AMEC Earth & Environmental Limited
610 Richard Road, Prince George, BC
Canada V2K 4L3
Tel +1 (250) 564-3243
Fax +1 (250) 562-7045
www.amec.com

STAGE 1 STATUS REPORT
WEST QUESNEL LAND STABILITY STUDY
QUESNEL, BC

Submitted to:

The City of Quesnel
405 Barlow Avenue
Quesnel, BC
V2J 2C3

Submitted by:

AMEC Earth & Environmental Limited
Prince George, British Columbia

13 August, 2001

KX03904

11

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PHOTOS

LIST OF APPENDICES

1.0 INTRODUCTION

Over the past few years, the possible presence of large scale landslide features has been proposed by others in a suburban area of West Quesnel. These reports have been largely based on airphoto interpretation, surface reconnaissance, and a review of reported utility breaks. More recently, lateral movements of up to 194 mm have been reported for hubs monitored by GPS in West Quesnel. Reviews of past work have been unable to conclusively determine whether or not the observed and postulated movements were due to seasonal frost heaving, shallow localized ground movements, larger scale deep-seated landsliding, settlement, measurement inaccuracies or a combination thereof. Detailed subsurface conditions in West Quesnel were unknown.

Based on the lack of detailed subsurface information, including whether a deep-seated slide existed, the City of Quesnel (CofQ) has contracted AMEC Earth & Environmental Limited (AMEC) to conduct the West Quesnel Land Stability Study. The proposed scope of work for the West Quesnel Land Stability Study was divided in 3 Stages:

- Stage 1: Project planning, reconnaissance, data gathering, slope inclinometer installation and monitoring. The aim of this work was to determine whether or not deep-seated sliding was present.
- Stage 2: Detailed drilling, sampling, piezometer installation and monitoring
- Stage 3: Analysis, remedial recommendations and final reporting

Stages 2 and 3 would only be undertaken in the event that deep-seated slide movements were found in Stage 1. The scope of work was detailed in AMEC's proposal of 31 May, 2000 to the CofQ. This report summarizes AMEC's work to date on the West Quesnel Land Stability Study and forms the final report for Stage 1, which is now completed. Figure 1 and Photo 1 show the study area.

2.0 SUMMARY OF WORK CARRIED OUT

2.1 Office Review/Background Research

During the work, the following documents have been reviewed:

1. Geotechncial Consultant Reports: Section 10.1 (References) lists the geotechnical consultant reports reviewed by AMEC. Reports reviewed included documents prepared by AMEC (and its predecessor companies), C.O. Brawner Engineering Ltd., GeoNorth Engineering Ltd., Golder Associates Ltd., Dr. N.R. Morgenstern and Dr. D.M. Cruden of the University of Alberta, R.E Graham Limited and Thurber Engineering Limited.

2. Geological Background Documents: Section 10.2 lists the geological background documents reviewed for this work.

3. Ministry of Transportation (MoT) Files: Files from the MoT Prince George office including weather data were reviewed.

4. Ministry of the Environment, Lands and Parks (MELP) Files: Water well records posted on the internet by the Water Management Division of the Ministry of Environment, Lands and Parks (MELP) were reviewed. The water well locations were shown on 1:5 000 scale groundwater location maps provided by MELP.

5. BC Gas Utility Data: AMEC has reviewed BC Gas GPS hub monitoring data which has been collected since September of 1998. In addition, BC Gas has provided AMEC with their line break data for the study area.

6. City of Quesnel Data: The CofQ is currently collecting utility break records, geotechnical reports submitted to the CofQ and information from West Quesnel homeowners. AMEC will review this information during future stages of the work.

7. Airphotos: Table 1 below details the airphotos reviewed during Stage 1.

Table 1: Airphotos Reviewed

Airphoto	Year	Scale	Colour
30BCC97136 no. 73 and 74, 143 and 144	1997	1:20 000	Colour
BCB91026 no.126 and 127	1991	1:15 000	Black and White
BCB85014 no. 203 to 204	1985	1:15 000	Black and White
BC5709 no. 241 and 242	1976	1:15 000	Black and White
BC5328 no. 225 and 226	1969	1:30 000	Black and White
BC949 no. 93 and 94	1949	1:50 000	Black and White

2.2 Site Reconnaissance Visit

On September Mr. Nick Polysou, P.Eng., Mr. Drum Cavers, M.Eng., P.Eng., P.Geo., and Mr. Doug Dewar, P.Eng., of AMEC, accompanied by Mr. Jack Marsh of the City of Quesnel, conducted a site reconnaissance visit to west Quesnel to review general site conditions and determine potential slope inclinometer (SI) locations. Following the site reconnaissance visit, seven potential SI locations were selected.

2.3 SI Installation

From 2 to 27 October, 2001, 7 boreholes were drilled using a compressed air-rotary water well drill supplied by Cariboo Water Wells of Prince George, BC. Mr. Doug Dewar of AMEC was present during the drilling of the boreholes to conduct a preliminary log of soil conditions and to supervise the installation of the 7 slope inclinometers (SI) in the boreholes. Photos 2 and 3 show the boreholes being drilled for SI-4 and SI-7. The SI installation data is summarized in Table 2 below.

This water well rig is not a conventional rig for a geotechnical drilling, since only disturbed sampling of materials returned in the air stream is possible. However, the water well rig was not chosen primarily for sampling, but to allow reliable and economic installation of the slope inclinometers.

Table 2: SI Installation Data

SI	SI-1	SI-2	SI-3	SI-4	SI-5	SI-6	SI-7
Street	Avery Lane	Avery Lane	Abbott Drive	Voyager School	Abbott Drive	Dixon Street	Pierce Crescent
Date of Completion	25 Oct., 2000	23 Oct., 2000	27 Oct., 2000	13 Oct., 2000	5 Oct., 2000	16 Oct., 2000	19 Oct., 2000
A_o Bearing (°) (True North)	120°	120°	120°	110°	110°	105°	100°
Depth of Installation * (feet/m)	143 feet 43.6 m	245 feet 74.6 m	336 feet 102.4 m	520 feet 158 m	475 feet 144.8 m	507 feet 154.5 m	412 feet 125.6 m
SI pipe stick up above ground surface (mm)	720 mm	800 mm	820 mm	726 mm	779 mm	840 mm	660 mm
Elevation of top of SI casing (m A.S.L.)**	480.267 m	485.862 m	503.43 m	537.581 m	517.666 m	557.723 m	542.217 m
Elevation of ground surface (m A.S.L.)**	479.547 m	485.062 m	502.61 m	536.855 m	516.887 m	556.883 m	541.557 m
Northing**	5869298.105	5869342.656	5869598.068	5869878.155	5869633.237	5869933.443	5870231.729
Easting**	532568.712	532489.826	532273.051	531829.52	531919.02	531509.906	531798.61

*The SI installation depth is deeper than the depth it is read (refer to Table 2) to avoid having the SI probe touch the bottom of the hole. The depth is measured from the top of the casing.
**World Geodetic System 94 datum

A slope inclinometer consists of a plastic casing that will deform in response to ground deformation caused by slope movements or settlement. Photo 4 shows SI casing being installed into SI-7. Photo 5 shows the grout pump and grouting supplies used to fill the annulus between the casing and the borehole wall.

2.4 SI Monitoring

An initial reading of the profile of the installed SI casing was taken with an SI probe following the installation of the SI casing once the grout had set (approximately 10 to 20 days after completion of installation). Subsequent readings are compared to the initial reading to determine if any ground deformation has occurred. Two directions monitored in the casing. The A direction was oriented parallel to the approximate direction of expected movement, in this case downslope toward the Fraser River. The B direction is across slope, perpendicular to the A direction.

The casing is read from the bottom at intervals of 2 ft, using a probe that ride in the grooves of the casing. At each depth increment, the inclination of the casing in the A. and B directions is measured. At each depth increment, the change in inclination of the casing from the original readings allows the movement of the casing to be calculated. By adding up the incremental movements of the casing, a complete profile of the change in inclination of the casing can be calculated. Where a discrete slide surface cuts across the casing, movement of the slide

surface will result in a more rapid change in tilt of the inclinometer casing, allowing the location of the slip surface to be determined.

To facilitate the handling of the large amounts of data from the field, the field measurements were recorded on a DataMate readout unit and transferred to a computer for processing. GTILT PLUS software (Mitre Software Corporation) was used to reduce and calculate the data.

The orientations of the A and B. directions may rotate with depth due to the accumulation of small amounts a spiral in the casing over large depths. In a deep casing, such as those installed on this project, the amount of rotation may be sufficient to appreciably rotate the apparent movement directions. The spiral rotation of the grooves was measured using a special spiral monitoring tool. The calculated results for the slope inclinometers were corrected for the measured spiral error. Photo 8 shows the spiral probe being prepared to be lowered down SI-3.

The SI monitoring schedule including the spiral readings are shown in Table 3 below:

Table 3: SI Monitoring Schedule

SI	SI-1	SI-2	SI-3	SI-4	SI-5	SI-6	SI-7
Location	Avery Lane	Avery Lane	Abbott Drive	Voyager School	Abbott Drive	Dixon Street	Pierce Crescent
Depth SI Read to (feet/m)	142 ft 43 m	244 ft 74 m	334 ft 102 m	504 ft 154 m	474 ft 144 m	502 ft 153 m	410 ft 125 m
Spiral Reading	11 Jun. 2001	11 Jun. 2001	12 Jun. 2001	11 Jun. 2001	12 Jun. 2001	11 Jun. 2001	12 Jun. 2001
Initial Reading Date	21 Nov. 2000	21 Nov. 2000	21 Nov. 2000	3 Nov.2000	28 Oct. 2000	22 Nov. 2000	22 Nov. 2000
Initial Reading	7 Dec. 2000	7 Dec. 2000	6 Dec. 2000	24 Nov. 2000	24 Nov. 2000	6 Dec. 2000	7 Dec. 2000
Reading 2	12 Jan. 2001	11 Jan. 2001	12 Jan. 2001	6 Dec. 2000	6 Dec. 2000	11 Jan. 2001	12 Jan. 2001
Reading 3	5 Mar. 2001	5 Mar. 2001	6 Mar. 2001	11 Jan. 2001	12 Jan. 2001	5 Mar. 2001	6 Mar. 2001
Reading 4	2 Apr. 2001	2 Apr. 2001	3 Apr. 2001	5 Mar. 2001	6 Mar. 2001	2 Apr. 2001	3 Apr. 2001
Reading 5	28 Apr. 2001	28 Apr. 2001	28 Apr. 2001	2 Apr. 2001	3 Apr. 2001	28 Apr. 2001	29 Apr. 2001
Reading 6	18 Jun. 2001	13 Jun. 2001	14 Jun. 2001	28 Apr. 2001	29 Apr. 2001	13 Jun. 2001	14 Jun. 2001
Reading 7				13 Jun. 2001	14 Jun. 2001		

2.5 Public Meetings

AMEC has made presentations at two public meetings for the City of Quesnel detailed below:

21 September, 2000: AMEC provided a presentation to the residents of West Quesnel detailing the proposed scope of work of the West Quesnel Land Stability Study.

18 May, 2001: AMEC provided a presentation to the residents of West Quesnel detailing the preliminary results of the Stage 1 assessment.

3.0 PRELIMINARY DATA COLLECTED

3.1 Precipitation Data

The monthly total precipitation data was obtained from Environment Canada for the Quesnel Airport. Plots of the recorded data through 1975 to 2000 are shown in Figures 2 and 3 along with historical data and the cumulative difference. The historical data is based on a 30 year moving mean, where an average over 30 years was calculated for each month beginning with 1975. To calculate the thirty year moving mean for 1975, data was taken back to 1946 and all the monthly values were averaged over that 30 year interval. The cumulative difference is the sum of difference between the recorded data and the historical mean beginning with January 1975 and ending December 2000. This plot shows the trend of the recorded precipitation whether it is increasing or decreasing (i.e. wetter or drier trends) compared to the historical mean.

The precipitation data indicates that the period from 1975 through the spring of 1988 was close to or slightly below average. From the spring of 1988 through the end of 1996, conditions tended to be much wetter than normal, with 1991 being close to average. From 1997 to date, conditions have been average, tending to be drier than normal during the last two years.

3.2 Water Well Data

AMEC is currently in the process of collected water well data and interviewing local water well drillers. The data collection is not completed and information will be included in future reporting.

4.0 SUMMARY OF FINDINGS

4.1 Borehole Logs

During the drilling of the boreholes for the SI installations, AMEC compiled borehole logs based on the drill cuttings returned to the surface during the air rotary drilling. Appendix E contains the preliminary logs for the boreholes. Note that these borehole logs should be considered approximate due to the following limitations:

1. Samples collected from the drilling cuttings were disturbed and may be segregated during travel to the surface.
2. Bedding and other features would be destroyed or disturbed during drilling.
3. Water with a detergent additive was injected into the boreholes to assist with drilling in most boreholes, particularly at depth. The water many have further disturbed drill cuttings.
4. The depth where the cuttings originated was estimated based on the time for the cuttings to be returned to the surface from depth. Note that depths where there was a significant change in soil or rock type could be accurately estimated due to changes in the drill behavior.

5. Thin beds may be missed due to the cuttings being mixed with adjacent beds during travel to the surface.

In spite of the limitations of logging the disturbed cuttings on air rotary rigs, 10 years experience with the use of this method as shown that reasonable logs may be obtained.

4.2 Slope Inclinometer Data

4.2.1 Spiral Readings

Table 4 summarizes the spiral at the bottom of the SI casings. The complete data set includes the variation of spiral with depth down each casing. The spiral survey results show the clockwise rotation between the top and bottom of the SI casing.

Table 4: Results of Spiral Survey of SI Installations

SI	SI-1	SI-2	SI-3	SI-4	SI-5	SI-6	SI-7
Clockwise spiral at bottom of casing	9.9°	16.7°	24.1°	30.0°	29.6°	39.7°	17.8°

4.2.2 Calculated SI Data

The results of the SI readings to date corrected for measured casing spiral are attached in Appendix D. These plots presented include absolute profiles, cumulative displacement plots, incremental displacement plots and velocity plots. These terms are defined below.

1. Absolute profile plots show the actual profile of the casing after installation. The scale of the absolute profile plot varies with SI installation depending on the orientation of the hole. The absolute profile of the casing is relatively unimportant for most applications. In particular, whether or not the casing is vertical and straight is generally not a major factor in obtaining good movement data since the change from the initial orientations is measured, not the change from vertical. However, the absolute orientation of the casing can be useful in particular circumstances. For example, if the casing is undergoing compression, then the bends in the casing may tend to move out at existing bends.

2. Incremental plots show the individual changes in inclination of the casing at each reading elevation. The incremental plots have a 25 mm horizontal scale. These plots are useful for examining the depth and character of movements.

3. Cumulative plots show the overall apparent movement change of the SI casing since installation relative to the bottom of the hole. As discussed in Section 2.0, movement is measured in two mutually perpendicular directions, A and B. The A direction is oriented to be "downslope" whereas the B direction is across slope. The actual orientation of each of the casings is shown on Figure 4 and summarized in Table 2. Positive movements on the

cumulative plots are downslope on Direction A and across the slope to the right when looking downhill for Direction B. The cumulative plots have a 75 mm horizontal scale.

4. Velocity plots shows the displacement versus time over a given depth interval. Velocity plots are presented for A and B directions at selected intervals.

4.2.3 Discussion

The discussion below shows that there was good evidence of translational slide movements on discrete shear surfaces in most of the SI installations. Figure 5 shows the SI locations and summarizes the interpreted movement vectors.

A review of the velocity plots for all SI installations indicates a general acceleration of movements in the spring of 2001 as compared to the initial datasets collected during the winter or 2000/2001. This acceleration may be due to groundwater recharge from surface precipitation and snowmelt.

4.2.3.1 S1-1

1. Absolute position: SI-1 was relatively straight and vertical with relative deviations between the bottom and top of the hole of less than 50 mm in the A direction (downslope) and 400 mm in the B direction (across slope to the north).

2. Cumulative deflection: A small lateral shift of 2 mm was evident in the casing at approximately 41 m depth with some additional deflection around 28 m. The deflection at 41 m was first evident April 2001. There appeared to be surface deflections of less than 5 mm at the top of the casing. There was some bulging of the SI casing towards the east (downslope) and north above 28 m depth. This may be due to vertical settlement of the casing, possibly combined with grout loss in a gravel layer between 16 and 21.3 m depth (grout loss is not known for certain to have occurred in this gravel layer, but could explain the observed deformations).

3. Incremental deflection: The incremental deflections for SI-1 are characteristic of settlement above 28 m depth. The deflections at 40 m depth were small on the incremental plot.

4.2.3.2 S1-2

1. Absolute position: As shown on the plot contained in Appendix D, at the bottom of SI-2 there was 4800 mm of downslope deflection (A direction) and 2400 mm of across slope (B direction, north) relative to top of the hole.

2. Cumulative deflection: Clear translational movement surfaces are evident at 60 m and 42 m depth. The total deformation over the period of monitoring was approximately 21 mm to the

east (downslope) in the A direction and 5 mm to the south in the B direction at the ground surface. Very slight backward rotation was evident above 42 m depth in the A direction.

3. Incremental deflection: The two potential slip surfaces were shown as spikes in the data at approximately 60 m and 42 m depth. The shear surfaces appeared to be less than 0.6 m thick (i.e., the shear surface was contained within a the length of the slope inclinometer probe).

S1-3:

1. Absolute position: Relative to the top of the casing, the bottom of the casing in SI-3 was approximately 3000 mm downslope (A direction) and 3000 mm across slope to the north (B direction).

2. Cumulative deflection: There was a slip surface evident at approximately 39 m depth. Deflections along the slip surface over the period of monitoring were approximately 33 mm to the east (downslope) in the A direction and 2 mm to the north in the B direction.

3. Incremental deflection: The incremental deflection plot showed consistent movement along a slip surface at approximately 39 m depth. The was also a small incremental deflection evident on the 12 January, 2001 set of readings at 53 to 54 m which was not evident on later readings. The small deflection could be due to dirt in the casing and is not regarded as a true slope movement since the deflection was not evident in later data sets.

4.2.3.3 S1-4

1. Absolute position: Relative to the top of the casing, the bottom of SI-4 was less than 250 mm uphill (A direction) and was approximately 3700 mm south (B direction).

2. Cumulative deflection: There was clear evidence of translational movement at 51 m with movements of 32 mm in the A direction (downslope to the east) and 4 mm in the B direction (north toward Baker Creek).

3. Incremental deflection: The incremental deflection plot showed the slip surface at 51 m depth. As with most of the other shear surfaces, the thickness appeared to be less than the length of the slope inclinometer probe.

4.2.3.4 S1-5

1. Absolute position: The bottom of SI-5 was approximately 1100 mm downslope (A direction) and 2400 mm north (B direction) of the top of the casing.

2. Cumulative deflection As indicated on the log for BH-5, grouting problems were experienced during installation of the casing. Due to sloughing of the hole, it was not possible to lower the grout pipe below 73 m. It appears that after grouting of the hole, the grout may have drained past the obstruction, resulting in the lower part of the hole being grouted and the upper part of the hole being mostly ungrouted. As a result, the sinusoidal deflections of the casing between approximately 90 m and 38 m are interpreted to be a result of possible slight axial compression of the casing, combined with the casing moving relatively freely in the hole. The maximum deflections of the casing correspond to the approximate dimensions of the annular space around the casing. At a depth of 37 m, translational movement has occurred. It is likely that the total translational movement is greater than not shown, by an amount equal to the total annular space within the hole or approximately 63 mm.

3. Incremental deflection: As indicated above, the casing is likely ungrouted between at least 37 m and approximately 90 m. Incremental deflections reflect this ungrouted nature of the hole. It is possible that additional lateral deflections could become evident overtime within the zone from 38 to 90 m.

4.2.3.5 S1-6

1. Absolute position: Relative to the top of the casing, the bottom of casing SI-6 was approximately 20 000 mm downhill (A direction) and 11 000 mm south (B direction). The casing and increasing curvature with depth with an inclination of approximately 16° near the bottom of the hole.

2. Cumulative deflection: There was a slip surface at approximately 28 m depth in SI-6. There was approximately 34 mm of downslope (to the east) deflection in the downslope in the A direction and 2 mm of deflection toward the north in the B direction. There was also an apparent but gradual systematic shift evident on the plot below 28 m depth. The shift may be caused by small systematic errors in the readings due to some effect relating to the almost "J" shape of the casing installation.

3. Incremental deflection: The slip surface at 28 m was evident on the incremental plots.

4.2.3.6 S1-7

1. Absolute position: Relative to the top of the casing, the bottom of SI-7 was found in approximately 12 500 mm upslope (A direction) and 15 000 mm north (B direction).

2. Cumulative deflection: There were discreet slip surfaces evident at approximately 68 m and 27 m depth in SI-7. The total movement over the period of monitoring was approximately 25 mm downslope (to the east). In the B direction (across slope), the movement at 27 m was 3

mm to the south and the movement at 68 m was 3 mm to the north. Below 68 m depth, there appeared to be an apparent but gradual systematic shift on the plot. The shift may be caused by a minor shift in the readings due to some effect relating to the almost "J" shape of the casing installation.

3. Incremental deflection: The slip surfaces at 68 m and 27 m depth m were evident on the incremental plots.

4.3 BC Gas GPS Hub Monitoring Data

Figure 5 shows the location of the BC Gas GPS Monitoring Hubs and the associated displacement vectors over two periods:

1. From September 1998 to May 2001
2. From December 2000 to May 2001 (this period roughly corresponds to the period AMEC has been monitoring the SI's).

Appendix E contains the BC Gas Monitoring Hub data used to prepare the vector data shown on Figure 5.

5.0 DISCUSSION

5.1 Interpretation of Slope Inclinometer Data

Table 5 provides a summary of SI casing deformations to June 18, 2001.

Table 5: Interpretation of SI Displacements 18 June, 2001

SI	Location	Zone/Depth of displacement	Slip Surfaces	Interpretations
SI-1	Avery Lane	12 to 22 m	42 m	▪ There are small movements of 2 mm at 41 m depth and additional movements of 11 mm at 28 m depth in the A direction. ▪ The depth of the lower movement (41 m) corresponded approximately to the elevation of the shallower movement in SI-2. Given the depth of the slip surface in SI-2, the base of SI-1 could be above a deeper slip surface. ▪ Movement appeared to be within the Tertiary sediments. ▪ There was possible settlement in the casing between 12 and 28 m depth.
SI-2	Avery Lane	Above 60 m	40 and 60 m	▪ There were well-defined thin slip surfaces at 60 and 42 m depth. ▪ Displacements of the ground above the slip surface appeared to be towards the Fraser River. ▪ The movement zones were within Tertiary silt and clay.

Table 5: Interpretation of SI Displacements 18 June, 2001

SI	Location	Zone/Depth of displacement	Slip Surfaces	Interpretations
SI-3	Abbott and Bettcher	Above 39 m	39 m	▪ There was a well-defined slip surface at 39 m depth. ▪ Displacements of the ground above the slip surface appeared to be towards the Fraser River. ▪ The movements on was located a short distance above a gravel seam within Tertiary sand interbedded with clay silt.
SI-4	Voyageur School	Above 51 m	51 m	▪ There was a well-defined slip surface at 51 m depth. ▪ Displacements above the slip surface appeared to be towards the Fraser River. ▪ The shear surface was within soils logged as Tertiary sand.
SI-5	Abbott Drive	Above 93 m	37 m	▪ The casing was undergoing apparent compression movements from 36 to 93 m depth. The casing movements in this area may be a result of grouting problems; in particular, there may be no grout within this part of the hole. ▪ Apparent translational movement was occurring at a depth of approximately 37 m. ▪ The movement direction was east towards the Fraser River. ▪ The depth of movement corresponded to the top of the Tertiary sediments. There may be additional movements deeper in the hole that is not been detected to date.
SI-6	Dixon Street	Above 28 m	28 m	▪ There was a well-defined slip surface at 28 depth. ▪ Movements below 28 m may be a result of the deviation of the casing from vertical and may not represent real movement. ▪ The slip surface was within Tertiary sediments.
SI-7	Lewis and Price	Above 68 m	27 m and 68 m	▪ There were well-defined slip surfaces at 68 and 27 m depth. ▪ Displacements of the lower slip surface at 68 m depth appeared to be toward the Fraser River (east) with a small component towards the north. ▪ Displacements of the upper slip surface at 28 m depth appeared to be toward the Fraser River (east) with a small component towards the south. ▪ The upper slip surface appeared to be near the top of the Tertiary sentiments and the lower slip surface was within the Tertiary sediments.

Note that the displacements shown In Figure 5 for SI-6 and SI-7 are for the displacements of the SI's judged to be not caused by systematic shifts due to the bends in the casing installation.

There is a possibility that at SI-6 and SI-7 SI terminate above the bottom of the slide, given the shifts in the cumulative plots. However, a review of Figure 5 indicates that the corrected movements along the slip surfaces in SI-6 and SI-7 are comparable to the movements observed in the other SI installations. Additionally, it is evident that the base of the SI casing in SI-1 is above the probable slip surface of the slide, given the depth of the slip surface observed in SI-2.

Both of the foregoing factors indicate that most or all of the slide movements have probably been recorded by the slope inclinometer casings.

The velocity plots indicate an increased rate of movement during the spring between the Aril and May readings for all SI installations. This would be expected, as spring is typically the wettest time of year.

5.2 Comparison of Slope inclinometer Data to BC Gas Monitoring Hub Data

On Figure 5 the SI and GPS displacements are plotted as vectors. The SI data has been collected from November 2001 to June 2001 while the GPS data is shown as two vectors, one for all available GPS data from September 1998 to May 2001 and one from December 2000 to May 2001. The latter dates roughly correspond to the period AMEC has been monitoring the SI's.

The azimuths of the displacement for the vectors of the GPS Data from September 1998 to May 2001 appear to correspond to the general trend of the azimuths for AMEC's SI data. When the data is compared over the more recent period from December 2000 to June 2001, some of the GPS data appears to correspond to the SI data while some BC Gas data indicated upslope or side slope movements. Further discussion of the GPS data would require access to the original data sets and calculations.

It is understood that BC Gas currently has contracted a GPS consultant to provide comments on the potential accuracy and errors in the GPS data. At the time of writing this report, BC Gas had not received the report from their GPS consultant. Note that AMEC has also recommended that BC Gas obtain an outside review of their GPS data to confirm is accuracies.

AMEC will provide more comments and a detailed comparison of the GPS data and SI data during future stages of the work once more SI/GPS data has been collected and the accuracies of the GPS data are better understood.

6.0 CONCLUSIONS

The following conclusions can be drawn from the data collected during Stage 1 of the West Quesnel Land Stability Study:

1. The study area is located within a large ancient landslide complex that appeared to be slowly moving at average rates of approximately 25 to 50 mm/year (1 to 2 inches/year) over the period from November 2000 to June 2001.

2. The depths of the slip surface appeared to range from 28 to 68 m below the ground surface.

3. The simplest interpretation of the data is that there is one overall slide complex, rather than a series of smaller slides terminating between the various slope inclinometers. The relatively similar movement directions and magnitudes also favour the "single slide"

interpretation. The similarity of the movement vectors across the slide also indicates a possibility of limited differential movement between various slide blocks, compared to many other large slides.

4. The average inclination of the slide slip surface would be approximately 2° based on Figure 6. This is an extremely low angle, although not unprecedented, and may indicate that appreciable pore water pressures aid ongoing movement.

5. There is a possibility the toe of the slide may extend to the Fraser River in some areas.

6. The sliding may be within a pre-glacial (Tertiary) sediment sequence composed primarily of silt and clay.

Figure 6 shows a cross section of West Quesnel showing the depths of the zones of movement observed within the SI's. The preliminary borehole logs are summarized on the cross section.

In future stages of the West Quesnel Land Stability Study AMEC should investigate:

1. The material properties and nature of the soil within which the slide is moving,

2. The porewater/groundwater conditions in the study area, and

3. The probable lateral extent of the slide, including location of the top scarp, flanks and toe of the slide.

7.0 RECOMMENDATIONS FOR FURTHER WORK (STAGE 2)

Given the ground movements observed during Stage 1, AMEC recommends that Stage 2 of the work proceed. The scope of work for Stage 2 is detailed in AMEC's proposal of 31 May, 2000 to the City of Quesnel and includes:

1. Selection of borehole locations.
2. Drilling of boreholes to collect detailed soil samples.
3. Installation of piezomenters to monitor pore water pressures.
4. Logging the drill holes.
5. Detailed laboratory testing of collected core samples.
6. Continued monitoring of existing SI installations
7. Monitoring pore water pressures through at least 1 spring season

AMEC could start work on Stage 2 in early August, 2001. As part of the work, AMEC also recommends that a digital elevation model be produced for West Quesnel. This model could be used as a base for more accurate mapping, plotting of data, and production of cross sections for slope stability analysis.

8.0 LIMITATIONS

This report has been prepared for the exclusive use of the City of Quesnel and their representatives for specific application to the area within this report. Any use which a third party makes of this report, or any reliance on or decisions made based on it, are the responsibility of such third parties. AMEC accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

This report was prepared in accordance with generally accepted geotechnical engineering principles and practice. No other warranty, expressed or implied, is made.

9.0 CLOSURE

Please do not hesitate to contact the undersigned at (250) 564-3243 should you have any questions or require further information.

Sincerely,

AMEC EARTH & ENVIRONMENTAL LIMITED

Doug Dewar, M.Sc., P.Eng.
Geotechnical Engineer

Nick C. Polysou, P.Eng.
Senior Geotechnical Engineer
Regional Manager, Central BC.

DDE/rm
3904stage1status

Reviewed by:

Drum Cavers, M.Eng., P.Eng., P.Geo.
Principal Engineer
Member, Technical Council

10.0 REFERENCES

10.1 Geotechnical Consultant Reports

AGRA Earth & Environmental Limited, 1998, Postulated large ancient landslides in West Quesnel. Report prepared for the City of Quesnel, 14 p.

AGRA Earth & Environmental Limited (formerly HBT AGRA Limited) 1994. City of Quesnel Slope Stability Study Quesnel, BC. Report prepared for the City of Quesnel, KX01651, 22 p.

C.O. Brawner Engineering Ltd. 2000. Stability – Abbott Heights and Uplands, Quesnel, BC. Report prepared for Singleton Urquhurt, council acting on behalf of BC Gas Utility Ltd., 5p.

GeoNorth Engineering Limited 1998. Soils Investigation at Voyager Elementary School, School District No. 28, Quesnel, BC. Letter prepared for School District 28 (Quesnel), 3p.

Golder Associates Ltd. 2000. Inferred Limit of Ancient Landslide Area, Uplands and Abbott Heights Region, Quesnel, BC. Letter prepared for BC Gas Utility Ltd., 2p.

Golder Associates Ltd. 2000. GPS Monitoring Status Update to Early May 2000, Baker Landslide, Quesnel, BC. Letter prepared for BC Gas Utility Ltd., 3p.

Golder Associates Ltd. 2000. GPS Monitoring Status Update to February 2000, Baker Landslide, Quesnel, BC. Letter prepared for BC Gas Utility Ltd., 3p.

Golder Associates Ltd. 1999. Fall 1999 GPS Monitoring Results, West Quesnel Locations, Quesnel, BC. Letter prepared for BC Gas Utility Ltd., 7p.

Golder Associates 1997. Geotechnical Assessment of Probable Cause Gas Leak at Anderson Road Near Abbott Quesnel, BC. Report prepared for Legal Counsel for BC Gas Utility Ltd., 972-3060, 20 p.

Morgenstern, N.R. and Cruden, D.M. 1999. Evidence for Large Ancient Landslides in West Quesnel. Report submitted to the City of Quesnel, 18p.

R.E. Graham Limited 1993. Potential Landslide Hazard, Quesnel, BC. Letter to the City of Quesnel, J-738, 3 p.

Thurber Engineering Ltd. 1993. Preliminary Geotechnical Evaluation Proposed Subdivision Area, Quesnel. Prepared for R.E. Graham Engineering Limited, 19-162-17, 4 p.

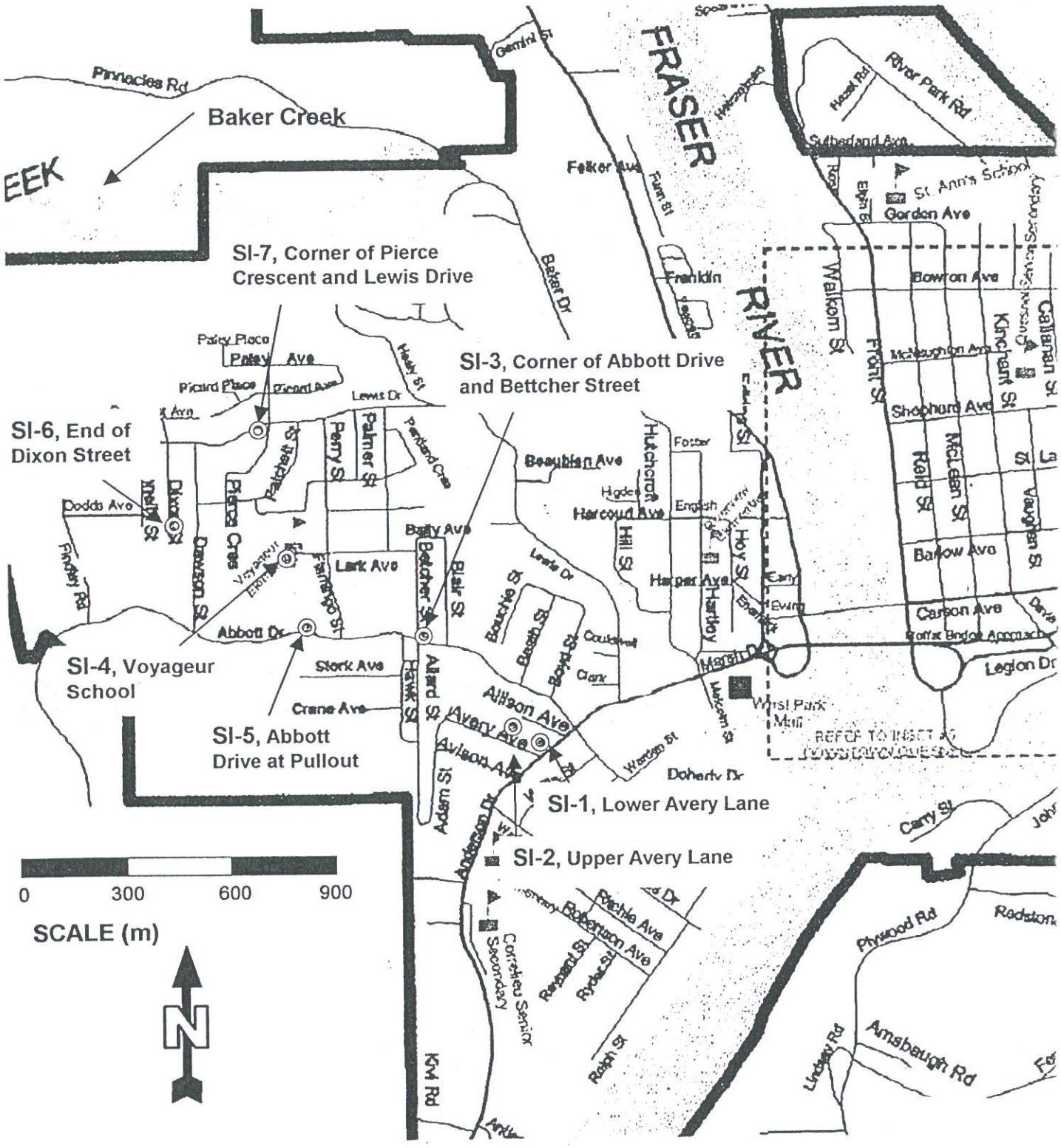
10.2 Geological Background

Claque, J.J. 1988. Quaternary Stratigaraphy and History, Quesnel, BC. Geographie physique et Quaternaire, 42: 279-288.

Eyles, N., and Clague, J.J. 1987, Landsliding caused by Pliestocene glacial lake ponding – an example from central British Columbia, Canadian Geotechnical Journal, 24: 656-663.

Long, D.G.F. and Graham, P.S.W. 1993. Sedimentology and Coal Resources of the early Oligocene Australian Creek Formation, Near Quesnel, British Columbia. Geological Survey of Canada, Paper 92-11, 73 p.

Rouse, G.E. and Mathews, W.H. 1979, Tertiary geology and palynology of Quesnel Area, BC. Bulletin Canadian Petroleum Geology, 27: 418-445.



Appendix A (parti

amec
Earth & Environmental

City of Quesne

West Quesnel Land Stability Study

Quesnel, BC

Figure 1: Slope Inclinometer (SI) Locations

DATE:	SCALE:	DRAWN BY:	PROJECT No: KX03904
Jan. 2001	NTS	HMN	

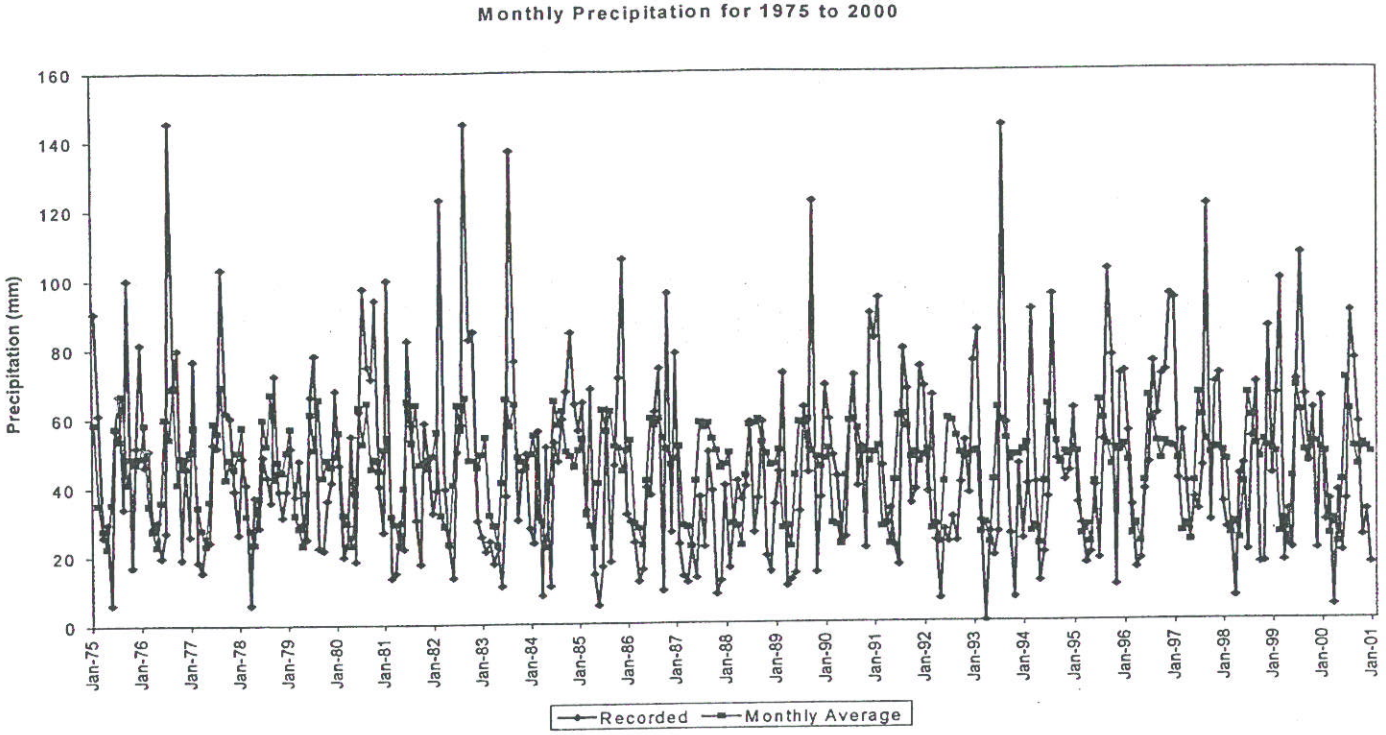


Figure 2

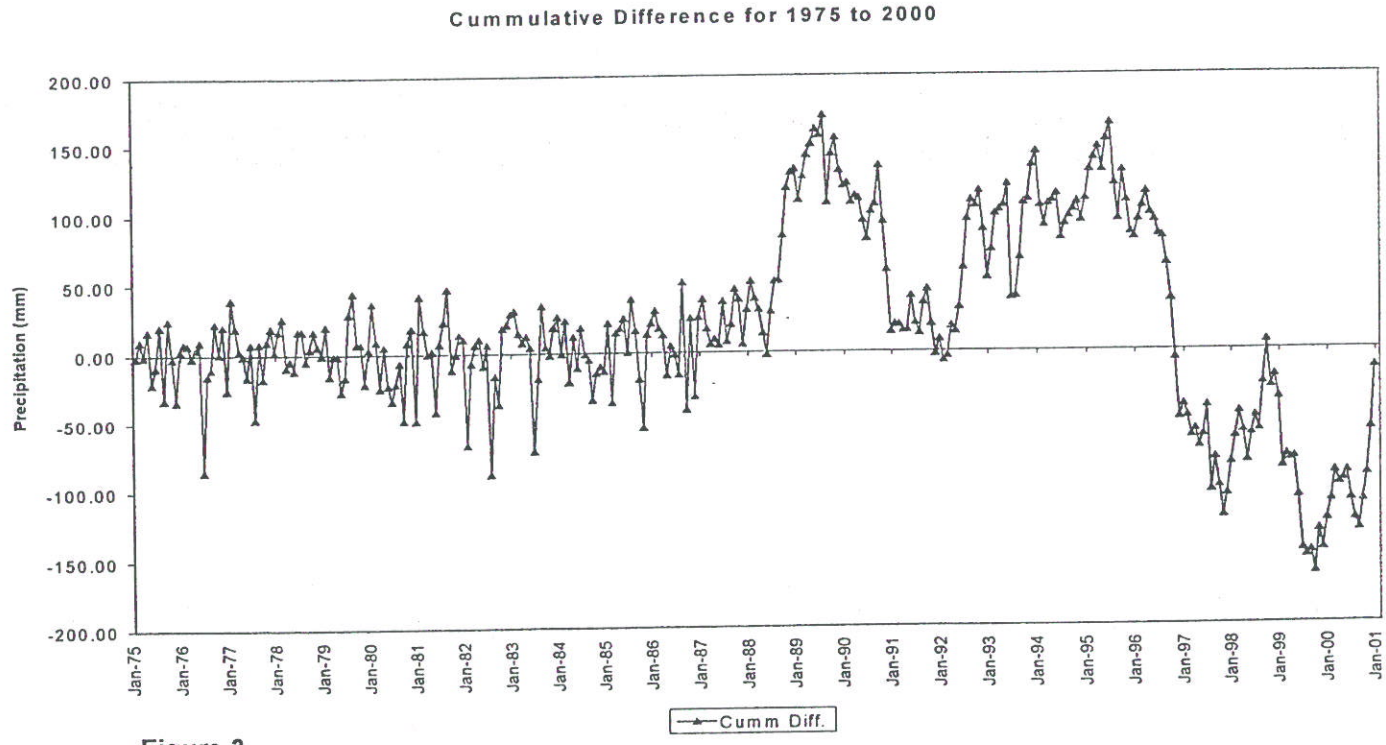
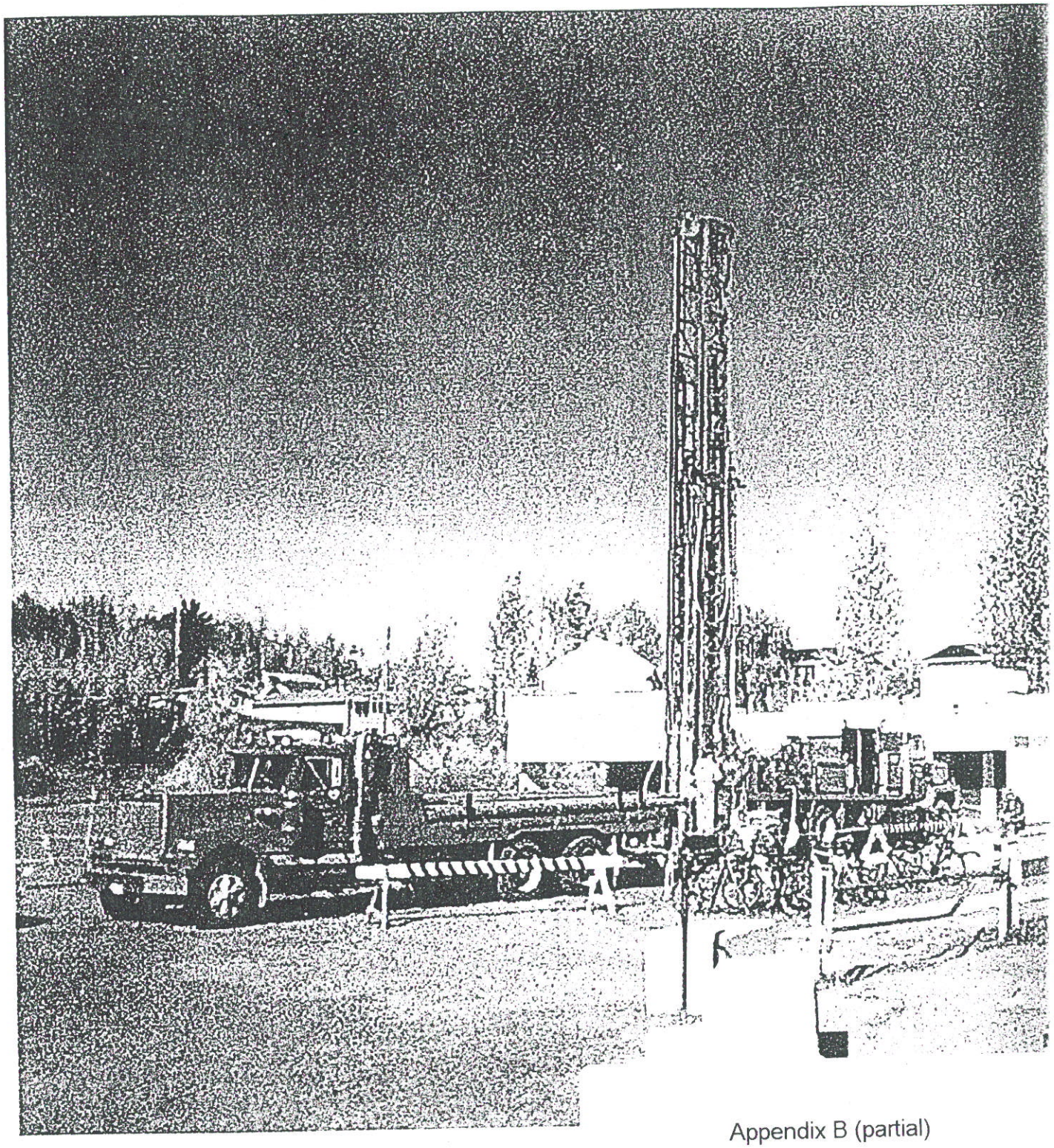


Figure 3

amec Earth & Environmental	City of Quesnel West Quesnel Stability Study Quesnel, BC			
Figure 2 and Figure 3	DATE: July 2001	SCALE: NTS	DRAWN BY: SMJ	PROJECT No: KX03904



Appendix B (partial)

Photo 2: Drilling SI-4 at Voyager School

amec Earth & Environmental

City of Quesnel

West Quesnel Land Stability Study

Quesnel, BC

Photo 2	DATE: Jun. 2001	SCALE: NTS	DRAWN BY: DLD	PROJECT No: KX03904 Taken: October 2000

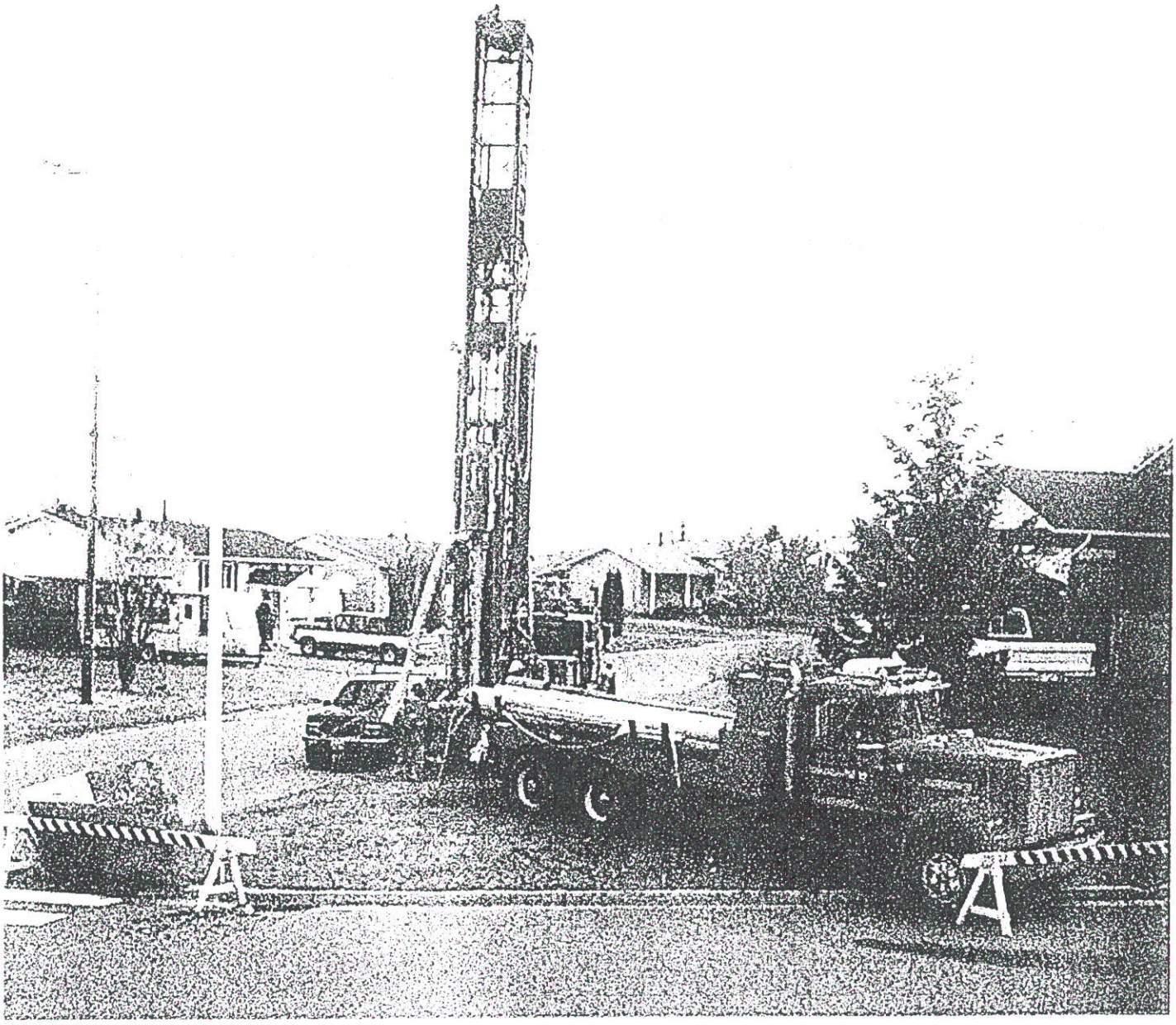


Photo 3: Drilling SI-7 at corner of Lewis Drive and Pierce Cresent

amec
Earth & Environmental

City of Quesnel

West Quesnel Land Stability Study

Quesnel, BC

Photo 3	DATE: Jun. 2001	SCALE: NTS	DRAWN BY: DLD	PROJECT No: KX03904 Taken: October 2000

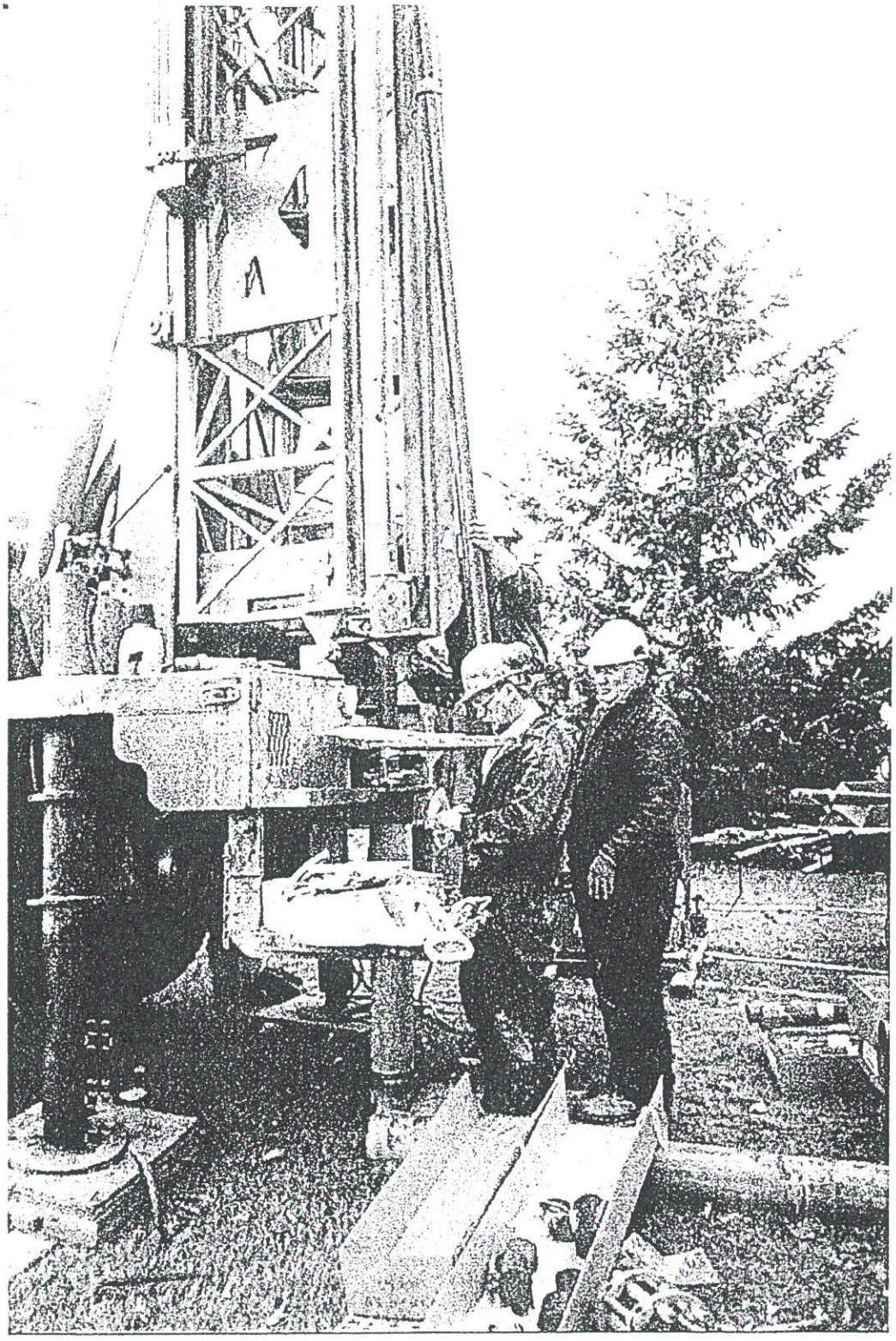


Photo 4: Installing SI Pipe in SI-7 at Lewis Drive and Pierce Crescent

amec Earth & Environmental

City of Quesnel

West Quesnel Land Stability Study

Quesnel, BC

Photo 4	DATE: Jun. 2001	SCALE: NTS	DRAWN BY: DLD	PROJECT No: KX03904 Taken: October 2000

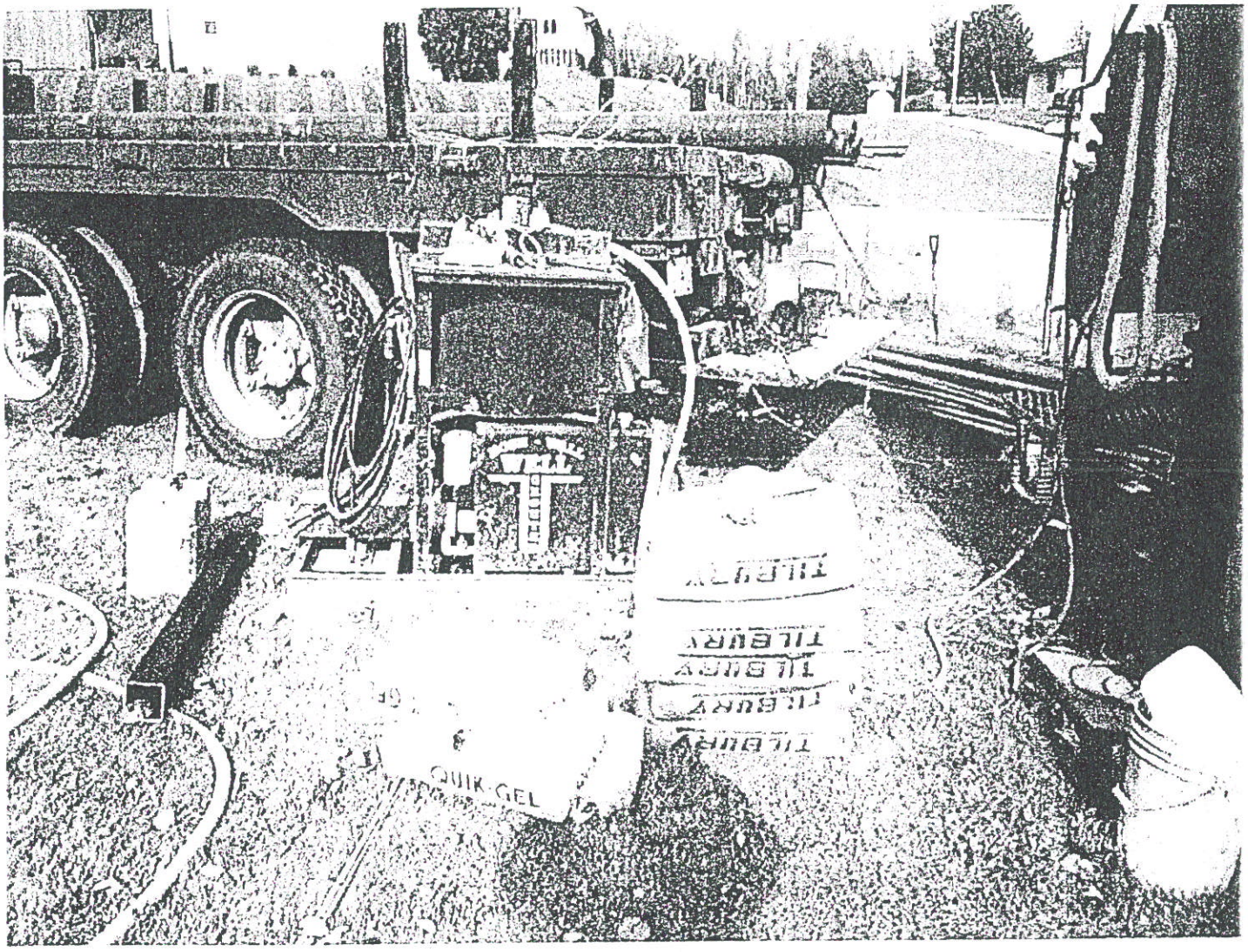


Photo 5: Grout Mixer and supplies taken at SI-7 located at Lewis Drive and Pierce Crescent

amec Earth & Environmental

City of Quesnel

West Quesnel Land Stability Study

Quesnel, BC

Photo 5	DATE: Jun. 2001	SCALE: NTS	DRAWN BY: DLD	PROJECT No: KX03904 Taken: October 2000

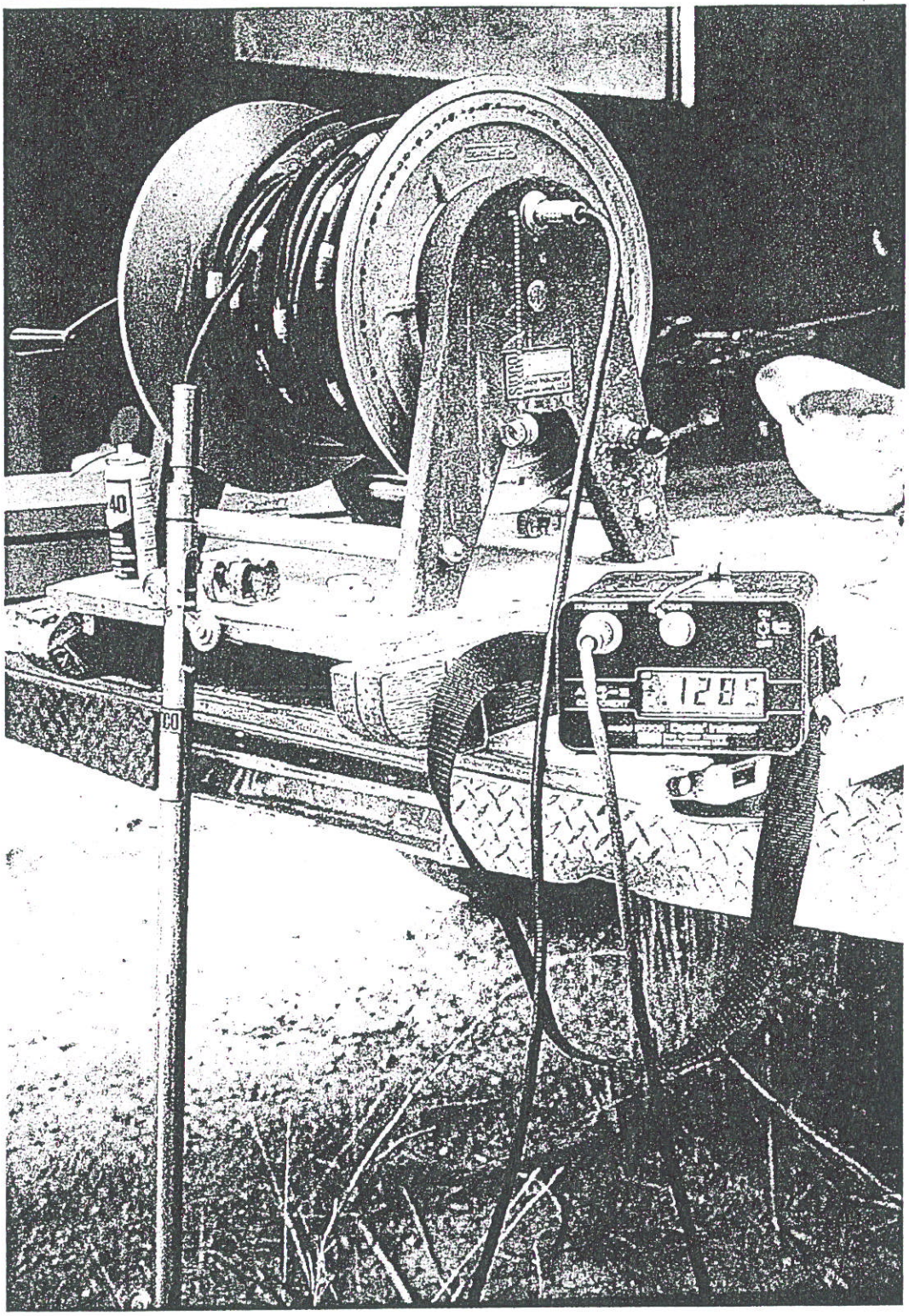


Photo 6: Example of SI probe and datamate reader

amec
Earth & Environmental

City of Quesnel

West Quesnel Land Stability Study

Quesnel, BC

Photo 6	DATE: Jun. 2001	SCALE: NTS	DRAWN BY: DLD	PROJECT No: KX03904
				Taken: Unknown

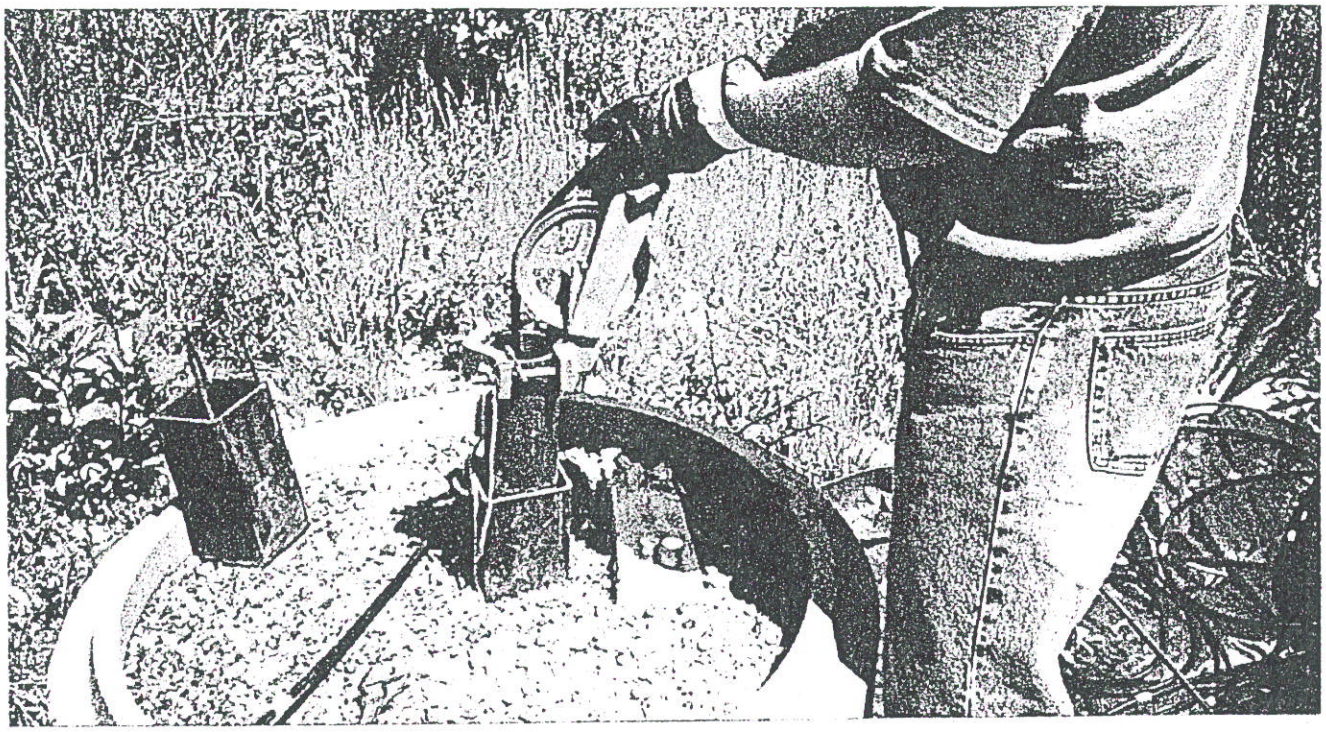


Photo 7: Lowering SI probe down SI pipe at SI-2 location.

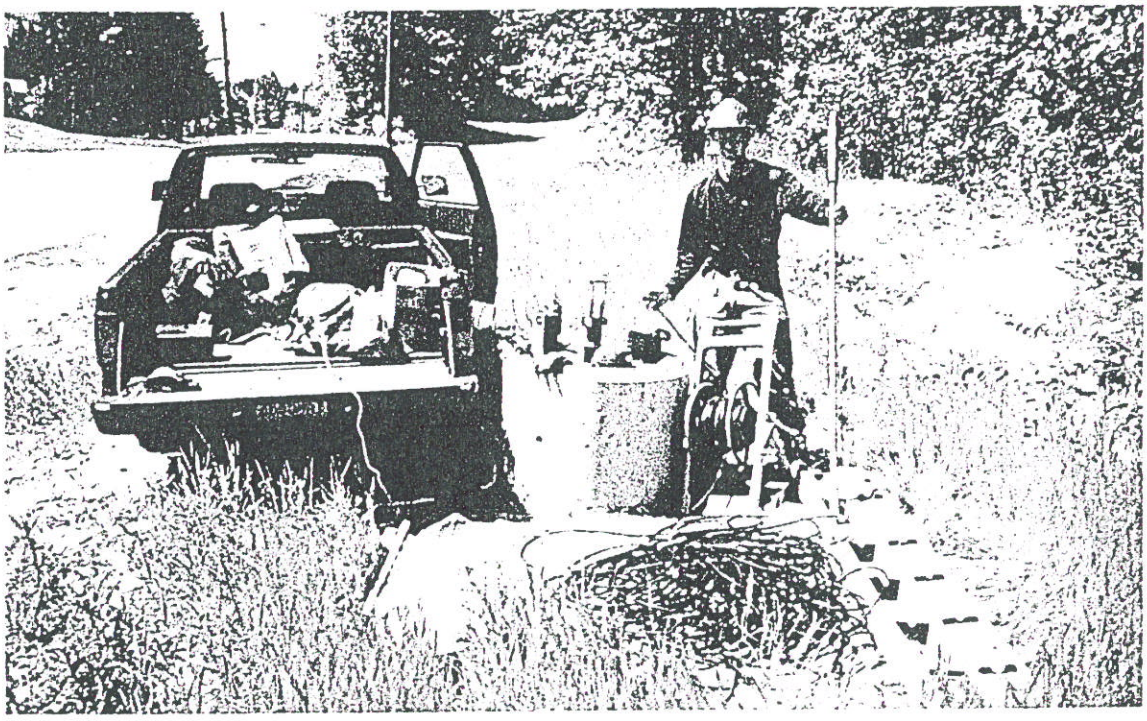


Photo 8: Spiral Probe and 505 foot SI cable ready to be lowered down SI-3 on Abbott Drive

amec Earth & Environmental

City of Quesnel

West Quesnel Land Stability Study

Quesnel, BC

Photo 7 and 8

DATE:	SCALE:	DRAWN BY:	PROJECT No: KX03904
Jun. 2001	NTS	DLD	Taken: June 2001

CLIENT: CITY OF QUESNEL	PROJECT: W.QUESNEL LAND STABILITY STUDY	BOREHOLE NO: BH-1
QUESNEL, B.C.	DRILLING CONTRACTOR: CARIBOO WATER WELLS	PROJECT NO: KX03904
DRILLING TYPE: WATER WELL RIG	DRILLING METHOD: AIR ROTARY	ELEVATION: 480.267 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN

Depth(m)	▲ SPT "N" (BLOWS/300 mm) ▲ 20 40 60 80 PLASTIC M.C. LIQUID 20 40 60 80	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT(N)	ADDITIONAL INFORMATION
0.0			SAND and GRAVEL, trace silt, bedded, brown to grey, damp				
5.0			SILT and CLAY, trace sand, trace gravel, medium to high plastic, bedded, light brown, moist		1		
8.0			SILT and CLAY, trace sand, trace organics (lignite), medium to high plastic, grey to blue, moist to wet, isolated sandy seams (Possible Australian Creek Formation)		2		
17.0			SILT, trace clay, organics (approx. 40% lignite by volume), soft, low plastic, structureless, black, wet		3		
19.0			SILT, trace clay, trace organics, soft, low plastic, structureless, light brown to blue, wet				
25.0					4		
37.0					5		
44.2			End of Borehole at 44.2 m SI installed to 43.6 m SI Ao groove oriented Az = 120 degrees Estimated well production 0 GPM No water observed, dry on completion				
50.0							

Appendix C

AMEC Earth & Environmental Limited

LOGGED BY: DLD | COMPLETION DEPTH: 44.2
REVIEWED BY: NCP | COMPLETE: 10/25/00

Page

01/07/22 12:49PM (HASO)

CLIENT: CITY OF QUESNEL	PROJECT: W.QUESNEL LAND STABILITY STUDY	BOREHOLE NO: BH-2
QUESNEL, B.C.	DRILLING CONTRACTOR: CARIBOO WATER WELLS	PROJECT NO: KX03904
DRILLING TYPE: WATER WELL RIG	DRILLING METHOD: AIR ROTARY	ELEVATION: 485.862 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN

Depth (m)	▲ SPT "N" (BLOWS/300 mm) ▲ 20 40 60 80 PLASTIC M.C. LIQUID 20 40 60 80	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT(N)	ADDITIONAL INFORMATION
0.0 – 3.0			SAND (medium to fine grained), trace silt, loose to compact, brown, damp to dry		1		
3.0 – 7.0			SAND, gravelly, trace silt, bedded, brown, damp to dry Cobbles encountered at 6.7 m				
7.0 – 16.0			SILT and SAND, trace gravel, trace cobbles, very stiff to hard, brown, moist (Till or Colluvium)		2		
16.0 – 21.0			GRAVEL (subrounded to subangular), some silt to silty, some sand, trace clay, brown, wet, NOTE: silt and sand are layered (Possible Australian Creek Formation)		3		
21.0 – 34.0			SILT, clayey, some sand, trace to some gravel, low to medium plastic, blue to brown, wet		4		
			SILT, gravelly to some gravel, some clay, trace sand, low to medium plastic, blue to brown, wet				
			SILT, clayey, some sand, trace to some gravel, low to medium plastic, blue to brown, wet				
34.0 – 35.0			GRAVEL and SAND (coarse grained), trace silt, trace clay, brown, wet		5		
35.0 – 43.0			SILT, clayey, trace to some sand, trace gravel, low plastic, blue to brown, wet		6		
43.0 – 50.0			SILT, clayey, trace gravel, trace sand (fine grained), medium to high plastic, blue to brown, wet, isolated sand or gravel seams or gravelly zones		7		

AMEC Earth & Environmental Limited

LOGGED BY: DLD
REVIEWED BY: NCP

COMPLETION DEPTH: 74.7 m
COMPLETE: 10/24/00

01/07/22 12:49PM (HASO)

CLIENT: CITY OF QUESNEL	PROJECT: W.QUESNEL LAND STABILITY STUDY	BOREHOLE NO: BH-2
QUESNEL, B.C.	DRILLING CONTRACTOR: CARIBOO WATER WELLS	PROJECT NO: KX03904
DRILLING TYPE: WATER WELL RIG	DRILLING METHOD: AIR ROTARY	ELEVATION: 485.862 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN

Depth(m)	▲ SPT "N" (BLOWS/300 mm) ▲ 20 40 60 80 PLASTIC M.C. LIQUID 20 40 60 80	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT(N)	ADDITIONAL INFORMATION
50.0 – 100.0					8		
			End of Borehole at 74.7 m SI casing installed to 74.6 m SI Ao groove oriented at Az = 120 degrees No water observed in hole after 50 hours Estimated well production 0 gpm				

AMEC Earth & Environmental Limited

LOGGED BY: DLD
REVIEWED BY: NCP

COMPLETION DEPTH: 74.7 m
COMPLETE: 10/24/00

01/07/22 12:43PM (HASO)

CLIENT: CITY OF QUESNEL	PROJECT: W.QUESNEL LAND STABILITY STUDY	BOREHOLE NO: BH-3
QUESNEL, B.C.	DRILLING CONTRACTOR: CARIBOO WATER WELLS	PROJECT NO: KX03904
DRILLING TYPE: WATER WELL RIG	DRILLING METHOD: AIR ROTARY	ELEVATION: 503.43 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN

Depth(m)	▲ SPT "N" (BLOWS/300 mm) ▲ 20 40 60 80 PLASTIC M.C. LIQUID 20 40 60 80	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT(N)	ADDITIONAL INFORMATION
0.0			SAND, silty to some silt, trace to some gravel (till or colluvium), structureless in pieces recovered, brown, wet				
1.0							
2.0							
3.0							
4.0							
5.0			Saturated zone encountered between 4.6 to 6.1 m. This zone may be sandier than the soil above and below				
6.0							
7.0							
8.0							
9.0					1		
10.0							
11.0							
12.0							
13.0			SAND, some silt to silty, trace to some gravel, trace clay, bedded with some clayey silt and gravel layers, brown. Rock fragments recovered appeared to be quartz, chert, limestone, basalt and coarse-grained igneous rocks. (Possible Australian Creek Formation)				
14.0					2		
15.0							
16.0							
17.0							
18.0							
19.0							
20.0							
21.0							
22.0							
23.0							
24.0							
25.0							
26.0							
27.0							
28.0							
29.0							
30.0							
31.0							
32.0							
33.0					3		
34.0							
35.0							
36.0							
37.0							
38.0							
39.0							
40.0			Soil colour is blue. Once recovered, samples appeared to oxidize to brown.				
41.0							
42.0							
43.0							
44.0							
45.0			GRAVEL (angular), sandy, some silt, trace clay, bedded, blue matrix which oxidized to brown.		4		
46.0					5		
47.0							
48.0			SILT, some clay, trace to some sand, trace gravel (mainly fine				
49.0							
50.0							

AMEC Earth & Environmental Limited

LOGGED BY: DLD | COMPLETION DEPTH: 109.8 m
REVIEWED BY: NCP | COMPLETE: 10/27/00

01/07/22 12:49PM (HASO)

CLIENT: CITY OF QUESNEL	PROJECT: W.QUESNEL LAND STABILITY STUDY	BOREHOLE NO: BH-3
QUESNEL, B.C.	DRILLING CONTRACTOR: CARIBOO WATER WELLS	PROJECT NO: KX03904
DRILLING TYPE: WATER WELL RIG	DRILLING METHOD: AIR ROTARY	ELEVATION: 503.43 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN

Depth(m)	▲ SPT "N" (BLOWS/300 mm) ▲ 20 40 60 80 PLASTIC M.C. LIQUID 20 40 60 80	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT(N)	ADDITIONAL INFORMATION
50.0 – 57.0			angular igneous fragments), very hard as noted by driller, low to medium plastic, bedded, blue to brown (oxidizes as above)		6		
57.0 – 76.0			SILT, sandy, some to trace gravel, trace clay, low to non plastic, bedded, blue to brown		7		
76.0 – 90.0			SILT, some sand (fine-grained), some gravel (rounded and angular fragments), some silt, trace clay, hard, low to non plastic, bedded, blue to brown (oxidized as above)				
90.0 – 100.0			GRAVEL and SAND (fine-grained or coarse-grained), some silt to silty, bedded, blue to steel grey which oxidized to brown		8		

AMEC Earth & Environmental Limited

LOGGED BY: DLD
REVIEWED BY: NCP

COMPLETION DEPTH: 109.8
COMPLETE: 10/27/00

01/07/22 12:50PM (HASO)

CLIENT: CITY OF QUESNEL	PROJECT: W.QUESNEL LAND STABILITY STUDY	BOREHOLE NO: BH-3
QUESNEL, B.C.	DRILLING CONTRACTOR: CARIBOO WATER WELLS	PROJECT NO: KX03904
DRILLING TYPE: WATER WELL RIG	DRILLING METHOD: AIR ROTARY	ELEVATION: 503.43 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN

Depth(m)	▲ SPT "N" (BLOWS/300 mm) ▲ 20 40 60 80 PLASTIC M.C. LIQUID 20 40 60 80	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT(N)	ADDITIONAL INFORMATION
100.0–150.0			End of Borehole at 109.8 m SI installed to 102.4 m SI Ao groove oriented Az = 120 degrees Estimated well production 0 GPM No water in hole upon completion		9		

AMEC Earth & Environmental Limited

LOGGED BY: DLD
REVIEWED BY: NCP

COMPLETION DEPTH: 109.8 r
COMPLETE: 10/27/00

01/07/22 12:50PM (HASO)

CLIENT: CITY OF QUESNEL	PROJECT: W.QUESNEL LAND STABILITY STUDY	BOREHOLE NO: BH-4
QUESNEL, B.C.	DRILLING CONTRACTOR: CARIBOO WATER WELLS	PROJECT NO: KX03904
DRILLING TYPE: WATER WELL RIG	DRILLING METHOD: AIR ROTARY	ELEVATION: 537.581 m

SAMPLE TYPE ■ TUBE ⊘ NO RECOVERY ⊠ SPLIT SPOON ⊟ GRAB ▯ MUD RETURN ▮ CORE RETURN

Depth(m)	▲ SPT "N" (BLOWS/300 mm) ▲ 20 40 60 80 PLASTIC M.C. LIQUID 20 40 60 80	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT(N)	ADDITIONAL INFORMATION
0.0 – 7.0			Possible FILL, SILT, some sand (fine-grained), trace rootlets/organics, soft, non to low plastic, ocasional thin sand layers, brown, moist to wet		1, 2		
7.0 – 15.0			SILT and SAND (fine-grained), trace gravel (mainly angular fragments), compact, non plastic, structureless, brown, damp to wet		3, 4		
15.0 – 33.0			SILT, some sand to sandy (mainly fine-grained), trace to some clay, trace gravel, non to low plastic, structureless, brown, moist to wet (Possible till or colluvium)		5, 6, 7, 7a, 8		
33.0 – 37.0			GRAVEL, sandy (mainly coarse-grained, trace fine-grained), trace silt (less than 3% estimated)		9, 10		
37.0 – 42.0			SAND (mainly coarse-grained, some fine-grained), gravelly, trace silt, bedded with some gravel layers, brown (Possible Australian Creek Formation)		11		
42.0 – 50.0			SAND (coarse and fine-grained), some gravel, some silt, bedded, brown		12		

AMEC Earth & Environmental Limited

LOGGED BY: DLD
REVIEWED BY: NCP

COMPLETION DEPTH: 158.5 r
COMPLETE: 10/13/00

01/07/22 12:50PM (HA50)

CLIENT: CITY OF QUESNEL	PROJECT: W.QUESNEL LAND STABILITY STUDY	BOREHOLE NO: BH-4
QUESNEL, B.C.	DRILLING CONTRACTOR: CARIBOO WATER WELLS	PROJECT NO: KX03904
DRILLING TYPE: WATER WELL RIG	DRILLING METHOD: AIR ROTARY	ELEVATION: 537.581 m

SAMPLE TYPE ■ TUBE ☒ NO RECOVERY ☒ SPLIT SPOON ☰ GRAB ▯ MUD RETURN ◧ CORE RETURN

Depth(m)	▲ SPT "N" (BLOWS/300 mm) ▲ 20 40 60 80 PLASTIC M.C. LIQUID 20 40 60 80	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT(N)	ADDITIONAL INFORMATION	Depth(ft)
50.0								16
51.0								17
52.0			SAND (mainly fine-grained) and SILT, trace clay, trace gravel, bedded, brown					17
53.0					13			
54.0								18
55.0								
56.0								18
57.0								
58.0					14			19
59.0								
60.0								19
61.0								20
62.0								
63.0								20
64.0								21
65.0								
66.0								21
67.0								22
68.0								
69.0								22
70.0								2
71.0					15			
72.0								2
73.0								
74.0								2
75.0								
76.0								2
77.0								
78.0								2
79.0								
80.0								2
81.0								
82.0					16			2
83.0								
84.0								2
85.0								
86.0								2
87.0								
88.0								2
89.0								
90.0								2
91.0								
92.0								2
93.0								
94.0					17			2
95.0								
96.0								2
97.0								
98.0								2
99.0								
100.0								2

AMEC Earth & Environmental Limited

LOGGED BY: DLD
REVIEWED BY: NCP

COMPLETION DEPTH: 158.5 m
COMPLETE: 10/13/00

01/07/22 12:50PM (HASO)

CLIENT: CITY OF QUESNEL	PROJECT: W.QUESNEL LAND STABILITY STUDY	BOREHOLE NO: BH-4
QUESNEL, B.C.	DRILLING CONTRACTOR: CARIBOO WATER WELLS	PROJECT NO: KX03904
DRILLING TYPE: WATER WELL RIG	DRILLING METHOD: AIR ROTARY	ELEVATION: 537.581 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN

Depth(m)	▲ SPT "N" (BLOWS/300 mm) ▲ 20 40 60 80 PLASTIC M.C. LIQUID 20 40 60 80	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT(N)	ADDITIONAL INFORMATION
100.0							
101.0							
102.0							
103.0							
104.0							
105.0							
106.0							
107.0							
108.0							
109.0							
110.0			SAND (coarse to fine-grained), silty, some gravel, trace to some clay, bedded, brown		18		
111.0							
112.0							
113.0							
114.0							
115.0							
116.0							
117.0							
118.0							
119.0					19		
120.0							
121.0							
122.0							
123.0							
124.0							
125.0					20		
126.0							
127.0			Layered siltstone (mudstone), sandstone conglomerate and coarse angular sand and fine gravel layers, light brown to reddish brown		21		
128.0							
129.0							
130.0					22		
131.0			Hole cased to 128 m due to gravel layer				
132.0			SAND (fine to coarse-grained), some silt, some to trace gravel, bedded, brown				
133.0							
134.0			Layered siltstone, sandstone and conglomerate, light grey to brown/black. There may be some non-lithofied coarse-grained sand/gravel layers				
135.0					23		
136.0							
137.0							
138.0							
139.0							
140.0							
141.0							
142.0							
143.0							
144.0					24		
145.0							
146.0							
147.0							
148.0							
149.0							
150.0					25		

AMEC Earth & Environmental Limited

LOGGED BY: DLD
REVIEWED BY: NCP

COMPLETION DEPTH: 158.5
COMPLETE: 10/13/00

01/07/22 12:50PM (HASO)

CLIENT: CITY OF QUESNEL	PROJECT: W.QUESNEL LAND STABILITY STUDY	BOREHOLE NO: BH-4
QUESNEL, B.C.	DRILLING CONTRACTOR: CARIBOO WATER WELLS	PROJECT NO: KX03904
DRILLING TYPE: WATER WELL RIG	DRILLING METHOD: AIR ROTARY	ELEVATION: 537.581 m

SAMPLE TYPE ■ TUBE ▨ NO RECOVERY ▩ SPLIT SPOON ▤ GRAB ▥ MUD RETURN ▧ CORE RETURN

Depth (m)	▲ SPT "N" (BLOWS/300 mm) ▲ 20 40 60 80 PLASTIC M.C. LIQUID 20 40 60 80	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT(N)	ADDITIONAL INFORMATION
150.0							
151.0							
152.0							
153.0							
154.0							
155.0							
156.0							
157.0							
158.0			End of Borehole at 158.5 m SI installed to 158 m SI Ao groove oriented at Az = 110 degrees Static water level at 97.6 m 18 hrs after completion of borehole Estimated well production 2 to 3 GPM				
159.0							
160.0							
161.0							
162.0							
163.0							
164.0							
165.0							
166.0							
167.0							
168.0							
169.0							
170.0							
171.0							
172.0							
173.0							
174.0							
175.0							
176.0							
177.0							
178.0							
179.0							
180.0							
181.0							
182.0							
183.0							
184.0							
185.0							
186.0							
187.0							
188.0							
189.0							
190.0							
191.0							
192.0							
193.0							
194.0							
195.0							
196.0							
197.0							
198.0							
199.0							
200.0							

AMEC Earth & Environmental Limited

LOGGED BY: DLD
REVIEWED BY: NCP

COMPLETION DEPTH: 158.5 m
COMPLETE: 10/13/00

01/07/22 12:50PM (HA50)

CLIENT: CITY OF QUESNEL	PROJECT: W.QUESNEL LAND STABILITY STUDY	BOREHOLE NO: BH-5
QUESNEL, B.C.	DRILLING CONTRACTOR: CARIBOO WATER WELLS	PROJECT NO: KX03904
DRILLING TYPE: WATER WELL RIG	DRILLING METHOD: AIR ROTARY	ELEVATION: 517.723 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN

Depth(m)	▲ SPT "N" (BLOWS/300 mm) ▲ 20 40 60 80 PLASTIC M.C. LIQUID 20 40 60 80	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT(N)	ADDITIONAL INFORMATION
0.0			Possible FILL, SAND, some gravel, trace silt, compact to loose, brown, damp				
1.0							
2.0			SAND and SILT, some to trace clay, trace gravel (till or colluvium), low plastic, brown, damp to moist				
3.0							
4.0							
5.0							
6.0			SAND, some silt, no rock fragments or gravel observed, brown, wet				
7.0							
8.0							
9.0							
10.0							
11.0			SAND and SILT, some to trace clay, trace gravel, low plastic, brown, damp to wet (possible till or colluvium)				
12.0							
13.0							
14.0							
15.0							
16.0							
17.0							
18.0							
19.0							
20.0							
21.0							
22.0							
23.0							
24.0							
25.0							
26.0							
27.0							
28.0							
29.0							
30.0							
31.0							
32.0							
33.0							
34.0							
35.0			SILT, some clay, trace sand, trace gravel, bedded with some sandy and gravelly layers, medium to low plastic, hard/partially lithified, steel grey to green (Possible Australian Creek Formation)		1		
36.0							
37.0							
38.0							
39.0							
40.0							
41.0							
42.0							
43.0							
44.0							
45.0					2		
46.0							
47.0							
48.0							
49.0							
50.0							

AMEC Earth & Environmental Limited

LOGGED BY: DLD
REVIEWED BY: NCP

COMPLETION DEPTH: 152.4 r
COMPLETE: 10/05/00

01/07/22 12:56PM (HASO)

CLIENT: CITY OF QUESNEL	PROJECT: W.QUESNEL LAND STABILITY STUDY	BOREHOLE NO: BH-5
QUESNEL, B.C.	DRILLING CONTRACTOR: CARIBOO WATER WELLS	PROJECT NO: KX03904
DRILLING TYPE: WATER WELL RIG	DRILLING METHOD: AIR ROTARY	ELEVATION: 517.723 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN

Depth(m)	▲ SPT "N" (BLOWS/300 mm) ▲ 20 40 60 80 PLASTIC M.C. LIQUID 20 40 60 80	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT(N)	ADDITIONAL INFORMATION
50.0							
51.0							
52.0							
53.0							
54.0							
55.0							
56.0					3		
57.0							
58.0			1.5 m thick white soil layer, no changes in composition				
59.0							
60.0							
61.0							
62.0							
63.0			1.5 m thick light grey soil layer, no change in composition		4		
64.0							
65.0							
66.0							
67.0					5		
68.0							
69.0							
70.0							
71.0							
72.0							
73.0			SILT, some clay, some sand, some gravel, low plastic, bedded, brown to blue		6		
74.0							
75.0							
76.0							
77.0							
78.0							
79.0							
80.0							
81.0							
82.0					7		
83.0			SILT, some sand, some clay, trace gravel, bedded with sandy and gravelly layers, low to non plastic, hard/partially lithified, steel, steel grey to green				
84.0							
85.0							
86.0							
87.0			SAND (medium to coarse with less fine-grained), trace silt, trace to some gravel (fine-grained), very dense/partially lithified, brown to blue				
88.0					8		
89.0							
90.0							
91.0							
92.0					9		
93.0							
94.0							
95.0							
96.0							
97.0							
98.0							
99.0							
100.0							

AMEC Earth & Environmental Limited

LOGGED BY: DLD
REVIEWED BY: NCP

COMPLETION DEPTH: 152.4
COMPLETE: 10/05/00

01/07/22 12:50PM (HASO)

CLIENT: CITY OF QUESNEL	PROJECT: W.QUESNEL LAND STABILITY STUDY	BOREHOLE NO: BH-5
QUESNEL, B.C.	DRILLING CONTRACTOR: CARIBOO WATER WELLS	PROJECT NO: KX03904
DRILLING TYPE: WATER WELL RIG	DRILLING METHOD: AIR ROTARY	ELEVATION: 517.723 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN

Depth(m) | ▲ SPT "N" (BLOWS/300 mm) ▲ 20 40 60 80 | PLASTIC M.C. LIQUID 20 40 60 80 | SOIL SYMBOL

SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT(N)	ADDITIONAL INFORMATION
Hole was left open for 15 hours, no static water observed when drilling recommenced		10		
		11		Wash Sieve Analysis: 16% Gravel 72% Sand 12% Silt or Clay
		12		
		13		
Possible water table encountered, some water flowing into hole		14		
		15		
		16		
Water producing seam encountered, estimated production 5 GPM		17		

100.0 101.0 102.0 103.0 104.0 105.0 106.0 107.0 108.0 109.0 110.0 111.0 112.0 113.0 114.0 115.0 116.0 117.0 118.0 119.0 120.0 121.0 122.0 123.0 124.0 125.0 126.0 127.0 128.0 129.0 130.0 131.0 132.0 133.0 134.0 135.0 136.0 137.0 138.0 139.0 140.0 141.0 142.0 143.0 144.0 145.0 146.0 147.0 148.0 149.0 150.0

AMEC Earth & Environmental Limited

LOGGED BY: DLD | COMPLETION DEPTH: 152.4
REVIEWED BY: NCP | COMPLETE: 10/05/00

01/07/22 12:50PM (HAS0)

CLIENT: CITY OF QUESNEL	PROJECT: W.QUESNEL LAND STABILITY STUDY	BOREHOLE NO: BH-5
QUESNEL, B.C.	DRILLING CONTRACTOR: CARIBOO WATER WELLS	PROJECT NO: KX03904
DRILLING TYPE: WATER WELL RIG	DRILLING METHOD: AIR ROTARY	ELEVATION: 517.723 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN

Depth(m)	▲ SPT "N" (BLOWS/300 mm) ▲ 20 40 60 80 PLASTIC M.C. LIQUID 20 40 60 80	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT(N)	ADDITIONAL INFORMATION
150.0					18		
151.0							
152.0			End of borehole at 152.4 m SI casing installed to 144.8 m due to cuttings at base of hole SI Ao groove aligned at Az = 110 degrees Static water level not measured Estimated well production 5 GPM Tremie pipe was only lowered to 73.2 m during grouting due to an obstruction at this depth				
153.0							
154.0							
155.0							
156.0							
157.0							
158.0							
159.0							
160.0							
161.0							
162.0							
163.0							
164.0							
165.0							
166.0							
167.0							
168.0							
169.0							
170.0							
171.0							
172.0							
173.0							
174.0							
175.0							
176.0							
177.0							
178.0							
179.0							
180.0							
181.0							
182.0							
183.0							
184.0							
185.0							
186.0							
187.0							
188.0							
189.0							
190.0							
191.0							
192.0							
193.0							
194.0							
195.0							
196.0							
197.0							
198.0							
199.0							
200.0							

AMEC Earth & Environmental Limited

LOGGED BY: DLD | COMPLETION DEPTH: 152.4 m
REVIEWED BY: NCP | COMPLETE: 10/05/00

01/07/22 12:50PM (HASO)

CLIENT: CITY OF QUESNEL	PROJECT: W.QUESNEL LAND STABILITY STUDY	BOREHOLE NO: BH-6
QUESNEL, B.C.	DRILLING CONTRACTOR: CARIBOO WATER WELL	PROJECT NO: KX03904
DRILLING TYPE: WATER WELL RIG	DRILLING METHOD: AIR ROTARY	ELEVATION: 557.723 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN

Depth(m)	▲ SPT "N" (BLOWS/300 mm) ▲ 20 40 60 80 PLASTIC M.C. LIQUID 20 40 60 80	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT(N)	ADDITIONAL INFORMATION
0.0			SILT and SAND, trace gravel, trace clay, very stiff, low plastic, moist ot wet (Possible till or colluvium)				
20.0			SILT, some sand, trace to some clay, trace gravel, low to non plastic, steel grey to blue (Possible Australian Creek Formation)		1		
					2		
			SILT, clayey, trace sand, medium to high plastic, blue to steel grey oxidizing to light brown		3		
					4		
36.0			SAND (coarse-grained) and GRAVEL (fine-grained, angular to sub-angular fragments), some silt to silty, trace clay, olive green Some seams of fine sand and silt were evident in cuttings				
45.0			Brown silty layers encountered		5		
46.0			Soil colour changed to rust, heavy oxidation evident		6		
50.0					7		

AMEC Earth & Environmental Limited

LOGGED BY: DLD | COMPLETION DEPTH: 154 m
REVIEWED BY: NCP | COMPLETE: 10/16/00

01/07/22 12:51PM (HASO)

CLIENT: CITY OF QUESNEL	PROJECT: W.QUESNEL LAND STABILITY STUDY	BOREHOLE NO: BH-6
QUESNEL, B.C.	DRILLING CONTRACTOR: CARIBOO WATER WELL	PROJECT NO: KX03904
DRILLING TYPE: WATER WELL RIG	DRILLING METHOD: AIR ROTARY	ELEVATION: 557.723 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN

Depth(m)	▲ SPT "N" (BLOWS/300 mm) ▲ 20 40 60 80 PLASTIC M.C. LIQUID 20 40 60 80	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT(N)	ADDITIONAL INFORMATION
50.0			POSSIBLE BEDROCK Cuttings appeared to be from bedded white sandstone with some less indurated gravelly or sandy layers. Cuttings were angular and sand sized, rounded fragments not recovered				
51.0							
52.0							
53.0							
54.0							
55.0							
56.0							
57.0							
58.0							
59.0							
60.0							
61.0							
62.0							
63.0							
64.0					8		
65.0							
66.0							
67.0							
68.0							
69.0							
70.0					9		
71.0							
72.0							
73.0							
74.0							
75.0							
76.0							
77.0							
78.0							
79.0							
80.0			Possible water bearing seam				
81.0							
82.0					10		
83.0							
84.0							
85.0							
86.0							
87.0							
88.0							
89.0							
90.0							
91.0							
92.0							
93.0							
94.0							
95.0					11		
96.0			POSSIBLE BEDROCK Cuttings appear to be light grey to dark grey siltstone/sandstone with some less indurated layers. Cuttings were angular and coarse sand sized.				
97.0							
98.0							
99.0							
100.0							

AMEC Earth & Environmental Limited

LOGGED BY: DLD | COMPLETION DEPTH: 154 m
REVIEWED BY: NCP | COMPLETE: 10/16/00

01/07/22 12:51PM (H:50)

CLIENT: CITY OF QUESNEL	PROJECT: W.QUESNEL LAND STABILITY STUDY	BOREHOLE NO: BH-6
QUESNEL, B.C.	DRILLING CONTRACTOR: CARIBOO WATER WELL	PROJECT NO: KX03904
DRILLING TYPE: WATER WELL RIG	DRILLING METHOD: AIR ROTARY	ELEVATION: 557.723 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN

Depth(m) | ▲ SPT "N" (BLOWS/300 mm) ▲ 20 40 60 80 | PLASTIC M.C. LIQUID 20 40 60 80 | SOIL SYMBOL | SOIL DESCRIPTION | SAMPLE TYPE | SAMPLE NO | SPT(N) | ADDITIONAL INFORMATION

100.0 101.0 102.0 103.0 104.0 105.0 106.0 107.0 108.0 109.0 110.0 111.0 112.0 113.0 114.0 115.0 116.0 117.0 118.0 119.0 120.0 121.0 122.0 123.0 124.0 125.0 126.0 127.0 128.0 129.0 130.0 131.0 132.0 133.0 134.0 135.0 136.0 137.0 138.0 139.0 140.0 141.0 142.0 143.0 144.0 145.0 146.0 147.0 148.0 149.0 150.0

Cuttings changed to white for approximately 1 m then soil was grey again

12

13

14

POSSIBLE BEDROCK
Cuttings appeared to be volcanics with some quartz and minor sedimentary rock composition. Cuttings were typically dark grey with some quartz and sandstone fragments

15

16

AMEC Earth & Environmental Limited	LOGGED BY: DLD	COMPLETION DEPTH: 154 m
	REVIEWED BY: NCP	COMPLETE: 10/16/00
		Page

01/07/22 12:51PM (H=50)

CLIENT: CITY OF QUESNEL	PROJECT: W.QUESNEL LAND STABILITY STUDY	BOREHOLE NO: BH-7
QUESNEL, B.C.	DRILLING CONTRACTOR: CARIBOO WATER WELLS	PROJECT NO: KX03904
DRILLING TYPE: WATER WELL RIG	DRILLING METHOD: AIR ROTARY	ELEVATION: 542.217 m

SAMPLE TYPE ■ TUBE ⊘ NO RECOVERY ⊠ SPLIT SPOON ▤ GRAB ▥ MUD RETURN ◧ CORE RETURN

Depth(m)	▲ SPT "N" (BLOWS/300 mm) ▲ 20 40 60 80 PLASTIC M.C. LIQUID 20 40 60 80	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT(N)	ADDITIONAL INFORMATION
0.0			SILT, trace to some sand (fine-grained), trace clay, low to medium plastic, structureless, brown, wet		1		
5.0			SILT and CLAY, trace sand (fine-grained), medium to low plastic, weakly bedded, light to tan brown, moist to wet (Possible glaciolacustrine deposits) Soil was dark brown		2		
10.0			Soil was blue/steel grey Soil was damp to moist		3		
15.0			Soil was brown Soil was blue				
20.0			Soil had alternating brown/blue layers		4		
25.0			Trace coarse sand observed				
30.0			SILT, some clay, trace sand, trace gravel (less than 2%), low yo high plastic, structureless in pieces recovered, blue/steel grey (Possible Australian Creek Formation)		5		
					6		
40.0					7		
45.0			Silt and clay with no sand or gravel from 45.7 m to 47.3 m				
50.0							

AMEC Earth & Environmental Limited

LOGGED BY: DLD
REVIEWED BY: NCP

COMPLETION DEPTH: 128 m
COMPLETE: 10/19/00

01/07/22 12:49PM (H:50)

CLIENT: CITY OF QUESNEL	PROJECT: W.QUESNEL LAND STABILITY STUDY	BOREHOLE NO: BH-7
QUESNEL, B.C.	DRILLING CONTRACTOR: CARIBOO WATER WELLS	PROJECT NO: KX03904
DRILLING TYPE: WATER WELL RIG	DRILLING METHOD: AIR ROTARY	ELEVATION: 542.217 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN

Depth(m)	▲ SPT "N" (BLOWS/300 mm) ▲ 20 40 60 80 PLASTIC M.C. LIQUID 20 40 60 80	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT(N)	ADDITIONAL INFORMATION
50.0							
51.0							
52.0							
53.0					8		
54.0							
55.0							
56.0							
57.0							
58.0							
59.0							
60.0							
61.0							
62.0							
63.0							
64.0							
65.0							
66.0							
67.0							
68.0							
69.0							
70.0							
71.0							
72.0							
73.0							
74.0							
75.0							
76.0							
77.0							
78.0							
79.0							
80.0							
81.0							
82.0							
83.0							
84.0							
85.0							
86.0							
87.0							
88.0							
89.0							
90.0							
91.0			SAND, some silt, trace gravel, trace clay, appeared weakly layered, blue/steel grey				
92.0							
93.0					9		
94.0							
95.0							
96.0							
97.0							
98.0							
99.0							
100.0							

AMEC Earth & Environmental Limited

LOGGED BY: DLD
REVIEWED BY: NCP

COMPLETION DEPTH: 128 m
COMPLETE: 10/19/00

01/07/22 12:49PM (HASO)

CLIENT: CITY OF QUESNEL	PROJECT: W.QUESNEL LAND STABILITY STUDY	BOREHOLE NO: BH-7
QUESNEL, B.C.	DRILLING CONTRACTOR: CARIBOO WATER WELLS	PROJECT NO: KX03904
DRILLING TYPE: WATER WELL RIG	DRILLING METHOD: AIR ROTARY	ELEVATION: 542.217 m

SAMPLE TYPE ■ TUBE ☒ NO RECOVERY ☒ SPLIT SPOON ☰ GRAB ▯ MUD RETURN ▮ CORE RETURN

Depth(m)	▲ SPT "N" (BLOWS/300 mm) ▲ 20 40 60 80 PLASTIC M.C. LIQUID 20 40 60 80	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT(N)	ADDITIONAL INFORMATION
100.0							
101.0							
102.0							
103.0							
104.0							
105.0							
106.0							
107.0							
108.0							
109.0							
110.0					10		
111.0							
112.0							
113.0							
114.0							
115.0							
116.0							
117.0							
118.0							
119.0			Casing refusal on boulder or rock				
120.0							
121.0							
122.0							
123.0							
124.0							
125.0					11		
126.0							
127.0							
128.0			End of borehole at 128 m				
129.0			SI installed to 125.6 m				
130.0			Ao groove oriented at Az = 100 degrees				
131.0			Borehole dry on completion				
132.0			Estimated well production of 0 GPM				
133.0							
134.0							
135.0							
136.0							
137.0							
138.0							
139.0							
140.0							
141.0							
142.0							
143.0							
144.0							
145.0							
146.0							
147.0							
148.0							
149.0							
150.0							

AMEC Earth & Environmental Limited

LOGGED BY: DLD
REVIEWED BY: NCP

COMPLETION DEPTH: 128 m
COMPLETE: 10/19/00

01/07/22 12:49PM (HASO)

CLIENT: CITY OF QUESNEL	PROJECT: W.QUESNEL LAND STABILITY STUDY	BOREHOLE NO: BH-6
QUESNEL, B.C.	DRILLING CONTRACTOR: CARIBOO WATER WELL	PROJECT NO: KX03904
DRILLING TYPE: WATER WELL RIG	DRILLING METHOD: AIR ROTARY	ELEVATION: 557.723 m

SAMPLE TYPE: TUBE | NO RECOVERY | SPLIT SPOON | GRAB | MUD RETURN | CORE RETURN

Depth(m) | ▲ SPT "N" (BLOWS/300 mm) ▲ 20 40 60 80 | PLASTIC M.C. LIQUID 20 40 60 80 | SOIL SYMBOL | SOIL DESCRIPTION | SAMPLE TYPE | SAMPLE NO | SPT(N) | ADDITIONAL INFORMATION

150.0
151.0
152.0
153.0
154.0
155.0
156.0
157.0
158.0
159.0
160.0
161.0
162.0
163.0
164.0
165.0
166.0
167.0
168.0
169.0
170.0
171.0
172.0
173.0
174.0
175.0
176.0
177.0
178.0
179.0
180.0
181.0
182.0
183.0
184.0
185.0
186.0
187.0
188.0
189.0
190.0
191.0
192.0
193.0
194.0
195.0
196.0
197.0
198.0
199.0
200.0

End of borehole at 154.5 m
SI installed to 154.5 m
SI Ao groove oriented at Az = 105 degrees
Static water level at 38.1 m upon completion
Estimated well production 5 to 7 GPM

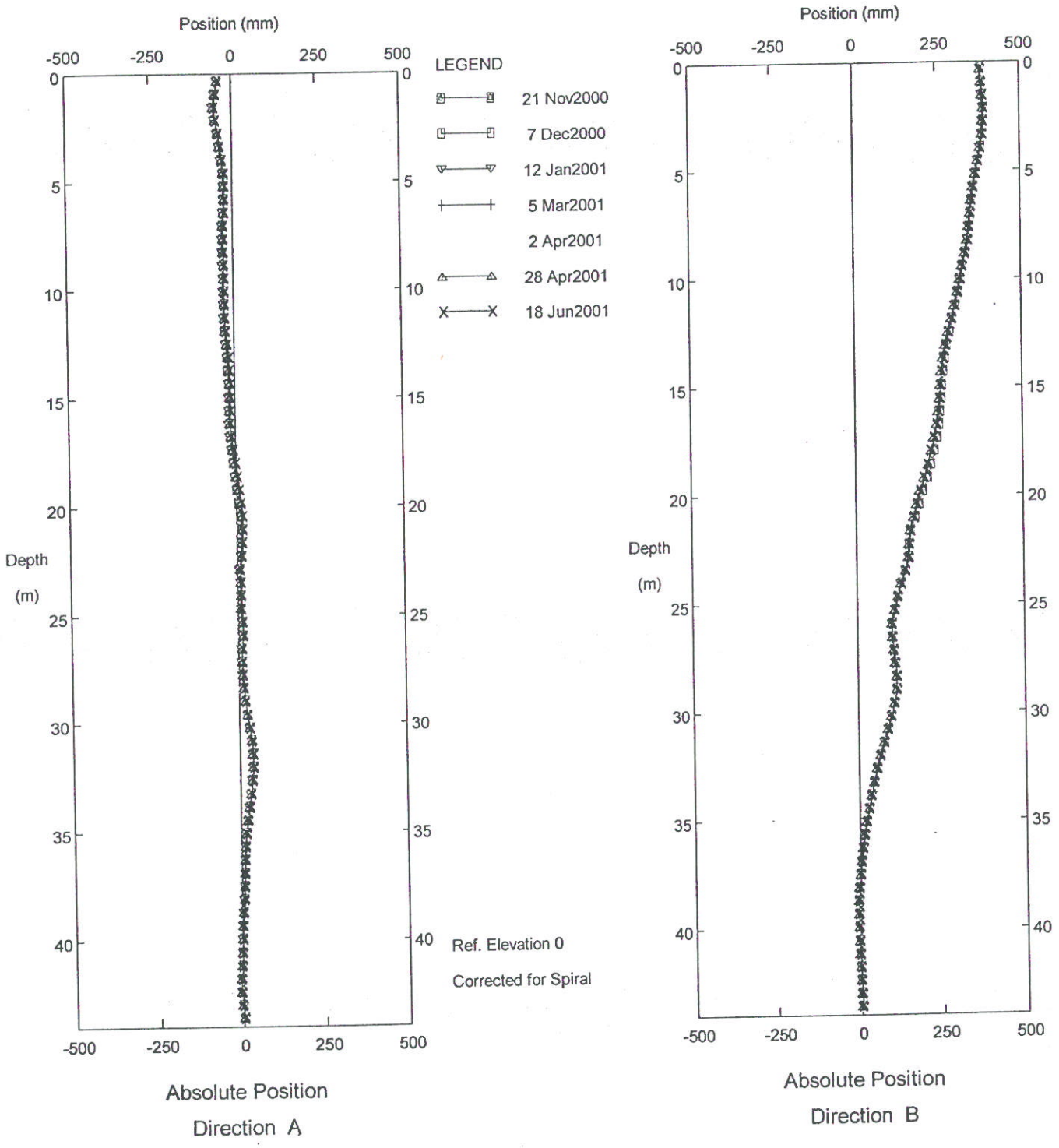
AMEC Earth & Environmental Limited

LOGGED BY: DLD
REVIEWED BY: NCP

COMPLETION DEPTH: 154 m
COMPLETE: 10/16/00

01/07/22 12:51PM (HASO)

AMEC Earth and Environmental - Pr. George

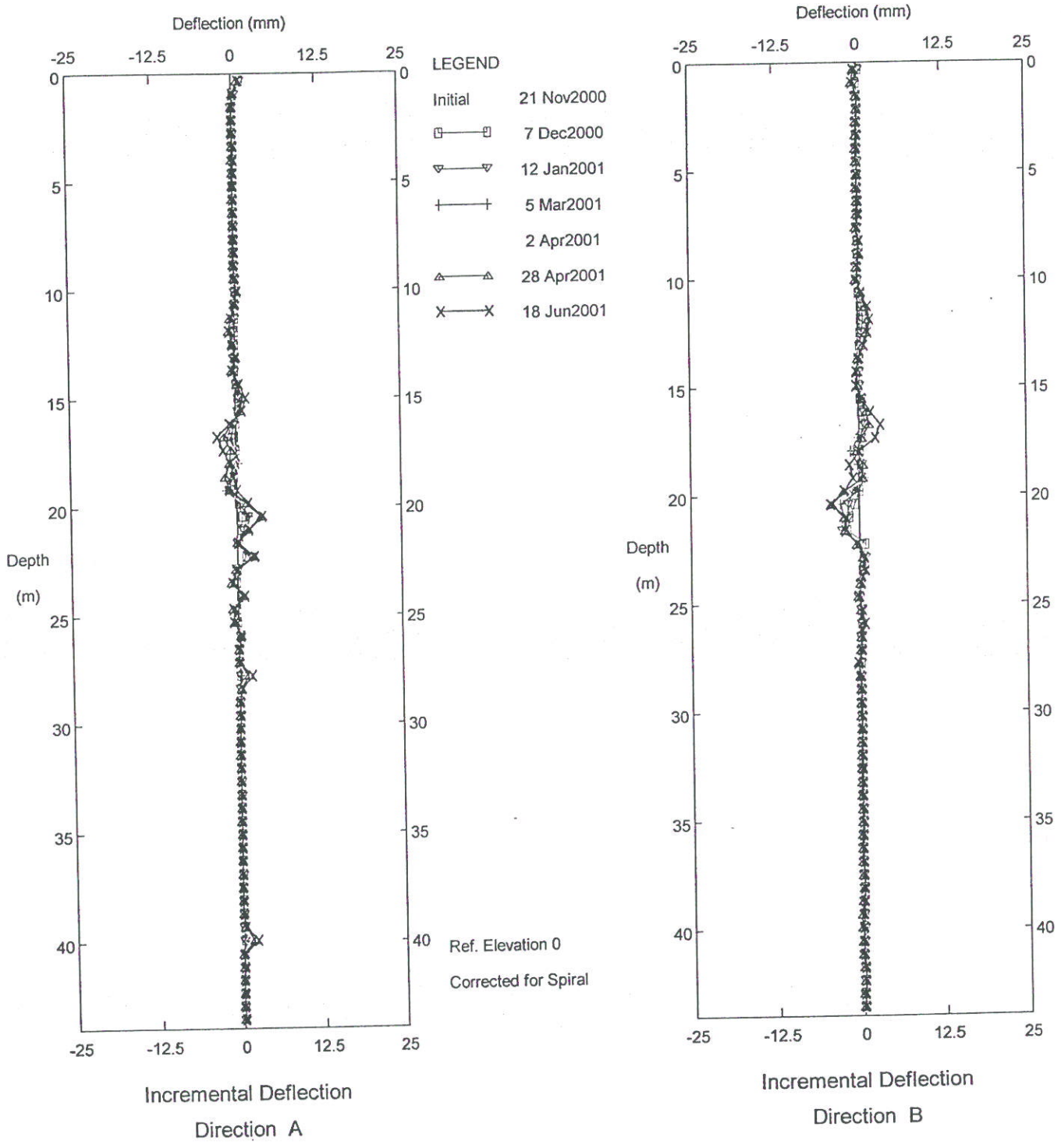


KX03904 W. Quesnel Stability Study, Inclinometer SI-1 Corr.

Lower Avery Lane

Appendix D

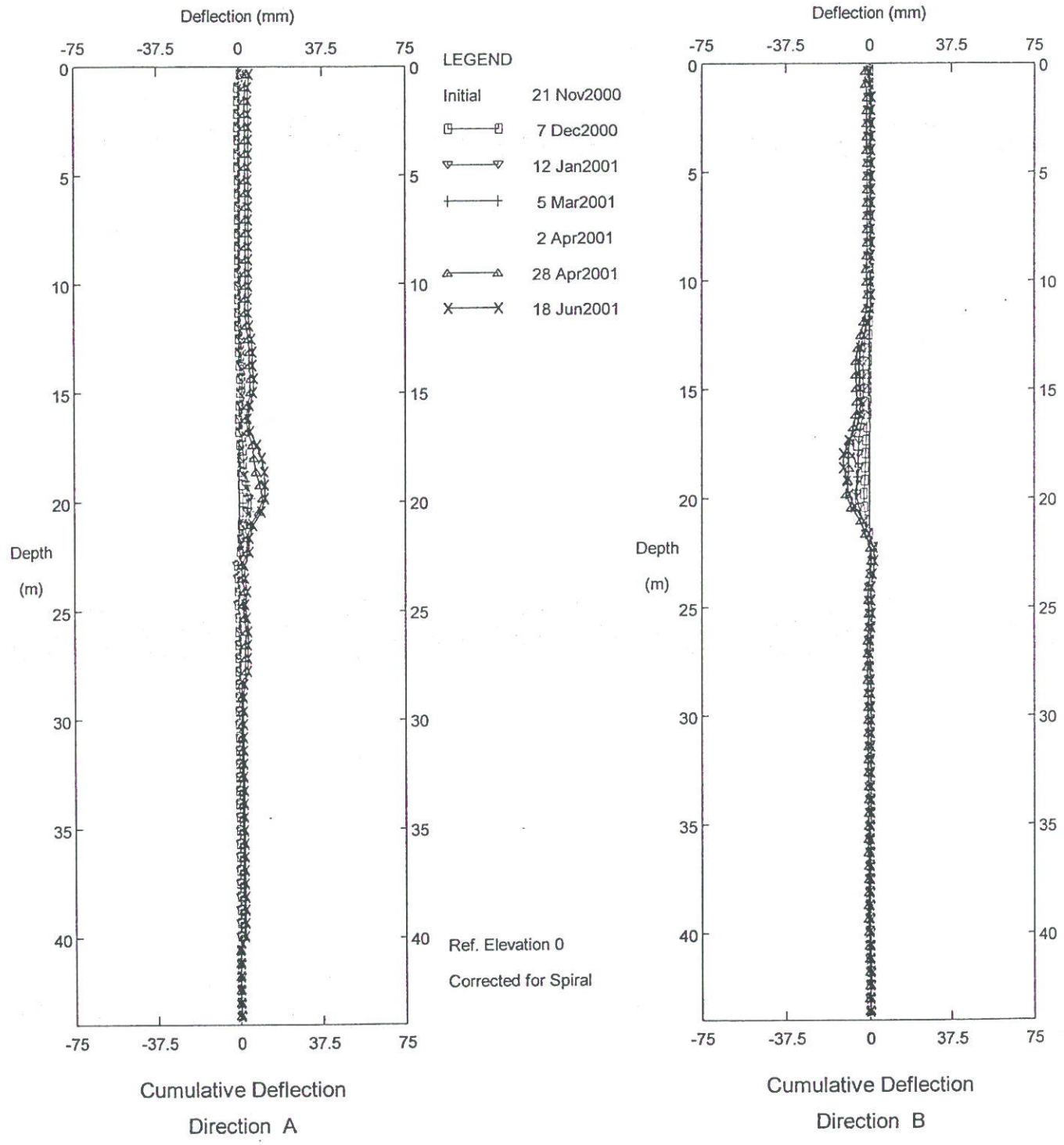
AMEC Earth and Environmental - Pr. George



KX03904 W. Quesnel Stability Study, Inclinometer SI-1 Corr.

Lower Avery Lane

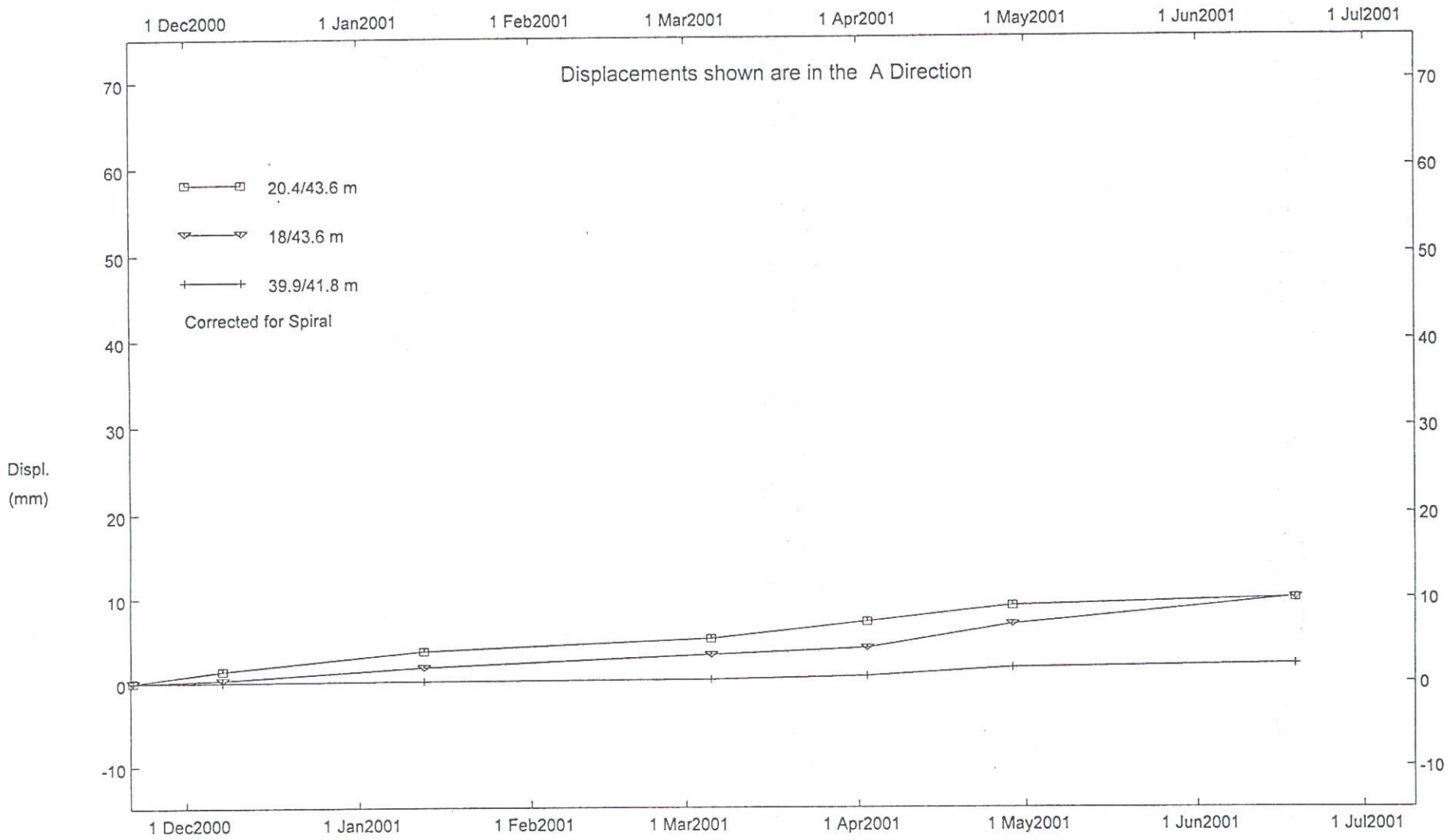
AMEC Earth and Environmental - Pr. George



KX03904 W. Quesnel Stability Study, Inclinometer SI-1 Corr.

Lower Avery Lane

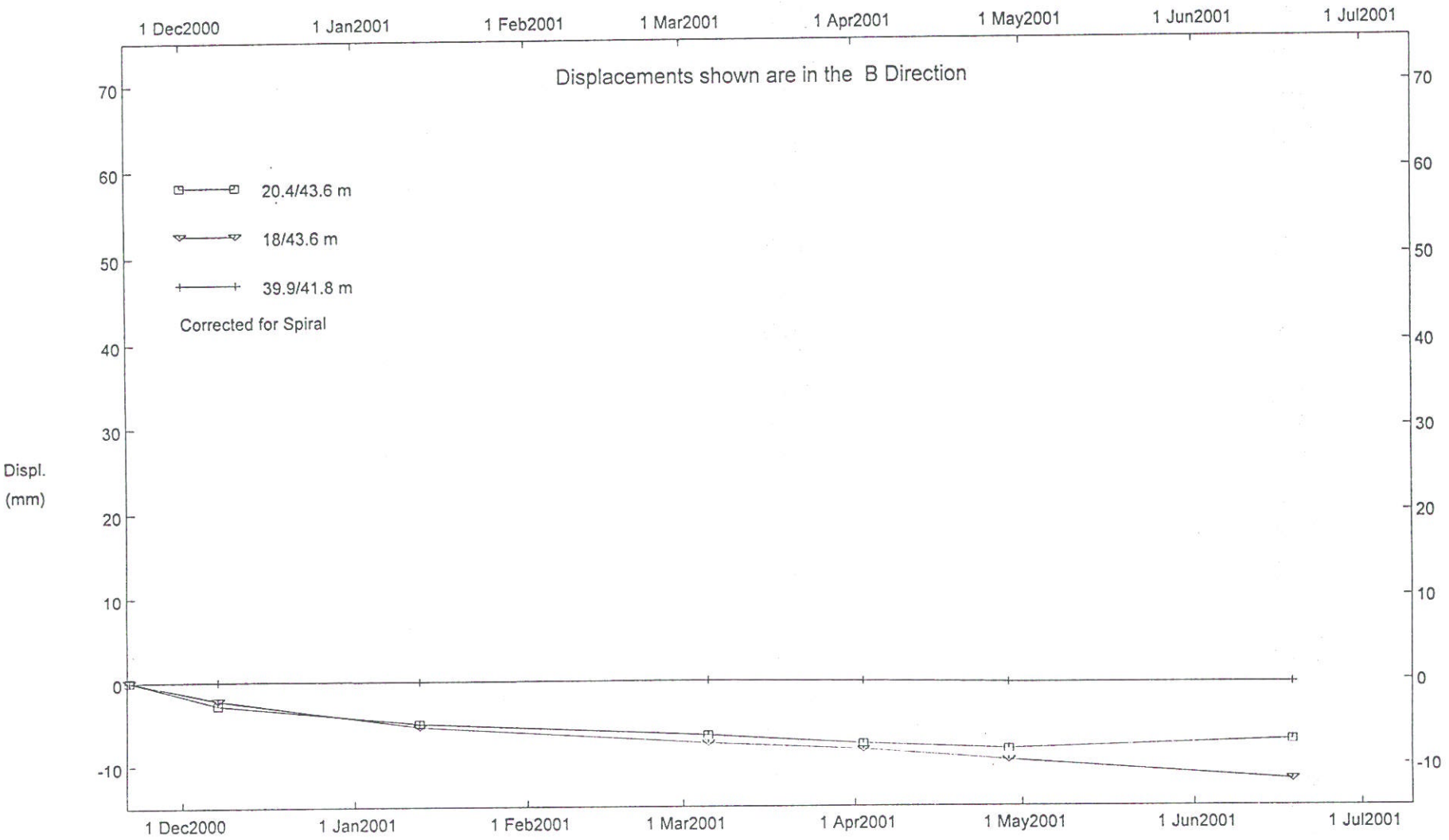
AMEC Earth and Environmental - Pr. George



KX03904 W. Quesnel Stability Study, Inclinometer SI-1 Corr.

Lower Avery Lane

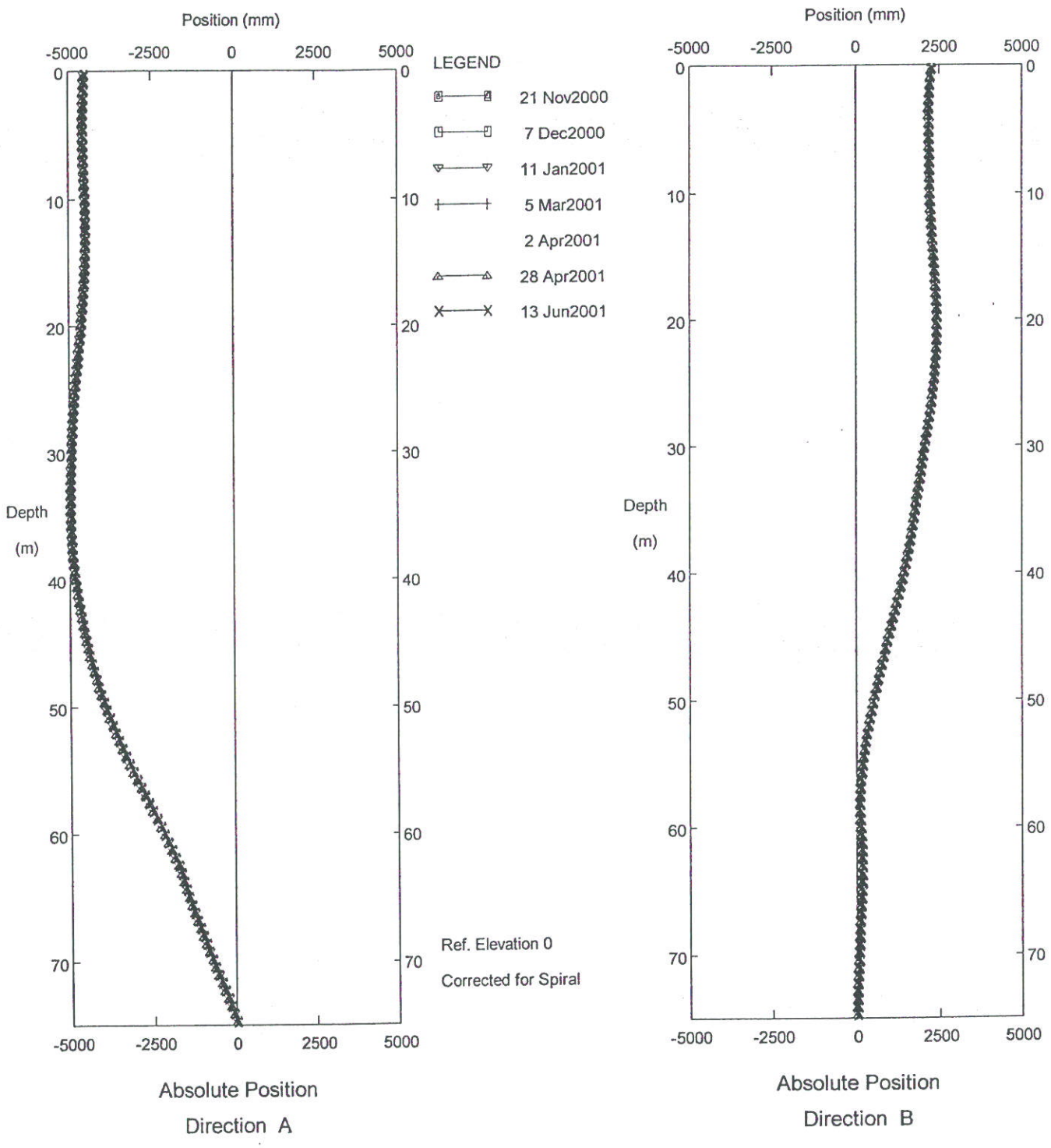
AMEC Earth and Environmental - Pr. George



KX03904 W. Quesnel Stability Study, Inclinometer SI-1 Corr.

Lower Avery Lane

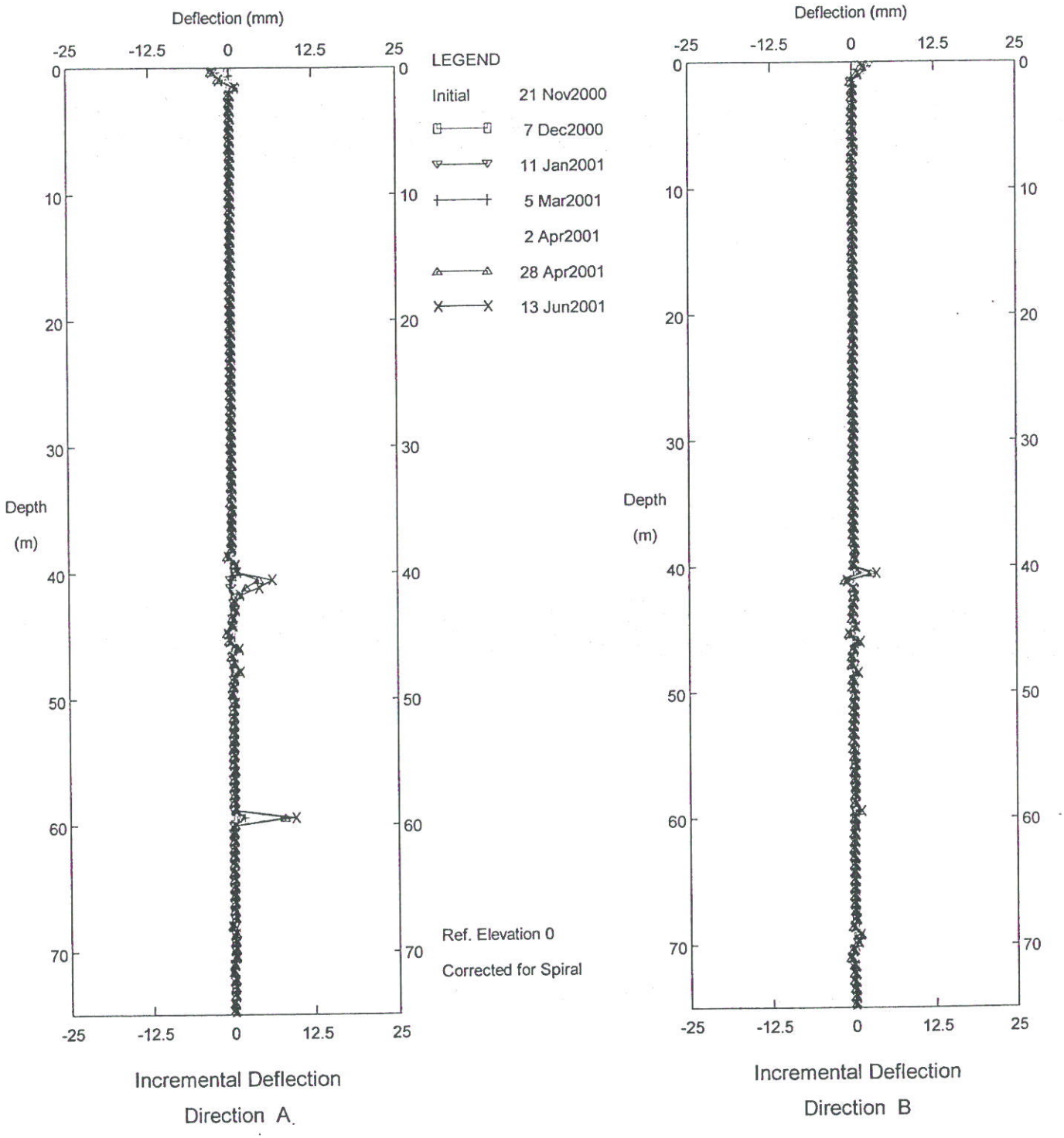
AMEC Earth and Environmental - Pr. George



KX03904 W. Quesnel Stability Study, Inclinometer SI-2 Corr.

Upper Avery Lane

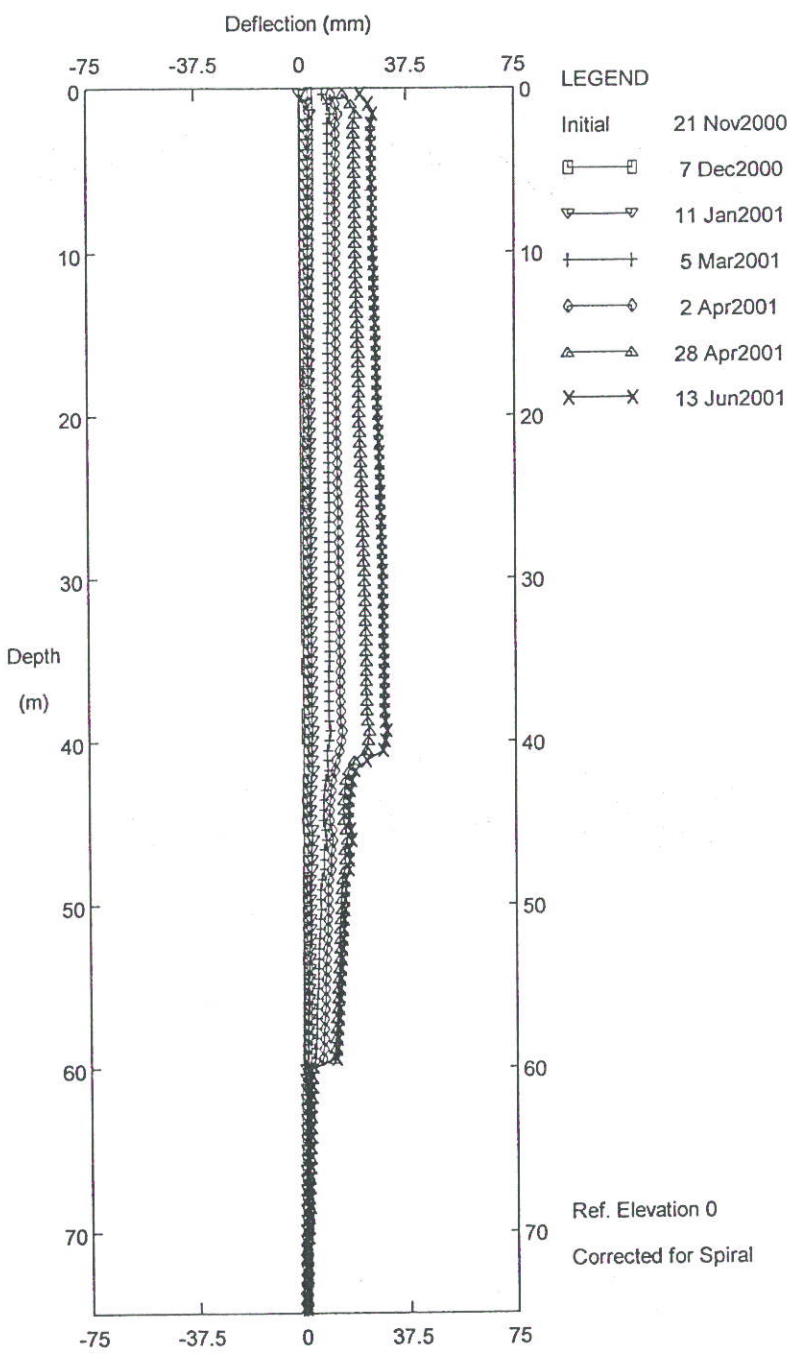
AMEC Earth and Environmental - Pr. George



KX03904 W. Quesnel Stability Study, Inclinometer SI-2 Corr.

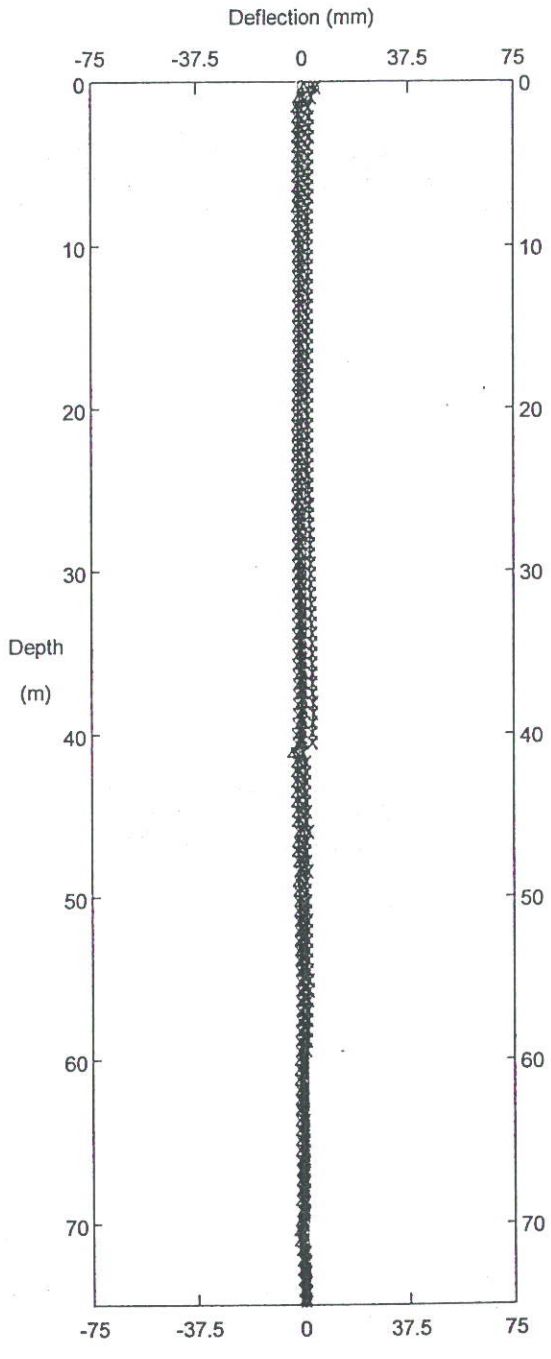
Upper Avery Lane

AMEC Earth and Environmental - Pr. George



Cumulative Deflection

Direction A.



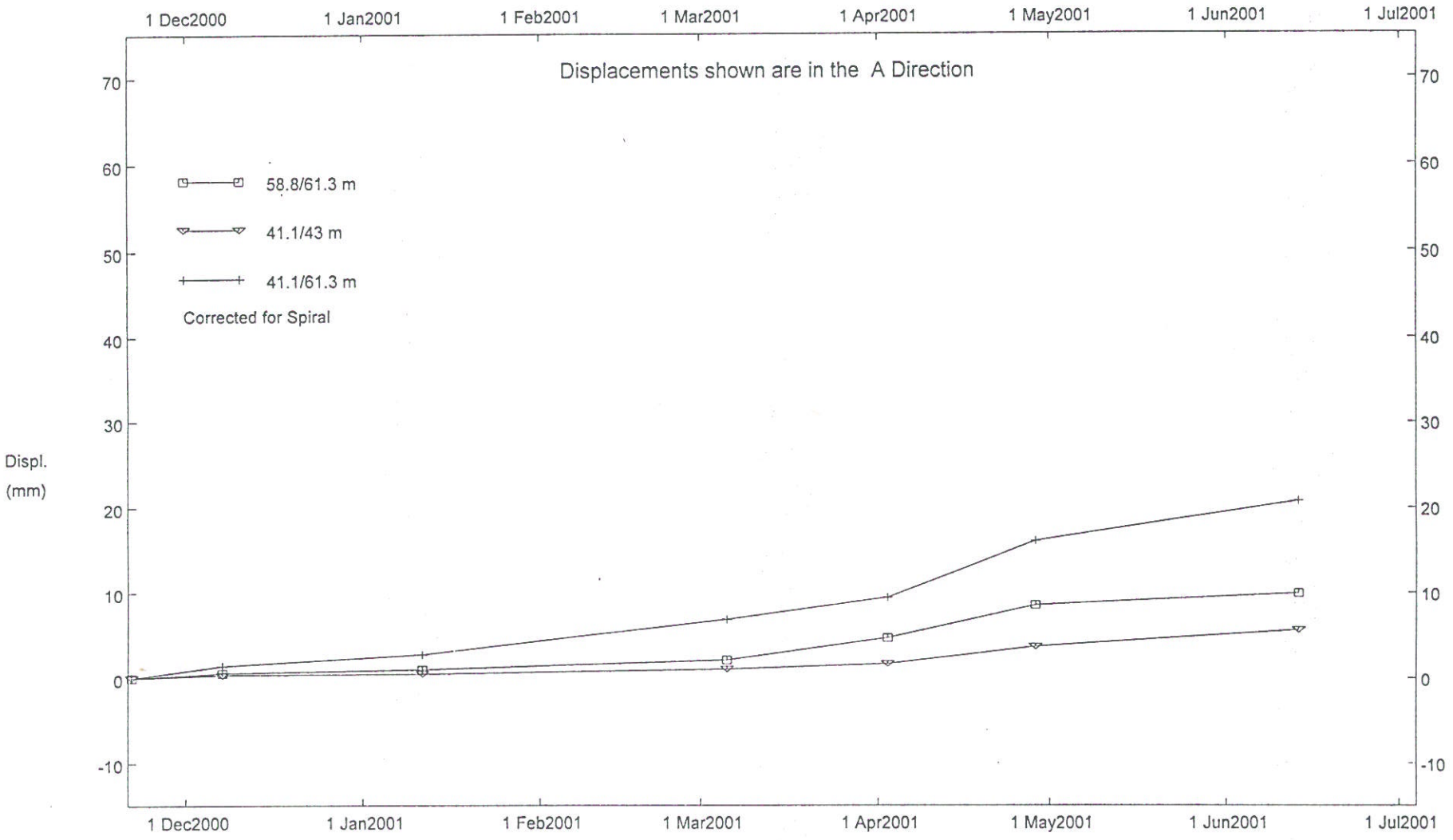
Cumulative Deflection

Direction B

KX03904 W. Quesnel Stability Study, Inclinometer SI-2 Corr.

Upper Avery Lane

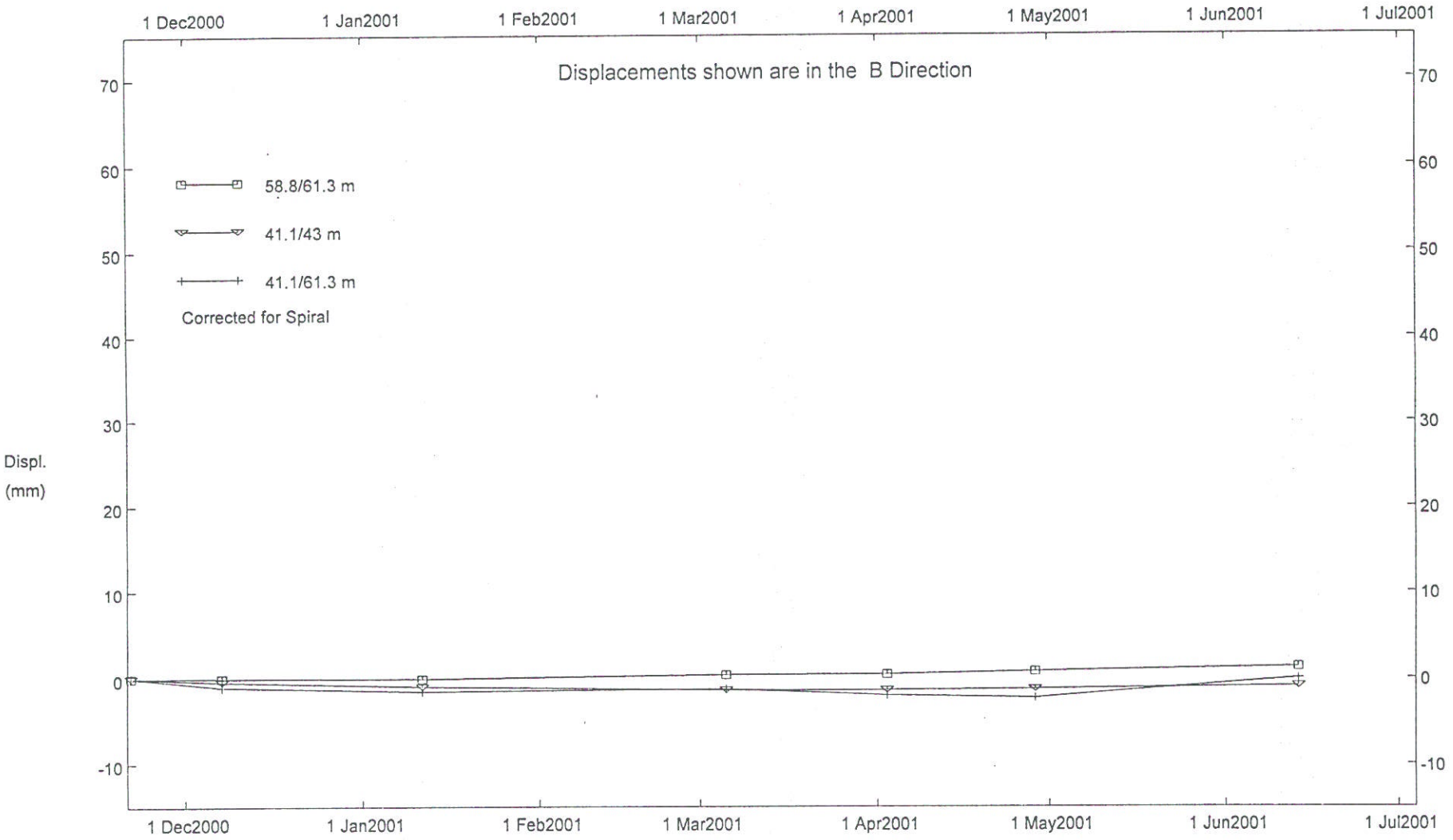
AMEC Earth and Environmental - Pr. George



KX03904 W. Quesnel Stability Study, Inclinometer SI-2 Corr.

Upper Avery Lane

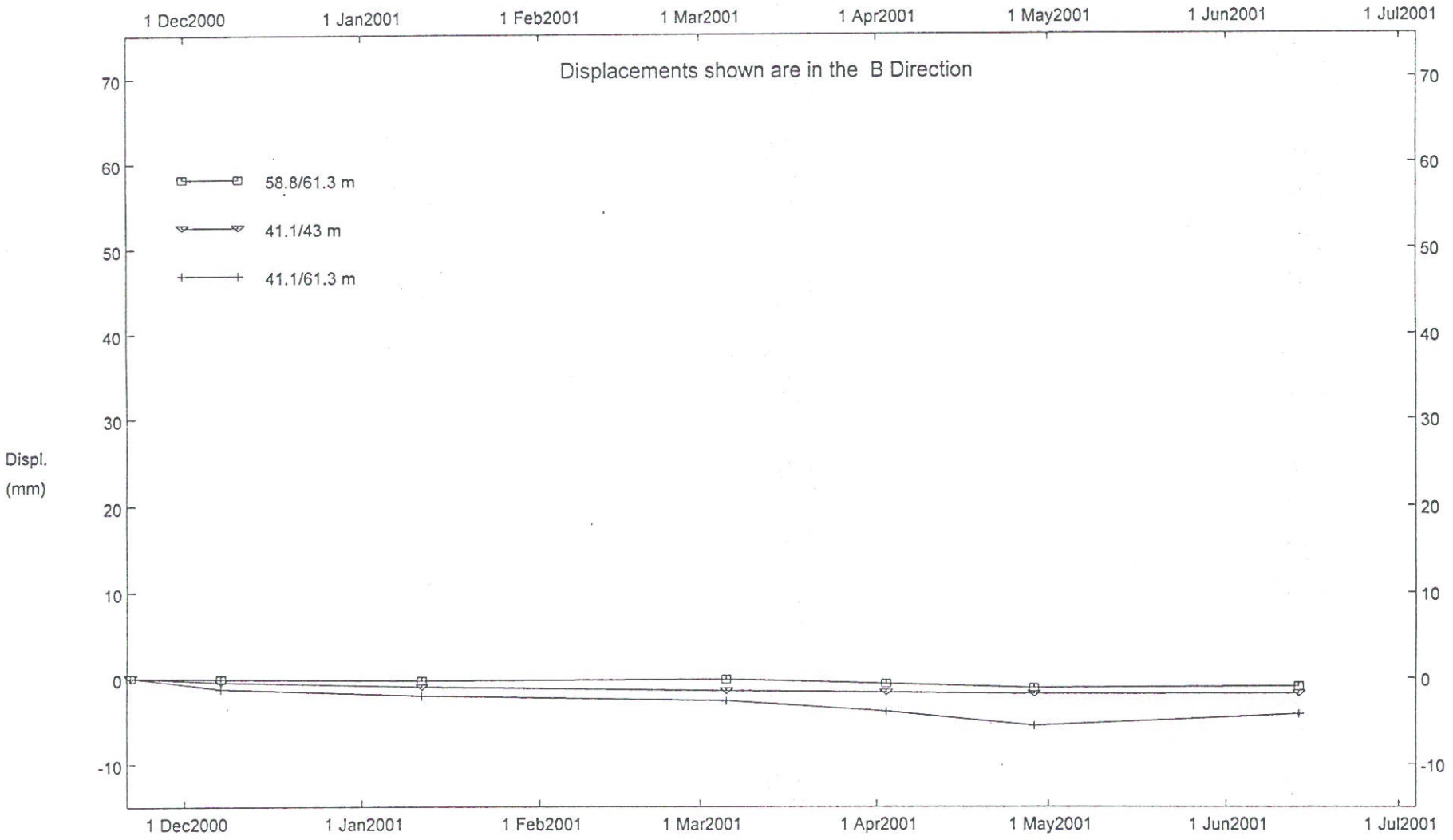
AMEC Earth and Environmental - Pr. George



KX03904 W. Quesnel Stability Study, Inclinometer SI-2 Corr.

Upper Avery Lane

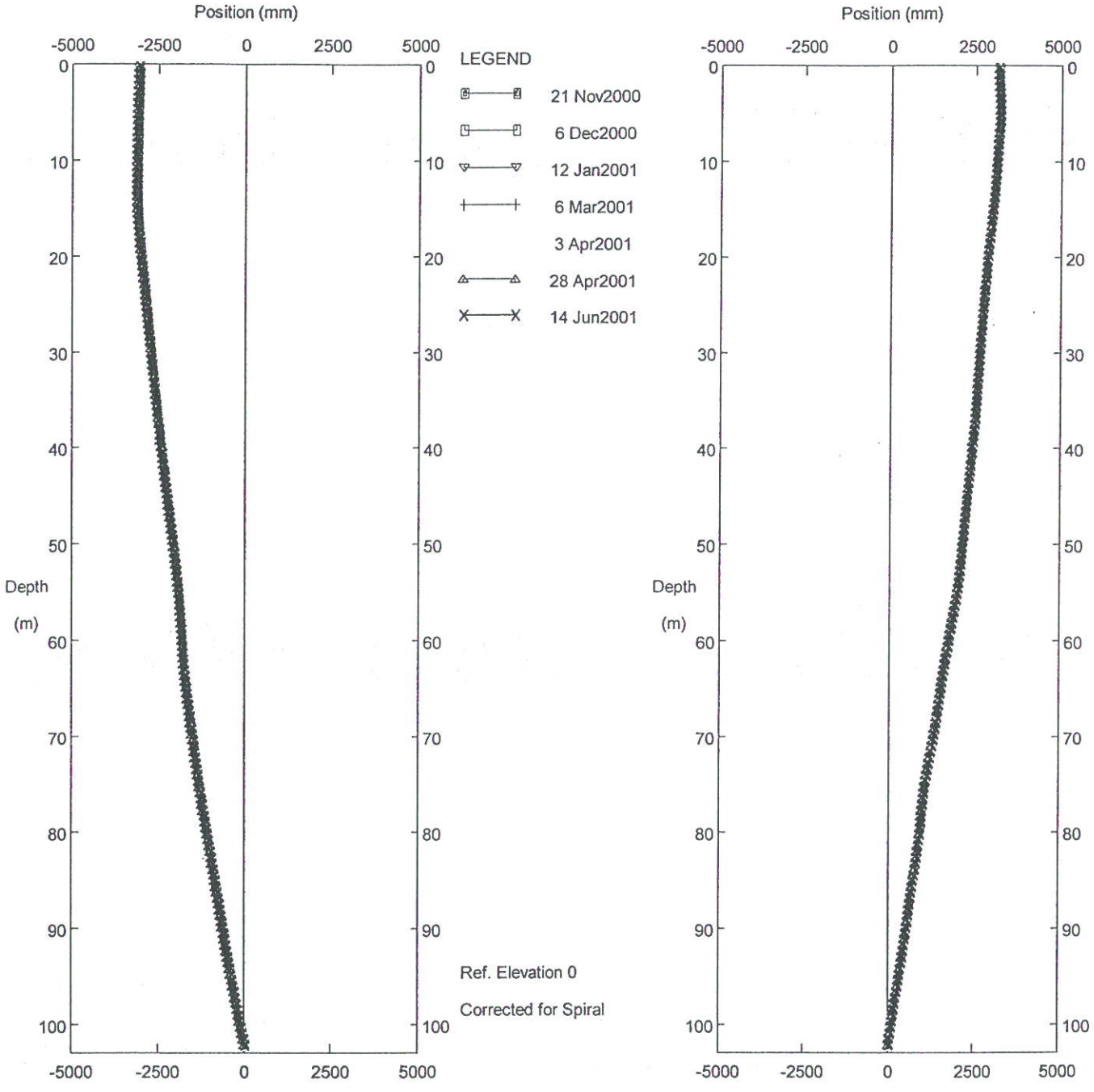
AMEC Earth and Environmental - Pr. George



KX03904 W. Quesnel Stability Study, Inclinometer SI-2 Corr.

Upper Avery Lane

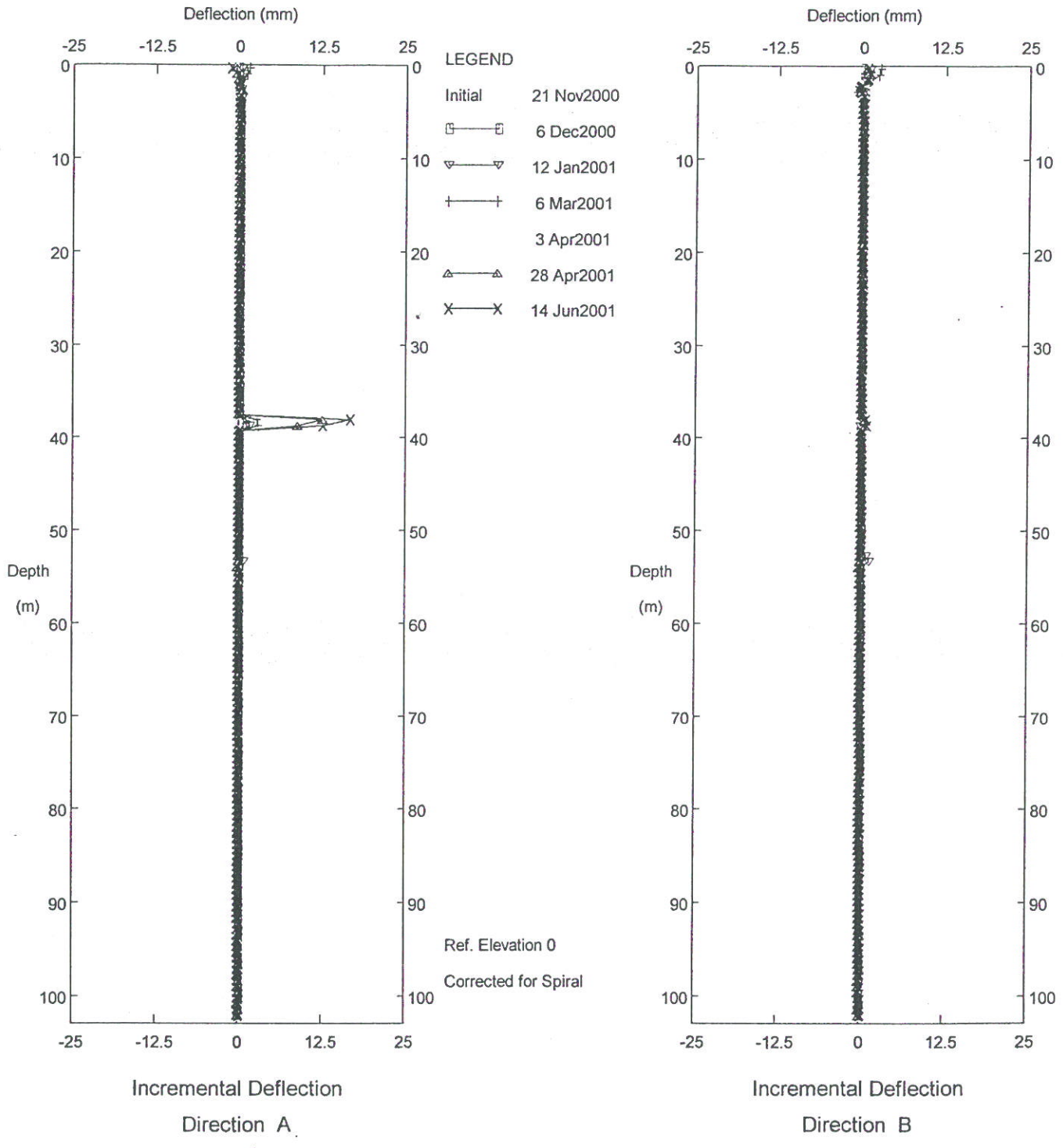
AMEC Earth and Environmental - Pr. George



KX03904 W. Quesnel Stability Study, Inclinometer SI-3 Corr.

Abbott Drive near Bettcher

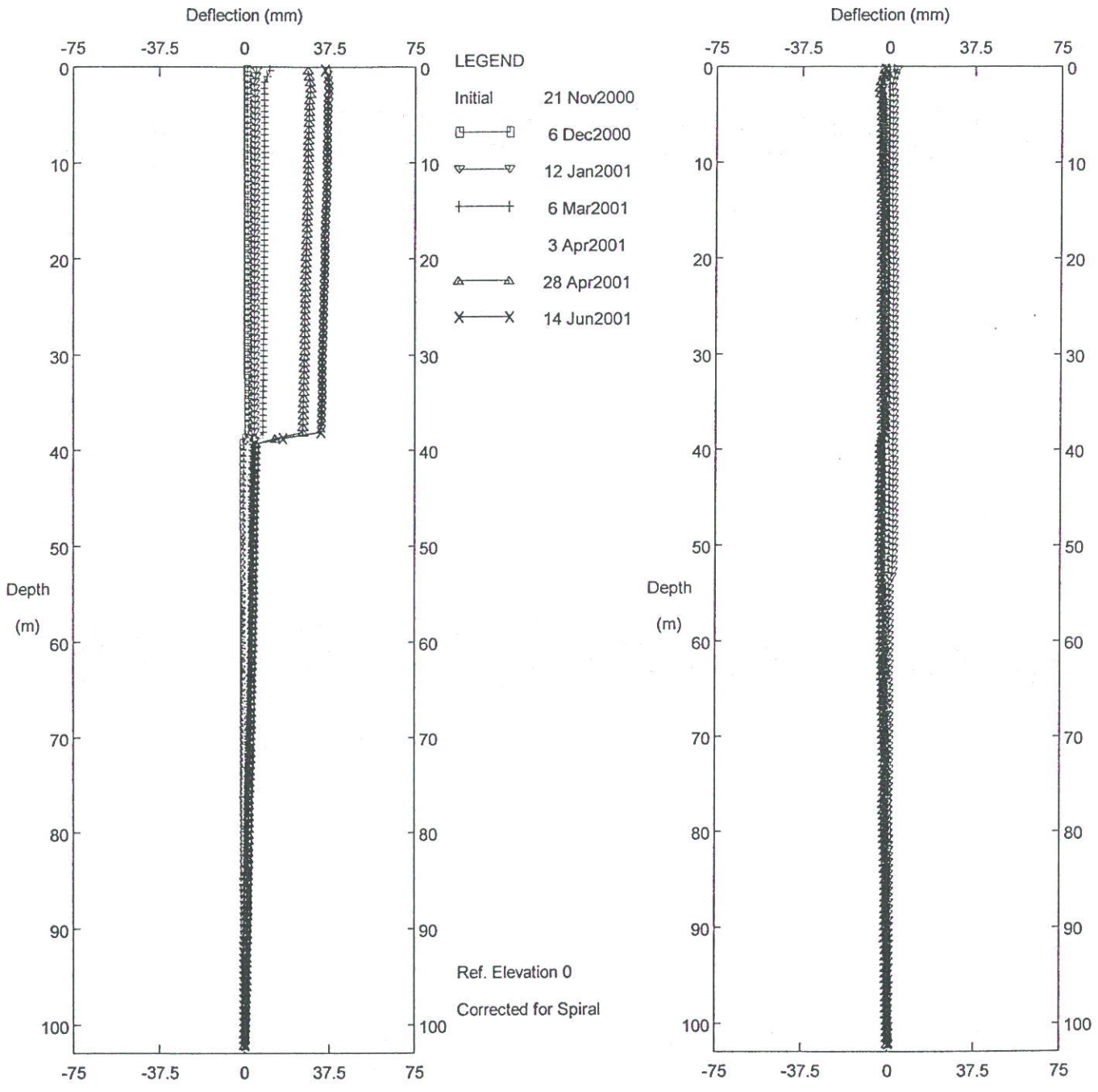
AMEC Earth and Environmental - Pr. George



KX03904 W. Quesnel Stability Study, Inclinometer SI-3 Corr.

Abbott Drive near Bettcher

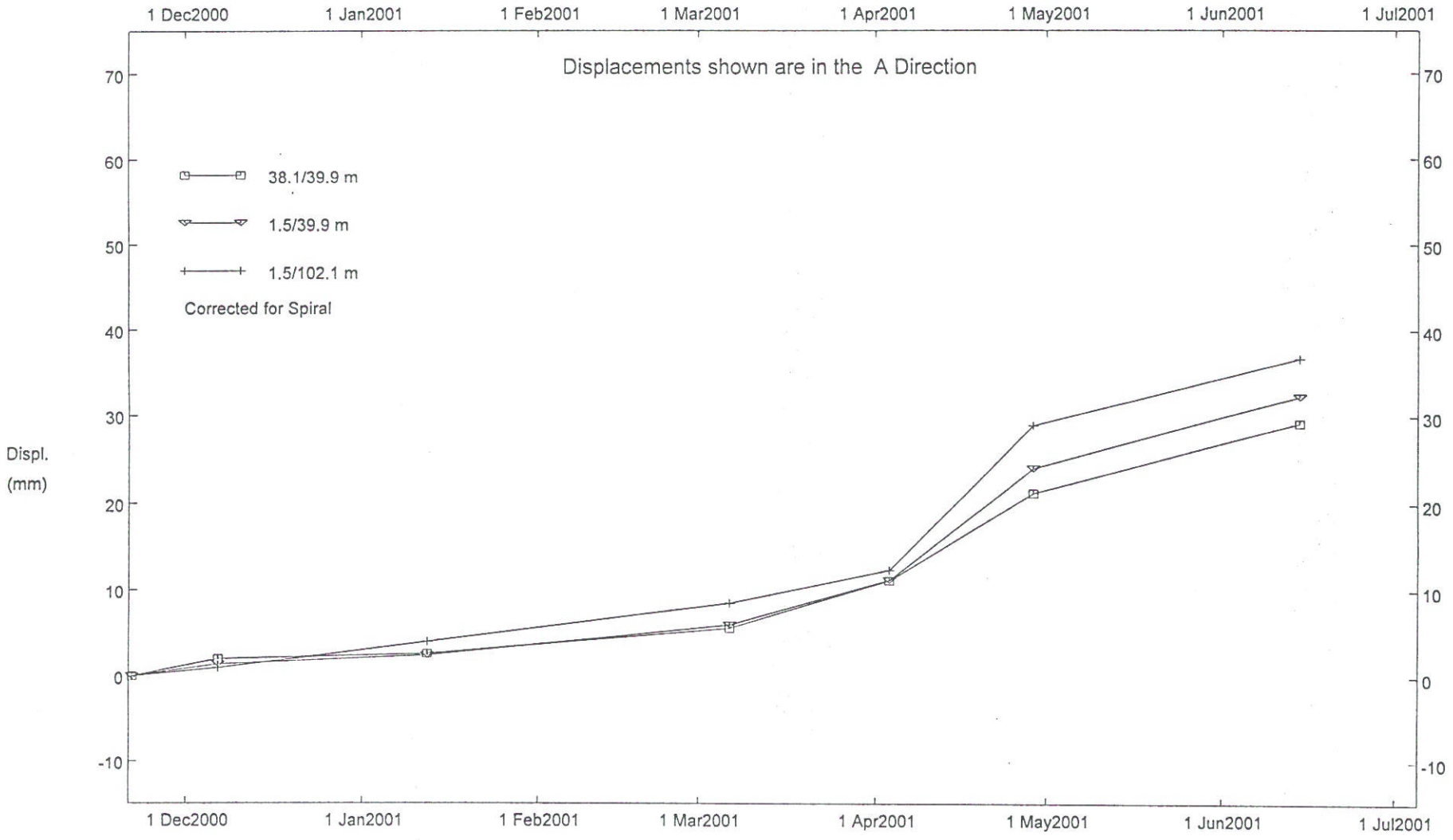
AMEC Earth and Environmental - Pr. George



KX03904 W. Quesnel Stability Study, Inclinometer SI-3 Corr.

Abbott Drive near Bettcher

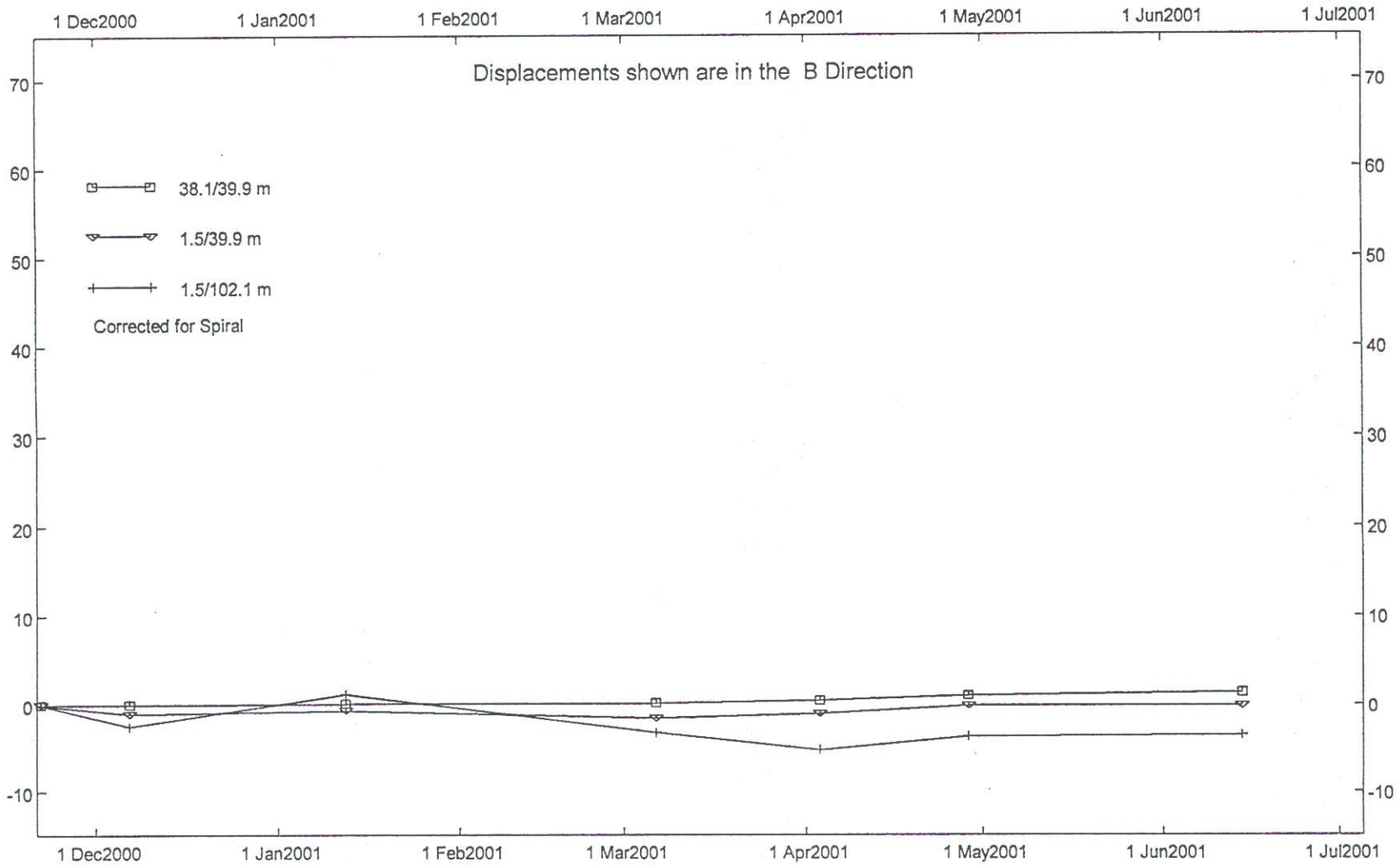
AMEC Earth and Environmental - Pr. George



KX03904 W. Quesnel Stability Study, Inclinometer SI-3 Corr.

Abbott Drive near Bettcher

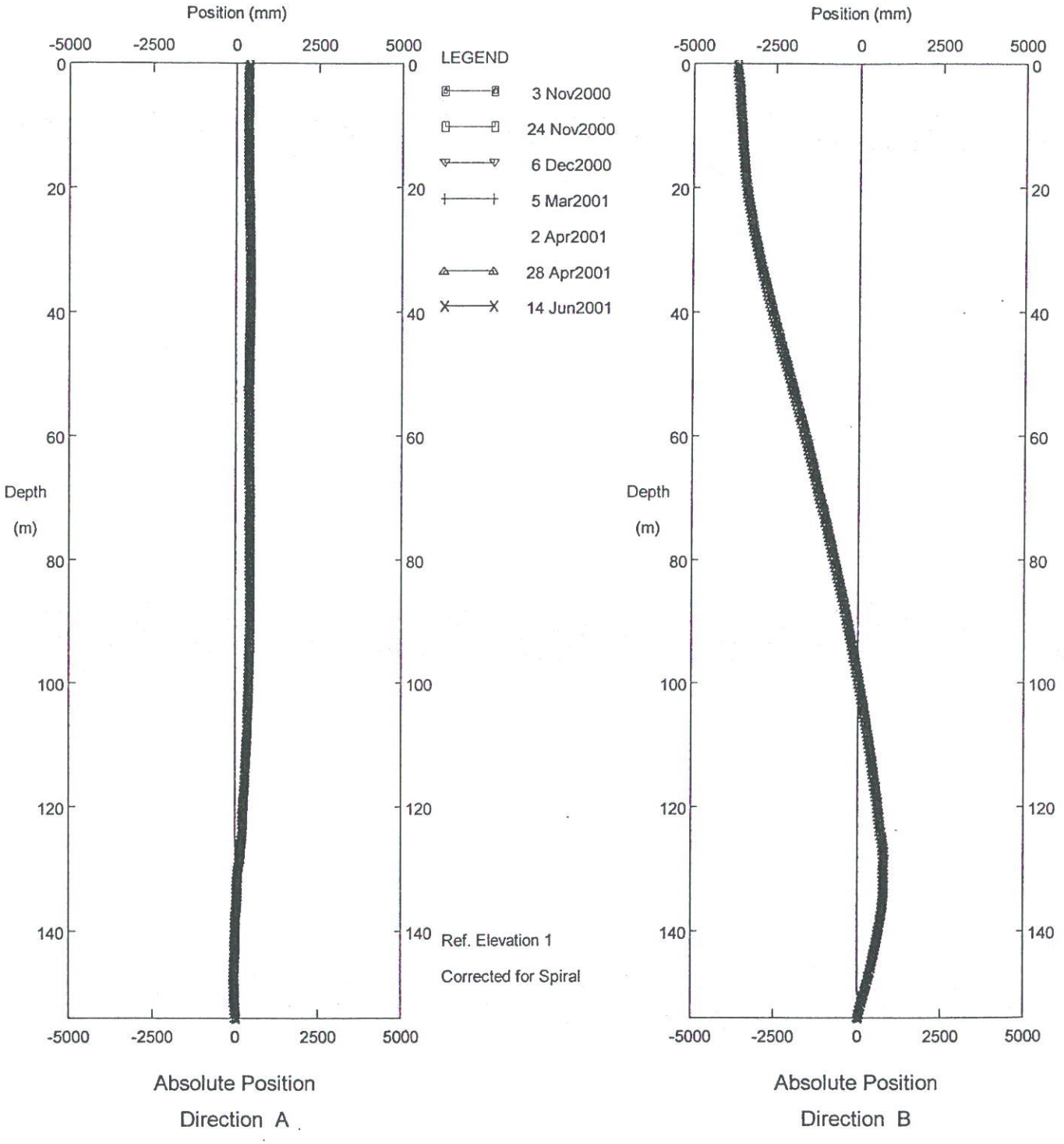
AMEC Earth and Environmental - Pr. George



KX03904 W. Quesnel Stability Study, Inclinometer SI-3 Corr.

Abbott Drive near Bettcher

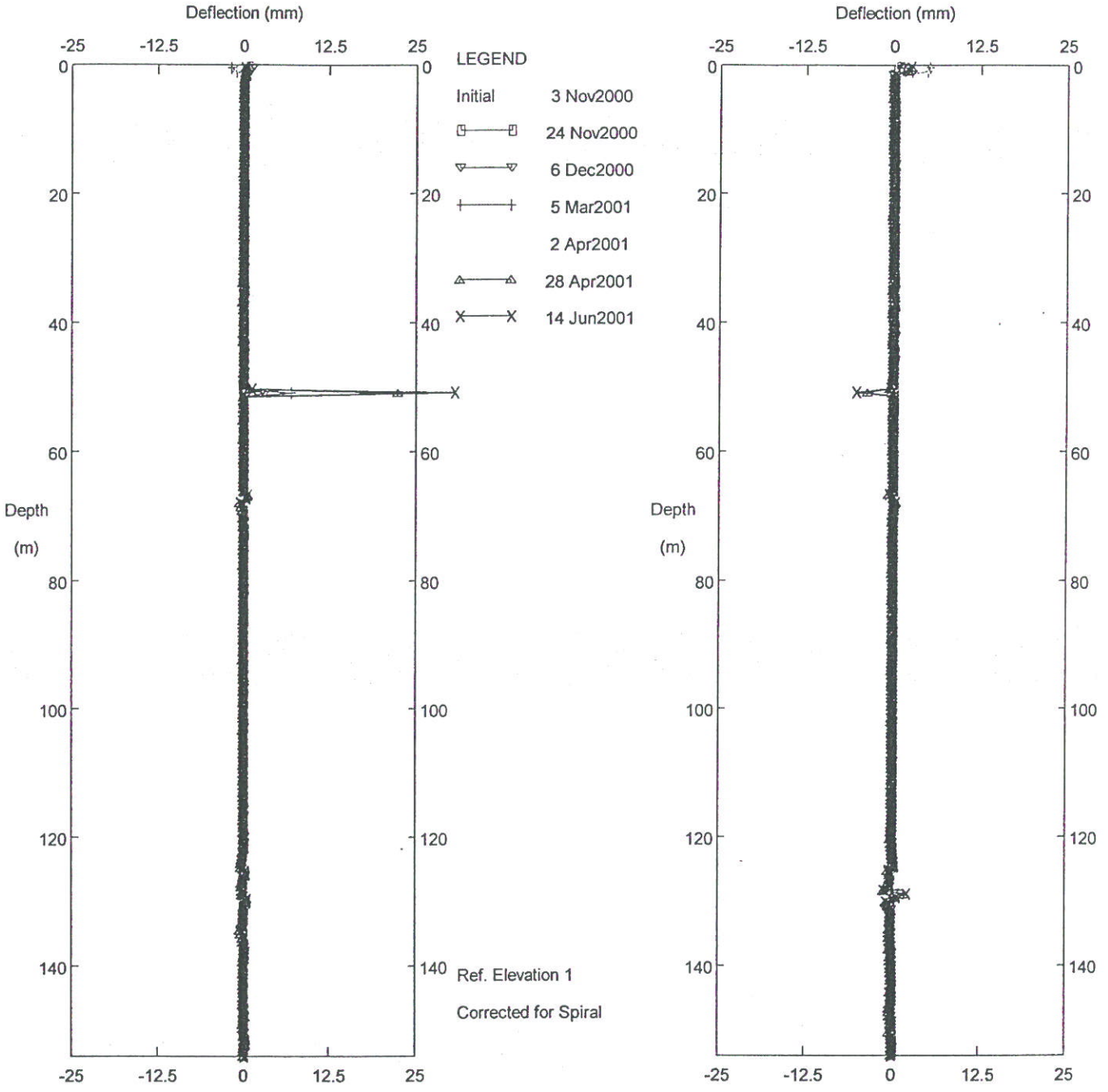
AMEC Earth and Environmental - Pr. George



KX03904 W.Quesnel Stability Study, Inclinometer SI-4 Corr.

Voyageur School

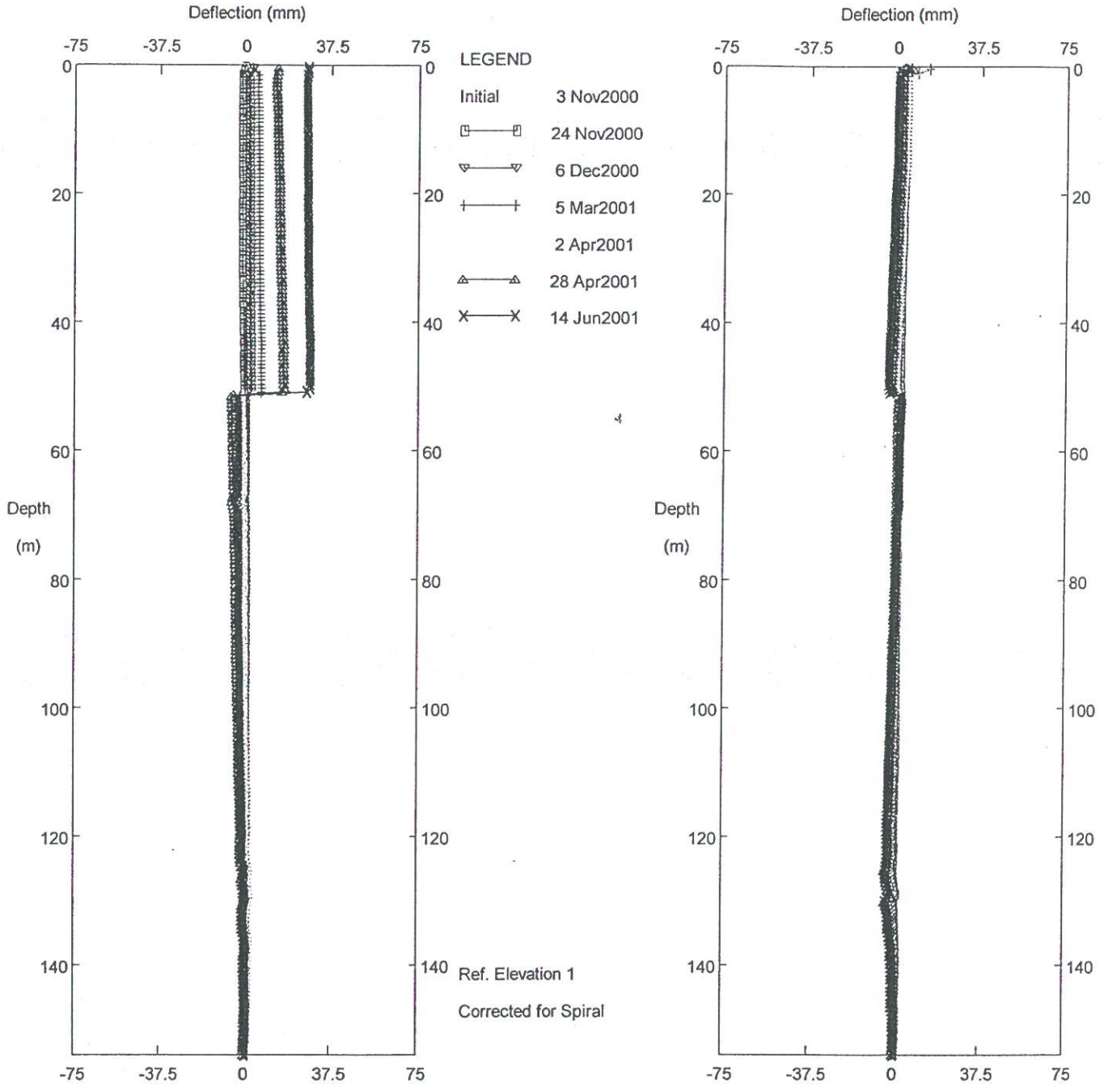
AMEC Earth and Environmental - Pr. George



KX03904 W.Quesnel Stability Study, Inclinometer SI-4 Corr.

Voyageur School

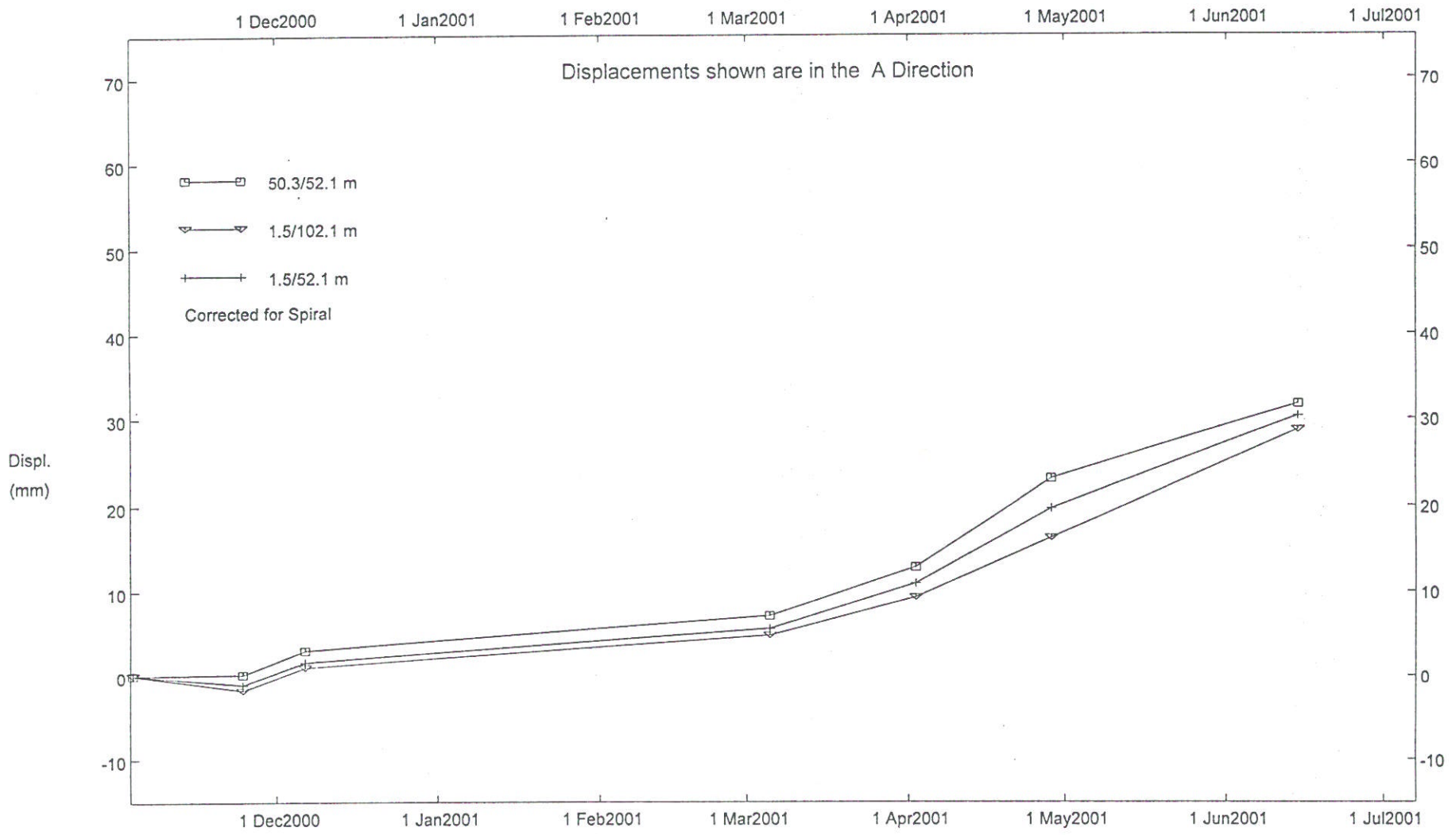
AMEC Earth and Environmental - Pr. George



KX03904 W.Quesnel Stability Study, Inclinometer SI-4 Corr.

Voyageur School

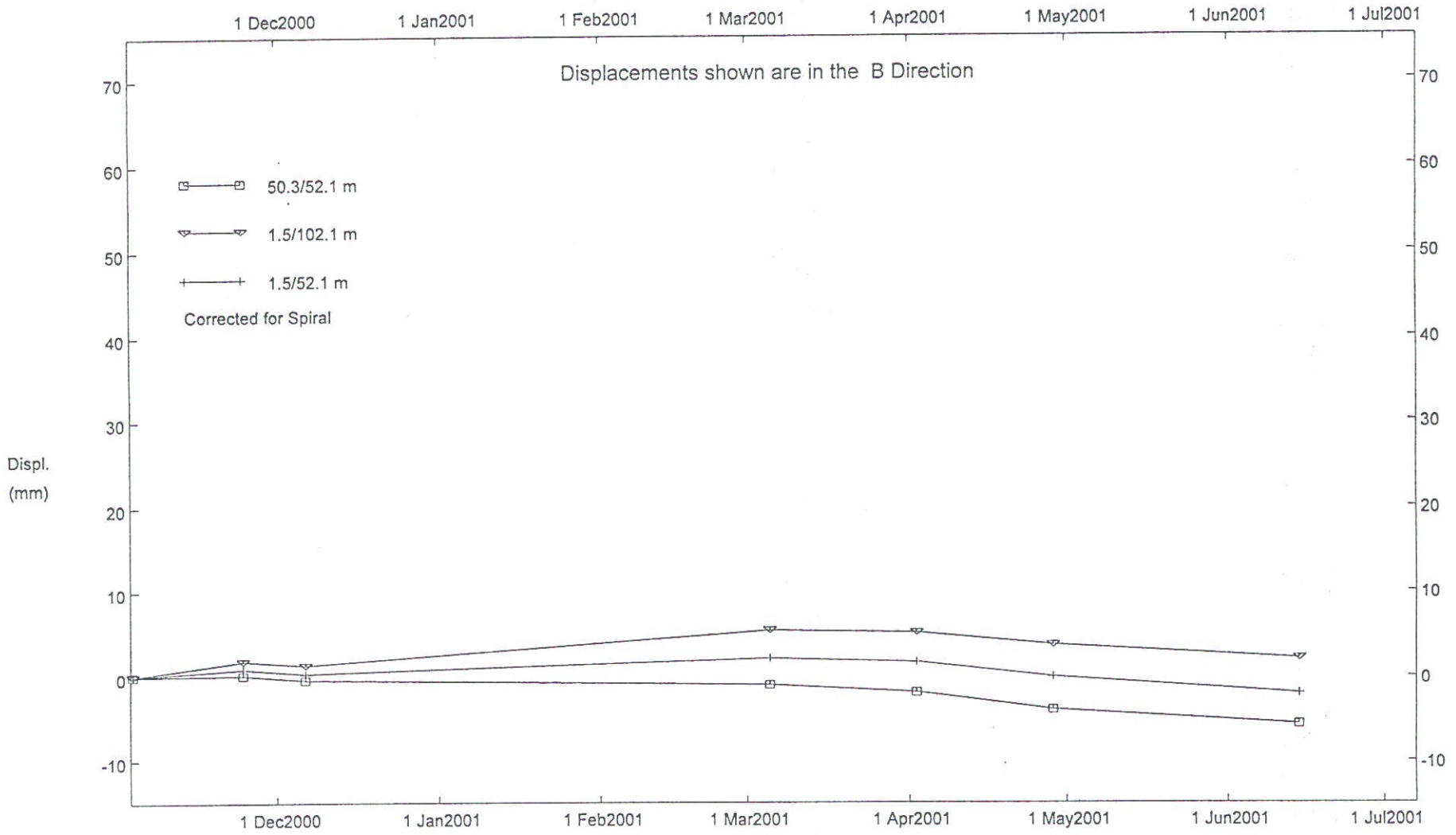
AMEC Earth and Environmental - Pr. George



KX03904 W.Quesnel Stability Study, Inclinometer SI-4 Corr.

Voyageur School

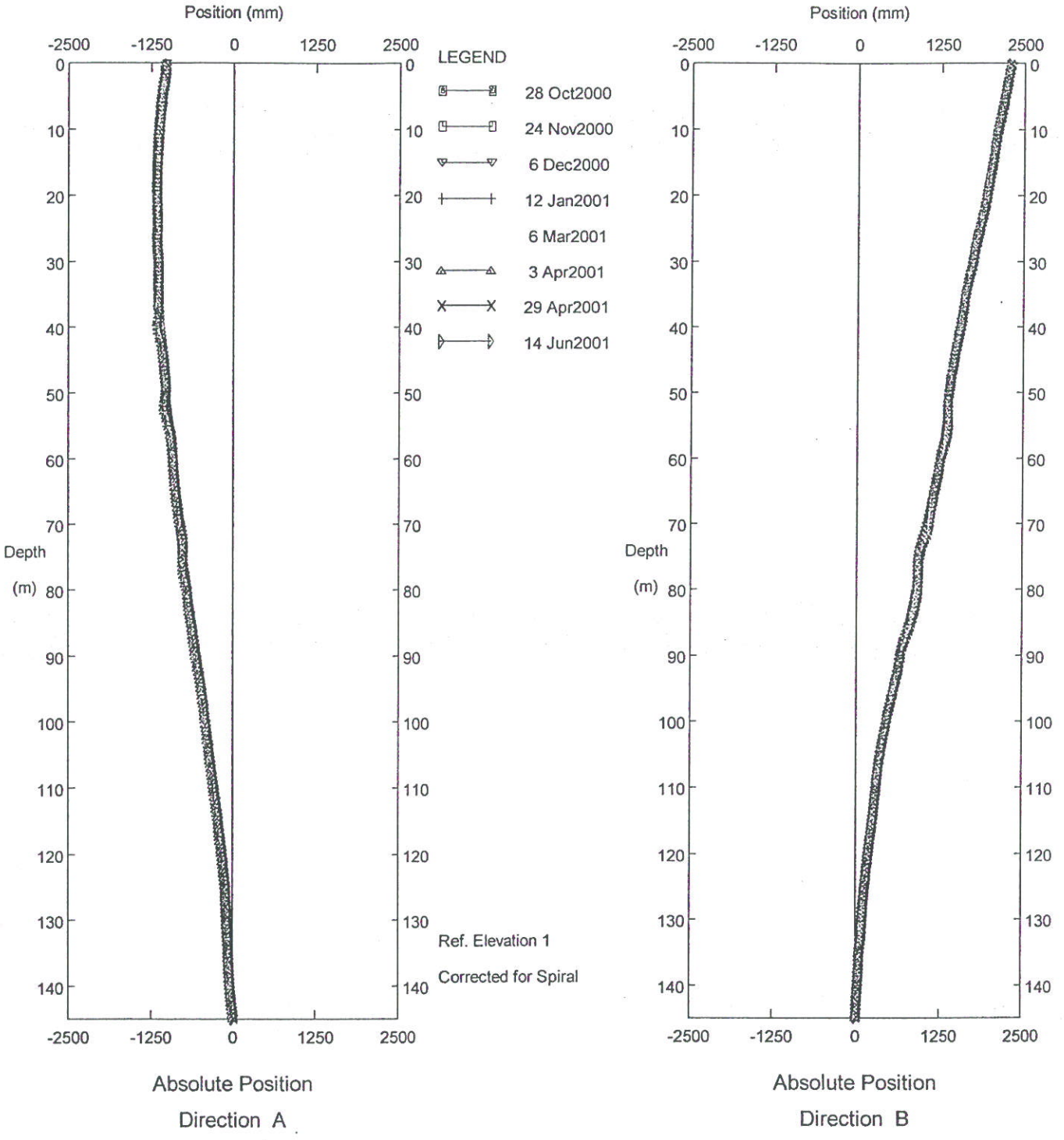
AMEC Earth and Environmental - Pr. George



KX03904 W.Quesnel Stability Study, Inclinometer SI-4 Corr.

Voyageur School

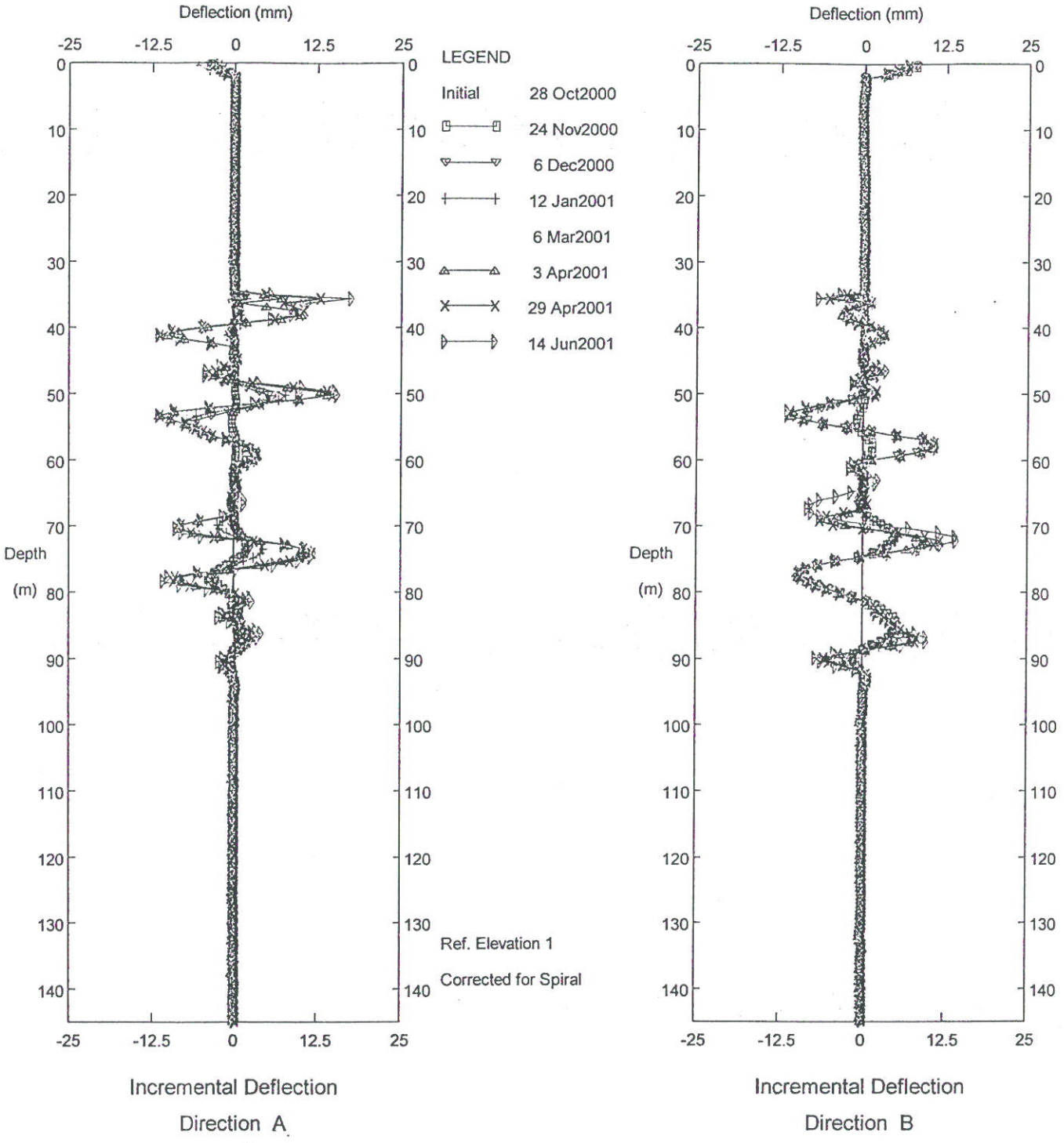
AMEC Earth and Environmental - Pr. George



KX03904 W. Quesnel Stability Study, Inclinometer SI-5 Corr.

Abbott Drive

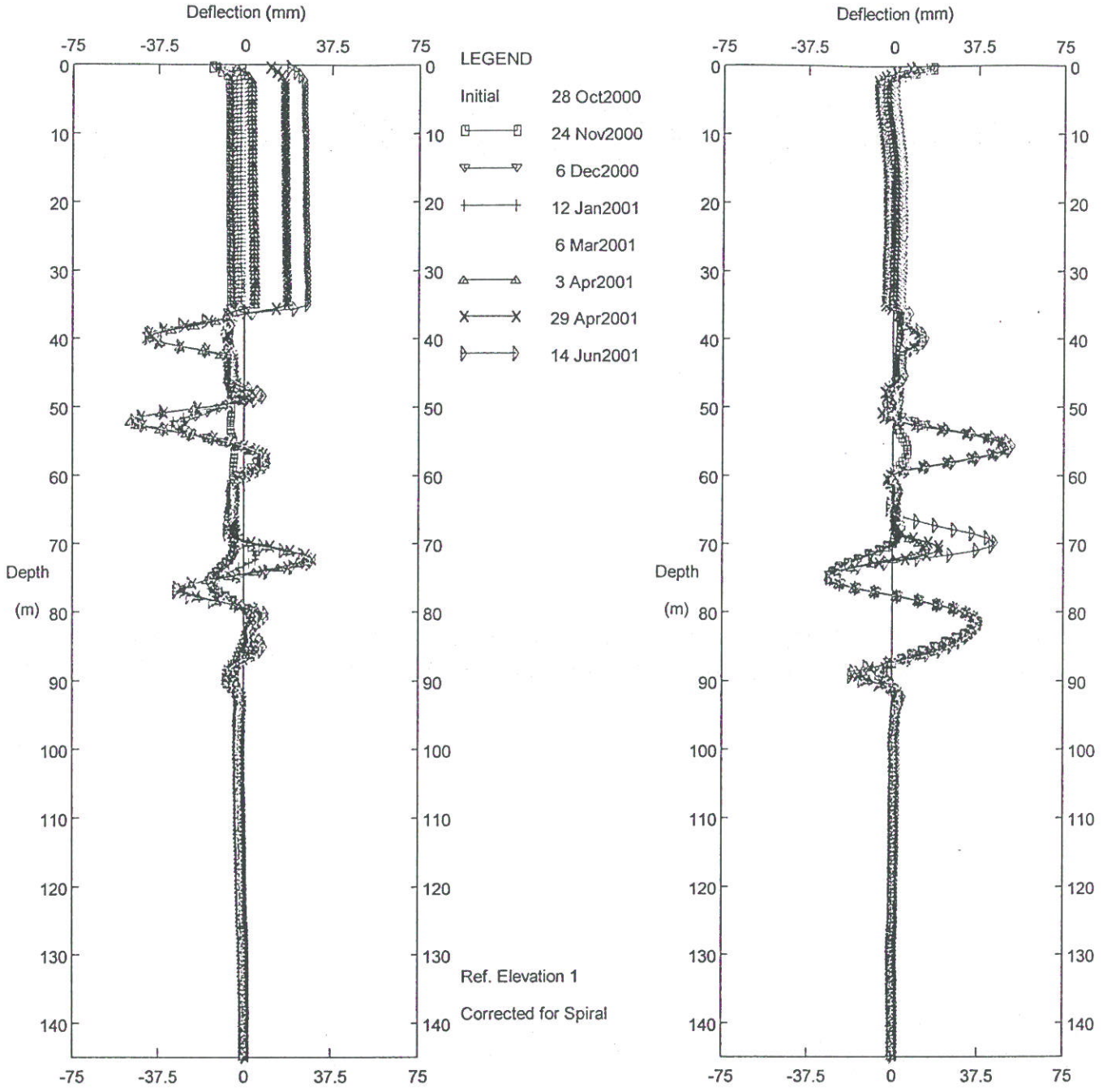
AMEC Earth and Environmental - Pr. George



KX03904 W. Quesnel Stability Study, Inclinometer SI-5 Corr.

Abbott Drive

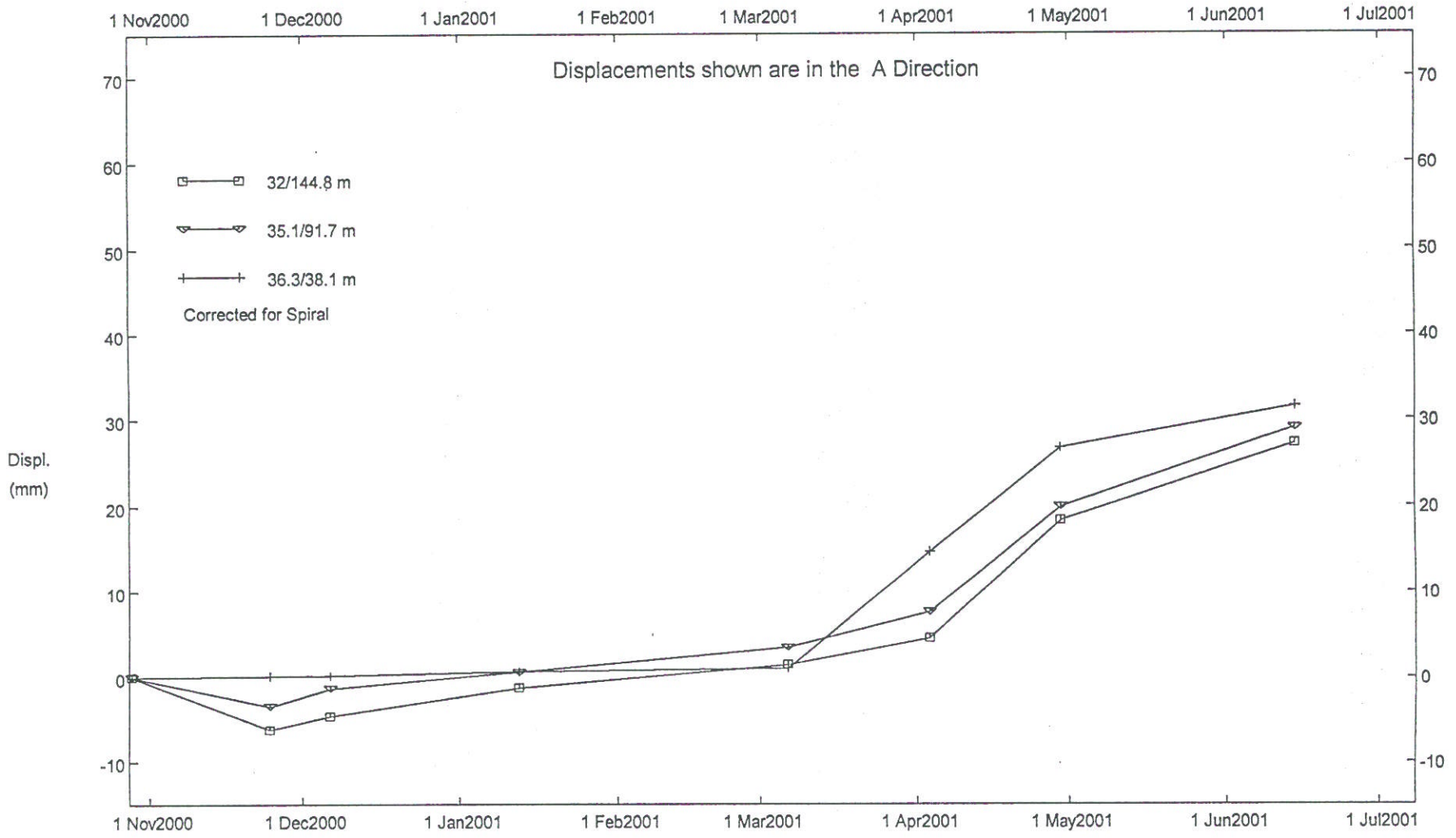
AMEC Earth and Environmental - Pr. George



KX03904 W. Quesnel Stability Study, Inclinometer SI-5 Corr.

Abbott Drive

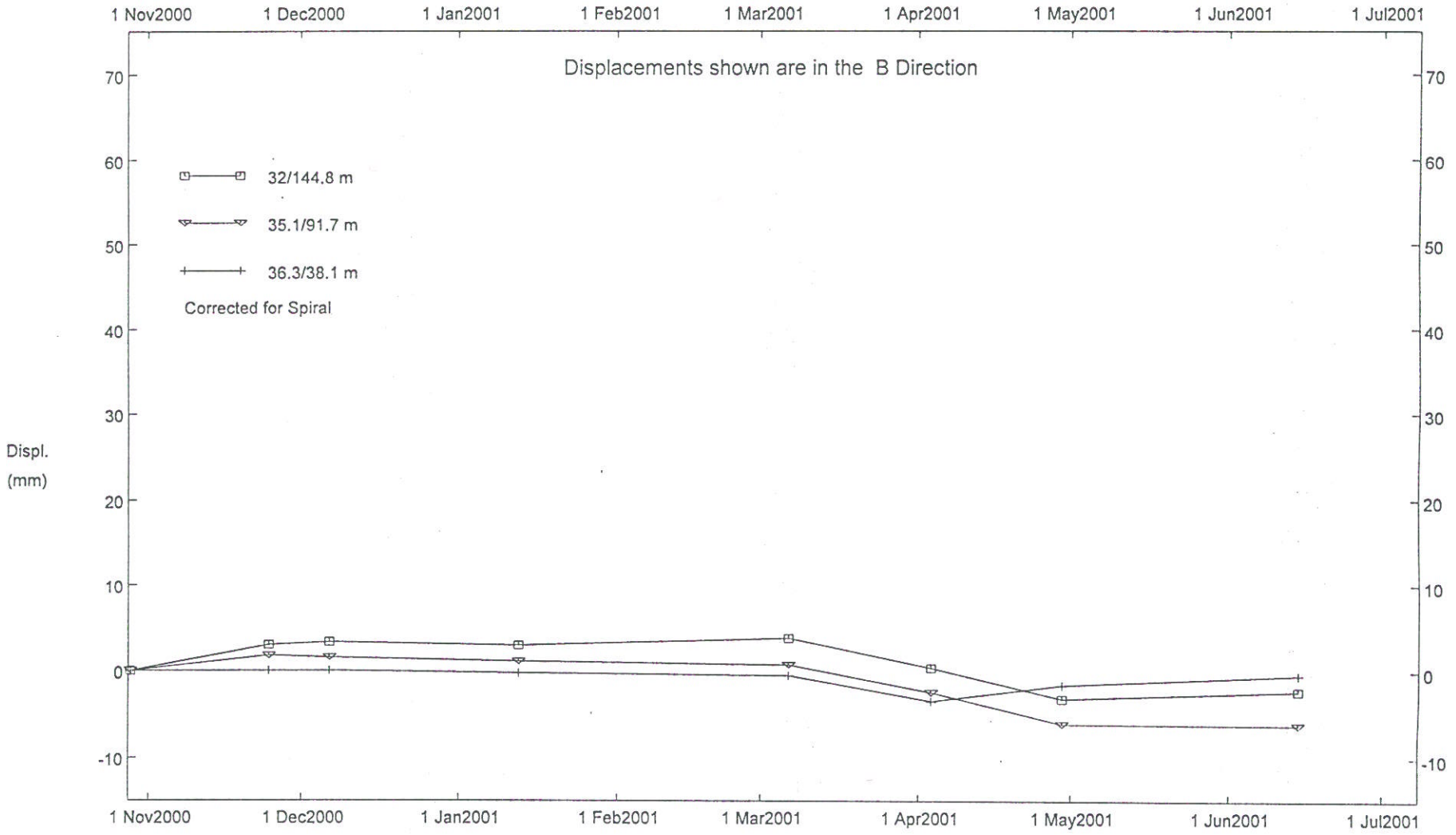
AMEC Earth and Environmental - Pr. George



KX03904 W. Quesnel Stability Study, Inclinometer SI-5 Corr.

Abbott Drive

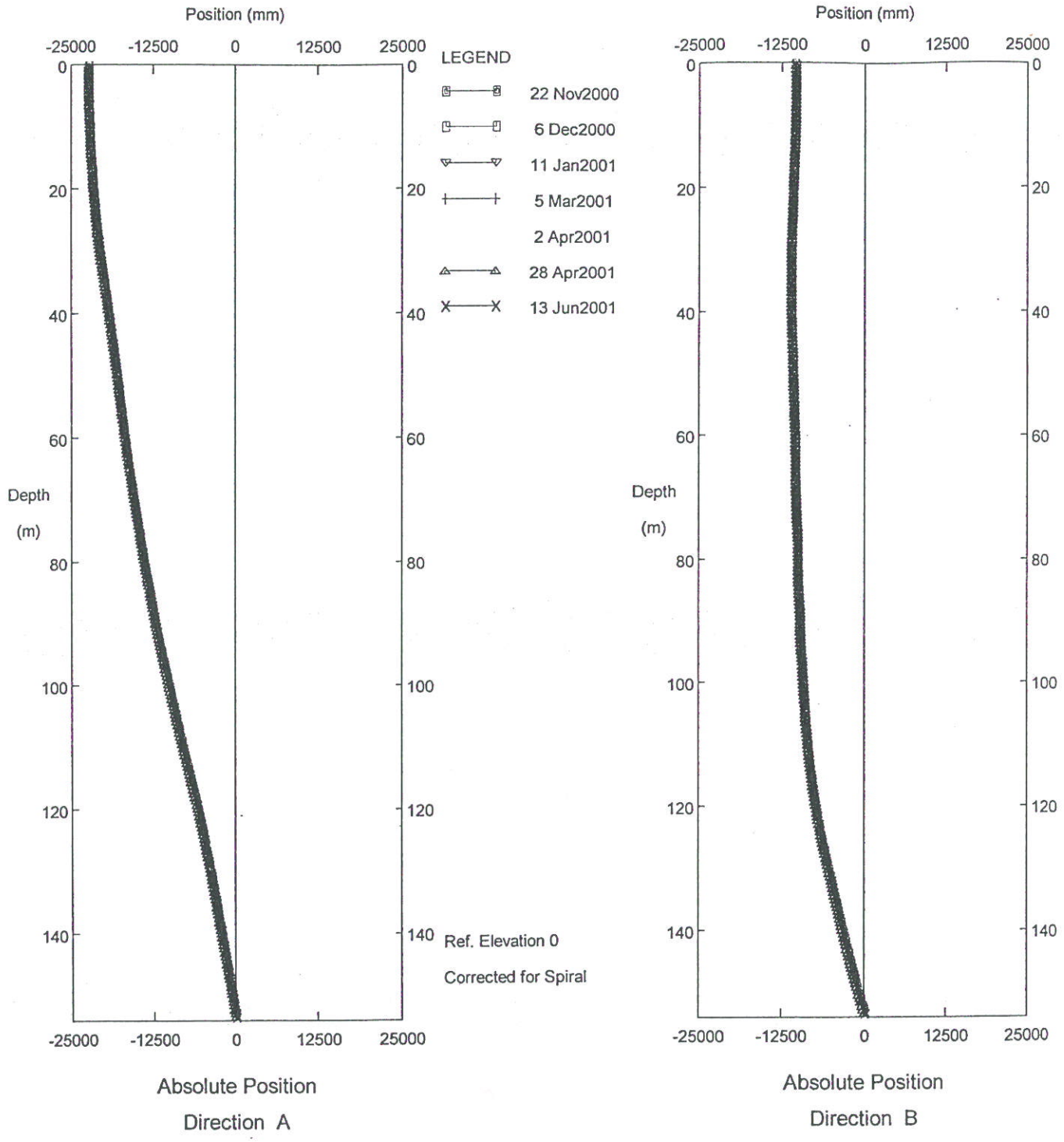
AMEC Earth and Environmental - Pr. George



KX03904 W. Quesnel Stability Study, Inclinometer SI-5 Corr.

Abbott Drive

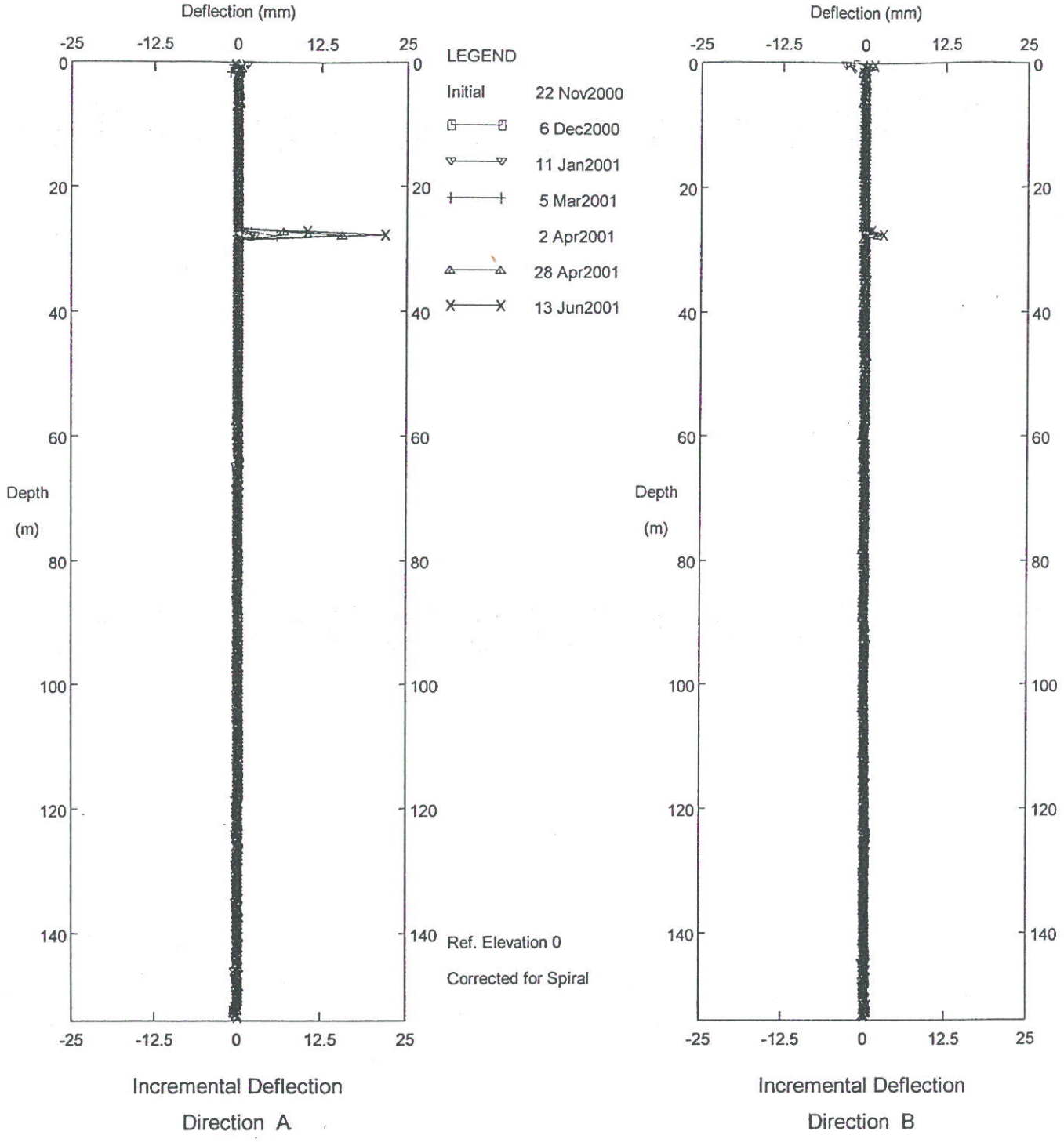
AMEC Earth and Environmental - Pr. George



KX03904 W.Quesnel Stability Study, Inclinometer SI-6 Corr.

End of Dixon Street

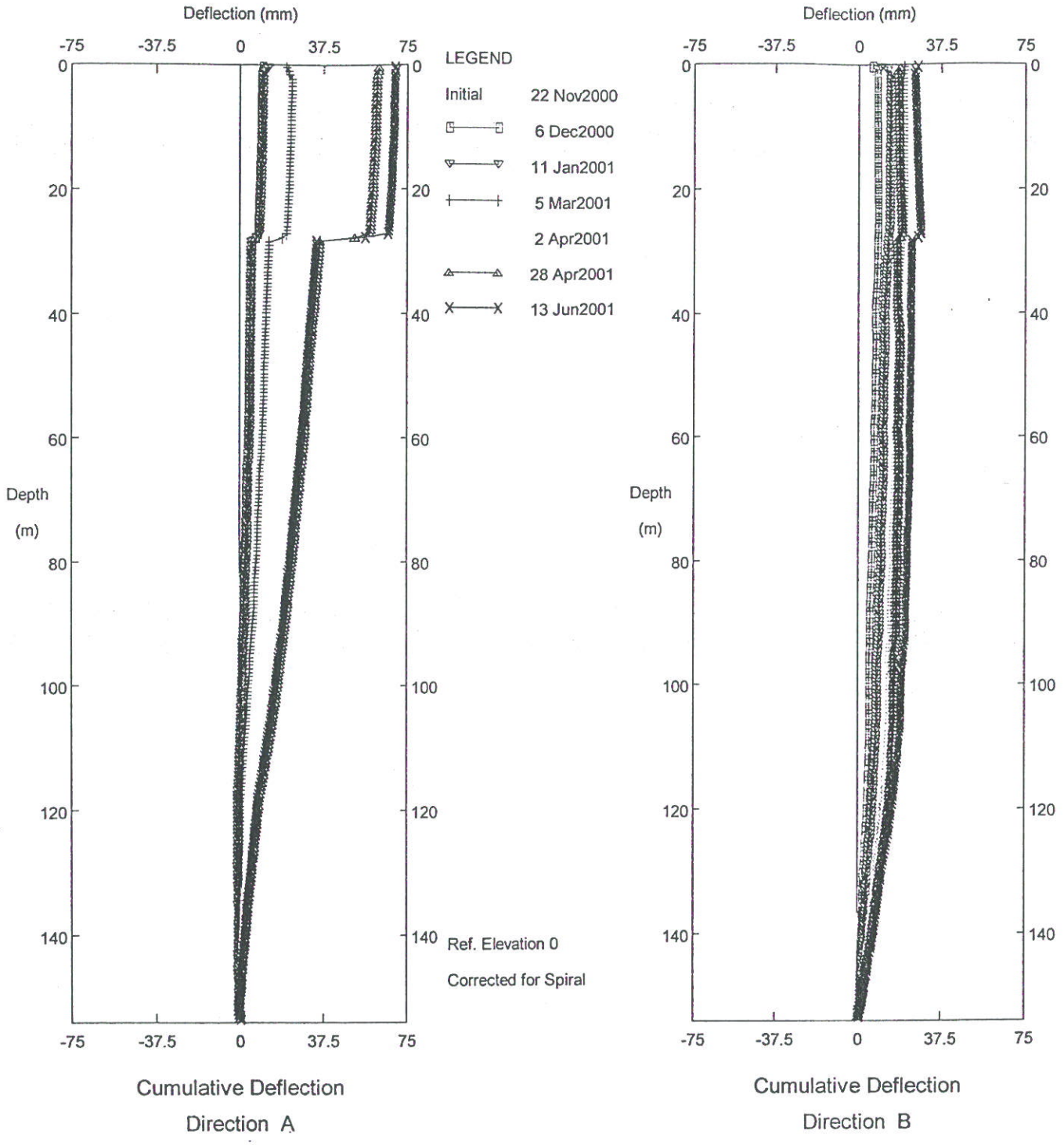
AMEC Earth and Environmental - Pr. George



KX03904 W.Quesnel Stability Study, Inclinometer SI-6 Corr.

End of Dixon Street

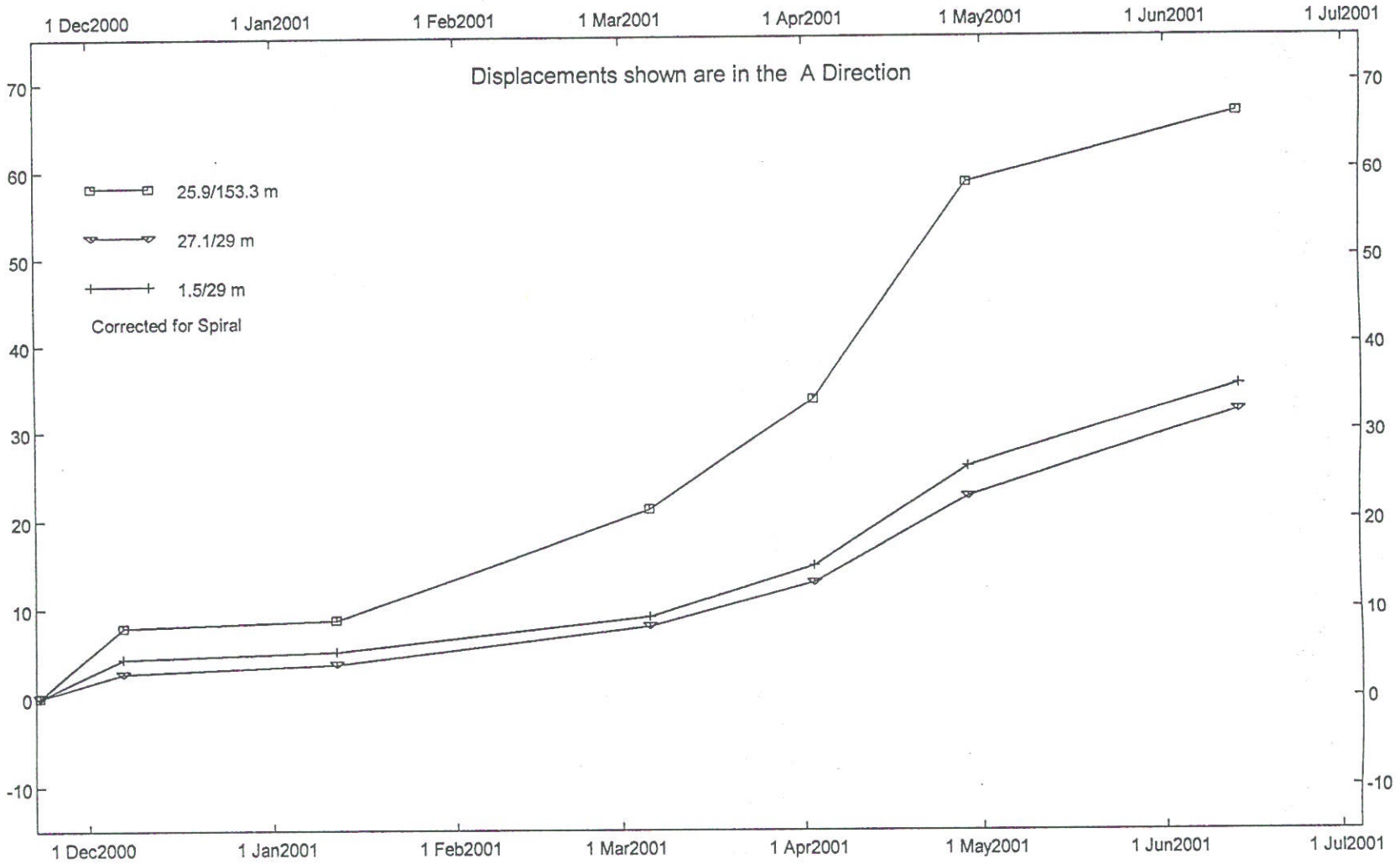
AMEC Earth and Environmental - Pr. George



KX03904 W.Quesnel Stability Study, Inclinometer SI-6 Corr.

End of Dixon Street

AMEC Earth and Environmental - Pr. George

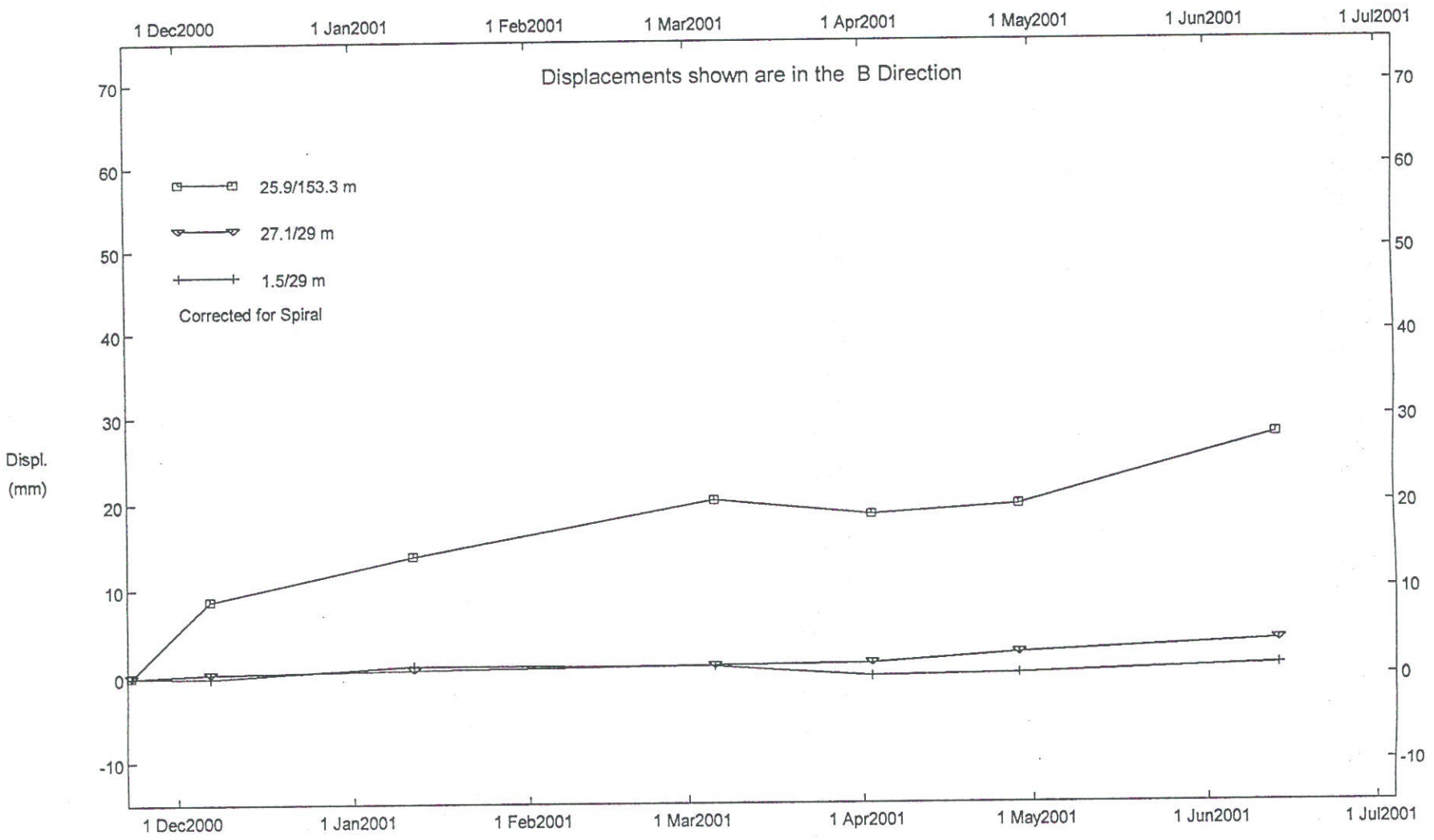


Displ. (mm)

KX03904 W.Quesnel Stability Study, Inclinometer SI-6 Corr.

End of Dixon Street

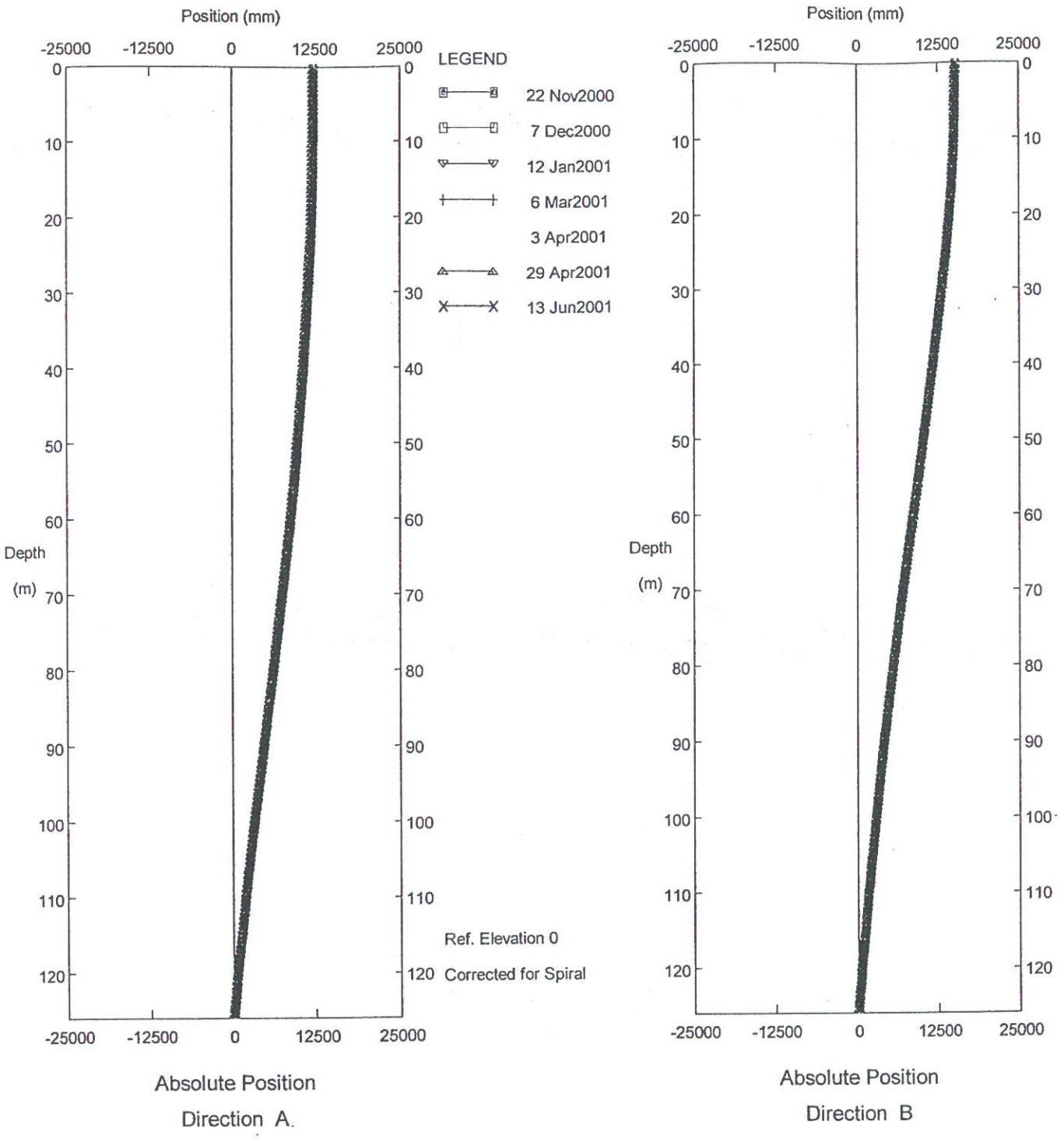
AMEC Earth and Environmental - Pr. George



KX03904 W.Quesnel Stability Study, Inclinometer SI-6 Corr.

End of Dixon Street

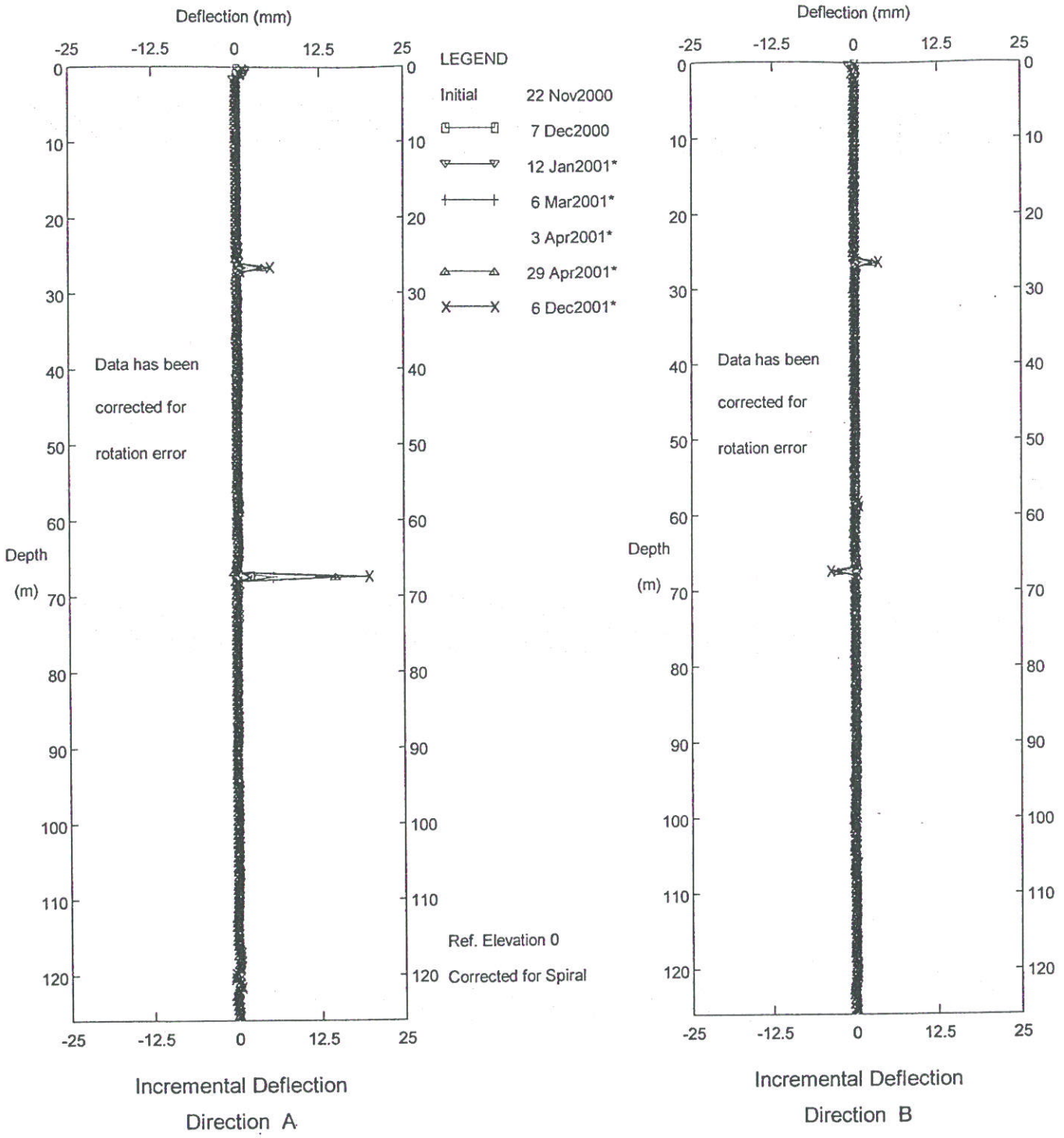
AMEC Earth and Environmental - Pr. George



KX03904 W. Quesnel Stability Study, Inclinometer SI-7 Corr.

Pierce Crescent & Lewis Drive

AMEC Earth and Environmental - Pr. George

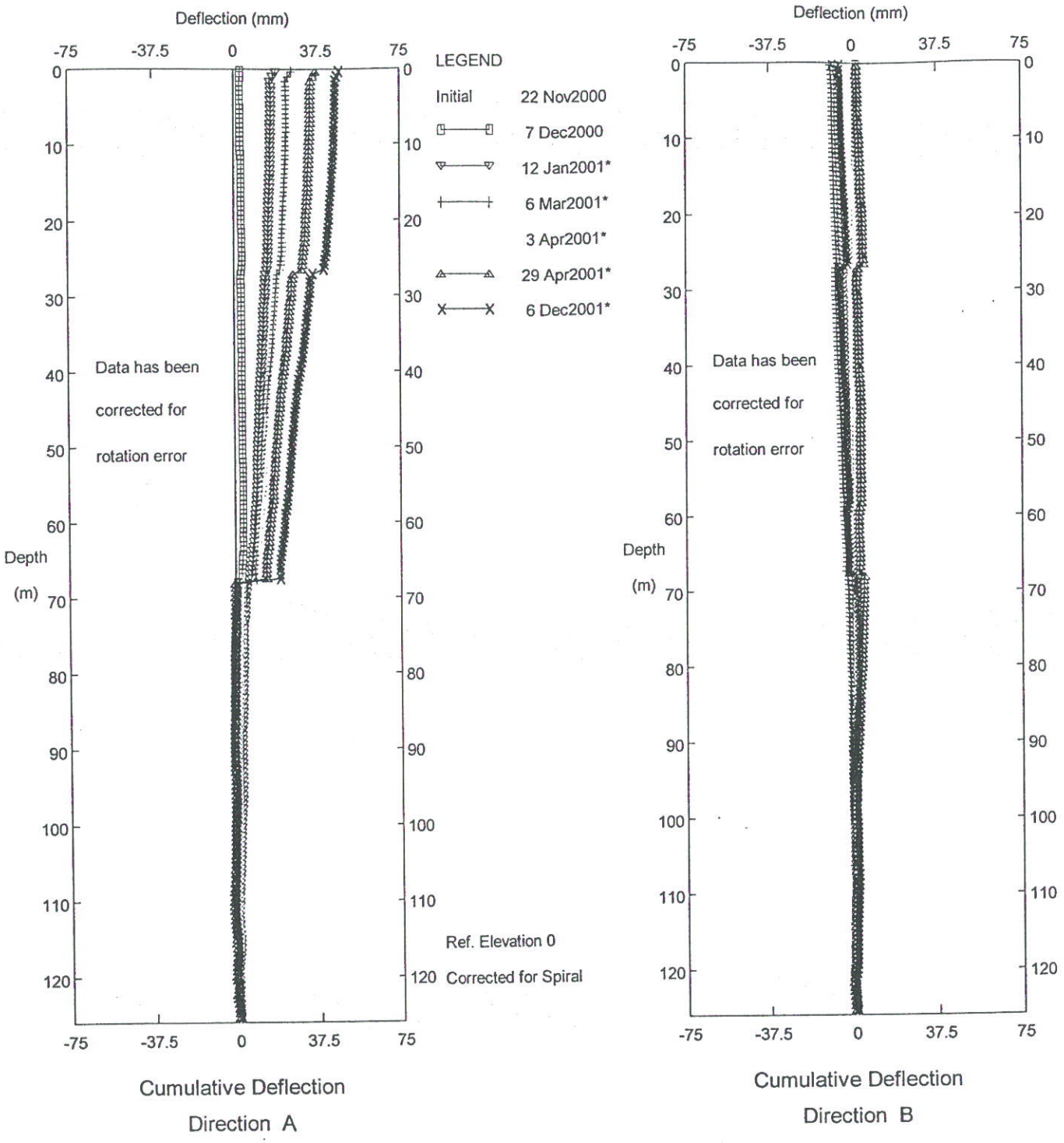


KX03904 W. Quesnel Stability Study, Inclinometer SI-7 Corr.

Pierce Crescent & Lewis Drive

Sets marked * include zero shift and/or rotation corrections.

AMEC Earth and Environmental - Pr. George

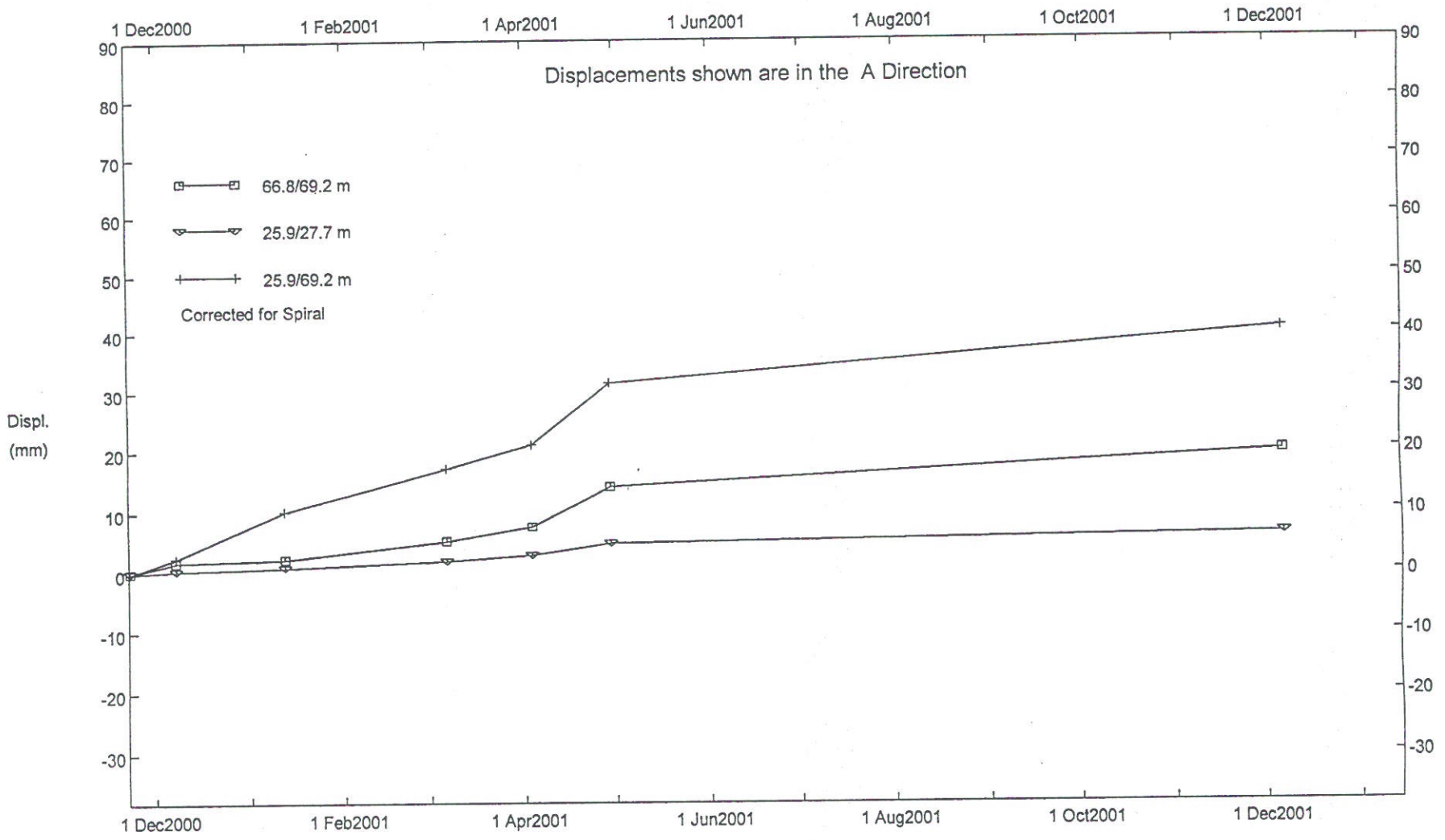


KX03904 W. Quesnel Stability Study, Inclinometer SI-7 Corr.

Pierce Crescent & Lewis Drive

Sets marked * include zero shift and/or rotation corrections.

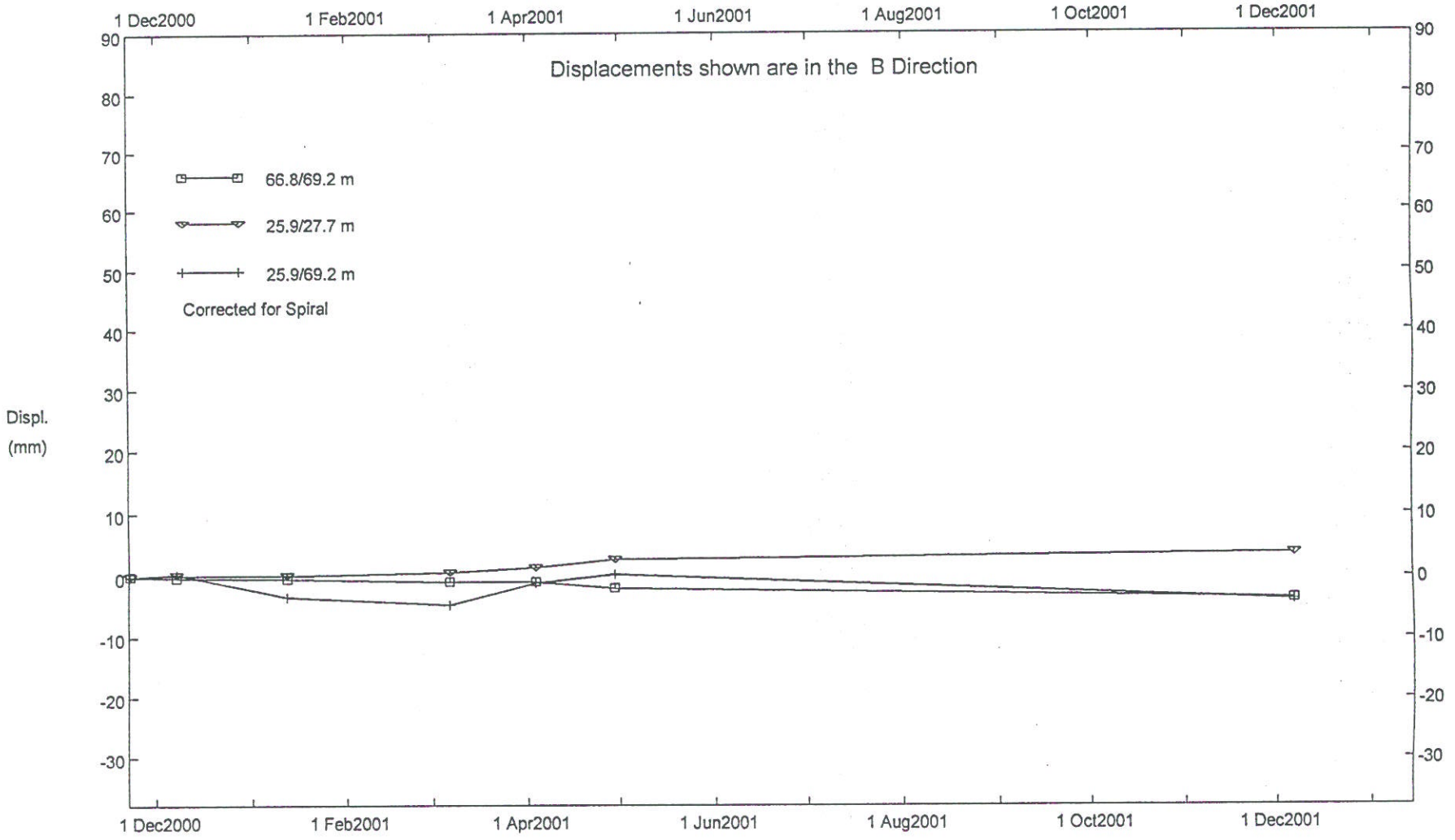
AMEC Earth and Environmental - Pr. George



KX03904 W. Quesnel Stability Study, Inclinometer SI-7 Corr.

Pierce Crescent & Lewis Drive

AMEC Earth and Environmental - Pr. George



KX03904 W. Quesnel Stability Study, Inclinometer SI-7 Corr.

Pierce Crescent & Lewis Drive

Summary of BC Gas Monitoring Data from September 1998 to May 2001

Station Number	Location (Landmark, Road)	September, 1998			December, 1998		
		Northing (m)	Easting (m)	Elevation (m ASL)	Northing (m)	Easting (m)	Elevation (m ASL)
2	Donnely/Dodds Intersection	5869992.878	531420.902	563.021	5869992.871	531420.907	563.014
4	Picard Place (Lane)	5870331.949	531626.829	557.171	5870331.961	531626.828	557.163
5	East of Dawson/Lewis Intersection	5870180.442	531627.209	551.978	5870180.445	531627.216	551.965
6	Paley West	5870474.774	531664.168	539.628	5870474.771	531664.179	539.615
7	Paley East	5870427.297	531932.241	533.473	5870427.299	531932.249	533.467
8	Picard Avenue	5870328.580	531909.295	536.943	5870328.580	531909.287	536.905
9	Lane between Patchett/Pierce	5870063.599	531714.863	549.785	5870063.588	531714.875	549.766
14	Pentland/Flamingo Intersection	5870067.437	531986.027	531.224	5870067.435	531986.023	531.210
15	Palmer/Lewis Intersection	5870275.888	532052.513	524.385	5870275.892	532052.515	524.393
16	Healy Road	5870413.504	532184.864	509.104	5870413.499	532184.859	509.086
17	Bettcher/Lark Intersection	5869847.647	532237.862	519.610	5869847.634	532237.872	519.599
18	Lark/Flamingo Intersection	5869826.923	531984.617	524.147	5869826.929	531984.611	524.132
19	Abbott/Flamingo Intersection	5869596.532	531978.061	517.225	5869596.534	531978.063	517.219
20	Hawk Street @ Crane Ave.	5869364.259	532199.105	504.356	5869364.263	532199.109	504.333
21	Lane between Avery/Allison	5869342.996	532493.483	485.474	5869343.005	532493.492	485.459
22	Lane between Beath/Bouchie	5869628.968	532631.086	478.920	5869628.968	532631.095	478.920
23	Doherty Dr. - BM	5869134.064	532888.607	475.384	5869134.061	532888.608	475.357
24	Salton Road (Hixon Road)	5878341.399	531399.210	589.609	5878341.373	531399.217	589.567
26	Benchmark by Airport - BM	5873887.634	533765.361	545.429	5873887.622	533765.361	545.406
28	Red Bluff Pump Station - BM	5870190.608	537039.418	595.773	5870190.608	537039.418	595.773
29	Quesnel Hill	5870484.887	536304.120	575.014	5870484.893	536304.135	575.004
82C256	**Government Benchmark at Airport**				**5875411.453**	**533109.702**	**542.947**

Appendix E

Summary of BC Gas Monitoring Data from September 1998 to May 2001

Station Number	Location (Landmark, Road)	April, 1999			December, 1999		
		Northing (m)	Easting (m)	Elevation (m ASL)	Northing (m)	Easting (m)	Elevation (m ASL)
2	Donnely/Dodds Intersection	5869992.867	531420.931	563.007	5869992.879	531420.978	563.027
4	Picard Place (Lane)	5870331.956	531626.856	557.150	5870331.993	531626.885	557.160
5	East of Dawson/Lewis Intersection	5870180.438	531627.250	551.951	5870180.448	531627.288	551.953
6	Paley West	5870474.788	531664.208	539.613	5870474.805	531664.239	539.608
7	Paley East	5870427.300	531932.279	533.462	5870427.321	531932.307	533.461
8	Picard Avenue	5870328.581	531909.314	536.909	5870328.609	531909.354	536.909
9	Lane between Patchett/Pierce	5870063.593	531714.910	549.753	5870063.614	531714.965	549.774
14	Pentland/Flamingo Intersection	5870067.428	531986.061	531.205	5870067.441	531986.116	531.199
15	Palmer/Lewis Intersection	5870275.902	532052.557	524.361	5870275.903	532052.589	524.376
16	Healy Road	5870413.501	532184.880	509.054	5870413.509	532184.907	509.068
17	Bettcher/Lark Intersection	5869847.634	532237.910	519.610	5869847.644	532237.958	519.608
18	Lark/Flamingo Intersection	5869826.930	531984.639	524.126	5869826.923	531984.695	524.127
19	Abbott/Flamingo Intersection	5869596.525	531978.098	517.218	5869596.519	531978.134	517.213
20	Hawk Street @ Crane Ave.	5869364.256	532199.136	504.327	5869364.259	532199.176	504.353
21	Lane between Avery/Allison	5869342.998	532493.516	485.473	5869342.998	532493.539	485.478
22	Lane between Beath/Bouchie	5869628.972	532631.109	478.920	5869628.969	532631.117	478.922
23	Doherty Dr. - BM	5869134.068	532888.623	475.365	5869134.069	532888.628	475.374
24	Salton Road (Hixon Road)	5878341.391	531399.224	589.587	5878341.393	531399.221	589.596
26	Benchmark by Airport - BM	5873887.631	533765.364	545.407	5873887.630	533765.367	545.409
28	Red Bluff Pump Station - BM	5870190.608	537039.418	595.773	5870190.608	537039.418	595.773
29	Quesnel Hill	5870484.898	536304.133	574.998	5870484.896	536304.133	575.002
82C256	**Government Benchmark at Airport**	**5875411.453**	**533109.702**	**542.947**	**5875411.453**	**533109.702**	**542.947**

Summary of BC Gas Monitoring Data from September 1998 to May 2001

Station Number	Location (Landmark, Road)	February, 2000			May, 2000		
		Northing (m)	Easting (m)	Elevation (m ASL)	Northing (m)	Easting (m)	Elevation (m ASL)
2	Donnely/Dodds Intersection	5869992.874	531420.976	563.006	5869992.860	531420.991	563.009
4	Picard Place (Lane)	5870331.985	531626.884	557.159	5870332.002	531626.898	557.136
5	East of Dawson/Lewis Intersection	5870180.447	531627.289	551.948	5870180.448	531627.297	551.936
6	Paley West	5870474.829	531664.236	539.608	5870474.840	531664.240	539.586
7	Paley East	5870427.327	531932.311	533.457	5870427.334	531932.321	533.449
8	Picard Avenue	5870328.601	531909.349	536.907	5870328.607	531909.363	536.886
9	Lane between Patchett/Pierce	5870063.597	531714.959	549.773	5870063.593	531714.979	549.763
14	Pentland/Flamingo Intersection	5870067.437	531986.106	531.221	5870067.432	531986.128	531.198
15	Palmer/Lewis Intersection	5870275.906	532052.581	524.364	5870275.909	532052.594	524.343
16	Healy Road	5870413.515	532184.912	509.064	5870413.516	532184.916	509.071
17	Bettcher/Lark Intersection	5869847.634	532237.962	519.603	5869847.626	532237.988	519.593
18	Lark/Flamingo Intersection	5869826.919	531984.684	524.127	5869826.903	531984.719	524.125
19	Abbott/Flamingo Intersection	5869596.525	531978.140	517.238	5869596.502	531978.164	517.224
20	Hawk Street @ Crane Ave.	5869364.255	532199.171	504.340	5869364.247	532199.193	504.330
21	Lane between Avery/Allison	5869342.994	532493.539	485.472	5869342.985	532493.547	485.486
22	Lane between Beath/Bouchie	5869628.979	532631.117	478.918	5869628.964	532631.113	478.913
23	Doherty Dr. - BM	5869134.068	532888.624	475.373	5869134.069	532888.617	475.376
24	Salton Road (Hixon Road)	5878341.378	531399.228	589.599	5878341.380	531399.216	589.577
26	Benchmark by Airport - BM	5873887.631	533765.367	545.417	5873887.633	533765.368	545.406
28	Red Bluff Pump Station - BM	5870190.608	537039.418	595.773	5870190.608	537039.418	595.773
29	Quesnel Hill	5870484.896	536304.131	575.008	5870484.892	536304.131	574.995
82C256	**Government Benchmark at Airport**	**5875411.453**	**533109.702**	**542.946**	**5875411.453**	**533109.702**	**542.946**

Summary of BC Gas Monitoring Data from September 1998 to May 2001

Station Number	Location (Landmark, Road)	December, 2000			May, 2001		
		Northing (m)	Easting (m)	Elevation (m ASL)	Northing (m)	Easting (m)	Elevation (m ASL)
2	Donnely/Dodds Intersection	5869992.847	531421.038	562.998	5869992.846	531421.051	562.986
4	Picard Place (Lane)	5870332.013	531626.939	557.146	5870332.019	531626.936	557.100
5	East of Dawson/Lewis Intersection	5870180.441	531627.341	551.947	5870180.438	531627.349	551.923
6	Paley West	5870474.883	531664.276	539.588	5870474.886	531664.285	539.551
7	Paley East	5870427.348	531932.349	533.436	5870427.359	531932.364	533.417
8	Picard Avenue	5870328.636	531909.396	536.885	5870328.636	531909.408	536.872
9	Lane between Patchett/Pierce	5870063.603	531715.031	549.752	5870063.598	531715.033	549.740
14	Pentland/Flamingo Intersection	5870067.429	531986.169	531.198	5870067.422	531986.189	531.193
15	Palmer/Lewis Intersection	5870275.922	532052.628	524.353	5870275.914	532052.630	524.335
16	Healy Road	5870413.524	532184.943	509.062	5870413.522	532184.942	509.052
17	Bettcher/Lark Intersection	5869847.618	532238.022	519.580	5869847.619	532238.054	519.581
18	Lark/Flamingo Intersection	5869826.907	531984.751	524.107	5869826.892	531984.774	524.104
19	Abbott/Flamingo Intersection	5869596.531	531978.200	517.202	5869596.487	531978.205	517.207
20	Hawk Street @ Crane Ave.	5869364.240	532199.240	504.315	5869364.221	532199.244	504.315
21	Lane between Avery/Allison	5869343.007	532493.555	485.488	5869342.971	532493.555	485.475
22	Lane between Beath/Bouchie	5869628.980	532631.118	478.908	5869628.962	532631.106	478.908
23	Doherty Dr. - BM	5869134.081	532888.636	475.383	5869134.053	532888.618	475.346
24	Salton Road (Hixon Road)	5878341.379	531399.224	589.591	5878341.388	531399.222	589.575
26	Benchmark by Airport - BM	5873887.631	533765.368	545.412	5873887.631	533765.369	545.407
28	Red Bluff Pump Station - BM	5870190.608	537039.418	595.773	5870190.608	537039.418	595.773
29	Quesnel Hill	5870484.890	536304.129	575.002	5870484.884	536304.133	574.998
82C256	**Government Benchmark at Airport**	**5875411.453**	**533109.702**	**542.946**	**5875411.453**	**533109.702**	**542.946**