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THURBER

ALBERTA INFRASTRUCTURE
LANDSLIDE RISK ASSESSMENT

SECTION A: GEOTECHNICAL FILE REVIEW

NORTH CENTRAL REGION

SITE NC14: SH661:02

LEGAL LOCATION:	**SW 1-62-5-W5M**
NEAREST LANDMARK:	**Ft. Assiniboine Hill near Northeast Boundary of Town of Ft. Assiniboine**
Highway Control Section:	**SH661:02**
Date of Initial Observation:	**1978**
Date of Last Inspection:	**1999**
Last Inspected By:	**AGRA Earth & Environmental**
Instruments Installed:	**3 Slope Inclinometers (one in 1985, two in 1997)** **2 Standpipe Piezometers (one in 1985, one in 1997)**
Instruments Operational:	**2 Slope Inclinometers (1999)** **2 Standpipes (1999)**
Risk Assessment:	PF(7) * CF(4) = **28**

1. LOCATION

An active slide area at the Fort Assiniboine Hill site affects a 50 m length of SH661 as it climbs out of the Athabasca River valley. The overall height of the valley wall at this location is approximately 50 m. The site is located at the north-eastern boundary of the Town of Ft. Assiniboine.

The site plans, Figures NC14-1 and NC14-2 in Section F, show the approximate locations of the slope movement and monitoring instrumentation.

2. GENERAL DESCRIPTION OF SLOPE INSTABILITY

The highway has been constructed as a side slope cut/fill. At the location of the slope failure, the elevation difference between the head and toe is approximately 18 m. The embankment fill at this location is relatively loose and is approximately 5 m thick.

High water levels have been measured in standpipe piezometers previously installed in the slide area. Water seepage has been noted exiting the side slope below the roadway in the vicinity of the slope instability. Significant slope movements occurred in 1999 when the toe of the slide encroached on a house located below the area of instability.

Water seepage has also been observed flowing over the ground surface mainly from wells located in the back slope above the roadway. This seepage causes significant ditch icing in the winter and spring periods each year. However these wells are located downslope from the active slide area and hence likely do not contribute to the local slope instability currently impacting the roadway.

The most probable cause of the slope instability at this site is high pore water pressures resulting from the natural groundwater conditions at this site, combined with loading from the fill placed during roadway construction. Some of the vertical displacement of the roadway has been attributed to settlement of the loose embankment fill.

3. GEOLOGICAL/GEOTECHNICAL CONDITIONS

Physiographic Region: Swan Hills Upland.

Bedrock Geology: Wapiti (Kwt) Formation, grey feldspathic clayey sandstone, bentonitic mudstone and bentonite, scattered coal beds.

Surficial Geology: Surficial sediments up to 30 metres thick. Surficial sediments are variable and can consist of:

- Fine and coarse lacustrine sediments
- Stagnation moraine
- Stream and slopewash along valley walls
- Coarse fluvial sediments in the base of the valley

Hydrogeology: Coarse surficial sediments can produce yields of up to 2 L/s of groundwater. In the river valley, alluvial deposits may produce yields of up to 8 L/s. Groundwater flow direction is toward the Athabasca River.

The above information is based on published data.

Stratigraphy: The general soil stratigraphy within the highway embankment determined by drilling at the slide area is as follows:

Material	Depth (below ground surface)
Sand (Fill) - compact, silty, fine grained	Below topsoil or asphalt pavement to 5.0 m
Sand and Clay (interbedded) - loose sand, medium to high plastic clay	Below sand (fill) to 12.5 to 14.7 m
Clay (till), very stiff, silty, sandy	Below sand and clay to full depth of drilling, maximum 15.0 m.

The water table is located near the base of the sand fill layer in the vicinity of the slide.

4. CHRONOLOGY

1978

Slope movement was first observed by the owner of the property located adjacent to the toe of the slide.

1979

A site investigation was conducted which included two boreholes. The main cause of the slide was attributed to high groundwater levels as evidenced by seepage from sand layers within the valley wall. In addition, icing of the ditches and frost heave by the roadway was noted in the lower and mid hill area.

A drainage trench was installed in the upslope ditch. It appears this ditch drain was installed downhill from the slide area to address the icing problem.

1981

Further highway distress and slope movement was observed in 1981 at the same location.

1985

Slide movements were observed again in 1985. Ditch icing resulting from seepage continued to be a problem.

Two boreholes were drilled for the installation of a slope inclinometer (subsequently labelled AT97-4) and a standpipe piezometer.

The trench drain in the upslope ditch was extended further up the hill. The installation was difficult due to the presence of wet silts resulting in sections of pipe not being connected properly.

Horizontal drains were installed into the slope from a point near the toe of the slide mass. Groundwater was collected in a vertical well to avoid icing problems at the exit point of the horizontal drains. The water was diverted into a deeper gravel layer via the vertical well. This drain arrangement was found to be unsuccessful.

1991

Vertical down-drains (800 mm diameter CSP standing on end, backfilled with free draining gravel) were installed upslope from the roadway in an attempt to divert water from the flowing wells to the existing trench drain to relieve the icing problem. This proved to be unsuccessful when later site inspection revealed the surface water appeared to be bypassing these wells.

1997

A site investigation was conducted including drilling of three boreholes within and immediately downhill of the slide scarp, and installation of a standpipe piezometer and slope inclinometer (97-3). A summary of the results and recommendations is provided as follows:

a. The SI installed in 1985 (ATU 97-4) was still functioning in 1997, indicating that the rate of slope movement has been relatively slow over the 12 year period since installation. The scarp of the slide is defined by cracks in the road and the slip surface is known at the location of the slope inclinometer (approximately 6 m depth). Water was observed to be seeping from the ground surface at various locations on the lower slope.

b. Based on discussions with Municipal District personnel the pavement surface has required frequent repair.

c. Remediation measures considered for the slope failure included additional horizontal drains, a toe berm, slope flattening, or a geogrid reinforced slope reconstruction (recommended option). Continued repair and observation of the slope (null option) was also provided.

1998

A trench drain was installed in the upslope ditch in the vicinity of the slide during the summer of 1998 to reduce the icing problem. The extent of the drain is unknown, however its depth is in the order of 3 to 4 m.

A total of 20 mm of downslope movement was recorded in the slope inclinometer ATU97-4, between July 1998 and January 1999 at a depth of about 7 m below the roadway surface. No significant movement was recorded in the second inclinometer (97-3).

1999

Signs of recent slope movement were observed during a site reconnaissance undertaken in May of 1999. Up to 10 mm of differential height was measured across the scarp crack in the roadway, and a toe bulge was observed to be encroaching on the house at the toe of the slope. Recommendations were provided to vacate the house and to repair the slide.

The water level measured in the (97-2) standpipe in 1999 was reported to have remained essentially unchanged after the installation of the trench drain undertaken in 1998.

A drainage option was proposed for stabilization which consisted of the installation of five directionally drilled drains. This option was identified as having a risk of being unsuccessful based on failure of previous attempts to drain the slope.

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THURBER

November 20, 2000

File: 15-76-11

Alberta Infrastructure
Room 223, Provincial Building
4709 – 44 Avenue
Stony Plain, Alberta
T7Z 1N4

Attention: Mr. Phonse Kelly, P.Eng.

**NORTH CENTRAL REGION LANDSLIDE ASSESSMENT
SH 661:02 NEAR NORTHEAST BOUNDARY OF
TOWN OF FT. ASSINIBOINE (NC14)
2000 ANNUAL INSPECTION REPORT**

Dear Sir;

This letter documents the 2000 annual site inspection of a 50 m long portion of Secondary Highway 661:02 located on the northeastern boundary of the Town of Ft. Assiniboine. The work was undertaken by Thurber Engineering Ltd. (Thurber) in partial fulfillment of our Geotechnical Services, Monitoring and Assessment of Instrumentation and Landslides contract with Alberta Infrastructure (AI).

The inspection was undertaken on June 15, 2000 by Mr. Don Law, P.Eng of Thurber. The site visit was carried out in the presence of Mr. Roger Skirrow, P.Eng. and Mr. Fred Cheng, P.Eng. of AI.

1. BACKGROUND

The slope has had a complicated history of slope failure and of drainage measures undertaken to mitigate the effects of groundwater on the slide area since the slide was first reported in 1978. A description of the slope instability and chronology of events as interpreted from the AI geotechnical files was provided in Section A of the documentation submitted for this site.

An assessment and recommendations for remedial measures were provided by AGRA Earth and Environmental (AGRA) in letter reports to the MD of Woodlands dated October 10, 1997 and January 22, 1999. These reports are included in Section G of the site binder.

Continued...

A brief summary of the background is as follows:

- At the failure location the side slope is approximately 18 m high and consists of 5 m of loose to compact sand fill overlying interbedded native sand and clay layers. A scarp crack has formed in the roadway pavement over a 50 m length of the southeast bound (i.e. down slope) lane of the highway. This crack feature in the active slide area is shown on Figure NC14-1 and NC14-2 in Section F.

- Settlement of the roadway has occurred over this portion of the roadway since 1978. It was reported that a portion of the toe of the slope was removed below the roadway to allow for housing development, and the side slope was stripped of vegetation in some areas. A drop in the roadway was observed in 1978-79 over a 60 m length above the area of toe removal. A number of "slip zones" developed in the side slope and several home owners at the toe of the slope experienced water in their back yards and basements.

- Water seepage has been noted over the years to be exiting the side slope below the roadway in the failure area. Horizontal drains were drilled into the slope in 1979 (likely from about midslope), however these drains did not develop significant flow. After further roadway distress from slope movement was observed in 1985, additional horizontal drains were installed from the toe of the slope. Significant flow from these wells was initially observed, however discharge of the collected groundwater into an underlying gravel layer via a vertical well (located approximately as shown on the site plan) was not successful. There is no record of subsequent observations of the flow from these drains in the geotechnical files.

The following trench drain installations were undertaken, primarily to address the icing problem in the upslope ditch:

a) 1979 - A trench drain was installed in the upslope ditch in the lower section of the hill, located approximately as shown on the site plan.

b) 1985 - The trench drain was extended upslope from the 1997 installation, however installation difficulties in wet silt led to the pipe being installed unconnected.

c) 1991 – Additional drains were proposed for the lower section of the hill (i.e. downhill of the active slide) to control water from flowing wells located upslope of the roadway. This drain was designed to be connected to an existing manhole at the bottom of the slope. It is not clear from the files if this drain was installed.

d) 1998 – Additional trench drain was installed in the upslope ditch adjacent to the slide area. The extent of the drain was not reported in the files.

Continued...

It is understood that the trench drains have been ineffective at reducing the groundwater levels in the vicinity of the slide.

- A number of remedial measures were considered in the 1997 AGRA report, including a toe berm, slope flattening (i.e. vertical and/or horizontal grade change, and additional horizontal drains). The favoured alternative was to excavate and rebuild the slope with geogrid reinforced granular fill. A directionally drilled horizontal drain alternative was put forward in the 1999 AGRA report, however it was noted that there is some risk that the drains will be ineffective based on the past performance of horizontal slope drains at this site.

- Toe bulging had caused deflection of the walls of a house located at the toe of the failed slope, as documented in a letter to the MD of Woodlands by AGRA dated May 21, 1999.

2. SITE OBSERVATIONS

The highway roadway surface, back slopes and side slopes were inspected during the reconnaissance along the upper hill area in the vicinity of the roadway distress. The side slope in the lower portion of the hill was also viewed. Photographs of the site taken during the site reconnaissance are included in Section F of the site binder.

The following features and observations were noted during the site reconnaissance. The locations of these features are shown on the site plans, Figures NC14-1 (overview) and NC14-2 (detail of active slide area), provided in Section F of the binder. A stratigraphic cross section from the 1997 AGRA report is also included as Figure NC14-3.

- A 50 m section of roadway is presently impacted by the active slide feature. This area is shown in detail on Figure NC14-2, and includes the approximate location of the instrumentation. The side slope at this location averages approximately 24° (2.2H:1V) over an 18 m height. The crack pattern indicates that only the down slope lane (i.e. right hand lane as you travel down hill) is substantially affected by the slope movements at this location at this time.

- No signs of seepage or active slope movement were noted in the side slope and back slope in the vicinity of the roadway distress. Some bulging and uneven ground was evident within the treed area near the toe of the slope below the area of roadway distress, however the toe of the slide was not well defined at the time of the site reconnaissance. In addition, the trees were not leaning significantly in this area.

- Crack filling had been undertaken in the recent past. Differential heights across the crack feature of up to about 8 mm and crack widths of up to about 6 mm were noted.

- A 15 m long shallow dip in the roadway shoulder and guard rail (down slope side) was noted at a location approximately 100 m uphill from the active slide feature. Some minor cracking was noted in the pavement surface in this area with no significant differential height noted across the cracks. No signs of recent instability were noted in the side slope below the dip feature.

- A possible graben feature was noted on the upper side slope adjacent to and further uphill from the dip feature, located approximately as shown on the site plan. This feature appears inactive at this time. This feature could also be a result of slope grading at the time of construction or later. The upslope side of the roadway has been patched in the recent past at this location.

- A sinkhole was noted in the side slope approximately half way down the slope, located approximately as shown on the site plan. The sinkhole was approximately 600 mm deep and 3 m in diameter. There was no evidence of seepage or piping discharge from the sinkhole feature.

- An inactive scarp area was noted in the lower portion of the slope. This feature does not appear to be impacting the roadway at this time.

- The house where distress to the walls was noted in the 1999 AGRA letter had been removed from the property below the failed slope at the time of the site reconnaissance in June, 2000.

3. ASSESSMENT

It is expected that the active slope instability has resulted from high pore water pressures in the slope generated from the natural groundwater regime, possibly combined with placement of embankment fill materials at the time of roadway construction and/or upgrading. The slope failure may have been triggered by the removal of soil at the toe of the slope for property development.

The flowing wells reported upslope of the roadway downhill from the active slide area indicate that there is likely a confined aquifer in this area that may be providing high pore pressures to the failure plane, potentially from below. Previous attempts at horizontal drain installation may not have been oriented properly to intercept this layer. The existing geotechnical information is insufficient to confirm the nature of the groundwater regime within this slope.

Continued...

As noted in the 1997 AGRA report, settlement of the roadway surface may also be occurring in conjunction with the slope movements due to densification of the loose sand embankment fill. The sand may also be piping to other areas of the slope. The sinkhole feature may be an indication of piping failure, however no evidence of piping discharge was observed. The dip feature uphill from the slide area may be a result of fill settlement, as there is no evidence of slope instability or piping failure in this area.

It is expected that, if no action is taken, the active slide area will continue to fail and cause further distress to the highway at this location.

The distress (patch, cracking and dip in roadway shoulder) noted 100 m uphill from the active slide area may be indicative of slope movements developing at this location. Ongoing movements may cause further distress at this location.

The scarp in the lower slope area appears inactive and is not expected to impact the highway. However, high groundwater levels in this area fed by the two flowing wells in the back slope may however trigger future movements at this location.

4. RISK LEVEL

A risk level of 28 is considered applicable to the active slide area of this site, based on a Probability Factor of 7 (active with perceptible movement rate and defined zone of movement) and a Consequence Factor of 4. Other areas on the hill are considered to have a lower risk level.

5. RECOMMENDATIONS

The following summarizes our recommendations for this site.

5.1 Active Slide Area

Consideration should be given to a toe berm below the active slide area. A berm in the order of 6 m high and 20 m wide may be appropriate. A detailed design should be undertaken, including stability analyses using existing stratigraphic information. However it is recommended to install a piezometer nest in the slide area to determine appropriate pore pressures for the analyses and to assist in estimating the approximate flow rate of groundwater from the slope. Control of water through the base of the berm would need to be incorporated into the design.

It is expected that the cost of a toe berm would be in the order of $100,000. Control of water from the base would be included in this amount, provided there is sufficient capacity in an existing sewer system near to the site to carry the anticipated flow. This would need to be assessed.

Continued...

Other options such as retaining wall or reinforced earthfill may be considered, however these are expected to be more expensive than a toe berm option. Slope drainage may also be considered in combination with other options to further enhance the stability.

5.2 Uphill from Active Slope Area

Slope inclinometers and a piezometer nest are recommended in the patched area located 100 m uphill from the active slide area to monitor potential slope movements and measure pore pressures. Consideration should be given to placing one SI in the roadway and one on the possible graben feature below the roadway. If movements are determined, a survey of the area is recommended to determine the slope profile for stability analyses.

As a minimum this area should be monitored visually by the MCI and if any further distress is noted, reassessment should be undertaken by a geotechnical engineer.

5.3 Downhill from Active Slope Area

Although inactive at the present time, the roadway and side slope adjacent to the inactive scarp feature downhill from the active slide feature should be monitored by the MCI on a regular basis. If distress to the roadway or side slope is observed, further geotechnical assessment should be undertaken.

5.4 Global Groundwater Considerations

Prior to considering further drainage measures at this site such as horizontal directionally drilled drains or trench drains, additional study should be carried out including hydrogeological assessment to provide a better understanding of the groundwater regime for the overall slope. This may involve a desk top study combined with field investigation, including the installation of nested piezometers (i.e. with tips at different depths) in various locations to determine the nature and extent of the lower artesian aquifer. The study should address the effect of groundwater on the slope movements and maybe expanded to address the ditch icing. Based on the results of the study, effective mitigative measures for groundwater control could then be designed and implemented.

Continued...

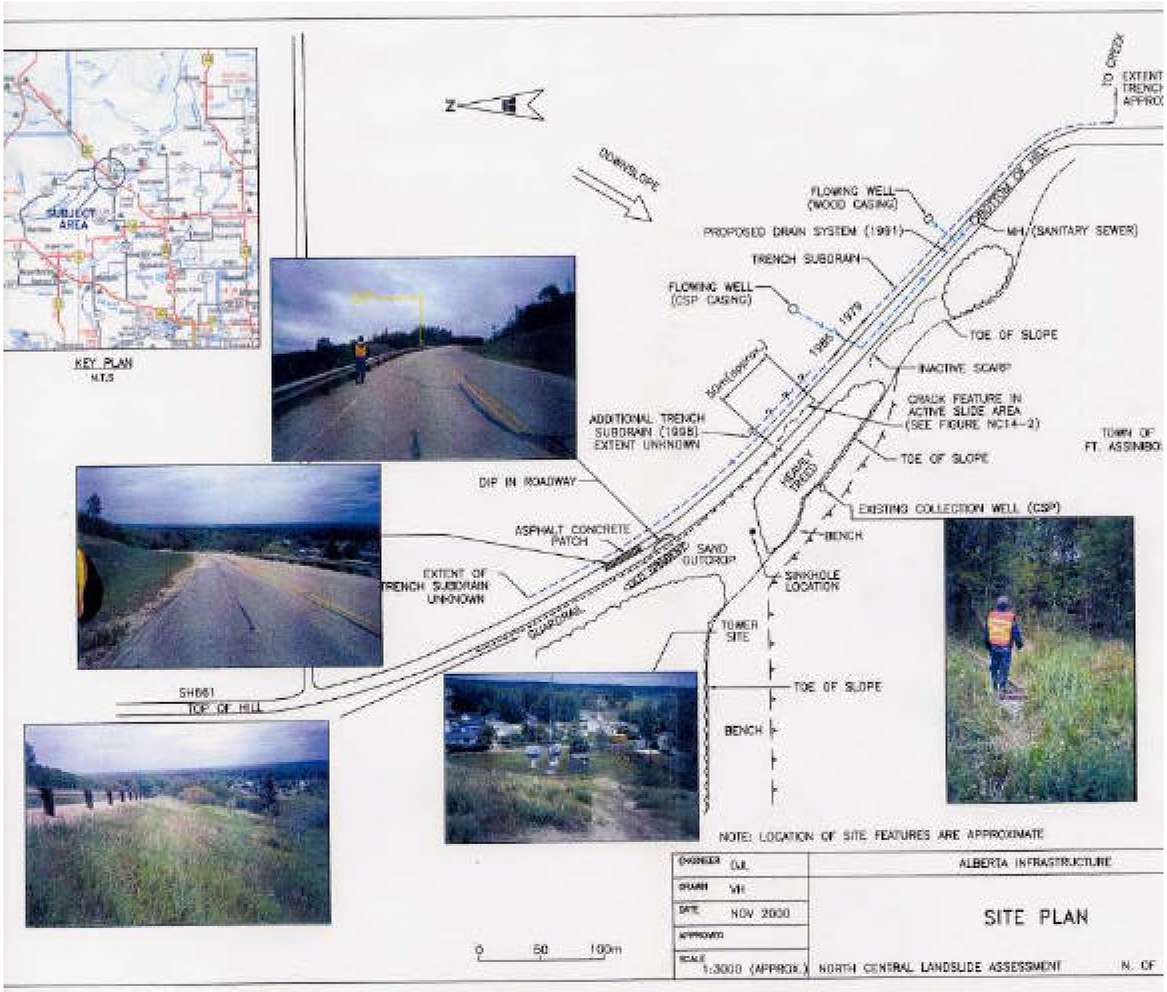
6. CLOSURE

We trust this assessment meets with your needs at this time. Please contact the undersigned should questions or concerns arise.

Yours very truly,
Thurber Engineering Ltd.
D. Papanicolas, P.Eng.
Review Principal

D.J. Law, P.Eng.
Project Engineer

attachments



KEY PLAN
N.T.S
SUBJECT AREA
DOWNSLOPE
TO CREEK
FLOWING WELL (WOOD CASING)
PROPOSED DRAIN SYSTEM (1991)
MH (SANITARY SEWER)
TRENCH SUBDRAIN
FLOWING WELL (CSP CASING)
TOE OF SLOPE
1986
1979
INACTIVE SCARP
CRACK FEATURE IN ACTIVE SLIDE AREA (SEE FIGURE NC14-2)
ADDITIONAL TRENCH SUBDRAIN (1998) EXTENT UNKNOWN
TOE OF SLOPE
TOWN OF FT. ASSINIBOI
DIP IN ROADWAY
EXISTING COLLECTION WELL (CSP)
ASPHALT CONCRETE PATCH
SAND OUTCROP
BENCH
EXTENT OF TRENCH SUBDRAIN UNKNOWN
SINKHOLE LOCATION
GUARDRAIL
TOWER SITE
SH661
TOP OF HILL
TOE OF SLOPE
BENCH
NOTE: LOCATION OF SITE FEATURES ARE APPROXIMATE
ENGINEER DJL
DRAWN VH
DATE NOV 2000
APPROVED
SCALE 1:3000 (APPROX.)
ALBERTA INFRASTRUCTURE
SITE PLAN
NORTH CENTRAL LANDSLIDE ASSESSMENT
0 50 100m

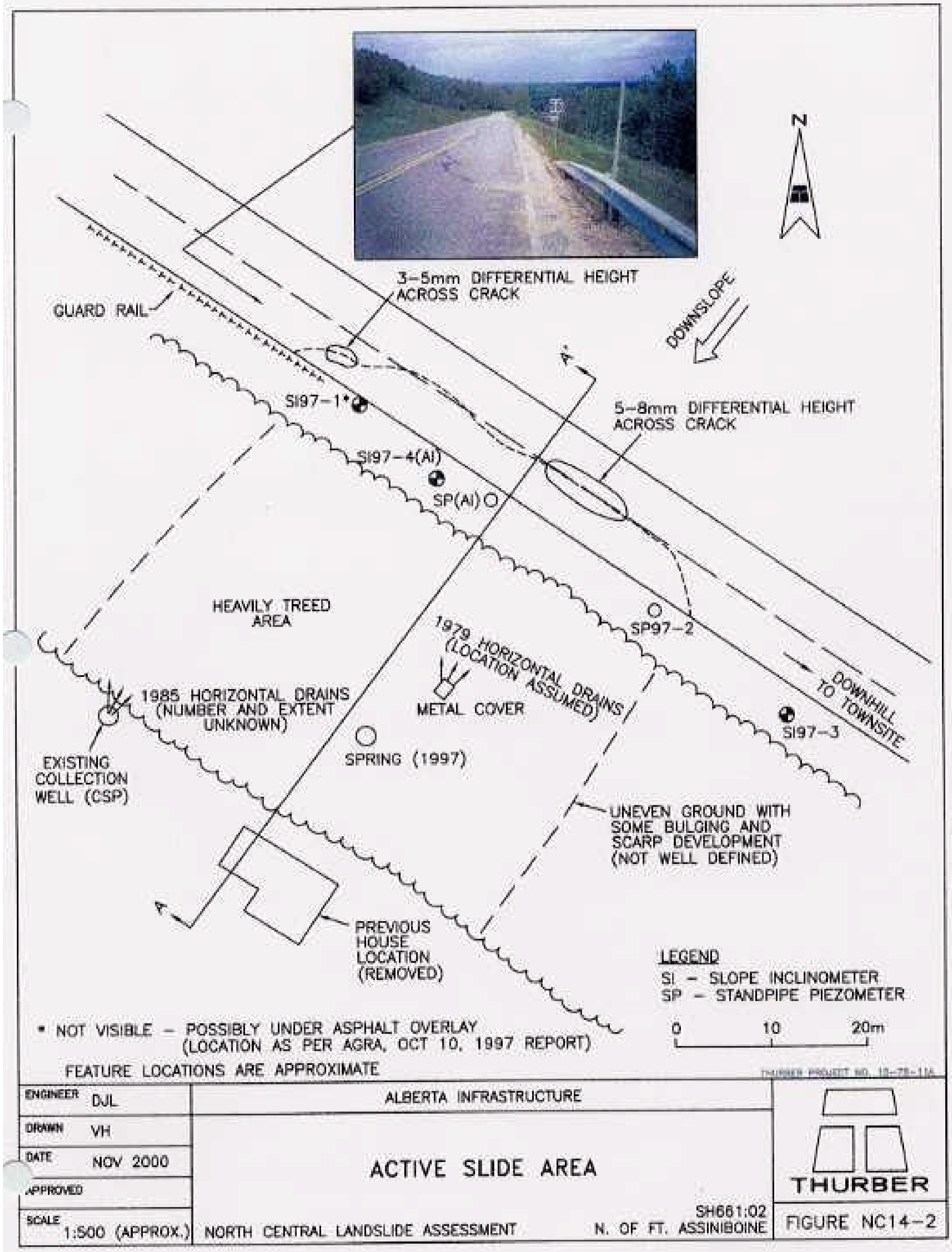

N
3-5mm DIFFERENTIAL HEIGHT ACROSS CRACK
GUARD RAIL
DOWNSLOPE
A'
SI97-1*
5-8mm DIFFERENTIAL HEIGHT ACROSS CRACK
SI97-4(AI)
SP(AI)
HEAVILY TREED AREA
SP97-2
1979 HORIZONTAL DRAINS (LOCATION ASSUMED)
DOWNHILL TO TOWNSITE
1985 HORIZONTAL DRAINS (NUMBER AND EXTENT UNKNOWN)
METAL COVER
SI97-3
EXISTING COLLECTION WELL (CSP)
SPRING (1997)
UNEVEN GROUND WITH SOME BULGING AND SCARP DEVELOPMENT (NOT WELL DEFINED)
A
PREVIOUS HOUSE LOCATION (REMOVED)
LEGEND
SI - SLOPE INCLINOMETER
SP - STANDPIPE PIEZOMETER
0
10
20m
* NOT VISIBLE - POSSIBLY UNDER ASPHALT OVERLAY (LOCATION AS PER AGRA, OCT 10, 1997 REPORT)
FEATURE LOCATIONS ARE APPROXIMATE
ENGINEER DJL
DRAWN VH
DATE NOV 2000
APPROVED
SCALE 1:500 (APPROX.)
ALBERTA INFRASTRUCTURE
ACTIVE SLIDE AREA
NORTH CENTRAL LANDSLIDE ASSESSMENT
SH661:02
N. OF FT. ASSINIBOINE
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FIGURE NC14-2

PHOTO NC14—1 LOOKING SOUTHEAST (DOWNSLOPE) AT ROADWAY DISTRESS AND INSTRUMENTATION.

PHOTO NC14—2 LOOKING NORTHWEST (UPSLOPE) AT DIP IN SHOULDER.

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DJL JUNE 15, 2000

PHOTO NC14-3 LOOKING SOUTHEAST AT PATCH IN ROADWAY (UPPER SLOPE).

PHOTO NC14-4 LOOKING SOUTHEAST AT POSSIBLE GRABEN AREA IN UPPER SLOPE.

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DJL JUNE 15, 2000

PHOTO NC14-5 LOOKING SOUTH AT TOWER SITE. (SAND OUTCROP IN FOREGROUND).

PHOTO NC14-6
LOOKING NORTHEAST AT
COLLECTION WELL AT
TOE OF SLOPE.