ABSTRACT

Salinity in the Northern Segment of the Brazos River Alluvium Aquifer:
A Hydro-Forensic Approach

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The Brazos River Alluvium Aquifer is a minor aquifer in central and east Texas under water table conditions. It is an underutilized resource and may be considered a supplemental water source. However, variability in salinity occurs throughout the Brazos River Alluvium Aquifer and the source of this variability is unclear. The objective of this study is to characterize the variability of salinity in the northern segment of the Brazos River Alluvium Aquifer and evaluate potential sources of elevated salinity. Three potential sources of elevated salinity were evaluated: Interactions between the aquifer and the river, concentration from irrigation, and brine contamination from historic oil and gas fields. Based on the ionic and isotopic composition of aquifer and river samples, in-situ water samples, core descriptions, batch leaching of sediment, and hydrographs, the Brazos River and historic oil and gas fields do not appear to be the source of elevated salinity for the aquifer; although, irrigation could impact aquifer salinity.

Salinity in the Northern Segment of the Brazos River Alluvium Aquifer:
A Hydro-Forensic Approach

by

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DEDICATION

To my parents Shawn and Kris and brother Heath Noonan, I could not have accomplished all that I have without you.

CHAPTER ONE

Introduction

Background

Growth along the I-35 corridor in central Texas has strained the regions water resources, particularly the Trinity Aquifer. The Trinity Aquifer is classified as a major aquifer and is the primary source of groundwater along the I-35 corridor. The aquifer is confined and consists of the Hensell and Hosston members, which are dominantly composed of sand. In the late 1800's, pumping from Trinity Aquifer began and cones of depression have formed in the Hensell member of the Trinity Aquifer in Waco, and in the Hosston member of the Trinity Aquifer in Dallas, Fort Worth, and Waco. During the period from 1980-2000, artesian pressure in the Hensell decreased by approximately 200 feet, while artesian pressure in the Hosston has decreased by almost 600 feet since 1945, near Waco, Texas (Bene and Harden 2004), (Figure 1.1). If artesian pressure in the Trinity Aquifer continues to decline, pumps will need to be set deeper and larger pumps may be required in wells to lift the water the additional distance to the surface. In addition, if the water level in the aquifer drops below the upper confining unit, the aquifer could become unconfined at which point the aquifer could be de-watered with further pumping.

While smaller communities rely on the Trinity Aquifer groundwater, larger cities along the I-35 corridor rely on surface water from rivers, reservoirs, or lakes. The primary water source for Waco, Texas, is Lake Waco Reservoir, located on the Bosque

River. However, significant cost is incurred as surface water must be treated and extensive infrastructure is necessary to distribute the water. The amount of surface water available for use is dependent on rainfall and thus can be significantly affected by drought. As growth along the I-35 corridor continues, the Trinity aquifer and other water resources will likely continue to become stressed, encouraging the development of new untapped or underutilized water resources, to meet the increasing demand for water.

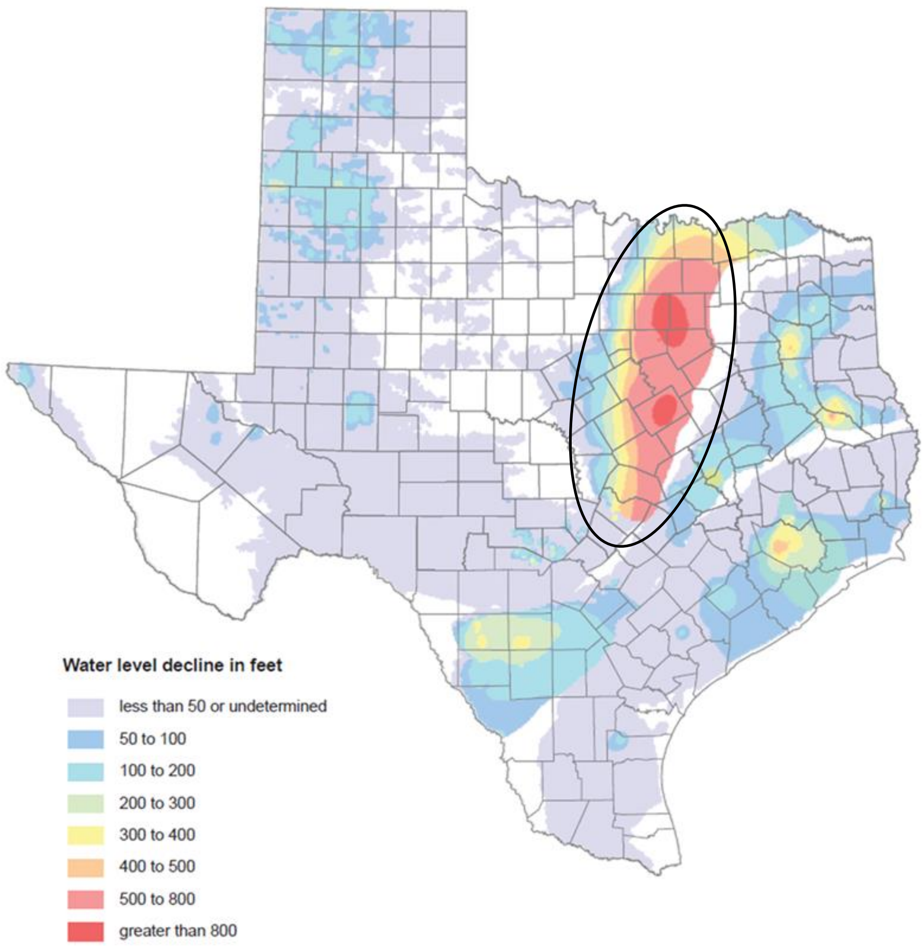

Figure 1.1. Drawdown in the Trinity Aquifer (Adapted from George and others 2011).

The Brazos River Alluvium Aquifer is classified as a minor aquifer in central and east Texas under water table conditions (George and others 2011). The aquifer spans from below Lake Whitney Dam in Bosque and Hill County to Fort Bend County (Cronin and Wilson, 1967), (Figure 1.2). The Brazos River Alluvium Aquifer is primarily used for irrigation and is an underutilized water resource that could provide a supplemental source of water, as growth along the I-35 corridor continues (Figure 1.3). However, areas of elevated salinity in the Brazos River Alluvium Aquifer have been documented as early as 1967 by Cronin and Wilson (1967), although the source of this variability is unclear.

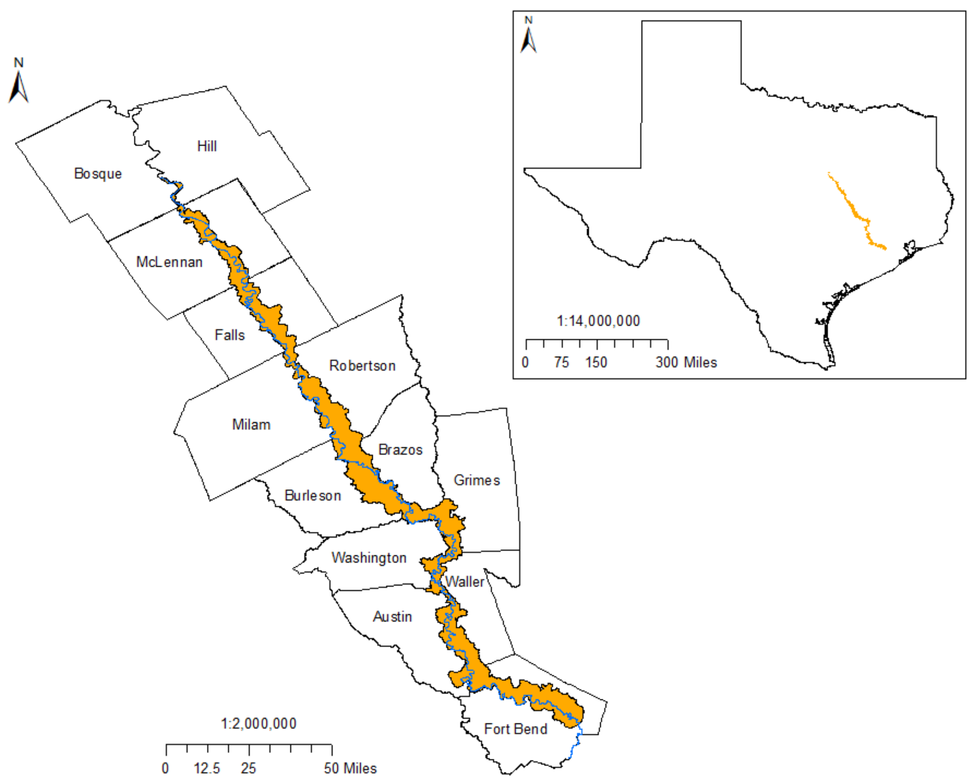

Figure 1.2. Location and extent of the Brazos River Alluvium Aquifer.

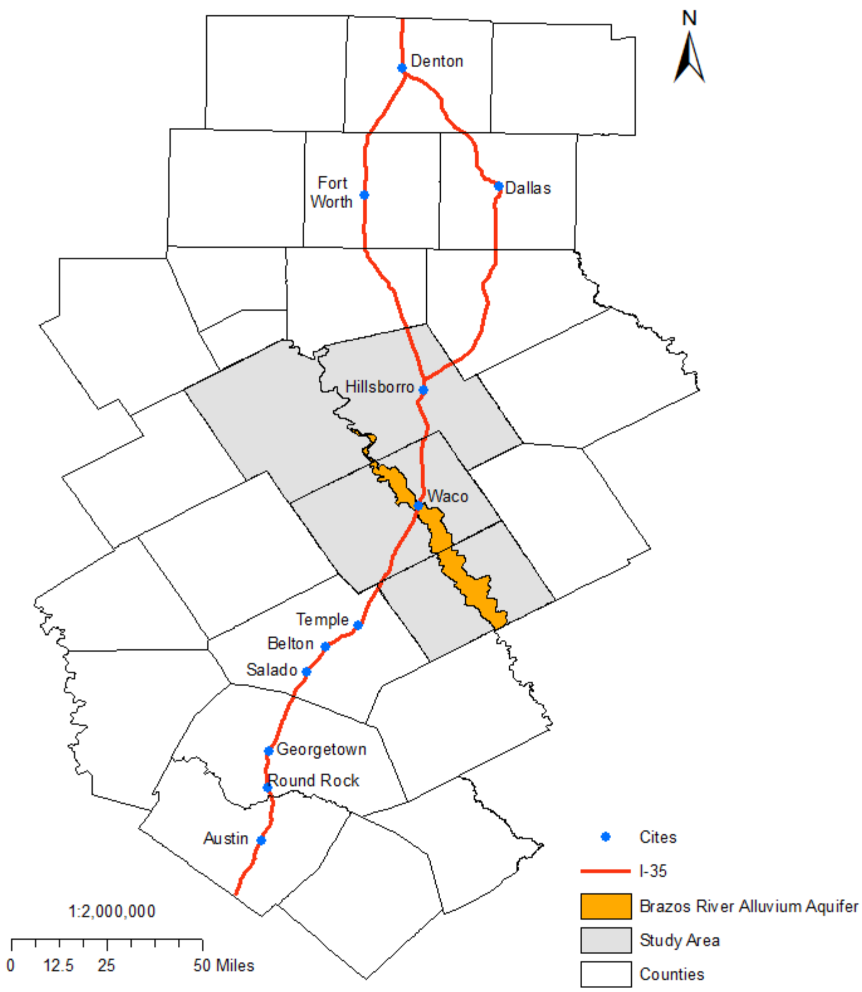

Figure 1.3. Location of the I-35 corridor in relation to the Brazos River Alluvium Aquifer.

Elevated salinity levels can cause groundwater to exceed the Environmental Protection Agency's (EPA) secondary drinking water standards of 500 mg/L for TDS and 250 mg/L for chloride and sulfate (United States Environmental Protection Agency 2018). It should be noted however, that secondary drinking water standards are only set in regard to effects such as taste, odor, and color (United States Environmental Protection Agency 2018). In addition, salinity can also affect the ability to use groundwater for irrigation as high concentrations of salts can significantly decrease crop yields, depending on a combination of water quality, soil properties, and crop sensitivity to salinity, (Richards and others 1954).

Purpose

The purpose of this study was to characterize the variability of salinity in the northern segment of the Brazos River Alluvium Aquifer and evaluate potential sources of elevated salinity. For this study, the term salinity is defined as equivalent to the amount of total dissolved solids. The results of this study potentially could be used by Groundwater Conservation Districts and the Brazos River Authority in managing both the Brazos River Alluvium Aquifer and the Brazos River, when assessing the viability of using the aquifer as a supplemental source of water. Water-rock interaction likely accounts for the majority of salinity exhibited in the aquifer and some of the variability of salinity, imparting on the aquifer a background salinity. However, areas of elevated salinity have been documented throughout the aquifer as early as 1967 by Cronin and Wilson (1967). Based on the magnitude and variability of salinity in the aquifer from Cronin and Wilson (1967) and historic Texas Water Development Board data, it is hypothesized that water-rock interaction does not account for areas of elevated salinity. Therefore, three potential sources for areas of elevated salinity were evaluated in this study, including interaction with the Brazos River, concentration from irrigation, and brine contamination from historic oil and gas fields. These three potential sources of elevated salinity were selected for investigation based on literature review and investigation of the study area, and it should be noted that while these three potential sources of salinity are thought to be the most probable, other sources of salinity likely exist.

Brazos River

The Brazos River forms at the confluence of the Salt Fork and Double Mountain Fork of the Brazos River in Stonewall County, Texas. The Brazos River is known to have elevated salinity levels and obtains the majority of its salinity from the Salt Fork of the Brazos River. Salt springs and seeps discharge from the Permian Whitehorse Group and Pease River Group into tributaries of the Salt Fork of the Brazos River (Winslow and Kister 1956 and Baker and others 1964). Groundwater flow in the Brazos River Alluvium Aquifer generally follows topography and thus discharges at the Brazos River; however, during high flow events the gradient can reverse, and water can flow from the river into the aquifer. In addition, inundation of the floodplain could also work to recharge the aquifer, and if the river has a higher salinity than the aquifer, it could cause an increase of salinity in the aquifer, (Cronin and Wilson 1956, Chowdhury and others 2010).

Irrigation and Evapotranspiration

Irrigation and evapotranspiration could be a potential source of salinity as evapotranspiration of applied irrigation water can result in an increase of salinity in the soil. Over time, continued irrigation with either groundwater and or water from the Brazos River could cause a buildup of salts in the soil, which continually leach through the soil profile and into the aquifer during subsequent irrigation and or precipitation. Goff and others (1998) have documented this process in an alluvial aquifer in the Arkansas River Basin in Colorado while Whittemore (2013) also describes this process.

Brines Associated with Historic Oil and Gas Fields

Two historic oil and gas fields exist near the northern segment of the Brazos River Alluvium Aquifer, the Deer Creek and Post Oak oil fields. Both oil fields are located in Falls County just outside the aquifer boundary (Figure 1.4). Due to the unconfined nature of the aquifer and the presence of a shallow water table, the aquifer is susceptible to contamination; therefore, brine spills, surface impoundment pits, and unplugged or poorly plugged wells have the potential to contaminate the aquifer.

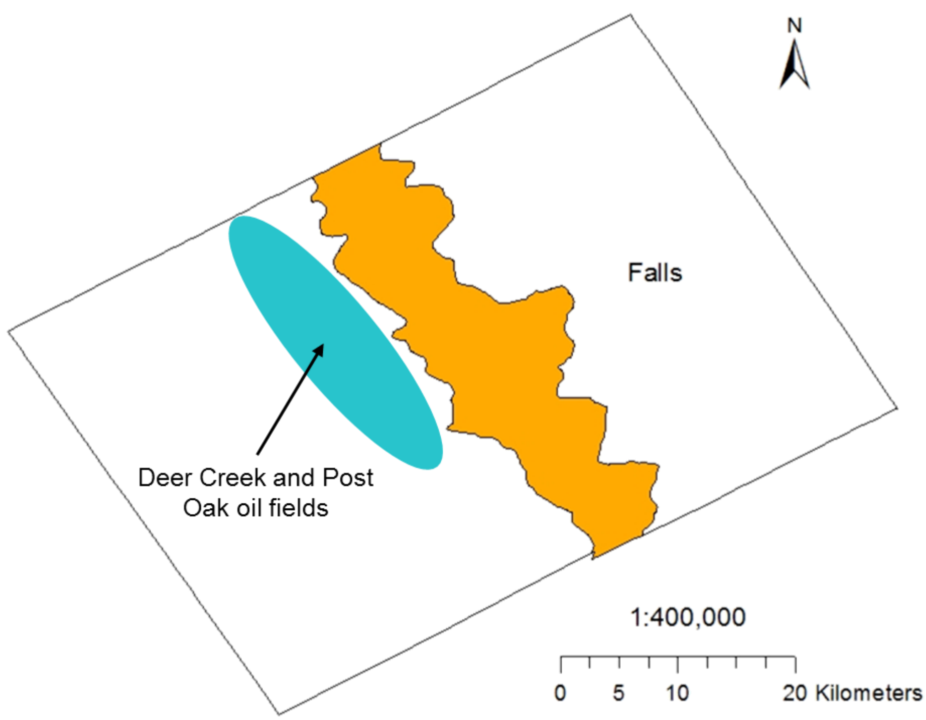

Figure 1.4. Location of historic oil and gas fields in Falls County.

Study Area

The focus of this study is the portion of the Brazos River Alluvium Aquifer in Bosque, Hill, McLennan, and Falls County, Texas (Figure 1.3 and 1.5). This portion of the aquifer will be herein referred to as the northern segment of the Brazos River

Alluvium Aquifer. The aquifer has been divided into a northern, middle, and southern segment based on differences in geology and geomorphology. The northern segment is thought to be compartmentalized into discrete flow systems due to bedrock and river boundaries (Jarvis 2019).

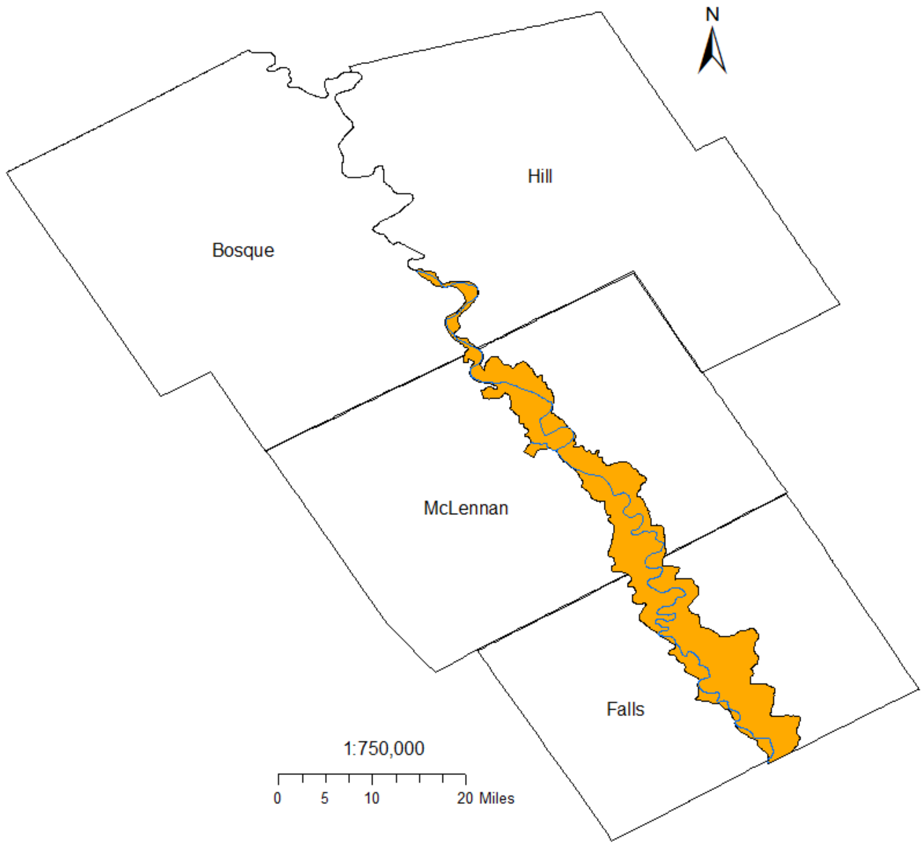

Figure 1.5. Study area extent.

Climate

The study area is located in the modified marine climate which is further divided into four zones. The majority of the study area is located in the subtropical humid zone characterized by warm summers, although the counties of Bosque and Hill and the northern portion of McLennan County lie in the transitional zone between the subtropical subhumid and subtropical humid climate zones. The subtropical subhumid climate zone is characterized by hot summers and dry winters, (Larkin and Bomar, 1983). Average annual rainfall for Waco, Texas is 34.69 inches, based on a period of record from 1981-2010 from the National Oceanic and Atmospheric Administration (NOAA) weather station at the Waco Regional Airport. The average annual temperature for Waco, Texas is 66.7°F with a minimum average annual temperature of 55.6°F and a maximum average annual temperature of 77.8°F (National Oceanic and Atmospheric Administration 2019b). The relatively hot dry summers encourage irrigation, as typically not enough precipitation is received during the growing season to maximize production.

Geology

The geology of the study area can be divided up into three components: Bedrock, older terraces of the Brazos River, and the floodplain alluvium. A geologic map and stratigraphic column for the study area can be found in figures 1.6 and 1.7.

Bedrock

Bedrock in the study area is primarily Cretaceous in age and dominantly consists of limestone and shale. A sliver of Tertiary-age bedrock out crops in the southern portion of the study area near the Falls-Robertson County line. Bedrock units out crop in parallel bands that trend from northeast to southwest and all units dip gently southeast, toward the Gulf of Mexico, (Barnes 1979, Shah and Houston 2007).

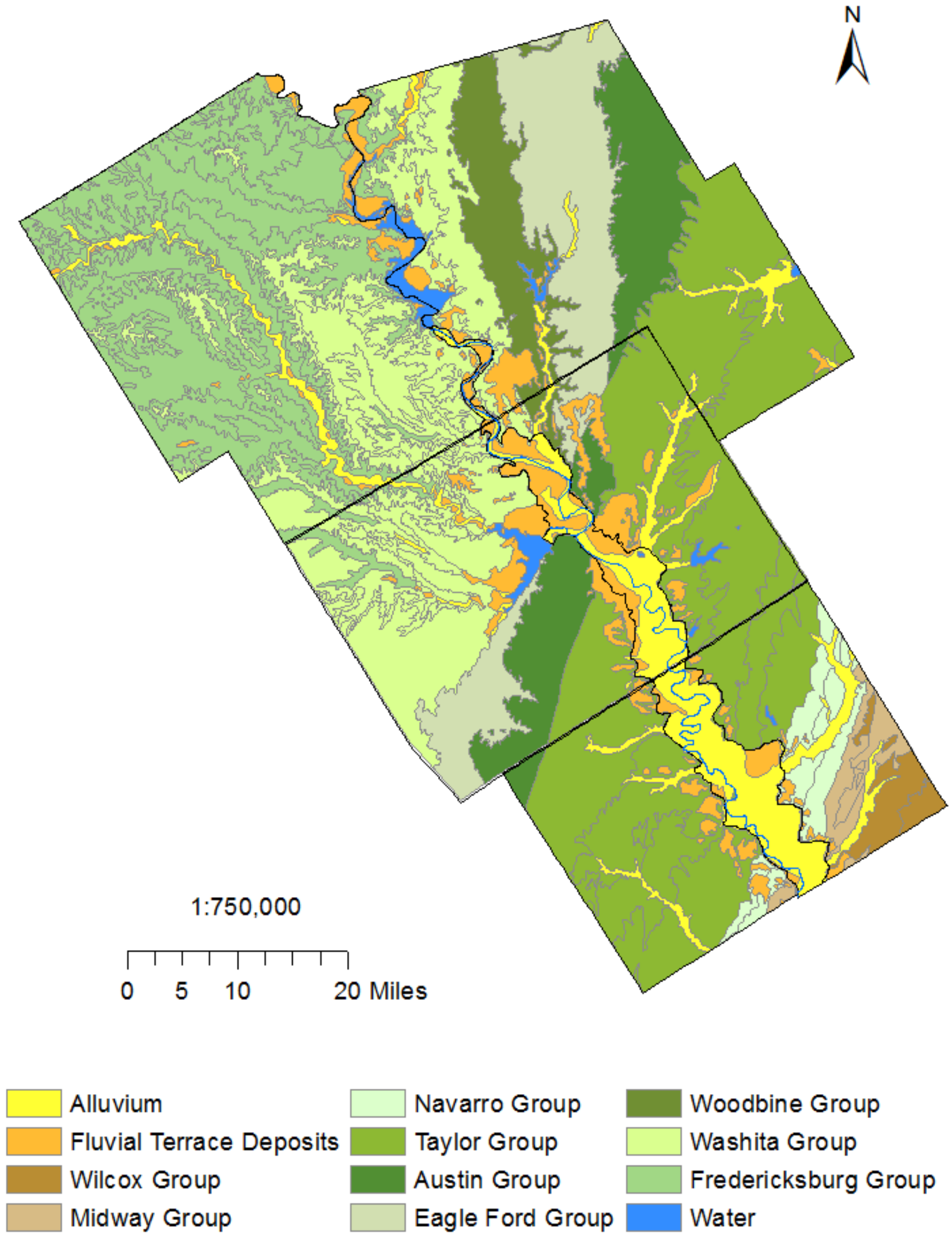

Figure 1.6. Geologic map of the study area.

Era	System	Series	Group
Cenozoic	Quaternary	Holocene	Alluvium
		Pleistocene	Fluvial Terrace Deposits
	Tertiary	Eocene	Wilcox
		Paleocene	Midway
Mesozoic	Cretaceous	Gulfian	Navarro
			Taylor
			Austin
			Eagle Ford
			Woodbine
		Comanchean	Washita
			Fredericksburg

Figure 1.7. Stratigraphic column for the study area (Modified from Shah and Houston 2007).

Terraces

The terraces are older deposits of the Brazos River that lie above the modern-day floodplain. The terraces rest unconformable on bedrock and generally consist of a fining upward sequence of gravel, sand, silt, and clay that is slightly cemented (Cronin and Wilson 1967). Epps (1973) found a total of four terraces in the study area. The first terrace is only slightly dissected and is located approximately 30 feet above the modern-day floodplain, while the second terrace is located 45-60 feet above the modern-day floodplain. The third terrace is located 90-120 feet above the modern-day floodplain, and miscellaneous high gravels are located from 200-500 feet above the modern-day floodplain. Epps (1973) did not document the miscellaneous high gravels as a fourth terrace due to the range in elevations and a lack of grading. Dissection and erosion of the terraces has occurred and older terrace deposits are typically not hydraulically connected to the floodplain alluvium; however, the younger, less dissected terraces are, in places, hydraulically connected to the floodplain alluvium and probably contribute some water to the floodplain alluvium through underflow (Cronin and Wilson 1967). Pinkus (1987) found that south of Waco, the first and second terraces are hydraulically connected to the aquifer while the third and fourth terraces are not.

Floodplain Alluvium

Beneath the modern-day floodplain of the Brazos River lies alluvium that was deposited unconformably on the underlying bedrock, by the Brazos River. The alluvium is the major water bearing unit and is flanked by older terrace deposits of the Brazos River. The floodplain ranges in width from less than 1 mile to greater than 8 miles (Cronin and Wilson 1967). The alluvium consists of gravel, sand, silt, and clay, and the deposits typically fine upward; although, due to the fluvial nature of the sediments, they are extremely heterogeneous and vary both laterally and vertically. Sediment packages commonly pinch out at both sharp and gradational contacts. The coarser sediments such as gravel and sand were deposited in the channel of the Brazos River and on point bars, while the finer sediments such as silt and clay were deposited on the floodplain as overbank materials. Sands and gravels are typically tan in color although some can appear orange-brown in color, while finer grained sediments such as silts and clays are typically orange-brown to dark brown in color.

The thickness of the alluvium ranges from 0 to 100 feet, with an average thickness of 45 feet, although the alluvium generally is thinner to the northwest and thickens to the southeast. Mining sand and gravel in the alluvium is quite common, with a large number of gravel pits located south of Waco, Texas (Cronin and Wilson, 1967, Wong 2012). Wong (2012) and Ju (2014) showed that sand and gravel mining has removed a significant volume of the alluvium.

Figure 1.8. shows a diagram of core GM9M from southern McLennan County and represents an example of the fining upward sequence typically seen in the Brazos River Alluvium Aquifer. Shale bedrock was located at 31 feet below the surface and was topped by a thick gravel and medium sand deposit consisting of 50 to 60% gravel. The gravel consisted of limestone and chert and ranged up to 1.2 inches in diameter. The size of the gravel is likely biased due to the small diameter (2.25 inches) of the core barrel used for sample collection. Cronin and Wilson (1967) found cobbles up to 5 inches in diameter and boulder size clasts likely from erosion of underlying bedrock. Above the gravel and medium sand deposit is very fine sand with some clay and gravel and then medium sand with some clay and gravel, followed by a deposit of very fine sand. A clay lense can be found from approximately 12 to 16 feet below the surface followed by very fine sand and then silt. Clay lenses are often found at various intervals in core collected from the alluvium aquifer and the proportion of sand and gravel and their sizes vary widely from core to core, but overall a fining upward sequence is exhibited throughout the aquifer.

Hydrogeology

The Brazos River Alluvium Aquifer is classified as a minor aquifer in central and east Texas under water table conditions, although local artesian conditions can occur due to the presence of clay lenses with low hydraulic conductivities (George and others

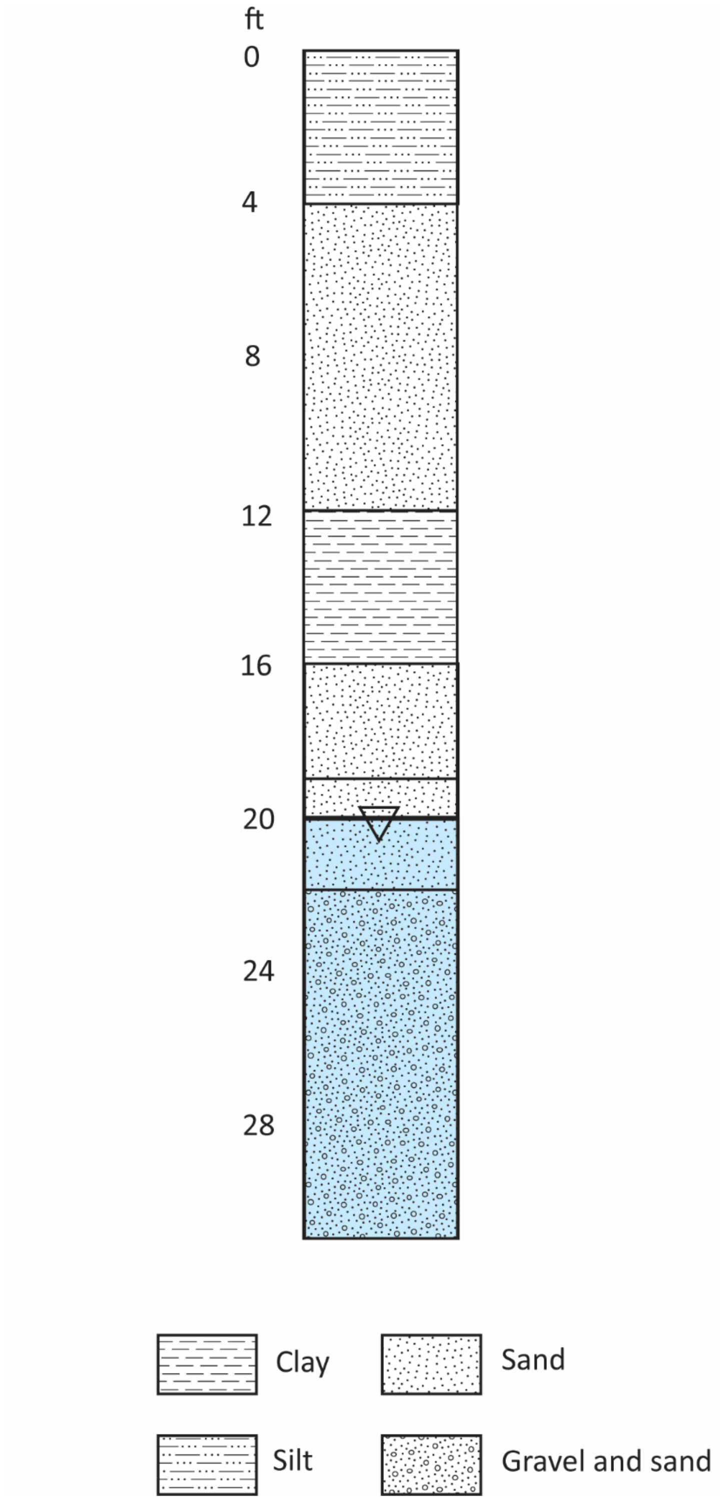

Figure 1.8. Diagram of core GM9M from southern McLennan County, demonstrating the fining upward sequence typically seen in the aquifer.

2011). The aquifer is underlain by slowly permeable Cretaceous and Tertiary bedrock in the northern segment which acts as a boundary to flow, and is flanked by older terrace deposits, some of which are hydraulically connected to the aquifer. The aquifer is primarily recharged by precipitation, although small amounts of recharge likely come from bedrock, inundation of the floodplain by the Brazos River, irrigation return flow, underflow from terraces, and bodies of surface water. The aquifer discharges at the Brazos River and water in the aquifer typically flows perpendicular to the river, making the Brazos River a gaining stream (Cronin and Wilson 1967, Harlan 1990, Pinkus 1987). However, Pinkus (1987) also found that high stream stage of the Brazos River, tributary dissection, preferred flow paths such as channels or highly transmissive zones, or low permeability obstructions such as clay liners or low transmissive zones can cause deviations to flow paths in the aquifer. Water is also discharged from the aquifer through wells and evapotranspiration (Cronin and Wilson 1967).

Cronin and Wilson (1967) found that the hydraulic conductivity of the aquifer ranged from 0.001 to 18,000 gpd and specific yield ranged from 4.4 to 35.4%. The transmissivity of the aquifer as calculated from short-term pumping tests ranged from 50,000 to greater than 300,000 gpd/ft, but ranged from 7,300 to 208,00 gpd/ft as calculated from specific capacity measurements (Table 1.1). Average recharge rates for the Brazos River Alluvium Aquifer calculated by Cronin and Wilson (1967), Dutton and others (2003), and Chowdhury and others (2010) using various techniques ranged from 0.33 to 3.0 inches per year. Estimates of groundwater velocity were 70-75 ft/yr by Cronin and Wilson (1967), but were significantly less at 9 to 27 ft/yr by Chowdhury and others (2010).

Table 1.1. Summary of aquifer properties determined by Cronin and Wilson (1967).

Parameter	Range of Values	Average Value	Method
Hydraulic Conductivity	0.001 - 18,000 gpd		Laboratory
Specific yield	4.4 - 35.4%	23.6%	Laboratory
Specific capacity	6 - 134 gpm/ft drawdown		Drawdown/discharge measurements
Transmissivity	50,000 - >300,000 gpd/ft		Short-term pumping tests
Transmissivity	7,300 - 208,000 gpd/ft	42,000 gpd/ft	From specific capacity measurements

Table 1.2. Estimated recharge for the Brazos River Alluvium Aquifer (Modified from Chowdhury and others 2010).

Year	Range of Recharge (in/yr)	Average Recharge (in/yr)	Method	Source
1994-2004	0.06 - 5.57	0.74	Digital base flow separation	Chowdhury and others (2010)
1934-1998	0.02 - 9.70	0.95	Digital base flow separation	Chowdhury and others (2010)
	0.11 - 3.39	0.33	Chloride Mass Balance	Chowdhury and others (2010)
1962-1964	1.7 - 5.5	3.0	Flow between successive flow lines	Cronin and Wilson (1967)
	0.30 - 0.40	0.35	Groundwater model	Dutton and others (2003)

Previous Works

A literature review of studies involving the Brazos River Alluvium Aquifer and Brazos River was performed. Relevant studies are described below in chronological order.

Stricklin (1961) investigated terrace and floodplain deposits of the Brazos River and determined that the Brazos River is a degradational stream and is characterized as braided upstream of Graham, incised meandering in between Graham and Waco, and meandering downstream from Waco.

In 1967, Cronin and Wilson completed a comprehensive study of the Brazos River Alluvium Aquifer, examining the extent and thickness of the alluvium, flow paths in the aquifer, water quality, and the relationship between the aquifer and Brazos River.An area with elevated sodium, chloride, and TDS concentrations was observed near the Falls-Robertson County line, although the source of salinity was unable to be determined. In addition, 80% of the samples collected during the study exceeded the EPA's secondary drinking water standard for TDS, and 20% of the samples exceeded the EPA's secondary drinking water standard for chloride (Cronin and Wilson 1967).

Epps (1973) examined the history of the Brazos River using drainage maps, geomorphology, stratigraphy, lithology, and soils and determined that the Brazos River was much larger in the past than it is today and experienced cyclic alterations in size due to climatic changes.

Harlan (1985) investigated the portion of the Brazos River Alluvium Aquifer between the low water dam in Waco, Texas and Marlin, Texas, specifically focusing on the geology and hydrogeology of two sites, the Flat Creek and Hay's Ranch site.

Birdwell (1986) conducted an evaluation of the potential of shallow groundwater in the second terrace of the Brazos River Alluvium Aquifer at Cow Bayou Farms in Falls County, Texas.

Pinkus (1987) examined three sites in the Brazos River Alluvium Aquifer with different solid waste disposal methods and found that all three sites showed significant contamination down-gradient of the disposal sites.

Ward (1989) examined the potential for contamination posed by abandoned gravel pits in the Brazos River Alluvium Aquifer, finding that while water quality at the three sites examined was good, the gravel pits still pose the potential for contamination. In addition, it was also found that the gravel pits typically act as flow-through lakes year-round, where groundwater flows in one side of the pit and out the other.

Harlan (1990) studied the hydrogeochemistry of the Brazos River Alluvium Aquifer between Waco and Marlin, Texas. Water chemistry showed that groundwater in the floodplain was dominantly calcium bicarbonate type, although some variability was exhibited.

Waters and Nordt (1994) performed a stratigraphic study of the late Quaternary floodplain alluvium deposited by the Brazos River, to examine changes in the hydrologic regime of the river and the controls on these shifts, particularly climate change.

To facilitate the development of the Groundwater Availability Model (GAM) for the Brazos River Alluvium Aquifer, Shah and Houston (2007), developed a geodatabase containing geologic and hydrogeologic information about the aquifer.

Chowdhury and others (2010) also documented elevated salinity levels between Marlin and Bryan as well as local areas of elevated chloride and sulfate levels throughout the aquifer. It was hypothesized that the variability in salinity was caused by evapotranspiration due to varying depths to the water table; however, little evidence was shown to support this hypothesis.

Hudak (2011) studied arsenic, nitrate, sulfate, boron, chloride, bromide, TDS, and chloride to bromide ratios in six aquifers located along the Brazos River, including the Brazos River Alluvium Aquifer. However, only 10 samples were obtained from the Brazos River Alluvium Aquifer, one of which was in the northern segment.

Wong (2012) found that well depth can often be used as a sufficient indicator of alluvium thickness and that sand and gravel mining has significantly impacted the volume of the Brazos River Alluvium Aquifer.

Ju (2014) worked to determine the effects different materials used to fill gravel pits had on the Brazos River Alluvium Aquifer, by estimating annual recharge using a water budget, characterizing the materials used to fill gravel pits, and determining the effects of gravel mining on the aquifer using a MODFLOW model. The study found that evaporation from gravel pit lakes significantly alters the water budget and flow paths of the aquifer, and that filling gravel pits with both native and foreign fill material decreases evaporation and creates conditions more similar to that of pre-mining conditions.

Ewing and Jigmond (2016) and Ewing and others (2016) detail the creation of the Groundwater Availability Model (GAM) for the Brazos River Alluvium Aquifer.

Jarvis (2019) determined that the northern segment of the Brazos River Alluvium Aquifer was compartmentalized into discrete flow systems due to bedrock and river boundaries. He also examined the effect of channel morphology of the Brazos River (incised meandering versus meandering) on the aquifer.

Despite the work performed on the Brazos River Alluvium Aquifer, little has been done to characterize and understand the variability of salinity within the aquifer and the sources of elevated salinity. The demand for water is likely going to continue to increase in the near future, emphasizing the importance of this study to try to better understand the variability and sources of elevated salinity and possibly improve the management of the aquifer and prevent further degradation.

CHAPTER TWO

Methods

To characterize and understand both the variability and sources of elevated salinity within the northern segment of the Brazos River Alluvium Aquifer the following methods were employed: 1) The analysis of historic chemistry data for the Brazos River Alluvium Aquifer and Brazos River. 2) The analysis of water samples collected from sites in the Brazos River Alluvium Aquifer and the Brazos River for common ions and isotopes. 3) The analysis of in-situ water samples from the Brazos River Alluvium Aquifer. 4) A batch leaching experiment on sediments collected from aquifer cores. 5) Hydrograph analysis using pressure transducer data loggers in selected monitoring wells.

Historic Brazos River Alluvium Aquifer and Brazos River Chemistry Data

To develop a baseline for this study an analysis of historic specific conductance and chemistry data for the Brazos River Alluvium Aquifer and Brazos River was performed. Historic specific conductance and chemistry data were obtained for the northern segment of the Brazos River Alluvium Aquifer through the use of the TWDB groundwater database (Texas Water Development Board 2019). Only specific conductance and chemistry data from wells that were pumped were utilized in this study. It was also ensured that only balanced chemical analyses were used. For the northern segment of the aquifer, 46 specific conductance measurements and 23 complete chemical analyses of water samples were available both spanning from 1961-2016.

Historic specific conductance and chemistry data for the portion of the Brazos River in the study area were obtained from the TCEQ Clean Rivers Program (Texas Commission of Environmental Quality 2019). One-thousand six-hundred and nine specific conductance measurements were obtained from six river stations, one in Bosque/Hill, four in McLennan, and one in Falls County spanning from 1972-2017. Ten chemistry analyses of river samples were obtained from river stations in Bosque/Hill and Falls County spanning from 1992-2002.

Brazos River Alluvium Aquifer and Brazos River Water Sampling

To characterize the spatial variability of salinity in the northern segment of the Brazos River Alluvium Aquifer, water samples were collected from wells and springs throughout the study area. Two sets of water samples were collected from the aquifer, one in the spring/summer of 2018 and another in the fall of 2018, to account for any seasonal chemistry variability. All wells were pumped or bailed until three casing volumes of water were removed or until specific conductance and temperature stabilized. Samples from both the spring/summer of 2018 and the fall of 2018 were analyzed for major cations and anions, and samples from the spring/summer of 2018 were also analyzed for hydrogen and oxygen isotopic compositions. The specific conductance and temperature of each sample was measured in the field and bicarbonate concentration was determined by titration. Duplicate samples, trip blanks, and field blanks were utilized to check lab precision and ensure no contamination of the samples occurred during collection, respectively. Detailed sampling procedures can be found in appendix A.

The first set of water samples consisted of 32 samples collected during the spring/summer of 2018 (Figure 2.1.). Water samples in Bosque, Hill, and McLennan

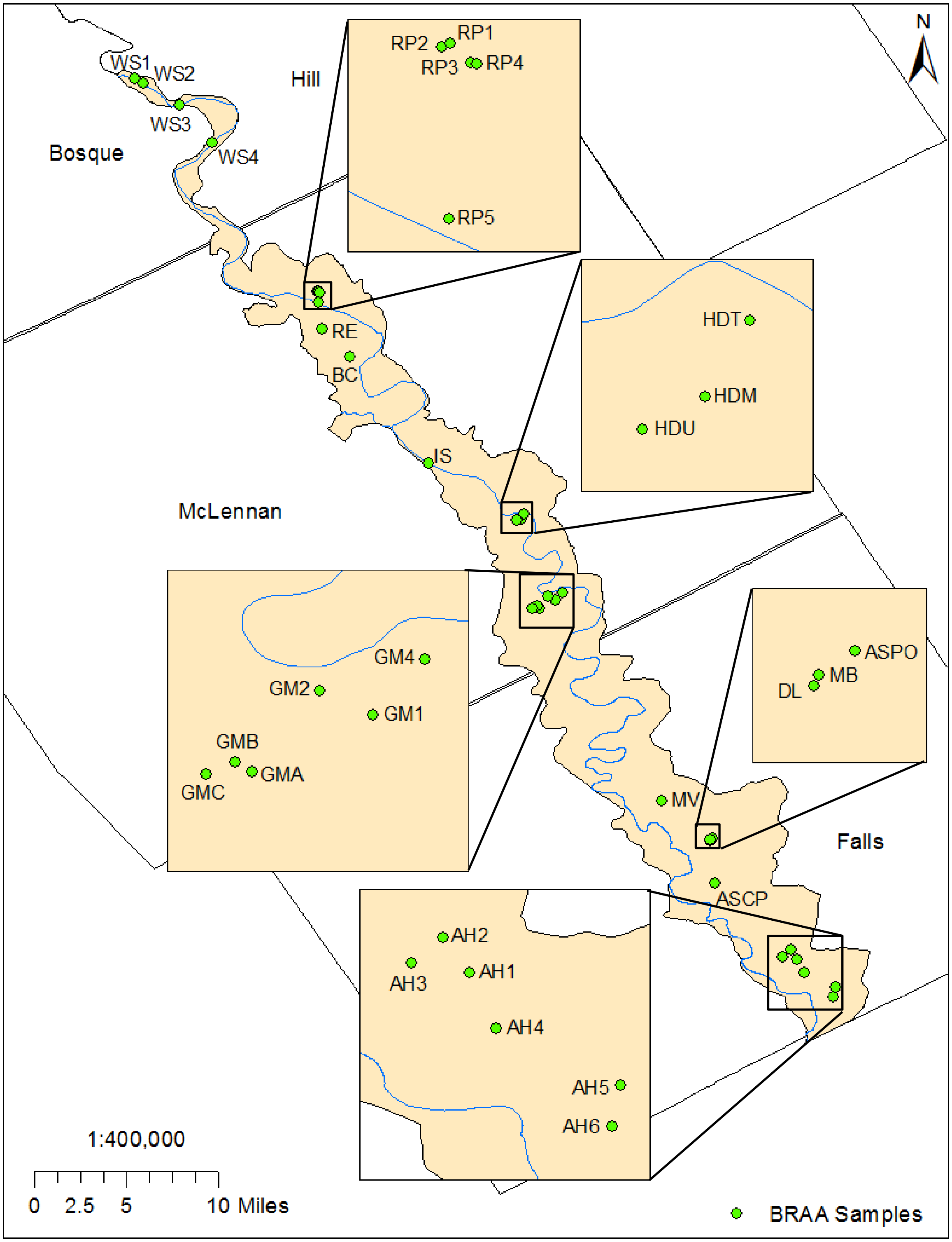

Figure 2.1. Location of Brazos River Alluvium Aquifer samples collected in the spring/summer of 2018.

County were collected from 1/27/18 to 3/3/18 and water samples in Falls County were collected from 6/21/18 to 7/24/18. One water sample from McLennan County was also collected during the summer of 2018. Four samples were collected in Bosque/Hill (4 springs), 17 samples were collected in McLennan County (16 wells, 1 spring), and 11 samples were collected in Falls County (11 wells). The goal of the study was to collect all samples during a much tighter time period; however, due to issues gaining access to wells this was not possible. Little rain was received during the spring and summer of 2018; therefore, it is likely the chemistry of the aquifer changed little between the spring and summer of 2018.

The second set of water samples consisted of 19 samples collected during the fall of 2018 from 10/5/18 to 11/20/18 (Figure 2.2). Eleven samples were collected from McLennan County and eight samples were collected from Falls County. An effort was made to sample the same wells as previously sampled; however, due to malfunctioning pumps and accessibility issues, not all wells could be re-sampled. The springs in Bosque/Hill were not re-sampled as based on specific conductance and ionic chemistry data, they did not appear to be representative of the aquifer and had significant potential for contamination. Indian Spring was not resampled as the stream stage of the Brazos River was high, preventing access to the spring. Since Indian Spring is located in downtown Waco, it likely had significant potential for contamination also.

Water samples collected during the period of 1/27/18 to 3/3/18 were sent to the Center for Reservoir and Aquatic Systems Research (CRASR) laboratory at Baylor University to be analyzed for major cations and anions using ion chromatography (IC). Per CRASR’s standard operating procedures, the water samples to be analyzed for

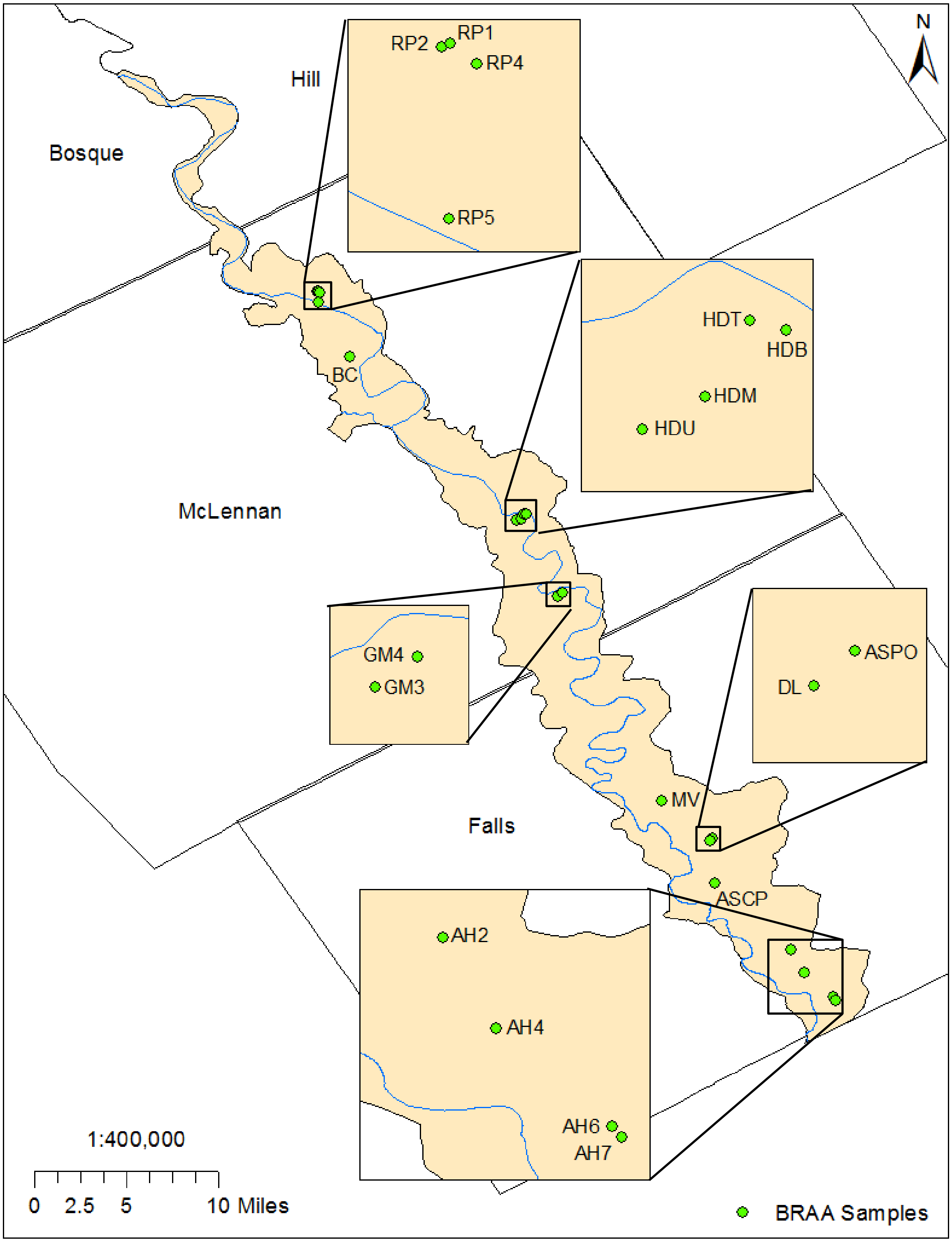

Figure 2.2. Location of Brazos River Alluvium Aquifer samples collected in the fall of 2018.

cations were not acidized. It was later determined that a significant amount of cation precipitation occurred, so cation data were not used for the samples collected during the period of 1/27/18 to 3/3/18. Analysis of the anions was also found to be unacceptable. In light of these findings, samples from 6/21/18 to 7/24/18 and all samples from the fall of 2018 were sent to the BIO CHEM Lab in West, Texas, to be analyzed for major cations and anions. Samples to be analyzed for cations were acidized with nitric acid, while samples to be analyzed for anions were not acidized. Cations were analyzed using an inductivity coupled plasma mass spectrometer (ICPMS), while anions were analyzed using IC.

All samples collected on or after 3/3/18 were also sent to the CRASR laboratory to be analyzed for dissolved nitrogen and phosphorus using the Lachat method.

Water samples collected during the spring/summer of 2018 were also sent to the Baylor University Department of Geosciences' stable isotope lab, to be analyzed for hydrogen and oxygen isotopic compositions. Samples were analyzed using a gas source isotope ratio mass spectrometer and all values are reported as per mil difference from the reference Vienna Standard Mean Ocean Water (VSMOW).

To develop a baseline for the chemistry and isotopic composition of the Brazos River, a synoptic set of samples were collected throughout the study area on 7/9/18 and 7/10/18 (Figure 2.3.). Fourteen samples were collected from the Brazos River. Major cations and anions were analyzed at the CRASR lab, and as previously described the cation and anion data are unusable. Hydrogen and oxygen isotopic compositions were analyzed at Baylor University Department of Geosciences' stable isotope lab. It is known that the chemistry

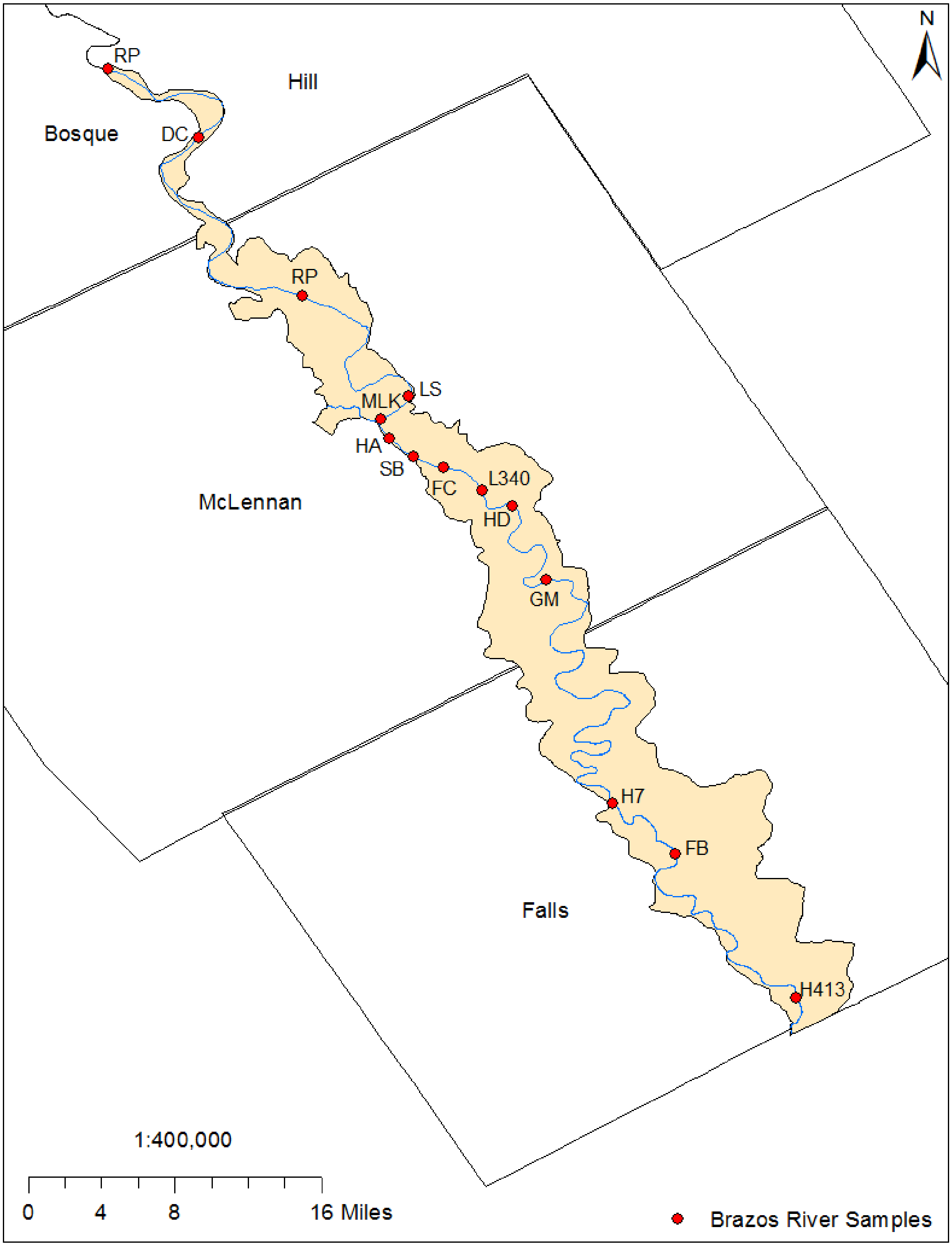

Figure 2.3. Location of Brazos River samples collected during the summer of 2018.

of the Brazos River varies throughout the year and with stream stage; however, the data provide valuable information for comparison to the chemistry of the aquifer.

Coring and In-situ Water Sampling

To determine if any salinity stratification was present within the aquifer, in-situ water samples were collected using a Geoprobe 6620DT. Core was also collected using the Geoprobe, to characterize the sediment types present at the in-situ sampling locations. Three sites were chosen in McLennan County a non-irrigated pasture, an irrigated orchard, and an irrigated row crop farm), and core and in-situ water samples were typically collected next to 3 to 4 wells at each site, in a transect perpendicular to the Brazos River. A total of 27 in-situ water samples and 10 cores were collected.

In-situ water samples were collected according to the Geoprobe Screen Point 22 Groundwater Sampler Standard Operating Procedures Technical Bulletin No. MK3173 (Geoprobe 2010). Typically, one in-situ water sample was collected just below the water table, a second was collected just above bedrock, and if the saturated thickness of the aquifer was large enough, a third sample was collected from in-between the first two. In-situ samples were collected using a 1.5-foot screened interval. The stainless-steel screen and polyethylene tubing and check valve were rinsed with distilled water in-between each use. The temperature and specific conductance of each sample was measured in the field and samples were analyzed for major cations and anions and ratios of hydrogen and oxygen isotopes. Bicarbonate concentration was determined by titration. Water samples were collected according the previously described procedures and detailed water sampling procedures can be found in appendix A. Ten of the in-situ water samples were analyzed at the CRASR lab and the cation data for these samples were unusable due to sample storage problems, although five of the samples were collected again at a later date. The rest of the samples were analyzed by the Bio Chem Lab.

Collecting the core allowed the identification of the sediment types from which the in-situ samples were obtained.

Batch Leaching

A batch leaching experiment on sediments from the 10 cores collected was performed and compared to the results of the in-situ water sampling. All cores were air dried for at least one month. For each core, the 1.5-foot core intervals corresponding to the 1.5-foot screened in-situ sample interval, were identified. At least two additional 1.5-foot segments were also identified in the unsaturated section of each core, at evenly spaced intervals. The top and bottom 3.5 inches of each 1.5-foot interval were removed. Then, four inches of core was collected from the top and bottom, leaving 3 inches of core in the middle that were not used. Both four-inch sections of core were cut in half lengthwise and one-half of each section was placed in a 1-quart glass jar labeled with the sample location and depth. Each jar was filled with 750 mL of distilled water and the sediments in each jar were periodically agitated to ensure all core disaggregated. The specific conductance of each jar was recorded weekly for a period of six weeks using a YSI conductivity probe. The goal of the experiment was to have a wide variety of sediment types, to see if any correlation between sediment type and or sediment depth and specific conductance exists. The observed specific conductance values from the batch leaching experiment were also compared to the specific conductance values of the in-situ samples. More detailed procedures can be found in appendix B.

Data Loggers

To monitor changes in water level and specific conductance of the Brazos River Alluvium Aquifer over time, two INW data loggers were installed in monitoring wells. Monitor well HDB was located approximately 0.08 miles from the Brazos River, while monitor well HDM was located approximately 0.42 miles from the Brazos River. The data loggers were set to record water level and specific conductance every 30 minutes. Data from the data loggers was downloaded monthly, and the desiccant was replaced as needed. The water level and specific conductance of each monitoring well was recorded monthly using a Solnist water level gage and compared to the measurements recorded by the data logger, to ensure it was functioning properly.

The specific conductance data recorded by the data loggers could not be used as it was determined that the data loggers did not accurately record changes in specific conductance. This conclusion was based on comparisons of specific conductance values recorded by the data loggers to field measurements taken by calibrated probes, observed linear data logger drift, and unreasonable spikes in specific conductance.

The data logger in monitoring well HDB started recording on April 17th, 2018 and the data logger in monitoring well HDM started recording on May 4th, 2018. Both data loggers will record for a full year before being removed, although only data from May 1^{st,} 2018 through January 1st, 2019 will be used in the analyses. The water level data collected by the data loggers were compared to the stream stage of the Brazos River and precipitation to help determine the controls on recharge rates and groundwater-surface water interactions. Data for the stream stage of the Brazos River were obtained from the USGS gage (08096500) on the Brazos River at Waco, TX (United States Geological

Survey 2019). Precipitation data were obtained from the NOAA weather station (USW00013959) at the Waco Regional Airport (National Oceanic and Atmospheric Administration 2019a).

Supplemental water level data were obtained from data loggers in an additional three wells maintained by the Southern Trinity Groundwater Conservation District (STGCD). Monitor well HDT was located 0.14 mi from the Brazos River, monitor well GM9M was located 0.72 mi from the Brazos River, and monitor well RP1 was located 0.56 mi from the Brazos River. STGCD data loggers were set to record water level and specific conductance every hour. Data from STGCD data loggers contain some lapses of data due to technical difficulties.

CHAPTER THREE

Results and Discussion

Specific Conductance and Ionic Composition of the Brazos River Alluvium Aquifer and Brazos River

The first step to understanding the sources of elevated salinity in the northern segment of the Brazos River Alluvium Aquifer was to characterize the current spatial variability of salinity in the aquifer. The last set of water samples collected throughout the northern segment of the aquifer was during the 1960's, and considerable changes in water chemistry could have occurred since then. A total of 32 water samples were collected from the Brazos River Alluvium Aquifer in the spring/summer of 2018 and 19 water samples were collected in the Fall of 2018, to account for any changes in water chemistry due to seasonality. In addition, a synoptic set of water samples was collected from the Brazos River throughout the study area, in July of 2018. The specific conductance and temperature of all samples were measured in the field and all samples were analyzed for major cations and anions.

Specific Conductance of the Brazos River Alluvium Aquifer and Brazos River

Analyses of the specific conductance of Brazos River Alluvium Aquifer and Brazos River samples collected in the spring/summer of 2018, show that the average specific conductance of the aquifer in Falls County was 1819 μS/cm, almost double that of the aquifer in McLennan County (986 μS/cm) (figure 3.1.). The box plot in figure 3.1. also shows that the average specific conductance of the Brazos River (in the study area)

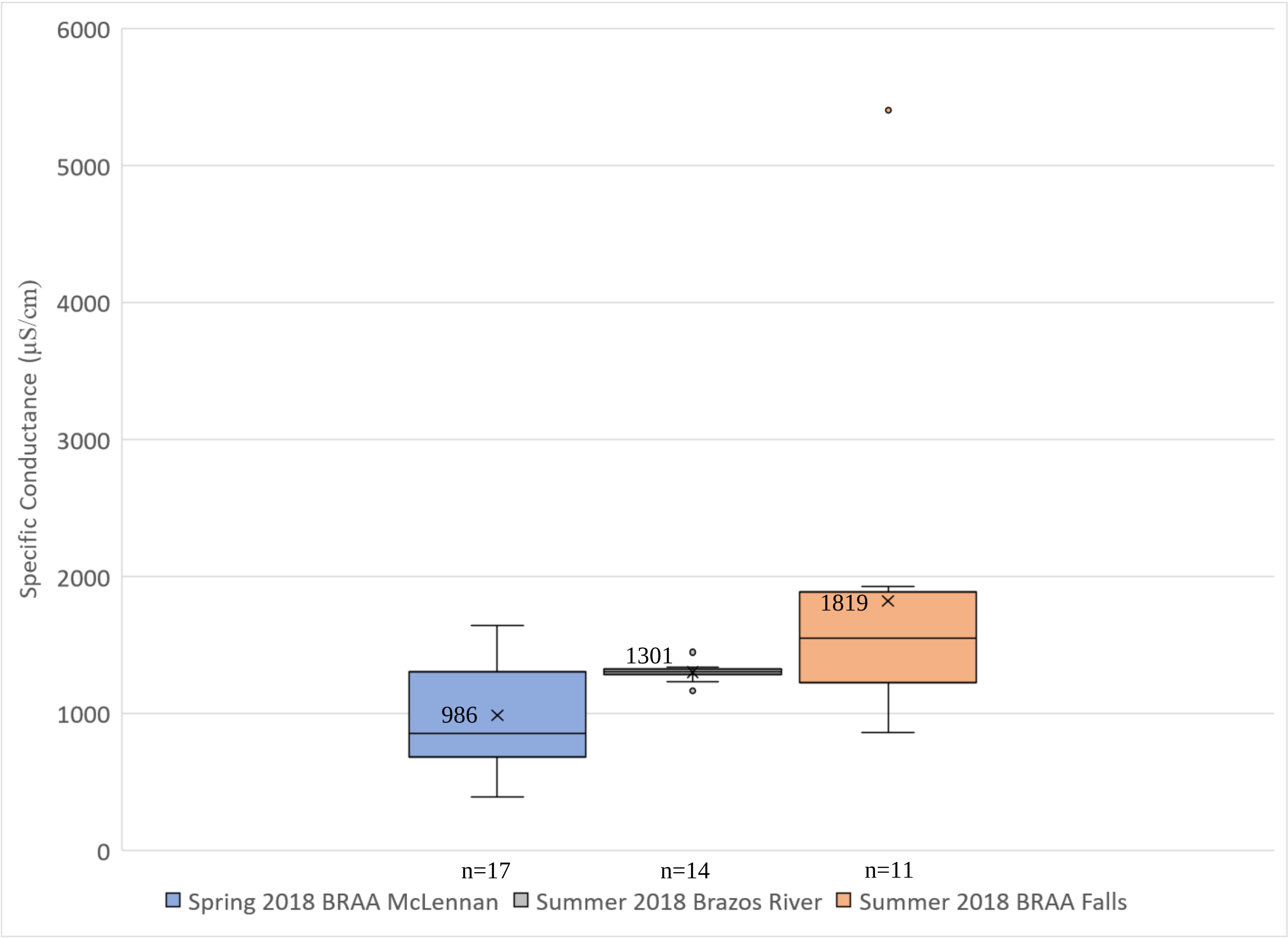

Figure 3.1. Box plot of the specific conductance of the Brazos River Alluvium Aquifer and Brazos River in the spring/summer of 2018.

was 1301 μS/cm, which is significantly less than the average specific conductance of the aquifer in Falls County but is slightly higher than the average specific conductance of the aquifer in McLennan County. It was also found that the specific conductance of the Brazos River decreased downstream, likely due to contributions from tributaries with fresher water. The river samples were collected over the course of a two-day period in July, and thus fail to capture variability in the specific conductance of the Brazos River due to changes in seasonality or due to flooding. Analyses of the specific conductance of Brazos River Alluvium Aquifer samples collected in the fall of 2018 resulted in similar trends and similar average specific conductance values for the aquifer in each county (figure 3.2.). All data sets can be found in appendix C.

The use of a Mann Whitney U-test showed that at the 5% significance level the specific conductance of the aquifer in McLennan County changed little from the spring of 2018 to the fall of 2018. Similarly, use of a Wilcox Signed Rank Test showed that at the 5% significance level the specific conductance of the aquifer in Falls County changed little from the spring of 2018 to the fall of 2018. These data indicate there was little change in the specific conductance of the aquifer due to changes in seasonality. A Mann Whitney U-test also showed that at the 5% significance level the specific conductance of the Brazos River Alluvium Aquifer in McLennan County was less than the specific conductance of the aquifer in Falls County (Frank, K., written communication, 2019).

To determine if the average specific conductance of the aquifer has changed over time, data collected from 2018 were compared to historic aquifer and river data sets from the TWDB and TCEQ, respectively. Data from the TWDB spanned from 1961-2016, although the majority of the data were collected during the 1960's, while data from the

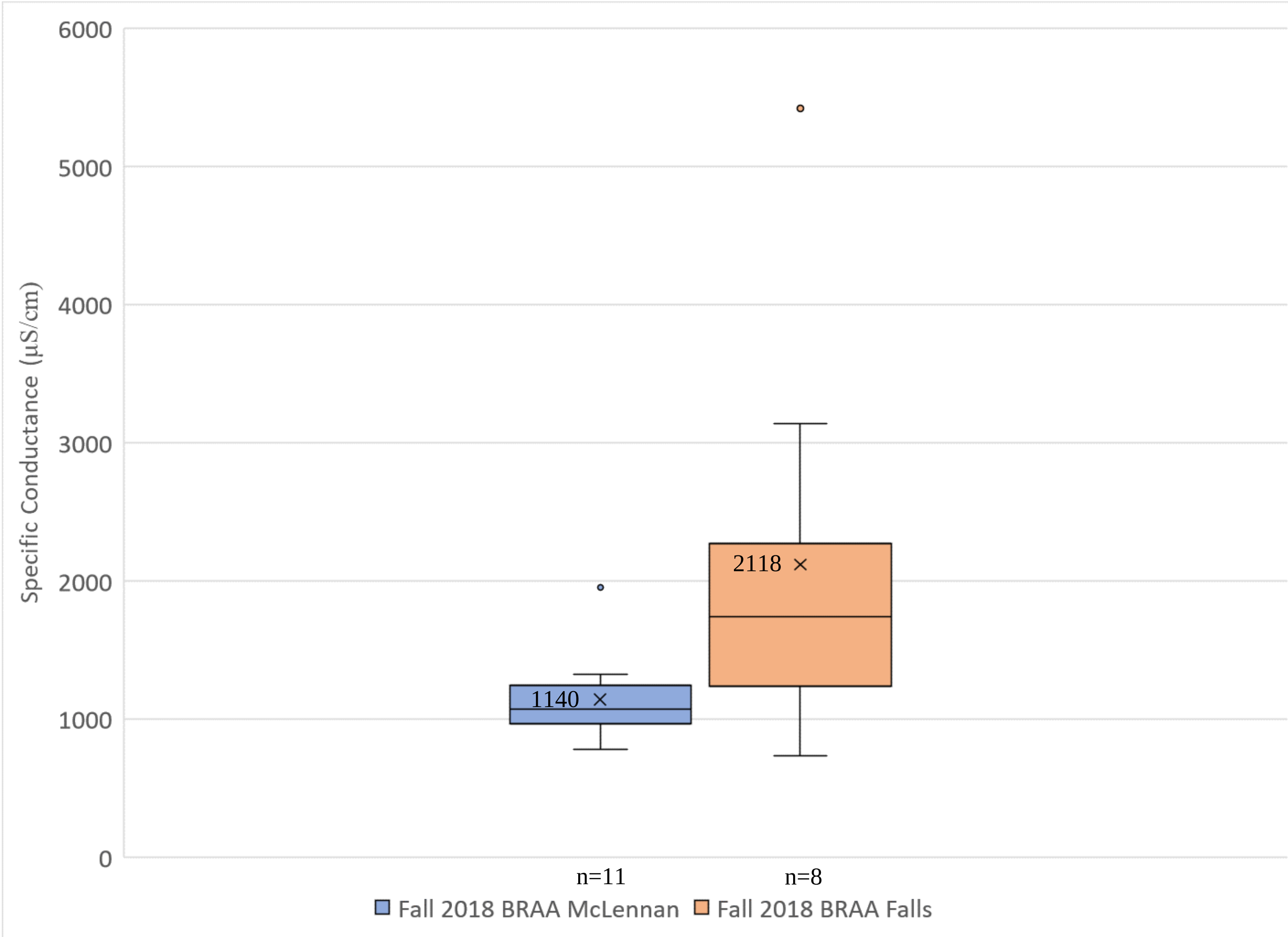

Figure 3.2. Box plot of the specific conductance of the Brazos River Alluvium Aquifer in the fall of 2018.

TCEQ spanned from 1972-2017. All data sets can be found in appendix D. The box plot of historic aquifer and river specific conductance data in figure 3.3. again shows that the average specific conductance of the aquifer in Falls County is significantly greater than that of McLennan County, and that the average specific conductance of the river is significantly less than the aquifer in Falls County, but is slightly greater than the aquifer in McLennan County. The average specific conductance values of the aquifer and river from the historical data sets were similar to those obtained in this study. However, the river showed much more variability in specific conductance likely because the historic data contained measurements from all seasons and over the course of many years, capturing not only the variability of the specific conductance of the river due to seasonality, but also the variability of specific conductance due to dilution from runoff during floods. Data from the TCEQ were obtained from multiple river monitoring stations in the study area and also confirmed that the specific conductance of the Brazos River decreases downstream.

Using a Mann Whitney U-test, it was also found that for the TWDB historical data set, at 5% significance level the specific conductance of the aquifer in McLennan County is less than the specific conductance of the aquifer in Falls County. The use of a Mann Whitney U-test also confirmed that at the 5% significance level the specific conductance of the aquifer in both McLennan and Falls County has changed little since the 1960's (Frank, K., written communication, 2019).

Spatial Variability of Salinity in the Brazos River Alluvium Aquifer

The spatial variability of salinity in the aquifer was analyzed by creating maps of the total dissolved solids (TDS) using each of the three aforementioned data sets. All

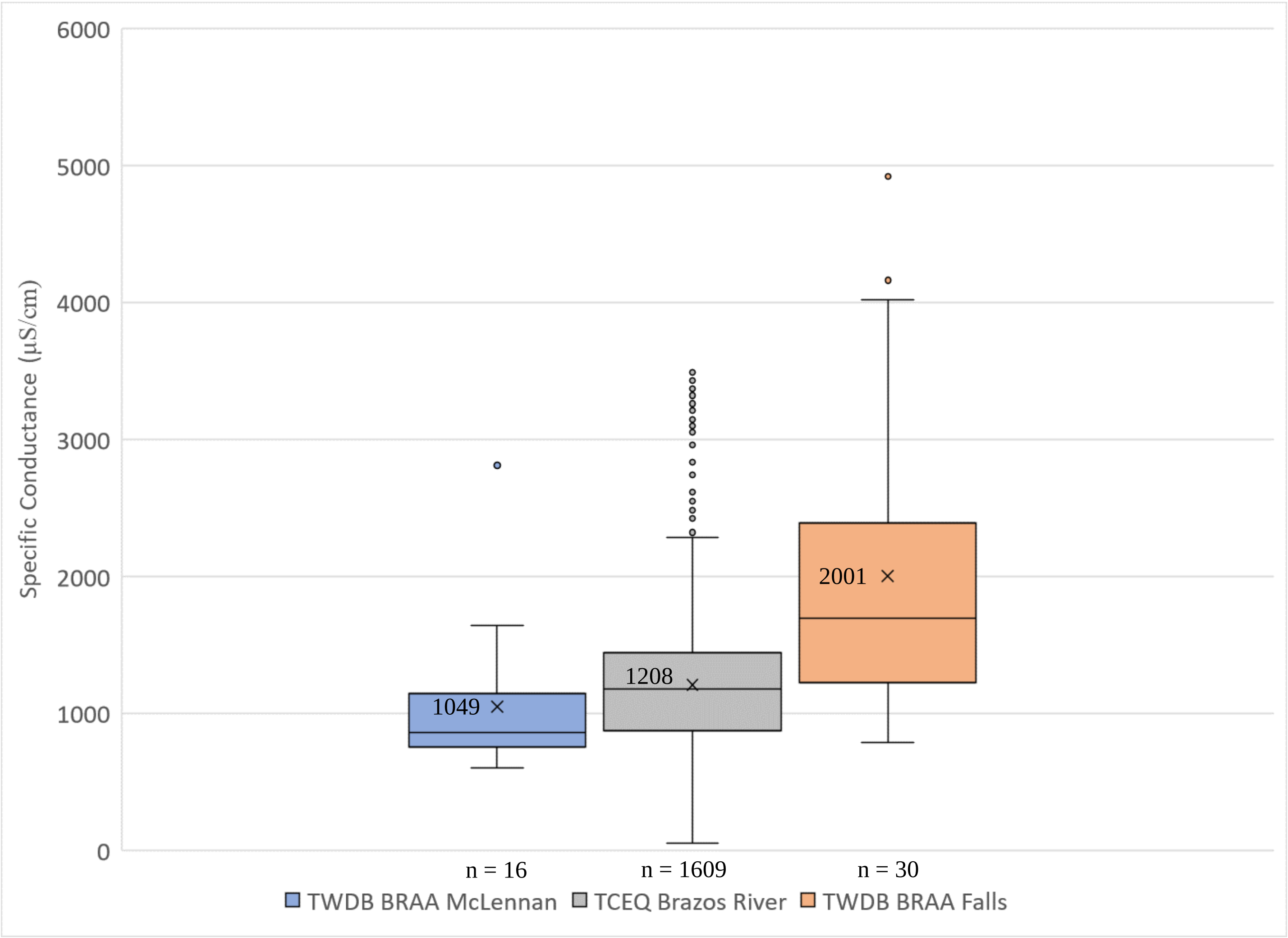

Figure 3.3. Box plot of the specific conductance of the Brazos River Alluvium Aquifer and Brazos River, based on historic data from the TWDB and TCEQ, respectively.

measurements were made in terms of specific conductance and then converted to TDS using the standard conversion of 0.65 for comparison to the drinking water standards and the general classification for natural waters. Hem (1985) states that conversion factors for converting specific conductance to TDS typically fall in the range of 0.55 to 0.75. All samples were grouped into four categories based on TDS including, less than 500 mg/L which meets the EPA's secondary drinking water standard for TDS, 500-1,000 mg/L which is considered fresh, 1,000-3,000 mg/L which is considered slightly saline, and 3,000-10,000 mg/L which is considered moderately saline by the TWDB (George and others 2011).

All three TDS maps of the Brazos River Alluvium Aquifer showed significant variability in salinity, as TDS ranged from less than 500 mg/L to greater than 3,000 mg/L (Figures 3.4 through 3.6). In addition, the salinity of the aquifer varied rapidly over short distances as TDS was found to double over the course of a few hundred yards at multiple locations. The higher salinity of Falls County is well documented by all three TDS maps. Water-rock interaction no doubt accounts for a significant portion of the salinity observed in the aquifer and likely accounts for some of the variability of salinity, due to variability in sediment type and residence time. However, given the large variability of salinity (<500 to >3,000 mg/L) and the fact that Falls County has a specific conductance almost double that of McLennan County (and no significant known changes in aquifer composition occur), water-rock interaction is not likely the cause of elevated salinity levels exhibited in Falls County.

The maps also show that TDS does not appear to increase towards the Brazos River, nor were the highest values solely located within a close proximity to the river. In

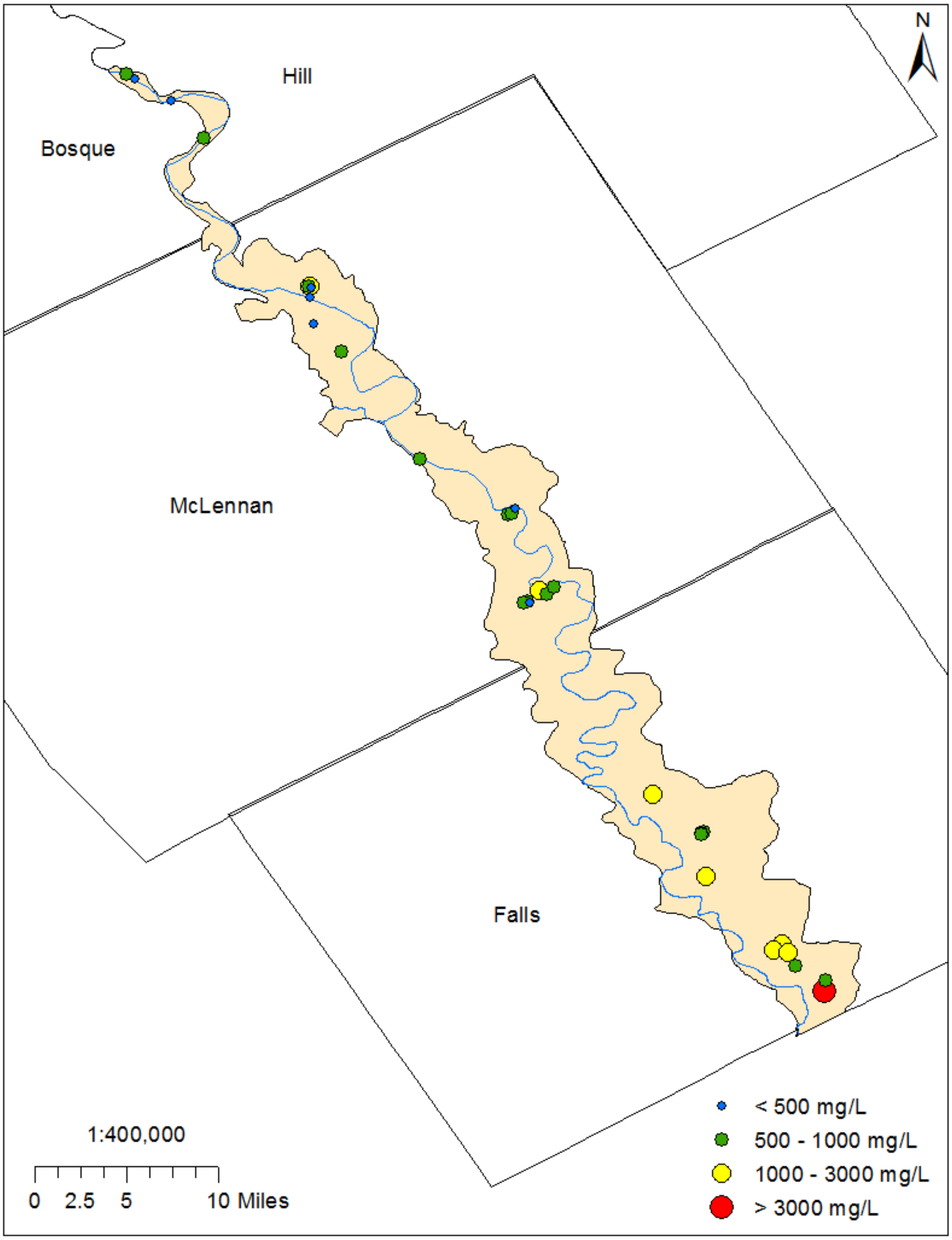

Figure 3.4. Map of the TDS of the Brazos River Alluvium Aquifer from samples collected in the spring/summer of 2018.

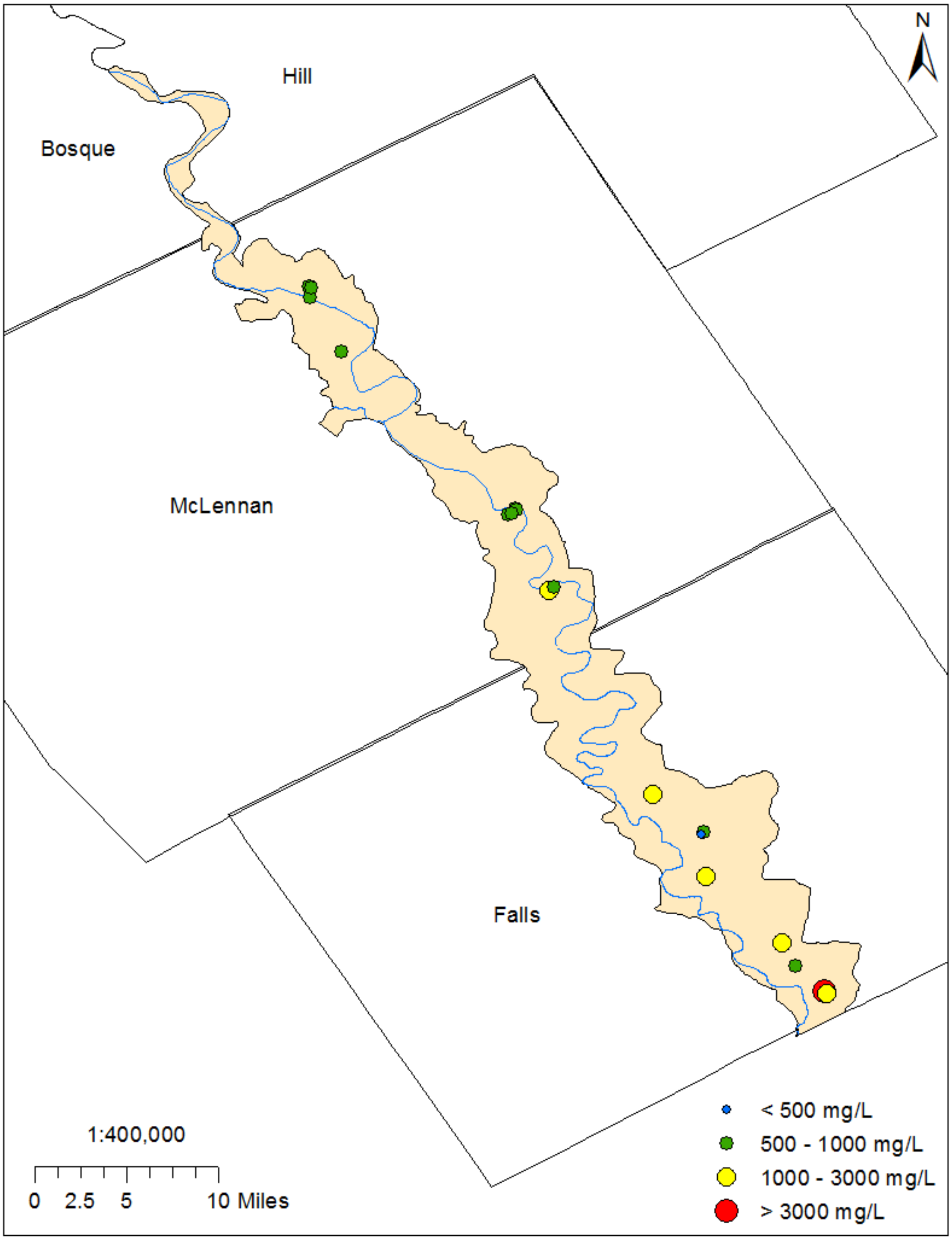

Figure 3.5. Map of the TDS of the Brazos River Alluvium Aquifer from samples collected in the fall of 2018.

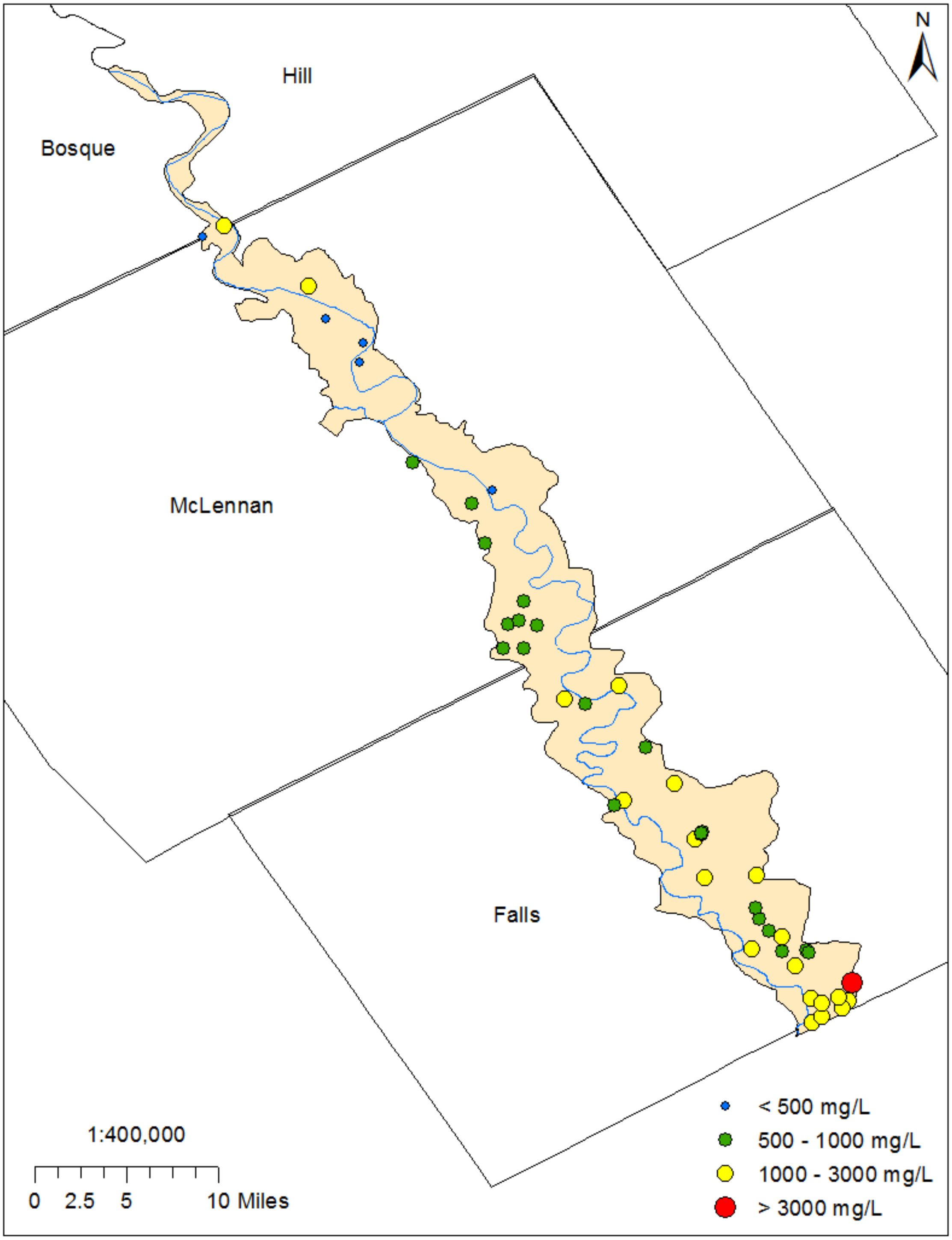

Figure 3.6. Map of the TDS of the Brazos River Alluvium Aquifer based on data from the TWDB.

addition, high TDS samples were found throughout Falls County, even on the opposite side of the river from the Deer Creek and Post Oak oil fields. Jarvis (2019) suggests that the river acts as a hydraulic boundary which would prevent brine contamination from the Deer Creek and Post Oak oil fields from reaching the northeast side of the river. Jarvis (2019) also introduced the idea that the aquifer is divided into compartments due to bedrock and river boundaries and that each compartment has a discrete flow system. Thus, water quality in one compartment would not affect the other compartments, and since flow in the aquifer is typically perpendicular to the Brazos River, contamination at any particular location will only affect the portion of the aquifer in between the contaminated site and the Brazos River (although some dispersion is possible). Specific conductance measurements from the TWDB groundwater database collected on the southwest side of the Brazos River in Falls County (near the oil fields) do not appear to show abnormally high TDS values, suggesting brine contamination from historic oil and gas fields is not the widespread cause of elevated salinity levels in Falls County. However, local contamination from the historic oil and gas fields is possible.

Table 3.1. shows that for the spring/summer of 2018 data set, 75% of the samples collected exceeded the EPA's secondary drinking water standard for TDS, while 95% and 89% of the samples in the fall of 2018 and TWDB data sets exceeded the secondary drinking water standard for TDS, respectively. The table also shows that most of the samples collected from the aquifer fall in the range of 500-3000 mg/L (fresh to slightly saline), while only a few samples have a TDS greater than 3000 mg/L (considered moderately saline). Cronin and Wilson (1967) also found similar results as 80% of the samples they collected exceeded the EPA's secondary drinking water standard for TDS.

Table 3.1. Table showing the percent of samples in each TDS category for the spring/summer of 2018, fall of 2018, and TWDB data sets.

TDS	Spring/Summer 2018 (n=32)	Fall 2018 (n=19)	TWDB (n=46)
< 500 mg/L	25%	5%	11%
500 – 1000 mg/L	50%	63%	46%
1000 – 3000 mg/L	22%	26%	41%
3000 – 10000 mg/L	3%	5%	2%

Ionic Chemsitry of the Brazos River Alluvium Aquifer and Brazos River

Descriptive statistics for the specific conductance and ion concentrations of the spring/summer 2018, fall of 2018, and TWDB aquifer data sets show that in general good agreement can be found between the ranges and averages among the three data sets for each individual county. Comparison of the descriptive statistics of the aquifer for McLennan and Falls County in tables 3.2 and 3.3 highlight the difference in aquifer chemistry between the two counties. The complete data sets can be found in appendices B and C.

Figures 3.7. through 3.14. show box plots of ion concentrations for McLennan and Falls County in the fall of 2018. Box plots of ion concentrations for the TWDB data set showed similar trends. The box plots show that the mean concentrations of most ions appear higher in Falls County than McLennan County, including sodium, magnesium, bicarbonate, and chloride. However, the mean concentrations of potassium, calcium, and sulfate are similar for the two counties and there is not likely a statistically significant difference between the two counties. Last, the mean concertation of nitrate in McLennan County is significantly higher than in Falls County.

Nitrate is of particular interest as it was the one ion found in greater average concentration in McLennan County than in Falls County. The fall of 2018 data sets show

Table 3.2. Minimum, maximum, and average specific conductance and ion concentrations for the Brazos River Alluvium Aquifer in McLennan County from the spring/summer of 2018, fall of 2018, and TWDB data sets.

Parameter	Spring/Summer 2018 McLennan County (n=17)			Fall 2018 McLennan County (n=11)			TWDB McLennan County (n=9)		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Specific Conductance (μS/cm)	390	1640	986	779	1954	1140	763	1640	1032
Sodium (mg/L)	N/A	N/A	N/A	24.6	134.0	60.1	17.0	116.0	58.1
Potassium (mg/L)	N/A	N/A	N/A	1.26	3.40	2.30	0.90	3.90	2.19
Magnesium (mg/L)	N/A	N/A	N/A	11.5	67.7	26.2	4.5	40.6	17.9
Calcium (mg/L)	N/A	N/A	N/A	91.2	198.0	144.3	113.0	247.0	143.9
Bicarbonate (mg/L)	212	613	368	203	574	393	318	438	374
Chloride (mg/L)	N/A	N/A	N/A	7.43	170.0	73.3	26.0	107.0	62.2
Sulfate (mg/L)	N/A	N/A	N/A	20.9	258.0	104.2	27.0	151.0	85.5
Nitrate as N (mg/L)	N/A	N/A	N/A	0.00	11.4	5.20	N/A	N/A	N/A

Table 3.3. Minimum, maximum, and average specific conductance and ion concentrations for the Brazos River Alluvium Aquifer in Falls County from the spring/summer of 2018, fall of 2018, and TWDB data sets.

Parameter	Spring/Summer 2018 Falls County (n=11)			Fall 2018 Falls County (n=8)			TWDB Falls County (n=14)		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Specific Conductance (μS/cm)	858	5402	1819	737	5419	2118	814	4020	2013
Sodium (mg/L)	N/A	N/A	N/A	37.2	510.0	205.5	52.5	380.00	194.1
Potassium (mg/L)	N/A	N/A	N/A	1.20	5.90	2.90	0.94	4.70	2.99
Magnesium (mg/L)	N/A	N/A	N/A	25.0	135.0	54.9	33.1	159.0	64.9
Calcium (mg/L)	N/A	N/A	N/A	50.3	416.0	165.4	56.0	320.0	165.2
Bicarbonate (mg/L)	426	913	637	434	713	612	295	878	561
Chloride (mg/L)	N/A	N/A	N/A	3.60	1192.0	289.6	9.04	880.0	279.0
Sulfate (mg/L)	N/A	N/A	N/A	14.2	487.0	172.2	23.2	473.0	210.5
Nitrate as N (mg/L)	N/A	N/A	N/A	0.00	6.80	1.20	N/A	N/A	N/A

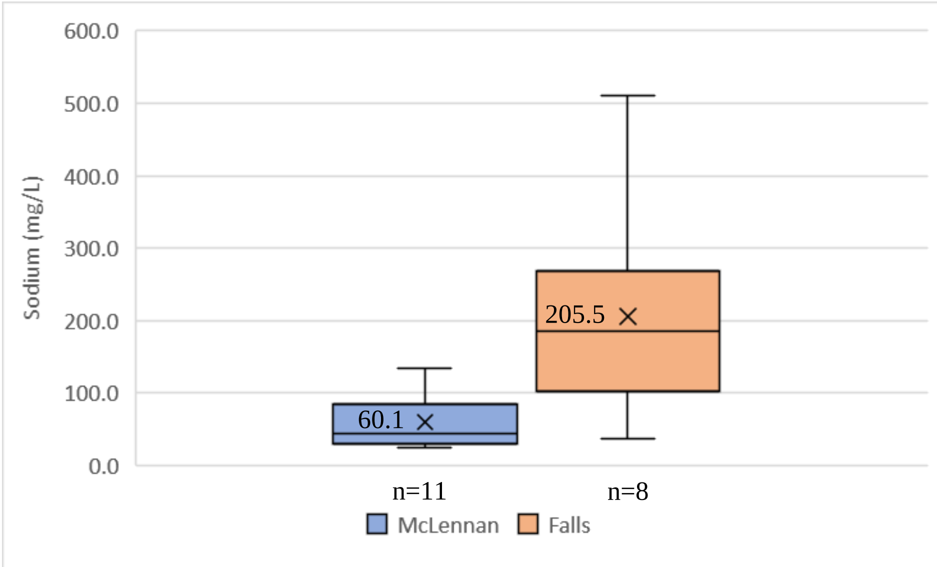

Figure 3.7. Box plot of sodium concentrations for fall 2018 aquifer samples from McLennan and Falls County.

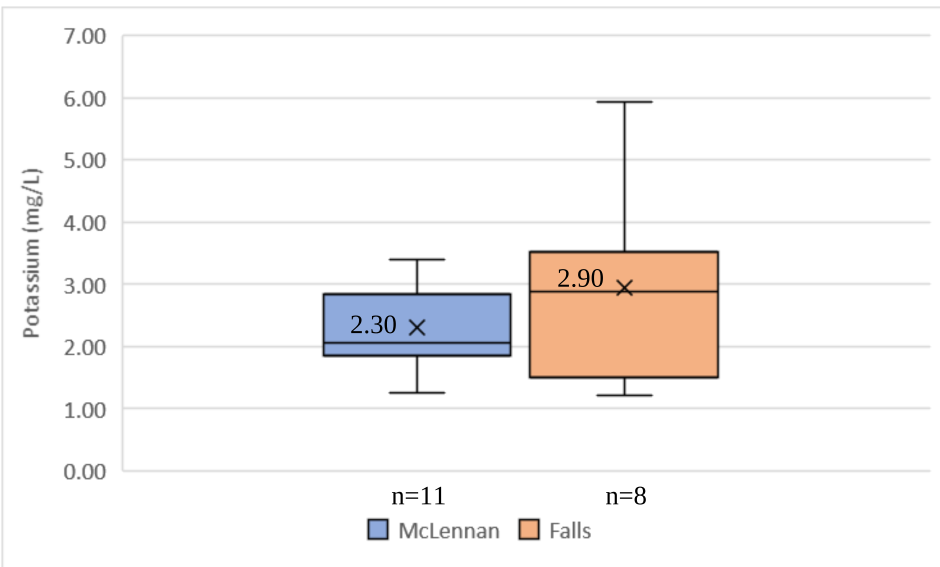

Figure 3.8 Box plot of potassium concentrations for fall 2018 aquifer samples from McLennan and Falls County.

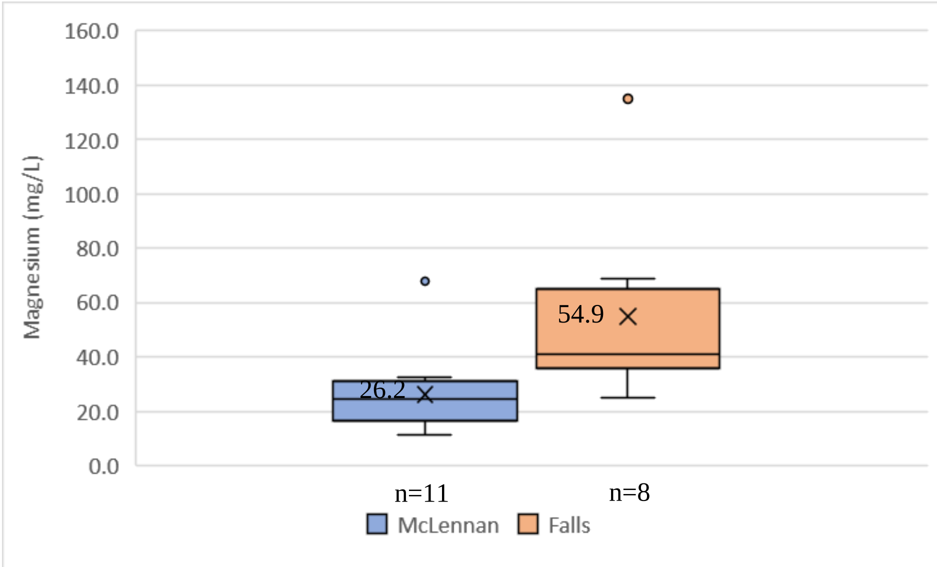

Figure 3.9. Box plot of magnesium concentrations for fall 2018 aquifer samples from McLennan and Falls County.

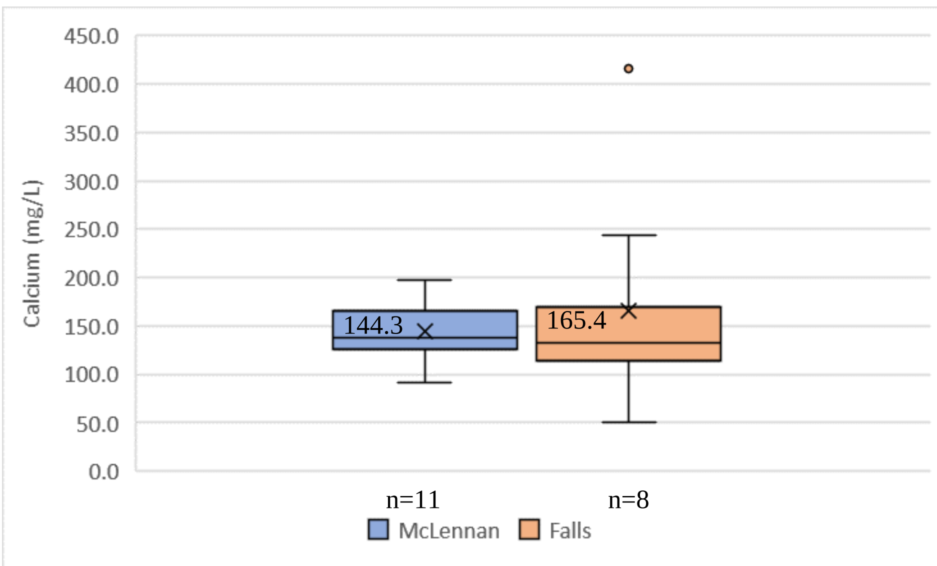

Figure 3.10 Box plot of calcium concentrations for fall 2018 aquifer samples from McLennan and Falls County.

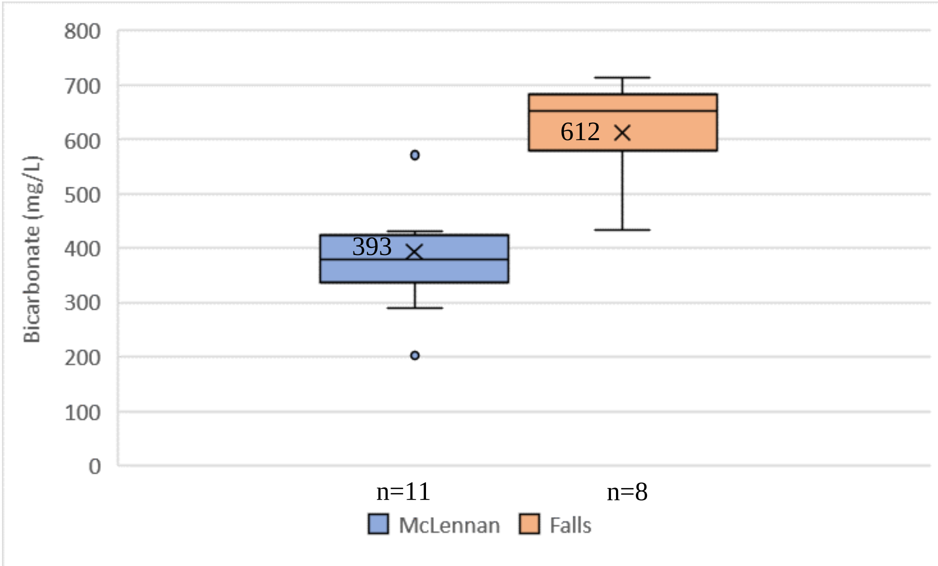

Figure 3.11. Box plot of bicarbonate concentrations for fall 2018 aquifer samples from McLennan and Falls County.

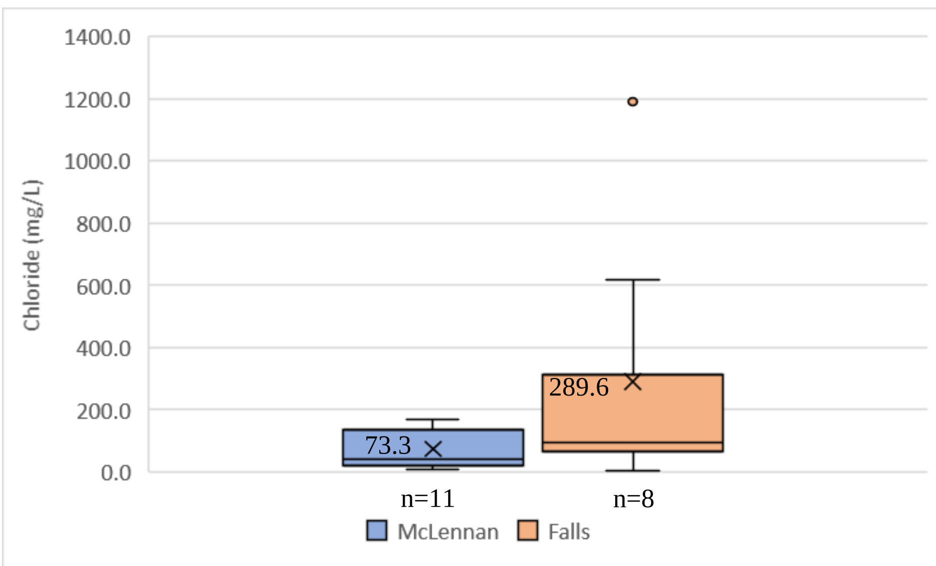

Figure 3.12. Box plot of chloride concentrations for fall 2018 aquifer samples from McLennan and Falls County.

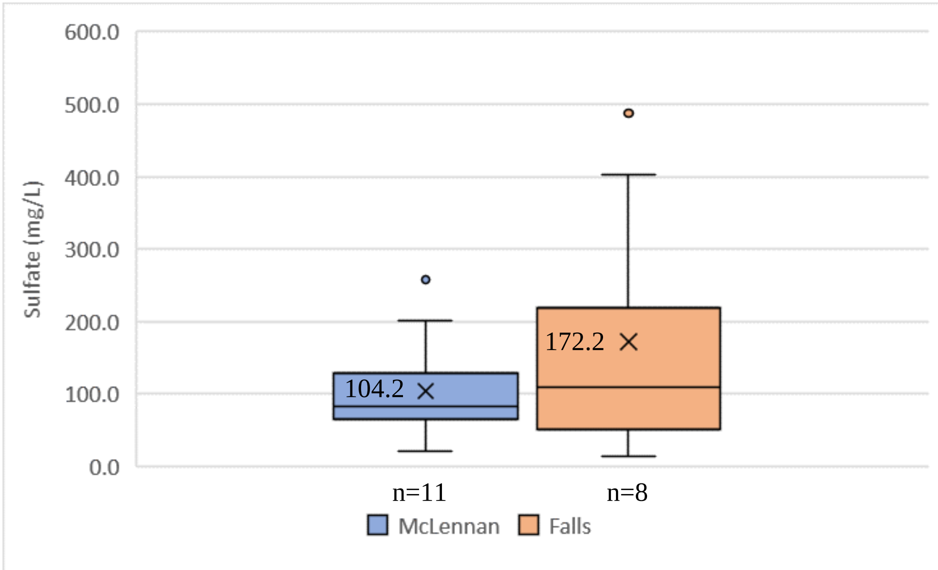

Figure 3.13. Box plot of sulfate concentrations for fall 2018 aquifer samples from McLennan and Falls County.

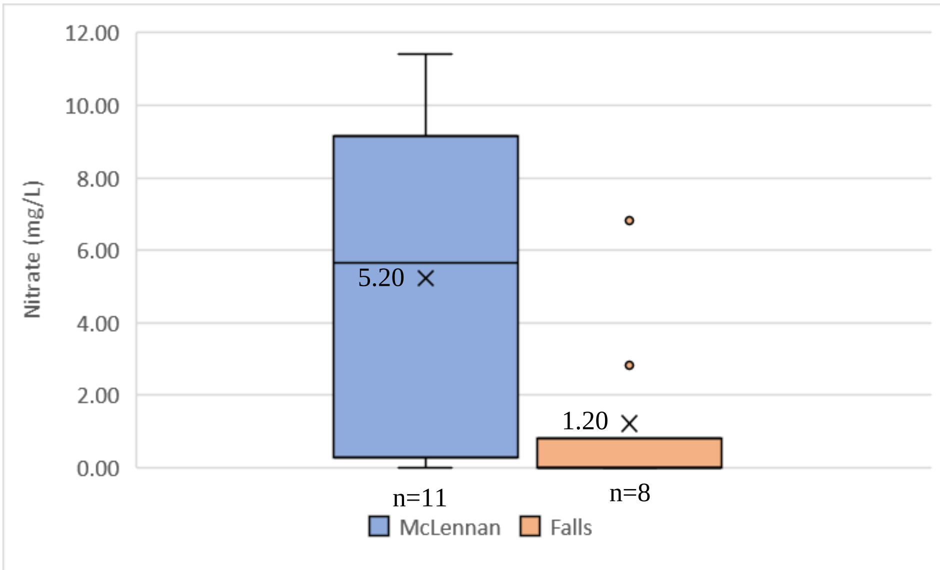

Figure 3.14. Box plot of nitrate concentrations for fall 2018 aquifer samples from McLennan and Falls County.

minimum nitrate concentrations of 0.00 mg/L were found in both counties; however, the maximum nitrate concentration found in McLennan County was 11.4 mg/L, almost double the maximum nitrate concentration of 6.80 mg/L found in Falls County. Three of the samples in McLennan County from the fall of 2018 exceeded the EPA's primary drinking water standard for nitrate (as nitrogen) of 10 mg/L (United States Environmental Protection Agency 2018). Elevated nitrate levels in drinking water can cause adverse health effects including blue-baby syndrome. Two of the samples exceeding the primary drinking water standard for nitrate were from an orchard with sandy soils and one was from a residential well. Other locations in McLennan County that had elevated nitrate concentrations were known to have been used as a dairy and feed lot, while samples collected from row crop farms in Falls County showed almost no nitrate. McLennan County likely has higher nitrate concentrations than Falls County, as McLennan County has a much higher population, and thus is subject to more anthropogenic influences.

Piper diagrams were used to illustrate the hydrochemical facies of aquifer samples from the fall of 2018 and for historical aquifer samples from the TWDB and river samples from the TCEQ. The piper diagram showing fall of 2018 Brazos River Alluvium Aquifer samples from McLennan and Falls County in figure 3.15 also displays the difference in water chemistry between the two counties. The diagram shows that of the 11 samples from the aquifer in McLennan County, 64% were calcium bicarbonate type water, while in Falls County 50% of the eight samples were mixed bicarbonate type water. In addition, the anion plot shows that in general, as specific conductance increases so does the proportion of chloride. This is also supported by the fact that the two samples in Falls County with the highest specific conductance values had mixed-chloride type waters.

Similar hydrochemical facies in McLennan and Falls County were found using the historical chemsitry data of the Brazos River Alluvium Aquifer from the TWDB. The historical piper diagram in figure 3.16. shows that of the nine aquifer samples from McLennan County, 78% were calcium bicarbonate type water. The chemistry of the aquifer in Falls County was much more variable as of the 14 samples 36% were of mixed bicarbonate type water while 21% were of mixed cation and anion type water. The piper

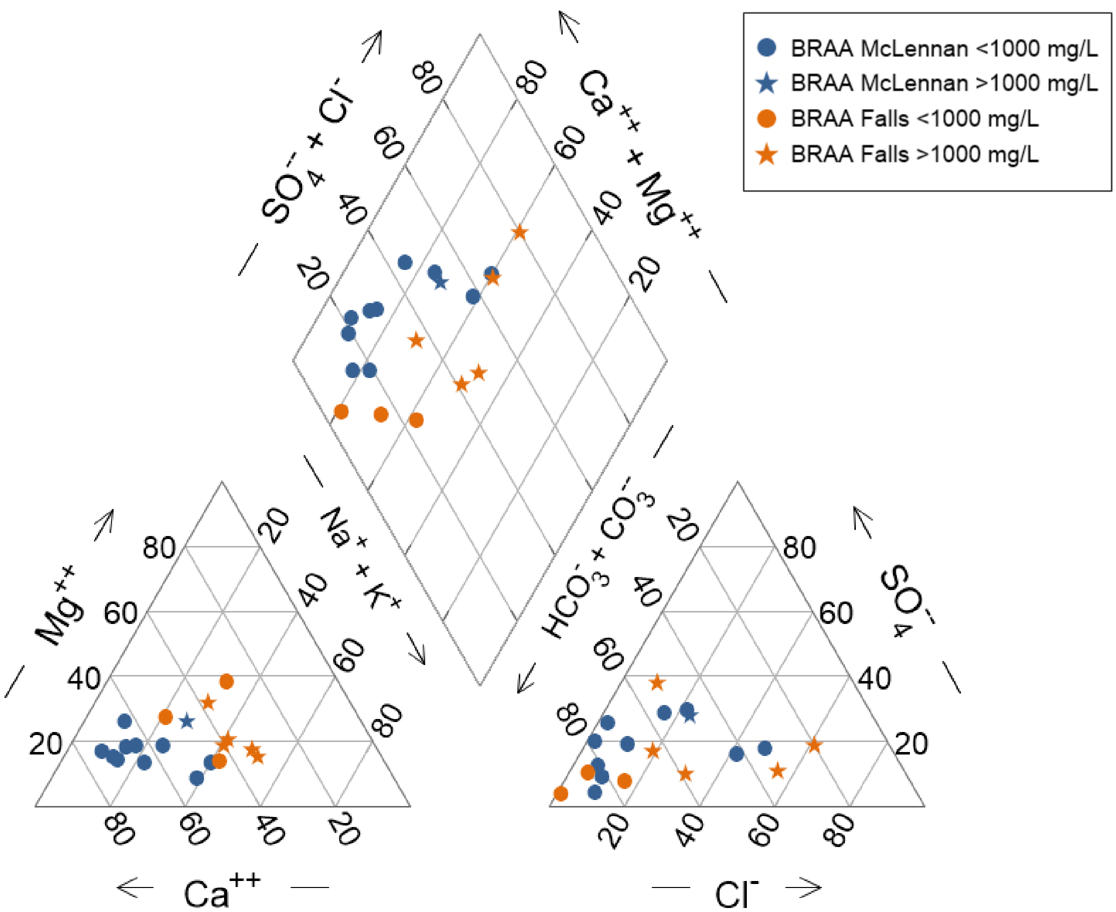

Figure 3.15. Piper diagram of Brazos River Alluvium Aquifer samples from the Fall of 2018.

diagram and differences in hydrochemical facies show the difference in water chemistry between the aquifer in McLennan and Falls County, and as the specific conductance of the aquifer increases so does the proportion of chloride.

The piper diagram in figure 3.16 also shows that of the 10 samples from the Brazos River, 50% were sodium chloride type water. Two of the river samples were collected just below Whitney Dam and eight were collected in Falls County. The river samples in Falls County tended to have much more variable hydrochemical facies.

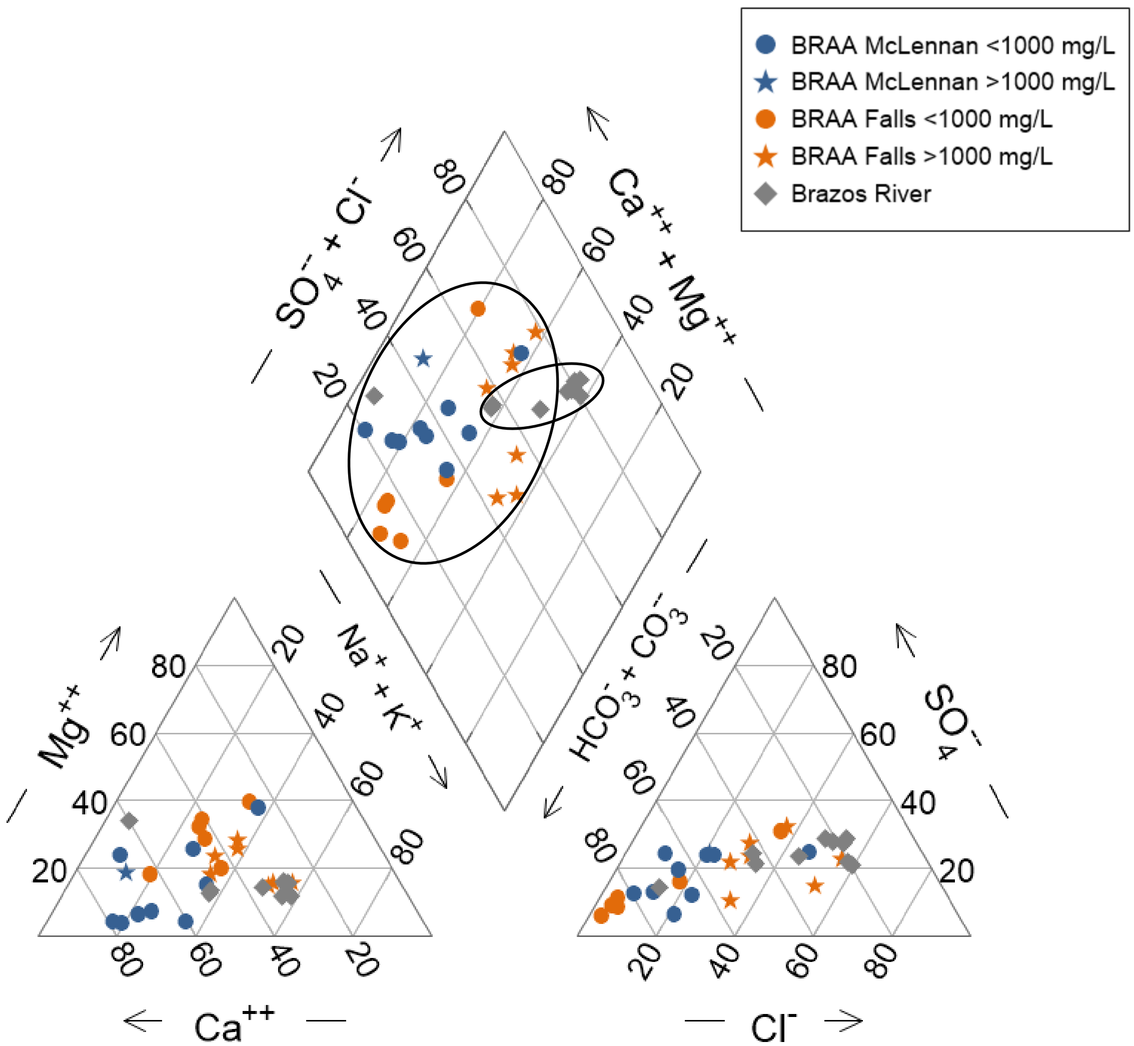

Figure 3.16. Piper diagram of Brazos River Alluvium Aquifer and Brazos River samples from the TWDB and TCEQ, respectively.

Cronin and Wilson (1967) found that below the Whitney Dam, the Brazos River consisted of sodium chloride type water, although downstream near Bryan and Richmond it consisted of mixed cation and anion type water. The one river sample containing extremely low sodium and chloride concentrations had a specific conductance of 340 μS/cm and is likely an outlier that was collected during high flow conditions when runoff would have diluted the river. Overall, figure 3.16. shows that while there is some overlap between the chemistries of the Brazos River Alluvium Aquifer and Brazos River, in general they tend to have different ionic chemistries.

Identification of Salinity Sources

The literature suggests numerous methods of identifying sources salinity in groundwater that have yielded varying degrees of success. Trabelsi and others (2012) and Ahmed and others (2013) suggest that strong correlations between chloride and other ions in solution indicate that the ions came from the same source of salinity as the chloride. Figures 3.17. through 3.22. show bivariate plots of all ions versus chloride for fall 2018 aquifer samples from McLennan and Falls County. The graphs show that for Falls County, there is a strong correlation between chloride and sodium, potassium, magnesium, and calcium; however, there was no correlation between chloride and bicarbonate and only a weak correlation between chloride and sulfate. Although, in McLennan County, there was only a strong correlation between chloride and sodium. The strong correlations between chloride and sodium, potassium, magnesium, and calcium for samples from Falls County, suggest they are coming from the same source of

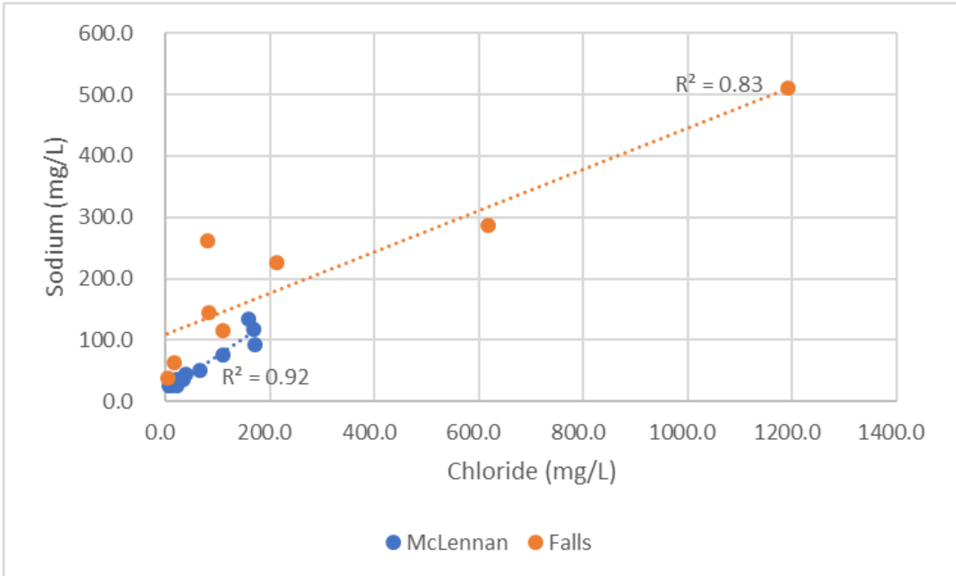

Figure 3.17. Bivariate plot of sodium and chloride for fall 2018 aquifer samples from McLennan and Falls County.

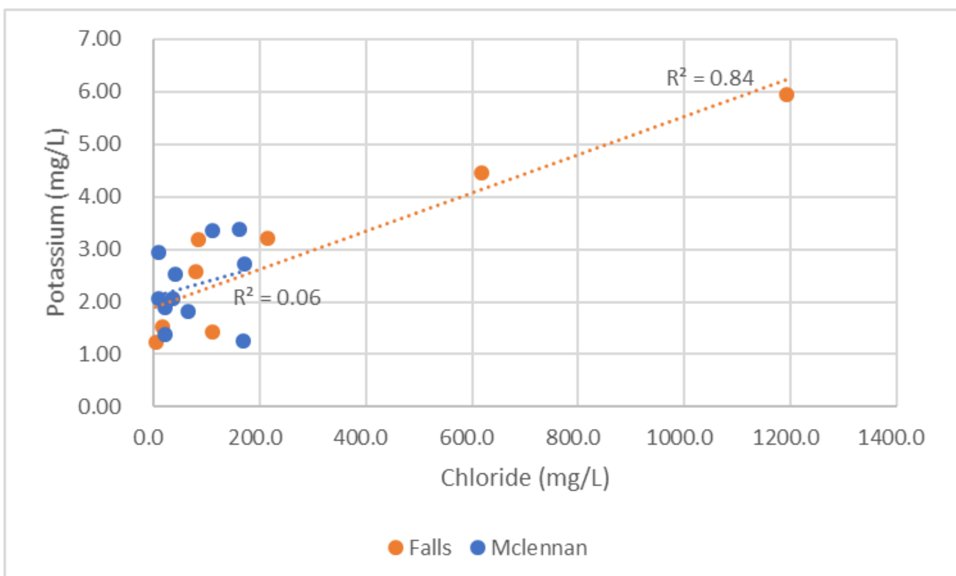

Figure 3.18. Bivariate plot of potassium and chloride for fall 2018 aquifer samples from McLennan and Falls County.

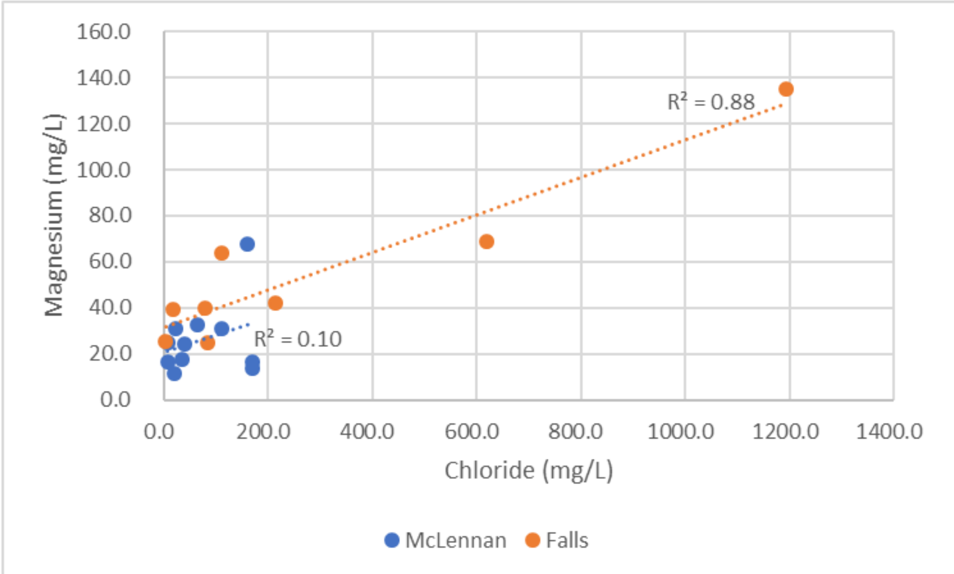

Figure 3.19. Bivariate plot of magnesium and chloride for fall 2018 aquifer samples from McLennan and Falls County.

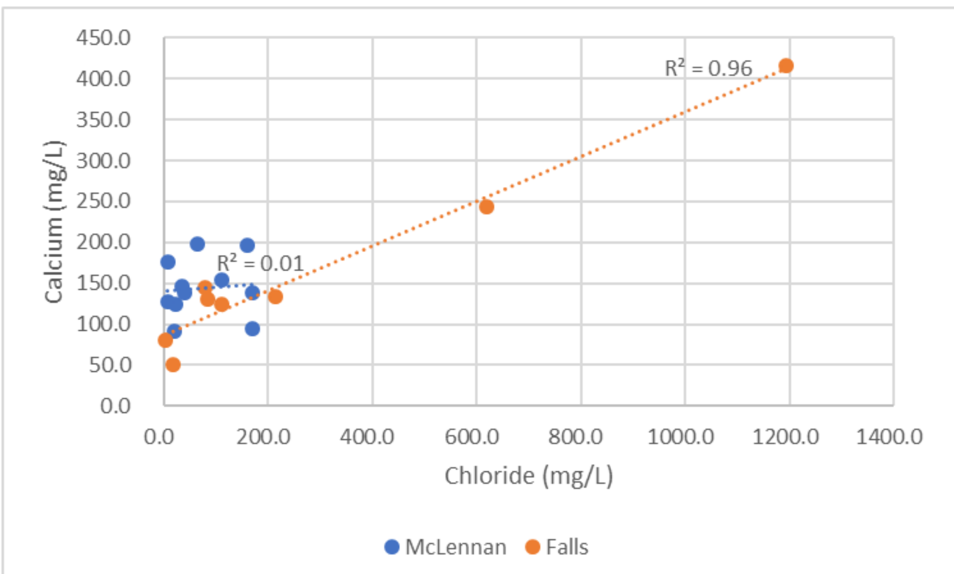

Figure 3.20. Bivariate plot of calcium and chloride for fall 2018 aquifer samples from McLennan and Falls County.

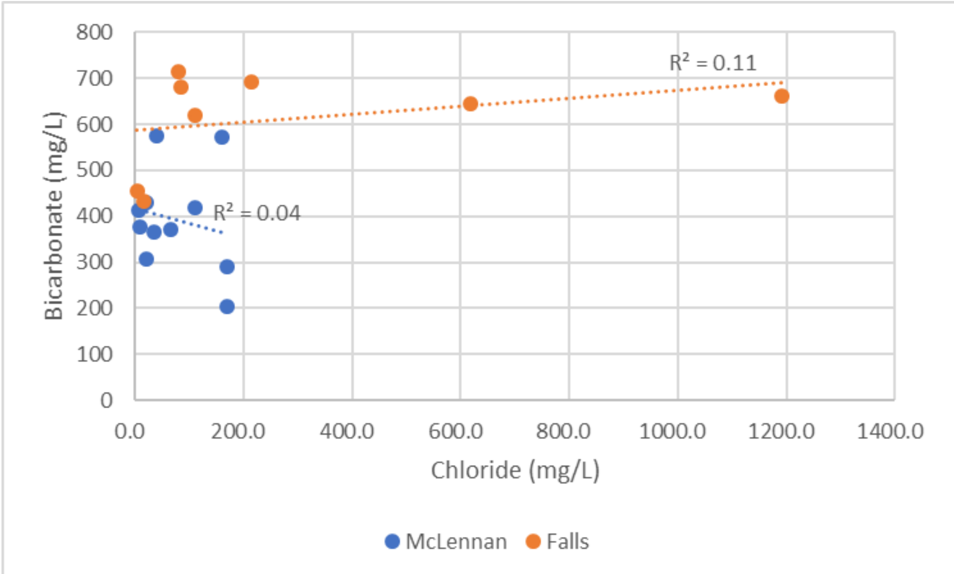

Figure 3.21. Bivariate plot of bicarbonate and chloride for fall 2018 aquifer samples from McLennan and Falls County.

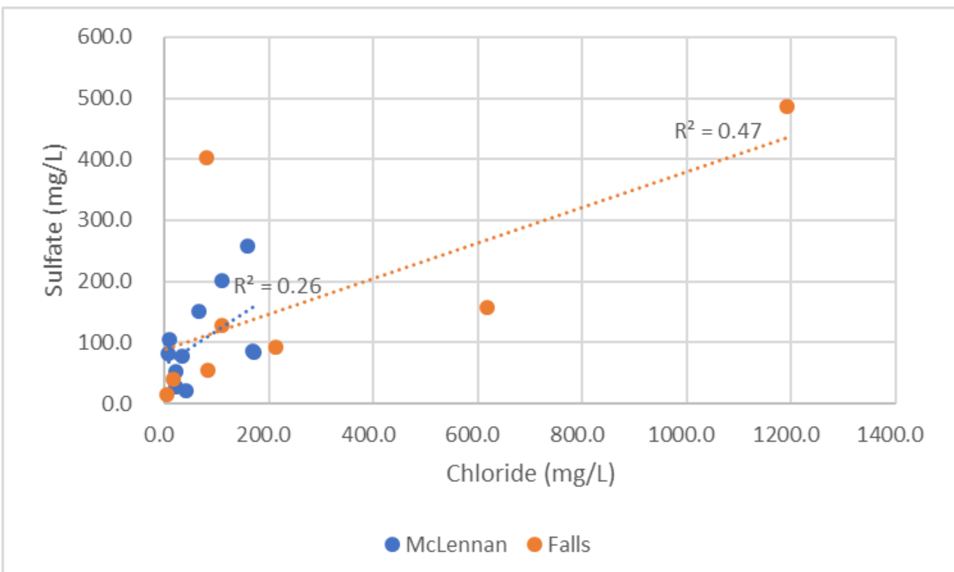

Figure 3.22. Bivariate plot of sulfate and chloride for fall 2018 aquifer samples from McLennan and Falls County.

salinity as the chloride. Since the correlation was exhibited for all samples from Falls County this suggests a single source of salinity. However, the poor correlation between chloride and the potassium, magnesium, calcium, bicarbonate, and sulfate in McLennan County, suggest that the salinity could be derived from a variety of sources.

Chowdhury and others (2018) used sodium to chloride ratios to help determine the source of salinity in the Gulf Coast Aquifer System in Texas. Their review of sodium to chloride ratios in the literature found that oilfield brine typically has a sodium to chloride ratio <0.5, halite dissolution has a ratio of 0.64, seawater has a ratio of 0.85, and freshwater typically has a ratio of 0.7-1.0. The TCEQ samples from the Brazos River had an average sodium to chloride ratio of 0.62. This corresponds with halite dissolution which is supported by the fact that the Salt Fork of the Brazos River has tributaries fed by discharge from salt springs and seeps and the Brazos River is known to have sodium chloride type water. Aquifer samples from the fall of 2018 exhibited a wide range of sodium to chloride ratios from 0.43 to 10.42, although 73% of the samples had a ratio greater than 0.7. The majority of these samples fell close to the freshwater range of 0.7-1.0; however, five samples exhibited high sodium to chloride ratios indicating significant enrichment of sodium in comparison to chloride. This enrichment of sodium in the groundwater could be the result of cation exchange with clay lenses in the aquifer, where the sodium in the clays is replaced by calcium or magnesium from the groundwater, releasing sodium into the groundwater. However, samples RP1, HDT, and GM4 had sodium chloride ratios near that of halite dissolution.

The graph of sodium versus chloride for fall of 2018 aquifer samples and TCEQ river samples in figure 3.23. shows that for the most part the aquifer and Brazos River

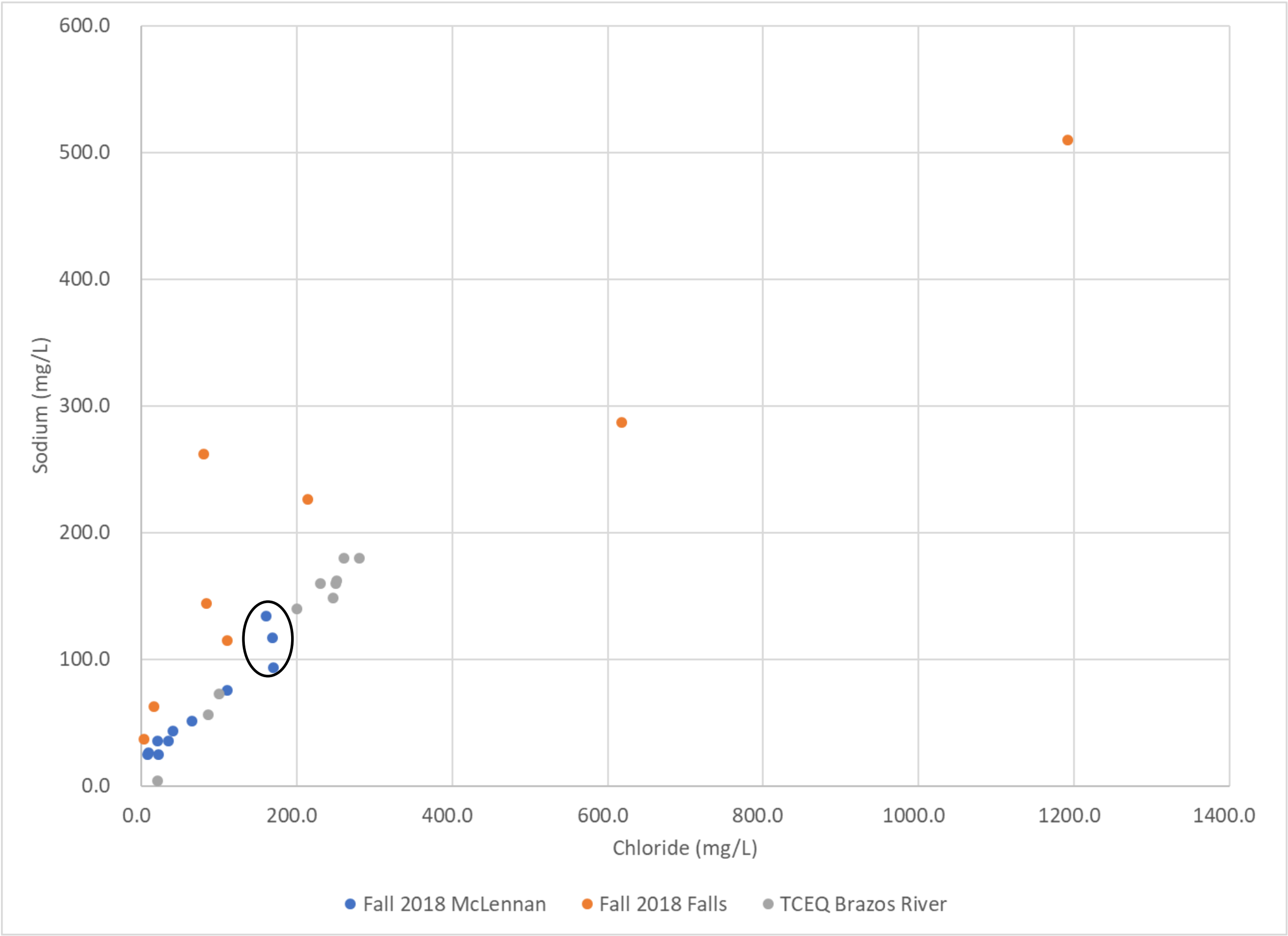

Figure 3.23. Bivariate plot of chloride and sodium for fall 2018 aquifer samples from McLennan and Falls County and Brazos River samples from the TCEQ.

have different sodium chloride ratios. In addition, the aquifer in McLennan and Falls County also appear to have different sodium chloride ratios. However, samples RP1, HDT, and GM4 (circled in figure 3.23) plot in between samples of the aquifer in McLennan County and that of the Brazos River, indicating mixing could have occurred.

Well HDT was located 0.14 miles from the Brazos River and showed a 448 μS/cm increase in specific conductance from the spring to the fall of 2018. The well also showed a significant decrease in bicarbonate concentration from 372 mg/L to 203 mg/L and significantly higher concentrations of sodium (93.3 mg/L) and chloride (170.0 mg/L) than the other wells on the property. During the fall of 2018 approximately 15 inches of precipitation were received and water level in this well rose almost 15 feet, while river stage rose almost 21 feet. The Brazos River is known to have sodium chloride type water and surface water generally has much lower bicarbonate concentrations than groundwater, thus it is possible that influence from the Brazos River caused the increase of specific conductance, decrease in bicarbonate concentration, and low sodium to chloride ratio seen in this well.

Well RP5 was located 0.05 miles from the Brazos River and showed a 400 μS/cm increase in specific conductance from the spring to the fall of 2018. This well also showed a decrease in bicarbonate concentration from 361 to 290 mg/L and significantly higher sodium (117.0 mg/L) and chloride (169.0 mg/L) concentrations than the other wells on the property. Similar to well HDT, the increase of specific conductance, decrease in bicarbonate concentration, and low sodium to chloride ratio could possibly be attributed to influence from the Brazos River. However, well GM4 is located a significant distance from the river and thus was not likely influenced by the river.

Samples AH6 and AH7 have sodium chloride ratios of 0.43 and 0.46 which would suggest oilfield brine; however, no known oilfields were located near the sampling location.

Analyses of the specific conductance and ionic chemistry of the northern segment of the Brazos River Alluvium Aquifer and Brazos River have shown the average specific conductance of the aquifer in Falls County is greater than that of the aquifer in McLennan County. The average specific conductance of the Brazos River is significantly less than the aquifer in Falls County but is slightly greater than the aquifer in McLennan County. In addition, the average specific conductance of the aquifer changed little due to seasonality and has changed little since the 1960's for each county. The Brazos River Alluvium Aquifer also shows significant variability of salinity in both the range of TDS values observed and in the change in TDS values over the course of short distances. The majority of samples exceeded the EPA's secondary drinking water standard for TDS and a few samples in McLennan County exceeded the EPA's primary drinking water standard for nitrate. The dominant hydrochemical facies of the aquifer in McLennan County was calcium bicarbonate type, while the dominant hydrochemical facies of the aquifer in Falls County was mixed bicarbonate type and mixed cation and anion type. Falls County also appeared to show different sodium chloride ratios than both the Brazos River and the aquifer in McLennan County. Analyses of the ionic chemistry of the aquifer and river suggest that they are relatively distinct from one another and that the salinity in Falls County is likely coming from a single source, while salinity in McLennan County is likely coming from a variety of sources. Overall, the large range in TDS values observed, the fact that Falls County has a specific conductance almost double that of

McLennan County, and the differences in hydrochemical facies and sodium chloride ratios between the two counties suggest that water-rock interactions are not the cause of elevated salinity levels exhibited in Falls County.

Land Use in the Northern Segment of the Brazos River Alluvium Aquifer

Different types of land use can have different impacts on the water quality of an aquifer. Land use often changes over time, although depending on the residence time of the aquifer and when changes in land use occurred, it is possible for the chemistry of certain areas of an aquifer to still reflect past land uses (Harding and others 1998, Foster and others 2003). The map in figure 3.24. shows the 2011 USGS land cover map for the northern segment of the Brazos River Alluvium Aquifer (United States Geological Survey 2018). The black dots on the land use map are the locations where water samples were collected during the spring/summer of 2018.

The map shows that land in Falls County is primarily used for cultivated crops, while land in McLennan County is primarily developed or used for pasture or hay. Land used for cultivated crops can be either irrigated or non-irrigated. However, the climate in the study area encourages irrigation as often not enough precipitation is received during the growing season to maximize production. Review papers by Wichelns and Manzoor (2015) and Pulido-Bosch and others (2018) demonstrated many cases world-wide, where irrigation has increased the salinity of soils, aquifers, and rivers. Evaporation and transpiration increase the salinity of irrigation return flow, causing a build up of salts in the soil, which can leach down through the soil profile and potentially into shallow aquifers with subsequent irrigation and or precipitation. In some cases, irrigation return flow has been shown to contribute significantly to shallow groundwater recharge. Goff

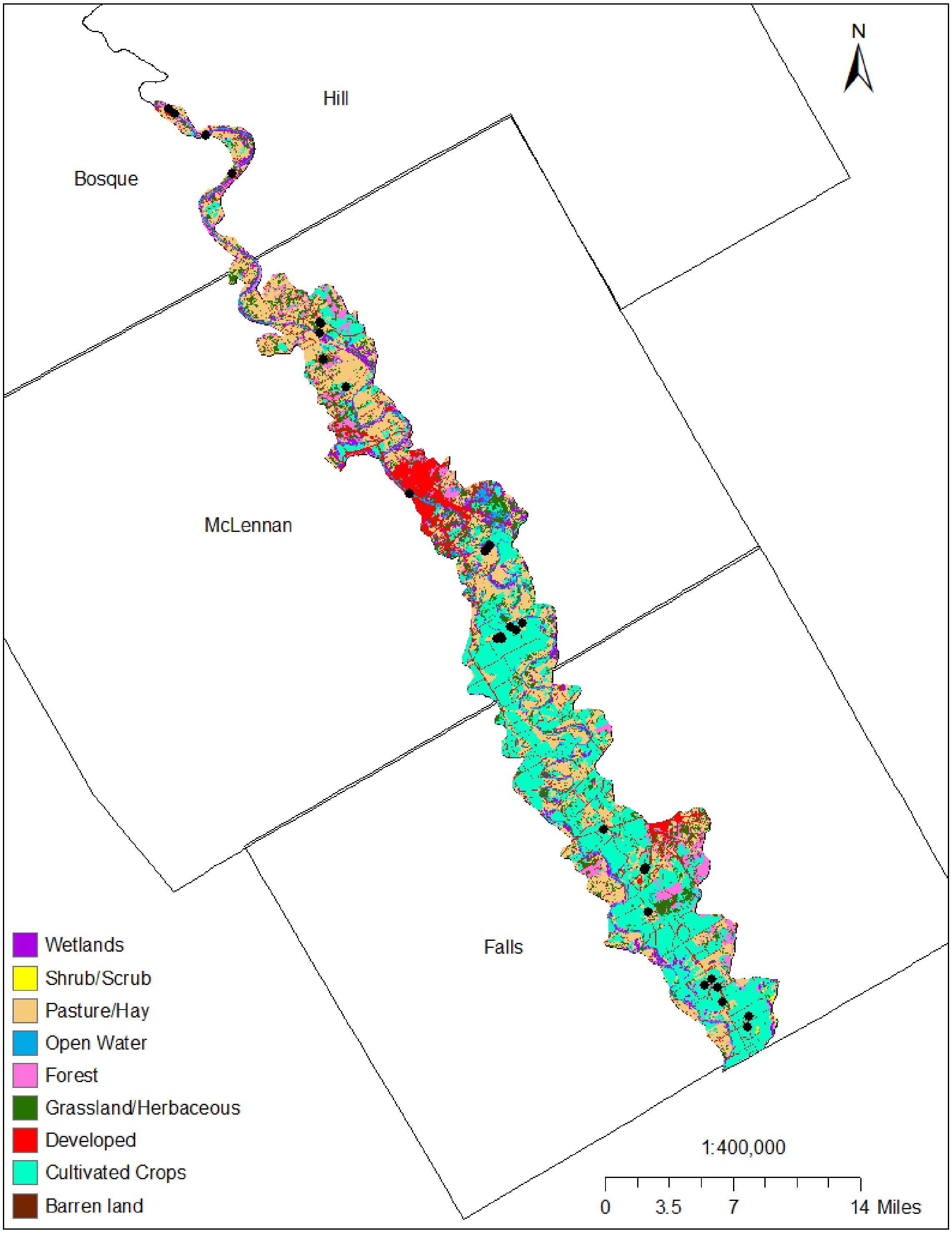

Figure 3.24. Land use map of the northern segment of the Brazos River Alluvium Aquifer.

and others (1998) documented increased salinity levels in an alluvial aquifer in the Arkansas River Basin in Colorado due to irrigation, through the use of a groundwater model. Cox and others (2018) also documented an increase of soil salinity due to flood irrigation along the Rio Grande in west Texas and calculated that 4 to 5 tons/acre of salt are added to the soil each year due to irrigation.

Irrigation from the Brazos River Alluvium Aquifer began in 1948 and expanded rapidly during the drought of the 1950's. By 1964 total estimated groundwater withdrawal from the Brazos River Alluvium Aquifer for irrigation was 49,000 acre feet and there were at least 1,112 wells in the alluvium. Estimated irrigated acres within the aquifer in 1964 was 72,000 acres and groundwater withdrawn for other uses was insignificant in comparison to irrigation. An estimated 24,000 acre-feet of surface water from the Brazos River were used to irrigate an estimated 23,000 acres in 1964, although Cronin and Wilson (1967) suggest that most of the surface water was not transported further than 1 mile from the river. Most of the irrigation occurred in the counties of Falls, Robertson, Brazos, and Burleson and in 1964, 85% of the groundwater used in Falls County was applied south of the town of Highbank (located in southern end of Falls County), (Cronin and Wilson, 1967).

Data on total surface water and groundwater irrigation over time in McLennan and Falls County were obtained from the Texas Water Development Board (2001). The data in figures 3.25. and 3.26. show that during the period from 1958 to 2000, the amount of water supplied for irrigation in Falls County was significantly greater than McLennan County. Irrigation in both counties appears to have decreased over time, but it should be kept in mind that the amount of water used for irrigation likely varies yearly, depending

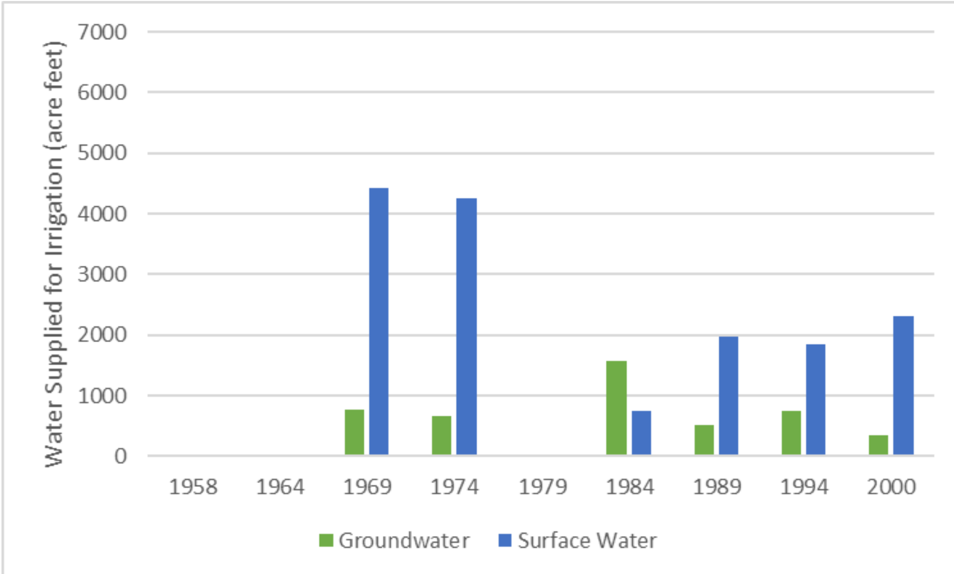

Figure 3.25. Groundwater and surface water supplied for irrigation in McLennan County over time.

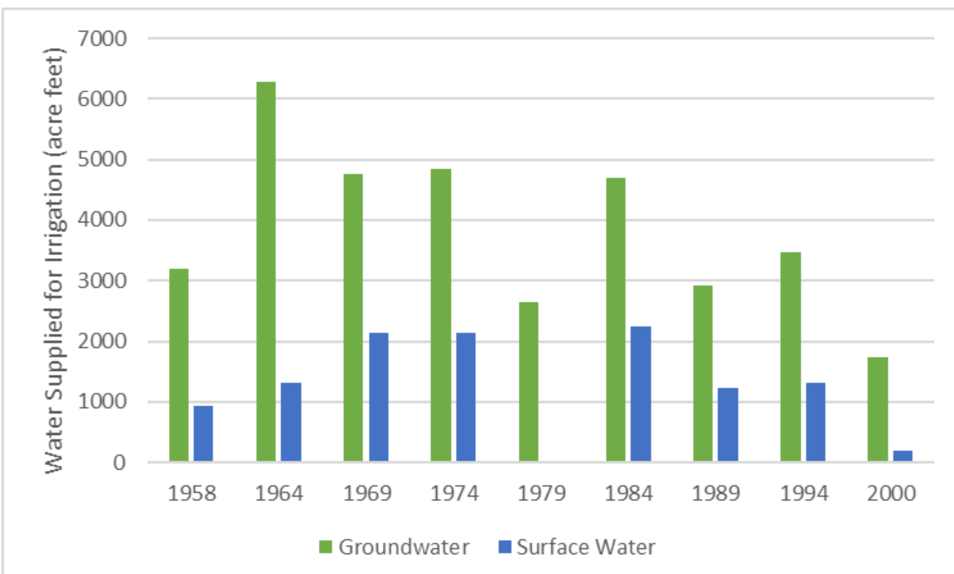

Figure 3.26. Groundwater and surface water supplied for irrigation in Falls County over time.

on how much precipation is received. In addition, irrigation in Falls County is primarly from groundwater although surface water still contributes a significant amount. In contrast, irrigation in McLennan County is primarly from surface water, with groundwater contributing a much smaller amount.

Isotopic Composition of the Brazos River Alluvium Aquifer and Brazos River

As water moves through the hydrologic cycle, it is often stored in various reservoirs such as lakes, rivers, aquifers, glaciers, the atmosphere, and oceans. Various chemical, physical, and biological processes operate in and upon these reservoirs causing fractionation, which can affect the isotopic composition of water resulting in isotopically distinct reservoirs. Hydrogen and oxygen isotopes (^{1}H, ^{2}H, ^{16}O, ^{18}O) are of particular importance as they can often be used to trace the movement of water between reservoirs. Since the Brazos River is a potential source of salinity for the Brazos River Alluvium Aquifer, hydrogen and oxygen isotopes were used to characterize both the aquifer and river in an attempt to determine the amount of interaction between the two reservoirs. Guo and others (2018) successfully demonstrated the ability to use stable isotopes to determine the degree of groundwater-surface water interaction in an alluvial aquifer in China.

Water samples from the Brazos River Alluvium Aquifer (including well and spring samples) were collected during the spring and summer of 2018 and water samples from the Brazos River were collected during the summer of 2018. Sampling locations are shown in figure 2.1. and all samples were collected during an extremely dry period during which little precipitation was received, and the river was in low flow conditions (base flow). Samples were analyzed for hydrogen and oxygen isotopic compositions using a gas source isotope ratio mass spectrometer at Baylor University Department of Geosciences' Stable Isotope Lab and are reported as per mil difference from VSMOW. Analysis of oxygen isotopes were both more accurate and precise, thus the isotopic composition of the Brazos River Alluvium Aquifer and Brazos River will be discussed in terms of their oxygen isotopic composition, although the same trends can be observed by examining the hydrogen isotopic composition. The isotopic composition of all samples can be found in appendix E.

Figure 3.27. shows a bivariate plot of the hydrogen and oxygen isotopic composition of samples collected from the Brazos River Alluvium Aquifer and Brazos River. The grey line represents the local meteoric water line (LMWL) which shows the variability in the isotopic composition of precipitation that can be seen throughout the year for Riesel, Texas. Riesel is located about 14 miles southeast of Waco, Texas. The LMWL was created using data on the hydrogen and oxygen isotopic compositions of precipitation collected at Riesel, Texas obtained from the International Atomic Energy Agency (IAEA) Global Network of Isotopes in Precipitation (GNIP) data set. The data were collected during the 1960s and 1970s and a strong positive correlation was observed when δD was plotted against $\delta^{18}O$. A trend line was fit to the data set with an equation of $\delta D = 6.51\delta^{18}O + 4.58$ and a regression coefficient of 0.91. The oxygen isotopic composition of precipitation ranges from -9.9‰ to 2.7‰ $\delta^{18}O$ VSMOW and the mean annual weighted oxygen isotopic composition is -4.03‰ $\delta^{18}O$ VSMOW (IAEA/WMO, 2017). The variability in isotopic composition of precipitation throughout the year is primarily due to changes in temperature, but the source of the water vapor, the distance it has traveled (interiority effect), and other factors also play a role in the variability.

Figure 3.27. and table 3.4. show that the oxygen isotopic composition of all water samples from the Brazos River Alluvium Aquifer range from -4.88 to 0.06 ‰ VSMOW, with an average of -4.09 ‰ VSMOW. The aquifer had a relatively consistent oxygen isotopic composition throughout the study area with all but one sample falling between the range of -4.88 to -3.35 ‰ VSMOW. The aquifer sample with an oxygen isotopic composition somewhat similar to the Brazos River had an oxygen isotopic composition of 0.06 ‰ VSMOW. This sample is thought to be an outlier and was collected from a well located next to a gravel pit filled with water. The water in the gravel pit was groundwater and the water table of the aquifer. Since the well was pumped for a long period of time it could have potentially drawn in water from the gravel pit, which would have experienced more evaporation than water in the aquifer, explaining the significantly heavier oxygen isotopic composition. This is supported also by a low bicarbonate concentration found in this sample. Therefore, the more realistic range of oxygen isotopic compositions for the Brazos River Alluvium Aquifer is from -4.88 to -3.35 ‰ VSMOW, with an average of -4.22 ‰ VSMOW. Some of the springs exhibited a slightly heavier oxygen isotopic composition, possibly because they experienced some evaporation as they discharged from the aquifer, although they were still included in the data set. Three well samples from a row crop farm in McLennan County (circled in figure 3.27) had a slightly heavier oxygen isotopic composition than the other aquifer samples, possibility indicating recharge from irrigation return flow or irrigation with water from the river.

The Brazos River Alluvium Aquifer is thought to be dominantly recharged by precipitation. This is supported by the average isotopic composition of the aquifer (-4.22

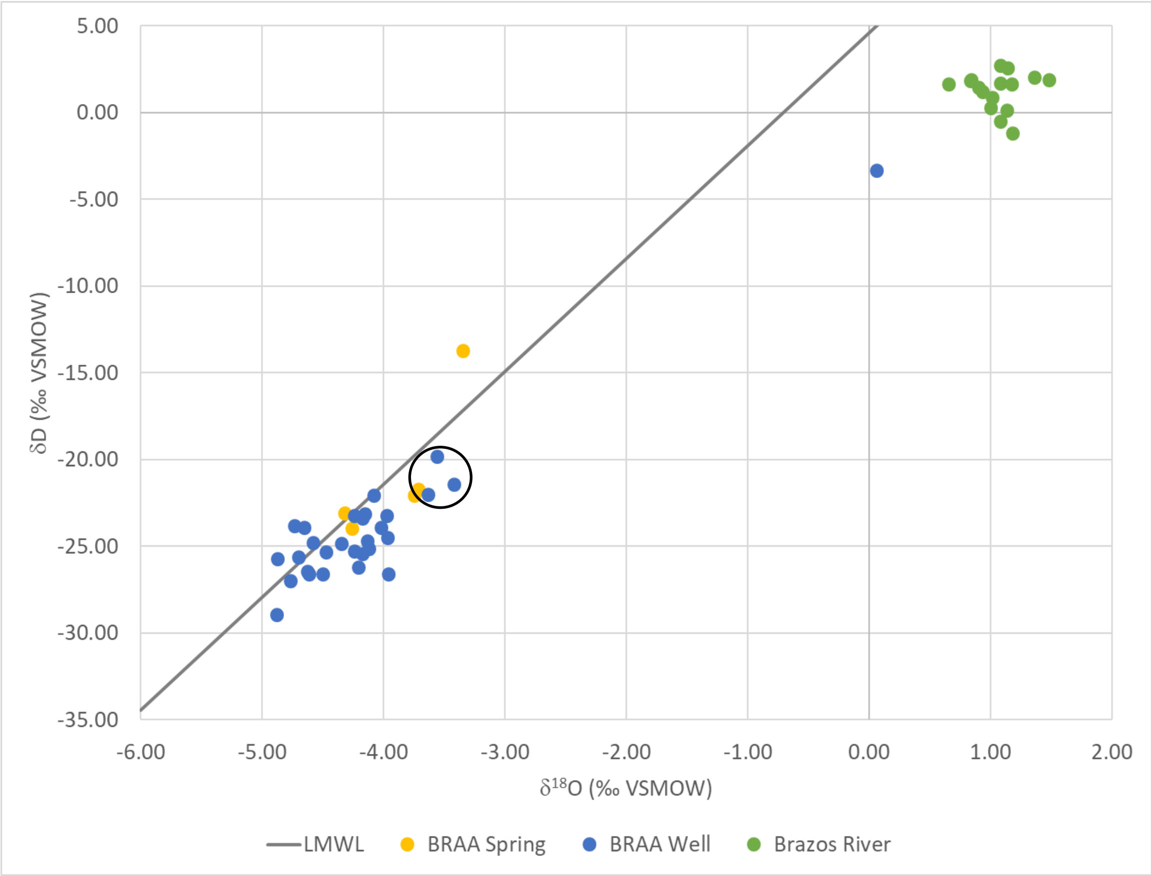

Figure 3.27. Bivariate plot of hydrogen versus oxygen isotopic composition of water samples from the Brazos River Alluvium Aquifer and Brazos River.

Table 3.4. Minimum, maximum, and average oxygen isotopic composition of the Brazos River Alluvium Aquifer and Brazos River.

Sample Name	Minimum $\delta^{18}O$ (‰ VSMOW)	Maximum $\delta^{18}O$ (‰ VSMOW)	Average $\delta^{18}O$ (‰ VSMOW)	Number of Samples
BRAA (including outlier)	-4.88	0.06	-4.09	34
BRAA (outlier removed)	-4.88	-3.35	-4.22	33
Brazos River	0.65	1.48	1.05	16

‰ VSMOW) which is near that of the average isotopic composition of precipitation in Waco, Texas (-4.03‰). The slightly more negative average oxygen isotopic composition of the aquifer in comparison to that of precipitation could be due to the fact the majority of the aquifer samples were collected north of Riesel. While the majority of aquifer samples cluster near the LMWL, some of the aquifer samples plot slightly below the LMWL suggesting that some evaporation might occur. It is possible that irrigation return flow recharging the aquifer could account for this deviation from the LMWL (particularly if surface water is used for irrigation), or in some areas the water table might be shallow enough for some evaporation to occur.

The oxygen isotopic composition of samples from the Brazos River are significantly heavier than that of the aquifer, ranging from 0.65 to 1.48 ‰ VSMOW, with an average of 1.05 ‰ VSMOW. The river samples show much less variability in isotopic composition than the aquifer although the river samples were collected over a much shorter time period. The river samples are much heavier than that of the aquifer and plot significantly off the LMWL indicating they experience significant evaporation, as expected for surface water. The Whitney Dam (located in Bosque/Hill County) and other dams located on the Brazos River likely increase evaporation of water flowing down the Brazos River. In addition, the oxygen isotopic composition of the river increases slightly downstream as the water continues to undergo evaporation (Table D.2.).

The data show the aquifer and river are isotopically distinct from one another. The isotopic composition of the aquifer likely varies little seasonally as it contains precipitation from throughout the year and thus likely always has an isotopic composition near the mean annual weighted isotopic composition of precipitation. However, the isotopic composition of the river likely varies throughout the year as evaporation rates change. Six samples collected during the spring of 2018 (not displayed in graph) show that the river had a lighter isotopic composition than in the summer, although the river was still isotopically distinct from the aquifer. Since the aquifer and river are isotopically distinct this suggests that overall the river has little influence on the large-scale isotopic composition of the aquifer. However, the isotopic composition of the aquifer could be affected on a more local scale in areas directly adjacent to or in close proximity to the river.

Coring and In-situ Water Sampling

The spatial variability of salinity in the northern segment of the Brazos River Alluvium Aquifer was characterized by collecting water samples in the spring/summer of 2018 and fall of 2018 and was also characterized in the 1960s by Cronin and Wilson (1967). However, no work has been performed to determine if any salinity stratification exists within the aquifer. Salinity stratification was thought to be possible due to the presence of a fining upward sequence, the discontinuous nature of the alluvial sediments, the density of higher TDS waters, and potentially due to irrigation. Core and in-situ water samples were collected from a non-irrigated pasture, an irrigated orchard, and an irrigated row crop farm, at the locations shown in figure 3.28.

In-situ sampling at well GM4 showed there was no stratification present at this location as there was little difference in the specific conductance of the samples. In addition, the composite sample from the well had a specific conductance of 1388 μS/cm, which is similar to that of the in-situ samples (Figure 3.29.). Conversely, in-situ

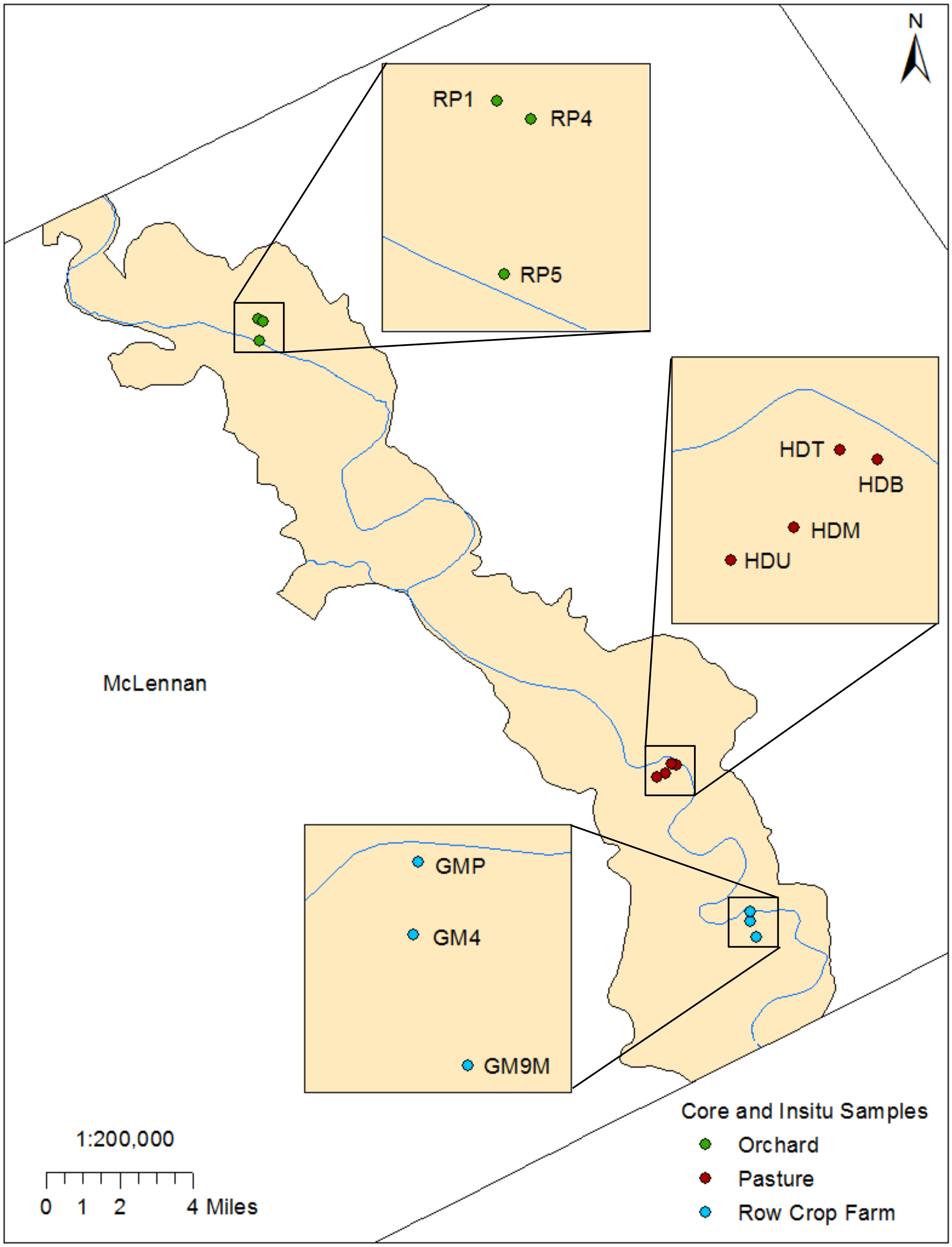

Figure 3.28. Map showing locations from which core and in-situ water samples were collected.

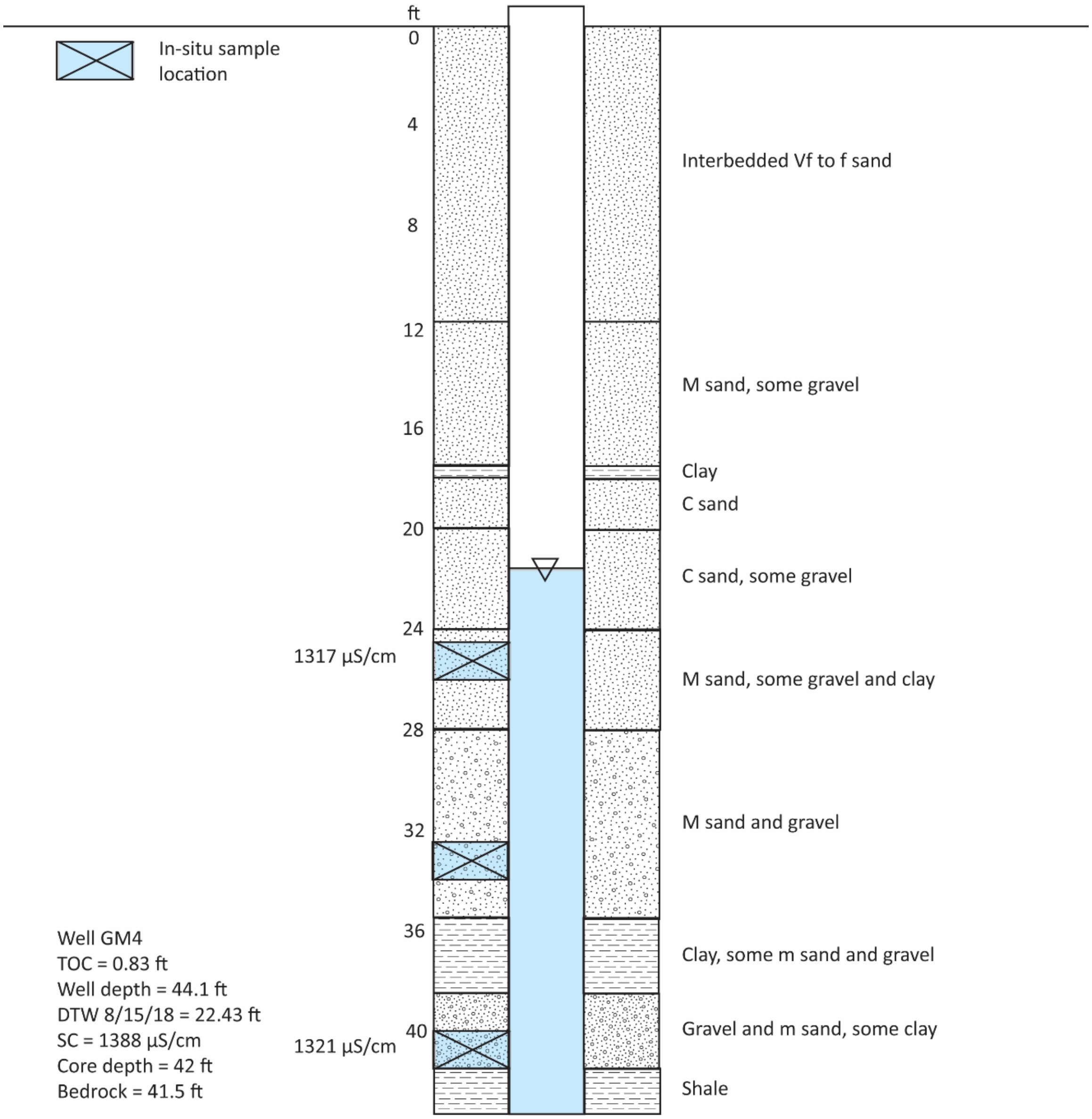

Figure 3.29. Diagram showing the specific conductance of in-situ samples collected near well GM4 and the lack of stratification in this well.

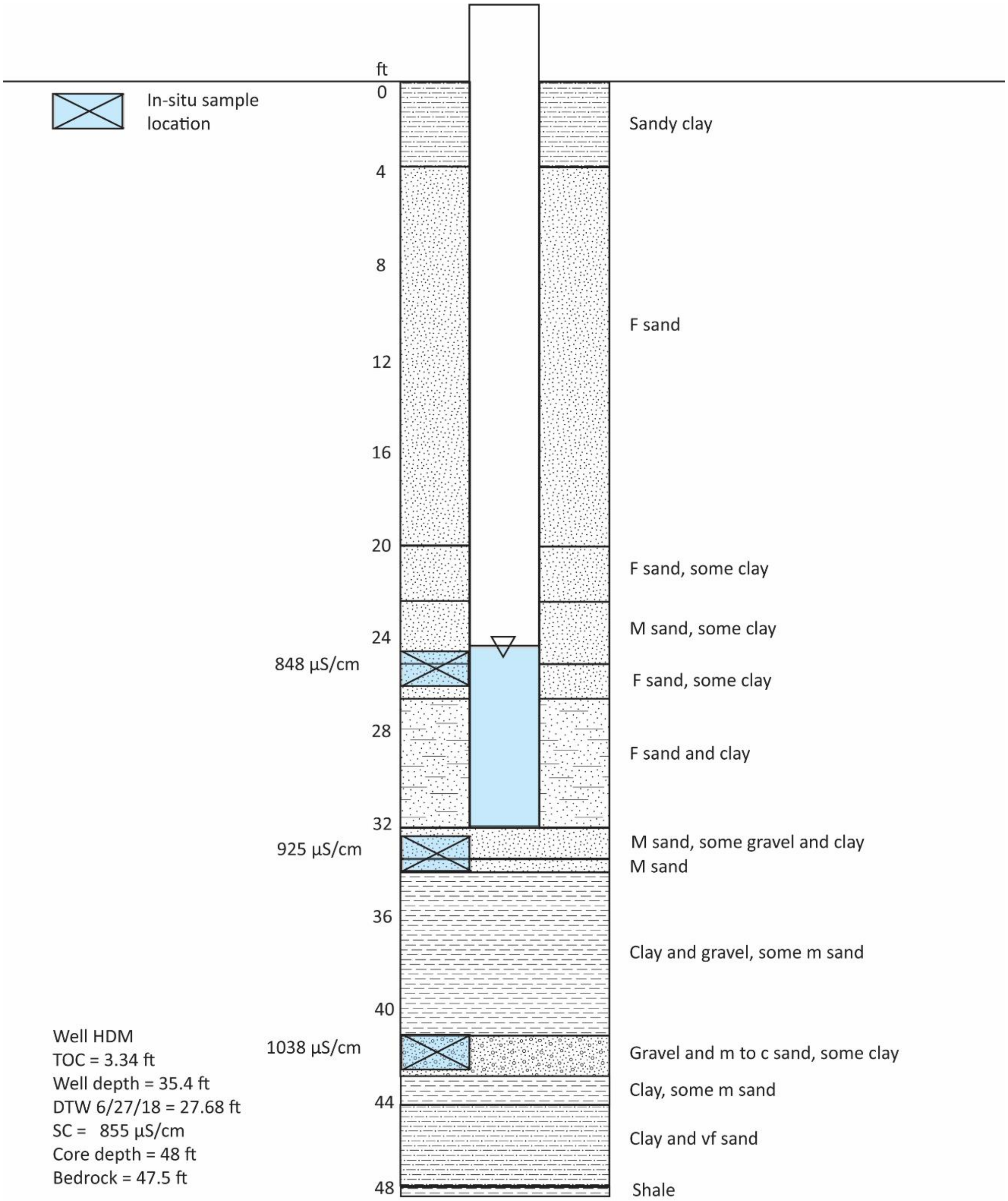

Figure 3.30. Diagram showing the specific conductance of in-situ samples collected near well HDM and the presence of stratification in this well.

sampling at well HDM showed some stratification as the specific conductance of the in-situ samples increased with depth (Figure 3.30). The composite sample from the well had a specific conductance of 855 μS/cm, which is similar to that of the in-situ sample collected near the interval where the well is screened. However, at other locations in-situ sampling also showed decreases of specific conductance with depth. At two locations the saturated section was so thin only one in-situ sample was obtained. All core descriptions and well diagrams can be found in appendix F and G, respectively.

The data indicate stratification occurs in the aquifer, although stratification was not consistent throughout the aquifer as specific conductance increased and decreased with depth, while no stratification was present at some localities. This is confirmed by the scatter plot in figure 3.31. which shows no correlation between depth and specific conductance for the in-situ samples. The lack of distinct stratification is likely due in part to the discontinuous nature of the alluvial sediments and the relatively thin saturated section at some localities. The specific conductance of the composite well samples (samples collected from the well by either bailing or pumping the well) generally showed similar specific conductance values to the in-situ samples, although some differences were observed. Differences between composite and in-situ samples may be the result of mixing biased towards the most productive layers of the aquifer.

The effect of sediment size on the specific conductance of each in-situ sample was examined by using the core collected at each site. All in-situ samples were classified into three groups, including fine grained sediments (clay, silt, and shale bedrock), sand, and sand and gravel. The box plot in figure 3.32. shows that the average specific conductance of in-situ samples from sand and gravel is similar to the average specific

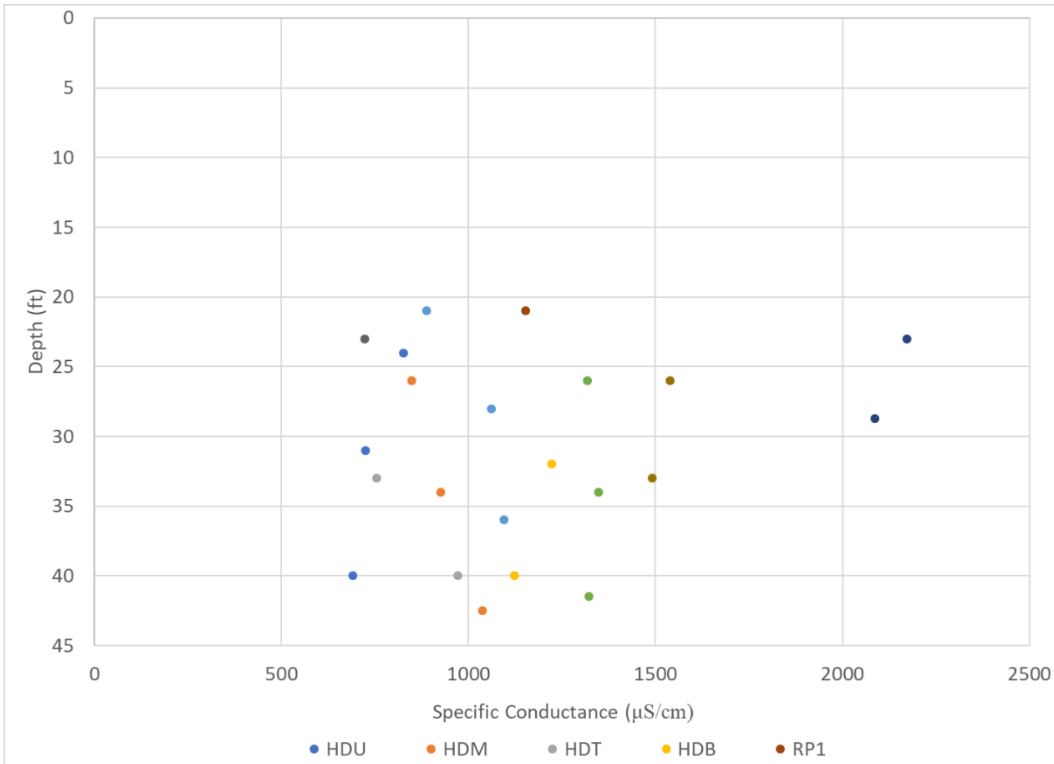

Figure 3.31. Scatter plot showing depth versus specific conductance for the in-situ water samples.

conductance of in-situ samples from fine grained sediments, both of which are significantly higher than those from sand. The sands were typically clean and well sorted while the sand and gravels tended to be more poorly sorted and often contained more clay, which could have increased the specific conductance of these samples. In addition, the sand consisted dominantly of quartz, while the gravel consisted mostly of limestone, although some chert gravel was present. The limestone gravel is more soluble than the quartz sand and thus could have also contributed to the higher specific conductance seen in the sand and gravel versus the sand. The fine grained sediments have a much lower hydraulic conductivity than the sand and sand and gravel and thus the increased residence time could cause the higher specific conductance than seen in sand. In addition, the more well-sorted fine-grained sediments and sand show much less variability in specific

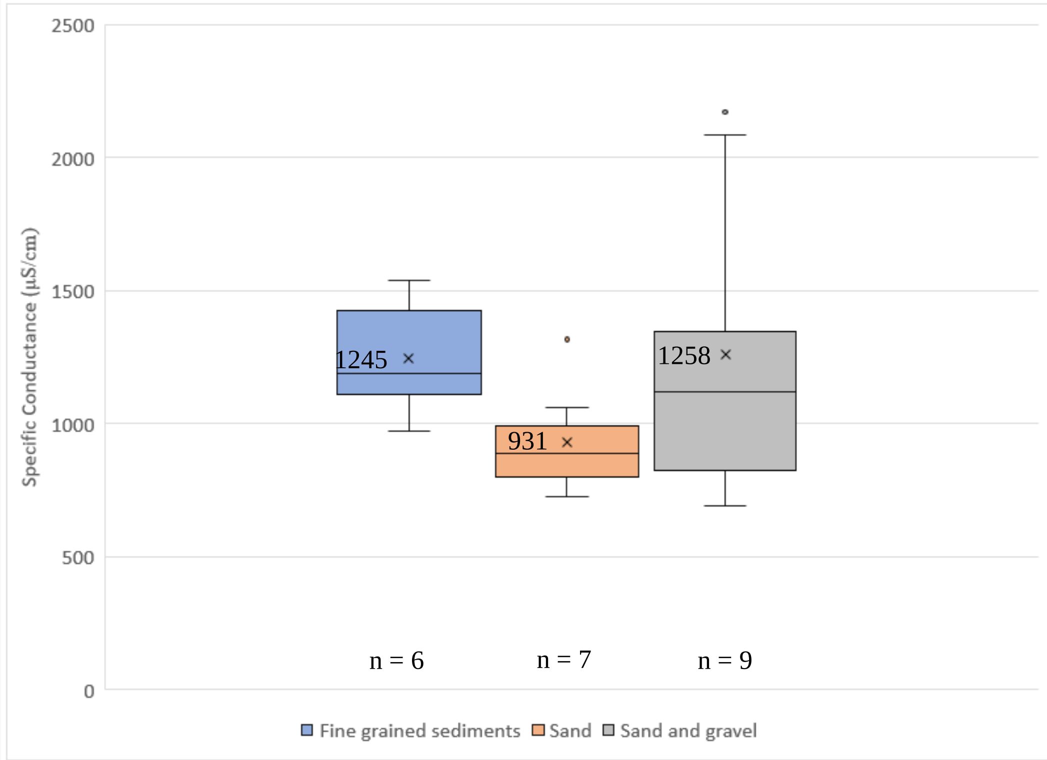

Figure 3.32 Box plot showing the specific conductance of the in-situ water samples by sediment size.

conductance than the more poorly sorted sand and gravel.

The relationships between the specific conductance and ionic chemistry of the in-situ samples and irrigation were also examined. The pasture is not irrigated while the orchard and row crop farm are both irrigated from the Brazos River Alluvium Aquifer, (although it is possible they were irrigated from the Brazos River in the past). The box plot in figure 3.33. shows that the non-irrigated pasture has the lowest average specific conductance at 912 µS/cm, while the irrigated orchard and row crop farm have significantly higher specific conductance values at 1226 and 1411 µS/cm, respectively.

The piper diagram in figure 3.34. shows the chemistry of the in-situ samples collected during this study, by site. The diagram shows that all of the in-situ water samples from the non-irrigated pasture, plot as calcium bicarbonate type waters, while

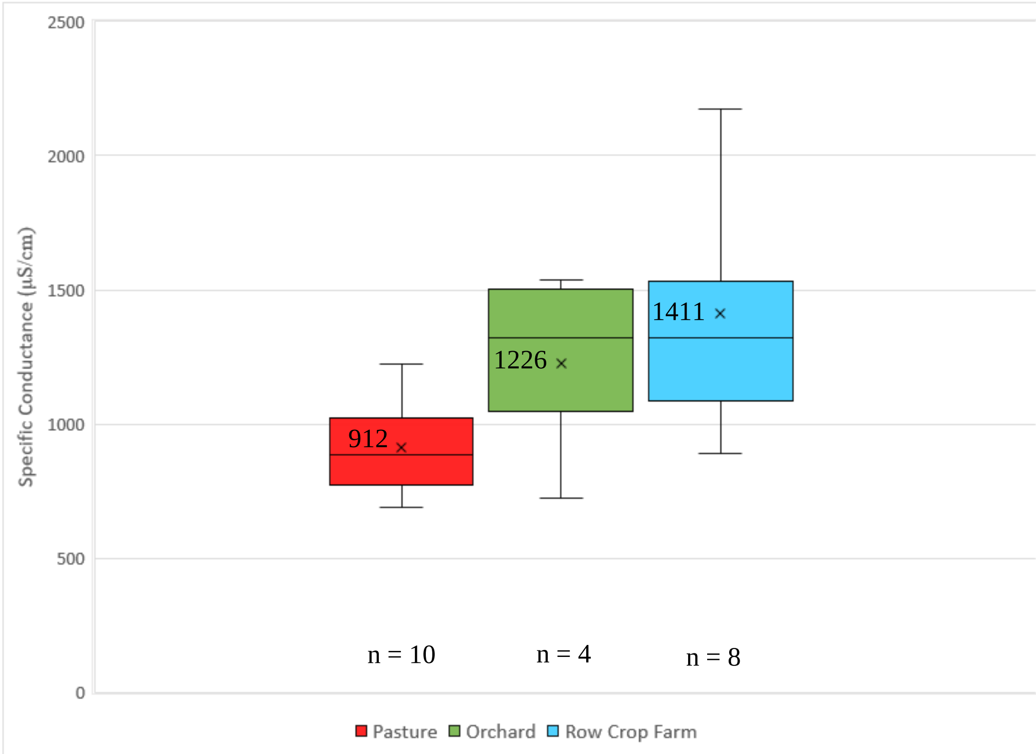

Figure 3.33. Box plot showing the specific conductance of the in-situ samples by site.
the in-situ water samples from the irrigated orchard and row crop farm have increasing

the in-situ water samples from the irrigated orchard and row crop farm have increasing proportions of chloride and trend toward being calcium-mixed or mixed cation and anion type waters. These data suggest that the irrigated and non-irrigated sites appear to be relatively chemically distinct from one another. In addition, the two sets of in-situ samples with the highest proportions of chloride (and highest specific conductance values) are RP5 and GM9M. RP5 is located near the bank of the Brazos River at the orchard in northern McLennan County and could possibly be influenced by the Brazos River, as river stage was high when the samples were collected. In addition, one of the in-situ samples from this location had a mixed-chloride type water and the Brazos River tends to have sodium chloride type water. However, GM9M which plots in the same

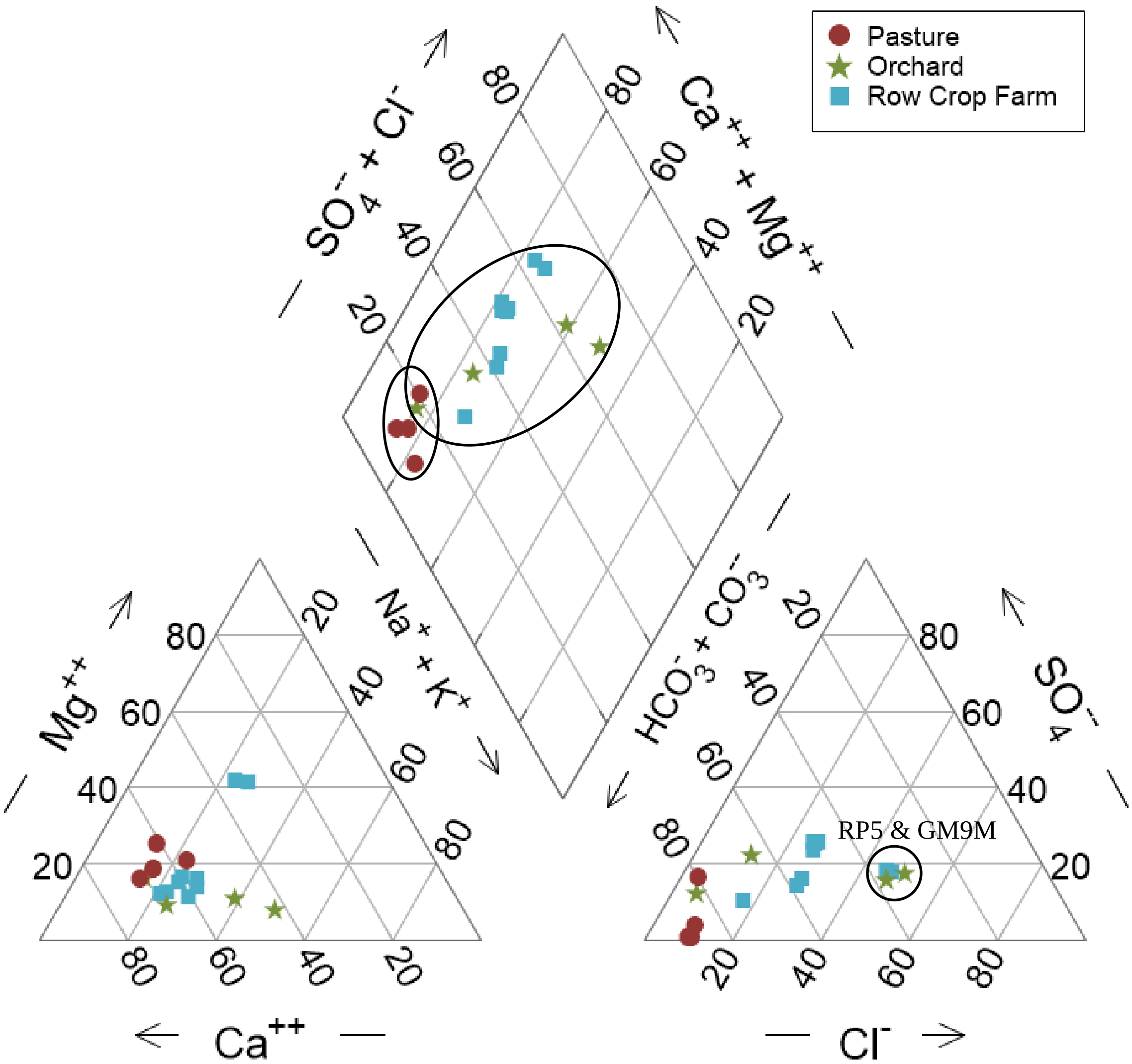

Figure 3.34. Piper diagram of in-situ water samples by site.

location on the piper diagram as RP5, is located a significant distance from the river, and thus is not likely influenced by it. Overall, the in-situ water sampling data indicate that irrigation could potentially impact the salinity of the aquifer; however, to confirm the effect of irrigation would require more sampling sites. Ionic chemistry of each individual in-situ sample can be found in appendix H.

Batch Leaching Experiment

To further investigate the effect of sediment type and depth on specific conductance independent of the initial condition of the water in the aquifer, a batch leaching experiment was performed on core collected at each in-situ sampling location. The hypotheses for the experiment were 1) There would be no significant difference in specific conductance between samples. 2) The finer grained sediments would have a higher specific conductance. 3) Shallower sediments would have a higher specific conductance.

After six weeks, the specific conductance of all samples began to level off. The percent difference of specific conductance between weeks five and six was below 10% for 40 of the 44 samples and was below 5% for 24 of the 44 samples. The specific conductance of the samples would likely continue to slowly increase over time; although, the same relative differences in specific conductance were approximately retained throughout the study for samples from the same core, even though magnitude slowly increased. Core logs can be found in appendix F and detailed methods can be found in appendix B.

As shown in appendix I significant differences in specific conductance values were observed between samples from the same core. The scatter plot in figure 3.35. compares depth of sample versus specific conductance and indicates there is no correlation between depth and specific conductance. The box plot of specific conductance by sediment size in figure 3.36. shows that the finer grained sediments (clay, silt, and shale bedrock) have a higher average specific conductance than sand, and that the sand has a higher average specific conductance than the sand and gravel. This

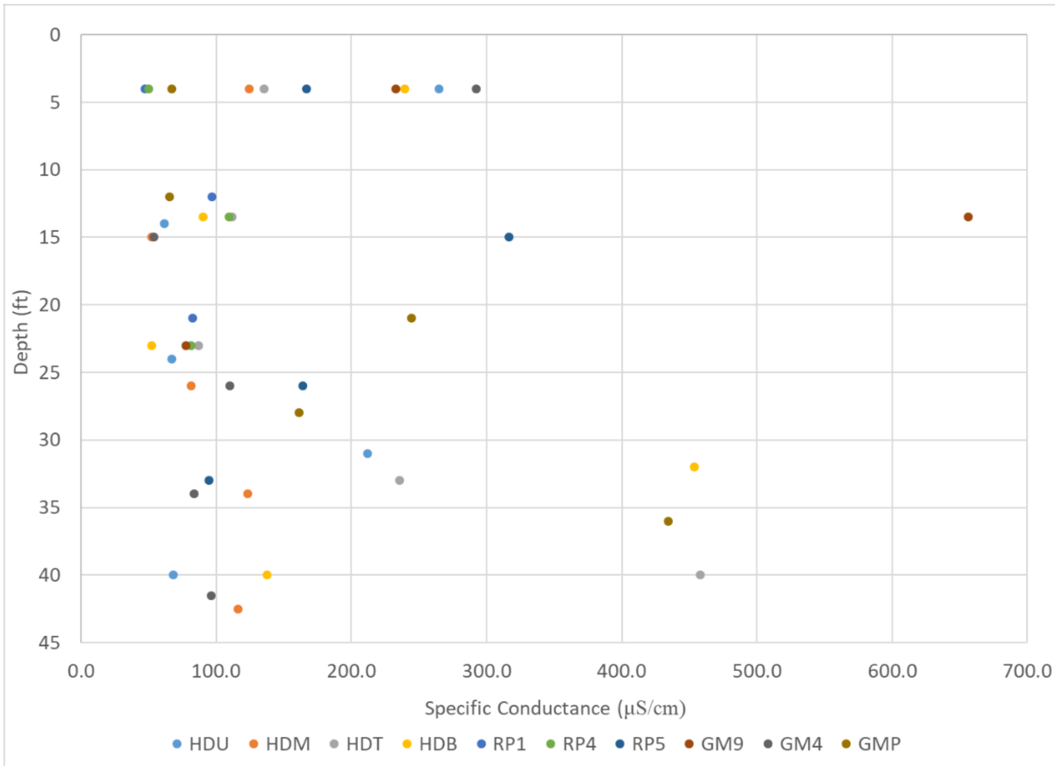

Figure 3.35. Scatter plot of depth versus specific conductance for batch leaching samples.

indicates that sediment size could play a role in the variability of salinity in the aquifer.

Studies by Cox and others (2018) and Pulido-Bosch and Sanchez (2018) found that finer grained textures like clay have higher salinities as the increased residence time allows more salt to accumulate and the low permeability limits flushing. The box plot of specific conductance by irrigated and non-irrigated sites in figure 3.37. shows no correlation between irrigation and the specific conductance of the samples in the batch leaching study.

The batch leaching study also attempts to exhibit some of the water-rock interaction which occurs in the aquifer. However, the magnitude of specific conductance is likely less than what realistically occurs in the aquifer, as water in the aquifer has a longer residence time and a higher partial pressure of carbon dioxide which encourages the dissolution of limestone gravels. It is also possible that the fine grained sediments contained interstitial water remaining from sample collection which could have contributed to the higher specific conductance values observed.

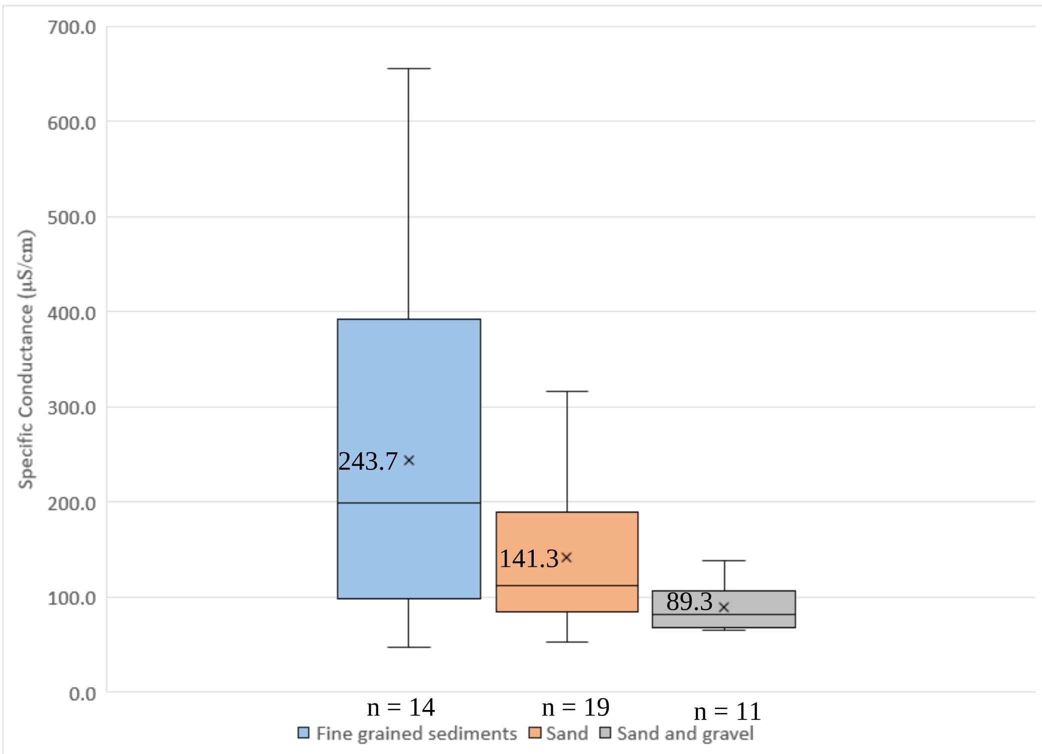

Figure 3.36. Box plot showing the specific conductance of batch leaching samples by sediment size.

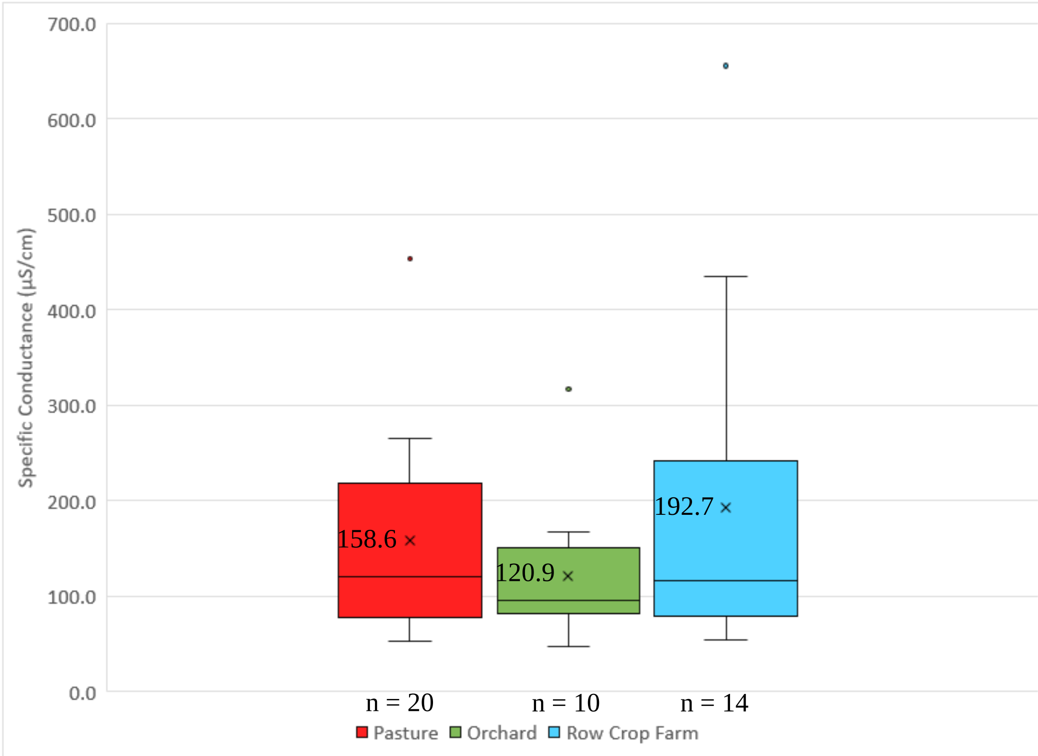

Figure 3.37. Box plot showing the specific conductance of batch leaching samples by site.

Comparison of In-situ and Batch Leaching Samples

The in-situ water sampling showed some salinity stratification although no correlation with depth or sediment type was observed. However, in-situ water sampling showed that the irrigated orchard and row crop farm had significantly higher average specific conductance values than the non-irrigated pasture, indicating that irrigation could potentially impact the salinity of the aquifer. In addition, the piper diagram showed that the orchard and row crop farm also had higher proportions of chloride. The batch leaching experiment also showed no correlation between depth and specific conductance. However, in contrast, the batch leaching experiment showed that the fine-grained sediments had a significantly higher specific conductance than the coarser grained sediments, suggesting sediment size could potentially impact the salinity of the aquifer.

Also, the batch leaching study showed little correlation between irrigation and specific conductance.

Comparison of the in-situ water samples and their corresponding batch leaching samples showed, that changes in specific conductance values of the in-situ samples for a particular core did not necessarily correspond to similar trends in the batch leaching experiment. In addition, the magnitude of the specific conductance for the batch leaching samples were much less than that of the in-situ samples. This large difference in magnitude suggests that even though sediment size significantly affected the specific conductance of the batch leaching samples, the initial condition of the water (possibly affected by irrigation) is likely far more importation than sediment size, even though texture may contribute to specific conductance. This is further supported by the fact that the in-situ samples showed little correlation to sediment size.

Hydrographs

Data loggers are often used in monitoring wells to create detailed hydrographs which can then be used to help determine the controls on water level in the aquifer. Since the Brazos River is a potential source of salinity for the Brazos River Alluvium Aquifer, hydrographs from five monitoring wells in the Brazos River Alluvium Aquifer were analyzed and compared to stream stage and precipitation to help determine the controls on recharge rates and groundwater-surface water interactions between the Brazos River Alluvium Aquifer and Brazos River. Hydrographs analyzed in this study spanned the period from 5/1/18 to 1/1/19.

Monitoring wells HDM, HDT, and HDB were located at a pasture in southern McLennan County and were 0.42, 0.14, and 0.08 miles from the Brazos River, respectively. Wells HDM and HDB roughly lie on a transect perpendicular to the Brazos River, while well HDT lies southwest of well HDB. Well RP1 was located 0.56 miles from the Brazos River at an orchard in northern McLennan County and well GM9M was located 0.72 miles from the Brazos River at a row crop farm in southern McLennan County (Figure 3.38.). Data loggers in monitoring wells HDM and HDB were installed and monitored by Baylor University while dataloggers in monitoring wells RP1, HDT, and GM9M were installed and monitored by STGCD.

Table 3.5. shows the monthly and annual precipitation normals from 1981-2010 and the monthly and annual precipitation received during the year of 2018, as recorded by the NOAA weather station at the Waco Regional Airport. The table shows that while the annual precipitation received during 2018 (34.55 inches) was extremely close to the annual precipitation normal of 34.69 inches, the months of January through August of 2018 were abnormally dry. During the months of January through August of 2018, only 9.61 inches of rain were received, in comparison to the precipitation normal of 22.16 inches. However, the period of September to December of 2018 was abnormally wet, as 24.94 inches of precipitation were received, in comparison to the precipitation normal of 12.53 inches, (National Oceanic and Atmospheric Administration 2019a and 2019b).

Due to the position of monitoring wells HDM and HDB in a transect perpendicular to the Brazos River and their close proximity to the river, data from these wells provided an excellent opportunity to better understand groundwater-surface water interactions between the Brazos River Alluvium Aquifer and Brazos River (Figure 3.38.).

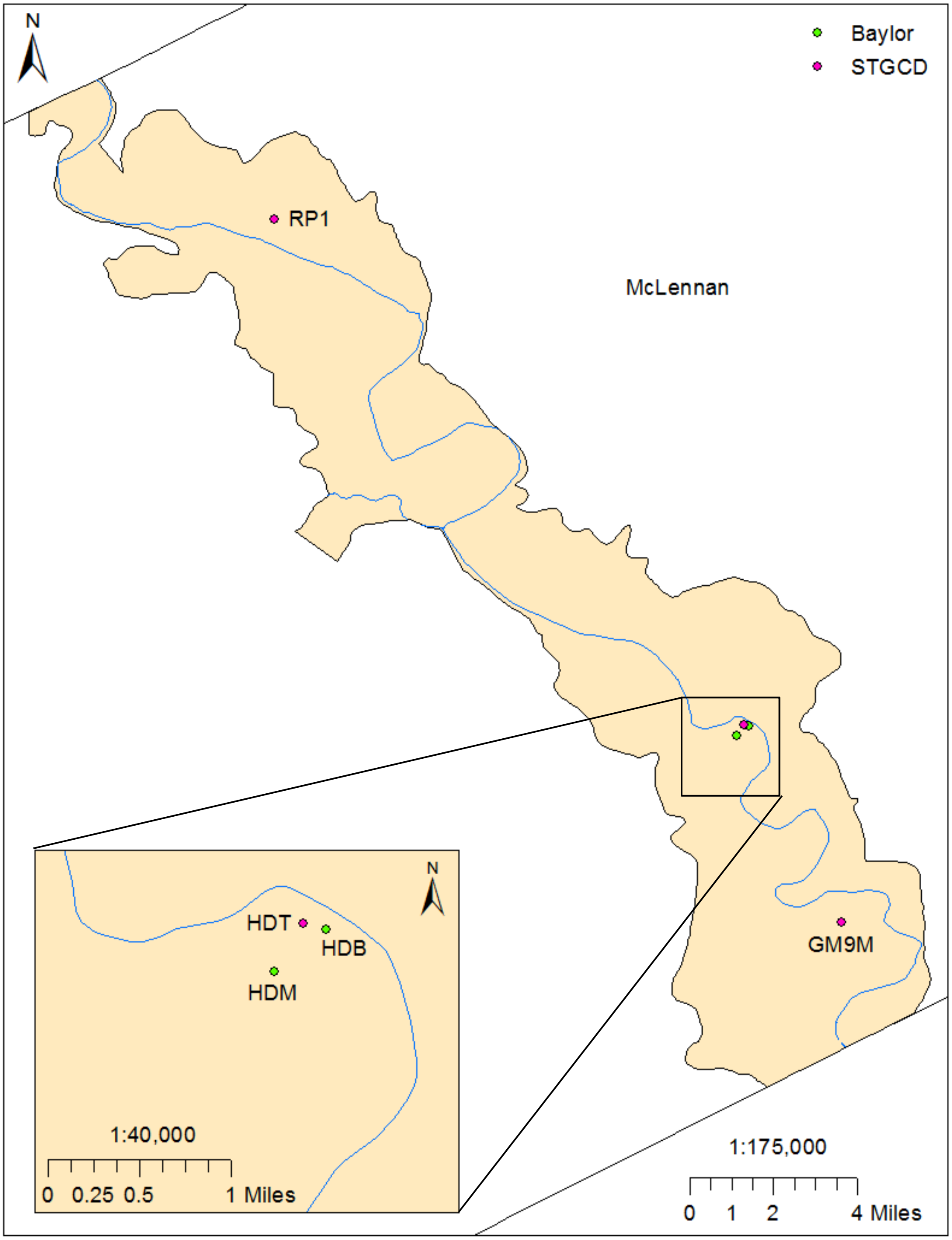

Figure 3.38. Map showing location of data loggers.

Table 3.5. NOAA monthly precipitation normals and 2018 monthly precipitation for the weather station at the Waco Regional Airport (National Oceanic and Atmospheric Administration 2019a and 2019b).

Month	Precipitation Normals (in)	2018 Precipitation (in)
January	2.12	0.31
February	2.63	2.12
March	3.15	2.49
April	2.69	0.51
May	4.30	2.94
June	3.43	0.2
July	1.79	0.47
August	2.05	0.57
September	3.06	4.9
October	3.9	12.56
November	2.82	3.19
December	2.75	4.29
Annual	34.69	34.55

Hydrograph for Well HDM

The graph of HDM groundwater elevation and precipitation in figure 3.39 shows that water level declined steadily over the dry summer months, dropping a total of 0.76 feet. Water level began rising on 10/15/18 and increased 4.74 feet before it began to level off. The graph also shows that water level in well HDM did not respond to precipitation received in both May and September, likely because there was little soil moisture present in the unsaturated zone. However, the aquifer did respond to precipitation received in October and the following months. From 10/6/18 to 10/9/18, 3.72 inches of precipitation were received, 2.30 inches of which were on 10/9/18. The aquifer began to respond on 10/15/18 suggesting a lag time of 6 to 9 days. The lag time of 6 days is likely more accurate as most of the rain was received on 10/9/18. To account for the 4.74 foot rise in water level observed in well HDM (assuming a porosity of 25%)

approximately 14.22 inches of recharge would be necessary. During this period 15.24 inches of precipitation were received, although it seems unlikely that nearly all of the precipitation received would infiltrate into the aquifer.

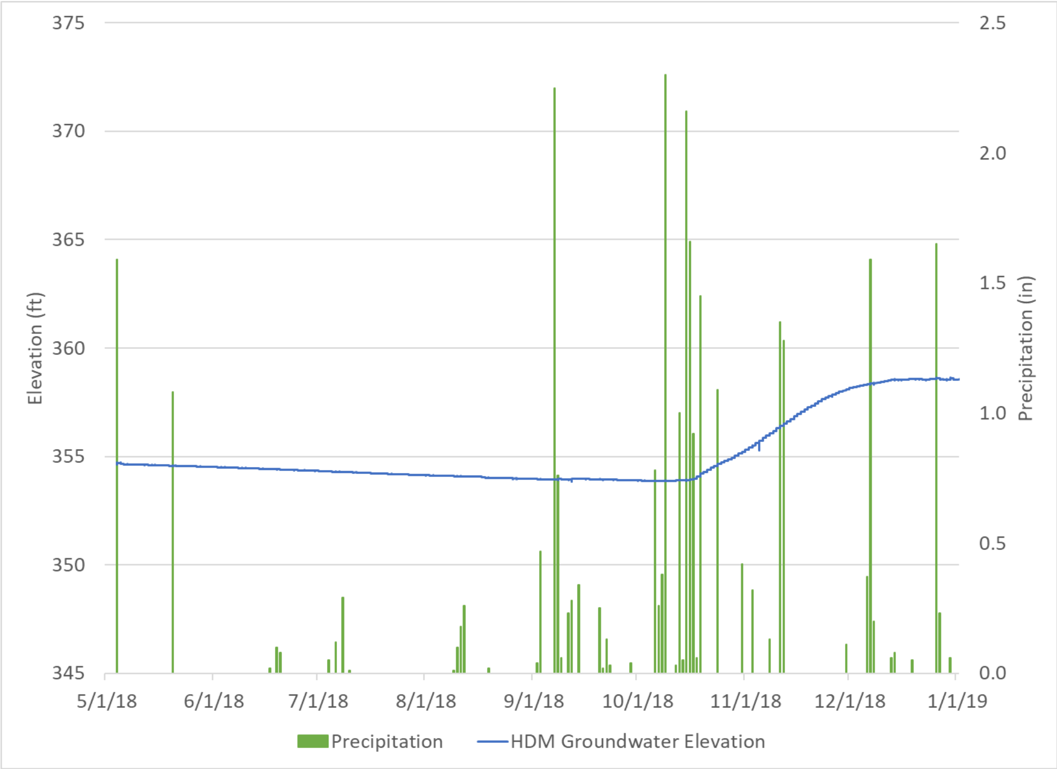

Figure 3.39. Groundwater elevation and precipitation for well HDM.

Figure 3.40. shows a graph of groundwater elevation in well HDM and river elevation. The graph shows that groundwater elevation does not respond to changes in river stage during the summer months as water was released from the dams. It does however show that groundwater elevation increases steadily during the 20.75-foot rise in river level from 10/2/18 to 10/20/18, but when river elevation begins to fall on 11/15/18, groundwater elevation continued to increase (although at a slower rate) and then eventually leveled off. In addition, there was a significant period of time during which

the river elevation was greater than that of the groundwater elevation in well HDM, suggesting that the gradient was reversed during this period.

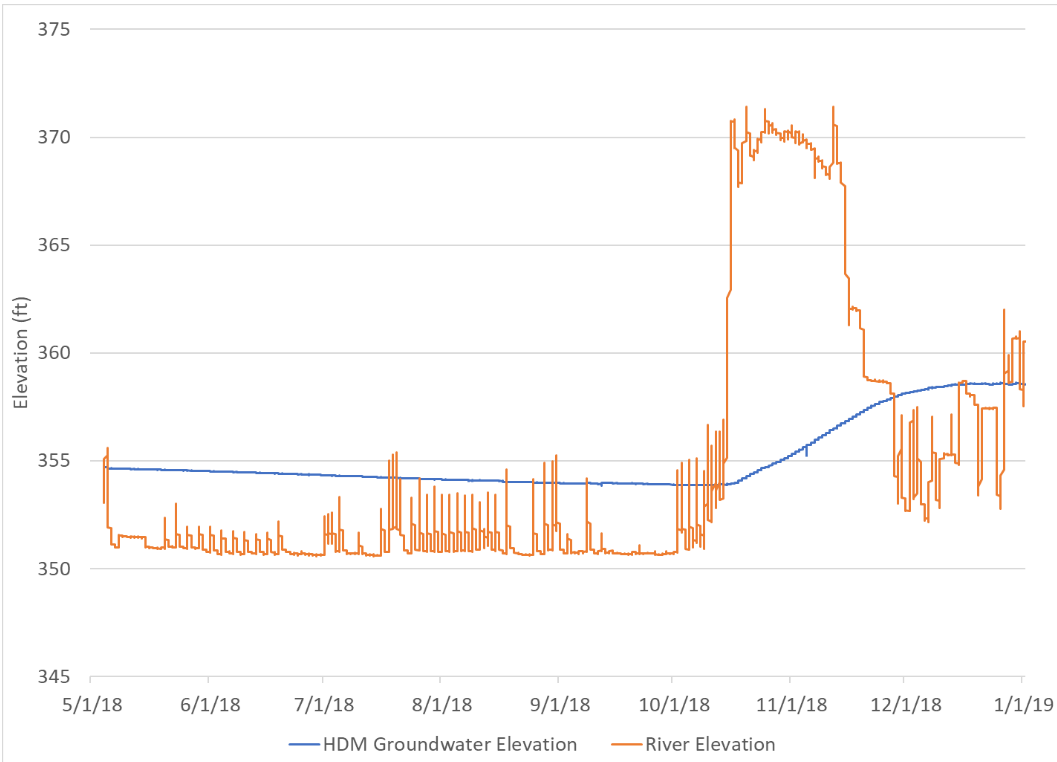

Figure 3.40. Groundwater and river elevation for well HDM.

Hydrograph for Well HDB

The graph of groundwater elevation and precipitation for well HDB in figure 3.41. shows water level decreased by 0.19 feet over the dry summer months, although slight variations in water level were observed. Groundwater elevation began rising on 10/2/18 and rose a total of 10.78 feet by its peak on 11/14/18-11/15/18. Groundwater elevation then began declining rapidly, decreasing 5.21 feet before it began to level off.

The graph also shows that groundwater elevation began rising on 10/2/18, before precipitation began on 10/6/18. In addition, to account for the 10.78 foot increase in water level observed in well HDB (assuming a porosity of 25%) 32.34 inches of recharge would be necessary, although only 15.24 inches of precipitation were received from October to December of 2018. Therefore, some other factor must have influenced water level in well HDB.

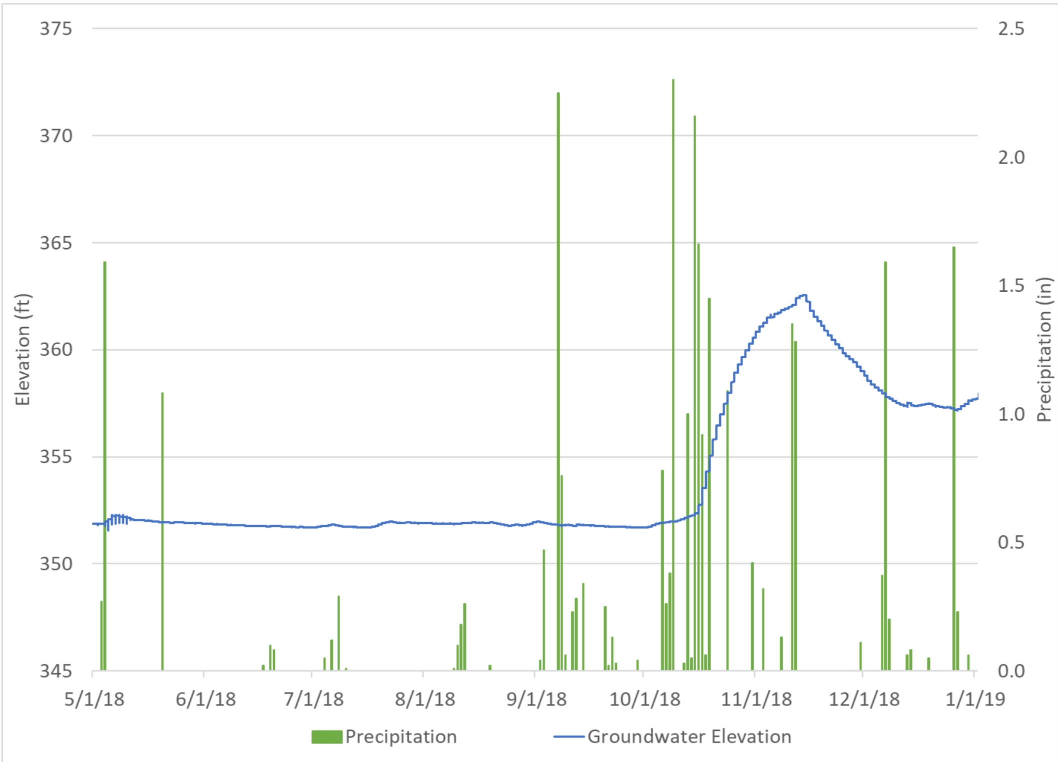

Figure 3.41. Groundwater elevation and precipitation for well HDB.

The graph of HDB groundwater and river elevation in figure 3.42. shows that during low flow conditions in the summer, groundwater elevation mirrors changes in river stage as water was released from the dams, causing the slight variations in groundwater elevation observed. River elevation began rising rapidly on 10/2/18 and peaked on 10/20/18 rising a total of 20.75 feet, and then began decreasing on 11/15/18. Similarly, groundwater elevation also began rising on 10/2/18 and closely mirrored the increase then decrease in river elevation. In addition, there was significant period of time during which the river elevation was greater than that of the groundwater elevation in well HDB, suggesting again that the gradient was reversed during this period.

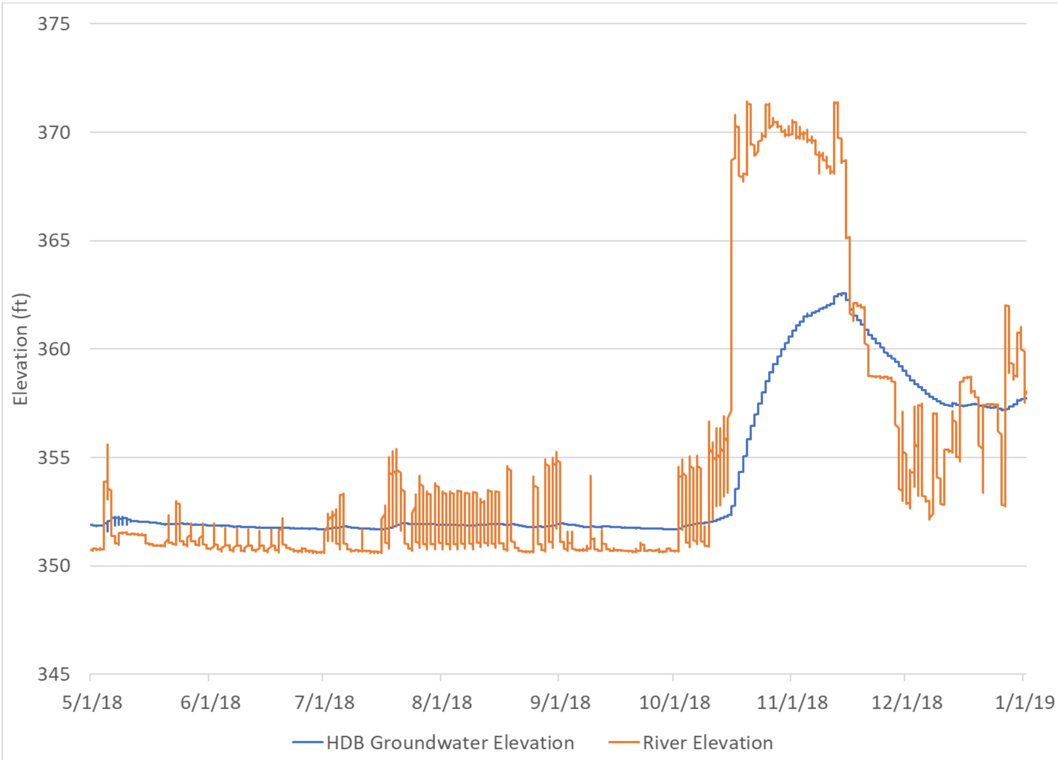

Figure 3.42. Groundwater and river elevation for well HDB.

Hydrograph for Well HDT

Due to technical difficulties, the data logger in well HDT did not record data during the period of 8/30/18 to 10/31/18. However, the water level in this well appeared to respond very similar to that of well HDB. Groundwater elevation decreased 0.16 ft over the dry summer months and then rose a total of 14.45 feet by 11/12/18. In addition, groundwater elevation closely mirrored increases and decreases in river elevation as seen in well HDB. Water level in well HDT rose 3.67 feet more than in well HDB, possibly due to the higher proportion of sand in well HDT. Hydrographs for well HDT can be found in appendix J.

Hydrographs for Well RP1 and Well GM9M

Hydrographs for wells RP1 and GM9M showed trends similar to those of well HDM, in that wells RP1 and GM9M did not respond to the precipitation received in May of 2018, and well RP1 did not respond to the precipitation received in September of 2018 either. Due to technical difficulties well GM9M did not record data after 9/9/18. Hydrographs for wells RP1 and GM9M are shown in appendix J. During October of 2018, water level in well RP1 showed a lag time of 3-6 days in response to precipitation. This appear to be less than seen in well HDM, although well RP1 tends to have sandier sediments than well HDM. In addition, water level in both wells RP1 and GM9M also did not respond to changes in stream stage during the summer months. Well RP1 was used for irrigation during the summer of 2018 and thus provides some insight into the effects of long-term pumping on the aquifer. These effects are described in detail in appendix J.

Discussion of Hydrographs

The cross section in figure 3.43. shows the water table of the aquifer on 10/1/18, 11/13/18, and 12/24/18 for wells HDU, HDM, HDB and the Brazos River. The location of all wells can be found in figure 3.44. Well HDU was a monitoring well located 0.63 miles from the Brazos River upgradient from well HDM. Water level in well HDU was measured monthly using a Solnist water level gage. Well HDT was not incorporated into the cross section because it is not likely on the same flow path as the other wells. The Brazos River Alluvium Aquifer typically discharges at the Brazos River and groundwater flow in the aquifer is generally perpendicular to the river. This so-called typical behavior of the aquifer was observed from 5/1/18 to 10/9/18 as the

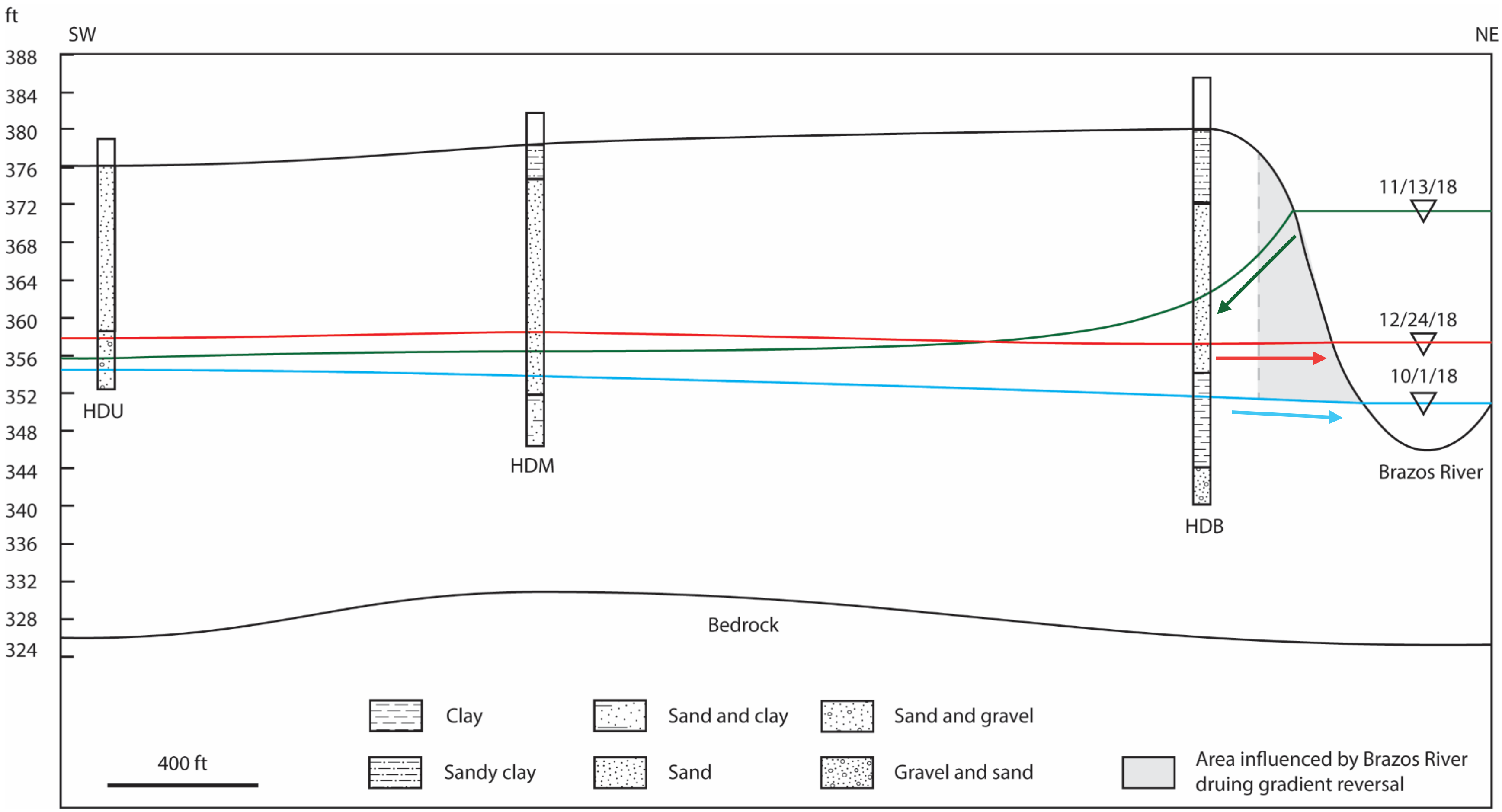

Figure 3.43. Cross section showing water table for wells HDU, HDM, HDB, and the Brazos River on 10/1/18, 10/24/18, and 12/24/18 and the area influenced by the Brazos River during the 37-day gradient reversal.

groundwater elevation of well HDU was greater than that of the river so water was flowing toward the river as seen in figure 3.43., although the gradient of the water table is quite low.

However, during the period from 10/10/18 to 11/16/18 the river elevation was significantly greater than that of the groundwater elevation as seen in figures 3.40. and 3.42. The change in head observed indicates that during this period the gradient was reversed and water was flowing from the river into the aquifer. The cross section in figure 3.43. shows the water table of the aquifer on 11/13/18 during the period when river elevation was greater than groundwater elevation. In close proximity to the river, the reversed gradient is quite steep, although it decreases rapidly moving away from the river. The question then becomes how far did river water travel into the aquifer during the period when the gradient was reversed.

Using Darcy's law, groundwater and river elevations from 11/13/18, the gradient between the river and well HDB, a hydraulic conductivity of 28.33 ft/day (Fetter 2001), and a porosity of 25%, the groundwater velocity flowing from the river to well HDB was 2.38 ft/day. The gradient was reversed for approximately 37 days so river water would have traveled approximately 88 feet into the aquifer from the edge of the river at this site (shown by the gray box in the cross section in figure 3.43.), and thus would not have reached well HDB, located 427 feet from the river. Therefore, the increase in water level observed in well HDB was not caused by river water flowing into the well, but was caused by the sudden change in head resulting from the rise in river elevation which acted like a hydraulic boundary or dam, causing water level in well HDB to rise.

Once river level began to fall, the water table began to return to the normal low gradient, although albeit at a significantly higher elevation due to the areal recharge from precipitation (figure 3.43.).

The cross section and hydrographs also show that the change in head due to the increase in river elevation caused a significant increase in water level in well HDB at 0.08 miles (and in well HDT) from the river, but this effect was small by well HDM at 0.42 miles from the river. Similarly, little river influence is seen in wells RP1 and GM9M at distances of 0.56 and 0.72 miles from the river. These findings are also supported by the work of Pinkus (1987) that showed changes in river stage of the Brazos River due to the opening and closing of the low water dam affected the water level of the Brazos River Alluvium Aquifer upstream of the dam and adjacent to the river. Pinkus (1987) also showed that within 50 feet of the Brazos River the gradient of the aquifer changed significantly with changes in river stage, but a well located 0.42 miles from the aquifer showed little change in water level with river stage.

Overall, the hydrographs and cross section indicate that during the 37-day gradient reversal when the river elevation was higher than that of the groundwater, river water would have only affected the portion of the aquifer within approximately 88 feet of the rivers' edge at this location. The map in figure 3.44. shows that the area of the Brazos River Alluvium Aquifer influenced by water from the Brazos River during the 37-day gradient reversal is extremely small when compared with the full width of the aquifer. Once the gradient reverses as river elevation subsides, this water will eventually flow back out of the aquifer and into the river. Using Cronin and Wilson's (1967) groundwater velocities of 70-75 ft/yr, it would take 1.17 to 1.26 years for the river water

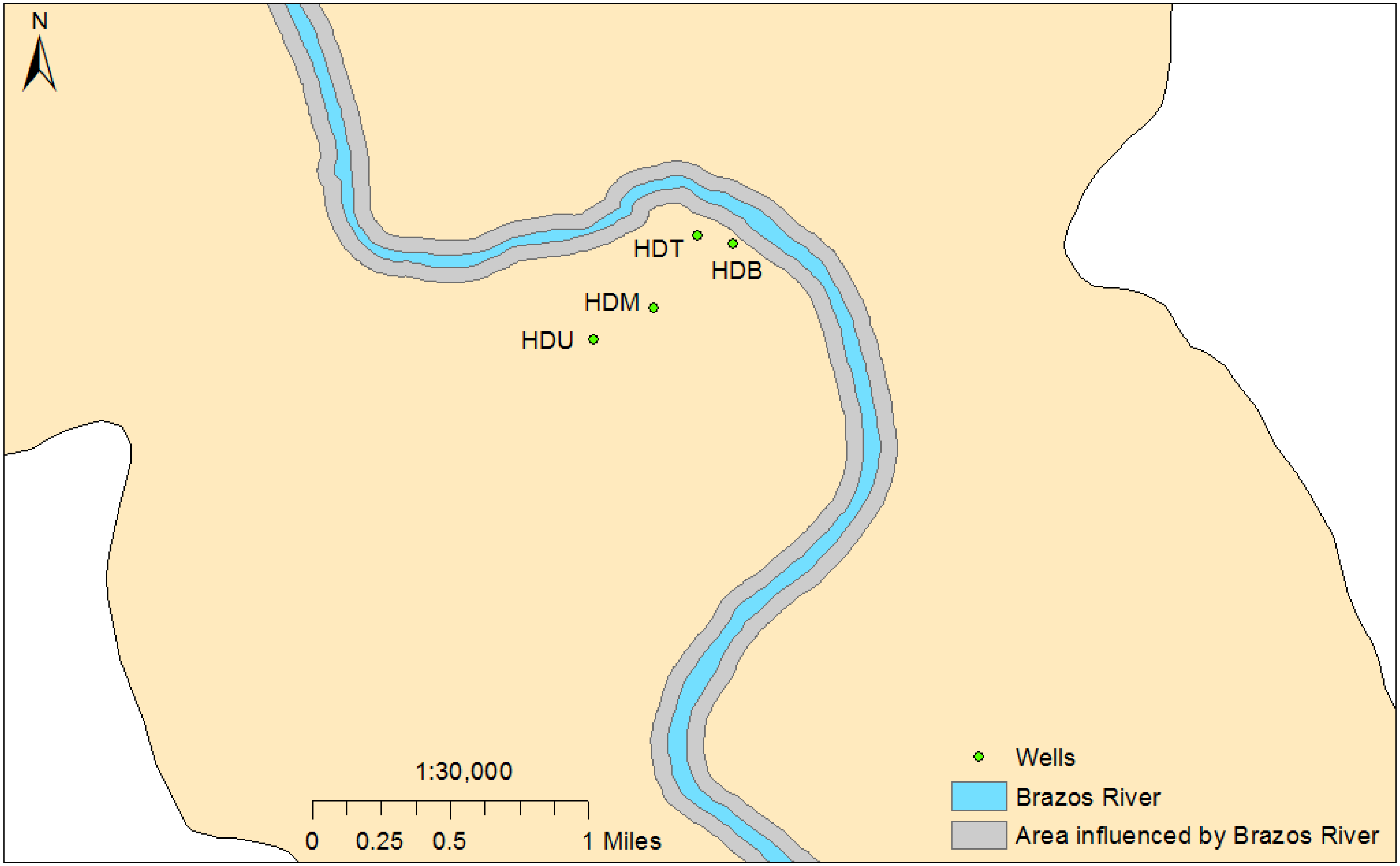

Figure 3.44. Map showing the area of the aquifer influenced by the Brazos River during the 37-day gradient reversal.

that flowed into the aquifer during the 37-day gradient reversal to flow back into the river. Although, using Chowdhury and others' (2010) groundwater velocities of 9-27 ft/yr it would take 3.26 to 9.78 years for the water to flow back into the river.

CHAPTER FOUR

Summary and Conclusions

Variability of Salinity

1. The Brazos River Alluvium Aquifer showed significant variability in salinity, as TDS ranged from less than 500 mg/L to greater than 3,000 mg/L. The salinity of the aquifer also varied rapidly over short distances as TDS was found to double over the course of a few hundred yards at multiple locations.
2. Brazos River Alluvium Aquifer sampling in the spring/summer of 2018 and fall of 2018 revealed that 75% and 95% of samples exceeded the EPA's secondary drinking water standard for TDS (500 mg/L), respectively.
3. The average specific conductance of the Brazos River Alluvium Aquifer in Falls County is significantly higher than that of McLennan County, while the average specific conductance of the Brazos River is less than the aquifer in Falls County and only slightly higher than the aquifer in McLennan County.
4. Comparison of the spring/summer of 2018 and fall of 2018 data sets indicate that the average specific conductance of the aquifer in McLennan and Falls County changed little due to seasonality. Comparison of the 2018 data sets to the historic TWDB data set indicate that the average specific conductance of the aquifer in McLennan and Falls County has changed little since the 1960's.
5. Chemical analyses from in-situ sampling showed some stratification was present within the aquifer; however, no consistent stratification was found as salinity was

found to both increase and decrease with depth or remain constant depending on the location. This is likely due to the discontinuous nature of the alluvial sediments and the thin saturated section in some locations. The batch leaching study showed no trends with depth, but that finer grained sediments had higher specific conductance values.

Sources of Salinity

Brazos River

1. The aquifer in McLennan County dominantly consists of calcium bicarbonate type water, while the aquifer in Falls County is much more variable but consists mostly of mixed-bicarbonate type water and mixed cation and anion type water. While there is some overlap between the chemistries of the Brazos River Alluvium Aquifer and Brazos River; overall, they tend to have different ionic chemistries.
2. Water samples from the Brazos River Alluvium Aquifer plot on the local meteoric water line and have an average isotopic composition near that of the mean annual weighted isotopic composition of precipitation, indicating the aquifer is primarily recharged by precipitation and that water in the aquifer could experience some evaporation. Isotopic data indicate that the aquifer and river are isotopically distinct from one another suggesting that the river has little influence on the large-scale isotopic composition of the aquifer. However, the isotopic composition of the aquifer could be affected on a more local scale in areas directly adjacent to or in close proximity to the river.

3. Hydrographs show that under normal conditions the aquifer discharges at the river; although, during the rise in river stage in the fall of 2018, the gradient reversed for approximately 37 days and water flowed from the river into the aquifer. Based on calculations using Darcy's Law, river water would have only flowed approximately 88 feet into the aquifer from the river's edge (at the location studied), which is insignificant in comparison to the entire width of the aquifer. The hydrographs also showed that at approximately 0.42 miles from the river, the aquifer was only slightly affected by changes in river stage; (as the river represented a hydraulic boundary which caused groundwater to rise significantly behind it) however, this appears to be approximately the outer edge of river influence.

Brines Associated with Historic Oil and Gas Fields

1. High TDS samples were found throughout Falls County, even on the opposite side of the river from the Deer Creek and Post Oak oil fields. Jarvis (2019) suggests that the river acts as a hydraulic boundary which would prevent brine contamination from the Deer Creek and Post Oak oil fields from reaching the northeast side of the river. In addition, specific conductance measurements from the TWDB groundwater database collected near the oil fields do not appear to show abnormally high TDS values, suggesting brine contamination from historic oil and gas fields is not the widespread cause of elevated salinity levels in Falls County.

Irrigation and Evapotranspiration

1. Falls County contains a significantly higher proportion of land used for cultivated crops than McLennan County. Cultivated crops can either be irrigated or non-irrigated, although historically Falls County contains a significantly higher amount of irrigation than McLennan County
2. In-situ sampling showed that samples collected at the irrigated orchard and irrigated row crop farm had significantly higher specific conductance values than the non-irrigated pasture, indicating that irrigation can potentially affect aquifer salinity.
3. Comparison of the specific conductance of in-situ water samples and batch leaching samples showed that they did not follow similar trends and that the specific conductance of the batch leaching samples was much less than the corresponding in-situ samples. This suggests that while sediment type may contribute to the salinity of the aquifer, the initial condition of the water likely plays a larger role in overall aquifer salinity.

Summary

1. Overall, the Brazos River and historic oil and gas fields in Falls County do not appear to be the source of elevated salinity in the Brazos River Alluvium Aquifer; however, irrigation could potentially impact the salinity of the aquifer.

CHAPTER FIVE

Recommendations

1. The majority of samples collected from the aquifer exceeded the EPA's secondary drinking water standard for TDS and a few samples in McLennan County exceeded the EPA's primary drinking water standard for nitrate. In addition, the shallow and unconfined nature of the aquifer make it extremely susceptible to contamination. While, these facts do not necessarily preclude the use of the aquifer as a source of drinking water, this is likely not the most efficient use of the aquifer. However, the aquifer does show potential for use in irrigation, watering livestock, and in small industrial operations where minimal treatment would be required.
2. Irrigation is thought to potentially impact the salinity of the aquifer particularly in Falls County; however, more work is needed to confirm this hypothesis. Brazos, Burleson, Milam, and Robertson County also have significant historical and current irrigation; therefore, collection and analysis of water samples in these counties could help to confirm this theory.
3. Contributions of water from bedrock are thought to be small in the study area but could contribute to the salinity of the Brazos River Alluvium Aquifer. Therefore, bedrock contributions (particularly the Tertiary age Midway Group in southern Falls County) need to be investigated further.

4. This study also worked to document the degree of groundwater-surface water interactions between the Brazos River Alluvium Aquifer and Brazos River at one location in the northern segment of the aquifer. Groundwater-surface water interactions are a highly politized topic, and more work needs to be performed to better understand and quantify groundwater-surface water interactions between the Brazos River Alluvium Aquifer and Brazos River.

APPENDICES

APPENDIX A

Water Sampling Procedures

Before water sampling, all applicable field equipment was triple rinsed with deionized water (DI). The pH meter was calibrated before each use with pH 4, 7, and 10 pH buffers and the YSI conductivity probe and Solnist water level gage were calibrated on a monthly basis using 1413 and 5000 μS/cm conductivity standards. In addition, a trip blank of DI water was prepared in the lab before each sampling trip. The trip blank is designed to check against possible contamination from the lab, procedures, or DI water. A field blank of DI water was prepared at a random site on each sampling trip to check against possible contamination from the site, procedures, or DI water. In addition, a duplicate of one sample was also prepared to check the precision of the laboratory. All blanks and duplicates were prepared according the guidelines outlined below.

When collecting water samples from a well, the location of the well was recorded using a GPS and the location was described in detail. Next, the plumbing of the well was observed (if applicable) to find the best location to collect the water sample, preferably where the sample bypassed any tanks or filters. The well was then pumped until three casing volumes of water were removed or until temperature and specific conductance stabilized. If the well had no pump, it was bailed until three casing volumes of water were removed or until temperature and specific conductance stabilized.

When collecting water samples from a spring, the location of the spring was recorded using a GPS and the location was described in detail.

When collecting water samples from a river, the location was recorded using a GPS and the location was described in detail. River samples were collected either using a bailer which was thrown out into the center of the river from the bank, or when a bridge was available, the bailer was lowered from the center of the bridge to collect the sample. This process ensured that stagnant water and obstructions near the bank were avoided.

Water samples were collected in a glass beaker, wearing gloves to prevent contamination of the sample. A clean pair of gloves was used to collect each sample. The temperature and specific conductance of each sample were recorded in the field, and each sample was titrated for bicarbonate in the field or immediately after returning to the lab on the sampling day. For each titration, 50 mL of water sample were placed in a 200 mL glass beaker and a burette with a stopcock was filled with 0.0200 N sulfuric acid. The initial pH of the water sample and the initial volume of the burette were recorded and sulfuric acid was slowly added to the sample, stirring the solution and recording the pH of the solution and burette volume after each addition. Sulfuric acid was added until a pH of 2.9 was reached. Then, pH was plotted against milliliters of acid used to determine the inflection point, as the inflection point represents the amount of acid necessary to neutralize all bicarbonate in solution. The concentration of bicarbonate in the sample was then calculated using the volume of water sample, volume of sulfuric acid, and normality of the sulfuric acid.

All samples were filtered using a 0.45 μm syringe filter and sample bottles were rinsed with sample prior to being filled. In addition, the first few drops of sample discharged through each new filter were discarded and filters were changed as deemed necessary. Samples were then labeled and put on ice and a chain of custody form was filled out. All sampling equipment was triple rinsed with DI water between samples. Each of the three labs samples used to analyze samples had slightly different procedures for sample collection which are described below.

CRASAR sampling procedures involved filling 40 mL of sample in a 50 mL sample bottle. Samples were then frozen until they were analyzed.

BIO CHEM sampling procedures involved filling at least 100 mL of sample in a 250 mL sample bottle. The cations were acidized with nitric acid and anions were not acidized. All samples were refrigerated before analysis.

Department of Geosciences Stable Isotope Lab sampling procedures involved leaving no head space in the sample bottle and taping the lid of the sample bottle with electrical tape to prevent any isotope fractionation due to evaporation after collection. All samples were refrigerated until they were delivered to the lab.

APPENDIX B

Batch Leaching Procedures

Introduction

Core and in-situ water samples were collected from three sites in McLennan County within the Brazos River Alluvium aquifer, including a non-irrigated pasture, an irrigated orchard, and an irrigated row crop farm. Core and in-situ water sampling sites were typically located adjacent to pumping wells. Core was collected to characterize the sediments present at each site and in-situ water samples were collected to characterize any vertical variability in water quality within the aquifer. "Composite" water samples were also collected from the adjacent wells for comparison to the in-situ samples. At each location, 1 to 3 in-situ water samples were collected at various depths depending on the thickness of the saturated section. Each in-situ water sample was collected from a 1.5-foot screened interval using the Geoprobe Screen Point 22 Groundwater Sampler. Typically, one in-situ sample was collected just below the water table, a second was collected just above bedrock, and if the saturated thickness was large enough, a third sample was collected in-between the first two.

Hypotheses

1. There will be no significant difference between samples.
2. Finer grained sediments will have a higher specific conductance.
3. Shallower sediments will have a higher specific conductance.

Methods

All cores were air dried for at least one month. One month may not be enough time for the core to dry out completely, but probably reduced water volume to an insignificant amount causing little if any dilution. In each core, the 1.5-foot core intervals corresponding to the 1.5-foot screened in-situ sample interval, were identified. At least two additional 1.5-foot segments were identified in the unsaturated section of each core, at evenly spaced interval. The top and bottom 3.5 inches of each 1.5-foot interval were removed, then four inches of core were collected from the top and bottom, leaving 3 inches of core in the middle that were not used. Both four-inch sections of core were cut in half lengthwise and one-half of each section was placed in a 1-quart glass jar labeled with the sample location and depth. This process attempted to ensure that the sediment used for the batch leaching experiment was as representative as possible of the 1.5-foot section from which the in-situ sample was obtained.

All glass jars were triple rinsed with distilled water and air dried before use. The amount of water needed to fill the 1-quart jar with the core was calculated and this volume of water was used for all jars. Due to differences in sediment type, the amount of water necessary to saturate the core likely differs slightly; however, a porosity of 25% was used for the calculation regardless of sediment type. Each jar was filled with 750 mL of distilled water in a set pattern and the condition of the core was recorded. It should be noted that some sections of core were completely disaggregated or loose, while others remained compacted or in nodules. Once each jar was filled with water, they were then agitated for 10 seconds using a stirring rod (in the same pattern in which they were filled) to attempt to disaggregate all core. Over the next four days, each jar was shaken for 10 seconds, once a day, to continue to disaggregate the core. After the first specific conductance measurement at 1 week, the jars were shaken once each week after the specific conductance measurement was made. The jars were no longer stirred as removing the lid many times can result in evaporation and stirring the jars many times results in loss of water.

On 1/11/19 the jar containing GMP 26.5-28 ft broke. It was replaced with the remaining core and filled with water according to the aforementioned specs. The specific conductance of this jar was always measured two days after the rest of the jars. In addition, on 2/13/19 the jar containing GM9M 27.2-28.7 ft broke. The core in all jars was completely disaggregated after 1 week.

The specific conductance of each jar was recorded weekly for six weeks using a YSI conductivity probe. The probe was triple rinsed with DI water between each measurement and calibrated each week using 1413 µS/cm and 5000 µS/cm conductivity solutions. The jars were not disturbed two days before any specific conductance measurement to prevent measurement error due to suspended sediment. Specific conductance values were relatively stable after six weeks.

APPENDIX C

2018 Brazos River Alluvium Aquifer and Brazos River Water Chemistry

Table C.1. Spring/summer of 2018 ionic chemistry of the Brazos River Alluvium aquifer.

Sample Name	Date	Specific Conductance (uS/cm)	Temperature (°C)	Latitude	Longitude	Sodium (mg/L)	Potassium (mg/L)	Magnesium (mg/L)	Calcium (mg/L)	Bicarbonate (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Nitrate as N (mg/L)
WS1	3/3/2018	1370	N/A	31.8630	-97.3575	66.4	1.62	23.8	69.8	456	185.6	N/A	0.23
WS2	3/3/2018	536	N/A	31.8598	-97.3515	25.0	0.39	12.1	40.8	359	31.9	28.4	N/A
WS3	3/3/2018	414.6	N/A	31.8427	-97.3224	3.4	1.15	3.54	45.6	242	5.3	14.8	0.12
WS4	3/3/2018	960	N/A	31.8126	-97.2969	56.2	2.25	18.6	41.6	464	71.4	54.4	N/A
ASPO	6/21/2018	927	22.1	31.2659	-96.9032	62.1	0.91	38.9	35.2	459	16.5	40.5	7.46
ASCP	6/21/2018	1926	23.3	31.2303	-96.9014	231.8	2.69	38.1	46.3	649	97.1	N/A	0.03
DL	6/22/2018	858	21.9	31.2642	-96.9052	59.4	1.62	31.5	44.2	486	11.3	24.0	1.11
MB	6/22/2018	899	25.4	31.2647	-96.9050	52.3	1.33	36.3	34.1	426	27.3	25.6	6.35
MV	7/23/2018	1549	29.2	31.2956	-96.9428	117.0	1.40	60.0	136.0	613	143.0	131.0	3.16
AH1	7/24/2018	1629	24.8	31.1708	-96.8361	182.0	8.68	25.9	146.0	913	70.1	9.3	0.00
AH2	7/24/2018	1906	23.2	31.1778	-96.8414	212.0	2.96	34.7	137.0	664	264.0	81.0	0.37
AH3	7/24/2018	1862	22.0	31.1728	-96.8475	220.0	2.90	35.7	144.0	696	208.0	129.0	0.09
AH4	7/24/2018	1515	23.6	31.1600	-96.8308	98.2	1.87	17.7	124.0	780	51.0	38.9	0.01
AH5	7/24/2018	1538	23.6	31.1486	-96.8064	157.0	3.62	27.5	135.0	657	129.0	114.0	0.29
AH6	7/24/2018	5402	22.6	31.1406	-96.8081	519.0	4.92	104.0	339.0	658	1260.0	412.0	0.00
IS	1/27/2018	792	20.5	31.5603	-97.1269	48.5	3.64	6.40	53.4	329	35.2	82.3	N/A

Sample Name	Date	Specific Conductance (uS/cm)	Temperature (°C)	Latitude	Longitude	Sodium (mg/L)	Potassium (mg/L)	Magnesium (mg/L)	Calcium (mg/L)	Bicarbonate (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Nitrate as N (mg/L)
RE	2/1/2018	390	23.3	31.6662	-97.2100	10.9	5.94	6.84	13.7	212	4.6	0.9	N/A
BC	2/1/2018	858	20.7	31.6446	-97.1884	16.5	0.67	22.0	44.6	327	18.2	20.3	N/A
GM1	2/19/2018	1502	N/A	31.4531	-97.0263	115.6	2.31	58.9	48.5	598	160.9	N/A	N/A
GM2	2/19/2018	1640	N/A	31.4557	-97.0320	117.2	2.16	55.6	80.3	613	190.2	N/A	N/A
GM4	7/16/2018	1388	24.4	31.4592	-97.0205	77.1	3.74	29.1	173.0	434	138.0	198.0	0.32
GMA	2/19/2018	683	20.6	31.4468	-97.0395	48.4	5.43	18.2	46.5	249	59.6	N/A	N/A
GMB	2/19/2018	1298	20.5	31.4479	-97.0414	95.8	3.95	41.6	69.0	452	138.9	0.2	N/A
GMC	2/19/2018	806	21.1	31.4466	-97.0445	49.0	1.97	22.9	58.7	254	77.8	N/A	N/A
HDU	1/27/2018	994	21.7	31.5157	-97.0569	31.5	2.00	21.5	57.4	387	6.0	N/A	N/A
HDM	2/19/2018	855	20.9	31.5207	-97.0497	16.5	1.63	10.9	52.3	256	6.9	N/A	N/A
HDT	2/5/2018	671	19.3	31.5211	-97.0515	17.7	2.19	25.9	25.2	372	6.1	57.5	N/A
RP1	3/2/2018	1306	20.2	31.6959	-97.2137	48.7	1.72	27.3	118.4	373	77.3	37.1	N/A
RP2	3/2/2018	1604	20	31.6960	-97.2133	61.6	1.47	41.8	164.5	371	100.9	327.1	N/A
RP3	3/2/2018	728	20.5	31.6951	-97.2122	29.3	2.04	13.2	43.0	332	25.15	45.53	N/A
RP4	3/2/2018	632	20.8	31.6950	-97.2120	36.3	2.89	8.66	56.1	334	14.13	42.80	N/A
RP5	3/2/2018	620	21.4	31.6874	-97.2133	25.7	0.41	12.9	41.0	361	17.36	36.41	N/A

Table C.2. Fall of 2018 ionic chemistry of the Brazos River Alluvium aquifer.

Sample Name	Date	Specific Conductance (uS/cm)	Temperature (°C)	Latitude	Longitude	Sodium (mg/L)	Potassium (mg/L)	Magnesium (mg/L)	Calcium (mg/L)	Bicarbonate (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Nitrate as N (mg/L)
ASPO	10/23/2018	813	21.9	31.2659	-96.9032	62.4	1.53	39.2	50.3	434	16.2	40.9	2.82
DL	10/23/2018	737	18.7	31.2642	-96.9052	37.2	1.22	25.7	80.0	456	3.57	14.2	0.13
ASCP	10/23/2018	1980	21.1	31.2303	-96.9014	262.0	2.58	40.0	144.0	713	79.8	403.0	0.01
MV	10/23/2018	1567	18.5	31.2956	-96.9428	115.0	1.42	63.7	125.0	620	110.0	127.0	6.81
AH2	11/20/2018	1914	16.7	31.1778	-96.8414	226.0	3.22	42.3	134.0	691	214.0	91.8	0.00
AH4	11/20/2018	1374	21.2	31.1600	-96.8308	144.0	3.18	25.0	130.0	680	83.6	55.3	0.02
AH6	11/20/2018	5419	21.3	31.1406	-96.8081	510.0	5.94	135.0	416.0	661	1192	487.0	0.00
AH7	11/20/2018	3140	21.2	31.1384	-96.8061	287.0	4.45	68.6	244.0	644	618.0	158.0	0.00
RP1	10/5/2018	915	21.8	31.6959	-97.2137	35.2	2.06	17.8	147.0	366	34.7	78.7	10.1
RP2	10/5/2018	1321	22.1	31.6960	-97.2133	51.4	1.81	32.7	198.0	371	64.7	152.0	11.4
RP4	10/5/2018	779	22.3	31.6950	-97.2120	35.8	1.89	11.5	91.2	430	20.4	52.9	7.57
RP5	10/5/2018	1020	21.9	31.6874	-97.2133	117.0	1.26	13.9	138.0	290	169.0	85.5	2.70
BC	10/22/2018	1033	21.5	31.6446	-97.1884	24.6	1.38	31.2	125.0	308	21.6	26.7	11.20
HDU	11/5/2018	1185	22.8	31.5157	-97.0569	24.8	2.07	24.7	176.0	412	7.43	82.3	5.66
HDM	11/5/2018	848	21.9	31.5173	-97.0538	26.1	2.95	16.5	128.0	378	8.64	105.0	0.15
HDT	11/5/2018	1119	21.9	31.5211	-97.0515	93.3	2.73	16.5	95.1	203	170.0	83.4	0.44
HDB	11/5/2018	1072	20.9	31.5207	-97.0497	43.5	2.53	24.3	138.0	574	39.9	20.9	0.00
GM3	11/16/2018	1954	20.6	31.4561	-97.0249	134.0	3.39	67.7	197.0	571	160.0	258.0	8.22
GM4	11/16/2018	1296	21.4	31.4592	-97.0205	75.8	3.36	30.9	154.0	420	110.0	201.0	0.07

Table C.3. Summer of 2018 ionic chemistry of the Brazos River.

Sample Name	Date	Specific Conductance (uS/cm)	Temperature (°C)	Latitude	Longitude	Sodium (mg/L)	Potassium (mg/L)	Magnesium (mg/L)	Calcium (mg/L)	Bicarbonate (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Nitrate as N (mg/L)
RP	7/9/2018	1320	22.7	31.8664	-97.3678	47.7	2.34	2.92	20.3	166	78.4	2.06	3.00
DC	7/9/2018	1445	27.8	31.8126	97.2970	64.0	3.01	6.50	21.7	144	105.8	1.87	1.76
RP	7/12/2018	1163	20.4	31.6872	-97.2148	153.0	6.50	17.0	35.9	104	250.1	N/A	1.64
LS	7/9/2018	1328	22.0	31.6084	-97.1304	91.1	4.32	9.82	31.5	154	150.5	N/A	1.81
MLK	7/9/2018	1303	29.1	31.5905	-97.1530	60.2	3.03	6.46	22.9	150	99.8	2.03	1.74
HA	7/10/2018	1300	27.8	31.5753	-97.1458	68.6	3.61	7.34	N/A	157	113.3	2.40	2.22
SB	7/10/2018	1306	28.7	31.5611	-97.1272	53.8	2.83	5.90	N/A	156	88.6	2.04	1.79
FC	7/10/2018	1337	28.8	31.5519	-97.1031	59.4	2.84	6.36	N/A	155	97.9	2.17	2.25
L340	7/10/2018	1324	30.7	31.5339	-97.0731	50.0	2.44	5.66	N/A	160	82.2	2.14	1.63
HD	7/10/2018	1282	31.4	31.5219	-97.0489	51.3	3.19	5.52	N/A	162	81.7	4.58	1.57
GM	7/10/2018	1326	34.9	31.4639	-97.0225	52.0	2.59	5.65	N/A	129	84.5	1.82	0.70
H7	7/10/2018	1290	26.5	31.2878	-96.9697	58.9	3.07	6.33	N/A	149	95.5	1.95	1.98
FB	7/10/2018	1229	33.5	31.2481	-96.9206	50.7	2.83	4.90	N/A	101	81.0	1.49	3.22
H413	7/10/2018	1259	12.7	31.1341	-96.8257	66.9	3.71	7.24	N/A	143	109.0	0.97	2.18

APPENDIX D

Historic Brazos River Alluvium Aquifer and Brazos River Water Chemistry

Table D.1. TWDB historic specific conductance data for the Brazos River Alluvium aquifer.

State Well Number	County	Date	Latitude	Longitude	Specific Conductance (µS/cm)
3933701	Falls	7/11/1963	31.38056	-96.9694	1780
3933701	Falls	3/18/1980	31.38056	-96.9694	2214
3933701	Falls	6/26/1986	31.38056	-96.9694	1826
3933701	Falls	9/15/1999	31.38056	-96.9694	1590
3941101	Falls	5/10/1961	31.36639	-96.9964	940
3941503	Falls	7/29/1963	31.33194	-96.9481	1420
3941504	Falls	7/11/1963	31.30417	-96.9258	1580
3941701	Falls	8/5/1993	31.28667	-96.9733	1201
3941702	Falls	8/4/1964	31.29028	-96.9653	3300
3941903	Falls	4/26/1961	31.26028	-96.9097	2120
3941903	Falls	8/3/1964	31.26028	-96.9097	2410
3941908	Falls	9/15/1999	31.26583	-96.9033	880
3941908	Falls	7/22/2004	31.26583	-96.9033	949
3941908	Falls	8/26/2009	31.26583	-96.9033	844
3941908	Falls	9/13/2016	31.26583	-96.9033	856
3941909	Falls	9/13/2016	31.26417	-96.9052	821
3941910	Falls	9/13/2016	31.26469	-96.905	814
3949301	Falls	4/26/1961	31.22972	-96.9017	3590
3949301	Falls	3/18/1980	31.22972	-96.9017	3192
3950101	Falls	8/13/1974	31.23139	-96.8608	1606
3950402	Falls	8/4/1964	31.20611	-96.8622	1450
3950410	Falls	7/20/1964	31.17389	-96.8644	2110
3950413	Falls	6/20/1963	31.17167	-96.8406	1170
3950421	Falls	6/20/1963	31.1875	-96.8511	1280
3950423	Falls	7/2/1963	31.19695	-96.8589	1460
3950426	Falls	6/20/1963	31.18306	-96.8408	1980
3950502	Falls	6/20/1963	31.17222	-96.8219	804
3950504	Falls	6/20/1963	31.17056	-96.82	788
3950801	Falls	7/2/1963	31.16028	-96.8303	2030
3950807	Falls	7/3/1963	31.13556	-96.7961	2820
3950813	Falls	6/20/1963	31.13028	-96.81	1780
3950814	Falls	4/26/1961	31.12667	-96.7936	4020
3950819	Falls	6/20/1963	31.13445	-96.8186	2080

State Well Number	County	Date	Latitude	Longitude	Specific Conductance (μS/cm)
3950903	Falls	7/3/1963	31.14695	-96.7861	4920
3950906	Falls	6/20/1963	31.13278	-96.7886	4160
3958204	Falls	6/21/1963	31.11583	-96.8169	2480
3958204	Falls	7/20/1964	31.11583	-96.8169	2330
3958210	Falls	6/20/1963	31.12056	-96.8094	1970
4048301	Falls	5/10/1961	31.37056	-97.0122	3150
4022201	McLennan	7/1/1963	31.73528	-97.2981	693
4022301	McLennan	7/1/1963	31.74333	-97.2811	2810
4023411	McLennan	9/13/2016	31.69586	-97.2137	1640
4023501	McLennan	7/1/1963	31.67056	-97.2008	646
4023801	McLennan	3/20/1963	31.65167	-97.1711	599
4023804	McLennan	8/3/1964	31.63639	-97.1739	763
4031617	McLennan	9/13/2016	31.5573	-97.1321	896
4032703	McLennan	5/10/1961	31.525	-97.0858	825
4032802	McLennan	7/29/1963	31.53556	-97.0697	721
4040202	McLennan	5/10/1961	31.49306	-97.0747	816
4040502	McLennan	7/12/1963	31.43278	-97.0489	911
4040505	McLennan	7/12/1963	31.42944	-97.0569	1130
4040509	McLennan	5/10/1961	31.4475	-97.0444	1180
4040601	McLennan	5/10/1961	31.42833	-97.0344	1340
4040801	McLennan	4/10/1969	31.41056	-97.0611	1395
4040801	McLennan	7/28/1980	31.41056	-97.0611	1204
4040801	McLennan	8/6/1993	31.41056	-97.0611	799
4040802	McLennan	7/10/1963	31.41028	-97.045	1020

Table D.2. TWDB historic ionic chemistry of the Brazos River Alluvium aquifer.

State Well Number	Date	Specific Conductance (µS/cm)	Latitude	Longitude	Sodium (mg/L)	Potassium (mg/L)	Magnesium (mg/L)	Calcium (mg/L)	Bicarbonate (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Nitrate (mg/L)
4023105	8/4/1993	N/A	31.7172	-97.2350	42.0	3.90	4.60	152.0	384	66.0	27.0	6.94
4023411	9/13/2016	1640	31.6959	-97.2137	53.9	1.67	40.6	247.0	336	77.6	117.0	N/A
4023804	8/3/1964	763	31.6364	-97.1739	17.0	1.80	25.0	117.0	414	26.0	51.0	N/A
4031617	9/13/2016	896	31.5573	-97.1321	47.9	1.82	7.22	135.0	321	29.8	93.8	N/A
4032703	5/10/1961	825	31.5250	-97.0858	48.0	1.60	7.20	113.0	318	67.0	46.0	N/A
4040202	5/10/1961	816	31.4931	-97.0747	33.0	0.90	4.50	135.0	358	36.0	49.0	N/A
4040509	5/10/1961	1180	31.4475	-97.0444	77.0	3.00	40.0	122.0	438	97.0	149.0	N/A
4040601	5/10/1961	1340	31.4283	-97.0344	116.0	2.60	26.0	142.0	428	107.0	151.0	N/A
4040801	8/6/1993	799	31.4106	-97.0611	88.0	2.40	5.80	132.0	365	53.0	86.0	17.75
3933701	9/15/1999	1590	31.3806	-96.9694	125.0	2.22	46.1	141.0	445	185.0	225.0	N/A
3941101	5/10/1961	940	31.3664	-96.9964	83.0	1.10	51.0	56.0	536	16.0	43.0	N/A
3941701	8/5/1993	1201	31.2867	-96.9733	88.0	3.90	44.0	248.0	295	192.0	219.0	11.07
3941702	8/4/1964	3300	31.2903	-96.9653	306.0	4.70	125.0	255.0	718	690.0	253.0	N/A
3941903	8/3/1964	2410	31.2603	-96.9097	312.0	3.70	48.0	181.0	732	310.0	303.0	N/A
3941908	9/13/2016	856	31.2658	-96.9033	53.7	0.94	39.5	78.2	370	12.1	38.5	N/A
3941909	9/13/2016	821	31.2642	-96.9052	60.3	1.84	33.1	82.2	434	9.0	23.2	N/A
3941910	9/13/2016	814	31.2647	-96.9050	52.5	1.34	36.3	79.6	379	15.9	29.8	N/A
3949301	3/18/1980	3192	31.2297	-96.9017	223.0	4.00	61.0	263.0	527	378.0	440.0	N/A
3950402	8/4/1964	1450	31.2061	-96.8622	136.0	3.30	39.0	142.0	648	104.0	125.0	N/A
3950410	7/20/1964	2110	31.1739	-96.8644	299.0	3.00	43.0	127.0	712	231.0	238.0	N/A
3950814	4/26/1961	4020	31.1267	-96.7936	380.0	4.40	136.0	320.0	574	880.0	473.0	N/A
3958204	7/20/1964	2330	31.1158	-96.8169	304.0	4.30	48.0	165.0	878	308.0	129.0	N/A
4048301	5/10/1961	3150	31.3706	-97.0122	295.0	3.10	159.0	175.0	602	575.0	408.0	N/A

Table D.3. TCEQ historic specific conductance data for the Brazos River.

Station ID	Date	Latitude	Longitude	Specific Conductance (μS/cm)
16782	11/29/2006	31.6923	-97.2313	3530
12044	12/13/2006	31.8122	-97.2973	3490
12044	3/1/2007	31.8122	-97.2973	3460
12044	9/13/2006	31.8122	-97.2973	3430
16782	8/30/2006	31.6923	-97.2313	3410
14226	8/15/2006	31.5517	-97.1017	3380
14226	8/15/2006	31.5517	-97.1017	3380
14226	8/15/2006	31.5517	-97.1017	3380
14226	8/15/2006	31.5517	-97.1017	3380
14226	8/15/2006	31.5517	-97.1017	3370
14226	8/15/2006	31.5517	-97.1017	3370
12044	6/28/2006	31.8122	-97.2973	3320
16782	5/30/2006	31.6923	-97.2313	3300
14226	8/30/2006	31.5517	-97.1017	3300
12044	9/14/2005	31.8122	-97.2973	3298
16782	2/21/2006	31.6923	-97.2313	3260
14226	2/21/2006	31.5517	-97.1017	3230
12044	3/15/2006	31.8122	-97.2973	3220
12038	8/24/2006	31.5361	-97.0739	3210
12038	12/20/2006	31.5361	-97.0739	3170
12044	8/17/1978	31.8122	-97.2973	3150
12044	12/14/2005	31.8122	-97.2973	3143
14226	5/30/2006	31.5517	-97.1017	3140
12038	11/30/2006	31.5361	-97.0739	3130
14226	5/30/2006	31.5517	-97.1017	3120
14226	5/30/2006	31.5517	-97.1017	3120
14226	5/30/2006	31.5517	-97.1017	3120
14226	5/30/2006	31.5517	-97.1017	3110
16782	10/26/2005	31.6923	-97.2313	3100
14226	11/29/2006	31.5517	-97.1017	3090
12038	9/28/2006	31.5361	-97.0739	3070
12032	8/24/1978	31.1339	-96.8250	3050
12037	10/26/2005	31.5000	-97.0506	3000
12037	10/26/2005	31.5000	-97.0506	3000
12037	10/26/2005	31.5000	-97.0506	3000
12032	8/24/2006	31.1339	-96.8250	3000
14226	10/26/2005	31.5517	-97.1017	2990
14226	10/26/2005	31.5517	-97.1017	2990
14226	10/26/2005	31.5517	-97.1017	2990

Station ID	Date	Latitude	Longitude	Specific Conductance (µS/cm)
14226	10/26/2005	31.5517	-97.1017	2980
16782	2/26/2007	31.6923	-97.2313	2960
14226	10/26/2005	31.5517	-97.1017	2960
12038	5/25/2006	31.5361	-97.0739	2862
12038	11/7/2005	31.5361	-97.0739	2834
12037	8/30/2006	31.5000	-97.0506	2750
12037	11/29/2006	31.5000	-97.0506	2750
12037	11/29/2006	31.5000	-97.0506	2740
12037	11/29/2006	31.5000	-97.0506	2740
12032	9/28/2006	31.1339	-96.8250	2640
12032	11/7/2005	31.1339	-96.8250	2615
12032	12/20/2006	31.1339	-96.8250	2570
14226	2/26/2007	31.5517	-97.1017	2560
14226	2/26/2007	31.5517	-97.1017	2560
14226	2/26/2007	31.5517	-97.1017	2560
14226	2/26/2007	31.5517	-97.1017	2550
14226	2/26/2007	31.5517	-97.1017	2550
12038	2/7/2006	31.5361	-97.0739	2482
12038	2/28/2007	31.5361	-97.0739	2460
12032	2/7/2006	31.1339	-96.8250	2431
12044	5/8/1986	31.8122	-97.2973	2420
12044	11/5/1985	31.8122	-97.2973	2320
12038	5/16/2007	31.5361	-97.0739	2280
12044	8/26/1986	31.8122	-97.2973	2210
12044	10/4/2011	31.8122	-97.2973	2200
12044	11/1/2011	31.8122	-97.2973	2190
16782	10/25/2011	31.6923	-97.2313	2140
12032	11/30/2006	31.1339	-96.8250	2130
12038	9/29/2011	31.5361	-97.0739	2100
12037	3/7/2006	31.5000	-97.0506	2100
12044	3/6/2012	31.8122	-97.2973	2100
16782	7/28/2005	31.6923	-97.2313	2097
12038	8/24/2011	31.5361	-97.0739	2060
12044	9/6/2011	31.8122	-97.2973	2060
14226	10/25/2011	31.5517	-97.1017	2050
12032	4/2/1981	31.1339	-96.8250	2050
14226	10/25/2011	31.5517	-97.1017	2040
12032	9/29/1981	31.1339	-96.8250	2040
12032	5/16/2007	31.1339	-96.8250	2030
12044	1/3/2012	31.8122	-97.2973	2030
12032	4/29/1987	31.1339	-96.8250	2020
12044	8/2/2011	31.8122	-97.2973	2020
12044	12/6/2011	31.8122	-97.2973	2020

Station ID	Date	Latitude	Longitude	Specific Conductance (µS/cm)
12044	4/2/2012	31.8122	-97.2973	2020
12032	7/26/1974	31.1339	-96.8250	2000
12044	10/23/1974	31.8122	-97.2973	2000
12044	9/11/1973	31.8122	-97.2973	2000
12044	1/15/1975	31.8122	-97.2973	2000
12044	2/10/1975	31.8122	-97.2973	2000
12044	8/5/1985	31.8122	-97.2973	1997
14226	10/25/2011	31.5517	-97.1017	1990
12032	1/22/1981	31.1339	-96.8250	1970
12032	12/20/1988	31.1339	-96.8250	1970
12032	2/23/1987	31.1339	-96.8250	1968
16782	8/3/2011	31.6923	-97.2313	1940
12032	7/31/1985	31.1339	-96.8250	1940
12044	1/26/2005	31.8122	-97.2973	1934
12032	5/28/1981	31.1339	-96.8250	1932
14226	10/25/2011	31.5517	-97.1017	1930
12038	7/27/2011	31.5361	-97.0739	1930
12044	9/1/2010	31.8122	-97.2973	1920
12044	7/5/2011	31.8122	-97.2973	1920
14226	10/25/2011	31.5517	-97.1017	1910
12038	4/26/2007	31.5361	-97.0739	1910
12038	11/30/2011	31.5361	-97.0739	1910
12032	9/29/2011	31.1339	-96.8250	1910
12032	12/30/1980	31.1339	-96.8250	1904
16782	2/22/2005	31.6923	-97.2313	1900
14226	8/3/2011	31.5517	-97.1017	1900
14226	8/3/2011	31.5517	-97.1017	1900
14226	8/3/2011	31.5517	-97.1017	1900
12032	5/7/1979	31.1339	-96.8250	1900
12032	3/6/1972	31.1339	-96.8250	1900
12032	8/19/1987	31.1339	-96.8250	1900
12044	4/26/1974	31.8122	-97.2973	1900
12044	6/4/1974	31.8122	-97.2973	1900
12044	3/28/1975	31.8122	-97.2973	1900
12044	5/10/1976	31.8122	-97.2973	1900
12044	9/4/2013	31.8122	-97.2973	1900
14226	2/22/2005	31.5517	-97.1017	1890
14226	2/22/2005	31.5517	-97.1017	1890
14226	2/22/2005	31.5517	-97.1017	1890
14226	2/22/2005	31.5517	-97.1017	1890
14226	8/3/2011	31.5517	-97.1017	1890
14226	8/3/2011	31.5517	-97.1017	1890
14226	8/3/2011	31.5517	-97.1017	1890

Station ID	Date	Latitude	Longitude	Specific Conductance (µS/cm)
12032	1/28/1986	31.1339	-96.8250	1890
12032	9/30/1986	31.1339	-96.8250	1879
14226	2/22/2005	31.5517	-97.1017	1870
12044	6/7/2007	31.8122	-97.2973	1870
12044	6/1/2011	31.8122	-97.2973	1870
16782	5/30/2007	31.6923	-97.2313	1860
14226	2/22/2005	31.5517	-97.1017	1860
12032	7/22/1986	31.1339	-96.8250	1860
12032	5/8/1985	31.1339	-96.8250	1860
12032	8/24/2011	31.1339	-96.8250	1860
12044	8/2/2010	31.8122	-97.2973	1860
12032	7/2/1981	31.1339	-96.8250	1855
12032	4/28/1988	31.1339	-96.8250	1850
12037	6/25/1991	31.5000	-97.0506	1840
12032	4/26/2007	31.1339	-96.8250	1840
12044	7/2/2015	31.8122	-97.2973	1840
12044	5/3/2011	31.8122	-97.2973	1830
12032	2/12/1981	31.1339	-96.8250	1826
12032	7/30/1985	31.1339	-96.8250	1824
12038	6/29/2011	31.5361	-97.0739	1820
12037	2/26/2007	31.5000	-97.0506	1820
12032	10/28/1987	31.1339	-96.8250	1820
16782	7/26/2010	31.6923	-97.2313	1810
12037	6/25/1991	31.5000	-97.0506	1810
12032	3/30/1987	31.1339	-96.8250	1806
12037	2/22/2005	31.5000	-97.0506	1800
12032	12/1/1972	31.1339	-96.8250	1800
12032	2/4/1987	31.1339	-96.8250	1800
12044	8/30/1976	31.8122	-97.2973	1800
12044	8/6/1974	31.8122	-97.2973	1800
12044	2/5/1974	31.8122	-97.2973	1800
12044	5/19/1975	31.8122	-97.2973	1800
12044	2/10/1976	31.8122	-97.2973	1800
12044	7/6/2010	31.8122	-97.2973	1800
12037	6/25/1991	31.5000	-97.0506	1790
12032	7/27/2011	31.1339	-96.8250	1790
12032	1/28/1982	31.1339	-96.8250	1783
12032	10/29/1986	31.1339	-96.8250	1780
12044	10/5/2010	31.8122	-97.2973	1780
12032	9/28/1987	31.1339	-96.8250	1777
12032	10/16/1972	31.1339	-96.8250	1775
12032	8/29/1985	31.1339	-96.8250	1774
12044	5/23/1988	31.8122	-97.2973	1770

Station ID	Date	Latitude	Longitude	Specific Conductance (μS/cm)
14226	7/28/2005	31.5517	-97.1017	1763
16782	4/26/2011	31.6923	-97.2313	1760
14226	7/28/2005	31.5517	-97.1017	1760
12038	6/25/1991	31.5361	-97.0739	1760
14226	7/28/2005	31.5517	-97.1017	1757
14226	7/28/2005	31.5517	-97.1017	1756
12044	12/4/1973	31.8122	-97.2973	1750
12044	11/2/2010	31.8122	-97.2973	1750
12044	12/1/2010	31.8122	-97.2973	1750
14226	7/28/2005	31.5517	-97.1017	1747
14226	7/28/2005	31.5517	-97.1017	1744
12032	5/29/1985	31.1339	-96.8250	1743
12032	7/30/1981	31.1339	-96.8250	1740
12032	5/12/1987	31.1339	-96.8250	1740
12032	3/26/1986	31.1339	-96.8250	1738
12032	4/29/1986	31.1339	-96.8250	1722
14226	7/26/2010	31.5517	-97.1017	1710
14226	7/26/2010	31.5517	-97.1017	1710
12038	1/25/2007	31.5361	-97.0739	1710
12038	5/25/2011	31.5361	-97.0739	1710
12037	8/3/2011	31.5000	-97.0506	1710
12032	8/29/1984	31.1339	-96.8250	1710
12044	4/15/2004	31.8122	-97.2973	1708
12032	2/25/1982	31.1339	-96.8250	1705
12032	7/23/1987	31.1339	-96.8250	1704
12038	10/27/2010	31.5361	-97.0739	1700
12032	3/20/1973	31.1339	-96.8250	1700
12032	12/3/1975	31.1339	-96.8250	1700
12032	3/23/1976	31.1339	-96.8250	1700
12032	11/20/1980	31.1339	-96.8250	1700
12044	10/1/1973	31.8122	-97.2973	1700
12044	1/15/1974	31.8122	-97.2973	1700
12044	12/16/1974	31.8122	-97.2973	1700
12044	1/3/2011	31.8122	-97.2973	1700
12044	11/5/2014	31.8122	-97.2973	1700
16782	11/2/2010	31.6923	-97.2313	1690
16782	4/29/2014	31.6923	-97.2313	1690
14226	11/2/2010	31.5517	-97.1017	1690
14226	11/2/2010	31.5517	-97.1017	1690
12037	6/25/1991	31.5000	-97.0506	1690
12032	2/17/1988	31.1339	-96.8250	1690
12044	6/1/2010	31.8122	-97.2973	1690
12032	7/27/1988	31.1339	-96.8250	1688

Station ID	Date	Latitude	Longitude	Specific Conductance (μS/cm)
12032	12/29/1981	31.1339	-96.8250	1686
12032	6/30/1986	31.1339	-96.8250	1685
14226	11/2/2010	31.5517	-97.1017	1680
14226	11/2/2010	31.5517	-97.1017	1680
14226	11/2/2010	31.5517	-97.1017	1680
14226	11/2/2010	31.5517	-97.1017	1680
14226	11/2/2010	31.5517	-97.1017	1680
12044	2/6/2013	31.8122	-97.2973	1680
12044	1/7/2015	31.8122	-97.2973	1680
16782	5/8/2012	31.6923	-97.2313	1670
14226	10/25/2011	31.5517	-97.1017	1670
12037	8/3/2011	31.5000	-97.0506	1670
12032	10/11/1991	31.1339	-96.8250	1670
12044	5/7/2014	31.8122	-97.2973	1670
12038	11/23/2010	31.5361	-97.0739	1660
12037	11/2/2010	31.5000	-97.0506	1660
12037	11/2/2010	31.5000	-97.0506	1660
12037	11/2/2010	31.5000	-97.0506	1660
12037	11/2/2010	31.5000	-97.0506	1660
12037	11/2/2010	31.5000	-97.0506	1660
12032	9/1/1988	31.1339	-96.8250	1660
12032	2/28/2007	31.1339	-96.8250	1660
12032	8/26/2010	31.1339	-96.8250	1660
12032	6/29/2011	31.1339	-96.8250	1660
12044	4/7/2005	31.8122	-97.2973	1654
12037	8/3/2011	31.5000	-97.0506	1650
12037	8/3/2011	31.5000	-97.0506	1650
12032	11/24/1972	31.1339	-96.8250	1650
12032	1/4/1989	31.1339	-96.8250	1649
12044	7/15/2004	31.8122	-97.2973	1648
12032	10/29/1981	31.1339	-96.8250	1644
12032	6/30/1988	31.1339	-96.8250	1642
14226	7/26/2010	31.5517	-97.1017	1640
12032	6/24/1991	31.1339	-96.8250	1640
12044	3/5/2014	31.8122	-97.2973	1640
12044	10/9/2013	31.8122	-97.2973	1630
12032	11/30/1981	31.1339	-96.8250	1629
12044	10/19/2004	31.8122	-97.2973	1626
12032	7/27/2005	31.1339	-96.8250	1625
12038	6/29/2010	31.5361	-97.0739	1620
12037	7/26/2010	31.5000	-97.0506	1620
12044	2/7/2011	31.8122	-97.2973	1620
12044	2/4/2015	31.8122	-97.2973	1620

Station ID	Date	Latitude	Longitude	Specific Conductance (µS/cm)
14226	5/8/2012	31.5517	-97.1017	1610
14226	5/8/2012	31.5517	-97.1017	1610
14226	5/8/2012	31.5517	-97.1017	1610
14226	5/8/2012	31.5517	-97.1017	1610
14226	5/8/2012	31.5517	-97.1017	1610
12038	6/25/1991	31.5361	-97.0739	1610
12032	11/23/2010	31.1339	-96.8250	1610
12044	4/2/2014	31.8122	-97.2973	1610
12044	10/6/2015	31.8122	-97.2973	1610
12038	2/9/2005	31.5361	-97.0739	1606
16782	8/16/2004	31.6923	-97.2313	1600
16782	8/21/2013	31.6923	-97.2313	1600
14226	4/26/2011	31.5517	-97.1017	1600
14226	4/26/2011	31.5517	-97.1017	1600
14226	4/26/2011	31.5517	-97.1017	1600
12038	7/27/2005	31.5361	-97.0739	1600
12038	10/25/2011	31.5361	-97.0739	1600
12032	6/16/1975	31.1339	-96.8250	1600
12032	8/26/1980	31.1339	-96.8250	1600
12032	10/27/2010	31.1339	-96.8250	1600
12044	4/4/2011	31.8122	-97.2973	1600
12044	8/7/2013	31.8122	-97.2973	1600
12044	6/3/2014	31.8122	-97.2973	1600
12044	9/10/2014	31.8122	-97.2973	1600
16782	11/4/2014	31.6923	-97.2313	1590
14226	5/8/2012	31.5517	-97.1017	1590
14226	5/8/2012	31.5517	-97.1017	1590
12044	5/7/2013	31.8122	-97.2973	1590
12044	11/5/2003	31.8122	-97.2973	1589
12032	10/27/1987	31.1339	-96.8250	1588
12032	8/15/1988	31.1339	-96.8250	1584
14226	7/26/2010	31.5517	-97.1017	1580
14226	4/26/2011	31.5517	-97.1017	1580
12044	12/4/2014	31.8122	-97.2973	1580
12038	6/25/1991	31.5361	-97.0739	1570
12044	7/2/2013	31.8122	-97.2973	1570
12044	10/2/2014	31.8122	-97.2973	1570
12032	10/27/1986	31.1339	-96.8250	1564
16782	7/24/2012	31.6923	-97.2313	1560
16782	8/6/2014	31.6923	-97.2313	1560
14226	2/14/2011	31.5517	-97.1017	1560
14226	2/14/2011	31.5517	-97.1017	1560
14226	2/14/2011	31.5517	-97.1017	1560

Station ID	Date	Latitude	Longitude	Specific Conductance (µS/cm)
12038	4/26/2011	31.5361	-97.0739	1560
12038	6/27/2012	31.5361	-97.0739	1560
12032	11/3/1981	31.1339	-96.8250	1560
12032	12/7/1981	31.1339	-96.8250	1560
12032	9/29/2010	31.1339	-96.8250	1560
12044	8/2/2012	31.8122	-97.2973	1560
12044	7/12/2012	31.8122	-97.2973	1560
12044	8/6/2014	31.8122	-97.2973	1560
16782	5/21/2013	31.6923	-97.2313	1550
12044	6/5/2013	31.8122	-97.2973	1550
14226	2/14/2011	31.5517	-97.1017	1540
12038	6/25/1991	31.5361	-97.0739	1540
12032	12/1/1993	31.1339	-96.8250	1540
12032	11/30/2011	31.1339	-96.8250	1540
12044	3/1/2011	31.8122	-97.2973	1540
12044	5/8/2012	31.8122	-97.2973	1540
12044	1/8/2014	31.8122	-97.2973	1540
16782	7/23/2003	31.6923	-97.2313	1539
12038	3/19/2014	31.5361	-97.0739	1530
12032	11/6/1992	31.1339	-96.8250	1530
12032	7/29/2010	31.1339	-96.8250	1530
14226	7/26/2010	31.5517	-97.1017	1520
14226	2/14/2011	31.5517	-97.1017	1520
14226	2/14/2011	31.5517	-97.1017	1520
12038	3/29/2007	31.5361	-97.0739	1520
12037	7/28/2005	31.5000	-97.0506	1520
12044	3/6/2013	31.8122	-97.2973	1520
12032	9/27/1984	31.1339	-96.8250	1518
14226	7/23/2012	31.5517	-97.1017	1510
14226	7/23/2012	31.5517	-97.1017	1510
14226	7/23/2012	31.5517	-97.1017	1510
14226	7/23/2012	31.5517	-97.1017	1510
14226	7/23/2012	31.5517	-97.1017	1510
12032	3/9/1982	31.1339	-96.8250	1510
12044	9/6/2012	31.8122	-97.2973	1510
14226	7/23/2003	31.5517	-97.1017	1509
14226	7/23/2003	31.5517	-97.1017	1507
12044	9/14/2000	31.8122	-97.2973	1507
14226	7/23/2003	31.5517	-97.1017	1506
14226	7/23/2003	31.5517	-97.1017	1505
14226	7/23/2003	31.5517	-97.1017	1505
14226	7/23/2012	31.5517	-97.1017	1500
14226	8/28/2013	31.5517	-97.1017	1500

Station ID	Date	Latitude	Longitude	Specific Conductance (µS/cm)
12038	9/25/2012	31.5361	-97.0739	1500
12032	8/28/1973	31.1339	-96.8250	1500
12032	12/11/1973	31.1339	-96.8250	1500
12032	1/18/1974	31.1339	-96.8250	1500
12032	6/22/1976	31.1339	-96.8250	1500
12032	3/6/1975	31.1339	-96.8250	1500
12032	3/7/1974	31.1339	-96.8250	1500
12032	9/23/1972	31.1339	-96.8250	1500
12044	8/25/1975	31.8122	-97.2973	1500
12044	11/3/1975	31.8122	-97.2973	1500
12044	10/17/2007	31.8122	-97.2973	1500
12044	4/10/2013	31.8122	-97.2973	1500
12044	2/5/2014	31.8122	-97.2973	1500
12037	7/23/2003	31.5000	-97.0506	1499
12037	7/23/2003	31.5000	-97.0506	1497
12037	7/23/2003	31.5000	-97.0506	1495
12038	5/18/2004	31.5361	-97.0739	1493
14226	8/28/2013	31.5517	-97.1017	1490
14226	8/28/2013	31.5517	-97.1017	1490
14226	8/28/2013	31.5517	-97.1017	1490
14226	8/28/2013	31.5517	-97.1017	1490
14226	8/28/2013	31.5517	-97.1017	1490
12038	7/24/2012	31.5361	-97.0739	1490
12044	12/5/2012	31.8122	-97.2973	1490
14226	4/26/2011	31.5517	-97.1017	1480
12037	4/26/2011	31.5000	-97.0506	1480
12037	4/26/2011	31.5000	-97.0506	1480
12037	4/26/2011	31.5000	-97.0506	1480
12032	4/25/1984	31.1339	-96.8250	1480
12044	4/2/2008	31.8122	-97.2973	1480
12044	11/3/2015	31.8122	-97.2973	1480
16782	11/13/2012	31.6923	-97.2313	1470
12038	5/26/2010	31.5361	-97.0739	1470
12032	5/25/2011	31.1339	-96.8250	1470
12032	9/25/2012	31.1339	-96.8250	1470
12044	3/4/2008	31.8122	-97.2973	1470
12044	5/8/2000	31.8122	-97.2973	1463
14226	7/26/2010	31.5517	-97.1017	1460
12038	2/23/2011	31.5361	-97.0739	1460
12038	8/29/2012	31.5361	-97.0739	1460
12037	7/23/2012	31.5000	-97.0506	1460
12037	7/23/2012	31.5000	-97.0506	1460
12037	7/23/2012	31.5000	-97.0506	1460

Station ID	Date	Latitude	Longitude	Specific Conductance (μS/cm)
12032	10/24/1985	31.1339	-96.8250	1460
12032	2/15/1994	31.1339	-96.8250	1460
12032	8/29/2012	31.1339	-96.8250	1460
12044	12/11/2007	31.8122	-97.2973	1460
12044	11/13/2007	31.8122	-97.2973	1460
12044	2/5/2008	31.8122	-97.2973	1460
12044	10/2/2012	31.8122	-97.2973	1460
12044	1/15/2013	31.8122	-97.2973	1460
12032	5/19/1988	31.1339	-96.8250	1451
16782	11/14/2007	31.6923	-97.2313	1450
16782	5/11/2010	31.6923	-97.2313	1450
12038	8/27/2013	31.5361	-97.0739	1450
12038	8/17/2015	31.5361	-97.0739	1450
12044	6/27/1978	31.8122	-97.2973	1450
12044	9/2/2015	31.8122	-97.2973	1450
12032	10/10/1985	31.1339	-96.8250	1445
14226	4/29/2014	31.5517	-97.1017	1440
14226	4/29/2014	31.5517	-97.1017	1440
14226	4/29/2014	31.5517	-97.1017	1440
14226	4/29/2014	31.5517	-97.1017	1440
12032	8/3/1992	31.1339	-96.8250	1440
12032	6/29/2010	31.1339	-96.8250	1440
16782	2/16/2011	31.6923	-97.2313	1430
16782	7/29/2015	31.6923	-97.2313	1430
14226	7/23/2012	31.5517	-97.1017	1430
14226	4/29/2014	31.5517	-97.1017	1430
12044	9/1/2009	31.8122	-97.2973	1430
12044	8/4/2015	31.8122	-97.2973	1430
14226	4/29/2014	31.5517	-97.1017	1420
12032	9/30/1985	31.1339	-96.8250	1420
12032	7/24/2012	31.1339	-96.8250	1420
12044	11/6/2012	31.8122	-97.2973	1420
16782	5/9/2000	31.6923	-97.2313	1410
16782	2/25/2013	31.6923	-97.2313	1410
14226	11/14/2007	31.5517	-97.1017	1410
14226	4/29/2014	31.5517	-97.1017	1410
12038	9/29/2010	31.5361	-97.0739	1410
12032	7/31/1991	31.1339	-96.8250	1410
12032	7/28/1993	31.1339	-96.8250	1410
12032	8/30/1984	31.1339	-96.8250	1406
14226	1/29/1997	31.5517	-97.1017	1405
16782	8/28/2007	31.6923	-97.2313	1400
14226	11/14/2007	31.5517	-97.1017	1400

Station ID	Date	Latitude	Longitude	Specific Conductance (μS/cm)
14226	11/14/2007	31.5517	-97.1017	1400
14226	11/14/2012	31.5517	-97.1017	1400
14226	11/14/2012	31.5517	-97.1017	1400
14226	11/14/2012	31.5517	-97.1017	1400
14226	11/14/2012	31.5517	-97.1017	1400
12038	10/30/2012	31.5361	-97.0739	1400
12032	7/24/1973	31.1339	-96.8250	1400
12032	7/31/1984	31.1339	-96.8250	1400
12032	4/22/1975	31.1339	-96.8250	1400
12032	9/30/1980	31.1339	-96.8250	1400
12032	2/25/1986	31.1339	-96.8250	1400
12044	11/5/1973	31.8122	-97.2973	1400
12044	7/8/2009	31.8122	-97.2973	1400
16782	10/25/2001	31.6923	-97.2313	1397
16782	5/13/2003	31.6923	-97.2313	1397
14226	1/29/1997	31.5517	-97.1017	1396
14226	10/7/1997	31.5517	-97.1017	1390
14226	11/14/2007	31.5517	-97.1017	1390
14226	11/14/2012	31.5517	-97.1017	1390
14226	11/14/2012	31.5517	-97.1017	1390
14226	11/14/2012	31.5517	-97.1017	1390
14226	11/14/2012	31.5517	-97.1017	1390
14226	10/7/1997	31.5517	-97.1017	1389
14226	10/7/1997	31.5517	-97.1017	1389
12038	7/14/2004	31.5361	-97.0739	1389
14226	10/7/1997	31.5517	-97.1017	1388
14226	10/7/1997	31.5517	-97.1017	1385
12044	10/4/2000	31.8122	-97.2973	1385
14226	1/29/1997	31.5517	-97.1017	1382
12032	1/28/1987	31.1339	-96.8250	1382
16782	5/18/2015	31.6923	-97.2313	1380
14226	8/30/2004	31.5517	-97.1017	1380
14226	8/30/2004	31.5517	-97.1017	1380
14226	8/30/2004	31.5517	-97.1017	1380
14226	11/14/2007	31.5517	-97.1017	1380
14226	4/26/2011	31.5517	-97.1017	1380
14226	5/21/2013	31.5517	-97.1017	1380
14226	5/21/2013	31.5517	-97.1017	1380
14226	5/21/2013	31.5517	-97.1017	1380
14226	5/21/2013	31.5517	-97.1017	1380
14226	5/21/2013	31.5517	-97.1017	1380
12038	2/5/2008	31.5361	-97.0739	1380
12038	5/30/2012	31.5361	-97.0739	1380

Station ID	Date	Latitude	Longitude	Specific Conductance (μS/cm)
12038	5/21/2013	31.5361	-97.0739	1380
12037	4/29/2014	31.5000	-97.0506	1380
12037	4/29/2014	31.5000	-97.0506	1380
12037	4/29/2014	31.5000	-97.0506	1380
12044	1/2/2008	31.8122	-97.2973	1380
12044	8/4/2009	31.8122	-97.2973	1380
14226	1/29/1997	31.5517	-97.1017	1379
12044	6/10/2003	31.8122	-97.2973	1379
14226	1/29/1997	31.5517	-97.1017	1376
12032	9/6/2000	31.1339	-96.8250	1375
12032	8/6/2003	31.1339	-96.8250	1375
12038	12/28/2010	31.5361	-97.0739	1370
12038	11/29/2012	31.5361	-97.0739	1370
12038	12/18/2012	31.5361	-97.0739	1370
12037	2/14/2011	31.5000	-97.0506	1370
12037	2/14/2011	31.5000	-97.0506	1370
12044	3/11/2003	31.8122	-97.2973	1369
16782	8/9/2001	31.6923	-97.2313	1368
14226	1/29/1997	31.5517	-97.1017	1368
12032	4/19/1989	31.1339	-96.8250	1364
12044	10/5/2000	31.8122	-97.2973	1364
12044	11/6/2002	31.8122	-97.2973	1364
12038	5/11/2005	31.5361	-97.0739	1363
16782	8/5/2009	31.6923	-97.2313	1360
14226	7/29/2015	31.5517	-97.1017	1360
14226	7/29/2015	31.5517	-97.1017	1360
14226	7/29/2015	31.5517	-97.1017	1360
14226	7/29/2015	31.5517	-97.1017	1360
14226	7/29/2015	31.5517	-97.1017	1360
14226	7/29/2015	31.5517	-97.1017	1360
12038	12/19/2007	31.5361	-97.0739	1360
12038	8/21/2007	31.5361	-97.0739	1360
12038	8/26/2010	31.5361	-97.0739	1360
12038	6/25/2013	31.5361	-97.0739	1360
12037	11/14/2007	31.5000	-97.0506	1360
12037	2/14/2011	31.5000	-97.0506	1360
12032	10/13/1993	31.1339	-96.8250	1360
12032	10/13/1993	31.1339	-96.8250	1360
12044	8/23/2001	31.8122	-97.2973	1360
12044	9/10/2007	31.8122	-97.2973	1360
12044	3/3/2009	31.8122	-97.2973	1360
12044	6/3/2009	31.8122	-97.2973	1360
12038	8/6/2001	31.5361	-97.0739	1359

Station ID	Date	Latitude	Longitude	Specific Conductance (µS/cm)
12038	10/11/2000	31.5361	-97.0739	1358
12044	8/2/2000	31.8122	-97.2973	1358
12038	9/6/2000	31.5361	-97.0739	1357
14226	10/25/2001	31.5517	-97.1017	1353
14226	10/25/2001	31.5517	-97.1017	1353
16782	2/19/2001	31.6923	-97.2313	1352
14226	10/25/2001	31.5517	-97.1017	1350
12038	7/29/2010	31.5361	-97.0739	1350
12032	7/26/1994	31.1339	-96.8250	1350
12032	8/17/2015	31.1339	-96.8250	1350
14226	10/25/2001	31.5517	-97.1017	1349
14226	7/18/1994	31.5517	-97.1017	1346
14226	7/18/1994	31.5517	-97.1017	1346
14226	10/25/2001	31.5517	-97.1017	1346
14226	10/25/2001	31.5517	-97.1017	1345
12044	8/14/2001	31.8122	-97.2973	1344
14226	7/18/1994	31.5517	-97.1017	1343
12038	11/5/2001	31.5361	-97.0739	1343
16782	11/14/2002	31.6923	-97.2313	1342
14226	7/18/2001	31.5517	-97.1017	1342
12044	2/7/2002	31.8122	-97.2973	1341
14226	7/18/2001	31.5517	-97.1017	1340
12038	7/22/2009	31.5361	-97.0739	1340
12037	7/29/2015	31.5000	-97.0506	1340
12044	6/4/2008	31.8122	-97.2973	1340
12044	2/4/2009	31.8122	-97.2973	1340
14226	7/18/2001	31.5517	-97.1017	1339
12044	12/12/2001	31.8122	-97.2973	1339
14226	7/18/2001	31.5517	-97.1017	1337
14226	7/18/2001	31.5517	-97.1017	1335
12032	5/18/2004	31.1339	-96.8250	1335
12037	7/19/2001	31.5000	-97.0506	1334
16782	8/16/2000	31.6923	-97.2313	1331
14226	7/25/2000	31.5517	-97.1017	1331
12038	8/26/2014	31.5361	-97.0739	1330
12037	10/25/2011	31.5000	-97.0506	1330
12037	10/25/2011	31.5000	-97.0506	1330
12037	5/8/2012	31.5000	-97.0506	1330
12044	4/2/2009	31.8122	-97.2973	1330
16782	2/26/2003	31.6923	-97.2313	1329
14226	7/25/2000	31.5517	-97.1017	1329
14226	7/25/2000	31.5517	-97.1017	1328
14226	7/25/2000	31.5517	-97.1017	1328

Station ID	Date	Latitude	Longitude	Specific Conductance (μS/cm)
14226	7/25/2000	31.5517	-97.1017	1328
14226	7/25/2000	31.5517	-97.1017	1327
14226	7/25/2000	31.5517	-97.1017	1326
12038	8/2/2000	31.5361	-97.0739	1322
16782	7/30/2008	31.6923	-97.2313	1320
14226	11/14/2002	31.5517	-97.1017	1320
12037	10/25/2011	31.5000	-97.0506	1320
12037	5/8/2012	31.5000	-97.0506	1320
12044	12/7/2000	31.8122	-97.2973	1320
14226	11/14/2002	31.5517	-97.1017	1319
14226	11/14/2002	31.5517	-97.1017	1319
14226	11/14/2002	31.5517	-97.1017	1319
14226	11/14/2002	31.5517	-97.1017	1318
12032	8/6/2001	31.1339	-96.8250	1315
12032	3/25/1985	31.1339	-96.8250	1313
12044	7/17/1984	31.8122	-97.2973	1312
12044	6/6/2002	31.8122	-97.2973	1312
12044	3/13/2002	31.8122	-97.2973	1311
12038	11/29/2007	31.5361	-97.0739	1310
12037	5/8/2012	31.5000	-97.0506	1310
12037	5/8/2012	31.5000	-97.0506	1310
12032	10/25/2007	31.1339	-96.8250	1310
12032	7/22/2009	31.1339	-96.8250	1310
12037	11/14/2002	31.5000	-97.0506	1302
12038	7/10/2001	31.5361	-97.0739	1301
12032	6/29/1987	31.1339	-96.8250	1301
16782	2/18/2009	31.6923	-97.2313	1300
14226	8/5/2009	31.5517	-97.1017	1300
14226	8/5/2009	31.5517	-97.1017	1300
14226	8/5/2009	31.5517	-97.1017	1300
12038	4/22/2014	31.5361	-97.0739	1300
12037	8/28/2013	31.5000	-97.0506	1300
12037	8/28/2013	31.5000	-97.0506	1300
12037	8/28/2013	31.5000	-97.0506	1300
12032	10/28/1974	31.1339	-96.8250	1300
12032	7/31/1980	31.1339	-96.8250	1300
12032	6/20/1974	31.1339	-96.8250	1300
12032	1/31/2008	31.1339	-96.8250	1300
12032	12/18/2012	31.1339	-96.8250	1300
12032	8/27/2013	31.1339	-96.8250	1300
12044	8/16/1977	31.8122	-97.2973	1300
12044	7/2/1974	31.8122	-97.2973	1300
12044	12/3/2008	31.8122	-97.2973	1300

Station ID	Date	Latitude	Longitude	Specific Conductance (μS/cm)
12044	12/4/2013	31.8122	-97.2973	1300
16782	5/15/2002	31.6923	-97.2313	1297
16782	8/8/2002	31.6923	-97.2313	1290
12032	8/21/2007	31.1339	-96.8250	1290
12032	12/28/2010	31.1339	-96.8250	1290
12044	1/6/2009	31.8122	-97.2973	1290
12044	6/20/2001	31.8122	-97.2973	1288
14226	10/10/1996	31.5517	-97.1017	1287
14226	10/10/1996	31.5517	-97.1017	1286
12044	4/17/1984	31.8122	-97.2973	1285
14226	10/10/1996	31.5517	-97.1017	1284
12044	7/11/2002	31.8122	-97.2973	1284
12044	3/1/2002	31.8122	-97.2973	1284
12044	4/30/2001	31.8122	-97.2973	1283
14226	8/8/2002	31.5517	-97.1017	1282
14226	8/8/2002	31.5517	-97.1017	1282
12037	10/25/2001	31.5000	-97.0506	1281
12032	8/2/2000	31.1339	-96.8250	1281
16782	11/17/2008	31.6923	-97.2313	1280
14226	8/8/2002	31.5517	-97.1017	1280
14226	2/25/2008	31.5517	-97.1017	1280
14226	2/25/2008	31.5517	-97.1017	1280
14226	2/25/2008	31.5517	-97.1017	1280
14226	7/30/2008	31.5517	-97.1017	1280
14226	7/30/2008	31.5517	-97.1017	1280
14226	7/30/2008	31.5517	-97.1017	1280
14226	8/5/2009	31.5517	-97.1017	1280
12038	6/24/2008	31.5361	-97.0739	1280
12037	10/25/2001	31.5000	-97.0506	1280
12032	4/13/1982	31.1339	-96.8250	1280
12032	2/13/1985	31.1339	-96.8250	1280
12032	5/26/2010	31.1339	-96.8250	1280
12032	8/26/2014	31.1339	-96.8250	1280
12044	4/9/2002	31.8122	-97.2973	1280
12044	8/13/2002	31.8122	-97.2973	1280
12044	8/13/2002	31.8122	-97.2973	1280
12044	3/1/2002	31.8122	-97.2973	1280
12044	11/5/2008	31.8122	-97.2973	1280
12044	4/8/2015	31.8122	-97.2973	1280
14226	8/8/2002	31.5517	-97.1017	1279
14226	8/8/2002	31.5517	-97.1017	1279
14226	10/10/1996	31.5517	-97.1017	1278
14226	10/10/1996	31.5517	-97.1017	1278

Station ID	Date	Latitude	Longitude	Specific Conductance (µS/cm)
12037	8/19/2002	31.5000	-97.0506	1278
12032	4/14/1982	31.1339	-96.8250	1277
12037	10/25/2001	31.5000	-97.0506	1275
12032	12/30/1985	31.1339	-96.8250	1275
12044	8/6/2002	31.8122	-97.2973	1274
14226	2/19/2001	31.5517	-97.1017	1271
16782	11/30/1999	31.6923	-97.2313	1270
14226	7/30/2008	31.5517	-97.1017	1270
14226	7/30/2008	31.5517	-97.1017	1270
14226	7/30/2008	31.5517	-97.1017	1270
14226	7/30/2008	31.5517	-97.1017	1270
14226	7/30/2008	31.5517	-97.1017	1270
12038	9/17/2014	31.5361	-97.0739	1270
12032	6/22/1982	31.1339	-96.8250	1270
12032	10/30/1989	31.1339	-96.8250	1270
12032	9/17/2014	31.1339	-96.8250	1270
12032	7/16/2015	31.1339	-96.8250	1270
12044	8/5/2008	31.8122	-97.2973	1270
12044	7/1/2008	31.8122	-97.2973	1270
16782	5/8/2001	31.6923	-97.2313	1268
12044	5/7/2002	31.8122	-97.2973	1266
12038	9/8/1999	31.5361	-97.0739	1265
12038	10/26/2006	31.5361	-97.0739	1260
12038	8/18/2009	31.5361	-97.0739	1260
12044	12/1/2009	31.8122	-97.2973	1260
12032	11/4/1996	31.1339	-96.8250	1258
12044	4/19/2001	31.8122	-97.2973	1256
14226	8/8/1996	31.5517	-97.1017	1254
14226	8/8/1996	31.5517	-97.1017	1254
14226	8/8/1996	31.5517	-97.1017	1254
14226	8/8/1996	31.5517	-97.1017	1254
14226	8/8/1996	31.5517	-97.1017	1254
14226	8/8/1996	31.5517	-97.1017	1254
12044	1/7/2002	31.8122	-97.2973	1254
14226	10/10/1996	31.5517	-97.1017	1253
12044	7/9/2001	31.8122	-97.2973	1253
16782	1/13/2000	31.6923	-97.2313	1250
14226	2/25/2008	31.5517	-97.1017	1250
14226	2/25/2008	31.5517	-97.1017	1250
12038	10/25/2007	31.5361	-97.0739	1250
12038	2/27/2008	31.5361	-97.0739	1250
12038	12/30/2008	31.5361	-97.0739	1250
12038	3/27/2012	31.5361	-97.0739	1250

Station ID	Date	Latitude	Longitude	Specific Conductance (µS/cm)
12032	5/21/1974	31.1339	-96.8250	1250
12032	8/9/1972	31.1339	-96.8250	1250
12032	10/3/2000	31.1339	-96.8250	1250
12032	6/24/2008	31.1339	-96.8250	1250
12032	3/19/2014	31.1339	-96.8250	1250
12044	5/9/1985	31.8122	-97.2973	1250
12044	9/3/2008	31.8122	-97.2973	1250
12044	10/1/2008	31.8122	-97.2973	1250
12044	11/2/2009	31.8122	-97.2973	1250
12037	2/19/2001	31.5000	-97.0506	1249
12044	8/9/1999	31.8122	-97.2973	1249
14226	8/16/1999	31.5517	-97.1017	1247
12037	7/18/2000	31.5000	-97.0506	1247
14226	8/16/1999	31.5517	-97.1017	1246
12037	7/18/2000	31.5000	-97.0506	1246
12037	7/18/2000	31.5000	-97.0506	1246
14226	8/16/1999	31.5517	-97.1017	1245
12032	1/28/1985	31.1339	-96.8250	1245
14226	8/16/1999	31.5517	-97.1017	1244
12037	7/18/2000	31.5000	-97.0506	1244
12032	11/17/1997	31.1339	-96.8250	1243
14226	8/16/1999	31.5517	-97.1017	1242
14226	8/16/1999	31.5517	-97.1017	1242
12032	7/14/2004	31.1339	-96.8250	1242
12038	7/31/2008	31.5361	-97.0739	1240
12038	1/28/2009	31.5361	-97.0739	1240
12038	9/29/2015	31.5361	-97.0739	1240
12032	12/29/1982	31.1339	-96.8250	1240
12032	7/31/2008	31.1339	-96.8250	1240
12032	6/25/2013	31.1339	-96.8250	1240
12044	11/2/2016	31.8122	-97.2973	1240
12038	10/5/1999	31.5361	-97.0739	1236
16782	1/9/2002	31.6923	-97.2313	1230
14226	11/19/2008	31.5517	-97.1017	1230
12032	5/26/1987	31.1339	-96.8250	1230
12044	1/4/2010	31.8122	-97.2973	1230
12044	12/2/2015	31.8122	-97.2973	1230
12032	11/5/2001	31.1339	-96.8250	1225
12038	8/5/2002	31.5361	-97.0739	1224
12032	10/11/2000	31.1339	-96.8250	1222
14226	11/19/2008	31.5517	-97.1017	1220
14226	11/19/2008	31.5517	-97.1017	1220
14226	11/19/2008	31.5517	-97.1017	1220

Station ID	Date	Latitude	Longitude	Specific Conductance (µS/cm)
14226	11/19/2008	31.5517	-97.1017	1220
14226	11/19/2008	31.5517	-97.1017	1220
14226	11/19/2008	31.5517	-97.1017	1220
14226	11/19/2008	31.5517	-97.1017	1220
14226	8/5/2009	31.5517	-97.1017	1220
14226	8/6/2014	31.5517	-97.1017	1220
14226	8/6/2014	31.5517	-97.1017	1220
12038	4/24/2008	31.5361	-97.0739	1220
12038	4/26/2012	31.5361	-97.0739	1220
12038	7/31/2013	31.5361	-97.0739	1220
12037	5/10/2006	31.5000	-97.0506	1220
12032	9/19/1973	31.1339	-96.8250	1220
12032	5/27/1986	31.1339	-96.8250	1220
12032	1/19/1983	31.1339	-96.8250	1220
12032	8/14/1996	31.1339	-96.8250	1220
12032	2/23/2011	31.1339	-96.8250	1220
12044	5/6/2015	31.8122	-97.2973	1220
12038	10/1/2001	31.5361	-97.0739	1215
12038	8/3/1999	31.5361	-97.0739	1213
12032	9/10/1997	31.1339	-96.8250	1213
12032	11/25/1986	31.1339	-96.8250	1211
16782	5/28/2008	31.6923	-97.2313	1210
14226	8/6/2014	31.5517	-97.1017	1210
14226	8/6/2014	31.5517	-97.1017	1210
14226	8/6/2014	31.5517	-97.1017	1210
14226	8/6/2014	31.5517	-97.1017	1210
12032	6/7/1989	31.1339	-96.8250	1210
12032	9/8/1999	31.1339	-96.8250	1202
16782	2/3/2015	31.6923	-97.2313	1200
14226	8/26/1998	31.5517	-97.1017	1200
14226	8/6/2014	31.5517	-97.1017	1200
12038	9/22/2008	31.5361	-97.0739	1200
12032	11/6/1974	31.1339	-96.8250	1200
12032	2/17/1975	31.1339	-96.8250	1200
12032	8/16/1974	31.1339	-96.8250	1200
12032	6/13/1972	31.1339	-96.8250	1200
12032	12/7/1992	31.1339	-96.8250	1200
12032	10/26/2006	31.1339	-96.8250	1200
12032	4/24/2008	31.1339	-96.8250	1200
12032	12/30/2008	31.1339	-96.8250	1200
12032	8/18/2009	31.1339	-96.8250	1200
12044	2/1/2012	31.8122	-97.2973	1200
14226	5/15/2002	31.5517	-97.1017	1197

Station ID	Date	Latitude	Longitude	Specific Conductance (μS/cm)
14226	5/15/2002	31.5517	-97.1017	1197
12032	9/30/1982	31.1339	-96.8250	1197
12032	5/25/2006	31.1339	-96.8250	1197
14226	7/23/1998	31.5517	-97.1017	1196
14226	7/23/1998	31.5517	-97.1017	1196
12032	6/22/1998	31.1339	-96.8250	1196
12032	8/3/1999	31.1339	-96.8250	1196
14226	7/23/1998	31.5517	-97.1017	1195
14226	7/23/1998	31.5517	-97.1017	1195
14226	7/23/1998	31.5517	-97.1017	1195
14226	7/23/1998	31.5517	-97.1017	1194
14226	5/15/2002	31.5517	-97.1017	1194
12038	11/2/2000	31.5361	-97.0739	1193
14226	5/15/2002	31.5517	-97.1017	1192
14226	5/27/1998	31.5517	-97.1017	1190
12037	5/21/2013	31.5000	-97.0506	1190
12037	5/21/2013	31.5000	-97.0506	1190
12037	8/6/2014	31.5000	-97.0506	1190
12032	8/24/1982	31.1339	-96.8250	1190
12032	8/17/1983	31.1339	-96.8250	1190
12032	1/26/1995	31.1339	-96.8250	1190
12044	2/1/2010	31.8122	-97.2973	1190
14226	5/27/1998	31.5517	-97.1017	1186
14226	5/15/2002	31.5517	-97.1017	1184
12038	9/1/1998	31.5361	-97.0739	1184
14226	5/15/2002	31.5517	-97.1017	1182
14226	8/28/2007	31.5517	-97.1017	1180
12038	9/24/2002	31.5361	-97.0739	1180
12038	3/25/2013	31.5361	-97.0739	1180
12038	12/22/2014	31.5361	-97.0739	1180
12038	7/16/2015	31.5361	-97.0739	1180
12037	7/30/2008	31.5000	-97.0506	1180
12037	8/5/2009	31.5000	-97.0506	1180
12037	8/5/2009	31.5000	-97.0506	1180
12037	8/5/2009	31.5000	-97.0506	1180
12037	5/21/2013	31.5000	-97.0506	1180
12037	8/6/2014	31.5000	-97.0506	1180
12032	6/23/1982	31.1339	-96.8250	1180
12032	4/15/1986	31.1339	-96.8250	1180
12032	11/29/2007	31.1339	-96.8250	1180
12032	2/27/2008	31.1339	-96.8250	1180
16782	5/19/2005	31.6923	-97.2313	1177
12038	6/18/1998	31.5361	-97.0739	1177

Station ID	Date	Latitude	Longitude	Specific Conductance (μS/cm)
12038	8/4/1998	31.5361	-97.0739	1177
12032	6/8/1973	31.1339	-96.8250	1175
12032	8/4/1998	31.1339	-96.8250	1175
12032	6/18/1998	31.1339	-96.8250	1174
12044	2/21/2003	31.8122	-97.2973	1171
16782	11/17/2015	31.6923	-97.2313	1170
14226	8/30/2004	31.5517	-97.1017	1170
14226	8/28/2007	31.5517	-97.1017	1170
12038	9/20/2007	31.5361	-97.0739	1170
12037	8/6/2014	31.5000	-97.0506	1170
14226	5/27/1998	31.5517	-97.1017	1169
14226	5/27/1998	31.5517	-97.1017	1167
14226	5/27/1998	31.5517	-97.1017	1161
16782	2/4/2014	31.6923	-97.2313	1160
14226	8/28/2007	31.5517	-97.1017	1160
14226	8/28/2007	31.5517	-97.1017	1160
14226	8/5/2009	31.5517	-97.1017	1160
12038	11/25/2008	31.5361	-97.0739	1160
12037	8/28/2007	31.5000	-97.0506	1160
12037	2/25/2008	31.5000	-97.0506	1160
12037	2/25/2008	31.5000	-97.0506	1160
12037	2/25/2008	31.5000	-97.0506	1160
12037	2/25/2008	31.5000	-97.0506	1160
12037	11/19/2008	31.5000	-97.0506	1160
12037	11/19/2008	31.5000	-97.0506	1160
12037	11/19/2008	31.5000	-97.0506	1160
12032	11/19/1991	31.1339	-96.8250	1160
12032	7/10/2001	31.1339	-96.8250	1160
14226	5/27/1998	31.5517	-97.1017	1157
12044	3/26/2001	31.8122	-97.2973	1156
12032	5/11/2005	31.1339	-96.8250	1154
12032	9/24/2002	31.1339	-96.8250	1151
14226	8/28/2007	31.5517	-97.1017	1150
14226	8/28/2007	31.5517	-97.1017	1150
14226	5/11/2010	31.5517	-97.1017	1150
14226	5/11/2010	31.5517	-97.1017	1150
14226	5/11/2010	31.5517	-97.1017	1150
14226	5/11/2010	31.5517	-97.1017	1150
14226	5/11/2010	31.5517	-97.1017	1150
14226	5/11/2010	31.5517	-97.1017	1150
12037	2/25/2008	31.5000	-97.0506	1150
12032	12/19/2007	31.1339	-96.8250	1150
12044	11/5/2013	31.8122	-97.2973	1150

Station ID	Date	Latitude	Longitude	Specific Conductance (μS/cm)
12044	10/5/2016	31.8122	-97.2973	1150
12032	11/30/1982	31.1339	-96.8250	1146
14226	7/15/1997	31.5517	-97.1017	1144
14226	7/15/1997	31.5517	-97.1017	1143
14226	7/15/1997	31.5517	-97.1017	1141
14226	7/15/1997	31.5517	-97.1017	1141
14226	7/15/1997	31.5517	-97.1017	1141
16782	5/20/2004	31.6923	-97.2313	1140
16782	11/16/2016	31.6923	-97.2313	1140
12038	7/19/2007	31.5361	-97.0739	1140
12038	10/23/2008	31.5361	-97.0739	1140
12032	11/8/1982	31.1339	-96.8250	1140
12032	10/18/1988	31.1339	-96.8250	1140
12032	11/9/1983	31.1339	-96.8250	1140
12032	2/20/2001	31.1339	-96.8250	1140
12032	7/19/2007	31.1339	-96.8250	1140
12032	1/28/2009	31.1339	-96.8250	1140
12032	10/30/2012	31.1339	-96.8250	1140
12032	4/22/2014	31.1339	-96.8250	1140
14226	7/15/1997	31.5517	-97.1017	1139
12038	5/29/2008	31.5361	-97.0739	1130
12038	2/25/2009	31.5361	-97.0739	1130
12038	1/25/2012	31.5361	-97.0739	1130
12037	11/14/2012	31.5000	-97.0506	1130
12037	11/14/2012	31.5000	-97.0506	1130
12037	11/14/2012	31.5000	-97.0506	1130
12032	7/11/1983	31.1339	-96.8250	1130
12032	6/27/2012	31.1339	-96.8250	1130
12032	9/29/2015	31.1339	-96.8250	1130
12032	10/5/1999	31.1339	-96.8250	1122
14226	8/5/2009	31.5517	-97.1017	1120
12037	5/11/2010	31.5000	-97.0506	1120
12037	5/11/2010	31.5000	-97.0506	1120
12037	5/11/2010	31.5000	-97.0506	1120
12037	5/11/2010	31.5000	-97.0506	1120
12032	8/11/1997	31.1339	-96.8250	1120
12032	11/29/2012	31.1339	-96.8250	1120
12032	9/1/1998	31.1339	-96.8250	1116
14226	8/5/2009	31.5517	-97.1017	1110
12038	1/21/2015	31.5361	-97.0739	1110
12032	3/8/1995	31.1339	-96.8250	1110
12032	2/25/2009	31.1339	-96.8250	1110
12044	7/31/1989	31.8122	-97.2973	1110

Station ID	Date	Latitude	Longitude	Specific Conductance (µS/cm)
12044	7/1/2014	31.8122	-97.2973	1110
12032	5/26/1998	31.1339	-96.8250	1106
12032	6/13/2001	31.1339	-96.8250	1105
12038	12/3/1997	31.5361	-97.0739	1101
16782	10/20/2003	31.6923	-97.2313	1100
16782	2/22/2017	31.6923	-97.2313	1100
14226	11/4/2014	31.5517	-97.1017	1100
14226	11/4/2014	31.5517	-97.1017	1100
14226	11/4/2014	31.5517	-97.1017	1100
14226	11/4/2014	31.5517	-97.1017	1100
14226	11/4/2014	31.5517	-97.1017	1100
12038	7/28/2014	31.5361	-97.0739	1100
12032	9/29/1975	31.1339	-96.8250	1100
12032	1/9/1975	31.1339	-96.8250	1100
12032	2/1/1984	31.1339	-96.8250	1100
12032	11/25/2008	31.1339	-96.8250	1100
12044	6/3/2015	31.8122	-97.2973	1100
12032	8/18/1997	31.1339	-96.8250	1098
12032	10/1/2001	31.1339	-96.8250	1097
12044	11/28/2000	31.8122	-97.2973	1092
16782	2/24/2010	31.6923	-97.2313	1090
14226	5/28/2008	31.5517	-97.1017	1090
14226	11/4/2014	31.5517	-97.1017	1090
14226	11/4/2014	31.5517	-97.1017	1090
12038	7/7/1998	31.5361	-97.0739	1090
12032	7/31/2013	31.1339	-96.8250	1090
12032	10/20/2016	31.1339	-96.8250	1090
12032	10/14/1997	31.1339	-96.8250	1087
12038	12/1/1999	31.5361	-97.0739	1086
12032	11/24/1987	31.1339	-96.8250	1086
12032	10/1/1998	31.1339	-96.8250	1083
12032	1/13/1999	31.1339	-96.8250	1083
12044	10/5/1983	31.8122	-97.2973	1082
14226	2/18/2009	31.5517	-97.1017	1080
14226	2/18/2009	31.5517	-97.1017	1080
14226	2/18/2009	31.5517	-97.1017	1080
14226	2/18/2009	31.5517	-97.1017	1080
14226	2/18/2009	31.5517	-97.1017	1080
14226	2/18/2009	31.5517	-97.1017	1080
12038	9/24/2013	31.5361	-97.0739	1080
12032	11/24/1987	31.1339	-96.8250	1080
12032	4/26/2011	31.1339	-96.8250	1080
12044	3/2/2010	31.8122	-97.2973	1080

Station ID	Date	Latitude	Longitude	Specific Conductance (μS/cm)
12044	6/5/2012	31.8122	-97.2973	1080
12044	4/13/2016	31.8122	-97.2973	1080
12032	12/1/1999	31.1339	-96.8250	1079
12032	7/9/1997	31.1339	-96.8250	1079
12032	4/30/1984	31.1339	-96.8250	1073
16782	8/9/2017	31.6923	-97.2313	1070
12032	6/14/1987	31.1339	-96.8250	1070
12032	12/22/2009	31.1339	-96.8250	1070
12032	7/28/2014	31.1339	-96.8250	1070
12032	8/5/2002	31.1339	-96.8250	1069
12032	3/31/1982	31.1339	-96.8250	1067
12044	2/12/1986	31.8122	-97.2973	1067
12038	7/8/2003	31.5361	-97.0739	1066
12032	7/7/1998	31.1339	-96.8250	1066
12032	2/1/2000	31.1339	-96.8250	1065
14226	11/15/1999	31.5517	-97.1017	1064
12038	6/13/2001	31.5361	-97.0739	1064
12038	11/3/1999	31.5361	-97.0739	1062
16782	2/26/2004	31.6923	-97.2313	1060
14226	2/14/1996	31.5517	-97.1017	1060
14226	11/17/2015	31.5517	-97.1017	1060
12032	12/22/2014	31.1339	-96.8250	1060
12044	9/7/2016	31.8122	-97.2973	1060
12032	3/2/1999	31.1339	-96.8250	1058
12038	9/10/1997	31.5361	-97.0739	1056
12038	3/13/2001	31.5361	-97.0739	1056
12032	4/5/2001	31.1339	-96.8250	1056
14226	5/28/2008	31.5517	-97.1017	1050
14226	11/17/2015	31.5517	-97.1017	1050
12038	10/20/2016	31.5361	-97.0739	1050
12032	10/23/2008	31.1339	-96.8250	1050
12032	5/21/2013	31.1339	-96.8250	1050
12032	9/21/2016	31.1339	-96.8250	1050
12032	1/27/1988	31.1339	-96.8250	1049
12032	1/4/2000	31.1339	-96.8250	1049
12032	2/20/1996	31.1339	-96.8250	1043
16782	8/24/2016	31.6923	-97.2313	1040
14226	8/30/2004	31.5517	-97.1017	1040
14226	5/28/2008	31.5517	-97.1017	1040
14226	5/28/2008	31.5517	-97.1017	1040
14226	2/3/2015	31.5517	-97.1017	1040
14226	2/3/2015	31.5517	-97.1017	1040
14226	2/3/2015	31.5517	-97.1017	1040

Station ID	Date	Latitude	Longitude	Specific Conductance (μS/cm)
14226	2/3/2015	31.5517	-97.1017	1040
14226	2/3/2015	31.5517	-97.1017	1040
14226	2/3/2015	31.5517	-97.1017	1040
14226	11/17/2015	31.5517	-97.1017	1040
14226	11/17/2015	31.5517	-97.1017	1040
12038	4/22/2009	31.5361	-97.0739	1040
12038	3/29/2011	31.5361	-97.0739	1040
12032	12/4/1990	31.1339	-96.8250	1040
12032	4/23/2013	31.1339	-96.8250	1040
12044	7/14/1999	31.8122	-97.2973	1040
12038	3/5/2002	31.5361	-97.0739	1038
12032	11/20/1996	31.1339	-96.8250	1038
12032	11/3/1999	31.1339	-96.8250	1036
12044	6/8/1999	31.8122	-97.2973	1036
12044	5/11/1999	31.8122	-97.2973	1031
14226	5/28/2008	31.5517	-97.1017	1030
14226	11/17/2015	31.5517	-97.1017	1030
12032	7/18/2000	31.1339	-96.8250	1030
12032	9/22/2008	31.1339	-96.8250	1030
12032	5/30/2012	31.1339	-96.8250	1030
12044	5/14/2008	31.8122	-97.2973	1030
14226	5/8/2001	31.5517	-97.1017	1029
12032	2/28/1984	31.1339	-96.8250	1029
12032	11/2/2000	31.1339	-96.8250	1029
14226	5/8/2001	31.5517	-97.1017	1027
14226	2/14/1996	31.5517	-97.1017	1025
14226	5/8/2001	31.5517	-97.1017	1025
12032	7/8/2003	31.1339	-96.8250	1023
12038	6/10/2003	31.5361	-97.0739	1022
12038	7/1/2002	31.5361	-97.0739	1021
12032	3/18/1998	31.1339	-96.8250	1021
14226	11/17/2015	31.5517	-97.1017	1020
14226	8/9/2017	31.5517	-97.1017	1020
14226	8/9/2017	31.5517	-97.1017	1020
14226	8/9/2017	31.5517	-97.1017	1020
12038	2/24/2014	31.5361	-97.0739	1020
12037	2/18/2009	31.5000	-97.0506	1020
12032	1/25/2007	31.1339	-96.8250	1020
12032	5/29/2008	31.1339	-96.8250	1020
12032	1/30/1997	31.1339	-96.8250	1018
12038	7/10/1997	31.5361	-97.0739	1016
12032	11/22/1988	31.1339	-96.8250	1016
12032	6/10/2003	31.1339	-96.8250	1015

Station ID	Date	Latitude	Longitude	Specific Conductance (μS/cm)
14226	8/9/2017	31.5517	-97.1017	1010
12038	12/22/2009	31.5361	-97.0739	1010
12037	2/18/2009	31.5000	-97.0506	1010
12037	11/4/2014	31.5000	-97.0506	1010
12032	4/26/2012	31.1339	-96.8250	1010
12032	3/27/2012	31.1339	-96.8250	1010
14226	5/8/2001	31.5517	-97.1017	1008
12032	10/28/1982	31.1339	-96.8250	1008
12038	4/5/2001	31.5361	-97.0739	1006
12032	8/28/1986	31.1339	-96.8250	1003
12032	5/21/1998	31.1339	-96.8250	1003
12037	2/18/2009	31.5000	-97.0506	1000
12037	11/4/2014	31.5000	-97.0506	1000
12037	11/4/2014	31.5000	-97.0506	1000
12032	5/25/1972	31.1339	-96.8250	1000
12032	12/4/1974	31.1339	-96.8250	1000
12044	4/5/2010	31.8122	-97.2973	1000
12044	5/3/2010	31.8122	-97.2973	1000
14226	8/9/2017	31.5517	-97.1017	997
12032	3/6/1995	31.1339	-96.8250	997
12032	5/31/1983	31.1339	-96.8250	996
14226	5/8/2001	31.5517	-97.1017	993
12032	12/29/1986	31.1339	-96.8250	992
12032	10/15/2002	31.1339	-96.8250	986.2
12032	11/29/2016	31.1339	-96.8250	986
12038	1/4/2000	31.5361	-97.0739	985
12044	8/9/2016	31.8122	-97.2973	985
12037	5/30/2007	31.5000	-97.0506	984
12044	10/10/2001	31.8122	-97.2973	982.7
14226	1/9/2002	31.5517	-97.1017	982
14226	10/19/1994	31.5517	-97.1017	981
12038	3/2/1999	31.5361	-97.0739	980
12032	11/29/1978	31.1339	-96.8250	980
14226	2/14/1996	31.5517	-97.1017	978
14226	5/9/2017	31.5517	-97.1017	976
14226	5/9/2017	31.5517	-97.1017	976
12032	6/13/2007	31.1339	-96.8250	976
12032	9/20/2007	31.1339	-96.8250	976
12032	3/2/1988	31.1339	-96.8250	975
12038	5/23/2001	31.5361	-97.0739	973.79
12032	2/24/2014	31.1339	-96.8250	973
12038	6/13/2007	31.5361	-97.0739	972
14226	2/4/2014	31.5517	-97.1017	971

Station ID	Date	Latitude	Longitude	Specific Conductance (µS/cm)
14226	5/9/2017	31.5517	-97.1017	971
14226	2/4/2014	31.5517	-97.1017	970
14226	2/4/2014	31.5517	-97.1017	968
14226	2/4/2014	31.5517	-97.1017	967
14226	8/9/2017	31.5517	-97.1017	967
12032	4/6/1998	31.1339	-96.8250	967
14226	2/4/2014	31.5517	-97.1017	966
12032	8/31/1982	31.1339	-96.8250	966
16782	11/16/2009	31.6923	-97.2313	965
14226	2/4/2014	31.5517	-97.1017	965
14226	2/4/2014	31.5517	-97.1017	965
12037	1/13/2000	31.5000	-97.0506	965
12044	9/12/2001	31.8122	-97.2973	963.1
14226	2/22/2017	31.5517	-97.1017	963
14226	2/22/2017	31.5517	-97.1017	962
14226	5/25/1995	31.5517	-97.1017	961
14226	5/25/1995	31.5517	-97.1017	961
14226	2/22/2017	31.5517	-97.1017	961
14226	2/22/2017	31.5517	-97.1017	961
14226	10/15/1998	31.5517	-97.1017	960
14226	2/22/2017	31.5517	-97.1017	960
12032	3/29/1983	31.1339	-96.8250	960
14226	10/15/1998	31.5517	-97.1017	958
14226	2/14/1996	31.5517	-97.1017	957
14226	10/15/1998	31.5517	-97.1017	957
14226	10/15/1998	31.5517	-97.1017	957
14226	10/15/1998	31.5517	-97.1017	956
14226	10/15/1998	31.5517	-97.1017	956
14226	2/22/2017	31.5517	-97.1017	956
12044	7/6/2016	31.8122	-97.2973	956
14226	2/14/1996	31.5517	-97.1017	954
14226	5/9/2017	31.5517	-97.1017	954
14226	2/22/2017	31.5517	-97.1017	953
12037	2/3/2015	31.5000	-97.0506	953
12037	2/3/2015	31.5000	-97.0506	950
12032	1/22/1973	31.1339	-96.8250	950
12032	6/30/1997	31.1339	-96.8250	949
14226	5/30/2007	31.5517	-97.1017	948
14226	5/25/1995	31.5517	-97.1017	947
12037	11/16/1999	31.5000	-97.0506	947
12037	11/16/1999	31.5000	-97.0506	947
12037	2/3/2015	31.5000	-97.0506	947
14226	2/22/2017	31.5517	-97.1017	946

Station ID	Date	Latitude	Longitude	Specific Conductance (μS/cm)
12038	10/20/2014	31.5361	-97.0739	945
12037	11/16/1999	31.5000	-97.0506	945
12032	10/20/2014	31.1339	-96.8250	945
12032	2/3/2003	31.1339	-96.8250	944.3
12032	7/30/1982	31.1339	-96.8250	942
12032	7/26/2016	31.1339	-96.8250	942
12032	8/31/1987	31.1339	-96.8250	940
12032	3/3/2001	31.1339	-96.8250	940
12032	5/14/2003	31.1339	-96.8250	939.8
12032	3/5/2002	31.1339	-96.8250	939.6
12032	3/29/2011	31.1339	-96.8250	939
12044	3/3/2016	31.8122	-97.2973	937
12032	11/13/2014	31.1339	-96.8250	935
12032	5/18/1998	31.1339	-96.8250	931
12037	3/25/1991	31.5000	-97.0506	930
12032	8/21/1990	31.1339	-96.8250	929
14226	5/30/2007	31.5517	-97.1017	928
12032	2/19/2015	31.1339	-96.8250	928
14226	1/13/1999	31.5517	-97.1017	925
12032	10/31/1983	31.1339	-96.8250	925
12032	5/13/1997	31.1339	-96.8250	925
12032	3/27/2008	31.1339	-96.8250	925
12032	1/21/2015	31.1339	-96.8250	923
14226	5/30/2007	31.5517	-97.1017	922
14226	5/30/2007	31.5517	-97.1017	922
14226	5/30/2007	31.5517	-97.1017	922
14226	5/30/2007	31.5517	-97.1017	921
12038	2/19/2015	31.5361	-97.0739	921
12037	5/10/2001	31.5000	-97.0506	921
16782	2/17/2016	31.6923	-97.2313	920
12038	10/15/2002	31.5361	-97.0739	919.6
12037	8/9/2017	31.5000	-97.0506	919
12037	3/25/1991	31.5000	-97.0506	918
12037	5/10/2001	31.5000	-97.0506	918
12037	8/9/2017	31.5000	-97.0506	917
12037	5/10/2001	31.5000	-97.0506	916
12037	8/9/2017	31.5000	-97.0506	916
12037	5/9/2017	31.5000	-97.0506	916
14226	5/9/2017	31.5517	-97.1017	915
12037	5/10/2001	31.5000	-97.0506	915
12037	5/9/2017	31.5000	-97.0506	915
12037	5/9/2017	31.5000	-97.0506	914
12032	1/31/1984	31.1339	-96.8250	914

Station ID	Date	Latitude	Longitude	Specific Conductance (µS/cm)
12037	2/4/2014	31.5000	-97.0506	911
12037	2/4/2014	31.5000	-97.0506	911
14226	5/9/2017	31.5517	-97.1017	910
12037	2/4/2014	31.5000	-97.0506	908
14226	5/9/2017	31.5517	-97.1017	907
12032	4/23/1991	31.1339	-96.8250	906
12032	4/29/2010	31.1339	-96.8250	906
12038	11/29/2016	31.5361	-97.0739	905
14226	2/17/2016	31.5517	-97.1017	904
14226	2/26/2003	31.5517	-97.1017	903
12032	6/28/1983	31.1339	-96.8250	903
14226	2/17/2016	31.5517	-97.1017	902
14226	2/17/2016	31.5517	-97.1017	902
14226	5/9/2017	31.5517	-97.1017	902
14226	2/17/2016	31.5517	-97.1017	901
14226	2/17/2016	31.5517	-97.1017	901
12044	2/3/2016	31.8122	-97.2973	901
12038	1/26/2011	31.5361	-97.0739	900
12037	4/30/2002	31.5000	-97.0506	900
12037	4/30/2002	31.5000	-97.0506	900
12037	4/30/2002	31.5000	-97.0506	900
14226	2/17/2016	31.5517	-97.1017	899
12038	6/24/2009	31.5361	-97.0739	899
12038	4/23/2013	31.5361	-97.0739	899
12032	3/30/1988	31.1339	-96.8250	899
16782	11/28/2000	31.6923	-97.2313	897
14226	2/17/2016	31.5517	-97.1017	895
12032	7/6/1995	31.1339	-96.8250	895
12037	3/26/1991	31.5000	-97.0506	894
12037	1/9/2002	31.5000	-97.0506	894
12038	9/21/2016	31.5361	-97.0739	893
14226	5/13/2003	31.5517	-97.1017	891
14226	5/13/2003	31.5517	-97.1017	891
14226	5/13/2003	31.5517	-97.1017	891
14226	5/13/2003	31.5517	-97.1017	891
14226	5/13/2003	31.5517	-97.1017	889
12044	1/6/2016	31.8122	-97.2973	884
12037	5/13/2003	31.5000	-97.0506	882
12037	5/13/2003	31.5000	-97.0506	882
12032	6/22/2001	31.1339	-96.8250	882
16782	11/18/2013	31.6923	-97.2313	880
12037	5/28/2008	31.5000	-97.0506	880
12038	5/14/2003	31.5361	-97.0739	879.9

Station ID	Date	Latitude	Longitude	Specific Conductance (µS/cm)
14226	2/25/2013	31.5517	-97.1017	877
14226	2/25/2013	31.5517	-97.1017	876
14226	2/25/2013	31.5517	-97.1017	876
14226	2/25/2013	31.5517	-97.1017	875
14226	2/25/2013	31.5517	-97.1017	875
12037	5/13/2003	31.5000	-97.0506	873
12032	5/4/1999	31.1339	-96.8250	873
16782	5/9/2017	31.6923	-97.2313	872
12037	3/26/1991	31.5000	-97.0506	872
12037	5/13/2003	31.5000	-97.0506	871
12038	2/26/2013	31.5361	-97.0739	870
12037	5/28/2008	31.5000	-97.0506	870
12038	6/3/2002	31.5361	-97.0739	869.4
12032	3/25/2013	31.1339	-96.8250	869
12044	5/5/1987	31.8122	-97.2973	869
12044	11/13/2001	31.8122	-97.2973	867.8
12032	2/25/2010	31.1339	-96.8250	867
16782	5/18/2009	31.6923	-97.2313	866
12032	6/4/1997	31.1339	-96.8250	865
14226	4/14/1997	31.5517	-97.1017	862
14226	4/14/1997	31.5517	-97.1017	862
12032	6/12/1996	31.1339	-96.8250	862
14226	4/14/1997	31.5517	-97.1017	861
14226	4/14/1997	31.5517	-97.1017	861
12044	11/6/2000	31.8122	-97.2973	861
12037	2/22/2017	31.5000	-97.0506	858
12037	2/22/2017	31.5000	-97.0506	858
12037	2/22/2017	31.5000	-97.0506	857
12037	2/22/2017	31.5000	-97.0506	857
12032	5/19/1982	31.1339	-96.8250	857
12032	6/28/2016	31.1339	-96.8250	856
14226	4/14/1997	31.5517	-97.1017	854
12032	4/26/2016	31.1339	-96.8250	853
12038	12/11/2002	31.5361	-97.0739	852
12032	8/3/1989	31.1339	-96.8250	852
12037	2/17/2016	31.5000	-97.0506	850
12037	2/17/2016	31.5000	-97.0506	850
12037	2/17/2016	31.5000	-97.0506	849
12032	11/30/1983	31.1339	-96.8250	847
12032	2/26/2013	31.1339	-96.8250	847
12032	7/28/1986	31.1339	-96.8250	846
12038	4/1/2003	31.5361	-97.0739	845
12037	2/25/2013	31.5000	-97.0506	841

Station ID	Date	Latitude	Longitude	Specific Conductance (μS/cm)
12032	1/26/2011	31.1339	-96.8250	840
12037	2/25/2013	31.5000	-97.0506	839
12032	5/6/1998	31.1339	-96.8250	839
12044	5/4/2016	31.8122	-97.2973	839
12037	5/28/2008	31.5000	-97.0506	838
12037	2/25/2013	31.5000	-97.0506	838
12032	4/29/1996	31.1339	-96.8250	838
12038	11/13/2014	31.5361	-97.0739	837
12038	7/26/2016	31.5361	-97.0739	836
12032	6/24/2009	31.1339	-96.8250	834
12032	4/16/1997	31.1339	-96.8250	833
16782	5/23/2016	31.6923	-97.2313	831
12032	5/20/1993	31.1339	-96.8250	831
12038	1/13/1999	31.5361	-97.0739	826
12032	11/10/2004	31.1339	-96.8250	826
12044	6/2/2016	31.8122	-97.2973	826
12032	7/29/1983	31.1339	-96.8250	823
12044	10/6/2009	31.8122	-97.2973	822
12044	9/16/1974	31.8122	-97.2973	820
12032	5/21/1990	31.1339	-96.8250	818
12032	6/3/2002	31.1339	-96.8250	817.6
12032	2/1/1999	31.1339	-96.8250	815
12038	5/6/2002	31.5361	-97.0739	814.4
12032	12/3/2001	31.1339	-96.8250	813.9
14226	11/16/2016	31.5517	-97.1017	810
12044	2/11/1985	31.8122	-97.2973	808
14226	11/16/2016	31.5517	-97.1017	803
12038	4/26/2016	31.5361	-97.0739	803
14226	11/16/2016	31.5517	-97.1017	802
12038	4/29/2010	31.5361	-97.0739	801
14226	11/16/2016	31.5517	-97.1017	800
12038	4/24/1998	31.5361	-97.0739	800
12038	2/25/2010	31.5361	-97.0739	800
12032	11/15/1984	31.1339	-96.8250	800
12044	11/11/1974	31.8122	-97.2973	800
16782	11/2/2004	31.6923	-97.2313	799
14226	11/16/2016	31.5517	-97.1017	799
12038	11/11/2004	31.5361	-97.0739	799
12032	7/1/2002	31.1339	-96.8250	798.5
12032	3/13/2001	31.1339	-96.8250	797.09
14226	11/16/2016	31.5517	-97.1017	795
14226	1/19/1995	31.5517	-97.1017	794
12032	4/28/1995	31.1339	-96.8250	794

Station ID	Date	Latitude	Longitude	Specific Conductance (µS/cm)
14226	5/18/2015	31.5517	-97.1017	793
14226	1/19/1995	31.5517	-97.1017	792
14226	1/19/1995	31.5517	-97.1017	792
12038	3/30/2010	31.5361	-97.0739	791
14226	5/18/2015	31.5517	-97.1017	790
14226	5/18/2015	31.5517	-97.1017	790
14226	5/18/2015	31.5517	-97.1017	790
12038	1/29/2013	31.5361	-97.0739	790
12038	6/28/2016	31.5361	-97.0739	790
14226	5/18/2015	31.5517	-97.1017	788
12032	4/22/1998	31.1339	-96.8250	788
14226	5/18/2015	31.5517	-97.1017	787
12038	11/19/2015	31.5361	-97.0739	786
12032	10/29/1980	31.1339	-96.8250	786
12038	8/6/2003	31.5361	-97.0739	784.1
12032	1/26/2016	31.1339	-96.8250	778
12044	5/6/2009	31.8122	-97.2973	775
12032	12/17/2013	31.1339	-96.8250	774
12038	12/22/2015	31.5361	-97.0739	770
12038	2/3/2003	31.5361	-97.0739	768.6
12032	6/1/1999	31.1339	-96.8250	767
12038	1/26/2016	31.5361	-97.0739	765
12037	8/24/2016	31.5000	-97.0506	765
12037	8/24/2016	31.5000	-97.0506	765
12037	8/24/2016	31.5000	-97.0506	765
12032	12/29/2011	31.1339	-96.8250	763
12032	3/23/2016	31.1339	-96.8250	756
16782	2/6/2012	31.6923	-97.2313	754
12032	5/14/2001	31.1339	-96.8250	748.4
12038	11/4/1998	31.5361	-97.0739	746
12032	6/19/1997	31.1339	-96.8250	744
12038	5/4/1999	31.5361	-97.0739	742
12038	3/23/2016	31.5361	-97.0739	738
12037	11/16/2009	31.5000	-97.0506	736
12038	1/27/2014	31.5361	-97.0739	735
12037	10/20/2003	31.5000	-97.0506	735
12037	10/20/2003	31.5000	-97.0506	734
12037	10/20/2003	31.5000	-97.0506	733
12032	9/20/1990	31.1339	-96.8250	733
12038	4/4/2000	31.5361	-97.0739	731
12032	10/25/2011	31.1339	-96.8250	730
12032	12/22/2015	31.1339	-96.8250	726
12038	4/6/1999	31.5361	-97.0739	723

Station ID	Date	Latitude	Longitude	Specific Conductance (μS/cm)
12032	5/6/2002	31.1339	-96.8250	721.3
12032	1/29/2013	31.1339	-96.8250	720
12038	3/27/2008	31.5361	-97.0739	716
12032	6/18/2015	31.1339	-96.8250	715
12032	6/26/1985	31.1339	-96.8250	713
12038	8/22/2016	31.5361	-97.0739	711
12038	6/1/1999	31.5361	-97.0739	707
12032	5/2/2000	31.1339	-96.8250	704
12032	2/9/2005	31.1339	-96.8250	704
14226	8/24/2016	31.5517	-97.1017	703
12032	1/27/2014	31.1339	-96.8250	701
14226	8/24/2016	31.5517	-97.1017	699
14226	8/24/2016	31.5517	-97.1017	699
14226	8/24/2016	31.5517	-97.1017	698
12032	3/30/1984	31.1339	-96.8250	698
14226	8/24/2016	31.5517	-97.1017	697
12032	10/31/1985	31.1339	-96.8250	697
12038	5/13/1997	31.5361	-97.0739	696
14226	3/30/1999	31.5517	-97.1017	695
12038	2/24/2016	31.5361	-97.0739	692
12032	3/30/2010	31.1339	-96.8250	692
14226	8/24/2016	31.5517	-97.1017	690
14226	5/23/2016	31.5517	-97.1017	690
12032	4/10/2000	31.1339	-96.8250	690
14226	5/23/2016	31.5517	-97.1017	689
14226	5/23/2016	31.5517	-97.1017	688
12032	2/23/1988	31.1339	-96.8250	688
14226	5/23/2016	31.5517	-97.1017	687
14226	5/23/2016	31.5517	-97.1017	683
14226	5/23/2016	31.5517	-97.1017	682
12032	4/29/1985	31.1339	-96.8250	682
12032	4/27/1995	31.1339	-96.8250	682
12032	1/27/2010	31.1339	-96.8250	681
14226	3/30/1999	31.5517	-97.1017	679
14226	5/23/2016	31.5517	-97.1017	679
12038	11/24/2009	31.5361	-97.0739	679
12032	2/12/1993	31.1339	-96.8250	678
14226	3/30/1999	31.5517	-97.1017	676
12037	11/16/2016	31.5000	-97.0506	676
14226	3/30/1999	31.5517	-97.1017	675
12037	11/16/2016	31.5000	-97.0506	675
12037	11/16/2016	31.5000	-97.0506	675
12038	3/2/2000	31.5361	-97.0739	674

Station ID	Date	Latitude	Longitude	Specific Conductance (µS/cm)
12037	11/16/2016	31.5000	-97.0506	674
14226	3/30/1999	31.5517	-97.1017	672
12038	7/12/2000	31.5361	-97.0739	672
12032	2/3/2004	31.1339	-96.8250	670
14226	3/30/1999	31.5517	-97.1017	669
12038	12/17/2013	31.5361	-97.0739	669
12032	5/24/2016	31.1339	-96.8250	663
12037	5/23/2016	31.5000	-97.0506	662
12037	5/23/2016	31.5000	-97.0506	662
12037	5/23/2016	31.5000	-97.0506	662
12038	6/19/1997	31.5361	-97.0739	661
12038	8/19/2008	31.5361	-97.0739	661
12032	11/24/2009	31.1339	-96.8250	660
12032	1/29/1992	31.1339	-96.8250	654
14226	10/20/2003	31.5517	-97.1017	653
12032	6/9/1980	31.1339	-96.8250	650
12032	1/23/1991	31.1339	-96.8250	650
12032	3/25/1997	31.1339	-96.8250	649
12038	5/24/2016	31.5361	-97.0739	646
12038	6/18/2014	31.5361	-97.0739	638
14226	10/20/2003	31.5517	-97.1017	637
12037	8/30/2004	31.5000	-97.0506	637
12038	12/29/2011	31.5361	-97.0739	634
12032	12/6/2000	31.1339	-96.8250	633
12038	5/14/2015	31.5361	-97.0739	631
12032	4/1/2003	31.1339	-96.8250	627
14226	10/20/2003	31.5517	-97.1017	624
14226	10/20/2003	31.5517	-97.1017	621
12037	5/19/2005	31.5000	-97.0506	621
12032	5/24/1988	31.1339	-96.8250	620
12032	7/12/2000	31.1339	-96.8250	620
14226	11/28/2000	31.5517	-97.1017	619
12037	5/18/2015	31.5000	-97.0506	618
12037	5/27/2009	31.5000	-97.0506	612
12037	5/27/2009	31.5000	-97.0506	612
12037	5/27/2009	31.5000	-97.0506	612
12037	5/27/2009	31.5000	-97.0506	612
12038	5/27/2009	31.5361	-97.0739	611
12032	2/26/1986	31.1339	-96.8250	611
14226	5/18/2009	31.5517	-97.1017	608
14226	10/20/2003	31.5517	-97.1017	607
12032	2/29/2012	31.1339	-96.8250	607
12038	10/30/2003	31.5361	-97.0739	604

Station ID	Date	Latitude	Longitude	Specific Conductance (µS/cm)
12032	1/13/1998	31.1339	-96.8250	604
12032	2/27/1985	31.1339	-96.8250	603
14226	11/16/2009	31.5517	-97.1017	602
14226	11/16/2009	31.5517	-97.1017	602
14226	11/16/2009	31.5517	-97.1017	600
14226	11/18/2013	31.5517	-97.1017	600
12037	11/18/2013	31.5000	-97.0506	600
12032	2/21/1980	31.1339	-96.8250	600
14226	11/28/2000	31.5517	-97.1017	599
14226	11/16/2009	31.5517	-97.1017	599
14226	11/18/2013	31.5517	-97.1017	599
12037	11/18/2013	31.5000	-97.0506	599
14226	11/16/2009	31.5517	-97.1017	598
14226	11/16/2009	31.5517	-97.1017	598
14226	11/16/2009	31.5517	-97.1017	597
14226	11/16/2009	31.5517	-97.1017	597
14226	11/18/2013	31.5517	-97.1017	596
12037	11/18/2013	31.5000	-97.0506	596
14226	11/28/2000	31.5517	-97.1017	595
12032	5/25/1983	31.1339	-96.8250	595
14226	11/18/2013	31.5517	-97.1017	594
12032	11/28/1984	31.1339	-96.8250	592
12037	11/17/2015	31.5000	-97.0506	589
12032	4/22/2009	31.1339	-96.8250	588
12032	6/27/1984	31.1339	-96.8250	587
14226	2/23/1998	31.5517	-97.1017	586
14226	5/19/2005	31.5517	-97.1017	585
14226	11/28/2000	31.5517	-97.1017	584
14226	5/19/2005	31.5517	-97.1017	584
12032	4/26/1983	31.1339	-96.8250	584
12032	2/24/2016	31.1339	-96.8250	582
14226	11/18/2013	31.5517	-97.1017	581
12044	10/22/1984	31.8122	-97.2973	581
12032	3/24/2009	31.1339	-96.8250	580
14226	11/18/2013	31.5517	-97.1017	576
12037	11/28/2000	31.5000	-97.0506	576
14226	11/28/2000	31.5517	-97.1017	575
14226	5/19/2005	31.5517	-97.1017	575
14226	11/18/2013	31.5517	-97.1017	575
12037	11/28/2000	31.5000	-97.0506	575
12032	5/31/1984	31.1339	-96.8250	575
12037	11/28/2000	31.5000	-97.0506	572
12037	11/28/2000	31.5000	-97.0506	571

Station ID	Date	Latitude	Longitude	Specific Conductance (μS/cm)
12044	3/10/2015	31.8122	-97.2973	568
12038	2/1/2000	31.5361	-97.0739	566
14226	5/19/2005	31.5517	-97.1017	565
12038	12/3/2001	31.5361	-97.0739	564.7
12038	5/14/2014	31.5361	-97.0739	564
14226	5/26/2004	31.5517	-97.1017	563
14226	5/26/2004	31.5517	-97.1017	563
12032	4/6/1999	31.1339	-96.8250	563
12032	1/31/1983	31.1339	-96.8250	562
12032	2/28/1983	31.1339	-96.8250	561
14226	5/26/2004	31.5517	-97.1017	560
14226	5/26/2004	31.5517	-97.1017	556
12038	3/18/2015	31.5361	-97.0739	556
14226	5/26/2004	31.5517	-97.1017	554
12038	12/6/2000	31.5361	-97.0739	550
12032	4/18/1973	31.1339	-96.8250	550
12032	12/27/1984	31.1339	-96.8250	550
12032	2/13/1973	31.1339	-96.8250	550
12038	2/29/2012	31.5361	-97.0739	549
14226	5/9/2000	31.5517	-97.1017	542
12038	1/3/2002	31.5361	-97.0739	541.3
12037	2/26/2003	31.5000	-97.0506	539
12032	2/4/2002	31.1339	-96.8250	535.7
14226	8/1/1995	31.5517	-97.1017	534
14226	5/9/2000	31.5517	-97.1017	534
12032	4/1/2002	31.1339	-96.8250	533.2
14226	5/9/2000	31.5517	-97.1017	533
12038	11/26/2013	31.5361	-97.0739	533
12038	2/3/2004	31.5361	-97.0739	531
12032	3/18/2015	31.1339	-96.8250	531
14226	8/1/1995	31.5517	-97.1017	529
12032	5/30/1973	31.1339	-96.8250	525
12032	5/27/2009	31.1339	-96.8250	521
14226	5/19/2005	31.5517	-97.1017	520
14226	5/9/2000	31.5517	-97.1017	517
12037	1/27/2010	31.5000	-97.0506	516
12037	1/27/2010	31.5000	-97.0506	514
14226	8/1/1995	31.5517	-97.1017	513
12037	1/27/2010	31.5000	-97.0506	512
12037	1/27/2010	31.5000	-97.0506	510
12037	1/27/2010	31.5000	-97.0506	510
12037	1/27/2010	31.5000	-97.0506	510
12032	12/1/1998	31.1339	-96.8250	510

Station ID	Date	Latitude	Longitude	Specific Conductance (μS/cm)
12032	9/29/2009	31.1339	-96.8250	510
12038	1/27/2010	31.5361	-97.0739	509
12037	5/9/2000	31.5000	-97.0506	507
12037	5/9/2000	31.5000	-97.0506	507
12037	5/9/2000	31.5000	-97.0506	507
12037	5/9/2000	31.5000	-97.0506	506
12032	3/2/2000	31.1339	-96.8250	505
12032	11/19/2015	31.1339	-96.8250	504
14226	1/27/2010	31.5517	-97.1017	502
14226	1/27/2010	31.5517	-97.1017	502
14226	1/27/2010	31.5517	-97.1017	502
12032	9/26/1974	31.1339	-96.8250	490
12032	5/14/2014	31.1339	-96.8250	486
12044	1/26/1984	31.8122	-97.2973	486
12032	4/4/2000	31.1339	-96.8250	484
12032	9/29/1983	31.1339	-96.8250	481
12032	1/3/2002	31.1339	-96.8250	479.1
14226	5/9/2000	31.5517	-97.1017	478
12037	11/2/2004	31.5000	-97.0506	478
14226	5/9/2000	31.5517	-97.1017	477
12032	6/7/1988	31.1339	-96.8250	477
12032	1/4/2001	31.1339	-96.8250	476.9
12038	4/1/2002	31.5361	-97.0739	476.6
14226	11/2/2004	31.5517	-97.1017	475
14226	11/2/2004	31.5517	-97.1017	475
14226	11/2/2004	31.5517	-97.1017	475
14226	11/2/2004	31.5517	-97.1017	474
14226	11/2/2004	31.5517	-97.1017	474
12038	4/21/2015	31.5361	-97.0739	473
12032	12/29/1983	31.1339	-96.8250	470
12032	2/5/1990	31.1339	-96.8250	470
12032	8/31/1983	31.1339	-96.8250	468
14226	5/18/2009	31.5517	-97.1017	467
12038	5/2/2000	31.5361	-97.0739	466
12032	6/11/1997	31.1339	-96.8250	464
12032	2/23/1998	31.1339	-96.8250	458
14226	5/18/2009	31.5517	-97.1017	456
12037	2/6/2012	31.5000	-97.0506	455
12032	3/10/2003	31.1339	-96.8250	453.1
12037	2/6/2012	31.5000	-97.0506	453
12037	2/6/2012	31.5000	-97.0506	453
14226	8/1/1995	31.5517	-97.1017	452
14226	8/1/1995	31.5517	-97.1017	452

Station ID	Date	Latitude	Longitude	Specific Conductance (μS/cm)
14226	5/18/2009	31.5517	-97.1017	452
14226	8/1/1995	31.5517	-97.1017	451
12038	6/18/2015	31.5361	-97.0739	448
12038	1/4/2001	31.5361	-97.0739	445.9
12038	2/6/2001	31.5361	-97.0739	440.9
12038	2/4/2002	31.5361	-97.0739	438
12038	2/1/1999	31.5361	-97.0739	434
12032	8/8/1989	31.1339	-96.8250	432
12032	11/26/2013	31.1339	-96.8250	430
12032	6/18/2014	31.1339	-96.8250	427
12032	7/14/1999	31.1339	-96.8250	424
12038	9/29/2009	31.5361	-97.0739	422
12032	2/28/1989	31.1339	-96.8250	422
12032	1/30/2001	31.1339	-96.8250	420
14226	5/18/2009	31.5517	-97.1017	414
12038	10/21/2013	31.5361	-97.0739	412
12032	1/15/1998	31.1339	-96.8250	407
14226	2/6/2012	31.5517	-97.1017	403
14226	2/6/2012	31.5517	-97.1017	401
14226	2/6/2012	31.5517	-97.1017	401
14226	2/6/2012	31.5517	-97.1017	400
14226	2/6/2012	31.5517	-97.1017	400
12032	4/28/1980	31.1339	-96.8250	400
14226	2/6/2012	31.5517	-97.1017	399
12032	9/24/2013	31.1339	-96.8250	393
12032	5/19/1992	31.1339	-96.8250	390
12032	2/6/2001	31.1339	-96.8250	384.6
12038	12/1/1998	31.5361	-97.0739	382
12032	4/21/2015	31.1339	-96.8250	376
12032	5/18/1989	31.1339	-96.8250	373
14226	5/18/2009	31.5517	-97.1017	369
14226	5/18/2009	31.5517	-97.1017	369
12037	2/26/2004	31.5000	-97.0506	369
14226	2/26/2004	31.5517	-97.1017	366
14226	2/26/2004	31.5517	-97.1017	366
14226	2/26/2004	31.5517	-97.1017	366
14226	2/26/2004	31.5517	-97.1017	366
14226	2/26/2004	31.5517	-97.1017	364
14226	5/18/2009	31.5517	-97.1017	362
12038	3/10/2003	31.5361	-97.0739	354.9
12032	1/17/1991	31.1339	-96.8250	350
12044	4/8/1975	31.8122	-97.2973	350
12032	10/21/2009	31.1339	-96.8250	346

Station ID	Date	Latitude	Longitude	Specific Conductance (µS/cm)
12032	3/29/2007	31.1339	-96.8250	344
12032	10/21/2013	31.1339	-96.8250	344
12032	5/17/1994	31.1339	-96.8250	341
12032	8/22/2016	31.1339	-96.8250	336
12038	10/21/2009	31.5361	-97.0739	331
12032	1/25/2012	31.1339	-96.8250	327
12032	5/14/2015	31.1339	-96.8250	324
12038	3/24/2009	31.5361	-97.0739	311
12038	10/27/2015	31.5361	-97.0739	310
12032	12/29/1987	31.1339	-96.8250	292
12032	3/14/1990	31.1339	-96.8250	280
12032	12/11/2002	31.1339	-96.8250	269.1
12032	10/29/1984	31.1339	-96.8250	259
12032	8/19/2008	31.1339	-96.8250	256
12032	10/27/2015	31.1339	-96.8250	250
12032	11/29/1984	31.1339	-96.8250	215
12032	8/31/1981	31.1339	-96.8250	209
12032	8/28/1979	31.1339	-96.8250	170
12044	8/27/1979	31.8122	-97.2973	150
12032	2/22/1979	31.1339	-96.8250	80
12032	5/12/1998	31.1339	-96.8250	55
12032	8/26/1977	31.1339	-96.8250	50

Table D.4. TCEQ historic ionic chemistry of the Brazos River.

Station ID	Date	Specific Conductance (μS/cm)	Latitude	Longitude	Sodium (mg/L)	Potassium (mg/L)	Magnesium (mg/L)	Calcium (mg/L)	Bicarbonate (mg/L)	Chloride (mg/L)	Sulfate (mg/L)
12032	12/7/1992	1200	31.1339	-96.8250	140	5.5	21	88	244	200	140
12032	2/12/1993	678	31.1339	-96.8250	56	3.4	10	67	187	86	71
12032	5/20/1993	831	31.1339	-96.8250	73	3.7	14	86	226	100	99
12032	7/28/1993	1410	31.1339	-96.8250	160	5.6	25	77	181	230	180
12032	12/1/1993	1540	31.1339	-96.8250	180	6.1	27	81	155	280	200
12032	2/15/1994	1460	31.1339	-96.8250	180	5.4	26	85	183	260	190
12032	5/17/1994	341	31.1339	-96.8250	4.2	2	15	44	188	21	29
12032	7/26/1994	1350	31.1339	-96.8250	160	5.4	24	76	150	250	170
12044	8/13/2002	1280	31.8122	-97.2973	162	5.45	17	73	143	251	119
12044	3/1/2002	1284	31.8122	-97.2973	148	4.85	16.5	74.5	148	246	125

APPENDIX E

Isotopic Composition of the Brazos River Alluvium Aquifer and Brazos River

Table E.1. Spring/summer 2018 isotopic composition of the Brazos River Alluvium Aquifer.

Sample Name	Sample Type	Date	County	Specific Conductance (uS/cm)	Temperature (°C)	Latitude	Longitude	$\delta^{18}O$ VSMOW	δD VSMOW
WS1	Spring	3/6/2018	Bosque/Hill	1370	N/A	31.8630	-97.3575	-4.26	-23.95
WS2	Spring	3/7/2018	Bosque/Hill	536	N/A	31.8598	-97.3515	-4.32	-23.07
WS3	Spring	3/8/2018	Bosque/Hill	414.6	N/A	31.8427	-97.3224	-3.35	-13.72
WS4	Spring	3/9/2018	Bosque/Hill	960	N/A	31.8126	-97.2969	-3.72	-21.73
IS	Spring	1/27/2018	McLennan	792	20.5	31.5603	-97.1269	-3.75	-22.08
HDU	Well	1/27/2018	McLennan	994	21.7	31.5157	-97.0569	-4.21	-26.20
BC	Well	2/1/2018	McLennan	858	20.7	31.6446	-97.1884	-4.35	-24.84
HDT	Well	2/5/2018	McLennan	671	19.3	31.5211	-97.0515	-4.50	-26.60
HDM	Well	2/13/2018	McLennan	855	20.9	31.5173	-97.0538	-4.61	-26.61
GMA	Well	2/19/2018	McLennan	683	20.6	31.4468	-97.0395	-4.24	-25.28
GM1	Well	2/19/2018	McLennan	1502	N/A	31.4531	-97.0263	-3.56	-19.84
GM2	Well	2/19/2018	McLennan	1640	N/A	31.4557	-97.0320	-3.63	-22.01
RP1	Well	3/2/2018	McLennan	1306	20.2	31.6959	-97.2137	-4.88	-28.95
RP2	Well	3/2/2018	McLennan	1604	20.0	31.6960	-97.2133	-4.87	-25.74
RP3	Well	3/2/2018	McLennan	728	20.5	31.6951	-97.2122	-4.70	-25.61
RP4	Well	3/2/2018	McLennan	632	0.8	31.6950	-97.2120	-4.58	-24.77

Sample Name	Sample Type	Date	County	Specific Conductance (uS/cm)	Temperature (°C)	Latitude	Longitude	$\delta^{18}O$ VSMOW	δD VSMOW
RP5	Well	3/2/2018	McLennan	620	21.4	31.6874	-97.2133	-4.65	-23.91
HDB	Well	6/7/2018	McLennan	N/A	N/A	31.5207	-97.0497	-3.96	-26.59
GM4	Well	7/16/2018	McLennan	1388	24.4	31.4592	-97.0205	-3.42	-21.42
RE	Well	2/1/2018	McLennan	390	23.3	31.6662	-97.2100	0.06	-3.32
ASPO	Well	6/21/2018	Falls	927	22.1	31.2659	-96.9032	-4.12	-25.15
ASCP	Well	6/21/2028	Falls	1926	23.3	31.2303	-96.9014	-3.97	-23.23
DL	Well	6/22/2018	Falls	858	21.9	31.2642	-96.9052	-4.47	-25.33
MB	Well	6/22/2018	Falls	899	25.4	31.2647	-96.9050	-4.73	-23.81
MV	Well	7/23/2018	Falls	1549	29.2	31.2956	-96.9428	-4.24	-23.23
AH1	Well	7/24/2018	Falls	1629	24.8	31.1708	-96.8361	-4.63	-26.43
AH2	Well	7/24/2018	Falls	1906	23.2	31.1778	-96.8414	-4.17	-25.43
AH3	Well	7/24/2018	Falls	1862	22.0	31.1728	-96.8475	-4.02	-23.91
AH4	Well	7/24/2018	Falls	1515	23.6	31.1600	-96.8308	-4.08	-22.05
AH5	Well	7/24/2018	Falls	1538	23.6	31.1486	-96.8064	-4.15	-23.13
AH6	Well	7/24/2018	Falls	5402	22.6	31.1406	-96.8081	-3.97	-24.51

Table E.2. Summer 2018 isotopic composition of the Brazos River.

Sample Name	Sample Type	Date	County	Specific Conductance (uS/cm)	Temperature (°C)	Latitude	Longitude	$\delta^{18}O$ VSMOW	δD VSMOW
RP	Brazos River Upper	7/9/2018	Bosque/Hill	1320	22.7	31.8664	-97.3678	0.84	1.89
DC	Brazos River Upper	7/9/2018	Bosque/Hill	1445	27.8	31.8126	97.2970	0.90	1.46
RP	Brazos River Upper	7/12/2018	McLennan	1163	20.4	31.6872	-97.2148	0.93	1.19
LS	Brazos River Upper	7/9/2018	McLennan	1328	22	31.6084	-97.1304	0.83	1.86
MLK	Brazos River Upper	7/9/2018	McLennan	1303	29.1	31.5905	-97.1530	1.14	2.56
HA	Brazos River Lake Brazos	7/10/2018	McLennan	1300	27.8	31.5753	-97.1458	1.01	0.86
SB	Brazos River Lake Brazos	7/10/2018	McLennan	1306	28.7	31.5611	-97.127217	1.17	1.64
FC	Brazos River Lake Brazos	7/10/2018	McLennan	1337	28.8	31.5519	-97.103056	1.08	1.71
L340	Brazos River Lower	7/10/2018	McLennan	1324	30.7	31.5339	-97.073056	1.08	-0.48
HD	Brazos River Lower	7/10/2018	McLennan	1282	31.4	31.5219	-97.048889	1.00	0.28
GM	Brazos River Lower	7/10/2018	McLennan	1326	34.9	31.4639	-97.0225	1.36	2.02
H7	Brazos River Lower	7/10/2018	Falls	1290	26.5	31.2878	-96.969722	1.18	-1.17
FB	Brazos River Lower	7/10/2018	Falls	1229	33.5	31.2481	-96.920556	1.48	1.91
H413	Brazos River Lower	7/10/2018	Falls	1259	12.7	31.1341	-96.8257	1.13	0.12

APPENDIX F

Core Descriptions

Table F.1. Locations and names of all core collected during this study.

Core ID	Sample Name	Latitude	Longitude	Date Drilled	Driller
080917-1	HDU	31.515708	-97.05689	8/9/2017	Jacob Jarvis
041618-1	HDM	31.51734	-97.053767	4/16/2018	Jacob Jarvis
080417-1	HDT	31.521131	-97.051491	8/4/2017	Jacob Jarvis
041718-1	HDB	31.520689	-97.04965	4/17/2018	Jacob Jarvis
RP1	RP1	31.695861	-97.213694	10/2/2018	Jacob Jarvis and Erin Noonan
RP2	RP4	31.69499	-97.21199	10/2/2018	Jacob Jarvis and Erin Noonan
RPRV	RP5	31.68738	-97.21332	10/4/2018	Jacob Jarvis and Erin Noonan
GM9	GM9M	31.4527222	-97.0178333	September 2018	Jacob Jarvis and Erin Noonan
GM4	GM4	31.4591667	-97.0205278	September 2018	Jacob Jarvis and Erin Noonan
GMRV	GMP	31.462778	-97.020278	September 2018	Jacob Jarvis and Erin Noonan

Table F.2. HDU core log.

Depth (ft)	Formation / Aquifer	Bedrock / Unconsolidated	Sediment Type	Grain Shape	Grain Sorting	Hardness	Color	Recovery Rate
0-1.4	BRAA	U	Vf sand	Subrounded	Well sorted	Dense/stiff	Light Brown	85%
1.4-2.3	BRAA	U	Vf sand with nodules of vf sand	Subrounded	Well sorted	Loose	Light Brown	85%
2.3-4	BRAA	U	Clay, dominantly broken up into nodules	N/A	Well sorted	Dense/stiff	Dark brown	85%
4-5	BRAA	U	Vf sand	Subrounded	Well sorted	Loose	Tan	100%
5-5.25	BRAA	U	Clay nodules	N/A	Well sorted	Loose	Light Brown	100%
5.25-5.4	BRAA	U	Vf sand	Subrounded	Well sorted	Loose	Tan	100%
5.4-5.5	BRAA	U	Clay nodules	N/A	Well sorted	Loose	Light Brown	100%
5.5-5.95	BRAA	U	Vf sand	Subrounded	Well sorted	Loose	Tan	100%
5.95-6.2	BRAA	U	Clay nodules	N/A	Well sorted	Loose	Light Brown	100%

Depth (ft)	Formation / Aquifer	Bedrock / Unconsolidated	Sediment Type	Grain Shape	Grain Sorting	Hardness	Color	Recovery Rate
6.2-8	BRAA	U	F sand	Subrounded	Well sorted	Loose	Tan	100%
8-12	BRAA	U	F sand	Subrounded	Well sorted	Loose	Tan	100%
12-14.5	BRAA	U	F sand	Subrounded	Well sorted	Loose	Tan	100%
14.5-16	BRAA	U	F sand	Subrounded	Well sorted	Dense/stiff	Tan	100%
16-17.1	BRAA	U	F sand	Subrounded	Well sorted	Dense/stiff	Tan	83%
17.1-17.55	BRAA	U	F sand	Subrounded	Well sorted	Loose	Tan	83%
17.55-18.05	BRAA	U	M sand, little gravel. Gravel dominantly chert, up to 0.5 cm, 1%	Sand subrounded, gravel subrounded to subangular	Moderately sorted	Dense/stiff	Tan	83%
18.05-19.35	BRAA	U	M to c sand and gravel, some f sand. Gravel dominantly limestone some chert, up to 2.0 cm, up to 10% in places, dominantly <5%.	Sand subrounded, gravel subrounded to subangular	Poorly sorted	Dense/stiff	Tan	83%

Depth (ft)	Formation / Aquifer	Bedrock / Unconsolidated	Sediment Type	Grain Shape	Grain Sorting	Hardness	Color	Recovery Rate
19.35-20	BRAA	U	M sand, little gravel. Gravel dominantly limestone, up to 1.0 cm, <1%	Sand subrounded, gravel subrounded to subangular	Moderately sorted	Loose	Tan	83%
20-22.2	BRAA	U	F sand, little gravel. Gravel dominantly limestone, up to 1.0 cm, <1%	Sand subrounded, gravel subrounded to subangular	Moderately sorted	Loose	Tan	80%
22.2-24	BRAA	U	M sand and gravel. Gravel dominantly limestone, up to 2.0 cm, <5%	Sand subrounded, gravel subrounded to subangular	Poorly sorted	Loose	Tan	80%
24-25.7	BRAA	U	F sand	Subrounded	Well sorted	Loose	Tan	75%
25.7-26.85	BRAA	U	M sand	Subrounded	Well sorted	Loose	Tan	75%
26.85-26.95	BRAA	U	Clay nodules	N/A	Well sorted	Loose	Orange brown	75%
26.95-28	BRAA	U	M sand	Subrounded	Well sorted	Loose	Tan	75%
28-29.5	BRAA	U	M sand	Subrounded	Well sorted	Loose	Tan	75%

Depth (ft)	Formation / Aquifer	Bedrock / Unconsolidated	Sediment Type	Grain Shape	Grain Sorting	Hardness	Color	Recovery Rate
29.5-30.3	BRAA	U	M sand and clay	Subrounded	Poorly sorted	Dense/stiff	Light Brown	75%
30.3-31.3	BRAA	U	M sand and gravel, some clay. Gravel dominantly limestone, up to 1.5 cm, 30%	Sand subrounded, gravel subrounded to subangular	Poorly sorted	Dense/stiff	Light Brown	75%
31.3-32	BRAA	U	Clay	N/A	Well sorted	Dense/stiff	Orange brown	75%
32-35.35	BRAA	U	Clay	N/A	Well sorted	Dense/stiff	Orange brown	73%
35.5-36	BRAA	U	F to m sand and gravel. Gravel dominantly limestone, up to 2.0 cm, 40%	Sand subrounded, gravel subrounded to subangular	Poorly sorted	Loose	Tan	73%
36-37.7	BRAA	U	M sand and gravel, some f and c to vc sand. Gravel dominantly limestone, up to 2.0 cm, 40%	Sand subrounded, gravel subrounded to subangular	Poorly sorted	Loose	Tan	85%
37.7-38.15	BRAA	U	M sand, some f and c to vc sand	Subrounded	Moderately sorted	Loose	Tan	85%

Depth (ft)	Formation / Aquifer	Bedrock / Unconsolidated	Sediment Type	Grain Shape	Grain Sorting	Hardness	Color	Recovery Rate
38.15-40	BRAA	U	M sand and gravel, some f and c to vc sand. Gravel dominantly limestone, up to 2.0 cm, 40%	Sand subrounded, gravel subrounded to subangular	Poorly sorted	Loose	Tan	85%
40-41.5	BRAA	U	Clay and sand and gravel. Gravel dominantly limestone, up to 3.0 cm, 10-15%	Sand subrounded, gravel subrounded to subangular	Poorly sorted	Dense/stiff	Orange brown	88%
41.5-42.5	BRAA	U	Clay	N/A	Well sorted	Dense/stiff	Orange brown	88%
42.5-44	BRAA	U	Gravel and m to c sand, some clay. Gravel dominantly limestone, up to 1.5 cm, 50-60%.	Sand subrounded, gravel subrounded to subangular	Poorly sorted	Loose	Tan	88%
44-47.1	BRAA	B	Shale - Bedrock rip up clast	N/A	Well sorted	Dense/stiff	Light gray	55%
47.1-48	BRAA	U	M to c sand and gravel, some clay. Gravel dominantly limestone, up to 1.0 cm, 30%.	Sand subrounded, gravel subrounded to subangular	Poorly sorted	Dense/stiff	Tan	55%

Table F.3. HDM core log.

Depth (ft)	Formation / Aquifer	Bedrock / Unconsolidated	Sediment Type	Grain Shape	Grain Sorting	Hardness	Color	Recovery Rate
0-2.85	BRAA	U	Sandy clay. Sand is vf	Subrounded	Moderately sorted	Dense/stiff	Dark brown	58%
2.85-2.95	BRAA	U	F sand	Subrounded	Well sorted	Loose	Tan	58%
2.95-3.2	BRAA	U	Sandy clay. Sand is vf	Subrounded	Moderately sorted	Dense/stiff	Dark brown	58%
3.2-3.3	BRAA	U	F sand	Subrounded	Well sorted	Loose	Tan	58%
3.3-3.65	BRAA	U	Sandy clay. Sand is vf	Subrounded	Moderately sorted	Dense/stiff	Dark brown	58%
3.65-4	BRAA	U	F sand	Subrounded	Well sorted	Loose	Tan	58%
4-6.1	BRAA	U	F sand	Subrounded	Well sorted	Loose	Tan	85%
6.1-6.2	BRAA	U	Sandy clay. Sand is vf	Subrounded	Moderately sorted	Dense/stiff	Light brown	85%
6.2-8	BRAA	U	F sand	Subrounded	Well sorted	Loose	Tan	85%

Depth (ft)	Formation / Aquifer	Bedrock / Unconsolidated	Sediment Type	Grain Shape	Grain Sorting	Hardness	Color	Recovery Rate
8-9.7	BRAA	U	F sand	Subrounded	Well sorted	Loose	Tan	88%
9.7-10.1	BRAA	U	Sandy clay. Sand is vf	Subrounded	Moderately sorted	Dense/stiff	Orange brown	88%
10.1-11.1	BRAA	U	F sand	Subrounded	Well sorted	Loose	Tan	88%
11.1-12	BRAA	U	F sand	Subrounded	Well sorted	Loose	Tan	88%
12-16	BRAA	U	F sand	Subrounded	Well sorted	Loose	Tan	100%
16-20	BRAA	U	F sand	Subrounded	Well sorted	Loose	Tan	100%
20-20.4	BRAA	U	Clay	N/A	Well sorted	Dense/stiff	Dark brown	100%
20.4-22.4	BRAA	U	F sand, some clay	Subrounded	Moderately sorted	Loose	Tan	100%
22.4-24	BRAA	U	M sand, some clay	Subrounded	Moderately sorted	Loose	Tan	100%
24-25.1	BRAA	U	M sand, some clay	Subrounded	Moderately sorted	Dense/stiff	Tan	88%

Depth (ft)	Formation / Aquifer	Bedrock / Unconsolidated	Sediment Type	Grain Shape	Grain Sorting	Hardness	Color	Recovery Rate
25.1-26.6	BRAA	U	F sand, some clay	Subrounded	Moderately sorted	Dense/stiff	Tan	88%
26.6-28	BRAA	U	F sand and clay, little gravel	Sand subrounded, gravel subrounded.	Poorly sorted	Dense/stiff	Light brown	88%
28-32	BRAA	U	F sand and clay, some gravel. Gravel dominantly limestone, up to 1.0 cm, 5%	Sand subrounded, gravel subrounded to subangular	Poorly sorted	Dense/stiff	Light brown	83%
32-33.25	BRAA	U	M sand, some gravel and clay. Gravel up to 0.5 cm, 1%	Sand subrounded, gravel subrounded to subangular	Poorly sorted	Loose	Tan	88%
33.25-33.35	BRAA	U	Sandy clay. Sand is m	Subrounded	Moderately sorted	Dense/stiff	Dark brown	88%
33.35-33.95	BRAA	U	M sand	Subrounded	Well sorted	Loose	Tan	88%
33.95-36	BRAA	U	Clay and gravel, some m sand. Gravel up to 1.0 cm, 5%	Gravel subrounded to subangular, sand subrounded	Poorly sorted	Dense/stiff	Dark brown	88%

Depth (ft)	Formation / Aquifer	Bedrock / Unconsolidated	Sediment Type	Grain Shape	Grain Sorting	Hardness	Color	Recovery Rate
36-40	BRAA	U	Clay and gravel, some m sand. Gravel dominantly limestone, up to 1.0 cm, gravel 15%	Gravel subrounded to subangular, sand subrounded	Poorly sorted	Dense/stiff	Dark brown	100%
40-41	BRAA	U	Clay and gravel, some m sand. Gravel dominantly limestone, up to 1.0 cm, 15%	Gravel subrounded to subangular, sand subrounded	Poorly sorted	Dense/stiff	Dark brown	90%
41-41.25	BRAA	U	F to m sand and clay, some gravel. Gravel up to 0.5 cm, <1%	Sand subrounded, gravel subrounded to subangular.	Poorly sorted	Dense/stiff	Tan	90%
41.25-42.75	BRAA	U	Gravel and m to c sand, some clay. Gravel dominantly limestone, up to 2.0 cm, 80%	Gravel subrounded to subangular, sand subrounded	Poorly sorted	Loose	Tan	90%
42.75-44	BRAA	U	Clay some m sand	Subrounded	Moderately sorted	Dense/stiff	Light brown	90%
44-47.5	BRAA	U	Clay and vf sand	Subrounded	Moderately sorted	Dense/stiff	Light brown	100%
47.5-48	Ozan Formation	B	Shale	N/A	Well sorted	Dense/stiff	Light gray	100%

Table F.4. HDT core log.

Depth (ft)	Formation / Aquifer	Bedrock / Unconsolidated	Sediment Type	Grain Shape	Grain Sorting	Hardness	Color	Recovery Rate
0-2	BRAA	U	Vf sand	Subrounded	Well sorted	Dense/stiff	Orange brown	73%
2-2.45	BRAA	U	Clay nodules	N/A	Well sorted	Dense/stiff	Light brown	73%
2.45-4	BRAA	U	Vf sand	Subrounded	Well sorted	Loose	Orange brown	73%
4-6.4	BRAA	U	Sandy clay. Sand is vf	Subrounded	Moderately sorted	Dense/stiff	Orange brown	88%
6.4-8	BRAA	U	F sand	Subrounded	Well sorted	Loose	Tan	88%
8-9.05	BRAA	U	F sand	Subrounded	Well sorted	Loose	Tan	100%
9.05-12	BRAA	U	Vf sand	Subrounded	Well sorted	Loose	Tan	100%
12-16	BRAA	U	Vf sand	Subrounded	Well sorted	Loose	Tan	88%
16-20	BRAA	U	F sand	Subrounded	Well sorted	Loose	Tan	88%

Depth (ft)	Formation / Aquifer	Bedrock / Unconsolidated	Sediment Type	Grain Shape	Grain Sorting	Hardness	Color	Recovery Rate
20-22	BRAA	U	F sand	Subrounded	Well sorted	Loose	Tan	75%
22-23.05	BRAA	U	M sand, little clay	Subrounded	Moderately sorted	Loose	Tan	75%
23.05-24	BRAA	U	Vf sand	Subrounded	Well sorted	Loose	Tan	75%
24-26.95	BRAA	U	M sand	Subrounded	Well sorted	Loose	Tan	75%
26.95-28	BRAA	U	Vf sand	Subrounded	Well sorted	Loose	Tan	75%
28-30	BRAA	U	F sand	Subrounded	Well sorted	Loose	Tan	75%
30-30.55	BRAA	U	M sand	Subrounded	Well sorted	Loose	Tan	75%
30.55-30.65	BRAA	U	Clay	N/A	Well sorted	Dense/stiff	Orange brown	75%
30.65-30.85	BRAA	U	Gravel and m sand. Gravel dominantly limestone, up to 1.0 cm, 50%	Gravel subrounded to subangular, sand subrounded	Poorly sorted	Loose	Tan	75%

Depth (ft)	Formation / Aquifer	Bedrock / Unconsolidated	Sediment Type	Grain Shape	Grain Sorting	Hardness	Color	Recovery Rate
30.85-31.5	BRAA	U	Vf sand	Subrounded	Well sorted	Loose	Tan	75%
31.5-31.55	BRAA	U	Organic material	N/A	N/A	Loose	Black	75%
31.55-32	BRAA	U	Vf sand	Subrounded	Well sorted	Loose	Tan	75%
32-34.25	BRAA	U	Vf sand	Subrounded	Well sorted	Loose	Tan	100%
34.25-34.95	BRAA	U	F sand	Subrounded	Well sorted	Loose	Tan	100%
34.95-36	BRAA	U	M sand	Subrounded	Well sorted	Loose	Tan	100%
36-38	BRAA	U	M sand and clay	Subrounded	Moderately sorted	Dense/stiff	Tan	88%
38-40	BRAA	U	Clay and gravel and sand. Gravel dominantly limestone, up to 1.5 cm, 20%.	Gravel subrounded to subangular, sand subrounded	Poorly sorted	Dense/stiff	Light brown	88%

Table F.5. HDB core log.

Depth (ft)	Formation / Aquifer	Bedrock / Unconsolidated	Sediment Type	Grain Shape	Grain Sorting	Hardness	Color	Recovery Rate
0-4	BRAA	U	Sandy clay. Sand is f	Subrounded	Moderately sorted	Dense/stiff	Light brown	65%
4-4.4	BRAA	U	Sandy clay. Sand is vf	Subrounded	Moderately sorted	Dense/stiff	Light brown	100%
4.4-5.1	BRAA	U	F sand	Subrounded	Well sorted	Loose	Tan	100%
5.1-5.6	BRAA	U	Vf sand	Subrounded	Well sorted	Loose	Tan	100%
5.6-8	BRAA	U	Sandy clay. Sand is vf	Subrounded	Moderately sorted	Dense/stiff	Orange brown	100%
8-9.1	BRAA	U	F sand	Subrounded	Well sorted	Loose	Tan	88%
9.1-9.85	BRAA	U	Sandy clay. Sand is vf	Subrounded	Moderately sorted	Dense/stiff	Light brown	88%
9.85-11.15	BRAA	U	F sand	Subrounded	Well sorted	Loose	Tan	88%
11.15-12	BRAA	U	Clayey sand. Sand is vf	Subrounded	Moderately sorted	Loose	Light brown	88%

Depth (ft)	Formation / Aquifer	Bedrock / Unconsolidated	Sediment Type	Grain Shape	Grain Sorting	Hardness	Color	Recovery Rate
12-12.75	BRAA	U	Vf sand	Subrounded	Well sorted	Loose	Tan	100%
12.75-12.85	BRAA	U	Clay	N/A	Well sorted	Dense/stiff	Light brown	100%
12.85-13.35	BRAA	U	F sand	Subrounded	Well sorted	Loose	Orange brown	100%
13.35-13.55	BRAA	U	Sandy clay. Sand is vf	Subrounded	Moderately sorted	Dense/stiff	Orange brown	100%
13.55-14.2	BRAA	U	Vf sand	Subrounded	Well sorted	Loose	Tan	100%
14.2-16	BRAA	U	F sand	Subrounded	Well sorted	Loose	Tan	100%
16-19.1	BRAA	U	F sand, some m sand, little gravel, and a few clay lenses. Gravel up to 1.0 cm, <1%	Sand subrounded, gravel subrounded.	Poorly sorted	Loose	Tan	100%
19.1-19.25	BRAA	U	Clay	N/A	Well sorted	Dense/stiff	Orange brown	100%
19.25-20	BRAA	U	F sand	Subrounded	Well sorted	Loose	Tan	100%
20-22.85	BRAA	U	F sand, little clay	Subrounded	Moderately sorted	Loose	Tan	88%

Depth (ft)	Formation / Aquifer	Bedrock / Unconsolidated	Sediment Type	Grain Shape	Grain Sorting	Hardness	Color	Recovery Rate
22.85-23.05	BRAA	U	Gravel and f sand. Gravel chert and limestone, up to 1.0 cm, 80%.	Gravel subrounded to subangular, sand subrounded.	Poorly sorted	Loose	Tan	88%
23.05-24	BRAA	U	Clay with some m sand and little gravel. Gravel chert and limestone, up to 1.0 cm, 1%	Sand subrounded, gravel subrounded to subangular.	Poorly sorted	Dense/stiff	Orange brown	88%
24-25.95	BRAA	U	M sand	Subrounded	Well sorted	Loose	Tan	85%
25.95-28	BRAA	U	Clay	N/A	Well sorted	Dense/stiff	Dark brown	85%
28-28.5	BRAA	U	M sand	Subrounded	Well sorted	Loose	Tan	100%
28.5-32	BRAA	U	Clay	N/A	Well sorted	Dense/stiff	Dark brown	100%
32-36	BRAA	U	Clay	N/A	Well sorted	Dense/stiff	Dark brown	100%

Depth (ft)	Formation / Aquifer	Bedrock / Unconsolidated	Sediment Type	Grain Shape	Grain Sorting	Hardness	Color	Recovery Rate
36-38.1	BRAA	U	Gravel and clay and m sand. Gravel dominantly limestone, up to 2.0 cm, 50%	Gravel subrounded to subangular, sand subrounded.	Poorly sorted	Dense/stiff	Light brown	60%
38.1-38.5	BRAA	U	Clay and m sand, some gravel. Gravel dominantly limestone, up to 1.0 cm, <5%	Sand subrounded, gravel subrounded to subangular.	Poorly sorted	Dense/stiff	Light brown	60%
38.5-40	BRAA	U	M sand and gravel, some clay. Gravel dominantly limestone, up to 2.0 cm, 30%	Sand subrounded, gravel subrounded to subangular.	Poorly sorted	Dense/stiff	Tan	60%

Table F.6. RP1 core log.

Depth (ft)	Formation / Aquifer	Bedrock / Unconsolidated	Sediment Type	Grain Shape	Grain Sorting	Hardness	Color	Recovery Rate
0-2.25	BRAA	U	F sand	Subrounded	Well sorted	Loose	Dark brown	68%
2.25-4	BRAA	U	Silt, some vf sand	N/A	Well sorted	Dense/stiff	Orange brown	68%
4-4.5	BRAA	U	Silt and f sand (50/50)	Subrounded	Moderately sorted	Loose	Dark brown	100%
4.5-8	BRAA	U	Silt, some vf sand	N/A	Well sorted	Dense/stiff	Orange brown	100%
8-9.95	BRAA	U	Silt and f sand (50/50)	Subrounded	Moderately sorted	Loose	Dark brown	58%
9.95-10.65	BRAA	U	M sand	Subrounded	Well sorted	Loose	Tan	58%
10.65-10.75	BRAA	U	Clay	N/A	Well sorted	Dense/stiff	Orange brown	58%
10.75-11.05	BRAA	U	M sand	Subrounded	Well sorted	Loose	Tan	58%
11.05-11.15	BRAA	U	Silty clay	N/A	Moderately sorted	Dense/stiff	Orange brown	58%

Depth (ft)	Formation / Aquifer	Bedrock / Unconsolidated	Sediment Type	Grain Shape	Grain Sorting	Hardness	Color	Recovery Rate
11.15-11.40	BRAA	U	F sand	Subrounded	Well sorted	Loose	Tan	58%
11.40-12	BRAA	U	M sand	Subrounded	Well sorted	Loose	Tan	58%
12-12.9	BRAA	U	F sand and some silt nodules (<5%)	Subrounded	Moderately sorted	Loose	Tan (silt nodules are black)	83%
12.9-15.3	BRAA	U	M sand	Subrounded	Well sorted	Loose	Tan	83%
15.3-16	BRAA	U	F sand	Subrounded	Well sorted	Loose	Tan	83%
16-17	BRAA	U	Silt, silt nodules (10%) , and nodules of f to vf sand (10%)	N/A	Well sorted	Loose	Silt and silt nodules are black, nodules of f to vf sand are tan	83%
17-17.45	BRAA	U	F sand	Subrounded	Well sorted	Loose	Orange brown	83%
17.45-18	BRAA	U	M sand and gravel, little clay. Gravel limestone (50%) and chert (50%), limestone gravel tend to be larger, up to 2.5 cm, 30%	Both subrounded	Moderately sorted	Loose	Orange brown	83%

Depth (ft)	Formation / Aquifer	Bedrock / Unconsolidated	Sediment Type	Grain Shape	Grain Sorting	Hardness	Color	Recovery Rate
18-18.8	BRAA	U	C to vc sand and gravel. Gravel chert (90%) and limestone (10%), limestone gravel tend to be larger, up to 3.0 cm, 50%	Both subrounded	Poorly sorted	Loose	Orange brown	83%
18.8-20	BRAA	U	Gravel and c to vc sand, some clay. Gravel chert (40%) and limestone (60%), limestone gravel tend to be larger, up to 3.0 cm, 60-70%	Gravel subrounded to subangular and sand subrounded	Poorly sorted	Loose	Orange brown	83%
20-21	BRAA	U	C to vc sand and gravel. Gravel chert (90%) and limestone (10%), up to 2.0 cm, 30-40%	Sand is subrounded and gravel subrounded to subangular	Poorly sorted	Loose	Orange brown	100%
21-22.8	Grayson Marl/Del Rio Clay	B	Shale (weathered/oxidized)	N/A	Well sorted	Dense/stiff	Yellowish gray	100%
22.8-24	Grayson Marl/Del Rio Clay	B	Shale (not weathered/reduced)	N/A	Well sorted	Dense/stiff	Dark gray	100%

Table F.7. RP4 core log.

Depth (ft)	Formation / Aquifer	Bedrock / Unconsolidated	Sediment Type	Grain Shape	Grain Sorting	Hardness	Color	Recovery Rate
0-2.9	BRAA	U	Vf to f sand (50/50)	Subrounded	Well sorted	Loose	Tan	65%
2.9-4	BRAA	U	Silt, some vf sand	Subrounded	Well sorted	Dense/stiff	Orange brown	65%
4-7.35	BRAA	U	Silt, some vf sand	Subrounded	Well sorted	Dense/stiff	Orange brown	65%
7.35-8	BRAA	U	Vf sand	Subrounded	Well sorted	Loose	Orange brown	65%
8-8.65	BRAA	U	Silt and vf sand	Subrounded	Well sorted	Loose	Light brown	88%
8.65-10.3	BRAA	U	Vf sand	Subrounded	Well sorted	Dense/stiff	Orange brown	88%
10.3-12	BRAA	U	F sand	Subrounded	Well sorted	Loose	Orange brown	88%
12-13	BRAA	U	Silt, some vf sand	Subrounded	Well sorted	Loose	Light brown	75%
13-13.55	BRAA	U	Clayey vf to f sand	Subrounded	Moderately sorted	Dense/stiff	Orange brown	75%

Depth (ft)	Formation / Aquifer	Bedrock / Unconsolidated	Sediment Type	Grain Shape	Grain Sorting	Hardness	Color	Recovery Rate
13.55-13.8	BRAA	U	Vf to f sand	Subrounded	Well sorted	Loose	Orange brown	75%
13.8-13.85	BRAA	U	Clay, some vf to f sand	Subrounded	Moderately sorted	Dense/stiff	Orange brown	75%
13.85-14.2	BRAA	U	F sand	Subrounded	Well sorted	Loose	Orange brown	75%
14.2-14.5	BRAA	U	Clayey vf sand	Subrounded	Moderately sorted	Dense/stiff	Orange brown	75%
14.5-14.9	BRAA	U	F sand	Subrounded	Well sorted	Loose	Orange brown	75%
14.9-14.95	BRAA	U	Clayey f sand	Subrounded	Moderately sorted	Dense/stiff	Orange brown	75%
14.95-15.05	BRAA	U	F sand	Subrounded	Well sorted	Loose	Orange brown	75%
15.05-15.2	BRAA	U	Clayey f sand	Subrounded	Moderately sorted	Dense/stiff	Orange brown	75%
15.2-15.4	BRAA	U	M sand	Subrounded	Well sorted	Loose	Orange brown	75%
15.4-15.6	BRAA	U	Clayey vf sand	Subrounded	Moderately sorted	Dense/stiff	Orange brown	75%

Depth (ft)	Formation / Aquifer	Bedrock / Unconsolidated	Sediment Type	Grain Shape	Grain Sorting	Hardness	Color	Recovery Rate
15.6-16	BRAA	U	F sand, some gravel. Gravel limestone and chert, up to 1.0 cm, 5%	Both subrounded	Moderately sorted	Loose	Orange brown	75%
16-17.3	BRAA	U	F to m sand, some gravel. Gravel chert, up to 1.0 cm, <5%	Both subrounded	Moderately sorted	Loose	Orange brown	75%
17.3-17.4	BRAA	U	Clay with f sand and gravel. Gravel chert, up to 1.0 cm	Both subrounded	Moderately sorted	Dense/stiff	Orange brown	75%
17.4-17.7	BRAA	U	M to c sand, some gravel. Gravel chert, up to 0.8 cm, <5%	Both subrounded	Moderately sorted	Loose	Orange brown	75%
17.7-17.75	BRAA	U	Clay and m sand	Subrounded	Moderately sorted	Dense/stiff	Orange brown	75%
17.5-18.35	BRAA	U	M sand and gravel. Gravel chert and limestone, up to 1.0 cm, 15%	Both subrounded	Moderately sorted	Loose	Orange brown	75%
18.35-18.55	BRAA	U	F sand and clay, some gravel. Gravel chert and limestone, up to 0.5 cm, <5%	Both subrounded	Moderately sorted	Loose	Orange brown	75%
18.55-19	BRAA	U	F to m sand and gravel. Gravel chert and limestone, up to 2.0 cm, 20-30%	Both subrounded	Moderately sorted	Loose	Orange brown	75%
19-20	BRAA	U	Gravel and c to vc sand. Gravel chert and limestone (dominantly limestone), up to 3.0 cm, 80%	Both subangular to subrounded	Poorly sorted	Loose	Orange brown	75%
20-23.1	BRAA	U	C to vc sand and gravel, some clay. Gravel chert and limestone, up to 1.5 cm, 40-50%	Both subangular to subrounded	Poorly sorted	Loose	Orange brown	75%

Depth (ft)	Formation / Aquifer	Bedrock / Unconsolidated	Sediment Type	Grain Shape	Grain Sorting	Hardness	Color	Recovery Rate
23.1-24	Grayson Marl/Del Rio Clay	B	Shale (weathered/oxidized)	N/A	Well sorted	Dense/stiff	Yellowish gray	75%

Table F.8. RP5 core log.

Depth (ft)	Formation / Aquifer	Bedrock / Unconsolidated	Sediment Type	Grain Shape	Grain Sorting	Hardness	Color	Recovery Rate
0-4	BRAA	U	Vf sand, some silt	Subrounded	Well sorted	Loose	Tan	78%
4-5.5	BRAA	U	Silt nodules	N/A	N/A	Loose	Light brown	73%
5.5-8	BRAA	U	F to m sand	Subrounded	Well sorted	Loose	Tan	73%
8-8.9	BRAA	U	Fine sand	Subrounded	Well sorted	Loose	Tan	83%
8.9-9.25	BRAA	U	Silt	N/A	N/A	Dense/stiff	Orange brown	83%
9.25-9.45	BRAA	U	F sand	Subrounded	Well sorted	Loose	Tan	83%
9.45-12	BRAA	U	Vf sand, some silt	Subrounded	Well sorted	Loose	Orange brown	83%
12-15.5	BRAA	U	Vf sand, some silt (more abundant in first foot)	Subrounded	Well sorted	Dense/stiff	Orange brown	85%
15.5-16	BRAA	U	F sand	Subrounded	Well sorted	Loose	Tan	85%

Depth (ft)	Formation / Aquifer	Bedrock / Unconsolidated	Sediment Type	Grain Shape	Grain Sorting	Hardness	Color	Recovery Rate
16-17.4	BRAA	U	Vf sand, some silt	Subrounded	Well sorted	Loose	Orange brown	85%
17.4-17.7	BRAA	U	F sand	Subrounded	Well sorted	Loose	Tan	85%
17.7-18.2	BRAA	U	Clay	N/A	N/A	Dense/stiff	Dark brown	85%
18.2-18.7	BRAA	U	Vf sand, some silt	Subrounded	Well sorted	Dense/stiff	Orange brown	85%
18.7-20	BRAA	U	F sand, ~5 mm clay lenses in bottom 0.5 ft	Subrounded	Well sorted	Loose	Tan	85%
20-21.15	BRAA	U	F sand	Subrounded	Well sorted	Loose	Tan	100%
21.15-21.3	BRAA	U	Clay	N/A	N/A	Dense/stiff	Dark brown	100%
21.3-21.8	BRAA	U	F sand	Subrounded	Well sorted	Loose	Tan	100%
21.8-23	BRAA	U	Gravel and f sand. Gravel, dominantly limestone, up to 3.0 cm, 60%	Gravel subrounded to subangular, sand well rounded	Poorly sorted	Loose	Tan	100%

Depth (ft)	Formation / Aquifer	Bedrock / Unconsolidated	Sediment Type	Grain Shape	Grain Sorting	Hardness	Color	Recovery Rate
23-23.5	BRAA	U	M to c sand, some gravel and clay. Gravel dominantly limestone, up to 1.0 cm, 10%. Clay 5%	Both subrounded	Poorly sorted	Loose	Tan	100%
23.5-24	BRAA	U	Clay and gravel, some m to c sand. Gravel dominantly limestone, up to 1.0 cm, 20%. M to c sand 10%	Both subrounded	Poorly sorted	Loose	Dark brown	100%
24-25.5	BRAA	U	Clay and gravel, some medium to coarse sand. Gravel dominantly limestone, up to 1.0 cm, 20%. M to c sand 10%	Both subrounded	Poorly sorted	Loose	Dark brown	68%
25.5-25.8	BRAA	U	F sand	Subrounded	Well sorted	Loose	Tan	68%
25.8-28	BRAA	U	Gravel and m to c sand. Gravel dominantly limestone, some chert, up to 4.0 cm, 60%. M to c sand 40%	Gravel subrounded to subangular, sand subrounded	Poorly sorted	Loose	Tan	68%
28-32	BRAA	U	Gravel and m to c sand. Gravel dominantly limestone, some chert, up to 4.0 cm, 60%. M to c sand 40%.	Gravel subrounded to subangular, sand subrounded	Poorly sorted	Loose	Tan	50%
32-34	Grayson Marl/Del Rio Clay	B	Weathered shale, some original bedding present	N/A	N/A	Dense/stiff	White gray	100%

Table F.9. GM9M core log.

Depth (ft)	Formation / Aquifer	Bedrock / Unconsolidated	Sediment Type	Grain Shape	Grain Sorting	Hardness	Color	Recovery Rate
0-4	BRAA	U	Silt	N/A	Well sorted	Dense/stiff	Light brown	75%
4-8	BRAA	U	Vf sand	Subrounded	Well sorted	Dense/stiff	Orange brown	100%
8-12	BRAA	U	Vf sand	Subrounded	Well sorted	Dense/stiff	Orange brown	100%
12-16	BRAA	U	Clay, little silt	N/A	Well sorted	Dense/stiff	Orange brown	85%
16-17.3	BRAA	U	Vf sand	Subrounded	Well sorted	Loose	Light brown	83%
17.3-19	BRAA	U	Vf sand	Subrounded	Well sorted	Dense/stiff	Orange brown	83%
19-20	BRAA	U	M sand, some silty clay and gravel. Gravel chert and limestone, up to 1.0 cm, 5%	Sand subrounded, gravel subrounded to subangular	Poorly sorted	Loose	Tan	83%

Depth (ft)	Formation / Aquifer	Bedrock / Unconsolidated	Sediment Type	Grain Shape	Grain Sorting	Hardness	Color	Recovery Rate
20-21.9	BRAA	U	Vf sand, some clay and gravel. Gravel chert and limestone, up to 0.5 cm	Sand subrounded, gravel subrounded to subangular	Poorly sorted	Dense/stiff	Tan	60%
21.9-24	BRAA	U	Gravel and m sand. Gravel chert and limestone, up to 3.0 cm, 50-60%	Sand subrounded, gravel subrounded to subangular	Poorly sorted	Loose	Tan	60%
24-28	BRAA	U	Gravel and m sand. Gravel chert and limestone, up to 3.0 cm, 50-60%	Sand subrounded, gravel subrounded to subangular	Poorly sorted	Loose	Tan	50%
28-31	BRAA	U	Gravel and m sand. Gravel chert and limestone, up to 3.0 cm, 60% gravel	Sand subrounded, gravel subrounded to subangular	Poorly sorted	Loose	Tan	83%
31-31.5	Ozan Formation	B	Shale	N/A	Well sorted	Dense/stiff	Gray	83%

Table F.10. GM4 core log.

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Depth (ft)	Formation / Aquifer	Bedrock / Unconsolidated	Sediment Type	Grain Shape	Grain Sorting	Hardness	Color	Recovery Rate
0-3	BRAA	U	Vf sand	N/A	N/A	Dense/stiff	Dark brown	75%
3-3.5	BRAA	U	F sand	Subrounded	Well sorted	Loose	Tan	75%
3.5-4	BRAA	U	Vf sand	Sand subrounded	Moderately sorted	Dense/stiff	Dark brown	75%
4-6.25	BRAA	U	Vf sand	Sand subrounded	Moderately sorted	Dense/stiff	Dark brown	50%
6.25-6.58	BRAA	U	F sand	Subrounded	Well sorted	Loose	Tan	50%
6.58-6.67	BRAA	U	Clay	N/A	Well sorted	Dense/stiff	Dark brown	50%
6.67-7.08	BRAA	U	Vf sand	Subrounded	Well sorted	Loose	Tan	50%
7.08-7.25	BRAA	U	F sand	Subrounded	Well sorted	Loose	Tan	50%
7.25-7.33	BRAA	U	Clay	N/A	Well sorted	Dense/stiff	Dark brown	50%

Depth (ft)	Formation / Aquifer	Bedrock / Unconsolidated	Sediment Type	Grain Shape	Grain Sorting	Hardness	Color	Recovery Rate
7.33-8	BRAA	U	F sand	Subrounded	Well sorted	Loose	Tan	50%
8-11.75	BRAA	U	F sand	Subrounded	Well sorted	Loose	Tan	75%
11.75-12	BRAA	U	M sand	Subrounded	Well sorted	Loose	Tan	75%
12-16	BRAA	U	M sand, little gravel. Gravel chert, up to 0.5 cm	Sand subrounded, gravel subrounded to subangular	Moderately sorted	Loose	Tan	75%
16-17.5	BRAA	U	M sand, some gravel pieces. Gravel chert and limestone, up to 1.5 cm	Sand subrounded, gravel subrounded to subangular	Moderately sorted	Loose	Tan	75%
17.5-18	BRAA	U	Clay	N/A	Well sorted	Dense/stiff	Dark brown	80%
18-20	BRAA	U	C sand	Subrounded	Well sorted	Loose	Tan	80%
20-24	BRAA	U	C sand, some gravel. Gravel chert and limestone, up to 2.0 cm, (more abundant 22-24 ft), 5%	Sand subrounded, gravel subrounded to subangular	Moderately sorted	Loose	Tan	63%

Depth (ft)	Formation / Aquifer	Bedrock / Unconsolidated	Sediment Type	Grain Shape	Grain Sorting	Hardness	Color	Recovery Rate
24-27.33	BRAA	U	M sand, little gravel. Gravel chert, up to 1.0 cm	Sand subrounded, gravel subrounded to subangular	Moderately sorted	Loose	Tan	56%
27.33-27.5	BRAA	U	Clay, some m sand	Sand subrounded	Moderately sorted	Dense/stiff	Dark brown	56%
27.5-27.75	BRAA	U	M sand	Subrounded	Well sorted	Loose	Tan	56%
27.75-28	BRAA	U	Clay, some m sand and some gravel. Gravel chert, up to 1.0 cm	Sand subrounded, gravel subrounded to subangular	Poorly sorted	Dense/stiff	Dark brown	56%
28-32	BRAA	U	M sand and gravel. Gravel chert and limestone, up to 3.0 cm, 50%	Sand subrounded, gravel subrounded to subangular	Poorly sorted	Loose	Tan	56%
32-35.5	BRAA	U	M sand and gravel. Gravel chert and limestone, up to 3.0 cm, 40%	Sand subrounded, gravel subrounded to subangular	Poorly sorted	Loose	Tan	38%

Depth (ft)	Formation / Aquifer	Bedrock / Unconsolidated	Sediment Type	Grain Shape	Grain Sorting	Hardness	Color	Recovery Rate
35.5-36	BRAA	U	Clay, some sand and gravel. Gravel chert and limestone, up to 1.5 cm	Sand subrounded, gravel subrounded to subangular	Poorly sorted	Dense/stiff	Dark brown	38%
36-38.5	BRAA	U	Clay, little sand	Sand subrounded	Moderately sorted	Dense/stiff	Dark brown	94%
38.5-40	BRAA	U	Gravel and coarse sand, some clay. Gravel chert and limestone, up to 2.0 cm, 50%	Gravel subrounded to subangular, sand subrounded	Poorly sorted	Loose	Tan	94%
40-41.5	BRAA	U	Gravel and coarse sand. Gravel chert and limestone, 60%	Gravel subrounded to subangular, sand subrounded	Poorly sorted	Loose	Tan	100%
41.5-42	Ozan Formation	B	Shale	N/A	Well sorted	Dense/stiff	Gray	100%

Table F.11. GMP core log.

Depth (ft)	Formation / Aquifer	Bedrock / Unconsolidated	Sediment Type	Grain Shape	Grain Sorting	Hardness	Color	Recovery Rate
0-1.8	BRAA	U	Vf sand	Subrounded	Well sorted	Dense/stiff	Light brown	73%
1.8-2.45	BRAA	U	F to m sand	Subrounded	Moderately sorted	Loose	Orange brown	73%
2.45-4	BRAA	U	Gravel and m to vc sand. Gravel dominantly limestone, some chert, up to 2.0 cm, 60-70%	Gravel subrounded to subangular, sand subrounded	Poorly sorted	Loose	Tan	73%
4-6.8	BRAA	U	M to c sand and gravel. Gravel chert and limestone, up to 1.0 cm, 15-20%	Sand subrounded, gravel subrounded to subangular	Poorly sorted	Loose	Tan	66%
6.8-8	BRAA	U	Gravel and m sand. Gravel dominantly limestone, some chert, up to 2.0 cm, 50%	Gravel subrounded to subangular, sand subrounded	Poorly sorted	Loose	Tan	66%

Depth (ft)	Formation / Aquifer	Bedrock / Unconsolidated	Sediment Type	Grain Shape	Grain Sorting	Hardness	Color	Recovery Rate
8-9.35	BRAA	U	M sand, little gravel	Sand subrounded, gravel subrounded to subangular	Moderately sorted	Loose	Tan	88%
9.35-12	BRAA	U	M sand and gravel, some clay. Gravel dominantly limestone, some chert, up to 2.5 cm, 15-20%	Sand subrounded, gravel subrounded to subangular	Poorly sorted	Loose	Tan	88%
12-15.5	BRAA	U	Clay, little m sand gravel	Sand subrounded, gravel subrounded to subangular	Poorly sorted	Dense/stiff	Orange brown	85%
15.5-16	BRAA	U	Clay, f to m sand, and gravel. Gravel dominantly limestone, up to 2.0 cm, 5%	Sand subrounded, gravel subrounded to subangular	Poorly sorted	Dense/stiff	Orange brown	85%
16-16.8	BRAA	U	F sand, gravel, and clay. Gravel dominantly limestone, up to 1.0 cm, <5%	Sand subrounded, gravel subrounded to subangular	Poorly sorted	Dense/stiff	Orange brown	100%
16.8-19.5	BRAA	U	M sand	Subrounded	Well sorted	Dense/stiff	Tan	100%

Depth (ft)	Formation / Aquifer	Bedrock / Unconsolidated	Sediment Type	Grain Shape	Grain Sorting	Hardness	Color	Recovery Rate
19.5-20	BRAA	U	F sand and clay, little gravel	Sand subrounded, gravel subrounded to subangular	Poorly sorted	Dense/stiff	Orange brown	100%
20-22.55	BRAA	U	F to m sand, clay, and gravel. Gravel dominantly limestone, up to 1.0 cm, <5%	Sand subrounded, gravel subrounded to subangular	Poorly sorted	Dense/stiff	Dark brown	100%
22.55-24	BRAA	U	Clay, some vf sand, little gravel	Sand subrounded, gravel subrounded to subangular	Poorly sorted	Dense/stiff	Dark brown	100%
24-25.85	BRAA	U	M sand, little gravel	Sand subrounded, gravel subrounded to subangular	Moderately sorted	Dense/stiff	Tan	80%
25.85-26.35	BRAA	U	Clay	N/A	Well sorted	Dense/stiff	Dark brown	80%
26.35-28	BRAA	U	M sand, some clay.	Subrounded	Moderately sorted	Dense/stiff	Tan	80%
28-32	BRAA	U	F sand	Subrounded	Well sorted	Loose	Tan	83%

Depth (ft)	Formation / Aquifer	Bedrock / Unconsolidated	Sediment Type	Grain Shape	Grain Sorting	Hardness	Color	Recovery Rate
32-35.5	BRAA	U	M to vc sand and gravel. Gravel dominantly limestone, up to 1.5 cm, 15%.	Sand subrounded, gravel subrounded to subangular	Poorly sorted	Loose	Tan	100%
35.5-40	Ozan Formation	B	Shale	N/A	Well sorted	Dense/stiff	Light gray	100%

APPENDIX G

Ionic Chemistry of Brazos River Alluvium Aquifer In-situ Water Samples

Table G.1. Ionic chemistry of Brazos River Alluvium aquifer in-situ water samples.

Sample Name	Sample Depth (ft)	Date	Specific Conductance (uS/cm)	Latitude	Longitude	Sodium (mg/L)	Potassium (mg/L)	Magnesium (mg/L)	Calcium (mg/L)	Bicarbonate (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Nitrate as N (mg/L)
HDU24	24.0	7/3/2018	826	31.51571	-97.0569	13.1	5.09	19.7	86.3	370	3.78	n.a.	2.86
HDU31	31.0	7/3/2018	725	31.51571	-97.0569	19.3	4.22	19.5	62.1	383	3.21	48.1	0.08
HDU40	40.0	7/3/2018	690	31.51571	-97.0569	42.8	3.93	16.4	51.3	327	8.12	65.0	0.01
HDM26	26.0	6/27/2018	848	31.51734	-97.0538	28.4	9.97	16.9	75.5	401	11.3	83.6	3.98
HDM34	34.0	7/6/2018	925	31.51734	-97.0538	22.1	2.25	8.52	43.8	520	11.1	9.62	0.00
HDM42	42.5	6/27/2018	1038	31.51734	-97.0538	46.1	6.24	24.0	55.2	596	33.7	2.98	0.14
HDT33	33.0	7/6/2018	754	31.52113	-97.0515	25.8	9.36	20.1	65.6	397	10.3	52.5	0.02
HDT40	40.0	7/6/2018	971	31.52113	-97.0515	69.2	5.51	17.6	57.4	549	34.8	11.6	0.01
HDB32	32.0	6/27/2018	1223	31.52069	-97.0497	31.2	4.36	37.6	85.1	712	41.9	1.02	0.01
HDB40	40.0	6/27/2018	1122	31.52069	-97.0497	45.7	5.40	24.7	56.7	606	37.9	20.7	0.02
GM9M23	23.0	8/16/2018	2172	31.45272	-97.0178	116	7.65	113	155	405	301	160	0.35
GM9M28	28.7	7/19/2018	2086	31.45272	-97.0178	124	5.00	103	133	400	315	159	8.73
GM426	26.0	8/16/2018	1352	31.45917	-97.0205	66.1	5.01	20.8	188	427	133	174	0.75
GM441	41.5	7/17/2018	1321	31.45917	-97.0205	74.5	4.08	28.3	168	422	128	172	0.02
GM426	26.0	7/17/2018	1317	31.45917	-97.0205	64.8	5.74	20.3	172	407	126	151	2.79
GM434	34.0	8/16/2018	1348	31.45917	-97.0205	68.4	6.58	24.6	163	423	136	176	12.60
GMP21	21.0	7/18/2018	888	31.46278	-97.0203	61.2	3.98	13.6	120	420	58.8	47.4	0.01

Sample Name	Sample Depth (ft)	Date	Specific Conductance (uS/cm)	Latitude	Longitude	Sodium (mg/L)	Potassium (mg/L)	Magnesium (mg/L)	Calcium (mg/L)	Bicarbonate (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Nitrate as N (mg/L)
GMP28	28.0	7/18/2018	1062	31.46278	-97.0203	66.4	5.36	17.9	123	400	109	76.2	0.00
GMP36	36.0	7/18/2018	1095	31.46278	-97.0203	67.8	4.23	21.3	126	393	113	87.8	0.03
RP121	21.0	10/2/2018	1152.5	31.69586	-97.2137	41.9	3.20	23.0	163	347	14.5	39.3	10.30
RP423	23.0	10/2/2018	722	31.69499	-97.212	40.3	2.15	8.21	98.9	303	36.0	81.9	7.56
RP526	26.0	10/4/2018	1538	31.68738	-97.2133	123	1.62	18.0	139	308	227	102	0.87
RP533	33.0	10/4/2018	1491.5	31.68738	-97.2133	161	2.64	12.9	122	256	231	107	0.57
HDM26	26.0	10/30/2018	831	31.51734	-97.0538	25.7	4.89	16.5	119	393	11.5	64.0	1.34
HDM42	42.5	10/30/2018	1018	31.51734	-97.0538	46.3	6.11	24.4	108	520	33.5	2.40	0.10
HDB32	32.0	10/30/2018	1211	31.52069	-97.0497	39.2	2.92	38.4	153	676	45.4	3.4	0.00
HDB40	40.0	10/30/2018	1097	31.52069	-97.0497	41.5	3.66	26.0	149	596	39.4	19.9	0.02

APPENDIX H

Well Diagrams

Well diagrams display well depth, water level, top of casing, sediment distributions and descriptions from cores, and the depth and specific conductance of in-situ samples. The abbreviation TOC stands for top of casing and indicates the length of casing above the land surface. Well depth was measured from the top of the well casing. The abbreviation DTW stands for depth to water, as measured from the top of the casing. The abbreviation Well SC stands for the specific conductance of a composite sample collected from the well either after pumping or bailing the well. The core depth indicates the depth to which core was collected. In cases where bedrock was not reached during coring, often bedrock was later identified by augering.

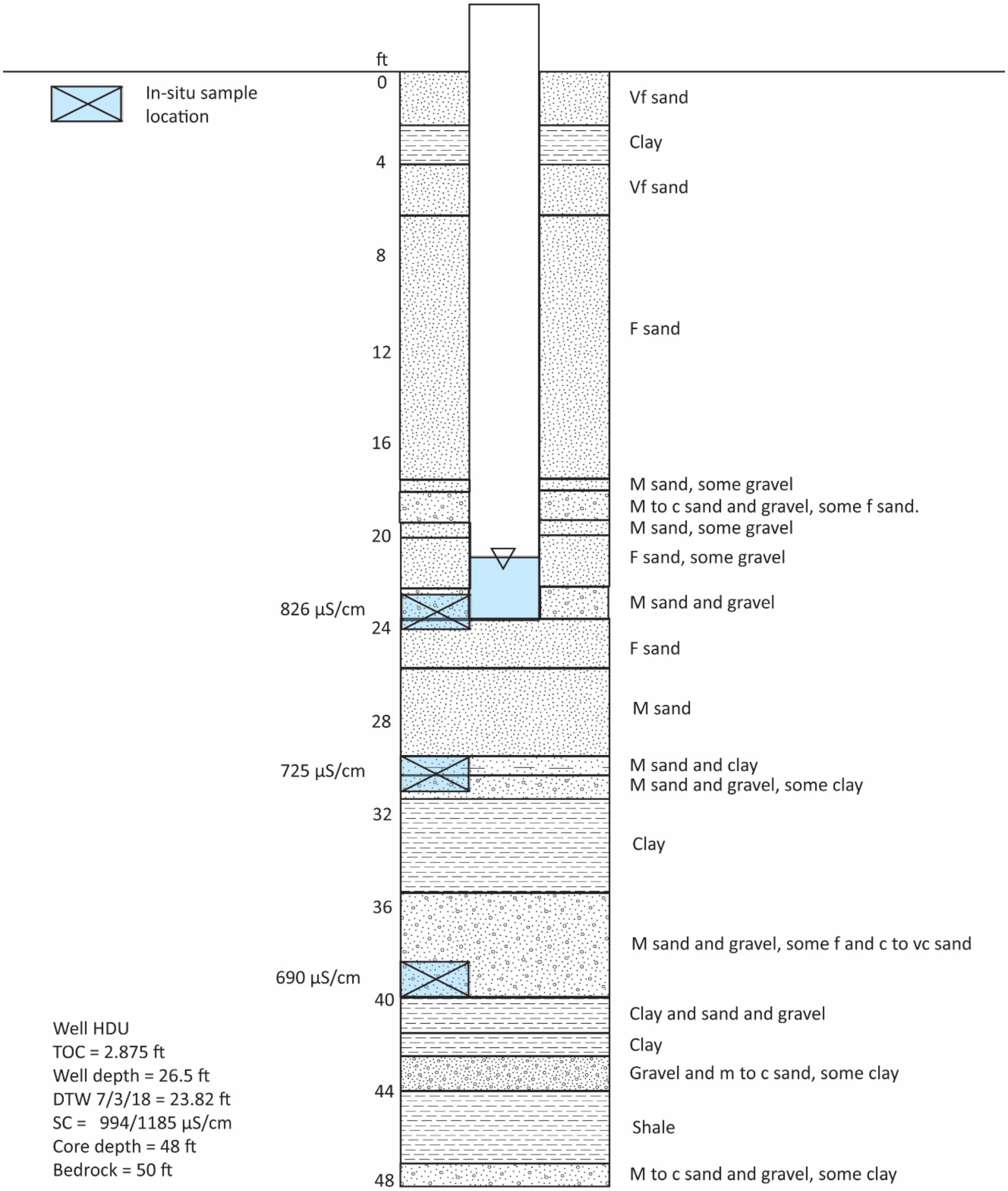

Figure H.1. HDU well diagram.

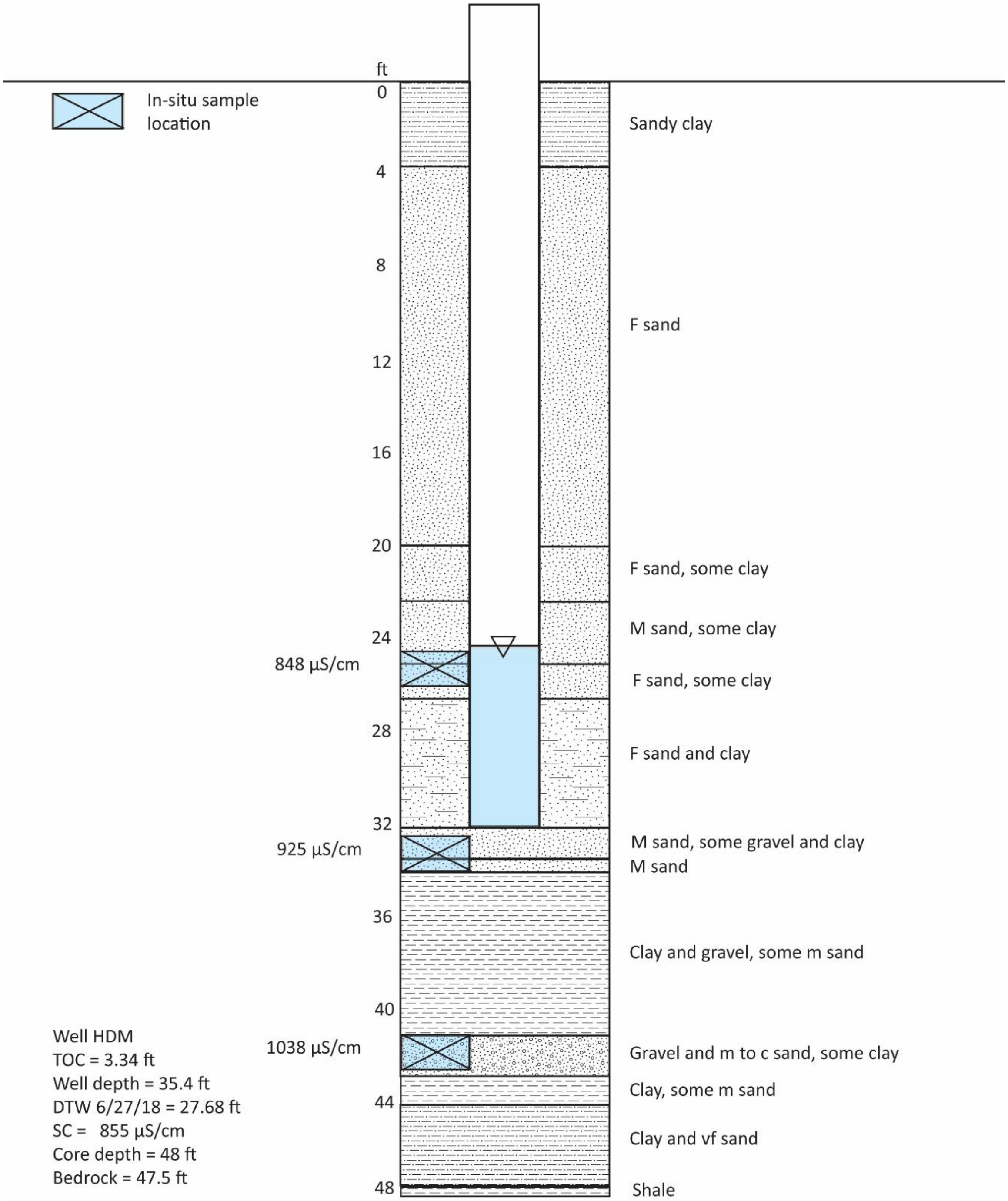

Figure H.2. HDM well diagram.

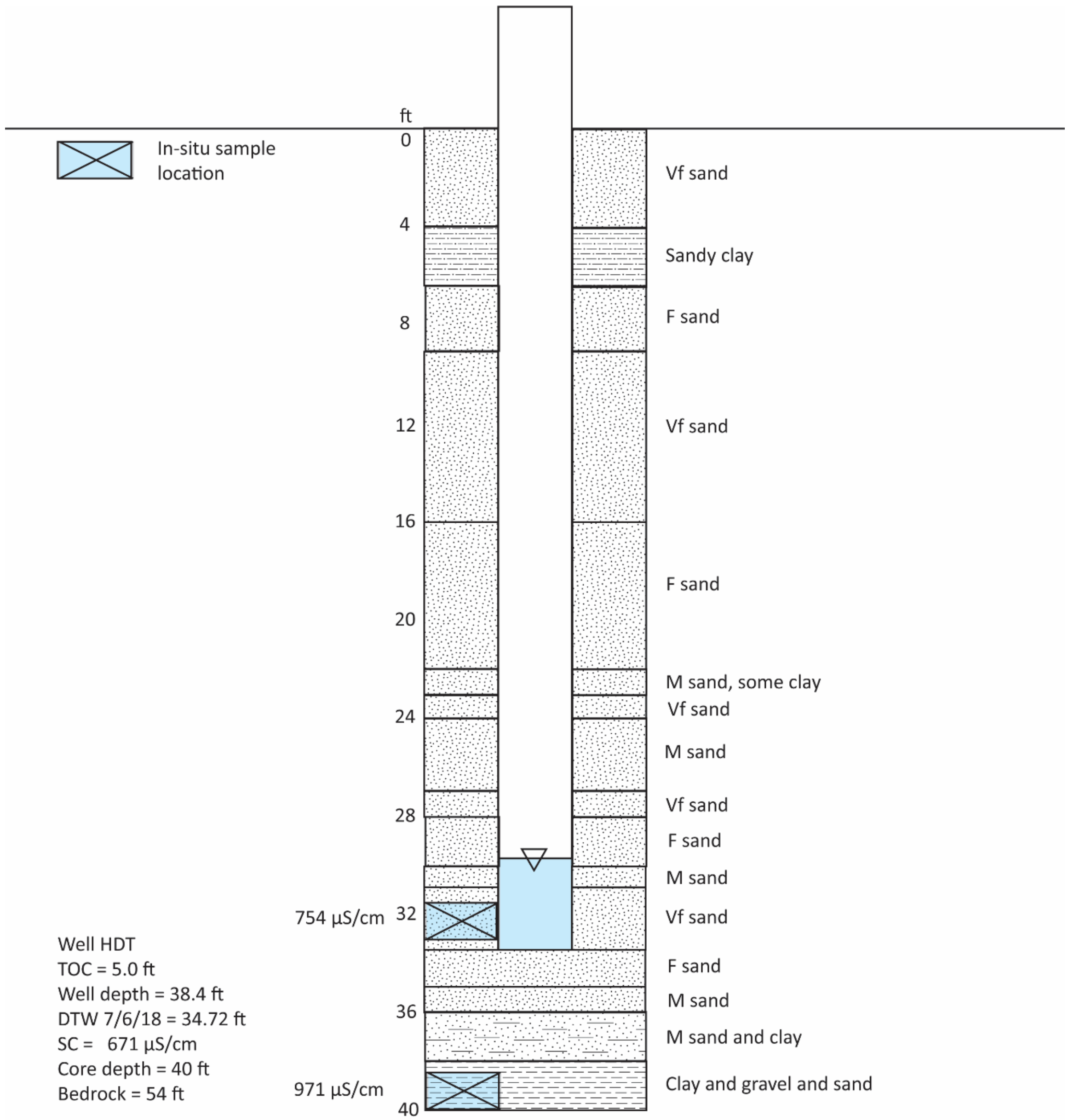

Figure H.3. HDT well diagram.

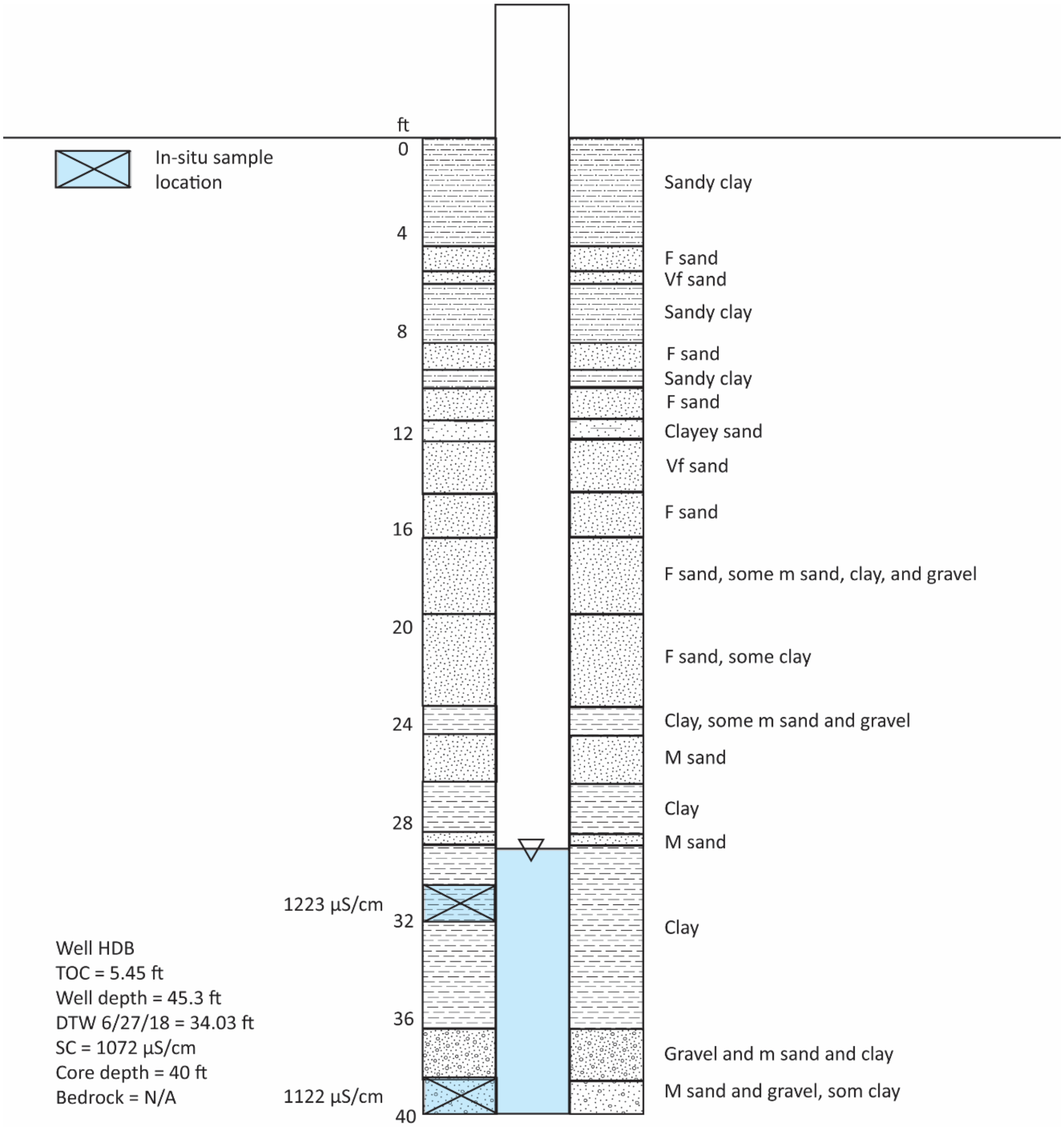

Figure H.4. HDB well diagram.

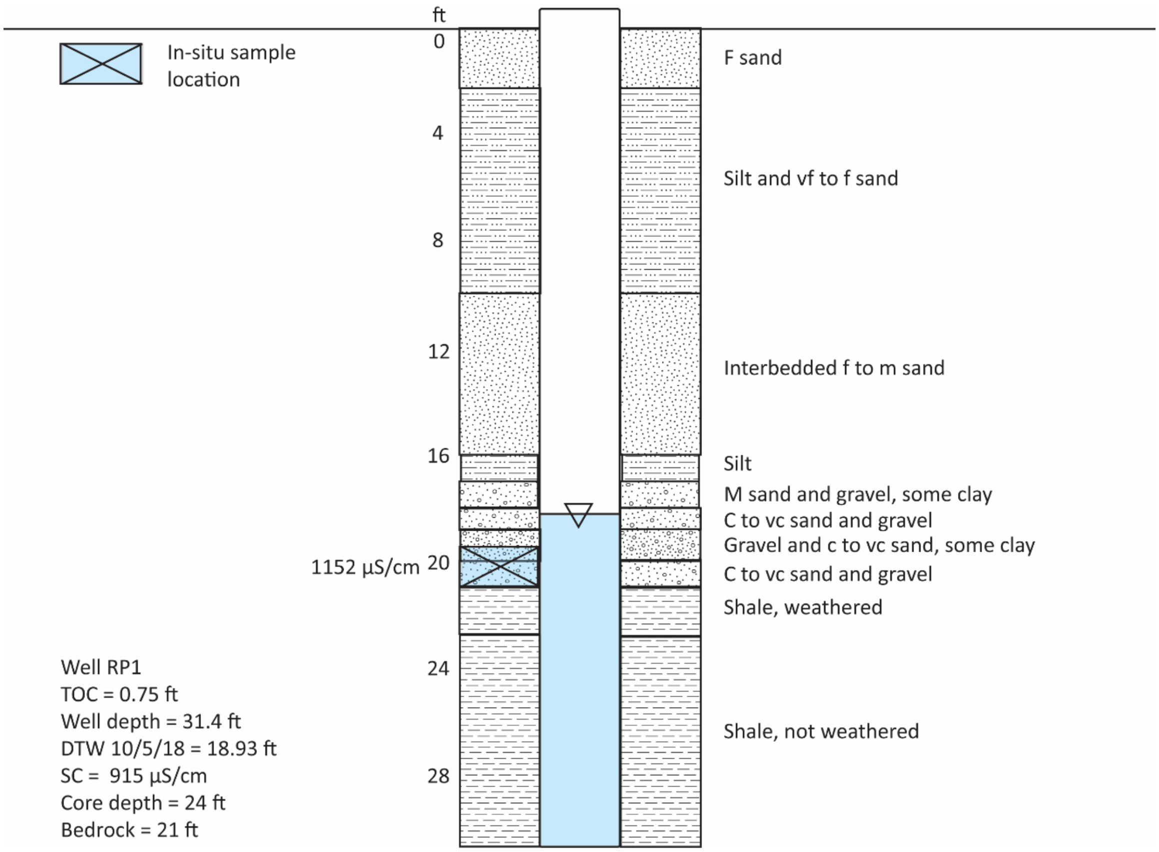

Figure H.5. RP1 well diagram.

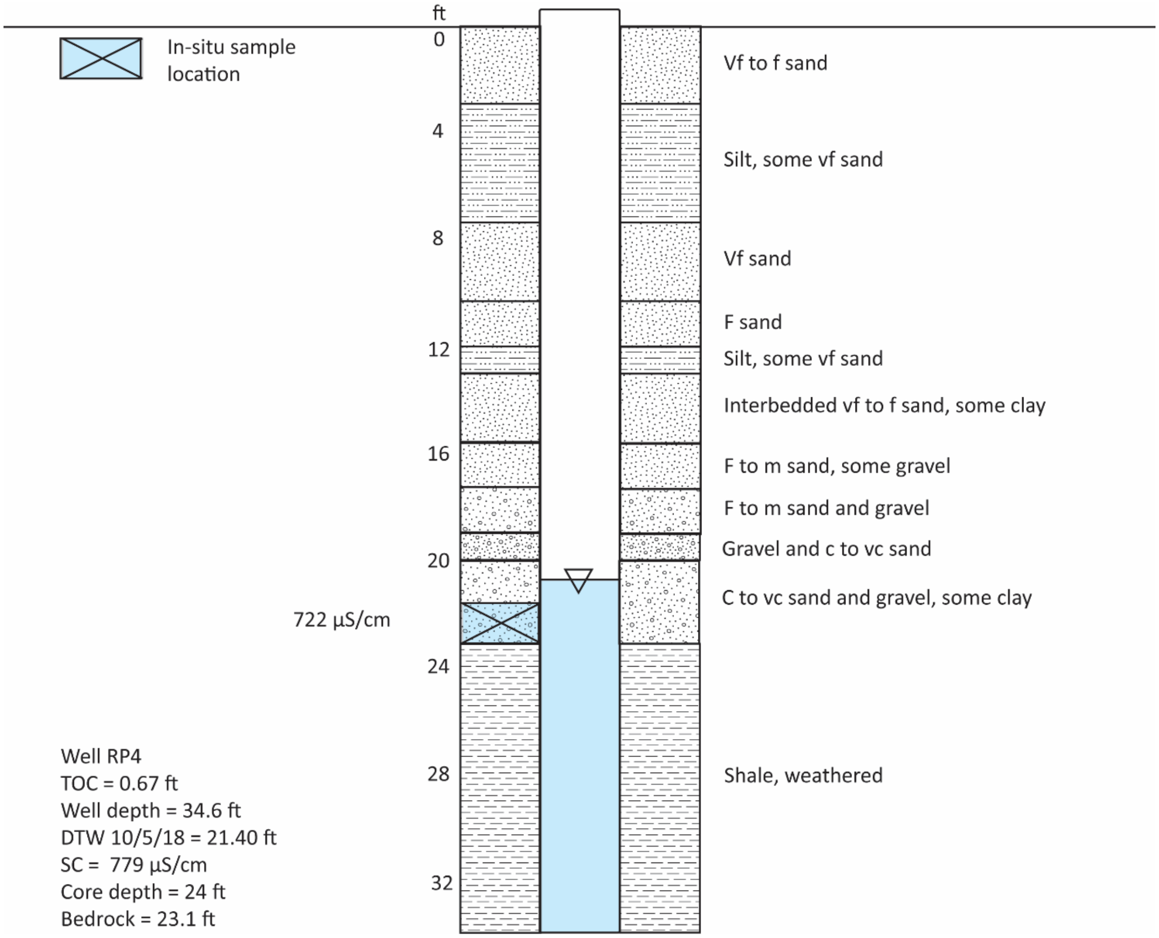

Figure H.6. RP4 well diagram.

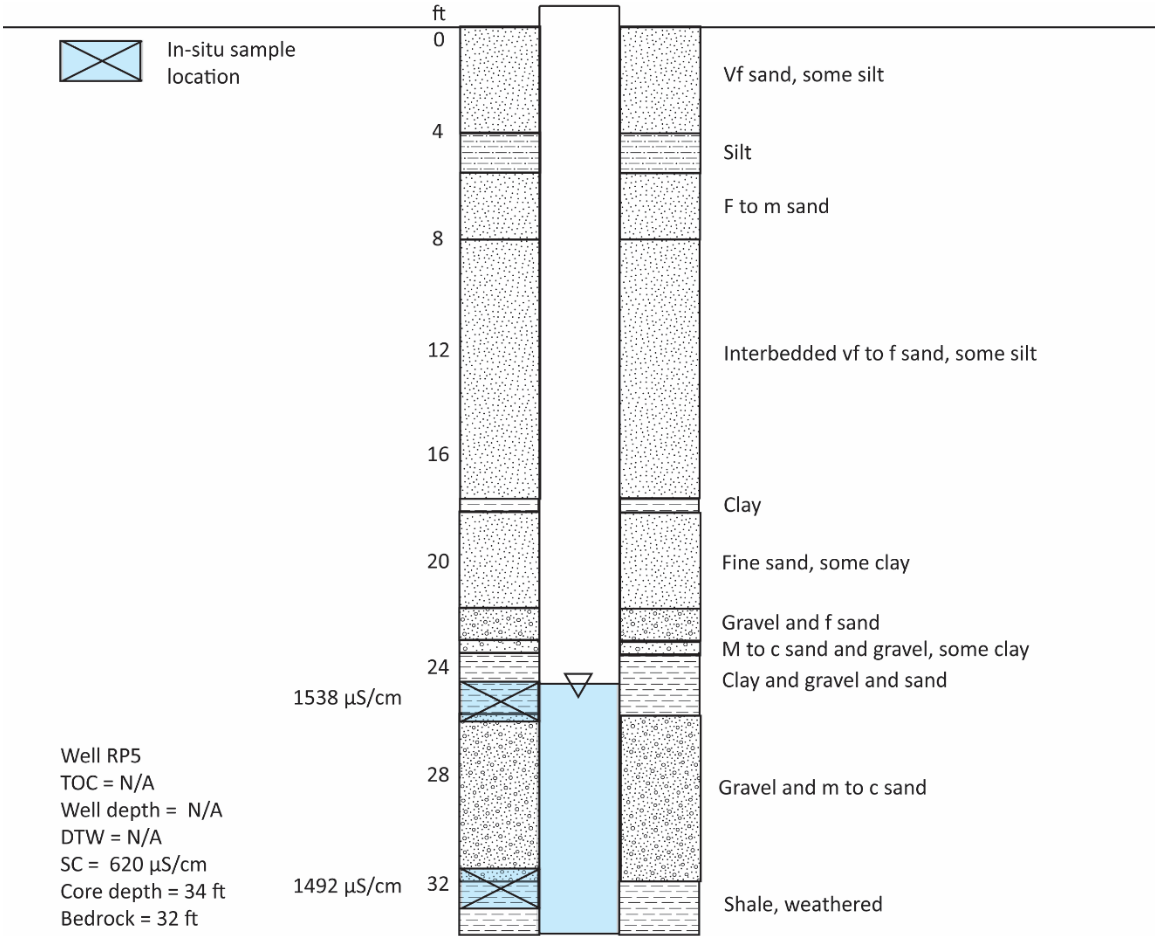

Figure H.7. RP5 well diagram.

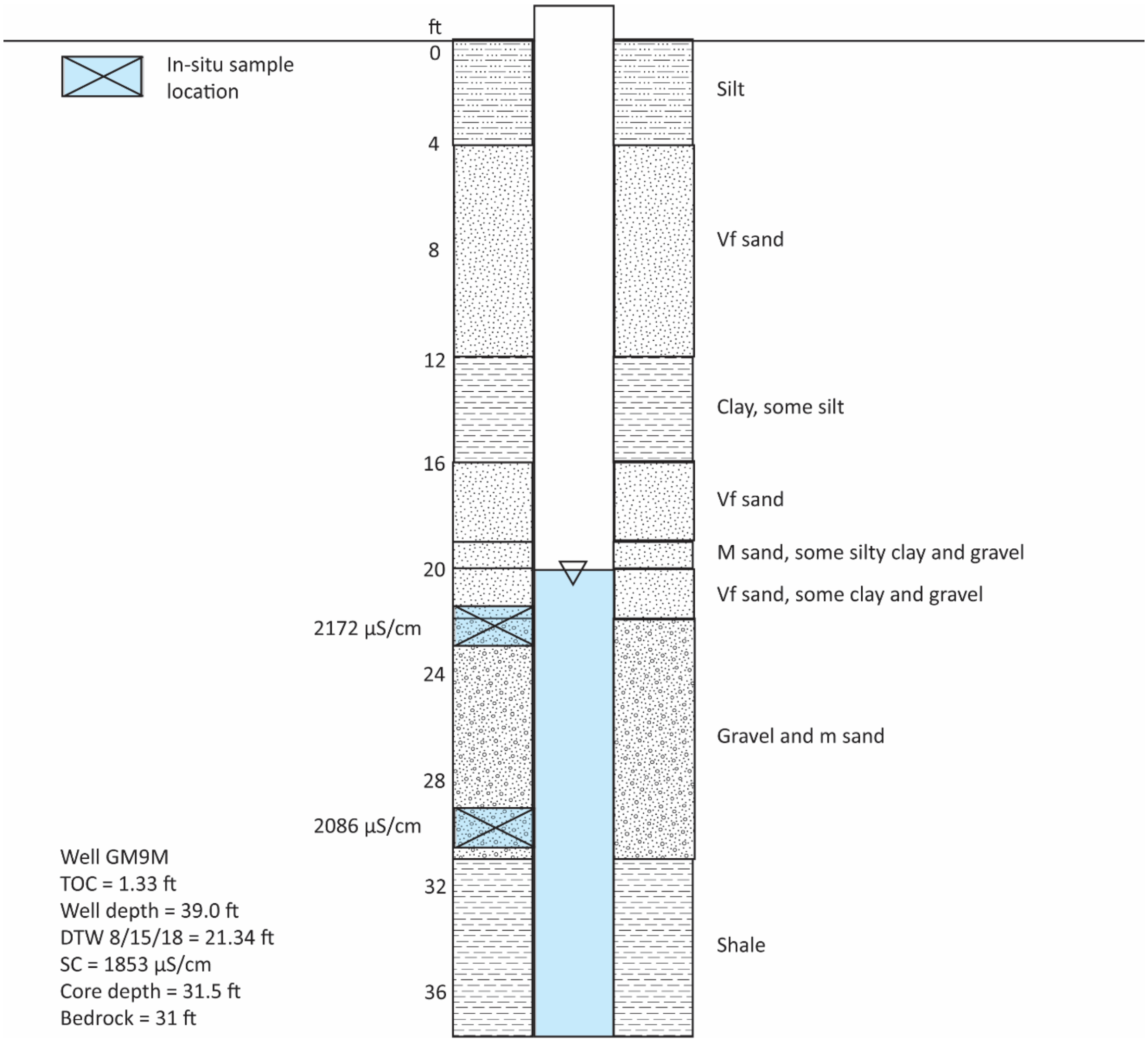

Figure H.8. GM9M well diagram.

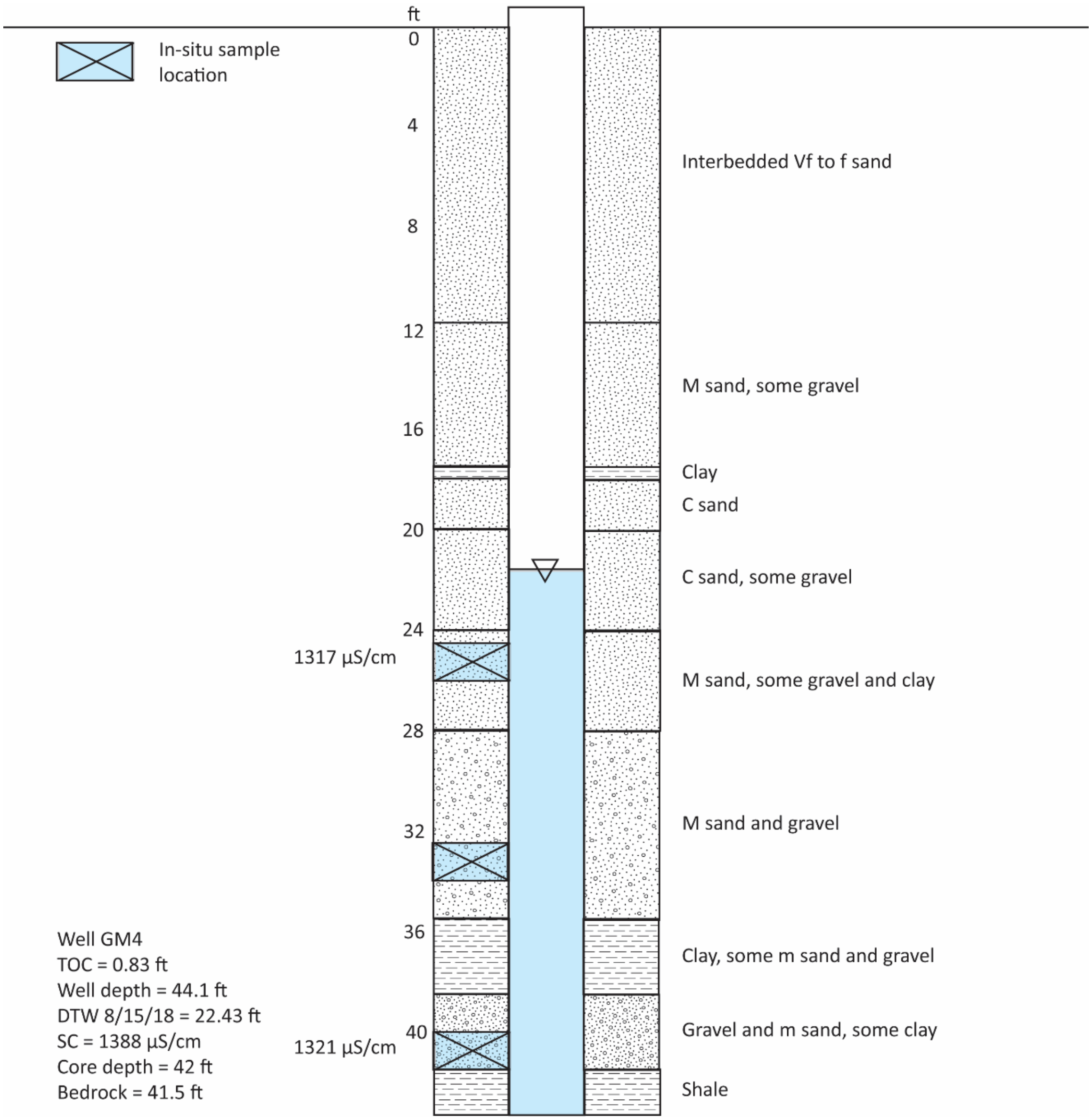

Figure H.9. GM4 well diagram.

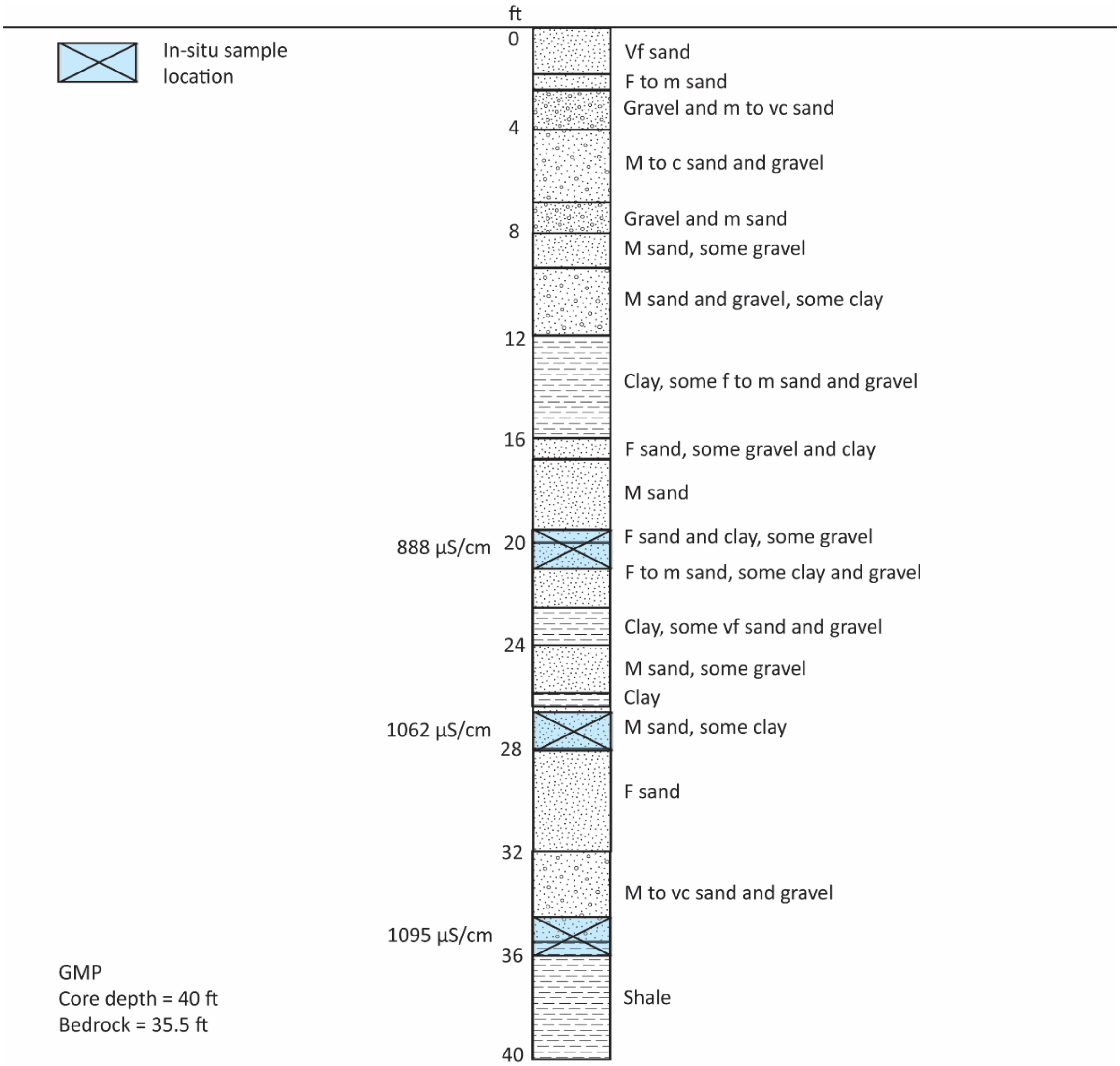

Figure H.10. GMP diagram.

APPENDIX I

Batch Leaching Results

Table I.1. Results of batch leaching study for core HDU.

Sample Interval (ft)	Sediment Type	Specific Conductance (µS/cm) 1/16/19	Specific Conductance (µS/cm) 1/23/19	Specific Conductance (µS/cm) 1/30/19	Specific Conductance (µS/cm) 2/6/19	Specific Conductance (µS/cm) 2/13/19	Specific Conductance (µS/cm) 2/20/19
2.5-4	Clay	147.4	170.9	192.4	224.6	239.6	265.0
12.5-14	Sand	47.9	52.4	54.2	58.0	58.7	61.4
22.5-24	Sand and gravel	56.1	59.1	61.2	63.3	65.1	67.0
29.5-31	Sand	137.3	151.9	177.5	198.0	207.6	212.0
38.5-40	Sand and gravel	52.3	55.3	60.2	64.4	64.0	68.5

Table I.2. Results of batch leaching study for core HDM.

Sample Interval (ft)	Sediment Type	Specific Conductance (µS/cm) 1/16/19	Specific Conductance (µS/cm) 1/23/19	Specific Conductance (µS/cm) 1/30/19	Specific Conductance (µS/cm) 2/6/19	Specific Conductance (µS/cm) 2/13/19	Specific Conductance (µS/cm) 2/20/19
2.5-4	Clay	78.9	92.4	99.6	105.3	114.8	124.4
13.5-15	Sand	42.4	42.2	45.7	48.5	48.1	52.3
24.5-26	Sand	64.3	68.6	73.5	76.0	76.8	81.2
32.5-34	Sand	93.3	97.3	105.5	110.5	117.5	123.4
41-42.5	Sand and gravel	79.3	87.5	96.4	106.8	109.7	116.0

Table I.3. Results of batch leaching study for core HDT.

Sample Interval (ft)	Sediment Type	Specific Conductance (µS/cm) 1/16/19	Specific Conductance (µS/cm) 1/23/19	Specific Conductance (µS/cm) 1/30/19	Specific Conductance (µS/cm) 2/6/19	Specific Conductance (µS/cm) 2/13/19	Specific Conductance (µS/cm) 2/20/19
2.5-4	Sand	78.6	89.9	103.5	117.7	121.7	135.5
12-13.5	Sand	79.6	86.4	90.8	101.7	105.5	112.0
21.5-23	Sand	73.5	77.9	79.7	84.9	86.0	86.7
31.5-33	Sand	175.9	190.0	205.9	222.9	230.2	235.4
38.5-40	Clay	305.6	342.5	382.9	425.0	437.8	458

Table I.4. Results of batch leaching study for core HDB.

Sample Interval (ft)	Sediment Type	Specific Conductance (µS/cm) 1/16/19	Specific Conductance (µS/cm) 1/23/19	Specific Conductance (µS/cm) 1/30/19	Specific Conductance (µS/cm) 2/6/19	Specific Conductance (µS/cm) 2/13/19	Specific Conductance (µS/cm) 2/20/19
2.5-4	Clay	129.3	152.2	175.8	197.1	218.1	239.3
12-13.5	Sand	68.4	71.0	73.4	75.9	83.2	90.3
21.5-23	Sand	44.0	46.3	47.9	49.8	50.3	52.3
30.5-32	Clay	294.9	342.0	386.2	420.5	435.8	453.6
38.5-40	Sand and gravel	95.8	103.5	109.6	118.7	123.7	137.6

Table I.5. Results of batch leaching study for core RP1.

Sample Interval (ft)	Sediment Type	Specific Conductance (μS/cm) 1/16/19	Specific Conductance (μS/cm) 1/23/19	Specific Conductance (μS/cm) 1/30/19	Specific Conductance (μS/cm) 2/6/19	Specific Conductance (μS/cm) 2/13/19	Specific Conductance (μS/cm) 2/20/19
2.5-4	Silt	36.6	42.0	45.0	48.0	50.0	47.1
10.5-12	Sand	75.8	83.1	86.2	89.7	92.4	96.8
19.5-21	Shale	63.6	68.4	68.7	76.1	78.5	82.5

Table I.6. Results of batch leaching study for core RP4.

Sample Interval (ft)	Sediment Type	Specific Conductance (μS/cm) 1/16/19	Specific Conductance (μS/cm) 1/23/19	Specific Conductance (μS/cm) 1/30/19	Specific Conductance (μS/cm) 2/6/19	Specific Conductance (μS/cm) 2/13/19	Specific Conductance (μS/cm) 2/20/19
2.5-4	Silt	36.8	41.2	45	47.0	49.0	50.0
12-13.5	Silt	71.1	78.6	85.6	96.3	100.8	109.8
21.5-23	Sand and gravel	62.3	63.9	69.8	75.4	76.5	81.3

Table I.7. Results of batch leaching study for core RP5.

Sample Interval (ft)	Sediment Type	Specific Conductance (µS/cm) 1/16/19	Specific Conductance (µS/cm) 1/23/19	Specific Conductance (µS/cm) 1/30/19	Specific Conductance (µS/cm) 2/6/19	Specific Conductance (µS/cm) 2/13/19	Specific Conductance (µS/cm) 2/20/19
2.5-4	Sand	88.3	99.0	118.4	140.8	149.1	166.6
13.5-15	Sand	251.4	278.1	290.1	298.4	302.4	316.7
24.5-26	Clay	133	149.4	149.8	155.2	157.8	164.2
31.5-33	Shale	80.2	88.1	88.0	87.2	91.9	94.4

Table I.8. Results of batch leaching study for core GM9M.

Sample Interval (ft)	Sediment Type	Specific Conductance (µS/cm) 1/16/19	Specific Conductance (µS/cm) 1/23/19	Specific Conductance (µS/cm) 1/30/19	Specific Conductance (µS/cm) 2/6/19	Specific Conductance (µS/cm) 2/13/19	Specific Conductance (µS/cm) 2/20/19
2.5-4	Silt	166.0	192.5	197.9	218.1	222.1	233.0
12-13.5	Clay	614	665	656	657	651	656
21.5-23	Sand and gravel	68.0	73.6	70.1	77.1	77.1	77.8
27.2-28.7	Sand and gravel	103.0	117.1	117.3	122.3	N/A	N/A

Table I.9. Results of batch leaching study for core GM4.

Sample Interval (ft)	Sediment Type	Specific Conductance (µS/cm) 1/16/19	Specific Conductance (µS/cm) 1/23/19	Specific Conductance (µS/cm) 1/30/19	Specific Conductance (µS/cm) 2/6/19	Specific Conductance (µS/cm) 2/13/19	Specific Conductance (µS/cm) 2/20/19
2.5-4	Sand	256.5	276.0	273.3	288.5	287.3	292.5
13.5-15	Sand	45.9	48.4	49.2	51.4	52.6	53.8
24.5-26	Sand	94.6	101.1	100.2	107.3	105.3	109.9
32.5-34	Sand and gravel	61.7	66.1	68.9	81.8	77.7	83.4
40-41.5	Sand and gravel	69.8	72.8	73.3	85.4	88.5	96.2

Table I.10. Results of batch leaching study for core GMP.

Sample Interval (ft)	Sediment Type	Specific Conductance (µS/cm) 1/16/19	Specific Conductance (µS/cm) 1/23/19	Specific Conductance (µS/cm) 1/30/19	Specific Conductance (µS/cm) 2/6/19	Specific Conductance (µS/cm) 2/13/19	Specific Conductance (µS/cm) 2/20/19
2.5-4	Sand and gravel	49.4	55.0	56.3	61.6	63.5	66.9
10.5-12	Sand and gravel	50.5	54.7	55.9	61.9	62.9	65.4
19.5-21	Sand	182.1	187.8	214.2	233.0	234.4	244.5
26.5-28	Sand	108.4	151.9	135.9	141.5	150.2	161.3
34.5-36	Shale	301.6	336.5	350.6	394.4	403.3	434.5

APPENDIX J

Hydrographs

Hydrographs for Well HDM

Well HDM was located in a pasture 0.42 miles from the Brazos River in southern McLennan County (figure 3.38). The hydrograph in figure J.1. shows that groundwater elevation declined steadily over the dry summer months, dropping a total of 0.76 feet from 5/1/18 to 10/15/18. Water level began rising on 10/15/18 and increased 4.74 feet by 12/30/18. To account for the 4.74-foot rise in water level observed in well HDM (assuming a porosity of 25%) approximately 14.22 inches of recharge would be necessary. During this period 15.24 inches of precipitation were received, and it seems unlikely that nearly all of this precipitation would make into the aquifer as recharge.

The graph of HDM groundwater elevation and precipitation in figure J.2. shows groundwater elevation in well HDM did not respond to rain received in both May and September, likely because there was little soil moisture in the unsaturated zone. However, the aquifer did respond to the rain received in October and the following months. From 10/6/18 to 10/9/18, 3.72 inches of precipitation were received, 2.30 inches of which were on 10/9/18. The aquifer began to respond on 10/15/18 suggesting a lag time of 6 to 9 days. The lag time of 6 days is likely more accurate as most of the rain was received on 10/9/18.

The graph of HDM groundwater and river elevation in figure J.3. shows that groundwater elevation does not respond to changes in river stage during the summer

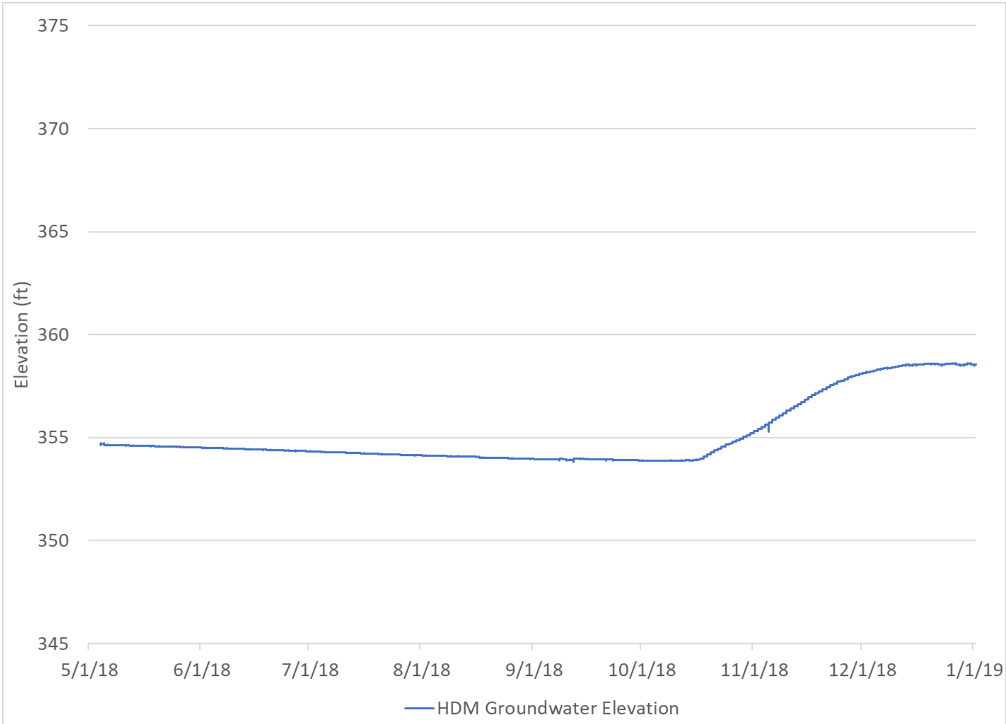

Figure J.1. Groundwater elevation for well HDM.

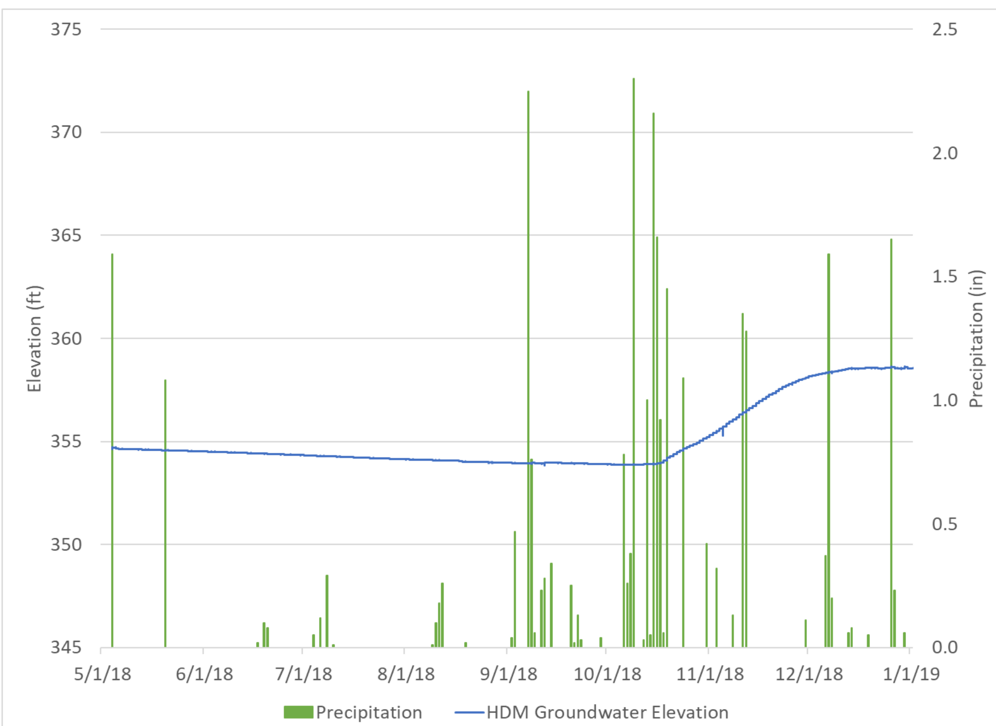

Figure J.2. Groundwater elevation and precipitation for well HDM.

months. However, it does show that groundwater elevation increased steadily during the 20.75-foot rise in river level from 10/2/18 to 10/20/18, but when river elevation begins to fall on 11/15/18, groundwater elevation continued to increase.

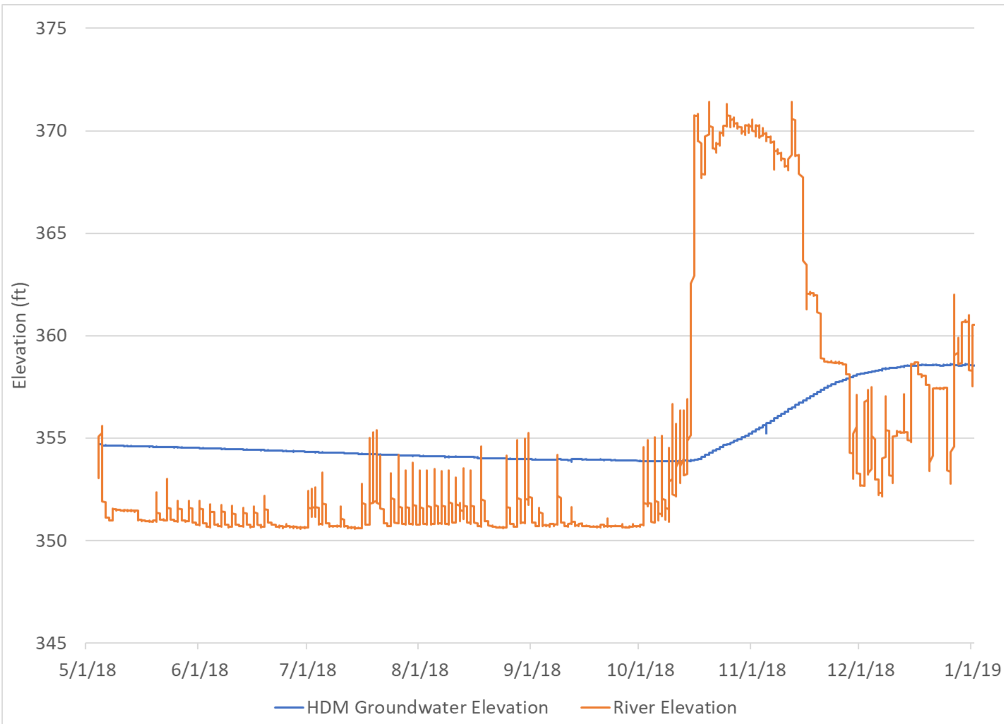

Figure J.3. Groundwater and river elevation for well HDM.

Hydrographs for Well HDB

Well HDB was located 0.08 miles from the Brazos River at a pasture in southern McLennan County (figure 3.38). The hydrograph in figure J.4. shows that water level decreased by 0.19 feet over the summer months from 5/1/18 to 10/2/18, although slight variations in water level were observed. Groundwater elevation began rising on 10/2/18 and rose 0.58 feet by 10/15/18. On 10/15/18, groundwater elevation began rising at a more rapid rate and rose 10.20 feet to its peak on 11/14/18 and 11/15/18. Total rise in groundwater elevation from 10/2/18 to 11/15/18 was 10.78 feet. Groundwater elevation then began declining rapidly and decreased 5.21 feet by 12/13/18.

The graph of HDB groundwater elevation and precipitation in figure J.5. shows that groundwater elevation began rising on 10/2/18, before precipitation began on 10/6/18. In addition, to account for the 10.78-foot increase in water level observed in well HDB (assuming a porosity of 25%) 32.34 inches of recharge would be necessary. Although only 15.24 inches of precipitation were received from October to December of 2018. Therefore, some other factor must have influenced water level in well HDB.

The graph of HDB groundwater and river elevation in figure J.6. shows that during low flow conditions in the summer, groundwater elevation mirrored changes in river elevation as water was released from the dams, causing the slight variations in

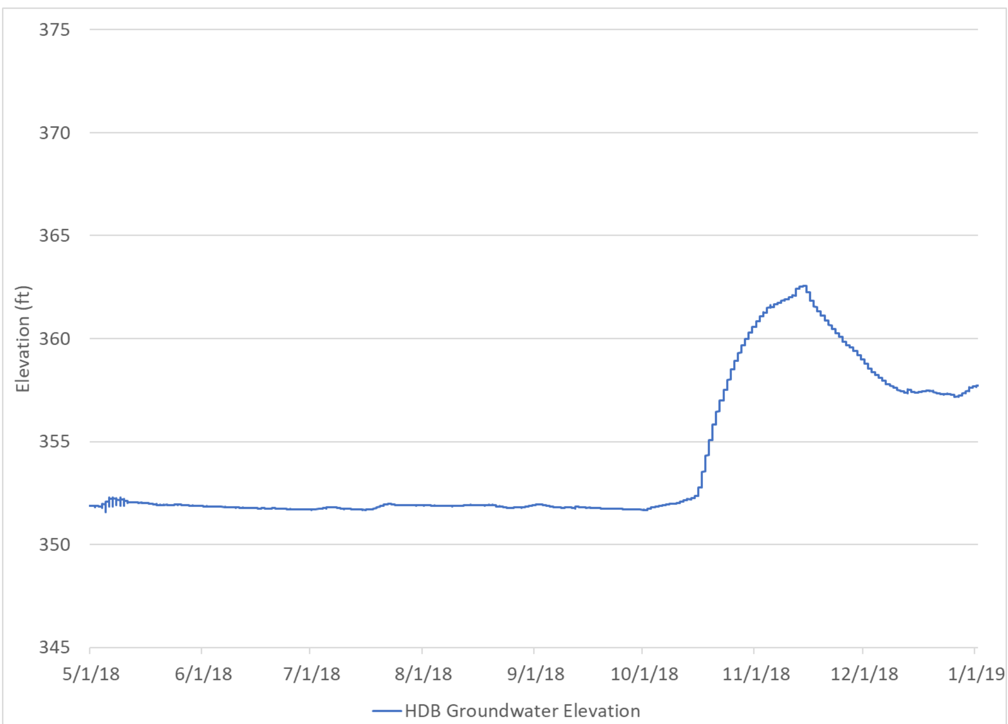

Figure J.4. Groundwater elevation for well HDB

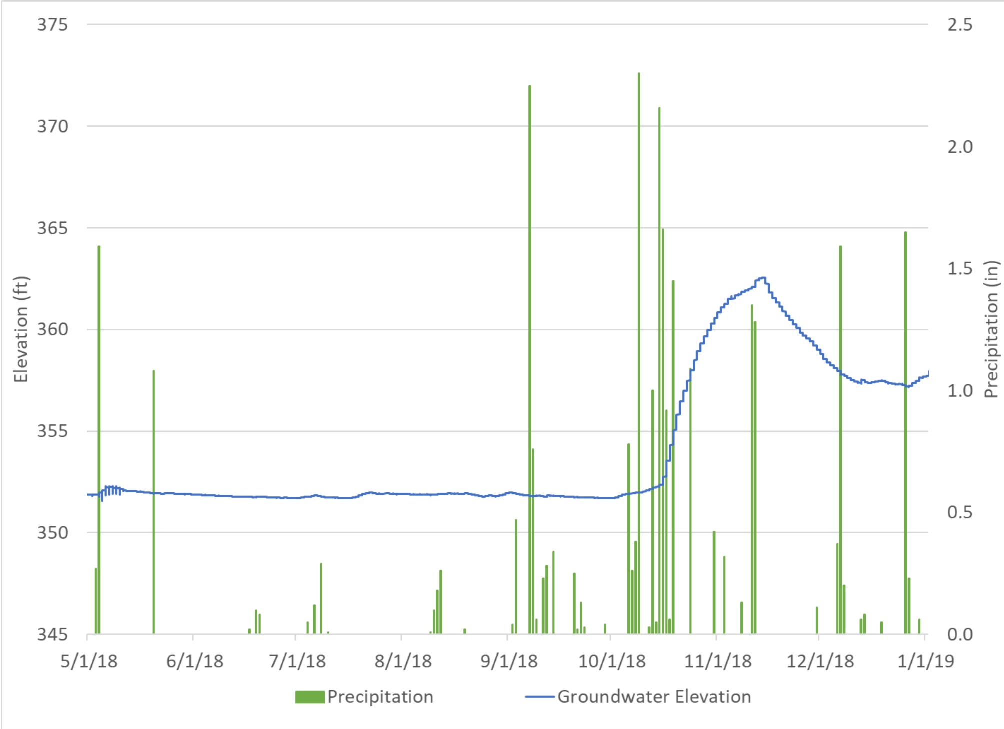

Figure J.5. Groundwater elevation and precipitation for well HDB.

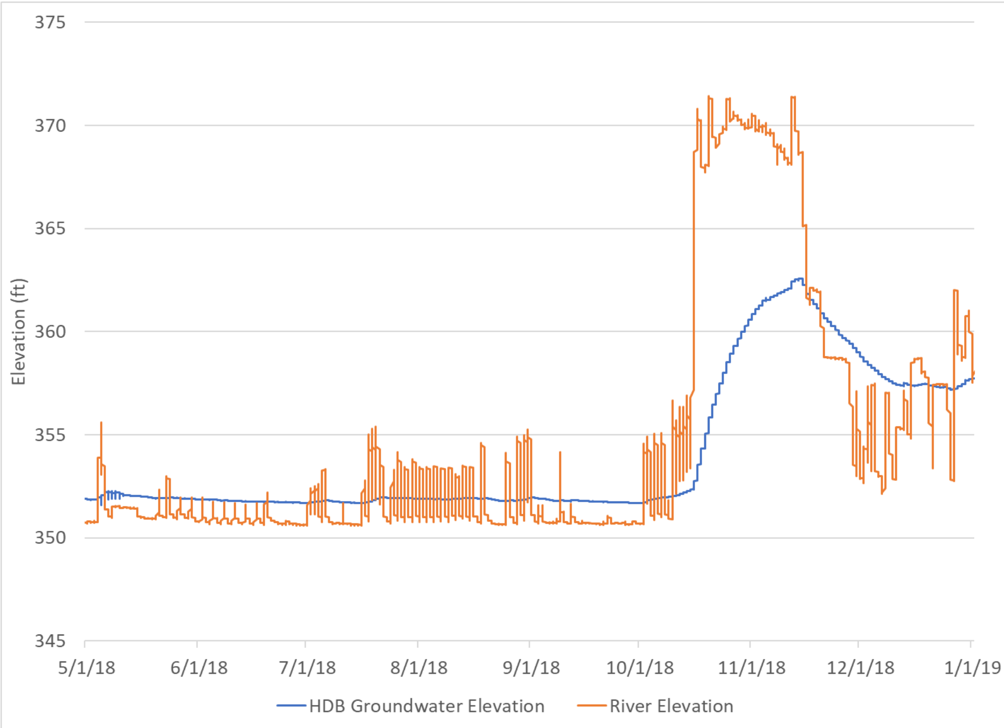

Figure J.6. Groundwater and river elevation for well HDB.

groundwater elevation observed. River elevation began rising rapidly on 10/2/18 and peaked on 10/20/18 rising a total of 20.75 feet, and then began decreasing on 11/15/18. Similarly, groundwater elevation also began rising on 10/2/18 and closely mirrored the increase then decrease in river elevation.

Hydrographs for Well HDT

Well HDT was located 0.14 miles from the Brazos River at a pasture in southern McLennan County (figure 3.38). The hydrograph in figure J.7. shows that groundwater elevation decreased by 0.16 feet over the summer months from 5/1/18 to 8/29/18, although slight increases and decreases in groundwater elevation were observed. Due to technical difficulties no data were recorded during the period of 8/30/18 to 10/31/18, although water level rose 14.45 feet from 8/29/18 to 11/12/18. To account for the 14.45-foot rise in water level observed in well HDT (assuming a porosity of 25%), approximately 43.35 inches of recharge would be necessary; however, the area only received 20.54 inches of precipitation during this period, suggesting some other contributing factor to the rise in water level.

Much of the precipitation received occurred during the period when the data logger did not record; however, the data logger did not appear to respond to the 2.94 inches of precipitation received in May of 2018 (Figure J.8.).

The graph of HDT groundwater and river elevation in figure J.9. shows that the slight variations in water level observed during the summer months correlate with changes in river elevation as water was released from the dams. Similarly,

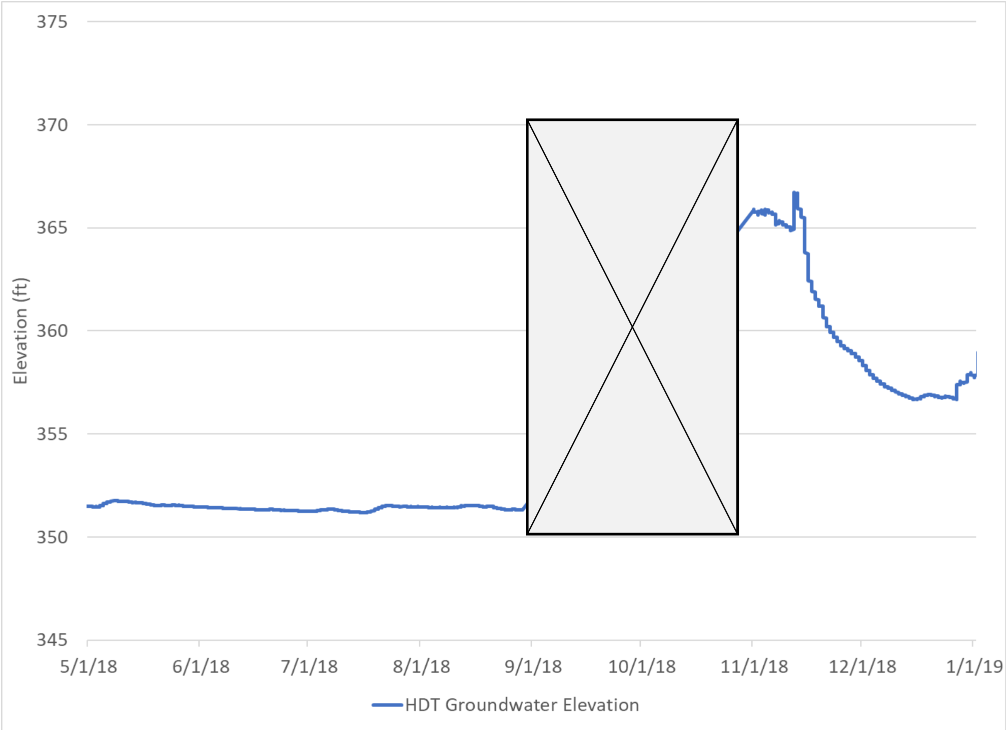

Figure J.7. Groundwater elevation for well HDT.

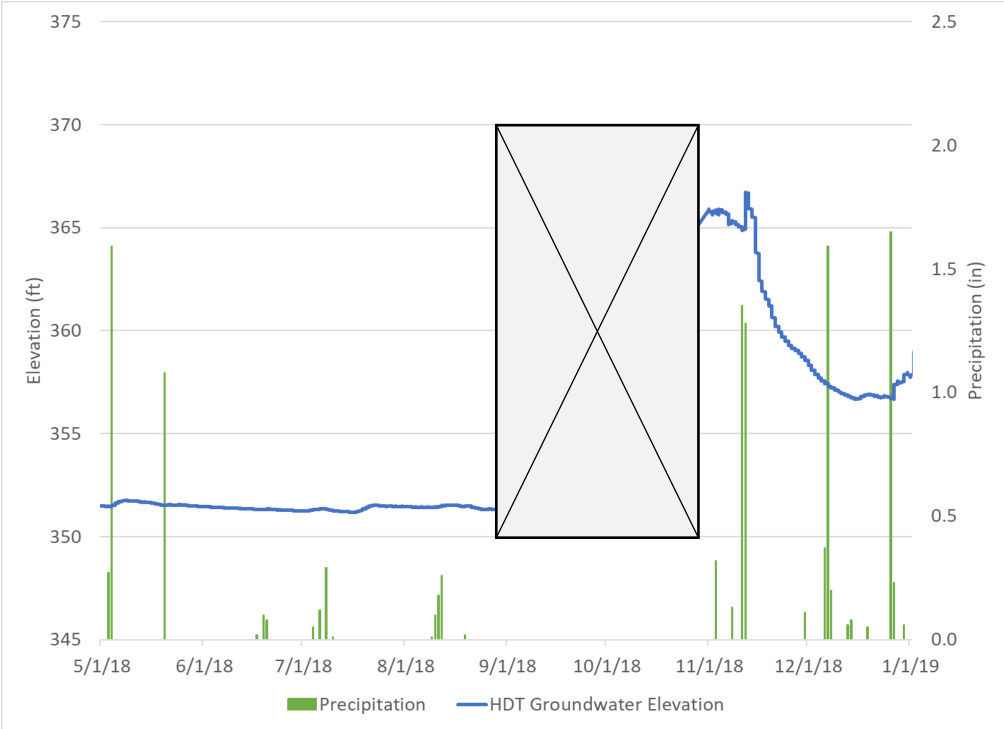

Figure J.8. Groundwater elevation and precipitation for well HDT.

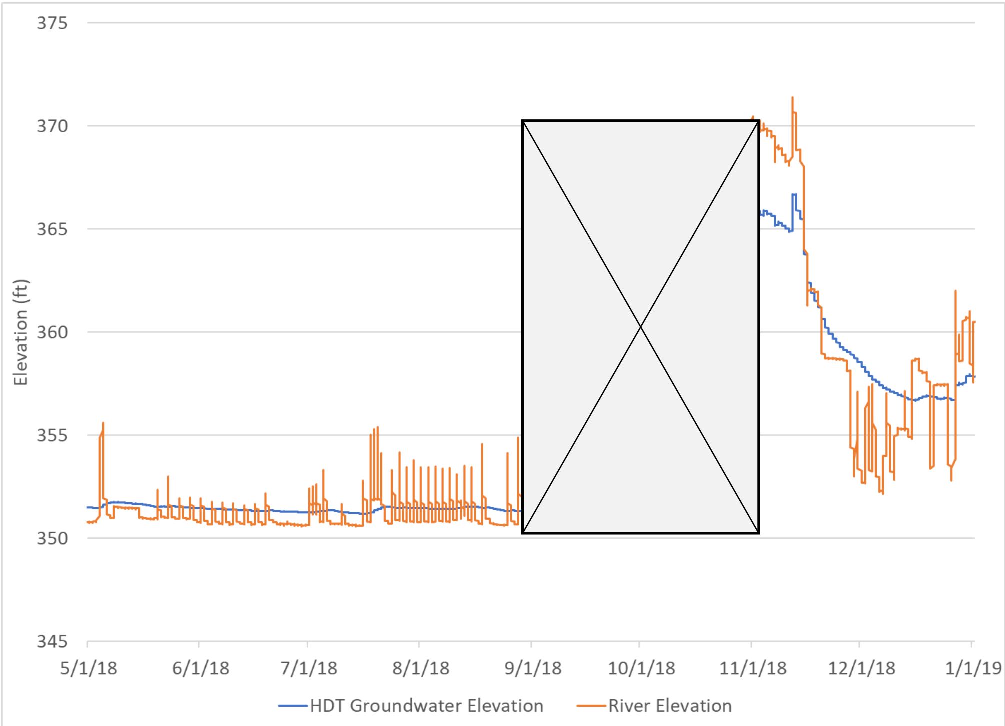

Figure J.9. Groundwater and river elevation for well HDT.

as river elevation began decreasing rapidly on 11/15/18, groundwater elevation began decreasing rapidly also.

Hydrograph for Well RP1

Well RP1 was located 0.56 miles from the Brazos River at an orchard in northern McLennan County (figure 3.38.). The well was actively pumping from 6/2/18 to 9/8/18 and significant drawdown was observed in well RP1 during this time period, with a maximum drawdown of 10 feet from the initial water level. Drawdown in this well may have been influenced by other pumping wells on the property and could have also been influenced by pumping wells on neighboring properties. Small recoveries in water level can be seen daily when the pump was shut off and three different rates of drawdown were observed during the pumping period (figure J.10.).

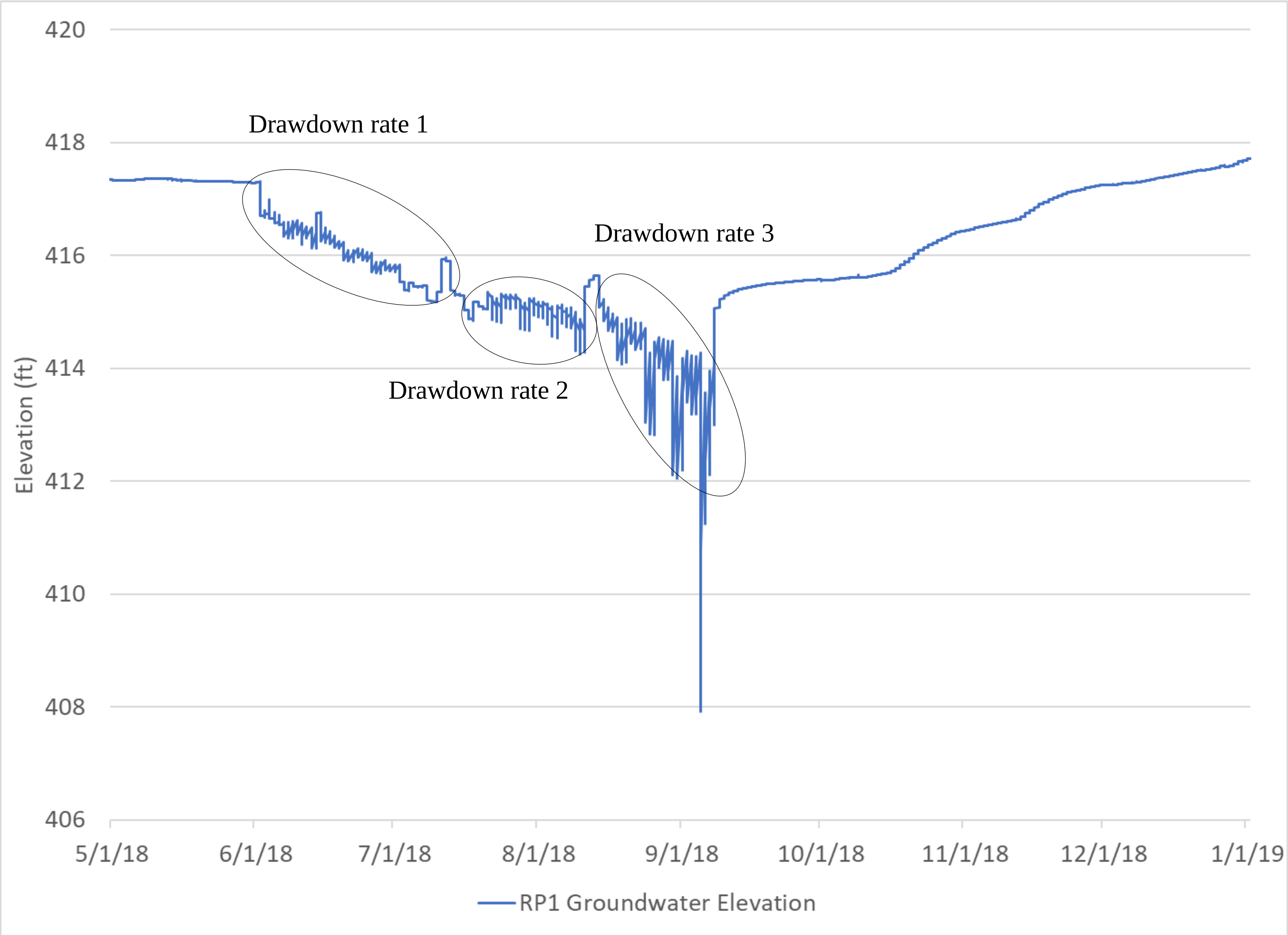

Figure J.10. Groundwater elevation for well RP1.

Initially, the saturated thickness of the aquifer near this well was 5.35 feet and the water table was located in a fine sand at an elevation of 417.35 feet. Once pumping began on 6/2/18, the water table steadily dropped and entered a silt layer from an elevation of 417 feet to 416 feet and then a fine sand from 416 feet to 415.55 feet, (Drawdown rate 1 in figure J.10. and well diagram RP1 in figure H.5.). As the water table continued to drop it entered the more transmissive layers of medium sand and gravel with little clay from an elevation of 415.55 feet to 415 feet and coarse to very coarse sand and gravel from 415 feet to 414.2 feet, and the rate of drawdown decreased due to the increase in transmissivity, (Drawdown rate 2 in figure J.10.). However, by this point the saturated thickness of the aquifer near the well was approximately 3 feet and as the saturated thickness of an unconfined aquifer decreases, so does its transmissivity. Therefore, even though the aquifer consisted of gravel and coarse to very coarse sand with some clay from an elevation of 414.2 feet to 413 feet and coarse to very coarse sand and gravel from 413 to 412 feet, the rate of drawdown (Drawdown rate 3 in figure J.10.) increased significantly in comparison to drawdown rates 1 and 2. Also contributing to the increase in drawdown rate 3 was the fact that well RP1 was drilled 9.65 feet into bedrock to provide extra storage, so when the water level in the well dropped below the bottom of the aquifer at an elevation of 412 feet, the majority of water pumped was being withdrawn from storage in the well, causing the two large spikes in drawdown seen on the hydrograph.

Once the pump was shut off on 9/8/18, the well recovered rapidly and water level rose 2.06 feet by the end of the day. The well then continued to recover at a much slower but constant recovery rate until 10/12/18, when water level began to rise at a much faster rate due to recharge from precipitation. From 10/6/18 to 10/9/18 3.72 inches of precipitation were received, 2.30 inches of which were on 10/9/18. This suggests a slight lag in water level response to recharge from precipitation, with a minimum of three days and a maximum of six days. The minimum of three days is thought to be the better estimate of the lag time between precipitation and water level response as most of the precipitation was received on 10/9/18. Water level in RP1 rose 2.09 feet from 10/12/18 to 1/1/19 in response to the 24.94 inches of rain received from October to December. Assuming a porosity of 25%, only 6.29 inches of recharge would be necessary to create the 2.09-foot rise in water level, suggesting that precipitation can account for the entire water level rise seen in well RP1.

In addition, the graph of groundwater elevation and precipitation shows that water level in well RP1 did not respond to the 2.94 inches of rain received in May of 2018 and may not have responded to the 4.90 inches of precipitation in September of 2018 as no change in recovery rate could be observed. This lack of response of water level to the precipitation in May and September is likely due to the extremely dry conditions from January through August, which would have caused the unsaturated zone to contain little moisture. The lack of a September response may have been difficult to notice due to pumping in the well.

River stage at the USGS gaging station downstream of Waco showed that stream stage began rising rapidly on 10/2/18 and rose 20.75 feet by 10/20/18 and then began decreasing rapidly on 11/12/18, falling 18.40 feet by 10/29/18. However, throughout these significant changes in river stage, water level in well RP1 continued to steadily increase, suggesting the Brazos River has little influence on water level in this well.

Hydrograph for Well GM9M

Well GM9M was located 0.72 miles from the Brazos River at a row crop farm in southern McLennan County (figure 3.38.). The hydrograph in figure J.11. shows that groundwater elevation in GM9M periodically increased and decreased over the summer months even though the area received little precipitation, possibly due to the periodic pumping and shutting off of other wells on the property. Overall, water level increased by 0.037 ft from 5/1/18 to 9/9/18. Due to technical difficulties with the data logger no data were recorded after 9/9/18. Water level in GM9M did not respond to 2.94 inches of precipitation received in May of 2018 and does not appear to respond to changes in stream stage of the Brazos River.

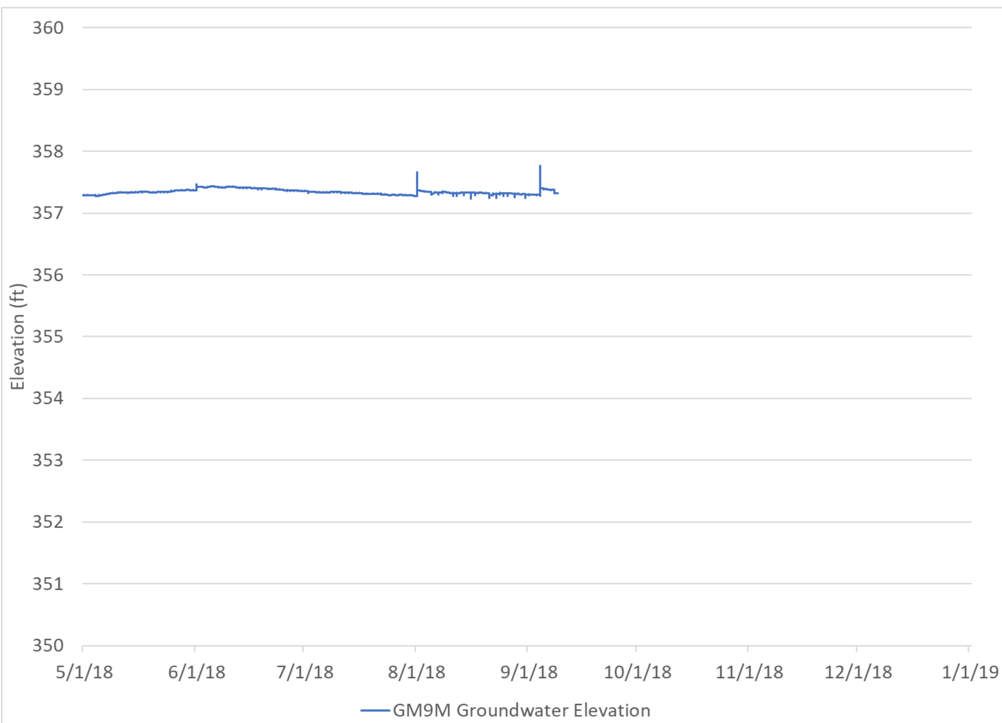

Figure J.11. Groundwater elevation for well GM9M

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