



Golder Associates

CONSULTING GEOTECHNICAL AND MINING ENGINEERS

Report To
CYPRUS ANVIL MINING CORPORATION
On
1982
PERFORMANCE MONITORING
Of The
DOWN VALLEY TAILINGS PROJECT
Faro Yukon

VOLUME 1

IN DRAFT

DRAFT

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Golder Associates

CONSULTING GEOTECHNICAL AND MINING ENGINEERS

Our File No. 822-2021
February 28, 1983

Cyprus Anvil Mining Corporation
P.O. Box 1000
Faro, Yukon
Y0B 1K0

Attention: Mr. N.G. Cornish

Dear Sir:

Re: 1982 Performance Monitoring of the
Down Valley Tailings Project

We are pleased to provide the attached draft copy of our report on the performance monitoring of the Down Valley Tailings project. This report is being forwarded without the benefit of a review of Glen Gilchrist who will conduct this review this week.

The report attempts to cover all aspects of the monitoring which was conducted over the past year and in which Golder Associates were involved in some way. The comprehensive and cooperative nature of the monitoring program may have resulted in the inclusion or omission of which you may consider as inappropriate or appropriate for our report. We have not included any information regarding chemical monitoring or canal flows.

We look forward to your critical review and discussion.

Yours very truly,
GOLDER ASSOCIATES

Dave Goodall
D.C. Goodall, P. Eng.

DCG/1a

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1.0 INTRODUCTION

The Down Valley Tailings Containment Project encompasses the expansion tailings containment facility which was constructed adjacent to the Cyprus Anvil Mining Corporation lead zinc mine near Faro, Yukon.

In 1980-81 Cyprus Anvil undertook a major expansion of their tailings containment facility at their lead zinc mine near Faro, Yukon. The expanded facility, which is referred to as the Down Valley Tailings Containment Project, is situated in the Rose Creek Valley adjacent to the mine and consists of a 4 km valley wall diversion of Rose Creek and two cross valley dams, the first serving to retain tailings (referred to as the Intermediate Dam) and the second to provide retention storage for the containment waters which decant over the Intermediate Dam (referred to as the Cross Valley Dam).

The Down Valley Project elements have been extensively monitored in response to the need to understand the complex geology which may result in performance requiring remedial measures. In particular an extensive network of thermistors has been installed to monitor the impact of Down Valley project construction on the discontinuous permafrost which is present in the area. An extensive network of surface movement hubs, inclinometer casings and incremental settlement rings has also been installed to measure movements which may occur as a consequence of the permafrost presence, of permafrost degradation, of cold weather construction and of the general geologic setting. Pneumatic and standpipe piezometers have been installed to examine the behaviour of the groundwater regime as a result of the diversion of Rose Creek along the valley wall and of the impoundments in the valley bottom.

The bulk of the instrumentation was installed in November, 1981 immediately after the Down Valley construction was completed. Additional instrumentation which survived the construction activities has been inherited from the design and abandonment studies for the project. Some was also installed during construction for immediate monitoring purposes. All such instrumentation is documented in Golder Associates' February 1982 report entitled "Performance Instrumentation of the Cyprus Anvil Down Valley Project" and is located on Figure 1.

The Down Valley Project instrumentation has been monitored throughout 1982 in general accordance with the schedule which was recommended in the aforementioned report and with the requirements of the 24 March 1982 Water Licence issued by the Department of Indian Affairs and Northern Development. Supplementary instrumentation which is also shown on Figure 1 has been installed and monitored in 1982 to focus on possible areas of concern flagged by the primary instrumentation. V-notch weirs were installed in the toe drain downstream of the Cross Valley Dam to monitor the quantity of seepage reporting at this location and its variation with time. Visual inspection of performance and seepage occurrences were also made from time to time.

The monitoring data has been obtained by Cyprus Anvil personnel with assistance and direction being provided by Golder Associates who, in turn were assisted by other specialist consultants previously involved in the project. Messrs. W.E. Hodge, H.G. Gilchrist, and D.C. Goodall of Golder Associates visited the site in early March, 1982 at the time of impoundment of the Cross Valley Dam. Mr. D. Kettle of Golder Associates visited the site in March and April to install supplementary instrumentation and to assist in the quarterly scheduled monitoring. Mr. Kettle again visited the site in May to install supplementary instrumentation at Sta. 2+100 of the canal. Mr. Goodall inspected the site in early June.

Mr. W. M. Veldman of Hydrocon Engineering visited the site in June, 1981 to review the hydraulic performance of the completed construction and initiate flow monitoring in the diverted Rose Creek.

Underhill Engineering conducted precise movement monitoring surveys in April and in September, 1982 with some assistance being provided by Cyprus Anvil for the September fieldwork.

This report summarizes the findings of the Down Valley Project monitoring program after its first year of operation. Analyses of these findings and assessment of their significance to system operation are presented. Recommendations for future system monitoring and management are offered.

1.1 Report Organization

The report is organized in two volumes. The first volume summarizes the trends and observations and provides recommendations regarding the monitoring program and project performance. The second volume provides the factual information and calendar plots which result from data reduction. Procedures followed in actual observation of the instrumentation and reported in of Volume II.

Some cross referencing from Volume 1 to Volume 2 is necessary to avoid needless reproduction in Volume 1 of the calendar plots in Volume 2. For example, a reference in Volume 1 to thermistor string CD20 - 2+000 will require examination of the data for this installation in Volume 2.

2.0 OBSERVATION PROGRAM 1982

With exception of the supplementary instrumentation which was installed in 1982, all instrumentation had been monitored in late 1981 as reported in Golder Associates' February, 1982 report entitled "Performance Instrumentation of the Cyprus Anvil Down Valley Project". Observations from 1981 and from earlier years (for some installations) constitute the reference base for post construction behaviour and are included in the data package (Volume II) for completeness.

2.1 Monitoring Schedule

Observations of the instrumentation were generally taken in 1982 as follows:

- (i) Thermistors and incremental settlement rings in March, May/June, August/September and November;
- (ii) Piezometers in March, May and August;
- (iii) Slope indicators and movements hubs in March and September

In addition to these scheduled observations weekly readings of piezometers and thermistors were made at the Intermediate and Cross Valley dams during their initial impoundments from March to May, 1982. Sets of readings were also obtained at the Cross Valley Dam in July and December to better define the seasonal variation in piezometric regime in this area.

2.2.1 Supplementary Instrumentation, Canal Backslope

Analyses of the November, 1981 and March, 1982 data indicate anomalously high pore pressures in the canal backslope in the vicinity of Sta. 2+100. A field program was therefore undertaken to assess the distribution of pore pressures in the canal backslope in this area.

Details of the installation and monitoring of the supplementary piezometers and thermistors are embodied in a letter dated 27 May 1982 which is reproduced in Appendix 1. These installations are now monitored on the same schedule as for the primary installations.

2.2.2 Supplementary Instrumentation, Seepage Flows

A total of 3 V-notch weirs were installed in the toe drain of the Cross Valley Dam in March, 1982 as the seepage flows increased in response to the impoundment of the dam. Weirs were installed in the toe drain at Sta. 0+215 and 0+380 and at the toe access road culvert where all of the toe drain seepage collected is relayed to the old drainage ditch. A weir could not be installed in the south abutment area because the seepage flows were low and tended to form ice.

A schematic drawing of the weir devices is provided on Figure 2. These installations have been monitored on a weekly basis except for minor disruptions. In fact these flows are monitored simultaneous with the water sampling which Cyprus Anvil routinely conducts as a part of their environmental program.

2.2.3 Supplementary Instrumentation, Canal Flows

Flow staff gauges were installed in June after the canal was free of ice at locations selected by Hydrocon Engineering during the site visit by Mr. W.M. Veldman. Additional flow gauges were subsequently installed for permanent monitoring.

The flow gauges are situated near the inlet to the canal (diversion dam to Sta. 0+250) and in the vicinity of Sta. 3+600 between the two reaches of drop weirs.

Initially daily readings were obtained for the flow gauges. However, significant variations were not observed and the schedule was reduced in frequency.

2.3 Site Inspections

Golder Associates inspected the project in the field in early March and June with particular reference to the impoundment of the Cross Valley Dam. Golder Associates were also on site for parts of March, April and May to supervise and install supplementary instrumentation as well as to assist in the monitoring. Photographic records resulting from these site inspections are given in Appendices II and III which respectively document canal icing conditions in March and dam performance at full impoundment in early June.

Hydrocon Engineering visited the site in June to review the hydraulic performance of the project. The report generated as a consequence of this site visit is reproduced in Appendix IV.

Routine inspection of the site was the responsibility of Cyprus Anvil personnel with Golder Associates providing comment and direction.

Observations of new seepage occurrences, ponding of seepage, surfaces of seepage, water balance, pond level fluctuation, canal icing, structural cracking and canal erosion are periodically made by Cyprus Anvil.

2.4 1982 Construction and Maintenance

Cyprus Anvil undertook the construction of the canal overflow structure, the raising of the canal dyke in the vicinity of Sta. 3+500 and the opening of the North Valley Wall Interceptor Ditch. Maintenance measures such as the grading of the dam emergency spillways and the removal of ice in the canal and North Valley Wall Interceptor Ditch were also conducted by Cyprus Anvil.

2.5 Water Sampling

Cyprus Anvil have undertaken piezometer and surface water sampling according to the requirements of the Water Licence and as deemed appropriate by Cyprus Anvil to evaluate groundwater and surface water chemistry in the mine and tailings pond vicinity. The review and presentation of this data is beyond the scope of this report; however, some falling and rising head permeability tests were conducted in the Cross Valley Dam foundation piezometers in association with this program and the results are recorded herein.

3.0 DATA PRESENTATION AND ANALYSIS

3.1 Introduction

The amount and volume of detail of the monitoring data precludes its inclusion in the main body of this report. Instead a "data package" has been prepared and is assembled in a second volume which accompanies this report. This data package includes both tabulations and calendar plots of the data obtained to date.

The data is organized and discussed in terms of project elements and sub-elements. For example the canal is subdivided into sub-elements referred to as the canal dyke, the canal backslope and the canal spoilpiles. The implication is that the thermal and piezometric regimes of these sub-elements will be influenced by construction history and relative location with respect to the canal hydraulic channel.

3.2 Diversion Canal

3.2.1 Introduction

A typical cross-section showing the canal construction on the south valley wall of the Rose Creek valley is presented on Figure 3. The valley wall is generally mantled by up to about 1.2 m thickness of black and brown organic silts and colluvium, some of which is permanently frozen. Glacial till of variable characteristics is found beneath these surficial strata and varies in thickness from a few metres to about 15 metres. In some areas buried erosion surfaces as evidenced by organic and ice layers can be found at depth. The top of the till unit is often characterized by white volcanic ash and erosion or water modification. The till is discontinuously frozen.

The till is underlain by phyllite schist bedrock whose prominent foliation dips into the valley wall at angles ranging between 20 and 30 degrees although local irregularities and faulting are observed. In some areas foliation is inconspicuous as a consequence of regional metamorphism.

The distribution between frozen and unfrozen areas along the canal route seems to be related to natural drainage patterns as well as geology. In general the second half of the canal (from Sta. 1+500 onwards) is more fine grained and has a greater incidence of permafrost.

Canal construction was conducted through the winter of 1980-81 with diversion of Rose Creek being achieved on 11 May 1981. The canal dyke was completed to its design elevation by October, 1981.

3.2.2 Canal Thermal Regime

The present canal thermal regime is a product of the original discontinuous permafrost environment of the 1980-81 winter construction activity, of the impact of a changed groundwater flow regime resulting from Rose Creek diversion and valley bottom impoundment, and of the new geometrical and thermal boundary conditions resulting from canal construction.

There are a total of 17 thermistor strings along the canal dyke, 11 on the canal backslope and 3 installed from the top of the spoil piles. The thermistor strings are generally installed to depths of about 10 m with 10 thermistors per string spaced at 1 m intervals. The thermistor readings are considered to be accurate to about $\pm 0.1^{\circ}\text{C}$. The temperature data reported in Volume II has been contoured with respect to time and depth; these contours will be referred to as isotherms although they are not truly isotherms in strict definition.

The thickness of the active layer of annual freeze and thaw for 1982 was about 4.0 and 5.0 metres for the canal dyke and spoil piles, but only 2 to 3.5 metres for the backslope (for example CD15-1+530, SP2-1+530, and BS12-2+260). The near surface (approximately 0.5 m depth) ground temperatures for the canal dyke and spoil pile vary approximately between -13°C in March to $+10^{\circ}\text{C}$ in August/September compared to a temperature variation of -4°C to $+4^{\circ}\text{C}$ for the backslope over the same time period. These reduced temperature effects along the backslope are a result of the relatively undisturbed 0.3 to 1.2 metre organic covering on the natural ground and of vegetation shading. The depth to the canal dyke subexcavation (which varies from 1.6 to 5.0 m) appears to have little effect on the depth of the active layer or the temperature distribution within it.

An overall summary of the thermal regimes encountered at depth along the Diversion Canal is presented in Table 1. The thermal regimes at depth along the backslope and in the spoil piles have essentially remained unchanged throughout the backslope but temperatures have all remained relatively constant, that is, $\pm 0.2^{\circ}\text{C}$. The spoil piles are showing fully frozen conditions generally between -0.3 to -0.5°C . For the canal dyke, however, the thermal regimes at depth can be divided up into three types:

Type I - Thermal Regime Influenced by Seepage from the Canal.

(Stations 0+400, 1+000, 2+000, 2+350 to 2+500 and 3+100)

The temperature isotherms for this type of behaviour show a relatively sudden increase in temperature from June to August and then a similar sudden decrease from September to November. The temperatures range typically from 0.0°C to $+5.0^{\circ}\text{C}$ (for example CD25-2+460). This behaviour is thought to be brought about by water seepage from the canal for two reasons. Firstly, there are relatively sudden changes in ground temperatures corresponding to the summer period and secondly, the relatively high ground temperatures of $+5^{\circ}\text{C}$ compared to natural ground water temperatures of only $+1^{\circ}\text{C}$ (as seen for example in the thermistor installation BS4-0+710 at Goodall Creek).

Type II - Thermal Regime Showing Progressive Thaw at Depth.

(Stations 0+500, 1+700, 2+600 to 2+900)

For this type of behaviour the temperature isotherms indicate a relatively gradual increase in temperature continuing from June through to mid-November (the latest set of readings). The temperatures typically increase from about 0.0°C to 0.3°C (for example see CD17-1+705).

Type III - Thermal Regime Essentially Unchanged by Canal

(Stations 1+500, 1+900, 2+100 and 3+000)

For this case, the ground temperatures at depth have not shown any significant changes during 1982. For frozen ground this means seasonal temperature variations of less than 0.2°C (for example CD19-1+900. In thawed ground the temperatures may show a seasonal variation of as much as 0.8°C perhaps as a consequence of connective heat flow (for example see CD15-1+530).

The changes in thermal regime beneath the canal dyke which are documented as Type I and Type II behaviour in Table 1 are believed to be a consequence of canal construction. The effects of such changes on valley wall slope stability are difficult to evaluate and are best defined by continued monitoring of the project. Most of the effects of Type I behaviour have been felt by now. However, the progressive nature of Type II behaviour could lead to slight increases in seepage losses and the emergence of new seepage springs downslope of the canal.

3.2.3 Canal Settlements and Movements

3.2.3.1 Introduction

The settlements and movements of the canal have been monitored using the movement hubs, incremental settlement rings and inclinometer casings which were installed in November 1981. Details of these installations are provided in Golder Associates' February, 1982 report entitled "Performance Instrumentation of the Cyprus Anvil Down Valley Project".

The movement monitoring grid along the canal is comprehensive. Vertical movement hubs are spaced at about 100 to 200 m intervals along the canal dyke and the canal backslope as shown on Figure 1. Five vertical movement hubs have also been established on the canal excavation spoilpiles. Horizontal movements along the canal are monitored by 12 hubs on the dyke, 10 on the backslope and 5 on the spoilpiles, all of which are located at selected locations and are shown on Figure 1.

Observation of the hub movements has been made by Underhill Engineering in April and September using state of the art survey techniques and equipment. The resulting redundant data is also treated statistically to yield most probable locations and confidence limits. These procedures and techniques are described in detail in the 1982 Underhill

Engineering report which is reproduced in Appendix V. Experience has indicated that vertical movements of less than 5 mm can be reliably detected. Horizontal movements of about 10 mm are also considered to be detectable.

In addition to the surface movement monitoring network, slope indicator casings and incremental settlement rings have been installed in boreholes to measure respectively horizontal and vertical movement distribution with depth. These installations were monitored by Cyprus Anvil as a part of the overall instrumentation monitoring program.

Inclinometer casings have been installed at 8 locations on the backslope, 6 on the canal dyke and 3 on the excavation spoilpiles, all of which are shown on Figure 1. The indicator casings are installed generally to a depth of 10 m and are observed incrementally and 0.5m depth intervals. Horizontal movements of about 5 mm are considered to be detectable using this technique.

As shown on Figure 1 settlement ring installations are present at 8 locations on the canal dyke, 7 locations on the backslope and 3 locations on the spoilpiles. On the canal dyke the rings are spaced at about 1 m intervals to a depth of about 10 m. On the backslope the rings are installed at depths of 2 and 5 m with an additional 2 rings being provided at depth for the installation at Sta 3+000. The spoilpile installations have rings spaced at 1 to 2 m to a depth of about 10 m. These installations can be monitored to a precision of about 10 mm although some detected movements may be a consequence of borehole backfill readjustments.

The sign convention which has been adopted in reporting movements is as follows:

- + sign indicates increase in elevation or horizontal movements towards the valley wall or in the upstream direction with respect to the canal flow
- sign indicates decrease in elevation or horizontal movements away from the valley wall or in the downstream direction with respect to the canal flow.

3.2.3.2 Vertical Surface Movements

A summary of the vertical surface movements is provided on Table 2. A detailed examination of the movements follows.

(i) Backslope

December to April

Mostly small settlements have occurred. These settlements are probably a consequence of both the construction of the canal and the initial "seating" of the installations.

Two points in particular show heave downstream of Sta. 1+700 -

- 2+100 heave + 44 mm
- 2+760 heave + 11 mm

In view of the frozen conditions from December to April one could only expect frost heave to account for these two observations.

April to September

The data indicates that some points have continued to settle between April and September but that several points have heaved. Again, heave is expected to be related to frost action on the hub installations. Heave was particularly noticeable at Stations 0+990, 1+300, 2+500 1+500. Settlement was particularly noticeable at Stations 0+600, 2+900 and 3+000.

Overall

Some settlement of the hubs occurred after installation. Following this heave developed over the winter and spring seasons. The heave is usually less than 20 mm and possibly results from jacking of the monitor hubs by freeze thaw action. The most significant settlements occurred at Stations 0+600 (17 mm), 2+900 (11 mm) and 3+000 (29 mm); these settlements may underestimate the true settlements due to jacking of the hub installations.

(ii) Canal Dyke

December to April

Mostly small settlements occurred probably as a result of small real settlement and of stabilization of the hub installations. Frost action also accounted for some heaving of less than 10 mm.

Notable settlements occurred at chainages 1+800, 2+200, 2+300, 2+400, and 3+100 but generally did not exceed 20 mm.

April to September

As for the backslope the data clearly identifies some points which have continued to settle a significant amount in spite of the heaving of several other points. Heaves ranged as high as 21 mm. Points which show notable net settlement are as follows:

2+400 (81 mm)
2+200 (62 mm)
3+000 (37 mm)
3+100 (25 mm)
2+250 (16 mm)
2+900 (12 mm)

Overall

Several points have undergone heave of at least 20 mm. Superimposed on this heave action is the settlement which is observed particularly downstream of Station 1+750. Significant overall settlements have been observed at the following points:

2+350 (96 mm)
2+200 (78 mm)
3+100 (35 mm)
3+000 (32 mm)
2+250 (30 mm)
1+800 (16 mm)
2+000 (10 mm)

(iii) Spoil Piles

December to April

All installations indicate settlements ranging from 23 to 50 mm.

April to September

With exception of Sta. 0+990 which heaved 7 mm, all points continued to settle by 11 to 110 mm.

Overall

All points have settled by amounts ranging from 18 to 133 mm. This must be considered as net settlement as it is expected that the installations suffered some permanent heave as a consequence of freeze/thaw action.

(iv) Vertical Surface Movement Summary and Analysis

Many monitor points have experienced heave of the order of 20 mm as a consequence of freeze thaw action. This phenomenon is not of particular concern except possibly in the implication which it has to the hydraulic integrity of the seepage control liner elements. The design of the canal dyke is such that the seepage control liner will remain intact in spite of ice lensing although increased seepage flows could be anticipated. Another implication which the frost action phenomenon has is that settlements are generally underestimated by the amount of permanent heave.

Of more concern are the significant settlements which have occurred in the canal backslope and dyke since they tend to indicate mass movement in response to gravity. The relatively large settlements of the spoilpiles need not be a concern because they do not constitute an integral part of the canal system.

For the most part the points which have experienced significant settlement occur downstream of Sta. 1+750 which corresponds to the beginning of pravalent permafrost. The areas of significant settlement from the above analysis are summarized as follows:

<u>Station</u>	<u>Backslope</u>	<u>Dyke</u>
0+600	17 mm	insignificant
1+800	insignificant	16 mm
2+000	insignificant	10 mm
2+200	insignificant	78 mm
2+250	insignificant	30 mm
2+350	insignificant	96 mm
2+900	11 mm	11 mm
3+000	29 mm	32 mm
3+100	6 mm	35 mm

The above summary tabulation indicates that significant settlements are local to the dyke or the backslope except in the vicinity of Sta. 3+000. It is suggested that the local problems may reflect occurrences of permafrost or some construction deficiency resulting from winter construction. Such possibilities have previously been identified as causes for cracking of the dyke. However, the general settlement in the dyke and in the backslope in the vicinity of Sta 3+000 may reflect the occurrence of an ice rich organic layer at depth which has been previously documented. Indeed the area in the vicinity of Sta 3+000 is one of the most intensely instrumented.

3.2.3.3 Horizontal Movements

Although not as precise as vertical movement methods, horizontal movements can reveal additional information with respect to mass movement. Horizontal movements have generally been resolved into components perpendicular and parallel to the canal centreline with the expectation that the canal sideslopes will move towards the canal centreline or generally downslope perpendicular to the valley wall contour which the canal centreline follows approximately.

A summary of the resolved horizontal movements for the canal is provided on Table 3. The horizontal data has been reviewed using histogram techniques.

(i) Backslope

December to April

All monitor points indicate movement towards the canal centreline with some consistent movements in the downstream direction from Sta. 2+900 onwards. Of particular note are the following movements.

Sta.	Perpendicular*	Parallel*
2+100	-18 mm	0 mm
2+900	-26 mm	-9 mm
2+950	-13 mm	-7 mm
3+000	-25 mm	-4 mm
3+250	-9 mm	-11 mm
3+500	-11 mm	-6 mm

* (-)ve sign indicates movement in downslope (towards the centre of valley) or downstream directions.

April to September

The observations are much less consistent than for April possibly as a consequence of thawing. Some upslope movements are observed but downslope movements prevail particularly at Sta 3+000 (-14 mm) and at 3+500 (-10 mm). The movements parallel to the centreline also tend to be in the downstream direction with the largest movement being observed at Sta 2+100 (-19 mm).

Overall

With exception of one station (1+900) all points have moved downslope towards the canal centreline. Further, with exception of station (0+400) all points have moved in the downstream direction. Of particular note are the following:

Sta.	Perpendicular*	Parallel*
2+100	-12 mm	-19 mm
2+900	-26 mm	-13 mm
2+950	-13 mm	-1 mm
3+000	-39 mm	-4 mm
3+200	-8 mm	-18 mm
3+500	-21 mm	-6 mm

* (-)ve sign indicates movement in downslope (towards the centre of the valley) or downstream directions.

These movements are consistent with the observed settlements reported above (except 2+100 which has heaved significantly). The movements parallel to the canal centreline in the downstream direction particularly in the vicinity of Sta. 3+000 are an indication of the influence of overall slope topography in addition to canal cut orientation and they are suggestive of overall slope movement rather than canal bank instability. These conclusions are completely consistent with those resulting from analysis of the vertical movements and with prior knowledge of the geology.

(ii) Canal Dyke

December to April

The movements are generally small and in the downslope or downstream directions. The most significant horizontal movements were observed at Sta 2+900, 3+000 and 3+130 where the movements were as follows:

<u>Sta.</u>	<u>Perpendicular*</u>	<u>Parallel*</u>
2+900	-15 mm	+4 mm
3+000	-15 mm	0
3+130	-12 mm	-9 mm

* (-)ve sign indicates movement in downslope (towards the centre of the valley) or downstream directions.

April to September

In contrast to the April trends, the data indicates that the canal dyke monitor points, which are generally located near the inside crest of the dyke, moved towards the canal centreline at many locations. This means that the inside crest of the canal dyke is moving in the upslope direction with respect to the overall slope albeit downslope with respect to the canal bank. It should be anticipated that the observed data represents the net effect of two movements in opposite directions, one being the overall slope movement in the downslope direction and the other being the canal bank slope movement. Therefore the observed movements may underestimate the actual local relative movements.

Some of the more significant movements are as follows:

<u>Sta.</u>	<u>Perpendicular*</u>	<u>Parallel*</u>
0+400	+16 mm	-6 mm
1+530	+10 mm	-2 mm
2+200	+63 mm	0
2+360	+17 mm	+21 mm
3+000	+52	+18 mm
3+550	+10	+3 mm

* (-)ve sign indicates movement in downslope (towards the centre of the valley) or downstream directions.

These observations are consistent with the dyke cracking patterns which were observed in August 1981 and documented in a letter which is reproduced in Appendix VI. In fact the areas which are showing significant movement are precisely the ones where cracking was observed in August 1981.

Overall

The overall movements reflect the summation of movements from April and September which tend to be in opposite directions due to differing fundamental mechanisms. Whereas it is clear that some general downslope movement (in terms of the valley wall) is occurring and is dominant during the winter months, it is also clear that a movement of the inside dyke crest towards the canal centreline during the summer dominated the overall movements of most of the monitor points over the past monitoring season.

(iii) Spoil Piles

No clear trends are evident in the horizontal movements of the spoil piles. The movements are generally less than 20 mm and it appears that overall downslope (in terms of the valley wall) movement occurred up to April and then that some upslope movement occurred perhaps in a fashion similar to that which was observed for the canal dyke i.e. spreading of the piles.

(iv) Horizontal Movement Summary and Analysis

The canal backslope is tending to move horizontally in the direction of the valley wall gradient or in the direction of the canal cut slope gradient. The canal dyke exhibits a mixed behaviour with movement in the downslope direction (in terms of the valley wall) being observed up to April and movements of the inside dyke crest towards the canal centreline being observed from April to September. The latter movements tend to dominate overall behaviour at some locations.

The largest movements were observed downstream of Sta. 1+750 (corresponding to the beginning of prevalent permafrost) and are summarized as follows:

Sta.	<u>Backslope</u>		<u>Dyke</u>	
	<u>Perpendicular*</u>	<u>Parallel*</u>	<u>Perpendicular*</u>	<u>Parallel*</u>
0+400	-7 mm	+2 mm	+13 mm	-5 mm
1+530	-9 mm	-6 mm	+10 mm	0
2+100	-12 mm	-19 mm	-9 mm	+1 mm
2+200	-	-	+63 mm	+5 mm
2+360	-	-	+14 mm	+25 mm
2+900	-26 mm	-13 mm	-15 mm	0
2+950	-13 mm	-1 mm	-	-
3+000	-39 mm	-4 mm	+37 mm	+18 mm
3+550	-21 mm	-6 mm	+5 mm	-5 mm

* (-)ve sign indicates movement in downslope (towards the centre of the valley or downstream directions).

Comparison of this tabulation with that made for significant overall vertical movements confirms a correlation of areas of significant horizontal and vertical movement although the correlation is less marked where movements are small.

Horizontal movement of the spoilpiles is surprisingly small and is not of concern.

3.2.3.4 Horizontal Movement Monitoring at Depth

Inclinometer casings which had been installed in November 1981 and initially monitored in Dec. 1981 were monitored in March and September 1982 which correspond closely to the times of surface monitoring.

Inclinometer casings show the distribution of horizontal movements at depth which contribute to the observed surface horizontal movement provided that all such movements are within the depth of investigation of the slope indicator (10 m).

Plots of the observed inclinometer casing behaviour are provided in Volume 2. The more significant observations are summarized as follows: (note these conclusions assume that the bottom of the borehole does not move):

Location	Backslope	Dyke	Spoilpiles
0+400	movement in top metre indicating 14 mm movement upslope March to September		
1+530			Downslope movement in spoilpile materials of about 10 mm by September
1+900		Slight movements downslope in Mar. and then upslope to September (within upper 3m)	Downslope movements up to 30 mm and upstream by 12 mm (within top 2 m)
2+100	Downslope movement by 12 mm within the top 2 m.		
2+900	(Lower) Slight movement downslope to March then 17 mm upslope movement to September; 13 mm downstream movement March to Sept. (within upper 2 m) (Upper) 6 mm upslope and 14 mm downstream Mar. to September within upper 2 m.	Downslope movement March and September. (6 mm) (within upper 3m)	Downslope movement in foundation of spoilpile. Downstream movement in top 2 m March to September.
3+000	Slight movements downslope and upstream within the upper 5 m.	Upslope movement 25 mm towards canal March to September.	

The observations indicate that there have been no large movements. In the backslope there appears to have been slight downslope movements from December 1981 to March 1982 with subsequent upslope movements from March to September. These upslope movements are surprising but usually arise in the upper few metres and are believed to be related to thawing during the summer months. At Sta. 2+100 downslope movement of the backslope is indicated consistent with observed surface movements.

Movements of the canal dyke are generally small: at Sta. 1+900 and 3+000 movement of the dyke crest towards the canal centreline is indicated during the summer months; at Sta 2+900 a general albeit slight downslope movement is indicated consistent with surface monitoring at this location. In spite of these small movements, however, the slope indicator casing at Sta. 3+000 on the canal dyke required some special attention. The December set of readings (for incremental settlements) indicated that installation CD 29-3+000 was frozen below a depth of about 7 m. While this may indeed be the case an alternative explanation could be that the inclinometer casing has sheared at this depth. Melting of the ice in the casing using antifreeze or equivalent should be attempted to ensure that the casing remains intact and that the casing has not been sheared.

Horizontal movements at depth in the spoil piles are surprisingly small except near surface where freeze-thaw is active.

3.2.3.5 Vertical Movements at Depth

The incremental settlement data is presented in Volume 2 and summarized on Table 4. Interpretation of some of the data has been necessary to eliminate imperfect instrumentation errors and obvious observation errors which are prone to occur. Some of the data cannot be explained and it is surmised that such data defines the accuracy of the method.

For example heaves of about 10 mm have been noted at depth at Stations 0+400 and 0+990 of the canal dyke and at Sta. 1+530 of the backslope in spite of continuous thaw throughout 1982. Nevertheless, it is possible to note some trends in the data particularly where movements are relatively large.

As shown on Table 4 the annual total average settlement within the upper 2 m of the backslope is about 35 mm with most of this settlement occurring between June and September. This movement is much greater than that for a similar depth interval observed at the canal dyke (2 mm) and somewhat greater than that at the spoil piles (23 mm). Furthermore, it is much greater than the surface movements observed for the hub installations (average 3 mm heave). Observations within the upper 2 m reflect relative movements of a surface casing and the first settlement ring implanted at about a 2 m depth. Therefore movements of the surface casing which may be a consequence of active layer freeze/thaw, of borehole backfill settlement or of permafrost thaw around the casing will be included in the incremental movements observed for the upper depth interval (this extraneous effect could be eliminated by surveying the casings). Such movements appear to be responsible for the large movements recorded for the upper depth increment particularly where the surficial soils are ice rich or loose as is the case in the backslope and in the spoil piles respectively. Observations for the canal dyke do not indicate large settlement within the upper 2 m because the reference casings are well anchored in engineered fill.

Examination of Table 4 also indicates that the incremental settlements at depth observed for the spoil piles are relatively large. The average settlement from depth 5 to 10 m for the three spoilpile locations is indicated to be 124 mm for the 1 year (approx.) monitoring period. The 5 to 10 m depth interval tends to include the base of the spoil pile and its upper foundation strata which remained frozen at about -0.4°C

throughout 1982. The data therefore infers that the observed settlements result from compression of frozen materials near the base of the spoil pile and within the upper few metres of the unstripped natural ground. These indications are quite credible in view of the tendency for snow and debris to have been buried at the base of the spoilpile and in view of the ice rich materials which tend to occur within the upper two metres of the natural soil profile.

Average vertical movements at depth indicated for the backslope and for the canal dyke are small although over the one year monitor period all movements are settlements. For the backslope a compression of 4 mm is indicated from depth 2 to 5 m (see Table 4). For the canal dyke a compression of 7 mm is indicated from depth 3 to 10 m.

Attempts to explain local short term incremental movements on the basis of thermal changes and freeze/thaw have been unsuccessful and the changes between the observation months may be more observation error than real. However, as mentioned previously it should be expected that any individual observation may be in error by as much as 10 mm. When such observations are averaged, however the errors are reduced in inverse proportion to the square root of the number of observations. The number of observations used to generate the average annual totals on Table 4 is 7 for the backslope, 8 for the canal dyke and 3 for the spoil piles. Hence, if the expected error for any given observation is about 10 mm the expected error for the average annual totals would be about 4 mm for the backslope and canal dyke and 6 mm for the spoil piles.

Direct comparison of the incremental settlement ring observations with the surface movement hubs must be done with caution since the rings have been monitored for nearly a full year and the hubs for only 8 months. The hubs are believed to be subject to frost heave and the reference

casings for the rings have been shown above to be moving. Finally movements at great depth are not reflected by the ring installations whereas the surface monitoring reflects total movement.

With respect to general trends the settlement rings confirm the trends flagged by the surface hubs. In general, the spoil piles have typically settled about 100 mm; the canal dyke and the backslope have settled on average less than 10 mm. The significant movements at Sta. 3+000 are confirmed by each method. However, there are a few differences primarily for the reasons cited above.

3.2.4 Canal Piezometric Regime

The canal piezometric regime is monitored by 9 piezometers in the backslope and 21 in the canal dyke. In addition 9 supplementary piezometers were installed in the backslope in the vicinity of Sta 2+100 in May 1982. Most of the piezometers are pneumatic. All locations are shown on Figure 1.

The piezometer observations for the canal are summarized in Volume 2. In general, the pore pressures are low and indicate good underdrainage of the backslope and the canal dyke. Seasonal peaks are often seen in May for the shallow piezometers situated at an elevation approximating that of the canal bed. Of particular note is piezometer #358 at Sta. 0+710. Some cyclic seasonal behaviour is also seen at depth.

Some piezometers are indicating anomalously high pore pressures. As mentioned previously pneumatic piezometer #347 in the canal backslope in the vicinity of Sta. 2+100 indicated excessively high pore pressures beginning in March 1982 and concern about these high pore pressures lead to the examination of the area in detail in May 1982. Some of the pneumatic piezometers installed in the latter program have responded similar to #347 (viz. #058, #067) but other piezometers installed in the same program exhibit more reasonable behaviour [e.g. #065 (Sta 2+070), #055 (Sta 2+100), #057 (Sta 2+130)]. A standpipe piezometer which was installed within about 1.5 m of #347 has remained dry at all monitorings since installation. These facts have lead to the hypothesis that the high pneumatic pore pressures indicated in the backslope in the vicinity of Sta. 2+100 are fictitious probably as a consequence of the discontinuously frozen environment in which they are installed. Studies of the behaviour of a freezing pneumatic piezometer under conditions of constant hydraulic head and controlled temperature have been conducted

in Golder Associates' laboratory and tend to confirm this hypothesis (see Appendix VII). The same testing has also indicated that the freezing of a dry piezometer leads to essentially zero pore pressures which may be the reason that several piezometers downstream of Sta 1+700 give essentially zero readings.

The high seasonal pore pressures however which are indicated in the backslope at Sta 0+710 and to a lesser extent at Sta 0+960, are considered to be real because the piezometer tip environment in each case is unfrozen. The higher pore pressures are probably a response to surface runoff at these locations and indicate a potential for gulying and erosion over the long term.

3.3 DAMS

3.3.1 Introduction

The Intermediate and Cross Valley Dams were constructed during the summer of 1981. Zoned earthfills were constructed at each location with a central till core being used as the principal water barrier. This core extended downwards beneath the general foundation subexcavation grade by a few metres. At the Cross Valley Dam an upstream blanket was constructed which extended approximately 90 m upstream of the dam centreline.

The dams traverse the Rose Creek Valley which has been infilled with up to about 60 m of variable sand and gravel alluvium although the stratigraphy also includes till and silt strata. The south abutments of both dams appear to have a till/colluvial origin with shallow bedrock occurring at the Intermediate Dam south abutment. The north abutments tend to have a glacio-fluvial origin.

Occurrences of permafrost have been noted in the south abutment of the Intermediate Dam, in both abutments of the Cross Valley Dam, and in the upstream blanket foundation area upstream of the toe of the dam.

3.3.2 Pond Impoundment Records

Detailed records of the pond filling rates and the computed impoundment storage are presented on Figure 4 for both the Cross Valley and Intermediate Dams. The computed storage rates are based on post construction valley sectioning at about 60 m intervals and they do not include any allowance for saturation of the geologic materials in the valley walls or in the dams.

The computed storage rates reflect inflow to the system from natural groundwaters, from surface runoff and from the tailings discharge line. Further, as pond elevations rise it is clear that the pond storage rates decrease as a consequence of increased seepage. (In the final stages of filling of the Intermediate Dam the storage increases as a result of the rising Cross Valley Dam pond and the consequent decrease in seepage due to decreased head difference across the Intermediate Dam).

3.3.3 Cross Valley Dam

3.3.3.1 Introduction

The Cross Valley Dam began to impound water in October, 1981 as a consequence of natural groundwater seepage and subsequently of seepage resulting from the impoundment of the Intermediate Dam. The reservoir level rose steadily until about mid-March when the Intermediate Dam surface decant started to flow. Subsequently, the reservoir rose at the relatively rapid rate of about 3.5 m in 25 days. Throughout the balance of 1982 the reservoir was maintained full at about El.1063.2 except for

small changes of about 0.15 m occasioned for groundwater chemistry control measures in late November and December (see Appendix VIII).

During March, April and May the piezometers, thermistors and pond levels were measured on approximately a weekly schedule to ensure that consistent behaviour of the system was occurring. A set of V-notch weirs were also established at the downstream toe of the dam and have been monitored on a routine basis since March.

Scheduled observations were also taken in late May and late August. Additional supplementary readings were obtained in July and December at the request of Golder Associates.

Movement monitoring was conducted by Underhill Engineering Ltd. in April and September.

3.3.3.2 Movements

A summary of the horizontal and vertical movements observed at the Cross Valley Dam are reported on Table 5.

In general, horizontal movements have been within the 95 percent error ellipses (see Volume 2) and as such are insignificant. There appears to be some consistent indications, however, of movement in a northward direction parallel to the axis of the dam. This trend is also observed to a lesser extent at the Intermediate Dam suggesting that it is a regional movement of the valley walls or a consistent survey error.

Vertical movements of the Cross Valley Dam have been monitored using reinforcing bars implanted at surface, movement monitoring hubs similar to those which were used on the canal, and settlement plates which were placed at the base of the fill during construction. Monitoring of these

installations can therefore give an indication of the degree of compression of the embankment fills as a result of impoundment.

Examination of the settlement plate data in Table 5 indicates that on average the dam foundation settled by about 14 mm from December to April and by about 6 mm from April to September. A decreasing rate of foundation settlement is to be expected and the results are very consistent with previous settlement observations as shown on Figure 5. In general areas of greatest current foundation settlement coincide with the areas of greatest previous settlement.

The surface settlement of the dam which includes both foundation and fill compression is indicated by the reinforcing bars and the movement hubs as shown on Table 5. These types of installations are both subject to frost heave effects although the movement hubs are designed to eliminate such effects within the upper 1.2 m. Therefore the actual amount of settlement could be slightly greater than that indicated. Interestingly there is not a significant difference in results from the two types of installations. The surface settlement from December to April averaged about 11 mm and from April to September about 22 mm. Comparison of the average surface and foundation settlements indicates that:

- (i) From December to April the surface and foundation settlements were about equal although the surface settlement at Sta.0+570 is anomalously and substantially less than the foundation settlement perhaps as a consequence of frost heave.
- (ii) From April to December, when the major impoundment of the dam was occurring the surface settlement exceeded the foundation settlement by about 19 mm indicating that a fill compression of at least this amount occurred due to inundation.

3.3.3.3 Thermal Regime

The thermal regime is monitored by thermistor strings in the north and south abutments and in the foundation of the dam. Unfortunately, a thermistor string which was installed in the upstream blanket foundation was lost when the reservoir was filled (the lead was heaved upwards by the rising ice cover).

The chronological isotherm plots are presented in Volume II.

At the north abutment permafrost has been observed between El.1055 and El.1075 (or the base of the active layer whichever is lower). Impoundment of the Cross Valley Dam to an elevation of about 1063.5 therefore may affect the lower boundary of the permafrost layer. Indeed this would appear to be the case as indicated by the thermistor strings 79-20 and CVDC1 - 0 + 050. At each of these installations a marked rise of the 0°C chronological isotherm is noted in early June corresponding to the delayed effect of reservoir impoundment. As of December 1982 the base of the permafrost appears to have risen to an elevation of 1058.5 at location 79-20 and to about 1061 at location CVDC1-0+50. The piezometric elevations at these locations are about 1052.8 and 1055.5 respectively.

The thermistor string installation in the foundation of the dam at Sta. 0+350 shows a general warming trend probably as a consequence of seepage flow beneath the dam. Tracing of seepage flow paths by interpretation of the thermal distribution does not appear possible as yet due to transient response to the initial temperature distribution. Clearly there is no permafrost in the foundation in this area although the foundation of the upstream blanket is expected to be undergoing appreciable thaw. Indeed it is unfortunate that the thermistor string in the upstream

blanket area at this location was unavoidably destroyed (see discussion on blanket foundation thawing in Piezometric Regime below).

There is little if any evidence of thawing of the permafrost at the south abutment of the dam in spite of permafrost presence ranging from El.1045 and El.1061 (elevations vary depending on ground surface elevations). (See chronological isotherms CVDC11-0+645, CVDT4-0+630, in Volume II). However, the installation at the toe of the dam is showing thaw in its bottom thermistor (El.1044) as of mid-May, 1982.

3.3.3.4 Seepage Flow Observations

The flows measured by the three V-notch weirs installed in March are summarized in Volume 2. These weirs are located in the toe drain at the downstream toe of the Cross Valley Dam see Figure 1 and 2 and collect seepage as follows:

Weir #1 - measures seepage from north abutment up to about Sta.0+215

Weir #2 - measures flow from Weir #1 plus seepage from Sta.0+215 to 0+380

Weir #3 - measures all seepage reporting at the toe of the dam and flowing downstream into the drainage ditch.

The flow measurements clearly indicate a strong seasonal behaviour particularly with respect to the flow observations at the north abutment. The peak total summer seepage in July ws about 3300 i.g.p.m., almost 1000 i.g.p.m. more than the November 1982 flows. It is noted that the seepage flows in December may be artificially low due to the closure of the Cross Valley Dam decant in late November. Indeed the seepage flow chemistry (which is outside the terms of reference of this report) would appear to confirm the contention that a significant amount of seepage at the north abutment originates from the decant over the dam.

Examination of the seepage flow increments (i.e. weir #1, weir #2 - weir #1, weir #1 - weir #2 as shown in Volume 2) suggests that a significantly greater amount of water is being collected between weir #2 and weir #3 probably as a consequence of more permeable foundation materials in this area. The variations in the incremental flows are probably due to measurement difficulties. In particular the incremental seepage flow between weir #2 and weir #3 is computed as the difference between two large numbers which are imprecise in themselves.

The seepage flows collected and reporting at the weirs are believed to represent a major proportion of the seepage by the Cross Valley Dam. A few boils may be observed in the abandoned Rose Creek channel and adjacent to the toe drain but the actual flows are not in significant quantity.

3.3.3.5 Piezometric Regime

Piezometric cross-sections have been established at each of the north and south abutments and approximately at Sta. 0+210, 0+360 (partial), 0+450 and 0+570 (see Figure 2). In addition to scheduled monitoring the piezometers have been extensively monitored during filling and on a few other occasions when additional data was deemed necessary. The piezometer observations are reported in Volume II.

During impoundment the piezometers increased regularly and in approximate proportion to the reservoir head. When impoundment was complete, however, the piezometers continued to rise slightly until they peaked in about July and decreased slightly thereafter. The piezometer peaking in July corresponds well to the peaking of the measured seepage flows at the toe of the dam suggesting that the piezometer peaking is related to seasonal groundwater regime variations. Nevertheless it must be

realized that the set of piezometric observations taken in July were recorded by different personnel than for other monitorings. Analysis of the piezometric regime at full impoundment has been made previously. Memoranda pertinent to this subject are reproduced in Appendix IX. These memoranda were written prior to the most current observations in December. The consistent decrease in piezometer levels and flows in December further alleviate the concerns raised in these memoranda.

The reported freezing of the pneumatic piezometers at location 81-126 is surprising in view of the tendency for thawing of the base of the permafrost upon impoundment and in consideration of the more than year long record of observations without freezing.

The loss of the leads to the two piezometers in the upstream blanket area in the vicinity of Sta. 0+360 was unfortunate because these would have been useful in the observation of the performance of the secondary blanket upon thaw of its foundation. The maximum recorded thickness of permafrost in this area was about 10 m. Computations of thaw thicknesses by heat conduction from pond water at temperatures of about 4°C indicate that about 1.5 m of permafrost will thaw in the first year adjacent to such heat sources. For complete conductive thaw of the permafrost a 50 year time period is estimated. However, it is conceivable that much more rapid thaw will occur due to convective heat transport by seepage into the blanket foundation and that thaw of the blanket foundation permafrost could be complete within 10 years. The impact of thus thaw on the piezometric regime and seepage cannot be reliably predicted but the fact that such thaw will continue to occur over the next several years is sufficient basis for continued careful monitoring of the dam.

3.3.4 Intermediate Dam

3.3.4.1 Introduction

Impoundment of the Intermediate Dam began in December, 1981 when the dewatering pumps upstream of the dam were shut off. Thereafter, the reservoir rose at a regular rate in response to the tailings line discharge and the influx of groundwater to the tailings pond. In March tailings deposition was initiated in the reservoir by decanting slime thickened flow from the previously existing tailings dam. The deposition of the tailings was controlled in the sense that a small dyke (approx. 4m high) was constructed across the abandoned Rose Creek channel (opposite Sta 1+200 of the diversion canal) to trap the slimes which decanted from the filtration/sedimentation pond system downstream of the existing pond decant (see Figure 1). Deposition of tailings ceased on about 4 June, 1982 when the milling operation was shut down indefinitely. However, the reservoir was subsequently maintained at full elevation (1066.5) throughout the balance of 1982 by nominal mill discharge of clean water, and by runoff and groundwater from the valley walls.

The decant of the Intermediate Dam was closed in late November thereby raising the pond elevation by about 0.3 m (see Appendix VIII).

Aside from the detailed monitoring of the dam during impoundment the instrumentation was monitored on the schedule required by the water license. This dam was monitored less frequently and has less instrumentation than the Cross Valley Dam because it was designed to function as a tailings dam with tailings on its upstream side shortly after initial impoundment.

3.3.4.2 Movement Monitoring

A tabulation of incremental movements observed for the 3 movement hubs and single rebar installation is provided on Table 6. These results are computed from data obtained by Underhill Engineering in April and September in comparison with original December 1981 data.

The horizontal movements generally have a strong component parallel to the dam centreline and towards the north valley wall. This trend, although more subdued here, was also noted for the Cross Valley Dam and may be the consequence of regional movement or survey error. Movements perpendicular to the centreline are essentially nil which is not surprising in view of the location of the hubs at the downstream toe of a relatively low embankment (about 5m high). (The rebar at Sta. 0+350 is installed on the dam crest.)

Vertical movement monitoring shows a definite trend for heave from December to April and a minor amount of subsequent settlement to September. The installations on the terrace (Sta 0+100 to 0+450 approx.) tend to indicate small net heaves overall perhaps as a consequence of jacking of the installations by frost heave. The hub installations appear to be as prone to this phenomenon as the standard rebar station. In the high fill area (Sta 0+630) settlements are more noticeable although subdued in comparison with those at the Cross Valley Dam. Evaluation of the fill compression is not possible because the settlement plates were not observed in 1982.

Although not specifically monitored or instrumented, a minor amount of cracking of the dam fill was noted locally at the west side of the south abutment (south of the decant). This cracking appeared to be due to subsidence of the fill at the abutment. This may be caused by thaw of permafrost or by local piping of the fill by springs. It is not

considered to be of immediate concern but demands careful examination periodically to ensure that progressive degradation is not occurring.

3.3.4.3 Seepage Flow Monitoring

Because the downstream toe of the Intermediate Dam is inundated to an elevation of about 1064 and the valley bottom lies at an elevation of about 1052, it is impossible to assess the seepage reporting at the downstream toe of the dam.

3.3.4.4 Thermal Regime

The thermal regime is monitored by a single thermistor string at the south abutment where permafrost was believed to exist at the time of construction. Chronological isotherms for this installation (ID7-0+740) are presented Volume II.

Inspection of the data clearly indicates a complete degradation of all permafrost by late August. Further the temperatures are such as to indicate a strong influence of seepage from the pond on the thermal regime of the south abutment. Temperatures of about 4 to 5°C at an elevation of about 1064 must reflect seepage water temperatures which in turn reflect reservoir temperatures.

3.3.4.5 Piezometric Regime

The piezometric regime at the Intermediate Dam is monitored by dual standpipe piezometers at the toe of the low embankment (5m high) which were installed at 5 principal locations along the dam. In addition three pneumatic piezometers which were installed during construction monitor the pore pressures in the high fill zone in the vicinity of the abandoned Rose Creek channel. Data for all installations is provided in Volume II.

The artesian conditions which are observed at Sta 0+240 are surprising in view of the substantial seepage cutoff which has been installed on the upstream face of the dam to considerable depth. This artesian condition however, is prevalent over much of the area downstream of the main embankment (from about Sta. 0+215 to about Sta 0+300, see Figure III-5, Appendix III) and appears to originate from deep permeable layers rather than from seepage through the dam proper. No significant development of a surface of seepage on the downstream face of the embankment has been noted.

Similar conditions to those at Sta 0+240 are observed at Sta 0+450 where the pressures are not adequate to be observed at surface due to a higher downstream berm elevation.

At Sta 0+630 many of the piezometers are grouped at about the same elevation in spite of differing locations with respect to the core. It is noted that piezometer P1 is situated within the silt foundation of the dam. The sizeable difference in head between P1 and the pond may be a consequence of the use of till fill for the upstream zone of dam at this location. The same cannot be said for the installation at Sta 0+690 where the upstream zone was less consistent till and the silt foundation of the dam was less prevalent. Consequently, P4 indicates a piezometric head much closer to the reservoir elevation. At both 0+630 and 0+690 the piezometers downstream of the core closely approximate the tailwater elevation although the most recent observation of P4 at Sta 0+690 shows an increasing trend which should be checked.

The piezometric regime at the south abutment requires some attention as both bedrock and permafrost were exposed in this area during construction. As shown in Volume II the piezometric readings had not reached an equilibrium as of the most current readings in late August. Further, piezometer ID8 which is located between ID7 and ID9 indicates a

piezometric elevation of 1065.5 which is higher than that at ID7 (1065) despite being downstream of ID7 and downstream of the central core. This condition could be artificial and tentative due to the lack of equilibrium measurements but it could also be the result of seepage through highly permeable bedrock. If the latter prognosis is correct some potential for south valley wall instability exists downstream of the dam where seepage exits.

The increasing piezometric conditions at the south abutment are also worthy of note. Although the majority of piezometers on this dam indicate subdued if any peak shortly after full impoundment the south abutment piezometers continue to increase to August. The lack of peak may be a consequence of a lack of data from late May to August in that these observation events may have straddled a peaking seasonal influence in July similar to that postulated at the Cross Valley Dam. However, the increasing piezometric levels may also reflect the thawing of permafrost which thermistor string ID7 indicates was complete by July.

4.0 SUMMARY

4.1 Diversion Canal

The various components of the canal appear to be behaving satisfactorily. Some gullying in the canal backslope has been observed and remedial armouring of such gullies is recommended.

Canal construction does not appear to have precipitated significant permafrost degradation in the canal backslope. ✓ Annual freeze-thaw depths vary from 1 to 2 m and the temperatures at depth agree closely with preconstruction data. The permafrost beneath the canal dyke however, appears to have been noticeably degraded at several locations probably as a consequence of seepage from the canal and the stripping of the natural ground beneath the dyke. Seasonal freeze-thaw depths at the canal dyke and also in the excavation spoil piles are typically about 4 to 5 m.

Movements of the canal components are generally small. ✓ The largest surface displacements were observed on the canal dyke in the vicinity of Stations 2+300 and 3+000 and appear to occur during summer thaw. At Station 2+200 the crest of the dyke is indicated to have moved as much as 63 mm towards the canal centreline with an accompanying vertical settlement of as much as 96 mm. At Station 3+000 the crest of the dyke is indicated to have moved about 52 mm towards the canal centreline with an accompanying vertical settlement of about 35 mm. Although the Sta. 2+200 area is not monitored by slope indicators and incremental settlement instrumentation, such installations in the vicinity of Sta 3+000 indicate that the movements are relatively deep seated but within the upper 4 m. If these observations are correct, surface cracking or other evidence of deformation should have been visible during the summer of 1982 just as it was in 1981. Such cracking was not noted by Cyprus

Anvil personnel.

? Inconsistent!

Significant movements, although somewhat less than those for the canal dyke, were also observed in the backslope and in the spoil piles. The largest movement in the backslope was noted at Sta 3+000 where a horizontal downslope movement of about 39 mm was measured with a vertical settlement of 29 mm. The depth monitoring instrumentation again indicates that these movements are generated within the upper 5 m. Lesser movements in the backslope were also observed at Sta 2+900 and at Sta 2+100.

The spoil pile instrumentation has generally shown sizeable settlement which results from compression of frozen spoil and of the spoil pile foundation as well as from the thaw of originally near surface materials. These settlements (up to 133 mm) do not appear to be accompanied by large horizontal movements although many of the latter are significant.

Piezometric observations along the canal route generally support the hypothesis that the canal is underdrained. Piezometers in the backslope in the vicinity of Sta 0+710 and Sta 0+990 show a marked response to spring runoff and therefore these areas should be expected to form gullies in the long term. High pore pressures indicated in the backslope in the vicinity of Sta 2+100 appear to result from the freezing of pneumatic piezometer tips in the presence of water. On the other hand, pneumatic piezometers which have never been wetted and have been installed in permafrost exhibit an essentially null pressure condition. ✓

4.2 Cross Valley Dam

Settlement and movement of the Cross Valley Dam has been slight since the completion of construction. ✓ About 16 mm of settlement is attributed

to compression of the embankment fill upon reservoir impoundment. Insignificant horizontal movements tend to be in the northerly direction parallel to the dam.

Degradation of permafrost at depth is occurring at the north abutment. A minor amount of degradation has been observed at the south abutment.

what effect will this have?

The volume of seepage collected by the toe drain and piezometric levels appear to have peaked in about July as a consequence of seasonal groundwater discharge. The observed July total seepage flow was 3300 i.g.p.m.; currently 2200 i.g.p.m. is being observed. Seepage from the decant is also believed to contribute to the north abutment seepage flow. The piezometers in the vicinity of Sta 0+570 indicate a regime different from that observed north of that location. Degradation of permafrost beneath the upstream blanket in the vicinity of Sta 0+360 is expected to continue for several years and this may impact both observed flows and piezometric conditions in the long term.

4.3 Intermediate Dam

coincides with decant position

Settlement and movement of the Intermediate Dam followed the same trends as discussed for the Cross Valley Dam except that lesser magnitudes of movement were observed. The largest surface settlement of the Intermediate dam was about 16 mm with a negligible amount of horizontal movement occurring albeit in a direction consistent with those observed at the Cross Valley Dam.

Some degradation of permafrost occurred at the south abutment probably as a consequence of seepage. The piezometers in the south abutment did not appear to have peaked as of the most recent observations in August and there is a need to define the current piezometric regime in view of the permafrost degradation. Further, at the south abutment, the

As
piezometer downstream of the core shows a higher elevation than the one upstream of the core suggesting that there are local hydraulic connections in the bedrock.

Slight artesian pressures have developed in the vicinity of Sta 0+300. These pressures have probably resulted from permeable layers beneath the depth of upstream core cutoff and are a consequence of the high tailwater imposed by the Cross Valley Dam reservoir.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Remedial Works and Inspection Program

5.1.1 Canal

Erosion and gullying in the canal backslope should be prevented as soon as possible by armouring to preclude loss of control of permafrost degradation and to preclude meandering of the canal as a consequence of sediment deposition in the adjacent canal. If such action is not undertaken soon, access along the backslope will become extremely difficult and costly. It is recommended that broadly graded class IV type armouring ($D_{50} = 200$ mm) or equivalent cobbly gravel be used as armouring materials.

Done Maintenance of the weir structures and armouring of the hydraulic cross sections should be undertaken on the basis of careful visual inspections which define areas of active erosion and areas where the riprap is being undermined. It is noted that Hydrocon Engineering indicated in their report (see Appendix IV) that the last 5 weirs require minor modification. Hydrocon also identified other areas which require attention.

5.1.2 Dams

Current closing of the Intermediate Dam decant has resulted in flow over the emergency spillway. The emergency spillways are not designed for such operation and the performance must therefore be regularly and carefully monitored. All temporary installations which may be undertaken to control reservoir levels should be monitored carefully. Breach of such installations may result in accelerated erosion and precipitate a need for maintenance. The spillway structures are designed for short term emergency flows only and such flows may result in a need for maintenance depending upon the magnitude and nature of the

flow. Further, rapid changes in pond levels are not desirable from point of view of general slope stability.

Erosion of materials at seepage emergence points does not appear to be a problem. The boils and springs which have been noticed downstream of the Cross Valley Dam appear to be a consequence of local silt beds and progressive deterioration has not been observed. However, should such deterioration be noted a clean sand and gravel berm may be required to filter these seepage discharges. The occurrence of new springs or boils should be reported immediately to Golder Associates.

The surface of seepage which has developed in the vicinity of Sta 0+300 of the Intermediate Dam should be monitored closely for any indication of deterioration. If seepage increases and erosion occurs additional clean sand and gravel fill should be placed on the downstream berm area (up to about 2000 m³).

At the southwest corner of the Intermediate Dam south abutment, a transverse tension crack has developed in the decant berm/thermal liner. This phenomenon may be the consequence of local piping of thawed permafrost and therefore demands careful inspection. Continued slumping in this area may dictate a need for a downstream blanketing of the natural slope with clean sand and gravel particularly if the Intermediate Dam reservoir is raised without the benefit of tailings in the reservoir. The situation could also worsen as a consequence of south valley wall thaw.

5.2 1983 Instrumentation Monitoring Schedule

The 1982 monitoring schedule followed that which was proposed by Golder Associates in 1981 when the monitoring program was initially conceived. Additional supplementary observations have also been taken as requested by Golder Associates.

The initial monitoring schedule was conceived on the basis that the Down Valley system would respond to seasonal variations and that it was necessary to define such seasonal response to understand the behaviour of the various structures. It was therefore considered necessary to examine the thermal and piezometric regimes at times of extreme seasonal frost penetration, at times of extreme thaw, and at times of extreme runoff and groundwater flux. The movements of the structures in response to such changes were also of interest with respect to the interpretation and prediction of long term movements due to construction in a discontinuous permafrost area.

After a year of comprehensive monitoring, the practical value and detail of continued monitoring must be examined. Seasonal trends have been established. Many areas have been identified as being inactive over the past year and it would not appear to be fruitful to monitor such areas on a more frequent time basis than yearly. Further, certain types of instrumentation have been found to be diagnostic in terms of performance evaluation. Hence it would appear to be possible to reduce both the frequency and the scope of the monitoring without sacrifice of performance detail.

It is recommended that all instrumentation including the surface hubs which require precise survey be observed in September 1983 and tentatively in Septembers of ensuing years. Additional observations are also recommended in accordance with the following tabulation:

(i)	<u>Canal Backslope</u>	<u>Observation Month(s)</u>	<u>Instrumentation</u>
	BS2-0+400	March	SI,PP
	BS5-0+960	March	PP
	BS9-1+530	March	SI,PP,T
	BS10-1+900	March	SI,T

BS11-2+100	March	SI,T,S,PP
82-1, 82-8 2+130	March	PP,PP
82-9	March	HP

<u>Canal Backslope</u>	<u>Observation Month(s)</u>	<u>Instrumentation</u>
BS16-2+900	March, June	SI,T
BS17-2+900	March, June	SI,T
BS18-3+000	March, June	SI,T,S

(ii) <u>Canal Dyke</u>	<u>Observation Month(s)</u>	<u>Instrumentation</u>
CD4-0+400	March	T
CD5-0+510	March	T
CD9-0+960	March	PP
CD10-0+990	March	T,PP
CD13-1+350	March	PP
CD15-1+530	March	T,PP
CD17-1+705	March	T
CD19-1+900	March	SI,T
CD20-2+000	March	T
CD21-2+100	March, June	SI,S,T
CD24-2+365	March	T
CD25-2+460	March	T
CD26-2+600	March	T
CD27-2+765	March	T
CD28-2+900	March, June	SI,S,T
CD29-3+000	March, June	SI,S,T
CD30-3+130	March	T

(iii) Canal Spoilpiles - annual readings only (September)

(iv) Dams

All piezometers and thermistors should be observed on a quarterly basis in March, June, September and December. Seepage flow measurements should be observed at least monthly. The settlement plates at both dams should also be monitored as a part of the annual September precise survey.

The schedule given above attempts to give emphasis to areas where changes are to be expected and where changes have occurred. The thermal regime beneath the canal dyke appears to be changing and hence all thermistors located there should be observed more frequently.

Similarly, movements appear to be progressive in the vicinity of Sta 2+200 and Sta 3+000 of the canal and monitoring of such movements and other instrumentation is recommended in more detail. Finally the dams should be monitored regularly due to the possible impacts of permafrost degradation and to the need to monitor progressive internal erosion.

5.3 Annual Inspection

It is recommended that an annual inspection be made by a Golder Associates' project engineer who is aware of the geotechnical environment and performance concerns. This inspection should be made in July or August and instrumentation of particular concern should be monitored at this time as a check for equipment operation and observation techniques. ✓

A report and photographic record of this site visit should be prepared immediately after the visit. ✓

5.4 Performance

The performance of the Down Valley structures is of relevance to both the short term and the long term (abandonment) success of project. Performance should therefore be evaluated in terms of a 20 year operational life and abandonment. ✓

Although the thermal regime is still reacting to the construction of the canal on the valley wall particularly beneath the canal dyke it would appear that the canal has been successfully integrated into the discontinuous permafrost regime. ✓ Some maintenance with respect to gullying of the backslope is necessary in the near future to ensure this successful integration. ✓

The movements of canal elements which have been observed in the vicinity of Sta 2+200 and 3+000 are of some concern and deserve continued careful observation. These movements appear to be slow creeping movements and as such will accumulate with time.

The canal dyke movements in the vicinity of Sta 2+200 appear to be in response to local ice rich permafrost in the foundation of the canal dyke; the movements are credible in view of our knowledge of the area but the lack of observation of cracking in the area is inconsistent with the measured lateral movements of the order of 50 mm. This inconsistency requires checking due to the possibility that snow clearing equipment has disturbed or deflected the installations. The movements in the backslope at this location also demand attention although present indications are that they are of lesser magnitude (10 mm).

Progressive thaw may well be occurring in the vicinity of Sta 2+200 and if this is the case the movements would be expected to decrease with time. Further instrumentation (slope indicators) at this location should be considered to determine more precisely the mechanism of movement.

In the vicinity of Sta 3+000 of the canal there are indications of movements in both the canal backslope and in the canal dyke. Surface movements indicate that over the year a downslope movement of about 40

mm has occurred in the backslope and that a movement of the canal dyke crest towards the canal centreline of up to 50 mm has occurred. These movements appear to have developed within the upper 5 m and appear to occur as a steady creep irrespective of frozen or thawed condition. These movements therefore can be expected to continue and monitoring of the rate of movement over several years is recommended to define the scope of this problem with respect to abandonment. The area should be monitored carefully in general for the developemnt of tension cracks in both the backslope and the dyke. Such cracks may lead to active permafrost degradation which would also lead to increased movement rates.

The observed movements in the vicinity of Sta 3+000 do not preclude the use of a diversion canal scheme in abandonment. ✓ However to develop a practical scheme the movements may need to be stopped by remedial works or by flattening of slopes. Further it would not seem inappropriate to consider a short section of tunnel if the surface problems prove to be unmanageable.

Is this what is meant?



The performance of the dams appears to be satisfactory in terms of seepage quantity and water pressures. The behaviour of the Intermediate Dam south abutment demands attention with respect to piping as a consequence of permafrost thaw and high seepage pressures which may result also from the lack of tailings in the upstream reservoir. At the Cross Valley Dam changing piezometric conditions should be expected in response to permafrost degradation in the abutments and in the upstream blanket foundation area. These changing conditions should be monitored closely because increases of water pressures above the present levels would precipitate a need, particularly at the south abutment in the vicinity of Sta 0+570, for remedial measures such as a drainage blanket or relief wells. Additional monitoring capacity could also be required to evaluate the scope of any problems which may develop.

The operation of the tailings system in the absence of tailings deposition results in long term conditions which were not anticipated in design. Experience has shown that seepage rates generally reduce as a consequence of direct tailings deposition against the upstream face of the dam or as a consequence of precipitation or sedimentation in a stilling pond. In essence these conditions have not existed in the new containment ponds and therefore it may be surmised that the structures are presently being exposed to rather severe conditions. Further the absence of buttressing of the south valley wall by tailings means that this slope has a lower factor of safety than if there were tailings buttressing. Consideration of all of these factors defines a need for careful monitoring of the Down Valley Project in spite of mill shut-
down.

Station	Original	Backslope		Canal Dyke		Spoil Pile		Definitions
		Status	Change	Status	Change (Type)	Status	Change	
0+400		discont. frozen	no change	thawed	Canal Seepage(I)	-	-	Original: Thermistors installed during 1979 and 1980 drilling investigation programs and have been subsequently destroyed.
0+500		-	-	discont. frozen	Progressive Thaw (II)	-	-	
0+710 (Goodall Creek)		thawed	no change	-	-	-	-	
1+000	discont. frozen	discont. frozen	no change (seasonal)	thawed	Canal Seepage(I)	-	-	Status: Ground conditions at depth (5 to 10m) as of November 1982. - thawed temperatures greater than 0.0°C - discontinuously frozen, temperatures generally between +0.5°C to 0.3°C. - frozen, temperatures less than 0.0°C. Change: Change in thermal conditions observed at depth from November 1981 to November 1982. - Type I, change influenced by seepage from the canal - Type II, change showing progressive thaw at depth - Type III, essentially unchanged (+0.2°C) by the canal, may show a small seasonal variation.
1+500	(1+320) thawed	thawed	no change	thawed	no change (III) (seasonal)	frozen	no change	
1+700		-	-	discont. frozen	Progressive Thaw (II)	-	-	
1+900	discont. frozen	frozen	no change	frozen	no change (III)	frozen	no change	
2+000		-	-	discont. frozen	Canal Seepage(I)	-	-	
2+100	discont. frozen	frozen	no change	frozen	no change (III)	-	-	
2+250		discont. frozen	no change (seasonal)	-	-	-	-	
2+350		-	-	discont. frozen	Canal Seepage(I)	-	-	
2+500		-	-	thawed	Canal Seepage(I) (seasonal)	-	-	
2+600		-	-	discont. frozen	Progressive Thaw (II)	-	-	
2+750		discont. frozen	no change (seasonal)	discont. frozen	Progressive Thaw (II)	-	-	
2+900	discont. frozen	frozen	no change	discont. frozen	Progressive Thaw (II)	frozen	no change	
3+000		frozen	no change	frozen	no change (III)	-	-	
3+100		-	-	thawed	Canal Seepage(I)	.		

TABLE 1 - DIVERSION CANAL THERMAL REGIME

Table: 2

CANAL VERTICAL SURFACE MOVEMENT MONITORING (mm)

STATION	BACKSLOPE			DYKE			SPOIL PILES		
	Dec to Apr	Apr to Sept	TOTAL	Dec to Apr	Apr to Sept	TOTAL	Dec to Apr	Apr to Sept	TOTAL
0+100	-2	+2	0	-1	-3	-4			
0+200									
0+300				-1	+7	+6			
0+400	-3	+9	+6	-2	+1	-1			
0+500				+2	+12	+14			
0+600	-7	-10 ✓	-17 ✓	-4	+17	+13			
0+700				-4	+6	+2			
0+800				+1	+9	+10			
0+900									
1+000	-5	+13 ✓	+8 ✓	-3	+21	+18	-25	+7	-18
1+100				-3	+17	+14			
1+200	+2	+9	+11	+3	+3	+6			
1+300	-9			-1	+1	0			
1+400	-6	+12 ✓	+6	+3	+8	+11			
1+500				0	+12	+12			
1+600	-3	+13 ✓	+10	+4	+5	+9	-44	-11	-55
1+700				0	+6	+6			
1+800				-2	+6	+4			
1+900	-7	+2	-5	-11	-5	-16			
2+000				0	-6	-6	-23	-110	-133
2+100				-3	-7	-10	-50	-44	-94
2+200	+44	+3	+47	-5	+1	-4			
2+300	-1	+9	+8	-16	-62	-78			
2+400				-14	-16	-30			
2+500	-9	+13 ✓	+4	-15	-81	-96			
2+600	-1	+8	+7	-4	+1	-3			
2+700				-4	-3	-7			
2+800	+11	-2	+9						
2+900				+2	-8	-6			
3+000	+7	-18 ✓	-11	+7	-12	-5			
3+100	-3 ⁺¹	-26 ✓	-29 ⁺¹	+5	-37	-32	-5	-27	-32
3+200									
3+300	+1	-7	-6	-10	-25	-35			
3+400	-9	+5	-4						
3+500									
	-4	-3	-7	-9	+5	-4			

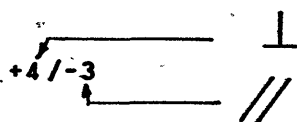
- indicates movement downwards

+ indicates movement upwards

Table: 3

CANAL HORIZONTAL SURFACE MOVEMENT MONITORING (mm)

STATION	BACKSLOPE			DYKE			SPOIL PILES		
	Dec to Apr	Apr to Sept	TOTAL	Dec to Apr	Apr to Sept	TOTAL	Dec to Apr	Apr to Sept	TOTAL
0+100									
0+200									
0+300									
0+400	-12/0	+5/+2	-7/+2	-3/+1	+16/-6	+13/-5			
0+500									
0+600									
0+700									
0+800									
0+900	-2/-1	-3/-7	-5/-8	+2/+1	0/-6	+2/-5	+4/0	-8/+1	-4/+1
1+000									
1+100									
1+200									
1+300									
1+400				+1/0	+2/-2	+3/-2			
1+500	-13/0	+4/-6	-9/-6	0/+2	+10/-2	+10/0	-7/+4	+4/-8	-3/-4
1+600									
1+700									
1+800									
1+900	-2/+2	+8/-3	+6/-1	-1/+1	+5/-6	+3/-5	-4/0	0/+12	-4/+12
2+000									
2+100	-18/0	+6/-19	-12/-19	-6/+1	-3/0	-9/+1	-5/+3	+17/+4	+12/+7
2+200				0/+5	+63/0	+63/+5			
2+300				-3/+4	+17/+21	+14/+25			
2+400									
2+500									
2+600									
2+700									
2+800									
2+900	-26/-9	0/-4	-26/-13	-15/+4	0/-4	-15/0			
3+000	-13/-7	0/+6	-13/-1	-15/0	+52/+18	+37/+18	-11/+2	0/-9	-11/-7
3+100	-25/-4	-14/0	-39/-4						
3+200				-12/-9					
3+300	-9/-11	+1/-7	-8/-18		-26/+19				
3+400									
3+500	-11/-6	-10/0	-21/-6	-5/-8	+10/+3	+5/-5			


 to canal centre line.
 to canal centre line.

- indicates downstream or downslope.

+ indicates upstream or upslope.

Depth (m)	BACKSLOPE (Average of 7 loc'ns)					DYKE					SPOIL PILES				
	Dec to Mar	Mar to Jun	Jun to Sept	Sept to Dec	Annual Sum	Dec to Mar	Mar to Jun	Jun to Sept	Sept to Dec	Annual Sum	Dec to Mar	Mar to Jun	Jun to Sept	Sept to Dec	Annual Sum
1	+15	-1	-49	+2	-35	+4	-6	-1	+1	-2	-2	-34	-37	+50	-23
2															
3															
4	-6	+2	+3	-2	-4						-1	+1	-1	-5	-16
5						+1	-1	-6	+1	-6					
6	*NOTE: Information reported is the average of all readings taken for the time intervals and depths shown. + indicates heave or expansion - indicates settlement or compression All quantities reported are in mm.														
7											-74	-8	-1	-42	-124
8															
9						-2	0	-3	+4	-1					
10															

TABLE 4 AVERAGE CANAL INCREMENTAL SETTLEMENT OBSERVATIONS - 1982

Table: 5
CROSS VALLEY DAM MOVEMENTS (mm)

Station	Reinforcing Bar			Movement Hub			Settlement Plate		
	Dec to Apr	Apr to Sept	Total	Dec to Apr	Apr to Sept	Total	Dec to Apr	Apr to Sept	Total
0 + 100									
0 + 200	-3	-14	- 17	-8	-17	- 25	-8	-2	- 10
0 + 300	-8	-17	- 25						
	-9								
	-6	-18	- 24						
	-9	-17	- 26						
0 + 400	-15	-17	- 32	-20	-22	- 42	-20	-10	- 30
	-22	-16	- 38						
	-36		- 36						
0 + 500	-7	-31	- 38	-12	-32	- 44	-11	0	- 11
	-10	-20	- 30						
	-10	-24	- 34						
0 + 600	-14	-30	- 44	-4	-29	- 33	-18	-11	- 29
	-15	-35	- 50						
0 + 700									
Average	-11	-22	- 33	-11	-25	- 36	-14	-6	- 20

(a) Vertical Movements

- + indicates upward movement
- indicates downward movement

Station	Apr	Sept	Total
0 + 205	-2 / +10	+9 / +2	+7 / +12
0 + 338	0 / +8	+3 / -5	+3 / +3
0 + 460	-5 / +15	+4 / +1	-1 / +16
0 + 568	-3 / +12	+7 / -1	+4 / +11
Average	-2 / +11	+6 / -1	+3 / +10.5

(b) Horizontal Movements (Movement Hub Only)

- indicates movement downstream, or towards south valley wall.
- + indicates movement upstream, or towards north valley wall.
- 2/+10 indicates 2mm movement downstream and 10mm movement towards north valley wall.

Table: 6
INTERMEDIATE DAM MOVEMENTS (mm)

Station	Reinforcing Bar			Movement Hub			Settlement Plate		
	Dec to Apr	Apr to Sept	Total	Dec to Apr	Apr to Sept	Total	Dec to Apr	Apr to Sept	Total
0 + 100									
0 + 200				+7	+1	+8			
0 + 300									
0 + 400	+10	-11	-1					NOT	
0 + 500				+11	0	+11		OBSERVED	
0 + 600				+4	-16	-12			
0 + 700									
Average	+10	-11	-1	+7	-5	+2	—	—	—

(a) Vertical Movements

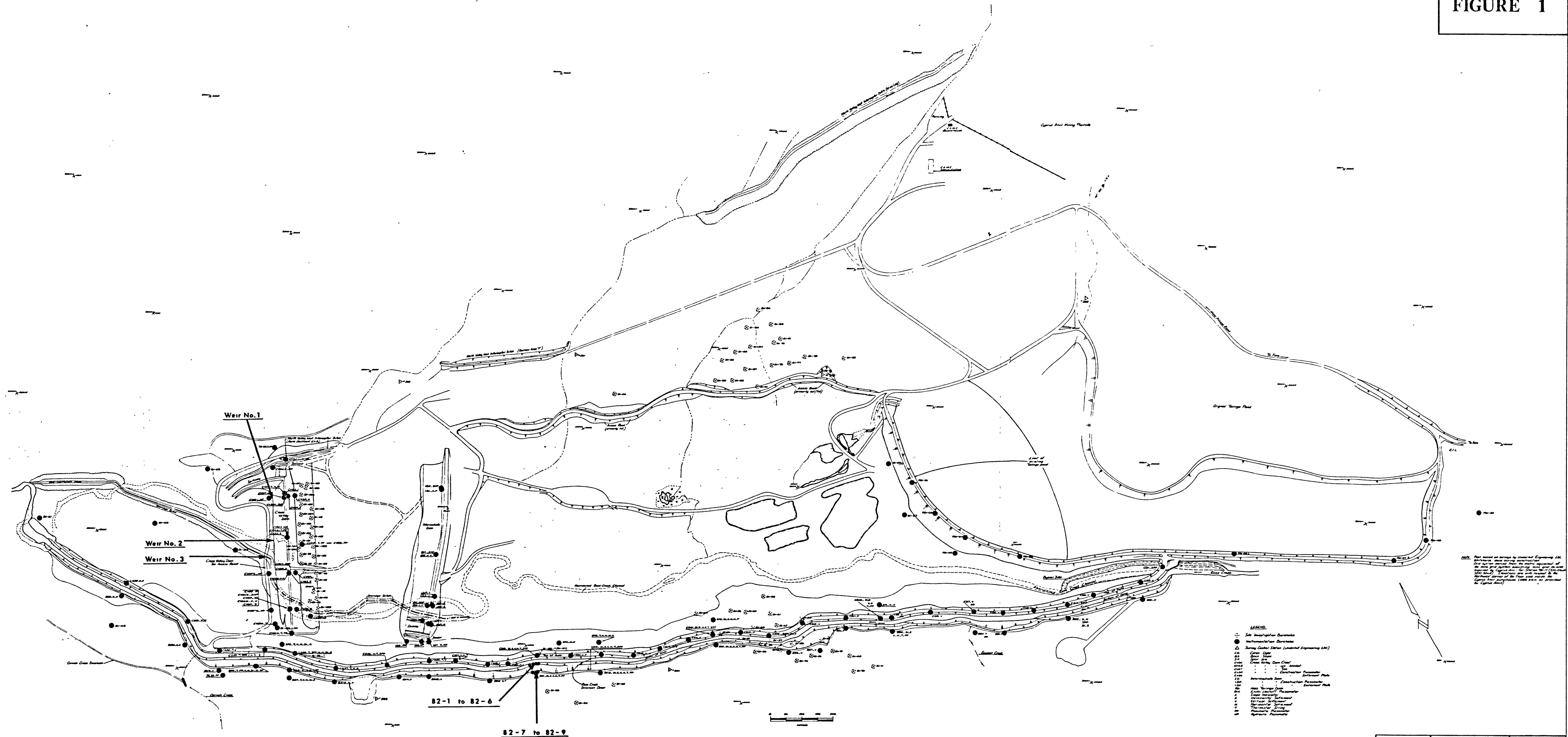
- + indicates upward movement
- indicates downward movement

Station	Apr	Sept	Total
0 + 250	-4/+9	-4/-10	-8 / -1
0 + 350	+5/+13	+3/-7	+8 / +6
0 + 450	-2/+12	+2/-3	0 / +9
0 + 627	-1/+2	-1/+3	-2 / +5
Average	0 / +9	0 / -4	0 / +5

(b) Horizontal Movements (Movement Hub Only)

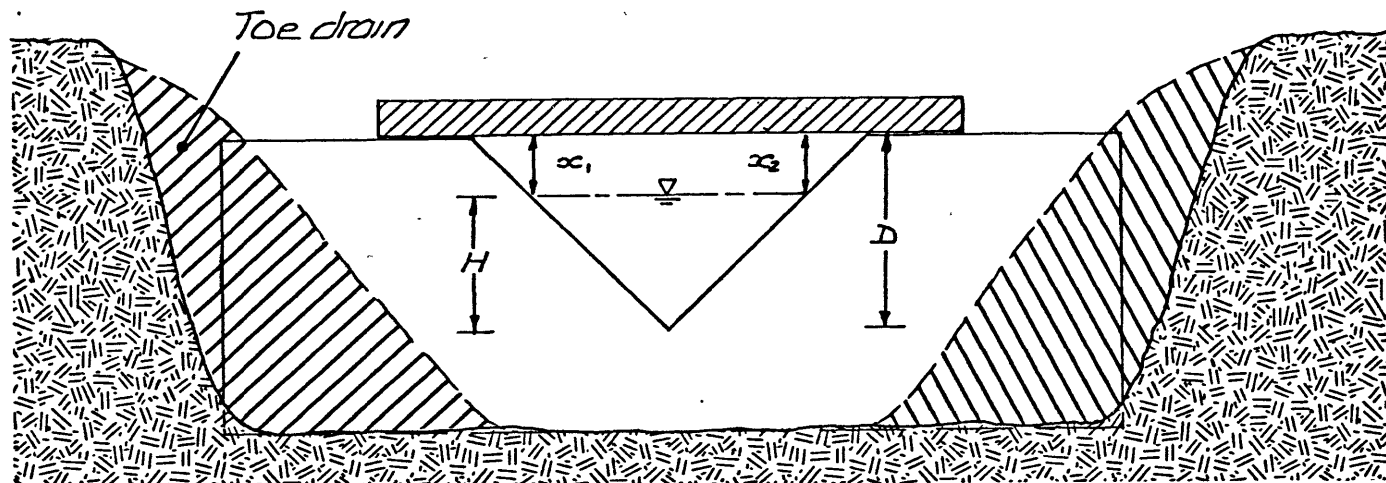
- indicates movement downstream, or towards south valley wall.
- + indicates movement upstream, or towards north valley wall.
- 2/+10 indicates 2mm movement downstream and 10mm movement towards north valley wall.

FIGURE 1



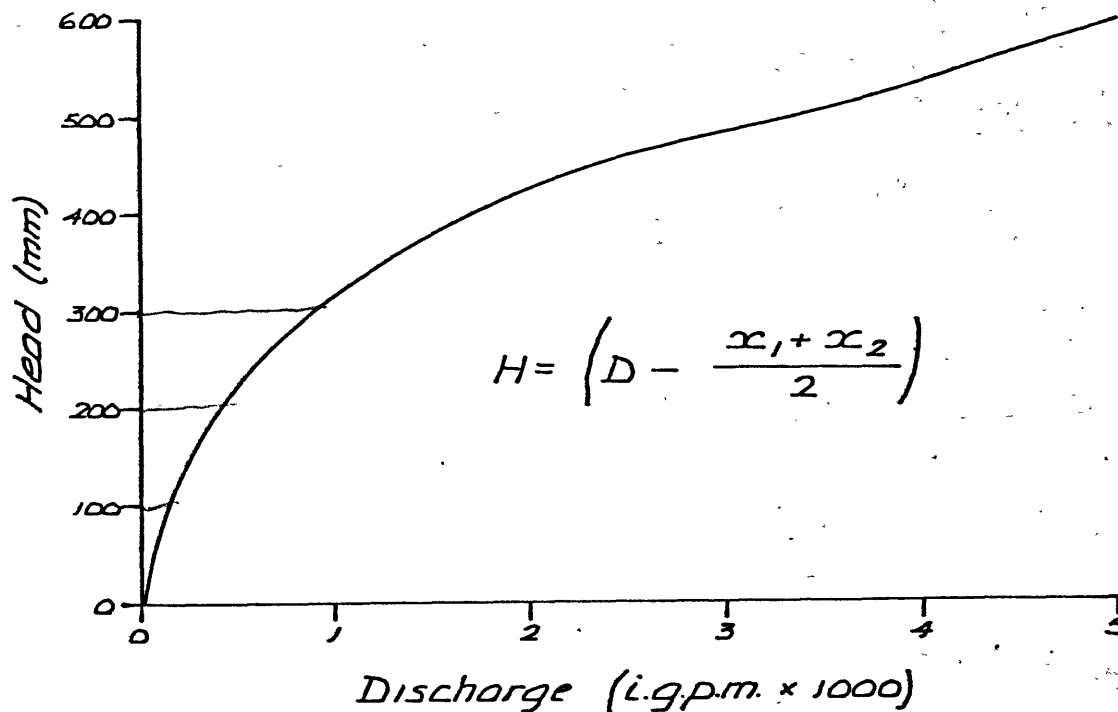
WEIR SCHEMATIC

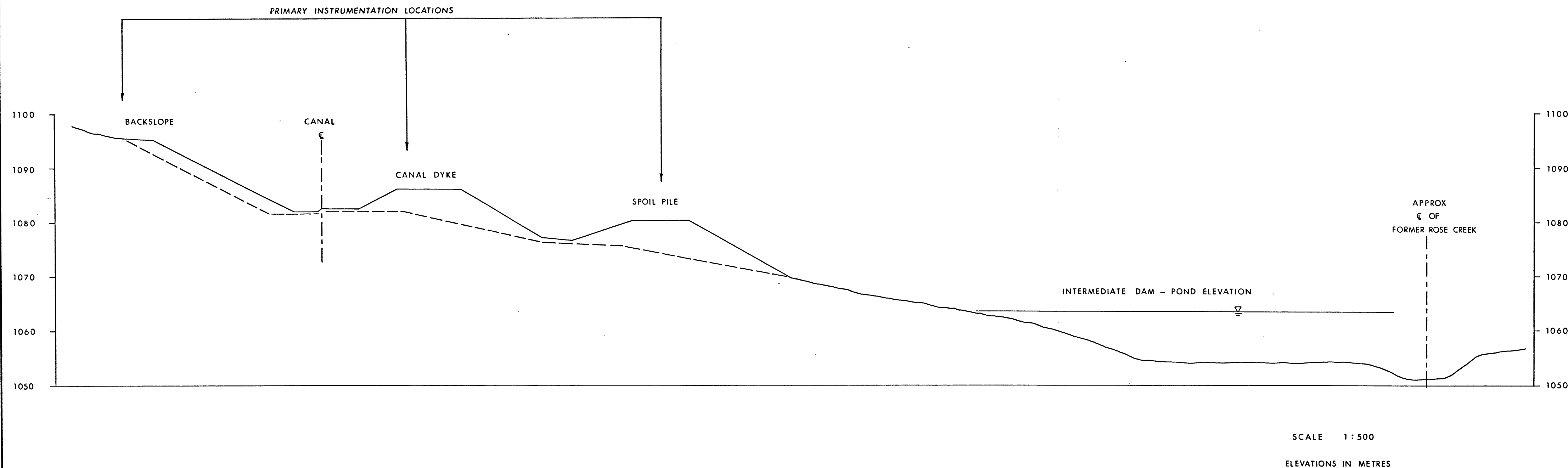
Figure 2



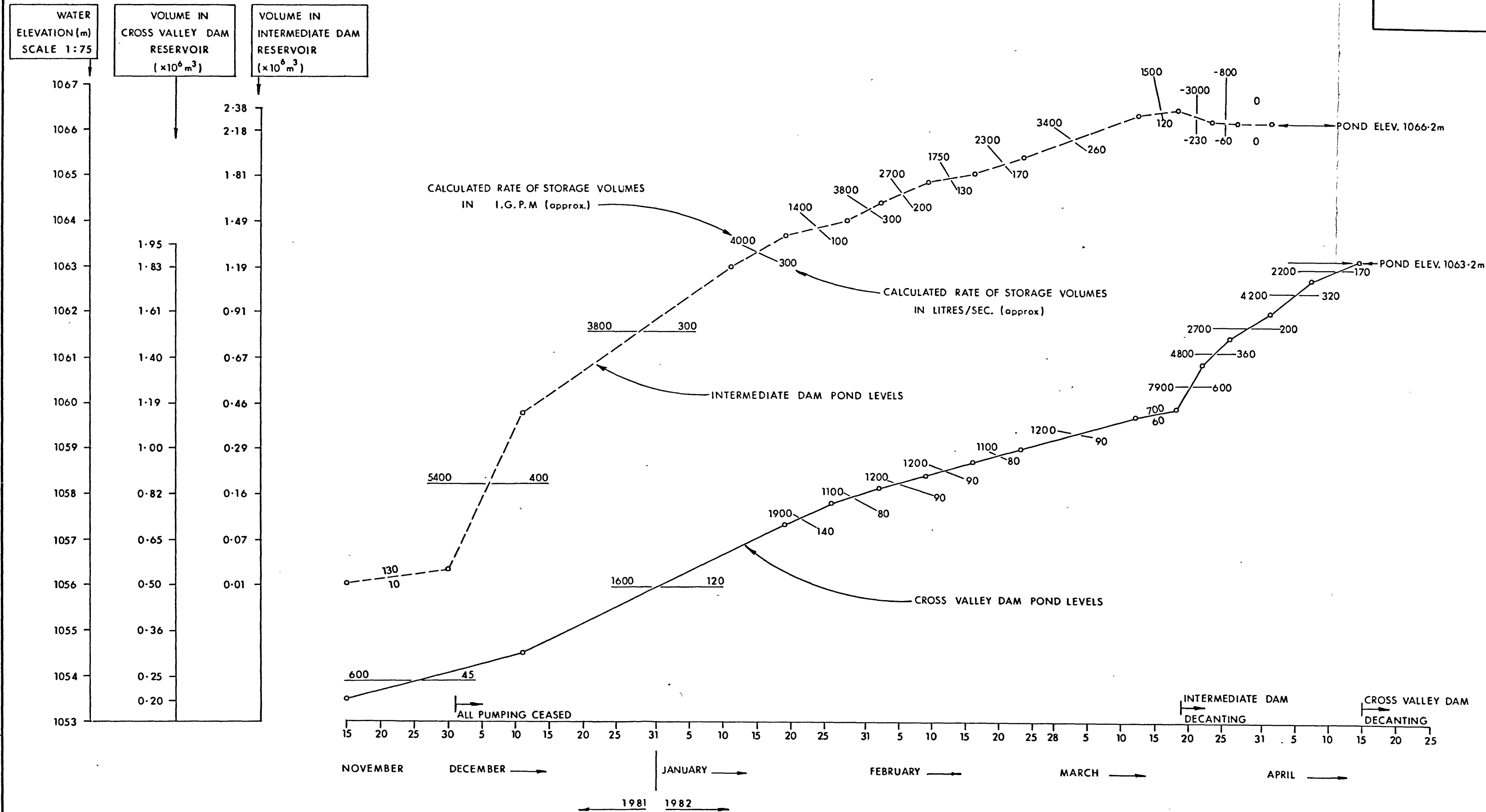
WEIR No.	D=(mm)	STN.
1	460	0+215
2	456	0+380
3	600	Collector

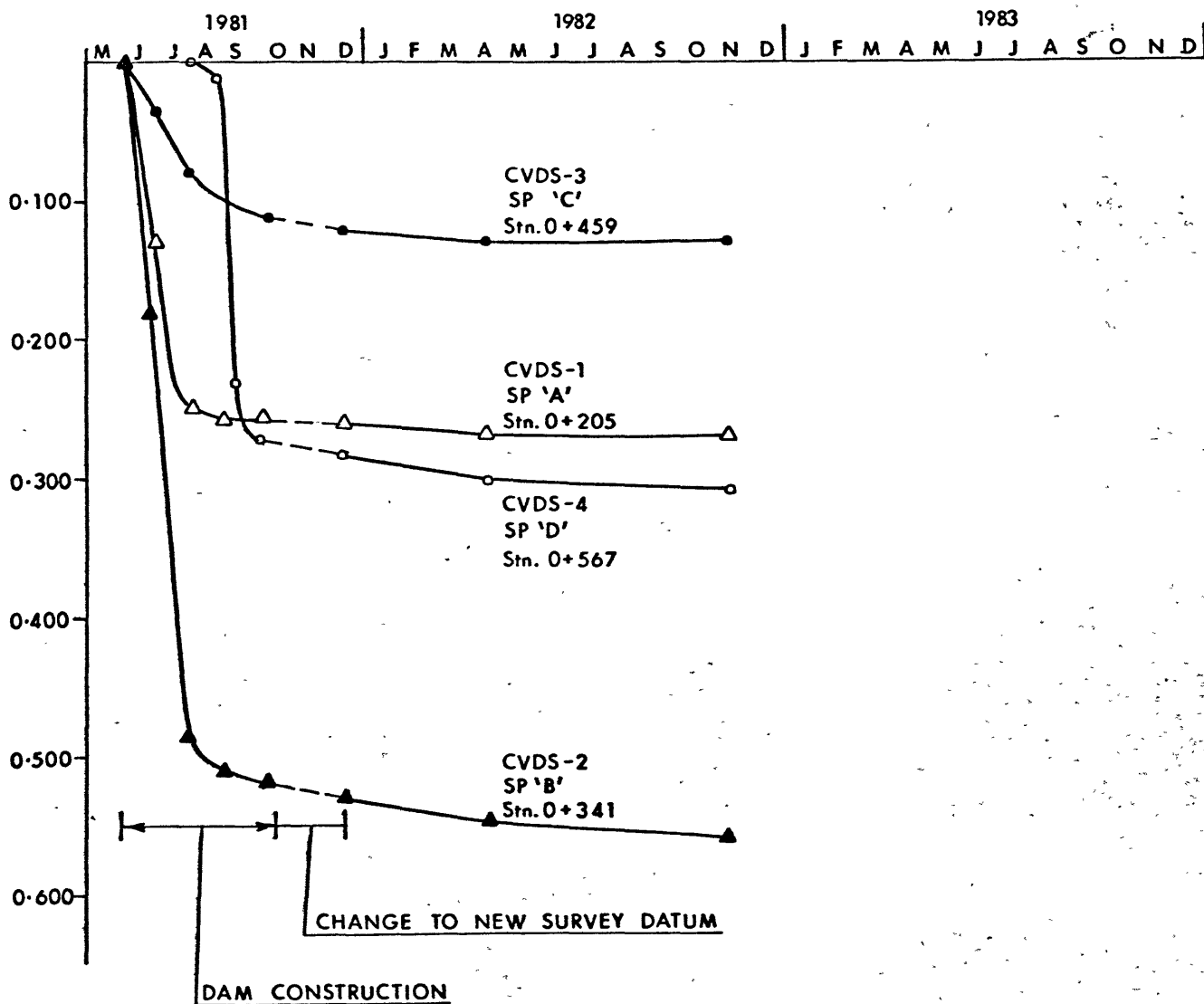
For each observation distances x_1 and x_2 are recorded.





Golder Associates





APPENDIX I
SUPPLEMENTARY INSTRUMENTATION - CANAL BACKSLOPE



Golder Associates

CONSULTING GEOTECHNICAL AND MINING ENGINEERS

May 27, 1982

Ref. No. 822-2034

Cyprus Anvil Mining Corporation
P.O. Box 1000
Faro, Yukon
Y0B 1K0

ATTENTION: Mr. N.G. Cornish

Dear Sir:

Re: Early May 1982 Canal Backslope Stability
Investigation Sta. 2+100 Vicinity

A detailed field and office examination of the piezometric conditions in the canal backslope in the vicinity of Sta. 2+100 has been completed. The need for this work resulted from the relatively high observed pore pressures which have been indicated by the backslope piezometer BS11-2+100 which was installed in November, 1981 as a part of the Down Valley Project Instrumentation. Its location is shown on Figure 1 attached.

The field investigation generally followed the program which was proposed by a telex to you dated April 29, 1982 (a copy of which is attached), although some modifications were made when it became apparent that the high pore pressures indicated by piezometer BS11-2+100 are surprisingly local.

A total of 9 boreholes were advanced over the period between May 3 and May 7 under the supervision of Golder Associates field engineer Mr. D. Kettle using the track carrier mounted air percussion drill owned and operated by Cyprus Anvil. Single installations were made in each of the 57 mm diameter boreholes. Installation consisted of 7 pneumatic

piezometers, 1 standpipe (hydraulic) piezometer and 1 thermistor string and these were installed as follows (numbered in chronological order of drilling):

<u>Borehole No.</u>	<u>Depth(m)</u>	<u>Installation</u>	<u>Location/Remarks</u>
82-1	7.3	pneu. piez.	ice bench-slope toe, Sta.2+130
82-2	5.8	pneu. piez.	ice bench-slope toe, Sta.2+100
82-3	7.3	pneu. piez.	ice bench-slope toe, Sta.2+070
82-4	10.7	pneu. piez.	ice bench-slope toe, Sta.2+100
82-5	7.7	pneu. piez.	ice bench-slope toe, Sta.2+160
82-6	11.0	thermistors	ice bench-slope tope, Sta.2+100
82-7	10.8	pneu. piez.	top edge of backslope cut, Sta. 2+100
82-8	10.7	pneu. piez.	top edge of backslope cut, Sta. 2+130
82-9	10.4	~~pneu. piez.~~ standpipe	top edge of backslope cut, Sta. 2+115

The approximate locations of the boreholes are plotted on Figure 1. All locations and elevations (shown on the borehole logs) must be considered as approximate since the boreholes were not surveyed. Details of the stratigraphy observed during drilling and the installation details are presented on the attached Record of Borehole sheets.

Observations of the instrumentation installed during this program and of the previously installed BS11-2+100 piezometer are provided on the attached working copies of the data sheet records and summary calendar plots. This data was obtained by our field engineer while on site and subsequently by Cyprus Anvil personnel. The installations should be observed in future on the same schedule as the other Down Valley Project instrumentation.

Examination of the data clearly indicates that there is no immediate slope stability concern on a large scale. The piezometric conditions observed in the critical area at the toe of the slope are generally comparable to those observed beneath the canal dyke at Sta. 2+100, that is the pore pressures are generally less than the equivalent of 1 m of water pressure. An exception is observed at Sta. 2+130 (BH 82-1) where a pore pressure head of about 5 m was observed; this is not a concern however because this piezometric head corresponds to the invert elevation of the canal. We consider that the piezometer at Sta. 2+160 (BH 82-5) is registering a high pressure due to freeze up of the piezometer.

Piezometer levels for the newly installed piezometers in the backslope are also low particularly in comparison with the original piezometer BS-11-2+100. The pore pressure heads observed in the backslope are as follows:

<u>Installation</u>	<u>Pore Pressure Head (m)</u>	<u>Remarks</u>
82-7	<1 m	Sta. 2+100
82-8	2 m	Sta. 2+130
82-9	0	dry standpipe
*BS-11-2+100	6.3 m	previous installation

* actually located at Sta. 2+115.

The above results indicate that the high pore pressure observed at BS-11-2+100 are anomalous and are not generally pertinent to overall slope stability. We note that the standpipe installed in Borehole No. 82-9 was installed only 1.2 m in plan distance away from the piezometer BS-11-2+100.

There are several possible reasons for the anomalously high pore pressure reading at BS-11-2+100. The bedrock and consequently the stratigraphy is very irregular in this area. Boreholes drilled 15 m on each side of

BS-11 encountered bedrock at 7.6 m (BH 82-7) and 5.2 m (BH 82-8) depths whereas no bedrock was observed at BH 82-9 or at BS-11 within the depths of investigation (10.4 and 11.6 m respectively). Groundwater flow would therefore be expected to be irregular. Another possibility is that the piezometer in BS-11 is not functioning properly, although we do not believe this to be the case since the record of observations appears to fluctuate in a consistent fashion. Finally, pore pressures in marginally frozen ground may reflect rather unique conditions resulting from discontinuously frozen soil or from advancing or retreating frost fronts. The thermistor string installed in Borehole No. 82-6 indicates discontinuously frozen ground below a depth of about 8 m, consistent with other thermal information in this area.

Continued observation of the instruments installed in this program will be useful in understanding the origin and nature of the pore pressures in this specific area of the canal where one of the highest backslope cuts occurs in a complex discontinuous permafrost setting.

Yours very truly,

GOLDER ASSOCIATES

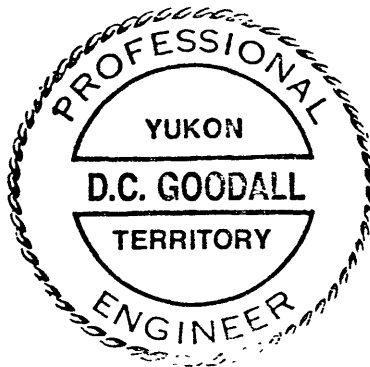
Dave Goodall

D.C. Goodall, P. Eng.

H.G. Gilchrist

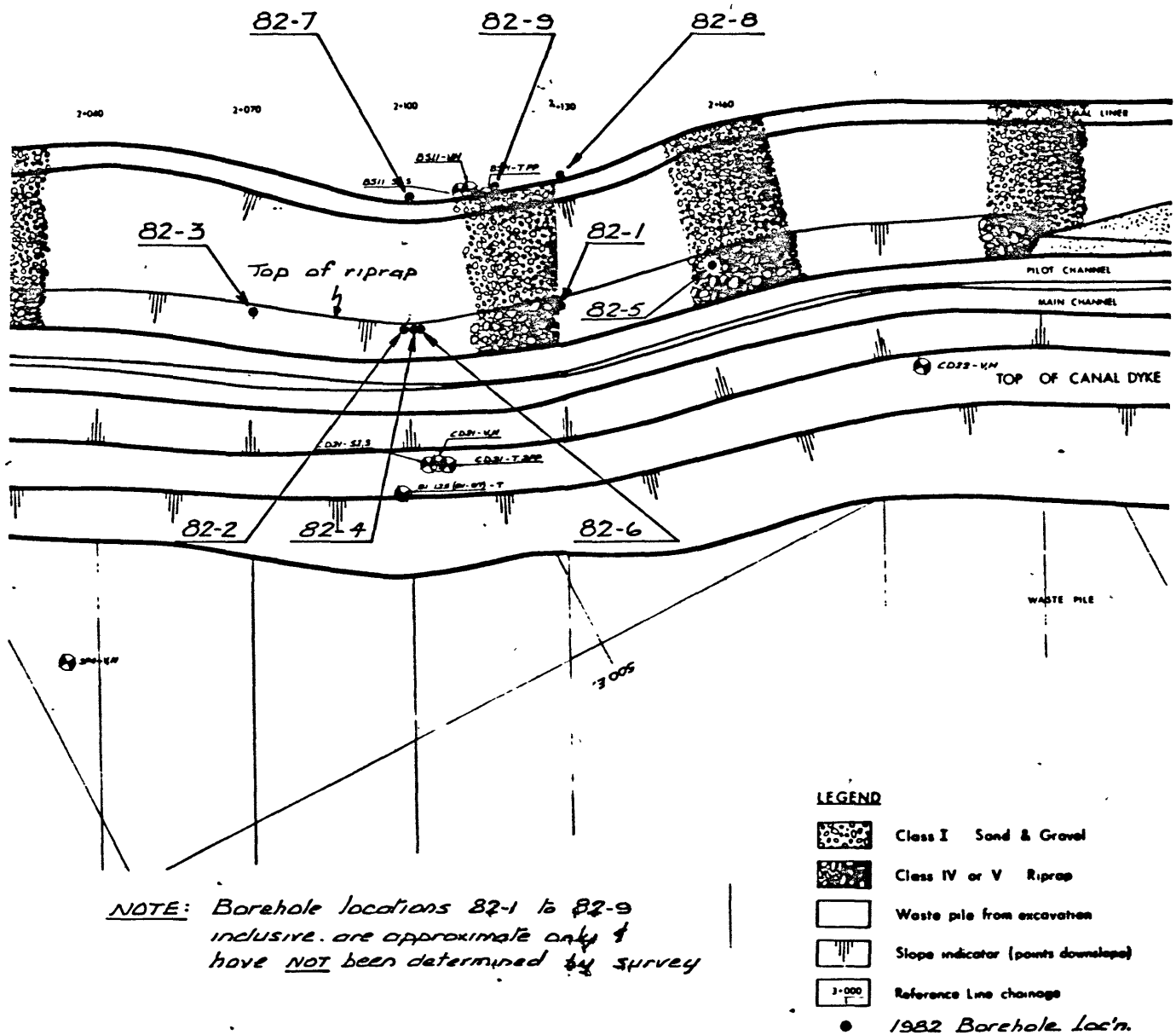
H.G. Gilchrist, P. Eng.

DCG:HGG:cr



BOREHOLE LOCATION PLAN

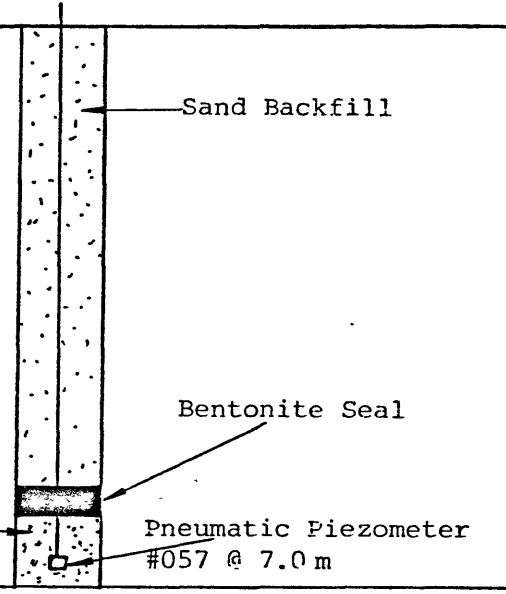
Figure 1



Project No. 812-2041 Drawn G Reviewed Date MAY 82

RECORD OF BOREHOLE 82-1

LOCATION (See Figure. .) Sta.2+130 (through rip rap on backslope) BORING DATE May 3, 1982
 BOREHOLE TYPE Tank Mounted Air Drill BOREHOLE DIAMETER 57 mm
 DATUM *Project*

SOIL PROFILE		DEPTH SCALE	INSTALLATION
ELEV.	DESCRIPTION		
Depth m.			
1084.5	<i>Ground Surface</i>	m	
0.0	Grey Schist Rock	1.0	 Sand Backfill Bentonite Seal Sandpack Pneumatic Piezometer #057 @ 7.0 m
1083.6			
0.9	Brown Sand and Gravel	2.0	
1082.1	Boulder	3.0	
2.4	Grey brown Sand & Gravel Till	4.0	
		5.0	
1079.5		6.0	
5.0	Grey Schist Bedrock	7.0	
1077.2		8.0	
7.3	End fo Borehole Borehole dry after drilling	9.0	
		10.0	NOTE: Borehole location and elevation not surveyed
		11.0	
		12.0	
		13.0	
		14.0	
		15.0	
		16.0	
		17.0	

Project No 812-2041 Drawn Date Nov '81

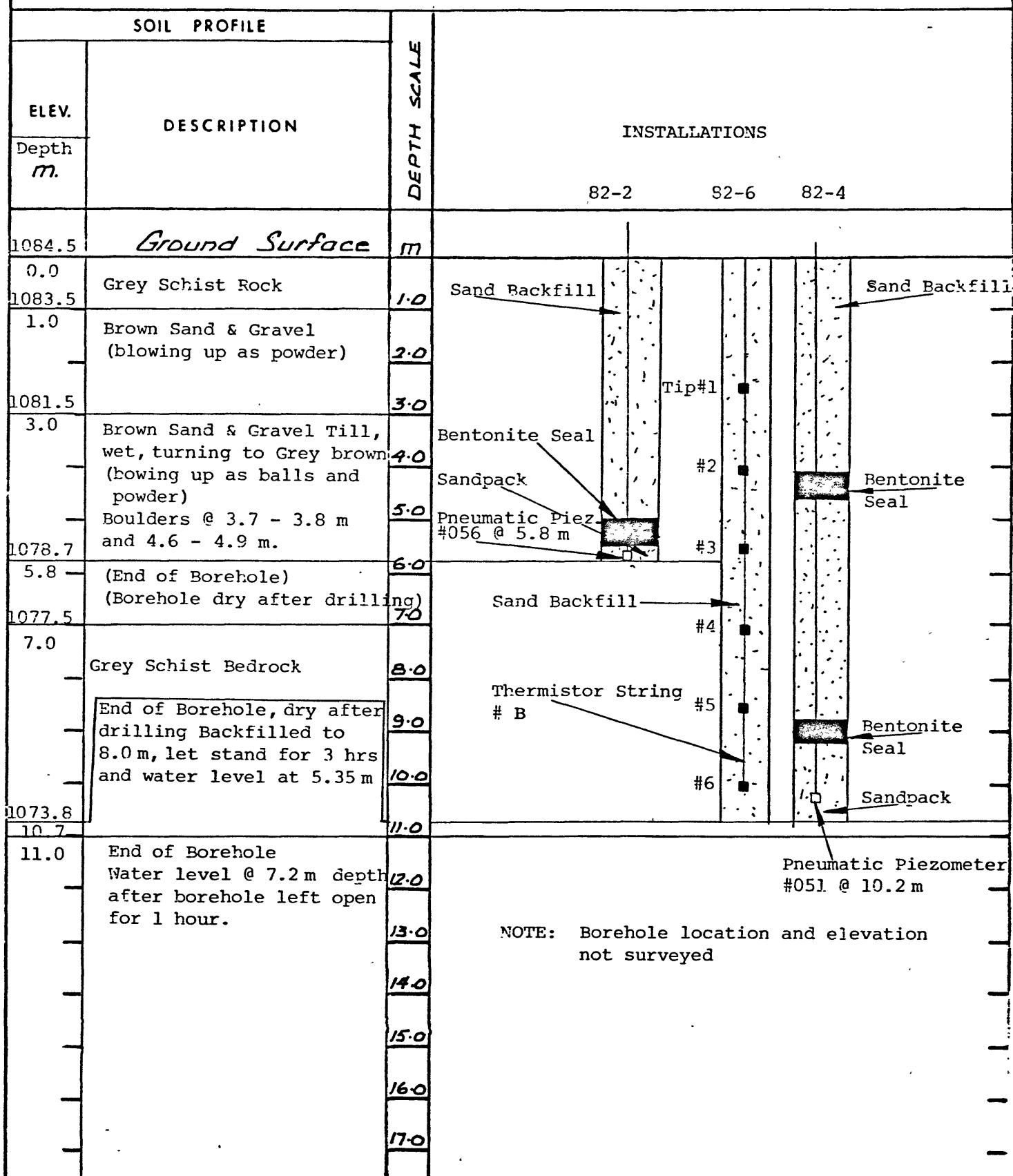
VERTICAL SCALE 1:100

Golder Associates 82-1

82-2, 82-4, 82-6

LOCATION (See Figure. .) Sta. 2+100 (through rip rap on backslope) BORING DATE May 3, 4, 1982
BOREHOLE TYPE Tank Mounted Air Drill BOREHOLE DIAMETER 57 mm

DATUM *Project*



VERTICAL SCALE 1:100

Golder Associates 82-2, 82-4, 82-6

RECORD OF BOREHOLE 82-3

LOCATION (See Figure. .) Sta. 2+070 (through rip rap on backslope)
 BOREHOLE TYPE Tank Mounted Air Drill

BORING DATE May 3, 1982

BOREHOLE DIAMETER 57 mm

DATUM *Project*

SOIL PROFILE		DEPTH SCALE	INSTALLATION
ELEV.	DESCRIPTION		
Depth m.			
1084.6	<i>Ground Surface</i>	m	
0.0	Grey Schist Rock	1.0	 Sand Backfill Bentonite Seal Sandpack Pneumatic Piezometer #065 @ 7.0 m
1083.6	Brown Sand & Gravel Till (blowing up in balls & powder)	2.0	
1.0		3.0	
		4.0	
		5.0	
1078.80	Grey Brown Sand & Gravel Till	6.0	
5.8		7.0	
1077.6	Grey Schist Rock	8.0	NOTE: Borehole location and elevation not surveyed
7.0	End of Borehole Borehole dry after drilling	9.0	
7.3		10.0	
		11.0	
		12.0	
		13.0	
		14.0	
		15.0	
		16.0	
		17.0	

Project No. 812-2041 Drawn Date Nov '81

VERTICAL SCALE 1:100

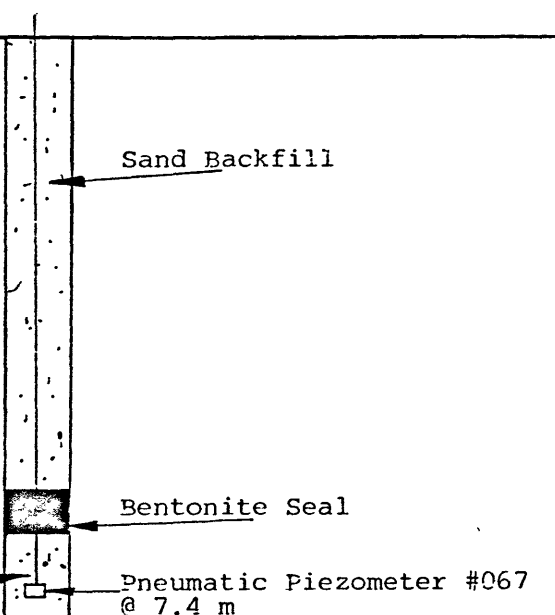
Golder Associates

82-3

RECORD OF BOREHOLE 82-5

LOCATION (See Figure. .) Sta. 2+160 (through rip rap on backslope)
 BOREHOLE TYPE Tank Mounted Air Drill

BORING DATE May 4, 1982
 BOREHOLE DIAMETER 57 mm
 DATUM *Project*

SOIL PROFILE		DEPTH SCALE	INSTALLATION
ELEV.	DESCRIPTION		
Depth m.			
1084.3	<i>Ground Surface</i>	m	
0.0	Grey Schist Rock	1.0	
1083.3		2.0	
1.0	Brown Sand and Gravel (boulder @ 2.4 m)	3.0	
		4.0	
1080.3		5.0	
4.0	Brown, very schisty (blowing up as dry powder)	6.0	
1078.2		7.0	
6.1	Grey Schist Bedrock		
1076.6		8.0	
7.7	End of Borehole Borehole dry after drilling	9.0	NOTE: Borehole location and elevation not surveyed
		10.0	
		11.0	
		12.0	
		13.0	
		14.0	
		15.0	
		16.0	
		17.0	

Project No. 812-2041 Drawn _____ Date Nov '81

VERTICAL SCALE 1:100

Golder Associates 82-5

RECORD OF BOREHOLE 82-7

LOCATION (See Figure. .) Sta. 2+100 (top of backslope) BORING DATE May 5, 1982
 BOREHOLE TYPE Tank Mounted Air Drill BOREHOLE DIAMETER 57 mm
 DATUM *Project*

SOIL PROFILE		DEPTH SCALE	INSTALLATION
ELEV.	DESCRIPTION		
Depth m.			
1095.6	<i>Ground Surface</i>	m	
0.0	Brown Sand & Gravel Till with boulders. (blowing up as powder)	1.0	Sand Backfill Bentonite Seal Sandpack Pneumatic Piezometer #055 @ 10.8 m
		2.0	
		3.0	
		4.0	
	(blowing up as balls and powder)	5.0	
		6.0	
		7.0	
1088.0	numerous boulders ? rock	8.0	
7.6	Grey Schist Bedrock	9.0	
		10.0	
1084.8	turning to light grey	11.0	NOTE: Borehole location and elevation not surveyed
10.8	End of Borehole Borehole dry after drilling	12.0	
		13.0	
		14.0	
		15.0	
		16.0	
		17.0	

VERTICAL SCALE 1:100

Golder Associates 82-7

Project No. 812-2041 Date Nov '81
 Reviewed
 Drawn

RECORD OF BOREHOLE 82-8

LOCATION (See Figure. .) Sta. 2+130 (top of backslope) BORING DATE May 5, 1982
 BOREHOLE TYPE Tank Mounted Air Drill BOREHOLE DIAMETER 57mm
 DATUM *Project*

SOIL PROFILE		DEPTH SCALE	INSTALLATION
ELEV.	DESCRIPTION		
Depth m.			
1094.2	<i>Ground Surface</i>	m	
0.0	Brown Sand and Gravel Till, with boulders. (blowing up as balls and powder)	1.0	Sand Backfill Bentonite Seal Sandpack Pneumatic Piezometer #056 @ 10.3 m
		2.0	
		3.0	
		4.0	
		5.0	
1089.0	Grey Schist Bedrock (some quartz)	6.0	
5.2		7.0	
		8.0	
		9.0	
		10.0	
		11.0	
1083.5		12.0	
10.7	End of Borehole Borehole dry after drilling	13.0	NOTE: Borehole location and elevation not surveyed
		14.0	
		15.0	
		16.0	
		17.0	

VERTICAL SCALE 1:100

Golder Associates 82-8

Project No 812-2041 Drawn Date Nov '81

RECORD OF BOREHOLE 82-9

LOCATION (See Figure. .) Sta. 2+115 (top of backslope)

BORING DATE May 5, 1982

BOREHOLE TYPE Tank Mounted Air Drill

BOREHOLE DIAMETER 57 mm

DATUM *Project*

SOIL PROFILE		DEPTH SCALE	INSTALLATION
ELEV.	DESCRIPTION		
Depth m.			
1094.6	<i>Ground Surface</i>	m	0.8 m Stickup
0.0	Brown Sand and Gravel Till with boulders. Wet (blowing up in balls and wet spray)	1.0	Sand Backfill
		2.0	Bentonite Seal
		3.0	25mm ϕ PVC tubing
	Very Wet	4.0	Questionable sand backfill because of small borehole dia.
	Boulder	5.0	
	Very Wet	6.0	
		7.0	
		8.0	
	Not as wet (blowing up in balls and powder)	9.0	Slotted P.V.C., 1.5 m long from 8.4 - 9.9 m
	Dry light grey brown powder	10.0	
	Boulder		
1084.2	Very Wet		Cave in
10.4	End of Borehole due to plugged bit. Borehole dry after drilling	11.0	NOTE: Borehole location and elevation not surveyed
		12.0	
		13.0	
		14.0	
		15.0	
		16.0	
		17.0	

VERTICAL SCALE 1:100

Golder Associates

82-9

Project No. 812-2041 Date Nov '81

Pneumatic Piezometer Data Sheet

Tip Number: 056

Ground Elev: $\approx 1084.5\text{ m}$

Tip Number: 05/ 82-4

Tip Depth : 10.2 m

Ground Elev: $\approx 1084.5\text{m}$

Tip Elev. : $\approx 1074.3m$

N.B. Ice in Conal approx 1.5m below top of dyke

[illegible]

Pneumatic Piezometer Data Sheet

Tip Number: 065

Tip Depth : 7.0m

Ground Elev: 1084.6 m

Tip Elev. : 1077.6m

N.B Ice in Canal approx 1.5m below top of dyke

[illegible]

- ** Indicates thermistor for which the ice bath calibration differs more than 0.2 $\mu\Omega$ from the mean of 16.20 $\mu\Omega$

Pneumatic Piezometer Data Sheet

82-8

Tip Number: 058

Tip Depth : 10.3m

Ground Elev: 1094.2 m

Tip Elev. : 1084.8 m

Tip Elev. : 1083.9m

[illegible]

Hydraulic Piezometer Data Sheet

Location: Sta 2+115 Installed from top of thermal liner
on backslope 3-7 May '82

Tip Depth : 8.4 - 9.9m

82-9

Ground Elev: 1094.6 m

Tip Elev. : 1086.2 - 1084.7m

Top of tube above ground: 0.8 m

[illegible]

Pneumatic Piezometer (PP) Data Sheet

Location : BS11-2+100

$$1413.2 \text{ mN}$$

Tip Number: #347

 480.1 mE

Tip Depth : 11.0 m

Ground Elev: 1095.0 m

Tip Elev. : 1084.0 m

[illegible]

BS11-2+100

CANAL 2+070

Note: Canal configuration is
vertically exaggerated 20x

1075

1070

1065

1060

1075

#065
82-3

#065

J F M A M J J A S O N D J F M A M J J A S O N D
1982 1983

CANAL 2+130

Note: Canal configuration is vertically exaggerated 20x

1075

1090

1085

#058
82-8

1080

#057
82-1

1075

J F M A M J J A S O N D J F M A M J J A S O N D
1982 1983.

CANAL 2+160

Note: Canal configuration
is vertically exaggerated 20x

1075

1090

1085

1060

1075

(Frozen)

*C67
82-5

J F M A M J J A S O N D J F M A M J J A S O N D
1982 1983

T**

ANVIL ADM FARO

GOLDERSAND CGY

APRIL 29, 1982

MSG NO C123

ATTN: N G CORNISH

RE: CANAL BACKSLOPE STABILITY STA 2+100

THE STABILITY OF THE CANAL BACKSLOPE OF STA 2+100 IS COMPUTED TO BE MARGINAL AS DISCUSSED PREVIOUSLY. THE PORE PRESSURE INDICATED BY PIEZOMETER BS11-2+100 HAS BEEN INCREASING AT A FAIRLY STEADY RATE SINCE INSTALLATION IN NOVEMBER 1981 AND THE PRESENT HIGH PORE PRESSURE MAY BE REDUCING STABILITY TO THE POINT THAT FAILURE CAN OCCUR. WE THEREFORE RECOMMEND THAT SUPPLEMENTARY PIEZOMETERS BE INSTALLED TO CONFIRM OUR CONCERNS AND TO ASSIST IN THE DESIGN OF MITIGATIVE MEASURES IF NECESSARY. THIS WORK SHOULD BE UNDERTAKEN AS SOON AS POSSIBLE.

WE BELIEVE THAT THE TYPE OF PROBLEM WHICH WE ARE SEEING AT STA 2+100 COULD BE TYPICAL OF THE AREA BETWEEN STA 1+950 AND STA 2+130. WE THEREFORE RECOMMEND THAT PNEUMATIC PIEZOMETERS BE INSTALLED IN VERTICAL HOLES FROM THE ICE BENCH AT THE CANAL BACKSLOPE. THE HOLES WOULD BE SPACED AT 30 M INTERVALS AND WOULD BE ABOUT 6.5 M DEEP (BELOW FROST). TWO DEEPER PIEZOMETERS (10 M) WOULD ALSO BE INSTALLED FROM THE ICE BENCH TO ASSESS PORE PRESSURE BEHAVIOUR WITH DEPTH IF CONSIDERED NECESSARY.

WE ALSO RECOMMEND THAT AT LEAST TWO BOREHOLES BE DRILLED TO A DEPTH OF 10 M FROM THE TOP OF THE BACKSLOPE FOR PIEZOMETER INSTALLATIONS. THE PRECISE LOCATION OF THESE WOULD BE DETERMINED BY THE RESULTS OF THE PREVIOUSLY DISCUSSED INSTALLATIONS.

THE ABOVE WORK SHOULD BE CLOSELY SUPERVISED AND OBSERVED BY AN EXPERIENCED GEOTECHNICAL ENGINEER TO OBTAIN MAXIMUM INFORMATION REGARDING OCCURRENCE OF FROZEN GROUND, FREE WATER AND STRATIGRAPHY. THIS INDIVIDUAL COULD ALSO INITIATE REMEDIAL WORK IF THE RESULTS OF THE ABOVE WORK CONFIRM OUR CONCERNS. RELIEF OF PORE PRESSURES WILL PROBABLY BE THE KEY OBJECTIVE OF ANY REMEDIAL WORK. ONE POSSIBILITY INVOLVES THE USE OF HORIZONTAL DRAINS WHICH WOULD BE DRILLED HORIZONTALLY FROM THE ICE BENCH IN THE CANAL. MAJOR DIFFICULTIES WITH THIS METHOD PERTAIN TO THE FREEZEUP OF THE DRAIN. ANOTHER POSSIBILITY (WHICH WE HAVE NOT DISCUSSED WITH YOU) IS BASED ON THE POSTULATED UNDERDRAINAGE OF THE AREA; RELIEF OF HIGH PORE PRESSURES IN THE UPPER HORIZONS IS ACHIEVED BY DRILLING VERTICAL HOLES INTO THE DEEPER FORMATIONS TO ALLOW MORE EFFECTIVE UNDERDRAINAGE TO OCCUR. THIS METHOD APPEARS TO HAVE PROMISE SINCE FREEZING WOULD NOT BE A PROBLEM BUT EXTREME CARE MUST BE EXERCISED TO ENSURE THAT OVERALL DEEP SEATED STABILITY IS NOT AGGRAVATED BY INCREASING PORE PRESSURES AT DEPTH AND THAT THE DEEP STRATUM HAS ADEQUATE PERMEABILITY.

ER ASSUMPTION THAT YOUR TANK MOUNTED DRILL CAN BE USED TO DRILL THE 3 IN DIA HOLES WE ESTIMATE THE COST OF THE ABOVE PROGRAM AS FOLLOWS:

(1) DRILL TIME - 7 - 6M HOLES SAY 8 HRS
4 - 10M HOLES SAY 8 HRS
REMEDIAL WORK TRIALS 8 HRS

REMEDIAL WORK UNKNOWN - A LARGER DRILL MAY BE
REQUIRED POSSIBLY 5-8HR
DAYS

(2) SUPERVISION AND INSPECTION (GOLDER ASSOCIATES)

- INVESTIGATION - JUNIOR ENG	20 HRS
SENIOR ENG	5 HRS
- REMEDIAL WORK - JUNIOR ENG	60 HRS
SENIOR ENG	15 HRS
- MONITORING - JUNIOR ENG	10 HRS
- SOME MONITORING BY CYPRUS ANVIL MAY BE RECOMMENDED	SAY 10 HRS
- MOB/DEMOB JUNIOR ENG	20 HRS
- AIRFARE	650 DOLLARS
- ACCOMMODATION 11 AT 80	880 "
- OTHER EXPENSES	100 "

TOTAL SC SENIOR ENG 20 HRS AT 68 = 1360 DOLLARS
JUNIOR ENG 110 HRS AT 49 = 5390 DOLLARS
EXPENSES = 1630 DOLLARS
TOTAL (GOLDER) ----
8380 DOLLARS
PLUS CAMC MONITORING SAY 10 HRS

(3) SPECIAL REPORTING (GOLDER ASSOCIATES)

- TYPING	200 DOLLARS
- DRAFTING	400 "
- SENIOR ENG 20 HRS AT 68	1360 "
- REVIEW BY PRINCIPAL	500 "
- JUNIOR ENG 20 HRS AT 49	980 "

TOTAL	3340 "

(4) MATERIALS

- PIEZOMETERS 14 AT 161	2254 "
- PELTONITE 6 AT 40	240 "
- DRAINS (UNKNOWN)	500 "
- TRANSPORTATION	500 "

TOTAL	3493 "

TOTAL OF ALL ITEMS
EXCLUDING CAMC INVOLVEMENT 15,310 DOR

SS

WE BELIEVE THAT IT IS NECESSARY TO PROCEED WITH THIS PROGRAM TO IMPROVE THE PIEZOMETRIC COVERAGE OF THE AREA AND SO TO ASSESS THE VALIDITY OF OUR CURRENT CONCERN FOR STABILITY IN THE 180 M REACH OF BACKSLOPE. WHILE HORIZONTAL DRAINS MAY NOT BE THE LONG TERM ANSWER THEY DO OFFER SOME POTENTIAL FOR IMMEDIATE RELIEF OF PRESSURES IN THE TOE AREA SHOULD SUCH EXIST. ON THE BASIS THAT THE TANK DRILL SHOULD BE ABLE TO HANDLE BOTH THE PIEZOMETERS AND THE DRAINS QUICKLY AND ECONOMICALLY WE BELIEVE THE PROGRAM SHOULD PROCEED IMMEDIATELY WHILE THE ICE CAN BE USED AS A WORKING PLATFORM. ANALYSIS OF DATA MAY DICTATE USE OF MORE SOPHISTICATED DRILLING EQUIPMENT LATER. NOW IT IS IMPORTANT TO ENHANCE OUR UNDERSTANDING OF PIEZOMETRIC CONDITIONS IN THE AREA.

REGARDS

GOODALL/GILCHRIST

CORRECTIONS FIRST WORD IN PARAGRAPH BEFORE COST ESTIMATE - UNDER
LAST PARAGRAPH THID LAST LINE SECOND WORD - ANALYSIS

APPENDIX II
CANAL ICING CONDITIONS, MARCH 1982

Icing of the canal occurred during the winter of early 1982 because of inconsistent mill consumption of water released from the water impoundment dam. In March, the canal had generally filled up to within 1.3 to 1.6 m of freeboard. The icing was especially bad between 3+420 and 3+480 at the start of the canal outfall 0.19% grade section where there was only 0.5 m of freeboard in March. To prevent overflowing of the dyke structure by the spring freshet a channel was ripped in the ice in the canal by Cyprus Anvil equipment and personnel in mid-April.



View looking S.E. at 1975 diversion near pumphouse.

View looking west showing old tailings dyke and new diversion dam headpond.





View looking west
from about Sta
0 + 400.



View looking west
from about Sta
1 + 100.



View S.E. from
about Sta 3 + 200.



View S From
about Sta 3 + 400



Icing accumulation from about Sta 3 + 500 to Sta 3 + 600.
View looking N.W.

APPENDIX III
DAM PERFORMANCE PHOTOGRAPHS, JUNE 1982

decant
spillway

weir No. 3
(approx.
3000 i.g.p.m.,
subsequently
decreased)

Sta 0+570

south abutment



View looking NNE along CVD crest c. 1 June at full impoundment. Note installations at crest and at toe at Sta 0+570 in foreground (as flagged by red casing). Note seepage collection at dam toe.

decant/
spillway

Weir No. 2
Sta 0+380
(approx. 1900
i.g.p.m.)



View NNE showing toe drain CVD (c. 1 June)

decant/
spillway

weir No. 1
Sta 0+210
(approx.
1000 i.g.p.m.)

toe drain



View north showing north abutment area where seepage emerges at downstream toe. Weir No. 1 (Sta 0+215) is near beginning of seepage. (c. 1 June 1982)



Closeup view of weir No. 1 (1000 i.g.p.m. approx.) showing also observation point for pneumatic piezometers at Sta 0+210.



south
abutment

Sta 0+570
pneumatic
piezometer
observation
point

View south from approx. Sta 0+500 (c. 1 June 1982) showing toe drain.



south
abutment

Sta. 0+570

toe drain

Closeup of above photo showing south abutment area.

PROJECT NO. DRAWN REVIEWED DATE



View east from end of decant/spillway (c. 1 June 1982). Note that decant flow over natural materials is not resulting in unacceptable erosion.



Seepage boils in abandoned meander of Rose Creek. Note active sand boil and craters from previous activity. Such boils are not a present concern.



Diversion
Canal

Spillway/
decant

CVD reservoir

embankment
base

View SSW of Intermediate Dam at full impoundment. Note surface of seepage at downstream toe of embankment from approx. Sta 0+220 to Sta 0+350 (c. 1 June 1982)



View NE from south abutment Int. Dam showing I.D. reservoir at full impoundment. Note that construction stakes in left foreground and trees have been jacked from the valley bottom by the reservoir ice surface due to winter impoundment.



View NW showing Intermediate Dam decant/spillway function at full impoundment. CVD reservoir in the background (c. 1 June 1982)



View SE of Intermediate Dam decant functioning at full impoundment.

APPENDIX IV
PROJECT HYDRAULIC PERFORMANCE AND RECOMMENDATIONS,
HYDROCON ENGINEERING

**ROSE CREEK DIVERSION
DOWN VALLEY TAILINGS DISPOSAL PROJECT
CYPRUS ANVIL MINING CORPORATION
REVIEW OF LICENSING REQUIREMENTS
AND AS-BUILT CONDITIONS**

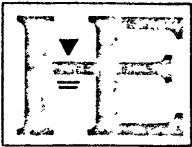
Prepared for:
**GOLDER ASSOCIATES
CALGARY, ALBERTA**

Prepared by:
**HYDROCON ENGINEERING (Continental) LTD.
CALGARY, ALBERTA**

**AUGUST 18, 1982
FILE: 47-7.3**

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47-7.3-3 Emergency Overflow Spillway	



HYDROCON ENGINEERING (Continental) LTD.
ENGINEERING CONSULTANTS IN WATER RESOURCES

August 18, 1982

File: 47-7.3

Mr. Glen Gilchrist, P.Eng.
Golder Associates
7017 Farrell Road S.E.
Calgary Alberta
T2H 0T3

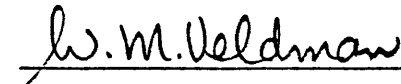
SUBJECT: Rose Down Valley Tailings Disposal Project
Review of As-Built Conditions and License Requirements

Dear Mr. Gilchrist:

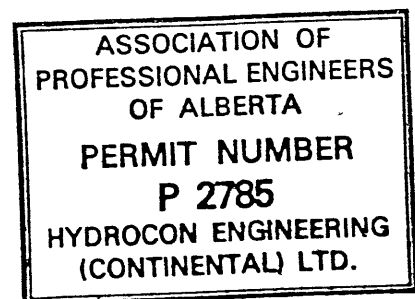
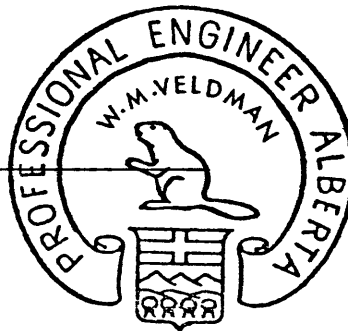
We are pleased to herein submit our review of the 1982 as-built conditions of the Rose Creek Diversion and the emergency spillways for the Intermediate and Cross Valley Dams. Licensing requirements as per the Yukon Water Board and particularly the design of the proposed emergency overflow for the Diversion are discussed and addressed. The North Valley Interceptor Ditch was not reviewed since it is not yet operational.

We trust this meets with your requirements at this time. When some of the recommendations given herein are agreed to in principle, such as the discharge monitoring, we can provide additional details as necessary. Please call if you have any questions or comments.

Yours truly,
HYDROCON ENGINEERING (Continental) LTD.


W.M. Veldman, P. Eng.

WMV/po



INTRODUCTION

BACKGROUND

The Rose Creek Diversion Channel around the Down Valley Tailings Disposal Dams became operational in May 1981 and was fully completed later in the same year. The hydraulic capacity of the channel and its as-built conditions as of July 1981 were reviewed by Hydrocon¹. Recommendations were made to ensure the channel met the initial hydrologic and hydraulic design objectives².

Golder Associates, general consultants to Cyprus Anvil Mining Corporation for the tailings facilities, prepared a comprehensive as-built report in February 1982³. Hydrocon, based on Golder's report, concluded that the deficiencies noted in the August 21, 1981 report were rectified except for the provision of an overflow section near the upstream end of the channel⁴. Implementation of a hydrologic monitoring program was also recommended.

In March 1982, the Yukon Territory Water Board issued a water license to Cyprus Anvil Mining Corporation (No. Y2L3-2226) pursuant to regulations of the Department of Indian and Northern Affairs. The license requires among other things, that the licensee "...shall ensure that the diversion canal has the hydraulic capacity to carry a 1:500 year flood flow" and that a flood contingency overflow structure be constructed to channel flows in excess of the 1:500 year return flood out of the diversion.

A further hydrologic requirement is that two streamflow measurement sites,

¹ "Hydraulic Review of As-Built Conditions, Rose Creek Diversion, Down Valley Tailings Disposal Project, Cyprus Anvil Mining Corporation, Faro, Y.T." Hydrocon Engineering (Continental) Ltd. August 21, 1981.

² "Hydrologic and Hydraulic Design of Down Valley Tailings Disposal Project, Cyprus Anvil Mining Corporation, Faro, Y.T." Hydrocon Engineering (Continental) Ltd. May 8, 1980.

³ "Down Valley Tailings Containment Project, 1980-1981 Construction." Golder Associates. February 1982.

⁴ Letter dated February 26, 1982 from W.M. Veldman, P.Eng. of Hydrocon to Mr. Glen Gilchrist, P.Eng. of Golder Associates.

one of them to be a continuous recording station, be established on the diversion. Furthermore, the license requires that the emergency spillways for the Intermediate and Cross Valley Dams have a capacity to carry to 1:500 year Rose Creek flood flow.

PURPOSE OF THIS REPORT

Golder Associates (meeting with D. Goodall, P.Eng., June 7, 1982) requested Hydrocon to:

- prepare the hydraulic design of the contingency overflow from the diversion channel into the tailings dams.
- re-assess the roughness of the channel to provide design input for the overflow.
- review the need to raise a low dyke area near the downstream end of the upper reach of drop structures. (Station 3+350+).
- review of the as-built conditions of the emergency spillways at the Intermediate and Cross Valley Dams (these had not been completed at the time of Hydrocon's August 21, 1981 as-built review).
- comment on the hydrologic and hydraulic requirements of the water license.

Wim M. Veldman, P.Eng. of Hydrocon visited the site on June 15-16, 1982. He was assisted in discharge measurements and surveys by Mr. Ian Booth, of Cyprus Anvil. Through discussions with Mr. Peter Taggart, P.Eng., of Cyprus Anvil, it was decided to prepare a single hydraulic - hydrologic report addresssing the above scope of work.

The North Valley Interceptor Ditch is at this time not operational and it was not reviewed except the downstream section approaching the decant channel of the Cross Valley Dam was assessed.

CONTENTS

The order of the report essentially follows the purposes outlined above. Some additional comments on the general as-built conditions of the diversion channel are also provided. Drawings and photos are included in Appendices.

ROSE CREEK DIVERSION CHANNEL

EMERGENCY OVERFLOW

Purposes - Rose Creek flows could exceed the capacity of diversion channel in the event of:

- . flows greater than the contingency flood of 1:500 years,
- . a slope failure which reduces the capacity of the diversion,
- . severe icings combined with high breakup flows.

Location - The emergency overflow would control, during a flood greater than the contingency flood, the location and magnitude of overflow into the tailings pond. In the case of slope failures and severe icings which could occur at various locations along the channel, a single emergency overflow could not provide a controlled release into the tailings pond. This is due to the gradient of the channel. For example in the case of partial blockage of the channel due to a slope failure near the beginning of the drop weirs (station 2+820), the result would probably be, if it occurs during a high flow period, overtopping of the dyke near the same location rather than at the designed upstream site which is at a much higher elevation.

To act as an emergency "safety valve" for the diversion channel for higher than contingency flows, the overflow must therefore be located at the upstream end of the diversion channel.

Photos 1 and 2 of Appendix A illustrate panoramic views of the upstream and downstream faces of the diversion dam respectively. This structure, located at the upstream end of the channel, is recommended to serve as the emergency overflow. Overflow would discharge into the bypass channel (see left of Photo 2) and thence be conveyed into the reservoir of the Intermediate Dam.

Design Criteria - Clause B-3(e) of the Water License (see Appendix B) states that "...the licensee shall ...construct a flood contingency

overflow structure to channel flows in excess of 1:500 year flood out of the diversion".

To fully limit flows to the 1:500 year flood would require either a fixed crest overflow at an elevation less than the 1:500 year flood elevation or a gated control facility that could pass any and all flows in excess of the 1:500 year magnitude. The former approach is recommended as it requires no operation during the critical flood period.

The recommended design criteria are thus:

- set the emergency overflow weir elevation 0.5 metre below the 1:500 year flood stage in the channel. This results in commencement of spillage at approximately the 1:160 year flood.
- provide the maximum possible length of overflow weir to reduce stage increases with increasing flow depths.

Capacity Check - The 1981 design report¹ assumed a Manning's roughness of 0.030. Based on a discharge metering of 6.37 m³/sec. by Hydrocon on June 15, 1982, the computed roughness values are 0.022 and 0.032 for the locally surveyed and average water level design slopes respectively. Since the actual slope is relatively variable due to variations in the as-built cross sections of the channel, the lower value may not be representative. Since roughness is inversely proportional to depth, a design value of 0.030 at the contingency flow depth remains realistic in view of the computed value of 0.032 for a much lower flow.

Due mainly to extensive ice buildup in the channel during the 1981-1982 winter, it became necessary to remove ice from the channel in the Station 3+350 area to prevent overtopping. Raising of this area as deemed necessary by Cyprus Anvil personnel is recommended.

Design - A rock overflow is recommended as shown in Drawing 3 of Appendix B. In lieu of placing Class IV and V armouring and riprap respectively down the full length of the overflow into the bypass channel, the largest locally available material should be placed below the designed crest

section. In the event of overflow, some erosion of this lower segment can be expected. This erosion, if repaired in a timely fashion, will not affect the integrity of the crest of the overflow. Maintenance of it on an as-needed basis (very infrequently) will be more cost effective than fully riprapping the entire structure at this time.

FLOW MONITORING

Purposes - From Cyprus Anvil's viewpoint, the purposes of flow monitoring are:

- to provide hydrologic data to assess the performance and capacity of the channel. This will be particularly useful during extreme events.
- to provide hydrologic data which combined with precipitation data, can be used to verify or modify present hydrologic design values for the abandonment program. Maximum probable flood values computed for the abandonment plan have been judged by some reviewers as excessively high. A hydrologic monitoring program will, particularly if major floods occur during the life of the mine, provide some much needed input data for the hydrologic computer model.

The hydrologic requirements of the water license issued by the Yukon Board are:

- a water balance for the tailings facility and diversion canal (A9bii)
- ensuring that the diversion canal has the capacity to convey the 1:500 year flood flow (B3d)
- streamflow measurements to be taken downstream of the water supply pumphouse and in the flat slope section between the drop weir reaches. One of the stations shall be established as a continuous recording streamflow station. (Schedule C1e)

Other hydrologic license requirements, not specifically involving flow monitoring, pertain to glaciation (Schedule C1f), erosion (Schedule C1g) and sedimentation (Schedule C1h).

Methods - To provide a continuous streamflow record, as required by the license, necessitates a continuous water level recorder supplemented with sufficient discharge measurements at varying stages to establish a

relationship between water elevation and discharge. A manual staff gauge, if read daily, could supply adequate information except during short duration intensive rainfall events, which as noted before, could provide valuable design information for the abandonment program. Discharge metering at moderate to high flows will require a pedestrian bridge across the diversion canal. The flow becomes too deep and fast to meter by wading. The bridge can be "home-made" out of sufficiently long logs or can be manufactured out of various other materials. Another option is to construct A-frames on both banks of the channel to support a cablecar from which the measurements can be made. A third option may be to meter from a boat in the wider and slower section of the canal between the two drop weir sections. Due to the tributary inflow into the canal and possible short-term sedimentation in this reach (due to washout of "fish gravel" and tributaries transporting thermal liner material), this downstream section is less preferred and is not recommended as the site for the continuous recording station.

DROP WEIRS

The lower five drops (see Photos 3 and 4) are less than optimum from a hydraulic viewpoint. It is understood that some relocation of the rocks may have been undertaken here to facilitate fish passage. Rather than being a series of distinct drops, the flow is a concentrated high velocity jet in several locations. The drops should be reconstructed.

OUTLET INTO ROSE CREEK

The outlet is as shown on Photo 4. It appears there was overtopping of the low area on the right bank between the spoil and dykes downstream and along the channel respectively. This could lead to eddy formations and erosion downstream of the riprapped section and can be prevented by filling in the low area using material from the spoil dyke downstream.

TRIBUTARY INFLOW

The major tributaries, Goodall and Cornish Creek, appear to be performing reasonably well. At Goodall Creek the majority of the flow is entering the channel next to the blasted rock section although this is posing no

particular problems (Photo 5). There was little inflow from Cornish Creek at the time of the field trip (Photo 6). It appeared that some flow had been conveyed along the top of the diversion channel dyke in a downstream direction. Fill across the dyke right-of-way where Cornish Creek enters could ensure that all the flow is directed straight into the diversion channel.

Since the as-built review in July 1981, additional erosion of the thermal liner has occurred at numerous locations due to minor local inflow. Although posing no hydraulic problems at the present, some of the rills could cause, if allowed to develop unchecked, in eventual erosion of the granular material underlying the channel armouring and riprap. This could result in loss of this armouring or riprap. Some of the more major rilling is illustrated in Photos 7 and 8 and their locations and severity rating as of June 15, 1982 are as listed below.

<u>Station (Number)</u>	<u>Degree of Rilling and Erosion</u>
0+165	Major
0+397	Minor
0+420 (2)	Minor
1+960 (5)	Major to Minor
2+130	Intermediate
2+200	Major
2+258	Intermediate
2+300 (3)	Intermediate - - Major
2+350	Minor
2+777	Minor
2+800 (3)	Intermediate
2+835	Minor
2+870 (4)	Intermediate
3+090	Intermediate
3+120	Intermediate
3+135	Intermediate

EMERGENCY SPILLWAYS

INTERMEDIATE DAM

The emergency spillway and decant channel are as shown in Photo 9. Photos 10 and 11 illustrate close-ups of the two outflow channels. Rock sizes in the decant channel meet design requirements. The horizontal dimensions of the emergency spillway (width and lengths of riprapped sections) meet design requirements. As-built rock sizes are more difficult to review due to levelling and finer material placed over the rock however it is believed that the rock crest will fully meet the design intent.

The emergency spillway channel downstream of the riprapped crest has the central part slightly higher than that adjacent to the two non-riprapped dykes. To prevent erosion of these dykes during low to moderate spillages, - a maintenance rather than an integrity concern - regrading of the outflow channel to depress the center area is recommended. A "funnel-shaped" grading plan (looking downstream) would collect the overflow from the weir and channelize it down the center away from the unprotected dykes. It should be expected however - as in the original design approach - that erosion of the dykes will occur during major overflows.

CROSS VALLEY DAM

The decant channel and emergency overflow for the Cross Valley Dam are shown in Photo 12. The North Valley Interceptor Ditch which joins the decant channel at the dam is also shown. Photo 13 is another view across the Dam while Photos 14 and 15 are close-ups of the decant channel and emergency spillway respectively. The decant channel is totally adequate. The riprap in the emergency spillway meets design requirements. As in the case of the intermediate dam, "funnel shaped" grading of the non-riprapped spillway outlet channel is recommended to reduce the frequency of erosive attack on the left dyke (looking downstream) and possible undermining of the decant channel riprap. The latter is a particular concern since the alignment of the decant results in a reduced width of the emergency spillway downstream of the crest (see Photo 12).

Although the North Valley Interceptor Ditch was not yet operational at the time of the visit and thus was not assessed, it is recommended that the roadway adjacent to the ditch where it commences its route parallel to the reservoir, be raised. The curvature of the channel in this location combined with icings (see Photo 16) could result in overflow into the reservoir of the Cross Valley Dam when the ditch becomes operational.

CONCLUSIONS AND RECOMMENDATIONS

1. The emergency overflow for the Rose Creek Diversion should be constructed as a rock-armoured weir in the diversion dam at the upstream end of the diversion as shown on Drawing No. 3, Appendix C.
2. The capacity of the diversion channel, based on discharge measurements and capacity checks to date, is adequate to convey the 1:500 year flood.
3. The emergency overflow spillway will commence operation at approximately the 1:160 year flood.
4. The dykes in the area near the downstream end of the upper reach of drop structures should be raised to prevent overtopping during icing conditions.
5. A continuous water level recorder combined with discharge meterings at stage intervals of 0.5 metres from a pedestrian bridge is the optimum method to meet the license requirements, assess the performance of the diversion and to aid in verifying abandonment flood design values. Manual staff gauges supplemented by discharge meterings by wading and/or from a boat could perhaps initially satisfy the licensing requirements provided the staff gauges are read daily during normal flow conditions and more frequently during breakup and major flood events when water level changes are rapid.
6. The optimum location of a continuous recording station is near the upstream end at Station 0+160 approximately.
7. The lower five drop weirs will require some modifications to perform adequately from a hydraulic viewpoint.
8. The right bank height at the downstream of the diversion channel should be raised to prevent spillage and subsequent erosion at the right riprapped bank.

9. The major tributaries, Goodall and Cornish Creek are performing well. A small dyke should be constructed for the latter to ensure all its flow is directly into the diversion channel.
10. The minor tributaries are resulting in increased rilling compared to 1981. If left unchecked, some undermining of channel armouring and riprap may occur at some locations. Continued monitoring of this is recommended. Possible solutions are armouring of the rills or half-round culverts.
11. The emergency spillway and decant channel at the Intermediate Dam meet the design intent. Some grading of the non-armoured section downstream of the riprapped crest is recommended to reduce the potential for erosion of the downstream non-armoured guide dykes.
12. The emergency spillway and decant channel at the Cross Valley Dam meet the design intent. As in the case of the Intermediate Dam, minor grading is recommended.
13. The dyke along the North Valley Interceptor Ditch where it begins to flow parallel to the Cross Valley Dam reservoir should be raised to prevent its overtopping.

APPENDIX A

PHOTOGRAPHS

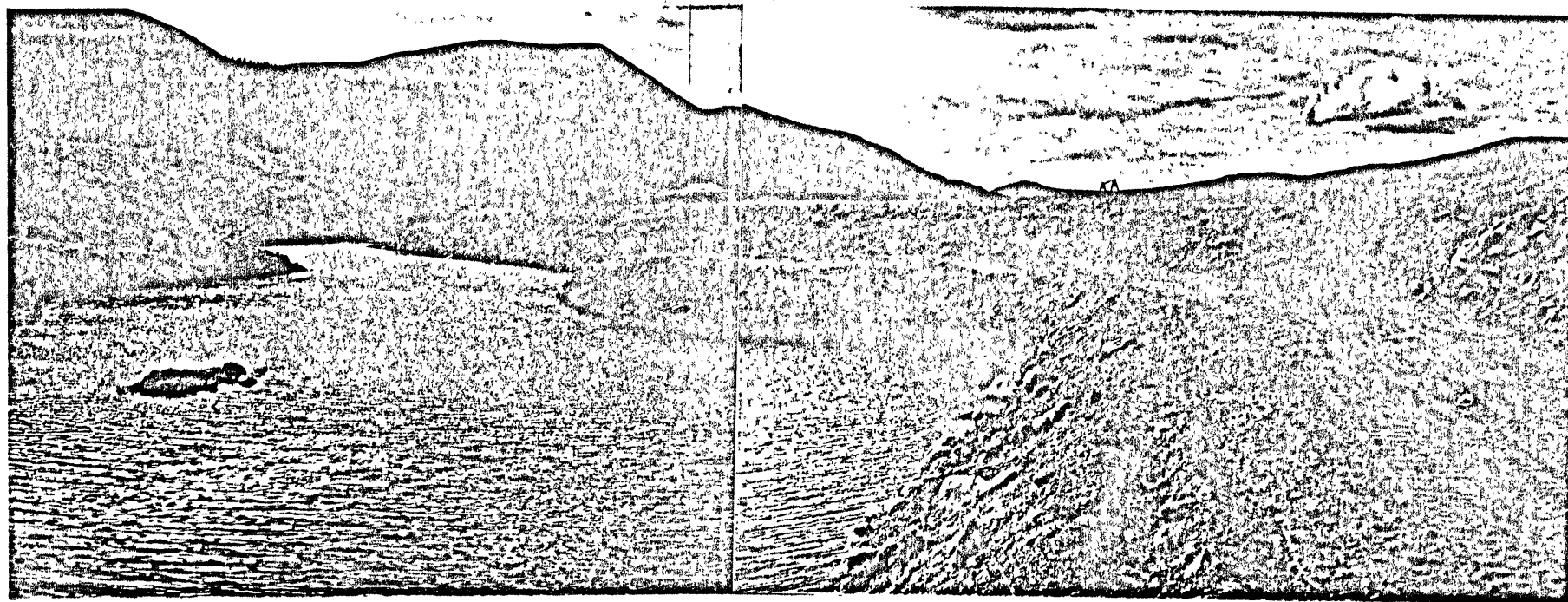


PHOTO 1 Looking downstream at channel inlet and diversion dam.
July 17, 1981. [47-3-1,2].

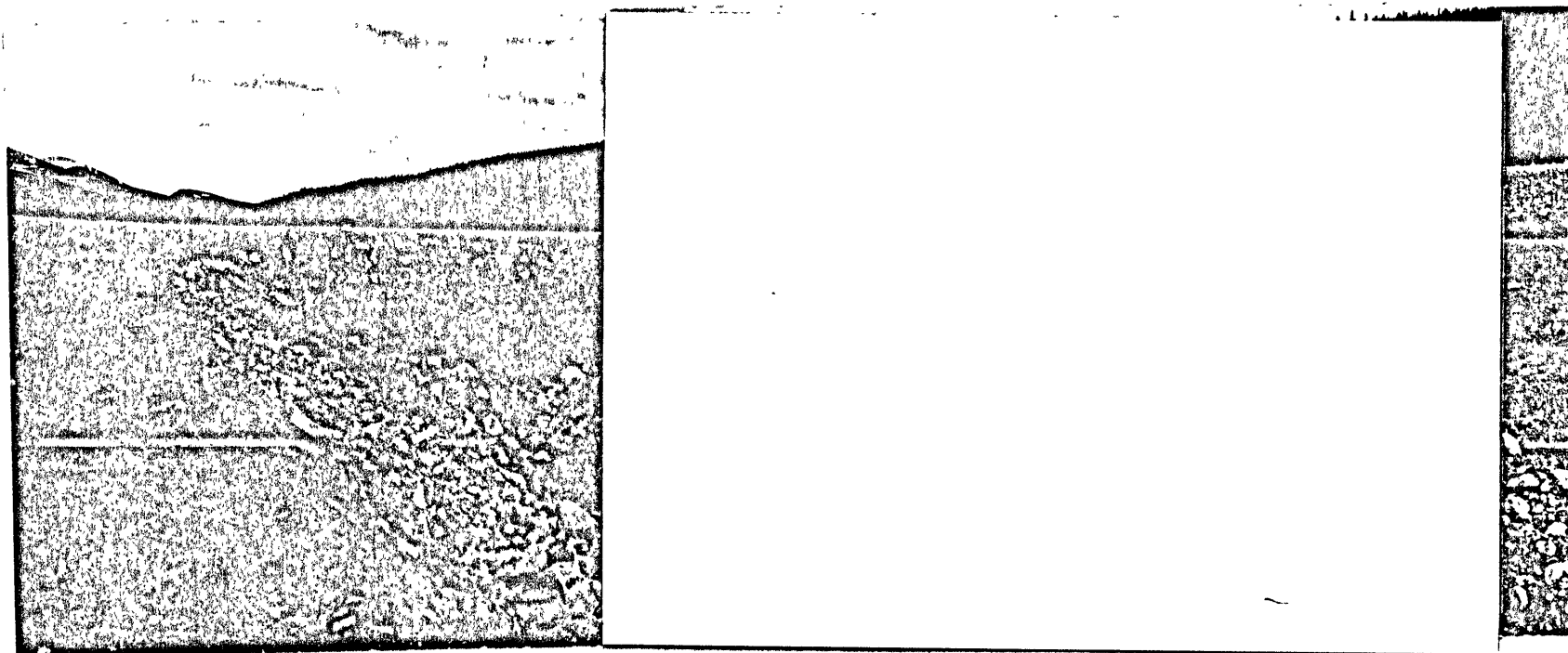


PHOTO 2 Looking upstream at diversion dam. Temporary diversion channel in lower foreground would convey flow into Intermediate Dam reservoir. June 15, 1982. [47-5-31A,32A,33A].

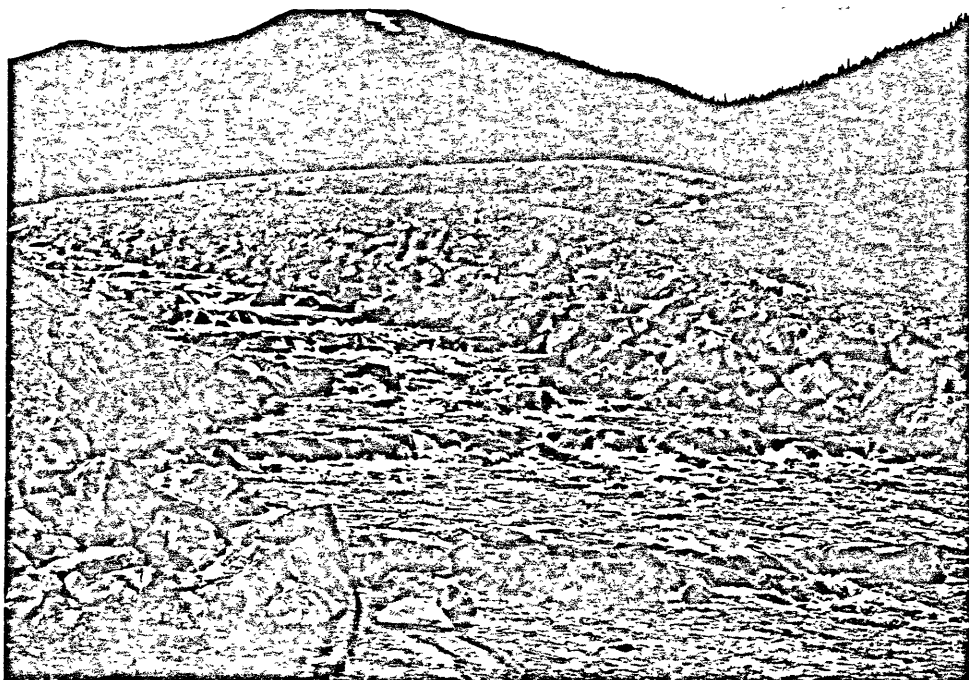


PHOTO 3
47-6-18

June 15, 1982

Looking upstream at drop weirs at downstream end of channel. Some chute flow rather than drops in this area.



PHOTO 4
47-6-17

June 15, 1982

Looking downstream at outlet. Overtopping of right bank fill has occurred near survey stake. Note chute flow at downstream end of channel.

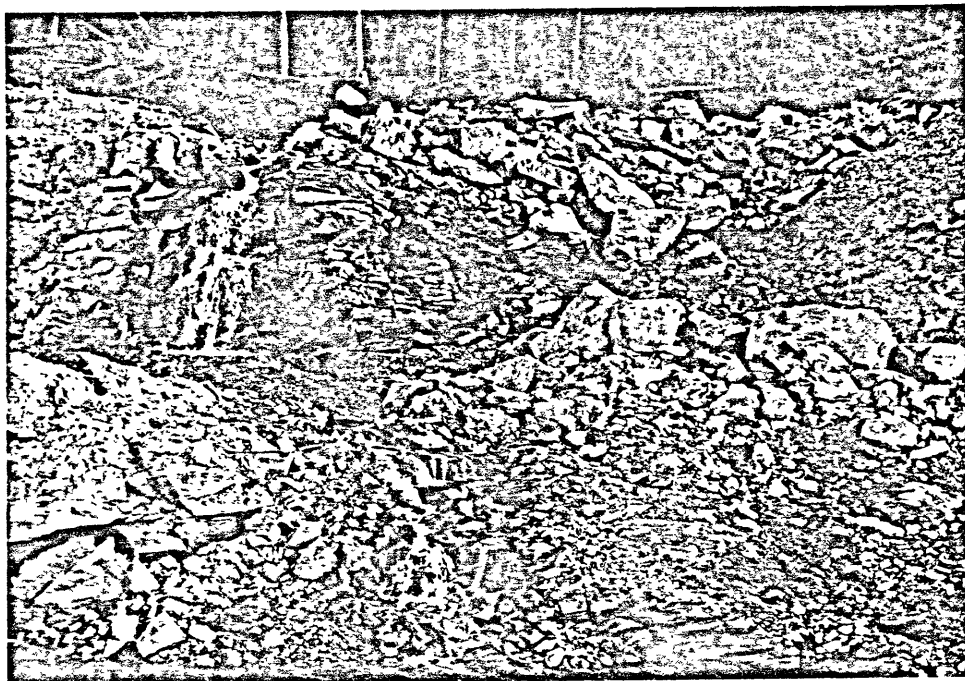


PHOTO 5
47-6-5
Goodall Creek.

June 15, 1982

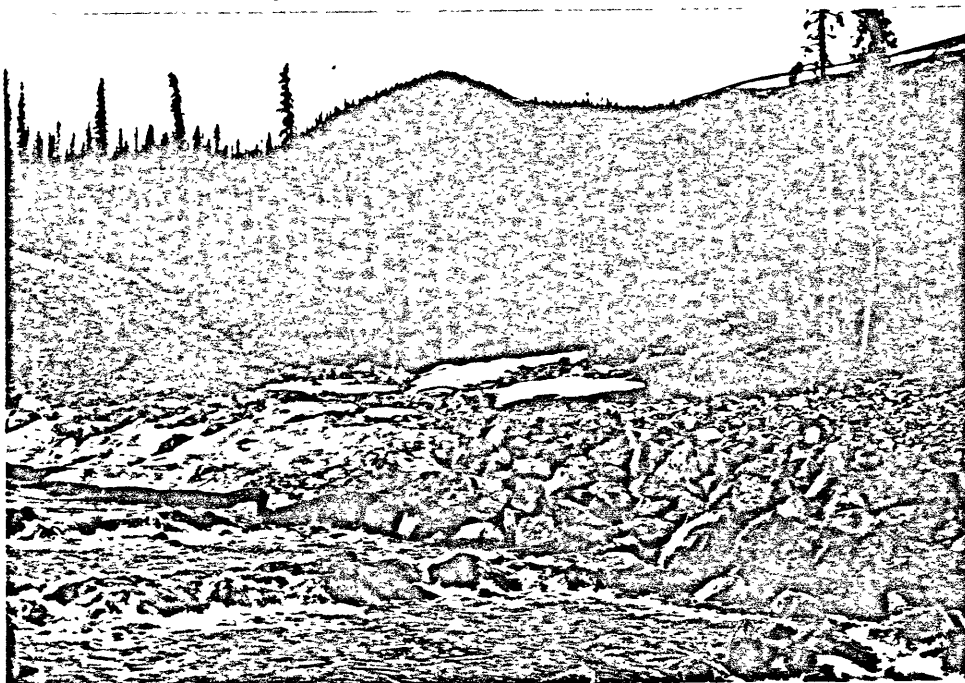


PHOTO 6
47-6-15
Looking across to Cornish Creek.

June 15, 1982

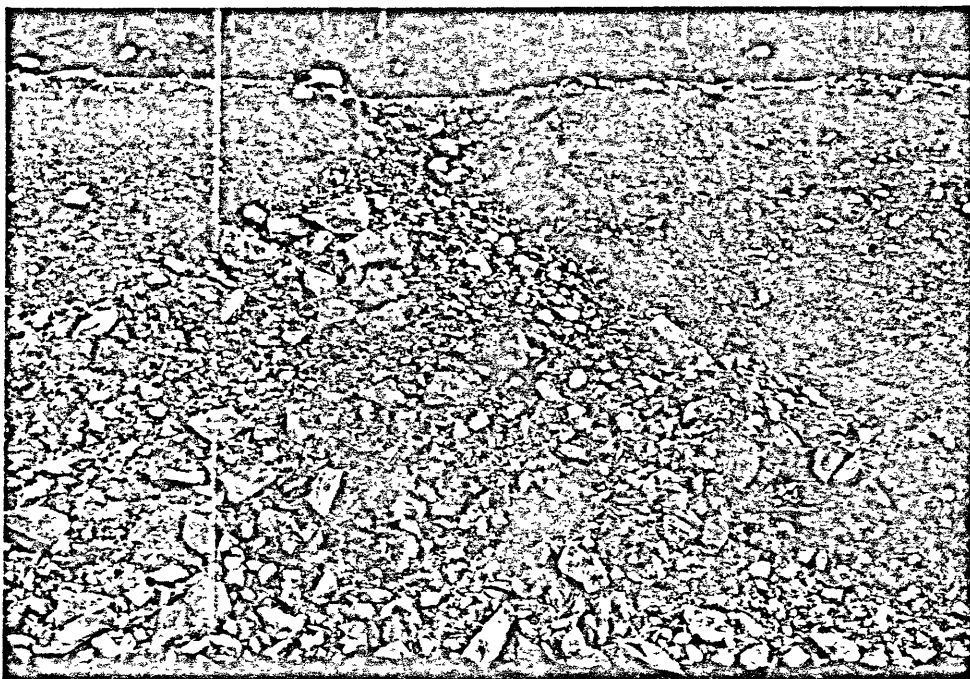


PHOTO 7
47-6-3
Local inflow at Station 0+165.

June 15, 1982

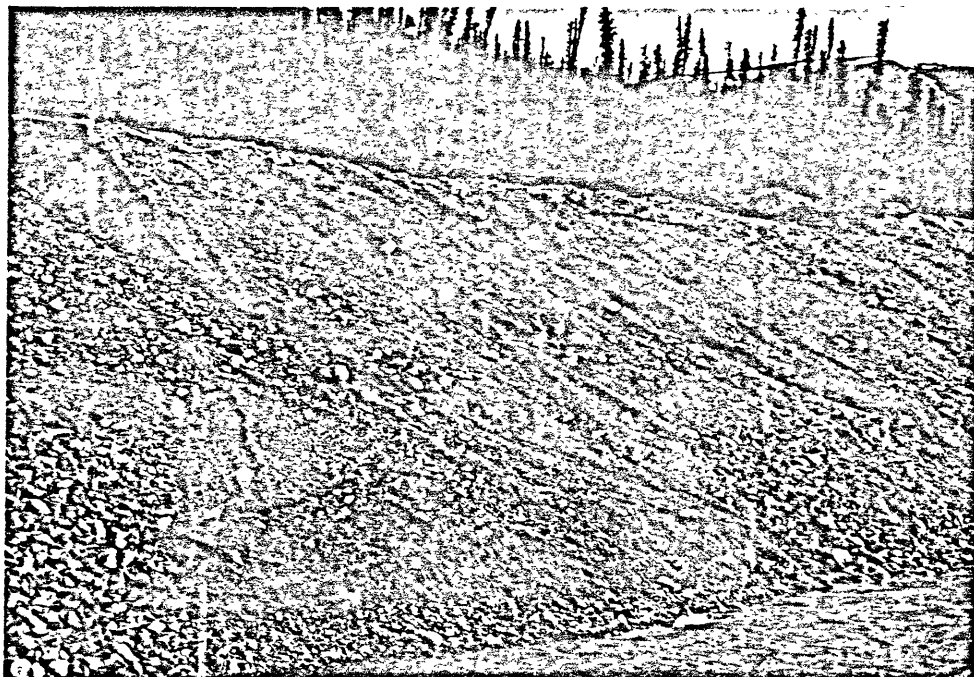


PHOTO 8
47-6-6
Local inflow at Station 1+960. Some granular deposition over the riprap.

June 15, 1982



PHOTO 9
47-6-8

June 15, 1982

Overall view of intermediate dam with decant channel in foreground and emergency overflow in center.

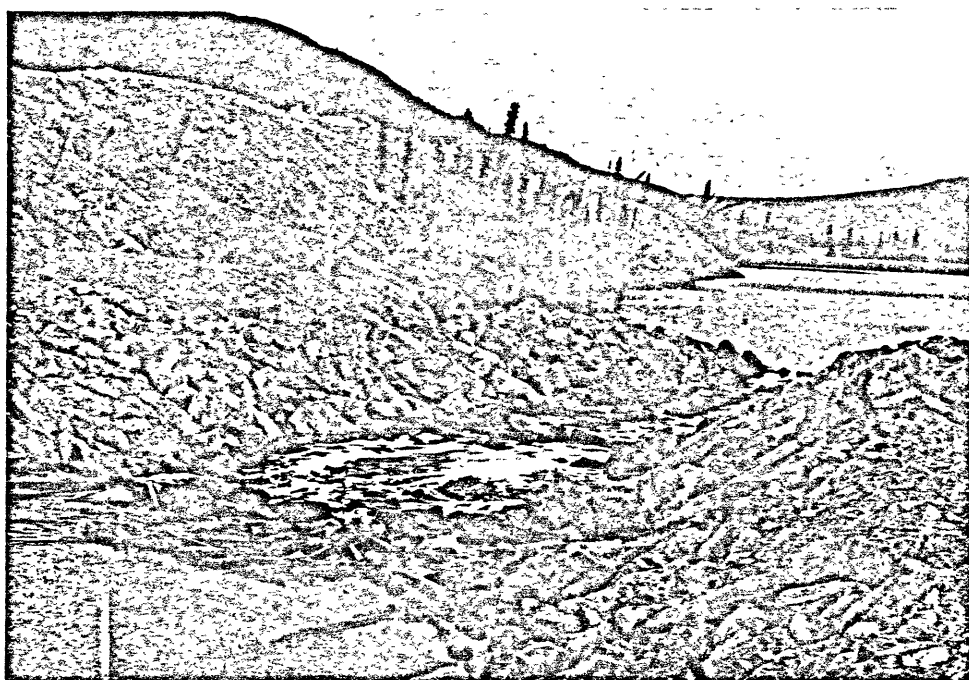


PHOTO 11
47-6-10

June 15, 1982

Downstream at decant channel of intermediate dam.

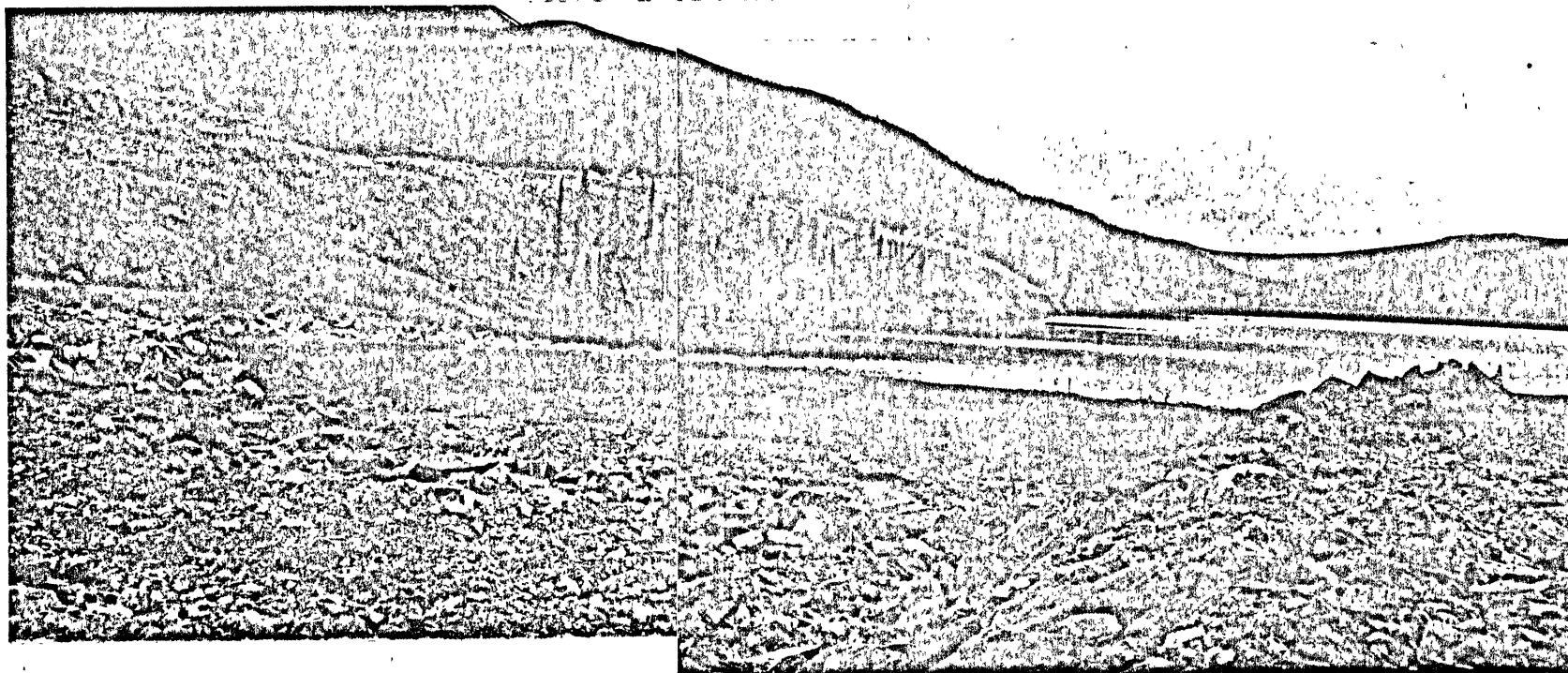


PHOTO 10 Looking downstream at emergency overflow, intermediate dam.
July 15, 1982. [47-6-12,13].

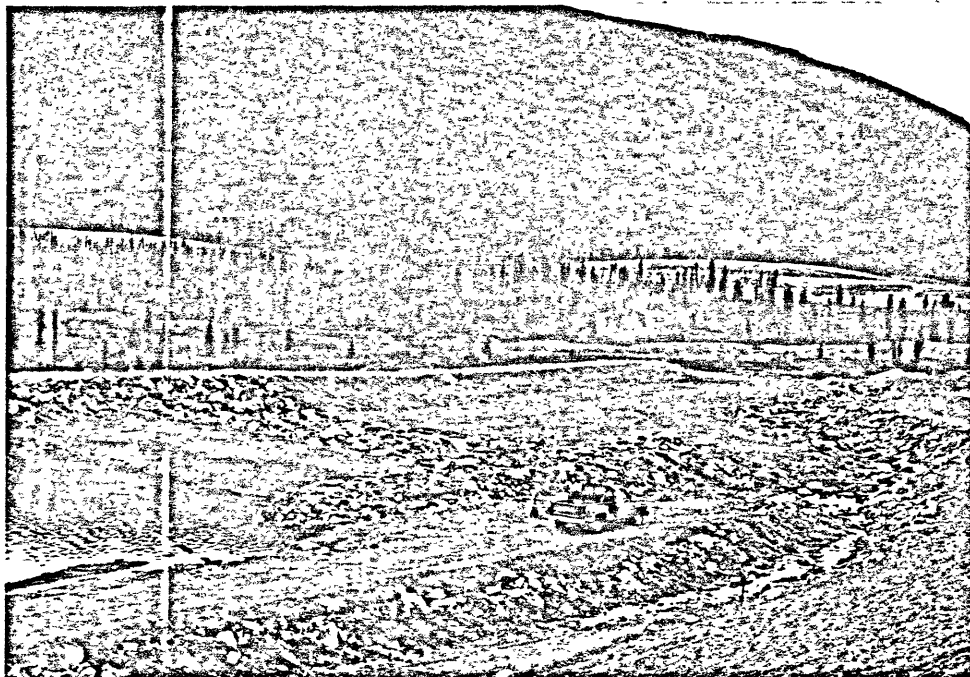


PHOTO 12

47-6-20

June 15, 1982

Overall view of outlet facilities for the Cross Valley Dam. North Valley Interceptor Ditch in foreground, then decant channel and then emergency overflow spillway.



PHOTO 13

47-6-21

June 15, 1982

Looking across the Cross Valley Dam.

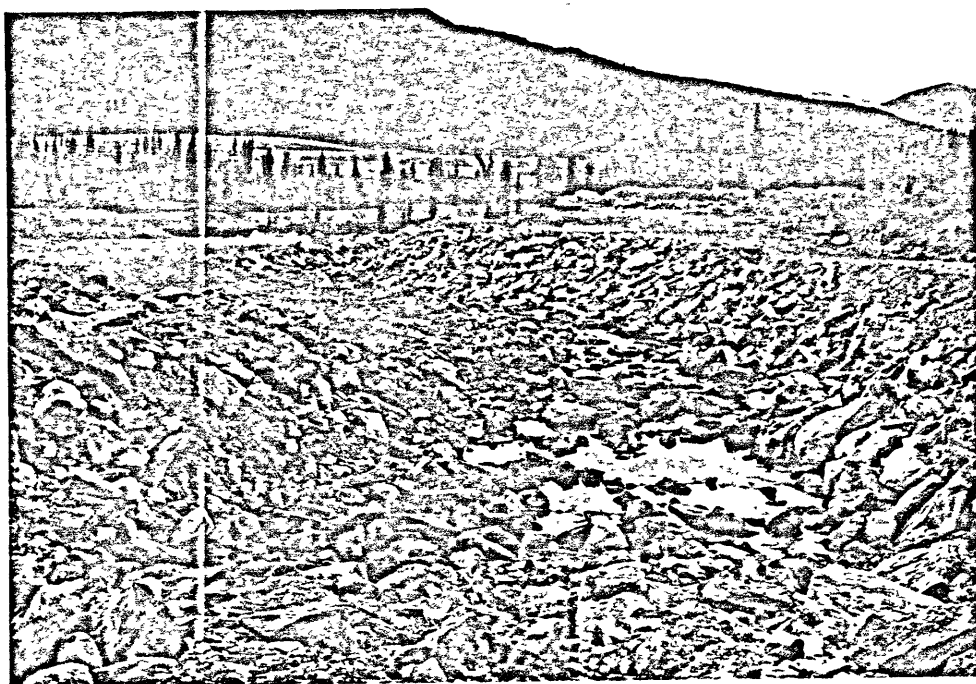


PHOTO 14

47-6-22

June 15, 1982

Looking downstream at decant channel, Cross Valley Dam.

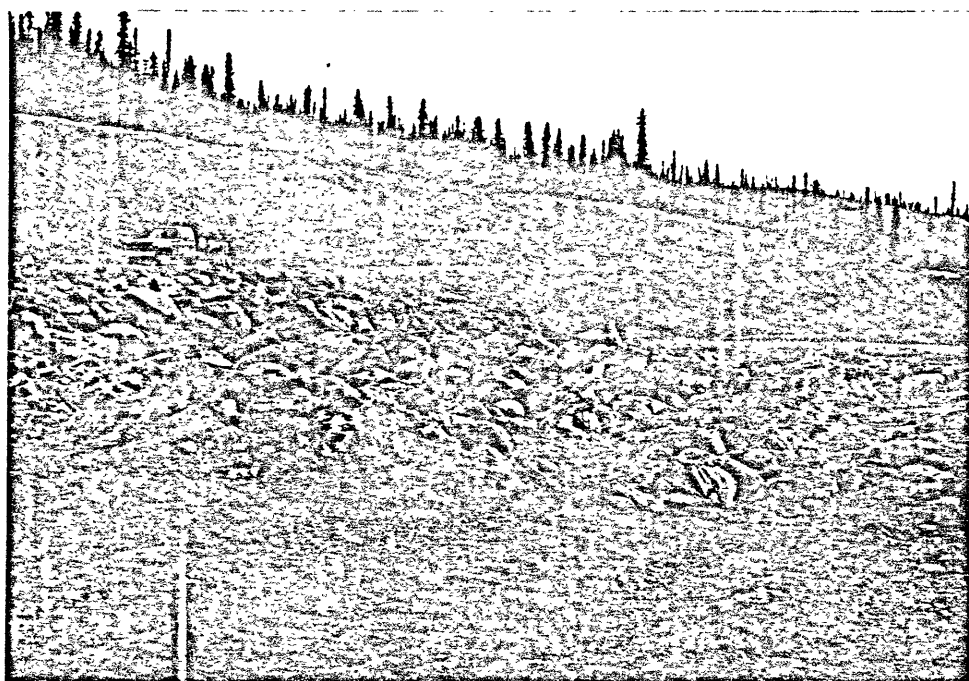


PHOTO 15

47-7-6

June 15, 1982

Close-up looking upstream of crest of emergency spillway, Cross Valley Dam.



PHOTO 16

47-6-19

June 15, 1982

Looking downstream at point where North Valley Interceptor Ditch flows parallel to the Cross Valley Dam Road.

APPENDIX B

WATER LICENSE



Indian and Northern Affairs Affaires indiennes et du Nord

WATER LICENCE

issued pursuant to
Northern Inland Waters Act and Regulations

CYPRUS ANVIL MINING CORPORATION LTD.

Licensee) - 00 1.1

License Number Y2L3-2226 issued on March 24, 19 82

Location Rose Creek, Yukon Territory

Pursuant to the Northern Inland Waters Act and Regulations the Yukon Territory Water Board, hereinafter referred to as the Board, hereby grants to

CYPRUS ANVIL MINING CORPORATION LTD.

(Licensee)

of P. O. Box 1000, Faro, Yukon Territory
(Mailing address)

hereinafter called the Licensee, the right to alter, divert or otherwise use water subject to the restrictions and conditions contained in the Northern Inland Waters Act and Regulations made thereunder and subject to and in accordance with the conditions specified in this licence:

Licence Number _____

Water Management Area 02-Yukon

Location Rose Creek, a tributary of the Pelly River near Faro.

Purpose To obtain, store and return a flow of water.

Description Storage reservoir, industrial use in milling process and a tailings impoundment.

Quantity of Water Not to be Exceeded $9.0868 \times 10^6 \text{ m}^3/\text{yr.}$ (2×10^9 imperial gallons per yr.)

Rate of Use of Water Not to be Exceeded $3.27 \times 10^4 \text{ m}^3/\text{day}$ (7.21×10^6 imperial gallons per day)

Effective Date of Licence March 24, 1982

Expiry Date of Licence March 24, 1989

This Licence issued and recorded at Whitehorse includes and is subject to the annexed conditions.

DATED this 17 day of

March, A. D. 1982

Yukon Territory Water Board

Frances Hawasul
Witness

Ensieb Stedeh
Chairman

DATED this 24th day of

March, A. D. 1982

Approved by

[Signature]
Minister of Indian Affairs
and Northern Development

PART A - GENERAL CONDITIONS

1. Definitions

- a) "Act" means Northern Inland Waters Act, R.S.C. 1969 (first supplement) Chapter 28 and any amendments thereto.
- b) "Regulations" means the regulations made under the Act.
- c) "Board" means the Yukon Territory Water Board.
- d) "Controller" means the Controller of Water Rights for the Yukon Territory.
- e) All terms in this licence, unless otherwise expressly stated, shall be defined in the same manner as in the Act and Regulations thereunder.

2. Fees

The Licensee shall pay the water use fees prescribed in the regulations, annually in advance on the 1st day of January in each and every year of the term.

3. Security

The Licensee shall, within sixty (60) days of receipt of this licence, deposit with the Board, in accordance with the Regulations, Section 13 (2) security in the amount of five hundred thousand (\$500,000.00) dollars.

4. Non-compliance

In the event the Licensee fails to comply with any provision or condition of this licence the Board may, subject to the Act, cancel the licence and without limiting its rights to cancellation of the licence, if the Licensee has failed to perform the works as specified in the licence, or has performed works contrary to the licence, the Board may apply to the Courts for a mandatory injunction compelling the Licensee to perform the works, or for an injunction to restrain the Licensee from performing the works, as the case may be.

5. Waste Discharge Standards

This licence is issued to the Licensee subject to the conditions contained herein with respect to depositing or permitting the deposit of waste of any type in any waters or in any place under any conditions where such waste, or any other waste that results from the deposit of such waste, may enter any waters. However, it is also a condition of the granting of this licence to the Licensee that, whenever future regulations are made by the Governor in Council under the Northern Inland Waters Act, or any other statute imposing conditions relating to the quantity and types of waste that may be so deposited, that are more stringent than any conditions included in this licence, that this licence shall be deemed, upon prescription of such regulations, to be automatically amended to conform within such regulations.

6. Compensation

The Licensee shall provide appropriate compensation to any person whose rights are adversely affected as a result of the granting of this water use licence.

7. Correspondence

Where any direction, notice or order under this licence is required to be in writing, it shall be given:

- a) to the Licensee, if left at or mailed by registered mail to the following address:

Cyprus Anvil Mining Corporation Ltd.,
P. O. Box 1000,
FARO, Yukon Territory
Y0B 1K0

and shall be deemed to have been given to the Licensee on the day it was left or seven (7) days after the day it was mailed as the case may be.

- b) to the Board, if left at or sent by registered mail to the following address:

Yukon Territory Water Board,
200 Range Road,
Whitehorse, Yukon Territory.
Y1A 3V1.

and shall be deemed to have been given to the Board on the day it was left or seven (7) days after the day it was mailed as the case may be.

8. Appeals

An appeal may be filed with the Board within ten (10) days of any action taken by the Controller under the provisions of this licence.

9. Annual Reports

- (a) Pursuant to Section 15 of the Regulations the Licensee shall submit to the Board, on or before 01 March of the year next following the year reported, an annual report which shall detail all water quantities used during the year with a summary and an interpretation of any trends or variations in the data.
- (b) In addition to the information referred to under Part A, Section 9 (a) of this licence the annual report shall contain:
- (i) both tabular and graphical summaries of all data generated under Schedules A, B, C and when appropriate D, of this licence, including an analysis and interpretation by a qualified individual or firm and a discussion of any variances from base line conditions or from previous years.
 - (ii) A water balance for the tailings facility and the diversion canal.
 - (iii) a detailed record of any major maintenance work carried out on the tailings facility, diversion channels, water supply reservoir or any other aspect of works on the property which may have an impact on water.
 - (iv) any other details on water use or waste disposal requested by the Board.

10. Deposit of a Waste

The Licensee shall advise by telex (036-8-342) or telephone (668-5151, local 115 or 667-7244 the 24 hour/day spill report number) the Controller immediately should a deposit of a waste in excess of licence limits occur or seem likely to occur. A detailed written report on any such event including but not limited to dates, quantities, parameters, causes and other relevant details and explanations, shall be submitted to the Controller not later than fifteen (15) days after its occurrence.

11. Term

The term of this licence shall be for a period of seven (7) years from the effective date of this licence.

PART B - CONDITIONS APPLYING TO OPERATION

1. Water Supply

- (a) The licensee shall withdraw water from Rose Creek downstream of the freshwater reservoir in a quantity not to exceed $9.0868 \times 10^6 \text{ m}^3$ per year and at a rate not to exceed $3.27 \times 10^4 \text{ m}^3$ per day.
- (b) The licensee shall impound the flow of the Right Fork of Rose Creek in a manner that ensures Part B Section 4 is fulfilled and in a manner satisfactory to the Controller.

2. Waste Discharge

- (a) Without restricting the generality of the definition of "waste" in the Act, "waste discharge" in this licence includes the tailings pond effluent, tailings pond seepage, tailings pond groundwater seepage and contaminated surface drainage prior to entering the receiving waters, and including the Faro Creek diversion waters.
- (b) No waste discharge shall exhibit constituents or characteristics exceeding the following limits:

Suspended Solids	- not greater than 15 mg/l
pH	- not less than 6.5 pH units
Colour	- not greater than 20 Pt-Co units
Turbidity	- not greater than 15 Jackson Turbidity units

- (c) No waste discharge shall contain floating solids.
- (d) No visible or floating oils or greases shall be present in any waste discharge.
- (e) No waste discharge shall be toxic to fish.
- (f) The concentrations of substances which shall not be exceeded in any waste discharge are listed below:

		Maximum Concentration for any grab sample mg/l	
Ammonia	(as N)	total	1.00
Antimony	(Sb)	extractable	0.10
Arsenic	(As)	dissolved	0.05
Barium	(Ba)	extractable	1.00
Cadmium	(Cd)	extractable	0.02
Copper	(Cu)	extractable	0.20
Cyanide	(as CN)	total	0.05
Lead	(Pb)	extractable	0.20
Mercury	(Hg)	total	0.005
Molybdenum	(Mo)	extractable	0.50
Nickel	(Ni)	extractable	0.50
Selenium	(Se)	extractable	0.05
Silver	(Ag)	extractable	0.10
Zinc	(Zn)	extractable	0.50

- (g) The effluent standards listed in Part B, Sections 2 (b), (c), (d), (e), and (f) of this licence shall be met at all points of entry to receiving waters including but not limited to ZBC-X5, ZBC-X11, ZBC-X12, ZBC-X13 or at any other sample stations specified by the Controller.

3. Tailings Disposal System

- (a) From the effective date of this licence and for a period to be determined by the Controller, the licensee shall place only fines from the mill tailings in the tailings pond behind the intermediate dam and shall distribute those fines as evenly as practicable over the floor of the pond to the satisfaction of the Controller.

- (b) During the period referred to in Part B, Section 3 (a) of this licence, coarse tailings shall be deposited in the tailings pond in use prior to the effective date of this licence.
- (c) Commencing at a date to be determined by the Controller, the licensee shall place all mill tailings in an unclassified distribution in the tailings pond behind the Intermediate dam in the valley of Rose Creek.
- (d) The licensee shall channel the waters of Rose Creek around the tailings facility and shall ensure that the diversion canal has the hydraulic capacity to carry a 1:500 year flood flow.
- (e) Within one (1) year of the effective date of this licence, the licensee shall, on the basis of data collected under Schedule C of this licence, construct a flood contingency overflow structure to channel flows in excess of 1:500 year return flood out of the diversion.
- (f) The licensee shall ensure that the spillways on the Intermediate dam and the Cross Valley dam have the hydraulic capacity to carry 1:500 year flood flow of Rose Creek.
- (g) The licensee shall, within three (3) years of any temporary cessation of tailings discharge, cap and or flood the surface of the tailings to the satisfaction of the Controller.
- (h) Flow weirs shall be constructed at the decant structures on the Intermediate and Cross Valley dams.

4. North Fork of Rose Creek

When the North Fork of Rose Creek is being diverted into the pumping reservoir an overflow of one thousand (1,000) gallons per minute shall be maintained over the pumping reservoir spillway. In order to permit the passage of fish to the North Fork of Rose Creek, this diversion shall be operated from 01 November to 30 April only.

5. Modification and Construction

- (a) The licensee shall file with the Board the final design and construction plans and specifications for any modifications to the existing water supply and associated facilities, the tailings dykes and related structures, and other waste treatment or handling facilities prior to the proposed start of any construction or work and receive a letter of approval from the Board, prior to the start of any construction.
- (b) The licensee shall file with the Controller at least ten (10) days prior to commencing any construction work referred to in Part B, Section 5 (a), a detailed construction schedule.
- (c) The licensee shall construct each structure and carry out work in accordance with the plans and specifications as approved by the Board.
- (d) All design alterations from those approved by the Board shall be submitted to the Controller, and the licensee shall receive approval from the Controller prior to any alterations being made.
- (e) The licensee shall provide as-constructed plans and drawings of the works referred to in Part B, Section 5 (a) within sixty (60) days after completion of construction. These shall be submitted on transparencies reproducible with the use of a standard printer.

6. Maintenance

During the term of this licence, including any period of temporary cessation of tailings discharge, the licensee shall maintain all works on the property, and, in particular, the tailings disposal facilities, diversion canals, freshwater supply reservoir, waste rock dumps and all associated works to the satisfaction of the Controller.

7. Waste Rock

- (a) Within two (2) years of the effective date of this licence, the licensee shall submit to the Board a plan and implementation schedule for the physical and chemical stabilization of all waste rock dumps. Such a plan shall ensure that the ultimate limit of waste rock dumps does not prevent abandonment as described in Schedule "E", Section 3 (g) and (h).
- (b) Upon receipt from the Board of written approval of the plan referred to in Part B, Section 7 (a), the licensee shall implement the plan according to the schedule contained therein to the satisfaction of the Controller.
- (c) If, in the opinion of the Controller, leaching of oxidized waste piles is occurring, the licensee shall cap the high sulphide waste rock areas with impermeable materials.
- (d) Mining and waste dump operations shall be carried out in a manner which ensures that durable calc-silicate gneiss waste rock material is available for the Scheme 2 rockfill flow through dam referred to in Schedule "E", Section 2 of this licence.
- (e) Testing of the durability of the calc-silicate gneiss rock shall be undertaken to establish its suitability for use in the abandonment dam structure to the satisfaction of the Controller.
- (f) A program to verify the availability of suitably durable rock for the construction of the abandonment dam shall be undertaken and reported to the satisfaction of the Controller.

8. Groundwater Contingency Plans

- (a) Within five (5) years of the effective date of this licence, the licensee shall submit to the Board a contingency plan or plans for handling any groundwater downstream of the Cross Valley dam which contains concentrations of substances in excess of licence limits as set forth in Part B, Section 2 (f) of this licence. The objective of such a plan shall be to ensure that licence standards are maintained in groundwater.
- (b) Should it be determined by the licensee or by the Controller that groundwater downstream of the Cross Valley dam contains sustained concentrations of substances in excess of licence limits as set forth in Part B, Section 2 (f) of this licence, the Board may require that the licensee implement one or other of the contingency plans referred to in Part B, Section 8 (a) of this licence.

PART C - GENERAL PROVISIONS FOR REPORTS, SAMPLING AND ANALYSIS

1. (a) The licensee shall submit to the Controller monthly reports based on the previous month's Surveillance Network program data and shall include the date and time each sample was taken and analyzed.
(b) The licensee shall collect and conduct four (4) bioassays each year from sampling points 2BC-X5, and 2BC-X13 on dates approved by the Controller.
(c) Procedures for the bioassays shall be obtained from the Environmental Protection Service and approved by the Controller.
2. (a) The Licensee shall comply with the Surveillance Network Program attached as Schedule "A" hereto and with any variations thereof made by the Controller and shall comply with all provisions for sampling, sample preservation, reporting and analysis specified by the Controller.
(b) Unless otherwise specified or approved by the Controller, all analyses shall be conducted in accordance with the current edition of "Standard Methods for the Examination of Water and Waste Water", prepared and published jointly by the American Water Works Association and the Water Pollution Control Federation.
(c) All analyses shall be performed in a laboratory approved by the Controller.
(d) The licensee shall perform the analysis for cyanide in accordance with a method to be specified by the Controller.
3. The licensee shall comply with the program of biological monitoring attached as Schedule "B" hereto and with any variations thereof made by the Controller and shall comply with all provisions for sampling preservation, reporting and analysis specified by the Controller.
4. The licensee shall carry out the physical monitoring program attached as as Schedule "C" hereto and with any variations thereof prescribed by the Controller.

PART D - REHABILITATION AND ABANDONMENT

1. The licensee shall notify the Board of its intention to permanently cease operations on the property, not less than five (5) years before such cessation of operations.
2. Upon permanent cessation of operations on the property, the licensee shall carry out the program of abandonment-related activities set out as Scheme 2 in the report entitled "Faro Mine Tailings Abandonment Plan", prepared by Kiohn Leonoff, Consulting Engineers, September 1981, and summarized in Schedule "E" to this licence.
3. The licensee shall carry out the program of abandonment-related investigations set forth in Schedule "D" to this licence or modifications thereof as directed by the Controller and shall submit to the Controller, at intervals approved by the Controller, all relevant data, together with an interpretation of that data in relation to the program of abandonment-related activities set forth in Schedule "E" to this licence.
4. Prior to the expiry of this licence, the licensee shall submit to the Board, financial proposals with regard to the eventual implementation of the program of abandonment-related activities set forth in Schedule "E" to this licence.
5. In addition to the provisions of Part B, Section 6 of this licence the licensee shall maintain all works on the property, and in particular, the tailings disposal facilities, diversion channels, and waste rock dumps, to the satisfaction of the Controller, during the period after permanent cessation of operations on the property, but prior to the receipt of a written statement from the Board to the effect that all provisions of this licence have been implemented in a manner satisfactory to the Board.

SCHEDULE A
SURVEILLANCE NETWORK PROGRAM
FOR
CYPRUS ANVIL MINING CORPORATION LTD.
1982

SAMPLING POINTS FOR THIS PROGRAM:

<u>Yukon Territory Water Board Identification No.</u>	<u>Sampling Station</u>
2BC-X1	Old tailings pond decant (equivalent to S1 in 1980 licence)
2BC-X2	North Fork of Rose Creek at road bridge (former S2)
2BC-X3	Rose Creek freshwater at Pumphouse (former S3)
2BC-X4	Intermediate dam decant
2BC-X5	Cross Valley dam decant
2BC-X6	Seepage from old tailings pond (former S6)
2BC-X7	Mine water at road crossing
2BC-X8	At diversion of Faro Creek
2BC-X9	Tailings line to tailings pond
2BC-X10	Rose Creek diversion canal below weirs
2BC-X11	Seepage from north toe of the Cross Valley dam
2BC-X12	Seepage from south toe of the Cross Valley dam
2BC-X13	Combined seepage flows downstream from the culvert and upstream of the decant confluence
2BC-X14	Rose Creek after mixing downstream of the diversion canal confluence
2BC-X15	Rose Creek at mouth
2BC-X16a	Groundwater monitor well-K1 at depth of 5 m
2BC-X16b	Groundwater monitor well-K1 at depth of 30 m
2BC-X17a	Groundwater monitor well-K2 at depth of 5 m
2BC-X17b	Groundwater monitor well-K2 at depth of 20 m
2BC-X18a	Groundwater monitor well-K3 at depth of 10 m
2BC-X18b	Groundwater monitor well-K3 at depth of 20 m
2BC-X19a	Groundwater monitor well-K4 at depth of 12 m
2BC-X19b	Groundwater monitor well-K4 at depth of 27 m
2BC-X20	Groundwater monitor well-K5
2BC-X21a	Groundwater monitor well-K6 at depth of 10 m
2BC-X21b	Groundwater monitor well-K6 at depth of 27 m
2BC-X21c	Groundwater monitor well-K6 at depth of 40 m
2BC-X22	Discharge from Faro #1 Pit pumps (F11)
2BC-X23	Pit drainage at toe of waste dumps (F12)
2BC-X24	Groundwater monitor well I.D. 2
2BC-X25	Groundwater monitor well I.D. 6

SCHEDULE A CONTINUED . . .

SURVEILLANCE NETWORK PROGRAM

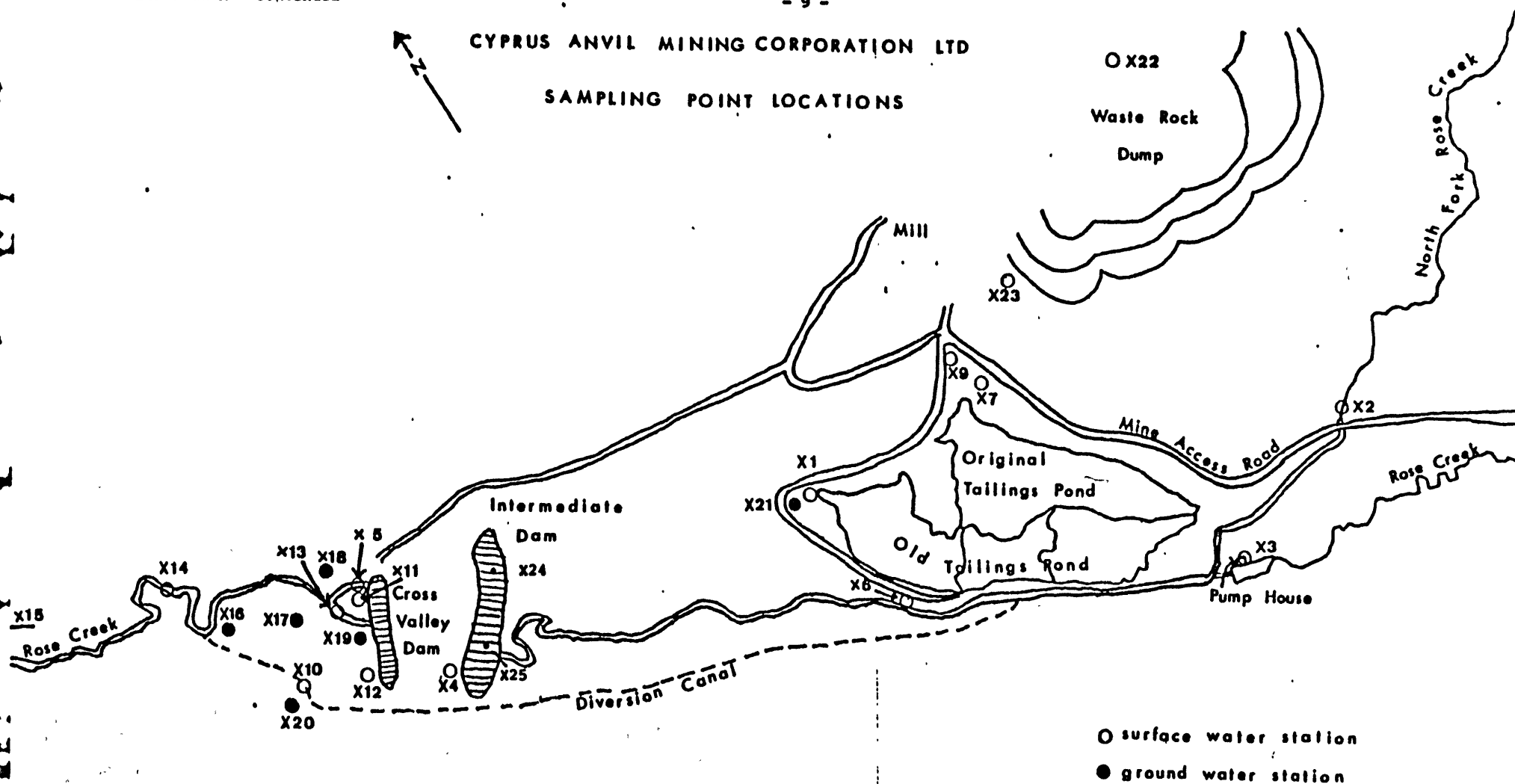
	X1	X2	X3	X4	X5	X6	X7	X9	X10	X11	X12	X13	X14	X16	X17	X18	X19	X20	X21	X22	X23	X24	X25
pH	w	m	m	w	w	m	m	w	m	w	w	w	m	2m	2m	2m	2m	2m	2m	w	w	2m	2m
Temp °C	w	m	m	w	w	m	m	w	m	w	w	w	m	2m	2m	2m	2m	2m	2m	--	--	2m	2m
Suspended solids mg/l	w	m	m	w	w	m	m	w	m	w	w	w	m	2m	2m	2m	2m	2m	2m	w	w	2m	2m
Flow m ³ sec	w	m	m	w	w	m	m	w	m	w	w	w	m	--	--	--	--	--	--	--	--	--	--
Ammonia mg/l	w	m	m	w	w	m	m	w	m	w	w	w	m	2m	2m	2m	2m	2m	2m	w	w	2m	2m
Copper mg/l (extractable)	w	m	m	w	w	m	m	w	m	w	w	w	m	2m	2m	2m	2m	2m	2m	w	w	2m	2m
Lead mg/l(extractable)	w	m	m	w	w	m	m	w	m	w	w	w	m	2m	2m	2m	2m	2m	2m	w	w	2m	2m
Zinc mg/l(extractable)	w	m	m	w	w	m	m	w	m	w	w	w	m	2m	2m	2m	2m	2m	2m	w	w	2m	2m
Cyanide mg/l (total)	w	m	m	w	w	m	m	w	m	w	w	w	m	--	--	--	--	--	--	--	--	--	--
Manganese mg/l (extractable)	w	m	m	w	w	m	m	w	m	w	w	w	m	2m	2m	2m	2m	2m	2m	w	w	2m	2m
Sodium mg/l	w	m	m	w	w	m	--	--	m	w	w	w	m	2m	2m	2m	2m	2m	2m	--	--	2m	2m

NOTE: w - weekly sampling
 m - monthly sampling
 2m - sampling every 2 months

SCHEDULE A continued

- 9 -

CYPRUS ANVIL MINING CORPORATION LTD
SAMPLING POINT LOCATIONS



SCHEDULE B

YUKON TERRITORY WATER BOARD

BIOLOGICAL MONITORING PROGRAM

FOR

CYPRUS ANVIL MINING CORPORATION LTD.

1. Sampling Points:

- (a) R1: above the confluence of the North Fork and South Fork of Rose Creek (EPS sample station 1)
- (b) R2: in the mixing zone downstream of the intersection of the Rose Creek diversion canal.
- (c) R3: Rose Creek about one-half way to Anvil Creek. (E.P.S. sample station 5)
- (d) R4: Rose Creek just above Anvil Creek. (E.P.S. sample station 6)
- (e) R5: Anvil Creek just below the confluence of Rose Creek.

- 2. The Company shall collect three replicate samples annually from each station using an artificial substrate sampler for approximately five weeks.
- 3. The Company shall on each visit perform tests for pH, conductivity, temperature, and dissolved oxygen. Water samples shall be collected and analyzed for cyanide, copper, lead, zinc, manganese, iron, calcium and sodium.
- 4. Samples shall be collected by an independent consultant.
- 5. Sample identification and enumeration shall be done by an independent consultant.

SCHEDULE C - PHYSICAL MONITORING PROGRAM

1. a) The Rose Creek diversion canal shall be monitored through the instrumentation installed as per the Golder Associates Performance Instrumentation Report dated February 1982 (812-2041). Gathered data shall be analyzed to show:

- (i) Adjustment in thermal regime and melting of the permafrost,
- (ii) Potential downslope creep of the excavated canal wall,
- (iii) Settlement of the dyke and distribution of settlement within the dyke foundation due to permafrost thaw.
- (iv) Areas and rates of seepage from the diversion canal.
- (v) Performance of the waste piles adjacent to the canal with respect to canal stability.
- (vi) Other areas of concern.

b) If the analyses referred to in Schedule C, Section 1 (a) show design objectives for geotechnical performance and project safety have not been met, the licensee shall identify remedial measures to the Controller and implement them upon receipt of the Controller's approval.

c) The network of monitoring instrumentation as detailed in Figure 1 of the Golder Associates Performance Instrumentation Report (812-2041) shall be monitored according to the following schedule:

Item	MONTH				
	Mar.	Apr.-May	June	Sept-Oct.	Dec.
Vertical Settlement Hubs		X		X	
Horizontal Settlement Hubs		X		X	
Inclinometer Casings		X		X	
Incremental Settlement Casings	X		X	X	X
Thermistor Strings	X		X	X	X
Pneumatic Piezometers	X		X	X	
Hydraulic Piezometers	X		X	X	

↑
We have never, to my knowledge requested monitoring in April/May.

- d) Monitoring of vertical and horizontal movement hubs shall be performed by qualified surveyors.
 - e) Stream flow measurement shall be taken at two sections in the canal: one just downstream of the water supply pump house and the other on the gently sloping section, midway along the outfall reach of the canal. One of these sections shall be established as a continuous recording streamflow station.
 - f) Glaciation within diversion canal shall be monitored under the following program:
 - (i) weekly inspections of ice build-up on the south wall, and bottom of the canal shall be made.
 - (ii) The licensee shall prepare a surveyed cross section of any significant ice build up at said locations.
 - (iii) Inspection observations and related weather conditions shall be documented.
 - (iv) All corrective or preventative action shall be documented.
 - (v) A photographic record shall be taken of any glaciation.
 - g) Any erosion activity within the diversion canal shall be studied and documented and preventative measures taken to stabilize the activity.
 - h) Several selected cross sections and profiles shall be surveyed and routinely re-surveyed to measure the amount of sedimentation build-up within the diversion canal. The following points shall be established as control sections: the upstream end of the pond formed in the old canal by the diversion dam; and just downstream of Goodall Creek.
 - i) Data shall be collected to aid in the design of an overflow structure to pass flows in excess of the canal's capacity into the down valley tailings pond area as prescribed in Part B, Section 3 (e).
2. The Intermediate and Cross Valley dams shall be monitored through the instrumentation installed as per Golder Associates Performance Instrumentation Report dated February 1982 (812-2041). Monitoring shall commence prior to reservoir filling and a monitoring schedule shall be followed as laid out in Section 1 (C) of Schedule "C" to this license.

SCHEDULE D - PROGRAM OF INVESTIGATIONS
RELATING TO ABANDONMENT

1. (a) Tailings test ponds shall be constructed and monitored to the following extent:
 - i) The area of the bottom of the test pit shall be a minimum of 10m².
 - ii) The pit walls shall be of low permeability.
 - iii) The test pond shall be placed in a location such that pond elevation is significantly above ground-water elevation.
 - iv) Water used in the ponds shall be natural surface water and tailings shall be washed before placement in ponds.
 - v) A minimum of four pit tests shall be conducted with 2 pits filled with low permeability tailings and 2 pits filled with tailings sands. Each grain size shall have one pit with water depth of 2m and one other with water depth of 5m.
 - vi) Tailings shall be placed in the pits to a minimum depth of 0.5 m.
 - vii) Tailings solids shall be analyzed at the time they are placed in the pit and once every five years for the following constituents, sulphide sulphur, lead, zinc, iron and copper.
 - viii) A minimum of four water samples shall be taken from each pit at the following points, surface water in pit, pore water 0.1m below tailings surface, pore water 0.1m above the base of the tailings and pore water from below the tailings.
 - ix) A minimum of eight sample times shall be established during the year with analyses for the following constituents, lead, zinc, iron, silver, copper, alkalinity, hardness and sulphate.
 - x) A dissolved oxygen profile shall be prepared of the surface water column and, for the pore water. Field pH and temperature shall be taken along with each water sample.
2. (a) A trial embankment design to simulate the flow through zone of the abandonment dam described in Schedule E to this licence shall be constructed in an area of continuous winter flow below the present Down Valley dam but above the confluence of the diversion ditch and Rose Creek.
 - (b) The test section shall be constructed to the satisfaction of the Controller.
 - (c) The test section shall be monitored during the year with special attention paid to winter operation. Instrumentation shall be installed to adequately define conditions within test section during operation to the satisfaction of the Controller.
 - (d) Any changes to design during test period and all monitoring data shall be documented in detail each year.

SCHEDULE E - SUMMARY OF ABANDONMENT-RELATED ACTIVITIES

1. General

- a) The licensee shall abandon the property in such a way as to ensure, without any maintenance whatsoever, the long term physical stability of all water courses and tailings deposits.
- b) The licensee shall abandon the operation in such a manner that the long term water quality of Rose Creek downstream of the tailings facility is equal to or better than that during operation.

2. Abandonment of Tailings Facility

- a) An abandonment dam and reservoir shall be constructed as shown in Appendix I and II, and in accordance with the specifications and recommendations of the Klohn Leonoff Report entitled, "Faro Mine Tailings Abandonment Plan", dated September 1981, and the associated Klohn Leonoff addendum dated October 20, 1981, and incorporating design revisions based on the information gained from the program of abandonment-related investigations carried out pursuant to Part D, Section 3 and Part B, Section 7 (e) and (f) of this licence, or from any other investigations undertaken by the licensee.
- b) The licensee shall ensure that all tailings are flooded to an average depth of five (5) meters and that no tailings are flooded to a depth of less than four (4) meters.
- c) The licensee shall construct a pervious rock berm at the extreme upper end of the tailings reservoir to control the influx of debris to the abandonment reservoir.
- d) The abandonment dam shall satisfy the following criteria:
 - i) passage of the possible maximum flood without damage to the structure,
 - ii) maintenance of structural stability under loads of maximum credible earthquake,
 - iii) works constructed shall be maintenance-free.

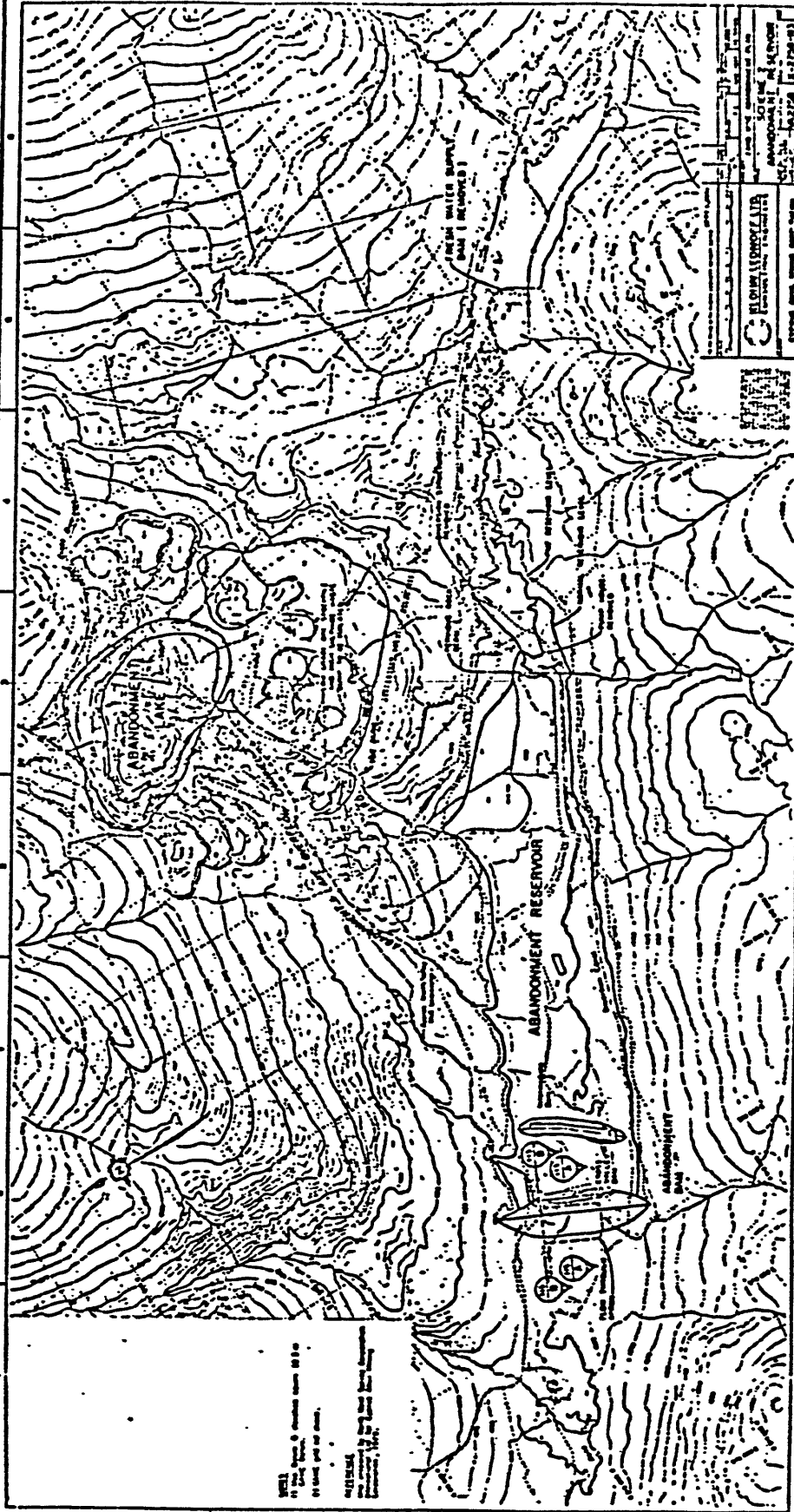
3. Abandonment of Other Facilities

- a) The licensee shall abandon other facilities at least in accordance with the specifications and recommendations detailed in the Klohn Leonoff report entitled, "Faro Mine Tailings Abandonment Plan", dated September 1981.
- b) The licensee shall restore the bed of Rose Creek in the area of the freshwater reservoir to a stable condition and shall ensure that the channel is suitable for fish passage.
- c) The licensee shall remove the pumphouse and cover its foundation.
- d) The licensee shall remove the pumphouse dam and the freshwater reservoir dam.
- e) The licensee shall restore North Fork of Rose Creek to pre-mine condition.
- f) The licensee shall remove the Faro Creek diversion structure and route Faro Creek into open pit No. 1.
- g) The licensee shall ensure that waste rock dumps constructed of durable rock have slope crests with a set back distance equivalent to a slope of two horizontal to one vertical.
- h) The licensee shall ensure that waste rock dumps constructed of weak or friable rock and overburden have slope crests with a set back distance equivalent to three horizontal to one vertical.
- i) The licensee shall abandon sulphide-rich waste rock in a manner such that oxidation and leaching are unlikely to occur.

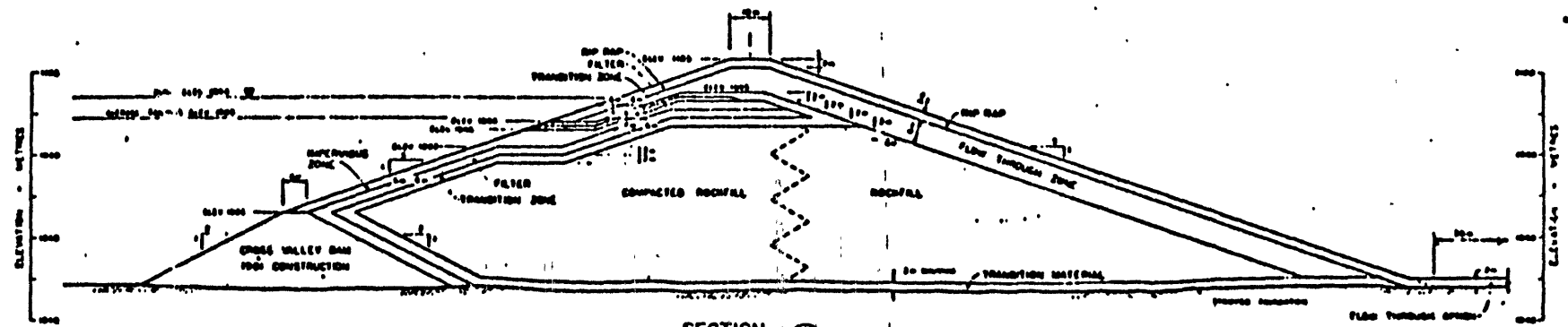
- j) The licensee shall establish the outflow from open pit No. 1 such that exposure of mineralized rock in the pit is minimized to the satisfaction of the Controller.

4. Seepage Control

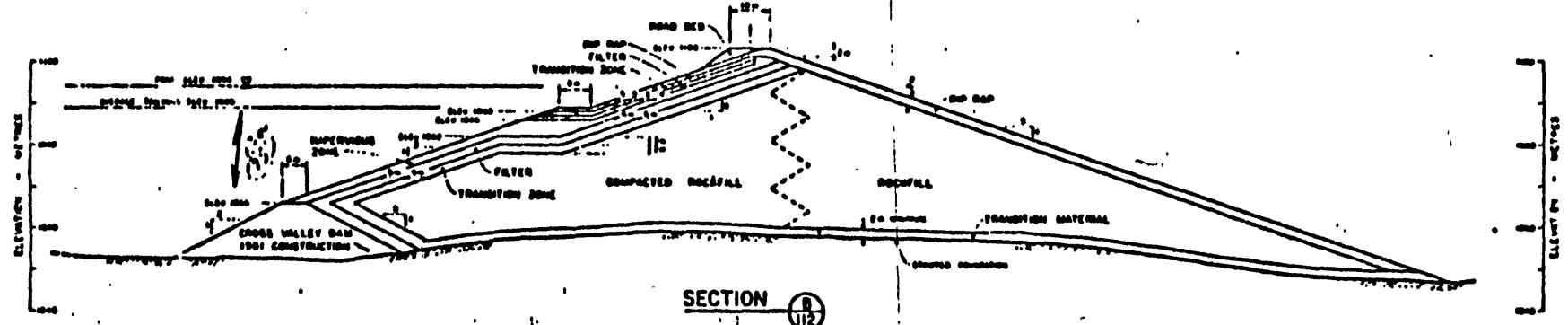
Should it be determined upon permanent cessation of operations by the Controller or by the licensee that any high seepage zones exist in the tailings reservoir, the licensee shall cap such zones to the satisfaction of the Controller.



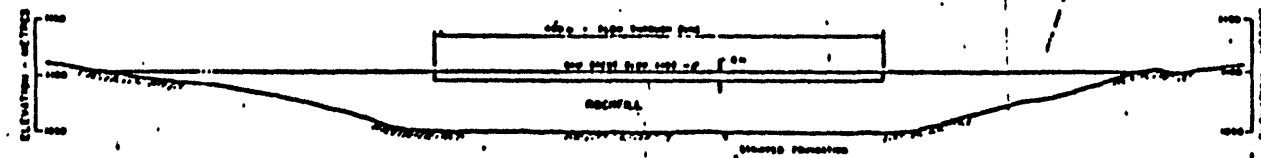
SCHEDULE E Appendix II



SECTION A-112



SECTION B-112



ABANDONMENT DAM PROFILE

NOTES

- 1 Elevations are G.A.M.C. Datum.
- 2 These sections are preliminary only and must not be used for construction.

KLOHN LEONOFF LTD. CONSULTING ENGINEERS		FARM 100% ABANDONMENT PLAN ABANDONMENT DAM TYPICAL SECTIONS	
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APPENDIX C

DRAWING

APPENDIX V
DEFORMATION MONITORING STUDY, UNDERHILL ENGINEERING

DEFORMATION MONITORING STUDY
DOWN-VALLEY TAILINGS CONTAINMENT PROJECT
CYPRUS ANVIL MINE
FARO, YUKON

Conducted for
GOLDER ASSOCIATES
Consulting Geotechnical Engineers

October, 1982

by
UNDERHILL ENGINEERING LTD.
Engineers and Surveyors
Whitehorse, Yukon

A technical report intended to critically examine
the design and observation of the survey network
established in 1981, with a view to prediction of
the expected accuracy of detected movements.

File Y-2678



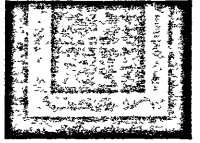
UNDERHILL ENGINEERING LTD.

Consulting Engineers

Mailing address: P.O. Box 4068, Whitehorse, Yukon Y1A 3S9

Office: 312 B Hanson Street, Whitehorse

Telephone (403) 668-2048 ■ Telex 036-8-465



OUR FILE:

1982 11 01

YOUR FILE:

Golder Associates
7017 Farrell Road S.E.
Calgary, Alberta
T2H 0T3

Attention: D. C. Goodall, P.Eng.

Dear Sirs:

Re: Your request for a report on the Deformation Study of the
Down-Valley Tailings Containment Project

We are pleased to submit herewith our technical report in compliance
with your request.

We trust the report satisfies your requirements.

Respectively submitted,

UNDERHILL ENGINEERING LTD.

P. E. Thomson, BCLS, CLS

PET/mln

ABSTRACT

The deformation of the structures comprising the Down-Valley Tailings Containment project at Faro must be considered to determine whether the constructed works behave according to expectation.

The use of sophisticated surveying techniques to determine the position of the structures at various epochs of time will provide information relative to their deformation. While a detected movement of one centimetre might not be significant when one is considering the safety of a structure, steps should nevertheless be taken to insure that the accuracy of the displacement vector is one centimetre, or as close to that figure as may reasonably be achieved. Thus the engineer will have meaningful data available when he is determining the long term deformation of the constructed works.

This report examines the survey network established and the procedures followed on the project to date. Optimum network design parameters and methods for deformation studies in general are discussed and where and why some of these were deviated from will be explained. The general theory of Least Squares Adjustment is outlined as are certain statistical analysis techniques.

The results of the measurement of the network to date are critically examined in order to show that the network and methods are capable of accuracies of the order of one centimetre.



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HISTORY

The site was visited on September 6th, 1981 to determine the scope of the survey. Cognizance was taken at that time of the order of magnitude of the distances involved and that problems could be expected in establishing permanent reference monuments due in part to the presence of permafrost along the north facing slopes. The occurrence of bedrock was also noted and all such occurrences were determined prior to the first snowfall.

Initial investigations into the availability and accuracies of the special equipment required were commenced and a preliminary methodology was postulated.

The site was re-visited on November 10th, 1981 at which time Golder Associates were just completing the installation of the monuments in the various structures that required monitoring. The geodetic control network was finalized and installation of the permanent reference monuments followed. Certain lines between monuments were cleared of trees to allow intervisibility.

Baselines for the testing of Electronic Distance Measuring equipment (EDM) were established in Whitehorse and two types of EDM were tested on them. One proved not to be performing within specifications so the other was chosen.

A mathematical pre-analysis of the weakest figure in the network was performed which led to the finalization of the observation procedure. All other equipment ancillary to the observations was tested, adjusted, calibrated or standardized as required.

The survey network has been measured three times to date with observation dates as follows:

EPOCH A - December 1981
EPOCH B - April 1982
EPOCH C - September 1982



GENERAL CONSIDERATIONS

If any deformation study is to provide meaningful data, the observed (or computed) displacement vectors must be referred to some frame of reference or datum. The most convenient, both for ease of computation and clarity in the presentation of results, is a three dimensional system defined by three mutually orthogonal axes. Three coordinates therefore serve to explicitly define any point within such a space and any observed variances of these coordinates are evidence of the magnitude and direction of the displacement vector. For such a scheme to consistently provide accurate results, the stability of the monuments placed to reference the coordinate system must be proven. This can only be accomplished by repeated measurement of the network at subsequent epochs and showing that the fixpoints have no or only neglectable displacements. There must be at least four such fixpoints as it is possible (although highly unlikely) that three points may retain their positional orientation to one another but suffer some rotation with respect to the spatial coordinate system. It is also desirable that there be some distant fixpoint that serves as a directional reference only.

Within the network under consideration, there are five candidates for fixpoints, all of which are monuments placed in consolidated bedrock. They are stations 282, 284, 288, 289 and 292. The one possible location for a distant fixpoint was rejected due to its altitude. This high elevation meant access to the point would be by helicopter only and that the probability of it being obscured by cloud was high.



GENERAL CONSIDERATIONS continued

All surveying observations or measurements are subject to two main types of errors which are classed as either random or systematic. Random errors are accidental errors and they tend to have a normal distribution. Therefore they have a standard deviation a priori which is either known from experience or is obtained by calculation from the physical makeup of the device or instrument used for the observation. Alternatively, the value may be provided by the manufacturer. Systematic errors, on the other hand, are constant errors which introduce a bias into all observations and while observational methods and techniques have been developed to minimize their effect, they cannot be totally eliminated.

There is a school of thought, therefore, which says that since deformation surveys are concerned with movement of points and not their absolute positions, then systematic errors are best dealt with by keeping them the same when possible and thereby eliminating their effect. To this end it is suggested that one should use the same instruments, equipment, observers, etc. for each element of the network and make the observations under the same conditions at each epoch.

This point was carefully considered before the methodology for the survey was decided upon. No commitment could be made to dedicate any equipment or personnel to a project likely to span decades. Who cannot say that new and better methods and equipment will be available in years to come? The observational environment can contribute substantially to systematic errors. The present plan for epochal scheduling virtually guarantees severe differences of weather patterns. For these reasons it was decided to attempt to reduce systematic errors to a minimum by employing all the best known survey techniques developed for the purpose.



MONUMENTS

All of the monuments placed on the pertinent structures were designed and installed by Golder Associates. They comprise a 5 foot long 3/4 inch rod with footplate and are protected from frost action by a neoprene sleeve and from surface disturbance by a 6 inch steel collar.

The five monuments located on bedrock were placed by drilling an 18 inch deep hole in the rock and inserting a 5/8 inch rod secured with non-shrinking grout. Where the surface rock was weathered to the extent that it was impossible to drill a hole, the unconsolidated material was chipped with a breaking hammer and an excavation made by hand to solid rock. A longer rod was then drilled into the rock and the hole backfilled with concrete to original ground level. All monuments placed, including those placed by Golder Associates, were either centre-punched or enscribed with a cross to facilitate centering.

Two monuments of the Golder design were placed at stations 290 and 291 (not on bedrock) to strengthen the design network. Additionally, an iron bar at station 814 which was placed in the Intermediate Dam during construction was occupied and used in the network. This monument was not of the Golder design and as such is not protected from frost action.



CHOICE OF EDM

Two instruments were considered for the measurement of the distances in the network.

The first EDM considered was the Tellurometer model MA 100, an infrared device with resolution to 0.1 mm and a stated range of about 2 km. The manufacturer's claimed accuracy is ± 1.5 mm ± 2 ppm making it theoretically possible to measure the longest distance in the network with a root mean square error of less than 5 mm.

The other EDM considered was the Geodimeter model 120, also an infrared device but with only 1 mm resolution. The Geodimeter offered better range, faster measuring time, and was considerably easier to transport and operate. The accuracy claimed was ± 5 mm ± 3 ppm leading to a maximum root mean square error of less than 8 mm.

Both instruments were subjected to complete error analysis tests in Whitehorse before the choice of EDM was made.



EDM ERRORS

EDM errors fall into three classes: cyclic error, constant error and proportional error.

Cyclic error is caused by electrical and optical "crosstalk" between components within the instrument, leading to contamination of the detected phase shift. Since all electro-optical EDM equipment resolve the distance in terms of phase shift, each EDM will exhibit a cyclic error which is directly related to the modulation frequency imposed on the carrier wave. Most manufacturers claim that cyclic error is practically non-existent in their products and for the most part this is true; however aging of components can lead to this error and periodic checks on a suitable baseline should be carried out.

A precise baseline of 10 metres was established at Whitehorse comprising 10 bays of exactly one metre each. The stations were lead plugs in a concrete floor and were centered with copper tacks. This baseline is suitable for those instruments which have a characteristic wavelength of 10 metres (the usual case). The procedure is simply to set up the EDM off one end of the baseline and measure to each station in succession. The absolute distances obtained are not important but the differences between each measurement should be one metre exactly, otherwise cyclic error is present.

The data obtained from the Geodimeter 120 test for cyclic error was so consistent that no plot resembling a typical cyclic error curve could be constructed. The only conclusion that could be inferred therefore was that if cyclic error was present it most certainly had an amplitude of less than one millimetre and could be considered to be zero.

To test the Tellurometer MA 100 the test base had to be modified somewhat as the expected wavelength of the error cycle was 2 metres due to a different modulation frequency. A fully graduated steel bar was laid between the points in the test base and measurements were taken at intervals of 20 cm. A plot of the results revealed a classic sine wave cyclic error curve of 2 metre wavelength that had an amplitude of 7 mm. This was almost 5 times the manufacturer's specifications and was interpreted as an indication of a serious problem within the instrument.



EDM ERRORS continued

No further tests were performed on the MA 100 and the choice of EDM fell to the Geodimeter providing it passed further tests.

Constant error is that property exhibited by an EDM whereby each result differs from the true value by an amount which does not vary in magnitude or in algebraic sign.

EDMs can self test themselves for this error on a suitable baseline. A baseline of 210 metres was laid down consisting of three bays of 70 metres each. These bays were not required to be exact distances but were kept within a few centimetres of being equal lengths so that any cyclic error would not contaminate the constant error test.

The principle of the test is simply that if the EDM measures each bay and then measures the total length, the sum of the first three results should equal the total, otherwise constant error is present. With three bays there are 5 combinations of distances which will give five values of the error.

The results of this test for the Geodimeter 120 were a constant error of -0.0015 mm. This constant was applied to all measured distances.

Proportional error in EDM equipment is that error due to an incorrect modulation frequency which affects directly the nominal wavelength. The result is that greater errors will be exhibited on greater distances and vice versa.

The only way to check for this error is to have a precisely known baseline against which to compare the results. Such a baseline exists in Whitehorse and a comparison of the Geodimeter 120 result with the known distance revealed that the instrument was performing within specifications.

The final test having been passed the decision was made to use the Geodimeter 120 for the deformation study.



TEST OF ANCILLARY EQUIPMENT

Barometers: were compared against the station pressure at the Whitehorse weather office. As a result, corrections were applied to all readings taken in the field.

Thermometers: were also compared against those on the screen of the Whitehorse weather station. Appropriate corrections were applied to all temperature readings.

Tribrachs
& Targets: all were tested and adjusted prior to their use in the field to insure accuracy of their optical plummets.



VERTICAL CONTROL

The vertical datum chosen was that used in the construction of the project, i.e. the Cyprus Anvil Mine datum. All elevations are referred to the bench mark at the mine pumphouse.

A Zeiss Ni007 first order Geodetic level and invar levelling rods were used to run differential levels from the pumphouse to all stations in the network and also to several other monuments which are to be monitored in the vertical direction only. Levels were also run to two bench marks placed on either side of the valley near stations 282 and 292.

A rigorous least squares adjustment was performed on the vertical network giving us elevations of the monitoring stations with a standard deviation of 3 mm.



HORIZONTAL CONTROL

The horizontal datum chosen was also the Cyprus Anvil Mine datum. Horizontal ties were made to 3 existing mine grid control points, (78-17, 78-18 and 78-19) to establish coordinates, in the local coordinate plane, for bedrock station 284. Station 284 was coordinated for use as the fixed station of the control network in the subsequent adjustment.

Control points were chosen on either side of the valley to give the most favourable geometric configuration possible and, at the same time, utilize all available rock outcropping to ensure stability of the network.

The base figure in the control network is a fully observed braced quadrilateral, 3 vertices of which are bedrock stations. Geometrically, this figure is very strong. This braced quadrilateral is centrally located with respect to the Golder monuments, giving a very strong basis for the subsequent coordination.

The 4 other major control stations were located with geometric considerations within the topographical limitations to allow as many redundant observations as possible.

Station 290 and station 291 are not bedrock stations (and therefore are not likely candidates for "fixed points") but are used to strengthen the network and thus the accuracy of the major control.



HORIZONTAL CONTROL continued

Distance and direction observation procedures were carefully designed so as to reduce systematic errors and improve the accuracy of the results as much as practically possible.

Height differences rather than observed zenith angles were used in reducing slope distances to the horizontal. This method necessitates the measuring of the height of the reflector and the EDM above their respective stations, the elevations of which were determined by spirit levels. As a check against errors in these measurements, heights were also measured to the head of the tripod. A quick subtraction would verify the constant relationship between the height of the tripod and the reflector. A simple but effective check against human error.

All prisms used were of identical design and were mounted in the previously tested tribrachs.

Temperature and barometric pressure were measured at both ends of the line for each measurement. The mean of the measurements was used to give an average refractive index along the line of sight. The meteorological correction was calculated using a rigorous mathematical formula rather than relying upon the built-in computer in the EDM.

The measurements were observed in a mode known as "D Stroke". In this mode the instrument automatically repeats its measurement while the built-in calculator integrates the measurements and displays the continuous arithmetic mean.

Distances were initially reduced to Mean Sea Level and then factored to a common plane at 1080 m a.s.l. (the average elevation of the job site).

A Kern DKM-3 was used to observe the directions. This is a first order theodolite, reading direct to 0.5 seconds. Rather than an optical plummet this instrument has a plumbing rod. Three sets of directions were measured i.e. there were 6 pointings on each target, 3 on each face. The standard deviation of the mean of the observations at each set up was checked before moving to the next point.

The sighted signals were opaque, tribrach mounted, plate targets which have a white geometrically symmetric configuration on a black background.



LEAST-SQUARES ADJUSTMENT

To calculate the coordinates of new points (unknowns) the number of observations must be at least equal to that of the unknowns. Geodetic networks typically contain observations far greater than the number of unknowns. An adjustment of the observations, which is necessary before any definitive coordinate values can be computed, should be performed by a rigorous method such as the parametric least-squares method, which allows for a full statistical analysis of the accuracy of the network.

This is only possible on large scale computers. The adjustment of this network was performed at the University of New Brunswick on their IBM computer using the program GEOPAN (Geodetic Plane Adjustment and Analysis).

The basic criterion of the least-squares adjustment is that the sum of the squares of the residuals of the observations is a minimum. This leads to a unique and the most probable solution to the network that contains more observations than unknowns. Additionally, we have the ability to weight the observations in proportion to the inverses of their a prior standard deviations.

The direct product of the adjustment is the residuals of the observations. This leads to the corrected observations from which the final adjusted coordinates may be computed. A by-product of the adjustment is the covariance matrix from which we can determine many statistical quantities.



ACCURACY ANALYSIS

The accuracy of a surveying network is fully defined if errors of relative positions between any two points in the network are known at a certain confidence level (probability level). Usually a 95% probability that the error of the relative position does not exceed the given value is accepted as the confidence level. The relative position of one point with respect to another point is the difference in the adjusted positions of the two points as defined by the differences of the correspondingly adjusted coordinate values. If the positional accuracy of a point is related to the reference points that are treated as fixed (errorless) in the process of the network adjustment, the term absolute positional accuracy is applied.

Variances and covariances of coordinates of the analyzed network are a basis for calculations of the absolute and relative positional errors. They allow the calculation of the following quantities that are frequently used in describing the positional accuracies:

- Standard deviations of coordinates or differences in coordinates.
- Semimajor and semiminor axes of standard-error ellipses (absolute or relative)

The most general description of the positional accuracy of a point is given in a graphical form by an error curve. Brief definitions of the above terms and quantities are given below.

The variance of a coordinate value or of an observation is a statistical measure of reliability of the value. It is also called mean square error.

The covariance of a pair of coordinate values belonging to one or two points is a measure of statistical dependence of the two values. The same applies to the covariance of two observations. If two coordinates or two observation values are uncorrelated their covariance equals zero. In most cases, coordinates of points that are calculated using the same set of observations are highly correlated.



ACCURACY ANALYSIS continued

The standard deviation of a coordinate value, a difference in coordinates, or an observation is the positive square root of the corresponding variance. It is also called standard error or root mean square error. Standard deviation represents a probability (confidence level) of 68% that the difference between the given (calculated) coordinate and its true value is not more than the standard deviation. To increase the confidence level to 95%, the standard deviation must be multiplied by 1.96.

The standard-error ellipse of a calculated absolute position is an ellipse described by the semimajor and the semiminor axes. If drawn around a point, it is usually interpreted as depicting the region in which we have 39% confidence that it contains the position of the corresponding point determined from errorless observations. To increase the confidence to 95%, the semiaxes of the error ellipse must be multiplied by 2.45. If an error ellipse is calculated on the basis of variances and covariances of differences of coordinates of two points, it is called a relative standard-error ellipse, which describes the relative positional accuracy between the points.

The error curve, also called pedal curve, if drawn around a point describes positional standard deviations in any desired direction at an angle measured clockwise from the semimajor axis of the error ellipse. Error curves are only very slightly larger than error ellipses and the more circular the ellipse, the closer it approximates the error curve.



NETWORK ADJUSTMENT

Input into the GEOPAN program were the approximate coordinates of the stations, the reduced observations, and the a priori estimates of the standard deviations. Using this information the program was run giving us the results of the adjustment.

Included in the output, of interest to us, was the following:

- the final adjusted coordinates of the stations.
- a summary of reduced observations, residuals and adjusted observations.
- the results of various statistical tests.
- the station confidence ellipses.
- the covariance matrix of the parameters.



CONCLUSIONS

The conceptual design of the survey network and the subsequent observations satisfied the initial requirements. This is concluded from both the standard deviations of the coordinates and the average dimensions of the relative error ellipses. The average standard deviation of the coordinates was 3.5 millimetres leading to an average semi-major axis of the relative error ellipse of 13 mm at the 95% confidence level.

One may conclude therefore, that the design and observation of the network is suitable for the detection of deformations, with an order of accuracy of about one centimetre.



REFERENCES

Blachut, T.J., Chrzanowski, A., Saastamoinen, J.H. "Urban Surveying and Mapping" (Springer-Verlag New York Inc., New York, N.Y., 1979), Chapters 2, 3, 4.

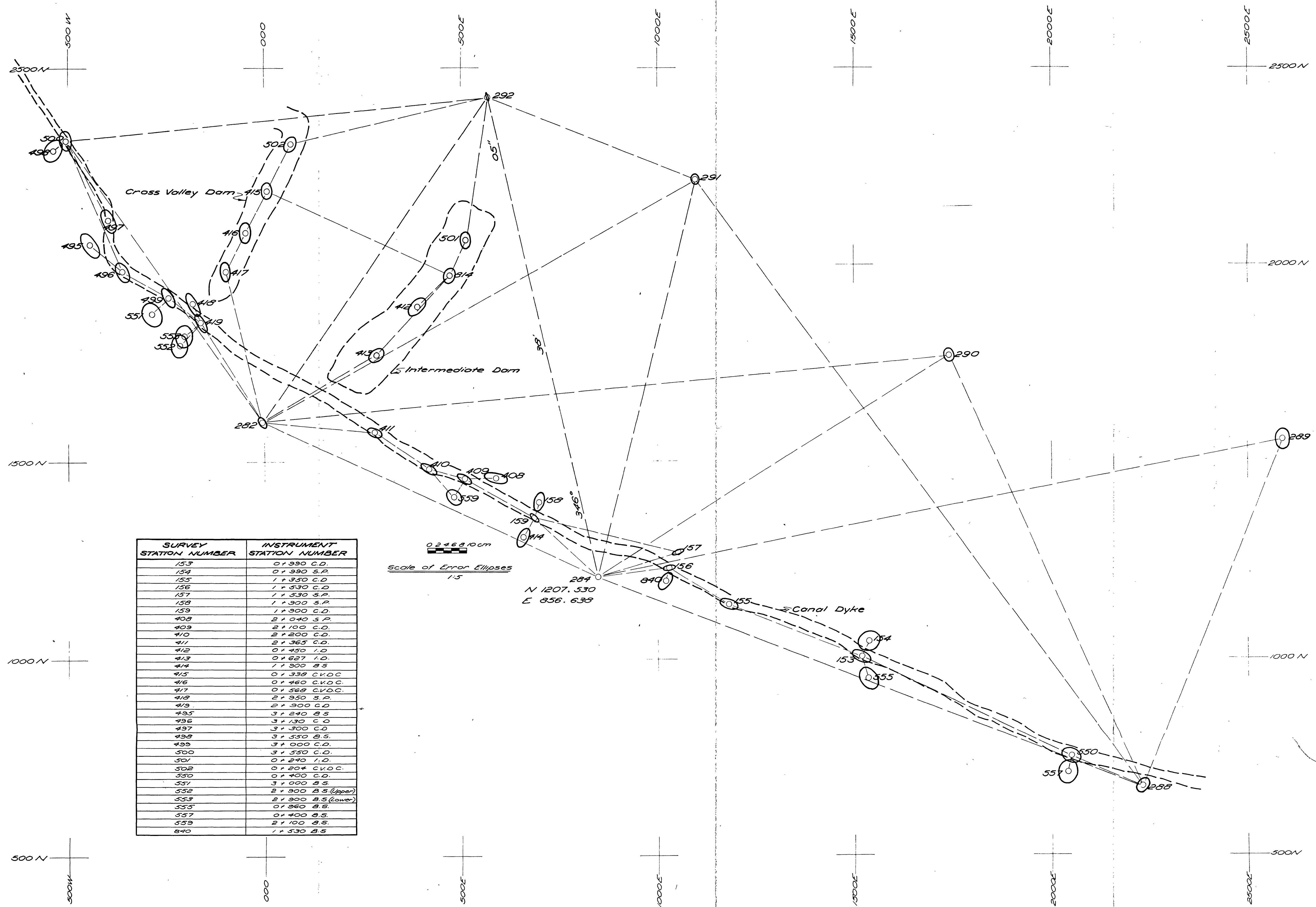
Chrzanowski, A. "Design and Error Analysis of Surveying Projects" Lecture Notes No.47, Dept. of Surveying Engineering, U.N.B., Fredericton, N.B., Canada, 1977.

Chrzanowski, A., Steeves, R. "Determination of Displacements and Deformation of Structures and Their Environment by Geodetic Means" Based on Lectures given by T. Lazzarini at U.N.B., Fredericton, N.B., 1972. Revised and Modified, 1976.

Mikhail, E.M., Gracie, G. "Analysis and Adjustment of Survey Measurements" (Van Nostrand Reinhold Co., New York, N.Y., 1981) Chapters 4, 5, 6, 7, 8, 9.

Steeves, R. "A User's Manual for Program GEOPAN Geodetic Plane Adjustment and Analysis" Technical Report No.54, Dept. of Surveying Engineering, U.N.B., Fredericton, N.B., Canada, 1978.





SURVEY STATION NUMBER	INSTRUMENT STATION NUMBER
153	01 990 C.D.
154	01 990 S.P.
155	11 930 C.D.
156	11 930 C.D.
157	11 930 S.P.
158	11 900 S.P.
159	11 900 C.D.
408	21 040 S.P.
409	21 100 C.D.
410	21 200 C.D.
411	21 365 C.D.
412	01 450 I.O.
413	01 627 I.O.
414	11 900 B.S.
415	01 338 C.V.O.C.
416	01 460 C.V.O.C.
417	01 568 C.V.O.C.
418	21 950 S.D.
419	21 900 C.D.
495	31 240 B.S.
496	31 130 C.D.
497	31 300 C.D.
498	31 350 B.S.
499	31 000 C.D.
500	31 550 C.D.
501	01 240 I.O.
502	01 204 C.V.O.C.
550	01 400 C.D.
551	31 000 B.S.
552	21 900 B.S. (Upper)
553	21 900 B.S. (Lower)
554	01 860 B.S.
557	01 400 B.S.
559	21 100 B.S.
840	11 530 B.S.

0.246810 cm
Scale of Error Ellipses
1:5

N 1207.530
E 856.638

UNDERHILL ENGINEERING LTD.

CONSULTING ENGINEERS

VANCOUVER, BRITISH COLUMBIA

WHITEHORSE, YUKON

1. MAR/92 PET	STATION ERROR ELLIPSES	DESIGN BY	JOB NO	CLIENT
	AT 99% CONFIDENCE LEVEL	PLT	V-2678	GOLDER ASSOCIATES
		DRAWN BY	DATE	PROJECT
		MLT	JAN/92	CYPRUS ANVIL
		APPROVED	SCALE	DOWN-VALLEY TAILINGS
			1:5000	CONTAINMENT PROJECT
NO	DATE	BY	REVISION	APP'D

TITLE
**OBSERVATION NETWORK
DEFORMATION STUDY**

SHEET 2 OF
DRAWING NUMBER
126-21
REVISION

APPENDIX VI
AUGUST 1981 CANAL DYKE INSPECTION



Golder Associates

CONSULTING GEOTECHNICAL AND MINING ENGINEERS

January 29, 1982

Ref. No. 802-2041

Cyprus Anvil Mining Corporation
P.O. Box 1000
Faro, Yukon
Y0B 1K0

ATTENTION: Mr. N.G. Cornish

Dear Sirs:

Re: Inspection - Canal Dyke at Cyprus Anvil Mine

This letter discusses the results of our inspection of the canal dyke at the Cyprus Anvil Down Valley tailings site, which was carried out on August 25 and 26, 1981. The purpose of the inspection was to assess the performance of the dyke with particular reference to some cracking that has occurred along the canal side. The inspection was carried out by Dr. J.I. Clark, P. Eng. Mr. Glen Gilchrist, P. Eng., and Mr. Dave Goodall, P. Eng.

The dyke is in remarkably good condition. The cracking that has occurred appears to be related to thawing of the subgrade which is producing some minor differential settlement. This is schematically illustrated on Figure 1. Mr. Goodall has an excellent record of the soil profile for the entire length and confirmed that, where cracks appeared, they coincided with silty material which contained minor ice lenses.

A number of monitoring points were set up to measure the opening of the cracks. The photographs of Figure 2 record a typical example consisting

of the cracking at location 6 at about station 1+850 (see Figure 1). Figures 3 - 17 show the results of crack monitoring along the canal dyke to the end of August. Figures 18 - 20 show the results of thermistor readings at two locations along the dyke. The total movement is minor and is of no concern relative to stability.

Figure 21 illustrates, at one location, the condition along part of the top of the thermal liner fill. Its condition is considered to be the consequence of lack of compaction and melting of shallow ice and snow along the top face of the cut which received the gravel fill during the previous winter. Figure 22 illustrates the wasted excavation material condition at one location along the north valley wall interceptor ditch. Typically, this waste material was uncompacted, and was placed on unstripped ground. The condition of these areas may be compared with the relatively smaller cracks which occur in the engineered dyke shown in Figure 2, the material of which has been compacted and placed on stripped ground.

Even though some small cracks are observed, there is no indication of instability along the canal side of the dyke; therefore a recommendation was made that no action be taken. Most of these cracks were obliterated by the final raising of the dyke during September and October 1981. Cracking will continue and eventually you may wish to undertake cosmetic treatment, but we would expect that it will be at least two or three years before such effort is warranted. This would consist of dressing up the top of the dyke to restore any settlement that occurs. The crack monitoring that continued until late August should be initiated again next May, using the same simple system of driven spikes and a carpenter's level.

As the subgrade thaws as a result of the thermal exposure provided by the embankment, some differential settlement and associated cracking should be expected. As the thaw front proceeds under the embankment, we would expect that initial cracks would tend to close, and that some new cracks would open behind them. Indeed, the monitoring that has taken place to this point has indicated that this is happening in some areas. We also observed cracks which had apparently been open and are now virtually closed with a small amount of surface over-thrusting due to the fact that some of the surface material entered the crack before it started to close again. This process will continue until the system is in thermal equilibrium. Not very much action would be expected between the inspection date and spring 1982 because the freeze-back had already started at the time of inspection as indicated by the ground temperatures recorded by the thermistor installations during the period early August to early December, 1981.

While the now completed extensive instrumentation of the canal is more directed toward assessing long-term performance, it will also provide valuable ground temperature and movement data and will assist in establishing when the system comes into thermal equilibrium.

To summarize, the cracking of the dyke is normal and to be expected. The dyke is performing remarkably well and, except for some minor sloughing of the uncompacted gravel skin in localized areas on the downslope side, there is no sign of instability. The cracks have developed as a result of thawing of the subgrade. As the thaw front develops, the existing cracks will tend to close, but new cracks will open further into the dyke. The now completed instrumentation of the canal will provide the necessary data base to assess when the system is in thermal equilibrium and to predict long-term performance and maintenance requirements. At

this time we do not recommend that any cosmetic treatment be carried out until the monitoring indicates that the system is at or near equilibrium.

The attachments to this letter provide the results of the crack related monitoring completed during August, prior to some dyke raising, and observations of thermistors at Station 2+900 on the inside face of the dyke and at Station 2+100 on the outside face of the dyke, and photo documentation.

Yours very truly,

GOLDER ASSOCIATES

per Dave Gorder

J.I. Clark, P. Eng.



H.G. Gilchrist, P. Eng.

JIC:HGG:cr

Figure 1

PLAN OF CANAL DYKE
SHOWING
CRACKS ALONG CREST

(Mapped during Aug. 1981)

*reproduced in full
at end of this Appendix.*

LEGEND



Denotes Location Number
(for details see Figures 3 to 17)

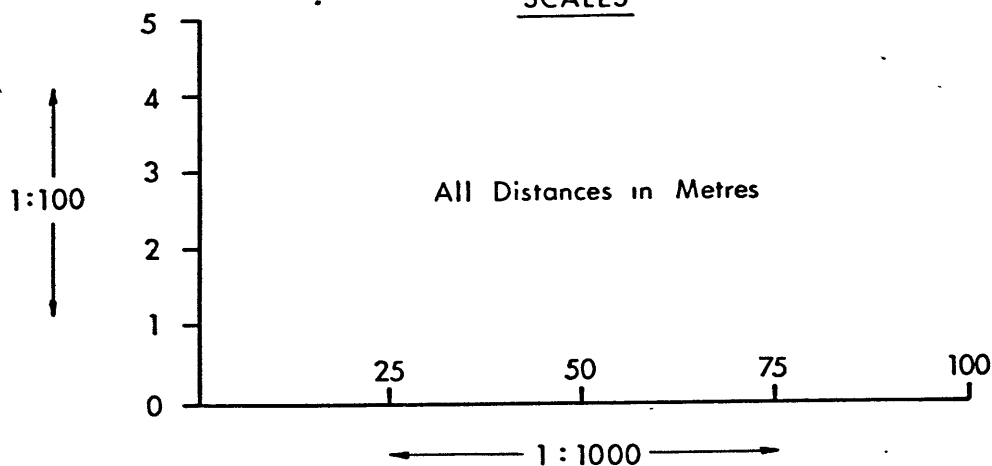


Denotes Thermistor Location
(see Figures 18 & 19 for records)



Cracks

SCALES

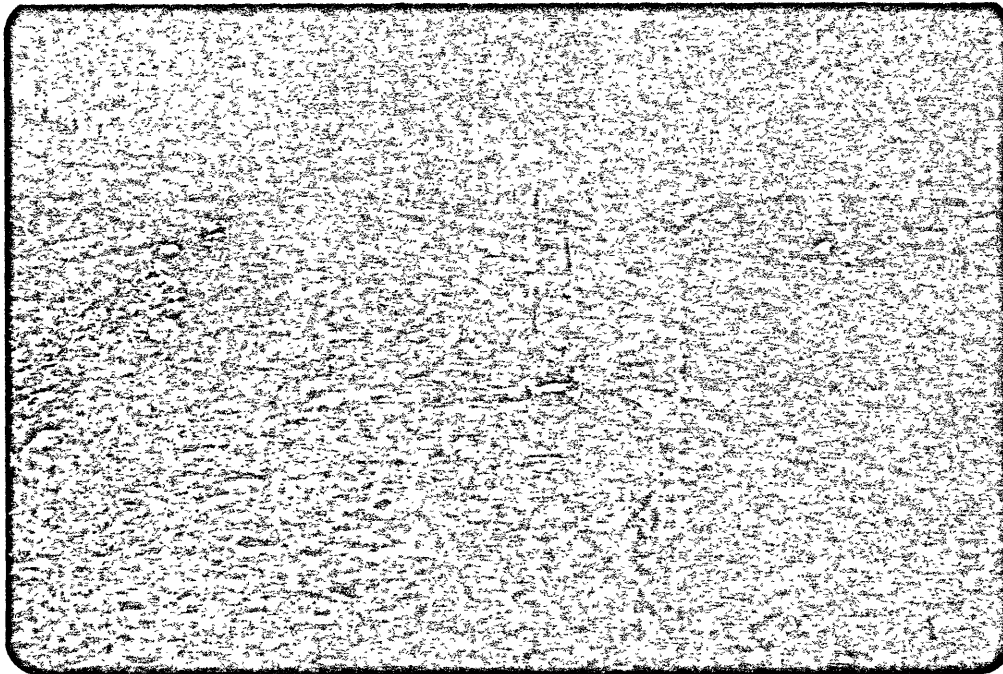


Golder Associates

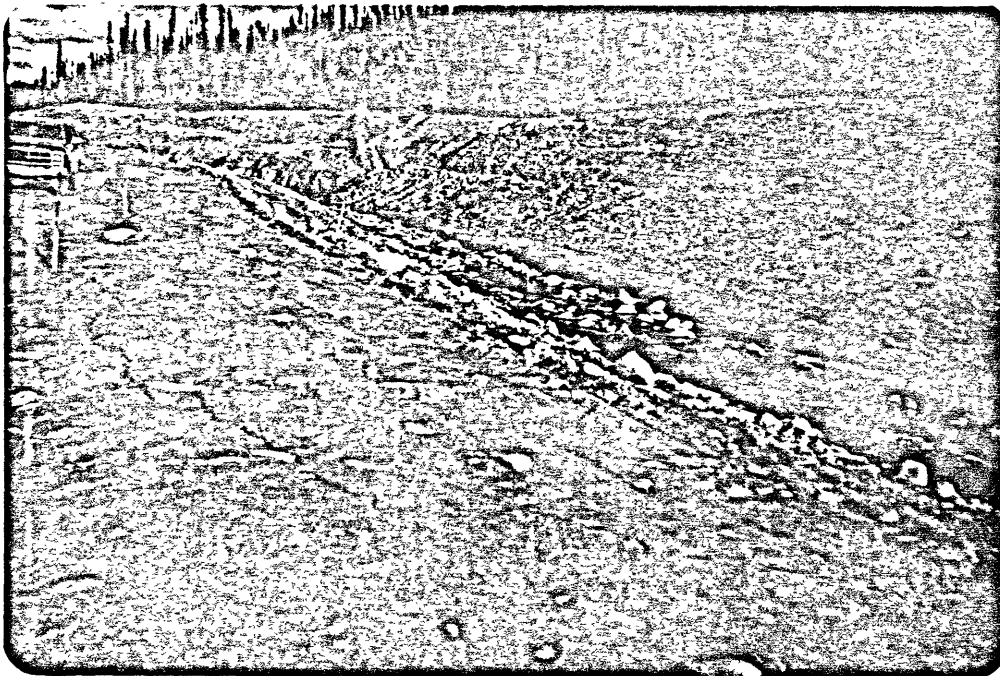
Drawn GB:GP.

Date Jan 82

Revised KS



Station 1+838 to 1+885 viewed downstream *

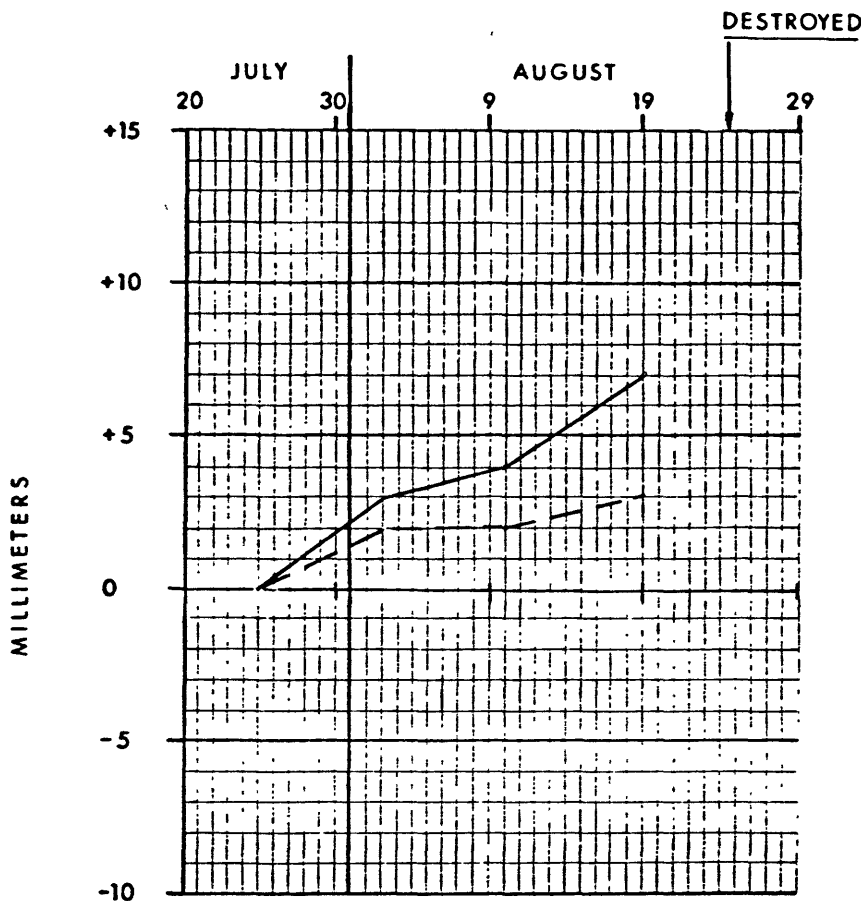


Station 1+838 to 1+885 viewed upstream *

* See location 6, Figure 1 for further details

GRAPH SHOWING INFORMATION RELATIVE TO CRACK
AT LOCATION 0 +444 ALONG CANAL DYKE CREST

Figure 3

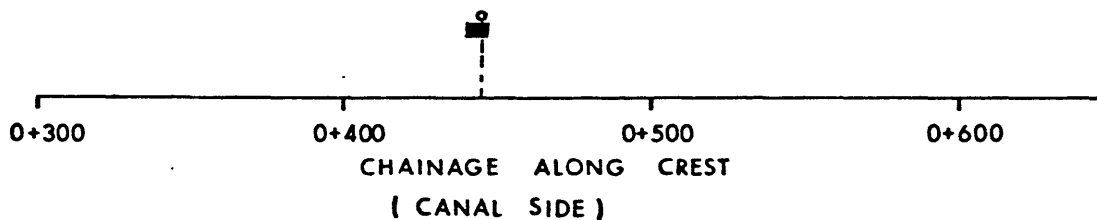


'0' on this graph has two indeterminate values, as follows:

1. Width of crack at start of investigation
2. Elevation of measuring pin on the canal side of the crack

For location see Figure 1

LOCATION 1



LEGEND

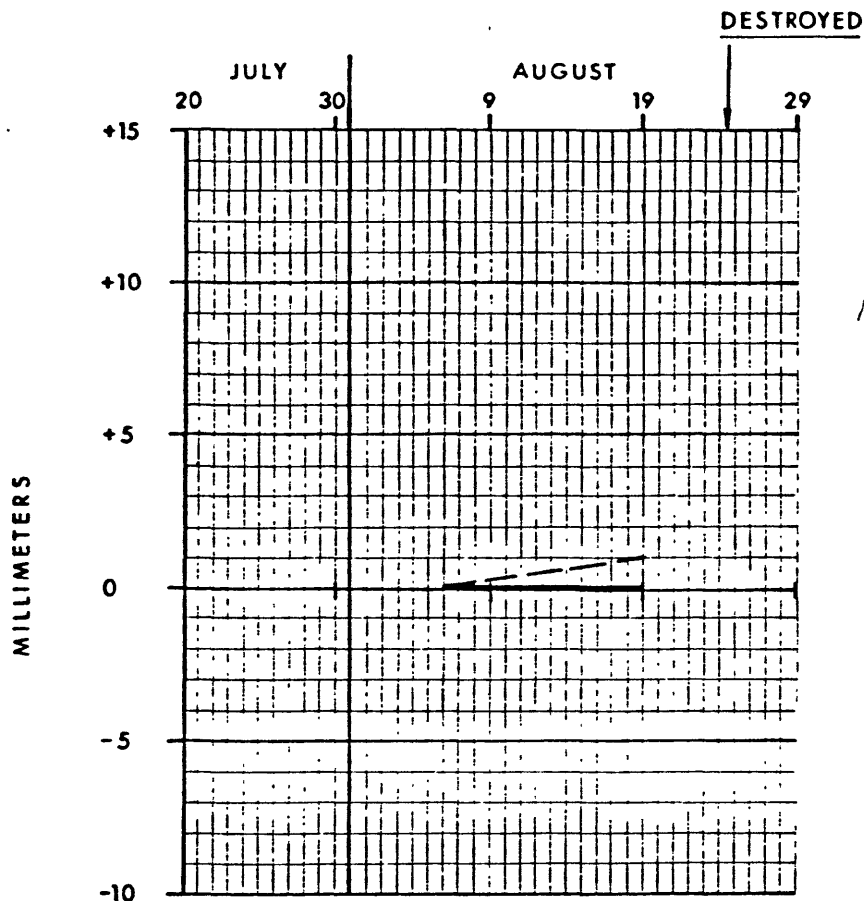
Cracked as at 06 August 1981

— Horizontal movement. (+ = wider: - = narrower)

- - - Vertical movement (+ = up: - = down)

GRAPH SHOWING INFORMATION RELATIVE TO CRACK AT LOCATION 0+444 ALONG CANAL DYKE CREST

Figure 4



'0' on this graph has two indeterminate values, as follows:

1. Width of crack at start of investigation
2. Elevation of measuring pin on the canal side of the crack

For location see Figure 1

LOCATION 2



LEGEND

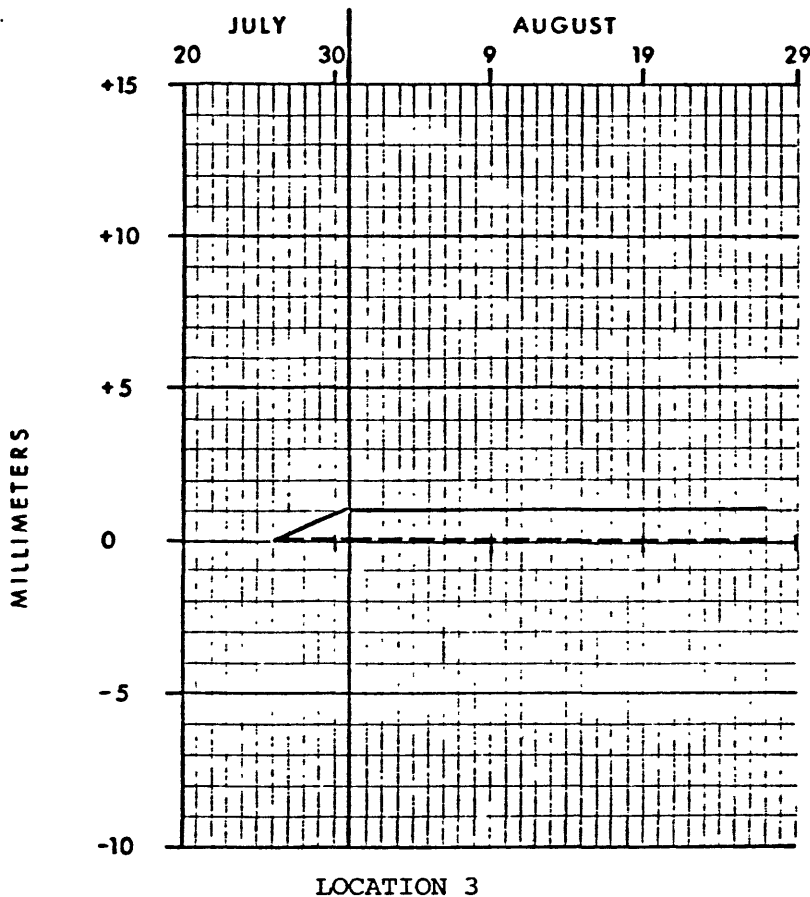
Cracked as at 06 August 1981

— Horizontal movement. (+ = wider: - = narrower)

--- Vertical movement (+ = up: - = down)

GRAPH SHOWING INFORMATION RELATIVE TO CRACK
AT LOCATION 1+324 ALONG CANAL DYKE CREST

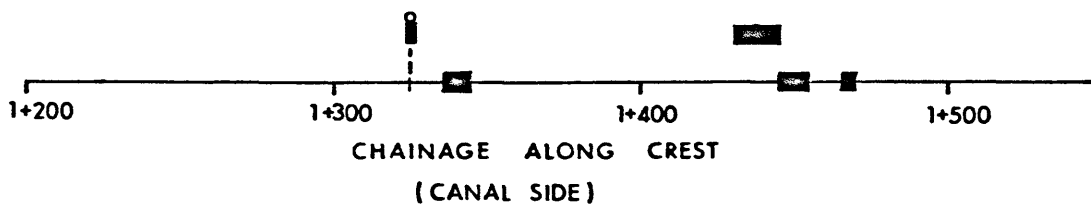
Figure 5



'0' on this graph has two indeterminate values, as follows:

1. Width of crack at start of investigation
2. Elevation of measuring pin on the canal side of the crack

For location see Figure 1



LEGEND

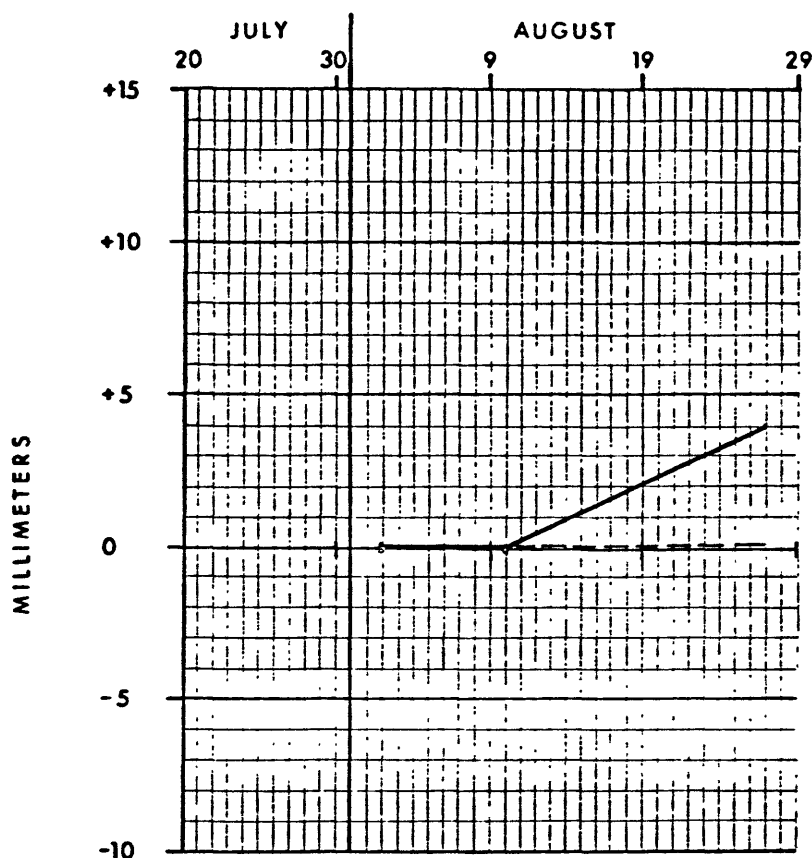
Cracked as at 06 August 1981

— Horizontal movement. (+ = wider : - = narrower)

--- Vertical movement (+ = up : - = down)

GRAPH SHOWING INFORMATION RELATIVE TO CRACK
AT LOCATION 1+562 ALONG CANAL DYKE CREST

Figure 6

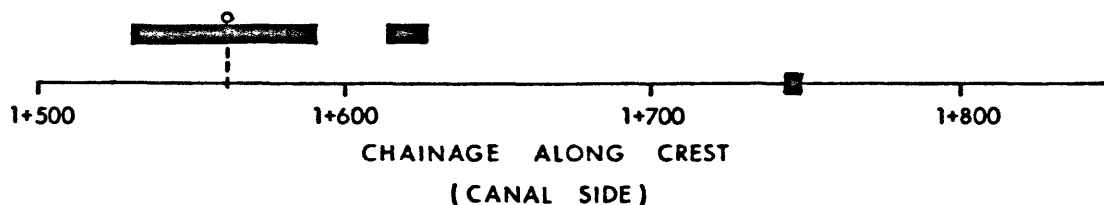


'0' on this graph has two indeterminate values, as follows:

1. Width of crack at start of investigation
2. Elevation of measuring pin on the canal side of the crack

For location see Figure 1

LOCATION 4



LEGEND

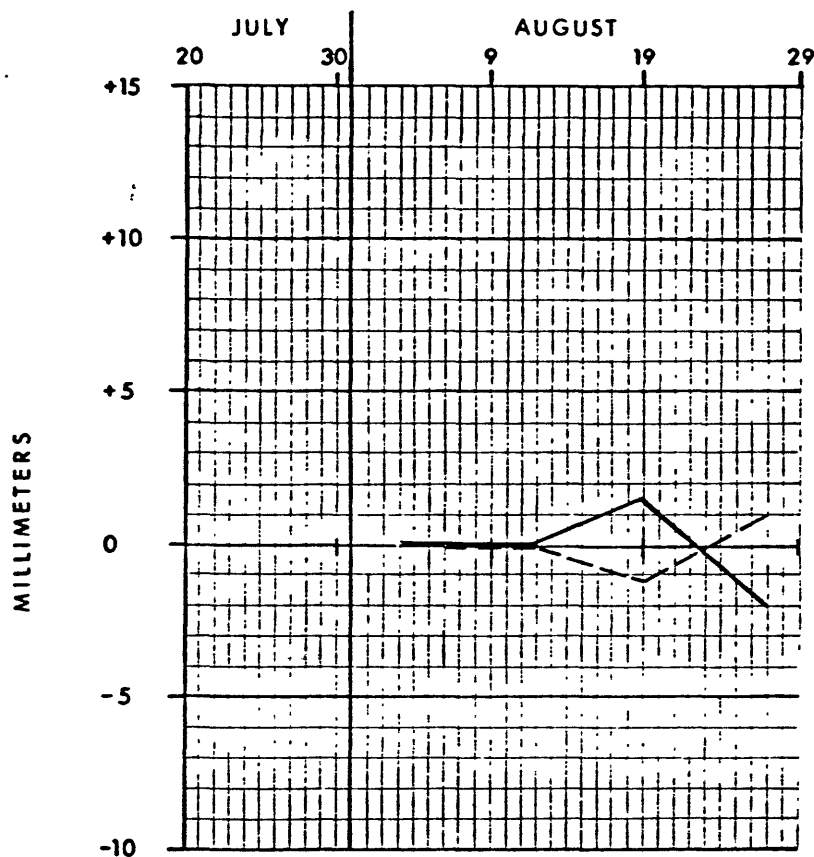
Cracked as at 06 August 1981

— Horizontal movement. (+= wider: - = narrower)

- - - Vertical movement (+= up: - = down)

GRAPH SHOWING INFORMATION RELATIVE TO CRACK
AT LOCATION 1+620 ALONG CANAL DYKE CREST

Figure 7

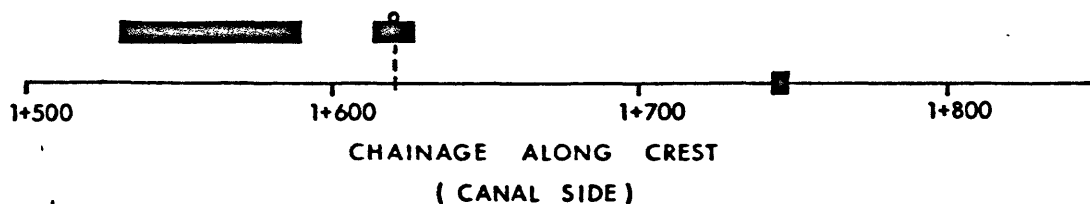


'0' on this graph has two indeterminate values, as follows:

1. Width of crack at start of investigation
2. Elevation of measuring pin on the canal side of the crack

For location see Figure 1

LOCATION 5

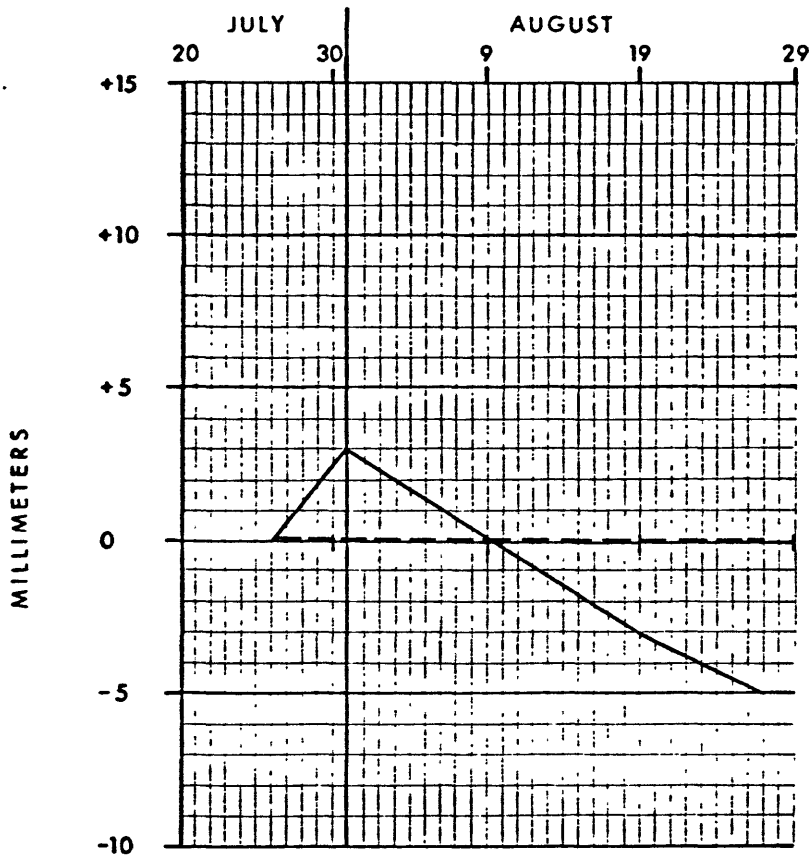


LEGEND

- Cracked as at 06 August 1981
- Horizontal movement. (+ = wider: - = narrower)
- - - Vertical movement (+ = up: - = down)

GRAPH SHOWING INFORMATION RELATIVE TO CRACK
AT LOCATION 1+814 ALONG CANAL DYKE CREST

Figure 8

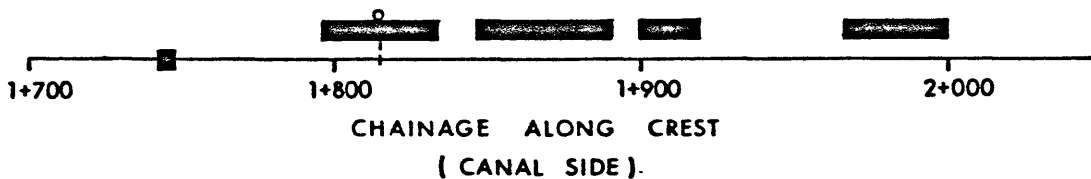


'0' on this graph has two indeterminate values, as follows:

1. Width of crack at start of investigation
2. Elevation of measuring pin on the canal side of the crack

For location see Figure 1

LOCATION 6

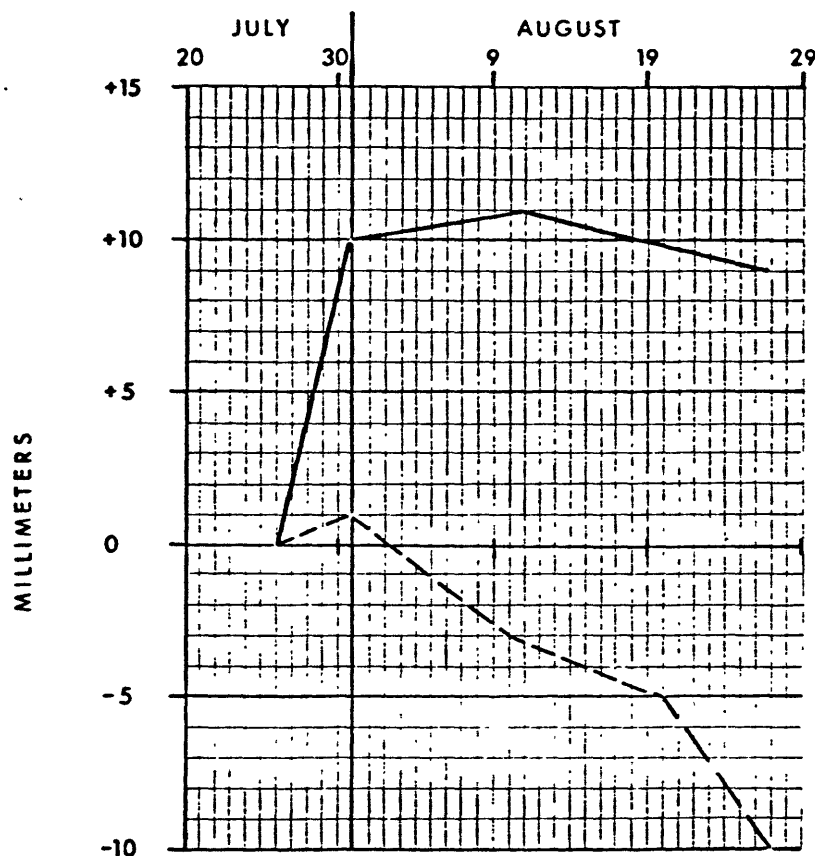


LEGEND

- Cracked as at 06 August 1981
- Horizontal movement. (+ = wider : - = narrower)
- - - Vertical movement (+ = up : - = down)

GRAPH SHOWING INFORMATION RELATIVE TO CRACK
AT LOCATION 1+870 ALONG CANAL DYKE CREST

Figure 9

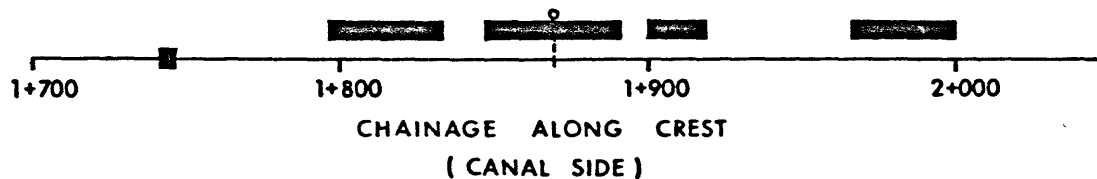


'0' on this graph has two indeterminate values, as follows:

1. Width of crack at start of investigation
2. Elevation of measuring pin on the canal side of the crack

For location see Figure 1

LOCATION 7



LEGEND

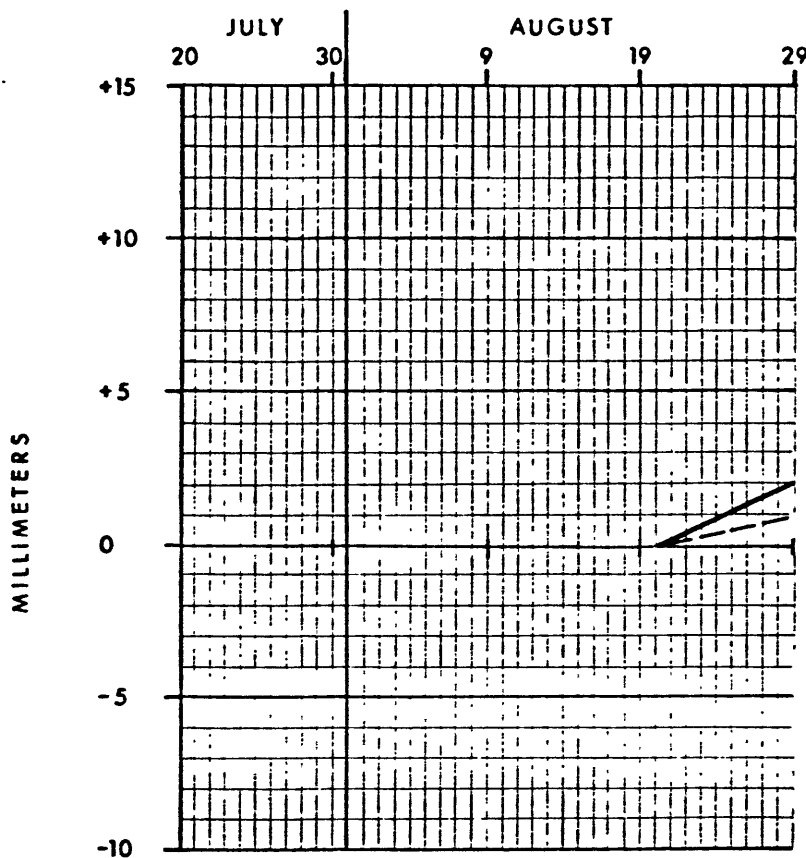
Cracked as at 06 August 1981

— Horizontal movement. (+ = wider: - = narrower)

- - - Vertical movement (+ = up: - = down)

GRAPH SHOWING INFORMATION RELATIVE TO CRACK
AT LOCATION 1+910 ALONG CANAL DYKE CREST

Figure 10

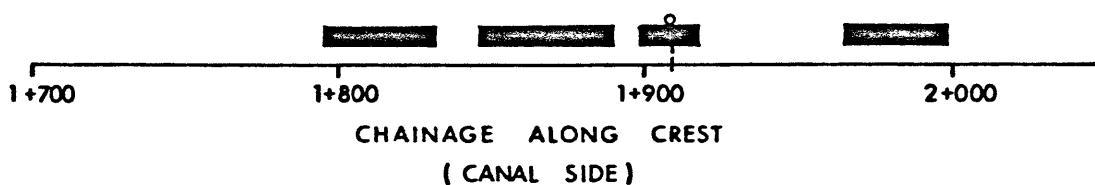


'0' on this graph has two indeterminate values, as follows:

1. Width of crack at start of investigation
2. Elevation of measuring pin on the canal side of the crack

For location see Figure 1

LOCATION 8



LEGEND

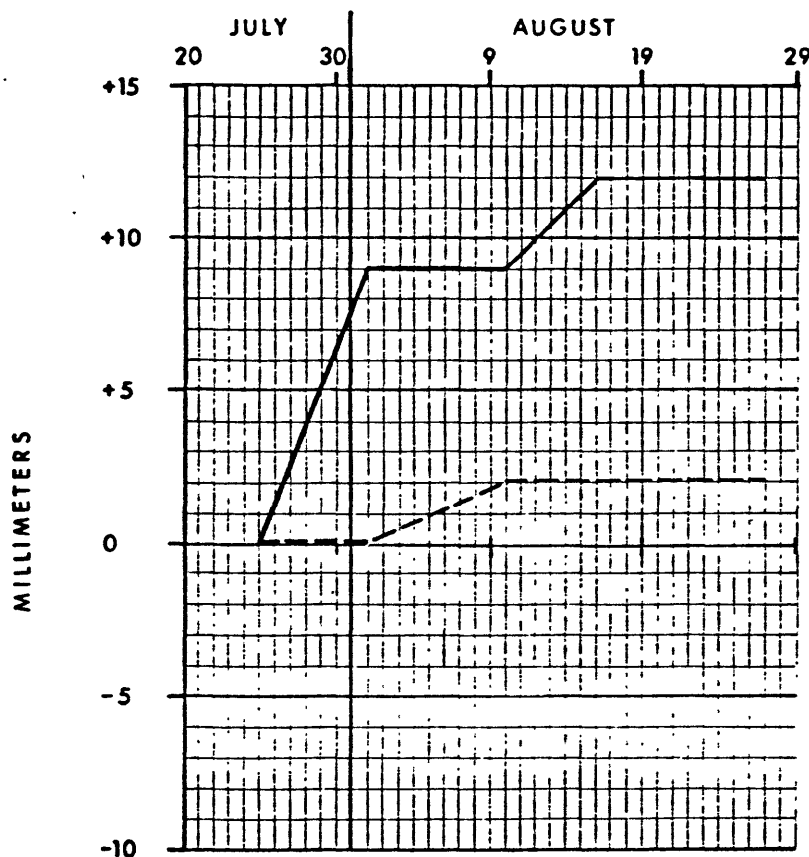
Cracked as at 06 August 1981

— Horizontal movement. (+ = wider: - = narrower)

--- Vertical movement (+ = up: - = down)

GRAPH SHOWING INFORMATION RELATIVE TO CRACK AT LOCATION 1+983 ALONG CANAL DYKE CREST

Figure 11

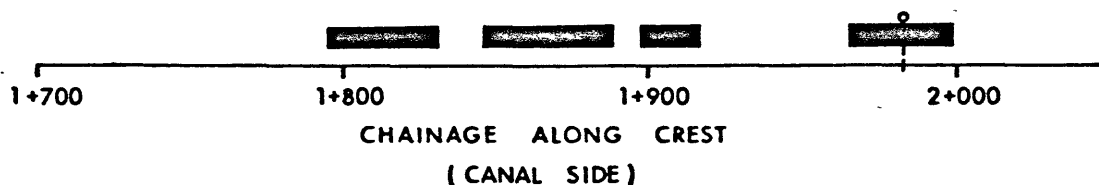


'0' on this graph has two indeterminate values, as follows:

1. Width of crack at start of investigation
2. Elevation of measuring pin on the canal side of the crack

For location see Figure 1

LOCATION 9



LEGEND

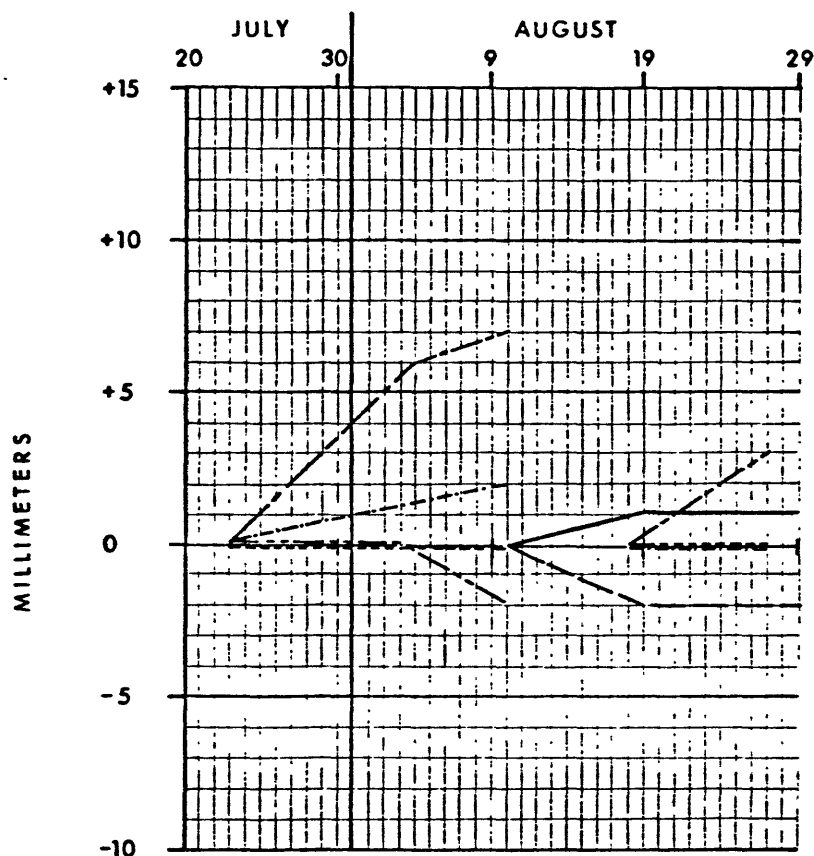
Cracked as at 06 August 1981

Horizontal movement. (+ = wider: - = narrower)

Vertical movement (+ = up: - = down)

GRAPH SHOWING INFORMATION RELATIVE TO CRACK AT LOCATION 2+143 ALONG CANAL DYKE CREST

Figure 12



NOTES

'0' on this graph has two indeterminate values, as follows:

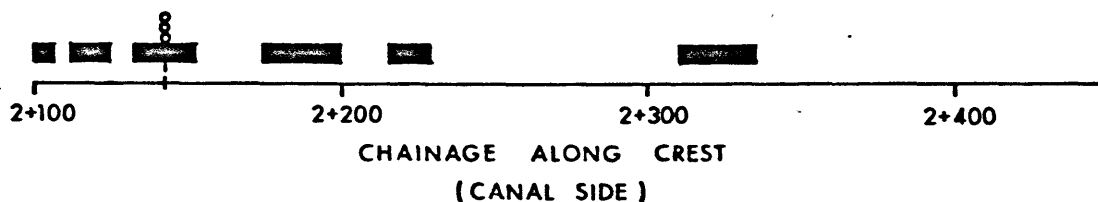
1. Width of crack at start of investigation
2. Elevation of measuring pin on the canal side of the crack

The different symbols for the offsets at 2m, 3m and 4m, are shown below.

The 3m & 4m offsets were reinstalled Aug 18.

For location see Figure 1

LOCATION 10



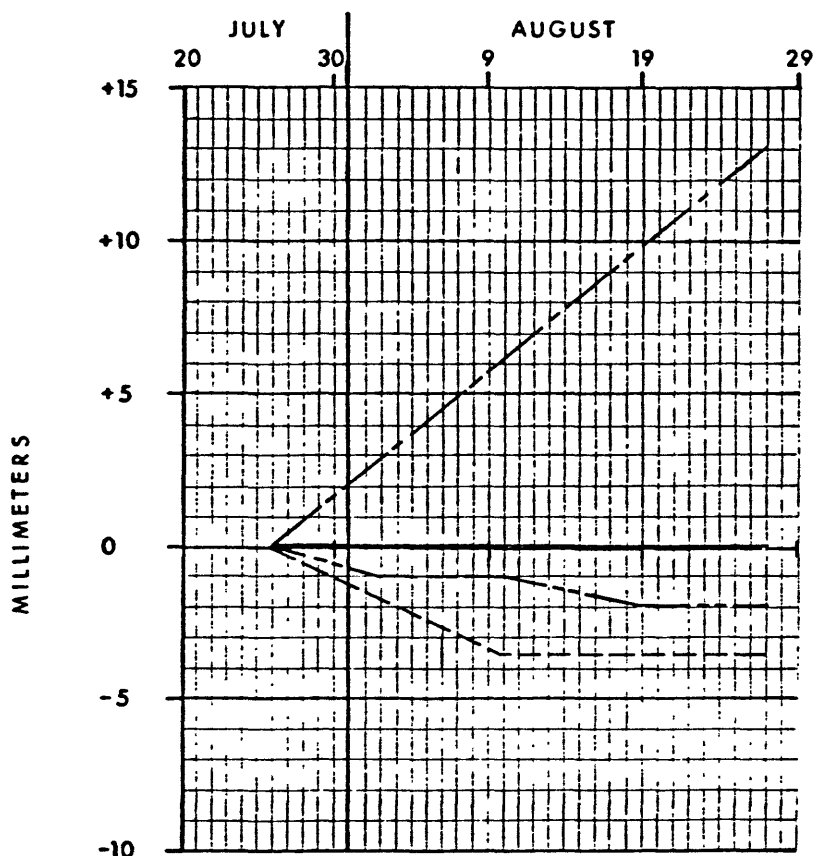
LEGEND

Cracked as at 06 August 1981

Horizontal movement. (+ = wider: - = narrower)
Vertical movement (+ = up: - = down)

GRAPH SHOWING INFORMATION RELATIVE TO CRACK
AT LOCATION 2+183 ALONG CANAL DYKE CREST

Figure 13



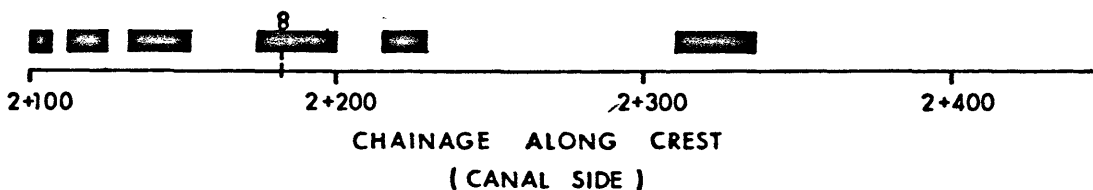
'0' on this graph has two indeterminate values, as follows:

1. Width of crack at start of investigation
2. Elevation of measuring pin on the canal side of the crack

The different symbols for the offsets at 1m & 3m, are shown below

For location see Figure 1

LOCATION 11



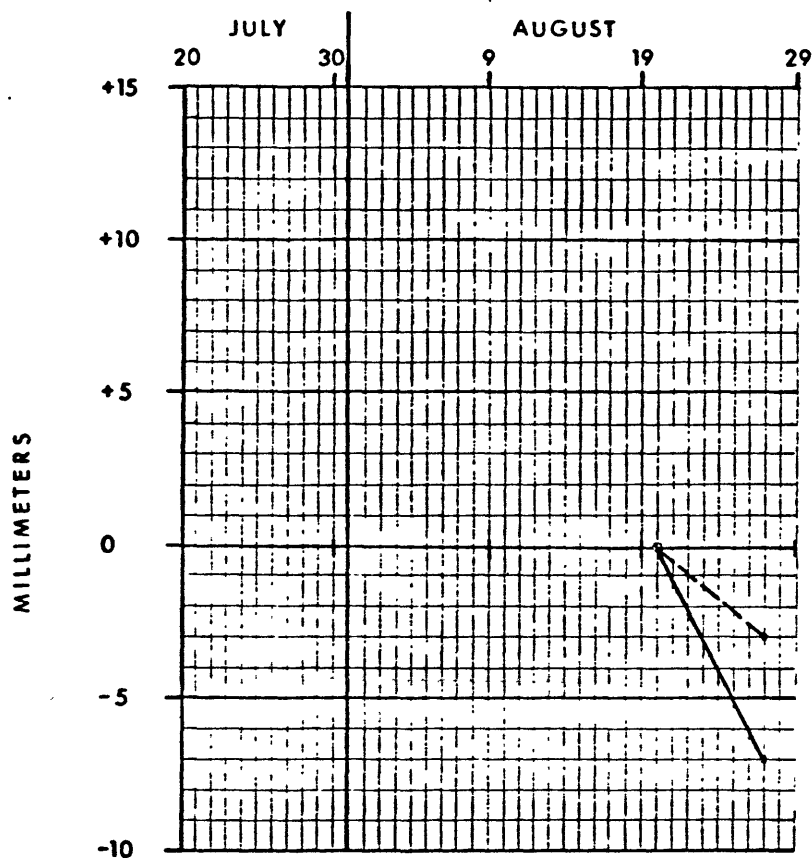
LEGEND

Cracked as at 06 August 1981

Horizontal movement. (+ = wider : - = narrower)
Vertical movement (+ = up : - = down)

GRAPH SHOWING INFORMATION RELATIVE TO CRACK
AT LOCATION 2 + 220 ALONG CANAL DYKE CREST

Figure 14

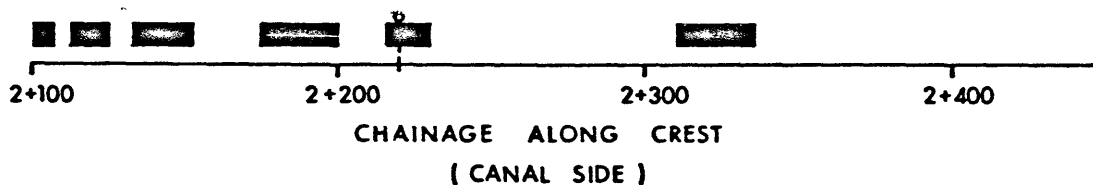


'0' on this graph has two indeterminate values, as follows:

1. Width of crack at start of investigation
2. Elevation of measuring pin on the canal side of the crack

For location see Figure 1

LOCATION 12

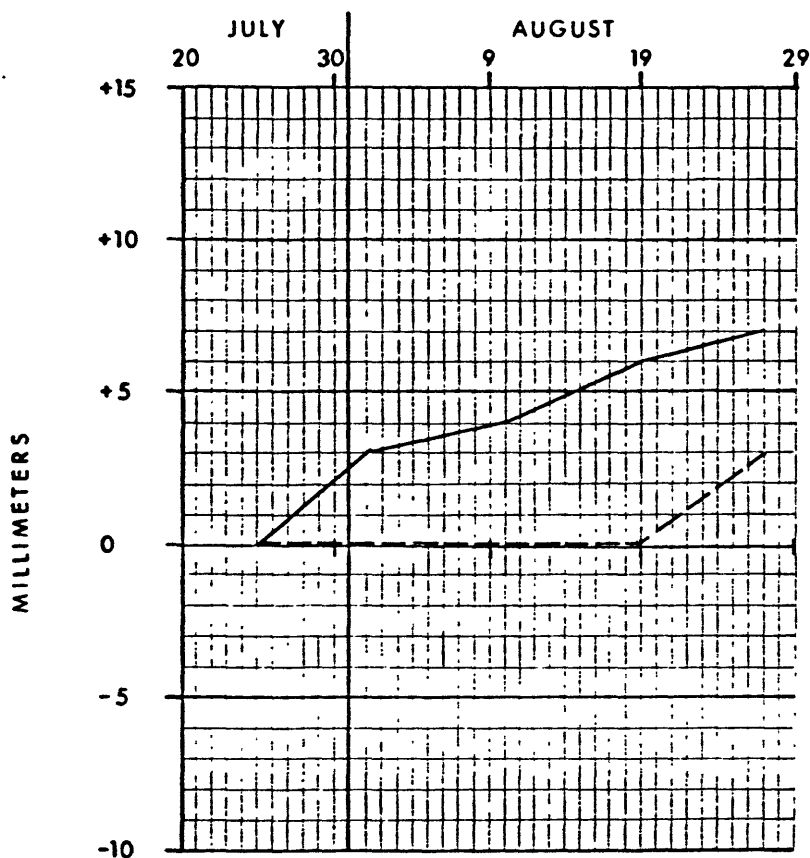


LEGEND

-  Cracked as at 06 August 1981
- Horizontal movement. (+ = wider : - = narrower)
- - - Vertical movement (+ = up : - = down)

GRAPH SHOWING INFORMATION RELATIVE TO CRACK
AT LOCATION 2+365 ALONG CANAL DYKE CREST

Figure 15

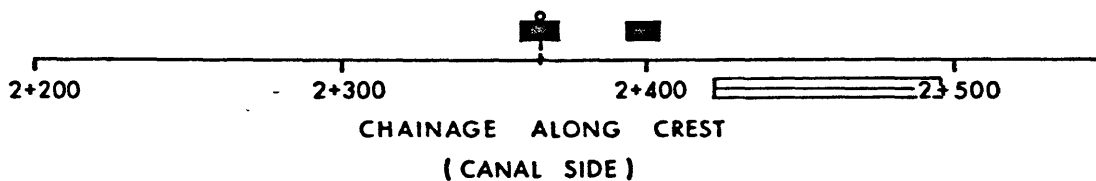


'0' on this graph has two indeterminate values, as follows:

1. Width of crack at start of investigation
2. Elevation of measuring pin on the canal side of the crack

For location see Figure 1

LOCATION 13

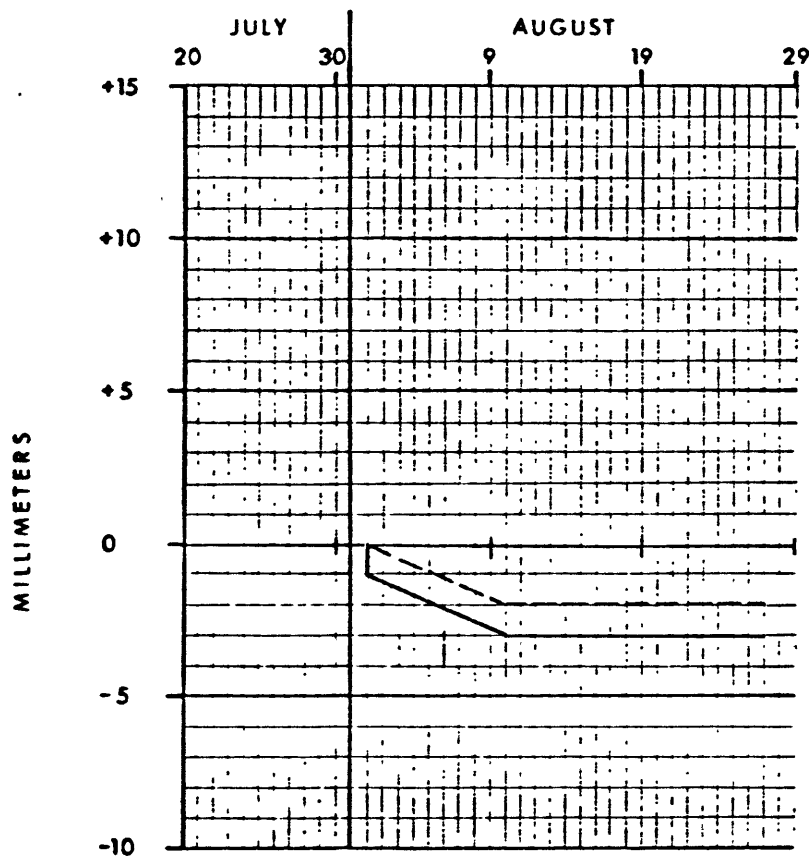


LEGEND

- Cracked as at 06 August 1981
- Small discontinuous cracks.
- Horizontal movement. (+ = wider: - = narrower)
- Vertical movement (+ = up: - = down)

GRAPH SHOWING INFORMATION RELATIVE TO CRACK
AT LOCATION 2+400 ALONG CANAL DYKE CREST

Figure 16

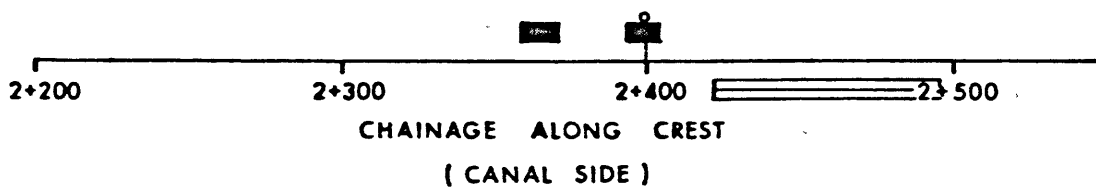


'0' on this graph has two indeterminate values, as follows:

1. Width of crack at start of investigation
2. Elevation of measuring pin on the canal side of the crack

For location see Figure 1

LOCATION 14

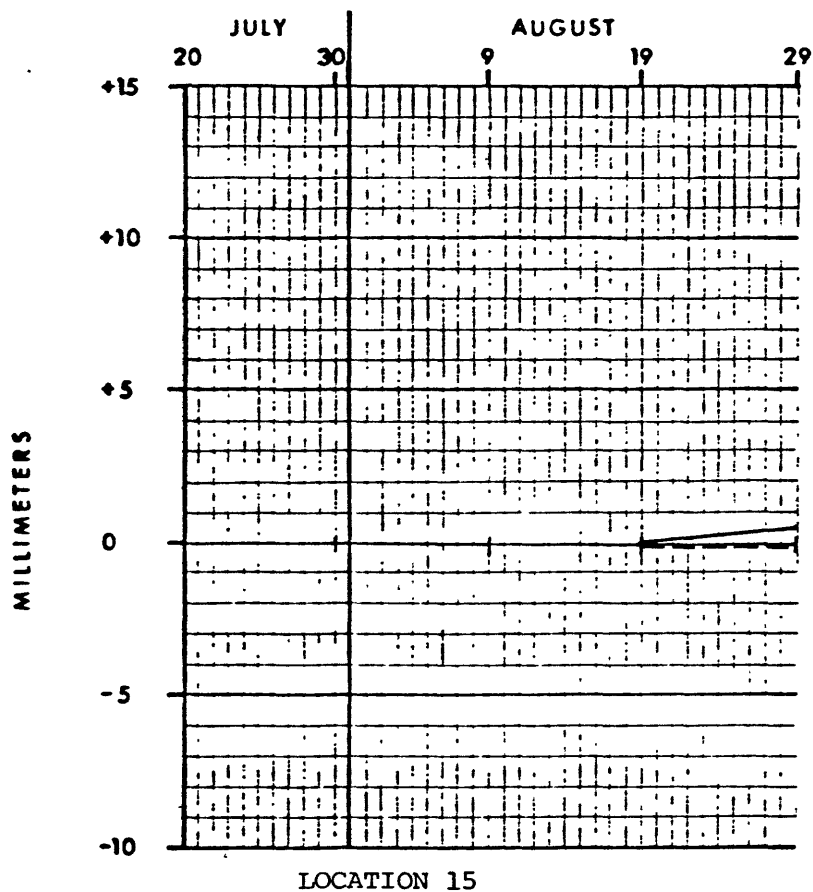


LEGEND

- Cracked as at 06 August 1981
- Small discontinuous cracks.
- Horizontal movement. (+ = wider: - = narrower)
- Vertical movement (+ = up: - = down)

GRAPH SHOWING INFORMATION RELATIVE TO CRACK
AT LOCATION 2+460 ALONG CANAL DYKE CREST

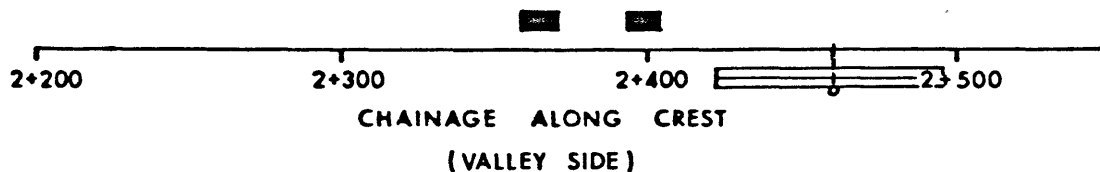
Figure 17



'0' on this graph has two indeterminate values, as follows:

1. Width of crack at start of investigation
2. Elevation of measuring pin on the canal side of the crack

For location see Figure 1



LEGEND

- Cracked as at 06 August 1981
- Small discontinuous cracks.
- Horizontal movement. (+ = wider: - = narrower)
- Vertical movement (+ = up: - = down)

THERMISTOR DATA : STATION 2+100 (VALLEY SIDE)
THERMISTOR STRING NO.2 (LOCATION T-1, FIGURE 1)

Figure 18

TIP No.	1	2	3	4	5	6	7	8	9	10
DEPTH (m)	0.0	1.0	2.0	3.0	4.0	5.0	6.0	6.9	7.8	8.8
Calibration at 0°C Ice Bath	no ice bath calibrations available therefore use theoretical 0°C value of 16.32 Ω for temperatures									
KOHMS Temp.°C										
DATE										
14 Aug '81	8.99 +12.1	9.74 +10.5	11.35 +7.2	13.42 +3.9	15.76 +0.7	16.45 -0.2	16.45 -0.2	16.45 -0.2	16.39 -0.1	16.52 -0.3
22 Aug '81	9.29 +11.4	10.21 +9.5	11.41 +7.1	13.33 +4.0	15.39 +1.1	16.46 -0.2	16.46 -0.2	16.96 -0.7	17.09 -0.9	17.23 -1.1
16 Sept '81	12.62 +5.1	11.96 +6.2	12.18 +5.8	13.25 +4.1	14.67 +2.1	16.05 +0.3	16.61 -0.4	16.93 -0.7	17.03 -0.8	17.16 -1.0
24 Sept '81	13.71 +3.4	12.61 +5.1	12.69 +5.0	13.45 +3.8	14.65 +2.1	15.91 +0.5	16.51 -0.2	16.80 -0.6	16.82 -0.6	16.85 -0.6
30 Sept '81	15.87 +0.5	13.57 +3.6	13.14 +4.3	13.67 +3.5	14.65 +2.1	15.83 +0.6	16.60 -0.4	16.84 -0.6	16.88 -0.7	16.94 -0.7
16 Oct '81	15.73 +0.7	15.13 +1.5	14.55 +2.2	14.41 +2.5	14.86 +1.8	15.86 +0.6	16.53 -0.3	16.79 -0.6	16.88 -0.7	17.01 -0.8
26 Oct '81	17.58 -1.5	15.36 +1.2	14.87 +1.8	14.30 +2.6	14.00 +3.0	14.66 +2.1	16.35 0.0	16.47 -0.2	16.36 -0.1	16.51 -0.2
28 Oct '81	17.76 -1.7	15.53 +1.0	15.02 +1.6	14.92 +1.8	15.26 +1.3	15.83 +0.6	16.45 -0.2	16.69 -0.5	16.63 -0.4	16.50 -0.2
15 Nov '81	-	16.52 -0.3	16.05 +0.3	15.89 +0.5	15.98 +0.4	16.26 +0.1	16.62 -0.4	16.82 -0.6	16.88 -0.7	17.02 -0.8
9 Dec '81	35.7 -14.6	19.85 -3.8	16.47 -0.2	16.35 0.0	16.33 0.0	16.41 -0.1	16.58 -0.3	16.78 -0.5	16.84 -0.6	16.96 -0.7

THERMISTOR DATA : STATION 2+900 (CANAL SIDE)
THERMISTOR STRING NO.1 (LOCATION T-2, FIGURE 1)

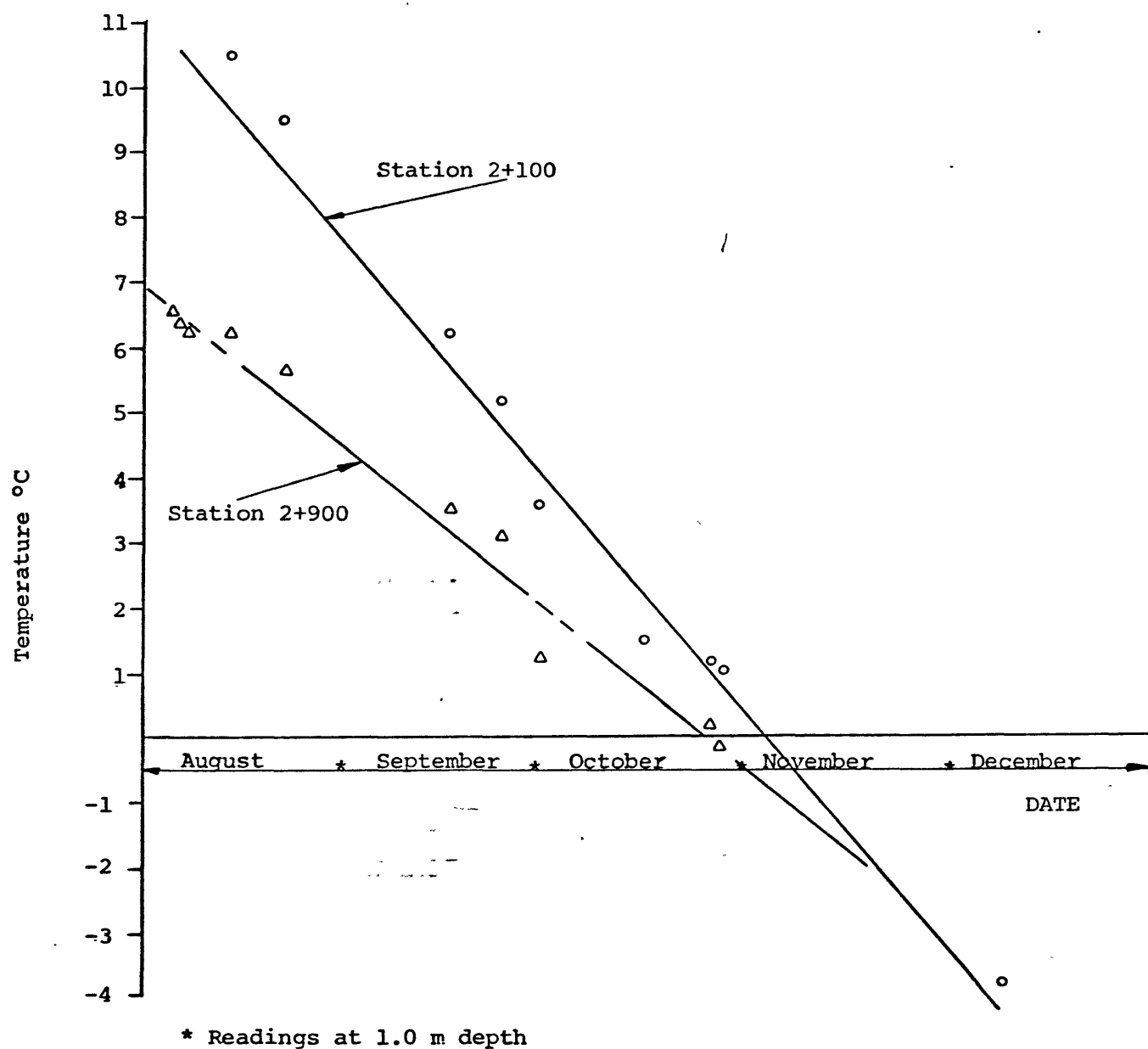
Figure 19

TIP No.	1	2	3	4	5	6	7	8	9	10
DEPTH (m)	1.0	2.0	3.0	3.5	3.9	4.5	4.9	5.6	6.5	9.5
Calibration at 0°C Ice Bath	no ice bath calibrations available therefore use theoretical 0°C value of 16.32 K Ω for temperatures									
DATE	KOHMS									
	Temp.°C									
5 Aug '81	11.76	15.78	16.41	16.55	16.41	16.11	16.10	16.09	16.13	16.29
	+6.5	+0.7	-0.1	-0.3	-0.1	+0.3	+0.3	+0.3	+0.2	0.0
6 Aug '81	11.88	15.83	16.42	16.56	16.53	16.41	16.39	16.31	16.25	16.33
	+6.3	+0.6	-0.1	-0.3	-0.3	-0.1	-0.1	0.0	+0.1	0.0
7 Aug '81	11.94	15.84	16.42	16.55	16.54	16.47	16.49	16.37	16.30	16.34
	+6.2	+0.6	-0.1	-0.3	-0.3	-0.2	-0.2	-0.1	0.0	0.0
14 Aug '81	11.94	15.61	16.44	16.58	16.59	16.57	16.62	16.50	16.41	16.37
	+6.2	+0.9	-0.2	-0.3	-0.3	-0.3	-0.4	-0.2	-0.1	-0.1
22 Aug '81	12.29	15.44	16.46	16.57	16.58	16.57	16.64	16.53	16.41	16.37
	+5.6	+1.1	-0.2	-0.3	-0.3	-0.3	-0.4	-0.3	-0.1	-0.1
16 Sept '81	13.64	15.18	16.45	16.60	16.61	16.59	16.65	16.71	16.45	16.41
	+3.5	1.4	-0.2	-0.4	-0.4	-0.3	-0.4	-0.5	-0.2	-0.1
24 Sept '81	13.94	8.22	16.24	16.52	16.59	16.52	16.42	16.27	16.21	16.12
	+3.1	+14.0*	+0.1	-0.3	-0.3	-0.3	-0.1	+0.1	+0.1	+0.2
30 Sept '81	15.01	15.67	16.44	16.59	16.59	16.58	16.65	16.55	16.44	16.38
	+1.2	+0.8	-0.2	-0.3	-0.3	-0.3	-0.4	-0.3	-0.2	-0.1
15 Oct '81	8.11	8.11	16.34	16.41	16.42	16.47	16.51	16.45	16.33	16.29
	+14.3	+14.3*	0.0	-0.1	-0.1	-0.2	-0.2	-0.2	0.0	0.0
26 Oct '81	16.19	16.10	16.35	16.40	16.33	16.40	16.49	16.46	16.29	16.32
	+0.2	+0.3	0.0	-0.1	0.0	-0.1	-0.2	-0.2	0.0	0.0
28 Oct '81	16.44	16.36	16.40	16.55	16.48	16.45	16.59	16.47	16.32	16.35
	-0.2	-0.1	-0.1	-0.3	-0.2	-0.2	-0.3	-0.2	0.0	0.0
15 Nov '81	8.28	8.28	16.44	16.61	16.63	16.61	16.65	16.56	16.46	16.42
	+13.9*	+13.9*	-0.2	-0.4	-0.4	-0.4	-0.4	-0.3	-0.2	-0.1
9 Dec '81	8.54	8.54	16.46	16.60	16.64	16.61	16.67	16.56	16.46	16.43
	+13.2*	+13.2*	-0.2	-0.4	-0.4	-0.4	-0.4	-0.3	-0.2	-0.1

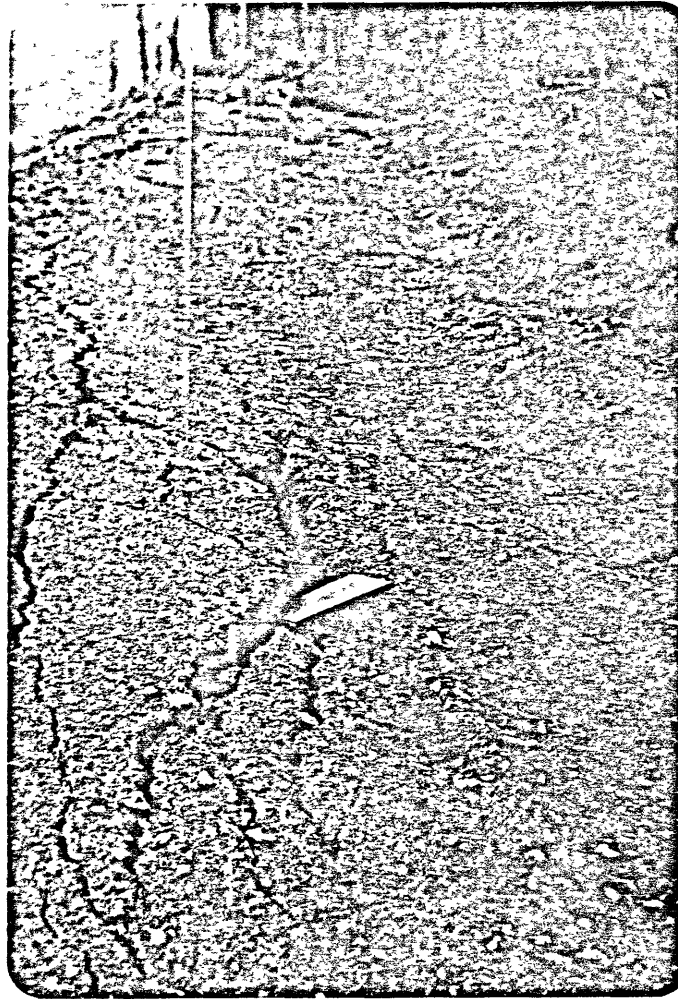
* Questionable Data

GRAPH SHOWING VARIATION OF TEMPERATURE WITH TIME AT STATIONS 2+100 AND 2+900 ALONG THE CANAL DYKE CREST

Figure 20



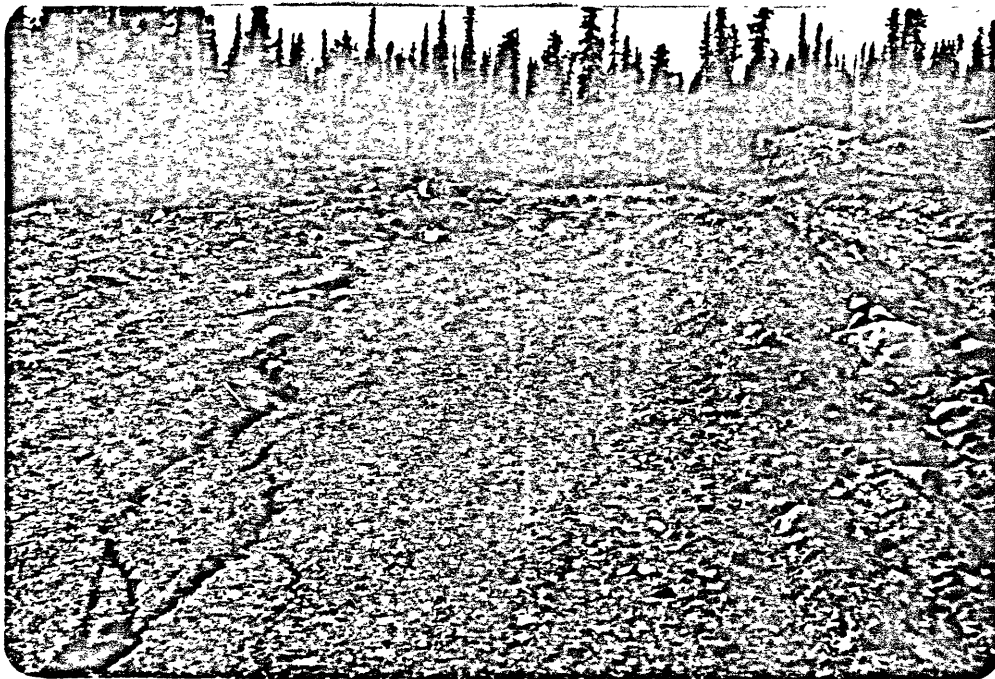
For specific location of this instrumentation see Figure 1



Thermal liner fill at station 2+900 (approx.) viewed
upstream (notebook size 8½" x 11")

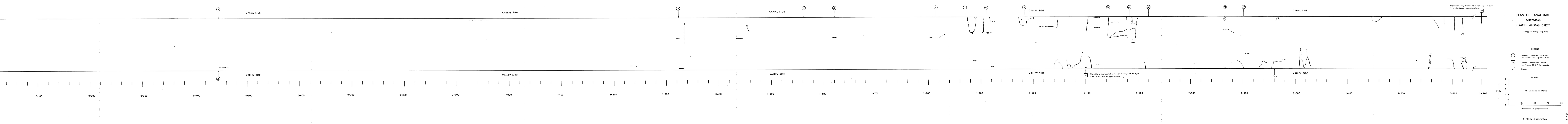


North valley wall
interceptor ditch
viewed upstream



An example of fill response to foundation settlement (taken at about station 0+400 looking downstream which is beyond the reach of the ditch shown in the above photo).

Figure 1



APPENDIX VII
BEHAVIOUR OF PNEUMATIC PIEZOMETERS DURING
AND AFTER FREEZE/THAW

APPENDIX VII Behaviour of Pneumatic Piezometers During and After Freeze/Thaw

This report presents the results of five freeze and thaw cycles conducted on a Petur pneumatic piezometer tip, model P103, supplied by Petur Instruments Ltd., carried out in Golder Associates, Calgary freeze room during January/February, 1982.

The purpose of the tests was to examine the piezometer response during freezing and thawing and its behaviour after several freeze and thaw cycles.

The overall test set up is shown on Figure 1 with a more detailed sketch of the piezometer and thermistor tip on Figure 2.

It must be noted that, as shown on Figure 2, the thermistor tip was taped to the outside of the pneumatic piezometer tip and thus may not reflect precisely the true temperature within the piezometer tip itself.

For three of the freeze and thaw cycles the piezometer tip was frozen at a freeze room temperature of -15°C while for the other two tests the freeze room was held between 0 and -4°C . All tests were thawed at room temperatures of about $+20^{\circ}\text{C}$.

The pressure and temperature readings with time are presented in Table 1 and the results are plotted in graphical form on Figures 3, 4 and 5.

Four of the freeze/thaw cycles were conducted with the piezometer tip submerged in tap water at approximately 20 kPa of pressure (1.9 m of head). These tests showed that at temperatures around the freezing point (for the tap water used this appeared to be approximately -0.2°C)

the pneumatic piezometer indicated measurable pressures greater than 20 kPa (the hydrostatic pressure) before complete freeze of the tip occurred (considered to be when the measured pressures were greater than 100 kPa). These high measurable pressures between 20 and 100 kPa occurred during both freezing and thawing of the piezometer tip. This observed behaviour indicates that pressures measured with the tip at about freezing temperature may not represent the true piezometric regime within the soil.

The fifth test was conducted on the dry pneumatic piezometer tip subjected to no water pressure. The tip was frozen at -3°C and continued to give a reading of 2.0 to 2.2 kPa throughout the entire freeze/thaw cycle. This essentially zero pressure of 2kPa is thought to reflect imprecise calibration of the test setup.

The piezometer tip continued to function properly after several freeze/thaw cycles.

TABLE 1
PNEUMATIC PIEZOMETER FREEZE/THAW TEST DATA

Date 1983	Time		Temperature		Pressure	Comments
	Real	Net	Kohms	°C	kPa	
Cycle 1						
Jan. 12	09:25		6.01	+20.8	20.5	Freezing started
	13:00	0	5.92	+21.2	19.8	
	13:40	40m	8.31	+13.8	19.7	
	13:56	56m	10.74	+8.4	19.7	
	14:31	1h31m	15.64	+0.8	19.5	
	15:04	2h04m	16.48	-0.2	19.6	
All above readings were continuous readings, ie. air continuously going through piezometer. For all subsequent readings the air was turned off and reduced to zero between readings.						
Jan. 13	15:47	2h47m	16.52	-0.2	19.6	Thawing started
	16:02	3h02m	16.47	-0.2	19.6	
	16:49	3h49m	16.50	-0.2	19.6	
	17:30	4h30m	16.65	-0.4	19.8	
	08:30	19h30m	30.2	-11.6	>200	
	09:30	1h00m	19.87	-3.8	>200	
	10:00	1h30m	16.60	-0.3	>200	
	10:30	2h00m	16.54	-0.3	26.0	
	11:10	2h40m	16.51	-0.2	26.4	
	11:30	3h00m	16.50	-0.2	20.8	
	12:00	3h30m	16.49	-0.2	20.8	
	13:05	4h35m	16.10	+0.3	18.8	
	13:40	5h10m	15.27	+1.3	17.9	
	14:20	5h50m	15.36	+1.2	20.0	
	15:05	6h35m	14.45	+2.4	20.1	
	15:35	7h05m	11.74	+6.5	20.1	
Jan. 14	17:30	9h00m	7.00	+17.5	21.2	Water low in tube, filled tube back up to 20 kPa
	10:37		6.02	+20.7	20.8	
Cycle 2						
	11:28	0	6.08	+21.4	20.6	Freezing started
	11:58	30m	8.30	+13.8	20.3	
	13:00	1h32m	16.64	-0.4	19.9	
	14:10	2h42m	16.46	-0.2	20.0	
	15:00	3h32m	16.48	-0.2	19.9	
	15:30	4h02m	16.51	-0.2	19.9	
	15:56	4h28m	16.62	-0.4	19.9	
	16:14	4h46m	16.73	-0.5	20.2	
	16:28	5h00m	17.05	-0.9	118.5	
	16:50	5h22m	18.31	-2.2	>200	
Jan. 14	17:15	5h47m	19.44	-3.4	>200	

Date 1983	Time		Temperature		Pressure	Comments
	Real	Net	Kohms	°C	kPa	
Jan. 17	08:20	0	30.2	-11.6	>200	Thawing started Low on water, filled tube back up to 20 kPa
	09:23	1h03m	16.61	-0.3	>200	
	10:30	2h10m	16.50	-0.2	>200	
	11:20	3h	16.45	-0.2	>200	
	11:50	3h30m	16.24	+0.1	>200	
	13:05	4h45m	15.79	+0.6	18.0	
	13:10	4h55m	15.52	+1.0	20.0	
	16:23	8h03m	11:34	+7.2	19.6	
Cycle 3						
Jan. 18	10:30	0	5.94	+21.0	20.7	Freezing started
	11:00	30m	7.54	+16.8	20.4	
	11:30	1h00m	11.82	+6.2	20.2	
	12:00	1h30m	15.47	+1.0	20.1	
	13:00	2h30m	16.46	-0.2	20.1	
	13:30	3h00m	16.46	-0.2	20.1	
	14:00	3h30m	16.48	-0.2	20.3	
	14:30	4h00m	16.48	-0.2	20.2	
	15:00	4h30m	16.62	-0.4	20.2	
	15:15	4h45m	16.71	-0.5	24.3	
	15:21	4h51m	16.80	-0.6	35.2	
	15:26	4h56m	16.89	-0.7	98.7	
	15:31	5h01m	17.03	-0.8	>200	
	15:40	5h10m	17.39	-1.2	>200	
	16:22	5h52m	19.72	-3.7	>200	
	18:00	7h30m	24.9	-8.1	>200	
Jan. 19	09:00	0	30.3	-11.6	>200	Thawing started
	09:40	40m	16.72	-0.5	>200	
	10:15	1h15m	16.54	-0.3	>200	
	10:50	1h50m	16.50	-0.2	>200	
	11:30	2h30m	16.48	-0.2	>200	
	11:55	2h55m	16.44	-0.2	>200	
	12:10	3h10m	16.37	-0.1	>200	
	12:20	3h20m	16.28	0.0	>200	
	12:25	3h25m	16.22	+0.1	>200	
	12:31	3h31m	16.18	+0.2	>200	
	12:42	3h42m	16.13	+0.2	55	
	12:56	3h56m	15.99	+0.4	40	
Jan. 19	13:10	4h10m	16.00	+0.4	19.6	return bubbles started at 205 kPa and took 5 mins to reduce to approx. 1 bubble/sec. water level 0.2m low
	13:30	4h30m	15.94	+0.5	18.1	
	14:50	5h50m	15.02	+1.7	17.9	
	17:00	8h00m	14.33	+2.6	17.9	
Jan. 20	8:30	23h30m	5.92	+21.2	18.0	

Date 1983	Time		Temperature		Pressure	Comments
	Real	Net	Kohms	°C	kPa	
		freezing	at 0 to -4°C			
Cycle 4 Jan. 27	9:50	0	12.17	+5.9	23.3	Freezing started Freezer temperature varies between 0 to -4°C
	9:35	45m	14.53	+2.3	22.3	
	10:00	1h10m	15.15	+1.5	22.2	
	10:30	1h40m	15.88	+0.5	22.0	
	11:00	2h10m	16.47	-0.2	22.0	
	11:15	2h25m	16.72	-0.5	22.0	
	11:45	2h55m	16.59	-0.3	21.8	
	12:00	3h10m	16.51	-0.3	21.7	
	12:25	3h35m	16.51	-0.3	21.6	
	12:30	3h40m	16.50	-0.2	21.9	
	12:45	3h55m	16.55	-0.3	21.9	
	13:00	4h10m	16.48	-0.2	21.9	
	13:15	4h25m	16.49	-0.2	21.6	
	13:30	4h40m	16.49	-0.2	21.5	
	13:45	4h55m	16.48	-0.2	21.4	
	14:00	5h10m	16.48	-0.2	20.9	
	14:15	5h25m	16.48	-0.2	21.0	
	14:30	5h40m	16.49	-0.2	21.0	
	14:45	5h55m	16.52	-0.3	21.3	
	15:00	6h10m	16.49	-0.2	20.8	
	15:25	6h35m	16.49	-0.2	21.3	
	15:45	6h55m	16.49	-0.2	21.3	
	16:10	7h20m	16.48	-0.2	21.1	
	16:55	8h05m	16.50	-0.2	21.1	
	17:55	9h05m	16.52	-0.3	21.1	
	19:25	10h35m	16.52	-0.3	21.9	
	20:40	11h50m	16.54	-0.3	22.8	
	21:00	12h10m	16.54	-0.3	23.1	
Jan. 27	21:45	12h55m	16.55	-0.3	36.4	
	22:15	13h25m			52.1	
	22:55	14h05m	16.49	-0.2	80.5	
	23:25	14h35m	16.49	-0.2	109.5	
	24:00	15h10m	16.49	-0.2	180	
Jan. 28	34:10	25h20m	16.82	-0.6	>671	
	37:30	28h20m	17.05	-0.9		
Jan. 29	57:30	48h40m	17.97	-1.9		
Jan. 31	76:00	67h10m	18.30	-2.3		
Feb. 1	95:30	86h40m	18.08	-2.1		
Feb. 7	10:15	0	18.08	-2.1	>100	Started thawing at +17 to +19°C
	10:30	15m	16.86	-0.7	>100	
	11:00	45m	16.55	-0.3	>100	
	11:30	1h15m	16.52	-0.3	>100	
	12:00	1h45m	16.51	-0.3	>100	
	12:30	2h15m	16.49	-0.2	48.3	

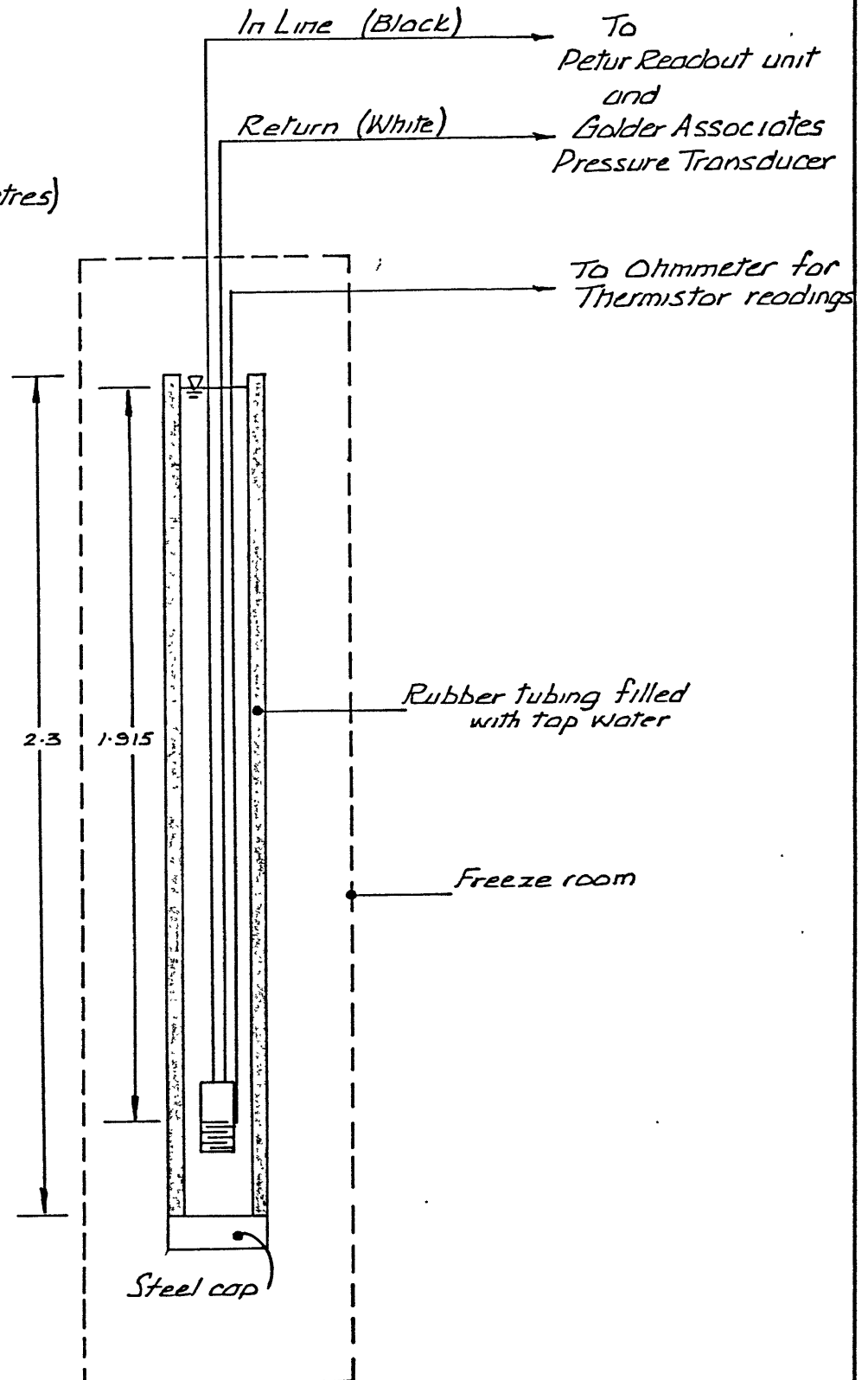
Date 1983	Time		Temperature		Pressure	Comments
	Real	Net	Kohms	°C	kPa	
	13:00	2h45m	16.24	+0.05	42.0	
	13:30	3h15m	15.57	+0.9	21.4	
	14:15	4h00m	15.52	+1.0	21.1	
	14:30	4h15m	15.51	+1.0	21.0	
	15:00	4h45m	15.17	+1.4	20.8	
	15:30	5h15m	15.26	+1.3	20.6	
	16:12	5h57m	14.88	+1.8	20.3	
	17:20	57h05m	11.00	+7.9	20.4	
Feb. 8	8:30	22h15m	5.45	+23.0	20.3	Temp. reached 24°C in room over night
Cycle 5		Freezing	at -3°C			
Feb. 16	09.37	0	6.62	+18.7	2.1	Dry piezometer
	10:11	34m	16.91	-0.7	2.0	tip no water
	10:51	1h14m	18.99	-2.9	2.1	pressure
	11:55	2h18m	19.40	-3.4	2.0	
	14:34	4h57m	18.83	-2.8	2.1	
Feb. 17	08:23	22h46m	19.20	-3.2	2.1	Started thawing
Feb. 21	09:30		6.76	+18.2	2.2	

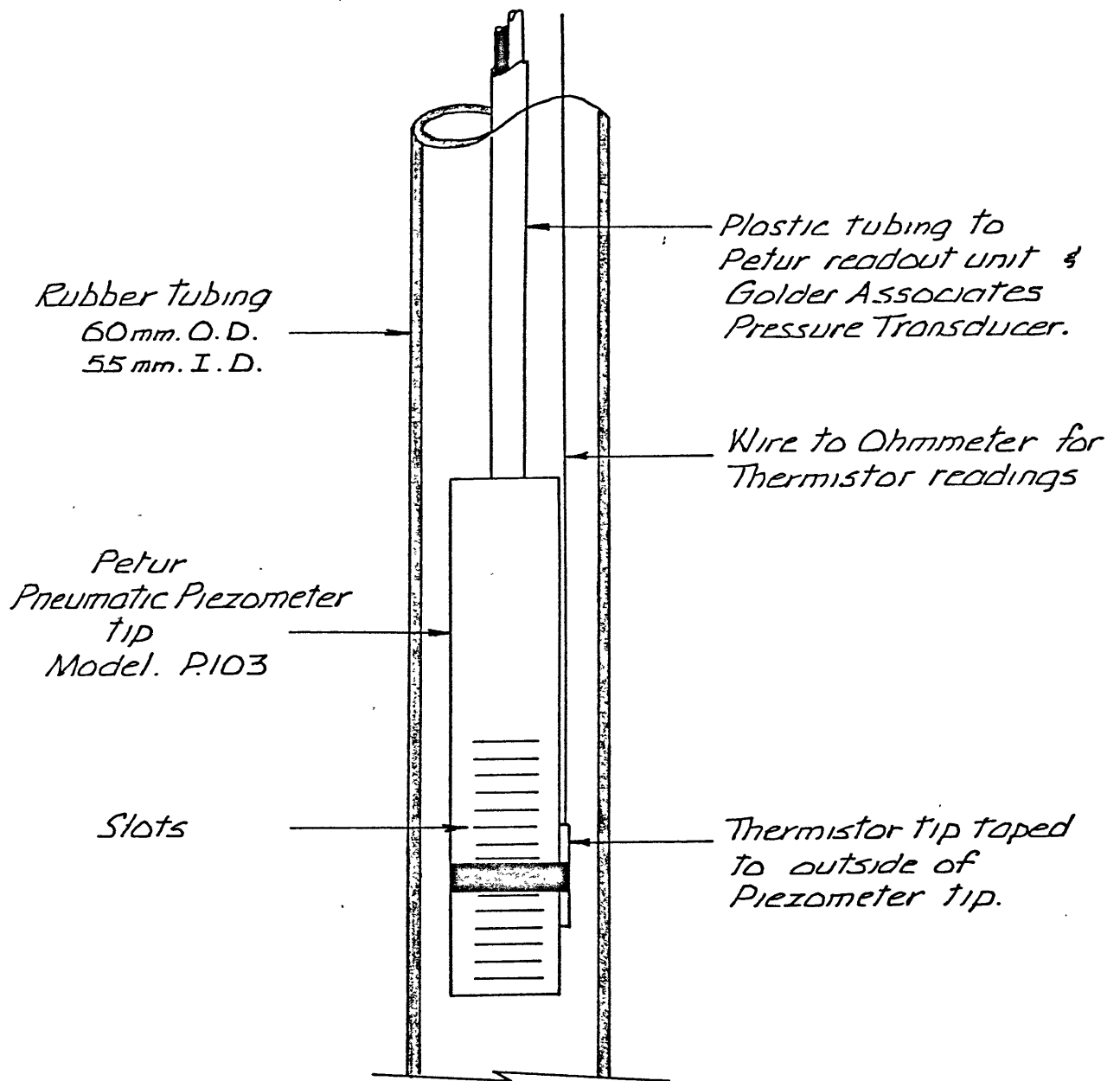
* Calibration of the thermistor tip in an ice bath (assumed to be at 0.0°C) gave a reading of 16.34 k , therefore the theoretical 0.0°C value of 16.32 k was used for temperature calculations.

OVERALL TEST SET UP

Figure VII - 1

NOT TO SCALE
(Dimensions in metres)

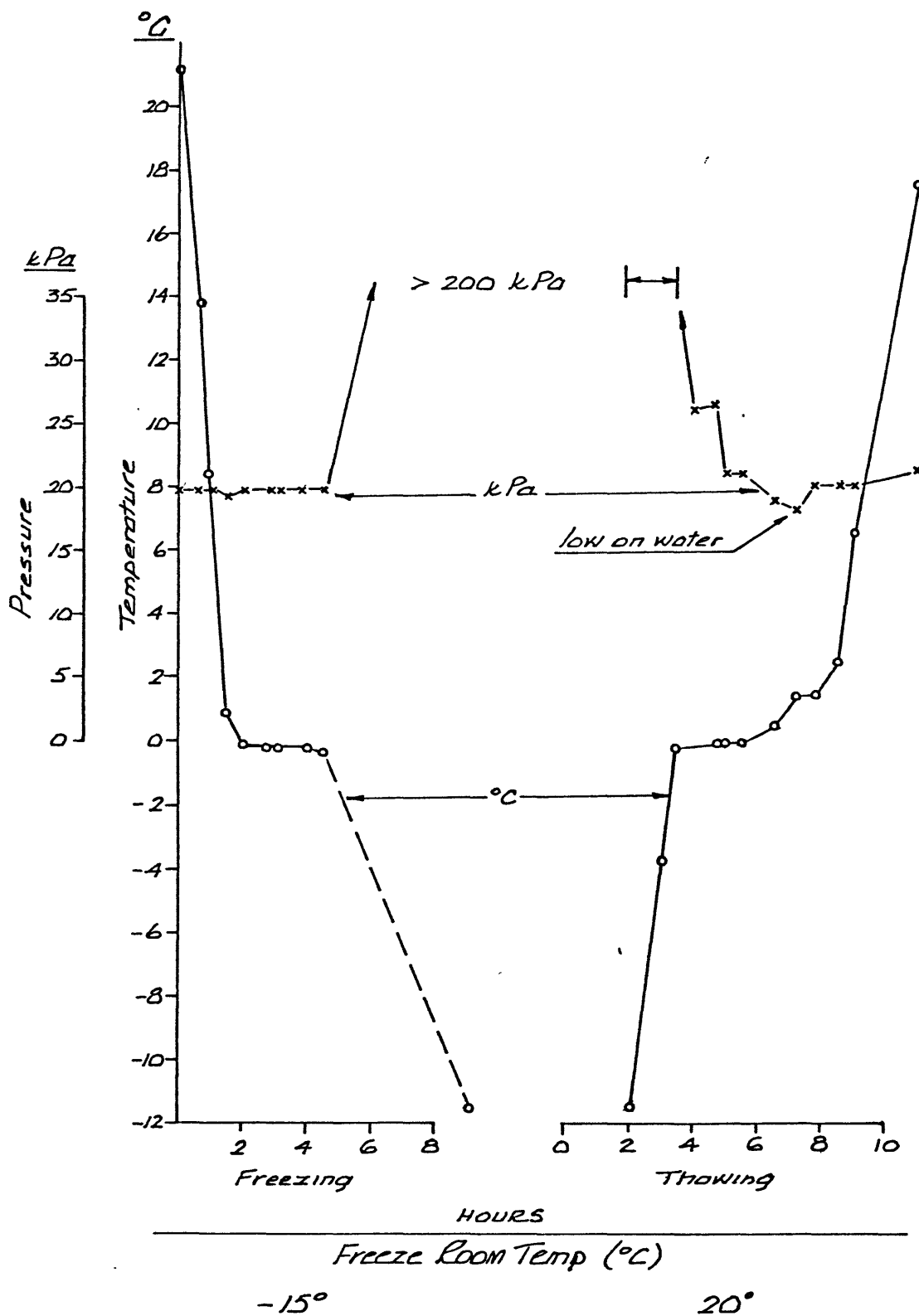




Scale 1:2

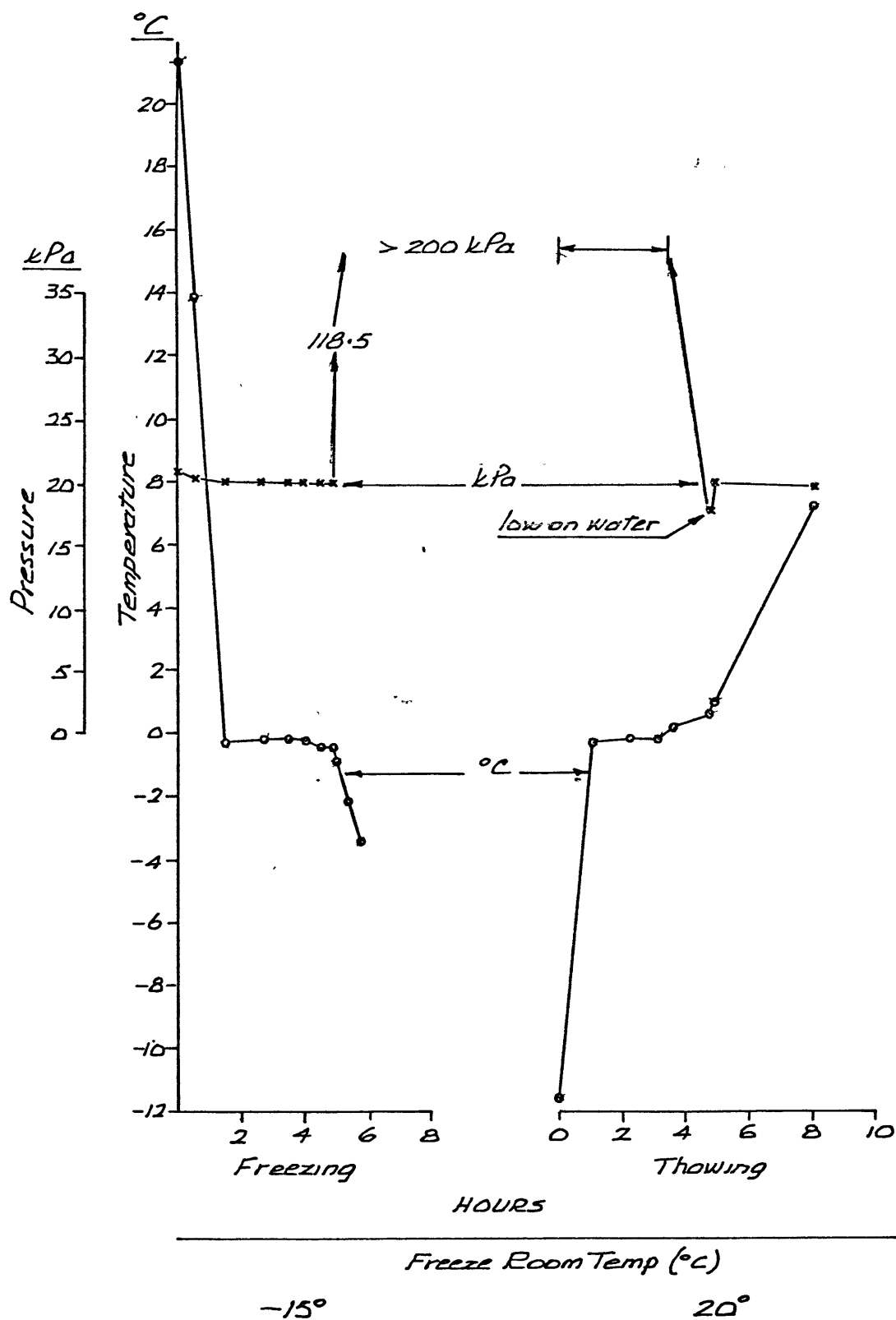
PRESSURE & TEMPERATURE VERSUS TIME CYCLE .1.

Figure VII-3



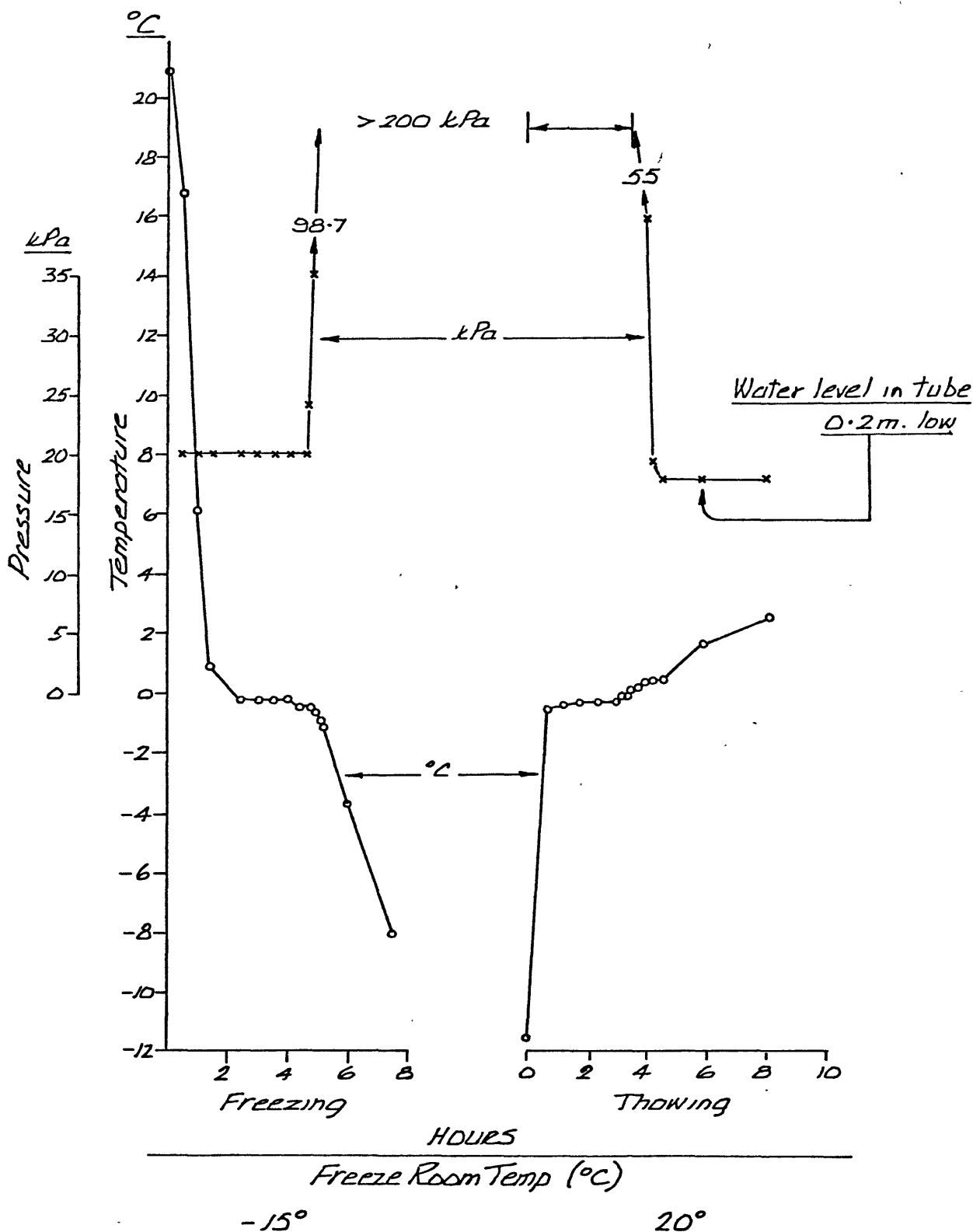
PRESSURE & TEMPERATURE VERSUS TIME CYCLE 2.

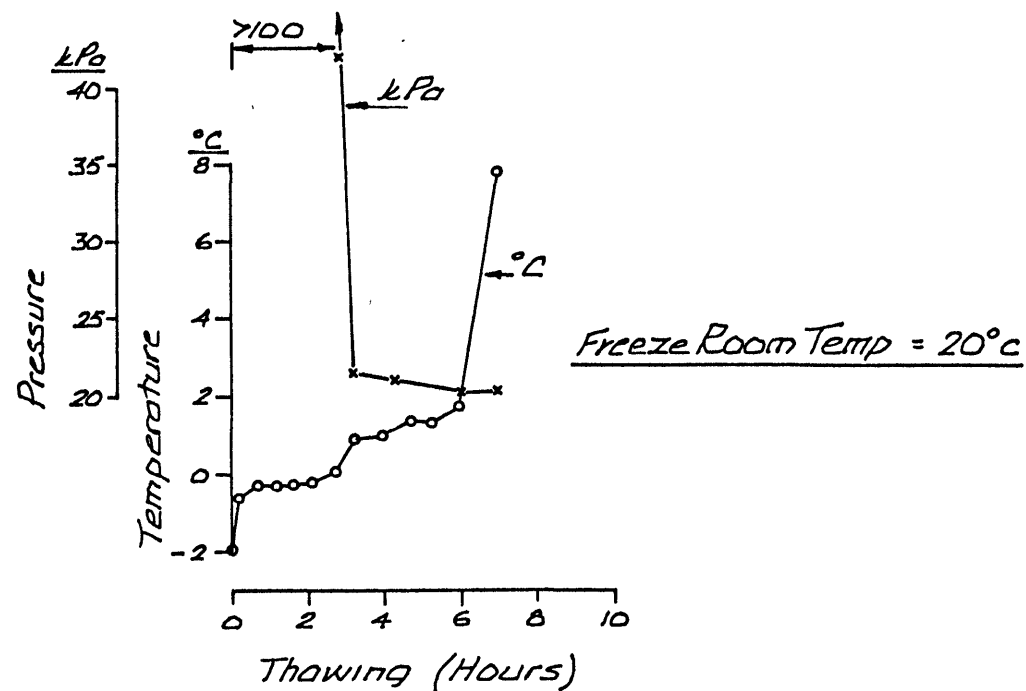
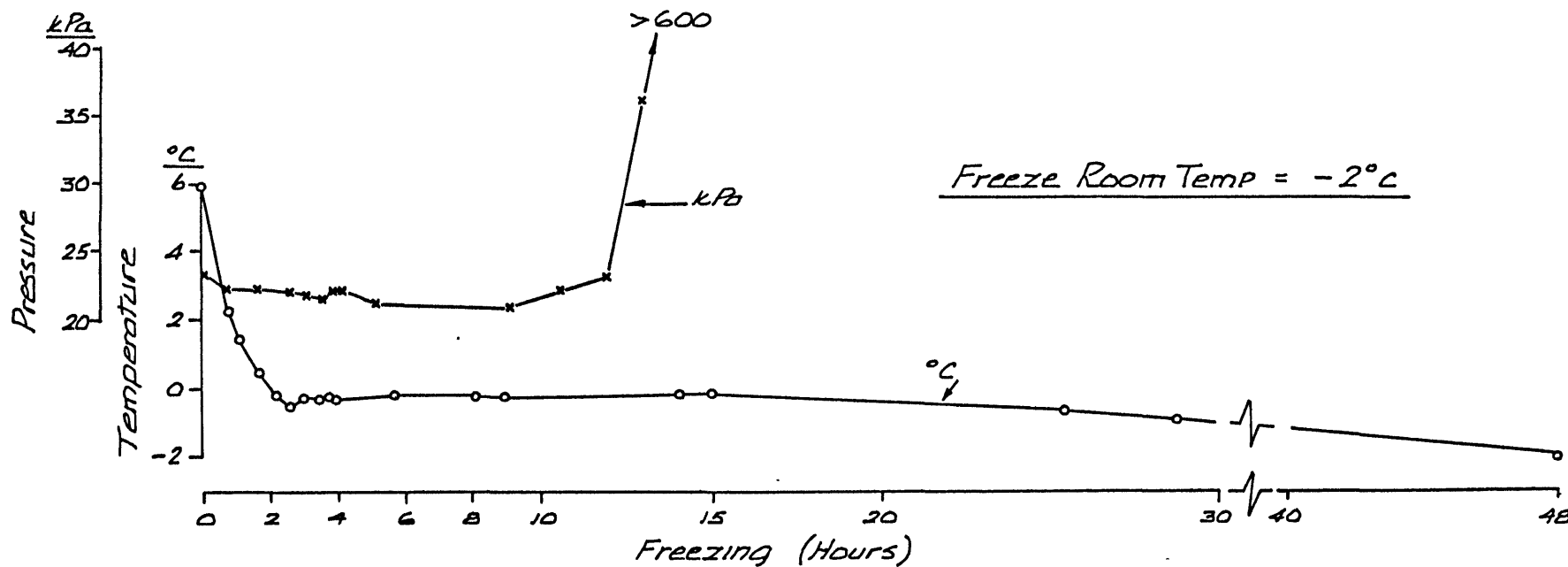
Figure VII-4



PRESSURE & TEMPERATURE VERSUS TIME
CYCLE.3.

Figure VII-5





PRESSURE & TEMPERATURE VERSUS TIME
CYCLE. 4.

Figure VII-6

APPENDIX VIII
CYPRUS ANVIL REPORT ACTIVITIES NOVEMBER/DECEMBER 1982

SUMMARY REPORT OF ACTIVITIES
PERTAINING TO
CYPRUS ANVIL TAILING POND
FROM NOVEMBER 19, 1982 TO DECEMBER 13, 1982
WITH A PROJECTION OF PROPOSED ACTIVITIES
IN THE NEAR FUTURE

December 16, 1982

CYPRUS

During the period November 20 to present, the following tailings pond activities have taken place, see page 6.

I. To Reduce Zinc Level in X5 Decant

On November 20, 21 and 22, 1982, as a short term emergency measure, bagged lime was added to the X5 decant to increase the pH and lower the dissolved zinc.

II. To Eliminate X5 Decant

On November 22 the X5 decant was closed by building a small dyke with sand bags across this decant channel.

The Cross Valley dam pond surface elevation was monitored daily to determine the rate of rise. The rate of rise in this dam indicated that a decant would start to flow from the emergency spillway invert in about 10 days which was too short a period to eliminate the high zinc from the pond.

The intermediate dam decant X4 was blocked off by a dyke on November 24 and the intermediate pond daily elevation was monitored to determine the rate of rise of this pond. The Cross Valley pond levels started to fall when X4 decant was closed. The projected date of a decant from X5 was calculated and indicated a decant would start in about 20 days.

At that time the mine was pumping approximately 350 gallons per minute to the pond and the mill was also discharging about 1,100 gallons per minute to the pond. On November 27 Number 1 Zone pit pumps were stopped and on November 29 about 900 gallons per minute of mill discharge was piped across the tailing pond and discharged into the Rose Creek diversion canal. This reduced the flow to the pond from 1,450 gallons per minute to 250 gallons per minute.

The intermediate dam pond started to overflow the emergency spillway on November 30 and the pond had reached a constant elevation by December 6. The Cross Valley dam level was falling until December 3, at which time it started to rise again.

The Zone 3 pit pump was diverted into Zone 1 pit on December 13 which further reduced the flow to the pond to 200 gpm.

Present indications are that X5 decant can remain closed for an additional 50 days. The Cross Valley dam will rise 0.45 metres before reaching the invert elevation of the emergency spillway. It is anticipated that the rise in pond

elevation will cause an increase in the seepage from the pond so that no decant will occur until milder weather in the spring. The present rise of the Cross Valley pond is equivalent to 300 gpm.

III. To Study Water Balance of the Tailing Pond System

The closing of the Cross Valley dam and the intermediate dam decant, along with accurate pond elevation surveys and controlled pit and mill water additions has allowed a more accurate water balance survey of the tailing pond that was previously possible.

The water balance survey results are appended to this report in the form of a table. This table is Appendix I. During the 20 day period the measured flow into the pond was 742,000 gallons less than the measured increase in the volume stored. This indicates that the seepage from the pond system is approximately 25 gallons per minute less than the groundwater recharge to the ponds.
*1) measured seepage is not all of seepage
 2) measured "groundwater" in dam is only measured*

The rate of rise of the intermediate dam from November 24 to November 30 showed a net increase in the pond of 2,370 gallons per minute. The measured seepage from the toe of the Cross Valley dam at flow weir X13 for the same period was 2,320 gallons per minute.

We are aware of 600 to 800 gpm of inflow into the Cross Valley dam near the south abutment of the intermediate dam. This would indicate that a similar volume of seepage from the Cross Valley dam is not reporting to weir X13.

IV. To Monitor Seepages, the Receiving Stream and Ponds

On November 22 a daily monitoring program for pH and zinc was initiated and included the following sample points:

- X1 which was a combined mine water and mill water which had lime added
- X4 when flowing
- X10 Rose Creek
- X11 seepage from Cross Valley north abutment
- X12 seepage from Cross Valley south abutment
- X13 all surfacing seepages from Cross Valley pond
- X14 Rose Creek below tailing pond effluent
- X5-13 tailing pond effluent just prior to entering Rose Creek
- X23 pit water from toe of dump

~~The summary of results is located in Appendix II.~~

The average zinc level in X14 from November 23 to December 12 was 0.055, in X13 for the same period was 0.048 and sample X5-13 (the combined effluent just before entering Rose Creek) was 0.065. Rose Creek during this period averaged 0.07 indicating the effluent was lower in zinc than the receiving stream.

A small area of the Cross Valley pond near X5 decant was limed on a 15 metre grid and samples were taken near the surface and near the bottom at several holes during the liming process. The results are shown on Sample Grid Sheet I, Appendix III.

A 100 metre sample grid was cut on the Cross Valley dam and sampled on December 6 and 8. The results are shown on Sample Grid Sheet II, Appendix III.

A partial grid was sampled on December 10 and results are shown on Sample Grid Sheet III, Appendix III.

V. To Test Storage Pond Lime Requirements and Add Lime to Storage Ponds

Lime requirements to precipitate out the dissolved zinc were determined on mine water and tailing pond water. The mine water required .1 gms/l to raise the pH to 8.5 and reduce the zinc from 20 mg/l to less than 0.5 mg/l. The pond water was tested on three occasions and each test indicated less than 0.06 gms/l of lime required to precipitate out the dissolved zinc.

The volume of water in the Cross Valley dam and intermediate dam is shown on Storage Volume versus Elevation Curve for the two dams, Appendix IV.

The lime required to treat the Cross Valley dam volume of 1,950,000 m³ at 0.06 gms/l is 117,000 kg. or 258,000 pounds.

By December 10, 24,000 pounds of lime had been added just up stream of X4 and 247,000 pounds had been added into the Cross Valley dam pond. Grid samples indicated the lime was less effective in the field than in the lab or some unreacted lime still existed in the pond. See Sheet II, Appendix III and Appendix V for location and quantities of lime added.

The lime addition was reduced on December 10 to only that quantity of lime added directly to X4 decant to neutralize this decant (2,000 pounds per day.) The reduced liming program will be followed for a week and the pond resampled to monitor any change.

VI. To Determine Existing Tailing Pond Contributions to Existing Zinc Problem

The Number 3 Zone pit pump discharge has been redirected to Number 1 Zone pond. This removes the last flow from the pit to the tailings pond. After a few days the mill lime addition will be eliminated and the decant past the plug (sample S6A of Appendix VI) will be sampled daily starting on December 15. All the dissolved zinc in this sample (S6A) will eventually be coming from the existing pond.

VII. Future Action

The action required to ensure that licence standards are maintained will be determined as additional information as such as date of starting to decant at X5, Zinc levels in the Cross Valley dam pond, zinc contribution from the existing tailing pond and confirmed date for mill start-up, is obtained.

TAILING POND EVENT SCHEDULE

	NOVEMBER												DECEMBER													Future
	19	20	21	22	23	24	25	26	27	28	29	30	1	2	3	4	5	6	7	8	9	10	11	12	13	
Reported to Controller	X																									
Limed X5		X	X	X																						
Closed X5 decant				X																						
Water Resources present			X	X	X								X	X												
Started daily samples				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Limed mine water				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Monitored pond levels					X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	Water balance attached
Closed X4 decant						X	X	X		X	X															
Stopped Zone #1 pumps									X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
X4 decant flowing												X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Reduced mill water												X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Limed pond at "A"										X	X	X	X	X												
Limed pond at "B"													X	X	X	X	X	X	X							
Limed pond at "C"																X	X	X	X	X	X	X				X
Limed pond at "D"																			X	X		X				
Samples area "A"											X	X														
Grid samples pond																	X		X		X					
Stopped Zone #3 pumps																								X		

WATER BALANCE

cvd decant
22-X5 closed.

ID decant
X4
closed.

Date	Intermediate Dam		Cross Valley Dam		Tailing Dam	Vol. to Tailing	Difference x 1,000 gals. [A - B]
	Surface Elevation	Storage Vol. Change x 1,000 gals.	Surface Elevation	Storage Vol. Change x 1,000 gals.	Storage Vol. Change x 1,000 gals. [A]	Dam From Mine And Mill x 1,000 gals. [B]	
23	1066.371	-	1063.682				
24	.371	-	.742	+1,929	1,929	2,088 1450 gpm.	-159
25	.422	4,145	.692	-1,470	2,675	2,088	587
26	.468	3,738	.657	-1,678	2,060	2,088	-28
27	.514	3,738	.616	-1,883	1,855	2,088	-233
28	.555	3,332	.584	-1,470	1,862	1,656 pit pumps stopped	206
29	.588	2,682	.552	-1,470	1,212	1,656 1150 gpm. water pumped across	-444
30	-ID overflow .623	2,844	.520	-1,470	1,374	504 350 gpm. pond.	870
1	.647	1,950	.501	-1,118	832	360 250 gpm	472
2	.652	406	.479	-1,295	-889	360	-1,249
3	.654	162	.479	-	162	360	-198
4	.656	162	.483	+183	345	360	-15
5	.659	249	.487	183	432	360	72
6	.661	162	.492	230	392	360	32
7	1066.661	-	.505	597	597	360	237
8			.518	597	597	360	237
9			.527	413	413	360	53
10			.537	459	459	360	99
11			.546	413	413	360	53
12			.555	413	413	360	53
13			1063.565	459	459	360	99
TOTAL		23,570		-5,978	17,592	16,848	744

av. 1480

↑
how accurate
say 170 176
570 880

200 gpm.
division of
Rt 3 to Pit 1.

(-) indicates water
loss from the system

WATER SAMPLE SUMMARY

Date	X1		X4		X5		X10		X11		X12		X13		X14		X23		X5-13	
	pH	Zn	pH	Zn	pH	Zn	pH	Zn	pH	Zn	pH	Zn	pH	Zn	pH	Zn	pH	Zn	pH	Zn
Nov. 19																				
20																				
21																				
22					6.8	3.52	6.8	0.01	7.2	N.D.	7.0	N.D.	7.1	N.D.	7.0	0.46				
23			6.8	2.59	11.4	0.09	7.3	0.20	7.4	0.14	7.5	0.09	7.3	0.12	7.2	0.04	6.6	11.96		
24	7.9	0.16	7.0	2.81			7.3	0.11	7.3	0.30	7.2	0.05	7.2	0.04	7.2	0.02	6.6	15.02		
25	9.5	0.03					7.0	0.06	7.1	0.07	7.3	0.02	7.1	0.03	7.3	0.03	6.7	11.30	7.3	0.11
26	8.7	0.18					7.1	0.03	7.1	0.03	7.2	0.04	7.1	0.05	7.1	0.06	6.6	17.38	7.0	0.05
27	9.1	0.01					7.2	0.01	7.0	0.01	7.3	0.06	7.2	0.10	7.3	0.08			7.1	0.11
28	9.2	0.05					7.0	0.01	7.1	0.01	7.3	0.02	7.2	0.08	7.2	0.08			7.1	0.07
29	10.9	0.01					7.6	0.03	7.3	0.04	7.4	0.05	7.3	0.03	7.2	0.04			7.2	0.04
30	11.5	0.14	6.7	5.63			7.8	0.14	7.0	0.13	7.4	0.09	7.3	0.07	7.4	0.09	6.7	11.34	7.5	0.09
Dec. 1	11.2	0.05	7.2	4.67			7.5	0.08	7.4	0.06	7.3	0.06	7.2	0.04	7.3	0.06			7.1	0.14
2	11.1	0.05	7.2	3.31			7.5	0.01	7.4	Tr	7.3	Tr	7.6	Tr	7.5	0.01			7.3	0.02
3	8.0	0.23	7.2	3.01			7.8	0.07	7.5	0.10	7.7	Tr	7.6	Tr	7.7	Tr			7.5	0.04
4	12.1	0.02	7.1	2.97			7.8	0.04	7.6	0.07	7.7	Tr	7.6	Tr	7.4	Tr			7.5	0.03
5	12.0	0.19	7.1	2.97			7.6	0.08	7.5	0.02	7.6	Tr	7.5	0.01	7.4	Tr			7.5	0.03
6	11.9	0.06	7.2	3.01			7.6	Tr	7.5	0.04	7.5	0.01	7.5	0.01	7.5	0.02			7.4	0.01
7	12.1	0.07	7.4	2.91			7.8	0.07	7.6	0.07	7.6	0.07	7.6	0.04	7.7	0.14	7.1	10.20	7.6	0.08
8	12.0	0.16	7.3	2.89			7.8	0.10	7.6	0.12	7.7	0.20	7.6	0.13	7.5	0.15			7.5	0.13
9	11.7	3.94	7.1	2.58			7.7	0.20	7.5	0.04	7.7	0.09	7.6	0.07	7.6	0.07			7.6	0.16
10	12.0	N.D.	7.2	3.60			7.9	0.07	7.5	0.08	7.6	0.03	8.0	0.07	7.6	0.16			7.5	0.01
11	11.8	N.D.	7.0	3.84			7.7	0.05	7.5	0.02	7.4	0.01	7.6	0.03	7.5	0.04			7.4	0.03
12	11.6	0.01	7.2	3.93			7.8	0.05	7.8	0.05	7.6	0.01	7.7	0.03	7.3	0.02			7.3	0.02
13																				

X VALLEY DAM

1/15

LINIE ADDED
AREA A

1-4

D	PH	Zn
42	7.3	0.40

2-4

D	PH	Zn
40	7.2	0.33

3-4

D	PH	Zn
39	7.5	2.19

4-4

D	PH	Zn
50	7.6	0.36

5-5

D	PH	Zn
37	8.4	0.27

1-3

D	PH	Zn
5	7.3	1.35
8.8		0.05

2-3

D	PH	Zn
16	7.4	3.74
32	7.8	0.39

3-3

D	PH	Zn
5	7.5	2.75
8.3		0.24

4-3

D	PH	Zn
5	7.5	2.12
26	7.7	0.68

5-3

D	PH	Zn
5	7.5	3.36
7	7.5	4.03

1-2

D	PH	Zn
5	7.5	1.05
41	7.6	0.60

2-2

D	PH	Zn
5	7.4	1.31
15	7.6	1.15

3-2

D	PH	Zn
5	7.5	2.70
18	7.8	0.80
36	7.7	0.51

4-2

D	PH	Zn
5	7.6	3.08
23	8.2	0.34
47	7.6	0.05

5-2

D	PH	Zn
5	7.5	3.61
14	7.9	0.95
28	8.0	0.42

1-1

D	PH	Zn
5	7.4	0.42
24	8.7	0.22

2-1

D	PH	Zn
5	7.6	0.58
8.9		0.15

3-1

D	PH	Zn
5	7.6	2.25
8.5		0.05

4-1

D	PH	Zn
5	7.6	3.24
8.2		0.34

5-1

D	PH	Zn
5	7.5	3.97
12	8.0	0.68

DEC 6 & 8
water sample

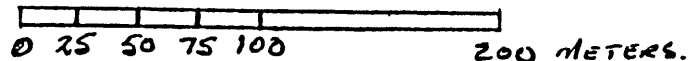
LINIE ADDED
AREA B

AREA D

LINIE ADDED

INT DAM. AREA C

scale



D: Depth of sample in feet.

SANTA FE RIVER X VALLEY DAM?

x5

1-4
⊕

D	PH	ZN
AZ		

2-4
⊕

D	PH	ZN
5	7.6	1.00
40	7.6	1.11

3-4
⊕

D	PH	ZN
39		

4-4
⊕

D	PH	ZN
5	7.5	2.21
25	8.5	0.29
50	7.6	0.42

5-5
⊕

D	PH	ZN
5	7.5	3.16
37	7.8	1.27

5-4
⊕

D	PH	ZN
5	7.5	3.18
24	7.8	1.29

1-3
⊕

D	PH	ZN

2-3
⊕

D	PH	ZN
5	7.5	2.02
16		
32	7.5	2.43

3-3
⊕

D	PH	ZN

4-3
⊕

D	PH	ZN
5	7.5	2.89
26	8.6	0.04

5-3
⊕

D	PH	ZN
7		

1-2
⊕

D	PH	ZN
5	7.4	0.57
A1	8.8	0.23

2-2
⊕

D	PH	ZN
5	7.7	0.47
15	9.1	0.04

3-2
⊕

D	PH	ZN
5	7.5	2.88
18	8.9	0.07
36	8.4	0.34

4-2
⊕

D	PH	ZN
5	7.6	3.16
23		
47	7.9	0.02

5-2
⊕

D	PH	ZN
5	7.5	3.36
14	7.5	2.52
28	7.9	0.38

AA

4-1
⊕

D	PH	ZN
31	9.4	10.15

2-1
⊕

D	PH	ZN
5	7.6	1.15
18	9.0	0.03

3-1
⊕

D	PH	ZN

4-1
⊕

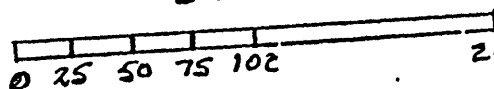
D	PH	ZN

5-1
⊕

D	PH	ZN
12		

DEC 10
WATER SAM

scale



INT DAM?

sample in feet.

3.18

X VALLEY DAM?

1-4

D	PH	Zn
AZ		

2-4

D	PH	Zn
40		

3-4

D	PH	Zn
39		

4-4

D	PH	Zn
50		

1-3

D	PH	Zn

2-3

D	PH	Zn
16		
32		

3-3

D	PH	Zn

4-3

D	PH	Zn
26		

5-3

D	PH	Zn
7		

1-2

D	PH	Zn
A1		

2-2

D	PH	Zn
15		

3-2

D	PH	Zn
18		
36		

4-2

D	PH	Zn
23		
47		

5-2

D	PH	Zn
14		
28		

1-1

D	PH	Zn
29		

2-1

D	PH	Zn

3-1

D	PH	Zn

4-1

D	PH	Zn

5-1

D	PH	Zn
12		

5-5
0
01-4
01-3
01-2
01-1
02-4
02-3
02-2
02-1
03-4
03-3
03-2
03-1
04-4
04-3
04-2
04-1
05-4
05-3
05-2
05-1

AREA "A"

SAMPLED

NOV 29

1-4 5' 6.8 2.67
23' 7.1 2.78

NOV 30

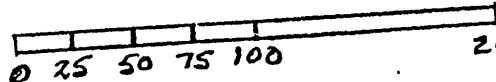
1-3 10' 6.9 2.94
23' 7.4 0.73

2-3 5' 7.0 3.89
23' 7.4 0.80

2-1 11' 7.1 4.03

3-1 13' 8.3 0.3

scale



INT DAM

Sample in Feet.

VOLUME
($10^6 m^3$)

Storage VOLUME VS ELEVATION CURVES

Jan, 1982

CVD area from plan at 1063.5 = 210,000 m^2
tangent from this plot 230,000 m^2

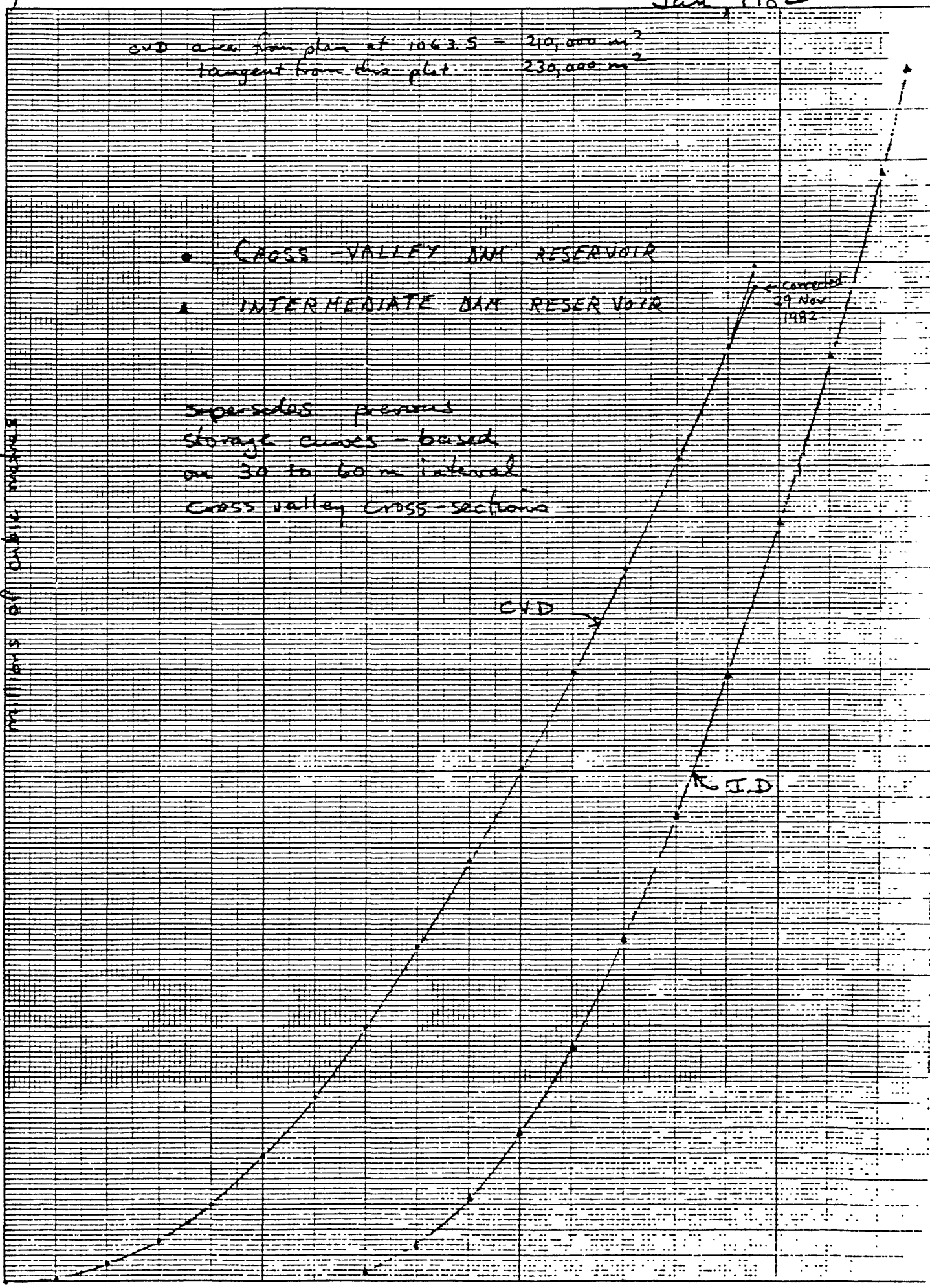
- CROSS-VALLEY DAM RESERVOIR
- INTERMEDIATE DAM RESERVOIR

Supersedes previous
storage curves - based
on 30 to 60 m interval
cross valley cross-sections

corrected
29 Nov
1982

CVD

I.D.

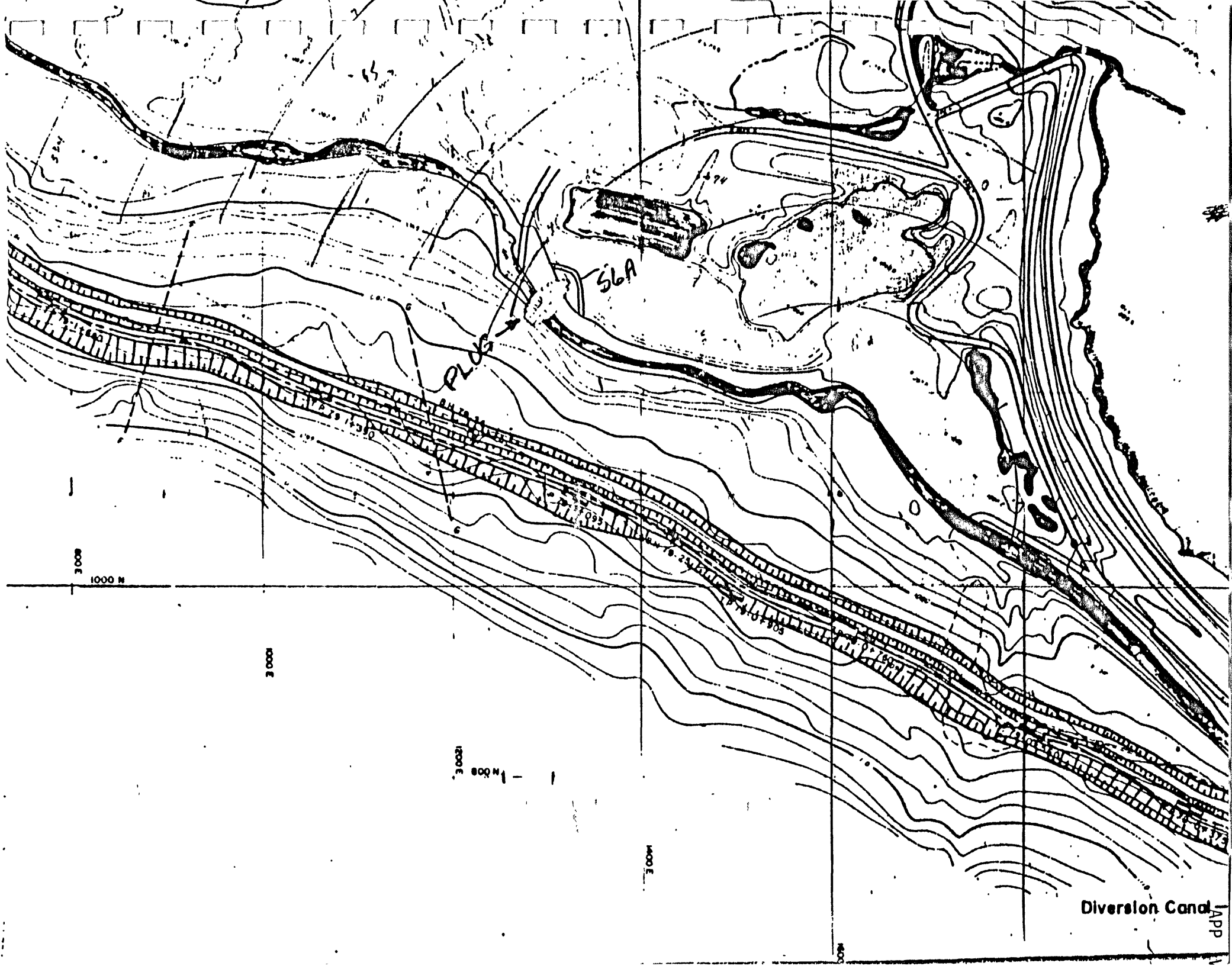


LIME ADDITION SUMMARY

<u>Date</u>	<u>Mill-Mine Water</u>	<u>Area A</u>	<u>Area B</u>	<u>Area C</u>	<u>Area D</u>
Nov. 22	7,884				
23	7,884				
24	7,834				
25	7,884				
26	7,884				
27	7,884				
28	7,884	1,000			
29	7,884	5,000			
30	7,884	5,000			
Dec. 1	4,032	4,000			
2	7,200	5,000	19,000		
3	4,368		28,000		
4	7,862		8,000	24,000	
5	8,640		8,000	16,000	
6	8,640		8,000	16,000	
7	8,640		8,000	16,000	8,000
8	8,640			24,000	8,000
9	8,640			40,000	
10	8,640			8,000	8,000
11	8,640				
12	8,640				
13	8,640			2,000	
14	<u>8,640</u>	<u> </u>	<u> </u>	<u>2,000</u>	<u> </u>
Total	180,818	20,000	79,000	148,000	24,000

Intermediate dam - 204,818 pounds of lime added

Cross Valley dam - 247,000 pounds of lime added



Diversion Canal
APP

APPENDIX IX
MEMORANDA RE CROSS VALLEY DAM PERFORMANCE

December 3, 1982

Ref.No. 822-2021

Cyprus Anvil Mining Corporation
P.O. Box 1000
Faro, Yukon
Y0B 1K0

ATTENTION: Mr. N.G. Cornish

Dear Sir:

Re: V. Milligan Review of Cross Valley Dam

We are enclosing herewith a copy of a memorandum written by Mr. V. Milligan who generally reviewed in June and August the performance data for the Cross Valley Dam. We are also enclosing a copy of Mr. Milligan's curriculum vitae for your information.

Mr. Milligan makes the following points:

1. The upstream blanket is performing reasonably well overall (although he has used a permeability of 10^{-2} cm/sec as noted in the middle of P.2 of his memo).
2. The piezometer conditions at Sta.0+570 diverge from what would be expected for an upstream blanket configuration (top P.3 of memo).
3. The piezometric levels and seepage flows generally continued to rise in spite of constant pond level and this is particularly marked at Sta.0+570.
4. Subject to the review of Golder, Calgary, an additional weir should be installed at Sta.0+500; additional piezometers should be installed at the south abutment; monitor and if necessary increase the monitoring of thermal degradation at the south abutment.

We believe that the piezometric conditions observed at Sta. 0+570 are most probably the consequence of a relatively fine grained stratum at shallow depth which results in high head losses beneath the core cutoff trench. In effect it would appear that the core cutoff trench is constricting the shallow flow beneath the dam more effectively than the upstream blanket is capable of doing. We believe that the upstream blanket is intact in this area and that, had a core cutoff not been installed the piezometric conditions would be similar to those observed at Sta.'s 0+210 and 0+450. The relatively high pore pressures downstream of the core could reflect a lack of drainage due to inferior quality drain material, groundwater discharge from the south valley wall, and or higher toe drain elevation.

We note that, since Mr. Milligan's review was made, the piezometers have not changed significantly with two exceptions. The shallow and deep piezometers in CVD9 indicate essentially the same elevations for the 26 August, 1982 readings meaning that the deep piezometer decreased in elevation by about 1 m and the shallow piezometers increased in elevation by about 1 m (with respect to 20 July, 1982). These readings should be checked. If they are correct it would mean that:

- a) The seal between the piezometers has failed.
- b) The confinement which had been indicated previously by the deep piezometer has been lost due to communication developing through the fine grained layer between the screened sections of the two piezometers.

We also understand that the total seepage flows have decreased.

With respect to the present situation, we believe that the best course of action is to continue to monitor the situation closely. A set of piezometric levels should be obtained for December for the Cross Valley Dam. The toe area should be inspected for evidence of seepage discharge

December, 1982

3

822-2021

and changing seepage volume particularly in the vicinity of Sta.0+570 although our experience from last year indicated that the seepage flows in this area (0+570) are difficult to monitor due to icing. A review of weir flow data, although indirect, would give an important indication of whether south abutment flows are changing.

A review of the December data should be made promptly with particular attention being focused on the piezometric levels in CVDC 9 and on the seepage flows at the toe (Sta.0+570) of the CVD. When this review has been completed the need for additional piezometers and thermistors should be reassessed.

We are presently preparing a summary report of all the Down Valley Project monitoring data to date. We expect that this report will be useful in understanding the phenomena which are occurring.

Yours very truly,

GOLDER ASSOCIATES


D.C. Goodall, P.Eng.

H.G. Gilchrist, P.Eng.

DCG:HGG:cr

encls.

cc: V. Milligan

MEMORANDUM

TO: ~~H.G. Gilchrist~~ (Calgary)
D.C. Goodall (Calgary)

FR: V. Milligan (Mississauga)

RE: CYPRUS ANVIL - CROSS VALLEY DAM
YOUR REF: 822-2021

September 1, 1982



Our ref: 821-1212

Further to our recent discussions, I have reviewed the recorded seepage and piezometric data supplied to me by D. Goodall.

Pertinent Understandings

From the drawings supplied and our discussions, I understand that:

- i) Impoundment behind the dam commenced about December 1981 and was essentially complete about mid April 1982 with a pond level at about El. 1063.5 (m).
- ii) An approximate plan outline of the dam is sketched on Figure 1; flow monitoring weirs are located about as shown.
- iii) The dam is a simple earth fill embankment with a central till core and pervious shells; the till core is wrapped into an upstream blanket extending some 90 m. upstream from the centre line of the dam. The dam foundation consists of sands and gravels of varying stratification and extent, interspersed with till and possibly overlying till or less pervious deposits at depth. My simplifying assumptions are sketched on Figure 2.
- iv) Varying and erratic zones of permafrost exist in the south valley wall and adjacent to the south abutment of the dam.

...2

Estimates of Seepage

Based on my simplifying assumptions, estimates of seepage through the pervious foundation materials are sketched on Figures 3 and 4. (It is assumed that relative seepage through the dam is modest).

Figure 3 assumes a 'perfect' blanket. (The length shown of about 110 m. as compared to an actual length of 130 m. has little difference on the flow net sketched). Figures 4A and 4B illustrate an 'imperfect' and 'zero' blanket respectively.

Assuming that the average permeability of the foundation materials, insitu, is about 10^{-2} cm/sec, the total under seepage calculated for the 'perfect' blanket is about 3,000 IGPM (Figure 3), that for an 'imperfect' blanket (Figure 4A) is only about 30 per cent more, but that for 'zero' blanket (Figure 4B) could be 300 per cent more. Assuming that weir 3 is representative of the approximate total seepage flow (about 3,000 IGPM), it seems reasonable to assume that the blanket is performing reasonably well and that Figure 3 is probably representative of the approximate average flow conditions within the foundation materials.

Estimated Piezometric Conditions

For the flow conditions sketched in Figures 3 and 4, the corresponding approximate piezometric conditions (in terms of head loss) in the foundation material at the base of the dam are sketched on Figure 5. It must be recognized that these estimates are grossly approximate, but when they are compared to the actual piezometric conditions recorded (piezometric tips at El. 1048± 1m) two significant points arise — firstly, that at stations 0 + 210 and 0 + 450 there is reasonable correspondence with the 'blanket'

assumption but secondly, that at station 0 + 570 there is a marked divergence from such correspondence. Indeed, in the area of the core, there is a pattern of piezometric observations comparable to the 'zero' blanket assumption. (However, in the upstream portion of the dam at 0 + 570, the 'blanket' assumption still appears to be tenable).

Recorded Piezometric Levels

The majority of piezometers (with specific exceptions) continue to rise even with a constant pond level. It is significant that at stations 0 + 450 and 0 + 570, the shallow piezometers, HP/S, exhibit lower levels than the HP/D series thus suggesting upward flow into the drain downstream of the core, yet the contrary is evident at station 0 + 210. A large measure of those changes in piezometer pattern may be due to erratic stratification within the foundation with attendant local anomalies in piezometric level. However, the consistent rise exhibited at station 0 + 570 is most marked and this pattern, together with the measured increased flow in weir 3, suggests more than just localized variations in stratification.

Recommended Further Steps

As compared to the other sections monitored, that at station 0 + 570 appears to be anomalous. Part of this anomaly may be related to seepage flows from the south abutment area induced by thawing of local permafrost zones or by leakage from the diversion canal. Of particular concern, are the relatively high piezometric levels in the foundation at the location of the core and just upstream of it. It is recommended that further instrumentation be installed in this general area to check these concerns:

- i) Install a new monitoring weir at about station 0 + 500 near the downstream toe.
- ii) Install piezometers just upstream and downstream of the core and outside the toe (HP series) with tip elevations of about 1040 at stations 0 + 600 and 0 + 620+ = 6 piezometers in total. [These new piezometers can then be related to piezometer CVDC 11 at the south abutment to define a possible seepage pattern relative to the abutment.]
- iii) Monitor, and if necessary, increase the 'thermistor' instrumentation in this and to monitor possible thawing of permafrost.

Please review these comments and, as you see fit, convey them to Cyprus Anvil.

VM:baw
821-1212

Attachment: Figures 1 to 5

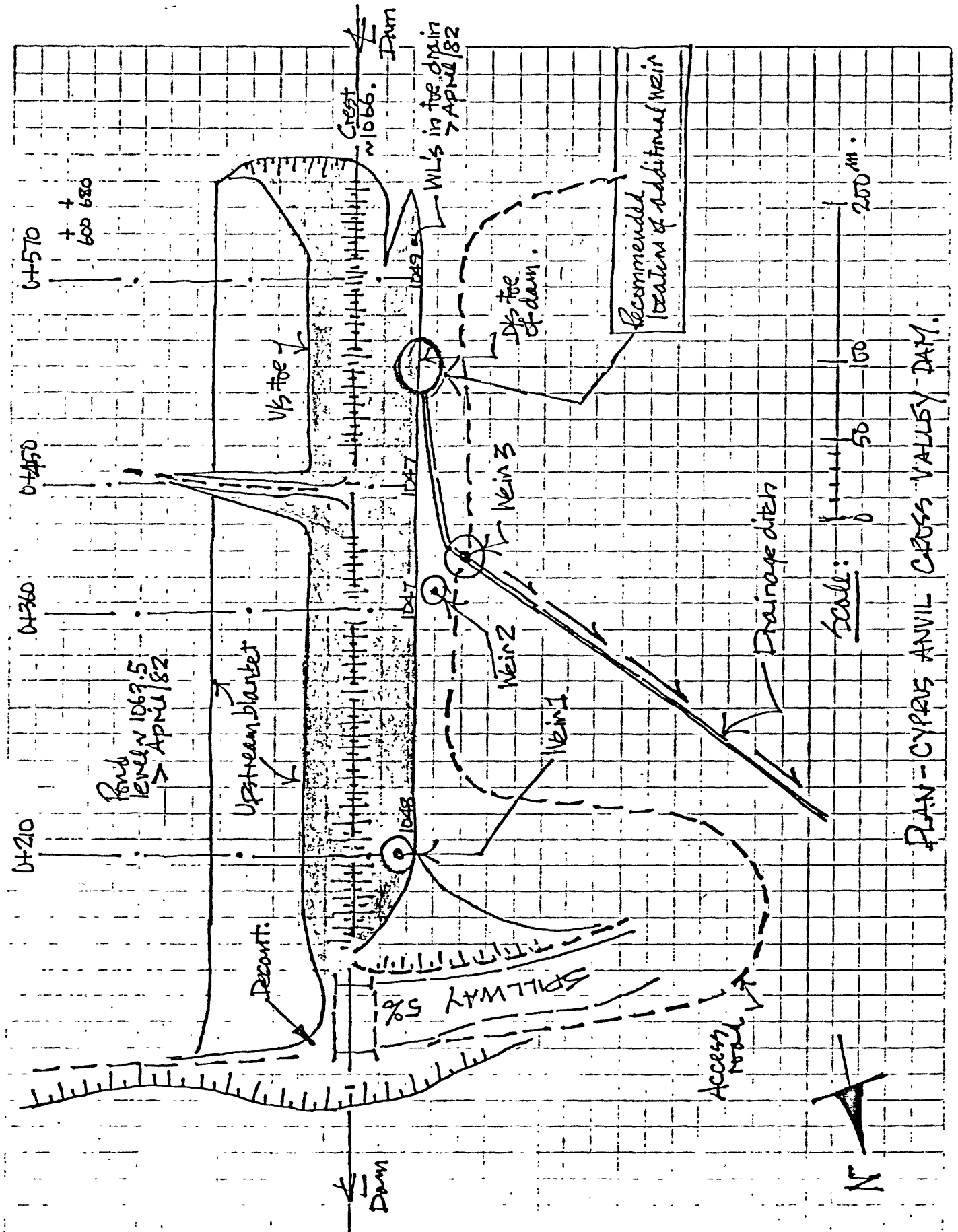
**Golder
Associates**

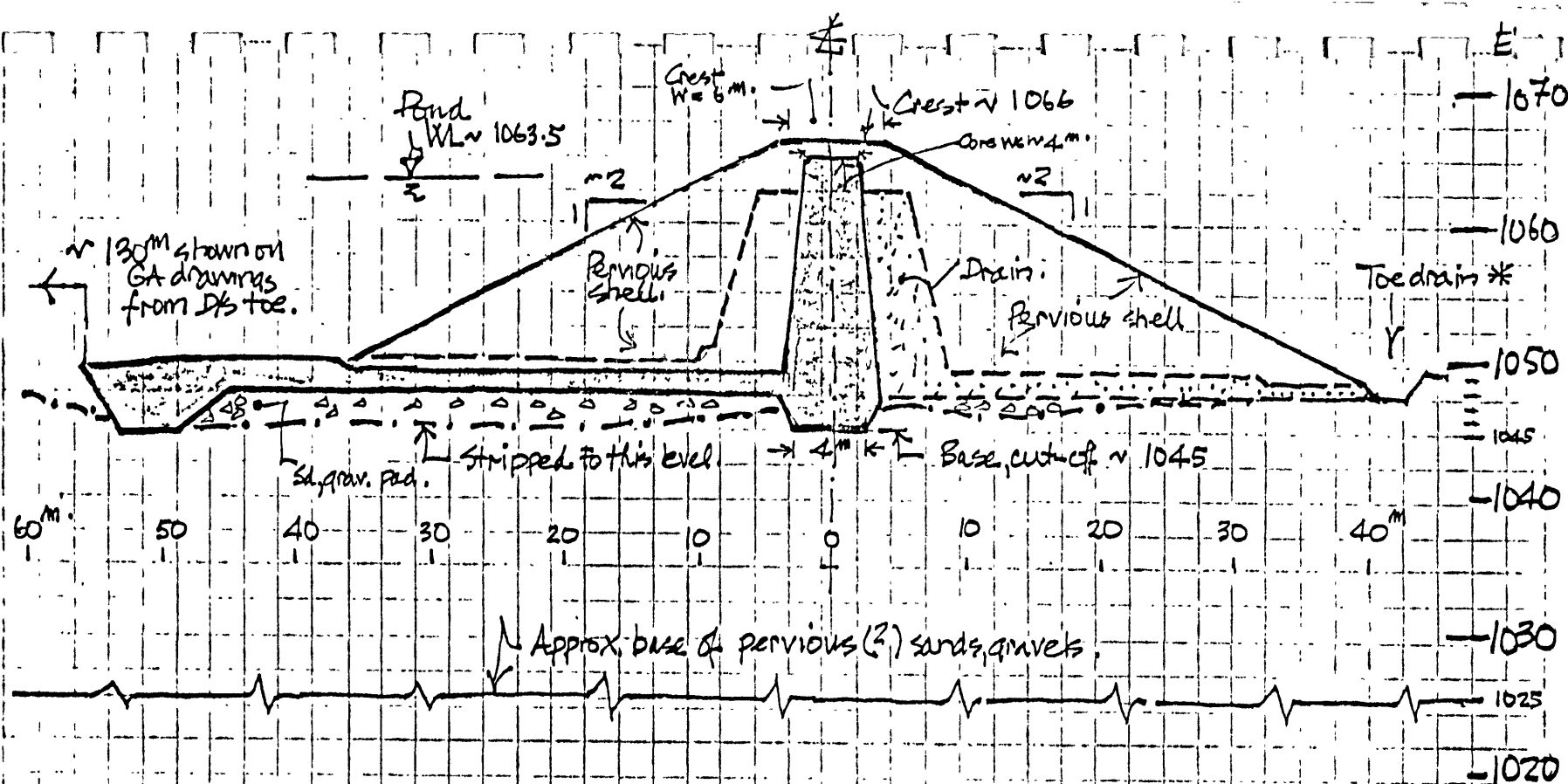
SUBJECT **CYPRUS ANVIL - CROSS VALLEY DAM**

Job No **821-1212**
Ref. **822-2621 (WC).**

Made by **H-1**
Checked
Approved

Date **Aug. 27 / 82**
Sheet **(1)**



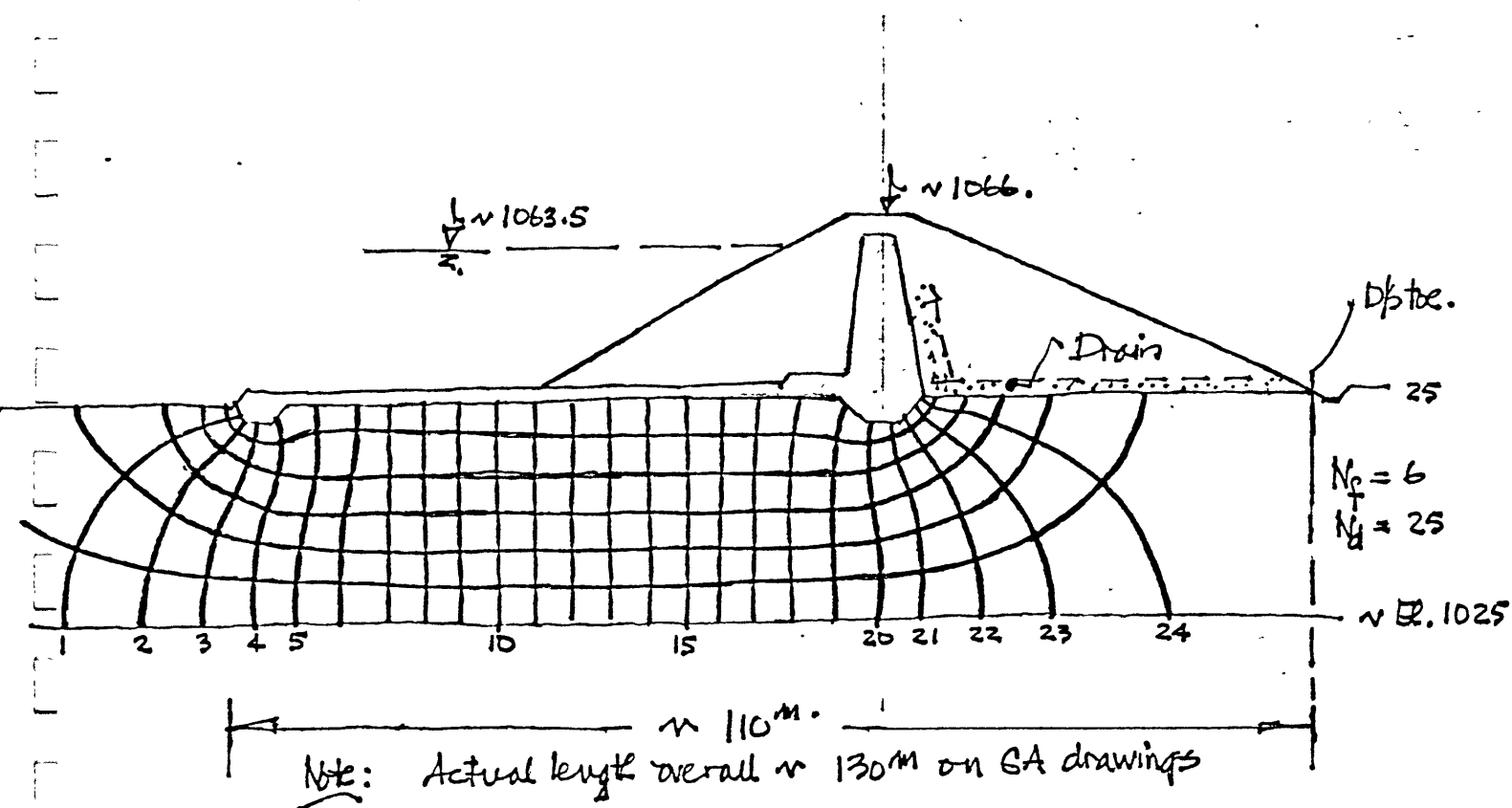


CROSS SECTION - CROSS VALLEY DAM, CYPRUS ANVIL.
Scale 1:500 (m)

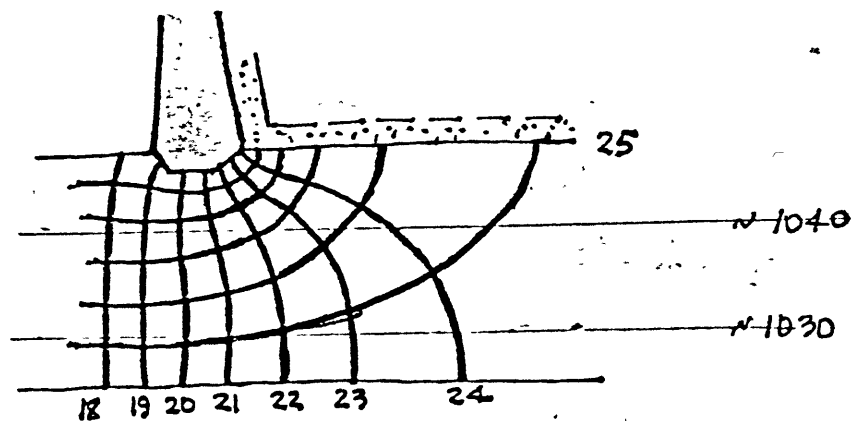
WLs in toedrain:

* 0+210	1048.
0+360	1047.
0+450	1047.
0+570	1049.

SIMPLIFIED C/S. Scale: 1: 750(m)

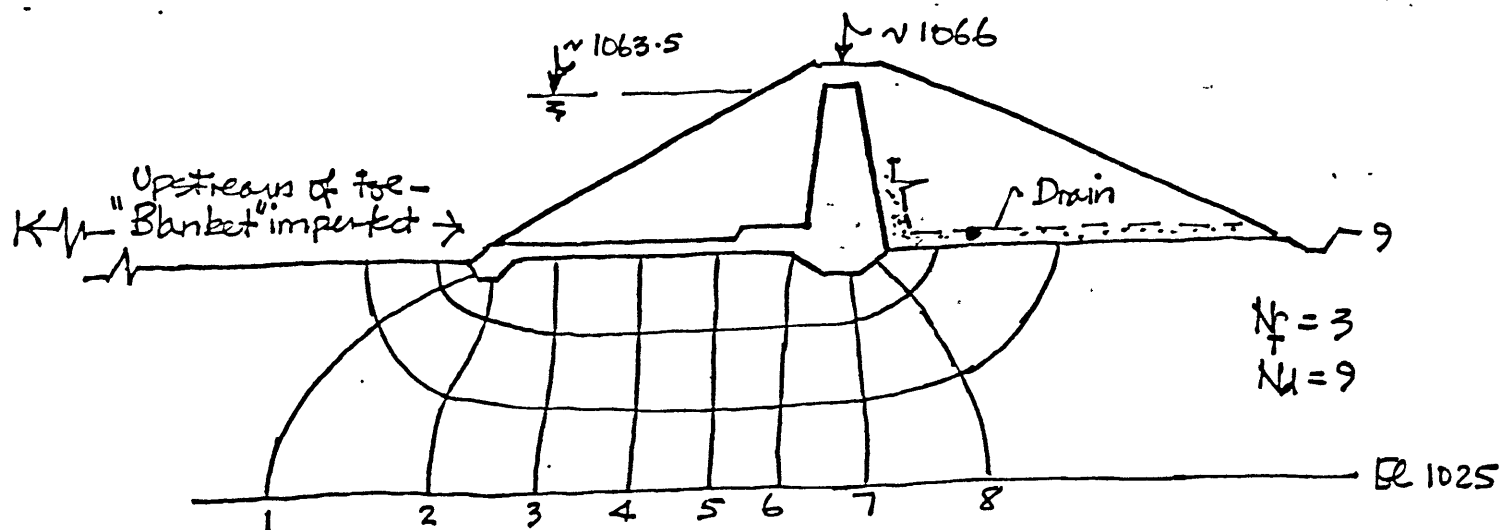


DETAIL AT CORE CUT-OFF.

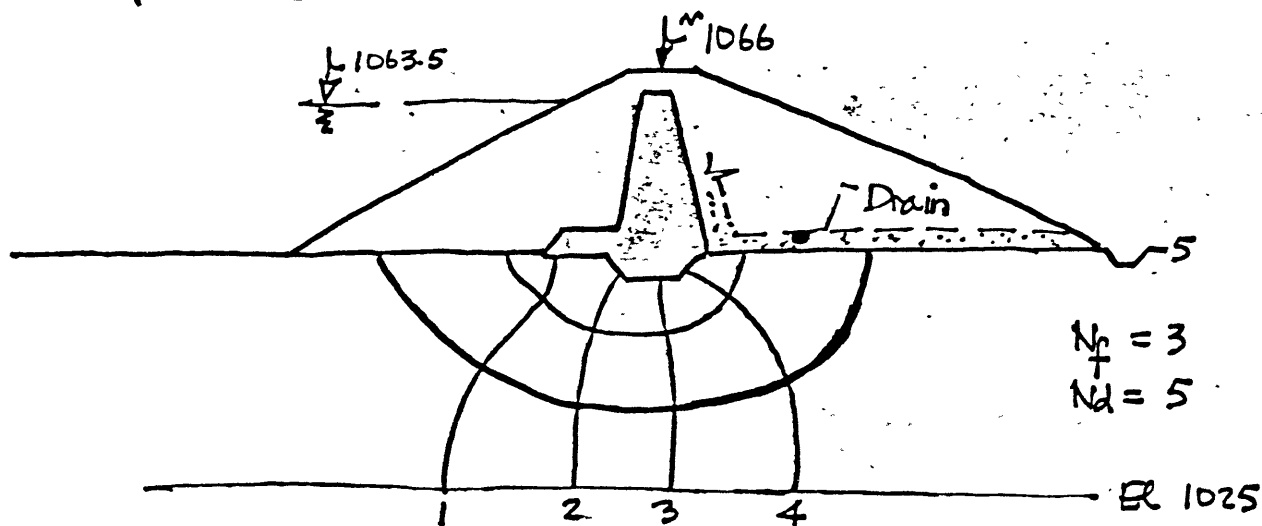


SIMPLIFIED C/S. Scale. 1: 750 (M).

A) Blanket imperfect upstream.

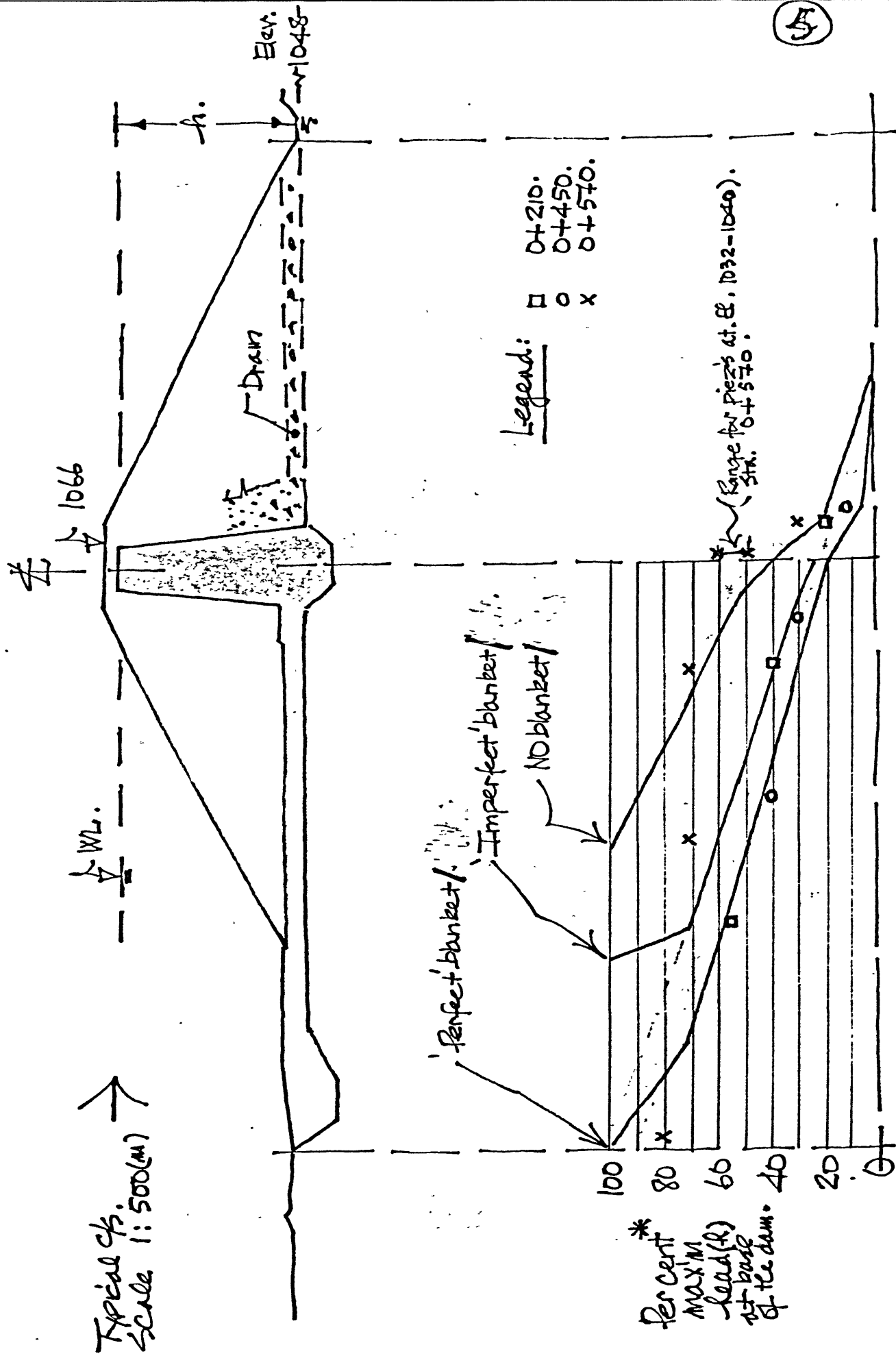


B) Blanket wholly "absent".



unrealistic detachment

COMPARISON OF MEASURED PIEZOMETRIC LEVELS WITH POSSIBLE SEEPAGE PATTERNS AS ASSUMED IN FIG'S 2 AND 3.



* For piezometer tips E. (1048 $\pm$ 1) m.