Project Number: 6-CD109.55

Landslide Monitoring Report – Howard Street

15 June 2023

CONFIDENTIAL

wsp

Contact Details

Bryce Harrison

WSP
197 Rattray Street
Dunedin
+64 3 471 5506
+64 27 258 7439
Bryce.Harrison@wsp.com

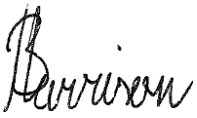
Document Details:

Date: 7/02/2023
Reference: 6-CD109.55
Status: Final

Prepared by

Christopher Hall | Surveyor

Prepared by:



Bryce Harrison | Graduate Geotechnical Engineer

Reviewed by:

Latasha Templeton | Service Line Leader – Engineering Geology

Approved for Release by:

P.P 

Abdul Obaid | Project Director

Document History and Status

Revision	Date	Author	Reviewed by	Approved by	Status
A	15/06/2023	Bryce Harrison/Christopher Hall	Latasha Templeton	Abdul Obaid	Final

Revision Details

Revision	Details
A	Final

Contents

List of Figures

List of Tables

List of Appendices

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 Howard Street site has been undertaken in December 2022 to assess the extent of movements compared with previous surveys. Deformations found to exceed the accuracy of the survey (± 15 mm horizontal, ±30 mm vertical) are presented in Table 1.

Table 1: Summary of recorded displacements.

	Horizontal	Vertical
Displacements from the previous survey	0 – 53 mm	-27 – +36 mm
Displacements from the original survey	4 – 222mm	-41 – +107mm

The results indicate that deformation is continuing. We recommend the next survey to be undertaken in late-2023 and late-2024.

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 Howard Street site, as well as monitoring recommendations. A mark displacement diagram is provided in Appendix A.

2 Survey Monitoring

2.1 Monitoring History

The network at Howard St was established and first surveyed in May 1998. Monitors have been undertaken on a roughly biennially, with increased frequency following slip events.

2.2 Methodology

The survey was completed by a WSP Surveyor on 7 December 2022. Two Trimble R8 GNSS receivers were used with the local base receiver logging static at 1 Hz and rover observing monitor marks in PPK mode.

2.2.1 Field Survey

The survey was completed using post processed kinematic measurement to a local base on IS 101, newly installed in 2021. This base logged static for the duration of the day. Before monitoring marks were measured, check marks were measured with static logging for 20 minutes at 1 Hz on AFF3, A23K, and newly installed Nail 102. New marks IS 101 and Nail 102 had been installed to increase redundancy. Historically, A23K had been reported with differing heights and AFF3 is now surrounded with visible signs of ground disturbance, being adjacent to a failing seawall. Accuracy of monitor mark observation has been improved from previous surveys where a fixed pole was used to now utilising a tripod and optical plumet. PPK shots were taken for 3 minutes to allow for a precise solution. This involved taking one shot for 90 seconds, waiting 60 seconds to allow satellite changes, then taking another 90 second shot with the receiver rotated 180 degrees. Doing this allows for a real time field assessment of the precision of the survey by comparing the two measurements.

2.2.2 Office Processing

PPK vectors were processed using Trimble Business Centre. RINEX data for the day was imported to TBC to constrain the survey in terms of the continually operating reference stations DUND and OUSD. Baselines between control points and monitoring marks were processed and the network adjusted giving a standard error of unit weight equal to 0.94 when minimally constrained, and 1.10 when constrained in 3D by DUND and AFF3 (X75), indicating an acceptable fit of the measured vectors to known control marks. Reported results are minimally constrained holding DUND fixed with baseline lengths of 800 – 1400m to the monitor marks. Monitor marks are also braced by baselines to the local base at IS 101 and OUSD.

2.2.3 Geodetic Parameters

The survey was completed in NZ Geodetic Datum 1949 North Taieri circuit in accordance with previous surveys. Historically, vertical datum was quoted as WGS84; however, it is likely that the ellipsoid used was International 1924 which is the conventional (local) ellipsoid for NZGD49. We note the historical record shows unusual upwards vertical movements, which is likely due to inconsistent geodetic parameters, but cannot be confirmed due to a lack of reporting record. It is important the geodetic parameters in Appendix D are maintained for future monitors.

2.3 Accuracy

The survey has been undertaken to the following accuracy:

Horizontal position: +/- 15mm (@ 95% CI)

Vertical position: +/- 30mm (@ 95% CI)

These figures have been affirmed using a statistical t-test.

2.4 Future Monitoring

Accuracy of results would improve with longer occupation time, however two shots of 90 seconds combined with the additional PPK baselines are considered sufficient. Of greater significance is the poor GNSS environment in some of the streets around the lower part of the monitor. This could get worse over time as trees grow larger, reducing satellite visibility. Some of these marks may be better suited to other measurement methods such as levelling.

As noted, historic control marks may become un-reliable for checking on in future. As this happens additional marks should be installed with primary checks continuing on IS 101 and Nail 102.

3 Monitoring Results

The cumulative results spreadsheet is presented in Appendix C. A summary of the monitoring results is presented in Table 2. Although height movements are positive from the baseline survey, they are negative compared to previous survey, indicating general subsidence (within survey tolerances). Directional movements are towards the harbour, as expected, also within tolerance.

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	29 mm	<30 mm	70 mm	50 mm
Maximum	53 mm	36 mm	222 mm	107 mm

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) using the Musselburgh Station (Agent ID #15752). Mean monthly rainfall was calculated for the Musselburgh Station using data between 1997 and 2022.

A significant rainfall event during July 2022 is evident in Figure 5, whereby 234 mm was recorded in the calendar month, including 98 mm on 13 – 14 July and 95 mm on 26 – 28 July 2022.

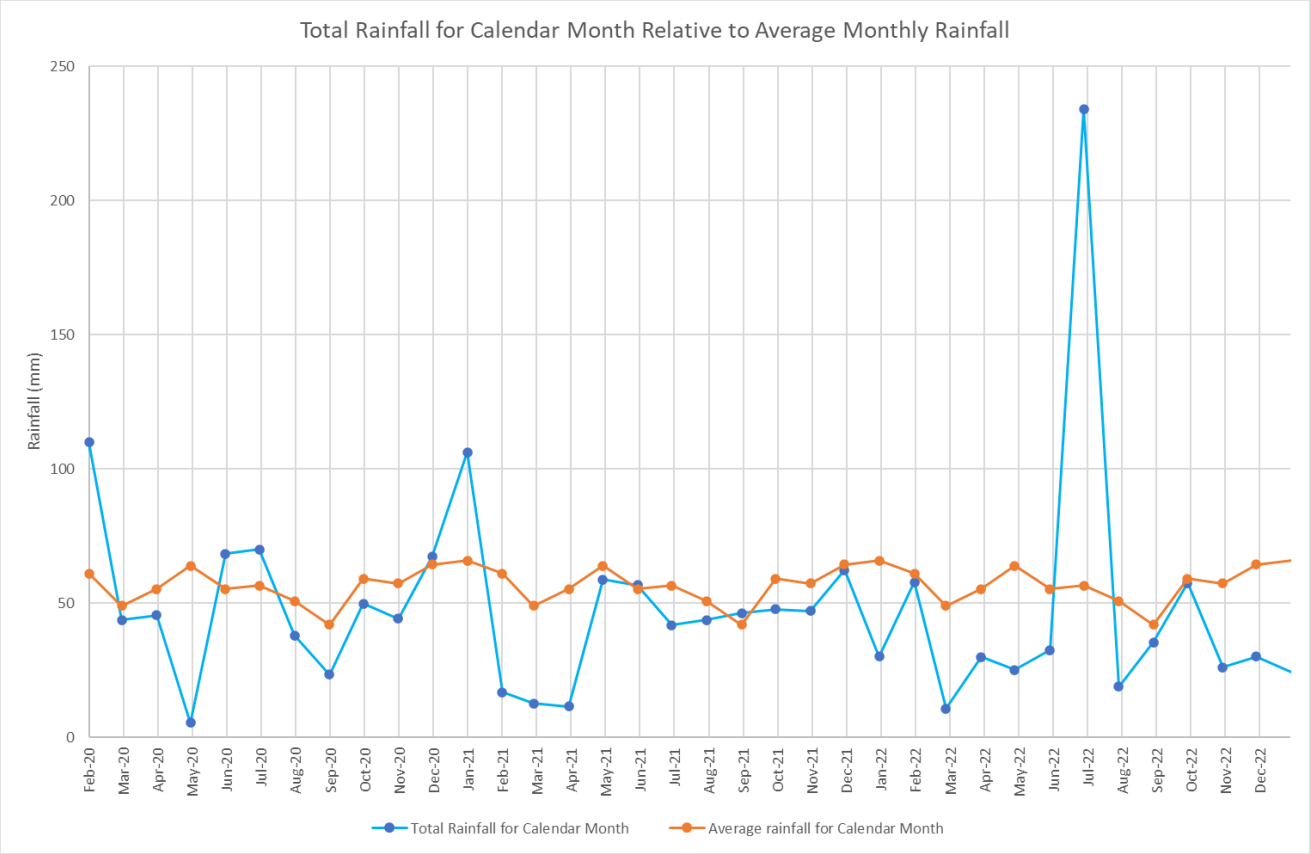


Figure 1: Measured monthly rainfall compared with average monthly rainfall (CliFlo.niwa.co.nz).

5 Conclusions and Recommendations

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

- 222 mm horizontally,
- 107 mm vertically.

When analysing survey data back to the base survey from 1998, there is clear indication that all the points are moving in the direction of the harbour. Maximum horizontal deformations recorded since the base survey have almost all exceeded the accuracy of the survey. However, positive vertical deformation has been reported across all but one of the survey marks, which is atypical of landslides. The current survey methodology has been developed to address the anomaly observed in the vertical deformations. It is expected that subsequent surveys will provide an improved observation of the vertical deformation trend.

It is recommended that the survey frequency is to continue on a yearly or two-yearly interval, using the same survey method described in Section 2. This will help establish a more reliable history of survey data. At present, deformations are still relatively minor but the last two surveys have indicated most of the deformations between surveys have exceeded the accuracy of the survey which may indicate an increase to the deformation rate.

If subsequent surveys indicate that the deformation rate is increasing, then it would be recommended to reduce the intervals between surveys. Increasing the survey frequency will provide a better understanding of the nature and conditions in which these deformations are occurring which will help to inform the risk posed to affected dwellings and strategies for long-term risk management.

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

1:2000@ A1
1:4000@ A3
0 20 40 60 80 100 120 140 160 180 200 m

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

DUNEDIN CITY COUNCIL | kaunihera a-rohe o Ōtepoti

wsp
Dunedin Office
+64 3 471 5500
Private Bag 1913
Dunedin 9016
New Zealand

CIVIL

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

2022 SURVEY RESULTS

PROJECT: DUNEDIN CITY COUNCIL
HOWARD STREET
LONG-TERM LANDSLIDE MONITORING

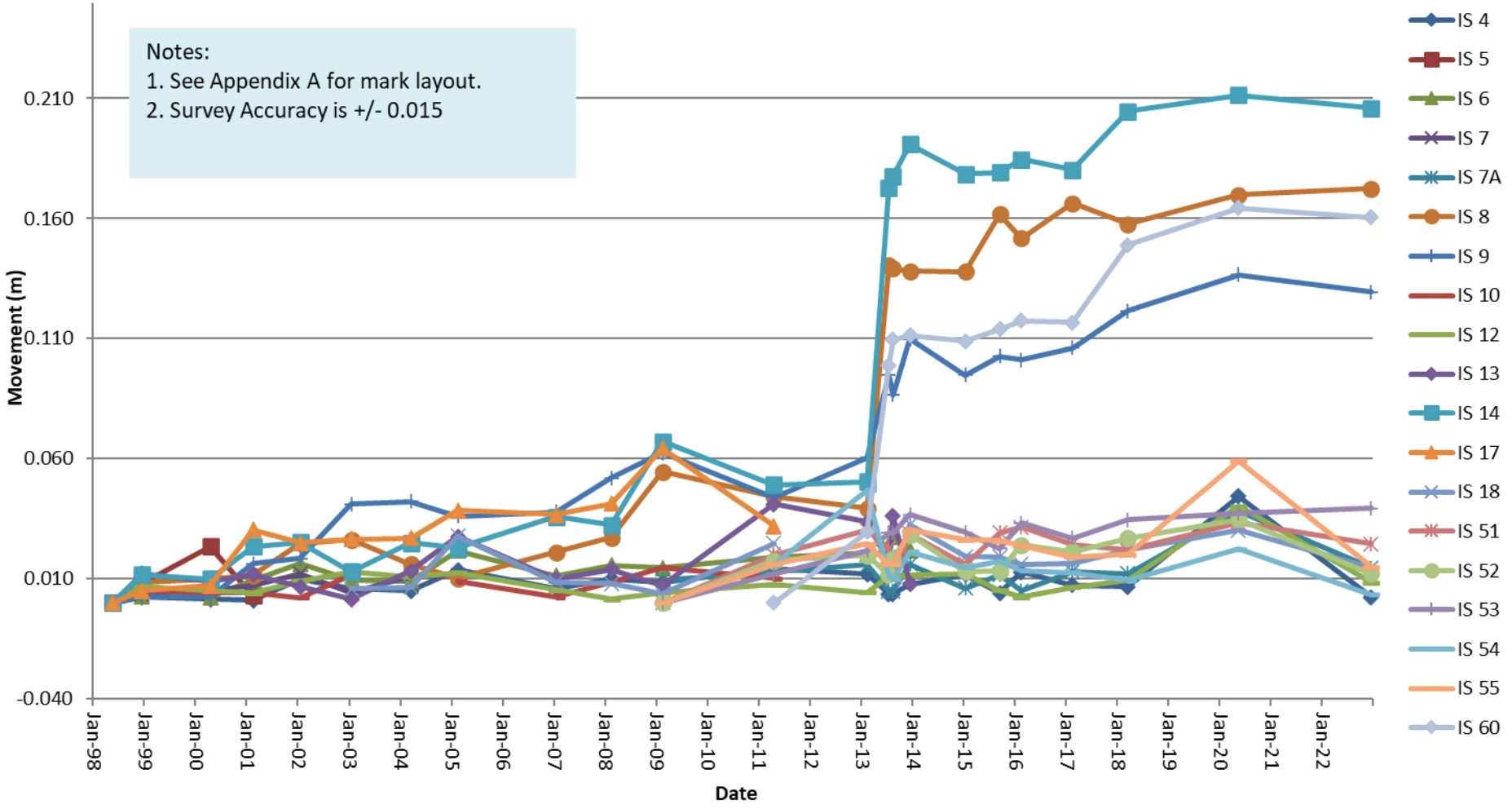
TITLE: CUMULATIVE LANDSLIDE DISPLACEMENTS
HOWARD STREET

WSP PROJECT NO.	PROJ ORIG VOL LOC TYPE	SHEET NO.	REVISION
6-CD109.55	6-CD109.55	C01	A

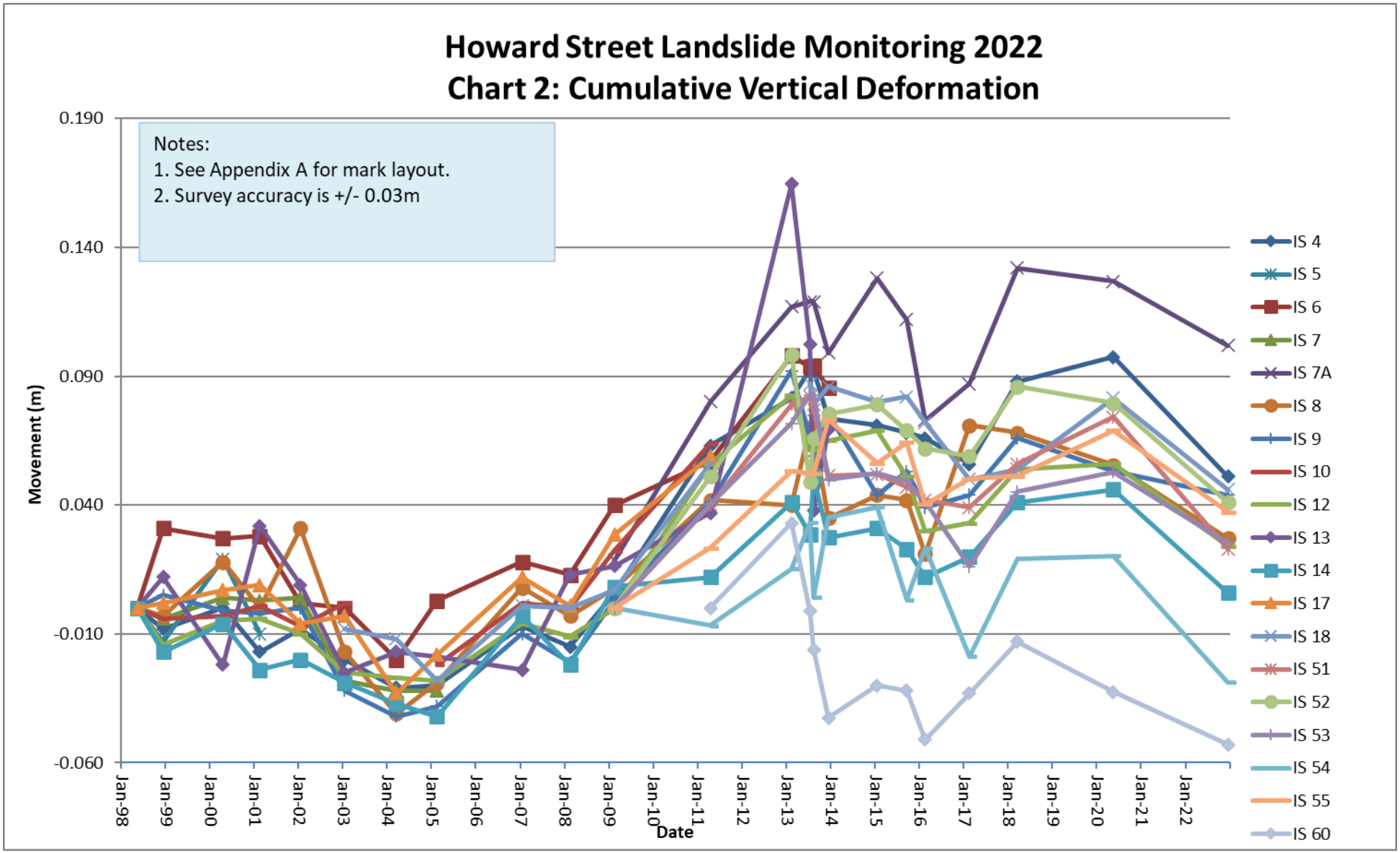
Original sheet size A1 (841x594) Plot Date 2023-06-02 at 4:19:20 PM \\corp\anz\ProjectsNZ\6c\6-CD109.55 LTES Long-term Landslide Monitoring\Home\03_Delivery\Site Plans - DWG\80509491 C006 Howard Street.dwg Layout2

Appendix B
Selected Monitoring Charts

Howard Street Landslide Monitoring 2022
Chart 1: Cumulative Horizontal Deformation



Howard Street Landslide Monitoring 2022
Chart 2: Cumulative Vertical Deformation



Appendix C
Cumulative Monitoring Results Spreadsheet

Survey Data Dated 07/12/2022

Additional survey					Present to previous					Present to original Data derived from original survey				
Point Number	Northing NZGD49	Easting NZGD49	Height	Code	dN	dE	Azim.	Dist	dRL	dN	dE	Azim.	Dist	dRL
AFF3	700335.968	324527.003	6.990	BM X75	0.002	0.005	68	0.005	-0.010					
A23K	698553.383	323584.280	8.393	I NO 3	0.014	0.017	52	0.022	-0.027					
DUND	***697311.104***	***324412.321***	***386.734***	***DUND***	0.000	0.000	FIXED	0.000	0.000					
OUSD	698908.140	317721.859	25.915	OUSD										
IS 101	699022.346	324432.493	6.963	IS 101										
N 102	699035.011	324463.926	7.049	Nail 102										
IS4	698161.933	323756.586	88.197	ISIV	0.035	0.029	40	0.046	-0.025	0.007	-0.005	324.4623	0.009	0.072
IS7A	698021.217	324014.475	168.584	IS7A	0.043	0.031	36	0.053	-0.020	0.017	0.003	10.0080	0.017	0.107
IT8B	698363.307	324109.645	97.342	IT8B	0.013	-0.023	299	0.027	-0.022	0.046	-0.190	283.6097	0.195	0.034
IS9	698265.248	323937.607	87.572	IS9	0.010	0.008	40	0.012	-0.007	0.098	-0.096	315.5907	0.137	0.046
IS12	698564.105	323849.763	21.229	IS12	0.027	0.029	48	0.040	-0.017	-0.003	0.002	146.3099	0.004	0.039
IS14	698385.055	323947.446	60.613	IS14	0.017	0.013	38	0.021	-0.002	0.209	-0.075	340.2594	0.222	0.044
IS18	698489.740	323898.093	35.425	IS18	0.003	0.034	85	0.034	-0.014	0.015	0.006	21.8014	0.016	0.068
IS 51	698396.329	323856.056	43.555	IS51	-0.004	0.010	112	0.011	-0.025	0.009	-0.020	293.7026	0.022	0.049
IS 52	698388.200	323779.261	41.073	IS52	0.037	0.032	41	0.049	0.002	0.020	0.003	7.2143	0.020	0.081
IS 53	698544.463	323694.699	8.703	IS53	0.037	0.029	38	0.047	-0.014	0.046	-0.007	351.1381	0.047	0.039
IS 54	698497.811	323955.635	33.177	IS54B	0.035	0.031	42	0.047	0.036	0.029	0.010	18.7334	0.030	0.056
IS 55	698629.991	323833.208	11.465	IS55	0.010	0.038	75	0.039	-0.011	0.004	-0.021	280.7843	0.021	0.058
IS 60	698263.197	324011.791	88.874	IS56	0.011	0.003	17	0.011	-0.008	0.142	-0.096	325.7068	0.171	-0.041

Appendix D
Geodetic Parameters

wsp

wsp.com/nz

Coordinate system group:	New Zealand/NZGD1949 (LC)
Zone:	North Taieri
Datum transformation:	New Zealand Geodetic 1949 (LC) (Seven Parameter)
Global reference datum:	NZGD2000
Global reference epoch:	2000
Displacement model:	NZGD2000 Deformation Model (20180701)
Geoid model:	None
RTX calibration:	No

Figure B1: Coordinate System to be maintained.

Method:	Seven Parameter
Translation X:	-59.470 m
Translation Y:	5.040 m
Translation Z:	-187.440 m
Rotation X:	0°00'00.47000"
Rotation Y:	-0°00'00.10000"
Rotation Z:	0°00'01.02400"
Scale factor:	6.333ppm
Local ellipsoid used:	International (NZLC)
Local ellipsoid semi-major axis:	6378399.059 m
Local ellipsoid inverse flattening:	297.000000000

Figure B2: Transformation Parameters to be maintained.

Name:	Transverse Mercator
Origin latitude:	S45°51'41.44810"
Origin longitude:	E170°16'57.32080"
False easting:	300000.000 m
False northing:	700000.000 m
Scale factor:	0.9999600000
South azimuth system:	No
Positive coordinate direction:	North / East

Figure B3: Projection Settlings to be maintained.

Geoid Model	
Geoid model:	None
Geoid model file name:	
Geoid model quality:	Unknown quality
Vertical Datum	
Vertical datum:	

Figure B4: Vertical Datum to be maintained.

wsp.com/nz