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RE: Review of Thirteenth (13th) Re-measure of the Waterline W1A and W2A Benchmark Elevations in the Woodlands, Texas in September 2021 and Evaluation of Potential Damage to the Transmission Line along Segments W1A and W2A from Land Subsidence

Dear Aaron:

This letter provides an update to our review of a September 2021 re-measure of benchmarks placed along four lines in The Woodlands in March 2015.

The work was performed under Master Professional Services Agreement Contract No. 20-0077 and under Work Order 5 (PO Number: 21-1257). The technical lead for this task was Dr. Steve Young.

Respectfully submitted,

Steven C Young

Steven Young, PHD
Professional Geologist
Professional Engineer

ATTACHMENT A
Review of W1A and W2A Benchmark Elevations

The September 2021 survey represents is the thirteenth (13th) re-measure of the benchmarks since their initial measurements in March 2015. The benchmarks are grouped into two areas: W1A and W2A. Each of the two areas include benchmarks along two transects. **Figure 1** shows the locations the two transects. **Tables 1** and **2** show the re-measured benchmark elevations for the two W1A transects located near the Egypt Fault. **Tables 3** and **4** show the measured benchmark elevations for the two W2A transects located near the Big Barn Fault (Table 3) and Panther Branch fault (Table 4).

The thirteenth re-measure includes measurements of elevations at 45 benchmarks along the W1A and W2A transects. Along the W1A segment with 4 benchmarks, the changes in benchmark elevation suggests that the Egypt fault is one of several factors that contributes to the differences in land subsidence rates, which are about 0.005 ft/year, across the transect it divides. Along the W2A segment, the differences in changes in benchmark elevation suggest that the Panther Branch fault may be a one of several factors that contributes to the differences in land subsidence rates of about 0.005 ft/yr, across the transect it divides.

Figure 2 is a satellite map that shows the SJRA transmission line and the faults that have been identified in the W1A and W2A area by Fugro (2012). The lateral extent of the Egypt fault, the Big Barn Fault, the Jones Fault, and the Panther Branch Fault mapped by Fugro (2012) are represented by the georeferenced fault lines. In their study, Fugro (2012) did not extend the Panther Branch Fault across the transmission line route. The interpolated portion of the Panther Branch Fault was mapped by INTERA based on the evaluation of the benchmark elevation for Segment W2A and scarp locations in the parking lot of The Woodlands High School. At three locations where the transmission line crosses a fault, SJRA constructed safeguards specifically designed to protect the transmission line from damage caused by land subsidence and installed benchmarks to monitor land subsidence. Because the Fugro report (2012) did not show the Panther Branch fault crossing Research Forest Drive and the planned route for the transmission line, SJRA did not construct safeguards to specifically protect the transmission lines from damage caused by land subsidence. However, in order to help investigate whether an extension of the Panther Branch Fault as mapped by the Fugro report (2012) existed along Research Forest Drive, SJRA installed the benchmarks associated with the Segment W2a Monitoring System.

Based on the changes in benchmark elevations during the last 6.5 years, INTERA has concluded that the SJRA transmission line is not at risk of damage from land subsidence where it crosses the Egypt Fault and the Big Barn Fault for the next 50 years if land subsidence continues at its current rate and if the SJRA safeguards work as designed. INTERA also has concluded it has insufficient evidence to determine whether or not the SJRA transmission line are protected from damage from land subsidence where it crosses the Panther Branch Fault.

Review of Thirteenth (13th) Re-measure of the Waterline W1A and W2A Benchmark Elevations

W1A Transects

Tables 1 and 2 provide the differences in elevations for 22 benchmarks located along the W1A Segment. The differences in benchmark elevations for the last 6 months and for the last 6.5 years are discussed below.

Last 6 months- Over the last 6 months, 13 out of the 22 benchmarks had no change in elevation, 8 benchmarks had a decrease in elevation of 0.01 foot (ft), and 1 benchmark had no increase in elevation of 0.01 ft. In Tables 1 and 2, there are no notable differences in the average change in elevations between the 8 benchmarks located on the upthrown side of the fault compared to the 9 benchmarks located on the downthrown side of the fault.

Last 6.5 years- Since March 2015, the elevation changes at the 22 benchmarks are as follows: 9 benchmarks had a decrease in elevation of 0.01 ft, 9 had a decrease of in elevation of 0.02 ft, 1 benchmark had a decrease in elevation of 0.03 ft, 1 benchmark had a decrease in elevation of 0.04 ft, 1 benchmark had no change in elevation, and 1 benchmark had a decrease in elevation of 0.12 ft. The decrease of 0.12 ft occurred at benchmark MbM-11 located near the upper edge of the downthrown fault block at the midpoint of the transect segment A1A.

The -0.12 ft difference at benchmark MbM-11 is an outliner among the other measured differences and is attributed the benchmark being located in a narrow zone of highly disturbed soil in the downthrown fault blocks. The 0.12 ft drop in ground surface elevation is likely caused by the slow, progression compaction of soil. Looking at the pattern of elevation changes at the remaining 17 benchmarks associated with the Segment W1A Monitoring System in Table 1 and in **Figure 3**, the elevations of the southern benchmarks has dropped about 0.007 ft more than the northern segment. Across the southern benchmarks that include MbM-7 through MbM-20(with Mbm-11 excluded), the 6.5-year elevation differences range between -0.01 and -0.02 and average -0.0169 ft. Across the northern benchmarks, the benchmarks MbM-1 to MbM-4, all have a -0.01 elevation difference the last 6.5 years. The difference between the benchmarks north and south of the faults is less than 0.01 ft. Given that this change is relatively small relative to measurement error there is insufficient evidence to conclude that the fault is active. For instance, the analysis of the benchmarks during the last six months does not support the trend observed over the last 6.5 years.

Over the last 6.5 years, the net change in elevation for the 4 benchmarks at Egypt Monitoring System (see Table 2 and Figure 3) range between 0 and -0.04 ft and the average is -0.02 ft. The two benchmarks on the upthrown side of the fault have an average decrease of 0.005 ft in elevation whereas the two benchmarks on the downthrown side of the fault have an average decrease of 0.035 ft. Over the last 6 months, the two benchmarks on the upthrown side of the fault had an averaged a rise in elevation of 0.005 ft whereas the two benchmarks on the downthrown side of the fault had average drop in elevation of 0.005 ft. The changes in benchmark elevations that occur over both the 6 month and 6.5 year periods suggest that Egypt fault could be a contributing factor to the difference in the measured rate of elevation change, which are about 0.005 ft/year, across the transect it divides.

<u>W2A Transects –</u>

Tables 3 and 4 provide the differences in elevations for 23 benchmarks located along the W2A Transect. The differences in benchmark elevations for the last 6 months and for the last 6.5 years are discussed below. For the discussion below, the September 2021 for benchmark MbM-10 has been omitted because it appears to be an outlier

Last 6 months - Over the last 6 months, 11 out of the 22 benchmarks had no change in elevation, 9 had a decrease of 0.01 ft, 1 had a decrease of -0.02 ft, and 1 benchmark had an increase of 0.01 ft. In Table 3, there is no difference in the average change in elevations for the 2 benchmarks that are on the upthrown side of the fault and the two 2 benchmarks on the downthrown side of the fault. In Table 4, western benchmarks MbM-1 through MbM-12 (with MbM-10 excluded) and MbM-20 averaged less than a 0.01 ft decrease in elevation and the eastern benchmarks MbM-13 through MbM-18 average no change in elevation.

Last 6.5 years – Over the last 6.5 years, 5 out of the 22 benchmarks had no change in elevation, 4 had a decrease of 0.01 ft, 1 had a decrease of 0.02 ft, 4 had a decrease of 0.03 ft, 5 had a decrease of 0.04 ft, 2 had a decrease of 0.05 ft, and 1 had a decrease of 0.07 ft.

In Table 3 and in **Figure 4**, the 2 benchmarks that are on the downthrown side of the fault have an averaged elevation decrease that is 0.01 ft more than the two benchmarks on the upthrown side of the fault. Our interpretation of the results from the 6 month and 6.5-year intervals suggest that there is no conclusive evident of an active fault zone between the location of the benchmarks.

In Table 4 and in **Figure 5**, the 19 benchmarks associated with the Segment W2A Monitoring System indicate that the western portion (downthrown side) of the transect has decreased in elevation more than the eastern portion (upthrown side) of the transect. At the western benchmarks MbM-1 through MbM-12(with MbM-10 excluded) and MbM-20, the elevation change ranged from -0.0 to -0.07 ft and averaged about -0.041 ft. At the eastern benchmarks MbM-13 through MbM-18, the elevation change ranged from -0.00 to -0.01 ft and averaged -0.004 ft. Along the W2A segment, the differences in elevation suggest that the Panther Branch Fault is located near benchmark MbM-12 and may be a one of several factors that contributes to the differences in land subsidence rates of about 0.005 ft/yr between the benchmarks located on the western and eastern portion of the W2A segment.

Evaluation of Potential Damage to the Transmission Line along Segments W1A and W2A from Land Subsidence

To assess the risk of potential damage to the transmission line, INTERA gather information assembled information on the design of these safeguards through construction drawings and discussions with persons knowledgeable of the safeguards. The construction drawings included the design of the casing pipe for the W1A area by Lockwood, Andrews & Newman, Inc and the design of the casing pipe for the W2A area by Binkley & Barfield, Inc. The design of the safeguards for the Big Barn Fault is based on the design used for where the Egypt Fault intersects the 48-inch transmission line.

W1A Area

In the vicinity of the Egypt Fault Monitoring System, SJRA's 48-inch diameter transmission line is protected by a pipe casing along a 500-ft section that crosses over the Egypt Fault. The transmission line is constructed of steel and capable of shifting approximately 1-ft over the 500-ft interval without problems. Because of the possibility that the transmission line could eventually have a differential movement of more than 1 ft, SJRA constructed a safeguard using pipe casing. The pipe casing safeguard is designed to protect the transmission line for up to 0.25 inches of vertical movement at the fault per year over a 50-year period, or a total of 12.5 inches. The dip angle of the fault was estimated at 70 degrees. A 12.5-inch vertical movement is expected to cause the casing and pipe to bow and move horizontally up to 4-inches. The pipe and casing can deflect and "flex" with the vertical movement but a horizontal movement of 4 inches could stress the steel enough to break the joints. To protect against the horizontal movement, two expansion couplings, each of which can move up to 4 inches horizontally, were added at the pipe connections. These expansion joints allow up for 8-inches of horizontal movement. Several methods are in place to monitor the condition of the transmission pipe. One of these methods is measuring the change in elevations in the casing and pipe at the ends of the pipe casing. After 6.5 years of monitoring the differences the benchmark elevations over time are less than 0.05 ft.. Based on the information that INTERA has reviewed, INTERA concludes the transmission line is not at risk of damage from land subsidence where it crosses the Egypt Fault along Research Forest Drive for the next 50 years if land subsidence continues at its current rate and if the SJRA safeguards work as designed.

Along FM 2978, the transmission line has a 16” diameter and extends to SJRA Woodlands Division Plant No. 4. Instead of using pipe casing to protect the transmission line, SJRA installed a series of ball connections in the vicinity of Egypt Fault to accommodate movement of up to 0.25 inches of vertical movement per year over a 50-year period, or a total of 12.5 inches. Along a length of approximately 400 ft, six ball couplings were installed. After 6.5 years of monitoring the differences the benchmark elevations over time are less than 0.05 ft. Based on the information that INTERA has reviewed, INTERA concludes that the transmission line is not at risk of damage from land subsidence where it crosses the Egypt Fault along FM 2978 for the next 50 years if land subsidence continues at its current rate and if the SJRA safeguards work as designed.

W2A Area

INTERA has reviewed the drawings for the safeguard that SJRA has constructed for the transmission pipe at the Big Barn Fault Monitoring System. The safeguard is similar to the safeguard SJRA constructed using pipe casing for the Egypt Fault Monitoring System. The differences in the benchmark elevations at the Big Barn Fault Monitoring System over 6.5 years are less than 0.05 ft. The safeguards that SJRA have constructed are designed to handle 12.5 inches of vertical move over 50 years. Based on the information that INTERA has reviewed, INTERA concludes that the transmission line is not at risk of damage from land subsidence where it crosses the Big Barn Fault along Research Forest Drive for the next 50 years if land subsidence continues at its current rate and if the SJRA safeguards work as designed.

Because the Fugro report (2012) did not show that Panther Branch Fault crossing the transmission line, SJRA did not construct specific safeguards to protect the transmission line from differential subsidence associated with the Panther Branch Fault. However, based on the location of the Panther Branch Fault mapped by INTERA in Figure 5, the Panther Branch Fault crosses a section of the transmission line that has been provided additional protection by being enclosed in pipe casing. Per discussion with SJRA, SJRA plans to continue to monitor any subsidence that is observed from the Segment W2A Monitoring System and discuss with transmission line experts if significant movement is observed.

References

Fugro Consultants, Inc., 2012. Geologic Fault Delineation Study SJRA Distribution Lines – Route W1 San Jacinto River Authority Montgomery County, Texas. Report No. 04.12110014-9 Prepared for Lockwood, Andrews & Newman, Inc., Houston Texas.

Table 1 Benchmark Elevations for SJRA Segment W1A Geological Monitoring Survey for March 2015, March 2021, and September 2021

Point ID	Measured Elevation			Calculated Differences	
	(a) Initial Survey March, 2015 Elev.	(b) March 2021 Elev.	(c) September 2021 Elev.	Sept 2021 minus Mar 2015 (c) - (a)	Sept. 2021 minus Mar. 2021 (c) - (b)
MbM-1	189.24	189.24	189.23	-0.01	-0.01
MbM-2	189.27	189.27	189.26	-0.01	-0.01
MbM-3	189.45	189.44	189.44	-0.01	0.00
MbM-4	189.73	189.72	189.72	-0.01	0.00
MbM-5	190.41	Destroyed	Destroyed	na	na
MbM-6	190.26	Destroyed	Destroyed	na	na
MbM-7	188.81	188.80	188.80	-0.01	0.00
MbM-8	188.28	188.27	188.27	-0.01	0.00
MbM-9	187.93	187.92	187.91	-0.02	-0.01
MbM-10	187.76	187.75	187.75	-0.01	0.00
MbM-11	188.00	187.89	187.88	-0.12	-0.01
MbM-12	187.77	187.75	187.75	-0.02	0.00
MbM-13	187.50	187.49	187.48	-0.02	-0.01
MbM-14	187.75	187.73	187.73	-0.02	0.00
MbM-15	188.49	188.48	188.48	-0.01	0.00
MbM-16	187.86	187.84	187.84	-0.02	0.00
MbM-17	189.31	189.30	189.29	-0.02	-0.01
MbM-18	189.75	189.73	189.73	-0.02	0.00
MbM-19	189.32	189.31	189.30	-0.02	-0.01
MbM-20	188.55	188.53	188.53	-0.02	0.00

note: na= not applicable

Table 2 Benchmark Elevations for SJRA Segment W1A for March 2015, March 2021, and September 2021 at Existing Fault Protection System| Egypt Fault

Station/Description	Measured Elevation			Calculated Differences	
	(a) Initial Survey March 2015 Elev	(b) March 2021 Elev.	(c) September 2021 Elev	Sept. 2021 minus Mar. 2015 (c) - (a)	Sept. 2021 minus Mar. 2021 (c) - (b)
Sta 103 + 72 Top Square Nut on 2" Steel Cap	187.2	187.19	187.2	0.00	0.01
Sta 103 + 82 Top 2" Steel Pipe (NO CAP)	186.93	186.92	186.92	-0.01	0.00
Sta 108 + 70 Top Square Nut on 2" Steel Cap	190.28	190.25	190.24	-0.04	-0.01
Sta 108 + 80 Top 2" Steel Cap	190.31	190.28	190.28	-0.03	0.00

Table 3 Benchmark Elevations for SJRA Segment W2A for March 2015, March 2021, and September 2021 at Existing Fault Protection System Big Barn Fault

Station/Description	Measured Elevation			Calculated Differences	
	(a) Initial Survey March 2015 Elev	(b) March 2021 Elev.	(c) September 2021 Elev	Sept. 2021 minus Mar. 2015 (c) - (a)	Sept. 2021 minus Mar. 2021 (c) - (b)
Sta 9 + 25 Top 2" Steel Cap	177.81	177.8	177.81	0.00	0.01
Sta 9 + 35 Top 2" Steel Cap	177.74	177.73	177.73	-0.01	0.00
Sta 9 + 85 Top 2" Steel Cap	176.73	176.71	176.71	-0.02	0.00
Sta 9 + 95 Top 2" Steel Cap	176.78	176.76	176.77	-0.01	0.01

Table 4 Benchmark Elevations for SJRA Segment W2A Geological Monitoring Survey for March 2015, March 2021, and September 2021

Point ID	Measured Elevation			Calculated Differences	
	(a) Initial Survey March, 2015 Elev.	(b) March 2021 Elev.	(c) September 2021 Elev.	Sept 2021 minus Mar 2015 (c) - (a)	Sept. 2021 minus Mar. 2021 (c) - (b)
MbM-1	142.59	142.56	142.55	-0.04	-0.01
MbM-2	142.80	142.78	142.77	-0.03	-0.01
MbM-3	143.31	143.27	143.26	-0.05	-0.01
MbM-4	143.35	143.30	143.28	-0.07	-0.02
MbM-5	143.85	143.82	143.81	-0.04	-0.01
MbM-6	144.14	144.11	144.11	-0.03	0.00
MbM-7	144.29	144.26	144.26	-0.03	0.00
MbM-8	145.20	145.17	145.16	-0.04	-0.01
MbM-9	145.51	145.48	145.48	-0.03	0.00
MbM-10	145.63	145.60	145.63	0.00	0.03
MbM-11	146.16	146.12	146.11	-0.05	-0.01
MbM-12	145.42	145.38	145.38	-0.04	0.00
MbM-13	145.00	145.00	145.00	0.00	0.00
MbM-14	144.99	144.98	144.98	-0.01	0.00
MbM-15	144.79	144.79	144.79	0.00	0.00
MbM-16	144.78	144.78	144.78	0.00	0.00
MbM-17	144.79	144.79	144.79	0.00	0.00
MbM-18	144.55	144.55	144.54	-0.01	-0.01
MbM-20	145.86	145.83	145.82	-0.04	-0.01

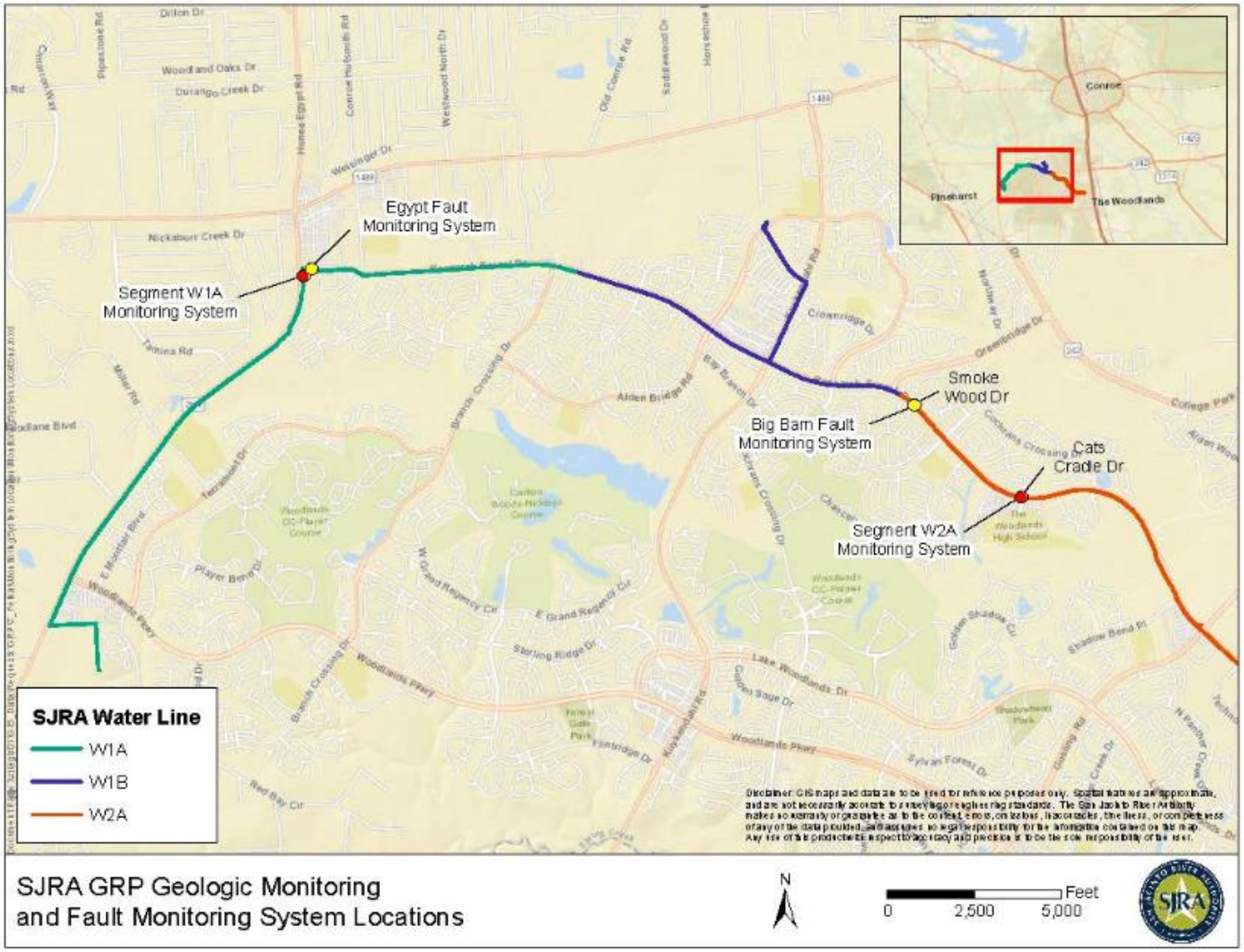

Figure 1 SJRA GRP Geological Monitoring and Fault Monitoring System Locations (https://www.sjra.net/grp/fault-monitoring/)

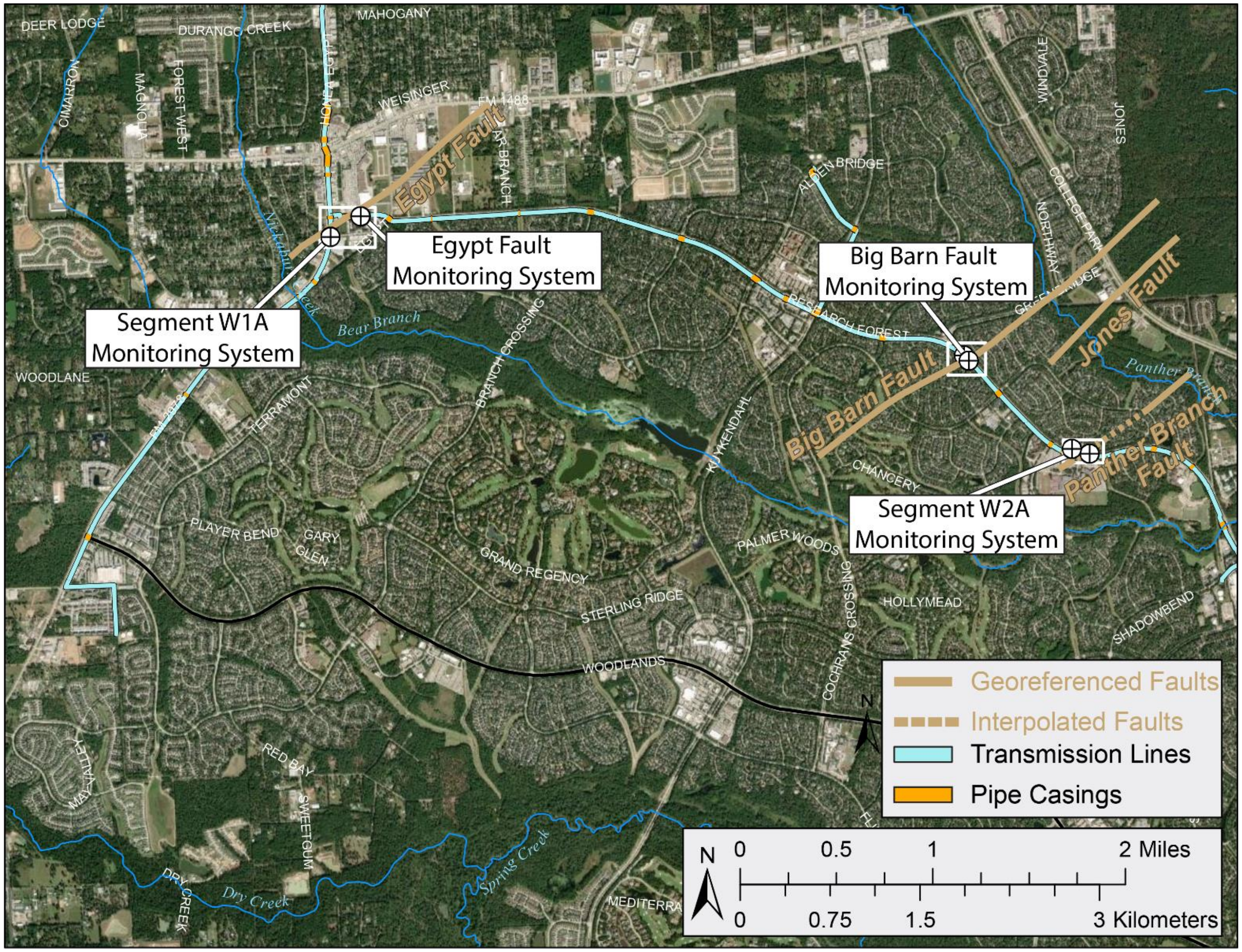

Figure 1 g/)

Figure 2 Satellite map showing the location of the SJRA transmission line, the fault locations mapped by Fugro (2012), and SJRA monitoring locations for benchmark elevation

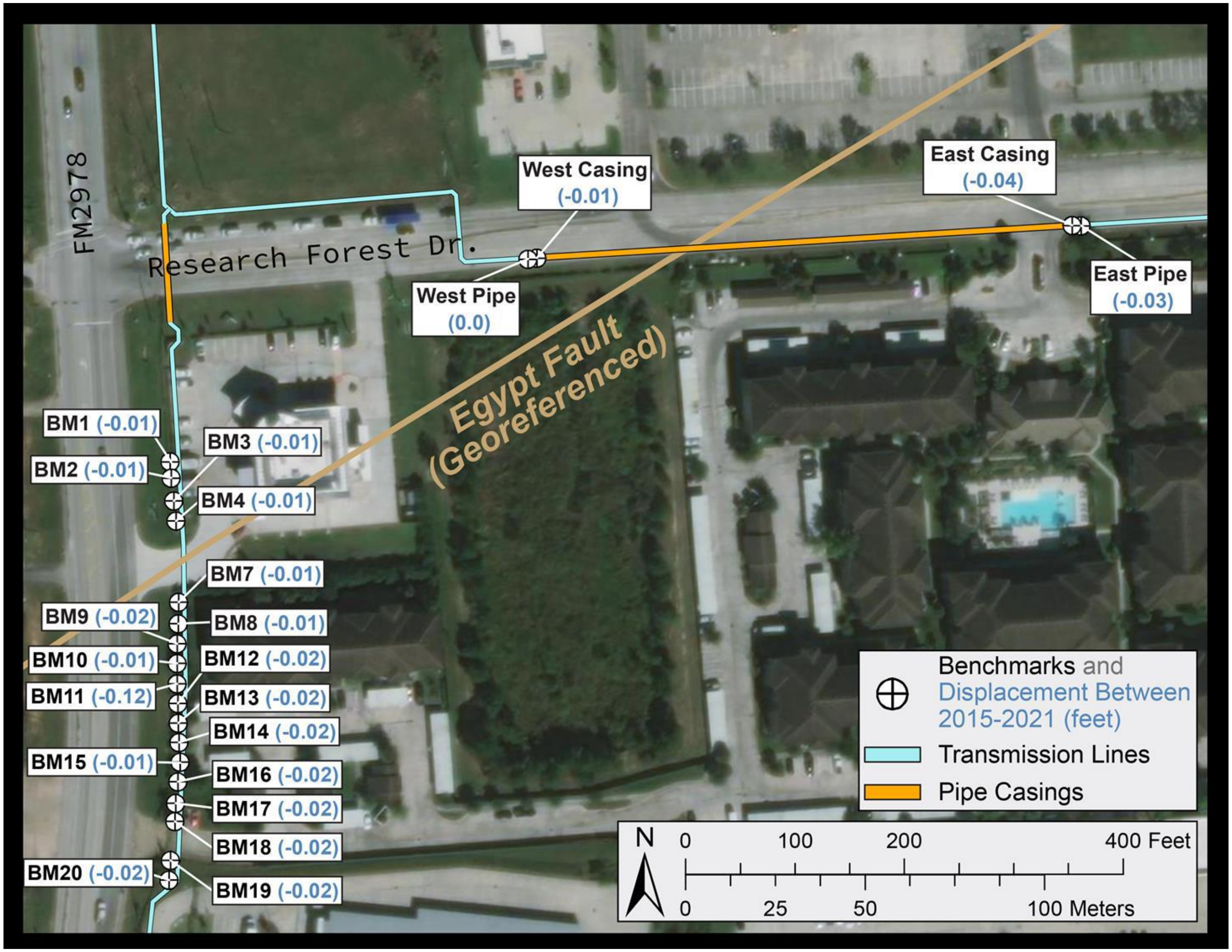

Figure 3 Satellite map showing the location where the Egypt Fault (Fugro, 2012), the W1A monitoring locations and calculated displacement from September 2015 to March 2021and the SJRA transmission line and pipe casing.

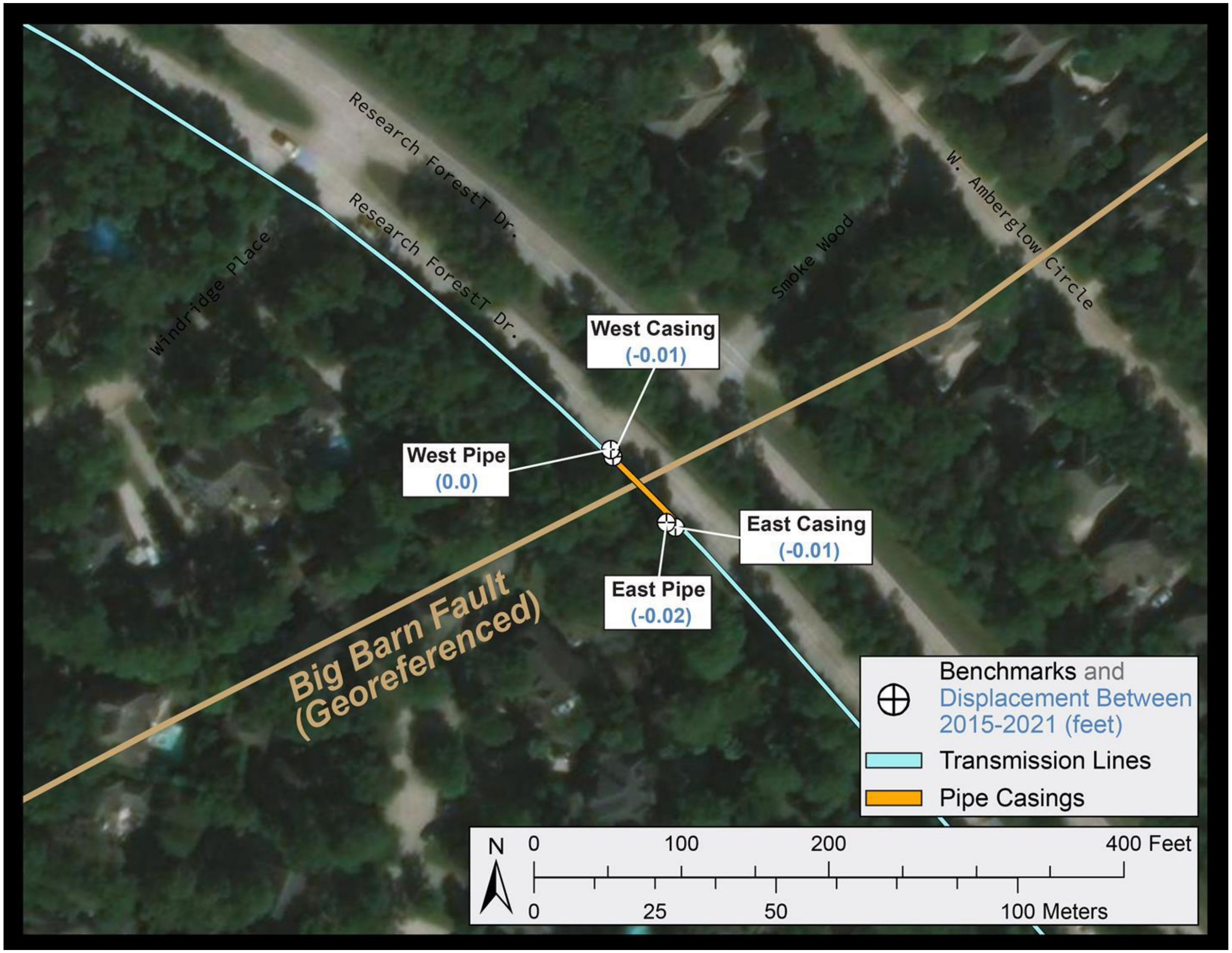

Figure 4 Satellite map showing the location the Big Barn Fault (Fugro, 2012), the Big Barn Fault Monitoring System, calculated displacement from September 2015 to March 2021, and the SJRA transmission line and pipe casing.

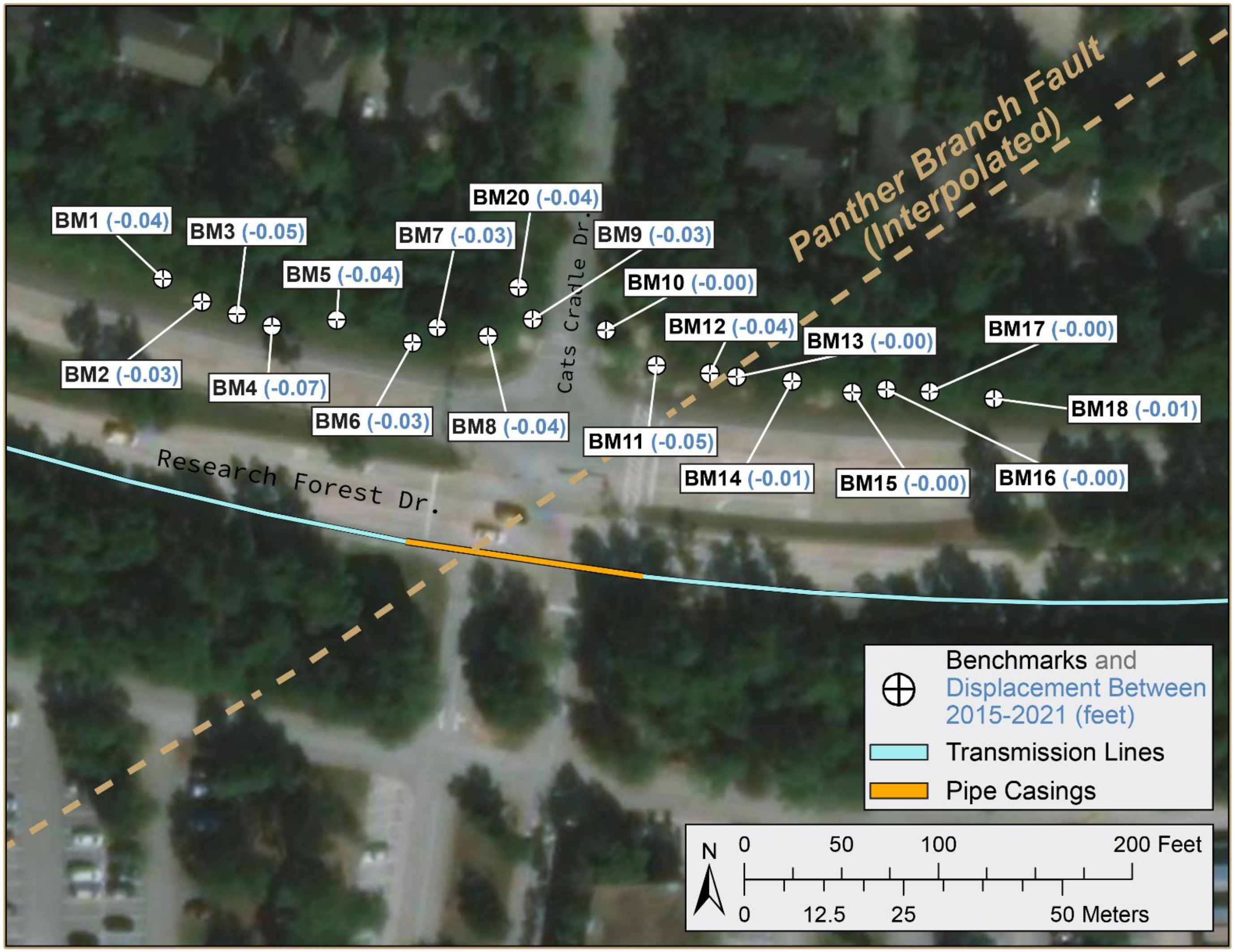

Figure 5 Satellite map showing the location the Panther Branch Fault mapped by INTERA, the Segment W2A Monitoring System, calculated displacement from September 2015 to March 2021, and the SJRA transmission line and pipe casing.