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Observations and Recommendations regarding the Goulais River Bank Slump of October 13, 2003

Prepared by:

MNR Northeast Region Engineering Unit
Field Service Division,
Ministry Of Natural Resources

October 27, 2003

Executive Summary

On October 13, 2003 a significant embankment failure occurred on the banks of the Goulais River north of Sault Ste. Marie, Ontario. The slump destroyed two residences, threatened a third one, and resulted in severe property damage as well as damage to the environment. The slump is one incident in a long history of embankment stability problems along certain stretches of the river.

The purpose of this report is to provide a review of the October 13, 2003 incident in particular, and an update on the historical context and status of Goulais River bank stability issue in general terms.

In the short term, it is recommended that the site of the October 2003 slump be adequately secured against public access, and steps be taken to mitigate environmental damage resulting from the slump.

Following a review of the site of the latest incident and an overview of the available technical reports on the embankment stability, it has been concluded that other events similar and perhaps more severe than the October 2003 incident are certain to occur in the future, as there are other potential areas were the stability of the river banks at present does not meet acceptable safety standards. It is most likely that there are cases were another significant landslide could be triggered by a relatively small change in groundwater conditions, river flows, river bank erosion, or man-induced event.

Given the nature of the residential development along the river, the potential for a slide at some future point presents a real and serious threat to life and property for the residents. It is therefore strongly recommended that immediate steps be taken to accurately identify those areas where the threat is imminent, and that residents be advised accordingly of the risks and consequences.

It is also recommended that the identification of embankment failure areas referred to in this report as "zones of concern" along the Goulais River be formally identified as natural hazard areas in accordance with MNR's "Natural Hazards Technical Guides".

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1. Introduction

An embankment failure occurred along a portion of the Goulais River and affected three private properties on the evening of October 13, 2003 (see attached Drawing 1). MNR Engineering assistance was requested by the MNR District Manager of Sault Ste. Marie on October 15, 2003. Two staff members, Messrs. Rob Schryburt, P.Eng. and Ron Lapointe, CET, from the Regional Engineering Office arrived on site on the afternoon of October 15, met with Mr. Kip Bradfield of the Sault Ste. Marie District and conducted visual observations. On October 16 a meeting was held at the District office in the morning followed up by a second site visit. This report is the result of the site observations made and Regional and District file reviews on the Goulais River issue.

This report is structured as follows. Section 2 discusses the background of the site while Section 3 details observations made during the site visit. Section 4 discusses the Goulais River in general with Section 5 summarizes the geotechnical conditions along the impacted area of the Goulais River. Section 6 discusses the erosion process of stream banks with Section 7 detailing the post-failure embankment profile near the slump site. Section 8 presents conclusions and postulates possible causes while Sections 9 and 10 provide recommendations both short term and long term, respectively.

Disclaimer – This Report is issued to MNR's Sault Ste. Marie District for internal use only. This report is based on general site observations made of the post failure conditions, on two geotechnical reports (Trow 1993 and 1994) on the embankments of the Goulais River for MNR, and on a report (Dillon 1988) for a bridge crossing over the Goulais River for MTO. Conclusions and recommendations in this report pertain to the site affected by the October 13, 2003 embankment failure and are made to be informative only and not instructive in nature. Prior to undertaking any future ground alterations, modifications or remedial repairs, proper geotechnical advice should be obtained.

This report is based on technical information concerning the 1988 and 2003 slump observations. The reader should consult policy, planning and/or legal opinions prior to acting on the recommendations of this report.

2. Background

According to local homeowners, a slump occurred on the evening of October 13, 2003 at approximately 8:10 p.m. along a portion of the Goulais River in Fenwick Township. Fenwick Township is located approximately 20 km north of Sault Ste. Marie in the Ministry of Natural Resources (MNR) Northeast Region Sault Ste. Marie District (see Drawing 1). The slump affected three single-family properties that were located at least 60 metres from the rivers edge. These properties are located in an unincorporated township in an area under the jurisdiction of the Sault North Planning Board, along the Nardi Road.

This area of the Goulais River has experienced many similar embankment slumps of varying magnitude in the past including one on January 10, 1988, a much larger event on June 2, 1989, one in 1990 as well as others that have been identified as having a lesser extent or impact (Drawing 2). Of note is that the January 10, 1988 slump is located immediately adjacent and upstream (East) to the present slump under review. In addition, anecdotal evidence indicates that a slump occurred in the summer of 1969 and was immediately adjacent to the current slump but on the downstream side (West) of the current slump.

3. Site Observations

Visual observations made during the site visit indicate that a compound or complex failure occurred along the outside bank of the Goulais River. A compound failure is defined as both a rotational and translational type failure of an embankment. In simple terms, this means that the failure surface of the embankment underwent a movement both downwards and in a horizontal direction toward the river. This particular type of failure is problematic in that the area affected by the failure can often be quite large and can extend a significant distance back from the top of the embankment.

Typical indications of rotational type failures include a well defined failure surface that is concave upward and often occurs within an intact soil mass. Translational failures involve movement along planes of weakness such as saturated sand or silt seams (Abramson et. al. – Slope Stability and Stabilization Methods, 1996) or in cohesionless soil slopes where a change in conditions such as seepage occurs (McCarthy – Essentials of Soil Mechanics and Foundations, 1988).

The slump was observed to have semi-circular and concentric slips dipping back towards the main scarp in a typical rotational failure pattern (Photo 1), giving the appearance of backward sloping steps moving away from the location of the back or main scarp. (A main scarp is defined as a steep face on undisturbed ground at the upper edge of the slump). The main scarp was estimated to be between 2 and 5 metres in height and approximately 200 metres in length (Photo 2). The failure or slump area was measured using a hand held GPS unit and found to be slightly less then 2 ha. in size, measured approximately three days after the event. The overall post failure slope profile of the embankment was determined to be at approximately 7.5H:1V (horizontal to vertical). It should be noted that the area is still experiencing ground movements and as such the overall slope is likely to flatten further.

The toe of the slump area was observed to be protruding into the Goulais River and has subsequently reduced the normal waterway opening width from approximately 50 metres to approximately 15 metres over a distance of more than 100 metres (as measured along the axis of the river). The toe of the slumped embankment material that is within the original waterway path was observed to be partially covered with trees and other stream bank vegetative matter (Photo 3). It was not possible to determine whether the remaining open river section below the slump has been altered below the water surface (i.e., has the river bottom been heaved upwards but still remains below the surface of the water). The bank, directly across from the slump area, was observed to be eroding and this can be attributed to the significant reduction in the cross-sectional area of the river and increased velocities of the water at the slump location.

As a result of the embankment slump one home has been shifted from its original location and moved toward the river and down into the slump area (Photo 2). A second home, located less than 20 metres from the 1988 slump, was observed to be severally undermined and is on the verge of tumbling into the slump area as the main scarp runs under a portion of the house (Photo 4). Due to the extent of undermining of this house and the continued ground movements, it is highly probable that this house will eventually fall into the slump area. The third home that was observed to be impacted by the slump is located less than 20 metres from the main scarp. What the effect will be on this home is uncertain, given continued ground movements experienced and the proximity to the steep main scarp.

4. The Goulais River

According to Dillon Consulting Engineers (Dillon) who undertook a hydrology study for the Ontario Ministry of Transportation (MTO) for a crossing of the Goulais River (Highway 552 Crossing of Goulais River - Hydrology Study, April 18, 1988), the Goulais River has a sinuosity index greater than 1.5 and is therefore classified as meandering. (The sinuosity index is given as the ratio of the channel length to the meander length or one full sinusoidal wave length (Chow, Open–Channel Hydraulics, 1959)). For meandering rivers, meander patterns change over time and bends tend to migrate in the downstream direction (Dillon, 1988). Another characteristic of meandering type rivers are that they continually undergo active erosion along the outer banks which are accompanied by periodic land movements or slumps.

A comparison of the Goulais River was undertaken using old aerial photographs and current survey data for a 42 year period, from 1945 to 1987 (Dillon, 1988). Findings from the comparison indicated that while nearly 5 metres of lateral expansion at the apex of the meander was observed over the 42 year period, longitudinal migration was measured and found to be over 30 metres in the downstream direction. What this means is that the magnitude and rate of the changes observed over the 42 year period can be expected to continue if left unmitigated until the meander features evolve into oxbow basins or lakes or ultimately until the Goulais River mouth area becomes an outwash plain. Furthermore, given the nature of the soils in the area in question, the problems can be expected to continue indefinitely and will result in significant future changes in the landscape around the river in the areas of concern.

5. Geotechnical Conditions

After several embankment failures or slumps, the MNR undertook a geotechnical evaluation of bank stability of the Goulais River. MNR retained the services of engineering consultants, Trow Consulting Engineers Ltd. (Trow March 1993 and April 1994). The 1993 report involved a geotechnical investigation of the soil conditions at four separate locations along the banks of the Goulais River (Figure 1), one of which was in the vicinity of the 1988 and 2003 slumps. The 1994 study involved analyses of the stability of slopes at four representative sections, corresponding to the locations of boreholes from the 1993 study.

The following is a brief description of the soil stratigraphy above the 1988 slump and adjacent to the 2003 slump. According to the Trow reports, the soil conditions at the slump area are comprised of a topsoil veneer or mantle which is underlain by a uniform sand several metres in thickness of medium size in a loose to compact state, brown and moist (Figure 2). The sand is in turn underlain by clayey silt that is characterised as grey, non-plastic silt with thin, red, clay veins, having loose silt with soft clay. The clayey silt is in turn underlain by silty clay with alternating layers of grey silt and red clay, saturated and soft to firm in nature. The silty clay layer is silt that is grey, non-plastic, saturated, and compact. Visual and tactile observations of the soil at the 2003 slump indicate a somewhat similar soil stratigraphy and compositions. However, slight variations were observed in the sequencing and thicknesses of the layers and can be attributed to the variable nature of soils in general. Laboratory testing for the 1993 geotechnical investigation was conducted on samples including grain size analysis, moisture content, unconfined compression tests, and an Atterberg Limit Test.

Standpipe piezometers were installed during the geotechnical investigation, one of which is located above the 1988 slump. Readings taken after the installation was completed and during the following year indicate that the groundwater table is present at about 8 metres below the ground surface or approximately 8 metres above the normal river level. Such an elevated groundwater level results in continuous seepage from the bank slopes. Based on the geotechnical borehole logs, the groundwater level is within the clayey silt which was found to consist of loose, non-plastic silt with thin soft clay veins. Seepage in non-cohesive soils, such as the loose silts, is likely to result in removal of some of the embankment material which can cause localised sloughing into the river. Groundwater seepage out of the embankment has been substantiated by past visual observations.

6. Erosion of Stream Banks

The Goulais River ~~has undergone~~ erosion of the ~~embankments~~ for many years, ~~as~~ is indicative of the degree of sinuosity and the many oxbow basins. The rate of bank erosion depends also on many factors including clay content, bulk density, antecedent water and temperature, wind and wave conditions, susceptibility to precipitation erosion, vegetation cover, etc. (Smerdon and Beasley – The Tractice Force Theory Applied to Stability of Open Channels in Cohesive Soils, 1959).

There are many factors that contribute to bank erosion and include stream erosion, wave action, seepage, and ice flows. Stream erosion results from the lateral or shear forces that are induced by flowing water along or parallel to the bank and results in undercutting of the toe of the bank and subsequent collapsing of the bank. Wave attack on exposed banks, by fast flowing water, wind, or boat travel also results in erosion at the toe of the bank. Seepage can be another contributing factor and can cause erosion from an elevated water table above the channel level. Ice flows during spring break-up can cause gouging of the bank face or removal of vegetation at the waters edge.

Forces causing embankment failure include driving forces (like the weight of the soil and/or manmade structures) and hydrostatic (water) pressure and seepage forces within the slope. Seismic events can also trigger or contribute to a slope failure. Resisting forces for embankment failure include the shear strength of the embankment ~~soil~~ material along a failure plane, hydrostatic pressure ~~at the toe of the failure plane,~~ and the weight of material at the toe of the embankment. A sudden increase in one or more of the driving forces or a decrease in the resisting forces can precipitate an embankment failure.

Erosion of embankment material along the toe of the embankment is likely to result in undermining and steepening of the banks beyond the natural angle of repose of the soil. (Angle of repose is considered the steepest angle at which a sloping surface formed of loose material is stable.) Subsequently, bank sloughing is initiated and results in the addition of material to the toe by the stream thereby decreasing the angle back to the angle of repose. Cohesive (clayey) banks can withstand steeper slopes for longer periods than for non-cohesive material.

7. Post-Failure Embankment Profile

As part of the 1994 Trow investigation, a post-failure surface profile was to be developed at four locations, one of which was immediately adjacent to the recent slump (Figure 3). The profile sections commenced at the boreholes and extended down to the river. The post-slump bank configuration was found to comprise the following three distinct slope or inclination zones:

i. An upper zone (for all material located above the groundwater level and comprised of sands and the clayey silt). This zone was observed to stand at approximately 18° or 3H:1V (horizontal to vertical);

ii. A lower zone (below the groundwater level but above river level and comprises the silty clay). This zone was found to stand at a relatively flat angle of approximately 5° or 10H:1V;

iii. An underwater zone (below the normal river water level and can comprise silty clay and silt). This zone was measured at a relatively steep slope of approximately 39° or 1.25H:1V.

Note that the above description is for the location at or near the 1988 and the 2003 slump locations only. The description for other sites were found to vary in some cases significantly and can be possibly attributed to post-failure configuration versus a present metastable condition. A metastable condition is one where the existing embankment would have a factor of safety against sliding approaching 1, or where a slide is imminent, and only waiting for a trigger to occur.

8. Conclusions – Possible Cause of Slump

It is well known that a meandering type stream generally erodes bank material along the outside embankment while depositing material along the inside of the stream thereby increasing the sinuosity of the river. This effect has been observed along the Goulais River as is indicated by the many oxbow features along the river system. The erosion of material along the toe of the embankment is caused be many forces including normal river flow and ice flows. As embankment material is removed from the bottom of a bank, the slope is steepened to an angle greater than the natural angle of repose. Eventual sloughing of the embankment is inevitable.

Additionally, sections of the Goulais River have an elevated groundwater table or phreatic surfaces that seep out of the embankment well above the normal river level. Such an elevated phreatic surface results in seepage from the embankment and is likely to continue to remove some of the non-cohesive materials from the embankment. This seepage and consequent erosion likely produces planes of weaknesses that can result in embankment instability. Based on the 1994 Trow report, "the critical time for the stability of the slopes occurs not only during and immediately after heavy run-off or when the river is rapidly drawn down after flood conditions but almost permanently, since continuous seepage is occurring from the slopes toward the river".

Due to the many contributing factors, the main provocation that induced the slump may never be known. However, due to the erosion effect of the meandering river along the toe of the embankments and combined with the continuous seepage from the elevated groundwater levels, progressive erosion can be expected along the outermost banks of the Goulais River resulting in periodic slumps or failures.

During the site visit, some local people had indicated that the 1988 slump was a result of an earthquake around the Montreal, Quebec area just prior to the slump occurring. In a review of archival seismic data from the National Earthquake Centre for events of earthquakes, blasts or rock bursts, a 2.2 magnitude blast occurred near Sudbury on the morning of January 9, 1988. Of interest is that on the morning of October 12, 2003 a 4.5 magnitude earthquake occurred northwest of Maniwaki Quebec (see Figures 4 and 5). It is noteworthy that both of these events occurred several hours prior to the embankment failures. Also noteworthy is that a seismic event occurred in the Goulais River area on April 11, 1989 with a magnitude of 2.5 but it is unknown if any slumps were report around the time of this event. While this information is interesting, more specific information would be required to establish a correlation between the seismic events and the slumps of 1988 and 2003.

It is postulated that a possible cause of the January 1988 slump was due in part to an increase in the phreatic surface level in the embankment. When the embankment at the river's edge freezes, it is plausible that seepage out of the embankment would be impeded. At the same time seepage or leakage from sewer or water systems or nearby elevated ponds or lakes would tend to increase the level of the water table. This combination can be a possible failure trigger for a slope that is already in a metastable condition.

9. Recommendations- Short Term

Concern for public safety and for environmental damage remains paramount. Public safety concerns are due in part because no site control exists other than a moveable barricade that simply states that the road is closed to public access. The general public, home owners and students from a nearby University, were observed walking around and below the slump area and damaged homes. Recognising that the area is continuing to experience ground movement and probably will so for some time, all unauthorised people should be kept a safe distance away from the area. This must include the home owners and any contractors acting on their behalf. Furthermore, if unrestricted access to the site continues, these activities may trigger additional uncontrolled ground movement.

The three homes immediately affected by the slump pose an immediate risk to the environment. Specifically, septic systems for two of the homes have been damaged or destroyed and have been observed leaking effluent (Photo 5). With unrestricted site access, exposed raw sewage not only poses a risk to the environment but to the people as well. In addition, home fuel oil tanks have not been drained.

A large section of the Goulais River has been impeded upon and nearly closed off due to the slump. The area of the slump contains large trees, brush, etc. and is located within the normal watercourse area (Photo 6). The larger material, if not removed prior to the spring freshet, may contribute to an ice or debris jam. This is of importance as the Goulais River generally experiences ice and debris jams during the spring freshet. These jams often result in flooding of developed areas. This material should therefore be removed from the watercourse to the greatest possible extent.

A further serious matter concerns the safety of residents in similar areas on the river that are in a metastable situation, but have not experienced a significant landslide recently. These "sites at risk" areas would include any areas along the outside or downstream bend of river meanders where development has occurred within a "zone of concern" as measured from the waters edge. This "zone of concern" can range from 6H:1V to nearly 10H:1V (Figure 3) and will depend on such factors as embankment material composition, height of water table level, elevation of embankment in comparison to the normal water level. There may be a real or imminent risk to the life and property for residents located in the "zone of concern". The "zone of concern" needs to be established as soon as practically possible and the consequences of a future landslide needs to be communicated to any residents with these areas.

10. Recommendations- Long Term

Due to the meandering nature of the Goulais River, any residence or property that is located on an outside bend is likely to experience embankment erosion and possible slumping at some time in the future. However many variables contribute to embankment slumping and the timing of the slumping of a particular section of an embankment is impossible to predict. Manifestation of a possible future slump may include but may not be limited to surface tension cracks, localised surface slumps along the river bank, leaning trees that were once straight, cloudy well water, bulging toe of the embankment near river, new cracks in foundation or widening existing cracks, doors or windows in nearby residences that either now stick or are able to move that once were sticky. These may be some of the signs that embankment failure may be occurring or imminent. However, given the Goulais River situation, a future major slump may occur suddenly and unpredictably. All properties located in active erosion areas or "zones of concern" should be considered at high risk for a future landslide. Any such future landslide could result in loss of human life, property and environmental damage.

As stated previously, further characterization of the nature and type of an embankment failure must be undertaken to accurately evaluate the risk in the case of any individual property and certainly before any mitigative measures are undertaken. However, some possible solutions could include the following:

- unloading crest of embankment by removal of fill, structures, etc.;
- flattening of the embankment to a more stable slope;
- benching or terracing of the embankment;
- buttressing of the embankment toe;
- armourment of toe;
- enhancement of slope drainage and mitigating groundwater recharge to the slope;
- some combination of the above.

As discussed previously throughout this report, many parameters contribute to a safe slope geometry of the river bank. As such it is difficult to determine and delineate an adequate set-back distance from the river in order to avoid impacts by slumps. However, some generic rules could be developed based on conservative parameters and using post-failure geometries. Additional studies should be undertaken to accurately define which sites are at risk or are within the "zone of concern".

It is further recommended that the "sites at risk" be formally identified as natural hazard areas in accordance with MNR's "Natural Hazards Technical Guides".

We trust that the information provided in this report is sufficient in detail to meet your needs. Should you have any questions or comments with regards to the information contained in this report, please do not hesitate to contact the undersigned.

Yours truly,

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Sr. Project Engineer
NE Region FSD

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Sr. Project Engineer
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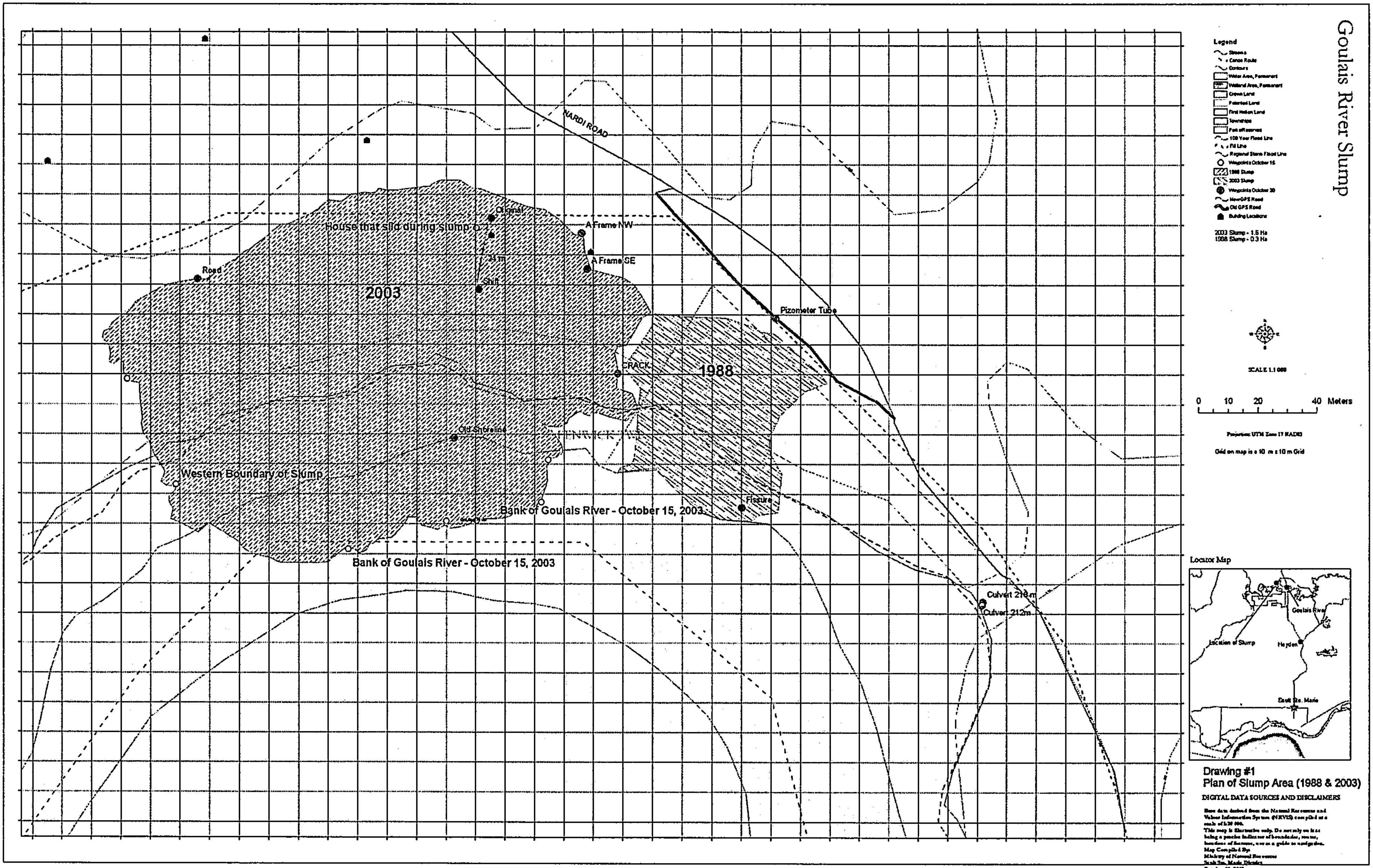
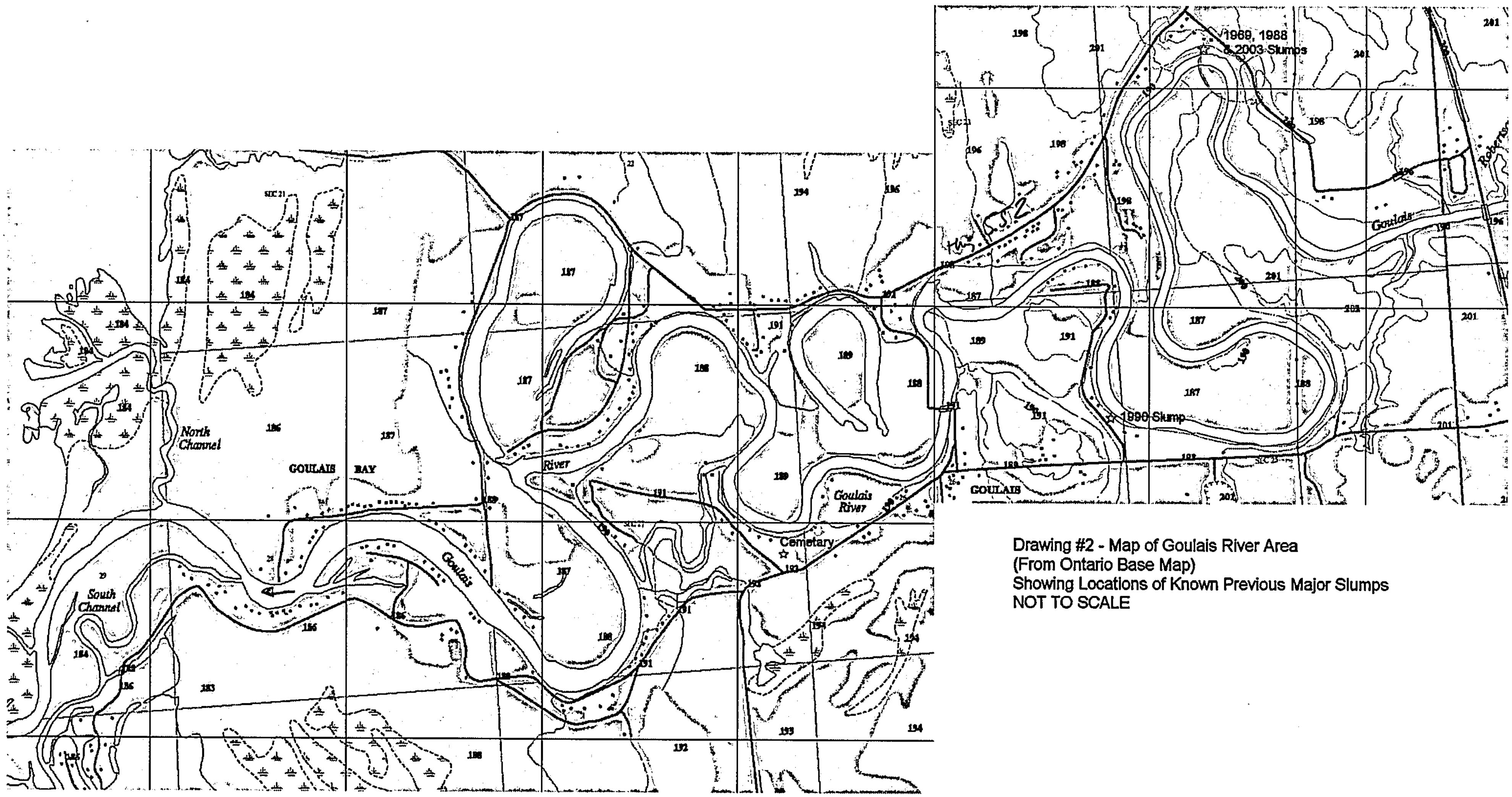
Appendices

Drawing 1 – Plan of Slump Area (1988 and 2003)

552

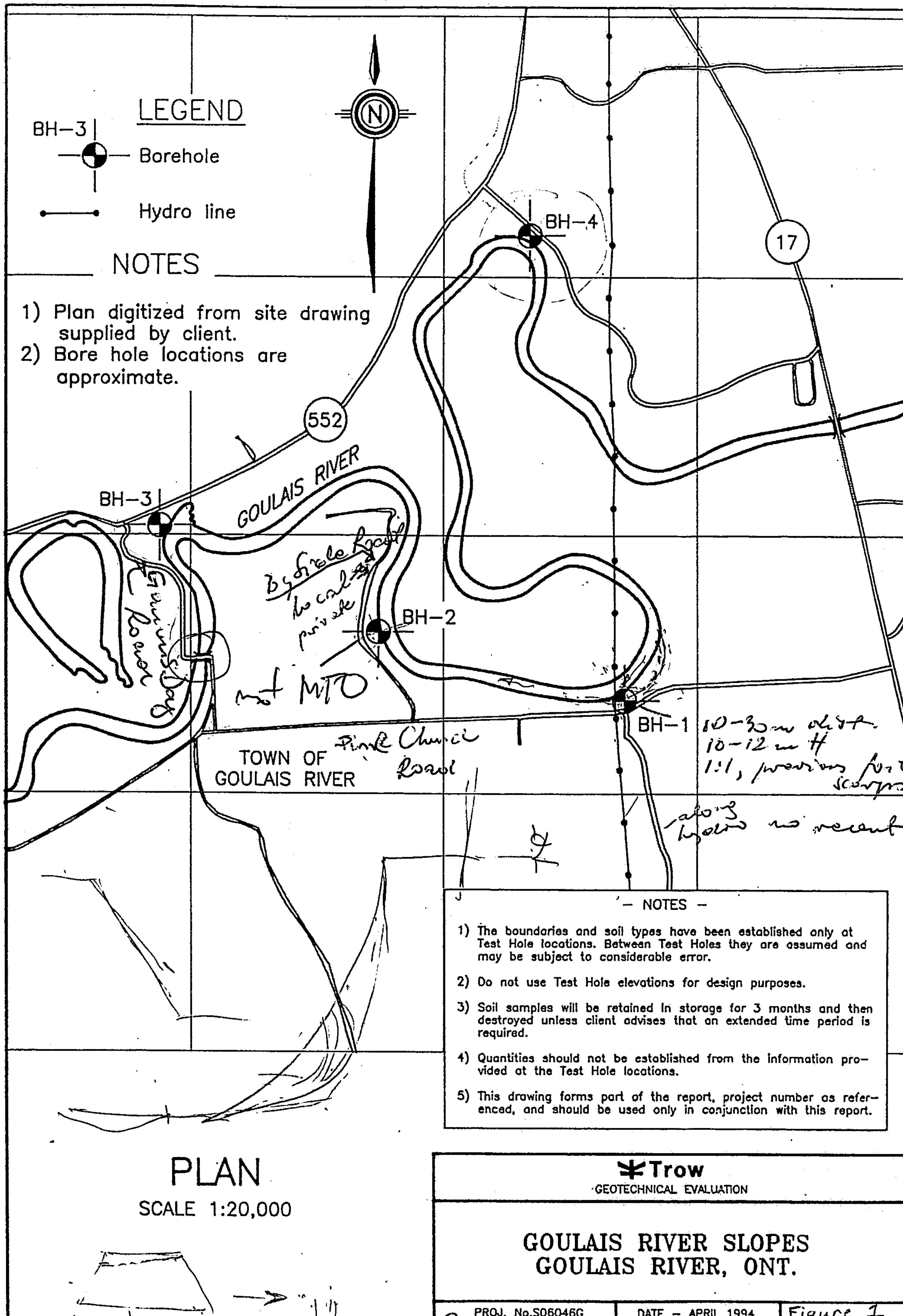

Goulais River Slump
Legend
2003 Slump - 1.5 Ha
1988 Slump - 0.3 Ha
NARDI ROAD
House that slid during slump
Original
A Frame NW
A Frame SE
Road
21 m
Shift
2003
Pizometer Tube
CRACK
1988
Old Shoreline
Western Boundary of Slump
Bank of Goulais River - October 15, 2003
Fissure
Bank of Goulais River - October 15, 2003
0 10 20 40 Meters
Locator Map
Location of Slump
Sault Ste. Marie
Drawing #1
Plan of Slump Area (1988 & 2003)
DIGITAL DATA SOURCES AND DISCLAIMERS

Drawing 2 – Plan of Goulais River



Drawing #2 - Map of Goulais River Area
(From Ontario Base Map)
Showing Locations of Known Previous Major Slumps
NOT TO SCALE

Figure 1: Trow Goulais River Geotechnical Investigation – Location of Boreholes.



Wilding Road along – ~~West~~ South of Hy 552
approx 3m high emb, rip-rap at toe, remove old trees
move road as far to the ...

Figure 2: Trow Goulais River Geotechnical Investigation – Borehole Log Adjacent to 2003 Slump.

BOREHOLE LOG

JOB No. S06046G/S05576G BOREHOLE No. 4 DRAWING No. 6

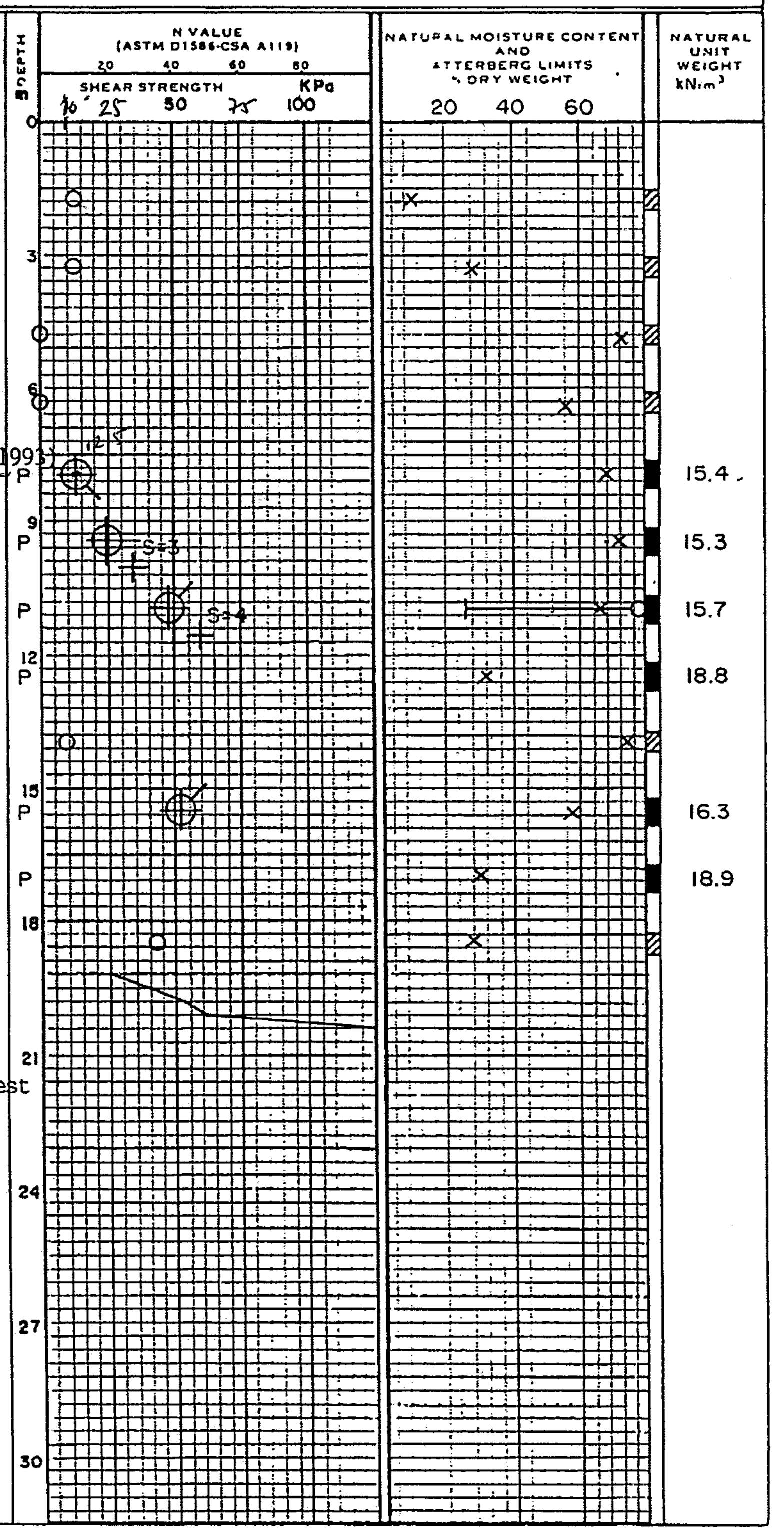
PROJECT Goulais River Slopes

LOCATION Goulais River, Ontario

HOLE LOCATION AND DATUM SEE DRAWING NO. 1

AUGER SAMPLE	☒	NATURAL MOISTURE	×
SPT (N) VALUE	○ ○ ▨	PLASTIC AND LIQUID LIMIT	├─○
DYNAMIC CONE TEST	———	UNDRAINED TRIAXIAL AT OVERBURDEN PRESSURE	15 ⊕ 5 (o)
SHELBY TUBE	● ● ■	% STRAIN AT FAILURE	10
FIELD VANE TEST	+ S		
LAB VANE TEST	t	PENETROMETER	▲

SOIL DESCRIPTION	Elev. m	Depth m
	200.0	0
Organic gravelly sand fill ±380 mm over **Sand**, brown, moist, uniform, medium (loose/compact)		
	197.6	
Clayey Silt, generally grey, non-plastic silt with thin red clay veins (loose silt with soft clay)		3
	195.5	
Silty Clay, alternating layers of grey silt and red clay, saturated (soft to firm)		6
7.5m	191.9 (March 1993)	9
Standpipe	River 184	12, 15
	183.5	
Silt, grey, non-plastic, saturated (compact)		18
	181.3	
END OF BOREHOLE	179.6 End of Cone Test	21



Notes:

(1) Borehole advanced using hollow stem augers on March 19, 1993.

(2) Dynamic cone penetration test driven at bottom of borehole through hollow stem augers.

(3) Water level at ±7.2 m depth and hole was open to ±16.8 m depth on completion.

(4) Standpipe installed to ±18.3 m depth.

(5) Water Level Records

Date	1994 Mar 19	1994 May 3	1994 June 8	1994 Mar 15
GWL below grade (m)	7.2	8.1	8.0	8.3

NOTE: BOREHOLE DATA REQUIRES INTERPRETATION ASSISTANCE FROM TROW BEFORE USE BY OTHERS.

Figure 2

Figure 3: Trow Goulais River Geotechnical Investigation – Post-Failure Embankment Profile.

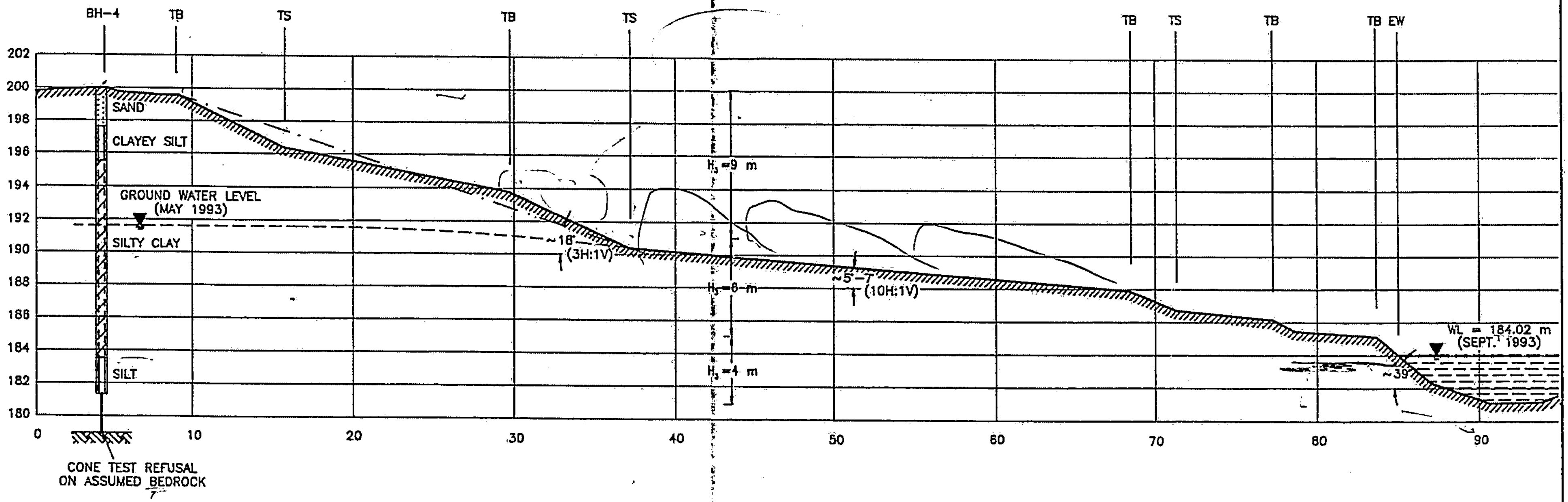
Total height of slope; H=~19 m

SLOPE ZONES

Generally drained with seasonal seepage, H_1=~9 m, β_1=~18°

Continuous seepage on face of slope + wave attack, H_2=~6 m, β_2=~5°-7°

Continuously under water, H_3=~4 m, β_3=39°



SECTION 4

SCALE 1:250

NOTE – Sections digitized from drawing no. 1, of file no. 146-4-13, supplied by M.N.R.

Trow GEOTECHNICAL EVALUATION		
SECTION 4 GOULAIS RIVER SLOPES GOULAIS RIVER, ONTARIO		
PROJ. No. 5055786/A	DATE: 1, 1993	Figure 3

~ 120m avg @ 10H:1V

Figure 4: National Earthquake Database, Earthquakes Prior to 1988 Slump

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Query the National Earthquake Database

Search parameters:

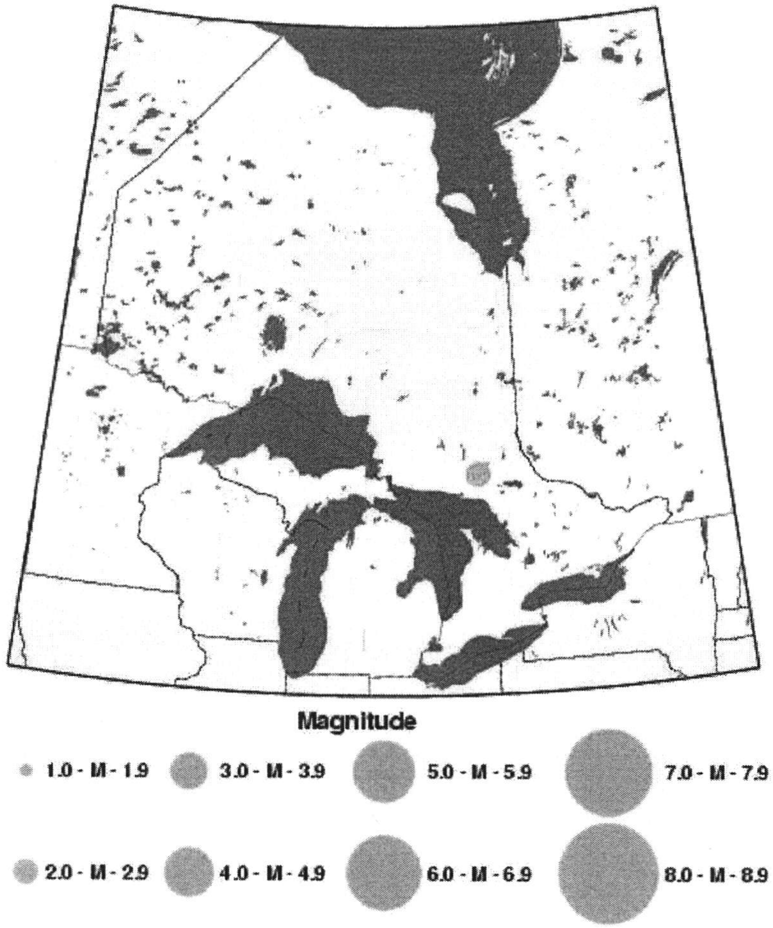
earthquakes, rock bursts, blasts
41.24 < latitude < 57.13 and -96.50 < longitude < -72.18 and and -1.00 < magnitude < 10.00
from 1988/01/09 01:00 to 1988/01/10 23:55
order by date

Search results:

Solution ID	Date	Time(UT)	Lat	Long	Depth	Mag	Agncy	Region and Comment
19880109.0121001	1988/01/09	01:21:20	46.54N	80.99W	1.0g	0.2ML	GSC	BLAST
19880109.0614001	1988/01/09	06:14:41	46.54N	80.99W	1.0g	2.2MN	GSC	BLAST
19880110.0334001	1988/01/10	03:34:14	46.49N	81.07W	1.0g	1.5MN	GSC	VRM BLAST

Pour l'information en francais... finger seisme@seismo.nrcan.gc.ca

PLEASE DIRECT ANY ENQUIRIES TO info@seismo.nrcan.gc.ca



Last modified 2003-08-15
HTTP://www.seismo.nrcan.gc.ca/nedb/eq_db_e.php

Important notices
Printer version

Figure 5: National Earthquake Database, Earthquakes Prior to 2003 Slump

Query the National Earthquake Database

Search parameters:

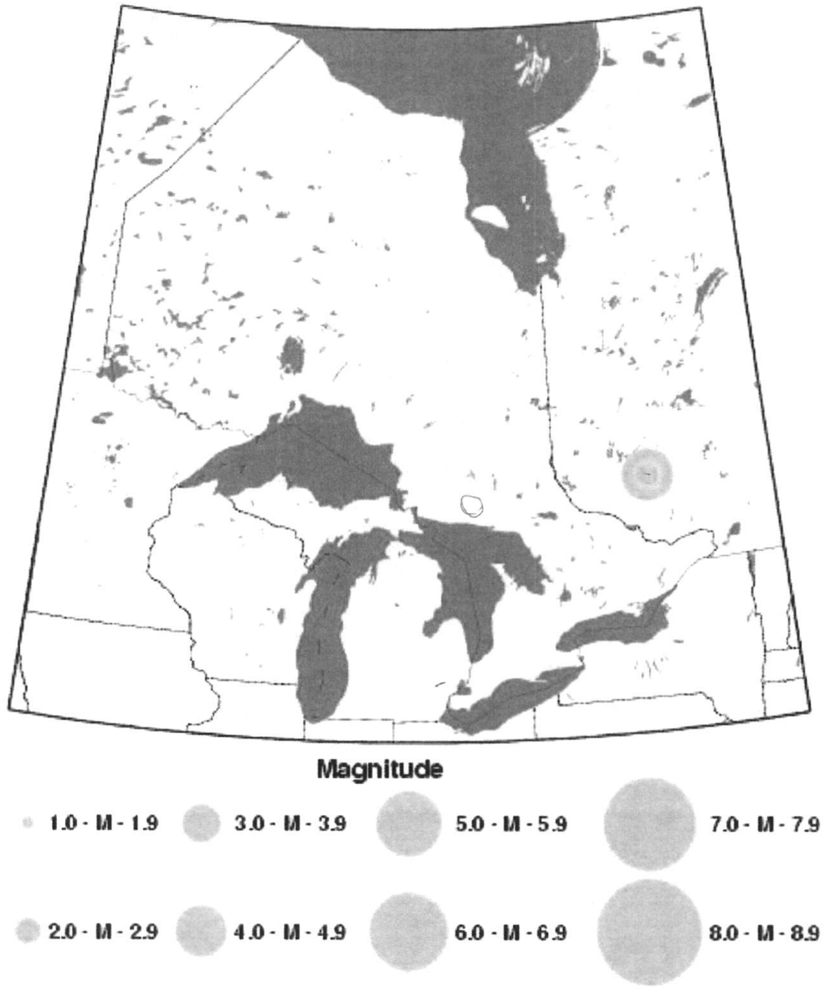
earthquakes, rock bursts, blasts
41.24 < latitude < 57.13 and -96.50 < longitude < -72.18 and and -1.00 < magnitude < 10.00
from 2003/10/12 01:00 to 2003/10/13 23:55
order by date

Search results:

Solution ID	Date	Time(UT)	Lat	Long	Depth	Mag	Agncy	Region and Comment
20031012.0826002	2003/10/12	08:26:07	47.01N	76.36W	18.0g	4.5MN	GSC	76 km NW from MANIWAKI,
20031013.0937001	2003/10/13	09:37:01	46.99N	76.35W	18.0g	2.1MN	GSC	74 km NW from MANIWAKI,

Pour l'information en francais... finger seisme@seismo.nrcan.gc.ca

PLEASE DIRECT ANY ENQUIRIES TO info@seismo.nrcan.gc.ca


Magnitude
1.0 - M - 1.9
3.0 - M - 3.9
5.0 - M - 5.9
7.0 - M - 7.9
2.0 - M - 2.9
4.0 - M - 4.9
6.0 - M - 6.9
8.0 - M - 8.9

Photos of October 15 and 16, 2003 Site Visit

Photo 1 – Sectional View of Compound Failure. Note concentric slips dipping backwards.

Photo 2 – Sectional View of Main Scarp. Note house on right within slump area.

Photo 3 – Toe of slump at Goulais River. Note large trees within normal waterway opening area.

Photo 4 – Home severally undermined and on verge of tumbling into slump area.

Photo 5 – Note Groundwater and effluent at base of slump.

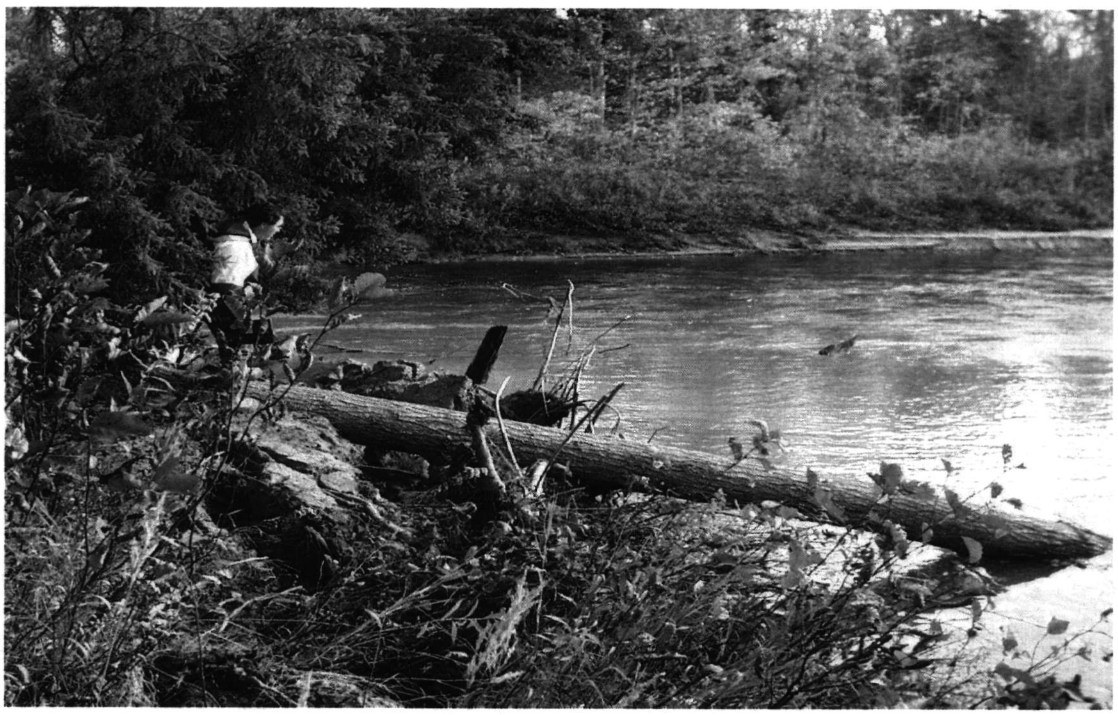


Photo 6 – View of toe of slump at river. Note large trees and other woody debris now within the waterway opening.

FDS W.O. 88-11002

FIGURE 1