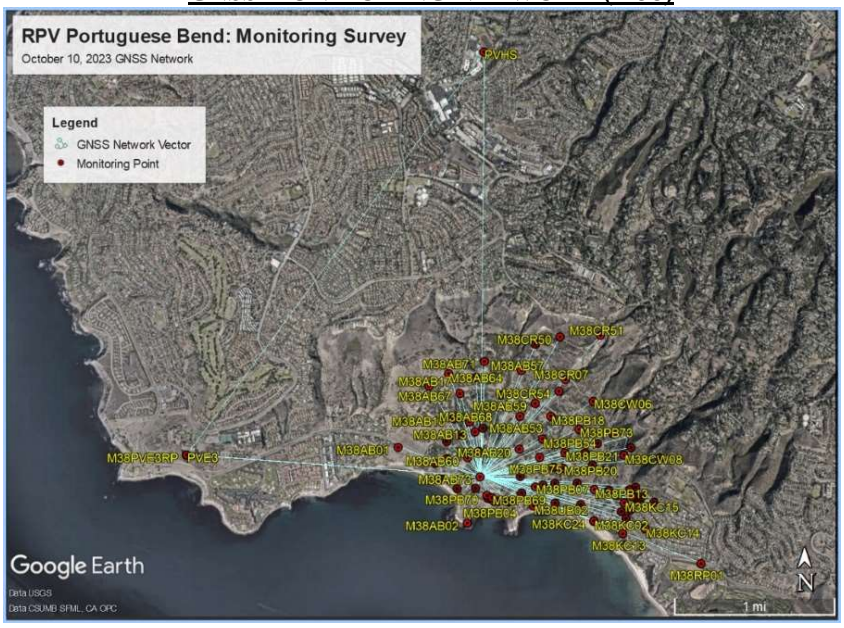
Survey Report
of the
Portuguese Bend Oct. 2022-Oct. 2023
Land Movement Monitoring Surveys
for the
City of Rancho Palos Verdes
prepared by
McGee Surveying Consulting
Date: October 30, 2023

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. This is the Report on the Initial Fall 2023 Monitoring Survey. Movements are reported from ***October 10, 2022 (M34) to October 10, 2023 (Initial Fall Survey M38)****. Movements listed for this period on Page 5.*

ATTACHMENT: "PB MOVEMENT DATA POSTING (Revised) 2007-Oct2023.xlsx"

OVERVIEW:

GNSS MONITORING NETWORK (M38)



McGee Surveying Consulting (MSC) performed the Fall 2023 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 79 monitoring points to assess their annual and overall movements and verify the recovery of the reference frame. The survey included 10 new points set in September 2023, two new points set in July for the Klondike Canyon (Seaview) M37 Monitoring, and a new point KC24 set to replace KC02. Movements of new points will be reported on subsequent surveys.

For details and procedures utilized in this survey but not re-stated here, see the 2021-2022 Monitoring Survey Report published in May 2022 and previous reports. The October 2023 coordinates and the annual October 2022 to October 2023 movements are listed in the attached spreadsheet titled "PB MOVEMENT DATA POSTING…..". An annual summary is listed below.

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) Datums (reference frames). Although more current epoch adjustments are available (e.g. NAD83 (2011) Epoch 2010.00), Epoch 2007.00 is retained to maintain consistently relative positions over time. The NGS Geoid03 is used to model NAVD88 Orthometric Heights (elevations) based on measured ellipsoid heights referenced to NGS

Benchmarks. Although more current models are available (e.g. Geoid18), Geoid03 is retained to maintain consistently relative heights over time as explained in the May 2022 Report. The latitudes and longitudes determined by GNSS measurements are projected into NAD83 California State Plane Coordinates Zone 5 in US Survey Feet.

The method for recovering the monitoring survey reference frame was modified in 2019 to improve the efficiency and simplify the processing and analysis of the monitoring surveys. Since 2007, Point AB02 (at the south end of Portuguese Point) has proven to be stable relative to PVE3 ((a California Spatial Reference Center (CSRC) Continuously Operated GPS Station (CGPS) at City Hall)). The previous procedure was modified by fixing point AB02 instead of PVE3 and checking to PVE3RP (a PK Nail set on the concrete base of PVE3 for a reference mark to PVE3). The proven positions relative to PVE3 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

Comparing the positions of AB02 on Portuguese Point with PVE3RP at City Hall provides a redundant verification that the reference frame is stable and successfully recovered for each monitoring survey.

The rate of movement (velocities) of the landslides have increased over the past five years compared to the previous 12-year average. A notable increase in the velocities of the landslides were observed between the October 2022 and May 2023, with additional increases in velocities observed between May and July and again between July and the October 2023 survey. See "Assessment of Movements & Accelerations" addressed on Page 8. Notwithstanding the 2019 process noted in the above paragraph, the processing of observations was necessarily modified for this fall survey as follows.

The October 2023 observations were processed as follows. The Base Station AB73 was occupied over a six-day period and was found to have moved about 0.016 feet per day as were other monitoring points in the slides. To determine accurate position and therefore precision movements it was necessary to determine a daily position of AB73. This was accomplished by processing the static data collected each day at AB73 with static data downloaded from the CSRC for PVE3 and PVHS. PVE3 is and has always been the basic constraint for the monitoring survey's reference frame. PVHS was used to verify the stability of PVE3. Subsequently positions of AB73 were computed for each day referenced to PVE3. The identity for processing the daily observations of AB73 and related RTK measurements was to assign to AB73 the identity of AB731, AB732, AB733, AB734 & AB735 for days 1 through 5 occurring on October 8, 9, 10, 11 & 13.

AB61 and AB20 have previously served as suitable GNSS Base Stations for referencing measured positions of the monitoring points. AB61 is no longer accessed due to its environmental sensitivity. Presently AB73, located on the US Pony Club property, is utilized as the Base Station. Access was obtained unilaterally by MSC from the Pony Club manager. MSC has exclusive permission to enter the property which is confirmed prior to each survey entry with the understanding that strict driving protocols are observed. This privilege at this time does not extend to others. Point AB73 was not a planned monitoring point but given the increased rates of movement, it fills in a gap between AB20 and AB50 and moves consistent with AB20.

The Fall 2023 Survey is the 38th Monitoring Survey. For data management purposes the point names are prefixed with a sequential monitoring number to distinguish subsequent surveys. For example, on the 16th monitoring survey, AB02 was named M16AB02 where M16 indicates the sequence number since the first Monitoring Survey "M01" in September 2007. The prefix is stripped in these Reports.

October 2023 GNSS Survey Network: Monitoring Points


Portuguese Bend: Monitoring Survey
October 10, 2023 Monitoring Point Array
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GNSS Survey Parameters, Metadata & Equipment

Date of Annual Initial Survey: M38 – October 10, 2023 (mean date) between 0800-1700 PDST (+7 hrs for UTC).
Constellations: GPS (31 Satellites), Russian GLONASS (23 Satellites), Galileo (23 Satellites) and Beidue (40 Satellites).
Observables: L1 & L2 Carrier Waves on GPS, GLONASS and Beidue; 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 1-3 averaging 2 (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
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

Prior to 2019, geodetic grade GNSS receivers collected static satellite signal data for post processing. The instrumentation was upgraded in 2020 to a Leica GS18 Base with a GS18T RTK Rover operating in real-time with an FM radio system which utilizes the latest technology to deliver increased productivity and precision of point positions. The GS18 receiver incorporates an Inertial Measurement Unit and tracks four Global Navigation Satellite Systems (GNSS) including GPS, GLONASS, Galileo and Beidue 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 0.02 feet.

ADJUSTMENTS & ANALYSIS

Network Adjustment: A minimally constrained adjustment is utilized to develop NAD83 (2007) 2007.00 Epoch Zone 5 State Plane Coordinates and NAVD88 Heights of the monitoring points. The NAVD88 orthometric heights (elevations) are determined by combining the measured ellipsoid heights with the Geoid 03 Model. Previously, Point AB02 was fixed, and the stability verified relative to PVE3RP which is two miles westerly outside the influence of the land movements and noted above. AB02 is expected to be stable and unaffected by the land movement; however, due to the substantially increased rates of movement resulting in dynamically differential movements across the slide complex the process was modified to produce accurate positions as noted above. This was accomplished by computing daily positions on the Base Station AB73 (AB731, AB732, AB733, AB734, AB735) relative to the reference frame fixed at PVE3 also noted above. Listed here are the differences.

	Differences in Feet			
ID	dN	dE	dZ	
AB02	-0.022	-0.008	0.000	Fixed Elevation & Horizontal Check
PVE3RP	-0.010	-0.003	-0.055	Closure Check from PVE3 to AB73 to PVE3RP at City Hall
PVE3	0.000	0.000		Fixed Horizontal, CGPS Station at City Hall
PVHS	-0.035	0.003		Horizontal Check on CGPS Station 2 Miles North of PB

Comments: Fixing PVE3 (original 2007 constraint) finds the differences at PVHS, PVE3RP or AB02 are insignificant measurement noise. Given that AB02, PVE3RP, PVE3 and PVHS are in good relative agreement, the survey reference frame is deemed stable and successfully recovered from which local land movements were determined.

ACCURACY STATEMENTS

Vector Residuals: The two-dimensional vector residuals average 0.012 feet and the absolute value of the vertical residuals average 0.016 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
131-16391	3792	0.012	0.006	0.029	0.02	0.02	-0.03 to +0.08

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 October 2022 (M34) and October 2023 (M38) statistically attained a relative average accuracy of 0.014 feet at the 95% Level of Confidence with a Standard Deviation of 0.004 feet and a Range of 0.01 to 0.03 feet. See the attached file "PB MOVEMENT DATA POSTING….." for movements and errors estimates.

Table of Annual Movements of Monitoring Points

2D Horizontal and Vertical Movements in Feet
(M34) October 10, 2022 to (M38) October 10, 2023 = 12.0 Months

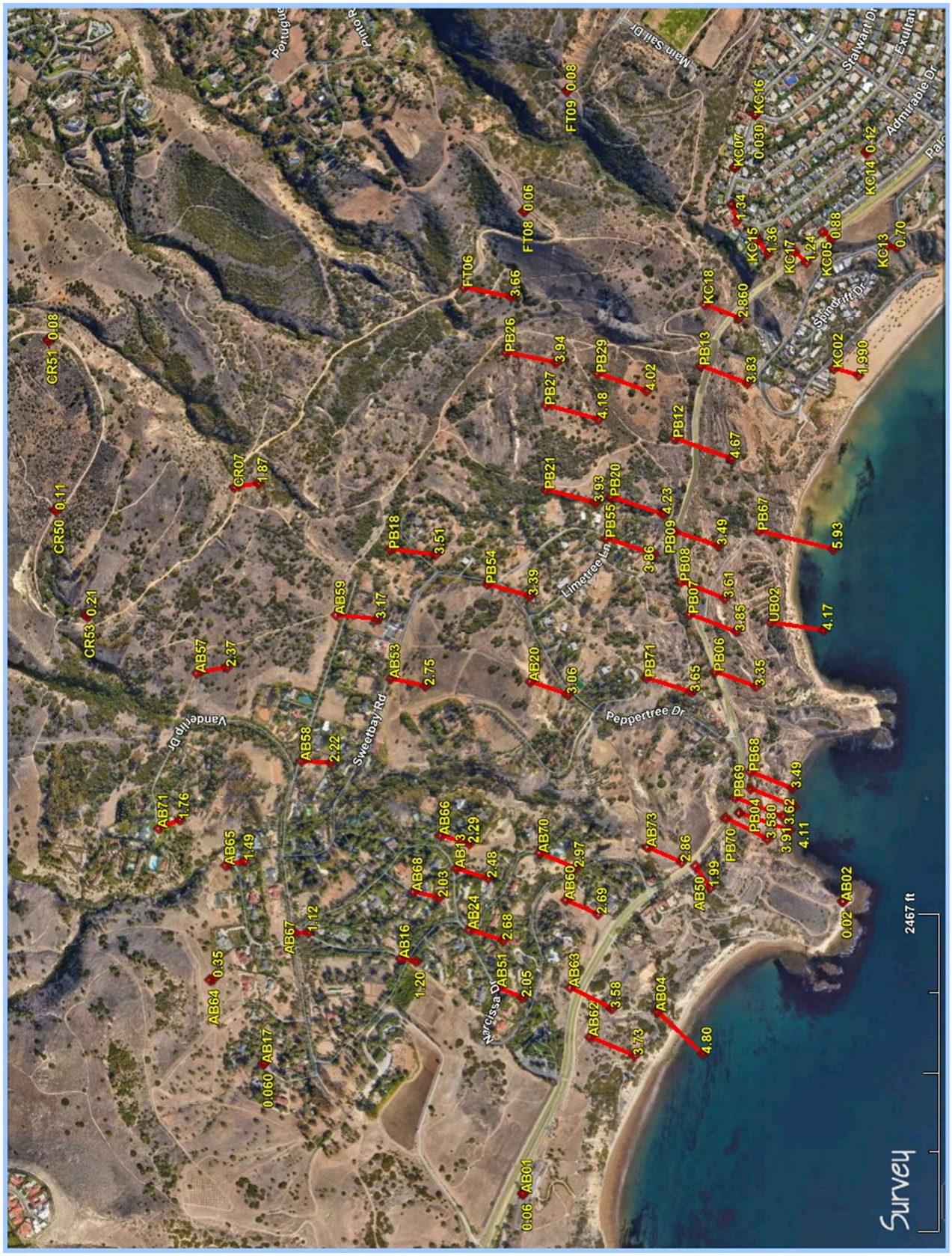
Listed below are the movement Azimuths (directions from North) in degrees, the two-dimensional horizontal movements and vertical (elevation) changes during the period. Units are in US Survey Feet. See the attached spreadsheet "PB MOVEMENT DATA POSTING (Revised) 2007-Oct2023.xlsx". Note: The horizontal measured movement confidence is estimated at +/-0.02' (1/4"); therefore, movements of less than 0.03' are statistically indeterminate. The estimated vertical measured movement confidence is +/-0.05'. *Control Point: Verifies Stability of Reference Frame.

Point ID	Azimuth°	Horizontal Movement	Vertical Movement		Point ID	Azimuth°	Horizontal Movement	Vertical Movement
AB01	244	0.06	0.0		KC02	196	1.99	0.1
AB02	201	0.02	0.0		KC05	219	0.88	-0.1
AB04	223	4.80	-0.6		KC06	253	1.34	-0.5
AB05	231	3.51	-0.6		KC07	256	0.02	0.0
AB13	198	2.48	-0.6		KC13	193	0.70	0.1
AB16	191	1.20	0.0		KC14	259	0.12	-0.1
AB17	187	0.06	0.0		KC15	233	1.36	-0.4
AB20	199	3.06	-0.1		KC16	251	0.03	0.0
AB24	198	2.68	0.0		KC17	222	1.24	-0.3
AB50	236	1.99	0.2		KC18	202	2.86	-0.3
AB51	202	2.05	-0.2		PB04	203	3.62	-0.3
AB53	192	2.75	-0.4		PB06	200	3.35	-0.3
AB57	169	2.37	-0.7		PB07	201	3.85	-0.1
AB58	183	2.22	-0.4		PB08	201	3.61	0.0
AB59	186	3.17	-0.8		PB09	198	3.49	-0.1
AB60	204	2.69	-0.3		PB12	200	4.67	-0.3
AB62	203	3.73	-0.4		PB13	201	3.83	0.1
AB63	207	3.58	-0.9		PB18	187	3.51	-0.5
AB64	155	0.35	-0.1		PB20	199	4.23	-0.4
AB65	167	1.49	-0.3		PB21	195	3.93	-0.6
AB66	196	2.29	-0.5		PB26	192	3.94	-0.4
AB67	180	1.12	-0.2		PB27	195	4.18	-0.8
AB68	193	2.03	-0.6		PB29	200	4.02	-1.0
AB70	203	2.97	-0.1		PB54	196	3.39	-0.2
AB71	158	1.76	-0.6		PB55	199	3.86	-0.8
AB73	203	3.00	-0.3		PB59	199	4.11	-0.6
CR07	171	1.87	-1.6		PB67	194	5.93	-0.8
CR50	225	0.11	-0.1		PB68	202	3.49	-0.1
CR51	223	0.08	0.0		PB69	202	3.91	-0.3
CR53	231	0.21	0.0		PB70	207	3.58	-0.8
FT06	192	3.66	-1.7		PB71	198	3.65	-0.4
FT08	257	0.06	0.0		UB02	189	4.17	0.3
FT09	271	0.08	-0.1		*PVE3RP	195	0.00	0.0

McGEE SURVEYING CONSULTING
5290 Overpass Road, Ste#107, Santa Barbara, CA 93111

October 10, 2022 to October 10, 2023 Movement Distances (Feet) & Directions as Indicated

Note: Distances are exaggerated x 100 for viewing



MONITORING POINT MONUMENT NOTES & STATUS

See the May 2022 Survey Report for prior monument notes.
2023: 13 points added to the monitoring program as listed below

MONITORING POINT MONUMENT DESCRIPTIONS

For the NAD83 (2007) Epoch 2007.00 California State Plane Coordinates Zone 5 and NAVD88 Heights, see the attached file "PB MOVEMENT DATA POSTING…." Spreadsheet.
See Point Descriptions Sheets for more details.

Point	Brief Description
Points added in October 2023	
PB72	2" mag nail & washer in conc. in 2"x 24" GIP Collared in Concrete
PB73	2" mag nail & washer in conc. in 2"x 24" GIP Collared in Concrete
PB74	2" mag nail & washer in conc. in 2"x 24" GIP Collared in Concrete
PB75	2" mag nail & washer in conc. in 2"x 24" GIP Collared in Concrete
CR54	2" mag nail & washer in conc. in 2"x 24" GIP Collared in Concrete
CW06	Found ½″ x 48″ Punched Rebar in Concrete Collar
CW08	Found 2″ Mag nail in Concrete Base of 3′ Pedestal
KC19	2″ Mag Nail Drilled in a Concrete Curb on South side of Dauntless
KC20	2″ Mag Nail Drilled in a Concrete Curb on West side of Excelsior
KC21	2" mag nail & washer in conc. in 2"x 24" GIP Collared in Concrete
KC22	2" mag nail & washer in conc. in 2"x 24" GIP Collared in Concrete
KC23	2″ Mag Nail Drilled in a Concrete Curb on South side of
KC24	2″ Mag Nail Drilled in the Southwest Corner of a Concrete Vault for Drop Inlet; Replacement for KC02

ASSESSMENT of MOVEMENTS & ACCELERATIONS

Others performed monitoring surveys of land movement between 1994 and 2006. MSC assumed responsibility for the Portuguese Bend Monitoring Program in 2007. The annual measured movements between 2007 and 2018 were fairly small and stable as shown below by the averages and maximums of a sampling of points for the 2014-2018 period compared with the 2018-2022 period. In the fall of 2019, the annual average rate of movements (velocities) increased 4 to 6 times and then remained stable for the next four years as shown below for the 2018-2022 period. Note: The year is defined as the 12-month rainy season beginning October first each year.

Annual Average Movements in Feet, Maximum Movements & Change in the Average of a Sample of Points

	2014-2018 (4 Yrs)		2018-2022 (4 Yrs)		Change in
ID	Average	Max.	Average	Max.	Average
AB20	0.09	0.20	0.48	0.54	+5X
AB53	0.07	0.18	0.43	0.49	+6X
AB68	0.05	0.11	0.31	0.32	+6X
CR07	0.06	0.13	0.30	0.32	+5X
KC06	0.04	0.09	0.16	0.22	+4X
PB55	0.89	1.31	0.89	1.23	+1X (No Change)

Then in the last twelve months between October 2022 and October 2023, the annual rate of movements accelerated again. The table below shows a sample of points within the Abalone Cove (AB), Klondike Canyon (KC) and Portuguese Bend (PB) Landslides. The left half of the table compares the annual movements and rate of movements per month for the October 2021-October 2022 with the October 2022-October 2023 period. The annual rate of movement for the sample averages for each landslide AB, KC, & PB increased 6, 8 and 5 times respectively in the last 12 months. However, in the last 12-month period (October 2022-October 2023), accelerations are noted in the first seven months and again in the last five months as shown in the right half of the table below.

In the first seven months of October 2022-October 2023, the average rate of movements for these samples in each slide AB, KC, & PB increased 3, 4 and 2 times respectively over the previous 12-month period (October 2021- October 2022). In the last five months of October 2022-October 2023, the average rate of movements for the samples in each slide AB, KC, & PB increased 4, 4 and 3 times respectively over the previous seven months.

Movements & Rate of Movement per Month in US Survey Feet									
		M32 > M34 (12 Mo.)		M34 > M38 (12 Mo.)		M34 > M36 (7 Mo.)		M36 > M38 (5 Mo.)	
Point		Oct '21 > Oct '22		Oct '22 > Oct '23		Oct '22 > May '23		May '22 > Oct '23	
		Movement	Rate/Mo	Movement	Rate/Mo	Movement	Rate/Mo	Movement	Rate/Mo
AB20		0.51	0.042	3.06	0.255	0.84	0.119	2.22	0.444
AB53		0.49	0.041	2.75	0.229	0.74	0.105	2.01	0.403
AB58		0.41	0.034	2.22	0.185	0.60	0.085	1.62	0.325
AB60		0.45	0.038	2.69	0.224	0.80	0.114	1.90	0.379
AB67		0.18	0.015	1.12	0.094	0.32	0.046	0.80	0.160
AB68		0.32	0.027	2.03	0.169	0.54	0.077	1.49	0.299
AB70		0.48	0.040	2.97	0.248	0.84	0.120	2.14	0.427
CR07		0.31	0.026	1.87	0.156	0.44	0.062	1.43	0.287
Av Move		0.39	0.033	2.34	0.195	0.64	0.091	1.70	0.340
KC06		0.16	0.014	1.34	0.111	0.33	0.047	1.01	0.202
KC13		0.09	0.007	0.70	0.058	0.19	0.027	0.51	0.102
KC17		0.14	0.012	1.24	0.104	0.31	0.044	0.93	0.187
Av Move		0.13	0.011	1.09	0.091	0.27	0.039	0.82	0.163
PB55		0.80	0.067	3.86	0.321	1.06	0.151	2.80	0.560
PB70		0.72	0.060	3.58	0.299	1.14	0.163	2.44	0.488
Av Move		0.76	0.063	3.72	0.310	1.10	0.157	2.62	0.524

RECOMMENDATION

Continuity in consistency of the methods, precision and reporting are necessary to continue to evaluate survey results relative to the prior 2007-2024 monitoring survey campaigns. These monitoring survey campaigns require the services of an independent GNSS/Geodetic expert to evaluate and validate results to assure program integrity.

Clearing foliage and tree trimming are a necessary on-going task to assure as much sky visibility as possible for tracking satellites to obtain the required precision and productivity. Although improvements in GNSS (GPS) technology and additional constellations help mitigated some of these issues. Points AB13, AB16, AB17, AB51, AB58, AB66 and PB18 are examples of points with limited sky visibility benefiting from annual clearing.

SURVEYOR'S STATEMENT

This is the Fall 2023 through Spring 2024 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 on October 30, 2023 at the request of Ramzi Awwad, City Engineer of the City of Rancho Palos Verdes.

Michael R. McGee, PLS3945