

Survey Report
of the
Portuguese Bend Sept. 2021-Oct. 2022-May 2023
Land Movement Monitoring Surveys
for the
City of Rancho Palos Verdes
prepared by
McGee Surveying Consulting
Date: October 19, 2022 Revised June 6, 2023

The Portuguese Bend Landslide is monitored on a tri-annual basis beginning with the initial survey of all current monitoring points at the beginning of the rainy season in the Fall of each year followed by two subsequent partial monitoring surveys in the winter and spring. The following is a summary of the Initial Fall 2022 Monitoring Survey followed by addendums for the winter and spring Partial Monitoring Surveys. The movement results are listed as follows: for the Initial Fall Survey for the period of September 2021 to October 2022, the Winter Partial Survey for October 2022 to March 2023, and for the Spring Partial Survey for March 2023 to May 2023 and October 2022 to May 2023. The movements for these periods are listed on Pages 4 & 6.

Initial (Fall) Survey - October 10, 2022 Full Monitoring Survey No. 34
Second (Winter) Survey - March 13, 2023 Partial Monitoring Survey No. 35
Third (Spring) Survey - May 12, 2023 Partial Monitoring Survey No. 36

ATTACHMENT: "PB MOVEMENT DATA POSTING 2007-2022.10.xlsx"

OVERVIEW:

McGee Surveying Consulting (MSC) performed the Fall 2022 land movement monitoring survey of the Portuguese Bend Landslides. The survey was planned, coordinated, and executed by Michael McGee, PLS3945 of MSC who is responsible for the field surveys, processing observations, network adjustments, analysis, and reports. This survey determined the precise positions of 67 monitoring points to assess their annual and overall movements. Subsequent Addendum Partial Surveys in the Winter and Spring assessed the movements between October 2022 and May 2023. See the previous 2021-2022 Report published in May 2022 for more survey details and procedures utilized in this survey but not re-stated here. The annual Fall 2021 to 2022 movements and 2022 coordinates are listed in the attached spreadsheet titled "PB MOVEMENT DATA POSTING 2007-2022.10.xlsx". A substantial increase in movement velocities was observed between the October 2022 and May 2023 compared to the previous four year average. See the "Partial Assessment of Observations" on Page 8.

The horizontal and vertical positions of the monitoring points are based on the North American Datum of 1983 (NAD83) Epoch 2007.00 and the North American Vertical Datum of 1988 (NAVD 88) reference frames. The NGS Geoid03 is used to model orthometric heights (elevations) based on measured ellipsoid heights as explained in said May 2021-2022 Report. The latitudes and longitudes determined by GNSS measurements are projected into NAD83 California State Plane Coordinates Zone 5 in US Survey Feet.

Given the proven stability, since 2007, of Point AB02 (at the south end of Portuguese Point) relative to PVE3 (CGPS Station at City Hall), the method for recovering the reference frame was modified in 2019 to improve the efficiency and simplify the processing and analysis of the surveys. The previous procedures were modified by fixing point AB02, instead of PVE3 and checking to PVE3RP (control point on the concrete base of PVE3). Point AB61 (on Portuguese Point) provides redundant verification that the reference frame is stable and successfully recovered. Beginning in the fall of 2019, the network adjustments were constrained to the 2018 NAD83 position and NAVD88 height of AB02 checking to PVE3RP and AB61. The positions are listed below.

Pt#	Latitude	Longitude	NAVD88 Ht	Source)
AB02	33-44-13.84878	118-22-26.19243	116.47 ft	Oct. 2018 position
PVE3RP	33-44-35.74239	118-24-15.27451	346.88 ft	Average of 5 years
AB61	33-44-18.5730	118-22-25.9580	140.43 ft	Average since 2007

The Fall 2022 Survey is the 34th Monitoring Survey. For data management purposes the point names are prefixed with a sequential number to distinguish between surveys. For example, on the 16th monitoring survey AB61 was named M16AB61 where M16 indicates the sequence number since the initial M01 Monitoring Survey in September 2007. The prefix is stripped in the attached “PB MOVEMENT DATA POSTING” document.

AB61 and AB20 previously served as suitable GNSS Base Stations. Presently AB73 is utilized as a Base Station. AB73 is located on the US Pony Club property and exclusive permission for MSC to enter the property is confirmed prior to each survey with the understanding that strict limited driving protocols will be observed. Access was obtained unilaterally by MSC from the manager of the Pony Club and does not extend to others. Point AB73 is not a planned monitoring point, is not necessary and not to be include in surveys by others.

Prior to 2019, geodetic grade GNSS receivers collected static satellite signal data for post processing. Presently, a Leica GS18 Base with a GS18T RTK Rover operating in real-time with an FM radio system is used to measure the monitoring points. This system is the latest technology and delivers increased productivity and greater precision of point positions in real time. The GS18 receiver incorporates an Inertial Measurement Unit and tracks four Global Navigation Satellite Systems (GNSS) including GPS, GLONASS, Galileo and Beidou Satellites. The differences in two measured vectors are acceptable if they fall within 0.03 feet (1 cm) horizontally; otherwise, additional measurements are obtained. Experience has shown the independent measurements agree generally 0.01 to 0.02 feet.

M34 MONITORING NETWORK



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GNSS Survey Parameters and Metadata

Date of Initial Annual Survey: M34 – October 10, 2022 (mean date) between 0800-1700 PDST (+7 hrs for UTC).

Constellations: GPS (31 Satellites), Russian GLONASS (23 Satellites), Galileo (23 Satellites) and Beidou (40 Satellites).

Observables: L1 & L2 Carrier Waves on GPS, GLONASS and Beidou; and four Carrier Waves on Galileo Satellites

Data Epoch Rate - 0.2 seconds (20HZ) at the GS18 RTK Rover; 1 second RTK at the GS18 Base

Satellites: 20-40; **GDOP:** < 2; **Elevation Mask:** 0° at the Rover and Base Station

Ephemeris: Broadcast for RTK vectors.

Weather: Mostly calm clear skies, temperature 65-75° F, no significant weather.

Space Weather: Boulder K Index 2-4 averaging 3 (gauges ionospheric activity on a scale of 0-9; less than 6 preferred)

Equipment: GNSS Base Receiver Unit No.: M11, Operator: M. McGee, PLS; Occupied Base Station

 Make & Model: Leica GS18 with integrated Antenna; Mount: Tribrach on Tripod

 GNSS Rover Receiver Unit No.: M10, Operator: M. McGee, PLS

 Make & Model: Leica GS18T with integrated Antenna; Mount: Fixed Height Pole #4

Processing & Adjustments: Leica Infinity v4.0 and "Starnet-PRO" version 11.0.6 Software

ADJUSTMENTS & ANALYSIS

Network Adjustment: A minimally constrained adjustment was computed to develop NAD83 (2007) 2007.00 Epoch Zone 5 State Plane Coordinates and NAVD88 Heights of the monitoring points by fixing Point AB02 as noted previously. The NAVD88 orthometric heights (elevations) were determined by combining the measured ellipsoid heights with the Geoid03 Model. AB02 is unaffected by the land movement and the stability was verified relative to PVE3RP which is outside the influence of the land movements. Listed here are the differences from the stable position of AB02 to the measured positions of other stable points.

ID	Differences in Feet		
	dN	dE	dZ
AB02	0.000	0.000	0.000
			Fixed
AB61	-0.003	-0.006	0.016
			Stable Check Point on Portuguese Point
PVE3RP	-0.002	-0.015	0.000
			Stable Check Point at City Hall

Comments: Fixing AB02 finds no horizontal differences at PVE3RP or AB61 other than insignificant random measurement noise. Given that AB02, PVE3RP, and AB61 are in good relative agreement, the survey reference frame is deemed stable and successfully recovered from which accurate local land movements are determined.

ACCURACY STATEMENTS

Vector Residuals: The two-dimensional vector residuals average 0.007 feet and the absolute value of the vertical residuals average 0.009 feet as listed below. The vector residuals are based on a network adjustment of independent point positions.

Vector Lengths (ft)		Two Dimensional Residuals			Absolute Vertical Residuals		
Vary	Average	Average	Std.Dev.	Maximum	Average	Std.Dev.	Range
419-9657	3218	0.007	0.004	0.016	0.009	0.007	-0.05 to +0.04

Movement Accuracy: A point is deemed to have moved if, at the 95% level of confidence the horizontal movement (signal) of a point between two epochs is greater than the 95% Error (noise). Based on multiple independent occupations, the horizontal (2D) movements reported between September 2021 (M31) and October 2022 (M34) statistically attained a relative average accuracy of 0.022 feet at the 95% Level of Confidence with a Standard Deviation of 0.003 feet and a Range of 0.013 to 0.031 feet. See the attached file "PB MOVEMENT DATA POSTING 2007-2022.10.xlsx" for movements and errors estimates.

Table of Annual Movements of Monitoring Points

2D Horizontal and Vertical Movements in Feet
September 28, 2021 (M31) to October 10, 2022 (M34) = 12.4 Months

Listed below are the two-dimensional horizontal movements and vertical (elevation) changes during the period. See the attached spreadsheet “PB MOVEMENT DATA POSTING 2007-2022.10.xlsx”. Note: The horizontal measurement confidence is estimated at +/-0.02’ (1/4”); therefore, movements of 0.02’ or less are deemed statistically to not have moved. The estimated vertical measurement confidence is +/-0.05’.

Point ID	Horizontal Movements	Vertical Changes		Point ID	Horizontal Movements	Vertical Changes
AB01	0.02	-0.07		KC02	0.21	-0.03
AB02	0.00	0.00		KC05	0.09	-0.02
AB04	0.90	-0.12		KC06	0.16	-0.06
AB05	0.62	-0.11		KC07	0.02	0.01
AB13	0.49	-0.24		KC13	0.09	0.00
AB16	0.15	-0.05		KC14	0.00	0.01
AB17	0.02	-0.05		KC15	0.16	-0.03
AB20	0.51	0.00		KC16	0.02	-0.01
AB24	0.43	-0.01		KC17	0.14	-0.04
AB50	0.34	0.02		KC18	0.40	-0.02
AB51	0.31	-0.10		PB04	0.80	-0.15
AB53	0.49	-0.01		PB06	0.66	-0.06
AB57	0.44	-0.14		PB07	0.72	-0.24
AB58	0.41	-0.03		PB08	0.66	0.05
AB59	0.55	-0.15		PB09	0.65	-0.04
AB60	0.45	-0.06		PB12	0.94	-0.15
AB61	0.01	0.02		PB13	0.70	-0.02
AB62	0.78	-0.09		PB18	0.60	-0.20
AB63	0.72	-0.19		PB20	0.85	-0.14
AB64	0.06	-0.03		PB21	0.71	-0.13
AB65	0.26	-0.11		PB26	0.62	-0.01
AB66	0.38	-0.07		PB27	0.82	-0.17
AB67	0.18	-0.05		PB29	0.72	-0.15
AB68	0.32	-0.11		PB54	0.59	0.04
AB70	0.48	-0.03		PB55	0.80	-0.04
AB71	0.32	-0.08		PB59	1.02	-0.24
AB73	0.45	-0.05		PB67	1.43	-0.21
CR07	0.31	-0.27		PB68	0.75	-0.12
CR50	0.02	-0.02		PB69	0.86	-0.14
CR51	0.02	-0.04		PB70	0.72	-0.34
CR53	0.02	-0.03		PB71	0.62	-0.15
FT06	0.58	-0.28		UB02	0.78	0.04
FT08	0.03	-0.02		PVE3RP	0.02	0.00
FT09	0.01	0.01				

Addendum No. 1
Monitoring Survey No. M35 Report
Portuguese Bend Landslide Monitoring
March 13, 2023 Partial Monitoring Survey

Addendum No. 1: Report on the second of three annual Portuguese Bend Monitoring Surveys (M35). The average date of the field survey is March 13th. This partial survey included 43 points (30 required) which are a sub-set of the monitoring network. A minimally constrained adjustment was processed to develop NAD83 (2007) Epoch 2007.00 CA State Plane Coordinates and NAVD88 Heights. The estimated vector horizontal (2D) residuals at unobstructed sites averaged 0.007 feet with a Standard Deviation of 0.006 feet and a Range of 0.004 to 0.024 feet. The estimated absolute value of the vertical residuals averaged 0.008 feet with a Standard Deviation of 0.007 feet and a Range of -0.05 to +0.04 feet. At the 95% Level of Confidence, the horizontal (2D) movements reported below attained an estimated accuracy of better than 0.02 feet. The adjustment fixed AB02 and checked to AB61 and PVE3RP as shown below confirming the successful recovery of a stable reference frame (coordinate system). Differences from the known fixed positions to the measured positions in this survey are listed here with their north, east and vertical components in feet.

Differences in Feet

ID	dN	dE	dZ
AB02	0.000	0.000	0.000 Fixed
AB61	-0.006	0.009	0.020 Stable Check Point on Portuguese Point
PVE3RP	-0.002	-0.004	0.072 Stable Check Point at City Hall

Addendum No. 2
Monitoring Survey No. M36 Report
Portuguese Bend Landslide Monitoring
May 12, 2023 Partial Monitoring Survey

Addendum No. 2: Report on the third of three annual Portuguese Bend Monitoring Surveys (M36). The average date of the field survey is May 13th. This partial survey included 39 points (30 required) which are a sub-set of the monitoring network. A minimally constrained adjustment was processed to develop NAD83 (2007) Epoch 2007.00 State Plane Coordinates and NAVD88 Heights. The estimated vector horizontal (2D) residuals at moderately obstructed sites averaged 0.007 feet with a Standard Deviation of 0.004 feet and a Range of 0.002 to 0.030 feet. The estimated absolute value of the vertical residuals averaged 0.016 feet with a Standard Deviation of 0.009 feet and a Range of -0.08 to 0.04 feet. At the 95% Level of Confidence, the horizontal (2D) movements reported below attained an estimated accuracy of better than 0.02 feet. The adjustment fixed AB02 and checked to PVE3RP as shown below confirming the successful recovery of a stable reference frame (coordinate system) as shown below. Differences from the known fixed positions to the measured positions in this survey are listed here with their north, east and vertical components in feet. AB61 was not accessible at the time of the survey.

Differences in Feet

ID	dN	dE	dZ
AB02	0.000	0.000	0.000 Fixed
AB61	----	----	---- Deleted on future surveys to avoid public access/damage to environ
PVE3RP	0.020	-0.014	-0.067 Stable Check Point at City Hall

The Addendum Field Surveys, Equipment, Data Collection and Network Design were as described in the above Initial Survey Report. The Winter and Spring Horizontal (2D) and Vertical Movements are summarized in the “Periodic Horizontal & Vertical Movement in Feet” table below. The Direction of Movement is generally south to south-southwest. See “PB MOVEMENT DATA POSTING 2007-20##.xlsx” for the direction, distance, and confidence.

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Note, a substantial increase in movement velocities was observed between the October 2022 and May 2023 surveys compared to the previous four years. Points AB61, PB12, PB18 and PB26 were not accessible in the May 2023 Survey due to an extraordinary spring growth of Mustard plants. PB09 was added in May as a nearby substitute for PB12. A Pepper Tree has overgrown PB18 to the point where it will be abandoned if not cleared for future surveys.

“Partial Monitoring” Movements Periodic Horizontal & Vertical Movements in Feet								
	Oct. 10, 2022 (M34) to March 13, 2023 (M35) = 5.0 mo			March 13, 2023 (M35) to May 12, 2023 (M36) = 2.0 mo			Oct. 10, 2022 (M34) to May 12, 2023 (M36) = 7.0 mo	
Monitoring Point	Movement Distance	Elevation Change	Monitoring Point	Movement Distance	Elevation Change	Monitoring Point	Movement Distance	Elevation Change
AB02	0.00	0.00	AB02	0.00	0.00	AB02	0.00	0.00
AB04	0.93	-0.12	AB04	0.87	-0.08	AB04	1.80	-0.20
AB13	0.31	-0.18	AB13	0.38	-0.06	AB13	0.70	-0.24
AB16	0.13	0.02	AB16	0.16	0.04	AB16	0.29	0.06
AB17	0.05	0.01	AB17	0.01	0.01	AB17	0.05	0.03
AB20	0.38	-0.06	AB20	0.46	0.04	AB20	0.84	-0.02
AB24	0.34	-0.06	AB24	0.38	0.05	AB24	0.73	-0.01
AB50	0.25	-0.02	AB50	0.30	0.05	AB50	0.55	0.03
AB53	0.32	-0.13	AB53	0.41	0.03	AB53	0.74	-0.10
AB58	0.25	-0.14	AB58	0.35	-0.03	AB58	0.60	-0.16
AB59	0.38	-0.10	AB59	0.47	-0.08	AB59	0.85	-0.17
AB60	0.39	-0.06	AB60	0.41	0.01	AB60	0.80	-0.05
AB61	0.01	0.02						
AB62	0.72	-0.11	AB62	0.68	-0.03	AB62	1.40	-0.14
AB65	0.20	-0.03	AB65	0.24	-0.01	AB65	0.43	-0.04
AB66	0.27	-0.12	AB66	0.35	-0.02	AB66	0.63	-0.14
AB67	0.15	-0.08	AB67	0.18	0.02	AB67	0.32	-0.07
AB68	0.23	-0.12	AB68	0.31	-0.05	AB68	0.54	-0.17
AB70	0.38	-0.06	AB70	0.45	0.05	AB70	0.84	-0.01
AB73	0.36	-0.08	AB73	0.42	-0.01	AB73	0.78	-0.09
CR07	0.19	-0.24	CR07	0.25	-0.19	CR07	0.44	-0.43
CR50	0.03	-0.12	CR50	0.02	0.08	CR50	0.05	-0.04
FT06	0.41	-0.26	FT06	0.53	-0.21	FT06	0.93	-0.47
FT09	0.01	-0.11	FT09	0.03	0.08	FT09	0.04	-0.03
KC06	0.13	-0.12	KC06	0.20	-0.04	KC06	0.33	-0.16
KC07	0.02	-0.07	KC07	0.02	0.01	KC07	0.01	-0.06
KC13	0.08	-0.01	KC13	0.11	0.06	KC13	0.19	0.06
KC16	0.01	-0.05	KC16	0.03	0.04	KC16	0.04	-0.01
KC17	0.11	-0.08	KC17	0.20	0.03	KC17	0.31	-0.05
PB04	0.63	-0.12	PB04	0.61	-0.05	PB04	1.23	-0.17
						PB09	1.00	-0.05
PB12	0.62	-0.08						
PB13	0.48	-0.02	PB13	0.60	0.04	PB13	1.08	0.02
PB18	0.39	-0.11						
PB26	0.46	-0.13						
PB54	0.39	-0.04	PB54	0.54	0.03	PB54	0.93	-0.02
PB55	0.50	-0.16	PB55	0.58	-0.17	PB55	1.06	-0.33
PB59	0.77	-0.22	PB59	0.72	-0.08	PB59	1.49	-0.30
PB67	0.96	-0.20	PB67	1.12	-0.13	PB67	2.08	-0.33
PB68	0.57	-0.09	PB68	0.59	-0.04	PB68	1.16	-0.12
PB69	0.63	-0.12	PB69	0.69	-0.07	PB69	1.32	-0.19
PB70	0.54	-0.28	PB70	0.60	-0.19	PB70	1.14	-0.48
PB71	0.47	-0.13	PB71	0.57	-0.15	PB71	1.03	-0.27

Note: Movements greater than 0.02 feet (1/4") are deemed to have moved. See attached "PB MOVEMENT DATA POSTING" for a details.

PARTIAL ASSESSMENT of OBSERVATIONS

In the last seven months the movement velocities have accelerated over the average velocity for the previous four years which saw an acceleration over the previous 15-20 years. A year is defined generally as 12 months from the beginning of October to the end of September of the following year. Below are the average measured movements for a sample of monitoring points from five to nine years back, one to four years back and this partial year with a projection to the Fall of 2023. It appears the Abalone Cove slide is beginning to match the Portuguese Bend slide.

<u>Movement Summary in Feet</u>					
ID	2014-2018		2018-2022		Projected for 1 Yr.
	4 Yr. Av.	Max.	4 Yr. Av.	Max.	
AB53	0.07	0.18	0.43	0.49	0.74
AB20	0.09	0.20	0.48	0.54	0.84
AB68	0.05	0.11	0.31	0.32	0.54
CR07	0.06	0.13	0.30	0.32	0.44
KC06	0.04	0.09	0.16	0.22	0.33
PB55	0.89	1.31	0.89	1.23	1.06

Velocities were stable prior to 2018. After the Fall of 2018 they increased about 3 to 6 fold at most points and remained stable to the Fall of 2022. In the last seven months since the Fall of 2022 the velocities generally have doubled more or less. The Projected Movements for the end of the year in the Fall of 2023 were based on the previous years results.

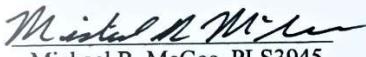
RECOMMENDATION

Continuity in terms of consistency of the precision of the surveys and methods of reporting are necessary to continue to evaluate future survey results relative to the 2007-2023 monitoring survey campaigns. If in the future, monitoring survey campaigns are performed by others it is recommended the City of Rancho Palos Verdes secure the services of an independent expert GNSS/Geodetic consultant to evaluate and validate results to assure program integrity.

Clearing foliage and tree trimming to allow for full sky visibility for tracking satellites results in improved accuracy and production. Points AB13, AB16, AB17, AB51, AB58, AB66 and PB18 have limited sky visibility due to surrounding trees and would benefit from annual clearing. Improvements in GNSS (GPS) instrumentations and constellations have helped mitigate some of these issues. A Pepper Tree has overgrown PB18 and it will be abandoned if not cleared for future surveys.

SURVEYOR'S STATEMENT

This is the Fall 2022 through Spring 2023 Report on the procedures, criteria, and results of the City of Rancho Palos Verdes Portuguese Bend Landslide Monitoring Surveys. This survey was performed, and Report prepared by me June 7, 2023 at the request of Ron Dragoo, Principal Engineer of the City of Rancho Palos Verdes.


Michael R. McGee, PLS3945

