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Landslide Monitoring Report – Greenacres Street, Macandrew Bay

6 August 2021

CONFIDENTIAL

Contact Details

Nima Taghipouran

WSP
197 Rattray Street
Dunedin
+64 3 211 3582
+64 021 0857 1841
Nima.Taghipouran@wsp.com

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Prepared by:

Scott Kvick | Intermediate Engineering Geologist

Reviewed by:

Mark Easton | Principal Geotechnical Engineer

Approved for Release by:

Kevin Wood | Project Director

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Disclaimers and Limitations

This report **('Report')** has been prepared by WSP exclusively for Dunedin City Council **('Client')** in relation to the landslide monitoring at selected sites in Dunedin (Long-Term Landslide Monitoring 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 Greenacres Street site has been undertaken in June 2021 to assess the extent of movements compared with previous surveys. The main findings, where deformations were found to exceed the accuracy of the survey (±15mm Hz, ±20mm V), are presented in Table 1 below.

Table 1 Summary of recorded displacements.

	Horizontal	Vertical
Displacements from the previous survey	<15mm	<20mm
Displacements from the original survey	310 – 1,610mm	240 – 680mm

The results indicate that horizontal and vertical movement has slowed relative to previous rates and no detectable movement has been measured since the previous survey (May 2020).

We recommend the next survey to be undertaken in mid-2022.

1 Introduction

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 Greenacres Street site, as well as monitoring recommendations. A survey network diagram is provided in Appendix A.

2 Survey Monitoring

2.1 Monitoring History

Survey monitoring of the site has been undertaken since 2015 the baseline was recorded on 31 July 2015. The first 3 surveys (including the base survey) were initially completed at 2 – 4 month intervals. The frequency was then extended to approximately 1 year, however the survey in mid-2019 was missed. Approximate survey dates are shown in monitoring charts presented in Appendix B.

2.2 Methodology

This survey monitoring round was undertaken by a WSP Surveyor on 17 June 2021. The specific equipment used were 2 x Trimble R8-3 GNSS receivers.

2.2.1 Field Survey

The survey was undertaken using Static GNSS with 20-minute observations to each monitor mark, logging data at 1s intervals. Monitor marks were occupied by setting the GNSS receiver over the mark with an optical plummet and tripod. Receiver heights were measured by steel tape with slant distance reduced to true vertical.

The CORS network mark DUND, approximately 1.2km from the site, served as the local base station.

IS 5 was not measured as it could not be accessed due to a stockpile of slash from pine forest clearance.

2.2.2 Office Processing

Survey data is processed using Trimble Business Centre post-processing software. Static data from CORS network marks DUND and OUSD were combined with the static data from the rover. A minimally constrained network adjustment was carried out holding control point DUND fixed horizontally in terms of NZGD2000 (Global Reference Epoch 2000.0), North Taieri Circuit projection.

DUND was also held fixed vertically in terms of the GRS80 ellipsoid height. The NZVD2016 geoid was applied in the background during processing for checking purposes. The current ellipsoid height of DUND has been updated since the survey began in 2015, so it is important the original height is maintained to keep measurements in the same terms. The origin of coordinates for the survey is:

DUND	797475.867mN	424425.439mE	386.925mh	(0Hz , 1V)

Vertical check X75 (AFF3, order 2V) failed vertical datum check, being 0.034m higher than the LINZ database level relative to DUND, which agreed with OUSD to 0.003m. This could in part be due to the level of DUND being updated (lowered 0.009m ellipsoid). The observation is relatively consistent with the historical measurements of X75 being 0.013m lower than the 2020 monitor. It was also noted that the seawall adjacent to the mark had been under-cut and ground around the mark had noticeable cracks.

2.2.3 Geodetic Parameters

For continuity of future surveys, it is critical the following geodetic parameters are maintained:

Coordinate System

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
Geoid model:	New Zealand Geoid 2016
RTX datum:	No

Transformation Parameters, Local Ellipsoid

Datum Transformation

Method:	Molodensky
Translation X:	0.0000 m
Translation Y:	0.0000 m
Translation Z:	0.0000 m
Local ellipsoid used:	Geodetic Ref System 1980
Local ellipsoid semi-major axis:	6378137.0000 m
Local ellipsoid inverse flattening:	298.257222101

Projection Settings

Projection

Name:	Transverse Mercator
Origin latitude:	S45°51'41.00000"
Origin longitude:	E170°16'57.00000"
False easting:	400000.0000 m
False northing:	800000.0000 m
Scale factor:	0.9999600000
South azimuth system:	No
Positive coordinate direction:	North / East

Vertical Datum (Background Use Only)

Geoid Model

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

Vertical Datum

Vertical datum:	

2.3 Accuracy

Considering the equipment, methodology and site observing conditions, this survey is considered to meet the following accuracy:

Horizontal position	+/- 15mm (@ 95% CI)
Vertical position	+/- 20mm (@ 95% CI)

2.4 Future Monitoring

It is recommended that future survey monitors follow the methodology and geodetic parameters detailed above. The lack of redundant control points to check to means the accuracy and repeatability of the survey cannot be confirmed by a simple, practical measurement. Also considering the sole check mark at X75 could be subject to ground disturbance, additional control points should be installed or checked on to during the next monitor. This would add approximately 0.75 hours per control point on all future monitors.

3 Monitoring Results

The cumulative results spreadsheet is presented in Appendix C of this report. The monitoring results are discussed below.

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	<15mm	<20mm	1,070mm	-410mm
Maximum	<15mm	<20mm	1,610mm	-680mm

4 Rainfall Data

A summary of the rainfall data since the previous survey is presented in Figure 1 below. 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 between 1981 and 2010 (source: https://niwa.co.nz/education-and-training/schools/resources/climate/meanrain).

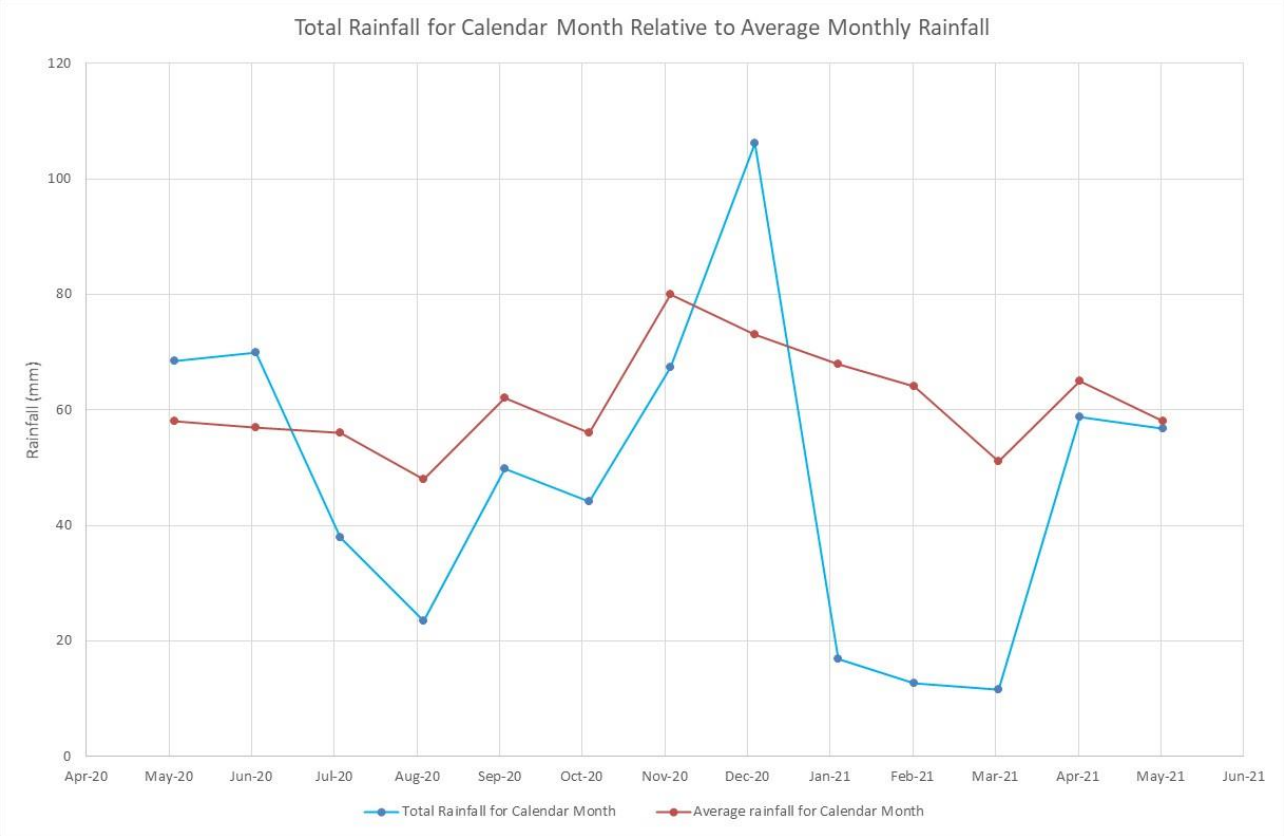


Figure 1 Measured monthly rainfall compared with average monthly rainfall (CliFlo.niwa.co.nz).

5 Aerial Photo Inspection

A brief assessment of aerial photographs (DCC Rates WebMap) and the mapped landslide extent (see Network Diagram in Appendix A) has shown that some of the landslide area was covered by a pine plantation which was harvested at some point between 2013 and 2018/19. In addition, machinery has damaged much of the grassed area overlying the lower reaches of the landslide. It is considered possible that the removal of trees, and resultant damage to the vegetated surface, may have contributed to the recorded movement.

6 Conclusions and Recommendations

In conclusion, the maximum displacements recorded since the July 2015 base survey are as follows:

- 1,610mm in plan,
- 680mm vertically.

Survey results indicate the rate of movement has slowed since large deformations (up to 1.0m horizontally, mark IS4) were recorded between 2017 and 2018. A maximum of 0.4m horizontal movement (up to -0.43m vertically, mark IS2) has been recorded since March 2018. No detectable deformation has been recorded since the previous survey (May 2020); on this basis, we do not see any requirement to change the currently established communication plan with the affected residents.

Previous surveys have shown that large deformations are possible, likely the result of adverse conditions such as heavy rainfall events or a change in land use (e.g. removal of vegetation). Due to this consideration, and the close proximity of residential dwellings (38, 42, and 46 Greenacres Street) to the toe of the landslide, it is recommended a follow-up survey is completed on a 12-monthly basis.

In addition, we recommend consideration be given to a walkover inspection of the site following any significant rainfall event. Without undertaking a close review of deformation relative to daily rainfall, a preliminary threshold has been proposed below as a point for discussion.

- >40mm in 24 hours;
- >60mm in 48 hours; or,
- >100mm in 7 days, as reported by the Musselburgh NIWA weather station, or other equivalent weather monitoring site.

If future surveys or inspections reveal adverse deformation trends, we recommend the DCC discuss possible treatment options with WSP. Given the data presented thus far, some examples of this may include vegetation management (planting grass and shrubs) and improving control of surface water.

Finally, it is recommended that the logging debris obscuring mark IS 5 be cleared to enable access for future surveys.

Appendix A
Network Diagram

NOTE:

1. COORDINATES ARE IN TERMS OF NZGD2000 NORTH TAIERI GRS 80 ELLIPSOID
2. HEIGHT ARE IN TERMS OF NZGD 2000
3. ORIGIN: DUND 797475.866 mN
   424425.440 mE
   386.925 mH
4. NEW MONITORING NETWORK ESTABLISHED JULY 2015
5. REFER TO SPREADSHEET FOR COORDINATES
6. HORIZONTAL ACCURACY IS +/- 10mm AND VERTICAL ACCURACY IS +/- 15mm
7. HORIZONTAL VECTOR ARROWS ARE AT 1:10 OF THE DISTANCE MOVED.

LEGEND

LANDSLIDE - OTAGO REGION (CERTAINTY)

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

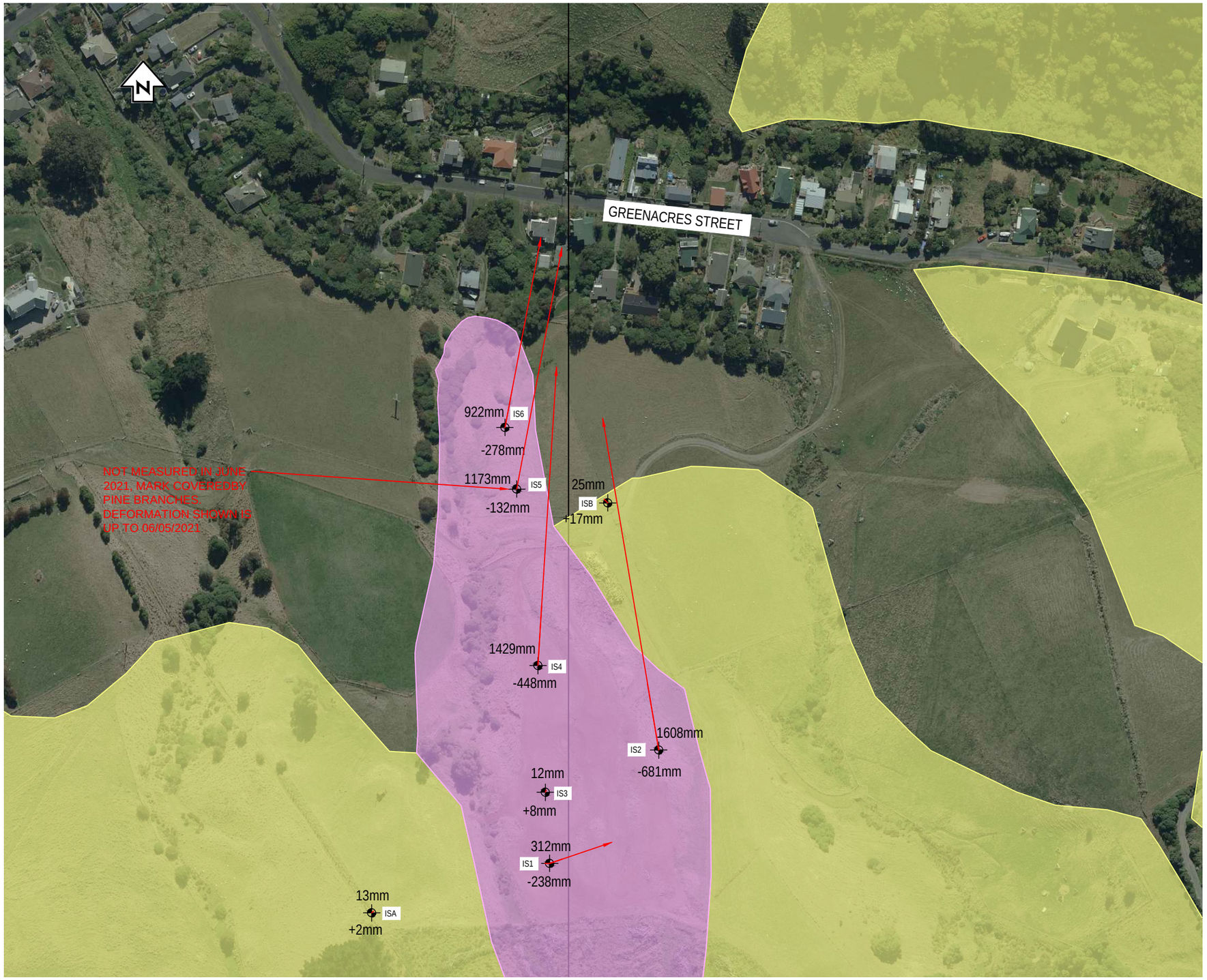
INDICATIVE LANDSLIDE EXTENTS ARE BASED ON "REVISED LANDSLIDE DATABASE FOR THE COASTAL SECTOR OF THE DUNEDIN CITY DISTRICT" BY BARRELL, D.J.A., SMITH LYTTLE, B., GLASSEY, P.J. GNS SCIENCE CONSULTANCY REPORT 2017/41, JULY 2017, SOURCED FROM THE OTAGO REGIONAL COUNCIL (ORC) NATURAL HAZARDS PORTAL.

OTHER

+/- Xmm = CUMULATIVE VERTICAL DISPLACEMENT

CUMULATIVE HORIZONTAL DISPLACEMENT (1:100 SCALE)

SURVEY MARKER



300 mm
200
100
50
0 10 mm

1:1000 @ A1
1:2000 @ A3
0 10 20 30 40 50 60 70 80 90 100 m

WORK IN PROGRESS

PRINTED 5/08/2021 8:41:28 AM

REVISION	AMENDMENT	APPROVED	DATE

DUNEDIN CITY COUNCIL | kaunihera a-rohe o Ōtepoti

Dunedin Office
+64 3 471 5500

Private Bag 1913
Dunedin 9016
New Zealand

CIVIL

SCALES 1:1000

ORIGINAL SIZE A1

DRAWN | DESIGNED | APPROVED

DRAWING VERIFIED | DESIGN VERIFIED | APPROVED DATE

FOR INFORMANTION

PROJECT
DUENDIN CITY COUNCIL
GREENACRES STREET
LONG TERM LAND SLIDE

TITLE
LAND SLIDE MONITORING
GREENACRES 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 2021-08-05 at 8:41:28 AM Layout1

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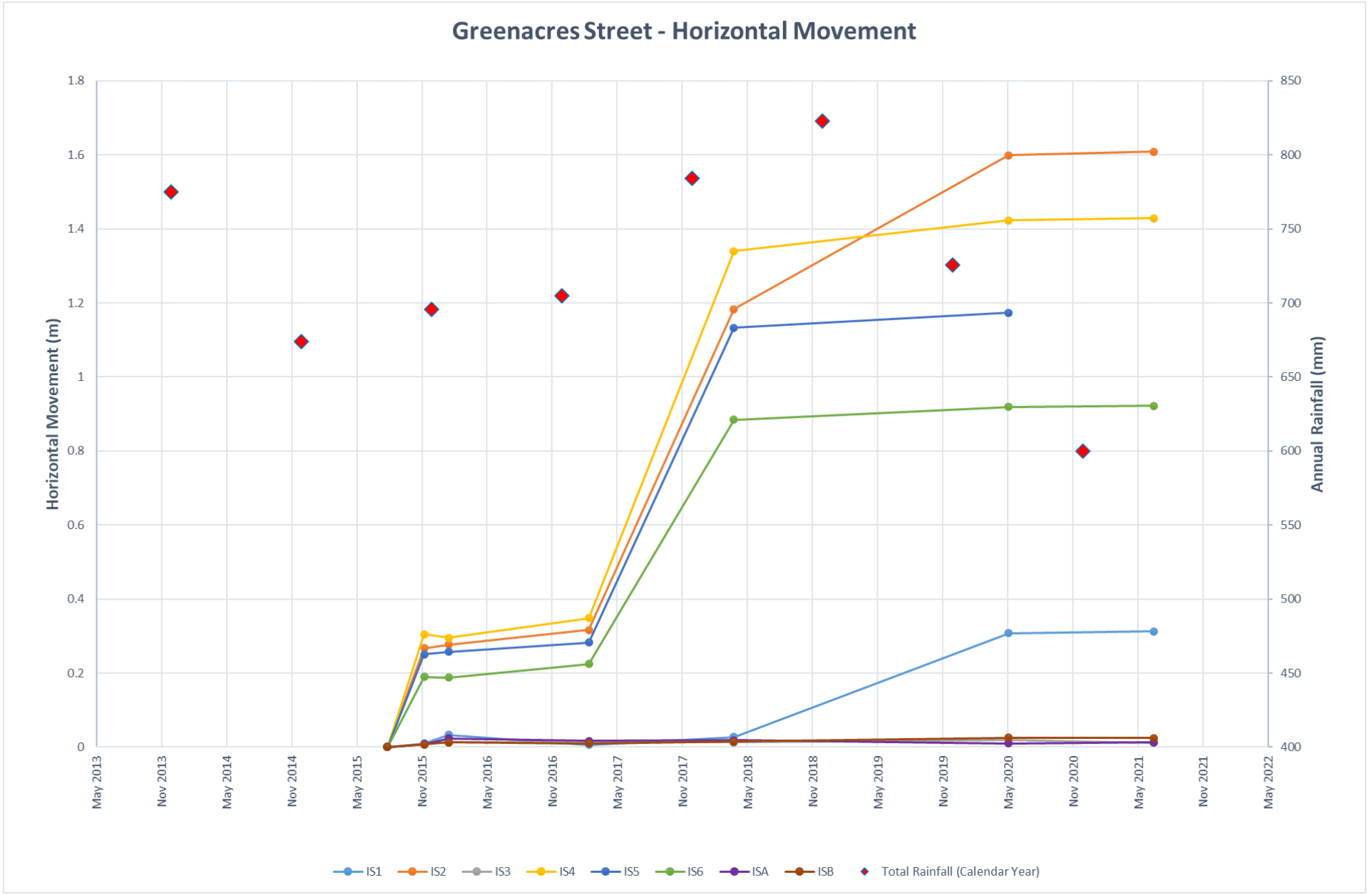
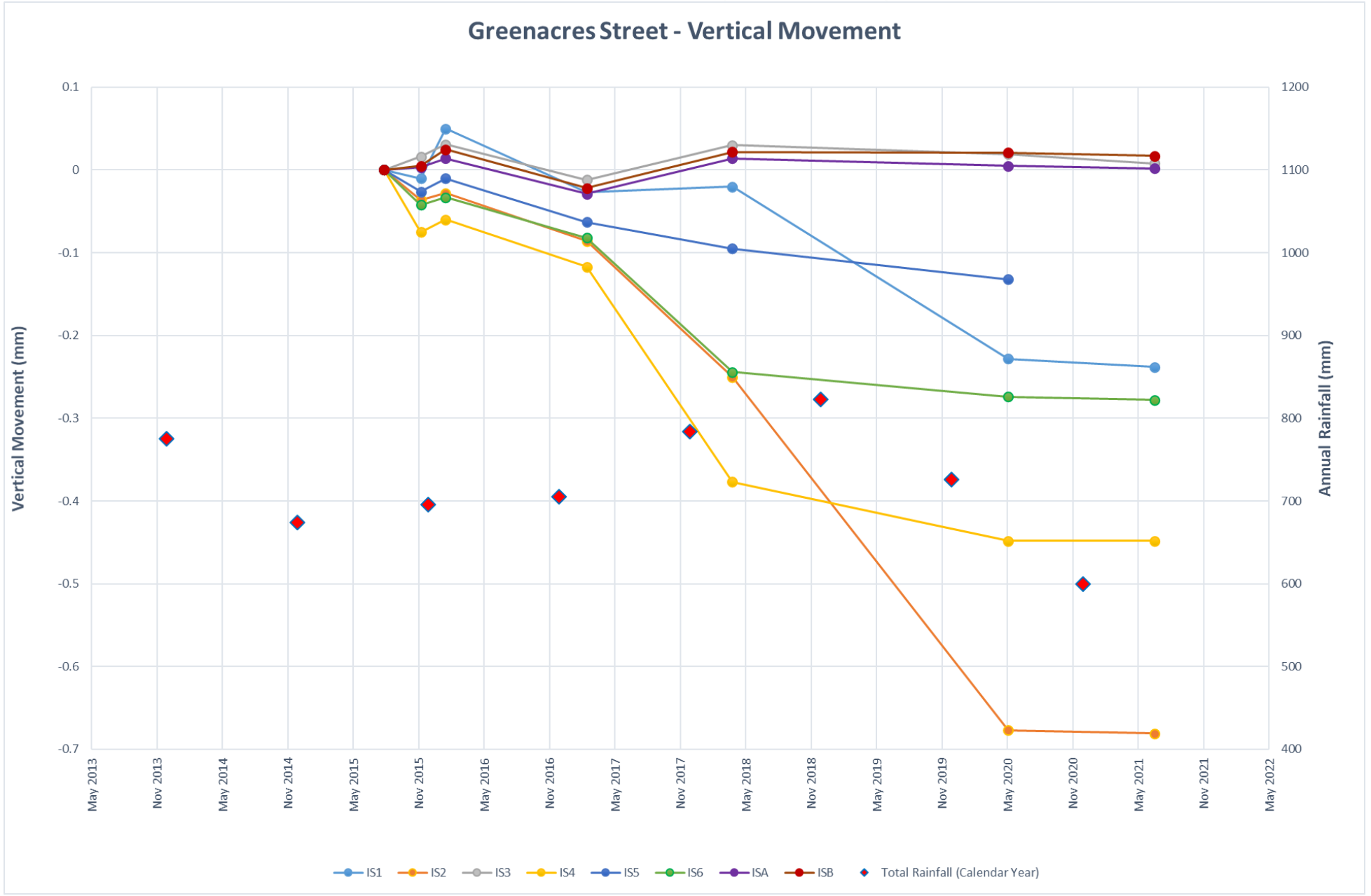
Appendix B
Selected Monitoring Charts


Greenacres Street - Horizontal Movement
Horizontal Movement (m)
Annual Rainfall (mm)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
850
800
750
700
650
600
550
500
450
400
May 2013
Nov 2013
May 2014
Nov 2014
May 2015
Nov 2015
May 2016
Nov 2016
May 2017
Nov 2017
May 2018
Nov 2018
May 2019
Nov 2019
May 2020
Nov 2020
May 2021
Nov 2021
May 2022
IS1
IS2
IS3
IS4
IS5
IS6
ISA
ISB
Total Rainfall (Calendar Year)


Greenacres Street - Vertical Movement
Vertical Movement (mm)
Annual Rainfall (mm)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
1200
1100
1000
900
800
700
600
500
400
May 2013
Nov 2013
May 2014
Nov 2014
May 2015
Nov 2015
May 2016
Nov 2016
May 2017
Nov 2017
May 2018
Nov 2018
May 2019
Nov 2019
May 2020
Nov 2020
May 2021
Nov 2021
May 2022
IS1
IS2
IS3
IS4
IS5
IS6
ISA
ISB
Total Rainfall (Calendar Year)

Appendix C
Cumulative Monitoring Results Spreadsheet

Greenacres Monitoring Survey

Datum: North Taieri 2000
Heights: Ellipsoidal
Origin: DUND
Field Method: Rapid Static
Processed: TBC
Precision: 15mm Hz & 20mm Vt

Date: 18-Jun-21

Point ID	Easting	Northing	Elevation	Feature Code	Present to Previous Survey					Present to Original				
DUND	424425.439	797475.867	386.925	Base Station	mE	mN	Bearing	Dist	mZ	mE	mN	Bearing	Dist	mZ
IS1	424790.737	798547.500	94.366	IS1	-0.002	0.010	348.690	0.010	-0.010	-0.296	0.100	288.667	0.312	-0.238
IS2	424789.187	798582.929	86.454	IS2	-0.003	0.010	343.301	0.010	-0.004	0.268	1.586	9.591	1.608	-0.681
IS3	424843.107	798601.568	80.951	IS3	0.003	-0.006	153.435	0.007	-0.011	-0.004	0.011	340.017	0.012	0.008
IS4	424785.357	798643.333	72.469	IS4	0.002	0.006	18.435	0.006	0.000	-0.088	1.426	356.469	1.429	-0.448
IS5	Not available			IS5										
IS6	424769.421	798756.668	49.680	IS6	0.004	0.004	45.000	0.006	-0.004	-0.172	0.906	349.251	0.922	-0.278
ISA	424705.909	798523.729	100.976	ISA	-0.001	0.005	348.690	0.005	-0.003	-0.010	0.009	311.987	0.013	0.002
ISB	424818.751	798719.701	59.369	ISB	0.001	-0.002	153.435	0.002	-0.004	0.017	0.018	43.363	0.025	0.017
X75	424540.135	800500.719	7.264	X75	0.005	0.006	39.806	0.008	-0.013	0.000	-0.006	180.000	0.006	-0.006

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