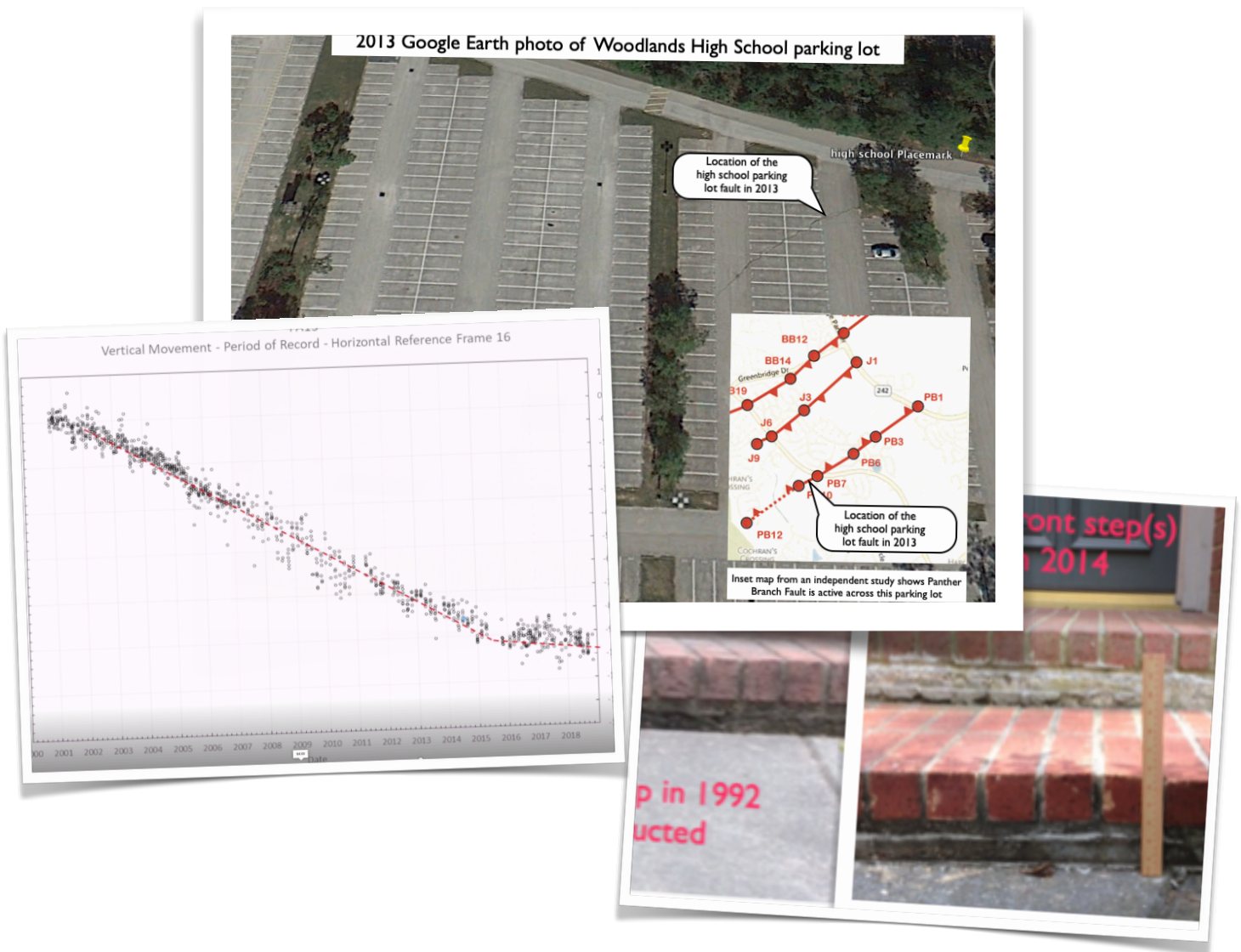


Subsidence & Pipeline Integrity

"I put high odds on either the Panther Branch or Jones fault, breaking the transmission line when elevations are at their lowest point this summer or next."



Subsidence & Pipeline Integrity

“I put high odds on either the Panther Branch or Jones Fault, breaking when elevations are at their lowest point this summer or next.”

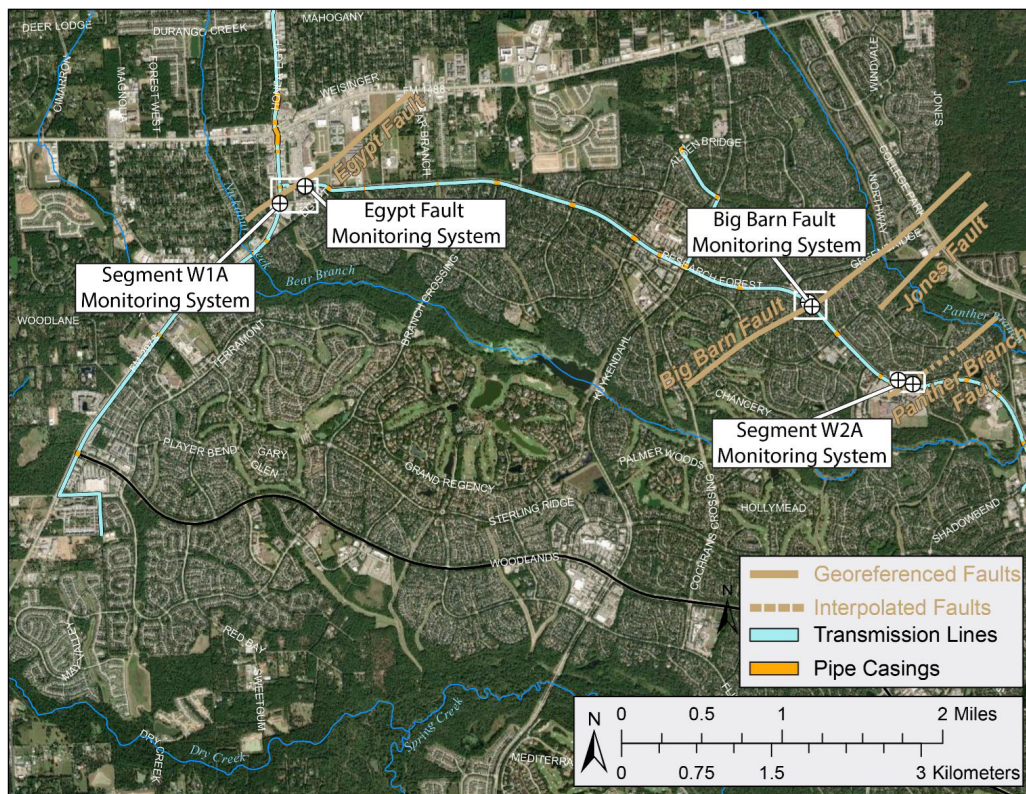
Lone Star Groundwater Conservation District (LSGCD) and GMA-14 recently agreed to a "Desired Future Condition" (DFC), which allows unlimited groundwater pumping until Montgomery County has subsided one foot. At one foot of subsidence, Lone Star plans to restore pumping limits. Several Woodlands residents concerned about the impact of sustained aggressive groundwater pumping on the security of the GRP surface water transmission line attended the GRP Review Committee-Special Meeting on February 22, 2022. The Woodlands residents were concerned that the GRP water pipeline might be in jeopardy before Montgomery County reached this Desired Future Condition.

The GRP water transmission line carries surface water from Lake Conroe to The Woodlands. When the GRP water transmission line opened in 2015, residents in The Woodlands who were drinking 100% groundwater began to imbibe 65% surface water. But an unexpected benefit of this switch to surface water was the annual rate of subsidence in the Village of Cochrans Crossing slowed down by 80%.

The GRP transmission line crosses four known active faults (Figure 1) as it traverses The Woodlands: the Egypt, Big Barn, Jones, and Panther Branch faults. At two of these faults, the Egypt and Big Barn are protected

by a unique pipe-within-a-pipe design (Figure 2), where a larger outer pipe shields a suspended inner transmission line to protect against land subsidence.

Figure 1. Map illustrating the GRP pipeline and the location of the major faults.

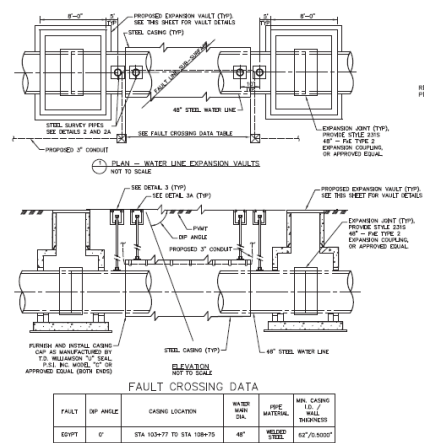


According to engineering specifications obtained through a Public Information Act request, this pipe-within-a-pipe safeguard protects the internal transmission line for up to 0.25 inches of land subsidence per year, over 50-years, or 12.5 inches total. Again, the total allowed subsidence under the proposed DFC (12 inches of subsidence over greater Montgomery County) is almost the same as the DFC triggering point (12.5 inches over the lifetime of the pipe segment) to cut back

unlimited groundwater pumping. In other words, the maximum land subsidence that the most hardened parts of the pipeline can withstand is about the same as the level of subsidence that would trigger a cut back in pumping.

Figure 2. SJRA’s design specifications for subsidence safeguards at the Egypt and Big Barn faults.

Current Protection Systems



W1A – Egypt Fault

0.25" of movement per year,
for 50 years

12.5" in total

W2A – Big Barn

0.25" of movement per year,
for 50 years

12.5" in total

The GRP representative explained that since Terracon's original fault study did not show the Panther Branch fault to be active across Research Forest Drive, SJRA [San Jacinto River Authority] decided not to harden the pipeline at the Panther Branch Fault. Instead, they chose to monitor elevations around the fault-pipe crossing for evidence of subsidence to anticipate and prevent a pipe break.

Parenthetically, SJRA's fault studies along the planned route of the GRP transmission line [Terracon, 2012] said that the Panther Branch fault is not active across the GRP pipeline. They did, however, report the Jones

Fault is an active fault and crosses the GRP transmission line under the entrance to Powell Elementary School, less than a mile west of the high school. Nevertheless, SJRA opted not to harden the pipelines at either the Jones or Panther Branch faults. They only monitored the segment where the Panther Branch Fault crosses the GRP transmission line for indications of land subsidence. The Jones fault is unprotected and unmonitored where it crosses the pipeline at Powell Elementary School along Research Forest.

Where the Jones and Panther Branch faults cross the 48-inch GRP transmission line at Powell Elementary and The Woodlands High School, respectively, there are no special safeguards from land subsidence. The pipe's original design and construction material provides the only protection from subsidence and faulting. Engineering specifications obtained through a Public Information Act request show the maximum allowed lifetime subsidence at these two faults is only one inch (Figure 3).

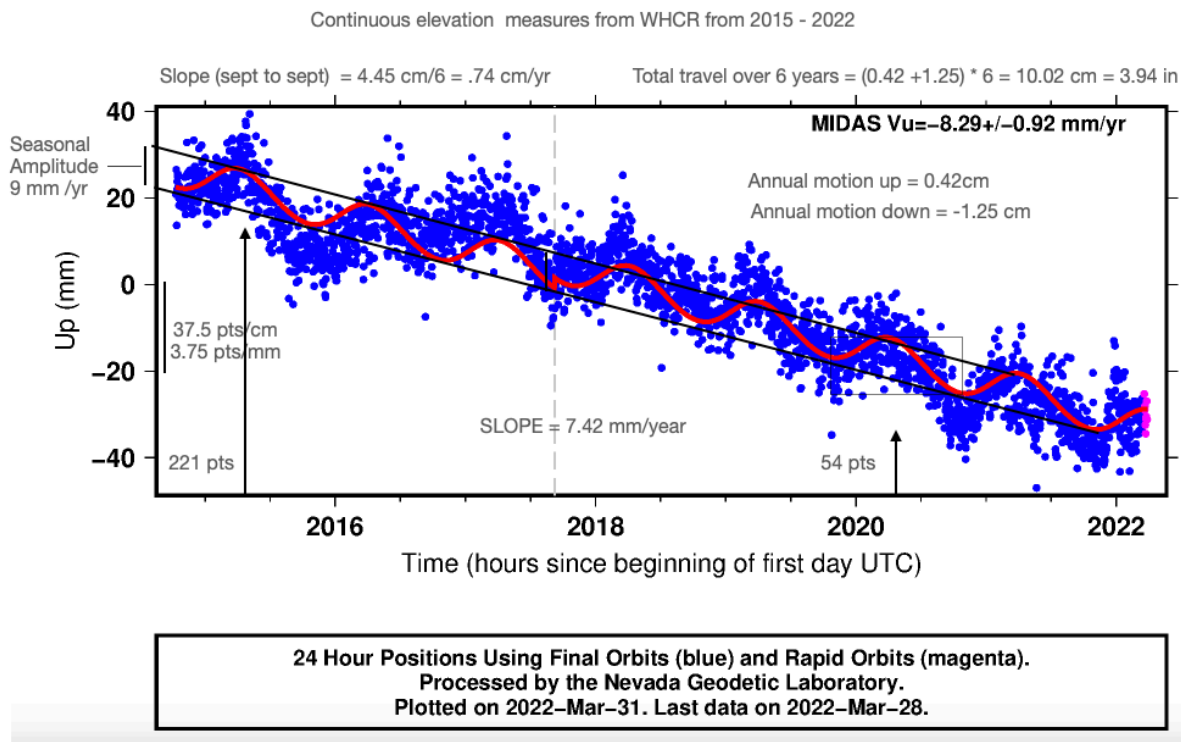
Figure 3. Land subsidence safeguards at the Jones and Panther Branch Faults.

Current Protection System – W2A

<u>Geotechnical Investigation</u>	<u>Pipe Details</u>	<u>Allowable Movement</u>
<u>Terracon</u> <u>2012</u> “The Panther Branch Fault approaches Research Forest from the northeast, but apparently dies out before reaching it.”	Spiral welded steel pipe with interior and exterior cement mortar coating. Welded joints within casing Outside of casing bell and spigot with O-rings	0.04” of horizontal movement per year, for 20 years 1” in total

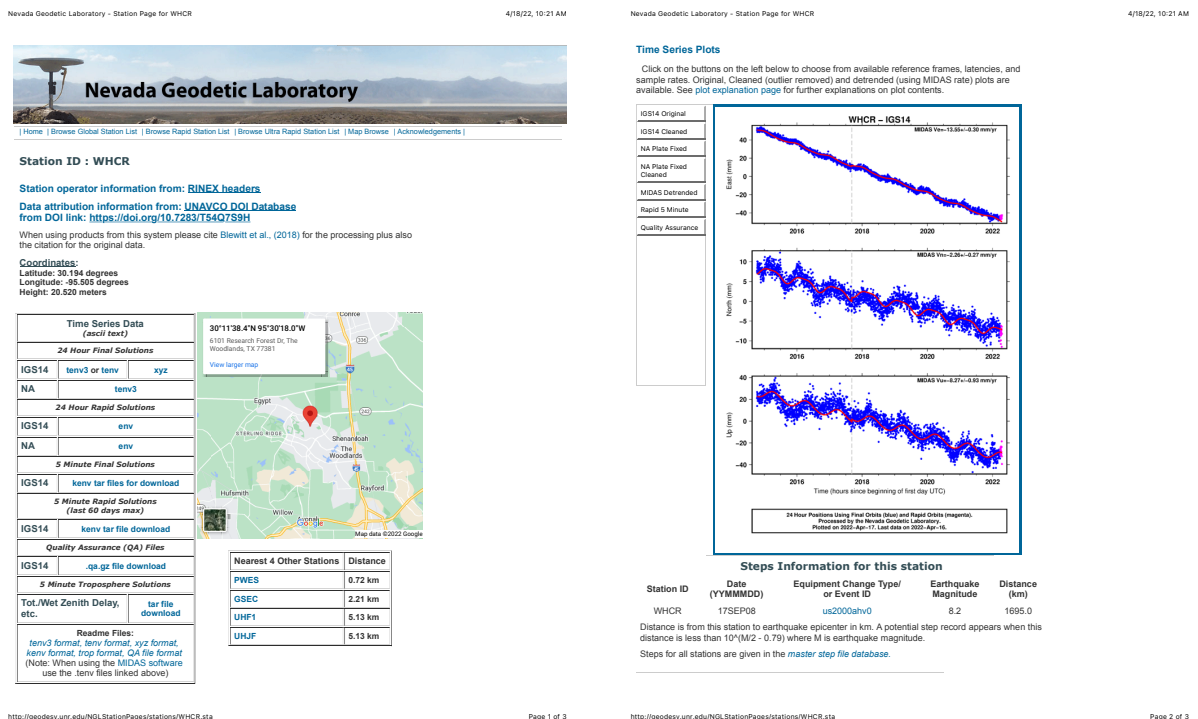
Continuously Operating Reference Stations (CORS) stations are fixed GPS monitoring sites that record latitude, longitude, and elevation every minute of every day, 24 hours a day, seven days a week, 52 weeks a year. Using "big data" techniques, CORS stations provide precise elevation measurements compared to the traditional survey technology employed by SJRA. CORS stations measure altitude in millimeters, whereas conventional survey techniques measure elevation in fractions of a foot.

Figure 4. Elevations of WHCR on the ROTC Building at The Woodlands High School 2015 - present



As the GRP surface water pipeline entered service in 2015, the University of Houston placed a CORS at The Woodlands High School on the upthrown side (east side) of the Panther Branch Fault (Figures 4 & 5). Other stations are on the Jones Fault (at Powell Elementary) and beside the Big Barn Fault (Galatas Elementary).

Figure 5. The Internet station page for CORS WHCR on the roof of the ROTC Building at The Woodlands High School.



The following table (Figure 4) compares subsidence rates at the unprotected Panther Branch and Jones Faults and the subsidence-hardened Big Barn Fault. As is evident from this table, the rate of subsidence is most significant at the unmonitored Jones Fault (-1.0 cm/

year) and least at the Panther Branch Fault (-0.8 cm/yr). The Big Barn Fault subsides at -0.9 cm/yr. At these rates, the Jones Fault met the maximum allowed one-inch subsidence at 2.54 years, the Panther Branch at 3.18 years, and the Big Barn at 2.75 years. In conclusion, the unprotected pipes at the Panther Branch and Jones faults exceeded the maximum allowed land subsidence of 1.0 inch a couple of years ago.

Figure 4. Velocity of Subsidence measured by CORS units at the Panther Branch, Jones, and Big Barn Faults.

Analysis of CORS elevations in Cochrans Crossing					
	Years Monitoring	Slope in cm/yr	MIDAS Ve	SLOPE between Sept 2015 - 2022	Subsidence 15-22
WHCR. — Panther Branch	6.26	-0.71	-8.29 mm/yr	-0.90 cm/yr	2.13 inches
PWES — Jones	5.82	-0.94	-10.83 mm/yr	-1.07 cm/yr	2.53 inches
GSEC — Big Barn	5.29	-0.75	-8.97 mm/yr	-0.90 cm/yr	2.13 inches
UHJF - Jone Forest Control	6.09	-0.45	-8.21 mm/yr		
PAM-13 - Control	19.98	-0.67			

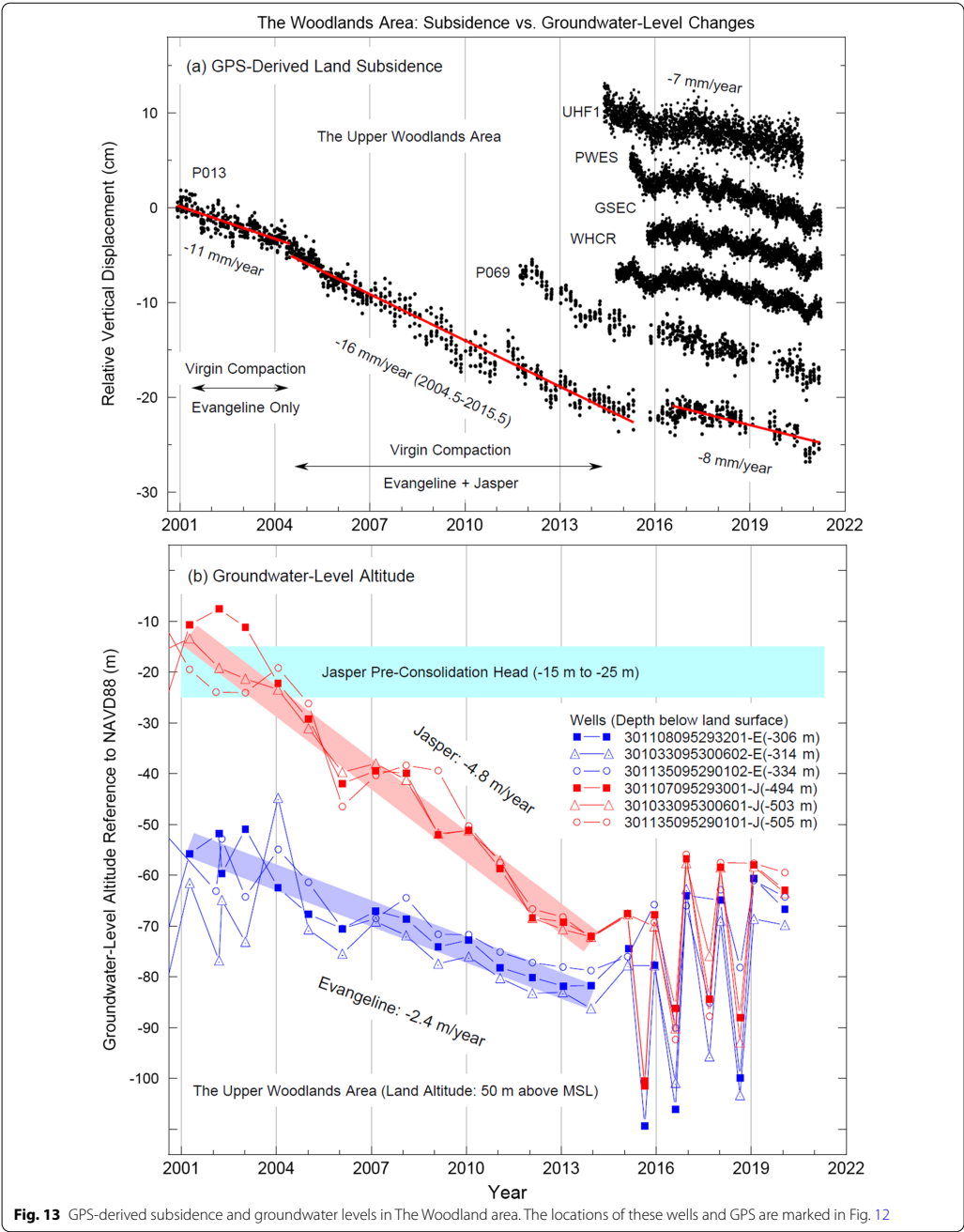
Each pipeline shows an average linear elevation velocity of about -7 mm per year; however, seasonal changes ride on top of this linear elevation velocity. Between September and March, the altitude of the

pipes increases by about half of a centimeter. Then, between March and September, the height of the lines drops by a full centimeter. The stress on the GRP transmission lines is like a tectonic hand lifts them 0.5 cm and then pounds them down -1.0 cm repeatedly each year, more than doubling the -0.7 mm average total vertical travel of the pipelines. Subsidence is not bidirectional. Once it reaches a new low, it never fully rebounds. I put high odds on either the Panther Branch or Jones fault, breaking the transmission line when elevations are at their lowest point this summer or next.

Does this seem unlikely? Look at what this tectonic hand did to my two-story brick home with a built-in garage in the first twenty years I lived here. My front sidewalk is a foot lower than it was in 1992, when I purchased my house. If we await for a DFC of 1 foot more, my sidewalk will be a foot lower than the picture on the right.

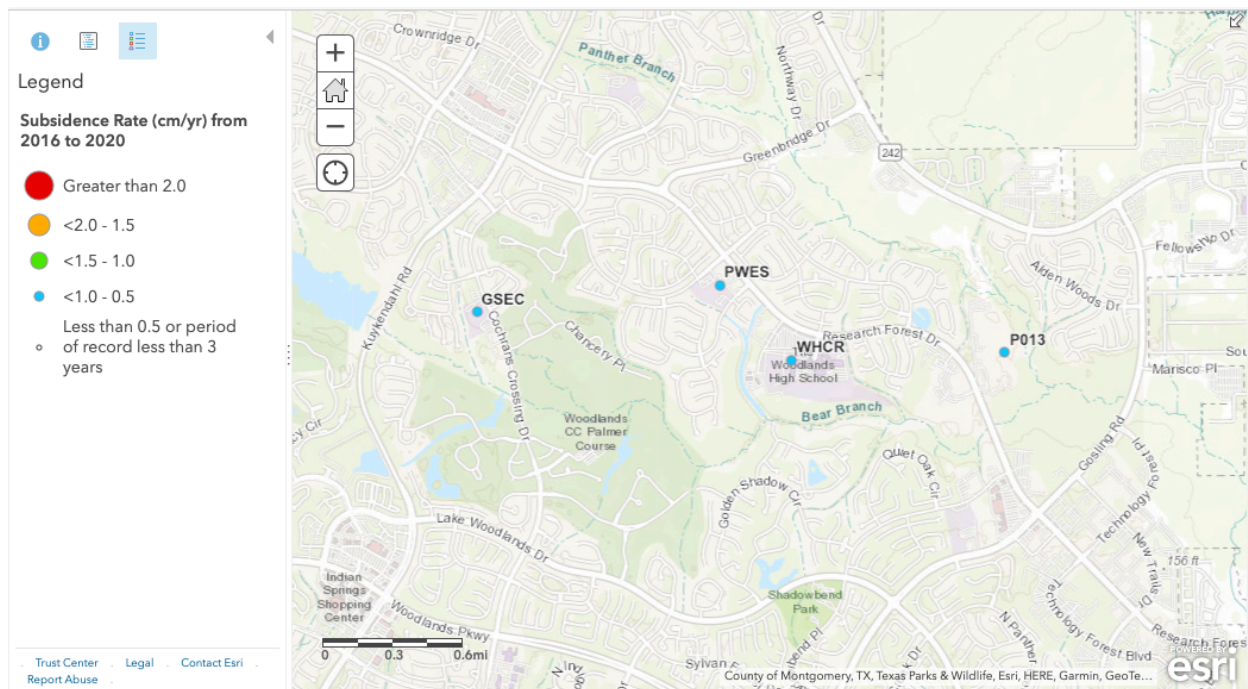


Appendix 1. Woodlands Area and Ground Water Changes



Wang, K., Wang, G., Cornelison, B. *et al.* Land subsidence and aquifer compaction in Montgomery County, Texas, U.S.: 2000–2020. *Geoenviron Disasters* **8**, 28 (2021). <https://doi.org/10.1186/s40677-021-00199-7>
[Shareable link: <https://rdcu.be/cMeGC>]

Appendix 2. Links to relevant CORS stations



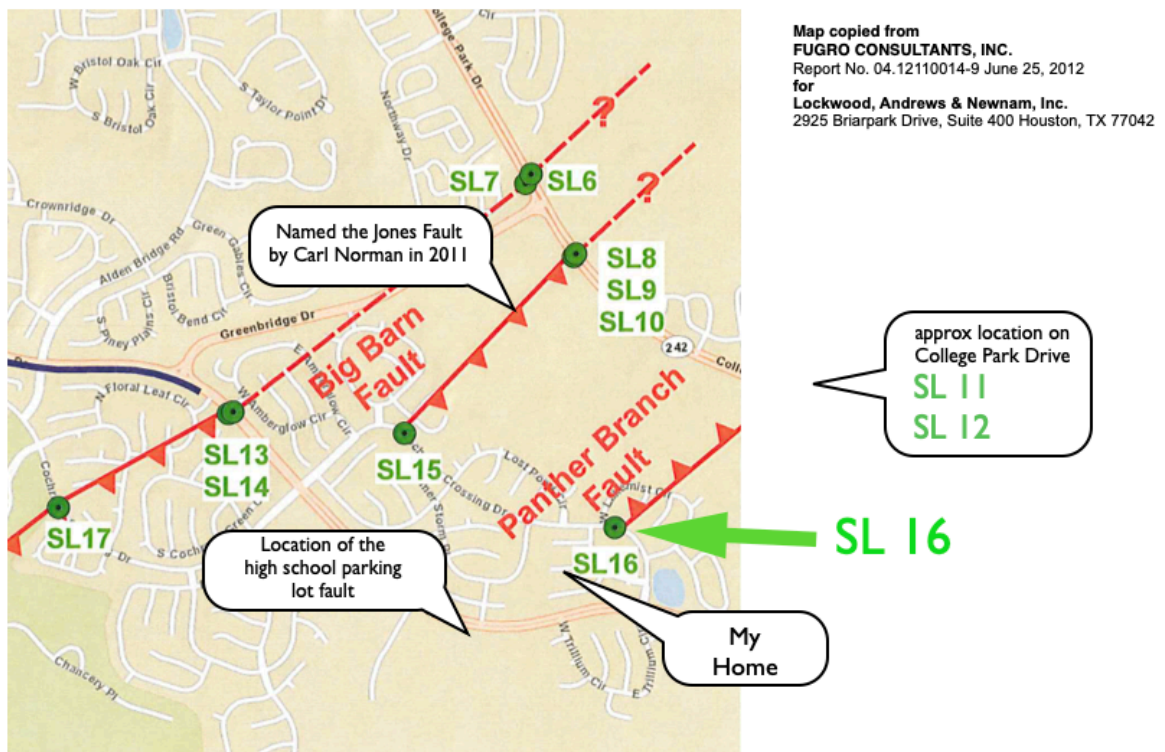
WHCR at The Woodlands High School for the Panther Branch Fault

PWES at Powell Elementary School for the Jones Fault

GSEC at Galatas Elementary School for the Big Barn Fault

Appendix 3. Fugro Map of relevant Faults

Location of elevation sections of the Panther Branch Fault at Bentgrass
and on the north and south lanes of Highway 242 (SL 11 & 12)



Appendix 4. Relevant portions of Terracon's fault study along the route of the GRP Transmission line.

TERRACON
11133 I-45 South
Building T
Conroe, Texas 77302

Phase I Fault Study

Attention: John D. Guida, P.E.

SUBJECT: PHASE I GEOLOGIC FAULT STUDY OF A 6.8-MILE WATERLINE ROUTE THROUGH THE WOODLANDS, MONTGOMERY COUNTY, TEXAS FOR EVIDENCE OF SURFACE GEOLOGIC FAULTS.

- The study included a review of both published and proprietary geologic reports on surface faults in the general area; an examination of petroleum industry maps of geologic structures 9000 to 9300 feet beneath the area; a study of topographic maps and aerial photographs of the route and surrounding areas; and an on-site visit to the area to search for field evidence of faults previously identified in the eastern part of The Woodlands.

- **IN SUMMARY, FIELD AND AERIAL PHOTOGRAPHIC EVIDENCE INDICATES THAT (ONLY) TWO FAULTS, THE BIG BARN FAULT AND THE JONES FAULT, CROSS SEGMENT W2 OF THE SAN JACINTO RIVER AUTHORITY WATERLINE.**

- The Panther Branch Fault approaches Research Forest Drive from the northeast, but apparently dies out before reaching it. I was unable to trace it southwest of a zone on Bentglass Place 115 to 130 feet west of the centerline of Mystic Lake Circle. That location is approximately 570 feet north of Research Forest Drive.

- In summary, field and aerial photographic evidence indicates that two faults, the Big Barn Fault and the Jones Fault, cross Segment W2 of the San Jacinto River Authority waterline.

Appendix 5. Photographic evidence from 2011 that the Panther Branch Fault is active on both sides of the GRP water line at the entrance to The Woodlands High School.

