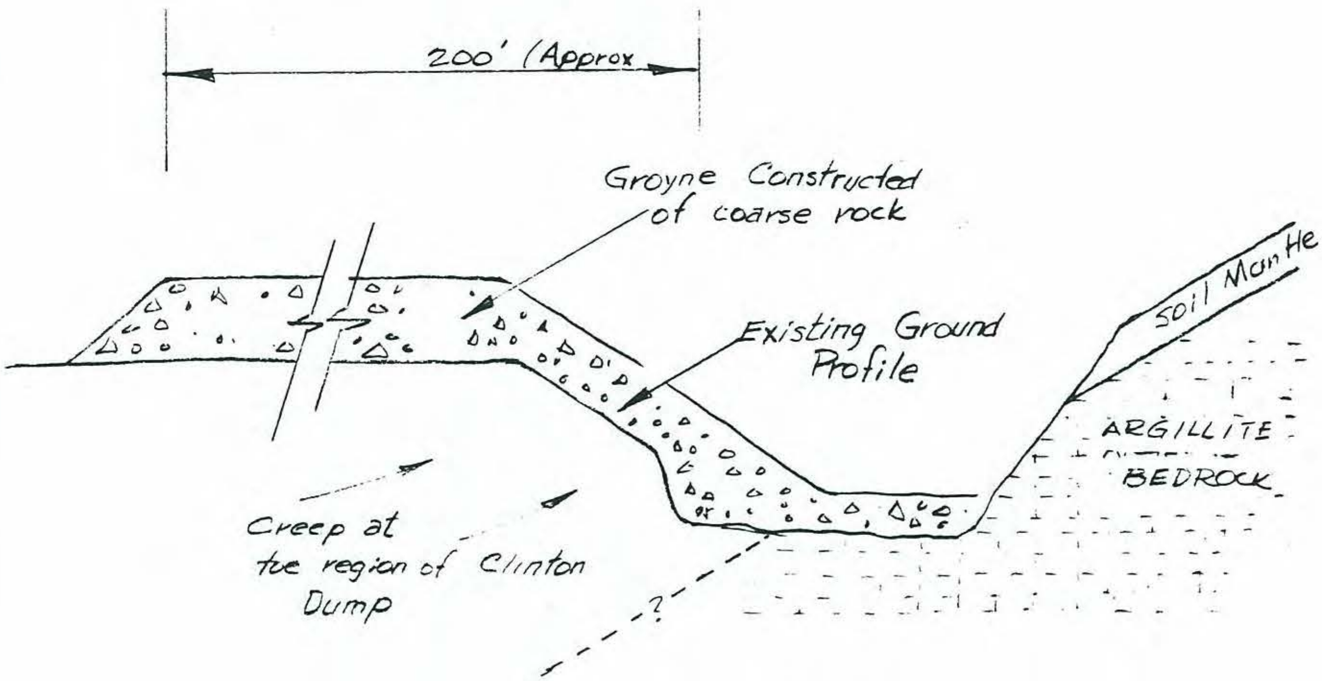
V77016

HORIZONTAL SURFACE MOVEMENTS CLINTON WASTE DUMP

Figure 1



ROCK GROYNE - CLINTON CHANNEL **Figure 2**



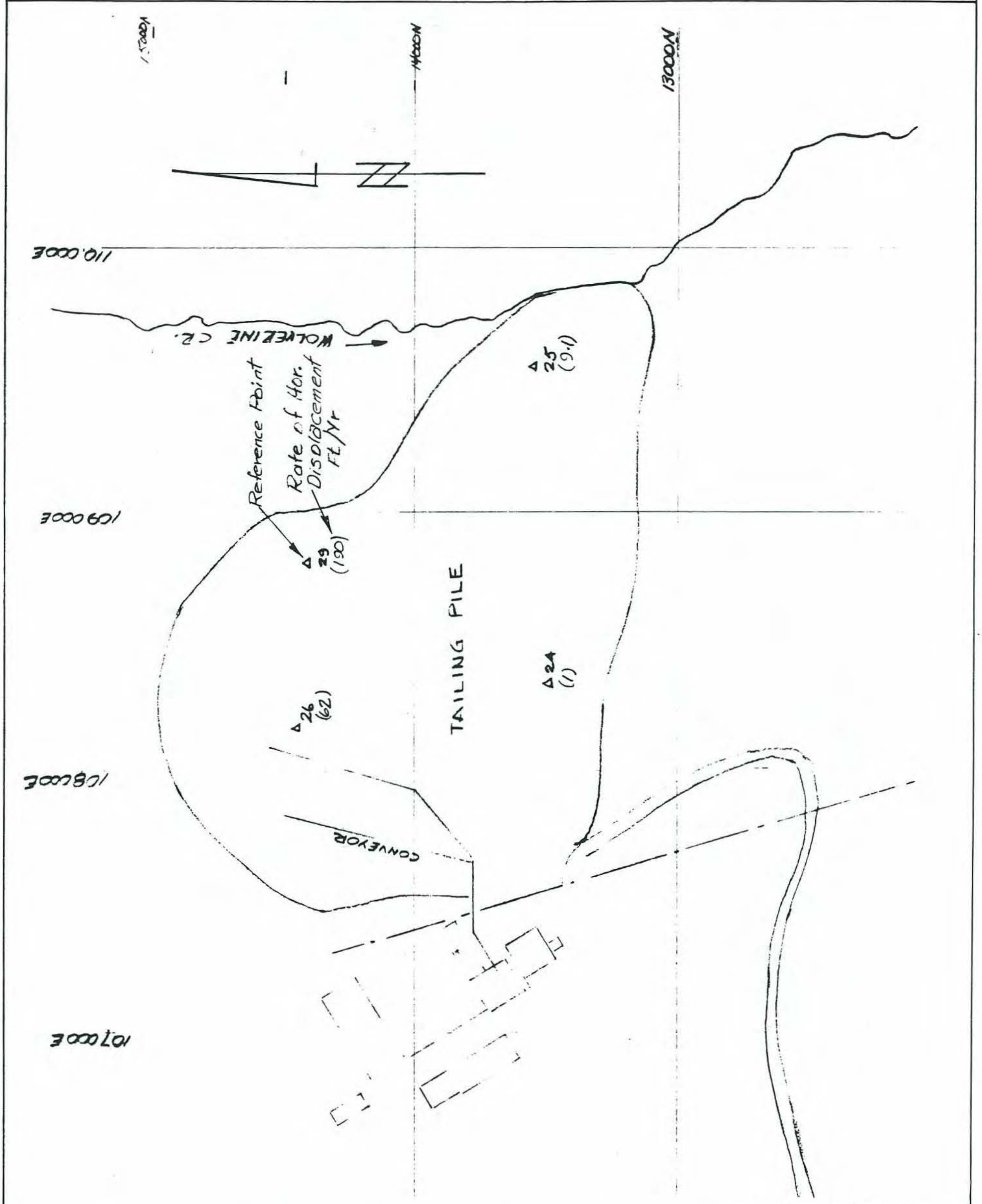
SCHEMATIC CROSS SECTION
SHOWING ROCK GROYNE
TO CONTROL DOWNCUTTING OF CHANNEL

(Not to Scale)

Project No. ______ Drawn ______ Reviewed ______ Date ______

HORIZONTAL SURFACE MOVEMENTS
TAILING PILE

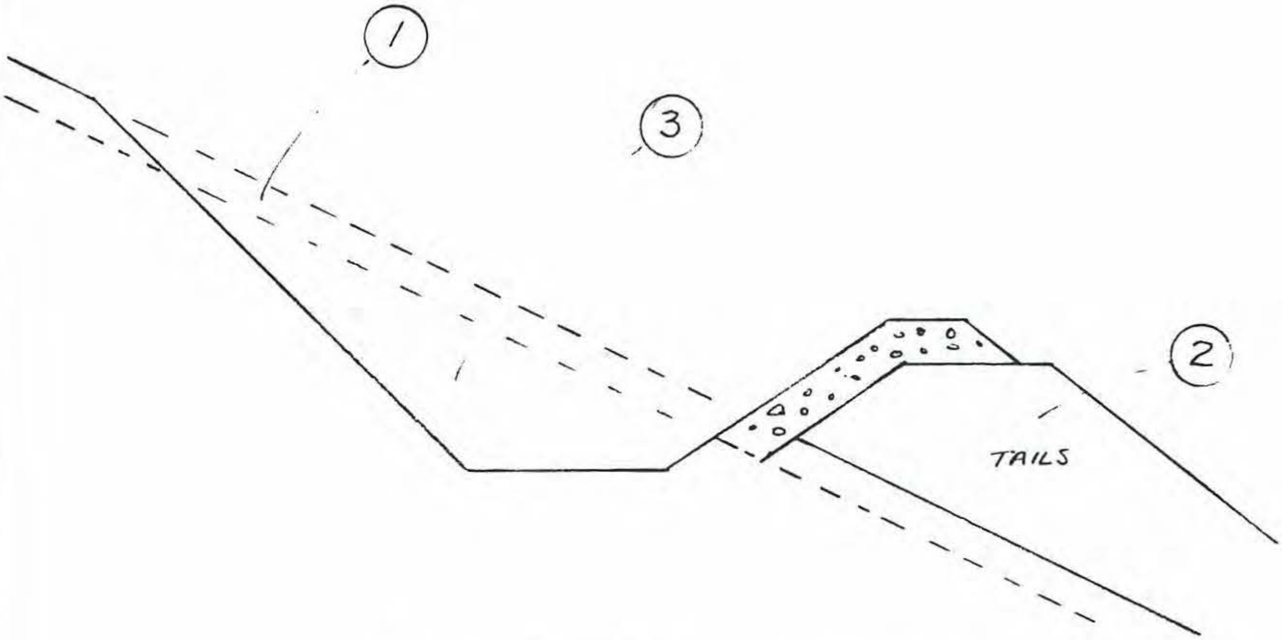
Figure 3



Scale 1" to 50'

WOLVERINE CREEK
PROPOSED SIDEHILL CHANNEL

Figure 4



1. Strip Soil to Expose upper surface of bedrock

2. Place Tails to form supporting berm on downhill side of ditch

3. Excavate channel into bedrock. Place excavated rock over tails to keep stream flows out of contact with tails

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