

Project Number: 6-CD109.55

Landslide Monitoring Report – Sidey Street

6 April 2023

CONFIDENTIAL



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Disclaimers and Limitations

This report (**'Report'**) has been prepared by WSP New Zealand Limited exclusively for Dunedin City Council (**'Client'**) in relation to the landslide monitoring at selected sites in Dunedin (Landslide Monitoring Long-Term SoW DCC Reference 9662). The scope of this report is to present the survey monitoring results and recommendations for future surveys for the site (**'Purpose'**). The findings in this Report are based on and subject to the assumptions specified in the Report. WSP accepts no liability whatsoever for any reliance on or use of this Report, in whole or in part, for any use or purpose other than the Purpose or any use or reliance on the Report by any third party.

Executive Summary

A recent survey of the Sidey Street site was undertaken in December 2022 to assess the extent of movements compared with previous surveys. Deformations found to exceed the accuracy of the survey (± 10 mm horizontal, ± 10 mm vertical) are presented in Table 1.

Table 1: Summary of recorded displacements for the Sidey Street site.

	Horizontal	Vertical
Displacements from the previous survey	N/A	N/A
Displacements from the original survey	N/A	10 mm

The results indicate there is no definitive movement occurring as all deformations are within the accuracy of the survey. Given that no conclusive on-going movement trends have been established, we recommend that on-going surveys are to be undertaken on a one- or two-year basis.

1 Introduction

WSP New Zealand Limited (WSP) have been commissioned by Dunedin City Council (DCC) to undertake monitoring of 12 landslide sites around Dunedin. The purpose of monitoring is to identify the trend and magnitude of movements and provide recommendations for future monitoring.

This report presents a summary of the factual survey monitoring results for the Sidey Street site, as well as monitoring recommendations. A mark displacement diagram is provided in Appendix A.

2 Survey Monitoring

2.1 Monitoring History

Monitoring at Sidey Street began in 1997 with an initial survey network that was monitored until 2010 when the initial survey network was damaged beyond repair from footpath construction works. The network was subsequently re-established with new survey marks in November 2010 and has been monitored ever since. WSP completed their first survey of the site in December 2021, however these results were not reported on at the time due to budget constraints.

2.2 Methodology

The survey was completed by WSP Surveyors in December 2022. Coordinates were derived from horizontal angles and distances using a 3" Trimble S6 robotic total station on 2 December 2022, while heights were determined using a Leica DNA03 digital level on 5 December.

2.2.1 Field Survey

The total station was set over nail 1 and a resection completed using control nails 2, 3, 4, 5, and 6. The calculated resection coordinate was reported as the coordinate for nail 1. This setup was then used to take two rounds of measurements on all other monitoring marks. A mini-prism was used to minimise plumbing errors.

Digital levelling was completed in three runs between nail 2 and nail 14, nail 14 and nail 8, and nail 8 and nail 6. Each run was closed onto the starting coordinate, forming a closed loop. Setups were positioned roughly in the midpoint between foresight and backsight to minimise the effect of any collimation error.

2.2.2 Office Processing

Trimble Business Centre was used to process the field data. Total station data was adjusted using the network adjustment tool holding nails 2, 3, 4, 5, and 6 fixed horizontally. This produced a satisfactory SEUW of 0.74, meaning the total station data is more precise than expected. Level data was also processed using the TBC level editor, with all run miscloses within tolerance. Heights were transferred from nail 2, which was chosen as a fixed point due to its distance from the movement zone.

2.2.3 Geodetic Parameters

The survey is completed using a false datum around 8000 mN, 5000 mE, with heights around 100 m. Control coordinates from this and previous surveys must be used to make comparisons in future.

2.3 Accuracy

The survey has been undertaken to the following accuracy:

- Horizontal position +/- 10 mm
- Vertical position +/- 10 mm

3 Monitoring Results

The cumulative results spreadsheet is presented in Appendix C. A summary of the monitoring results is presented in Table 2.

Table 2: Summary of deformation monitoring results since the previous and base surveys.

	Deformation since previous survey		Deformation since base survey	
	Horizontal	Vertical	Horizontal	Vertical
Average*	<10 mm	<10 mm	<10 mm	<10 mm
Maximum	<10 mm	<10 mm	<10 mm	10 mm

* Deformations less than the accuracy of the survey (± 10 mm horizontal, ± 10 mm vertical) were excluded when calculating averages.

3.1 Future Monitoring

No significant movement has been detected in this survey. Continue monitoring in late 2023.

4 Rainfall Data

A summary of the rainfall data since the previous survey is presented in Figure 1. The rainfall data was retrieved from the NIWA (National Institute of Water and Atmospheric Research) National Climate Database website ([CliFlo.niwa.co.nz](https://cliFlo.niwa.co.nz)) using the Musselburgh Station (Agent ID #15752).

Mean monthly rainfall is calculated for the “Dunedin” area using data between 1981 and 2010 (source: <https://niwa.co.nz/education-and-training/schools/resources/climate/meanrain>).

Significant rainfall during July 2022 is evident in Figure 1, whereby 235 mm was recorded in the calendar month, including 97.6 mm on 12 – 13 July and 94.6 mm on 26 – 28 July 2022.

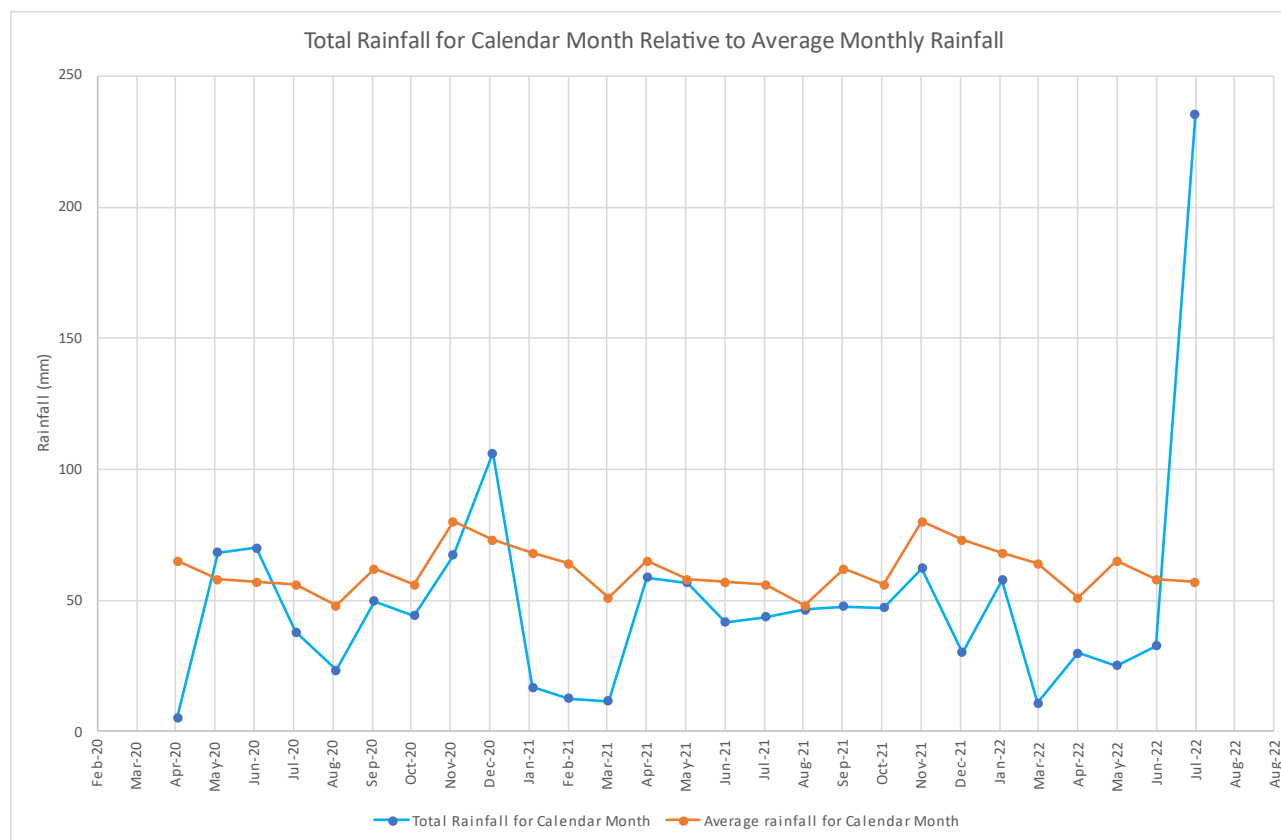


Figure 1: Measured monthly rainfall compared with average monthly rainfall (Climo.niwa.co.nz).

5 Conclusions and Recommendations

The maximum displacements recorded since the base survey was completed are as follows:

- <10 mm horizontally,
- 10 mm vertically.

The review of survey data back to the base survey conducted in 2010 shows no conclusive trend of movement. The deformations recorded between surveys have so far not exceeding the accuracy of the survey. Additional surveys will be required to establish if there is movement actively occurring.

Furthermore, positive vertical deformations have been recorded across multiple survey marks, which is atypical of landslides. This is possibly attributable to some of the control points residing within the zone of movement. On this basis it is recommended that additional control points are established outside of the observed zone of movement. Surveys are recommended to continue on one- or two-yearly intervals, using the same survey method described in Section 2.

Appendix A

Mark Displacement Diagram

LEGEND

LANDSLIDE - OTAGO REGION (CERTAINTY)

- DEFINITE
- LIKELY
- POSSIBLE
- NOT ASSESSED
- NO INFORMATION

INDICATIVE LANDSLIDE EXTENTS ARE BASED ON "REVISED LANDSLIDE DATABASE FOR THE COASTAL SECTOR OF THE DUNEDIN CITY DISTRICT" BY BARRELL, D.J.A., SMITH LITTLE, B., GLASSEY, P.J. GNS SCIENCE CONSULTANCY REPORT 2017/41, JULY 2017, SOURCED FROM THE OTAGO REGIONAL COUNCIL (ORC) NATURAL HAZARDS PORTAL.

OTHER

- +/- Xmm = CUMULATIVE VERTICAL DISPLACEMENT SINCE THE BASE SURVEY
- CUMULATIVE HORIZONTAL DISPLACEMENT SINCE THE BASE SURVEY (1:1000 SCALE)
- SURVEY MARKER



1:250 @ A1
1:500 @ A3

REVISION	AMENDMENT	APPROVED	DATE
A	2022 DEFORMATION MONITORING DATA	SK	10/01/2023



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CIVIL

SCALES			ORIGINAL SIZE
N.T.S			A1
DRAWN	SURVEYED	APPROVED	
J.W	C.H	S.K	
DRAWING VERIFIED	DESIGN VERIFIED	APPROVED DATE	
C.H	S.K	10/01/2023	

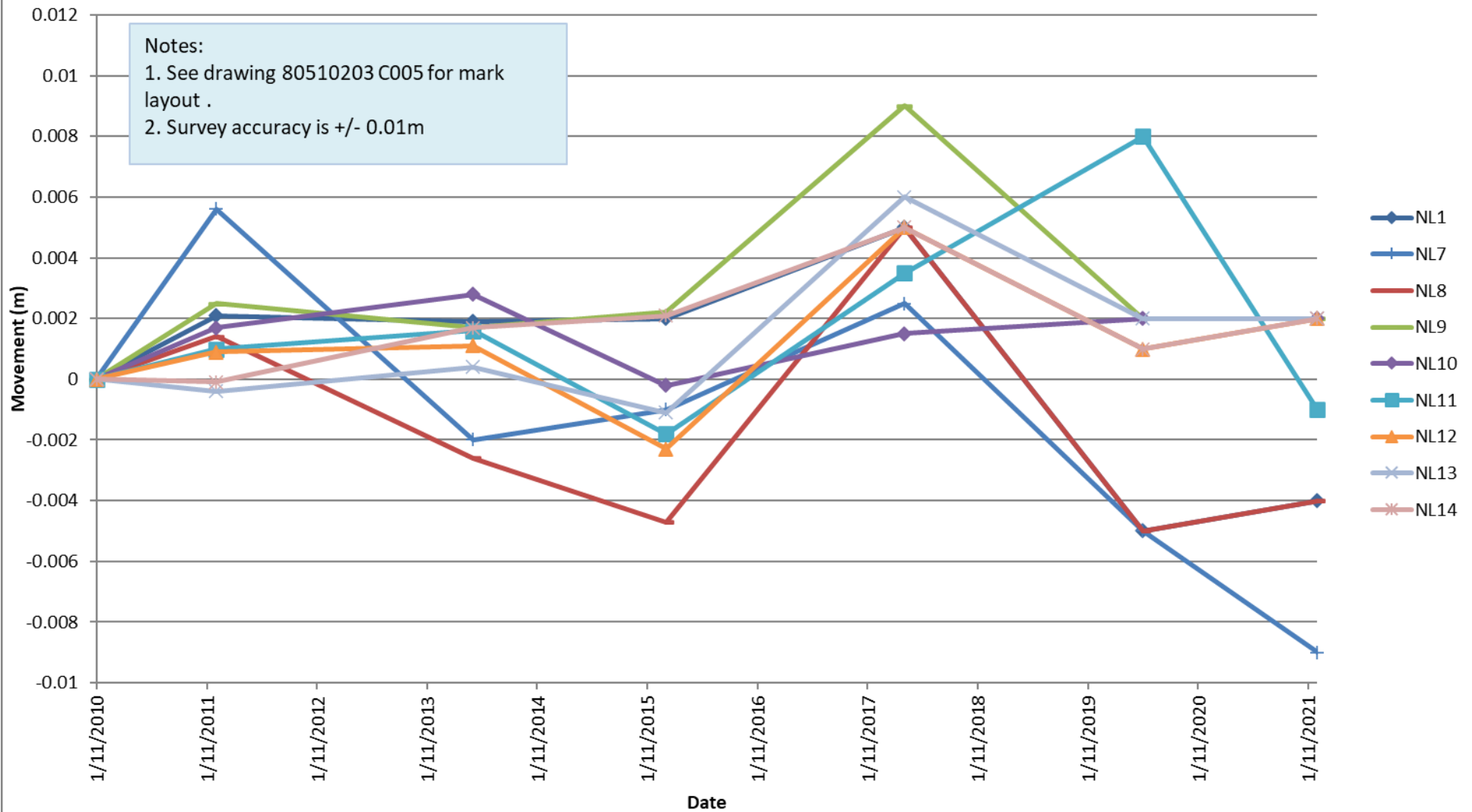
2022 SURVEY RESULTS

PROJECT DUNEDIN CITY COUNCIL SIDEY STREET LONG TERM LANDSLIDE MONITORING			
TITLE CUMULATIVE LANDSLIDE DISPLACEMENTS SIDEY STREET			
WSP PROJECT NO. 6-CD109.55	PROJ-ORIG-VOL-LOC-TYPE 6-CD109.55	SHEET NO. C01	REVISION A

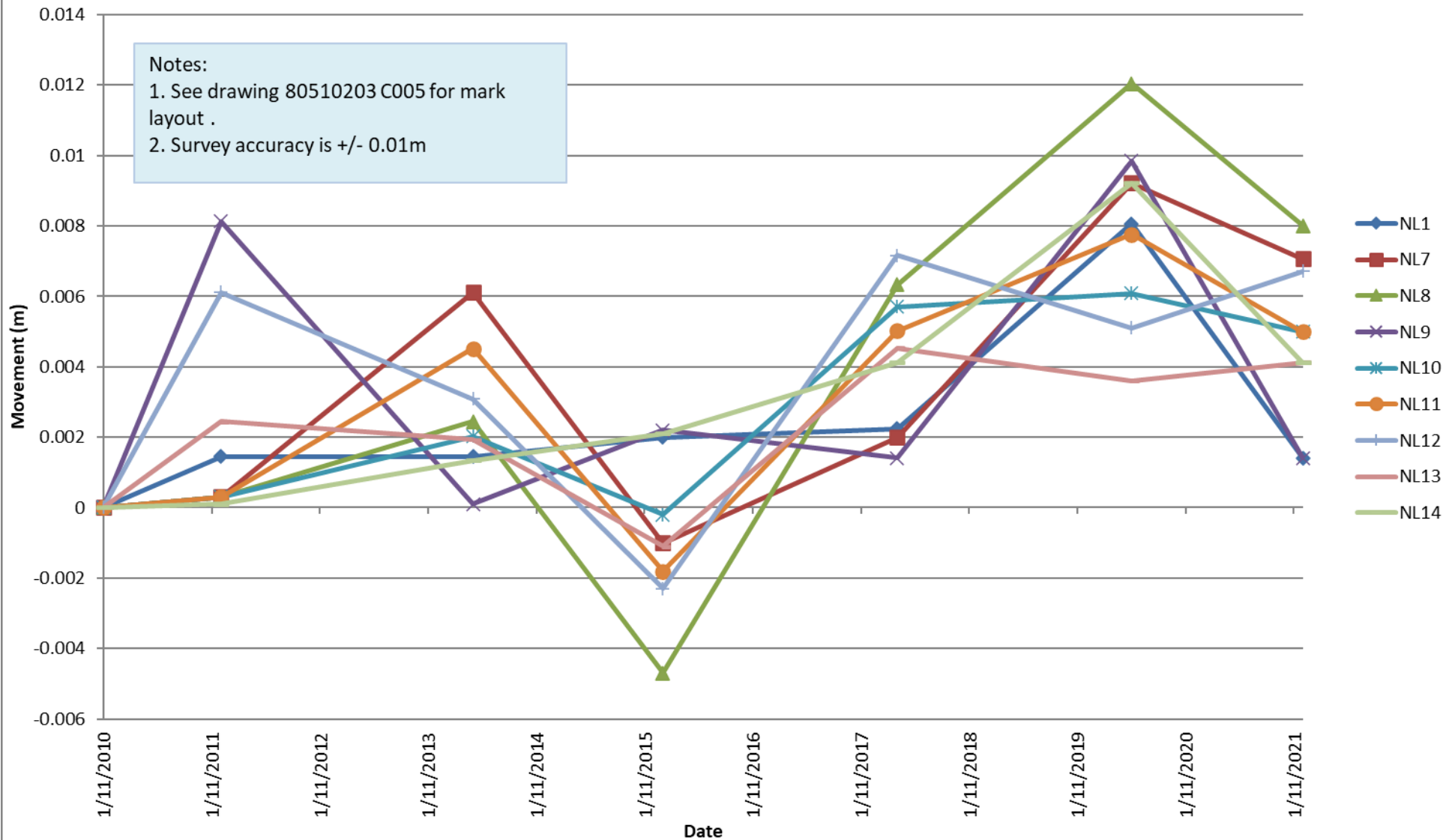
Appendix B

Selected Monitoring Charts

Sidey Street Landslide Monitoring
Chart 1: Vertical Deformation - November 2010 to present



Sidey Street Landslide Monitoring
Chart 2: Horizontal Deformation - November 2010 to present





Appendix C Cumulative Monitoring Results Spreadsheet

Survey 6:

2/12/2022

				Present to Previous			20/12/2021		Present to Original (Nov 2010)				
Mark	Northing	Easting	Height	dN	dE	Azim.	Dist	dRL	dN	dE	Azim.	Dist	dRL
NL1	8000.001	5000.000	95.598	0.000	0.001	90.000	0.001	0.003	0.001	0.000	0.000	0.001	-0.001
NL2	8000.000	4899.997	89.580	0.000	0.000	270.000	0.000	0.000	0.000	0.000	270.000	0.000	0.000
NL3	7991.974	4985.424	94.763	0.000	0.000	0.000	0.000	0.006	0.000	0.000	0.000	0.000	0.006
NL4	7990.881	4997.841	95.521						0.000	0.000	15.680	0.000	0.005
NL5	7988.076	5018.999	96.994	0.000	0.000	90.000	0.000	0.009	0.000	0.000	90.000	0.000	0.009
NL6	7977.722	5075.746	100.541	0.000	0.000	197.475	0.000	-0.010	0.000	0.000	197.475	0.000	-0.010
NL7	7990.727	5054.317	99.070	0.000	-0.001	270.000	0.001	-0.002	0.007	0.000	0.000	0.007	-0.011
NL8	7995.636	5020.202	96.875	0.000	-0.002	270.000	0.002	-0.003	0.008	-0.002	345.964	0.008	-0.007
NL9	7996.815	5011.110	96.288	0.001	0.000	0.000	0.001	-0.001	0.002	-0.001	333.435	0.002	0.001
NL10	7997.751	5004.175	95.713	0.001	0.002	63.435	0.002	0.000	-0.002	-0.002	225.000	0.003	0.002
NL11	7998.654	4997.309	95.436	0.002	-0.001	333.435	0.002	0.004	-0.003	-0.001	198.435	0.003	0.003
NL12	7999.515	4990.363	95.058	0.002	0.004	63.435	0.004	0.000	-0.001	-0.002	243.435	0.002	0.002
NL13	8000.138	4983.461	94.670	-0.001	0.003	108.435	0.003	0.001	0.000	-0.001	270.000	0.001	0.003
NL14	8000.693	4975.719	94.233	-0.001	0.005	101.310	0.005	0.001	-0.002	0.001	153.435	0.002	0.003

