

SASKATCHEWAN RESEARCH COUNCIL

QUATERNARY GEOLOGY OF THE  
LORADO MILL AREA, SASKATCHEWAN

Report 0071-001 February 8, 1982



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February 8, 1982

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Attention: Mr. J. Whiting

Dear Mr. Whiting:

Enclosed are three copies of Report 0071-001 on the "Quaternary geology of the Lorado Mill area, Saskatchewan".

If you have any queries, please contact me.

Sincerely yours,



E.A. Christiansen

## SUMMARY

The Quaternary deposits in ascending order are: Pink Till, Lower Gray Silt, Gray Till, Upper Gray Silt, Postglacial Silt, and Peat.

The Pink Till is both calcareous and noncalcareous, whereas the Gray Till in the tailings pile area and Gray Silt are noncalcareous.

The Postglacial Silt includes lacustrine silts and carbonaceous and fossiliferous zones.

The Lorado Tailings are composed of up to 4 m of silt and sand overlying Peat. Silts occur at the base of the pile and remotely from the slurry discharge. Because the discharge points were moved toward Nero Lake from the mill, the tailings become finer with depth, with medium-grained sand on top to silt at the base of the pile. The upper few centimetres to two metres of the pile are oxidized.

The Nero-Beaverlodge Lakes Isthmus is composed of calcareous and noncalcareous Pink and Gray Tills, Peat, and a till-fill to control the discharge from Nero Lake into Beaverlodge Lake. The Gravel and Fractured Bedrock unit is believed to occur between bedrock and Pink Till and may constitute a permeable path for discharge of water from Nero Lake into Beaverlodge Lake. The carbonate in the tills has the potential of neutralizing the acidic groundwater passing through the isthmus.

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## INTRODUCTION

### 1.1 Objective

The objectives of this study are to provide a geological framework of the Quaternary deposits of the Lorado Mill area and to examine the stratigraphy of the Lorado Tailings Pile. This geologic investigation is part of a larger interdisciplinary study being conducted by the Saskatchewan Research Council for Environment Saskatchewan on the environmental impact of the Lorado Tailings Pile. The bedrock geology is being investigated by Kermeen J.S. Consulting Geological Engineer Ltd. A separate report will be prepared on the bedrock geology of part of the Lorado Mill area by this firm.

### 1.2 Location

The northern boundary of the Lorado Mill area is about 1 km south of Uranium City (Figs.1,2). The Lorado Tailings Pile and Nero - Beaverlodge Lakes Isthmus areas are shown in Figure 2.

### 1.3 Previous Work

A geologic reconnaissance of the Lorado Mill area was conducted by the Saskatchewan Research Council as part of their investigation of the Quaternary deposits of northern Saskatchewan. The location of their information in the Lorado Mill area is shown in Figure 2.

### 1.4 Present Study

Prior to beginning the field work, the Lorado Mill area was examined on June 5 to 8 by P. Machibroda and E.A. Christiansen, at which time all of the roads in the area were traversed and a study-proposal was drafted. From this reconnaissance, it was decided to focus

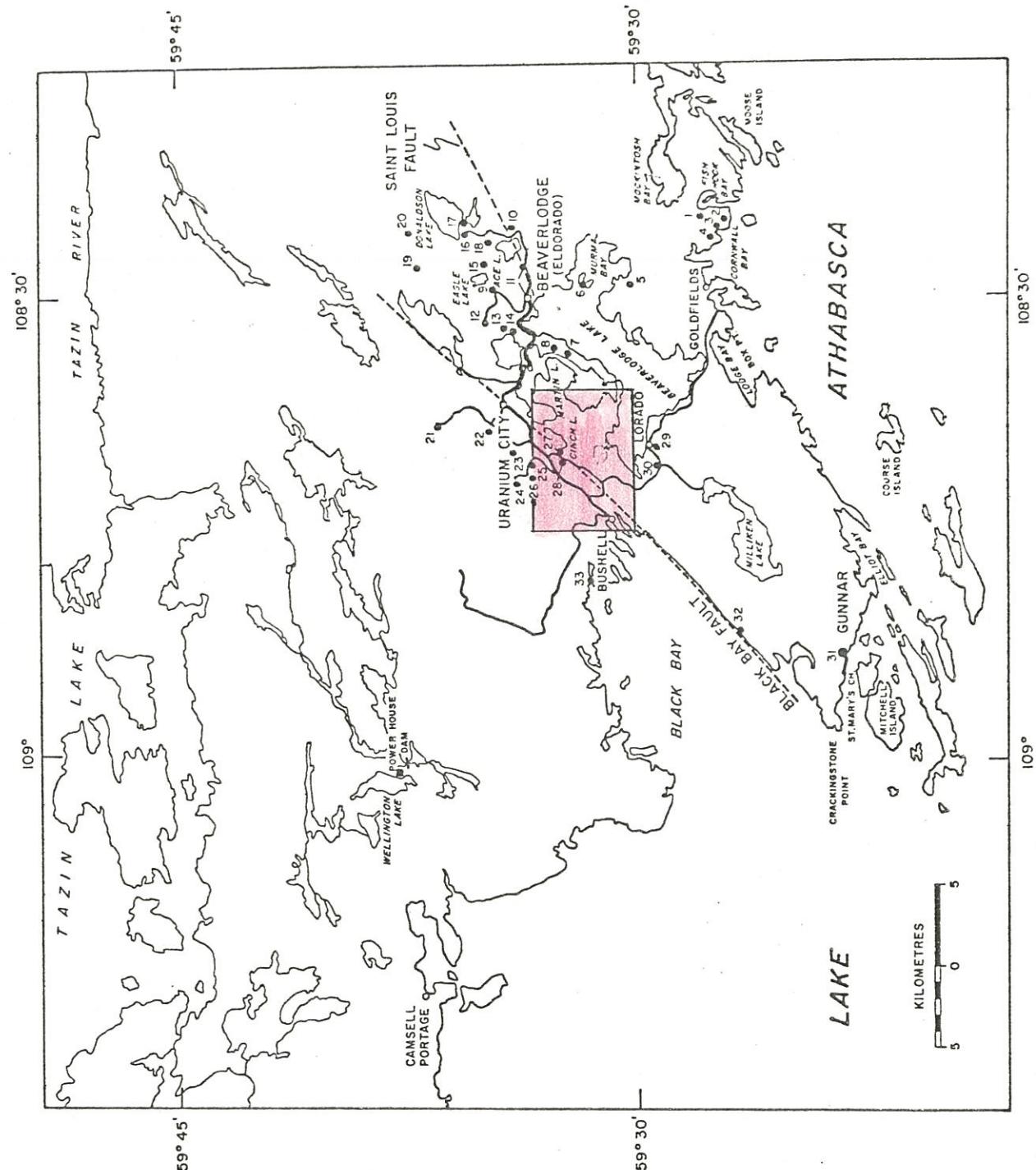


Figure 1. Location of Lorado Mill area.

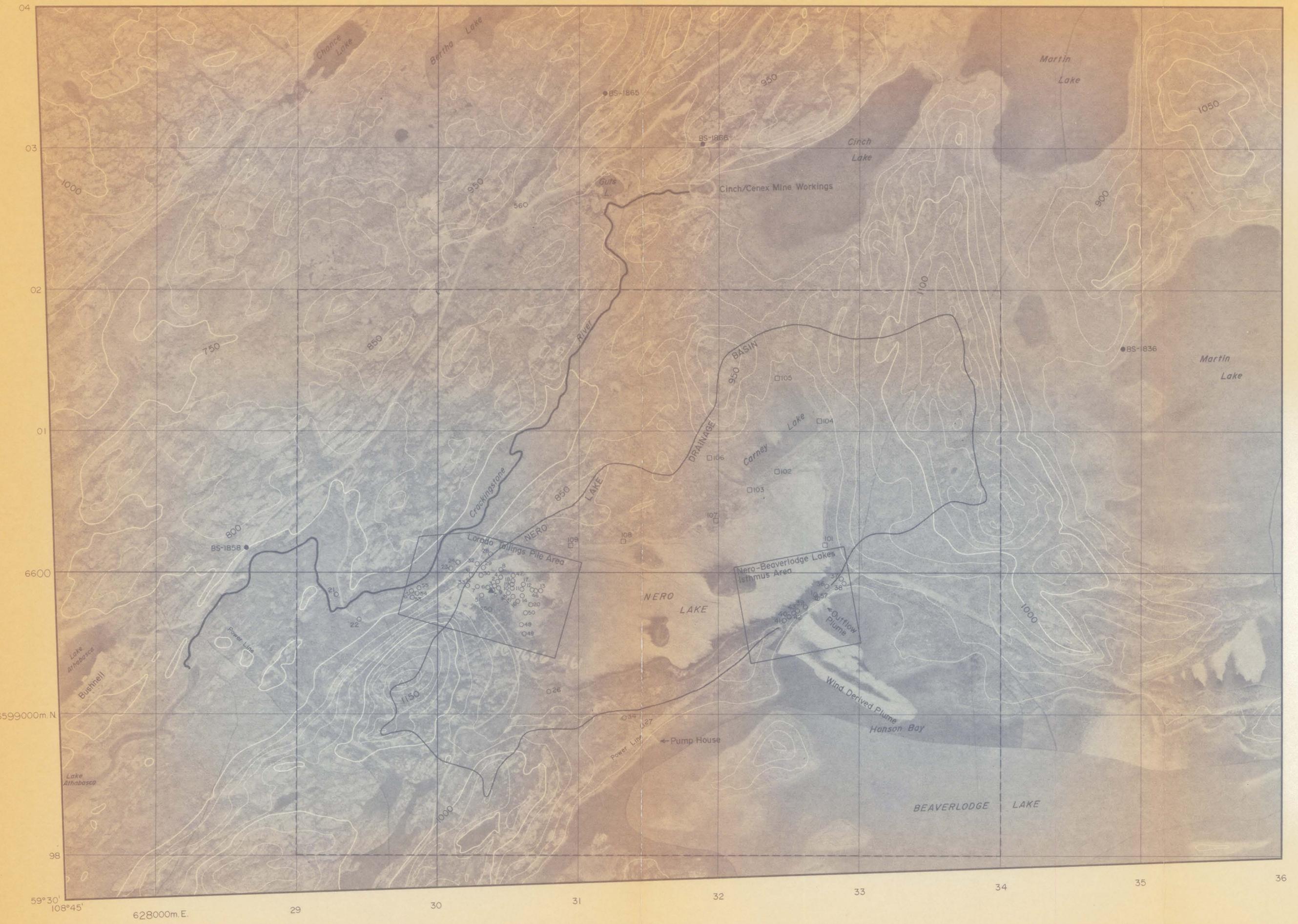


Figure 2. Index Map, Lorado Mill Area

EXPLANATION

- [Dashed Box] Bedrock geology map boundary, Appendix 2
- 50 Borehole
- 105 □ Test pit
- SRC Geology overburden sample site
- △ Water quality and lake level monitoring site
- ▲ Groundwater level monitoring

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Contours from Dept. of Energy, Mines, and Resources, Ottawa  
Compiled by Saskatchewan Research Council

the field work on the Lorado Tailings Pile and the Nero-Beaverlodge Lakes Isthmus areas (Fig. 2). It was also decided to conduct a stratigraphic reconnaissance of the Nero Lake Drainage Basin by drilling boreholes where access permitted and test pits where access did not permit the use of mounted drilling equipment.

During the field study, 56 borehole sites were drilled (Appendix 1), and 9 test pits were dug (Appendix 2). The boreholes were drilled, sampled, and geophysically logged and the test pits were dug by P. Machibroda Engineering Ltd. who provided E.A. Christiansen Consulting Ltd. with borehole samples and field logs compiled by an engineer.

Most of the samples were obtained from continuous auger flights (Fig. 3) which were tripped out-of-the hole at one to one half metre intervals. The remaining samples were taken with shelby tubes, hand augers, hand samples from exposures and test pits, and as cutting samples from drilling fluid (Appendices 1,2). The test pits were dug by P. Machiborda Engineering Ltd. and sampled by E.A. Christiansen Consulting Ltd. (Figs. 4,5).

The dried samples were examined by E.A. Christiansen Consulting Ltd. with the aid of dilute HCL, a Munsell Color Chart, and a hand lens. Based on this description, field logs, and geophysical logs, the geological logs were compiled (Appendices 1,2). Samples from Borehole 5 (Appendix 1) were submitted for grain size analyses.

On the basis of this subsurface information, four maps (Drawings 0071-001-01-03,09) and six cross sections (Drawings 0071-001-04-08,10) were constructed.. The water quality of the tailings pile, Nero Lake, the Isthmus, and Beaverlodge Lake is discussed in the Machibroda Report.

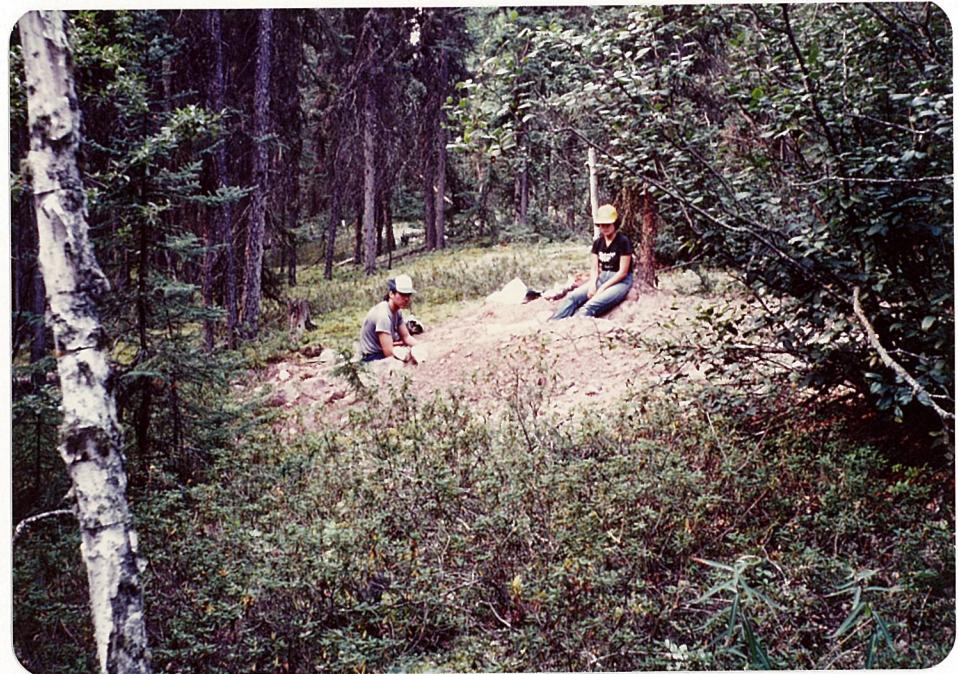


A



B

Figure 3. Sampling: (A) Engineer taking sample from continuous auger flight and (B) tailings overlying peat deposits, contact at 1.6 m.



A



B

Figure 4. Test pit 102 (Appendix 2) in Pink Till.



A



B

Figure 5. Test pit 106 (Appendix 2) in Gray Till.

## 2. STRATIGRAPHY OF QUATERNARY DEPOSITS

### 2.1 Introduction

The Quaternary deposits in the Lorado Mill area rest on glacially eroded Precambrian bedrock (Drawing 0071-001-01, 04-08,10) as indicated by glacial striae and roche moutonnee on bedrock outcrops. In augerholes, the bedrock surface was inferred from the nature of drilling. If the auger turned smoothly without penetrating, the depth was taken as the bedrock surface. If, on the other hand, the auger turned roughly with little or no penetrating, the material was interpreted as gravel. A more detailed discussion of the bedrock is included in the Kermeen Report. The Quaternary deposits in ascending order are: Pink Till, Lower Gray Silt, Gray Till, Upper Gray Silt, and Postglacial Silt.

### 2.2 Pink Till

The Pink Till (Fig. 4) is composed of pinkish gray, reddish gray, and reddish brown till, sand, and gravel (Drawings 0071-001-04-08,10; Appendices 1,2). The Pink Till is both calcareous and noncalcareous (Drawing 0071-001-10). The gravel is believed to represent transported material and fractured rock forming a transition from bedrock to till (Drawing 0071-001-10, Borehole 1). Potential sources of carbonates in the Pink Till include the Lower Arkose and amygdalites in the Martin Formation and limestone and dolomite in the Murmac Bay Formation (Tremblay, 1972).

### 2.3 Lower Gray Silt

The Lower Gray Silt is patchy but extensive in the Lorado Mill area. The silt is light gray to white, noncalcareous and has the appearance of rock flour. In Borehole 21 (Fig.2, Appendix 1), the Lower Gray Silt is composed of 8 m of massive silt and laminated silt and clay. The Lower Gray Silt is firm and appears to be overconsolidated (Drawings 0071-001-04,05,07).

The Lower Gray Silt is glacio-lacustrine in origin and was presumably deposited in glacial Lake Athabasca which rose to about 1000 feet (300 m) or about 300 feet (90 m) above the present lake level during the last deglaciation. This former level is indicated by beaches and delta deposits. The Lower Gray Silt is interpreted as rock flour derived from glacial erosion of the grayer Precambrian rocks which surrounded the Martin and Murmac Formations.

2.4 Gray Till

The Gray Till (Fig. 5) is composed of 0 to 3 m of gray to white, noncalcareous silty, till (Drawings 0071-001-04,05,07). Locally, the Gray Till is composed almost entirely of silt with a few floating sand grains and small pebbles and can be distinguished from the underlying silt only on the basis of this float (Appendix 1, Borehole 6).

This great resemblance of the Gray Till with the underlying Lower Gray Silt suggests the former till is derived from the latter silt.

2.5 Upper Gray Silt

The Upper Gray Silt is restricted to the Crackingstone River Valley (Appendix 1, Borehole 21). Here the Upper Gray Silt is composed of 1.1 m of white, noncalcareous silt. This silt represents the last glacio-lacustrine deposition in glacial Lake Athabasca in the Lorado Mill area and ended glacial sedimentation in the area.

## 2.6 Postglacial Silt

Postglacial Silt is composed of 0 to 2 m of gray, noncalcareous, carbonaceous silt (Appendix 1, Boreholes 4,8; Drawings 0071-001-04, 07) and olive gray, calcareous, fossiliferous silt (Appendix 1, Bore-hole 2). The Postglacial Silt, encountered during this study, is restricted to a pond deposit (Fig. 6A) which was partly filled with tailings (Fig. 6B). Both snail and clam shells are abundant in the fossiliferous silt. The pond in Figure 6A existed since the last deglaciation and, undoubtedly, owes its origin in part to the bedrock depression which underlies it (Drawings 007-001-04,07).

## 2.7 Peat

The Peat unit is composed of up to 50 cm of peat, muck, roots, etc. The Peat is missing in the pond deposit (Fig. 6A) and on bedrock subcrops and outcrops (Drawing 0071-001-04-08).

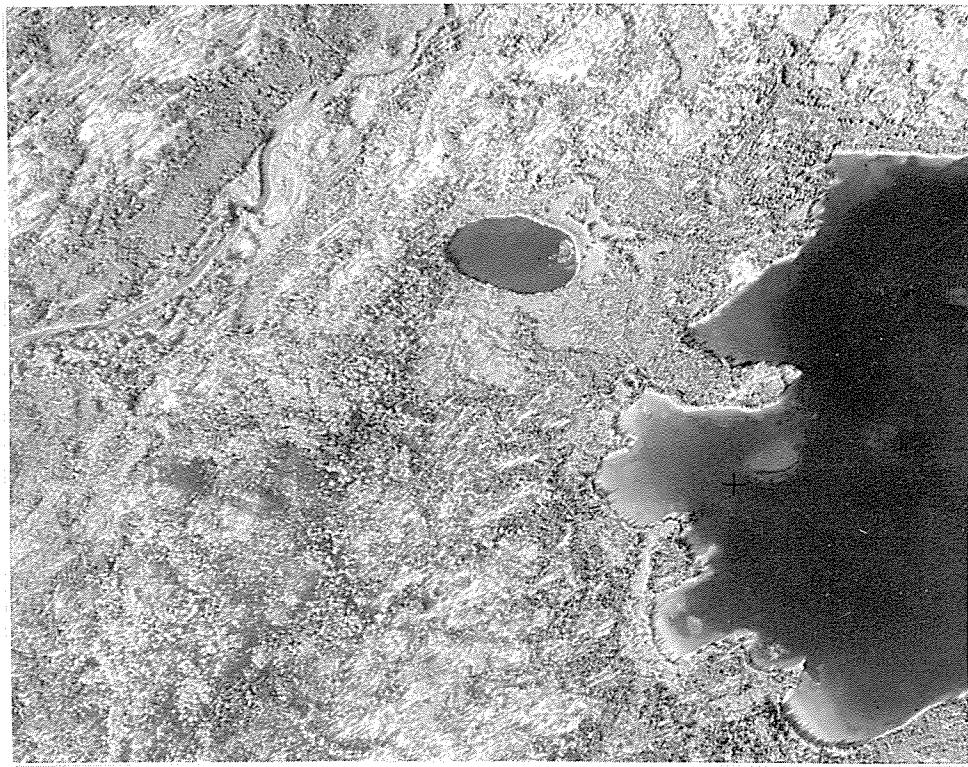
# 3. STRATIGRAPHY OF THE LORADO TAILINGS PILE

## 3.1 Introduction

The Lorado Tailings Pile (Figs. 6B,7,8) extends from southeast of the Lorado Mill to under Nero Lake (Drawings 0071-001-03,04,05), a distance of more than 600 m. The pile ranges in width from about 200 to 400 m (Drawings 0071-001-03,07,08).

## 3.2 Lithology

The base of the Lorado Tailings Pile is marked by peat and organic soils which represent the original surface (Drawing 0071-001-02). This surface shows a depression under the pond in the western part of the pile, a topographically high area in the central part, and a gradual slope toward Nero Lake (Drawing 0071-001-02).



A



B

Figure 6. Lorado Tailings Pile area before (A) and after (B) deposition of tailings. The pond (A), in which the Postglacial Silt was encountered in boreholes, is partly filled with tailings (B).



Figure 7. Oblique photograph showing Lorado Tailings Pile, Lorado Mill, Nero Lake, Carney Lake to the left, and Martin Lake in upper right corner. Photo by Hart Horn-Johnson.



A



B

Figure 8. Lorado Tailings Pile: (A) looking toward Lorado Mill and (B) toward Nero Lake. Trestles indicate position of tailings slurry line.

The Lorado Tailings, which are up to 3.9 m thick (Drawing 0071-001-03), are composed of lower silt and upper sand deposits (Drawings 0071-001-04,05,07). The lower silt deposits, which are up to 2 m thick, occur in the pond area (Drawings 0071-001-04,07), toward Nero Lake (Drawings 0071-001-04,05), and at Borehole 5 (Drawings 0071-001-05,07). The lower silt is composed of gray and dark gray, noncalcareous silt which becomes sandy in the upper part of the unit.

The upper sand unit in the Lorado Tailings, which is up to 3.5 m thick, is composed of brown, gray, dark gray, red, and olive, very fine - to medium-grained angular sand which is locally pyritiferous. The tailings commonly grade from very fine-grained sand at the base to medium-grained sand in the upper part.

The upper 0.1 to 2.2 m of the upper sand unit exhibits a yellow staining which is interpreted as a criterion for oxidation. The sands on the surface of the tailings are commonly cemented with yellowish brown iron oxide to form concretions (Fig. 9). The base of oxidized tailings is shown in the cross sections (Drawings 0071-001-04,05,07,08).

### 3.3 Origin

The Lorado Tailings Pile was formed by extending the slurry pipes toward Nero Lake during the milling operations (Fig. 8). As the tailings accumulated near the mill, the slurry pipe was extended eastward in segments as accumulation of tailings took place.

The medium sand, which is the coarsest fraction in the pile, was deposited in the vicinity of the slurry outlet with progressively



A



B

Figure 9. Sand cemented with iron oxide to form concretionary material.

finer-grained sand and silts being deposited eastward. When the slurry pipe was moved eastward, medium-grained sand was deposited on fine-grained sand, fine-grained sand on very fine-grained sand, very fine-grained sand on silt and so on. This method of constructing a tailings pile results in a decrease of grain size with depth. Because of this mode of origin the lower silt and upper sand units are time transgressive.

Because the sand in the upper sand unit becomes coarser grained upward, it follows that the highest permeability in the tailings pile is in its upper part where most of the lateral groundwater flow would be expected.

### 3.4 Geologic Factors Affecting the Lorado Tailings Pile

#### 3.4.1 Introduction

Since deposition, the Lorado Tailings Pile has been modified by fluvial and wave erosion, wind activity, and oxidation.

#### 3.4.2 Fluvial Erosion

Fluvial erosion of the Lorado Tailings Pile and accompanying deposition in Nero Lake is considerable (Fig. 10). According to Hart Horn-Johnson (personal communication, 1981), runoff from the tailings pile during a rainstorm was impressive. Because the permeability in the pile decreases with depth and the surface gradients are low, groundwater flow will be sluggish. Once the upper metre or so of unsaturated sand becomes saturated, most of any additional rain would run off causing considerable fluvial erosion.



A



B

Figure 10. Fluvial erosion: (A) erosion caused by runoff from pond area and (B) erosion of tailings and deposition in Nero Lake.

### 3.4.3 Wave Erosion

Wave-cut cliffs, up to 50 cm high, are being cut in the Lorado Tailings Pile by Nero Lake (Fig. 11). Although some tailings is being eroded by this method, it is minor compared to fluvial erosion.

### 3.4.4 Wind Activity

Wind erosion and deposition is taking place on the Lorado Tailings Pile (Fig. 12). Because the upper part of the pile is mostly medium-grained sand, most of the sand moves close to the ground by traction and saltation. Most of the wind-blown sand comes to rest in the lee side of topographically high areas. Some of the sand will be deflated from the pile into either Nero Lake or the surrounding bushland depending on the wind direction.

### 3.4.5 Oxidation

The upper 0.1 to 2.2 m of the subaerial part of the tailings pile is oxidized as indicated by a yellowish staining (Fig. 12; Drawings 0071-001-04,05,07,08). The depth of oxidation is governed by the elevation of the water table which in turn is governed by the level of Nero Lake. The upper part of the entire tailings pile above Nero Lake (Drawing 0071-001-03) is oxidized. The volume of oxidized tailings and the relationship of the depth of oxidation to the water table in the pile are dealt with in the Machibroda Report.



A



B

Figure 11. Wave - cut cliffs in Lorado Tailings Pile by Nero Lake.



A



B

Figure 12. Wind-blown sand: (A) Wind-blown sand being deposited in lee side of ridge and (B) exposure being filled with wind-blown sand.

#### 4. STRATIGRAPHY OF NERO-BEAVERLODGE LAKES ISTHMUS

##### 4.1 Introduction

The Nero-Beaverlodge Lakes Isthmus is a narrow neck of land lying between these lakes (Drawing 0071-001-10; Figs. 13-15). This Isthmus is the outlet for the Nero Lake Drainage Basin (Fig. 2). During construction of the dam-access road, a culvert was installed to conduct drainage from Nero Lake into Beaverlodge Lake. The nature of groundwater discharge from Nero Lake to Beaverlodge Lake will be discussed in the Machibroda Report.

The bedrock beneath the Isthmus is composed of up to 10 m of Gravel and Fractured Bedrock; calcareous, calcareous and sandy, and noncalcareous Pink Till; Gray Till; Peat; and Fill (Drawing 0071-Q01-09,10).

##### 4.2 Lithology

The Gravel and Fractured Bedrock is inferred from the drilling performance and the resistance log which shows an intermediate zone between bedrock and till. Such zones of disturbed bedrock between bedrock and till are common in glacial terrain .

The calcareous and noncalcareous Pink Tills, which are up to 8 m thick, are believed to be separated by a more sandy till (calcareous, sandy Pink Till). The sandy nature of this unit is suggested by the presence of sand in Borehole 39 and a higher electrical resistance in Boreholes 1 and 43 (Drawing 0071-001-10).

Although it was recognized the calcareous tills in the Isthmus area are potential buffering materials for the acidic Nero Lake water, budgetary restraints did not permit their quantification. It is recommended, therefore, the quantity and quality of carbonates in the Isthmus area be investigated.



A



B

Figure 13. Nero-Beaverlodge Lakes Isthmus: (A) Drilling Borehole 1 in dam-access road on Isthmus and (B) plume forming in Beaverlodge Lake where lagoon empties through lake rampart.



A



B

Figure 14. Nero and Beaverlodge Lakes: (A) Nero Lake looking toward Lorado Mill from Isthmus and (B) shoreline of Beaverlodge Lake along Isthmus. Indentation of shoreline in centre of photograph is location of Fig. 15B.



A



B

Figure 15. Nero-Beaverlodge Lakes Isthmus: (A) lagoon between dam-access road along Nero Lake and rampart along Beaverlodge Lake and (B) lagoon draining across rampart into Beaverlodge Lake. This is where plume originates in Fig. 13B.

The Gray Till is composed of 0 to 60 cm of silty, calcareous light gray to white till (Drawing 0071-001-10). Whether this till is equivalent to the noncalcareous, silty, light gray to white till elsewhere in the Lorado Mill area is not known. If these gray tills belong to the same stratigraphic unit, the glacier that deposited the calcareous Gray Till must have derived carbonates locally from a source other than the Lower Arkose because the pink color is totally missing in this till.

The peat which underlies the dam-access fill ranges in thickness from a few cm to 30 cm. The maximum thickness of fill penetrated is 1.7 m (Borehole 39, Drawing 0071-001-10).

4.3 Source

The pinkish and reddish color of the Pink Till indicates it is derived from the Martin Formation (Kermeneen Report). Potential sources of carbonates in the Pink Till include the Lower Arkose and amygdules in the Martin Formation and limestone and dolomite in the Murmac Bay Formation (Tremblay, 1972).

5. GEOLOGIC PROCESSES

5.1 Introduction

Glacial erosion was an important geologic process during glaciation, and permafrost has been an important process since glaciation.

## 5.2 Glacial Erosion

Glaciers erode, transport, and deposit material. Glacial striae and roche moutonnee attest to glacial erosion, and tills record direct glacial deposition. Glacial erosion occurred near the glacier margin where bedrock and glacial material were eroded and carried upward along diverging flowlines in the glacier (Fig. 16). Such erosion resulted in the formation of the upward-facing concave surfaces which were used as the model for many of the contacts shown in the cross sections.

Most of the relief in the Lorado Mill area is attributed to glacial erosion. The depressions such as the Nero Lake Basin and the basin on the bedrock surface under the western part of the Lorado Tailings Pile (Drawing 0071-001-01) are interpreted as ice-thrust depressions.

## 5.3 Permafrost

Permafrost is used herein as defined by Brown and Kupsch (1974) which states "The thermal condition in soil or rock of having below 0°C persist over at least two consecutive winters and the intervening summer".

Permafrost was encountered in all test pits dug through peat (Test pits 103;104, Fig. 17; 105, Fig. 18B; 107; 109). Any construction in areas of peat would probably encounter permafrost. Permafrost was not encountered in the remaining test pits where peat was absent.

Permafrost is also suggested by a mound with falling trees west of Guts Lake along the Crackingstone River (Fig. 18A). The mound is interpreted

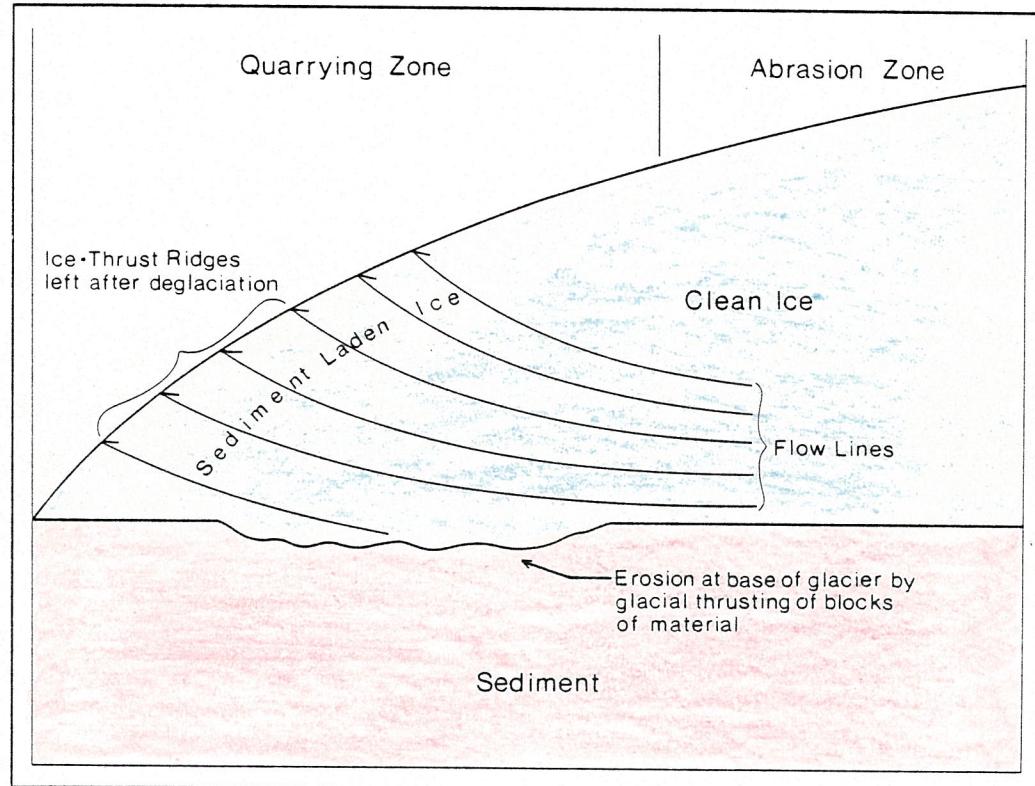


Figure 16. Schematic diagram showing the process of glacial erosion.



A

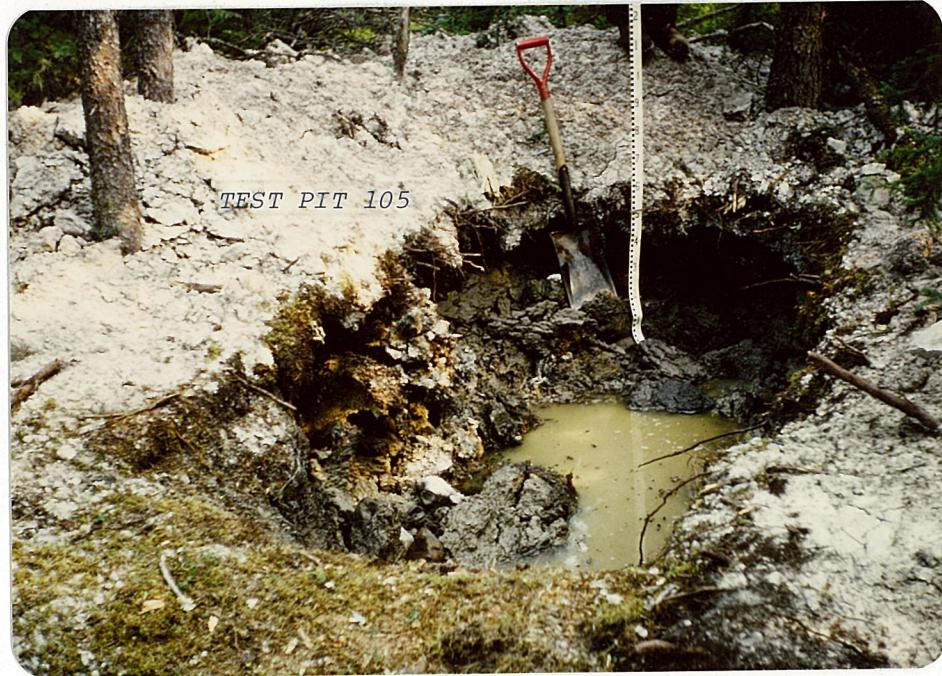


B

Figure 17. Test pit 104. (A) Test pit in peat supporting Labrador tea. (B) Test pit showing from surface 30 cm peat, 60 cm sand, 20 cm peat, and 10 cm sand over permafrost. The buried 20 cm of peat was radiocarbon dated at 7290 yrs. B.P. (S-2143, p.93).



A



B

Figure 18. Permafrost. (A) Palsa on far side of a pond west of Guts Lake along the Crackingstone River (Fig. 2). (B) Melted permafrost under 45 cm of Gray Till and 15 cm of peat. Permafrost melted during the weeks the test pit was open.

as a palsa which was defined by Brown and Kupsch (1974) as follows: A palsa -- "has a perennially frozen core which extends from within the covering peat layer downward into or toward the underlying mineral soil".

## 6. QUATERNARY HISTORY

### 6.1 Glacial History

The presence of Pink and Gray Tills indicates the Lorado Mill area was glaciated at least twice. The presence of calcareous and noncalcareous Pink Tills suggest: (1) more than one glaciation, changes in direction of ice movement, or changes in source because of glacial erosion. The lack of weathering on top of the Pink Till suggests the overlying Lower Gray Silt rest conformably on the Pink Till.

During the retreat of the glacier that deposited the uppermost Pink Till, Lake Athabasca inundated the Lorado Mill area up to about 300 m , and the Lower Gray Silt was deposited. This silt was covered by the Gray Till during a re-advance of the glacier from the west (Schreiner personal communication, 1981). During the retreat of this glacier, the Upper Gray Silt was deposited.

About 10,000 years ago during the last deglaciation, the ice front stood at the Cree Lake Moraine (Drawing 0071-001-11). According to radiocarbon dates in the Lorado Mill area (Appendix 3, Table 1), the glacier had retreated from the Lorado Mill area more than 7345 years ago (S-2142). If the postglacial sedimentation in this pond deposit (Lorado 8, Appendix 1, p.40; Drawing 0071-001-07) was uniform, then postglacial sedimentation may have commenced at least as early as about 8500 years ago or even as early as 9000 years ago as inferred by Prest (1970). It is concluded, therefore, the glacier which deposited the Gray Till and its associated Upper Gray Silt (Appendix 1, p. 53) left the Lorado Mill area about 8500 to 9000 years ago.

## 6.2 Postglacial History

According to the above synthesis of deglaciation, the postglacial history in the Lorado Mill area began about 8500 to 9000 years ago. This entire history prior to the deposition of the Lorado Tailings Pile was recorded in a pond deposit (Fig. 6A, Drawing 0071-001-07). Two radiocarbon dates (Table 1, S-2141, 2142), indicate postglacial sedimentation began at least as early as 7345 (S-2142) years ago and was continuing 5965 (S-2141) years ago. In Test Pit Lorado 104 (Appendix 1, p.93), 20 cm of peat, which was radiocarbon dated at 7190 years B.P. (S-2143), is overlain by 60 cm of medium-grained brownish-gray sand. This sand represents either outwash or alluvium. The radiocarbon date, however, which is younger than the older date in the Postglacial Silt (S-2142), suggests the sand is alluvium as a result of postglacial erosion. Except for peat accumulation and postglacial sedimentation in ponds and lakes, there has been little geological activity in the Lorado Mill area since the last withdrawal of the glacier and the final draining of Lake Athabasca from the Lorado Mill area.

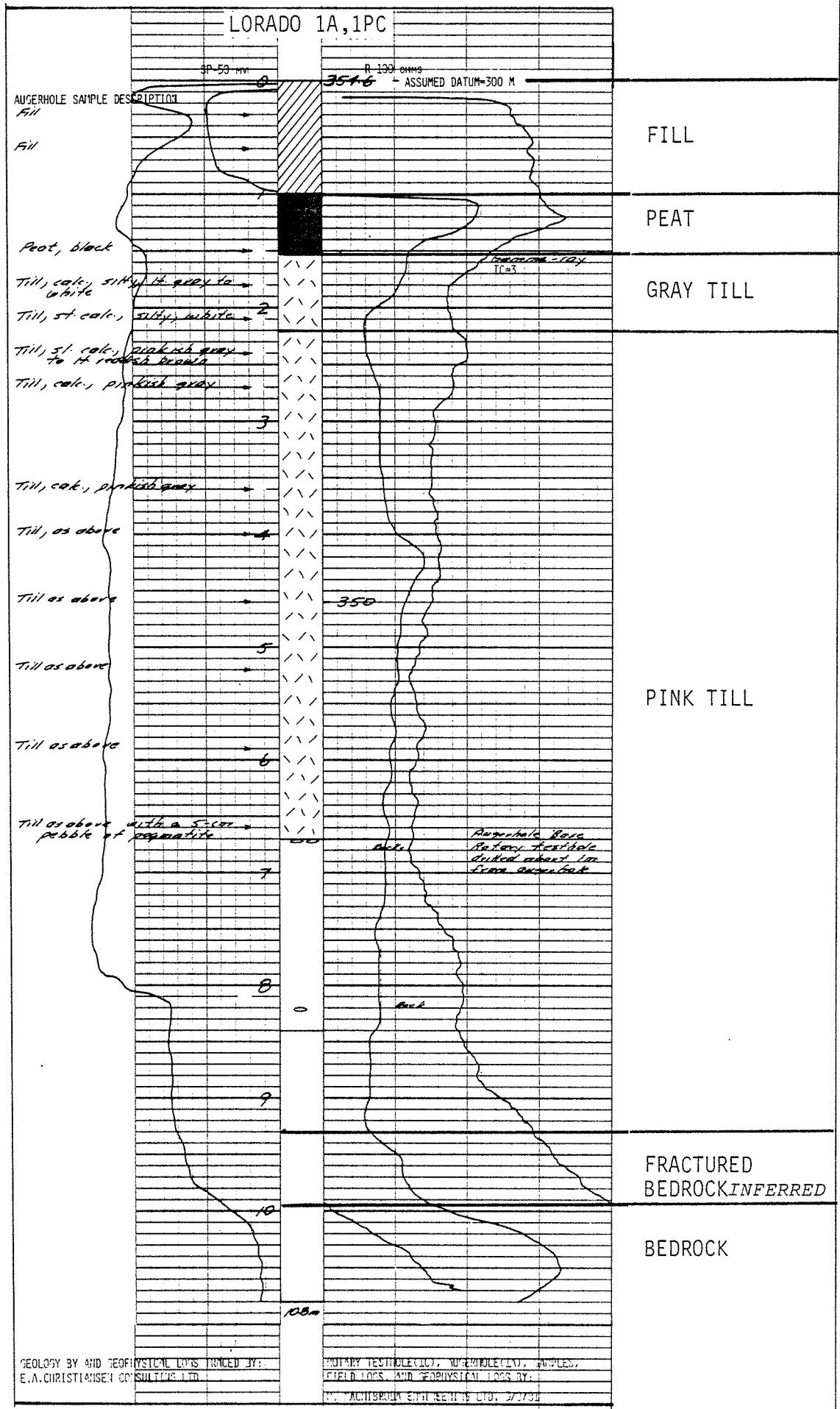
## 7. LITERATURE CITED

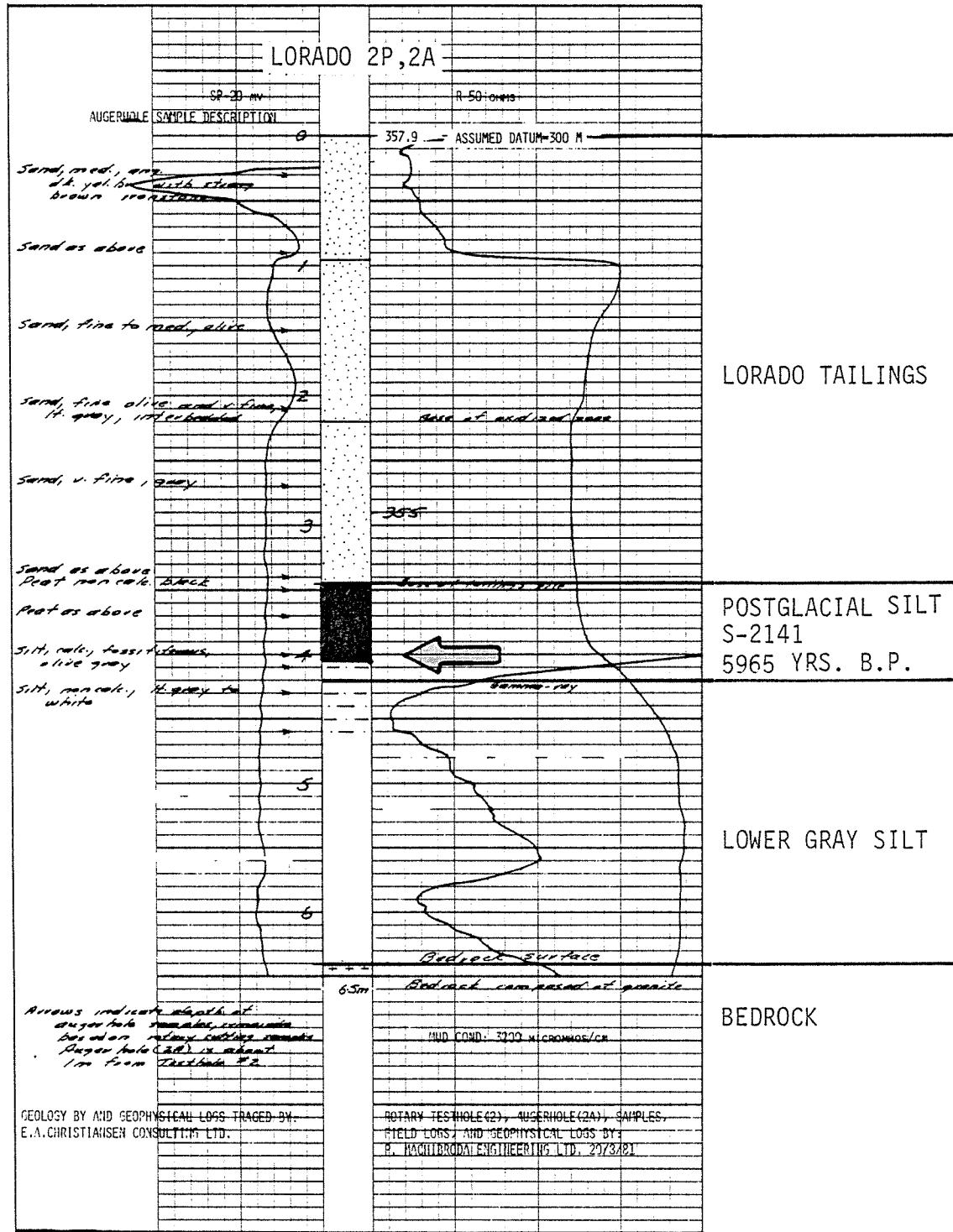
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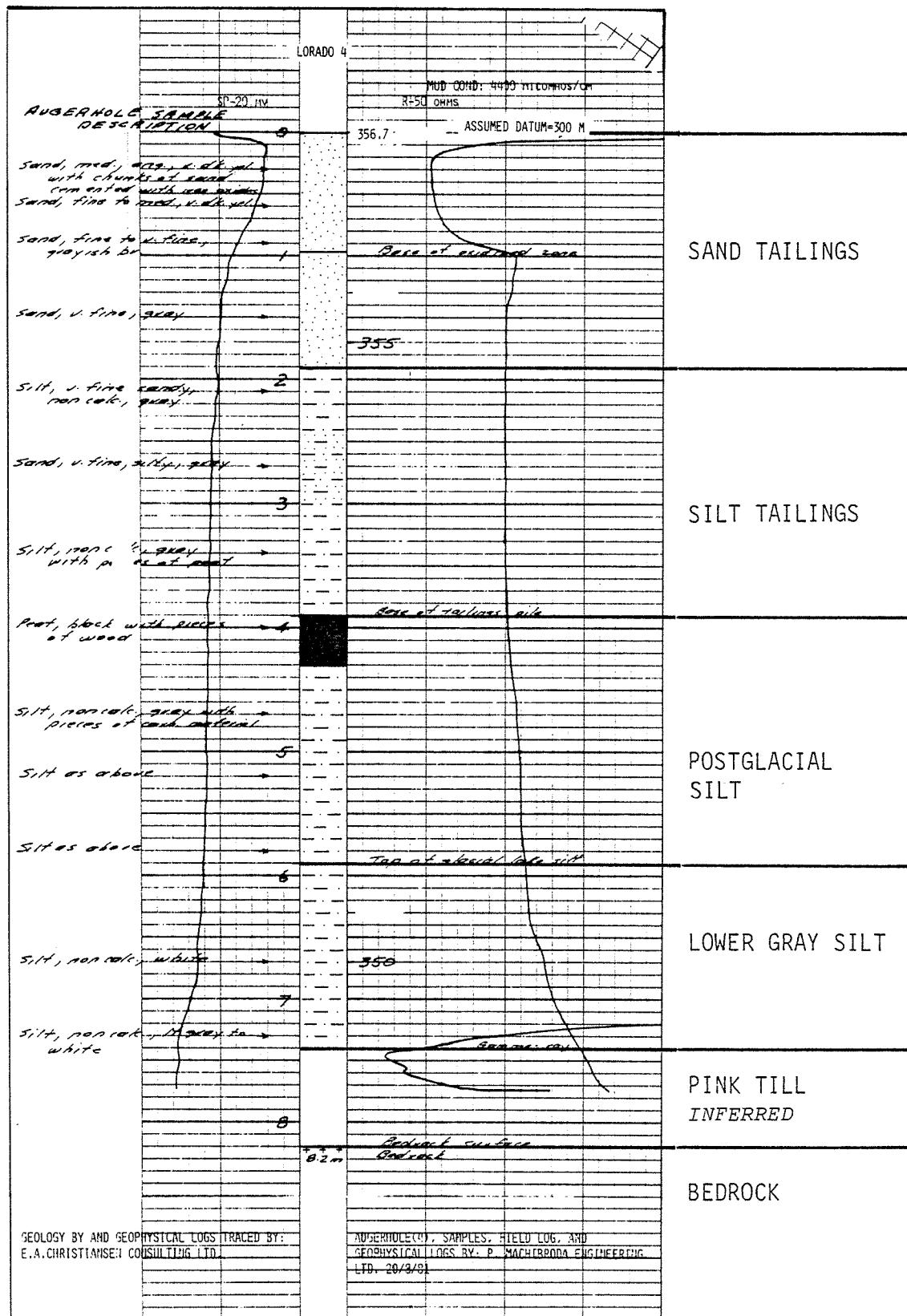
Appendix 1. Geologic logs from boreholes in the Lorado Mill area.

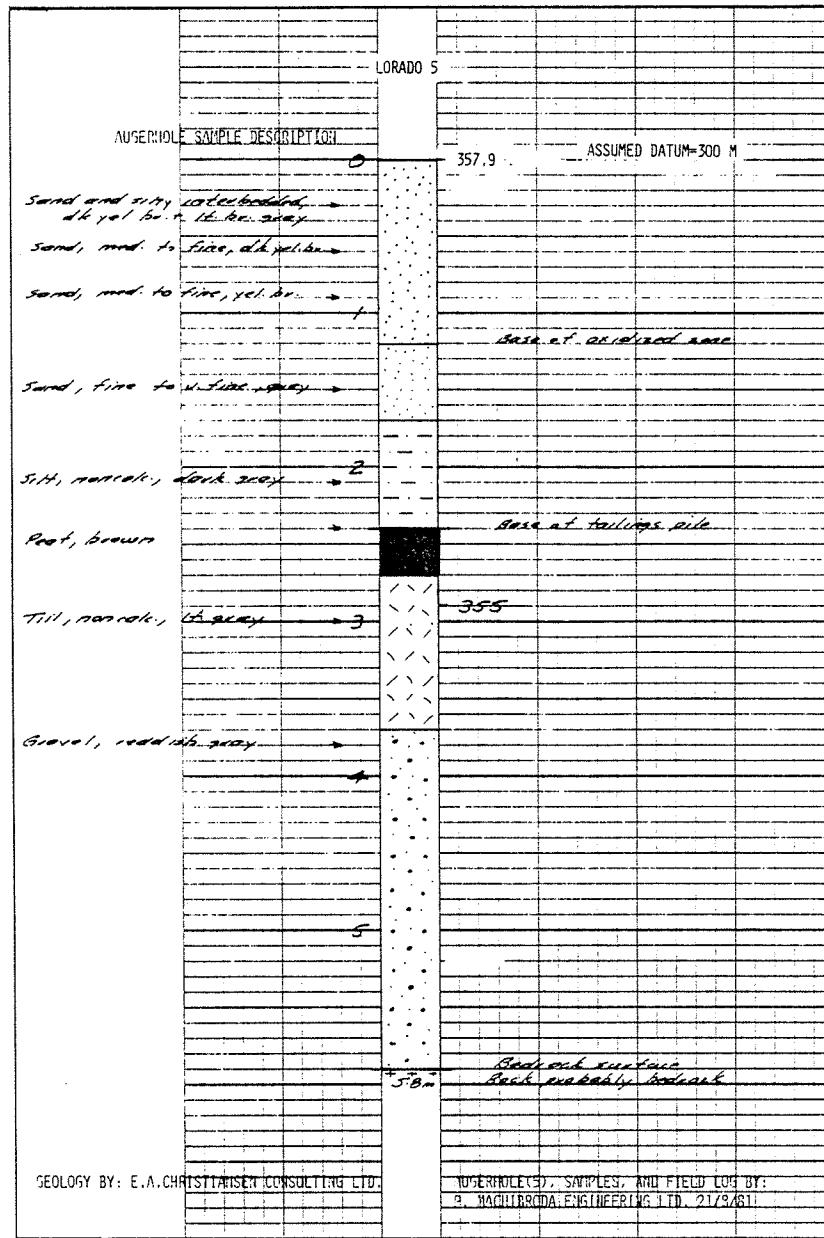
- NOTE
1. LOGS NOT AVAILABLE FOR BOREHOLES 35 AND 51.
  2. BOREHOLES AT A PARTICULAR SITE ARE ESTIMATED TO BE WITHIN A DIAMETER OF 2 METRES.



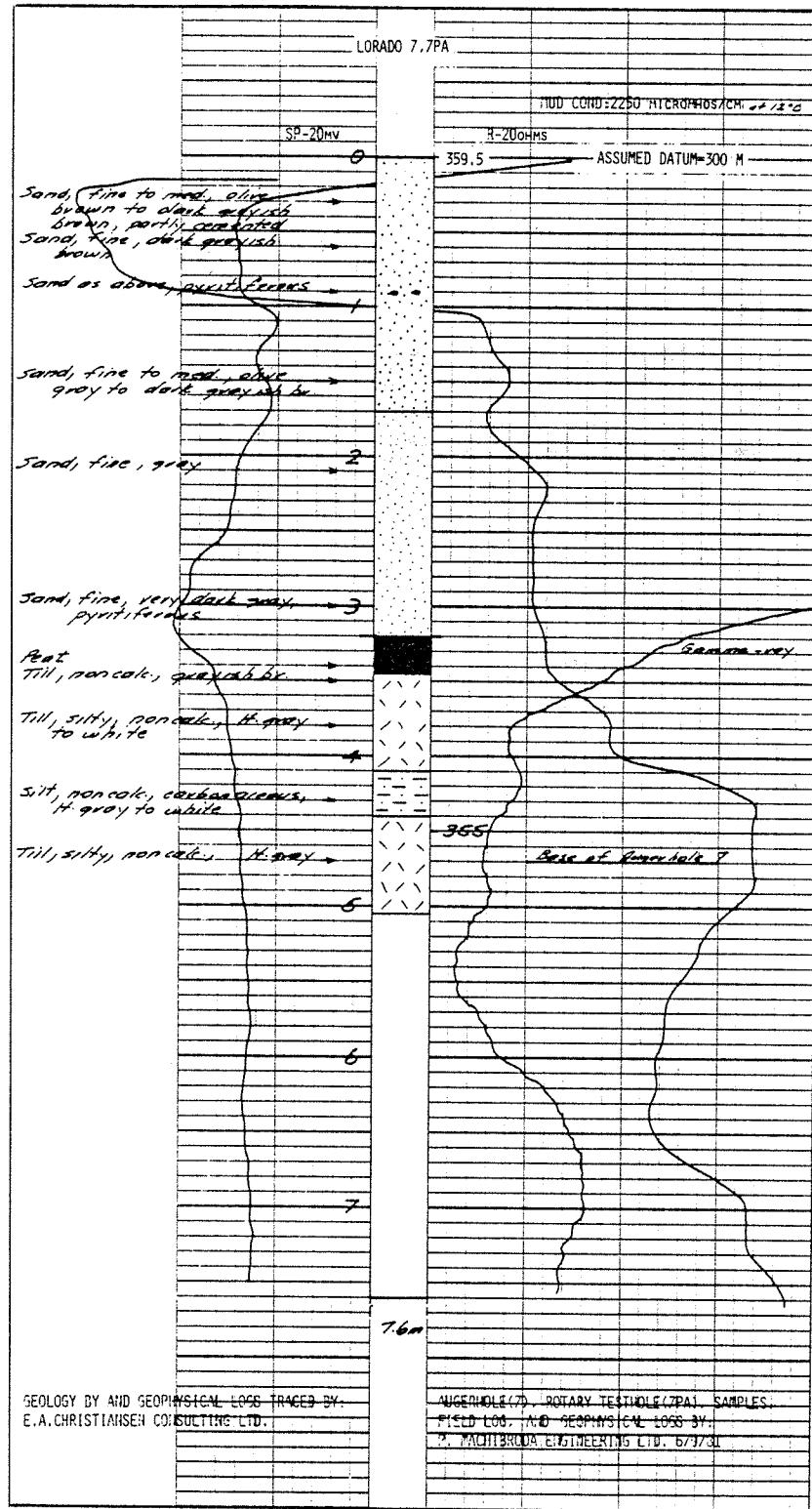


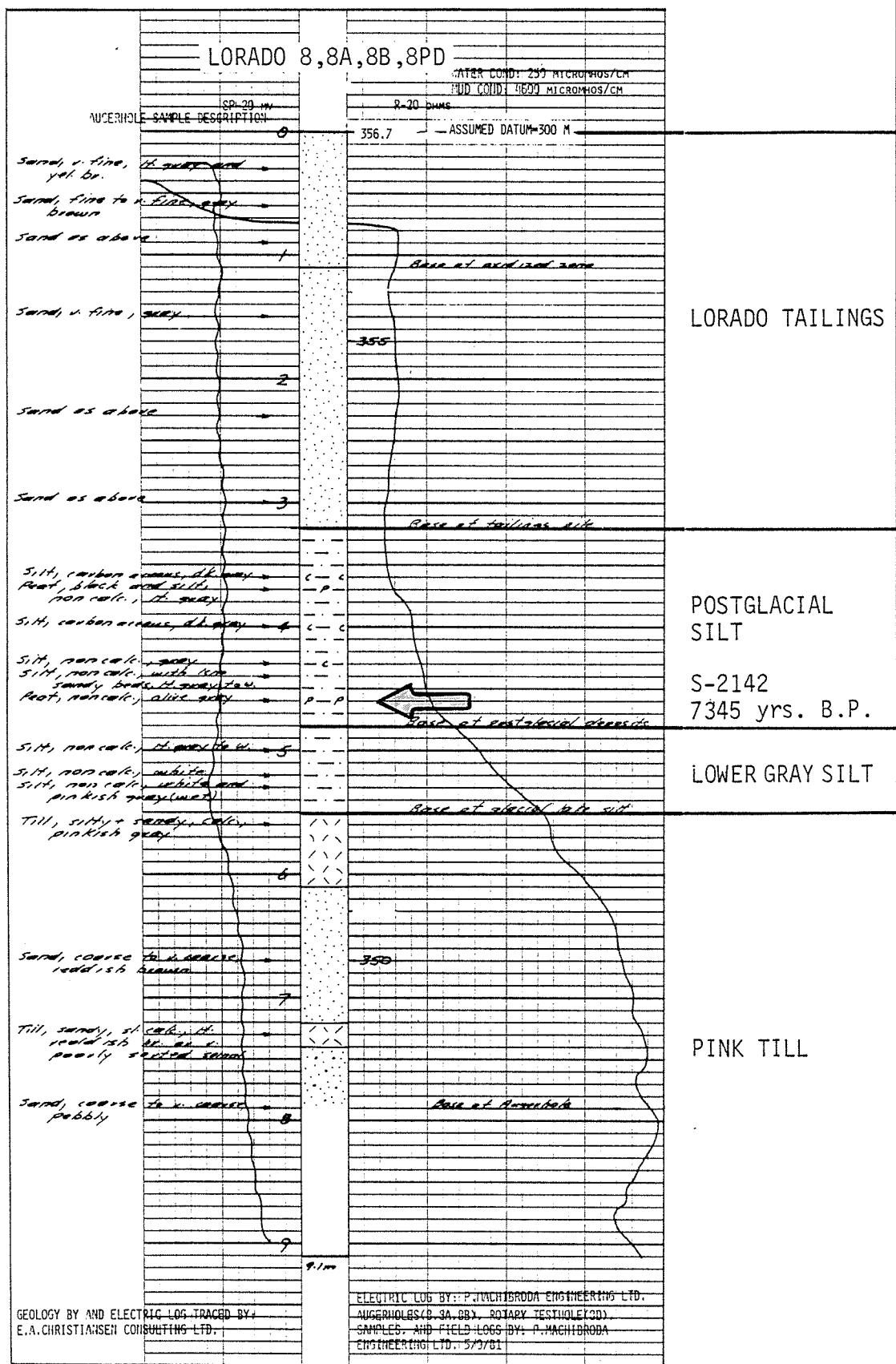
AUGERHOLE SAMPLE DESCRIPTION	0	357.2	-- ASSUMED DATUM=300 M.
Sand, firm to soft, mainly fine rounded to silt reddish brown			
Sand, firm and yellow, olive to odd grey, interbedded	1		Base of oxidized zone
Sand, firm to soft, grey			
Sand, v. firm, yellow to grey			Base of ferruginous zone
Carbonaceous material composed of mass, rootlets etc	2		355
Carbonaceous material, mainly wood			Top of glacial lake silt
Silt, non calc., lt grey to white	3		
Silt as above			
Silt, non calc., white	4		
Silt, non calc., white with lt br. gray laminae	5		Bedrock surface
GEOLOGY BY: E.A.CHRISTIANSEN CONSULTING LTD.			AUGERHOLES 13-3A). SAMPLES, AND FIELD LOGS BY: P. MACHIBRODA ENGINEERING LTD. 25/8/81

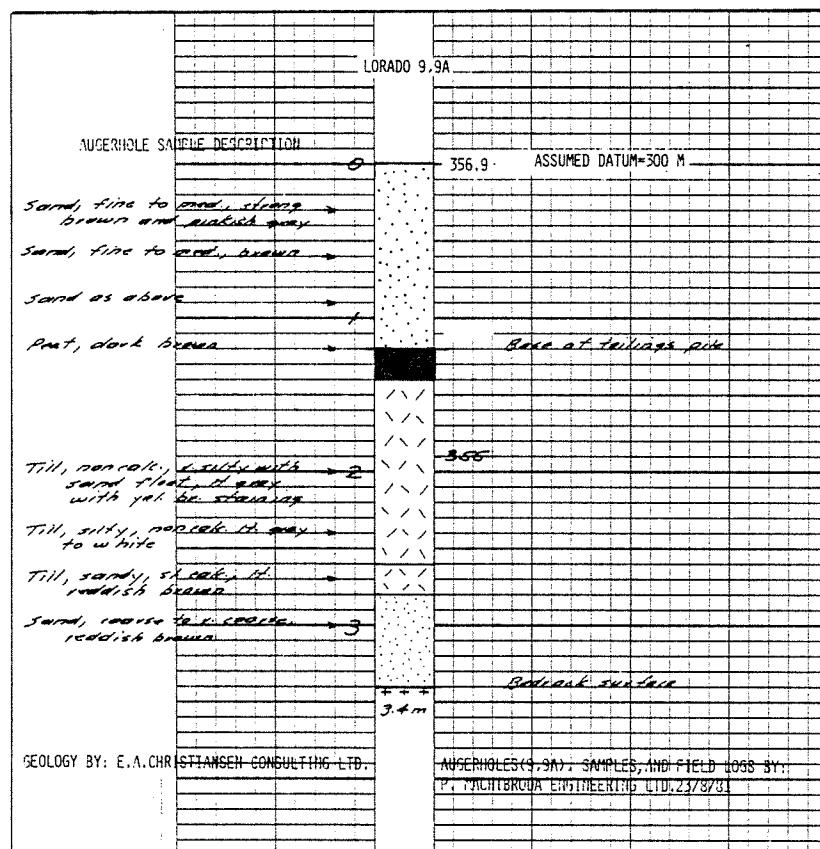


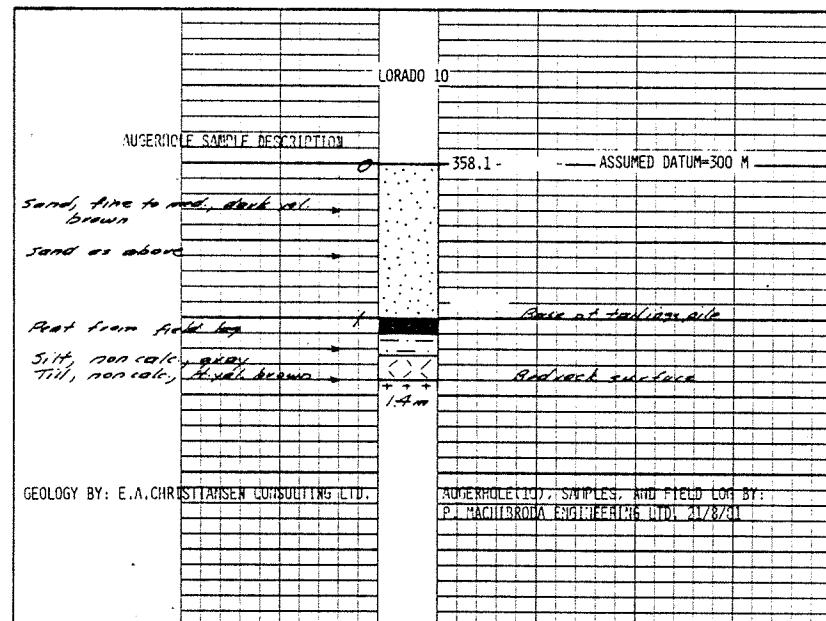


AUGERHOLE SAMPLE DESCRIPTION		LORADO 6	
		357.3	ASSUMED DATUM=300 M
Sand, med. to coarse, dark yellowish brown	→		
Sand, fine, dark greyish brown	→		
Sand, fine to v. fine grey	→		
Sand, v. fine, grey to dark grey, dark brown	→		
Peat, dark brown	→		
	2		
Silt, non calc., bl. grey, mixed	→	355	
sand float			
Silt with Plant material	→		
	3		
			Base of sand sheet in silt
Silt, non calc., bl. grey	→		
Silt, non calc., bl. grey to white	→		
Silt, non calc., bl. grey, and pinkish grey, calcerous	→		
Till, sl. calc., to calc., bl. reddish brown	→	111	
		46m	
GEOLOGY BY: E.A.CHRISTIANSEN CONSULTING LTD.			AUGERHOLE(6), SAMPLES, AND FIELD LOG BY: P. VIKTBRODA ENGINEERING LTD. 2/17/81

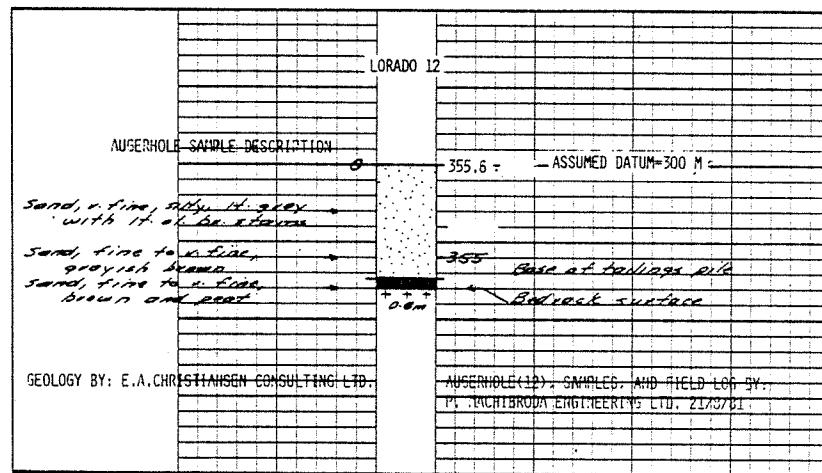




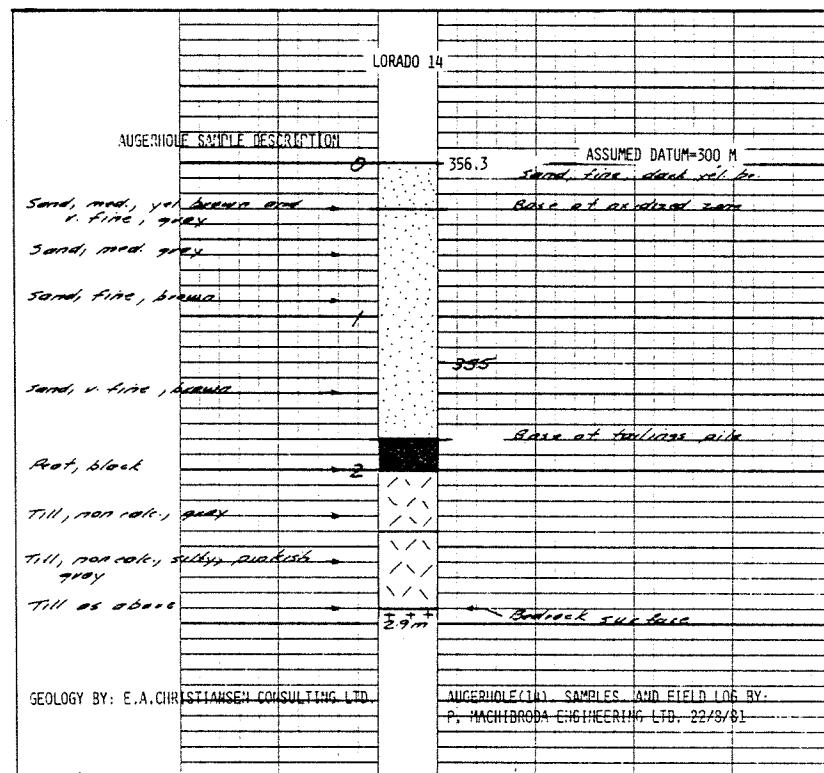


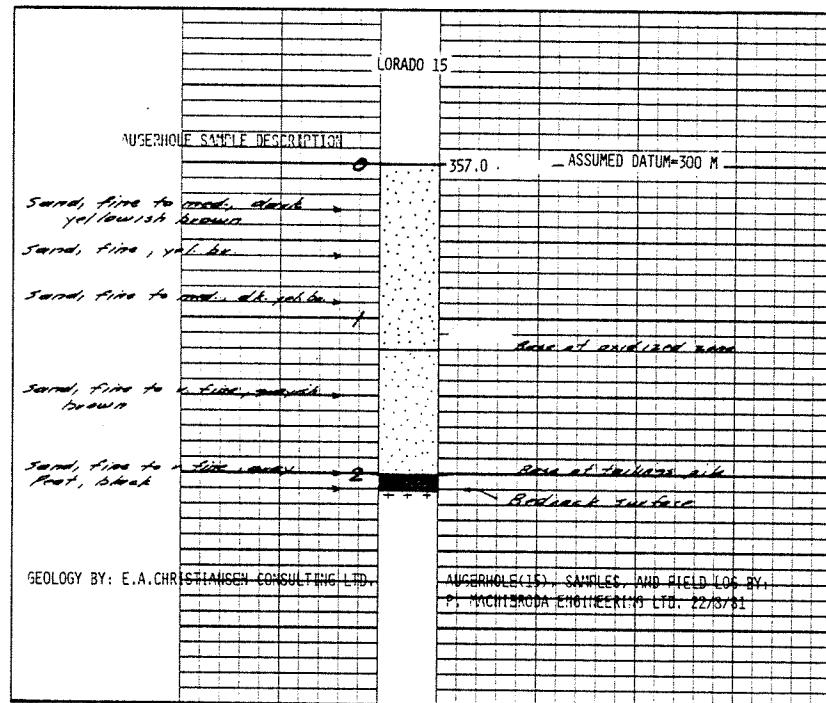


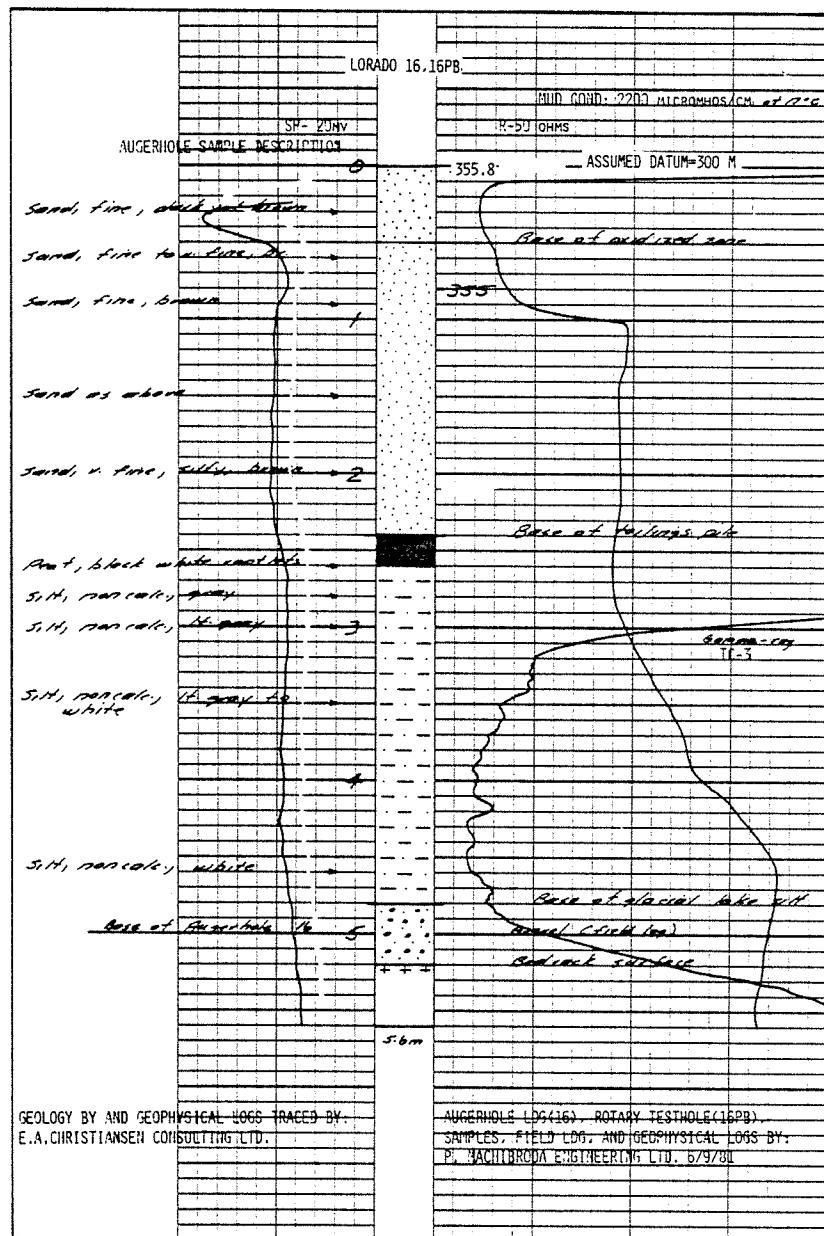
AUGERHOLE SAMPLE DESCRIPTION		LORADO 11	356.6	ASSUMED DATUM=300 M
Sandy fine to medium dark yellowish white cemented chunks				
Sand as above				base at tailings site
Root, dark green				
Silt, non calc., H grey with H yellow staining				red soil surface
Till, silty, H grey with olive brown staining			1.1m	
GEOLOGY BY: E.A.CHRISTIANSEN CONSULTING LTD.				AUGERHOLE(11), SAMPLES, AND FIELD LOG BY: P.J. NAGIBBROOK ENGINEERING LTD. 21/8/81

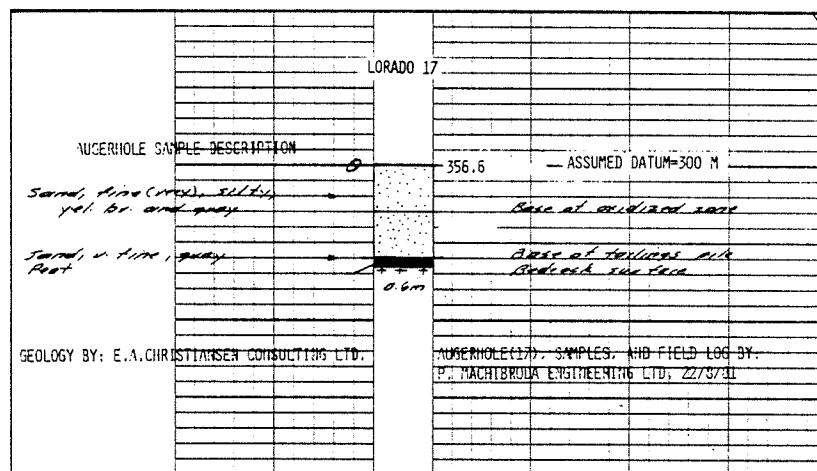


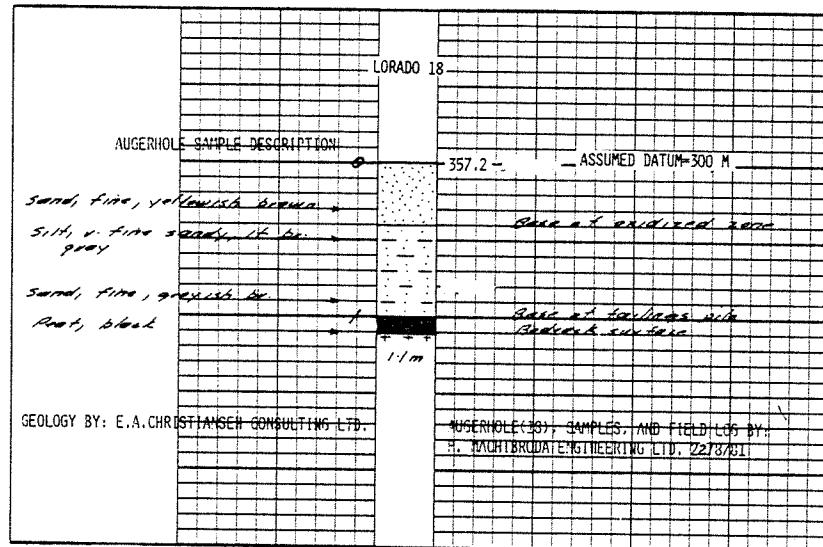
		LORADO 13			
AUGERHOLE SAMPLE DESCRIPTION		354.3	ASSUMED DATUM=500 M		
Sands fine, gray			Soil type variable		
Silt, non calc., gray			Base at oxidized zone		
Silt as above					
Sands silty, non calc., gray		2			
Till, silty, non calc., lt gray and white			Base at tillage pile		
Till, silty, non calc., white		29m			
GEOLOGY BY: E.A.CHRISTIANSEN CONSULTING LTD.			AUGERHOLE 13 SAMPLES AND FIELD LOG BY: P. HYDROGEA ENGINEERING LTD. 22/6/01		

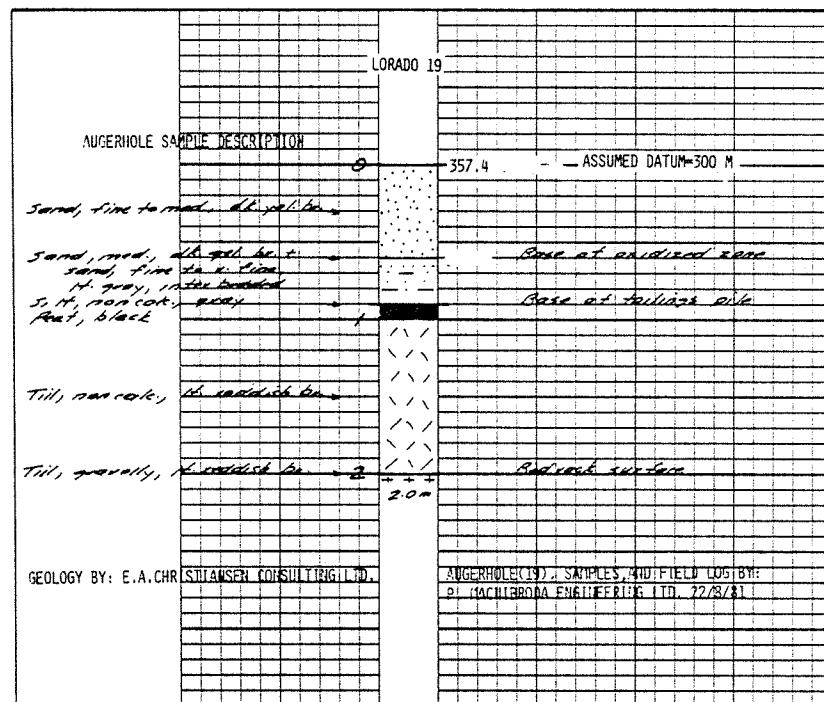




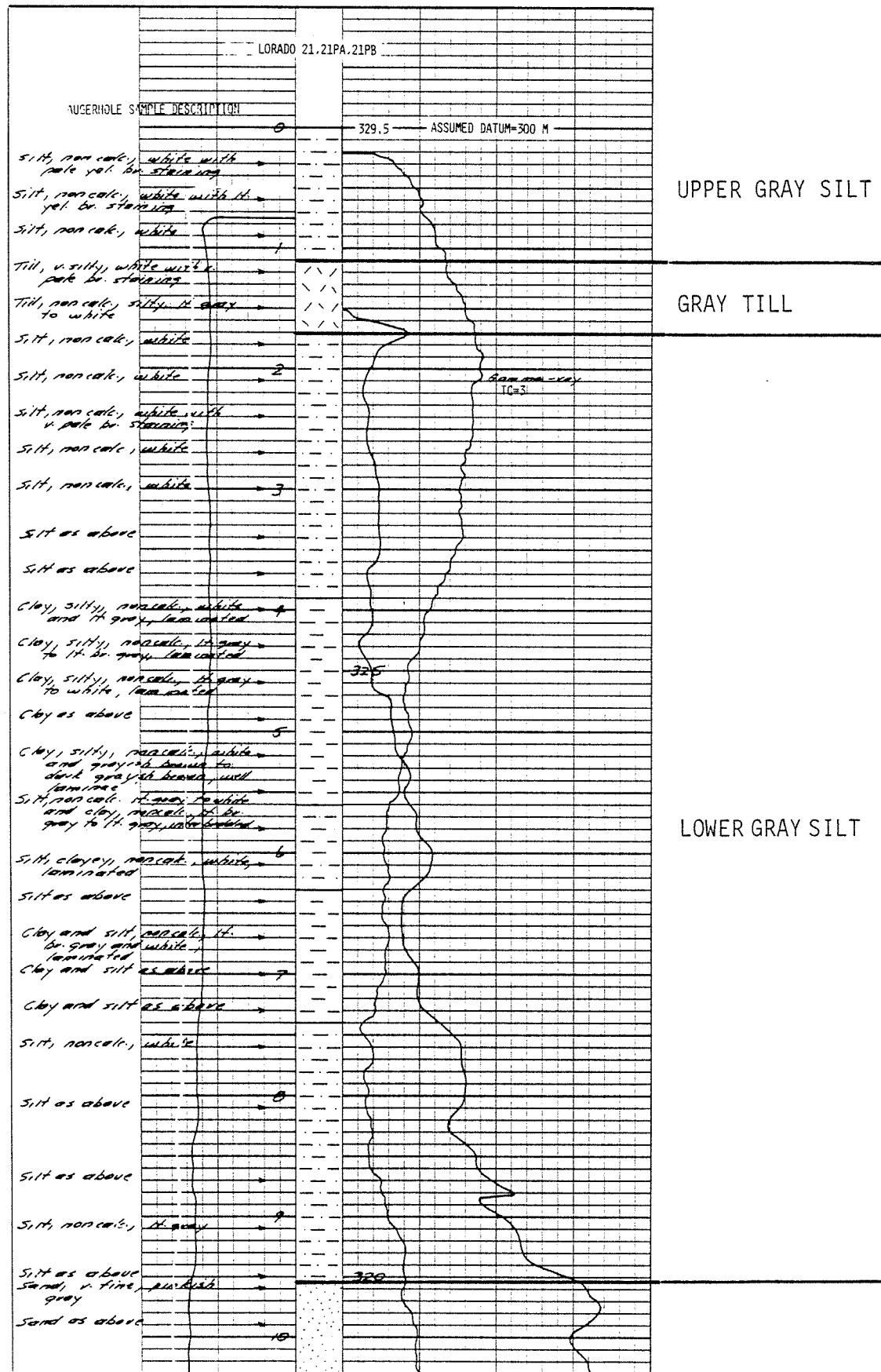


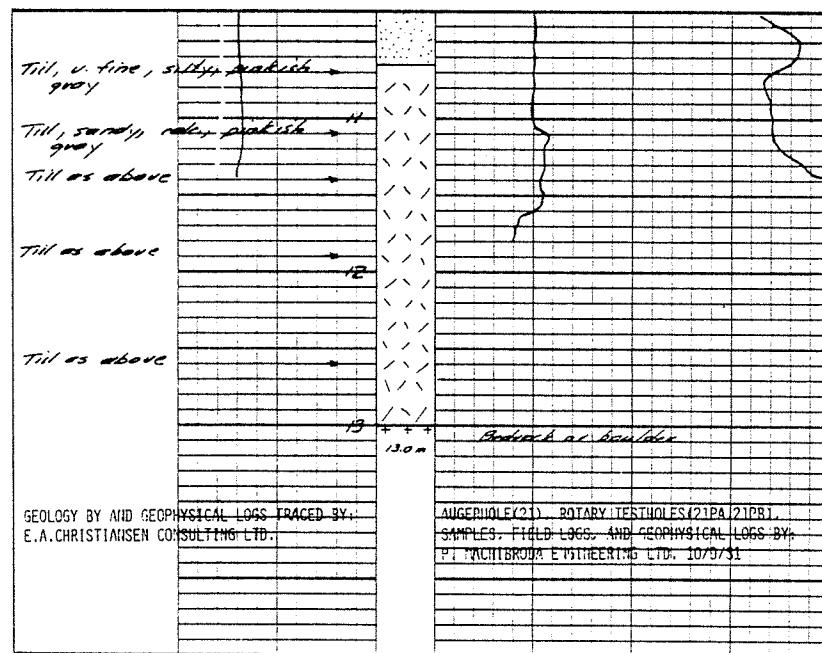


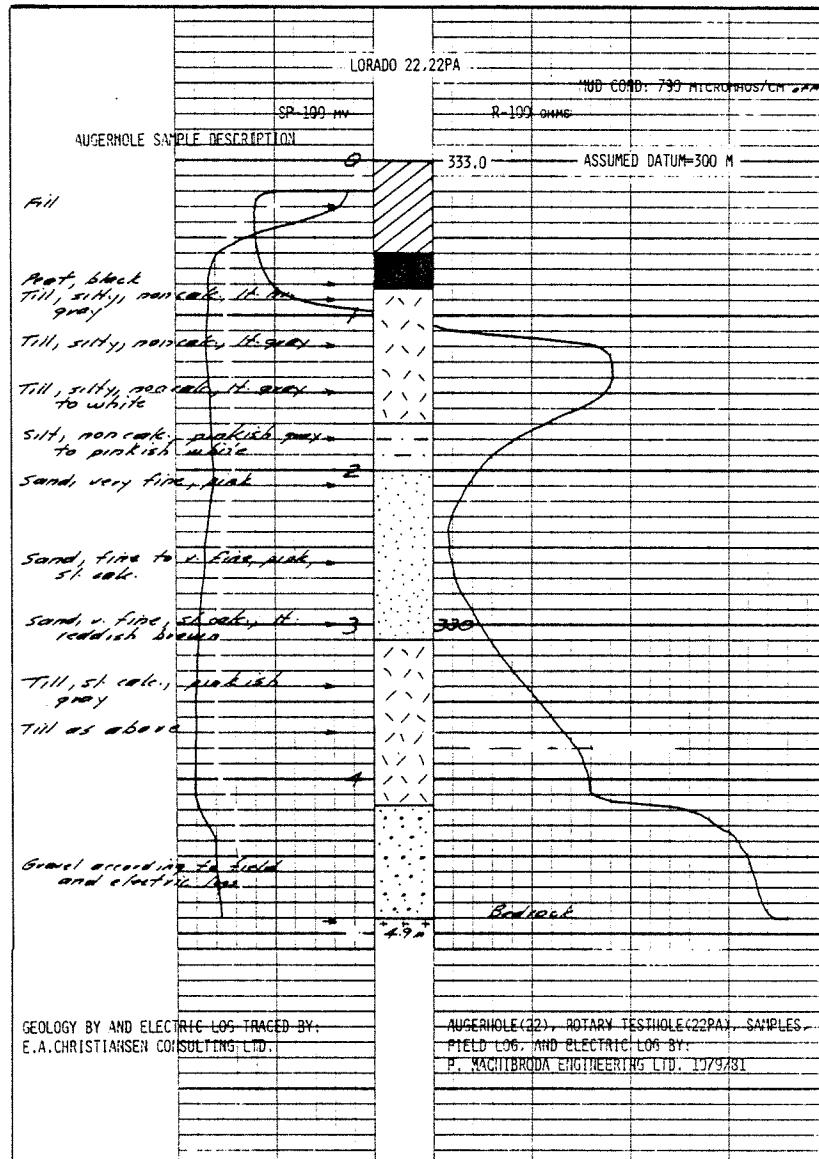


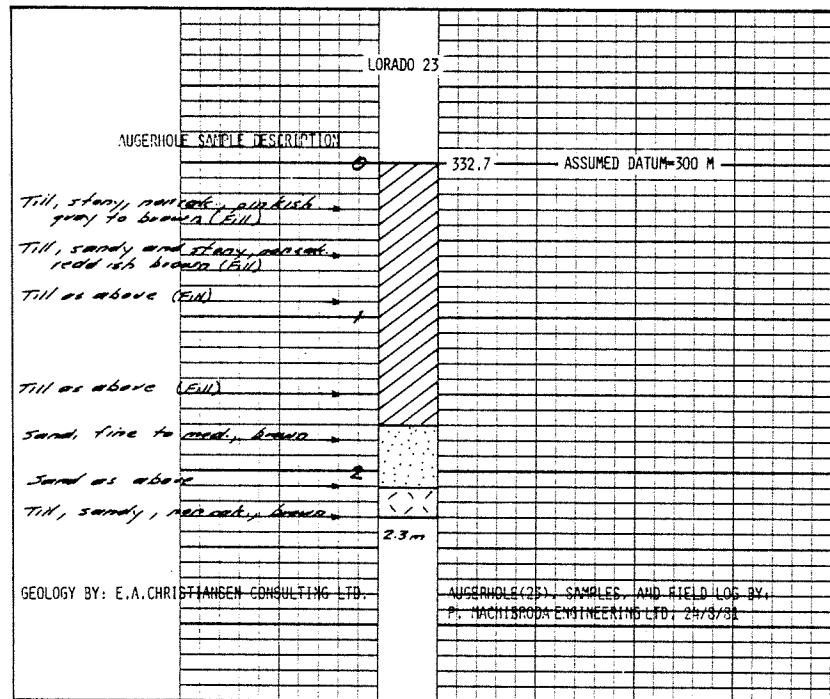


AUGERHOLE	SAMPLE DESCRIPTION	LORADO 20		355.1 - ASSUMED DATUM=300 M
		0	1	
Sand, fine, greyish brown with short dark brown clay streaks	→			Base at oxidized zone
Sand, v. fine, greyish brown	→			
Sand, fine, brown	→	X		
Sand, v. fine, brown	→	X		
Peat, black	→	█	█	
Till, silty, greyish grey with dark stains	→	X X		
Silt, non calc., H. grey	→			
Silt, non calc., white brown and v. pale brown, locally sandy	→			
Silt, non calc., H. grey to white with dark stains pinkish grey when wet	→			
Till, calc., H. reddish brown to pale	→	/ / /		
			3.8 m	
GEOLOGY BY: E.A.CHRISTIANSEN CONSULTING LTD.				AUGERHOLE(20), SAMPLES, AND FIELD LOG BY: P. YACHT GROUP ENGINEERING LTD. 23/3/91

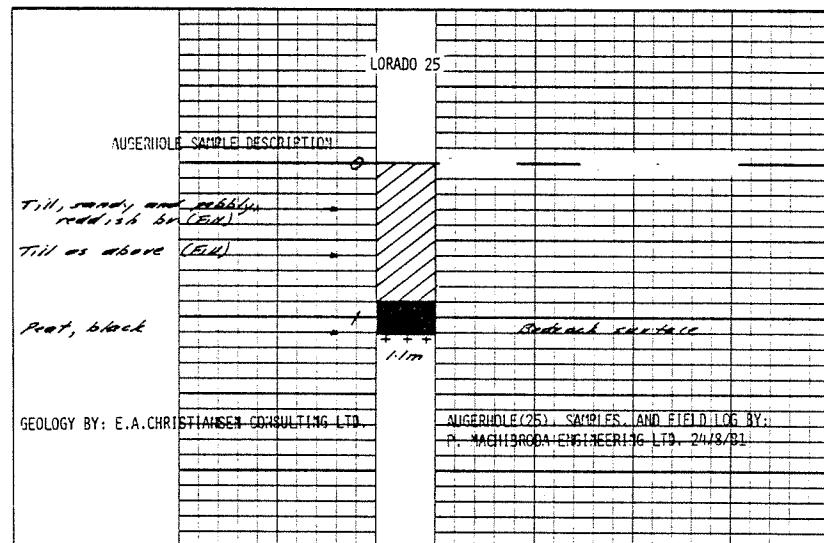




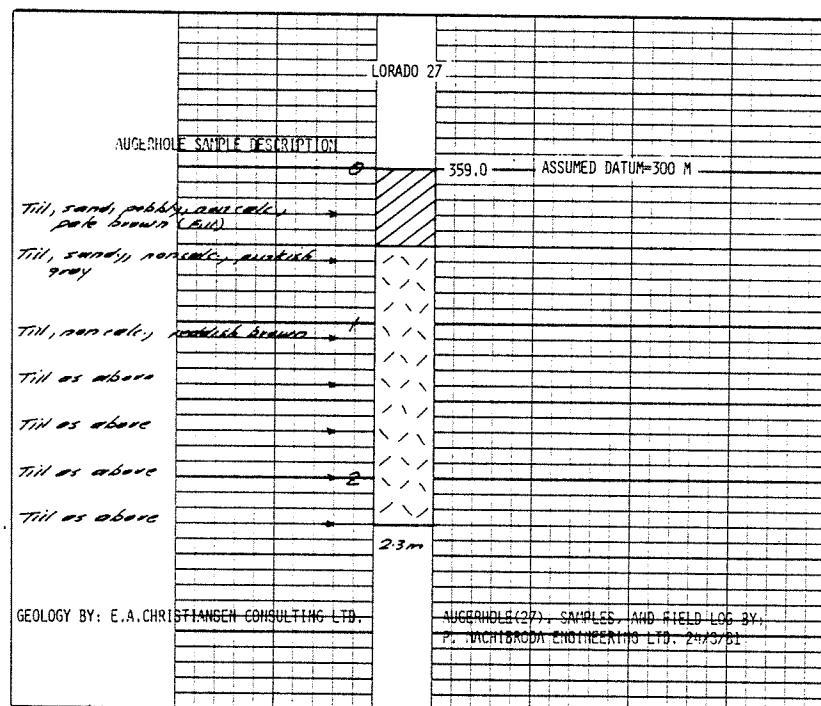




AUGERHOLE SAMPLE DESCRIPTION		LORADO 24	
		0	337.1 ASSUMED DATUM=300 M
Till, sandy, gray		1	
		2	335.0
		3	
Till, sandy, and gravelly red		4	
		5	
Till, sandy, caly, reddish brown		6	331.0 Base of exposure Top of auger hole 24
Sand, medium, reddish brown		7	330.0
Till, sandy, caly, reddish brown		8	
Till, sandy, silty, reddish brown		9	9.1m
GEOLOGY BY: E.A.CHRISTIANSEN CONSULTING LTD.			AUGERHOLE 24, SAMPLES AND FIELD LOG BY: P. MACHIRAGODA ENGINEERING LTD. 24/3/81



AUGERHOLE SAMPLE DESCRIPTION		LORADO 26	
		0	354.6 ASSUMED DATUM=300 M
Sand, fine to + fine, greyish brown			
Silt, noncalcareous, dark grey			
Till, noncalcareous, grey, cobbles	1		
Till, noncalcareous, grey to grayish brown	2		
Till as above			
Till as above			
Silt, noncalcareous, H. grey, with H. pinkish tinge	2		
Till, noncalcareous, H. grey	3		
Silt, noncalcareous, white			
Silt, noncalcareous, H. grey			
Silt as above	3		
Silt as above			
Silt, noncalcareous, H. grey to white with a few small grey			
Silt as above	4		
Silt, noncalcareous, H. grey to white			
Silt as above		350	
Silt as above	5		
Silt, noncalcareous, white			
Silt, noncalcareous, H. grey to white with H. grey			
Silt, noncalcareous, with a H. pinkish tinge			
Silt as above	6		
Clay, silty, noncalcareous, H. grey, with a pinkish tinge and a sand laminae 1cm thick	7		
Silt, noncalcareous, white			Bedrock surface erodable
		7.8m	
GEOLOGY BY: E.A.CHRISTIANSEN CONSULTING LTD.			AUGERHOLE(26). SAMPLES. AND FIELD LOG BY: P. MACHIBRODA ENGINEERING LTD. 20/8/81



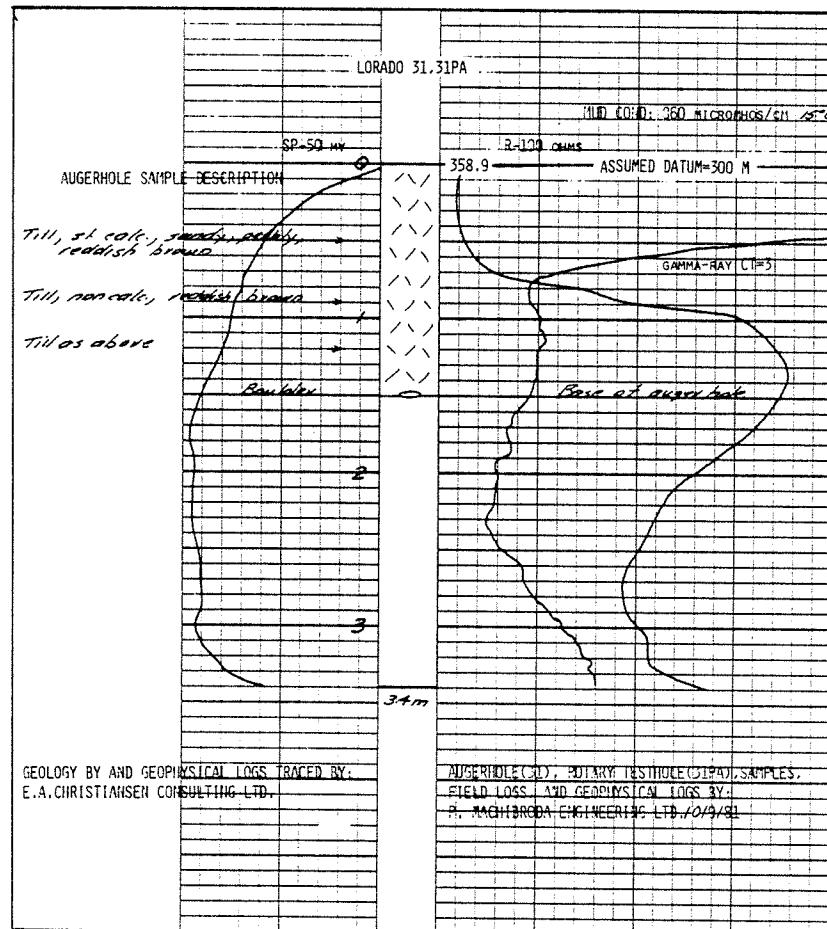
AUGERHOLE	SAMPLE DESCRIPTION	LORADO 28	
		361.7	ASSUMED DATUM=300 M
Till, calc., reddish brown, pebbly		/ / /	
Till, non calc., sand, and pebbly, rounded pebbles		/ / /	
Sands, med. to coarse, reddish brown		/ / /	
Till, non calc., sand, and reddish brown to dark reddish brown		/ / /	360
Till, sh. calc., more silty, dark reddish brown		/ / /	
Till, non calc., reddish brown to dark reddish brown		/ / /	
Till as above		/ / /	Stopped augering due to rocks
		2.7 m	
GEOLOGY BY: E.A.CHRISTIANSEN CONSULTING LTD.			AUGERHOLE (37), SAMPLES, AND FIELD LOG BY: P. MAGNUSSON ENGINEERING LTD. 25/3/81

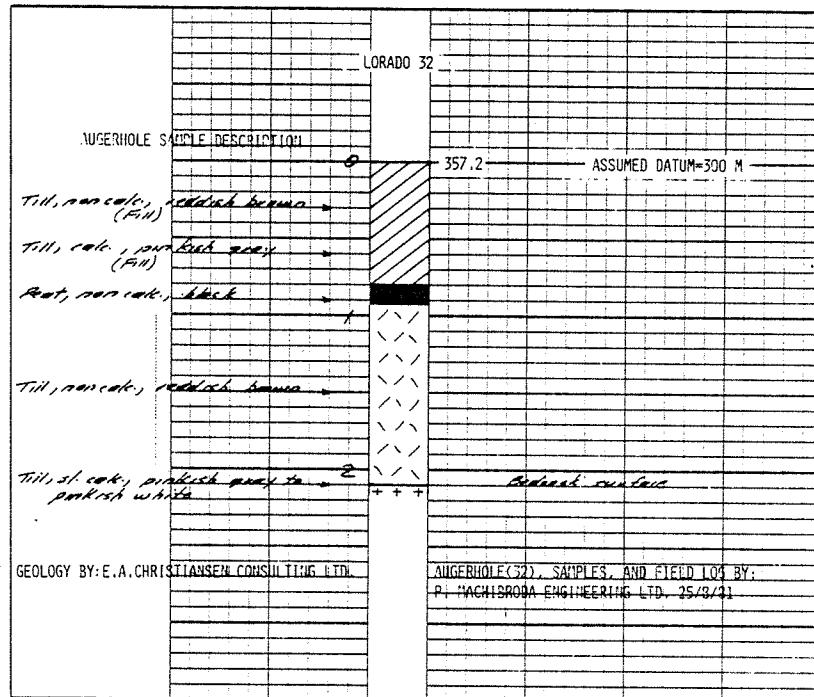
AUGERHOLE SAMPLE DESCRIPTION		LORADO 29	
		0	357.1±1 ASSUMED DATUM=300 M
Sand, fine to v. fine granular lt. yel br. and yel red with needles of white material			
Sand, v. fine, silty, dark red non calc.			
Silt, v. fine sandy, lt. grey with lt. yel underlying			Base of oxidized zone
Silt, non calc., grey			
Silt, non calc., grey with needles of white material			
Silt, non calc., lt. grey			
Peat, v. dk grey, compact			Base at tailings pile
Sands, dk. greyish brown with pieces of white material	2	355	
Till, non calc., lt. grey to white, silty	3	/ / /	
Till, silty at base		/ / /	
sand, coarse to v. coarse reddish brown		3.0m	Twisted off
GEOLOGY BY: E.A.CHRISTIANSEN CONSULTING LTD.			AUGERHOLE(29), SAMPLES, AND FIELD LOG BY: P. MACHIBRODA ENGINEERING LTD. 25/8/31

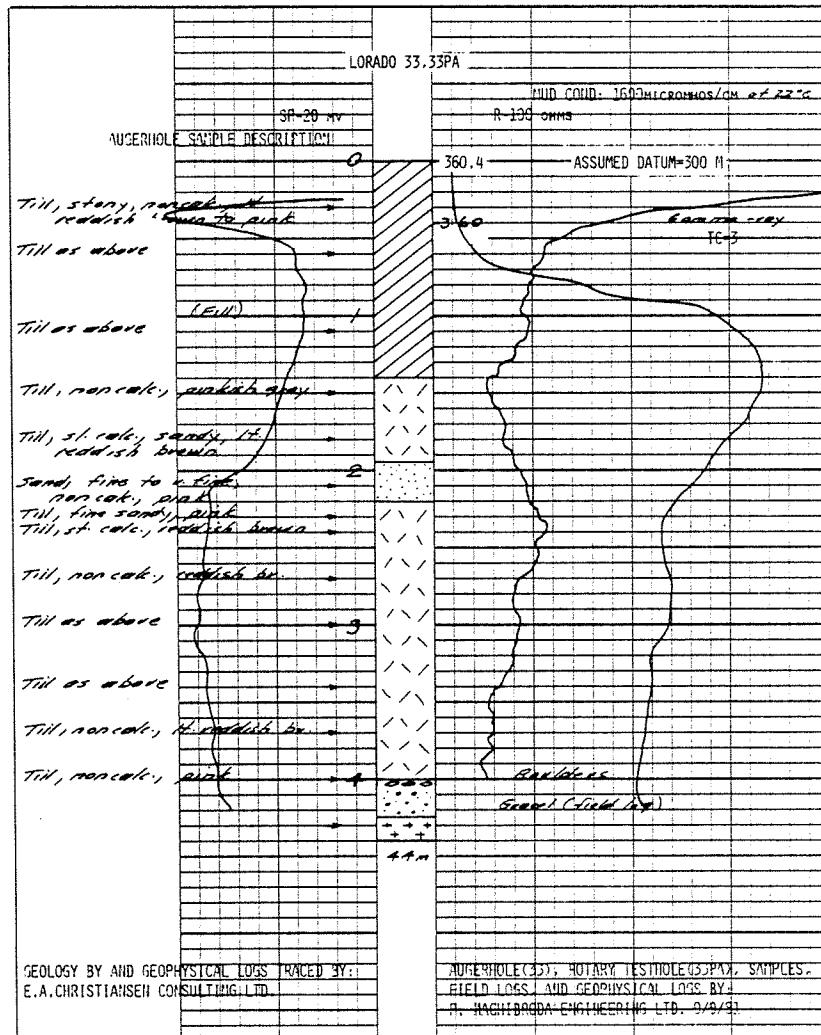
LORADO 30	
AUGERHOLE SAMPLE DESCRIPTION	357.6 ASSUMED DATUM=300 M
Sand, fine to mod. pebbles, brown to pale brown	
Sand as above, pebbly	
Silt, noncal., sticky red, forms chunks on digging	
Gravelly sand, reddish brown	
Sand, silty, probably pebbly, reddish brown	
Peat, noncal., black	355
Sandy sand, to coarse, dark reddish brown	
Sand as above	3
Sand, mod. to coarse, pinkish gray	
Sand, mod., pinkish gray Till, noncal., silty, lt gray to white	
Sand, mod. to coarse, weak red	
Sand as above	5
Sand as above	
Till, silty, noncal., lt gray to white	/\ /
Till, silty, noncal., lt gray to white	/\ /
Till, sandy, pebbly, pinkish gray	/\ /
Till, silty, noncal., lt gray to white	/\ /
Silt, noncal., lt gray to white	350
Silt as above and clay, noncal., lt gray intercalated	8
Silt and clay as above	/\ /
Till st. calc., lt reddish brown	/\ /
	+/+ +
	9.6m
	Bedrock surface
GEOLGY BY: E.A.CHRISTIANSEN CONSULTING LTD.	AUGERHOLE(30), SAMPLES, AND FIELD LOG BY: P. MACHIGODA ENGINEERING LTD. 25/3/01

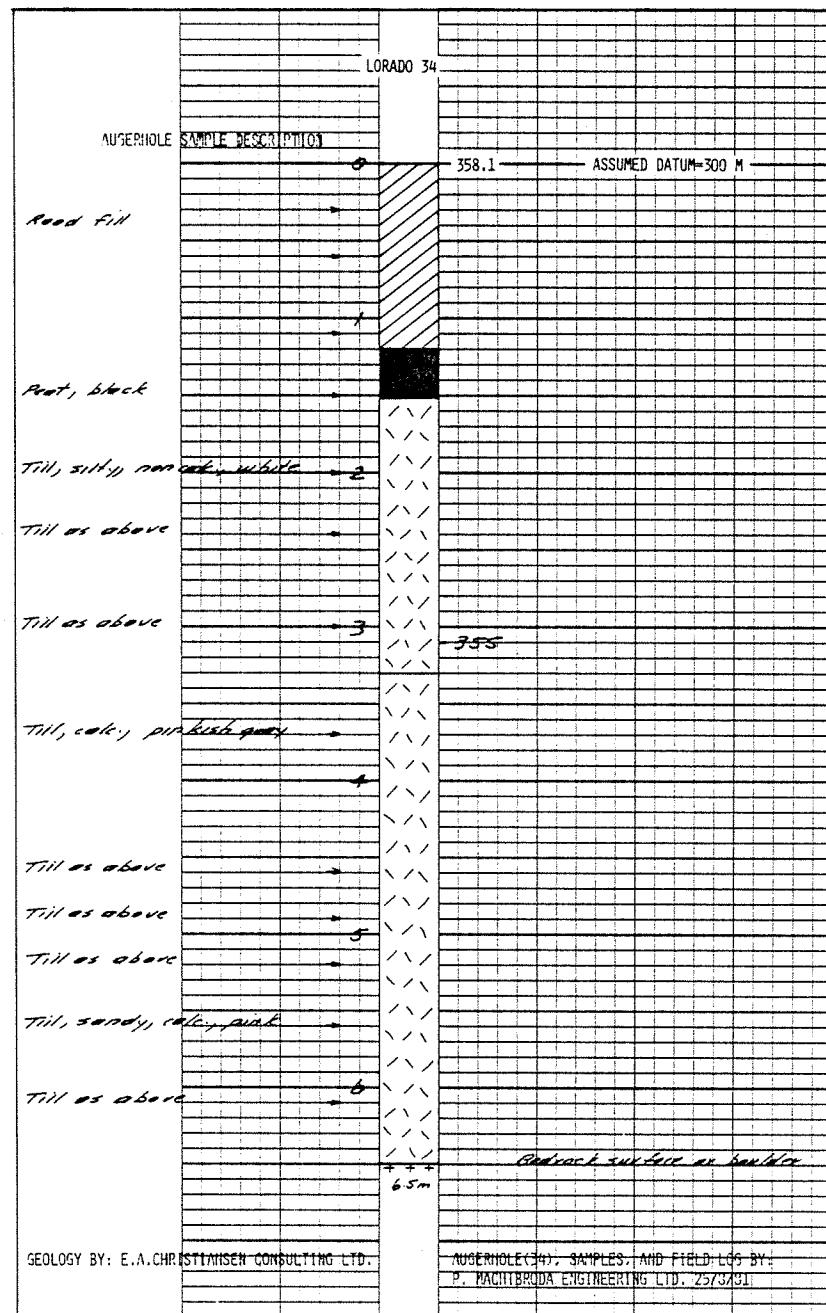
GEOLOGY BY: E.A.CHRISTIANSEN CONSULTING LTD.

AUGERHOLE (3), SAMPLES, AND FIELD LOG BY:  
P. MACHIBRODA ENGINEERING LTD. 25/3/81





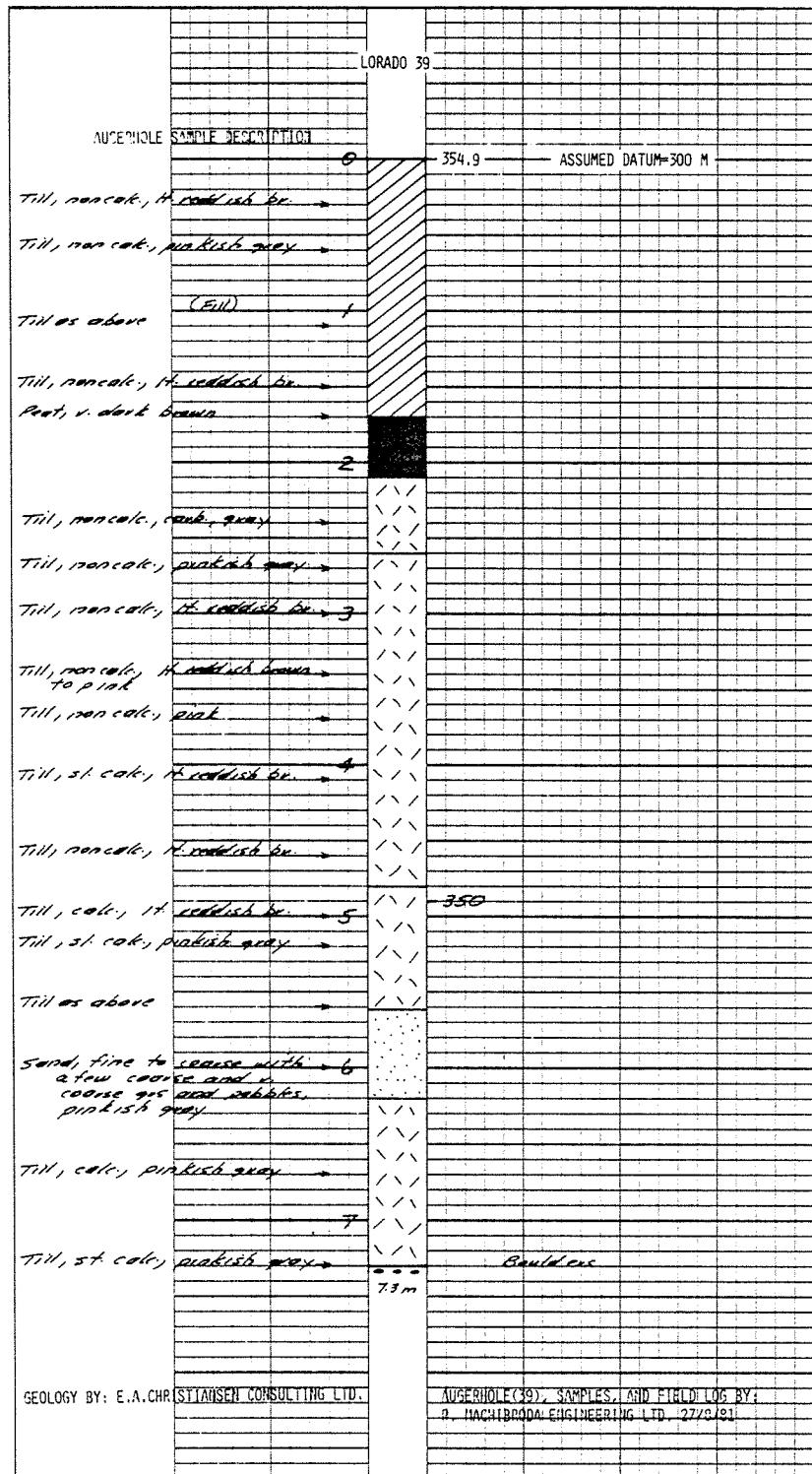


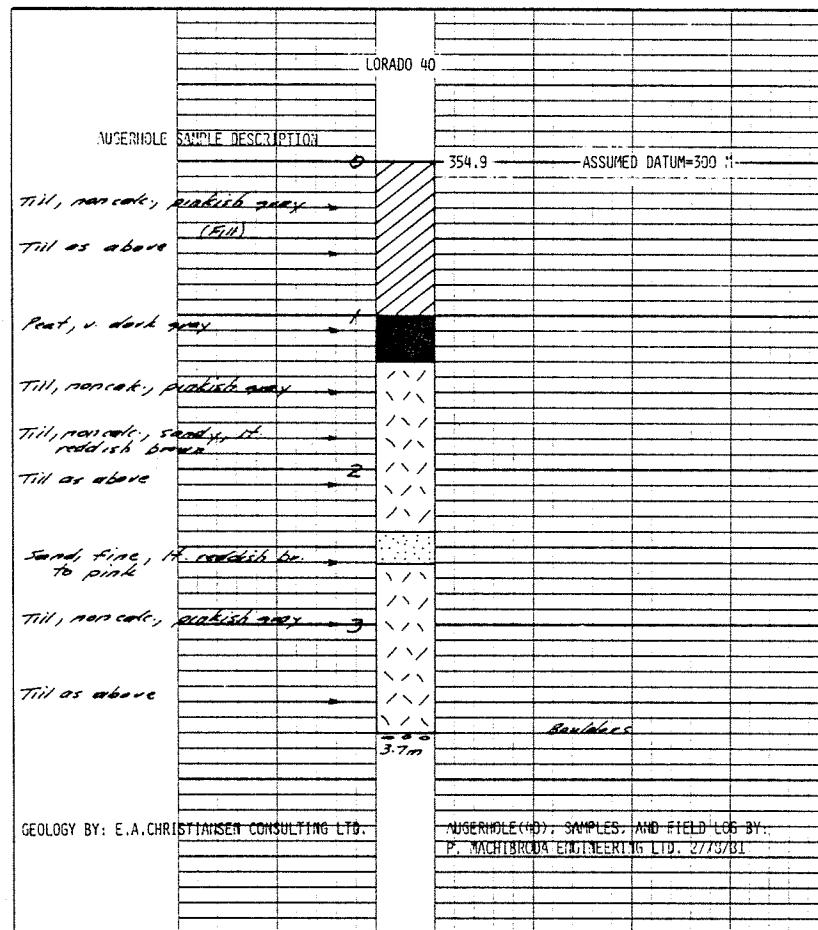


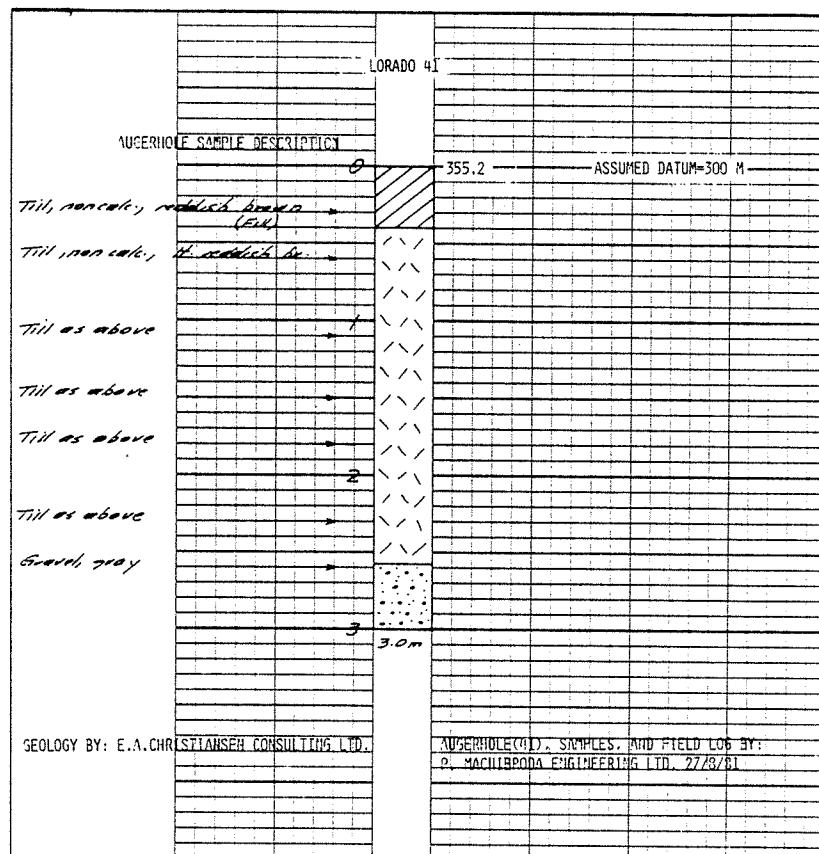
AUGERHOLE SAMPLE DESCRIPTION		LORADO 36	
Till, non calc., H. reddish brown	(Till)	8	354.6±1 ASSUMED DATUM=300 M
Till as above		→	
Till as above		→	1
Till, calc., H. reddish brown		→	
Till as above		→	2
Till as above		→	
Till, st. calc. to macaque, pinkish gray		→	
Till, st. calc. to macaque H. reddish brown		→	3
Till, st. calc., pinkish gray		→	
Till as above		→	
Gravel, sandy, pinkish gray		→	
Till, st. calc., pinkish gray		→	350
Till as above		→	
Till, calc., pinkish gray		→	5.6m
GEOLOGY BY: E.A. CHRISTIANSEN CONSULTING LTD.			AUGERHOLE (36) SAMPLES AND FIELD LOG BY P. MACIBRODA ENGINEERING LTD. 26/8/91

		LORADO 37	
AUGERHOLE	SAMPLE DESCRIPTION		
Till, noncal., <del>dark</del>		354.7	ASSUMED DATUM=300 M
Till, noncal., <del>light reddish brown</del>			
		+/+\n+/+\n+/+\n+/+\n+/+\n+++\n0.9m	bedrock surface or boulder
GEOLOGY BY: E.A.CHRISTENSEN CONSULTING LTD.			AUGERHOLE (37), SAMPLES, AND FIELD LOG BY: P. MACHIBORODA ENGINEERING LTD. 26/3/31

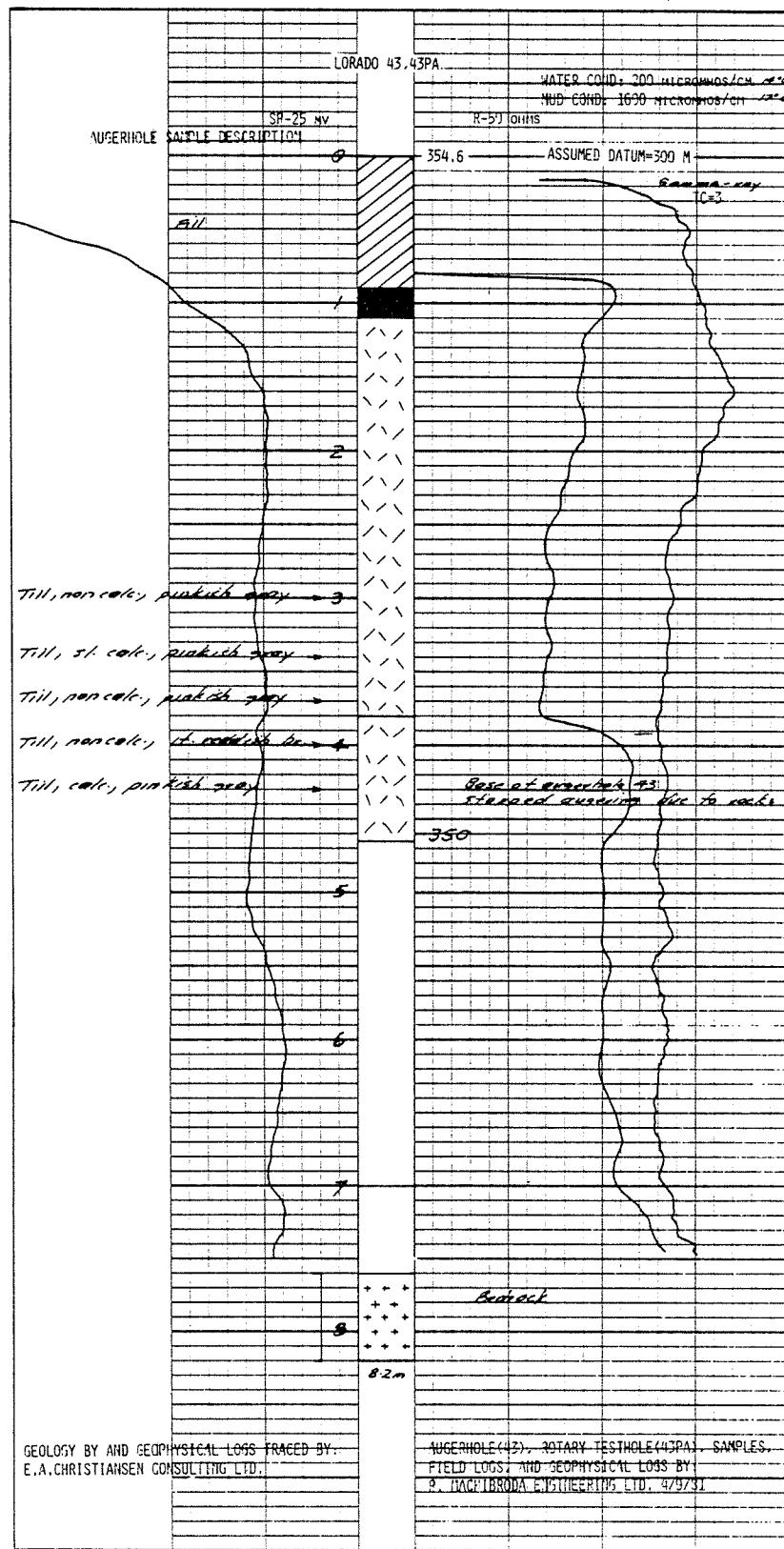
AUGERHOLE SAMPLE DESCRIPTION		LORADO 38	
		356.0	ASSUMED DATUM=300 M
Till, non calc., white			
Till, non calc., pebbly grey			
Till as above			300
Till as above			
Till as above			
Till, non calc., pebbly grey to white			
Till, st. calc., pebbly grey			
Till, st. calc. with patches of white calciferous peat	3	4++ 3.0m	Bedrock surface
GEOLOGY BY: E.A.CHRISTIANSEN CONSULTING LTD.			AUGERHOLE(3R) SAMPLES, AND FIELD LOG BY: P. YACHIBRODA ENGINEERS LTD. 26/9/81

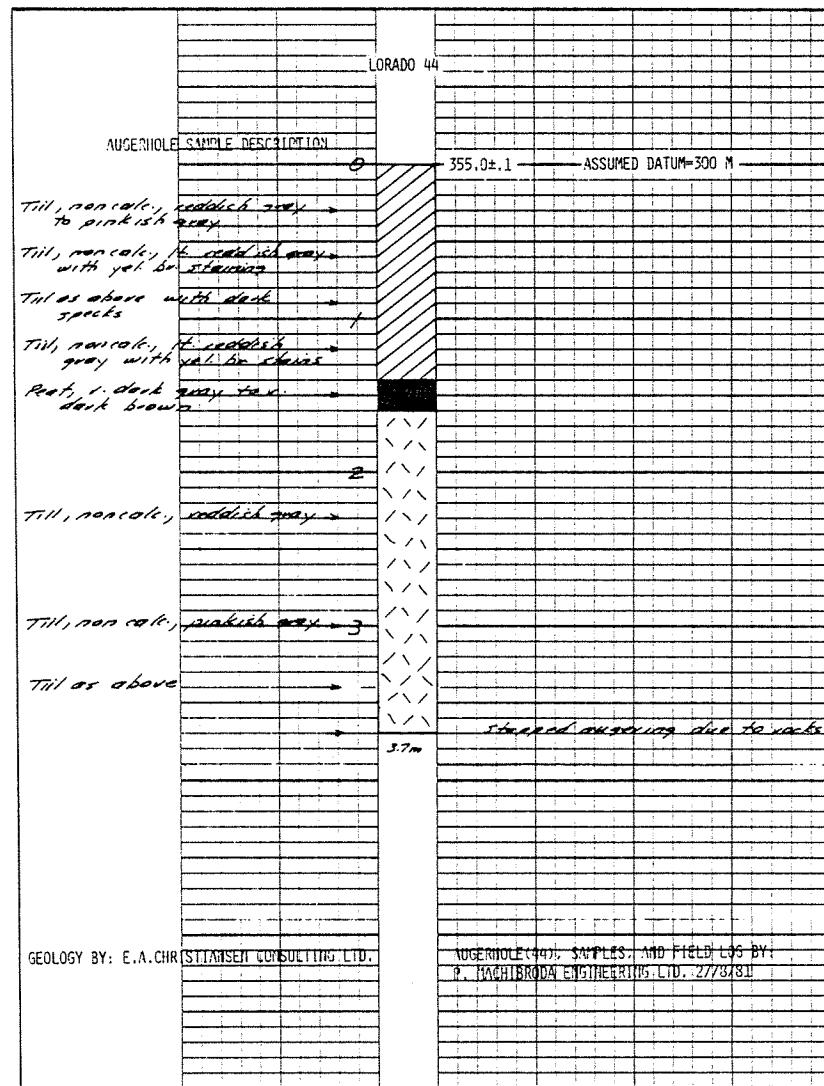


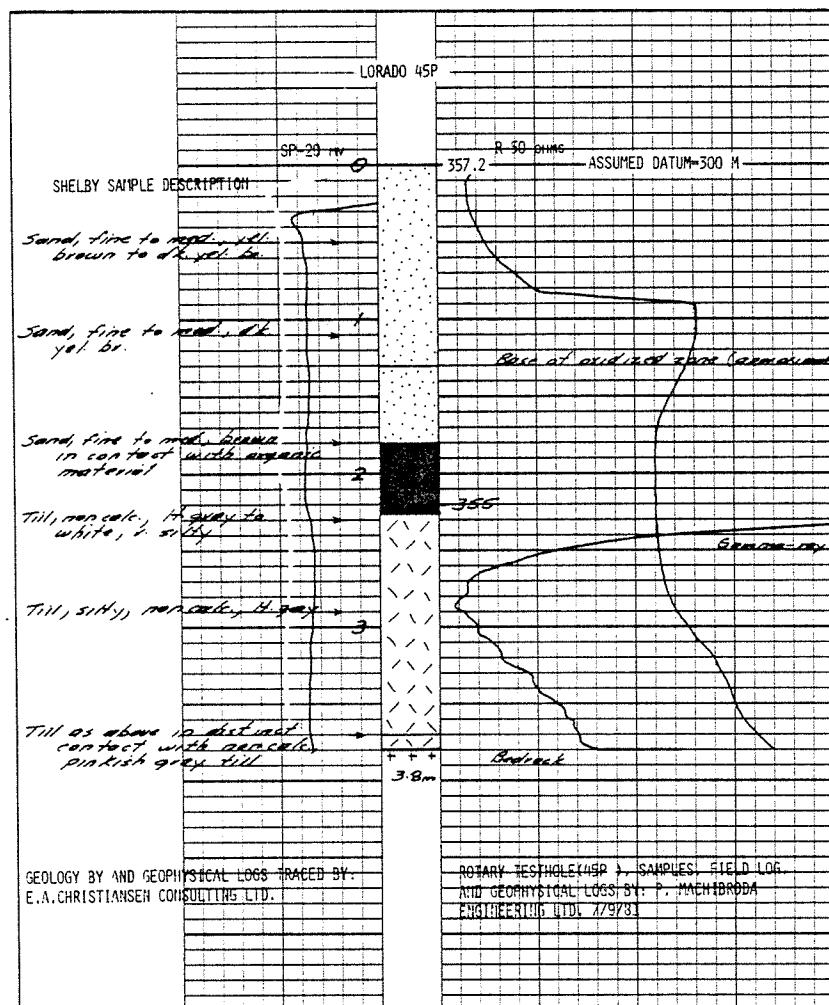


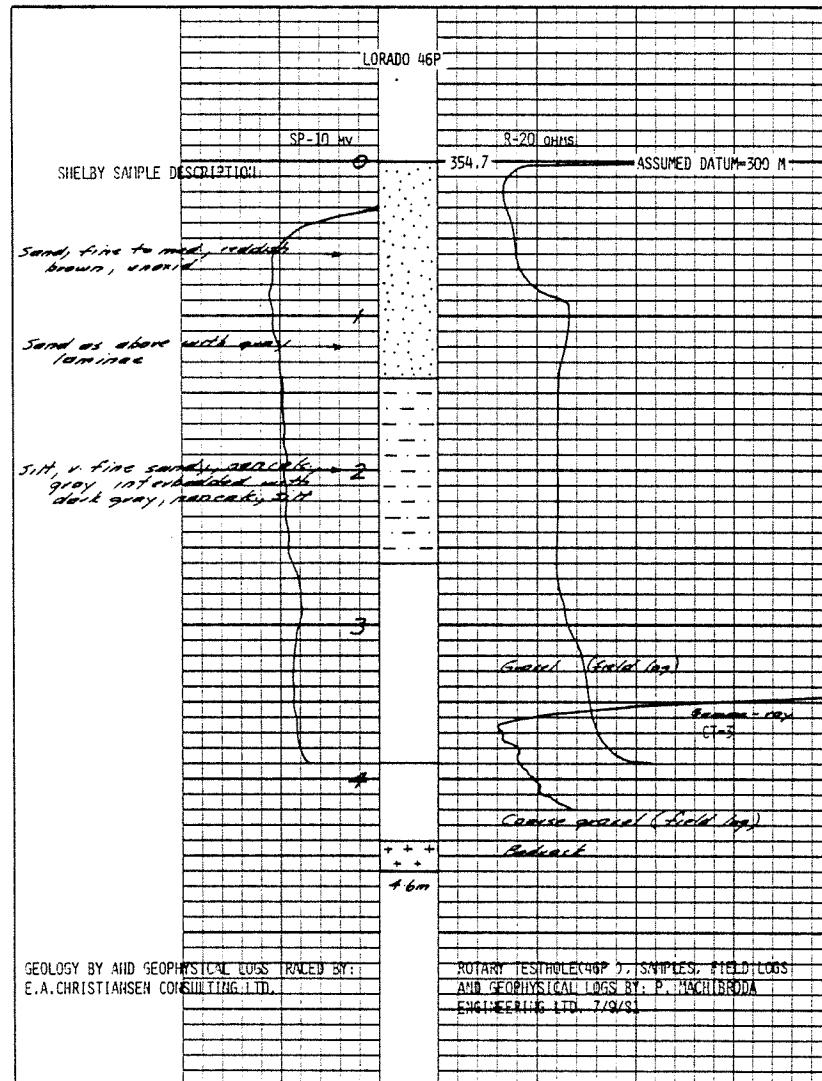


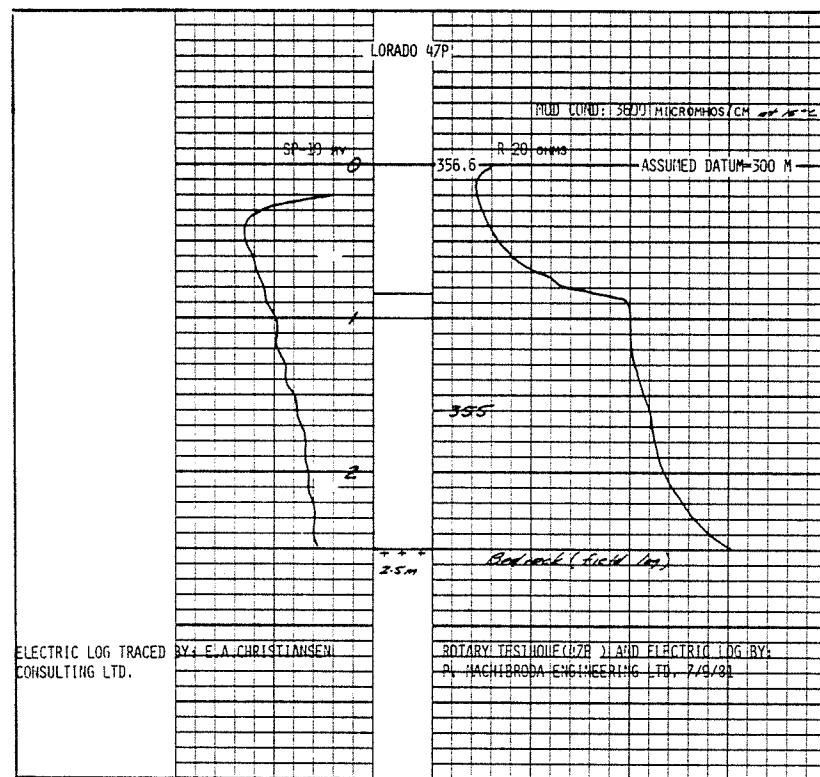
AUGERHOLE SAMPLE DESCRIPTION		
	LORADO 42	
Till, non calc., pinkish grey to pinkish grey	0	354.9 ASSUMED DATUM=300 M
Till, non calc., pinkish grey to pinkish grey	1	
Till, non calc., pinkish grey	1	
Till, st calc., light grey	1	
Till as above	2	
Till as above	2	
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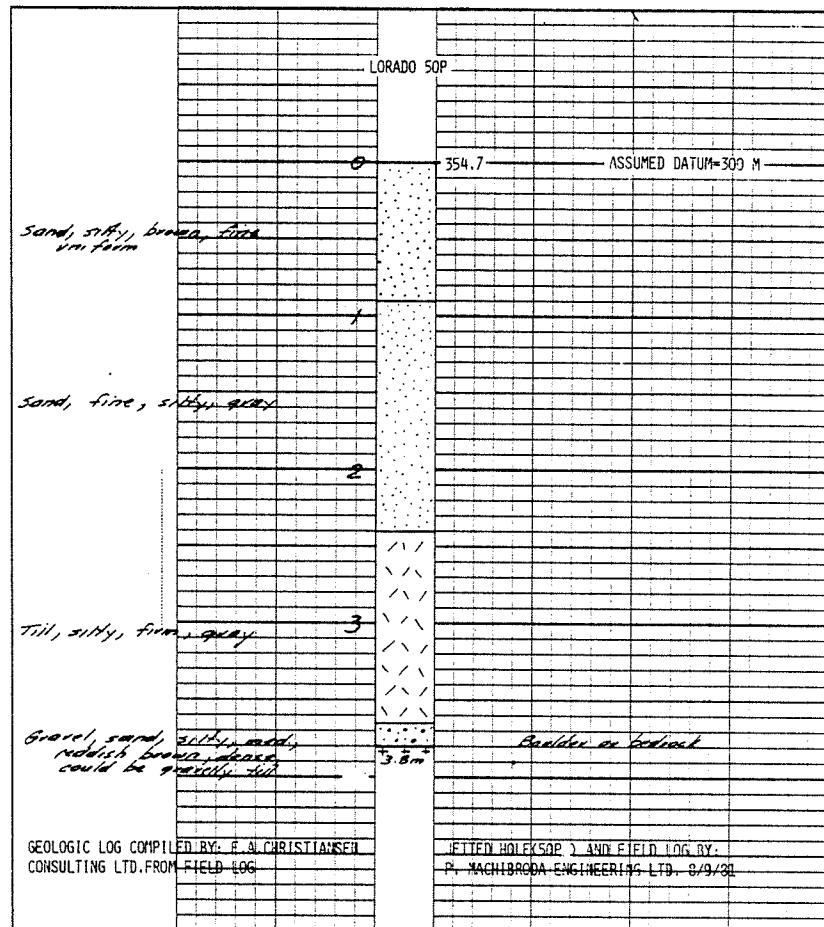


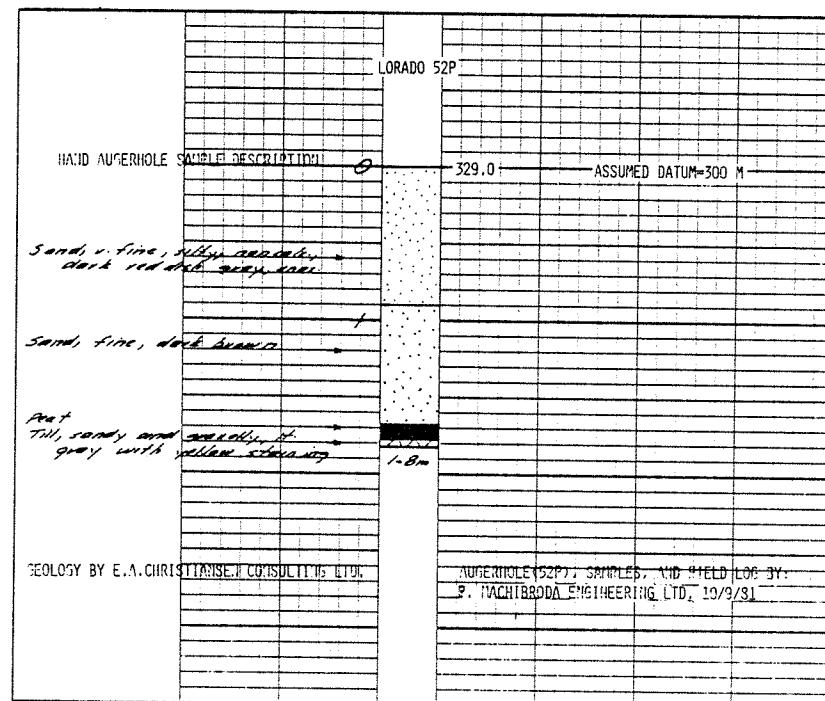




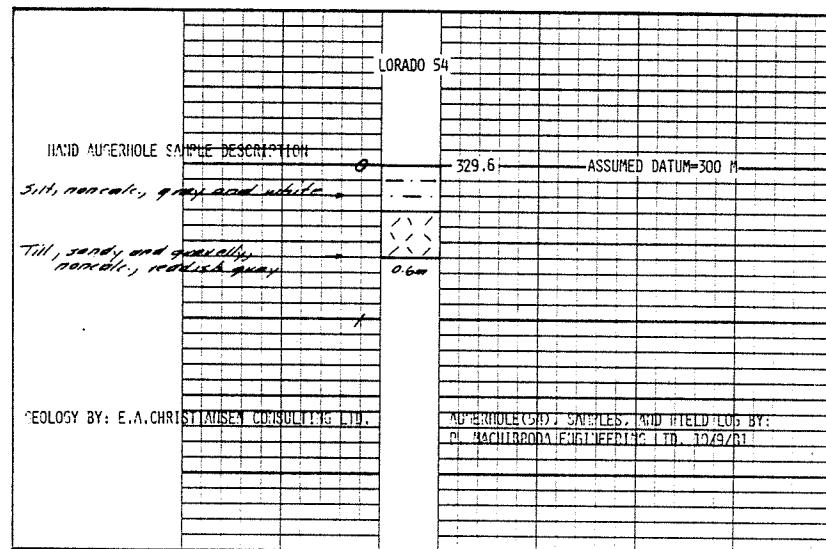
		LORADO 48P	
HAND AUGERHOLE SAMPLE DESCRIPTION		354.1	ASSUMED DATUM=300 M
Sand, silty, w/ fine gravel, grey with slate weathered material and gl. brown staining			
Sand, w/ fine, silty, gravel, radish grey, unsorted			
Silt, mottled, dark grey with sand laminae	2		25mm zone at top sand, fine to medium
Till, silty, mottled, N grey to white		2.3m	
GEOLOGY BY: E.A.CHRISTIANSEN CONSULTING LTD.			AUGERHOLE(48P) - SAMPLES, AND FIELD LOG BY: P. MACHIBRODA ENGINEERING LTD. 8/97/SI

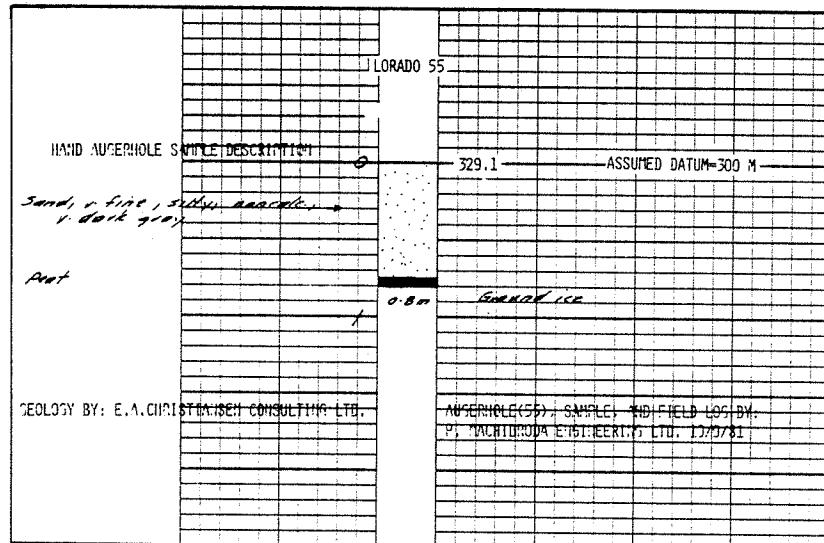
SAMPLE DESCRIPTION	LORADO 49	354.1	ASSUMED DATUM=300 M
Sands, fine to very fine, silty porcalite, pinkish grey to reddish grey, very fine material			
Silt, fine, grey, angular, grey with white angular fine material			Benton or bedrock
GEOLOGY BY: E.A.CHRISTIANSEN CONSULTING LTD.			JETTED HOLE(49), SAMPLES, AND FIELD LOG BY: P. MACHIBRODA ENGINEERING LTD. 3/9/81



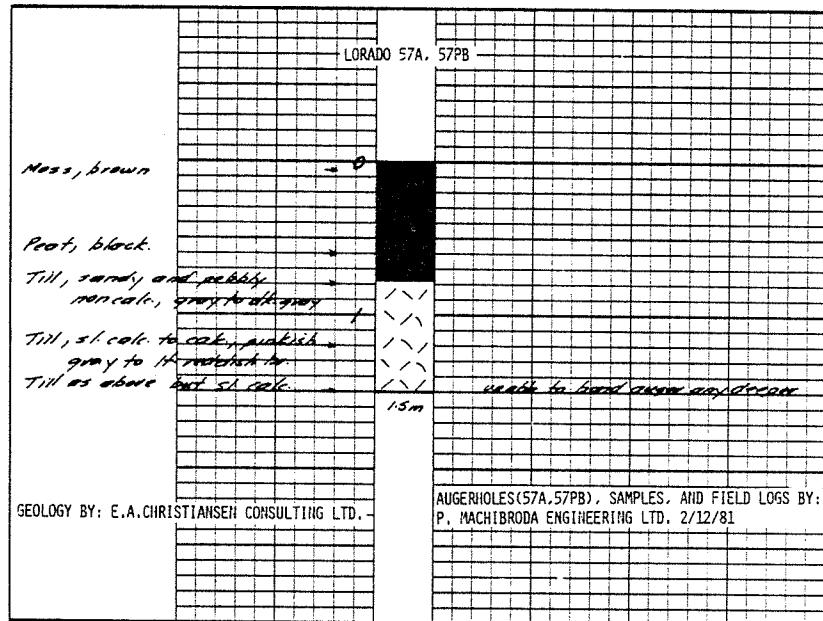




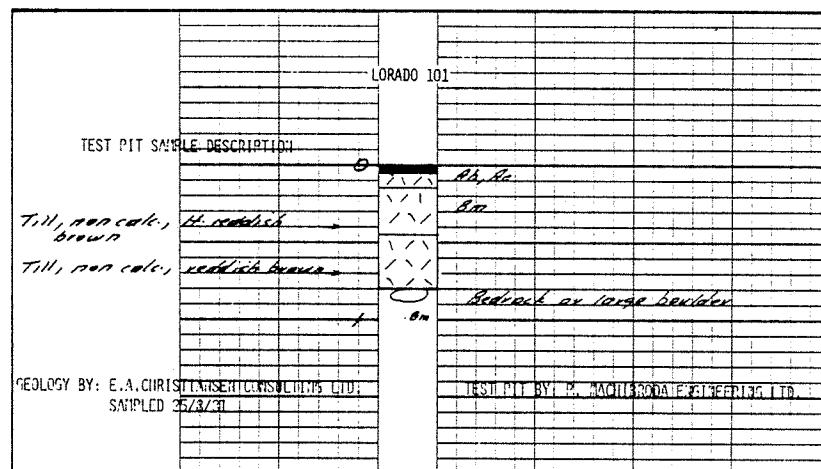




SAMPLE DESCRIPTION	LORADO 56,56A
Sand, fine, noncalcareous, to be Gravel, coarse to coarse sandy with yellowish staining	0
Silt, v. fine sandy, powdery, non calc., to gray to white	1
Sand, fine, v. pale brown	2
Sand, fine, H. to gray to pale brown	3
Sand, med. to coarse, brown	4
Sand, med., pale brown	5
Gravel, sandy, light gray to H. gray	6
Gravel, med. to coarse sandy, pinkish gray	7
Sand, med. to coarse, pebbly, pale brown to brown	8
Gravel, coarse to coarse sandy, gray	9
Sand, med. to coarse pebbly, pinkish gray to be.	10
Sand, med. to coarse, pinkish gray	11
	7.3 m
GEOLOGY BY: E.A.CHRISTIANSEN CONSULTING LTD.	AUGERHOLE (56), EXPOSURE (56A), SAMPLES, AND FIELD LOG BY P. MACHIBBODA ENGINEERING LTD. 11/9/81

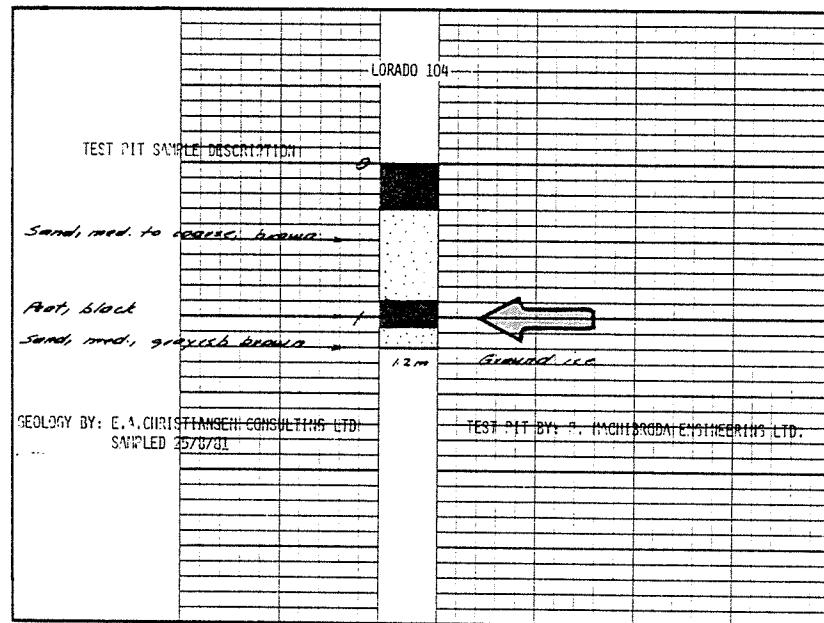


Appendix 2. Geologic logs from test pits in the Lorado Mill area.



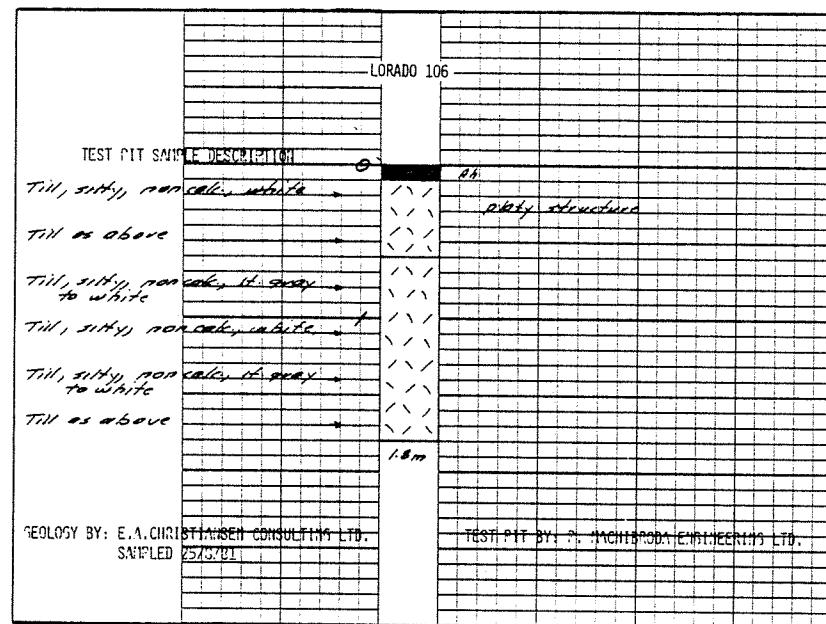


		LORADO 103									
		TEST PIT SAMPLE DESCRIPTION									
Root											
*	Till, calc., w. reddish brown to pink		/	/	/						
*	Sample taken from excavation pink previously dug pit area filled with melted snow rec. depth of pit estimated from photographs		/	/	/						
GEOLOGY BY E.A. CHRISTIANSEN CONSULTING LTD.		TEST PIT BY: F. VAGHISODA ENGINEERING LTD.									
Sample 25/10/81											



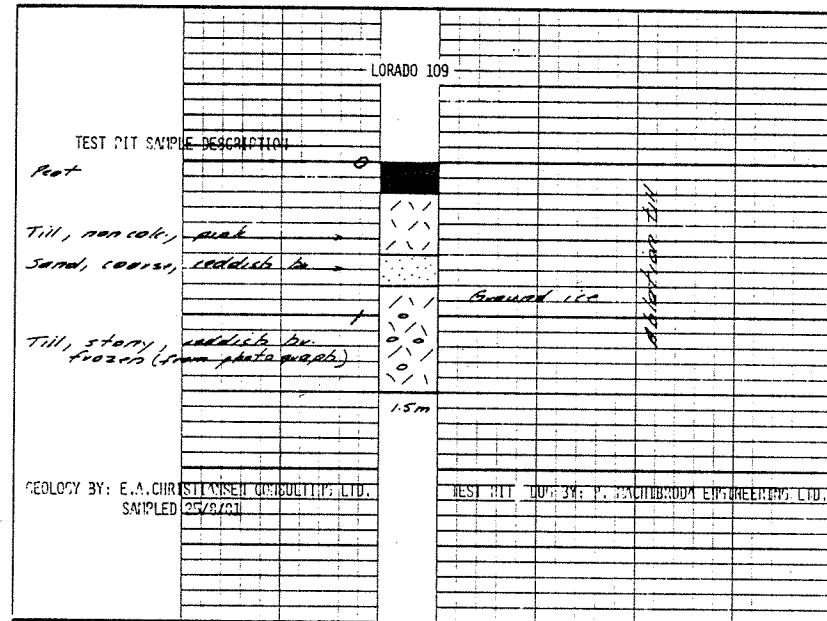
S-2143  
7190 yrs. B.P.





TEST PIT SAMPLE DESCRIPTION		LORADO 107									
Root											
Till, non calc., silty, N 3000X		Ground ice									
GEOLOGY BY: E.A.CHRISTIANSEN CONSULTING LTD.		TEST PIT BY: F. MACHIBODA ENGINEERING LTD.									
SAMPLED 25/R/91											

		LORADO 108									
		TEST PIT SAMPLE DESCRIPTION									
Till, non calc., pinkish gray	0	/	/	/	/	/	/	/	/	/	/
Till, non calc., reddish br.		/	/	/	/	/	/	/	/	/	/
Till, as above		/	/	/	/	/	/	/	/	/	/
	1	+	+	+	1.0m	Bedrock					
GEOLOGY BY: E.A.CHRISTIANSEN CONSULTING LTD.		TEST PIT BY: P. ARCHIBROD ENGINEERS LTD.									
SAMPLED 5/6/81											

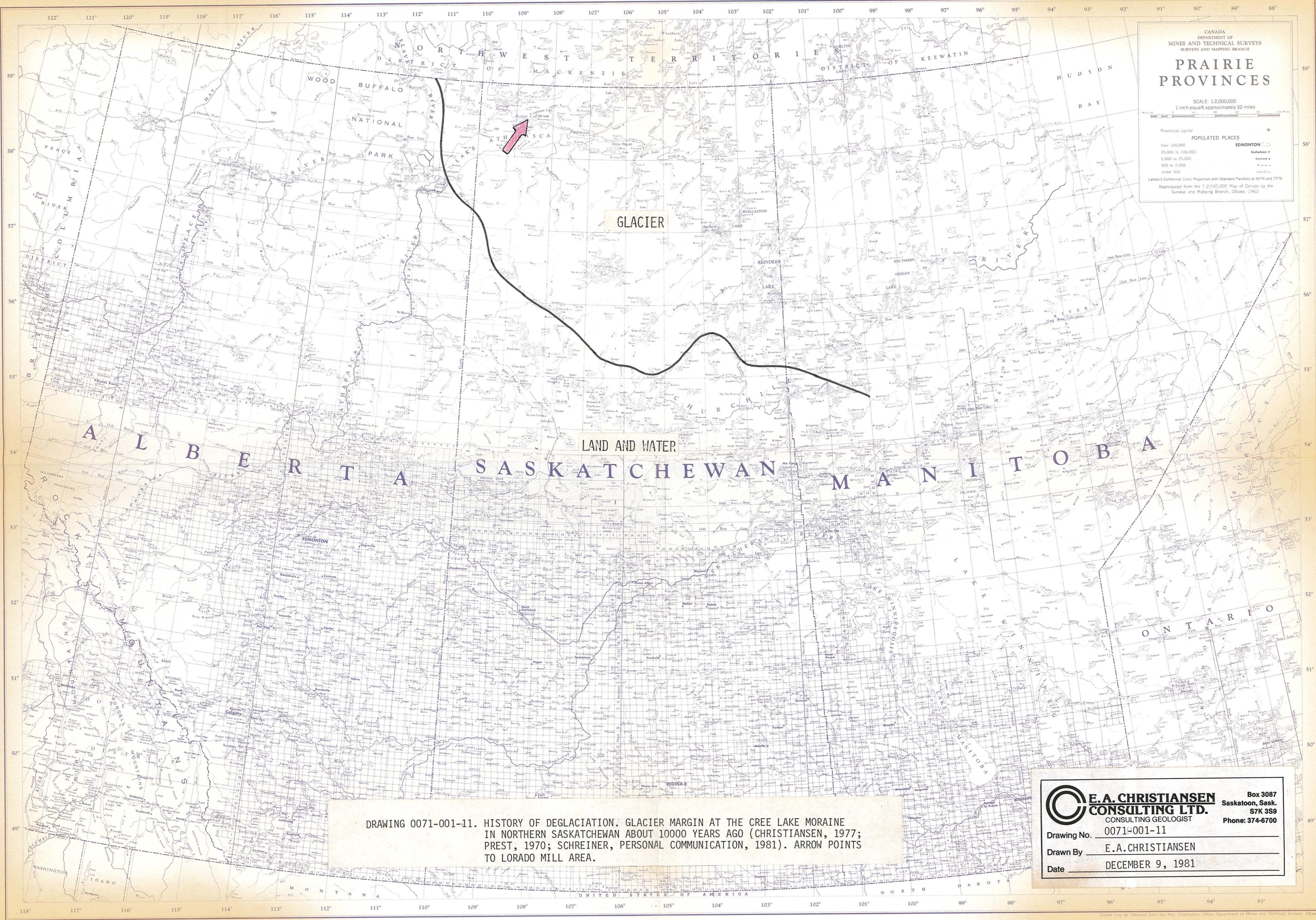


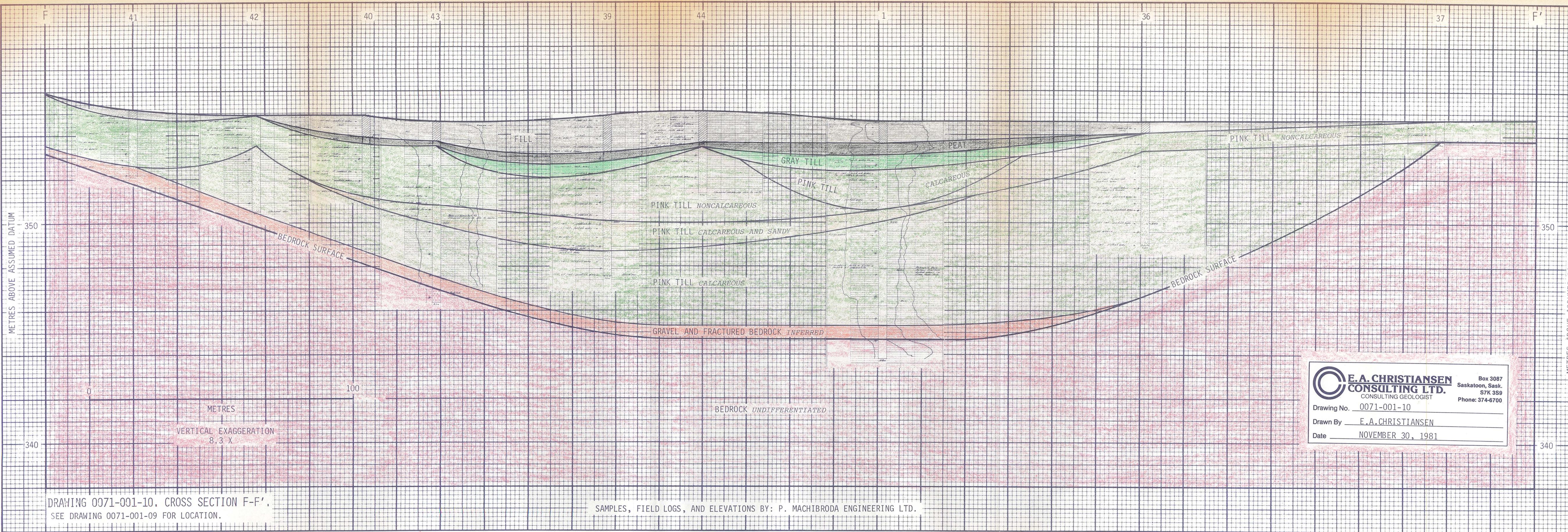
Appendix 3.

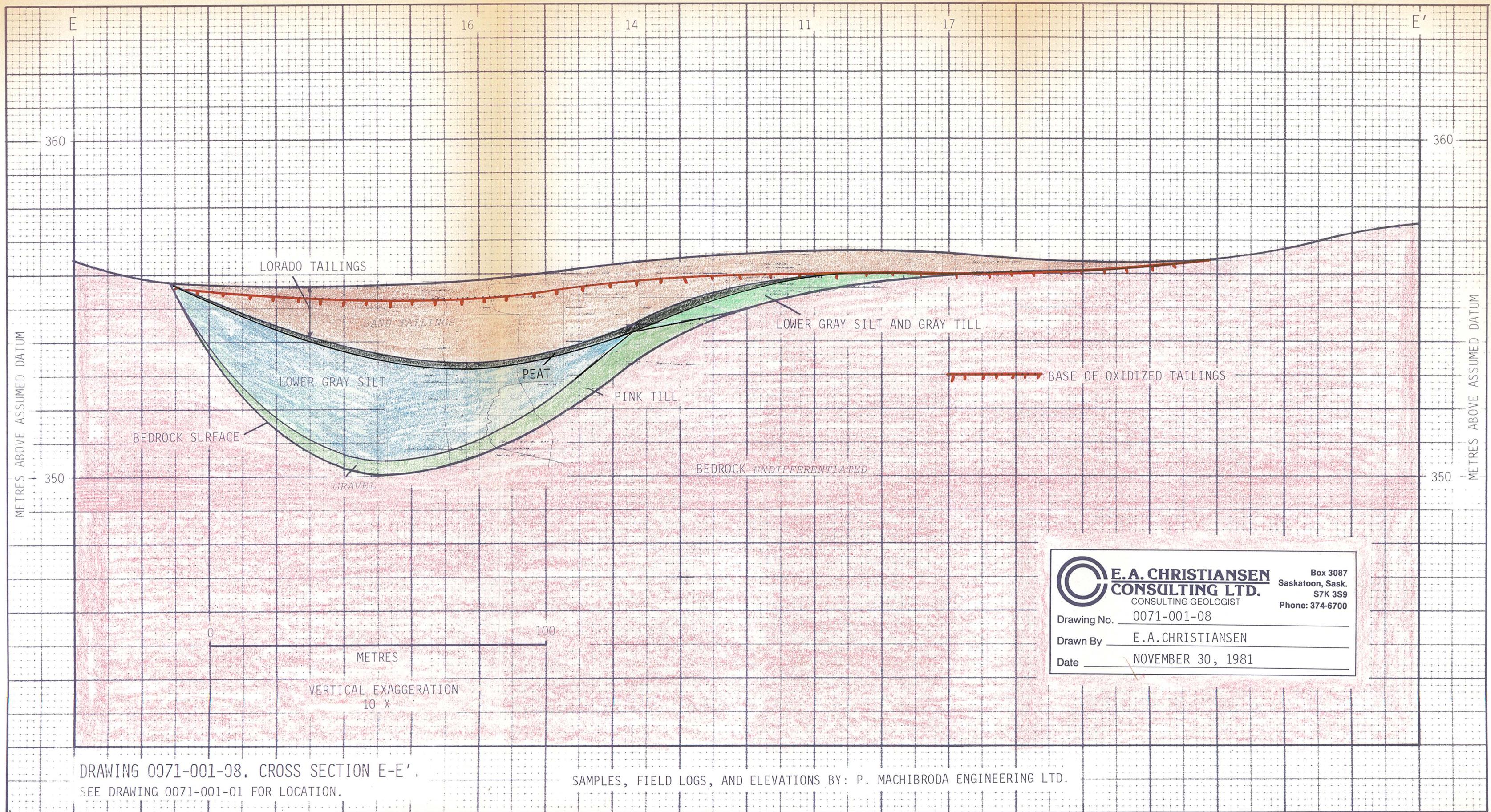
Table 1. Radiocarbon Dates, Lorado Mill Area

Lab No.	Name	Age (Yrs.P.B.)	Page No., Appendix 1
S-2141	Lorado 2	5965±110	34
S-2142	Lorado 8	7345±130	40
S-2143	Lorado 104	7190±125	93

Appendix 4. Drawings 0071-001-01-11.

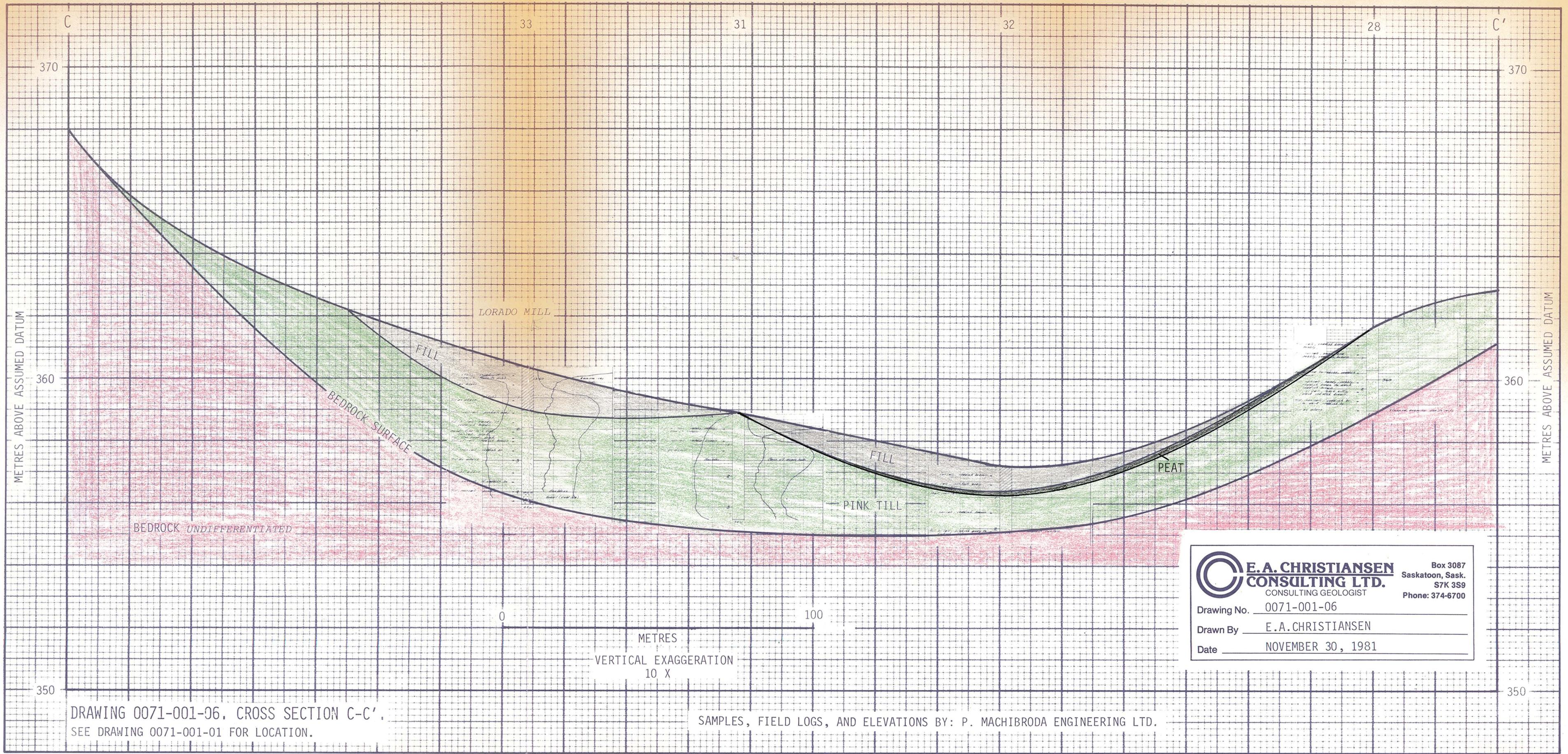






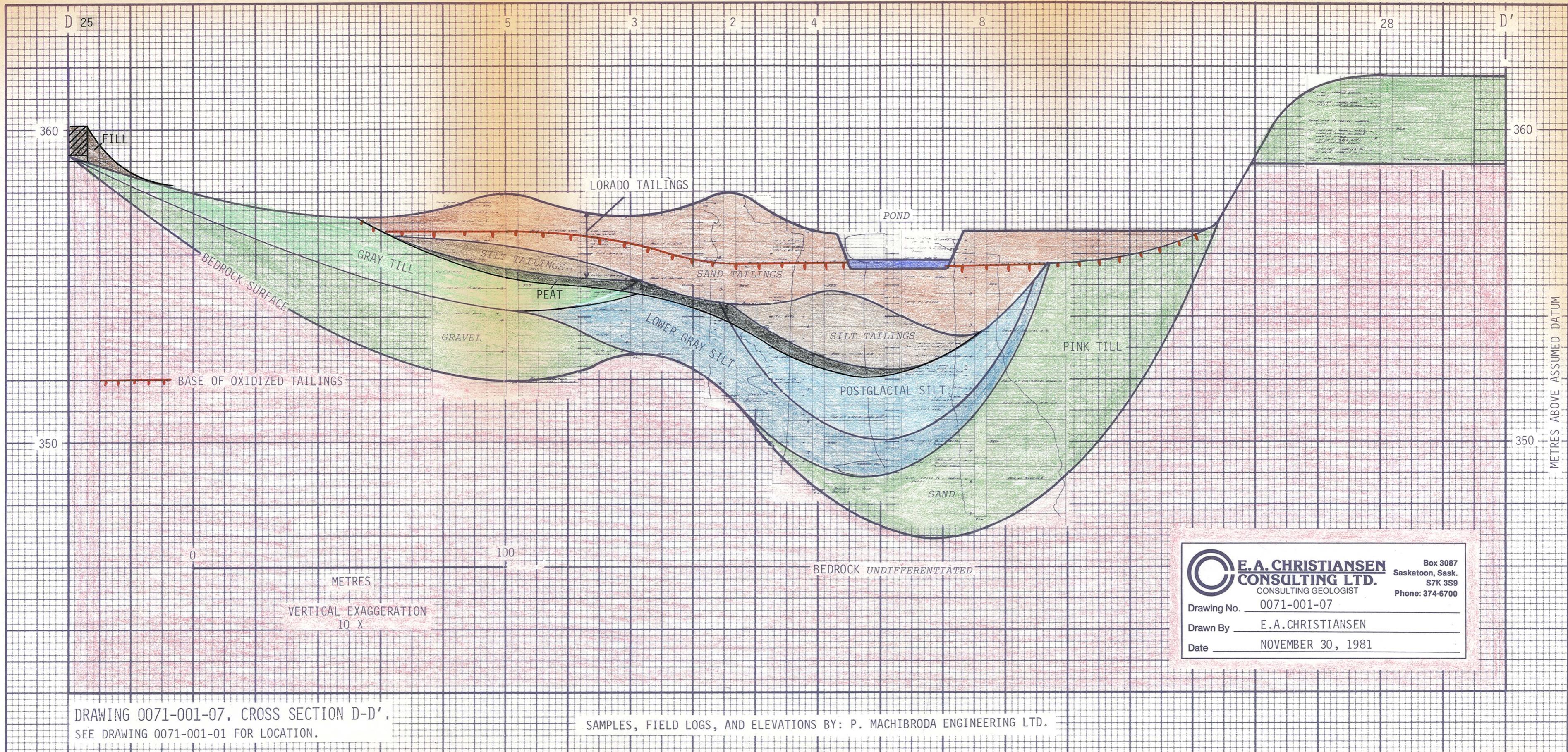
**E.A. CHRISTIANSEN**  
CONSULTING LTD.  
CONSULTING GEOLOGIST  
Drawing No. 0071-001-08  
Drawn By E.A. CHRISTIANSEN  
Date NOVEMBER 30, 1981

Box 3087  
Saskatoon, Sask.  
S7K 3S9  
Phone: 374-6700



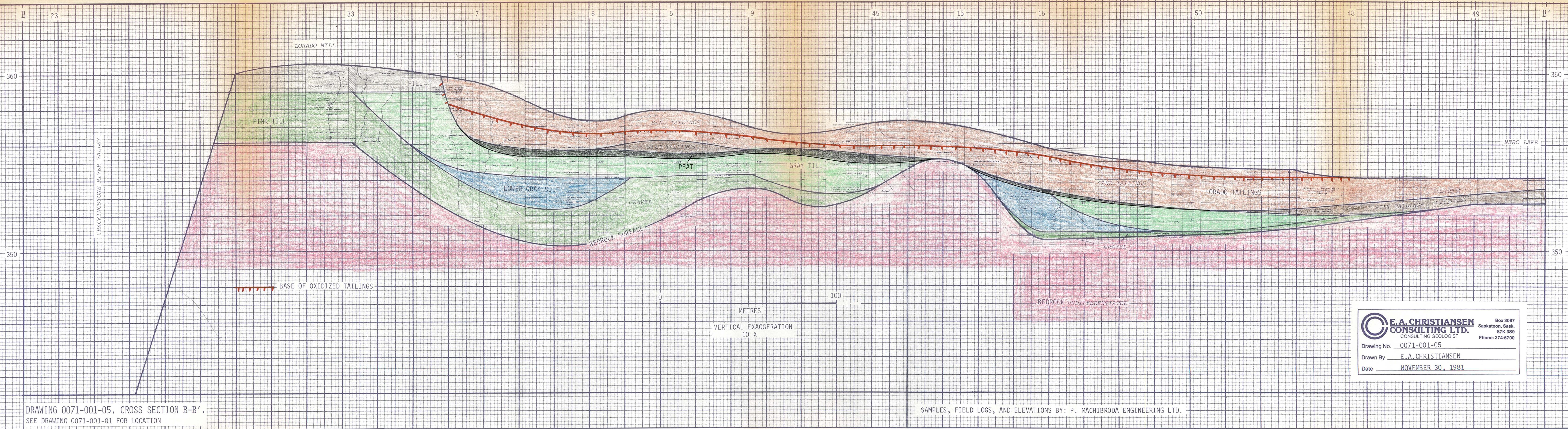
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Saskatoon, Sask.  
S7K 3S9  
Phone: 374-6700

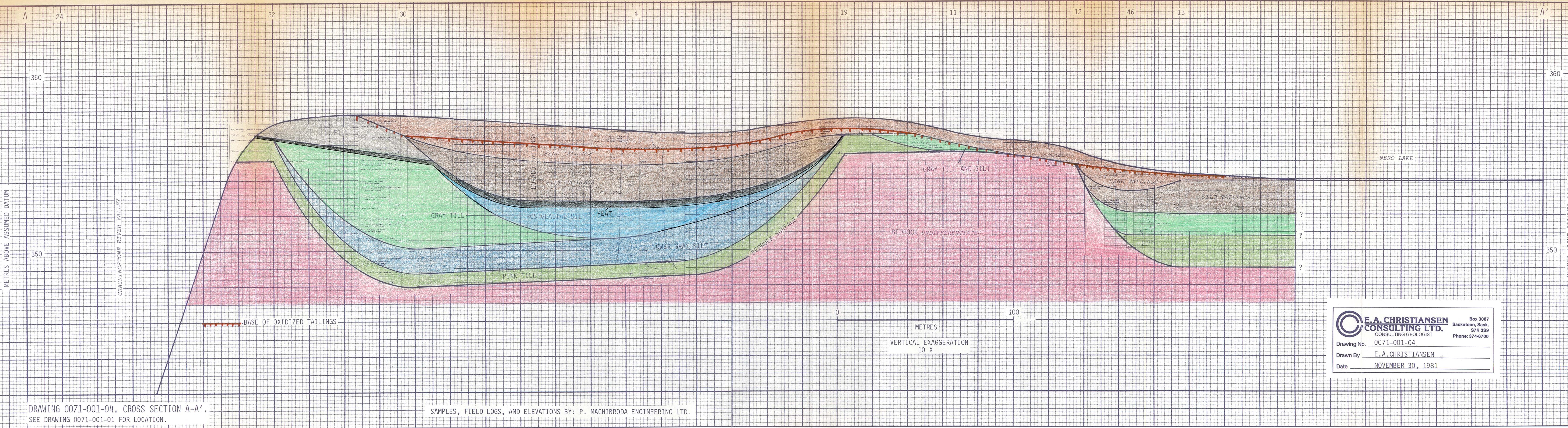
Drawing No.	0071-001-06
Drawn By	E.A. CHRISTIANSEN
Date	NOVEMBER 30, 1981



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S7K 3S9  
Phone: 374-6700

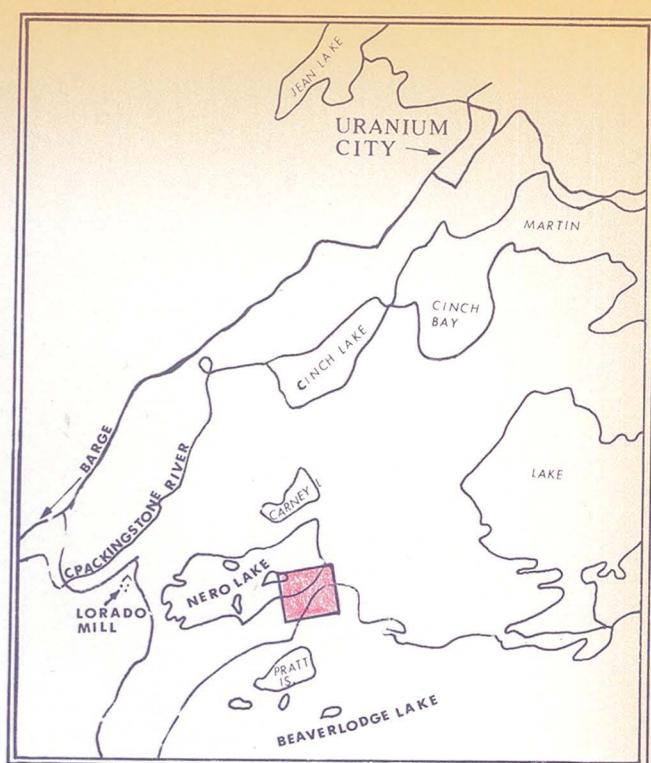
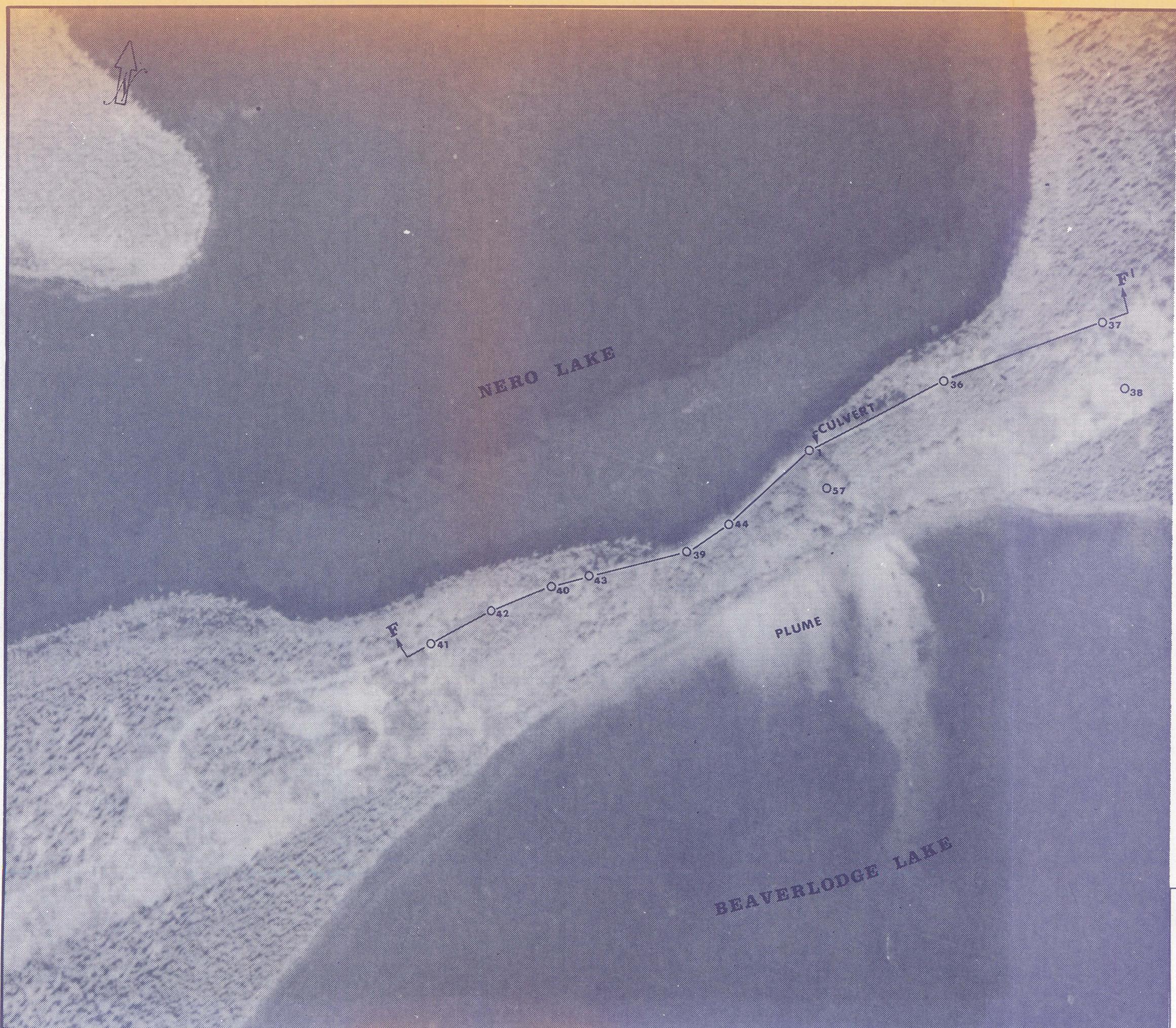
CONSULTING GEOLOGIST  
Drawing No. 0071-001-07  
Drawn By E.A. CHRISTIANSEN  
Date NOVEMBER 30, 1981





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Drawing No. 0071-001-04
Drawn By E.A. CHRISTIANSEN
Date NOVEMBER 30, 1981



**TITLE: LOCATION OF BOREHOLES AND  
CROSS SECTION F-F'**

**EXPLANATION**

O<sub>40</sub> BOREHOLE LOG NUMBER  
F-F' CROSS SECTION

SAMPLES, FIELD LOGS, AND ELEVATIONS BY:  
P. MACHIBRODA ENGINEERING LTD.

0 100 200  
METRES  
1: 2500

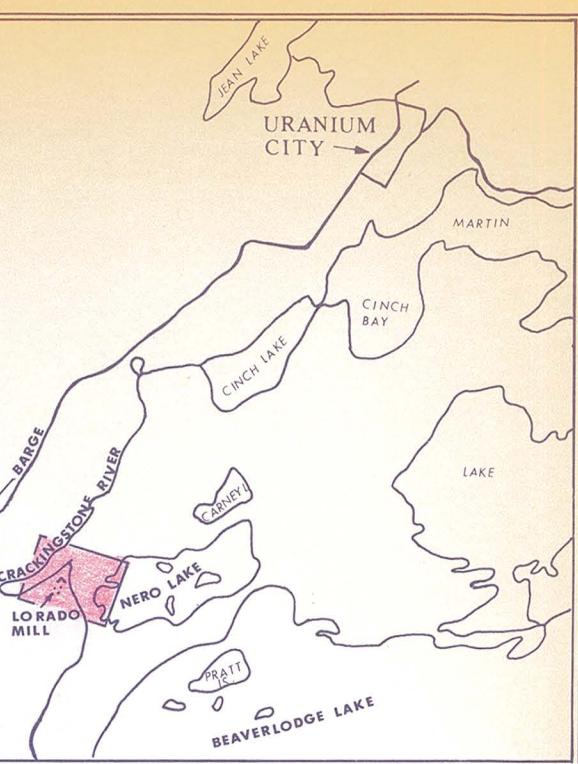
**E.A. CHRISTIANSEN**  
**CONSULTING LTD.**  
CONSULTING GEOLOGIST

Box 3087  
Saskatoon, Sask.  
S7K 3S9  
Phone: 374-6700

Drawing No. 0071-001-09

Drawn By E.A. CHRISTIANSEN

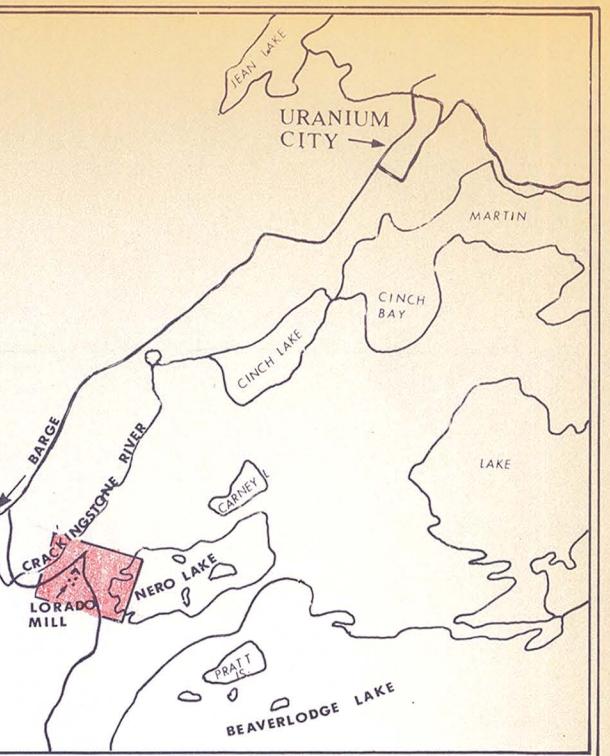
Date NOVEMBER 30, 1981



**TITLE: THICKNESS OF LORADO TAILINGS PILE**

Box 3087  
Saskatoon, Sask.  
S7K 3S9

Phone: 374-6700



**TITLE: TOPOGRAPHIC MAP OF BURIED SURFACE UNDER LORADO TAILINGS PILE**

**EXPLANATION**

BOREHOLE LOG NUMBER

BEDROCK OUTCROPS, LOCATED FROM PHOTOGRAPHS, NOT SURVEYED

A-A' CROSS SECTION

POINT ELEVATION ABOVE ASSUMED  
DATUM OF 300m  
CONTOUR INTERVAL = 1 m

SAMPLES, FIELD LOGS, AND ELEVATIONS BY:  
P. MACHIBRODA ENGINEERING LTD.

DEPRESSION CONTOUR

0 100 200 METRES  
1:2500

**E.A. CHRISTIANSEN**  
**CONSULTING LTD.**  
CONSULTING GEOLOGIST

Box 3087  
Saskatoon, Sask.  
S7K 3S9  
Phone: 374-6700

Drawing No. 0071-001-02

Drawn By E.A. CHRISTIANSEN

Date NOVEMBER 30, 1981



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Saskatoon, Sask.  
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Drawing No. 0071-001-01  
Drawn By E.A. CHRISTIANSEN  
Date NOVEMBER 30, 1981