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Golder Associates
CONSULTING GEOTECHNICAL ENGINEERS

REPORT TO
CASSIAR ASBESTOS CORPORATION LTD.
RE
MINE WASTE DUMP AND TAILING PILE
CLINTON CREEK OPERATIONS

CLINTON CREEK   YUKON TERRITORY

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1.0 INTRODUCTION

Since 1968 Cassiar Asbestos Corporation Ltd. have operated an asbestos mine and a mill at Clinton Creek in the Yukon Territory. The economically recoverable asbestos ore reserves at the Clinton Creek operations are now exhausted and the operators are preparing to cease mining and milling operations. As part of the mine closure, Cassiar Asbestos propose to carry out certain improvements so that the site will be left in a condition acceptable to the Yukon Territory Water Board, the government regulatory agency responsible for environmental control of land use in the Yukon.

Cassiar Asbestos Corporation Ltd. have requested Golder Associates to provide geotechnical assistance on matters relating to the Clinton overburden waste dump, and to the tailing pile. This report presents the results of geotechnical investigations that have been carried out at the site, interpretations regarding the nature and mechanisms of earth movements that have been occurring at the waste dump and the tailing pile over the past several years, and a description of possible earth work construction to ameliorate potential erosion problems associated with the earth movements.

2.0 SUMMARY

2.1 Clinton Dump

The Clinton waste dump has crept across the valley bottom of Clinton Creek, and now forms a dam which impounds Hudgeon Lake. The present discharge channel from Hudgeon Lake is located at the northern perimeter of the dump where the surface of the dump contacts the natural hillside of the north valley wall. Over most of its length, the present channel is incised into in situ material, including bedrock. As a result, the invert of the channel is below original ground surface.

The foundation area of the dump prior to its development was underlain by permafrost. The permafrost beneath the dump is degrading and, as a result, high pore water pressures have developed within the foundation soils beneath the base of the dump. These high pore water pressures reduce the shearing resistance of the foundation soils and permit the dump to creep as a result of base sliding.

Considering its ability to serve as a dam, the waste dump has a generously large factor of safety. Nevertheless, within the region of the northern boundary of the dump, creep movements are currently developing at an average of approximately 3.6 ft. per year. Since the channel remains open it must be concluded that, on an annual basis, stream erosion removes a 3.6 ft. wide slice of dump material from the right hand side of the channel. The Yukon Territory Water Board has expressed concern regarding water quality degradation and sedimentation in the drainage course attendant with erosion of material from the right hand side of the channel.

To arrest the problem of erosion, installation of a coarse rock, erosion-resistant channel lining and energy dissipating weirs would be required. However, unless the creep movements within the northern limit of the dump are first stopped, the right side of the channel lining would become displaced toward the centerline, thereby destroying the design cross-section of the rock-lined channel. Therefore, before a permanent channel lining is installed, the movements within the toe region of the dump should be stopped. The only practicable means of stopping the dump movements at the present time is placement of stabilizing fill along the northern perimeter of the dump. To achieve a factor of safety of 1.25 would require raising the lake to elevation 1370, 25 ft. above its present level, in order to accommodate placement of approximately 450,000 cu. yds. of stabilizing fill. The estimated cost for placement of the stabilizing fill, placement of rock to form an erosion-resistant channel lining, and ancillary works is estimated to be approximately $590,000.

Waste rock materials were last consigned to the Clinton dump in the summer of 1977. Disposal of waste rock at the Clinton dump is now complete, and 1978 represents the first year since the inception of its development that waste rock has not been consigned to the dumps. The survey data for reference points 19 to 23 inclusive, on the surface of the Clinton dump, show that since the fall of 1977 the rates of horizontal displacement have decreased by 50 per cent or more. This trend of decreasing rate of movement is expected to continue in future. In lieu of placement of the stabilizing fill to stop the movements, we suggest that observations be continued to indicate the rate at which the movements develop in future. This data may show that within the space of a few years the rate of horizontal movement adjacent to the channel has decreased to an acceptably slow rate.

In the meantime, we suggest that a 150 ft. long section of rock-lined channel be constructed commencing approximately 275 ft. downstream from the downstream end of the existing culverts. This segment of rock-lined channel would be designed to remain stable in the event of a 100-year flood occurrence, and would serve to preserve the channel grade and thereby preclude the possibility of rapid lowering of the level of Hudgeon Lake, and the danger of attendant flooding downstream. The remainder of the channel section would receive a modest application of rock fill to protect the invert of the channel against further lowering, and to guard against further undercutting of in situ rock and soil along the left side of the channel.

2.2 Tailing Pile

The principal concern with respect to the mill tailing pile is the transport by water of asbestos fibre and other fine-grained materials from the pile in those areas where the tails encroach, or may encroach upon Wolverine Creek, and the subsequent deposition of these sediments in the drainage courses of Wolverine and Clinton Creeks and thence in the Forty Mile and Yukon Rivers.

Field observations have shown that:-

a) The 1974 failure lobe at the south end of the pile continues to move slowly downslope, tending to result in lateral constriction of that segment of Wolverine Creek which extends from the upstream to the downstream limits of the toe of the failure lobe, resulting in erosion of tails and downstream sedimentation.

b) The lobe to the north of the 1974 failure is moving downslope at a current rate of approximately 77 ft. per year. If this rate were to continue, tails in this segment of the pile would reach Wolverine Creek in approximately 4-1/2 years.

Stability analyses, using data gathered in the field and laboratory, have shown that trimming of some portions of the 1974 failure lobe upslope from its toe, together with appropriate grading and lining of the Wolverine Creek channel where it bypasses the toe of the slope, will increase the factor of safety to a sufficient degree to stop further downslope movements. Construction of a rock-lined channel and weir system downstream of the failure lobe to conduct Wolverine Creek in a competent channel, and return it to its natural course will also be required. The cost of this work is estimated to be approximately $57,000.00.

Stability analyses carried out on the north lobe of the tailing pile indicate that removal of material from the surface of this segment of the pile will enhance its factor of safety with respect to downslope movement. The removal of approximately 20 ft. of tails from the surface of the more rapidly moving portion of the pile will increase its factor of safety from 1.0 to approximately 1.3. The cost of this work is estimated to be approximately $75,000.00.

A second environmental concern related to the tailing pile is the problem of wind-blown (fugitive) dust from the surface of the pile. The majority of fugitive dust has originated in the course of the belt conveyor transport of tails from the mill, and deposition on the tailing pile. When milling operations cease, this source will be eliminated. The materials at the surface of the tailing pile have formed an erosionresistant crust as a result of slight cementing of the particles. Except in those areas where active movements of the pile result in exposure of fresh material, no dust is raised by wind. When measures to stop the downslope movements of the pile are completed, no further exposure of loose fines on the surface of the pile will occur. It is our opinion that fugitive dust originating from the surface of the tailing pile is not a problem, and that placement of a waste rock cover on the surface of the pile is not required. Such a cover would have only aesthetic value.

3.0 PHYSICAL ENVIRONMENT

The Cassiar Asbestos Corporation Ltd. Clinton Creek operations are located within the triangle bounded by the Yukon-Alaska boundary, the Forty Mile River, and the Yukon River, at latitude 64° 30' N, longditude 141° 45' W, approximately. Local relief at the site is approximatley 800 ft., varying between elevation 1200 and 2000 ft., approximately.

Although the area was unglaciated during the last (Wisconsin) glacial period, the site is located within an area of wide-spread permafrost distribution. The maximum thickness of permafrost is of the order of 200 ft.

Based on records maintained by Cassiar Asbestos during the period 1965 to present, the mean annual temperature at the site is approximately -2.5 degrees C. Average maximum and minimum temperatures vary from +15 degrees C during the month of July, to -32 degrees C during the month of January.

The six-year period of records, 1972 to 1977 inclusive, indicate an average annual precipitation of 14.1 inches per year (360 mm/yr). During this period, the driest year was 1973 when measured total precipitation was approximatley 260 mm. The wettest year was 1975 when total precipitation was 430 mm.

An anemometer was installed at the site in early 1976. The records for the two-year period 1976 and 1977 indicate that the average annual wind speed is approximately 5 miles per hour (8 kmh). The maximum recorded wind speed is 20 mph (32 kmh).

4.0 CLINTON WASTE DUMP

4.1 Brief History

The Clinton waste dump comprises waste rock overburden consisting predominantly of argillite removed in the course of open pit mining operations at the Porcupine Pit. Development of the Clinton waste dump commenced approximately 1970. Overburden materials were excavated from the Porcupine Pit, loaded into trucks, and hauled to the Clinton dump. Development of the dump commenced by end-dumping of materials near the crest of the north-facing slope that forms the valley wall on the south side of Clinton Creek. Shortly after development of the Clinton dump commenced, a segment of the face of the dump began to slump, and the toe of the dump began to spread northward onto the flat valley floor of Clinton Creek. These creep movements of the dump materials continued to develop with continued consignment of overburden material to the dump, with the result that the waste rock overburden advanced northward across the valley bottom, resulting in blockage of the drainage course of Clinton Creek. The Clinton waste dump now constitutes a dam which impounds the water of Hudgeon Lake. The surface elevation of Hudgeon Lake is approximately 1345 ft., the surface area is approximately 180 acres, and the maximum water depth is approximatley 85 ft. The drainage outlet from the lake is via an open channel located along the junction of the northern limit of the waste dump and sloping surface of the north valley wall on the left hand side (left with respect to the viewer facing in the downstream direction) of the Clinton Creek valley.

4.2 Statement of Problem

The Clinton dump continues to experience creep movements. The movements on the surface of the dump have components northward in a direction transverse to the Clinton channel, as well as westward toward Hudgeon Lake.

Prior to development of the Clinton dump, the grade of the natural channel of Clinton Creek was approximately 0.075 per cent within the area now occupied by the dump. The present average grade of the Clinton channel between the upstream and downstream limits of the dump is approximately 5 per cent. Owing to the presence of Hudgeon Lake, peak instantaneous flows in the Clinton Creek channel are reduced somewhat compared to the conditions that existed prior to development of the dump, because the lake has the effect of reducing peaks, and smoothing the stream discharge curve. However, owing to the significant increase in the channel grade, a given discharge flows at higher velocity, and therefore has increased erosion capability.

Subsequent to the advance of the dump across the valley floor and impoundment of the stream flows, Clinton Creek channel has become incised in both waste dump material and in situ bedrock along the contact between the northern limit of the dump and the hillside that formed the north valley wall of Clinton Creek. The waste dump material contains scattered fragments of hard, durable rock which have accumulated within the channel bottom, and provide resistance to erosion of the bottom of the channel during normal flow conditions (e.g. Photo 5, Appendix A).

While downcutting of the channel does not appear to be a particularly serious problem, the Yukon Territory Water Board have expressed concern about stream siltation as a result of erosion of the right hand bank of the channel which keeps pace with creep movements of the dump in a direction transverse to the channel. That is, as the creep movements occur and tend to decrease the width of the channel, side channel erosion maintains the channel width. Clinton Creek discharges into the Forty Mile River at the townsite, and the Forty Mile in turn discharges into the Yukon River. Photograph No. 6 of Appendix A shows the point at which the Forty Mile River discharges into the Yukon.

4.3 Field Investigations

Instrumentation installed at the Clinton dump includes reference points for determining horizontal and vertical movements on the surface of the dump, thermistor installations to permit measurement of subsurface ground temperatures, and piezometers.

4.3.1 Surface Movements

Eight reference points have been established on the surface of the dump to permit measurement of horizontal and vertical movements using an EDM survey instrument. In addition, five cross-channel reference lines have been established to permit measurement of the apparent rate of lateral closure of the channel. The locations of these reference points are shown on Figure 2. Reference points 19 to 23 inclusive were established in November 1976, and reference points 66 to 69 inclusive were established in April 1978.

The azimuth of the horizontal movement vectors and rates of horizontal movement in units of feet per year at each of the reference points is indicated by the arrows marked on Figure 3. The data indicate that, in general, surface movements are occurring in directions radially outward from the central region of the dump. Movements toward Hudgeon Lake are also occurring as evidenced by the pressure ridge that developed on the ice surface parallel to the elevation 1345 contour on the western face of the dump during the winter of 1977-78 (see photo No. 1 of Appendix A). In general, the rates of horizontal movement are greater near the perimeter of the dump than they are within the central regions of the dump. Also, the rates of horizontal movement decrease proceeding in the downstream direction.

As indicated on Figure 3, reference points 66, 67, and 69 are located between the northern limit of the dump and the position of the toe of the north valley wall prior to dump development. Thus, the original ground surface beneath the position of these movement gauges slopes upward toward the north. The data for these reference points show that upward vertical movements are occurring currently with development of the horizontal movements. At reference point 66 and 69, the movement vectors are inclined upward toward the north at approximately 12 degrees, which is approximately parallel to the slope of the original ground surface at these locations. The indicated inclination of the surface movement vector at reference point 67 is approximately 6 degrees. This reference point is influenced by localized shear movements within the dump materials adjacent to the right hand side of the Clinton channel. As a result, the indicated rate of horizontal movement is considered to be somewhat greater, and the indicated inclination of the movement vector is somewhat less than the true dump movements that are occurring at this location.

In May 1978, five reference lines were established transverse to the Clinton channel between coordinate lines 108000 E and 107250E, approximately. The locations of these cross-channel reference lines are indicated on Figure 2. The northern end of each of these reference lines is located on the surface of the natural hillside beyond the northern side of the Clinton channel. The southern end of each of the reference lines is located on the surface of the dump near the northern edge of the main access roadway. The purpose of these cross-channel reference lines is to provide an indication of the rate of horizontal movement of the dump adjacent to the channel, which is an indication of the rate at which the dump movements tend to constrict the channel. The rates of horizontal movement, as based on records which extend over a period of approximately 2 weeks, are indicated on Figure 3. The data indicate that over this segment of the channel the dump movements tend to constrict the channel at an average rate of 3.6 ft. per year. As is the case for movement reference points 66, 67, and 69, the data for cross-channel reference lines AA to DD inclusive, show that the horizontal movements of the dump on the right hand side of the channel are accompanied by upward vertical displacements.

Although the horizontal movement data for reference points adjacent to the channel indicate that the dump movements tend to constrict the channel at rates varying from 3.5 and 4 ft. per year, field observations show that Clinton Creek is capable of maintaining the width of its channel, and that the invert of the channel has not increased in elevation as a result of the vertical component of the movement vectors within the toe region of the dump. It must, therefore, be concluded that on an average, a 3.5 to 4 ft. wide slice of dump material is lost from the right hand side of the channel on an annual basis. Most of this material is lost as a result of erosion during spring run-off. Over most of the remainder of the summer (Clinton Creek ceases to flow in the winter) the channel flows remain clear, and there is no visible evidence of reduction in water quality as a result of increase in suspended solids between the outlet from the lake and the downstream end of the channel.

4.3.2 Thermistors

Thermistors were installed at four locations within the boundaries of the Clinton dump to permit measurement of subsurface ground temperatures, and to determine whether permafrost is aggrading or degrading within the base of the dump. Each thermistor installation consists of a set of nine individual thermistors spaced at 5 ft. intervals, as shown on the schematic drawing included in Appendix D. Thus, at each thermistor installation, ground temperatures can be measured over a 40 ft. interval of depth.

The locations of the thermistor installations at the Clinton dump were selected to satisfy the following requirements:-

i. The waste dump at the location of the installation should have been in place for a minimum period of 4 to 5 years to provide sufficient time for changes to occur in the thermal conditions at the base of the dump.

ii. The thickness of the dump should be less than 80 ft. to permit drilling of the thermistor holes, using Cassiar's 40R drill.

iii. At each location, permafrost was to have been extant prior to commencement of dump development.

The subsurface temperatures, as determined by the thermistor readings, are summarized on the data sheets included in Appendix D. The data show that at thermistor installations T1 and T2, ground temperatures at the base of the dump are below 0 degrees C, indicating that at these locations permafrost has aggraded into the base of the dump.

At location T3, the data indicate that ground temperatures are above 0 degrees C to a depth of 30 ft. below original ground surface. At the location of T3, the original ground surface formed part of a north aspect slope that examination of aerial photographs shows to have been underlain by extensive permafrost prior to development of the dump. Thus, at the location of T3 the permafrost has apparently degraded to a depth of approximately 30 ft. below original ground surface.

Thermistor installation T4 is located near the northern edge of the dump, approximately coincident with the position of the toe of the north valley wall prior to dump development. During the installation at this location, the hole caved before the lower end of the cable had been lowered to the bottom of the hole. As a result, the thermistor installation at T4 does not extend into the in situ native materials beneath the base of the dump. The subsurface temperature fluctuations recorded at this location (see Appendix D) suggest that the thermistor is probably registering the temperature of the seepage water within the base region of the dump. As indicated on the data sheet for T4, the temperatures are within the range +1 to +2 degrees C below a depth of 35 ft. below surface. The temperature profile suggests that the phreatic surface at this location is at approximately elevation 1300 ft. This is approximately 10 ft. above the invert of the adjacent Clinton channel. Assuming that the temperatures below elevation 1300 ft. as recorded at thermistor installation, are indicative of the temperature of the seepage water within the base of the dump, it may be concluded that the seepage waters are applying heat to the original ground surface at the base of the dump, and that the permafrost within this region is degrading.

4.3.3 Piezometer Installations

Five Casagrande-type piezometers were installed along the south side of the main roadway that traverses the northern limit of the dump. Their locations are shown on Figure 2. The piezometers were placed in drilled holes, and sealed with bentonite. After placement of the bentonite seals, the segment of each hole within the dump material above the seal was permitted to collapse around the piezometer casing. None of the piezometers have functioned properly, and these installations have yielded negligible useful data.

4.4 Mechanism of Movement

The pattern of cracking on the surface of the Clinton dump, as well as the dump movement survey data, indicate that the dump movements are the result of horizontal spreading on its base. The results of direct shear tests on a representative sample of the 1/4 inch minus fraction of argillite comprising the Clinton dump are included in Appendix B. The test results indicate that the material has an angle of internal friction which varies from slightly greater than 40 degrees for the effective normal stress range 0 to 25 psi, to 33.5 degrees at an effective normal stress of 200 psi. The face of the Clinton dump, near the point where the tramline crosses the Clinton channel, has a maximum height of approximately 125 ft., and this face stands at an angle of slightly greater than 40 degrees. Since the angle of repose for cohesionless material is numerically equal to the angle of internal friction for that material under low stress, the angle of repose as observed in the field, and the angle of internal friction as determined by the laboratory tests, are in agreement.

The geometry of the Clinton dump, together with the angle of internal friction of the dump material, preclude the possibility that the horizontal movements of the dump are occurring as a result of shearing within the dump materials. The dump is sliding on its base as a result of shear displacements within the in situ native foundation soils beneath the base of the dump.

The in situ foundation soils beneath the flat valley bottom of Clinton Creek prior to development of the dump were beyond the reach of the drilling equipment available at site at the time that the 1978 subsurface investigations at the dump were underway. For this reason, samples of the native foundation soils within the region of the original flat valley bottom beneath the Clinton dump have not been sampled. However, discussions with personnel who were engaged in construction activities on the valley bottom during the initial stages of development of the Clinton dump, together with observations within the valley bottom downstream of the dump, indicate that the foundation soils were ice-rich. For example, at locations on the valley bottom downstream of the Clinton dump, where surface vegetation has been disturbed by the tracks of a bulldozer, this disturbance has resulted in development of water-filled thermo-karst depressions. These features are indicative of the presence of ice-rich permafrost soils at shallow depth below surface.

Prior to development of the dump, the site experienced approximately 3240 degrees C days of frost annually. The foundation area of the dump is now covered by waste rock up to 240 ft. in thickness. The dump now serves as an effective insulator which isolates the foundation from the ambient temperatures. More important, ground water seepage from Hudgeon Lake toward the eastern limit of the dump provides a continuous source of heat at the base of the dump. As a result, the permafrost beneath the dump is melting. As thawing occurs, water is changed from the solid to the liquid phase and, under the weight of the dump, this results in the generation of high pore water pressures within the foundation soils. Stability analyses of the present conditions indicate that the pore water pressures in the foundation soils are between 70 and 90 per cent of the pressures at the base of the dump due to the weight of the dump materials. These pore water pressures reduce the shearing resistance of the foundation soils beneath the base of the dump and, as a result, the Clinton dump is subject to horizontal spreading on its base. These spreading movements were responsible for development of a pressure ridge on the ice surface of Hudgeon Lake during the winter of 1977-78 (see Photo 1 of Appendix A), and they are also responsible for development of the cracks on the surface of the dump as illustrated on Photos 2 and 3. The mechanism of crack development, the orientation of the cracks, and the implied stress conditions within the dump are discussed in Appendix E.

4.5 Treatment of the Clinton Dump

4.5.1 Consequences of No Treatment

The horizontal movement vectors on the surface of the dump, shown on Figure 3, indicate that the northern perimeter of the dump is advancing toward the Clinton channel at rates varying between 3.5 and 4 ft. per year. The plots of horizontal displacement versus time for reference points 19 to 23 inclusive, see Appendix C, show that the rate of movement has decreased by greater than 50 per cent since the autumn of 1977. Materials were last consigned to the dump during the summer of 1977, and no further consignment of materials to the dump will take place. Under these circumstances, we expect that the rates of horizontal movement will continue to decrease in future.

Although the dump movements tend to result in lateral confinement of the Clinton channel, removal of dump material from the right side of the channel by stream erosion has maintained the channel cross-section. A major portion of the dump materials consist of fragments of a size that can be eroded by the stream. However, the dump also contains scattered large fragments which the stream is not capable of moving. Thus, if nothing were done to the Clinton channel, the bottom of the channel would eventually become paved with large boulders that would accumulate on the channel bottom through the process of advancement of the toe region of the dump into the channel cross-section, and removal of the finer fraction of the material by erosion.

4.5.2 Transverse Groynes

The Yukon Territory Water Board have expressed concern regarding the problem of suspended solids in Clinton Creek as a result of continued erosion of the dump, as well as concern about the possibility of continued downcutting of the channel, and headward erosion of the channel bottom which might eventually result in rapid lowering of the level of Hudgeon Lake, leading to flooding downstream.

In an interim report to Cassiar Asbestos Corporation Ltd., dated April 1978, we suggested that rock groynes constructed transverse to the channel, and extending approximately 200 ft. south of the channel, would be effective in maintaining the invert elevation of the channel at each of the groynes. This would preclude the possibility of rapid lowering of Hudgeon Lake and attendant flooding downstream. For rock groynes extending 200 ft. south of the channel, and considering a current rate of movement of 3.5 to 4 ft. per year at the edge of the channel, the rock groynes would continue to maintain the channel grade for a period of 50 to 60 years. If the current trend of reducing rate of horizontal displacement continues in future, the 200 ft. long groynes would provide protection for a period much greater than 50 to 60 years. Periodic field observations over the next few years would indicate whether or not the groynes should be extended in order to provide for permanent grade protection.

4.5.3 The Cadillac Treatment

4.5.3.1 General Requirements

Following submission of the interim report dated April 27, 1978, in which the rock groyne proposal was presented, the Yukon Territory Water Board expressed concern regarding the potential for erosion of dump materials from the right hand side of the channel between adjacent groynes, and the attendant problem of water quality degradation as a result of an increase in suspended solids. It is apparent that the problem of suspended solids would apply to that segment of the drainage course between the downstream limit of the Clinton dump, and the mouth of the Yukon River during spring run-off only. Inspection of photograph 6, Appendix A, suggests that a relatively small additional contribution of suspended solids to the Yukon River during spring run-off should not be considered as a serious problem.

If erosion during spring run-off within the Clinton channel must be completely stopped, installation of an erosion-resistant channel lining extending to the downstream limit of the dump will be required. If erosion within the Clinton channel is arrested, the movements of the dump must first be stopped, otherwise continued dump movements would result in lateral shifting of the right hand side of the channel toward the north, as well as in upward vertical displacement of the channel invert. The lining materials would eventually be displaced upward and to the left hand side of the channel, and the stream would again proceed to erode and to remove dump material.

The only practicable means of stopping the movements within the region within the northern limit of the dump, adjacent to the existing

Clinton channel, is to increase the resistance to movement by placement of additional fill. Since movement of the dump is occurring at the present time, it follows that the factor of safety of the dump with respect to sliding on its base is 1.0. That is, the sum of the forces tending to produce base sliding are just balanced by the forces that resist base sliding. The resistance to base sliding is governed primarily by the pore water pressures that are generated as thawing takes place within the foundation soils. As concluded by Morgenstern and Nixon, 1971, the distribution of excess pore water pressure, and the degree of consolidation within the foundation soils, are independent of time. Thus, the excess pore water pressures which govern the resistance to shearing at the base of the dump cannot be expected to decrease to any significant degree within the near future. Thus, at least for the next few years, the shearing resistance at the base of the dump can be expected to remain essentially the same as it is at present.

Stability analyses indicate that if the existing Clinton channel were backfilled, and a channel provided at a higher elevation, but on the same alignment as the existing channel, the factor of safety of the dump with respect to base sliding would be increased to approximately 1.1.

4.5.3.2 Design Discharge - Clinton Channel

In 1974, Sigma Resource Consultants Ltd. undertook a study of the hydroelectric power potential of the Yukon Territory. As part of that study, an investigation was made of the maximum recorded rates of discharge for drainage systems in the Yukon. The study considered drainages east and north of the Yukon main stem, and drainages west of the Yukon, including the main stem of the Yukon and Teslin Rivers. Clinton Creek falls within this latter classification.

The upper limit of the data points for drainages west of the Yukon, including the main stem, can be expressed by the equation:-

$$Q = 10^{(0.927 \text{ Log } A + 1.15)}$$

where:

Q = the maximum recorded discharge in cubic feet per second

A = the area of the drainage basin in square miles.

The drainage area of Clinton Creek above the Cassiar Asbestos operations is 106.2 sq. km or 41 sq. miles. Applying the above equation, Q for Clinton Creek is 442 cfs. In their report, Sigma Resource Consultants suggest that the maximum discharge in any of the drainages could be twice the maximum discharge on record. Thus, the maximum discharge in the Clinton channel could be as high as approximately 880 cfs. According to analyses carried out by the Whitehorse office of the Canada Department of Indian Affairs and Northern Development, the 50-year peak discharge for Clinton Creek is calculated to be 882 cfs, and the 100-year peak discharge is calculated to be 968 cfs. Thus, the predicted maximum discharge using the data contained in the Sigma report, and the predicted peak discharge rates provided by DIAND are in close agreement.

4.5.3.3 Channel Lining

If erosion of dump material and of the in situ bedrock as exposed on the left hand side of the existing Clinton channel is to be prevented in future, the channel must be lined with material that will remain stable during anticipated peak discharges. The channel cross-section and lining materials required are essentially the same, whether the design is based on the predicted 50-year peak discharge, or on the predicted 100-year peak discharge.

Rock rip-rap is the only practicable material available for construction of the channel lining. Rock rip-rap is capable of adjusting to minor movements that may occur following completion of construction of the improved channel. Rigid or semi-rigid control structures or energy dissipators are considered unsuitable because of their inability to adjust to the earth movements that may occur subsequent to their installation.

To accommodate the maximum anticipated discharge, a permanent 'fail-safe' channel lining would require approximately 21,000 cu. yds. of rip-rap, at an estimated cost of between $50,000 and $75,000. The rock would be placed in a manner which would form a series of energy dissipating weirs. Details of the rock lining and weirs are included on Figure 5. As noted above, filling of the existing Clinton Creek channel, and provision of a new channel above the existing channel, will increase the factor of safety to approximately 1.1. We are of the opinion that this low factor of safety does not justify the capital expenditure of $50,000 to $75,000 for the channel lining. For a capital expenditure of this magnitude, the factor of safety with respect to base sliding of the dump should be not less than 1.25.

4.5.3.4 Toe Fill to Stop Lateral Movements

To provide a factor of safety of 1.25 with respect to base sliding of the dump toward the Clinton channel, placement of approximately 460,000 cu. yds. of fill would be required along the northern boundary of the dump. This would necessitate raising the level of Hudgeon Lake to elevation 1370, 25 ft. above its present level.

The fill that would be required to increase the factor of safety with respect to dump movement toward the channel to 1.25 is illustrated on Figure 4. Extending for a distance of approximately 540 ft. downstream from the existing culverts, fill would not be placed, with the result that the elevation 1370 contour would form the perimeter of a wide forebay extending to the upstream end of the new channel. A segment of the new channel would extend approximately level for a distance of 500 ft., to the upstream end of the rip-rap section. The rip-rap section would form a series of energy dissipating weirs at an average channel grade of 8 per cent. Each weir would provide for a 2 ft. net drop in head, and the weirs would be spaced at 25 ft. on center. Details of the rock weirs are illustrated on Figure 5.

4.5.3.5 Timing and Sequence of Construction

Stream discharge records for Clinton Creek are available only for the year 1977 and part of 1978. The 1977 records show that the average discharge during the 3-month summer period (July, August, and September 1977) was approximately 14 cfs. For purposes of planning and scheduling, it would be prudent to assume that during any particular year, the average discharge during the summer period (July, August, and September) could be as high as 21 cfs. In order to carry out the construction work, discharge from the lake must be controlled. It would therefore be necessary to construct a cofferdam to a height sufficient to provide for impoundment of the Clinton Creek flows during the construction period. Based on an average stream discharge of 21 cfs, and a lake surface area of 180 acres, the lake could rise 21 ft., i.e. to elevation 1366 during the 3-month summer period. Placement of 460,000 cu. yds. of common fill in 60 working days, would require placement at an average rate of between 7000 and 8000 cu. yds. of fill per day.

We expect that the rock could be placed into the winter season. However, all of the 460,000 cu. yds. of common fill would have to be in place before freeze-up.

The overall sequence of construction would be approximately as follows:-

1. Construct a cofferdam to elevation 1372, approximately, immediately upstream of the existing culverts.

2. Place mill overs to form a pervious granular drain on the invert of the existing channel.

3. Place common fill (approximately 460,000 cu. yds. of waste dump material) to form the stabilizing toe fill. Shape the new Clinton channel to receive mill overs.

4. Place a 1 ft. thick layer of mill overs (approximately 4600 cu. yds. of material).

5. Place rock rip-rap to form rock weirs (approximately 21,000 cu. yds. of material).

6. Remove, replace, and backfill the four 60-inch diameter metal culverts to provide access over the new channel.

7. Breech the cofferdam.

4.5.4 Suggested Treatment

Horizontal movement data for reference points 66 to 69, and for the cross-channel reference lines AA to EE inclusive, have been in operation for a period which is too short to permit a meaningful assessment of the trend in the rates of horizontal movement at these locations. The data included in Appendix C for reference points 19 to 23 inclusive, show the average rates of movement over various intervals of time since the autumn of 1977. These data indicate that the rates of horizontal movement at reference points 19 to 23 inclusive, have decreased by 50 per cent or more over the last 9 months. We expect that this trend of decreasing rate of horizontal movement will continue in future.

Over virtually all of its length, the invert of the existing Clinton channel is below original ground surface, and over a considerable portion of its length the invert of the channel is located on in situ bedrock. Typical examples of the position of the existing channel in relation to the original ground surface are shown on Figure 4. With continued creep movements of the dump toward the north, the invert of the channel is not subject to lateral upward displacements. The dump movements result in advancement toward the channel centerline of the upper portion of the right hand bank, with the result that dump materials are fed into the channel by ravelling of the upper right bank.

The "Cadillac" treatment outlined in the foregoing section would be a very expensive undertaking, and would result in a degree of erosion protection which is incompatible with that provided by nature. In the event of an occurrence of a 50-year or 100-year flood, significant erosion could be expected to take place within natural undisturbed areas located beyond the perimeter of the dump. Thus, provision of a new channel complete with rock lining to provide complete security against erosion in the event of the 50-year or 100-year flood appears to be an unnecessarily severe requirement. However, security should be provided to preclude the possibility of rapid downcutting of the channel which could result in lowering of the level of Hudgeon Lake.

We suggest that the existing culverts should be left in place at their present location. Commencing at a point approximately 275 ft. downstream of the downstream end of the culverts, a 150 ft. long rock-lined channel section should be constructed. This section would consist of a series of five rock weirs with a net drop of 2 ft. of head across each weir. In longitudinal section, the weirs would be as illustrated on Figure 5. To accomodate the lateral crowding of the right hand side of the channel that may take place over the next few years as a result of continued dump movements, the weirs should have a crest width of 50 ft. This series of five weirs would be capable of remaining stable in the event of a 100-year flood occurrence. Thus, this rock-lined segment of the channel will preclude possible downcutting of the channel, and will therefore provide protection against rapid lowering of the level of Hudgeon Lake.

Over the remainder of the Clinton channel, we suggest that a modest application of rock rip-rap be applied to provide protection against downcutting of the channel invert, and undermining of the left hand bank.

Periodic measurements should be continued in future on the movement reference points that have been established. These data may show that horizontal displacements within the toe region of the dump have reduced to an acceptably slow rate. If the records show that the rate of movement in future does not decrease progressively, then further protective measures can be undertaken at that time.

4.6 The Function of Clinton Dump as a Dam

The Clinton waste dump, which has blocked the natural drainage course of Clinton Creek and resulted in impoundment of Hudgeon Lake, now serves as a dam which must remain secure in future.

We have carried out analyses to check the stability of the dump under the influence of the forces imposed by the self-weight of the dump materials, and the forces imposed by the hydrostatic pressures due to the impounded waters of Hudgeon Lake. Using conservative shear strength parameters, and values for the foundation pore water pressures as determined by back analyses, the indicated factor of safety of the dump with respect to gross movement in the downstream direction, is approximately 4.3.

The horizontal distance between the upstream and downstream limit of the Clinton dump is approximately 3000 ft. The water impounded in Hudgeon Lake has a maximum depth of 85 ft., and the topographic slope on the original valley bottom drops approximately 40 ft. between the western and eastern limits of the dump. Thus, the total head loss between the upstream and downstream limits of the dump is approximately 125 ft.

Empirical observations indicate that piping does not occur even in fine sands and silts, provided the creep ratio is equal to or greater than about 18 (reference page 305 Terzaghi and Peck, 1948). The maximum head loss between the upstream and downstream limits of the Clinton waste dump is approximately 125 ft., and the horizontal distance over which this head is dissipated is approximately 3000 ft. Thus, the creep ratio for the overburden dump is approximately 24, approximately 1-1/3 times greater than the value above which empirical observations show that piping does not occur. Under these circumstances, we conclude that there is no danger of failure of the waste dump dam by piping.

In our opinion, the Clinton waste dump will continue to serve as a dam for impoundment of the water in Hudgeon Lake. In spite of the creep movements that the dump is experiencing, as a dam, it exhibits a high degree of stability.

4.7 Estimated Costs

Following is a summary of the estimated quantities of materials, mine prices, and costs for the various schemes and items of work related to treatment of the Clinton Dump.

4.7.1 Transverse Groynes

The scheme for placement of rock groynes transverse to the channel is described in Section 4.5.2.

Placement of quarry-run rock to form 15 groynes 30 ft. wide, and extending 200 ft. south of the existing channel, each containing 1420 cu. yds. of material = 21,300 yd^3 of material.

21,300 yd^3 @ \$1.70/yd^3 = \$36,210.00 say \$40,000

4.7.2 The Cadillac Treatment (Ref. Section 4.5.3)

a)	Place common waste dump fill 460,000 cu. yds. @ \$1.00	\$460,000
b)	Place 4600 cu. yds. of mill overs @ \$1.00	\$ 4,600
c)	Rock rip-rap for channel lining and weirs 21,000 cu. yds. @ \$2.75	\$ 57,750
d)	Construct cofferdam 10,000 cu. yds. @ \$1.00	\$ 10,000
e)	Relocate culverts	\$ 4,000
f)	Contingencies 10% of sum of total	\$ 53,650
	TOTAL	\$590,000

4.7.3 Suggested Treatment (Ref. Section 4.5.4)

a)	Coarse rock rip-rap for 150 ft. long lined channel complete with weirs 2500 cu. yds. @ \$2.75	\$ 6,875
b)	Mill overs at base of rip-rap lined channel section 800 cu. yds. @ \$1.00/yd.	\$ 800
c)	Quarry run rock downstream of rip-rap contact section 10,000 cu. yds. @ \$2.00	\$ 20,000
d)	Contingencies 8.4% of sum of total	\$ 2,325
	TOTAL	\$ 30,000

5.0 TAILING PILE

5.1 Brief History

The separation of asbestos fibre at the Clinton Creek operation is a dry process. Tails are transported from the mill by belt conveyor and have been deposited in the form of a large pile located to the east and the northeast of the mill on the west slope of the Wolverine Creek valley. A photograph of the tailing pile is included as Photo 7 in Appendix A.

In 1974, a segment of the tailing pile, near its southern extremity, moved downslope and blocked Wolverine Creek. This failure occurred at the location of a small draw in the hillside on the west side of Wolverine Creek. According to aerial photographs of the area taken during 1970, the surficial earth materials in this draw were wetter than those in the surrounding area. It is probable that as the tailing pile advanced onto these materials, the shear stresses induced in them by the loads applied by the tails exceeded the available shear resistance, and failure occurred. No confirmed observations are available with regard to the length of time it took the tails to reach Wolverine Creek. Hence, it is not possible to define the type of failure in terms of velocity of movement.

Water from the Wolverine Creek drainage basin ponded upstream of the dam formed by the failure lobe of the tailing pile. The impounded water overtopped the failure lobe in July 1974 and the resulting flows eroded a large quantity of tails in a short period of time, downcutting a channel through the tails to approximately its present level and position. Serious flooding of Clinton Creek, to which Wolverine Creek is tributary, occurred at this time. In the process, substantial amounts of tails were deposited in the Wolverine Creek and Clinton Creek drainage courses.

Shortly after the failure of the southern segment of the tailing pile, the belt conveyor system was shifted and the disposal of tails continued to the north of the failed mass. No further sudden or catastrophic failures have occurred in the tailing disposal area since 1974. However, slow downslope movement in the failed mass continues to occur.

As the new disposal area north of the 1974 failure was developed and the pile expanded, downslope movement in this area also began to take place. No sudden or catastrophic failures have occurred in this segment of the tailing pile, but its continuous movement has extended the toe of this portion of the pile to within 350 ft. of Wolverine Creek as of mid-June 1978.

Disposal of tails from the mill is now being carried out in the northwest section of the disposal area and the pile is being extended in a northerly direction. The terrain in this area is much flatter than that over which previous disposal operations were carried out. No perceptible mass movements of the pile in this area have been noted.

5.2 Statement of Problem

The principal concern with respect to the mill tailing pile is the transport by water of asbestos fibre and other fine-grained materials from the pile in those areas where the tails encroach, or may encroach, upon Wolverine Creek, and the subsequent deposition of these sediments in the drainage courses of Wolverine and Clinton Creeks and thence the Forty Mile and Yukon Rivers.

In the case of the 1974 failure lobe, the tails are already in contact with Wolverine Creek. The lake created by the failure lobe has a maximum depth of approximately 25 ft. and the change in head between the lake and the downstream end of the failure lobe, a distance of approximately 750 ft., is approximately 45 ft., or an average gradient of 6.0 per cent. The tongue of the failure lobe continues to move eastward tending to close the channel cut through it by the stream. The rate of closure of the channel was approximately 4 ft. per year as of mid- June 1978. This rate appears to be slowing with time. Undercutting and erosion of the tails takes place as a result of both this continued movement and the high velocities attained by the stream as it travels past the failure lobe.

In order to deal with the basic problem of the downstream transport of tails from the failure lobe, it will first be necessary to halt the movement of the tailing pile in this region. If this is accomplished, then a permanent channel can be constructed in such a way that Wolverine Creek can be conducted past the failure lobe in a controlled manner. The problems of the water transport of asbestos fibre, erosion, and downstream sedimentation will then be eliminated.

The potential environmental problems associated with the more rapidly moving segment of the tailing pile to the north of the 1974 failure are basically the same as for the failure lobe. Contact of this portion of the tailing pile with the water in Wolverine Creek would lead to downstream transport of sediment, including asbestos fibre. If the tails from this source were to reach a higher elevation in the valley than that at

Wolverine Creek of the upstream end of the 1974 failure lobe, rapid erosion of the tails, and possibly downstream flooding, could occur.

As of June 1978, the rate of downslope movement of the faster moving segment of the pile was approximately 77 ft. per year. At this rate the tails will not reach the water line in the lake formed by the 1974 failure lobe before 1983. This rate of movement is significantly less than the 160 ft. per year average measured in 1977. Moreover, the rate now appears to be slowing continuously with time.

In order to prevent contact of tails in this region of the tailing pile with Wolverine Creek, measures to stop or significantly impede the downslope movement of the tailing pile will be required.

A further concern with respect to the tailing pile is the potential for wind transport of asbestos fibre from the surface of the pile. By far the most significant portion of fines susceptible to wind transport is from the belt conveyors as the tails are being transported from the mill to the disposal areas. When milling ceases, this source will no longer be of concern. The texture of the exposed tails on the pile is coarser than the material below the surface since most of the fines have already been removed by wind or cemented to form a crust on the surface of the pile. It is only in those areas of the pile which are moving at significant rates, and hence exposing fresh material, or in those areas where new tails are being deposited, that fines are susceptible to wind transport. The problems associated with wind-blown fibre will be accommodated when milling operations cease and by the measures to be recommended for stopping the movements in the tailing pile. No continuing or long term environmental problems with regard to fugitive dust are forseen.

5.3 Field Investigation

5.3.1 Site Observations

A number of on-site inspections of the tailing pile at the Clinton Creek mine have been carried out by Golder Associates personnel since May 1976. The principal observation concerning the 1974 failure lobe made during these inspections is the fact that this portion of the pile is continuing to move and to encroach upon the channel cut through it by Wolverine Creek in July 1974. Photograph 8 shows the effects of this continuing movement in terms of undercutting and erosion of the tails in the channel as well as erosion of the argillite bedrock along the toe of the east valley wall of Wolverine Creek. The crack patterns noted on the tongue of the failure lobe, and shown in Photos 9 and 10, indicate that the tails are also spreading toward the lake formed by the damming of the creek.

Observations on the lobe to the north of the 1974 failure have also indicated that movements in this area of the tailing pile continue to occur. The principal features in this area, noted during the field inspections, are concerned with the mechanisms of the movements as related to the behaviour of the foundation soils. As shown in Photos 11, 12 and 13 substantial amounts of the surficial foundation soils have been displaced and bulldozed ahead of the tailing pile as it has continued to move downslope. This phenomenon is believed to be related to both the soil type and permafrost conditions in the surficial deposits that mantle the slope in this area, and is discussed in detail in Section 5.5 of this report.

The region at the northwest extremity of the disposal area, in which mill tails have been disposed of most recently, is on relatively flat ground. No mass movement or creep of the pile in this region has been noted. However, small localized failures as a result of oversteepening of the pile as it is developed may occur. A photograph of this portion of the pile is included as Photo 14 principally to illustrate the segregation of the coarse fraction of the tails as they roll down the face of the pile forming a highly pervious layer at the bottom of the pile.

5.3.2 Drilling Program

A drilling program was carried out in May 1978 to identify the subsoils in the vicinity of the tailing pile, to recover samples for testing in the laboratory, and to install thermistors in the tailing pile and foundation soils in order to assess the ground temperature regimes in various parts of the tailing disposal area. A total of eight boreholes were made and thermistor cables were installed in four of them. The locations of these boreholes are shown on Figure 6 and their logs are included in Appendix F.

Briefly, the principal soil types encountered beneath the tailing pile and/or beneath the surface organic layer were a fluvial-lacustrine deposit of silty sandy gravel, overlying weathered argillite which, in turn, overlies unweathered argillite bedrock. In general, the fluvial-lacustrine deposit becomes thinner with decreasing elevation down the west valley wall of the Wolverine Creek valley, varying in thickness from greater than 40 ft. near the top of the slope to being virtually absent on the bottom portions of the slope.

5.3.3 Thermistor Installations

Thermistor cables were installed at three locations in the tailing pile and at one location in undisturbed ground about 200 ft. beyond the perimeter of the pile. Each cable included nine thermistors at 5 ft. intervals. The locations of these installations are shown on Figure 6 and records of the data collected from them are included in Appendix D.

Thermistor T-5 is located in the southwest corner of the tailing pile where the tails have been in place for an estimated 4 to 5 years. The data show that both the tails and the foundation soils, to a depth of at least 20 ft. beneath the tails, are unfrozen at this location.

Thermistor T-6 is in undisturbed ground near the northwest corner of the disposal area. The ground at this location is frozen from the surface downward, except during the summer months when thaw in the surface active layer occurs. The lowest temperature recorded at this location is at a depth of 15 ft. below the ground surface where measurements indicate a value of approximately -1.6 degrees C. The ground temperatures increase from this point downward to values in the order of -1 degrees C at depths of 35 and 40 ft.

Thermistor T-7 was placed in the tailing pile upslope of the moving north lobe of the pile. It is estimated that the tails have been in place at this location for between 1 and 2 years. The data indicate that both the tails and the foundation soils at this location are frozen with the coldest temperatures near the tailing/foundation soil interface. The temperatures of the foundation soil appear to increase with depth at this location to a value of 0.0 degrees C at a vertical distance of 25 ft. beneath the tails.

Thermistor T-8 was installed in the 1974 failure lobe at a location estimated to be close to the centerline of the draw in which the failure occurred. The temperature data gathered from this installation show that the tails and the foundation soils to a depth of between 5 and 10 ft. beneath the tails are unfrozen. Below this depth, for a further 10 to 15 ft., the data indicate temperatures of -0.1 degrees C.

5.3.4 Movement Observations

Survey monitors to determine the horizontal and vertical displacements on the surface of the tailing pile were installed in late 1976. Additional monitors were installed during the spring of 1978 to provide additional information with regard to these movements. Two lines of monitors were installed. One of these, located close to grid line 113500 N, is approximately along the centerline of the 1974 failure. The second, along grid line 114500 N, is close to the locus of the maximum rates of movement on the segment of the tailing pile to the north of the 1974 failure. The locations of all of the survey monitors on the tailing pile are shown on Figure 6.

a) <u>1974 Failure Lobe</u>

Survey monitors 24 and 25 were established on December 23, 1976. Plots of the magnitudes and rates of horizontal displacements of these points on the tailing pile are included in Appendix A. The recorded movements at the locations of monitors 24A, 24B, 24C and 25A havve been small and erratic, since their installation on March 30, 1978. Plots of their horizontal movements are shown on Figure C-8 in Appendix C.

Table 5.3.1 is a summary of the rates of horizontal movements at each of the monitors on the failure lobe. The data for monitors 24 and 25, established since December 23, 1976, indicate that the movements in this segment of the tailing pile are slowing with time.

The data in Table 5.3.1 also indicate that the movements in the failure lobe involve a downslope "stretching" of the materials in this segment of the pile except in the vicinity of monitor 25A. This reflects the fact that this monitor is located above the east slope of the Wolverine Creek valley and movements in this area can, therefore, only occur if the tails are pushed up the valley side. As a result of the forces required to move the tails upslope, some relative compression of the materials takes place in this area.

Table 5.3.2 summarizes the rates of vertical movements in the 1974 failure lobe. These rates reflect four components of vertical displacement. These are: vertical displacements corresponding to the horizontal movements of the tailing pile; displacements as a result of spreading and consequent thinning of the tails; displacements caused by thawing of, and subsequent consolidation of, the foundation soils beneath the tails; and displacement due to consolidation of the tails under self weight. The measurements of vertical displacement at the locations of monitors 24 and 25, which have been in place since December 23, 1976, indicate that their rates are decreasing with time.

b) North Lobe of Tailing Pile

Survey monitor 26 was established December 23, 1976 and monitor 29 was established June 10, 1977. Monitors 26A, 26B, and 29A were installed on March 30, 1978. Plots of the rates and magnitudes of the horizontal displacements at these locations are included in Appendix C.

Table 5.3.3 is a summary of the rates of horizontal movement for various time-spans for each of the survey monitors on this segment of the tailing pile. The data for monitors 26 and 29 indicate a substantial slowing down of their rates of movement with time. The records included in Appendix C also show this deceleration and the continuance with which it is occurring. The data for the more recently installed monitors provide the same indication.

The data in Table 5.3.3 for all of the monitors indicate that, in general, the tailing pile along the grid line on which the monitors have been placed is tending to "stretch". (The data relating monitors 26 and 26A are somewhat misleading in this regard insofar as the movement vector at the location of monitor 26 has a dominant component toward the north, whereas the dominant direction of movement for all of the other monitors on this grid line is toward the east, as shown in Figure 3. The net downslope movements for the monitors in this area definitely indicate "stretching" of the tailing pile). If the present rate of movement were to continue, the toe of the tailing pile would reach Wolverine Creek in approximately 4-1/2 years.

Table 5.3.4 provides a summary of the rates of vertical movements on the north lobe of the tailing pile. The same comments made in paragraph a) above, with regard to the components of changes in the vertical locations of the monitors on the 1974 failure lobe apply to this segment of the tailing pile. Also, it can be seen from Table 5.3.4 that the rates of vertical movement are tending to decrease with time in this region.

5.4 Laboratory Investigation

The laboratory investigation consisted of natural moisture content, unit weight and specific gravity determinations, grain size analyses, and direct shear tests on selected samples of the tails and foundation soils recovered during the field investigation.

The moisture content of the fluvial-lacustrine material sampled at the location of Borehole No. 13, which was made in undisturbed ground away from the tailing pile, varied between 28.2 and 40.6 per cent. The moisture contents of the same materials recovered from the boreholes made in the tailing pile were all within the range of 13.5 to 19.5 per cent. The difference in the moisture contents of this material between areas which have been subjected to the loads of the tailing pile, and those which have not, provides a clear indication of the effects of thaw consolidation of the foundation materials.

The natural moisture contents in the weathered argillite sampled at the location of Borehole No. 15 near the toe of the north lobe of the tailing pile varied between 5.2 and 11.4 per cent.

The specific gravity determinations indicated values of 2.64 for the fluvial-lacustrine soils and 2.72 for the weather argillite. The saturated unit weights of the fluvial-lacustrine materials varied between 112 pcf in the undisturbed ground away from the tailing pile to 138 pcf for the same class of material in areas surcharged with the tails. The unit weight of the weathered argillite varied between 145 and 156 pcf.

The results of the grain size analyses are included in Appendix B. The analyses of the fluvial-lacustrine soil were done on samples with the greater than 3/8 inch diameter particles removed. The material is classified as a silty sandy gravel and is frost-susceptible. The weathered argillite on which a grain size analyses were done indicates a particle size distribution equivalent to a sandy gravel of relatively high permeability.

Direct shear tests were carried out on samples of the mill tails, the fluvial-lacustrine gravels and the weathered argillite bedrock recovered during the field investigation. The results of these tests are included in Appendix B and are summarized in Table 5.4.1.

The direct shear tests were all performed on unfrozen samples and each sample was allowed to consolidate and drain, or, conversely to absorb water, under each increment of normal load before any shear stress was applied to it. (An exception was the sample of mill tails which was tested at its original moisture content.)

The test results are somewhat misleading in terms of the indicated shear strengths of the fluvial-lacustrine materials relative to those of the weathered argillite. The tests indicate that under drained conditions the shear strength parameters for the fluvial-lacustrine soils are slightly greater than those for the weathered argillite. However, as discussed in Section 5.5 of this report, the operative conditions leading to failure in the foundation soils under the tailing pile can involve undrained conditions. This will be reflected in a build-up of greater excess pore water pressures in the fluvial-lacustrine soils than in the weathered argillite due to the higher natural moisture content and lower permeabilities of the fluvial-lacustrine soils in their undisturbed state. Under similar conditions of temperature and loading, these larger excess pore water pressures will lead to significantly lower effective shear strengths in the fluvial-lacustrine soils than in the weathered argillite.

5.5 Mechanisms of Movement

5.5.1 Introduction

The observations made and the data collected from the site inspections and the field and laboratory investigations have provided insight into the mechanisms of failure which have been operative in the tailing disposal area. These mechanisms are discussed in the following paragraphs for the two segments of the tailing pile which are of concern.

5.5.2 1974 Failure Lobe

Only sparse information is available on the failure which occurred at the southern extremity of the tailing pile in 1974. However, it is possible to reconstruct the probable sequence of events which led to the failure.

The slope over which the tails were being placed prior to the 1974 failure was, in general, frozen. The vegetation on the slope, shown on aerial photographs taken in 1970, as well as field observations, confirm this point. The thickness of the active layer on the slope is not known with certainty but, judging by the vegetation, it is unlikely that it would normally be in excess of 2 to 3 ft. A localized exception to these observations was probably extant in the draw on the slope into which tails at the southern extremity of the disposal area were being placed prior to the failure. The 1970 aerial photographs show that the surficial soils in the draw were wetter than those on the remainder of the slope. It is therefore probable that the active layer in this localized area extended to a greater depth than elsewhere on the hillside. The dominant soil type on the upper portion of the slope is a fluvial-lacustrine deposit of silty sandy gravel and it is likely that this material was also the principal surficial deposit in the draw. This material was noted during the field investigation to be frost-susceptible with as much as 40 per cent, by volume, of ice in the form of lenses. ?

According to mine personnel, the tails at the southern extremity of the pile moved downslope in the draw on a continuous basis from soon after disposal began in this area until the failure occurred in 1974. No information is available regarding the configuration of the tailing pile immediately prior to the failure. However, the quantity of the material in the failure lobe at present suggests that even prior to the failure the toe of the pile must have extended a substantial distance downslope in the draw.

The mechanism of failure for this segment of the tailing pile probably involved the build-up of excess pore pressures within the active layer of the foundation soils beneath the tails in the draw to the point of incipient failure throughout the period of the continuous slow downslope movement of the pile before the 1974 failure. When the toe of the pile reached the break in grade on the slope where more resistant foundation materials were encountered, it is possible that the movements slowed at the toe to a sufficient degree to allow increased loads from newly deposited tails to accumulate upslope. This would induce still higher pore water pressures in the foundation soils in the draw which would, in turn, lead to an overall failure of the mass of tails in that segment of the pile.

Since the failure, the tails in the failure lobe have continued to creep downslope and to encroach on the Wolverine Creek channel. There is also spreading of the tails at the tongue of the failure in a direction toward the lake formed by the damming effect of the tails. The spreading of tails into the lake is probably due to thawing of the original soils in the bottom of the valley caused by the year-round presence of water at above- freezing temperatures in the lake. The continued downslope movement of the tails along the length of the failure lobe is slow and becoming slower with time. The movements themselves are likely related to the thaw-consolidation process taking place in the permafrost beneath the tails as observed at the thermistor installation in this segment of the pile, as well as to the continuous removal of support from the toe of the failure by erosion in the Wolverine Creek channel. The slowing down of these movements suggests that temperature equilibrium between the tails and the foundation soils is approaching, and that the excess pore pressures induced as a result of the thaw-consolidation process are dissipating with time.

5.5.3 North Lobe of Tailing Pile

Following the failure of the southern portion of the tailing pile in 1974, disposal of tails was shifted northwards. As this new area was developed and the pile extended, the tails in this area began slowly to move downslope. In this instance, no localized weak areas, such as the draw in which the 1974 failure occurred, exist. The segment of the pile that is moving, is doing so on a front of the order of 1000 ft. wide which is much greater the width that of the 1974 failure which is estimated to have had a maximum frontal width of approximately 400 ft.

The mechanism of this failure is related to thaw-consolidation phenomena in the permafrost foundation soils. In general, each year thawing takes place to some depth in the soils on the slope. As the thaw front advances, excess pore water pressures build-up in this active layer due to the presence of excess water and the self weight of the soil. Expulsion of this excess water and the consequent dissipation of excess pore pressures takes place at a rate which depends upon the permeability of the soil, the depth of thaw and the loads applied to the thawing soil. When freeze-back begins, it commences at the ground surface and proceeds downward, forming an upper impermeable barrier to further exit of water from the unfrozen saturated soil sandwiched between this frozen surface layer and the underlying permafrost. Depending upon the relative severities of seasons, or changes in surface conditions, such as the presence of a layer of tails, freeze-back may or may not reach the bottom of the unfrozen soil stratum each year. Clearly, if loads in addition to the self weight of the soil, such as those of the tailing pile, are applied when a layer of saturated unfrozen soil is sandwiched between frozen and, therefore, relatively impermeable soil strata, excess pore water pressures will be induced and will result in a significant reduction in the shear strength of the soil. In the case of the north lobe of the tailing pile, it is believed that these phenomena have led to its downslope movement.

The presence of a weak layer of soil confined at some depth below the ground surface would also allow the bulldozing of slabs and masses of earth ahead of the pile as it moved downslope. Photographs 11, 12 and 13 show this phenomenon at the toe of the north lobe of the tailing pile.

The rate of downslope movement of the pile is related to the magnitude of the loads applied to the foundation soils by the tailing pile and the pore water pressures induced by these loads. The pore water pressures are, in turn, related to the moisture contents and permeabilities of the soils in the foundation of the tailing pile. As noted in Section 5.3, the rates of movements of this segment of the tailing pile are slowing with time. It is probable that this slowing of the rate of movement is due to two factors. First, a reduction in the normal loads applied to the foundation soils because of the thinning of this portion of the pile as it continues to move downslope, to spread laterally on its base, and to cover a progressively larger area; and second, the thickness of the frost-susceptible fluvial-lacustrine foundation soils beneath the tailing pile diminishes in the downslope direction causing a reduction in the potential for high pore water pressures. (At several locations checked at the toe of the north lobe of the tailing pile the fluvial-lacustrine stratum was either absent or only a few inches thick. The foundation material in this region, and downslope from the toe of the pile, is predominantly weathered argillite which has a higher permeability and lower ice contact. The weathered argillite is therefore less susceptible to build-ups of excess pore water pressures).

5.6 Analyses

5.6.1 Introduction

Stability analyses of both the 1974 failure lobe and the lobe to the north of the failure have been carried out. The analyses show that trimming of some portions of the lobe upslope of the toe of the failure lobe, together with appropriate treatment of the Wolverine Creek channel, as it bypasses the toe of the slope, will increase the factor of safety to a sufficient degree to stop further downslope movements in this area. The analyses carried out on the north lobe of the tailing pile indicate that removal of materials from the surface of the pile in that area will bring the downslope movements to a halt.

5.6.2 1974 Failure Lobe

A section through the 1974 failure lobe is shown on Figure 7. This section was analyzed using the indicated geometry, together with the strength parameters and unit weights determined for the tails and foundation soils at the site. It was assumed that in its present condition the failure lobe has a factor of safety against failure of 1.0. The analysis provided a pore pressure distribution along the tails/foundation interface for these conditions, i.e. for the condition of incipient failure. Various altered geometries for the surface of the failure lobe were then assessed, using the calculated pore water pressure, which was appropriately adjusted in each case for the effects of the new geometries. A tabulation of the factors of safety for several possible slope configurations, which would lead to improved stability of the failure lobe is given on Figure 7. The analyses lead to the conclusion that trimming of the "knob" upslope from the toe of the failure lobe, as shown on Figures 6 and 7, together with appropriate grading and lining of the Wolverine Creek channel at the toe of the lobe, will provide an adequate safety against further downslope movement of the failure lobe. The factor of safety against downslope movement attendent with this solution is 1.20. Details of the measures required to effect this solution are given in Section 5.7 and 5.8 of this report.

5.6.3 North Lobe of Tailing Pile

Figure 8 shows a section through the north lobe of the tailing pile which is moving downslope. This section has been analyzed using the indicated geometry, together with the soil properties determined for the tails and the foundation soils at the site. A factor of safety of 1.0 against downslope movement was assumed for the tailing pile in its present condition. The analyses yielded a pore pressure distribution along the bottom of the pile for this condition of incipient failure. This pore pressure was then used in analyses of the north lobe of the tailing pile to determine factors of safety against downslope movement for altered geometries of this segment of the pile. Figure 8 shows these geometries and the graphical relationship between factor of safety and geometry of the pile.

The analyses indicate that removal of material from the surface of the moving segment of the tailing pile enhances its stability. As shown on the graph in Figure 8, removal of approximately 20 ft. of tails from the surface of the pile in this area will increase the factor of safety against downslope movement from 1.0 to 1.3. Details of the measures required to effect this solution are given in Sections 5.7 and 5.8 of this report.

5.7 Recommended Treatment

5.7.1 1974 Failure Lobe

The analyses outlined in Section 5.6 with regard to the 1974 failure lobe indicate that the most economical and practicable solution to the problem of continuing movements in this region of the pile will involve the removal of some material from the surface of the pile upslope from its toe, grading and lining of the Clinton Creek channel where it bypasses the toe of the failure lobe, and construction of a channel and weir system downstream of the failure lobe to conduct Wolverine Creek in a competent channel to return it to its natural course.

The required work in the sequence in which it should be done is as follows:-

a) The knob between coordinate lines 109200 E and 109500 E on section 113500 N should be trimmed according to the contours shown on Figure 6 and the profile denoted as (4) on Figure 7. Survey monitors should be established on the recontoured slope between approximately coordinates 109200 E and 109700 E on gridline 113500 N and checked periodically to assess any slope movements which may occur.

b) The Wolverine Creek channel, where it bypasses the toe of the failure lobe, should be straightened and graded at 0.3 per cent from approximately elevation 1322 ft. at coordinate 113950 N - 109800 E to elevation 1320.2 ft. at coordinate 113350 N - 109880 E, a distance of approximately 600 ft., as shown on Figure 6. The channel must be suitably lined to prevent erosion of tails by the stream in this reach of the channel. The bottom of the existing channel should be filled with mill overs to provide an underdrain at the toe of the slope in those areas where the creek channel will be raised to meet the required gradient. The materials used for fill above the drain rock and below the bottom of the channel lining can consist of tails taken from the excavation required to widen and contour the channel sides. Figure 9 shows a typical section through the Wolverine Creek bypass channel. The dimensions, gradient and material size requirements are based on a flow of 358 cu. ft. per sec., which is the 100-year flow taken from the flood frequency analysis provided to Golder Associates by the Department of Indian Affairs and Northern Affairs.

c) From the downstream end of the bypass channel at coordinate 113350 N to 109880 E, the stream must be conducted in a rock-lined channel and weir system at an overall gradient of 8 per cent to meet the existing Wolverine Creek channel at approximately elevation 1257 ft. at coordinate 112650 N - 110080 E. This portion of the channel will be approximately 800 ft. long and will accomodate a decrease in head in the stream of approximately 63 ft. Continuation of the coarse tails underdrain in the bottom of the existing channel for the full length of this construction will be required. Materials needed to raise the ground surface to the required gradient above the drain rock can consist of tails taken from those areas of the tailing pile where excavation is required. Figure 10 shows a typical section through this portion of the channel, as well as a profile of the channel with details of the weir construction, channel gradients and material size requirements. The specifications for the channel were determined on the basis of the DIAND flood frequency analyses for Wolverine Creek.

d) It is recommended that this work be carried out during the months of August and September 1978, when stream flows can be expected to be low and problems contingent with construction in freezing temperatures can be avoided. In the event that flows in Wolverine Creek are too high to allow construction of the proposed system, a cofferdam to contain the run-off from this drainage basin during the construction period can be constructed at the upstream end of the failure lobe.

5.7.2 North Lobe of Tailing Pile

The analyses carried out on the north lobe of the tailing pile, shown on Figure 8, indicate that removal of material from the surface of the more rapidly moving segment of the pile will enhance its factor of safety against downslope movement. Therefore, it is recommended that approximately 20 ft. of material be removed from the surface of the pile, according to the limits and contours shown on Figure 6. The analyses indicate that the factor of safety against further downslope movement of the pile, if this work is performed, will be approximately 1.3.

The excavated material can be moved onto undisturbed ground to the north of this segment of the pile. The thickness of the excavated tails should not exceed 20 ft. in their new location.

It is recommended that this work be performed during the months of September and October 1978, when the thickness of the active layer in the undisturbed ground is at its maximum. Dissipation of excess pore water pressures within the foundation soils can then proceed throughout the winter months, since the insulating effect of the tails will prevent freeze-back in the active layer.

Survey monitors should be established on the recontoured surface of this segment of the tailing pile and checked periodically so that any movements that do occur can be assessed with regard to their significance.

5.7.3 Fugitive Dust from the Tailing Pile

The majority of wind-blown dust from the tailing disposal area originates from the belt conveyor as the tails are being transported from the mill to the tailing pile. When milling operations cease, this source of fugitive dust will be eliminated.

The materials at the surface of the tailing pile have formed a crust as a result of cementing of the particles and, except in those areas where active movements of the pile are occurring, and fresh materials being exposed, no dust is raised by wind. When measures to stop the downslope movements of the pile are completed, further exposure of loose fines on the surface of the pile will be precluded.

As a result of these considerations, it is our opinion that no specific measures regarding control of fugitive dust from the surface of the tailing pile are required.

5.8 Summary of Estimated Quantities and Costs

The following is a summary of the estimated material quantities and costs involved in the proposed work for stabilization and stream control in the tailing disposal area:-

a) 1974 Failure Lobe

i)	excavation of knob on failure lobe approximately 30,000 cu. yds. @ \$0.50/cu. yd.	\$15,000.00
ii)	coarse tails underdrain in Wolverine channel approximately 1500 cu. yds. @ \$1.70/cu. yd.	\$ 2,550.00
iii)	tails for general backfill to raise channel to required grade approximately 30,000 cu. yds. @ \$0.50/cu. yd.	\$15,000.00
iv)	coarse rock (30% greater than 3 inch diameter) for bypass channel lining approximately 4500 cu. yds. @ \$1.70/cu. yd.	\$ 7,650.00
v)	rock for channel lining and weirs downstream of failure lobe approximately 6500 cu. yds. @ \$2.50/cu. yd.	\$16,250.00
		\$56,450.00

b) North Lobe of Tailing Pile

i)	excavation and removal of tails from surface of pile approximately 150,000 cu. yds. @ \$0.50/cu. yd.	\$75,000

TOTAL ESTIMATED COST FOR STABILIZATION AND STREAM CONTROL IN TAILING DISPOSAL AREA	\$131,450.00

TABLE 5.3.1

Horizontal Movements on 1974 Failure Lobe of Tailing Pile

Monitor	Date Established	Rate of Horizontal Movement (ft./day) Overall Average to June 16/78	March 78 - June 78
24	December 23/76	0.0023	0.0011
24A	March 30/78	0.0012	0.0012
24B	March 30/78	0.0072	0.0072
24C	March 30/78	0.0100	0.0100
25	December 23/76	0.0205	0.0104 (0.020 May 78 - June 78)
25A	March 30/78	0.0049	0.0049

TABLE 5.3.2

Vertical Movements on 1974 Failure Lobe of Tailing Pile

Monitor	Date Established	Rate of Vertical Movement (ft./day) Overall Average	March 78 - June 78
24	December 23/76	0.0020	0.0015
24A	March 30/78	0.0044	0.0044
24B	March 30/78	0.0047	0.0047
24C	March 30/78	0.0053	0.0053
25	December 23/76	0.0071	0.0051
25A	March 30/78	0.0004	0.0004

TABLE 5.3.3

Horizontal Movements on North Lobe of Tailing Pile

Monitor	Date Established	Rate of Horizontal Movement (ft./day) Overall Average to June 16/78	March 30/78 to May 5/78	May 5/78 to June 16/78
26	December 23/76	0.159	0.030	0.016
26A	March 30/78	0.020	0.017	0.014
26B	March 30/78	0.207	0.242	0.177
29	June 10/77	0.389	0.274	0.207
29A	March 30/78	0.249	0.295	0.210

TABLE 5.3.4

Vertical Movements on North Lobe of Tailing Pile

Monitor	Date Established	Rate of Vertical Movement (ft./day) Overall Average	March 78 - June 78
26	December 23/76	0.141	0.022
26A	March 30/78	0.013	0.013
26B	March 30/78	0.119	0.119
29	June 10/77	0.164	0.098
29A	March 30/78	0.087	0.087

TABLE 5.4.1

Shear Summary of Laboratory Direct Shear Tests

LOCATION	DEPTH	SOIL TYPE	NATURAL MOISTURE CONTENT W (%)	MOISTURE CONTENT BEFORE TEST	MOISTURE CONTENT AFTER TEST	EFFECTIVE ANGLE OF INTERNAL FRICTION Ø'
		Mill Tailings	1.9	1.9	1.9	35° - 45°
BH 13 (T-6)	15' - 20'	Fluvial Lacustrine Gravel	40.6	21.8	18.2	29°
BH 13 (T-6)	32' - 34'	Fluvial Lacustrine Gravel	32.9			27.5°
BH 14 (T-7)	46' - 48'	Fluvial Lacustrine Gravel	19.5	16.3	11.8	32°
BH 16 (T-8)	66' - 68'	Fluvial Lacustrine Gravel	13.5	13.4	13.0	27.5° - 32.5°
BH 15 (ST-8)	6' - 9'	Weatherd Argillite	5.2	15.8	12.9	26°
BH 15 (ST-8)	20' - 21'	Weathered Argillite	11.4	13.6	13.0	27°

6.0 PORCUPINE DUMP

The location of the Porcupine dump is indicated on the reproduction of the aerial photograph, Figure 1. This dump was developed on the sloping surface of the west valley wall of the Porcupine Creek. As in the case of the Clinton dump, the Porcupine dump has experienced downslope displacements which have interrupted the drainage course of Porcupine Creek. The Porcupine catchment area is smaller than the catchment area of Clinton Creek, and only minor ponding of water on the upstream side of the dump has occurred.

A field examination has been made of the toe region of the Porcupine dump, along the line where its limit contacts the sloping surface of the east valley wall of Porcupine Creek. Some segments along this contact zone at the toe of the Porcupine dump consist of serpentine rock to a maximum size of approximately 5 ft. These rock fragments are durable, and are not subject to degradation in the manner which is characteristic of the argillite that constitutes the majority of the waste rock materials which the dump comprises. Other segments along the toe of the Porcupine dump consist of highly degraded argillite bedrock. At these locations, the creek flows on a surface within a channel formed by the toe of the dump and the right valley wall of Porcupine Creek. At the locations where the material within the toe region of the dump consists of coarse serpentine rock, the creek dissapears into the waste dump and flows beneath the surface.

Examination of the area where the Porcupine Creek flows exit the toe of the dump showed that the discharge water is clear. On the basis of our field examinations, we conclude that the Porcupine dump does not present any environmental problems relating to erosion or degradation of water quality.

Yours very truly

GOLDER GEOTECHNICAL CONSULTANTS LTD.

Per: David B. Campbell, P. Eng.

E.B. Fletcher, P. Eng.

DBC/EBF:rme

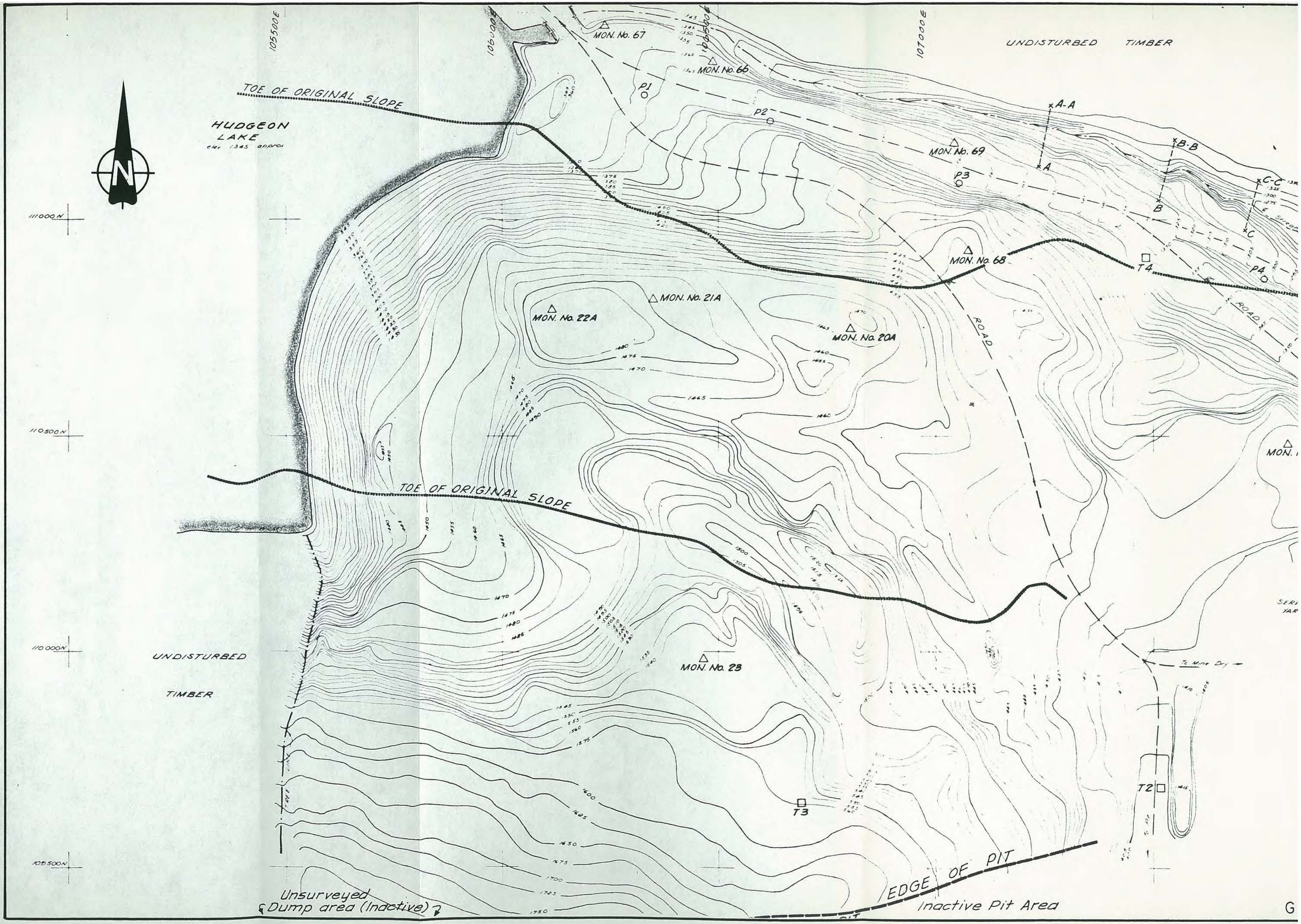
V77016

LIST OF REFERENCES

Morgenstern, N.R. and Nixon, F.J. - One Dimensional Consolidation of Thawing Soils, Canadian Geotechnical Journal, Volume 8, 1971.

Sigma Resource Consultants Ltd. - The Development of Power Potential in the Yukon, Addendum to, Hydrology, January 1975, Document prepared for the Northern Canada Power Commission.

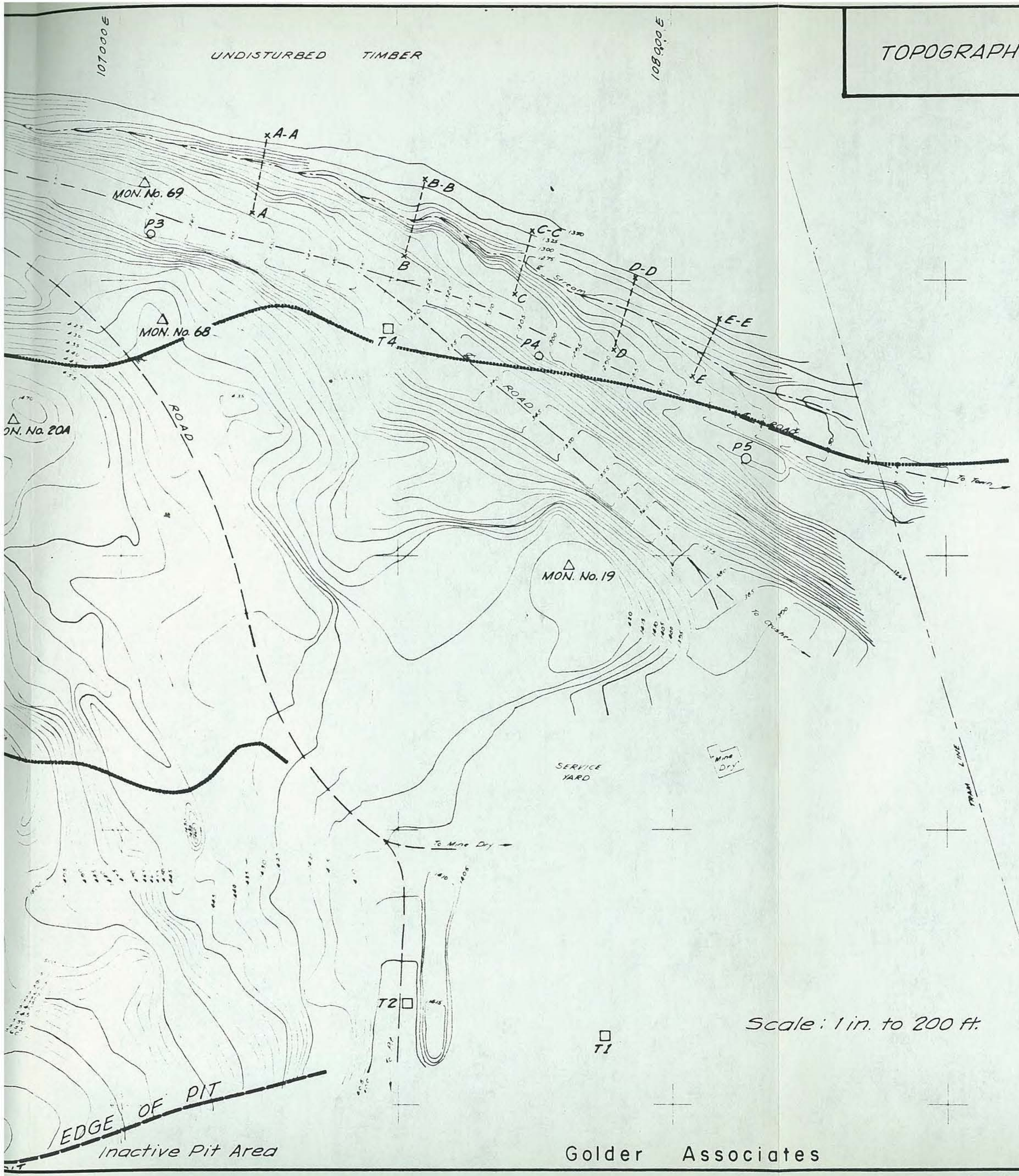
Terzaghi and Peck - Soil Mechanics and Engineering Practice, John Wylie and Sons, 1st Addition, 1948.



105500E
106000E
106500E
107000E
UNDISTURBED TIMBER
MON. No. 67
MON. No. 66
MON. No. 69
MON. No. 68
MON. No. 21A
MON. No. 22A
MON. No. 20A
MON. No. 23
P1
P2
P3
P4
T2
T3
T4
A-A
A
B-B
B
C-C
C
TOE OF ORIGINAL SLOPE
TOE OF ORIGINAL SLOPE
HUDGEON LAKE
elev 1345 approx
N
111000N
110500N
110000N
109500N
ROAD
ROAD
UNDISTURBED
TIMBER
To Mine Dry
EDGE OF PIT
Unsurveyed Dump area (Inactive)
Inactive Pit Area

TOPOGRAPHY - CLINTON DUMP

FIGURE 2



LEGEND:

- MON. No. 19 — Surface movement survey reference point.
- A-A / A — Cross-channel reference line.
- T2 — Thermister installation
- P4 — Piezometer.

REFERENCE:

Topo. plan of Inactive Waste Dump for Clinton Cr. Mine by Underhill Engineering Ltd.-Mar. 30, 1978. Coordinate grid from CASSIAR Asbestos Corp. Grid Origin.

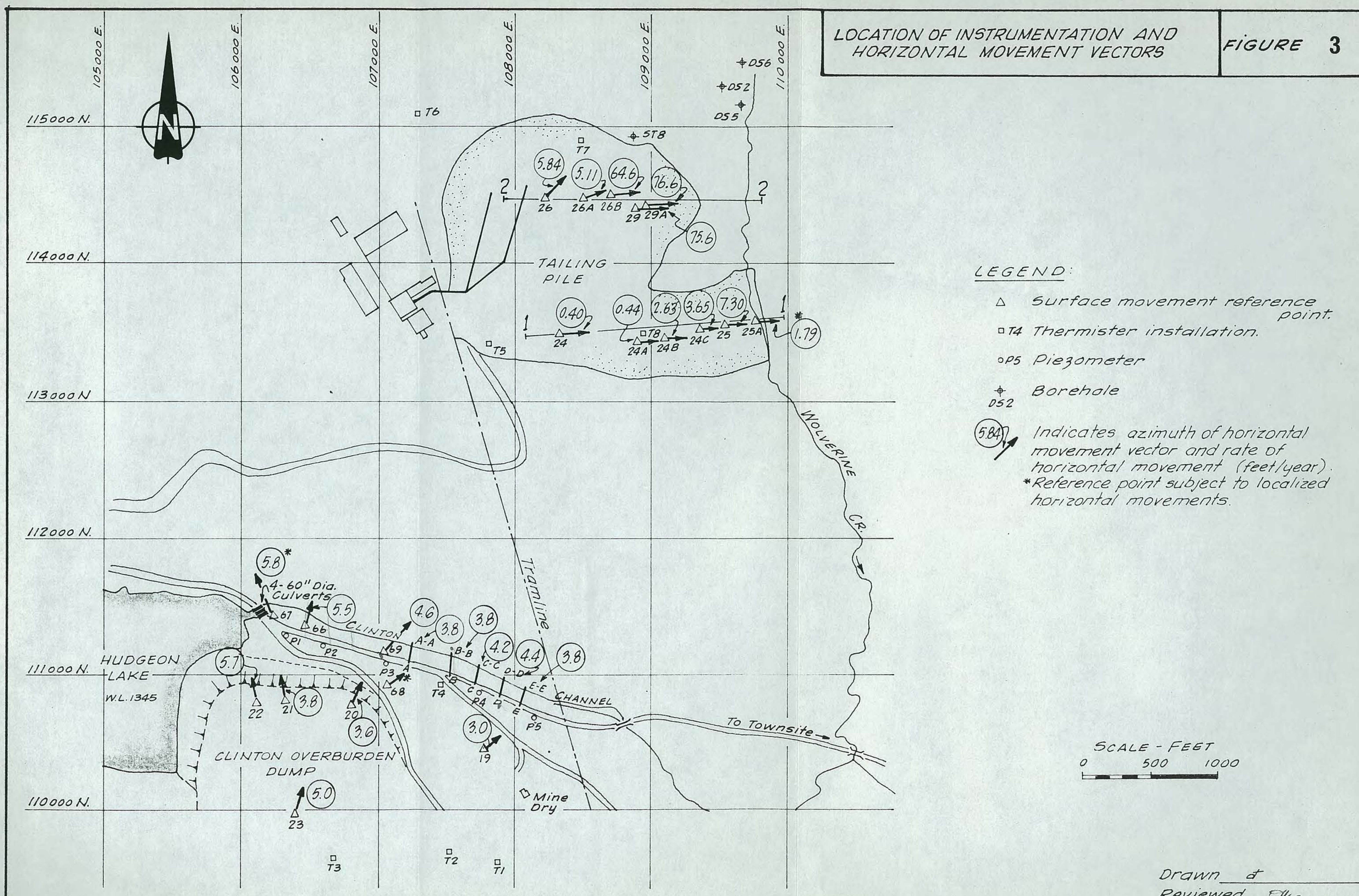
Scale: 1 in. to 200 ft.

Golder Associates

Drawn Ing.
Reviewed [signature]
Date June '78

LOCATION OF INSTRUMENTATION AND HORIZONTAL MOVEMENT VECTORS

FIGURE 3

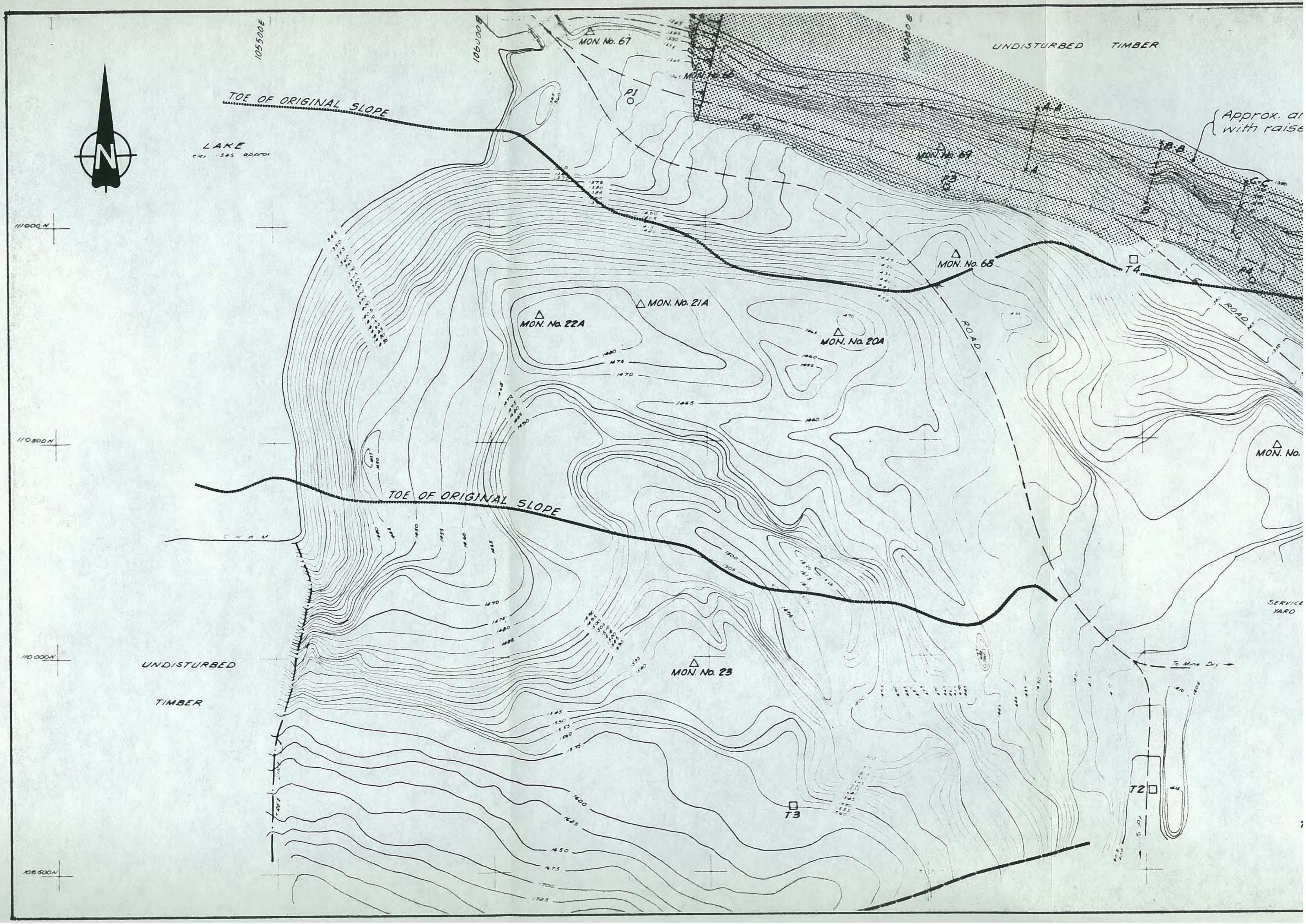


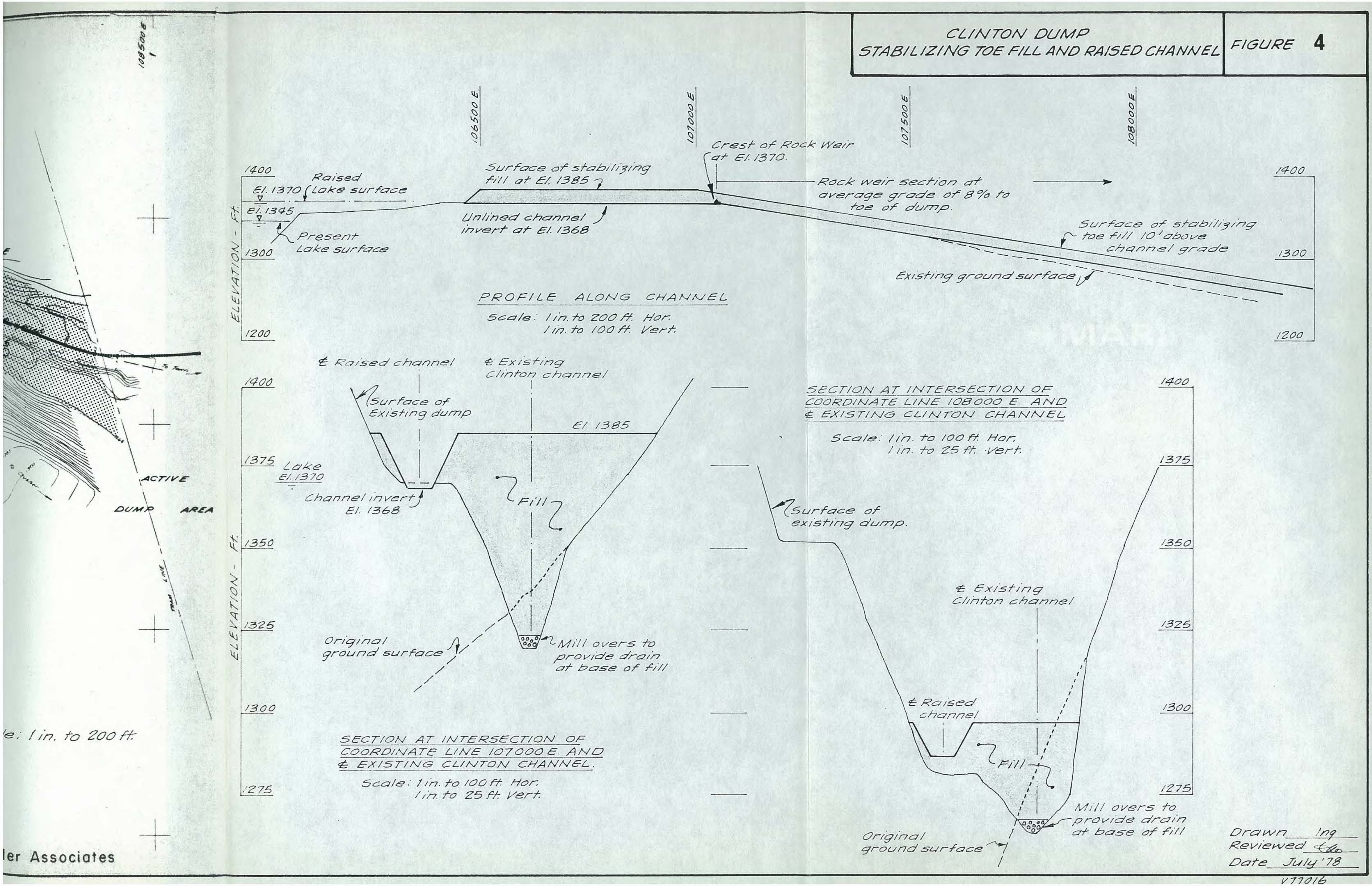
Drawn ________

Reviewed ________

Date July '78

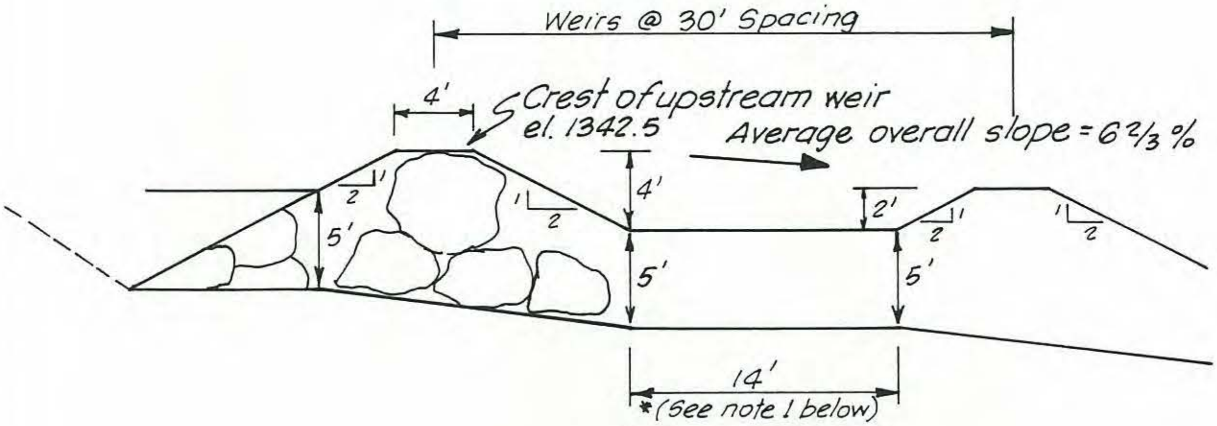
Golder Associates


N
LAKE
TOE OF ORIGINAL SLOPE
MON. No. 67
MON. No. 66
P1
P2
UNDISTURBED TIMBER
A-A
B-B
C-C
MON. No. 69
P3
MON. No. 68
T4
P4
ROAD
MON. No. 22A
MON. No. 21A
MON. No. 20A
111000N
110500N
110000N
105500E
TOE OF ORIGINAL SLOPE
SERVICE YARD
To Mine Dry
MON. No. 23
UNDISTURBED
TIMBER
T3
T2


CLINTON DUMP
STABILIZING TOE FILL AND RAISED CHANNEL
FIGURE 4
108500 E
ACTIVE
DUMP AREA
To Town
To Quarry
TRAM LINE
le: 1 in. to 200 ft.
ler Associates
106500 E.
107000 E
107500 E
108000 E
Crest of Rock Weir at El. 1370.
Surface of stabilizing fill at El. 1385
Raised Lake surface
El. 1370
El. 1345
Present Lake surface
Unlined channel invert at El. 1368
Rock weir section at average grade of 8% to toe of dump.
Surface of stabilizing toe fill 10' above channel grade
Existing ground surface
ELEVATION - Ft.
1400
1300
1200
PROFILE ALONG CHANNEL
Scale: 1 in. to 200 ft. Hor.
1 in. to 100 ft. Vert.
℄ Raised channel
℄ Existing Clinton channel
Surface of Existing dump
El. 1385
Lake El. 1370
Channel invert El. 1368
Fill
Original ground surface
Mill overs to provide drain at base of fill
1400
1375
1350
1325
1300
1275
SECTION AT INTERSECTION OF COORDINATE LINE 107000 E. AND ℄ EXISTING CLINTON CHANNEL.
Scale: 1 in. to 100 ft. Hor.
1 in. to 25 ft. Vert.
SECTION AT INTERSECTION OF COORDINATE LINE 108000 E. AND ℄ EXISTING CLINTON CHANNEL
Scale: 1 in. to 100 ft. Hor.
1 in. to 25 ft. Vert.
Surface of existing dump.
℄ Existing Clinton channel
℄ Raised channel
Fill
Mill overs to provide drain at base of fill
Original ground surface
Drawn Ing
Reviewed
Date July '78
V77016

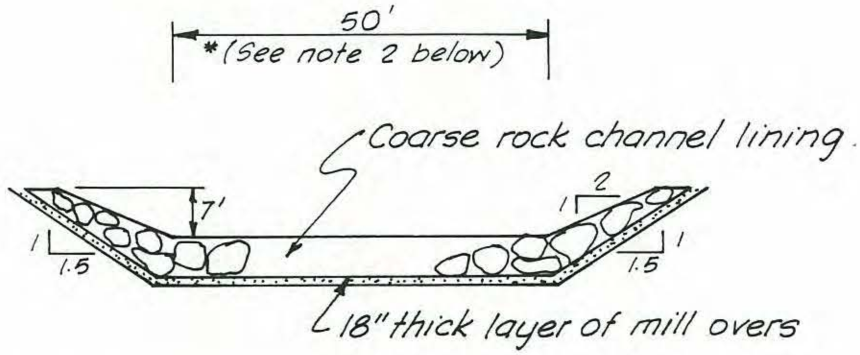
CLINTON CHANNEL
EROSION RESISTANT ROCK LINING

Figure 5



LONGITUDINAL SECTION

Scale : 1 inch to 10 feet



For the coarse rock channel lining,
20% of fragments by weight should be > 5500 lbs. size
50% of fragments by weight should be > 4300 lbs. size
80% of fragments by weight should be > 2700 lbs. size

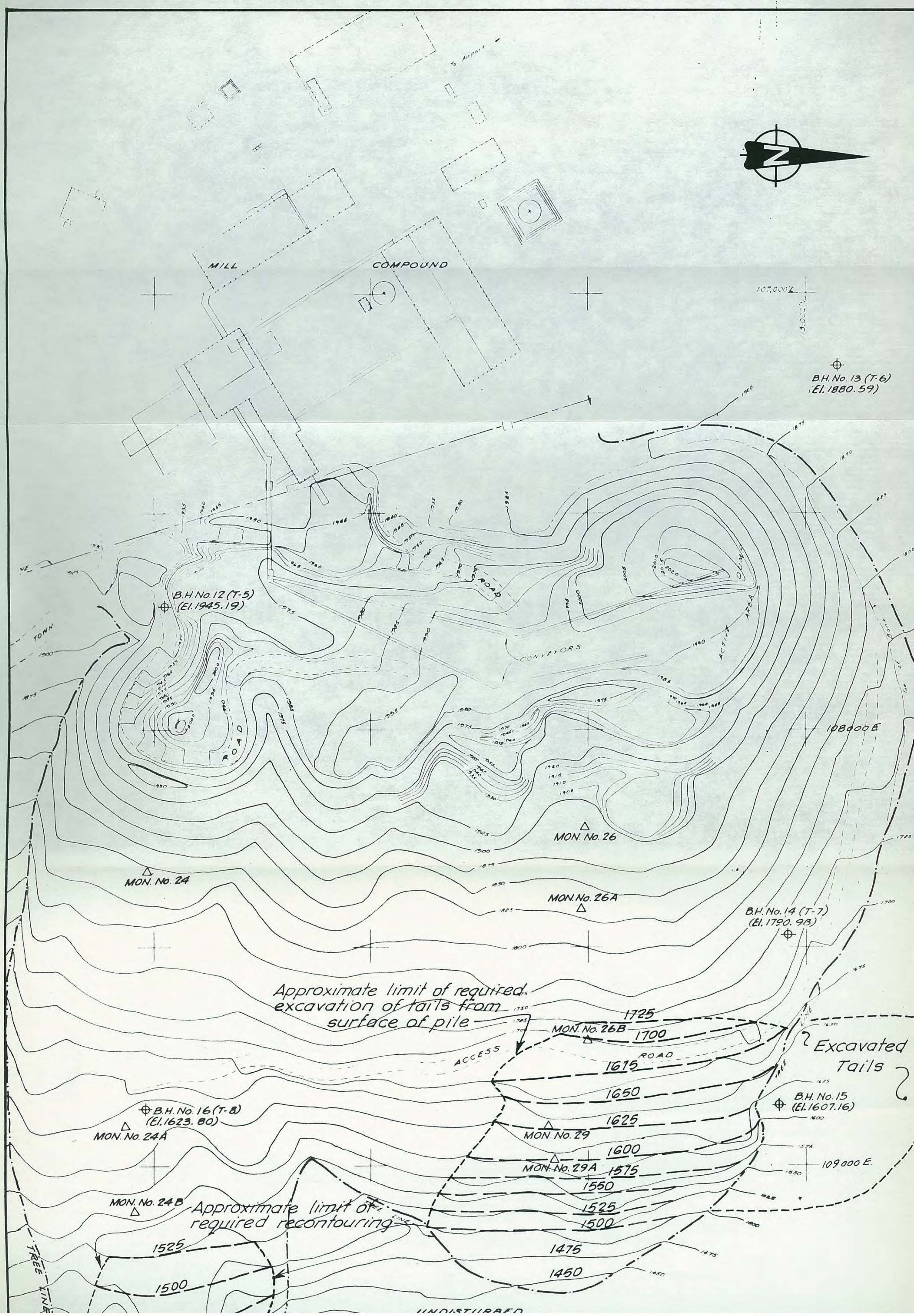
TRANSVERSE SECTION

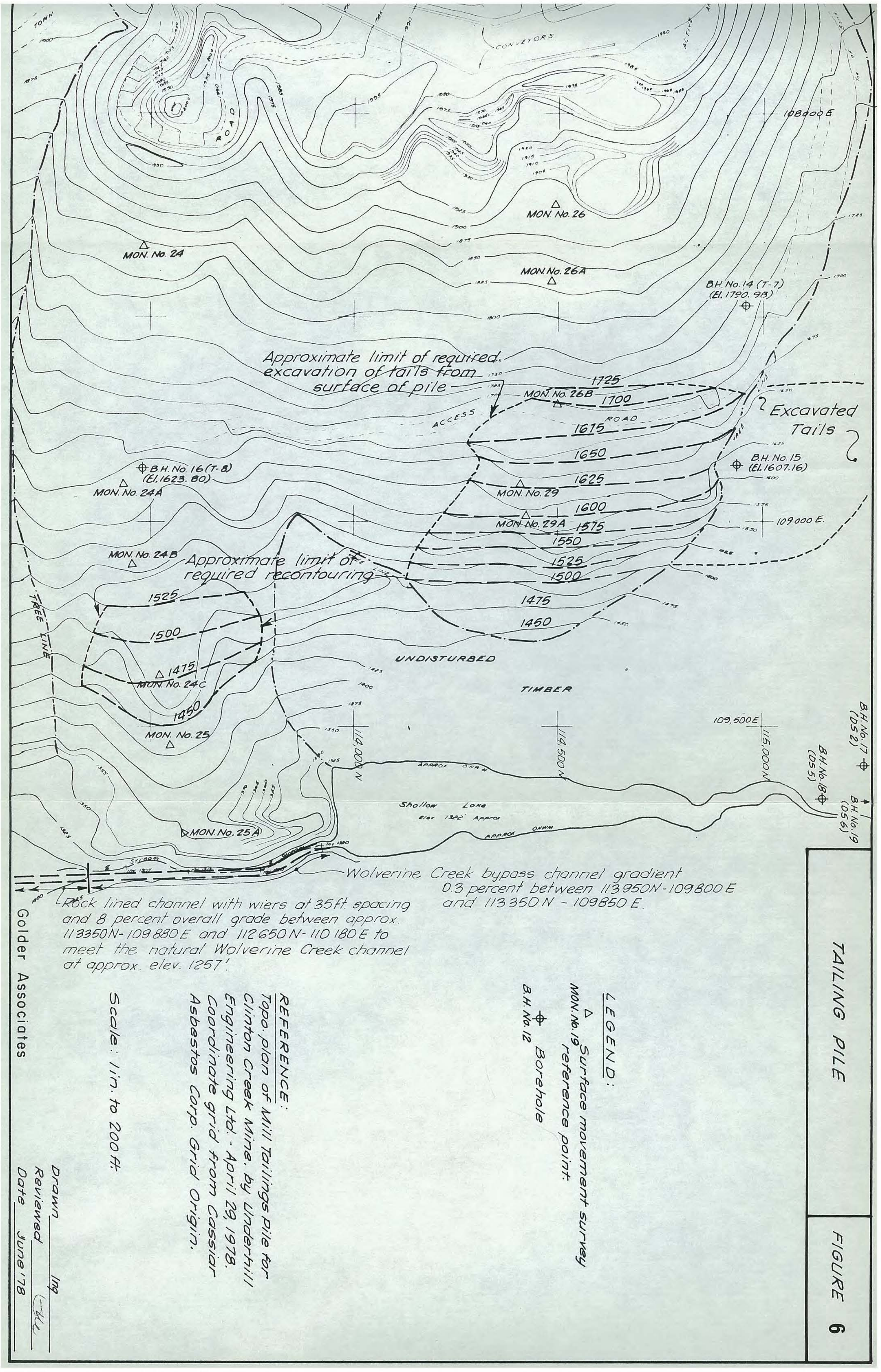
Scale : 1 inch to 25 feet

*Notes : 1. For the 'Cadillac' scheme, this dimension is 9 ft. which increases the overall average grade to 8%.

2. For the 'Cadillac' scheme, this dimension is 30 ft.

Project No V-77016 Drawn Reviewed EBF Date July '78


MILL
COMPOUND
N
107,000 E
B.H. No. 13 (T-6)
(El. 1880.59)
B.H. No. 12 (T-5)
(El. 1945.19)
ROAD
CONVEYORS
ACTIVE AREA
108000 E
MON. No. 26
MON. No. 24
MON. No. 26A
B.H. No. 14 (T-7)
(El. 1790.98)
Approximate limit of required excavation of tails from surface of pile
ACCESS
ROAD
MON. No. 26B
Excavated Tails
B.H. No. 15
(El. 1607.16)
B.H. No. 16 (T-8)
(El. 1623.80)
MON. No. 24A
MON. No. 29
MON. No. 29A
109000 E.
MON. No. 24B
Approximate limit of required recontouring
TREE LINE
TOWN
1725
1700
1615
1650
1625
1600
1575
1550
1525
1500
1475
1450
UNDISTURBED

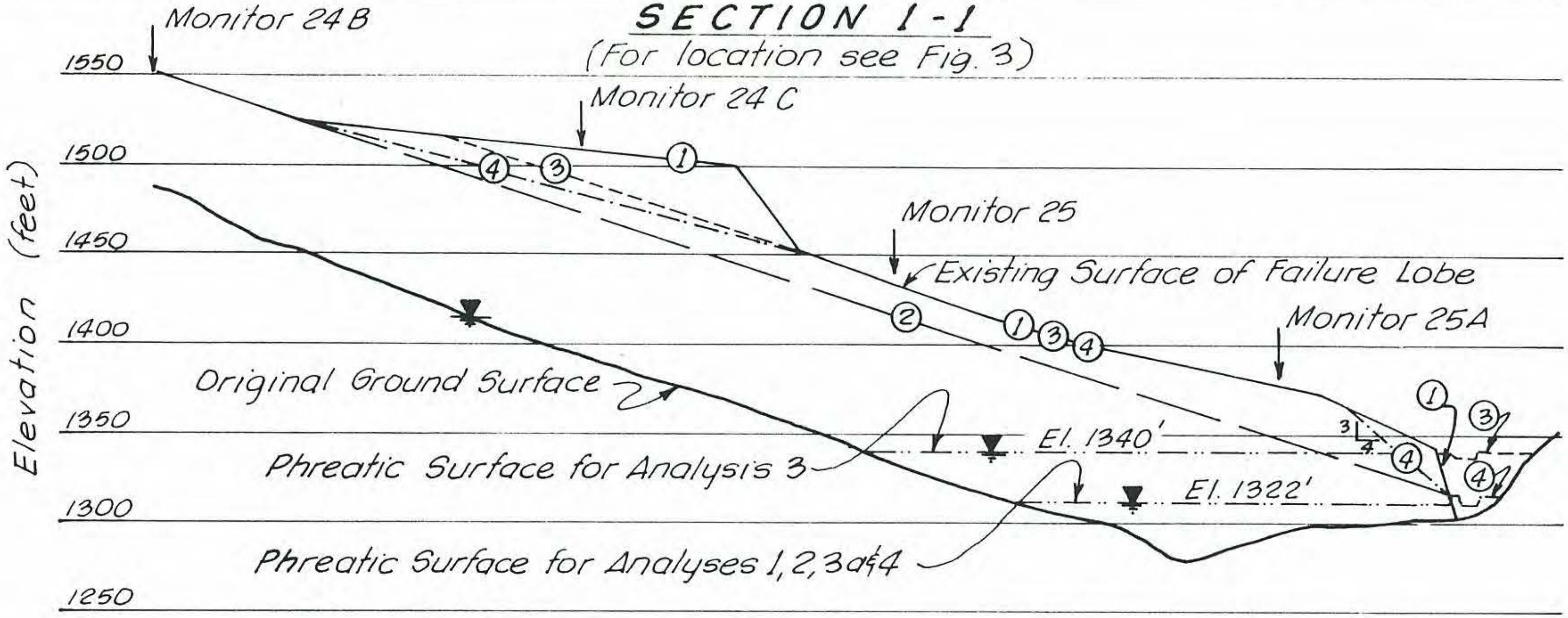


CONVEYORS
ROAD
MON. No. 26
MON. No. 24
MON. No. 26A
108000 E.
B.H. No. 14 (T-7)
(El. 1790. 98)
Approximate limit of required excavation of tails from surface of pile
MON. No. 26B
1725
1700
ACCESS ROAD
1615
1650
1625
1600
1575
1550
1525
1500
1475
1450
Excavated Tails
B.H. No. 16 (T-8)
(El. 1623. 80)
MON. No. 24A
B.H. No. 15
(El. 1607.16)
MON. No. 29
MON. No. 29A
109.000 E.
MON. No. 24B
Approximate limit of required recontouring
TREE LINE
MON. No. 24C
MON. No. 25
UNDISTURBED
TIMBER
109,500 E
114,000 N
114,500 N
115,000 N
B.H. No. 17 (DS2)
B.H. No. 18 (DS5)
B.H. No. 19 (DS6)
Shallow Lake
Elev 1322' Approx
MON. No. 25A
Wolverine Creek bypass channel gradient 0.3 percent between 113950N-109800 E and 113350 N - 109850 E.
Rock lined channel with wiers at 35 ft. spacing and 8 percent overall grade between approx. 113350N-109880 E and 112650N-110180 E to meet the natural Wolverine Creek channel at approx. elev. 1257'.
LEGEND:
MON. No. 19 Surface movement survey reference point.
B.H. No. 12 Borehole
REFERENCE:
Topo. plan of Mill Tailings Pile for Clinton Creek Mine, by Underhill Engineering Ltd. - April 29, 1978. Coordinate grid from Cassiar Asbestos Corp. Grid Origin.
Scale: 1 in. to 200 ft.
Golder Associates
Drawn
Reviewed
Date June '78
TAILING PILE
FIGURE 6

Y-77016 AH E.O.F. July '78

SECTION 1-1

(For location see Fig. 3)



Profile	Notes	Factor of Safety
1	Existing Slope	1.00
2	Slope trimmed to approximately 18° from Wolverine Channel	1.57
3	Wolverine Channel filled to elevation 1340'; phreatic surface in tails raised to elevation 1340'; upslope knob removed	1.04
3a)	Wolverine Channel filled to elevation 1340'; phreatic surface maintained at elevation 1322'; upslope knob removed	1.21
4	Wolverine Channel trimmed and armed against stream erosion; upslope knob removed	1.20

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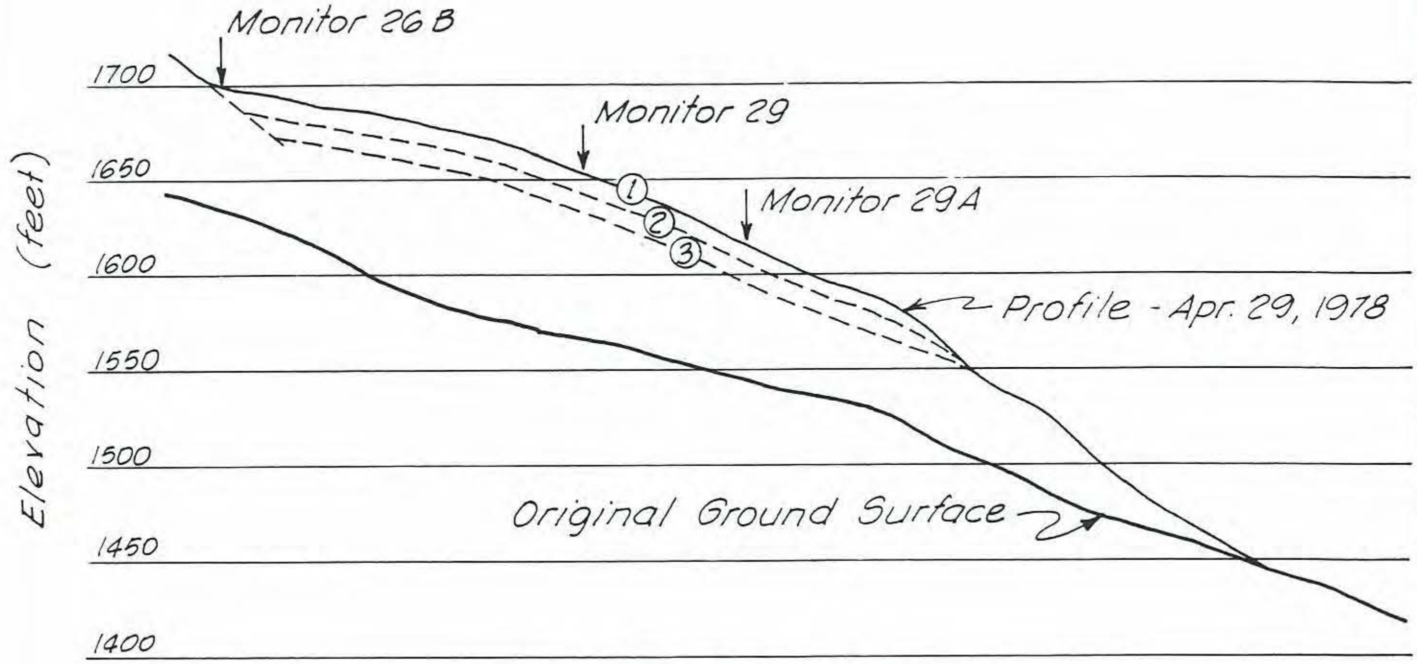
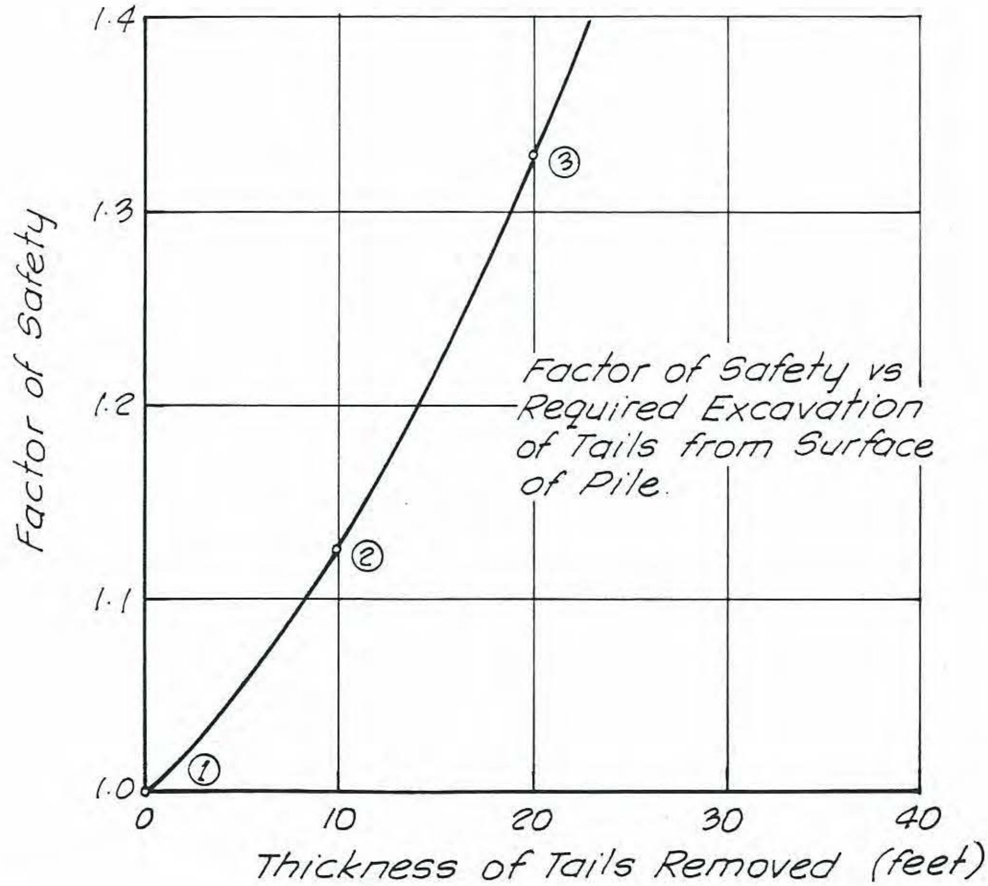
TAILING PILE - 1974 FAILURE LOBE

Figure 7

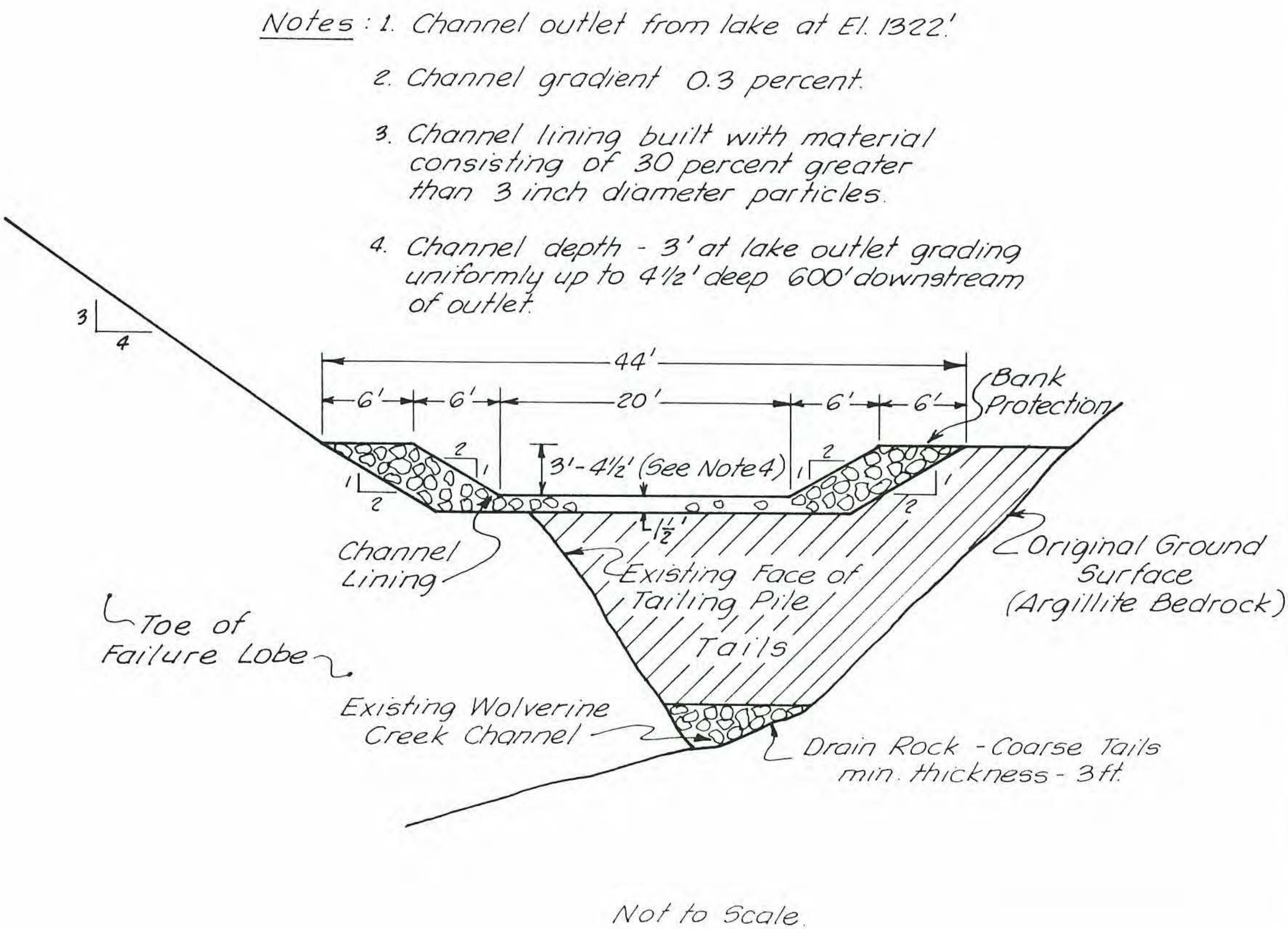
TAILING PILE - NORTH LOBE **Figure 8**



SECTION 2-2
(For location see Fig. 2)



V-77016 July '78



TYPICAL CROSS-SECTION OF WOLVERINE CREEK BYPASS AT TOE OF 1974 FAILURE LOBE

Figure 9

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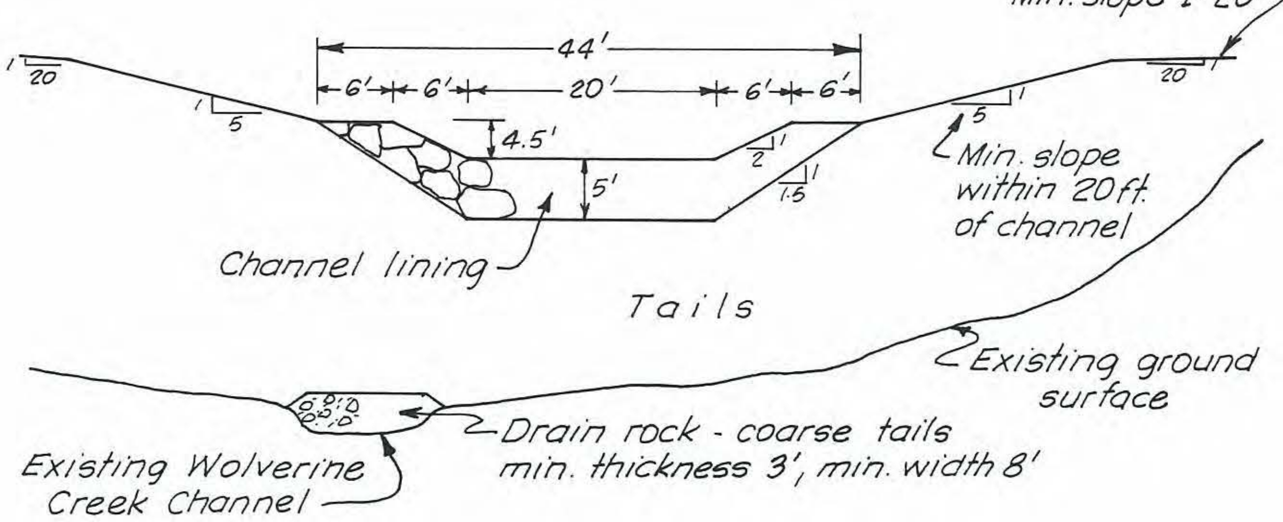
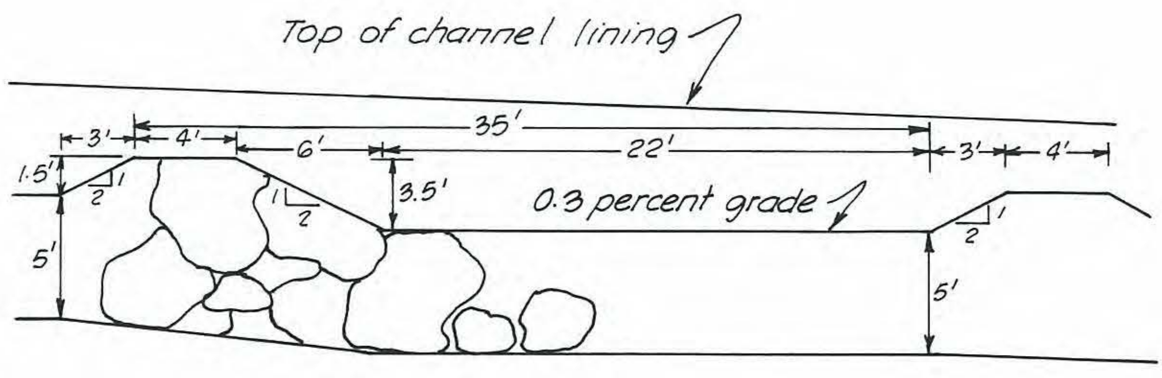
WOLVERINE CREEK CHANNEL DOWNSTREAM OF FAILURE LOBE

Figure 10



Note: 1. Channel lining and wier materials must conform to:
20 percent greater than 48 inch diameter (~5500 lbs.)
50 percent greater than 40 inch diameter (~4300 lbs.)
80 percent greater than 30 inch diameter (~2700 lbs.)

TYPICAL SECTION



Note: 1. Crests and downstream toes of weirs must be constructed of heavy rocks.

PROFILE OF WEIR SYSTEM

Not to Scale

Project No. V-77016 Drawn [illegible] Reviewed EBF Date July '78

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PHOTO 1

View of Clinton Dump looking downstream, and showing pressure ridge on ice surface as a result of creep movements during the winter of 1977-78. Date of Photo, March 9th, 1978.

PHOTO 2

Tension cracks on surface of Clinton Dump as a result of horizontal movements due to shear of the dump on its base.

PHOTO 3

Tension crack aligned approximately perpendicular to Clinton Channel.

PHOTO 4

Showing bedrock exposed on left side of Clinton Channel at a point midway between cross channel reference lines B-B and C-C (see Figure 2 for location).

PHOTO 5

View of Clinton Channel looking upstream showing exposed bedrock on north side. Bedding dips at approximately 20 degrees toward the channel, and well developed cross joints are aligned perpendicular to the bedding joints. Large rocks on left side of photo are remnants from the waste dump.

PHOTO 6

The junction of the Forty Mile river and the Yukon river. Clinton creek joins the Forty Mile just beyond the upper edge of the photo. Date of photo June 5th, 1978.

PHOTO 7

View of tailing pile-facing north

PHOTO 8

View of Wolverine Creek channel at toe of 1974 failure lobe showing the effects of stream erosion on the tailings.

PHOTOS 9 & 10

Aerial views of the 1974 failure lobe. Note the crack pattern at the toe of the failure.

PHOTO 11

Toe of north lobe of tailing pile showing foundation soils bulldozed ahead of the pile.

PHOTOS 12 & 13

Views of slabs of foundation soils pushed ahead of the tailing pile. These soil exposures are approximately 60 ft. in front of the toe of the tailing pile.

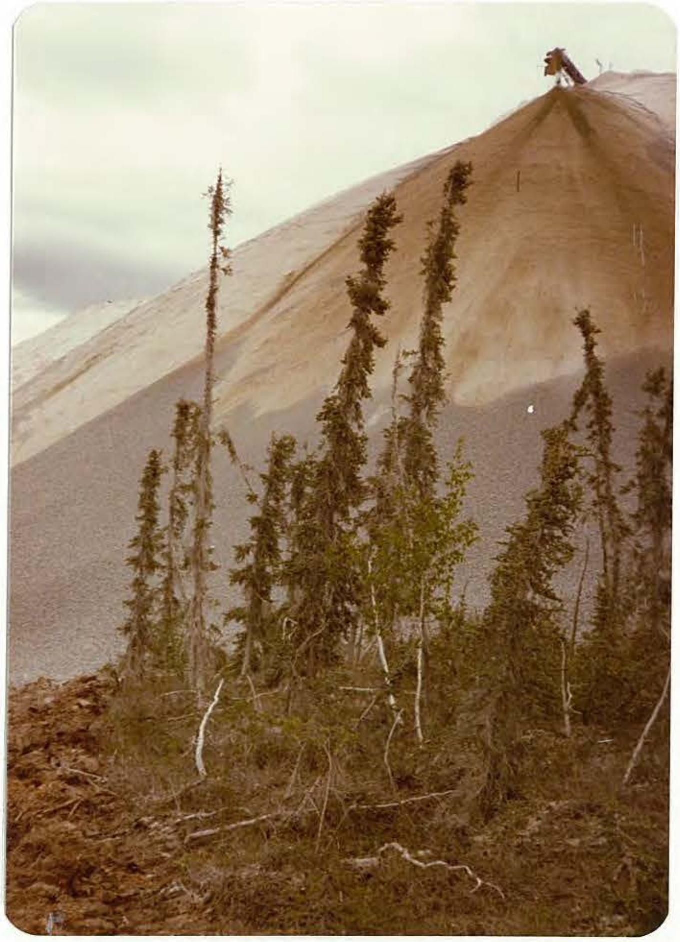


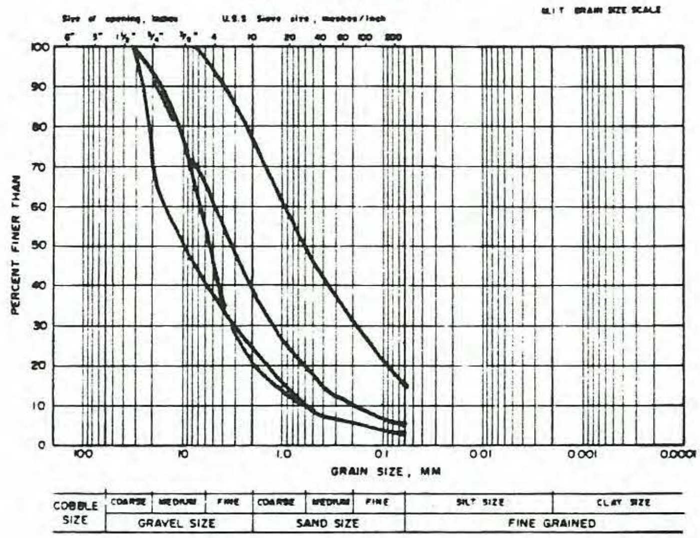
PHOTO 14

Northwest corner of tailing pile. Note the segregation of particle sizes as the tails travel down the face of the pile.

GRAIN SIZE DISTRIBUTION

Figure B - 1

GRAIN SIZE DISTRIBUTION



Borehole No. __________

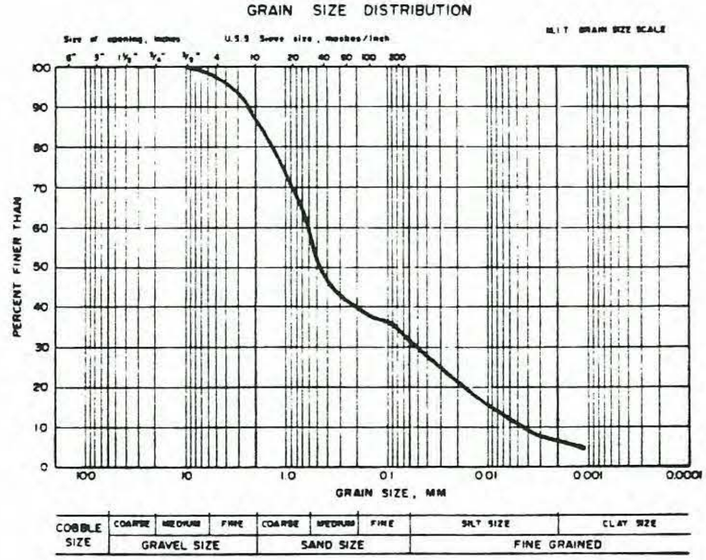
Location CLINTON WASTE DUMP

Sample No. __________

Depth __________

Soil Type WASTE ROCK FROM CLINTON DUMP

GRAIN SIZE DISTRIBUTION



Borehole No. 12 (T-5)

Location TAILING PILE

Sample No. 1

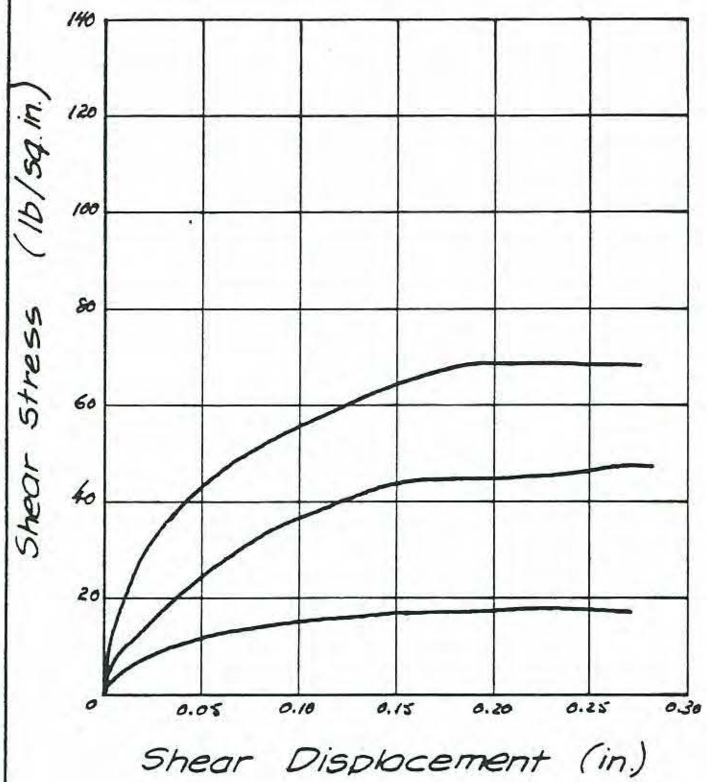
Depth 36.5' - 39'

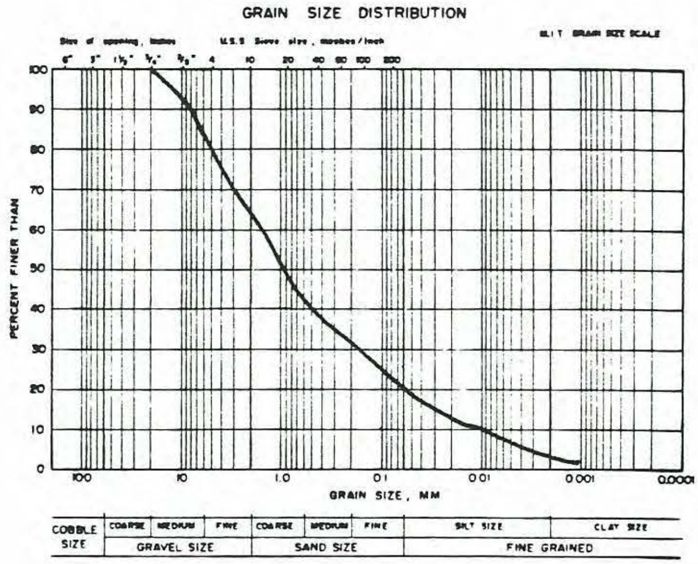
Soil Type FLUVIAL LACUSTRINE GRAVEL

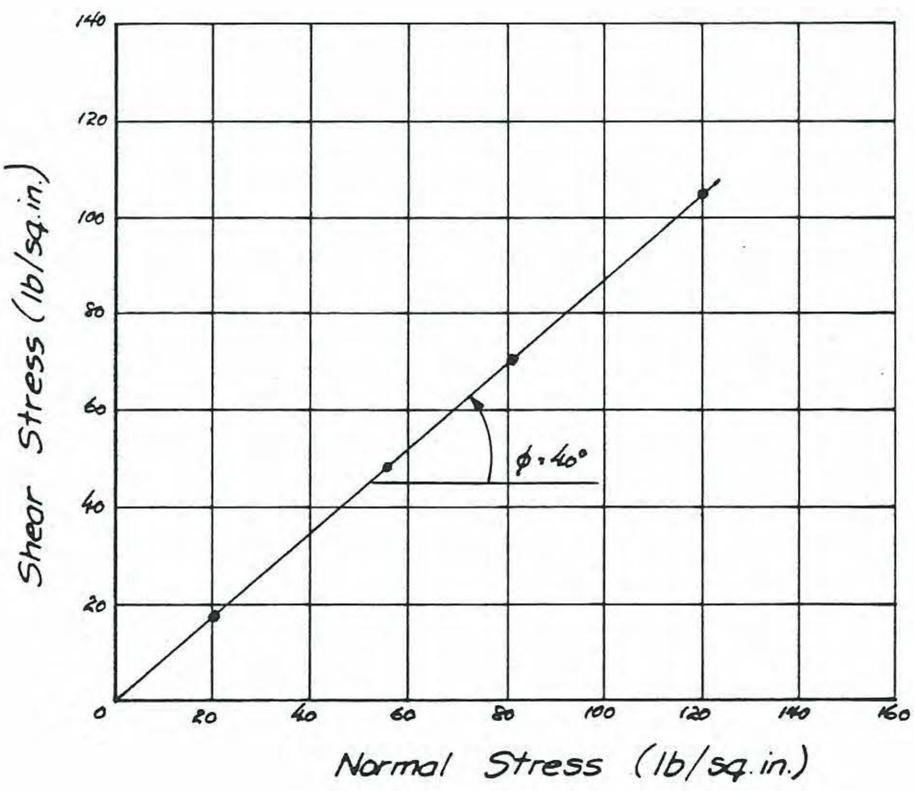
Project No. V77016 Drawn R.D. Reviewed EBF Date JUNE '78

GRAIN SIZE DISTRIBUTION & DIRECT SHEAR TEST RESULTS

Figure B - 2





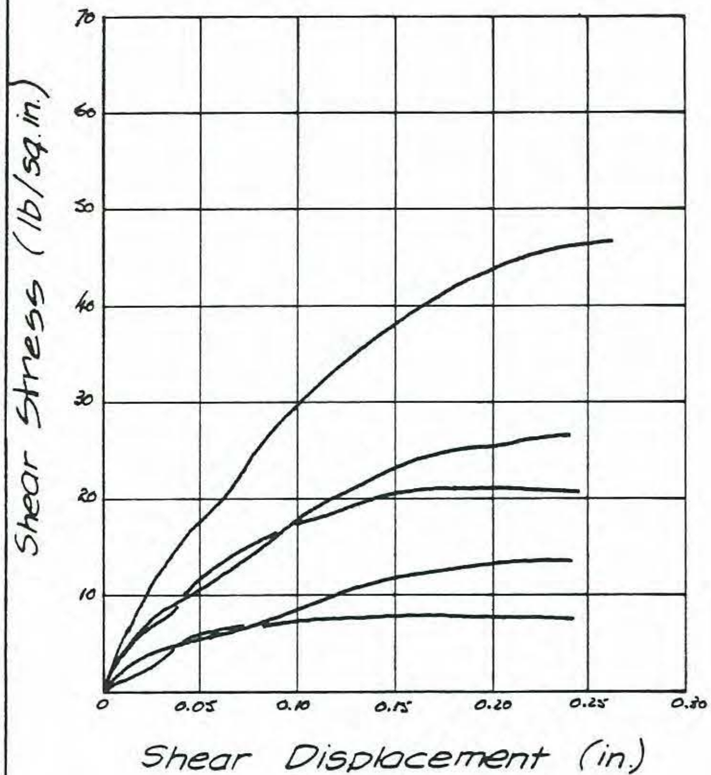


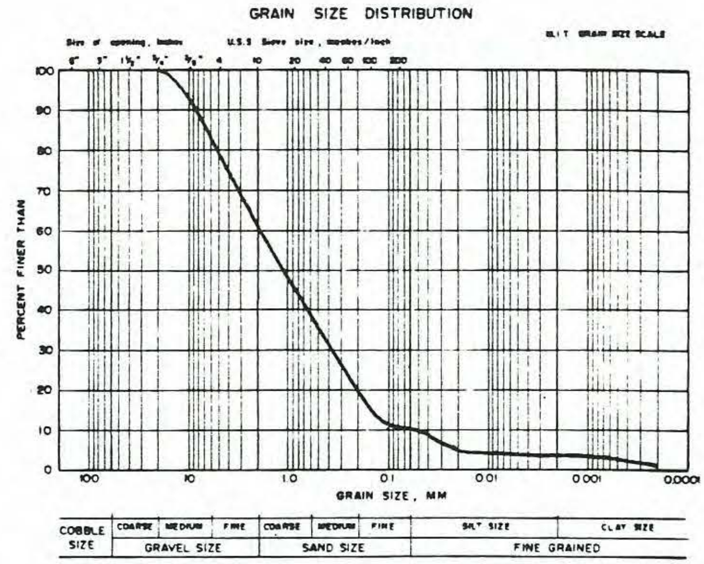
Borehole No. ______
Location CLINTON WASTE DUMP
Sample No. ______
Depth ______
Soil Type Weathered Argillite Bedrock

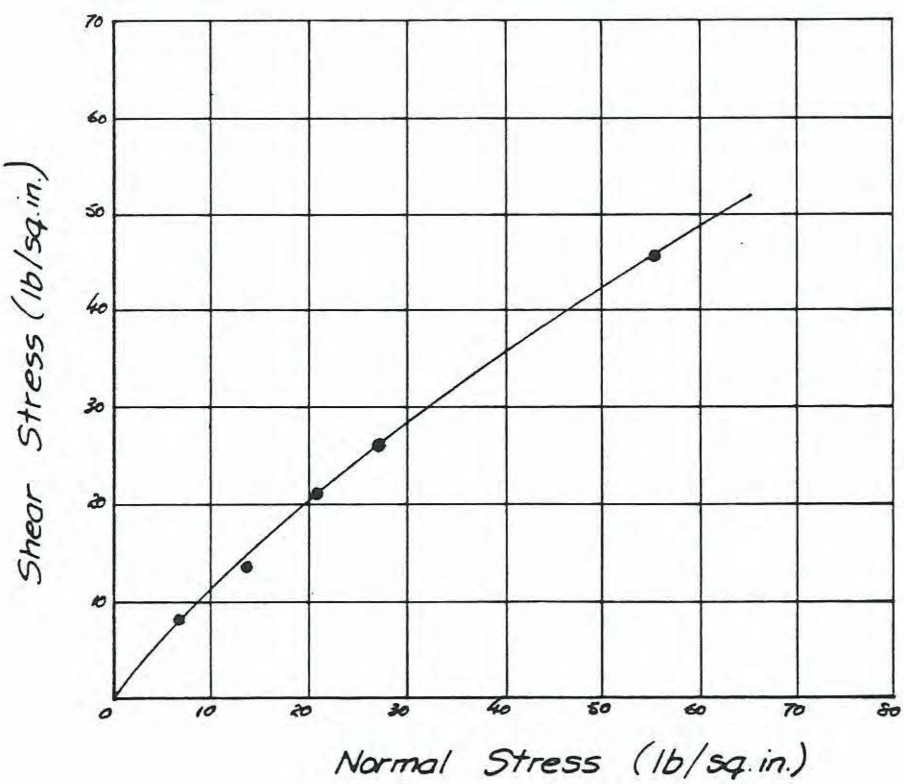
Project No. V77016 Drawn R.D. Reviewed EBF Date June '78

GRAIN SIZE DISTRIBUTION & DIRECT SHEAR TEST RESULTS

Figure B - 3







Borehole No. ________

Location ________

Sample No. ________

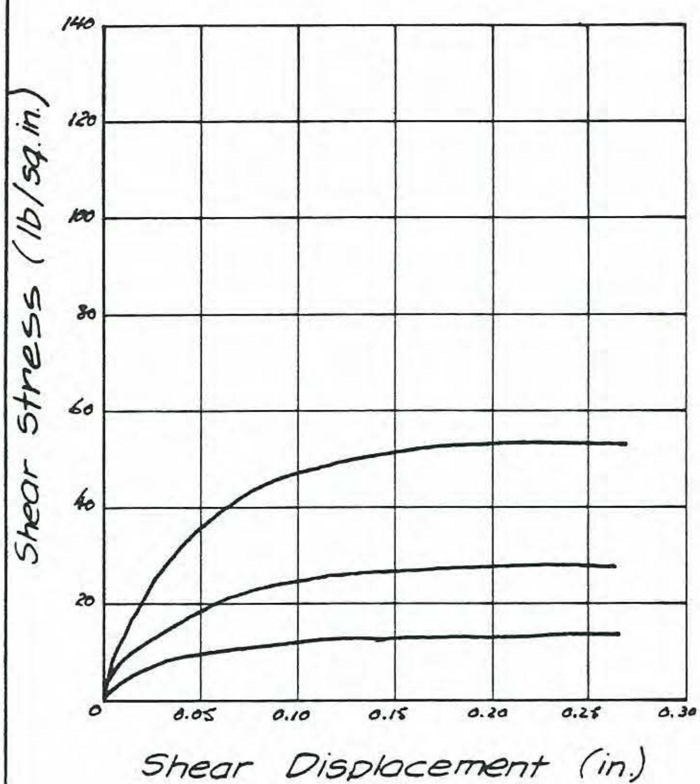
Depth ________

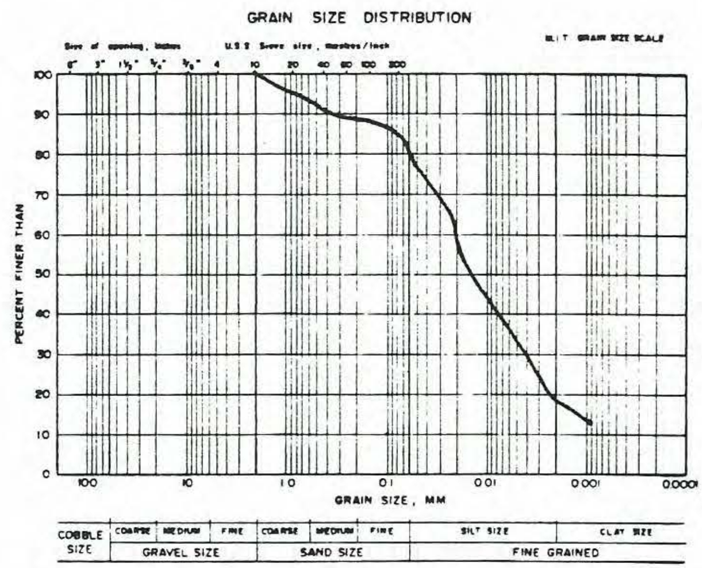
Soil Type MILL TAILINGS

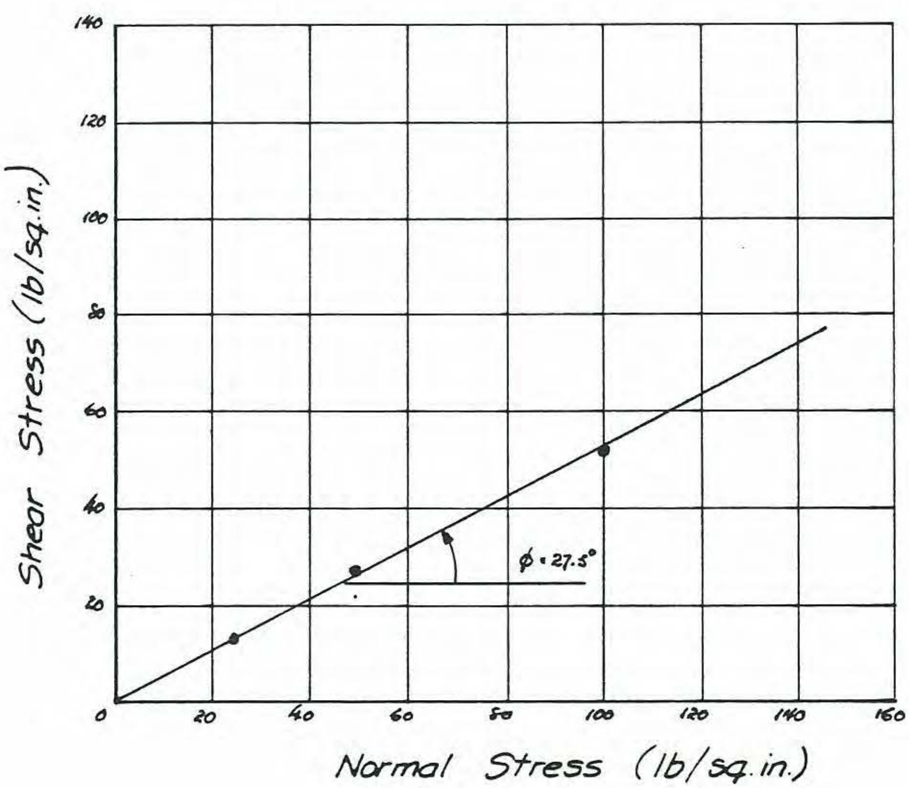
Project No. V77016 Drawn R.D. Reviewed E.B.F. Date June '78

GRAIN SIZE DISTRIBUTION & DIRECT SHEAR TEST RESULTS

Figure B - 4





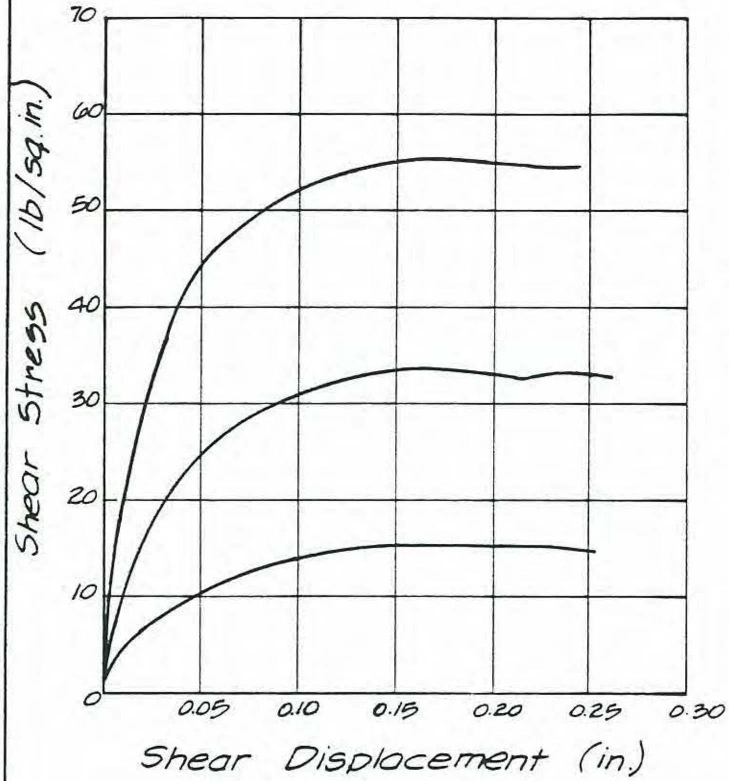


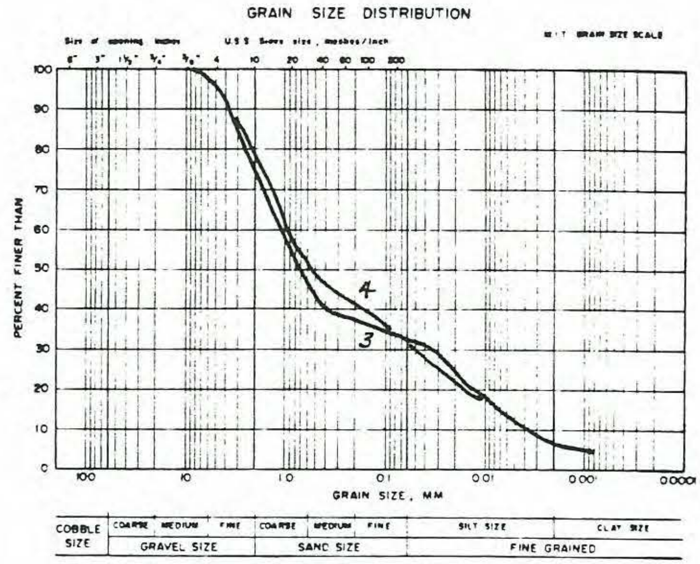
Borehole No. 13 (T-6)
Location North of Tailing Pile
Sample No. 2
Depth 15'-20'
Soil Type Fluvial-Lacustrine Gravel

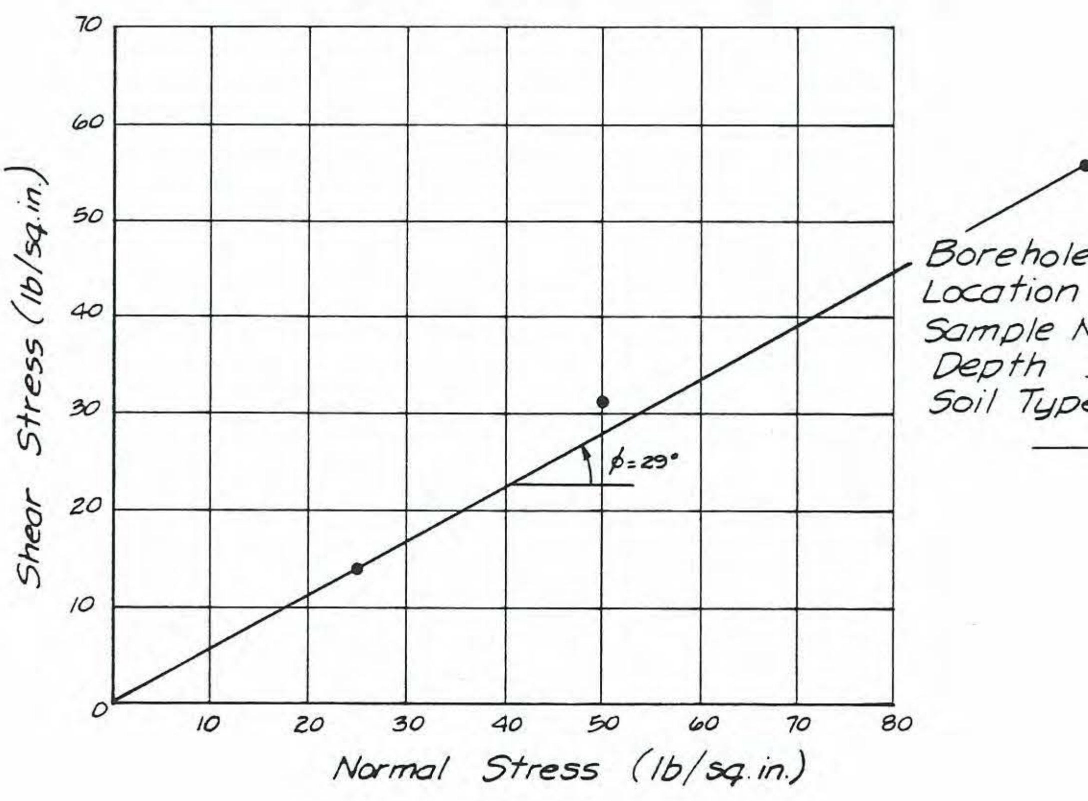
Project No. V77016 Drawn R.D. Reviewed E.B.F. Date June '78

GRAIN SIZE DISTRIBUTION & DIRECT SHEAR TEST RESULTS

Figure B - 5





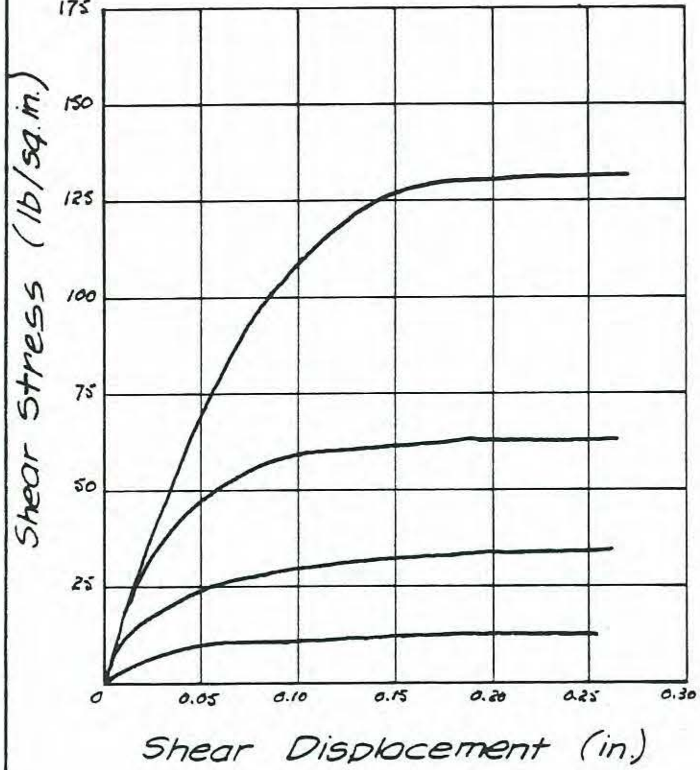


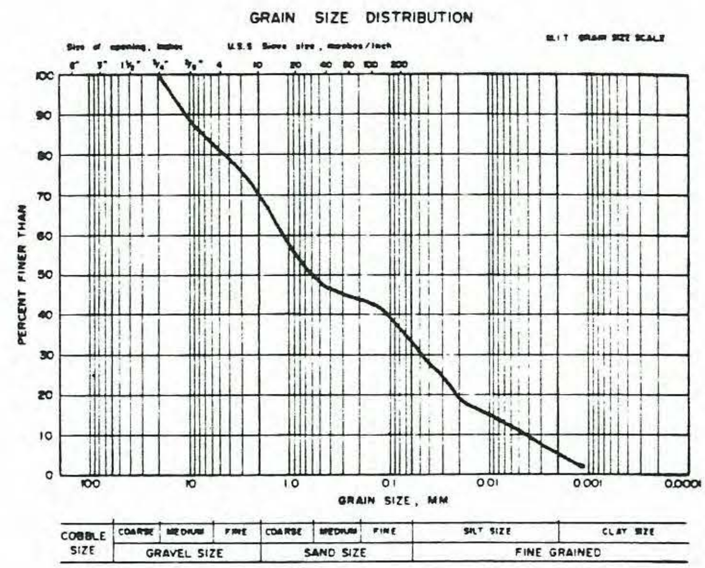
Borehole No. 13 (T-6)
Location NORTH OF TAILING PILE
Sample No. 3 & 4
Depth 23-25' & 32-34'
Soil Type FLUVIAL-LACUSTRINE GRAVEL

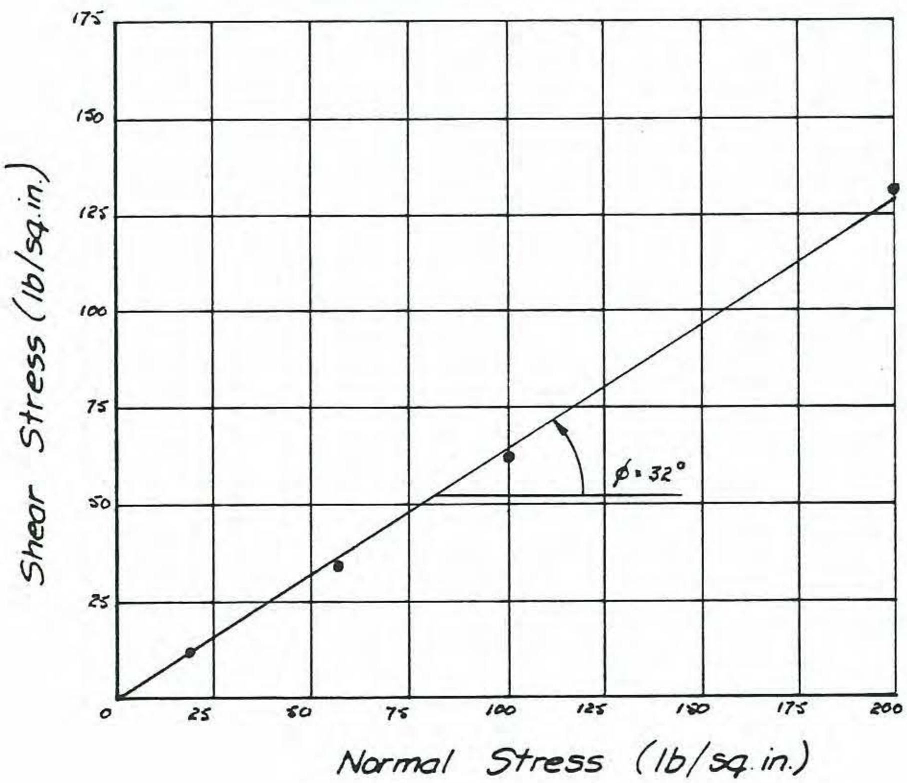
Project No. V77016 Drawn R.D. Reviewed EBF Date June '78

GRAIN SIZE DISTRIBUTION & DIRECT SHEAR TEST RESULTS

Figure B - 6





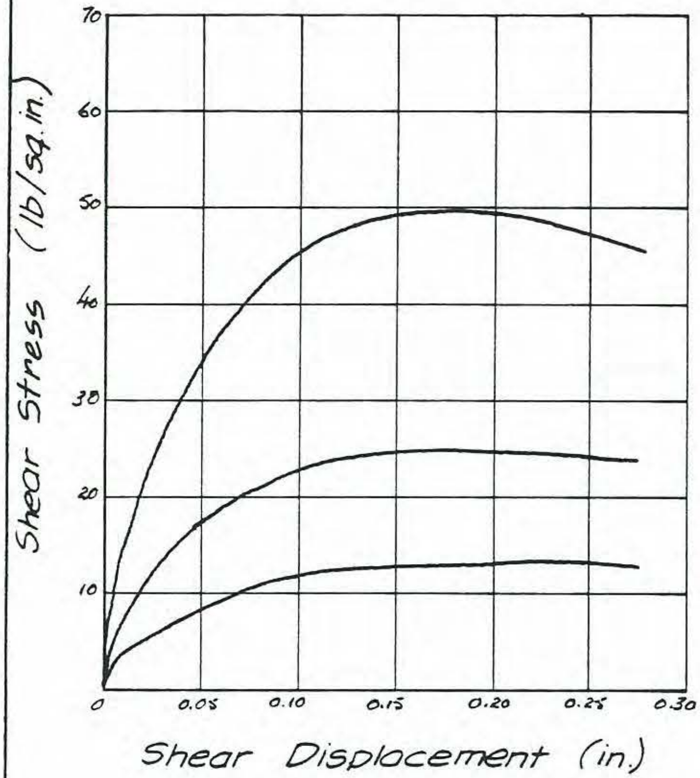


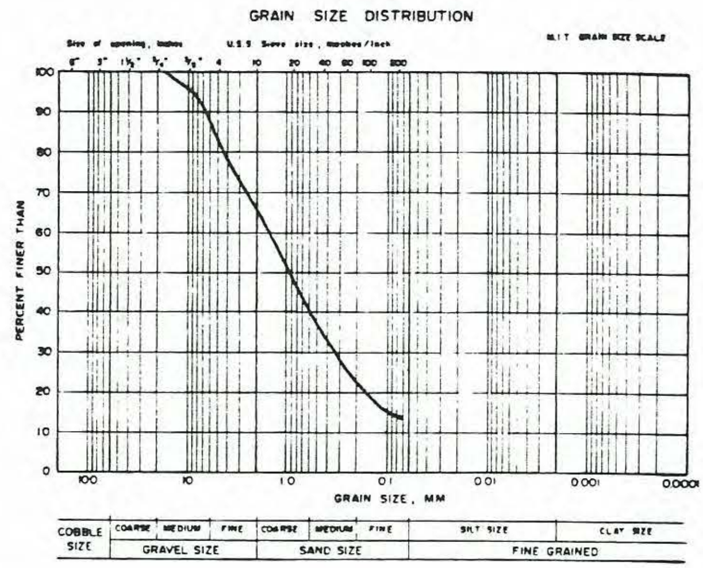
Borehole No. 14 (T-7)
Location TAILING PILE
Sample No. 1
Depth 46'-48'
Soil Type FLUVIAL-LACUSTRINE GRAVEL

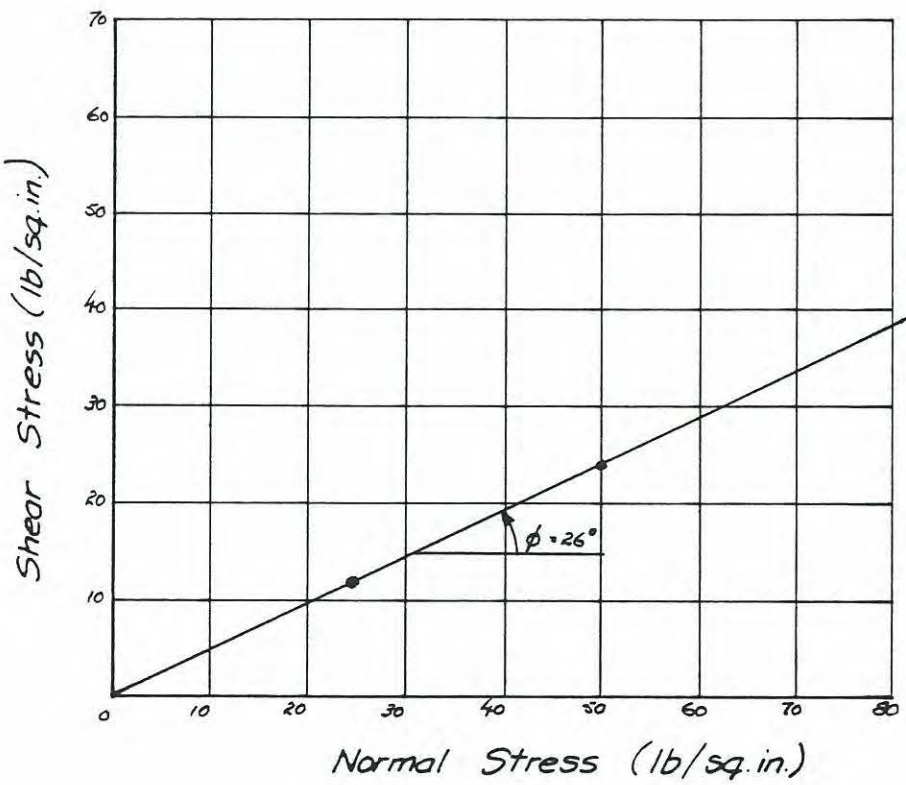
Project No. V77016 Drawn R.D. Reviewed EBF Date June '78

GRAIN SIZE DISTRIBUTION & DIRECT SHEAR TEST RESULTS

Figure B - 7





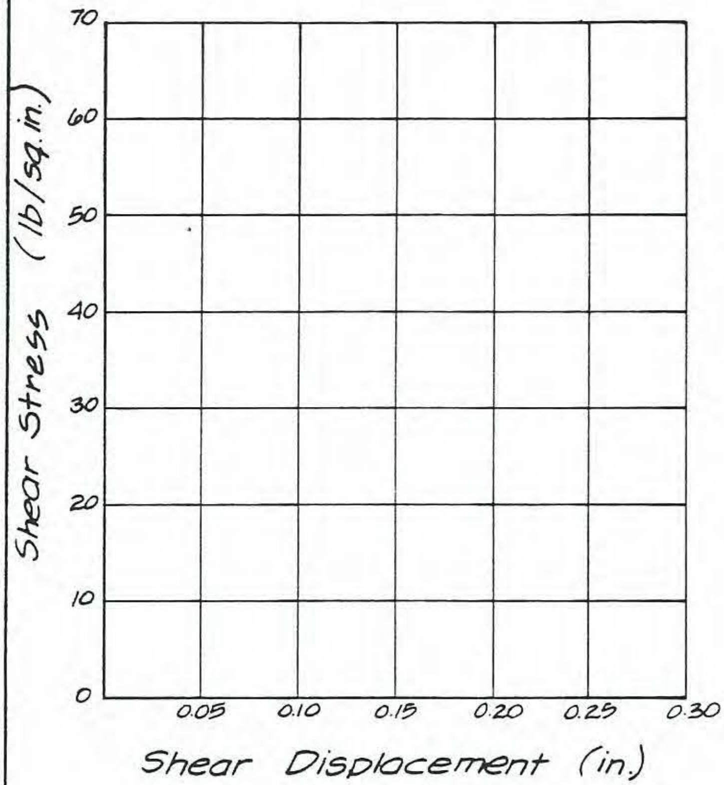


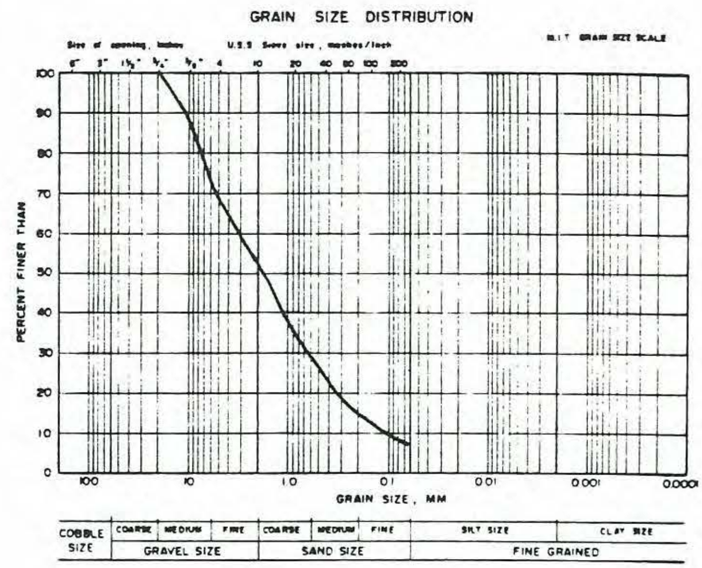
Borehole No. 15 (ST-8)
Location TAILING PILE
Sample No. 1
Depth 6'-9'
Soil Type WEATHERED ARGILLITE

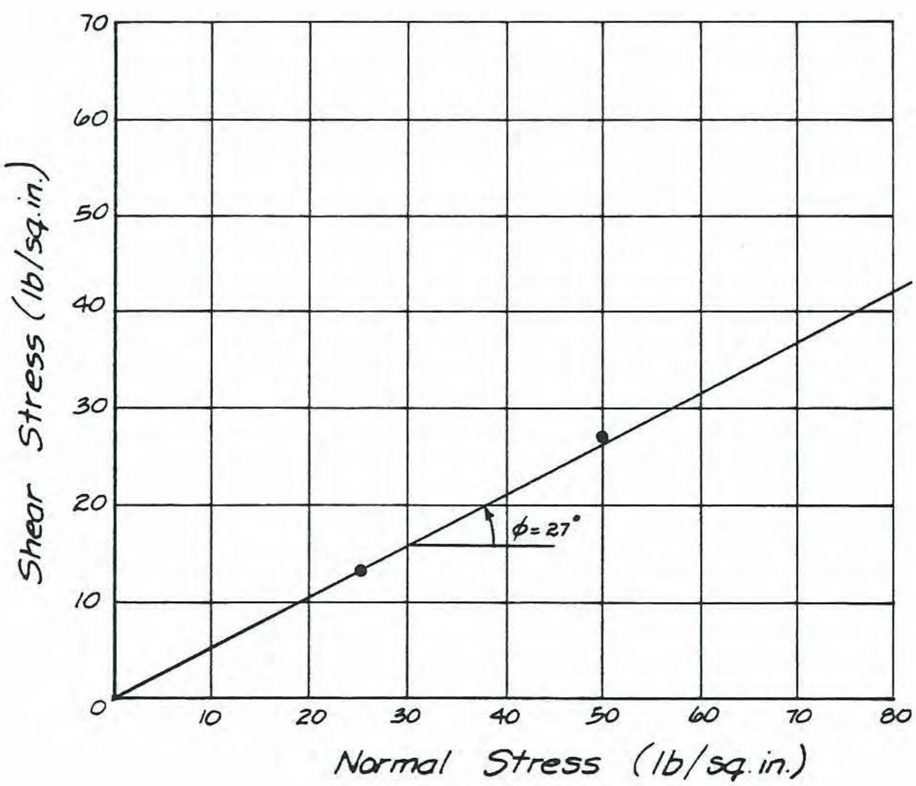
Project No. V77016 Drawn R.D. Reviewed EBF Date June '78

GRAIN SIZE DISTRIBUTION & DIRECT SHEAR TEST RESULTS

Figure B - 8







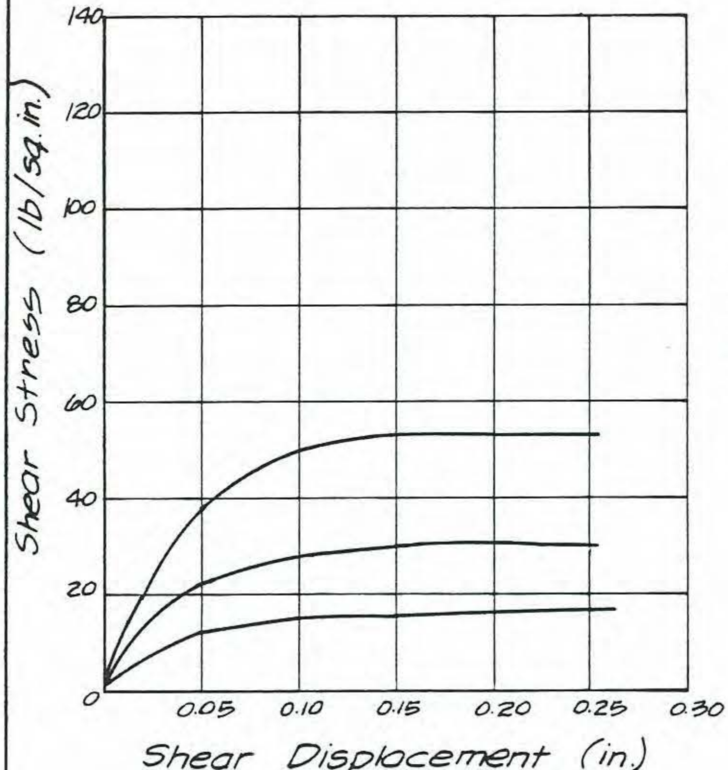
Borehole No. 15
Location TAILING PILE
Sample No. 2
Depth 20'-21'
Soil Type WEATHERED ARGILLITE

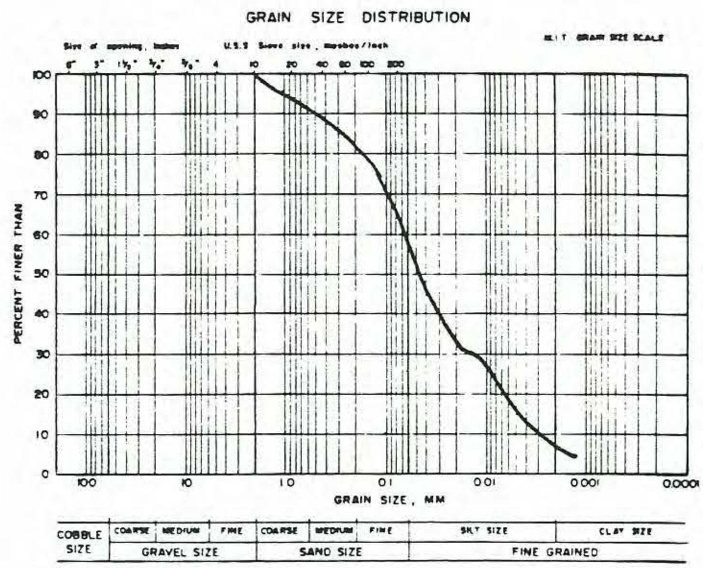
Project No. V77016 Drawn R.D. Reviewed EBF Date June '78

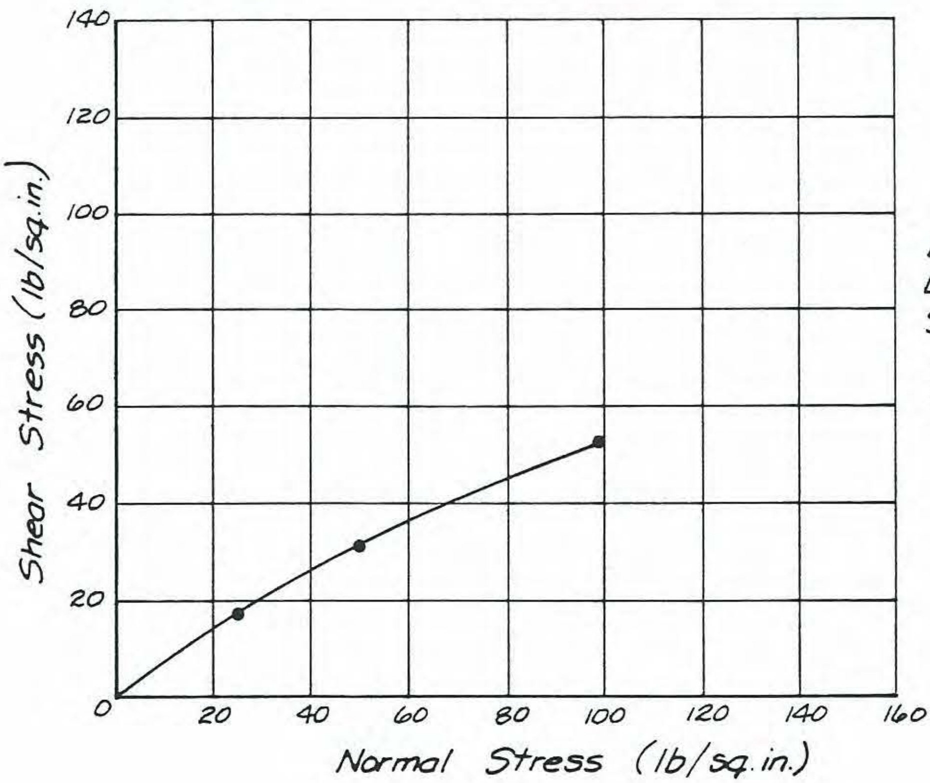
Golder Associates

GRAIN SIZE DISTRIBUTION & DIRECT SHEAR TEST RESULTS

Figure B - 9





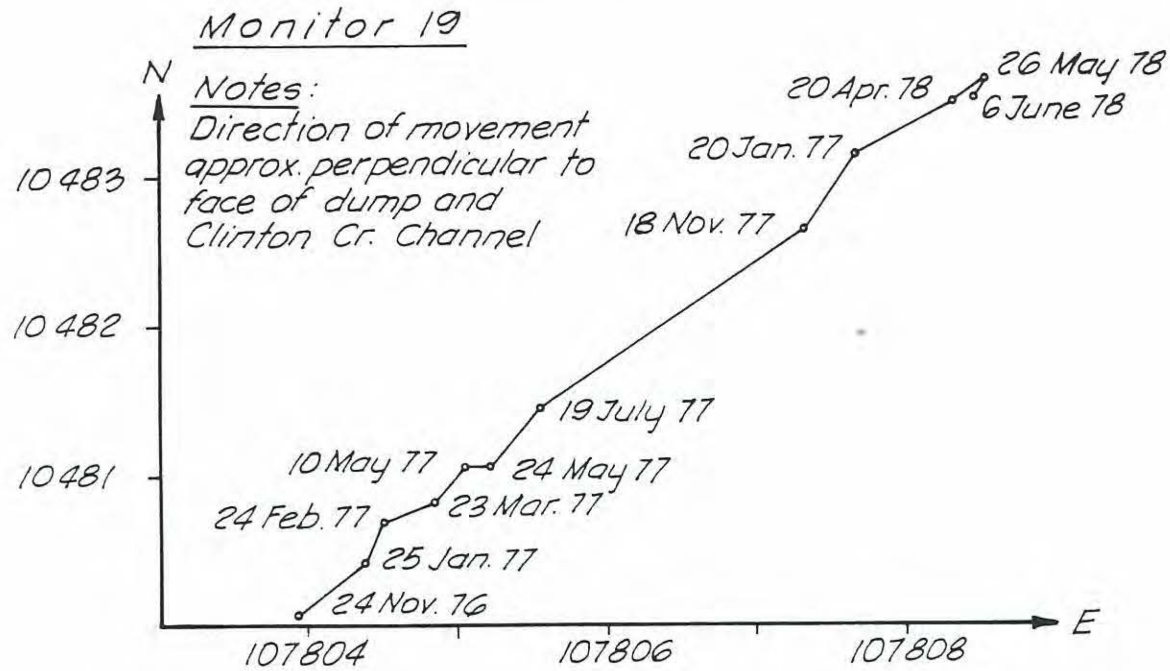


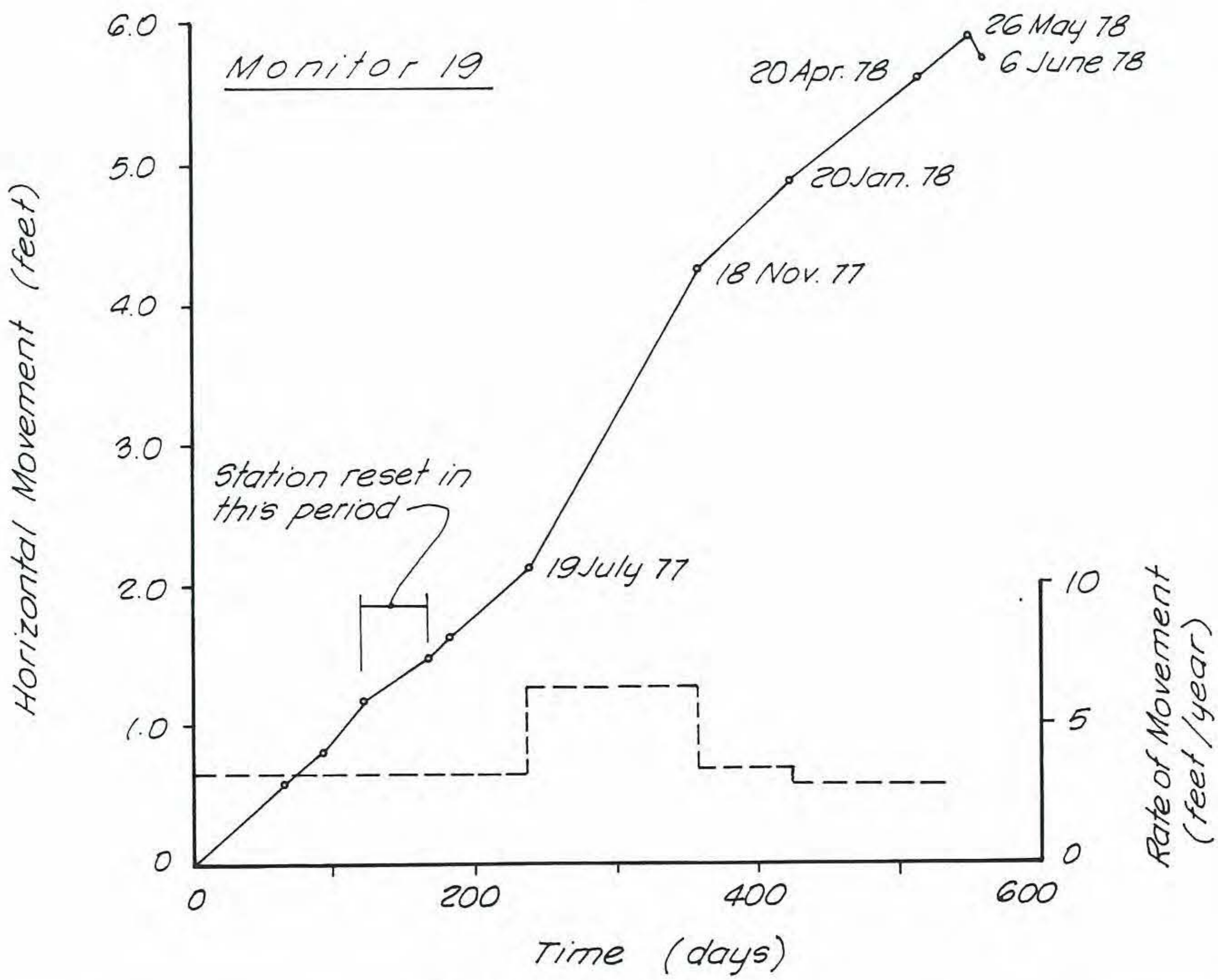
Borehole No. 16(T-8)
Location TAILING PILE
Sample No. 1
Depth 66'-68'
Soil Type FLUVIAL - LACUSTRINE GRAVEL

Project No. V77016 Drawn R.D. Reviewed EBF Date June '78

WASTE DUMP
HORIZONTAL MOVEMENT DATA
MONITOR 19

Figure C-1

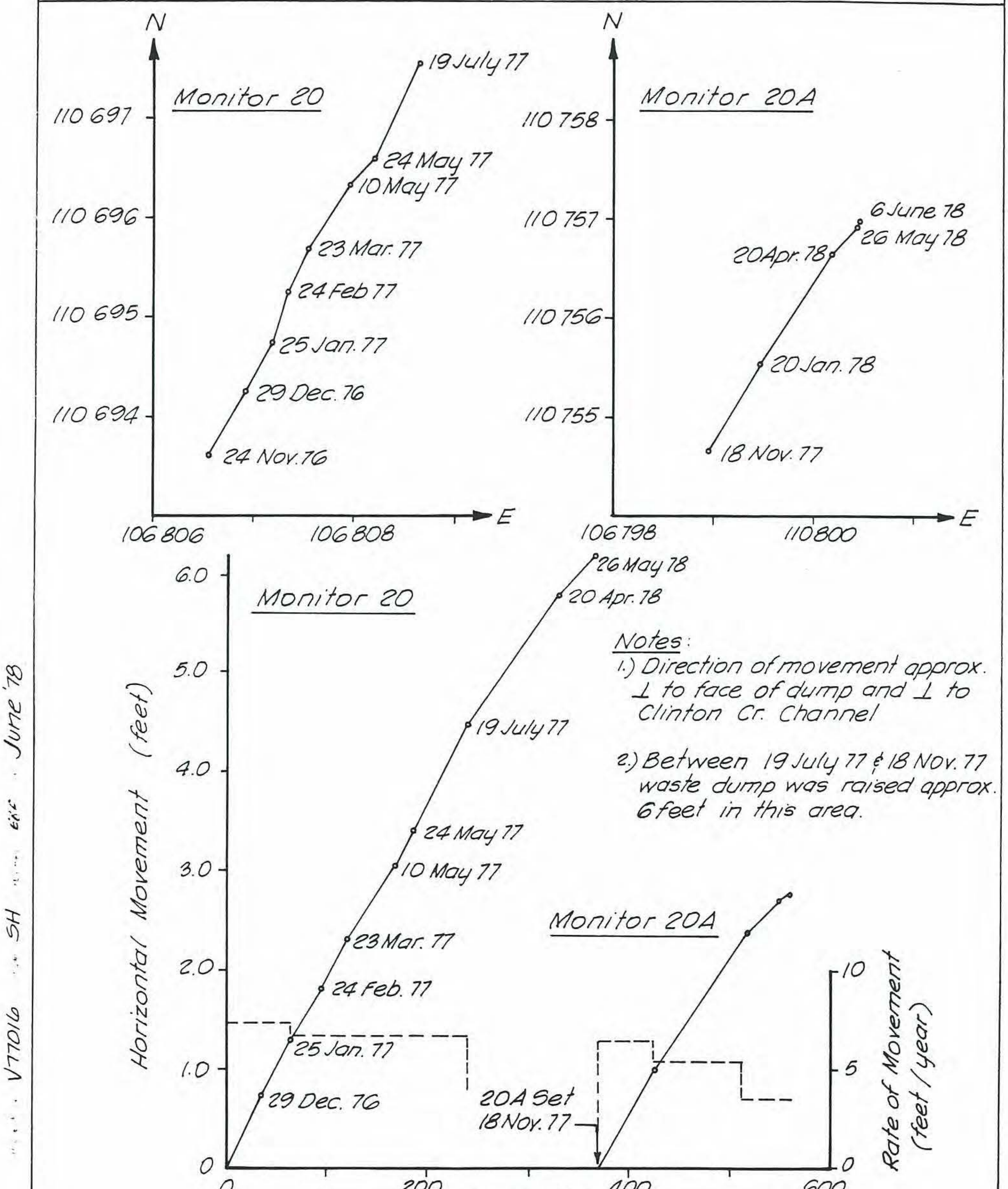




V77016 SH EBF June '78

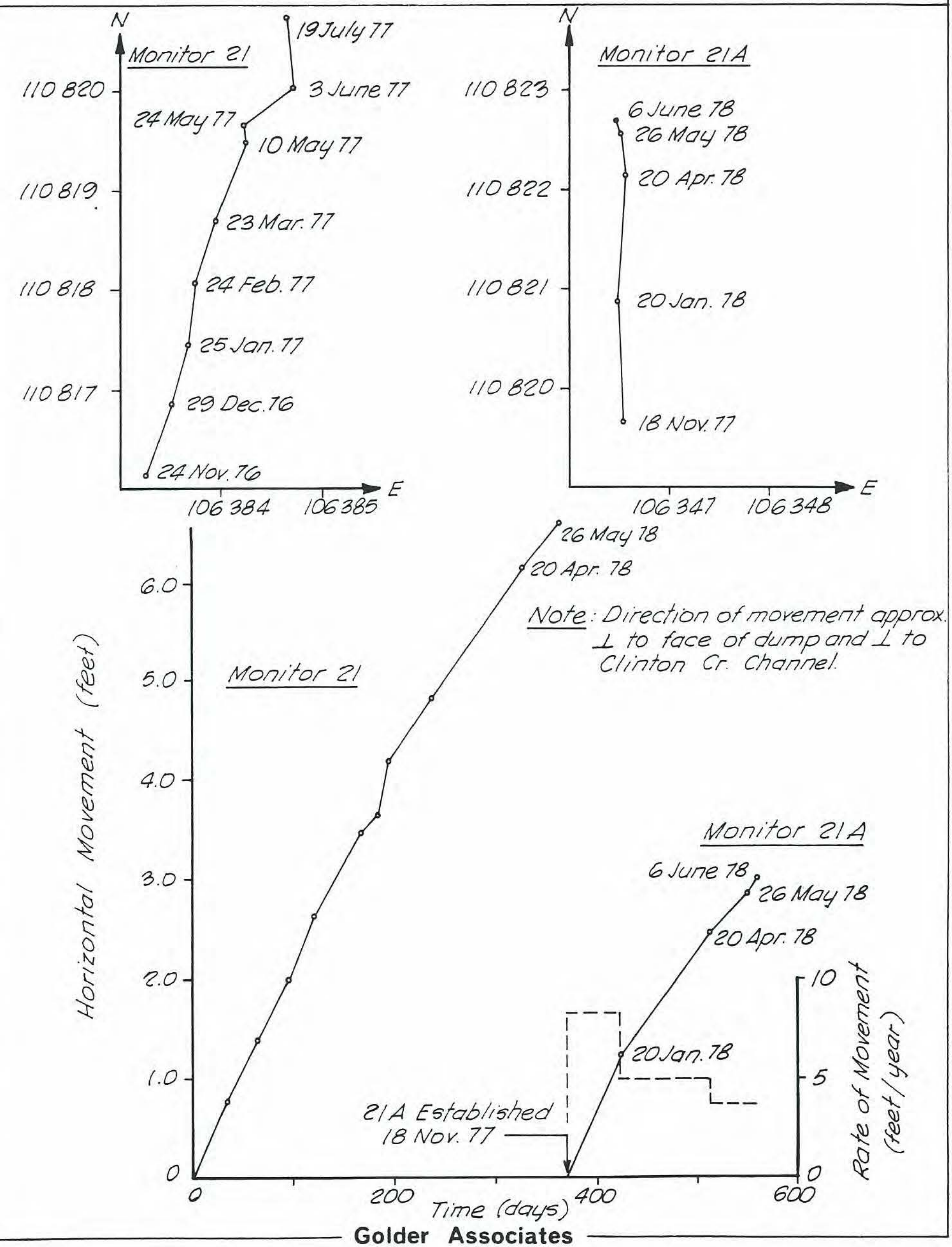
WASTE DUMP
HORIZONTAL MOVEMENT DATA
MONITOR 20

Figure C-2



WASTE DUMP
HORIZONTAL MOVEMENT DATA
MONITOR 21

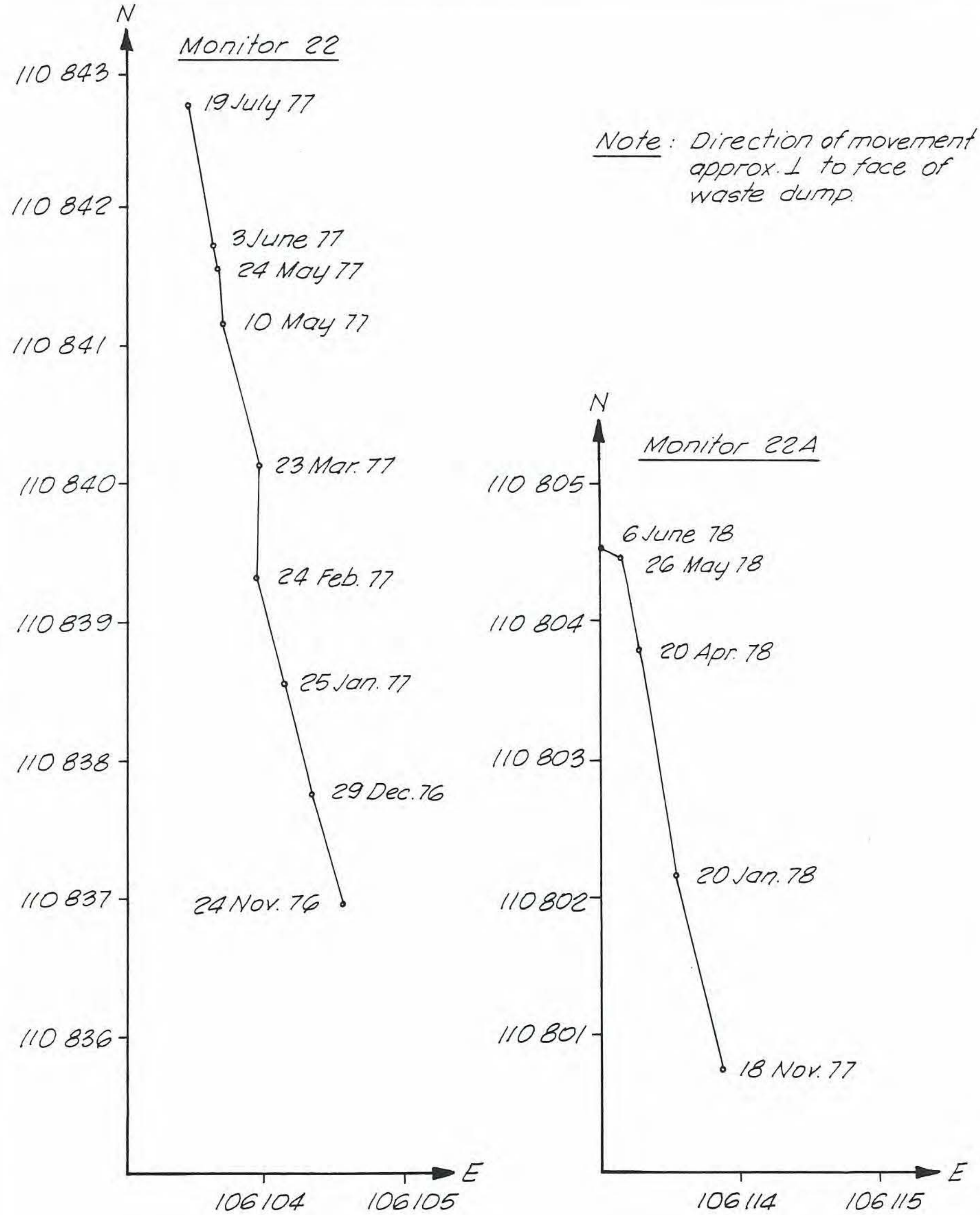
Figure C - 3



V77016 SH E&F June '78

WASTE DUMP
HORIZONTAL MOVEMENT DATA
MONITOR 22

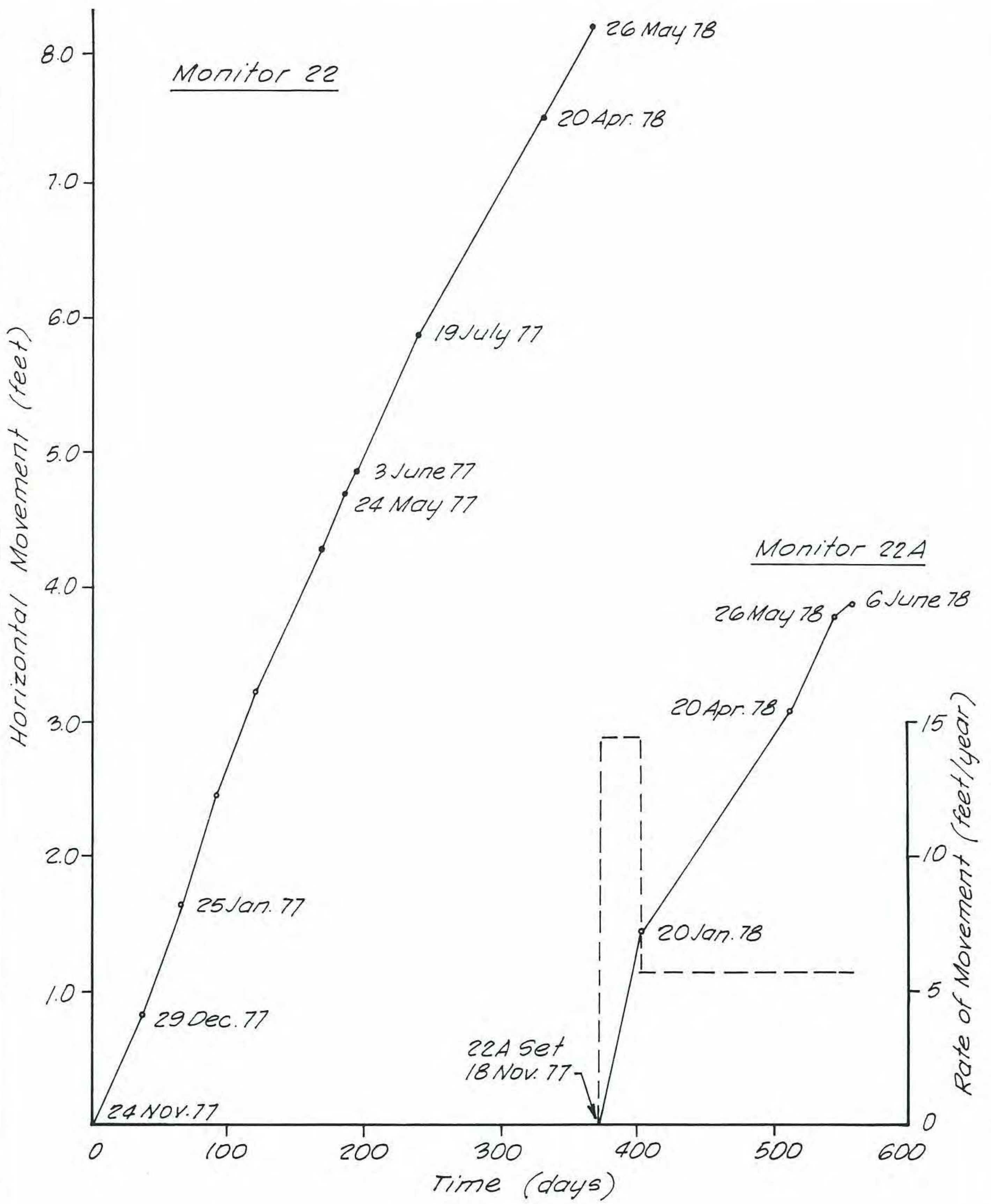
Figure C - 4



V77016 SH EKF June '78

WASTE DUMP
HORIZONTAL MOVEMENT DATA
MONITOR 22

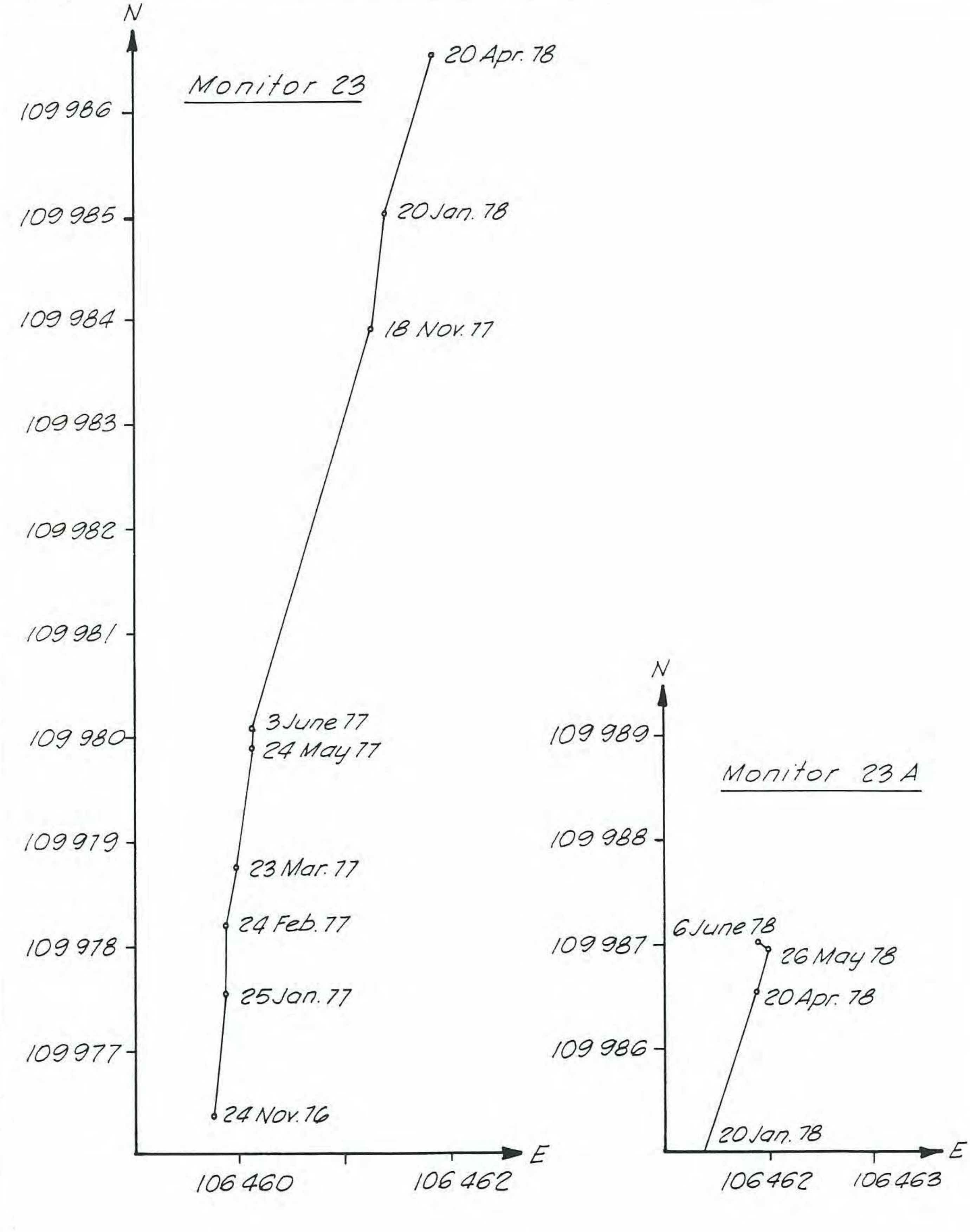
Figure C - 5



V77016 SH June '78

WASTE DUMP
HORIZONTAL MOVEMENT DATA
MONITOR 23

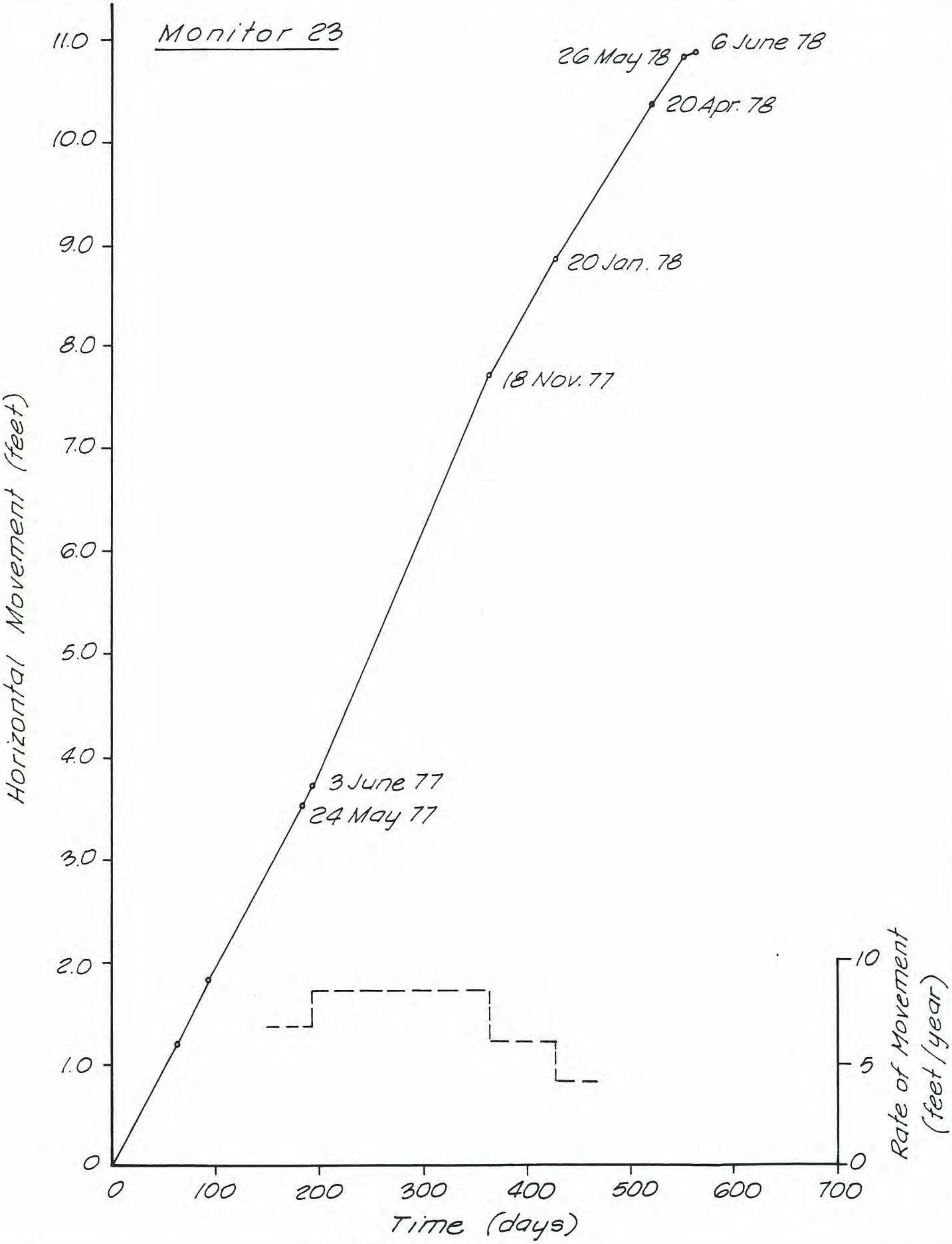
Figure C - 6



V77016 SH EBF June '78

WASTE DUMP
HORIZONTAL MOVEMENT DATA
MONITOR 23

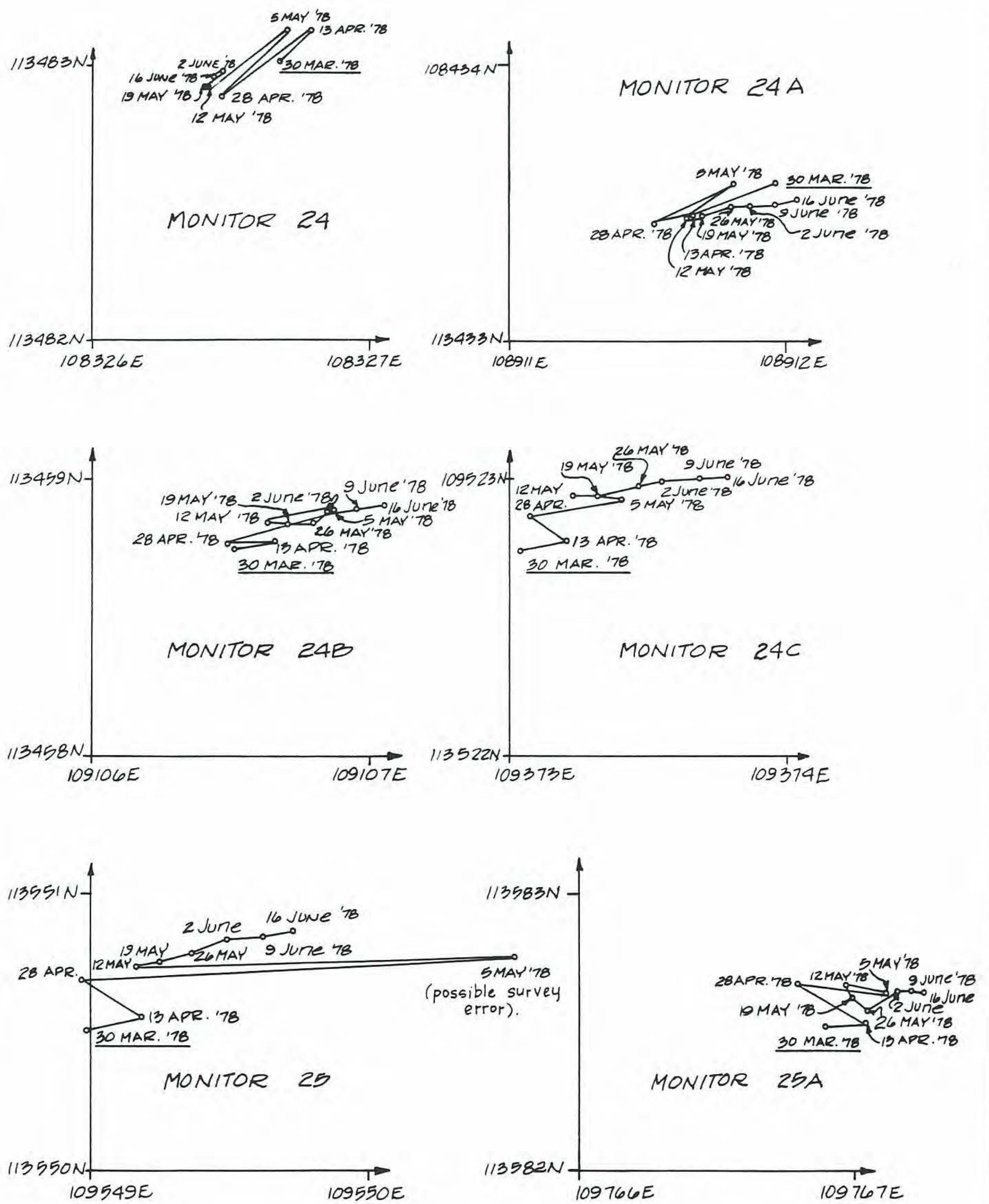
Figure C-7



V77016 SH June '78

Golder Associates

TAILING PILE
HORIZONTAL MOVEMENTS - FAILURE LOBE MONITORS Figure C-8
MARCH 30 TO JUNE 16, 1978

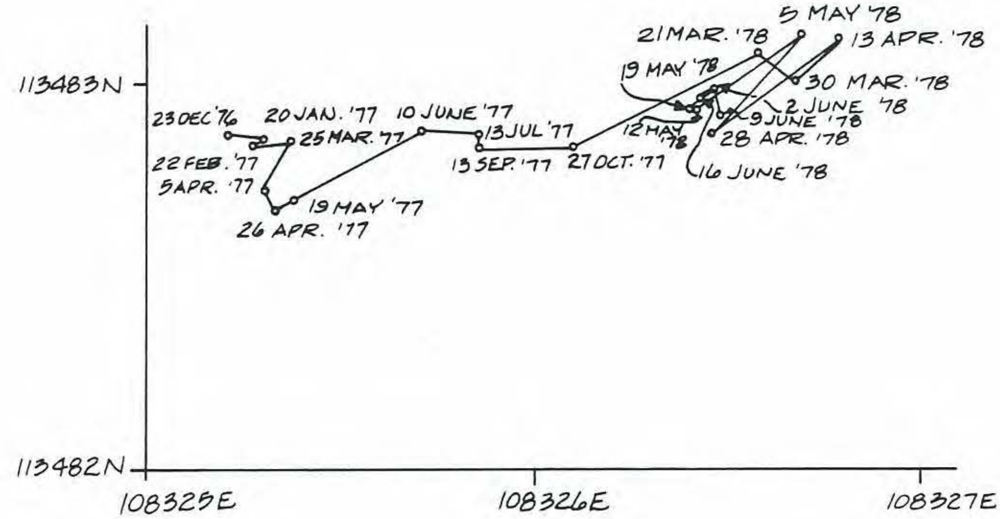


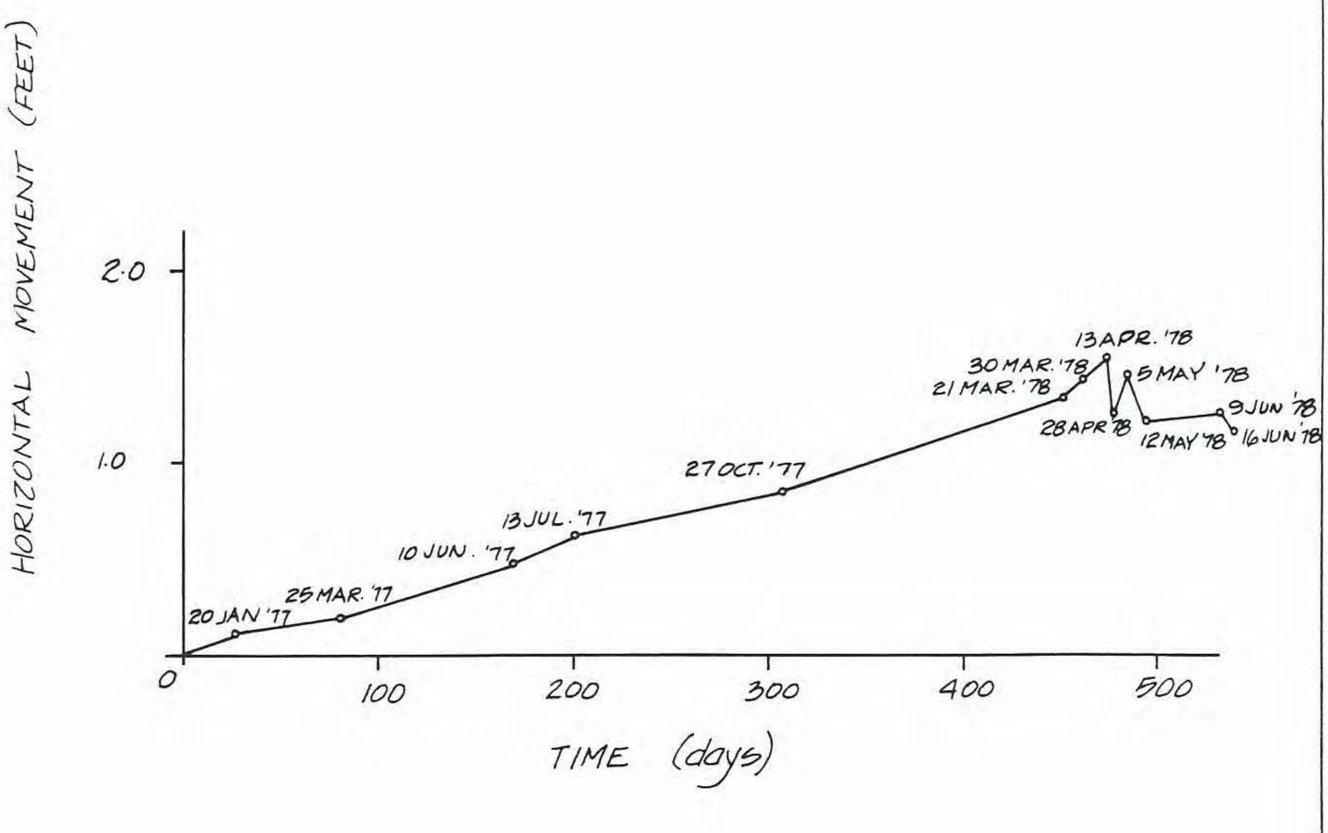
V77016 SMF

Golder Associates

TAILING PILE HORIZONTAL MOVEMENT DATA MONITOR 24

Figure C-9



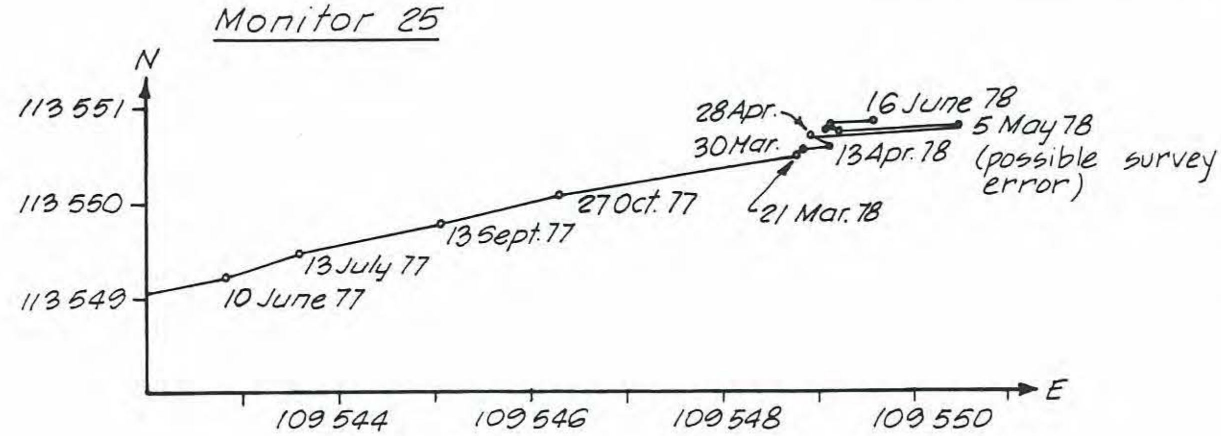


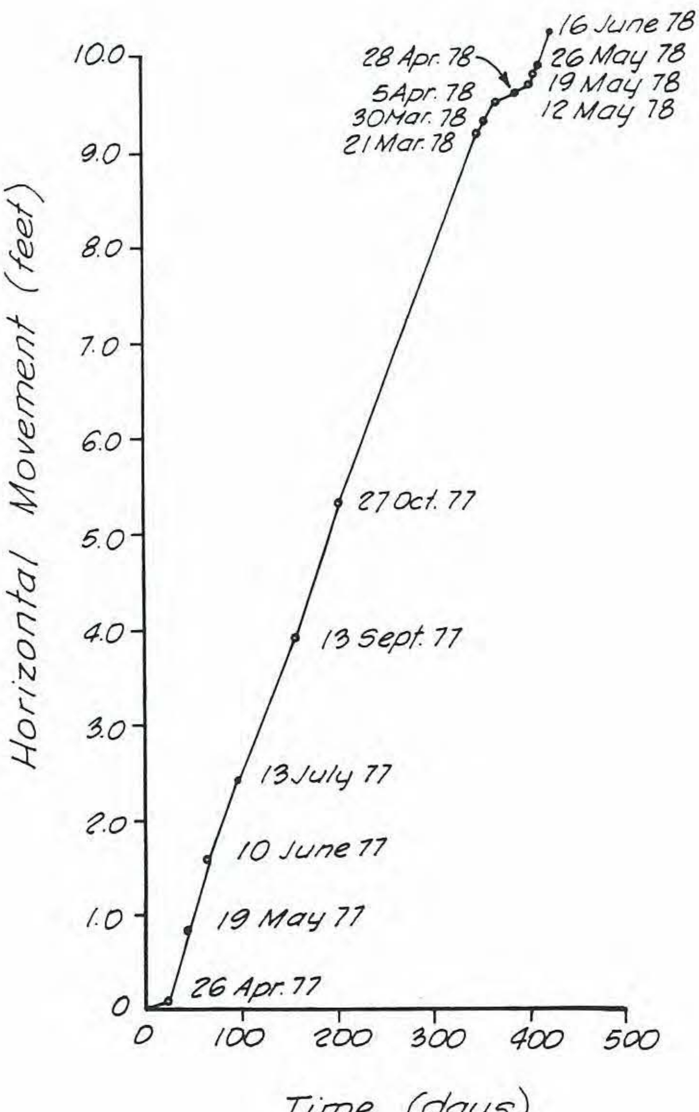
V77016 . SMF

Golder Associates

TAILING PILE
HORIZONTAL MOVEMENT DATA
MONITOR 25

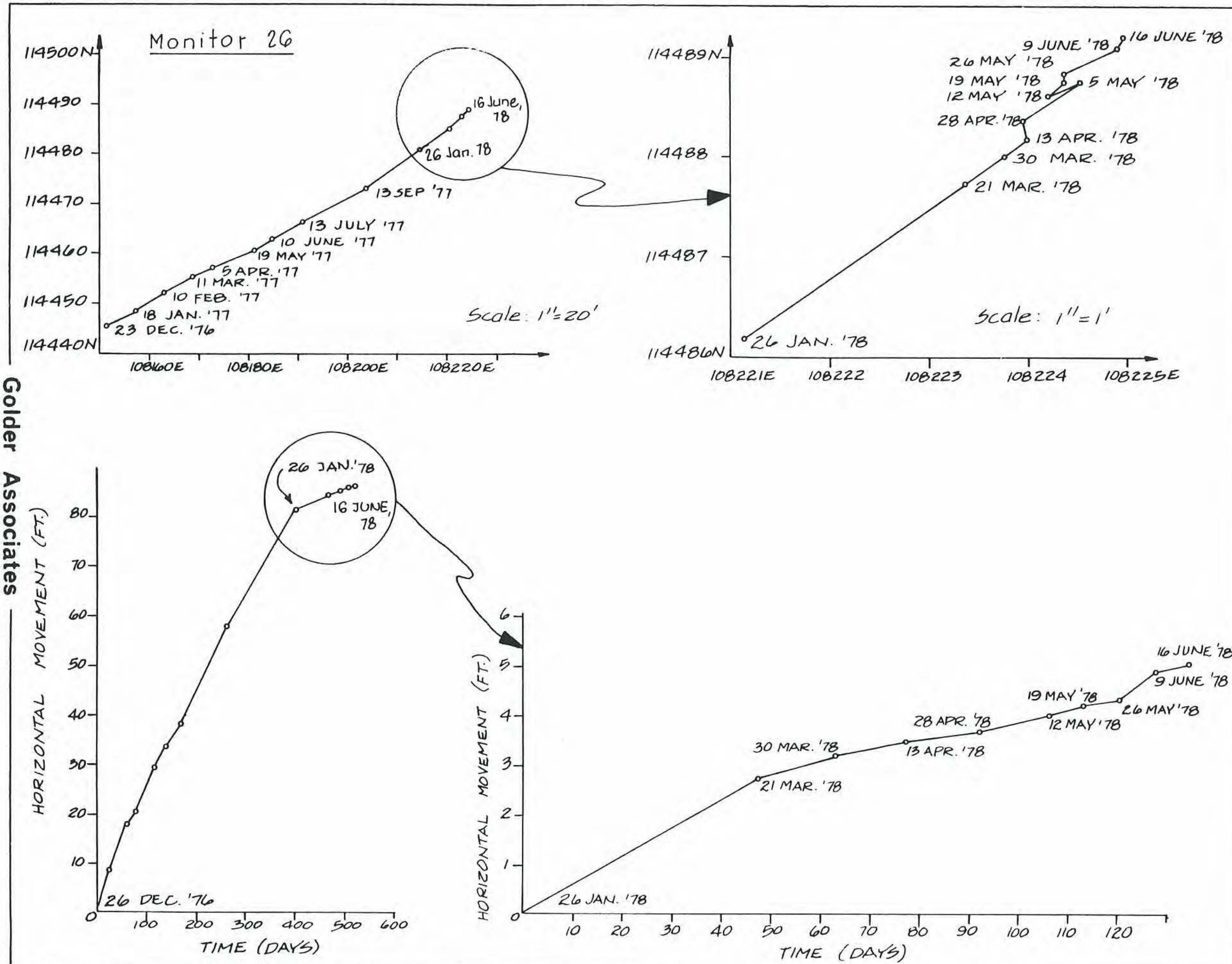
Figure C-10





V77016 SH June '78

V77016 SMF EBF June '78



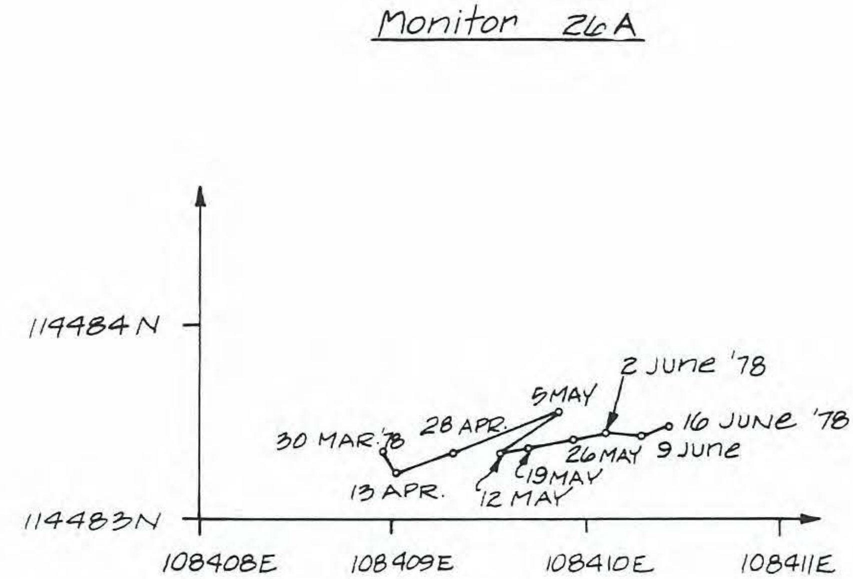
TAILING PILE
HORIZONTAL MOVEMENT DATA
MONITOR 26

Figure C-11

Golder Associates

TAILING PILE HORIZONTAL MOVEMENT DATA MONITOR 26A

Figure C - 12



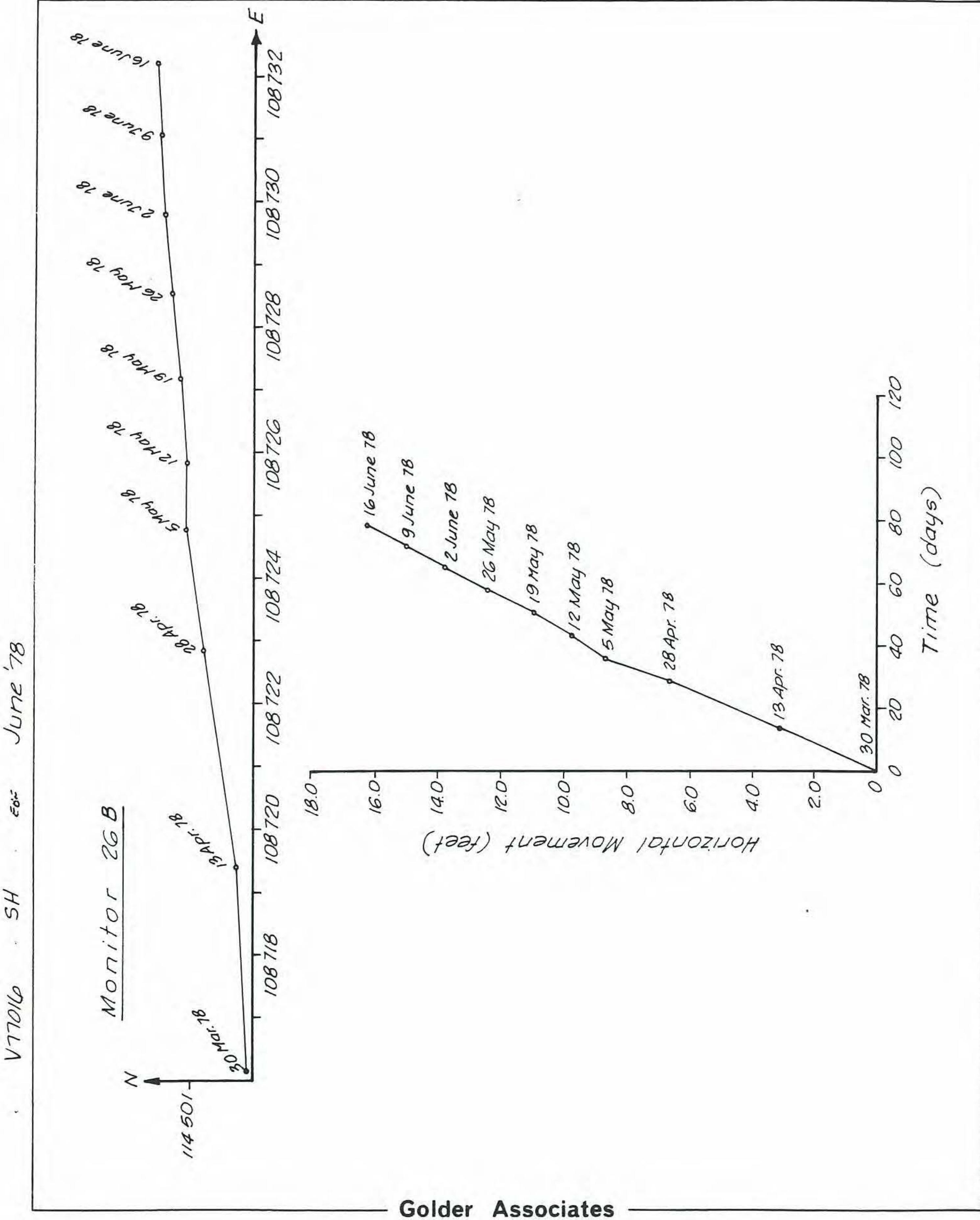
$$\frac{ds}{dt} = 0.014 \text{ ft/day}$$

(av. 5 May to 16 June '78

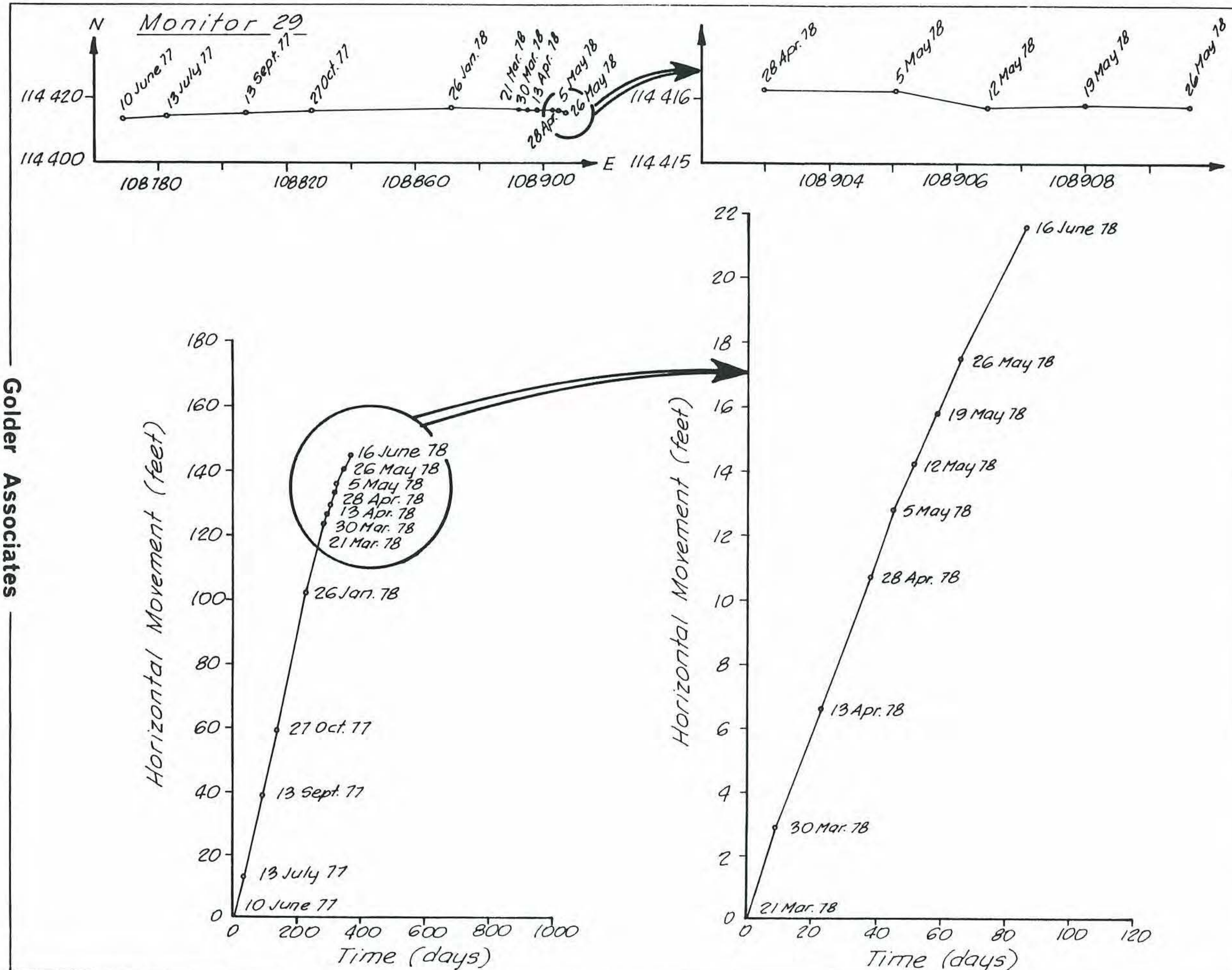
V77016 SMF ECE June '78

TAILING PILE
HORIZONTAL MOVEMENT DATA
MONITOR 26B

Figure C-13



V77016 SH June '78



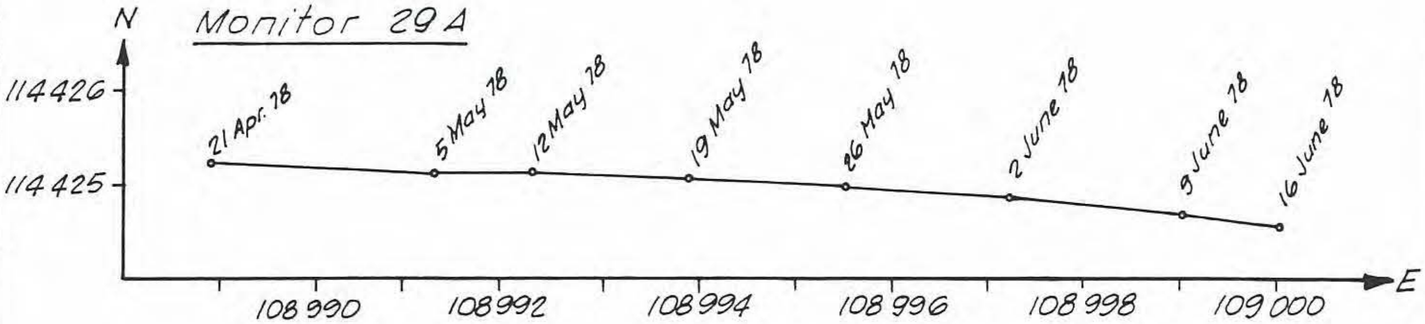
Golder Associates

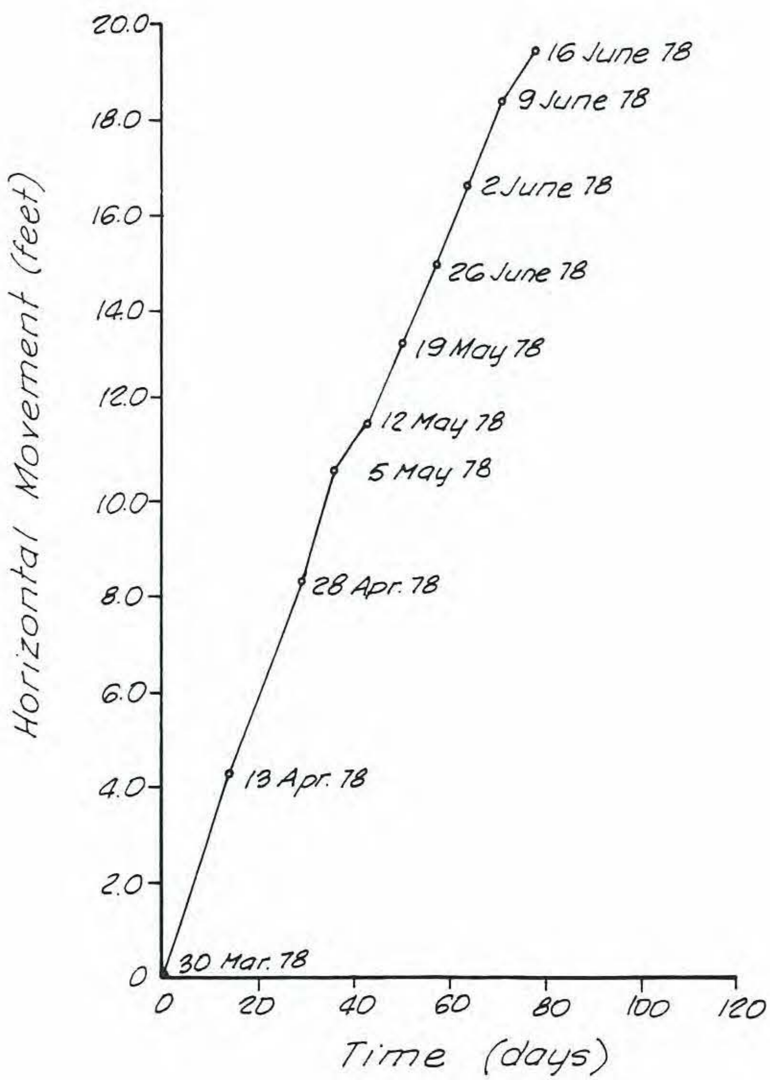
TAILING PILE
HORIZONTAL MOVEMENT DATA
MONITOR 29

Figure C-14

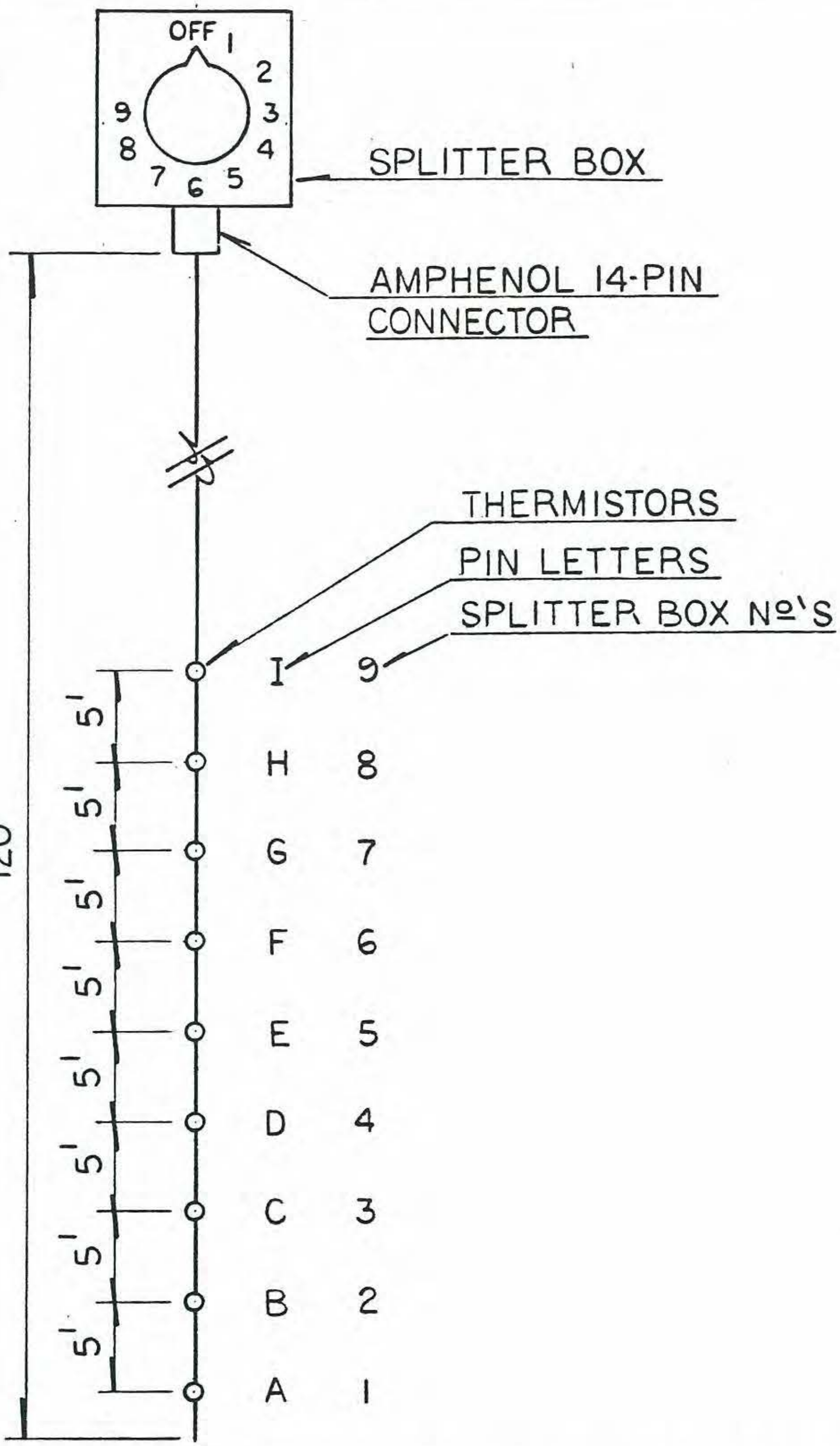
TAILING PILE
HORIZONTAL MOVEMENT DATA
MONITOR 29A

Figure C - 15





V77016 SH EBF June '78



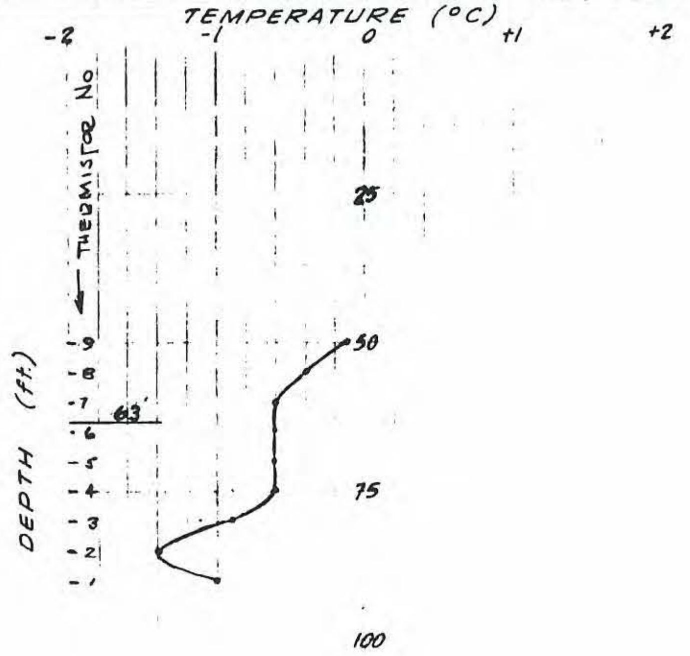
REVISIONS			CANTECH CONTROLS LTD. CALGARY—ALBERTA			
NO.	REVISED BY	DATE	120' THERMISTOR CABLE-ASS'Y.			
1			DESIGNED-	DRAWN- NM	SCALE- ✓	DATE- MAR '78
2			CHKD.-	APPR.-		
3			PROJECT NO.- 22-60028		DRWG. NO.- A 10172	
4						
5						
6						
7						
8						

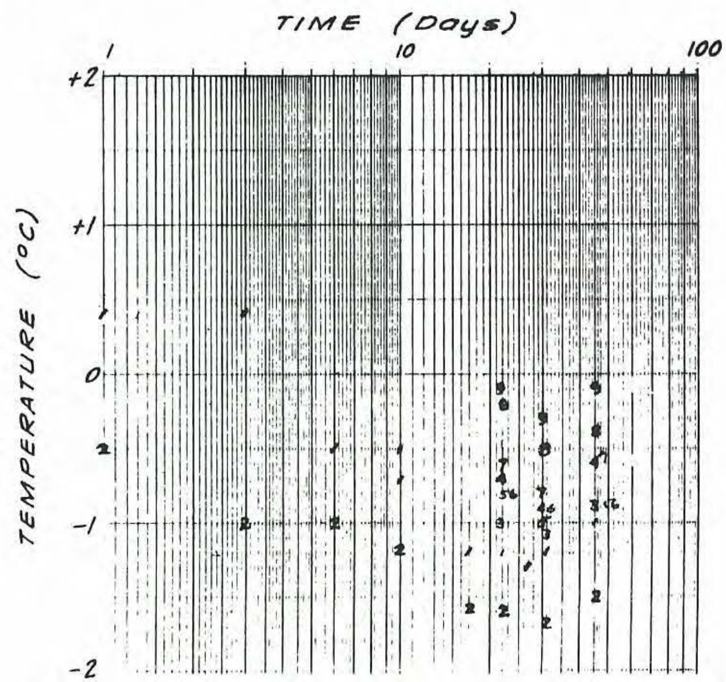
RECORD OF THERMISTOR DATA

THERMISTOR INSTALLATION No. 1
DATE OF INSTALLATION 4 April 78 (94)
LOCATION N 109626.75, E107872.04

Date of Temperature Measurement/Number of Days Subsequent to Installation

Thermistor No.	Depth (ft.)	4 Apr	5 Apr	7 Apr	10 Apr	14 Apr	21 Apr	1 MAY	5 MAY	15 MAY	19 MAY	2 JUNE	19 June			
			1	3	6	10	17	27	31	41	45	59	76			
9	50	+0.5	+0.5	+0.5	+0.5	+0.3	-0.1	-0.3	-0.3	-0.1	-0.1	-0.1	-0.1			
8	55	+1.5	+0.5	+0.5	+0.5	+0.2	-0.2	-0.5	-0.5	-0.4	-0.4	-0.4	-0.4			
7	60	+0.6	+0.5	+0.3	+0.2	-0.3	-0.6	-0.8	-0.8	-0.6	-0.6	-0.6	-0.6			
6	65	+0.5	0.0	0.0	0.0	-0.4	-0.8	-0.9	-0.9	-0.9	-0.6	-0.6	-0.6			
5	70	+0.3	0.0	0.0	0.0	-0.5	-0.8	-1.0	-1.0	-0.9	-0.6	-0.6	-0.6			
4	75	+0.5	0.0	0.0	0.0	-0.4	-0.7	-0.9	-0.9	-0.6	-0.6	-0.6	-0.6			
3	80	+0.5	0.0	0.0	-0.4	-0.6	-1.0	-1.1	-1.1	-0.9	-0.9	-0.9	-0.9			
2	85	0.0	-0.5	-1.0	-1.0	-1.2	-1.6	-1.7	-1.7	-1.5	-1.5	-1.5	-1.4			
1	90	+1.5	+0.4	+0.4	-0.5	-0.7	-1.2	-1.3	-1.2	-1.0	-1.1	-1.0	-1.0			



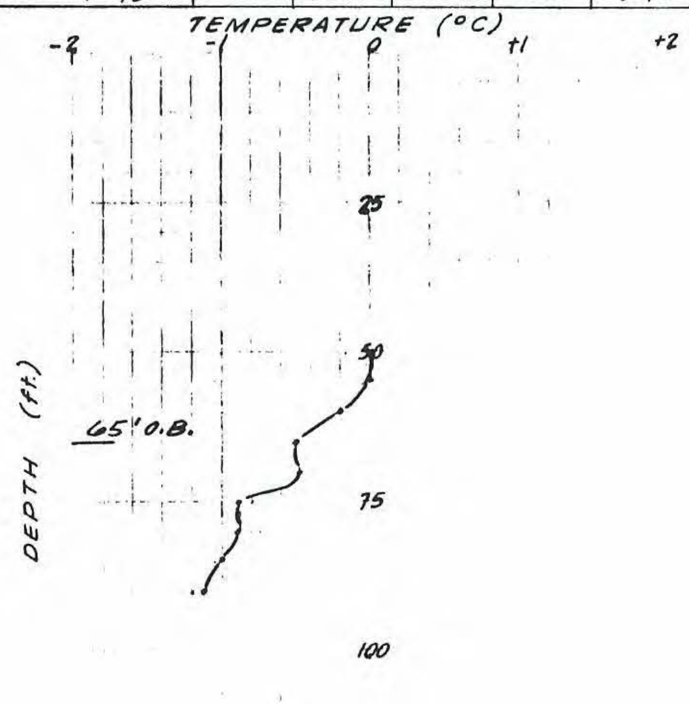


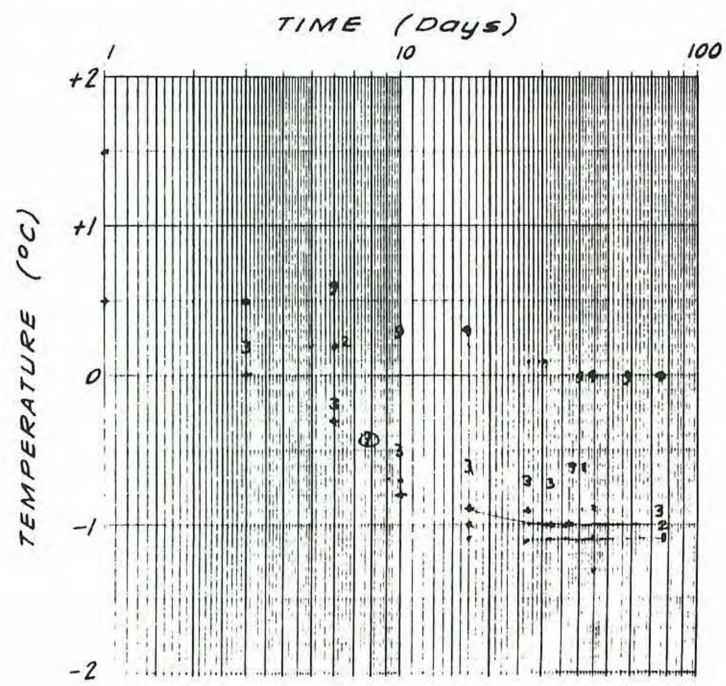
RECORD OF THERMISTOR DATA

THERMISTOR INSTALLATION No. 2
DATE OF INSTALLATION 4 APR 78 (84)
LOCATION N. 109692.92, E.107513.05

Date of Temperature Measurement/Number of Days Subsequent to Installation

Thermistor No.	Depth (ft.)	4 APR	5 APR	7 APR	10 APR	14 APR	21 APR	1 MAY	6 MAY	12 MAY	15 MAY	19 MAY	2 JUNE	19 June		
			1	3	6	10	17	27	32	38	41	45	59	76		
9	50		+0.5	+0.5	+0.6	+0.3	+0.3	+0.1	+0.1	0.0	0.0	0.0	0.0	0.0		
8	55		+1.0	+0.5	+0.5	+0.3	+0.2	0.0	0.0	0.0	0.0	-0.1	0.0	0.0		
7	60		0.0	+0.4	+0.2	+0.1	0.0	-0.1	-0.1	-0.1	-0.1	-0.4	-0.2	-0.2		
6	65		0.0	+0.2	+0.1	-0.1	-0.1	-0.4	-0.4	-0.4	-0.5	-0.5	-0.5	-0.5		
5	70		+1.0	+0.3	+0.1	-0.2	-0.3	-0.4	-0.4	-0.4	-0.4	-0.6	-0.5	-0.5		
4	75		+1.2	+0.4	+0.2	-0.3	-0.5	-0.6	-0.7	-0.6	-0.6	-0.9	-0.9	-0.9		
3	80		+0.5	+0.2	-0.2	-0.5	-0.6	-0.7	-0.7	-0.6	-0.6	-0.9	-0.9	-0.9		
2	85		+0.5	0.0	-0.3	-0.8	-0.9	-0.9	-1.0	-1.0	-1.0	-1.1	-1.0	-1.0		
1	90		+1.5	+0.5	+0.2	-0.7	-1.0	-1.1	-1.1	-1.0	-1.1	-1.3	-1.2	-1.1		



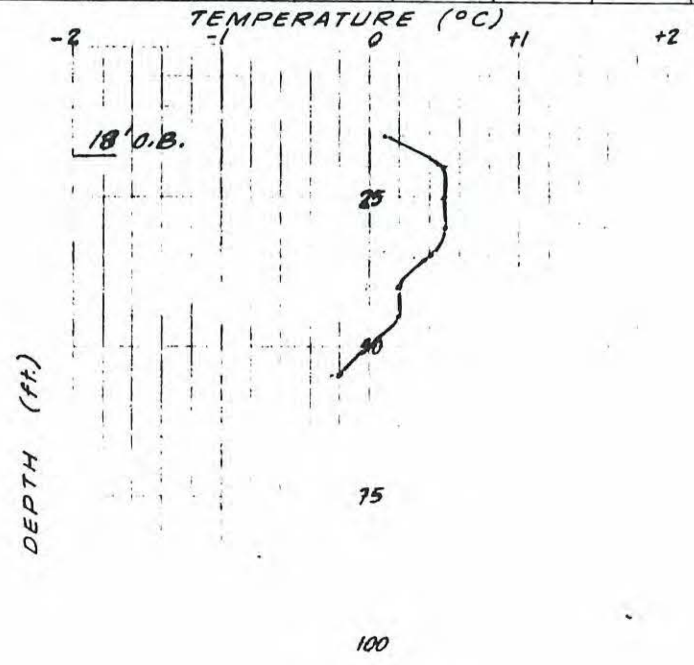


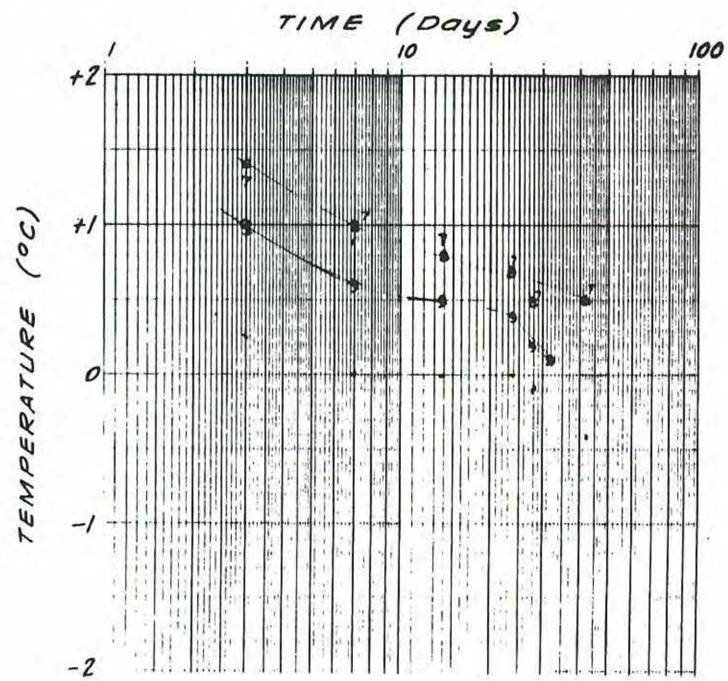
RECORD OF THERMISTOR DATA

THERMISTOR INSTALLATION No. 3
DATE OF INSTALLATION 7APR. 78 (97)
LOCATION (ON DUMP) N.109647.94
E.106690.27

Date of Temperature Measurement/Number of Days Subsequent to Installation

Thermistor No.	Depth (ft.)			7APR	10 APR	14APR	21APR	1 MAY	5MAY	19MAY	2JUNE	19 June				
					3	7	14	24	28	42	56	73				
9	15			+1.0	+1.0	+0.6	+0.5	+0.4	+0.2	+0.1	+0.1	+0.1				
8	20			+1.5	+1.4	+1.0	+0.8	+0.7	+0.5	+0.5	+0.4	+0.5				
7	25			+3.5	+1.3	+1.0	+0.9	+0.7	+0.5	+0.5	+0.4	+0.5				
6	30			+4.0	+1.4	+1.0	+0.8	+0.7	+0.5	+0.5	+0.5	+0.5				
5	35			+3.5	+1.1	+0.7	+0.6	+0.5	+0.3	+0.3	+0.3	+0.4				
4	40			+4.0	+0.9	+0.5	+0.4	+0.3	+0.2	+0.2	+0.2	+0.2				
3	45			+1.5	+0.5	+0.2	+0.3	+0.2	+0.1	+0.1	+0.1	+0.2				
2	50			+4.0	+0.25	0.0	+0.2	+0.2	0.0	0.0	0.0	0.0				
1	55			+5.0	+0.25	0.0	0.0	0.0	-0.1	-0.4	-0.4	-0.2				





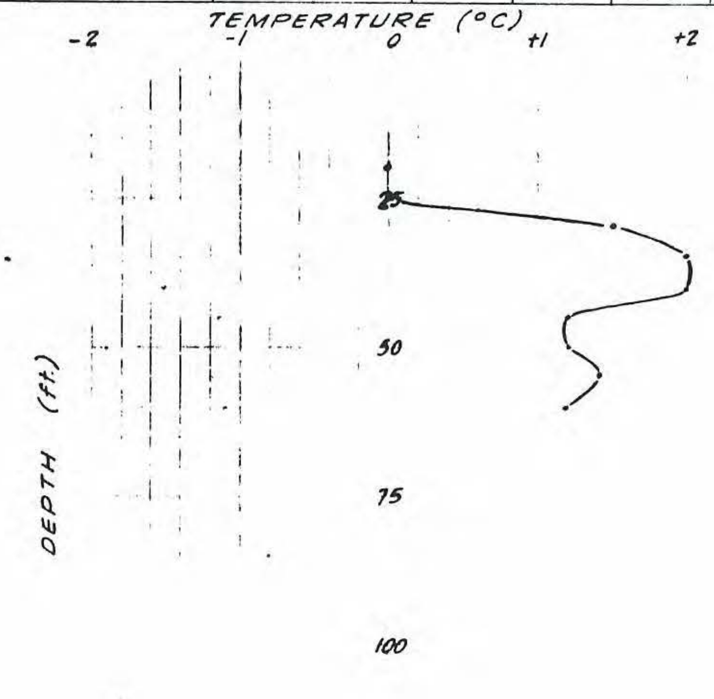
RECORD OF THERMISTOR DATA

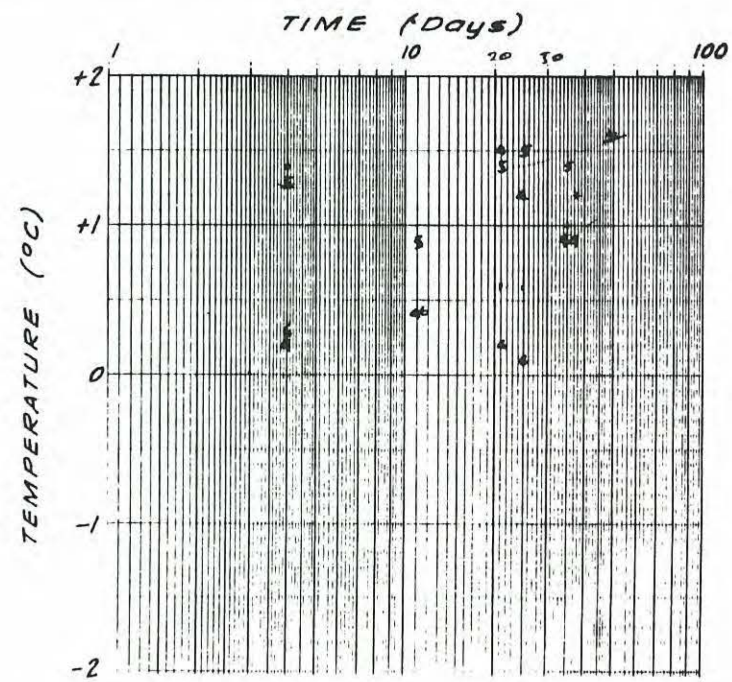
THERMISTOR INSTALLATION No. 4
DATE OF INSTALLATION 10 APR. 78
LOCATION N.110917.76, E.107487.30

(IN WATER)

Date of Temperature Measurement/Number of Days Subsequent to Installation

Thermistor No.	Depth (ft.)				10 APR	14 APR	21 APR	1 MAY	5 MAY	15 MAY	17 MAY	19 MAY	2 JUNE	19 June		
						4	11	21	25	35	37	39	53	70		
9	20				+2.5	+0.2	+0.2	0.0	0.0	-0.4	-0.4	0.0	-0.1	0.0		
8	25				+2.4	+0.2	+0.2	0.0	-0.1	-0.4	-0.4	-0.1	-0.2	0.0		
7	30				+2.0	+0.2	+0.3	+0.1	0.0	-0.1	-0.1	0.0	0.0	+1.5		
? 6	35				+2.3	+0.3	+0.4	+0.2	+0.1	+2.9	+2.9	+2.2	+1.6	+2.0		
5	40				+2.0	+1.3	+0.9	+1.4	+1.5	+1.4	+1.4	+1.6	+1.6	+2.0		
4	45				+2.4	+0.2	+0.4	+1.5	+1.2	+0.9	+0.9	+1.2	+0.9	+1.2		
3	50				+2.5	+0.25	+1.7	+0.8	+1.2	+1.5	+1.5	+2.4	+1.2	+1.2		
2	55				+2.3	+1.0	+1.7	+2.0	+1.6	+1.0	+1.0	+1.4	+1.1	+1.4		
1	60				+1.6	+1.4	+0.9	+0.6	+0.6	+1.0	+1.0	+1.2	+0.9	+1.2		





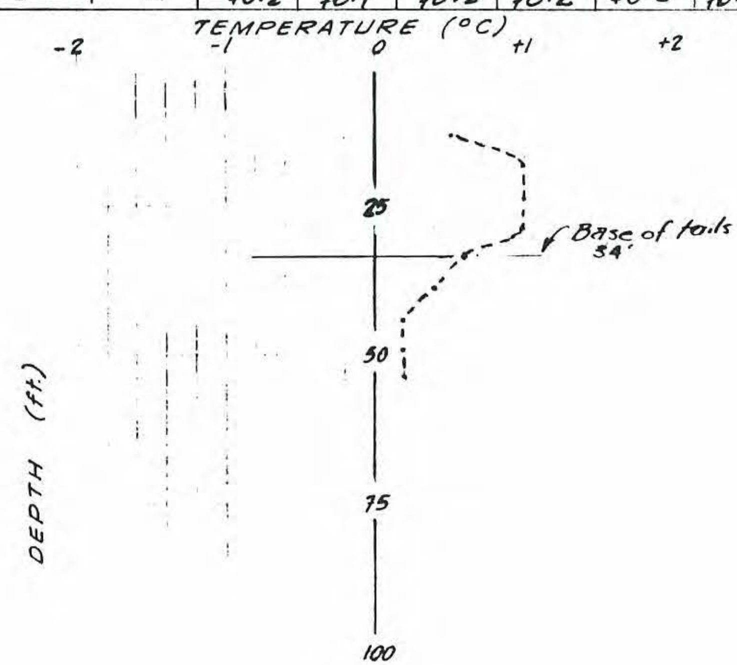
RECORD OF THERMISTOR DATA

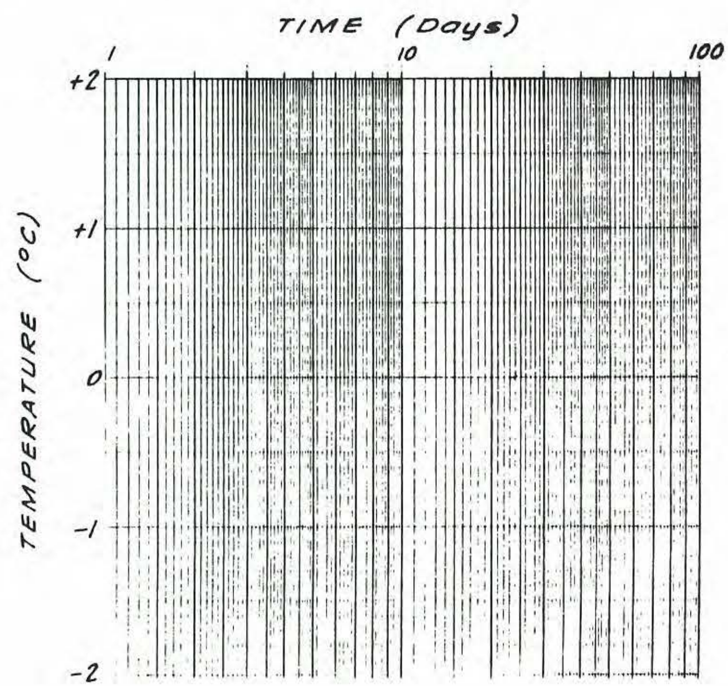
THERMISTOR INSTALLATION No. 5 (BH 12)
DATE OF INSTALLATION 9 MAY 78 (129)
LOCATION (TAILING PILE) N.113521.34, E.107717.23

TAILS IN PLACE 4.5 YRS

Date of Temperature Measurement/Number of Days Subsequent to Installation

Thermistor No.	Depth (ft.)	11 MAY	17 MAY	19 MAY	26 MAY	5 JUNE	19 June								
		2	8	10	17	27	41								
9	14	+1.1	+0.5	+0.5	+0.5	+0.5	+0.5								
8	19	+1.7	+1.0	+1.1	+1.1	+1.0	+1.0								
7	24	+1.7	+1.1	+1.1	+1.1	+1.0	+1.0								
6	29	+1.5	+1.0	+1.0	+1.0	+1.0	+1.0								
* 5	34	+1.1	+0.6	+0.7	+0.7	+0.6	+0.6								
4	39	+0.6	+0.4	+0.4	+0.4	+0.4	+0.4								
3	44	+0.3	+0.2	+0.2	+0.2	+0.2	+0.2								
2	49	+0.2	+0.1	+0.2	+0.2	+0.2	+0.2								
1	54	+0.2	+0.1	+0.2	+0.2	+0.2	+0.2								



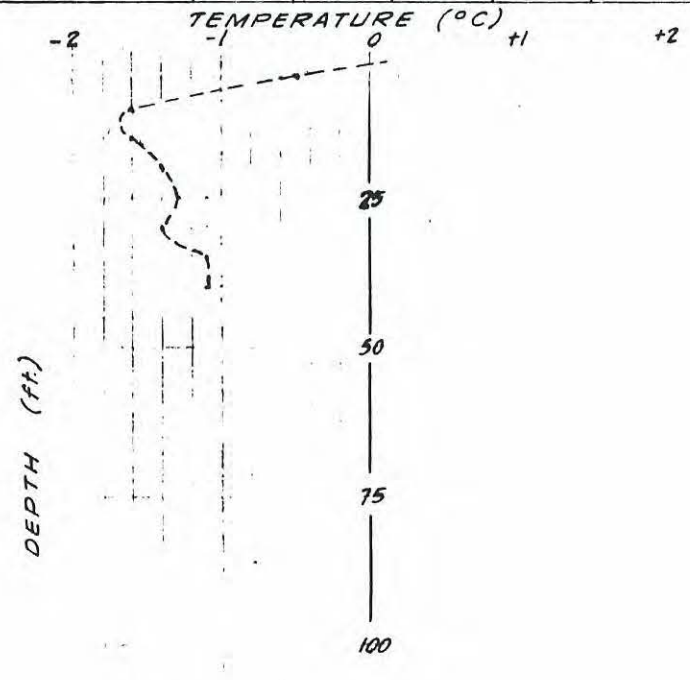


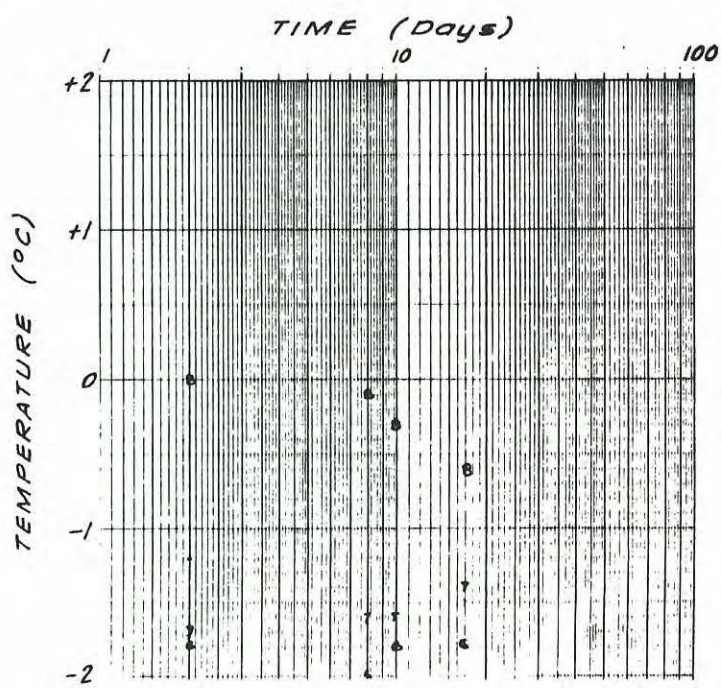
RECORD OF THERMISTOR DATA

THERMISTOR INSTALLATION No. 6 (BH-13)
DATE OF INSTALLATION 9 MAY 78 (129)
LOCATION ~ 200' NORTH OF TAILING PILE N. 115070.50
IN UNDISTURBED GROUND E. 107162.86

Date of Temperature Measurement/Number of Days Subsequent to Installation

Thermistor No.	Depth (ft.)	11 MAY	17 MAY	19 MAY	26 MAY	5 JUNE	19 June									
		2	8	10	17	27	41									
9	0	+1.7	+6.6	+5.4	+7.5	+8.4	+0.1									
8	5	0.0	-0.1	-0.3	-0.6	-0.6	-0.5									
7	10	-1.7	-1.6	-1.6	-1.4	-1.4	+1.6									
6	15	-1.8	-2.0	-1.8	-1.8	-1.6	-1.6									
5	20	-1.2	-1.4	-1.4	-1.4	-1.4	-1.4									
4	25	-1.0	-1.0	-1.1	-1.1	-1.1	-1.3									
3	30	-1.1	-1.1	-1.1	-1.1	-1.1	-1.4									
2	35	-1.1	-1.1	-1.0	-1.0	-1.1	-1.1									
1	40	-1.0	-1.0	-1.0	-1.0	-1.0	-1.1									



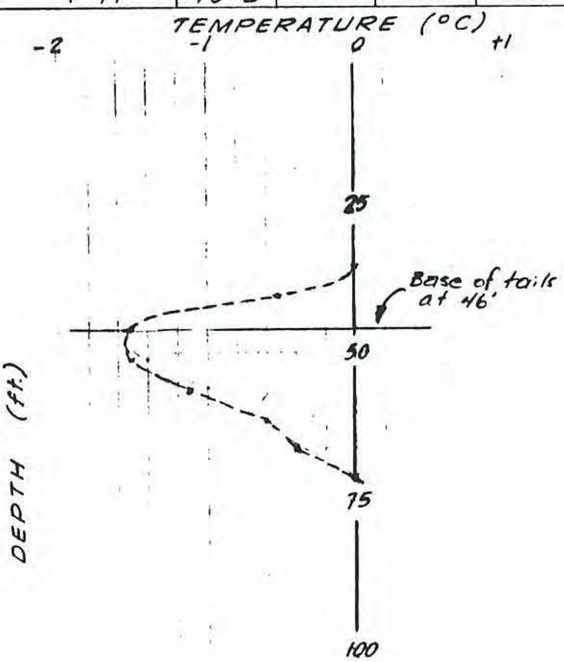


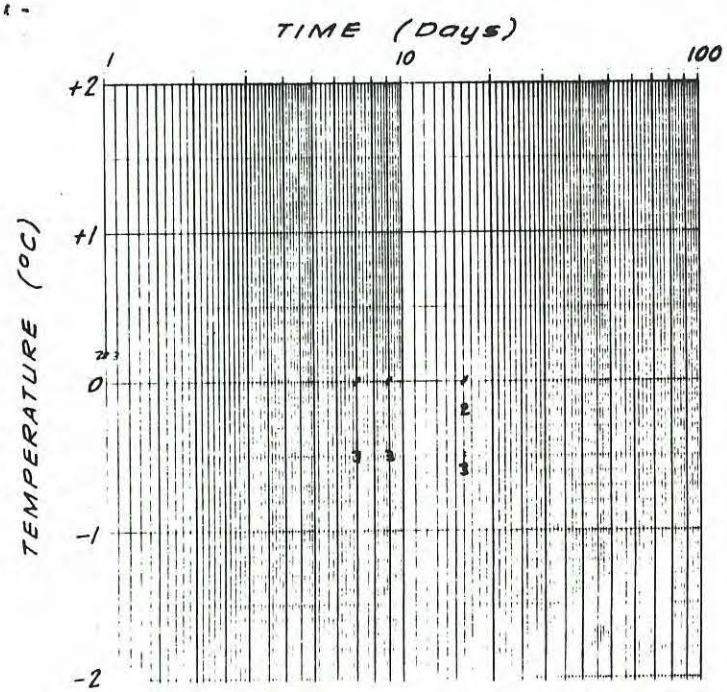
RECORD OF THERMISTOR DATA

THERMISTOR INSTALLATION No. 7 (8.H.14)
DATE OF INSTALLATION 10 MAY 70 130
LOCATION (TAILING PILE) N.114965.16, E.108473.94
TAILS IN PLACE 1 to 2 YRS

Date of Temperature Measurement/Number of Days Subsequent to Installation

Thermistor No.	Depth (ft.)	11MAY	17MAY	19MAY	26MAY	5JUNE	19June									
		1	7	9	16	26	40									
9	31	+2.1	-0.1	0.0	0.0	0.0										
8	36	+2.2	+0.2	+0.1	+0.1	+0.1	0.0									
7	41	+0.3	-0.2	-0.2	-0.4	-0.4	-0.5									
* 6 -	46	+0.2	-1.9	-1.6	-1.5	-1.4	-1.5									
5	51	+0.1	-1.5	-1.5	-1.4	-1.4	-1.5									
4	56	+0.2	-1.0	-1.0	-1.0	-1.0	-1.1									
3	61	+0.2	-0.5	-0.5	-0.6	-0.6	-0.6									
2	66	+0.2	0.0	0.0	-0.2	-0.3	-0.4									
1	71	+0.2	0.0	0.0	0.0	0.0	0.0									



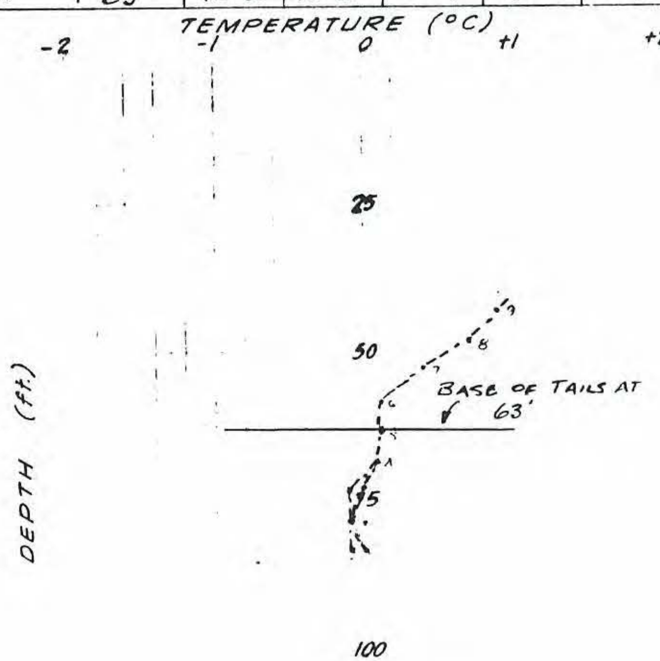


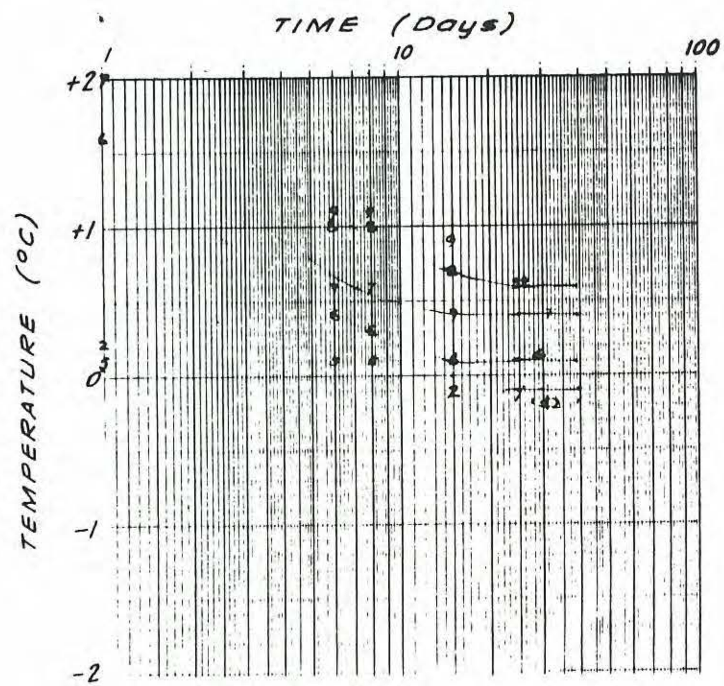
RECORD OF THERMISTOR DATA

THERMISTOR INSTALLATION No. 8 (B.H. 16)
DATE OF INSTALLATION 11 MAY 78 (131)
LOCATION TAILING PILE - 1974 FAILURE LOBE N.113481.47 E.108871.16
TAILS IN PLACE ~4 YRS

Date of Temperature Measurement/Number of Days Subsequent to Installation

Thermistor No.	Depth (ft.)	12 MAY	17 MAY	19 MAY	26 MAY	5 JUNE	19 June
		1	6	8	15	25	39
9	43	+3.0	+1.1	+1.1	+0.9	+0.6	+0.6
8	48	+2.4	+1.0	+1.0	+0.7	+0.6	+0.6
7	53	+2.0	+0.6	+0.6	+0.4	+0.4	+0.4
6	58	+1.6	+0.4	+0.3	+0.1	+0.1	+0.1
* 5	63	+0.1	+0.1	+0.1	+0.1	+0.1	+0.1
4	68	+0.1	+0.1	+0.1	+0.1	+0.1	+0.1
3	73	+0.1	+0.1	+0.1	0.0	-0.1	-0.1
2	78	+0.2	+0.1	+0.1	-0.1	-0.1	-0.1
1	83	+0.2	+0.3	+0.4	0	-0.1	-0.1





APPENDIX E

Horizontal Movements, Crack Patterns & Implied Stresses

As shown on Figure 3, the azimuth of the horizontal movement factors form a general pattern which fans outward from the central region of the dump toward the perimeter. The azimuth of the horizontal movement factors indicate that the primary direction of movement is toward the Clinton channel.

The surface of the Clinton dump is characterized by a series of prominent cracks which are clearly visible on aerial photographs. Characteristically, these cracks are simple tension features which, in general, do not show any evidence of differential vertical displacement from one side of the crack to the other. In some cases, the tension cracks form a zone which extends over a width of several feet. This tension zone gives rise to graben-like features on the surface of the dump. Typically, the tension cracks and graben-like features are aligned roughly perpendicular to the Clinton channel, and approximately parallel to the azimuth of the horizontal movement vectors. The mechanism of development of these prominant cracks is explained in the following paragraphs.

Consider three points, A, B, and C on the surface of the dump. The movement vectors for these three points over an interval of time, Δt, are as illustrated on Figure E-1(b). In the following discussion, the absolute movements of the points are considered to occur relative to the Cartesian coordinates x and y as illustrated in Figure E-1(a). Relating the coordinate system to the Clinton dump, the y-axis represents north.

The movement vectors clearly indicate that the movements are occurring predominantly in the y-direction. For example, at point A, the movement in the y-direction is 9 times greater than the movement in the x-direction. Similarly, at point C the movement in the y-direction is twice as large as the movement in the x-direction.

Although the absolute movements of points A, B, and C are predominently in the y-direction, the movements of the three points relative to one another are predominantly in the x-direction. Figure E-1 (c) shows the movement vectors of points A and C relative to point B. The movement of point A relative to point C is illustrated on Figure E-1(d). By the end of the time interval Δt, points A, B, and C have all moved further apart relative to one another, with the result that stretching has occurred between these points. This stretching could be expected to result in development of tension cracks on the ground surface. The alignment of these tension cracks could be expected to be approximately perpendicular to the relative movement vectors, that is approximately parallel to the azimuth of the vectors of absolute movement.

Figure E-2 shows a 1976 airphoto of the Clinton dump with some of the prominent tension cracks highlighted to facilitate reproduction. A sketch of the Clinton dump drawn to the same scale as the aerial photograph, and showing the crack patterns, together with the azimuth of the horizontal movement vectors that developed during late 1976 and early 1977 is also shown on the figure. The similarity between the azimuth of the horizontal movement vectors and the azimuth of the surface cracks is readily apparent.

Large segments of the surface of the dump are approximately level. Within these areas, the major principal stress planes are approximately horizontal (1).

The presence of the cracks on the surface of the dump indicate that tension strains have occurred at depth below the surface with the result that the horizontal stresses have been reduced to the active state. Thus, the minor principal planes are vertical (or approximately 30), and their azimuths are approximately coincident with the azimuths of the tension cracks, and the minor principal stresses are equal to the active earth pressures. Since the major principal stress is equal to geostatic pressure, and the minor principal stress is equal to the active earth pressure, it follows that the intermediate principal stress must be equal to or greater than the active pressure, and must be equal to or less than geostatic pressure. The pattern of cracking indicates that the intermediate principal stresses are greater than the active pressures.

Examination in the field shows evidence of tension cracks extending to the edge of the Clinton channel and aligned in directions perpendicular to the channel. The upward inclination toward the north of the movement vectors for reference points adjacent to the channel are clear evidence that within the northern limit of the dump, the toe of the dump is being displaced upward as a result of base sliding over the toe region of

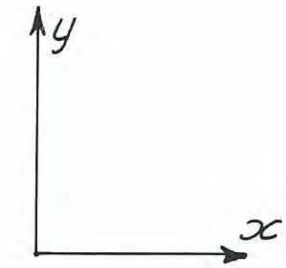
Within segments of the dump where the slope of the surface deviates significantly from the horizontal, and near the base of the dump which may be subject to the influence of base friction, the attitude of the major principal plane can be expected to deviate from the horizontal, with the result that the attitude of the minor and intermediate principal planes will also deviate from the vertical.

the original north valley wall. Thus, although the toe region of the dump is being displaced upward as a result of earth pressures in a direction approximately perpendicular to the channel, the stresses in a direction parallel to the channel remain at the active earth pressures (see Figure E-3). Thus, at least within the upstream portion of the channel, minor principal planes are approximately vertical, and are aligned approximately perpendicular to the channel. It follows that, within this region, the intermediate principal planes are approximately vertical, are aligned approximately parallel to the channel, and that the intermediate principal stresses are greater than the active earth pressures and are equal to or less than the geostatic pressures.

ABSOLUTE AND RELATIVE MOVEMENTS CLINTON DUMP

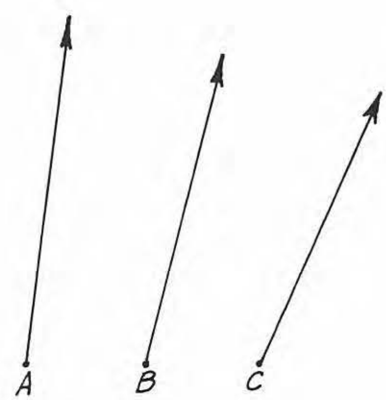
Figure E - I

a)



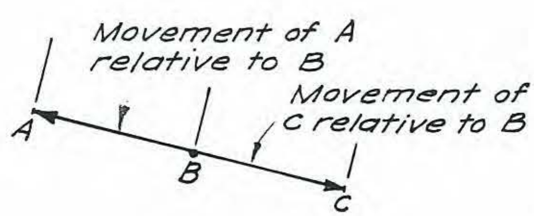
CARTESIAN COORDINATES IN PLAN - THE y - AXIS IS APPROXIMATELY NORTH.

b)



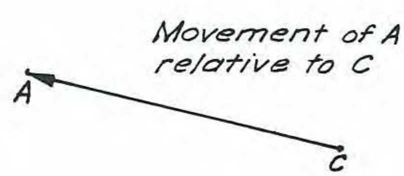
PLAN SHOWING ABSOLUTE HORIZONTAL MOVEMENT VECTORS DURING TIME ΔT RELATIVE TO x and y AXES.

c)



RELATIVE HORIZONTAL MOVEMENTS AT THE END OF TIME INTERVAL ΔT.

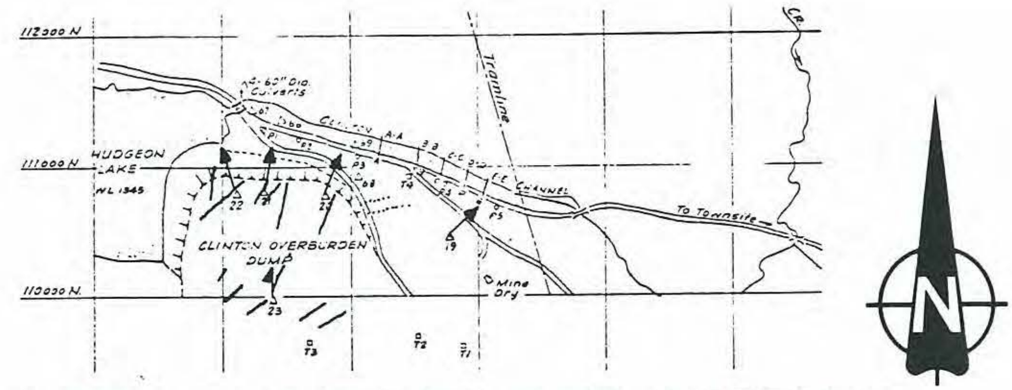
d)



Project No V77016 Drawn Ing. Reviewed E&F Date June '78

CRACK PATTERNS AND VECTOR AZIMUTHS CLINTON DUMP

Figure E - 2

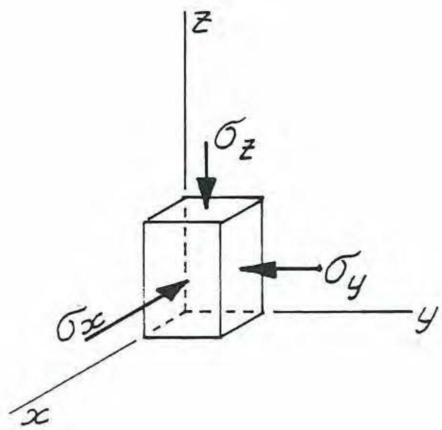


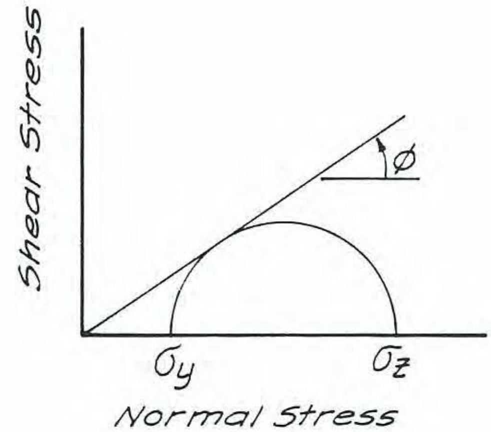
Approx. Scale: 1 in. to 1580 ft.

V77016 Ing EBF June '78

IMPLIED STRESSES CLINTON DUMP

Figure E-3





The z axis is vertical.

The x axis is horizontal and perpendicular to the channel (or approximately so).

The y axis is perpendicular to the z and x axes. i.e. approximately parallel to the channel.

σ_z = Geostatic pressure = γz where z = depth below surface and γ = effective unit weight of the material.

σ_y = $K_A \sigma_z$ where K_A = active earth pressure coefficient = $\frac{1}{\tan^2(45 + \phi/2}$

σ_x = The intermediate principal stress $\sigma_y \leqq \sigma_x \leqq \sigma_z$

V77016 · Ing. E&K June '78

Project No. V77016

RECORD OF BOREHOLE 1 (T-1)

LOCATION (See Figure 2)
BORING DATE April 4, 1978

BOREHOLE TYPE
BOREHOLE DIAMETER 6 in.

SAMPLER HAMMER WEIGHT 140 LB. DROP 30 IN.
DATUM

SOIL PROFILE — ELEV. / DEPTH	DESCRIPTION	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT (W_P — W — W_L)	PIEZOMETER OR STANDPIPE INSTALLATION / ADDITIONAL LAB. TESTING
1386.6' / 0.0'	WASTE ROCK - argillite - dry - grey - some asbestos fibres							
1370.6' / 16.0'	WASTE ROCK - argillite - dry - brownish grey - very fibrous.							
1364.6' / 22.0'	WASTE ROCK - argillite with some serpentine - dry to damp - grey to brown to green - some asbestos fibres Original Ground Surface							
1323.6' / 63.0'	ORGANICS - dark brown - moss, leaves etc. - ice chips							
65.0'	ARGILLITE - weathered - moist - grey brown - ice chips							
1306.6' / 82.0'	ARGILLITE - weathered - grey (brownish) - wet - ice chips							
1296.6' / 90.0'	End of Hole							Thermistor cable installed to 90' (9 units at 5' intervals)

VERTICAL SCALE
1 inch to 20 feet

Golder Associates

DRAWN R.D.
CHECKED EBF

Project No. V77016

RECORD OF BOREHOLE 2 (T-2)

LOCATION (See Figure 2)
BORING DATE April 5, 1978
BOREHOLE TYPE
BOREHOLE DIAMETER 6 in.
SAMPLER HAMMER WEIGHT 140 LB. DROP 30 IN.
DATUM

ELEV. / DEPTH	SOIL PROFILE – DESCRIPTION	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT (W_P – W – W_L)	PIEZOMETER OR STANDPIPE INSTALLATION / ADDITIONAL LAB. TESTING
1398.1' / 0.0'	WASTE Rock - argillite - dark grey - damp							
1386.1' / 12.0'	WASTE ROCK - argillite - dark grey - damp		1	D.O				
			2	"				
			3	"				
1333.1'	Original Ground Surface							
65.0' / 66.0'	ORGANICS - dark brown							
	ARGILLITE - dark grey - weathered - ice chips		4	"				
1308.1' / 90.0'	End of Hole							Thermistor cable installed to 90 ft. (9 units at 5 ft. interval)

VERTICAL SCALE 1 inch to 20 feet

Golder Associates

DRAWN R.D.
CHECKED EBF

Project No. V77016

RECORD OF BOREHOLE 3

LOCATION (See Figure 2)

BOREHOLE TYPE

SAMPLER HAMMER WEIGHT 140 LB. DROP 30 IN.

BORING DATE April 6, 1978

BOREHOLE DIAMETER 6 in.

DATUM

SOIL PROFILE: ELEV. DEPTH	SOIL PROFILE: DESCRIPTION	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT (W_P, W, W_L)	PIEZOMETER OR STANDPIPE INSTALLATION / ADDITIONAL LAB. TESTING
0.0'	WASTE ROCK -argillite -dry -dark grey							
8.0'	WASTE ROCK -argillite -damp		1	D.O.				
			2	"				
52.0'	End of Hole							

VERTICAL SCALE
1 inch to 20 feet

Golder Associates

DRAWN R.D
CHECKED EBF

Project No. V77016

RECORD OF BOREHOLE 4 (T-3)

LOCATION (See Figure 2) BORING DATE April 7, 1978

BOREHOLE TYPE BOREHOLE DIAMETER 6 in.

SAMPLER HAMMER WEIGHT 140 LB. DROP 30 IN. DATUM

ELEV. DEPTH	SOIL PROFILE DESCRIPTION	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT W_P W W_L	PIEZOMETER OR STANDPIPE INSTALLATION ADDITIONAL LAB. TESTING
1559.9' 0.0'	WASTE ROCK - argillite - dry - grey							
1541.9' 18.0'	Original Ground Surface ARGILLITE - damp - dark grey - original rock		1	D.O.				Thermistor cable installed to 55ft. (9 units at 5' intervals)
1504.9' 55.0'	End of Hole							

VERTICAL SCALE 1 inch to 20 feet

Golder Associates

DRAWN R.O.
CHECKED EBF

Project No. V77016

RECORD OF BOREHOLE 5

LOCATION (See Figure 2) BORING DATE April 8, 1978

BOREHOLE TYPE BOREHOLE DIAMETER 6 in.

SAMPLER HAMMER WEIGHT 140 LB. DROP 30 IN. DATUM

SOIL PROFILE								
ELEV. DEPTH	DESCRIPTION	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT W_P W W_L	PIEZOMETER OR STANDPIPE INSTALLATION / ADDITIONAL LAB. TESTING
0.0'	WASTE ROCK - argillite - dry to damp - grey							
80.0'	End of Hole (hole collapsed at 80ft.)							

VERTICAL SCALE
1 inch to 20 feet

Golder Associates

DRAWN R.D.
CHECKED EBF

Project No. K77016

RECORD OF BOREHOLE 6 (T-4)

LOCATION (See Figure 2)

BOREHOLE TYPE

SAMPLER HAMMER WEIGHT 140 LB. DROP 30 IN.

BORING DATE April 10, 1978

BOREHOLE DIAMETER 6 in.

DATUM

SOIL PROFILE: ELEV. DEPTH	SOIL PROFILE: DESCRIPTION	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT (W_P — W — W_L)	PIEZOMETER OR STANDPIPE INSTALLATION / ADDITIONAL LAB. TESTING
0.0'	WASTE ROCK - argillite - dark grey - dry - some asbestos fibre							
25.0'	WASTE ROCK - argillite - dark grey - damp							
50.0'	WASTE ROCK - argillite - wet - free water running into hole at 50.0' - some asbestos fibres - possible original ground surface at approx. 80'							Thermistor cable installed to 60' (9 units at 5' intervals) Borehole collapsed during installation preventing cable from reaching full depth in bore hole
82.0'	End of Hole							

VERTICAL SCALE
1 inch to 20 feet

Golder Associates

DRAWN R.D.
CHECKED EBF

Project No. V77016

RECORD OF BOREHOLE 7 (P-4)

LOCATION (See Figure 2) BORING DATE April 10, 1978

BOREHOLE TYPE BOREHOLE DIAMETER 6 in.

SAMPLER HAMMER WEIGHT 140 LB. DROP 30 IN. DATUM

ELEV. / DEPTH	SOIL PROFILE — DESCRIPTION	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT (W_P — W — W_L)	PIEZOMETER OR STANDPIPE INSTALLATION / ADDITIONAL LAB. TESTING
1304.6'								
	WASTE ROCK - argillite - dry - dark grey - damp at 40'							
1241.6' 63.0'	End of Hole							Piezometer el. 1245.17'

VERTICAL SCALE
1 inch to 20 feet

Golder Associates

DRAWN R.D.
CHECKED EBF

Project No. V77016

RECORD OF BOREHOLE 8 (P-5)

LOCATION (See Figure 2)
BOREHOLE TYPE
SAMPLER HAMMER WEIGHT 140 LB. DROP 30 IN.

BORING DATE April 10, 1978
BOREHOLE DIAMETER 6 in.
DATUM

SOIL PROFILE: ELEV. / DEPTH	DESCRIPTION	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT W_p — W — W_L	PIEZOMETER OR STANDPIPE INSTALLATION / ADDITIONAL LAB. TESTING
1271.5' / 0.0'	WASTE ROCK - argillite - dry - dark grey							
1241.5' / 30.0'	ARGILLITE - dark grey - damp. ARGILLITE bedrock-weathered							
1202.5' / 69.0'	End of Hole							Piezometer el. 1202.76'

VERTICAL SCALE
1 inch to 20 feet

Golder Associates

DRAWN R.D.
CHECKED EBF

Project No. 772016

RECORD OF BOREHOLE 9 (P-3)

LOCATION (See Figure 2)

BOREHOLE TYPE

SAMPLER HAMMER WEIGHT 140 LB. DROP 30 IN.

BORING DATE April 11, 1978

BOREHOLE DIAMETER 6 in.

DATUM

SOIL PROFILE: ELEV. DEPTH	SOIL PROFILE: DESCRIPTION	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT W_P W W_L	PIEZOMETER OR STANDPIPE INSTALLATION / ADDITIONAL LAB. TESTING
1364.3'								
	WASTE ROCK - argillite - dry to damp - dark grey - moist at 45.0'							
1301.3' 66.0'	End of Hole							Piezometer el. 1314.19'

VERTICAL SCALE
1 inch to 20 feet

Golder Associates

DRAWN R.D.
CHECKED EBF

Project No. V77016

RECORD OF BOREHOLE 10 (P-2)

LOCATION (See Figure 2) BORING DATE April 11, 1978

BOREHOLE TYPE BOREHOLE DIAMETER 6in.

SAMPLER HAMMER WEIGHT 140 LB. DROP 30 IN. DATUM

SOIL PROFILE								
ELEV. DEPTH	DESCRIPTION	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT W_P W W_L	PIEZOMETER OR STANDPIPE INSTALLATION / ADDITIONAL LAB. TESTING
1368.0' 0.0'	WASTE ROCK - argillite - dry to damp - dark grey							
1330.0' 42.0'	End of Hole							Piezometer el. 1329.43'

VERTICAL SCALE
1 inch to 20 feet

Golder Associates

DRAWN R.D.
CHECKED EBF

Project No. V77016

RECORD OF BOREHOLE 11 (P-1)

LOCATION (See Figure 2)
BOREHOLE TYPE
SAMPLER HAMMER WEIGHT 140 LB. DROP 30 IN.

BORING DATE April 11, 1978
BOREHOLE DIAMETER 6in.
DATUM

SOIL PROFILE: ELEV. / DEPTH	SOIL PROFILE: DESCRIPTION	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT (W_P — W — W_L)	PIEZOMETER OR STANDPIPE INSTALLATION / ADDITIONAL LAB. TESTING
1363.0' / 0.0'	WASTE ROCK - argillite - dry to damp - dark grey							Piezometer el. 1321.95'
1345.0' / 38.0'	End of Hole							

VERTICAL SCALE
1 inch to 20 feet

Golder Associates

DRAWN R.D.
CHECKED

Project No. V77016

RECORD OF BOREHOLE 12 (T-5)

LOCATION (See Figure 6)

BORING DATE May 9, 1978

BOREHOLE TYPE

BOREHOLE DIAMETER 6 in.

SAMPLER HAMMER WEIGHT 140 LB. DROP 30 IN.

DATUM

ELEV. / DEPTH	SOIL PROFILE – DESCRIPTION	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT (W_P, W, W_L; 10, 20, 30, 40)	PIEZOMETER OR STANDPIPE INSTALLATION / ADDITIONAL LAB. TESTING
19452'	Surface of Tailing Pile							
0.0'	Tails							
1911.7' / 33.5'	Compact, light brown, sub-rounded, fine to med. GRAVEL with clay, silt and sand - fluvial lacustrine traces of organics at bottom of tails		1, 2					Thermistor cable installed to 54 ft. (9 units at 5' intervals)
1891.2 / 54.0'	End of Hole							

VERTICAL SCALE 1 inch to 20 feet

Golder Associates

DRAWN R.O.
CHECKED EBF

Project No. Y77016

RECORD OF BOREHOLE 13 (T-6)

LOCATION (See Figure 6) BORING DATE May 9, 1978

BOREHOLE TYPE BOREHOLE DIAMETER 6 in.

SAMPLER HAMMER WEIGHT 140 LB. DROP 30 IN. DATUM

ELEV. DEPTH	SOIL PROFILE – DESCRIPTION	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT (W_P, W, W_L; 10 20 30 40)	PIEZOMETER OR STANDPIPE INSTALLATION / ADDITIONAL LAB. TESTING
1880.6'	Ground Surface in Roadway Cut							
0.0'	Frozen, light brown sub-rounded fine to med. GRAVEL with clay, silt & sand fluvial lacustrines		1					
			2				~41	
			3				~32	
			4				~28	
1840.6' 40.0'	End of Hole							Thermistor cable installed to 40 ft. (9 units at 5' intervals)

VERTICAL SCALE 1 inch to 20 feet

Golder Associates

DRAWN R.O.
CHECKED EBF

Project No. V77016

RECORD OF BOREHOLE 14 (T-7)

LOCATION (See Figure 6)

BORING DATE May 10, 1978

BOREHOLE TYPE

BOREHOLE DIAMETER 6 in.

SAMPLER HAMMER WEIGHT 140 LB. DROP 30 IN.

DATUM

ELEV. / DEPTH	DESCRIPTION (SOIL PROFILE)	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT (W_p — W — W_L; 10, 20, 30, 40)	PIEZOMETER OR STANDPIPE INSTALLATION / ADDITIONAL LAB. TESTING
1741.0 / 0.0'	Surface of Tailing Pile							
	Tails							
1696.0' / 45.0'	-Frozen - ice crystals - light brown - sub-rounded - fine to med. GRAVEL with clay, silt & sand. - fluvial - lacustrine		1 2					Thermistor cable installed to 74ft. (9 units at 5' intervals)
1667.0' / 74.0'	End of Hole							

VERTICAL SCALE
1 inch to 20 feet

Golder Associates

DRAWN R.D.
CHECKED EBF

RECORD OF BOREHOLE 15 (ST-8)

Project No. V77016

LOCATION (See Figure 6)
BORING DATE May 11, 1978
BOREHOLE TYPE
BOREHOLE DIAMETER 6 in.
SAMPLER HAMMER WEIGHT 140 LB. DROP 30 IN.
DATUM

SOIL PROFILE								
ELEV. DEPTH	DESCRIPTION	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT W_P W W_L (10 20 30 40)	PIEZOMETER OR STANDPIPE INSTALLATION / ADDITIONAL LAB. TESTING
1607.2'	Ground Surface in Road Cut							
0.0' / 1607	-Frozen - light brown - sub rounded - fine to med. GRAVEL with clay silt & sand - fluvial lacustrines		1				⊙	
	-Frozen - black - ARGILLITE weathered bedrock		2				⊙	
1567.2 / 40.0'	End of Hole							

VERTICAL SCALE
1 inch to 20 feet

Golder Associates

DRAWN R.D.
CHECKED EBF

Project No. V77016

RECORD OF BOREHOLE 16 (T-8)

LOCATION (See Figure 6)

BOREHOLE TYPE

SAMPLER HAMMER WEIGHT 140 LB. DROP 30 IN.

BORING DATE May 12, 1978

BOREHOLE DIAMETER 6 in.

DATUM

ELEV. / DEPTH	DESCRIPTION (SOIL PROFILE)	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT (W_P, W, W_L; 10, 20, 30, 40)	PIEZOMETER OR STANDPIPE INSTALLATION / ADDITIONAL LAB. TESTING
1623.8 / 0.0'	Surface of Tailing Pile Tails							
1560.8 / 63.0'	- light brown - sub-rounded - fine to med. GRAVEL with clay silt & sand. fluvial lacustrine		1				⊙ (approx. 13)	Thermistor cable installed to 83.0 ft. (9 units at 5' intervals)
1540.8 / 83.0'	End of Hole							

VERTICAL SCALE 1 inch to 20 feet

Golder Associates

DRAWN R.D.
CHECKED EBF

Project No. K77016

RECORD OF BOREHOLE 17 (D.S.-2)

LOCATION (See Figure 6)

BOREHOLE TYPE

SAMPLER HAMMER WEIGHT 140 LB. DROP 30 IN.

BORING DATE May 16, 1978

BOREHOLE DIAMETER 6 in.

DATUM

SOIL PROFILE: ELEV. DEPTH	SOIL PROFILE: DESCRIPTION	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT (W_P — W — W_L)	PIEZOMETER OR STANDPIPE INSTALLATION / ADDITIONAL LAB. TESTING
0.0'	Frozen dark brown organic silty SAND							
3.0'	Frozen dark brown PEAT							
5.0' / 7.0'	Frozen, light brown, sub-rounded, fine to med. GRAVEL with clay, silt & Sand (fluvial Lacustrine)							
	ARGILLITE -hard, dry unweathered							
19.0'	SERPENTINE, weathered frozen							
21.0'	ARGILLITE BEDROCK soft, weathered, frozen		1					
46.0'	ARGILLITE BEDROCK unweathered, frozen		2					
57.0'	End of Hole							

VERTICAL SCALE 1 inch to 20 feet

Golder Associates

DRAWN

Project No. V77016

RECORD OF BOREHOLE 18 (D.S-5)

LOCATION (See Figure 6)
BORING DATE May 17, 1978
BOREHOLE TYPE
BOREHOLE DIAMETER 6 in.
SAMPLER HAMMER WEIGHT 140 LB. DROP 30 IN.
DATUM

SOIL PROFILE								
ELEV. DEPTH	DESCRIPTION	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT W_P W W_L	PIEZOMETER OR STANDPIPE INSTALLATION ADDITIONAL LAB. TESTING
0.0'	Frozen, dark brown, organic silty, SAND							
8.0'	Frozen, light brown, sub-rounded, fine to med. GRAVEL with clay, silt & sand (fluvial lacustrian)		1					
19.0'	ARGILLITE frozen, weathered (ice lens approx. 3in. thick recovered with sample)		2					
37.0'	ARGILLITE - frozen, becoming harder with depth, unweathered		3 4					
60.0'	End of Hole							

VERTICAL SCALE
1 inch to 20 feet

Golder Associates

DRAWN R.D.
CHECKED E.B.F.

Project No. 177016

RECORD OF BOREHOLE 19(D-5·6)

LOCATION (See Figure 6)
BORING DATE May 18, 1978

BOREHOLE TYPE
BOREHOLE DIAMETER 6 in.

SAMPLER HAMMER WEIGHT 140 LB. DROP 30 IN.
DATUM

ELEV. DEPTH	DESCRIPTION	STRATIGRAPHY PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS / FOOT	ELEVATION SCALE	WATER CONTENT PERCENT W_P — W — W_L	PIEZOMETER OR STANDPIPE INSTALLATION / ADDITIONAL LAB. TESTING
0.0'	Frozen, light brown sub-rounded, fine to medium GRAVEL with clay, silt & sand (alluvial)							
7.0'	Frozen silt with layers of fibrous peat		1					
17.0'	Frozen, light brown sub-rounded, fine to medium GRAVEL with clay, silt and sand (fluvial lacustrine)							
20.0'	ARGILLITE frozen, weathered		2					
32.0'	ARGILLITE - frozen becoming harder with depth, unweathered		3					
60.0'	End of Hole							

VERTICAL SCALE
1 inch to 20 feet

Golder Associates

DRAWN R.D.
CHECKED E.B.F.