PHASE I GEOLOGIC FAULT DESKTOP REVIEW

MEMORIAL DRIVE RECONSTRUCTION AND ACCESS MANAGEMENT

HOUSTON, TEXAS

Report to

AVILES ENGINEERING CORPORATION
HOUSTON,TEXAS

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Project No. 119-019
August 7, 2019

Aviles Engineering Corporation
5790 Windfern Road
Houston, Texas 77041

Attention: Wilber L. Wang, P.E.

Phase I Geologic Fault Desktop Review
Memorial Drive Reconstruction and Access Management
From East of Beltway 8 to East of Tallowood Road
Harris County, Texas

Introduction

This report presents the results of our Phase I Geologic Fault Desktop Review and evaluation of nearly 4,700 lineal feet along Memorial Drive, from Beltway 8 to Tallowood Road.

Background for this project was provided by Wilber L. Wang, P.E. with Aviles Engineering Corporation (Aviles) via an e-mail dated July 8, 2019. The e-mail included LAN's proposed Underground Utility Plan and Profile sheets dated March 7, 2019; Aviles' geotechnical report dated March 8, 2019; and HVJ's Phase I Fault Study of surrounding subdivisions dated March 30, 2007. This study was performed in accordance with our proposal in an e-mail dated July 9, 2019, as authorized by Wilber L. Wang, P.E. with Aviles, on July 10, 2019.

Scope of Services

The study was performed in general accordance with the guidelines outlined by the Houston Geological Society entitled *Recommended Standards of Practice for Investigating Geologic Faults in the Texas Gulf Coast Region – Phase 1.* Accordingly, the following methods were used in this study:

1) Conducted a field reconnaissance to assess and map any observed surface expressions of faulting within the study area.
2) Reviewed available geologic literature pertaining to faulting in the area and surface fault identification.
3) Reviewed a Phase I Fault Study prepared by HVJ as provided by Aviles.
4) Reviewed topographic maps for geomorphic features which may have been the result of surface faulting.

5) Reviewed aerial photography to identify linear features which may be related to surface fault activity.

6) Performed raster processing and analysis on light detection and ranging (LiDAR) digital elevation models (DEMs) to identify linear features that may be related to surface fault activity.

Principal Findings

LiDAR analysis produced alignment agreement between a previously mapped principal fault, the Piney Point West Fault (PPWF), and a linear topographic expression intersecting the study site. The same linear feature is congruent with the orientation of a northeast-southwest trending segment of a Buffalo Bayou tributary further supporting the previously mapped alignment of the PPWF. A second, separate linear feature was identified in the study area using LiDAR; however, no visible surface scarp was present in the study area.

Geologic Faulting in the Houston Area

Active faults in the Gulf Coast region of Texas and Louisiana have been documented and interpreted as a result of local land-surface subsidence since 1926 (Pratt & Johnson, 1926). Since then, hundreds of active faults have been identified in the greater Houston area (Verbeek et al., 1979; O'Neill & Van Siclen, 1984; Mastroianni, 1991; Shaw & Lanning-Rush, 2005; Engelkemeir & Khan, 2007, 2008, Campbell et al., 2015).

Surface faulting in the area has been suggested to be caused by the reactivation of either pre-existing coastally linked growth fault systems, or faults related to salt dome intrusion into overlying strata (Heuer, 1979; Sheets, 1979; Van Siclen, 1967; Norman, 2005). Decreased pressure of groundwater, oil, and gas in the area have produced a drawdown effect that has been suggested to be the cause for locally induced subsidence. Over time, the localized subsidence has resulted in the formation of the Houston-Galveston area subsidence bowl (Schmidt, 2013). The formation of the subsidence bowl has resulted in a greater quantity of active faults than elsewhere in the coastal plain. Although efforts have been made to decrease groundwater pumping in the surrounding area, active faults are still being identified in Harris County and surrounding counties (Schmidt, 2013; Engelkemeir & Khan, 2008; Khan et al. 2013).

The study area is located proximal to both the Yegua and Wilcox fault trends, which are linear trends of the greater coastally-linked subsurface fault system. Furthermore, the study area is intersected by the previously mapped Piney Point West Fault (PPWF). The Piney Point Fault System includes both a west (PPWF) and east extension (Piney Point East Fault) that has been interpreted to be antithetic to the southeast dipping Long Point fault system. Thus, the fault system dips away from the Gulf of Mexico and towards the northwest (see Plate 3). Although the topographic expression of the Piney Point East fault (PPEF) is more prominent than its westward counterpart, structural damage has also been documented along the trace of the PPWF. The Piney Point fault system also shows alignment congruence with a trend of Buffalo Bayou tributaries in the downthrown block of both its west and east extensions. This correlation suggests that the faults may have had an order of control on the orientation and position of the local drainage pathways.

Considering the presence of fault systems proximal to and within the study area, there is a possibility that additional faults exist within the area, and that the previously mapped faults may still be active and displacing structures at the surface.

Analysis of Information

Literature Review: A review of geologic literature was conducted to gain a more detailed understanding of faulting in the project area; the literature included:

- "*Historically Active Faults in the Houston Metropolitan Area, Texas"* by E.R. Verbeek & U.S. Clanton (1981)
- *"Structural Styles of the Wilcox and Frio Growth-Fault Trends in Texas"* by T.E. Ewing (1987)
- *"Near-Surface Geophysical Studies of Houston Faults"* by R.M. Engelkemeir & S.D. Khan (2007)
- *"Lidar Mapping of Faults in Houston, Texas, USA"* by R.M. Engelkemeir & S.D. Khan (2008)
- *"A Geophysical Investigation of the Active Hockley Fault System Near Houston, Texas"* by S.D. Khan (2013)
- *"Growth Faulting and Subsidence in the Houston, Texas Area: Guide to the Origins, Relationships, Hazards, Potential Impacts and Methods of Investigation"* by M.D. Campbell et al. (2015).

One principal fault, PPWF, has been previously mapped to intersect the study site (See Plate 4).

LiDAR DEM Analysis. LiDAR-derived DEMs have been used for detecting surface faults in several studies in the Texas Gulf Coast (e.g., Haugerud, 2003; Wieczorek et al., 2004; Egnew, 2005; Engelkemeir & Khan, 2008). DEMs acquired from the Texas Natural Resource Information System (TNRIS) were used in raster processing and analysis to produce hillshade and shaded relief maps with an azimuth of 315 and an altitude of 45 degrees. By analyzing these maps and identifying linear features, potential candidates for surface faults can be identified. The following DEM was reviewed:

Quad Name	Date	Resolution	Source
Hedwig Village	2008	50cm	TNRIS

The alignment of the PPWF was supported by producing shaded relief maps of the study area. The shaded relief maps displayed a linear feature, the PPWF, with higher elevation in the southeast and a lower elevation in the northwest. A separate linear feature was present parallel to the PPWF approximately 500 feet to the north (see Plate 5). This second linear feature displayed a lower elevation to the southeast and a higher elevation to the northwest – antithetic to the PPWF. The separate linear feature will be referred to as Linear Feature 1 in the remainder of this report.

Aerial Photograph Analysis. Several forms of aerial photography were reviewed for evidence of linear features that may be related to faulting. Generally, fault-related linear patterns exhibit tonal differences between the downthrown and upthrown block of a fault due to an increase in moisture along the fault in its downthrown block. The following forms of aerial photography were reviewed in the Phase I fault study:

(1) *Aerial Photo Single Frames (APSF)* from the 1970 USGS Flight Programs. The images acquired from the program are in black & white. The photographs were taken at a scale of 1:80,000. Photographs are centered over USGS 7.5-minute quadrangles.

(2) *Aerial Photo Single Frames (APSF)* from the 1980-1989 USGS National High-Altitude Photography Program (NHAP). The images acquired are black-and-white (BW) and color infrared (CIR) aerial photographs. The color-infrared photographs were taken at a scale of 1:58,000. The black-and-white photographs were taken at a scale of 1:80,000. Photographs are centered over USGS 7.5-minute quadrangles.

(3) *Digital Ortho Quads (DOQs)* from the 1995 USGS National Aerial Photography Program (NAPP). The orthoimagery is 3.5-minute CIR and B&W.

(4) *DOQs* from the 2010 USDA National Aerial Imagery Program (NAIP). All orthoimagery acquired under this project are 4-band (R, G, B, NIR), natural color (NC) and color infrared (CIR) capable.

(5) *Digital Ortho Quarter Quads (DOQQs)* from the 2009 and 2014/2015 TNRIS Texas Orthoimagery Programs (TOP). All orthoimagery acquired under this project are 4-band (R, G, B, NIR), natural color (NC) and color infrared (CIR) capable. Each 0.5-meter image tile covers one 4th of a USGS Digital Orthophoto Quad (DOQ).

(6) *DOQs* from the 2016 USDA NAIP. All orthoimagery acquired under this project are 4-

band (R, G, B, NIR), natural color (NC) and color infrared (CIR) capable.

The maps reviewed are listed below:

Quad Name	Date	Resolution	Type	Source
Hedwig Village	2016	100cm	DOQQ:NC/CIR	TNRIS
Hedwig Village	2015	50cm	DOQQ:NC/CIR	TNRIS
Hedwig Village	2014	100cm	DOQQ:NC/CIR	TNRIS
Hedwig Village	2012	100cm	DOQQ: NC/CIR	TNRIS
Hedwig Village	2010	100cm	DOQQ: NC/CIR	USDA
Hedwig Village	2009	50cm	DOQQ: NC/CIR	TNRIS
Hedwig Village	1995	100cm	DOQ: CIR/B&W	USGS
Hedwig Village	1989	100cm	APSF: CIR/B&W	USGS
Hedwig Village	1970	100cm	APSF: B&W	USGS
Hedwig Village	1953	100cm	APSF: B&W	USGS

Topographic Map Review. Several of the U.S. Geological Survey 7.5-minute topographic maps, contoured at 1ft and 5 ft intervals, were reviewed in this study. Features including scarps, offset drainage alignment, and aligned ponds are typical geomorphic features often associated with faulting. The topographic maps were reviewed to identify geomorphic features of this nature. The reviewed maps are listed below:

Quad Name	Date	Scale	Contour Interval	Source
Hillendahl	1915	1:24,000	1-foot	USGS
Hillendahl	1918	1:24,000	1-foot	USGS
Hedwig Village	1955	1:24,000	5 feet	USGS
Hedwig Village	1982	1:24,000	5 feet	USGS
Hedwig Village	1995	1:24,000	5 feet	USGS
Hedwig Village	2016	1:24,000	5 feet	USGS

The Piney Point Fault System displays alignment with two northeast-southwest trending tributaries of Buffalo Bayou. The congruence in the orientation of both the faults and the tributaries can be seen when comparing the previously mapped position of the fault system and the 1-foot contour interval topographic maps (see Plates 4, 5, & 6). Furthermore, the presence of the tributaries along the down-thrown block (northwest) of the fault system further supports a relationship between geomorphology and faulting in the area; the correlation suggests that the topographic depression produced by movement of the down-thrown block could have provided a preferred drainage pathway along the trace of the fault.

Field Reconnaissance. On July 23th, Mr. Mike Johnson, Geologist with Cibor Geoconsultants, conducted an initial site visit to locate physical evidence of surface fault activity. Reconnaissance included looking for signs of distress in the location where the PPWF intersects the study area, in addition to locating evidence related to faults elsewhere that have not been previously mapped. Roadside observations were conducted along Memorial Drive, Broken Bough Drive, Gretel Drive, Mignon Lane, Faust Lane, Hallie Drive, Hollow Drive, Huntingwick Drive, and Tallowood Road.

On July 25th, Mr. Chase Parsons and Mr. Mike Johnson, Geologists with Cibor Geoconsultants, conducted a second site visit to complete reconnaissance of the study area. During the reconnaissance, the presence of several vacant lots was noticed in the neighborhood to the west of Memorial Drive along the alignment of the PPWF. Memorial Drive, Faust Lane, Mignon Lane, and Gretel Drive all had vacant lots along the alignment of the PPWF in an otherwise completed neighborhood. Based on a review of historical aerial photographs, these lots all became vacant subsequent to Hurricane Harvey. It is our opinion that damages were more severe along the PPWF alignment due to ponding along the fault's downthrown block. Furthermore, pavement distress was common throughout the study area making conclusions related to pavement distress mostly ambiguous. However, a north dipping slope and localized pavement distress at the intersection of the PPWF and Hollow Drive supports the previously mapped alignment of the PPWF. Furthermore, pavement distress with minor offset on Hallie Drive south of Old Oaks Drive was noted; it aligned with the previous mapping of the PPWF. Pavement distress along the alignment of Linear Feature 1 was *indiscernible* from the distress common to the area.

Conclusions and Remarks

The study described above has shown that one previously mapped principal fault intersects the study area along Memorial Drive approximately between Station 26+00 and Station 27+00 from LAN's plan set. This fault, the PPWF, is expressed in both the LiDAR Shaded Relief Maps and the Topographic Maps of the study area. Minor structural damage has also been documented by previous studies of the area, but observations made during our field reconnaissance found that the surface expression of the fault is subtle within the study area suggesting minor to negligible amounts of recent movement along the fault.

The presence of a principal fault intersecting the study area suggests the possibility of additional faulting in the area. The second linear feature detected in this study, denoted as Linear Feature 1, might be suggestive of this possibility. However, our field reconnaissance along Linear Feature 1 did not indicate any surface expression of a fault along its alignment.

Limitations of Study

Faults are not always associated with definitely recognizable fault scarps and their full extent may not be identifiable by visual inspection alone. Additionally, vegetation cover and recently constructed facilities (i.e. buildings, roads, sidewalks) may obscure the presence of a fault, especially if it is slow moving or currently inactive. Predicting future fault activity cannot be done with certainty due to the number of variables involved.

The report's findings are based on conditions that existed on the dates of Cibor Geoconsultants' site visit(s) and should not be relied upon to precisely represent conditions at any other time. All conclusions are qualified by the fact that no excavations or borings were made and no geophysical surveys or logging was conducted.

* * *

The following illustrations are attached and complete this report:

Closure

Cibor Geoconsultants appreciates the opportunity to be of service to AVILES Engineering Corporation. Please do not hesitate to call us should you have any questions or need additional assistance.

Sincerely,

CIBOR, INC.

TBPE Firm Registration No. F-15616

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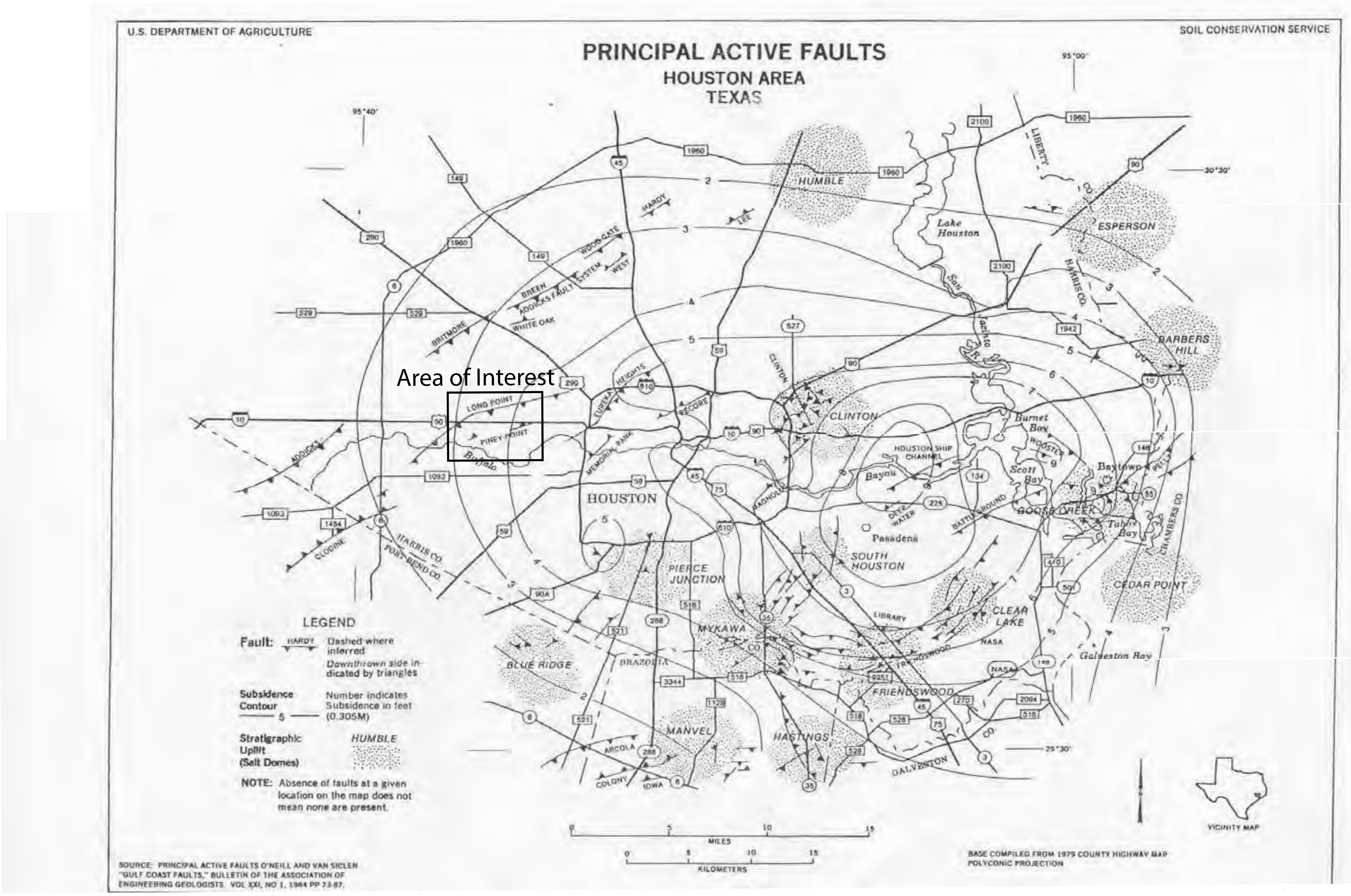
Project No. 119-019



PRINCIPAL FAULTS OF HOUSTON

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PLATE 1

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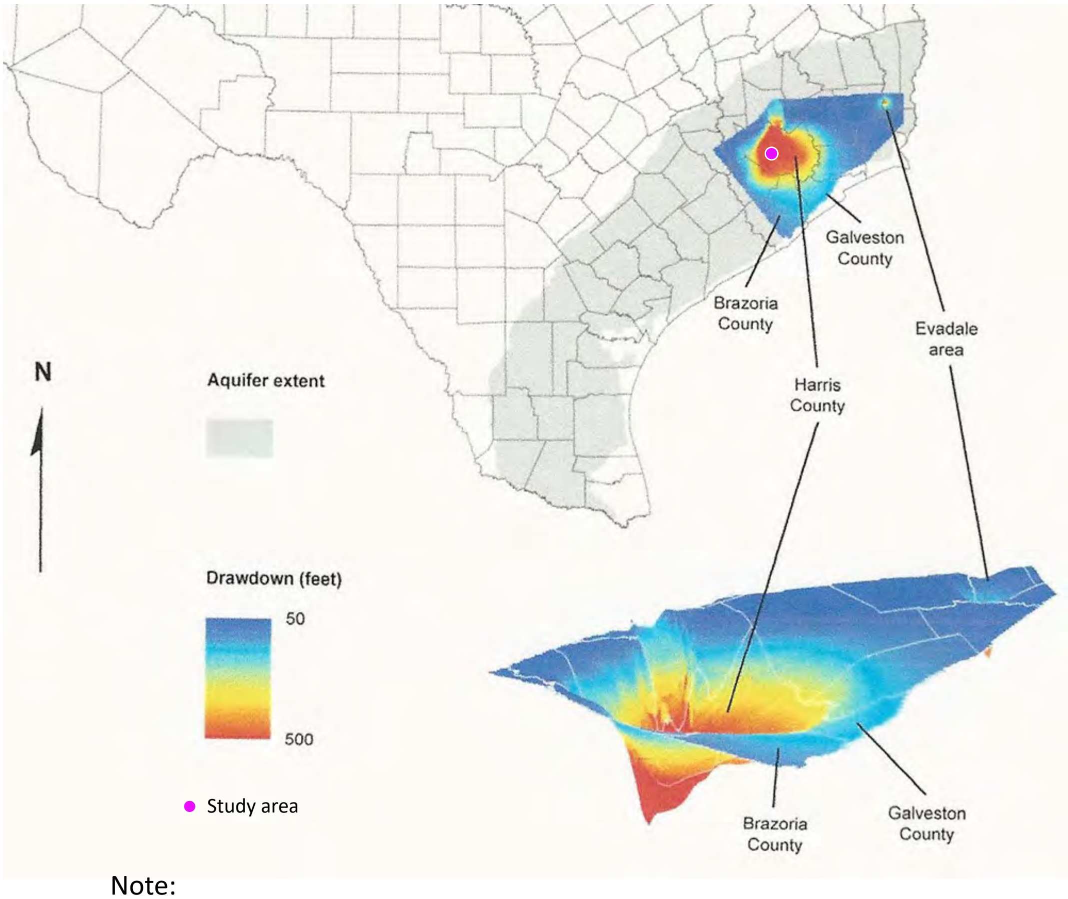
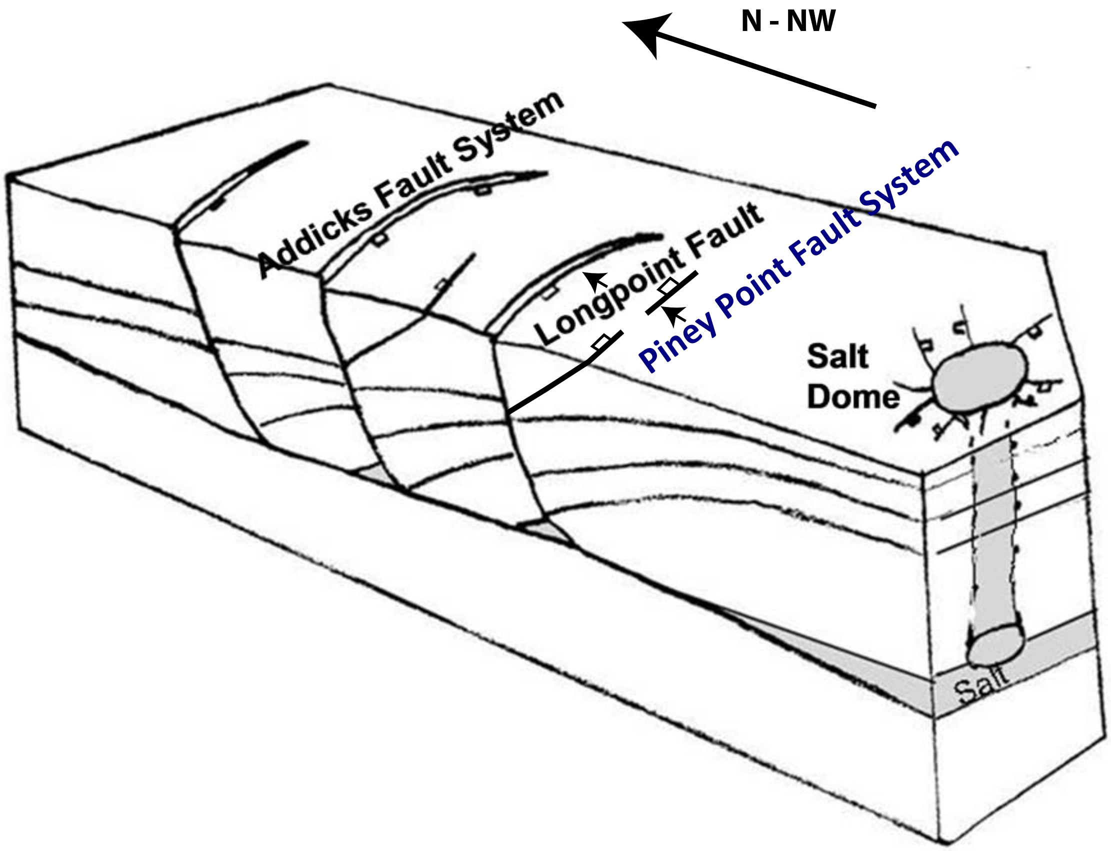


Note:
The study area is located within an area of heavy drawdown influence

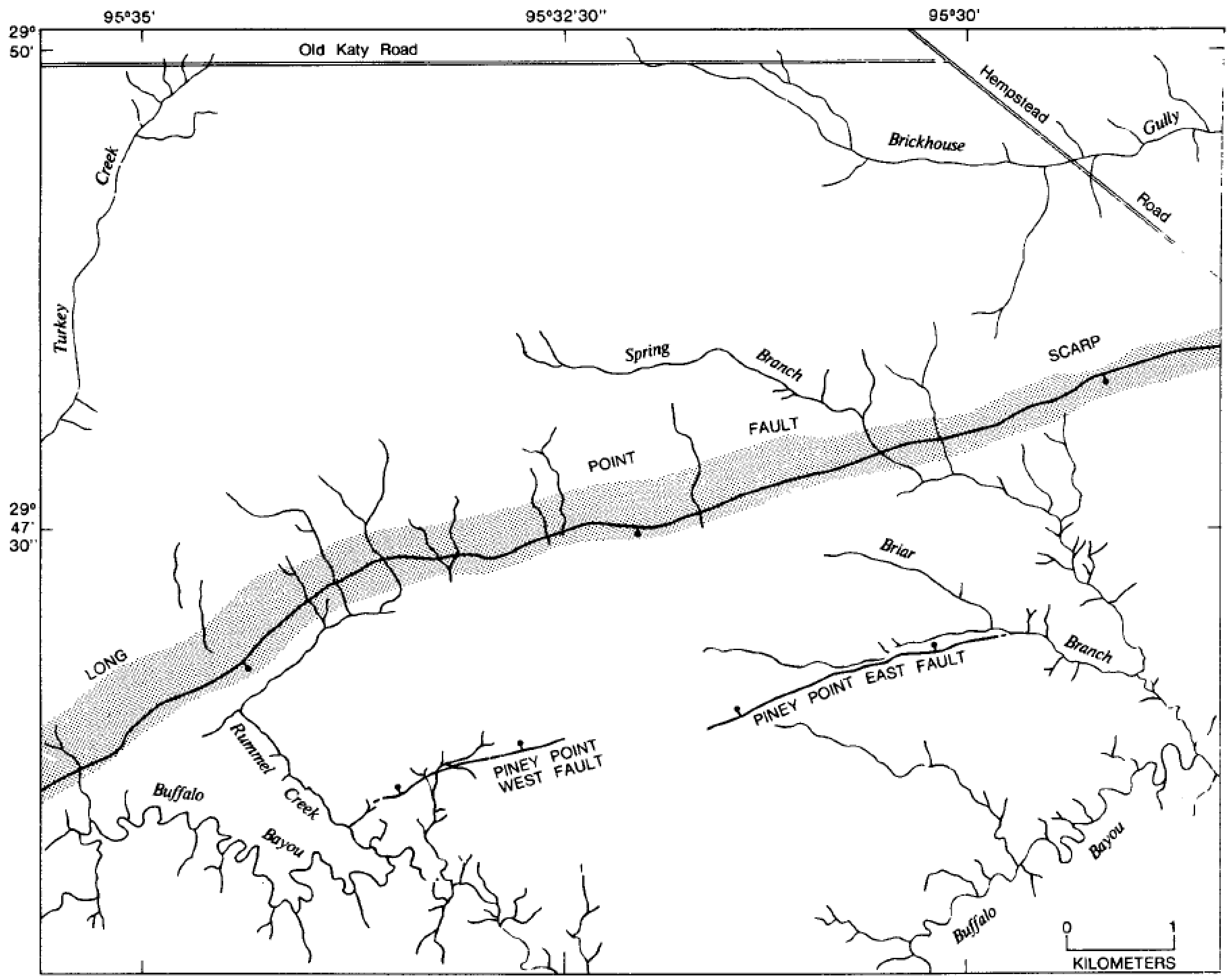
Resources: Campbell (2014)

MAP DISPLAYING AQUIFER DRAWDOWN OF HOUSTON AREA

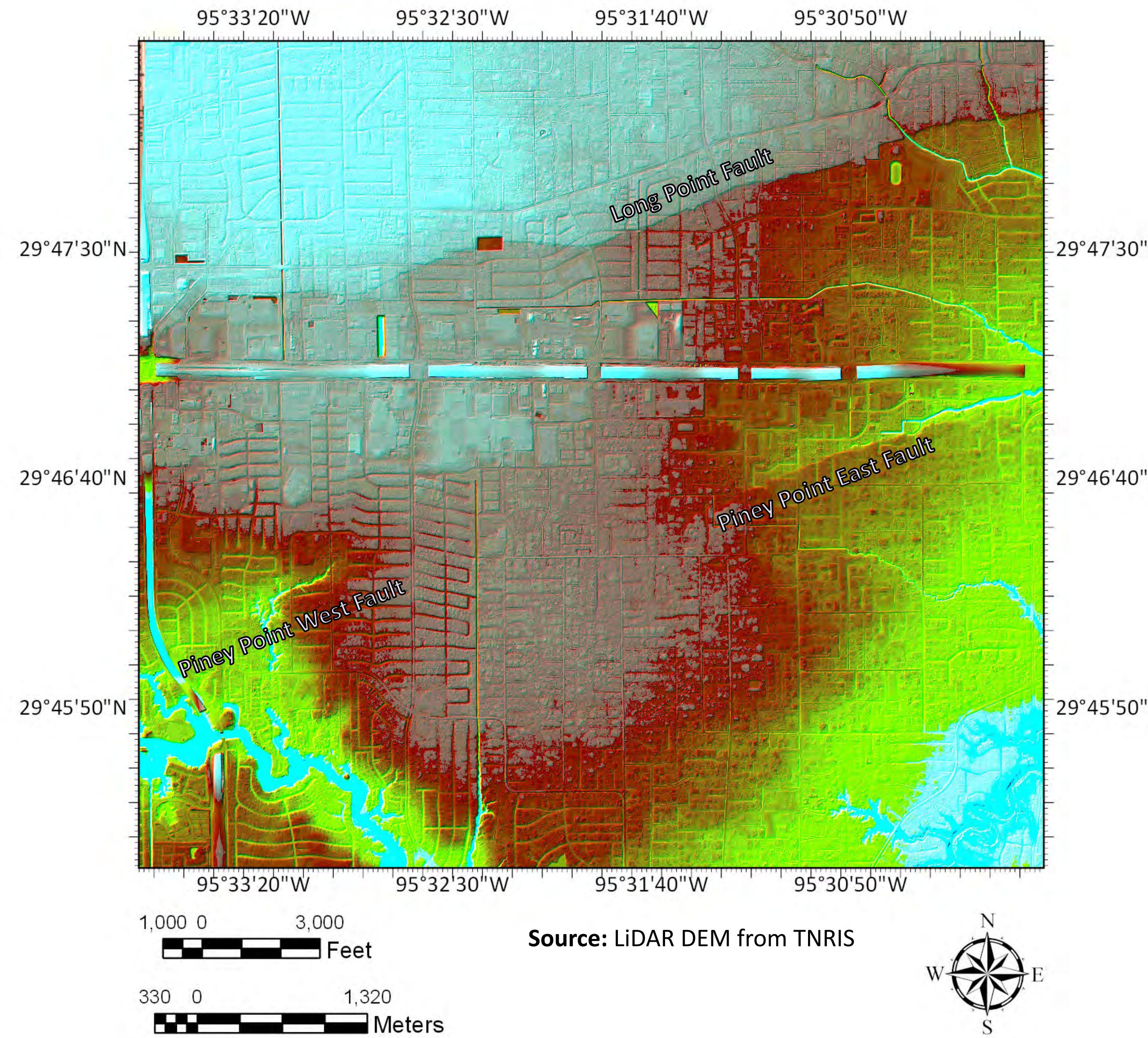


Source: Modified from Engelkemeir et al. 2008

HOUSTON FAULT MODEL

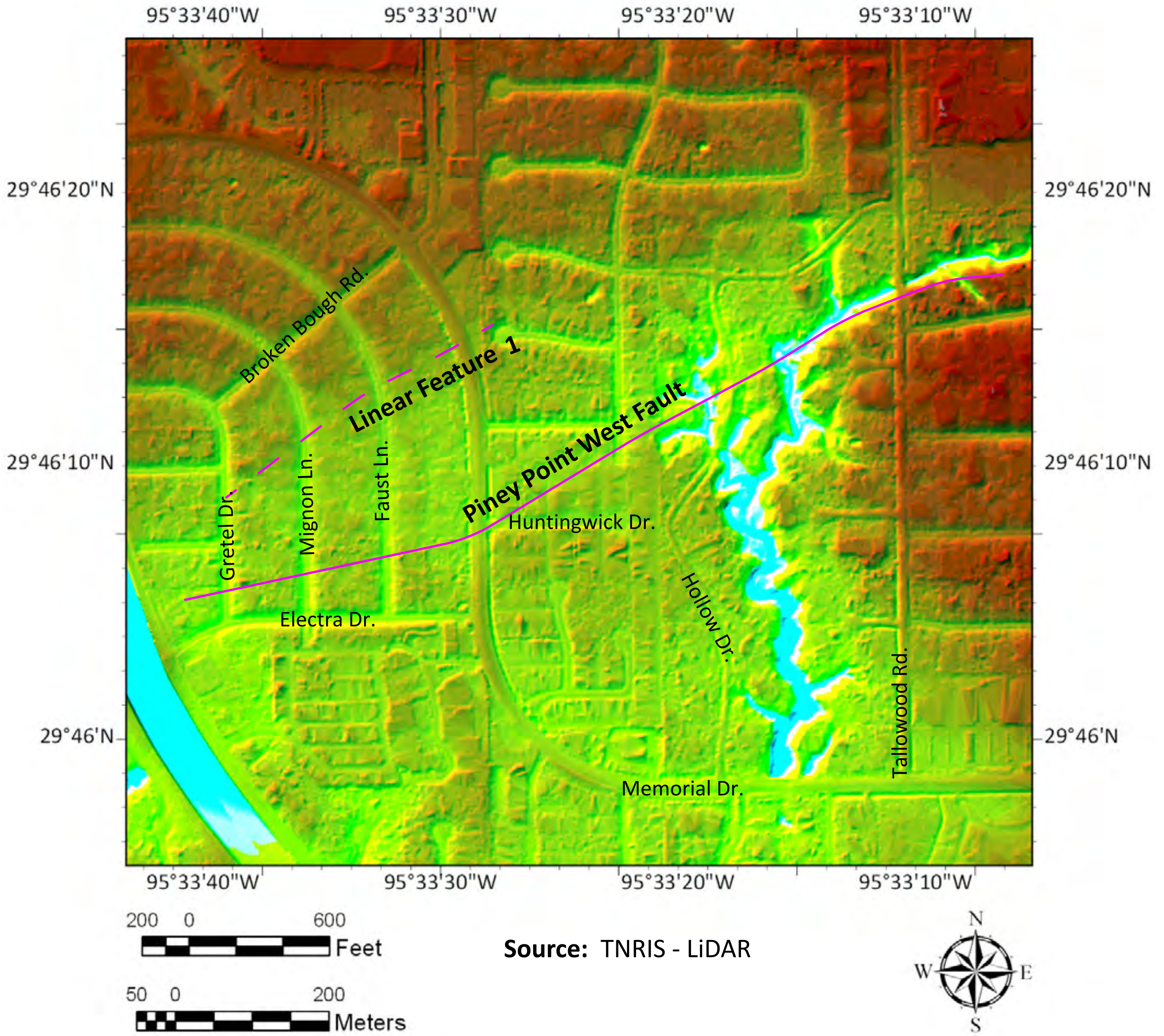


Source: Verbeek & Clanton, 1979



Source: LiDAR DEM from TNRIS

LONG POINT - PINEY POINT FAULT SYSTEM



Source: TNRIS - LiDAR

Legend:

Principal Fault

Linear Feature

LIDAR-DERIVED SHADED RELIEF MAP

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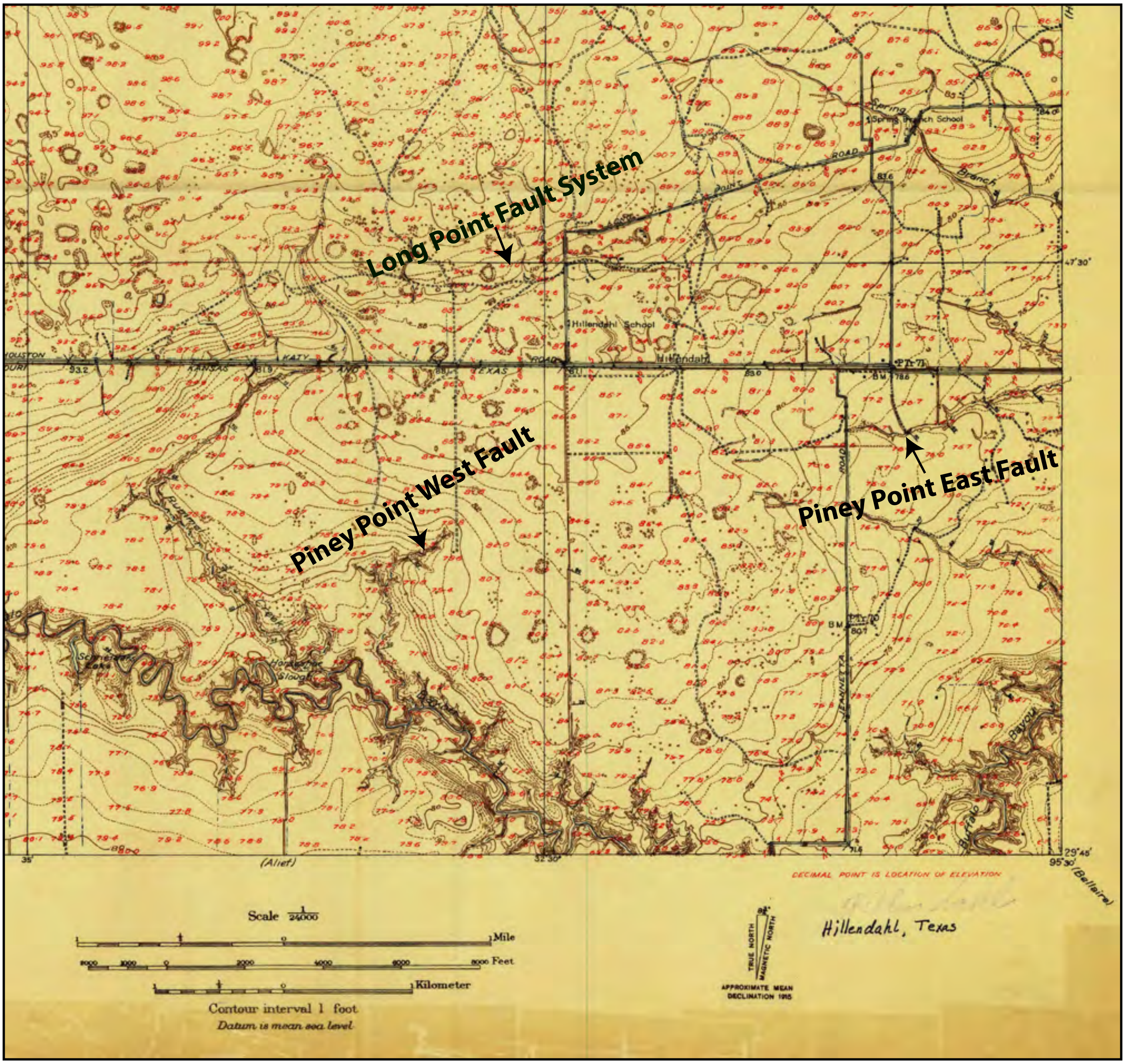

Source: USGS (1915)

TOPOGRAPHIC MAP