

SASKATCHEWAN HIGHWAYS AND TRANSPORTATION

GEOLOGY OF THE CN SUBWAYS AREA

Report 0163-002

May 20, 1997



E. A. Christiansen Consulting Ltd.

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May 20, 1997

Saskatchewan Highways and Transportation
3130 - 8th Street East
Saskatoon, Saskatchewan
S7K 2H6

Attention: Mr. N.W. Richardson P. Eng.

Dear Mr. Richardson:

Enclosed is a copy of Report 0163-002 on the "Geology of the CN subways area". I understand that one copy is sufficient because you will redraw the enclosed sections and draw additional ones.

If you have any queries or require additional copies of the report, please contact me.

Sincerely yours,

E.A. Christiansen P. Eng., Geol.



ASSOCIATION OF PROFESSIONAL ENGINEERS OF SASKATCHEWAN		
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<u>Geology</u>		<u>E.C.</u>

SUMMARY

At the new CN subway site, groundwater is discharging from sands in the Judith River Formation, sand and gravel in the Empress Group, intertill sand and gravel between tills of the Dundurn and Warman formations, and from the terrace deposits. The thickest and most extensive aquifer affecting the site is the Judith River Formation which has been traced to west of Borden. The eolian sand unit provides an excellent medium for groundwater recharge because of its extensive area and high permeability.

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1. INTRODUCTION

1.1 Objective

The objective is to draw a longitudinal section along the proposed south lane of highway 16 through the proposed new CN subway and a cross section across Highway 16 and the CN subways. The purpose of these sections is to provide a geological framework for the proposed drainage construction in the vicinity of the new CN subway along the south lane of Highway 16.

1.2 Location

The location of the CN subways area is shown in Drawing 0163-002-01. The old CN subway along the present north lane of Highway 16 was built in 1987, and the new CN subway along the south lane of the highway was built in 1994. The location of the new CN subway is shown in Figure 1.

1.3 Previous work

Previous work includes a map and cross sections of the Saskatoon area (Christiansen 1967), maps and cross sections of the Saskatoon region (Christiansen 1979), a longitudinal section along Highway 16 from Fielding to the North Saskatchewan River valley (Christiansen 1995), and a soil map of the Saskatoon area (Acton and Ellis 1978).

1.4 Present study

The present study includes the examination of borehole cutting samples from boreholes 101 to 111 and 120 (Table 1, Appendix A) and cores from



A

THE ARROW POINTS TO THE NEW CN SUBWAY IN THE UPPER PART OF THE WEST BANK OF THE NORTH SASKATCHEWAN RIVER VALLEY. TO THE RIGHT OF THE ARROW IS THE OLD CN SUBWAY ALONG HIGHWAY 16. THE NEW BRIDGE BETWEEN THE ABANDONED ONE AND HIGHWAY 16 IS UNDER CONSTRUCTION.



B

THE NEW CN SUBWAY TAKEN FROM BOREHOLE SITE 122. NOTICE THE DRAINAGE FROM THE INTERTILL SAND AND GRAVEL BETWEEN TILLS OF THE DUNDURN AND WARMAN FMS.

Figure 1. Location of the CN subways and area.

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Table 1. Index of borehole logs in longitudinal section A-A' and cross section B-B'.

NUMBER	NAME	DLS	UTM (ZONE 13)
101	SHT CN subway 101	SE-12-25-39-09-W3	5805764N/351948E
102	102	SE-02-25-39-09-W3	5804990N/352821E
103	103	SW-01-25-39-09-W3	5804926N/352943E
104	104	NW-16-24-39-09-W3	5804870N/353047E
105	105	NW-02-25-39-09-W3	5805136N/352609E
106	106	NE-03-25-39-09-W3	5805211N/352466E
107	107	SE-02-25-39-09-W3	5805024N/352770E
108	108	SE-02-25-39-09-W3	5805101N/352832E
109	109	SE-02-25-39-09-W3	5804934N/352733E
110	110	SW-01-25-39-09-W3	5804964N/352871E
111	111	SE-02-25-39-09-W3	5805042N/352784E
120	120	NW-01-25-39-09-W3	5805199N/352920E

boreholes 106A and 107. Till samples were selected from boreholes 101, 102 and 105 to 109 for carbonate analyses (Appendix B) and from boreholes 101, 102 and 106 to 109 for grain size analyses. Geologic logs were compiled for boreholes 101 to 111 and 120 and appear in the sections and Appendix A.

2. STRATIGRAPHY

2.1 Introduction

Bedrock sediments are composed of the Lea Park and Judith River formations, and the glacial deposits are composed of Empress, Sutherland, and Saskatoon groups (Fig. 2).

2.2 Lea Park Formation

The Lea Park Formation was penetrated to an elevation of 395m or a thickness of 47m in borehole 101 (Drawing 0163-002-02, Table 1, Appendix A) to penetrate a known structural marker bed, the top of which appears in longitudinal section A-A' as the lower structural horizon. After penetrating the known lower marker bed in boreholes 101 and 102, an upper structural marker bed was observed in the Lea Park Formation and, subsequently, drilling was to this marker bed or the contact between the Lea Park and Judith River formations.

The Lea Park Formation is composed of marine, noncalcareous, gray silty clay and light gray silty sand beds which constitute the structural marker beds in the formation.

2.3 Judith River Formation

The Judith River Formation extends from boreholes 101 to 103

TIME UNITS		STRATIGRAPHIC UNITS			
		Group	Formation	Deposit	
QUATERNARY	HOLOCENE	SASKATOON		12 Alluvium SILT+CLAY	
				11 Alluvium SAND	
				10 Terrace S + G**	
				9*	
	PLEISTOCENE	Battleford		8 Till	
				7 Sand and gravel	
		SUTHERLAND	Warman	6 Till	
				5 Sand and gravel	
		Dundurn		4 Till	
				Sand and gravel	
3 EMPRESS		MONTANA	2 Judith River		
CRETACEOUS			1 Lea Park		

*9 Eolian sand
**S + G Sand and gravel

Figure 2. Stratigraphic chart. Pleistocene nomenclature from Christiansen (1992).

where it was truncated by fluvial erosion during formation of the North Saskatchewan River valley. The formation is composed of less than 1 to 20m of deltaic, fine to medium grained, gray, noncalcareous, sand; light gray to white, calcareous sandstone; and noncalcareous silt and clay interbeds. In borehole 120 (Drawing 0163-002-03), the upper part of the Judith River Formation is oxidized to a olive brown color as the result of aeration, presumably because of its proximity to a spring downvalley (Drawing 0163-002-01). The Judith River Formation is the most extensive and thickest aquifer in the area. The contact between the Lea Park and Judith River formations is conformable.

2.4 Empress Group

The Empress Group is composed of up to 1m of coarse, sandy gravel between the Judith River Formation and the Dundurn Formation of the Sutherland Group in boreholes 102, 107, 109, and 111 (Drawings 0163-002-02, 03; Fig. 2). The contact between the Judith River Formation and the Empress Group is an erosional unconformity.

2.5 Sutherland Group

The Sutherland Group is between the Empress Group and the Battleford Formation of the Saskatoon Group and is composed of the Dundurn and Warman formations (Fig. 2).

2.5.1 Dundurn Formation

The Dundurn Formation is composed of till between the Empress Group and the Warman Formation. The till is less than 1 to 10m thick, gray to dark gray, unoxidized, calcareous (Table 2), and sandy and silty (Table 3). The upper part of the till is oxidized to a grayish brown

Table 2. Carbonate content of tills in the CN subways area.

STRATIGRAPHIC UNIT	NO. OF SAMPLES N	MEAN (mL CO ₂ /g)	SD
Battleford Formation	4	27.4	3.4
Warman Formation	13	16.5	0.6
Dundurn Formation	29	26.2	3.1

Table 3. Grain size analyses of tills in the CN subways area.

STRATIGRAPHIC UNIT	N	% SAND 2.0-.05 mm X SD	% SAND 2.0-.075 mm X SD	% SILT .05-.002 mm X SD	% SILT .075-.002 mm X SD	% CLAY .002 mm X SD
Battleford Fm.	1	56 -	50 -	31 -	37 -	13 -
Warman Fm.	3	44 2.5	38 1.7	32 1.2	38 1.2	24 2.1
Dundurn Fm.	9	36 3.8	30 3.7	37 3.7	43 4.0	27 2.5

color. The till of the Dundurn Formation is exposed in the new CN subway site (Fig. 1B). The contact between the Empress Group and the Dundurn Formation is nonconformable.

2.5.2 Warman Formation

The Warman Formation is composed of a lower intertill sand and gravel and an upper till unit. The lower unit is placed in the Warman Formation rather than the Dundurn Formation because the top of the till in the Dundurn Formation is oxidized and the overlying intertill sand and gravel is unoxidized.

The lower sand and gravel of the Warman Formation is the most extensive intertill sand and gravel in the area. Groundwater discharges from this unit at the new CN subway (Fig. 1B). The sediment is up to 3m in thickness. Rounded, transported pieces of wood were retrieved from this unit.

The till of the Warman Formation is composed of less than 1 to 8m of gray to dark gray (unoxidized) and grayish brown (oxidized), gypsiferous, slightly calcareous (Table 2), sandy and silty (Table 3) till. The lower carbonate content of till of the Warman Formation and stratigraphic sequence were the main criteria for separating this till from tills of the Dundurn and Battleford formations. The contact between the Dundurn and Warman formations is nonconformable.

2.6 Saskatoon Group

The Saskatoon Group is composed of Battleford Formation, eolian sand, terrace sand and gravel, and alluvium.

2.6.1 Battleford Formation

The Battleford Formation is composed of an intertill sand and gravel unit and an overlying till unit (Drawing 0163-002-02, log 101). The intertill unit is assigned to the Battleford Formation rather than the Warman Formation because the upper part of the Warman Formation is oxidized and intertill sand and gravel is unoxidized.

The till of the Battleford Formation is composed of less than 1 to 6m of gray (unoxidized) and grayish brown (oxidized), calcareous (Table 2), sandy (Table 3), soft till. This unit is assigned to the Battleford Formation mainly on the basis of the softness of the till.

2.6.2 Eolian sand

The eolian sand unit includes dune sand (Fig. 3A) and interdune, blanket cover sands (Fig. 3B). Eolian sand is composed of less than 1 to 6m of fine grained sand which, undoubtedly, is much thicker in the dunes. The eolian sand lies on a truncated surface between boreholes 101 and 111 (Drawing 0163-002-02) which, presumably, was eroded during the initial formation of the North Saskatchewan River valley.

In a hand augerhole, 3.4m of eolian cover sand was penetrated before encountering till (Figs. 3B, 4). The buried soil is poorly developed as indicated by a thin A-horizon and the absence of a Cca-horizon. The upper present-day soil, on the other hand, has a thick A-horizon and a Cca-horizon that has affected the A and B- horizons of the buried soil. These observations suggest that the dune area has been stabilized for most of the Holocene time.

The fact that 17m of clay and silt occur between till and deltaic sand



A

EXPOSURE THROUGH SAND DUNE SHOWING BURIED SOIL IN MIDDLE OF DUNE.



B

BLANKET OF EOLIAN COVER SAND AT BOREHOLE 113. ARROW SHOWS T-BAR OF AUGER IN HOLE. STRIP BY T-BAR IS SAMPLES AUGERED FROM HOLE. NOTICE BRIDGES AND NORTH SASKATCHEWAN RIVER VALLEY IN BACKGROUND.

Figure 3. Sand dune and eolian cover sand.

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PAGE 1 OF

GEOLOGIST-SITE		NAME OF SITE				PROJECT NO.		
E A C	0 1	C N	S U B W A Y			0 1 6 3		
N T S		UTM - ZONE		UTM-EASTING (M)		UTM-NORTHING (M)		
7 3 B	0 6							
1/4	LSD	S	T	R	M	LATITUDE $^{\circ}$ N,S		
N W	0 2	2 5	3 9	0 9	w 3			
LONGITUDE $^{\circ}$ E,W		TYPE OF OBSERVATION				DAY	MO.	YEAR
		A U G E R H O L E				0 8	0 5	19 9 7
ELEVATION (M)		SOURCE OF ELEVATION				AERIAL PHOTOGRAPH NO.		
FEET								
0		SAND, FINE, NONCALC., CARB., V. DK. GR. BR. (A-horizon)						
5		SAND, FINE, NONCALC., DK. GR. BR. (B-horizon)						
10		SAND, FINE, NONCALC., GR. BR.- LT. OL. BR. (C-horizon)						
15		SAND, FINE, CALC. WITH BLEBS OF WH. CALCITE, GR. BR. - LT. OL. BR. (Cca-horizon)						
20		SAND, FINE, CALC., CARB., DK. GR. BR. (A-horizon)						
25		SAND, FINE, CALC., GR. BR.- LT. OL. BR.+DK. GR. BR. (B-horizon with secondary calcite leached from above)						
30		SAND, FINE, NONCALC., LT. GR.+GR. BR., LT. OL. BR. STAINS (C-horizon)						
35		TILL, CALC., GR. BR.- LT. OL. BR.						
40								
45								
50								
55								
60								
65								
70								
75								
80								
85								
90								
95								
100								
105								
110								
115								
120								
125								
130								
135								
140								
145								
150								
155								
160								
E.A. CHRISTIANSEN 09/05/97								

Figure 4. Geologic log of eolian cover sand.

near Borden (SHT Radisson No. 6, Christiansen 1995) and none occurs between till and eolian sand in the CN subway area suggests that the glacial margin stood between these locations until Lake Saskatchewan drained and the North Saskatchewan River valley came into existence. This would allow eolian sand derived from deltaic sand farther west to be deposited directly on till in the CN subway area.

2.6.3 Terrace sand and gravel

Terrace sand and gravel occur on an erosional surface sloping gently eastward from boreholes 102 to near 104 (Drawing 0163-002-02), beyond which the sand and gravel was eroded during the formation of the deeper valley trench. Proceeding eastward on the terrace from borehole 102, the terrace sand and gravel unit overlies till of the Dundurn Formation and the Judith River and Lea Park formations.

The terrace sand and gravel unit is less than 1 to 3m thick. The upper sand in this unit may be eolian in origin. Upriver from Highway 16, eolian dune sand does cover the terrace.

2.6.4 Alluvium

The alluvium in the North Saskatchewan River valley is composed of a lower unit of mainly sand and an upper unit of organic sediments (Drawing 0163-002-02). In UofS Eagle No. 11 borehole near the west abutment of the old concrete bridge (Christiansen 1995, Drawing 0155-002-02, log 14), 33.5m of the lower sand was encountered. The configuration of the North Saskatchewan River valley east of borehole 104 is based on this Eagle borehole log. The lower sand unit in the alluvium is composed of fine to medium grained sand and silt interbeds. According to Christiansen (1983), this lower sand unit was deposited over the last 11,000 years.

The upper unit of organic deposits is about 2m thick and occurs in an abandoned river channel which was cut in recent time.

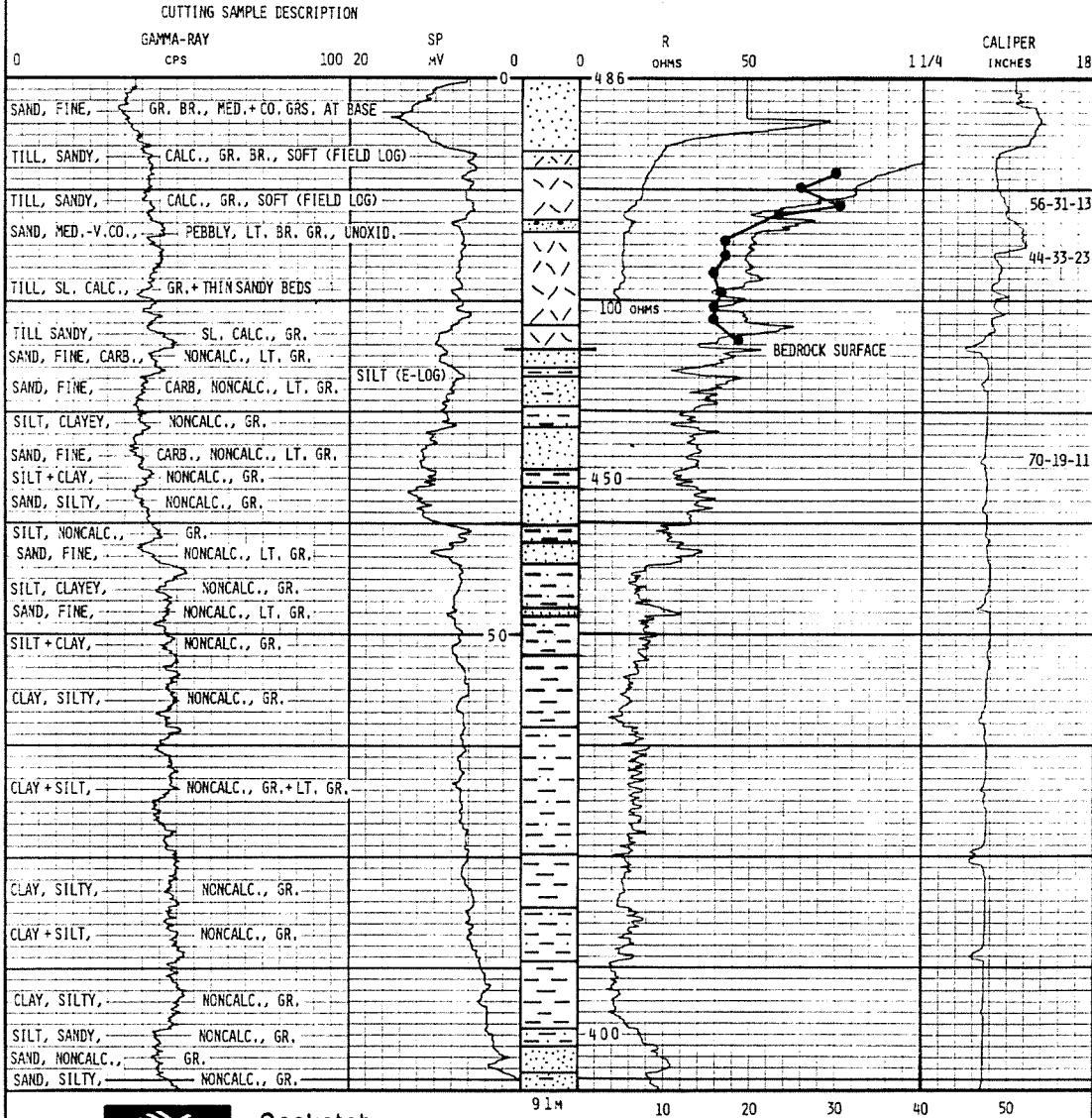
3. LITERATURE CITED

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Appendix A. Geologic logs in sections A-A' and B-B'.

SHT 73-B/06 1997
CN SUBWAY NO.101
SE-12-25-39-09-W3
ST 43260.0 OF 32.0 L
13:5805764N/351948E
BOREHOLE

BOREHOLE NO.	CN SUBWAY 101	MTS	73-3/06
LAND LOCATION	SM-12-25-39-09-W3		
UTM COORD.	13-5805754	381V	351948,332E
GRD. ELEV.	485.300 M	DEPTH	91.45 M
DATE DRILLED	JAN 13 TO JAN 19 1972		
COND. WATER	525	MICROSIEMENS/CM AT 25°C	
COND. MUD	975	MICROSIEMENS/CM AT 25°C	
SPECIFIC GRAVITY MUD			
SUPERVISOR	L. SINCLAIR		
ASST. SUPERVISOR			
LOGGED BY	L. SINCLAIR		
INSTRUMENT	WIDCO 1500		
PROBE ELECTRIC			
PROBE GAMMA			
PROBE CALIPER			
DATE LOGGED	JANUARY 14 1972		
TIME OF LOGGING	1530 HRS TO 1700 HRS		
DRILL OPERATOR	M. MILLER		
CONTRACTOR			
REMARKS	M. MINCHUK		
PROJECT	BORDEN RAILWAY OVERPASS		
CONTROL SECTION	16-24		
STATION	43250.0	OFFSET	32.0 LEFT
CUTTING SAMPLE INTERVAL	1.5 M		
CORE SAMPLE INTERVAL			
FROM			
CASING DEPTH			
CASING WALL THICKNESS			
WATER OR MUD LEVEL			
ABANDONMENT	POST IN HOLE		
BIT SIZE	4 3/4" WIMAC	INTERVAL	0-91.45 M
BIT SIZE		INTERVAL	
BIT SIZE		INTERVAL	
TYPE OF DRILL RIG	1250 FAILING		
DEPTH	SCALE SPEED		
SP.	91 M	20 MY	15 MM/MIN
RES.	91 M	50 OHMS	15 MM/MIN
GAMMA	91 M	0-100 CPS	8 MM/MIN
CAL	91 M	1 1/4"-18"	15 MM/MIN
GAMMA TIME CONSTANT (T.C.)	5 SECONDS		
GEOLOGY BY	E.A. CHRISTIANSEN	03/02/97	



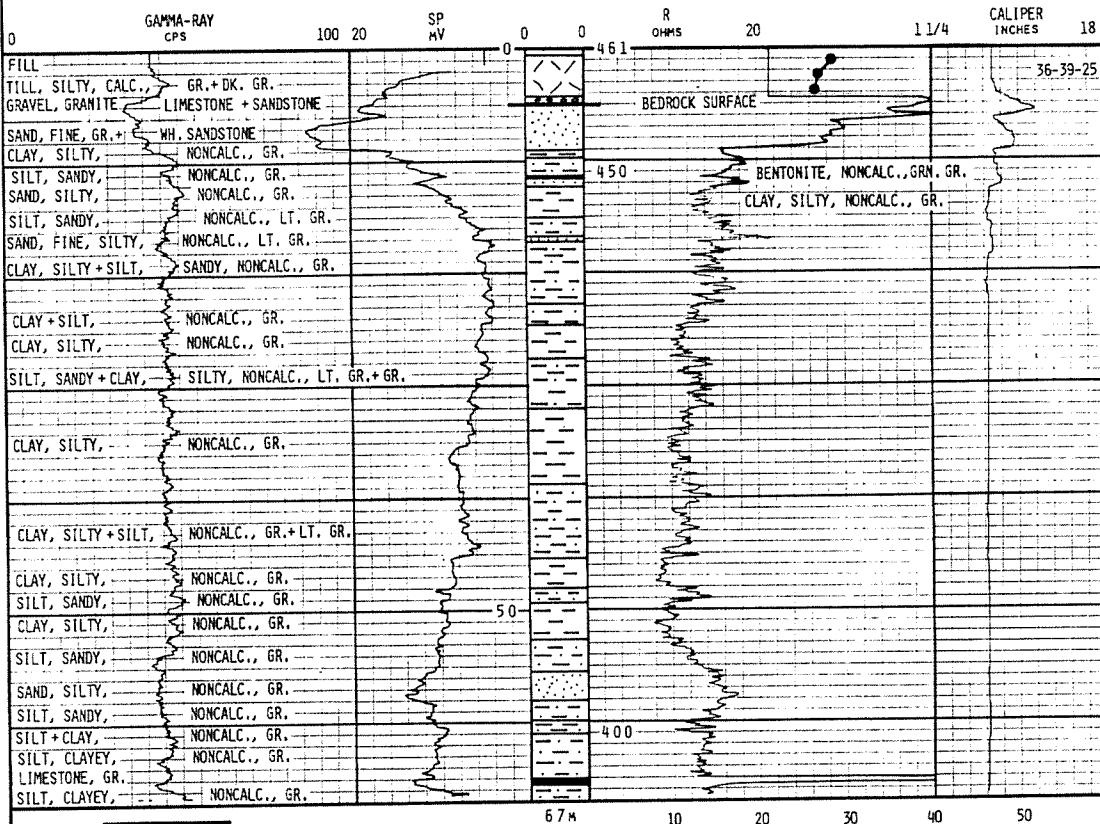
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$50 - 30 - 20 = 50\%$ SAND, 30% SILT, 20% CLAY

SHT 73-B/06 1997
 CN SUBWAY NO.102
 SE-02-25-39-09-W3
 ST 42085.0 OF 2.3 L
 13:5804990N/352821E
 BOREHOLE

BOREHOLE NO.	CN SUBWAY 102	MTS	73-B/06	PROJECT	BORDEN RAILWAY OVERPASS
LAND LOCATION	SE-02-25-39-09-W3	CONTROL SECTION	16-24	STATION	42085.0
UTM COORD.	13:5804989, 933N/352820, 536E	OFFSET	2.3 LEFT	CUTTING SAMPLE INTERVAL	
GRD. ELEV.	450.596 M. DEPTH	67.05 M		CORE SAMPLE INTERVAL	
DATE DRILLED	JAN. 15 TO JAN. 15 1997	FROM		CASING DEPTH	
COND. WATER	525	MICROSIEMENS/CM AT 25°C		CASING WALL THICKNESS	
COND. MUD	825	MICROSIEMENS/CM AT 25°C		WATER OR MUD LEVEL	
SPECIFIC GRAVITY MUD				ABANDONMENT	GROUTED AND POST IN HOLE
SUPERVISOR	L. SINCLAIR			BIT SIZE	4 3/4" HALMAC INTERVAL 0-67.05 M
ASST. SUPERVISOR				BIT SIZE	
LOGGED BY	L. SINCLAIR			BIT SIZE	
INSTRUMENT	XIDCO 1500			TYPE OF DRILL RIG	1250 FAILING
PROBE ELECTRIC				DEPTH	
PROBE GAMMA				SCALE	
PROBE CALIPER				SPEED	
DATE LOGGED	JANUARY 15 1997	SP.	66.5 M	20 HV	15 HV/MIN
TIME OF LOGGING	1400 HRS TO 1530 HRS	RES.	66.5 M	20 OHMS	15 HV/MIN
DRILL OPERATOR	M. MILLER	GAMMA	66.5 M	0-100 CPS	8 HV/MIN
CONTRACTOR		CAL	66.5 M	1 1/4-18"	15 HV/MIN
REMARKS	ASS'T OPERATOR: M. MIRCHUK			GAMMA TIME CONSTANT (T.C.)	5 SECONDS
				GEOLOGY BY E.A. CHRISTIANSEN	03/02/97

CUTTING SAMPLE DESCRIPTION



Saskatchewan
 Highways and
 Transportation

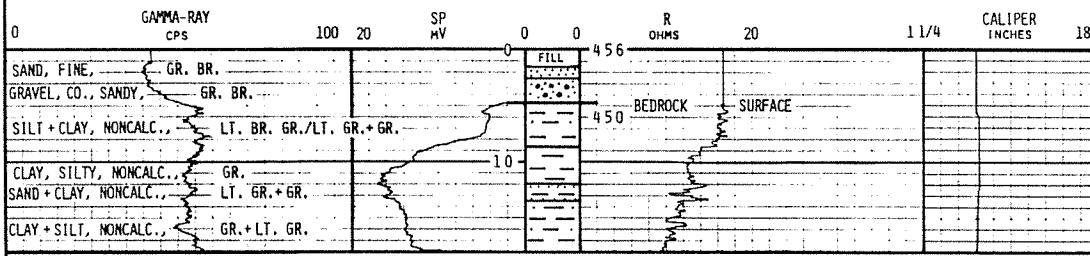


50-30-20 = 50% SAND, 30% SILT, 20% CLAY

SHT 73-B/06 1997
 CN SUBWAY NO.103
 SW-01-25-39-09-W3
 ST 41947.0 OF 0.0 CL
 13:5804926N/352943E
 BOREHOLE

BOREHOLE NO.	CN SUBWAY 103	MTS	73-B/06	PROJECT	BORDEN RAILWAY OVERPASS		
LAND LOCATION	SW-01-25-39-09-W3			CONTROL SECTION	16-24		
UTM COORD.	13:5804926, 312N/352943, 044E			STATION	41947.0		
GRD. ELEV.	456.136 M	DEPTH	18.3 M	OFFSET	0.0 CL		
DATE DRILLED	JAN. 21 TO JAN. 21	1997		CUTTING SAMPLE INTERVAL	1.5 M		
COND. WATER	323	MICROSIEMENS/CM AT 25°C		CORE SAMPLE INTERVAL			
COND. MUD	825	MICROSIEMENS/CM AT 25°C		FROM			
SPECIFIC GRAVITY MUD				CASING DEPTH	4.85 M		
SUPERVISOR	L. SINCLAIR			CASING WALL THICKNESS			
ASST. SUPERVISOR				WATER OR MUD LEVEL			
LOGGED BY	L. SINCLAIR			ABANDONMENT	GROUTED AND POST IN HOLE		
INSTRUMENT	MDCCO 1500			BIT SIZE	4 3/4" TRICONE		
PROBE ELECTRIC				INTERVAL	0-6.1 M		
PROBE GAMMA				BIT SIZE	4 3/4" HALMAC		
PROBE CALIPER				INTERVAL	6.1-18.3 M		
DATE LOGGED	JANUARY 21, 1997			BIT SIZE			
TIME OF LOGGING	1100 HRS	TO	1230 HRS	TYPE OF DRILL RIG	1250 FAILING		
DRILL OPERATOR	M. MILLER			DEPTH	SCALE	SPEED	
CONTRACTOR				SP	18 M	20 MV	15 M/MIN
REMARKS	ASS'T. OPERATOR: M. MINCHUK			RES.	18 M	20 OHMS	15 M/MIN
				GAMMA	18 M	0-100 CPS	8 M/MIN
				CAL	18 M	1 1/4-18"	15 M/MIN
				GAMMA TIME CONSTANT (T.C.)	5	SECONDS	
				GEOLGY BY	E.A. CHRISTIANSEN	05/02/97	

CUTTING SAMPLE DESCRIPTION

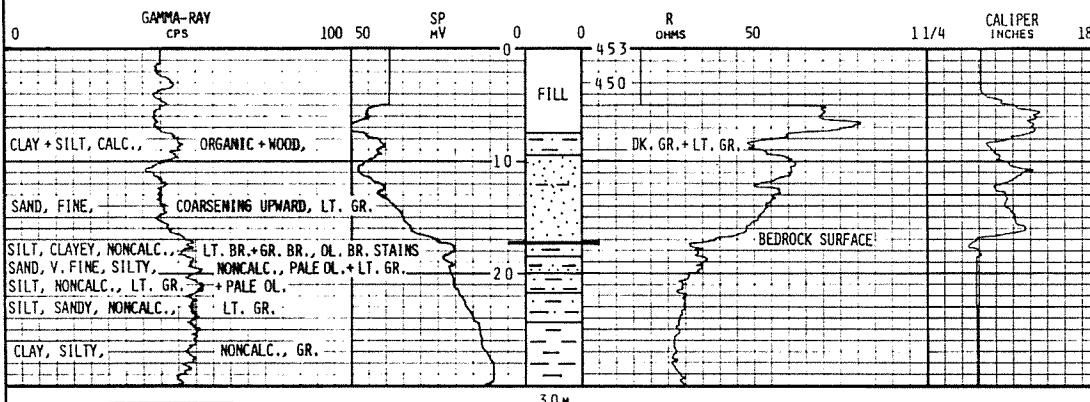


Saskatchewan
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Transportation

SHT 73-B/06 1997
CN SUBWAY NO.104
NW-16-24-39-09-W3
ST 41829.0 OF 0.0 CL
13:5804870N/353047E
BOREHOLE

BOREHOLE NO.	CN SUBWAY 104	MTS	73-B/06
LAND LOCATION	NW-16-24-39-09-W3		
UTM COORD.	13:5804870.376N/353046.944E		
GRD. ELEV.	452.806 M	DEPTH	30.5 M
DATE DRILLED	JAN. 21 TO JAN. 21 1997		
COND. WATER	525	MICROSIEMENS/CM AT 25°C	
COND. MUD	850	MICROSIEMENS/CM AT 25°C	
SPECIFIC GRAVITY MUD			
SUPERVISOR	L. SINCLAIR		
ASST. SUPERVISOR			
LOGGED BY	L. SINCLAIR		
INSTRUMENT	KIDCO 1500		
PROBE ELECTRIC			
PROBE GAMMA			
PROBE CALIPER			
DATE LOGGED	JANUARY 21 1997		
TIME OF LOGGING	1600 HRS TO 1730 HRS		
DRILL OPERATOR	M. MILLER		
CONTRACTOR	ASS'T OPERATOR: M. MINCHUK		
REMARKS			
PROJECT	BORDEN RAILWAY OVERPASS		
CONTROL SECTION	16-24		
STATION	41829.0	OFFSET	0.0 CL
CUTTING SAMPLE INTERVAL		1.5 M	
CORE SAMPLE INTERVAL			
FROM			
CASING DEPTH		4.85 M	
CASING WALL THICKNESS			
WATER OR MUD LEVEL			
ABANDONMENT	GROUTED AND POST IN HOLE		
BIT SIZE	4 3/4" TRICONE	INTERVAL	0-6.1 M
BIT SIZE	4 3/4" WALMAC	INTERVAL	6.1-30.5 M
BIT SIZE		INTERVAL	
TYPE OF DRILL RIG	1250 FAILING		
DEPTH	SP	SCALE	SPEED
SP	30 M	50 MV	15 M/MIN
RES	30 M	50 OHMS	15 M/MIN
GAMMA	30 M	0-100 CPS	8 M/MIN
CAL	30 M	1 1/4-18"	15 M/MIN
GAMMA TIME CONSTANT (T.C.)	5	SECONDS	
GEOLGY BY	E.A. CHRISTIANSEN	05/02/97	

CUTTING SAMPLE DESCRIPTION

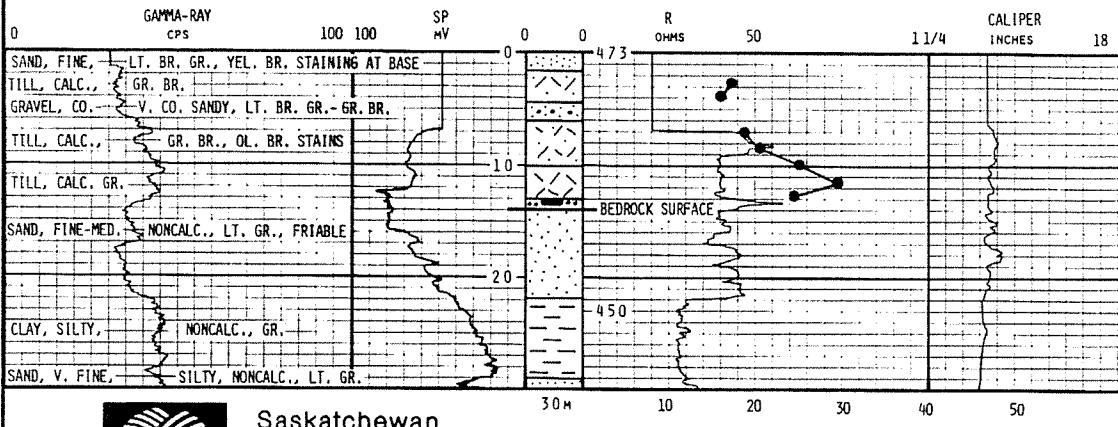


Saskatchewan
Highways and
Transportation

SHT 73-B/06 1997
 CN SUBWAY NO.105
 NW-02-25-39-09-W3
 ST 42342.8 OF 2.5 R
 13:5805136N/352609E
 BOREHOLE

BOREHOLE NO.	CN SUBWAY 105	NTS	73-B/06
LAND LOCATION	NW-02-25-39-09-W3		
UTM COORD.	13:5805136.176N/352608.537E		
GRD. ELEV.	472.540 M	DEPTH	30.5 M
DATE DRILLED	JAN. 22	TO	JAN. 22 1997
COND. WATER	525	MICROSIEMENS/CM AT 25°C	
COND. MUD	800	MICROSIEMENS/CM AT 25°C	
SPECIFIC GRAVITY MUD			
SUPERVISOR	L. SINCLAIR		
ASST. SUPERVISOR			
LOGGED BY	L. SINCLAIR		
INSTRUMENT	VIDCO 1500		
PROBE ELECTRIC			
PROBE GAMMA			
PROBE CALIPER			
DATE LOGGED	JANUARY 22, 1997		
TIME OF LOGGING	1500 HRS	TO	1630 HRS
DRILL OPERATOR	M. MILLER		
CONTRACTOR			
REMARKS	ASS'T OPERATOR: M. MINCHUK		
PROJECT	BORDEN RAILWAY OVERPASS		
CONTROL SECTION	16-24		
STATION	42342.8	OFFSET	2.5 RIGHT
CUTTING SAMPLE INTERVAL	1.5 M		
CORE SAMPLE INTERVAL			
FROM			
CASING DEPTH	7.25 M		
CASING WALL THICKNESS			
WATER OR MUD LEVEL			
ABANDONMENT	GROUTED AND POST IN HOLE		
BIT SIZE	4 3/4" HALMAC	INTERVAL	0-30.5 M
BIT SIZE		INTERVAL	
BIT SIZE		INTERVAL	
TYPE OF DRILL RIG	1250 FAILING		
DEPTH	SCALE	SPEED	
SP.	50 M	100 MV	15 M/MIN
RES.	50 M	50 OHMS	15 M/MIN
GAMMA	30 M	0-100 CPS	8 M/MIN
CAL	30 M	1 1/4-18"	15 M/MIN
GAMMA TIME CONSTANT (T.C.)	5	SECONDS	
GEOLOGY BY	E.A. CHRISTIANSEN	06/02/97	

CUTTING SAMPLE DESCRIPTION

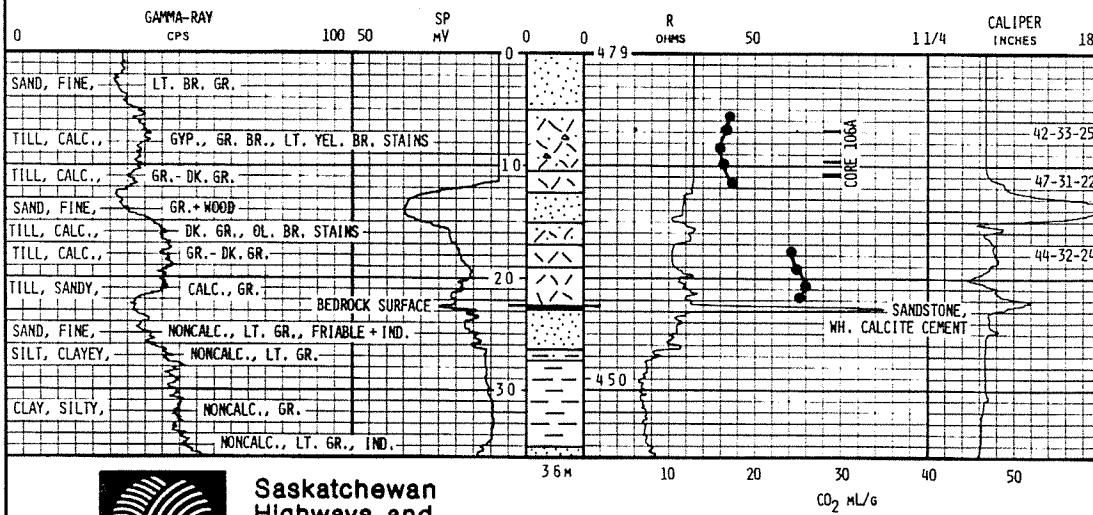


Saskatchewan
Highways and
Transportation

SHT 73-B/06 1997
 CN SUBWAY NO.106
 NE-03-25-39-09-W3
 ST 42498.0 OF 35.0 L
 13:5805211N/352466E
 BOREHOLE

BOREHOLE NO.	CN SUBWAY 106	MTS 73-B/06	
LAND LOCATION	NE-03-25-39-09-W3		
UTM COORD.	13:5805210.537N/352465.594E		
GRD. ELEV.	478.390 M	DEPTH 36.6 M	
DATE DRILLED	JAN. 28 TO JAN. 29 1997		
COND. WATER	525	MICROSIEMENS/CM AT 25°C	
COND. MUD	875	MICROSIEMENS/CM AT 25°C	
SUPERVISOR	L. SINCLAIR		
ASST SUPERVISOR			
LOGGED BY	L. SINCLAIR		
INSTRUMENT	WIDCO 1500		
PROBE ELECTRIC			
PROBE GAMMA			
PROBE CALIPER			
DATE LOGGED	JANUARY 29 1997		
TIME OF LOGGING	1000 HRS. TO 1130 HRS		
DRILL OPERATOR	M. MILLER		
CONTRACTOR			
REMARKS	ASST OPERATOR: M. MINCHUK		
PROJECT	BORDEN RAILWAY OVERPASS		
CONTROL SECTION	16-24		
STATION	42498.0	OFFSET 35.0 LEFT	
CUTTING SAMPLE INTERVAL	1.5 M		
CORE SAMPLE INTERVAL			
FROM			
CASING DEPTH	11.55 M		
CASING WALL THICKNESS			
WATER OR MUD LEVEL			
ABANDONMENT	GROUTED AND POST IN HOLE		
BIT SIZE	4 3/4" WALMAC	INTERVAL 0-36.6 M	
BIT SIZE		INTERVAL	
BIT SIZE		INTERVAL	
TYPE OF DRILL RIG	1250 FAILING		
DEPTH	SP.	SCALE	SPEED
	36 M	50 MV	15 M/MIN
	36 M	50 OHMS	15 M/MIN
	36 M	0-100 CPS	8 M/MIN
	36 M	1 1/4"-18"	15 M/MIN
GAMMA TIME CONSTANT (T.C.)	5 SECONDS		
GEOLOGY BY	F.A. CHRISTIANSEN 06/02/97		

CUTTING SAMPLE DESCRIPTION



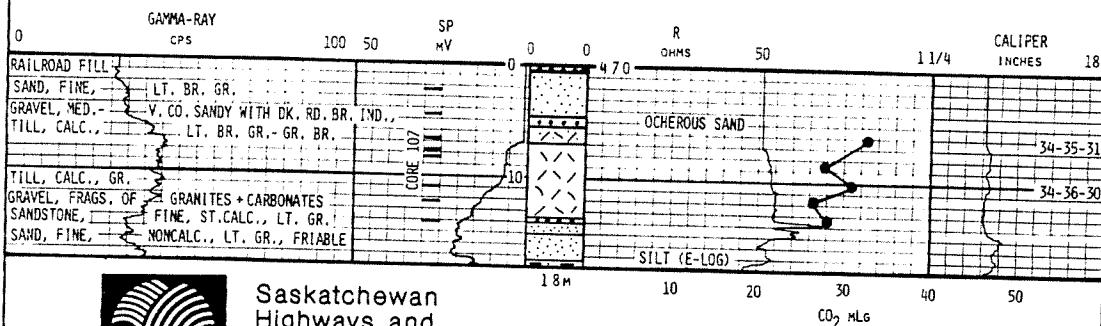
Saskatchewan
Highways and
Transportation

SHT 73-B/06 1997
 CN SUBWAY NO.107
 SE-02-25-39-09-W3
 ST 42145.7 OF 2.5 R
 13:5805024N/352770E
 BOREHOLE

BOREHOLE NO	CN SUBWAY 107	MIS	73-B/06
LAND LOCATION	SE-02-25-39-09-W3		
UTM COORD.	13:5805024,448N/352770,387E		
GRD. ELEV.	469.850 M.	DEPTH	13.3 M
DATE DRILLED	JAN. 29	TO	JAN. 29
COND. WATER	525	MICROSIEMENS/CM AT 25°C	
COND. MUD	800	MICROSIEMENS/CM AT 25°C	
SPECIFIC GRAVITY MUD			
SUPERVISOR	L. SINCLAIR		
ASST SUPERVISOR			
LOGGED BY	L. SINCLAIR		
INSTRUMENT	WIDCO 1500		
PROBE ELECTRIC			
PROBE GAMMA			
PROBE CALIPER			
DATE LOGGED	JANUARY 29, 1997		
TIME OF LOGGING	1700 HRS TO 1830 HRS		
DRILL OPERATOR	M. MILLER		
CONTRACTOR			
REMARKS	ASS'T OPERATOR: M. MINCHUK		

PROJECT	BORDEN RAILWAY OVERPASS		
CONTROL SECTION	16-24		
STATION	42145.7	OFFSET	2.5 RIGHT
CUTTING SAMPLE INTERVAL	1.5 M		
CORE SAMPLE INTERVAL	VARIOUS		
FROM	2.1-14.0 M		
CASING DEPTH	6.95 M		
CASING WALL THICKNESS			
WATER OR MUD LEVEL			
ABANDONMENT	PIEZOMETER INSTALLED		
BIT SIZE	4 3/4" TRICONIC	INTERVAL	0-6.1 M
BIT SIZE	4 3/4" WALMAC	INTERVAL	6.1-18.3 M
BIT SIZE		INTERVAL	
TYPE OF DRILL RIG	1250 FAILING		
DEPTH	SCALE	SPEED	
SP.	18 M	50 MV	15 M/MIN
RES.	18 M	50 OHMS	15 M/MIN
GAMMA	18 M	0-100 CPS	8 M/MIN
CAL	18 M	1 1/4"-18"	15 M/MIN
GAMMA TIME CONSTANT (T.C.)	5	SECONDS	
GEOLOGY BY	E.A. CHRISTIANSEN	06/02/97	

CUTTING SAMPLE DESCRIPTION



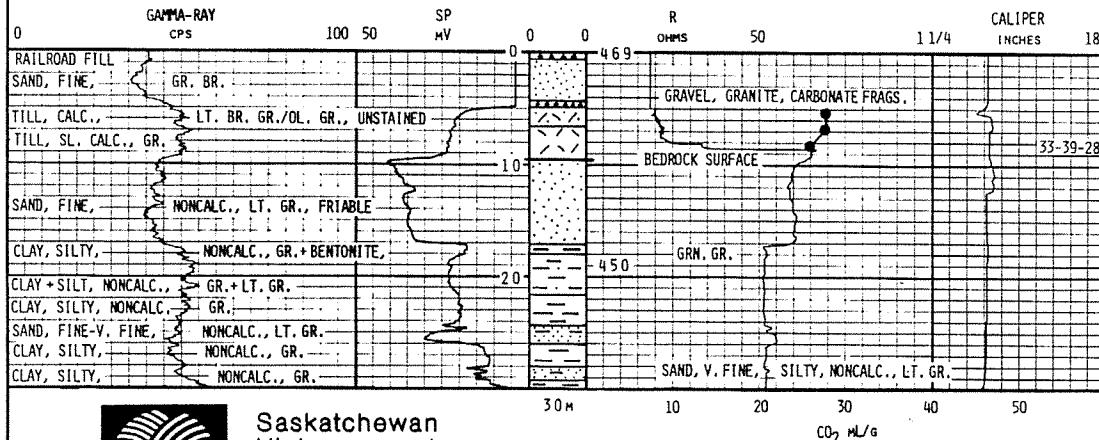
Saskatchewan
Highways and
Transportation

50-30-20 = 50% SAND, 30% SILT, 20% CLAY

SHT 73-B/06 1997
 CN SUBWAY NO.108
 SE-02-25-39-09-W3
 ST 42132.0 OF 100.0 R
 13:5805101N/352832E
 BOREHOLE

BOREHOLE NO.	CN SUBWAY 108	NTS	73-B/06
LAND LOCATION	SE-02-25-39-09-W3		
UTM COORD.	13:5805101.359N/352831.759E		
GRO. ELEV.	469.012 M	DEPTH	30.5 M
DATE DRILLED	JAN. 30 TO JAN. 30 1997		
COND. WATER	525		
COND. MUD	875	MICROSIEMENS/CM AT 25°C	
SPECIFIC GRAVITY MUD			
SUPERVISOR	L. SINCLAIR		
ASST. SUPERVISOR			
LOGGED BY	L. SINCLAIR		
INSTRUMENT	WIDCO 1500		
PROBE ELECTRIC			
PROBE GAMMA			
PROBE CALIPER			
DATE LOGGED	JANUARY 30 1997		
TIME OF LOGGING	1600 HRS TO 1730 HRS		
DRILL OPERATOR	M. MILLER		
CONTRACTOR			
REMARKS	ASS'T OPERATOR: M. MINCHUK		
PROJECT	BORDEN RAILWAY OVERPASS		
CONTROL SECTION	16-24		
STATION	42132.0	OFFSET	100.0 RIGHT
CUTTING SAMPLE INTERVAL	1.5 M		
CORE SAMPLE INTERVAL			
FROM			
CASING DEPTH	5.45 M		
CASING WALL THICKNESS			
WATER OR MUD LEVEL			
ABANDONMENT	GRouted AND POST IN HOLE		
BIT SIZE	4 3/4" WALMAC	INTERVAL	0-30.5 M
BIT SIZE		INTERVAL	
BIT SIZE		INTERVAL	
TYPE OF DRILL RIG	1250 FAILING		
DEPTH		SCALE	SPEED
SP.	30 M	50 MV	15 M/MIN
RES.	30 M	50 OHMS	15 M/MIN
GAMMA	30 M	0-100 CPS	8 M/MIN
CAL	30 M	1 1/4"-18"	15 M/MIN
GAMMA TIME CONSTANT (T.C.)	5	SECONDS	
GEOLOGY BY	E.A. CHRISTIANSEN	06/02/97	

CUTTING SAMPLE DESCRIPTION



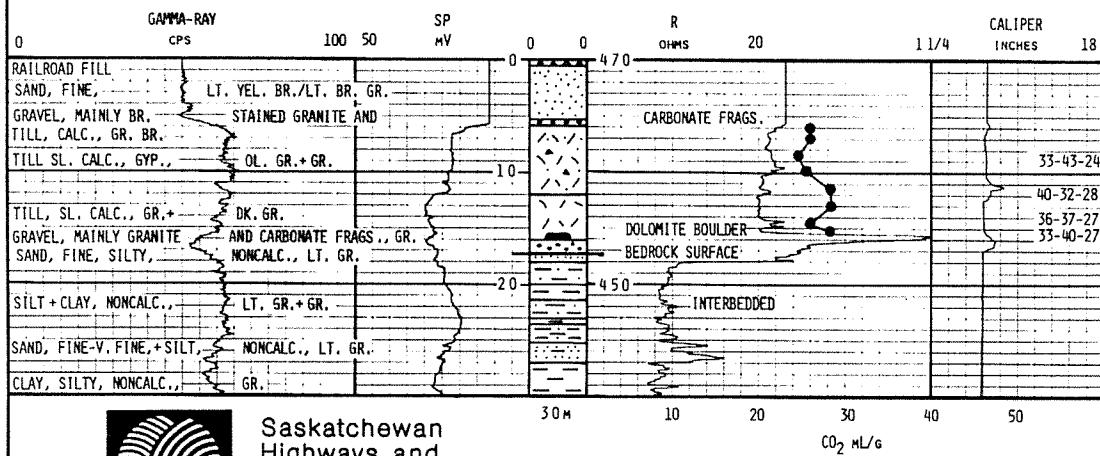
Saskatchewan
Highways and
Transportation

50-30-20 - 50% SAND, 30% SILT, 20% CLAY

SHT 73-B/06 1997
 CN SUBWAY NO.109
 SE-02-25-39-09-W3
 ST 42131.5 OF 94.1 L
 13:5804934N/352733E
 BOREHOLE

BOREHOLE NO.	CN SUBWAY 109	MTS	73-B/06
LAND LOCATION	SE-02-25-39-09-W3		
UTM COORD.	13:5804934,017N/352733,015E		
GRD. ELEV.	469.797 M	DEPTH	30.5 M
DATE DRILLED	FEB. 3	TO	FEB. 3
COND. WATER	525	MICROSIEMENS/CM AT 25°C	
COND. MUD	1500	MICROSIEMENS/CM AT 25°C	
SPECIFIC GRAVITY MUD			
SUPERVISOR	L. SINCLAIR		
ASST. SUPERVISOR			
LOGGED BY	L. SINCLAIR		
INSTRUMENT	WIDCO 1500		
PROBE ELECTRIC			
PROBE GAMMA			
PROBE CALIPER			
DATE LOGGED	FEBRUARY 3 1997		
TIME OF LOGGING	1500 HRS TO 1630 HRS		
DRILL OPERATOR	M. MILLER		
CONTRACTOR			
REMARKS	ASS'T OPERATOR: M. MINCHUK		
PROJECT	BORDEN RAILWAY OVERPASS		
CONTROL SECTION	16-24		
STATION	42131.5 M	OFFSET	94.1 M LEFT
CUTTING SAMPLE INTERVAL		1.5 M	
CORE SAMPLE INTERVAL			
FROM			
CASING DEPTH		6.1 M	
CASING WALL THICKNESS			
WATER OR MUD LEVEL			
ABANDONMENT	GROUTED AND POST IN HOLE		
BIT SIZE	4 3/4" WALMAC	INTERVAL	0-30.5 M
BIT SIZE		INTERVAL	
BIT SIZE		INTERVAL	
TYPE OF DRILL RIG	1250 FAILING		
DEPTH		SCALE	SPEED
SP.	30 M	50 MV	15 M/MIN
RES.	30 M	20 OHMS	15 M/MIN
GAMMA	30 M	0-100 CPS	8 M/MIN
CAL.	30 M	1 1/4-18"	15 M/MIN
GAMMA TIME CONSTANT (T.C.)	5	SECONDS	
GEOLGY BY	E.A. CHRISTIANSEN	06/02/97	

CUTTING SAMPLE DESCRIPTION

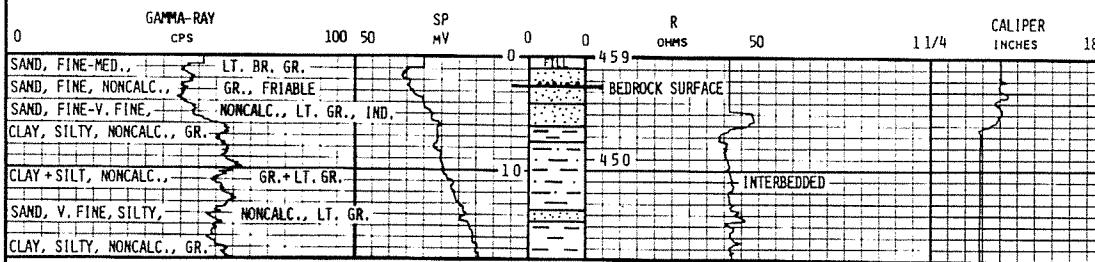


Saskatchewan
Highways and
Transportation

SHT 73-B/06 1997
 CN SUBWAY NO.110
 SW-01-25-39-09-W3
 ST OF
 13:5804964N/352871E
 BOREHOLE

BOREHOLE NO.	CN SUBWAY 110 MTS	73-B/06
LAND LOCATION	SW-01-25-39-09-W3	
UTM COORD	13:5804964, 630N/352871, 223E	
GRD. ELEV.	458.789 M	DEPTH 18.3 M
DATE DRILLED	FEB. 11 TO FEB. 11	1997
COND. WATER	525	MICROSIEMENS/CM AT 25°C
COND. MUD	1025	MICROSIEMENS/CM AT 25°C
SPECIFIC GRAVITY MUD		
SUPERVISOR	L. SINCLAIR	
ASST SUPERVISOR		
LOGGED BY	L. SINCLAIR	
INSTRUMENT	WIDCO 1500	
PROBE ELECTRIC		
PROBE GAMMA		
PROBE CALIPER		
DATE LOGGED	FEBRUARY 11 1997	
TIME OF LOGGING	0900 HRS. TO 1030 HRS	
DRILL OPERATOR	M. MILLER	
CONTRACTOR		
REMARKS	ASS'T OPERATOR: M. MINCHUK	
PROJECT	BORDEN RAILWAY OVERPASS	
CONTROL SECTION	16-24	
STATION	OFFSET	
CUTTING SAMPLE INTERVAL	1.5 M	
CORE SAMPLE INTERVAL		
FROM		
CASING DEPTH		
CASING WALL THICKNESS		
WATER OR MUD LEVEL		
ABANDONMENT	GROUTED AND POST IN HOLE	
BIT SIZE	4 3/4 WIDMAC	INTERVAL 0-18.3 M
BIT SIZE		INTERVAL
BIT SIZE		INTERVAL
TYPE OF DRILL RIG	1250 FAILING	
DEPTH	SCALE	SPEED
SP.	18 M	50 MV
RES.	18 M	50 OHMS
GAMMA	18 M	0-100 CPS
CAL	18 M	1 1/4-18 M
GAMMA TIME CONSTANT (T.C.)		5 SECONDS
GEOLOGY BY E.A. CHRISTIANSEN 20/02/97		

CUTTING SAMPLE DESCRIPTION



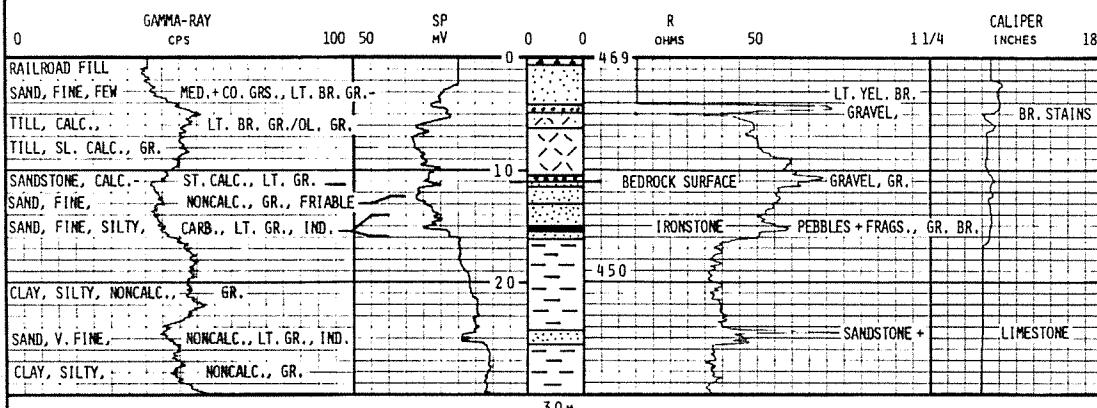
Saskatchewan
Highways and
Transportation



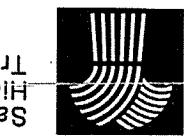
SHT 73-B/06 1997
CN SUBWAY NO.111
SE-02-25-39-09-W3
ST OF
13:5805042N/352784E
BOREHOLE

BOREHOLE NO.	CN SUBWAY 111	MTS	73-B/06	PROJECT	CN RAILWAY OVERPASS		
LAND LOCATION	SE-02-25-39-09-W3			CONTROL SECTION	16-24		
UTM COORD.	13:5805041.830N/352783.811E			STATION	OFFSET		
GRO. ELEV.	469.495 M.	DEPTH	30.5 M	CUTTING SAMPLE INTERVAL	1.5 M		
DATE DRILLED	FEB. 11 TO FEB. 11	1997		CORE SAMPLE INTERVAL			
COND. WATER	525	MICROSIEMENS/CM AT 25°C		FROM			
COND. MUD	850	MICROSIEMENS/CM AT 25°C		CASING DEPTH			
SPECIFIC GRAVITY MUD				CASING WALL THICKNESS			
SUPERVISOR	L. SINCLAIR			WATER OR MUD LEVEL			
ASST SUPERVISOR				ABANDONMENT	GROUTED AND POST IN HOLE		
LOGGED BY	L. SINCLAIR			BIT SIZE	4 3/4" TRICONIC INTERVAL 0-6.1 M		
INSTRUMENT	VIDCO 1500			BIT SIZE	4 3/4" WALMAC INTERVAL 6.1-30.5 M		
PROBE ELECTRIC				BIT SIZE			
PROBE GAMMA				TYPE OF DRILL RIG	1250 FAILING		
PROBE CALIPER				DEPTH	SCALE	SPEED	
DATE LOGGED	FEBRUARY 11 1997			SP.	30 M	50 MV	15 M/MIN
TIME OF LOGGING	1500 HRS	ID	1630 HRS	RES.	30 M	50 OHMS	15 M/MIN
DRILL OPERATOR	M. MILLER			GAMMA	30 M	0-100 CPS	8 M/MIN
CONTRACTOR	ASS'T OPERATOR: M. MINCHUK			CAL	30 M	1 1/4"-18"	15 M/MIN
REMARKS				GAMMA TIME CONSTANT (T.C.)	5	SECONDS	
				GEOLOGY BY	E.A. CHRISTIANSEN	20/02/97	

CUTTING SAMPLE DESCRIPTION



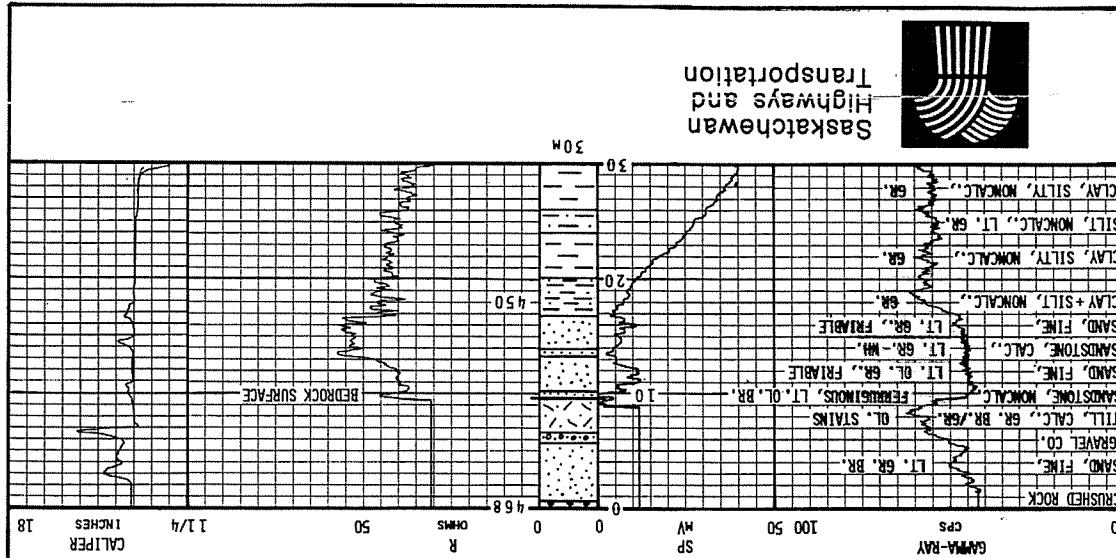
Saskatchewan
Highways and
Transportation



SASKATCHEWAN
HIGHWAYS AND
TRANSPORTATION

CUTTING SAMPLE DESCRIPTION

PROJECT NUMBER	120	UTM COORDINATES	NAD 1972	UTM COORDINATES	13:5805198.860N/352919.77E	GENERAL LOCATION	16-24	GENERAL SECTION	16-24
DEPTH	0.00 M	DEPTH	30.00 M	DEPTH	0.00 M	DEPTH	0.00 M	DEPTH	30.00 M
DETERMINATION	GRADIENT	DETERMINATION	GRADIENT	DETERMINATION	GRADIENT	DETERMINATION	GRADIENT	DETERMINATION	GRADIENT
TOOLS USED	L. SICKLE	TOOLS USED	MICROSIMENS CM AT 25°C	TOOLS USED	MICROSIMENS CM AT 25°C	TOOLS USED	MICROSIMENS CM AT 25°C	TOOLS USED	MICROSIMENS CM AT 25°C
SPRUE GRAVITY MUD	1.05 G/ML	SPRUE GRAVITY MUD	1.05 G/ML	SPRUE GRAVITY MUD	1.05 G/ML	SPRUE GRAVITY MUD	1.05 G/ML	SPRUE GRAVITY MUD	1.05 G/ML
CONSOLIDATION	250	CONSOLIDATION	250	CONSOLIDATION	250	CONSOLIDATION	250	CONSOLIDATION	250
CHASING DEPTH	1.5 M	CHASING DEPTH	1.5 M	CHASING DEPTH	1.5 M	CHASING DEPTH	1.5 M	CHASING DEPTH	1.5 M
CORE SAMPLE INTERVAL	1.5 M	CORE SAMPLE INTERVAL	1.5 M	CORE SAMPLE INTERVAL	1.5 M	CORE SAMPLE INTERVAL	1.5 M	CORE SAMPLE INTERVAL	1.5 M
DATE DRILLED	1997-05-10	DATE DRILLED	1997-05-10	DATE DRILLED	1997-05-10	DATE DRILLED	1997-05-10	DATE DRILLED	1997-05-10
L. SICKLE	1.56-2.98 M	L. SICKLE	1.56-2.98 M	L. SICKLE	1.56-2.98 M	L. SICKLE	1.56-2.98 M	L. SICKLE	1.56-2.98 M
SPONGE GRAVITY MUD	1.05 G/ML	SPONGE GRAVITY MUD	1.05 G/ML	SPONGE GRAVITY MUD	1.05 G/ML	SPONGE GRAVITY MUD	1.05 G/ML	SPONGE GRAVITY MUD	1.05 G/ML
SPONGE	1.56-2.98 M	SPONGE	1.56-2.98 M	SPONGE	1.56-2.98 M	SPONGE	1.56-2.98 M	SPONGE	1.56-2.98 M
ASSISTANT SWEEPER	1.56-2.98 M	ASSISTANT SWEEPER	1.56-2.98 M	ASSISTANT SWEEPER	1.56-2.98 M	ASSISTANT SWEEPER	1.56-2.98 M	ASSISTANT SWEEPER	1.56-2.98 M
ROCK TYPE	GRANITE	ROCK TYPE	GRANITE	ROCK TYPE	GRANITE	ROCK TYPE	GRANITE	ROCK TYPE	GRANITE
ROCK FABRIC	INTERBEDDED	ROCK FABRIC	INTERBEDDED	ROCK FABRIC	INTERBEDDED	ROCK FABRIC	INTERBEDDED	ROCK FABRIC	INTERBEDDED
ROCK COLOR	WHITE	ROCK COLOR	WHITE	ROCK COLOR	WHITE	ROCK COLOR	WHITE	ROCK COLOR	WHITE
ROCK SURFACE	BEDROCK SURFACE	ROCK SURFACE	BEDROCK SURFACE	ROCK SURFACE	BEDROCK SURFACE	ROCK SURFACE	BEDROCK SURFACE	ROCK SURFACE	BEDROCK SURFACE
SOIL TYPE	SAND STONE, CALC.	SOIL TYPE	SAND STONE, CALC.	SOIL TYPE	SAND STONE, CALC.	SOIL TYPE	SAND STONE, CALC.	SOIL TYPE	SAND STONE, CALC.
SOIL COLOR	LT. GR. - NH.	SOIL COLOR	LT. GR. - NH.	SOIL COLOR	LT. GR. - NH.	SOIL COLOR	LT. GR. - NH.	SOIL COLOR	LT. GR. - NH.
SOIL FABRIC	FINE	SOIL FABRIC	FINE	SOIL FABRIC	FINE	SOIL FABRIC	FINE	SOIL FABRIC	FINE
SOIL CONSISTENCY	FIRM	SOIL CONSISTENCY	FIRM	SOIL CONSISTENCY	FIRM	SOIL CONSISTENCY	FIRM	SOIL CONSISTENCY	FIRM
SOIL GRAIN SIZE	0-100 CPS	SOIL GRAIN SIZE	0-100 CPS	SOIL GRAIN SIZE	0-100 CPS	SOIL GRAIN SIZE	0-100 CPS	SOIL GRAIN SIZE	0-100 CPS
CLAY + SILT, NORMAL	LT. GR.	CLAY + SILT, NORMAL	LT. GR.	CLAY + SILT, NORMAL	LT. GR.	CLAY + SILT, NORMAL	LT. GR.	CLAY + SILT, NORMAL	LT. GR.
CLAY, SILT, NORMAL	LT. GR.	CLAY, SILT, NORMAL	LT. GR.	CLAY, SILT, NORMAL	LT. GR.	CLAY, SILT, NORMAL	LT. GR.	CLAY, SILT, NORMAL	LT. GR.



SHT 73-B/06 1997
CN SUBWAY NO.120
NW-01-25-39-09-W3
13:5805199N/352920E
BOREHOLE NUMBER

Appendix B. Carbonate content of tills in the CN subways area.

Saskatchewan Research Council Geoanalytical Services
 125-15 Innovation Blvd., Saskatoon, SK., S7N 2X8
 Phone: 306-933-5426 Fax: 306-933-5656

SHT BORDEN RR OVERPASS * = HOLE 1 * * = HOLE 2

M8 ANTUNES DEPT HIGHWAYS JAN23 1997 (16) [0.5 GM BR DIG.]
 1 %Ca BY ICP OT96.11

2 %Mg BY ICP

3 Wt% DOLOMITE=COL.2*7.5852

4 Wt% CALCITE=(COL.1-(COL.2*1.6486))*2.4973

5 TOTAL Wt% CO3 (COL.3+COL.4)

6 WT%DOLOMITE/Wt% CALCITE (COL.3/COL.4)

7 CO2 FROM CALCITE=COL.4*2.238

8 CO2 FROM DOLOMITE=COL.3*2.429

9 TOTAL CO2=COL.7+COL.8

	%Ca	%Mg	WT%DO	WT%CAL	CO3TOT	DO/CAL	CO2CAL	CO2DOL	CO2TOT
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BR2	5.32	1.57	11.91	6.82	18.73	1.75	15.27	28.93	44.19
*S 6 8.4M	3.65	1.04	7.89	4.83	12.72	1.63	10.82	19.16	29.98
*S 7 9.9M	2.90	1.04	7.89	2.96	10.85	2.66	6.63	19.16	25.79
*S 8 11.4M	3.46	1.19	9.03	3.74	12.77	2.41	8.37	21.93	30.30
*S 9 13.0M	2.42	1.07	8.12	1.64	9.75	4.95	3.67	19.71	23.38
*S 10 14.5M	1.83	0.73	5.54	1.56	7.10	3.54	3.50	13.45	16.95
*S 11 16.0M	1.81	0.73	5.54	1.51	7.05	3.66	3.39	13.45	16.84
*S 12 17.5M	1.63	0.71	5.39	1.15	6.53	4.69	2.57	13.08	15.65
*S 13 19.1M	1.73	0.72	5.46	1.36	6.82	4.03	3.03	13.27	16.30
*S 14 20.6M	1.66	0.72	5.46	1.18	6.64	4.62	2.64	13.27	15.91
*S 15 22.1M	1.69	0.68	5.16	1.42	6.58	3.63	3.18	12.53	15.71
*S 16 23.6M	2.06	0.77	5.84	1.97	7.81	2.96	4.42	14.19	18.61
*S 24 35.8M	0.75	0.40	3.03	0.23	3.26	13.42	0.51	7.37	7.88
**S 61 1.0M	3.56	0.93	7.05	5.06	12.12	1.39	11.33	17.13	28.46
**S 62 2.3M	3.39	0.89	6.75	4.80	11.55	1.41	10.75	16.40	27.14
**S 63 3.8M	3.29	0.90	6.83	4.51	11.34	1.51	10.10	16.58	26.68

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*SHT CN Subway Borehole 105

M26 CHRISTIANSEN HIGHWAYS FEBRUARY 4/97 (8) PG 126 [CA/MG DIG]

1 %Ca BY ICP OT97.23

2 %Mg BY ICP

3 Wt% DOLOMITE=COL.2*7.5852

4 Wt% CALCITE=(COL.1-(COL.2*1.6486))*2.4973

5 TOTAL Wt% CO₃ (COL.3+COL.4)

6 WT%DOLOMITE/Wt% CALCITE (COL.3/COL.4)

7 CO₂ FROM CALCITE=COL.4*2.238

8 CO₂ FROM DOLOMITE=COL.3*2.429

9 TOTAL CO₂=COL.7+COL.8

	%Ca	%Mg	WT%DO	WT%CAL	CO ₃ TOT	DO/CAL	CO ₂ CAL	CO ₂ DOL	CO ₂ TOT
BR2	5.05	1.47	11.15	6.56	17.71	1.70	14.68	27.08	41.76
LS7 138 2.6	1.91	0.71	5.39	1.85	7.23	2.92	4.13	13.08	17.21
LS7 139 3.8	1.73	0.69	5.23	1.48	6.71	3.54	3.31	12.71	16.02
LS7 141 7.1	2.05	0.79	5.99	1.87	7.86	3.21	4.18	14.56	18.73
LS7 142 8.4	2.39	0.80	6.07	2.67	8.74	2.27	5.99	14.74	20.73
LS7 143 9.9	3.12	0.83	6.30	4.37	10.67	1.44	9.79	15.29	25.08
LS7 144 11.4	3.82	0.90	6.83	5.83	12.66	1.17	13.06	16.58	29.64
LS7 145 12.6	3.01	0.83	6.30	4.10	10.40	1.54	9.18	15.29	24.47

BR2	5.05	1.47	11.15	6.56	17.71	1.70	14.68	27.08	41.76
LS7 138 2.6	1.91	0.71	5.39	1.85	7.23	2.92	4.13	13.08	17.21
LS7 139 3.8	1.73	0.69	5.23	1.48	6.71	3.54	3.31	12.71	16.02
LS7 141 7.1	2.05	0.79	5.99	1.87	7.86	3.21	4.18	14.56	18.73
LS7 142 8.4	2.39	0.80	6.07	2.67	8.74	2.27	5.99	14.74	20.73
LS7 143 9.9	3.12	0.83	6.30	4.37	10.67	1.44	9.79	15.29	25.08
LS7 144 11.4	3.82	0.90	6.83	5.83	12.66	1.17	13.06	16.58	29.64
LS7 145 12.6	3.01	0.83	6.30	4.10	10.40	1.54	9.18	15.29	24.47

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*SHT CN Subway Borehole 106

M27 CHRISTIANSEN HIGHWAYS FEBRUARY 4/97 (10) PG 127 [CA/MG DIG]

1 %Ca BY ICP OT97.24

2 %Mg BY ICP

3 Wt% DOLOMITE=COL.2*7.5852

4 Wt% CALCITE=(COL.1-(COL.2*1.6486))*2.4973

5 TOTAL Wt% CO₃ (COL.3+COL.4)

6 WT%DOLOMITE/Wt% CALCITE (COL.3/COL.4)

7 CO₂ FROM CALCITE=COL.4*2.238

8 CO₂ FROM DOLOMITE=COL.3*2.429

9 TOTAL CO₂=COL.7+COL.8

	%Ca	%Mg	WT%DO	WT%CAL	CO3TOT	DO/CAL	CO2CAL	CO2DOL	CO2TOT
--	-----	-----	-------	--------	--------	--------	--------	--------	--------

BR2	5.04	1.48	11.23	6.49	17.72	1.73	14.53	27.27	41.80
LS7 160 5.6	1.96	0.67	5.08	2.14	7.22	2.38	4.78	12.34	17.13
LS7 161 6.9	1.85	0.69	5.23	1.78	7.01	2.94	3.98	12.71	16.69
LS7 162 84	1.71	0.70	5.31	1.39	6.70	3.82	3.11	12.90	16.00
LS7 163 9.9	1.71	0.72	5.46	1.31	6.77	4.18	2.92	13.27	16.19
LS7 164 11.4	1.82	0.79	5.99	1.29	7.28	4.64	2.89	14.56	17.45
LS7 168 17.5	2.98	0.81	6.14	4.11	10.25	1.50	9.19	14.92	24.12
LS7 169 19.1	3.09	0.84	6.37	4.26	10.63	1.50	9.53	15.48	25.01
LS7 170 20.6	2.97	1.01	7.66	3.26	10.92	2.35	7.29	18.61	25.90
LS7 171 21.6	2.87	1.01	7.66	3.01	10.67	2.55	6.73	18.61	25.34

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*SHT CN Subway Borehole 107

M28 CHRISTIANSEN HIGHWAYS FEBRUARY 4/97 (6) PG 128 [CA/MG DIG]
 1 %Ca BY ICP OT97.25

2 %Mg BY ICP

3 Wt% DOLOMITE=COL.2*7.5852

4 Wt% CALCITE=(COL.1-(COL.2*1.6486))*2.4973

5 TOTAL Wt% CO₃ (COL.3+COL.4)

6 WT%DOLOMITE/Wt% CALCITE (COL.3/COL.4)

7 CO₂ FROM CALCITE=COL.4*2.238

8 CO₂ FROM DOLOMITE=COL.3*2.429

9 TOTAL CO₂=COL.7+COL.8

	%Ca	%Mg	WT%DO	WT%CAL	CO ₃ TOT	D0/CAL	CO ₂ CAL	CO ₂ DOL	CO ₂ TOT
BR2	5.14	1.58	11.98	6.33	18.32	1.89	14.17	29.11	43.28
LS7 185 6.1	3.96	1.14	8.65	5.20	13.84	1.66	11.63	21.00	32.63
LS7 188 8.5	3.42	0.96	7.28	4.59	11.87	1.59	10.27	17.69	27.96
LS7 190 10.2	3.99	0.94	7.13	6.09	13.22	1.17	13.64	17.32	30.96
LS7 192 11.7	3.21	0.91	6.90	4.27	11.17	1.62	9.56	16.77	26.32
LS7 194 13.2	3.37	1.00	7.59	4.30	11.88	1.76	9.62	18.42	28.05

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M42 CHRISTIANSEN HIGHWAYS FEBRUARY 12/97 (4) PG 217 [CA/MG DIG]

1 %Ca BY ICP OT97.27

2 %Mg BY ICP

3 Wt% DOLOMITE=COL.2*7.5852

4 Wt% CALCITE=(COL.1- (COL.2*1.6486))*2.4973

5 TOTAL Wt% CO₃ (COL.3+COL.4)

HOLE 108

6 WT%DOLOMITE/Wt% CALCITE (COL.3/COL.4)

7 CO₂ FROM CALCITE=COL.4*2.238

8 CO₂ FROM DOLOMITE=COL.3*2.429

9 TOTAL CO₂=COL.7+COL.8

	%Ca	%Mg	WT%DO	WT%CAL	C03TOT	D0/CAL	CO2CAL	CO2DOL	CO2TOT
--	-----	-----	-------	--------	--------	--------	--------	--------	--------

BR2	5.14	1.52	11.53	6.58	18.11	1.75	14.72	28.01	42.73
LS7 202 5.4	3.47	0.92	6.98	4.88	11.86	1.43	10.92	16.95	27.87
LS7 203 6.9	3.40	0.94	7.13	4.62	11.75	1.54	10.34	17.32	27.66
LS7 204 8.4	3.16	0.90	6.83	4.19	11.01	1.63	9.37	16.58	25.95

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M43 CHRISTIANSEN HIGHWAYS FEBRUARY 12/97 (9) PG 218 [CA/MG DIG]

1 %Ca BY ICP OT97.27

2 %Mg BY ICP

3 Wt% DOLOMITE=COL.2*7.5852

4 Wt% CALCITE=(COL.1-(COL.2*1.6486))*2.4973

5 TOTAL Wt% CO₃ (COL.3+COL.4)

HOLE 109

6 WT%DOLOMITE/Wt% CALCITE (COL.3/COL.4)

7 CO₂ FROM CALCITE=COL.4*2.238

8 CO₂ FROM DOLOMITE=COL.3*2.429

9 TOTAL CO₂=COL.7+COL.8

	%Ca	%Mg	WT%DO	WT%CAL	C03TOT	D0/CAL	CO2CAL	CO2DOL	CO2TOT
--	-----	-----	-------	--------	--------	--------	--------	--------	--------

BR2	5.16	1.61	12.21	6.26	18.47	1.95	14.00	29.66	43.67
LS7 222 6.0	3.11	0.93	7.05	3.94	10.99	1.79	8.81	17.13	25.95
LS7 223 6.9	3.20	0.89	6.75	4.33	11.08	1.56	9.68	16.40	26.08
LS7 224 8.4	2.95	0.87	6.60	3.79	10.38	1.74	8.47	16.03	24.50
LS7 225 9.9	3.06	0.91	6.90	3.90	10.80	1.77	8.72	16.77	25.48
LS7 226 11.4	3.49	0.94	7.13	4.85	11.98	1.47	10.84	17.32	28.16
LS7 227 13.0	3.52	0.93	7.05	4.96	12.02	1.42	11.10	17.13	28.24
LS7 228 14.5	3.08	0.95	7.21	3.78	10.99	1.91	8.46	17.50	25.96
LS7 229 15.5	3.61	0.86	6.52	5.47	12.00	1.19	12.25	15.85	28.10

Site characterization summary

of a

Groundwater investigation

for

CN underpass west of the Borden bridge

Control section 16 - 24

1997

by

E. K. Sauer Consulting Ltd.

E.K. SAUER CONSULTING LTD.

Geotechnical Research
& Engineering

May 20, 1997

N. W. Richardson, P.Eng.,
Senior Geotechnical Engineer
Saskatchewan Highways and Transportation
3130 8th Street East,
Saskatoon, Saskatchewan.
S7K 2H6

RE: Site characterization, C.S. 16-24 at the CN Subway

Dear Mr. Richardson:

The engineering services on this project consisted of planning and field supervision of test drilling, installation of piezometers, design reviews with Saskatchewan Highways and Transportation (SHT) personnel, and knowledge transfer to Jorge Antunes. The geology of the site was compiled by Dr. E. A. Christiansen which served as the framework for installation of instrumentation and interpretation of the hydrogeology of the area. The remaining data compilation and drafting was done by SHT personnel. Consequently, the content of the attached report is mainly a summary of the findings and their significance.

Yours truly



Dr. E. Karl Sauer P. Eng.

Executive Summary

Groundwater has been discharging since the summer of 1996 from the construction area at the CN underpass for the eastbound lanes of Highway 16. Two problems are associated with this phenomenon (1) construction of the highway subgrade below in the zone saturated with groundwater under hydraulic pressure, and (2) design and construction of a groundwater system for long term control of groundwater for subgrade stability, and erosion of ditches and backslopes.

The geology of the site was compiled by Dr. E. A. Christiansen which served as the framework for installation of instrumentation and interpretation of the hydrogeology of the area. The stratigraphy is consistent throughout the area consisting of clay shale of the Lea Park Formation, sands of the Judith River Formation, dense till of the Dundurn Formation, thin intertill gravel and boulders, till of the Warman Formation, an intertill gravel unit, till of the Battleford Formation (units of the Floral Formation are missing at this site), and a surficial sand (dunes) which covers the entire area. The sand has apparently drifted toward the river covering outcrops at the valley slopes of the intertill gravel, and the Judith River and Lea Park formations.

The groundwater regime at this site consists of artesian heads in the Judith River and intertill aquifers. The surficial sand is an unconfined aquifer. The natural groundwater flow is toward the North Saskatchewan River with the Judith River Formation acting as a drain except where it discharges into the surficial sands at about elevation 452 m.

There is no evidence of instability at the westbound underpass because the Judith River Formation acts as drain drawing the heads down to about 3 to 4 m below the pavement elevation.

The construction problems associated with the site conditions are as follows.

- 1. Excavation of material below heads in the three aquifers.**
- 2. Groundwater control to prevent subgrade instability and erosion of ditches and backslopes.**

Introduction

Location

The site under consideration includes a 900 m section of Highway 16 - 24 west of the Borden bridge where the road passes under a structure carrying the CN railway (Fig. 1). The historical development of the site is shown in Figs. 2, 3, and 4. The area in question passes through continuous sand dune terrain.

The Problem

Groundwater has been discharging since the summer of 1996 from the construction area at the CN underpass for the eastbound lanes of Highway 16 (Figs 5 to 16). Two problems are associated with this phenomenon (1) construction of the highway subgrade below the zone saturated with groundwater under hydraulic pressure, and (2) design and construction of a groundwater control system for long term subgrade stability, and erosion of ditches and backslopes.

Stratigraphy

The geology of the site was compiled by Dr. E. A. Christiansen as a separate report which served as the framework for installation of instrumentation and interpretation of the hydrogeology of the area.

The stratigraphy is consistent throughout the area lying west of the North Saskatchewan River crossing. The valley is eroded into a stratigraphic sequence defined in testhole 101 (Fig. 17) with lowermost unit a dense clay shale of the Lea Park Formation. The Judith River Formation overlies the Lea Park conformably and is truncated horizontally at about elevation 452 by valley erosion. Landslides on slopes in the ravines north of the highway indicate the Lea Park Formation outcrops on the original valley slope.

Dense till of the Dundurn Formation unconformably overlies the Judith River Formation; there is some evidence this till is fractured east of the underpass (Fig. 9). A thin layer of gravel and boulders overlies this till (Fig. 9, 15 and 16).

Till of the Warman Formation overlies the intertill unit. A gravel layer overlies the Warman Formation at the west end of the study area (Fig. 17). This gravel is covered by till of the Battleford Formation. Units of the Floral Formation are missing at this site.

A surficial sand covers the entire area. The sand is a wind deposit (dunes) derived from a proglacial delta in the area immediately east of Borden. The sand has apparently drifted toward the valley covering outcrops of the intertill gravel, and the Judith River and Lea Park formations.

Hydrogeology

The groundwater regime at this site consists of the Judith River aquifer, an intertill aquifer, and the surficial sand aquifer. The aquifers are separated by till aquitards with the clay shale of the Lea Park Formation serving as a basal aquitard. The Judith River and intertill aquifers are artesian with heads generally below ground elevation. The surficial sand is an unconfined aquifer.

The heads in the aquifers decrease with depth down to the Judith River sands, and decrease horizontally toward the valley slope. Thus, the natural groundwater flow is toward the North Saskatchewan River with the Judith River Formation acting as a drain except where it discharges into the surficial sands at about elevation 452 m.

Groundwater is discharging from the surficial sands and intertill gravels at the new CN underpass structure (Figs. 5 to 16). Head in the Judith River Formation rises close to surface elevation in the subgrade east of the underpass and is discharging into the borrow area between the eastbound and westbound lanes of the highway (Fig. 18).

The till aquitard covering the Judith River aquifer becomes thinner at the old underpass for the westbound lanes. The top of the aquifer rises in elevation toward the north. The net effect is that the lower head in the Judith River Formation drains the groundwater from the higher aquifers to an acceptable level below the pavement surface. Thus, there is no evidence of subgrade instability at the westbound underpass. Groundwater from the Judith River Formation can be seen discharging from a spring north of the westbound underpass (Figs. 2, 3, 4, and 19).

Engineering significance.

The construction problems associated with the site conditions are as follows.

1. Excavation of material below heads in the three aquifers.

The tills are heavily overconsolidated and thus may be relatively stable in the excavations, depending on groundwater flow conditions. The stability in the till will depend in large measure on the gradients that develop in the excavations. Excavation will be most difficult east of the underpass structure where the head in the Judith River Formation will be above the elevation of the base of the excavation (Figs. 11 to 14). The sediments of the Judith River are fine sands, silts and clays which will liquefy ("quick") when they are exposed.

The elevation of the highway grade rises to the west where excavation through the intertill gravel will be difficult in places. There are a lot of boulders concentrated in this unit and it is water bearing (Figs. 7 to 10). The unit will be exposed on highway backslopes (Figs. 15 and 16) creating an erosion problem. The severity of this problem is difficult to evaluate at this time (May 1997) but the unit is not very thick. Erosion east of the underpass appearing in Figs. 15 and 16 appears to be decreasing with time. West of the underpass it may be more severe.

Toward the west, head in the surficial sand will constitute the main construction problem. Experience during 1996 demonstrated that the surficial (dune) sand will liquefy when it is excavated (Figs. 20 and 21). The sand tends to become unstable when heavy equipment is within 1.5 m to 1 m of the groundwater head in the sand.

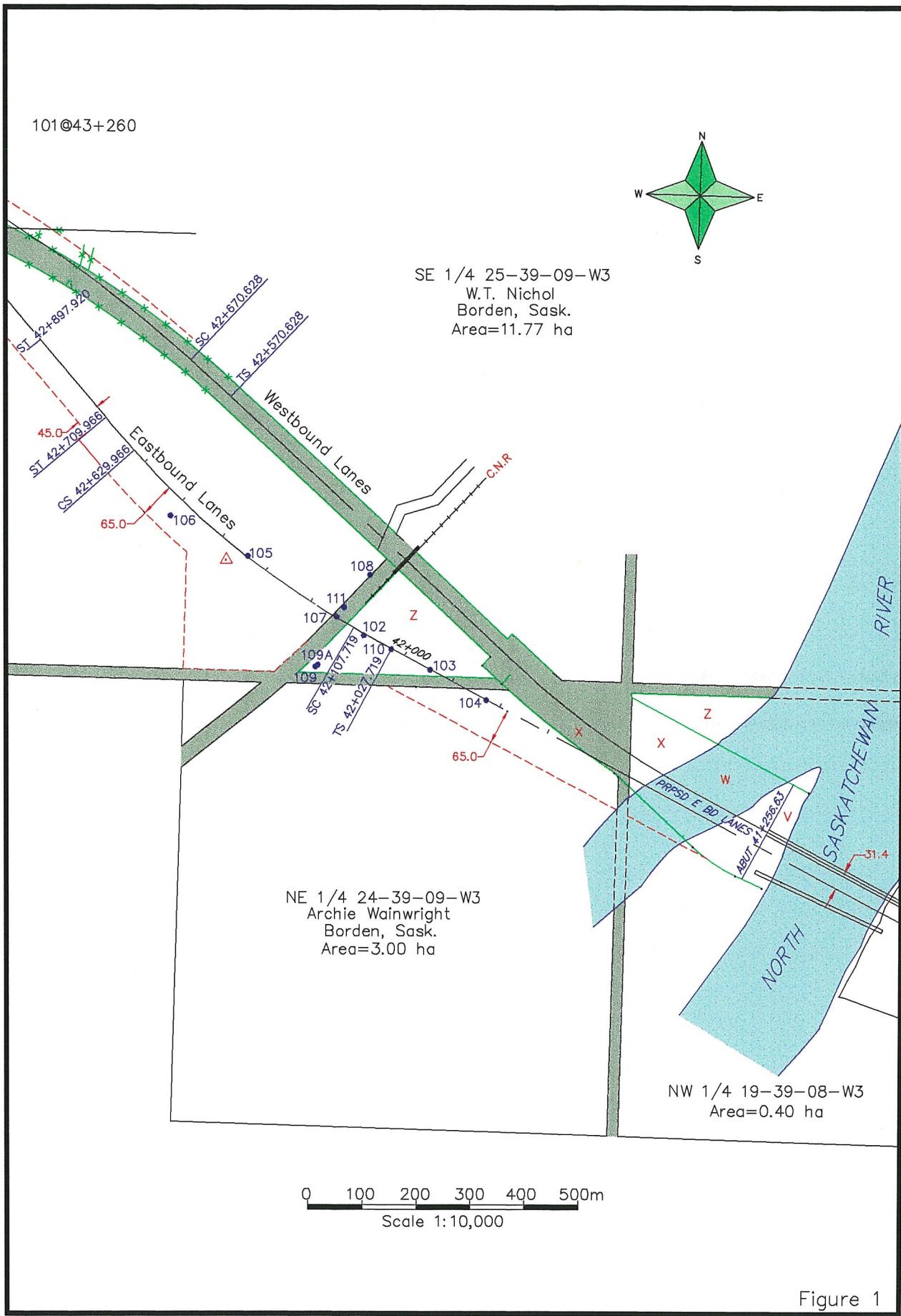
2. *Groundwater control*

A long term groundwater control system is required to ensure acceptable performance of the finished road pavement and erosion of the ditches and backslopes. Design of a "herring bone" pipe drain and gravel backfill in the subgrade subcut trench below the frost line was developed during discussions in your office. This type of system has proven successful in the past and should be adequate at this site. However, the expected volume of discharge from the system is not known, thus the required capacity is difficult to determine.

Erosion of the backslopes and ditches where the intertill aquifer is intercepted and below the head in the surficial sand may present a long term maintenance problem.



Dr. E. Karl Sauer P. Eng.



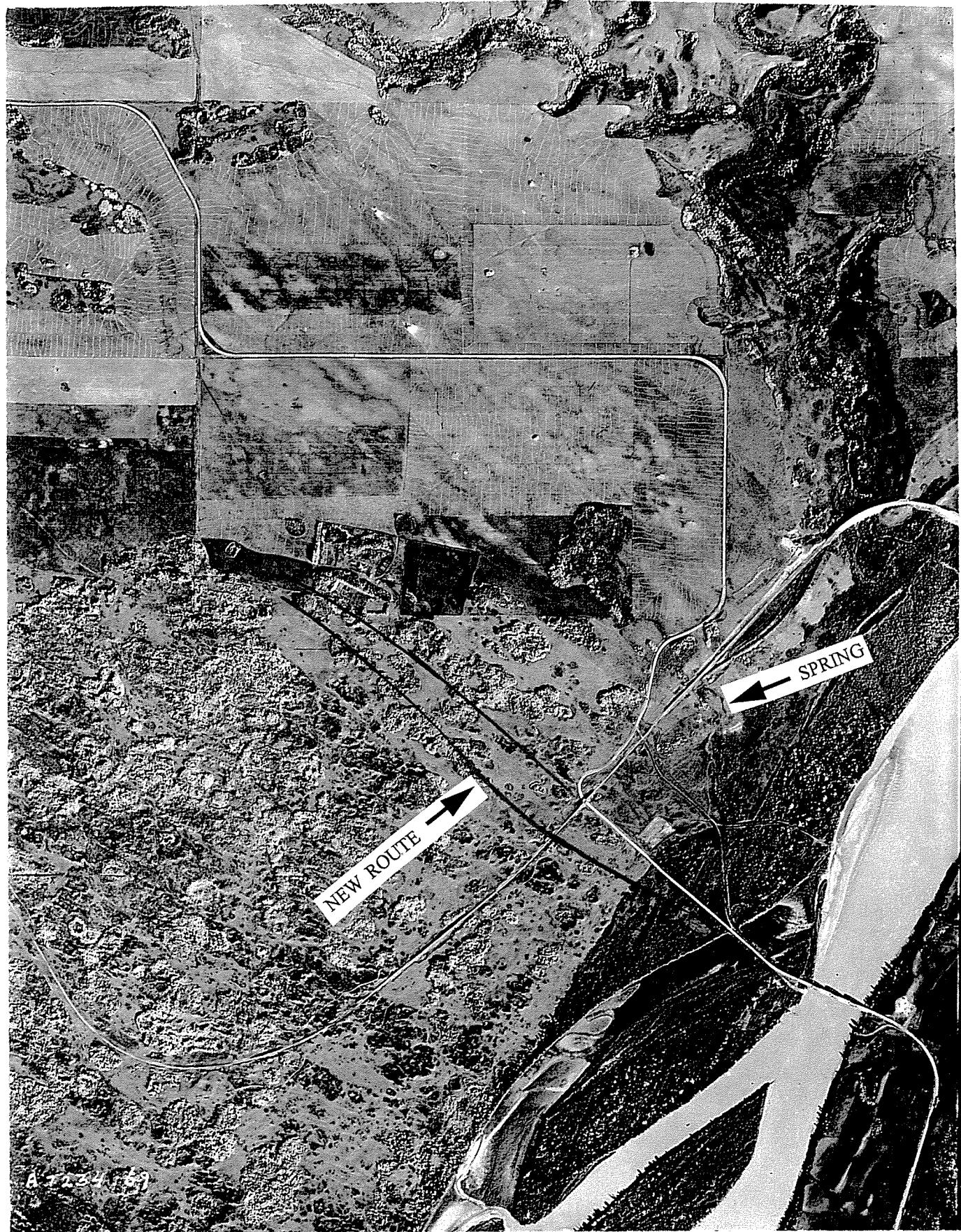


Fig. 2. 1944 aerial view of the site at a scale of 1:15840.



Fig. 3. 1968 aerial view of the site at a scale of 1:7200



Fig. 4. 1986 aerial view of the site at a scale of 1:10000

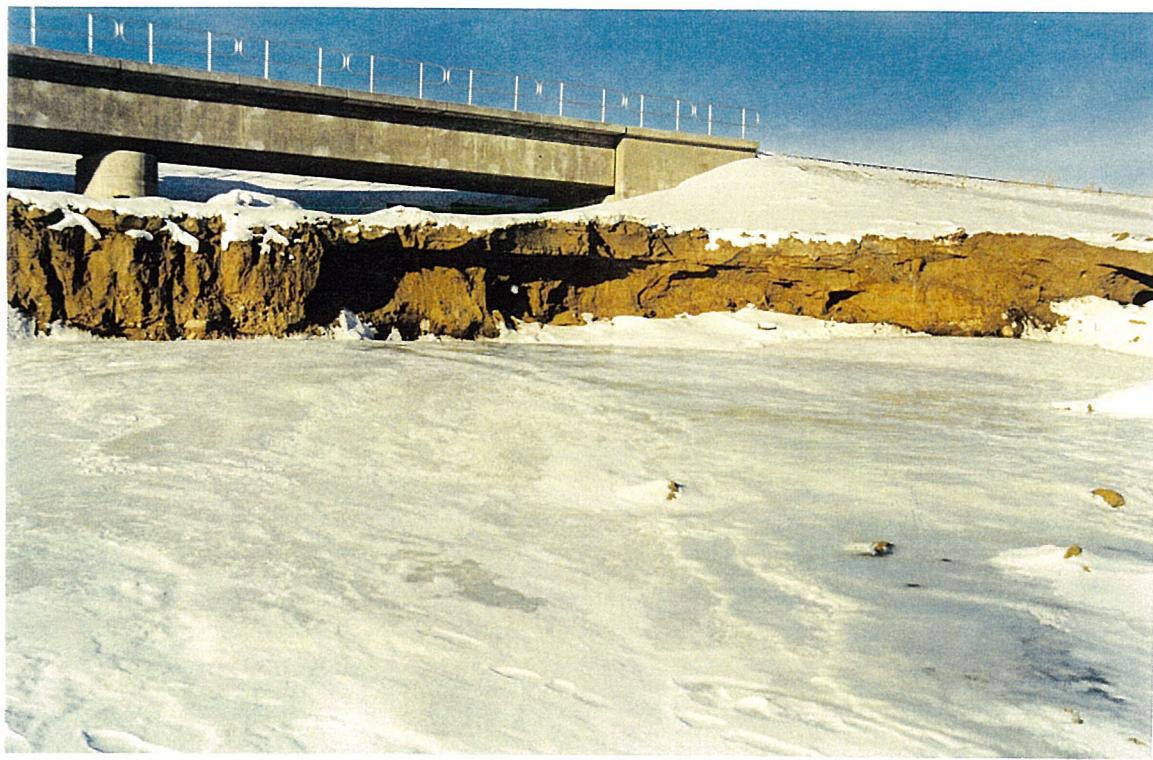


Fig. 5. Looking west toward the underpass showing ice buildup in February 1977 from groundwater seeping from the intertill aquifer and surficial sand.



Fig. 6. Looking east from the underpass in February 1997. Ice buildup from groundwater seeping from the intertill gravel and surficial sand.

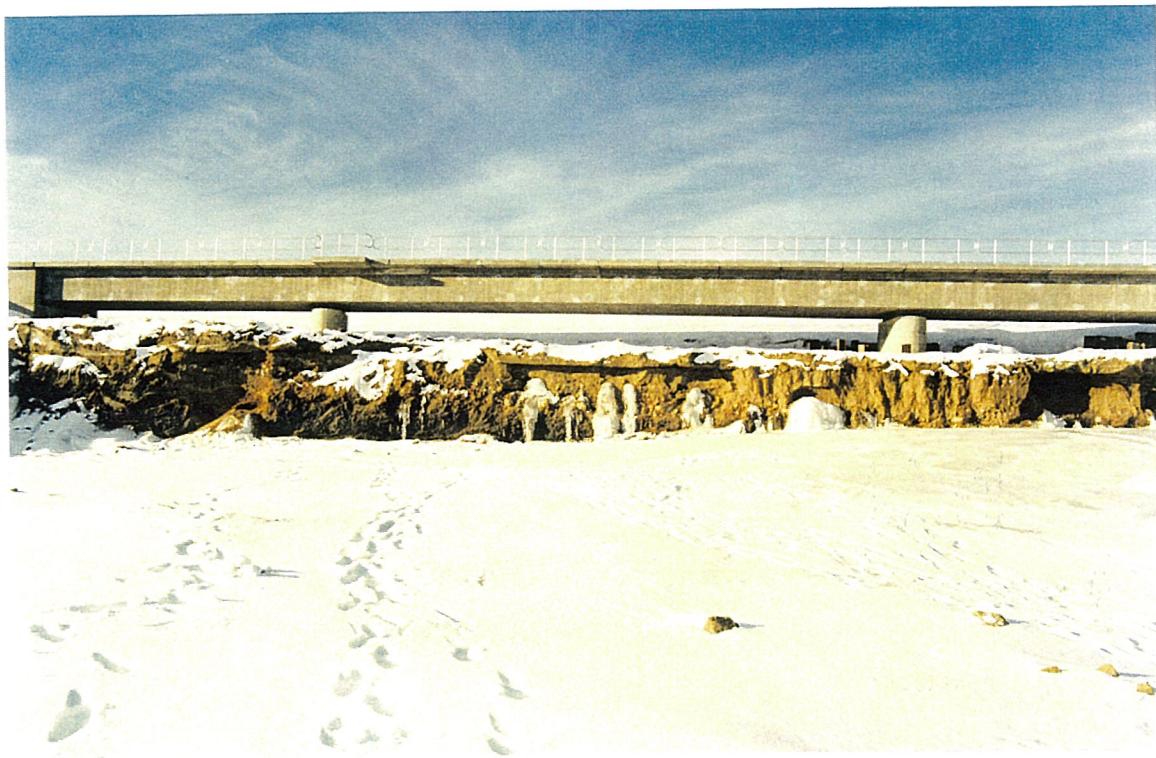


Fig. 7. Looking west toward the underpass showing ice from groundwater seeping in February 1997 from the intertill aquifer and surficial sand.



Fig. 8. Looking west from the underpass in February 1997. Ice buildup from groundwater seeping from the intertill gravel and surficial sand.

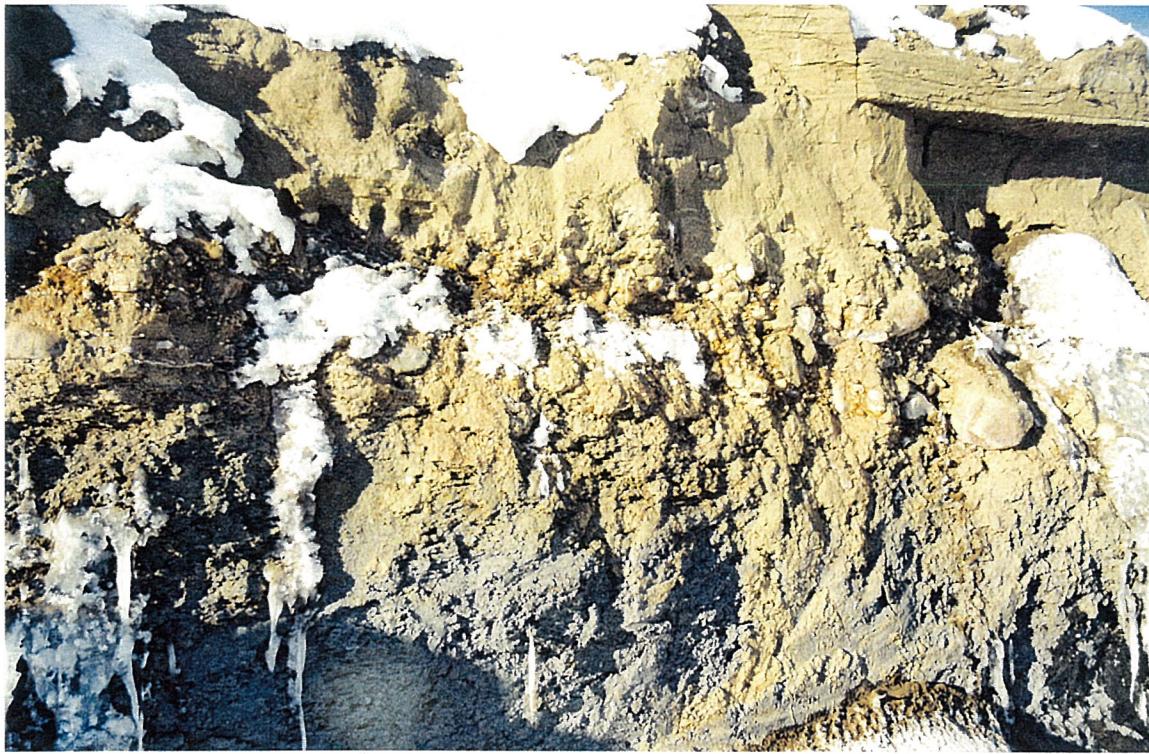


Fig. 9. Ice forming at the east face of the open excavation below the bridge structure from seepage at thin zone in the intertill gravel and joints in the unoxidized till in February 1997.



Fig. 10. Deformed beds in the intertill gravel and the unoxidized till of the underlying Dundurn Formation in February 1997.



Fig. 11. Looking north at the open excavation below the bridge structure showing seepage from the intertill gravel in early May 1997.



Fig. 12. Looking north at the open excavation east of the bridge structure showing seepage from the intertill gravel in early May 1997.



Fig. 13. Seepage in south ditch east of the underpass structure in early May 1997.



Fig. 14. Seepage in south ditch east of the underpass structure in early May 1997.

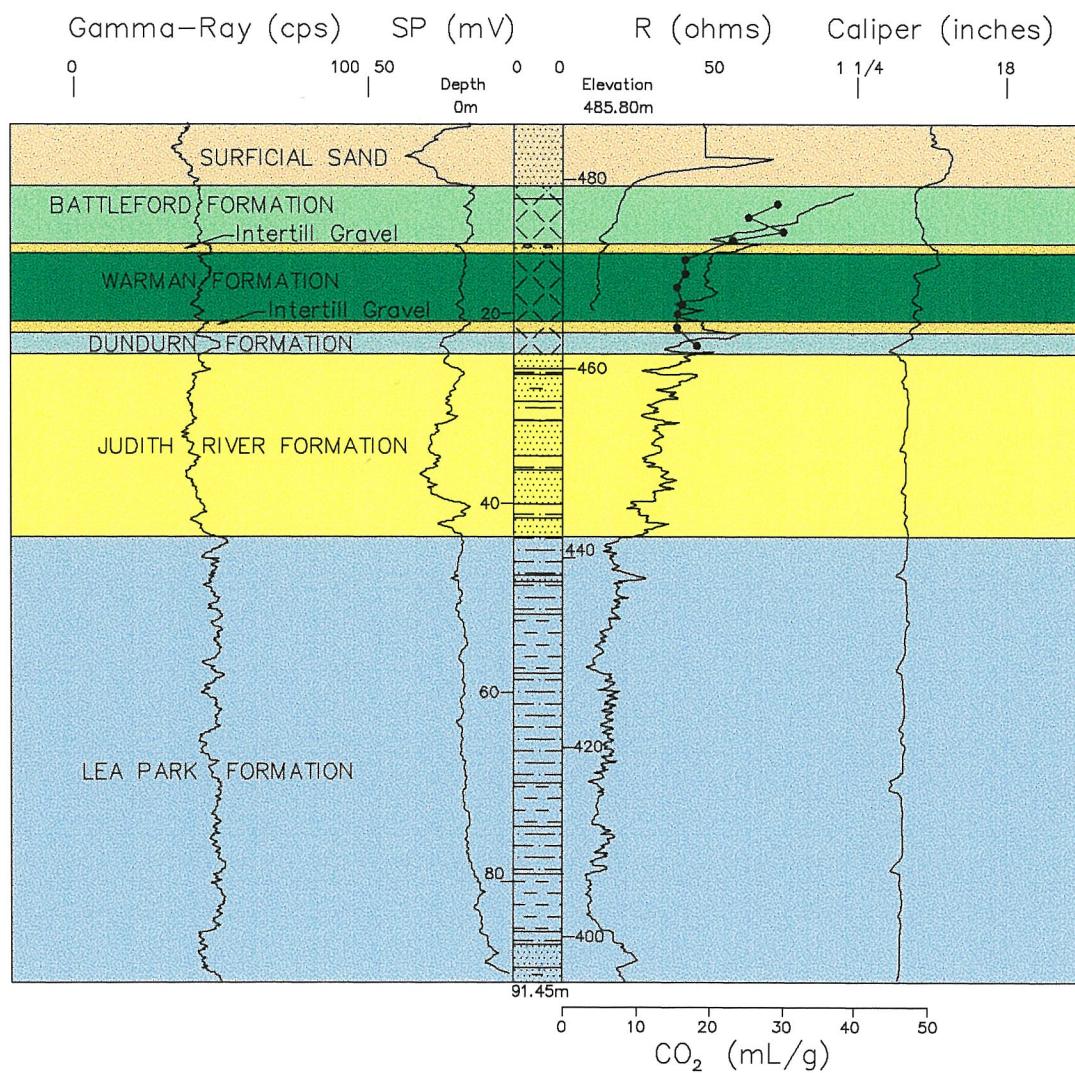


Fig. 15. Seepage from south backslope east of the underpass structure in early May 1997.



Fig. 16. Erosion from Seepage from south backslope east of the underpass structure in early May 1997. Seepage apparently from intertill gravel above Dundurn Formation.

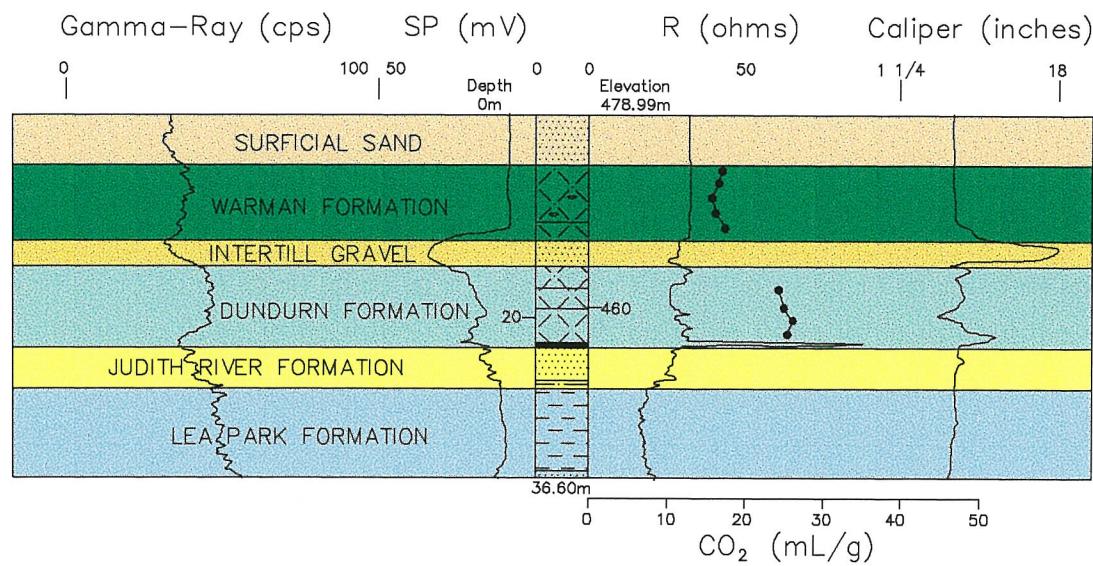
SHT 73B/06 1997
 CN SUBWAY NO.101
 SE-12-25-39-09-W3
 ST 43260.0 OFFS 32.0 L
 13:5805764N/351948E
 BOREHOLE



Scale 1:800

Figure 17

SHT 73B/06 1997
CN SUBWAY NO.106
NE-03-25-39-09-W3
ST 42498.0 OFFS 35.0 L
13:5805211N/352466E
BOREHOLE



Scale 1:750

Figure 18



Fig. 19. Seepage from Judith River aquifer and intertill gravel in borrow area between eastbound and westbound roadways in early May 1997.

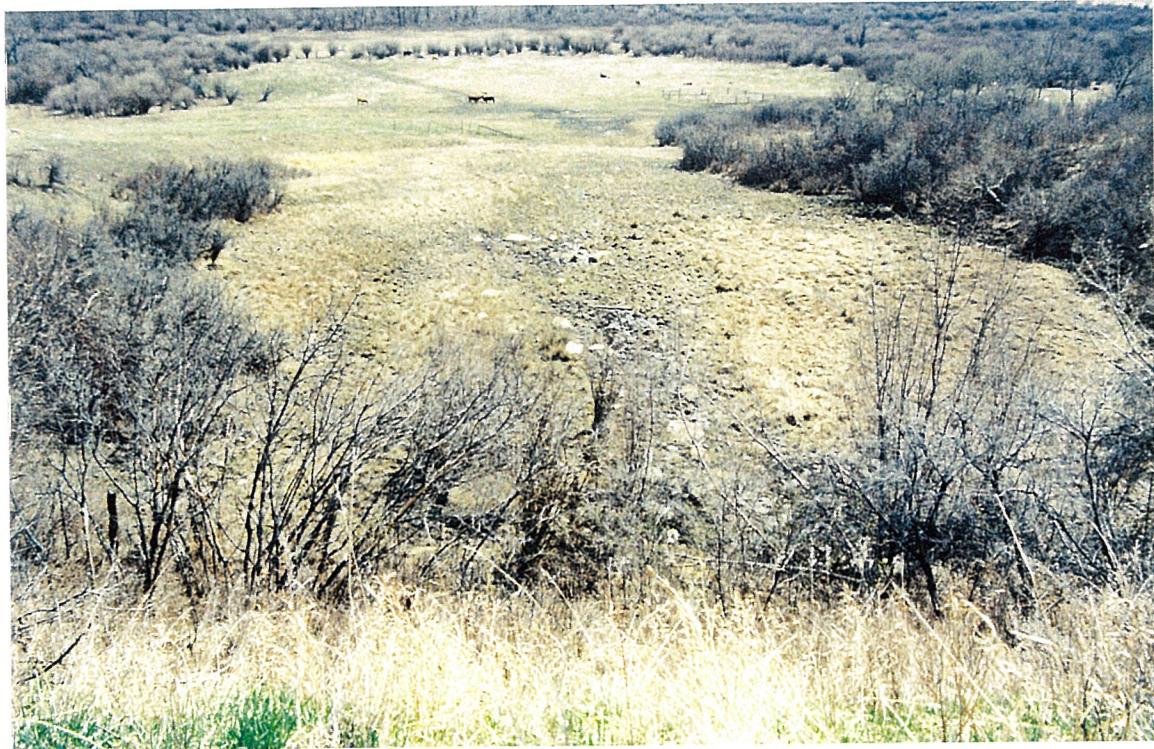


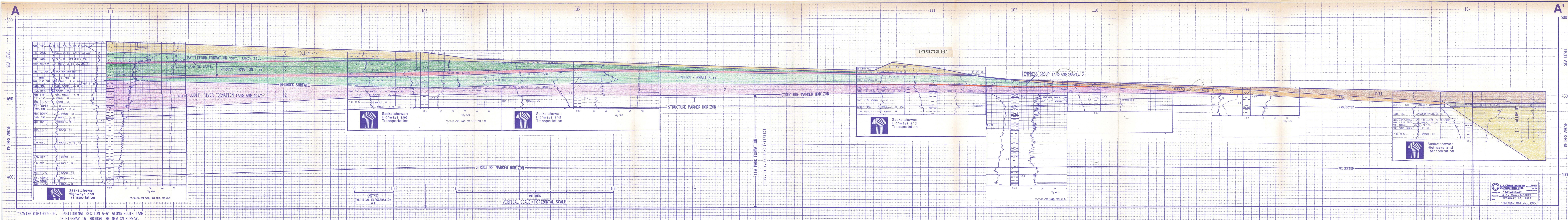
Fig. 20. Natural spring about 500 m north of the westbound underpass structure.

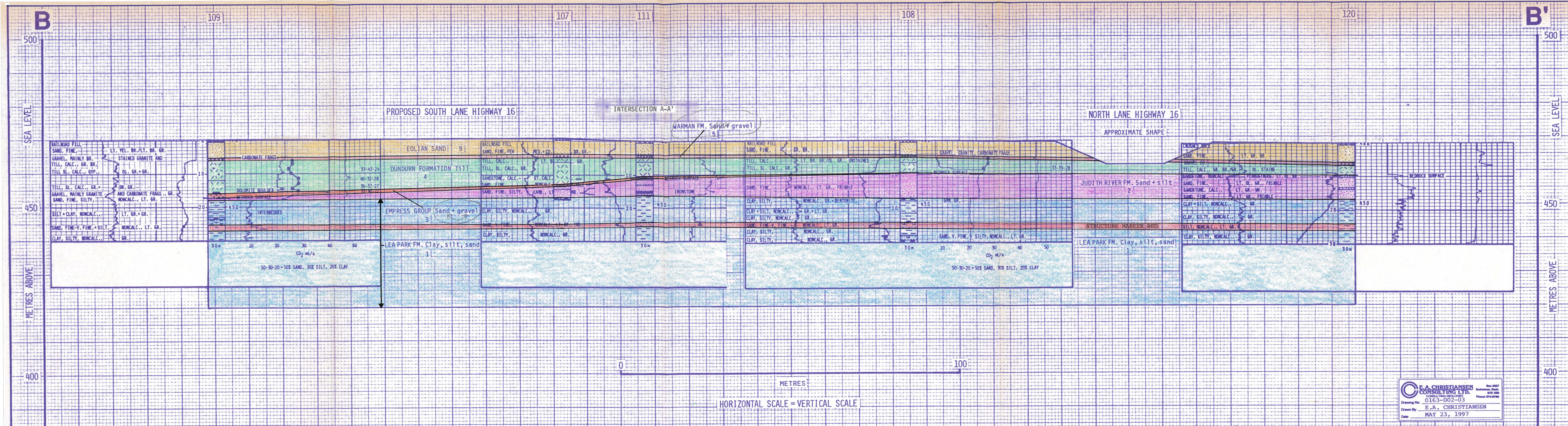


Fig. 21. Unstable ground in wet areas where head in the surficial sand is near the ground surface west of the underpass structure in early May 1997.



Fig. 22. Unstable ground in wet areas where head in the surficial sand is near the ground surface west of the underpass structure in early May 1997.





DRAWING 0163-002-03. CROSS SECTION B-B' ACROSS THE NORTH LANE
AND THE PROPOSED SOUTH LANE OF HIGHWAY 16.

