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Landslide Monitoring Report – Motu Street

29 June 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 Motu 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 (± 10 mm horizontal, ± 10 mm vertical) are presented in Table 1.

Table 1: Summary of recorded displacements.

	Horizontal	Vertical Settlement
Displacements from the previous survey	10 mm	-15 mm
Displacements from the original survey	11 – 45 mm	-18 – -11 mm

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

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 Motu 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 Motu St was established and surveyed in December 2018. 2020 saw a change of survey contractors and several new marks installed. WSP surveyors carried out the 2021 – 2022 monitors, new marks were installed each year due to private drainage work and road works. This report covers results of both WSP surveys.

2.2 Methodology

The survey was completed by a WSP Surveyor on 14 December 2022 using a 3" / 3 mm Trimble S6 robotic total station to carry out a 3-D closed loop traverse, followed by resections from the adjusted 3d traverse to facilitate measuring into the rear yard of private properties. Independent checks using either an optical or digital level were carried out in closed loops between Forbury Road and Motu Street.

2.2.1 Field Survey

A 3-D closed loop traverse beginning on BD4U on the corner of Forbury Road and Valpy Street follows marks along Valpy, Mavis and Motu Streets before connecting the West end of Motu Street up to Allandale Road then traversing downhill to Nail 7a at the corner with Forbury Road, closing back onto BD4U. To avoid losing bearing control on the short line on Allandale Road between Nail 8 and Nail 7a, WSP surveys have direct measured from Nail 6 to Nail 7a, double tying Nail 8 from both marks, the existing traverse mark Nail 8 becomes a redundant check.

The origin of bearings BD4U to Nail 1 is 149° 30' 07", as observed on the 2020 survey. At approximately 150 m this is sufficient bearing control to not require setting up on Nail 1 and observing BD4W to calculate the original missing line (non-intervisible) bearing origin. Origin of Levels is maintained at BD4U with a check on Nail 1.

Each traverse leg was measured conventionally with tripod and optical plumet prism targets with heights measured by steel tape. Where suitable, measurements using a 100 mm mini-prism were used as a check and to measure ties to monitoring marks. A small number of monitor marks were able to be measured directly during traverse, the rest were coordinated using resections from traverse and temporary marks placed for resection use. A conventional or digital level is used with closed loops as an independent check between marks on Motu Street and Forbury Road.

Since the 2020 survey, survey marks that have been destroyed and renewed have been presented in Table 2 below.

Table 2: Description survey marks that have been destroyed and renewed.

Mark	Comment	Replaced By
Nail 7	2021 Footpath resurfacing with new roundabout	Nail 7a
MIS 17	2021 Gone, new sub-soil drainage installed. Concreted in new 0.5m long IS, buried -0.3m.	MIS17A
Pin 201	2022 Destroyed, roadworks	Pin 201a
Pin 203	2022 Destroyed, roadworks	Nail 203a

2.2.2 Office Processing

Minor bearing mis-close is adjusted into shorter lines or a traditional bearing correction is carried out prior to applying a traverse spreadsheet Bowditch adjustment. Either 12d or Trimble Business Centre software are used. Reciprocal heights along traverse lines are averaged and closed.

The main traverse closed vertically to 0.008 m and had a horizontal bearing mis-close of 21". Vertical mis-close was distributed over the longest lines while bearing mis-close was given to the shortest lines. Level runs closed to 0.002 m or less. In most cases this was not distributed as it was insignificant. Resection calculations were re-processed in TBC against adjusted 3d traverse coordinates held fixed.

2.2.3 Geodetic Parameters

The survey was completed in NZ Geodetic Datum 2000 North Taieri circuit and NZ Vertical Datum 2016, in accordance with the previous surveys. It is important that the geodetic parameters presented in Appendix D are maintained for future surveys.

2.3 Accuracy

The survey has been undertaken to the following accuracy:

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

These figures have been confirmed based on traverse closures, independent checks and network adjustment total station observation statistics.

2.4 Future Monitoring

It is recommended that future survey monitors follow the methodology and geodetic parameters detailed above. MIS17A has been coordinated and should be measured again to test for movement. MIS9 showed evidence of possible movement and should continue to be monitored. A follow up survey should be undertaken late 2023.

3 Monitoring Results

Selected monitoring charts are presented in Appendix B and the cumulative results spreadsheet is presented in Appendix C. A summary of the monitoring results is presented in Table 3. Vertical movements indicate that there is settlement occurring that exceeds the survey accuracy. Directional movements are towards the Motu Street carriageway as expected. Horizontal deformations have exceeded the survey accuracy in multiple monitoring locations.

Table 3: 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	12 mm	<10 mm
Maximum	10 mm	-15 mm	45 mm	-18 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 is calculated for the "Dunedin Area" using the available data from Musselburgh Station from the earliest rainfall measurement (August 1997) to the time of the latest survey iteration (December 2022).

A significant rainfall 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.

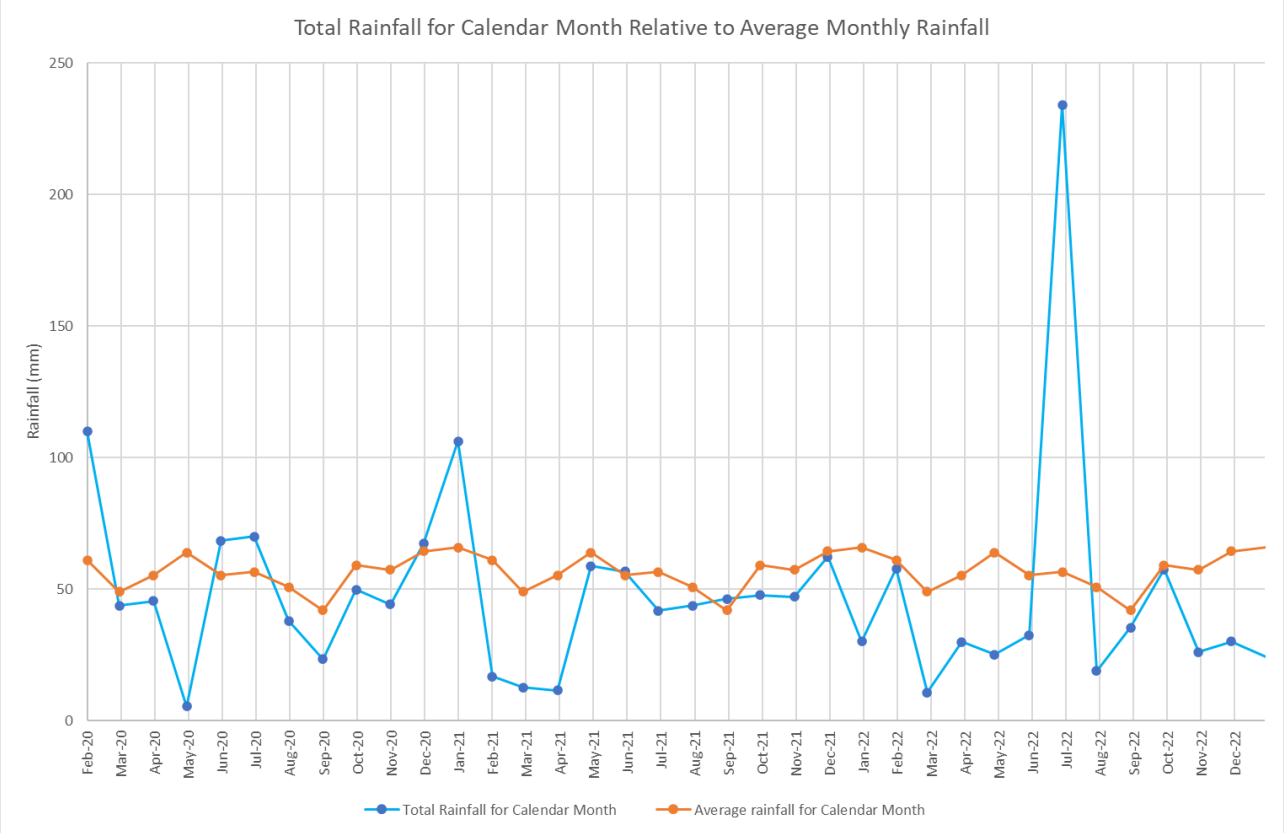

Figure 1: Measured monthly rainfall compared with average monthly rainfall (CliFlo.niwa.co.nz).

5 Conclusions and Recommendations

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

- 45 mm horizontally,
- -18 mm vertically.

The current survey iteration has indicated horizontal deformation from the base survey in four separate locations (MIS9, MIS14, MIS16A, MIS19A) that exceed the accuracy of the survey. The direction of this movement is towards multiple residential dwellings along the northern side of Motu Street, so monitoring should continue to provide insight to the long-term risk to this area. At present, there is insufficient monitoring history to establish if there is a deformation trend establishing or if these movements have occurred as a result of discrete events. It is recommended surveys continue at yearly or 2-yearly intervals, using the same survey method described in Section 2.

Appendix A
Site Plan and Mark Displacement Diagram

LEGEND

- SURVEY POINTS
- CONTROL POINTS

300 mm
200
100
50
0 10 mm

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

DUNEDIN CITY COUNCIL | kaunihera a-rohe o Ōtepoti

Dunedin Office
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New Zealand

CIVIL

SCALES: N.T.S
ORIGINAL SIZE: 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 PLAN

PROJECT
DUNEDIN CITY COUNCIL
MOTU STREET
LONG TERM LANDSLIDE MONITORING

TITLE
SURVEY MONITORING POINTS AND CONTROL POINTS
MOTU STREET SITE PLAN

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

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

300 mm
200
100
50
0 10 mm

1:250 @ A1
1:500 @ A3
0 4 8 12 16 20 24 m

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

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CIVIL

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

2022 SURVEY RESULTS

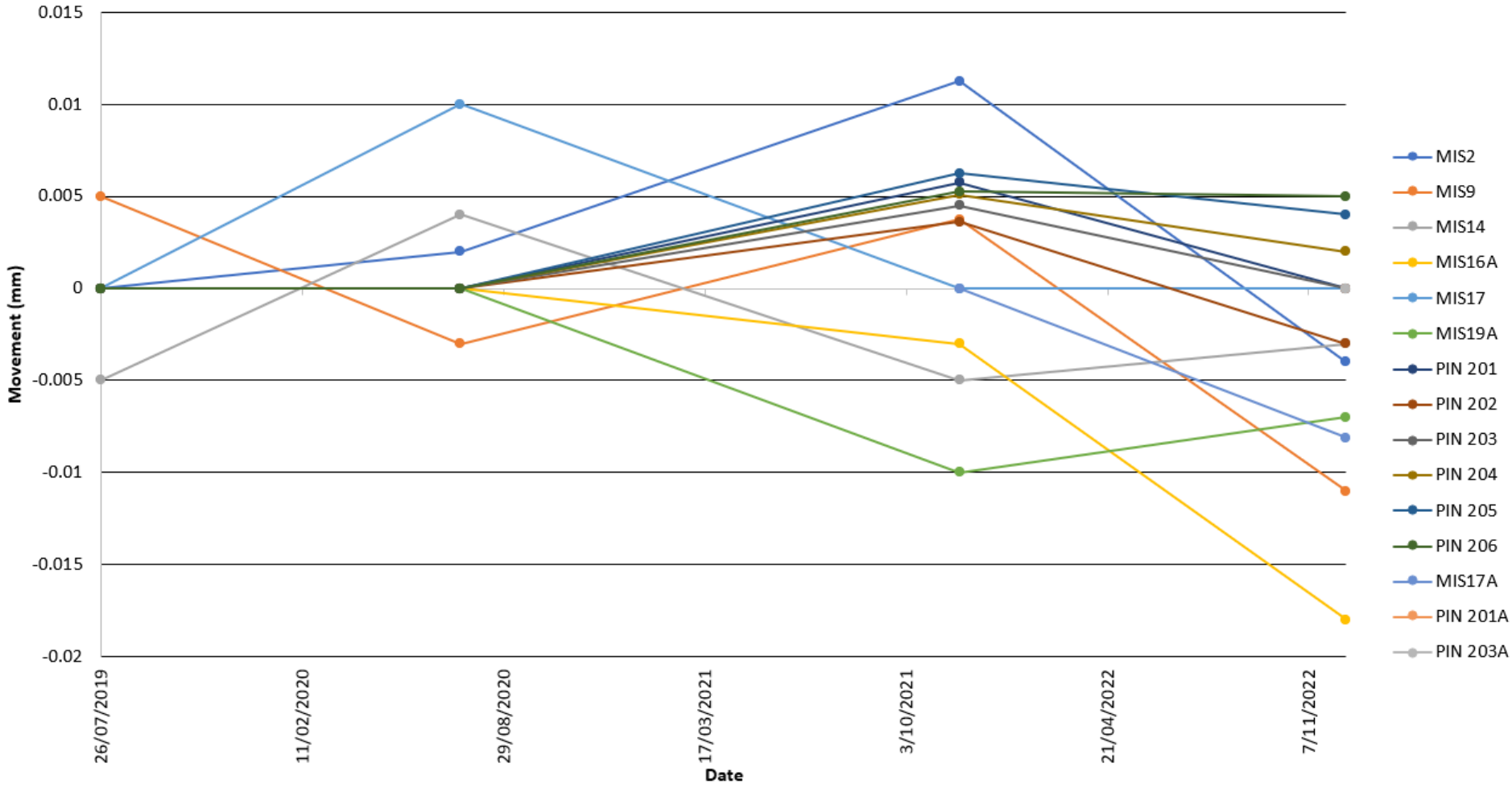
PROJECT
DUNEDIN CITY COUNCIL
MOTU STREET
LONG TERM LANDSLIDE MONITORING

TITLE
CUMULATIVE LANDSLIDE DISPLACEMENTS
MOTU STREET

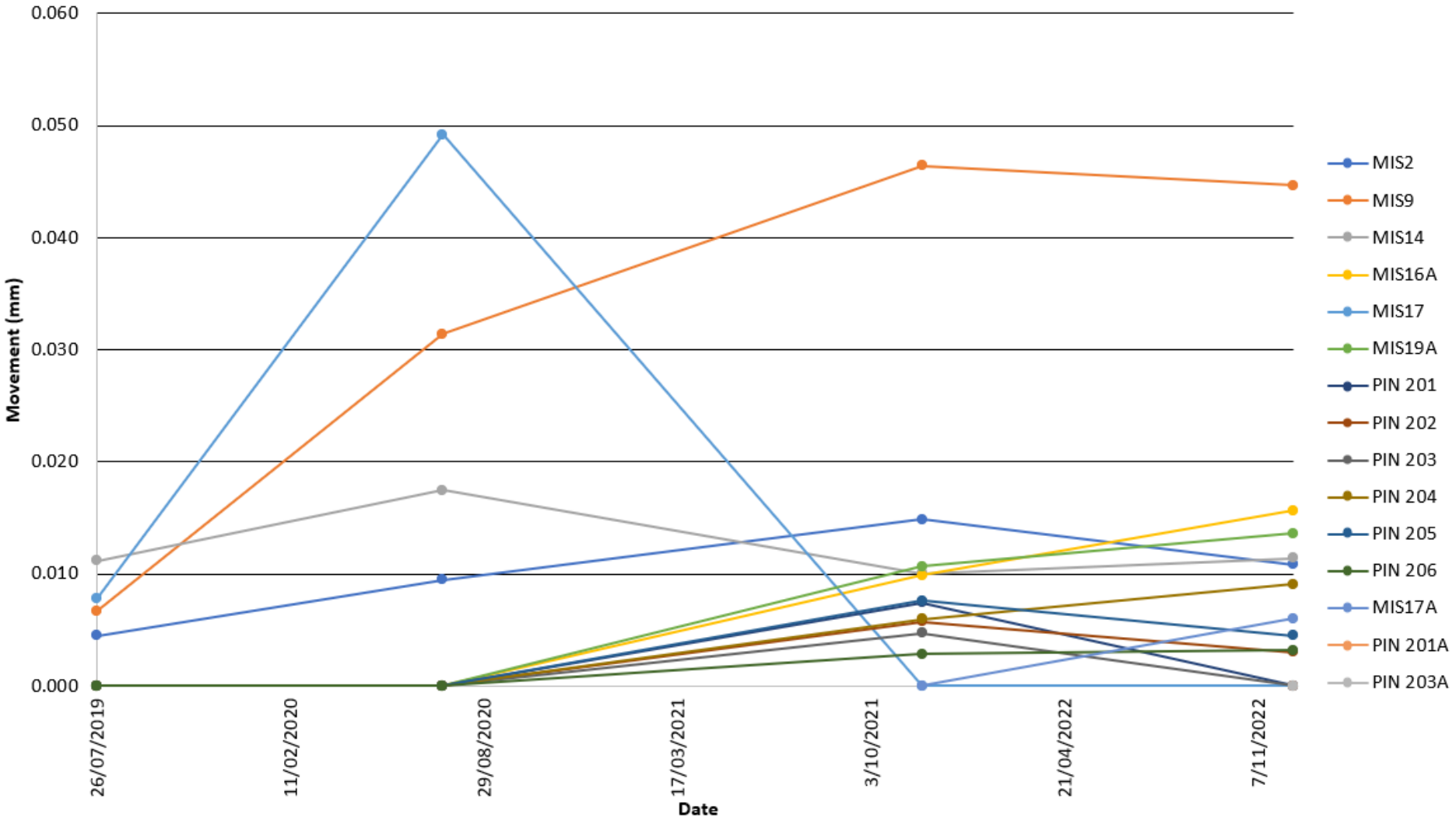
WSP PROJECT NO.	PROJ-ORIG-VOL-LOC-TYPE	SHEET NO.	REVISION
6-CD109.55	6-CD109.55	C01	A

Appendix B
Selected Monitoring Charts

Motu Street Landslide Monitoring
Chart 1: Vertical Deformation - May 2019 to present



Motu Street Landslide Monitoring
Chart 2: Horizontal Deformation - May 2019 to present



Appendix C
Cumulative Monitoring Results Spreadsheet

SURVEY 4
DATE 25/11/2021

SURVEY DATA				PRESENT TO PREVIOUS					PRESENT TO ORIGINAL				
POINT ID	*EASTING*	*NORTHING*	*HEIGHT*	*EASTING*	*NORTHING*	*HORIZONTAL*	*BEARING (dd)*	*HEIGHT*	*EASTING*	*NORTHING*	*HORIZONTAL*	*BEARING (dd)*	*HEIGHT*
MIS2	415651.259	794839.600	21.043	-0.004	-0.011	0.012	199	0.009	0.005	-0.014	0.015	159	0.011
MIS9	415649.080	794855.079	26.139	0.004	-0.018	0.019	166	0.007	0.031	-0.034	0.046	137	0.004
MIS14	415700.236	794886.965	21.451	-0.017	-0.003	0.017	260	-0.009	-0.001	-0.010	0.010	186	-0.005
MIS16A	415667.447	794852.377	21.313	0.004	-0.009	0.010	156	-0.003	0.004	-0.009	0.010	156	-0.003
MIS17													
MIS19A	415694.151	794867.873	17.534	-0.007	-0.008	0.011	221	-0.010	-0.007	-0.008	0.011	221	-0.010
PIN 201	415665.517	794816.457	19.729	0.002	-0.007	0.007	166	0.006	0.002	-0.007	0.007	166	0.006
PIN 202	415696.084	794836.544	15.616	-0.001	-0.006	0.006	186	0.004	-0.001	-0.006	0.006	186	0.004
PIN 203	415722.547	794857.196	14.069	-0.002	-0.004	0.005	201	0.004	-0.002	-0.004	0.005	201	0.004
PIN 204	415751.409	794879.709	14.840	-0.002	-0.006	0.006	198	0.005	-0.002	-0.006	0.006	198	0.005
PIN 205	415611.985	794874.885	35.497	0.005	-0.006	0.008	138	0.006	0.005	-0.006	0.008	138	0.006
PIN 206	415664.884	794891.596	30.818	0.001	-0.003	0.003	162	0.005	0.001	-0.003	0.003	162	0.005
MIS17A	415679.375	794862.352	20.075										

Note: yellow cells are processed in TBC, white cells are processed in 12D

SURVEY 5
DATE 14/12/2022

SURVEY DATA				PRESENT TO PREVIOUS					PRESENT TO ORIGINAL					
POINT ID	*EASTING*	*NORTHING*	*HEIGHT*	*EASTING*	*NORTHING*	*HORIZONTAL*	*BEARING (dd)*	*HEIGHT*	*EASTING*	*NORTHING*	*HORIZONTAL*	*BEARING (dd)*	*HEIGHT*	
MIS2	415651.263	794839.608	21.028	0.004	0.008	0.009	25	-0.015	0.009	-0.006	0.011	124	-0.004	
MIS9	415649.082	794855.084	26.124	0.003	0.005	0.006	26	-0.015	0.034	-0.029	0.045	130	-0.011	
MIS14	415700.244	794886.966	21.453	0.008	0.001	0.008	83	0.002	0.007	-0.009	0.011	142	-0.003	
MIS16A	415667.457	794852.379	21.298	0.010	0.002	0.010	79	-0.015	0.014	-0.007	0.016	117	-0.018	
MIS17														
MIS19A	415694.150	794867.870	17.537	-0.001	-0.003	0.003	198	0.003	-0.008	-0.011	0.014	216	-0.007	
PIN 201														PIN201 DESTROYED
PIN 202	415696.085	794836.547	15.609	0.001	0.003	0.003	13	-0.007	0.000	-0.003	0.003	180	-0.003	
PIN 203														PIN203 DESTROYED
PIN 204	415751.410	794879.706	14.837	0.001	-0.003	0.003	166	-0.003	-0.001	-0.009	0.009	186	0.002	
PIN 205	415611.984	794874.893	35.495	-0.001	0.008	0.008	352	-0.002	0.004	0.002	0.004	63	0.004	
PIN 206	415664.886	794891.598	30.818	0.002	0.002	0.003	51	0.000	0.003	-0.001	0.003	108	0.005	
MIS17A	415679.375	794862.346	20.067	0.000	-0.006	0.006	180	-0.008	0.000	-0.006	0.006	180	-0.008	
PIN 201A	415670.062	794820.298	18.937											
PIN 203A	415719.431	794854.988	14.076											

Appendix D
Geodetic Parameters

Summary

Coordinate system group:	New Zealand/NZGD2000
Zone:	North Taieri 2000
Datum transformation:	New Zealand Geodetic 2000 (Molodensky)
Global reference datum:	NZGD2000
Global reference epoch:	2000
Displacement model:	NZGD2000 Deformation Model (20180701)
Geoid model:	New Zealand Geoid 2016
RTX calibration:	No

Figure D1: Coordinate System

Datum Transformation

Method:	Molodensky
Translation X:	0.000 m
Translation Y:	0.000 m
Translation Z:	0.000 m
Local ellipsoid used:	Geodetic Ref System 1980
Local ellipsoid semi-major axis:	6378137.000 m
Local ellipsoid inverse flattening:	298.257222101

Figure D2: Transformation Parameters

Projection

Name:	Transverse Mercator
Origin latitude:	S45°51'41.00000"
Origin longitude:	E170°16'57.00000"
False easting:	400000.000 m
False northing:	800000.000 m
Scale factor:	0.9999600000
South azimuth system:	No
Positive coordinate direction:	North / East

Figure D3: Projection Settlings

Geoid Model

Geoid model:	New Zealand Geoid 2016
Geoid model file name:	nz2016.ggf
Geoid model quality:	Unknown quality

Vertical Datum

Vertical datum:	

Figure D4: Vertical Datum

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